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FURNITURE AND JOINERY INDUSTRIES FOR DEVELOPING COUNTRIES

FURNITURE AND JOINERY INDUSTRIES FOR DEVELOPING COUNTRIES

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Preface

Thirteen seminars on furniture and joinery industries have been organized by the United Nations Industrial Development Organization (UNIDO) in co-operation with the Government of Finland. The first was held at Lahti and Tuusula from 16 August to 11 September 1971; subsequent seminars were held in August each year (except in 1976). All seminars were held at Lahti, except the 1984 seminar, which was held at Reduit, Mauritius.[1] The success of the seminars was largely due to the hospitality and understanding of the Finnish authorities and the Finnish furniture industry in providing participants with an invaluable opportunity to learn firsthand from Finnish experts in furniture design, production and marketing.

The aim of the seminars was to familiarize factory managers in developing countries with modern plant, equipment and production techniques to enable them to upgrade their own operations and to establish priorities for such improvements. The seminars were attended by 364 participants from 62 developing countries who were for the most part technical managers and production supervisors of woodworking plants.

This publication is based on papers presented to the seminars, complemented by relevant documents prepared for other UNIDO training courses that have been included as background material.[2] Many of the lectures were illustrated with material that did not lend itself to reproduction in the present form. In addition to lectures, there were demonstrations, discussions and visits to medium-sized and small-scale furniture and joinery plants, manufacturers of particle board, plywood and blockboard and producers of upholstery foams, rigid shells used in upholstery, paints and woodworking machinery as well as to vocational and technical training institutions. This was supplemented by group work by the participants themselves.

Although the various papers constitute a coherent whole, for convenience they have been grouped into three parts.[3] Part one consists of articles on the materials from which furniture and joinery products are constructed; part two deals with processing technology; and part three concerns management problems and responsibilities in the areas of quality control, production management, marketing and export trade and occupational hazards and safety at work.

It is hoped that publication of the material issued in the course of the seminars will contribute towards increasing the awareness of the results that can be achieved when furniture and joinery enterprises are set up in developing countries following established, rational industrial procedures. It is also hoped that this material will be of use to teachers in training institutes in developing countries.

Readers should note that, in some instances, the examples cited and the descriptions given represent Finnish conditions and may not be wholly applicable to particular developing countries.

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[1] Documents originally prepared for the seminars bore the symbol numbers: ID/WG.105/-; ID/WG.133/-; ID/WG.163/-; ID/WG.183/-; ID/WG.209/-; ID/WG.256/-; ID/WG.302/-; ID/WG.348/-; and ID/WG.378/-.

[2] UNIDO/IS.410; ID/298; ID/WG.335/-; ID/265; and ID/WG.338/9.

[3] This publication was issued orginally in three seperate parts. In the first revision, published in 1977, the parts were brought together in one volume. The present revision is based on material contained in the first revision, which has been updated, and on papers presented to seminars held after 1977.

EXPLANATORY NOTES

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

References to pounds (£) are to pounds sterling, unless otherwise stated.

The term "billion" signifies a thousand million.

References to tonnes are to metric tonnes.

References to gallons are to British imperial gallons; one gallon equals 4.545 litres.

The following forms have been used in tables:

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

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

A blank indicates that the item is not applicable.

The following technical abbreviations are used in this publication:

c.i.f.	cost, insurance, freight
CMC	carboxymethyl cellulose
cP	centipoise
dB	decibel
EMC	equilibrium moisture content
f.a.s.	free alongside ship
f.o.b.	free on board
FRP	fibreglass reinforced plastic
FSP	fibre-saturation point
ha	hectare
HF	high frequency
ILD	indentation load deflection
kcal	kilocalorie
KD	knocked down
kN	kilonewton
kp	kilopond
lbf	pound force
MAC	maximum air concentration
MDF	medium density fibreboard
MPU	microprocessor control unit
N	newton (100,000 dynes)
NT	Nord Test (Scandinavian standard)
OSB	oriented strand board
p.s.i.	pounds per square inch
PIA	peripheral equipment
PVAc	polyvinyl acetate
PVC	polyvinyl chloride
r.h.	relative humidity
RAM	random access memory
RF	radio frequency
rm	running metre
ROM	read only memory
µm	micrometre (10^{-6})
UV	ultraviolet

The following abbreviations of standards institutes and other organizations are used in this publication:

ASTM	American Society for Testing and Materials (United States of America)
BS	British Standards (United Kingdom of Great Britain and Northern Ireland)
CPA	Chipboard Promotion Association (United Kingdom)
DIN	Deutsche Industrie-Norm (Federal Republic of Germany)
EMPA	Eidgenössische Materialprüfungs- und Versuchsanstalt (Switzerland)
EUMABOIS	European Association of Woodworking Machinery Manufacturers
FEFCO	European Federation of Corrugated Board Manufacturers
FEIC	Fédération européenne de l'industrie du contreplaqué
FIRA	Furniture Industry Research Association (United Kingdom)
FMVSS	Federal Motor Vehicle Safety Standard (United States)
FPRL	Forest Products Research Laboratory (United Kingdom)

III	**International Isocyanate Institute**
ISO	**International Organization for Standardization**
IUFkO	**International Union of Forestry Research Organizations**
NEMA	**National Electric Manufacturers' Association of New York**
NHLA	**National Hardwood Lumber Association (United States)**
SIO	**Society of Interior Designers (Finland)**
SIS	**Sveriges Standardiseringskommission (Sweden)**
TRADA	**Timber Research and Development Association (United Kingdom)**

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Introduction

Many developing countries are fortunate in having good reserves of timber; all require some sort of housing and home furnishings. Even if a country should lack sufficient timber to meet its needs, a strong wood-processing industry based on imported raw material may still prove an important asset. Such an industry could provide the framework for supplying requirements for housing and home furnishings and could create employment, thus leading to improved living standards.

Developing countries have a near monopoly in the tropical woods that are in increasing demand by developed countries for fine furniture and joinery work. However, the bulk of exports of tropical woods is still in the form of logs which are processed into veneers, sawn wood, furniture and joinery products in the developed countries, thus contributing very little to the economies of the exporting countries.

In nearly all developing countries, furniture and joinery industries are still at a handicraft or "mechanized craftsman" stage, that is, industrial production in large series is unknown. Because wood is a raw material that has been used for centuries in a great many ways, a nucleus of skilled carpenters and other woodworkers often exists.

As the production of furniture is not a difficult manufacturing process involving complex training programmes, many existing small-scale factories can, with judicious planning, be up-graded to industrial enterprises through assistance in production planning, quality control, designs for larger production series, the selection of equipment for modernizing their workshops and more efficient organization of work.

The requirements for manufacturing furniture and its components for the export market, however, are more stringent than those for the home market. New technologies must be mastered for kiln-drying, surface finishing and precision machining, since the changes in climatic conditions, customer demands and the need for shipment in knocked-down form imply the assembly of interchangeable components.

Some developing countries are well forested, have wood as a valuable and renewable natural resource and have abundant labour. As both the requisite skills and capital requirements are relatively low in furniture and joinery, these countries should strive to take advantage of this combination and work to export to the markets of the developed countries. For developing countries that lack adequate forest resources, the development of the furniture and joinery industries can lead to a reduction in imports of these products and of raw materials through more rational utilization.

The Second General Conference of UNIDO, in the Lima Declaration and Plan of Action on Industrial Development and Co-operation,[1] recommended that developing countries should place emphasis on, *inter alia*, the utilization and on-the-spot processing of raw materials to satisfy the needs of the population and to replace imports and increase exports. If the goals of the Lima Declaration are to be achieved, the furniture and joinery industries could well be a field in which the developing countries could play an increasingly important role.

[1]Report of the Second General Conference of the United Nations Industrial Development Organization (ID/CONF.3/31), chap. IV.

Part one

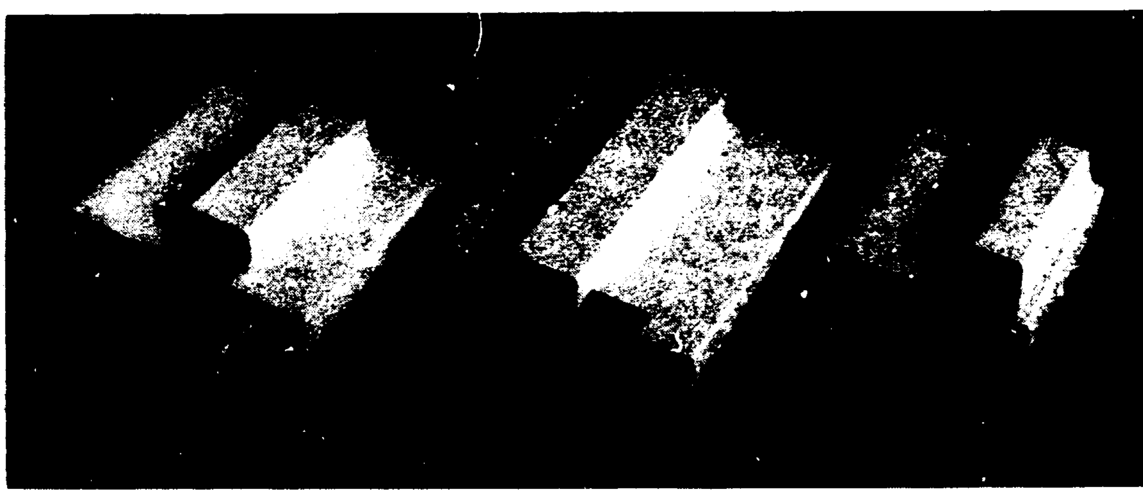
RAW MATERIAL INPUTS

1/2

I. Solid wood as raw material for the furniture and joinery industries*

Solid wood, or timber, was traditionally the basic raw material for the furniture and joinery industries. This is now only partly true: many semi-manufactured boards have come to the market and, as cheaper material, have been substituted for solid wood in the manufacture of furniture panels. These boards, usually called wood-based panels, are easy to veneer, lacquer and cover with various plastic laminates, sheets and foils. Unlike solid-wood parts, they also have very good dimensional stability in both directions of the surface. In many modern products solid-wood components are combined with panels made of particle board and similar materials and thus comprise only a part of the final product. To reduce material costs, low-cost solid wood is often veneered with expensive woods. Sometimes solid wood and plastic profiles are combined (figure 1), although the results have not been entirely positive. Combinations of preserved and untreated wood instead have proved to be excellent in window constructions, as shown in figure 2.

Figure 1. Combined solid wood and plastic profiles



In the future many new materials will be used in place of wood. On the other hand, when high-quality products are required, it will be difficult to substitute for natural wood, with its beautiful appearance. Solid wood is still essential in most furniture constructions as well as in joinery products.[1]

Figure 2. Window profile with exterior part of preserved wood

*By Pekka Paavola, Lahti Institute of Technology, Lahti, Finland. Originally issued as ID/WG.105/22/Rev.1.

[1]The examples included in the text are for Finnish birch, because a text treating even most of the important tropical species would have been beyond the scope of this publication. A selected bibliography has been appended to help readers in developing countries to adapt the material presented here to the wood species available in them.

Timber used in the furniture and joinery industries

The properties required of the wood used in furniture and joinery products vary greatly. Dissimilar properties may be needed for different parts of a given product. Therefore, the choice of appropriate raw materials is of prime importance. Properties that should be taken into consideration in the choice of timber are:

- Strength, together with rigidity and hardness
- Grain structure, homogeneity, colour shade and variations
- Drying properties, such as shrinkage, swelling and twisting
- Kiln-drying characteristics
- Workability and possible dulling effect on tools
- Suitability for gluing
- Finishing qualities
- Bending qualities (reaction to treatment by steam and ammonia)
- Resistance to weathering, fungi and to insect damage
- Density

The properties of each kind of wood are quite specific; certain species are better suited to some purposes than others. Conversely, no one wood is ideal for all purposes. For instance, most of the technical properties of teak are excellent; its grain structure and colour shade are beautiful, but it dulls woodworking tools rapidly and is not easy to glue because of its extractives. African gaboon is well suited for blindwood in veneered furniture panels owing to its low density and dimensional stability, but its strength is usually not sufficient for chairs and similar pieces that must bear considerable loads. Furthermore, African afrormosia, which is often used in place of teak, has good working qualities and is easy to dry but darkens noticeably with time.

Timber used in the furniture industry is either frame-sawn (small logs such as those of Finnish birch) or band-sawn (large logs, especially those of tropical woods). Circular sawing is also possible but is less used since it produces more waste. (The standard thicknesses of birch boards used in the furniture industry of Finland are shown in table 1.) While in Europe unedged timber is most commonly used, in North America the logs are generally "sawn around" and edged to maximize the recovery of sawn wood graded according to the grading rules of the National Hardwood Lumber Association (NHLA). After sawing, the timber is usually air-dried in a timber yard, where the boards are stacked with piling strips between the layers. This can be done either at the sawmill or at the furniture factory.

The first phases of work in a furniture factory are kiln-drying, cross-cutting and edging. Figure 3 shows the principle of cross-cutting and edging a board to avoid knots and other defects and to obtain defect-free pieces for the exposed parts of a product. For this reason the grading of boards prior to cross-cutting is usually unnecessary. For many parts, however, various kinds of defects are allowed to a certain extent. Because of the high quality required for furniture, the amount of waste of material is fairly great, usually 40 to 60 per cent of the volume of wood used. The consumption of raw material can often be reduced by gluing smaller pieces side by side when wide components are needed.

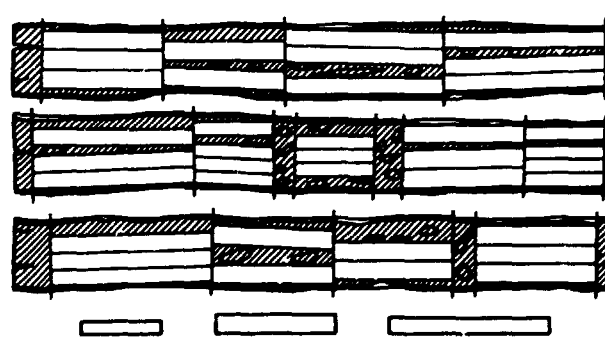
Table 1. Standard thicknesses of birch boards used in the Finnish furniture industry[a]

Raw thickness		*Average thickness after surface and thickness planing*
Millimetres	*Inches*	*(millimetres)*
19	3/4	14
25	1	20
32	1 1/4	26
38	1 1/2	32
50	2	44
63	2 1/2	56

[a]Average length of boards is 4.5 to 5 metres.

In furniture manufacture using unedged timber, the basis for estimating material consumption is usually the net rectangular area of board needed for a certain finished component. When the gross area of rough timber actually consumed is divided by the net area, the so-called waste coefficient is obtained. The value of this coefficient varies from case to case, averaging, in Finland, from 1.4 to 1.8, depending on the kind of wood, the sizes of timber used, the component to be made and quality requirements. Every factory should base the coefficients it uses on studies made in serial production by measuring both the total gross area of rough timber used and the net area obtained when a batch of a certain component is produced. Separate studies should be made for different types of components. The gross volume of raw material needed can then be calculated by simply multiplying the product of rough thickness of timber and the net area of the component by the waste coefficient. The net areas are normally obtained from working drawings or from the prototype of a new product.

Figure 3. Cross-cutting and edging boards



Key: a, b, c } Components to be produced

The timber used in the joinery industry is usually edged. As a conventional method, timber is first kiln-dried, then cross-cut to the required lengths. (Pieces with the worst defects are rejected.) Smaller knots are drilled and plugged. Afterwards the components are usually sorted, those with only minor defects are finished with clear lacquer and the remaining ones are painted. The development of the finger-jointing technique has, however, brought about a new method that greatly improves the material utilization. In this method the boards are cross-cut at the point of the defect; the final product lengths are not taken into consideration at this stage. Both ends of the pieces, which are of random lengths, are trimmed to remove the defects, the ends are machined with finger-jointing cutters, and the pieces are glued together to form a continuous profile. In automated finger-jointing lines, the process consists of four-side moulding followed by trimming to the needed product lengths. In the furniture and joinery industries the joint is normally glued with polyvinyl acetate (PVAc)-type glue. The glue line is colourless, and the joint is less conspicuous than it would be, for example, in structural members glued with weatherproof phenol-resorcinol glue. The finger-jointing technique has proved very suitable for joinery production but it is still less widely used in the furniture industry because of the higher visual quality requirements. It is evident, however, that finger jointing can also be applied in furniture production, at least when making constructional unexposed parts. Examples of finger joints are shown in figures 4, 5 and 6.

Figure 4. Straight and diagonal finger joints for end jointing

A. Machined ends

B. Glued joints showing joint patterns on sides

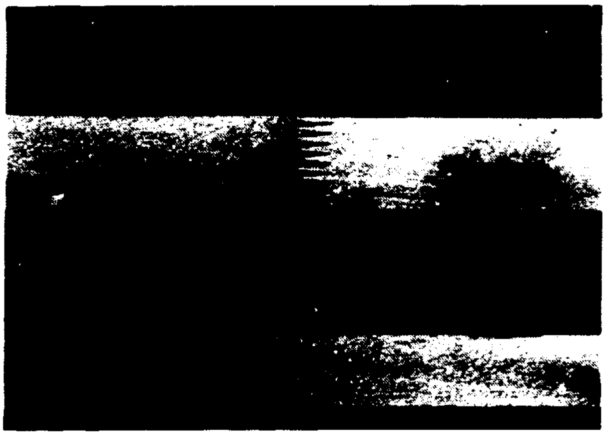


Figure 5. Finger joint as corner joint

A. Mitred end

B. Glued corner with "norms" (below) and finished (top)

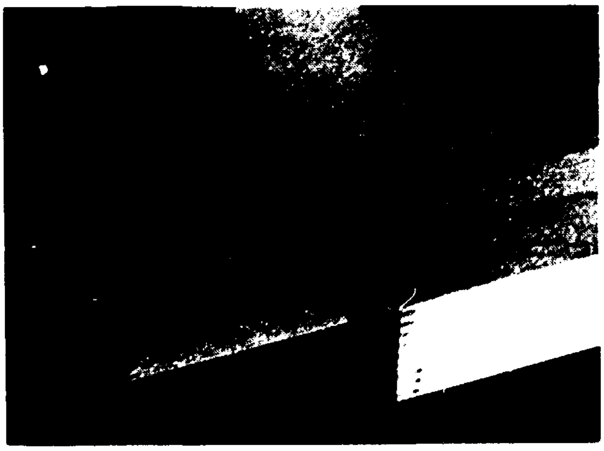
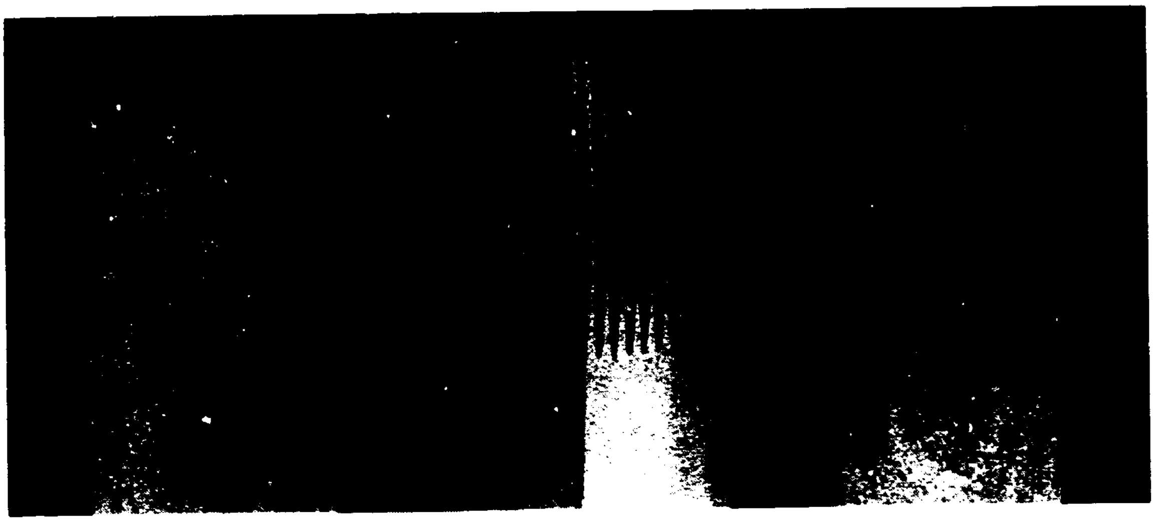


Figure 6. Three-way joint

A. Finger-jointed end, shown from three different directions



B. Glued joint showing voids in the inner corners

Hardwoods and softwoods

Species of trees are divided into two classes: hardwoods, which have broad leaves, and softwoods, or conifers, which have scale-like leaves such as cedars or needle-like leaves; such as pines. These terms do not always apply directly to the hardness or softness of the wood, although most of the commonly used hardwoods are harder than most softwoods. The regions of growth of hardwoods and softwoods are shown in figure 7. The basic properties of the wood are approximately the same in both classes of trees.

Hardwoods are divided further into three groups:

Ring porous (e.g. ash, oak)
Semi-ring-porous (e.g. hickory, teak)
Diffuse porous (e.g. mahoganies, rosewood, walnut)

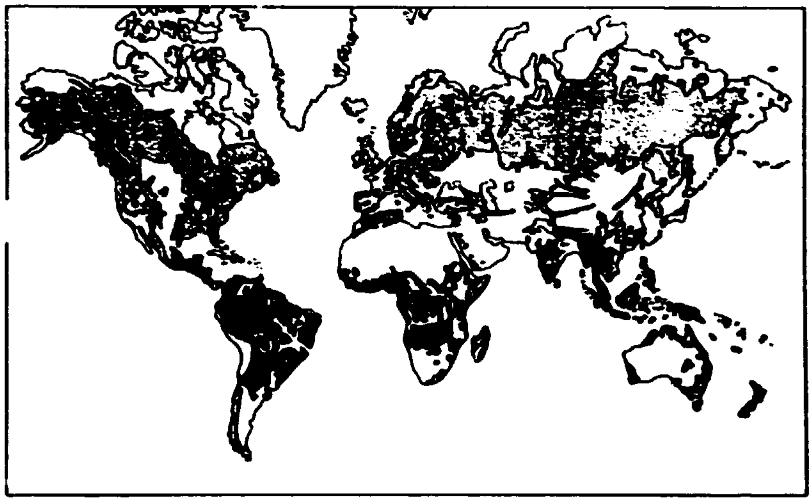
The pores are the cross-sections of water-conducting vessels seen as small round or oval holes in the wood substance when a tree is cut across the grain (figure 8). In a ring-porous species the vessels that develop at the beginning of the growing season are large and clearly visible, while in semi-ring-porous species the pores are more evenly distributed over the growth ring. In diffuse-porous species the pores are often very small and evenly distributed. Most hardwoods belong to the diffuse-porous group.

When the vessels in the wood substance are large (as in oak) they form visible grooves in the surface of the board and thus affect the appearance of the wood, its grain structure, and its finishing and certain other properties.

Factors affecting the properties of the wood substance

The life processes of a tree are divided into periods of growth and rest. Every growth period produces a new growth ring around the preceding ring. Between every two growth periods there is a period of rest caused by seasonal variations (summer and winter, rainy season and dry season). The growth rings are generally clearly visible in softwoods and ring-porous hardwoods, whereas in some diffuse-porous species they are very indefinite. In some tropical regions growth may be practically continuous throughout the year, with no well-defined growth rings being formed. In hardwoods, a rapid growth of thickness brings about a heavier wood substance with better strength properties. Softwoods, on the other hand, usually have a so-called optimal rate of growth that produces the best wood substance.

Figure 7. Regions of growth of hardwoods and softwoods



Note: Shaded areas represent hardwoods and softwoods of temperate and northern zones; black areas indicate tropical hardwoods.

Figure 8. The three main hardwood types

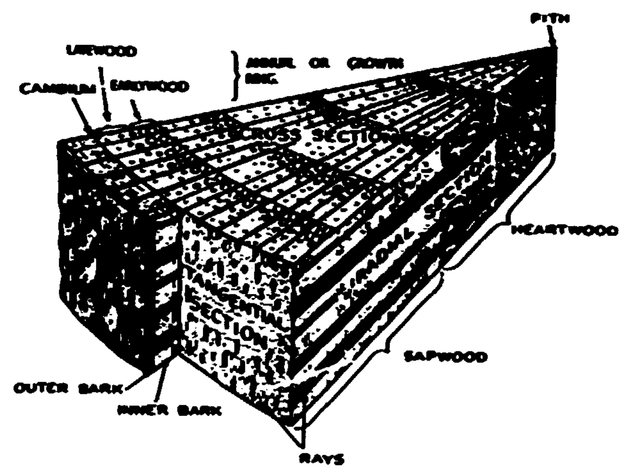
Ring porous Semi-ring porous Diffuse porous

The grain structure on the surface of a sawn board depends greatly on the direction in which the timber has been sawn. The three principal sections of wood are shown in figure 9. The cross-section is often called the end-wood, whereas the radial and tangential sections correspond to the principal sawing directions of timber (figure 10).

When a log is sawn radially (quarter sawing), a narrow striped figure will be obtained. If the tree has large and clearly defined rays, they will be split and appear as flakes on the surface of the board (figure 11). Tangential sawing (plain sawing) yields a more lively figure pattern, but the rays are visible only as cross-sections (figure 12). The more distinct the growth rings are, the more conspicuous the grain configuration will be. The species of tree used determines which sawing direction will yield a more attractive surface pattern. Most frequently, the actual sawing direction on the surface of, for instance, a furniture part is between the principal directions.

Tropical hardwoods, in particular, often have a coloured heartwood that differs very clearly from the more light-coloured sapwood that surrounds it; generally only the heartwood may be used for furniture and joinery products. On the other hand, the sapwood of softwoods, because of its light colour, is sometimes more valuable than the darker heartwood. In some species there is little or no difference in colour between the heartwood and sapwood.

Figure 9. Principal sections of wood



The density of a species is generally considered to be the best criterion of its general characteristics since all wood consists of similar material (density about 1.5 g/cm^3) which is distributed in different proportions in different species. Density affects the properties of wood as follows:

(a) A heavy wood is stronger than a light one;

(b) A heavy wood is harder than a light one, and its surface is usually easier to finish;

(c) A heavy wood increases the weight of structures made from it, since their dimensions, as in furniture, are based primarily on appearance;

(d) A heavy wood usually shrinks and swells more than a light one. This is a very unfavourable characteristic for furniture and joinery products.

Effect of moisture on wood

Wood is composed of hygroscopic cells that take on and give off moisture according to the humidity of the ambient air; under all conditions of service it contains water. The moisture content of wood is always stated as a percentage of dry weight. To determine the moisture content, a specimen is sawn from the timber and the determination is made as follows:

Undried specimen is weighed (m_u) $m_u = 48.6$ g

Specimen is dried to absolute dryness in a laboratory oven at 100 to 105°C

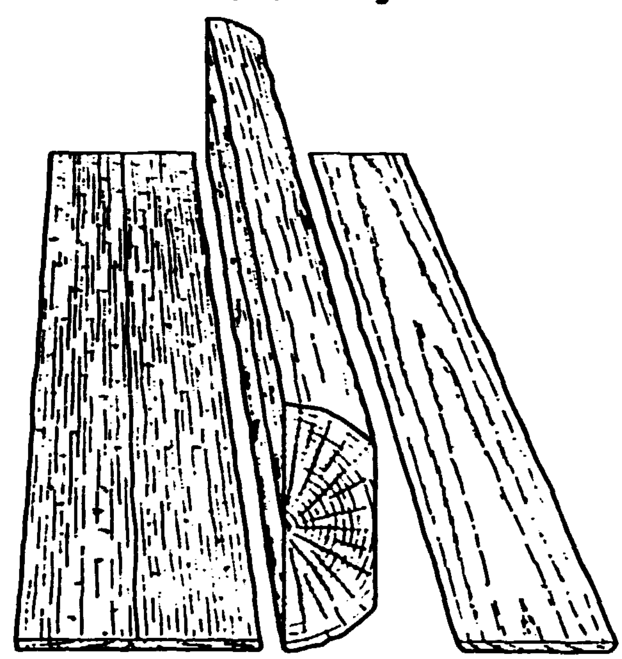
Oven-dried specimen is weighed (m_o) $m_o = 36.2$ g

Moisture content (u) is calculated from the following formula:

$$u = \frac{m_u - m_o}{m_o} = \frac{48.6 - 36.2}{36.2} = \frac{12.4}{36.2} = 0.343 = 34.3\%$$

This method gives a fairly accurate result using an ordinary laboratory balance.

Figure 10. Quarter-sawn (top) and plain-sawn (bottom) boards cut from a log



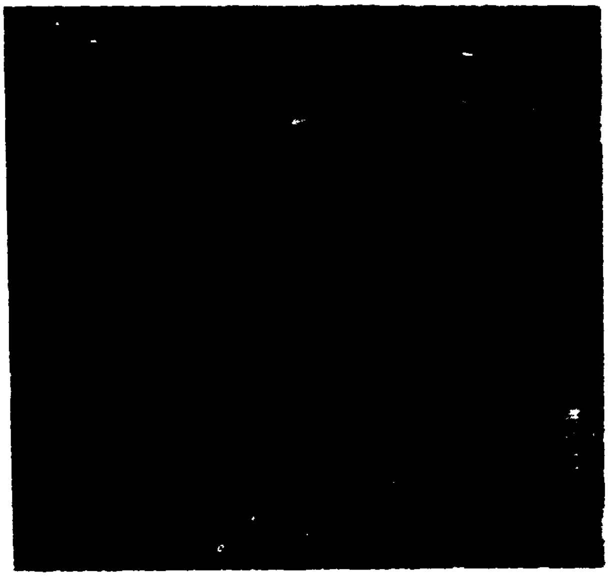
For the rapid measurement of the moisture content of wood, there are electrical moisture meters that give direct readings. They are not, however, as accurate as the drying method described above, but for moisture contents within the range of 6 to 25 per cent they give sufficiently accurate estimates.

The moisture in the trunk of a growing tree is usually so distributed that the sapwood has a considerably higher moisture content than the heartwood. The highest content may be as high as 200 per cent and the lowest only 30 per cent. The difference is greatest in softwoods. Boards sawn from unseasoned timber dry at first without shrinking because all the free water in the cell cavities evaporates first; the cell walls then begin to dry out and the wood begins to shrink. The stage at which the shrinking process begins is called the fibre-saturation point (FSP), and the moisture content at this point is about 30 per cent irrespective of the species of wood. In normal air-seasoning in a lumber yard, the surface of the boards usually reaches FSP quite rapidly and therefore begins to shrink much sooner than the inner parts. The moisture content of furniture and joinery products during manufacture and in service is normally considerably below FSP and therefore within the moisture range where shrinking and swelling take place.

Any piece of wood will give off or absorb moisture to and from the ambient atmosphere until the amount of moisture in the wood is in balance with that in the atmosphere. The moisture content of the wood at this point is called the equilibrium moisture content (EMC). Wood in service is exposed to daily and seasonal changes in relative humidity. Thus, wood is virtually always undergoing at least slight changes in moisture content because of its

Figure 11. Radially cut surfaces showing rays as flecks (life size)

A. Oak



B. Lacewood

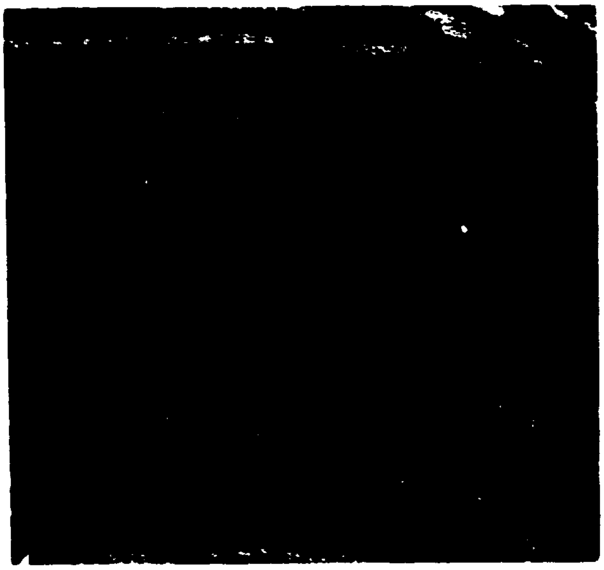
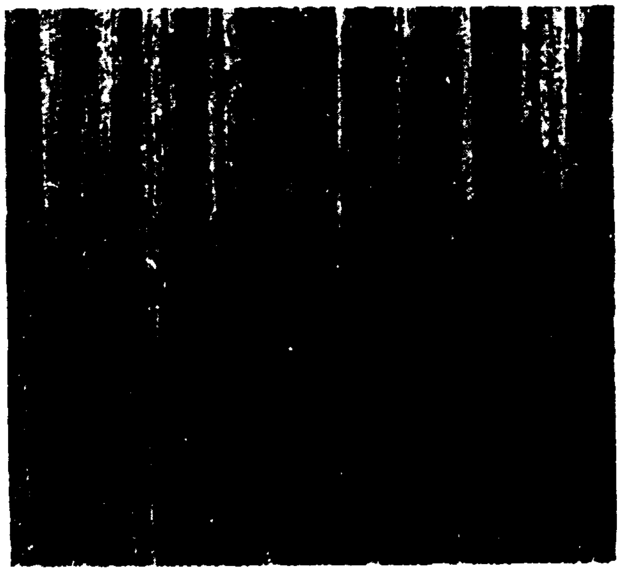


Figure 12. Tangentially cut surfaces showing rays as narrow cross-sections (life size)

A. Oak



B. Lacewood

tendency to come into balance with the relative humidity of the ambient air. The practical object of all correct seasoning, handling and storing methods is to minimize moisture content variations in wood in service by fabricating or installing the wood at a moisture content corresponding to the average atmospheric conditions to which it will be exposed.

EMC of wood depends not only on the relative humidity but also on the temperature of the ambient air. The correlation of EMC and the relative humidity of air at a constant temperature for spruce is presented in figure 13. The so-called sorption curves show that EMC is a little higher when reached by drying (desorption) than it is when reached by wetting (adsorption). The difference is small, however, and for all practical purposes an average curve, drawn between the two curves, is normally used. The behaviour of most wood species is very similar to that shown in figure 13. The curves in figure 14 apply to all species of wood with sufficient accuracy, giving EMC as a function of relative humidity and temperature. The effect of the latter is much less than that of the relative humidity. It should also be noted that EMC corresponding to 100 per cent relative humidity is FSP. Some values obtained from figure 14 are shown in table 2. The nominal moisture contents of timber for different uses are shown in figure 15. The values apply to average service conditions of wood in a Central European climate.

The shrinking and swelling of wood when exposed to variations in moisture are among the most unfavourable properties of wood. As shrinking and swelling are opposite phenomena, it has become customary to speak only of shrinking. Wood shrinks according to the following principles:

(a) Shrinking occurs only when the moisture content of the wood is below the FSP (approximately 30 per cent);

(b) The shrinkage in volume (V) of a piece of wood in the moisture range of 30 per cent to 0 is equivalent to the amount of water given off. For example, when 1 kg of water is given off, the shrinkage in wood volume is 1/dm³;

Figure 13. Sorption curves of untreated spruce timber at 25°C

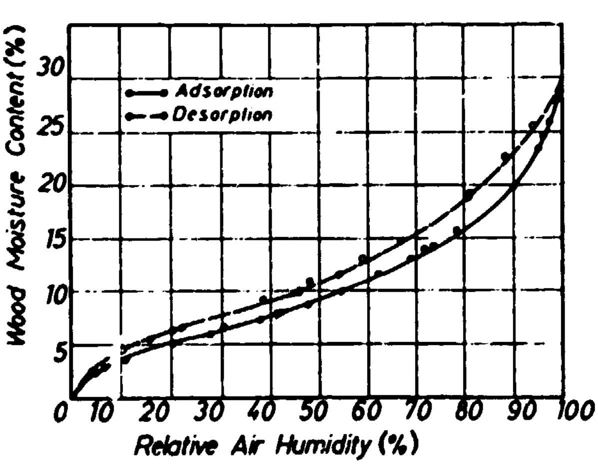


Table 2. Equilibrium moisture content of wood

Relative humidity of air (percentage)	*Temperature (°C)*	*Equilibrium moisture content of wood (percentage)*
	20	7.7
40	30	7.5
	40	7.0
	20	9.3
50	30	9.0
	40	8.6
	20	10.9
60	30	10.6
	40	10.1
	20	13.0
70	30	12.6
	40	12.1
	20	16.0
80	30	15.5
	40	15.0
	20	20.8
90	30	20.0
	40	19.3
	20	Fibre saturation
100	30	point, about 30%
	40	

(c) Shrinkage is greater in the tangential direction (T) than in the radial direction (R);

(d) Shrinkage in the longitudinal direction (L) is so slight that it can be disregarded in practice;

(e) In general, heavy species of wood shrink more than light-weight species. However, various additional materials contained in the wood substance cause exceptions to this rule, as in teak.

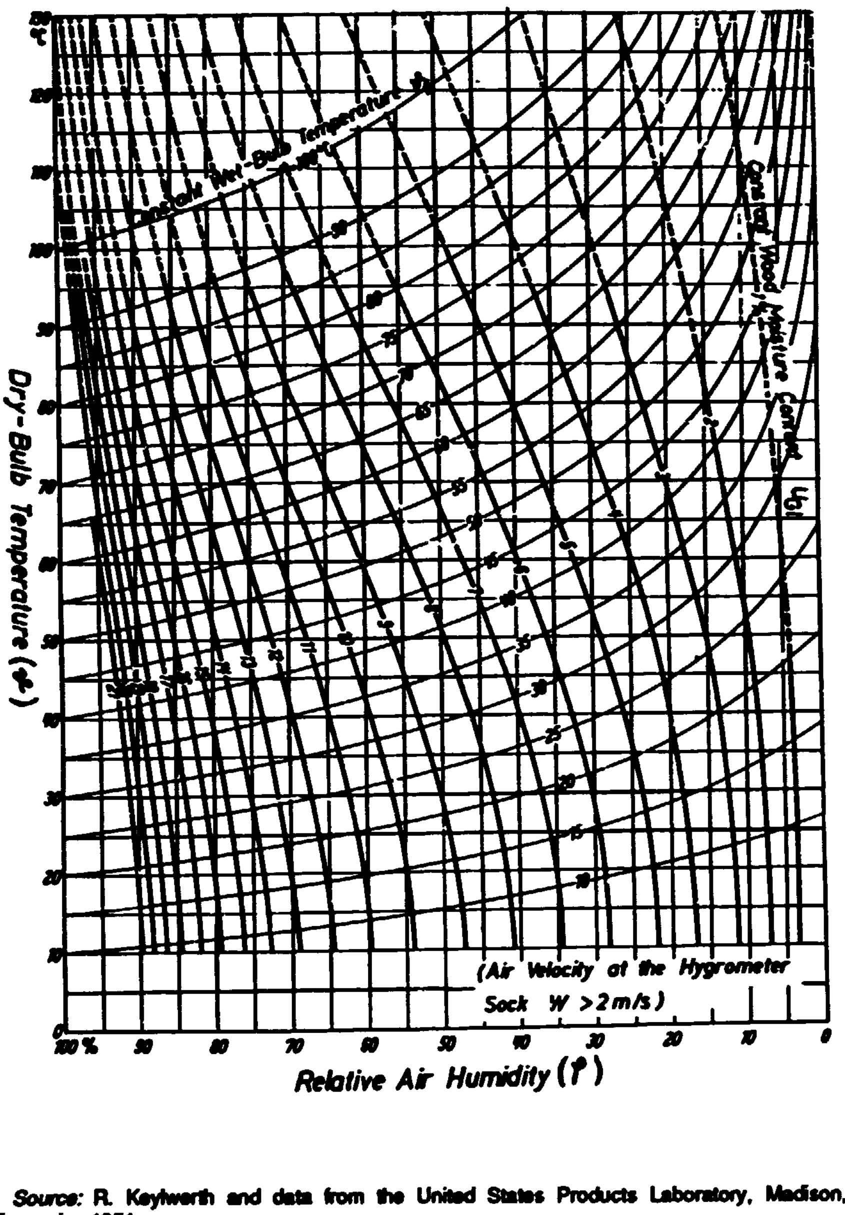
The moisture stability of different species of wood may be compared on the basis of their maximum shrinkage (table 3).

Table 3. Density and maximum shrinkage of some important wood species

Species	*Density at 0% moisture (g/cm³)*	*Maximum shrinkage*ᵃ L	R	T	V
			(percentage)		
Douglas fir *(Pseudotsuga taxifolia)*	0.51	0.3	5.0	7.8	13.0
Oak (European) *(Quercus pedunculata)*	0.65	0.4	4.0	8.8	13.0
English walnut *(Juglans regia)*	0.64	0.5	5.4	7.5	13.9
Teak *(Tectona grandis)*	0.63	0.6	3.0	5.8	9.4
Mahogany (American) *(Swietenia mahagoni)*	0.55	0.3	3.2	5.1	8.9
Gaboon *(Aucoumea klaineana)*	0.3	0.2	4.1	6.6	10.9

ᵃL = longitudinal, R = radial, T = tangential, V = volumetric

Figure 14. Moisture content equilibrium of timber



Source: R. Keylwerth and data from the United States Products Laboratory, Madison, Wisconsin, 1951.

(Example: With a dry-bulb temperature v = 45°C and a relative air humidity φ_L = 55%, respectively, the wet-bulb temperature would be v_f = 36°C and the wood equilibrium moisture content u_g = 9%).

he approximate dimensional changes of pieces of wood esulting from changes in their moisture content can be alculated rather simply. For example, the amount that 100-mm-wide mahogany board, cut tangentially to the growth rings, will shrink when its moisture content is reduced from 20 per cent to 10 per cent can be calculated as follows:

Maximum shrinkage in T direction (see table I.3)	5.1%
Original width at 20% moisture content	100 mm
Change in moisture content (20% to 10%)	10%
FSP	30%

Approximate shrinkage of board

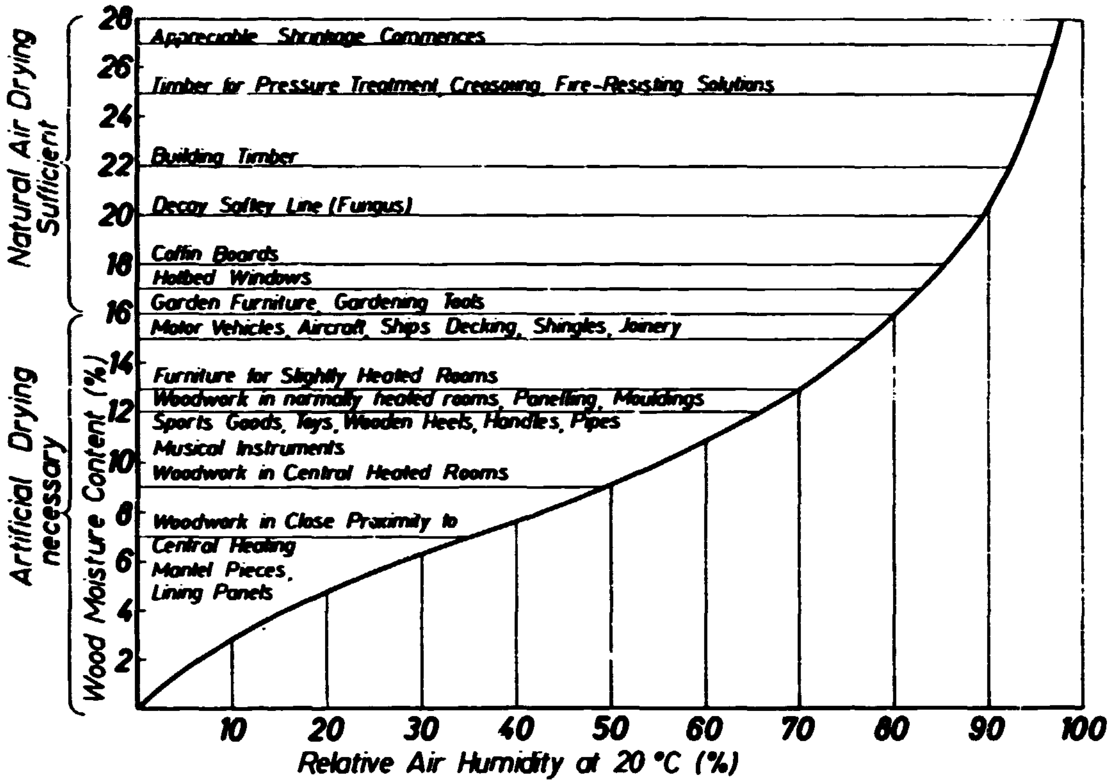
$$= 5.1\% \times 100 \text{ mm} \times \frac{10\%}{30\%}$$

$$= 0.051 \times 100 \times \frac{0.10}{0.30} \text{ mm}$$

$$= 1.7 \text{ mm}$$

The swelling that results from an increase in the moisture content may be calculated in a similar manner.

Figure 15. Nominal moisture contents of timber for different uses



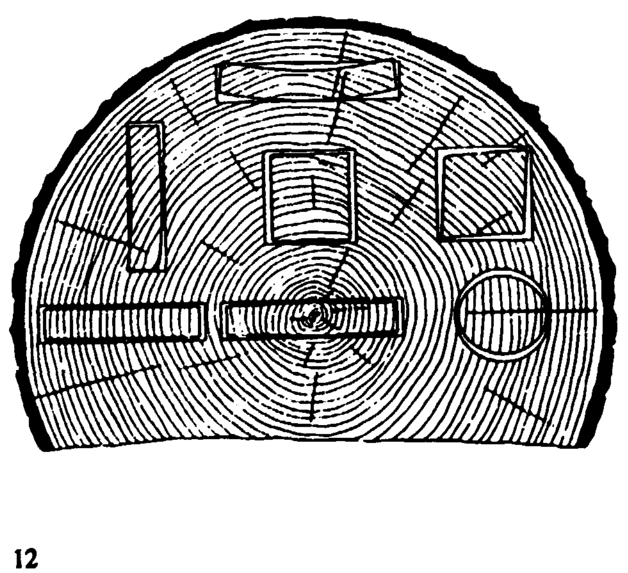
The shrinking and swelling of wood give rise to the following drawbacks:

(a) The dimensions of pieces undergo change;

(b) Deformations develop in the cross-section of pieces because shrinkage is considerably greater in the T direction than in the R direction (figure 16);

(c) If deformations are not allowed to develop freely, harmful internal stresses will arise in the pieces.

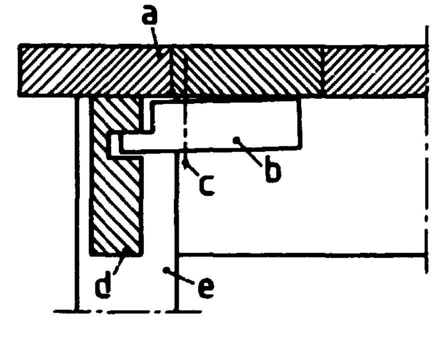
Figure 16. Shrinkage deformations in cross-sections



Two alternative principles are therefore followed in constructing furniture and joinery products. Deformations are either allowed to develop freely (figures 17 and 18) or are totally prevented (figure 19).

Figure 17. Construction that allows deformations to develop freely

A. Use of "buttoning" in a chair



Key: a Solid wood seat
b "Buttoning"
c Place for screw
d Rail
e Leg

B. Underside of chair, with the rear end of the seat panel glued on the rail

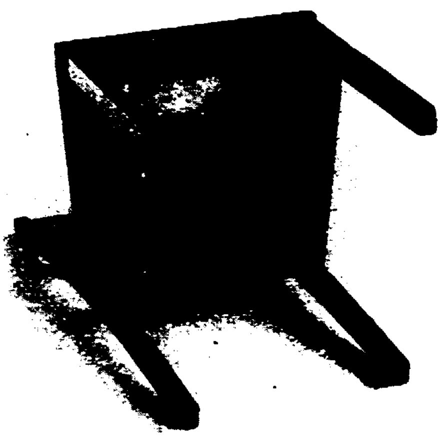


Figure 18. Damage as result of a high relative humidity and an insufficient moving allowance

Drying (seasoning) of timber

The following aspects are to be considered in the drying of timber:

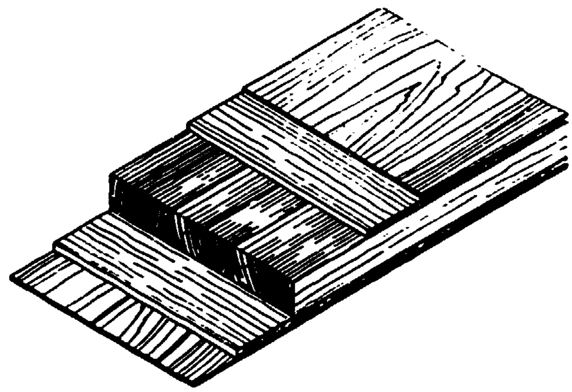
(a) The logs are "sawn wet", the moisture content of the wood usually being considerably above FSP;

(b) The object of drying is to attain a moisture content that will correspond to the conditions to which the wood will be exposed later when in use;

(c) The moisture in dried timber must be evenly distributed and the wood free from stresses. These results can be obtained only by correct drying.

Timber is seasoned either by air-drying or kiln-drying. In air-drying, the boards are stacked with piling strips ("stickers") between the layers, as noted above. The stacks must always be under a roof. The risk of damage by insects and fungi is great, particularly in tropical climates. The timber yard is normally composed of timber stacks laid out in straight rows separated by narrow aisles (1- to 2-metres wide). For transportation, broader lanes (8- to 10-metres wide) are needed between the stack blocks. Transportation is normally done with either fork-lift trucks or tractor-trailer units; narrow-gauge railway arrangements are considered obsolete. The orientation of the main lanes is usually made to follow the prevailing wind direction. The surface of the yard must be level and covered with gravel in order to be permeable to water and to be hard enough for the transportation arrangements. The stack foundations are made preferably from concrete blocks to permit air circulation under the stacks. The height of these blocks averages about 60 to 80 cm.

Figure 19. Construction to prevent the development of deformations

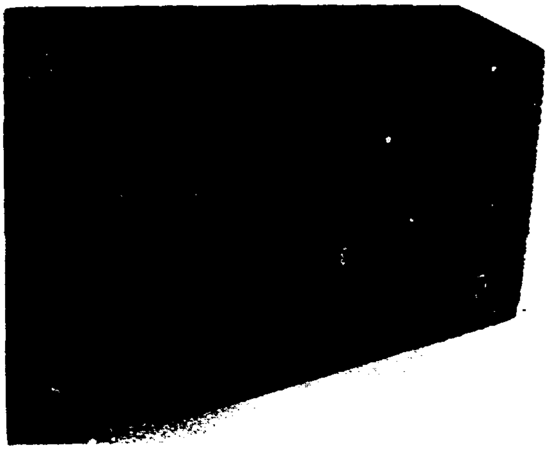


The principle of kiln-drying is to reduce the moisture content of the wood gradually by the application of heat. (Heated air can hold more water than cold air.) Moist air is removed from the drying kiln and replaced by dry air until the wood has attained the desired EMC. Careful attention to and close control of all phases of the process are necessary for successful drying.

The general practice is to kiln-dry furniture and joinery timber to a slightly lower moisture content than the service conditions demand, counting on a moderate increase in moisture content during the storage and manufacturing periods. This practice is intended to assure uniform distribution of moisture among the individual pieces. If the lowest equilibrium moisture content of a wood in indoor service during a given season is, for example, 10 per cent, the moisture content selected for furniture timber may be about 8 per cent.

Certain hardwoods, especially thick boards, present particular difficulties in drying. Kiln-drying that is begun too rapidly will result in case-hardening and consequently in splitting inside the board (figure 20). This phenomenon is usually called honeycombing because of the empty spaces inside the wood. Sometimes the total charge of timber may become unserviceable because of this drying defect (as shown in figure 20). Other common kiln-drying defects are surface checking, end splitting and checking, collapse and various forms of distortion. Some species of wood are more prone to develop these defects than others. In certain cases, special reconditioning treatments are possible at the end of the drying process.

Figure 20. Inside splits in oak timber caused by case-hardening



The best way to ensure good drying results is to follow carefully the drying schedule that is known to be most suitable for the species in question. The schedules available in literature are normally based on laboratory experiments or practical experience. Drying schedules suitable for certain timbers are given in tables 4, 5 and 6. During the drying operation the relative humidity of air in the kiln atmosphere must be maintained at the given value (column 6) until the moisture content of the wood has been lowered to the value given in column 1. The tables apply to timber thicknesses up to 38 mm. When the thickness is greater the values of relative humidity should be kept lower to avoid drying defects.

Table 4. Kiln schedule suitable for gaboon, iroko and Indian rosewood etc.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	*Temperature (dry bulb)*		*Temperature (wet bulb)*		*Approximate relative humidity (%)*
	°F	°C	°F	°C	
Green	120	48.5	115	46	85
60	120	48.5	113	45	80
40	125	51.5	116	46.5	75
30	130	54.5	117	47	65
25	140	60	120	49	55
20	155	68	127	53	45
15	170	76.5	136	58	40

Source: W. C. Stevens and G. H. Pratt, *Kiln Operator's Handbook* (London, HM Stationery Office, 1971).

The drying process is controlled by a kiln sample, which is frequently taken out of the kiln, usually through a small hatch in the kiln door, to determine the moisture content. The value thus obtained is regarded as the average for the whole charge. The recommended way to cut the kiln samples is as follows: a board, which can be assumed to have an average moisture content, is selected from the charge and cut as shown in figure 21. The average moisture content of the actual kiln sample (C) is determined from sections (A) and (B) by using the oven-drying method as explained above. The dry weight of the kiln sample (C) can be calculated according to the average moisture content obtained from sections (A) and (B). These samples are naturally sawn from timber to be dried before loading the kiln.

Table 5. Kiln schedule suitable for European birch, African, Central American and Cuban mahogany and red meranti etc.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	*Temperature (dry bulb)*		*Temperature (wet bulb)*		*Approximate relative humidity (%)*
	°F	°C	°F	°C	
Green	120	48.5	111	44	75
60	120	48.5	109	43	70
40	125	51.5	109	43	60
30	130	54.5	109	43	50
25	140	60	115	46	45
20	155	68	124	51	40
15	170	76.5	136	58	40

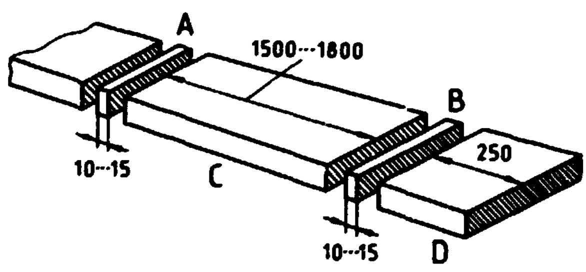
Source: W. C. Stevens and G. H. Pratt, *Kiln Operator's Handbook* (London, HM Stationery Office, 1971).

Table 6. Kiln schedule suitable for South American cedar, makoré and teak etc.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	*Temperature (dry bulb)*		*Temperature (wet bulb)*		*Approximate relative humidity (%)*
	°F	°C	°F	°C	
Green	135	57	127	53	80
50	135	57	126	52	75
40	140	60	126	52	65
30	150	65.5	129	54	55
20	170	76.5	136	58	40

Source: W. C. Stevens and G. H. Pratt, *Kiln Operator's Handbook* (London, HM Stationery Office, 1971).

Figure 21. Cutting kiln-drying samples



Key: A and B Section for moisture determination
C Actual kiln sample
D Rejected end

Example:

(A) Original weight $m_u = 93.1$ g
Weight at absolute dryness $m_o = 68.2$ g

$$u = \frac{m - m_o}{m_o} = \frac{93.1 - 68.2}{68.2} = 0.365 = 36.5\%$$

(B) Original weight $m_a = 98.4$ g

Weight at absolute dryness $m_o = 71.9$ g

$$u = \frac{m - m_o}{m_o} = \frac{98.4 - 71.9}{71.9} = 0.369 = 36.9\%$$

The average moisture content of the kiln sample (C) can be assumed to be

$$u = \frac{0.365 + 0.369}{2} = 0.367 = 36.7\%$$

Note: The final result should be given to one decimal place.

The weight of the kiln sample (C), when cut, was $m_u = 12.48$ kg. Now the dry weight of (C) can be calculated according to the average moisture content of 36.7 per cent (above) as follows:

$$m_o = \frac{m_u}{1 + u} = \frac{12.48 \text{ kg}}{1 + 0.367} = 9.13 \text{ kg}$$

When the kiln sample (C) is taken out through the sample hatch and weighed, the moisture content can be calculated, since the dry weight m_o is known. For instance, the moisture content of 10.90 kg of (C) will be as follows:

$$u = \frac{10.90 - 9.13}{9.13} = 0.194 = 19.4\%$$

The sample must be returned to the kiln immediately after weighing to prevent it from drying outside the kiln. If this happens, the weighing results will be misleading. It must also be pointed out that the sections chosen for moisture determination must be free of defects like knots.

Quality standards of sawnwood for furniture manufacture[2]

There are no international quality standards for sawn wood that is intended for furniture raw material, although there are for sawn softwood intended for building purposes. In North America it is common practice to grade according to NHLA standards, whereas in Europe the Malayan export grading rules for sawn hardwood are accepted increasingly for south-east Asian species. As noted above, the grading of boards in furniture manufacture does not answer the same purpose. Individual furniture manufacturers make up their own grading standards which define the quality of wood required for each particular part of a product. The standards usually contain 3 to 5 grades according to the type of products manufactured. These grades refer to the quality of individual cut-out pieces or components, not the quality of whole raw-dimensioned boards. The size and number of faults permissible in each grade of board must be closely specified. The grade required for each piece is noted in the piece list. In a four-grade classification, the uses of the different grades can be specified as follows:

Grade I: Parts always exposed, such as table-tops, drawer fronts and chair legs

Grade II: Temporarily exposed parts, such as drawer sides and backs

Grade III: Unexposed parts, such as binding components and parts to be painted

Grade IV: Blindwood (parts to be veneered)

The booklet "Technical protocol" published by the Danish Furniture Makers Control, an organization sponsored by Danish furniture makers and the Technological Institute of Copenhagen, defines the standard requirements of solid wood for use in high-quality furniture as follows:

Woods. All materials must be of good quality.

Softwoods. All softwoods used must be sound and free from fungal or insect attacks. Softwoods must be without barky edges, resin galls, checks, shakes or "dead" (i.e. black or loose) knots.

Occasional sound knots may be tolerated, provided that they do not tend to weaken the total stability of furniture or parts thereof, as in special constructive joints. Sound knots, however, should not be more than one fourth of the width of the material and never more than 20 mm in diameter.

Hardwoods. All hardwoods used must be sound and free from defects caused by fungal or insect attacks. There must be no checks, shakes or other defects, and knots should generally not be tolerated.

In hardwoods with specific formation of heartwood, such as oak, teak, mahogany and rosewood, there must be no sapwood. In the case of French, Italian or other European walnut, sapwood may be used.

For furniture, including especially tables and chairs, the designing and construction of which make special demands on the strength of the wood, annular-pitted woods such as ash, oak and teak must not be too "mild", that is, too slowly grown. If such furniture is made of annular-pitted woods, the width of annular rings, that is, the growth zones of the wood, should usually not be less than 2.5 to 3 mm.

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[2]See also chapter XVII, "Technical product design".

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II. The requirements and use of wood-based panels in furniture manufacture*

This chapter concerns some of the uses of the various panel products in the furniture industry. It may be worthwhile mentioning that there is no perfect product. The advantages must be weighed against the disadvantages, both technical and economic, in deciding on the appropriate product to make or use in any specific case. The choice depends on the needs and varies from country to country.

Trends

The demand for wood-based panel products has existed ever since flat surfaces became a requirement for furniture. There is a natural affinity between this class of product and almost all kinds of domestic and institutional furniture.

Technological improvements have permitted the manufacture of panels having not only flat surfaces but also many of the other rather exacting requirements of the furniture industry, such as dimensional stability and accuracy and appropriate surface and good strength properties. While solid wood or glued-up panels of solid wood may offer good standard qualities, the various wood-based panel products available today have particular improvements that make them more suited than planed wood for a wide variety of applications. In short, the processing methods have been improved and specialized by the introduction of large serial industrial production.

Many of these improvements in panel qualities and varieties have been brought about by pressures from the furniture industry. The qualities making panels suitable for building and packaging are usually related to rigidity, racking and impact resistance, durability and fire, insect and mould resistance. However, of special importance to the furniture industry are dimensional accuracy and stability, high strength perpendicular to the surface, screw-withdrawal resistance and surface characteristics that allow high quality coating and films and laminates to be applied. Development has gone hand in hand with the needs of these major user industries.

The general trend is towards healthy increases in consumption of all panel types, although trends in their uses in furniture differ by type. Particle board has become, in many countries, the prime panel material for most kinds of furniture, but fibreboard has maintained a strong position in certain very specific uses. Plywood was considered a relatively cheap product for furniture, but in countries that have established a particle board industry it has been replaced by the latter in lower-cost items. It is still used as a special material in modern, bold designs. Another factor accelerating the acceptance of particle board is that the large size of the panels results in smaller waste in serial production.

One reason for the generally expanding use of panels in the furniture industry is the higher cost of solid sawn wood, higher labour costs and the lower quality of sawn wood. The processing of flat components on a mass-production basis has been facilitated through the development of special high-capacity automated lines to machine and surface coat them.

A general shortage of good-quality solid wood and the accent on efficient utilization of residues have strongly influenced the greater use of panels in furniture. However, in developing countries this influence has been lessened by the generally high cost of resins and, to some extent, by the rather high initial investment required for mills and by the technological level of the processes.

The interrelationship between economies of scale, limited local demand and short economic transport distance are difficult to quantify, but, in general, local markets within delivery range are too often insufficient to warrant production. One major hindrance to more widespread acceptance of panels has often been their inconsistent quality during early stages of local production. Small plants cannot manufacture a complete range of panels, not only in thicknesses and densities but also in sanded or non-sanded form, using various glues etc. This limits demand because panels are often used incorrectly, leading to consumer resistance.

Prices

Since quality standards have been attained that permit panels to be successfully coated, overlaid or veneered, their availability in large custom-ordered sizes has saved furniture manufacturers considerable cost in raw materials. Thus, the panel manufacturers have borne large investment costs which smaller units could not afford. Waste from trimming to size and from the normal operations of lumber defecting has also been reduced through the use of custom-ordered panels.

Other cost advantages are the result of smaller demands for kiln-drying or air-drying lumber, although in most cases facilities for such purposes must be maintained for the smaller amount of solid wood used. Storage under controlled conditions of humidity is more important for panel materials than for solid wood, and the cost must be more than offset by savings in material and labour to justify the use of panels.

*Prepared by the secretariat of UNIDO as a background paper for the World Consultation on Wood-Based Panels, convened by the Food and Agriculture Organization of the United Nations (FAO) at New Delhi, India, from 6 to 16 February 1975. It has been issued as FAO document FO/WCWBP/75, Doc. No. 130, and as UNIDO document ID/WG.209/1. Excerpts from this paper have also been incorporated in chapters III, IV and V.

The tendency of firms to specialize in making only certain types of furniture and to become assemblers rather than processers is supported by more widespread use of panels and continuous improvements in their quality. This allows and in fact encourages the growth of producers of specialized components with a concomitant increase in efficiency and reduction in unit cost. Once again, long production runs for drawer side, turned parts and flat pieces to fill standing orders of large furniture makers provide the opportunity to plan and schedule machine and labour use and hence reduce costs.

A long-term effect of inflation is to make forest management a more expensive proposition unless great attention is paid to proper utilization of wood residues from sawmilling, veneer peeling and secondary manufacture. The profitability of plantations and managed woodlots is extremely sensitive even to small changes in interest rates, and this makes residue utilization (for panels) increasingly rational as higher and higher yields are sought from the exploited timber.

An increase in the number and size of wood-processing complexes will no doubt result from this pressure. The relative prices for solid wood and composite products may no longer be determined so much by market supply and demand as by the internal costing systems used by the complexes themselves. Furthermore, it is to be hoped that complexes will develop that will bring together several industries, each using the others' waste by-products to conserve raw materials and energy, reduce internal transportation and raw material costs and cut down on the amount of undesirable effluents released into the biosystem.

Principle uses of panels in furniture

The need for low-cost, flat, homogeneous and easily decorated surfaces has been largely responsible for the growth of panel application in the furniture industry. The qualities of precision planeness, dimensional stability, equal strength along the two axes and acceptable strength have made particle board especially suitable for the tops of tables and desks, the ends of buffets, commodes and dressers and the sides, tops and shelves of bookcases. Fibreboard has been most commonly applied in "backing" where its rigidity and light weight contribute to the solidity of desks, built-in closets and kitchen cupboards and dressers, commodes and buffet types of home furniture. Drawer bottoms are also very commonly made of fibreboard; however, moulded-plastic drawers are replacing this use to some extent in low- to medium-priced furniture.

The use of plywood in furniture seems to be diminishing, but its role is also changing. Whereas it had been considered primarily as cheap structural wood and was used in carcassing and hidden parts of upholstered furniture, it is now taking on a glamorous role for clear or brightly coloured, stained finishes with no attempt made to hide the plys. Better-quality, primarily hardwood and plywood must therefore by used for this purpose.

The advantages of particle board, and of fibreboard particularly, can be greatly enhanced with overlays either applied at the mill or in the user's factory. In fact, most particle board for the furniture industry is now delivered with an overlay and the edge-banding is left to be done by the user following cutting to size.

A newcomer on the market is medium-density fibreboard (MDF). The major user of MDF is the furniture industry. MDF has however also been used for doors and carcasses, drawer fronts, shelving units, kitchen cabinets, plain and carved mirror frames and various mouldings; it can be finished with coatings or by overwrapping with decorative papers, foils or real wood veneers.

It is increasingly apparent that technical after-sales service and advice must be provided to ensure that panel products shall be used to their fullest extent and that the processing and application of hardware shall be carried out properly. Otherwise, consumer acceptance will decrease after discouraging attempts to use traditional (wood) techniques. This service should also be extended to include maintenance of the carbide-tipped cutting tools generally recommended for particle board, particularly for the smaller industrial user, and stocking the special hardware used with it.

Technical requirements of, and use of panels by, the furniture industry

The furniture industry has exacting requirements for panels. The specifications of the building industry are concerned with characteristics of weathering, durability, fire, insect and mould resistance and such strength properties as racking resistance, rigidity and impact resistance (especially panels for doors and partitions). Panels intended for furniture, on the other hand, must be dimensionally accurate and stable, be flat with surface properties that allow high-quality coatings, laminates and films to be applied, have good strength perpendicular to the surface and also have suitable edge characteristics, screw-withdrawal resistance and other specific properties. Density alone does not specify quality in particle board.

Plywood and blockboard are less susceptible to the high quality requirements of particle board since they are more commonly used in structural or hidden applications. Fibreboard is usually coated or covered in the factory, and the main problem confronting users is in machinery since edge-chipping is common unless great care is taken.

Particle board is the one panel that can be readily covered or coated in the furniture plant or can be bought pre-finished. For any panel product, however, it is difficult to decide: *(a)* whether to make one's own or buy ready-made stock; and *(b)* whether to buy unfinished board and apply one's own surface coating or overlay or buy pre-finished panels. The decision depends *inter alia*, on the volume purchased, the size of the series, the availability and costs of local services etc. Modern methods of furniture construction, particularly with respect to fittings and finishes, have been made possible only by the recent improvements in particle board quality.

The main advantage of MDF over other wood-based panels, especially that of particle board, lies in its fine texture and solid core.

High-quality effects such as rounded edges or complex edge profiles, previously obtainable only with hardboard and solid wood, are obtainable using MDF. A piece of MDF that is edge-routed and face veneered can replace plywood or veneered particle board with hardboard or solid-wood lipping, hence reducing labour costs. However, its cost is higher than that of the other wood-based panels.

Built-in kitchen storage areas are an example of a rapidly growing consumer item, and panels—both particle board and fibreboard—are an ideal raw material for their construction. Standardized sizes and styles could well be produced in certain developing countries where Western-style housing is popular.

Plywood appears to be becoming too expensive to use in anything but "designer" furniture (often moulded), in Europe at least, and its use in developing countries will depend largely on whether local plywood is made in a variety of grades and on the availability and comparative cost of other wood-based panels. It is, however, a relatively low consumer of energy, and the Fédération européenne de l'industrie du contreplaqué (FEIC) has estimated that 916,200 kcal is required per m^3 produced. These energy requirements may be broken down as follows:

Electric power	15%	160 kWh/m^3
Heavy fuel oil	75%	0.070 tons/m^3
Wastewood	10%	0.030 tons/m^3

This aspect will become increasingly important since energy will probably continue to command premium prices and developing countries that must import energy will be even more conscious of this factor in the future.

The use of significant quantities of any panel in furniture making requires additional investments in handling and converting equipment. This applies down the line, from new or different storage areas and facilities for incoming panels, modified internal transportation means (and perhaps more space between machines) and special panel trim saws for initial cutting to size to specialized edge-banding machinery, presses to apply surface overlays, wide-belt sanders, curtain-coating equipment and driers. Double-end tenoners in tandem are also common in larger modern plants. These requirements put a different light on the decision to use panels in furniture in developing countries. It is no longer enough to add a few extra or higher-quality planers, drill presses, band-saws or such standard woodworking machinery; it is necessary to reorganize production and adopt modern serial production techniques to expand in this direction. An entrepreneur wishing to produce the type of furniture made possible by the ever-improving characteristics of panel products (especially particle board) must contemplate a near total reorganization of the existing plant or the erection of a new one.

Among others, the gluing department must be strengthened since most panel furniture joints are made with adhesives. Designs must be adapted to the new materials and craftsmen who are accustomed to working with solid wood will have to be reoriented towards the particular strengths and weaknesses of panels. For example, joints that would tend to cause delamination failure must be avoided (owing to the low strength perpendicular to the surface particularly of particle board).[1]

A recent estimate from the United Kingdom of Great Britain and Northern Ireland indicated that "about 90 per cent of domestic furniture and a high proportion of office and contract furniture were already being made from chipboard"[2] and concluded that any increased demand (for particle board) would arise from an increase in the production of furniture rather than from an increase in use per unit. These figures can be used by developing countries as targets and can be held up as examples of how much particle board can be used in furniture. Table 7 shows the percentage of panels used in furniture. Although the figures are somewhat out of date, they do point out the considerable variation in practice between countries and also the fact that panel products as a whole

Table 7. Percentage of panels used in furniture, 1964-1965

	Austria	*Belgium*	*Canada*	*Chile*	*France*	*Germany Fed. Rep. of*	*India*	*Japan*	*Nigeria*	*Poland*	*Sweden*	*United Kingdom*	*United States*	*Yugoslavia*
Plywood	60	30	5	30	35	55	3	28	20	72	48	...	42	83
Blockboard	86	20	...	75	...	62	67	...	30	88	90	...	...	88
Hardboard	62	15	15	42	15	56	...	11	15	36	41	5	18	77
Particle board														
Flat-pressed	71	70	60	26	56	68	39	46	...	99	61	52	44	93
Extruded	...	...	25	45	...	...	28	...	...	68	...	...	90	16

Source: Various sources, including FEIC and UNIDO secretariat files.

[1]For articles on particle board conversion, see Leo Mitlin, ed., *Particle Board Manufacture and Application* (Ivy Hatch, Sevenoaks, Kent, Pressmedia, 1968), chaps. I-III, pp. 121-137.

[2]T. Sparkes, "Chipboard in furniture", *Marketing Chipboard in the 70's*, *Timber Trades Journal, CPA Conference Report* (supplement to the *Timber Trades Journal and Woodworking Machinery*), 4 May 1974, pp. 12-13.

are widely accepted by the furniture industry. Table 8 shows a recent (1972) breakdown of the market for particle board in Australia.[3] Total consumption was 14 million m^2 (20-mm basis) in 1972 with a forecasted consumption of over 35 million m^2 in 1980.

Table 8. Breakdown of market for particle board in Australia, 1972 (percentages)

Furniture and fittings	
Domestic furniture	31
Domestic fixtures	17
Commercial furniture and shopfitting	10
Total	58
Appliances	
Cabinets	8
Partitions	4
Vehicles and other industry	8
Retail (do-it-yourself)	6
Total	26
Building	
Flooring	4
Formwork	2
Fittings	9
Total	15
Subtotal	99
Government	1
Total market	100

Source: T. Sparkes, "Chipboard in furniture", *Marketing Chipboard in the 70's, Timber Trades Journal, CPA Conference Report* (supplement of the *Timber Trades Journal and Woodworking Machinery*), 4 May 1974, pp. 12-13.

End-use patterns for developing countries will continue to vary widely since geographical and historical influences play such an important role in determining which panels are used for various products. As an example, Nigeria began using plywood because plywood mills were established in the country and thus cornered the market. It is veneered locally, but often with imported veneers since indigenous face veneers command high prices as exports. Some 6-mm particle board is produced as ceiling board, but the production of thicker boards suitable for veneering (for use by the furniture industry) has been proposed and will certainly take over a fair share of the furniture market. Fibreboard is little used because it is not made locally.

Such factors would indicate that the use of panels has less to do with the characteristics of the panels or boards themselves and more with their availability at reasonable prices. The local users (furniture makers) are probably able to adapt their designs to use whatever meterials are at hand, provided or course that the quality is acceptable. Greater use can naturally be obtained through the provision of appropriate technical help with cutting, machining and the fitting of hardware and connectors.

[3]From correspondence with Pyneboard Pty. Limited, Sydney, Australia.

III. The use of plywood and blockboard in the furniture and joinery industries*

Wood-based panels are among the main raw materials used in modern furniture and joinery industries. Their use has increased with the increase in the demand for smooth, uniform surfaces and simple furniture with straight lines, such as cupboards, chests, shelves, cabinets and other storage furniture. Accordingly, the construction of furniture has been changed to make use of panels. At the same time, the use of panels has taken more varied forms.

Plywood products (veneer, plywood and blockboard) are the oldest types of wood-based panels; they represent an intermediate stage in the change-over from solid wood to modern panel products.

Although in the industrialized countries modern plywood and blockboard have been developed in particular into structural building materials, plywood products are also widely used in furniture and joinery industries in many different ways. In the developing countries the importance of plywood and blockboard as raw materials for furniture is even greater because these products are easily manufactured and their use is simple and closer to the traditional wood technology than the use of fibreboard or particle board.

Products and their uses

There are various kinds of plywood products. This chapter is concerned mainly with the use of plywood panels and blockboard. It is worth mentioning, however, that veneer is also used in many different ways in the manufacture of furniture. Its use for veneering various panels and for surfacing wooden parts is well-known. Veneer is also used in the manufacture of various moulded furniture parts, such as table and chair legs, seats, backs and arms.

In different countries the use of plywood and other panels has naturally been influenced by various factors, such as supply, traditions, competition, standard of living etc. Canada and the United States of America are the largest consumers of plywood in the world; both hardwood and softwood plywoods are widely used in the furniture industries. In the United States approximately 25 per cent of the hardwood plywood is used in the furniture industry, and about the same proportion of softwood plywood is used for various home furniture, mainly for do-it-yourself construction.

Elsewhere, plywood and blockboard are less important as raw materials for furniture. In the industrialized countries the use of plywood in the fields concerned has decreased since the introduction of particle board. While plywood was at one time the main panel material in all possible components, it is now used mainly for purposes where special strength and durability are required.

For some ordinary purposes, such as back panels, cupboard side panels and plane surfaces, plywood is often too good and also too expensive. Earlier, when it could still be considered an inexpensive construction material, it was commonly used for the framework of upholstered furniture, that is, the hidden parts. Today such use is significant only in the United States where relatively cheap softwood plywood is available. Elsewhere, the applications of plywood have partly changed, and it has become a luxury product that is used in exposed parts and finished with colourless lacquer with no attempt made to hide its ply structure.

Blockboard has also suffered from competition with particle board and other panels. However, it has several of the technical advantages of plywood, and, since it is less expensive, it has maintained its position somewhat better.

Blockboard is particularly suitable for built-in furniture, cupboards and shelves. Because of its rigidity and stability it is also used in furniture parts requiring strength, rigidity and firmness, such as table and desk-tops, cupboard shelves etc.

Use in the developing countries

As mentioned earlier, the potential for manufacturing plywood and blockboard is good in developing countries that have the necessary prerequisites, above all, suitable wood and a sufficient degree of industrial development. Where veneer, plywood and blockboard can be manufactured economically and the product range is of sufficiently high quality and offers variety, these products could be the main raw materials for furniture, in addition to solid wood. In many developing countries the use of wood is traditional and wood technology is on a high level. In these cases plywood and blockboard could be adopted more easily than other wood-based panels since the latter differ more from the traditional wood technology.

In the developing countries plywood and blockboard could be pioneer panel products, and most furniture could be manufactured from them. Structurally light and durable furr ture can be produced of plywood even with simple manufacturing techniques, which could be adapted to prevailing conditions. As high-quality decorative hardwood species are often found in the tropics and subtropics, plywood with face veneers made of these species would also have an attractive appearance and could be used for purposes where quality is required. Surface finishing would also be easier.

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*By Antti Vaajoensuu, Jaakko Pöyry and Co., Helsinki, Finland. Originally issued as ID/WG.209/2. This chapter contains additional material excerpted from "The requirements and use of wood-based panels in furniture manufacture" (ID/WG.209/1).

The same possibility applies to blockboard. Another advantage of blockboard is that its core can be manufactured of wood of poorer quality; only the surface veneer needs to be made of high-quality wood which can be peeled or sliced. Thus, blockboard can be manufactured economically in connection with a plywood mill and, if possible, also a sawmill or a similar plant. In such cases the raw material for the core can be wood that otherwise would be wasted. The manufacturing method is simpler and more labour-intensive than that used for other composite boards; therefore, blockboard is suitable for the developing countries.

The properties and appearance of a blockboard product are almost the same as those of plywood, but it is clearly less expensive. An additional advantage is that blockboard differs from solid wood even less than plywood, so that there are no particular problems in its use. Therefore, blockboard is also suitable for small-scale production and requires less demanding manufacturing conditions.

In the developing countries blockboard, in addition to plywood, could thus be a basic material for built-in furniture, cabinets, cupboards, shelves and panel parts of furniture, i.e. for all furniture for which wood panels can be used. The framework could be made of blockboard or of thick plywood, and thinner plywood could be used as top and back panels, bottoms of drawers, bottoms of beds etc.

Requirements and properties

Requirements set by furniture and fitment industries

As pointed out earlier, plywood is a particularly important structural building material. Many of the requirements for building, however, do not have much significance for the furniture industries, in which different panel products are needed for different purposes.

Some of the requirements established for panels intended to be used for furniture are:

(a) Dimensional stability;

(b) Smooth, good surface, which enables high-quality finishing, coating with various films, laminates etc.;

(c) Sufficient strength and rigidity, particularly transverse tensile strength;

(d) Good screw-holding characteristics, ease of gluing etc.;

(e) Suitable edge properties;

(f) Good workability;

(g) Other special properties.

In addition, industrialized countries often have special requirements such as suitability for serial production, standardization of dimensions and quality and homogeneity of quality.

On the other hand, the developing countries may favour products that are simple and inexpensive to use and are suitable also for small-scale production and do not require special equipment or tools.

Properties of plywood and blockboard

The most common plywood used in furniture is thin 3-or 5-ply, except of course in frame parts, table-tops etc., in which thicker panels are required The most common thickness of blockboard is 18-19 mm, but thinner (15-16 mm) and thicker (22 and 25 mm) blockboard is also commonly used. Blockboard with even thinner and thicker dimensions are also manufactured.

The properties of plywood and blockboard generally meet the requirements of furniture industries. Plywood is particularly strong and durable. It has good rigidity and impact resistance, which makes for light-weight structures that are strong at the same time. Screw-holding capacity is high perpendicular to the board, and no special fittings are needed.

Plywood is easy to work; only the glue can cause dulling of blades and tools. Plywood endures working in the panel itself as well as in its edges. In addition, the edge properties are fairly good. Plywood also has better dimensional stability and moisture resistance than other wood-based panels. Thin boards may not retain their shape well, but this defect can be eliminated by using correct structures.

The surface of hardwood plywood meets fairly high requirements and it can be finished and coated in various ways. Normally, plywood as a veneered surface is finished with colourless lacquer or stained. Naturally, paint can also be applied. This type of finishing is relatively easy and it usually turns out well, although there are noticeable differences between different species.

A disadvantage of plywood surfaces made of peeled veneer is that they do not resist well the variations in humidity occurring during use. As a result, small or large checks may develop which crack the surface and make it less attractive.

Blockboard has similar properties. Blockboard has the good properties of wood—light weight, durability and workability. It also has the better properties of veneer — good surface, rigidity and dimensional stability. Thus blockboard is an excellent choice for furniture and fitments requiring good strength, rigidity and durability.

One of the disadvantages of blockboard, as well as of plywood, is that the properties of the board are different in directions of the plane, i.e. in the grain direction of the surface veneer and perpendicular to the grain. In blockboard, strength and rigidity are also dependent on the direction of the core strips in relation to the surface veneer. When these differences are considered and the panels used in a proper way, they cause little trouble in use.

Conclusion

The large-scale use of panels in furniture and fitments calls for structures that are suitable for the panels and the proper technological arrangements in manufacture. Special machines and equipment are needed in working the panels, in surface finishing and in several other phases, including transfer and intermediate storage between the different phases. Most panels require special gluing and finishing techniques, which in large-scale production sometimes require expensive machinery, equipment and manufacturing lines.

Such arrangements can seldom be considered in the developing countries where the manufacture of furniture and fitments is still based on traditional wood technology. Therefore, the properties of plywood and blockboard make them more adaptable than other wood-based panels for use in these countries.

The use of plywood in furniture and fitments could be increased considerably in developing countries where indigenous or plantation species suitable for plywood manufacture are available. Advantages of plywood are its workability and easy handling, good strength properties and simple manufacturing technology, which make it suitable for labour-intensive and small-scale manufacturing.

Although blockboard is a declining product in the developed countries, it should still be seriously considered in areas where there are good natural prerequisites for its manufacture. While blockboard can be compared with solid wood, its use does not require any exceptional skills, tools or fittings. Therefore, the production and use of blockboard are a natural phase in changing over from the traditional manufacture of wooden furniture to a modern furniture industry.

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IV. Applications of particle board in the furniture and joinery industries*

Particle board has been the "wonder child" of the industries producing wood-based panels in the developed countries. Per capita consumption in some European countries has reached 90 m³ per 1,000 persons per annum. It has replaced sawnwood as well as the other wood-based panels (fibreboard, plywood and blockboard) in many of their hitherto traditional applications. The acceptance of particle board in the developing countries has been far less spectacular, for several reasons, the most important being the unavailability of the necessary technical information on the applications of particle board in the furniture and joinery industry, its correct storage, machining, assembly and surface finishing.

The purpose of this chapter is to provide some of this information to potential users in the developing countries and thus help in the development of viable furniture industries. Much of the information has been taken from brochures and booklets prepared by the Chipboard Promotion Association (CPA) and the Timber Research and Development Association (TRADA) in the United Kingdom, the National Particleboard Association (NPA) in the United States and the Particle Board Guide of the Finnish Particleboard Association.

Definition

In the last 30 years, the industrial production of particle board has been developed as a means of using ligno-cellulosic materials and their waste (normally wood). Particle board panels are manufactured by reducing the ligno-cellulosic raw materials into particles that are then dried and bound with a synthetic resin (normally urea formaldehyde) under pressure and heat.

Newer types of panels have been developed recently by changing the particle geometry. Examples to these are waferboard, in which the particles are large wafers, and oriented strand board (OSB) in which the particles are thin, narrow and long strands, oriented along or across the face of the boards. These newer-type panels are used in construction and not in furniture and joinery.

Boards made from wood-wool, wood chips or similar materials and bound with inorganic binders such as cement are not classified as particle boards. These boards have rough surfaces.

Another recently developed panel product is the cement bonded particle board, with smooth surfaces. But again, this is also only used in the construction industry.

Materials

Particles or chips of wood comprise 90 per cent of the bulk of wood particle board. In developed countries they are generally obtained from coniferous softwoods, although hardwoods are sometimes used. The choice of wood species depends on the type of chip required, the availability and continuity of supply and the cost. Two main sources of raw material are:

(*a*) Forestry thinnings;

(*b*) Timber waste, such as off-cuts, edge rippings, sawdust, planer shavings or chips obtained from other timber-consuming processes.

Binders

The binder (adhesive) plays a key part in the stability of the final board and will to some extent increase the resistance of the wood chips to fungi, termites, wood borers etc. The most common binders are synthetic resins which, because their formation can be varied, have the advantage of flexible curing time. In addition, they are thermosetting and cure rapidly and irreversibly with the application of heat.

Either the wood chips can be treated or the binder can be mixed with additives to improve particular qualities of the finished board. The most common additive is paraffin wax, which is introduced in small proportions as an anti-swelling agent. Fire retardants, insecticides and fungicides can also be added in small proportions.

Properties

Particle board has about the same density as sawn wood of the same species but is more homogeneous. It contains no grain direction, knots or any other growth faults. Linear swelling owing to moisture is equal in both directions, although it is slighter in comparison with sawn wood and with thickness swelling. Particle board has the two disadvantages of low rigidity and fairly low resistance to tension perpendicular to the surface of the board. Without protective additives it tends to swell in thickness.

Some average strength ranges for particle board and birch are shown in table 9.

For applications where bending strength is important (such as shelving), veneered or laminated surfaces greatly increase strength.

Since the porous surface is uneven, it must first be filled before painting or lacquering. The surface must be of a high quality; otherwise overlays will show unevenness or particles show through. Care must be taken not to sand away too much of one surface since the stability of the board may thus be impaired, especially in multi-layered boards.

Multi-layered boards have been developed, and even boards with densified edges can be produced, that improve surface and edge qualities with respect to screw-holding and edge-banding and that allow machining with greatly reduced tear-out and chipping. The most common is a

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three-layer board. Flat-pressed boards are by far the most preferred by the furniture industry while extrusion types are used more in building.

Table 9. Average strength of a representative Finnish, flat-pressed particle board[a] and solid wood[b]

Characteristics	*Range* Particle board	*Range* Solid wood
	(N/mm²)	
Bending strength	18-25	130-160
Tensile strength		
(direction of plane)	8-12	
(direction of grain)		120-150
Tensile strength		
(perpendicular to plane)	0.3-0.8	
(perpendicular to grain)		6-8
	(N/mm)	
Withdrawal resistance of wood screws at surface	60-100	
Withdrawal resistance of wood screws at edge	40-70	

[a]Density = 650 kg/m^3.
[b]Finnish birch (*Betula spp.*). Values are valid for defectless wood.

The introduction of particle board into traditional wooden furniture making requires a change-over in manufacturing methods. Instead of building a normal wooden frame (for case goods and cabinets) using glues, nails and screws with a fibreboard or plywood backing, followed by the possible application of overlays, in the case of particle board precision-cut, pre-veneered or overlaid particle-board pieces are assembled using glue lines almost exclusively and nails or dowels only for locating and holding until the glue is set. Not only must methods change, but the means of producing precision-cut components must also be developed.

Board formation

The particles are carefully coated with controlled quantities of binder either in a discontinuous batch process or in a continuous system of spraying of particles as they go through cylinders. In all instances the final moisture content is controlled at about 10 per cent. The coated particles are formed into boards either by pressing between steel plates (platen-pressed) or by forcing the particles through a die (extruded) and at the same time applying heat to cure the binder.

Platen-pressed boards

Nearly all particle boards are produced by the platen-press method, which embraces a wide range of variations in mat-forming and pressing. The density of the boards depends on many factors including the type of particles and the pressure applied. One way of defining the type of platen-pressed board is by the structure resulting from the method of mat-forming. The shrinkage and swelling of this type of board in the direction of its surface is roughly 1/20 of that of solid wood perpendicular to the direction of the grain. The four basic types, which are represented in figure 22, are:

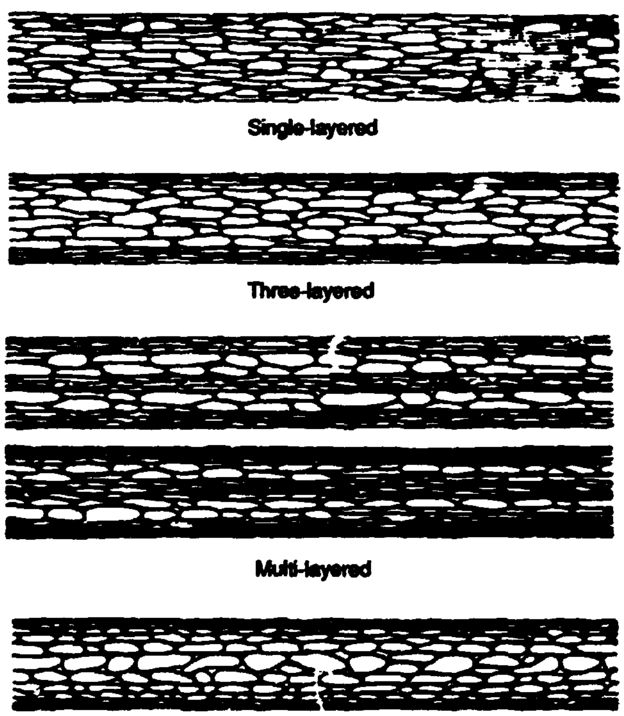
(*a*) Single-layered, in which the board is formed from particles of the same size or a mixture of sizes so that it has a consistent density throughout the thickness;

(*b*) Three-layered, in which the board is a sandwich construction usually consisting of relatively high-density outer layers, between 1-mm and 3-mm thick, comprised of fine or long thin particles or thin flakes with a middle layer of larger particles. The density will therefore be higher at the outer faces than in the centre;

(*c*) Multi-layered, which is similar to the three-layered type except for an increase in the number of layers. A core of high density can be introduced for improved flexural strength, and frequently a finer surface layer is included;

(*d*) Graded density is achieved through the method of spreading the particles, making it possible to use particles without pre-grading them; the boards are characterized by smooth, high-density surfaces and low-density cores without any abrupt change in particle size. This type has some of the attributes of both the single-layered and three-layered types.

Figure 22. Types of platen-pressed particle board



The mat of already glued particles obtained by any of the above methods may be cold pre-pressed to reduce its thickness. The main pressing is a critical operation requiring carefully controlled heat, pressure and timing. Pressing is usually done in a batch process, pressing a number of boards at the same time in a multi-daylight press. Alternatively, boards can be pressed in a single daylight press. A process of pressing boards in a moving single daylight press is sometimes used to produce a continuous board.

"Mende" thin boards produced on a calender

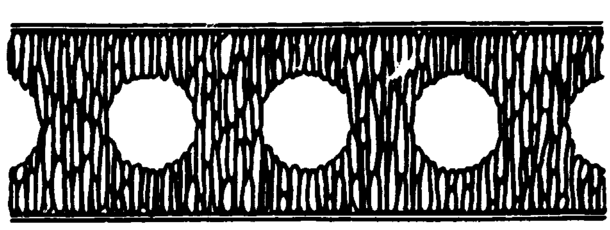
A thin particle board can be produced through continuous pressing between heated rollers. It produces a continuous board that can be cut in random lengths, resulting in little or no waste. Thin boards can be produced and surface treatments can be incorporated into the process. Because of the close tolerances achieved in the pressing, the resulting product, unlike platen-pressed boards, requires no sanding.

Extruded boards

The extrusion method is also one that allows for an almost unlimited board length, resulting in uses with little or no waste. It also enables the formation of thicker boards than is at present economically possible by means of platen-pressing. The particles are fed into an extrusion press where they are forced through a die formed of two parallel heated plates which can be adjusted to vary the thickness of the board. For the thicker boards, heated tubes can be incorporated in the die to produce a hollow-cored board. The orientation of the particles is at right angles to the plane of the board, thus giving boards that, unless veneered or surfaced with a laminate, have high swelling rates in the main plane and low screw-holding properties, except on edges. (See figure 23.) These boards are not commonly used in furniture but are used mainly as partitions.

Figure 23. Extruded particle board

Board with laminated faces



Board (tubular) with laminated faces

Choice of board sizes

Because of the continuous increase in the use of particle board, particularly in developed countries and where there are larger installed plant capacities, the board size, which was originally 1.22 × 2.44 m, has become larger. In the developing countries it is still common to produce only 1.22 × 2.44 m boards. The larger board sizes are manufactured since the losses are lower in cutting the boards to size for their use in furniture.

Utilization problems

In the developing countries the industry has many technological problems to overcome. These problems concern the quality of products, which can affect the acceptance of the boards by the furniture and joinery industries in these countries. The problems are:

(a) Lack of adequately trained management and workers to operate the plants, which in many instances are judged to be sophisticated by local standards;

(b) Total or partial lack of adequate quality and process control, adversely affecting product, particularly where plants have been erected with no or only rudimentary laboratories, which, if they exist, are often staffed by insufficiently trained technicians;

(c) Because of market limitations, and in the absence of capable management, plants resort to producing small runs of any given type of boards. This continuous changing of production parameters reduces the quality of boards;

(d) The possibility exists that the plant confronts specific problems that are unknown to industry in the developed countries; these can be due to the utilization of mixed tropical species of timber and the utilization of agricultural residues for which no known technology has been developed and for which the plant must introduce new industrial processes and techniques.

The lack of standards and of quality labels issued by recognized bodies is a considerable hindrance to the utilization of the boards produced in developing countries for more sophisticated end-uses and for their inclusion in the specifications of Governments, institutions and other large users, in the developing countries or in the neighbouring countries to which exports might be envisaged. Furthermore, because of their low per capita income and lack of an industrial base, few of the developing countries have utilized particle board to any extent.

Utilization in buildings

In buildings, uses such as door faces, ceilings and wall panels are of major importance. For such applications the extruded type of board could be used. However, it is not often used since the process is not common, and flat-pressed boards are often used in these applications. In developed countries special (higher-density) flat-pressed boards are used as floor underlays, e.g. under plastic tiles or wall-to-wall carpeting. This type of board would not have a large demand in the developing countries.

Normally, the actual end-uses in developing countries can be assumed to be similar to those of developed countries, and this similarity also generally applies with respect to technical requirements, except that in a number of developing countries additional resistance to decay, humidity and fungal and insect attack is needed. There are preservative treatments available that can be applied where the natural durability of the raw material is not sufficient. Methods of treatment have been developed to fit particle board for different exposures. Glues with a high degree of moisture resistance are also available; still exterior-grade particle boards are not commonly available.

In general, internal walls, ceilings and built-in furniture should not be affected by humidity. Situations do arise however in some developing countries in the tropics where, because of the open nature of the houses and the habit of frequently washing the internal surfaces, there is the risk that the board will deteriorate because it retains excessive humidity.

For roofs and floors in particular, and also for walls and ceilings, correct ventilation to prevent the build-up of humidity and condensation is necessary. It is important, therefore, that the end-users, in particular architects, are informed of correct installation methods so that the board does not fail as a result of fungal attack.

Utilization by the furniture and joinery industry

Particle board appears to possess properties of unlimited scope for its use in furniture or joinery manufacture, chiefly because of the following technical characteristics:

Good machineability, uniform and relatively low density
Sufficient strength perpendicular to the surface
Sufficient screw-holding strength
Minimum show-through (or "telegraph") tendency
Low swelling tendency
Uniform thickness
Freedom from warping, plus good stability
Equal strength and expansion properties in two directions
Availability in large sizes, thus eliminating the need of producing panels from glued-up solid wood
Ease of surface finishing with paint, wood veneer, low or high-pressure plastic laminates

Manufacturers of home and institutional furniture have found particle board to be an answer to their needs. They utilize the flat-pressed type of board in the production of items such as office desks, kitchen cabinets, shelving, case goods, drawers and bookcases. Furthermore, it is not limited to any particular design or style. It is an efficient panel product that may be cut into a range of sizes with close tolerances that meet the requirements of the furniture and woodworking manufacturers with a minimum amount of waste.

The suppliers of particle board should be able to provide technical advice to users and, in some areas, to maintain stocks of special hardware. Hinges, slides and knock-down fasteners of different designs must be available, as well as screws with a deeper pitch threaded all the way to the head. Some hinges, for example, rely on special boring or mortising machines for application. The following services should therefore be considered by suppliers of board for the furniture industry, at least until it has attained its own capabilities:

Precision cutting to specific sizes
Surfacing with melamine-impregnated foils, wood veneers and other overlays
Edge lipping
Maintenance of carbide-tipped cutting tools
Technical design assistance

Despite the efficiency of particle board, however, in many developing countries it has not been accepted by the furniture industry for the following reasons:

(a) It is sometimes more expensive than solid wood;

(b) Furniture is still produced by craftsmen who lack the equipment to veneer and edge-band the particle board, and board that is already veneered is not available commercially;

(c) The low (or fluctuating) quality of locally produced boards has created consumer resistance to this "man-made" product;

(d) Users in the developing countries have not realized that whereas particle board can replace sawn wood, it is not sawn wood (i.e. it does not have properties identical to those of solid wood). Because of ignorance it has been used as though it were solid wood and has failed, leading to consumer resistance (i.e. it has been used without the necessary modifications to the design);

(e) The wrong fittings have been used (especially hinges) which worked loose, thus prompting end-users to declare it unsatisfactory;

(f) The wrong construction methods have been used (i.e. the use of thin particle-board "faces" on a solid-wood "frame", such as is common with plywood). These have pushed up the price unnecessarily and eliminated the price advantage that particle board would have had if the product had been specially designed for construction from particle board.

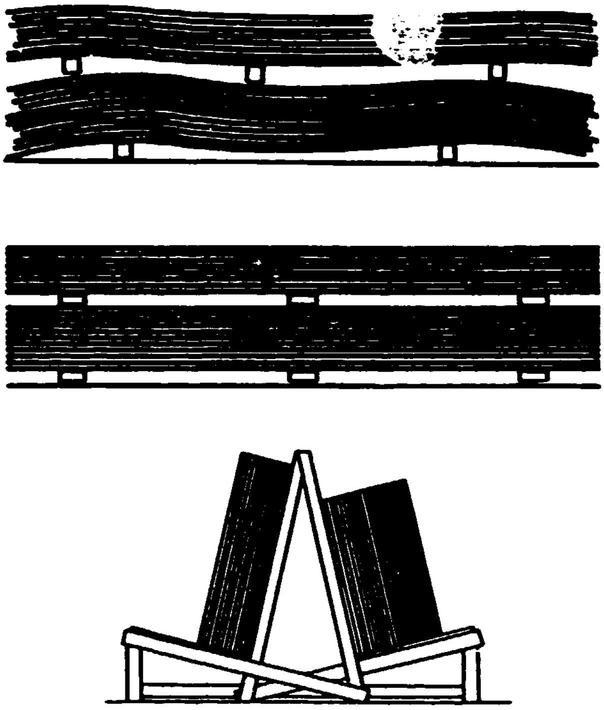
Other end-uses

While numerous other outlets possibly exist for particle board in industries such as motor transport, caravans, railways (furnishings) and containers, regulations exist in some countries according to which no foodstuffs can be packed in particle-board containers. Such containers, however, have been accepted for packing tobacco.

Storage of particle board

It is important to follow a few simple procedures for storing the board under the right conditions. Particle board should not be stored in sheds with slatted sides, outside or in an excessively damp location. It is preferable to store it flat on a flat surface. If more than one bundle is stacked horizontally, the stickers or bearers on which the bundles rest should be aligned one above the other to avoid warping or bowing. Particle board can also be stacked in an almost vertical position, provided it is placed in a special type of rack as shown in figure 24.

Figure 24. Incorrect above and correct below method for stacking particle board



Machining

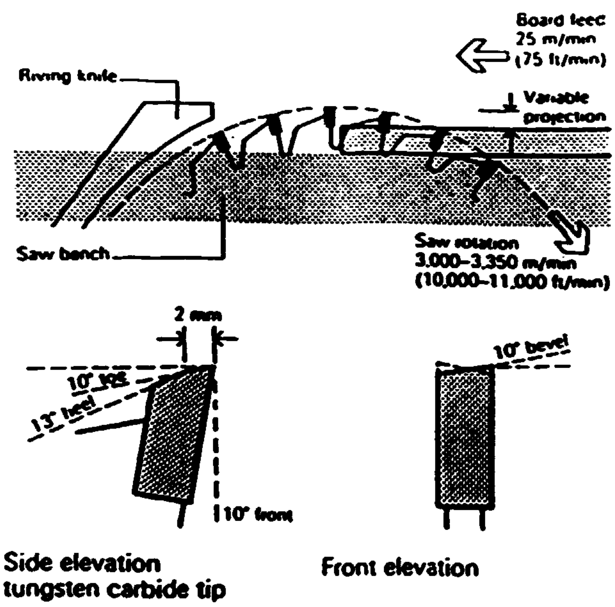
Particle board can be sawn, routed, spindled, planed or bored. The rate of feed should generally be slower than that used for sawn wood, and cutting edges should be kept thoroughly sharp. This is particularly important in the case of boards faced with plastic laminate.

Sawing plain particle board

For quantity production, any of the conventional machines used for cutting sawn wood timber are suitable. Saw blades should have a peripheral speed of about 3,000-3,500 m/min. The angles of teeth are also important; a positive front angle is particularly necessary. The recommended details for circular saw are indicated in figure 25.

The saw blade should rotate in the opposite direction to the feed, and a riving knife should be fitted to open the cut. Control over the board during machining is also important; boards should be properly supported and pressed down firmly against the cutting table and guides to avoid vibration. The projection of the saw above the board has a direct influence on the cleanliness of the cut. The top surface will break out or chip if projection is insufficient, and the bottom surface will break or chip if it is too great. If either occurs, the projection should be adjusted accordingly until the defect disappears. If the fault persists, the saw speed should be increased or the rate of feed reduced. While it is suggested that tungsten-carbide tipped saws should be used, other types of saws are capable of doing the same kind of work if sharpened frequently. The feed speed should not exceed 15 m/min. Mechanical feed is best but, if hand feeding is used, a steady rate is more preferable than precise speed. The projection of the saw above the workpiece should be between about 8 mm and 20 mm.

Figure 25. Sawing method for particle board



Use of spindle and router

As wood particle board has a non-directional grain, grooves, recesses and housings can be easily and cleanly cut; these processes are best carried out on a router with tungsten-carbide-tipped cutters. While it is not possible to give precise details, in general feed speeds should be slower than for sawn wood and the maximum possible number of cutting edges should be provided. The following are suggested:

Spindle moulder

Speed	4,000-6,000 rev/min
Cutter-block	minimum of 4 cutters preferred
Cutters	toe 42°, heel 45°
Material feed	4-5 m/min

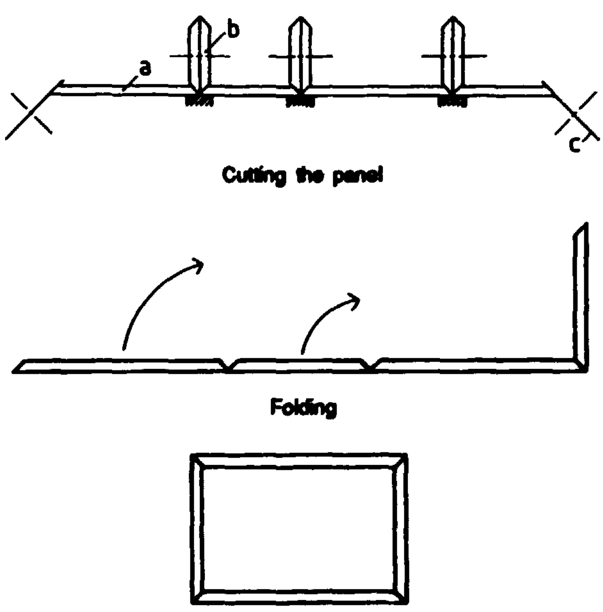
Router

Speed	18,000-24,000 rev/min
Cutters	double-edge bit, minimum 25-mm cutting edge ground to a 53° angle
Material feed	4-5 m/min

V-grooving for V-folding process

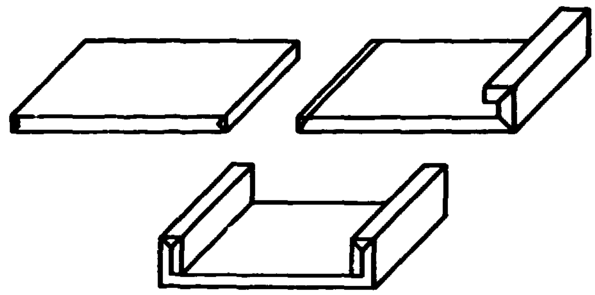
The V-grooving process may appear somewhat advanced for application in most developing countries, but for some the furniture industry could benefit from its use. The process consists of the utilization of a particle board with a flexible laminate or film surface. For the method in its simplest form, a circular solid cutter is used with a 90° V-cutting edge to machine two 45° mitres through the entire thickness of the particle board but without touching the bottom laminate. With the foil used as a hinge at its fulcrum, the material is folded and glued to make a perfect 90° joint. A typical machining and folding operation for cabinet sides and top is shown in figure 26. To accomplish this process, conventional machines, such as double-end tenoners with appropriate modifications and attachments, can be set up to make not only simple but also more complex cuts for V-grooved end-products such as, for example, the machining, folding and gluing of kitchen cabinet tops so that the laminate is folded under the part of the board that overhangs. The system can also be used to machine and fold non-rectangular polygons. The use of this process implies the use of particle boards with very small thickness variations and a very precise machine, as well as special tungsten carbide cutter-heads. A more advanced and sophisticated method of V-grooving for edge-folding and doubling appears in figure 27.

Figure 26. Machining and assembly of V-grooved panels into case goods



Key: a. Panel
b. V-groove cutter
c. Mitre saw

Figure 27. V-grooving for edge-folding and doubling



Jointing

Two of the desirable characteristics of particle board are its non-directional grain and its gluing qualities. Pieces can be cut from a board in the most convenient and economical way irrespective of their orientation in the board. Furthermore, because the particles lie in a random pattern, a consistently good gluing surface can be obtained from a saw cut irrespective of the direction or angle of the cut. For the majority of situations glued joints are the most appropriate and economical. They take full advantage of the characteristics of the material and make more complicated mechanical methods unnecessary. There are many ways of detailing to join one board to another. The selection of a particular method will depend largely upon the finished appearance required and the equipment and facilities available. If boards are to be painted, laminated or veneered, a plain butt joint is normally suitable. If the edges have been clearly cut, planing will not be necessary. Both edges should be liberally coated with adhesive, and pressure should be applied and maintained until the adhesive has set.

With care in the design and selection of joints, wood particle board is well suited to carcass construction. Simple glued joints are characteristic of the use of the material for this purpose, and their advantages are a main reason for the widespread application of particle board in the mass production of furniture. The gluing qualities of particle board are good in all planes, and full advantage should be taken of this in the design of joints. Provided that edges have been clearly cut, a plain butt joint provides adequate strength for many situations and is economic. At vertical corner junctions a plain mitred joint can be successfully used. Some means of ensuring the accurate location of the components to be joined is often of practical advantage in assembly; for example, a loose tongue may be incorporated in a mitred joint. There are various other ways in which such provision can be made; some of these are indicated in figure 28.

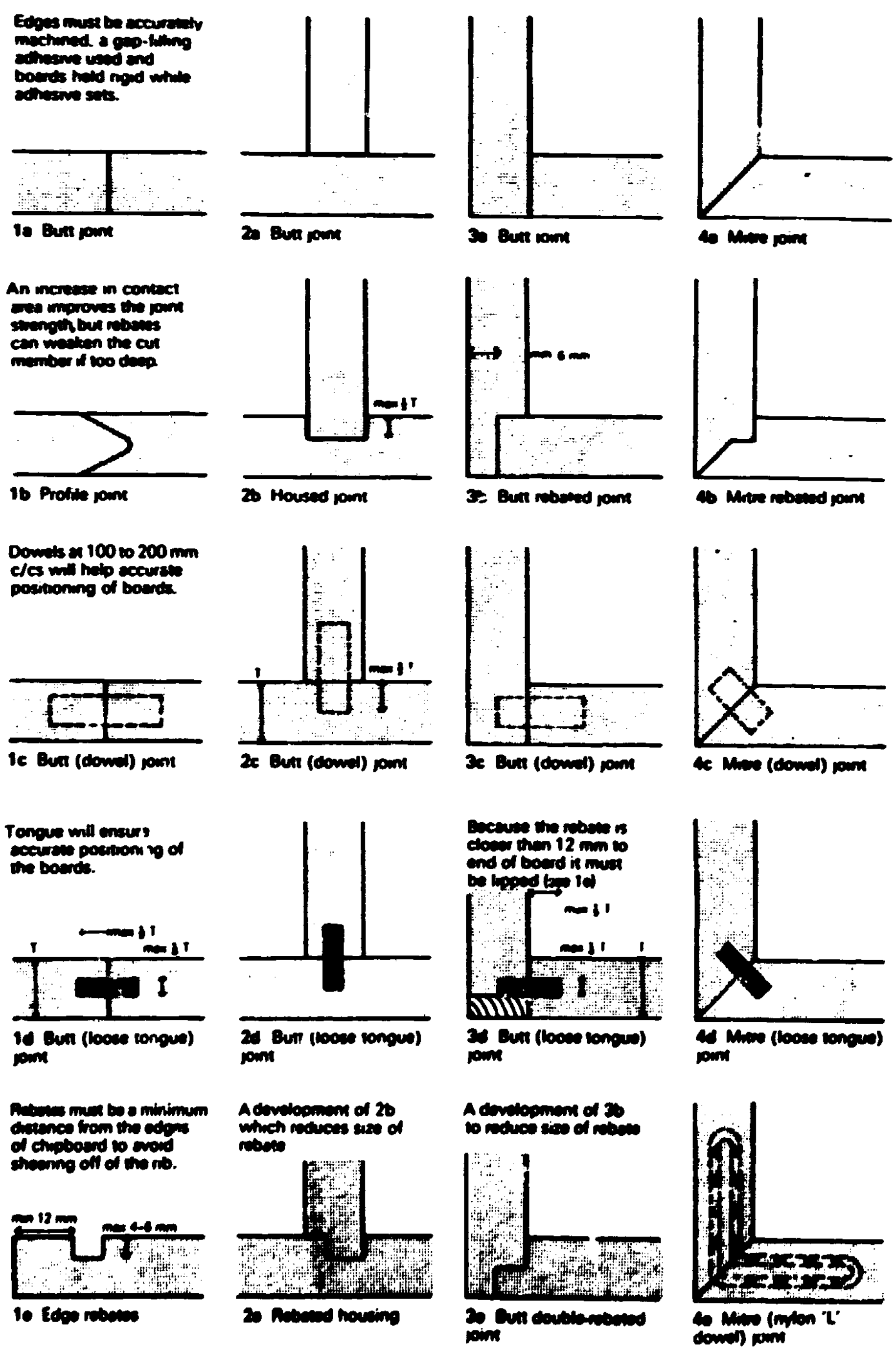
Edge-banding

Particle board may be edged or lipped in a variety of ways (see figure 29). Edges can be veneered easily to provide a matching finish to the surface. Provided that a clear saw cut has been made, further treatment of the edge surface is unnecessary. Veneers can be applied by hand or machine, and the use of a urea-formaldehyde adhesive is suitable for most situations. An alternative edge detail is to use a plastic strip with a toothed tongue on the back face which is pressed into a thin groove at the edge of the board.

Solid wood lippings of any suitable width can be satisfactorily glued with a plain butt joint direct to a cleanly cut edge of the particle board. While a tongue-and-groove detail may be used, it only serves to facilitate accurate location, but when it is used the groove should be in the particle board edge.

Figure 28. Jointing

Carcass joints



<u>Note</u>: T = thickness of the board.

Figure 29. Edge-banding and lipping

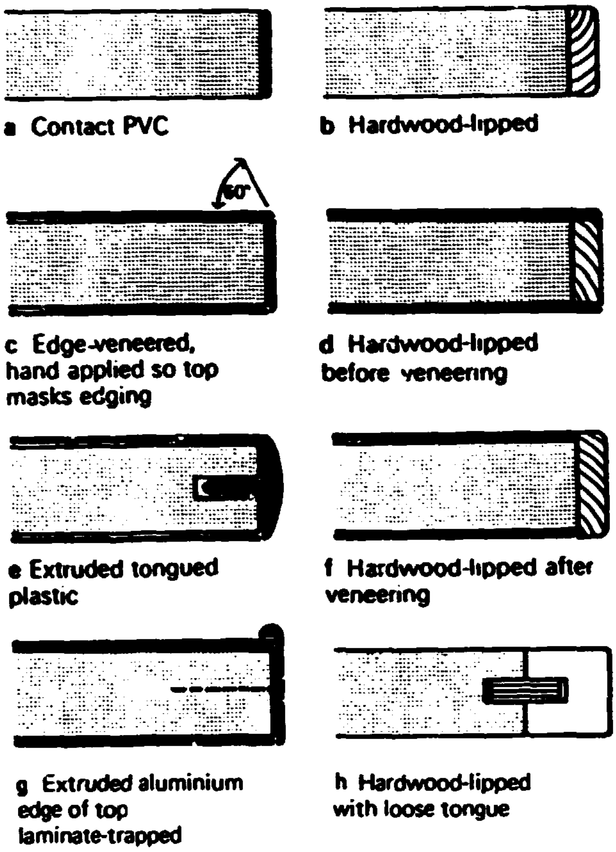
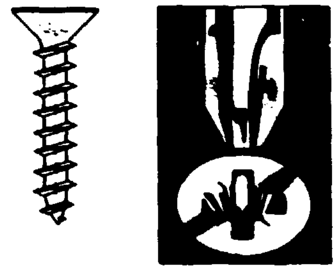
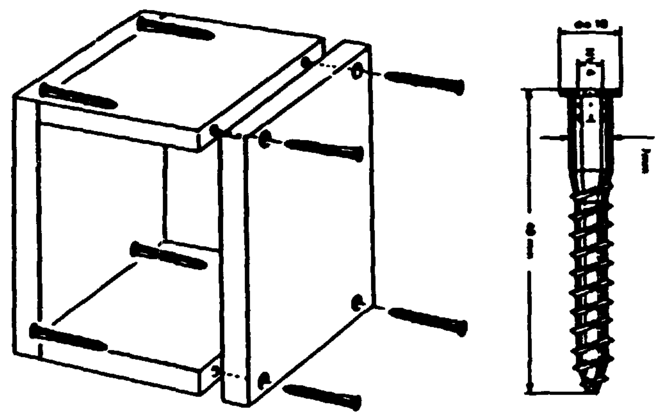


Figure 30. Particle-board screws

A. Screw for permanent fixing



B. Screws (with hexagonal key slot) for knock-down use



Use of nails, screws or fittings

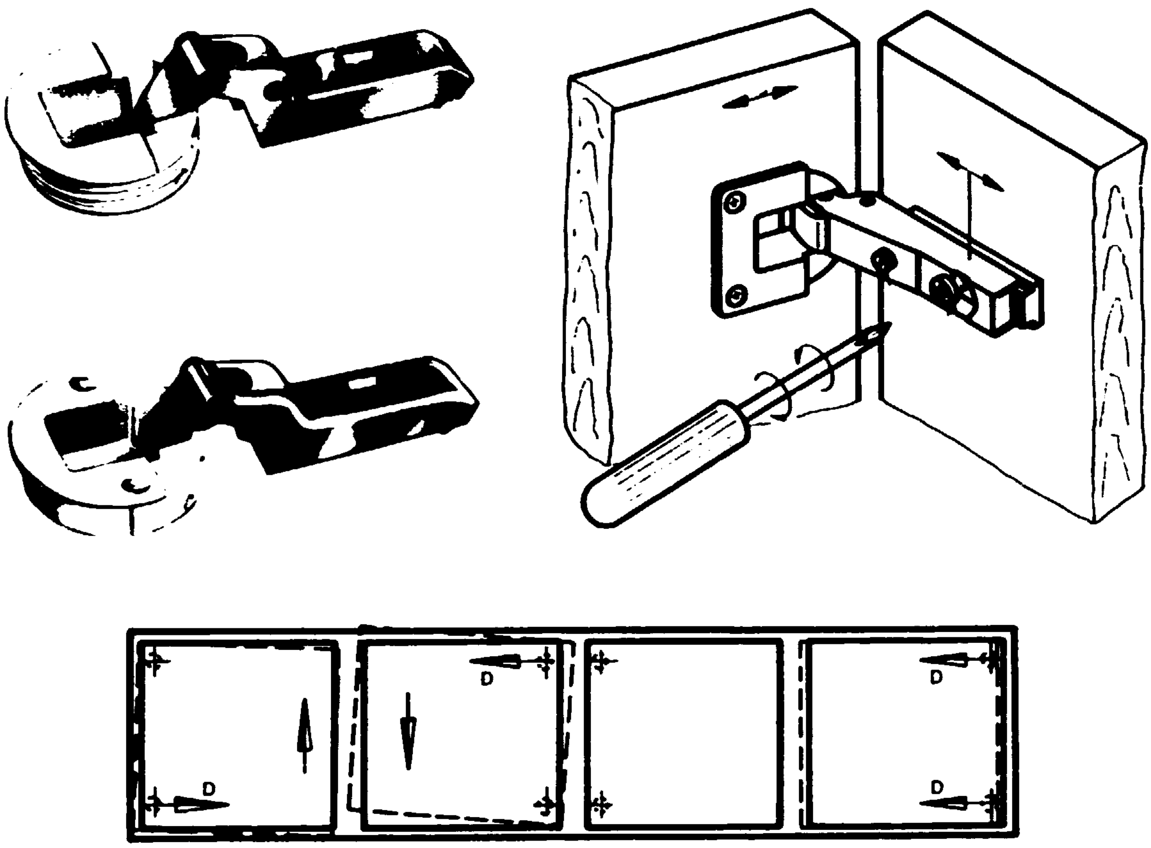
Although nails and screws may be used in particle board, nailing into the board edges should be avoided. Special particle-board screws with deeper threading than that of ordinary wood screws are available. These screws require a bored hole. The hole diameter must be about the inner diameter of the screw (measured at the bottom of the threading). Dipping the screws into PVAc glue before driving improves their withdrawal resistance. (See figure 30.) Furthermore, it is recommended that fittings and structures particularly suited for the purpose should be used, as indicated in figure 31. As regards the use of hinges, the more modern type requires a bored hole on the door panel, which is very practical because boring is the simplest of all machining operations. The other side of the hinge is fixed with screws directly on the inside surface of the cabinet side panel. Only a fixing of a permanent nature should be applied directly into the board. Where demountability and reassembly will be required, the use of special inserts or "knock-down" fastenings is advised. There are three groups of knock-down or assembly fastenings, namely the concealed, surface and flush type (see figure 31).

Surface treatment of particle board

Particle board can be painted or lacquered in the ordinary way. First, however, the porous surface must be filled with an appropriate filler. Coating with wood veneer or plastic foil is also frequently done since particle board is a suitable core material for this purpose. The widespread use of wood-veneered particle board in the furniture industry gives some indication of the suitability and economy of the material for this purpose. There is no difficulty in applying wood veneers provided that a board with a good smooth surface is used. A hard-wearing, scratch-resistant and easily cleanable surface is obtained by the application of melamine-based plastic laminates to wood particle board; it is used extensively in the furniture industry, particularly for kitchen units and work surfaces. Soft plastic sheet coverings are also being used by the furniture industry since they can be readily applied to the board; they are also cheaper than the melamine plastic laminates but still provide a wear-resistant and easily cleanable surface.

Figure 31. Metallic and plastic fittings suitable for use with particle board

A. "Invisible" hinges, easily adjustable



B. Knock-down fittings for corner joints

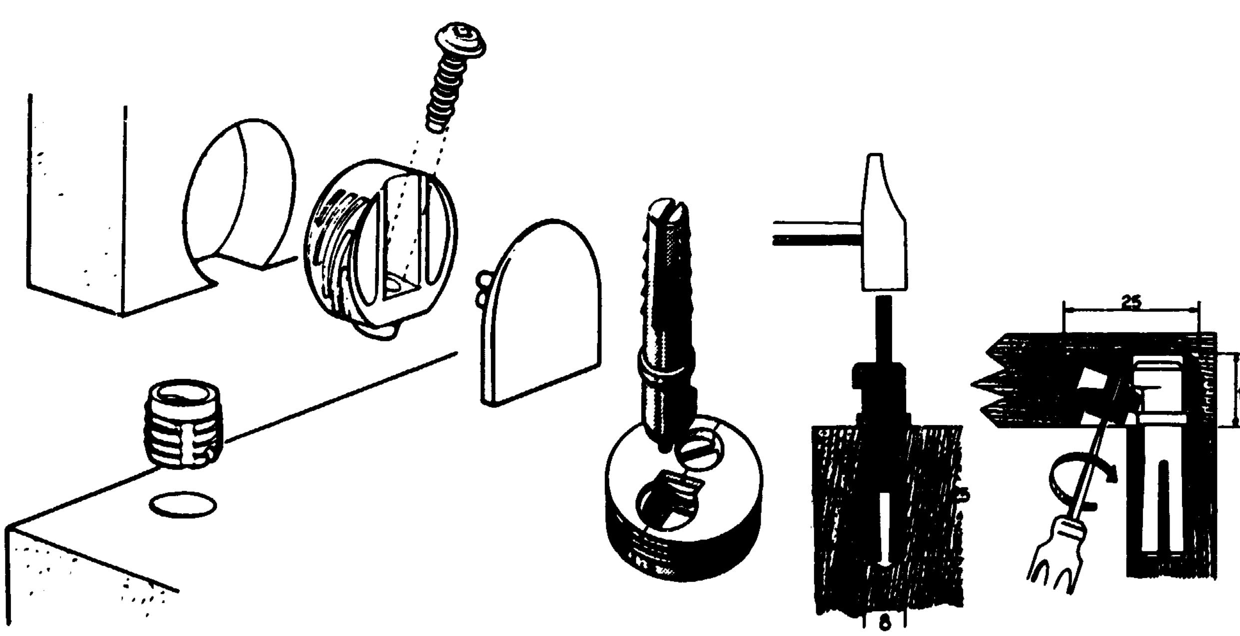
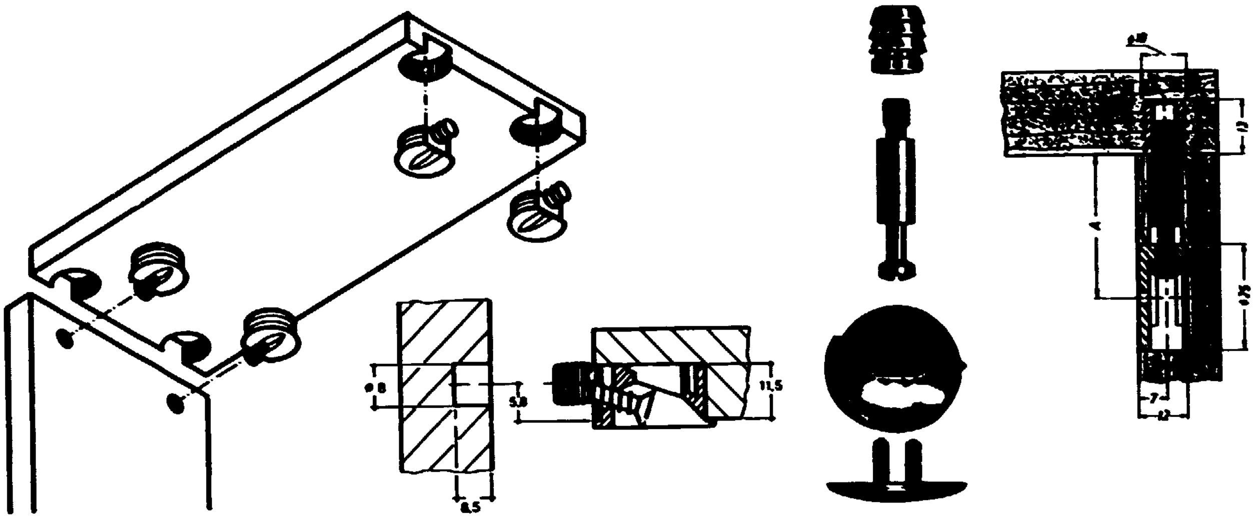


Figure 31. B *(continued)*



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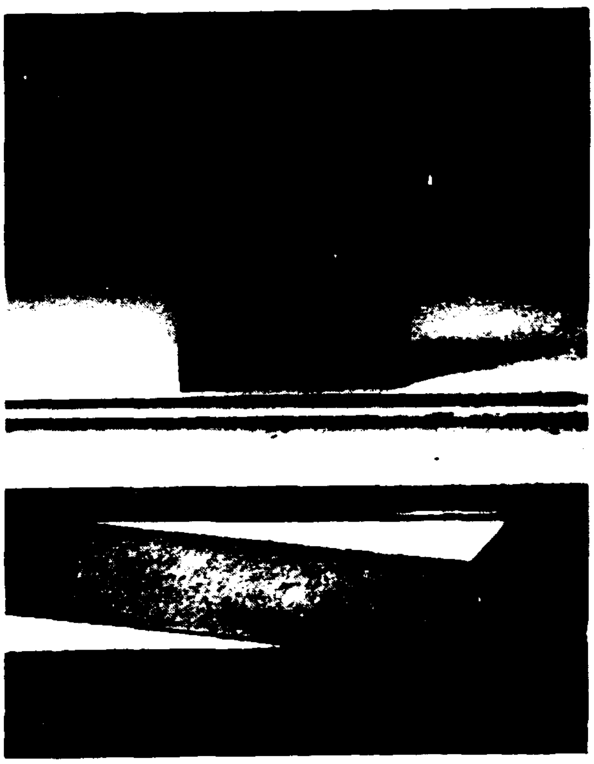
V. The production and use of medium density fibreboard in the furniture and joinery industries*

Properties of medium-density fibreboard

Medium-density fibreboard (MDF) is a re-constituted wood product. The panel is produced in thicknesses from 4 mm to as high as 50 mm. The most outstanding feature of MDF is that it is made from wood fibre. The MDF process results in a uniform density distribution throughout the panel. The panel has a tight smooth surface and a tight and even core. It has excellent machining and profiling characteristics, on both the surface and the edges. (See figure 32.) It is more consistant and uniform than natural wood and, in many of its applications, is used as a substitute for solid lumber.

Figure 32. Two pieces of machined MDF (on a particle board)



History

MDF in its present form was developed in the United States during the early 1960s. The first MDF plant was built in Deposit, New York, using Bauer pressurized double-disc refiners and a radio frequency heated hot press. In its initial conception, this plant was to produce 12-mm thick exterior siding panels, a product very commonly used in the United States. The product utilized a melamine-reinforced urea resin that was specially developed for this process. The result of the venture to make a medium-density siding in competition with the well-established hardboard industry, which used phenol formaldehyde resins, was a failure. The production of siding was discontinued in 1968, and the plant completely switched to panel production, which was marketed mainly in the furniture industry.

Several plants were built in the early 1970s; most were in the United States, one was in the German Democratic Republic and one in Japan. By 1975, 12 MDF plants were in production with a total capacity of 1,333,000 m^3 per year; of this total, only 300,000 m^3 per year were produced outside the United States.

In the period between 1975 and 1980 another 19 MDF plants have been built or were under construction. The total capacity of these new plants was 975,000 m^3 per year. Most of the plants are of much smaller capacity than those built in the preceding years, and, except for one, all of them were built outside the United States.

From a historical point of view, the plants in the United States generally had capacities in excess of 350 tonnes per day whereas the plants in the rest of the world had capacities of 200 tonnes or less per day.

Physical properties

The physical properties of MDF are quite similar to those of particle board, although the appearance and the application of the product can vary considerably from those of the particle board. A comparison of the different physical properties is made in table 9. The only existing standard for high-grade MDF is a very loose standard, as it does not make any differentiation between different board densities. It is interesting to note, however, how closely it compares with United States and also European particle board standards. Typical MDF board standards for very low density board and for board of flooring grade are also presented in the table.

End-uses and markets for MDF

The major end-use for MDF is in the furniture industry, which uses about 80 per cent of the total production. The second most commonly encountered end-use is in the cabinet industry. This industry utilizes MDF for kitchen

*By Peter H. Wiecke, Sunds Defibrator A.B., Stockholm, Sweden. Originally issued as ID/WG.335/14.

cabinets as well as for television cabinets and loudspeaker enclosures. A third application for MDF is for wall panelling. The final most common application is in the form of trim and mouldings both in the home-building industry and in other applications. In all of these applications, the MDF product is upgraded through machining, printing, overlaying, veneering, embossing or other means.

Table 9. Comparison of physical properties of MDF and particle board

Characteristic	MDF standard: United States[a]	MDF standard: Japan[b]	MDF standard: New Zealand[c]	Particle board standard: United States[d]	Particle board standard: Federal Republic of Germany[e]	Particle board standard: Federal Republic of Germany[f]
Density (kg/m^3)	500-800	507	700	590-800		
Modulus of rupture (N/mm^2)	26.4	25.0	39.0	16.8	16.0	18.0
Modulus of elasticity (kN/mm^2)	2.11	2.50	3.06	2.81		
Internal bond (N/mm^2)	0.70	0.60	0.77	0.42	0.35	0.40-0.50
Linear expansion[g] (percentage)	0.30	0.16	0.25	0.30		
Screw-holding						
Face (kN)	1.59		1.83	1.02		
Edge (kN)	1.25		1.73	0.91		

[a] National Particle Board Association, NPA 4-73.
[b] Hokushin, fibreboard.
[c] Canterbury Timber Products, Pinus radiata.
[d] National Particle Board Association.
[e] Deutsche Industrie-Norm, PBV 20.
[f] Deutsche Industrie-Norm, PBV 100.
[g] 50-90 per cent relative humidity.

Furniture

The furniture industry was the first industry to utilize MDF and has the greatest experience in its use and application. The development of this application is perhaps of some interest since it highlights a distinct characteristic of MDF that particle board cannot share.

In the United States, where this development first occurred, lumber has been and continues to be, to a certain extent, extensively used in the manufacture of furniture. Particle board was used mainly for the cheaper grades of furniture, especially for table-tops and other flat and square or rectangular surfaces. When furniture was built in a more refined fashion, the particle board was lumber banded so that the edges could be treated in a more appealing fashion. It is in this application that MDF first made its great inroads. Furniture manufacturers found that they could replace the lumber-banded particle-board sheet for the table-top by a raw and unbanded MDF panel. It was found first of all that an MDF panel has a much smoother and tighter surface than particle board, which allowed direct printing or overlaying with veneer of a higher quality that was possible with particle board. Secondly, the edges of MDF could be very easily machined, and, owing to its great uniformity, it machined better than the solid lumber because knot-holes and other irregularities in natural wood made machining sometimes difficult. Thirdly, the direct finishing of the edges after machining presented no major problem, since some fairly sophisticated painting processes had been developed to match the general appearance of the surface of the board to exotic veneer overlays. It was found that a table-top manufactured with an expensive grade of MDF (see figure 33) was cheaper than the lowest cost that could be achieved with edge-banded particle board. The process also eliminated the additional step of banding, and thus provided a faster turnover for the product.

One method of producing table-tops had been perfected, and the next step/was to use MDF in drawer fronts, cabinet doors and any application where an exposed edge previously presented problems using particle board. (See figure 34.)

It is interesting to note here that MDF was applied in the United States first in expensive and decorative type furniture, probably because of the higher cost of MDF to the manufacturer. However, it quickly became evident to furniture manufacturers that considerable savings could also be achieved in the production of low-cost furniture using MDF instead of particle board. For low-cost furniture, panels are finished by painting only. The ability of MDF to readily accept paint on both its surface and on the edges without any special filling process resulted in immediate savings to furniture manufacturers.

The next step in the development process then rapidly became very obvious. MDF can be readily machined and profiled not only on the edges but also on the surfaces. (Examples of this process can be seen in the following figures.) Owing to this characteristic, MDF is now being used in many furniture lines for both expensive and less-expensive types of furniture. (See also figure 35.) For more sophisticated furniture, the board is overlaid with veneers and patterns are machined into the surface for a decorative effect and then specially treated by hand painting. In the case of the less-expensive and somewhat simpler furniture, the entire piece is painted and engravings or machining is touched up by hand for special decorative features.

Figure 33. Table made entirely of MDF

Figure 34. Table with drawers made entirely of MDF

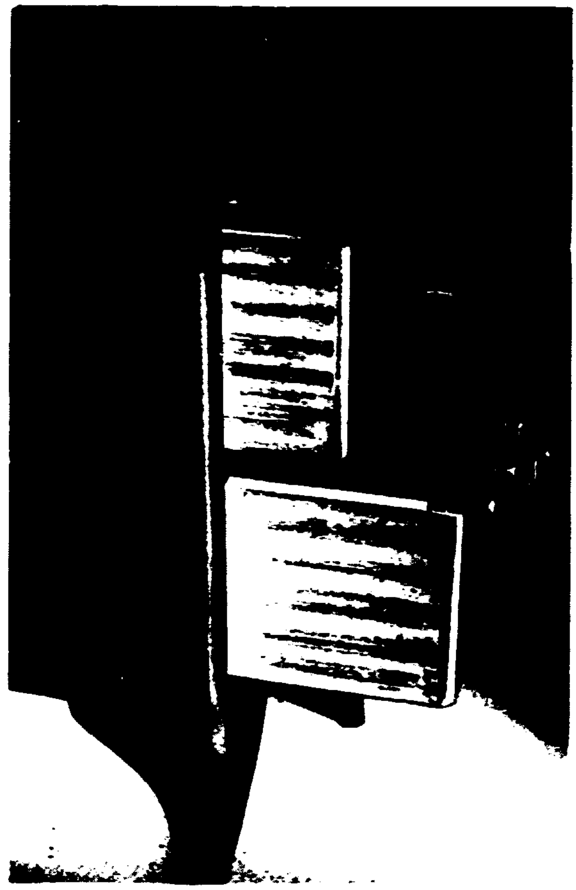
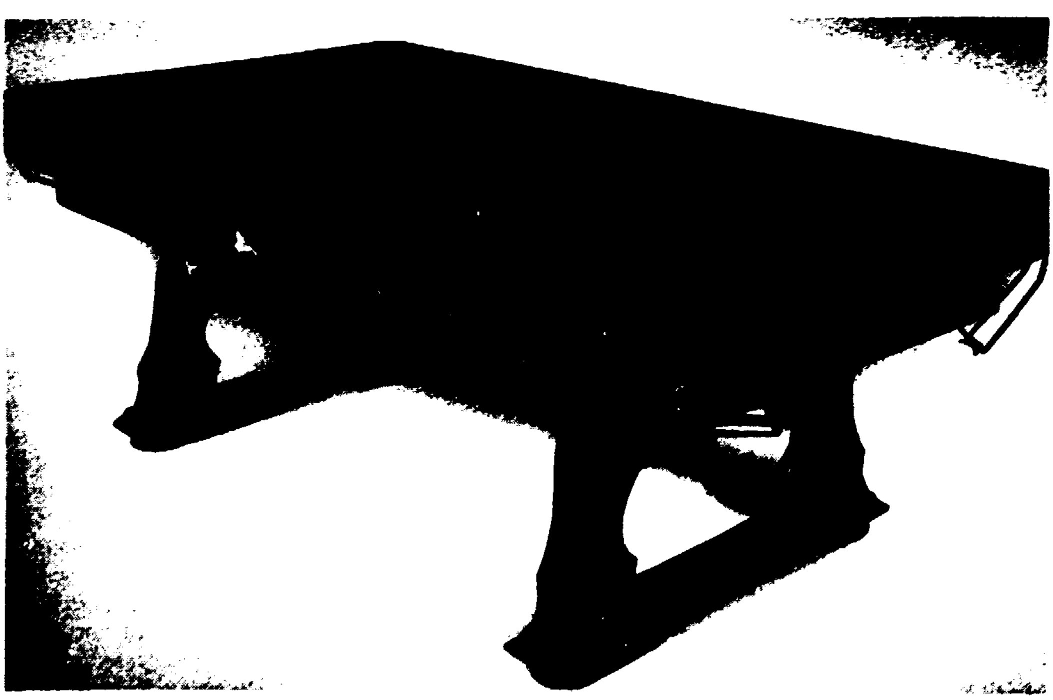
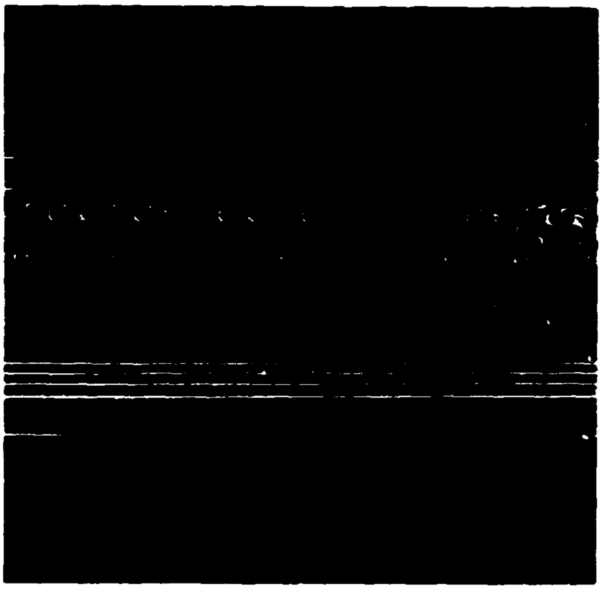


Figure 35. Billiard-table made entirely of MDF



A further development in MDF use is the post-embossing process for decorative effect (see figure 36). The process can be applied in two ways. For relatively simple and decorative effects a pattern is pre-machined into the panel and subsequently placed in a moulding press where it is compressed with the application of heat. This process burns the decorative pattern into the panel, which is subsequently enhanced by painting. This process is relatively straight forward but is used only for simple patterns and for a limited decorative effect.

Figure 36. Embossed MDF



A more sophisticated process has been developed recently whereby whole panels are pre-cut to the size of table-tops and then pressed under application of pressure as high as 18 MPa in a moulding press with very little heat. The pattern is not burned into the surface, but the surface material is textured to a depth of about 2 mm. The moulds designed for this process can be very elaborate and are normally laid out to represent natural wood grains.

Another application in the furniture industry is the use of MDF in combination with plywood. Owing to the much lower strength of MDF compared to natural wood or plywood, its application in the manufacture of chairs was thought to be restricted. However, several furniture manufacturers have developed the process whereby MDF is laminated around a plywood core. Thus, advantage can be taken of the good machining properties of MDF in the construction of the legs, back and seat of the chair.

Some applications of MDF in furniture production are quite sophisticated; for example MDF can be used to give a Venetian-blind effect (see figure 37) or in particular lattice work or decoratively glazed display cabinets.

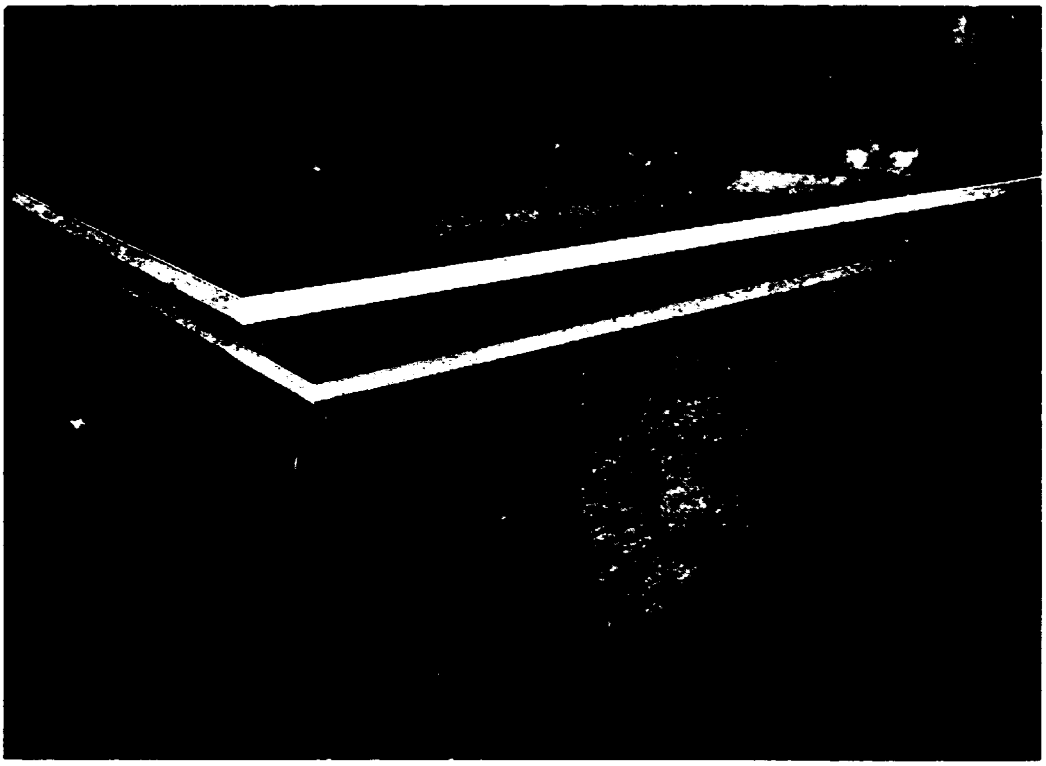
The worldwide application of MDF in the furniture industry is growing rapidly. The plants that are being built in Europe are all aimed towards this industry. New applications are developed almost daily, and the demand for MDF in the furniture industry will grow considerably in the next decade.

Figure 37. Venetian-blind effect using MDF

Cabinets

MDF can also be used to advantage in the cabinet industry. Wherever there are exposed edges, MDF has the advantage over particle board. The edge-banding step can be eliminated, and the edge can be treated artistically through machining and special painting techniques. In addition, the sawing of an MDF panel is a very smooth and easy process, and MDF does not ruin a saw as particle board does. The edges are clean and smooth because sawing does not break or chip the edges. The edges are very strong and can take a considerable impact. The screw-holding ability of an MDF panel both in the face and in the edge is superior to particle board. Because both the surface and the edges of an MDF panel can be easily decorated through machining, MDF is being used more and more in the cabinet industry. (See figure 38.)

Figure 38. Kitchen cabinets



Since the cabinet industry used MDF, it was natural for this product to be used for television cabinets and loudspeaker enclosures, and it has gained acceptance in the Hi-Fi and stereo market very rapidly. One very interesting additional feature of the MDF panel is that it has excellent acoustic characteristics, and all leading manufacturers of loudspeakers will only use MDF for speaker enclosures.

Panelling

Because of its superior ability to accept direct print, some MDF is finding its way into the panelling market, especially in thicknesses of 4 mm and 6 mm. In this field MDF is in direct competition with hardboard but has found acceptance owing to its lower cost, lower density and greater stiffness.

Trim and mouldings

As has been mentioned, MDF has increasingly become a replacement for lumber. It is therefore natural that it should be used as trim and mouldings, an application that was particular to the solid lumber industry. The great uniformity of MDF and its ability to be machined into various shapes and patterns have made it very attractive in this field. It is used for window casings, door frames, floor and ceiling mouldings, picture frames (a very large market) and as door cores. The latter application is very popular because of the good screw-holding ability of MDF.

In manufacturing hollow-core doors, MDF is used in the area where hinges are attached and where the door handles and locks are inserted. MDF can be planed with ordinary carpenter planers normally used on lumber.

For trim and mouldings hot embossing (described under furniture) is extensively used for decorative effects.

Flooring

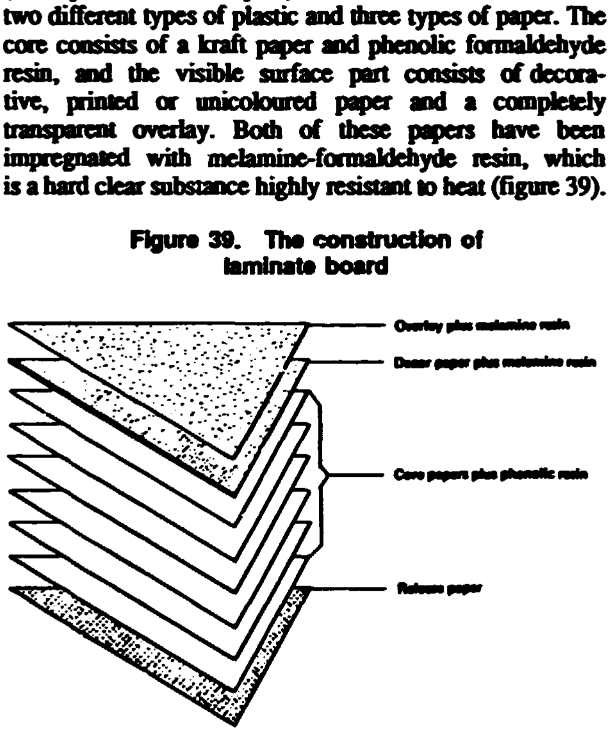
MDF is used for flooring only in New Zealand. However, the use of MDF as flooring highlights its versatility and shows how different manufacturing techniques can be applied.

As pointed out, MDF is especially noted for its even density profile throughout the cross-section of the panel. This density profile is controllable during the pressing process of the board and can be altered to suit particular applications. In the use of MDF as flooring, a press technique has been developed that gives an extreme densification of the surface of the board and a relatively low densification in the core of the board. With high surface densification, the panel tends to simulate the structural characteristics of an I-beam, sometimes also referred to as double T-beam. The board thus created has a very high modulus of elasticity of 4,300 N/mm^2. Under the New Zealand code this permitted the installation of the flooring at 600-mm joist centres. Board delivered in 20 mm thickness and sheet sizes of 3,600 × 1,200 mm allowed the installation of the flooring in a single layer. The resulting overall savings in material and labour compared to a standard build-up floor have proven to be considerable.

VI. Properties and uses of paper-based decorative plastic laminate board*

At present many plastic materials such as imitation leather, plastic-covered textiles, plastic films and to a large extent laminate boards are used as interior linings. Paper-based decorative plastic laminate boards (in short, decorative laminates or laminate boards) are manufactured from paper and plastic. Plastic-impregnated papers are pressed between steel plates into a homogeneous board at an elevated temperature under particularly high pressure (100 kp/cm², i.e. 1,400 p.s.i). Decorative laminate contains two different types of plastic and three types of paper. The core consists of a kraft paper and phenolic formaldehyde resin, and the visible surface part consists of decorative, printed or unicoloured paper and a completely transparent overlay. Both of these papers have been impregnated with melamine-formaldehyde resin, which is a hard clear substance highly resistant to heat (figure 39).

Figure 39. The construction of laminate board



Decorative laminate boards with a melamine resin surface have been manufactured industrially in several countries since the 1940s. The best-known trade marks are Formica in the United Kingdom and the United States, Resopal in the Federal Republic of Germany, Perstorp in Sweden and IKI-board in Finland. World production is over 200 million m² per year (2,000 million ft² per year).

The main producers, in their order of importance, are the United States, Italy, Japan, the Federal Republic of Germany, France, the United Kingdom and Sweden. The largest factory units manufacture over 10 million m² a year and the middle-sized units about 2 to 3 million m² a year. The minimum economic size of a laminate plant depends on local circumstances, but 1 million m² a year is in many cases the smallest possible size. This production is achieved by one machine line.

According to European statistics, decorative laminate is used mostly for kitchen furniture (about 42 per cent); about 35 per cent is used for other furniture; 7 per cent for passenger transport vehicles, such as ships, buses and trains; 12 per cent for doors and wall coverings; and 4 per cent for other purposes. The figures may vary noticeably in different countries, e.g. in Scandinavia the proportion used for vehicles has been 17 per cent. The most typical and oldest use of laminate is still for table-tops in kitchens, shops and cafes; this use has since been extended to the vertical surfaces of kitchen cabinets, doors, bathrooms, hotel interiors and furniture and cabin walls of passenger ships, buses and trains. For example, about 50,000 m² of decorative laminate is needed for one deluxe cruiser. Decorative laminates have recently been introduced for exterior wall coverings, but experience in this application is as yet insufficient. Great demands are made on laminate's resistance to light in these cases. Laminate for exterior walls usually h: large patterns and is about 3-mm thick.

Modifications of laminate boards

There are a few modifications of laminate boards; three could be mentioned:

- Post-forming laminates
- Fireproof laminates
- Low-pressure laminates, i.e. direct-laminated particle boards

In principle, post-forming laminates are manufactured in the same way as ordinary laminates. The resin has been modified so that it is possible to soften it once more and thus to bend the board two-dimensionally. As a result, curved corners can be made. For this, the user of the board must have equipment for heating the board up to 160°C and for bending it as desired.

Fireproof boards are used in ships. For these boards, certain substances are added to the resin or paper that prevent the board from burning. It is possible to make the board self-extinguishing and unable to burn further. However, the laminate may be charred depending on the circumstances of the fire.

Direct laminated boards differ most from ordinary laminate. They are made by pressing decorative paper straight onto the particle board surface. A pressure of only 15 kp/cm² must be used to avoid compressing the particle

*By Heikki J. Ahonen, G. A. Serlachius Oy, Kolho, Finland. Originally issued as ID/WG.163/28.

board. Direct-laminated particle board is used for inner surfaces of kitchen furniture but not for table-tops. It is of course less durable than the actual laminate but cheaper because subsequent gluing of the laminate to the board is not needed since lamination and gluing are done at the same stage. The use of laminate has continuously increased in the world; in Western Europe the increase has been about 10 per cent a year, mainly because laminate makes it possible to obtain durable, beautiful and hygienic surfaces.

The decorative high-pressure laminates are ready-made sheets with a phenolic resin core that are glued onto particle board as a separate operation.

The low-pressure method is much simpler: the melamine-resin-impregnated decorative paper, usually a single layer, is directly pressed onto the particle board surface. This paper is impregnated with melamine formaldehyde resin and corresponds to the decorative paper used in the high-pressure method. In horizontal surfaces both an under sheet and a surface film are necessary, but even so the heat and impact strengths are not as good as in the high-pressure laminates.

The resin content of the decorative paper is 55 to 56 per cent. The paper can be stored at a maximum of three months if it is to remain in usable condition. The storage temperature must be below 20°C, and relative humidity may not exceed 50 per cent. Papers are stored flat in stacks of less than 1,000 sheets to avoid sticking.

The pressure used in the low-pressure laminating is only 2 to 3 MPa because of the low crushing strength of particle board. The temperature is about 145°C. The quality of the particle board used is more important in the low-pressure method than in the high-pressure process.

The surface pattern can be altered by changing pressure plates. If natural wood grain is imitated, the grooves must not be very deep because of the thin paper used.

Appearance of laminate boards

The appearance of laminate board depends on the decor paper and surface finish. As mentioned before, the paper may be decorated, printed or unicoloured. Printed patterns are divided into three main groups: wood-grain imitations, textile imitations and fantasy patterns. The printing cylinders are etched by photogravure; thus it is possible, for example, to make the wood grain look genuine.

However, the diameter of the cylinder is usually only about 30 cm (1 ft), which means that the same pattern is repeated at intervals of one metre. The largest factories have their own printing machines and pattern collections; the middle-sized and small ones buy printed papers from the same subcontractors. Thus, exactly the same patterns are included in the collections of several different producers. It is also possible to buy sole rights for a certain cylinder and in this way to have an individual pattern in a collection.

Unicoloured decor papers are already thoroughly coloured in the production stage. The result is that it is not worthwhile to manufacture small quantities of a colour that is separately chosen. Thus, attempts must be made to explain to architects that it is easier to harmonize the paints according to the laminate than to find a laminate to match a certain shade of paint.

It is also possible to affect the appearance of the board by the surface finish, which is normally glossy, semi-mat or mat. Recently, marketing has started of so-called three-dimensional surfaces. Perhaps the most popular of them is the wood-grain imitation with a porous finish; it has a surface that is more like wood than those made previously. The third dimension has also been employed in textile imitations in order to obtain textured surfaces.

If the decorative paper and overlay of the laminate are omitted, the product is called industrial laminate or technical laminate. It is mainly used in machine parts and in furniture, e.g. on the reverse side of table-tops to give a balanced construction.

Sizes of laminate boards

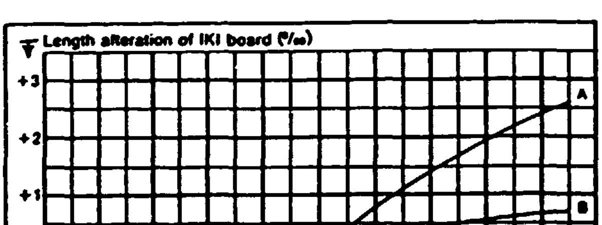
By changing the amount of core paper in the laminate it is possible to vary the thickness considerably. As a curiosity, it is even possible to make a board 50 mm (2 in.) thick. The thinnest laminates produced for sale are 0.5 mm. The most common thicknesses on the market are 1.6, 1.4, 1.0, 0.8, and 0.7 mm. Generally, the manufacturers prefer thicknesses of from 1.6 to 1.0 mm, because it is difficult to handle the thin laminates as large sheets; they are inclined to break and crack, and the result thus is no cheaper than if thicker boards were used. Boards between 1.6 and 1.0 mm are used mainly for horizontal surfaces. Thin sheets (from 1.0 to 0.7 mm) are used for vertical surfaces; they do not require especially high resistance to abrasion, and the overlay can thus be omitted, especially where unicoloured boards are concerned. As a result, the hardness and fragility of the board is decreased. The thickness tolerance is usually ± 10 per cent. The size of the boards varies considerably for different manufactures. The length normally varies between 245 and 360 cm (8 ft and 12 ft), and the width between 125 and 185 cm (4 ft and 6 ft); the usual dimensions are 125 × 245 cm (4 × 8 ft) and 125 × 305 cm (4 × 10 ft). By far the most common width is between 122 and 127 cm; two kitchen table widths may be obtained from it. Because the product is sold cut to certain sizes and not for example in rolls, waste occurs both in longitudinal and transverse directions.

The most common types of laminates and their properties

Decorative laminate is very resistant to wear abrasion. Another important advantage is that it tolerates temperatures over 100°C (212°F). A kettle filled with boiling water can safely be placed on laminate board, and even a burning cigarette may remain on it for two minutes without damaging the surface. These good properties are mainly due to the melamine resin, which is hard and transparent. In boards for horizontal surfaces, this property is increased by an overlay with a particularly high resin content.

Decorative laminate also has certain disadvantages because it contains three different materials: paper, phenolic resin and melamine resin. All the substances have their own peculiar physical and chemical characteristics. When these materials are laminated, the core and the surface behave in different ways. Variations in temperature and humidity cause tensions between the layers which may result in delamination and warping. The characteristics of the paper cause most of the negative effects, and because 60 per cent of the laminate consists of paper, the resins cannot offset these effects completely. However, paper fibres can absorb moisture from the air and expand; in dry conditions they can give out water and shrink. The result is that the dimensions of the board change somewhat with the relative humidity of the air (figure 40). For example, if the laminate is taken from cold and moist storage, glued on particle board and later kept under dry conditions, it will shrink; however, when glued it only stretches and causes heavy tension. If the particle board is not firmly fixed, it will bend and in extreme circumstances the laminate will crack. This danger may be avoided by gluing the laminate under normal climatic conditions, not particularly moist or dry. The disadvantages are thus partly eliminated. The strength of the board also depends on the paper as well as the difference in the above-mentioned dimensional stability in transverse and longitudinal directions. The paper fibres are oriented more in the longitudinal direction; the same characteristic is also apparent in the laminate. The result is that board swells and shrinks in the transverse direction more than it does in the longitudinal direction. Swelling from bone dry to tropical moist may be 0.8 per cent cross-wise and 0.3 per cent in the longitudinal direction; if this is prevented, a corresponding tension will exist. The same difference also appears in the tensile strength and modulus of elasticity which are greater in the longitudinal than in the transverse direction. Although paper causes the above disadvantage, on the other hand it reinforces the board. It is also easy to print various imitation patterns on paper.

Figure 40. Dimensional stability of laminate board



Stored laminates should be protected from moisture. The best method of storing is a horizontal stack that is kept under a light weight (see figure 41). If the stacks are properly supported storing almost vertically (80°) is also possible.

The laminate and base panels must be aerated about two weeks before gluing in a space where the relative humidity is 50 to 60 per cent or corresponds to the conditions of the later use of the laminated structure (figure 42).

The standards of the National Electric Manufacturers' Association (NEMA) of New York are mainly used to control the quality of laminate boards. Some other standards could also be mentioned, such as Deutsche Industrie-Norm (DIN) in the Federal Republic of Germany, British Standards (BS) and Sveriges Standardiseringskommission (SIS) in Sweden.

Figure 41. Storage of laminates

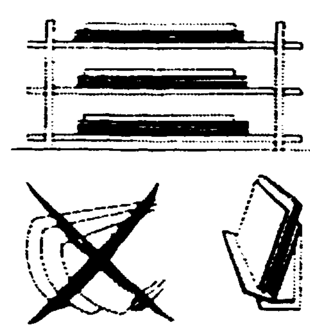
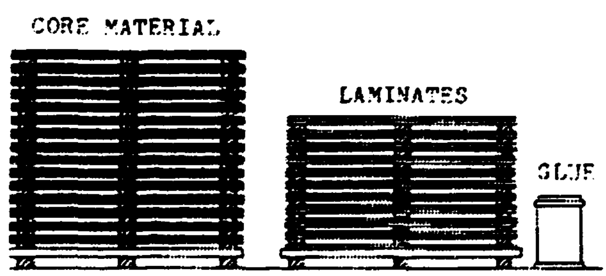


Figure 42. Storing core material, laminates and glue



Their code numbers and the properties they test are given in the table.

Most laminates are used for covering furniture or for covering walls that are exposed to wear and that easily get dirty, especially those in public buildings.

Normal decorative laminates with melamine surfaces are used for these purposes. In the manufacture of table-tops, a so-called counter-board (a technical laminate board without the melamine layer) has to be fixed under the table-top. This prevents the warping of the board. These counter-boards normally represent about 30 per cent of the cost of decorative laminates. If the board is long and warping is to be fully prevented, both sides must have identical laminates with a melamine surface glued to them.

Table 10. Comparative list of standards for decorative plastic laminate boards

Test element	*NEMA*	*SIS*	*DIN*	*BS*
Abrasion resistance	LD 3-3.01			
Resistance to boiling water	LD 3-3.05	R 70 50 02	53799	3794
Resistance to high temperature	LD 3-3.06	24 58 03	53799	
Resistance to burning cigarettes	—	—	53799	
Stain resistance	LD 3-3.09	24 58 05	53799	
Resistance to light	LD 3-3.10	24 58 05	53799	
Wetting resistance	—	24 58 01		2782
Dimensional stability	LD 3-3.04	24 58 06	53799	
Flexural strength	—			3794
Modulus of elasticity	—			3794
Deflection at rupture	LD 3-3.11			3794
Inspection for appearance	—		53455	3794
Tensile strength	LD 3-3.03			
Impact strength	—			
Scratch resistance by pencils	—	18 41 87		
Water vapour transmission	—		53122	

Finally, so-called post-forming laminates may be mentioned. These laminates can be bent to permanent form by warping the laminate board at about 135°-140°C and bending it quickly against a mould. After cooling the laminate board, the bending radius remains permanent. The post-forming laminates generally represent about 5 to 20 per cent of the total quantity of normal decorative laminates. The following technical characteristics are typical properties of decorative laminates:

- Bending strength (lengthwise) ca. 1,800 kp/cm^2
- Bending strength (crosswise) ca. 1,300 kp/cm^2
- Tensile strength (lengthwise) ca. 800 kp/cm^2
- Tensile strength (crosswise) ca. 600 kp/cm^2
- Modulus of elasticity (lengthwise) ca. 143,000 kp/cm^2
- Modulus of elasticity (crosswise) ca. 95,000 kp/cm^2
- Thermal expansion (lengthwise) 0.11×10^{-4}/°C
- Thermal expansion (crosswise) 0.14×10^{-4}/°C
- Heat conductivity 0.208 W/m/°C/sec

Normal 1.0 to 1.4 mm laminates can be bent to a radius of about 30 to 40 cm without risk of damage in long-term use. When using so-called post-forming laminates, the best qualities can be bent to the radius of about 4 to 5 mm; a radius of about 10 mm can usually be obtained easily.

So-called melamine plastics are very resistant to all chemicals, and generally the laminate surface resists all chemicals that are used in the household, hospitals and institutions, with the exception of some easily staining organic colourants, which may leave a spot that is difficult to clean on the surface.

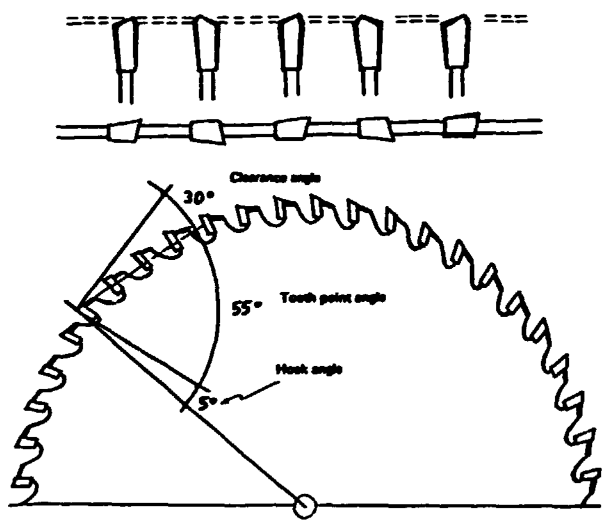
Machining and gluing of laminates in the furniture industry

Machining laminates

As a general rule, the majority of machines used in joinery production are suitable for the machining of laminate board. Nevertheless, for constant use it is advisable to provide machines with tungsten-carbide bits, since their lasting sharpness improves the finishing of board edges and speeds up the manufacturing process. When laminate boards are sawn into sizes corresponding to those of the base material, the board must be placed against the saw blade so that it will cut the decor side first.

In factory processing, straight cuts are made by circular saws and curved cuts by band-saws (see figure 43).

Figure 43. Recommended blade for cutting laminate board

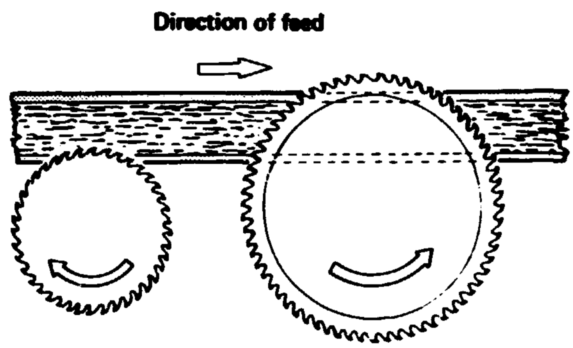


The purpose of machining laminates before gluing is usually to cut them to suitable sizes for gluing and installation. Tungsten-carbide bits with a rim speed of 50 to 60 m/sec are used for sawing, with a feed speed of 0.2 to 0.3 m/sec. Laminate boards can also be cut in the same way as glass, by incising the decor side with a sharp cutting tip and by bending quickly towards a steep edge; the laminate breaks but the core part splits with about 0.2 mm tolerance. This method of working is much used when laminate boards are installed for covering walls, with the help of installation strips to cover the edges. Often a normal guillotine is used for cutting laminate boards.

When the laminate is to be glued to a base material, e.g. on particle board, the finishing must usually be final in order to avoid extra costs; therefore a very good cutting edge is needed. If a normal saw is available, laminate boards must be cut with 5 to 10 mm tolerance more than the final size and then planed to exact dimensions and a good edge finish. A cutter rotating at high speed (about 15,000 to 18,000 rev/min) and a rim speed of about 80 m/sec should be used. In sawing the laminate board direct to the final size—a method that is used more and more—very fast tungsten-carbide bits with quite closely spaced teeth should be used. The best tooth pitch is 10 to 12 mm with a rim speed of up to 100 m/sec.

When a decorative laminate is laminated on both sides of the core (e.g. particle board) and a finishing track is demanded on both the upper and the underside, the underside has to be scored with a separate blade before final sawing. This method is shown in figure 44. When sawing several laminate boards (3 to 5 boards) at one time only the undermost board need be scored, but strong pressure has to be used to bind the boards firmly together during the sawing.

Figure 44. Scoring saw used to saw a board laminated on both sides



The edges of the boards are machined as in figure 45 to avoid splitting. This is carried out either with a cutter or a file after the edging.

About 500 to 1,000 m of laminate boards can be cut with the present tungsten-carbide bits before resharpening. The shape of a blade profile known to be very durable was shown in figure 43.

Gluing laminates

Laminate board is fixed by gluing on the framework, which is usually of wooden board, such as particle board, blockboard or laminboard, and plywood. Metal and stone bases may also be considered (figures 46 and 47).

There are general rules for the application of such wood glues as urea-formaldehyde glue, PVAc, glues based on phenol and contact glues and hot-melting glues. The following rules can be applied depending on the particular circumstances and the available means for pressing:

(a) Use PVAc dispersion glue (cold-cured) when good resistance to heat and moisture is not essential;

(b) Use cold-curing glues if ample pressing capacity is available and there is no special need for moisture resistance;

(c) Use hot-curing urea glue if the framework material is sufficiently sturdy to preclude the effects of tension resulting from thermal expansion (30 per cent PVAc dispersion with urea glue);

(d) Use phenol and resorcinal glues when special moisture resistance is required;

(e) Use contact glues when a press is either not available or impractical to use;

(f) Use epoxy glues or two-component-contact glue when laminate boards are to be fixed to metal surfaces;

(g) Use hot-melting glues for edging table-tops and other edged panels.

Figure 45. Filing the edges

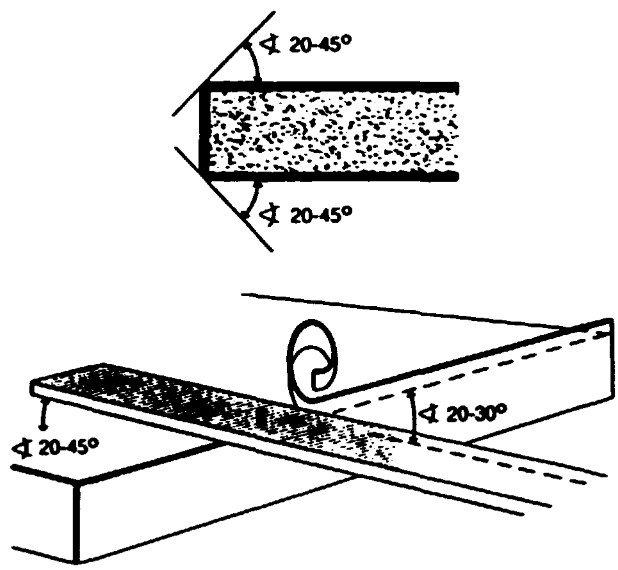
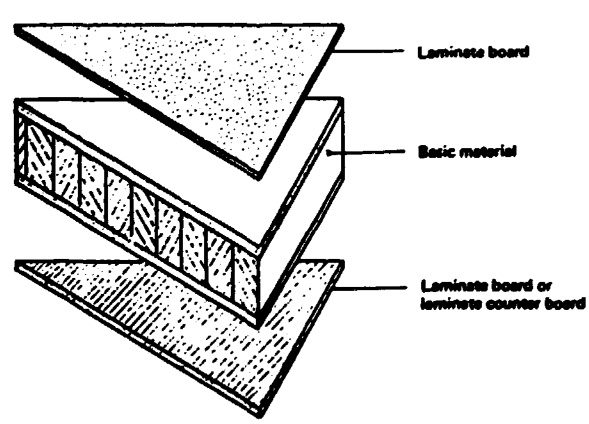


Figure 46. Laminate counter board



Note: When particle board or blockboard, plywood, door frames and similar items are covered with laminate board, it is also necessary to use a counter board.

Figure 47. Cross-section of a door

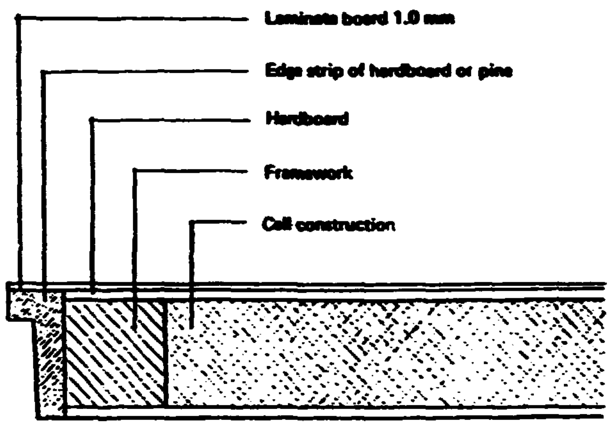
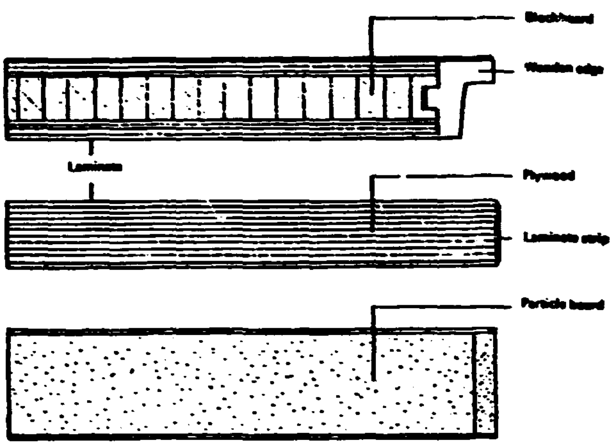


Figure 48. Core materials and edge forms



In any case, the manufacturer's instructions should be observed during gluing.

The glue is generally spread on both sides of the core material, e.g. particle board, at the same time so that the amount of glue is about 120 to 140 g/m². On the even core material, as on a surfaced wood, a smaller amount of glue is enough. Rollers are used to spread the glue, the board being pushed between them. The amount of glue is regulated by adjusting the margin between the scrapers and rollers.

Particle boards, laminboards and fibreboards are considered the best core materials for gluing. Plywood and wood are more difficult materials because changes in moisture content on their surface cause unevenness.

After the glue is spread, laminates are placed on the core and set into the gluing press. As a rule up to 50 boards can be pressed at one time. Then, however, care should be taken that the compression strength is about 3 to 4 kp/cm² to compensate for warping etc. A sufficient pressing time is about 15 minutes. In this method, cold-curing PVAc or urea-formaldehyde glues are used.

When hot-curing glues are used, such as urea-formaldehyde or phenol glues, temperatures higher than 70°C are not recommended. Pressing time is generally about 5 to 15 minutes.

Suitable materials for edging strips are wood, metal or plastic.

Wood and plastic strips should be affixed by gluing. When metal strips are used, they should be firmly attached to the framework with screws set as closely together as is expedient (figures 45 and 48).

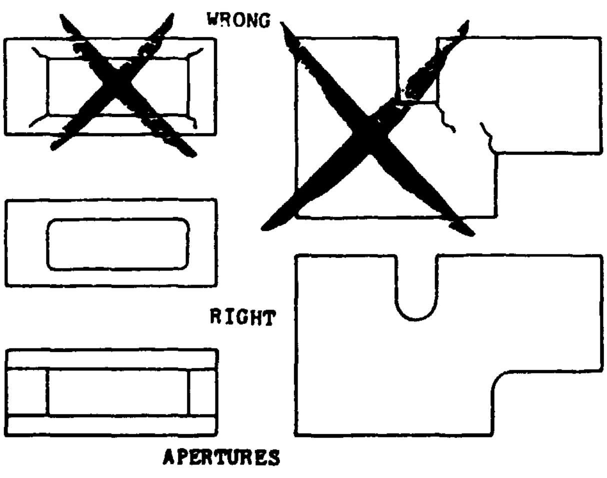
Laminate board can be used as edging material simply by gluing it on the framework and by rounding off or planing the joining edges.

On the vertical surfaces, laminate can also be attached with strips. Either link strips or capping strips, which may be of aluminium, plastic or wood, are used. In addition to strips, elastic glue may also be used in the middle part of the board. This installation method is used, e.g. in kitchens for covering the wall between cupboards, in bathrooms and toilets and in ships and trains.

In handling laminates the most usual error occurs when insufficient notice is given to the moisture content. In figure 40 the dimensional changes of the laminate board can be seen as a function of the relative humidity of the air. If the laminate board is glued on the core material when too moist, the board may split during drying. This occurs because the core material cannot dry and shrink in the same way as the laminate; the laminate is a good moisture barrier for the core material. It would be desirable for laminates to be kept for about two weeks at 50 per cent relative humidity or about 12 hours in a warm drying room at 50°C where the relative humidity is quite low.

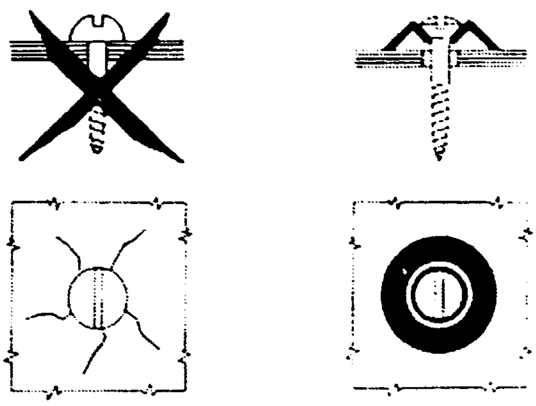
In machining laminates the most usual fault of this material is splitting, which begins from edges and holes. Therefore, a small hole should always be drilled first at the corner before making acute openings. In like fashion, a wide hole ought to be drilled before fixing nails or screws to the board. (Figures 49 and 50).

Figure 49. Corners in cut-outs and machined holes



Note: Sharp corners should be avoided.

Figure 50. Drilling holes for screws or nails



Note: Holes should be a little larger than the thickness of the screw or nail to avoid cracking.

As a rule, laminates are recommended for use where surfaces of high quality which are highly resistant to wear and chemicals are desired, e.g. for covering walls in kitchens, hospitals and public buildings and for theatres, schools, ships and buses.

VII. The use of glues and other adhesives in furniture and joinery*

History

The bonding of elements with glues and other adhesives is an ancient technique; it dates back to the earliest recorded history. Precise information has been recorded in Egypt from around 2000 B.C., and there are records from about 1500 B.C. from Thebes in ancient Greece. The time since these first indications to the present is thus 3,500 to 4,000 years. The Roman historian Pliny the Elder (A.D. 23 to 74), in his book *Historia Naturalis*, gave clear working instructions on gluing.

During the seventeenth and eighteenth centuries gluing was a rather common working method in various parts of the world. During the nineteenth century systematic research on this subject began to appear. All glues up to the end of the nineteenth century were materials taken from nature. Among these were the true glues, made from various animal residues and milk casein, the gummy secretions of certain trees and other vegetable-based materials.

Synthetic adhesives made their appearance at the beginning of the twentieth century. Between 1902 and 1909 L. H. Baekeland of Belgium introduced phenol-based bakelite. This was the beginning of the enormous rise in the use of plastics and plastic-based adhesives. The 1930s saw the introduction of several synthetic glues, among them urea (carbamide). Since then, particularly during the Second World War, bonding techniques have been intensively developed. This rapid progress in gluing, particularly in the use of plastic-based glues, continues unabated.

Gluing and other methods of joining

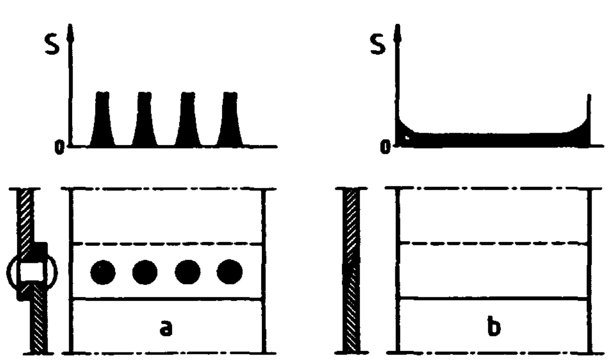
Gluing is not a substitute for other joining methods but rather complements them in an excellent way. Some of its advantages and disadvantages are listed below.

Advantages

(a) An essential advantage of glued joints is the comparatively even distribution of stress. This, however, depends to a certain extent on their construction. Figure 51 illustrates this advantage as compared with a riveted joint, where the stress distribution is very uneven;

(b) Glue can be used to join very dissimilar materials that cannot be welded or that are difficult to work by mechanical means. Typical examples are hard metals, ceramic materials and cement-based and certain other inorganic materials. If the materials to be joined are very different with respect to temperature expansion, a glued joint may well be the only alternative, provided the right glue is chosen;

Figure 51. Comparison of the distribution of stresses in a rivetted joint and a glued joint



Key: a Rivetted joint
b Glued joint
S Stress

(c) The even distribution of stress makes possible the use of thin pieces, so that weight and cost can be saved. Gluing is therefore very advantageous in the case of dynamic loads such as vibration and shaking;

(d) Glues can be used in sandwich structures and in connection with light insulating materials such as rigid foams where other joining methods are hardly possible;

(e) Suitable types of glues show a smoothing action on pores and other surface irregularities. The glue layer is, moreover, resistant to variations in pressure;

(f) The glue layer can act as a vibration damper;

(g) The surface of glued parts is smooth, which is not true of screwed, riveted or welded joints;

(h) Owing to its insulating qualities, a glued seam prevents galvanic corrosion between metal parts.

Disadvantages

(a) All glued seams have relatively narrow zones of heat resistance. If the temperature goes below or, especially, over the limits, the strength values and also the

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ability to withstand varying loads are impaired. The temperature value of 250°C (480°F) should be regarded as the very highest limit in this respect;

(b) A static load of very long duration can cause fatigue (strain) in the glued seam. In some cases it gradually begins to crack, which in turn greatly increases its sensitivity to impact. The continuous presence of water, solvents and other chemicals intensifies the effects of aging;

(c) Many glues need an appreciable time to harden. During this interval, very expensive equipment is often involved in the process;

(d) Surfaces to be glued must be carefully prepared. This is a particularly laborious task in metal gluing;

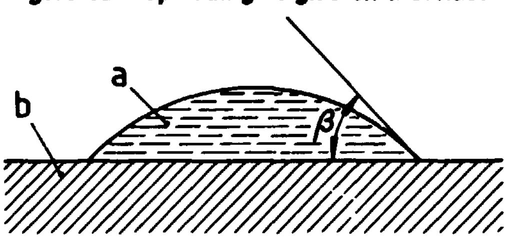
(e) Gluing requires great care during the process and continuous control (suitable proportion of components in the glue; viscosity and acidity of the component parts and of the mixture; amount of dry substance in the mixture; amount of glue spread and the smoothness of the layer; the time interval during which the glue layer is open; pressure and pressing time; temperature; and after-hardening time).

The rapid progress of gluing techniques and glue chemistry is continually shortening this list of disadvantages. Through careful workmanship and meticulous control, such disadvantages can be avoided. In no case do they detract appreciably from the advantages of gluing as a joining method in furniture and joinery.

Factors that effect gluing

The gluing phenomenon itself is characterized by molecular forces of attraction. The radius of the sphere of influence of a single molecule is very small (3 x 10^{-8} cm); solid bodies cannot be brought together within this distance. Therefore, a liquid layer (glue) is put between the bodies to fulfil this distance condition. Thus, adhesion through glue binds the pieces together. Successful gluing is greatly dependent on how the liquid glue is spread on the surface. Figure 52 gives some concepts connected with gluing.

Figure 52. Spreading of glue on a surface



Key: a Liquid (glue)
b Solid
β Contact angle (should be as small as possible)

The gluing of wood

Every material to be glued has its own special features. The special factors of wood gluing may be classified as those attributable to the wood, to the glue and to the gluing process.

Wood factors

Various species of wood differ considerably, and even the same species vary with regard to structure, density, porosity, oil and resin content, acidity, hygroscopic properties, differences between spring wood and summer wood and differences between heartwood and sapwood etc. Furthermore, there are differences in the state of the wood (such as its moisture content).

Light, porous wood absorbs too much thin glue; thus thicker glues must be used with it. Resins and oils as are present in teak, make adhesion more difficult. Adhesion is weaker in summer wood than in spring wood. Also, the closed cellular web and higher resin content of heartwood cause difficulties.

The fibre direction in the pieces to be glued is important because of differences in shrinkages. Butt joints, moreover, have small gluing surfaces, so that both pieces must have the same fibre direction.

Gluing heavy and light woods together must be avoided. The moisture content of the wood is important: different glues require optimum moisture content in service. The suitable moisture content is generally between 10 and 15 per cent. In the case of dry-film glues it is lower (8 to 10 per cent), and the moisture range is also smaller. The surface of the wood must be smooth. In certain cases, a pre-treatment must be applied in order to remove oil and resin. Also, many glues are adversely affected by wood preservatives.

Glue factors

The amount of dry substance in the glue has a considerable effect on the result of gluing. The solvent is usually water, which is removed from the seam, which thus shrinks. While the amount of shrinkage is inversely proportional to the amount of dry substance, it is also dependent on the thickness of the seam. Shrinking causes stresses within the seam. For these reasons, increasing the amount of dry substance in the glue assures a better result.

The amount of dry substance and possible filler have an effect on the viscosity of the glue, the range of which is very wide: 100 to 15,000 centipoises (cP). The viscosity to be selected depends on the pressure. When it is high, thin glues are too strongly absorbed in the wood, so that thicker glue is better. The choice of viscosity depends further on the relative density and moisture content of the wood: light and moist woods take thick glue while heavy and dry woods take thinner glues.

The acidity of glue is an important factor since strong acids and bases damage the seam. The reaction of the wood itself must also be taken into account; it is usually acid. As the catalysts used as hardeners are usually also acids, the seam may become weaker, and the wood in the vicinity of the seam may be lightly hydrolyzed (softened). Thick seams also make the situation worse in this respect.

Process factors

A very important stage in gluing is the application of pressure to the pieces. In the gluing of softwoods lower pressures are used (1,500 kPa, 213 lbf/in²) than for medium-density hardwoods (2,000 kPa, 284 lbf/in²). In the case of Finnish softwoods, at least, these values do not yet cause the wood to shrink.

Very heavy hardwoods, of course, can tolerate higher pressures, but such pressures are disadvantageous for light woods since the glue is pressed into the wood and the seam becomes discontinuous. Uneven pressure also has this result, and too low pressure may well fail to close the seam.

The temperatures of the workplace, the pieces and the press must correspond to the process requirements. Errors easily occur in this respect, especially in cold conditions.

Types of glues

General classifications

Glues may be classified in various ways: the most usual one is the ability to withstand environmental conditions. A main distinction is made between indoor and outdoor glues. This division is generally used in technology.

Glues are also commonly classified according to their origin. The two main groups are natural glues and plastic glues. The former are further divided into two subgroups: vegetable glues and protein glues. The plastic glues can be divided into three subgroups: thermosetting glues, thermoplastic glues and elastomers.

Natural glues

Although this old class of glues has become less important during the last 20 or 30 years, certain natural glues are still important, both alone and in combination with plastic glues.

Vegetable glues. This group comprises macromolecular carbohydrates, vegetable proteins and water-soluble glues containing lignin. They are used in easy gluing applications with modest requirements. Potatoes, wheat, rice, maize etc. can be used as raw material for starch glue. Tapioca starch, which is obtained from cassava (manioc) roots, is also worth mentioning.

Tannin. Tannin is also a vegetable adhesive. The mixture of materials is usually as follows:

Starch	100 parts
Water	190-400 parts
Tannin	1-5 parts
NaOH	3-10 parts

The mixture is cooked at about 88°C until materials are dissolved to produce a strong, water-resistant adhesive.

The tannin is extracted for example from *Acacia mollissima, Eucalyptus redunea* (E. crebra and considaniara). It reacts with formaldehyde to form resins that have been tested as adhesives for wood. It sets at room temperature to give bonds that are somewhat less strong than that obtained from typical commercial adhesives but that have a water-resistance superior to that of the cold-set UF adhesives.

Dextrin glues. This group is a near relative of vegetable glues. Dextrins are produced by hydrolyzing starch. Their application in gluing paper should be avoided (cigarettes, paper pads, cardboard etc.). PVAc glue has in many cases superseded dextrin glue.

Cellulose glues. These are of two main types: cellulose ethers (methylcellulose) and cellulose glycolates (carboxymethyl cellulose (CMC)). Both are made from sodium cellulose. The main field of application is wallpaper paste. They can also be used on wood, leather, metals and almost any other material.

Carbohydrate glues. Gum arabic, the most important of these, is used for stamps and envelopes.

Protein (glutin) glues. The glues of this group (the true glues) are usually made from animal residues (hides, leather, bones, fish residues). The protein (collagen) contained in these residues is hydrolyzed into glue by aqueous extraction. It is easily dissolved in hot water and easily forms a gel. Collagen glue is suitable for indoor use; its main field of application is in furniture. The glued seam is colourless, elastic, chemically inactive and in all respects excellent in indoor conditions. The glue sets very quickly and is easy to apply, only simple equipment being needed. On the other hand, it must be protected against microorganisms. Resistance to moisture can be increased through the addition of formaldehyde or oxalic acid in cases where the relative humidity of the environment is high.

Casein glues. These adhesives have also been used for a long time. Casein is a protein precipitated from milk whey by means of enzymes or acids. The latter kind—acid casein—is the raw material for these glues. The casein is dissolved in alkaline water. The usual base in this connection is calcium hydroxide ($Ca(OH)_2$). The durability of this glue is very short, but it can be increased by chemical additives such as phosphates and fluorides.

Casein glues have several advantages:

(a) Casein powder can be stored for many years in airtight packages;

(b) Its use is simple (mixed with cold water);

(c) The seam can be rather thick without serious effects (gluing of sawnwood);

(d) The strength is good;

(e) Exposure to water is tolerated;

(f) Temperature resistance is very good;

(g) It is suitable for gluing resinous or oily woods.

Its disadvantages are the following:

(a) There can be colour defects in the case of woods containing tannic acid, such as oak and mahogany;

(b) The mineral components (calcium) in the glue cause tool wear. Casein glue is still used especially in the case of large pieces (glued girders).

Albumen glues. Albumen is a constituent of blood. Albumen-based glue was formerly used widely in the plywood industry, but now it is only used in certain combinations, as with phenol (FENALB glues).

Soybean glues. Certain oily plant seeds yield an extraction residue containing proteins that can be used for glues. The best known of these seeds is soya bean. Soya bean glue is much used in Japan and in the United States. Its properties are comparable with those of casein and albumen glues.

All protein glues can be combined, in varying ratios, and can also be mixed with certain plastic glues (phenol, urea).

Plastic glues

This is the main group of glues, owing to their good properties:

(a) Good resistance to water, even when boiling;

(b) Good resistance to chemicals and micro-organisms;

(c) Quickness of setting.

Plastic glues have made possible many new applications, and their development is still rapid in this respect.

The plastics used in gluing wood can be divided into thermosetting resins, which are irreversible and can be used only once, and thermoplastic resins, which are reversible and can be used many times. This is a physical division. Chemically, the division is as follows: polycondensates, polymers and polyadditives. Only the most important of the plastic glues used in woodworking are discussed here. A discussion of resin glues in the joinery industry is presented in the annex.

Polycondensates. When plastic monomers combine to form polymers, a small molecule is split off from the point of adjoining molecules; usually this is water (polycondensation). In glue manufacturing, the reaction is carried halfway. In gluing, the reaction continues to the end, and a hardened irreversible group of macromolecules, namely the glue seam, is formed. The polycondensate group includes four important basic glue plastics that have in common a reaction with formaldehyde. These are the two phenolic (phenolformaldehyde and resorcinol) and the two amino (urea and melamine) resins.

Phenol is distilled from coal tar or synthesized from benzene. It is easily dissolved in hot water (65°C, 150°F). Phenol reacts readily with formaldehyde. The reaction has three stages, and it is broken at a certain stage. The solvent is evaporated or the solution is absorbed in paper which, in turn, is dried. In the former case, a powder is obtained; in the latter case, a dry film.

The phenolics can be used as cold glues, but this is restricted by their high acidity (pH around 1.0). Their main use is in hot gluing. The powder is dissolved in water so that the dry-substance content is 40 to 50 per cent. The glue sets by means of a hardener under pressure and heat. Suitable hardeners are resorcinol, paraformaldehyde and hexamethylene-tetramine. The process data are roughly as follows:

Pressure = 1,800 kPa (256 lbf/in^2) for hardwoods
Temperature = 120° to 160°C (250 to 320°F)

Phenolic seams are very dark. They are resistant to water, even when boiling, and are more heat resistant than wood.

The use of phenolic film is simple. The moisture content of the wood must be very even (between 5 and 10 per cent). Phenolic glue is suitable for joining wood and metal but not for joining metal to metal without additional measures.

Resorcinol is a close relative of phenol. It is also made from benzene that has been impregnated with suphuric acid. As resorcinol is very reactive with formaldehyde, some caution is required. Resorcinol glue is in many respects similar to phenol glue (dry substance, hardeners etc.); seams made with it set at room temperature. The price of this glue is high, owing to manufacturing costs, but it is widely used in exacting jobs such as the construction of aircraft, boats and glued girders.

Urea (carbamide) is an amino compound. It is easily made from carbon dioxide and ammonia, and therefore its price is relatively low. Like resorcinol, urea reacts with formaldehyde to form a thermosetting resin. Urea resins are white, crystalline water-soluble substances. The content of dry substance in a glue ready for use is 50 to 60 per cent, and it sets with the use of heat and/or of acid hardeners (free acids or their ammonium salts, such as ammonium chloride).

Urea resins may be used in cold or hot gluing. In the former case, the hardener must be quick-acting. The dry strengths of the seams are good (comparable with those made with phenolic glues), but their wet strengths are considerably lower (below 50 per cent after prolonged immersion). Alternate wetting and drying is harmful because the seam cracks rapidly. Cracking with age is a drawback of urea resins, but it can be prevented by the use of suitable additives such as kaolin, vegetable powders, wood dust and some alcohols. The seam must also be very thin. Urea resins may be foamed mechanically or chemically; thin and even spreading can be achieved in that way. The properties of urea glue can be considerably improved by adding melamine, but this raises its price. Urea resins are used widely, for instance in the manufacture of composite boards.

Melamine is also an amino compound. It is manufactured from limestone, carbon and nitrogen in a multi-stage process, and its cost is therefore high. Melamine is also a colourless crystalline powder. Condensed with formaldehyde it yields a plastic that is thermosetting; therefore the hot-gluing method must be used. The content of dry substance in the glue solution is 40 to 50 per cent. The process data are:

Pressure = 800 to 2,000 kPa (115 to 280 lbf/in^2)
Temperature = 110° to 120°C (230° to 250°F)

The wide pressure range is applied according to the density of the wood.

Melamine seams are colourless, strong, elastic and water resistant. This glue is particularly suitable for high-frequency gluing. Its advantage is the possibility of drying the surfaces after spreading the glue, which facilitates the working process greatly.

Polymers. In the polymerizing process, nothing is removed from the monomer molecules as in the case of the polycondensation process. The most important glue of this group is PVAc, which belongs to vinyl plastics. It is manufactured from acetylene and acetic acid. The polymerization is easy, and the price is low. Water is used as a solvent when gluing wood. When gluing other materials, other solvents with low boiling points such as alcohols, esters and ketones are used. The setting of PVAc glue is a purely physical process; the solvent is absorbed into the wood. The seam is colourless. The biggest advantage of this glue is its ease of use; no hardeners are needed, it is easy to spread and easy to clean, it sets quickly and only low pressures are needed. The seam is very elastic, and it can be made thick. This glue is suitable for the assembly gluing of furniture. The dry strength is good, but a long continuous load causes "creep". The wet strength is poor. This glue is mostly used cold. Hot gluing is also possible, but in this case cooling must be done under pressure to below 50°C (120°F).

The process data are:

Pressure = 100 to 300 kPa (14 to 43 lbf/in^2)
Temperature = 20°C (70°F)

PVAc glue begins to soften when heated to above 60°C (140°F). If the relative humidity in the air is high, the seam becomes somewhat more resistant to heat.

Other polymers that can be used as glues are:

(a) Polyacrylic glues, which are water-soluble materials suitable for paste-type glues; they are used in the same way as PVAc;

(b) Polyethylene glues, which are suited for use in the wood industry as elements of melting glues. The composition of melting glue is 1/3 PVAc + polyethylene, 1/3 paraffin + wax and 1/3 resin. The spreading temperature is about 180°C (356°F) (spreading by roller). The pressing is done immediately after spreading by means of a cold roller. The hardening time is about 2 to 3 seconds. Melting glues are used, among others, in moulding the edges of panels, for instance in the furniture industry;

(c) Polyisobutylene (butylene rubber);

(d) Polystyrol glues (Buna S rubber), which give a very firm and tough joint;

(e) PVC glues, which are resistant to oil and are thus valuable in the automotive industry.

The three last-mentioned glue groups are elastomeric by nature.

Polyaddition resins. Polyaddition is a variant of polymerization. When monomers are combined, some bonds are opened and new reacting groups of atoms are added to the chain. In this group two excellent glues, the polyurethanes and the epoxies, should be mentioned.

Polyurethane is made from a suitable isocyanate and a di-valent alcohol. The seam has a good cohesion strength and good adhesion to various substances. It is very elastic and fully resistant to boiling, chemicals, oils and micro-organisms. The seam does not shrink; it can therefore be made thick. Polyurethane glue begins to set at room temperature. Urea or ammonium chloride can be used as hardeners. While raising the temperatures quickens the hardening, the top limit in this case is 60°C (140°F) because when this limit is exceeded, poisonous vapours are generated. The moisture content of wood must not exceed 10 per cent.

The process data are:

Pressure = 300 to 800 kPa (43 to 115 lbf/in^2)
Temperature = 10° to 60°C (50° to 140°F)

Polyurethane glue has many uses in exacting jobs.

Epoxy glue is manufactured by a complicated process. Phenol, acetone, chlorine compounds, hydrochloric acid and sodium hydroxide are needed, and the price is accordingly high.

Epoxy glue has excellent qualities; it has all the advantages of polyurethane glue, and it is suitable for gluing almost any substance, even smooth glass. In cold gluing, triethylene tetramine is used as a hardener. The setting time is long, in the case 12 hours. Hot setting is achieved with phthalic acid anhydride, for instance. If the temperature is elevated to above 220°C (428°F) the setting time is reduced to below 10 minutes.

Elastomers

The primary constituents of elastomers are synthetic rubbers, whose basic material is polyethylene. The most important are butadiene, isoprene and chlorbutadiene (neoprene or Perbuna C). These synthetic rubbers can easily be blended in various proportions.

The following materials are also widely used: butadiene plus styrene which is known as Buna S, and butadiene plus vinyl chloride which is called Buna N.

Contact glues have four components: synthetic rubber, resin, filler and softener. The usual resins are phenolics (indene, coumarone, terpenes), the fillers are zinc oxide and magnesium oxide and the usual softeners are amines and mineral oils.

Contact glues are of two principal kinds: permanent ones such as those used in tapes (permanent plasticity) and setting ones that harden firmly.

Neoprene contact glues are rubber-based substances that use a mixture of ketones as solvent. Another possibility is to use a rubber emulsion in water. The former alternative is to be preferred, however. The application of pressure is not absolutely necessary, but a pressure of, say, 500 kPa increases the strength sixfold to eightfold. The pressure can be applied by means of rollers because no appreciable time is needed for the application of pressure. After spreading, the glue is left to dry before the surfaces are joined.

This is particularly necessary when gluing non-porous materials such as metals. Neoprene contact glues have good resistance to water.

All of the glues mentioned above are the most important members in their groups. Together, they represent the majority of glues now in use. Those not mentioned here have little significance in the gluing of wood. Some data on various glues as well as a comparison between different glue types used in Finnish industry are given in tables 11 and 12.

Table 11. Glues used in Finland (1982)

Group of glue	*Share of total use (percentage)*	*Price relative to urea, by weight (%)*
Natural glues	5-6	105
Urea formaldehyde	40	100
Phenol formaldehyde	20	150
Resorcinol formaldehyde	2	1 200
Melamine formaldehyde	5	800
PVAc	25	600
Contact glues	3	1 800

Table 12. Properties of glues
(Average values—no special materials)

A. Protein glues	*Glutin*[a]	*Casein*[b]	*Albumen*	*Soyabean*
General properties				
Trade form	Sheet, pearl, powder, solution	Powder	Powder, solution	Powder
Shelf-life	Dry: several years solution: 1 year	6 months 2 years	1 year (powder)	1 year
Colour	From yellowish to brown	Light yellow	Dark brown	Light yellow
Toxicity	Not dangerous	Not dangerous (bad-smelling)	Not dangerous	Not dangerous
Technical properties				
Moisture content of wood (percentage)	4 to 10	4 to 10	4 to 10	8 to 14
Dry substance of glue (percentage)	35 to 55	30 to 35	14 to 20	20 to 25
Pot-life (hours)	70 to 120	4 to 12	2 to 4	4 to 8
Spreading (grams of solution/m^2)	150 to 300	250 to 300	200 to 350	250 to 300
Assembly time, open (hours)	5 to 10	10 to 15	25	15
Pressing time:				
cold (hours)	1 to 3	1/2 to 2		3 to 12
hot (minutes)	10 to 15		5 + 1/mm[c]	
Pressure (kPa)	200 to 800	500 to 1 200	800 to 1 400	800 to 1 600
Temperature (°C)	20 to 100	20	90 to 120	20
Maturing time (hours)	12 to 72	20 to 24	—	48
Seam properties[d]				
Water resistance	4	3	3	3
Weather resistance:				
Temperate	4	2	2	3
Tropical	2	2	2	2
Temperature resistance	3	2	3	3
Micro-organism resistance	4	4	4	4
Organic solution resistance	4	4	4	4
Acidity (pH)	7 to 8	11 to 13	10 to 14	10 to 14
Colour defects	None	Ample	Ample	Ample
Wearing of knives	Small	Rather strong	Normal	Normal

B. Plastic glues—polycondensates I	*Phenol-formaldehyde hot*[e]	*Phenol-formaldehyde cold*[e,f]	*Phenol film*[e,g]
General properties			
Trade form	Powder, solution	Solution	Film
Shelf-life (months)	2 to 4	2 to 3	6 to 10
Colour	Brown	Reddish brown	Yellowish
Toxicity	Irritation of skin	Irritation of skin	Not dangerous

B. *Plastic glues—polycondensates I*	*Phenol-formaldehyde hot*[e]	*Phenol-formaldehyde cold*[e,f]	*Phenol film*[e,g]
Technical properties			
Moisture content of wood (percentage)	3 to 8	6 to 14	5 to 10
Dry substance of glue (percentage)	40 to 50	60 to 80	90 to 100
Pot-life (hours)	24	1 to 3	—
Spreading (grams of solution/m²)	100 to 150	150 to 300 (two coats)	40 to 60
Assembly time, open (hours)	40 to 50	60 to 600	—
Cold (hours)		1/2 to 10	
Hot (minutes)	3 + 1.25/mm (125°C)		6 + 1/mm[c] (140°C)
Pressure (kPa)	1 200 to 2 000	200 to 1 000	1 000 to 2 000
Temperature (°C)	120 to 180	10 to 60	135 to 150
Maturing time (hours)	12		
Seam properties[d]			
Water resistance	1	1	1
Weather resistance:			
Temperate	1	1	1
Tropical	1	1 to 2	1
Temperature resistance	1	1	1
Micro-organism resistance	1	1	1
Organic solution resistance	1	1	1
Acidity (pH)	10 to 13	1 to 3	7 to 9
Colour defects	Only in penetrating	Rather strong	—
Wearing of knives	Strong	Strong	Rather strong

C. *Plastic glues—polycondensates II*	*Resorcinol-formaldehyde*	*Urea-formaldehyde*[h]	*Melamine-formaldehyde*
General properties			
Trade form	Solution	Solution, powder	Solution, powder
Shelf-life (months)	3	3 (solution) 12 (powder)	6 (solution) 12 (powder)
Colour	Dark brown	Colourless	Colourless
Toxicity	Irritation of skin and respiratory tract	Irritation of skin in long-term work	Irritation of skin in long-term work
Technical properties			
Moisture content of wood (percentage)	8 to 14	4 to 12	4 to 12
Dry substance of glue (percentage)	45 to 60	50 to 70	40 to 70
Pot-life (hours)	2 to 3	6 to 8	4 to 6
Spreading (grams of solution/m²)	200 to 300	100 to 200	100 to 150
Assembly time, open (hours)	10 to 40	10 to 15	24 8 (with hardener)
Pressing time:			
Cold (hours)	10		
Hot (minutes)	5 (80°C)	1 1/2 + 1/2/mm	4 + 1/mm[c] (120°C)
Pressure (kPa)	200 to 1 000	600 to 1 800	500 to 2 000
Temperature (°C)	20 to 80	110 to 140	90 to 140
Maturing time (hours)	24	48 to 72	
Seam properties[d]			
Water resistance	1	2 to 3	1
Weather resistance:			
Temperate	1	2	1
Tropical	1	2	1
Temperature resistance	1	2	2
Micro-organism resistance	1	1	1
Organic solution resistance	1	1	1
Acidity (pH)	11 to 12	6 to 8	3 to 6
Colour defects	Only in penetrating	Slight	None
Wearing of knives	Rather strong	Normal	Small

Table 12 (*continued*)

D. Plastic glues—polymers[i]	*PVA*[j]	*Hot-melt adhesives (PVAc + polyethylene)*	*Contact glue (permanent)*	*Contact glue (setting)*[k]
General properties				
Trade form	Liquid dispersion	Firm, paste-like	Tape	Paste-like
Shelf-life (months)	6 to 12	6	12	3
Colour	Colourless	Colourless	Colourless	Colourless
Toxicity	Not dangerous	Not dangerous	Not dangerous	Not dangerous
Technical properties				
Moisture content of wood (percentage)	5 to 12	8 to 10		5 to 12
Dry substance of glue (percentage)	40 to 60		20 to 40	20 to 40
Pot life (hours)	1 1/2 to 24			1/4
Spreading (grams of solution/m²)	150 to 200			100 to 200
Assembly time, open (hours)	5 to 15	—		5 to 30
Pressing time:				
Cold (hours)	1/2 to 2			
Hot (minutes)	3 to 7 (50°C)	1 to 3 seconds		
Pressure (kPa)	200 to 400		20 to 50	50
Temperature (°C)	20 to 80	80 to 95 (cold roller)		
Maturing time	2 months			6 months to 2 years
Seam properties[d]				
Water resistance	3	1	1	1
Weather resistance:				
Normal	3	1	1	1
Tropical	2	1		1
Temperature resistance	3	4	4	4
Micro-organism resistance	1	1	1	1
Organic solution resistance	2	2		2
Acidity (pH)	5 to 7	5 to 7		
Colour defects	None	None		None
Wearing of knives	Small	Small	Small	Small

E. Plastic glues-polyadditives[i]	*Epoxy*[l]	*Polyurethane*[m]
General properties		
Trade form	Mixture of liquids, paste-like	Mixture of liquids, lump
Shelf-life (months)	12	6 to 9
Colour	Brownish	Dark brown
Toxicity	Not dangerous	Dangerous over 60°C
Technical properties		
Moisture content of wood (percentage)	6 to 12	10 (maximum)
Dry substance of glue (percentage)		20 to 90
Pot-life (hours)	1/2	24
Spreading (grams of solution/m²)	150 to 250	200 to 250
Assembly time, open (minutes)	30 to 240	30 to 60
Pressing time:		
Cold (hours)	12 to 18	
Hot (minutes)	30 (200°C)	
Pressure (kPa)	200 to 1 200	300 to 800
Temperature (°C)	20 to 280	10 to 60 (maximum)
Seam properties[d]		
Water resistance	1	1
Weather resistance:		
Normal	1	1
Tropical	1	1
Temperature resistance	2	3

E. *Plastic glues-polyadditives* [i]	*Epoxy* [l]	*Polyurethane* [m]
Micro-organism resistance	1	1
Organic solution resistance	1	1
Colour defects	None	None
Wearing of knives	Rather strong	Small

Key:

Water resistance

1. Boilproof
2. Waterproof
3. Humidity proof
4. Dry state proof

Weather resistance:

Temperate

1. Most difficult conditions (permanent)
2. Most difficult conditions (temporary)
3. Ordinary conditions
4. Interior conditions

Tropical

1. Durable
2. Not durable

Other resistances:

Temperature, micro-organisms, organic solutions

1. Extraordinary
2. Good
3. Tolerable
4. Poor

[a] Recommended temperature of wood and room, 25°C.

[b] Possible to use in special cases as warm glue (70° to 100°C).

[c] Primary time + 1 min/mm (distance between surface and middle seam of plywood).

[d] The key to the numerical values of the various resistances is given on the last page of this table.

[e] Sunlight can damage phenol.

[f] Cold phenol can hydrolize wood near the joint. Also, it needs an organic solvent (alcohol).

[g] Storage of film rollers in vertical position.

[h] Urea glues are suitable for pre-pressing systems, and they can be caused to foam. Joints made with them must be thin, since they are subject to weathering. (The addition of melamine is useful.)

[i] All glues in this group require organic solvents.

[j] PVAc joints must cool under pressure; also, they creep under continuous loading. The temperature of both the wood and the ambient air must be at least 18°C when PVAc joints are made.

[k] The strength of setting contact glues runs between about 2,000 to 4,000 kPa. The value becomes higher if pressures from 500 to 1,000 kPa are used.

[l] Epoxy glues lose about 10 per cent of their strength under continuous loading for more than one year.

[m] Polyurethane has very high resistance to oils and greases. On the other hand, it emits poisonous vapours at temperatures above 60°C.

The gluing process

Instructions for the use of products are usually provided by the manufacturer. They should be observed carefully. When ordering glue, all factors affecting gluing must be stated (machines, tools, working method) as well as the final conditions of service. At the gluing location, storage is of prime importance. Powder glues are easier to store than liquid ones. Both must be protected from heat and oxidation (air-tight storage).

When preparing glue for use, all constituents must be accurately measured or weighed so that the proportions are correct. The prescribed order of mixing and gradual stirring time must be observed. Viscosity and acidity must be continuously controlled. The time for gluing must be known as well as the amount of glue needed so that the batch size can be determined.

The "pot-life" indicated by the glue manufacturer presupposes an ambient temperature of 20°C; it decreases very rapidly with increasing temperature. The following examples of two urea glues illustrate this phenomenon:

Temperature (°C)	*Pot-life* Glue A [a] *(minutes)*	Glue B [b] *(hours)*
15	70	40
20	40	24
25	25	15
30	15	10

[a] Cold gluing.
[b] Hot gluing.

The glue must be spread in a manner suitable to the glue, the type of joint and the scale of production (manual work, roller spreading, spraying, pouring etc.). Even spreading and thin layers are to be desired. The wood must be optimally moist and at the same temperature as the workplace. The surfaces must be clean and smooth. To ensure evenness of spreading, the glue layer must not be left exposed for too long.

For each gluing job, a programme should be prepared for timing the changes in pressure and temperature during the setting, cooling and curing of the adhesive and including allowed times before handling and machining of the product. If a multi-daylight press is used, all platens should close simultaneously.

Evenness of temperature and pressure throughout the working area is important. In uninterrupted gluing, continuous process control is needed. The basic tasks and means are the following:

(a) Measuring the moisture content of the wood before and after gluing. The instruments needed are scales and a drying cabinet. Electrical instruments are not reliable enough;

(b) Measuring the viscosity and acidity of the glue. The instruments needed are a viscosimeter and a pH metre;

(c) Measuring seam strength with standard test pieces. The instrument needed is a machine to test shear, tensile, compression and bending strengths;

(*d*) Inspecting seam structure and absorption of glue to wood. The instruments needed are a microtome and a microscope;

(*e*) Spot checks to inspect adhesion by means of a knife test. The instrument used is a chisel.

This equipment is sufficient for the essential tasks in the control of glued joints.

Effect of wood preservatives on gluing

The gluing process can be considerably affected by the use of wood preservatives. If oily substances such as creosote are used as preservatives, gluing can be very difficult indeed. The wetting properties of the glue can be improved by adding 2 to 4 per cent by weight of formaldehyde to the solution. A low glue viscosity also facilitates spreading.

Wood preservatives also tend to slow the hardening process. Therefore, with treated wood, a gluing temperature of about 10°C (18°F) higher than that for non-treated wood is recommended. Preservatives containing boron have the least effect on gluing.

Annex

RESIN GLUES IN THE JOINERY INDUSTRY*

The most important glues in the joinery industry are the thermoplastic PVAc and thermosetting urea, melamine, phenolic, resorcinolic and epoxy glues. Pressure-sensitive glues and hot-melt glues have acquired some significance in recent years.

PVAc is used as 50 to 60 per cent water dispersion containing 30 to 40 per cent whiting and additional softeners. The bond is purely physical and is based on wood absorbing the water from the glue line and small glue spheres sticking together. The moisture content of wood should not exceed 12 per cent. The glue has some gap-filling qualities. The spread is 160 to 200 g/m². The "open" time for veneering may be as much as 30 minutes, but that for assembly work is only a few minutes. The pressures needed vary from 0 to 1,500 kPa. Pressing time also varies greatly. In veneering, the pressing temperature should not exceed 60°C or fall below about 15°C. The bond strength in dry conditions is remarkable, but it decreases when wet. The bond is elastic, and thus the glue is very suitable for furniture assembly. Since wood stain does not colour the glue seam, the glue should be coloured before use.

Urea glues are delivered in liquid or powder form or as thin film. The glue can be extended by starch, wheat flour or water. The lowest possible urea content is 20 to 30 per cent. Kaolin and wood flour are often used as fillers. In cold setting, the amount of filler can reach 50 per cent. The pot-life can be extended by freezing or adding a little alcohol. The hardener can be applied only to one of the two surfaces to be joined. The hardening and setting process cannot be speeded up by adding more hardener; rather the composition of the glue should be changed.

The highest allowable moisture content is 15 per cent. The best results are obtained in the limits of 8 to 14 per cent water. The spread is 100 to 200 g/m². The maximum pot life for cold setting is 30 minutes, but for hot setting it can be over 24 hours. The pressure needed varies between 200 and 1,600 kPa for liquid glues and is around 2,000 kPa for film glues. The setting time for cold-setting types ranges from 30 minutes to 4 hours and for hot setting (*temperature range:* 105° to 115°C) about 3 minutes; by using high-frequency radiation (HF) it is from 15 seconds upwards. If the glue shows through in veneers the reasons may be that the veneer is too thin or moist, the glue is too thin or the hardener is too slow. If there are black spots, they may be caused by iron in the glue barrels or mixing pots. In some cases acid from the hardener penetrates the veneer and dissolves iron from the platens.

Melamine glues react faster than urea glues. At temperatures over 100°C there is no need for a hardener because the setting occurs through heat. Melamine glues are superior to urea glues, but they are rather expensive. The most important sector of use is in finishing and paper laminate production.

Phenolic glues are divided into two groups: hot setting and room-temperature setting. The first are sold in alkaline solutions of 40 to 50 per cent water content. Before use they are blended with fillers (chalk, cereal flours) and hardeners (quebracho, paraformaldehyde). The glues setting at room temperature are alcohol solutions; the hardening is achieved by use of strong acids. There is danger of wood damage if the pH value falls below 3. This type is used for assembly in furniture industry. The pot-life is 1 to 2 hours, and the maximum moisture content of wood is 15 per cent. The spread is 150 to 300 g/m², and the "open" time is 30 to 40 minutes. The pressure needed is maximum 1,000 kPa, and pressing time may be as long as 10 hours. The glue line withstands weather, micro-organisms, chemicals, oils and organic solvents very well.

When foil form is used, gluing is carried out at 135° to 150°C temperature and at a pressure of 2,000 kPa. the moisture content must be within the narrow limits of 8 to 10 per cent.

Resorcinolic glues resemble the phenolic ones in many ways, but because of their noticeable ability to react, they set readily at room temperatures. The setting is chemically quite neutral. The glue is sold as a 50 to 60 per cent water solution, and paraformaldehyde, mixed with wood-flour filling, is used as hardener beforehand. The open time is 2 to 6 hours, and the pressing time is 2 to 6 hours. The moisture content can be over 20 per cent. The minimum pressing temperature is 15°C; if it is higher the pressing time shortens accordingly. When gluing heavy woods the pressing temperature must be 30° to 40°C.

A grave fault may occur if the hardener is not in air-tight storage. If the paraformaldehyde has evaporated from the hardener, there will be no real glue setting but only drying of the glue line. If later the glue line is wetted, the glue dissolves.

Resorcinol is mostly used in demanding operations such as in boat and shipbuilding and in the production of load-bearing structures. Because of the high price there is sometimes a mixture of resorcinol and phenolic glues used where the phenolics represent a maximum 30 per cent.

Epoxy glues are used specially in cases where wood is fastened to metals. These glues are the strongest and most easily attaching today. The price, however, is very high.

Pressure-sensitive glues are usually solutions of neoprene rubber. They can be spread by spatula, brush, roller coater or even by spraying. The faces can be pressed together when the glue is dry. For more demanding tasks a pressure of 500 kPa is recommended. If hot presses are used the temperature should be at least 60°C. The maximum permitted ambient temperatures are from 60° to 70°C.

Hot-melt glues are being used with increasing success in lining and recently also in veneering. These glues, which are mixtures of polyamides, epoxy resins, polyethylene etc., are melted at 200°C and spread. The glue cools quickly, and the bond reaches its maximum strength in a few minutes. The moisture content of wood should be 7 to 9 per cent. The spread is about 250 g/m². The open time is only a few seconds while normally the maximum permissible ambient temperature is 70°C; for very short periods (as in lacquering) 120°C is allowed.

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VIII. Textiles as upholstery materials*

Textiles, which are traditional upholstery materials, are classified according to their origin as natural or man-made fibres. Man-made fibres are nowadays widely used in upholstery textiles. The most important reason for this is the high price of natural fibres. Moreover, during the last few years, man-made fibres have been developed that attain many of the good properties of natural fibres.

Natural fibres can be of animal, vegetable or mineral origin; man-made fibres are grouped into organic and inorganic fibres and organic fibres into regenerated fibres and synthetic fibres, as follows:

	Man-made fibres		
	Organic fibres		
Natural fibres			*Inorganic fibres*
Animal fibres	Regenerated fibres	Synthetic fibres	Carbon fibre
Vegetable fibres	Cupro	Elastane	Ceramic fibre
Mineral fibres	Viscose	Elastodiene	Glass fibre
	Modal	Fluorofibre	Metal fibre
	Deacetylated acetate	Chlorofibre	Metallic fibre
	Acetate	Modacrylic	
	Triacetate	Acrylic	
	Protein	Polyamide	
	Alginate	Polyesterether	
	Elastodiene	Polyester	
		Polyethylene	
		Polycarbonate	
		Polypropylene	
		Polystyrene	
		Polycarbamide	
		Polyurethane	
		Trivinyl	
		Vinylal	
		Thermfibres	

The choice of upholstery material to be produced depends on both the consumer's and the producer's demands. Because their demands are not always the same, an optimum balance must be sought. Therefore it is very important for a producer to know about the customers, for example whether the market consists of home furniture or of contract furniture.

The main properties required for upholstery textiles are: good colour fastness and good resistance to abrasion and pilling.

There are many standards to determine colour fastness.[1] The colour fastness in water, to washing and to xenon arc light must be determined. Colour fastness is graded by the grey scale for assessing a change in colour according to standard ISO/R 105/I-1959/A2-1968. The scale is from 1-5. Criterion 5 is given only if there are no noticeable differences between the original and the cloth tested. The required value for wet-fastness properties of colour is 4. Colour fastness to xenon arc light is graded by the blue scale and by the grey scale. The blue scale is from 1-8; criterion 1 for very bad, criterion 8 for very good fastness to light. The requirement of fastness to light for upholstery fabrics is 6 on this scale.[2]

A simple test for colour fastness is to rub the textile with wet and dry white cotton cloths. If the colour rubs off from the textile onto the dry cotton cloth, the degree of colour fastness is very low. If the colour does not rub off onto the wet cotton cloth, the textile can be presumed to be extremely colour fast. Although simple tests can give a lot of information about the suitability of fabrics, they do not replace the need for comprehensive testing.

Fraying can occur during the cutting and handling of an upholstery cover in production. This can lead to slightly undersized panels, which do not allow wide seam edges to be sewn. The problem is exacerbated when using materials that tend to fray. Slippage can occur in the middle of loosely woven fabric and is therefore another cause of seam failure owing to fraying. The distortion of the fabric structure that occurs in slippage is due to the fact that the yarns in the weave structure move irreversibly apart.

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[1]For example those of the International Organization for Standardization (ISO) such as: ISO/R 105/I-1959 part 22; ISO/R 105/IV-1968 part 8-12; ISO/R 2181; and ISO/R 105/V-1969 part 2

[2]Equipment and ready-made scales to grade textiles after testing according to these standards are available from the Benth-Vertrieb, Federal Republic of Germany; the British Standards Institution, United Kingdom of Great Britain and Northern Ireland; and the Eidgenössische Materialprüfungs- und Versuchsanstalt (EMPA), Switzerland.

Therefore the weave must be tight enough to prevent the slippage of yarns in the seam. Both slippage and fraying can lead to complete seam failure, but slippage can also show as an unsightly space at the seam without actually leading to seam failure. When the fabric structure slips, the slipping yarns can sometimes be prevented from sliding off the edge of the cover panel because they are held by the friction of yarns further away from the seam; that is, the sliding yarns pack together in the seam edge to give a more solid material, there is a corresponding space near the seam.

Plain surface fabrics, e.g. velvets, will show seam slippage more than heavily textured or patterned materials where the slippage can be camouflaged by the texture or pattern.

Back coating may initially solve slippage and fraying problems. However, a few back coatings age and become brittle with use. Another way to prevent slippage and fraying is to use a safety-stitch machine in the sewing process. By sewing with a safety-stitch machine, the panels are sewn together with a chain stitch and overlocked with an overlock stitch. Nevertheless, the seam is the weakest part of a cover, and a weak material cannot be made stronger at the seams by most forms of double sewing. To a certain degree, a relatively weak material can be more suitable for upholstery if it extends easily and recovers quickly from extension because it transmits any stress on it onto the underlying upholstery more quickly. However, a very extensible material will show unsightly spaces at seams where the material stretches away from the relatively rigid sewing threads.

The tear strength of woven fabrics can be determined using the standard DIN 53859 (second part) and the standard of the American Society for Testing and Materials (ASTM) ASTM D 2261.

The determination of the abrasion resistance of fabrics, using the Martindale method, is described in BS 5690, 1979. If the result of a Martindale test is 15,000 rubs, the fabric is considered to be suitable for normal use as upholstery fabric. If it is 25,000 rubs, the fabric would be considered good for normal home furniture. If the result is 50,000 or more, the fabric is sufficient for office chairs and other furniture that receives a great deal of use.

The contract furniture industry has numerous requirements for the fire retardancy of upholstery materials. It cannot be said that fire retardant materials will not burn. However, a suitably formulated covering material has three important advantages: *(a)* it can prevent a fire from starting, whereas non-fire retardant materials may ignite; *(b)* it can prevent flames from spreading to interiors of furniture where less fire-resistant components may have been used for a certain period of time; and *(c)* it will extinguish soon after the flame source has been removed. Perhaps the most well-known standard for fire retardancy is BS 5852 (British cigarette test).

In addition to the technical properties of textiles, there must be typical textile properties as well. Such properties include pleating characteristics (including optical characteristics, i.e. whether the surface is mat or shiny), the resistance to pilling and the amount of elasticity and stretchability.

Pilling resistance gives a good indication of the weaving properties of upholstery fabrics. A test for pilling resistance is carried out in a rotating box in which four samples of the material are wound on rubber tubes and rotated and rubbed against each other for 10 hours. The number of small fibre balls or neps on the fabric's surface is noted. The pilling effect occurs in fabrics in which fibres are a mixture of a low and a high breaking strengths, such as mixtures of viscose or wool with synthetics. It is possible to increase resistance to pilling by adding certain ingredients in the spinning or in the finishing process.

The determination of the pilling resistance of fabrics is prescribed in the standard ASTM D 1375-72. The scale is from 1 to 5, criterion 5 being the best, i.e. the minimum pilling.

Other typical textile properties are softness and attractiveness. Textiles should be permeable to air and moisture, and they should transfer heat. Textiles should also keep their shape when in use, and they should not shrink or wrinkle easily.

Soiling can be a problem in textiles that are made of cellulosic-based fibres; wool, for example is more soil resistant than such textiles. If soiling is considered to be a problem, upholstery fabrics with cellulosic-based yarns in light shades should be avoided or removable covers could be used.

When selecting an upholstery material a manufacturer must consider a number of factors. The most important, in addition to the quality and price, are of course the design and the pattern of the fabric.[3] The manufacturer's capacity to deliver is also very important. Other factors to be considered are the style of the furniture, which determines the design and the quality of the cloth. The width should also be considered when selecting the material because the amount of waste can vary a great deal depending on the width. (The width of normal upholstery textiles is from 130 to 150 cm.)

The machinery available can also affect requirements for cloth. If there are no safety-stitch machines, a thin latex backing could also help if loosely woven fabrics are used.

Velvets are perhaps one of the most popular materials besides leather in the upholstery industry. Velvet is normally a mixture of polyacryl (pile) and cotton or viscose. The more expensive velvets have wool pile. The pile is W-pile or sometimes U-pile. Because of the construction of W-pile, it is more suitable for pleated and self-piped styles of upholstery. The grip exerted on the pile tufts by the weft yarns of the backing fabric is less for U-pile material, and the pile tufts can be more easily drawn out owing to wear of plucking. Similarly, where the front edge of a seat cushion is folded on relatively abrasive underlying upholstery filling, e.g. polyurethane (PU) foam, during use, this can pull U-pile tufts through the back of the fabric and make the fabric appear bald. For this reason U-pile velvets should have an interlining or a soft polyester fibrefill to separate the back of the material from underlying foam. The interlining is also recommended for use with W-pile.

[3] As the price of the fabric is important, all costs, including freight, insurance etc., should be included, and calculations should be thoroughly checked to avoid unnecessary mistakes.

The test of the quality of the velvet, U-pile or W-pile, is made using adhesive tape. The adhesive-tape test gives positive results only on poor fabrics. The test is made on the back of the material.

Upholstery fabrics can also be treated for special purposes; examples are anti-soiling, water-repellent, flame-resistant and antiseptic treatments. The final consumer and the purpose of the furniture should always be kept in mind when selecting the upholstery textile in order to achieve the optimum quality and design.

The following glossary gives terms common to the upholstery textile industry.

Bouclé fabric. A flat woven fabric containing special looped-effect yarns giving the material a textured appearance. It is an intermediate between a flat-woven fabric and a pile fabric.

Figured velvet. A patterned velvet in which the background to the pattern comprises areas where pile is absent, or a patterned velvet containing areas of pile of different heights and pile densities.

Loop-raised warp-knitted fabric. A warp-knitted fabric in which one surface is brushed after manufacture to give a raised appearance similar to that of a velvet containing a low pile.

Pile. A surface effect on a fabric formed by tufts or loops of yarn that stand up from the body of the cloth.

Raschel knitted fabric. A type of warp-knitted fabric that can have a wide variety of appearances. In upholstery fabrics it is commonly a pile fabric that, upon superficial inspection of the surface, is indistinguishable from a true velvet.

Staple-fibre fabric. A staple yarn is made by twisting together short fibres while drawing the yarn out to make it finer. It has a somewhat hairy appearance. Most upholstery fabrics contain staple-fibre yarns, and virtually all natural-fibre yarns are of this type.

Warp-knitted fabric. A knitted fabric in which the yarns incorporated in the material run in the length (warp) direction.

Weft knitted fabric. A knitted fabric in which any non-pile yarns transverse the width (weft) of the fabric.

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IX. Polyurethane in the furniture industry*

Flexible polyurethane foam technology

The "MAXFOAM" technology is the first important development to have taken place since the 1950s, when the "one-shot" method began to be used in the production of flexible urethane foam. To produce rectangular foam blocks in order to reduce the raw material waste to a minimum has been a main objective for a long time. In this new production method, the sides need not be raised artificially; the foam block obtains its rectangular shape in a natural way. In the ordinary foaming process the foam rises like a dough. In the MAXFOAM process, the semi-foamed reaction mixture is allowed to expand "downwards" instead, whereby its upper surface remains in a relatively horizontal position. This new technology has the following advantages:

(a) The cross-section profile of the foam block is rectangular;

(b) Thicker blocks can be produced;

(c) The bulk density differences between the upper and lower sections of the foam block are comparatively small;

(d) It has an excellent physical property;

(e) It has almost no formation of so-called "side skins";

(f) It has a thin surface skin.

The first machines based on the MAXFOAM technology were brought into use in the summer of 1972. The use of this method has resulted in a great increase in the quality of the products manufactured.

Properties of flexible urethane foam

The consumer expects foam mattresses and upholstered furniture to be pleasantly comfortable and to retain their elasticity and firmness for a period from 5 to 10 years or even more. These, like all other properties, are based on the structure of the smallest visible element in flexible urethane foam—the cell structure. A close study of the cell shows that it is a somewhat extended pentagonal dodecahedron.

To produce an ideal cell structure, an accurate formula must be developed. Special catalytic agents and other substances must be carefully chosen for this cell structure. These make it possible to give the foam the desired optimal properties. Even though the formula is in every way complete, this is not enough to secure high quality, as other factors connected with the foaming process must also be mastered. These are for example the feed pressure of the raw materials, the rotation speed of the mixers, the volume and pressure of the mixing head etc.

Although a great deal has been written about the correlation between the polymer structure and physical properties, very little has been written about the cell structure of flexible urethane foam in correlation to its physical properties. (The properties of standard and special qualities are shown in table 13.)

The production of flexible urethane foams is at present subject to extremely strict controls, even from an international point of view. The finished product is carefully tested according to international standards, which means that the results obtained are internationally comparable. This procedure, to a certain extent, guarantees the high quality of the product. This continuous guarantee of quality also means that furniture manufacturers can produce high-class furniture for competitive export markets.

More than 10 different tests are performed on each foaming batch to check the foam's properties. Some of the research results pass directly to the customer in the form of various tables of properties, and some of the results are used as feedback in process control.

Density

The main property that must be checked in modern quality control is the density distribution for the whole area of the cross-section of the foam block, as a change in the density also means a change in firmness (see table 14).

If the density varies considerably, for example from 2 to 3 kg/m³, there may be fluctuations in quality at later stages of production.

At present, using up-to-date production technology, density differences as small as from 0.4 to 1.0 kg/m³ can be achieved. Heavier foam qualities have considerably better fatigue resistance. Thus foam qualities under 30 kg/m³ cannot be recommended for such uses as seat upholstery or mattresses.

Indentation load deflection hardness

For furniture upholstery, indentation load deflection (ILD) hardness, in addition to bulk density, is a very important factor. The sitting comfort of the seat upholstery is evaluated on the basis of these two factors, for example, ILD hardness is determined by measuring the load necessary to produce 25 per cent, 40 per cent, 50 per cent and 65 per cent indentation of the foam product. A thorough knowledge of the properties of the raw material is needed

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as well as the ability to apply this information to the formula to prevent the quality of the foam from fluctuating from batch to batch. This knowledge also facilitates product development; prototype qualities can be screened in advance. Foam plastic hardness curves are shown in figure 53.

Table 13. Properties of flexible urethane foam

Property	*Standard qualities*[a] *E-20*	*E-25*	*E-30*	*E-35*	*Superflex 33*[b]	*Special qualities* *E-20EW*	*E-25HS*	*E-25EP*	*E-30EP*	*E-36P*
Specific weight of compound (kg/m^3)	34-36	19-21	24-26	29-31	34-36	32-34	19-21	24-26	24-26	29-31
Specific weight of sheets (kg/m^3)	17.0-19.0	22.5-24.5	27.5-29.5	32.5-34.5	30.0-32.0	17.0-19.0	22.0-24.0	22.5-24.5	27.5-29.5	31.5-33.5
Hardness (N/323 cm^2 25 per cent pressure)[c]	60-90	105-140	120-155	135-175	85-115	30-60	10-30	45-75	45-75	70-100
Maximum deformation (per cent of maximum)[d]	6	5	3	3	3	6	6	5	4	3
Maximum loss of thickness under dynamic strain (%)[e]	5	5	3	3	3	4	4	4	3	3
Minimum tensile strength (kN/m^2)	60	80	100	100	50	50	80	50	50	50
Minimum stretch (%)	220	220	220	200	150	220	400	220	200	200
Minimum tear strength (kN/m)	0.30-0.40	0.40	0.30	0.30	0.20	0.25	0.40	0.20	0.20	0.20
Cell strength (pieces/cm)	14-18	14-18	14-18	16-20	Hetero	14-18	14-18	14-18	14-18	16-20

Note: ESPE foam plastic has been tested according to ASTM D1564.

[a] The numbers given are ESPE quality identification codes. Most firms have similar ranges.

[b] Superflex is a high-quality combination foam plastic. Superflex 33 fills the requirements of ASTM D1692 and MVSS-302 with respect to self-extinguishing properties.

[c] Hardness is tested on 5 cm thick sheets.

[d] Deformation is tested at 70°C for 22 hours at 50% pressure.

[e] Thickness loss is tested under dynamic strain according to DIN 53574.

Table 14. Properties of upholstery foams used in domestic furniture

Foam grade (density)	*Indentation/ hardness*	*Type of service*
Back upholstery		
20 kg/m^3	Normal	Light
20 kg/m^3 (special formulation, low hardness loss after dynamic fatigue test)	Super-soft	Light/average
25 kg/m^3	Super-soft	Average
30 kg/m^3	Super-soft	Severe
Seating upholstery		
25 kg/m^3[a]	Normal	Light
27 kg/m^3	Normal	Light
30 kg/m^3	Normal	Average
35 kg/m^3	Normal	Average
36 kg/m^3	Soft	Average
40 kg/m^3	Soft	Severe
Superflex-33 (Polystyrene-polyurethane composite foam)	Initial softness, high load bearing	Severe

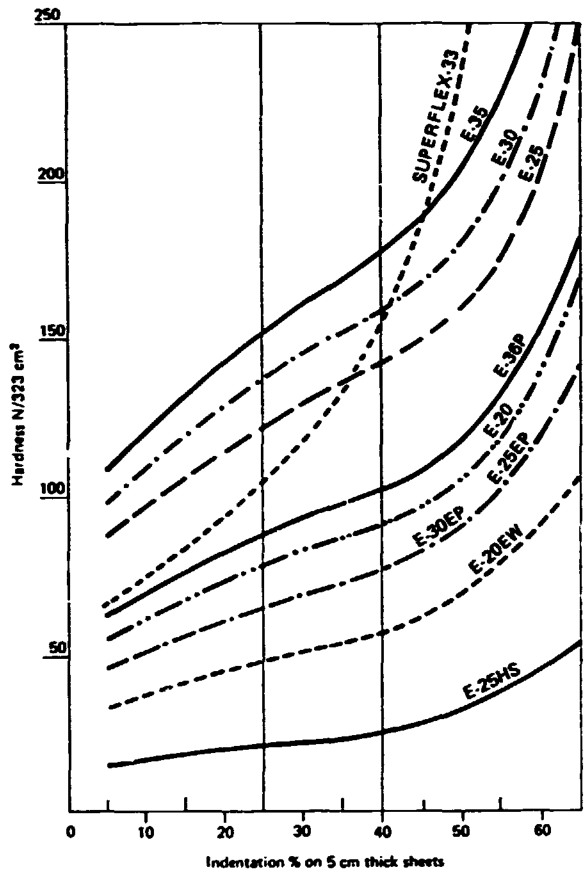
[a] Hypersoft foam (density 25 kg/m^3) should be used between the seating upholstery and the covering material. Instead of hypersoft foam, polyester fibre matting can be used.

Surface softness and load-bearing capacity are closely connected to ILD hardness (see figure 54). Generally, soft surface qualities lack load-bearing capacity, and qualities with good load-bearing capacity lack surface softness. These factors must be taken into consideration in the upholstery design. In many cases, it is necessary to create a layer structure, for example two or three layers of different ILD hardness, to obtain the correct level of comfort in the upholstery. Such layering would not be necessary with so-called high-resilience foams (cold foams) as well as the polystyrene-urethane composite foam Superflex-33, which is the result of intense product development and which combines pleasant surface softness with elasticity and an extremely good load-bearing capacity. (The hardness properties of various materials are shown in figure 55.)

Compression set and fatigue resistance

Compression set is a factor that affects the service life. If this compression set figure is known, it is easy to calculate the reaction of the upholstery under static fatigue. For example, under 90 per cent pressure the compression set of the upholstery is 3 per cent, which gives a service life of nearly 10 years, whereas with a compression set of 5 per cent, service life is only about four years. If all factors in the foam production process are Figure 53. Foam plastics hardness known, it is possible to produce elastic and fatigue-resistant material. In practice, the material will have these properties if the air permeability of the material is good.

Figure 53. Foam plastics hardness



In addition to static fatigue, upholstered furniture and mattresses are also subject to dynamic fatigue in normal use. In order to determine the total fatigue reaction of flexible urethane foam, its dynamic fatigue is tested according to the DIN 53574 standard. A foam specimen undergoes a dynamic fatigue test of 80,000 cycles, the load applied being 75 kg (diameter of fatigue area 250 mm). Testing time is about 19 hours, after which the percentage of thickness and hardness loss is determined.

Fatigue-resistance classes for upholstery

According to British Standards, flexible polyurethane foams are divided into four different fatigue-resistance classes (see figures 56 and 57). These are: class 1, seat upholstery for use in public places; class 2, seat upholstery for use in domestic furniture and back and arm support upholstery in public places; class 3, back and arm support upholstery for domestic furniture; and class 4, neck support upholstery and cushions.

Figure 54. Range of hardness of foam plastics

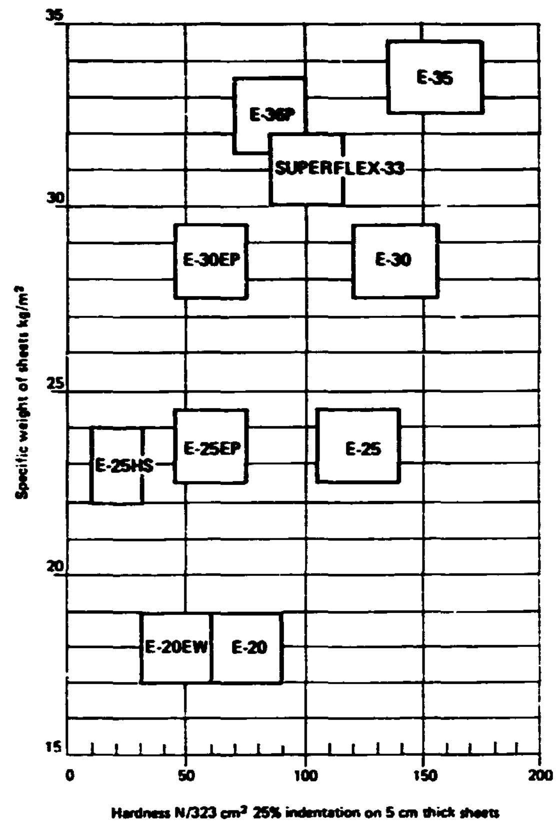


Figure 55. ILD hardness

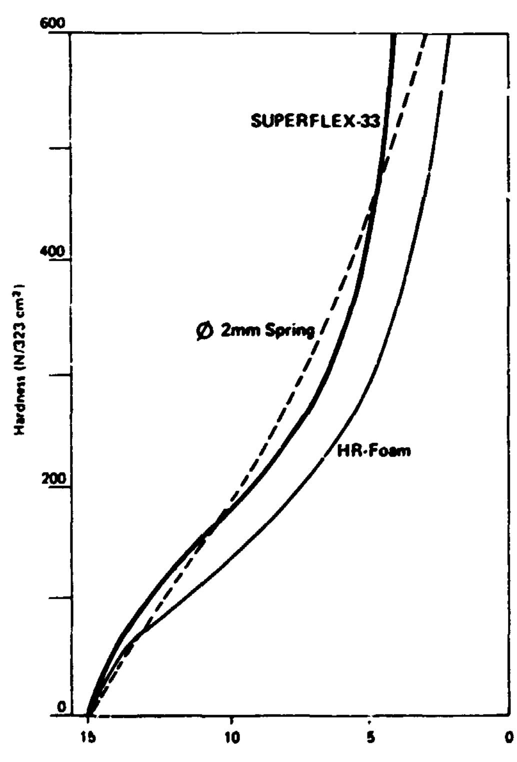
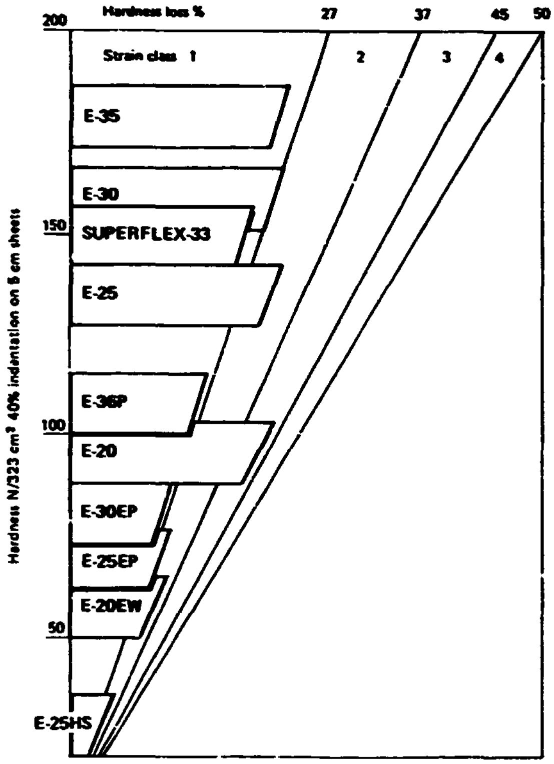


Figure 56. Foam plastics strain



Recommendation of strain class for furniture cushions

Class 1: Seat cushions for public houses.
Class 2: Seat cushions for homes, handrail cushions and back cushions for public houses.
Class 3: Back cushions and hand rail cushions for homes.
Class 4: For pillows and neck supports.

Of ESPE-foamplastics, all types over 25 kg/m³ specific weight belong to strain class 1 and all the rest except E20 to strain class 2. Therefore they cover a large usage area.

Cutting tolerances for foam upholstery

Strict cutting tolerances are necessary not only for the quality of the final product but also to achieve savings in raw materials. Cutting tolerances that exceed international requirements can be achieved using heavily automated cutting machines operated by highly skilled personnel. The tolerances specified in the standard BS 3379:1978 are shown in table 15.

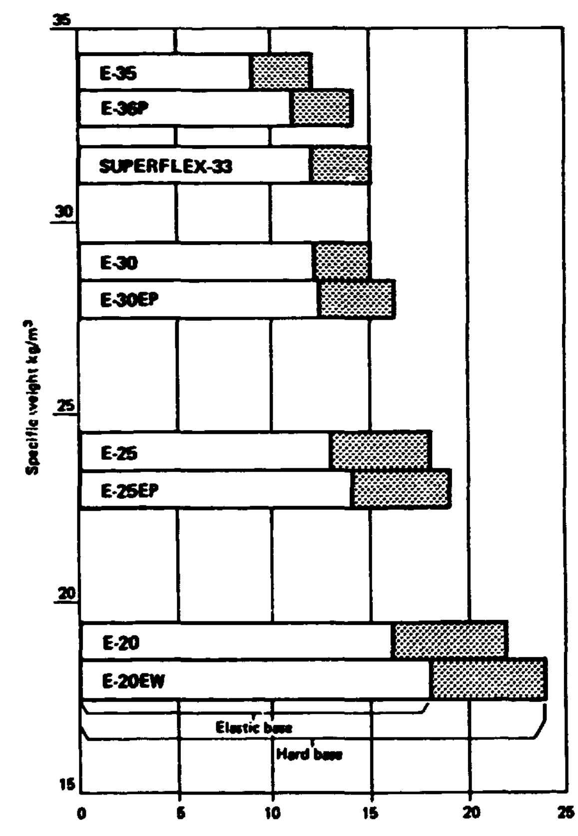
Table 15. Cutting tolerances of plastic foam cushions

Measurement of cushion (mm)	*Maximum tolerance according to BS 3379:1978 (mm)*	
5-25	+3	-0
26-100	+4	-0
101-250	+6	-0
251-500	+10	-0
501-1 000	+20	-0
1 001-1 500	+30	-0
1 501-2 000	+40	-0
over 2 000	+50	-0

Polystyrene-urethane composite foam

Polystyrene-urethane composite foam (Superflex 33) is a combination of polyether and expanded polystyrene beads; it is not a normal polystyrene. It can withstand the reaction heat; the beads expand during the foaming reaction. The result is a compound in which the expanded beads are in exactly determined positions with regard to the elasticity and the desired load-bearing capacity. The composite foam has proven to be extremely durable when tested. Owing to its structure, it has a pleasant soft surface and elasticity and an extremely high load-bearing capacity. Of the foam qualities produced, it is best suited for seat upholstery and mattresses. Its density is also sufficient (33 kg/m³).

Figure 57. Thickness of foam plastic seat cushions



Composite foams can also be made fireproof when the fire-retarding substances are added during the reaction stage. This product meets the requirements of the ASTM 1692 standard and standard FMVSS 302 of the Federal Motor Vehicle Safety Standard (FMVSS).

Flame-laminated foams for the textile industry

In flame laminating, textiles and foams are joined by means of a flame. Polyesther-based foams can be used for this purpose, but the normal polyether-based foam used for upholstery cannot. Only recently has a polyether foam for flame laminating been developed with a very good adhesive capacity and a short drying time. The latest product is a fire-proof flame-laminated polyether that meets the fire protection requirements of the automobile industry and passes the so-called "fogging" test.

Fire-resistant foams

It is possible to make flexible polyurethane foam fire resistant by adding certain fire-retarding substances during the production process. These substances tend to have a deteriorating effect on the physical durability properties, however, and extensive research is often needed in order to develop a suitable formula.

Fire-proof foam is not produced in large quantities, owing to its high price and the fact that fire protection regulations vary from country to country. The following fire-proof foam qualities are available:

- Automobile industry (to meet ASTM and MVSS standards)
- Construction industry quality (to meet NT[1]: FIRE002), which fulfils the class 1 flammability requirements according to the Finnish construction regulations and has structural fire protection
- Fire-proof mattress quality (to meet ASTM, FMVSS).

In 1977 there were 93,360 fires in the United Kingdom; 2,618 started in upholstery, and 1,085 of these were caused by careless smoking.

Of all the European countries, the United Kingdom has carried out the most research on fires and their causes. During the last decade, this subject has been of particular interest to labour unions as well as to the Government.

In 1978, the British Consumer Safety Act laid down regulations concerning fire safety for upholstered furniture. According to these regulations, the upholstery material must be of such quality that it cannot be ignited by a negligent smoker. The British Parliament passed the Upholstered Furniture (Safety) Regulation Act 1980 on 22 May 1980.

In cases where a piece of furniture does not fulfil these regulations, it must carry a warning of its inflammability. Only furniture that is fire resistant with respect to cigarettes, gas flames and matches needs no warning sign. Furniture that is fire resistant only with respect to cigarettes must carry a warning. The protection against fire prescribed by law is measured according to BS 5852: Part 1: 1979.

Nearly 50 per cent of all fires begin in beds.

Although the use of plastics has increased, their share as the cause of fires has not increased to a corresponding degree, whereas the share of other causes of fire is steadily increasing.

Both natural materials and plastics develop toxic gases when burning. The greatest risk is constituted by carbon monoxide; other gases are generally present to a lower extent, but they nevertheless have an irritating effect. The spontaneous ignition temperature of polyurethane foam is 415°C. Most plastics and natural materials have a spontaneous ignition temperature of 350°-600°C. The amount of heat produced by the combustion of different materials is shown in table 16.

Table 16. Calorific value of selected foams and wood species

Foam or wood	*Megajoules per kg*	*Megajoules per m³*
Polystyrene	41	—
Polyurethane	28	—
Urea-formaldehyde foam	20	—
Birch	19	—
Flexible polyurethane foam (25 kg/m³)	—	620
Oak	—	12 800
White birch	—	13 400

The combustion of birch wood produces 19 megajoules per kilogram and the combustion of the same quality of polyurethane produces 28 megajoules, or 46 per cent more heat.

Materials with molecules containing nitrogen atoms produce the following quantities of hydrogen cyanide under combustion:

	μg/g
Polyurethane	41
Nylon	116
Wool	124
Acryl	260

The combustion temperature must always be known before the amount of gases produced can be measured. Generally, no fixed standard temperature occurs in fires.

Tests have been carried out using polyurethane, cork and pine wood. Equal quantities of these materials were burned and the combustion gases were directed into cages containing rats. No relationship was observed between hydrogen cyanide and the death of rats, but there was a clear connection between the development of carbon monoxide and the death of rats. The larger the quantity of carbon monoxide produced, the more rats died. Blood tests proved that carbon monoxide had caused the deaths. Thus, the most dangerous gas developed in fires is carbon monoxide.

Furniture design plays a significant role in fire security. It must always be remembered that vertical surfaces burn three times faster than horizontal surfaces. Fire security is improved by leaving sufficient space between the seat and the back support. If the upholstery material is not correctly applied, the chances of the object catching fire are greatly increased. Fire security can be improved by using an intermediate layer of cloth.

Fire protection methods for plastic foam are:

1. Additive fire retarders
2. Reactive fire retarders
3. Synergetic fire retarders
4. Fire protection based on a reaction mechanism

[1]Nord Test (NT) is a Scandinavian Standard.

In ESPE fire-protected polyether foams, a combination of methods 1 and 3 is used, and in high-resilience foams a combination of methods 1 and 4 is used. The best results are achieved when all the materials utilized are fire protected, in which case no risk occurs even if the upholstery cloth is damaged. When ignition is prevented, a fire is prevented.

One method of increasing the fire safety of a product is to add a layer of fire-proof foam between the upholstery and the cover. A foam with very effective fire resistance should be used. The working mechanism of this inserted layer is as follows:

(a) At the first stage, water is released, which has a cooling effect;

(b) At the second stage, a fire-protective substance having an extinguishing effect is released;

(c) Finally, an isolating layer of carbon is formed.

At present, the most commonly used standards are FMVSS-302 (used by the car industry) and ASTM D 1692 (used by shipyards and the bedclothes industry). All upholstery materials used by the aircraft industry are subjected to a vertical fire test.

The Nord NT 002 fire test is an extremely demanding test, in which a strong draught, or "chimney effect", is created. Foam plastic can only pass this test if the second layer does not catch fire.

Factors to be considered when choosing a foam mattress

The general rule when choosing a mattress is that it must allow the spine to be in a resting position. When sleeping face up, the discs between the spinal vertebrae should not be under stress but should take their natural positions. When sleeping on the side, the spine should form a horizontal line. If the wrong bed has been chosen, a hammock effect is the result, and the user will have a sore back.

According to anatomical-physiological research on mattresses, the mattress must have a minimum flexible depth of 6 to 7 cm. This ensures that the spine remains in a horizontal position even when the user is lying on his or her side. The thinnest foam mattresses are 7 cm thick; the load-bearing capacity of a mattress of this thickness is low, and the mattress softens after three to four weeks' use. When a person weighing 80 kilograms sleeps on a 7- to 10-cm thick mattress with a density of less than 30 kg/m³ on a bed with a hard base, the hard base is felt in the form of increased surface pressure in the hip and shoulder regions within a few weeks. Thin foam mattresses can thus be recommended only for persons who want to sleep on a hard bed. Such foam mattresses give only surface softness; they do not have any load-bearing capacity.

According to the Swedish publication Möbelfakta, the flexible depth of a foam mattress on a non-flexible base must be from 9 to 14 cm and on a flexible base from 6 to 9 cm. If the flexible depth of a foam mattress is correctly dimensioned, the spine is always in a resting position. The load-bearing capacity of the foam ensures that the user does not feel the base of the bed through the mattress.

When buying a high-quality foam mattress, attention must be paid to its surface softness, flexible depth and load-bearing capacity. The surface softness is especially important for sleeping in comfort. All these three properties—surface softness, flexible depth and load-bearing capacity—form a harmonic whole, and the circulation of the blood remains undisturbed. R. Coerman[2] has pointed out the significance of skin surface pressure. If the surface pressure rises above 0.07 kg/cm², the result is always an inhibition of the blood circulation. The use of a thin extra mattress adds to sleeping comfort by increasing the surface softness and makes it easier to make up a bed.

The size and weight of the user should be taken into consideration when choosing a mattress. The following specifications serve as an example:

Users	*Thickness (cm)*	*Density (kg/m³)*
Children	5-7	20-25
Youth	7-10	25-30
Adults	10-15	30-35

For a person weighing 80 kilograms, the following types of mattress might be used:

	Thickness of mattress (cm)	
Density of foam (kg/m³)	*Hard base*	*Flexible base*
30	15	12
35	12	9

The body weight of the prospective user of the mattress must always be taken into consideration. If the user's weight is considerably less than 80 kilograms, the above figures can be adjusted to suit personal requirements. Overweight persons are advised to pay attention to thickness and density when choosing their mattress.

Rigid foams

Rigid polyurethane foams are used for thermal insulation, for structures and for packaging. Those used for insulation and packaging have densities of 8 to 40 kg/m³; structural foams are used in densities of 40 kg/m³ and over.

All rigid foams have closed cells. Rigid polyurethane foam is used in furniture in densities from 40 to 80 kg/m³. Owing to the low density of these materials, relatively thick walls as well as inserts for bolts, screws and nails are needed. Rigid integral skin foams are used for decorative details and structural purposes. They have a tight skin and a cellular core. The overall density of these foams is 200 to 600 kg/m³.

[2]R. Coerman, "Arbeitsphysiologische Gesichtspunkte bei der menschengerechten Gestaltung von Fahrzeugen", 11. Internationaler automobiltechnischer Kongress, Munich, June 1966.

Handling equipment

The number of mixtures (batches) are determined as shown in the following example:

Required production rate	75 per hour
Mould time	5 min
Load time	0.5 min
Unload time	0.5 min
Total mixture time	6 min

Units per mixture per hour $\frac{60}{6} = 10$ units

Number of mixtures required $\frac{75}{10} = 7.5 = 8$

Polyurethane foams are made by continuous methods as well as by moulding in batches. Continuously foamed polyurethane must be cut to size; items produced by batch foaming are generally produced in their final shape through use of a mould. Polyurethanes are produced by blending two or more components in a mixer.

Blow index

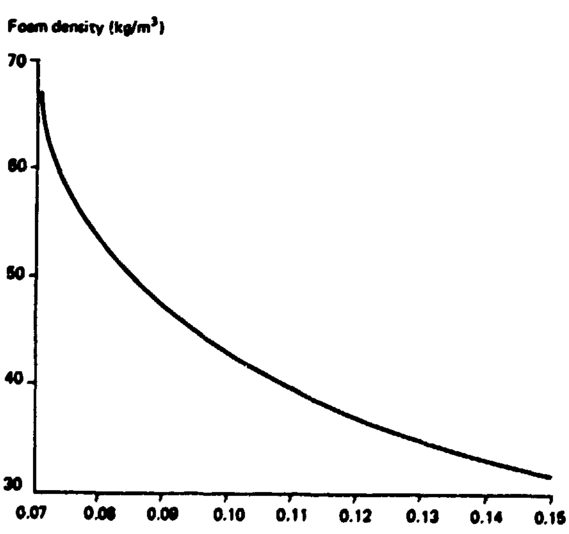
The blow index is used to estimate the approximate foam density that a specific formulation will give (in parts by weight):

$$\text{Blow index (rigid foams)} = \frac{(\text{trichloromonofluoromethane} - 11) + (10 \times \text{water})}{\text{polyol} + \text{flame retardent} + \text{silicone oil} + \text{catalyst} + \text{isocyanate}}$$

$$\text{Blow index (flexible foams)} = \frac{\text{water} + (\text{trichloromonofluoromethane} - 11)}{10}$$

The relationship between foam density and the blow index is shown in figure 58.

Figure 58. Relationship between foam density and blow index



Quality control

The following test should be carried out every production day:

Density:	The weight of a unit volume of a material.
Cream time:	The time between mixing the foam and the visible start of the foaming reaction. The start of the reaction is when the mixture turns a creamy colour or begins to rise.
Gel time:	The time between mixing of foam components and the time that it is possible to draw a 10- to 25-cm long string or whisker when the surface of the foam is touched with a wooden spatula.
Tack-free time:	The time between mixing the foam components and the time that the mixture ceases to stick to a wooden spatula that touches the foam surface.
Rise time:	The time between mixing the foam components and the time that the foam stops rising in an open container.

The safe handling of isocyanates

All persons handling isocyanates and products containing isocyanates must be conversant with the hazards and trained in the recommended handling procedures because all isocyanates are potentially hazardous materials.

The following recommendations for the handling of aromatic isocyanates have been prepared by the Safety Committee of the International Isocyanate Institute (III):

Technical Information 1: Recommendations for the handling of toluene diisocyanate (TDI) (November 1980).

Technical information 4: Recommendations for the handling of 4, 4' diphenylmethane diisocyanate (MDI) monomeric and polymeric (August 1981)

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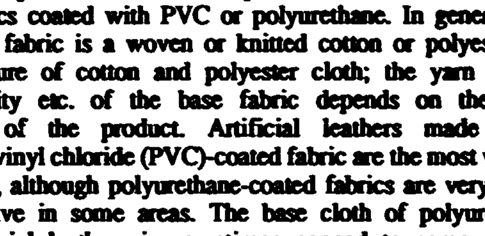
X. The use of synthetic leathers as upholstery materials*

At present, the most important artificial leathers are fabrics coated with PVC or polyurethane. In general the base fabric is a woven or knitted cotton or polyester or mixture of cotton and polyester cloth; the yarn count, density etc. of the base fabric depends on the end-use of the product. Artificial leathers made from polyvinyl chloride (PVC)-coated fabric are the most widely used, although polyurethane-coated fabrics are very competitive in some areas. The base cloth of polyurethane artificial leathers is sometimes napped to some extent. There are also foils, but these are no longer in wide use. They are made of PVC (at least 0.5 mm in thickness) without a backing cloth. Their tear strength and tensile properties are not good, and are not easy to handle. Foils are used only for very hard and cheap chairs.

Both PVC and polyurethane artificial leathers are made by coating the base cloth with a plastic paste and then heating it. This system is illustrated in figure 59. Most of the so-called compact coatings are applied in this way.

Figure 59. Spreading machine for direct coating



Key: 1. Base cloth
2. Spreading
3. Heating oven

The transfer method is now very popular for upholstery materials because knitted backings can be correctly handled. Using this method the top (plastic) coat of the end-product is spread on a silicone-treated special paper and dried in an oven. The base coat is spread on the top coat, and the base cloth is laminated to them. This is followed by a heat treatment, after which the end-product is separated from the paper and both are wound separately. The process and the apparatus used, a tandem spreading machine, is illustrated in figure 60. This method is used in the manufacture of expanded-PVC synthetic leathers and in most of the compact-coated polyurethane leathers.

Special machines for printing, lacquering and embossing are used to make the product look more like real leather. (It should be noted that synthetic leathers are not substitutes for real leathers but are complementary materials).

Some of the more important characteristics of synthetic leather for use in the upholstery industry are considered below.

The colours of synthetic leathers must have good light-fastness; they must change in sunlight very little, if at all. On the ISO scale, a value of 6 is good and 8 is excellent. Normally the pigments in plastics are very good as regards their colour-fast and waterproof characteristics.

Synthetic leathers resist most of the commonly used chemicals. However, the effect of adhesives is of great interest to the furniture industry. Although adhesives are discussed in detail in chapter VII, the following facts should be mentioned here:

(a) PVC is sensitive to strong solvents such as thinners. Gasoline, fats and oils have a harmful effect on PVC. Polyurethane can resist chemicals much better;

(b) In cooler countries special attention must be paid to cold flexibility. PVC stiffens at lower temperatures and cracks at about −40°C (−40°F). Polyurethane is superior in this respect.

In warm countries with relatively high humidity, the hydrolysis property must be taken into account. For this, a laboratory test is made under conditions of 100 per cent relative humidity at a temperature of 70°C. The test lasts for seven days and the plastic must not crack. After the hydrolysis test the sample is tested for abrasion. After 3,000 cycles its surface will have changed and taken on a dull appearance, but artificial leather must not have cracked. This test is usually carried out accordingly to the test method of Polyurethane-Gesellschaft Lemförde mbH und Co., Osnabrück, Federal Republic of Germany.

A phenomen known as "fogging" appears in PVC products used in automobile upholstery. This occurs because their plasticizers evaporate at high temperatures (even in northern countries the temperature in an automobile can be 60°C when it has been left for a long time in direct sunlight) and condense on the windscreen and windows. It is very difficult to remove this thin film condensate, which impairs visibility.

The above-mentioned properties are the most important chemical characteristics of PVC-fabric, synthetic leathers and naturally the plastic itself. The base cloth must in some cases be impregnated to resist mildew and bacteria. There is a specific test for fogging (usually performed at 90°C) that is used in the automobile industry.

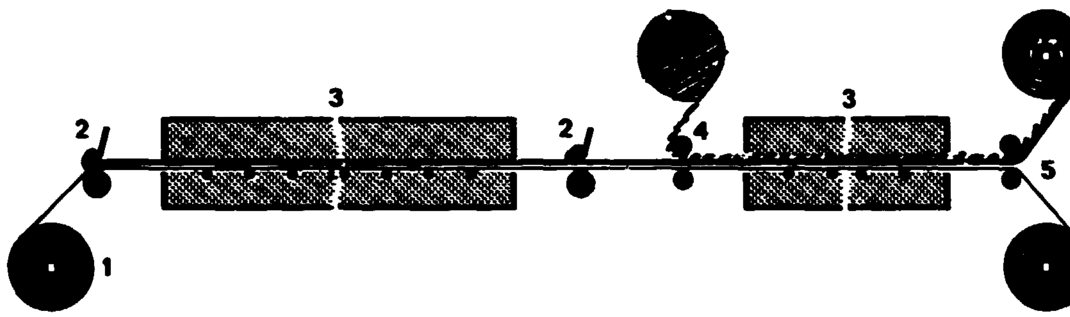
One of the more important mechanical properties of PVC products is its handling characteristics, i.e. stiffness or

*By Gunnar Södermann, Oy Finlayson Ab Plastics Works, Forssa, Finland. Originally issued as ID/WG.105/27/Rev.1.

flexibility. While this property is difficult to quantify, it is clear that materials must have a good texture and an attractive appearance and be appropriately soft. Generally, it is best to use hard synthetic leather for a hard chair and softer material for a soft one.

Since normal PVC synthetic leather is impermeable to air, many people find it uncomfortable to sit for a long time on a chair covered with it. Efforts have been made to overcome this disadvantage, for instance by perforating the plastic or by mixing certain chemicals in the paste that later dissolve and leave small pores and canals in the plastic. These are the so-called "poromeric" materials. Unfortunately, these efforts have not yet been very successful.

Figure 60. Tandem spreading machine for transfer coating



Key:
1. Paper
2. Spreading
3. Heating oven
4. Cloth lamination
5. Separation

A better material is made with expanded PVC; the PVC is foamed and has a thin skin at the surface. When this top layer is perforated, a better and more attractive material results. It is quite comfortable to sit on a chair covered with this kind of synthetic leather. Furthermore, the base cloth is usually a knitted fabric, which improves handling. The property specifications of the base cloth and of finished synthetic leathers can be seen in table 17.

The tensile strength of synthetic leathers is very important. No standard values can be cited since different kinds of chairs and couches require different strengths. Furthermore, the manner in which the material has been assembled has some effect. Elongation must also be taken into account, in particular when soft and semi-soft furniture has been covered with synthetic leathers. The greater the elongation, the smaller the patterns must be when they are cut. Ideally, there should be the same degree of stretch in both the warp and weft directions, but this seldom happens. If the elongation is correct, the material can be nicely tightened over round edges. However, the elongation must not be too small or too great or wrinkling will occur.

In the Oy Finlayson Ab Plastics Works, the specified elongation is as follows: in the warp direction, 35 to 70 per cent and in the weft direction, 50 to 100 per cent (see table 17).

The plastic must have good abrasion resistance. In tests made with a Taber abraser the norm for upholstery materials is at least 3,000 revolutions.

The tear strength of synthetic leather is also important. Usually the material is sewn first and then assembled. There appear to be no general standards; individual furniture manufacturers have their own testing procedures. The best results are achieved, however, when long stitches are used and the thread is not pulled too tightly.

Table 17. Specifications for base cloth and finished synthetic leathers

Property	*TK50*[a]	*TK60*[a]
Total weight (g/m^2)	570 ± 30	670 ± 20
Width (cm)	138 ± 2	138 ± 3
Thickness (mm)	1.0 ± 0.1	1.2 ± 10%
Coating	PVC	PVC
Weight of coating (g/m^2) approx.	Approx. 500	600
Backing	100% polyester	100% polyester
Weight of backing (g/m^2) approx.	Approx. 70	Approx 70
Tensile strength (N)[b]	512/234	516/251
Elongation at breaking point (%)[b]	66/345	68/349
Elongation 10 % (N)	66/18	60/19
20 % (N)	141/31	133/32
30 % (N)	214/41	207/44
Tearing strength (N)[c]	Approx. 31/31	Approx. 30/30
Cold crack (°C)	Approx. 40	Approx. 40
Abrasion (Taber abraser)[d]	10,000	10,000
Bending (number of cycles)[e]	100,000	100,000
Flame retardance[f]	Not flame retardant	Does not burn

[a]TK50 and TK60 are brand names of Oy Finlayson for plastics with a knitted base used as a covering material (the origin of both is "Arelan").

[b]Finnish Standards Commission Standard SFS 2983.

[c]Finnish Standards Commission Standard SFS 2981.

[d]Minimum. CS-10/250 g.

[e]DIN 53359 B.

[f]FMVSS 302.

Detailed tests of upholstery materials made by the Furniture Industry Research Association (FIRA) in the United Kingdom include the following:

- Composition
- Construction/thickness
- Tensile strength at break
- Extension strength at break
- Tear strength
- Seam strength
- Resistance to wear
- Resistance to scuffing
- Flex cracking
- Coating adhesion
- Coating weight
- Tension set/surface drag
- Colour-fastness to rubbing
- Colour-fastness to light
- Resistance to light degradation
- Thermoplasticity and resistance to solvents
- Hydrolysis

One question that is often asked is how synthetic leathers should be cleaned. The best and simplest way is to use water, soap or detergent and a soft brush or cloth. When such cleaning is not successful, alcohol may be tried. If this does not help, it is advisable to turn to the manufacturer of the material for help.

Different types of plastic materials have different possible uses. Compact PVC may be used as upholstery material for very cheap furniture used in public buildings such as hospitals and railway stations. In Finland, about 10 per cent of the furniture produced is covered with this material. Expanded PVC may be used for better-quality funiture used in public buildings and for domestic furniture. Its share of the market is about 80 per cent.

Perhaps the most important characteristic of upholstery material today is the flame-retarding properties of the products, especially in the automobile and ship-building industries.

XI. Surface finishing materials used in the furniture and joinery industries*

Protection

Before use, most objects made of wood must be protected with a finish because the porosity and considerable softness of wood make impurities stick to it, and cleaning a dirty wooden surface is laborious. Surface finishing also protects the wood against wear, micro-organisms and insects.

Aesthetic and commercial consideration

When necessary, surface finishing can be used to change the natural shade of wood: to give colour, to make light wood darker and even to make dark wood lighter. By the use of different materials and methods of surface finishing, various degrees of gloss can be obtained: glossy, semi-glossy, semi-matt and matt.

The choice of the proper method of surface finishing makes the wood more attractive and at the same time gives it more appeal to the buyer.

Putties

Putties can be made of various filling and binding materials, such as those listed in the following section which are suitable for finishing surfaces to be lacquered or painted.

Putty made from wood powder

One method of producing putty is to scrape off or sand from the end of a piece of wood. (It is recommended that the same species of wood be used as that of the surface to be repaired.) Wood dust obtained this way is finer than that obtained by scraping in any other direction. It is mixed either with glue or with lacquer to form a dough-like material. The binding material used can be a nitro-cellulose or alkyd formaldehyde, also known as alkyd lacquer, both of which have a fairly short setting time; other lacquers may also be used. Almost any type of glue may be used.

Properties and use:

(a) It is usual for putty to shrink as it dries. As a result a hole tends to develop and it may crack. Therefore, the putty should be left slightly above the surface;

(b) If the putty is too soft and thin, residues of the binding material may remain around the filling in the wood after levelling off and sanding;

(c) Colour adhesion is not very good, and therefore the areas repaired show easily;

(d) Adhesion can be somewhat improved by sanding in connection with the coating;

(e) Wood putty is generally applied on lower-grade objects only.

Shellac putty

To produce shellac putty, shellac particles are heated to form a thin cylinder (a stick may be used as a core). In the actual filling, heated lacquer is dropped into the hole and pressed in immediately, using a moistened scraping plate so that the filling goes into the hole and dries immediately.

Properties and use:

(a) The putty does not shrink or crack;

(b) It offers good adhesion to wood;

(c) Preparation for use can be done in a short time;

(d) It does not stain the wood; owing to its dark colour, however, it can be distinguished on light woods;

(e) Spirit-based stain dissolves the filling;

(f) Ordinary water-based stain does not adhere;

(g) It is used to fill in holes in dark wood species and in filling dark knots in light woods.

Wood fillers

The filling powder may be fine wood dust, chalk, gypsum, clay, talcum etc. The binding agents are oil or alkyd varnish. Wood fillers are generally factory-manufactured, and they are available in shades of various wood species, such as light and dark oak and mahogany. Untinted and black fillers are also available. It is also possible to tint the filler with pigment mixed with turpentine.

This type of filler is used when a lacquered or polished surface with full pores is desired in wooden objects with large pores; the filler can reduce the number of coatings and speed up the work.

Stains

Water-based stain

The most common water-based stain is water-soluble anilin colour. It is available in shades of some wood species, either as granules or powder.

It is produced by dissolving the colour pigments in distilled or rain water at 60° to 80°C. A usual concentration of this so-called basic solution is 50 g/l. The final shades

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*By Kaarlo Ilonen, School for Small-scale Industry and Teachers Training, Lahti, Finland. Originally issued as ID/WG.209/26.

are obtained by mixing the basic solution with water in a given ratio. For continuous use, the mixing formula of the batch to be used should be written down on the reverse side of a stained sample so that the same shade may be produced at a later date.

Before use, some ammonia may be added to the cold stain solution to improve the penetration of the stain. The basic solution can be diluted with a spirit (in non-acid pigments), which improves the ability of the stain to penetrate into and adhere to surfaces to be re-coated.

Properties and use:

(a) The desired shade is easy to obtain;

(b) The stain is easy to apply;

(c) It is inexpensive;

(d) The colour is not waterproof;

(e) All stains are not completely fast to light;

(f) Stains do not resist wear;

(g) Staining changes the natural configuration of the wood whereby a negative figure is formed.

Spirit-based stain

To produce a spirit-based stain, approximately 4 per cent of pigment is dissolved in 96 per cent of alcohol, with a similar amount of shellac being added.

Properties and use:

(a) Surface drying is fast;

(b) It adheres to a surface that is to be re-stained;

(c) It is somewhat waterproof;

(d) Large surfaces are difficult to coat owing to the fast drying properties of the stain;

(e) It is usually not stable to light;

(f) The stain gives a negative configuration;

(g) It is expensive.

Factory-made stains with organic solvent

Factory-made stains with organic solvent are the newest available stains, in which the pigment (anilin colour) is dissolved in an organic solvent (ethyl-glycol). Concentrated solutions are diluted with organic thinners until they reach the desired colour.

Properties and use:

(a) Surface drying is very fast;

(b) It has good adhesion and penetration, also when applied to surfaces to be re-stained;

(c) It is partially waterproof;

(d) Treating large surfaces requires experience owing to the fast drying time;

(e) It gives a negative configuration;

(f) It is expensive;

(g) It is time-saving in the staining of furniture and other wooden objects.

Spirit-based lacquer

The ingredients of spirit-based lacquer are:

(a) Shellac (excreta of an insect indigenous to India living in certain trees) and 96 per cent alcohol plus a small amount of other ingredients;

(b) Thinner, which is 96 per cent alcohol (generally not necessary).

It may be applied by spraying or with a brush.
No special measures are necessary to protect health.
Its drying time in a temperate climate (20°C) is:

Touch dry	10 minutes
Handling dry	1 hour
Subsequent coating	3 hours

Properties and use:

(a) Its glossy finish dries through evaporation;

(b) It is satisfactorily waterproof;

(c) It is satisfactorily wear-resistant;

(d) It has fairly good filling properties;

(e) It has satisfactory resistance to solvents, turpentine and benzine (not alcohol);

(f) It is suitable for surface finishing musical instruments (violins, guitars);

(g) It is suitable for the restoration of old furniture where the surface has been finished with these materials;

(h) It is suitable for surface finishing of new furniture in areas where these raw materials are available at a low cost, particularly where more sophisticated finishing materials are not readily obtainable.

Nitro-cellulose lacquers

The ingredients of nitro-cellulose lacquers are cellulose nitrate to which softening ingredients and an organic solvent are added and thinner which consists of a mixture of organic solvents.

Lacquer may be applied by spraying, with a brush, by curtain coating, immersion (dipping) and drum lacquering. For spraying, a viscosity of 18 to 20 seconds using a standard DIN cup size 4 at 20°C is recommended. Depending on the method of application, 7 to 10 m^2/l of coated area is obtained.

Sufficient ventilation must be arranged or breathing masks should be worn.

Inflammability is class I, flash point below 30°C.

The drying time at 20°C is:

Touch dry	10 minutes
Handling dry	1 hour
Subsequent coating	1 hour

Main properties:

(a) It is glossy or matt;

(b) It dries through evaporation;

(c) Owing to the small amount of solid material, it does not fill very well;

(*d*) It resists mild solvents, turpentine and benzine;

(*e*) It is satisfactorily waterproof;

(*f*) Because of the strong solvent that it contains, it dissolves the underlying coating.

Main uses:

(*a*) For lacquering new wooden objects for interior use;

(*b*) As a primary coating when a fast-drying lacquer is required or if catalyst lacquer reacts harmfully with the wood or the stain contained in it.

Alkyd lacquers

Ingredients of alkyd lacquers are alkyd resin (synthetic) and linseed oil. The thinner can be wood or mineral turpentine.

Alkyd lacquer can be applied by spraying, with a brush, by immersion or by drum lacquering. For spraying, 18 to 20 seconds DIN 4 at 20°C is the correct viscosity; for application with a brush, it is about 24 seconds DIN 4 at 20°C.

Depending on the method of application, a coated area of 15 to 20 m²/l is obtained.

When using mineral turpentine thinner, sufficient ventilation must be provided or breathing masks should be worn.

Inflammability is class II, flash point above 30°C.

The drying time at 20°C is:

Touch dry	3 hours
Handling dry	8 hours
Subsequent coating	16 hours

Main properties:

(*a*) It is glossy or matt;

(*b*) It dries through evaporation and oxidation;

(*c*) Owing to the large amount of solid ingredients, the lacquer has good filling properties (the amount of solid ingredients is about 45 per cent);

(*d*) It resists mild solvents, such as turpentine and benzine, and can be washed with water;

(*e*) It has good wear resistance.

Main uses:

(*a*) Interior and exterior lacquering;

(*b*) Re-lacquering of old objects (does not dissolve the underlying coating);

(*c*) When the lacquered surface can be allowed a long drying time.

Alkyd-carbamide lacquers (acid catalysed two-component lacquers)

The ingredients in alkyd-carbamide lacquers are alkyd resin and carbamide (urea-formaldehyde) resin, together with certain other substances, and a hardener, which is an acid. The thinner is a special mixture of organic solvents suited to this lacquer.

It can be applied by spraying, brushing, curtain-coating or immersion. The correct viscosity for spraying is 18 to 20 seconds DIN 4 at 20°C. Depending on the method of application, a coated area of 12 to 15 m²/l is obtained. Sufficient ventilation must be provided, or effective breathing masks should be worn.

Inflammability is class I, flash point below 30°C.

Main properties:

(*a*) It gives either glossy or matt finishes;

(*b*) The lacquer dries owing to a chemical reaction, initiated by the hardener and accompanied by the evaporation of solvents;

(*c*) It resists mild solvents such as turpentine, benzine and alcohol;

(*d*) The hardened surface can be wiped with strong solvents for cleaning purposes;

(*e*) It has a good resistance to heat (80° to 120°C);

(*f*) It has a good resistance to water;

(*g*) It has a good wear resistance;

(*h*) Discoloration may occur for certain wood species.

Owing to the above properties this lacquer group has gained wide use in the industrial surface finishing of furniture, but it can be used also for various other purposes.

Pre-catalysed alkyd-carbamide lacquers (one-component lacquers)

One-component catalyst lacquers contain a hardener that is already mixed in (self-contained). The setting reaction begins after the solvent has been evaporated. One-component catalyst lacquers are usually weaker than those with two components. They are used both for prime coating and final surface coating. These lacquers also exist as two-component types.

When applying a priming lacquer coating on light-coloured wood species, a type of lacquer that leaves it with an unfinished look is often used (it does not wet the surface). The light colour of the wood can also be accentuated by mixing into the lacquer a small amount (1 to 2 per cent) of white paint of the same type or white pigment mixed with thinned lacquer.

General information about other types of lacquers

Polyester lacquers

Originally, polyester resin was used mainly reinforced with fibreglass in car bodies, boats etc. Later it became an important raw material for lacquer. Polyester lacquers contain no evaporating ingredients, and consequently they have good filling properties. With the use of mechanical polishing methods, very high-quality lacquered surfaces can be obtained.

Polyester lacquers are two-component lacquers (like alkyd-carbamide lacquers). A hardener is needed to start the setting reaction. So far, their use in small and medium-scale industries has been less significant than the use of nitro-cellulose and two-component alkyd-carbamide lacquers.

Polyurethane lacquers

Polyurethane lacquers set like alkyd-carbamide lacquers. They either contain a hardener or one may be added by the end-user. The coating is resistant to chemicals and mechanical wear. These lacquers are used in kitchen and bathroom furniture and also on boats.

Factors affecting the choice of lacquers are:

- Wood used in the object
- Requirements of the lacquer
- Surface-finishing materials available
- Equipment available
- Method used in surface finishing
- Conditions for surface finishing
- Skill and experience of workers

Choice of surface finishing

The choice of surface finishing depends on:

- Use of the object to be surface finished
- Material used in the object to be surface finished
- Equipment available for surface finishing
- Surface-finishing materials available
- Conditions under which surface-finishing operations will be performed
- Conditions under which the object will be used
- Skill of the workers

Part two

PROCESSING TECHNOLOGY

XII. Meeting the design needs of the furniture industry in developing countries*

The introduction of industry into a country without industrial traditions always stimulates new demand. The more one branch of industry is developed and the more its product is sold to retail consumers, the greater the need is for good design. As export markets become more necessary, the role played by good design becomes greater.

Increasing consumer demand places new pressures on industry. Although there is great interest in good design among producers in many developing countries, the services of capable designers are difficult to obtain. Such people are not only scarce, but paying them adequately is not economic because of the risk that competitors may pirate their models.

While mass production would be one way of covering design expenses, in many developing countries local consumers are very individualistic and do not like to buy mass-produced furniture. Another obstacle is the frequent lack of storage space in existing furniture factories.

Mass-produced furniture is always cheaper than custom-made pieces, but in most developing countries furniture is still produced on an individual basis. However, local people will probably come to accept mass-produced furniture in the same spirit as they accept automobiles, radios and other everyday, obviously mass-produced items.

Consumers are becoming more and more critical of design when selecting goods. In both mass-produced and individually produced furniture, design and designers have very important roles to play in developing the furniture industry of a developing country. The following section describes different ways of meeting design needs and illustrates the positive and negative aspects of each.

Education of local designers

Almost all industrialized countries have their own national systems of design education. In several countries the tradition reaches into the last century. Usually design institutes serve several branches of industry, producing industrial designers of all kinds. In many countries industry itself plays a remarkable part in design education, which is often under the jurisdiction of the ministry of industry or commerce rather than under the ministry of education. Artistic aptitude and the ability to think creatively are the main criteria in selecting applicants, who must have completed at least secondary school. A two-week special selection course is usually used to select them.

Positive aspects

If a developing country adopts its own system of design education, the future needs of its industry can be guaranteed. The tightening competition in world markets is raising design standards, and products with the exotic touch that only designers familiar with tradition can increase the possibilities for a country to penetrate foreign markets.

A design institute set up in one developing country should, if possible, serve other countries in the region or subregion.

Negative aspects

Although good designers are now scarce and the need for them is increasing, a new institute could produce too many designers after a while. If industry is unable to provide these designers with enough work at appropriately high salaries, they may migrate to other countries where their designs may be more appreciated. In such a case, the investment in their education would be largely wasted. This phenomenon is not new in some European countries; it is the problem of the "brain drain".

A major difficulty in setting up a design education system would be finding qualified, well-informed teachers. Unfamiliar local conditions, inadequate knowledge of the country and possibly political factors could be obstacles to procuring such people even at high salaries.

The establishment and operating costs of a design institute would be high and its benefits apparent only after a number of years.

Education abroad

All these factors considered, sending talented young people abroad for their education seems highly recommendable. All industrialized countries, especially the United States and most industrialized European countries, have high levels of design education. Instruction is usually given in English as well as in the local language. Candidates for training could be selected through competitive examination or through the two-week selection courses mentioned above.

Positive aspects

As with local training, training abroad can fill future designer needs if enough students are able to participate. There would be no danger of too many designers, since the number of designers educated could be limited to the actual needs of local industry.

*By Simo Pelppo and Ahti Taskinen, Lahti, Finland. Originally issued as ID/WG.105/31/Rev.1.

The professional level of designers trained abroad would be noticeably higher than that of those educated in newly established local design institutes owing to the better teaching available in established schools. Designers must keep abreast of current developments in industry and make contacts in international markets in order to see the competition at first hand. It is therefore very important that student designers use their vacations to gain experience in modern industry.

Upon completion of training abroad, the students would be able to pass on their experiences and knowledge to local designers, with a positive effect on local industry.

Negative aspects

If education abroad is financed by the Government, as it usually is, a designer normally undertakes to stay for a certain time in the service of the State. Unfortunately the State is seldom in a position to offer work commensurate with the education of people trained abroad, who are thus in danger of becoming officials rather than creative designers. A designer needs to begin working in industry immediately after finishing schooling; the tangible results of his or her work and its success on the market are a student's best encouragement.

The failure of local industry to employ new designers may cause them, unless the State demands their return, to remain in the country where they were trained, especially if better earning possibilities exist there. Thus, their knowledge and ability may be lost to their own countries.

Education abroad takes just as long as local education. In either case, the practical results are not evident for several years. It should also be remembered that education abroad is very expensive, requiring an average of three to four years' residence abroad.

Importing designers

The migration of designers from one country to another has been common for a long time. One reason for this is the internationalization of products, the national characteristics of which have tended to disappear as a result of the large-scale production required for profitability.

When factories are willing to co-operate with foreign designers the results are mainly positive.

Positive aspects

The importation of designers makes possible the creation of new saleable collections in a moderately short time. To make the best use of the new designs it is necessary to modernize factory and production methods, in other words, to increase know-how. This system can keep local industry informed of the quality demands of modern markets.

Negative aspects

Initiallly, designers from industrialized countries will have difficulty understanding local working methods. Their attempts to become accustomed to them may take a long time and impair their interest in local design development. Furthermore, if local salaries are appreciably lower than those in the home country, they may return home more quickly.

If foreign designers' incomes are on a royalty basis, mass production of their designs must be on a very large scale if they are to earn as much as they could in their own countries, local factory prices being much lower than in industrialized countries. If it is a question of only a few years' contract work, remuneration may barely cover designers' expenses for travelling, returning and making a new start. Moreover, by losing contact with the main trends of development in design for several years, the designers' quality of work may decline. A different climate and the break with familiar social patterns may accelerate such a decline in working capacity. In sum, it is difficult to attract competent designers from abroad, and even when this is possible their long-term usefulness tends to be limited.

Importation of plans and designs

It is quite usual to use imported plans and designs. They can be obtained from designers with whom contact has already been made or by approaching internationally known designers.

Positive aspects

When plans and designs are imported, a saleable collection can be made in a reasonably short time provided that information about production possibilities is given and agreement is reached on forms of payment. The technical level of local industry will improve as new demand is created and difference between international and local designs decreases.

Negative aspects

The value of imported plans and designs may decline if long distances and lack of personal contact cause designers to lose interest, especially if their remuneration has not been strictly defined. Such a lack of co-ordination may lead to poor results and to the end of the business relationship.

Production under licence

Production under licence has been very common and will continue to grow in importance in international industry. This method is an economical means of producing well-known products and of obtaining industrial know-how.

Positive aspects

Production under licence makes it possible to produce good, well-known models. Since such products are already successful in other markets, there is less uncertainty about their acceptability in the domestic market. Their introduction encourages modernization and streamlining of production and may permit the installation of new machines that could greatly enlarge production capacity.

New possibilities for export are provided to countries where there is no licensee. In sum, production under licence is an economical way of obtaining good designs if there are good faith and fair dealing on both sides.

Negative aspects

Every enterprise should have its own target for design development. Continuously successful production under licence, with long runs, will probably undermine the future design plans, independence and originality of the licensee. Furthermore, if the licensee does not have a design policy and the licensor stops co-operating, it will be difficult to replace the discontinued products.

A local enterprise has an obligation to its community not to make too many products under foreign licence. It must in the long run support its own designers, which it will be unable to do with production entirely under licence.

Unless sufficiently large production volumes are guaranteed, co-operation between licensor and licensee will be difficult to achieve. Moreover, the licensor cannot control the quality of the goods produced locally and may become dissatisfied.

Manufacture from the designs of foreign customers

In Finland, several large furniture sales chains and interior service firms have their own designers. The chains purchase their collections from the factories that supply products on the best terms. New industries in developing countries could compete successfully in this way, although transportation costs would be a problem even if production costs were comparable and the quality was acceptable. Design offices may also encounter difficulties with specially designed models for quick delivery to customers: large factories have planned their production for years ahead, and small ones, if delivery is urgent, charge prices that are unprofitably high. Local factories could alleviate this situation with products of acceptable quality.

Positive aspects

Manufacture from the designs of foreign customers involves the local furniture industry in the production of goods that meet international standards of quality. Furthermore, it obviates the need to make marketing investments in other countries. It provides a market for local industry, encourages better production methods and may also lead to the purchase of new machines to replace old ones.

Negative aspects

If deliveries are to be completed by the time arranged, the factory's own programme may be disturbed. Furthermore, customers are sometimes unfamiliar with local production capabilities, and it may happen that only a part of an order can be made in a given local plant. When this occurs, customers usually cancel the entire order and place it elsewhere.

International furniture design competitions

A popular way of acquiring a new collection of designs, especially when a factory needs new ideas, is to sponsor an international design competition. In this case it is important that the jury be of international repute. The contest may consist of several parts: home furniture, hotel furniture etc. The competition rules should give very careful descriptions of local production capabilities and of the materials that may be used.

Positive aspects

The outcome of the competition can be known and published in a comparatively short time. If the contest has stimulated interest among capable designers, the collection should be original and suitable for international markets. It may suggest ways of modernizing production methods by exposing local producers to contemporary design.

Negative aspects

A disadvantage of the international design competition is its comparatively high cost, not only the actual cost but also in terms of the normally short-lived influence of the competition on production. If the prizes offered are below the usual international level, there will be little interest in the contest, with the result that old drawings that were rejected by other factories will be submitted.

If local production capabilities are not clearly specified, the results may be unsatisfactory since the designers competing will have no knowledge of local industry.

Conclusions

Training local designers abroad is probably the best alternative if an industry is planning far into the future and seriously wants really capable designers. The rapid changes in modern methods and markets make it necessary for local industry to keep track of developments elsewhere. It is not enough for a factory to give work to its designers; it must also keep them on the same level as those of other countries. This may be done by sending them regularly to international events related to the factory's line of production, to fairs, to designer meetings etc. Membership in an international association of designers would also keep industry up to date on international trends (see the annex for information on two such associations). It is also necessary to expand international contacts continuously if products are to compete successfully in markets that are already highly competitive. Discussions with buyers are always useful to designers. Over the short term, however, the production under licence would probably be the best way to solve quickly and effectively a local industry's present inability to offer products of its own design. Furthermore, production under licence is an equitable arrangement, and its costs are reasonable.

Annex

INTERNATIONAL ORGANIZATIONS OF DESIGNERS

There are a number of international organizations of designers. Information on two of them, the International Council of Societies of Industrial Design (ICSID) and the International Federation of Interior Designers (IFI), is given below.

International Council of Societies of Industrial Design

The aims of ICSID are: to advance the discipline of industrial design, as an effective force between needs and aspirations of people; to encourage co-operation between individuals, agencies and other related international design organizations; to contribute to the study of industrial design in theory and practice; and to stimulate creativity and maintain high standards for quality in design and professional practice.

ICSID was formally established in London in 1957. It is directed by an Assembly of 60 professional and promotional societies from 39 countries—professional organizations defending the interests of professional designers and promotional organizations established and subsidized by the Government to devote its effort to the advancement of industrial design by means of information or promotional activities. In addition, industrial, commercial, research or academic institutions apply for representation as Associate members. ICSID may also appoint as Patron an individual or organization if such patronage is in accord with the aims of ICSID.

ICSID collects, co-ordinates and disseminates information to its members as well as to Governments, industry and the general public. Congresses, seminars, interdesigns, commissions, working groups and publications are the main activities of ICSID. Congresses are organized biennially in a country by the hosting member society and based on a theme that is timely and important to designers and society in general. A General Assembly is held every two years which reviews the activities, establishes the future programme and elects its Board of Officers.

Working seminars—Interdesigns—are also organized devoted to a general area that deserves unique attention. Mid-career designers gather from abroad and the host country to study a specific problem with international significance. Biennial awards are created by ICSID with the co-operation and support of member societies such as the ICSID Philips Award and the ICSID Kyoto Award.

Areas of particular importance and concern to ICSID and the industrial design discipline are international relations, communication, awards/competitions, professional affairs, promotion, interdesign and education. ICSID also maintains a working group to study issues affecting education and to co-ordinate such studies with other international design organizations. It also organizes international seminars for the purpose of exchanging information on methodology and working towards acceptable international standards in design education.

ICSID examines and supports by endorsement competitions and exhibitions that are in the best interest of its Council members and its organizers. It also collaborated with ICOGRADA and IFI in developing appropriate international standards.

ICSID has been granted consultative status by the United Nations (Economic and Social Council), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and works closely with the International Labour Office, the United Nations Conference on Trade and Development (UNCTAD), the General Agreement on Tariffs and Trade (GATT) as well as with the non-governmental organizations with common interest in design. It also has a UNIDO Commission that represents ICSID in all of its relations with UNIDO and works to further implement the programme and initiate action following the Memorandum of Understanding of 1977.

The members of ICSID are listed below.

Argentina

Foundation Center of Art and Communication (CAYC), Viamonte 452, 1053 Buenos Aires, Tel.: 566-8046

Centro de Investigación del Diseño Industrial y Gráfico (CIDIG), Leandro N. Alem 1067, Pisos 5°, 6°, 7°, 1001 Buenos Aires, Tel.: 221-3013

Australia

Design Institute of Australia (DIA), 21 Burwood Road, P.O. Box 21, Hawthorn, Victoria, 3122, Tel.: (03) 819 1311

Industrial Design Council of Australia (IDCA), GPO Box 1669N, Melbourne, Victoria 3001, Tel.: 63-1684, Cable: Austdesign

Austria

Österreichisches Institut für Formgebung (OIF), Salesianergasse 1, 1030 Vienna, Tel.: (222) 72 56 11/351

Belgium

Design Centre (DC), Galerie Ravenstein 51, 1000 Bruxelles, Tel.: (2) 511 62 35

Bulgaria

National Centre of Industrial Design, Committee for Science, Technical Progress and Higher Education, 8 rue Slavyanska, Sofia, Tel.: 88 56 61, Telex: 22348 Tehpro BF

Canada

Association of Canadian Industrial Designers, c/o Humber College of Applied Arts and Technology, 205 Humber College Boulevard, Rexdale, Ontario M9W 5L7, Tel.: (416) 675-3111, ext. 536

National Design Council (NDC), Department of Industry, Trade and Commerce, 235 Queen Street, Ottawa, Ontario K1A OH5, Tel.: (613) 992-0341

China (Taiwan Province)

China Productivity Center (CPC), 11th Floor, 201-26 Tun Hua N. Road, Taipei, Taiwan, Tel.: 773-2200, Cable: CPTC

Czechoslovakia

Czechoslovak Institute of Industrial Design, Na Porici 24, 110 00 Prague 1, Tel.: 24 07 41/9, Cable: CIDESIGN

Union of Czechoslovak Artists, Section of Applied Arts and Industrial Design, Nove Mesto, Gotwaldovo Nabrezi 250, 110 00 Prague 1, Tel.: 29 24 41/5

Cuba

Oficina Nacional de Diseño Industrial, Calle 19, No 552, Esquina D, Plaza, Havana

Denmark

Industrielle Designere Danmark (IDD), Nyhavn 53B, DK-1051 Copenhagen K, Tel.: (1) 13 72 30

Ecuador

Asociación de Diseñadores del Ecuador, Casilla 214, Quito

Finland

Finnish Society of Crafts and Design (FSCD), Pohjoisesplanadi 25 A, 00100 Helsinki 10

Finnish Association of Designers (ORNAMO), Pohjoisesplanadi 25 A, 00100 Helsinki 10, Tel.: (0) 17 59 77

France

Centre de Création Industrielle (CCI), Centre Georges Pompidou, 75004 Paris, Tel.: (1) 4277-1233

Formes Utiles (FU), 104 rue Michel-Ange, 75016 Paris, Tel.: (1) 4743-1247

Union Française des Designers Industriels (UFDI), 101 Avenue Raymond Poincare, 75016 Paris, Tel.: (1) 4544-1741

German Democratic Republic

Ministerrat der DDR, Amt für industrielle Formgestaltung (AiF), Breite Strasse 11, DDR-1020 Berlin, Tel.: (2) 200 0101

Germany, Federal Republic of

Rat für Formgebung (RfF), Eugen-Bracht-Weg 6, D-6100 Darmstadt, Tel.: (6151) 44 051

Verband Deutscher Industrie Designer (VDID), Drususstrasse 3, Postfach 11 13 21, D-4000 Düsseldorf, Tel.: (211) 57 30 82

Hong Kong

Hong Kong Industrial Design Council, Eldex Industrial Building, 21 Ma Tau Wei Road, 12th floor, Unit A, Hunghom, Kowloon, Tel.: 3-659061, Cable: FEDINDUSTRY

Hungary

Association of Hungarian Fine Artists (AHFA), Industrial Design Section, Vorosmarty Ter. 1 Pf 51, Budapest V, Tel.: 12 96 26

Hungarian Council of Industrial Design, Martinelli Ter. 8, 1052 Budapest, Tel.: 11 24 89

India

Industrial Design Centre (IDC), Indian Institute of Technology, Powai, Bombay 400 076, Tel.: 58 14 21/58 41 41, Cable: TECHNOLOGY Bombay 400 076

National Institute of Design (NID), Paldi, Ahmedabad 389 997, Tel.: 79 69 3/4/5, Cable: INSTITUTE

Society of Industrial Designers in India (SIDI), Care Communica, Anjali 12B, Off Arthur Bunder Road, Colaba, Bombay 400 005

Ireland

Kilkenny Design Workshops (KDW), Kilkenny, Tel.: (56) 22 118, Cable: DESIGNSHOP, Telex: 8727 KDW EI

Society of Designers in Ireland (SDI), 8 Merrion Square, Dublin 2

Israel

Israel Centre for Packaging and Industrial Design (ICPID), 2 Carlibach Street P.O.B. 20038, 6100 Tel-Aviv, Tel.: (3) 28 21 58, Cable: INSTIPACK

Israel Industrial Designers Association (IIDA), 4 Shaar Hayam, Nof Yam, Herzliyya 46606, Tel.: (52) 7 29 46

Italy

Associazione per il Disegno Industrial, Via Montenapoleone 18, 20121 Milan, Tel.: (2) 78 20 44

Japan

Japan Industrial Designers Association, P.O. Box 198, Trade Center, Tokyo 105, Tel.: (3) 433-6391/3, Cable: JAPANDESIGN Tokyo

Japan Industrial Design Promotion Organisation (JIDPO), World Trade Center Building annex, 4th floor, 2-4-1 Hamamatsu-cho, Minato-ku, Tokyo, Tel.: (3) 435-5633/4

México

Colegio de Diseñadores Industriales y Gráficos de México A.C. (CDIGM), Apartado Postal 20-308, México 20, D.F.

Instituto Nacional de Diseñadores Industriales y Gráficos de México A.C. (INDIGM), Sonora No. 80, México 7, D.F.

Netherlands

Kring Industriële Ontwerpers (KIO), Keizersgracht 321—Postbus 19610, 1000 GP Amsterdam Tel.: (20) 25 49 59

Norway

Norwegian Council of Industrial Design (NCID), Uranienborgveien 2, Oslo 2, Tel.: (2) 56 69 68

Norwegian Group of Industrial Designers (NGID), (Norske Grafiske Designere (NGD)), Uranienborgveien 2, Oslo 2, Tel.: (2) 56 69 68

Pakistan

Pakistan Design Institute, 16 Muslimabad, Karachi 5, Tel.: 41 15 12, Cable: PAKDEE Karachi

Philippines

Design Center Philippines, Cultural Center Complex, Roxas Boulevard, Manila, Tel.: 59 03 38—50 12 61/66, Cable: DESIGNPHIL

Poland

Stowarzyszenie Projektantow Form Premyslowych, Domek Mauretanski, Ul. Pulawska 55, Skr. Poczt 14, 00975 Warsaw, Tel.: 49 54 37

Zwiazek Polskich Artystow Plastykow (ZPAP), Ul. Foksal 2, 00366 Warsaw, Tel.: 27 54 11, Cable: ZPAP

Portugal

Associaçao Portuguesa de Designers (APD), Rue Barata Salgueiro, Lisbon 2

Republic of Korea

Korea Design and Packaging Center (KDPC), 128 Yunkun-Dong, Chongro-ku, Seoul 110, Tel.: 69 31 81/5—68 38 39, Cable: EXPACK

South Africa

Design Institute, South African Bureau of Standards, Private Bag X191, Pretoria 0001, Transvaal, Tel.: 48 13 11, Cable: COMPARATOR, Telex: 3626 SA

Society of Designers in South Africa, P.O. Box 23394, Joubert Park 2044, Tel.: 37 18 41

Spain

Agrupación de Diseño Industrial del FAD (ADIFAD), Calle Brusi 45, Barcelona 6, Tel.: (3) 277-5908 218-0347

Asociación de Diseñadores Profesionales (ADP), Apartado 121/74, Barcelona, Tel.: 218-4758/218-4700

Barcelona Centro de Diseño Industrial, Paseo de Gracia 55-57, Barcelona 7, Tel.: (3) 215-8750 / 215-8124 / 215-8582

Sweden

Foreningen Svensk Form (Swedish Society of Industrial Design) (FSF), Nybrogatan 7, S-103 91 Stockholm, Tel.: (8) 63 59 20

Society of Swedish Industrial Designers (SSID), Box 1419, Malsmkillnadsgatan 48A, S-111 84 Stockholm, Tel.: (8) 14 20 00

Switzerland

Verband Schweizer Industrial Designers (VSID), Weinbergstrasse 1, CH-8001 Zurich, Tel.: (1) 69 03 11

Union of Socialist Soviet Republics

All-Union Research Institute of Industrial Design (VNIITE), Moscow 129 223, Tel.: 181-9919/181-9367/181-9756

United Kingdom

Design Council (DC), 28 Haymarket, London SWIY 4SU, Tel.: (1) 839-8000, Telex: 8812663

Society of Industrial Artists and Designers (SIAD), Nash House, 12 Carlton House Terrace, London SWIY 5AH, Tel.: (1) 930 1911

United States

Industrial Designers Society of America (IDSA), 6802 Poplar Place, McLean, VA 22101, Tel.: (703) 556 0910

Yugoslavia

Federation of Artists of Applied Arts of Yugoslavia (SPID-YU), Industrial Design Secretariat, Titova 21/I, 61000 Ljubljana, Tel.: 31 17 60

International Federation of Interior Designers*

What is IFI?

The International Federation of Interior Architects/Interior Designers, founded in 1963, is a non-political organization of professional associations of interior architects/interior designers and schools and institutions engaged in the field of interior architecture/interior design.

What are the aims of IFI?

To co-ordinate all activities relevant to the profession in matters of professional codes of conduct, professional practice, registration and professional training as well as to secure the integrity of the profession and the public confidence in interior architects/interior designers.

What is IFI doing?

IFI organizes meetings, seminars and congresses; sets up working groups, research groups and committees; and investigates the situation of the profession and its current needs and demands. IFI contacts other international organizations and publishes reports and statements to promote and inform about its activities and points of view.

How is IFI organized?

Members are national associations of interior architects/interior designers and associations and institutions otherwise engaged in the field of interior architecture/interior design.

Individual membership can only be obtained by individual persons specially appointed as correspondents.

The ultimate authority of IFI is the General Assembly. Each member association has a delegation to the Assembly. The delegations meet every second year at the General Assembly.

What are the aims and purposes of IFI

Paragraphs 2 and 3 of the IFI articles of association read:

"IFI is neutral in respect of politics, creed and trade unions. Its objectives are:

a. to raise the standard of interior architecture/interior design and of professional practice;

b. to improve and expand the contribution of interior architecture/interior design to society both in advanced and developing countries;

c. to initiate or further programs that are concerned with public health, safety and welfare, which apply interior architecture/interior design to the solution of problems affecting the material and psychological well-being of man;

d. to serve the interests of the interior architect/interior designer, in particular to promote the recognition of the professional designation and the professional practice;

e. to support the Member associations where feasible.

IFI does not aim to make a profit.

IFI seeks to attain these objectives in any manner suitable, and in particular by:

a. evolving a common definition of the profession;

b. promoting contacts among the national associations in respect of their codes of professional conduct, regulation of fee structure, and participation in competitions;

c. promoting the achievement of minimum standards in interior design education;

d. issuing IFI bulletins and promoting the exchange of publications;

e. organizing congresses, meetings, study trips, exhibitions and the participation in same;

f. assisting in the exchange of specialized teachers, speakers, trainees and students;

g. working towards collaboration with international institutions having similar objectives;

h. actively supporting, at a request of a Member association, the professional interests of that association within the scope of common interests.

* The term interior designer is used in most English-speaking countries, whereas the term interior architect, or its equivalent in other languages, is usual in a majority of other countries. Both terms are fully recognized by IFI and by all member associations as being equivalent and having the same meaning.

Who are the members of IFI?

Secretariat

Keizersgracht 321, 1016 EE Amsterdam, Netherlands. Tel.: (020) 25 49 59. Correspondence: P.O. Box 19610, 1000 GP Amsterdam, Netherlands, Liesbeth Hardenberg, General Secretary

Austria

Bund Österreichischer Innenarchitekten (BOIA), Penzingerstrasse 23, A-1140 Vienna 14, Tel.: (0222) 82 72 46

Belgium

Beroepsvereniging voor Binnenhuisarchitecten (BVB), c/o Emmanuel Botte, Oude Zak 45, B-8000 Brugge, Tel.: (050) 33 79 76

Canada

Interior Designers of Canada (IDC), Post Office Box 752, Station, B, Ottawa, Ontario KIP 5P8

Denmark

Foreningen af Mobelarkitekter & Inretningsarkitekter i Danmark (MMI), Fredericiagade 57, D-1310 Copenhagen K, Tel.: (01) 14 82 61

Finland

Sisustusarkkitehdit - Inredningsarkitekter (SIO), Pohjoisesplanadi 25 A, 00100 Helsinki 10

France

Syndicat National des Architectes d'Intérieur (SNAI), 57, Boulevard Richard Lenoir, 75011 Paris, France, Tel.: (01) 4355 90 67

Germany, Federal Republic of

Bund Deutscher Innenarchitekten e. V. (BDIA), Königswintererstrasse 709, D-5300 Bonn 3, Tel.: (0228) 44 24 14

Hungary

Magyar Kepzöes Iparmuvészek Szövetsége (MKIS), (Association of Hungarian Fine Artists Belsoepitesz), Szakosztaly, Interior Architects' Division, Vörösmarty tér 1, 1364 Budapest Pf. 51, Tel.: (01) 184-074

Iceland

Félag Húsgagnaog Innanhusarkitekta (FHI), P.O. Box 5051, Reykjavik

Ireland

Society of Designers in Ireland (SDI), 8 Merrion Square, Dublin 2

Israel

Association of Interior Architects in Israel (AIAI), c/o N. Maron, P.O. Box 7169, Jerusalem

Italy

Associazione Italiana Proggettisti d'Interni (AIPI), Via Aurispa 2, 20122 Milan, Tel.: (02) 83 77 989

Japan

The Japan Interior Designers' Association (JID), Secretariat: Kenchikuka-kaikan, 3-16, 2-chome, Jingumae, Shibya-ku, Tokyo, 150, Tel.: (03) 403 3649

Netherlands

Beroepsvereniging van Nederlandse Interieurarchitekten (BNI), Keizersgracht 321, 1016 EE Amsterdam, Tel.: (020) 25 49 59. Correspondence: P.O. Box 19610, 1000 GP Amsterdam

Norway

Norske Interiör-arkitekters Landsforening (NIL), Uranienborgveien 2, Oslo 2, Tel.: (02) 566 048

Poland

Zwiazek Polskich Artystow Plastykow (ZPAP), Ul. Foksal 2, 00-366 Warsaw, Tel.: (022) 27 54 11/27 54 12

Spain

Colegio Nacional de Decoradores (CND), Ayala 20-2-B, Madrid 1, Tel.: (01) 276 45 15

Sweden

Svenska Inrednings-arkitekters Riksförbund (SIR), (The National Association of Swedish Interior Architects), Odengatan 3, S 11424 Stockholm, Tel.: (08) 240 230

Switzerland

Vereinigung Schweizer Innenarchitekten (VSI), Weinbergstrasse 11, CH-8001 Zurich, Tel.: (01) 47 16 86

United Kingdom

Society of Industrial Artists and Designers (SIAD), 12 Carlton House Terrace, London SW 5AH, Tel.: 01-930 19 11

United States

American Society of Interior Designers (ASID), 1430 Broadway, New York, N.Y. 10018, Tel.: (212) 586 71 11

Puerto Rico

Colegio de Decoradores y Diseñadores de Interiores de Puerto Rico (CODDI), G.P.O. Box 3703, San Juan, 00936, Tel.: (809) 753-0865 and 754-8304

Other members

Academy of Arts and Design (BEZALEL), 8 Ido Hanavi Street, Jerusalem 95 106, Israel

Centre de création industrielle (CCI), Centre National Georges Pompidou, F-75 191 Paris Cedex 04, France, Tel.: (01) 4277 12 33

Foundation for Interior Design Education Research (FIDER), 242 West 27th Street, New York, N.Y. 10001, United States of America, Tel.: (212) 929 83 66

Hochschule für künstlerische und industrielle Gestaltung, Hauptplatz 8, A-4020 Linz, Austria

Interior Design Educators Council (IDEC), Box 8744, Richmond, VA. 23226, United States of America

National Council for Interior Design Qualification (NCIDQ), 75 East 55th Street, New York, N.Y. 10022, United States of America, Tel.: (212) 688 78 59

Sindicat d'interioristes de Catlunya (IN-FAD), Brusi 45, Barcelona 6, Spain, Tel.: (93) 209 11 55

XII. Service conditions of furniture designers in Scandinavian countries*

Furniture designers in Scandinavia, primarily in Finland, fall into three categories: free-lancers who are remunerated entirely on a royalty basis; designers who receive both a fixed salary and royalties on products made from their designs; and designers who work on a salary (perhaps with such benefits as housing privileges or the use of an automobile). Some designers do not fit exactly into any of these three categories; for example, an interior decorator who may occasionally design furniture is not considered a furniture designer.

Furthermore, the mobility of furniture designers, in Finland at least, is very high, so that their distribution over the three categories changes constantly. There may be as few as 40 active, full-time furniture designers in Finland, although this number is less than 20 per cent of the membership of the Society of Interior Designers (SIO).

Salaries and fees

Free-lance designers

Free-lance designers are remunerated in the following ways:

- Straight royalties, with possibly an initial pre-payment advance
- A relatively large fee plus a proportionately small royalty
- A relatively small fee and a relatively large royalty
- A lump-sum fee for each design accepted
- A salary for a fixed term (such as two years) with the obligation to complete a specified number of designs (perhaps three chairs)

From the designers' point of view, the first arrangement has the important advantage of giving them independence, if they receive advances against royalties, they may be able to devote considerable time to a given design. Moreover, if they work with several different firms, the end of a working relation with one of them will not be catastrophic; it will mean the loss of only part of an income, and new working relations can be established. The disadvantages are that they must pay all of the development costs and bear all of the risks before their designs are sold—if they ever are! There is also a feeling among designers that, under this system, their share of any profits tends to be too small.

In the second system, in which there is a relatively large fee and a relatively small royalty, designers still enjoy a large measure of independence, and the employing firm pays part of the development costs. On the other hand, since the designers' total share is still felt to be too small, their share of the risk is considered to be proportionately too large.

In the third system, with a larger royalty and smaller fee, designers still maintain a great deal of independence. A properly calculated relation can be advantageous to both parties. The difficulty is setting the shares to the satisfaction of both parties; the negotiations may degenerate into rather ungraceful haggling.

In the fourth system, in which a lump-sum payment is made for each design accepted, the advantage to designers is that they receive money at once. On the other hand, they must bear all of the development costs. Furthermore, the fee must be negotiated, which can result in the same kind of unseemly haggling as in the third system. There is the additional disadvantage to both parties that the work is discontinuous.

Finally, in the fifth system, if free-lance designers sign fixed-term contracts to produce a certain amount of work within a given time for a set remuneration, they have given up independence for the duration of the contract. This disadvantage may be offset, however, by the possibility of conducting research free from immediate financial pressure.

Designers on salary and royalty

Thus far, salary-and-royalty arrangements with furniture producers are extremely rare in Finland. Nevertheless, since arrangements of this kind can be quite advantageous to both designers and producers, they will probably gain a foothold in the future; indeed, there have already been some experiments in this direction. The arrangements are generally of two kinds: *(a)* the payment of a fixed salary, supplemented by royalties on furniture designed during the life of the contract; and *(b)* a fixed salary plus a normal royalty. In the latter case, the salary is considered to be an advance (pre-payment) deductible from royalties, but this is not strictly correct since a designer in this situation normally has other duties, such as participation in exhibitions.

In the first system, that is, fixed salary plus royalties for furniture designed during the life of the contract, the greatest advantage is continuity of income. Even if designers change employers or become free-lance designers, they will continue to draw income from earlier work. They can also give precedence to their own ideas over those of the employer, but this could be considered a disadvantage by the employer.

The situation in the second system, namely the payment of a fixed salary plus a normal royalty, is much the same as in the first system. The principal drawback, from the

*By Ahti Taskinen, Lahti, Finland. Originally issued as ID/WG.105/47.

designers' point of view, is that the salary may be too small.

Designers on straight salary

When designers receive fixed salaries and perhaps some benefits such as housing privileges or the use of a company automobile but not royalties or other supplemental remuneration, it is probable that the salary will be rather substantial. As long as the relation continues, the situation of the designers is satisfactory. When it is terminated, however, designers retain no rights in or income from earlier work.

Working place and time

Free-lance designers

Free-lance designers normally work in their own studios and at their own pace. However, their income tends to fluctuate with changes in productivity, the state of the market, changes in fashion and so on. Moreover, they may have difficulty in maintaining contact with sources of commissions, and they run the risk of losing familiarity with the production methods of clients. Another consideration is that difficulties may arise when the working rhythms of designers and producers differ widely.

Designers on straight salary

Designers who are salaried, whether they receive royalties or not, normally work at a plant and put in normal working hours. They have the advantages of being in close touch with all of the other staff, from whom they can get support for their work. They are also aware of the production methods and the mechanical and other resources of the producer. On the other hand, some designers find the factory milieu depressing. They sometimes feel that they are losing contact with the outer world and are unable to see their work in relation to human life.

Fixed working times are particularly distasteful to creative people such as designers. With a time-control system during regular working hours, designers must use their own time for personal development and the collection of external stimuli. There are, of course, visits to furniture fairs, but these occasions are usually brief and busy ones.

Working relations and commissions

Free-lance designers

Free-lance designers normally receive commissions direct from the producer. They can maintain their independence and need not limit themselves to certain types of furniture. As the relationship develops, mutual confidence tends to increase and the exchange of information to become freer and more open. The risks are divided between the two parties. Furthermore, when free-lance designers accept commissions from several different producers, it becomes easier for them to propose solutions suitable to the general situation in the industry without transmitting information about one supplier to a competing one. On the other hand, if a long-term, continuing relationship does not develop, contacts with sources of commissions will be incidental and short-lived, and designers will find themselves taking all of the risks.

Free-lance designers must thus concentrate on a few producers and become dependent upon them to some degree. They must often guess at the real requirements of clients, since the latter may be reluctant to give information that might be of value to a competitor. Perhaps the principal disadvantage is that designers do not participate in the decision-making process; the acceptance or rejection of designs is entirely in the hands of the client. Also, for reasons of cost, producers are often reluctant to accept a design that might be expected to become a fast seller from a free-lance designer; the fee and/or royalty would be too great. Work of this kind is usually assigned to a salaried designer.

Designers on straight salary

Designers who work for salaries, with or without royalties, normally work on a commission basis. They are usually part of the development team of a producer and participate in all decisions when an item is put into production, including the purchase of new materials, paints and fittings. The employer normally bears all of the risks and provides accurate information about the requirements and capacities of the plant. In this situation, designers have the support of the entire organization and will have good possibilities for team-work, research and specialization.

Conversely, such a team approach is seldom successful, and the employer-employee relation is often distasteful to a creative person such as a designer. They will have to follow the development plan of the employer and may well find themselves involved in routine or distasteful tasks that are difficult to refuse, such as the modification of designs of competing firms.

All too often, when a salaried designer comes up with a new and original idea, it is rejected out of hand by the decision-makers, who are inclined to depreciate the abilities of their own employees. When this happens, the designer cannot offer the idea elsewhere.

It may be said that the employer-employee relation tends to be stultifying to designers. They see and work with the same people year after year and comes to resemble them, since they know the opinions, attitudes and reactions in the employing firm in advance. Furthermore they run the risk of becoming entangled in the various intrigues that are found in most large organizations.

Connections with consumers, retailers and factory agents

Free-lance designers

Free-lance designers in contact with several manufacturers can obtain a wide range of information. They can thus see things from a broader perspective than designers who are tied to one enterprise, and they can try to look at things from the point of view of the consumer.

On the other hand, actual contacts with consumers are usually rather slight and the information designers receive is generally out-dated. Since they cannot conduct surveys of consumers, retail salesmen or factory representatives, they have no current information about what is being sold and where and why.

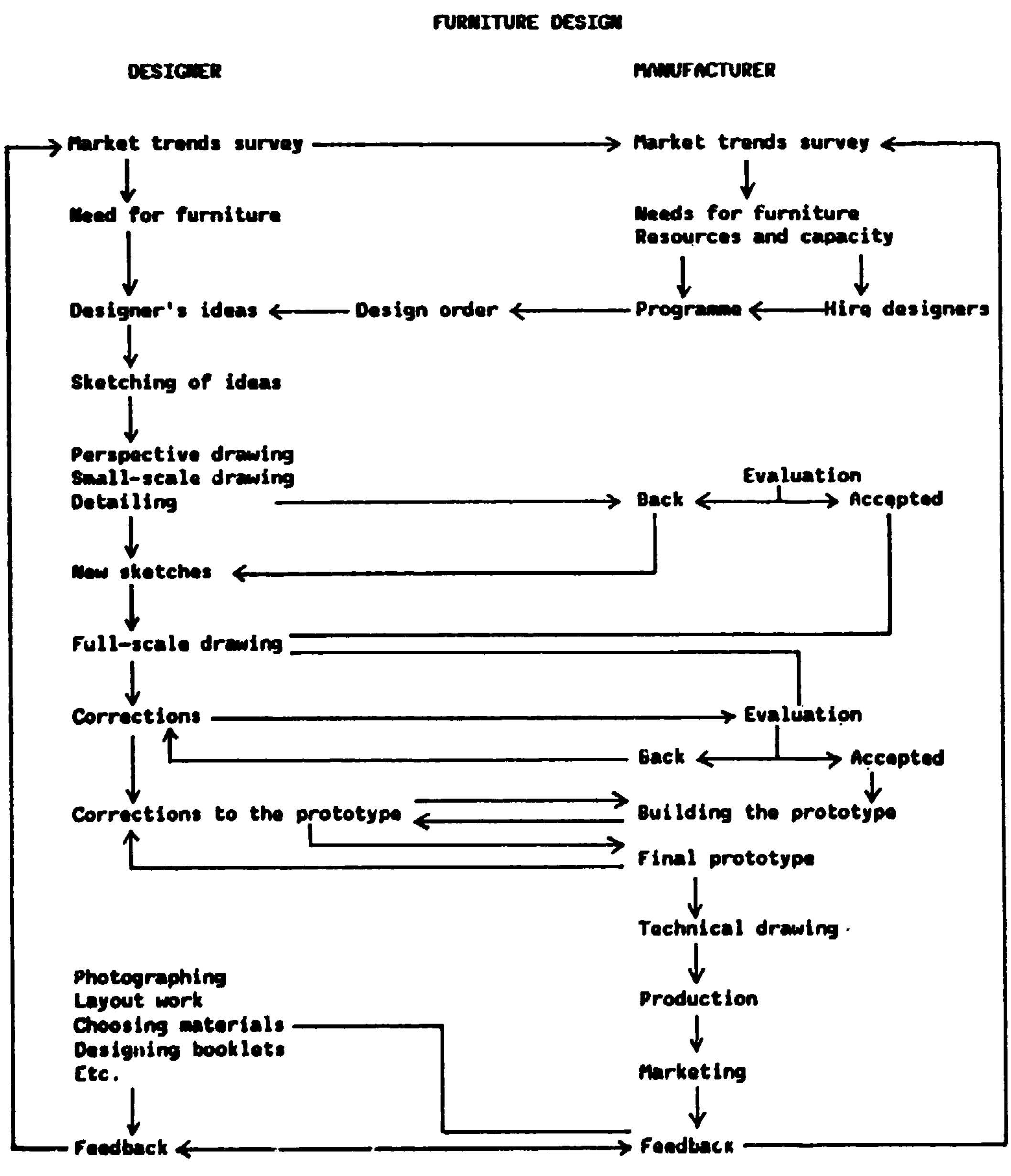
Designers on straight salary

Designers who are employees in an enterprise have good opportunities for contacting consumers. They can also obtain information straight from the market. Nevertheless, some of this information will be unreliable because of loss of detail and the time it takes to pass it from consumer to retail sales representatives to retail manager to factory representative to sales manager and, finally, to the designer. In any case, much of ` information thus accumulated is unsuited for use at the plant.

Research and development

The traditional approach in the furniture industry has been and continues to be that of trial and error. Research and development have so far had insignificant roles. Nevertheless, they have their importance.

Figure 61. Work flow betw~en designer and manufacturer



Free-lance designers

If free-lance designers conduct research and development work on their own, they can base designs on it and offer them to enterprises they consider most capable of making good use of them. If offers are turned down, they may approach other enterprises with the same ideas. In actual practice, however, free-lance designers do not have the resources to conduct investigations of this kind.

Designers on salary and royalty and straight salary

Designers who are retained by an enterprise on a salary or salary-plus-royalty basis have available to them information on new materials and other news of the furniture branch, since all such data are first presented to manufacturers. On the other hand, it is still true that most furniture-producing enterprises have little interest in research and development. It is not unlikely, however, that the furniture industry, as it continues to evolve, will reach a point at which research and development work will become as important as they are in many other industrial branches.

Conclusion

Any discussion of the working arrangements of designers must also take into account the interests of manufacturers. (A typical flow of work between designer and manufacturer is shown in figure 61.) The interests of these two parties are more convergent than divergent. Both sides are desirous of producing attractive, practical and realistically priced furniture that will benefit everyone.

XIV. Product development in a large furniture enterprise*

The belief is current that product development is market-oriented. In actual practice, however, the determining factors are the possibilities for production. Management does not ordinarily request the design office to produce a certain item specified by the consumer. Rather, it first determines whether the facilities exist to produce such an item; if not, it attempts to persuade the consumer to order another product, one that the firm can produce.

It would thus be more accurate to say that product development is design-oriented. In Finland and in the other Scandinavian countries the word "design" has an almost mystical connotation, as something connected with the arts in general and with sculpture in particular, embracing asthetics as well as engineering. As the word is used here it should be understood in the broader sense given it in the marketing and advertising fields and not in its purely technical sense.

Product development at the Asko Oy plant in Finland, for example, is also materials-oriented in that the primary raw material used is Finnish birch, birch being plentiful in Finland. When metal, glass fibre and plastics are used, the use of these materials is outside the everyday activity of working with birch wood; even painting and upholstery are related to birch. On the other hand, product development is materials-oriented in the sense that new materials are becoming available for experimentation to determine whether their use would be advantageous in furniture production.

Product development at Asko Oy comprises all four of the factors mentioned above: marketing, design, materials and production. Representatives from these phases of work form the Product Development Committee. This Committee, which meets once a week, also includes representatives of the production and marketing divisions and retailing and exporting personnel. The manager of the woodworking factory chairs the meetings, is responsible for the continued existence of the Committee and is also answerable for its decisions.

The work of the Committee has been divided into two groups; one is involved with home furniture and the other with contract (institutional) furniture. People who work in both these areas attend meetings of both groups. The manager-secretary of the home furniture group of the Committee acts as full-time manager of home-furniture development work. The marketing director is responsible for financing the Committee's work. The chairman oversees the work of the entire Committee.

*By Asko Karttunen, Asko Oy, Lahti, Finland originally issued as ID/WG.105/44, with additional text (on product development in small companies) by Ahti Keronen.

The Committee has developed along with the company in response to its changing needs and in accordance with the capabilities of its staff. The idea for its formation did not come from a textbook; it was developed over the years and is subject to modification. It can change at any time when and if a situation arises in which a different structure or organization would be considered preferable. The Committee has been flexible and different people from outside the Committee have been involved; for example, people who know about the American market, the Finnish market etc. These people have, in co-operation with the Committee, developed new products.

The Committee does not do its own designing; it merely examines drawings and prototypes submitted to it. Free-lance designers are used extensively; there are almost no staff designers from whom the Committee may request a design. The designers are entirely independent of Asko. This is important, because it enables the firm to get designs that the marketing or production people could not conceive. The designers are specialists in their fields, but they are not necessarily specialists in design trends, or at least in future design trends.

The firm on occasion advises designers that the marketing (or sales) people would like to have a chair of a certain size, shape and cost, and the designer tries to solve the problem. The designer may feel entirely free to create whatever he or she thinks that people might buy and then presents drawings to the Committee.

Most of the designs in the firm's collection that have become internationally known, advertised, photographed and publicized, however, are designs brought to the company by someone with an idea that would fit well into its collection.

However, the creative freedom of the designer must be limited by the facts revealed by product analysis, which is now performed with computerized data on the firm's past and projected performance, based on day-to-day operation. Thus, while the designer is asked to "dream up something", operational data will reveal whether these dreams are realizable. This conflict makes the work of the Committee difficult, for a balance must be achieved between practical considerations and the free play of creative imagination.

The marketing and technical people may look at the figures and say that 2 + 2 = 4, but if the designer says that 2 + 2 = 5, that opinion must also be accepted. This approach is difficult to explain and is certainly not to be found in textbooks. It may seem to be unbusiness-like, but it is a typically Finnish attitude and one that keeps the country's export industries growing.

Market research is concerned mainly with the attitudes of consumers towards furniture, not with how much money they intend to spend on it. It is important for the Product

Development Committee to have data on market research. Such research helps to determine general attitudes about furniture, such as how people feel about it, their needs for specific items or whether they would rather buy a new automobile or take their vacations in the Canary Islands than buy furniture. Analyses of this type of opinion sampling can determine what makes furniture attactive to the consumer.

Function is considered beautiful *per se;* it is viewed as an additional attraction to furniture. Problems created by aesthetic design must often be solved by technical design despite the many difficulties that this may present. In general, the aesthetics are the prime consideration, or possibly more the form given by the designer and accepted by the Product Development Committee. The opinion of the Committee prevails in a case in which the technical planners advise that something cannot be done. It is this distinction that orients the work more towards marketing and design than towards production.

Designers are paid on a royalty basis; they receive a certain percentage of the gross receipts for the items they have designed. There is no down payment and no advance on royalties or additional allowances. The designer thus shares the risk. Elsewhere in Europe, and especially in France and Italy, it is customary for the designer to be paid something before work starts and a royalty after that. This system has not been adopted at Asko Oy in order to keep the designer free from pressure.

The basic lines of product development in a small enterprise are similar to those of a large company. However, since resources are limited, the determining factor is often production capability. Materials also play a more significant role in a small enterprise than in a large one. That is why generally speaking product development is more material-oriented.

One further basic difference between a large and a small company may be that while a "professional" team is usual in many large companies, in a small company the owner may be much involved in product development. Thus the "team" may consist of three people: the owner, the designer and someone from the technical or sales department. (The owner very often represents either one of these.) To succeed in product development, all these aspects have to be taken into consideration.

XV. Furniture design and dimensioning for serial production*

The pursuit of comfort is probably the most important starting point when designing objects suited to the living conditions and environment of human beings. Various means have been used in different cultures throughout history to achieve this goal. The various stages of style in Western history are evidence of this. From the designer's point of view, it is important to study the physical and cultural characteristics of human beings in order to produce designs of furniture that will be comfortable. To such basic data the designer can add national or traditional ideas according to his or her own experience and skills.

Designing based on the proportions of the human body

Choosing a human being as a basis for establishing the principles of design involves certain difficulties. Standing or sitting upright are postures found fairly late in the history of human evolution. Such positions result in all kinds of weaknesses and a tendency to illness caused by strain. The human being functions best when either moving and a little tense, as in sports, or quite relaxed and immobile, as while playing chess. Thus the posture best suited to creative thinking is a reclining position. Drawing and writing are done best in a sitting position. Except for certain vocations, people in general sit a lot. They are required to stand up less and less, and can even remain seated when switching the television to another channel. Thus it has been rightly claimed that people are living in a "sit-down-culture".

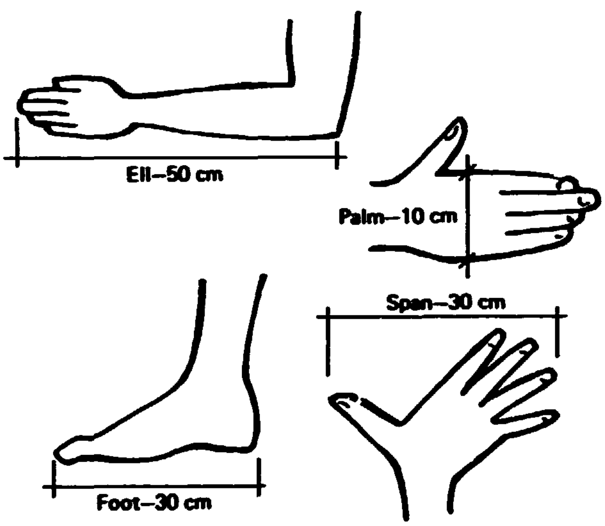
Various parts of the human body have been used as a basis for measurements and definitions of units (see figure 62). In addition to limbs as measurements, there are more indefinite units, such as a step, fathom, stone's throw, day's journey etc.

The modern scientific way of measuring the size and proportions of the human body is called anthropometry (Greek anthropos = man, metria = measuring). A complementary branch of modern science is ergonomics, in which muscular strength, endurance and different tolerances are observed and ideal values for them are defined. The amount of time required to carry out a task is also taken into account.

There are only a few reliable surveys of the measurements of human beings available. The difficulty is that, in addition to the high cost of such surveys, the results become obsolete in a few years. The human race is continuously growing, the average height increasing by several centimetres every 10 years.

The data and graphs needed in designing should contain all kinds of information. Besides representing the two sexes, they should also represent different sizes and races. A good anthropometric survey must contain data about tall, average and small male and female adults, as well as children. The best tables give the data necessary for designing the most common objects. In some cases, even the special requirements of invalids have been presented.

Figure 62. Traditional measurements based on the human body
(Centimetres per unit)



Examples of drawings defining sizes are given in figures 63 to 66. A common method of dividing people into size groups is to use percentiles. They are values representing the percentage of people at or below a certain measurement. For example in Europe and North America 2.5 per cent of the males measure 164 cm or less; 50 per cent or half of the males are 175 cm or less. Of all the males measured, 97.5 per cent are 188 cm or smaller. Accordingly, only 2.5 per cent of the males are over 188 cm tall. For the designer it is important that the dimensions of the object to be designed correspond to the correct size group. In general, objects are designed to fit the average size best. Therefore, in designing it is not necessary to accommodate the groups representing small people (less than 2.5 per cent of the total) or tall people (also less than 2.5 per cent of the total). This is the so-called "5-per cent rule".

Three dimensional data are also needed, for example when designing clothing or objects connected with the use of space (see figure 67). The recommended working posture of an average adult male and female when sitting are shown in figures 68 and 69. Of course, certain jobs may have significant special requirements which would affect the dimensions of objects to be designed.

*By Mauri Laatikainen, Designer and Interior Architect, Lahti, Finland. Originally issued as ID/WG.302/3.

Figure 63. Some dimensions of European adult males
(Centimetres)

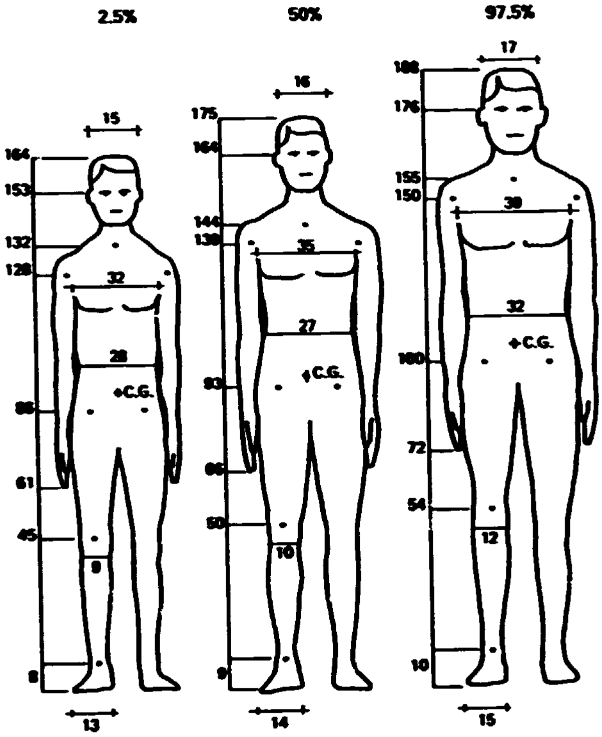
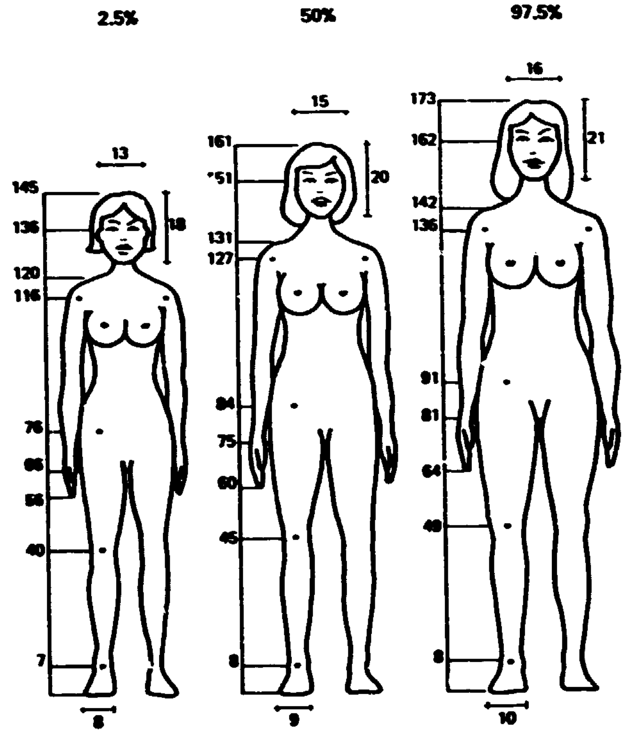


Figure 65. Some dimensions of European adult females
(Centimetres)



Note: C.G. = Centre of gravity

Figure 64. Some dimensions of the average European adult male
(Centimetres)

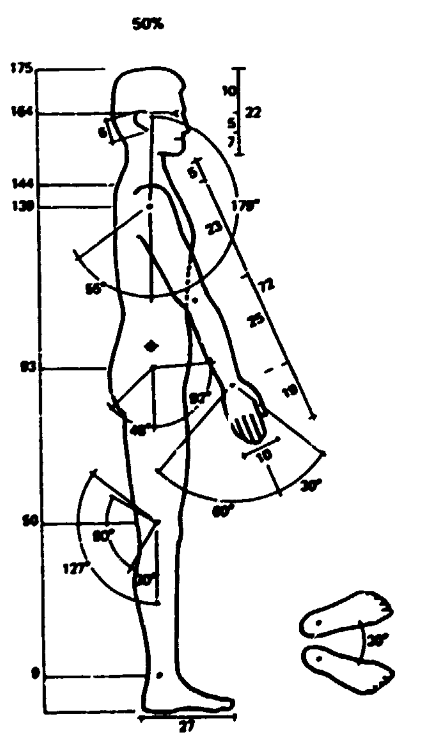


Figure 66. Some dimensions of the average European adult female
(Centimetres)

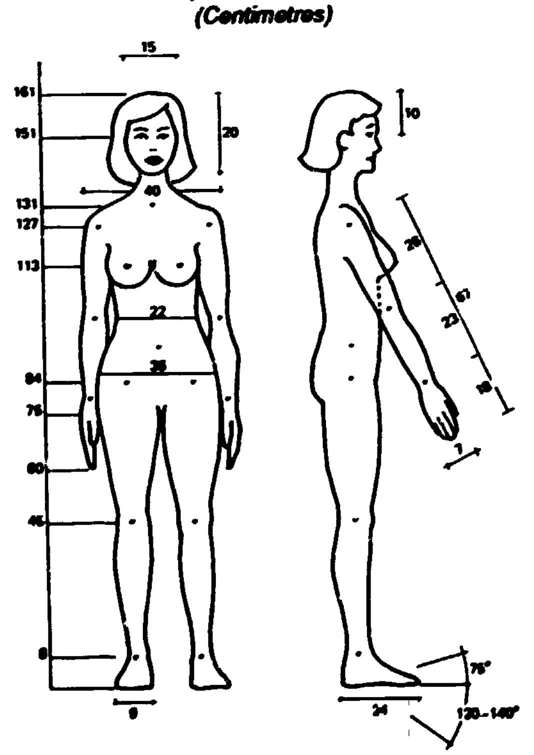
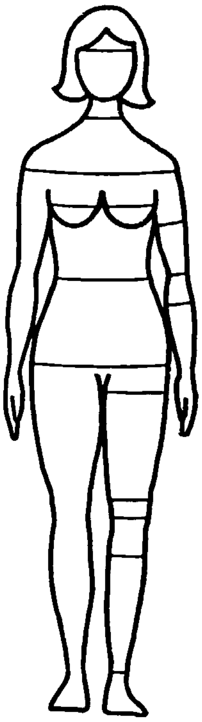


Figure 67. Circumference measurements
(Centimetres)



	Sex	2.5%	50%	97.5%
Head	M	54.1	56.4	58.7
	F	51.8	54.9	57.9
Neck	M	34.8	37.6	40.9
	F	32.5	35.1	37.8
Shoulder	M	107.4	116.3	125.5
	F	90.4	98.0	108.2
Chest	M	88.9	98.3	108.7
Bust	F	91.9	95.8	100.1
Upper arm	M	28.4	32.3	35.8
	F	26.9	29.0	30.7
Waist	M	75.4	86.9	100.3
	F	72.4	74.2	80.3
Elbow	M	28.4	31.2	34.8
	F	25.7	28.2	31.2
Forearm	M	26.7	29.2	32.0
	F	24.4	26.2	27.7
Hip	M	88.6	97.8	107.4
	F	93.2	100.8	105.9
Upper thigh	M	50.8	58.7	66.0
	F	53.3	59.2	63.0
Lower thigh	M	35.1	39.4	43.9
Knee (sitting)	M	36.1	39.4	43.2
	F	35.6	38.1	41.9
Calf	M	33.8	37.3	40.6
	F	32.8	35.8	39.4
Ankle	M	20.3	22.1	23.9
	F	19.6	21.8	23.6

Figure 68. Recommended working posture for an average European adult male, when sitting
(Centimetres)

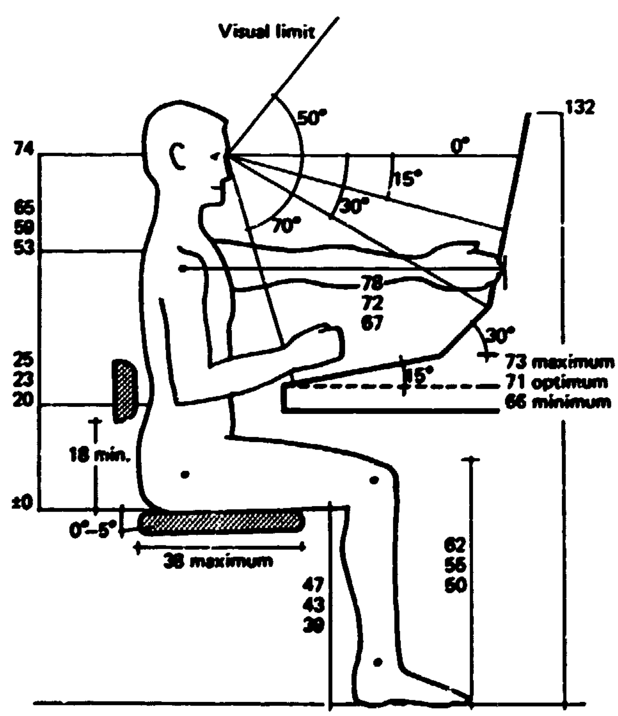
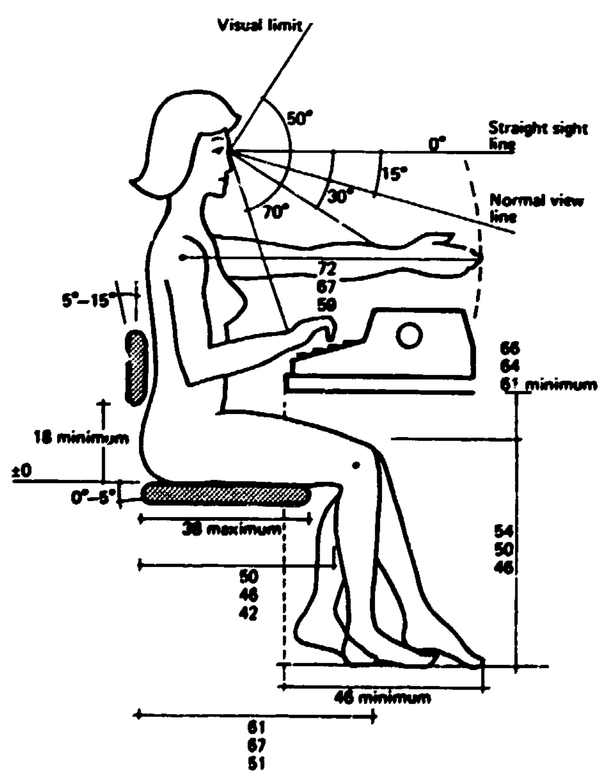


Figure 69. Recommended working posture for an average European adult female, when sitting
(Centimetres)



Designing chairs

As noted earlier, sitting is a very characteristic posture of human beings. Bad habits or faulty design can lead to severe health hazards. Faulty designs and dimensioning can affect sitting comfort even after a short period of time (see figures 70 and 71). Even slight imbalances owing to wear or faults in a seat can be felt months or even years later as pain over the entire back.

In a typical "hanging" sitting posture that a tired person might take, the back is stretched and the vertebral laminae are forced outwards (see figure 72). All too often the person dealing with the results is the surgeon.

Figure 70. Effect of correct and incorrect support in sitting

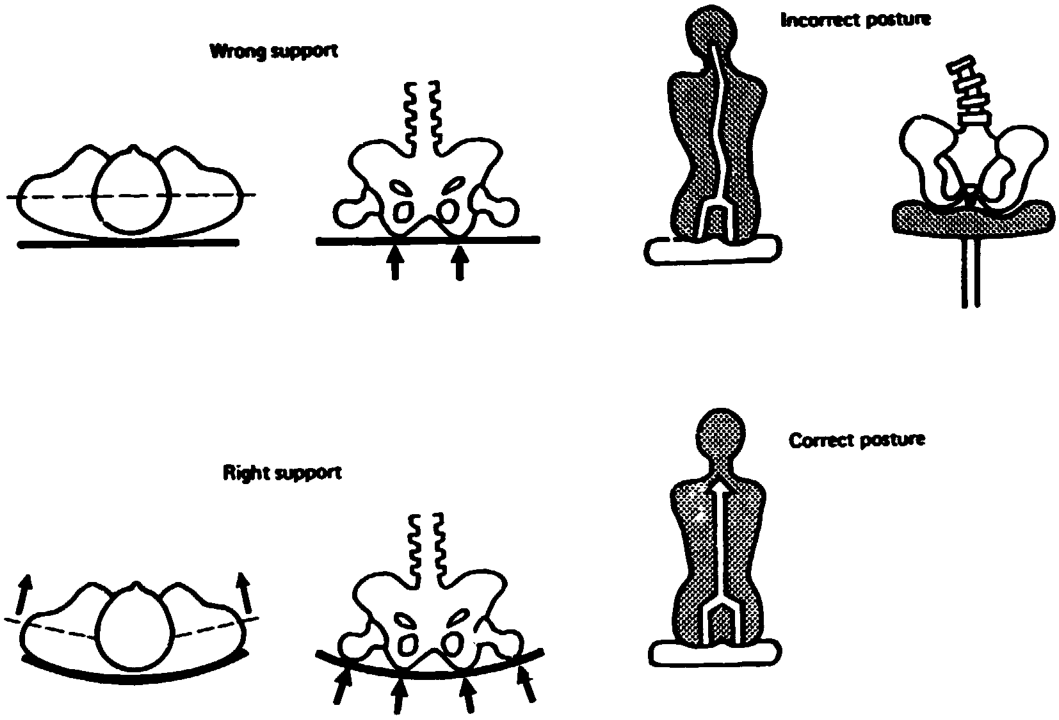


Figure 71. Chairs with and without proper support

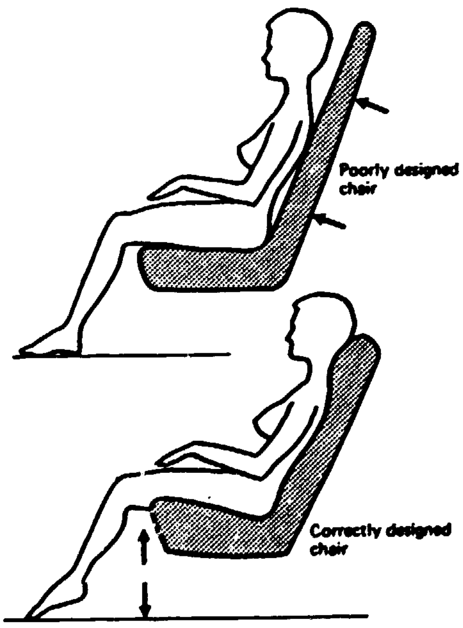


Figure 72. Incorrect and correct sitting postures

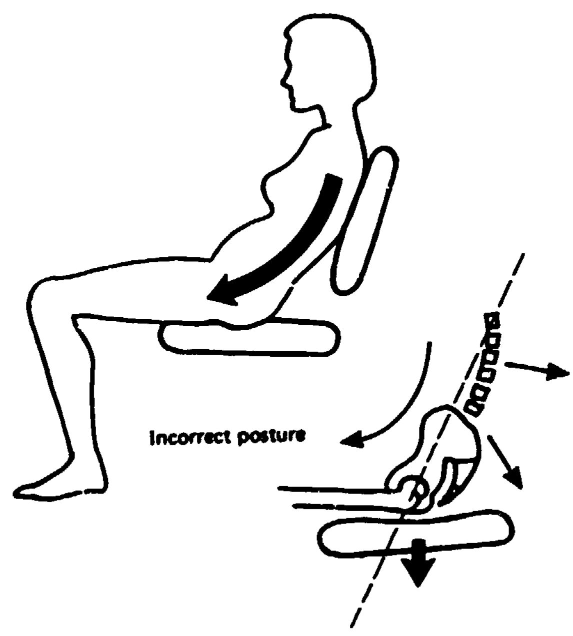
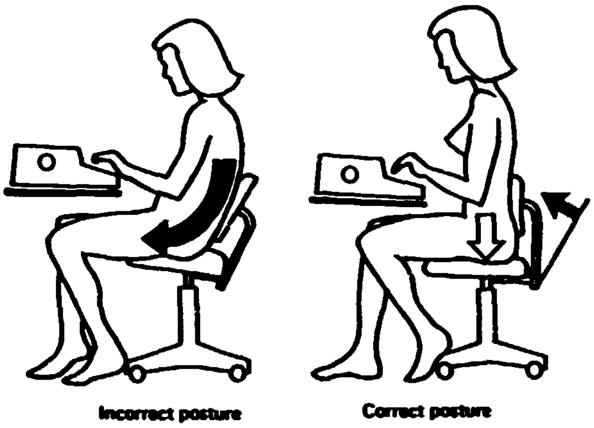
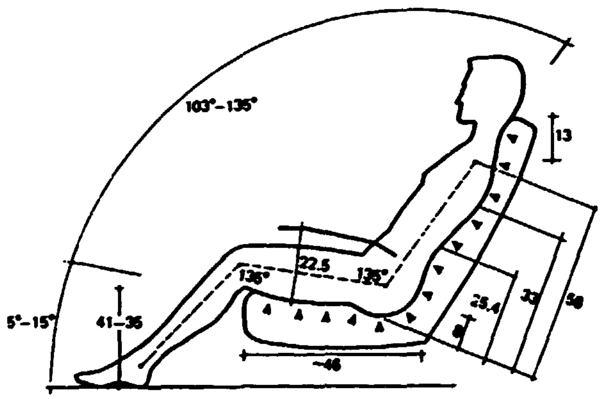


Figure 72 *(continued)*



Typical dimensions of an armchair and work chairs are shown in figures 73, 74 and 75. Well-designed chairs should have ample possibilities for adjustment; it is important that the materials should breathe, but softness is not necessary, except perhaps as a selling point.

Figure 73. Typical dimensions of an armchair
(Centimetres)



Calculating table space

The eating position closely resembles the working position. A prerequisite for a pleasant dining atmosphere is the correct relationship between the table and the chair (see figure 76). The requirements for a dining table are much the same as those for a conference table. A diagram (similar to that in figure 76B) should be used in both cases. Triangle ABC in that figure is the minimum amount of space that should be allowed per person, irrespective of the size and shape of the table concerned. Diagram B of figure 76 has been superimposed on tables of various sizes in figure 77.

Figure 74. Typical dimensions of a work chair
(Centimetres)

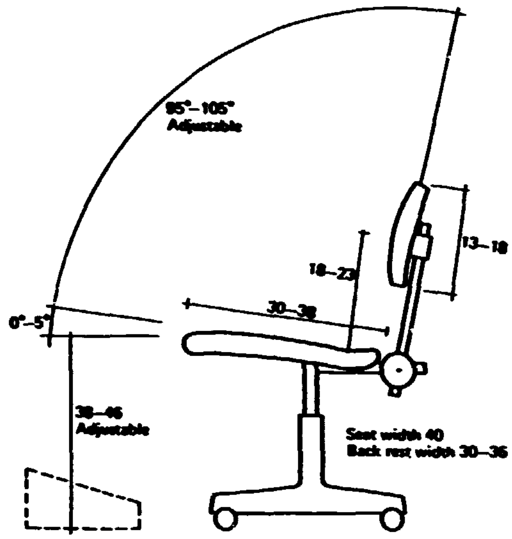
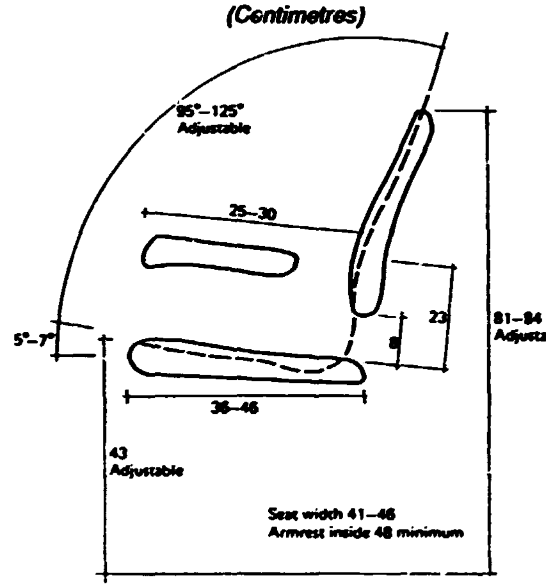


Figure 75. Typical dimensions of an armchair and a work chair
(Centimetres)



Designing beds

Often a well-deserved rest is spoiled by faulty design or dimensioning of the bed. A bed must be designed to support certain parts of the body; it is quite wrong for the body to hang in a hammock-like pit (see figure 78). Ideal resilience, which provides the back with the best relaxation and rest, is shown in figure 79.

Numerous surveys have indicated that people still do not use beds with the proper dimensions. The situation, of course, varies from country to country and with time. Beds should be designed that are long and wide enough to allow a person to stretch out full length and to move (see figure 80).

Figure 76. Dimensions of a chair and table for dining

(Centimetres)

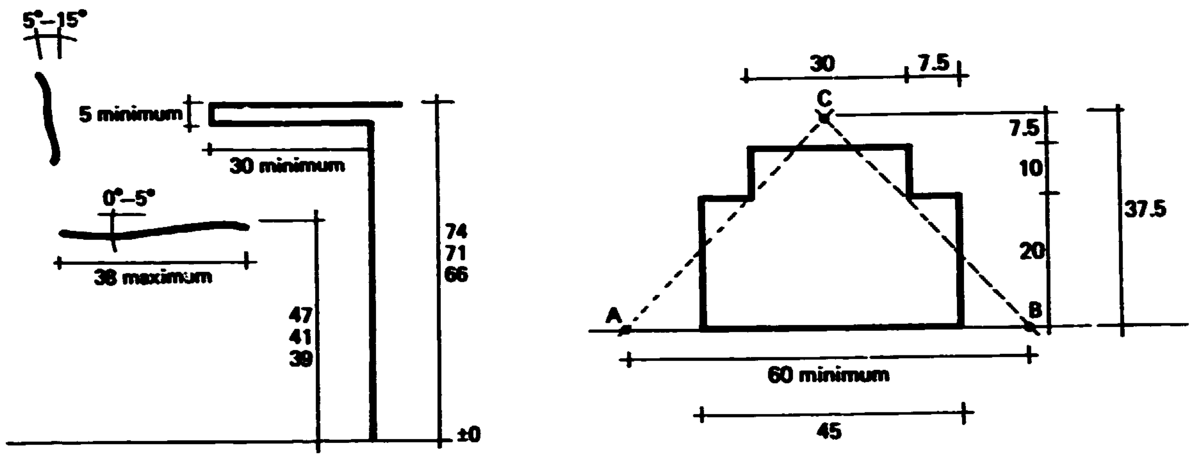


Figure 77. Space requirements for various sizes of dining and conference tables

(Centimetres)

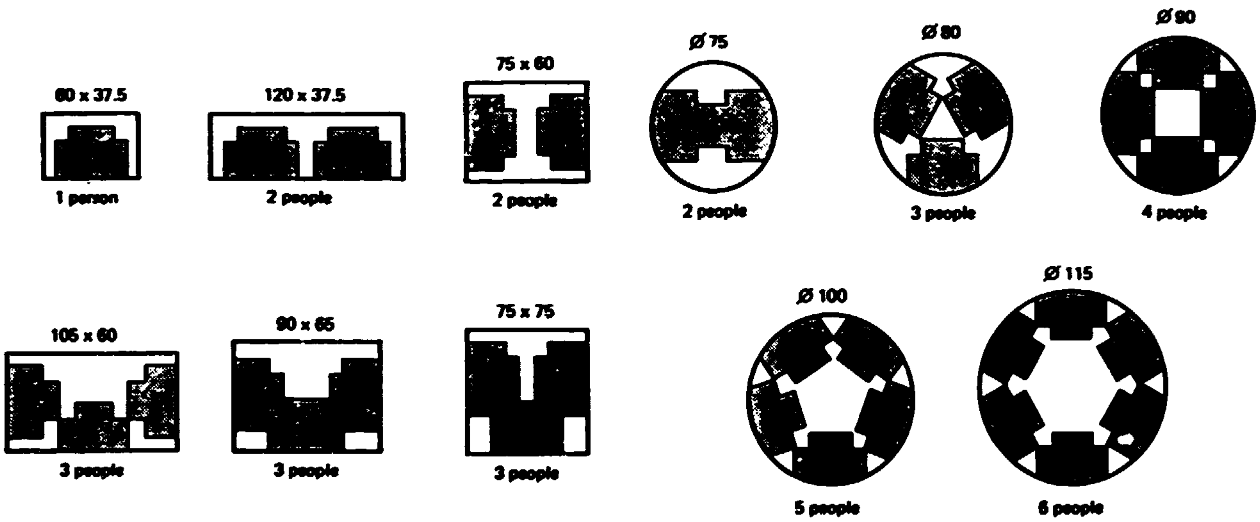


Figure 78. Support needed for a body in bed

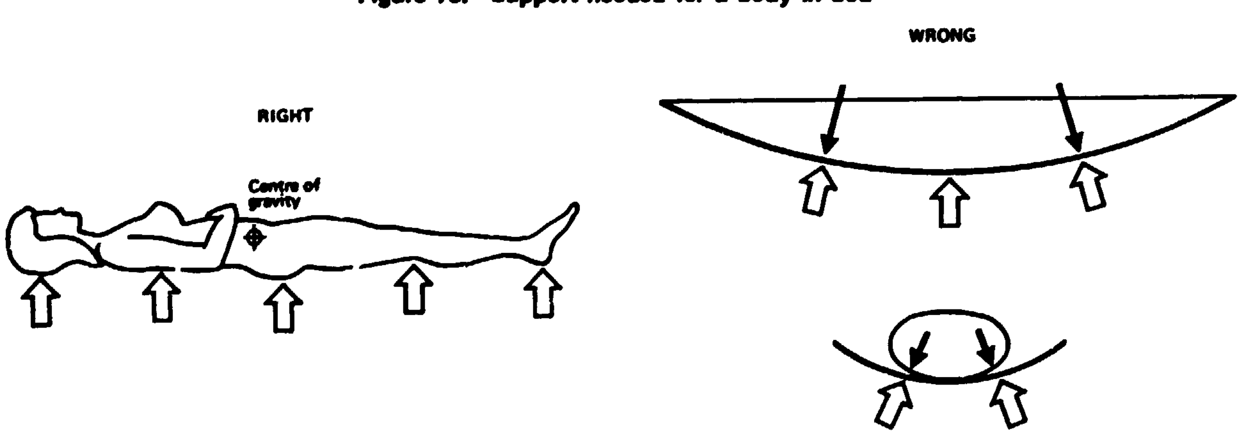


Figure 79. Ideal resilience of a bed

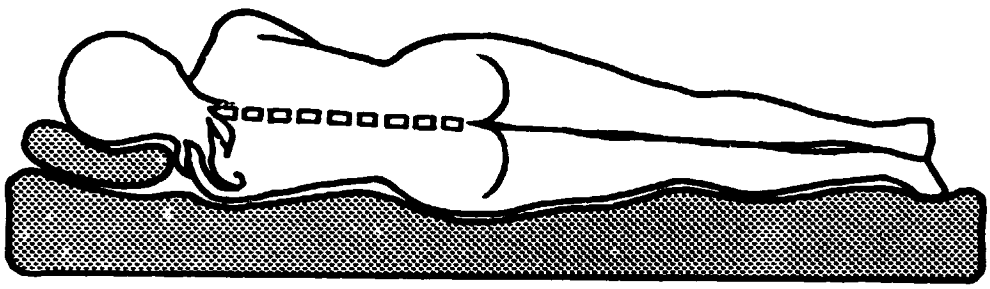
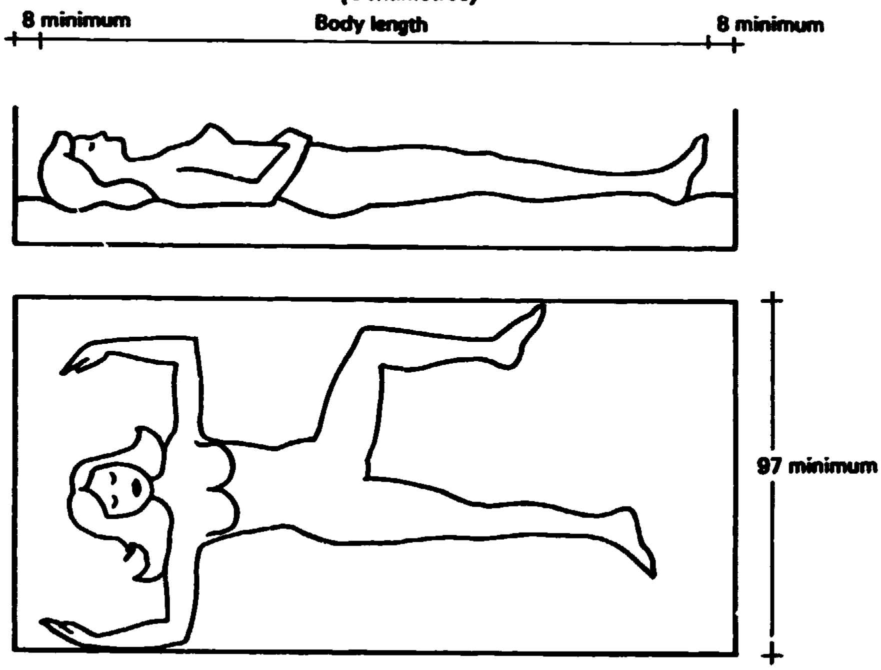


Figure 80. Bed dimensions

(Centimetres)



Conclusion

The designer of furniture for serial production bears quite a weighty responsibility in view of the amount of harm and inconvenience that can be caused by even a small error when repeated in thousands of pieces of furniture. Fortunately, a well-designed product, also repeated in the thousands, makes for comfort and thus for satisfied consumers. Furthermore the designer should be familiar with standard dimensions of sawn wood and wood-based panels so as to design products for serial production that result in minimum wastes of raw materials.

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XVI. Value analysis*

Background

Value analysis is a useful tool for product development in the furniture and other wood products industries. It was developed after the Second World War by an American, Larry Miles, who was seeking new applications for raw materials and a systematic method to assure continuous development. Several years' work resulted in a technique that led to better and cheaper raw materials: he called it "value analysis". Later on the technique spread to other industrialized countries. It should perhaps be called "value analysis and development".

Value analysis can be applied to many activities other than product development—such as development of operations, methods and organizations. However, it is used mostly for product development (90 per cent), where concrete results can be seen and measured in terms of money. The results are better products that are cheaper to manufacture (resulting in savings in labour and/or raw material), improved work safety etc. Even technologically advanced factories obtain savings of up to 10 per cent when design cannot be changed and up to 20 to 30 per cent when major changes in design can be made. Yet the products are better than before. The improvements come through a systematic approach, team work, creative sessions without criticism and a comprehensive function-oriented approach.

The introduction of value analysis requires training in its application. Both skills, knowledge and—most important—attitudes have to be introduced to the members of the team applying it. The value analysis procedure should be integrated into the product-development procedure. That may sound complicated and bureaucratic, but once it is done systematically from the beginning of product development many headaches are avoided. Good planning is half the job.

Definitions and terminology

The term "analysis" is clear to most persons. To analyse is to find things out. A chemist analyses chemical mixtures to find out what compounds are in it. Value analysis is an analysis of values instead of compounds in a product, part of product, method or whatever object is to be analysed. Through it the values and their relative importance in the object are determined.

Value analysis is not only an analysis technique but also a development technique. New values are also created in value analysis.

The term "value" is not so clear. In value analysis, value is defined as function divided by cost. The more the cost of a function is reduced, the better is its value. The more functions obtained with the same cost, the better is their value. The manufacturer sees value in terms of the above definition, but to the client value is "suitability" divided by the price that has to be paid. The more the product "suits" the client, the better is its value; the cheaper the price, the better the value is to the client.

Value analysis is a systematic, function-oriented method. It compares systematically functions and costs, creates new ideas and finds out the optimum combination of function and cost. Value analysis is a kind of philosophy that assumes everything can be made in a better way or in a less expensive way. It finds completely new, better and less expensive solutions without implying criticism of previous decisions.

Values

Values cannot be determined exactly. The price/cost ratio can be calculated precisely and expressed in a numerical form, but the function or suitability has to be agreed upon, and it can normally be expressed only verbally. This agreement, or estimation, depends on the persons who are defining the function or suitability. Their thinking is influenced by their needs and living standards; their historical, political and cultural backgrounds; fashion and trends; and weather, climate, surroundings etc. For example, what is the value of a glass of water in a desert or at a cocktail party? An umbrella when the sun is shining?

It is obvious that the function (or suitability) is also affected by the limited availability of the item or of its competitors. If the best-suited raw material is not available, the next best available becomes acceptable, and users would then be willing to pay a high price for it.

Values are categorized as follows:

Use value
Prestige value
Exchange value
Reuse value
Loss value
Cost value

The use value indicates how practical the item is for its original purpose. A stamp has use value—to mail letters. A chair has use value—to sit on. A bicycle has use value—as a means of transportation.

Prestige value is also called status value. In many products prestige is extra outlook, design, comfort etc. This value is often added to the use value. It adds functions but, unfortunately, usually also adds costs. Typical items

*By Arto Juva, A. J. Consultants Oy, Vääksy, Finland. More detailed procedures and forms that can be used in value analysis are available in *Value Analysis in the Furniture Industry* (ID/298), by the same author.

having prestige value are fur coats, leather sofa sets and kitchen cabinets with solid wooden doors.

Exchange value is found in products that are changed after having been used for a while. A good car has a good exchange value, and the salesman can use this fact as a sales argument when selling a new car. In the furniture trade the exchange value cannot normally be used as a sales argument, so in carrying out value analysis in the furniture industry it has to be omitted. (There are some companies that take old furniture when new items are bought from them, but this practice is a sales trick, not a normal exchange of products as in the case of trading in a car.)

Reuse value is referred to when the item can be used for a second purpose when it is no longer used for its original purpose. A package may have a reuse value. A glass originally containing mustard can be used as a milk glass when all the mustard has been consumed; another package can be reused as a deep-freezer package. Reuse values are very seldom found for furniture. The reuse value cannot be used as a sales argument for furniture. Furniture sellers would not tell clients that when they are tired of a new dining room set, they can always burn it in an oven to get energy!

An item that has more value when lost than it had before has loss value. A special button of a club jacket has loss value. The same applies to buttons of expensive sofa sets. That is why extra buttons should be sewn onto the bottom of expensive sofa sets.

An item may have cost value, when it can be considered to be an investment. The item will bring about savings, direct or indirect, and these savings can be used as a sales factor. An ergonomic chair may save because whoever sits in it works more efficiently. A well-insulated door may save in heating costs, or a good door lock may save in insurance bills. After the energy crisis many product-development teams emphasized the cost value of their new products, for example:

(a) New motor engines bring about savings in gasoline;

(b) Better insulated houses save on heating;

(c) Longer periods between maintenance result in saving in lubrication, oil and maintenance costs.

Costs

The value depends on the cost or the price and the function. The cost can be broken down into:

Variable costs	*Fixed costs*
Direct material cost	Production
Direct labour cost	Marketing
Indirect labour cost	Administration
Other variable costs (mainly electricity)	Interest
	Depreciation
	Taxes

Fixed costs and profits together are called overhead requirements.

Only variable costs are normally used in value analysis to make the calculations simple and fast. To get the total picture when new investments are involved, interest and depreciation should also be calculated.

The cost structure in the furniture industry is often: variable cost, 70 per cent, of which 45 per cent is raw materials and 25 per cent direct labour; and overhead requirements, 30 per cent. These figures are averages for the industry in Scandinavia. They do not apply to extreme cases such as the very labour-intensive wood-carving industry or to the other extreme of material-intensive leather upholstered furniture factories and automatic panel lines, where the labour/material ratio is different.

Based on this cost structure, costs are calculated and the price is set. The manufacturer sets the price, but it is the client who accepts or rejects it. Experience in setting prices is gained by getting a feeling of the market through trial and error.

Function

What actually is function? Before embarking on a value analysis, a team must learn a common language, and only then can it decide on the function of furniture. A common language can be learned, for example, by defining the functions of a dog, bicycle, car, chair and sofa using as few words as possible.

Such an analysis is not so easy as one might think. Take the first example (dog). What kind of dog is being analysed? Is the dog to be a watch-dog, a companion, a hunting aid or a dog carrying brandy to persons who are freezing on a mountain top?

The function of a bicycle could be defined as "to permit 1-2 persons to travel at a speed of 15 kilometres per hour". The function of a car could be defined as "to permit 4-5 persons to travel at a speed of 100 kilometres per hour, protected against weather and without physical stress".

The difference between a function of an easy chair and a sofa is that more people can sit on the sofa and the sofa can be used temporarily as a bed.

A distinction should be made between "purpose" and "function". If more thought is given to what is the actual function, different answers may be arrived at. For example, electric light bulbs used in various surroundings may have a variety of purposes and functions:

Surroundings	*Purpose*	*Function*
In a house	To give light	To make it possible to see
At a crossroad	To give signals	To improve traffic safety
In a hospital	To give heat	To cure people
In a shop window	To illuminate the wares	To make window shopping possible, to protect the goods against thieves

In value analysis, the more exact the definition of the function, the more ideas will be generated when identifying alternatives. For example:

Definition	*Question*	*Answer*
The function of a traffic light is to give signals	What else gives signals?	A radio
The function of a traffic light is to improve traffic safety	What else would improve safety?	New lane arrangements Two-level crossings Tunnels for pedestrians Speed limits Police officers and video cameras to control traffic

A sample of an attempt to define the types of value, main functions and secondary functions of a sofa bed (convertible bed), a small chair for a restaurant and a small chair for household use is shown in table 18.

Table 18. Identification of functions

Item	*Type of value*	*Main function*	*Other functions*
Sofa bed	Use value Prestige value Cost value Loss value for mechanism	Permits sitting and sleeping Is flexible Saves space	Prestige Design[a] Comfort Allows rational storage of bed linen
Small chair for restaurant	Use value Prestige value (cost value)	Permits comfortable sitting	Prestige Design[a] Comfort Savings in cleaning costs if well-designed
Small chair for household	Use value Prestige value	Permits sitting	Prestige Design[a] Comfort Is part of an interior furnishing "system" (dining set etc.)

[a]That is, it is aesthetically pleasing.

Steps in applying value analysis

Value analysis can be applied in all areas and functions of an organization, but the most common ones are:

- Product development
  - Products
  - Parts of products
  - Production methods
  - Raw materials
- Operations and administration
  - Fixed costs in general
  - Paper work systems
  - Information systems etc.

Value analysis[1]

- Information gathering
- Function analysis
- Value determination
- Creating ideas
- Evaluation
- Implementation

Information phase. The whole team is not necessarily needed for the information phase. The following questions are asked about an item:

- What is it?
- What does it do?
- What is its present cost?
- What is its present price?
- How much is being sold today and how much was it planned to sell?
- Who are the customers now and who should they be?

All drawings as well as a prototype or a product should be available at the meeting of the team.

Function analysis. After information has been gathered, the group splits the product into parts or components and determines the functions of each item in the product. It is important to start with the whole product and to go into details part by part unless the analysis is already limited to certain details of the product.

The functions are divided into groups depending on the product. For furniture these may be the following:

Type of value	*Function group*	*Code*
Use	Structure	1.1
	Establish structure	1.1.1
	Give strength	1.1.2
	Join elements	1.1.3
	Other use functions	1.2
Prestige	Design	2.1
	Comfort	2.2
	Other prestige	2.3
Cost	Cost	3.1
	Knock-down (KD) construction	3.2
Package	Package	4.

The purpose of the codes is to make the writing easier when filling in forms. The co-ordinator will soon know the codes by heart. Note that the KD construction is included as a cost item because it saves transportation and warehousing costs.

A different kind of grouping would most likely be used for another industry. However, this "standard" makes the function analysis easier. The function has to be known and be given the right code, which will simplify calculations. It is also practical to separate the package, because later on

[1]Usually nine forms are used during the value analysis process. They are filled out by the co-ordinator or group secretary as the process proceeds. Blank forms and a case study, including completed forms, are contained in the UNIDO publication *Value Analysis in the Furniture Industry* (ID/298).

the packing costs can be compared product by product. Packing cannot be easily grouped with other values; it has been found useful to separate it.

Value determination. After the function analysis is completed, the costs are calculated for each function usually by the team co-ordinator alone: if an item has more than one function code, the cost has to be split to cover each code. This can be done either by using common sense or by thinking along the following lines:

Part:	Design hinge
Cost:	$1.50
Values:	Use
	Prestige

There is a simple way of dividing the cost as follows: if a standard hinge costs $0.50, there is a use value per component of $0.50 and prestige value per component of $1.00, the $0.50 being the lower cost of a hinge having the same function (to open the door).

In determining the value, a part-function matrix must also be filled out. This will reveal very interesting information. Not only can the costs of each part be found, but also the cost of each function. After analysing several products in the same product group, information can be recorded in table form and analysed (see table 19).

Table 19. Allocation of functions by item code
(Percentage)

Product	Code 1.1.1	1.1.2	1.1.3	1.1	1.2	2.1	2.2	etc.
Sofa "Helsinki"	20.1	5.2	8.4	33.7	5.1	33.3	22.2	...
Sofa "Lahti"	19.0	6.0	8.5	33.5	—	30.3	22.0	...
Sofa "Vääksy"	21.0	4.0	6.0	31.0	2.1	29.1	40.1	...
etc.								

This information reveals that much of the cost of the sofa "Vääksy" is allocated to code 2.2 (comfort). If the sofa is really comfortable the value is acceptable, bearing in mind that value is defined as:

$$\frac{\text{Comfortability}}{\text{Cost of comfort}}$$

If, however, the sofa is not more comfortable than the others, there must be something wrong. The value is low, and the team has to do something about it.

Creative phase. The most interesting phase is the creative one. The cost and the function of each item in the product are obtained from the forms that have been completed during the previous phases. The team "creates" ideas item by item by asking what else would do the function in a better or less expensive way.

All ideas should be written down as they come along. No criticism is accepted during this phase so that as many ideas as possible are voiced, which is important because the first 50-80 ideas for each product are usually the logical solutions or alternatives; only after these solutions have been identified do the really good ideas emerge. To prevent criticism, a standard rule in many factories is that anyone who makes a negative comment about any idea has to buy coffee for everyone on the team. Even a silly idea may cause other members of the team to take an unusual approach, and they may then get some good ideas.

Evaluation phase. Once the co-ordinator or a cost technician has calculated the effect of the ideas suggested on the cost of the product, the team selects the ideas to be implemented and identifies those that are worthy of further development in the future.

Implementation phase. The implementation phase brings with it hard work. The question to be decided is who does what and when. Implementation has to be planned and controlled like any other project or activity. After implementation, a summary form is filled out, and the actual savings and improvements in the product appear. Knowing how much time and money were spent on the process, the benefits of value analysis can be determined accurately.

Value analysis in product development

Product development and marketing can be compared to an aeroplane taking off:

(a) A product can be taken into production shortly after the first product idea has crystallized, but, because of poor planning, it does not turn out well, and sales drop quickly. This is often the case when either there is a great need for new products or the company believes it has a good idea. This is called an "unsuccessful take-off";

(b) The product has been planned and developed long enough, and it is believed that there is nothing wrong with it. After a good start, however, the sales are no longer increasing and may even be slowing down. It may then be decided that the product has to be improved somehow, and a technician is given the task of making changes in it. A new version of the product is obtained, resulting in improved sales figures, which, however, after a while decline again. This is called "short flight", and the product improvement is an "unsuccessful rescue operation";

(c) The planning time may be compared to the aeroplane's runway. Good aeroplanes need a long runway. New products need good, systematic planning over a long enough period. The marketing staff often draw product-life curves, but in doing so they forget the planning time. A product for which value analysis has been made may need a long "runway" and good engines, but it will fly far and high. Thus, systematic product development is a good investment.

Common causes for failure in product development are:

(a) *Lack of information.* Not enough information has been collected about the clients' actual needs, about competitors' products, manufacturing methods and raw materials;

(b) *Misconceptions.* Often ideas are killed before they have been carefully studied in the belief that "the client would not accept them" or "that jigs and tools would be too expensive";

(c) Changing circumstances. The product could still be made in the same way as it was 15 years ago, but certain things have changed:

(i) New, better, raw materials are available;
(ii) New methods and machinery are available;
(iii) The client expects something new;
(iv) The relative costs of utilities and labour and the prices of raw materials are different from what they were when the product was first designed;

(d) Habits and attitudes. People are often suspicious of other people's ideas or opinions. It is easy to accept the idea that new products shall be made the same way as the old ones were—the risks are limited—but there is a risk of not creating good new products.

By using value analysis in product development these troubles can be eliminated.

In value analysis all information concerning function and cost, marketing, manufacturing and raw materials should first be collected. New ideas will be created systematically by a team. All ideas will be listed, carefully studied and evaluated. Finally, the idea with the highest value will be implemented.

The following comparison points out differences between traditional cost reduction and value analysis:

Traditional cost reduction	*Value analysis*
1. The product is analysed	1. The function is analysed
2. The work is usually done by only one person	2. Group work results in more knowledge
3. The only reason for reducing costs is to increase profit	3. The reason for reducing costs is to look for value, i.e., to produce a better value and quality for the consumer
4. Traditional cost-reduction procedures make the company more competitive in the short run, but omit research	4. Value analysis procedures find new market areas, end-use areas and develop R and D potential

Summing up, the goal in the traditional cost-reduction approach is to save money, whereas the goal of value analysis is to increase value.

A well-planned product-development process is shown in figure 81. There are two value analysis procedures in the process. The goal of the product-development work is to have methods, work flow and quality standards ready after planning is completed. On the marketing side, the product's pricing is part of the integrated product development.

The description of the process, step by step, is:

1. Somebody gets an idea. Usually this is the designer or a marketing-minded person in the organization. The need for new products will be noted when sales statistics show negative trends. Also the success of competitors may serve as a trigger. The need may come from either inside or outside the organization. Normally in a creative organization there are several ideas in an "idea bank";

2. Some key figures and sketches are required before a decision can be made to accept the idea. The designer and the product manager (marketing manager) normally do this as a two-person team;

3. Quick value analysis is then carried out. The purpose is to find the right track as soon and as easily as possible. This procedure also eliminates excess prototype making. There are normally four to six persons in the team, depending on the size of the organization;

4. The idea bank is too often in the individuals' heads. It is not a big task to organize an idea bank. All that is needed is a file and a filing system. It is good to go through the files every now and then;

5. The results of the quick value analysis are then presented to the product development team, the same team that is co-ordinating and supervising value analysis in the organization. It accepts or rejects proposals;

6. The technical department then prepares drawings for making the prototype, and the buyer buys materials that are not in stock. The prototype is made;

7. Value analysis takes place as has been described in this chapter. The value analysis team may consist of persons who did not do the quick value analysis. It will produce ideas for the idea bank and will not limit itself to use ideas to be implemented immediately;

8. The results of the value analysis are then again taken up by the product-development team. It will take the final decision;

9. At this point the technical department finalizes many technical product-development tasks that have already been covered during the value analysis. These jobs will thus also be simplified because these persons are familiar with the tasks to be done, being members of the value analysis team. At the same time, the marketing department plans its marketing procedures, sets the prices and prepares sales brochures etc.

Introducing value analysis in a company

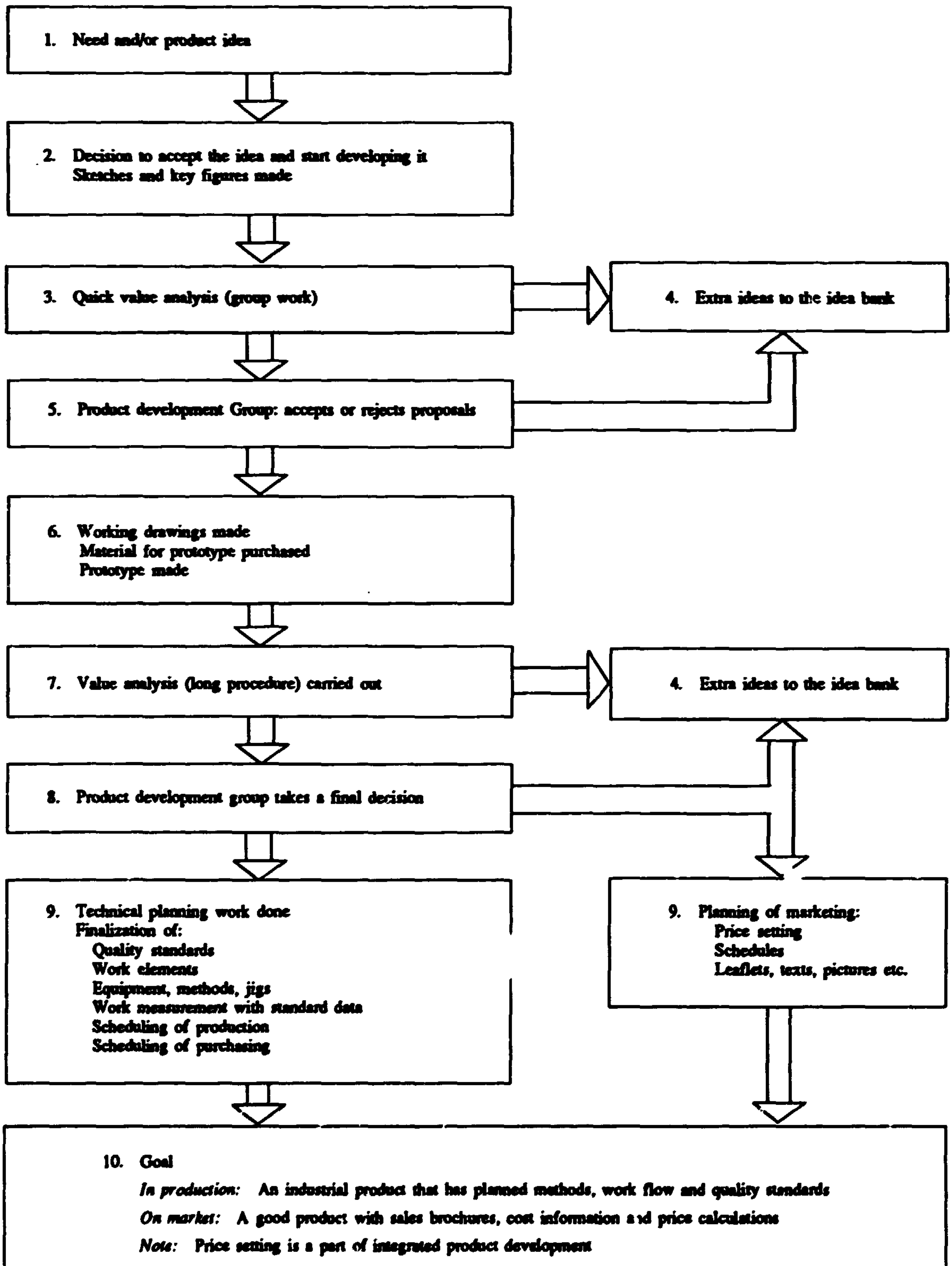
When the decision has been taken to introduce value analysis in a company, there should first of all be a training course. This course should take place within the company, and the items to be analysed should be selected from among the company's products. It is advisable for the instructor to follow up for a while the work of the newly established team, so that application of the concept will get off to a good start.

The goals for the value analysis should be established and should include the following:

Schedule
Plan for personnel resources
Budget, including prototypes and other product-development costs
Qualitative goals referring to:
- Product policy
- Price ranges
- Savings
- New products as against improvement of old products

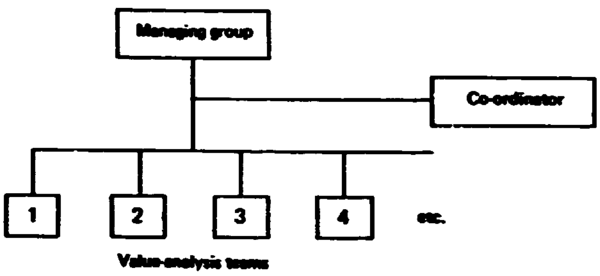
A small company normally has only one value analysis team. The chairman is called the "co-ordinator". He often reports to the marketing manager or in some cases to the managing director. Even in a small company value analysis has to be team work.

Figure 81. Value analysis procedure for product development



In larger companies where there are many products or product lines to be developed, the organization shown in figure 82 is common.

Figure 82. Organization of value analysis in a large firm



In a factory producing solid-wood furniture, panel furniture and upholstered furniture, a value analysis team may be created for each product line.

The managing group consists of the managers that normally determine the company policy, especially its product policy. The responsibilities of the group are:

To appoint the co-ordinator and the teams
To set the master timetable for the value analysis
To define priorities and goals
To supervise and control value analysis in the company

The co-ordinator has a full-time job with the following responsibilities:

To act as chairman (and secretary) of all the value analysis teams
To act as a secretary of the managing group
To collect all basic information for new products
To prepare all necessary reports
To prepare all meetings thoroughly so that decisions can be made without wasting time
To report to the managing group on the implementation of the accepted projects and follow-up on all projects

The value analysis teams meet every week. The team members represent all main functions of the company, such as product development, production, materials management and sales or marketing. The optimal size of a team is five persons, and a team should always have at least three but not more than seven members. The members spend only 5-10 per cent of their weekly working time in these meetings, unless they are members of several teams.

A team should have three to four objects being analysed at different stages concurrently. It is thus possible to jump from one product to another if for some reason there should be no possibility of proceeding with the first product.

The decisions and the follow-up tasks should be marked on value analysis forms so that everybody knows the decisions taken at the previous meeting and also the tasks to be carried out by each member in the meantime. The forms are the base of the documentation and communication; excess writing of more formal communications is thus eliminated.

Short procedure—quick value analysis

In connection with the product-development procedure, it was mentioned that the normal value analysis procedure may be extremely time-consuming, and for this reason a short procedure—quick value analysis—has been developed. This procedure uses only two forms and jumps quite soon into the creative phase and then to the evaluation.

Quick value analysis should be used:

(a) When an idea is still at a very rough stage and more ideas are needed (i.e., more creativity);

(b) When time is a limiting factor.

The best applications for quick value analysis are at the beginning of product development, when only a product idea exists (a rough sketch or the very first prototype).

In quick value analysis the co-ordinator presents an opinion about the function of each part, and cost information is also presented. The team creates new ideas using this information. The savings are estimated (if possible) at the end of the meeting, and the ideas put forward are either accepted or rejected. A good idea may also end up in the idea bank of the company.

The result of the work of the quick value analysis team is then presented to the management, which accepts or rejects it. If the decision is positive, a prototype with drawings is constructed, and a complete value analysis is then carried out.

XVII. Technical product design*

Technical product design is the planning and design of a product and its parts in such a way that its serial production is as rational as possible and that it is done at the lowest possible cost. The quality of the product must not be too high or too low; it must meet the demands commonly placed on such products. Serial production is a manufacturing process in which a large number of one item is fabricated in a single batch by performing each operation for each member of the series at the same stage. The number of pieces fabricated in one batch depends greatly on the nature of the product and hence on the demand. For example, low-priced kitchen chairs may be made in quantities of 5,000 pieces, but expensive managers' desks can be made in batches of only about 50. The storage situation at a factory determines when a given item is produced again.

The starting point of a technical product design is the product idea. It may be obtained from a free-lance designer, who is usually paid a royalty according to the number of pieces eventually manufactured. The development of the idea to suit serial production calls for expert knowledge and experience on the part of the technical designing staff as regards raw materials, construction, machining, surface finishing etc. It is particularly important that industrial designers be fully familiar with the size, dimension and price of the raw materials, semi-manufactured products and supplies available on the market.

The need for technical product design

A thorough technical product design, together with a good product idea and an attractive product, is one of the most important requirements for an industrial enterprise that wishes to maintain a competitive position on the market. Every part of a product must be carefully designed in order to maximize the utilization of the existing manufacturing facilities and other investments. Some of the numerous tasks of technical product design in the furniture and joinery industries are:

(a) To reduce raw-material consumption to a minimum;

(b) To reduce the number of different manufacturing stages required to make a product;

(c) To reduce the need for manual operations. This is of prime importance in countries with high labour costs;

(d) To design parts in such a way that interchangeable components can be manufactured and automation can be used in production as much as possible;

(e) To produce high quality at low cost;

(f) To adapt original designs by interior architects to the manufacturing facilities without major changes in the external appearance of the products.

Today, even the smallest factories attempt to carry out systematic product design and development in which every detail of design and fabrication is thoroughly considered.

Properties required of a serial product

Modern serial-production techniques usually require the product to have the following characteristics:

(a) The product must be suitable for the manufacturing process of the plant in question and permit the efficient use of special-purpose machines (for example, double-end tenoning machines and edge-banding machines);

(b) No manual work should be included; there should be no hand-fitting in the assembly phase;

(c) Surface finishing of parts should be done, where possible, before assembly (for instance by a curtain-coating machine or by dipping);

(d) In countries where timber is expensive and labour costs are high, solid wood should be replaced as far as possible by various kinds of semi-manufactured materials that can be veneered, covered with plastic sheets or painted. The level of development of the industry and its degree of automation are additional factors to be considered in the selection of materials;

(e) The constructions should, to the extent possible, be collapsible (knock-down) to reduce storage and shipping costs, especially in export trade;

(f) Similar parts should be usable for as many components of a product and in as many products as possible;

(g) Dimensions, joints, metal fittings and so on should be standardized as far as possible. Profiles, roundings etc. should be standardized to suit the existing tools of a factory;

(h) Products should be dimensioned in such a way that semi-manufactured products available on the market can be used with a minimum of waste (figure 83);

(i) The forms and joints of a product must be designed so that the machining of each part is possible by a continuous through-feeding operation (figure 84). It is a further advantage if several machining operations can be carried out at the same time, as with the four-side moulding machine (figure 85).

Raw materials for different constructions

With the introduction of particle board and other semi-manufactured products, many traditional constructions

*By Pekka Paavola, Lahti Institute of Technology, Lahti, Finland. Originally issued as ID/WG.105/30/Rev.1.

have been abandoned. Today the raw materials used for panel furniture such as cabinets and bookcases are chiefly particle board and various combination boards; solid wood is used mainly for chairs, drawers, structural components and bases. For export, solid-wood furniture of tropical woods may command better prices and have a different demand.

Figure 83. Large material waste (a) minimized by properly dimensioning of panel components (b)

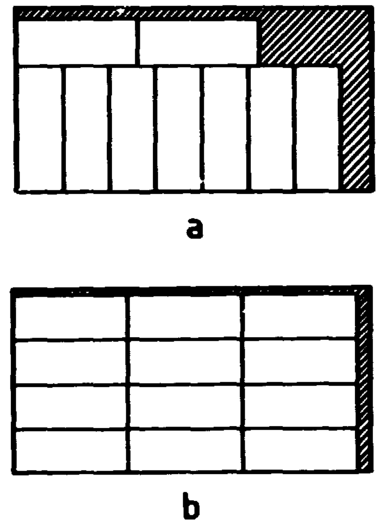
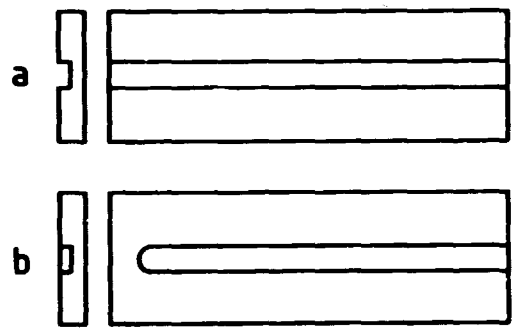


Figure 84. Machining grooves in a through-feed operation (a) possible with standard machines (b) not possible with standard machines



The following is a brief review of the uses of various raw materials in different constructions and of their characteristics:

(a) Furniture members made of one piece of solid wood are seldom more than 100 mm in width. These include table and chair legs and rails, drawer parts and other narrow pieces;

(b) To reduce costs, solid wood is often veneered. The blind wood may be of low quality provided it is sufficiently strong. If the blind wood pieces are narrow, they are usually glued to form a panel first and then planed and veneered. The veneered panel is sawn into the required pieces, and the edges are veneered, as shown in figure 86;

(c) Cell construction (figure 87) is commonly used in joinery products (doors, kitchen furniture); however, frame and panel constructions are also used in doors. In cell construction, the corners of the frame are stapled (no joints) to keep it together during the process. The frame is filled with paper honeycomb and covered with fibreboard in a hydraulic gluing press;

(d) The most common panel constructions used in furniture manufacture are the solid-wood panel, the veneered solid-wood panel, veneered particle board and the panel with frame. These are shown in figure 88. The solid-wood panel shrinks and swells across the grain and therefore must be fastened to, for example, a table base in a manner that allows it to move ("buttoning"). Shrinkage is prevented in the two veneered panels and the external dimensions of the frame in the frame construction are also practically constant. In certain developing countries where particle board is not produced, plywood is used in thick dimensions for furniture and joinery panels. Like particle board, plywood also has an excellent moisture stability in the direction of its surface;

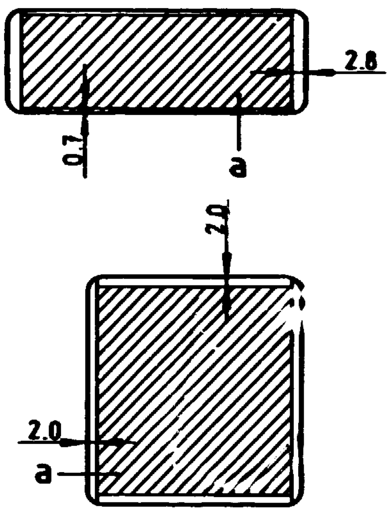
(e) Back panels of cabinets and bottoms of drawers are usually made of hard or semi-hard fibreboard that is painted or veneered. Plywood is considerably more expensive than fibreboard in many countries;

(f) MDF is among the newest semi-manufactured materials for the furniture and joinery industries. The fibres are glued with urea formaldehyde glue as in particle board, whereas fibres in ordinary fibreboards are held together only by the natural adhesives contained in wood. The

Figure 85. Furniture and joinery profiles machined by a four-side moulder

average density of MDF is usually slightly lower than 0.7 g/cm³. Common thicknesses are 8-45 mm, but thicker components can be easily made by gluing several pieces together. The surface finish is very smooth, also after machining, making staining, lacquering and painting easy. MDF is particularly well-suited for all types of molded components, as shown in figure 89. MDF is more expensive than hard fibreboard and particle board.

Figure 86. Veneered solid wood components



Key: a Solid wood core

Figure 87. Cell or honeycomb construction commonly used for flush doors and kitchen furniture

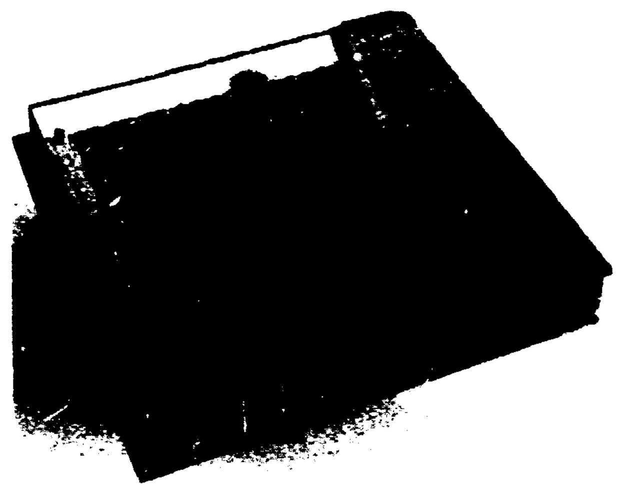
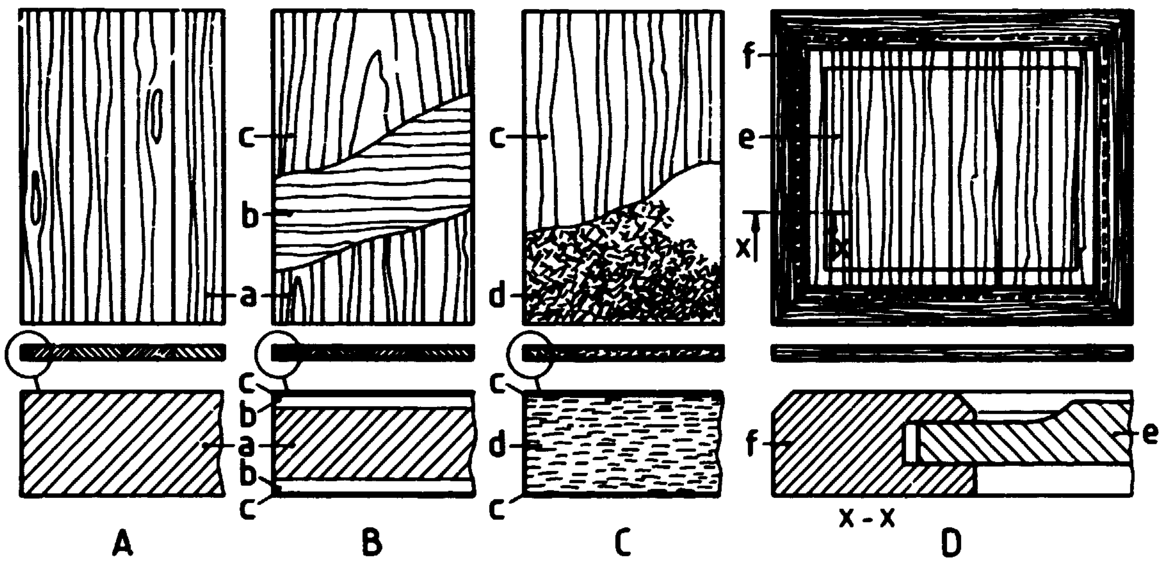


Figure 88. Four common furniture panel constructions



Key:			
A	Glued solid-wood pane	a	Solid wood
B	Glued solid-wood panel but veneered using blind veneer	b	Blind veneer
C	Veneered particle board	c	Surface or decorative veneer
D	Solid wood frame construction	d	Particle board
		e	Solid-wood panel of type (A)
		f	Solid-wood frame

Joints

The dowel joint (figure 90) has rapidly gained wide use as a general method of joining the structural members of furniture. Its principal advantages are the following:

(a) Machining is simple and accurate with multi-spindle boring machines; the two components of the joint always fit closely;

(b) Dowels are driven rapidly with a special fixed or hand-held machine;

(c) The joint is easy to assemble;

(d) The wood is weakened very little by the holes because the fibres are cut over such a small area;

(e) Surface finishing of panel components may be carried out with a curtain-coating machine after boring but before assembly, since lacquer flowing into the holes does not affect the gluing (unless, of course, there are large open spaces in the surfaces to be joined);

(f) Raw material consumption is reduced by the use of waste wood of an appropriate hardness for dowels;

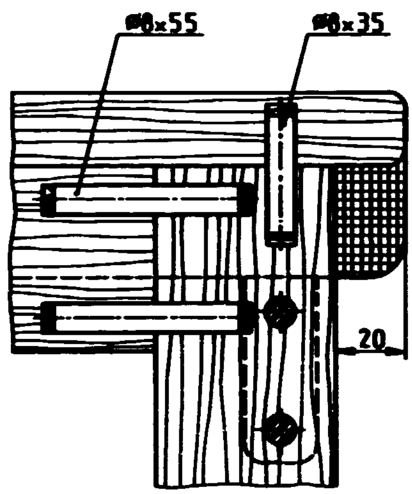
(g) The use of dowel joints contributes to rationalization as well as to automation;

(h) The dowel is the joint best suited for particle board constructions.

Figure 89. Moulded components made of MDF

The dowels, although usually made of edging waste, are sorted after cutting to length and are therefore free of defects, giving maximum strength. In Europe the wood species most commonly used for dowels are beech and birch, both of them being strong and tough hardwoods with very even grain structures. The dowel surface should be grooved by pressing, and the ends should be bevelled (figure 91) to facilitate driving with special machines or handheld power tools. The purpose of the grooving is to prevent the dowel from scraping the glue from the surface of the hole too thoroughly when driven into the boring. When driven, the dowel absorbs water from the glue and swells, particularly at the points of the grooves, resulting in a strong joint. The grooves also act as channels for the escaping air. The common diameters are from 6 to 12 mm. For a better hold the dowels usually have a diameter 0.1 to 0.3 mm larger than that of the boring (0.1 mm for hardwood species, 0.3 mm for soft species).

Figure 90. Detail of an assembly drawing showing dowel joints



Experience has shown that the use of dowels for jointing offers the best possibilities for automation in the furniture industry in the production of both solid wood and panel furniture. Products have to be designed accordingly, however, for example by using overlaps to conceal dimensional inaccuracies. Today it is common for a factory to limit the number of joints used to two types only: dowels and grooves. Dowels are also commonly used in connection with KD fittings as guiding elements. This type of standardization also means considerable savings in investments for tools.

Figure 91. Press-grooved dowels with bevelled ends (8, 10 and 12 mm in diameter)

Of the traditional joints, the corner-lock joint, the tongue-and-groove joint and the mitre joint are fairly well-suited to modern manufacturing processes (figure 92). Mass-produced loose tongues, suitable, for example, for mitre jointing flat cabinet door frames, are shown in figure 93. These tongues are cut from thick beech veneer by stamping. The surface is pressure-grooved for better strength in gluing. The shape of the jointing slit normally corresponds to the curvature of the tongue.

Figure 92. Three traditional joints suitable for modern furniture manufacturing processes

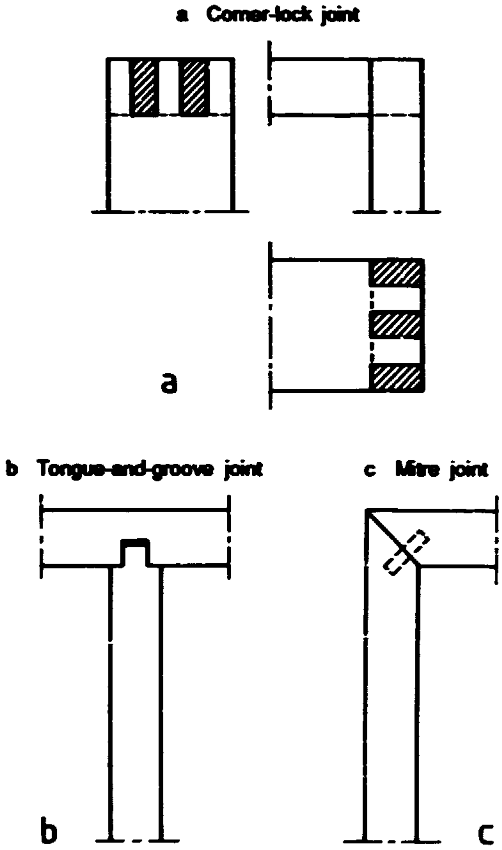
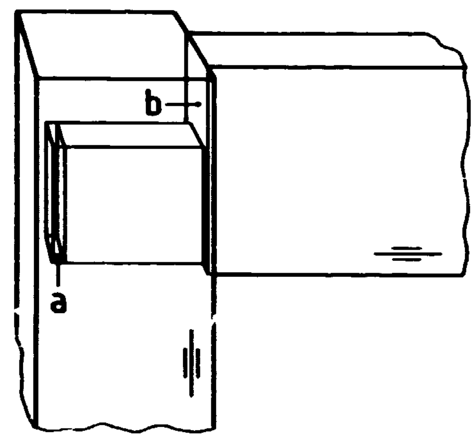


Figure 93. Mass-produced loose tongues with pressed surface pattern (1:1)

The stub-tenon joint (figure 94) is a traditional joint for furniture and joinery but is becoming less common because it takes time to make a mortise with the ordinary hollow-chisel mortising machine that is normally used and a rough interior surface is produced, which results in a weaker joint. If, however, an oscillating mortising machine is used, the finish of the surfaces will be very good, and the joints will be stronger.

Figure 94. Stub-tenon joint



Key: a Empty space necessary for excessive glue and chips
b "Shoulder" surface, in contact with the leg

Tenons with rounded edges and mortises with the corresponding shape are widely used today to replace the traditional stub-tenon joint. The tenon part is cut with a special tenoning machine which also trims, saws and bevels the sharp edges of the tenon end. The mortise is machined with a slot-boring machine.

The dovetail joint is a traditional joint particularly for drawers (figures 95 and 96). The condition in serial production is normal that both the front and side components can be machined at the same time according to the principle shown in figure 97. This can be done quite rationally with multi-spindle dovetailing machines (with up to 25 spindles). Although it has excellent strength and a favourable appearance, the principal drawback of this joint is that the sides with the dovetail pattern have to be sanded after assembly if high quality is to be achieved.

Various kinds of metal fasteners, usually called knock-down fittings, are being substituted for glued joints. Their advantage is that the product can be shipped to the customer packed compactly in knocked-down form. The parts can be easily assembled at destination, even without special skills. An additional advantage is that surface finishing can be done on the unassembled parts. Some examples of commonly used knock-down fittings are shown in figures 98 to 102. The fitting in figure 98 is very suitable for table and cabinet bases provided that all four rails are permanently fixed to the reverse side of the table top or cabinet bottom. The rail ends must be straight cut with a trim saw without any jointing or guiding details. There must also be a clearance between the inner corner of the leg and the angular fitting when the legs are assembled. This ensures a tight joint. The fitting in figure 99 consists of a screw and a cylindrical nut implanted in wood (normally in the rail). The screw, going through a leg, for example, is driven into the threaded hole of the cylindrical nut and tightened. One or two short guiding dowels are usually needed to prevent the rail from turning. The strength obtained is very good, and therefore this fitting is widely used for chairs and bases. The screw head often has a hexagonal slot which makes tightening easy with an L-shaped key, which is usually packed with the product. The nut in figure 100 has a rough outer threading like a standard wood screw; the hole is threaded like ordinary steel nuts. This fitting is mostly used for direct fixing on the surface of a solid wood part or panel. The fittings in figures 101 and 102 are designed primarily for panel furniture. The tightening element in both is a revolving cam. The only tool necessary in assembly is an ordinary screwdriver.

Figure 95. Semi-concealed dovetail joint

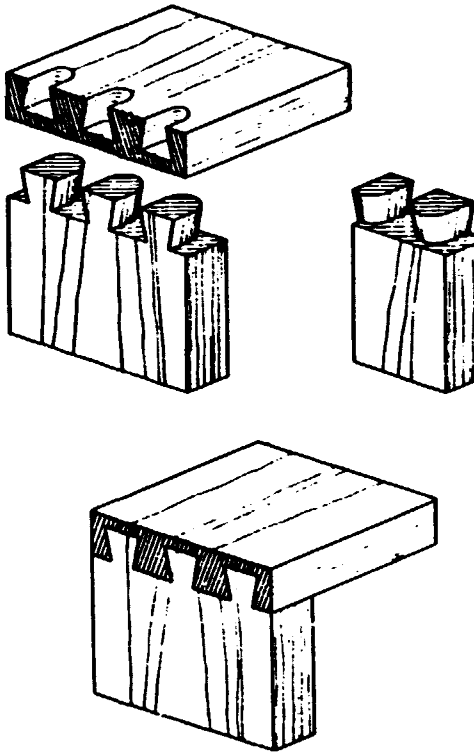


Figure 96. Non-concealed (through-going) dovetail joint

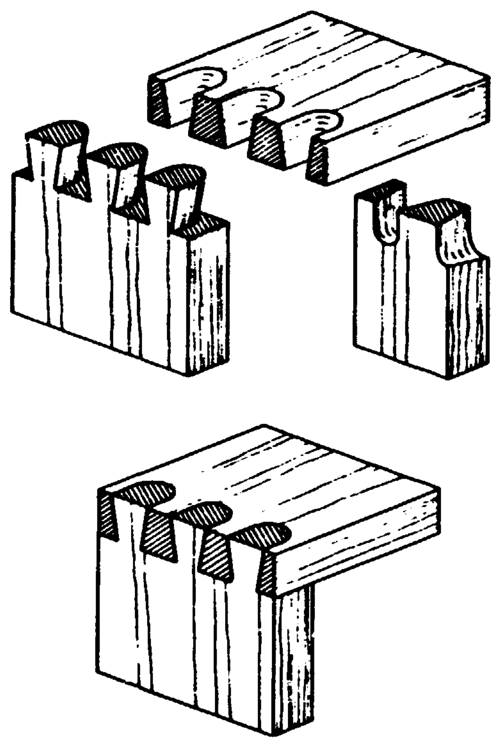
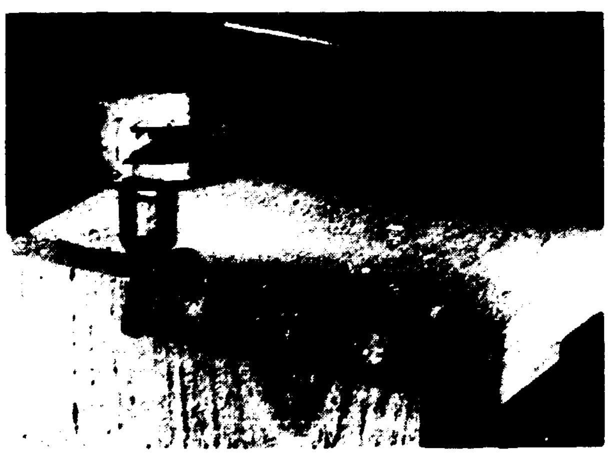


Figure 97. Dovetail joint

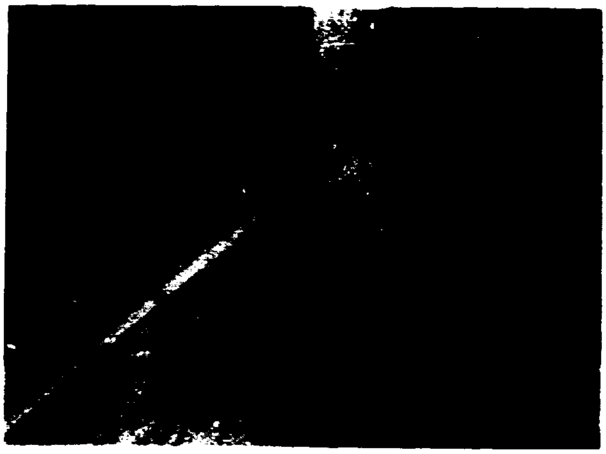
A. Machining



B. Finished joint

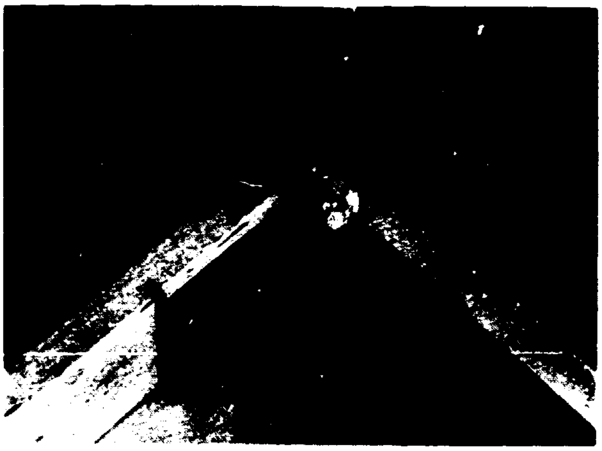
Figure 98. Knock-down fitting for table and cabinet bases

A. KD fitting for rectangular legs



B. KD fitting for rectangular legs

C. KD fitting for turned legs



D. KD fitting for turned legs

Figure 99. Knock-down fitting using a cylindrical nut

A. Fitting with L-shaped key used for tightening

Figure 99. *(continued)*

B. Assembled joint cut open to show fitting with guiding dowels

C. Joint with short-type cylindrical nut for less-stressed constructions

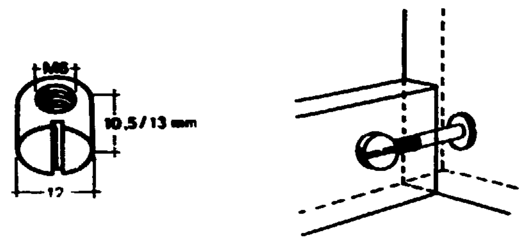


Figure 100. Nut with rough outer threading

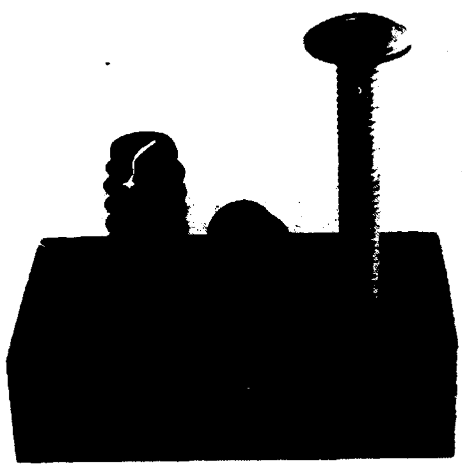


Figure 101. Knock-down fitting for panel furniture with tightening element visible on inside surface of cabinet

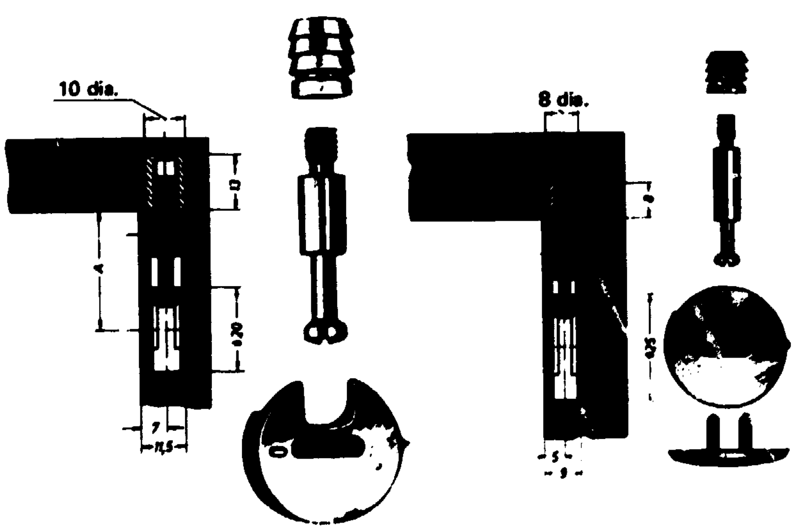
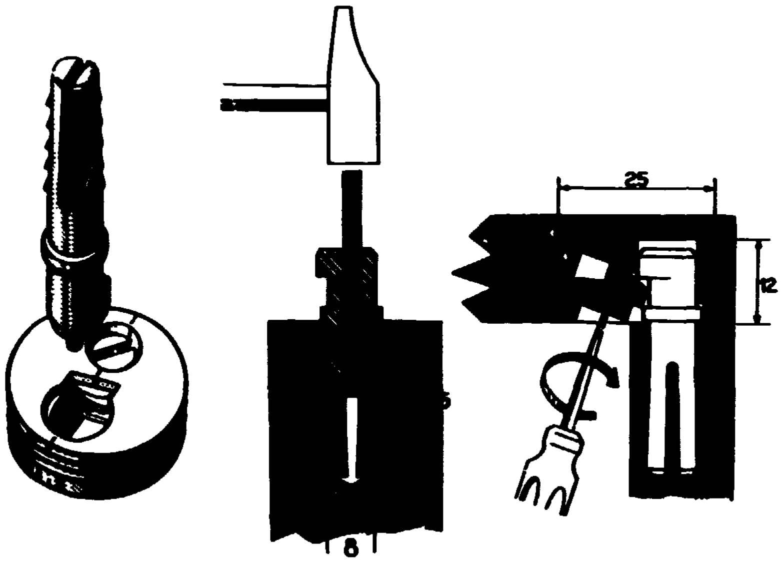


Figure 102. Knock-down fitting for panel furniture, fitting only partly visible after assembly



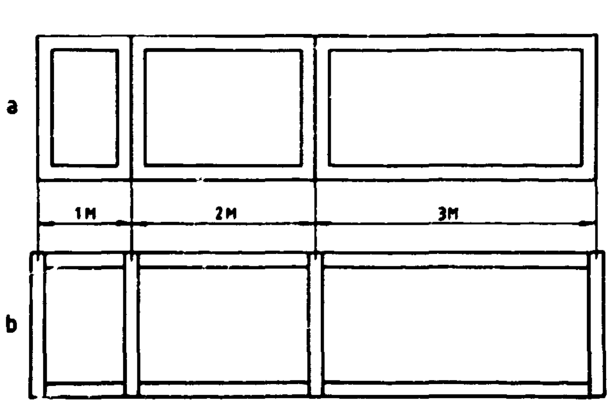
Most knock-down fittings today need only circular holes, which can be machined by boring, one of the simplest woodworking operations. The same designing principle is commonly applied to all other types of fittings such as hinges, handles and locks.

The modular dimension principle and element-furniture combinations

A module is a basic unit of measurement, all larger dimensions being multiples of it. This means in practice, where panel furniture is concerned, that the final product or unit, having a certain length or height, can be composed of standard elements, varying according to the individual needs and tastes of the customer. The particular advantage of this system is that a large number of products can be produced using a small number of different standard elements. The number of different parts to be manufactured and stored is thus minimized. The modular dimension principle is commonly used for kitchen furniture, storage cabinets, office furniture and bookcases. The most usual modular systems are shown in figure 103. The main drawback of system A is the double partitions which are avoided in system B by using the centre-to-centre measurement as modular dimension. Drawers can also be dimensioned according to the modular principle.

One-module and two-module drawers are shown in figure 104. A modular dimensioning system for windows is shown in figure 105.

Figure 103. The two most common modular systems

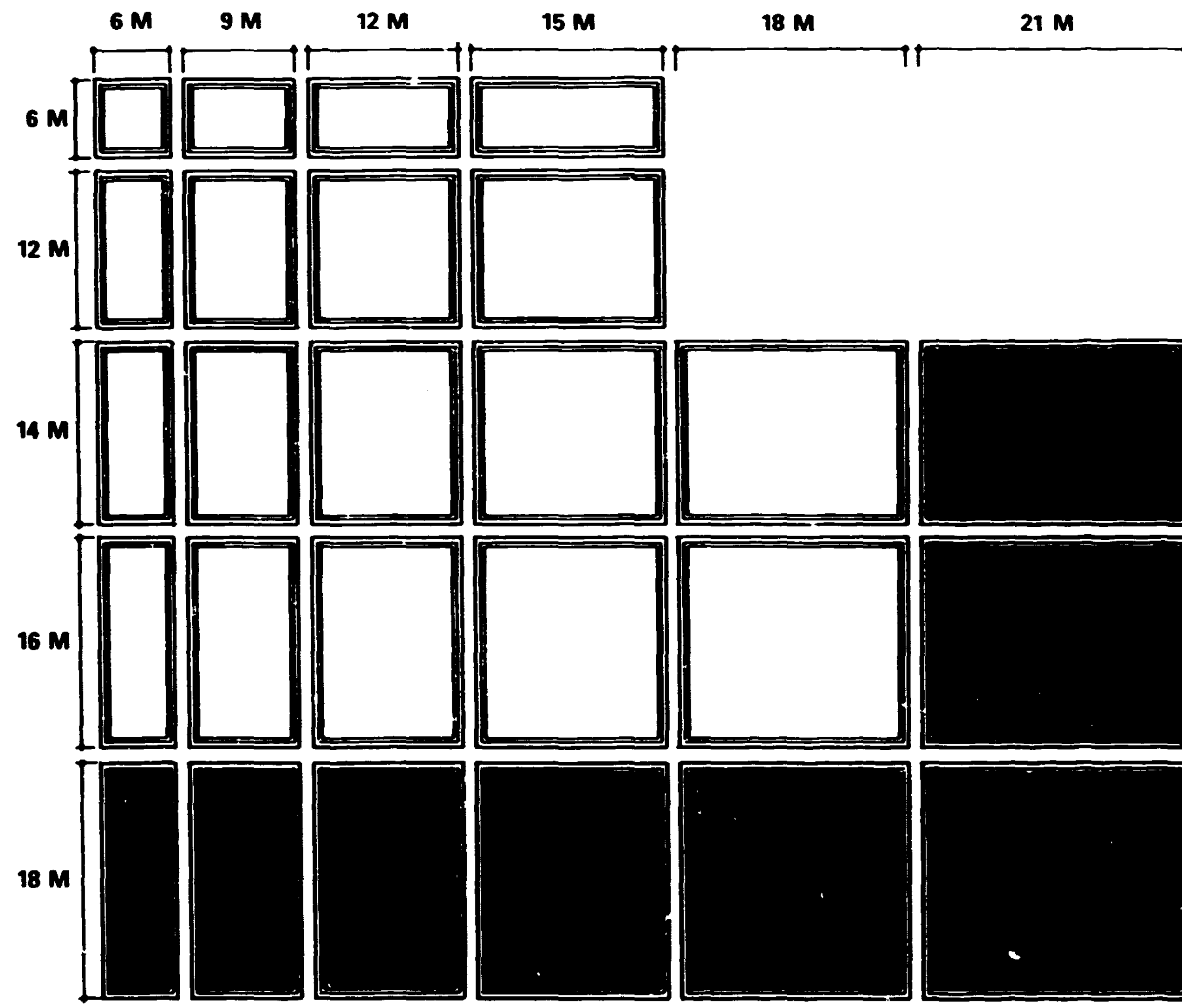


Key: a Outside measurements in a modular system
b Centre-to-centre measurements in a modular system
M Module

Figure 104. Drawer units with one-module and two-module drawers

Note: One module is 90 mm high.

Figure 105. Modular dimensioning system for windows used in Finland



Key: M = module = 100 mm

XVIII. Drawings and dimensions for the furniture and joinery industries*

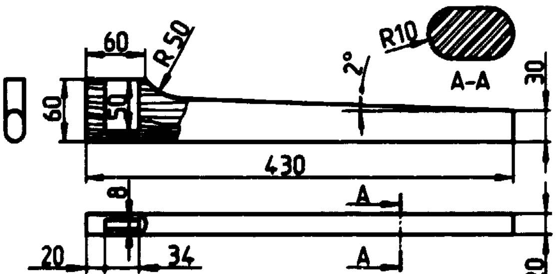
The principal types of drawings used in a modern factory that produces furniture or joinery serially are the prototype drawings and the actual production drawings. The latter group can be subdivided into part or component drawings, sub-component assembly drawings and final assembly drawings.

Prototype drawings are often made to full scale (1:1), particularly those for chairs. The most important dimensions may be given in figures; other dimensions, together with the shapes, are obtained directly from the drawing using a millimetre ruler. The prototype must be similar in all respects (joints, knock-down fittings etc.) to the intended serial product so as to bring out any defect in construction or fabrication. A prototype drawing, however, must never be used for production.

Actual production drawings are made only after the prototype has been tested and corrected to its final form. All measurements are given numerically, which makes it easy to draw to a reduced scale (1:2.5, 1:5, 1:10), except for the sections and other details which are usually drawn to a 1:1 scale. The numerical values of dimensions are decisive. Dimensional changes are possible by changing the numbers and leaving the drawing itself unchanged.

The component or part drawings (figure 106) are usually made on separate standard A4-size sheets, which can easily be copied on any office photocopying machine. The information included should be only for the machining stages (giving for example numbers of jigs and special tools used for an operation) and the necessary quality-control operations connected with machining. Each sheet should include a drawing for one single part only. Left- and right-handed components should each be presented on an individual sheet.

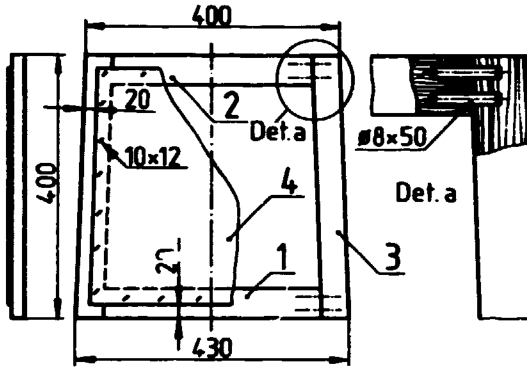
Figure 106. Dimensioned part drawing for a furniture component



*By Pekka Paavola, Lahti Institute of Technology, Lahti, Finland.

Sometimes sub-component assembly drawings (figure 107) are also prepared, which helps to rationalize the assembly operations. The information included covers only the assembly of the part in question, since all parts have already been machined at this stage.

Figure 107. Dimensioned assembly drawing for sub-assembly

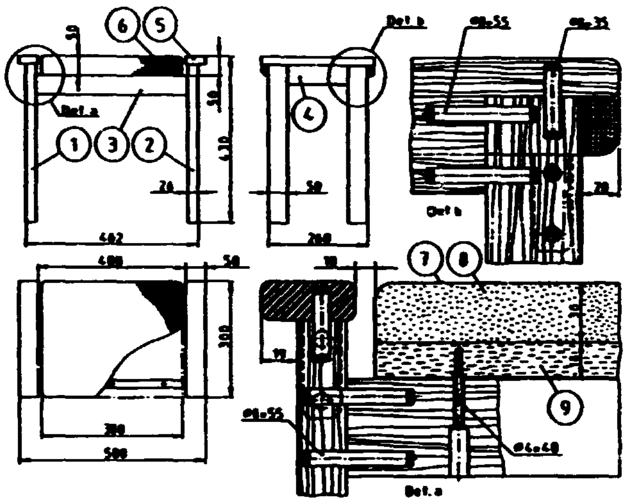


The final assembly drawings (figure 108) show in what way the parts are assembled and what kind of parts are needed. Each part or component should have an individual reference number (the same as that used in the other drawings). A complete list of parts is usually included in the final assembly drawing. The measurements on the final drawings are for the assembly and related quality control operations only and show the final dimensions when parts are put together. Some factories still use full-scale drawings in which all details are dimensioned. In this case one drawing includes all information for machining, assembly and quality control. This drawing system, however, is much less practical and rational than that explained above because even for the machining of a very small part a large-sized drawing is used.

The dimensioning of furniture and joinery parts is usually based on practical experience and tradition. Strength tests carried out by some laboratories have shown, however, that correct proportions of joint details strengthwise, may differ considerably from the ones that are traditionally used. Two examples of dimensioning instructions, based on laboratory tests, are given in figures 109 and 110.

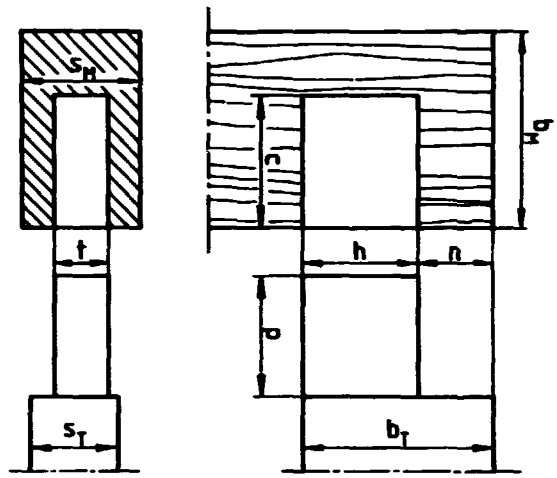
The main problem encountered when using a reduced scale, e.g. 1:5, is the lack of space for the proper dimensioning of small details with ordinary double-headed arrows and reference lines. To solve this problem a standard system of symbols and abbreviations can be used as shown in figure 111. The principle followed is that only exceptions to the simplest alternative call for explanation, e.g., information about the centricity of a centrally located hole in a narrow component (leg, rail etc.), or about the depth of a hole that goes completely through the part needed. The depth of a hole that does not go completely through the part must be indicated, however. The proper dimensioning of production drawings calls for thorough knowledge of the measuring equipment, machinery, tools and methods used in manufacture.

Figure 108. Dimensioned final assembly drawing for a simple piece of furniture



The dimensions given in production drawings are normally so-called nominal measurements, i.e. desirable dimensions. Absolute accuracy is, however, impossible to attain, and therefore the actual dimensions of a workpiece always differ from the nominal measurements, within a certain range. If a high degree of accuracy is to be obtained, the range is narrow. In a technologically advanced production unit the size of the accepted range and its location in respect of the nominal measurement is given numerically. The difference between the maximum and minimum allowable dimensions is called the tolerance. One of the major tasks of systematic quality control is to maintain the dimensions within the tolerance range, thus ensuring that all components produced are fully interchangeable. The tolerance system has already been used in metalworking industries for several decades, it being an essential part of the manufacture. In the furniture and joinery industries, however, only very few factories have applied this technique to production process. The main reason for this "is that wood is not homogeneous and components shrink ..." under moisture variations. Although this problem is quite serious and impossible to avoid, tolerance systems have been developed and used to some extent for wood and wood-based materials. Typical details that have often been dimensioned with toleralances are joints, machinings for fixing knock-down and other fittings and moving parts in which a clearance is necessary. In all these examples a high degree of accuracy is required to make the parts interchangeable and to fit without any manual adaptations in assembly. An example of practical dimensions for the traditional stub-tenon joint is given in the caption to figure 109.

Figure 109. Dimensioning of a stub-tenon joint



Millimetres		Millimetres		
S_M	t	b_T	h	n
6	3	14	8	6
8	4	17	10	7
11	5	20	12	8
14	6	26	16	10
17	8	32	20	12
20	8	38	22	16
26	10	44	26	18
32	14	50	30	20
38	16	56	34	22
44	20	60	36	24
50	23	70	42	28
56	26	80	48	32
		100	60	40
c = p + (2-5) mm		120	72	48

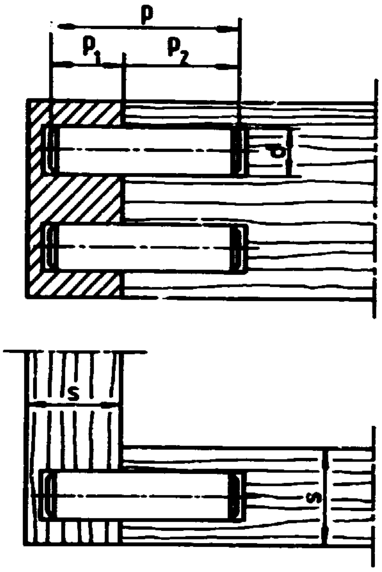
Concealing dimensional inaccuracies by structural means[1]

Inaccuracies resulting from dimensional deviations in raw materials, such as variations in the thickness of particle board and inaccurate machining, may be rendered inconspicuous and practically invisible to the naked eye by appropriate constructional designing. At the same time, hand-fitting in the assembly phase is avoided. Structural means of this kind include the overlap of one component and rabbeting or bevelling at the line of joining (figure 112).

In veneered particle board products, owing to the thin surface veneer, only overlap can be used, whereas rabbeting and bevelling are particularly suitable in solid wood constructions.

[1]See also chapter XVII on technical product design.

Figure 110. Dimensioning of a dowel joint used as a corner joint



		Millimetres		
s	*d*	*p*	*p*	*p*
11	6	20	8	12
14	6	25	10	15
17	8	30	12	18
20	10	40	15	25
26	13	50	20	30
32	16	60	25	35
38	19	70	30	40
44	19	80	35	45
50	22	90	40	50

Prototypes

Hardly any new product can be designed and developed in a modern mass-producing plant without first making one or more prototypes. The importance of a prototype increases with the complexity of the product and the degree of automation used in the process. Particularly products in which ergonomic aspects must be considered, e.g. chairs, as a rule cannot be designed on the drawing board only, unlike simple bookcases or coffee tables. The main advantages of making a prototype before accepting a new design for production are the following:

(a) The product can be seen three-dimensionally and in actual size;

(b) The functions and ergonomics can be tested;

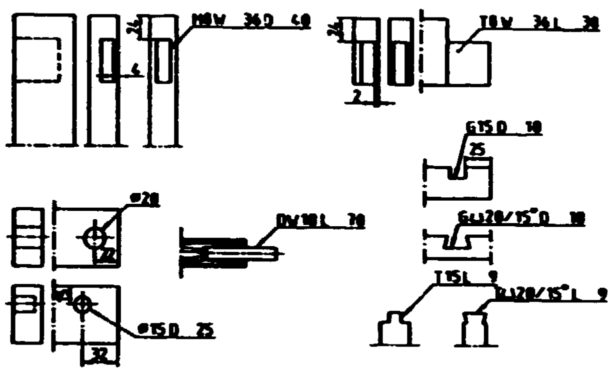
(c) The strength and rigidity can be tested using special equipment developed for this purpose (an example is shown in figure 113);

(d) Ease of assembly, using knock-down fittings, can be tested;

(e) Packages can be designed for knocked-down parts;

(f) The final corrected prototype can be photographed for introduction to retailers or other clients and for promotional/publicity purposes.

Figure 111. Dimensioning symbols and abbreviations



Key:

D	Depth
DW	Dowel
G	Groove
L	Length
M	Mortise
T	Tenon
W	Width

The organization of technical product design

A great number of different tasks and steps are involved in designing and developing a new product for a modern mass-producing factory. Thus, thorough knowledge is necessary about, *inter alia*, marketing, production costs, raw materials, semi manufactured products, supplies, constructions, existing machinery and other equipment, tools, machining, gluing, low-cost automation, surface finishing, assembly, upholstery, quality control. To facilitate the design procedure, many larger factories have established a special body, usually called a product development group. This group, consisting of experts from all the important fields of management and production (normally factory personnel), acts as a selecting, evaluating and approving body that meets at certain intervals. The role of the product development group is shown in figure 114 which represents the organization of the design process in a modern furniture factory. The starting point is a new product idea, usually submitted to the product development group by a free-lance designer, e.g. in the form of a sketch or other type of preliminary drawing. The design process progresses from one stage to another, ending at the manufacture of a product. A large number of ideas may be rejected at the introduction stage or after the prototype has been made. It is therefore not uncommon that only a small number of the ideas originally submitted to the product development group actually result in production.

Figure 112. Structural means of concealing dimensional inaccuracies

A. Overlap B. Rabbet C. Bevelling

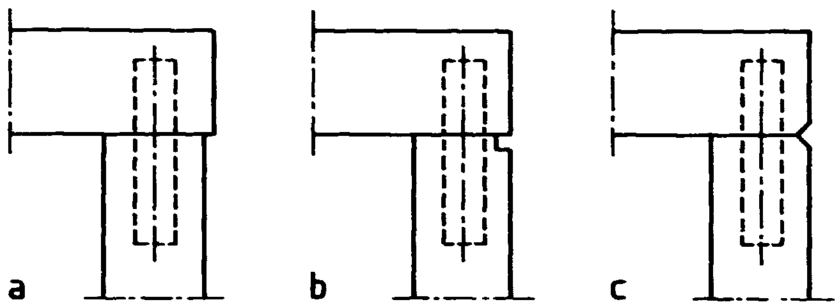
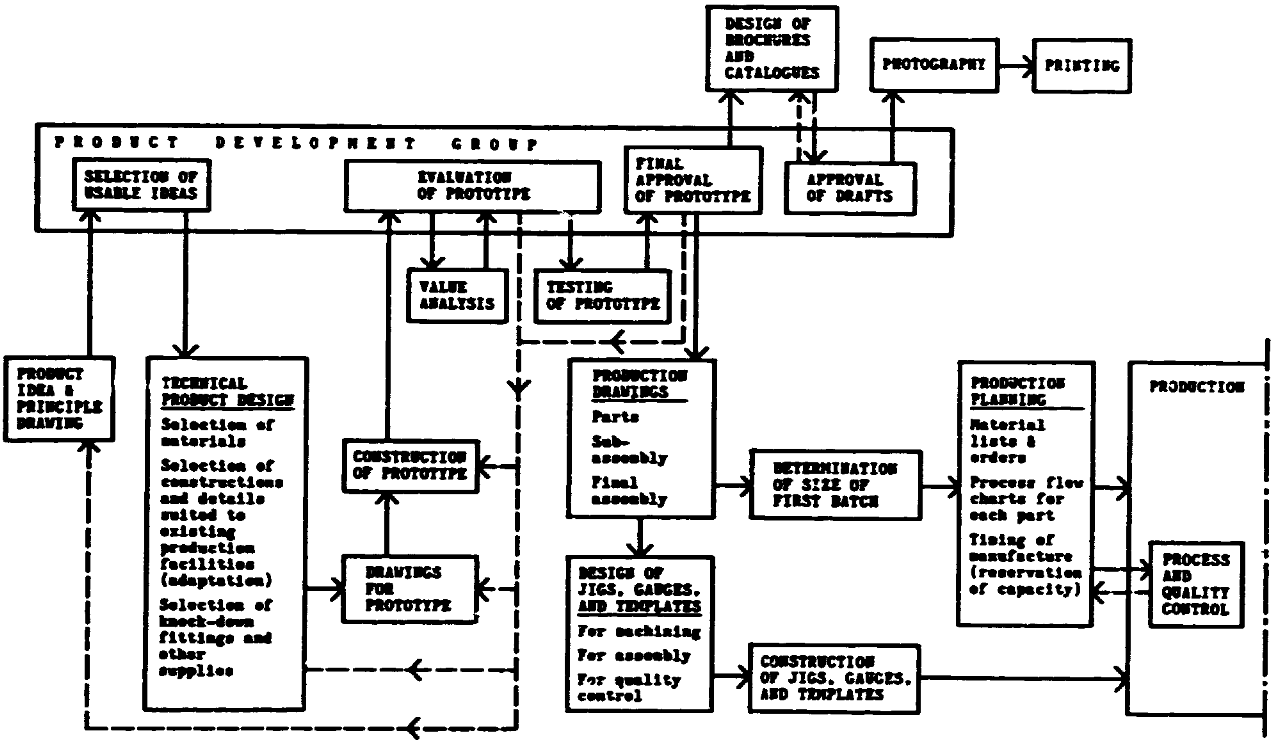


Figure 113. Strength testing a chair (photograph courtesy of the Forest Products Laboratory, Technical Research Centre of Finland)

Figure 114. Organization of product design process in a modern furniture factory



XIX. Plant layout*

The term plant layout signifies the general organization of production and the placement of machines, equipment and working areas as well as the planning of internal transport and of the factory building itself in a way that will provide optimal conditions for the manufacturing process.

The following degrees of plant layout may be distinguished according to the comprehensiveness of the task:

Complete planning of a new plant
Changes of plant layout necessary when moving into an existing factory building
Rearrangement of an existing factory within a total plan
Minor rearrangements in various sections of a plant

The principles of plant layout presented below are independent of branch of industry and are generally applicable to any kind of plant or establishment (for example, a service station, farm, kitchen or photographic laboratory). Plant layout should be understood not as a one-time process but as a continuous activity that is necessary to maintain the ability of an enterprise to compete.

Objects of plant layout

The main objects of plant layout may be divided into the following groups:

Working methods and places
Their placement into operating sequence
Planning machine groups and sections
Locating different sections at appropriate places (see figure 115)
Designing factory buildings around machines and processes
Designing electrical installations and pipe networks (water, heating, steam, sewage disposal, compressed air, chip and dust extraction etc.)
Installing a power plant (or supply)
Planning waste disposal and utilization
Laying out the factory area

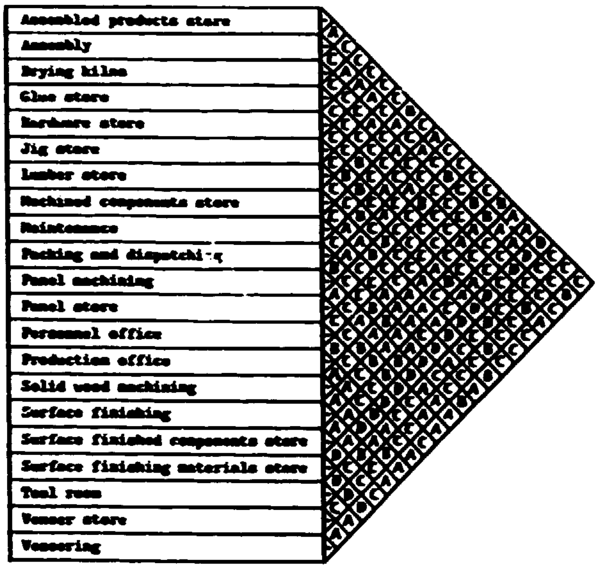
Starting point for plant layout

The basic information necessary for layout planning is:

Present and projected production programme
Type, construction and materials of products
Desired quality standard
Desired production capacity

*By Pekka Paavola, Lahti Institute of Technology, Lahti, Finland. Originally issued as ID/WG.133/27.

Figure 115. Analysis of the importance of the location of various departments



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

Special characteristics of production in the furniture and joinery industries

The following characteristics of the furniture industry affect layout planning:

(a) The product assortment is usually large;

(b) Production runs tend to be rather small;

(c) The life of most designs is short;

(d) Continuous production of the same models is seldom possible;

(e) In addition to solid wood, plastics and metals, as well as many wood-based semi-manufactured products such as particle board, plywood and fibreboard, are used as raw materials.

In the joinery industry, the assortment of products is considerably smaller than in the furniture industry.

Although product size is variable, as with windows and doors, many products are standardized—at least in Finland—so that their continuous manufacture is often possible. Consequently, a joinery factory is often easier to design than a furniture factory. The life of the products (e.g. flush doors) is long, and the principal raw material is solid wood.

Arrangement of production

The following principles of arrangement may be distinguished:

(a) Stationary working places. This is the usual arrangement in the manufacture of fixtures based on individual orders (fixtures for banks, restaurants, hotels, public places, individual home interiors etc.) and for the production of prototypes. Each worker has a special working station with all the necessary hand and power tools. This section must always be separated from serial production and therefore equipped with easily adjustable basic woodworking machines;

(b) Method-oriented arrangement. In this widely used arrangement for the furniture and joinery industries, the machines are grouped according to their working or manufacturing method. For example, all planing machines are in one group, all machines for boring and mortising are in another, all sanding machines again comprise a group etc. Each group is then specialized in a certain working method regardless of the type of products or components handled. Transportation between successive manufacturing stages calls for special transportation passages and intermediary storage areas within the factory;

(c) Product-oriented arrangement. Production is carried out in automated production lines which thus constitute the transportation medium. This method is used in the large-scale mass production of standardized products.

The arrangement in modern furniture and joinery factories today is usually a combination of *(b)* and *(c)* and is often termed sequential automation. This means that some of the machines are separate basic or multi-purpose machines while some sequences of the process consist of automated production lines. This type of arrangement is much more flexible than type *(c)*.

Production capacity

In conventional production using a set of separate machines and equipment, the *machining* or *manufacturing* capacity of the entire line is determined by the output of its least productive unit (that is, the bottle-neck). This means that one machine or piece of equipment may be operating at 100 per cent capacity while any or all of the other equipment is operating below capacity. The bottle-neck can be removed only by the addition of another machine at this critical point. There will be two results: first, the overall capacity of the equipment will be increased and, secondly, the bottle-neck will later appear elsewhere in the line. Thus, in conventional machine lines, capacity can be increased only in multiples of the outputs of single machines.

The requirements of a machine line may be estimated either on the basis of the number of machining hours per machine per year for a given production programme or on the wood-handling capacity (expressed in cubic metres per year) of individual machines (table 20). In an automated line, however, the capacity is the same throughout.

Table 20. Average capacities of some basic woodworking machines[a]

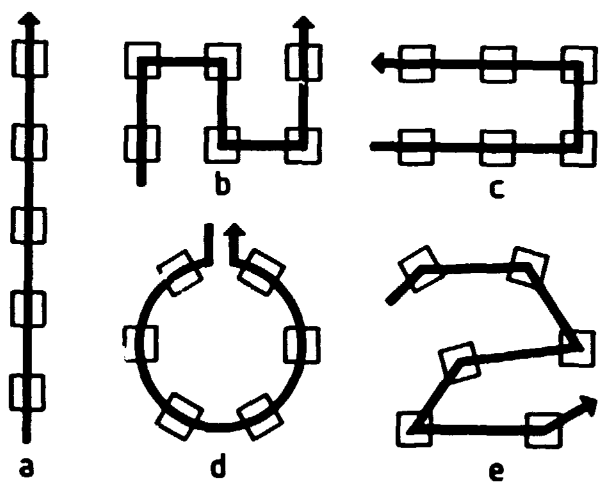
Machine	Capacity (cubic metres/year)
Cross-cut saw	2 300
Edging saw, chain-fed	2 300
Surface planer	1 400
Thickness planer	4.7/mm in width
Four-side moulder	2 300 to 4 700
Trimming saw, single-blade	1 400 to 1 900
Trimming saw, double-blade	2 800 to 3 700
Band-saw	2 300 to 4 700
Vertical-spindle moulder	700 to 1 400
Router	2 300
Chisel mortiser	1 400 to 1 900
Horizontal-belt sander	1 900 to 2 800

[a] The values are valid for average furniture production in which different kinds of furniture are manufactured from solid wood in one shift.

Production flow

In general, the flow of production takes one of the five following forms: straight-line, zigzag, U-shaped, ring-shaped or odd-angle (figure 116).

Figure 116. Five patterns of production flow



Key: a Straight flow
b Zigzag flow
c U-shaped flow
d Ring flow
e Odd-angle flow

Means and facilities for plant layout

The most important means and facilities for plant layout are:

Internal standardization (of products, materials, working methods and parts of factory buildings and factory equipment and fixtures such as transportation pallets, storage shelves, work-benches and tool cabinets)

Operation process charts, machine operation charts, material flow charts, schemes and drawings (figures 117 and 118)

Scale models (figures 119 and 120)

Figure 117. Machine operation chart

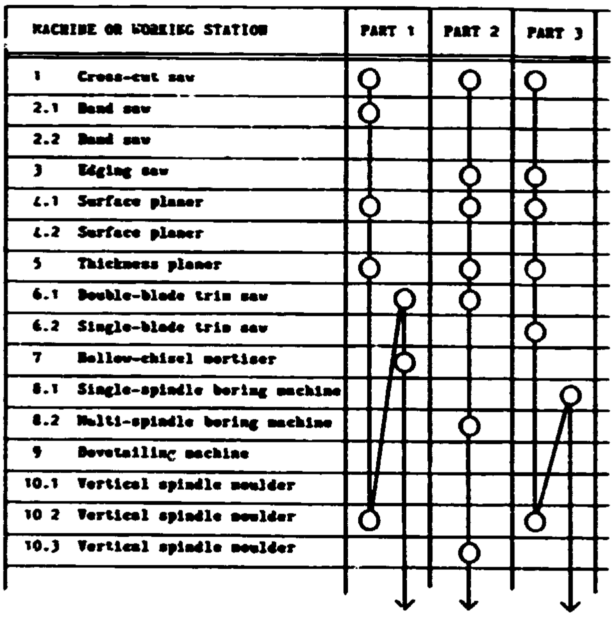


Figure 118. Material flow chart
(The numbers 1 to 13 indicate different machines or working stations)

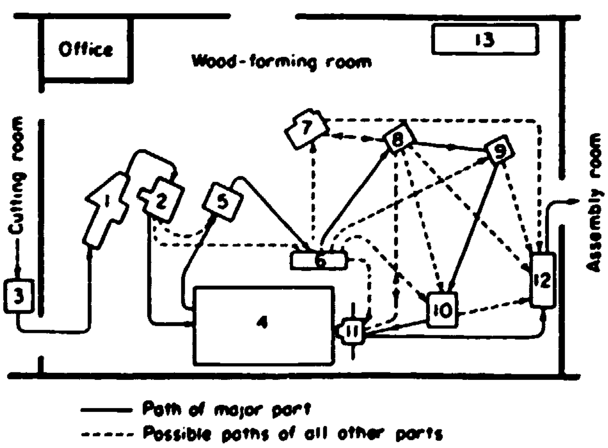
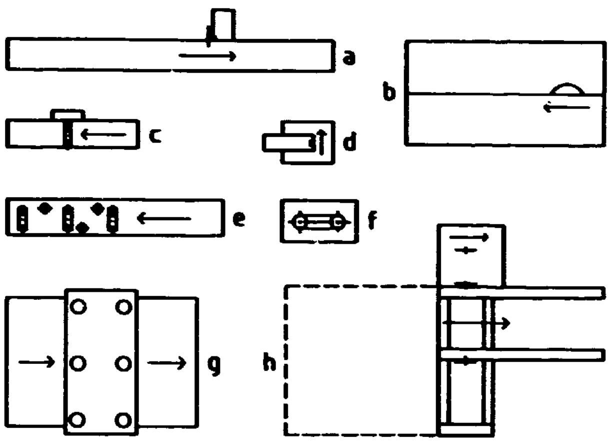
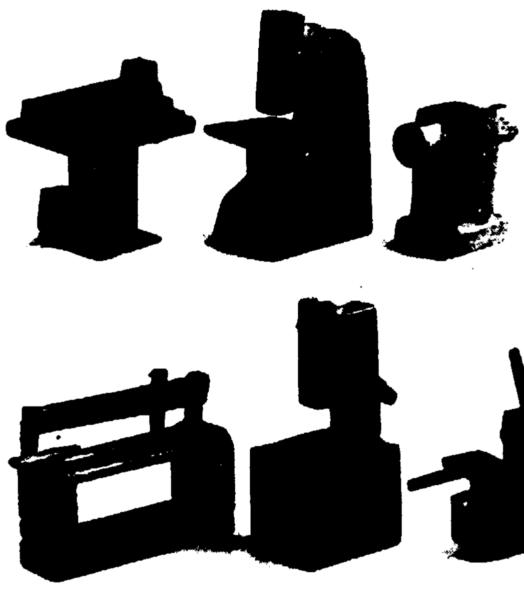


Figure 119. Two-dimensional scale models



Key:
- a Cross-cut saw
- b Panel sizing saw
- c Surface planer
- d Band saw
- e Four-side moulder
- f Vertical-belt sander
- g Veneering press
- h Triple-blade trimming saw

Figure 120. Wooden three-dimensional scale models (Originally made to a scale of 1:50) of some woodworking machines



Plant layout

The plant layout of a totally new factory should always be based on the process and not the factory building. Although the ideal way would be to design the building around the finished process, the construction cost factors must already be considered at the process-design stage. For example, if a pillar module is used, the centre-to-centre distance of pillars determines the width span, which further determines the dimensioning of the load-bearing beams and thus greatly affects the building cost. Construction costs also depend to a large extent on the material selected. If the layout design is to be adapted to an existing factory building, the hands of the process designer are much more tied than when starting mainly from the requirements of the process only.

A good practice is to cover a piece of soft fibreboard (of insulating type) with 1-mm graph paper and to use this panel as a design base before final drawings are prepared. The construction details, which impose limits, are drawn on the paper. Next the working, transportation and storage areas and machines and other equipment are placed on the board. This is best done by using scale models (construction drawings are normally to a scale 1:100 or 1:50) cut from colo ..d cardboard as shown in figure 119 and fixing them with pins on the design base. Three-dimensional scale models, such as those shown in figure 120, can also be used. The pins make it easy to change the layout in the course of design. It is advisable, for later use, to photograph each alternative before the layout is changed.

In many cases the production of a factory is divisible into two distinct parts or lines:

The solid-wood line (chairs, legs, rails, drawers etc.)
The panel line (cabinet parts, table-tops etc. and other components made from wood-based panels)

A common practice that has proved advantageous is to place machines of similar function (in respect of working principle) into groups, as follows:

Cross-cutting saw and edging saw
Planing machines
Mortising and boring machines
Tenoning machines
Vertical-spindle moulders and routers
Sanding machines
Veneering machines etc.

In the placing of the machines and other equipment, it should be remembered that a lot of extra space is needed around the machine for pallet loads, for handling the workpieces (sometimes very long or wide or both), for moving parts of the machines such as feed tables and for tool cabinets, auxiliary tables and waste boxes etc. Furthermore, all maintenance points on the machines must be easily accessible, and enough space must be reserved to ensure ease of maintenance (e.g. the location of machines in respect of pillars). Examples of the design of complete working stations are shown in figures 121, 122 and 123.

In the furniture industry, internal transportation is done mostly with pallets and hand-operated lift trucks. This system is very flexible and well-suited to furniture manufacture. Roller tables and motor-operated fork-lift trucks are also used particularly in the joinery industry. The conveyors used in surface-finishing shops are usually of a special type and thus unsuited to other stages of production. The modern tendency, especially in the furniture industry, is to do surface finishing before assembly.

Figure 121. Working station for surface planing

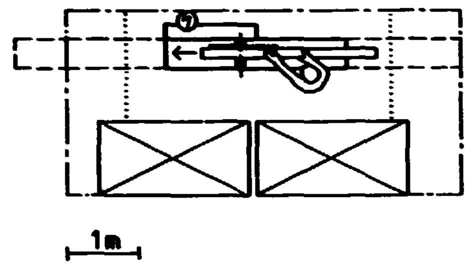


Figure 122. Working station for slot boring

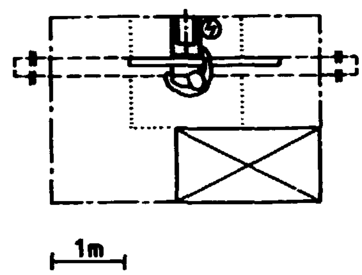
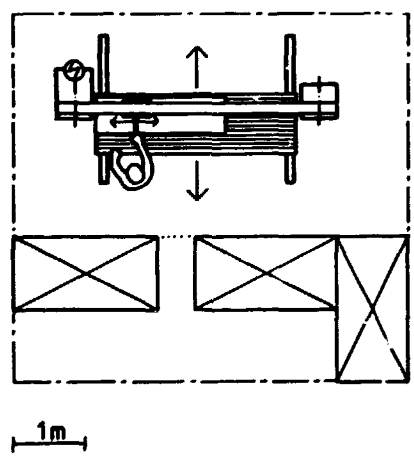


Figure 123. Working station for horizontal-belt sanding

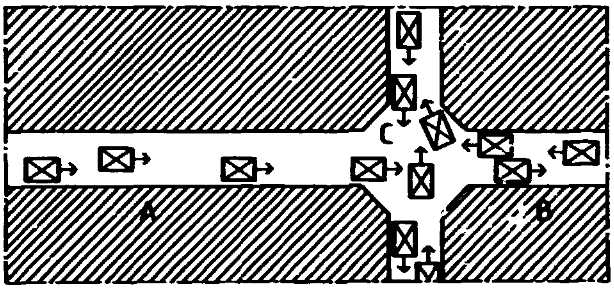


Load transportation (on pallets) must be in a continuous one-way direction in factory passages. Opposing and crossing traffic must be avoided (figure 124).

The areas needed for various kinds of storage are always noticeably large in furniture and joinery factories—roughly one half of total factory area in many plants. Two kinds of storage areas are needed for components and products under manufacture:

Intermediate storage between different work stages (free floor area between machines or other work places)
Storage areas between main manufacturing stages (such as for machined parts, assembled products, finished parts and finished products)

Figure 124. Pallet transportation



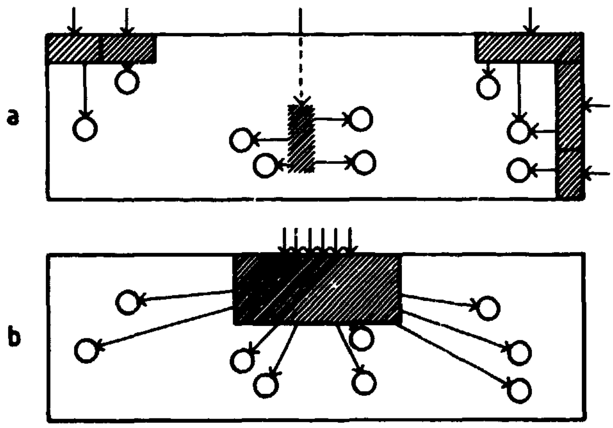
Key: A Continuous one-way direction (preferred)
B, C Opposing and crossing traffic (to be avoided)

Further storage facilities are needed for the following items:

Kiln-dried timber
Veneers
Wood-based panels, plastic laminates etc.
Glues
Fittings and hardware, sanding materials etc.
Upholstery materials
Surface-finishing materials
Packing materials

The storage areas must be easily accessible from the factory side by workers and from outside by trucks or railway cars. Storage areas located too centrally cause wasted time owing to the long distances from the remoter parts of the plant to its centre. It is thus more rational to place storage areas near the points where the materials in question will be needed (figure 125).

Figure 125. Location of storage areas

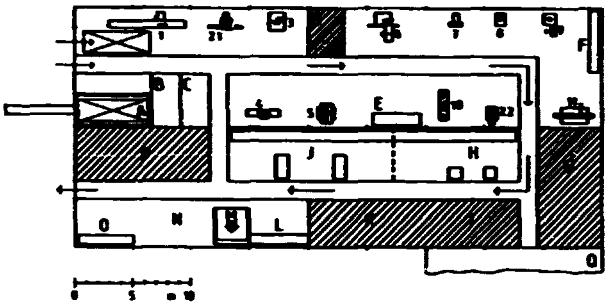


Key: a Dispersed areas (preferable)
b Central area

Electrical installations and pipe networks (e.g. for waste extraction and compressed air) are generally positioned above the machines and equipment in the ceiling and trusses of a factory building to facilitate later rearrangements. Safety must be taken into consideration in all details of plant layout.

Two examples of final plant layout drawings for furniture factories are shown in figures 126 and 127.

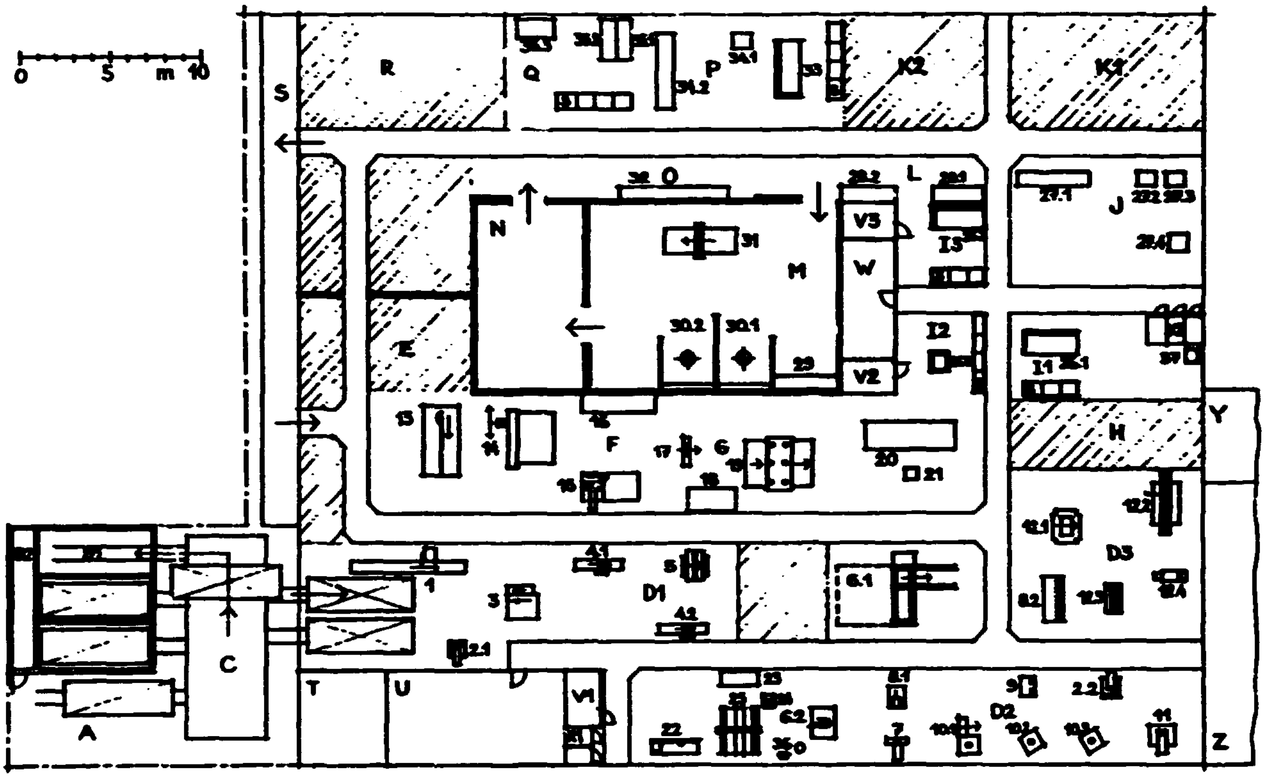
Figure 126. Plant layout for a small furniture factory producing only solid-wood furniture



Key:
A Drying kiln
B Tool room
C Supervisors
D Plywood storage
E Solid-wood panel gluing
F Manual sanding and other related work
G Storage for machined components
H Parts assembly (bases, frames, drawers etc.)
I Storage for assembled parts
J Final assembly
K Storage for assembled products
L Check-up before surface finishing and staining
M Lacquer spraying
N Lacquer drying
O Fixing of fittings and final check-up
P Packaging
Q Office

1 Cross-cut saw
2.1 Band saw (with detachable feed slide for first straight edge)
2.2 Band saw
3 Circular bench saw (for edging)
4 Surface planer
5 Thickness planer
6 Single-blade trim saw with feed table
7 Hollow-chisel mortiser
8 Borer
9 Vertical-spindle moulder (with detachable feed table for tenoning)
10 Lathe (tool manually operated)
11 Horizontal-belt sander

Figure 127. Plant layout for a medium-sized furniture factory producing both solid wood and panel furniture



Key:

A Kiln load piling
B1 Kiln compartment
B2 Kiln control room
C Traverse transport
D1 Machining shop
D2 Machining shop
D3 Machining shop
E Panel and veneer storage
F Veneer handling
G Hot pressing
H Stock area for machined components
I1 Detail assembly
I2 Detail assembly
I3 Detail assembly
J Final assembly
K1 Stock area for assembled products
K2 Stock area for assembled products
L Cleaning glue lines, putty-ing, repairing, checking before surface finishing
M Surface-finishing shop (with fire doors)
N Drying room (with fire doors)
O Sanding between coatings
P Assembly after surface finishing
Q Fixing of fittings, final check
R Stock area for finished products, packing
S Loading platform
T Chip and dust exhaust fan
U Tool room
V1 Supervisor (kiln drying and machining)
V2 Supervisor (veneering and assembly)
V3 Supervisor (surface finish-ing and shipping)
W Storage for hardware and fittings
X1 Toilets
X2 Toilets
Y Electric transformers and pneumatic compressors
Z Office

1 Cross-cut saw
2.1 Band saw
2.2 Band saw
3 Edging saw with return transport
4.1 Surface planer/compo-nents
4.2 Surface planer/edge straightening for solid-wood panel gluing
5 Thickness planer
6.1 Double-blade trimming saw
6.2 Single-blade saw bench
7 Hollow-chisel mortiser
8.1 Single-spindle boring ma-chine
8.2 Multi-spindle boring ma-chine
9 Multi-spindle dove-tailing machine
10.1 Vertical-spindle moulding machine with feed mechanism for tenoning
10.2 Vertical-spindle moulding machine
10.3 Vertical-spindle moulder
11 Router
12.1 Wide-belt sander
12.2 Horizontal double-belt sander
12.3 Vertical-belt sander
12.4 Form sander
13 Panel saw for particle boards etc.
14 Veneer saw
15 Veneer-jointer
16 Joint checking table (glass top, lamps below the top)
17 Glue spreader (for urea formaldehyde glue)
18 Stacking table
19 Hydraulic hot gluing press with loading and unload-ing racks
20 Edge-veneering table with pneumatic fire hose pressure units and re-sistance heating

Figure 127. *Key* **(continued)**

21	Transformer for resistance heating	27.1	Carcase clamp for cabinets, fire hose units	34.1	Carcase clamp, fire hose units
22	Semi-automatic lathe	27.2	Clamp for drawer unit bodies, fire hose units	34.2	Carcase clamp, fire hose units
23	Assorting table for panel gluing	27.3	Clamp for drawer unit bodies, fire hose units	35.1	Table for fixing of fittings, metal parts etc. after surface finishing
24	Glue spreader (for PVA glue)	27.4	Chair clamp with cylinders	35.2	Table for fixing of fittings, metal parts etc. after surface finishing
25	Mechanical press for solid-wood panel gluing, rotating construction	28.1	Handling table	35.3	Table for fixing of fittings, metal parts etc. after surface finishing
26.1	Pneumatic assembly table with cylinders	28.2	Handling table	36	Dowel-making equipment
26.2	Pneumatic assembly table with cylinders	29	Staining place with table	37	Dowel-driving equipment
26.3	Drawer clamps with pneumatic cylinder	30.1	Spraying cabin/lacquering	s	Storage shelves for small components
		30.2	Spraying cabin/painting		
		31	Curtain-coater		
		32	Sanding table		
		33	Pneumatic assembly table with cylinders		

The factory building

Modern factory buildings in the furniture and joinery industries have the following principal characteristics:

(a) The buildings are on one level. The avoidance of vertical transportation permits cheaper foundations and facilitates future expansions;

(b) The buildings are rectangular in form. In large buildings, natural illumination through skylights is possible through roof windows. In practice, however, electrical illumination is of decisive importance;

(c) Partition walls between sections are avoided (except in the surface-finishing section). It is especially for this reason that factories are provided with sprinkler networks;

(d) Pillars are avoided whenever possible;

(e) The number of corners is kept to a minimum;

(f) Future expansions are taken into consideration from the outset (figures 128 and 129).

Figure 128. Three-way expansion of a factory building (A commonly used method)

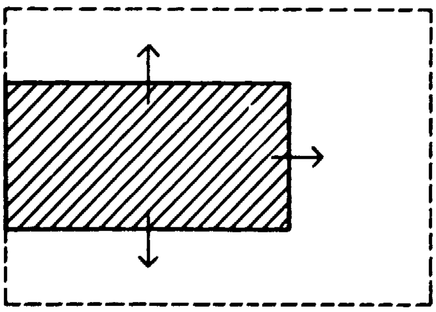
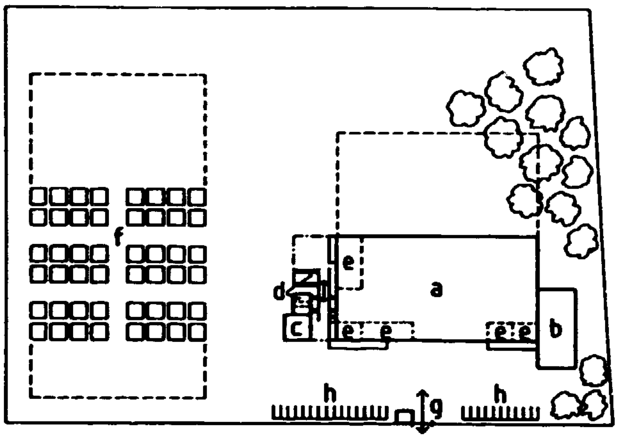


Figure 129. Example of planning the factory area



Key:
- a Production shop
- b Office
- c Boiler room
- d Kilns with sawn wood transportation facilities
- e Storage areas
- f Sawn wood yard
- g Gate
- h Car park

Factory area

In planning a factory area consideration is given to the following details:

(a) Positioning the factory building on the lot in such a way that future expansions will be possible. It is advantageous if the starting point of production can be maintained in spite of expansions;

(*b*) Placing the timber yard and outer storage areas so as to minimize transportation problems;

(*c*) Organizing a traffic plan within the factory area for the movement of people, raw materials, finished products etc.;

(*d*) Providing office space, either in the factory or in a separate building.

An example of factory area layout is presented in figure 129.

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XX. Methodology for the purchase of woodworking machines*

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

This chapter deals solely with this last topic, because in the selection of equipment the furniture and joinery industries of the developing countries lag a long way behind those of the developed countries. Industrialists in the developing countries have often purchased the wrong pieces or the wrong assortment of machines. Once this is done, scarce foreign currency—from the point of view of the national economy—has been misspent. In addition, at the level of profitability of the plant, the investment is unsound because poor use has been made of available funds, affecting the plant's overall profitability. In the developing countries capital is the scarcest resource, and misspent capital affects the company's profitability for the entire life expectancy of the machine. Because the industry of these countries is not developed, producers know more about one another than in the larger, more secretive conditions of the developed countries. Consequently, once a wrong decision has been made it is more difficult to get rid of an inappropriate machine in a developing country than in a developed country.

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

(a) Ignorance about what is needed;

(b) Ignorance about what is available;

(c) Ignorance about the specific requirements of the wood being machined;

(d) Lack of consideration of economics of scale and full utilization of the machine.

Other considerations also come into play when selecting a machine. In many instances manufacturing firms have no local representatives or, when they do exist, the machine in question only represents a very small part of the local firm's turnover, and the local firm's staff are not competent to give any technical advice. In the rare instances when technical advice is available, sales representatives are far better equipped than the purchaser, since they tend to know what is on the market and the shortcomings of their products compared to those of the competitors, and they can easily avoid mentioning these points. In this chapter an attempt will be made to give a methodology that 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 reasons:

(a) To mechanize manual operations thus reducing labour requirements (that is, increasing 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 that are dangerous.

In the developed countries there is one further reason that is seldom applicable in developing countries: to mechanize handling 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 the purchaser is in reality interested in obtaining a machine to perform a specific operation. It is useful before a decision to purchase a machine is made to use value analysis[1] for the components to be machined, in order to determine whether it is possible to use a simpler, and

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

[1]For a description of this management tool, see chapter XVI.

consequently less expensive, machine. Unfortunately, this can only be done in factories that specialize in selected ranges of products and manufacture their own line for the market, as opposed to factories (often the case in developing countries) that produce anything provided the price is right. Value 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 that 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 that have higher productivity, although they require longer machine set-up times;

(*d*) Machining requirements (type of operations, precision etc.): this is the last item in the value analysis of the components. The process presently used should be studied in depth to determine whether the machining operation can be carried out on an existing machine that 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 is seldom the case, as the tendency is to allow poor machining precision, and the object is then hand finished before assembly, which creates 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.

Once this analysis has been completed, the type and capacity of the machine to be purchased can be chosen. The result might be that, through improved efficiency, the purchase of components from outside or the re-designing 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.

In the case of secondary wood processing (such as the production of furniture and joinery), the production process is composed of various individual operations such as sawing, planing, shaping, sanding, boring, turning, gluing, nailing, coating etc. that can be performed using machines with similar basic functions; such machines are available with increasing levels of sophistication or additional functions. The level of sophistication necessary is, to a large extent, dependent on the required output, precision and labour costs. A descriptive list of types of machines is given in annex I. It could be of use in identifying and comparing options for various types of machines.

Assessment of existing resources

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

While in no way wishing to minimize the need to introduce changes and modern processing techniques in the developing countries, there is no point in purchasing a machine that is far more advanced technologically and in its operating precision than 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 the 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 the intermediate storage of components. A new machine would justify an increase of this area, but more often than not it is the cause for the reduction of this area. Thus, the advantages of the increased capacity are often lost owing 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 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 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, the availability of electric power sources with respect to available power, voltage and the number of phases must be considered. Sufficient supplies of compressed air at the required pressure must be available without starving machines further down the line of compressed air. Enough steam (for kiln and presses) at the required pressure as well as dust- and waste-extraction capacity must also be available. 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. Electric installations—including lighting—should be replaced by "explosion proof" equipment.

In considering the purchase of a machine, the effects of the introduction of a new machine on the existing toolroom 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 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 planer 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 those in developed countries and therefore labour-intensive methods of production should be encouraged. It is often overlooked that in this case productivity is often 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 amortization rate for equipment. This is not the tax-deductible depreciation allowed by law but a faster rate, related not to the life expectancy of machine for tax purposes but to the duration during which the machine is still considered technologically advanced. (This refers more to the machine's resale value than to its bookkeeping value.) In the case of special machines that are 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 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 should 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 for 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.[2] In many developed countries, there are

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[2]Some of these are given in chapter II, "Criteria for acceptance of and technical standar[illegible] woodworking machines", of *Technical Criteria for the Selectic[illegible] odworking Machines* (ID/247/Rev.1).

firms that specialize in the re-conditioning of machines. Purchasing such re-conditioned machines, provided that they are still suitable from a productivity point of view and are sold with a guarantee, should not be ruled out as inappropriate. When the firm has a good reputation, the concept of buying a re-conditioned second-hand machine should not be rejected;

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

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

If the above points are taken into account, 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, the size of batches etc. After the use of hand tools, the first stage in mechanization is to use power tools. However, even heavy-duty power tools are inadequate for continuous industrial production because of lack of precision and worker fatigue (except in assembly operations such as sanding, nailing, screwing, 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 actual technical specifications of the machine to be purchased can be decided upon.

An internationally accepted decimal classification of woodworking machines was adopted by the European Association of Woodworking Machinery Manufacturers (EUMABOIS) in 1965. This original classification, which was adopted by France and the Federal Republic of Germany as their national standards, has been updated by the technical committee of EUMABOIS and published as a second edition of the classification in 1980. It is given in annex II, and it will help an entrepreneur in a developing country to define the machines to be purchased in technical terms. The various specifications of the machine have to be clearly defined: in the case of thicknessers and sanders, for example, 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 not powerful enough for such heavy-duty work. Information must also be given on the power available; and it might prove useful to mention other characteristics that 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, or 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, purchasing without an 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 to 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. Good sources of addresses are the various national associations of woodworking machinery manufacturers of the various developed countries. These exist in Japan, the United States of America and most European countries (in the latter, grouped under EUMABOIS). Their addresses are given in the UNIDO *Information Sources on the Furniture and Joinery Industry.*[3] 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

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

best possible sources. A list of these specialized fairs and their scheduling is given in annex III.

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 simple, yet sturdy, designs suited to the conditions in other developing countries. It is important to note that the ideal solution would be to visit one of the specialized fairs.

Methodology for the comparison of bids received

The comparison of the bids received in reply to the inquiries 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 is to be purchased, for example, the following are some of the technical parameters that should be compared (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 constant, variable by stages or infinitely variable;

(c) The rated power of the motors driving machining heads and the feed chain. The suitability of the motors for machining dense tropical hardwoods;

(d) The number of cutter heads provided and their position;

(e) The possibility of incorporating additional machining heads at a later date;

(f) The rotation speed of the cutter heads;

(g) The availability of scribing saws;

(h) The possibility of rotating cutter heads for making mitred joints;

(i) The maximum and minimum size of saws (diameter) and cutter heads (diameter and height);

(j) The interchangeability of saws and cutter heads with other tools used in the factory;

(k) The level of precision for various machining operations;

(l) The ease of setting up the machine and ease of changing tools;

(m) The ease of maintenance (e.g. centralized lubrication);

(n) The type of electric controls required;

(o) The safety features of the machine;

(p) The consumption of compressed air (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 (not listed in order of importance):

(a) The production capacity (pieces of a given size per hour);

(b) The labour requirements (number and qualifications of workers);

(c) The cost of the basic machine;

(d) The cost of basic spare parts;

(e) The cost of attachments that could be purchased at a later date;

(f) The cost of auxiliary equipment needed in the tool room and equipment for dust extraction;

(g) The cost of tools for the various machining heads;

(h) The cost of installing the machine (including foundations, electric and pneumatic connections, dust extraction connections);

(i) The cost of training workers to operate the machine.

The following commercial considerations should be taken into account:

(a) The availability of services offered by a local agent;

(b) The existence in the plant of machines from 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 an instruction manual in a locally understood language for installing and operating the machine;

(h) The currency of payment and currency guarantee clauses;

(i) The *force majeure* clause;

(j) The conditions for price increases at the 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 that the purchaser has to provide;

(b) Items that the supplier states should be obtained locally (starters, motors etc.) and that 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, it is not possible to 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 IV. By now some of the considerations listed are obsolete technologically. However, these have to be updated, and a similar list would have to be devised for each and every special processing line.

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 impartial, free-lance industrial consultants specialized in the woodworking sector, 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 have even 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

OPTION COMPARISON FOR WOODWORKING MACHINES: TYPES OF MACHINES BY TYPE OF OPERATION*

A. *Sawing/cross cutting*

1. Portable circular saw (61.213.1)
   Circular saw guided by hand across the board for cutting to length.
2. Table band saw (12.121.51)
   Stationary band saw that could also be used for cross-cutting operations. Long boards have to be guided on supports.
3. Circular saw bench (12.131.36)
   Stationary circular saw that could also be used for cross-cutting operations by using a mitre fence or cross-cut jig for guiding long boards.
4. Cross-cut saw (12.131.1)
   Circular saw for cross-cutting operations of the radial-arm, pendulum or swing type. The guiding of the saw is either above or below the table.
5. Double cross-cut saw (12.132.31)
   Circular saw with two saw blades, one fixed and one with an adjustable blade. Stock to be cross cut will be guided on a sliding table between the two saw blades.
6. Multi trim saw (12.132.31)
   Set of circular saws on one shaft, placed at adjustable distances from one another, with a chain feed for the boards to be multiple cross cut.

B. *Sawing/ripping*

1. Portable circular saw (61.213.1)
   Circular saw moved by hand along a metal straight-line ripping guide to ease edging and ripping operations (machine proper basically the same as a portable circular saw (A.1)).
2. Table band saw (12.121.51)
   Stationary band saw equipped with a fence for guiding stock when ripping or re-sawing.
3. Circular saw bench (12.131.36)
   Stationary circular saw equipped with a fence for guiding stock when ripping.
4. Circular saw with mechanical feed (12.131.351)
   Machine with a single blade for straight-line ripping.
5. Multi-blade circular saw with mechanical feed (12.131.351)
   Same as B.4 above, but with multiple saw adjustment for multiple ripping.

C. *Planing*

1. Portable planer (61.22)
   Portable machine for surfacing stock, hand-guided or used as a stationary surfacer and jointer on a work-bench.
2. Surfacer and jointer (12.211.11)
   Stationary hand-fed planer for trueing surfaces and edges of boards and jointing edges (cutter block under table and stock).
3. Thicknesser (12.212)
   Stationary planer for thicknessing boards after trueing up (cutter block over table and stock).
4. Combined surfacer and thicknesser (12.81)
   Stationary planer with one cutter block for consecutive trueing up, edge jointing and thicknessing of stock.
5. Combined surfacer and edge jointer (12.221)
   Stationary planer with a horizontal cutter block and a vertical cutter head for trueing up of the surface and simultaneously jointing the edges.
6. Two-sided planer (12.223)
   Stationary planer with two horizontal cutter blocks, one on top and one below the table, for dressing two surfaces simultaneously.

*Listed in order of sophistication. Numbers refer to EUMABOIS Decimal Classification of Woodworking Machines. Given in annex II.

7. **Four-sided planer (12.34)**
Stationary planer with two horizontal cutter blocks and two vertical cutter heads for dressing two surfaces and two edges in one pass. Sophisticated planer moulders have more than four cutter heads.

D. *Shaping*

1. **Spindle moulder (12.311)**
Stationary moulder with a vertical spindle for straight or contoured work.

2. **Double-spindle moulder (12.311)**
Stationary moulder identical to D.1 except that it has two vertical spindles for straight or contoured work. The spindles can be used individually.

3. **Four-sided moulder (12.34)**
Stationary moulder with from 4 to 10 spindles in horizontal and vertical arrangement and mechanical feeding appropriate to the specific jobs.

4. **Single-spindle moulder with rotating table (12.315.11)**
Stationary moulder with a vertical spindle and a jig with chain that is engaged with a driving sprocket on the spindle. The machine is used for repetition, edge moulding and shaping.

5. **Double-spindle rotary profiler (12.315.31)**
Stationary machine with automatic rotating table and two follower spindles controlled along a template of the rotating table for machining edges.

6. **Single-spindle or double-spindle in-line profiler (12.315.21)**
Stationary machine with automatic straight feed of table and template control of tools for machining edges.

7. **Double-spindle shaper (12.322)**
Stationary machine with automatic straight feed of table and template control of tools operating on both sides of the table for machining stock on two edges in one pass.

E. *Tenoning*

1. **Table band saw (12.121.51)**
(Described under B.2.) Tenons can be made on a band saw following the scribe.

2. **Circular saw bench (12.131.36)**
(Described under B.3.) Tenons can also be made on a circular saw using the height of the saw and the fence (as a distance plate).

3. **Spindle moulder (12.311)**
Similarly, tenons can be made on a spindle moulder (described under D.1) fitted with a pair of oscillating saw blades (wobble-saw) or two tenoning discs.

4. **Single-end tenoner (82.1)**
Stationary machine with sliding table and two or more spindles for cross cutting and tenon shaping.

5. **Rounded-end tenoner (12.312)**
Stationary machine with a combined tool (saw, cutter head) moving around the end of stock for shaping rounded-end tenons fitting into slot-mortized holes.

6. **Double-end tenoner (82.2)**
Stationary machine with sliding table or continuous chain feed, machining both ends simultaneously while passing the different cutter heads for machining a centre or twin tenon.

7. **Corner-locking machine (12.313.1)**
Stationary machine with automatic rise and fall of table or cutter spindle for machining straight tenons for corner locking or with special tools for single-end tenoning.

F. *Combined machines—machining of solid wood*

1. **Combined circular saw, moulding and slot-mortising machine (12.84)**

2. **Combined surfacer, thicknesser, circular saw, slot mortiser (12.83)**
Stationary machines that can be used for different operations. Equipped with appropriate tools, operations described for individual machines can be performed. Only one operation can be carried out at one time.

G. *Round stock shaping (turning)*

1. **Turning lathe (12.61)**
Stationary machine for turning, using hand-guided tools.

2. **Back knife lathe (template control) (12.64)**
Stationary machine with template control for the gouges and chisels for machining shaped round stock.

3. **Spiral-moulding and fluting machine (12.315.39)**
Stationary machine with a routing unit for cutting plain or spiral work or fluting.

4. **Rotary-knife turning lathe (12.36)**
Stationary machine with a rotating knife (adze) set in the shape of the round stock profile; square and octagon turning is also possible.

5. **Turning lathe with shaping disc (12.39)**
Stationary machine with template control for the shaping disc.

6. **Multi-spindle copy lathe (12.315.31)**
Stationary machine with template control for reproducing simultaneously from 2 to 16 workpieces, which are shaped by cutterheads controlled by a master pattern.

7. **Centreless turning machine (12.35)**
Stationary machine with rotating cutter head through which the stock passes during the milling operation.

H. *Combined machines—turning, shaping, sanding*

1. **Turning/shaping/sanding (boring) (82.9)**
Stationary machine with turning or shaping units followed by a sanding unit so that shaping and sanding are performed in one pass. A subsequent boring operation is also possible.

I. *Drilling/routing*

1. **Power drill (61.24)**
Hand-held machine for drilling and boring operations. A boring jig can be used for repetitive work.

2. **Drill press (12.41)**
Vert[illegible] stationary machine for drilling holes mounted on a work-bench or on the floor (column type).

3. **Single-spindle boring machine (12.41)**
Stationary machine for horizontal drilling and boring operations.

4. **Slot-mortizing and boring machine (12.531.1)**
Stationary machine that can be used for horizontal boring operations and, when using mortize bits, for slot-mortizing operations.

5. **Chisel mortizer (12.511)**
Stationary machine with chisel for machining square or rectangular holes (mortizes).

6. **Chain mortizer (12.521.1)**
Stationary machine with mortize chain for machining rectangular or round-ended slots. The bottom of the hole is semicircular.

7. **Multi-spindle dowel-hole boring machine (12.432.2)**
Stationary machine with boring bar for boring a number of dowel holes simultaneously.

8. **Portable router (61.23)**
Portable machine with routing bits to perform various operations depending on the tool used. A portable router equipped with a different base plate can also be used as a stationary machine.

9. **Router with guide fin (12.315.12)**
Stationary machine with a vertical overhead routing unit and former pin corresponding to the router bit guiding jigs.

10. **Dovetailer (12.313.2)**
Stationary machine with one or a multiple set of dovetail bits for machine-dovetailed corner joints.

11. **Overhead recessing machine (12.314)**
Stationary machine equipped with cross slide for recessing, stair housing, boring (large diameter), lapping, moulding, pattern making etc.

12. **Multi-spindle carving machine (12.315.39)**
Stationary machine with up to 16 rectangular or square workpieces for flat stock. The routing bits are controlled by a tracer pin following the master pattern.

J. *Joining solid wood*

1. **Glue jointer (31.121.1)**
Single opening clamp with one or several sections for glueing stock. Pressure is applied by a screw, cam or pneumatic cylinder. No heating available.

2. **Clamp carrier (31.13)**
Multi-station rotary or chain clamp for glueing stock. Pressure is applied by a screw, cam or pneumatic cylinder. No heating available.

3. **Radio frequency (RF) glue jointer (31.13)**
Stationary or continuous operating press (see J.1 and J.2 above) with a RF curing unit.

K. *Finger jointing*

1. **Spindle moulder (used for finger jointing) (12.311)**
Standard stationary moulder fitted with a special tool.

2. **Combined moulding head with glue applicator and clamp (83.22)**
Combined stationary machine consisting of a mobile machining head and a glue applicator (brushes, spraying etc.) followed by a pneumatic or hydraulic clamping device.

3. **Combined machine (as K.2) with RF or other heating (83.22)**
Combined stationary machine (as K.2) with RF heating to cure the adhesive.

4. **Combined machine (as K.3), plus cut-off saw (83.22)**
Combined stationary machine (as K.3) with automatic cut-off circular saw to cut finger-jointed pieces to the required length.

L. *Fasteners (nailing and stapling)*

1. **Staplers (61.32)**
Hand-operated machine for fastening with staples; pneumatic or electric drive.

2. **Nailers (61.31)**
Hand-operated machine for fastening with nails or corrugated fasteners; pneumatic or electric drive.

3. **Portable power screw driver (61.33)**
Hand-operated machine with automatic feeding system.

4. **Single- or multi-head nailer (32.11)**
Stationary machine with one or more nailing heads for driving one nail or nail sets simultaneously.

5. **Single or multi-head nailer with automatic feed (32.11)**
Same as L.4, except for mechanical feeding of stock to be nailed.

6. **Wire-stitching machine (32.19)**
Stationary machine for driving staples cut and formed from wire rolls.

7. **Screw setting and driving machine (32.15)**
Stationary machine with one or more driving heads for driving one screw or screw sets simultaneously.

M. *Sanding of solid-wood components*

1. **Pad sander (61.261.1)**
Portable sander with oscillating pad for smoothing surfaces; electric or pneumatic.

2. **Edge and contour sander (12.721.4)**
Stationary machine with narrow sanding belt for straight-edge and contour sanding.

3. **Bobbin sander (12.741.1)**
Stationary machine with a vertical bobbin for sanding inside contours or large holes.

4. **Brush-backed sander (12.749)**
Stand with horizontal spindle, equipped with a brush drum on which sanding strips are fixed at one end and backed by rows of brushes.

5. **Flexible drum sander (12.742.11)**
Stand with horizontal spindle, equipped with a pneumatic drum for polishing three-dimensional stock.

6. **Profile sander (12.753)**
Stationary belt or roller sander for sanding profiles (mouldings) by belt with counter-profiled back or rollers with sanding sleeves.

7. **Convertible-belt, drum and disc sander (12.75)**
Stationary machine with belt-sanding unit that can work in a horizontal or upright position. One pulley is extended to be equipped with a sanding disc and/or a sanding drum.

N. *Surface finishing*

1. **Dipping equipment (34.25)**
Equipment with a dipping unit for individual components or mass elements to be coated by dipping.

2. **Portable spray-coating equipment (61.42)**
Portable spray guns operating with compressed air or electrically with cold or hot spray systems.

3. **Fixed spray-coating equipment (34.24)**
Same as N.2 but fixed. When using specially prepared lacquers, electrostatic charges can be applied to the

workpiece to save paint. Components to be painted are advanced mechanically.

4. Roller coater (34.21)
Stationary machine for applying lacquers to surfaces either through direct or reverse roller coater. Components to be coated are advanced by the rollers.

5. Curtain coater (34.22)
Stationary machine for applying lacquers to surfaces by pouring lacquers through a slit nozzle. Components are advanced mechanically.

O. *Sanding of coated surfaces*

1. Denibbing sander (12.71)
Stationary machine for smoothing surfaces with a prime coat.

2. Buffing machine (12.763)
Stationary machine equipped with buffing drums or belts for polishing high-gloss surfaces.

P. *Panel sizing*

1. Vertical panel saw (12.131.261)
Stationary machine with vertical support and a guide-sawing unit mounted on a vertical guide rail travelling horizontally so that vertical and horizontal sawing is possible.

2. Single-blade horizontal panel saw (12.131.21)
Stationary machine with an overhead or under-table travelling saw unit for subdividing panels. If the overhead saw unit can turn 90°, panels can be subdivided in two directions.

3. Double-blade horizontal panel saw (12.132.26)
Stationary machine with sawing units that are adjustable at right angles for sawing in two directions.

Q. *Veneer jointing*

1. Hand-operated veneer pack jointer (11.52)
Stationary machine with a hand lever for veneer pack jointing as well as cross-cutting.

2. Veneer saw (manual feed of saw) (12.131.22)
Stationary machine with manual feed of saw unit to joint veneer packs.

3. Veneer saw (automatic feed of saw) (12.131.22)
Stationary machine with automatic feed of saw unit to joint veneer packs.

4. Mechanically operated veneer pack jointer (11.52)
Stationary machine with knife for joint veneer packs.

5. Combined pack jointer with glue spreader (83.24)
Stationary machine with jointing unit (11.52) and glue spreader (34.111).

R. *Veneer splicing*

1. Tape splicer (31.111.1)
Stationary machine with glue tapes for splicing veneer sheets lengthwise.

2. Tapeless veneer splicer (31.119.1)
Stationary machine with heating bar and jointing rollers for continuous splicing of veneer sheets (uses PVA glue).

3. Glue spot splicer (31.119.1)
Stationary machine with splicing unit using glue spots across the veneer joint (uses hot melt glue).

4. Zig-zag veneer splicer (31.119.1)
Stationary machine applying thermoplastic thread in zig-zag form across the veneer joint.

S. *Glue spreading*

1. Single-side edge glue spreader (34.111)
Bench-type glue spreader for glue coating of narrow workpieces.

2. Single-side glue spreader with scraper blade (34.112)
Stationary machine for direct glue coating one side of the substrate or veneer.

3. Double-side glue spreader with doctor roll (34.112)
Stationary machine for glue coating two sides of a substrate in one pass.

T. *Veneering*

1. Cold press, single (large) opening (31.331.1)
Veneering press with pressure applied by screw or pneumatic or hydraulic non-heated platens.

2. Single-opening press (31.331.1)
Veneering press with electrically heated platens.

3. Multi-opening press (31.331.1)
Veneering press with platens heated electrically by hot water or steam or thermal oil.

4. Mould press (31.312)
Single-opening press with forming die for glueing shaped plywood. For rapid curing of adhesives RF units can be applied.

5. Laminating press (31.322)
Press for laminating substrates with duroplastics or thermoplastics.

6. Single-opening short-cycle press (31.331.2)
Veneering press with endless belt for infeed and outfeed of stock. Steam, hot-water or thermal-oil heating.

7. Shuttle feed press with one or two openings (31.331.2)
Veneering press with two shuttle platens for reciprocal loading. Steam, hot-water or thermal-oil heating.

8. Profile laminating press (83.17)
Post-forming of laminate to profiled stock.

U. *Panel trimming*

1. Panel-sizing circular saw (12.131.371)
Stationary machine with table extension and additional panel support.

2. Panel-sizing circular saw with scoring unit (12.131.372)
Stationary machine with extended ripping slide and extended panel support plus a scoring unit.

3. Double-blade panel trim saw (12.132.31)
Stationary machine with sliding table for panel sizing.

4. Double-end tenoner (82.2)
Stationary machine with chain feed for panel sizing.

V. *Edge banding*

1. Edge-banding clamp (31.41)
Vertical or horizontal clamp with heated bars for edge banding in a fixed position.

2. Frame clamp (31.41)
Vertical frame clamp with electrically heated bars for edge banding in a fixed position.

3. Edge-banding table (31.41)
Table with adjustable electrically heated clamps for edge banding in a fixed position.

4. Contour edge bander (31.42)
Stationary machine for contour edge banding in a fixed position.

W. *Veneer edge trimming*

1. Veneer knife (hand tool)
Hand block with a fixed knife for flush cutting of veneer.

2. Portable veneer edge saw (61.213.9)
Hand-operated tool with one or two saws on the same shaft for flush cutting of veneer.

3. Edge router (61.231)
Portable router with cutter for flush trimming of veneer.

Y. *Combined edge banding and machining*

1. Single-edge banding and veneer edge-cutting machine (83.151)
Stationary machine for single edge banding and veneer edge cutting.

2. Single edge-banding, veneer-cutting and sanding machine (83.151)
Stationary machine with chain feed for edge banding, flush cutting, cut off, sanding and chamfering.

3. Double edge bander (83.152)
Stationary machine with chain feed, same as Y.2, except that it operates on both edges simultaneously.

4. Double-edge sizing and edge-banding machine (83.21)
Stationary machine with chain feed for double sizing, banding, flush cutting, cut off, sanding and chamfering.

Z. *Boring machines for panel components*

1. Boring machine with single- or multi-spindle head (12.41)
Stationary machine with single-spindle and multi-spindle boring heads.

2. Multi-spindle dowel-hole boring machine (12.432.2)
Stationary multi-spindle boring machine for boring dowel holes in vertical and/or horizontal position.

3. Multi-spindle boring machine with chain feed (12.432.2)
Stationary machine with automatic infeed and workpiece positioning for multi-boring operations in two directions.

Annex II

TECHNICAL CLASSIFICATION OF WOODWORKING MACHINES AND AUXILIARY MACHINES FOR WOODWORKING*

Introduction

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

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

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

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

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

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

Comité européen des Constructeurs de Machines à Bois (EUMABOIS)
150, boulevard Bineau, F-92200 Neuilly-sur-Seine (France).
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Foreword

(Very important)

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

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

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

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

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

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

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

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

Definitions

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

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

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

*Published by the European Committee of Woodworking Machinery Manufacturers in 1980.

1 Cutting machines change the shape or dimension of a workpiece:

a) without removal of chips (11)

b) with removal of chips (12)

11 Chipless machines change the shape or dimension of a workpiece:

11.1 Cleaving is riving the fibre bond by wedge action.

11.2 Reducing machines effect the chipless of the material 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, deckplaners etc.

62 Machining heads (unit heads) are self-contained production units designed for mounting on and supplementing existing machines, or when mounted on a separate base form an independent machine.

8 Multi-purpose machines using working methods covered by groups 1 to 6; in these machines, the workpiece, after initial entry is fully processed without further manual assistance.

91 The special machines or sets of special machines are designed for the sole purpose of manufacturing particular end products.

1 MACHINES DE DÉBITAGE

11 Machines travaillant sans enlèvement de copeaux

11.1 Machines à fendre :
- 11.11 Machines à fendre les rondins
- 11.12 Machines à fendre le bois de chauffage
- 11.13 Machines à fendre les rhizomes
- 11.14 Machines à fendre les verges de saule et les joncs d'Inde
- 11.19 Autres machines à fendre

11.2 Machines à fragmenter le bois :
- 11.21 Machines à faire des éclats de bois
- 11.22 Machines à couper les bois ou les éclats pour obtenir des particules
- 11.23 Machines à défibrer les éclats ou autres pièces de bois
- 11.24 Machines à broyer à outils travaillant par chocs
- 11.25 Machines à faire la laine de bois
- 11.29 Autres machines à fragmenter le bois

11.3 Machines à estamper (ex. : estampeuses à placage)

11.4 Machines à trancher :
- 11.41 Machines à faire les planchettes :
  - 11.411 mouvement alternatif du porte-outil
  - 11.412 mouvement rotatif du porte-outil
  - 11.413 mouvement basculant du porte-outil
- 11.42 Machines à faire les feuilles de placage :
  - 11.421 trancheuses
    - 11.421.1 course verticale
    - 11.421.2 course horizontale
    - 11.421.3 course inclinée
  - 11.422 dérouleuses
- 11.49 Autres machines à trancher

11.5 Machines à cisailler de placage :
- 11.51 Massicots pour placage isolé
- 11.52 Massicots pour paquets de placage
- 11.53 Machines à découper le placage (ex. contourneuses à marqueterie)
- 11.59 Autres machines à cisailler le placage

11.9 Autres machines travaillant sans enlèvement de copeaux (ex. : cisailles circulaires à panneaux de fibres, machines à trancher le bois en bout, machines à trancher les croisées de fenêtres, découpeuses à bois de gazogène etc.).

12 Machines travaillant par enlèvement de copeaux :

12.1 Machines à scier :
- **12.11 Machines à scier, outil à mouvement alternatif :**
  - 12.111 Scies à tronçonner :
    - 12.111.1 fixes
    - 12.111.2 transportables
  - 12.112 Scies à chantourner
  - 12.113 Scies alternatives horizontales
  - 12.114 Scies alternatives verticales :
    - 12.114.1 fixes
    - 12.114.2 transportables
  - 12.119 Autres scies, outil à mouvement alternatif
- **12.12 Machines à scier, outil à mouvement de révolution :**
  - **12.121 Machines à scier à ruban :**
    - 12.121.1 Machines à scier à ruban, à grumes :
    - 12.121.11 horizontales :
    - 12.121.111 fixes :
    - 12.121.111.1 à chariot mobile

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 (eg: 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 (eg: 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

1 MASCHINEN ZUM TRENNEN

11 Maschinen zum Teilen:

11.1 Spaltmaschinen:
- 11.11 Rollenspaltmaschinen
- 11.12 Brennholzspaltmaschinen
- 11.13 Wurzelstockspaltmaschinen
- 11.14 Weidenruten- und Peddigrohrspaltmaschinen
- 11.15 Baumabechermaschinen
- 11.19 Sonstige Spaltmaschinen

11.2 Zerkleinerungsmaschinen:
- 11.21 Hackmaschinen
- 11.22 Spanschneidemaschinen
- 11.23 Zerfaserungsmaschinen
- 11.24 Mühlen
- 11.25 Holzwolleschneidemaschinen
- 11.29 Sonstige Zerkleinerungsmaschinen

11.3 Stanzmaschinen (z.B. Furnierstanzen)

11.4 Schneidemaschinen für die Erzeugung von Brettchen und Furnieren:
- 11.41 Brettchenschneidemaschinen:
  - 11.411 mit hin- und hergehenden Messern
  - 11.412 mit kreisenden Messern
  - 11.413 mit wippenden Messern
- 11.42 Schneidemaschinen für die Furniererzeugung:
  - 11.421 Furniermessermaschinen
    - 11.421.1 Vertikale Schnittbewegung
    - 11.421.2 Horizontale Schnittbewegung
    - 11.421.3 Schräge Schnittbewegung
  - 11.422 Furnierrundschälmaschinen
- 11.49 Sonstige Schneidemaschinen

11.5 Furnierscheren:
- 11.51 Furnierscheren für einzelne Furniere
- 11.52 Furnierpaketschneidemaschinen
- 11.53 Furnierkonturscheren
- 11.59 Sonstige Furnierscheren

11.9 Sonstige Teilmaschinen (z.B. Hartfaserplatten-Streifenschneidemaschinen bzw. Rollenscheren, Gehrungsschneid- und Bestoßmaschinen, Tankholzhackmaschinen...)

12 Maschinen zum Spanen:

12.1 Sägemaschinen:
- **12.11 Sägemaschinen mit hin- und hergehendem Werkzeug:**
  - 12.111 Fuchsschwanzsägemaschinen:
    - 12.111.1 stationäre
    - 12.111.2 fahrbare
  - 12.112 Dekupiersägemaschinen
  - 12.113 Horizontalgatter
  - 12.114 Vertikalgatter:
    - 12.114.1 stationäre
    - 12.114.2 transportable
  - 12.119 Sonstige Sägemaschinen mit hin- und hergehendem Werkzeug
- **12.12 Sägemaschinen mit umlaufendem Werkzeug:**
  - 12.121 Bandsägemaschinen:
    - 12.121.1 Blockbandsägemaschinen:
    - 12.121.11 horizontale:
    - 12.121.111 stationäre:
    - 12.121.111.1 Wagenvorschub

12.121.111.2 à bâti mobile	12.121.111.2 stationary log, mobile machine	12.121.111.2 Rahmenvorschub
12.121.112 transportables avec chariot mobile	12.121.112 transportable with mobile log carriage	12.121.112 transportable mit Wagenvorschub
12.121.12 verticales :	12.121.12 Vertical:	12.121.12 vertikale:
12.121.121 fixes :	12.121.121 non transportable:	12.121.121 stationäre:
12.121.121.1 avance manuelle du chariot	12.121.121.1 hand feed of carriage	12.121.121.1 Wagenvorschub von Hand
12.121.121.2 avance automatique du chariot	12.121.121.2 automatic feed of carriage	12.121.121.2 Wagenvorschub automatisch
12.121.121.21 monolame	12.121.121.21 single-blade	12.121.121.21 mit 1 Sägeblatt
12.121.121.22 multilames	12.121.121.22 multi-blade	12.121.121.22 mit mehreren Sägeblättern
12.121.122 transportables :	12.121.122 transportable:	12.121.122 transportable:
12.121.122.1 avance manuelle du chariot	12.121.122.1 hand feed of carriage	12.121.122.1 Wagenvorschub von Hand
12.121.122.2 avance automatique du chariot	12.121.122.2 automatic feed of carriage	12.121.122.2 Wagenvorschub automatisch
12.121.2 Machines à scier à ruban, à chariot libre :	12.121.2 Band sawing machines with carriage but without dogging:	12.121.2 Bandsägen mit Freilaufwagen ohne Spannelemente:
12.121.21 fixes :	12.121.21 non transportable:	12.121.21 stationäre:
12.121.211 avance manuelle du chariot	12.121.211 hand feed of carriage (push bench)	12.121.211 Wagenvorschub von Hand
12.121.212 avance automatique du chariot	12.121.212 automatic feed of carriage (rack bench)	12.121.212 Wagenvorschub automatisch
12.121.22 transportables :	12.121.22 transportable:	12.121.22 transportable:
12.121.221 avance manuelle du chariot	12.121.221 hand feed of carriage	12.121.221 Wagenvorschub von Hand
12.121.222 avance automatique du chariot	12.121.222 automatic feed of carriage	12.121.222 Wagenvorschub automatisch
12.121.3 Machines à scier à ruban, à table à rouleaux :	12.121.3 Band sawing machines with rollers or roller table:	12.121.3 Bandsägemaschinen mit Rollentisch oder Rollenbahn:
12.121.31 fixes :	12.121.31 non-transportable:	12.121.31 stationäre:
12.121.311 avec chariot	12.121.311 with push table	12.121.311 mit Wagen
12.121.312 sans chariot	12.121.312 without push table	12.121.312 ohne Wagen
12.121.32 transportables :	12.121.32 transportable:	12.121.32 transportable:
12.121.321 avec chariot	12.121.321 with push table	12.121.321 mit Wagen
12.121.322 sans chariot	12.121.322 without push table	12.121.322 ohne Wagen
12.121.4 Machines à scier à ruban, à refendre :	12.121.4 Band resawing machines:	12.121.4 Trennbandsägemaschinen:
12.121.41 horizontales	12.121.41 horizontal	12.121.41 horizontale
12.121.42 verticales :	12.121.42 vertical:	12.121.42 vertikale:
12.121.421 à dédoubler ou à refendre	12.121.421 self-centring and gauge cutting	12.121.421 für Mittel- und Trennschnitt
12.121.421.1 monolame	12.121.421.1 single-blade	12.121.421.1 mit 1 Sägeblatt
12.121.421.2 multilames	12.121.421.2 multi-blade	12.121.421.2 mit mehreren Sägeblättern
12.121.429 autres (bois de mine etc.)	12.121.429 others (eg: for mine timber etc.)	12.121.429 sonstige (Grubenholz-Spaltbandsägemaschinen usw.)
12.121.5 Machines à scier à ruban, à table :	12.121.5 Table band sawing machines:	12.121.5 Tischbandsägemaschinen:
12.121.51 machines fixes	12.121.51 non-transportable	12.121.51 stationäre
12.121.52 machines transportables	12.121.52 transportable	12.121.52 fahrbare
12.121.9 Autres machines à scier à ruban (ex. : scies à rubans multiples pour faire les frises de parquets, scies pour l'industrie papetière, scies à ruban à 3 volants, scies à ruban inclinable etc.)	12.121.9 Other band sawing machines (eg. multi-blade band sawing machines for parquet strips, pulpwood cross-cutting band sawing machines, three pulley band sawing machines, band rip sawing machines)	12.121.9 Sonstige Bandsägemaschinen (z.B. Mehrblattbandsägemaschinen für Parkettriemen, Schleifereisägen, Dreirollenbandsägemaschinen, Maschinen mit neigbarem Sägerahmen)
12.122 Scies à chaîne :	**12.122 Chain sawing machines:**	**12.122 Kettensägemaschinen:**
12.122.1 pour coupe transversale	12.122.1 Cross-cutting chain sawing machines	12.122.1 für Querschnitt
12.122.2 pour coupe longitudinale	12.122.2 Chain sawing machines for log breakdown	12.122.2 für Längsschnitt
12.122.9 autres scies à chaîne	12.122.9 Other chain sawing machines	12.122.9 sonstige Kettensägemaschinen
12.13 Machines à scier, outil à mouvement circulaire :	**12.13 Sawing machines with rotating tool:**	**12.13 Sägemaschinen mit sich drehendem Werkzeug:**
12.131 Scies circulaires monolame :	**12.131 Single blade circular sawing machines:**	**12.131 Einblattkreissägemaschinen:**
12.131.1 Scies circulaires monolame, outil mobile pour coupe transversale :	**12.131.1 Single blade stroke circular sawing machines for cross-cutting:**	**12.131.1 Einblatthubkreissägemaschinen für Querschnitt:**
12.131.11 à mouvement d'avance curviligne de l'outil :	12.131.11 with arcuate tool stroke:	12.131.11 mit bogenförmiger Vorschubbewegung des Werkzeuges:
12.131.111 scies circulaires pendulaires avec axe d'articulation en haut	12.131.111 with axis of articulation above workpiece (pendulum)	12.131.111 Pendelkreissägemaschinen
12.131.112 scies circulaires pendulaires avec axe d'articulation en bas	12.131.112 with axis of articulation below workpiece	12.131.112 kippende Kappkreissägemaschinen

12.131.113	scies circulaires basculantes avec bras horizontal	with axis of articulation level with workpiece (snipper)	wippende Kappkreissägemaschinen
12.131.119	autres, à mouvement d'avance curviligne de l'outil	Other with arcuate tool stroke	sonstige mit bogenförmiger Vorschubbewegung des Werkzeuges
12.131.12	à mouvement d'avance rectiligne de l'outil :	with straight-line tool stroke:	mit geradliniger Vorschubbewegung des Werkzeuges:
12.131.121	scies circulaires à mouvement parallèle	Parallel link sawing machines	Parallelschwingkreissägemaschinen
12.131.122	scies radiales	Overhead arm supporting moving saw carriage	Auslegerkreissägemaschinen
12.131.129	autres, à mouvement d'avance rectiligne de l'outil	Other with straight-line tool stroke	Sonstige mit geradliniger Vorschubbewegung des Werkzeuges
12.131.19	autres scies circulaires monolame à outil mobile pour coupe transversale	Other single blade circular sawing machines for cross cutting	Sonstige Einblatthubkreissägemaschinen für Querschnitt
12.131.2	scies circulaires monolame, outil mobile, coupe longitudinale et en direction variées :	single blade stroke circular sawing machines, cutting lengthwise and in various directions:	Einblatt-Hubkreissägemaschinen Schnitt in Längs- und in verschiedenen Richtungen
12.131.21	coupe longitudinale pour bois massifs et panneaux	cutting lengthwise for solid wood and panels	Für Längschnitt von Massivholz und Platten
12.131.22	coupe longitudinale pour paquets de placage	cutting lengthwise for veneer packages	Für Längsschnitt von Furnierpaketen
12.131.25	coupe longitudinale autres	other cutting lengthwise	Für sonstige Längsschnitte
12.131.26	coupe longitudinale et transversale :	cutting lengthwise and crosswise:	Für Längs- und Querschnitt:
12.131.261	scies à panneaux sur chevalet	panel sizing saw machines	Gestellkreissägemaschinen
12.131.3	**Scies circulaires monolame, outil à position fixe :**	**Single blade non-stroke circular sawing machines:**	**Hublose Einblattkreissägemaschinen:**
12.131.31	scies circulaires monolame à grumes avec table mobile	Log circular sawing machines with carriage	Blockkreissägemaschinen mit Laufwagen
12.131.32	scies circulaires monolame à grumes avec table à rouleaux	log circular sawing machines with roller table	Blockkreissägemaschinen mit Rolltisch
12.131.33	scies circulaires monolame à dédoubler avec aménage par cylindres	Resawing machines with roller feed	Trennkreissägemaschinen mit Walzenvorschub
12.131.34	scies circulaire monolame de précision avec table mobile pour planchettes	Precision cut circular sawing machines with travelling table for small boards	Feinschnittkreissägemaschinen mit beweglichem Tisch für Brettchen
12.131.35	scies circulaire monolame, à déligner :	Single blade edging circular sawing machines:	Einblatt-Besäumkreissägemaschinen:
12.131.351	déligneuses à aménage à rouleaux ou à chaînes	edging circular sawing machines with roller or chain feed	Besäumkreissägemaschinen mit Walzen-oder Plattenbandvorschub
12.131.352	déligneuses avec table mobile	edging circular sawing machines with moving table	Besäumkreissägemaschinen mit Laufwagen
12.131.36	scies circulaires monolame à table, de menuisier, avec ous sans table mobile	Single blade circular saw benches with tilting and vertical saw adjustment with or without travelling table	Tischkreissägemaschinen für Tischler (auch mit Schiebetisch)
12.131.37	scies circulaires monolame à table, spéciales :	Single blade circular sawing machines for special purpose:	Tischkreissägemaschinen für Sonderzwecke:
12.131.371	scies circulaires avec table mobile pour coupe transversale	sliding table circular sawing machines for cross-cutting	Schiebetischkreissägemaschinen für Querschnitt
12.131.372	scies circulaires au format avec table mobile	circular sawing machines for firewood table (dimension saw)	Formatkreissägemaschinen
12.131.373	scies circulaires de chantier	circular sawing machines for building sites	Baustellenkreissägemaschinen
12.131.374	scies circulaires à bois de chauffage	circular sawing machines for firewood	Brennholzkreissägemaschinen
12.131.39	autres scies circulaires monolame, outil à position fixe	Other single blade non-stroke circular sawing machines	Sonstige hublose Einblattkreissägemaschinen
12.131.9	autres scies circulaires monolame	Other single blade circular sawing machines	Sonstige Einblattkreissägemaschinen

12.132 **Scies circulaires à deux ou plusieurs lames :**

12.132.1 **Scies circulaires à deux ou plusieurs outils mobiles :**

12.132.11 scies circulaires pour coupes parallèles des panneaux

12.132.12 scies circulaires pour coupes d'équerre des panneaux

12.132.13 scies circulaires pour coupes parallèles et d'équerre des panneaux

12.132.14 scies circulaires à entailler pour pliage

12.132.15 scies circulaires à épauler

12.132.2 **Scies circulaires à deux ou plusieurs outils mobiles et outils à position fixe :**

12.132.21 scies circulaires pour coupes d'équerre des panneaux

12.132.22 scies circulaires pour coupes parallèles et d'équerre des panneaux

12.132.3 **Scies circulaires à deux ou plusieurs outils à position fixe :**

12.132.31 scies circulaires à tronçonner doubles et multiples

12.132.32 scies circulaires à 2 lames, à grumes et à bois équarris :

12.132.321 avec lames de scie sur le même plan

12.132.322 avec lames de scie sur plans parallèles

12.132.33 déligneuses multilames pour dégrossissage

12.132.331 lames à écartement fixe

12.132.332 lames à écartement réglable

12.132.34 déligneuses multilames de finition

12.132.39 autres scies circulaires à deux ou plusieurs outils à position fixe

12.132.9 **Autres scies circulaires, à deux ou plusieurs lames**

12.139 autres machines à scier, outil à mouvement rotatif (ex. : scies circulaire concave scies tubulaires)

12.2 **Machines à raboter :**

12.21 **Machines à raboter pour le travail sur une face :**

12.211 Machines à dégauchir :

12.211.1 machines à dégauchir avec porte-outil cylindrique à lames :

12.211.11 avec avance à main

12.211.12 avec entraînement automatique incorporé

12.211.2 machines à dégauchir avec plateau porte-lames circulaire en bout d'arbre

12.211.3 machines à dresser les paquets de placages

12.212 Machines à raboter avec outil rotatif

12.213 Machines à raboter a fers fixes

12.219 Autres machines à raboter pour le travail sur une face (ex. : raboteuses pour bois de grandes dimensions)

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 timbler 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

.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)

12.132 **Zwei- und Mehrblattkreissägemaschinen:**

12.132.1 **Doppel- und Mehrblatt-Hubkreissägemaschinen:**

12.132.11 Plattenformatkreissägemaschinen für Parallelschnitt

12.132.12 Plattenformatkreissägemaschinen für Winkelschnitt

12.132.13 Plattenformatkreissägemaschinen für Parallel- und Winkelschnitt

12.132.14 Kerbschnittkreissägemaschinen

12.131.15 Klinkschnittkreissägemaschinen

12.132.2 **Zwei- und Mehrblatthubkreissägemaschinen mit teils feststehenden Werkzeugen:**

12.132.21 Plattenformatkreissägemaschinen für Winkelschnitt

12.132.22 Plattenformatkreissägemaschinen für Parallel- und Winkelschnitt

12.132.3 **Hublose Zwei- und Mehrblattkreissägemaschinen:**

12.132.31 Doppel- und Mehrfachabkürzkreissägemaschinen

12.132.32 Zweiblatt-Block- und Kantholzkreissägemaschinen:

12.132.321 Sägeblätter in einer Ebene

12.132.322 Sägeblätter in parallelen Ebenen

12.132.33 Zwei- und Mehrblattkreissägemaschinen für Grobschnitt:

12.132.331 mit festem Sägeblattabstand

12.132.332 mit variablem Sägeblattabstand

12.132.34 Besäum- und Mehrblattleistenkreissägemaschinen für Feinschnitt

12.132.39 Sonstige hublose Zwei- und Mehrblattkreissägemaschinen

12.132.9 **Sonstige Zwei- und Mehrblattkreissägemaschinen**

12.139 **Sonstige Sägemaschinen mit sich drehendem Werkzeug** (z.B. Konkavsägemaschinen Zylindersägen)

12.2 **Hobelmaschinen:**

12.21 **Hobelmaschinen für einseitige Bearbeitung:**

12.211 Abrichthobelmaschinen:

12.211.1 Abrichthobelmaschinen mit Messerwelle:

12.211.11 Vorschub von Hand

12.211.12 mit eingebautem automatischem Vorschub

12.211.2 Abrichthobelmaschinen mit stirnendem Werkzeug

12.211.3 Fügehobelmaschinen für Furnierpakete

12.212 Dickenhobelmaschinen mit Messerwelle

12.213 Hobelmaschinen mit feststehendem Werkzeug

12.219 Sonstige Hobelmaschinen für einseitige Bearbeitung (z.B. einseitige Blockhobelmaschinen)

12.22 **Machines à raboter pour le travail sur deux faces :**
- 12.221 Machines à dégauchir et à dresser sur chant en une seule passe
- 12.222 Machines à raboter et à dresser sur chant en une seule passe
- 12.223 Machines à raboter en dessous et en dessus en une seule passe
- 12.229 Autres machines à raboter pour le travail sur deux faces (ex. : raboteuses sur deux faces pour bois de grandes dimensions)

12.23 **Machines à raboter pour le travail sur trois faces**, table mobile, arbre horizontal fixe

12.24 **Machines à raboter pour le travail sur quatre faces**, table mobile, arbre horizontal supérieur fixe :
- 12.241 arbre vertical fixe (ex. : corroyeuses)
- 12.242 arbre vertical reglable en hauteur

12.29 Autres machines à raboter

12.3 **Machines à fraiser, outil rotatif :**

12.31 **Machines à fraiser sur une face :**
- 12.311 Toupies monobroche et toupies à deux broches à entre-axes fixe
- 12.312 Tenonneuses simples à une broche avec ou sans scie circulaire amovible
- 12.313 Machines à faire les queues :
  - 12.313.1 les queues droites
  - 12.313.2 les queues d'aronde
  - 12.313.9 les queues autres
- 12.314 Défonceuses fraiseuses à modeleur et boîtes à noyaux
- 12.315 Machines à copier :
  - 12.315.1 avec gabarit pour guider la pièce à usiner :
    - 12.315.11 toupies
    - 12.315.12 défonceuses
    - 12.315.19 autres machines
  - 12.315.2 avec gabarit pour guider l'outil :
    - 12.315.21 toupies
    - 12.315.22 défonceuses
    - 12.315.29 autres machines
  - 12.315.3 avec modèle pour guider l'outil :
    - 12.315.31 avec mouvement tournant automotiqua de la pièce
    - 12.315.39 autres (ex. : machines à sculpter)
- 12.316 machines à moulurer avec un arbre et amenage mécanique
- 12.317 machines à fraiser les entailles pour pliage
- 12.319 Autres machines à fraiser sur une face (ex. : bouveteuses)

12.32 **Machines à fraiser sur deux faces :**
- 12.321 Toupies doubles avec distance des broches réglable

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 cutterblocks:
- 12.241 fixed vertical spindle
- 12.242 vertical spindle, adjustable in height

12.29 Other planing machines

12.3 **Moulding (shaping) machines with rotating tool:**

12.31 **One side moulding machines:**
- 12.311 Single spindle moulding machines and double spindle moulding machines with fixed spindle centres
- 12.312 Single end tenoning, machines with one tool holder, or with detachable circular saw
- 12.313 Interlocking machines:
  - 12.313.1 corner locking machines
  - 12.313.2 dovetailing machines
  - 12.313.9 Other interlocking machines (e.g. finger jointing)
- 12.314 Pattern milling and recessing machines, routing machines
- 12.315 Copying machines:
  - 12.315.1 with template control of 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)

12.22 **Hobelmaschinen für zweiseitige Bear beitung:**
- 12.221 Winkelkantenabrichthobelma schinen zum Abrichten und Fü gen in einem Arbeitsgang
- 12.222 Dickenhobel- und Fügemaschi nen zum Dickenhobeln und Fü gen in einem Arbeitsgang
- 12.223 Zweiseitige Hobelmaschinen zum Abrichten und Dickenho beln
- 12.229 Sonstige Hobelmaschinen fü zweiseitige Bearbeitung (z.B zweiseitige Blockhobelmaschi nen)

12.23 **Hobelmaschinen für dreiseitige Bear beitung**, verstellbarer Tisch, feste obere Horizontalwelle

12.24 **Hobelmaschinen für vierseitige Bear beitung**, verstellbarer Tisch, feste obere Horizontalwelle
- 12.241 mit fester Vertikalwelle
- 12.242 mit höhenverstellbarer Verti kalwelle

12.29 Sonstige Hobelmaschinen

12.3 **Fräsmaschinen (Kehlmaschinen) mit kreisendem Werkzeug:**

12.31 **Fräsmaschinen für einseitige Bearbei tung:**
- 12.311 Einspindlige Tischfräsmaschi nen und Zwillingstischfräsma schinen mit unveränderlichem Spindelabstand
- 12.312 Zapfenschneidmaschinen, ein spindlig, auch mit Anbaukreis säge
- 12.313 Zinkenfräsmaschinen:
  - 12.313.1 für gerade Zinken
  - 12.313.2 für schwalbenschwanzför mige Zinken
  - 12.313.9 für andere Zinkenformen
- 12.314 Modell- und Kernkastenfräsma schinen
- 12.315 Kopierfräsmaschinen:
  - 12.315.1 mit Schablonensteuerung des Werkstücks:
    - 12.315.11 Unterfräsmaschinen
    - 12.315.12 Oberfräsmaschinen
    - 12.315.19 Sonstige Maschinen
  - 12.315.2 mit Schablonensteuerung des Werkzeugs:
    - 12.315.21 Unterfräsmaschinen
    - 12.315.22 Oberfräsmaschinen
    - 12.315.29 Sonstige Maschinen
  - 12.315.3 mit Modellsteuerung de Werkzeugs:
    - 12.315.31 mit automatischer Dreh bewegung des Werk stücks
    - 12.315.39 sonstige (z.B. Bildschnitz maschinen)
- 12.316 Einspindelige Profilstabfräs maschinen mit mechanischem Vorschub
- 12.317 Faltsystem- Fräsmaschinen
- 12.319 Sonstige einseitige Fräsma schinen (Kehlmaschinen) (z.B Spundmaschinen)

12.32 **Fräsmaschinen für zweiseitige Bea beitung:**
- 12.321 Doppelend-Tischfräsmaschinen (veränder licher Spindelabstand)

12.322 Toupies à copier, avec broches mobiles par gabarit, à deux faces
12.323 Machines à moulurer sur deux faces
12.329 Autres machines à fraiser sur deux faces (ex. : bouveteuses)
12.33 Machines à moulurer sur trois faces, table fixe, arbres réglables
12.34 Machines à moulurer sur quatre faces, table fixe, arbres réglables
12.35 Machines à fraiser les bâtons ronds (à lunettes)
12.36 Machines à façonner avec pièces tournantes
12.37 Machines à fraiser les grumes :
12.371 à une fraise
12.372 à deux fraises
12.379 autres
12.39 Autres machines à fraiser
12.4 Machines à percer :
12.41 Perceuses monobroche (aussi à tête porte broches multiple)
12.42 Perceuses multibroches :
12.421 position des broches fixe
12.422 position des broches réglable
12.43 Perceuses pour usages particuliers :
12.431 perceuses bouchonneuses
12.432 perceuses à cheviller :
12.432.1 monobroche
12.432.2 multibroches
12.433 perceuses à mèche pour trous profonds
12.434 perceuses pour plaques d'insonorisation
12.439 autres perceuses pour usages particuliers
12.49 Autres perceuses
12.5 Machines à mortaiser :
12.51 Mortaiseuses, outil oscillant :
12.511 à un porte-outil
12.512 à un outils multiples
12.52 Mortaiseuses, outil à mouvement de révolution :
12.521 Mortaiseuses à chaîne :
12.521.1 mortaiseuses à chaîne, simples
12.521.2 mortaiseuses à chaîne, multiples
12.522 Mortaiseuses à chaîne et bédane creux
12.529 Autres mortaiseuses, outil à mouvement de révolution
12.53 Mortaiseuses, outil à mouvement circulaire :
12.531 Mortaiseuses à mèche :
12.531.1 mortaiseuses à mèche, simples
12.531.2 mortaiseuses à mèche, multiples
12.531.9 mortaiseuses à mèche, spéciales (pour persiennes, etc.)
12.532 Mortaiseuses à bédane creux
12.539 Autres mortaiseuses, outil à mouvement circulaire
12.59 Autres mortaiseuses
12.6 Tours :
12.61 Tours parallèles
12.62 Tours en l'air
12.63 Tours à façonner avec outil de forme
12.64 Tours à copier, gabarit avec outil non rotatif
12.69 Autres tours

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 spindle multi
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

12.322 Kopierunterfräsmaschinen mit Schablonensteuerung der Spindeln
12.323 Profilstabfräsmaschinen
12.329 Sonstige zweiseitige Kehlmaschinen (z.B. Nut- und Federfräsmaschinen)
12.33 Fräsmaschinen für dreiseitige Bearbeitung, festes Bett, verstellbare Wellen
12.34 Fräsmaschinen für vierseitige Bearbeitung, festes Bett, verstellbare Wellen
12.35 Stabfräsmaschinen mit Rundstabkopf
12.36 Fassonfräsmaschinen mit sich drehendem Werkstück
12.37 Profilzerspaner:
12.371 mit 1 Fräswerkzeug
12.372 mit 2 Fräswerkzeugen
12.379 sonstige
12.39 Sonstige Fräsmaschinen
12.4 Bohrmaschinen:
12.41 Einspindlige Universal-Bohrmaschinen (auch mit Mehrspindelbohrkopf)
12.42 Mehrspindlige Bohrmaschinen:
12.421 mit unveränderlichem Spindelabstand
12.422 mit veränderlichem Spindelabstand
12.43 Bohrmaschinen für Sonderzwecke:
12.431 Astlochbohrmaschinen
12.432 Dübellochbohrmaschinen:
12.432.1 einspindelig
12.432.2 mehrere Spindeln
12.433 Tieflochbohrmaschinen
12.434 Bohrmaschinen für Schallschluckplatten
12.439 Sonstige Bohrmaschinen für Sonderzwecke
12.49 Sonstige Bohrmaschinen
12.5 Stemmaschinen:
12.51 Stemmaschinen mit Schwingmeißelwerkzeug:
12.511 mit einem Meißel
12.512 mit einer Meißelreihe
12.52 Stemmaschinen mit umlaufendem Werkzeug:
12.521 Kettenstemmaschinen:
12.521.1 mit einem Werkzeug
12.521.2 mit mehreren Werkzeugen
12.522 Ketten- und Hohlmeißelstemmaschinen
12.529 Sonstige Stemmaschinen mit umlaufendem Werkzeug
12.53 Stemmaschinen mit sich drehendem Werkzeug:
12.531 Langlochfräsmaschinen:
12.531.1 mit einer Spindel
12.531.2 mit mehreren Spindeln
12.531.9 für Sonderzwecke (z.B. für Rolladen)
12.532 Hohlmeißelstemmaschinen
12.539 Sonstige Stemmaschinen mit sich drehendem Werkzeug
12.59 Sonstige Stemmaschinen
12.6 Drehmaschinen:
12.61 Langdrehmaschinen
12.62 Plandrehmaschinen
12.63 Fassondrehmaschinen
12.64 Kopierdrehmaschinen mit schablonengesteuertem Drehstahl
12.69 Sonstige Drehmaschinen

12.7 Machines à poncer—machines à polir:

12.71 Ponceuses à patin oscillant

12.72 Ponceuses à bande :

12.721 ponceuses à bande étroite :

12.721.1 ponceuses à table fixe

12.721.2 ponseuses à table ou châssis coulissant :

12.721.21 non automatique

12.721.22 semi-automatique

12.721.3 Ponceuses automatique à bande étroite :

12.721.31 ponceuses à une bande

12.721.32 ponceuses à deux ou plusieurs bandes

12.721.4 Ponceuses pour travaux spéciaux :

12.721.41 ponceuses pour chants, feuillures et liteaux profilés

12.721.42 ponceuses pour courbes et pièces de forme

12.721.43 ponceuses pour bâtons ronds

12.721.44 ponceuses pour pièces tournées

12.721.49 ponceuses autres

12.721.9 autres perceuses à bande étroite

12.722 Ponceuses à bande large :

12.722.1 ponceuse à une bande

12.722.2 ponceuse à deux ou plusieurs bandes

12.73 Ponceuses à disques

12.731 ponceuses à disque non-profilé

12.731.1 ponceuses à axe fixe

12.731.2 ponceuses à axe orientable

12.731.9 ponceuses autres

12.732 ponceuses à disque profilé

12.739 autres ponceuses à disques

12.74 Ponceuses à outil cylindrique

12.741 Ponceuses à tambours (tambour ponceur en porte à faux) :

12.741.1 avec alimentation à main

12.741.2 avec alimentation automatique

12.742 Ponceuses à cylindres (cylindres ponceurs non en porte à faux) :

12.742.1 à un cylindre :

12.742.11 avec alimentation à main

12.742.12 avec alimentation automatique

12.742.2 à plusieurs cylindres (alimentation automatique)

12.749 Autres ponceuses à outil cylindrique

12.75 Ponceuses à outils différents

12.751 ponceuses pour surface plane (ex. : travaillant en croix)

12.752 ponceuses pour plusieurs surfaces planes

12.753 pour pièces profilées

12.76 Machines à polir

12.761 Polisseuses à bande :

12.761.1 avec alimentation à main

12.761.2 avec alimentation automatique

12.7 Sanding machines-Buffing machines:

12.71 Sanding machines with oscillating action

12.72 Belt sanding machines:

12.721 Narrow belt sanding machines:

12.721.1 with fixed table

12.721.2 with sliding table or frame:

12.721.21 non-automatic

12.721.22 semi-automatic

12.721.3 Automatic narrow belt sanding machines:

12.721.31 with one belt

12.721.32 with two or more belts

12.721.4 Special purpose sanding machines:

12.721.41 for edges, rebates and profiled laths

12.721.42 for curves and forms

12.721.43 for round stocks

12.721.44 for swivels

12.721.49 others

12.721.9 Other narrow belt sanding machines

12.722 Wide belt sanding machines:

12.722.1 with one belt

12.722.2 with two or more blets

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

12.7 Schleifmaschinen — Poliermaschinen:

12.71 Schleifmaschinen mit oszillierendem Werkzeug

12.72 Bandschleifmaschinen:

12.721 Langbandschleifmaschinen:

12.721.1 Bandschleifmaschinen mit festem Tisch

12.721.2 Bandschleifmaschinen mit Schiebetisch oder Rahmen:

12.721.21 nicht automatisch

12.721.22 halbautomatisch

12.721.3 Automatische Langbandschleifmaschine:

12.721.31 mit einem Band

12.721.32 mit 2 oder mehreren Bändern

12.721.4 Spezielle Bandschleifmaschinen:

12.721.41 für Kanten, Falze und Profilleisten

12.721.42 für Kurven und Formteile

12.721.43 für Rundstäbe

12.721.44 für Drehteile

12.721.49 Sonstige

12.721.9 Sonstige Langbandschleifmaschinen

12.722 Breitbandschleifmaschinen:

12.722.1 mit einem Band

12.722.2 mit 2 oder mehreren Bändern

12.73 Scheibenschleifmaschinen:

12.731 mit nicht-profilierter Scheibe

12.731.1 mit fester Spindel

12.731.2 mit verschiebbarer Spindel

12.731.9 Sonstige

12.732 mit profilierter Scheibe

12.739 andere Scheibenschleifmaschinen

12.74 Schleifmaschinen mit zylindrischem Werkzeug

12.741 Schleifmaschinen mit fliegend gelagerter Spindel:

12.741.1 für Handvorschub

12.741.2 mit automatischem Vorschub

12.742 Schleifmaschinen mit zweiseitig gelagertem Zylinder:

12.742.1 mit einem Zylinder:

12.742.11 für Handvorschub

12.742.12 mit automatischem Vorschub

12.742.2 mit mehreren Zylindern (automatisch)

12.749 Andere Zylinderschleifmaschinen

12.75 Schleifmaschinen mit verschiedenartigen werkzeugen:

12.751 für eine Planfläche (z.B. Kreuzschliff)

12.752 für mehrere Planflächen

12.753 für profilierte Teile

12.76 Poliermaschinen (Schwabbelmaschinen)

12.761 Bandpoliermaschinen:

12.761.1 für Handvorschub

12.761.2 mit automatischem Vorschub

12.762 Polisseuses à tambour

12.763 Polisseuses à cylindre
12.763.1 avec alimentation à main
12.763.2 avec alimentation automatique
12.769 Autres polisseuses

12.79 Autres machines à poncer - machines à polir

12.8 Machines combinées, de menuiserie :

12.81 Raboteuses-degauchisseuses

12.82 Degauchisseuses (sans raboteuse) combinees avec une ou plusieurs autres operations
12.83 Raboteuses-degauchisseuses combinees avec une ou plusieurs autres opérations
12.84 Scies circulaires — toupies — mortaiseuses
12.89 Autres machines combinees de menuiserie

12.9 Autres machines travaillant par enlèvement de copeaux (ex. : pour rendre les surfaces rugueuses par brosses ou jet de sable)

2 MACHINES A DÉFORMER

21 Machines à comprimer et densifier des bois massifs
22 Machines à cintrer
23 Machines à faire des empreintes
23.1 Presses à estamper
23.2 Machines à marquer
23.9 Autres
29 Autres machines à deformer

3 MACHINES A ASSEMBLER ET A REVÊTIR LES SURFACES

31 Machines à assembler par liants (colles et papiers gommés) :
31.1 Machines à assembler sur chants :
31.11 Machines à jointer les placages :
31.111 avec papier gomme :
31.111.1 longitudinalement
31.111.2 transversalement
31.119 Autres machines à jointer les placages :
31.119.1 longitudinalement
31.119.2 transversalement
31.12 Machines à coller les bois massifs

31.121 Longitudinalement :
31.121.1 par application directe des chants
31.121.2 par coulissement des chants
31.122 par assemblage en bout :
31.122.1 par joints à queues

31.122.2 par joints biseautés superposés
31.13 Machines à coller les panneaux entre eux
31.2 Machines à assembler les angles :

31.21 Presses à cadrer
31.22 Presses à carcasses

31.29 Autres machines à assembler les angles
31.3 Machines à assembler sur plats :
31.31 Presses à contreplaquer :
31.311 les surfaces planes
31.312 les surfaces non planes (galbées, gauches)
31.32 Presses à bois stratifiés :
31.321 avec surfaces planes
31.322 avec surfaces non planes (galbées, gauches)
31.33 Presses à plaquer :
31.331 les surfaces planes :
31.331.1 alimentation manuelle
31.331.2 alimentation automatique, pression intermittente

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 wood-workers):
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 thicknesing 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 pressure

12.762 Spindelpoliermaschinen

12.763 Zylinderpoliermaschinen
12.763.1 für Handvorschub
12.763.2 mit automatischem Vorschub
12.769 Sonstige Poliermaschinen

12.79 Andere Schleifmaschinen-Poliermaschinen
12.8 Kombinierte Tischlereimaschinen:

12.81 Abrichtdickenhobelmaschinen

12.82 Abrichthobelmaschinen (ohne Dickenhobelmaschinen), kombiniert mit einer oder mehreren anderen Maschine(n)
12.83 Abrichtdickenhobelmaschinen, kombiniert mit einer oder mehreren Maschine(n)
12.84 Kreissage-, Fras- und Langlochfras(bohr)maschinen
12.89 Sonstige kombinierte Tischlereimaschinen

12.9 Sonstige Maschinen zum Spanen (z.B. zum Aufrauhen der Oberflache mit Bursten oder Sandstrahlen)

2 MASCHINEN ZUM UMFORMEN

21 Maschinen zum Verdichten (Vollholz)

22 Maschinen zum Biegen
23 Pragemaschinen
23.1 mit Pressstempel
23.2 mit Profilrolle
23.9 andere
29 Sonstige Maschinen zum Umformen

3 MASCHINEN ZUM ZUSAMMENFUGEN UND ZUM AUFTRAGEN HAFTENDER SCHICHTEN

31 Maschinen zum Zusammenfügen durch Bindemittel (Leime und Kleber)
31.1 Verleimmaschinen für Schmalseiten:
31.11 Furnierzusammensetzmaschinen.
31.111 mit Papier:
31.111.1 Langsdurchlauf
31.111.2 Querdurchlauf
31.119 Sonstige Furnierverleimmaschinen
31.119.1 Langsdurchlauf
31.119.2 Querdurchlauf
31.12 Massivholzverleimung

31.121 Längsverleimung:
31.121.1 Spanner

31.121.2 Einschiebemaschinen

31.122 Stirnverleimung:
31.122.1 Keilzinkenverleimpressen

31.122.2 Schäftverleimpressen

31.13 Plattenverleimmaschinen

31.2 Verleimmaschinen für Eckverbindungen:

31.21 Rahmenpressen
31.22 Korpuspressen

31.29 Sonstige Verleimmaschinen fur Eckverbindungen
31.3 Verleimmaschinen für Breitseiten:
31.31 Sperrholzpressen:
31.311 für ebene Flächen
31.312 für gebogene Flächen und Formteile
31.32 Schichtholzpressen:
31.321 für ebene Flächen
31.322 für gebogene Flächen und Formteile
31.33 Furnierpressen (Deckschichtpressen):
31.331 fur ebene Flächen:
31.331.1 Handbeschickte Pressen
31.331.2 Automatisch beschickte Taktpressen

Français	English	Deutsch
31.331.3 alimentation et pression continue	31.331.3 continuous feeding and pressure	Pressen
31.332 les surfaces non planes (galbées, gauches) :	31.332 For formed surfaces:	31.332 für gebogene Flächen und Formteile:
31.332.1 avec contreforme rigide	31.332.1 with rigid form	31.332.1 mit festem Druckelement
31.332.2 avec contreforme souple (par vide ou pression externe)	31.332.2 with flexible form	31.332.2 mit flexiblem Druckelement
31.4 Machines à coller les placages ou autres pièces, sur chants :	**31.4 Edge lipping and bonding machines:**	**31.4 Kantenverleimmaschinen:**
31.41 sur chants plans	31.41 for plane edges	31.41 für gerade Kanten
31.42 sur chants profilés	31.42 for profile edges	31.42 für profilierte Kanten
31.5 Machines à coller des pièces de sections rectangulaires (liteaux) pour constituer des panneaux	**31.5 Core stock composing** and joinery stock offset composing and gluing up machines	**31.5 Leisten- und Mittellagenverleimmaschinen**
31.6 Presses à agglomérer les particules :	**31.6 Presses for coated particles:**	**31.6 Verleimpressen für Späne:**
31.61 Presses pour panneaux de particules :	31.61 Chip and particle board pressing machines:	31.61 Spanplattenpressen:
31.611 Presses à alimentation intermittente	31.611 for intermittent processing	31.611 Taktpressen
31.612 Presses à alimentation en continu :	31.612 for continuously processing	31.612 Durchlaufpressen:
31.612.1 presses à bandes	31.612.1 Belt presses	31.612.1 Bandpressen
31.612.2 presses à extruder	31.612.2 Extrusion presses	31.612.2 Strangpressen
31.612.9 autres presses à alimentation en continu	31.612.9 Other continuous process presses	31.612.9 Sonstige Durchlaufpressen
31.62 Presses à mouler	31.62 Mould presses	31.62 Spanformpresser
31.69 Autres presses à agglomérer les particules	31.69 Other presses for coated particles	31.69 Sonstige Verleimpressen für Späne
31.7 Presses à agglomérer les fibres :	**31.7 Fibre presses:**	**31.7 Faserplattenpressen:**
31.71 Presses à bandes métalliques tressées	31.71 Continuous metal link belt presses	31.71 Langsiebpressen
31.72 Presses à plateaux	31.72 Platen presses	31.72 Etagenpressen
31.79 Autres presses à agglomérer les fibres	31.79 Other fibre presses	31.79 Sonstige Faserplattenpressen
31.9 Autres machines à assembler par liants (ex.: presse rotative avec alimentation intermittente automatique)	**31.9 Other joining and assembling machines** using binding agents (adhesives) (e.g. rotating press with automatic feeding in intervals)	**31.9 Sonstige Maschinen zum Zusammenfügen durch Leime und Kleber** (z.B. rotierende Taktpressen mit automatischer Beschickung)
32 Machines, à assembler par éléments tels que clous, agrafes, fils etc. :	**39 Machines for joining by means of fasteners as nails, staples, wire etc.:**	**32 Maschinen zum Zusammenfügen durch Verbindungsstücke wie Nägel, Klammern, Draht usw.:**
32.1 Machines à enfoncer les clous, agrafes etc. :	32.1 Machines for driving nails, staples etc.:	32.1 Maschinen zum Eintreiben von Nägeln, Klammern usw.:
32.11 Machines à clouer les caisses, les palettes, les tambours de cables	32.11 nailing machines for boxes, for pallets, for for cable-drums	32.11 Nagelmaschinen für Kisten, Paletten und Kabeltrommeln
32.12 Machines à clouer les feuillards	32.12 Machines for nailing on strips	32.12 Maschinen zum Aufnageln von Bändern
32.13 Machines à agrafer, à plats ou d'angles	32.13 Flat and/or corner staplers	32.13 Flach- und Eckenheftmaschinen
32.14 Machines à agrafer les caisses armées	32.14 Stapling and stiching machines for wirebound boxes	32.14 Heftmaschinen für Drahtbundkisten
32.15 Machines à visser	32.15 Machines for inserting screws	32.15 Maschinen zum Eindrehen von Schrauben
32.16 Machines à poser les quincailleries	32.16 Machines for fitting hardware	32.16 Beschlägesetzmaschinen
32.19 Autres machines à enfoncer (ex.: enfoncer les bandes ondulées ou les crampons, machines à enfoncer les chevilles, billoteuses)	32.19 Other driving machines (e.g. corrugated fastener, cramp and dowel pin driving machines, basket stapling machines)	32.19 Andere Maschinen zum Eintreiben (z.B. Wellenbandeintreibmaschinen, Bandklammermaschinen, Spitzdübelnagelmaschinen, Obstkorbheftmaschinen)
32.2 Machines à assembler au moyen de fils (ex.: machines à botteler le bois de chauffage, machines à tisser etc.)	32.2 Machines for assembling by means of wire (e.g.: firewood bundling machines, weaving machines etc.)	32.2 Maschinen zum Bündeln und Weben (z.B. Brennholzbündelmaschinen, Webmaschinen usw.)
32.9 Autres machines à assembler par éléments tels que clous, agrafes, fils etc.	32.9 Other machines for joining by means of fasteners such as nails, staples, wire etc.	32.9 Sonstige Maschinen zum Zusammenfügen durch Verbindungsstücke
33 Machines à assembler sans liant ni élément d'assemblage :	**33 Machines for joining without bindling agents and without fasteners:**	**33 Maschinen zum Zusammenfügen ohne Bindemittel und ohne Verbindungsstücke:**
33.1 Presses de montage (ex.: pour échelles, à sertir les pièces métalliques sur planches de coffrage etc.)	33.1 Squeeze presses for framework (ladders etc.)	33.1 Montagepressen (z.B. für Leitern, Maschinen zum Einschieben von Kantenbeschlägen für Schalungstafeln usw.)
33.2 Presses à faire les balles	33.2 Baling presses	33.2 Ballenpressen
33.3 Presses à briquettes	33.3 Briquetting presses	33.3 Brikettierpressen
33.4 Machines à faire les cordes en laine de bois	33.4 Wood wool rope spinning machines	33.4 Holzwollespinnmaschinen
33.5 Machines à natter	33.5 Interweaving machines	33.5 Flechtmaschinen
33.9 Autres	33.9 Others	33.9 Sonstige Maschinen zum Zusammenfügen ohne Bindemittel und ohne Verbindungsstücke
34 Machines à revêtir les surfaces :	**34 Coating machines (adding coats to wood):**	**34 Maschinen zum Auftragen haftender Schichten:**
34.1 Machines à encoller :	34.1 Glue spreading machines:	34.1 Maschinen zum Beleimen:
34.11 Encolleuses de panneaux et placages :	34.11 Machines for glue speading on boards and veneers:	34.11 Maschinen zum Beleimen von Platten und Furnieren:
34.111 encolleuses sur chants	34.111 glue spreaders for edges	34.111 Beleimmaschinen für Schmalseiten
34.112 encolleuses sur plats	34.112 glue spreaders for surfaces	34.112 Beleimmaschinen für Breitseiten
34.12 Encolleuses de copeaux	34.12 Chip and glue blending machines	34.12 Spanbeleimmaschinen
34.19 Autres encolleuses	34.19 Other glue spreading machines	34.19 Sonstige Maschinen zum Beleimen

34.21 par rouleaux
34.22 par rideaux
34.23 par arrosage
34.24 par projection
34.25 par immersion
34.26 par procédé électrostatique
34.29 autres machines à vernir

34.3 Machines à imprimer
34.9 Machines à revêtir par autres produits (ex. : résines synthétiques etc.)
39 Autres machines à assembler et à revêtir les surfaces

4 MACHINES ET EQUIPEMENTS POUR LE TRAITEMENT DES BOIS (SÉCHAGE IMPREGNATION ETC.)

41 Installations à étuver
42 Séchoirs :
42.1 Séchoirs à bois débités
42.2 Séchoirs à placages
42.3 Séchoirs à particules
42.4 Séchoirs à vernis
42.9 Autres séchoirs
43 Installations d'humidification
44 Installations d'imprégnation et de préservation
45 Installations pour le blanchiment de la coloration
46 Installations de refroidissement
49 Autres machines pour le traitement des bois

5 MACHINES ET APPAREILS AUXILIAIRES POUR L'INDUSTRIE DU BOIS :

51 Dispositifs pour le déplacement des pièces et/ou matières :
51.1 Appareils de levage :
51.11 Tables élévatrices
51.12 Tables et plateformes élévatrices fixes
51.13 Elévateurs basculants
51.19 Autres appareils de levage
51.2 Dispositifs d'alimentation et d'évacuation
51.3 Dispositifs de retournement
51.4 Entraineurs
51.5 Installations de transport et stockage des copeaux, fibres, déchets, particules etc.
51.51 Installations de transport
51.511 Mécanique
51.512 Pneumatique
51.52 Installations de stockage (ex. : silos)
51.6 Appareils pour centrer automatiquement
51.9 Autres dispositifs pour le déplacement des pièces et/ou matières
52 Installations de triage
52.1 des bois
52.2 des particules
53 Installations pour la distribution des particules
54 Appareils à préparer la colle
55 Machines pour l'entretien des outils :
55.1 Machines pour l'entretien des lames de scies :
55.11 Machines à affûter, à meules
55.12 Machines à affûter, à limes
55.13 Machines et appareils à avoyer, écraser, égaliser
55.14 Appareils à braser et souder
55.15 Machines à tendre, à planer
55.16 Machines à biseauter
55.17 Machines à affûter les lames circulaires à mise rapportée
55.19 Autres machines pour l'entretien des lames de scies
55.2 Machines à affûter les couteaux :
55.21 Couteaux à tranchant rectiligne

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 Larquer cast 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 work pieces)
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
55.2 Cutter sharpeners:
55.21 for straight edges

34.21 durch Walzen
34.22 durch Gießen
34.23 durch Fluten
34.24 durch Spritzen
34.25 durch Tauchen
34.26 im elektrostatischen Feld
34.29 Sonstige Maschinen zum Auftragen von Lacken
34.3 Maschinen zum Bedrucken
34.9 Maschinen zum Auftragen anderer haftender Schichten (z.B. von Kunstharzen usw.)
39 Sonstige Maschinen zum Zusammenfügen und zum Auftragen haftender Schichten

4 MASCHINEN UND ANLAGEN ZUR HOLZKONDITIONIERUNG (TROCKNUNG, TRÄNKUNG USW.)

41 Dämpfanlagen
42 Trockner:
42.1 Schnittholztrocker
42.2 Furniertrockner
42.3 Spänetrockner
42.4 Lacktrockner
42.9 Sonstige Trockner
43 Befeuchtungsanlagen
44 Imprägnieranlagen
45 Bleich-, Beiz- und Räucheranlagen
46 Kühleinrichtungen
49 Sonstige Maschinen zur Holzkonditionierung

5 HILFSMASCHINEN UND -GERÄTE FÜR DIE HOLZBEARBEITUNG:

51 Hilfsmittel für die Materialbewegung:
51.1 Hubgeräte:
51.11 Tische, fahrbare
51.12 Hubtische und Bühnen, stationäre
51.13 Neigbare Hubgeräte
51.19 Sonstige Hubgeräte
51.2 Einschiebe- und Abnehmevorrichtungen
51.3 Wendevorrichtungen
51.4 Vorschubapparate
51.5 Einrichtungen zum Fördern und Lagern von Spänen, Fasern, Abfällen, Kleinteilen usw.
51.51 Fördereinrichtungen
51.511 mechanische
51.512 pneumatische
51.52 Lagereinrichtungen (z.B. Silos)
51.6 Einrichtungen zum automatischen Zentrieren
51.9 Sonstige Hilfsmittel für die Materialbewegung
52 Einrichtungen zum Sortieren
52.1 Holz
52.2 Spängut
53 Spaneschütteinrichtungen
54 Geräte zur Leimaufbereitung
55 Maschinen zur Werkzeugpflege:
55.1 Maschinen zur Pflege von Sägeblättern:
55.11 Schärfmaschinen mit Scheiben
55.12 Feilmaschinen
55.13 Schränk-, Stauch- und Egalisiermaschinen und -geräte
55.14 Bandsägelöt- und -schweißapparate
55.15 Walz- und Planiermaschinen für Sägeblätter
55.16 Bandsägeblatt-Trenn- und Schäftmaschinen
55.17 Maschinen zum Schärfen von hartmetallbestückten Kreissägeblättern
55.19 Sonstige Maschinen zur Pflege von Sägeblättern
55.2 Maschinen zum Schärfen von Messern:
55.21 mit geraden Schneiden

55.22 Couteaux à tranchant profilé

55.3 Machines à affûter les outils pour fraiser et raboter
55.4 Machines à affûter les forets et outils de défonceuses
55.5 Machines à affûter les bédanes
55.6 Machines à affûter les chaînes coupantes
55.7 Machines à affûter universelles
55.9 Autres machines pour l'entretien des outils

56 Dispositifs de protection et de réduction du niveau sonore :
56.1 Dispositifs de protection
56.2 Dispositifs de réduction du niveau sonore
57 Appareils de serrage, pressage, montage

58 Appareils de mesure, réglage et contrôle

59 Autres machines et appareils auxiliaires (ex. : machines à nettoyer les surfaces)

6 MACHINES PORTATIVES ET UNITÉS D'USINAGE

61 Machines portatives :
61.1 Machines portatives travaillant sans enlèvement de copeaux :
61.11 Machines portatives à écorcer, à lame
61.19 Autres machines portatives travaillant sans enlèvement de copeaux (ex. : cisailles portatives)

61.2 Machines portatives travaillant par enlèvement de copeaux :
61.21 Machines portatives à scier :
61.211 outil à mouvement alternatif
61.212 outil à mouvement de révolution :
61.212.1 scies portatives à ruban
61.212.2 scies portatives à chaîne :
61.212.21 tronçonneuses à lame-guide
61.212.22 tronçonneuses à arc
61.212.29 Autres scies portatives à chaîne
61.213 à outil circulaire :
61.213.1 scies portatives circulaires
61.213.2 scies portatives annulaires
61.213.9 Autres scies portatives à outil circulaire
61.22 Machines portatives à raboter
61.23 Machines protatives à fraiser :
61.231 pour défonçage
61.232 pour affleurage
61.239 autres
61.24 Machines portatives à percer
61.25 Machines portatives à mortaiser :
61.251 à outil oscillant
61.252 à outil à mouvement de révolution (à chaîne)
61.259 Autres mortaiseuses portatives
61.26 Machines portatives à poncer ou polir :
61.261 Ponceuses portatives :
61.261.1 outil à mouvement oscillant
61.261.2 outil à mouvement de révolution (ponceuses portatives à bande)
61.261.3 outil à mouvement rotatif :

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
61.262.2 with continuous action (portable belt sanding machines)
61.261.3 with rotating action:

55.22 mit profilierten Schneiden

55.3 Maschinen zum Schärfen von Fräs- und Hobelwerkzeugen
55.4 Schärfmaschinen für Bohrer und Oberfräser
55.5 Schärfmaschinen für Stemmwerkzeuge
55.6 Schärfmaschinen für Kettenwerkzeuge
55.7 Universal-Werkzeugschärfmaschinen
55.9 Sonstige Maschinen zur Pflege von Sägeblättern

56 Vorrichtungen für Sicherheit und Lärmminderung:
56.1 Sicherheitsvorrichtungen
56.2 Vorrichtungen zur Lärmminderung
57 Vorrichtungen zum Spannen, Halten u. Montieren
58 Meß-, Regulier- und Kontrollvorrichtungen

59 sonstige Hilfsmaschinen und -geräte (z.B. Maschinen zur Reinigung von Oberflächen)

6 HANDMASCHINEN (HANDGEFÜHRTE MASCHINEN) UND BEARBEITUNGSEINHEITEN:

61 Handmaschinen (handgeführte Maschinen):
61.1 Handmaschinen zum Teilen:
61.11 Handentrindungsmaschinen
61.19 Sonstige Handmaschinen zum Teilen, (z.B. Handkunststoffscheren)

61.2 Handmaschinen zum Spanen:
61.21 Handsägemaschinen:
61.211 mit hin- und hergehendem Werkzeug
61.212 mit umlaufendem Werkzeug:
61.212.1 Handbandsägemaschinen
61.212.2 Handkettensägemaschinen:
61.212.21 Handschienenkettensägemaschinen
61.212.22 Handbügelkettensägemaschinen
61.212.29 Sonstige Handkettensägemaschinen
61.213 Handsägemaschinen mit sich drehendem Werkzeug:
61.213.1 Handsägemaschinen mit Kreissägeblatt
61.213.2 Handsägemaschinen mit Sägering
61.213.9 Sonstige Handsägemaschinen mit sich drehendem Werkzeug
61.22 Handhobelmaschinen
61.23 Handfräsmaschinen:
61.231 für Einfräsarbeiten
61.232 für Planfräsarbeiten
61.239 andere
61.24 Handbohrmaschinen
61.25 Handstemmaschinen:
61.251 Handstemmaschinen mit oszillierendem Werkzeug
61.252 Handstemmaschinen mit umlaufendem Werkzeug (Handkettenstemmaschinen)
61.259 Sonstige Handstemmaschine
61.26 Handschleif- und -poliermaschinen:
61.261 Handschleifmaschinen:
61.261.1 mit oszillierendem Werkzeug
61.262.2 mit umlaufendem Werkzeug (Handbandschleifmaschinen)
61.261.3 mit sich drehendem Werkzeug

61.261.31 ponceuses portatives à disque
61.261.32 ponceuses portatives à outil cylindrique
61.261.9 Autres ponceuses portatives
61.262 Polisseuses portatives
61.3 Machines portatives à assembler :
61.31 Machines portatives à clouer
61.32 Machines portatives à agrafer
61.33 Machines portatives à visser
61.39 Autres machines portatives à assembler

61.4 Machines portatives à revêtir les surfaces par application d'enduits adhésifs :
61.41 Pistolets à colle
61.42 Pistolets à vernir et peinture
61.49 Autres machines portatives à revêtir

61.8 Machines à transmission flexible

61.9 Autres machines portatives
62 Unités d'usinage :
62.1 Unités travaillant sans enlèvement de copeaux
62.2 Unités travaillant par enlèvement de copeaux :
62.21 Unités à scier
62.22 Unités à raboter
62.23 Unités à fraiser
62.24 Unités à percer
62.25 Unités à mortaiser
62.26 Unités à poncer ou polir
62.29 Autres unités travaillant par enlèvement de copeaux
62.3 Unités d'assemblage et à revêtir les surfaces
62.9 Autres unités d'usinage

7 LIBRE

8 MACHINES A OPÉRATIONS DIFFÉRENTES UTILISANT PLUSIEURS PROCÉDÉS DE TRAVAIL DES CHAPITRES 1 A 6

81 Machines de première transformation à opérations différentes à usiner les grumes (ex. : écorcer, scier, fragmenter)

81.1 Scies alternatives à opérations différentes

81.2 Scies à ruban à opérations différentes

81.3 Scies circulaires à opérations différentes

81.4 Machines à fraiser à opérations différentes

81.9 Autres

82 Machines de deuxième transformation à opérations différentes à usiner le bois massif, panneaux, placage (ex. : scier, fraiser, poncer) :
82.1 tennoneuses simples à plusieurs broches

82.2 tenonneuses doubles
82.3 machines à usinages longitudinaux et transversaux (ex : fraisage, sciage)

82.4 machines doubles à tenonner avec dispositifs complémentaires
82.5 machines à raboter avec scies circulaires

82.6 machines à opérations différentes à percer les trous de chevilles (ex. : scier, fraiser, percer, mortaiser)
82.7 machines à opérations différentes à usiner les emplacements de quincailleries (ex. : scier, fraiser, percer, mortaiser)
82.9 autres machines à opérations différentes pour usiner (ex. : sur table indexée)

83 Machines à opérations différentes pour assembler par colles et usiner :

61.261.31 Portable disc sanding machines
61.261.32 Portable drum sanding machines

61.261.9 Other portable sanding machines
61.262 Portable buffing machines
61.3 Portable machines for joining and assembling:
61.31 Portable nailing machines
61.32 Portable stapling machines
61.33 Portable screw drivers
61.39 Other portable machines for joining and assembling

61.4 Portable machines for application of adhering coats:
61.41 Glue guns
61.42 Spray guns
61.49 Other portable machines for application of adhering coats
61.8 Portable machines with flexible driving shaft
61.9 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 operation
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:

61.261.31 Handscheibenschleifmaschinen
61.261.32 Handschleifmaschinen mit zylindrischem Werkzeug
61.261.9 Sonstige Handschleifmaschinen
61.262 Handpoliermaschinen
61.3 Handmaschinen zum Zusammenfügen:

61.31 Handnagelmaschinen
61.32 Handheftmaschinen
61.33 Handmotorschrauber
61.39 Sonstige Handmaschinen zum Zusammenfügen

61.4 Handmaschinen zum Auftragen haftender Schichten:
61.41 Leimpistolen
61.42 Lack- und Farbpistolen
61.49 Sonstige Handmaschinen zum Auftragen haftender Schichten
61.8 Handmaschinen mit biegsamer Welle

61.9 Sonstige Handmaschinen
62 Bearbeitungseinheiten:
62.1 Einheiten zum Teilen

62.2 Einheiten zum Spanen:

62.21 Sägeeinheiten
62.22 Hobeleinheiten
62.23 Fräseinheiten
62.24 Bohreinheiten
62.25 Stemmeinheiten
62.26 Schleif- und Poliereinheiten
62.29 Sonstige Einheiten zum Spanen

62.3 Einheiten zum Zusammenfügen

62.9 Sonstige Bearbeitungseinheiten

7 FREI

8 MEHRSTUFIGE MASCHINEN FÜR MEHRERE VERSCHIEDENARTIGE BEARBEITUNGSVERFAHREN DER GRUPPEN 1 BIS 6

81 Mehrstufige Maschinen für die Rohholzbearbeitung (z.B. entrinden, sägen, zerspanen)

81.1 Gattersägemaschinen mit zusätzlichen Arbeitsgängen
81.2 Bandsägemaschinen mit zusätzlichen Arbeitsgängen
81.3 Kreissägemaschinen mit zusätzlichen Arbeitsgängen
81.4 Profilzerspaner mit zusätzlichen Arbeitsgängen
81.9 Andere

82 Mehrstufige Maschinen zur spanabnehmenden Weiterverarbeitung von Massivholz, Platten und Furnierholz (z.B. sägen, fräsen, schleifen):
82.1 Einseitige Zapfenmaschinen mit mehreren Spindeln
82.2 zweiseitige Zapfenmaschinen
82.3 Maschinen zur Bearbeitung in Vorschubrichtung und quer hierzu (z.B. profilieren und ablängen)
82.4 Doppelendprofiler mit Zusatzaggregaten

82.5 Hobelmaschinen kombiniert mit Vielblattsägemaschinen
82.6 Mehrstufige Dübellochbohrmaschinen (z.B. sägen, fräsen, bohren, stemmen)

82.7 Beschlagsitzbohr- und Fräsmaschinen (z.B. sägen, fräsen, bohren, stemmen)

82.9 andere mehrstufige Maschinen zur spanabhebenden Weiterverarbeitung (z.B. auf einem Rundschalttisch)
83 Mehrstufige Maschinen zum Zusammenfügen mit Bindemitteln und Bearbeiten:

83.11 constitution de [illegible] à partir de placage
83.12 constitution de panneaux à partir de lattes
83.13 constitution de pièces à partir de particules, fibres etc.
83.14 constitution de pièces à partir de stratifiés
83.15 machines à plaquer sur chants (ex. : placage, alésés, baguettes, plastique) :
83.151 une face
83.152 deux faces
83.16 machines à envelopper
83.17 machines à postformer
83.19 autres

83.2 usinages plus collage et autres opérations éventuelles :
83.21 machines doubles à tenonner et plaquer sur chants
83.22 machines pour bois aboutés
83.23 machines à joints biseautés
83.24 massicots pour paquets de placage avec dispositifs d'encollage
82.25 bouchonneuses encolleuses, machines automatiques à rapiécer le placage
83.26 machines à usiner les emplacements de chevilles, coller, poser
83.29 autres

84 Machines à opérations différentes à usiner et assembler par éléments métalliques ou plastiques :
84.1 machines à usiner les emplacements de quincailleries et/ou à les poser
84.2 machines à cadrer des chassis, caisses etc. et assembler par connecteurs
84.9 autres

89 Autres machines à opérations différentes

9 AUTRES MACHINES

91 Machines spéciales ou ensembles de machines spéciales exclusivement conçus pour une fabrication de produits bien définis :
Machines et installations pour :

91.1 balais et brosses
91.2 crayons
91.3 tonneaux
91.4 porte-plumes
91.5 casiers à bouteilles
91.6 stylos et stylos à bille
91.7 crosses de fusils
91.8 bois de mines
91.9 talons de chaussures
91.10 sabots et semelles
91.11 pièces de cambrure de souliers
91.12 éléments de charpente en bois lamelles
91.13 peignes
91.14 porte-manteaux
91.15 boutons
91.16 produits en liège (bouchons etc).
91.17 règles graduées (mètres, décimètres, etc.)
91.18 instruments de musique
91.19 parquets
91.20 pavés de bois
91.21 pinceaux
91.22 hélices
91.23 règles de calcul
91.24 volets et persiennes
91.25 pièces pour cercueils
91.26 formes, embouchoirs de chaussures
91.27 traverses de voies ferrées
91.28 articles de sport (skis, raquettes etc.)
91.29 dresser les billots (constitués par des éléments de bois en bout)

83.11 for production of veneer strip
83.12 for production of core stock from laths
83.13 for production of pieces from chips, particles, fibre etc.
83.14 for production of pieces from laminated material
83.15 Edge bonding machines (e.g. veneer, solid wood, plastic):
83.151 single-end
83.152 double-end
83.16 Wrapping machines
83.17 Postforming machines
83.19 Others

83.2 For machining and gluing with or without additional operations:
83.21 Double-end sizing and edge bonding machines
83.22 Finger jointing machines
83.23 Splicing (scarfing) machines
83.24 Veneer pack edge shears with gluing device
83.25 Automatic knot-plugging, veneer patching machines
83.26 Dowel boring, gluing, driving in machines
83.29 Others

84 Multipurpose - machines for cutting and joining by fasteners of metal or plastic:
84.1 machines for preparing the seat of hardwares and or driving-in
84.2 machines for fitting frames, boxes etc. and joining by fasteners
84.9 Others

89 Other multi-purpose machines

9 OTHER MACHINES

91 Special machines or sets of special machines designed for the sole purpose of manufacturing a particular en product:
Machines and equipment to make:

91.1 Brooms 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 blocks (facing)

[illegible]
83.12 für die Herstellung von Platten aus Latten (z.B. Mittellagenverleimmaschinen)
83.13 für die Herstellung von Teilen aus Fasern, Spänen etc.
83.14 für die Herstellung von Teilen aus Schichtstoffen
83.15 Kantenverleimmaschinen (z.B. für Kanten aus Furnieren, Leisten, Stäbchen, Kunststoff):
83.151 einseitig
83.152 zweiseitig
83.16 Ummantelungsmaschinen
83.17 Postforming-Maschinen
83.19 andere

83.2 Zum Bearbeiten, Beleimen mit oder ohne weitere Arbeitsgänge:
83.21 doppelseitige Formatbearbeitungs- und Kantenverleimmaschinen
83.22 Zinkenmaschinen
83.23 Schäftmaschinen
83.24 Furnierpaketschneidemaschinen mit Beleimvorrichtung
83.25 Astlochausflickautomaten, Furnierausflickautomaten
83.26 Dübelbohr-, -beleim- und -eintreibmaschinen
83.29 andere

84 Mehrstufige Maschinen zum Bearbeiten und Zusammenfügen durch Verbindungsstücke aus Metall oder Kunststoff:
84.1 Beschlagsitzbohr-oder Fräs- und Einsetzmaschinen
84.2 Maschinen zum Zusammenpassen von Rahmen, Kisten usw. und zum Eintreiben von Verbindungsstücken
84.9 andere

89 andere mehrstufige Maschinen

9 SONSTIGE MASCHINEN

91 Maschinen oder Maschinensätze, die ausschließlich für Sonderfertigungen konstruiert sind :
Maschinen und Geräte zur Herstellung folgender Erzeugnisse:

91.1 Besen und Bürsten
91.2 Bleistifte
91.3 Fässer
91.4 Federhalter
91.5 Flaschenkästen
91.6 Füllfederhalter und Füllschreiber
91.7 Gewehrschäfte
91.8 Grubenholz
91.9 Schuhabsätze
91.10 Holzschuhe und Holzsohlen
91.11 Holzstützgelenke für die Schuhindustrie
91.12 Ingenieur-Holzbau
91.13 Kämme
91.14 Kleiderbügel
91.15 Knöpfe
91.16 Korkerzeugnisse
91.17 Massstäbe
91.18 Musikinstrumente
91.19 Parkett
91.20 Pflasterklötze
91.21 Pinsel
91.22 Propeller
91.23 Rechenschieber
91.24 Roll- und Klappläden
91.25 Sargteile
91.26 Schuhleisten
91.27 Schwellen
91.28 Sportgeräte (Skier, Tennisschlager usw.) usw.)
91.29 Maschinen zum Abrichten von Stanzklötzen klötzen

91.30 cageots, paniers à fruits, boîtes à fromage, etc.

91.31 pièces pour sièges (chaises, fauteuils)
91.32 accessoires pour machines de textile (bobines, navettes, etc.)
91.33 pinces à linge
91.34 charronnage
91.35 cure-dents
91.36 allumettes
91.37 chevilles
91.38 pallisades et piquets
92 Machines diverses
92.1 Machines à écorcer non portatives (à poste fixe ou transportable)

91.30 Basket work etc.

91.31 Parts of chairs and settes
91.32 Accessories for textile machines (bobbins and shuttles etc.)
91.33 Clothes pegs
91.34 Wheels
91.35 Toothpicks
91.36 Matches
91.37 Dowels
91.38 Fences and posts
92 Various machines:
92.1 Non-portable debarking machines

91.30 Spanerzeugnisse (z.B. Spankörbe, Spanschachteln, jedoch keine Spanplatten)
91.31 Sitzmöbelteile
91.32 Zubehör für Textilmaschinen (z.B. Spulen, Webschützen)
91.33 Wäscheklammern
91.34 Wagnereien, Einrichtungen für
91.35 Zahnstocher
91.36 Zündhölzer
91.37 Dübel
91.38 Zäune und Pfosten
92 Verschiedene Maschinen:
92.1 Entrindungsmaschinen (ausschließlich Handmaschinen)

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Annex III

LIST OF SPECIALIZED INTERNATIONAL WOODWORKING MACHINERY FAIRS

City and country	*Name of fair*	*Time held*
*Paris, France	Expobois	Spring, even years
*Hanover, Federal Republic of Germany	Ligna	Spring, odd years
*Milan, Italy	Interbimall	Spring, even years
*Nagoya, Japan	Mokkiten	Autumn, even years
Rotterdam, Netherlands	Hout	Autumn, odd years
Valencia, Spain	FIMMA	Autumn, even years
Basel, Switzerland	Holz	Autumn, 3-year cycle
Birmingham, United Kingdom	IWIE	Spring, even years
*Atlanta, Georgia, United States	World woodworking exposition and furniture supply fair	Autumn, even years
Fredericia, Denmark	TRAE	Autumn, even years

*Main exhibitions.

Annex IV

CLASSIFICATION SYSTEM

The classification system, devised by the late Arnost Travik,* is a method of evaluation of the desirability of equipment. If four levels are specified (that is 0,1,2,3), level 3 represents the best available technology, level 1 is technology to satisfy the basic requirements and level 2 is intermediate. Level 0 means doing without the machine and is only specified when the machine is not an absolute requirement. In other cases where the machine is necessary level 0 is omitted. The numbers are not quantitative, they cannot be added to arrive at averages. The prime use of such a system is to quickly compare various mixes of machines in designing a factory. By now some of the considerations listed are technologically obsolete. However, the 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
Manufacture of particles	
System proposed	
Separate manufacturing lines for surface and for core layer particles and separate storing of sawdust, shavings and particles produced from hogged chips	3
Separate manufacturing lines for surface and for core layer particles but without separate storing of sawdust, shavings and of particles produced from hogged chips	2
One manufacturing line for both surface and core particles without differentiated storing of sawdust, shavings and of particles produced from hogged chips	1
Capacities	
1 shift for 3-shift production of boards	3
2 shifts for 3-shift production of boards	2
3 shifts for 3-shift production of boards	1
Removal of splinters	
Combination of air and mechanical sifting	3
Air sifting	2
Mechanical sifting	1
Not proposed	0
Silo for particles	
Large: over 100 m^3	3
Medium: over 50 m^3 but less than 100 m^3	2
Small: below 50 m^3	1
Drying	
Drier	
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

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

	Number of points
Possibility of reusing dust from board production	
Combined reuse of dust in the production line as well as by burning in the drier	2
Burning dust in the drier or in the boiler	1
No provision made	0
Screening unit behind the drier	
Combination of air and mechanical sifter	3
Air sifter	2
Mechanical sifter	1
Not proposed	0

Glue blending

	Number of points
Bin for dry particles	
Capacity over 25 m³ with level indicator at several points of the bin	3
Capacity below 25 m³ with indicator for "full" or "empty"	2
Low capacity without level indicator	1
Dosing of particles	
Continuous quantity control	3
Non-continuous 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

	Number of points
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, periodical quantity control	2
Sifting fine particles into outer layer, no quantity control	1
Prepressing of mat	
Included	1
Not offered	0
Returning of unduly formed mat	
included	1
Not offered	0

Pressing

	Number of points
Type of press	
Single opening	3
Multi daylight simultaneous closing	2
Multi daylight 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 multi-opening press has a certain advantage in the potential possibility of increasing the capacity.

	Number of points
Working pressure	
Min. 3,500 kPa/cm²	3
Min. 3,000 kPa/cm²	1
Accumulator station	
Pumps for each piston	3
Accumulator	2
Pumps	1
Feeding system	
Without supporting cauls	3
With transport cauls or divided band	2
Transport band for maintenance 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
Temperzture regulation	
Included	1
Not offered	0
Temperature adjustment of pressing table	
Included	1
Not offered	0

Sizing of pressed boards

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

Cooling of pressed boards

	Number of points
Forced-air stream	2
Natural-air stream	1
Not offered	0

Volume/weight control behind the press

	Number of points
Not necessary owing to provisions in other equipment	3
Necessary, measuring at several points	2
Necessary, weighing of whole boards	1
Necessary but not proposed	0

Thickness control of pressed boards

	Number of points
Measuring the whole width of board	3
Measuring at several points	2
Measuring at one point	1
Not offered	0

Metal detector

	Number of points
Before the press	2
Behind the press	1
Not offered	0

Sanding line

	Number of points
Processing on both sides with several tools	3
Processing on both sides with one tool	2
Processing on one side	1

	Number of points
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 offered	0
Storing and preparation of glue	
Raw-material store	
Handling proposed including storing racks	2

	Number of points
Handling proposed without storing racks	1
Not offered	0
Preparation of glue blend	
Mechanized, allowing for one worker to prepare the blend for three shifts	3
Not mechanized, one worker is provided for each shift	2
Simple, with more than one 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 offered	0

XXI. Jigs used in the furniture and joinery industries*

The term jig usually means a self-constructed appliance that facilitates production, lowers labour cost and improves product quality. (Examples of jigs are shown in figures 130 and 131.)

Figure 130. Machining jig for spindle-moulding the edges of chair legs

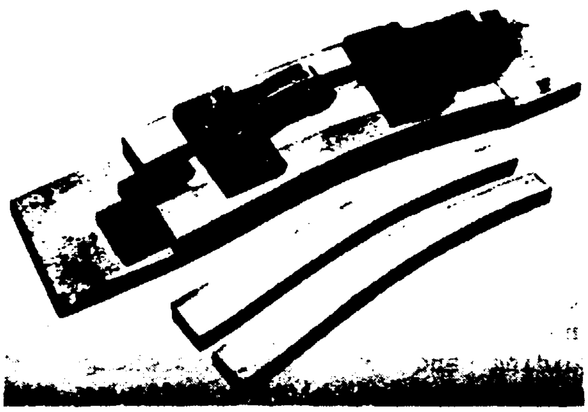
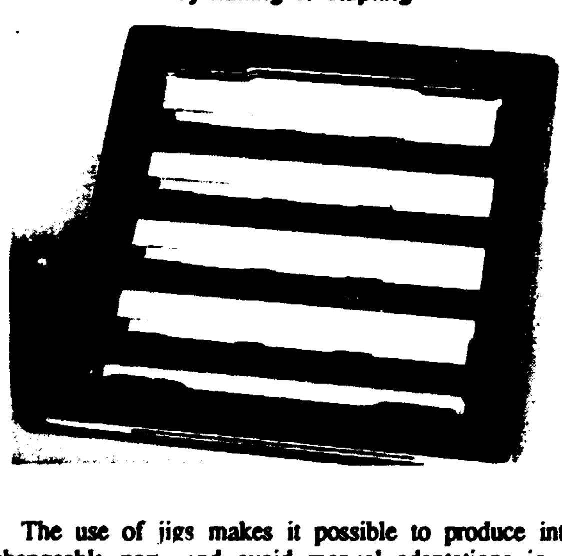


Figure 131. Assembly jig for fixing supporting slides for drawers on cabinet side panels by nailing or stapling



The use of jigs makes it possible to produce interchangeable parts and avoid manual adaptations in the assembly.

The development of jigs from the craft to the industrial level

The development of the furniture industry in industrialized countries has been very fast during the past two decades. The most advanced factories now operate according to the same production principles as, for example, the metalworking industries.

The present level of development has been achieved by a gradual, step-by-step process. The main development stages from the craft level to highly mechanized and automated mass production are:

Level 1: manual or craft level. Only hand tools; manufacture according to individual orders; no standard products.

Level 2: semi-mechanized level. Simple machines used for rough cutting of material; finishing stages with hand tools; manufacture principally according to individual orders, eventually small batches of certain standard designs.

Level 3: mechanized level. Most working stages done using basic woodworking machinery and equipment; simple jigs used in machining and assembly; manual adaptations necessary in assembly; standard models in small batches but products not systematically designed.

Level 4: advanced mechanized level. Machinery consists of basic and multi-purpose machines using sophisticated jigs and low-cost automation in machining and assembly when applicable; systematic quality control at decisive points of the process makes possible the production of interchangeable parts; each part or component is considered as a final product and the assembly as a stage where the components are combined; systematic process control; no manual adaptations in the assembly; standard products in large batches designed according to internal standards (standarized materials, sizes, joints and working methods), taking into account machinery and equipment requirements already at the design stage.

Level 5: automated mass-production level. Machining lines to produce standard components in large quantities; machining heads programmed to produce the desired shapes instead of using jigs; production very capital-intensive; highly specialized product range; microprocessor technology to be applied to a large extent in the future development of the process; robots partly to replace workers.

The above classification is very schematic because most existing factories have a certain overlapping of the various stages. Since the objective of this chapter is to describe the design, construction and use of jigs in furniture production,

*By Pekka Paavola, Lahti Institute of Technology. This text is based on chapters I to III of the *Manual on Jigs for the Furniture Industry* (ID/265) by the same author.

it will deal principally with levels three and four, which still predominate in most furniture factories in both developing and developed countries.

Definition and importance of jigs

A characteristic of manual production is working according to pencil markings when making parts and in certain assembly fixing operations. Usually a tape ruler or a plywood template is used to locate the markings correctly. The markings are no longer necessary when jigs are used, since the guiding elements of the jigs control the workpieces in machining and assembly.

In general, all production jigs in the furniture industry can be divided into machining and assembly jigs. The definitions of the two types of jigs are as follows:

(a) Machining jigs are appliances used in a machine shop for accurately guiding and locating tools or workpieces during the operations involved in producing interchangeable parts;

(b) Assembly jigs are appliances used in an assembly shop for accurately guiding and locating interchangeable parts in joint gluing, fixing and other assembly operations controlling the parts to be handled or the angularity of the product.

Economic aspects of jig design

Cost of jig

The cost of a machining or assembly jig covers the following major items: designing (drawing-board stage, sometimes requiring experimentation); materials (wood, wood-based panels, various sheet materials); supplies and ready-made parts (bolts, nuts, springs, hinges, eccentrics, pneumatic components etc.); construction; and testing and adjusting prior to use for serial production. The proportion of the jig cost in the production cost of one part or final product decreases when the batch size increases. The product development policy of a furniture factory should therefore favour mass production with as long a product life as possible to minimize the jig cost per product. Contracts may be concluded involving the design and construction of jigs for a certain definite number of products without any continuity of production. Even a small batch may justify making a jig if the reduction in labour costs is large enough.

Minimum economic batch size

The minimum economic batch size that justifies the construction of a jig can be calculated from the following formula:

$$n_{min} = \frac{A}{B - C}$$

where

A = total cost of the jig
B = labour cost per unit without a jig
C = labour cost per unit with a jig
B – C = saving in labour cost per unit

Suppose, for example, that a certain assembly stage without a jig lasts an average of 0.25 hours per product. If a special jig is constructed for the purpose, the duration of the same working stage is estimated to be only 0.05 hours. Wages are $1.20 per hour in both cases. The jig cost covers the following items:

Designing (10 h at $2.00 per hour)	$20.00
Materials and supplies	$14.00
Construction (8 h at $1.50 per hour)	$12.00
Testing and adjusting (2 h at $1.50 per hour)	$3.00
Total cost of jig (A)	$49.00

Labour cost per product without jig (B):	0.25 × $1.20 = $0.30
Labour cost per product with jig (C):	0.05 × $1.20 = $0.06
Saving in labour cost per product (B – C):	$0.30 – $0.06 = $0.24

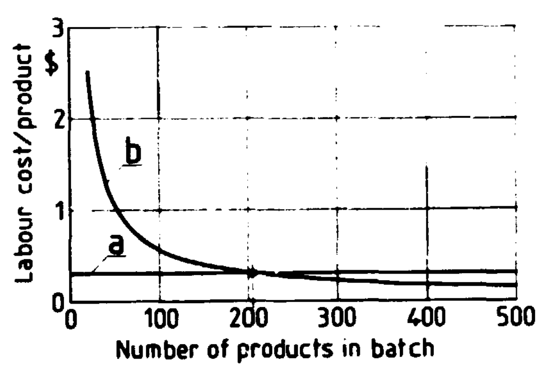
The minimum batch size that would justify the jig is:

$$n_{min} = \frac{A}{B - C} = \frac{\$49.00}{\$0.24} = 205 \text{ pieces}$$

The break-even point is presented graphically in figure 132.

The curve is calculated according to the above example. The intersection point of the curves gives the break-even point at which the making of a jig is justified.

Figure 132. Labour cost per product manufactured based on the number of products in batch



Key: a Without a jig
b With a jig

Increasing the productive capacity of the equipment installed

The time saved by the use of jigs varies so much from case to case that even average figures for the amount saved are difficult to estimate. In that connection, however, the following points should be noted:

(a) Certain woodworking operations may be performed by machine with or without a jig (for example, boring or mortising a row of holes either according to pencil markings or by using a special jig to control the location of holes);

(b) Certain woodworking operations must be done either using hand tools and pencil markings or with a machine and a special jig (for example, safe and accurate spindle moulding of the curved edges of a chair leg is possible only with a jig);

(c) Most assembly operations can be carried out with or without a jig. It is not uncommon that the use of efficient jigs may increase capacity by up to 50 times the results achieved without a jig, depending on the circumstances.

Quality improvements

The above method of calculation does not, however, take quality improvements (finishing, regularity of shape, accuracy of assembly) into account but is based on production cost only. In fact, the use of a jig may also be justified in certain cases below the calculated minimum batch size if the improved quality has a positive effect on the marketing of the product.

Savings in raw-material consumption

One further positive consequence of the use of jigs is the decrease in raw-material consumption as a result of the smaller number of faulty parts or products. This is naturally related to the improved manufacturing accuracy made possible by the use of jigs. The typical faults causing material and labour wastage are as follows:

(a) A part may be inaccurately worked or machined (for example, faulty dimensions or shape, wrongly located joint details, incorrect angularity);

(b) An assembled product includes faulty parts or the assembly is incorrectly done (for example, the product is not rectangular, clearances are not even, movable parts do not move properly), causing the rejection of the whole finished product.

Labour skills

Manual or semi-manual furniture production sets high requirements for the skills of the workers since the quality of the product depends directly on the work of the carpenter. In more advanced production involving the use of jigs, workers must be well-trained but not to the same high level of skills as in the case of manual production. This further reduces labour and production costs.

Safety considerations

One of the advantages of the use of jigs from the human point of view is the fact that jigs function as effective safety devices, particularly in machining. Most machining jigs can be provided with special handles for safe machine feeding. Splinter guards are to be recommended in certain jigs. A machining jig usually makes a solid base for the part to be machined so that the hands of the machine operator can be quite far away from the cutting tool during the feed. The safety aspects are reflected in the jig illustrations presented later in this chapter.

Technical aspects in design of jigs

Design according to working drawings and prototypes

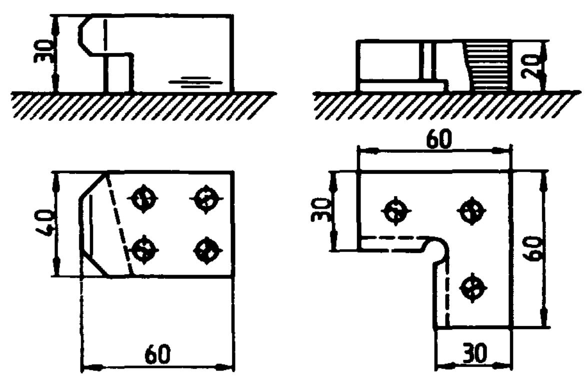
In modern furniture production the manufacturing stages are based on drawings that also provide the necessary information on jig design. The drawings are usually classified as parts drawings and assembly drawings. For details on the system recommended see the corresponding text in the chapter on technical product design (chapter XVII).

Position and construction of stoppers

Special stoppers are needed for the accurate positioning of workpieces in both machining and assembly jigs. Their design should be based on the following rules:

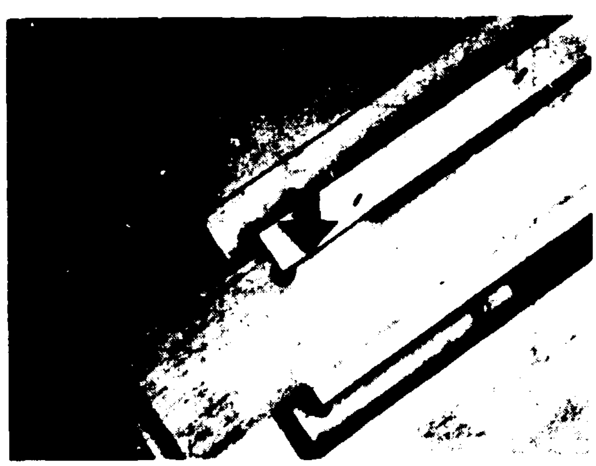
(a) The stoppers must hold the workpiece at specific points and not over long lengths, so as to prevent small particles such as wood chips and dust from supporting the part at the wrong places. Extra space should be available for splinters that may become lodged in the corners of the workpiece (figure 133);

Figure 133. Wooden stoppers



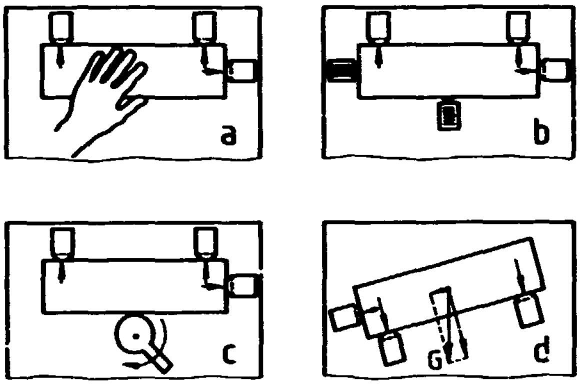
(b) The location of the stoppers must correspond to the primary measurements whenever possible (figure 134);

Figure 134. Location of stoppers



(*c*) The workpiece can be pushed against the stoppers by hand, using rubber or steel springs, eccentrics or some other mechanical means or by gravity (figure 135);

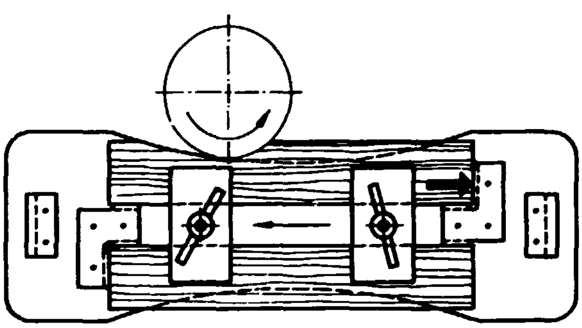
Figure 135. Alternative methods of holding the workpiece against the stoppers



Key: a Pushing by hand
b Spring
c Eccentric
d Gravity

(*d*) In machining jigs the stoppers in the direction of the feed should be positioned against the cutting force (figure 136);

Figure 136. Spindle-moulding jig for a curved furniture component (The cutting force pushes the workpiece against the stoppers.)



(*e*) If the workpiece must be held symmetrically between two stoppers, both should be provided with similar springs. For workpieces with a circular or square cross-section, special holders should be constructed (figure 137).

Fixing elements

The workpiece must be tightly secured in the machining jigs. Certain assembly jigs also require good fixing of the workpiece. The commonly used fixing elements are:

(*a*) Thin steel pins sharpened like a chisel. The sharp edge must penetrate into wood in the direction of the grain to avoid cutting the fibres. Such pins are often used in jigs for band sawing, spindle moulding and routing (figure 138);

Figure 137. Stoppers for holding the workpiece symmetrically with respect to the jig (A piece of medium-hard rubber (a) acts as spring in the wooden stopper.)

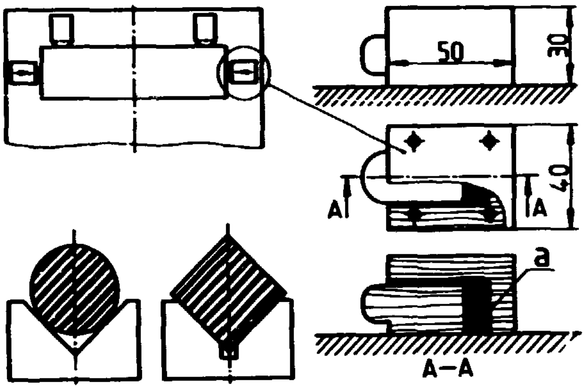
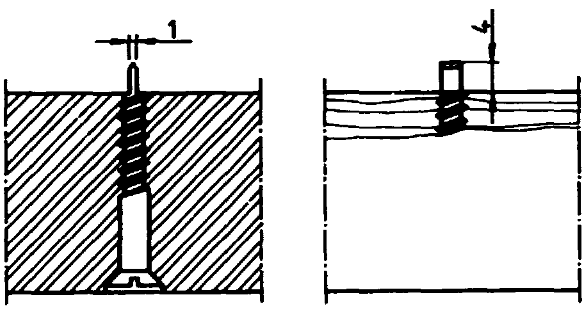
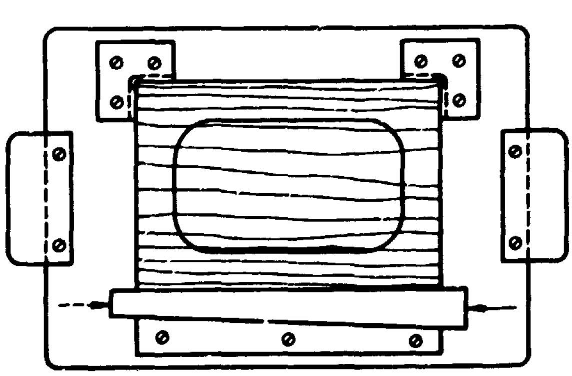


Figure 138. Sharpened steel pin used as fixing element



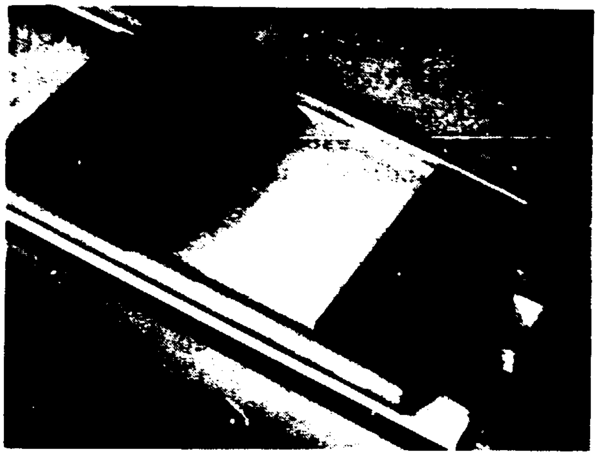
(*b*) Wedges, usually made of wood or plywood, are common in spindle moulding and routing jigs (figure 139);

Figure 139. Routing jig with a wooden wedge for fixing the workpiece (A hammer is used to tighten and loosen the wedge.)



(*c*) Screws, which were formerly very common in all kinds of machining jigs (figure 140), are being superceded by eccentrics, which can be tightened more rapidly;

Figure 140. Spindle moulding jig with a screw-type clamp for fixing the workpiece



(*d*) Eccentrics, often used both in machining and assembly jigs. The material may be wood, plywood or metal. Car engine valve springs can be used to return the pressure shoes when opening the eccentrics (figures 141 and 142);

Figure 141. Spindle-moulding jig with eccentrics as fixing elements (Sandpaper is glued on top of the jig base to increase the friction.)

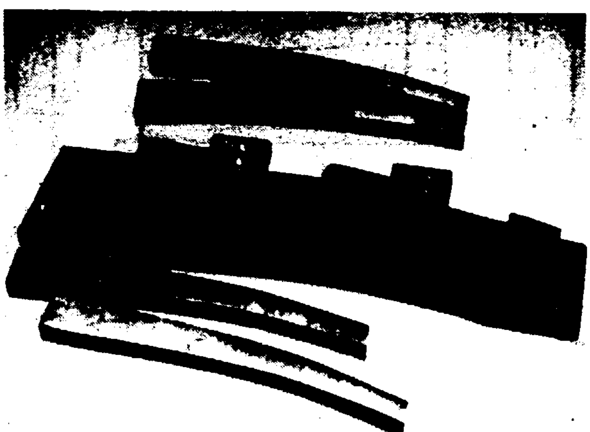
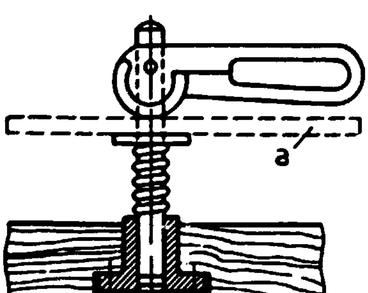
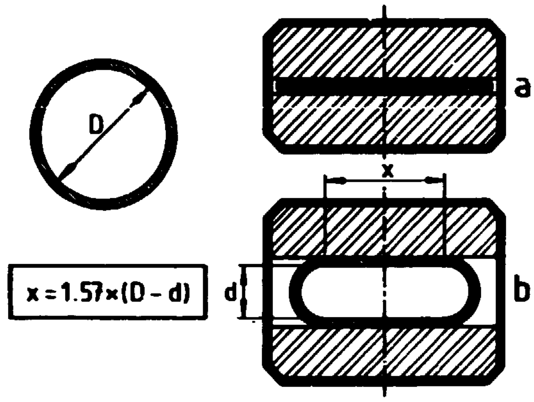


Figure 142. Eccentric with pressure plate (a) for fixing the workpiece



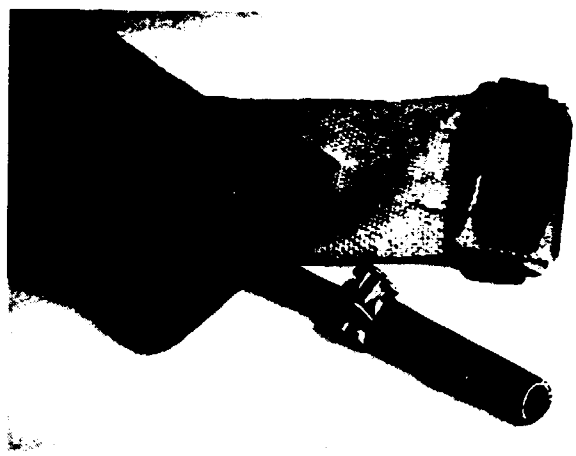
(*e*) Fire-hose clamps, used particularly in assembly jigs (figures 143 and 144). The fire hose must have a plastic lining on its inner face;

Figure 143. Principle of a fire-hose clamp (Rubber bands around the clamp work as return springs.)



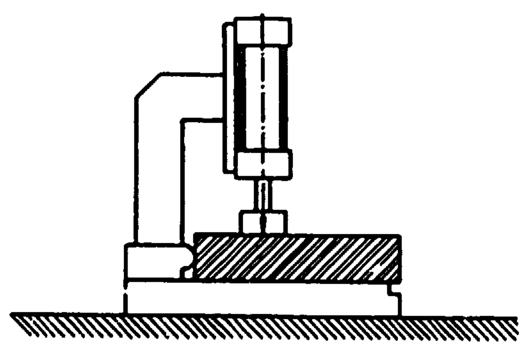
Key: a With no pneumatic pressure applied
b With pressure applied

Figure 144. Construction of a fire-hose unit (The ends of the hose are sealed by riveting.)



(*f*) Pneumatic cylinders and suction cups, used in advanced jigs for both machining and assembly (figure 145).

Figure 145. Pneumatic cylinder for fixing a workpiece on a jig



The friction between the workpiece and the jig can be easily increased by gluing a piece of sandpaper or abrasive cloth on the base panel of the jig (figure 141).

Single and multi-purpose jigs

Jigs may be classified as single and multi-purpose according to their uses. The first type of jig is designed to serve one definite purpose, whereas the latter may be adjusted for various purposes. Most spindle-moulding and routing jigs are constructed for a certain component and specific machining operation and will be discarded when the production of the component is finished. Good examples of multi-purpose jigs are the adjustable jigs for the band sawing of circular pieces with unequal radii from various panels, and those assembly jigs in which the guiding and clamping elements can be readjusted within certain limits.

Accuracy of jigs

Machining jigs

The accuracy of the working heads of woodworking machines is at most ± 0.05 mm when the bearings are in good condition. Studies made in furniture and joinery industries have shown, however, that the actual maximum accuracy with which parts and their details can be machined is ± 0.1 mm to ± 0.3 mm, taking into account the changes in dimensions resulting from variations in the moisture content of wood during the manufacturing process. The accuracy with which small details such as joints can be machined is usually higher than the accuracy with which larger parts can be manufactured.

The measurements in such studies were taken from workpieces in which the standard guiding elements of the machine have been used (straight fences and feed tables and chains) for feed control in the machining.

When machining with jigs, the standard guiding elements are replaced by the guiding surfaces of the appliances with a special attachment in the machine, but the machining principle itself remains the same. For example, when spindle moulding a longitudinal groove into a furniture component, the component is fed along the straight fence of the machine, but in spindle moulding a curved chair leg, the guiding edge of the jig is fed along a collar around the spindle opening in the machine table, keeping the jig tightly in contact with the collar. If the stoppers, which control the positioning of the workpiece within the jig, are properly designed, the machining accuracy should not differ very much from the standard method, provided that the following conditions are met:

(a) The guiding collar is precisely circular and fits tightly into the spindle opening;

(b) There are no chips or dust between the jig stoppers and the workpiece;

(c) The workpiece is carefully secured in the jig.

Various experiments have shown that the machining accuracy of spindle-moulding jigs falls within the limits of overall machining accuracy given above. The same may be expected to apply to most machining jigs.

Assembly jigs

The dimensional accuracy of an assembled furniture detail or a finished product depends on the accuracy with which the manufacture of parts is carried out and on the precision of the assembly stage itself. If the parts are interchangeable and the proper jigs are available, the assembly can be done very accurately and efficiently. The main functions of the assembly jigs are as follows:

(a) One or more parts have to be fixed to another part by gluing, nailing, stapling or screwing according to the primary measurements without any machined joints (known as surface fixing);

(b) Parts with machined joints must be glued to each other. The jig must take care of the clamping and proper angularity of parts so that manual corrections before the setting of the glue will not be necessary (figure 146);

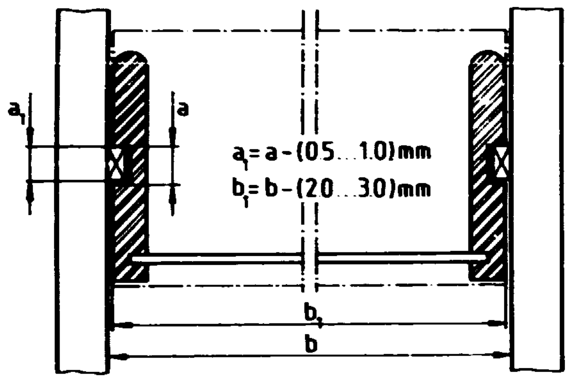
Figure 146. Frame assembly jig with pneumatic cylinders (The jig also ensures the rectangularity of the frame.)

(c) The jig must ensure correct clearances at proper points when assembling moving parts.

The assembly jigs have so many different uses that any generally applicable figures about their precision cannot be given. Experiments carried out by the author have shown that the accuracy with which a part can be located within another part in surface fixing corresponds to the average machining accuracy of about ± 0.2 mm to ± 0.3 mm.

The nominal clearance between two sliding parts must be chosen according to the size of the detail in question. Usually the clearances vary between 0.5 mm and 3 mm. For example, the nominal clearance between the sliding groove of the drawer side and the supporting wood strip should be about 0.5-1 mm in the width of the groove, whereas the outer width of the same drawer, when assembled, should be 2-3 mm less than the inner width of the cabinet (figure 147). Particular attention must be paid to the supporting principle of the drawer. The distances of the upper edges of the supporting strips from the cabinet top are decisive for the proper location of the drawer or a set of drawers if there are several of them on top of each other. The distances will therefore be primary measurements for the jig designed for nailing or stapling the strips.

Figure 147. Cross-section of a portion of a cabinet with a drawer showing nominal clearances necessary for the proper moving of the drawer



Jig materials

The properties of the materials used for the jig body (base, frame etc.) and the guiding elements are decisive for the precise functioning and manufacturing accuracy of the jigs. The general material requirements are as follows: good resistance to wear (hardness); good moisture stability, that is, low tendency to warp, shrink or swell under moisture variations; and rigidity, smoothness and easy working with machines and hand tools.

The traditional material, solid wood, is well-suited for many jig details such as stoppers, pressure shoes, eccentrics and handles but not recommended for the guiding elements of high-precision jigs because wood shrinks and swells with variations in the moisture content. The best-suited wood-based materials are of cross-laminated structure and include the following: cross-laminated solid wood, plywood, blockboard, hard fibreboard and particle board.

For the guiding elements very high-quality material can be made of the above-mentioned panels by gluing a sheet of rigid melamine plastic laminate on each side. The surface and edges of the combined panel are very resistent to wear. Easy sliding, affecting the accuracy of the jig and the quality of finish, particularly in spindle-moulding and routing, can be ensured by rubbing solid paraffin as a lubricant on the surfaces. Plastic laminates are also among the best materials for machining jig bottoms because they ensure easy sliding.

Before being used, all wood-based jig materials should have a moisture content in equilibrium with the relative humidity of air inside the factory so as to avoid inaccuracies caused by later deformations. If several panel or sheet materials are combined by gluing, the construction should always be symmetrical to avoid warping and curving. When a particularly long service life is required, aluminium sheet can be used to make the guiding parts, particularly in routing jigs.

Rigid frames are necessary in certain assembly jigs. They can eventually be constructed of wood or wood-based panels, but very often steel or aluminium profiles are also used because of better strength and stiffness. If the weight is not decisive, steel is more practical because it can be easily welded in any factory maintenance workshop.

Quality and price of jigs

High quality in a jig does not necessarily mean a high jig cost but rather proper design and material selection. In fact the material cost of the majority of machining and assembly jigs is very low, and in many cases the material can literally be picked up from the factory floor. Excluding complicated assembly jigs with pneumatic components, the following rules apply to most ordinary production jigs:

(a) The design stage of a jig seldom takes more than a few hours to complete provided proper working drawings or an acurately made prototype of the new product are available;

(b) The cost of materials and supplies for a jig can sometimes be disregarded because of the use of waste pieces. Even in the case of big jigs, the material consumption is rarely more than that of an average piece of furniture produced by the factory. Certain jig components such as eccentrics, screws and springs can be recycled after a jig has become useless;

(c) The construction, if proper jig drawings are available, seldom takes more than a few hours.

Jig storage and identification

Planning of storage areas

Jigs designed and built for serial production of furniture form an important part of production facilities and should therefore be carefully stored. The following storage requirements should be met:

(a) Storage should be close to the tool maintenance workshop. In large factories it is advisable to keep assembly jigs in a special storage area in the assembly shop;

(b) The storage area must be a special room separated from the actual production workshop to avoid chips and dust on the jigs stored;

(c) The relative humidity in the storage area should be the same as in the factory in general. A jig should never be exposed to water (rain, pipe leakages);

(d) The most practical means of storing smaller jigs is by hanging them from special racks fixed to the walls. Shelves can be constructed for large and heavy jigs;

(e) The jigs must be provided with an identification number or code and stored accordingly.

Identification of jigs

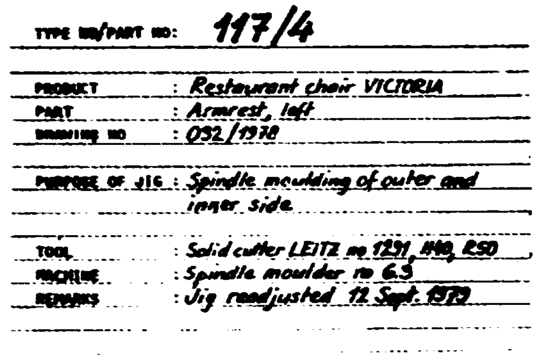
The standard models produced serially in furniture factories usually carry a type number or code for easy identification. A factory may choose the following type of coding system:

Chairs	100 . . . 199
Tables	200 . . . 299
Cabinets	300 . . . 399
Bookcases	400 . . . 499
Beds	500 . . . 599
etc.	

The first number of the three-digit codes indicates the product group. The code number can serve as the general storage number of all the jigs used to make the product in question. The different jigs of the set are further identified by the part number in the working drawing. Similarly, the jig numbers should be used in the drawings as references to the part in question or in the column of remarks in the list of parts.

A good practice is to complete a filing card for each jig in storage, including all information necessary for the use of the jig. An example of such a filing card is shown in figure 148.

Figure 148. Filing card used for the identification of jigs


TYPE NO/PART NO: 117/4

PRODUCT : Restaurant chair VICTORIA
PART : Armrest, left
DRAWING NO : 032/1978

PURPOSE OF JIG : Spindle moulding of outer and inner side

TOOL : Solid cutter LEITZ no 1231, 1140, R50
MACHINE : Spindle moulder no 6.3
REMARKS : Jig readjusted 12 Sept. 1979

XXII. Furniture technology*

Special features of the furniture industry

The products of the furniture industry represent the highest degree of processing compared with the products of other secondary wood-processing industries. The key characteristic of furniture products is that their external appearance has a decisive effect on their ability to compete on the market. In the climatic conditions of e.g. northern Europe, the demand for furniture is seasonal. Furthermore, furniture sales are considerably affected by fashion, which means that the life of a particular design is often very limited. Furniture manufacture can seldom be real mass production because consumers want their homes to have individuality. A reflection of this is the large number of wood species used for veneering or as solid components. Products are frequently lacquered in natural colour or stained in different shades. At the moment furniture painted in bright colours is also quite popular.

The greatest production problem in most furniture factories, is, however, the wide assortment of items. In many cases the different kinds of workpieces in various phases of machining may be numbered in the hundreds or even thousands.

A solution to this problem is specialization; this means limiting the production programme in one way or another. For instance the basis of specialization may be:

Kind of product (for example, a factory may specialize in chairs only)

Product group and end-purpose of the product (home, office etc.)

Raw material and construction (solid wood, particle board etc.)

Manufacturing method (special machines or techniques)

Another very practical method is to order from subcontractors the parts that are not suited to the production programme of a particular manufacturer.

Mode of production

Industrially produced furniture is made almost without exception in series production. The number of items manufactured at the same time usually varies from a few hundred to a few thousand, depending on the kind of product. The following features are characteristic of furniture series production:

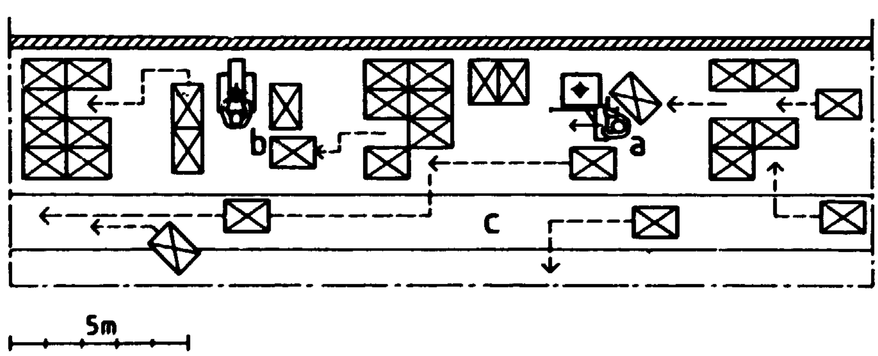
(a) Stock or storage areas are needed between the different phases of manufacture (figure 149);

(b) Transport costs make up a significant proportion of production costs;

(c) The components are usually transported on pallets using hand-operated hydraulic lift trucks. This method of transport is the most flexible in series production;

(d) Belt conveyors and other types of conveyors can be used to a limited extent only (assembly, surface finishing) because of the great variety of items produced.

Figure 149. Stock areas between different stages of manufacture



Key: a Vertical spindle moulder with feed table
b Router
c Factory passage for pallet transportation

*By Pekka Paavola, Lahti Institute of Technology, Lahti, Finland.
Originally issued as ID/WG.105/35/Rev.1.

The manufacture of furniture as a continuous process is, of course, possible in principle, using a fixed production line without stock areas. It would, however, require a large expansion of the market. In any case, a clear trend towards the extended use of machine lines and automated production has been noted in recent years.

Accuracy of manufacture

The accuracy of woodworking machines is, at the most, ± 0.05 mm when the bearings are new. The actual accuracy of working pieces in practice is ± 0.1 to ± 0.3 mm, taking into account changes in dimensions resulting from variations in moisture content during the manufacturing process together with other inaccuracy factors.

High accuracy in manufacturing is generally aimed at for the following reasons:

(a) Parts of products belonging to different series are interchangeable;

(b) A sliding fit between parts is possible without manual fitting in assembly;

(c) Joints are strong and easy to assemble;

(d) Manufacture in large series is possible.

To achieve high accuracy the following measures are taken:

(a) The machines are regularly serviced according to their working instructions;

(b) Dimensioned working drawings are used throughout. The numerical values indicate the nominal dimension to be achieved;

(c) High quality measuring instruments, gauges and templates are used to control the dimensions during machining (see chapter XXXV on quality control in the furniture industry);

(d) Jigs are used in machining and assembly whenever possible (see chapter XXI on jigs used in the furniture and joinery industries).

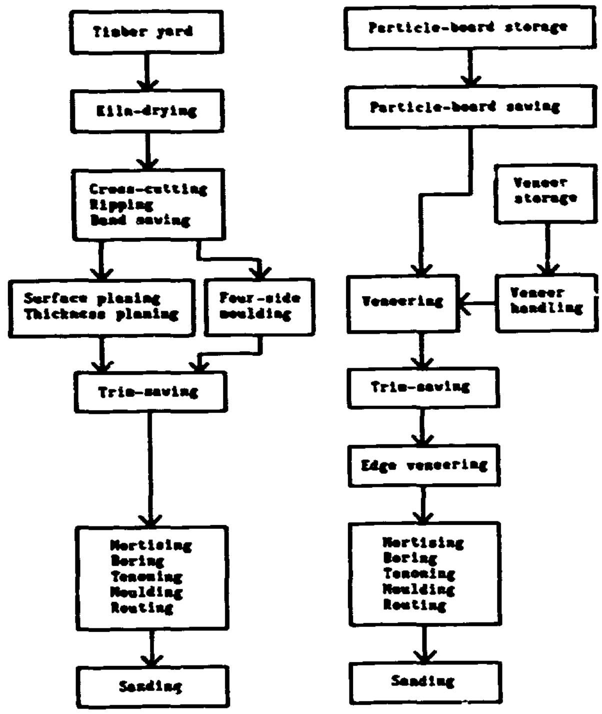
Drying of timber

At present, timber is usually dried in sawn lengths before cross-cutting, thus minimizing the loss of material owing to end checks. The drying kilns are in a separate building or in a wing of the factory building. The kiln charges are usually transported by means of wagons on rails or heavy fork-lift trucks.

The arrangement of phases of work in machining

The order of machining stages in furniture manufacture is generally that indicated in figure 150.

Figure 150. Machining stages in a furniture factory



Machining

In machining, special attention should be paid to the following points:

(a) Whenever possible, the machining should be done in continuous through-feed. This must be taken into account in the design phase of products;

(b) Protective devices must always be used;

(c) A chip and dust exhaust system is a necessity;

(d) The use of tungsten-carbide-tipped tools is advantageous, especially when machining particle boards and very hard woods. Proper tool maintenance is of prime importance;

(e) The choice of feed speed strongly affects the quality of the finish;

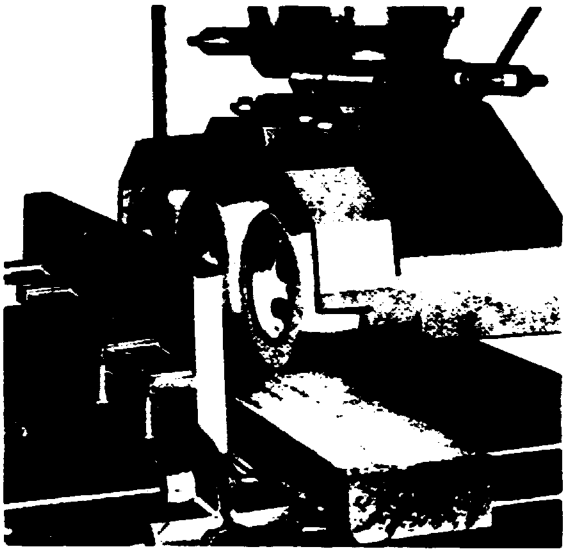
(f) Automatic feed attachments (figure 151) increase machine capacity, quality of finish and safety;

(g) Machines with many working heads (such as four-side moulders and double-end tenoners) are advantageous with large series. In small-scale production the setting costs are too high.

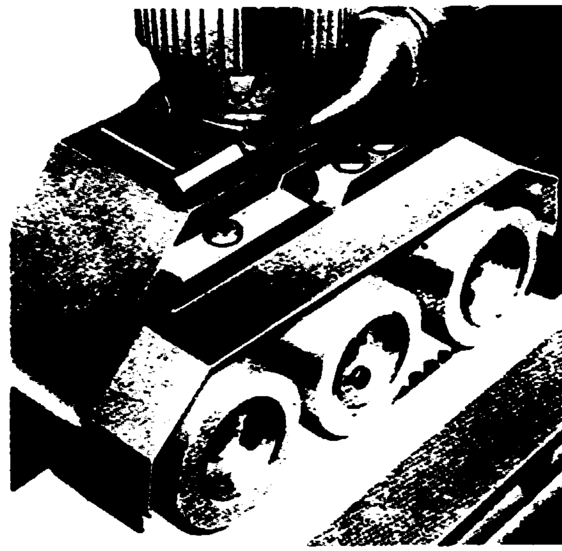
Some of the most important machining phases and their special features are treated briefly below.

Figure 151. Automatic feed attachments

A. Automatic feed attachment on a band saw



B. Automatic feed attachment on a circular saw



Cross-cutting and ripping

Cross-cutting is usually done with a machine having a circular saw that moves horizontally. The timber to be cut is loaded on a wagon that can be lifted pneumatically or hydraulically (figure 152). The operator must possess a good working skill in order to achieve material losses that are as small as possible (usually 5 to 20 per cent). The cutting margin varies between 10 and 50 mm, depending on the length of the pieces and type of timber.

Cut material is usually transported for ripping on pallets, but a rotating circular sorting table or other methods can also be used (figure 153). The ripping saw usually cuts from above and is provided with a feed chain and a return belt conveyor (figure 154); the position of the blade is made visible on the surface of the board by means of a shadow-line device. The cross-cutting and ripping are done according to a piece list; other raw materials needed may be marked on the same list.

Figure 152. Timber wagon on a lift table (pneumatic or hydraulic)

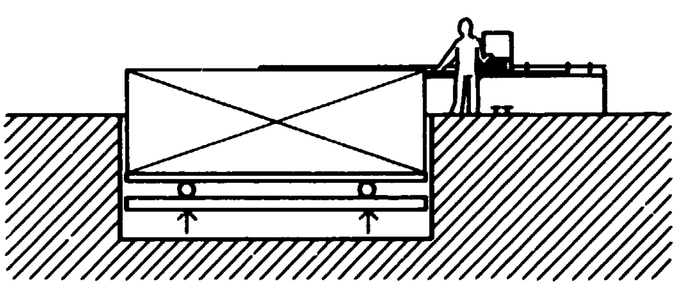
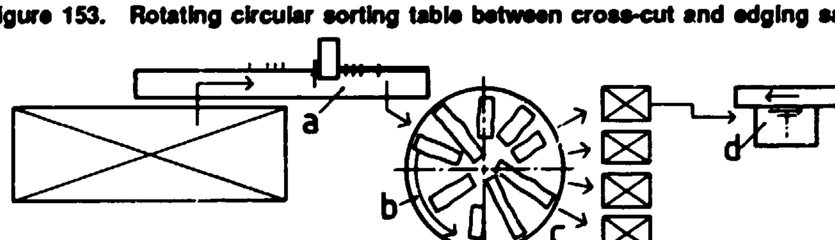


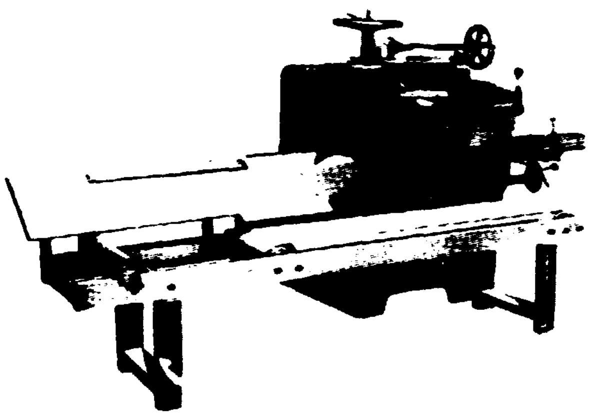
Figure 153. Rotating circular sorting table between cross-cut and edging saws



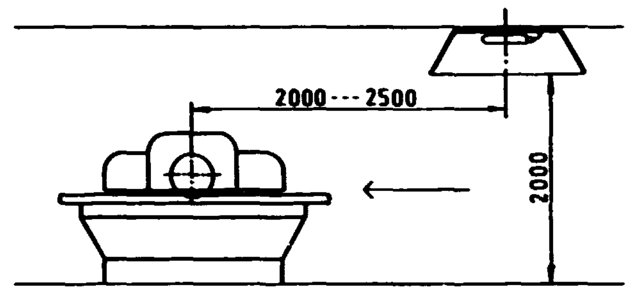
Key: a Cross-cut saw
b Sorting table
c Sorting to different lengths
d Edging saw

Figure 154. Ripping saw

A. Ripping saw with a return belt conveyor



B. Correct positioning of a shadow-line device



Band sawing

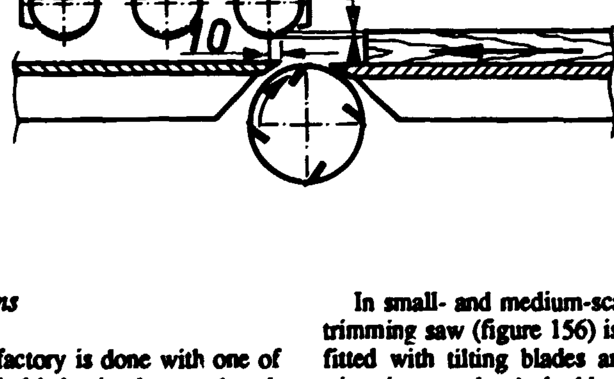
Band sawing is necessary in the manufacture of all curved parts, such as round table-tops and parts of chairs. The sawing is done either along a line drawn with a template or with a jig.

Surface planing, thickness planing and moulding

Normally, the cross-cut and ripped pieces are machined first in a surface planer and then in a thickness planer. The pieces emerge from these phases with a rectangular cross-section. The surface planer can be provided with an automatic feed attachment installed on the rear table side (see figure 155).

When more complicated profiles are machined, a four-sided moulder is efficient provided the scale of production is large enough. In the furniture industry such machines have a long front table, similar to that of a surface planer, for straightening the undersides of boards as the first machining operation.

Figure 155. Placement of an automatic feed attachment for a surface planer

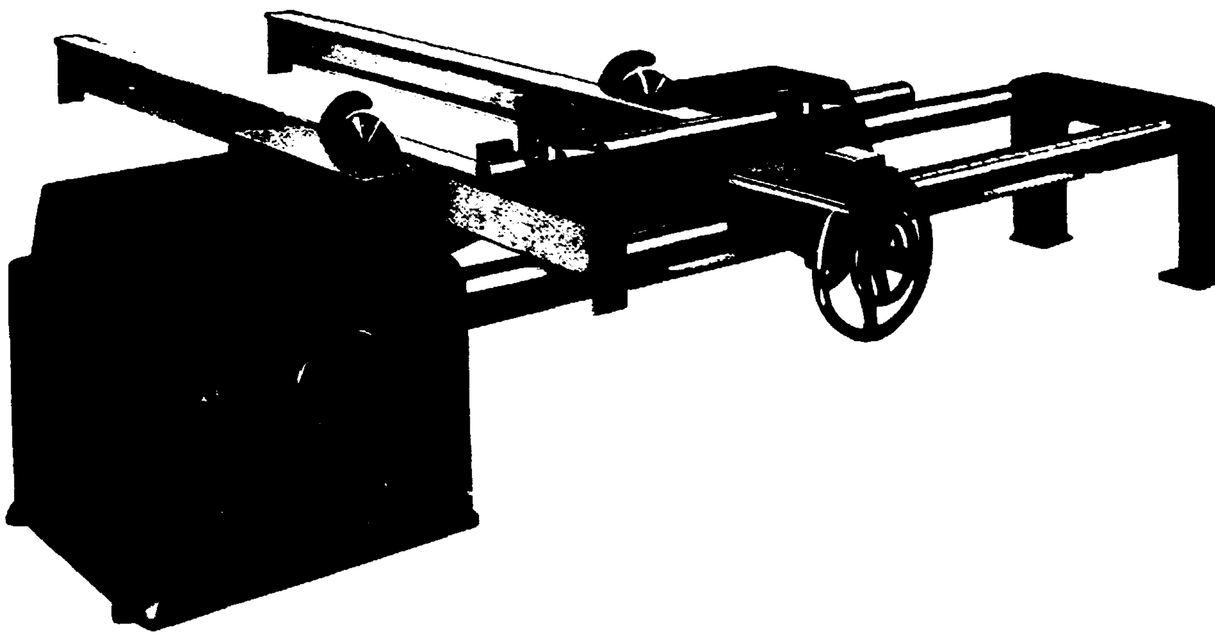


Trimming to final dimensions

Trim-sawing in a furniture factory is done with one of the following machines: a single-blade circular saw bench (often with sliding table), a single-blade trimming saw, a double-blade trimming saw or a double-end tenoner.

In small- and medium-scale production, a double-blade trimming saw (figure 156) is very efficient and versatile if fitted with tilting blades and is particularly suitable for trimming panels. A double-end tenoner is also useful for trimming and for many other machining phases such as tenoning and moulding.

Figure 156. Double-blade trimming saw

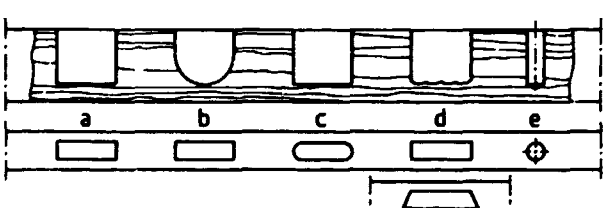


Mortising and boring

The mortises and holes needed in furniture joints may be turned out with hollow-chisel, chain, slot and oscillating mortisers or with a boring machine (figure 157).

Hollow-chisel mortising is the traditional way of making rectangular holes. Because the machine is normally hand-fed, its efficiency is low; the method is therefore poorly suited to modern production.

Figure 157. Mortises produced by five different machines



Key:
- a Hollow chisel mortiser
- b Chain mortiser
- c Slot borer
- d Oscillating mortiser
- e Boring machine

Chain mortising is mainly used in the joinery industry for making deep mortises. Slot mortisers make a hole that is rounded at the ends. Thus the tenons must be machined in a special machine to give them the corresponding form. For this reason, slot mortisers are not used very widely.

Mortisers with oscillating tools make rectangular holes but also other forms are possible using proper tools. By combining several such units, capacity may be substantially enlarged.

The dowel joint is presently one of the most important jointing methods in furniture production. The machining of panel components is usually done with multi spindle boring machines with a normal standard pitch of 32 mm (figure 158). For boring narrow parts of chairs, drawers etc., special boring heads with fixed or adjustable spindle centres are used (figure 159).

Tenoning

For machining corner-locks, tongue-and-groove and stub-tenon joints, any of the following machines may be used: a vertical spindle moulder with a special attachment, a single-end tenoner or a double-end tenoner. The tenoners are provided with many tool heads, and they always trim the piece to be machined by length with the aid of circular blades (figures 160 and 161).

Many models of double-end tenoners are available. In addition to horizontal and vertical working heads, there are router units that machine grooves as the workpiece is going throught the machine. The machine can be programmed to make various cut-outs and other complicated machining operations.

Figure 158. Multi spindle boring machine

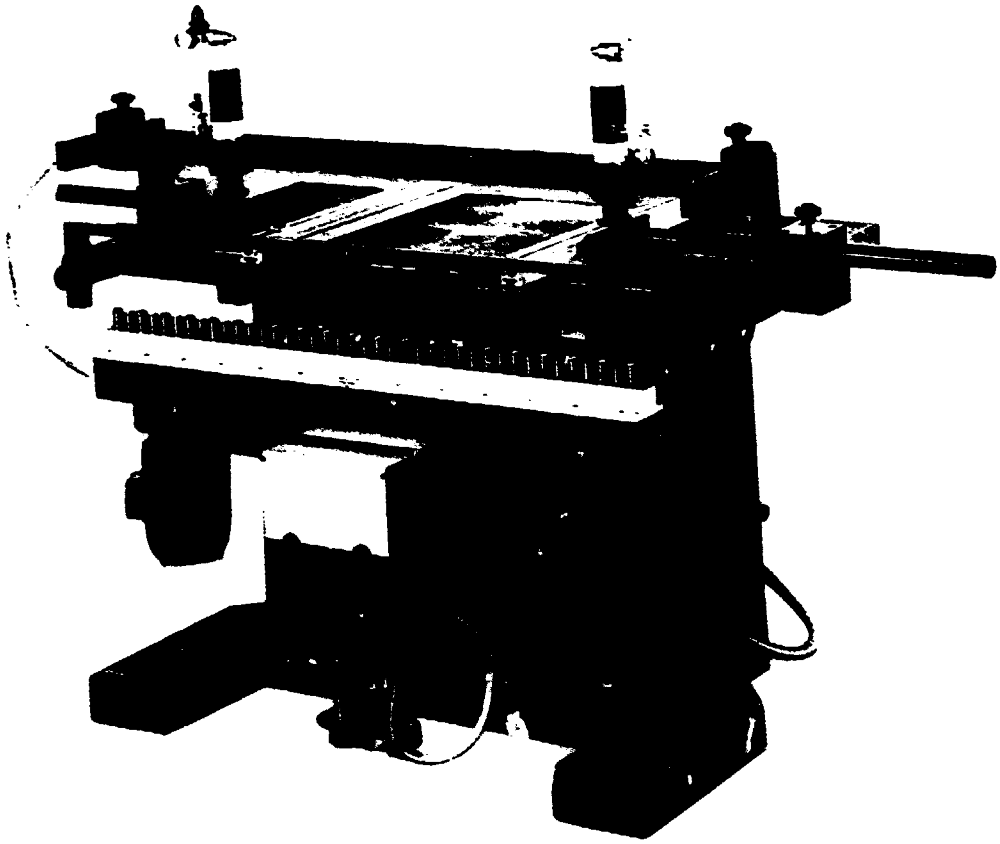
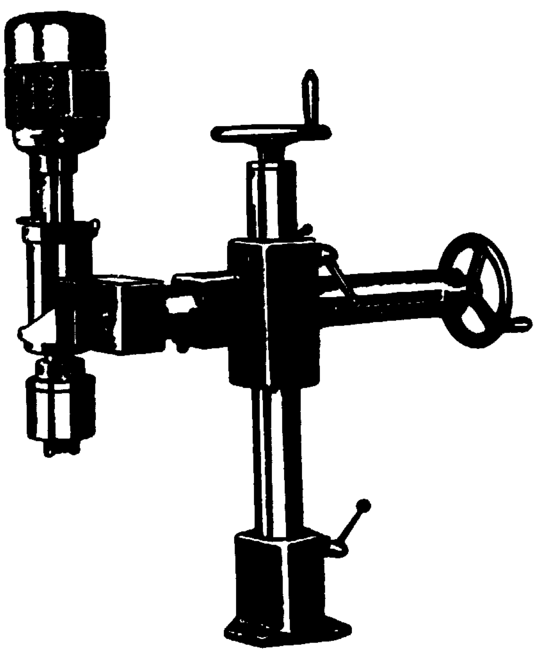


Figure 159. Multi spindle boring machines for narrow parts

A. Independently adjustable boring unit with a multi spindle boring head

B. Machine with three multi spindle boring heads



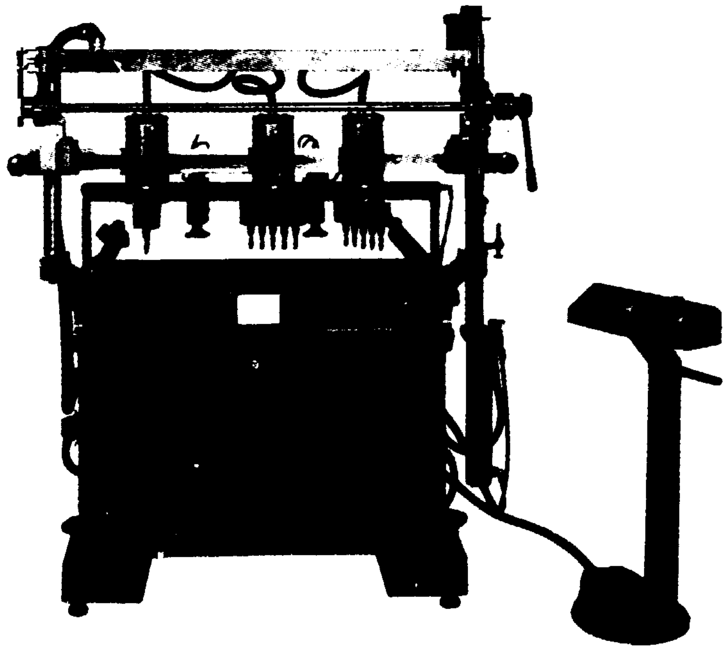


Figure 160. Single-end tenoner

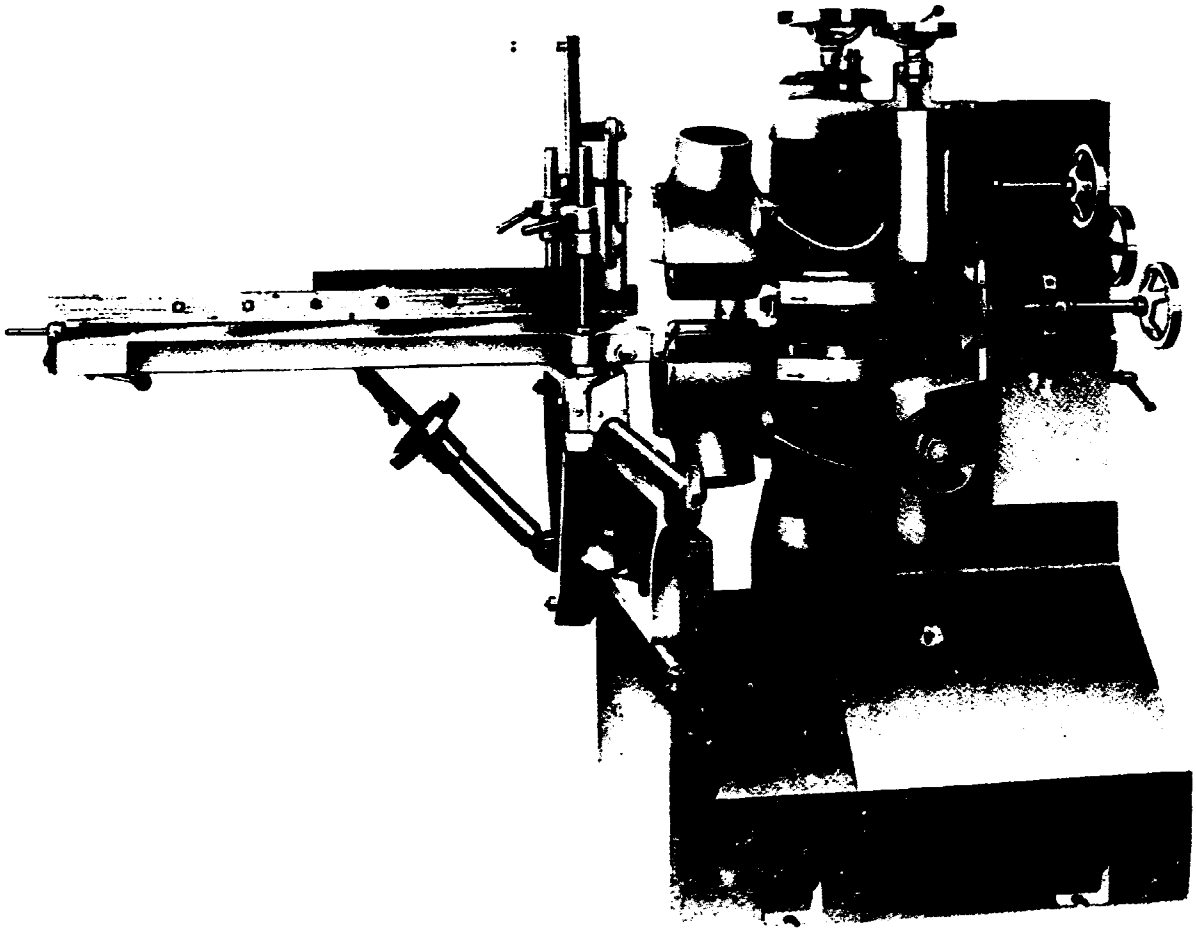
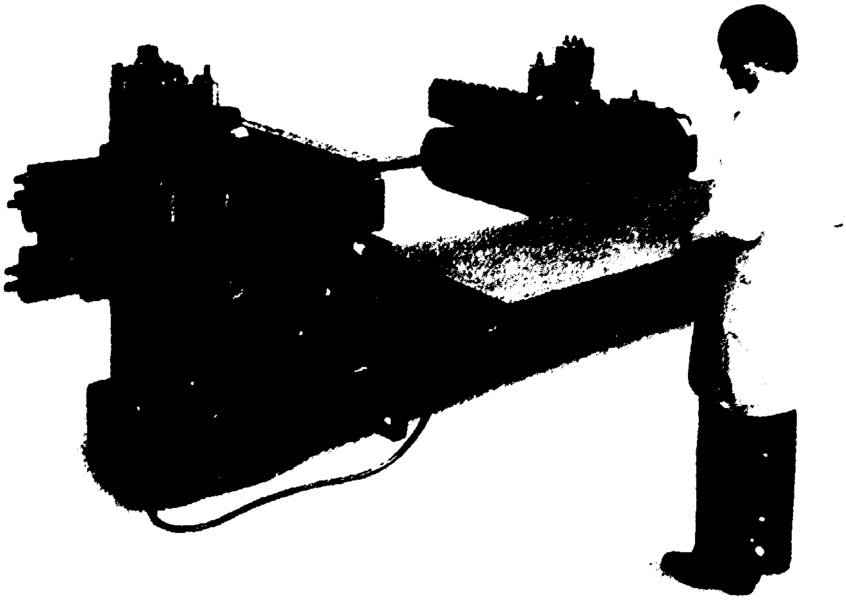


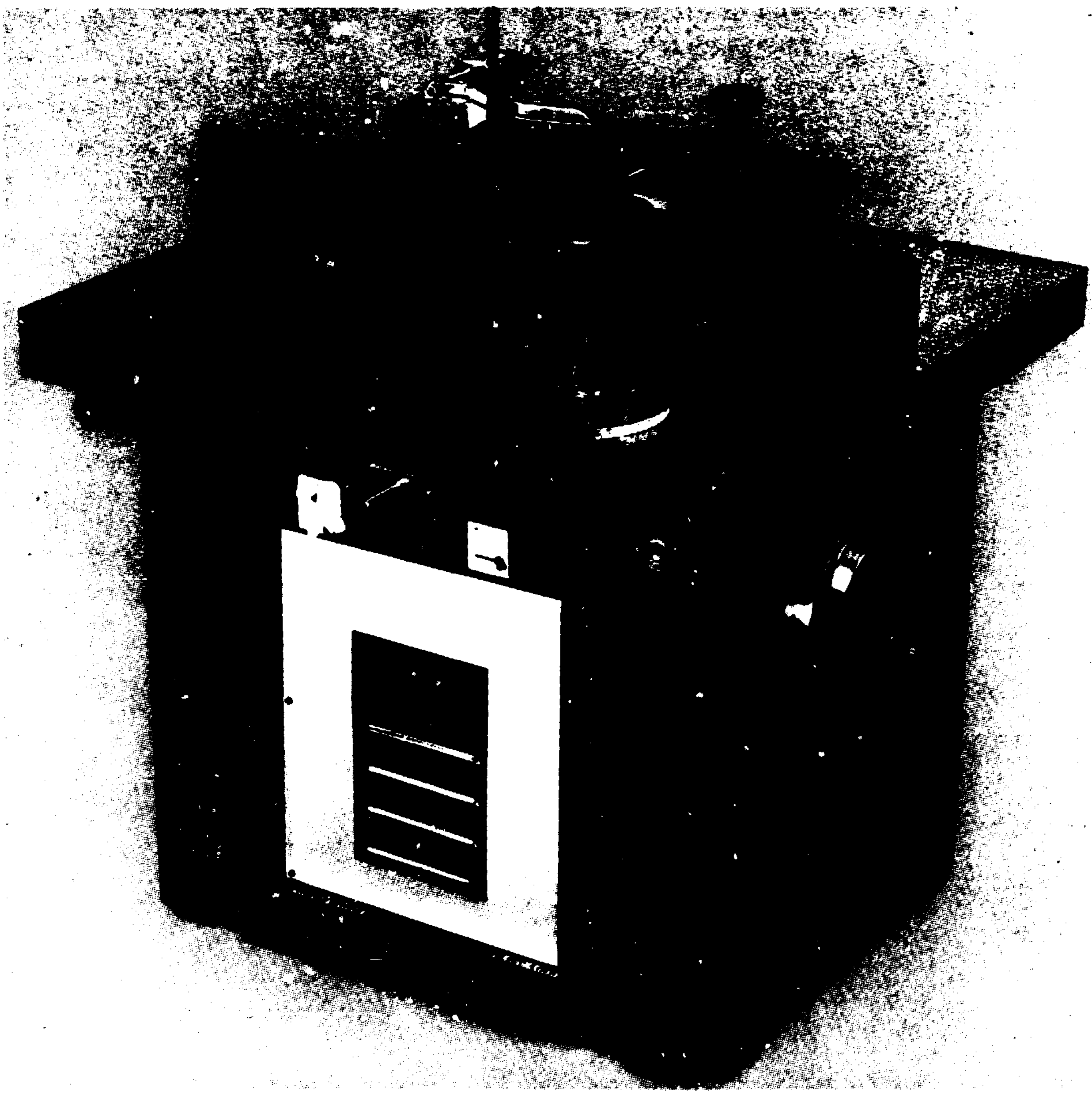
Figure 161. Double-end tenoner



Vertical-spindle moulding

The vertic ndle moulder (figure 162) is one of the most versatile .. chines used in the furniture industry. It is used most commonly for making grooves and rabbets, roundings and more complicated profiles, tenons and slits and moulding with a jig. If a feed attachment is used, the capacity may be considerably increased, the quality of the finish improved and the risk of accident diminished. (A large proportion of the accidents in furniture factories occur in connection with the careless use of a vertical spindle moulder.)

Figure 162. Vertical spindle moulder



Sanding

Sanding is the last working phase before assembly or surface finishing. The quality of surface finishing depends greatly on the quality of sanding. At present, the most important sanding machines are narrow-belt sanders with vertical or horizontal belts, wide-belt sanders, and special-purpose sanders such as profile sanders and curve and form sanders.

Narrow-belt sanders with vertical belts (figure 163) are used especially for sanding the edges and e.g. sides of assembled drawers or frames. Horizontal-belt machines (figure 164) are chiefly used for sanding panels. The newest type of sander is the wide-belt sander, which has rapidly become prevalent in the furniture industry because of its versatility and the good quality of the finish it produces. It is suitable for sanding solid parts as well as veneered panels. The construction principle for one such machine is shown in figure 165.

Figure 163. Vertical-belt sander

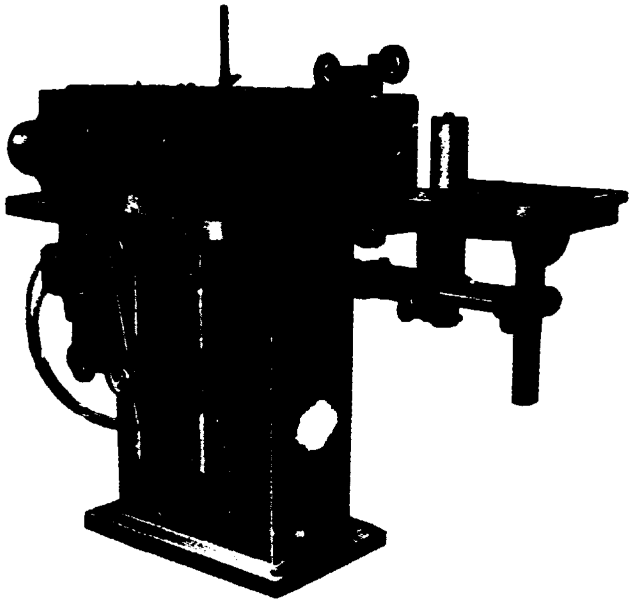


Figure 164. Horizontal two-belt sander

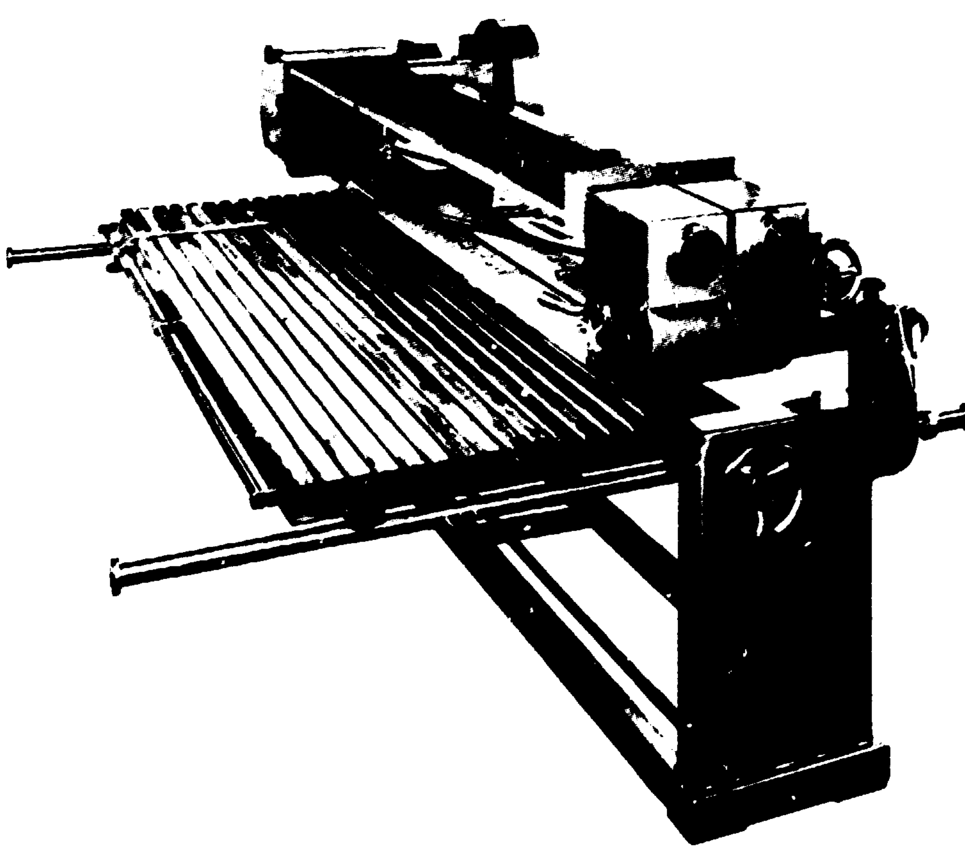
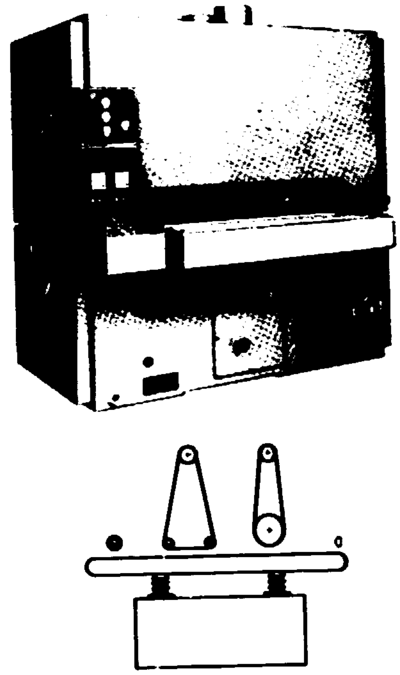
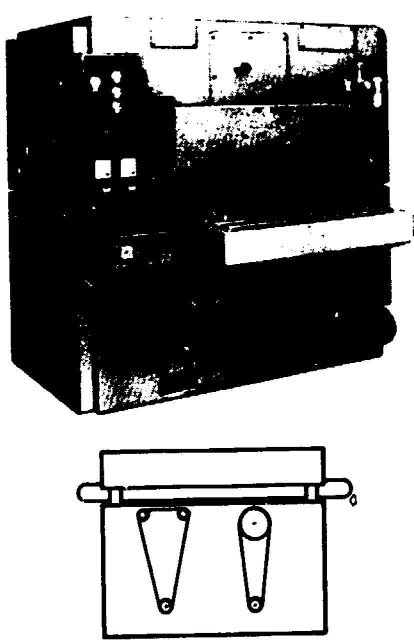


Figure 165. Wide-belt sanders

A. Wide-belt sander for upsides



B. Wide-belt sander for downsides



Of the abrasives used in sanding belts, aluminium oxide is the most important. Silicon carbide, however, is better suited for sanding hard species of wood. In sanding soft woods, belts with an open structure of abrasive material are used. The backing is paper or cloth (for heavy sanding).

Sanding is best done in two phases at least, but sometimes a third sanding is necessary. Coarseness is usually selected as follows:

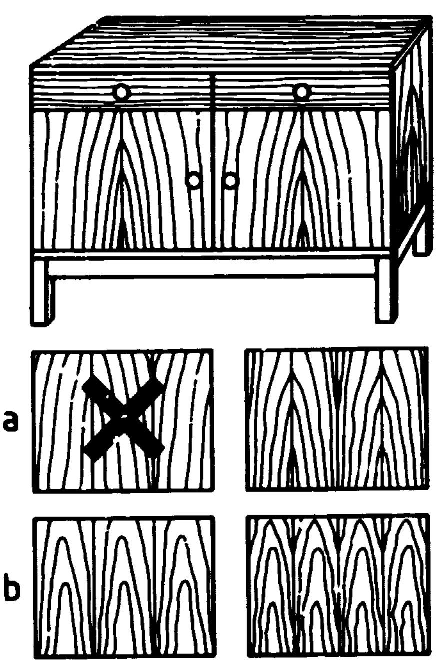
	Grit number
First sanding	50 to 70
Second sanding	80 to 100
Third sanding	120 to 140

There is considerable danger of sanding through when smoothing thinly veneered boards (0.7 mm veneer); therefore in this case the grit numbers 50 to 70 should be avoided.

Veneering

The surface veneering of furniture is usually made with veneers of about 0.7 mm thickness. For veneering edges and for blind veneer (cross banding), thicknesses of 1.5 to 3 mm are used. Veneer is cut with veneer saws or clippers. Veneer sheets used for surface veneering are usually composed as shown in figure 166. The pieces are joined with glued tape, point gluing or with a zigzag machine. The tape must be sanded away after veneering, but the plastic glue points or thread used in the zigzag machine melt are left underneath the veneer.

Figure 166. Composing veneer sheets



Urea-formaldehyde glue is used to secure the veneer, and the pressing is done at a high temperature (100°C to 120° C) with a multiplaten hydraulic press. Recently, the type of a single-opening press shown in figure 167 has become more common. The boards are fed to the press by means of a moving band. For edge veneering, devices with pneumatic or hydraulic cylinders or fire-hose pressure units are used (figures 168 and 169). The pressure of the compressed air in the network of a factory is usually 600 to 800 kPa. In large factories, use of edge-banding machines (figure 170) is already widespread. Usually these machines have several additional working units for finishing the edges.

Figure 167. Single-opening press with mechanical feed

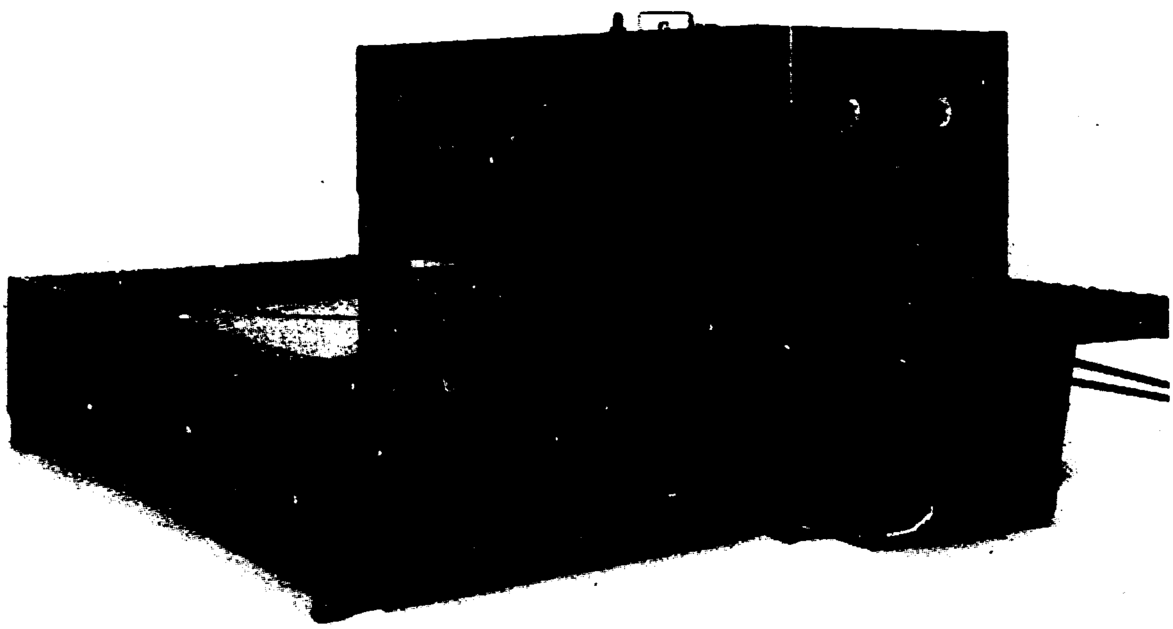


Figure 168. Pneumatic edge-veneering clamp with electrically heated pressure bars

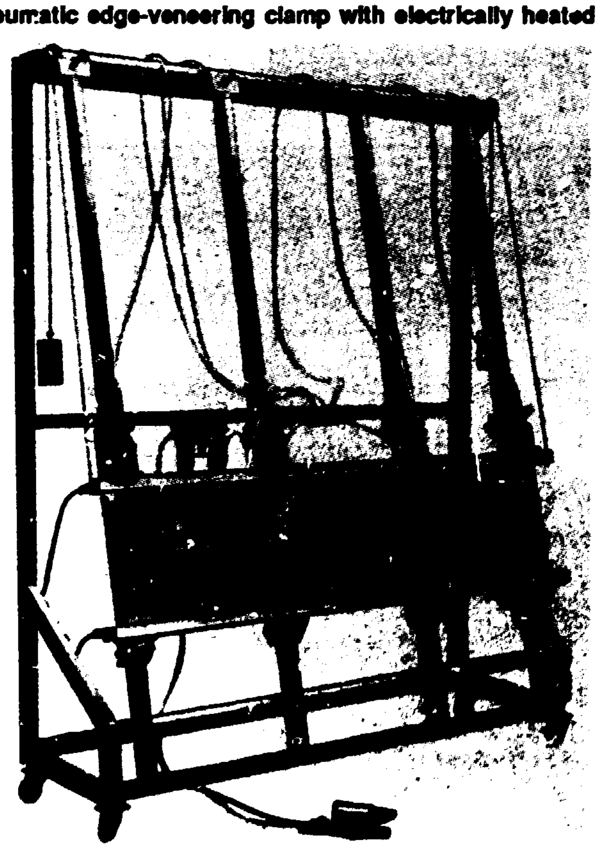


Figure 169. Pneumatic assembly table with set-up for edge veneering

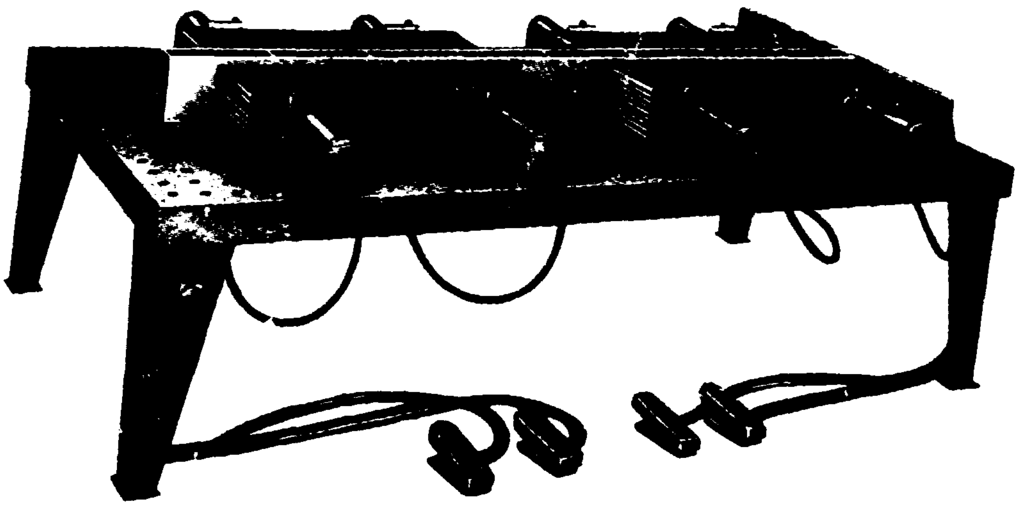
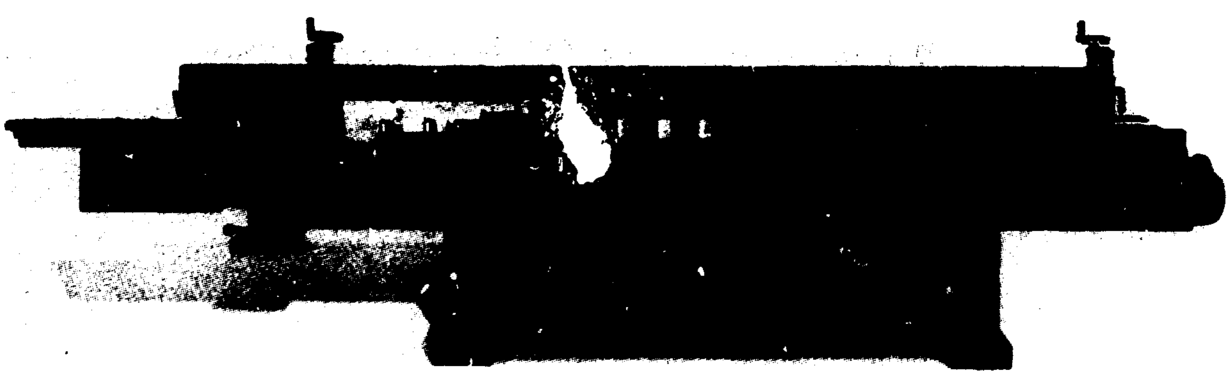
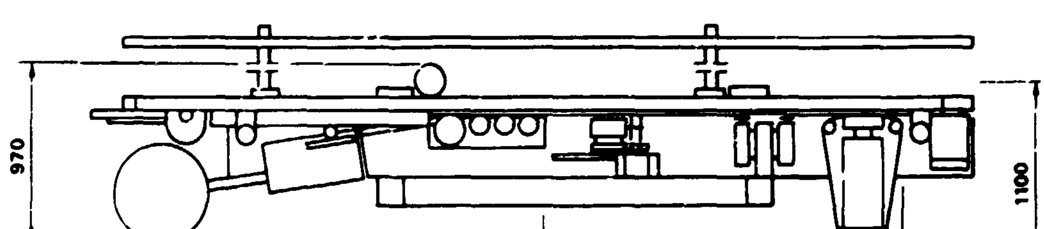


Figure 170. Edge-banding machines

A. Single-end edge-banding machine



B. Working units of an edge-banding machine



Formerly, assembly was always the next phase after machining. Today, however, it is usual to carry out surface finishing before assembly whenever possible. To do this, a curtain-coating machine may be used advantageously particularly for panels. The two main phases of assembly are detail or sub-component assembly (drawers, frames, bases etc.) and final assembly. (Cabinet and cupboard frames etc. are fitted with parts from detail assembly.) In assembly the adhesive commonly used is polyvinyl acetate (PVAc) glue, which is strong and sets rapidly.

The most important tools and equipment in assembly are the following:

- Glue spreaders (soft plastic squeeze bottle or pneumatically operated devices)
- Dowel-driving machines (figures 171 and 172)
- Staple guns
- Mechanical screwdrivers
- Assembly jigs
- Frame, chair, and carcass clamps (figures 173, 174, 175 and 176)

As noted previously, manual fitting in assemoly should be avoided.

Because of storage-space limitations, assembly series cannot usually be as large as machining series. For this reason, assembling is done in smaller lots according to orders received. It is possible, however, to store products as ready-machined surface finished parts even in the case of very large production series. In this way the competitive capacity of a factory may be improved by shortening delivery time.

Figure 171. Dowel-driving machines

A. Pistol-type dowel-driving machine

B. Pistol in operation

Figure 172. Multiple single-end dowel driving machine

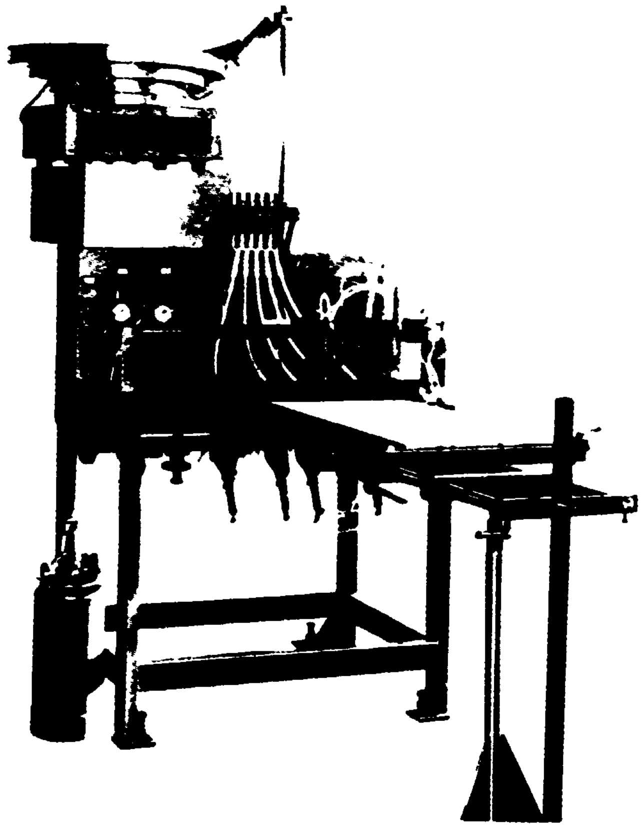


Figure 173. Pneumatic frame clamp

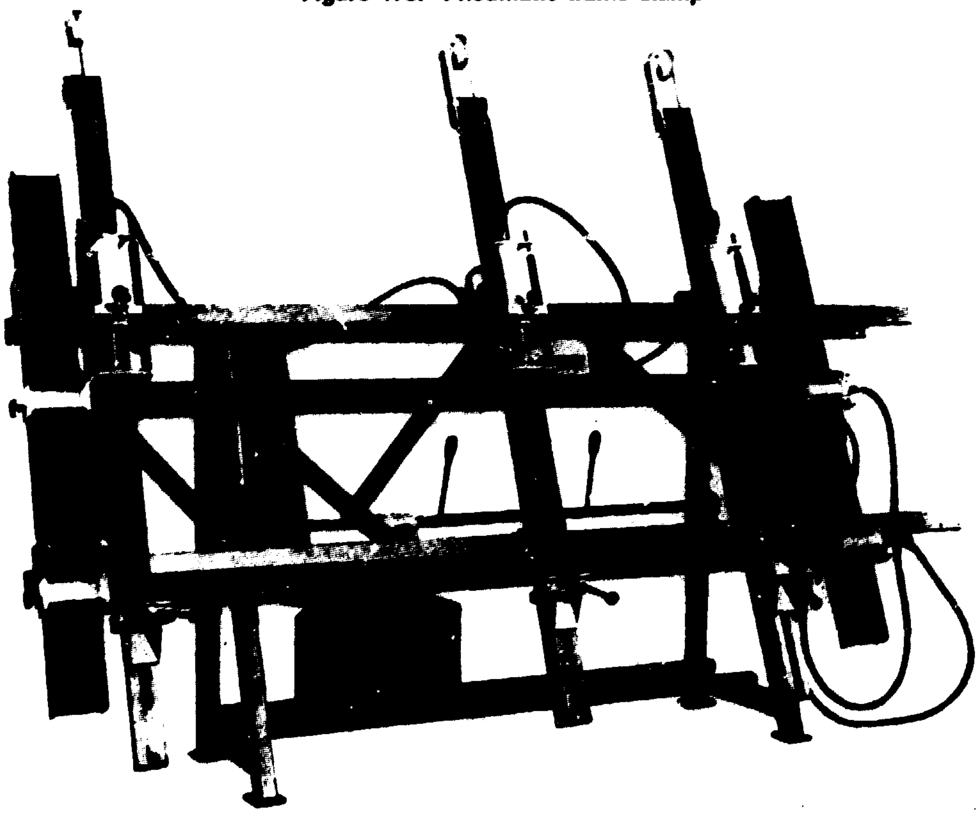


Figure 174. Pneumatic chair clamp

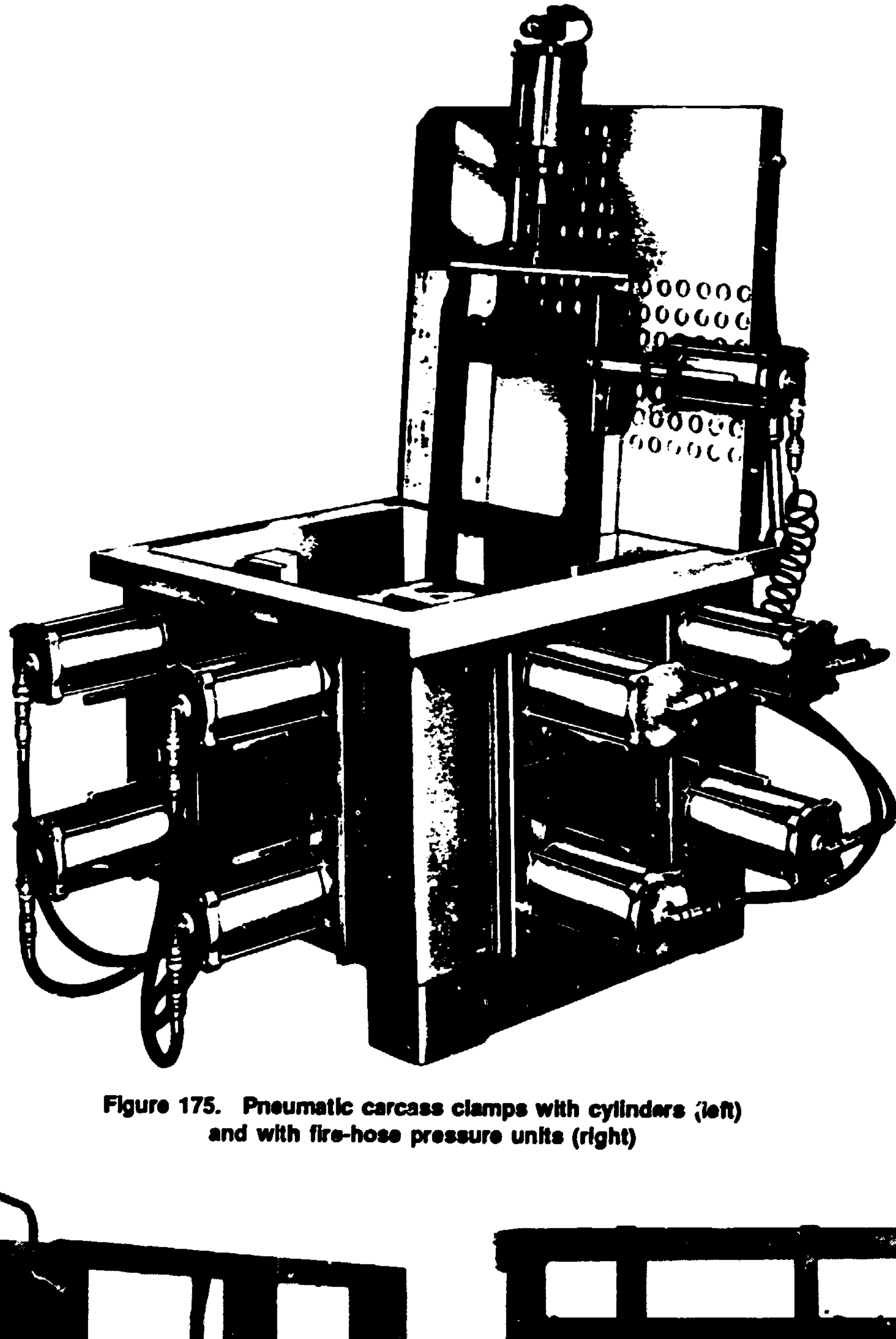


Figure 175. Pneumatic carcass clamps with cylinders (left) and with fire-hose pressure units (right)

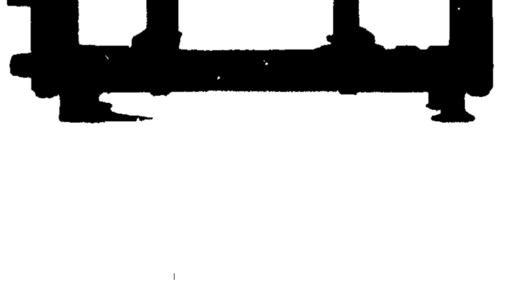
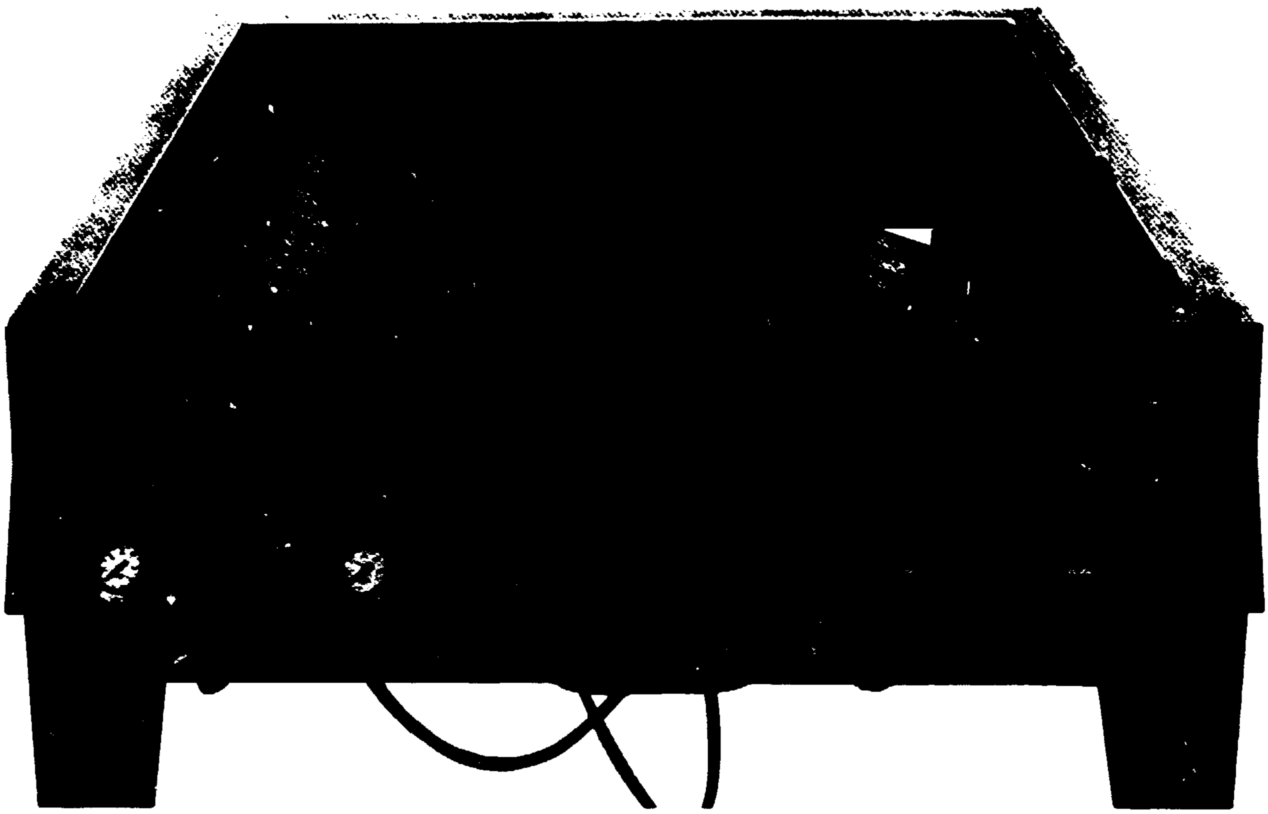


Figure 176. Drawer clamp



XXIII. Some aspects of export packaging of furniture*

The packaging of furniture for export is one of the most difficult problems in packaging technology. There are several different reasons for this:

(a) Furniture is an expensive commodity;

(b) Furniture is very fragile, and even small defects, caused by damage during transport or handling, will make it difficult to sell;

(c) Unless shipped in a knock-down form, furniture has a big shipping volume, resulting in high freight and packaging costs;

(d) Furniture is often irregular in shape, making the construction of the package difficult;

(e) Furniture is often heavy, requiring sturdy, good-quality and expensive packaging materials;

(f) Furniture packages are often difficult to handle owing to their volume, shape and weight.

Damage caused during furniture transport

There are three main reasons for damage to furniture during distribution: incorrect handling; inadequate packaging; and inadequate warehouse facilities.

Handling

Most of the damage to furniture during transport and storage occurs because of incompetent and rough handling. Lorry drivers, long-shoremen and warehouse workers seldom receive any specific training in how to handle furniture. Because of their low weight per volume, furniture packages make the problem even worse. Markings, such as "this side up" or "fragile - do not drop" have little effect in this context. Because of their awkward shapes and, sometimes, heavy weight, furniture packages are dropped, rolled and mishandled in other ways during all phases of the distribution cycle. When choosing the mode and route of transport, maximum effort should be made to avoid reloading in order to bring down the number of handling operations as much as possible. Export shipments in freight containers, particularly if they are used "from door to door", have brought about considerable improvements in this context, simply by reducing the number of times that furniture packages are handled on the way from the manufacturer to the buyer. If it is not feasible to dispatch a full container load to one customer (or even city or country), which is the best way to minimize damage, it might be possible to arrange for a pooled shipment, combining deliveries from several exporters through joint arrangements by the national export promotion agency, by a national furniture manufacturers' association etc. There are several things a furniture manufacturer can do to minimize the risk of damage that is due to bad handling methods. Some of them are:

(a) Making sure that the furniture is not damaged in the producing factory itself during storage in an unpacked condition, during the packing process or during storage in a packed condition in the factory's own warehouse;

(b) Training the factory's personnel in correct handling methods when taking furniture packages out of the warehouse and loading them into trucks or containers;

(c) Supervising in one way or another the reloading process, e.g. from the truck to the freight container or directly into the ship, from the truck to the railway car etc. In most cases, the mere presence of an "inspector" results in more careful handling;

(d) Designing the packages from the start with the objective of facilitating handling, e.g. adapting package dimensions to the dimensions of available shipping space (freight containers, trucks, pallets etc.) and incorporating features in the construction of packages that make them easier to handle by fork lifts, hand holes for manual handling etc. Plastic or steel straps for reinforcement are often used to pick up and handle packages; such straps should consequently be kept from cutting into and damaging the furniture inside the package. When furniture is exported to highly developed industrialized countries, the packages in most cases will be handled by mechanical means and should therefore lend themselves to being stacked on standard size pallets or to being picked up directly by fork-lift trucks.

Packaging

In most cases, damage to furniture packed for export is attributed to the inferior quality of the packaging material available. A thorough investigation of packing material should be made by the exporter. Better material might be available that is more expensive but has a more efficient cost-performance ratio. In many cases, the maximum strength of available materials has not been used owing to inadequate constructions, sloppy workmanship or simply ignorance about how the material should be used correctly. In order to fully understand the protective capacity of available export packaging raw materials, the furniture manufacturer has to acquire a basic knowledge of technology for packaging raw materials, their protective properties, package constructions etc. A certain amount of advice can be obtained from the package supplier, but only if the furniture manufacturer is well-informed and can conduct a meaningful dialogue with the package supplier. If a certain type of material or accessory is not available on the local market, it might be necessary to import it, or, in

*By Johan Selin, Senior Advisor, Export Packaging International Trade Centre (UNCTAD/GATT).

rare cases, it might be possible to find a substitute through the development of an alternative, indigenous solution. Some of the most important points in furniture package design are discussed later in this chapter.

Warehouse facilities

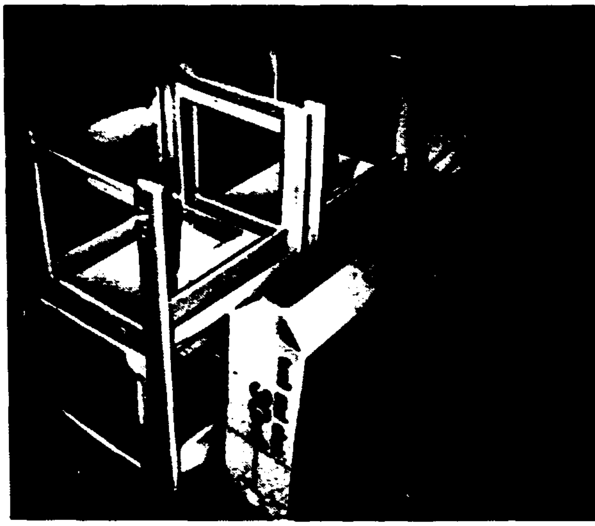
Often, both furniture manufacturers and furniture dealers have inadequate warehouse facilities. Usually the space itself is insufficient, which leads to high or improper stacking of the goods. The warehouse should be effectively ventilated and as dry as possible. In this context, it is also important to note that corrugated boxes lose most of their stacking strength, sometimes up to 80 per cent, in climates with high humidity. It is therefore important not only to protect the furniture against excessive moisture but also to protect the package itself in order to get the most out of its protective strength, e.g. through the use of surface treatment or overwrapping.

Furniture design and export package design

It is often said that package design should be started at the same time as product design, particularly in the furniture industry. This statement is particularly true for furniture that has to be packed and exported over great distances at expensive freight rates that are based upon volume rather than on the weight of the goods. Figure 177 shows the volume advantage of knocked-down furniture. The box on the right-hand side contains all the parts necessary to assemble the four chairs shown on the left. In order to be competitive on the market, it is therefore essential for the furniture designer to take this into consideration before work on the design of the furniture itself begins. If a KD construction, to be assembled by the buyer, cannot be used, it should at least be possible to place two or more pieces of furniture in a nested position in the same package. Protruding ornaments, knobs, legs etc. should be made detachable to save costly shipping space. Some types of furniture, e.g. rattan products, do not readily lend themselves to delivery in a KD form.

Modern metal or plastic fittings can be used to advantage in many difficult cases, and the furniture manufacturer or designer therefore needs to keep well-informed about the available accessories. The assembly of dismantled and KD furniture in the consumer's home has become much more acceptable today owing to the increased interest in and capacity for do-it-yourself techniques that are greatly facilitated by the large variety of simple tools, accessories and materials that are available on the market. The whole furniture trade is turning into more of a self-service operation: purchases are made more and more on impulse and consumers transport the furniture in the trunk or on the roof of their automobiles. This trend calls for a new approach to furniture packaging. It should be convenient to handle, easy to transport and provided with clear and promotional information about its contents. The well-known Swedish furniture dealer IKEA has been a pioneer in this context, and the same distribution principles are now being followed by an increasing number of furniture dealers and distributors in all parts of the world.

Figure 177. Volume advantage of knock-down furniture



Containerization

A freight container is not a substitute for packaging. Only in rare cases, when a container load of furniture is delivered door-to-door from the manufacturer directly to the final retail outlet, would it be possible to reduce, to a certain degree, the amount and strength of packaging used. In most cases, however, furniture packages are taken out of the container, put into a central warehouse and later reloaded into a truck, railroad car or other container for transport to its final destination. This means that the package will be handled a number of times during storage and transport.

The use of freight containers for furniture shipments is rapidly increasing. However, the stresses on goods inside a freight container can be considerable. Even inside a container, the furniture needs to be well-protected. A container ship is subject to the same forces as a conventional general cargo ship; at sea it may move violently in as many as six different directions simultaneously (surge, roll, sway, pitch, heave and yaw) (see figure 178 A). A freight container stowed on deck, for instance, might move as much as 40° in both directions and travel a distance of 21 metres (70 feet) with each complete roll of the ship and as often as 7 to 10 times each minute as illustrated in figure 178 B. Heat and moisture problems might also be more severe in containers than in break-bulk shipments. Movements of the cargo, constant vibrations and sudden shocks are also common when the container is transported by road, by railway or by air. Movements of cargo in containers transported by road are created as a result of the acceleration, braking or turning of the vehicle (see figure 179).

Containerized transports have certain definite advantages, however. The most important ones, in connection with furniture, are:

(a) The number of handling times during reloading is reduced, and thereby the risk, e.g. of drops and other shocks, is less;

(*b*) Stowage of the container can be carried out or at least supervised by the exporter's or furniture manufacturer's own personnel;

(*c*) Other possibly heavy goods are not placed on top of the furniture packages, and it is not likely that someone will step on the packages, which is almost always the case when general cargo is loaded and unloaded in a ship's hold;

(*d*) If the packages are correctly dimensioned to fit into the containers, they are likely to be placed in the correct and most resistant position;

(*e*) Marking and documentation procedures are simplified.

Figure 178. Movement of a container ship at sea

A. Directions of movement (A ship can move in all six directions simultaneously)

B. Movement of a container stowed on deck

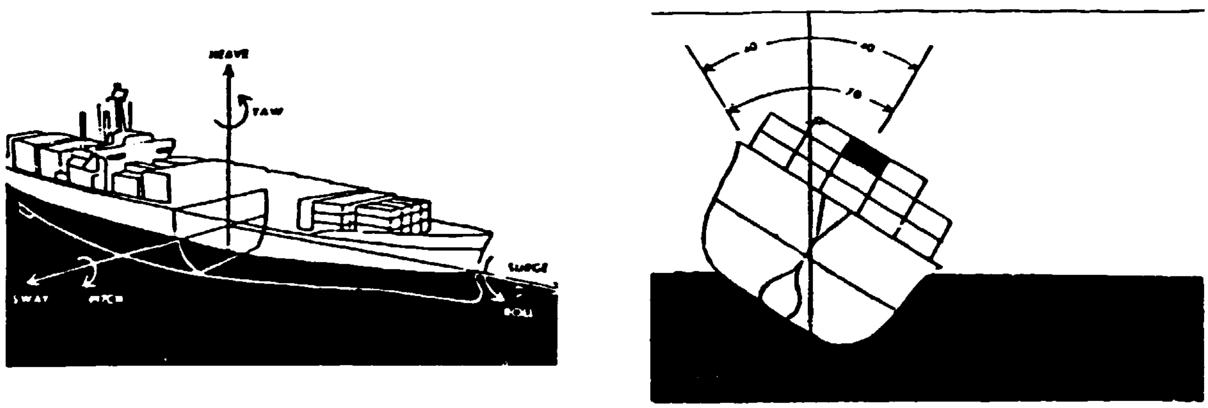
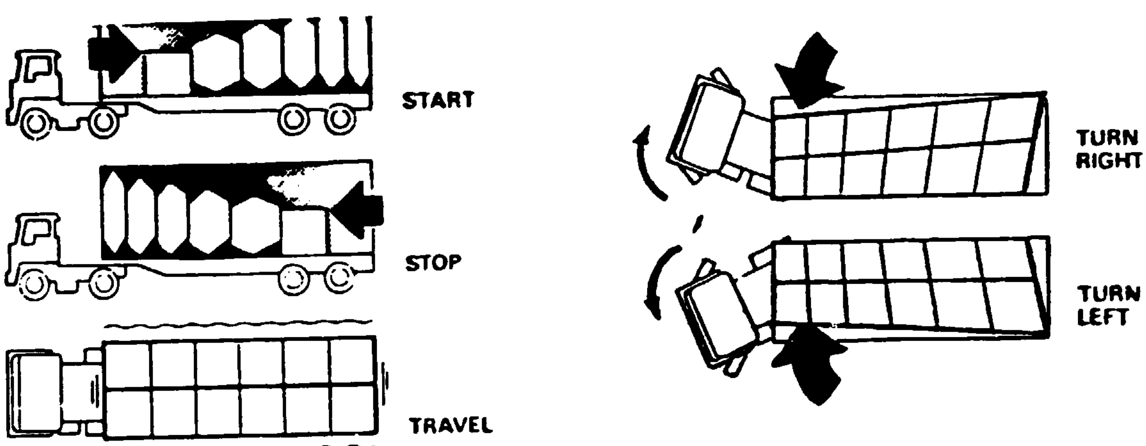


Figure 179. Movement of cargo containers transported by road



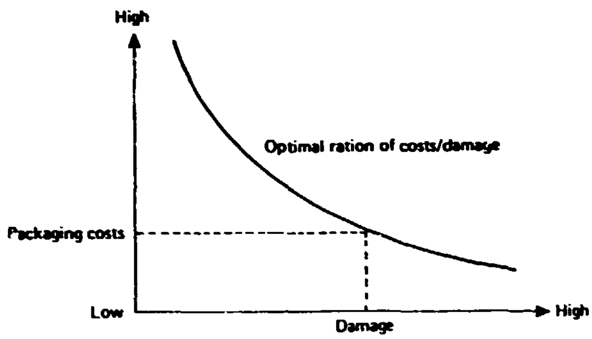
Furniture packaging costs

It is possible to give only very general indications about the normal, average cost of packaging in relation to the sales price of a particular product. The unit price of furniture of the same weight and volume may vary greatly. As a matter of fact, more expensive and therefore often more solidly constructed furniture might need less packaging protection than cheaper and more easily damaged furniture. Some indicative figures in this context could be, for instance: for domestic shipments 0.5-3 per cent of the ex-factory sales price; and for export shipments 2-8 per cent of the ex-factory sales price.

Furniture shipped in knocked-down form results not only in substantial savings in freight and warehousing but also in packaging, particularly in material costs, because KD furniture usually takes one third to one fourth of the space required for assembled furniture.

Packaging has to provide adequate protection at minimum cost. The difficulty in this context is to avoid both "over-packaging" and "underpackaging". A package that has a damage ratio of zero will certainly be too expensive. A compromise must therefore be found. This can be illustrated by a simple graph (see figure 180).

Figure 180. Optimal ratio of costs/damage



The objective is to find the optimal ratio of cost in relation to damage or, in other words, a reasonable packaging cost for an acceptable rate of damage.

It is estimated that about 15 per cent of the furniture shipped overseas is damaged during transport, which is thus unacceptably high. FIRA has estimated that damages in domestic shipments of furniture in the United Kingdom represent about 4.5 per cent of the sales value, representing a yearly loss to the industry of about £4 million at 1978 prices. In 1967, the Canadian Government estimated that the annual damage rate for furniture in transit was of the order of 10 per cent.

A reasonable objective for export shipments might be an average damage rate of 4-5 per cent. However, IKEA of Sweden reports an average damage of only 1 per cent for all shipments of furniture, a major part of which is packed, stored and transported in KD form. The whole materials handling process is closely supervised by IKEA itself.

Export package development

The development of a type of furniture packaging for export that gives sufficiently effective protection at a reasonable price is a long and difficult process, particularly since there are very few simple and unconditional guidelines or rules to rely upon. Most of the time development must be based on "trial and error", and a theoretical knowledge of packaging technology is not a substitute for long practical experience in good furniture package design. However, there are certain facts that help in the development of packaging. The furniture manufacturer or exporter needs to have:

(a) A basic knowledge of the types of mechanical forces, stresses, shocks and climatic conditions that could occur during all phases of the distribution cycle. A basic knowledge of physics would be useful in order to understand the impact of various types of shocks, the shock-absorbing properties of cushioning materials etc. Data on the frequency and heights of drops to which the package will be subjected as well as what happens inside a ship's hold or in a freight container in rough weather when the container is placed on deck etc. is also useful;

(b) Practical knowledge about storage, distribution and consumer requirements in the target markets. In industrialized target markets, for example, there are high stacking heights in warehouses and extensive use of mechanical handling equipment such as fork lifts for goods on pallets. The manufacturer or exporter should also bear in mind the fact that the retailing system for furniture has turned more and more into a self-service, a do-it-yourself operation, as mentioned above;

(c) A detailed practical knowledge, based upon long practical experience, of the types of damages to furniture that have occurred in the past together with the likely reasons for such damages. FIRA has found out that very few furniture manufacturers keep detailed records of the types of damages and their causes. No claim for damages should be accepted and paid unless a detailed report is filed on the exact nature of the damage, if possible with photographs; such reports are the easiest way for a furniture manufacturer to correct packaging methods. Close monitoring through the "trial and error" method gives more valuable background data for the improvement of packaging than any tests carried out by a professional packaging laboratory, a service which, in any case, is not available to the majority of the furniture exporters in developing countries;

(d) A basic knowledge of the most important packaging materials and their properties, limitations, functions, costs and availability. It is essential for the furniture manufacturer to know enough about packaging materials and the way they are manufactured to be able to conduct a meaningful dialogue with the supplier of such materials. This is seldom the case with the users of packaging in developing countries: most of them are at the mercy of their suppliers simply because they do not know how to specify their needs and are not aware of what services they can demand from suppliers. The person responsible for export packaging also needs to be informed about new materials and methods. Even if a new packaging material is not yet available on the local market, it might be advantageous to import it if it can substantially reduce damage to exported furniture and thus help to increase the total export business.

Corrugated paper board has good possibilities for the construction of tailor-made interior fitments, edge protectors etc. for all kinds of furniture packages (figure 181). Wood is still an important raw material for the packaging of furniture, particularly for heavy items. A corner construction called the "three-way corner" gives the best possible strength to wooden boxes and crates (see figure 182). For wooden crates, maximum strength with a minimum amount of raw material is achieved by the use of diagonal reinforcements on the sides of the crate. A crate made with "three-way corners" with diagonal reinforcements on its sides is shown in figure 183.

Practical hints in furniture package design

Each type of furniture has its own particular requirements, which have to be considered in designing the most effective construction of the package. Packaging techniques for a rattan chair, an upholstered sofa or a knocked-down kitchen cupboard differ considerably. It is consequently very difficult to give detailed guidelines for packaging various types of furniture, but certain common principles have been summarized below.

The package should be tightly fitting in order to prevent any movement of the furniture item, or its parts, inside the package. This will give maximum stacking strength and minimize the risk of abrasion and scuffing or scratching. It should be remembered, however, that one of the most important functions of the package is to absorb shocks, which it cannot do if the whole unit is compressed into a solid block. Some packaging materials, such as corrugated paper board, shredded paper, wood-wool and cellulose wadding, have poor resiliency characteristics and a package that has originally been tightly packed might become loose after a long storage time, stacking or shocks during handling and transport.

Figure 181. Tailor-made corrugated paper board interior fitments, edge protectors etc. for furniture packages

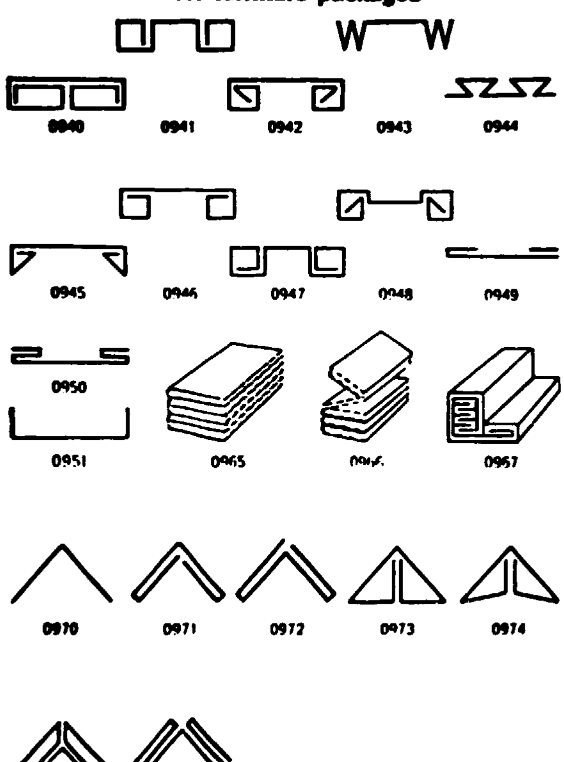


Figure 182. "Three-way" corner construction for wooden boxes and crates

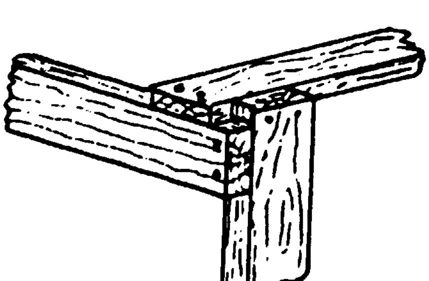
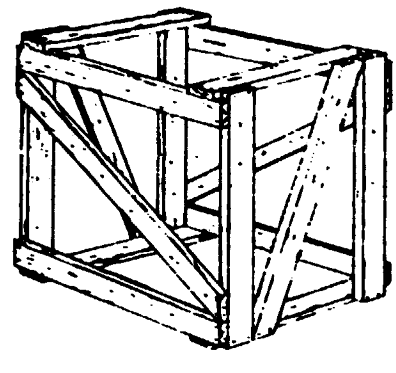
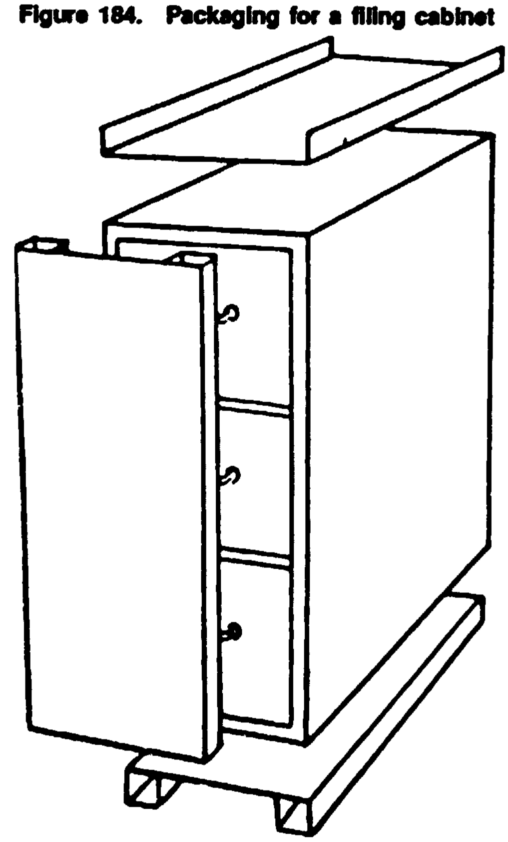


Figure 183. Crate with diagonal reinforcements and "three-way" corners



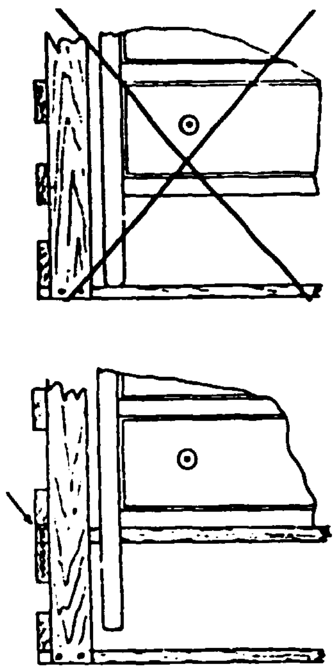
Doors, shelves, drawers etc. should be fully secured and immobilized during transit. For instance, it is not enough just to lock cabinet doors: both the lock and the hinges could be damaged if the doors are not fixed in position or removed and wrapped separately. Detached legs, glass or mirrors, ornaments, fittings, hardware etc. should also be packed separately and attached firmly to the furniture or to the inside of the package to prevent any movement, whatever position the package might be put into. An example of packaging for a filing cabinet with clearance at the top, bottom and front (to protect the drawer handles) is shown in figure 184.

Figure 184. Packaging for a filing cabinet



If furniture legs cannot be detached during transport, it is necessary to secure the furniture item inside the crate in a suspended position. The supporting piece of wood is nailed to the underside of the furniture and fastened to the sides of the crate. The correct way of nailing is shown in figure 185. The inside of the package should also be checked for any loose nails, screws or other foreign matter that could damage the finish of the furniture; e.g. by chafing.

Figure 185. Suspending furniture in a crate to secure it



Corners, edges, legs and protruding parts of furniture must be adequately protected against mechanical shocks by using cushioning materials in the form of pads, supports, interior fitments etc. Edge or corner protection pads should be placed correctly and fastened securely so that they cannot work themselves loose. Expanded polystyrene is becoming more and more popular for corner and edge protection. It is delivered in standard sizes and can easily be cut to fit individual furniture items (see figure 186). Shrink or stretch wrapping is ideal for this purpose. The shrink wrapping technique is low-cost; a hand-held shrink-gun, much like an over-sized hair drier, which is usually heated by gas, is used (see figure 187). An alternative to shrink wrapping is stretch wrapping, using a stretchable plastic film which is wrapped tightly around the package or packet. This can be easily done using a hand dispenser as illustrated in figure 188. Some types of protection pads that have an abrasive surface require the addition of a soft material, e.g. cellulose wadding or tissue paper, between the pad and the surface of the furniture in order to avoid markings or scratches.

Figure 186. Expanded polystyrene used for corner and edge protection

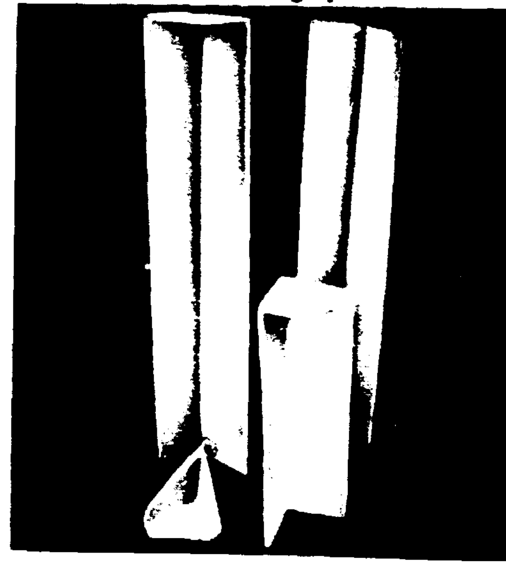
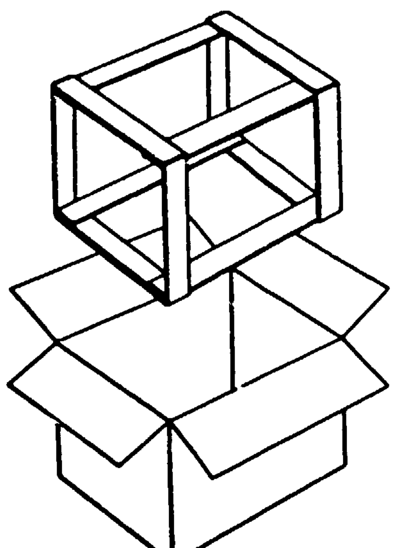


Figure 187. Shrink wrapping with a hand-held shrink gun

Figure 188. Stretch wrapping using a stretchable plastic film

An example of an interior wooden frame for the reinforcement of corrugated boxes is shown in figure 189. If strings or straps are used for holding protection pads in place, special attention should be given to the prevention of damage at the contact points where tightening pressure is applied.

Figure 189. Example of interior wooden frame for the reinforcement of corrugated boxes

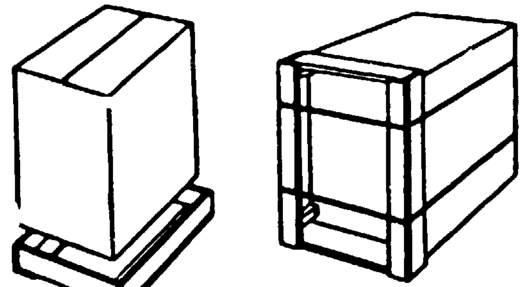


Lacquered or painted surfaces should be especially protected against abrasion and scuffing by using plastic films, tissue paper, cellulose wadding, soft cotton fabric or similar soft materials with a smooth and even surface. Even regular brown wrapping paper is too rough for this purpose in most cases, and corrugated fibreboard in direct contact with polished furniture would certainly leave marks on its surface. When plastic films, waxed paper or similar materials are used in direct contact with furniture, it is essential to make sure that they do not react with the surface of the furniture or stick to or tarnish it. This is also true for textile and leather upholstered furniture. In this context, special consideration should be given to the behaviour of packaging materials under high temperatures and high relative humidity.

In most cases, packed furniture should be protected against dust, dirt and excessive moisture during shipping by using external or internal plastic film wrapping, specially treated paper etc. Shrink and stretch wrapping is being used increasingly for this purpose in furniture packaging. The package should also be effectively closed, e.g. with good-quality paper or plastic adhesive tape.

A wooden tray can be strapped to the box to the bottom of the package, as shown in figure 190.

Figure 190. Wooden tray strapped to the box to protect the bottom of the package



For most furniture packages, there should be clearance between the outer wall of the package and the surface of the furniture. Double-faced corrugated boards (see figure 191) are used to provide clearance between the walls of the package and the surface of the furniture. Wooden skids and reinforcements, used as protection for furniture in corrugated boxes are shown in figure 192. Corner and edge protectors (made out of corrugated fibreboard in figure 193) maintain the required $^3/_4$-inch clearance around the packed furniture. Reinforcement for a large furniture box with an extra frame for clearance at the bottom of the package is shown in figure 194. Top and bottom corrugated trays, reinforced with collars and light wooden frames to achieve the $^3/_4$-inch clearance between the furniture and all six sides of the outside box, is shown in figure 195.

Official requirements for each type of furniture and package for export to markets in the United States are given in the "F-specifications", published in the Uniform Freight Classification.[1] A commonly used clearance requirement in these specifications is $^3/_4$" (19 mm), or 1 $^1/_2$" (38 mm) for especially delicate furniture. Furniture with legs exceeding 8" (203 mm) should be suspended inside the package providing a leg clearance of $^3/_4$" (19 mm). The

[1]Of the United States railroads contained in Bohman Industrial Traffic Consultants, *Furniture Packaging* (Gardner, Massachusetts, 1973).

F-specifications also include detailed requirements for timber dimensions, corrugated board grades and the cushioning pads to be used for each type of furniture. Many shippers require a quality stamp on the corrugated boxes certifying the strength of the material used (see figure 196). This stamp is required, for example, by railroad and trucking companies in the United States, but it has also found wide use elsewhere. ISO symbols should be used to give information to shippers on handling requirements for transport packages. Note particularly the symbols that indicate where a sling should be attached (upper left-hand corner in figure 197) and where the centre of gravity is located (lower left-hand corner of figure 197).

Figure 191. Applications of single and double-face corrugated board to provide clearance between the wall of the package and the surface of the furniture

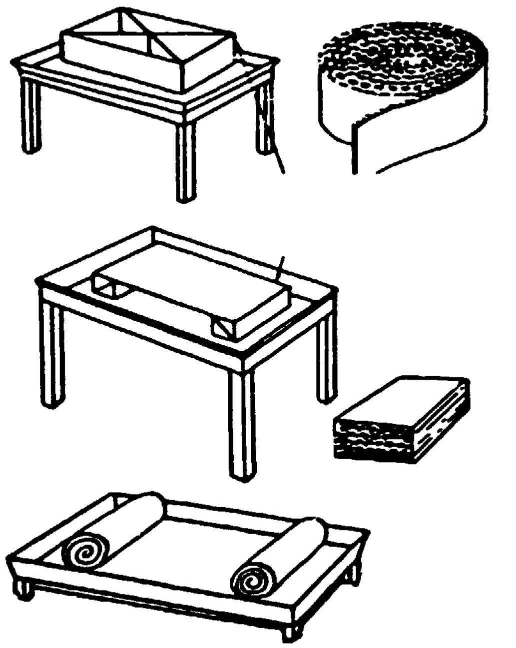


Figure 192. Wooden skids and reinforcements for corrugated boxes

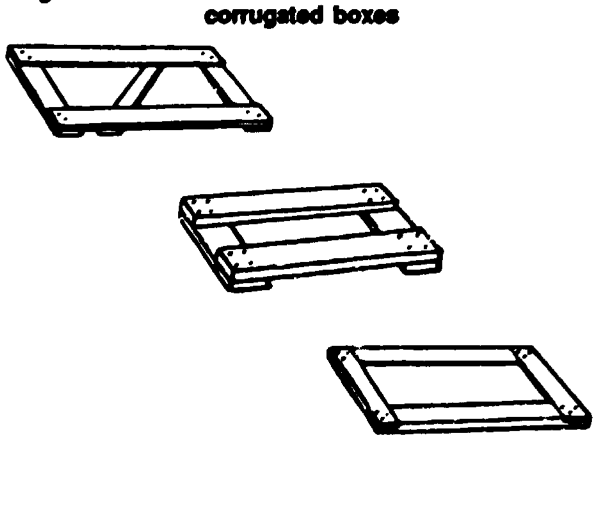


Figure 193. Use of corrugated fibreboard corner and edge protectors to provide the ³/₄-inch clearance around the packed furniture

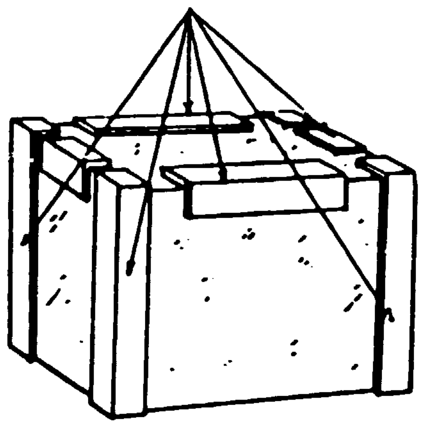


Figure 194. Reinforcement for a large furniture box with an extra frame for clearance at the bottom of the package

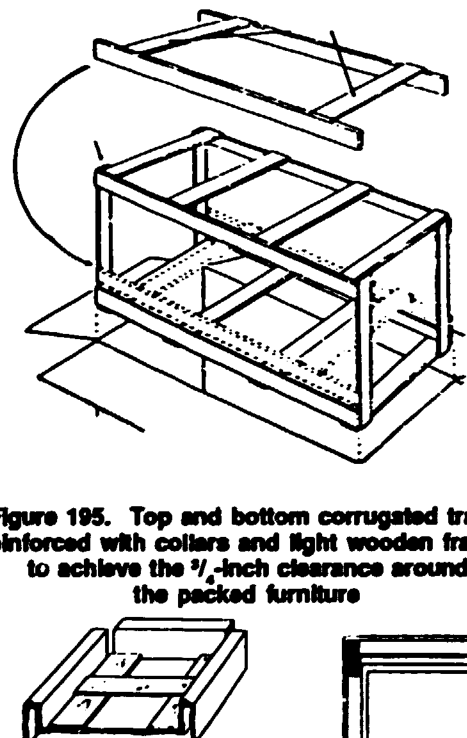


Figure 195. Top and bottom corrugated trays, reinforced with collars and light wooden frames to achieve the ³/₄-inch clearance around the packed furniture

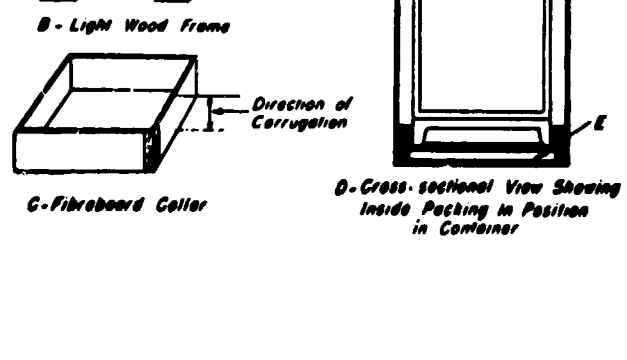


Figure 196. Quality stamp to be affixed to the corrugated boxes. (This stamp is required by railroad and trucking companies in the United States.)

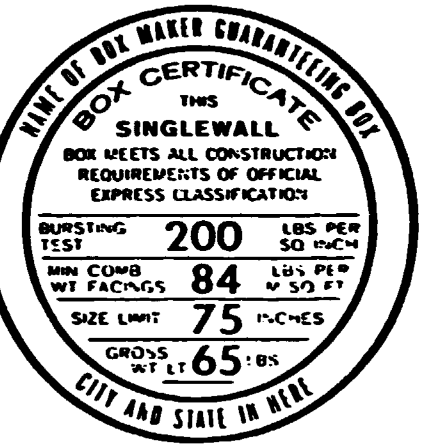
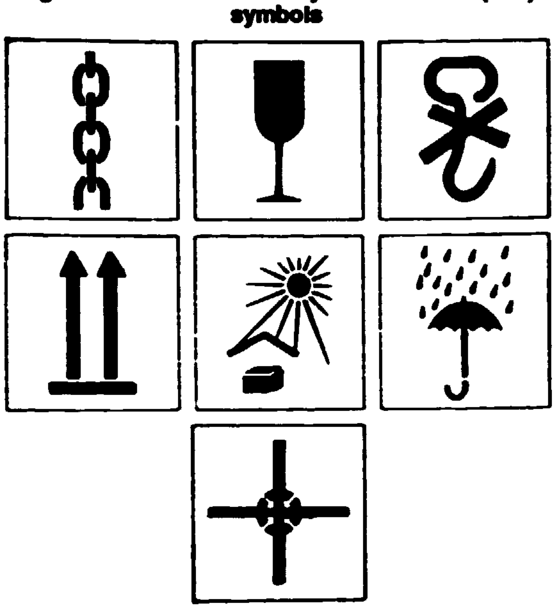


Figure 197 Internationally standardized (ISO) symbols



Detailed technical information and specifications for the packaging of furniture are available from the following sources:

Bohman Industrial Traffic Consultants Inc.
P.O. Box 889
Gardner, Massachusetts 01440
United States of America

Forintek Canada Corp., Eastern Forests Products Laboratory
800 Montreal Road
Ottawa 7, Ontario K1G 3Z5
Canada

Furniture Industry Research Association (FIRA)
Maxwell Road
Stevenage, Herts. SG1 2EW
United Kingdom

Bibliography

General packaging handbooks

Freidman, W. F. *and* J. J. Kipnees. *Distribution packaging* (Huntington, New York, Robert E. Krieger Publishing, 1977).

A standard reference book covering all materials for shipping containers and their applications.

Paine, F. A. *Fundamentals of packaging*. Elm Park, Middlesex, Institute of Packaging, 1974.

A basic textbook, contains chapters on specific packaging principles, such as cushioning, adhesion, permeability etc.

Paine, F. A., ed. *The packaging media*. Bishopsbriggs, Glasgow, Blackie and Son, 1974.

Corrugated paper board and boxes

Fibre box handbook. Chicago, Ill., Fibre Box Association.

Descriptions of the manufacture and use of corrugated boxes, definitions of terminology, types of boxes and a section on United States carrier regulations.

International Trade Centre (UNCTAD/GATT). International fibreboard case code. Export packaging note No. 19.

This is a reprint of the Code jointly developed by the European Federation of Corrugated Board Manufacturers (FEFCO) and the European Solid Fibreboard Case Manufacturers Association. It illustrates the most commonly used constructions for paper board packages, interior fitments, cushioning pads etc.

International Trade Centre (UNCTAD/GATT). Technical notes on the use of corrugated paperboard boxes. Export packaging note No. 13.

Wooden packages

Hérard, P., *comp. A user's guide to wooden packaging*. International Trade Centre (UNCTAD/GATT), 1982.

This publication gives detailed information on the technical aspects of wooden package materials, construction etc.

International Trade Centre (UNCTAD/GATT). Technical notes on the use of wooden packaging. Export packaging note No. 15.

Furniture packaging

Langston, C. *Furniture packing manual.* 2nd ed. Stevenage, Herts., Furniture Industry Research Association, 1980.

A comprehensive collection of information on furniture packing, its problems and methods of solving them.

Furniture packaging. Gardner, Massachusetts, Bohman Industrial Traffic Consultants, 1973.

A comprehensive and detailed guide on furniture packaging, based on the Uniform Freight Classification of the United States railroads.

Furniture packaging guide: common causes of damage and its prevention; protective packaging of furniture. Vancouver, FORINTEK Canada Corporation.

Boberg, B., *The furniture industry: corrugated board versus shrink film*. EFCO Bulletin No. 81. Paris, European Federation of Corrugated Board Manufacturers.

A collection of 80 slides on packaging of furniture is available, upon request and payment of $60, from the International Trade Centre (UNCTAD/GATT).

XXIV. Surface finishing of wood and wooden products*

Many materials are currently available for the surface finishing of wood, and there is also a great variety of methods for applying the materials. Furthermore, as there are many different species of wood, the problem facing the wood finisher is a complex one. That the beauty of any wood surface depends on its finish and that it takes time and patience to obtain a good finish are, of course, truisms. The materials and methods used must be suited to the wood. Some species have large pores, others have small ones. Sometimes large pores are emphasized to achieve certain effects.

The finisher must always know for what purpose an article will actually be used, otherwise it will be difficult, if not impossible, to select the proper finishing material. In doubtful cases the finisher should check with the suppliers of the articles to be finished.

Paint is a formulation that includes a vehicle or binder, white or coloured pigments, solvents and various additives. In air-drying paints, the additives may be derivatives of lead, cobalt or manganese. Linseed oil was formerly the most important vehicle, but alkyds (also known as synthetics) have overtaken it. Some other vehicles are PVAc and the acrylates, which are used in water-dispersed paints, and the polyurethanes, polyesters, epoxies and combinations of various resins are used in the more conventional paints. At present, titanium dioxide is the most widely used white pigment. White spirit is still frequently used as a solvent, but in many modern paints stronger solvents such as xylene, toluene, acetates, ketones and alcohols are required.

Preparation of the surface for finishing

Proper preparation of the surface is of great importance in wood finishing. The finish coat will not, however, cover defects; on the contrary, it will magnify them. Before finishing begins, the surface must be clean and smooth. Rough spots on the edges and elsewhere must be smoothed by sanding, planing etc. The wood must also have the proper moisture content. The effects of moisture in woodworking are discussed in considerable detail elsewhere in this publication.[1]

Most wood is vulnerable to attack by bacteria and fungi. Sometimes their effect is only a change in colour, such as blue stain, but sometimes they cause rot. Not only the wood but also the paint film may be attacked by bacteria; it has been observed that micro-organisms living between the paint film and the wood surface can have an injurious effect on the adhesion of the paint film. The appearance of a painted surface can very often be destroyed by mould even when the paint film is still fully intact.

Joinery factories in Finland use various wood species, the most important being pine, oak and birch. Many tropical species (such as mahogany and teak) and beech are also used. Few of these can withstand the elements without surface finishing; an exception is teak, whose mechanical properties do not decrease with weathering, although the surface will quickly lose its attractive colour under the influence of rain and sunlight and turn grey.

Pine and spruce must be protected against bacteria by being brushed with or dipped in wood preservatives. Oak and mahogany do not need this preparation. Some tropical species such as teak contain agents that can make their surface finishing difficult. For example, they can prevent an alkyd lacquer from drying. Even when the lacquer has dried over a long period, adhesion will be poor and blistering and peeling will occur very soon.

Before such species can be finished, their surfaces must be washed with a solvent such as xylene or a thinner for nitro-cellulose lacquer; this treatment will ensure good drying and adhesion. However, the agents remain within the wood and may emerge to the surface and attack the paint film. Prolonged investigations have shown that the best results can be achieved by priming the surface with products that prevent these agents from coming into contact with the surface finish. The two-component polyurethane products and some special acid-catalysed lacquers are useful for this purpose. After the priming the final finish can be done with urethane or acid-catalysed lacquers.

Sanding

Sanding is very important in preparing wood for finishing. It removes defects in the surface and smooths it so that the reflective properties of the finishing materials will bring out the full beauty of the wood grain. If sanding is done properly and unhurriedly, using correct procedures and the proper grades of abrasives, finishes of truly professional appearance and quality can be achieved. It should be noted that when glossy finishing materials are used, especially in dark colours, quite small defects in the surface may be observed very easily. A fine sanding paper (No. 150 to 240) should always be used for the last sanding; although this will take a little more time, the work will be not only good but the cost of the finishing materials will be reduced in the long run. It is important to remember that the final sanding must be done along the grain.

Bleaching and staining

Although wood is bleached chemically in some countries, this is not done in Finland because it is very difficult

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*By P. A. Birström, Tikkurilan Väritehtaat, Tikkurila, Finland. Originally issued as ID/WG.105/32/Rev.1.

[1]See part one, chapter I, "Solid wood as raw material for the furniture and joinery industries".

to get constant results. Instead, special primer lacquers that do not wet the surface too much are used. Sometimes small amounts of a white-pigmented product (0.5 per cent) of the same binder type are added, in this way giving the impression of whiter wood.

Staining is normally done with solvent-soluble products, but a more modern method is to put a coloured solution in the primer lacquer and thus apply both colour and primer in one operation. The colour solution must, of course, have an excellent resistance to light-induced fading.

Industrial painting and varnishing

In Finland's furniture industry painting and varnishing on an industrial scale have been done for a long time. This is also true of such joinery products as kitchen equipment, doors and window frames.

In recent years many factories have invested a great deal in equipment for finishing. There are still a few factories that use brushes and rollers, but the more advanced ones use spraying techniques with air and airless guns and curtain-coating machines. The increased use of machines in industrial painting has imposed new demands on paints and lacquers. For example, it has been possible to speed up the drying properties of finishing products so that coated articles can be stacked or packed directly and passed on to storage or transported to the customer. Despite quick drying, the quality of the finish must be first-class, and it must be achieved with as few applications as possible.

In the board industries (such as hardboard and blockboard), surfaces are increasingly being finished by the producers. Blockboard is puttied on roller coaters with products normally based on alkyds. The putties contain volatile solvents, and at least two applications are normally needed.

The modern tendency is towards the use of polyester putties. They are solvent free, and boards coated once with them are completely smooth and have compact surfaces. The drying process is forced by ultravoilet (UV) radiation; drying time in special ovens is only from 10 to 20 seconds. An excellent finish can be achieved with only one application on such surfaces. Acid-catalysed paints are normally used.

Hardboards may also be pre-coated with UV polyester sealers, but the usual modern practice is to use pre-coating with an acid-catalysed primer and then an acid-catalysed finish paint. It is often enough to use only one finish paint. Application is done by spray or with a curtain-coating machine.

Pigmented finishes

Several procedures for painting furniture, birch kitchen furniture, doors and hardboard or blockboard are used in Finland at present:

Filling with alkyd putty or UV putty (blockboard) and painting with acid-catalysed paint one to two times

Painting with acid-catalysed primer (wood surface or hardboard) and an acid-catalysed topcoat

Sealing with a UV polyester sealer (wood and hardboard) applied with a roller coater and painting with an acid-catalysed topcoat

Painting with water-thinnable acrylic paint one to two times (mostly for hardboard)

Unpigmented finishing

Some procedures for lacquering furniture, kitchen cabinets, doors etc. are described below.

Lacquers for light-coloured woods

The following procedures can be used for lacquering light coloured woods:

Applying a little wetting nitro-cellulose primer lacquer with UV protection and acid-catalysed top lacquer

Applying an acid-catalysed top lacquer two times (the lacquer is coloured with a small amount of white-coloured tint)

Applying a UV polyester sealer with a roller coater and an acid-catalysed lacquer

Applying a water-thinnable acrylic lacquer two times (can also be used in electrostatic spraying)

Lacquers for dark or stained woods

The following procedures can be used for dark or stained woods:

Staining with solvent-stains and applying an acid-catalysed lacquer two times

Staining with solvent stain, sealing with a UV polyester or UV acrylic sealer and applying an acid-catalysed lacquer

Staining with a solvent stain, sealing with a UV polyester or UV acrylic sealer and applying a UV acrylic top lacquer with a roller coater two to three times

Staining with a solvent stain and applying a water-thinnable acrylic lacquer two times

About 10 per cent of the lacquer used in the system can be used in the solvent stain. The acid-catalysed lacquers can be glossy, semi-glossy or matt.

Window frames made from coniferous woods

Wood preservative system

Treatment with a coloured wood preservative is followed by a treatment with a clear wood preservative. In Finland, 90 per cent of the window frames produced are treated in this way. An extra coat of an alkyd lacquer, glossy or matt is applied on the inner side.

Alkyd system

Pre-treatment is the same as above. Holes are filled with an alkyd putty. (Putty should not be used on the outside of frames.) The surface is primed with a quick-drying alkyd primer and smoothed again with an alkyd putty before sanding. An undercoating is applied with a quick-drying alkyd paint and sanded again. For the top coat, a quick-drying alkyd paint is used with an air or airless spray.

Acid-catalysed system

This system also begins with treatment with a wood preservative. Next, holes are filled with an alkyd putty. Priming is done with an acid-catalysed primer, and the article is smoothed with alkyd putty, sanded and finally given a top coat of acid-catalysed finish paint. The acid-catalysed paints should be of a special quality, so that they can withstand "living" in the frames. The acid-catalysed paints normally used for kitchen furniture interiors are too hard for this purpose.

Polyurethane system

Treatment begins with the application of a wood preservative or a special primer lacquer. Next, all holes are filled with an alkyd putty, and a polyurethane primer is applied. After sanding, the article is given a top coat with a polyurethane finish.

Some comments on paints

Alkyd paints

The alkyd resins used in the production of alkyd paints are made by heating mixtures of higher alcohols such as glycerol or pentaerythritol with dicarbonxylic acids such as phthalic acid anhydride, and fatty acids of drying or non-drying oils. The properties of the resulting resins depend on how the heating is done and on which raw materials were used.

Nitro-cellulose

Nitro-cellulose is still a widely used material for wood finishing because of its drying speed. Nitro-cellulose products dry because of the evaporation of their solvents. At room temperature or higher, drying can be speeded up by good ventilation. Since nitro-cellulose products have very low flash points, precautions must be taken against fire and static electricity. Furthermore, these products have a very low solid content, so that three to six coats must be applied before articles finished with them can be marketed.

Acid-catalysed products

This is the largest group of industrial wood-finishing materials in Finland. The acid curing products are normally based on combinations of urea formaldehyde, melamine and alkyd. The alkyd is of a non-drying type. In the presence of the catalytic acid that is mixed in before the paint is used, the urea resin reacts with the alkyd to form a rather hard film. The film has good resistance to abrasion, alcohol and other household chemicals.

An acid-catalysed top coat should not be combined with a primer based on linseed oil or alkyd. Normally such an underlay is too soft for the top coat, and there will be cracking within a short time. Furthermore the film of an acid-catalysed paint will be harder if the relative humidity of the air is low at the time of curing. The risk of paint film cracking increases as the relative humidity rises. Some modern paints can stand changes in the relative humidity from 20 to 80 per cent without cracking. Not more than two coats should be applied on the same day unless oven-drying is used.

Acid-catalysed products can withstand a dry heat of 100°C. Because they do not burn easily, shipyards are using boards finished with acid-catalysed materials for the interiors of vessels. Metal surfaces may be finished with acid-catalysed paints, but they must be pre-treated with an etch primer.

Polyurethanes

Pigmented or unpigmented polyurethanes can be used on outdoor furniture. Such paints are still not used very much in Finland, but they are very sophisticated products and are still in the process of development. Polyurethane films have high chemical and moisture resistance. Normal polyurethane products consist of an isocyanate component and a component with two or more hydroxyl groups. When these two components are mixed, a chemical reaction begins and a film is produced by cross-linking. The isocyanate component is very sensitive to water or moisture; if the can is not closed tightly, its contents will soon form a gel. This is caused by the isocyanate reacting with the hydroxyl in the water.

Polyesters

Two-component polyester lacquer with peroxide hardener is rarely used in Finland. Polyester sealers, however, are used to some extent for priming panels with a roller coater, applying 10-30 g/m², the drying times being 6-10 seconds.

Water-thinnable products

Water-thinnable acrylic lacquers are being used more and more in Finland. They can be applied very well by electrostatic spraying on wood and also by dipping or normal spraying or used on a curtain coating machine. The difficulties caused by many solvents are removed with the use of water-thinnable lacquers, and a lot of energy is saved through reduced ventilation needs.

Painting equipment and ventilation of the paint shop

Modern painting equipment is of many kinds, among them brushes, rollers, curtain-coating machines, dipping devices, roller coaters and spraying devices. The choice of equipment or painting method depends on the article to be coated and on the most economical way to do the job.

In air spraying, the surface-finishing material is transported from a pressure container (50 to 150 kPa) through a hose to the gun and atomized by air at 250 to 400 kPa. In airless spraying the paint or lacquer passes through a hydraulic pump (air pressure: hydraulic pressure = 1:25 to 1:40) and is atomized on passing through the nozzle of the gun. Different nozzles are available that give varying amounts of finishing material per time unit at constant pressure and with varying spray angles. Air spraying is mostly used on small items or when extreme surface smoothness is desired. The normal practice is to use a well-thinned paint or lacquer and spray it at as low a pressure as possible. Airless spraying is used on larger, flat surfaces and on items such as cupboard interiors. For the latter, air spraying causes a considerable increase in paint consumption because of rebounding.

The application of paints and lacquers on wood with electrostatic spraying equipment is also possible. The paints and lacquers should have a flash point higher than 23°C. The moisture content of the wood is normally about 6 per cent, and the grounding contact should not be too far apart (50-60 cm). Before applyig the solvent-based lacquers the wood is given a better conductivity by spraying it with a fine spray of water. By using a water-thinnable lacquer this operation can be omitted and the lacquer can be sprayed directly on dry wood. This method has advantages for small items, where the overspray with other methods is rather high. However, its possibilities should always be carefully investigated before investments are made.

When an investment in equipment for the application of drying of paints is being considered, several manufacturers should be consulted before a decision is made.

In many factories, the drying of applied finishes such as acid-catalysed paints is accelerated by high-temperature ovens. With modern equipment, curing time can be reduced to about 40-60 seconds. Special care should be given to the adhesives used to ensure that they can withstand high temperatures. The paint on coniferous woods is difficult to dry at high temperatures because the resin is forced out. For such species, drying temperatures of 50°-60°C will suffice.

An advantage of curtain-coating machines and roller coaters over other paint-application equipment is that the film thickness is easily controlled, thus simplifying calculation of the painting costs.

The air-conditioning and ventilation of a paint shop is necessary to prevent the content of solvent vapours and paint dust in the air from rising to dangerous levels. Poor ventilation increases health and fire risks and affects surface finishing negatively. When there is an excess of solvent vapours in the air, explosion limits are approached. These limits are different for different solvents; some of them are presented in table 21.

Table 21. Flash points, explosion limits and MAC values[a] of some important solvents

Solvent	*Flash point (°C)*	*Explosion limits (vol. %)*	*MAC value (cm^3/m^3)*
Butyl acetate	20	1.4-7.6	200
Ethyl acetate	−3	3-19	1 000
White spirit	30	0.7-4	500
Xylene	23	1-6	200
Toluene	6-10	1.[illegible]-6.7	200
Trichlorethylene	—	—	100
Turpentine	39	—	100
Acetone	−10	2.1-13	—

[a]MAC = maximum air concentration.

The degree of ventilation depends on how big the paint shop is and on the painting method used. In Finland the law requires that the air be changed 30 times per hour in a shop using spray application. The efficiency of the ventilation depends not only on how many cubic metres of air are blown in or out but also upon the placement of the ventilator.

Overall ventilation of the paint shop is insufficient. In places where the solvent evaporation is high, as in spray booths and in the neighbourhood of dipping equipment, local ventilation must be arranged. In planning the ventilation system, it should be remembered that solvent vapours are heavier than air.

XXV. Surface finishing of furniture and joinery in small plants*

Choice of surface finishing

The choice of surface finishing depends on:

- Use of the object to be surface-finished
- Material used in the object to be surface-finished
- Equipment available for surface finishing
- Available surface-finishing materials
- Conditions under which surface-finishing operations will be performed
- Conditions under which the object will be used
- Workers' skill

Preliminary treatment of surface

Removal of residual glue

In assembling the objects, care should be taken to avoid that glue spreads out of the joints. If this does happen, the glue should be immediately removed (a moist piece of cloth is suitable for removing most glues). In factories dried glue drops are usually removed mechanically with a chisel or a special scraper without damaging the surface. Glue stains and drops show from under the lacquered surface, and they should be avoided.

Intermediate sanding

The wavy cutter-head marks caused by machining must not appear in visible places, and the edges and corners must have sufficient roundings. Final sanding is done with fine sanding paper in the direction of the grain so that the surface is completely smooth.

Repair

Any possible sinking of the surface is brought up with moistening. Holes in solid wood are plugged or filled with either wood putty (lacquer and wood dust) or dissolved shellac lacquer or by some other method. Tears in the corners and edges of veneered surfaces are plugged with veneer plugs (taking care to have the grain directions of the plug and surface veneer in the same direction). The plugging veneer and the plugging itself must be chosen with care. The plugs are worked and sanded flush with the surface, and the dust is removed.

Moistening

Moistening is used to bring up the pore edges of wood sunk in sanding. The addition of 2-3 cm^3/litre of a chromium salt to the moistening water makes the wood brittle and easier to sand. The effect of moistening hardwood surface is shown in figure 198. This method is used when the highest surface quality is required.

*By Kaarlo Ilonen, School for Small-scale Industry and Teachers Training, Lahti, Finland. Originally issued as ID/WG.209/26.

Final sanding

Final sanding is done with sharp and fine sanding paper or cloth in the direction of the grain, but not until the surface is completely dry.

Staining with anilin colours

A basic solution of standard concentration is made for each required colour which is then diluted in a predetermined proportion. This way the exact shades can be reproduced in the future.

The addition of about 10 per cent of ammonium hydroxide to the stain makes the liquid enter the wood better. The stain is applied on the surface in a large quantity with a brush or sponge. The whole surface of the object is smoothed at the same time. Smaller objects can also be immersed in the stain.

If the wood is resinous or greasy, water-soluble stains do not adhere sufficiently well. The removal of resin and grease is necessary. Surfaces treated with water colours are sensitive to water before lacquering. Moist hands, water and stain drippings may leave marks that are difficult to repair. Therefore the objects must be dried in a sheltered place.

Lacquering

The environment for lacquering should have:

- No dust
- Good ventilation
- Good lighting
- Suitable work-tables
- Well-arranged drying and storage of objects to be lacquered

Equipment

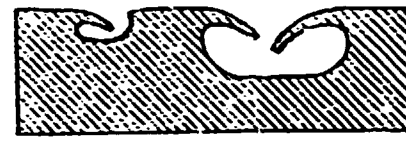
The lacquering brush should have a sufficiently strong edge (thickness of 10-15 mm), and it should have a wide base and become narrower towards the points (see figure 199). Bristle is a better material than hair because it becomes thinner towards the point and thus gives the edge the correct shape and resiliency. The most common bristles used are white swine and black Shanghai bristles. The container for lacquer for example can be a scoop or a pot with a handle. The brushes and pots for cellulose lacquer stay in good condition when stored in a tin container (figure 200) which can be closed tightly with a lid and contains thinner, either on the bottom or in a separate container inside. The brush bristles stay straight when hung through a hole bored through the handle and supported on a thick metal wire. The equipment also comprises a scraping plate with a special edge (see figure 201) for levelling the lacquered surface and a dusting brush and a piece of chamois, or something similar, to remove the dust.

Figure 198. Effect of moistening hardwood surface before lacquering

Lacquering unmoistened wood

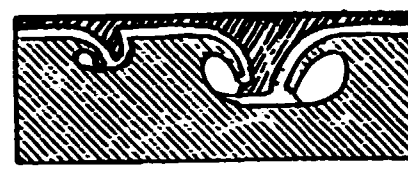
The magnified pores have collapsed from their original round shape. The broken upper edge of the pores has sunk in.

Unmoistened wood



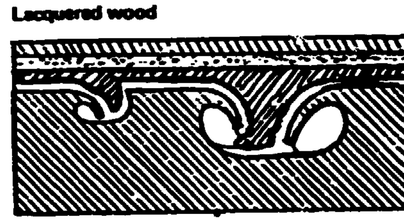
In prime coating with brush, spray gun or some other means the pore edges sink even further, preventing the lacquer from entering the pores completely. If wood filler is used—as in the figure—even that cannot fill the pore bottoms.

Wood with prime coating and filling



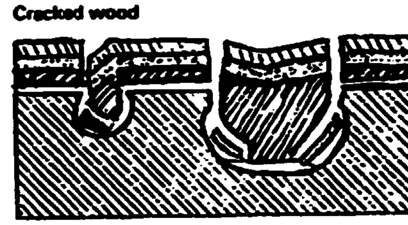
Actual surface lacquers fill the surface, leaving the pores hollow.

Lacquered wood



Because the wood later "lives", the pores tend to return to their original round shape. Tensions develop in the lacquer film, and these can result in longitudinal cracks.

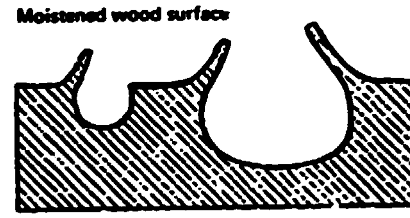
Cracked wood



Lacquering moistened wood

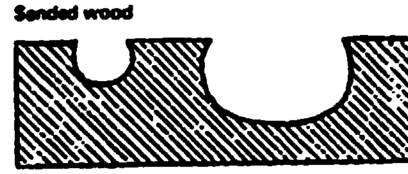
The wood surface has been moistened with water at 60° to 70°C using a sponge. The wood surface swells fast and the pores return to their original shape. The pores open and the surface becomes rough.

Moistened wood surface



Moistened wood surface has been sanded and the pores have opened. A rotating sanding wheel has been used with semihard base and 220 sanding paper. The sanding dust has been carefully removed from the pores in the longitudinal direction.

Sanded wood



In lacquering, the pores fill up to the bottom and the lacquering becomes durable.

Lacquered wood

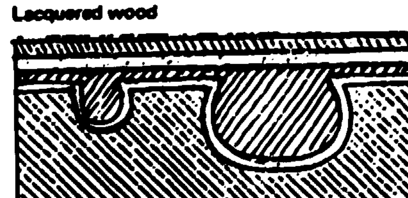


Figure 199. Lacquering brush

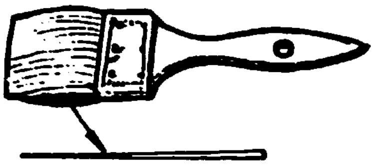


Figure 200. Container for brush storage

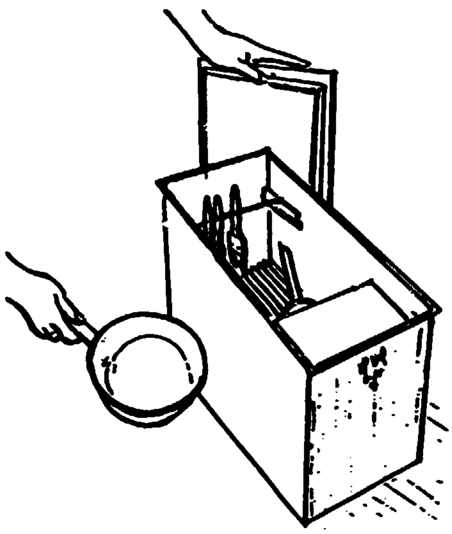
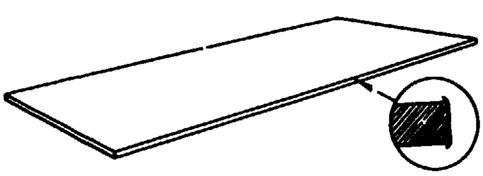


Figure 201. Scraping plate



Lacquering instructions

Cellulose and catalyst lacquers can be best applied with a spray gun, but a brush can also be employed. Since these lacquers dry fast their application, particularly on large surfaces, requires experience and skill in lacquering; therefore, the following instructions are applicable:

(a) The surfaces to be lacquered should preferably be set horizontally so that light is reflected from the lacquered surface (see figure 202);

(b) Lacquer application must begin from the edge farthest from the worker;

(c) Lacquer is applied from the centre towards the ends;

(d) Lacquer, immediately after application, is levelled with strokes across the whole surface, beginning exactly from one edge and making the stroke lighter on getting closer to the other edge;

(e) The brush must be held at an angle of about 60° towards the surface and near the brushing (see figure 202);

(f) The stroke speed and pressure of the brush must be suitable;

(g) The lacquer that has flowed on the edge must be immediately wiped off before the underlying lacquer coating becomes soft;

(h) With each stroke the surface must be observed against the light;

(i) It is advisable to coat horizontal surfaces with a thick layer of lacquer to make the surface level off;

(j) For vertical surfaces the brush strokes must be from the bottom to the top;

(k) The lacquering sequence of an object must be planned so that the whole object can be lacquered at the same time, whenever possible;

(l) The surfaces must be allowed to dry sufficiently before they can be turned onto their own base, an exception being a case in which a special spiked lacquering and drying base can be used (see figure 203);

(m) Between the coatings the surface should be either sanded lightly or scraped to remove lacquer points;

(n) Cellulose lacquer dissolves the underlying layer of lacquer but catalyst lacquer does not.

In lacquering with a brush, the viscosity of the lacquer does not play an important role. In prime coating both the cellulose and the catalyst lacquers are thinned 10-30 per cent, depending on the temperature of the air, to ensure better adhesion. The hardener is added to the catalyst lacquer in a ratio of 1:10 of the actual amount taken into the container. The lacquer containing hardener remaining on completion of the job must not be mixed with the rest of the lacquer. If the catalyst lacquer changes the normal shade of the wood, the prime coating can be made with cellulose lacquer.

Figure 202. Reflection of light from the lacquered surface and the position in which the brush is held

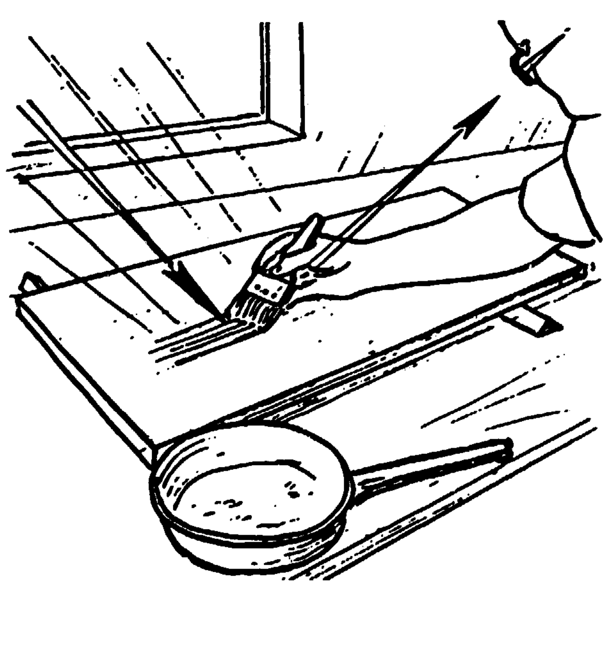


Figure 203. Spiked lacquering and drying base

Care of equipment

Dripping lacquer is removed from the brushes and they are then hung in a brush container. The lacquer containers may also be put into the same container (see figure 200). Brushes and pots must be cleaned with thinner after use with catalyst lacquer. The brushes are stored with the bristles pressed tight and flat at their extremity. If the brushes are well taken care of, they give the worker good service and satisfaction.

Spray lacquering

Environmental requirements for lacquering consist of a special fire-resistant booth provided with fans, particularly in the case of spray lacquering (see figures 204 and 205). This prevents lacquer particles and fumes from spreading to other work areas and keeps the environment clean, thus diminishing the danger of fire and health hazards. By providing a cleaner working environment, higher-quality items can be produced.

Figure 204. Spraying booth provided with dry filter

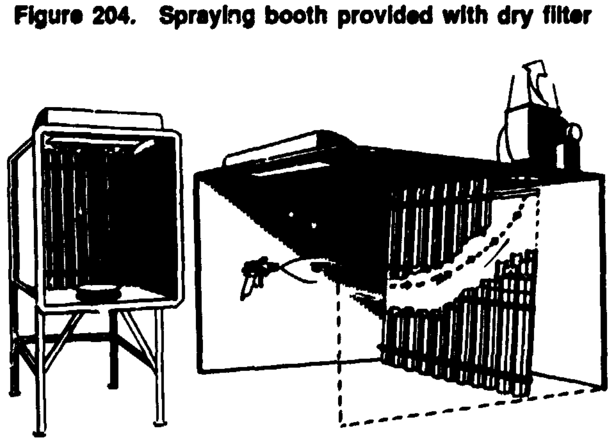
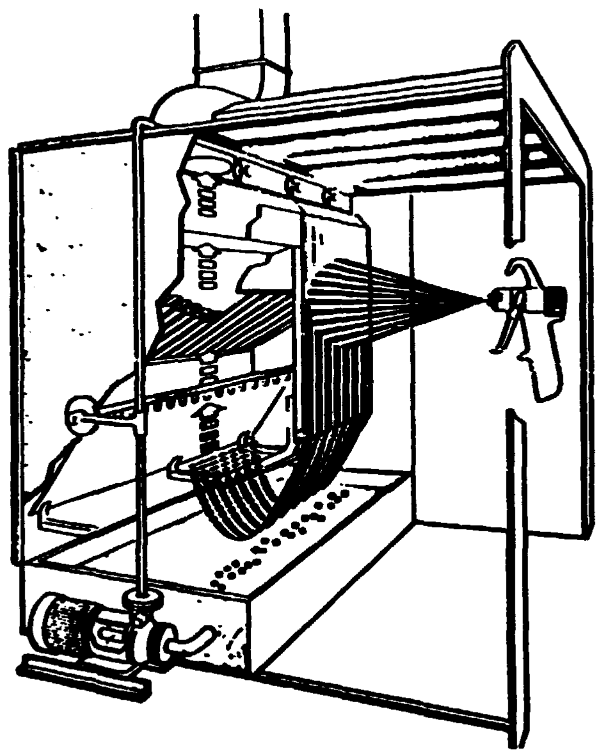


Figure 205. Spraying closet provided with water curtain



Spraying equipment

Electric spray gun. An electric spray gun (see figure 206) is a piece of equipment that supplies a high-pressure spray without a compressor and is suitable for spraying all liquid materials. The operation is based on a high-pressure pump operated by an electromagnet. The liquid to be sprayed is sucked by the current as a result of a vacuum being created and is ejected at a high pressure (100 impulses per second are obtained from 50-cycle alternating current).

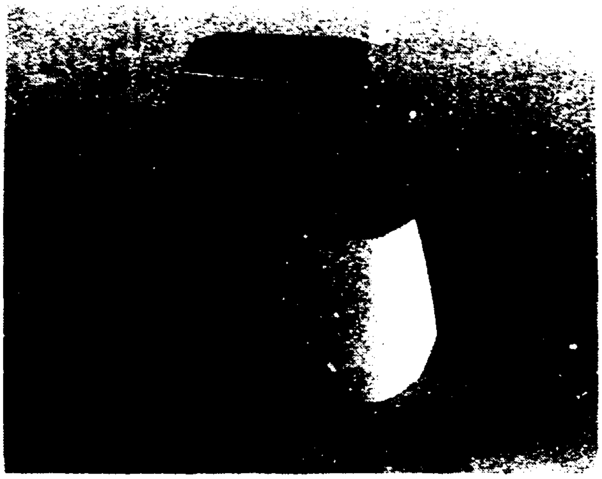
This type of spray gun is suitable for small-scale production, rapair shops etc. These guns must not be used in areas where a danger of explosion exists.

Pneumatic spray gun. Compressed air is fed either directly to the spray gun or to a pressure chamber and from there through an air filter and pressure-control valve to the spray gun. The suction air coming through the air cap, or the pressure created in the lacquer container, raises the lacquer to the spray head, and the compressed air coming through the air cap atomizes the lacquer, which is ejected at the desired angle of spread.

Light pneumatic spraying device. The compressor used is a small film or piston compressor (see figure 207). The spray guns usually operate on low pressure and are either suction- or pressure-fed. The lacquer can be fed from a container attached to the head or from a separate container through pipes. The lacquer spray is uniform, just as in large spraying devices. This device cannot be used to spray materials requiring high pressures because of its design characteristics.

A light pneumatic spraying device is suitable for small-scale production, repair shops etc. that have no separate compressor and where a spray gun with high capacity is not required.

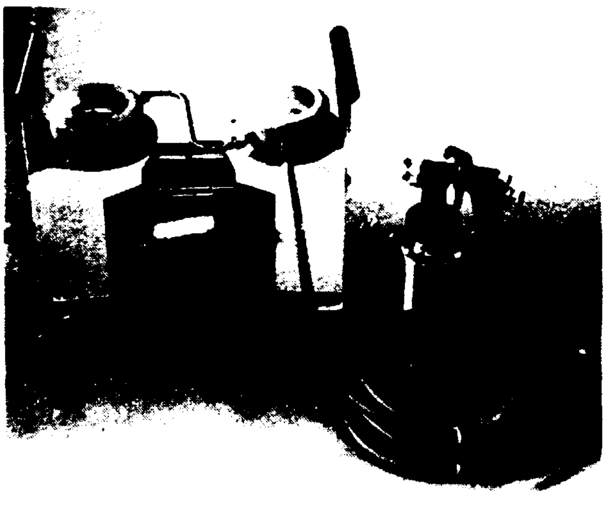
Figure 206. Electric spray gun



Technical data

Weight: about 1 kg
Capacity: 170 to 320 g of paint per minute
Power consumption: 35 to 60W

Figure 207. Light spraying device



Technical data

Weight (including compressor): 15 to 30 kg
Compressor with monophase electric motor under 0.5 kW
Pressure in continuous operation: 200 to 280 kPa
Capacity: 8 litres per minute of free air at pressure 200 kPa

Fixed spraying device. Fixed spraying devices (see figure 208) often have more complete auxiliary equipment and they also have a wider range of application than the light-weight ones. The main parts of a fixed spraying device are:

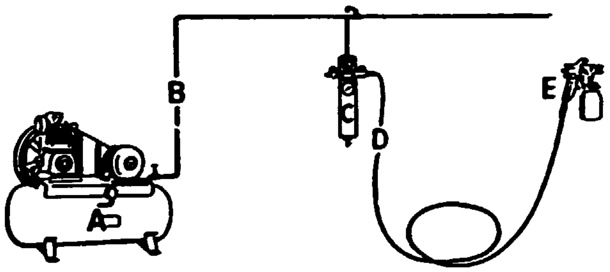
Spray gun
Compressor
Pressure chamber
Pressurized material container
Air line
Pipes for transport of material to be sprayed
Pressure-reducing valve provided with water extractor, air filter and pressure gauge

Technical data:

The capacity of the compressor must correspond to the consumption of air, both with respect to pressure and volume
The amount of air needed for one spray gun is 100-600 litres per minute, depending on the material to be sprayed, operating pressure and the spray head used
The weight of these spray guns varies between 300 and 1,000 grams

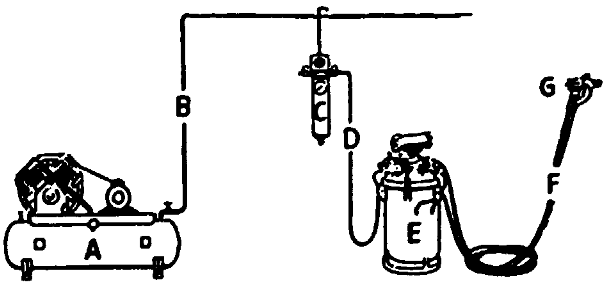
Figure 208. Fixed spraying devices

A. Container mounted on gun



Key: A Tank of compressed air
B Compressed air pipe
C Regulator
D Flexible hose
E Spray gun with container

B. Large separate container



Key: A Tank of compressed air
B Compressed air pipe
C Regulator
D Flexible hose
E Pressurized material container
F Pipe for transport of material to be sprayed
G Spray gun

Instructions for spraying

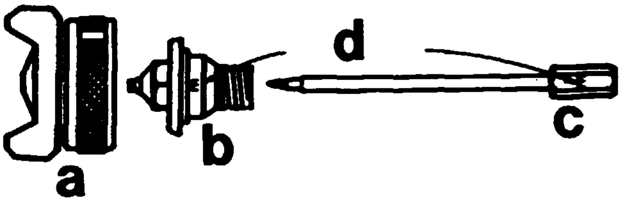
There are spray head combinations (spray head and needle valve) available for each spray gun (see figure 209). The choice depends on the type of spray gun, the material to be sprayed and the operating pressure. Rough rules to follow are:

(a) The thinner the material to be sprayed and the lower the operation pressure, the smaller the size of the spray head;

(b) Spray-head sizes suitable for lacquering have diameters of 0.4-0.5 mm for electric spray guns, and of 1.0-1.4 mm for suction and pressure-fed spray guns (see annex);

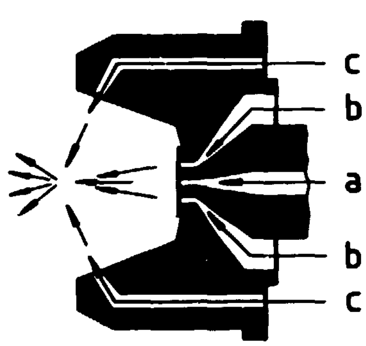
(c) In suction feed an external-mix gun is best for fast-drying catalyst and cellulose lacquers (see figure 210).

Figure 209. Spray head components



Key: a Air cap
b Spray head
c Needle valve
d Size marking

Figure 210. External-mix spray gun



Key: a Material
b Suction air
c Atomizing air

Determining the lacquer viscosity

Lacquer viscosity is most important for obtaining good spraying results. It can be checked in a number of ways. The simplest method is to measure the time in seconds that it takes for the lacquer to flow from a standard viscosity cup (see figure 211). The viscosity is measured in seconds. The better known viscosity meters are Ford and DIN cups. The lacquer viscosities are normally given in these units. The lacquer viscosity can be diminished either by adding thinner to it or warming it. Warmer lacquer gives a stronger coating in a single spraying since it contains less evaporating material. The viscosities for cellulose and catalyst lacquers are about the same: 18-20 seconds using DIN cup No. 4.

Figure 211. Measuring viscosity

Pressure control

In electric spray guns the spraying pressure cannot be controlled. In compressor-operated suction and pressure-fed spray guns the lacquer is atomized at 200-400 kPa, depending on the lacquer viscosity.

Spraying techniques

Learning the correct spraying technique and use of equipment is most important because the work rate, quality and material used are affected. In addition to the technique, the spray-gun operator must also be able to regulate the spray gun and find out possible disturbances and their causes as well as eliminate them. Some instructions on techniques and problems connected with spraying are indicated in figures 212 to 218.

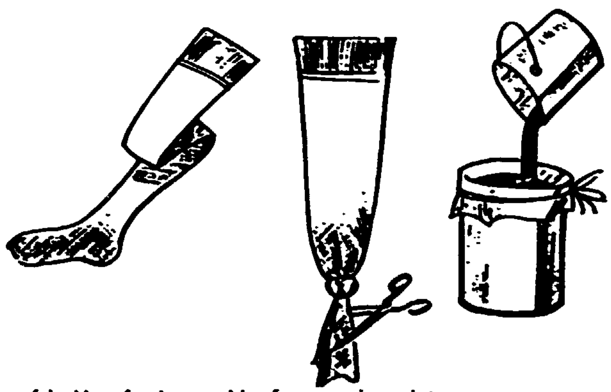
To locate the faults of points *(a)* and *(b)* in figure 214, the air nozzle should be turned half a revolution and sprayed. If the pattern has turned the same amount, the fault is in the air cap. If, however, the spray head is blocked, careful cleaning is necessary. In figure 214, points *(c)* and *(d)*, if the pressure of atomizing air or pressure of lacquer has been wrongly regulated, the pressure and the width of the fan or the spray must be regulated again. This is done until the right pattern is found. The right pattern is shown in figure 215.

Suitability of cellulose and catalyst lacquers for spraying and production

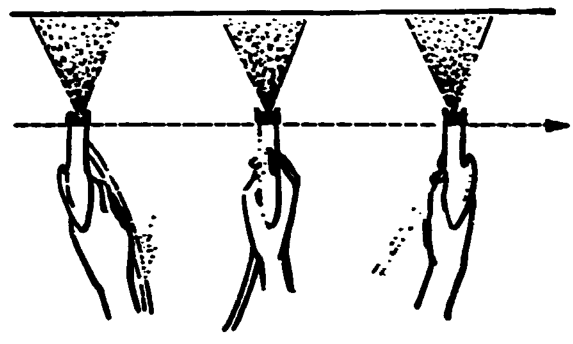
As fast-drying lacquers cellulose and catalyst lacquers are particularly suitable since the time between coatings at normal room temperature is relatively short. Owing to the rapid film formation, the lacquer levels off well. Catalyst lacquer gives a more durable surface than cellulose, with respect to mechanical wear, resistance to chemical substances and other stresses.

With some species of wood catalyst lacquer may cause changes in colour. In such cases the prime coating should be made with cellulose lacquer. The surfaces must be dry and clean from dust and other impurities.

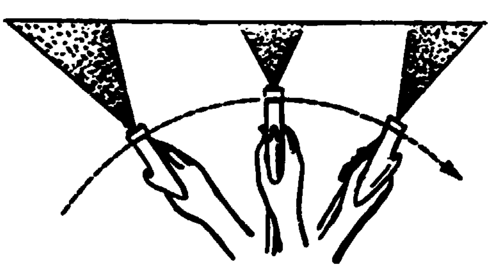
Figure 212. Spray-lacquering techniques



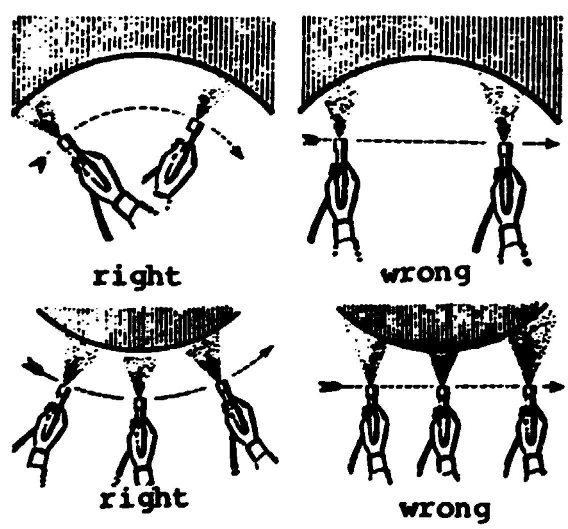
(a) Use of nylon stocking for screening paint



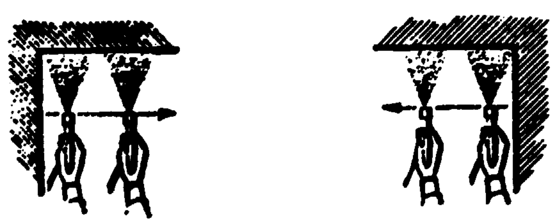
(b) Correct pointing of spray gun for level surface



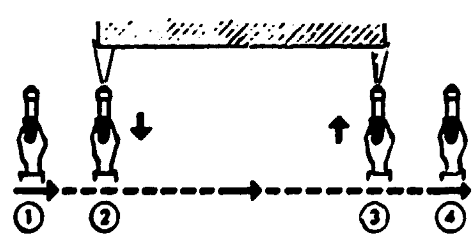
(c) Wrong pointing of gun for level surface. The gun is turned so that the surface becomes uneven and paint is atomized at the edges.



(d) Spraying curved surfaces. The figures on the right show wrong pointing of the gun. On the left the pointing is correct.

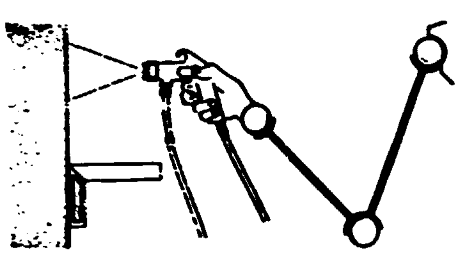


(e) Correct pointing of gun at corners

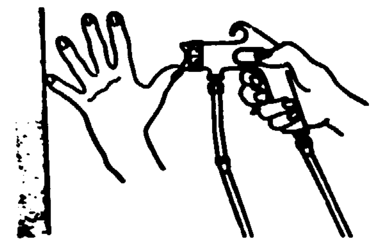


(f) Spraying is started from the outside of the surface. The trigger is pressed when the gun reaches the surface and released after the gun has passed it, but the movement is continued a little on the outside of the surface.

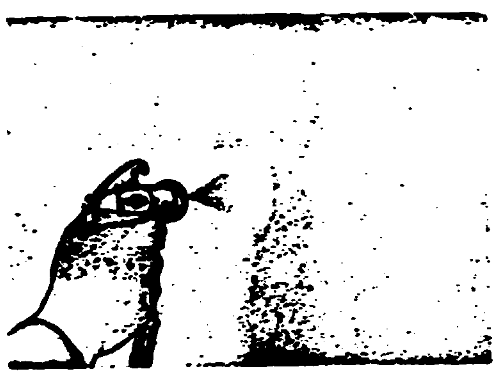
Figure 212 *(continued)*



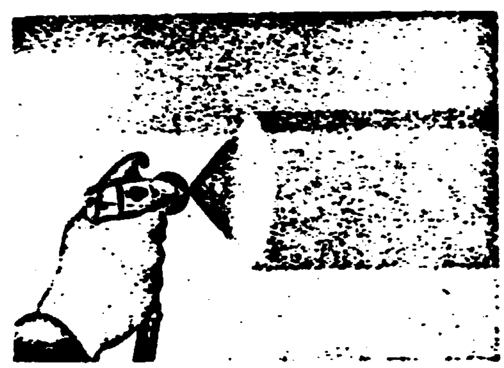
(g) The paint s sprayed with long even strokes. The arm must not be held rigidly, but all joints must move and in this manner the gun can be pointed straight, which is essential to achieve an even surface.



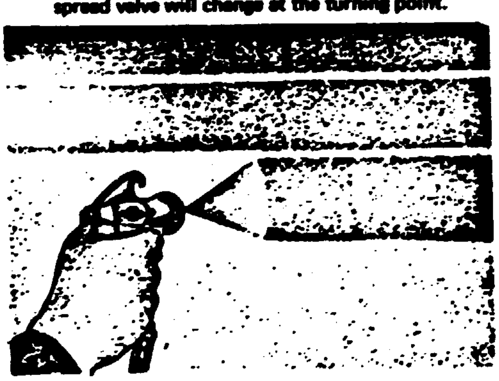
(h) The gun is moved with an even speed across the surface. The distance between the surface and gun must remain constant at between 15 and 25 cm.



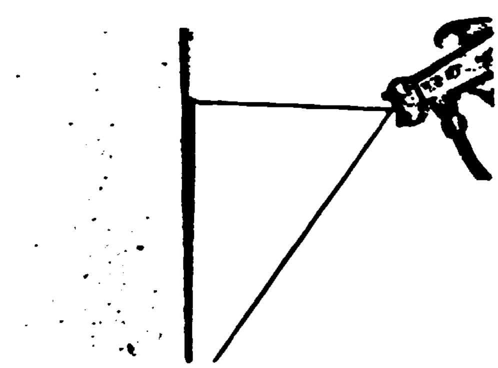
(i) The direction of the movement should not be changed during spraying; otherwise the surface spread valve will change at the turning point.



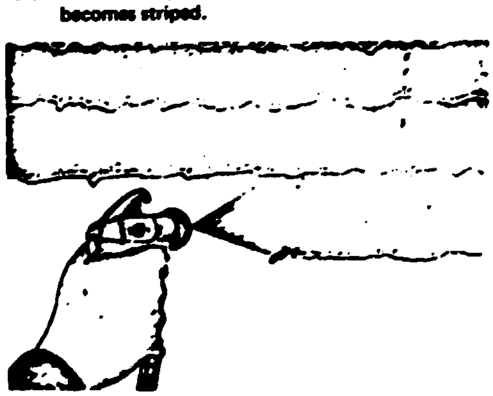
(j) The sprayed coatings must not overlap too much.



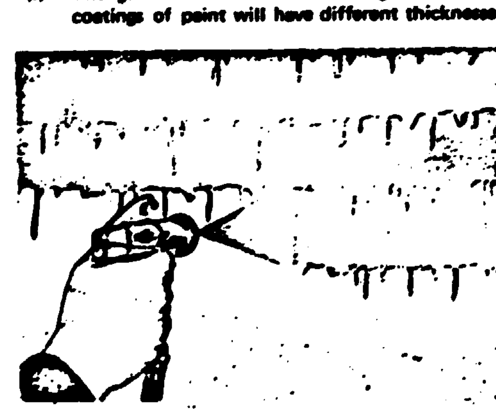
(k) Unless the sprayings cover each other the surface becomes striped.



(l) The gun should not be held diagonally or the coatings of paint will have different thicknesses.

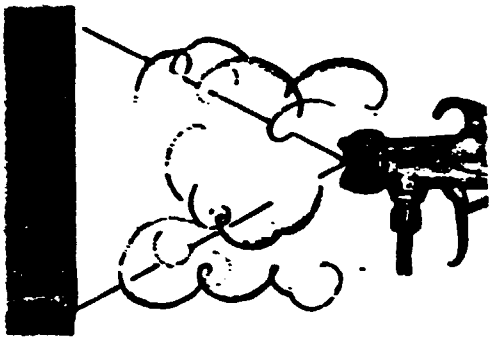


(m) Too much and too thick a paint will settle in folds.

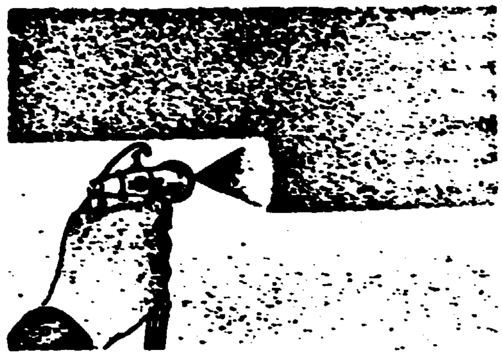


(n) Too much and too thin a paint will run.

Figure 212 *(continued)*

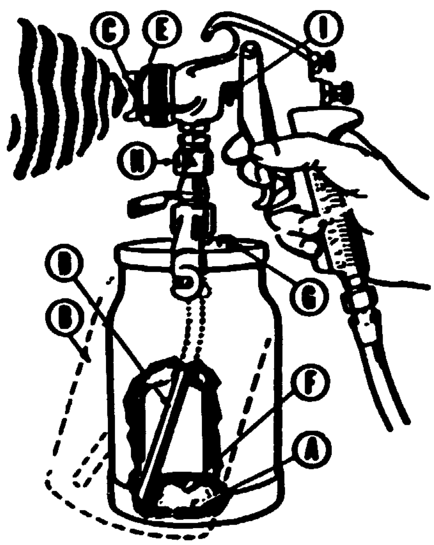


(o) The pressure should not be too high or the surface will be like the peel of an orange.



(p) The distance between the surface and the gun must not be too great or the paint will dry on its way.

Figure 213. Possible reasons for uneven spray



Key: If the colour sprayed is uneven, the defect could be due to any of the following reasons:

A Too little colour in the container
B Position of container too slanted
C Blocked suction pipe
D Loose or damaged suction pipe
E Loose or damaged seal

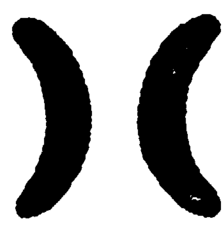
When using a suction container also, defects could be because:

F Colour is too thick
G Opening in the lid of container is blocked
H Air pipe or pipe connector is damaged
I Seal of needle valve is poor or loose

Problems also arise if the colour tube reaches the container bottom.

Figure 214. Irregular spray patterns

(a) The reasons for narrowing of the pattern at the bottom or top could be: that the side openings of spray head are blocked; that the spray head is partly blocked; or that impurities exist in the air cap or spray head.



(b) The reason for the pattern turning to the left or right could be: blocked side opening of the air cap, left or right; or a partly blocked spray head.

(c) The reason for the pattern spreading in the middle could be: too narrow a spray; too low a pressure or paint is too thick; too small an air cap with pressure feed; or too large a spray head.

Figure 214 *(continued)*

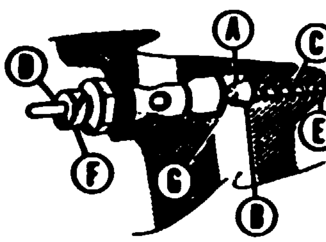
(d) If the pattern narrows in the middle, the reason could be wrong pressure. Make the spray narrower or add pressure. Regulating the pressure increases the amount of colour but the spray movements must be speeded up.

Source: DeVilbiss Company, Toledo, Ohio, USA.

Figure 215. Correct spray pattern

Source: DeVilbiss Company, Toledo, Ohio, USA.

Figure 216. Lacquer leak through the air cap



Key: The reasons for a leak through the air cap could be:

A Impurities in the sealing surfaces or the air valve
B Sealing cone of needle or its chuck worn or damaged
C A weak spring
D Poor greasing
E Bent needle
F Too tight a seal
G Damaged or poor seal

Accident prevention in spraying

Fine lacquer spray is dangerous because it is highly inflammable and must be dispersed with proper ventilation. The following rules should be observed:

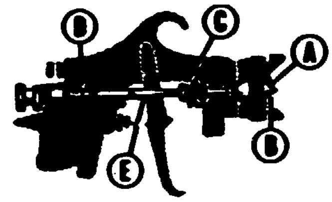
(a) There should be no smoking;

(b) Painting should not be done near open flames or other sources of heat, including spark-emitting equipment, electric or other motors in the vicinity of the spraying area;

(c) The area should be explosion proof with sufficient ventilation when lacquering indoors. Ventilation of a well-designed spraying booth is shown in figure 219;

(d) Protective masks of the type shown in figure 220 should be worn when lacquering indoors.

Figure 217. Lacquer leak through the needle valve seal

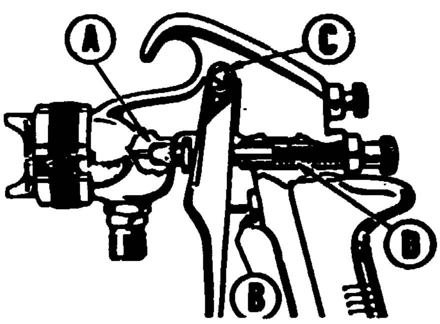


Key: If the lacquer leaks through the tightening nut of the needle valve seal, the reason might be:

A Damaged or worn needle valve or spray head
B Impurities in spray head
C Too tight a seal for needle valve
D A weak spring
E Colour needle and spray head not of the same size

Source: DeVilbiss Company, Toledo, Ohio, USA.

Figure 218. Greasing the spray gun



Key: The following parts of the spray gun are greased regularly:

A Seal of the needle valve
B Seal of the air valve
C Tightening bolt of trigger
D Springs of the needle

Source: DeVilbiss Company, Toledo, Ohio, USA.

Figure 219. Suitably ventilated spraying booth

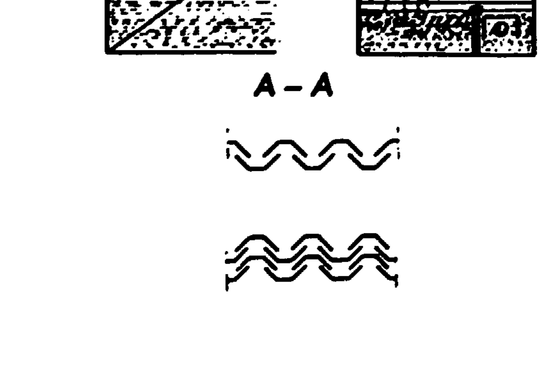
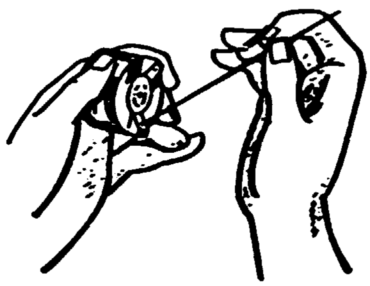


Figure 220. Protective masks

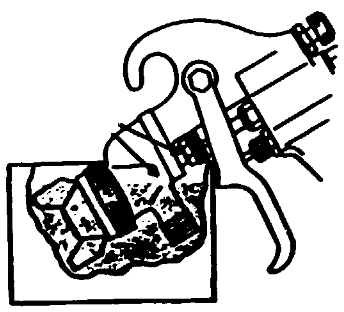
Cleaning the spray gun (figure 221)

To obtain good lacquer suction and spray formation, it is important to keep the spray-head openings clean. They are cleaned with a sharp piece of wooden stick. Metal wire can damage the orifice of the opening.

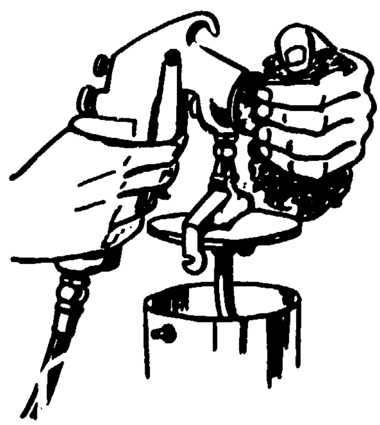
Figure 221. Cleaning the spray gun



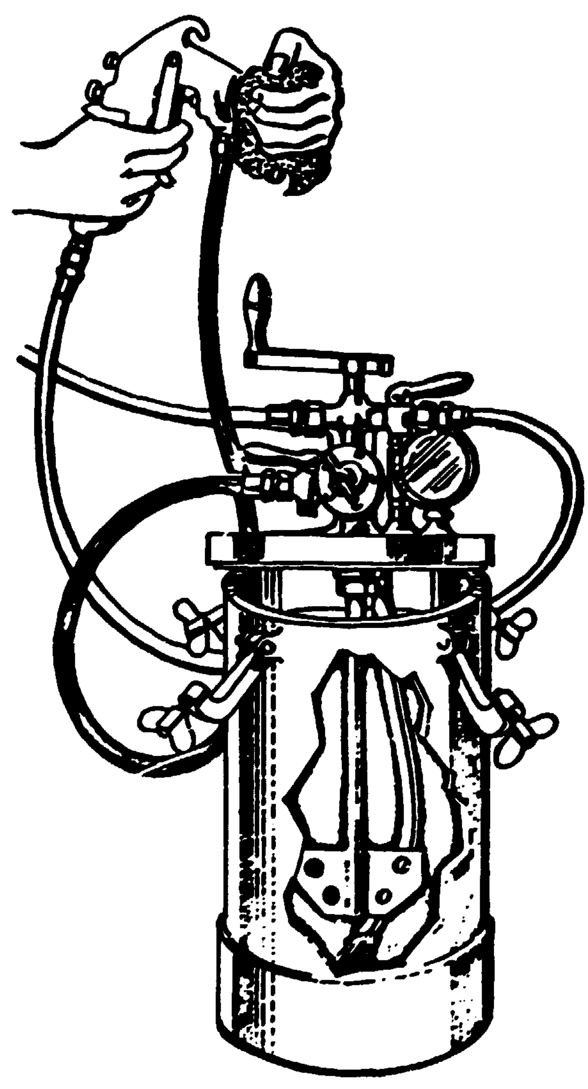
(a) Cleaning side openings



(b) Upper limit of thinner must not rise above the seal



(c) Cleaning spray gun with suction-feed container



(d) Cleaning the pressure system

If the work is temporarily interrupted, the lacquer in the spray head can be prevented from drying by wrapping a cloth moistened with thinner around it and then covering it with a plastic foil. The spray head can also be immersed in thinner. When the work has been finished the spray gun must be cleaned with care. In suction-feed spray guns the container is removed, the spray head blocked with a piece of cloth and the trigger released. Pressure makes the paint go back to the container. After this has been done, thinner is sprayed into the container. Finally, the spray heads are removed, rinsed in thinner and dried, and the outside of the spray gun is wiped clean.

Cleaning a pressure-feed spray gun is similar, but pressure flow to the compression chamber must be prevented and the pressure must be reduced in the container before the lid is opened.

Important rules to remember are:

(a) The spray gun must not be immersed completely in thinner;

(b) Lye and alkaline fluids must not be used in cleaning as they damage metal parts;

(c) Joints, threads and seals must be oiled or greased after cleaning.

Immersion lacquering

If only immersion is used in lacquering, good final results in surface finishing require special equipment that will ensure an adjustable rate of lift of the item from the lacquer, of 2.5-10 cm/min. Lacquer viscosity and temperature must be carefully controlled. Simple protective lacquering with thin lacquer can be applied manually so that the objects are immersed one by one, or several at one time. Small objects can be immersed in lacquer in a large sieve made of metal wire. Objects moistened one by one are hung and those immersed in a sieve (see figure 222) are turned over on a wire mesh to dry. Satisfactory results can be obtained by combining the use of a brush with immersion lacquering and arranging the hanging and drying in a proper way. Objects should be shaped so that when hung the lacquer drips off and drying occurs when they are placed on a wire mesh or hung from an appropriate support; such objects are sticks, pins, tool handles, parts of toys, pegs and beads. Cellulose lacquer is suitable for this application since it does not set in the pot, and, because the thinner evaporates rapidly, it sets and dries quickly.

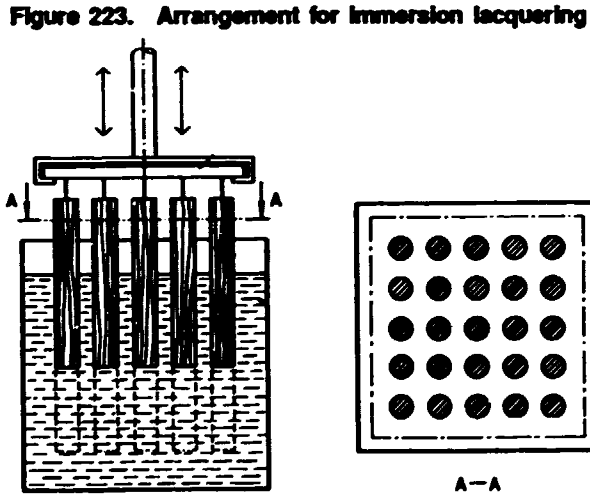
A special device can be constructed that can make the immersion method very economical, e.g. for furniture legs or other parts that can be treated before assembly. A typical arrangement is shown in figure 223. A series of workpieces are carefully fixed onto sharp spikes of the base plate, the set is turned upside down and placed into the immersion apparatus which slowly feeds the set into the lacquer container and again slowly lifts it from the lacquer. The feed movement is best controlled by a pneumatic cylinder. The immersed sets are placed on a special rack for drying. The excessive lacquer still flowing from the workpieces can be returned to the container.

Figure 222. Equipment for immersion lacquering

A. Wire sieve

B. Meshes

Figure 223. Arrangement for immersion lacquering



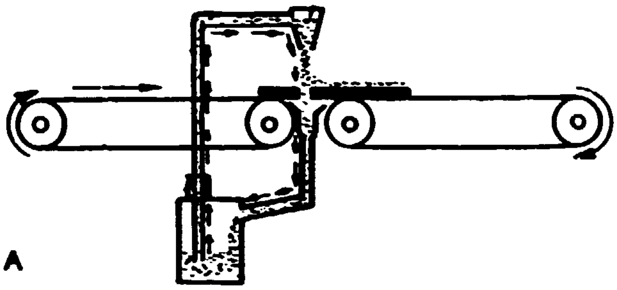
Curtain coating

The curtain-coating machine, shown in figure 224, is already a standard machine, even in smaller factories that produce serially panel components such as cabinet parts, table-tops, bookcases, flush doors etc. The panel component to be lacquered is fed on a two-part belt conveyor through the thin lacquer film flowing from the adjustable slit of the lacquer head above the conveyor. The spreading, normally indicated in g/m^2, can be adjusted by changing the feed rate (30-150 m/min) or, in some machines, the flowing speed of the material. If a panel is fed diagonally through the machine those edges which face the lacquer film will also be thinly covered by lacquer. By constructing special racks, a series of furniture legs with square cross-section, for example, can be easily lacquered so that two sides of each leg will be covered per feed. For this purpose the racks must hold the legs horizontally but be placed on a notched rack so that all faces of the components are at 45° to the horizontal.

The principal advantage of the curtain-coating machine is that material waste is small. Practically all lacquer that does not adhere to the workpiece is collected in the machine and returned to circulation. The cleaning of the machine is, however, quite laborious, and therefore the machine is well-suited only for longer production runs with same type of lacquer or paint. Using the curtain-coating method, products can be surface finished before assembly. In most cases this means knock-down constructions, particularly for panel furniture.

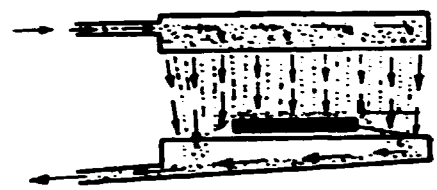
Figure 224. Curtain-coating machine

A. Side view



A

B. Lacquer film or curtain as seen in direction of feed



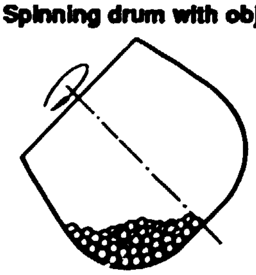
B

Tumble lacquering

In lacquering small items, such as beads, buttons and ends of small tools, tumble lacquering can be used. The drum in which the items are tumbled is round or octagonal, and it spins slowly and can be tilted to an angle of 45° (see figure 225).

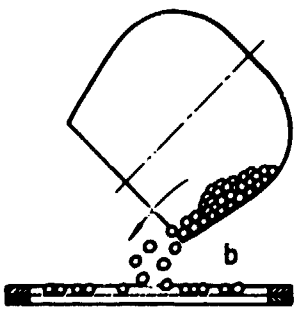
Figure 225. Tumble lacquering

A. Spinning drum with objects



a

B. Lacquered objects are turned over to dry on a wire mesh



b

There are two different ways of drum lacquering:

(a) About two thirds of the drum is filled, a measured amount of lacquer is added (e.g. 1/150 of the volume of the items) and tumbling is continued until all items are coated with lacquer; they are then turned over on a wire mesh to dry;

(b) While the objects are moving in a spinning tumble, lacquer is sprayed until all objects are coated with lacquer; they are then turned over to dry on a wire mesh.

A suitable spray gun for this operation is an electric gun, which sprays less material than suction or pressure-feed guns owing to its counter pressure. Cellulose lacquer is also more suitable for this type of lacquering, since lacquer that has dried in the drum can be removed with thinner.

Drying techniques

The drying process for cellulose lacquer is based on the evaporation of the thinner material. The drying of catalyst lacquers takes place through a chemical reaction. The drying time for cellulose and catalyst lacquers are approximately the same. They are (for an ambient temperature of 20°C):

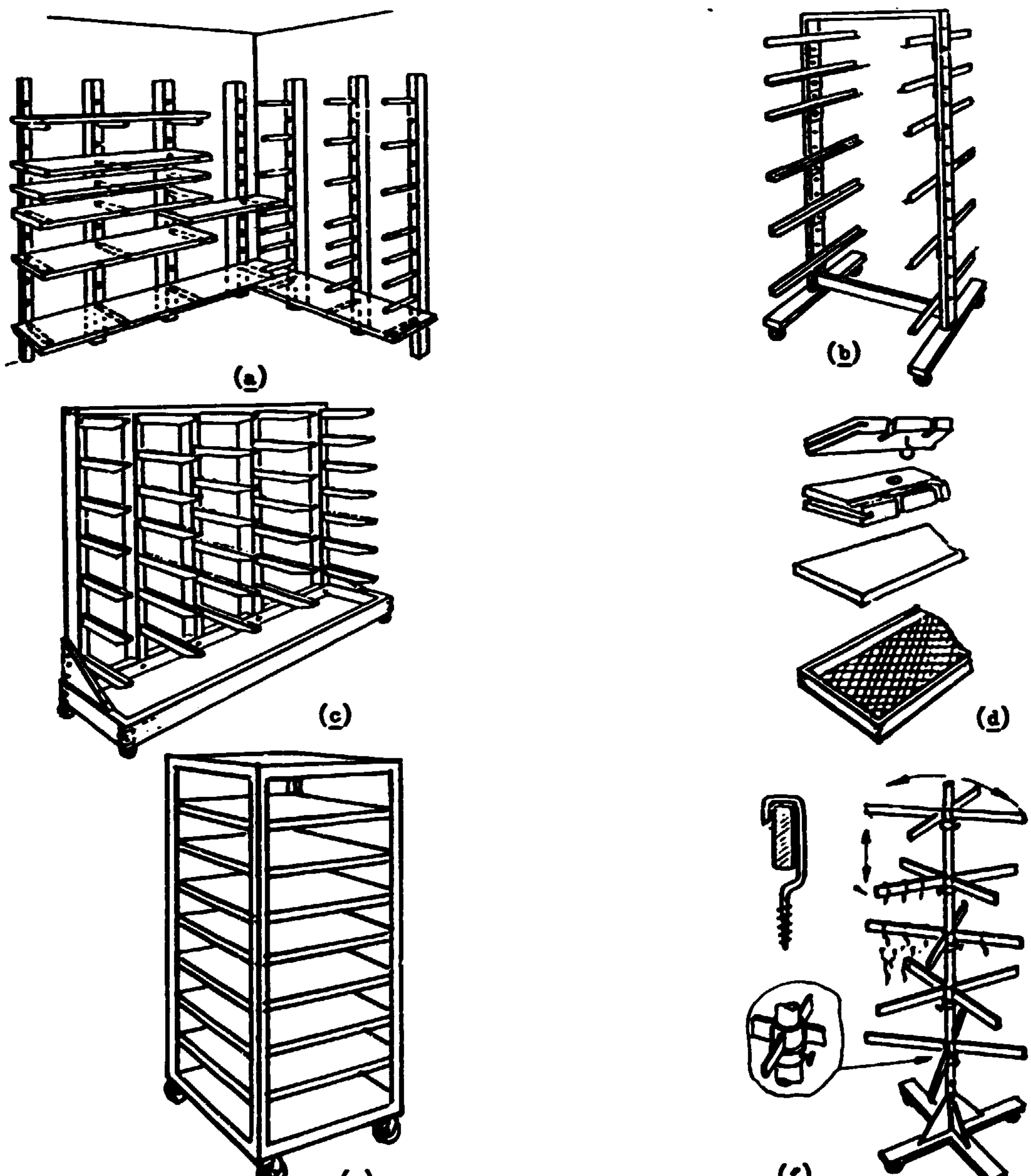
Touch dry after about 10 minutes
Handling dry after about 1 hour
Package dry after about 24 hours
(At higher temperatures the drying is more rapid.)

The drying of cellulose lacquer coatings depends on the thickness of application, or spraying, and the thickness of the whole film, since cellulose lacquer partly dissolves the coatings under it.

Drying stands (figure 226)

In small and medium-scale production, articles are usually dried at room temperature in well-ventilated rooms. The objects to be dried can be positioned on shelves or racks along walls in the immediate vicinity of the application area (figure 226 *(a)*). In spraying, mobile stands are recommended where spraying and drying areas are separate. In this manner the objects can be transferred and dried in the same stand. The stand model depends on the need. Often the needs change, and therefore the stands used should be so constructed that they are versatile (usable for as wide a range of objects as possible). The stands can be made from wood or metal. For flat-surfaced objects they are usually of the type shown in *(b)* (for small items) or *(c)* (for larger panels). Shelves of the types shown in *(d)* are sometimes used on the horizontal supports. Another less common type is shown in *(e)*. Objects that are turned or dipped are often dried on stands similar to the one shown in *(f)*.

Figure 226. Drying stands and shelves



Key:
- *a* Shelves or racks along the wall
- *b* Stand for small, flat-surfaced objects
- *c* Stand for larger panels
- *d* Shelves for use on horizontal supports
- *e* Drying stand with shelves
- *f* Stand for turned or dipped objects

Post-treatment processes

If a matt lacquer surface is required, it can be obtained either by using matt lacquer or rendering a glossy lacquer surface matt. Dry matting is obtained by rubbing the surface with thin steel wool (No. 000) and a pad in the direction of the grain or strewing pumice powder on the surface and then rubbing it with a brush, also in the direction of the grain. Instead of a brush, fine steel wool wrapped around a sanding pad can be used. When using the wet method, the pumice powder is mixed with turpentine, oil or vaseline, and sanding is performed with a soft cloth with sanding support in the direction of the grain. After sanding, the surface must be cleaned with thinner, petrol or some other solvent that removes the grease but does not dissolve the lacquer.

In wood with rough grains matt lacquer gives a more attractive surface, since even the bottoms of the pores become matt. In matting with steel wool or pumice powder, they remain glossy.

Post treatment of lacquered surfaces with wax produces an attractive silk-like surface. The wax is applied on the surface and rubbed firmly in the direction of the grain with a piece of woollen cloth. The durability is not as good as that of lacquered surfaces. If the surface must be lacquered later, the wax must first be removed carefully, otherwise the lacquer will not dry.

Repairing lacquered surfaces

Flow

The lacquered surface is allowed to dry completely, after which it is levelled with a well-sharpened scraping plate or wet-sanding paper using a sanding pad. For the final coating of lacquer, or if a coating leaving the pores open develops, flows should be particularly avoided since the levelled points may remain visible.

Holes resulting from sanding

If excessive sanding results in the removal of the veneered surface, it must be repaired with lacquer before the next coating, either by using a spray gun, brush or finger. If the surface of the wood has been stained before lacquering, the damaged part must be re-stained. Stain that is soluble in ammonium hydroxide or alcohol is more suitable than ordinary water-soluble stain. Colour adhesion can be improved with light sanding.

Old lacquered items

Before surface finishing, grease and other surface impurities must be removed with an appropriate cleaning substance, such as soap or crystal soda solution, spirit etc., that does not dissolve the lacquer. The surface is then sanded in the direction of the grain. If the colour has worn off on the edges or corners, these are repaired as described above. For surfaces with cellulose lacquer, the first two coatings should be made with almost pure thinner. Thus the small cracks in the old lacquered surface can be levelled out. After each coating the surface is sanded or scraped lightly. When using catalyst lacquer, the lacquer for the first coatings need not be applied more thinly than normal, since the thinner does not dissolve the underlying coating.

Removing old lacquer

An old coating of cellulose lacquer can be removed mechanically, using a scraping plate, other types of scrapers or sanding paper. To facilitate the work, the lacquer can first be softened with a lacquer remover. Thinner can also be used; it may be applied on a piece of cloth or a sheet of paper spread on the surface. To prevent evaporation it can be covered with a plastic foil. The cloth and the plastic foil are then rolled away when the softened lacquer is being scraped off.

The surface is sanded before lacquering. If special lacquer removers are used, the surfaces must be cleaned according to instructions (usually with a white spirit); otherwise the lacquer may not dry and the adhesion of a new coating can be rather poor. In surfaces with colour and decorative carvings or moulded shapes the lacquer can be removed using a lacquer remover and scraper that does not damage the colour and the surface of the wood. A scraper made of hardwood, plastic or bone can be used. A dull scraping plate is also suitable. Catalyst lacquers are removed mechanically. Before lacquering, the surfaces are sanded and worn or damaged stained points are repaired.

SPRAY-HEAD DATA[a]

Spray materials	Spray model[b]	Spray head combination[b]	Feed	Spray head size (mm)	Air intake (litres/min)		(pressure kg/cm²)
Thin:		74-FX	P	1,07	285–3,5	330–4,2	395–5,3
	P-MBC-510	704-FX	P	1,07	285–2,1	350–2,8	420–3,5
Water	P-JGA-502	705-FX	P	1,07	205–1,4	230–1,8	260–2,1
	P-AGA-502	2-FX	P	1,07	225–2,1	275–2,8	330–3,5
Stain	P-AGB-501	203-FX	P	1,07	200–2,1	240–2,8	285–3,5
Solvents	P-AGA-517	36-FX	P	1,07	190–2,1	235–2,8	285–3,5
Thinner	P-AGB-504	58-FX	P & I	1,07	145–2,1	180–2,8	215–3,5
Fixer		58-FF	P & I	1,40	145–2,1	180–2,8	215–3,5
		110-FX	P	1,07	95–2,1	120–2,8	140–3,5
	P-CM-501						
	P-AGA-504	37-FX	I	1,07	160–2,1	200–2,8	230–3,5
	P-AGA-505	29-F	P	1,04	140–2,1	170–2,8	205–3,5
	P-AGA-571	100-F	P & I	1,04	90–2,1	100–2,8	120–3,5
	P-WDA-502						
	P-CMF-501	F-49-F	P	1,04	85–2,1	105–2,8	125–3,5
	P-TGA-501	944-F	P	1,04	135–2,1	165–2,8	190–3,5
		90-F	I	1,04	100–2,1	125–2,8	150–3,5
	P-EGA-502	392-H	P & I	0,46	40–2,1	–	–
		126-H	P & I	0,46	20–2,1	–	–
	P-CGA Kaikki maalit	84-FF	P & I	1,40	90–2,1	110–2,8	130–3,5
	OGA-501	84-F	P & I	1,04	90–2,1	110–2,8	130–3,5
Medium thick:		160-FF	P	1,40	540–3,5	615–4,2	695–4,9
		160-FZ	P	1,19	540–3,5	615–4,2	695–4,9
Lacquers		161-FF	P	1,40	465–3,5	540–4,2	610–4,9
Cellulose paints		161-FZ	P	1,19	465–3,5	540–4,2	610–4,9
		765-FF	P	1,40	415–3,5	545–4,9	675–6,3
Synthetic paints	P-MBC-510	765-FX	P	1,07	415–3,5	545–4,9	675–6,3
Varnish	P-JGA-502	74-FF	P	1,40	285–3,5	330–4,2	395–5,3
Thin glues	P-AGA-502	74-FX	P	1,07	285–3,5	330–4,2	395–5,3
Fillers	P-AGB-501	704-FF	P	1,40	285–2,1	350–2,8	470–3,5
	P-AGA-517	704-FX	P	1,07	285–2,1	350–2,8	420–3,5
	P-AGB-504	43-FF	I	1,40	245–2,1	295–2,8	345–3,5
		43-EX	I	1,78	245–2,1	295–2,8	345–3,5
		30-EX	I	1,78	210–2,1	255–2,8	300–3,5
		705 FF	P	1,40	205–1,4	230–1,8	260–2,1
		705-FX	P	1,07	205–1,4	230–1,8	260–2,1
		401-D	P	2,18	180–2,1	220–2,8	260–3,5
		36-EX	I	1,78	190–2,1	235–2,8	285–3,5
		64–FX	P	1,07	165–2,1	205–2,8	240–3,5
		58-FF	P & I	1,40	145–2,1	180–2,8	215–3,5
		58-FX	P & I	1,07	145–2,1	180–2,8	215–3,5
		45-FF	P & I	1,78	100–2,1	125–2,8	140–3,5
		48-E	P & I	1,40	100–2,1	125–2,8	140–3,5
		110-FF	P	1,40	95–2,1	120–2,8	140–3,5
		490-FF	P	1,40	100–2,8	–	–
	P-AGA-520	Z-19	P	4,38	365–4,2	–	–
		78-FF	P	1,40	505–3,5	615–4,2	670–4,9
		78-FX	P	1,07	505–3,5	615–4,2	670–4,9
	P-JGA-502-A	78-FZ	P	1,19	505–3,5	615–4,2	670–4,9
	P-AGA-502	770-FZ	P	1,19	480–3,5	560–4,2	635–4,9
	P-AGB-501	775-FF	P	1,40	490–3,5	565–4,2	640–4,9
		775-FZ	P	1,19	490–3,5	565–4,2	640–4,9
	P-CM-501	37-E	I	1,78	160–2,1	200–2,8	230–3,5
	P-AGA-504	37-FF	P	1,40	160–2,1	200–2,8	230–3,5
	P-AGA-505	29-F	P	1,04	140–2,1	170–2,8	205–3,5
	P-AGA-571	100-F	P & I	1,04	90–2,1	100–2,8	120–3,5
	P-CMF-501	Z-47-FF	P	1,40	90–2,1	115–2,8	140–3,5
	P-CM-502	Z-47-FF	P	1,40	90–2,1	115–2,8	140–3,5
	P-TGA-501	944-F	P	1,04	135–2,1	165–2,8	190–3,5
		92-E	I	1,78	120–2,1	150–2,8	180–3,5
		395-E	P & I	1,78	70–2,1	–	–
	P-EGA-502	390-F	P & I	1,04	65–2,1	–	–
		124-F	P & I	1,04	40–2,1	–	–
	P-CGA Kaikki maalit	84-FF	P & I	1,40	90–2,1	110–2,8	125–3,5
		Z-46-FF	P	1,40	60–2,1	75–2,8	90–3,5
	OGA-501	84-F	P	1,40	90–2,1	110–2,8	125–3,5
		Z-46-F	P	1,40	60–2,1	75–2,8	90–3,5

Source: DeVilbiss Company, Toledo, Ohio, United States of America.

[a]This table has been included to give an idea of the range of products available.

[b]Numbers refer to DeVilbiss products.

XXVI. Upholstery technology*

Introduction

The main purpose of upholstery is to make a piece of furniture more comfortable for the end-user. The main products that are upholstered are seats of all kinds; sometimes other furniture, such as parts of beds or parts of writing tables are upholstered too. The bedding and mattress and upholstery industries are related, and in many factories the two departments are combined.

Typical upholstered products include:

Small chairs
Small chairs with armrests
Cosy chairs
Sofa sets:
  With upholstered cushions
  With upholstery and visible wooden parts
  Fully upholstered
Bed sofas

Many other different fancy products may also go through the upholstery department of a factory, thus complicating the task of production management.

Upholstery materials have become versatile, and synthetics have often replaced natural materials. Production methods are still very labour-intensive, although many machines and work aids have been developed. Skill requirements remain high, especially in efficient sewing and difficult upholstering. Upholstery constructions have been developed, standardized and modulized. Upholstery today is made up of components and parts which are put together during the final assembly stage. The present chapter concentrates on the modern upholstery technology used to produce modern furniture.

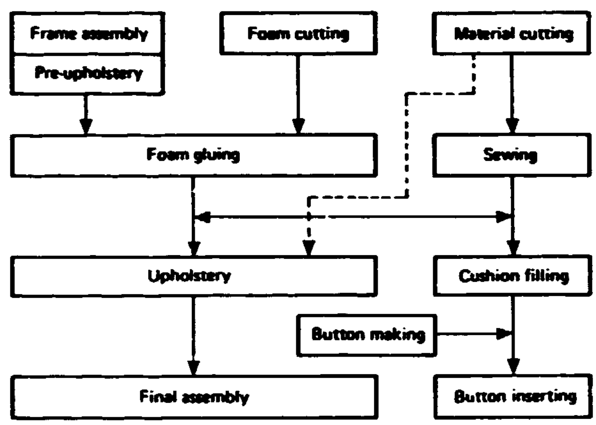
Operations

The operations necessary in an integrated upholstery department are shown in the flow chart (figure 227).

Wooden frames are often assembled in the upholstery department in order to save storage space. In frame assembly zig-zag springs or other elastic materials are inserted, if possible in one operation. Plastics have become a popular frame material. Plastic frames do not normally require any assembly or pre-upholstery work, only the foam will be glued. Metal frames are normally used for furniture for public buildings and ships because it is non-combustible.

Foam can be cut by the supplier or at the furniture factory, depending on price and availability, delivery times and warehousing cost. The cutting waste can be used for chopped foam, which is then used for lower-quality products (the cut foam and the frame are glued together in the foam-gluing operation). Instead of cutting from a block of foam, it is possible to use mould-cast foam. The moulds are costly, but can lead to subsequent savings.

Figure 227. Flow chart of upholstery operations



Fabric or leather is cut in the cutting room and sewn into covers for upholstery or cushions. In a modern factory it is common to have more sewing operators than upholsterers. This is because a large part of the upholstery can be constructed with various special sewing machines.

The pre-upholstered frame and the cover are sent to the upholstery department, where the cover is pulled over and stapled to the frame.

Buttons and cushions are prepared for final assembly in the cushion-making department. The operations are:

Button making
Cushion filling
Inserting buttons

In final assembly the parts are assembled all fittings are inserted, cushions are put on the frames and the product is inspected at a final quality-control station before packing and shipping to the client.

Construction

Products are normally designed so that parts going through various operations are small and easy to handle. Assembling before upholstering is old-fashioned and costs money owing to extra handling. Upholstering separately also makes it easier to train workers because the tasks are easier.

Knocked-down constructions are also used in upholstered products. However, the relative space savings are smaller than with shelvings, tables etc.

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*By Arto Juva, Managing Director, AJ – Consultants Ltd., Vääksy, Finland. For further information, see ID/275, by the same author.

Although designs vary, it is possible to standardize the products to a certain extent. The following are items that can be standardized:

Parts and components
Accessories
Joints, seam construction
Methods, machinery and tools
Materials

The goal of standardization is to simplify and improve:

(a) Materials management: fewer items in stock and fewer items missing from stock;

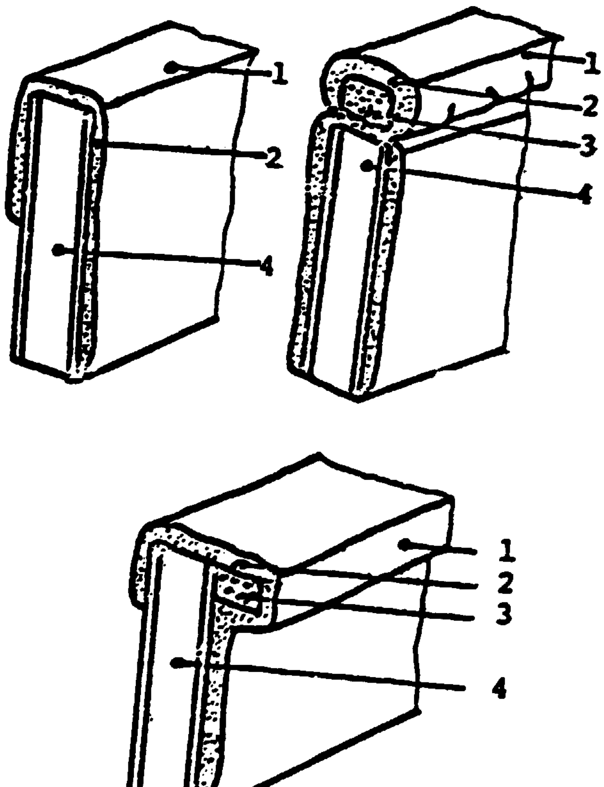
(b) Production planning and control: longer series and thus fewer work orders to be planned and controlled;

(c) Production management: fewer work methods and time studies, less training etc.;

(d) Production efficiency: workers have less to learn.

As an example, several designs can be made by using different arm rests on standard sofa seats and backs (see figure 228), and a standard upholstered seat can be used for various small chairs.

Figure 228. Three types of arm rests



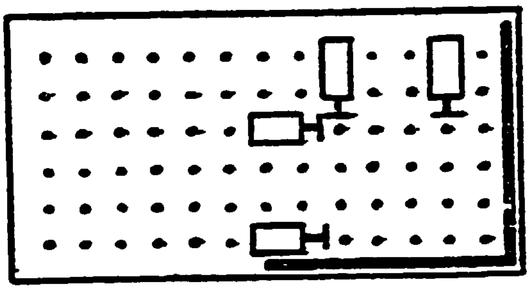
Key: 1 Fabric
2 Standard polyester foam
3 Harder foam
4 Frame

Methods and machinery

Assembly

The frame is assembled in a jig with pneumatic cylinders. The jig or press has to be flexible and easy to set up (figure 229). It is possible to insert the zig-zag springing when the frame is in the press. Clips are stapled before the components are put in to the jig. A template must be used to show the correct placing of the clips. Machines have been developed for automatically stapling clips, but these are for very advanced production methods. Elastic webbings are normally stapled in a separate operation after frame assembly.

Figure 229. Pneumatic assembly jig



The use of a pneumatic stretching machine results in better productivity and quality. Not only does it always stretch the same amount of webbing, but it also stretches several bands at one time. For example, a machine can stretch a particular webbing 100 per cent, but the operator working manually achieves 90 per cent in the morning and averages only 60 per cent in the evening. Not only is quality lost, but additional material is also utilized.

Cutting

The cutting operations are:

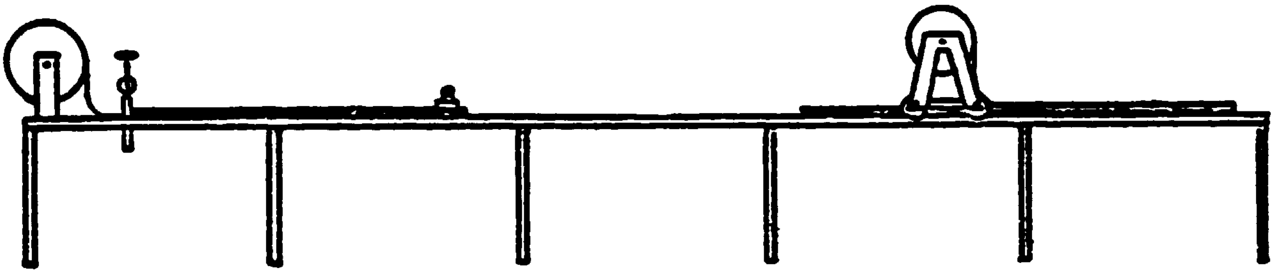
Marker making (pattern layout)
Spreading
Cutting
Bundling

There are several ways of laying out a pattern. It can be traced on to fabric or paper, sprayed on the top fabric, perforated etc. The paper layout can be duplicated with carbon paper or can be photocopied in a special machine.

The layout of patterns is normally planned using full-size patterns, but large, technologically advanced factories use miniature patterns. The reduced patterns (scale 1:5) can be made with a pantograph and the layout is planned on a special table, also reduced to the same scale. The miniature patterns are moved around until a layout is found that will have the smallest material consumption. The layout is then traced or photographed. The marker then follows the miniature layout when placing the actual patterns. With this technique, which is widely used in the clothing industry, substantial material savings have been achieved.

It may be possible to cut more than one fabric ply at the same time, but if so, the material has to be spread out first. Spreading is done either from a stand (for short lays) or with a machine (for long lays) (see figure 230). The machine can be driven manually or by a motor. After spreading each ply, up to the desired number, the material is cut with scissors, with a cutting device or with the cutter of the spreading machine. Normally two persons are needed. With machine spreading, one person can manage depending on the material being spread.

Figure 230. Cutting table with material-spreading devices



For short lays | For long lays

For cutting, electric scissors (figure 231) or straight knives (figure 232) are used. (Electric scissors are used when cutting from one to five plies.) Round knives (figure 233) are commonly used in the mattress industry where many long, straight lines are cut. They are normally not suited for the upholstered furniture industries.

Figure 231. Electric scissors

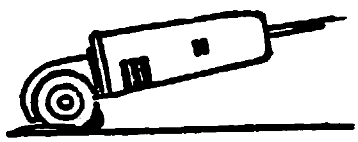


Figure 232. Electric straight knife

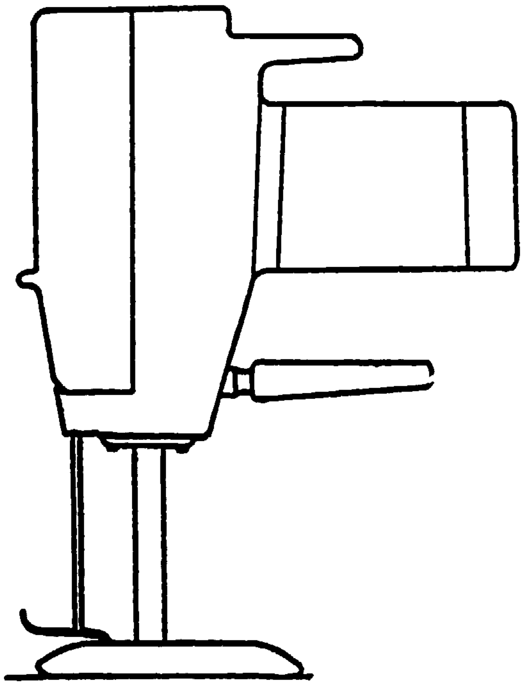
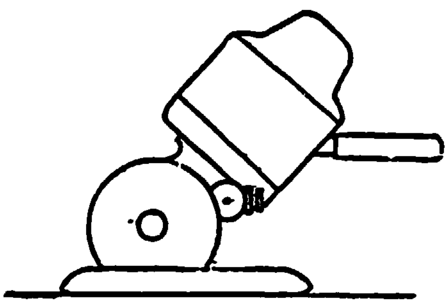


Figure 233. Electric cutter with round knives



After cutting, the material is bundled and taken to the sewing room. In some cases, plies must be numbered in order to avoid different colour shades in different parts of the product. This can be done with a numerator machine or with a manual ticketing device.

Leather can be cut very efficiently with a sharp knife on a table with a glass or hard plastic top. The cutter's knife follows the pattern. Die-cutting is sometimes used, but the investment is large and the savings are questionable, especially when a skilled knife cutter is employed. Sometimes electric scissors are used for leather too.

Sewing

Heavy-duty sewing machines are used to sew upholstery. The types of machines are:

(a) Single-needle lock stitch, which is usually equipped with needle feed or unison feed to improve the feeding of heavy materials such as napped fabric, synthetic leather or leather;

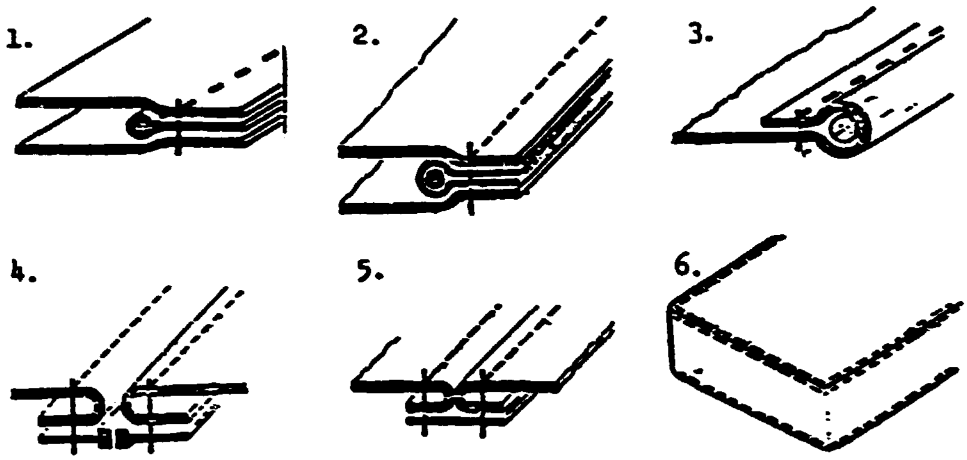
(b) Safety stitch, which chain stitches and over-locks simultaneously and can thus be used to eliminate one operation. It can also be used for over-edging only. The purpose of over-edging is to make coarse materials stronger for sewing or stapling in upholstery;

(c) Two-needle machine, which is used for zippers and for decorative stitching;

(*d*) Special machines and work aids, which are used for pleating, ruffling, tacking, welting etc.

The most common stitch constructions are shown in figure 234.

Figure 234. Various seam constructions



A standard sewing machine with an ordinary table, designed for the clothing industry, is not sufficient for a work station. The table must be extended so that there is room for the pieces to be sewn, for the completed workpiece and to support large pieces of upholstery when sewing. Guides, binders, folders, thread trimmers etc. help the operator and make the sewing process more efficient.

Foam cutting and gluing

Foam is cut from a block or from a sheet of polyurethane. A block can be cut with a horizontal cutter followed by a band saw (see figures 235 and 236). Sheets can be cut with a special hand cutter, which is similar to the fabric-cutting machines. There are also many special machines for cutting special shapes. If polyester wadding is to be used, it can be cut on a suction table which shrinks the lay so that 50-70 cm can be cut in one lay. The disadvantage is the cost of plastic needed to cover each lay when cutting.

The equipment necessary for foam gluing is a suction table (figure 237) to control air pollution and a spray gun for glue, although for small-scale production glue can be applied with a brush. A staple gun might be needed at the work station for cardboard supports. Modern glues need to be applied to one side only, but most factories still use glue that has to be applied to both sides.

Figure 235. Horizontal foam-cutting machine

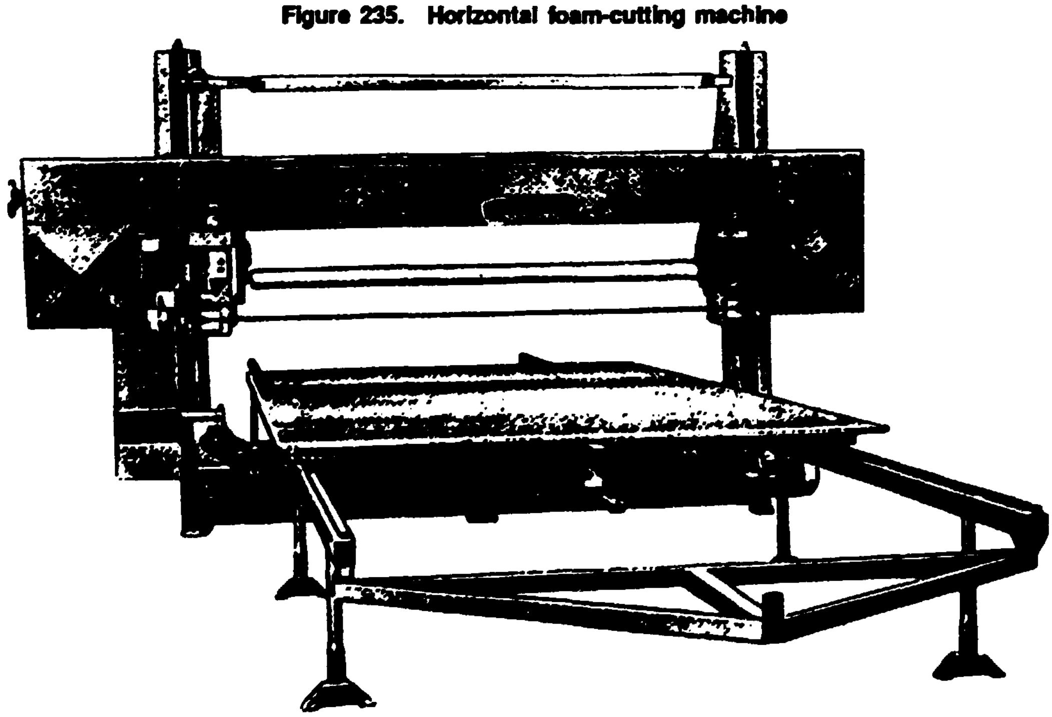


Figure 236. Vertical foam-cutting machine

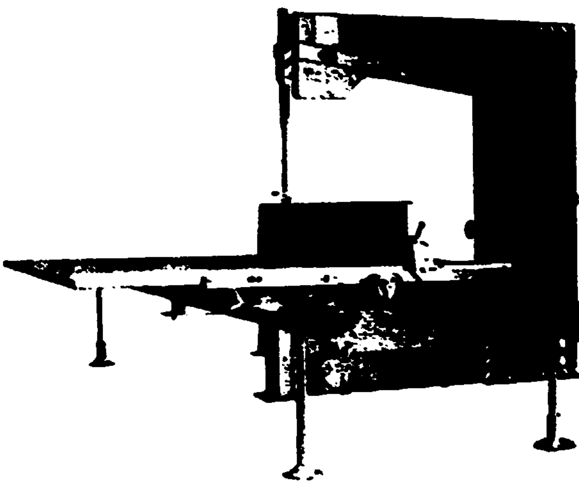
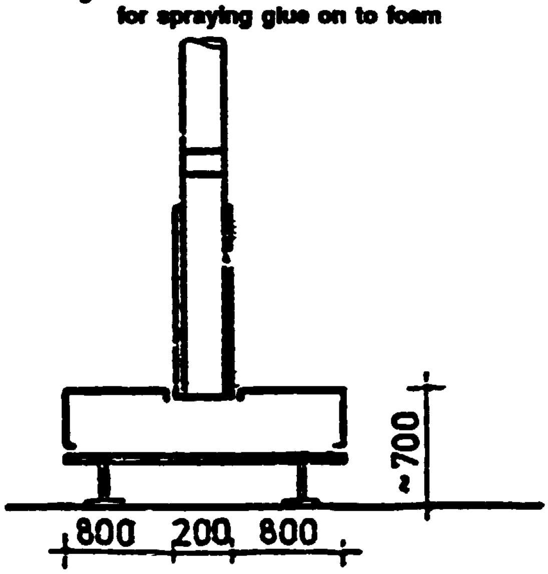


Figure 237. Double-sided suction table for spraying glue on to foam



The most common mistake made in foam gluing is spraying too much glue. The result will be that:

(a) Glue is wasted;

(b) The drying time is longer, which increases the production time and the cost;

(c) The quality is not good, and seams will open later on because the solvent has not evaporated;

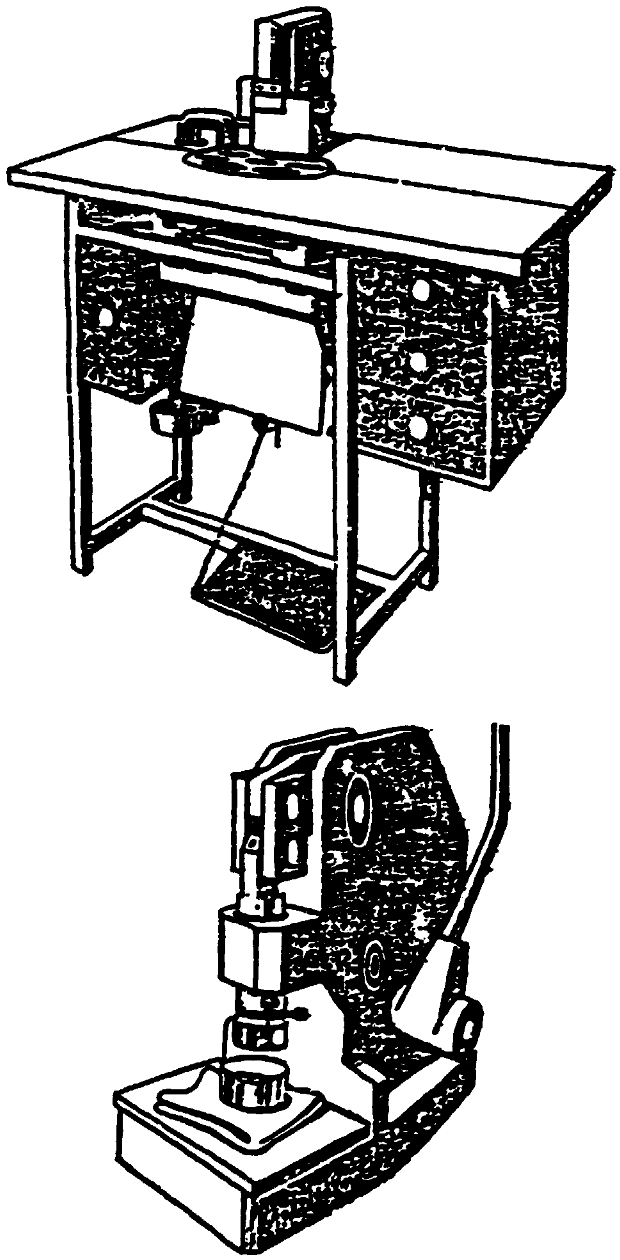
(d) The thick, hard seam may be felt in the final product;

(e) More compressed air is needed.

Buttons

Covered buttons are made in two operations. First, the cover is cut from the waste from fabric cutting, normally using dies that cut several pieces and plies at one time. Depending on the size of the factory manual or pneumatic equipment is used. The second operation is to cover the button with the button-covering machine (figure 238). Hand-operated covering machines are sufficient for small-scale production. Other machines of increasing sophistication are: foot-operated covering machines; pneumatic machines with a turning work head or rotating work head; and automatic machines with automatic button feeding and disposing which can cover as many as 3,000 buttons per hour.

Figure 238. Button-covering machines



Cushion filling

Cushion filling can be done by hand or using semi-automatic or fully automatic machines (figure 239). Buttons are then inserted by hand or with a machine, depending on the size of production (figure 240).

Figure 239. Cushion-filling machine

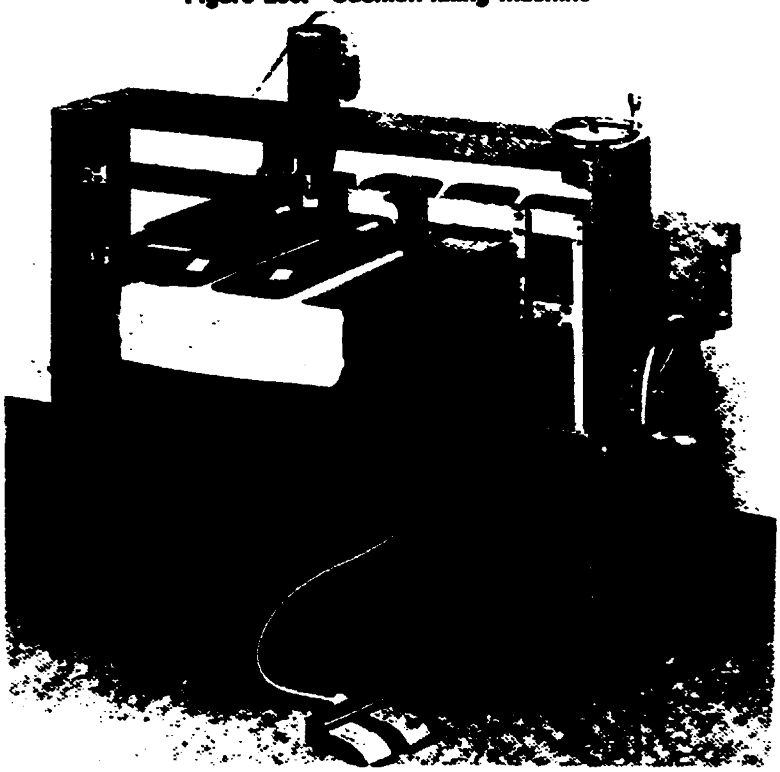
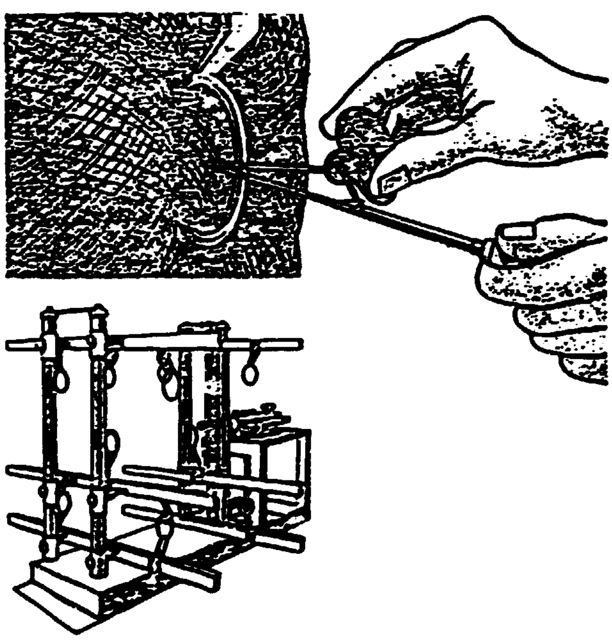


Figure 240. Inserting buttons

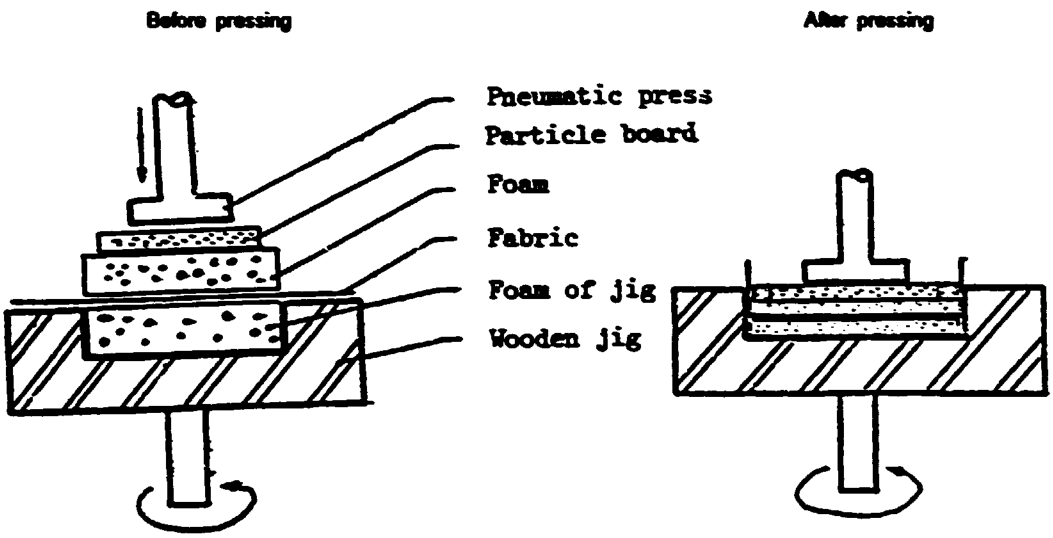


Other machines used in an upholstery department

A work-table, benches or supports are needed in an upholstery department, and an upholstery column is useful (figure 241). The purpose of the pneumatic column is to hold the workpiece in position and leave both of the operator's hands free for pulling, straightening, stapling, holding, measuring etc. The disadvantage, however, is that the column is not suited for all construction. The tool that is used most in an upholstery department is the staple gun; others are hammers, glue applicators, needles, scissors, knives, tape-measures, templates and staple removers. For small parts, upholstery presses (figure 242) that hold the piece can be used. With a proper jig the fabric is folded, and the gluing of the foam may even be eliminated. Material is also saved because it is not needed for pulling the fabric (this is done by the jig).

Figure 241. Upholstery column

Figure 242. Upholstery jig for small chair seats (Note that the sides of the fabric are turned up so that the stapling can be done quickly and with material savings.)



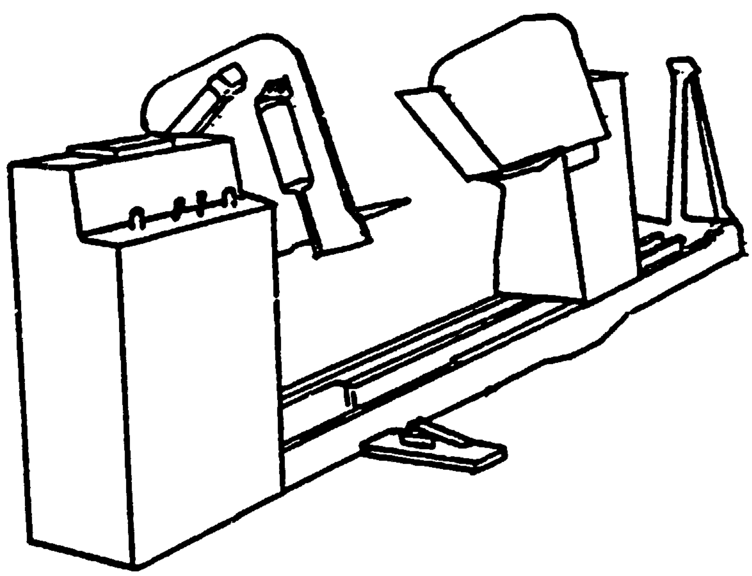
Final assembly

The piece of furniture is assembled from upholstered components. This is done on tables or benches or with an assembly press. The most advanced presses are for sofa sets (figure 243). The operator puts the components with glue on dowels onto the press, presses it together and turns the piece to fix the legs and the lining under the product. There are also special presses for assembling small chairs.

In small-scale production where series are short, work stations and tools have to be flexible. For pressing carpenter clamps are used.

Following the final assembly, a final inspection is normally carried out whereby the product is cleaned if damaged by dust, oil or dirt and is steamed if wrinkled.

Figure 243. Upholstery presses



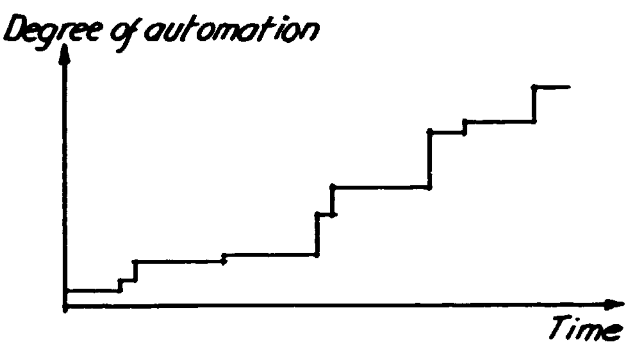
XXVII. Low-cost automation systems*

What is automation?

Automation is frequently associated with robots and computer programs, giving the impression that automation is a complicated and expensive process in which the machine performs human tasks. This results in prejudices on the part of entrepreneurs: it is too expensive; the production capacity is too small; the labour force is sufficient without it; automation causes unemployment; the workforce is not specialized enough; workers do not know how to operate automated machines; the market is small; there is no justification for automated production etc.

These are all assumptions. Therefore, it should be emphasized that automation does not mean a revolution in production; it means evolution. The degree of automation depends on the number of automated production functions. It can range from 0 to 100 per cent. Thus automation means production development that can proceed step by step according to the company's resources and current needs (figure 244).

Figure 244. Step-by-step implementation of automation



Why automate?

Automation is interesting in itself, but in industrial production, technology and automation are not goals as such; the company has to be able to benefit from automation.

The human factor

The main reason for automation is the human factor. This means developing production in such a way that the work is as pleasant as possible. This goal can be reached by removing monotony, danger, high speeds etc. All of these factors cause stress and make the work unpleasant. The work has to motivate the worker, be pleasant and be inspiring.

Safety

All work involves some degree of danger, but the machining phases in the furniture and joinery industries are particularly dangerous because the blades and knives rotate very fast. When the worker does not have to be near the blades and knives, safety at work increases considerably. Radiant heat, dust, humidity and noise also can be hazardous to the worker, and prolonged exposure can cause injury. Automation aims at distancing the worker from these hazards.

Accuracy

A human being can never work as accurately as a machine. Particularly when a difficult task has to be performed at a high speed, workers become tired, their senses dull and their muscles tend to slacken. This results in errors in measurement, shapes and surface quality. A machine can operate without tiring, and the accuracy of the work performed by machine is usually better and remains constant throughout the production process; therefore, the measurements, shape and quality are consistently accurate.

Capacity

The work to be done may require extremes of force, speed and efficiency, and the movements may be repetitive and monotonous. Human force is limited; it is approximately 1 kN, i.e. a human being's capacity is about 100 W. For a machine, this amount of force is quite small and there is practically no limit to repetitive actions (other than the wearing of the tool). Therefore, whenever a lot of power, speed, capacity and repetitive actions are required, only a machine can do the work.

Economic considerations

When the working speed, quality and accuracy increase, costs decrease. Also, since the performance of a machine is more uniform, machines last longer and knives and blades have longer lives, which also make the process more economical. In addition, the need for supervision decreases, less material is wasted and energy consumption diminishes; the result is lower production costs.

Concepts associated with productive work

Two elements in productive work can be distinguished: force and control. Force is derived from muscles or machines and control from the brain or control equipment.

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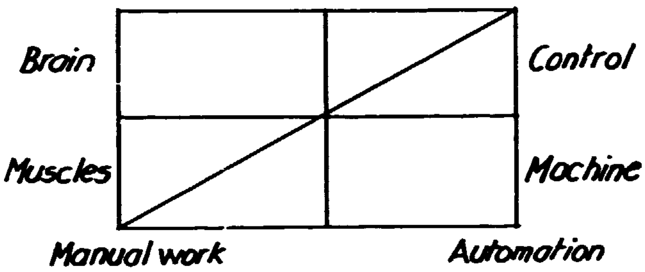
With human labour, the muscles provide the force and the brain and the nervous system provide the control (figure 245).

Figure 245. Components of work performance



Manual work

Manual work can be defined as a task in which a person performs all of the work using muscles, and the brain controls the muscles. At the most, a worker can use small hand tools to help do the job.

Machinization

Machinization can be defined as work in which the machine does the muscle work but the actual control is done by a person. Machines can generate forces and speeds that are considerably higher than those generated by a worker. As a result, the working speed increases.

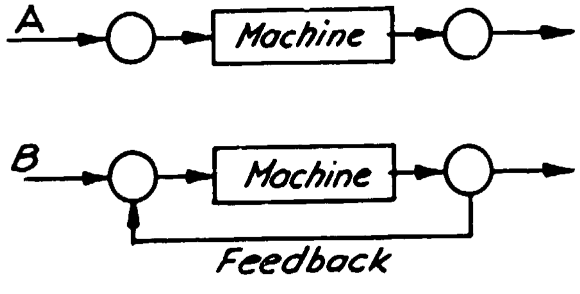
Mechanization

Mechanization means that a workpiece moves from one machine to another, or from one phase to another, mechanically; a worker does not have to perform these tasks. However, it is essential that the transfer takes place mechanically without the machine making any decisions.

Automation

In automation, the machine does both the muscle work and the brain work. The share of the brain work can vary from 0 to 100 per cent, depending on the degree of automation. Automation always includes feedback, which means that the product is measured and the result is fed back to the control system for eventual adjustment (figure 246).

Figure 246. Machining performed without (A) and with (B) feedback

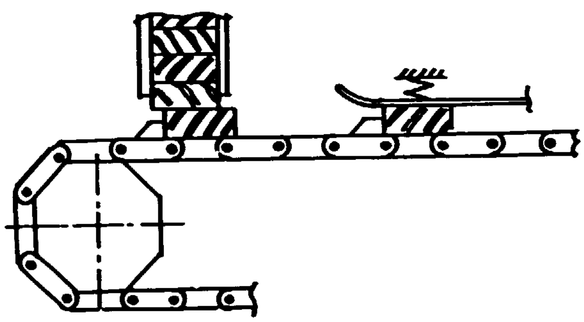


Tools of automation

Mechanical devices

Mechanical devices are the oldest tools of automation, because they are large and cumbersome and durable. However, their use has decreased to such an extent that only certain simple devices, e.g. mechanical feed systems (figure 247) are used today.

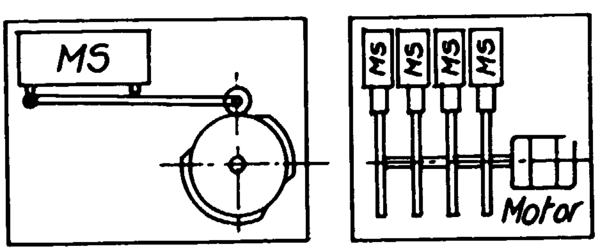
Figure 247. Mechanical component feed system



Electric and electronic devices

Electric devices have long been used in automation, and their use has continued to increase. Programming equipment can operate a device with micro-switches (see figure 248). Owing to the rapid development during the last decade, the role of electronics in automation has increased. Electronics has made it possible to design sophisticated automated control systems. A control unit using a microprocessor (MPU) with read only memory (ROM), random access memory (RAM) and connection to peripheral equipment (PIA) is illustrated in figure 249. Electronics is a complicated tool in automation, however, and it is not possible to discuss it in the context of this chapter.

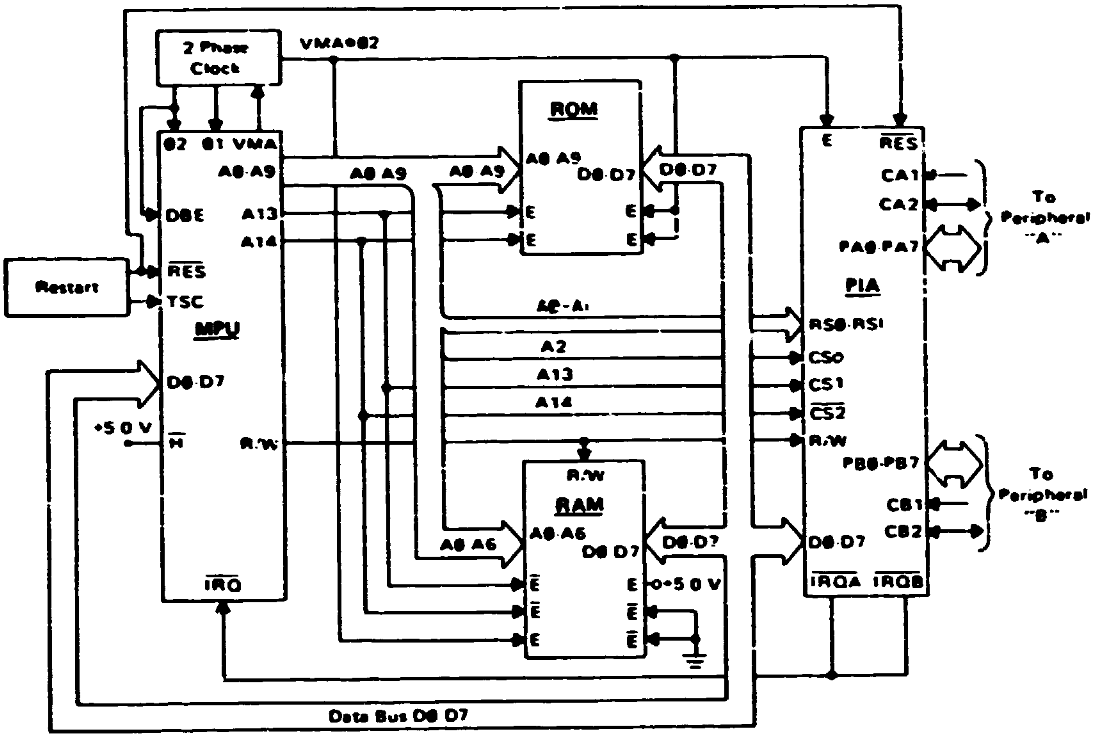
Figure 248. Micro-switch control for a programming device



Pneumatic devices

Owing to their simple construction, pneumatic devices have become popular in automation processes in which no complicated controls are required. This chapter will concentrate on pneumatic devices, which are discussed in more detail below.

Figure 249. Microprocessor control unit (MPU)



Key: ROM Read only memory
RAM Random access memory
PIA Peripheral equipment

Hydraulic devices

Hydraulic devices operate on basically the same principles as pneumatic ones; however, pneumatic devices use compressed air whereas the substance used for hydraulic devices is a fluid. Hydraulic devices operate at high pressures, and a large amount of force can be obtained with small-sized equipment. Since the fluid cannot be compressed, movements are accurate. Owing to the limited applications for hydraulic devices in furniture and joinery, they will not be discussed in detail here.

Pneumatics

Pneumatics is a technique in which compressed air is used to control and operate machines and devices, particularly in automatic operations.

Why is compressed air used?

Compressed air is used in automatic operations for a number of reasons, namely:

(a) Compressed air presents no hazard;

(b) Machines are fairly small and light in weight;

(c) Pneumatic machines are simple;

(d) Leaks do not cause problems;

(e) No return lines are necessary;

(f) Movements are soft and resilient;

(g) Rotation speed is easy to adjust;

(h) Machines can be loaded until they stop due to the resistance of the workpiece without risk of them being damaged.

Cylinders

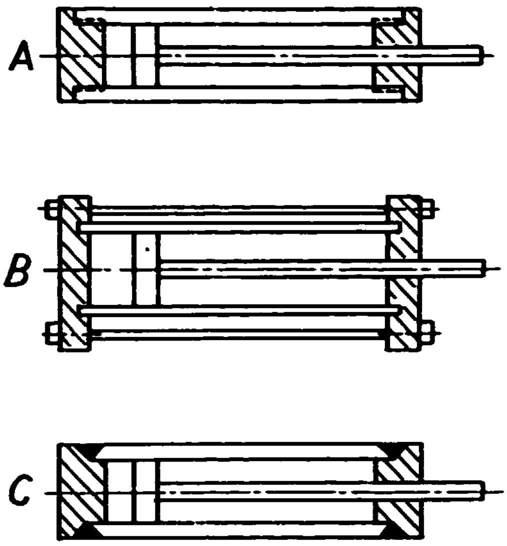
Cylinder functions

The cylinder forms the "muscles" of the pneumatic system, i.e. it performs the work requiring power.

Construction

A pneumatic cylinder can be constructed as a threaded cylinder, a bolted cylinder or a welded cylinder (figure 250). A threaded cylinder is used in small cylinders with a diameter of less than 25 mm; a bolted cylinder is used in larger cylinders. A welded cylinder is seldom used. The bolted cylinder is the most common type, its main components are the end covers, including the cushions; a barrel; a piston; and a piston rod. The end covers are usually made of light-metal alloys, the cylindrical barrel is of copper or light-metal alloys, the piston is of steel or light-metal alloys and the piston rod is always of steel. The piston rod and piston are sealed with rings of different cross-sections to prevent the leakage of compressed air.

Figure 250. Three main types of cylinders

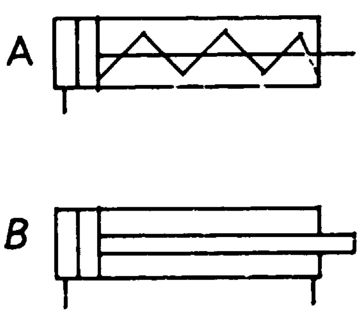


Key: A Threaded cylinder
B Bolted cylinder
C Welded cylinder

Cylinder functions

There are two kinds of cylinders: a single-acting cylinder and a double-acting cylinder (figure 251). A single-acting cylinder has pneumatic control in one direction only, and therefore it has only one opening through which the air enters and leaves. The return stroke is effected by a spring or, in lifting cylinders, by the load. Double-acting cylinders have pneumatic control alternately in opposite directions. The return stroke is also effected by compressed air. Since the double-acting cylinder is easier to control, it has become the most common cylinder; therefore the examples given in this chapter are usually for double-acting cylinders.

Figure 251. Single- and double-acting cylinders

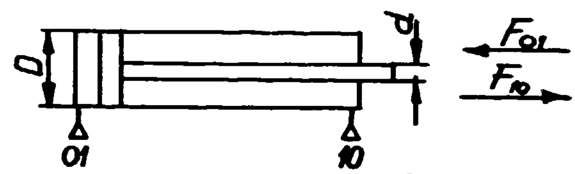


Key: A Single-acting
B Double-acting

Cylinder dimensioning

When dimensioning the cylinder, the things to consider are the cylinder friction and the fact that the piston rod reduces the piston area on one side and therefore the force obtained is not equal in both directions. The equation shown in figure 252 is used in dimensioning the cylinder.

Figure 252. Pneumatic cylinder dimensioning



$$F_{01} = 0.8 * p * 3.14 D^2/4$$

$$F_{10} = 0.8 * p * 3.14 (D^2 - d^2)/4$$

Key: p Pressure of compressed air
D Diameter of the piston
d Diameter of the piston rod
F_{01}, F_{10} } Force

The air volume used by the cylinder (V_0) can be calculated for a double-acting cylinder from the following equation:

$$V_0 = 2nAs \frac{P_1}{P_0}$$

Where: n = number of strokes
A = cylinder area
s = stroke length
P_1 = pressure of air in pipeline
P_0 = pressure of outside air (100 kPa)

Efforts have been made to establish international standards for cylinder sizes. The sizes of cylinders that are available locally should be taken into account when designing a circuit.

Cylinder installation

An important fact to keep in mind when installing a cylinder is that it should only receive loads in the direction of the piston rod. All other forces should be eliminated. The reason is that the piston and the piston rod move on seals, and if the piston receives forces perpendicular to the rod, they wear the seals very quickly which results in air leaks and decreased performance in cylinder operation. There are two main installation methods for cylinders:

(a) Non-articulated installation, where the forces are always in line;

(b) Articulated installation, which is used when the direction of the force varies (figure 253).

The cylinder is fixed on the frame with joints that move in the direction of two co-ordinates or are so-called ball-joints, which allow movement in three dimensions.

Figure 253. Articulated installation of pneumatic cylinder

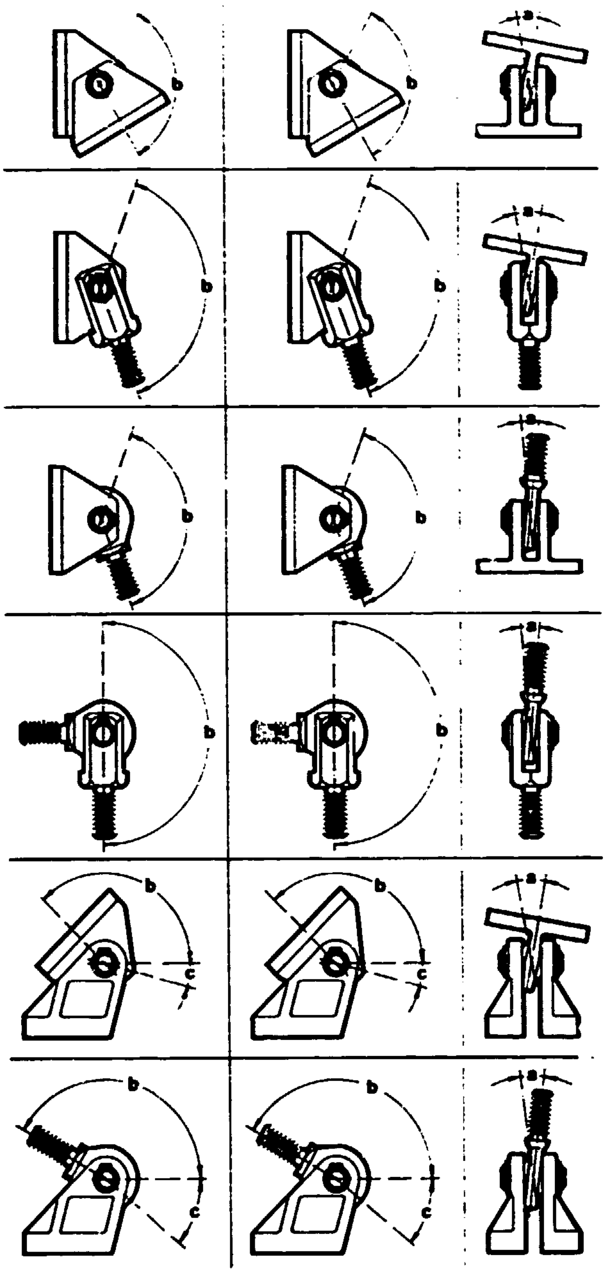


Figure 254. Pneumatic cylinder positions

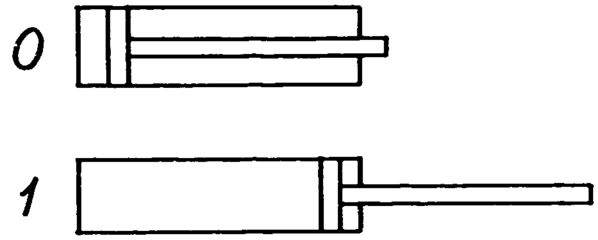
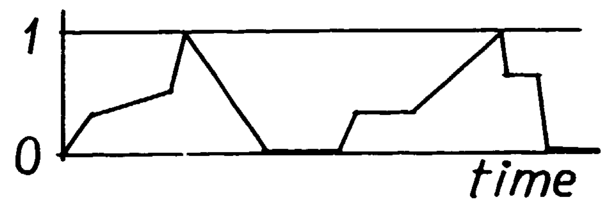


Figure 255. Motion diagram of cylinder



Motion of the cylinder

The operation of the cylinder can be shown in a diagram, in which the horizontal axis is time and the vertical axis is the cylinder motion (see figures 254 and 255). This depicts both the movement and the speed of cylinder movement. The end positions of the cylinder are designated with the numbers 0 and 1. The 0 indicates the basic position of the cylinder, i.e. the position in which the piston rod is inserted in the cylinder, and number 1 indicates the position in which the piston rod is withdrawn from the cylinder. Because of the time axis, the diagram can also indicate the speed, which can be seen from the slope of the line in figure 255.

Special cylinders

In addition to standard cylinders, a large number of special cylinders are also manufactured. These are e.g. diaphragm cylinders, cylinders with double-ended piston rods, three-position cylinders, four-position cylinders, telescopic cylinders and cylinders with adjustable stroke length.

Applications

Some cylinder applications are shown in figure 256. Cylinders can be used in several different places wherever linear motions occur.

Valves

Valve functions

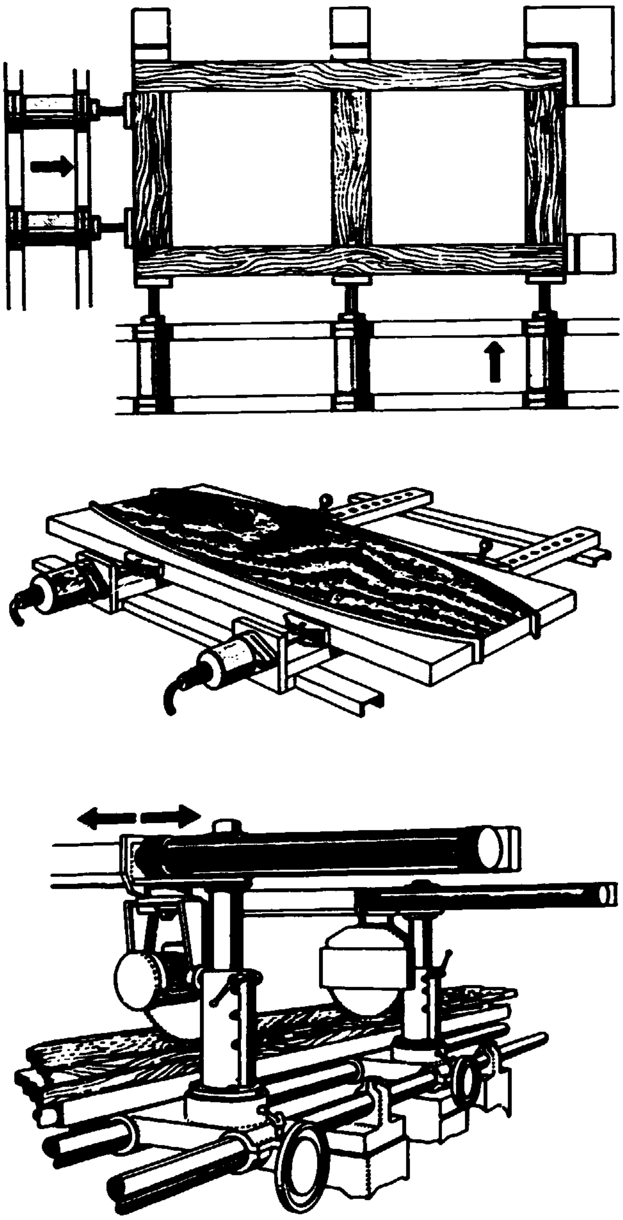
The function of valves is to guide the air so that the desired operation is performed. The valves are the brains or operators of the system. They ensure that the cylinders and motors move in the desired way.

Control valves

The symbol for a control valve is a square. The square represents one valve position. If the valve has several operating positions, the diagram has the same number of squares as there are positions in the valve. Lines inside the squares indicate open or closed flow lines. The control method is marked at the ends of the valve. A number of valve diagrams are shown in figure 257.

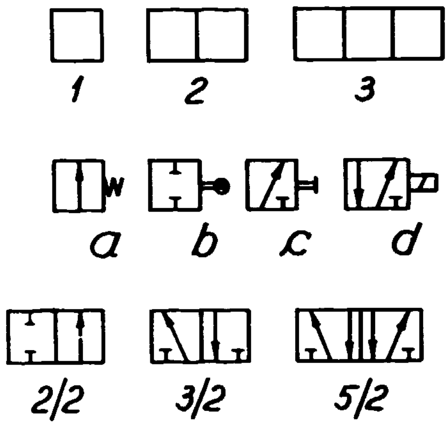
Directional control valves. The function of the directional control valves is to guide the air along different lines to other valves or operational equipment in the system (cylinders and motors). Directional control valves are designated by numbers; the first number indicates the number of connections and the second number, following a slash, indicates the number of positions, as was shown in figure 257. For example, a 2/3 directional control valve is a valve with two connections and three positions; 5/2 has five connections and two positions. The most common directional control valves used in pneumatics are shown in the diagrams in figure 258.

Figure 256. Examples of pneumatic cylinder applications



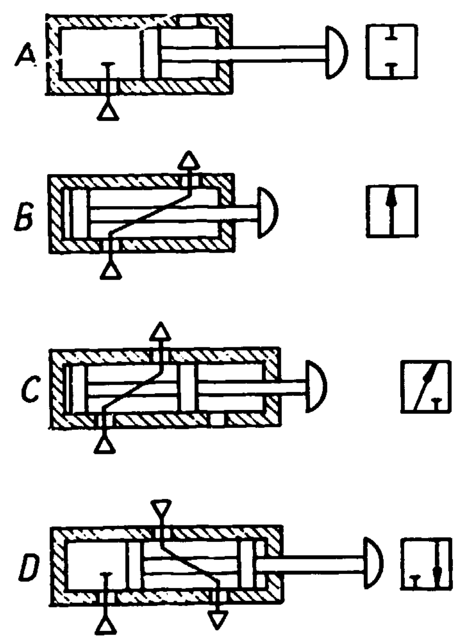
Non-return valves. Non-return valves allow a flow in one direction only (figure 259). A shuttle valve has two inlet ports, which join at the starting connection.

Figure 257. Control-valve diagrams



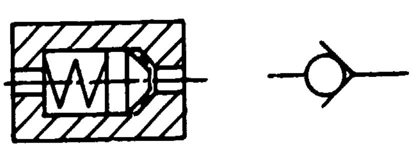
Key:
- 1 One position
- 2 Two positions
- 3 Three positions
- a, b, c and d Different flow-paths
- 2/2 Control valve with 2 ports and 2 positions
- 3/2 Control valve with 3 ports and 2 positions
- 5/2 Control valve with 5 ports and 2 positions

Figure 258. Control-valve construction principles



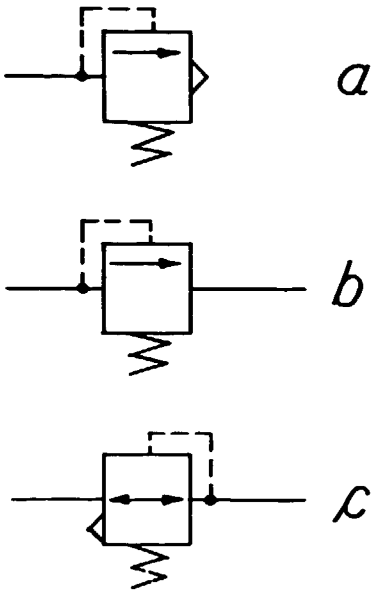
Key:
- A 2/2 valve closed
- B 2/2 valve open
- C 3/2 valve allows compressed air flow through
- D 3/2 valve allows exhaust air flow through

Figure 259. Construction of and symbol for a non-return valve



Pressure-control valves. Pressure-control valves regulate the pressure (figure 260). The pressure-relief valve is a so-called safety valve, which opens when the inlet pressure exceeds a pre-set valve. The pressure-control valve opens when the inlet pressure overcomes the opposing force of the spring force, and its purpose is to regulate the pressure for some subsequent operation. The pressure-reducing valve with variable inlet pressure gives substantially constant outlet pressure.

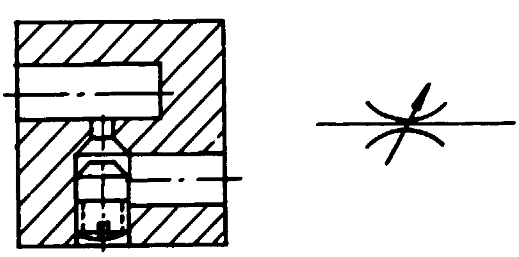
Figure 260. Different pneumatic valves



Key: a Pressure-relief valve
b Sequence valve
c Pressure-reducing valve

Flow-control valves. Flow-control valves are designed to control the volume of air flow. The simplest flow-control valve is a restrictor valve in which the air volume is regulated with a screw (figure 261). If a non-return valve is connected in parallel with the restrictor valve, the flow in the opposite direction becomes unrestricted, the speed of the operation increases and the flow is controlled in one direction only. Other types of flow-control valves are rarely used in pneumatics, while several different types are used in hydraulics, where the control of fluid is much more accurate than that of air.

Figure 261. Construction of and symbol for a flow-control valve



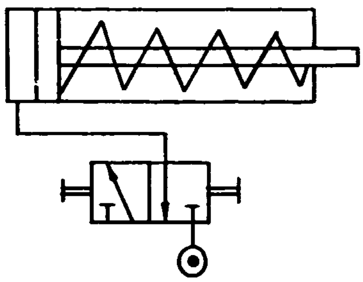
Installation diagrams

The operation of valves and cylinders is usually depicted in installation diagrams using the symbols mentioned above. The figures below present installation diagrams and the operations in detail.

Control of a single-acting cylinder

The control of a single-acting cylinder is shown in figure 262. There is only one incoming flow path, and the cylinder is controlled by a 3/2 valve.

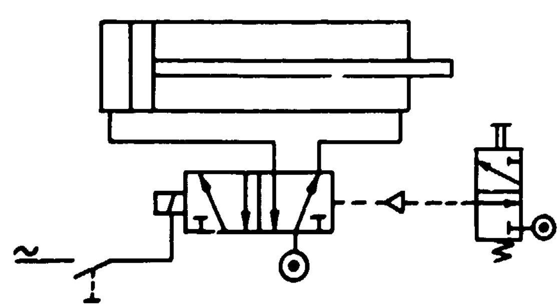
Figure 262. Manual control of a single-acting cylinder



Control of a double-acting cylinder

The cylinder is controlled either with direct control, which means that the main valve is operated directly, or through remote control, which means that the main valve receives its control from a remote-control point by means of air or electricity. Air is usually recommended, although electricity provides greater control speed, and the control line is smaller and lighter. Therefore, if the distance is long, electricity is more convenient. Electricity is suitable when pneumatics forms part of another system using electricity. The control of a double-acting cylinder is shown in figure 263. The diagram in the figure is only an example; each system requires its own design. Making these schematics is an essential function of pneumatics, and the schematics usually form the most difficult part of the design of pneumatic systems. If the schematic design is successful, the basic task of pneumatics has been carried out. The choice of the equipment, its installation and location is easy. It can be done only after precise information has been obtained about the type of machines and equipment to which they will be connected.

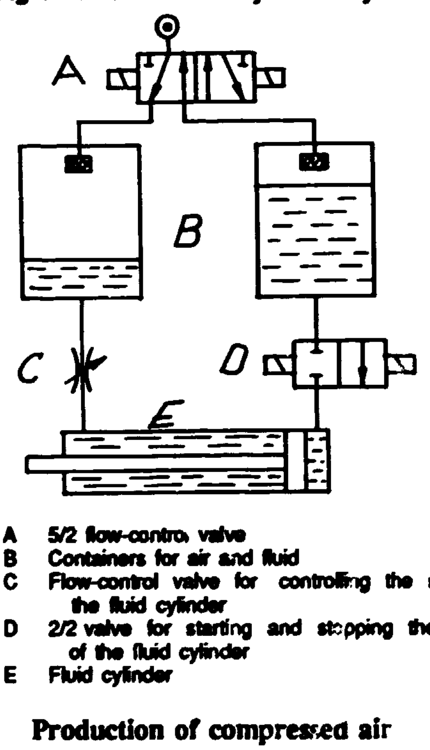
Figure 263. Electric and pneumatic control of a double-acting cylinder



Pneumo-hydraulic systems

A disadvantage of compressed air, when precise and even motions are desired, is its elasticity. An alternative to pneumatics is hydraulics, but if that cannot be considered alone, a combination of the two can be used. In pneumo-hydraulic systems the source of energy is air, but the actual motion is generated by fluid. Thus the precision of a hydraulic system, as regards distance and speed, can be obtained. The best kind of pneumo-hydraulic systems is one where the reservoirs are located on both sides of the acting cylinder. Such a system is completely hydraulic in its operation and has the accuracy required of hydraulic systems. The reservoir is filled partly with air and partly with fluid. To prevent the air from mixing with the fluid, a separate nozzle has to be installed in the feed unit, which distributes the air so that it will not mix with the fluid. Hydraulic systems are used in lifting and working operations when stable motion is required. A diagram and functional principle of a pneumo-hydraulic system is shown in figure 264.

Figure 264. Pneumo-hydraulic system



Key: A 5/2 flow-control valve
B Containers for air and fluid
C Flow-control valve for controlling the speed of the fluid cylinder
D 2/2 valve for starting and stopping the motion of the fluid cylinder
E Fluid cylinder

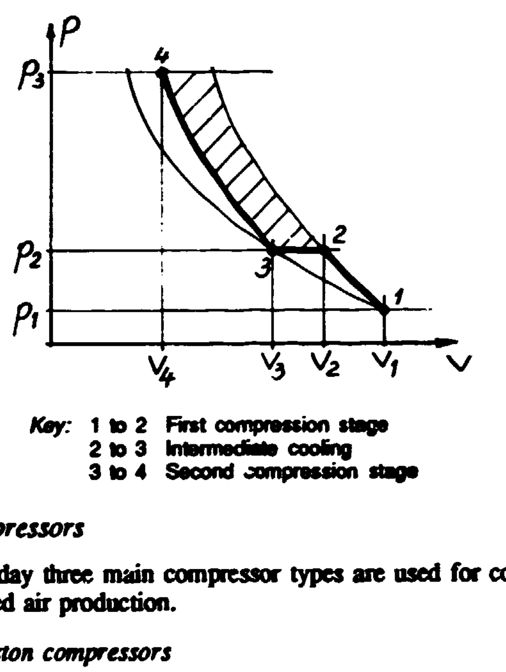
Production of compressed air

Compressing of air

When air is compressed, its temperature rises; the temperature of compressed air when it comes out of the compressor ranges from 100° to 200° C. At the same time, the relative amount of water in the compressed air increases; in other words its humidity increases. While the air is hot, the increased amount of water remains in the air as vapour, but as the air cools, it starts to condense and a considerable amount of water is released. The amount of water depends on the humidity of the outside air; therefore, in a warm climate where the humidity of the air is high, a lot of water is condensed from compressed air. The amount varies from 50 to 200 g per cubic metre of compressed air.

Air can be compressed either in one stage, which means that the final pressure is obtained in one operation, or in two stages (figure 265), in which case the air is removed from the compressor after the first stage, cooled and fed back to the second stage, in which the final required pressure is attained. From the point of view of energy consumption, two-stage compression is more economical, and therefore almost all industrial compressors are two-stage compressors. Only very small compressors are still manufactured for one-stage compression. Intermediate cooling in two-stage compression is done with water or air. Air-cooling has become common, owing to its simplicity. Only large compressors use water-cooling. The most common operational pressure of compressed air ranges from 600 to 1,000 kPa, and the volume of compressed air ranges from 10 to 1,000 litres per second.

Figure 265. Air compression in two stages



Key: 1 to 2 First compression stage
2 to 3 Intermediate cooling
3 to 4 Second compression stage

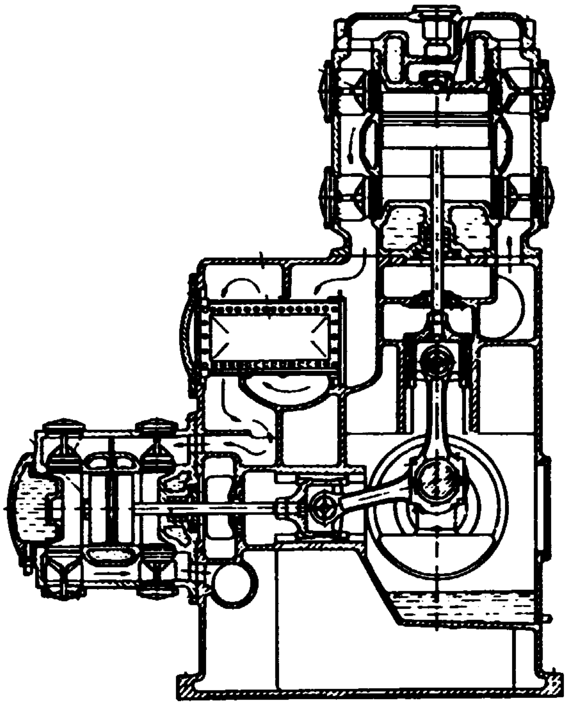
Compressors

Today three main compressor types are used for compressed air production.

Piston compressors

In the piston compressor (figure 266), the piston draws the air into the cylinder and compresses it there to the required pressure. After that, the piston forces the air into the pneumatic pipeline. Air intake and outlet are regulated through valves, which can operate freely or be controlled. The compressor can also operate so that the air is taken in and let out from both sides of the piston. This operation is more efficient since there is simultaneous suction on one side and compression on the other side. The piston compressor is the most common industrial compressor in use today because it is efficient and the required pressures are easily obtainable. Its construction has also been tested and proven, and, after decades of experience in its manufacture, defects have been eliminated. A disadvantage of the piston compressor is the vibration caused by the reciprocal motion of the piston. Owing to this fact, the compressor has lost some popularity within the past few years.

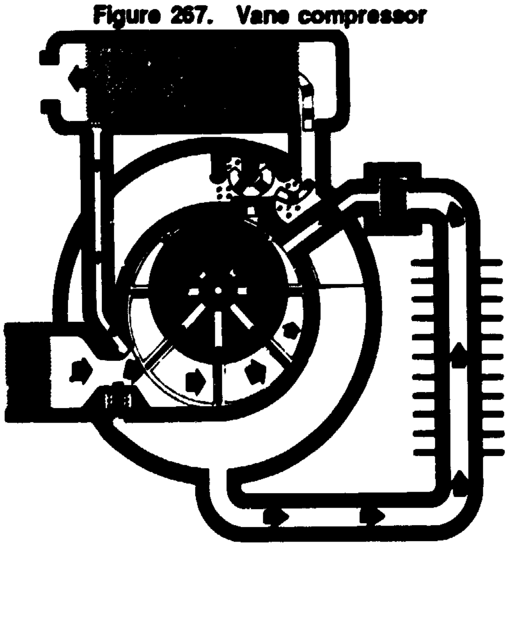
Figure 266. Two-stage water-cooled pneumatic compressor



Vane compressors

The vane compressor (figure 267) has an eccentric rotor with vanes in its grooves. The vanes move freely in the radial direction. Since the rotor is eccentric, the volume of air between the vanes changes and the air becomes compressed while the rotor rotates. Efficiency is not quite as good as in the piston compressor, but the vane compressor rotates evenly and without vibration, which makes it popular as a small compressor. However, the vanes rubbing against the frame cause heat owing to friction, and therefore the compressor has to be cooled with large amounts of oil. The compressor must be provided with an oil trap, which returns the oil through coolers for recycling.

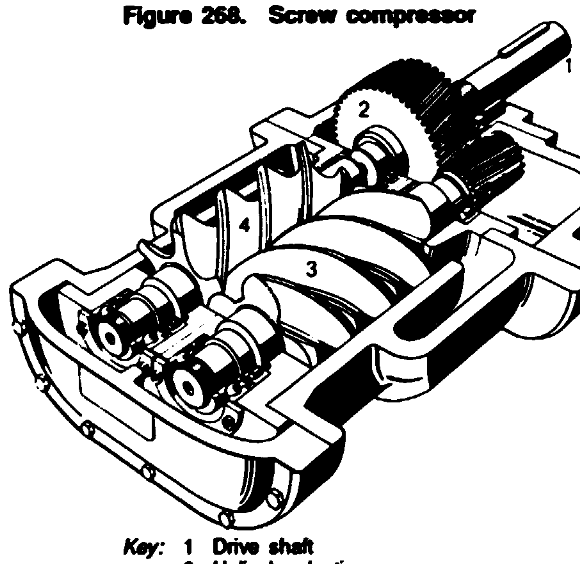
Figure 267. Vane compressor



Screw compressor

The screw compressor (figure 268) is the newest type of compressor and has therefore not been used much. It has become increasingly popular during the past few years, however. Its manufacture and use have increased to the extent that it is already threatening to replace the piston compressor. The screw compressor has some restrictions, and therefore it is not as suitable for general purposes as the piston compressor. It seems probable, therefore, that both the piston and screw compressors will keep their positions as commonly used types of compressors. The screw compressor is most applicable for heavy tasks. It usually has two screws, between which the air is taken in. While the screws rotate, the air is compressed and removed from the other end. The compressor is well-balanced and rotates without much noise, although high speeds of air can cause high-pitched sounds. These compressors are usually larger than 200 l/s.

Figure 268. Screw compressor



Key: 1 Drive shaft
2 Helical reduction gear
3 Compressor screw
4 Compressor screw

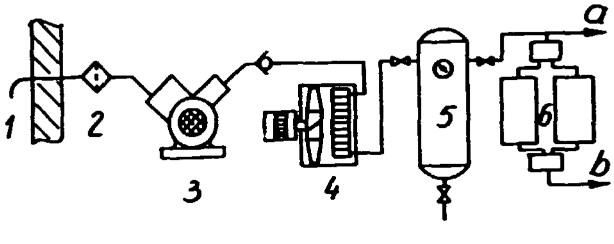
Pneumatic centre

In addition to the compressor, a number of other devices are required for the production of compressed air. They are located in the pneumatic centre (figure 269). Recently, compressor packages, manufactured for small compressors, have become popular. They contain all the equipment needed in a pneumatic centre.

Location of the pneumatic centre

The pneumatic centre should be located in the centre of the operation where it is to be used. It is not always possible to use this ideal location. Therefore, it should be positioned in a place near the centre of activities where the compressor does not disturb other activities and where the supply of clean cold air is sufficient. Also, access for easy maintenance should be considered as well as the availability of cooling air or water. The pneumatic centre for a piston compressor should be positioned on the ground so that vibrations will not be transferred to the building and as noise to the environment. Other compressors do not require any special foundation.

Figure 269. Pneumatic centre diagram



Key:
1 Air intake from outside
2 Air filtering
3 Compressor
4 Cooling of compressed air
5 Reservoir for compressed air
6 Drying of compressed air
a Compressed air for immediate use
b Compressed air to be dried

Air intake

Air should be taken into the compressor from a place where it is as cold and as clean as possible, ideally from outside the building and, if possible, from the shade. The immediate surroundings of the location for air intake must be clean, preferably a grassy area; air intake from a dusty area or near gravel piles or unpaved roads should be particularly avoided. The air intake should also be protected from rain and debris. The incoming air is filtered before it comes into the compressor, either through dry or oil filters. Dry filters are the most common because of their simple structure.

Cooling compressed air

The air coming from the compressor is hot and contains a lot of water. If the air is not cooled before use, it cools on its way and the excessive vapour in it is condensed into water and the pipeline will have water in it. Therefore the compressed air is cooled after it has come from the compressor, and in this way a considerable amount of the water can be removed. Compressed air cools a little after this stage, and some water is condensed, which has to be taken into consideration later on. This amount of water, however, is insignificant compared with the amount of water that would otherwise be in the pipeline. Compressed air is cooled either with air or water: small amounts are cooled with air and large amounts with water. In the cooling process large amounts of water are removed from the air and disposed of.

Reservoir for compressed air

Compressed air is stored in a reservoir. Its volume must be at least 10 times the production of the compressor per second. The reservoir is a pressure-resistant steel container, which is protected with rust-preventing paint. The reservoir must be inspected from time to time to ensure that no corrosion occurs. If possible, the reservoir should be located in the shade and painted silver on the outside. The reservoir is equipped with a pressure-regulating device and a safety valve and the necessary valves for air intake and outlet and water removal.

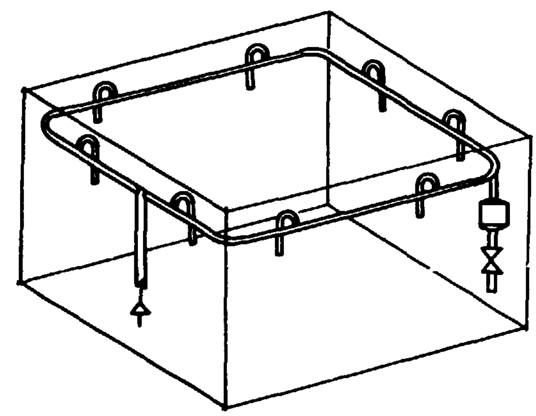
Drying compressed air

After all the water that could be condensed from the compressed air has been removed, it must be dried. This is especially important if the equipment that uses compressed air is very sensitive or contains narrow passages. Compressed air is usually dried with aluminum oxide, which absorbs the water into its porous surface. Water contained in the aluminium oxide can be removed with warm dry air, and thus the same substance can be used several times. Compressed air can also be dried with a refrigeration unit. This is a very clean and neat method of drying, but it is somewhat expensive.

Pneumatic pipeline

The function of the pneumatic pipeline (figure 270) is to transfer the air to the point of operation with as little loss as possible, at the right pressure and in sufficient quantity.

Figure 270. Pneumatic pipeline



Shape and dimensioning of the pipeline

The design for a pipeline is in the shape of a ring; if the pipeline is large, the ring is further divided into sections so that the distance in one ring between the reservoir and its furthest use point does not exceed 40 m. Straight mains should be avoided, since there is usually little compressed air at the end. The simplest way to dimension a pipeline is to have an air-flow speed of 5-10 metres per second in the main pipeline and 15-20 metres per second in the side lines. The pressure losses usually remain reasonable. Diagrams are available to assist in selecting the dimensions.

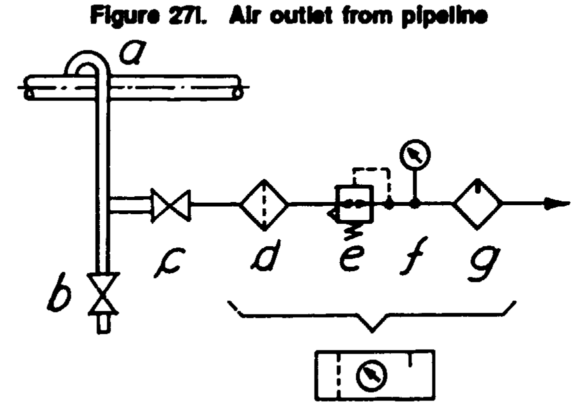
Pipeline construction

The pipeline is of welded steel pipes, either of ordinary or stainless steel. The distribution pipes can be also made of stainless steel, copper or plastic. The pipeline is installed so that it is inclined in the direction of the flow with a slope of about 1:100. In this way the water flows with the air flow to the water-removal pipes. For water removal vertical pipes are used as water traps at 30-50 metre intervals.

Air outlet from the pipeline

The air used in the operation must be dry, clean, at the correct pressure and usually lightly oiled. To prevent the water from the pipeline from entering the instrument line, the air has to be taken out from the top through a small curved pipe (figure 271 a). In case water should enter the instrument pipe, a horizontal pipe is equipped with a water trap at the bottom (figure 271 b). The water should be removed from that container from time to time. The pipe leading to the point of operation should branch off at least half a metre above the water container. To ensure that the air is pure, it is first led to a filter (figure 271 d), which usually consists of a centrifugal separator and a ceramic filter. There any eventual water and all impurities, such as rust, organic material and other debris, will be separated. To obtain the correct air pressure, a pressure regulator (figure 271 e) and a pressure gauge (figure 271 f) are installed after the filters. The pressure regulator is actually a pressure-reducing valve, since the pressure of the incoming air can be regulated only to a lower level than the pipeline pressure. The pressure regulator guarantees uniform operating pressure to the point of operation, since the pipeline pressure can vary depending on the use. In this way pipeline pressure variations do not cause changes at the point of operation. To provide light lubrication of the air coming to the point of operation, a lubricating device (figure 271 g), which feeds oil spray into the compressed air, is installed immediately after the pressure regulator. This oil spray lubricates the valves, cylinders and the motors, which do not usually require additional lubrication except in some special cases.

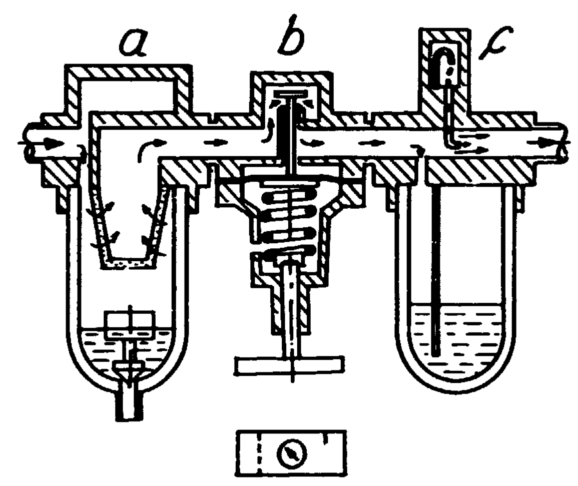
Figure 271. Air outlet from pipeline



Key: a Air intake
b Water trap
c Valve
d Filter
e Pressure-reducing valve
f Gauge
g Lubricator

Three components, filter, pressure regulator and lubricator, form one entity and it is called the maintenance unit (figure 272). They are usually constructed together and also purchased as a package. Such a maintenance unit must be placed before every operating point to ensure that the air that will be used meets pre-determined requirements. There is a main valve in connection with the maintenance unit, which opens and closes the air flow to the point of operation.

Figure 272. Maintenance unit



Key: a Water trap and filter
b Pressure-reducing valve
c Lubricator

Maintenance of pneumatic systems

The maintenance of a pneumatic system is similar to that for machinery and equipment in general, and therefore only some details that are important in pneumatic system maintenance will be discussed here.

The compressor is a machine that requires quite a lot of adjustment. Therefore most components of a compressor are equipped with automatic control and regulation, so that continuous maintenance is not necessary. However, the operator must take care to ensure that the amount of oil is sufficient, the cooling equipment operates properly, the motor is not overloaded and the compressor bearings, valves and pistons operate properly. Often these are controlled by automatic equipment that alerts the operator in case of over-heating, low oil pressure and other critical parameters. Other pneumatic devices generally require only little maintenance if water removal has been arranged automatically. If this is not the case, care should be taken to remove water regularly. Because of rust, the reservoir, water trap and other parts must be inspected regularly. They have to be painted and cleaned at regular intervals. The pipeline generally requires only little maintenance, and only when there is often water in the pipeline must the pipeline be inspected for corrosion and the corroded places replaced. Particular care should be taken in removing water. If automatic water traps are not used, maintenance should include regular emptying of water containers.

The maintenance unit requires constant care as it is one of the components in the system that requires the most maintenance. The filter has to be kept clean, the water has to be removed from it at regular intervals, the operation of the pressure regulator must be observed, and oil must always be added to the lubricator as it is consumed.

In the operating equipment the valves are the most sensitive part of the system. They can be easily clogged by dust, water, rust, corrosion waste and dry oil. A functional disturbance in the valves can lead to a functional defect of the whole system, and it is therefore necessary to clean them regularly. The seals and rings should be inspected, and they must be replaced early enough to prevent leaks. It is of particular importance to have spare valves in stock, so that they can be exchanged easily and quickly in case of malfunction. To facilitate the change, all valves should be selected to provide a so-called installation base so that the valve can be exchanged quickly without having to touch the actual connection.

Cylinders and motors require very little maintenance and therefore can often remain unattended until they break down or the operation stops. It is therefore reasonable to periodically open the cylinders and motors, check the seals, inspect for corrosion and lubricate the rotating parts of the motors.

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Installation and maintenance of pneumatic systems. Malmö, AB Mecman Pneumatics, 1978.

United Nations Industrial Development Organization. *Low cost automation for the furniture and joinery industries*. By Brion H. P. *and* A. C. Constantino. ID/154/Rev.1.

XXVIII. The safe operation of woodworking machines*

Introduction

This chapter is based on a manual on the safe operation of woodworking machines prepared by the Association of Professionals in the Wood Industry (Holz-Berufsgenossenschaft), one of the 34 associations for various branches of industry in the Federal Republic of Germany. The Associations supervise and give advice on accident prevention.

The safety and accident-prevention specifications contained in this chapter cover the minimum requirements for safety in the work place in the Federal Republic of Germany; they are legal obligations that have been agreed upon in technical committees consisting of manufacturers, machinery users, industrial managers and employees as well as experts and government civil servants and approved by the legislative body of the Association.

Symbols and labels

All machines and equipment should be clearly and indelibly marked with important instructions for safe operation, i.e. the purpose of the equipment and the permitted safe operating limits.

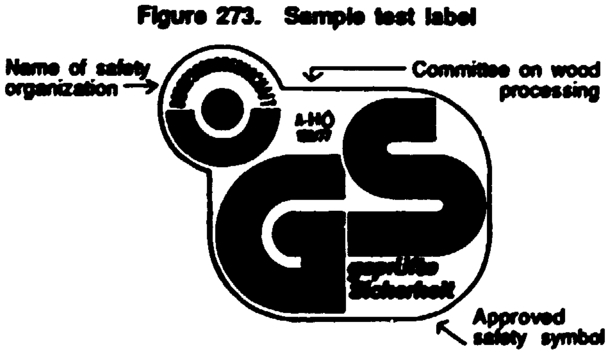
Machines for the primary and secondary processing of wood and similar materials should be marked with the following information:

Manufacturer or supplier
Type
Product No.
Year of manufacture

Labelling machines that have been tested and approved for safety

Various test centres in the Federal Republic of Germany are authorized to issue labels, as shown in figure 273, for machines that conform to safety requirements.

Figure 273. Sample test label

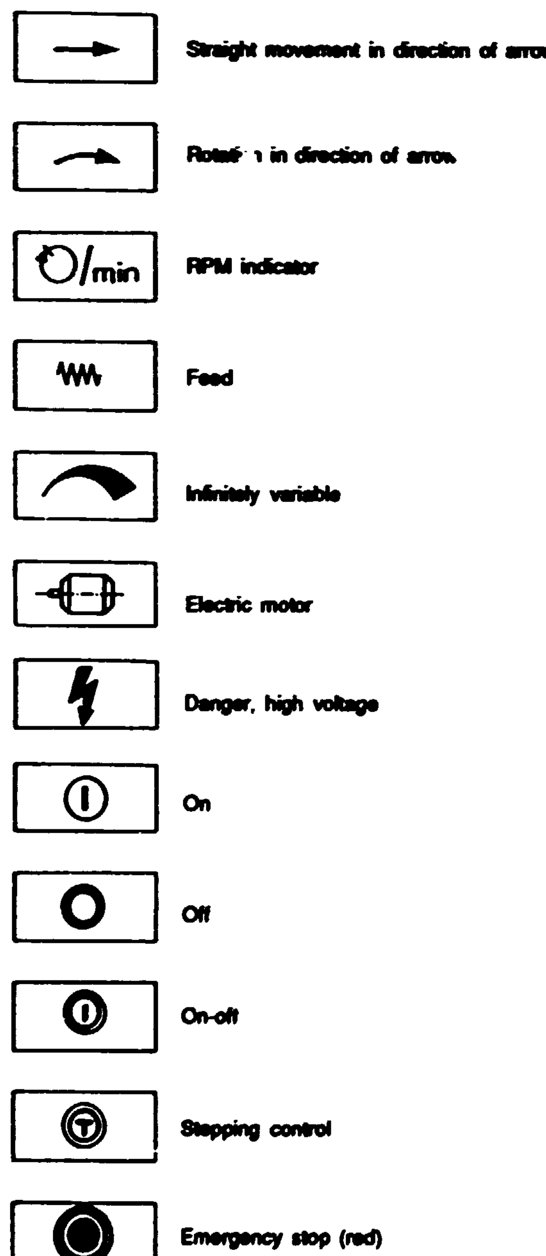


*Prepared as a training manual on the safe operation of woodworking machines by the Technical Supervisory Service (Technischer Aufsichtsdienst) of the Association of Professionals in the Wood Industry (Holz-Berufsgenossenschaft), Federal Republic of Germany.

Standardized control symbols

Control symbols, such as those shown in figure 274, should be clear and unambiguous. They must be placed on machines where they can be easily seen.

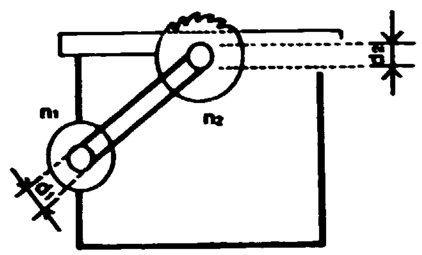
Figure 274. Control symbols



Calculating the RPM on a belt drive

The RPM on a belt drive is calculated as shown in figure 275.

Figure 275. Calculation of RPM



n_1 = RPM of the motor
n_2 = RPM of the drive shaft of the machine
d_1 = Motor pulley diameter
d_2 = Machine pulley diameter

$$n_2 = \frac{n_1 \cdot d_1}{d_2} \text{ RPM}$$

$$n_1 = \frac{d_2 \cdot n_2}{d_1} \text{ RPM}$$

$$d_2 = \frac{d_1 \cdot n_1}{n_2} \text{ cm}$$

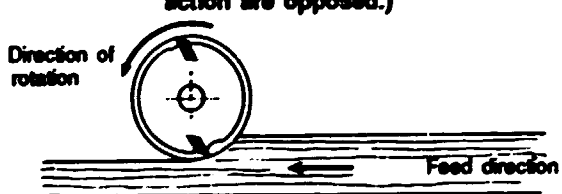
$$d_1 = \frac{d_2 \cdot n_2}{n_1} \text{ cm}$$

Direction of rotation and feed

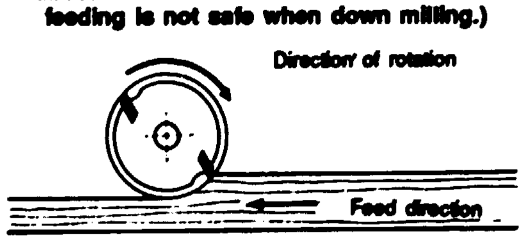
The direction of rotation and feed is shown in figure 276.

Figure 276. Direction of rotation and feed

A. Up milling (Workpiece feed direction and cutting action are opposed.)



B. Down milling (Feed direction and cutting direction are in the same direction. Hand feeding is not safe when down milling.)



Only skilled electricians should be employed to install, modify, maintain or repair electrical parts of equipment. A skilled electrician must have adequate training and experience as well as a good knowledge of the requisite regulations and be aware of the dangers and precautions in this field.

Electrical installations and equipment should not be operated unless they are properly installed and conform to all safety regulations. Any faults or defects should be reported immediately, and repairs should be made before the equipment is put into use again.

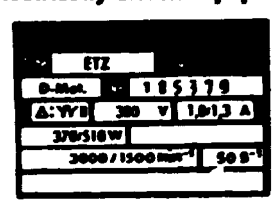
The following are examples of abbreviations used for electrical equipment:

Electrical voltage (U): 1 volt = 1 V
Electrical current (I): 1 ampere = 1 A
Power (P): 1 watt = 1 W
Resistance (R): 1 ohm = $\frac{1\ V}{1\ A}$ = 1 Ω
Frequency (F): 1 herz = 1 sec^{-1}
Multiples of units: 1,000 watts = 1 kilowatt = 1 kW; 1,000 volts = 1 kV

Labelling electrically-driven equipment

Electrically-driven equipment must carry a label of origin (name plate) giving all relevant information for its safe operation (see figure 277). This label must be clearly visible when equipment is mounted.

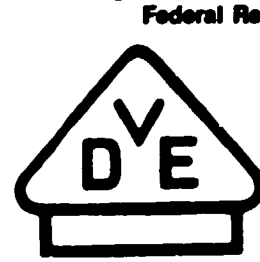
Figure 277. Label of origin for electrically-driven equipment



Preventing electrical accidents

Only safety-tested equipment that has been correctly and safely installed should be used. In the Federal Republic of Germany, the VDE test symbol is used for electrical parts or components and the GS test symbol is used for complete pieces of equipment (see figure 278).

Figure 278. Test symbols used in the Federal Republic of Germany



VDE symbol of the Organization Electrical Professionals

GS (tested safety) symbol of the Association of Professionals in Industry

Important safety precautions (electrical equipment)

Safety precautions for equipment that is not earthed. The maximum safe approved low-voltage level is 42 V. Protection against contact is, in this case, unnecessary, as there is not a serious shock hazard, except in explosion-endangered areas.

Protective isolation. The machine and connecting cable are isolated from the mains supply by means of an isolating transformer (figure 279 A) to avoid any return path through the body. Only one unit of a maximum of 16 A can be connected.

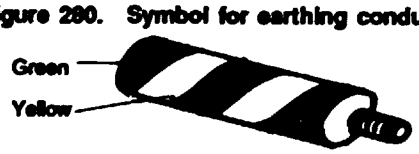
Protective double insulator (figure 279 B). Additional insulation is employed between the electrical part and the exposed casing as an additional safety measure; the casing cannot become electrified in case of a failure in the electrical part.

Figure 279. Symbols for isolating transformers and protective double insulators

A. Isolating transformer symbol **B. Protective double insulator symbol**

Protection using an earthing conductor. The earth lead colours are yellow and green (figure 280); leads of this colour should not be used for any other wiring. If a fault develops, the current flowing in the earth lead interrupts the supply of electricity. Earthing conductors should not be connected to faulty plugs or extension cords, as this can endanger lives.

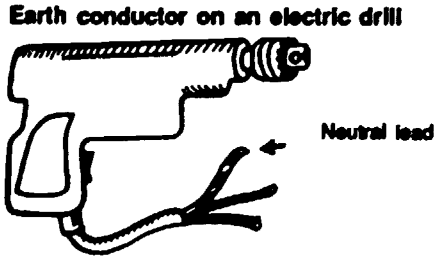
Figure 280. Symbol for earthing conductor



Types of protection

Earthing. Equipment is provided with an earth conductor (figure 281) which is connected to the neutral conductor of the supply line. In case of a fault, a short-circuit will cause fuse failure. Testing and repairs must be left to skilled electricians.

Figure 281. Earth conductor on an electric drill



A trip or cut-out device disconnects the supply to all leads within 0.2 seconds of a fault in the current.

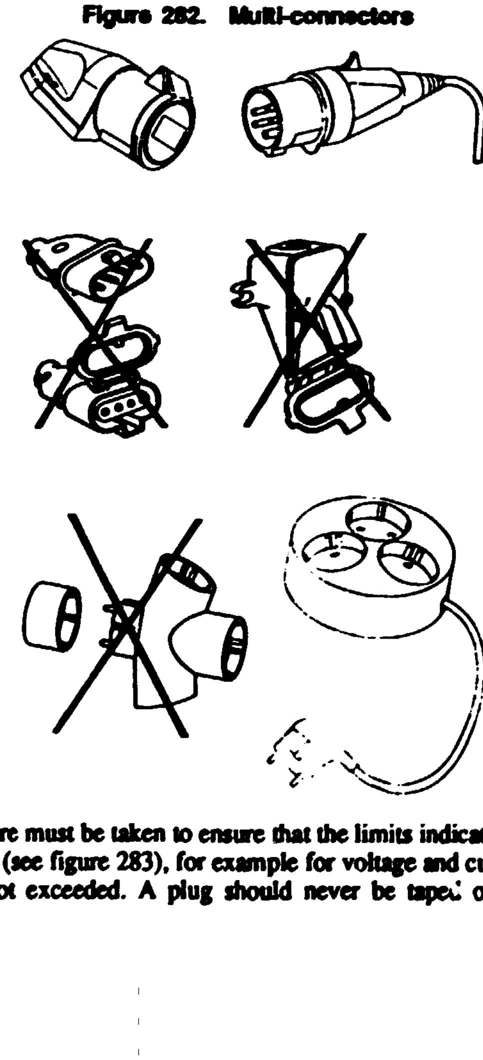
Only equipment that is adequately protected for the job should be used. The level of protection must be indicated on the casing. For example, a machine with the symbols IP 54 is protected against mist and dust deposits. This is the usual level of protection for equipment used in the woodworking industry, including exposed outdoor equipment. Protection against exposure to water jets and dust deposits is indicated by the symbol IP 55. This is the minimum protection level required for glue-spreading machines, for example.

Machines that have explosion protection are labelled (Ex). Extra safe is indicated in addition by: "e". The choice of equipment depends upon the intended use and must be made by a skilled electrician. Explosion-protected equipment is usually called for in lacquer-coating and lacquer-storage rooms.

Light fittings with built-in relay or remote-switching devices suitable that can be mounted closer than the usual safety distance of 35 mm from inflammable material (wood) are indicated by the symbol: F.

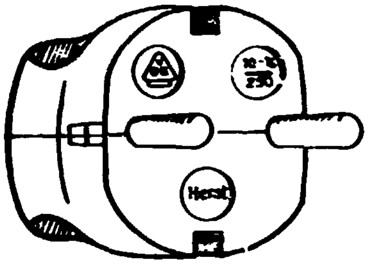
Sockets and connecting cables. Only approved and tested multiple sockets for alternating current supplies should be used. Flat multiple sockets are no longer approved for use in the Federal Republic of Germany. Examples of approved and forbidden multiple sockets are shown in figure 282.

Figure 282. Multi-connectors



Care must be taken to ensure that the limits indicated on plugs (see figure 283), for example for voltage and current, are not exceeded. A plug should never be taped or tied down to a socket. This could strain the cable, and in an emergency the plug may not be able to be disconnected quickly enough. A plug should not be pulled out of the socket by the cord. Home-made connecting cables and extension cords should not be used. Unless otherwise specified, cables on drums should be unwound before use to avoid overheating.

Figure 283. Common plug with safety-tested symbol and maximum voltage information



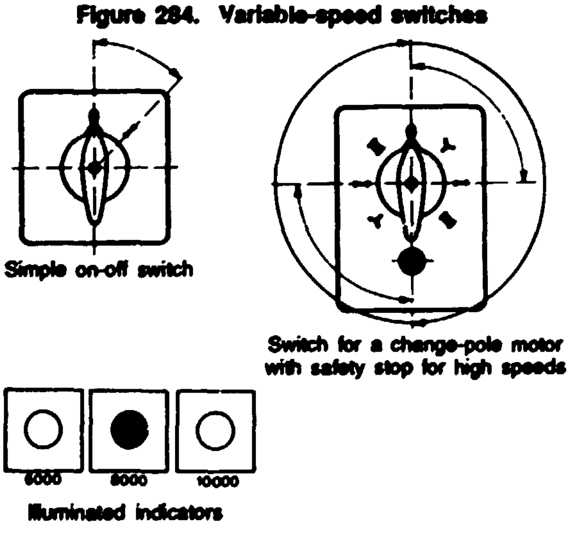
Variable speed controls (figure 284)

Machines with speed control should always be turned on at the slowest speed position. Machines should have a locking device to prevent the switch from being turned in the wrong direction or to a higher speed position inadvertently; however, it should be possible to switch off the machine at any speed setting. The direction of rotation and the speed setting should be clearly indicated, e.g. with illuminated indicators.

Labelling switches. Switches should be readily accessible and clearly marked to avoid mistakes. They should be placed where they can be used safely but cannot be turned on accidentally (e.g. switches should be recessed or foot-operated switches should have a cover). Emergency switches should be clearly marked, be readily recognizable (red colour) and be within easy reach.

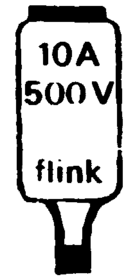
Lighting. Metal light fixtures should be connected to the earth conductor. Good earthing is particularly important for equipment that is used outside and exposed to the weather. Only shock-resistant and properly double insulated, hand-held lights should be used.

Figure 284. Variable-speed switches



Fuses. Blown fuses should never be bridged over, as this could lead to further damage or even fire hazards. Common fuses should be used throughout as prescribed by the equipment manufacturers (figure 285). Special delayed-action types should only be used where approved by a skilled electrician.

Figure 285. Common fuse



Woodworking machines and tools

Cutting tools and bodies must be made of appropriate materials that are capable of withstanding the stress imposed upon them in operation. The design should allow for safe operation and maintenance.

The following materials are commonly used in various cutting machines and tools in the woodworking industry; their reference symbols are:

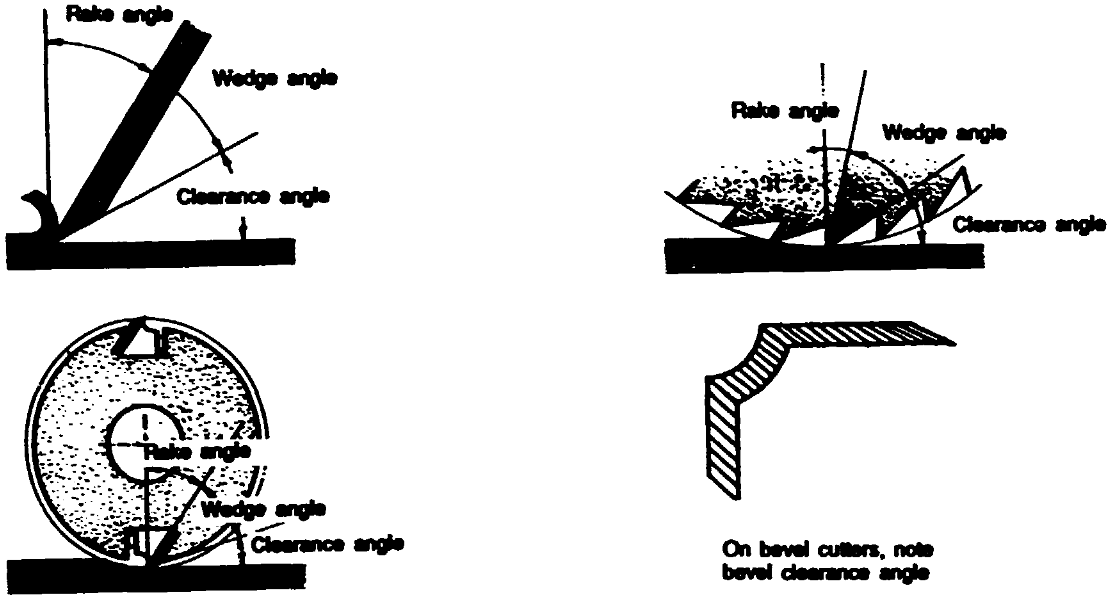
Unalloyed steel for boring bits and band-saw blades	WS
Alloyed steel (special steel) with up to 5 per cent alloy content for circular- and band-saw blades, boring bits and mortise chains	SP
High-alloy steel (high-tensile steel) with more than 5 per cent alloy content for milling cutters	HL
High-speed steel with not more than 12 per cent alloy content for milling cutters and planer knives	SS
High-speed alloy steel (high-tensile high-speed steel) with more than 12 per cent alloy content for planer knives, milling cutters and compound cutters	HSS
Carbide (sintered tungsten, carbon, cobalt) for heavy-duty cutting with tipped cutters and inserted tooth blades	HM
Hard alloyed steel for use as carbide	Stellite

Cutting angles

Cutting angles are designated rake angle, wedge angle and clearance angle. Examples of such angles and various cutting tools are shown in figure 286 A. If any of these angles are too small, problems will occur, as indicated in figure 286 B.

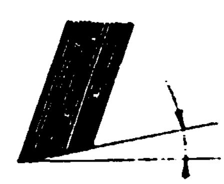
Figure 286. Cutting angles

A. Cutting angles, using various tools



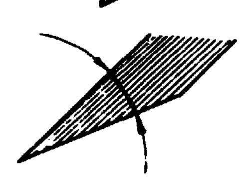
B. Incorrect cutting angles

Clearance angle too small: Excessive friction on back of cutting edge, heat generated during cut, loss of sharpness, probable reduction of feed rate



Rake angle too small: poor chip generation, high pressure on cutter edge, higher feed force required with increased danger of kickback

Wedge angle too small: breakout on cutting edge, reduced life of cutting edge



Cutting angles vary depending on the type of cutter edge and material to be cut, as can be seen in the following example:

	Steel cutter edge	*Carbide cutter edge*	
	Solid wood	*Particle board*	*Plastics*
Rake angle	30°	20°	10°-15°
Wedge angle	42°-45°	55°-58°	60°-70°
Clearance angle	15°-18°	12°-15°	10°-15°

Note that the angles should not be altered after resharpening tools.

Cutting speed

Cutting speed refers to the displacement of a point on the largest diameter of the cutter in metres per second (m/s). Formulae for calculating cutting speed are:

Rule of thumb $$v = \frac{d \cdot \pi \cdot n}{60} \text{ [m/s]}$$

$$v = \frac{r \cdot n}{1000} \text{ [m/s]} \qquad n = \frac{v \cdot 1000}{r} \text{ [min}^{-1}\text{]}$$

$$r = \frac{v \cdot 1000}{n} \text{ [cm]}$$

Where: v = cutting speed (m/s)
n = RPM (min^{-1})
r = radius (cm)

The maximum RPM shown (e.g. n up to 10,000 min^{-1}) on cutting tools should never be exceeded. The economic cutting speed is generally well below this limit. The following are guidelines for economic cutting speeds:

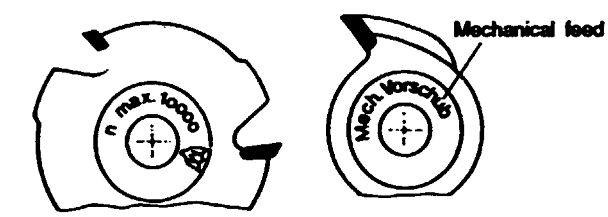
Tool	Cutter	
	Steel	Carbide tipped
Circular-saw blades	60-70 m/s	70-100 m/s
Band-saw blades	20-30 m/s	
Milling heads	30-50 m/s	45-70 m/s
Sanding wood using belts and discs	16-22 m/s	
Sanding lacquer coats	7-10 m/s	

Labelling

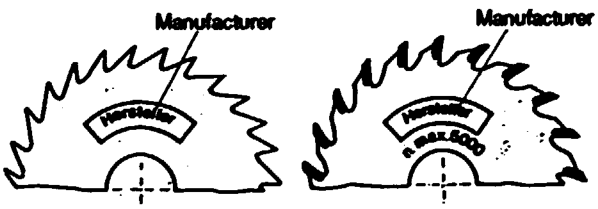
Rotating tools must be clearly and endurably marked with the maximum allowable RPM. (See figure 287 A.) Planer heads and milling cutters for use with mechanical feed only must be clearly and endurably marked "mechanical feed" (see figure 287 B). Solid-steel circular-saw blades should show the manufacturer's name (figure 287 C); carbide-tipped circular-saw blades should also show the name as well as the maximum allowable RPM (figure 287 D).

Figure 287. Markings

A. Maximum RPM label **B. Mechanical feed label**



C. Solid steel circular-saw blade label **D. Carbide-tipped circular-saw blade labels**



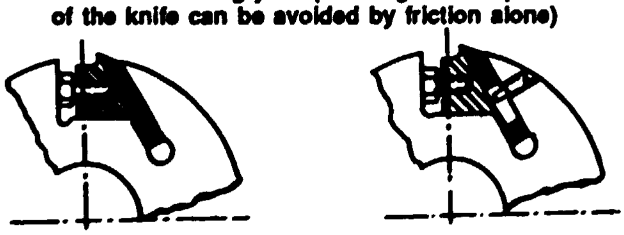
The manufacturer's stated maximum RPM on cutting tools must never be exceeded. Cutting tools made before April 1954 are not marked with the maximum RPM; they must not be used above 4,500 min^{-1} or cutting speeds in excess of 40 m/s.

Clamping of knives

Knives are clamped into place with pressure or form-locking joints, as shown in figure 288.

Figure 288. Locking joints

A. Pressure locking joint (a change in the position of the knife can be avoided by friction alone)

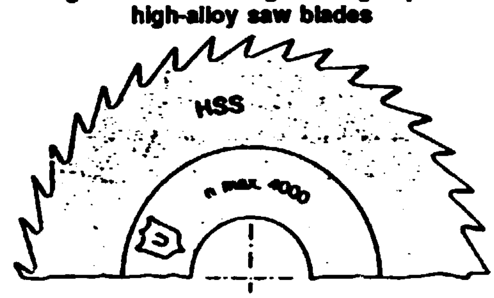


B. Form locking joint (the form and arrangement of the parts ensure that no relative change in their position occurs)

High-speed high-alloy steel (HSS) saw blades

High-speed high-alloy steel saws must be clearly marked showing the maximum RPM, steel quality (HSS) and manufacturer's name or trade mark (see figure 289).

Figure 289. Markings on high-speed high-alloy saw blades



When using HSS saw blades on circular saw benches the following guidelines should be followed:

(a) The workpiece must be securely clamped;

(b) Feeding should be mechanical or partially mechanical;

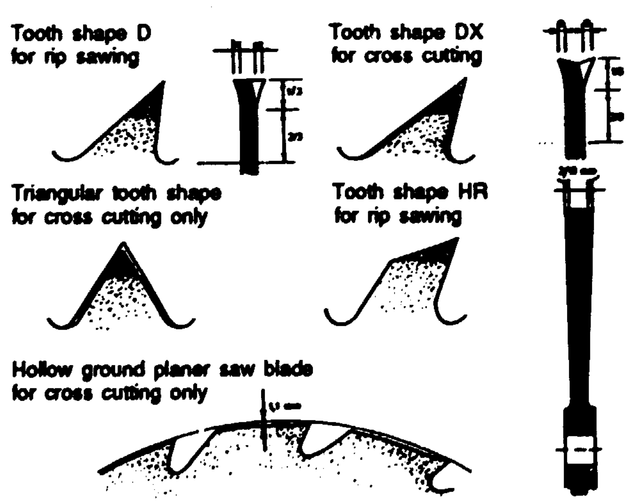
(c) The rim speed must not exceed 40 m/s;

(d) The saw blade must be covered by a guard.

Circular-saw blades (tooth shapes)

Tooth shapes of steel circular-saw blades are shown in figure 290.

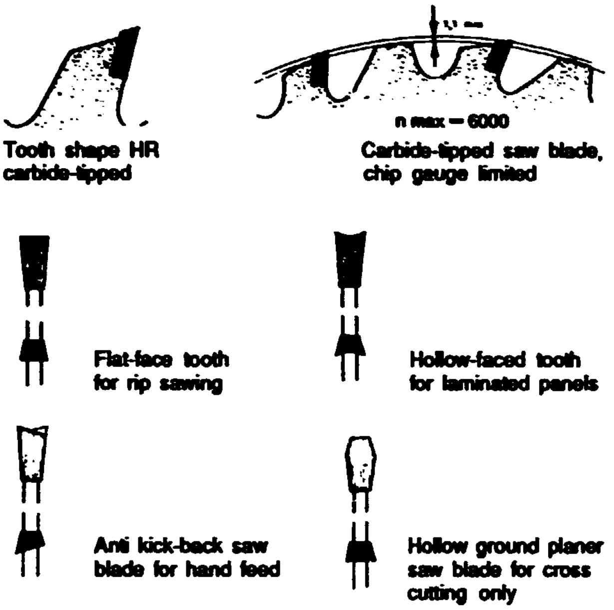
Figure 290. Tooth shapes, steel blades



Carbide-tipped (HM) circular-saw blades

Tooth shapes of carbide-tipped circular-saw blades are shown in figure 291.

Figure 291. Tooth shapes, carbide-tipped blades



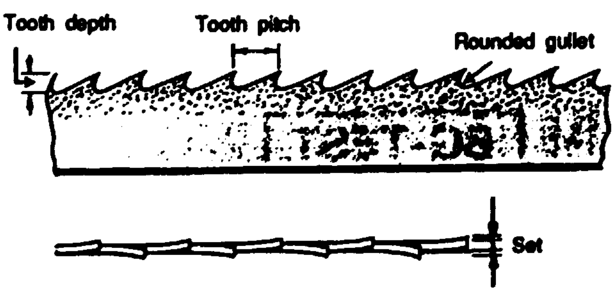
Maintenance of circular-saw blades

Cracked or buckled saw blades should not be used under any circumstances; they should be disposed of immediately. After the saw has been turned off, the operator should not try to slow down or stop the blade by exerting pressure on the sides of the blade.

Band-saw blades (figure 292)

The thickness of a band-saw blade is approximately 1/1,000 of the diameter. The blade width depends upon the application: wide blades are used for rip cutting and tenon cutting; narrow blades are used for contour work.

Figure 292. Band-saw blade

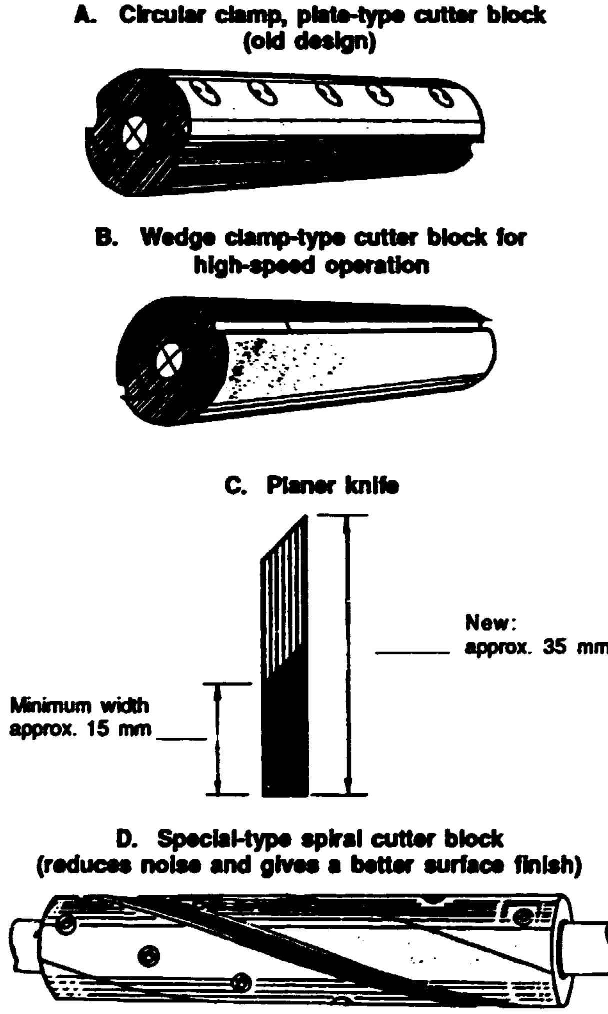


Saw blades should not be allowed to become blunt because if this happens the saws tend to run off the pulleys and tear.

Clamping of knives

Knives are clamped to cutter blocks as shown in figure 293. The locking bolts should be tightened with wrenches specified by the manufacturer; they should be tightened starting from the centre outwards. Extensions should not be used on the wrench. Both the head and knife should be cleaned before assembly.

Figure 293. Cutter blocks and planer knife



Milling tools

Manual feeding

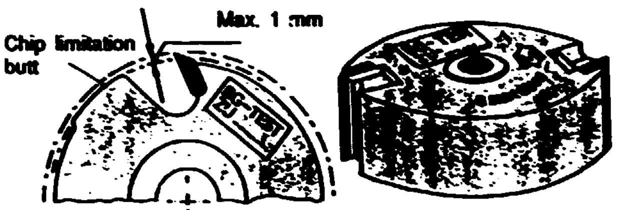
Manual feeding is the loading and feeding of workpieces without using clamps or feed attachments, for instance when moulding along the fence without mechanical feed or shaping on a ball-bearing collar.

Tools intended for hand-feeding operations must have the following properties:

Chip gauge limitation, maximum 1.1 mm
Circular form
Narrow chip clearance gullet
No danger of kick-back

In the Federal Republic of Germany these requirements are met by all tools carrying the test symbol BG-TEST.

Figure 294. Tools for machines with hand feeding



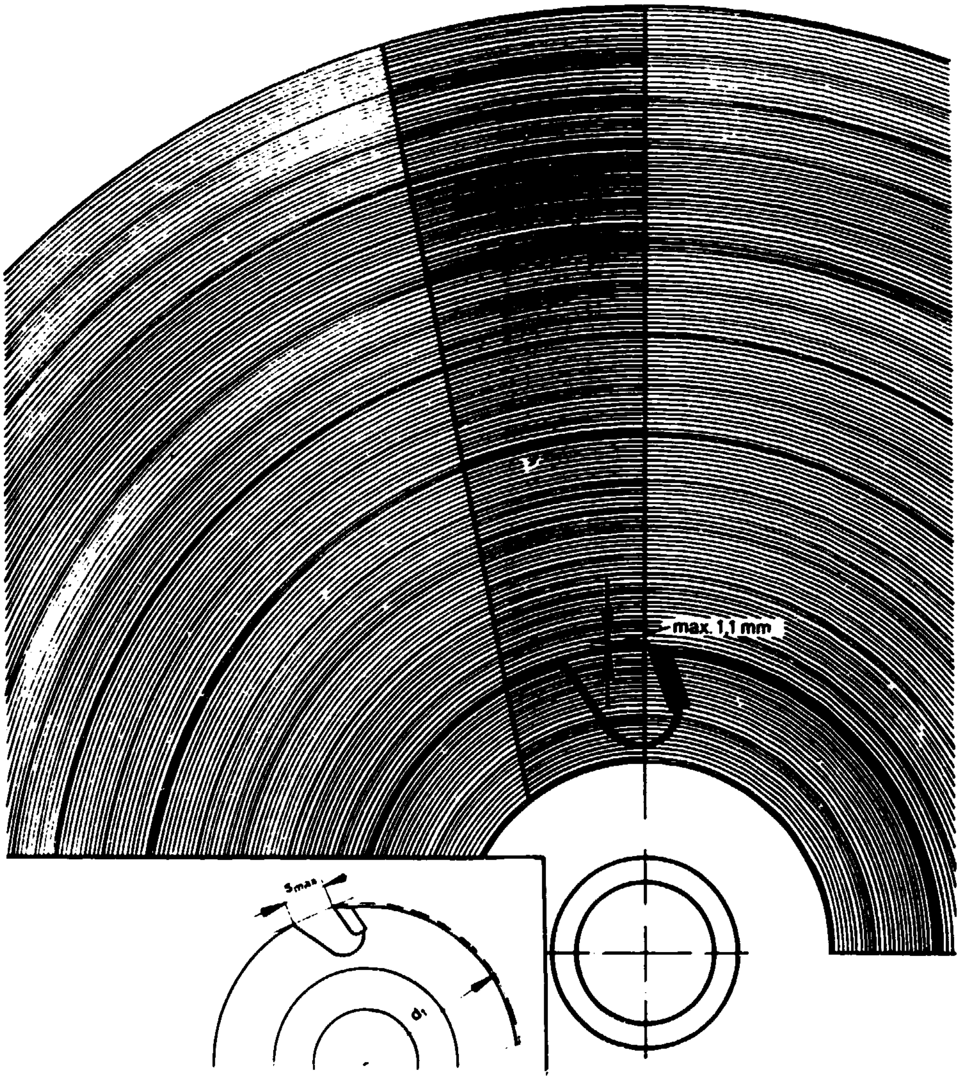
The template used for checking milling tools according to the BG-TEST is shown in figure 295. Cutters are approved for hand feeding when:

(a) The chip clearance gullet (S max) dimension falls within the shaded area of the figure;

(b) The cutting edge protrusion does not exceed 1.1 mm beyond the tool diameter.

Cutting tools exceeding these limits should be used only with mechanical feeders or, if appropriate, with partial mechanical feed attachments.

Figure 295. Template for checking milling tools with hand feeding (BG-TEST)



Note: The S max dimension of the gullet on profile tools is measured from the largest cutting diameter d_1.

Partial mechanical feeding (feed attachments)

In partial mechanical feeding, workpieces are loaded and fed by hand but using built-in clamping and feeding devices, such as feed attachments or sliding tables.

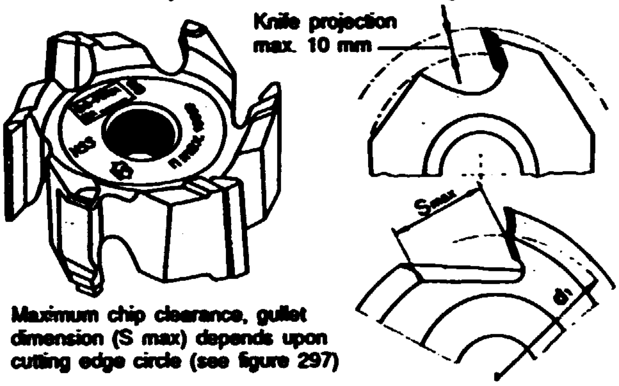
Constructional details of tools used on machines with partial mechanical feed are:

Cutting edge projection, maximum 10 mm
Mainly closed circular form

Limited width of chip clearance gullet
No danger of kick-back

These requirements are all met by tools carrying the test symbol BG-FORM.

Figure 296. Tools for machines with partial mechanical feeding



The template used for checking milling tools according to the BG-FORM test is shown in figure 297. The cutters can be used for partial mechanical feeding (with feed attachment, on slide etc.) when:

(a) The chip clearance gullet (S max) dimension falls inside the shaded area;

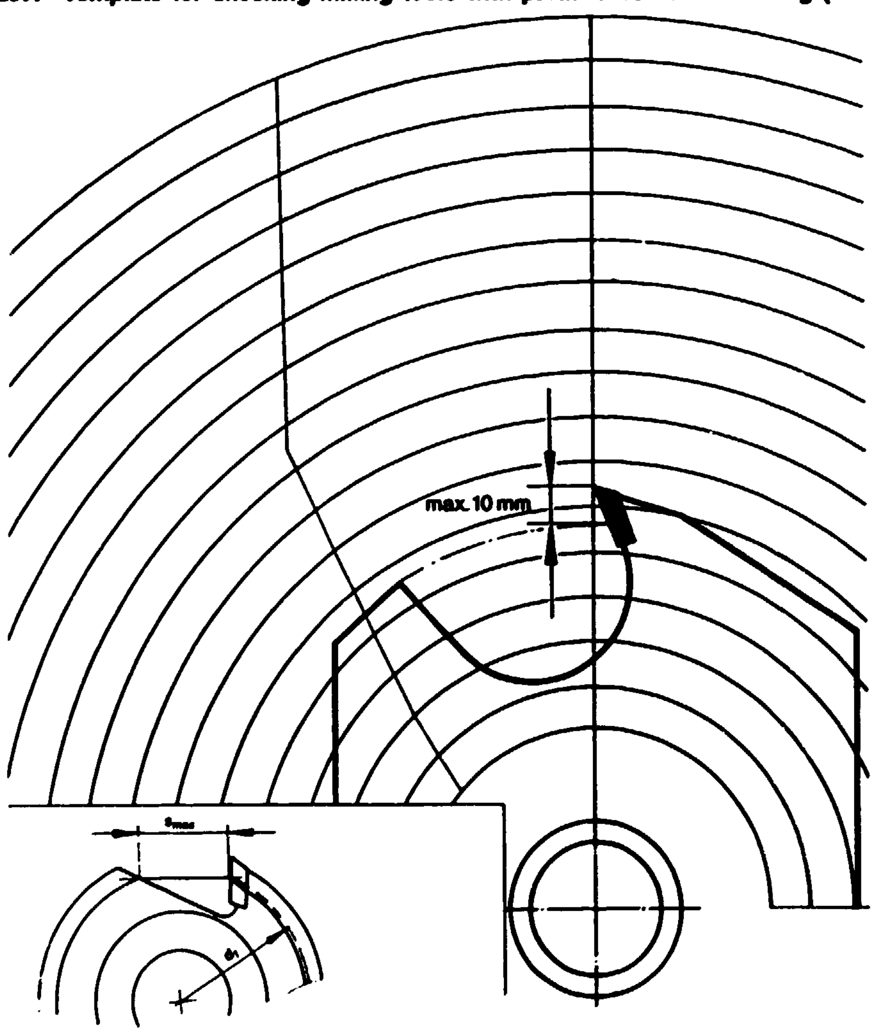
(b) The cutting edge protrusion does not exceed 10 mm beyond the tool diameter.

Cutting tools exceeding these limits should be used only with mechanical systems.

Mechanical feeding

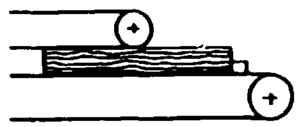
With mechanical feeding, the loading and feeding of the workpiece is done by means of power-driven clamping and feed equipment, for example on double-end tenoning machines (see figure 298).

Figure 297. Template for checking milling tools with partial mechanical feeding (BG-FORM)



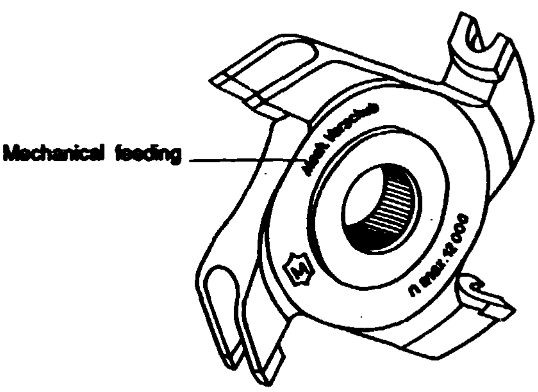
Note: The S max dimension of the gullet on profiled tools is measured from the smallest cutting diameter d_1.

Figure 298. Mechanical feeding



Requirements for mechanical feed systems are the same as those for use with manual or partial mechanical feed; other tools can also be used on machines with mechanical feeding.

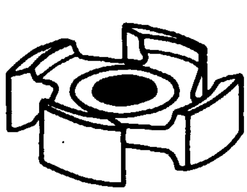
Figure 299. Mechanical feeding tool



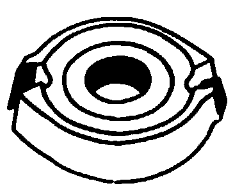
Standardized machine tool types

Standardized machine tool types are shown in figure 300.

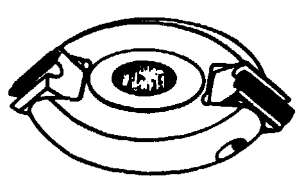
Figure 300. Standardized machine tool types



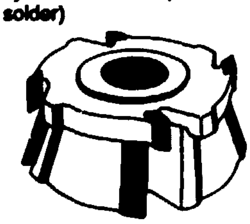
One-piece tool: no detachable parts; tool body and cutting edge made from one piece



Compound tool (tipped tool): knives are joined to the body by an adhesive (for instance solder)



Assembled tool: one or more knives are clamped to the body of the tool; they can be adjusted or replaced



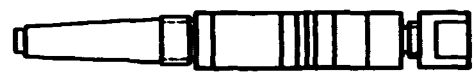
Tooling set: a combination of any of the other three tool types attached together

Tooling spindles (figure 301)

Tooling spindles must be sturdy enough to stand up to the various loads applied during operation. Loose spindles must be at least 30 mm in diameter. They must be provided with spacer rings and a securing nut. Loose spindles with a counter-bearing shaft must never be used without a counter bearing because of danger of spindle breakage.

Figure 301. Tooling spindles

A. Standard loose spindle



Diameter 30 mm; usable lengths 80, 100 and 125 mm

Diameter 40 mm; usable lengths 100, 125 and 140 mm for use with larger-diameter tools, e.g. tenoning discs

B. Loose spindle with counter-bearing shaft

Diameter 3 mm; usable length 160 mm

Spacer rings (reducer bushes)

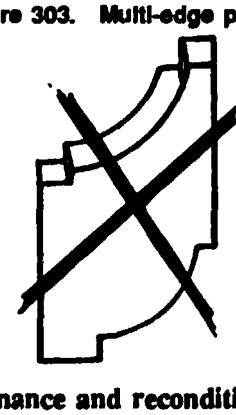
Spacer rings or reducer bushes should only be used on rotating tools when they fit both the spindle and the tool accurately. The length of such pieces should not be less than 0.7 times or more than 0.9 times that of the bore of the tool.

Figure 302. Spacer rings

Multi-edge profile blades

Profile cutter blades with multiple cutting edges (see figure 303) are no longer permitted by safety regulations.

Figure 303. Multi-edge profile blade



Maintenance and reconditioning of tools

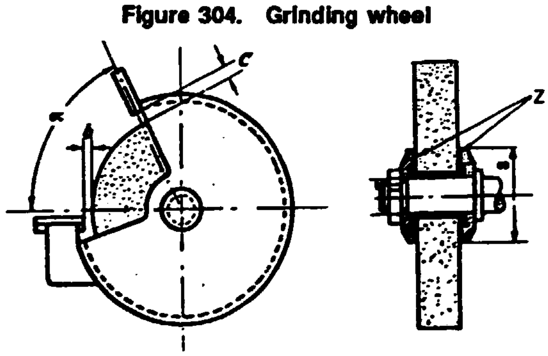
The following guidelines for tool maintenance should be observed:

Blunt tools do not perform efficiently and are dangerous
Damaged tools (worn threads, cracked tools etc.) must not be re-used
Tools that have resin deposits should be cleaned
Lay tools on soft surfaces (wood)
Always return tools to their place of storage after use
Qualified technicians must carry out the maintenance of composite tools

The following are guidelines for the reconditioning of tools on grinding wheels:

Reconditioning of assembled tools must be done only by skilled personnel
The grinding wheel guard must be adjustable, with a maximum distance from wheel of 5 mm (figure 304 (c))
The guard must adequately cover the wheel right up to the grinding aperture (maximum 65°) (figure 304 (α))
The grinding support must be sufficiently large and adjustable to within 3 mm (figure 304 (b))
The grinding wheel must be clamped between collars with a diameter at least 1/3 that of the wheel (figure 304 (s))
The collars must be of the same size and relieved
Compressible packing pieces must be fitted between the wheel and collars

Figure 304. Grinding wheel



Grinding wheel labels

Grinding wheels must be labelled with the following information:

Manufacturer
Type of binder, e.g. V = ceramic, B = resin bonded, R = rubber bonded
Wheel dimensions
Permitted RPM of a new wheel

Bonded mineral wheels must be marked with a white stripe. Wheels containing materials likely to be injurious to health must be marked in an appropriate manner. Other necessary data are:

Abrasive grit size (lower numbers for larger grit sizes, higher numbers for finer grit sizes)
Hardness, indicated by letters (very soft, E-G; soft, H-K; medium, L-O)

Cutting tools

Only grinding machines with index adjustment for sharpening tools, should be used; cutter angles should not be altered when re-sharpening.

Planer knives

The following are guidelines for the reconditioning of planer knives:

(a) Grinding faults:

(i) Too much pressure applied: the knife turns blue and the edge is distorted;

(ii) Incorrect alignment: the width of the knife is uneven and unbalanced in weight distribution;

(b) Grinding:

(i) The knife width and weight should be checked; any difference should be equalized during grinding. Do not re-use knives when less than 15 mm clamping width is left after grinding;

(ii) The wedge angle should not be altered. It should be approximately 32° for circular clamp plate-type cutter block knives, and approximately 40° for wedge clamp type cutter block knives;

(c) Jointing: The jointing of knives is done on a jointing jig. An oilstone should be used.

Figure 305. Jointing jig for planer knife

Replacing knives on surface planers and thicknessers:

(a) Surface planers and thicknessers should be constructed such that they cannot be switched on accidentally. After loosening the securing bolts, the knives should be removed. The knife and clamp faces should be cleaned; new knives should be degreased before mounting;

(b) To set the knife using a wooden gauge block (figure 306 A), the locking bolts should be tightened from the centre outwards; after a test run, the locking bolts should be retightened);

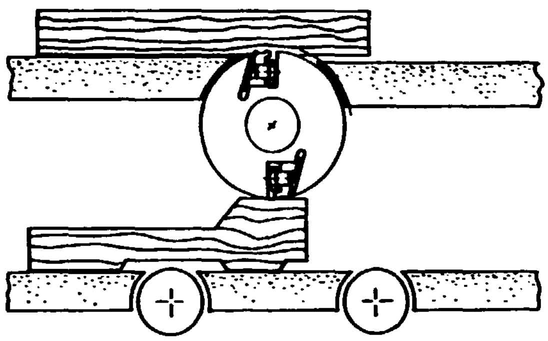
(c) To set the knife using adjustable gauge or dial indicator (figure 306 B), the locking bolts should be tightened from the centre outwards; after a test run, the locking bolts should be retightened.

Using grinding wheels

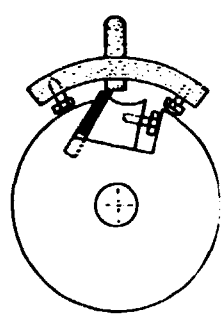
There are well-defined safety regulations for the use of grinding wheels as set down by the metalworking industry and covering the maximum permissible rim speed. Wheel mounting and fixing should be done by skilled personnel, and the wheel should be given a ringing test to ensure that there are no invisible cracks or defects. Only approved collars and packing pieces should be used. The wheel bore should match the spindle dimensions such that there is no noticeable play when the wheel is mounted by hand on the spindle before tightening.

Figure 306. Setting the knife

A. Using a wooden gauge block



B. Using an adjustable gauge or dial indicator



After any adjustment to the mounting or remounting of a wheel a test run of at least 5 minutes' duration should be made (care should be taken to ensure that no one is within the danger zone during the test run). When using grinding wheels, goggles should always be worn or a splinter-proof shield should be put on the machine. Only wheels with a manufacturer's safety certification should be used.

Band-saw blades

The following instructions should be adhered to when carrying out maintenance on band-saw blades:

(a) Elimination of resin incrustations: goggles and gloves should be worn;

(b) Setting with a setting device: the set of each tooth should be 1/3 of the blade thickness; for wider settings, the raker tooth should remain straight. The set height should be 1/3 to 1/2 of the tooth height;

(c) Sharpening with a triangular file whose corners have been rounded off: filing should be against the root.

Circular-saw blades

The following instructions should be adhered to when carrying out maintenance on circular-saw blades:

(a) Elimination of resin incrustations: goggles and gloves should be worn;

(b) Setting with setting pliers, lever-operated setting device or automatic setter: the set should be checked with a dial indicator; unbalanced setting of the blade will cause drift;

(c) Sharpening with a triangular file (this is outdated and seldom practised); with a grinding wheel, the wheel gullet should be ground before the back, leaving a burr facing the front.

Cutter knives

The following instructions should be adhered to when carrying out maintenance on cutter knives:

(a) Grinding faults:

- (i) If the grinding wheel is too small (diameter smaller than 140 mm) the result will be concave grinding—the wedge angle will be too small, decreasing the life of the tool, and the cutting edge will break;
- (ii) Incorrect support on the grinder causes tipping into the gap;

(b) Grinding:

- (i) For straight knives, a gauge or template should be used;
- (ii) For profile knives, the profile contour drawing should be followed;

(c) The wedge angle should be checked and maintained, taking care to maintain the side clearance angle.

Operating band saws

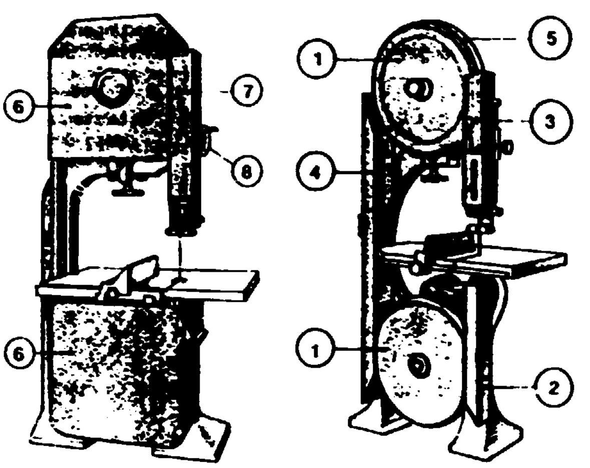
The constructional details of band saws and new features of band saws that have been constructed since 1980 are shown in figure 307.

Wheel tyres and table inserts

The material used and the shape of the tyres (figure 308 (1)) ensure true running of the band saw and protect the tooth set. (The tyre shape is usually slightly convex.) Table inserts must be flush with the table-top. Worn table inserts (figure 308 (2)) should be replaced without delay. This is made easier where table inserts are provided with replaceable wear-resistant parts (figure 308 (3)).

Figure 307. Band saws

A. Typical band saw constructed before 1980 | B. Typical band saw constructed after 1980



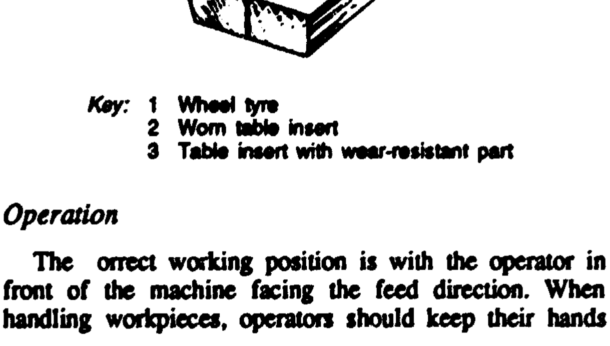
Key: Constructional details for machines designed before 1980:

1 Cover of wheel disc with spoked, fluted or punched cover (including rear)
2 Covering over down-stroke part of the band-saw blade below table
3 Height-adjustable cover over down-stroke part of the band-saw blade above table (cover can be placed down to cutting height)
4 Cover over up-stroke part of the band saw blade
5 Metal ring to catch torn band-saw blades

Design features of new machines (since 1980):

6 Enclosure over band-saw wheels and up-stroke part of blade
7 Height-adjustable saw-blade front and side cover (setting adjustment to suit workpiece height)
8 Adjustment control for setting top band-saw guide (for machines with wheel diameters larger than 315 mm)

Figure 308. Wheel tyres and table inserts

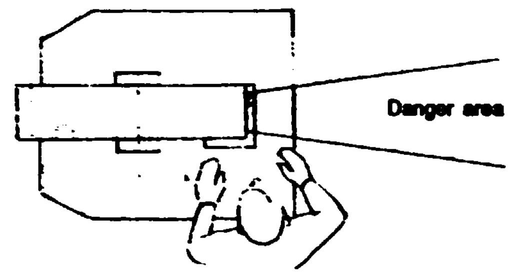


Key: 1 Wheel tyre
2 Worn table insert
3 Table insert with wear-resistant part

Operation

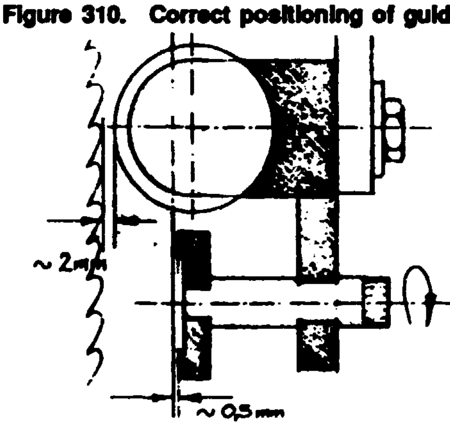
The orrect working position is with the operator in front of the machine facing the feed direction. When handling workpieces, operators should keep their hands away from the cutting area; hands should be placed flat on the workpiece surface, with thumbs close together. The workpiece should be moved forward evenly, following the cut, and should not be pulled backwards (see figure 309).

Figure 309. Correct working position for operating a band saw



To adjust band-saw blade guides, the guides should be set about 2 mm behind the tooth gullets. The band-saw blade support roller guide should be placed close behind the saw blade (approximately 0.5 mm) so that it rotates only when cutting pressure is applied to the band-saw blade (figure 310).

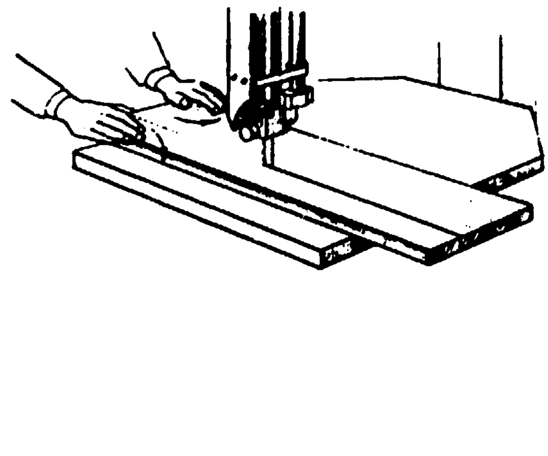
Figure 310. Correct positioning of guides



Rip sawing (figure 311)

A wide, sharp, correctly set saw blade should be used. The workpiece should be moved forward smoothly following the scribed line. At end of a cut, the workpiece parts should be moved as shown by the arrows off the saw blade; it should not be pulled backwards. For short runs cutting longer workpieces, a roller conveyor or table extension should be mounted behind the saw so that the workpiece does not tip over the edge of the machine.

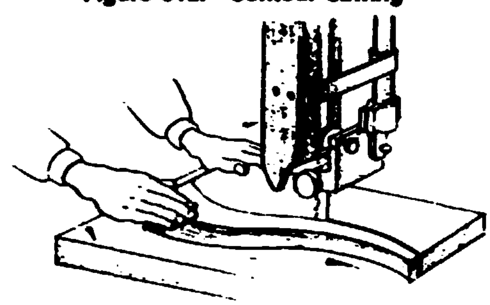
Figure 311. Rip sawing



Contour sawing (figure 312)

A narrow, sharp, correctly set saw blade should be used. The workpiece should be moved forward smoothly, turning as required to follow the scribed contour. The workpiece should not be withdrawn or pulled back as this could cause run out of the blade. On wide workpieces, the centre contour should be cut first.

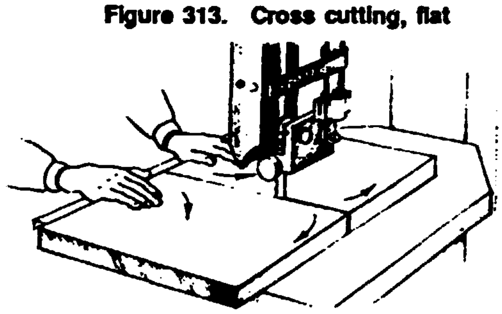
Figure 312. Contour sawing



Cross cutting, flat (figure 313)

A wide, sharp, correctly set saw blade should be used. Hands should be placed on the workpiece as shown in figure 313. The workpiece should be fed smoothly by applying pressure in the directions shown by arrows to avoid any tendency of the kerf to close.

Figure 313. Cross cutting, flat



Cross cutting, upright (figure 314)

A wide, sharp, correctly set saw blade should be used. The height of the cover and band-saw guide should be appropriate for the workpiece dimensions. The work should lean on the machine frame or the cover on the left side as shown in figure 314. The workpiece should be fed smoothly forward to the cutting position. Very long pieces should be supported on a table extension or rollers to avoid tipping when cut. The workpiece should never be fed in such a way that cutting starts at the top edge of the work-piece.

Resawing along a scribed line (figure 315)

A wide, sharp, correctly set saw blade should be used. A scribe cut is required. The workpiece should be fed smoothly forward in the direction of the cut and guided by means of a right-angled guide piece, as shown in figure 315, by applying sideways pressure as necessary. The right-angled guide should be centred slightly forward of the saw blade (if placed behind it, there is a tendency to close the kerf). A pushing stick should be used to feed the last part through to keep hands safely away from the saw blade. For longer pieces, a table extension or roller supports should be used to avoid tipping.

Figure 314. Cross cutting, upright

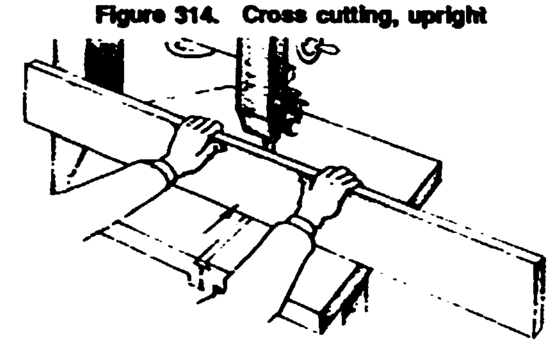
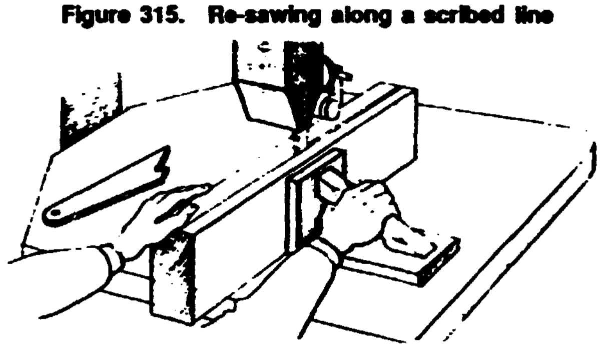


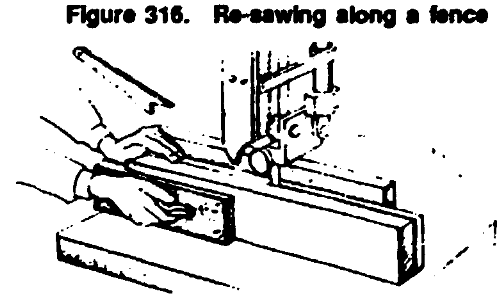
Figure 315. Re-sawing along a scribed line



Re-sawing along a fence (figure 316)

A wide, sharp, correctly set saw blade should be used. The fence should be set and aligned parallel to the saw blade. When re-sawing thin pieces, a pushing stick and guiding block, as shown in figure 316, should always be used for safety.

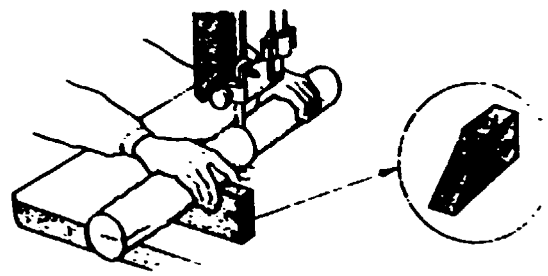
Figure 316. Re-sawing along a fence



Cutting round pieces (figure 317)

A wide, sharp, correctly set saw blade should be used. A special fixture should be used to prevent the workpiece from rotating. A simple wedge support like that shown in figure 317 is adequate to ensure that round pieces do not turn while sawing. For longer runs, an appropriately shaped wedge support to suit the workpiece shape should be used.

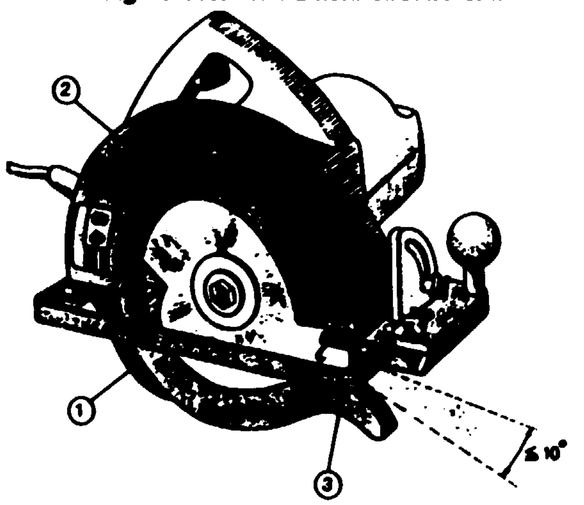
Figure 317. Cutting round pieces



Operating hand-held circular saws

Hand-held circular saws (figure 318) manufactured after 1975 must be equipped with a riving knife (figure 318 (1)) when the maximum cutting depth exceeds 18 mm. The saw rim above the table must be protected by a solid enclosure (figure 318 (2)). Protection in the cutting area is provided by a swivelling guard (figure 318 (3)), which is spring-loaded to return it to the protected position after sawing. This guard must be capable of being secured in place when the saw is at rest and not in use. Dip circular saws and those with a self-adjusting swivel guard must have a means of locking the guard. The distance between the saw rim and the riving knife must not exceed 5 mm.

Figure 318. Hand-held circular saw

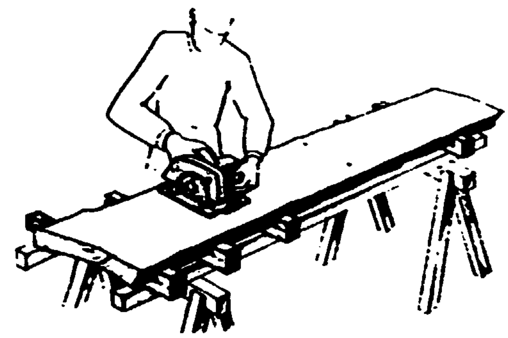


Key: 1 Riving knife
2 Solid enclosure
3 Swivelling guard

Cross cutting sawn wood (figure 319)

A cross-cutting circular-saw blade should be chosen for the operation. The operator should check that the riving knife is correctly placed and tightened. The correct cutting depth should be set (allowing a maximum of 10 mm more than workpiece thickness). The electrical cable and plug should be checked, and the workpiece should be secured in position such that feed pressure during sawing will not jam the kerf. There should be plenty of clearance under the board for the saw blade. After cutting, the operator should wait for the saw to come to a stop and ensure that the swivel guard is secured in position before putting the saw away. The working layout and operator position are shown in figure 319.

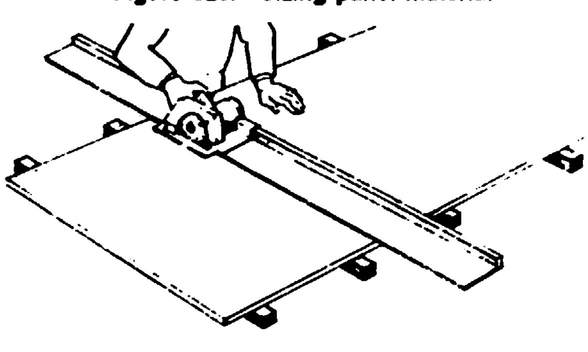
Figure 319. Cross cutting sawn wood



Sizing panel material (figure 320)

A panel-cutting saw (e.g. carbide-tipped saw blade) should be used. The operator should check that the riving knife is correctly placed and tight. The correct cutting depth should be set. The workpiece should be securely held in position. Special guides or rails can be used to ensure a steady and straight cut. The working layout and operator position are shown in figure 320.

Figure 320. Sizing panel material



Operating pendulum cross-cutting circular saws

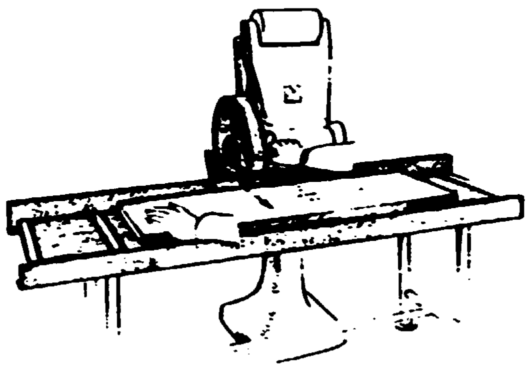
Constructional details

The saw blade must be fully enclosed when at rest. The saw should return automatically to the rest position after use and be firmly held there. The fence should be solidly constructed, extending to the saw opening slot. The end stop must ensure that the saw teeth do not extend beyond the table edge, or a protective cover should be provided to ensure that the saw remains fully enclosed.

Operation

A cross-cut saw blade should be used. The operator should stand to one side of the cut and hold the workpiece firmly against the fence, with the left hand placed well away from the cutting area (see figure 321). After releasing the retaining lock with the right hand, the saw should be pulled forward smoothly to cut.

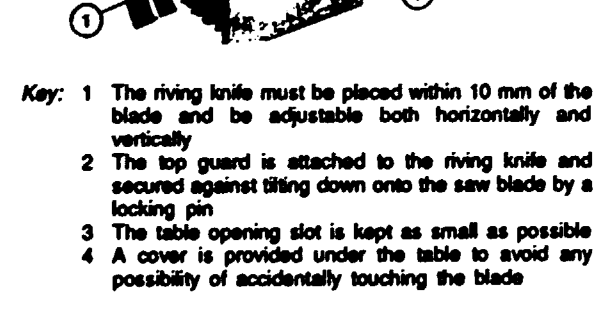
Figure 321. Pendulum cross-cutting circular saw



Operating panel-sizing saws and saw benches

The constructional details of panel saws and saw benches built up to 1979 and new features of such machines that have been built since 1980 are shown in figures 322 and 323, respectively.

Figure 322. Features of a panel-sizing saw built before 1980

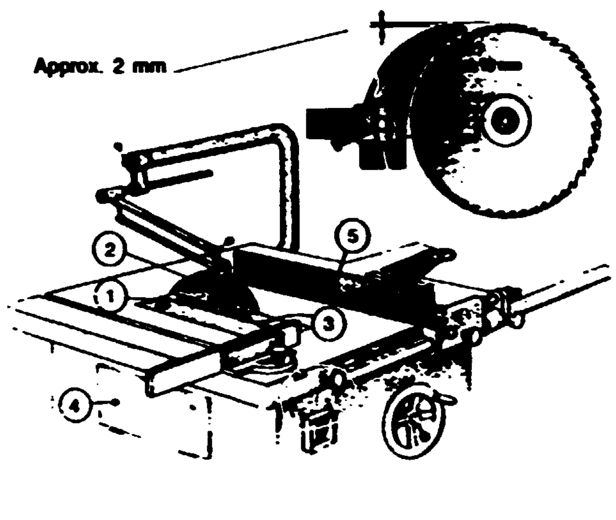


Key:
1 The riving knife must be placed within 10 mm of the blade and be adjustable both horizontally and vertically
2 The top guard is attached to the riving knife and secured against tilting down onto the saw blade by a locking pin
3 The table opening slot is kept as small as possible
4 A cover is provided under the table to avoid any possibility of accidentally touching the blade

Blind (covered) sawing (figure 324)

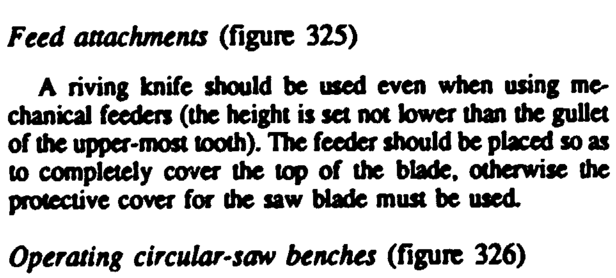
The top guard should be removed and the riving knife should be positioned such that its top is some 2 mm below the top of the saw blade and tightened (if need be, a shorter riving knife should be fitted).

Figure 323. Features of a panel-sizing saw built after 1980



Key:
1 The riving knife can be adjusted both horizontally and vertically. It is secured against the possibility of tilting and can be set to within 10 mm of the saw blade. Its top should never be placed lower than the gullet of the uppermost saw tooth
2 In machines built to take circular-saw blades exceeding 250 mm in diameter, a separately mounted top guard is provided to avoid any possibility of accidentally touching the blade
3 The saw-blade slot in the table-top should be as narrow as possible (the gap on each side of the blade should not exceed 3 mm)
4 The saw blade must be fully enclosed below the table
5 The fence must be adjustable such that its rear end can be placed facing a point lying between the front of the blade and the blade centre. With tilting tables it should also be possible to place the fence on either side of the saw blade

Figure 324. Blind sawing



Feed attachments (figure 325)

A riving knife should be used even when using mechanical feeders (the height is set not lower than the gullet of the upper-most tooth). The feeder should be placed so as to completely cover the top of the blade, otherwise the protective cover for the saw blade must be used.

Operating circular-saw benches (figure 326)

Only well-sharpened, even and correctly set blades should be used. The riving knife should be set not further than 10 mm from the blade and tightened. The top cover over the blade should be set at an appropriate height depending on the thickness of the work. The operating position is as shown in figure 326. The operator must be sure to stand clear of the danger area.

Figure 325. Feed attachment

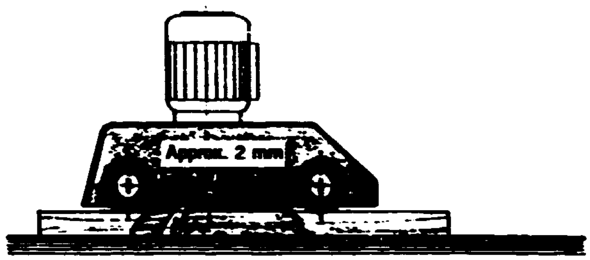
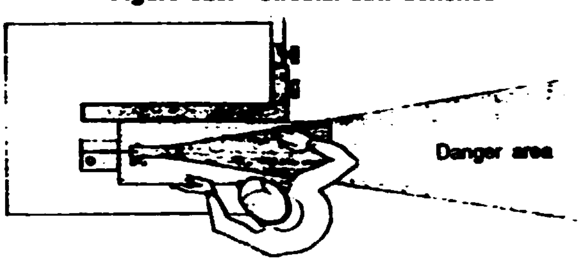


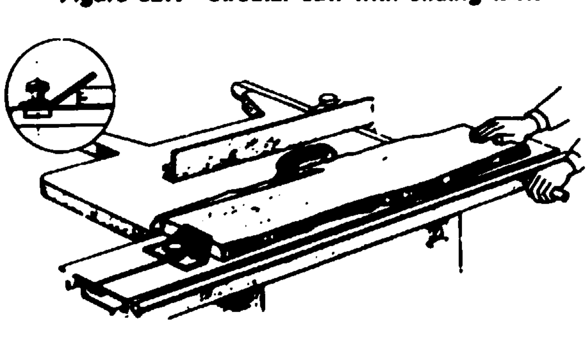
Figure 326. Circular-saw benches



Circular saw with sliding table used for edging and ripping (figure 327)

A rip-saw blade should be used. The end clamp should be set to suit the workpiece length and pushed under the clamp. The operator should hold the workpiece down with the right hand and push the sliding table forward smoothly with the left hand, as shown in figure 327. The setting of the riving knife should be checked regularly, and it should be tightened constantly. A top cover, positioned correctly for the workpiece thickness, should be used.

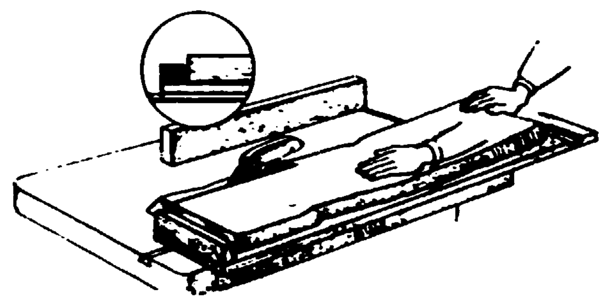
Figure 327. Circular saw with sliding table



Circular-saw bench: edging and ripping (figure 328)

A rip-saw blade should be used. The operator should place the ripping board on the table engaging the runner in the table's slot, place the workpiece on the bed, hollow side down if warped, and push it forward to engage the end firmly in the grip's spikes. Hands should be placed flat on the workpiece, with fingers and thumbs close together. The workpiece should be pushed forward evenly, with the palm of the right hand on the end of the workpiece. Operators should keep their hands well away from the cutting area.

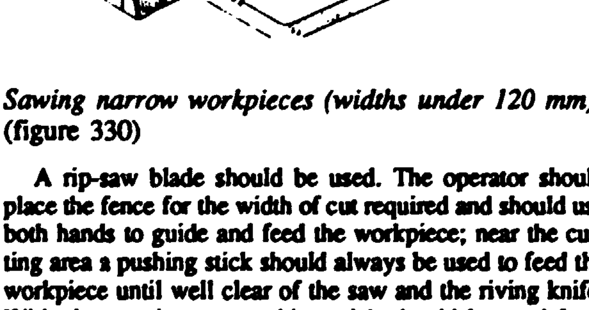
Figure 328. Circular-saw bench



Sawing wide workpieces (widths over 120 mm) (figure 329)

A rip-saw blade should be used. The operator should place the fence for the width of cut required. If narrow strips must be cut off, care should be taken to keep the hands clear and to use a push stick in the vicinity of the cutting area. To avoid any tendency for the workpiece to jam between the saw, the riving knife and the fence, the fence should be placed such that its end does not extend beyond the centre of circular-saw blade, or a shorter fence should be used.

Figure 329. Sawing wide workpieces



Sawing narrow workpieces (widths under 120 mm) (figure 330)

A rip-saw blade should be used. The operator should place the fence for the width of cut required and should use both hands to guide and feed the workpiece; near the cutting area a pushing stick should always be used to feed the workpiece until well clear of the saw and the riving knife. With shorter pieces, a pushing stick should be used from the start of the cut.

Sawing edges (lippings) and slate (figure 331)

A planer saw blade should be used. The operator should place the fence as appropriate, with the edge facing the saw or using an additional right-angled fence as shown in figure 331. The workpiece should be guided with a pushing block only until clear of the blade. Table extensions should be used to avoid tipping of longer workpieces.

Figure 330. Sawing narrow workpieces

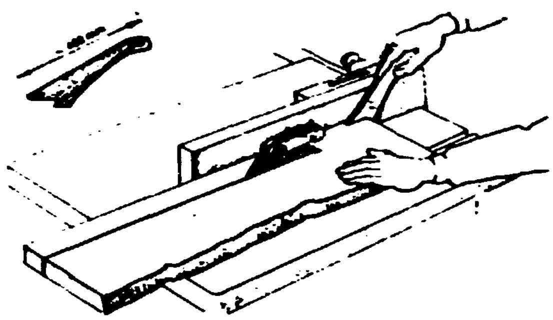
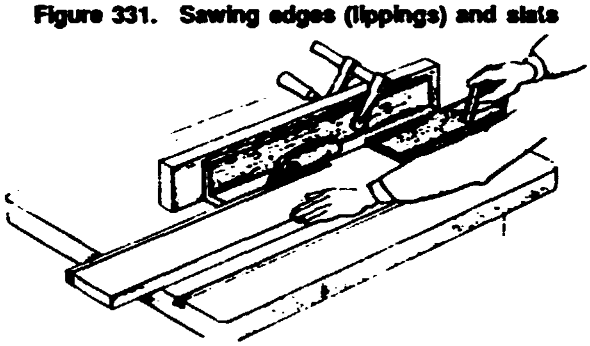


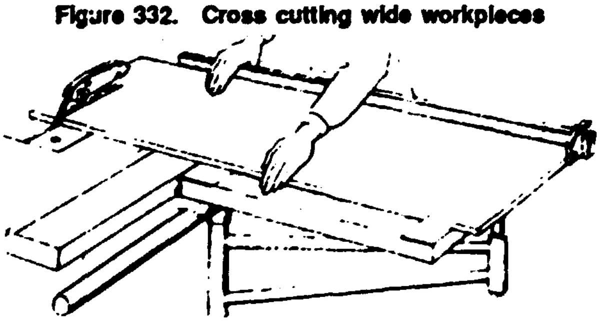
Figure 331. Sawing edges (lippings) and slats



Cross-cutting wide workpieces (figure 332)

A cross-cutting saw blade should be used. The operator should place the workpiece against the cross-cut stop, using the left hand to press the piece against the fence while feeding. When using a ruled cross-cut fence, it should be tilted up before returning it to the starting position and to offset the workpiece, or the workpiece should be taken off at the end of the saw-blade rim. The position of the riving knife should be checked regularly to make sure that it is tight. The top guard or cover should be kept over the saw blade, placed to clear workpiece thickness.

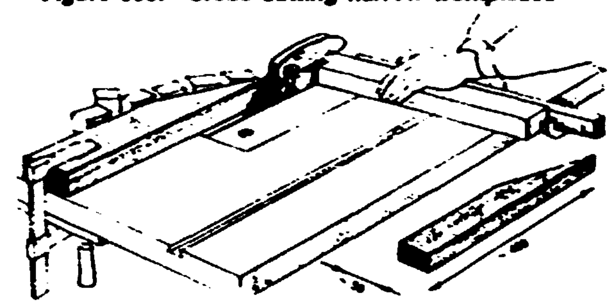
Figure 332. Cross cutting wide workpieces



Cross cutting narrow workpieces (figure 333)

A planer circular-saw blade should be used. The operator should place the deflector as shown in figure 333 to deflect sawn pieces away from the rear of the saw blade. A cross-cut fence should be used. The operator should not remove any piece from the table near the blade by hand.

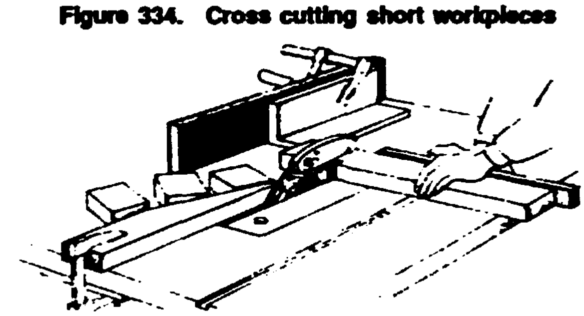
Figure 333. Cross cutting narrow workpieces



Cross cutting short workpieces (figure 334)

A planer circular-saw blade should be used. The operator should place a clearance fence to guide workpieces as far as the front of the blade (start of cut). A cross-cut fence and a deflector appropriately placed near the riving knife should be used.

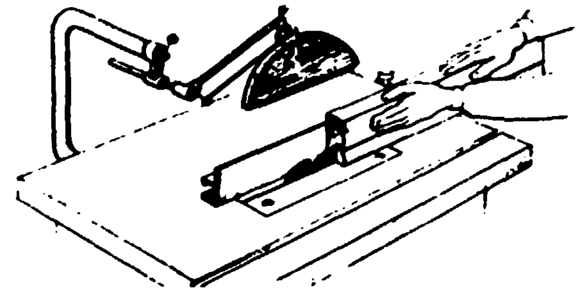
Figure 334. Cross cutting short workpieces



Blind (covered) sawing, rebating (figure 335)

A planer circular-saw blade should be used. The operator should, when rebating, place the workpiece along the fence so that the sawn piece falls on the side of the blade opposite to that of the fence. The fixed top guard should be removed (or the adjustable top guard should be raised) and the riving knife should be lowered for rebating and blind covered sawing.

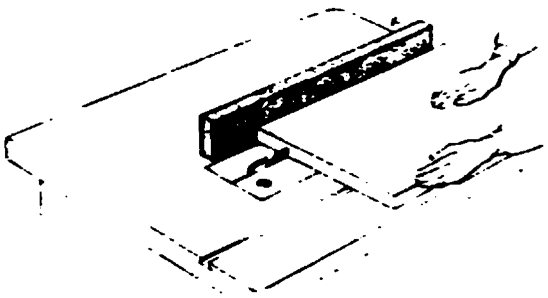
Figure 335. Blind sawing and rebating



Blind (covered) sawing, grooving (figure 336)

The riving knife should be lowered. When feeding, the workpiece should be pressed firmly down onto the table-top to avoid jump grooving. When grooving across the grain on narrower pieces, a cross-cut fence should be used. When using special grooving tools, the appropriate slot-lining insert should be fit to the table, which allows sufficient tool clearance on both sides.

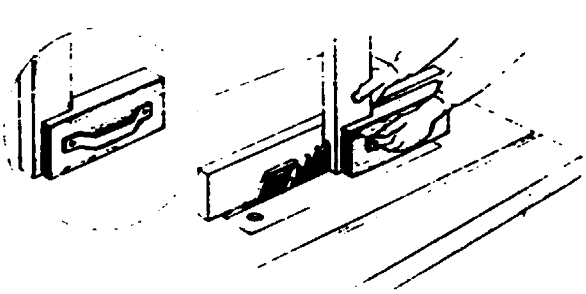
Figure 336. Blind sawing and grooving



Blind (covered) sawing, tenoning (figure 337)

The riving knife should be lowered and tightened. The fence should be positioned and tightened for the correct tenon size. The operator should use the pushing block to feed and the right hand to steady the workpiece, keeping fingers away from the leading side. After sawing, both the workpiece and the pushing block should be withdrawn backwards together. Pushing block dimensions should be 120 mm × 250 mm, rebate according to the workpiece size.

Figure 337. Blind sawing, tenoning



Sawing tenon shoulders (figure 338)

A planer saw blade should be used. The operator should move the fence back or clamp a shorter block on it to avoid sawn off pieces being caught against the blade and the fence. A right-angled guide clamped firmly to the fence can also be used; this should be placed slightly above the piece to be cut off but such as to serve as a guide for the tenon. The workpiece should always be fed past the blade to clear the riving knife.

Sawing using a template (figure 339)

A planer saw blade should be used. The operator should set the fence allowing for the template and ensure that the workpiece is held against the template during whole sawing period. The left hand should be used to guide the work and the right hand to feed it. The setting of the riving knife and the top guard should be checked to make sure that both are tight. The height of the top guard should be set to suit the workpiece thickness.

Figure 338. Sawing tenon shoulders

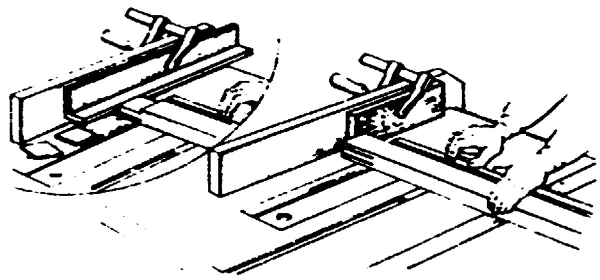
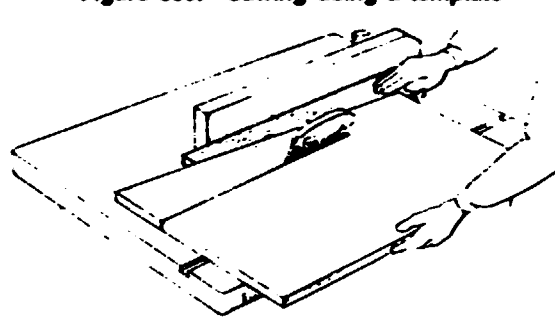


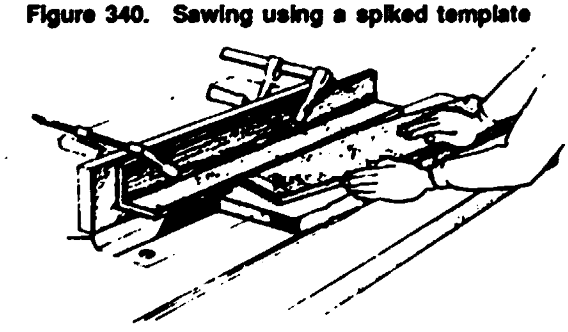
Figure 339. Sawing using a template



Sawing using a spiked template (figure 340)

A planer saw blade should be used. The operator should firmly clamp the right-angled piece to the fence so that its underside is clear of the saw blade yet such that it will accurately mate with and guide the template. The workpiece and the template should be pressed together, ensuring that the spikes bite firmly into the workpiece. The workpiece and template should be firmly pressed to the guide edge and advanced to cut. Loose pieces that have been sawn off should not remain under the right-angled guide piece.

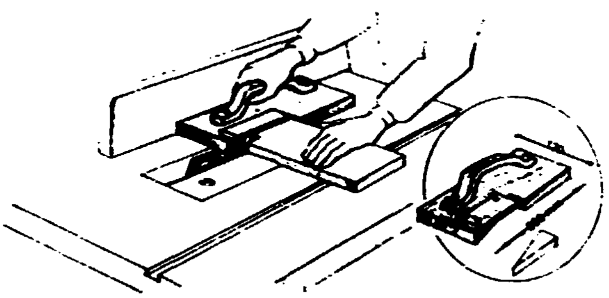
Figure 340. Sawing using a spiked template



Sawing wedges (figure 341)

A planer saw blade should be used. The operator should keep the table slot opening on either side of the blade to a minimum. The workpiece should be pushed with a wedge jig until it is clear of the riving knife before removing the sawn wedge. Only well-fitting jigs that feed and guide the workpiece smoothly across the table should be used. There should be a guard over the blade or over the entire length of the wedge jig.

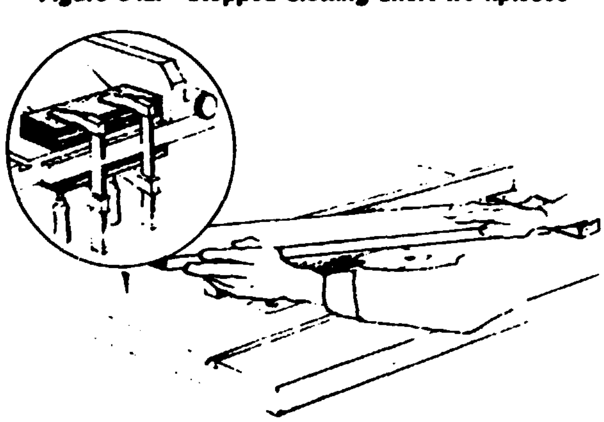
Figure 341. Sawing wedges



Stopped slotting (grooving)

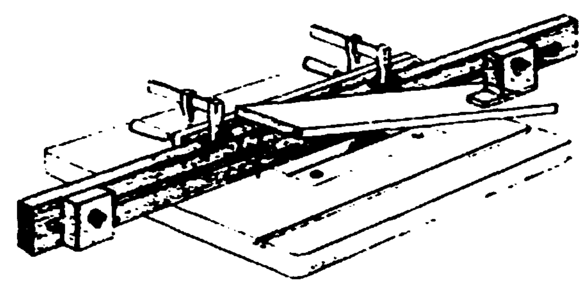
For slotting short workpieces the top guard and the riving knife should be removed and the riving knife clamp should be secured. An end stop and clamp should be placed using a packing block on the underside of the table. The workpiece should be placed against the end stop and dropped down smoothly on to the table and fed to the scribe or to the second stop, lifting it up smoothly after sawing (figure 342).

Figure 342. Stopped slotting short workpieces



For slotting long workpieces the top guard and the riving knife should be removed. The jig should be firmly clamped to the fence. The kick-back stop and the end stop should be set and locked to determine the start and stop length of cut required. The workpiece should be placed firmly on the kick-back stop and pressed against the stop. The workpiece should be dropped down smoothly to cut and fed into the limiting end stop (figure 343). The operator should always remember to replace the riving knife and the top guard after the slot cutting work is completed.

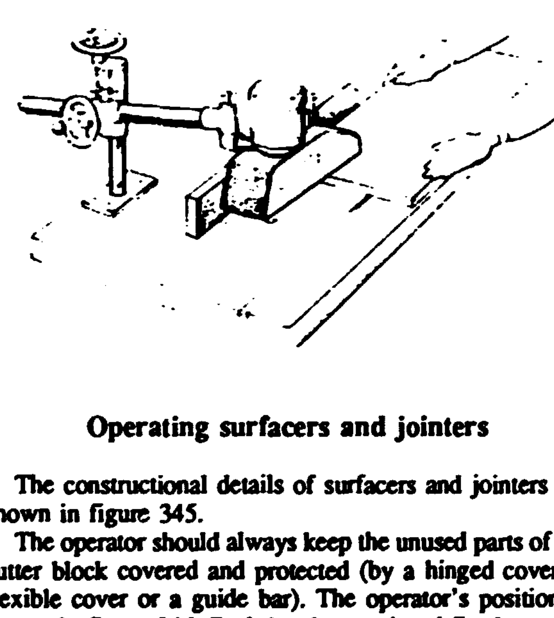
Figure 343. Stopped slotting long workpieces



Working with a feed attachment (figure 344)

The riving knife should be set as a kick-back stop. The feeder should be placed such that it holds the workpiece firmly against the fence while sawing. The operator should make sure that the fence is firmly clamped in position. The workpiece should be placed against the fence and fed smoothly until it engages with the feeder rollers and the cut commences.

Figure 344. Working with a feed attachment



Operating surfacers and jointers

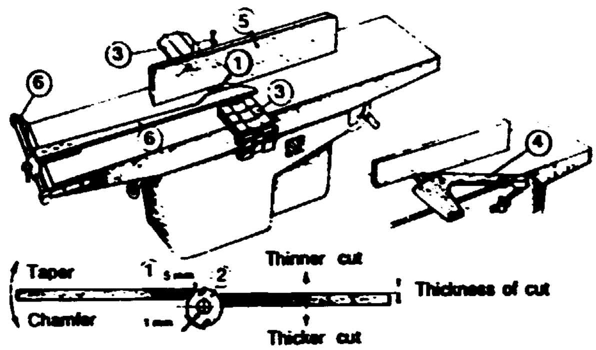
The constructional details of surfacers and jointers are shown in figure 345.

The operator should always keep the unused parts of the cutter block covered and protected (by a hinged cover, a flexible cover or a guide bar). The operator's position is shown in figure 346. Both hands are placed firmly on the workpiece, with fingers and thumbs close together and well clear of edges. For stopped planing, both tables should be firmly aligned; the kickback stop on the infeed table should be secured and the outfeed table reset after use.

Surfacing wide workpieces (figure 347)

The table setting should be checked and set for correct cutting depth. On rough workpiece surfaces, the operator should always start with a low removal rate. The exposed parts of the cutter block should be covered both in front and behind the fence. The operator should feed the workpiece very smoothly forward, maintaining pressure down onto the table, standing to one side as shown in figure 347.

Figure 345. Surfacer and jointer



Key:
1 Round cutter block with knife projection not more than 1.1 mm above block circumference
2 Clearance between table lips and knife edge circumference as small as possible (maximum 5 mm)
3 Protective cover over cutter block and table slot both in front and behind the fence, i.e. bridge guard or folding cover
4 Swivel guard in front of fence
5 Jointing fence
6 Adjustable guide bar (the guide bar keeps the workpiece pressed against the fence and covers the exposed cutter block area)

Figure 346. Operating surfacers and joiners

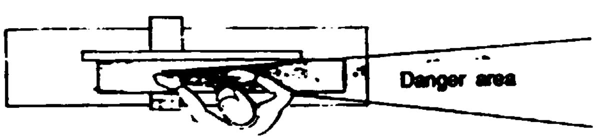
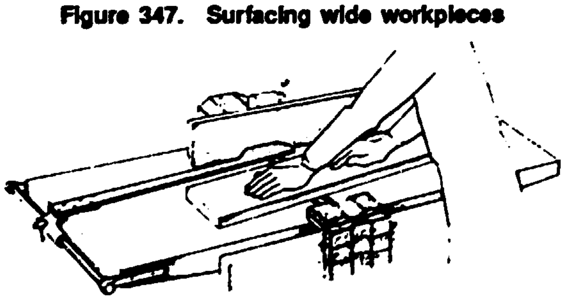


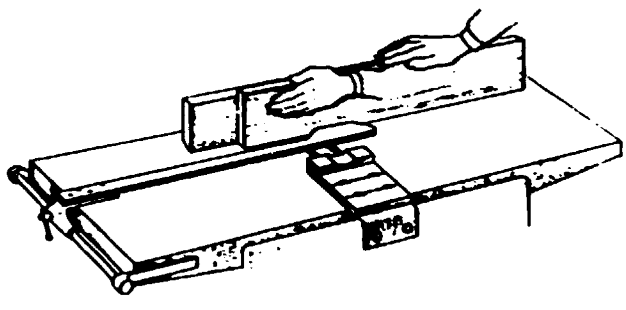
Figure 347. Surfacing wide workpieces



Jointing wide workpieces (figure 348)

The operator should check the table and fence settings, ensuring that the fence is well tightened. The adjustable guide bar should be set to keep the workpiece against the fence. Unused parts of the cutter block should be covered. The workpiece should be fed forward smoothly, firmly pressing it down on the table.

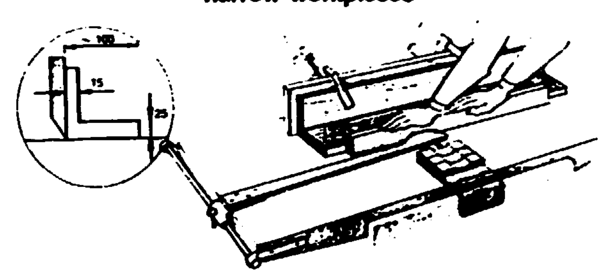
Figure 348. Jointing wide workpieces



Trueing up and jointing narrow workpieces (figure 349)

The operator should secure a right-angled guide to the fence. A correctly placed adjustable guide bar should be used. The operator should make sure that unused parts of the cutter block are covered.

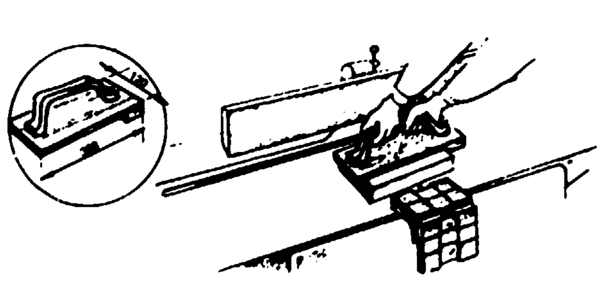
Figure 349. Trueing up and jointing narrow workpieces



Trueing up short workpieces (figure 350)

The operator should check the setting of the machine table and adjust it for a low removal depth of cut. The workpiece should be fitted into the feeder block, holding the block with both hands firmly at an angle of some 20° to the direction of feed smoothly to cutter. Slotted and perforated table lips help reduce noise.

Figure 350. Trueing up short workpieces



Operating thicknessers

The constructional details of a thicknesser are shown in figure 351.

Figure 351. Thicknesser

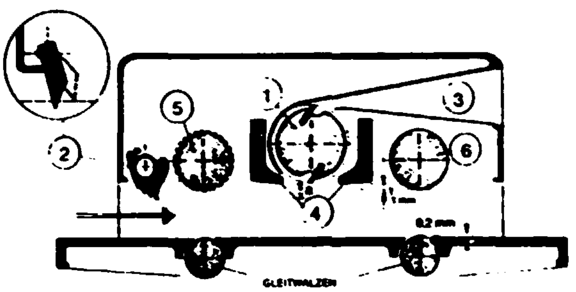
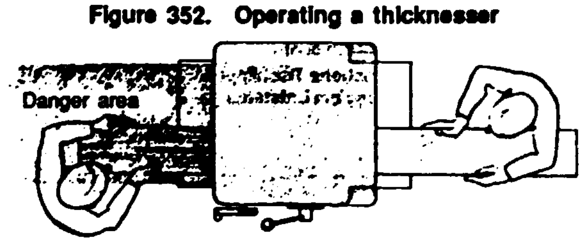


Table rollers
(Dimensions shown for guidance only)

Key:
1 Cutter block: knives set no more than 1.1 mm above cutting block circumference
2 Kickback fingers (alternatives) with restricted turning angle (width 8 to 15 mm spacing between stops not to be more than half their width)
3 Chip ejector opening: the opening should be constructed or placed such as to avoid access to the cutter
4 Pressure bars
5 Infeed roller
6 Outfeed roller
a Dimension: the kickback fingers should be at rest at least 3 mm below the cutter knife circumference.

The operator should wait for the cutter block to attain full operating speed before use. Should any blockage or fault occur, the feed units should be switched off immediately. The operator should not try to remove any chips or splinters from the table while the machine is still running. The surfacing of very short pieces should be avoided; instead, a longer piece can be surfaced and then cut to the smaller sizes required. The operator's position is as shown in figure 352.

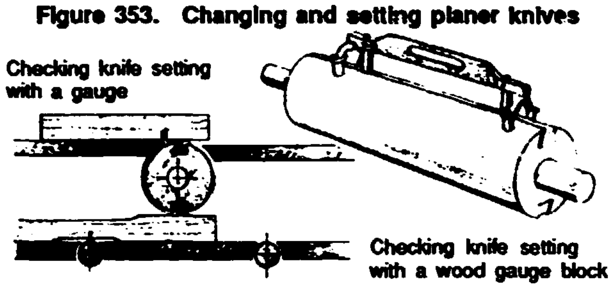
Figure 352. Operating a thicknesser



Changing and setting planer knives (figure 353)

The machine should be constructed such that it cannot be switched on accidentally. Securing bolts should be loosened and the knife should be removed. The mounting slot should be cleaned and the new knife should be degreased and assembled. The knife height should be set by means of a setting block or gauge (maximum projection 1.1 mm). The manufacturer's instructions should be followed for setting the retaining and lock screws (if there are none, screws should be set starting from the centre and working outwards to the ends). After any change of knife or adjustments to it, a test run should be carried out and the lock bolts should be tightened again.

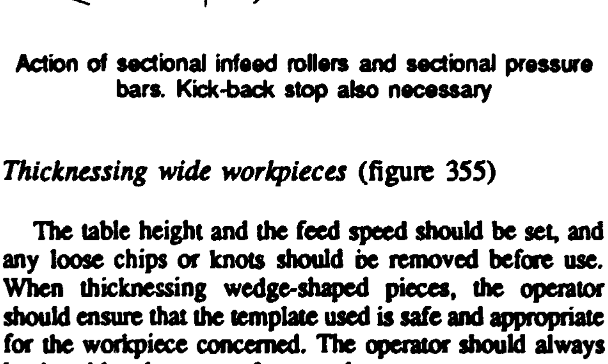
Figure 353. Changing and setting planer knives



Thicknessing narrow workpieces (figure 354)

The table height should be set for the required workpiece thickness. The appropriate feed speed should be selected and set. The operator should always feed in two pieces together on machines having fixed infeed rollers and back-pressure bars (place workpieces one near each end as shown in figure 354). When the machine is equipped with sectional top infeed rollers and sectional pressure bars, more pieces can be fed in simultaneously.

Figure 354. Thicknessing narrow pieces



Action of sectional infeed rollers and sectional pressure bars. Kick-back stop also necessary

Thicknessing wide workpieces (figure 355)

The table height and the feed speed should be set, and any loose chips or knots should be removed before use. When thicknessing wedge-shaped pieces, the operator should ensure that the template used is safe and appropriate for the workpiece concerned. The operator should always begin with a low rate of removal.

Operating spindle moulders (shapers)

The constructional details of a spindle moulder and the fence are shown in figures 356 and 357, respectively.

Figure 355. Thicknessing wide workpieces

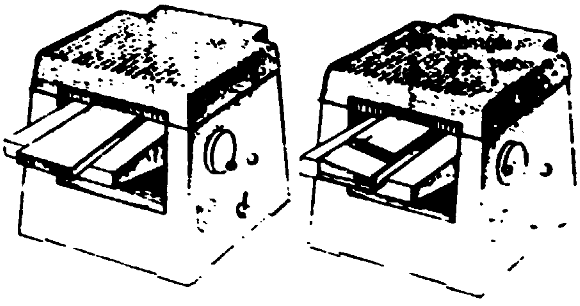
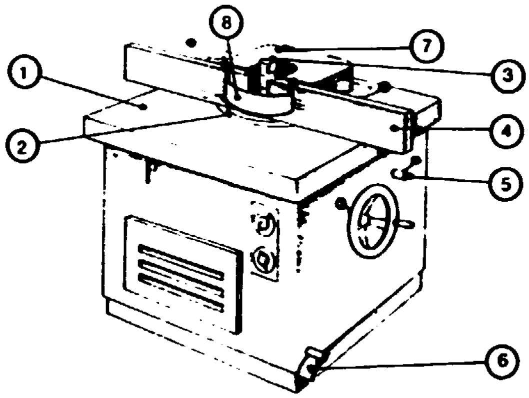
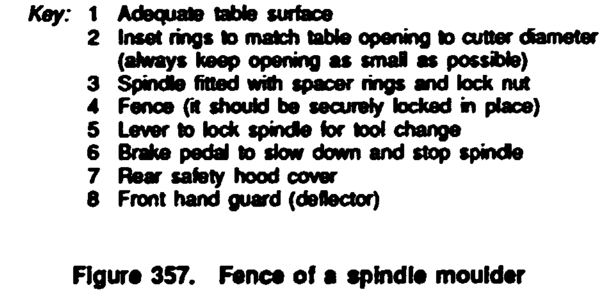


Figure 356. Spindle moulder



Key:
1 Adequate table surface
2 Inset rings to match table opening to cutter diameter (always keep opening as small as possible)
3 Spindle fitted with spacer rings and lock nut
4 Fence (it should be securely locked in place)
5 Lever to lock spindle for tool change
6 Brake pedal to slow down and stop spindle
7 Rear safety hood cover
8 Front hand guard (deflector)

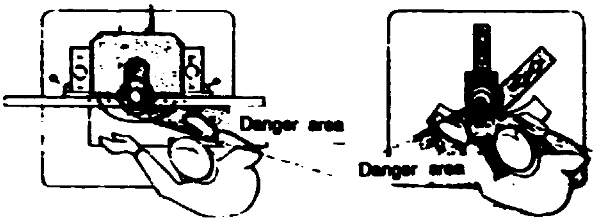
Figure 357. Fence of a spindle moulder



Key:
1 Fence parts bored with a series of holes for setting the front guard deflector adjusted according to tool diameter
2 Front hand guard deflector placed as shown
3 Back cover
4 Securing knobs for the placing and securing of fence to table
5 Securing levers for placing of fence parts

For straight feeding, the operator should set the fence as shown in figure 357 and make sure that the fence is securely clamped to avoid any danger of movement during cutting. The fence parts should be placed as near as possible to the tool and locked. The front hand guard deflector should be lowered to the workpiece's thickness. When contour shaping, there should always be a cover over the top of the tool. The operator's position and the position of the hands are as shown in figure 358.

Figure 358. Operating a spindle moulder



Setting up the spindle moulder (figures 356 and 359)

The careful preparation and setting up of the spindle moulder saves time in the end and is essential for safe operation. The following steps should be taken:

(a) When choosing the tool, the feed method, workpiece material etc. should be taken into consideration;

(b) The tool should be checked to make sure that it is tightly attached to the spindle. The knife faces must be clean and the cutting edges should be checked to ensure that they are not damaged;

(c) The RPM should be set to suit the tool and the workpiece;

(d) The cutting height and depth should be set to suit the workpiece with the machine stopped;

(e) The fence parts and the protective covers should be placed and tightened to suit the work to be done;

(f) To ensure safe operation, all the connecting parts, fixing knobs and levers (fence, protective covers, accessories, table extensions etc.) should be checked and tightened;

(g) The table opening should be closed with insert rings to suit the tool diameter;

(h) The front hand guard deflector should be put in place, and the rear cover hood should be closed;

(i) A test run should not be carried out without the protective covers in place;

(j) Ear muffs should be used to protect ears in noisy areas.

Moulding straight edges (figure 360)

An appropriate cutting tool with a chip gauge limit should be chosen for hand feeding. A sufficiently long piece for trial cuts should be used, and cutting should always start from the end of the workpiece. Stopped recess cutting should be avoided, or a kick-back stop appropriate to the workpiece should be used. The operator should never adjust the fence position with the machine running. The workpiece should be firmly pressed against the fence. The operator's hands should be placed in such a way that they need not be moved during cutting.

Figure 359. Setting up a spindle moulder

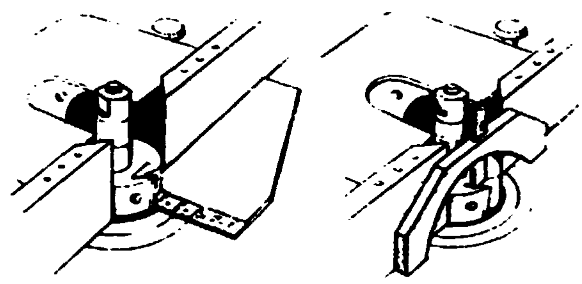
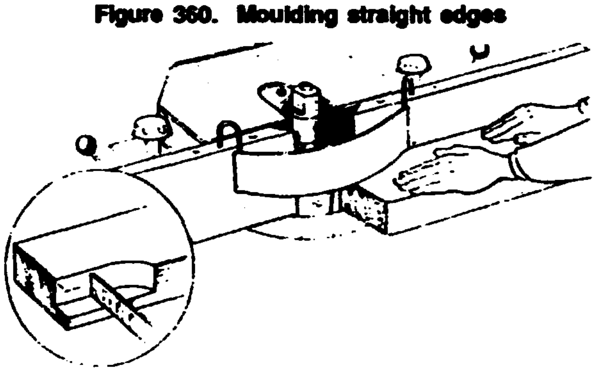


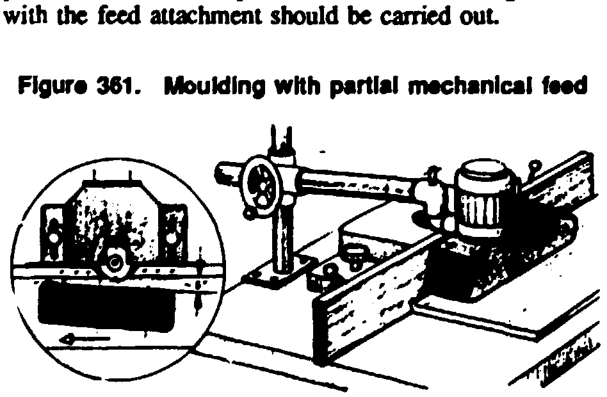
Figure 360. Moulding straight edges



Moulding with partial mechanical feed (feed attachment) (figure 361)

An appropriate cutting tool should be chosen for hand feeding or partial mechanical feeding. The operator should place and secure the fence. The feed attachment should be mounted slightly inclined to the direction of feed towards the fence to ensure that the workpiece is kept pressed against the fence. The fence gap should be kept to a minimum. The mechanical feed attachment should be mounted close to the tool, even when shaping wider workpieces, as it acts as a protective cover. A cutting test run with the feed attachment should be carried out.

Figure 361. Moulding with partial mechanical feed

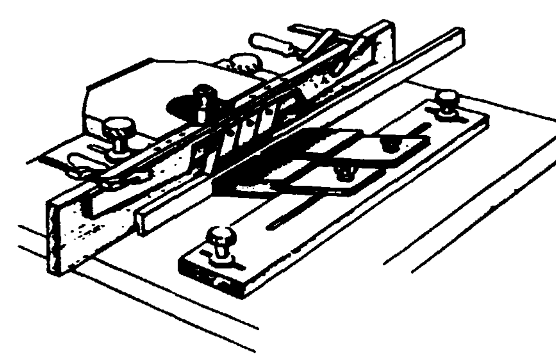


Moulding narrow workpieces (figure 362)

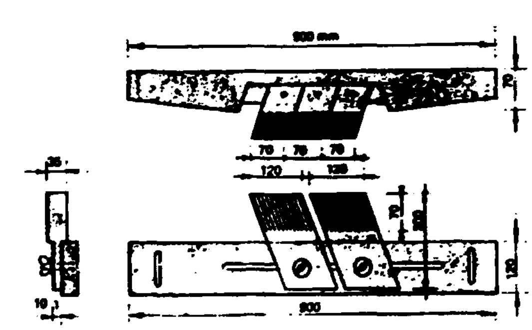
An appropriate cutting tool should be chosen for hand feeding. The operator should adjust the tool and place the fence as appropriate and place and clamp the comb-guide fingers in place where they will firmly hold and guide the workpiece against the cutting pressure. The comb-pressure fingers should always be placed where they will also act as an effective protective cover over the cutting area. When correctly mounted, the comb-pressure fingers will prevent the workpiece from being kicked back (in the direction against the arrow in figure 362 A). The comb (figure 362 B) can be made of hard wood; the teeth are cut parallel to the direction of the grip. The angle of the teeth to the workpiece's edge is approximately 70°.

Figure 362. Moulding narrow workpieces

A. The moulder



B. The comb



Moulding ends of thin workpieces (figure 363)

An appropriate cutting tool should be chosen for hand-feeding operations. The operator should attach an auxiliary guide block to the fence with a dove-tail slot in the fence gap area. The front cover deflector of the bent pressure spring should be put in place. A clearance in the auxiliary guide block stop should be cut, and the depth of cut required should be set accurately. A pusher block should always be used to feed the workpiece, and a support is needed for larger pieces to avoid tipping.

Moulding frames (figure 364)

An appropriate tool for hand feeding operations should be chosen. An auxiliary guide block should be attached to the fence. An arched pressure spring should be used as a front guard, or a front guard deflector should cover the top of the cutting area. A pusher block should be used for feeding to avoid tear out. A support that extends beyond the table should be used for longer frames.

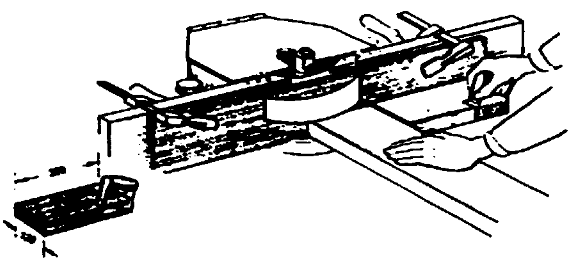


Figure 363. Moulding ends of thin workpieces
(Dimensions for guidance only)

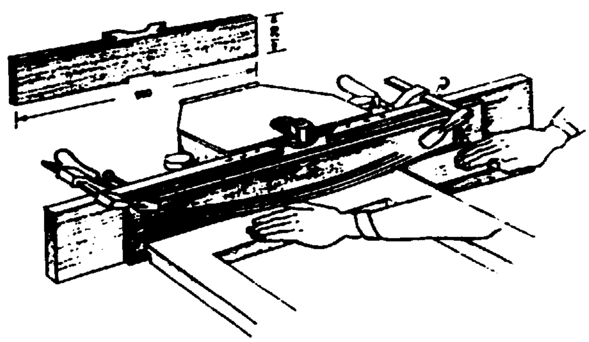
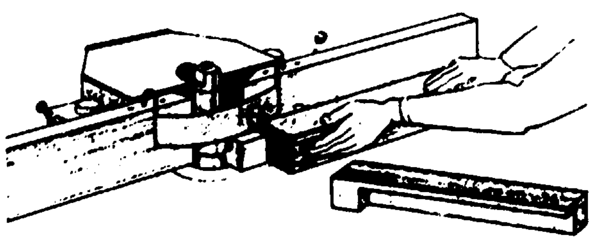


Figure 364. Moulding frames
(Dimensions for guidance only)

Moulding workpieces with a small cross-section (figure 365)

An appropriate cutting tool for hand feeding operations should be chosen. With the machine stopped, the operator should place the fence parts as close as possible to the tool. The workpiece should be fed only with a pusher block long enough to ensure a proper grip. The pusher should be so placed to ensure that it firmly holds the workpiece against the table and the fence while machining.

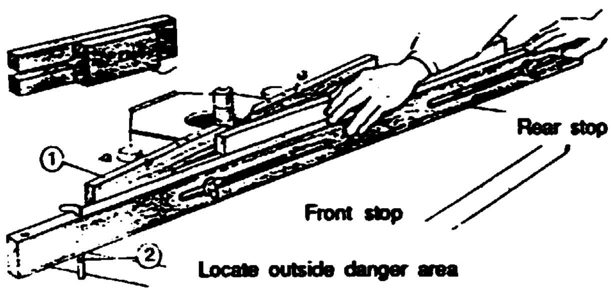
Figure 365. Moulding workpieces with a small cross-section



Stopped cutting of short workpieces (figure 366)

An appropriate cutting tool for hand feeding should be chosen. The spindle moulder should be set up, using a front hand guard deflector when cutting narrower pieces. The workpiece should be fit into an appropriately dimensioned recessed pusher block. The pre-set stops in the jig should be set for the correct length and the position of cut. The operator should make sure that the workpiece is securely held in the pusher block (using if necessary steel spikes firmly imbedded in the workpiece). The pusher block should be placed against the left-hand fence (see figure 336 (1)). The operator should make sure that the securing pivot (figure 336 (2)) of the jig is firmly located and swing the jig into place. Both hands should be kept well clear on the right-hand side of the cutter, as shown.

Figure 366. Stopped cutting of short workpieces

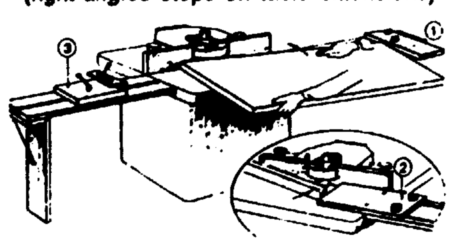


Key: 1 Left-hand fence
2 Securing pivot

Stopped cutting of long workpieces (figure 367)

An appropriate cutting tool for hand feeding should be chosen. The spindle moulder should be set up; a front hand guard deflector and a table extension should be used. Right-angled stops should be placed for the start and finish positions of cuts (figure 367 (1) and (3)). The workpiece should be placed as shown and dropped in to cut.

Figure 367. Stopped cutting of long workpieces
(right-angled stops on table extensions)

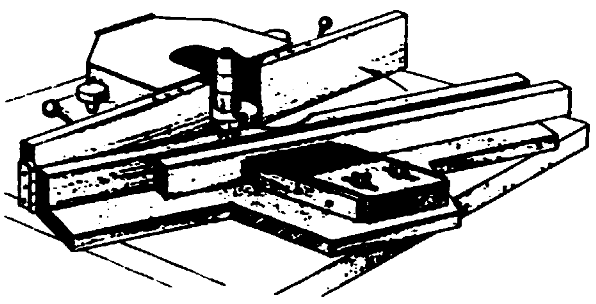


Key: 1 Stop for starting the cut (long workpiece)
2 Stop for starting the cut (shorter workpiece)
3 Stop for finishing the cut

Stopped cutting of long, thin workpieces (figure 368)

An appropriate cutting tool for hand feeding should be chosen. The spindle moulder and the hinged jig should be set up and the cutting centre marked on the jig arm and on the workpiece. The workpiece should be placed as shown with the jig arm swung out. The operator should align the cutting marks, swing the jig arm in to cut, feed the workpiece forward to the end of the cut required and then swing the jig arm out again to remove the workpiece. The operator should ensure that the jig is firmly held at the hinge. The pressure comb must hold the workpiece securely in place while cutting without danger of slipping. A comb with steel springs on the ends should be used.

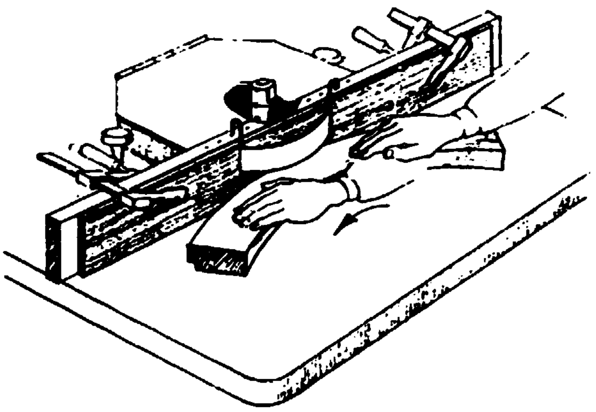
Figure 368. Stopped cutting of long, thin workpieces



Outside contour shaping (figure 369)

An appropriate cutting tool for hand feeding should be chosen. The operator should set up the spindle moulder, fit the auxiliary guide board to the fence and clamp it firmly in position and fit the front deflector. The centre of the deepest cut should be marked on the auxiliary board to keep the workpiece pressed to this point while cutting.

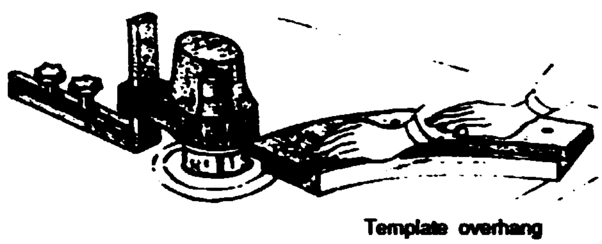
Figure 369. Outside contour shaping



Contour shaping using a template (figure 370)

An appropriate cutting tool for hand feeding should be chosen. The operator should fix a guide roller on top of the tool where it will safely guide the template and fix a ring guard with a sturdy bracket firmly above the guide roller and centred over it. The ring guard should extend some 15 mm beyond the tool circumference. The template overhang end should be placed against the shaping collar. The operator should begin the cut slowly and then feed steadily on, pressing and guiding on the collar. When cutting against the grain, the operator should proceed by turning over the workpiece.

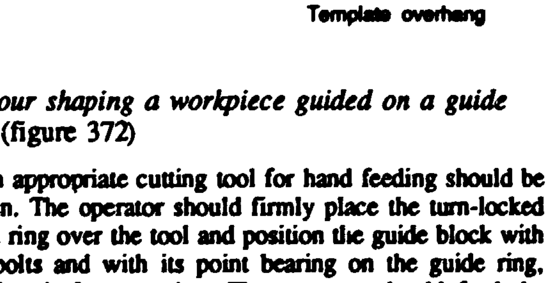
Figure 370. Contour shaping using a template



Contour shaping using a clamping template (figure 371)

An appropriate cutting tool for hand feeding should be chosen. The operator should securely fit the guide roller below the tool, position a suitable size of ring guard over the tool, set the workpiece in the template and clamp it securely and bring the template overhang to bear on the roller and feed inward to cut steadily. The workpiece should be turned over when cutting against the grain. The operator's hand should be placed on the template well away from the cutting area. When a template is needed for long runs, it can be fitted with quick-release toggle clamps for securing workpieces.

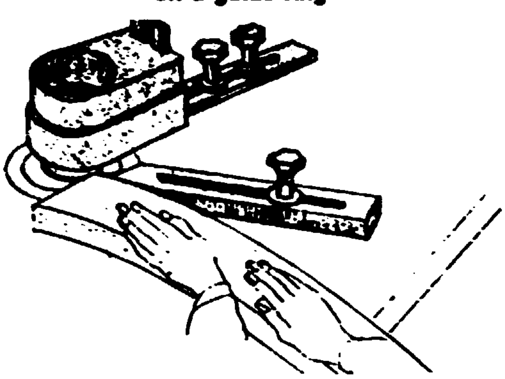
Figure 371. Contour-shaping a clamping template



Contour shaping a workpiece guided on a guide ring (figure 372)

An appropriate cutting tool for hand feeding should be chosen. The operator should firmly place the turn-locked guard ring over the tool and position the guide block with two bolts and with its point bearing on the guide ring, stopping it from turning. The operator should feed the workpiece along the guide block to the guide ring and start the cut, keeping the workpiece firmly pressed against the ring. When contour shaping, there should always be adequate protection over the tool. An additional ring guard should be used if necessary.

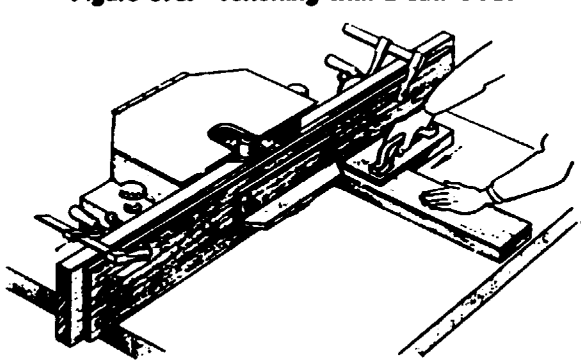
Figure 372. Contour shaping a workpiece guided on a guide ring



Tenoning with a saw blade (figure 373)

A saw blade with a wide-tooth pitch, preferably with a chip gauge limitation, should be chosen. The operator should firmly clamp a guide board in position along the fence. A suitable front guard deflector or a right-angled guard (the height of which can be adjusted as shown in figure 373) should also be used. A pusher block should be used to feed the workpiece, and pressure should be applied on to the table. The guide board along the fence must provide continuous guidance.

Figure 373. Tenoning with a saw blade

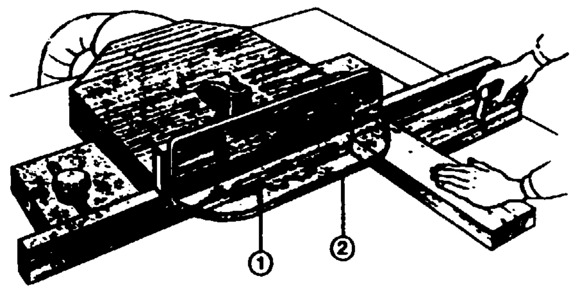


For larger saw blades, an appropriate protective cover should be used, as shown in figure 374. The fence or guide on the safety box must provide continuous guidance. This can be by means of a lower guide rail (figure 374 (1)). An angle piece (figure 374 (2)) should be mounted as a front guard, and the height appropriate for the workpiece thickness should be set.

Tenoning with a tenoning disc (figure 375)

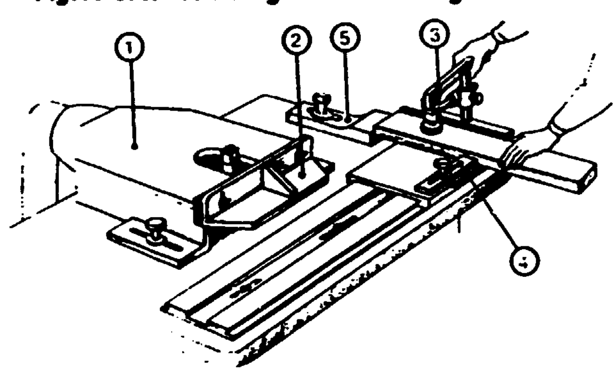
A cutting tool designed for hand feeding or partial mechanical feeding should be chosen. The workpiece should be firmly clamped on a workpiece slide (partial mechanical feed). The tool-carrying spindle must be sturdy (loose spindle diameter 40 mm or with counter bearing 30 mm diameter). An appropriate hood (figure 375 (1)) with an angle guide (2) should be used for the cutting tool. The operator should firmly clamp the workpiece against turning. The operator's hands should remain on the clamp lever (3) during the cut to prevent accidental loosening. The stop (4) is set so as to prevent the workpiece from being rotated when it comes in contact with the cutting tool. The block (5) should be mounted on the table to help place the workpiece correctly before clamping.

Figure 374. Tenoning with a large saw blade



Key: 1 Lower guide rail
2 Angle piece

Figure 375. Tenoning with a tenoning disc



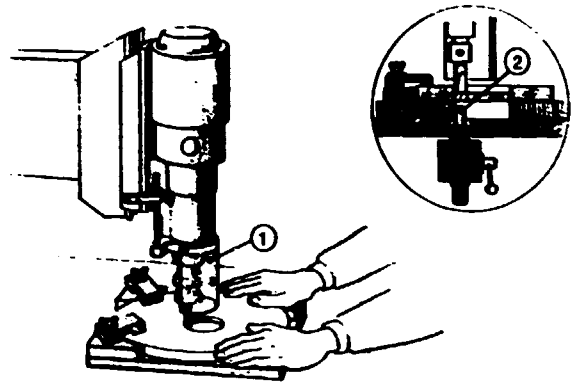
Operating routers

The operator should place the protective covers in the correct position (deflector, brush ring, spring loaded ring) (figure 376 (1)). Covers that also protect the cutting area while machining are preferable to other covers. The operator should feed the workpiece or the template against the prepositioned guide or the copying pin (2), which should be set to suit the template thickness, and set the protective cover to the template height. After the machine is switched on, the router tool should be lowered to the cutting position, avoiding milling when feeding. The workpiece or the template should be held firmly, keeping the hands clear of the cutting area.

Operating chain mortising machines

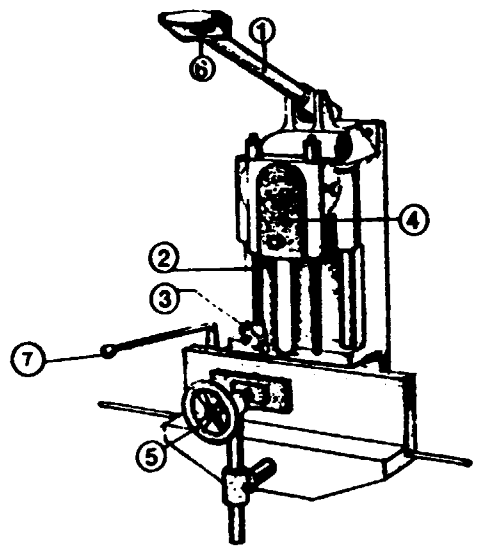
The constructional details of a chain mortising machine are shown in figure 377.

Figure 376. Router



Key: 1 Protection cover
2 Guide pin

Figure 377. Chain mortising machine

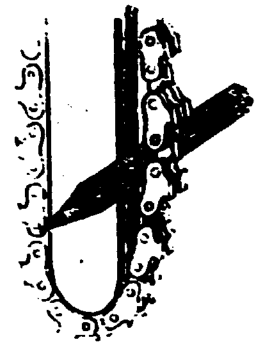


Key: 1 Lever for lowering mortising head
2 Adjustable protection rods
3 Chip breaker mounted on a rod on the chip throwing side
4 Enclosure over the chain drive head
5 Workpiece clamp
6 Safety switch to avoid unintentional start when the lever (1) is used to maintain operation
7 Slide lever

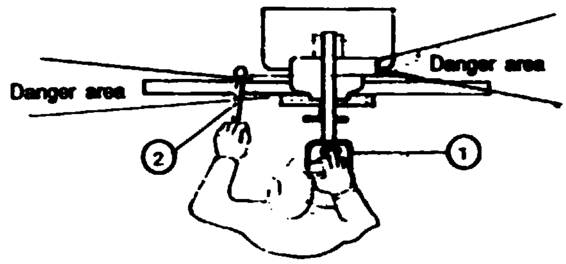
To operate the chain mortising machine, the operator should first check the chain's tension, using the pencil test (figure 378 A). The workpiece should be firmly clamped in place. The operator should check to see that the protection rods move freely and set them for the workpiece's height. With the right hand on the lever handle (figure 378 B (1)), the operator should lower to cut and feed the workpiece with the left hand with the lever (figure 378 B (2)). When the machine is in operation, hands should be kept clear of the workpiece.

Figure 378. Operating a chain mortising machine

A. Pencil tension test



B. Worker's position in operating chain mortising machines



Key: 1 Operating handle
2 Slide lever handle

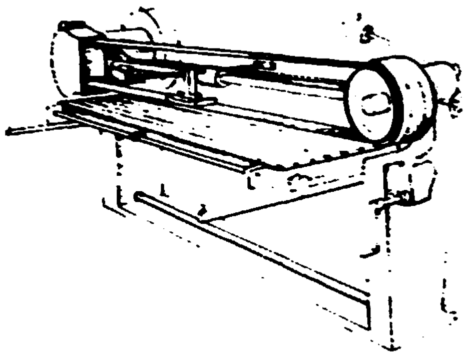
Operating belt sanders

The constructional details of a belt sander are shown in figure 379. For machines built before 1980: the outside parts of the pulley rims must be covered and the spoked wheels enclosed; maximum displacement of the table must be restricted to ensure that the guide hand rail remains clear of the belt edges at the full extremity of the table travel; and dust-exhaust facilities must be provided. For machines built since 1980 the sanding belt is fully enclosed over its return length and over the shaft right up to the immediate working area; attachments must be fitted to avoid any danger of injury from the belt edges (limited travel of table, pressure pad, sanding pad guide); and dust-exhaust facilities must be provided.

To operate a belt sander (figure 380) the table height should be set for the thickness of the workpiece to be sanded. Sanding should preferably be near the dust collector end whenever possible, particularly with short pieces. Damaged sanding belts should be removed and replaced without delay. The belt's tension should be checked regularly. Any accumulated dust from the machine should be cleaned out regularly.

Figure 379. Belt sander

A. Belt sander built up to 1979



B. Belt sander built since 1980

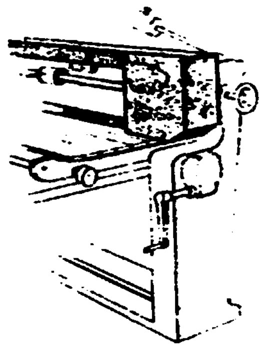
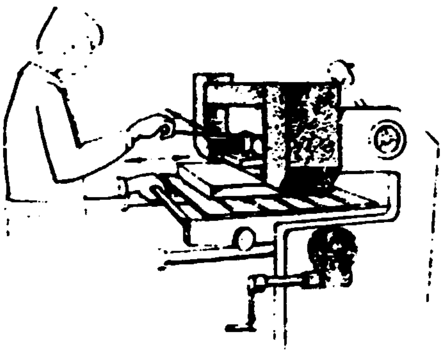


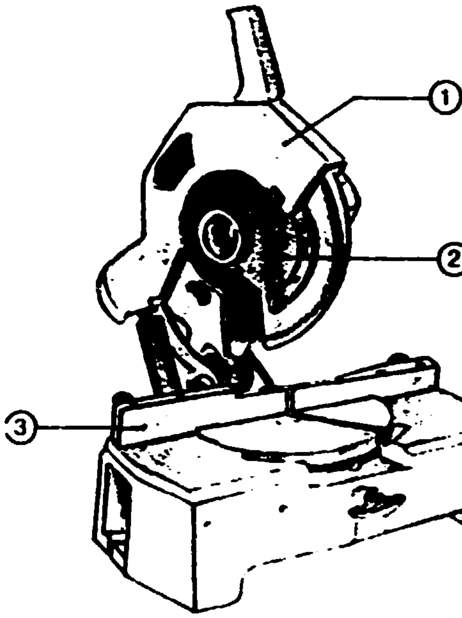
Figure 380. Operating a belt sander



Operating cross-cut saws

The constructional details of a cross-cut saw are shown in figure 381. Machines produced after 1980 should be provided with an attachment that automatically returns the saw head to its rest position and locks it after use. The operator should check and set the fence parts open to the smallest possible safe clearance, particularly when cutting strips or battens. The operator should then set the mitre angle and place the workpiece firmly against the fence, holding it with the right hand, well clear of the cutting area, firmly against the table and fence and lower the saw unit to its cutting position with the left hand.

Figure 381. Cross-cut saw



Key: 1 Integral enclosure of the unit and the saw blade up to its maximum cutting depth
2 Sliding saw blade guard with safety catch to secure the guard in the rest position
3 Fence

Operating boring machines

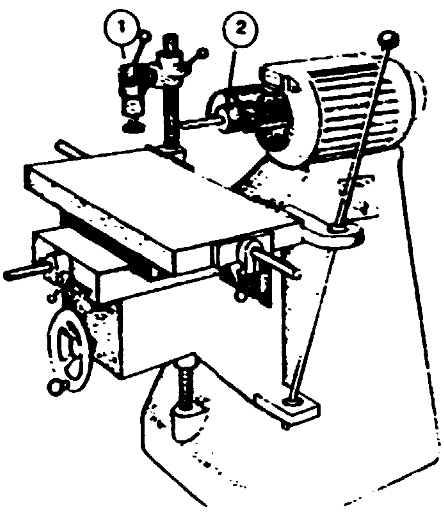
Slot mortising machines

The constructional details of slot mortising machines are shown in figure 382. The operator should clamp the workpiece securely, adjust the table height and the stops, limiting the table's movements in both axes, adjust the boring depth on the machines with a travelling boring unit and bore smoothly, boring a depth fully and then moving to the next depth and boring it.

Drill press

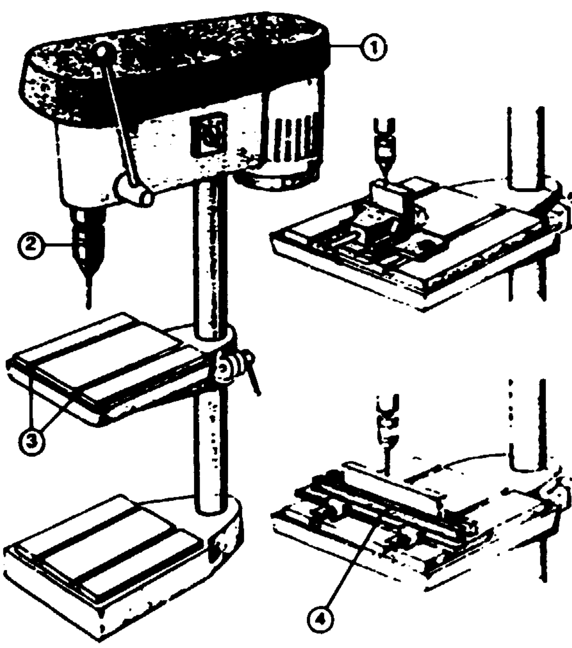
The constructional details of a drill press are shown in figure 383. The work table must be equipped for mounting and securing the workpieces (figure 383 (3)). Large open pulleys and drive belts (on older machines) must be enclosed (l) with additional protective covers. The operator should place the workpiece on the table and secure it firmly to prevent turning. Smaller pieces can be held in a machine vice (the vice should be secured to the table with at least two bolts). For drilling a series of holes in line, a drill template that is firmly clamped to the table (figure 383 (4)) should be used. The operator should not wear rings and a wrist watch and should have close-fitting clothes, wear a cap or hair net to keep hair from getting caught in rotating parts and, when drilling brittle material, use goggles.

Figure 382. Slot mortising machine



Key: 1 Workpiece clamping attachment
2 Hinged flap cover for chuck

Figure 383. Drill press



Key: 1 Drive mechanism enclosure
2 Drill chuck (Tool chucks with protruding parts must be equipped with additional slots or other covers.)
3 Base for mounting the workpiece
4 Drill template clamped to table

Operating power tools

The operator must be able to switch off power tools without a need to release the hand grip. To use, the operator should check the cable and the plug, lay the cable clear of any obstructions or danger of damage and where it is not likely to be tripped over and place the workpiece firmly on a suitable support, ensuring that it will not move about when working pressure is applied. Any safety and switching mechanisms should be checked before use. The operator should use both hands whenever possible to hold and guide the machine. Where appropriate an extra handle, provided for the purpose on many power drills, should be attached.

The machine should be switched on only in the work position; before placing the machine aside it should be disconnected from the mains. The operator must be sure to use only the machine's on-off switch and never use the plug as a switching device. After use the operator should switch off the machine immediately, wait for it to come to a complete stop and place it securely aside where there is no danger of it tilting over or falling.

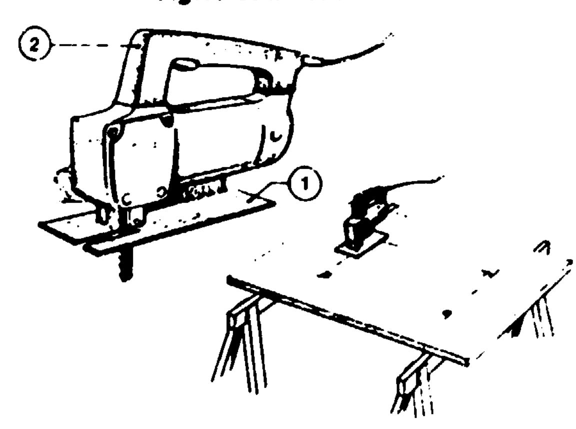
The machine must be disconnected from the mains before changing tools, servicing it, maintaining it or setting up its accessories. All hand-held machines should be regularly checked and maintained by skilled technicians.

The proper protective covers etc. designed specifically for the purpose must in all cases be fitted to the machines in accordance with their intended use (drilling, boring, sawing, routing). Hand-held machines, when used as stationary machines (built in or mounted on stands or tables etc.), should be equipped with the safety features recommended for stationary machines.

Sabre saws (jig saws) (figure 384)

The operator should place the workpiece and secure it against movement during cutting. For inset cuts, a starting hole should preferably be drilled in advance. The operator should not hold the workpiece near the cutting area and should place the machine in a starting position before switching it on.

Figure 384. Sabre saw

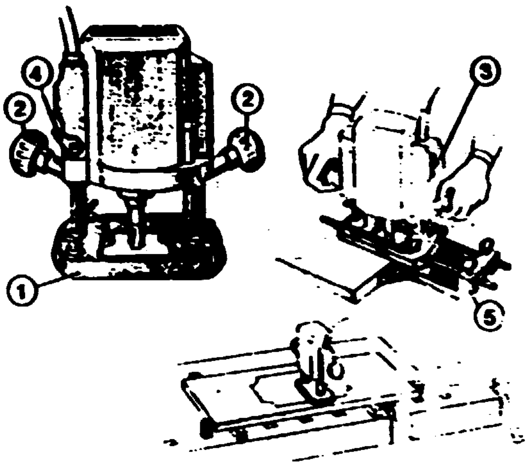


Key: 1 Large rigid guide plate
2 Hand grip with on-off trigger

Hand router (figure 385)

The operator should choose and fit appropriate bits and set the depth of cut, using a jig to guide the machine safety. The workpiece should be conveniently placed for routing and securely clamped. When using a template, it should be firmly secured.

Figure 385. Hand router

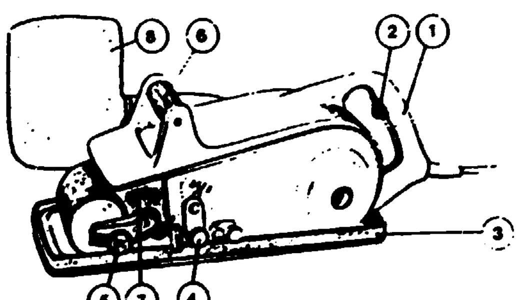


Key:
1 Machine guide frame
2 Hand grips
3 On-off switch within easy reach of grip
4 Release lever, automatic safety catch for guide frame
5 Use machine safety guide

Hand-held belt sanders

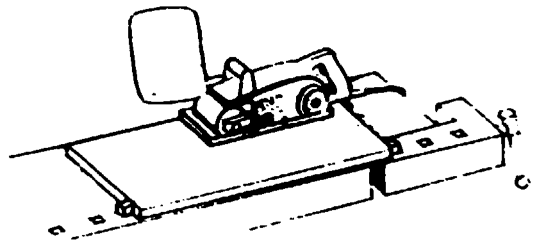
The constructional details of a hand-held belt sander are shown in figure 386. The operator should check the electrical cable and the fittings, check the sanding belt tension and make sure that it is running true, use both hands to hold and guide the machine and ensure that the workpiece is securely held in position before using the machine (figure 387).

Figure 386. Hand-held belt sander



Key:
1 Hand grip switch
2 Built-in on-off switch
3 Machine frame with brush rim
4 Sanding belt tensioner
5 Roller guide adjustment to centre sanding belt run
6 Guiding grip
7 Belt protective cover
8 Dust collecting bag

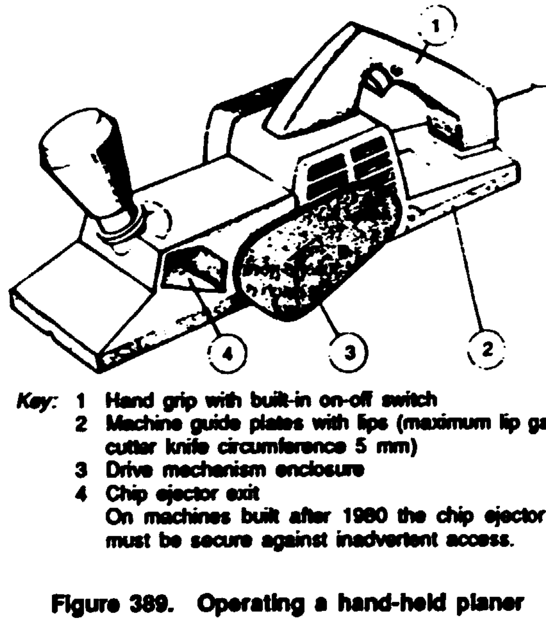
Figure 387 Operating a hand-held belt sander



Hand-held planer

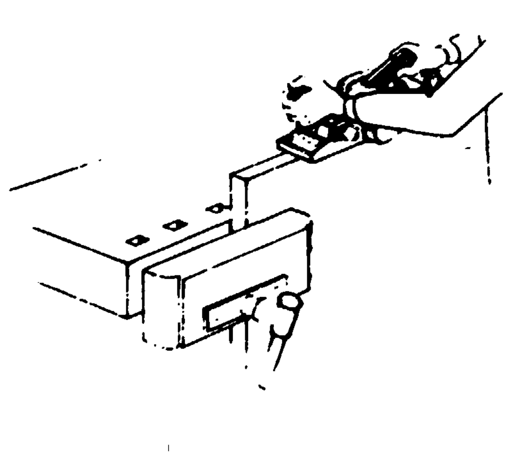
The construction details of a hand-held planer are shown in figure 388. The operator should check and set the table position for the cutting depth required, securely clamp the workpiece and place the machine on the workpiece before switching it on (figure 389). Immediately after use, the operator should switch off the machine and make sure that the machine comes to a complete stop before putting it aside.

Figure 388. Hand-held planer



Key:
1 Hand grip with built-in on-off switch
2 Machine guide plates with lips (maximum lip gap to cutter knife circumference 5 mm)
3 Drive mechanism enclosure
4 Chip ejector exit
On machines built after 1980 the chip ejector exit must be secure against inadvertent access.

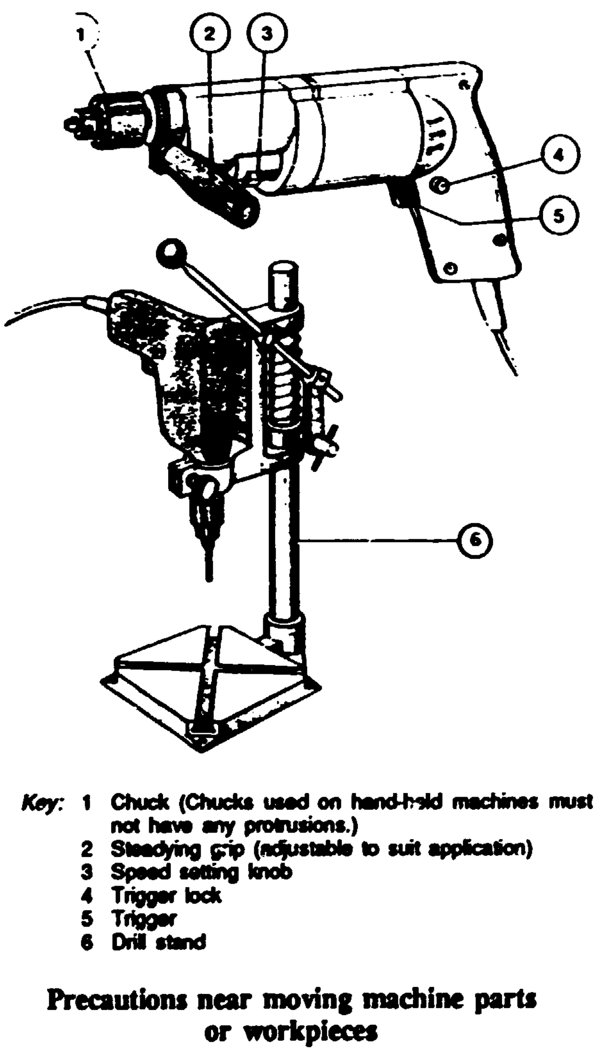
Figure 389. Operating a hand-held planer



Power drills (figure 390)

An appropriate bit to suit the material of the workpiece should be chosen. When working on brittle materials or overhead, the operator should always use goggles. The grip should be placed to suit working conditions. Smaller workpieces should be clamped against turning before drilling. Whenever possible, a fixed depth bore stop should be used (stops mounted on the chuck rotating with the drill can cause an additional torque effect). A drill stand should be used whenever possible.

Figure 390. Power drill



Key: 1 Chuck (Chucks used on hand-held machines must not have any protrusions.)
2 Steadying grip (adjustable to suit application)
3 Speed setting knob
4 Trigger lock
5 Trigger
6 Drill stand

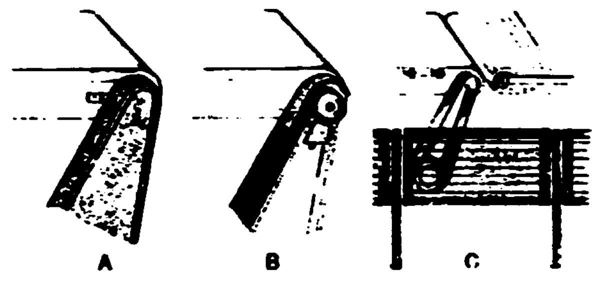
Precautions near moving machine parts or workpieces

Dangerously exposed parts on power-driven machines can cause squeeze, sheer, cut, press, push, catch, crush etc. effects. To minimize the risks of any accidental contact with such parts of machines, they must be enclosed or covered where possible or guarded so that the operator cannot inadvertently touch them.

Machine tools and other power-driven machine parts must be protected from the risk of accidental contact by means of enclosures, covers, guards, deflectors or automatic switch-off facilities, as shown in figure 391.

A safety enclosure device (figure 391 A) is placed directly over and completely encloses the dangerous area, on its own or with other parts, closing it off from reach. A cover (figure 391 B) is a safety device placed directly over the dangerous area; it covers the dangerous area from one or more sides. A guard (figure 391 C) is a safety device provided in the form of a fence or railings to close off dangerous parts.

Figure 391. Protection devices

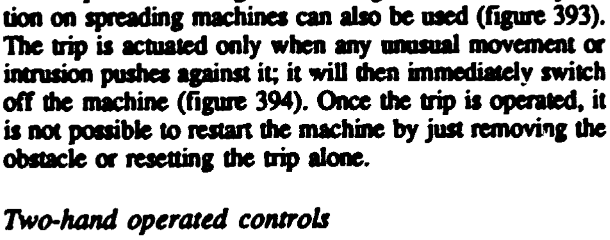


Protection devices in feed units

Where none of the previously mentioned and illustrated methods can be applied, some means should be provided to stop the moving parts before anyone can approach too closely.

A danger trip switch fitted with a rip cord can be placed in front of the drive shaft of feed systems of certain machines—such as double-end tenoners—(figure 392). The emergency trip switch must switch the machine off whenever the rip cord is either extended or broken. The rip cord must be so placed as to effectively protect the entire length of the danger zone.

Figure 392. Trip switch fitted to infeed side of mechanical systems



A trip bar extending the full length of the infeed position on spreading machines can also be used (figure 393). The trip is actuated only when any unusual movement or intrusion pushes against it; it will then immediately switch off the machine (figure 394). Once the trip is operated, it is not possible to restart the machine by just removing the obstacle or resetting the trip alone.

Two-hand operated controls

In specific cases, where a danger to the operator still exists despite other safety measures, additional safety can be achieved by using two-hand controls (figure 395). Both hands must be on the controls to start the machine, thus ensuring that they are clear of any danger area. Two-hand controls must meet the following conditions:

(a) The control buttons must be placed well clear of the danger area and be of a non-latching self-release type;

(b) They should also be spaced far enough apart to make sure that both hands are used;

(c) Should either button be released, the machine should be temporarily switched off;

(d) To switch the machine on again, both control buttons must be returned to their rest position.

Figure 393. Trip bar

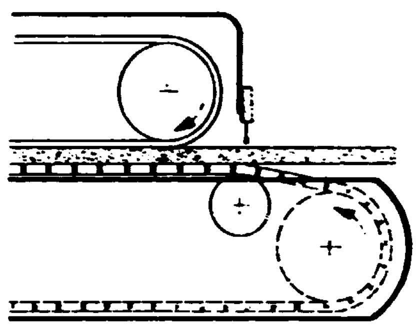


Figure 394. Trip bar in use

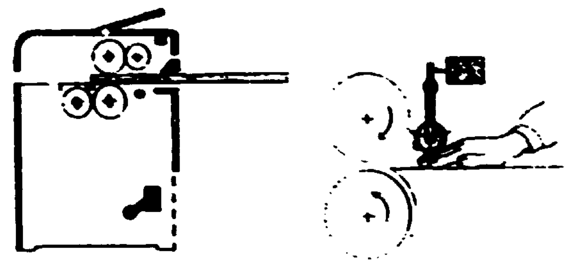
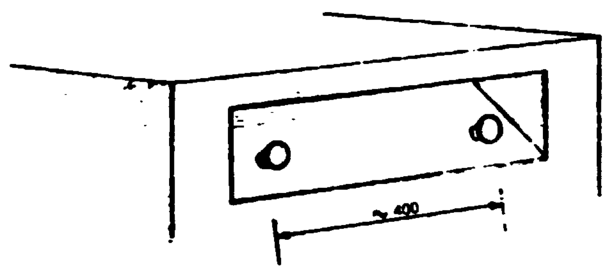


Figure 395. Two-hand control



XXIX. Maintenance of machines and equipment*

This chapter is limited to the machines and equipment that perform primary functions in large and middle-sized industrial plants, although much of the information given is also applicable to well-managed smaller plants. These functions comprise:

- Maintenance of machines and tools
- Advance service and lubrication
- Erection of new machines and equipment
- Modifications of various kinds
- Generation and distribution of electricity, steam, compressed air etc.

The so-called secondary functions in maintenance work comprise:

- Cleaning
- Handling of trash, waste etc.
- Experimental work, building of new machines and equipment
- Certain stocking functions
- Plant security and fire protection

These secondary functions must be accomplished as a centralized part of maintenance in a large-scale plant if it includes several shops or if it deals with several fields of the woodworking industry and not only with furniture and joinery products.

The amount of maintenance work in industry has continually increased, and the same tendency may be expected to continue. At present, the number of maintenance workers in the mechanical wood-processing industry is 10 to 15 per cent of the total number, and in the particle board industry this number is even greater.

The continual increase of maintenance work results from the following circumstances:

(a) The rapid and continual increase in mechanization, automation and the general development of the industry which have greatly reduced the number of production workers in actual industry;

(b) The considerable increase in facilities and tools for maintenance;

(c) The decreasing importance of worker absenteeism and the increasing importance of machine down time;

(d) The increasingly capital-intensive nature of industry with the concomitant need for continuous operation, in other words, for two- or three-shift work;

(e) The increasing speeds, pressures, temperatures and capacities of machines, resulting in more rapid wear;

(f) Consumer demand for higher precision of machines and improved quality of products;

(g) Need to rearrange machines and equipment;

(h) Safety at work, air-conditioning and industrial hygiene;

(i) The increased awareness of the social and economic problems related to the treatment and disposal of industrial wastes.

The demand for craftsmanship required for maintenance has also continually increased, especially for instrumentation and automation. The use and handling of new materials, such as plastics, contribute to this trend. Previously, maintenance meant simply repairing something that had broken down. At present, however, there is a strong tendency towards preventive maintenance, which must be considered as a fairly advanced form of maintenance.

Equipment is becoming complicated, and its maintenance and repair call for workers with such great professional skill that only large companies can afford to employ them. Other enterprises must resort to spare-part replacement arrangements. Damaged parts are sent to a special factory or shop for repair. Importers or licensed manufacturers give information on such special repair shops. Annual or other long-term agreements will ensure that the special repair shop always has spare parts or machines in readiness for the customer.

In general, such external help in repair work will become more usual, particularly since it will make possible specialized service for tasks that cannot be done within small organizations. The diesel motor for trucks or for other machines is a good example of such a changeable part. This motor is usually changed and taken to a special shop for repair, where a new motor is in readiness if some damage occurs. This arrangement is suitable for lumber and log yards. However, it should be remembered that when machines are purchased their motors should be of the same type and at least made by the same manufacturer.

Organization of maintenance

The organization of maintenance has changed decisively over the years. Formerly, all repair work was done by one person, but a modern form of organization has gradually developed. The position of maintenance in an enterprise has also changed: once subordinate to production, it is now becoming equal to it and directly accountable to the highest management.

In connection with the reorganization of maintenance and with organization in general, the following circumstances should be noted:

(a) If the field of tasks becomes wider, technical and economic know-how should be added to the supervision of

*By Ahti Akkanen, Lahden Rautateollisuus Oy, Lahti, Finland. Originally issued as ID/WG.133/25.

maintenance. In general, when the amount of work increases, the number of fitters and other workers is also increased but not the number of engineers and technicians. If the office staff is inadequate, the maintenance supervisory personnel must often do much mechanical and routine work, to the detriment of planning control etc. It is often forgotten that increasing the number of persons and the amount of labour always calls for additonal staff for supervision, control and routine work. If technical staff is lacking, foremen can be designated in certain areas, leaving supervisory personnel to control larger groups;

(b) The use of too many unskilled workers should be avoided; the number of such auxiliary workers should not exceed 20 per cent of that of craftsmen. The maintenance department, however, should not become a place for superannuated persons, and the repair shop should not become a museum of outdated woodworking machines. Securing new and skilled labour calls for training, but the training should not be done in such a way that a young worker goes on year after year helping an older craftsman. It should be done under the leadership of competent trainers;

(c) Furthermore, it should be noted in budgeting and in future planning that entirely new tasks and departments are coming into the maintenance organization such as, for instance, separate departments for preventive maintenance, scrapping and repair, plastics and instrumentation and automation (possibly even electronics).

In general, within the overall maintenance organization, there are so-called decentralized and centralized systems. In the former, maintenance personnel are divided into small groups around the factory and are often in some way subordinated to the local production supervision, whereas in the latter, work is directed from one point and is subordinated to centralized supervision. Both systems have their benefits and disadvantages. The appropriate system should be selected separately in each particular case, taking into consideration such circumstances as the nature of the working process, the cost of down time per minute, the number of interruptions in work, the degree of mechanization and automation and the general development of maintenance work.

As a rule, small enterprises should strive for centralization. However, when the factory area becomes so large that unnecessary (and time-consuming) walking is a considerable cost factor, it is advisable to consider at least a partly decentralized organization. It is, however, advisable to try to retain centralized supervision. The same applies to automation and to a situation in which expensive basic machines with high capacities (for instance, in the furniture and joinery industries, a painting line) are in operation. In such cases it is worth having maintenance workers to control the operation and the condition of the equipment.

Nevertheless, the following functions should be centralized:

- Planning work
- The generation and distribution to production areas of electricity, steam, compressed air etc.
- Maintenance of elevators, cars, trucks etc.
- Care of the sprinkler fire-extinguishing system, pneumatic conveyors and air-conditioning
- Machining works
- The major part of wood-based panel plants
- Building and repair shops
- The internal telephone network
- Assignment of auxiliary labour power

In principle, each group should be led by a foreman of the same occupation. It is inadvisable, for instance, to make maintenance workers subordinate to production leadership. It would be advisable, however, to subordinate decentralized maintenance groups directly to the maintenance leadership, but their work should be assigned by the production leadership.

Maintenance card files

The proper organization of maintenance is not possible without card files. It is almost impossible even to begin preventive maintenance without repair statistics made over several months and, preferable, over several years for each individual machine. It is easy to record data on a machine card when it is at hand—such data as the number of the bearings when the machine is disassembled, the number of the belts before they are worn out and the weight of a machine when it is to be seen on the bill of lading.

The objects that should have file cards are similar in various industrial plants. However, it is worth noting which objects should or should not have such records. For instance, in the furniture and joinery industries, the objects for filing are woodworking machines, presses, conveyors and certain hand tools such as sanders.

The basic card also serves as an inventory list for fire and other insurance. If it includes sufficient data on belts, bearings, lubricants and the like, it makes an excellent starting point for the standardization of maintenance procedures. Cards have sometimes been prepared separately for each machine type, but in the furniture and joinery industries, such differentiation is of little value. In practice, the data common to different machines are most generally needed. Thus, a single form with plenty of room for notes is generally sufficient.

The card for electric motors might be mentioned as an exception. This form may be small and should usually be kept in the electrical repairs department. Only basic electro-technical data such as motor type, serial number and revolutions per minute need to be entered on the card. For practical reasons, data on repairs and maintenance are entered on a separate blank form, which can be kept together with the machine card. Data on repairs accumulate quickly, and it is difficult to provide space enough on the basic card for detailed work descriptions, data on spare parts used etc. The basic card and repair card as such can also be used for time-schedule control (inspections of preventive service, lubrication service etc.).

The numbering of machines for the machine card file can be done in various ways; the most usual way is to give a running number to the buying or arriving order or a certain number series for each machine type. A third alternative is to have a separate series of numbers for the machines of each individual department.

Preventive maintenance

Correct preventive maintenance should cover the entire plant, including the factory building and its transportation lines and utility mains and not merely the machines and equipment.

In general, the nature of maintenance is still passive; its function normally begins only when the machine breaks down. It should be active, however, through inspection and service lubricating and continuous observation of the condition of the machine. Basic repairs, carefully planned, should be made at the appropriate time in conjunction with production.

Preventive maintenance is not a new idea. In some fields, as for instance in lifts, aircraft, railroads and pressure chambers, regular inspection has been standard practice for decades. It is an extensive function, entailing:

(a) Inspection of machines and devices;

(b) Minor repairs, adjustments, cleaning and the like performed during inspections;

(c) Complete overhauls planned in advance and work done during shut-downs;

(d) Lubrication service;

(e) Investigation into, and selection of, new parts and raw materials;

(f) Investigation, comparison and recommendation of various protective devices and coatings.

Preventive maintenance naturally involves some costs, so that the objects and scope of maintenance should be carefully planned. In the furniture and joinery industries, maintenance should be extended to painting and laminating equipment, rapidly rotating bearings, drive belts, chains and sprockets.

Before an extensive maintenance programme is begun, the persons concerned should be entrusted only with this work and with nothing else. The following documents and data will then be essential:

Card files on all machines and devices
All documents and instructions for each machine
Drawings of machines and devices, particularly of large ones
Statistics on breakdowns
Data on repairs
Diagrams of all utility lines
Organization of a reliable spare-parts service

Furthermore, it is important that the preventive service group consist of eager and active workers.

Inspection includes two different functions: routine inspection and maintenance; and inspection according to the programme for each particular machine. In the furniture and joinery industries, the former functions should be applied to:

Electric motors
Power transmission devices
Piping, valves and pumps
Conveying equipment, elevators and lift tables
Air-conditioning and dust-extraction devices
Lighting devices
Office machines
Instruments and automation devices

As examples of inspection periods, the functions could comprise:

(a) Weekly inspection of scales, cooling equipment, photoelectric cells, tools with electric or compressed-air motors and spraying and air-conditioning devices for paint shops;

(b) Inspection every second week of belts, couplings, starters and electric motors; of instruments and electrical control devices; and of air compressors, pumps and air-conditioning equipment;

(c) Monthly inspection of blowers and belt, pneumatic and hydraulic conveyors; of water-treating plants; and of lifting devices and elevators;

(d) Inspection every three months of chargers for accumulators, boilers and lighting, welding machines and transformers;

(e) Inspection every six months of fire-extinguishing equipment, water tanks and their fittings, piping, power lines and heating apparatus;

(f) Yearly inspection of small electric blowers and normally operating ball-bearings.

A good example of preventive maintenance is the observation of a shaft bearing the cutter heads which, for a high-speed machine such as a single-spindle shaper, operates at more than 9,000 rev/min. A broken bearing may cause the breakdown of the entire machine. By observing this bearing regularly, it will be possible to determine the right moment for replacing it, and thus damage can be avoided.

The above lists serve only as examples; some equipment may require several different inspection periods, such as daily cleaning, weekly adjustment, monthly inspection of operation and annual overhaul. The correct determination of the inspection period is the basic requirement for a successful programme of preventive maintenance. Too frequent inspection wastes labour and money; too infrequent inspection jeopardizes the machinery. The periods between inspections must be changed to conform to changed conditions, and by observing the changes that have occurred, it is possible to adjust these periods.

Inspections may take place either when the machines are operating or when they are not. In the first case, this is done when abnormal vibration, wear, lubrication faults (oil leakages), excessive heating, poorly fixed parts, play of shafts etc. can be observed. However, it should be noted that in the furniture and joinery industries a knife in poor condition may cause some of these abnormalities, so that the intervals between the replacement of knives in wood-working machines should be carefully observed.

When machines are not operating, the possibilities for inspection are considerably greater; experience has shown that at least every third inspection should be made at this time since inspection and measuring of shafts, bearings, gear wheels, slide surfaces, belts and flanges, as well as of tensions, will then be possible. Machines that produce a great deal of sawdust and chips should be inspected especially when idle because parts not normally visible can then be checked. For inspection, the dust and chips should be removed from the machines. In tropical conditions, the thickness and degree of protection of grease coatings should be ascertained at the same time.

Preventive engineering

Preventive engineering entails the investigation and selection of raw materials and various protection, so that the need for repair can be avoided or reduced. When the preventive maintenance programme has developed, some causes of breakdowns and repairs are discovered, and in many cases this can be attributed to poor construction, raw materials and protection. Much work remains to be done in this area.

The first task is to investigate repair statistics and analyse the most essential and frequent repair jobs. The second task is to determine whether changes in construction, raw material or protection would improve the situation.

Lubrication maintenance

The primary purpose of lubrication is to reduce the effects of friction. Successful lubrication has the following advantages:

(a) The machines are kept in condition;

(b) The lifetime of machines is extended when wear is reduced;

(c) The efficiency of the machines is increased;

(d) Accident hazard is reduced.

To attain these advantages, it is essential to use the proper lubricant at the right place and time.

All the following considerations are important in lubricaton:

(a) The assortment of greases to be stocked should be as small as possible;

(b) The lubricants chosen should be included in the factory standards and marked with the same sign as that on the lubrication points and tools;

(c) All lubrication points should be lubricated correctly; that is, the lubrication must be done according to a plan drawn up by an expert. Oil companies distribute such plans free of charge;

(d) Lubrication should be carried out at the right time, but unnecessary lubrication must be avoided. It has been ascertained that over-lubrication is more frequent than under-lubrication, especially where ball-bearings are concerned. In general, a small or medium-sized bearing in normal use and with usual rates of rotation will need lubrication only once a year.

The amount of grease in one filling can be calculated approximately from the formula:

$$G = \frac{D \times B}{200}$$

where:

G = amount of grease required (in grams)
D = major diameter of the bearing (in millimetres)
B = width of the bearing (in millimetres)

To economize on lubrication costs and to ensure reliable lubrication, some large enterprises, and especially sawmills and plywood factories, have installed automatic lubrication whereby hydraulic pumps press grease through piping to lubrication points, as required. The amount of grease for each point is adjustable. This way of lubricating is becoming general, as for instance on the slide surfaces of conveyors and in the process industry. In the furniture and joinery industries, however, there are not many points that can be lubricated in this manner.

Oils that have been used once or even several times should not be discarded; efforts should be made to clean them. In general, waste oil is taken to special cleaning plants. If this is not possible, a filter arrangement can be easily built, using waste wool.

Prevention of corrosion

Most damage to machines and other equipment used in industry is caused by corrosion. While this is always a problem, it is particularly severe in warm and moist environments. For instance, the speed with which steel rusts is directly proportional to the temperature. Usually, corrosion is caused by water or oxygen. Oxygen is an especially difficult factor because the strength of the metal in some cases calls for its presence, since it causes the formation of a protective film of oxide on the surface of the metal; sometimes, however, it contributes greatly to corrosion.

In principle, the prevention of corrosion is rather simple. By protecting steel surfaces, for example, the speed of corrosion is reduced, either by mechanically preventing the surface of the steel from coming into contact with oxygen or moisture or by inhibiting the rusting process. In practice, the following methods of preventing corrosion are used:

(a) Making constructions in ways that protect corrodable materials from air, warmth and moisture;

(b) Changing the environmental conditions;

(c) Covering vulnerable materials with corrosion-resistant materials (paints, plastics, rubber, ceramic materials), glazing or using protective boiler masonry, metal coatings or platings;

(d) Cathodic protection;

(e) Use of inhibitors of some reactions involved in corrosion;

(f) Using materials that do not tend to corrode in the given circumstances.

Stocks for maintenance

The materials to be held in maintenance stock are mainly:

Parts of standard nature: pipes, nuts, bolts, fuses, bearings etc.

- Parts for separate machines: special bearings, spare parts etc.
- Spare assemblies: motors, pumps, condensers, couplings etc.
- General supplies: packing materials, lubricants, paints etc.
- Machine tools: knives, drills, grinding wheels etc.
- Hand tools: wrenches, measuring gauges, compressed-air tools, electrical tools etc.

Ever-increasing mechanization and automation have also contributed to the capital value of maintenance stock. The increasing costliness of down-time has had the same tendency. Repairs must be accomplished as quickly as possible, and there should be sufficient spare parts in stock to permit this.

There are two opposing factors to be considered in relation to maintenance materials. On the one hand, in order to expedite repairs and reduce down-time, increasing amounts of spare parts and devices for the most essential machines should be held in stock. On the other hand, however, in order to hold down costs, the stock should be kept as small as possible. In general, the final solution must be some kind of compromise.

If the factory is located far from the country here its machinery is produced, as is the case in most developing countries, the spare-part stock should be rather large to ensure continuous operation of the factory. However, the spare parts that will probably be needed should be noted when the machine is being ordered, and a list of spare parts to ensure the operation for two years, and even for a longer period, should be ordered.

Standardization should also be striven for; for instance, all the machines and machine parts, threads, holes and bearings should be either in the metric system, or the so-called imperial (inch) system. The concurrent use of both systems should be avoided.

It is easy to keep the stock up-to-date if it is kept in order and the cards duly filed. The so-called "alarm limit" or required time of ordering should be marked on as many cards as possible, so that an order may be placed immediately as soon as the amount of parts in stock falls beneath the limit. The use of a goods card or spare-part card is helpful. With regard to small machines, only the most essential spare parts are written on the machine card. With standard spare parts that are used in many machines, a summary must be prepared for departments and for the whole plant to indicate their total number. Such parts are, for example, belts, chains, motors and bearings. The summary list forms a base for acquisition, stocking and internal standardization. In all such listings, spare parts are usually identified by a number or letter code. The spare parts list and its record should be kept up-to-date in an orderly fashion so that needed items can be found without loss of valuable time.

As the maintenance function evolves to meet changing needs, repairs can be made with increasing rapidity. On the other hand, they entail costs, and there is inevitably a limit which it would be uneconomic to exceed. It is thus advisable to calculate in advance how much capital should be tied up in spare parts for the more essential machines; alternative methods should be costed carefully. The example given in table 22 is for a large, essential electric motor in three-shift operation. Although not directly applicable to the furniture and joinery industry, it has been included to draw the principle to the attention of the reader. Its down-time cost has been calculated at $52/hour. When it is time for the regular servicing of this machine, this work can be done in any of four ways: *(a)* complete overhaul with no replacement of parts; *(b)* complete rewinding etc.; *(c)* replacement of the entire rotor; and *(d)* replacement of the entire motor. The costs of these four methods would compare as shown in the following table. Inspection of this table reveals that the third of these ways, namely the replacement of the rotor, is the most appropriate, and it is therefore economic to keep a complete rotor in reserve.

Table 22. Comparative costliness of four ways of performing the periodic overhaul of a large electric motor

Type of overhaul	*Repair time (hours)*	*Costs ($)*[a]			
		Downtime	*Parts*	*Labour*	*Total*
Complete overhaul	240	12 400	—	1 500	18 400
Rewinding etc. of rotor	144	7 400	300	700	8 400
Replacement of rotor	7	400	2 100	75	2 500
Replacement of motor	3	200	4 100	25	4 300

[a]Based on original figures in FmK, rounded to the nearest hundred.

Mounting the machines

Each machine must be mounted with great care, since incorrect or faulty mounting can cause irreparable damage in operation. Before mounting is begun, the instructions that are normally delivered with the machine should be carefully studied. Indeed, when possible, these instructions should be ordered and received before the machine is delivered. Even though the ways of mounting the most usual woodworking machines do not differ greatly, it is worth while to note the necessary tools and arrangements in the instructions for each particular machine. This is important even if the machine is familiar, because designs of machines and devices change frequently.

Some heavier machines such as wide-belt sanders and wide planing and thicknessing machines can be mounted in place without fastening. In such a case, a vibration-damping rubber mat should be placed below the machine. However, this method of mounting requires an absolutely even and straight floor level.

In any case, no matter what the machine is, the mounting can be done with fastening bolts. When the site of the machine has been fixed, cavities for the foundation bolts should be made in the floor or, if the plant is under construction, the required holes can be located at an early stage. These holes or cavities must conform absolutely to the drawings of the manufacturer; in no case must the hole or cavity for the bolt be smaller than the drawing indicates or the fastening bolt will work loose as soon as the machine is started.

In the installation, the machine is placed exactly, and the foundation bolts are inserted into the holes of the frame and project downward into the holes or cavities in the floor. The machine is then hoisted from the floor (about 20 to 25 mm) by means of metal wedges, lead plates or the like between the frame and the floor level. The wedges should be placed as near as possible to the fastening holes. (At the same time, a spirit level should be employed to check the horizontal position of the machine.) The bolt cavities are then filled with cement grout. When it has hardened, the foundation bolts are tightened. At this stage, care should be taken that no tension is created in the machine; in other words the bolts must not exert a bending or twisting effect on the frame, which can occur if the machine is not steady or level. Torsion and bending hinder the functioning of moving parts, and even the frame may be damaged.

When the placement of the machine is planned, the needed electric cables, compressed-air and hydraulic pipes, and dust-extraction ducts must be provided.

The removal of sawdust and wood shavings is a matter of prime importance. If this is not properly done, the efficiency as well as the health and safety of the workers will be impaired. Furthermore, the maintenance of a dusty machine is easily neglected. There is also an increased fire hazard, since drive motors embedded in wood shavings and chips often become over-heated, and their windings burn, with the consequent risk of major damage. Finally, it should be stressed that a clean factory produces more and better goods in fewer working hours per product unit and that it runs with minimal maintenance costs.

The best way to cope with shavings and sawdust is to remove them pneumatically from the cutter-head knife, where they originate. The pneumatic shaving suction system must be extended to the whole factory hall and to each machine. The advantages of such a centralized system are not limited to safety and cleanliness; the waste thus gathered can be further used to generate steam or even sold to particle board or pulp mills.

The fitting of such wood-waste duct work in old buildings may present difficulties and extra costs, but they are not usually disproportionate. In such cases, ducts hanging from the ceiling are often the only solution. The suction network should also have ducts at the floor level so that the shavings on the floor can be swept into holes to be transported away.

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XXX. Maintenance of machine parts*

General points

A company's machinery represents a considerable investment. Therefore, it is necessary to realize the importance of machine maintenance. Proper maintenance lengthens the life of the machinery considerably and accordingly lowers capital costs.

Continuous wear and increasing age cause the value of the machine to decrease. The life of the woodworking machine is 4 to 20 years, depending on the use and the quality of the machine.

The first consideration before deciding to purchase a new machine is whether there is enough work for it. This depends on the size of the company and number of its orders.

The capacity of the machine depends on its size and quality, which must be in correct relation to each other. The more expensive the machine, the more work it should perform. Therefore, it is not wise for a company to buy a very efficient and expensive machine and only use it part of the time.

Arrival of a new woodworking machine

When the machine has arrived in the factory, it is important to check that it has not been damaged during transporation. The cutter spindles and the rotors of electric motors must revolve freely and silently when rotated manually from the end of the shaft.

The next thing to check is that the stampings on the plate of the machine are correct and in accordance with the order. It is important to check the voltage of the electric motors and whether it is a Y or D coupling.

When mounting and test running, it is very important that the electric motor runs in the desired direction, since rotation in the wrong direction can break the machine immediately.

During complete service the motor must always be disconnected. Before starting the machine it is necessary to check the rotation direction using a short start, i.e. giving a start impulse and, immediately thereafter, a stop impulse.

The company that manufactures the machine must always be asked to supply the purchaser with detailed installation, maintenance and safety instructions with diagrams in the language agreed upon. These must be carefully observed.

In general, manufacturing companies lubricate the bearings of a machine before delivery. Owing to the exceptionally high temperature and relative humidity in many developing countries, considerably shorter intervals between service are required. Accordingly, the bearings must be protected by lubricating them more frequently than would be necessary in a dry and cool atmosphere.

Only high-quality lubrication materials must be used in the lubrication of machine parts, preferably those recommended by the manufacturer. If another brand of lubrication material is going to be used, the old material must be thoroughly cleaned away. Mixing lubrication materials often results in thickening and an almost complete loss of lubricating qualities and consequently damaged bearings.

The most suitable materials for cleaning ball- and roller-bearings are white spirit, good water white, petrol or benzine. The last two are inflammable and must therefore be handled with extreme care.

After they are cleaned, the bearings must not stay dry; immediate oiling or greasing is necessary. The bearings are rotated so that the oil or grease enters all important points and prevents them from rusting. This is particularly important when lubricating the bearings of machines that will stay unused for a long time.

Intervals between lubrications of ball- and roller-bearings should be:

Rev/min	*Lubrication*
1 000	After 2 400 hours in operation
1 500	After 1 200 hours in operation
3 000	After 200 hours in operation
Over 24 000	Daily

Maintenance of electric machine parts

An electric motor must never be covered or encased. It is recommended that dust be brushed off daily or blown off with an electric blower. Encased electric motors are equipped with a fan on the outside which cools the motors. The fan opening must not be placed against the wall or in a way that would prevent air from flowing into the opening. If the electric motor is situated in a place where glue, paint, lacquer or grease might drop on it, daily cleaning is necessary. A thin layer of grease on the surface prevents the glue or paint from sticking to the surface.

Inspection of starting equipment

Starting equipment is inspected in connection with the annual service. If the model is simple and has a pressure switch with an on-off control or a 3-stage switch with a lever, the contacting surfaces are sanded with abrasive paper No. 400 or 600 wrapped around a wood or plastic strip. This must always be done by an electrician.

An improved, and also more expensive, model has been equipped with a heat-protection release. In case of overload, e.g. if the blade of a circular saw is struck in the workpiece, the "on" switch is automatically released and

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the machine will not start again until the bi-metal strip of the protective equipment has cooled off. The machine is serviced in the same way as the one described above, except that in addition the bi-metal strips of the heat-protection equipment are inspected. Their fasteners are standard parts and can be replaced.

There are also switches that can be locked with a key. In general, special machines are locked so that they will not be operated by unauthorized persons. The mains current can also be locked, thus preventing the start of all machines. It is very important to have a spare key.

The most common starting switches of electric motors are heat-protection switches and contactor switches which are provided with automatic release mechanisms; if the machine is overloaded or if the blade is stuck in the workpiece, the heat-protection release stops the motor. The motor will not start unless the heat protection is set again in the starting position. There are also constructions in which the start button automatically sets the heat protection.

A contactor is safe to use since disturbances in the distribution net of electric energy release the switch, and the machine will not start again by itself even when the current is on again. This is called a memory switch.

Maintenance and service of a contactor switch

Contactors, heat protection and coil are standard parts and can be easily replaced. The contactor coil can be 220 V or 380 V, the latter being normal for industrial use.

Contactors filled with transformer oil are used for switching on strong currents. The contacting surfaces of the switch must be serviced annually and replaced if necessary. They are standard parts. The oil must be changed if it is not transparent or seems to have particles in it that will result in its losing its insulation qualities.

The moving connection cables must be carefully inspected. The insulation of the cables may have worn or be otherwise broken or damaged; they can be dangerous in operation and may even cause a fire. Any faulty electric equipment must immediately be replaced.

Inspection and maintenance of ball- and roller-bearings of electric motors

Listening to ball- and roller-bearings while they are in operation is a way of checking that they are faultless. This can be done e.g. by putting one end of a stick against the ear and the other end against the bearing chamber. If the bearing is in good condition, a silent humming sound is heard. If the sound becomes louder or one of the bearings is louder than the others, there is something wrong with that bearing. If the bearing ring is faulty, a clinking sound is heard. Frequently, a faulty bearing ring causes overheating of the bearing chamber soon after start-up. As soon as a faulty bearing has been found it must be replaced. It is very important to have spare bearings in stock.

Changing the bearing

In changing the bearing, the fuses of the feed conductor of the electric motor should be removed and a sign should be put up in the distribution centre to warn people that work is in progress. Only the person who put up this sign should take it down again.

A skilled mechanic must change the bearings in an electric motor. Most makes of motor are equipped with their own tool sets. There are operation instructions in the service manual which must be carefully observed.

If a bearing is broken during operation, particles of it and grease are thrown into the coil of the motor. Only detergents that do not damage the lacquer and the coils can be used.

The intervals between lubrications of the bearings of an electric motor should be the ones given above.

If the motor is situated in a place where excessive moisture, dust, corrosive agents etc. can enter the bearing chamber, it has to be protected by more frequent lubricating than would be necessary in a clean place. Only high-quality ball-bearing grease should be used, preferably one recommended by the manufacturer.

When changing from one grease to another, it is important to wash away carefully the remnants of the grease used before; mixtures of lubrication materials thicken and lose their lubrication qualities almost completely.

If an electric motor is disconnected from its conduits, the wiring must be marked with tape to ensure the correct revolution direction.

In case of flood or if the motor has become wet, no attempts should be made to start it. It must be disconnected from its wiring and taken apart. The coil must be dried carefully. Trying to start a moist or wet motor will damage the coil.

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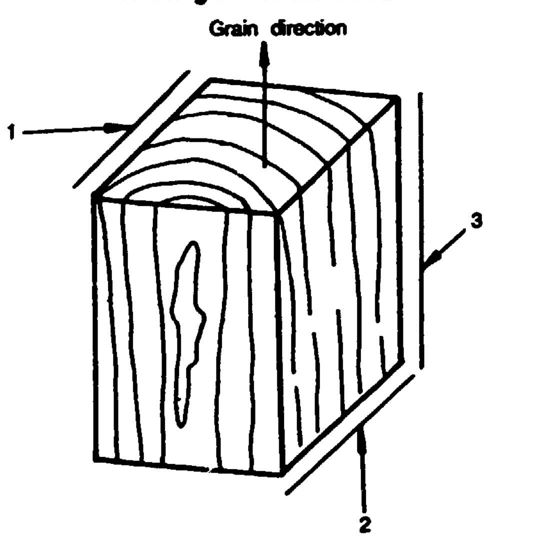
XXXI. Types of machine tools for woodworking*

When contemplating the manufacture of furniture and joinery products on an industrial scale, the planners must have a good knowledge of machine tools for woodworking and of their proper maintenance. Such equipment is both complicated and costly, and its proper selection, operation and maintenance will be vital to the success of the operation. The nature, mode of operation and proper upkeep of some of the more important types of woodworking machinery are considered here in some detail.

Some machine tools used for cutting are illustrated in the figures that follow. As shown in figure 396, there are three ways in which logs and lumber can be sawn: (1) perpendicularly to the grain (cross-cutting); (2) parallel to the grain (ripping); and (3) parallel to the grain but moving across it. The tools used to perform these operations must be designed accordingly.

Figure 396. Cutting directions with respect to the grain of the wood

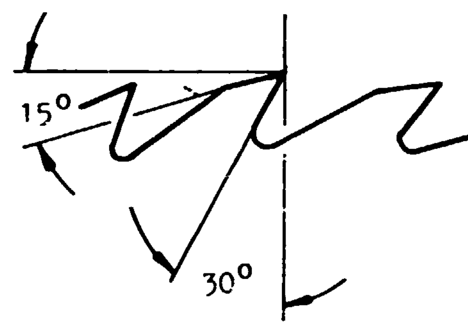


Key: 1 Cutting surface perpendicular to the grain
2 Cutting surface and movement parallel to the grain
3 Cutting surface parallel to the grain but moving perpendicularly to it

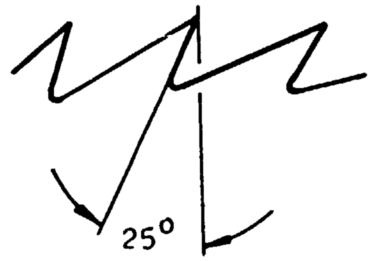
Circular-saw blades

Circular saws can be obtained with tooth shapes suitable for either ripping or cross-cutting. The standard tooth forms and angles are shown in figure 397. The saw must be well-balanced when running, and, in order to secure its satisfactory and steady rotation, the centre portion must be hammered in advance (pre-tensioned) so that it receives an extension corresponding to that produced in the saw rim when running at full speed.

Figure 397. Standard tooth forms and angles for circular saw blades



A. Front bevel angle = 0°
Back level angle = 5°



B. Front bevel angle = 0°
Back level angle = 5°

C. Front bevel angle = 0°
Back level angle = 5°

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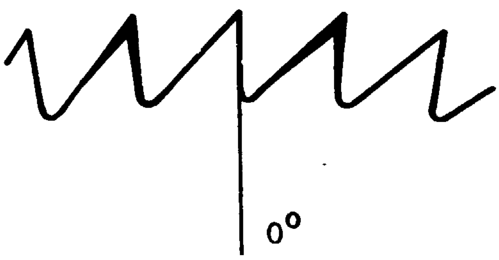
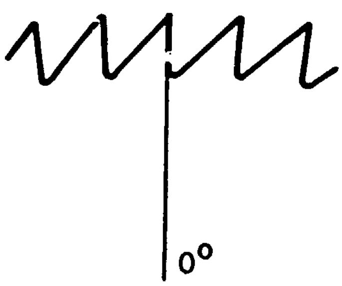
Figure 397 *(continued)*



D. Front bevel angle = 15°
Back level angle = 15°



E. Front bevel angle = 0°
Back level angle = 0°

F. Front bevel angle = 15°
Back level angle = 15°

Note: For definitions of front and back bevel angles, see figure 400.

The saws are balanced and tensioned correctly when received from the manufacturer, but cutting conditions will cause them to lose tension, which must be renewed by experienced personnel.

Normally the speed at the periphery is approximately 50 m/s. Rim speeds higher or lower than normal require adjustment of the tension; higher speeds require "looser" tensions and vice versa.

It is very important that the blades be absolutely even and flat when rotating and that they not deviate more than a couple of tenths of a millimetre from the straight plane. Hence the importance of tensioning.

Steel qualities for saws usually have an even hardness of approximately 46 HRC (Rockwell scale) with no sizable deviations. For the saw blades to do good work, it is necessary that they be filed and set correctly and that correct tooth shape, with suitable angles, be maintained by the saw filer.

The saw blade is mounted on a shaft which exactly fits its centre hole. The shaft is usually driven by a pulley drive, but direct drive by the motor shaft is used on some smaller machines.

In sawing, the log is fed towards the saw blade on a separate table or log carriage. Manual feed is still used in old-fashioned sawmills.

In joinery shops and similar industrial plants, manual feed is common, but rollers or conveyors are also used. The sawing of logs using circular saws is cheap as regards machine costs, but the exactness of the sawn wood is often not good, owing to the difficulty in supporting the saw blade mechanically. Correct tensioning and levelling of the saw blade are very important.

No sorting of the working material is necessary except to remove logs that are too large. In certain countries so-called twin saws are used for sawing big logs. A twin saw consists of two saw blades, one placed above the other in such a way that the saw curves meet in the kerf.

Circular-saw blades are not economical, since much wood is lost in the form of sawdust. These machines are therefore gradually disappearing, especially for log sawing. Instead, band saws and carbide-tipped circular saws will take over more and more of the market share held by the conventional smaller circular saw blades.

Carbide-tipped circular saws

Carbide-tipped circular-saw blades are gaining steadily in popularity. The introduction of more stable machines, designed especially with carbide-tipped saw blades in mind and better understanding of the use and care of these blades have resulted in increasingly improved economy.

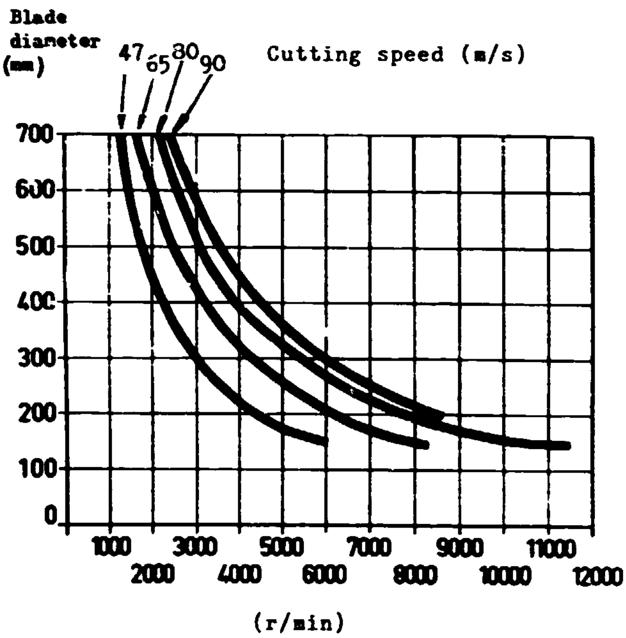
The wood-products industry in Sweden has undergone a thorough reorganization in recent years, and efficiency measures have been widely adopted. Increasingly stiff competition has forced most companies to try to concentrate their efforts on a limited range of products, resulting in long runs. In the course of this development the previously used universal machines have lost ground in favour of specialized machines of great precision and capacity.

When acquiring these frequently expensive specialized machines it is necessary, however, to see that the tools used with them permit the full exploitation of the machines' potential. Carbide-tipped circular-saw blades play an important role in this context. Because of their high durability, it has been possible to raise the ouptput and reduce the manufacturing costs per unit. However, the optimum performance of carbide-tipped blades can be achieved only under certain definite operating conditions.

Cutting speed

As a rule, machines of older types used in the wood-products industry are not adjustable for different speeds. They frequently have a speed that, with ordinary blades, gives a cutting speed of approximately 47 m/s (155 ft/s—see figure 398). When a switch is made to carbide-tipped blades, a smaller diameter can be employed because, with such blades, the diameter reduction will be much less than for an ordinary blade. Given these circumstances, a carbide-tipped blade in an older type of machine will give a much lower cutting speed than a conventional blade, which means in many cases that it cannot be used in the most economical way.

Figure 398. Cutting speed as a function of revolving speed of blade



Recommended cutting speeds for various types of material are given in table 23. The cutting speed for each group can be given only within relatively broad limits because of the differences in workability between wood species and wood-based panels. At the upper limits, it is necessary for the machine to be stable enough to ensure vibration-free blade running. If the feed per tooth is too low, no proper chip will be formed, the tooth edge merely acting abrasively on the material with excessive wear as a result. To reduce wear it is best to employ a large feed per tooth, since edge wear is principally dependent on the course of the tooth through the material. If an excessive feed speed is used, the cutting forces may become so large that the sintered carbide in the cutting edge will break down. The required finish of the section will always be an important factor in selecting feed rate.

Table 23. Cutting speeds of carbide-tipped circular saws in different materials

Material	*Cutting speed* m/s	*Cutting speed* ft/s
Softwood	60-90	200-300
Hardwood	50-70	160-230
Plywood	60-80	200-260
Hardboard	70-90	230-300
Particle board	60-80	200-260
Veneered board	60-90	200-300

Feed speed

The feed per tooth should be between 0.05 and 0.30 mm (0.002 and 0.012 in.), according to the material being worked and the standard of finish required. It can be calculated using the formula:

$$F = \frac{s \times 1.000}{n \times z}$$

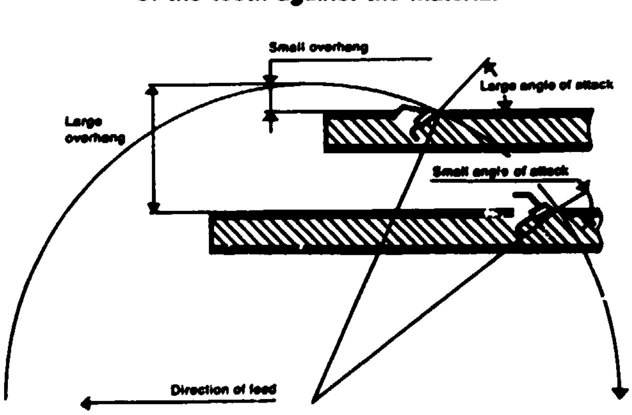
where:

F = feed/tooth in mm
s = feed in m/min of the piece being sawn
n = revolutions/min
z = number of teeth working on the saw in question

Height of blade over work

The hook angle of standard catalogued carbide-tipped blades is usually designed for a blade height over the work of 10 to 15 mm (3/8 to 5/8 in.). The angle of attack of the tooth against the material varies as the height of the blade is changed (see figure 399). In other words, it is possible to influence the finish of the section to some extent by varying the overhang. This is especially true of materials faced with plastic laminates or veneers. The optimum height of the blade must be established by trial and error in each case. Generally speaking, the greater the overhang the worse will be the breakthrough at the underside of the material, while the top face will be better. Reduced overhang, on the other hand, results in breakthrough on the top side but a fault-free underside. The former situation gives a shorter cutting path through the material, meaning less feed force and, in theory, reduced edge wear. The latter case, however, results in smoother blade running and therefore a better finish in the cut.

Figure 399. Variation of the angle of attack of the tooth against the material



Angles

The clearance angle is kept between 10° and 12° (figure 400). Thorough studies have shown that increasing the angle above this range will not lead to reduced cutting forces but may well weaken the edge. The tooth-point angle should not be less than 45°, for the sake of strength.

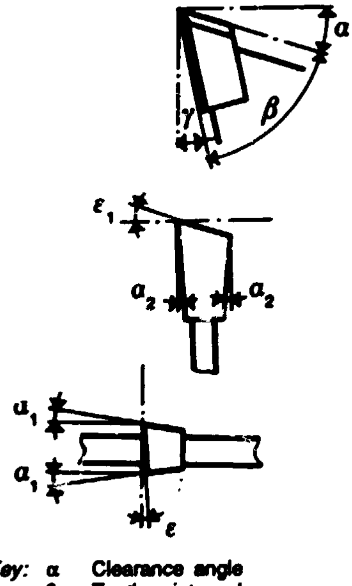
The hook is determined by the specific cutting properties, workability and hardness of the work. Normal values lie between 0° and 30°, the largest angles being employed for ripping softwoods and the smallest for cross-cutting and for trimming.

In ripping, the wood tends to separate ahead of the saw, which reduces the cutting forces. It is therefore possible to increase the hook without any risk of overloading the edge. Increased hook results in lower feed forces.

The tangential clearance angle is normally between 3° and 4°. The radial clearance angle is kept between 1.5° and 2°. If the blade tends to pick up deposits, however, this angle should be increased to 3°.

Front bevel is used on ordinary carbon steel blades with tooth shapes D and F, this being about 15° (see figure 397). On carbide-tipped blades front bevel is employed for mitre cutting and also for plywood and veneered boards where a clean cut is required. In these cases the angle is never greater than 5° in order not to weaken the edge. Back bevel is currently featured on most carbide-tipped blades. Compared with a blade having straight teeth, a blade with back bevel requires less power and less feed force. The angle is between 5° and 15°.

Figure 400. Accepted angle designations for carbide-tipped circular saw blades in Sweden



Key: α Clearance angle
β Tooth-point angle
γ Chip angle
α_1 Tangential clearance angle
α_2 Radial clearance angle
ε Front bevel angle
ε_1 Back bevel angle

As a rule, alternate teeth have left- and right-hand bevels; this applies to both front and back bevels. This practice results in smoother blade running than if all teeth were bevelled alike, although this would be desirable in some cases for the sake of a good finish in the cut.

Dimensions

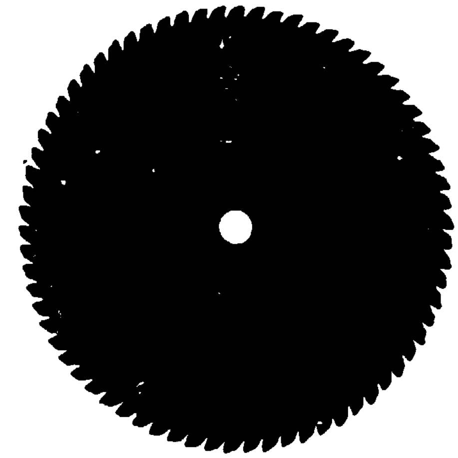
Swedish standards (SIS) governing the dimensions of circular saw blades with carbide tips have been established. Swedish standard 2370 contains a dimension schedule comprising diameter series, three tooth-width series and tooth-number series for pitches of 75, 49, 30, 19, 14 and 10 mm. Swedish standard 2371 sets forth data for cross-cutting circular saw blades and Swedish standard 2372 for ripping saw blades.

The thickness of the blade itself has not been standardized. Normally it is about 1 mm (1/32 to 3/64 in.) less than the width of the cutting edge. In other words, the blade has a clearance of about 0.5 mm (0.02 in.).

Blades with extra narrow cutting edges are sometimes made with a clearance of only 0.3 mm (0.012 in.). It is therefore necessary to pay special attention to the setting of such blades and to take particular care in sawing. Blades with carbide tips are usually somewhat thicker than ordinary carbon steel blades for steady running and to provide a good brazing attachment for the carbide tip.

In order to release the stresses arising in the periphery of the blade, which result mainly from the heat generated in sawing, carbide-tipped blades feature expansion slits and pin-holes, as shown in figure 401. These slits are found on all close-pitch blades and on those used for continuous sawing.

Figure 401. Expansion slits and pin-holes of carbide-tipped saw blades

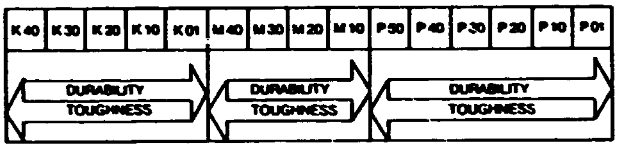


Grades of sintered carbide

Since 1959 sintered carbides have been described by ISO designations with regard to chip-forming machining operations. There are three main groups, as shown in figure 402. The arrows indicate the directions in which durability and toughness, respectively, increase. In woodworking, sintered carbides reveal the abrasive wear known as flank wear.

The grades of sintered carbide falling within group K (see figure 402) are particularly resistant to flank wear and are therefore employed in circular-saw blades. The grade used depends on the design of the blade itself and the material to be worked. It is important that the sintered carbide be sufficiently tough to resist breaking down the edge during sawing. Toughness and strength are mainly related to the kind of carbide, the cobalt content and the grain structure. Thus an increase in the cobalt content and a coarser grain structure result in greater toughness but less durability.

Figure 402. ISO grades of sintered carbide



Summary

The use of carbide-tipped blades is increasing steadily. The introduction of more stable machines, specially designed with the use of carbide-tipped blades in mind, and a better understanding of the use and care of carbide-tipped blades have resulted in inceasingly improved economy. New patterns and new grades of sintered carbide, suitably composed for various sawing conditions, will increase still further the potentialities of the carbide-tipped blades. It is desirable that the standards governing dimensions be observed and applied as far as possible.

Band-saw blades

Band-saw blades are normally toothed on one side only. The distance between tooth points (pitch) varies depending upon blade dimension and use. The size and type of material to be cut also affects the tooth pitch. Band-saw blades are exclusively used for ripping. Wider dimensions are used at sawmills and narrower dimensions at furniture and joinery plants.

Generally speaking, saw blades up to 70-mm wide are considered narrow, and those wider than 70 mm are considered wide. Band-saw blades for cutting logs are usually more than 150 mm in width.

The band-saw machine normally operates in a vertical position, but horizontal machines are gaining ground, especially in smaller sawmills. The machine consists of two wheels, held together by a rigid body, around which a toothed metal band, the saw blade, passes. The bottom wheel is driven by a motor and the top wheel by the saw blade, which acts as a transmission belt. In a vertical machine the band-saw blade always cuts in a downward direction, and all teeth work.

The purpose of tensioning, that is, the elongation of the middle of the blade by roller, is to make the blade fit the band wheels properly over its entire width during sawing, with normal friction and heating and with suitable strain in the machine. It is very important that the toothed edge be sufficiently stretched during sawing; otherwise the blade will not cut straight. The stretching of the blade is done by pushing the upper wheel upwards. This stretching should not be confused with the tensioning of the saw-blade centre.

Band-saw blades are normally purchased in coils, or cut to size, or with the ends joined, preferably by welding although it is done by brazing in some sawmills. A log carriage is used for log-breakdown saws but other forms of log feeding are usual, for example a table-feed machine with saw guides above and below the workpiece. The upper one can be moved vertically and adjusted as close to the workpiece as possible, which ensures a straighter cut.

The rims of the band wheels are convex to prevent the blade from wandering back and forth, provided the blade is correctly tensioned. Large machines with wide blades, for instance in the United States of America, have flat wheels, since the large surface contact is considered to give sufficient contact support without any extra measures.

Band sawing gives the smallest possible sawdust losses, and the sorting of logs according to diameters is not necessary. Band saws of various types are considered as the most economical machines for log breakdown and resawing. This is because of the thinness of the blade and because logs can be sawn according to dimensions and quality without waste of time in handling. Band sawing is becoming more and more popular all over the world.

The servicing of band-saw blades is more complicated than that of other machine-driven blades. The necessity of using good maintenance machines is more noticeable in band-saw mills than in other wood industries.

Machine knives

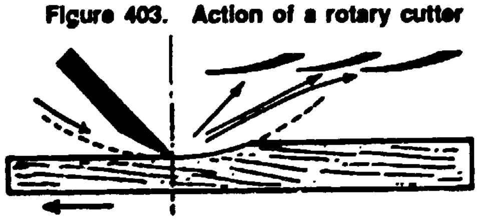
Most machine knives perform either reciprocating or rotary motions on discs, drums, shafts and the like; other knives remain stationary in the machine and the stock (workpiece) performs the necessary reciprocating or rotary motion. There are also single knives and knives that shear in conjunction with one another.

Machine knives can be classified by their cutting action as follows: rotating units, such as revolving cutters and chipper knives, and stationary units, such as veneer knives and surface scrapers.

Rotary cutters

In its simplest form, the individual rotary-cutter knife cuts principally along its face (cutting edge). Its function is to remove the surface, flat or curved, rather than to reduce the larger board into smaller units, which is the function of the saw. The action of such a device is shown in figure 403.

Figure 403. Action of a rotary cutter

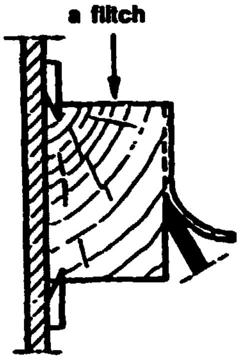


Stationary knives

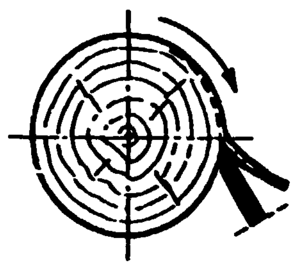
In many instances the knives for cutting wood are relatively stationary. The wood either revolves against the knife, as in a veneer lathe, or reciprocates across it, as in a veneer slicer. Another example is the suface scraper, wh he wood is fed across a rigid knife, with a slightly turned edge to remove a thin (about 0.15 mm - 0.006 in.) shaving. Some examples are shown in figure 404.

Figure 404. Cutting veneers with stationary knives

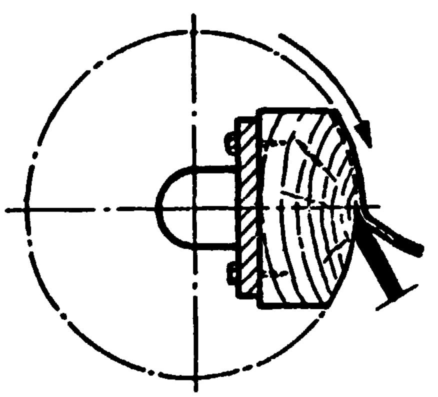
A. Slicing veneer from a flitch



B. Rotary cutting of veneer from a log or bolt



C Half-round cutting of veneer from a flitch with a lathe



Chipper knives

Chipper knives are of two kinds: compound and case-hardened (figure 405). Some companies use the case-hardening technique for chipper knives. The raw material (steel) has a low carbon content (around 0.10 per cent) and consequently cannot be hardened. The carbon content in that part of the knife that is to be hardened is increased to a suitable percentage by a carburization process that penetrates to the required depth. During subsequent hardening, only the carburized section becomes fully hardened. The toughness of the low-carbon steel is retained in the body of the knife. The transition from hard to soft material is progressive, with no sharply defined limits that could raise stress under certain conditions.

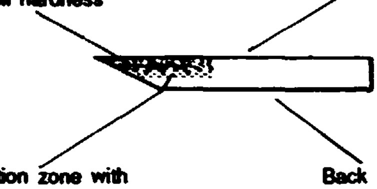
High-chromium steel is recommended for chipper knives because modern chippers operate at very high speeds and capacities, and the knife-edge temperature can rise to 450°C. For these machines it is therefore necessary to have knife material with a high annealing temperature. Thin knives are all hardened, but the thicker ones are high-frequency hardened. The hardness configuration is practically identical to that obtained with case-hardening.

Figure 405. Chipper knives

A. Case-hardened

Case-hardened part with full hardness

Steel side



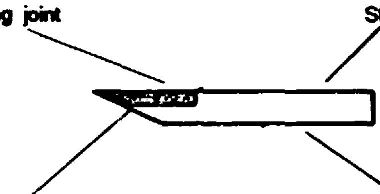
Transition zone with decreasing hardness

Back part (unhardened) with lower hardness and great toughness

B. Compound

Welding joint

Steel side



Alloyed steel part with full hardness

Body of soft steel (unhardened)

Hog knives

Hog machines are used primarily for reducing wastewood and bark into pieces of small size suitable for boiler fuel and are employed for this purpose by nearly all veneer mills and many other woodworking plants. Also, hog machines for converting bark to fuel are used by many sawmills that have a debarker and a steam plant and by a number of pulp mills. Other applications include the processing of pitch-pine stumps for the production of turpentine, chipping oak for tanning in extract plants and the preparation of fertilizing material for potting plants. Machines now in use include a large variety of models from 20 or more manufacturers. Between 10 and 36 knives are normally required for a set. Other machines of this general type, known as "hammer hogs" and "pulverizers", do not use knives.

Since there is hardly any quality requirement for the product from most hog-machine applications and plant procedures on handling waste frequently permit metallic and other foreign materials to go through the hog, the knives regularly receive much more abuse and careless maintenance than knives of other kinds. Thus, it is a common belief that the cheapest knives obtainable are probably adequate for the purpose and most economical in the long run.

This theory is valid only within certain limits. It is self evident that knives that stay in use longer before regrinding become essential and that have equal or superior resistance to damage from loose metal must offer worth-while extra value in reducing knife consumption and maintenance costs.

Some hog knives are made of very low-alloy steel with carbon content to permit hardness in the range of about 47 to 54 HRC. Cheap grades of ordinary commercial steel are used to permit the lowest possible prices in order to satisfy the prevailing wishes of buyers. Since the knives are fully hardened by conventional methods and properties of the low-grade steel can provide only moderate toughness, the hardness must be kept relatively low to avoid excessive breakage during use.

Veneer knives

Over the years, the Swedish company Sandviken has manufactured a case-hardened veneer knife. The knife is zone-hardened, which means that only a part of the knife (the cutting edge) has full hardness (59 to 60 HRC). The performance of this knife has proved to be very satisfactory with both softwood and hardwood.

Some years ago the company introduced a veneer knife of a new quality. It is a low-alloy steel knife, high-frequency hardened. Its construction is identical to that of the old case-hardened, zone-hardened type. Its edge hardness is 59 to 61 HRC. The edge-holding ability of this knife is very good; it stays sharp very long. In case of minor edge damages caused by stones, nails, hard knots and the like the edge can easily be restored in the lathe. In case of a bend, the edge can be straightened by using a hammer and then touched up by honing; if there is a nick, it can be corrected by filing and honing.

Pressure bars

Pressure bars are used on both veneer lathes and veneer slicers. On the former, there is either a roller bar or a solid pressure bar. The most usual type of pressure bar is manufactured with a Stellite edge, which gives it good edge-holding and wear properties. However, maintenance of this bar is expensive if it is damaged by a foreign item such as a steel nail. Often, the bar must be sent to a special shop for repair.

When certain species of wood, particularly oak, are peeled or sliced, staining is a problem, as all stained veneer is waste. To avoid such staining, the bar, together with the bar holder, must be removed quite frequently and cleaned. Attempts have been made to solve the problem by painting the bar, but with no great success. However, if the pressure bar is made from high-chromium steel, the staining problem seems to be solved. Furthermore, the customers are able to maintain the bar themselves, and in certain cases the edge-holding and wear properties are just about the same as in a Stellite bar.

Sharpening machine knives[1]

Careful sharpening of dulled knives results in improved cutting properties, longer life and a corresponding reduction of costs. Not infrequently, however, the sharpness of a reground knife is inferior to that of a new one and of shorter duration. In many cases, the reason for this is to be found in faulty regrinding, which has often given rise to unjustified complaints and may be prejudicial to the goodwill between a manufacturer and customer.

Knives should therefore be changed and reground before the cutting edge has become too blunt. If this precaution is taken, it is necessary to remove very little material when regrinding, which saves both time and costs for this operation and lengthens the life of the knife. A correctly ground cutting edge should be clean and straight along its whole length and free from burrs, burnt spots and grinding cracks.

The quality attained when sharpening machine knives is dependent on the following main factors: the grinding machine, the grinding wheel, the grinding method and the grinding performance. These factors are considered separately below.

The grinding machine

In most cases the machines used for grinding straight machine knives are surface grinders with horizontal spindles and reciprocating tables, fitted with cup- or cylinder-type grinding wheels. Small machine knives are frequently ground on surface grinders with vertical spindles and cup wheels.

In general, the machine knife is fixed by a magnetic chuck or by clamping it to the reciprocating table of the grinder, which moves reciprocally in front of the stationary spindle that carries the rotating grinding wheel. The quality of the grinding machine is of the greatest importance for the results obtained in grinding. It must not vibrate and be in good condition to ensure a uniform bevel and a clean, sharp cutting edge. In machines that are less rigid, particularly where no coolant is employed, grinding must be done with the greatest care.

The grinding wheel

It is extremely important to select a wheel of the proper grade and grain size for the job in hand.

Grade (hardness). The degree of hardness calls for special attention. A wheel that is too soft does not retain its size, particularly at the roughing stage; owing to its quick loss of shape its life is also shortened. On the other hand, a wheel that is very hard gives unsatisfactory working results. Such a wheel rapidly becomes glazed and dull and requires repeated dressing. A glazed and dull wheel tends to burn and ruin the knife. The grade of the wheel should be selected in accordance with the composition and hardness of the knife. The type and condition of the grinder, the shape and speed of the wheel as well as the cooling are also very important. It is preferable to try out a wheel that is soft, and then proceed gradually to a harder and more economical wheel.

Grain. Wheels with finer grains have come more and more into use for machine knives. In certain instances a No. 60 up to a No. 80 grit is employed, being correspondingly softer than coarser grits. The finer grains, being

[1] For more detailed information on the sharpening and maintenance of woodworking tools, see chapters XXXII and XXXIII.

smaller and sharper, penetrate the hard surface of the knife more readily than the coarser grains. A finer grit wheel therefore cuts with less pressure and less risk of burning and in addition produces a better surface.

The general rules applying to the selection of hardness and grain size are:

(a) Hard wheels: wheels of harder composition are used for soft material, small contact surfaces, greater depths of cut and with grinders that are not completely rigid;

(b) Soft wheels: wheels of looser composition are selected for hard material, larger contact surfaces, smaller cuts and very stable machines;

(c) Roughing and finishing: for roughing, large-grain wheels are used; wheels with a small grain should be employed for finishing;

(d) Standardized symbols: the system of symbols used for grinding wheels is internationally standardized; a grinding wheel designation contains all the data relating to the quality of the wheel;

(e) Wheels for machine knives: for grinding machine knives of tool steel, high-chrome alloyed steel or high-speed steel, Alundum vitrified wheels are generally used. As a rule only a vitrified bonding agent is used in wheels for knife grinding.

The grain sizes, grades and structure of wheels for grinding machine knives are presented in table 24.

Table 24. Optimal characteristics of grinding wheels for machine knives

Type of knife	*Grain size*	*Hardness*	*Structure*	*Wheel shape*	*Peripheral speed (m/s)*	*Peripheral speed (ft/s)*
Veneer knives	46	H	8	Cup	18-23	59-75
Chipper knives	46	H	8	Cup	18-23	59-75
Planer knives (high-speed steel)	60	J	8	Cup	20-25	66-82

The combinations presented in table 24 apply only to stable and vibrationless grinders; for machines that are less rigid, wheels with one or two more degrees of hardness should be selected. Similarly, lower peripheral speed necessitates harder wheels, and higher speeds need softer wheels than those recommended.

Segmental wheels. When a segmental wheel can be used in place of a solid one (particularly of larger sizes), this should be done, since the air circulating around the segments during rotation contributes to more rapid and cooler grinding. In addition, the removal of chips is more effective and the working capacity greater than with a solid wheel.

Truing and dressing the wheel. If the grinding wheel exhibits a tendency to burn, it must be dressed immediately. A newly mounted wheel must always be trued in order to get the grinding surface running evenly. The wheel must also be dressed from time to time to keep the cutting face clean, sharp and free-cutting, thereby minimizing the danger of burning the edge of the knife.

A special dresser for sharpening by hand, which is supported against the table and clamping plate, is recommended both for truing and dressing. A diamond tool may also be used but not an abrasive stone (such as a piece of grinding wheel) since it is difficult to hold it sufficiently steady. Furthermore, an abrasive stone is likely to produce a glazed surface on the wheel face instead of cleaning it and rendering it sharp and free-cutting.

The grinding procedure

Partially hardened knives. The grinding of selectively hardened machine knives (such as high-frequency hardened ones or compound steel) must be regarded as a very delicate job, since the grinding wheel must work on soft and hard material simultaneously. The soft material easily tends to stick to the wheel, which is then likely to become glazed and to burn the material.

Firm holding of the knife. The machine knife must be held firmly by a magnetic chuck or clamped to the table; it must never be held by hand. It is very important that the contact surfaces be free from projecting burrs, dirt or the like. The chuck should be rotatable to enable different angles of the cutting edge to be obtained according to the type of knife. When no suitable clamping device is available, the knife should be placed on an adjustable table with a stop against the rear edge of the knife.

Direction of rotation of the wheel. Machine knives should always be ground towards the cutting edge. By grinding towards the edge, the wheel retains its sharpness and the danger of over-heating the edge is reduced. If grinding is done in the opposite direction, the wheel draws the softer material of the bevel towards the cutting edge, causing the wheel to become glazed and lose its sharpness. Grinding is, however, sometimes carried out against the periphery of a cylindrical wheel. A hollow-ground bevel can be obtained by this method, which may be an advantage in certain cases. It is advisable not to employ a wheel with too small a diameter, since this will produce too deep a hollow and thus weaken the edge. Before grinding is begun, the coolant should be turned on; the wheel may then be set in rotation and a small feed is maintained.

Grinding finish. Grinding is finished with a die-out cut, that is, the wheel should be allowed to cut without any further feed until sparking ceases. In this way a bevel with a smoother surface is obtained and honing is simplified.

Grinding speed. The speed prescribed for each wheel should be carefully observed, since the maximum cut is obtained at this speed. If the speed is too low, the wear on the wheel is excessive, but, on the other hand, a speed that is too high produces such a heavy grinding effect that the cutting edge is burned and ruined. As mentioned earlier, however, an incorrect peripheral speed can be counteracted by selecting a suitable wheel hardness.

Maximum speed. It should be noted that, for safety's sake, the maximum speed given for every grinding wheel should not be exceeded. In general, the speed of the feeding table should be 18 to 24 m/min (about 60 to 80 ft/min).

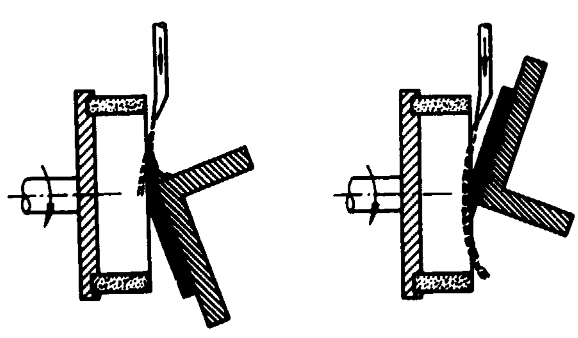
Feed. The feed must be small and should not exceed 0.05 mm/stroke (0.002 in./stroke); this also applies to roughing. If the feed and speed of the table are too great, the knives may easily be ruined. The best results are obtained by taking a light cut with a moderately rapid table feed.

Detrimental heating of the knife. Heating at the point of contact between the grinding wheel and knife may have a detrimental effect on the properties of the steel. If the original tempering temperature for the knife is exceeded, the steel will be annealed, with a consequent loss of hardness. If the temperature rises high enough, the cutting edge will become brittle and be ruined. An infallible indication of detrimental heating of the knife is the appearance of the tempering colours. As long as no colours are visible, the steel has not been converted. Tempering begins with a straw (yellow) colour at 250° to 300°C (480° to 570°F) and increases over blue at 300° to 350°C (570° to 600°F) to blue-grey and grey at 350° to 400°C (660° to 750°F). At the last of these temperatures the cutting edge is ruined, so that the damaged part must be entirely ground off.

Cooling (wet) grinding. Machine knives of any kind should preferably be ground wet. The flow of coolant should be directed at the point of contact between the wheel and the knife or close above in order to prevent burning the knife. A certain cleaning of the wheel is obtained at the same time (figure 406). The tank for the circulation coolant in a cooling system should be large enough to allow a minimum circulation time of 10 minutes, which calls for a capacity of 200 litres (44 gallons). The use of a filter in the cooling system is a great advantage because it prevents steel chips and fragments broken off the wheel from reaching the grinding point, where impurities of this kind may cause damage in the form of scratches on the bevel or edge of the knife.

Figure 406. Clamping and coolant feeding when sharpening machine knives

A. Correct B. Incorrect



Too little or intermittent cooling is worse than none at all. To direct the coolant against the knife when it becomes hot is a sure means of damaging or even entirely ruining the knife.

Coolant. Clear water may be employed as coolant, in which case plenty of it must be used, i.e. about 20 litres per minute (4 1/2 gallons) at least.

Rust-preventing coolant. The coolant must not cause rusting of the knife or the machine. When using water a rust-preventing agent should be added. This may be sodium carbonate, in a proportion of 4 kg sodium carbonate to 100 litres of water (or 4 lb per 10 gallons). A large number of oil emulsions also available on the market are very suitable as coolants, since they generally possess the excellent property of facilitating the production of a perfect surface.

Honing. After grinding has been completed, the cutting edge must be honed before the knife is ready for use. Not even the best grinding wheels are capable of producing a ground surface smooth enough for an entirely satisfactory knife edge. Scratches are always formed, resulting in a rough and uneven cutting edge that will soon become dull owing to the fact that the tops between the scratches on the edge are rapidly worn down. In order to obtain a satisfactory cutting edge that will retain its sharpness over a long period and permit the knife to work accurately, the wire or feather edge invariably left on the steel side by the grinding wheel must be honed away completely. Thorough honing has a direct influence on the life of the knife, the quality of its cut and on its operating economy.

The following rules may serve as a guide for honing the edges of machine knives:

(a) The knife should be supported in a vice or on a bench at a convenient height and with sufficient light on the edge;

(b) The oilstone must be perfectly even and should be applied against the bevel with a light pressure over the whole bevel and steel side to prevent the formation of a rounded edge (see figure 407);

(c) Honing of the steel side of the knife should be stopped as soon as the wire edge has disappeared or been straightened;

(d) Honing should not be forced and should be carried out with a sort of rotary motion along the bevel. It can best be carried out by first rough honing the edge with a coarse oilstone. A thin machine oil should be used on the stone and the pressure should be reduced gradually;

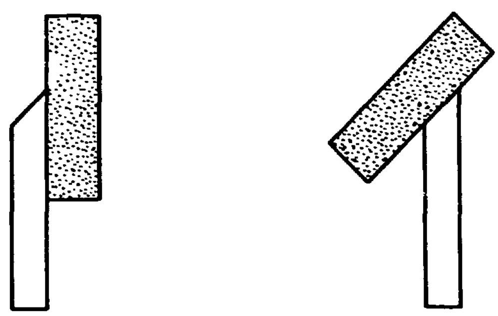
(e) Honing should be continued in the same way with a finer oilstone;

(f) Honing should be finished with a fine-grain hard oilstone on both sides of the cutting edge. For this purpose the stone should be tipped up slightly about 2 mm (or 1/16 in.) from the heel of the bevel;

(g) The edge should be examined with a magnifying glass (10-power, for instance) to ensure that it is free from all burrs and nicks.

One way of telling if a knife has been honed properly is to draw a piece of writing paper along the edge. It will cut the paper easily, but any uneven spots will cause slight but clearly perceptible vibrations of the paper. Such spots must be marked for further honing. After honing, the knife should be carefully wiped clean and dry.

Figure 407. Correct application of the oilstone on the hardened side and on the bevel of a machine knife



Inserted-tooth cutter

The inserted-tooth cutter is a relatively new tool intended for planing and milling. Its design is based on earlier designs used in the wood industry, but it incorporates the metal industry's advanced technique for mechanically clamped indexable inserts.

This tool is constructed on the changeable-insert principle so that the insert may be discarded instead of being reground after becoming worn. (See figure 408.) The miller body (cutter-head) is 25-mm thick (1) and is available in the five following standard forms:

Outside diameter (mm)	*Centre hole (mm)*	*Number of inserts*
100	40	3
120	60	4
140	60	4
160	60	4
180	60	6

The cutter can be used in all types of multi-cutting, table-milling (spindle moulder) and tenon-cutting machines. In the first of these, several millers can be joined to form a wide cutter (2), while in the latter two, the cutter can be used either as a single-tool or a multi-tool unit (1 and 2).

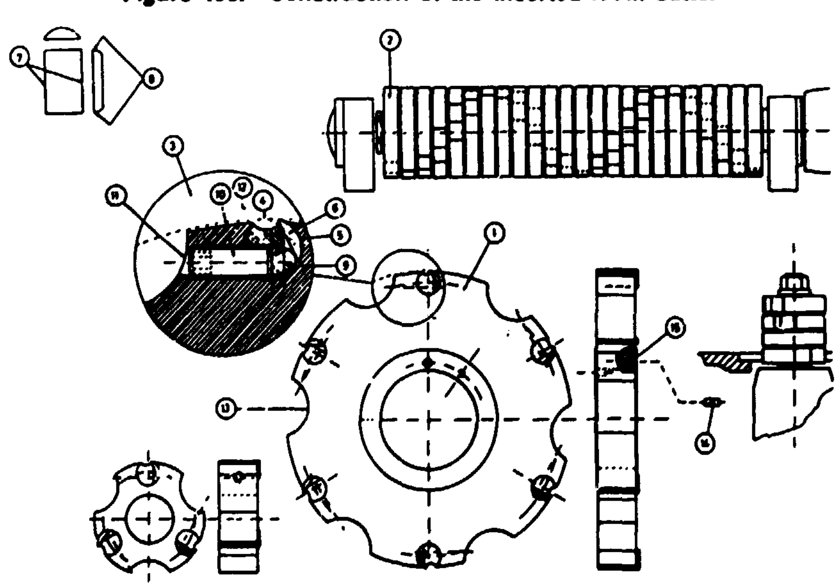
The purpose of the clamping system (3) is to locate and firmly hold the inserts; it consists of a flat bearing surface (4) and a cylindrical seat (5). The shape of the insert is a semicircle (6) with cutting edges 26 mm long (7). Each insert thus has two cutting edges. The ends of the inserts (8) can also be used for cutting purposes in rabbeting and grooving applications.

The inserts are clamped by a steel ball (9) and a screw (10) at right angles to the insert. The ball thrusts the insert against the seating and clamps it there firmly. The chip-breaker (12) in front of the insert breaks up and guides the chips away from the cutting zone.

The recesses (13) in the circumference of the miller body facilitate the adjustment or change of inserts when the tool is used as a multi-unit cutter (2). In order that the inserts of a multi-tool unit may be changed, an aperture is provided on the body lying alongside to permit access to the clamping system. Precise location is ensured by a pin and hole in each miller body. One advantage of this mounting system is that the inserts take a spiral form, which can be very useful from many points of view. In order to prevent the occurrence of lengthwise ridges in the material when utilizing a multi-tool layout (2), the inserts have been made 1 mm longer than the milling cutter's breadth. This creates the overlapping necessary to overcome this problem.

The steel used for the miller body is SIS 1672, apart from the component that forms the chip-breaker; to reduce the wear which chip removal creates, steel quality SIS 2140 is utilized for this latter component. By this means it is possible to supply the miller body without the necessity of special hardening processes.

Figure 408. Construction of the inserted-tooth cutter



XXXII. Woodworking tools and their maintenance*

Importance of tool maintenance

Proper tool maintenance is important for many reasons. The finish of a machined surface is rough if it is worked with a dull blade or knife because it scrapes the material. Dull tools also cause harmful vibrations of the spindle and cutter-block. Furthermore, a dull tool may cut only the soft part of the wood neatly; this is typical for softwood species (e.g. pine, which has a considerable hardness difference between early wood and late wood). When working against the direction of the grain, a dull tool has a tendency to tear the fibres of the wood, thus producing a poor surface quality.

High manufacturing accuracy is of prime importance for furniture parts, particularly in joints. When the pieces of the joint fit together exactly, gluing gives the best possible results. A smooth and even machining finish in straight and curved profiles also saves time-consuming sanding afterwards; only light sanding is necessary and, above all, the dimensions and the shape of the furniture will be exactly as designed. This is possible only if well-maintained and well-sharpened tools are used.

The danger of accidents is diminished when well-maintained tools are used. For example, a surface planer with dull knives causes the workpiece to vibrate so that it drops or may cause the hand to slip into the rotating cutter. Also, a dull band-saw blade that is not in good condition can easily get stuck in the workpiece, causing the blade to break and resulting in obvious personal hazard.

Energy consumption increases when using dull tools; the worker must push the workpiece harder against the vibrating cutter-block and becomes tired (see figure 409). For example, in edging, a dull circular saw blade may get stuck in the sawing groove, and power consumption will increase so much that the fuses blow out or the safety relay is released.

The life of the tool depends on the hardness of the workpiece and of the tool material. Tools should always be sharpened before they become too dull in order to eliminate chipping effectively. When very dull tools are ground, a good deal of tool material must be removed. In particular, expensive tungsten-carbide-tipped tools should be sharpened when they still work satisfactorily. Using dull tools too long shortens their life and increases wear of the grinding wheel.

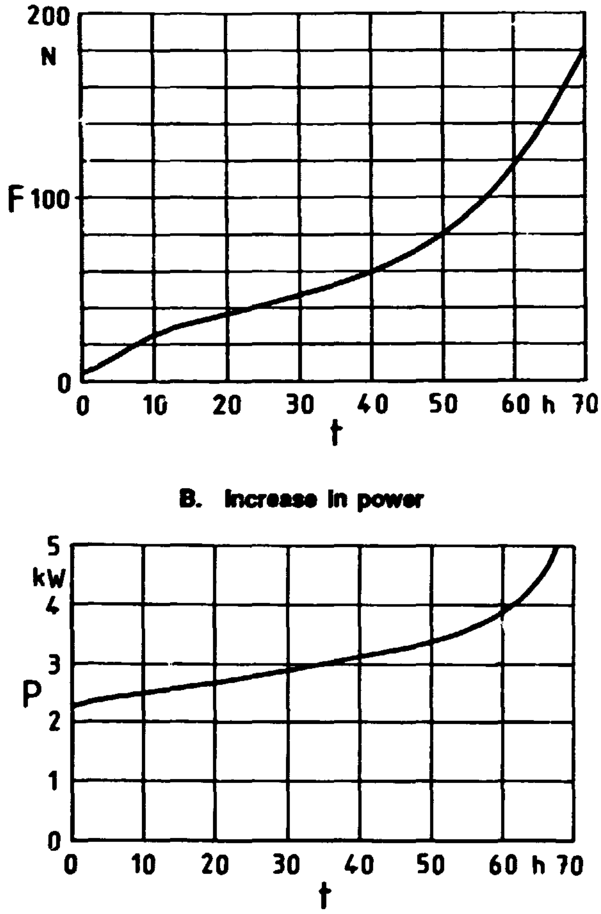
Correct intervals between sharpening are important for the reason mentioned above. Regular and frequent sharpening saves tool material as well as the time on a special grinding machine. Usually, it is better to sharpen tools too often than too seldom.

Tools that are ready for use must be properly stored so that each type is in its own box or stand. Special tools, such as cutters and carbide-tipped tools, must be stored in separate boxes. Proper boxes must always be used for moving tools from one place to another.

Figure 409. Increase in energy consumption owing to dull tools

A. Increase in feed force

B. Increase in power



Key: t = Time machined with the same circular-saw blade after sharpening
F = Feed force in N
P = Power in kW

The most common tools used in the furniture and joinery industries

As no known material meets all the requirements of a good woodworking tool, the tool must often be chosen according to the workpiece (wood species, plywood,

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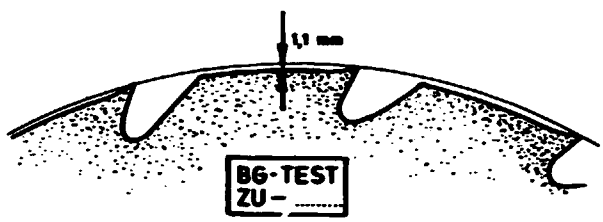
*By Eino Marttinen, Lahti Institute of Technology, and Peter Wagner, consulting engineer, Lahti, Finland. Originally issued as ID/WG.163/26.

particle board or wood and plastic laminates). For serial work high-speed steel tools are frequently used. When very hard, tool-wearing wood species are machined, e.g. teak, and wood structures containing several glue joints, only tools with carbide tips can be used. Inexpensive carbon-steel tools are suitable only for machining softwoods.

Circular-saw blades are chosen according to the material being sawn and the working method, i.e. whether the work entails edging or cross-cutting. Softwoods are sawn best with a wide-pitch circular saw blade (see figure 410 A). Thin material is sawn with a close-pitch blade (see figure 410 B). The most common circular saw tooth shapes are shown in figure 411. A selection of woodworking tools is shown in the annex.

Figure 410. Circular-saw blades

A. Wide-pitch circular-saw blade



B. Close-pitch circular-saw blade for thin material

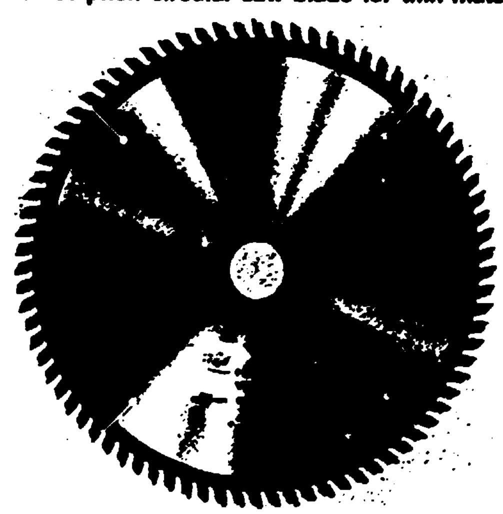
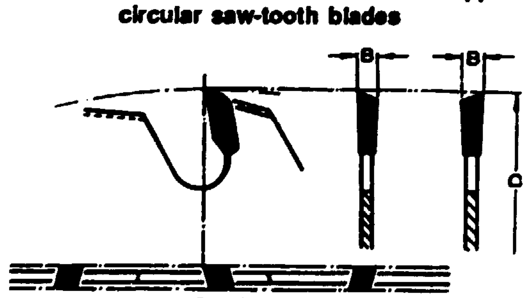
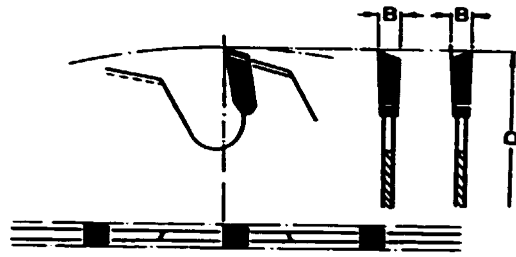


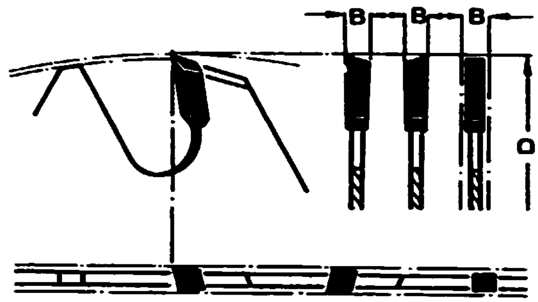
Figure 411. The most common carbide-tipped circular saw-tooth blades



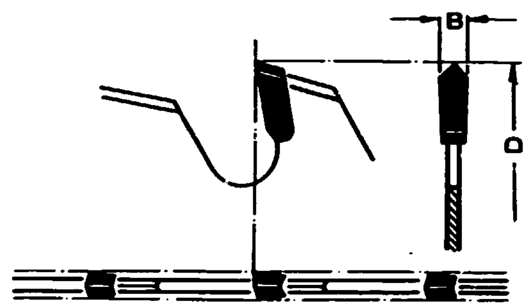
SBA



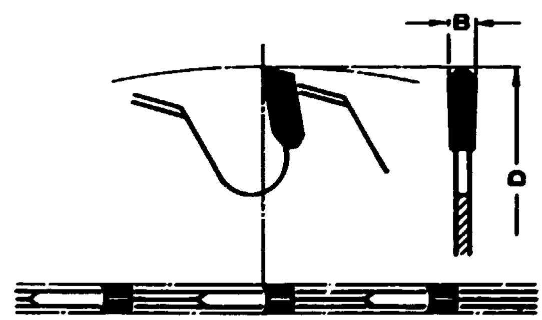
SB



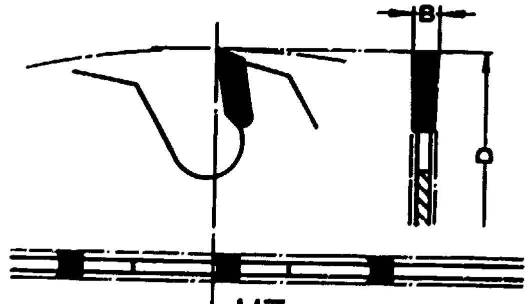
GHA-BG



VP



HZ VP



HZ

In a machine with a manual feed (e.g. vertical-spindle moulder or circular saw for trimming purposes) a blade with the tooth backs shaped to limit chip thickness is the most suitable (see figure 412).

Figure 412. Circular-saw blade, tooth-shaped to limit chip thickness

When very expensive wood is rip-sawn, a circular-saw blade with conical construction must be used. It can be used in mechanical feed only, and a riving knife must always be used in connection with it.

Band-saw blades are chosen according to the diameter of the band-saw wheels, the blade thickness being one thousandth or less of the diameter of the wheel.

In the furniture industry, the blade widths are chosen depending on the purpose. For straight sawing the blade can be as wide as the structure of the band saw allows. When curved pieces are sawn, narrower blades should be used, e.g. 15, 12, 8 or 6 mm. Band-saw blades with strong setting can be used to saw smaller curves than the width of the blade used implies; sawing is slower in this case.

When hardwoods are sawn the material of the blade used must be a hard, tough steel alloy, which is expensive. Surface and thickness planer knives must be of high-quality, high-speed steel alloy. They are fairly wear-resistant, even when cutting very hard woods. Depending on the structure of the circular cutter-block, the knives are 3 or 4 mm thick (see figure 413). The widths are standardized 35 and 40 mm. The lengths range from 40 mm up to 1,050 mm.

Today the carbide-tipped knives for surface and thickness planers are still expensive, and their sharpening and maintenance are time-consuming and laborious. The fact that they break easily has so far also restricted their use.

Tools used in four-side moulders are chosen according to their use and purchase price. The tools used in temporary machining and small series are always equipped with detachable knives made of high-speed steel alloy (see figure 414).

For reasons of safety, square cutter-blocks, which used to be common and are still used in some factories because the knives are inexpensive to make, are not recommended. (They are forbidden in some European countries.) This applies even to machines with mechanical feed, such as the four-side moulders. One of the most serious mistakes made with such cutter-blocks is running them at the same speed as the modern, more solidly constructed cutters. The newest method uses circular cutter-blocks and detachable knives in the four-side moulder. The knives are ground at the clearance surface as in the old square cutter-block method (figure 415). In this new arrangement, however, the knives are fixed in the cutter head during sharpening. The cutter head is on a spindle in the grinding machine to ensure maximum accuracy. The grinding wheel is guided by a template to copy the desired shape into each cutting edge.

Figure 413. Circular cutter-block

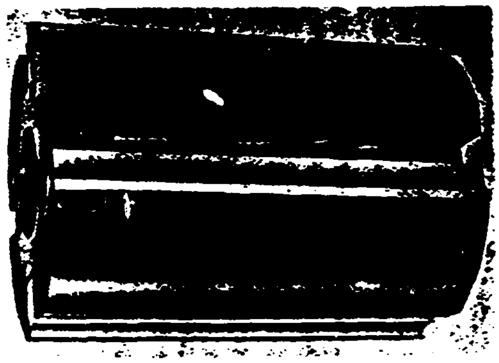


Figure 414. Circular moulding cutter

A. Cutter

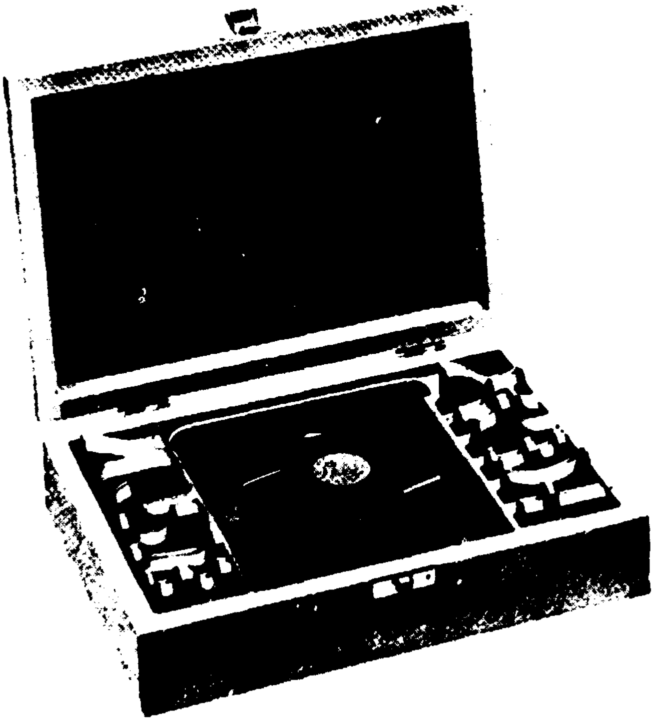
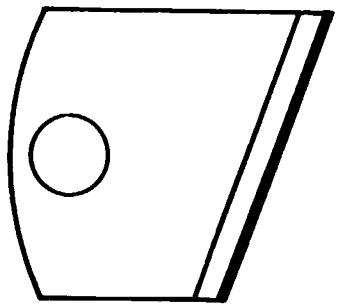


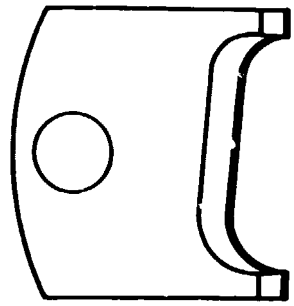
Figure 414 *(continued)*

B. Detachable profile knives

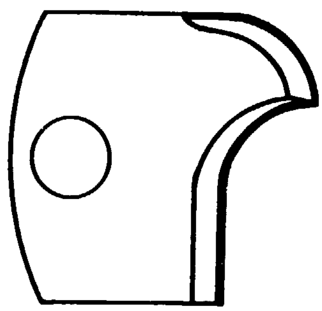
Standard knives true to size



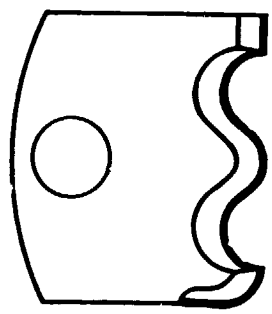
LEN 493-1



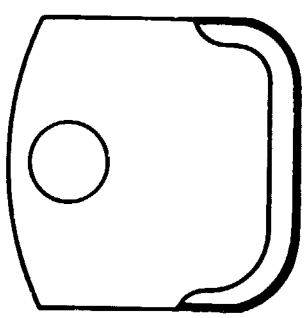
LEN 493-2



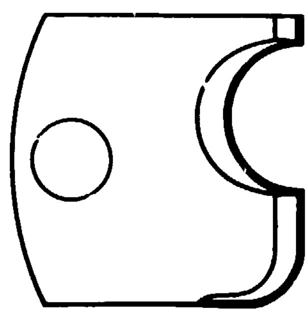
LEN 493-5



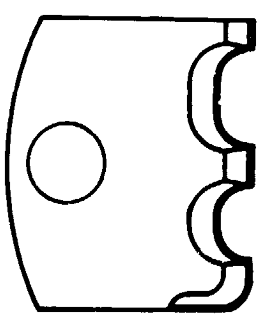
LEN 493-6



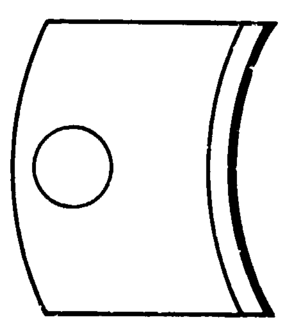
LEN 493-3



LEN 493-4



LEN 493-7



LEN 493-8

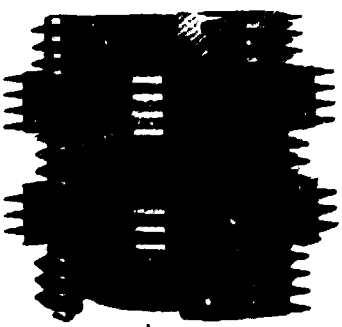
Figure 415. Circular cutter-block with detachable profile knives suitable for mass production on four-side moulders

The purchase price of solid (one-piece) moulding cutters (see figure 416) is high; they must be purchased only after careful consideration and should be well-maintained. There is no need to buy a separate special cutter for profiles of some shapes because they can be obtained using a succession of several cutters.

Figure 416. Solid cutters

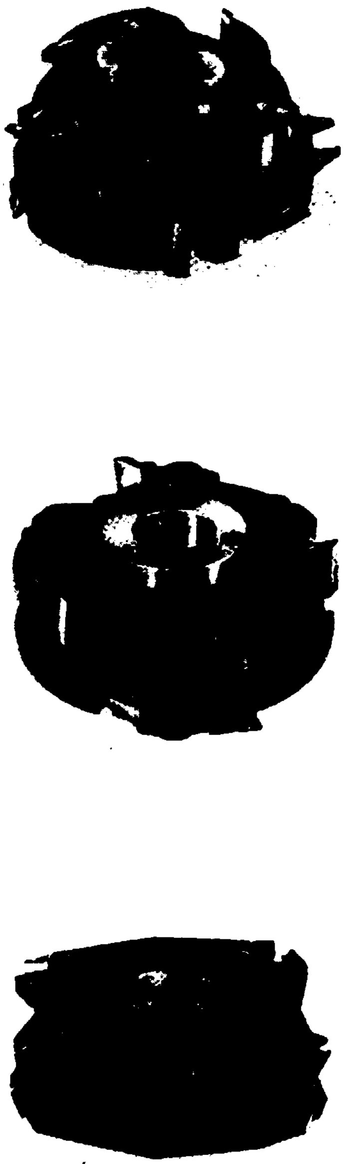
A. Moulding cutter for machines with non-manual feed

B. Cutter stack for a finger-jointing machine



Integrated cutters (see figure 417) are of the most expensive types of cutter and are therefore best suited to the large-scale mass production of standard products, particularly joinery products. The principal advantage of this type of cutter is that it is possible to machine even a very complicated profile on only one spindle. Some of these cutters are adjustable.

Figure 417. Integrated cutters for joinery purposes



The spindle moulding machine, one of the most versatile of woodworking machines, can be tooled with numerous different kinds of cutters selected according to the machining purpose for which they are intended. Since the workpiece is usually fed manually, preference should be given to solid-type cutters in which the chip thickness is limited by a special shape in front of each cutting edge, as shown in figure 418. Some adjustable cutters (see figure 419) are as strongly built as the solid ones. Square cutter-blocks should never be used in a manually fed spindle-moulding machine.

Figure 418. Grooving cutter shaped to limit chip thickness (suitable for manual feed)

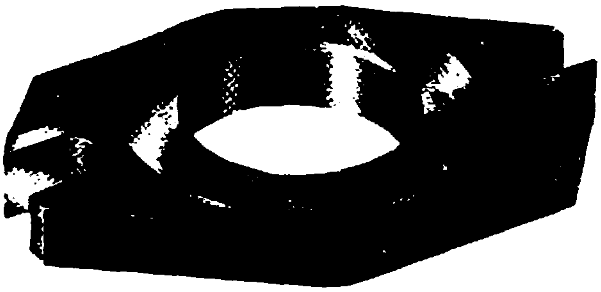
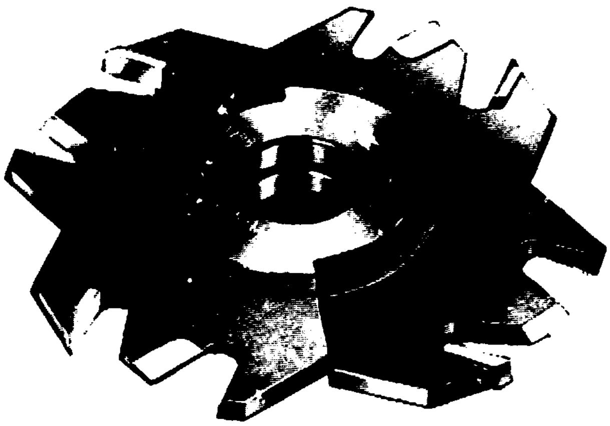
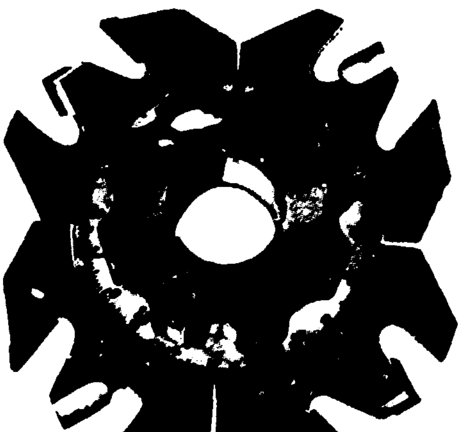


Figure 419. Strongly built adjustable cutters

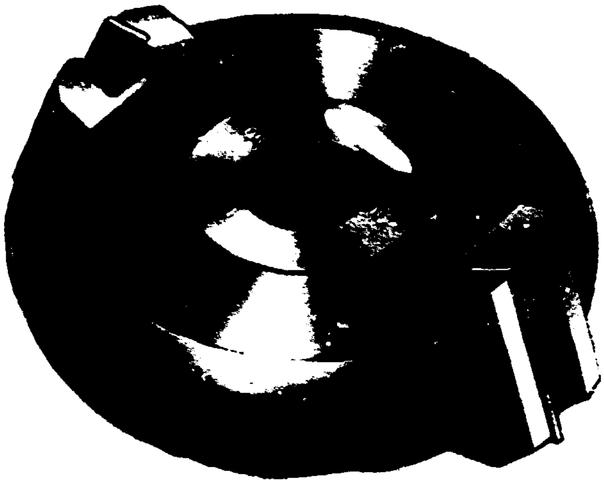
A. Grooving cutter, adjustable by spacers



B. Grooving cutter, adjustable by screw

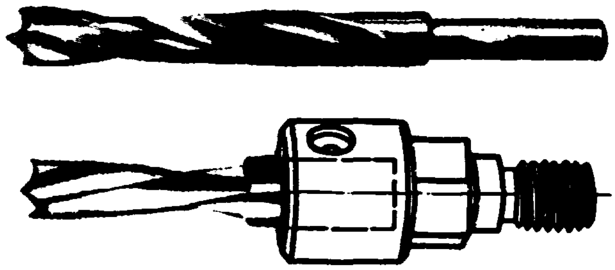


C. Bevelling cutter, adjustable at 5° intervals



Borers and mortisers are necessary in making furniture joints. The popular dowel joint is made with a spiral borer (see figure 420). A good borer is made of high-speed steel alloy and is suitable for machining hardwoods as well as softwoods

Figure 420. Spiral borers for dowel jointing

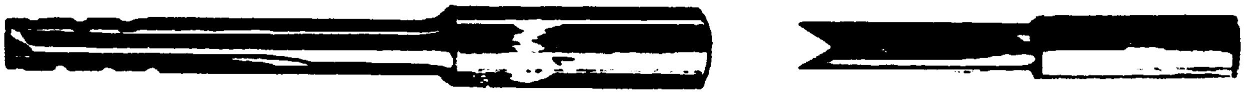


A slot borer is actually a router because it can be fed both in axial and radial directions. A hole with an even bottom and smooth walls can be made with a knot-hole borer. A knot-hole borer is necessary also when boring hole for plugging. When machining hardwoods, an oscillating mortising chisel can also be used, which gives a smooth and even finish. A hollow chisel can be used only when machining soft species of wood. A mortising chain, used in chain mortising machines, is necessary when deep mortises need to be machined as for example for the assembly of locks in door manufacture. This machine is very seldom necessary in furniture manufacture. Several types of mortising tools are shown in figure 421.

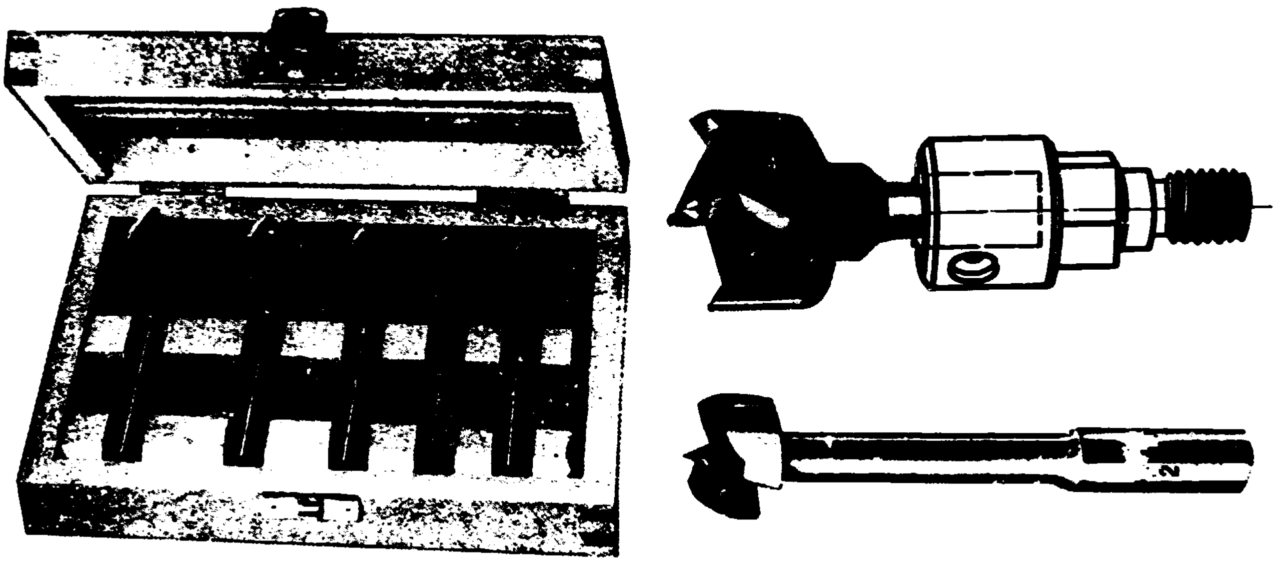
Routing cutters have small diameters. The cutting edge and the shaft are of high-speed steel alloy, but carbide-tipped tools are also manufactured. A routing cutter may be straight or curved and equipped with 1, 2 or 3 cutting edges (see figure 422).

Figure 421. Mortising tools

A. Slot borers for automatic (left) and manual (right) feed



B. Knot-hole borers



C. Oscillating mortising chisels

D. Hollow chisels

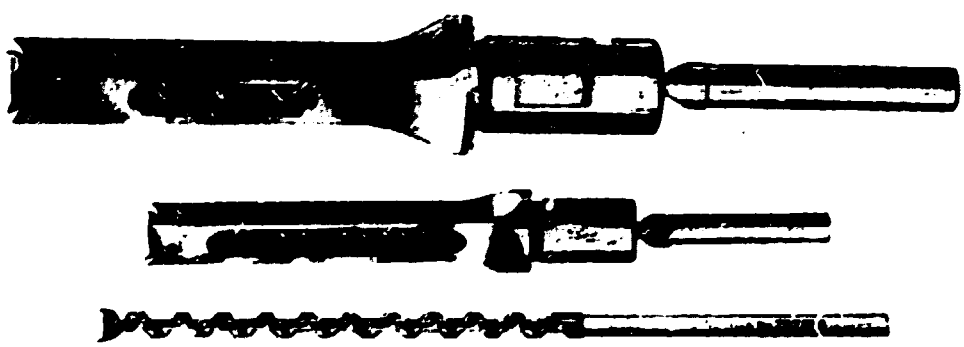


Figure 421 *(continued)*

E. Mortising chain

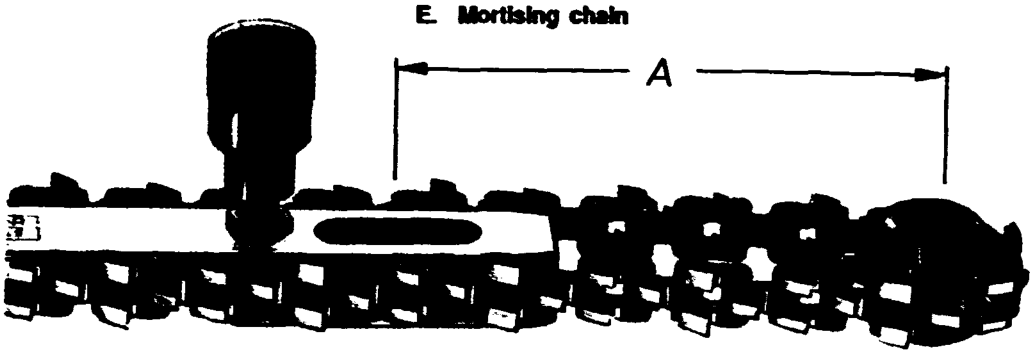
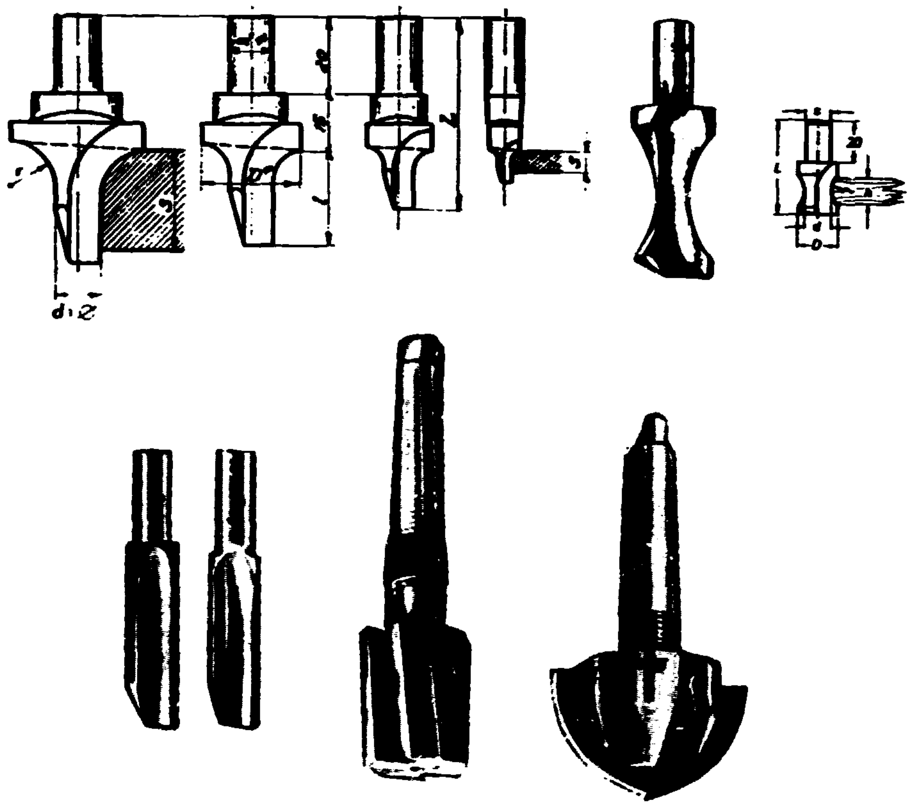


Figure 422. Various routing cutters



Other types of tools are necessary in special cases in furniture manufacture. Dowels are made with a dowel cutter, which comes in various diameters according to the joint (see figure 423). Lathe knives make up another group also used in furniture manufacture.

Sharpening of conventional-type tools

Simple but versatile standard grinding machines are best suited to the conditions in the developing countries. These machines are small in capacity, and, although versatile, setting them is time-consuming because of their simple construction. When changing from one type of tool to another, the worker must be very careful; otherwise mistakes may easily be made, for example faulty grinding, which may cause severe damage to the tool.

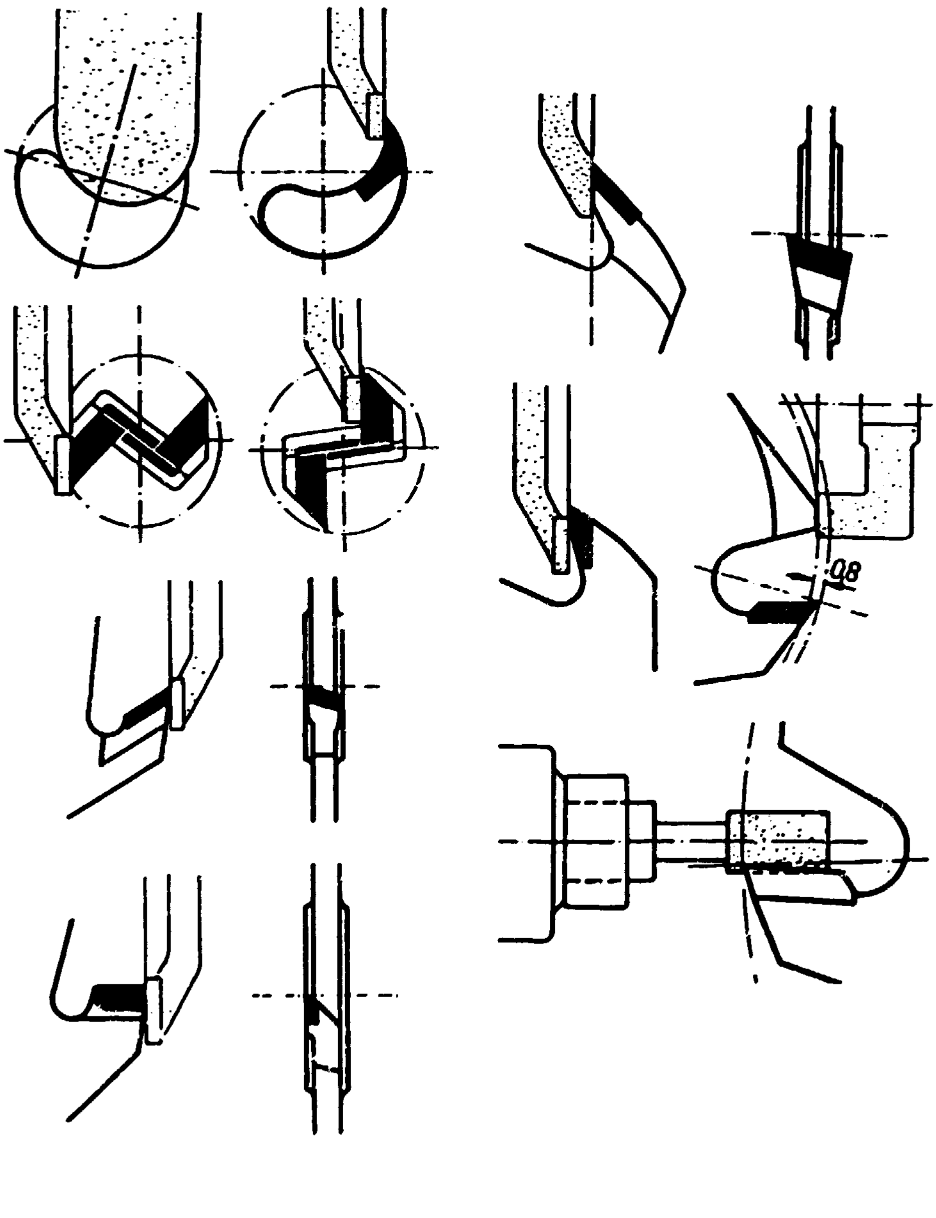
A different grinding wheel must be used for each profile (see figure 424). The grinding wheel must be cool-working, and the bond must be as soft as possible. This increases the costs of the grinding wheel, but, on the other hand, the tool costs decrease.

For grinding high-speed steel alloy, an aluminium-oxide Al_2O_3 grinding wheel is used. Pre-grinding is done with grinding wheel number 40-60; fine grinding is done with wheel number 100-150. Grinding in two stages results in a smoother finish and a sharper tool. A single grinding can be successful if grinding wheel number 80 is used and the depth of cut is small. Wet grinding must be used whenever possible.

It is important to check that the grinding wheel is not broken before being mounted to the machine and also that the cover is in its proper place.

Figure 423. Dowel cutters

Figure 424. Grinding wheels for different profiles



The most common fault in grinding is that the cutting edge burns as a result of a single grinding that is too rapid. This is particularly the case in dry grinding. Band-saw blades are a good example of this; when the edge of the blade becomes too hot, it breaks easily. When an attempt is made to grind a very sharp edge, the sharpening angle easily becomes too small and the edge breaks.

Sharpening angles (β in figure 425) recommended for different tool materials are:

Carbon steel	35°	For working softwood
Steel alloy	37°	
High-speed steel alloy	39°	
Stellite	42°	
Tungsten carbide K 40	45°	
Tungsten carbide K 30	55°	
Tungsten carbide K 20	60°	

It often occurs in grinding profile cutters that the knife pairs do not have the same form. They may have different weights and a different vibration owing to centrifugal force. Often only one of the knives cuts the correct profile. In that case, the feed rate of the workpiece must be slower or the finish will be uneven.

When solid cutters are ground, a pitch controller (indexing head) must always be used to ensure that the pitch remains the same. In manual grinding the pitch changes easily, with the result that only one edge cuts and the spindle vibrates. If moulder cutters, borers and mortising tools are sharpened too rapidly the grinding damages the whole tool.

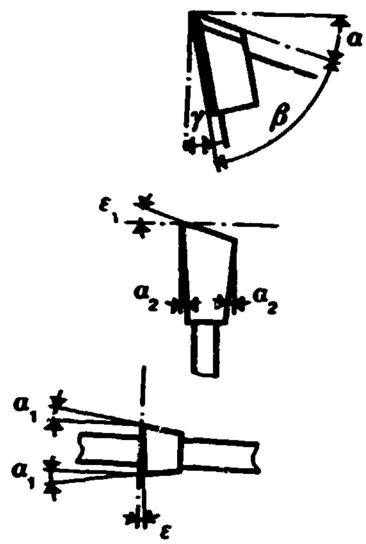
Sharpening of carbide-tipped tools

Carbide is made by sintering. Tools tipped with carbide are easily damaged by impact and knocks. They must never be laid on machine tables or other metal surfaces but instead on bases made of wood, rubber or plastic. This is particularly important in transfer and storage. The condition of a carbide-tipped tool must be constantly observed. When signs of wear occur, the tool must be serviced and repaired in time. If the worn area becomes too wide, the required force and energy increase unnecessarily, the blades may break and cracks may develop in the body. Also, service becomes uneconomical since the carbide and the diamond-impregnated grinding wheel are worn rather fast.

Before carbide-tipped tools are serviced, they must be carefully cleaned with resin remover or crystal soda solution. Steel brushes or hard and sharp metal objects must never be used. If the blades are badly damaged, they should be reconditioned with new carbide tips rather than repaired, for the sake of economy. All sharpening should be performed towards the blade. Only small counterpressure, i.e. small feed, should be used. At the beginning and end of each feed, the grinding wheel must never be fed along the blade. Instead, it must be inserted or removed perpendicular to the blade; otherwise the blade will bend. The original blade shape must be maintained if possible to keep the cutting capacity unchanged (see figure 425).

After sharpening, the carbide must be allowed to cool off gradually in the air. It must never be cooled suddenly, for it could cause splits or damage in the carbide. After each sharpening the blade must be checked to ensure that there are no splits, that it cuts well and that it maintains the correct shape and steady rotation.

Figure 425. Sharpening circular saws and grooving cutters



Key:
- α Clearance angle
- β Tooth point angle
- γ Chip angle
- α_1 Tangential clearance angle
- α_2 Radial clearance angle
- ε Front bevel angle
- ε_1 Back bevel angle

The following sequence should be followed:

- Cleaning the saw blade
- Inspection of the general condition
- Circular grinding of the blade diameter
- Sharpening of the chipping edge, if necessary
- Coarse grinding of the back edge
- Finishing of the back edge
- Careful removal of excess from the tooth back edges of the saw blade

Grinding of circular saws

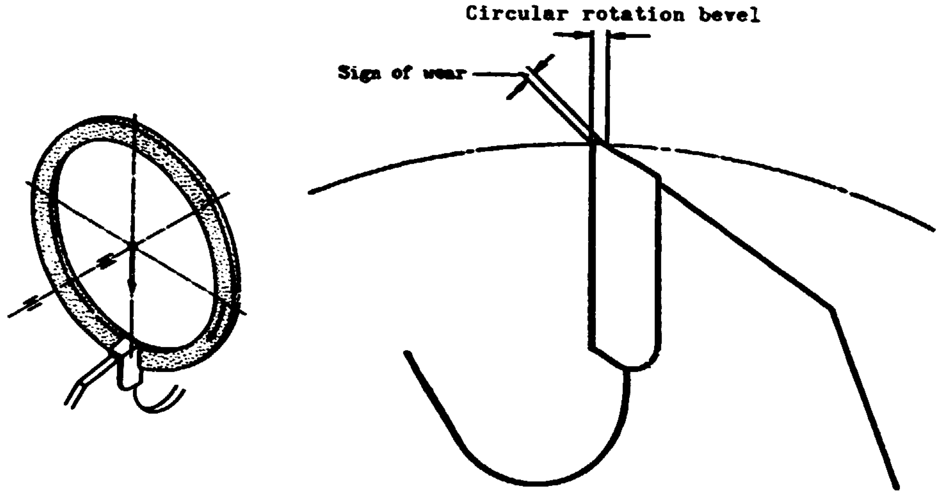
A diamond-impregnated grinding wheel, D 70/C50, should be used when there are cracks in the blade or it is badly worn. A diamond cup grinding wheel, D 30/C50, should be used for finishing circular grinding.

A carbide-tipped saw blade, which has been mounted to a saw-sharpening device, is rotated manually at the grinding wheel (see figure 426). The teeth must always be towards the cutting blade. The circular grinding bevel must be large enough not to leave any signs of wear. If the worn area is not extensive, circular grinding is not necessary.

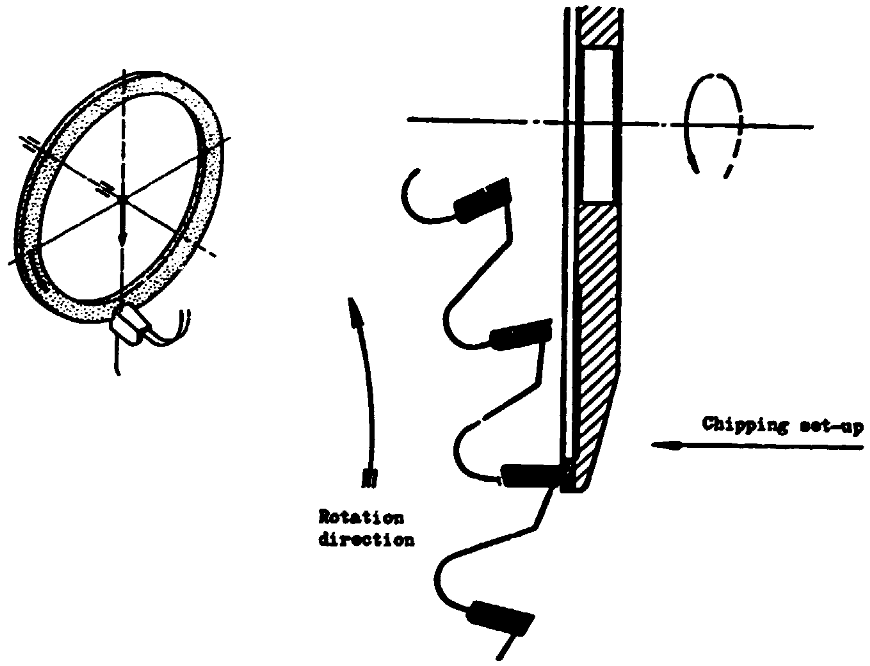
Instead, the lowest teeth (cutting edge) can be found with a measuring device and all other teeth sharpened to correspond to it. If there are severe cracks in multi-teeth saws, the smallest of these can be ignored, provided that they do not follow immediately one after another; thus, unnecessary reduction of the diameter is avoided and the saw blade's life is not shortened. Carbide tips that have become useless must be replaced. This can be done in the manufacturing plant; it is recommended that the saw-blade tensioning should be checked at the same time.

Figure 426. Sharpening of a carbide-tipped circular saw

A. Sharpening the chipping edge



B. Grinding the back edge



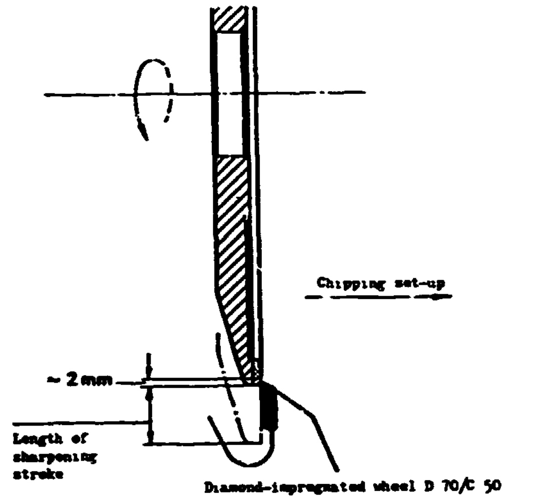
Sharpening the chipping edge

The operation for sharpening the chipping edge is shown in figure 426 A. The carbide-tipped circular saw is mounted on a device and is set to the sharpening machine so that the chipping edge is precisely aligned with the surface of the grinding wheel (see figure 427).

The chipping edge is ground lightly and finished only if necessary. The carbide tip, which is about four times as long as it is thick, determines the maximum number of sharpenings of the chipping edge and back edge. The number should be only one quarter of the number of sharpenings needed for the back edge. To obtain a steady rotation of the saw blade, the chipping of all teeth must be even. If economical use of the diamond-impregnated grinding wheel is desired, the maximum chipping set-up must not exceed 0.02 mm. When grinding, the cutting edge must not be crossed to prevent it from bending.

When finishing the grinding of the cutting edge, the sharpening stroke must be stopped about 2 mm before the tip of the tooth. If this is not done, the surface of the tooth could be deformed (see figure 427).

Figure 427. Setting for sharpening the chipping edge



Grinding the back edge

The operation for grinding the back edge is shown in figure 426 B. When sharpening the clearance angle, the diamond wheel must not touch the steel saw blade supporting the carbide tips. This is possible if the carbide-tipped circular-saw blade is directed so that the back grinding angle is 5° wider than the clearance angle at the carbide tip (i.e. $\alpha + 5°$) (see figure 428).

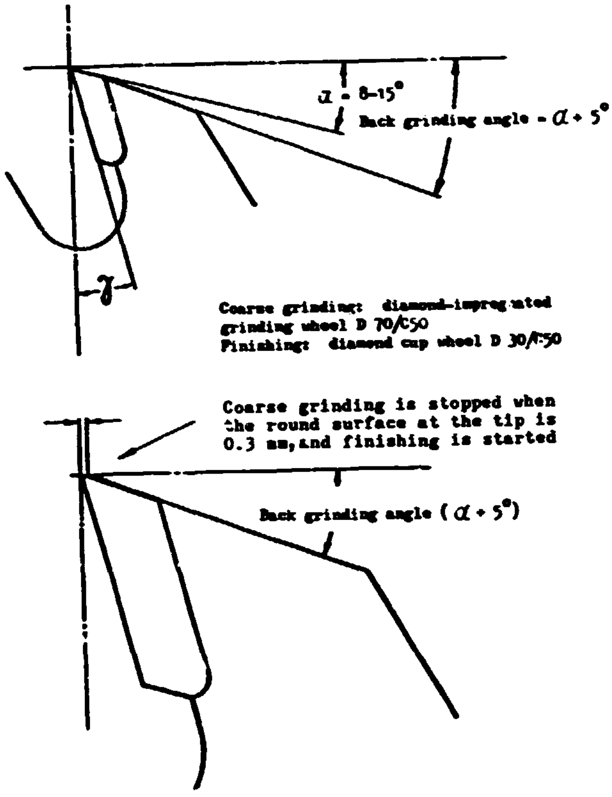
Coarse grinding is necessary only when there is a bevel larger than 1 mm in the steel saw blade after the last grinding of the clearance angle (α).

The back grinding angle must be about 5° larger than the desired clearance angle. In coarse grinding the remainder of the circular grinding bevel must be about 0.3 mm, so that when finishing the clearance angle, only the carbide tip is hardened with the diamond-impregnated wheel.

The finishing of the clearance angle has a decisive effect on sawing efficiency. It must be performed with particular reliability and care. The circular sharpening bevel is completely ground off but not further than the cutting edge. Thus special attention must be paid in order to have a perfectly steady rotation.

When grinding teeth with special shapes—such as trapezoid, convex, alternate front or back bevel teeth; mutually bevel teeth; alternate or mutual front and back bevel teeth etc.—the sharpening is performed in the same way. It is important to set up the angle exactly according to the manufacturer's instructions. If such instructions are not available, it is recommended that the angles be measured using a new unused saw blade as a model.

Figure 428. Setting for sharpening the back edge



Grinding of cutters

The instructions in this section apply to all kinds of cutters. Before grinding the cutter, it must be carefully cleaned and every cutting edge must be examined. If there are cracks in the carbide tips, the tips must be replaced to prevent accidents. Carbide tips with breaks must also be replaced.

When grinding, chip removal must be even and balanced. If large breaks prevent this, the cutter must be balanced again after the sharpening.

If the angles are not known, they must be defined so that proper set-up can be made. After sharpening, all cutting edges must be checked once more to locate possible cracks.

Circular grinding

A diamond-impregnated grinding wheel, D 70/C50, should be used when cutting edges are cracked or worn excessively. A diamond cup wheel D 30/C50 is used for finishing. The cutter is fixed to the tightening device of its hole, if necessary with concentric plates, and set to the pitch controller.

Grinding must always be performed towards the cutting edge. Circular grinding is regulated to sharpen the cutting knife with the largest signs of wear or cracking, in other words the cutter has to be rotated manually against the grinding wheel so that the tooth with the largest signs of wear or cracking touches the grinding wheel (i.e. the diameter of the cutter is reduced to that of the lowest tooth).

Grinding the chipping edge

A diamond-impregnated grinding wheel, D 70/C50, is used if coarse grinding is necessary. A diamond cup wheel, D 30/C50, is used for finishing. The cutter with its tightening device is fixed and set to the pitch controller. The pitch controller is turned according to the axial angle so that when the fixing carriage moves, the chipping edge touches the grinding wheel precisely.

All the sharpening instructions for circular saws are also applicable to all kinds of cutters.

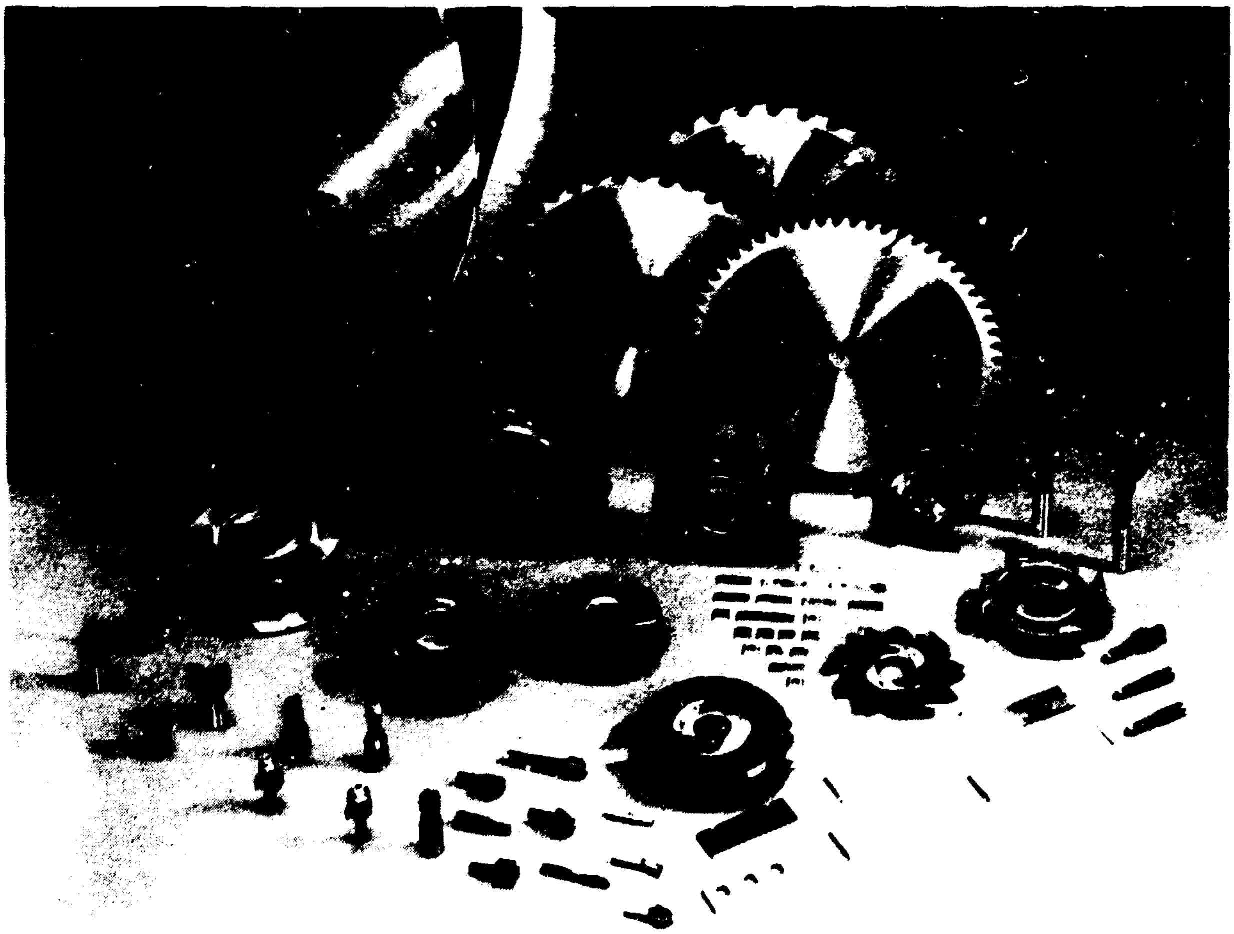
Grinding the chipping devices

Since the chipping devices made by various manufacturers often differ structurally, it is recommended that the manufacturer's service instructions be observed.

The general instructions for sharpening carbide-tipped circular saws can be applied to chipping devices as well. They are generally applicable without restrictions to circular saws for edging that can be detached from the chipping body, and they are partly applicable to tooth segments fixed to the chipping body.

Annex

SELECTION OF TOOLS FOR WOODWORKING



Part three

MANAGEMENT CONSIDERATIONS

XXXIII. Quality control in the furniture industry*

A product's ability to compete on the market is greatly dependent on its quality. For this reason the expressions "high-quality product", "export quality" and the like are widely used in advertising industrial products. From the user's point of view, the quality determines the usefulness or use value of a product.

In the manufacture of products the achievement of constant quality is impossible; certain variations are natural and cannot be avoided. The highest quality with the least variation can be attained in individual production, where each part or component is finished and fitted separately so that the desired standard is obtained.

Although certain variations in quality cannot be avoided, they can be kept under control in mass production or serial manufacture. The limits within which the quality of a product, its parts or materials may vary are first defined and then maintained by applying systematic quality control. (The technical conditions for the quality of materials for and processing in the furniture and interior fittings industries, established by the Union européne de l'ameublement, are given in appendix I.) The quality must not be too low or too high; in either case the product's ability to compete on the market is decreased. If the standard for the quality of a product is set higher than normally required of products in its category, the production costs will become too high and the product cannot be sold at a competitive price.

The application of systematic quality control, compared with manufacture not using this method, has two alternative advantages. Either higher quality products can be manufactured at the same production cost, or the same quality can be achieved at a lower production cost. It should also be noted that whereas certain aspects of quality control apply mainly to manufacturing, some of them serve the end-user of the product directly. For example, the systematic control of the dimensional accuracy of joint details will keep the percentage of rejected components low, but durability testing of a chair assembled from KD components serves the consumer. In the present chapter, emphasis is on the manufacturing side of the quality control, which makes it possible to produce interchangeable parts and sub-components. The testing of furniture is briefly covered in the last section of the chapter.

There are many reasons for variations in quality in the wooden furniture industry. Typical variables are the following:

(a) The properties and condition of the sawn wood used: moisture content, the number and size of knots and other faults, specific gravity, strength properties;

(b) The properties and condition of other raw materials and semi-manufactured products: veneer, wood-based panels, plastic parts, fittings;

(c) The dimensional accuracy of machined components: thickness, width, length, joints, forms;

(d) The dimensional accuracy of assembled products: external and internal measurements, clearances between moving parts;

(e) The quality of surface finishing: evenness of surface, colour, shade and gloss of lacquered surface;

(f) The durability of finished products.

Quality control includes many different systematically repeated measuring or other inspection actions. Despite the great number of variables, the quality standard of products can be greatly improved by using specially designed simple equipment. As much of this equipment can be made in the plant, only a minor capital investment is necessary.

Quality control of materials

The starting point for quality control is the inspection of materials to be processed or used. This can be done:

(a) When buying or ordering the material;

(b) When receiving the incoming material;

(c) Before processing or using the material.

Sawn wood, for example, is usually bought from outside sawmills and should be checked at the sawmill's yard or in storage at the time the lot is ordered. The same principle applies to veneers; they should be inspected on receipt at the factory to make sure that the correct lot has been delivered. All semi-manufactured products and other materials should be checked on receipt. One of the most important measures of control before processing is the checking of the moisture content of sawn wood, veneer and wood-based panels.

Inspection of the principal materials usually covers the items indicated briefly below.

Sawn wood

Sawn wood is inspected for:

(a) Kind of wood (species). This inspection is sometimes difficult for tropical species. Test planing may be necessary;

(b) Quality: number, size and distribution of knots, end splits, rot and other faults, colour shade and grain structure when appropriate;

(c) Dimensions of sawn wood: thickness and its variations; width and length of boards when appropriate;

(d) Average moisture content and moisture distribution within boards. This is necessary information for

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seasoning (air-drying, kiln-drying), and it requires cutting of test samples. (See the section on controlling of the moisture content of solid wood, below.)

Veneer

Veneer is inspected to determine:

(a) Kind of veneer (species);

(b) Colour shade and grain structure:

(i) Checking should be carried out preferably in daylight or in the light of special colour inspection lamps. Standard fluorescent tubes are not recommended because of their unsatisfactory spectral properties;

(ii) Uniform quality from batch to batch is of major importance, particularly in the production of element furniture;

(iii) Checking can be carried out by comparing the veneer batch with a master sample which is stored in a dark place when not being used;

(iv) A pyramid figure is normally allowed to some extent in parts in which the grain direction of the veneer will be vertical, e.g. cabinet doors and end panels (see figure 429);

(v) Parts in which the grain direction will be horizontal require straight and narrow-striped veneer, e.g. table and cabinet tops, drawer fronts etc. (see figure 429);

(c) Thickness and its variations: a micrometer is a suitable measuring instrument;

(d) Evenness of surface: the surface should be plane (not wavy) and smooth;

(e) Moisture content:

(i) Handling of veneer necessitates at least 10-12 per cent moisture content to avoid splitting. The veneer is too crisp at lower moisture contents;

(ii) The ideal moisture content at the moment of veneering in a hot press is about 2 per cent lower than the moisture content of the panel or core wood on which it is being applied;

(iii) In case the veneer is too moist when gluing, surface checking will result after the panel has attained its final equilibrium moisture content.

Wood-based panels

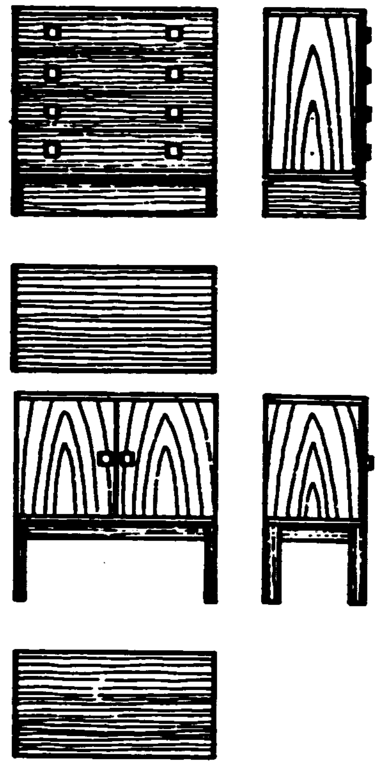
Particle board, plywood, blockboard and fibreboard are wood-based panels. The main objectives of inspection are:

(a) Surface quality: its suitability for veneering or painting. Urea-formaldehyde glue requires a smooth surface that offers good contact;

(b) Thickness and its variations: a standard thickness tolerance is normally about ± 0.3 mm, but rougher variations are not uncommon. A vernier caliper or micrometer is a suitable measuring instrument;

(c) Moisture content: the moisture content at the moment of processing should be about the same as that of solid wood, that is, the equilibrium moisture content of the intended conditions of use.

Figure 429. Veneering according to the pattern of the grain



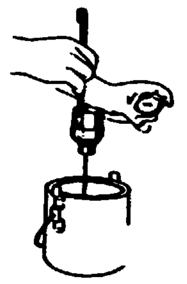
Glues, lacquers and paints

Glues can best be checked by making gluing tests. The viscosity of lacquers and paints must be checked before use. This is usually done with a special standard cup, e.g. a Ford Cup No. 4 (figure 430) having 100 cm³ volume. The viscosity is measured by the seconds it takes for the lacquer or paint to flow out through the bottom opening of the cup. The flowing time must meet the recommendations of the lacquer or paint manufacturer.

Controlling the moisture content of solid wood

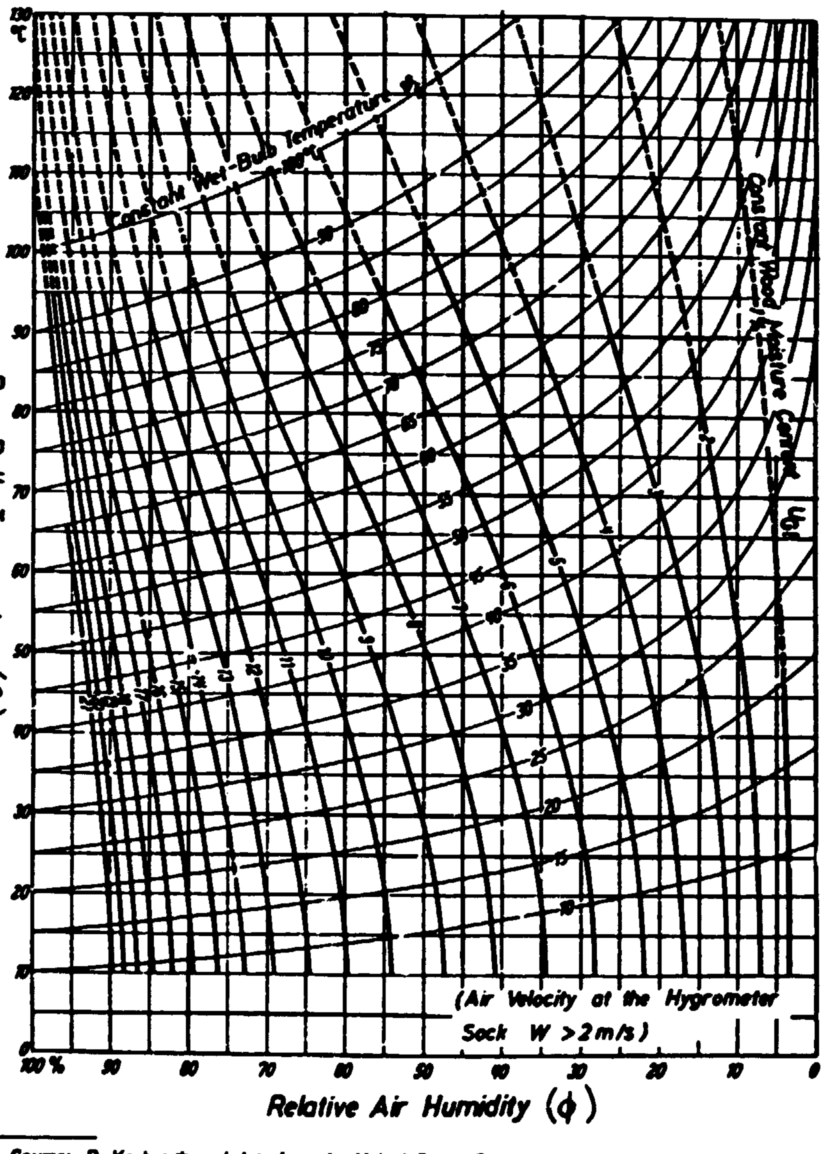
The proper moisture content of solid wood to be processed is the primary prerequisite for high-quality products. Wood is a hygroscopic material that has a tendency to set to a moisture balance with the surrounding atmosphere. This condition, which is called the equilibrium moisture content, depends on the relative humidity and temperature of the surrounding air. The relative humidity is decisive, the effect of temperature being minor. The average equilibrium moisture content as a function of the relative humidity and temperature of air is shown graphically in figure 431. These values apply to all species of wood with sufficient accuracy for all practical purposes.

Figure 430. A Ford Cup used to measure viscosity



The shrinking and swelling of wood when exposed to variations in moisture are among its most unfavourable properties. In addition to changes of dimension, deformations develop in the cross-sections of pieces because shrinkage or swelling is considerably greater in the tangential (T) than in the radial (R) direction (to growth rings). Typical shrinkage deformations in cross-sections are shown in figure 432. The average dimensional changes of wood in percentage for certain species when exposed to a 1 per cent change of moisture content is indicated in table 25. For example, assuming that the actual moisture content of wood in a furniture factory would vary ± 1 per cent during manufacture, the width of a part made of oak, having a nominal measure of 50 mm (T-direction), would vary ± 0.16 mm.

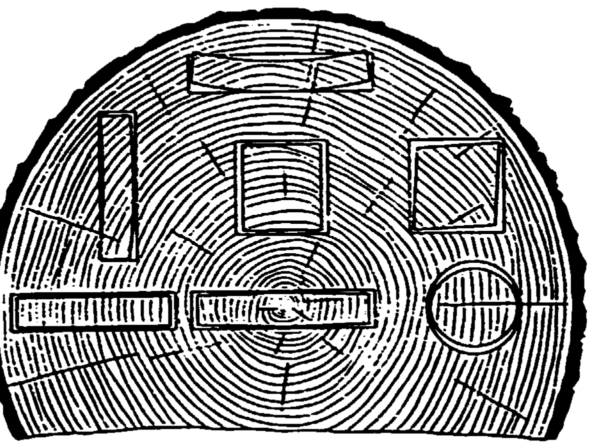
Figure 431. The determination of equilibrium moisture content of wood as a function of relative humidity and air temperature



Source: R. Keywerth and data from the United States Products Laboratory, Madison, Winconsin, USA, 1951. (Example: With a dry-bulb temperature θ = 45°C and a relative air humidity φ = 55% respectively a wet bulb temperature θ_f = 36°C the wood equilibrium moisture content is U_{gl} = 9%).

Figure 432. Cross-sections of wood showing deformations from shrinkage

A. Characteristic shrinkage and distortion of flats, squares and rounds as affected by the direction of the annual rings (Tangential shrinkage is about twice as great as radial.)



B. Deformations of one-piece and glued boards

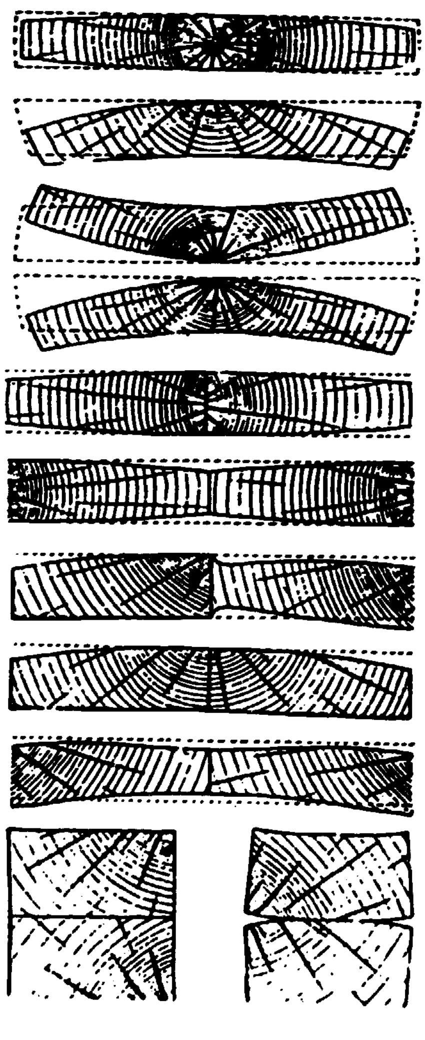


Table 25. Shrinkage in tangential and radial direction with a decrease of wood moisture content by 1 per cent for different wood species

(Percentage)

Wood species	*Tangential*	*Radial*	*Wood species*	*Tangential*	*Radial*
Parana pine	0.33	0.19	Karri	0.43	0.33
Fir	0.33	0.19	Limba	0.22	0.17
Hemlock	0.25	0.13	Lime	0.30	0.23
Pine	0.32	0.19	Lovoa	0.26	0.17
Thuja	0.20	0.09	Mahogany	0.20	0.15
Abachi	0.19	0.11	Makoré	0.27	0.22
Abura	0.29	0.18	Niangon	0.36	0.19
Afrormosia	0.32	0.18	Walnut	0.30	0.20
Afzelia	0.22	0.11	Gaboon	0.24	0.16
Agba	0.20	0.11	Kamin	0.39	0.19
Maple	0.30	0.20	Locust	0.33	0.24
Satin mahogany	0.25	0.16	Horse chestnut	0.25	0.10
Bilinga	0.30	0.16	Beech	0.38	0.22
Bongossi	0.40	0.31	Elm	0.29	0.20
Oak	0.32	0.19	Sapelli	0.26	0.19
Ash	0.38	0.21	Teak	0.26	0.16
Greenheart	0.35	0.29	Utile	0.25	0.20
Guarea	0.27	0.20	Willow	0.35	0.26
Iroko	0.28	0.19	Yang	0.41	0.25

The ideal moisture content for wood when processed is its equilibrium moisture content under the conditions in which the product will be used. From this it follows that the factory climate should have a corresponding relative humidity and temperature. As the time normally needed for all production stages in the serial manufacture of wooden furniture is several weeks or even months, the parts are likely to reach the balance during the process. This problem is typical and well-known in tropical climates with high humidity, particularly when manufacturing furniture for export to countries with less humid climates. For example, if the moisture requirement of the target market is 10 per cent but the equilibrium moisture content in the factory atmosphere is, say, 16 per cent, the wood should be machined, surface-finished and plastic-wrapped airtight immediately after kiln-drying. An ideal, but in practice expensive, solution to this problem would be to provide the entire factory space with air-conditioning. The relative humidity of the air in material stores and factory shops is best controlled with a hygrometer that gives readings in percentages. The meter should be ce trally located and fixed, e.g. on a pillar.

The moisture content of wood should be controlled at the following stages:

(a) Whenever possible when buying and ordering a lot of sawn wood from a sawmill;

(b) When receiving the lot at the furniture factory;

(c) Before kiln-drying; sawn wood is usually then air-dried;

(d) During the kiln-drying process to check that the drying is progressing according to the schedule suitable to the species and thickness in question;

(e) After kiln-drying to check the end moisture content;

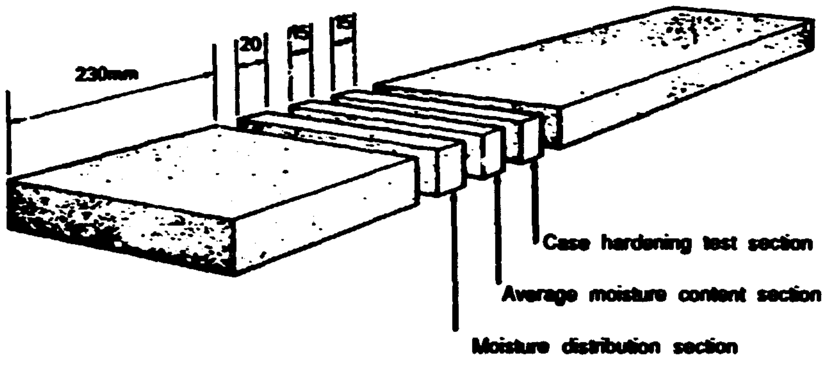
(f) During the subsequent machining and other manufacturing stages;

(g) For finished products before packaging.

Determining the moisture content

The moisture content of wood is usually determined either by the oven-dry method or by electrical moisture meters. The oven-dry method is the most exact, but it is slow and requires samples to be cut from material. Because of its accuracy, however, this method is used as a standard method for moisture determination in kiln-drying. The samples should be sawn from boards according to figure 433.

433. Sawing samples for determining the moisture content



The sample is weighed and then placed in a laboratory oven heated to 103°C ± 2°C, and kept there until constant weight is reached. This indicates that all water has been removed from the wood. The loss in weight gives the amount of moisture that was in the sample when sawn. The moisture content is calculated from the simple formula:

$$\text{Moisture content} = \frac{\text{Initial or wet weight} - \text{dry weight}}{\text{Dry weight}} \times 100\%$$

For weighing ordinary samples, balances having a capacity of about 200 g and a sensitivity to 0.1 g are used.

Electrical moisture meters

Electrical moisture meters are less accurate but facilitate the rapid determination of moisture content for control purposes and are quite satisfactory in this regard. If meters are maintained and used carefully and if the necessary corrections for species and temperature are applied, an accuracy of ±1 per cent may be expected in the range from 7 to 25 per cent moisture content. Resistance-type meters (see figure 434 A), using needle or blade electrodes about 10-mm long, give an average moisture content of a board of 25-mm thick. For thicker material the moisture distribution should always be determined by driving two needle-electrodes to different depths, or the value obtained for needles driven to one fifth the thickness should be regarded as representative of the average moisture content of wood.

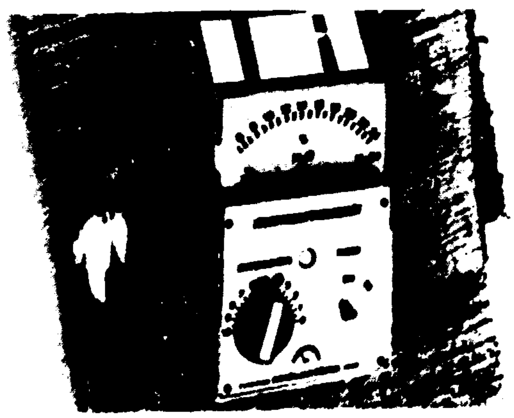
Electrical moisture meters can also be used to control the moisture of particle board and fibreboard, providing that the necessary corrections are applied. The correction tables needed are usually enclosed in the meter package. Testing of veneer requires plate types of electrodes.

The newest type of electrical moisture meters (figure 444 B) are based on a high-frequency electric field directed to the piece of wood to be measured for moisture content. The accuracy is satisfactory, and a particular advantage of these types of meters is that they do not damage the sample at all because the electrodes require only surface contact for measuring.

Figure 434. Electrical moisture meters

A. Resistance-type meter with needle and plate electrodes

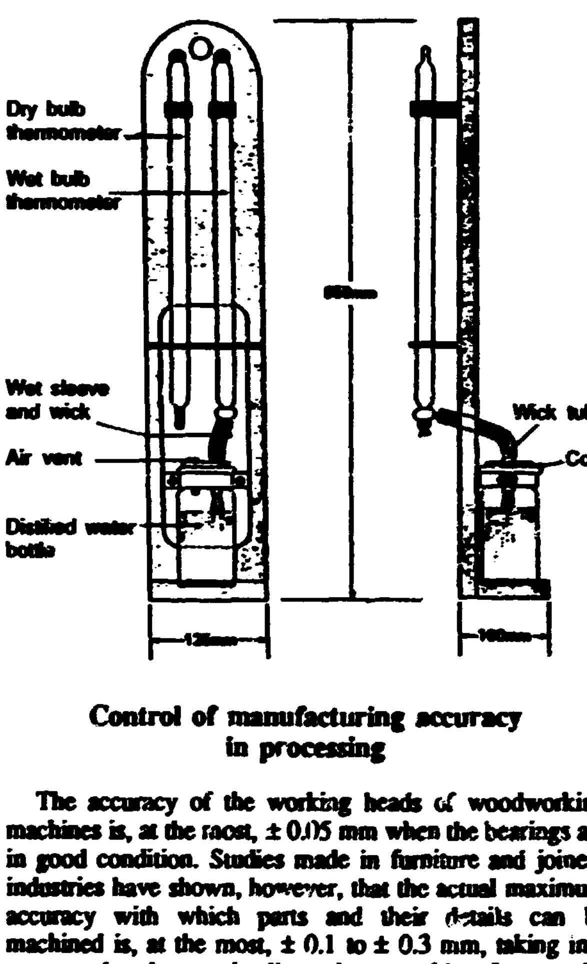
B. High-frequency field-type meter with contact electrodes



Moisture control in kiln-drying

The operation of a drying kiln is controlled by the relative humidity of the air in the kiln compartment. The relative humidity is measured either with simple wet- and dry-bulb hygrometers (figure 435) or with electrical instruments. The most advanced prefabricated kilns are completely automated and operate according to programmed schedules.

Figure 435. Wet- and dry-bulb hygrometer



Control of manufacturing accuracy in processing

The accuracy of the working heads of woodworking machines is, at the most, ± 0.05 mm when the bearings are in good condition. Studies made in furniture and joinery industries have shown, however, that the actual maximum accuracy with which parts and their details can be machined is, at the most, ± 0.1 to ± 0.3 mm, taking into account the changes in dimensions resulting from variations in the moisture content during the manufacturing process. The accuracy with which small details such as joints can be machined is usually higher than the accuracy with which larger parts can be manufactured, e.g., a 10-mm diameter dowel hole can normally be bored with an accuracy of about ± 0.15 mm, but a 1,000-mm long table rail is difficult to trim saw with a greater accuracy than ± 0.3 mm. These figures refer to accuracy in continuous work, that is, the extreme limits within which the actual measure varies. The accuracy of the rectangularity of panels is of particular importance in the production of element furniture such as bookcases, office furniture and kitchen furniture. At times the rectangularity may vary as much as ± 1 mm in panels less than 0.5-m wide if a double-end tenoning machine is used for trim sawing.

One of the prerequisites for fixing realistic quality demands for manufacturing accuracy is the knowledge of the precision of different machines and equipment. It is apparent that the actual precision of woodworking machines is lower than is generally believed, but, on the other hand, the practical accuracy attained in many cases is far lower than it could be. This is usually owing to improper use and setting of machines and tools, the poor condition of machines or tools or the use of the wrong type of tools.

Advantages of high accuracy

The main advantages of a high (highest realistic) and controlled accuracy in manufacturing are the following:

(a) Parts of products belonging to different series are interchangeable;

(b) A sliding fit between parts is possible without manual fitting in assembly;

(c) Joints are easy to assemble and have good strength;

(d) Manufacture in large series is possible;

(e) The number of faulty parts or products decreases;

(f) Higher quality means easier marketing;

(g) There are fewer claims from customers;

(h) Profitability improves.

To achieve high accuracy, measures must be taken to ensure that:

(a) The machines are serviced regularly according to their operating instructions;

(b) The proper type of tools are used;

(c) Only well-maintained tools are used;

(d) Machines are set up using high-quality special measuring instruments such as micrometer dials and set-up gauges. The set-up made is best checked by test feeds and using nominal measuring gauges (see the section on nominal measuring gauges, below, figures 444 and 445);

(e) Dimensioned working drawings are used throughout; the numerical values indicate the nominal dimension to be achieved;

(f) Only high-quality measuring instruments are used;

(g) The unavoidable variations in measurements are concealed by structural means by already taking them into consideration in the design stage of production (figure 436);

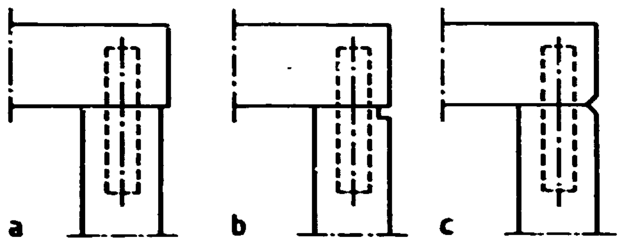
(h) Nominal measure gauges and templates are used to control the dimensions during machining;

(i) Jigs are used in machining and assembly whenever possible (see chapter XXII, "Jigs used in the furniture and joinery industries");

(j) The machining and assembly shops are adequately illuminated;

(k) The accuracy is continuously controlled by spot tests.

Figure 436. Structural means of concealing dimensional inaccuracies



As mentioned above, the use of dimensioned working drawings in which the numerical values indicate the nominal dimension to be achieved is the prerequisite for attaining high accuracy in serial production. This information on dimensions is needed for the following operations:

(a) Set-up of machines and equipment;

(b) Design and construction of jigs for machining and assembly;

(c) Control of measures in machining and assembly.

Ordinary measuring instruments

The following types of measuring instruments are necessary for the tasks mentioned above:

Metal tape rulers with a mm scale
Rigid straight rulers with a mm scale
Vernier calipers, reading by steps of 1/10 or 1/20 mm
Fixed-angle gauges for 90°
Adjustable-angle gauges

Only high-quality steel instruments should be used. Particular attention must be paid to proper handling and storage of all measuring instruments. Rulers with worn-out scales, vernier calipers with worn-out and rounded measuring surfaces or damaged instruments must be rejected. Some of the most important ordinary measuring instruments are shown in figure 437.

Special measuring instruments for furniture and joinery production

In addition to the standard measuring instruments, certain special instruments are available that have been developed by research laboratories to serve the particular needs of quality control in the furniture and joinery industries. Some examples of these are shown in figures 438, 439, 440, 441, 442 and 443.

Nominal measuring gauges

The set-up of machines and later the control of measurements in machining can be greatly facilitated by the use of specially constructed nominal measurement gauges. The most usual types are:

Length and width gauges
Thickness gauges
Boring pitch gauges
Joint gauges
Profile gauges or templates

The construction principle of these gauges is shown in figure 444. The best material is steel or hard aluminium alloy (Duraluminium). In certain cases wood or thick plywood is also usable, providing, however, that the variations of the relative humidity in the factory are small. Wood or plywood should be used only for the body of the gauge, the actual measuring pieces being made of metal (figure 445). It must be remembered that only the length (grain direction) of a solid wood piece can be regarded as constant for most practical purposes. In gauges made of metal plates, such as thickness gauges, the corners of the measuring openings must always be bored out to make space for small splinters and other machining remains at the edges of parts to be measured.

The gauges are often constructed to perform several measuring operations, e.g., a rod type of gauge may be constructed to give both the length and the width of a panel. If the gauge is made adjustable, it can easily be readapted for later measuring purposes. The adjustable types should be constructed of steel. The thickness gauge in figure 444 is intended for controlling in thickness planing. The selection of thicknesses it includes represents the standard thicknesses used in a factory. The values are based on standard raw thicknesses of sawn wood, e.g., a raw thickness of 25 mm usually gives a finished thickness of 20 mm, 19 mm gives 14 mm etc.

The correct workpiece measurement is achieved when the gauge fits the workpiece when pushing lightly. If the gauge fits without any force at all the workpiece is too small, and if strong pressing is necessary the workpiece is too large. The "tolerance feeling" is therefore in the fingertips of the person measuring. The proper use of nominal measurement gauges is easily taught to any user. The main advantages of gauges are the following:

(a) There is no risk of misreading;

(b) The machine and equipment set-up is more accurate and rapid than when using ordinary measuring instruments;

(c) Continuous measurement control during machining by making frequent spot tests is simple, reliable and rapid;

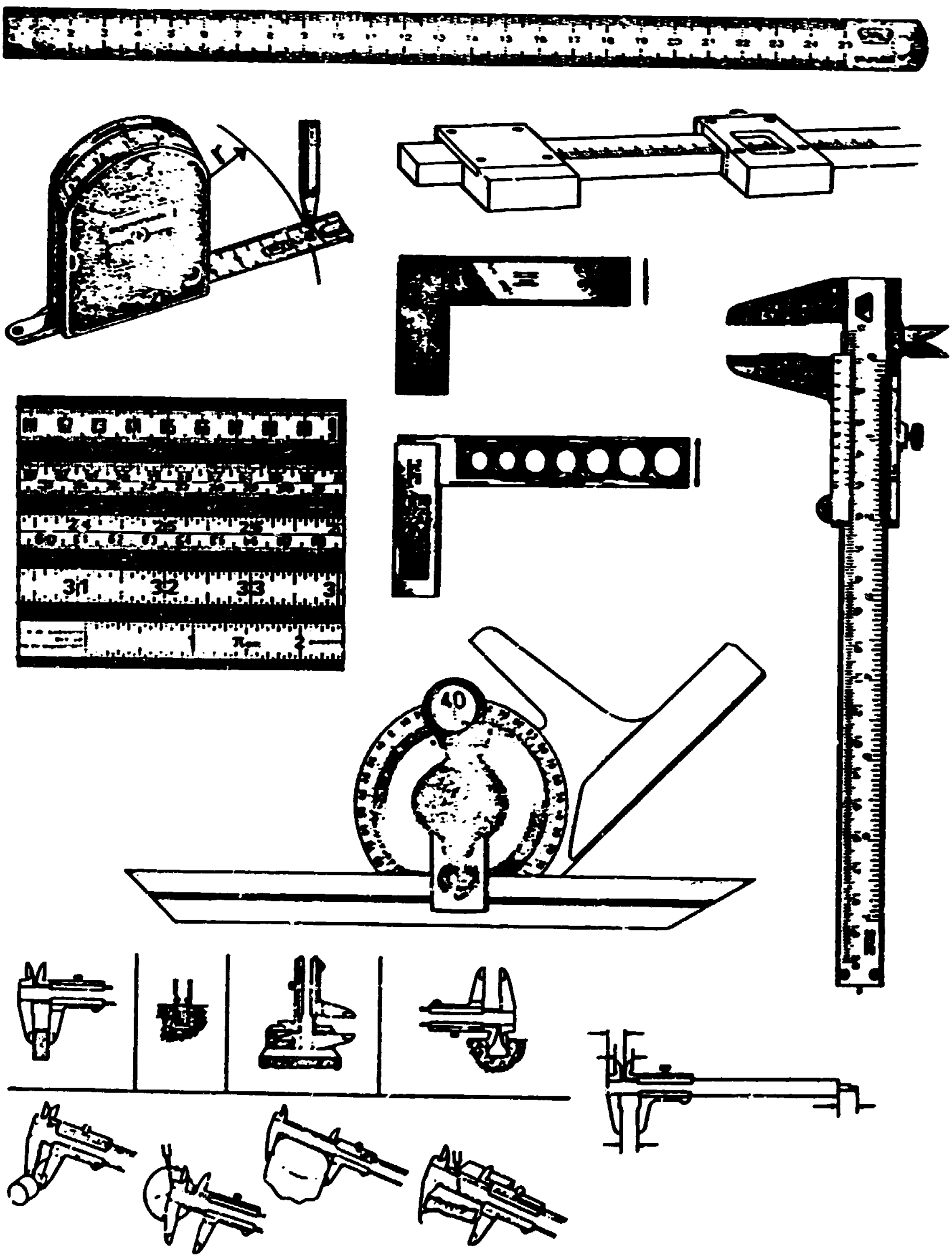
(d) Measurement control is also accurate in badly illuminated workshops.

Tolerance gauges

The actual tolerance gauges, which are standard quality-control instruments in metal industries, can also be used in the furniture industry with certain modifications. Their use for this purpose, however, requires reliable knowledge of the practical accuracy of the woodworking machines to be used. When the possibilities of different machines is known, realistic tolerances can be fixed.

"Tolerance" in this case means the range within which the actual dimension may vary around the nominal dimension. For example, if the width of a solid-wood component must be machined with a tolerance of ± 0.3 mm, the nominal measure being 62 mm, all pieces in the batch having a width between 61.7 and 62.3 mm can be accepted; the tolerance range is in this case 0.6 mm. A simple tolerance gauge with minimum and maximum dimensions is shown in figure 446. The other gauge in the same figure also includes the nominal measure step in the middle of the tolerance range. The middle step or nominal measure is needed, for example, for setting up the machines.

Figure 437. Ordinary measuring instruments



Source: Teknologisk Institut, Denmark, Department of Wood Technology, "Measuring Instruments".

Figure 438. Caliper for centre-to-edge measurements of holes, with interchangeable conical heads

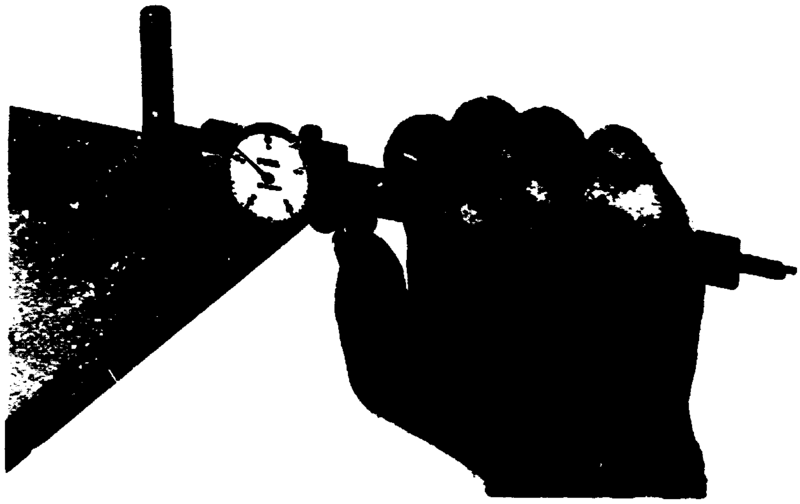


Figure 439. Caliper for centre-to-centre and centre-to-edge measurements of holes, with conical heads

Figure 440. Long-length caliper for outside measurements (on a wooden stand for quality control purposes)

Figure 441. Long-length caliper equipped with conical heads for centre-to-centre measurements

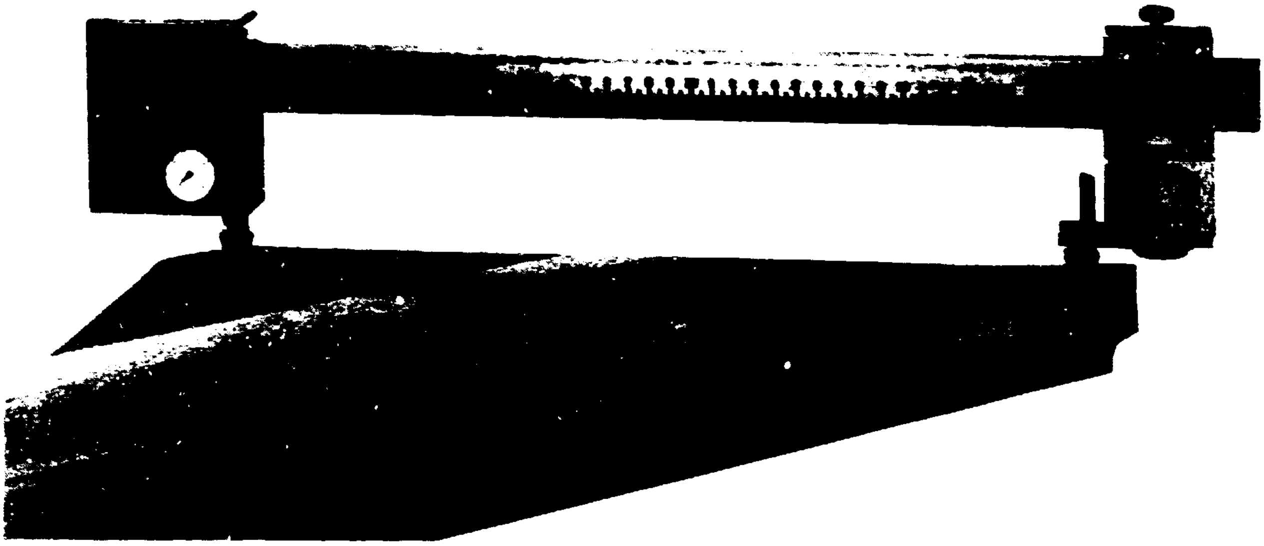


Figure 442. Angle gauge

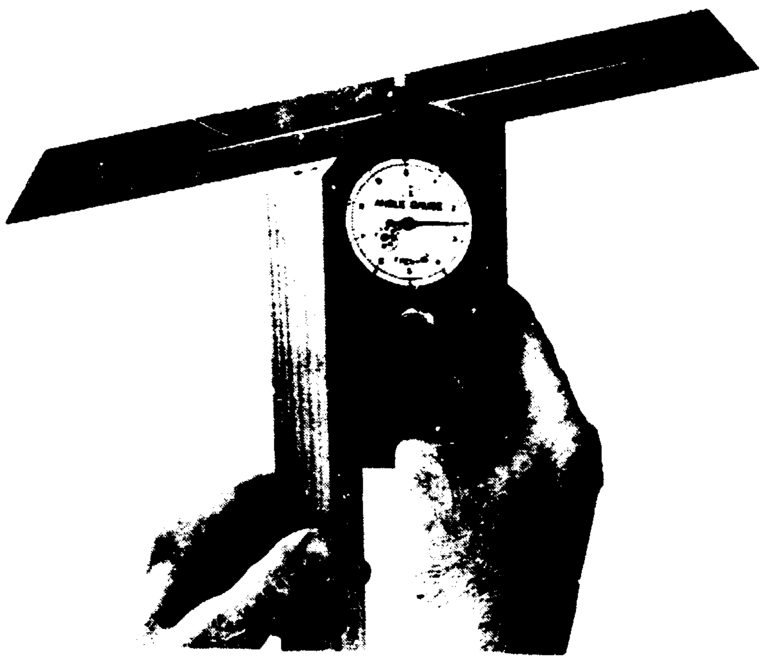


Figure 443. Dowel-hole gauges with 0.1-mm measuring steps for diameters

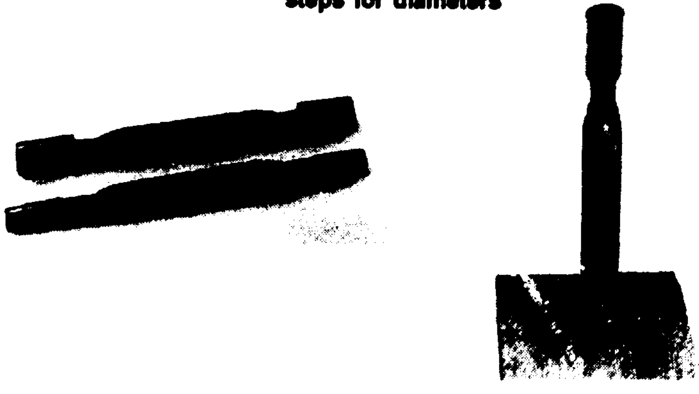
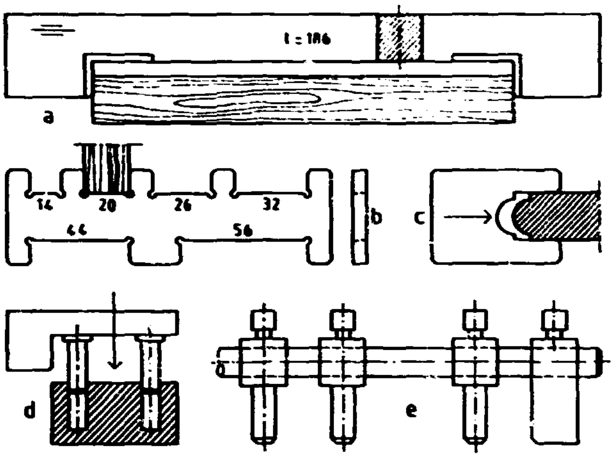


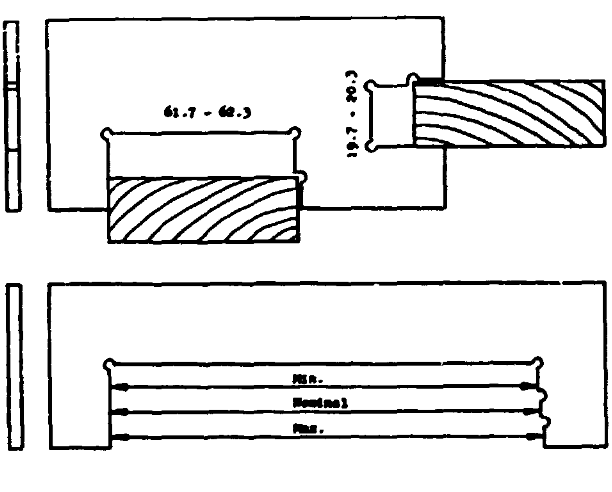
Figure 444. Nominal measuring gauges



Key: a Length gauge
b Thickness gauge for thickness planing
c Profile gauge
d Boring pitch and centre-to-edge measurement gauge
e Adjustable version of d

Figure 445. Nominal measuring gauge with laminated plywood body and steel heads

Figure 446. Tolerance gauges made of metal plate



Tolerance formula for assembly

The practical cumulative tolerance of a construction assembled of several parts is calculated from the following formula:

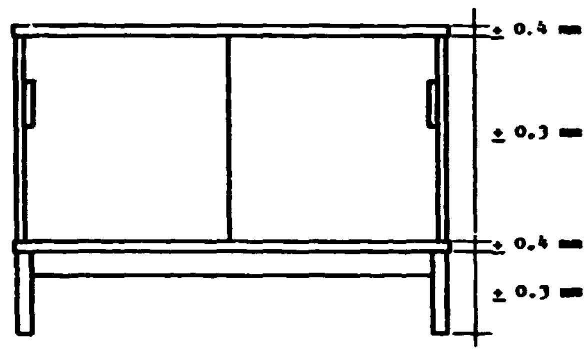
$$t = \sqrt{t_1^2 + t_2^2 + \ldots + t_n^2}$$

where $t_1, t_2 \ldots t_n$ are the tolerances or tolerance ranges of the components.

For example, the height tolerance of the cabinet shown in figure 447 is thus:

$$t = \sqrt{0.8^2 + 0.6^2 + 0.8^2 + 0.6^2 \text{ mm}}$$
$$= \sqrt{0.64 + 0.36 + 0.64 + 0.36 \text{ mm}}$$
$$= \sqrt{2.00 \text{ mm}}$$
$$= \underline{\underline{1.4 \text{ mm or } \pm 0.7 \text{ mm}}}$$

Figure 447. Tolerances of cabinet components



A tolerance system in a furniture factory, if realized as a complete programme, offers numerous advantages. Manual fitting and adaptation can be avoided in assembly because the application of tolerances throughout will control the value of clearances of drawers, doors, extension rails etc. The tolerances must be indicated in all work drawings. An example of tolerances that are directly applicable to production is given in table 26. The values are based on strength tests made in a laboratory. Corresponding tables can be found in some handbooks on wood technology. Creating a complete and realistic tolerance system is, however, a demanding and complicated task. Therefore, the use of tolerances is not yet widespread in the furniture or joinery industries.

Table 26. Lower and upper limits of mortise and tenon dimensions (nominal dimension of joint is 8 mm)

Hardness of wood	*Mortise*	*Tenon*
Soft (pine, spruce)	+0.05	+0.3
	-0.0	+0.2
Semi-hard (birch, beech)	+0.05	+0.2
	-0.0	+0.1
Hard (oak, teak)	+0.05	+0.1
	-0.0	+0.0
Very hard (rosewood, wenge)	+0.05	+0.0
	-0.0	-0.1

The normal practice in the use of gauges during machining is to make random spot tests by taking samples out of the batch. The check-up with gauges can be carried out by the machine operator, assembler or a quality control inspector.

Continuous quality control by workers

Quality control in a furniture plant must be understood as a continuous activity that should cover all stages of production. Much unnecessary work can be avoided if faulty parts are rejected immediately at the stage where the faults appear. For example, if a large quality-lowering knot is found in a chair leg when planed, the leg should be rejected and not put through the subsequent stages of production. A common mistake is to process faulty parts through all machining stages up to assembly. The use of a faulty part in assembly results in the rejection of the product or in expensive repairs to a product in which all other parts may have the required quality.

Visual piece-by-piece control

Visual piece-by-piece control is, in the first place, the responsibility of workers such as machine operators. Foremen and supervisors should therefore emphasize the importance of visual quality control when instructing their subordinates. If the workers are made aware of the aims of and reasons for quality control, they will be more willing to carry out that task.

Quality control in assembly

Furniture is usually assembled in two sub-stages: parts assembly and final assembly. Parts assembly covers drawers, frames, bases, stapling of sliding strips on drawer unit sides etc.; final assembly refers to the actual body of tables, chairs, beds, cabinets etc. The parts assembled in parts assembly are fitted into the bodies at this stage. The control of quality should consequently be divided into two parts.

Principal objects of control

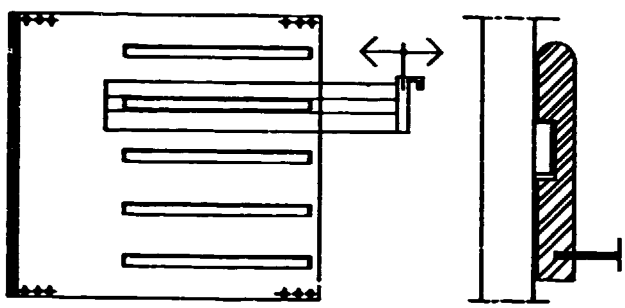
The principal objects of control are:

- Main dimensions
- Overlaps in minor measures
- Rectangularity
- Other angles
- Parallel run of parts (free of warp)
- Clearances and function of moving parts
- General check

Assembly jigs

Jigs should be used in assembly whenever possible to attain high accuracy. The guiding surfaces of jigs should correspond to the primary measures of the product. The concept "primary measure" means a measure that is essential to the proper function of a product or its part. For instance, a sliding strip supports a drawer at the upper edge of the side groove; therefore, the stapling jig must be constructed to give guidance to this edge. The distance of the ends of strips from the front edge of the side panel is also a primary measure because the end stops the drawer. The thicker lines in figure 448 illustrate the edges to be controlled by a stapling jig.

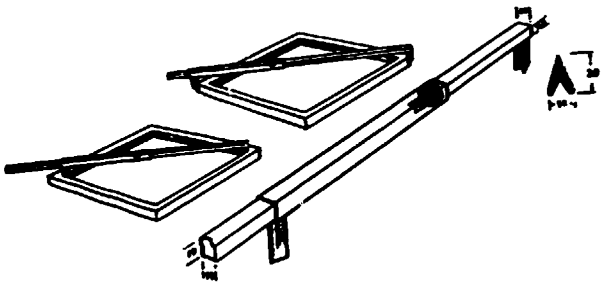
Figure 448. Side panel of drawer unit with sliding strips (Thick lines indicate edges that are guided by an assembly jig.)



Control of accuracy in assembly

The accuracy of assembly is best controlled with specially constructed nominal measurement or tolerance gauges if a tolerance system is used in the plant. Rectangularity is of major importance for element panel furniture and should be checked by using diagonal measurement gauges (figure 449). The parallel run of parts can be checked with gauges or in some cases by the naked eye.

Figure 449. Diagonal measurement gauges used for checking rectangularity



Quality control in surface finishing and the final check

Surface finishing has traditionally been the stage following the assembly. The present tendency is, however, to lacquer or paint the parts prior to their assembly. This usually necessitates special constructions with knock-down fittings. The quality-control check of the finished surfaces is principally the same in both cases. The finished surface is of major importance as regards the product's ability to compete on the market because the outer appearance of a piece of furniture is often dependent on its finish.

Checking is usually done by the naked eye without any instruments.

Principal objects of control

The principal objects of control are:

- Evenness of the surface
- Gloss of the surface
- Colour shade and its evenness in lacquered products
- Visible glue penetrations and remains under the surface film

Quality of edges and corners (through-sanding of veneer sometimes becomes visible only after lacquering)

Quality of surfaces close to joints

Final check

A final check is always made for products that are finished and ready for packaging. This last control stage includes a general check of the product. All functions of the product are checked: the closing of doors, drawers, the functioning of table-top extension mechanisms etc. If faults are found, the product is transported to a repairing point. An accepted product is provided with the manufacturer's stamp or self-adhesive sticker and is packaged.

Testing of finished products

The testing of finished furniture has already become common practice in several European countries. Testing serves both product development and the consumer of the furniture. The principal aim from the consumer's point of view is to obtain realistic and reliable information on the quality of a particular product before buying it. To make this possible the following prerequisites must be met:

(a) There must be generally approved standards that determine with what kind of testing equipment and how the tests must be carried out and how the test results must be interpreted;

(b) The tests must be carried out by neutral testing laboratories having no commercial interests in the results obtained;

(c) The way the results are presented must be simple and easily understandable for a customer. The test certificates must be available at the retailers' showrooms.

The purpose of all testing standards, such as BS (United Kingdom), DIN (Federal Republic of Germany), SIS (Sweden) and ISO (international), is to imitate the actual strains a piece of furniture is exposed to when in actual use. There are, however, some differences from standard to standard, and therefore the results, e.g. for the same strength characteristics, are not directly comparable. The aim of ISO has naturally been to create generally acceptable international standards that every furniture producing country could use. (See appendix II for a list of ISO furniture standards.) To what extent this goal will be realized will be seen in the near future. Today national standards are extensively used in several European countries. The Scandinavian countries have established a quality label for furniture, MOBELFAKTA, based on the Swedish standards. Examples of testing set-ups and equipment for the award of the MOBELFAKTA label, which are usually used in Finland, are shown in figures 450, 451, 452 and 453. A diagramatic description of the testing procedures for quality control of furniture in use in Yugoslavia is presented in the annex. A completed test certificate intended for customer information is shown in figure 454. A MOBELFAKTA label, attached to a product with a summary of test results is shown in figure 455.

Figure 450. Strength testing equipment for chairs (Photograph courtesy of the Forest Products Laboratory, Technical Research Centre of Finland (VTT))

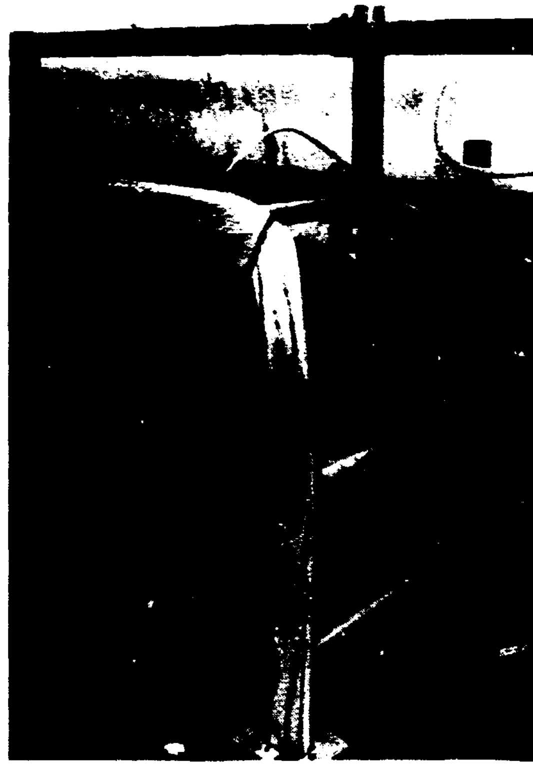


Figure 451. Strength and durability testing equipment for easy chairs (Photograph courtesy of the Forest Products Laboratory, Technical Research Centre of Finland (VTT))

Figure 452. Durability testing equipment for drawers and runners (Photograph courtesy of the Forest Products Laboratory, Technical Research Centre of Finland (VTT))

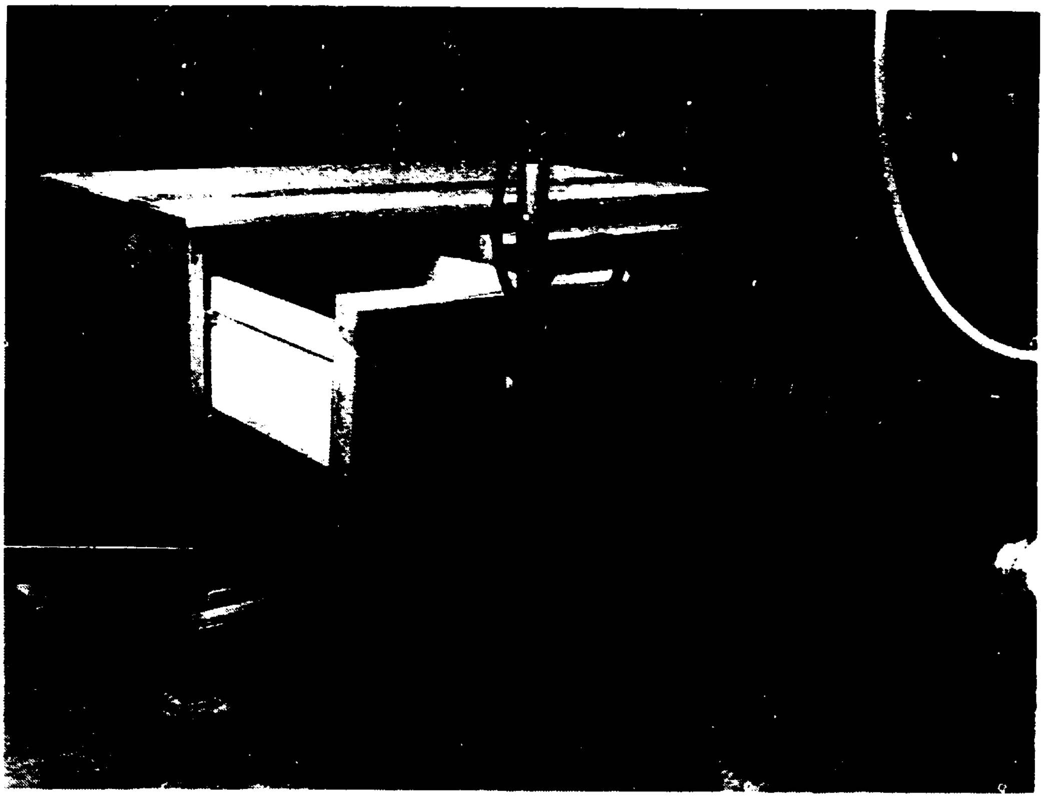


Figure 453. Stability testing equipment (Photograph courtesy of the Forest Products Laboratory, Technical Research Centre of Finland (VTT))

Figure 454. MOBELFAKTA test certificate

Date 1976-04-20 **Test certificate** Nr 832-10:S

Test requested by	Furniture type/identification of model
Axel Linial, arch MAA	Armchair 4711
Test made in accordance with test methods stated in the instruction A1:10. Test results compared with requirements for the following specific furniture type/use: Armchair for dining table with height 70–74 cm	Manufacturer: Möbel-Svensson, Sweden Material: Beech, moulded seat, plastic lacquer

		test results	requirements not fulfilled	requirements fulfilled: basic requirements	high requirements	extra high requirements
Function						
1 a	Height of seat	44 cm		x		
b	Sitting height	43 cm		x		
c	Sitting depth/depth of seat	38 cm		x		
d	Sitting width/width of seat	39 cm		x		
e	Clearance under front edge of seat	-60 °		x		
f 1	Height to lower edge of backrest	0 cm		x		
f 2	Height to upper edge of backrest	34 cm		x		
f 3	Height of backrest	34 cm		x		
g	Sitting angle	100 °		x		
h	Width between armrests	43 cm		x		
i	Appropriate table height	70–74 cm		x		
2 a-c	Stability forwards/backwards/sideways	20 N/50 N/20 N		x		
Strength						
3 a	Strength of frame: tilting	25.000 cycles			x	
	overturning	4x5 turns			x	
b	Seat, consistency of shape	- cycles				
Durability of surfaces						
c	Resistance to water: seat, armrest	24 h				x
	other parts	1 h				x
d	fats/fats on scratched surface: seat, armrest	24 h/ - h		x		
	fats: other parts	24 h				x
e	scratching: seat, armrest	3 N			x	

		fully exposed parts	less exposed parts	requirements not fulfilled	basic requirements	high requirements	extra high requirements
Quality of material and workmanship							
4 a	Quality of material: wood	B	C		x		
b	upholstery material	-	-				
c	finishing material	C	C		x		
d	Measurements and angles	-	-				
e	Bent parts	C	C		x		
f	Joinery	C	C		x		
g	Veneering	C	C		x		
h	Sanding	C	C		x		
i	Finish	C	C		x		
j	Frame and bottom for upholstery	-					
k	Seat: Upholstery	-					
l	Back- and armrest: Upholstery	-					
m	Tailoring of cover, sewing	-					

This test certificate may be published in its complete form. For publication of extracts a written permission from the Institute is required. The test refers to one sample provided by the client.
For furniture with corresponding properties the declaration below can be used.

The Swedish Furniture Research Institute

Erik Berg[illegible]

55fj:211

mobel fakta

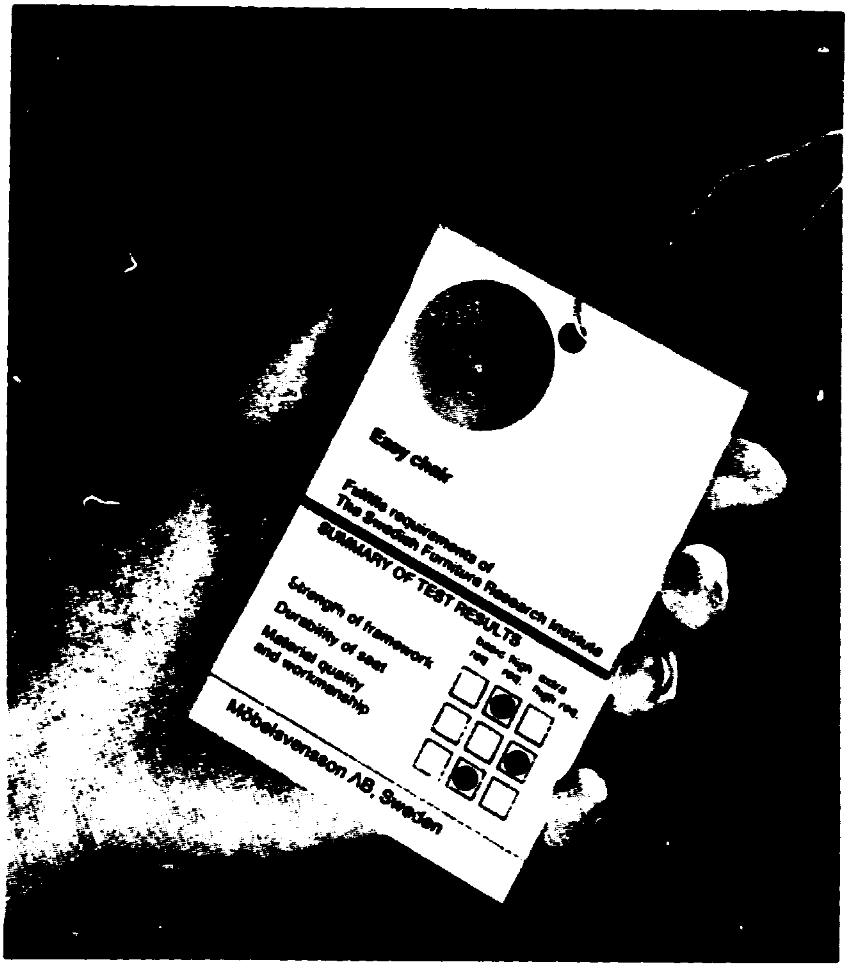
Armchair for dining table
with height 70–74 cm

Fulfils the requirements of the Swedish Furniture Research Institute

SUMMARY OF TEST RESULTS 832

	basic requirements	high requirements	extra high requirements
Strength	☐	●	☐
Durability of surfaces	●	☐	☐
Quality of material and workmanship	●	☐	☐

Figure 455. MOBELFAKTA label



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Appendix I

TECHNICAL CONDITIONS OF SUPPLY FOR FURNITURE AND INTERIOR FITTINGS*

A. *Materials*

1. *Wood*

(a) *Quality of wood.* Only sound wood should be used.

(b) *Moisture content of wood.* Only well-dried wood should be used. The moisture content of wood should be between 8 and 12 per cent. (If there are other requirements in force in one of the member countries of the Union européene de l'ameublement (UEA), they should be complied with.)

(c) *Visible wood.* Visible wood must be free from cracks, spiral growth, bluestain and worm holes and from large, torn or black knots. Firmly grown-in knots or knots glued with cross-grained wood up to a diameter of 25 mm are admissible for work with softwood in the interior and on back panels, as well as for all work to be coated with paint, provided that not more than four such knots are present per m². Sound wood that has become slightly bluestained may be used.

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(d) *Plywood.* The use of plywood is permissible provided it fully complies with the relevant requirements in respect of degree of dryness, use of core wood, top ply and gluing. The following terms apply to plywood.

All types of board consisting of at least three wooden plies glued to each other and with grain directions opposite to each other are known as plywood. It follows that plywood is a general term for different types of board.

The distinctions for the various types are as follows:

Veneer board	Plywood in which all plies consist of veneers that are bonded crosswise to each other in parallel with the plane of the board. Where there is an even number of veneers, the two innermost plies are arranged with the grain running in the same direction.
Cross-laminated wood	Veneer board made up of at least five plies of veneers glued together so that the grain direction of veneers on top of each other cross at angles of 45° or less.
Blockboard	Plywood with at least two outer veneers and a centre of wooden strips placed side by side. The grain direction of the centre ply is crosswise in the case of three-ply blockboard but parallel to that in the outer top veneers in the case of five-ply blockboard. All the plies are glued to one another crosswise.

Different types of blockboard may be distinguished in accordance with the nature of the centre ply, these being:

Laminboard	Wooden slats glued to each other to form a board and made of veneers of thickness up to 8 mm, which are arranged to be vertical to the plane of the board.
Normal blockboard	Wooden slats glued to each other to form a board, which are usually of a width of about 24 mm and which have a maximum width of 30 mm.
Unglued blockboard	Wooden strips not glued to each other and arranged in close proximity to form a board, which are normally of a width of about 24 mm to 30 mm.

The directions for "visible wood" apply to visible plywood surfaces (paragraph (c), above).

(e) *Other structures.* Other structures (for instance hollow, honeycomb or framed structures) are admissible provided that they are suitable for the specific purpose of application.

(f) *Crossbanding.* The thickness of the crossbanding should be about one tenth of the thickness of the core wood but not more than 3 mm. The crossband veneers should be as free as possible from stresses. During processing, the moisture content of the veneers should be 6-8 per cent.

(g) *Particle board.* Any particle board used must be suitable for the purpose intended in the piece of furniture. Wood particle boards are wood-based materials manufactured from chips of wood or wood-based raw materials with the use of synthetic resin as the binder. They may also be supplied with a veneer and/or laminate coating.

Wood particle board is classified according to:

Position of particles	Flat pressed board—the wooden chips are mainly parallel to the plane of the board. Extruded board—the wooden chips are mainly perpendicular to the plane of the board.
Cross sectional strucure of board (for flat-pressed board)	Single-layer board—the same structure through-out the entire cross-section. Three-layer board—structure made up of three layers (centre core and two outer layers). Multi-layer board—structure made up of more than three layers.

In graded-density board (for instance board made up of air-cast or dispersion-cast particles) there is a gradual transition from thin particles at the surface to thicker particles at the centre of the board.

The surface characteristics of particle board are:

Unsanded (straight from press)
Sanded
Veneered
Laminated

(h) *Other characteristics.* The external surfaces or top layers of wood or other materials must be suited to their normal use.

2. *Gluing and bonding*

Gluing and bonding must be sufficiently sound to remain stable in normal atmospheric humidity and temperature variations. No discolouration should appear on the surface of the wood due to the gluing, and the fillers should not cause any deterioration in the bonding power of the glue.

No visible residues should be caused by jointing tapes and parting agents.

3. *Fittings*

In order that fittings carry out their intended function, the material used must be of a suitable quality and they must be attached correctly, they should not change in appearance any more than is justified by natural chemical processes or the use to which they are subjected, provided that they receive suitable cleaning.

4. *Surface material*

The nature of the surface material must be such that on correct processing it clearly provides the effects specified in the description of the goods; it must be firmly bonded to the treated surface to resist normal stresses.

B. *Processing*

1. Processing must be carried out in accordance with the general rules of workmanship. Joints in wood must be cleanly and accurately fitted together and executed so that no blemishes are formed thereby and so that normal service stresses do not cause permanent changes.

2. Straight-grain wood free from enclosed heart must be used for rails (frames).

3. Visible edges must be cleanly worked or provided with edging strips or edge veneers. These must however be satisfactorily fitted, i.e. there should be no major unevenness visible.

Profiles or rabbetted edges (apart from rabbetted edges on back panels) must be worked so that the centre ply does not show through. When particle board is used, its quality must be selected so that the strength of a rabbet or profile is ensured by a centre ply of suitable density. In the case of glued timber attachments or inserts, the bond for attachment or insertion must be carried out so that after the surface has been veneered the glued attachment or insert cannot be seen.

Moving parts should be fixed so that they are anchored at strengths compatible with their functions. In the case of centre plies, the characteristics of which do not satisfy these requirements, it is necessary to take appropriate measures in order to establish the required strength level (for instance, added bonded strips, grooved strips).

4. In the case of veneered frame joints, the joints must be sufficiently dense and flush so that they do not project.

5. Veneered surfaces must be free from blisters.

6. Figured veneers should be free from checks. Larger faults in a figured veneer must be made good with matching veneer.

7. After treatments that do not recognizably affect the appearance or purpose of the furniture item may be carried out.

8. Timber panels must be fitted in such a way that they have space to swell and contract. The thickness of panels, plinths, bottom panels, back panels and hidden panels must be sufficient to ensure that they are strong enough for their intended functions.

9. Doors and drawers must close tightly and operate smoothly. Runners must be made of a material that allows for trouble-free sliding.

10. Furniture must be of a sufficiently solid construction to prevent sagging during normal conditions of use. A tolerance limit of 3 per thousand is admissible.

11. The directions for the processing of furniture apply to the execution of wall panelling and interior fitting work as well as to doors, as appropriate. In order to provide for a flow of air, wall panelling and the like must be fitted with air vents or louvres. The reverse side of wall panelling must be protected against wall moisture by painting or by means of insulating material.

12. In addition, joinery work done in interior fitting should be carried out in accordance with the technical directions for building work.

C. *Finishing operations*

1. *General*

Surfaces should not show any tears or patches that have been sanded through or any grey pores or stripes.

2. *Surface treatment*

(a) *Staining and bleaching.* Bleaching and staining agents must be evenly applied, without streaks or deposits. Smears, rag marks or light stripes must not be present. Dark glue pores, oil stains, light unstained pores etc. must not be noticeable.

(b) *Grain printing.* The grain-printing agent (applied either by hand or by machine) must reproduce the grain pattern without distortion or shift on a uniformly prepared background.

Adhesion of the surface material to the supporting layer must not be affected by the staining agent employed.

(c) *Polishing.* In the case of polished surfaces coated with polyesters, it is necessary to ensure that the moisture content should be appropriate to the material employed and the porosity of the wood used. Oil precipitation is regarded as a defect. All pores must be completely sealed.

Pore fillers must exactly match the colour of the wood; the surface must not show any residues. In addition, the surface should not be cloudy or have a grey film on it. The polish must not exhibit any rag marks. Polished surfaces must give a largely undistorted reflection of objects at a suitable incidence of light. Whenever the last condition is not satisfied, the surface is regarded as "partly polished", or "matt".

(d) In the case of lacquered furniture, the lacquer coating must be applied as the final treatment so that it cannot be wiped off.

(e) The surface material must have a faultless bond to the supporting material and within its separate plies. This condition may be tested by scoring tests or equivalent procedures.

(f) The surface must be free from visible cracks.

(g) The degree of gloss may be established by means of photo-electric measurements and classified into the following grades:

Grade	*Percentage reflection of incident light*
Dull matt	0
Matt	0-20
Semi-matt	21-40
Silky matt	41-60
Silk gloss	61-80
High gloss	81-100

During the measurements, the angles of incidence must be at least 20° and at most 40°. Standard readings must be carried out for comparison under the same conditions and at the same angle of incidence as the test readings. The reference standard is a deep black, flat and smooth surface that is polished to a high gloss.

These technical conditions should be applied in each member country, allowing for special conditions customary within its region.

Appendix II

LIST OF ISO DRAFT INTERNATIONAL STANDARDS, DRAFT PROPOSALS AND WORKING DOCUMENTS SUBMITTED TO THE ISO TECHNICAL COMMITTEE 136 (COVERING FURNITURE)

Reference number	*Title*
Test methods	*General methods*
	Estimation of resistance of surfaces
	Furniture, test methods. Estimation of surface resistance to staining materials other than liquids (ink paste, rubber feet etc.)
	Furniture, test methods. Estimation of surface resistance to light and ambient atmosphere (sunlight, gases etc.)
136/1 N 87, 88, 112, 113	Furniture, test methods. Estimation of resistance to changes in climate (change of temperature and humidity)

136/1 N 82, 83, 86, 110, 111, 116, 120	Furniture, test methods. Estimation of surface resistance to mechanical damage (scratches, wear, impact etc.)
136/1 N 84, 85, 117, 118	Furniture, test methods. Estimation of surface resistance to heat (warm pots and hot frying pans etc.)
	Furniture, test methods. Estimation of surface resistance to hot liquids
136/1 N 81	Furniture, test methods. Determination of functional sizes
	Determination of strength
	Storage units
DP 7170	Furniture, storage units. Determination of strength and durability
	Beds
DP 7175	Furniture, children's cots. Safety requirements and testing
136/1 N 104	Furniture, bunk beds. Safety requirements and testing
	Furniture, space-saving beds
	Furniture for seating
DP 7173	Furniture, chairs and stools. Determination of strength and durability
	Furniture, easy chairs and settees
	Tables
DP 8019	Furniture, tables. Determination of mechanical strength and durability
	Determination of stability
	Storage units
DP 7171	Furniture, storage units. Determination of stability
	Beds
DP 7175	Furniture, children's cots. Safety requirements and testing
136/1 N 104	Furniture, bunk beds. Safety requirements and testing
	Furniture, space-saving beds
	Furniture for seating
DP 7174	Furniture, chairs and stools. Determination of stability
136/1 N 101	Furniture, children's high chairs. Determination of stability
	Tables
DP 7172	Furniture, tables. Determination of stability
	Determination of rigidity
DP 7170	Storage units
DP 8019	Tables
	Determination of durability
136/1 N 36	Furniture, test methods, beds. Determination of durability (fatigue test of mattresses and bottoms of the bed)

	Furniture, test methods, chairs. Determination of durability (fatigue test of seats)
	Fire tests
DP 8191/1	Furniture, burning behaviour. Assessment of the ignitability of upholstered furniture. Part 1: Ignition source—cigarette
DP 8191/2	Assessment of the ignitability of upholstered furniture. Part 2: Ignition source—match equivalent flame
Specifications for properties of materials and workmanship	
	Furniture, specifications. Quality of materials
136/3 N 5	Furniture, specifications. Quality of workmanship
	Furniture, specifications. Specific material
136/3 N 4	Furniture, designations
	Shelf and shelf carriers for furniture requirements
Domestic furniture	
	Storage furniture
	Safety requirements and essential dimensions
136/5 N 19	Performance requirements (strength and durability)
	Beds
DP 7175	Furniture, children's cots. Safety requirements and testing
136/1 N 104	Furniture, bunk beds. Safety requirements and testing
	Furniture, space-saving beds
	Performance requirements (strength and durability) on beds
	Furniture for seating
	Safety requirements and essential dimensions on children's high chairs
	Safety requirements and essential dimensions on chairs
136/5 N 17, N 18	Performance requirements on seating
	Tables and desks
	Safety requirements and essential dimensions of tables
	Performance requirements of tables and desks
	Office furniture[a]
	Storage furniture
	Furniture for seating
	Tables and desks

Reference number	Title
	Furniture for educational institutions
	Storage furniture for educational institutions. Sizes
	Chairs and tables for educational institutions. Performance requirements
	Storage furniture for educational institutions. Performance requirements

*Awaiting CEN/TC 43

Note: If no number is given, it means that the topic is on ISO/TC 136's programme of work, but that no agreement on this topic has yet been reached.

Appendix III

DIAGRAMATIC DESCRIPTION OF TESTING PROCEDURES FOR QUALITY CONTROL OF FURNITURE*

Introduction

The sketches shown in figures A.1 to A.16 of this annex depict in diagram form the standard procedures for the testing of furniture. The procedures are those prescribed by Yugoslav standards, but they are along the same lines as furniture standards of many other developed countries.

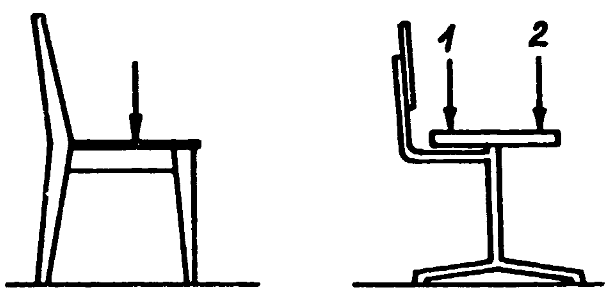
The number of test cycles, their speed etc. vary according to the envisaged end-use of the product; standards are higher for contract furniture than they are when the furniture is for domestic use, and the permitted defects are correspondingly lower.

The procedures shown in figures A.17 to A.38 are intended to give an indication of the loading specifications for various products.

Figures A.39 and A.40 illustrate the tests made to measure the quality of surfaces.

Tests for single-seat units (chairs and armchairs)

Figure A.1. Static loading test for a chair



*By Slavko Mihevc, Professor, Department of Woodworking, University of Ljubljana. Originally issued as ID/WC.390/14/Add.1.

Figure A.2. Fatigue test of the seat

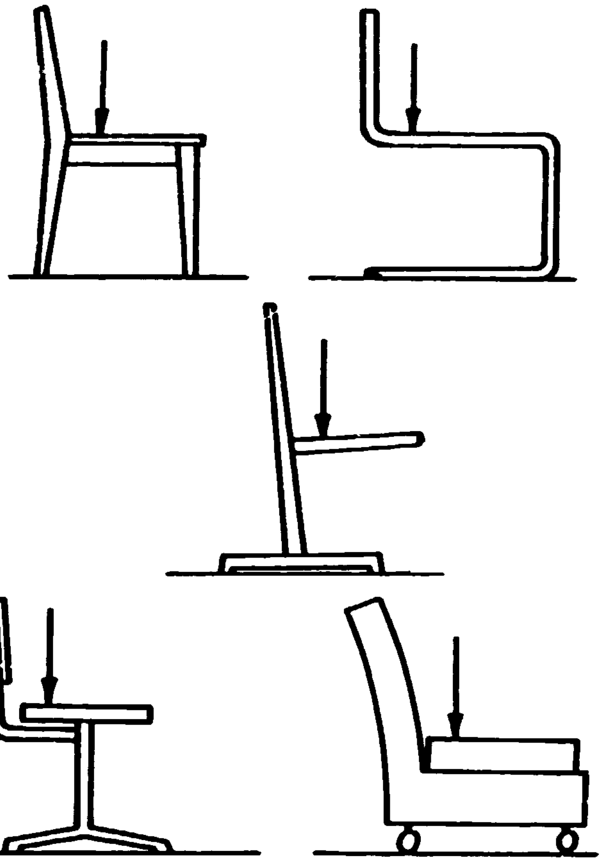


Figure A.3. Impact test of the seat

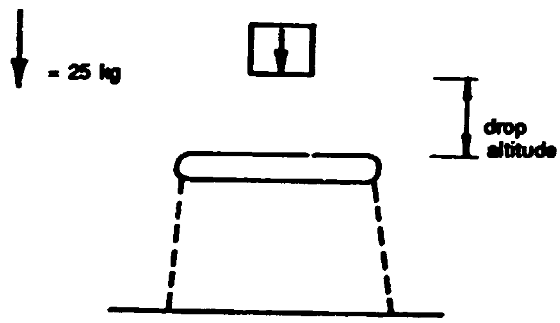


Figure A.4. Static loading test for a chair back

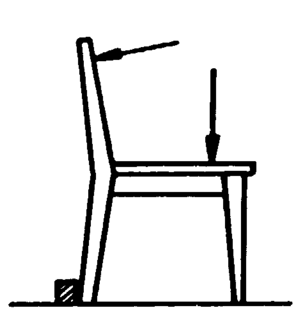


Figure A.5. Fatigue test of the back (this test reproduces movements by the user of the chair.)

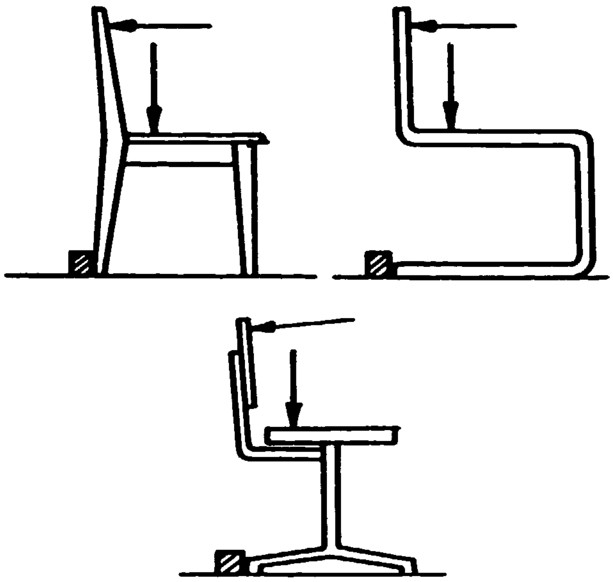


Figure A.6. Impact test of the back

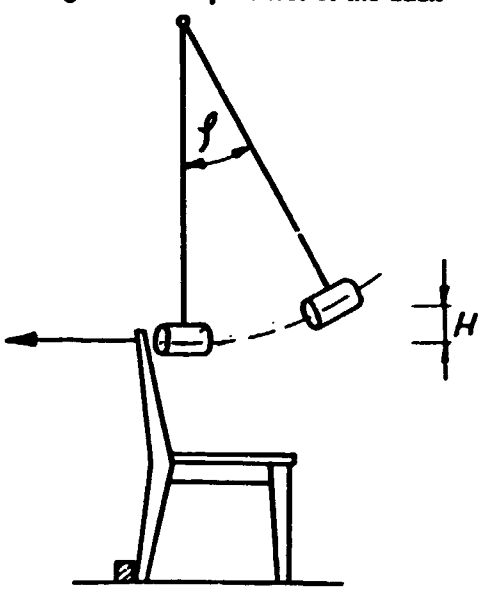


Figure A.7. Static lateral loading test of the arm supports

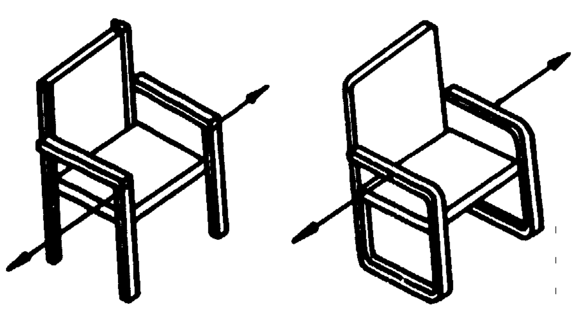


Figure A.8. Lateral impact test of the arm support

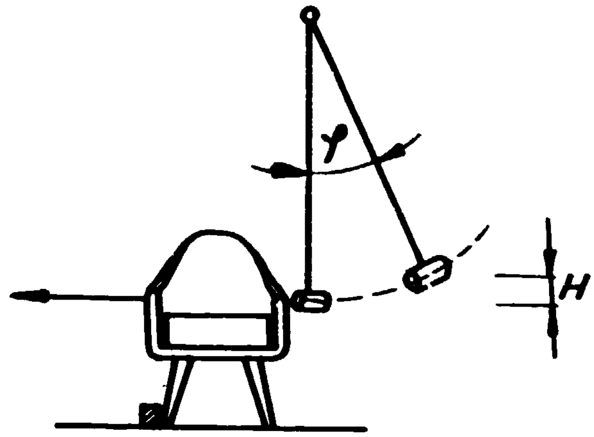


Figure A.9. Static loading test of the arm supports in the vertical direction (this test reproduces the forces on the arm supports when the person using the chair stands up.)

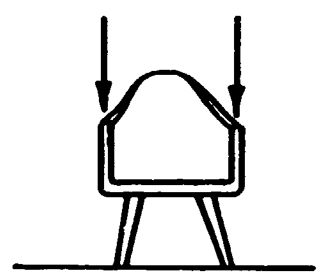


Figure A.10. Drop test for chairs

A. Ordinary chairs **B. Armchairs and chairs with castors**

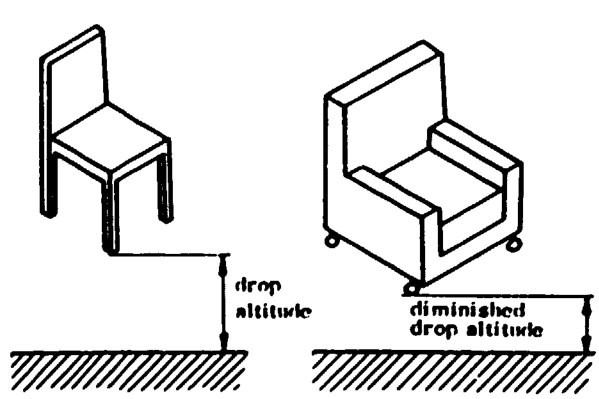


Figure A.11. Test of the rigidity of the front legs (forward thrust)

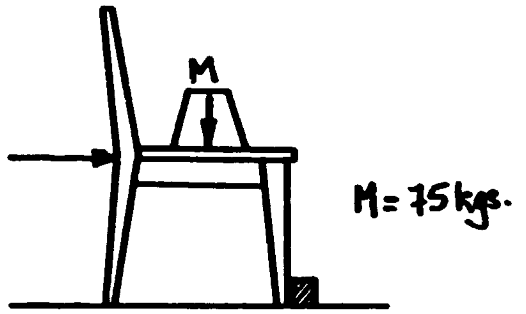


Figure A.12. Lateral test of the rigidity of the front legs

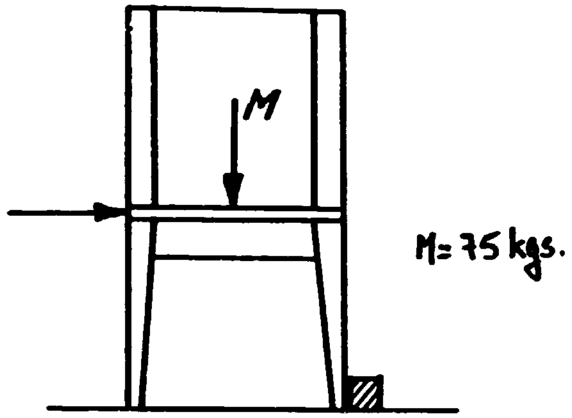
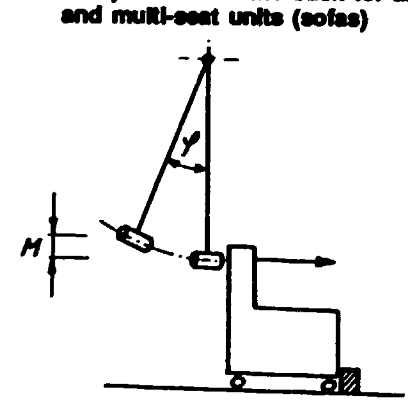


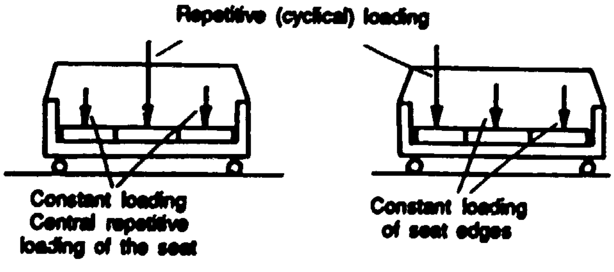
Figure A.13. Impact test of the back for armchairs and multi-seat units (sofas)



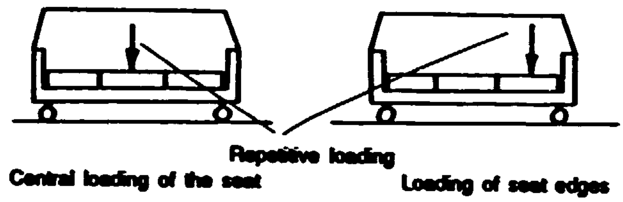
Tests for multi-seat units (sofas)

Figure A.14. Loading tests for sofas

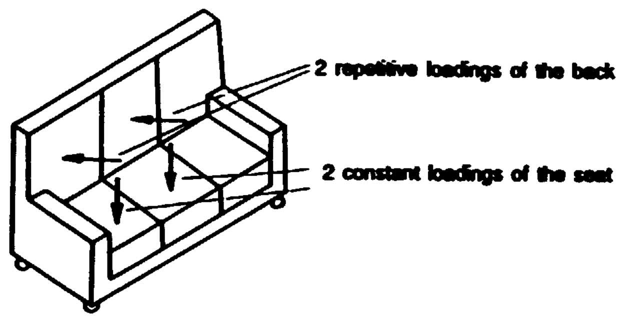
A. Static loading of the seat



B. Fatigue test of the seat



C. Static loadings of the back (double loading of the back)



D. Fatigue loading test of the back

Cyclic loading of the back

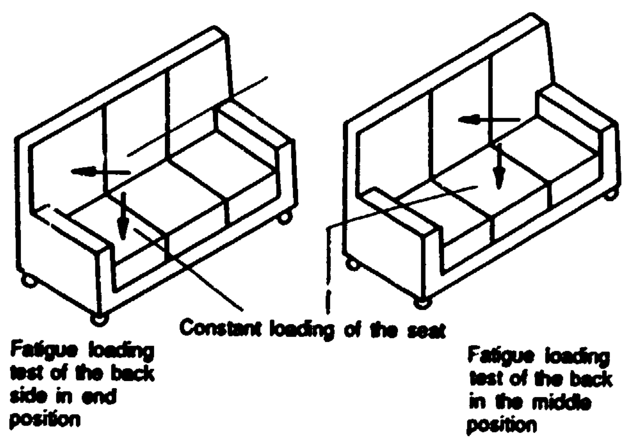


Figure A.15. Drop test for multi-seat units

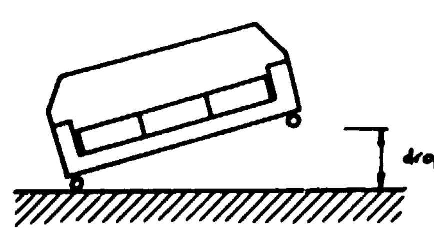
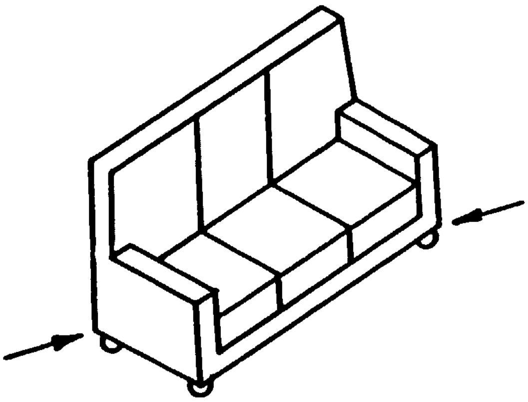
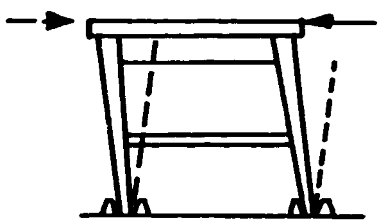


Figure A.16. Diagonal loading of the base

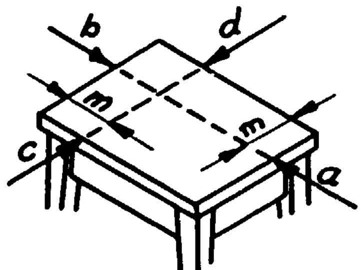


Loading specifications of the standards

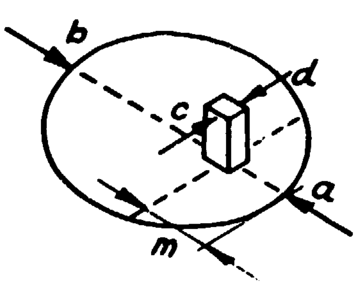
Figure A.17. Loading specifications for chairs without backs



= 150 N

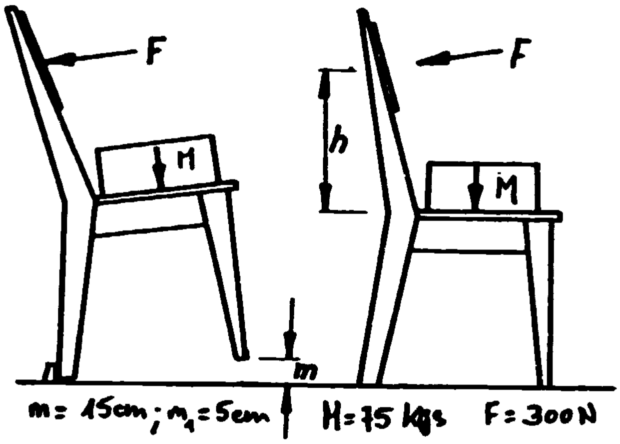


m = 50 mm



Note: Loading is applied in cycles: a, b, c, d, a, b etc.

Figure A.18. Loading specifications for chairs with backs



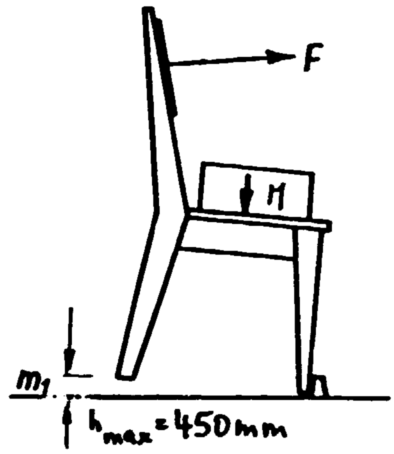


Figure A.19. Loading specifications for testing backs of armchairs

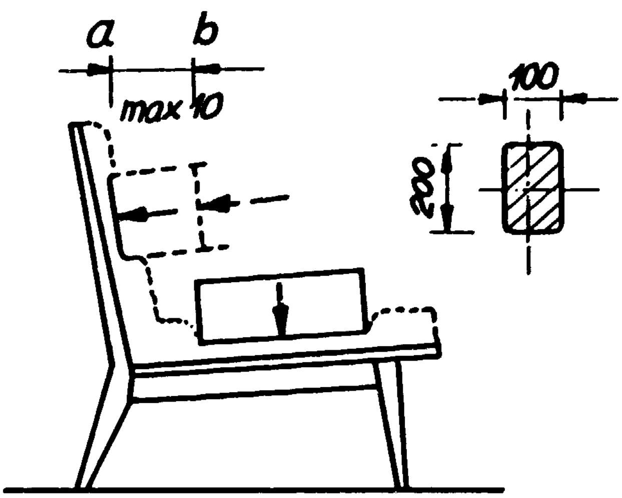


Figure A.19 *(continued)*

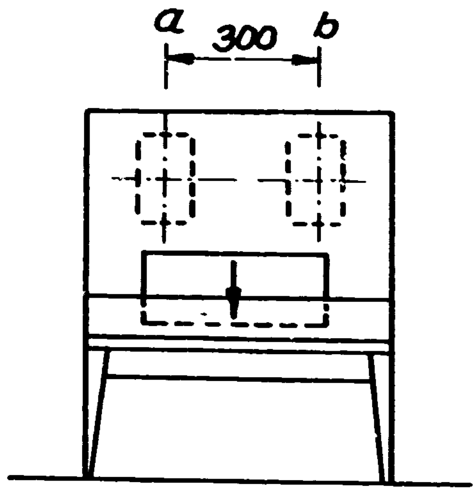


Figure A.20. Loading specifications for the fatigue test for seats of armchairs

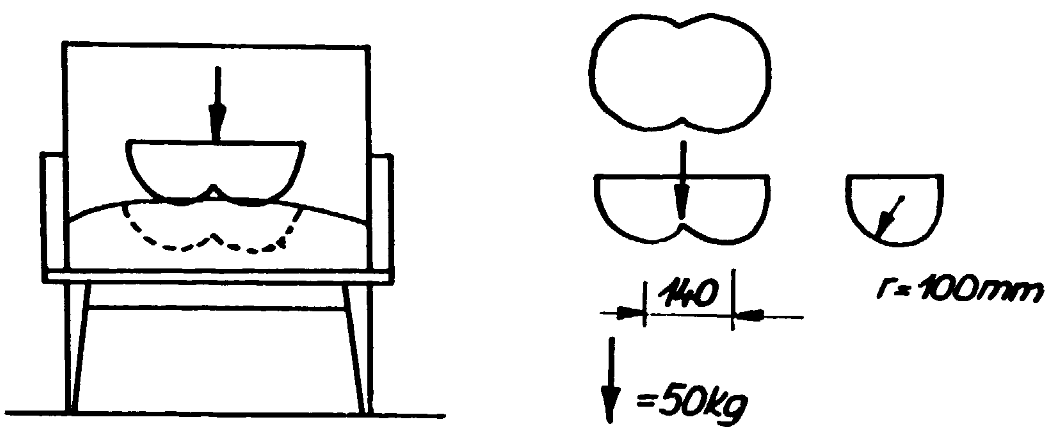


Figure A.21. Loading specifications for testing the stability of chairs (lateral loading of seat) (The force necessary for toppling the chair forward is recorded.)

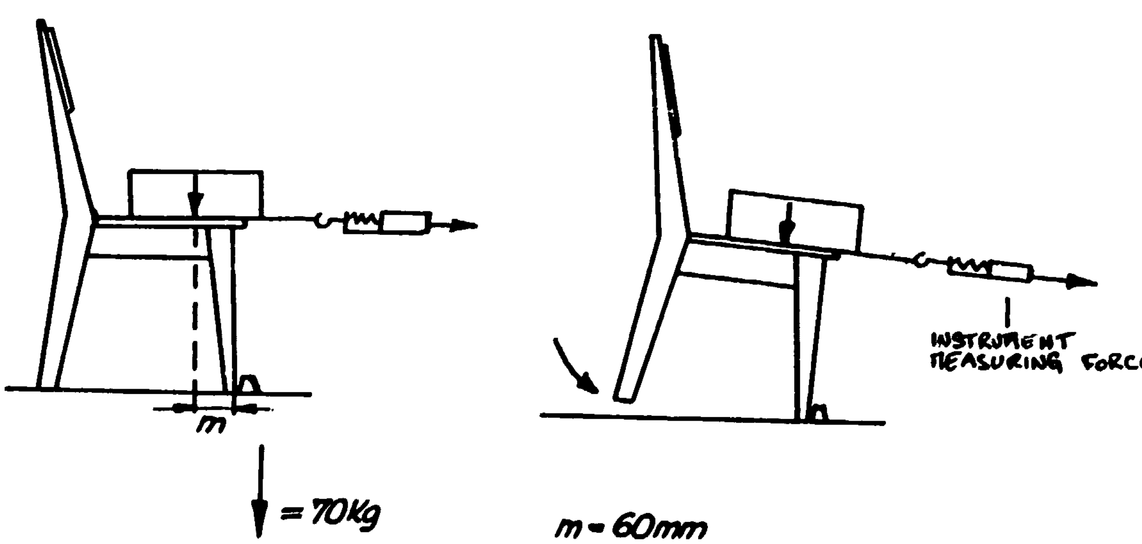


Figure A.22. Loading specifications for testing the stability of chairs (loading of backs)

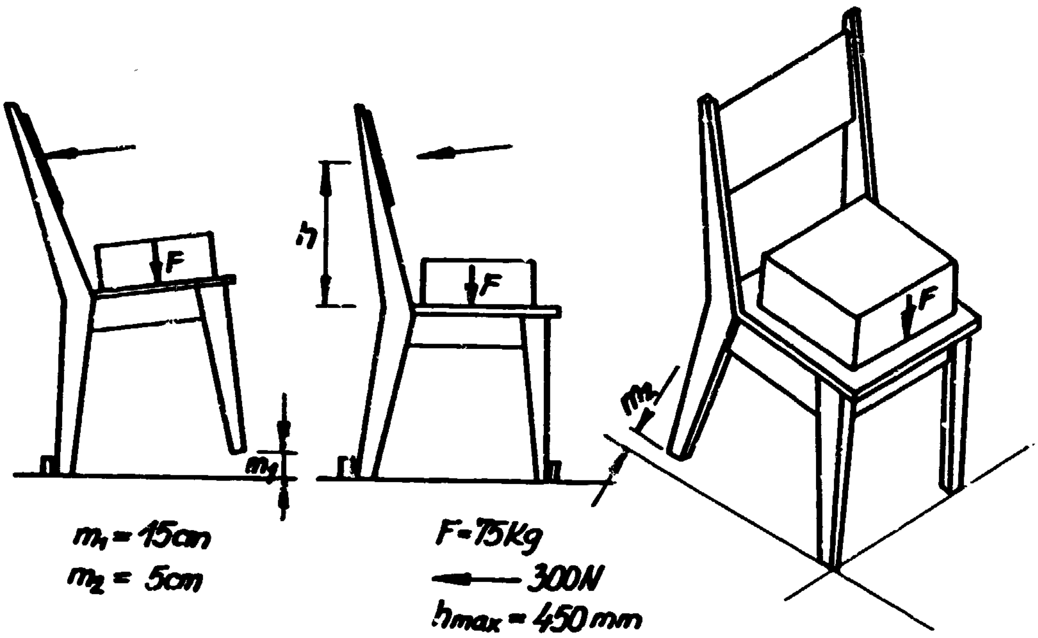


Figure A.23. Loading specifications for fatigue tests for the backs and arm supports of chairs (Loading of back and arm supports sequential—a and b applied sequentially.)

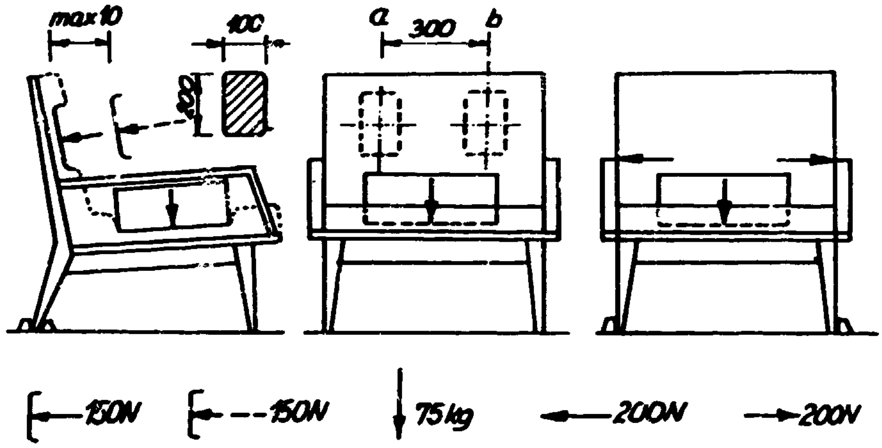


Figure A.24. Loading specifications for testing the stability of armchairs

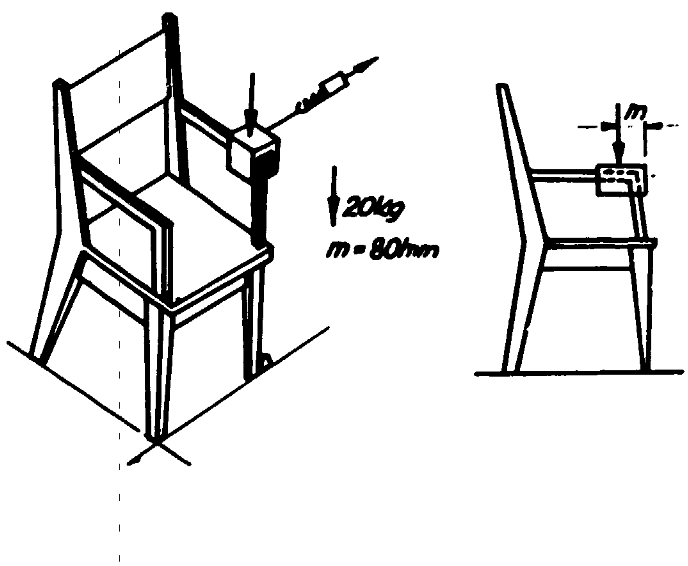


Figure A.25. Loading specifications for testing the stability of baby chairs (impact test)

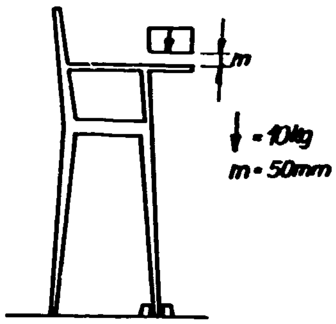
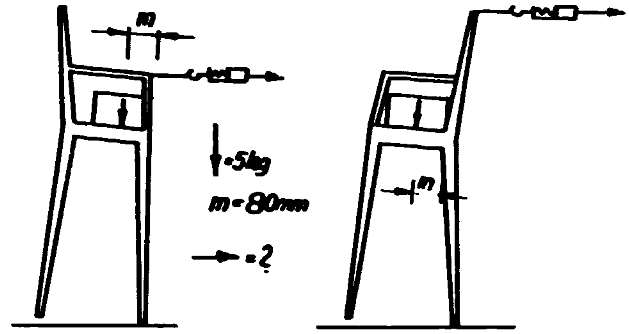


Figure A.26. Loading specifications for testing the stability of baby chairs



Bedding

Figure A.27. Loading specifications for testing the rigidity of legs and end boards of beds

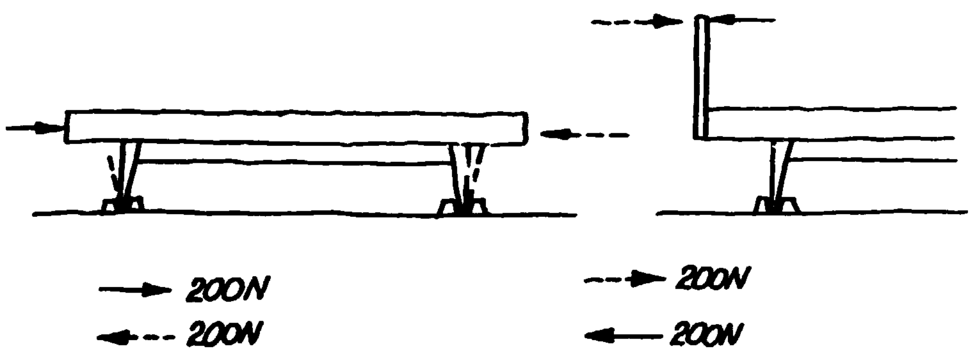


Figure A.28. Loading specifications for the fatigue test of beds (loads at a and b are applied sequentially)

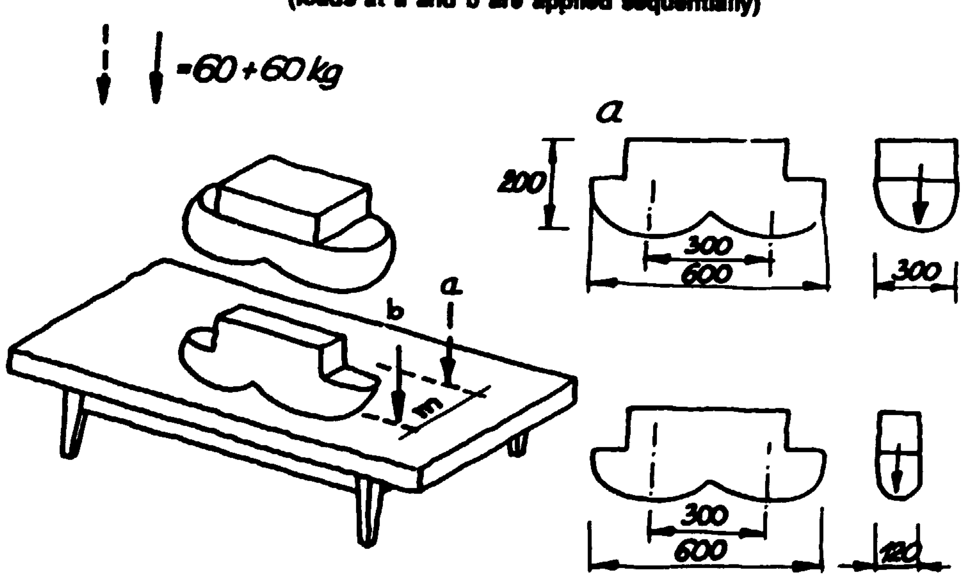


Figure A.29. Loading specifications for the impact test of beds

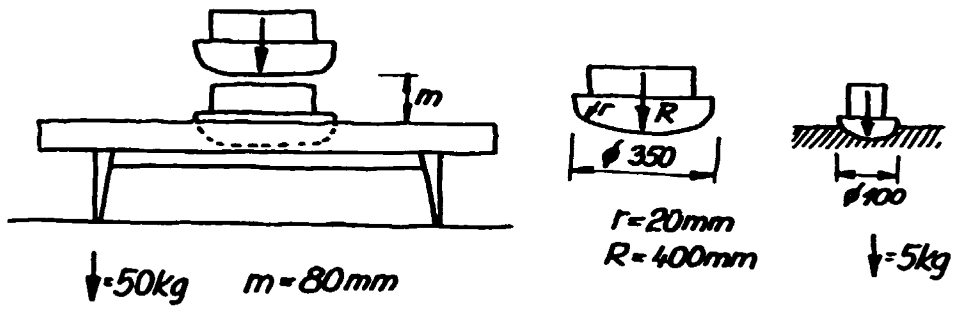


Figure A.30. Loading specifications for the (a) impact test for determining the strength of fences of baby beds and (b) the rigidity test of baby beds (each bar is tested)
(Loads at a, b, c and d are applied sequentially.)

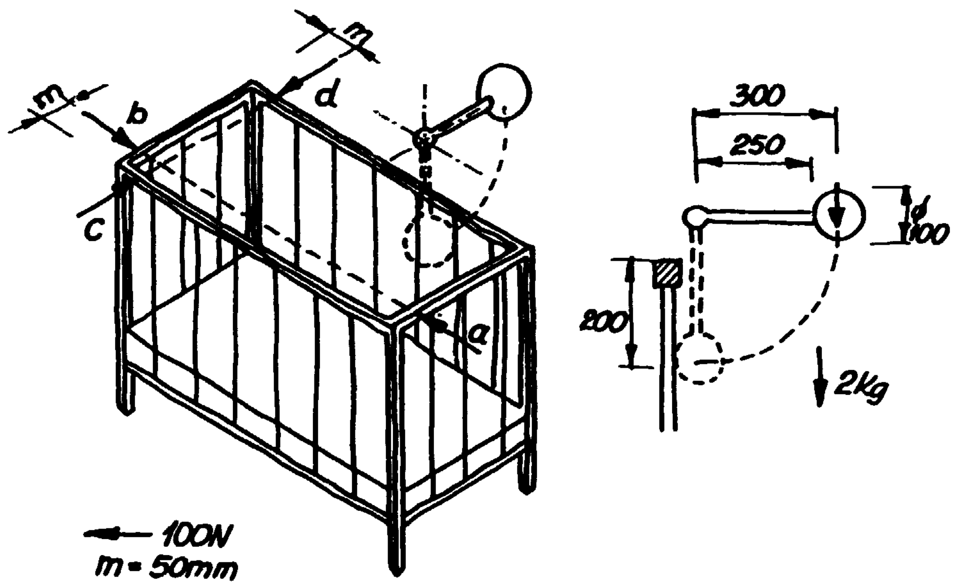
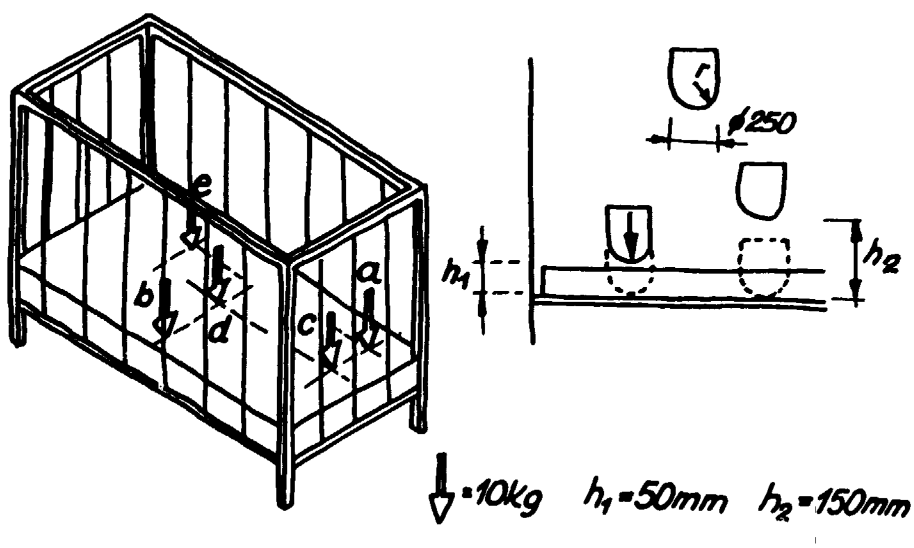


Figure A.31. Loading specifications for the impact test on the base of baby beds
(Loads at a, b, c and d are applied sequentially.)



Tables and chairs

Figure A.32. Loading specifications for testing the stability of tables and desks to raking forces

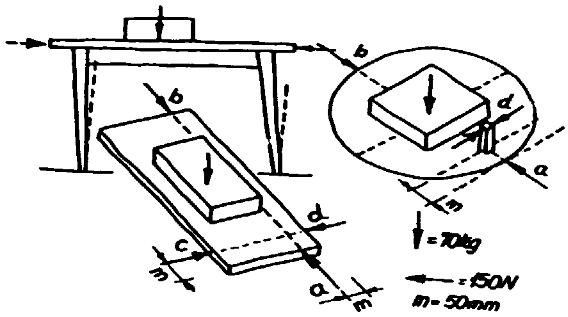
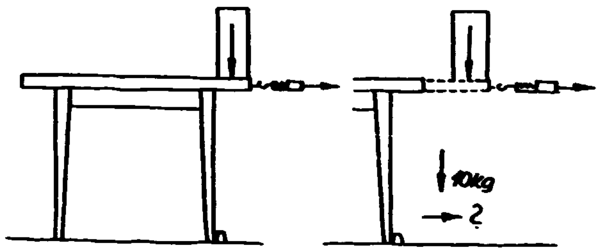


Figure A.33. Loading specifications for testing the stability of tables to loading of extremities



Chests of drawers and cabinets

Figure A.34. Loading specifications to test the rigidity of chests of drawers and cabinets

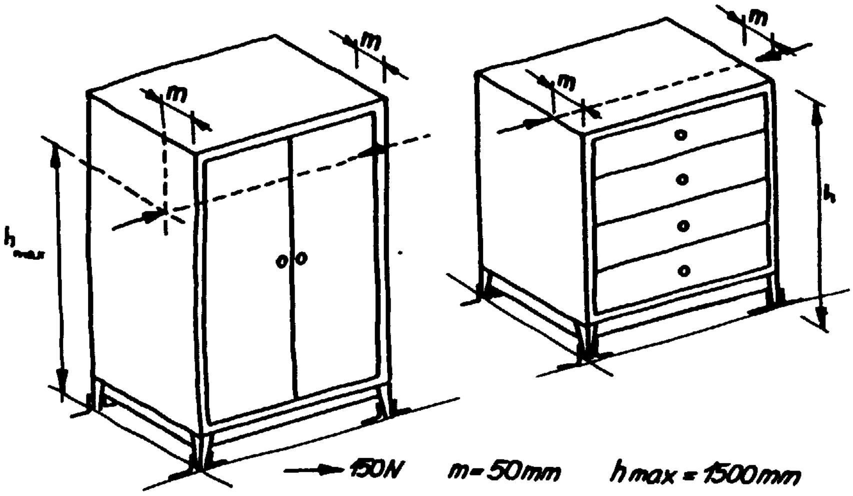


Figure A.35. Loading specifications to test the stability of chests of drawers and cabinets

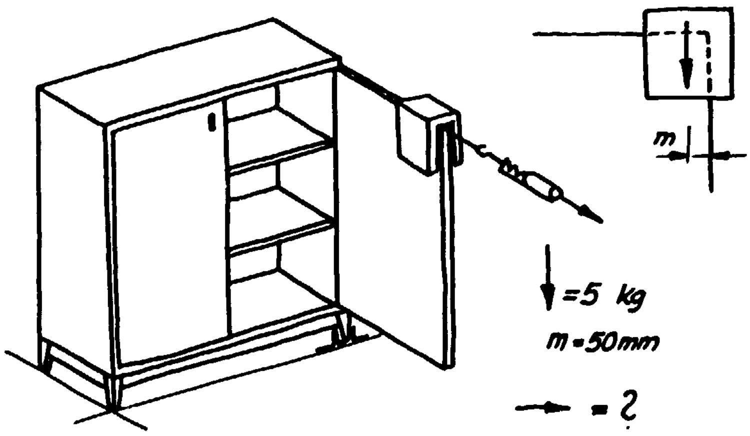
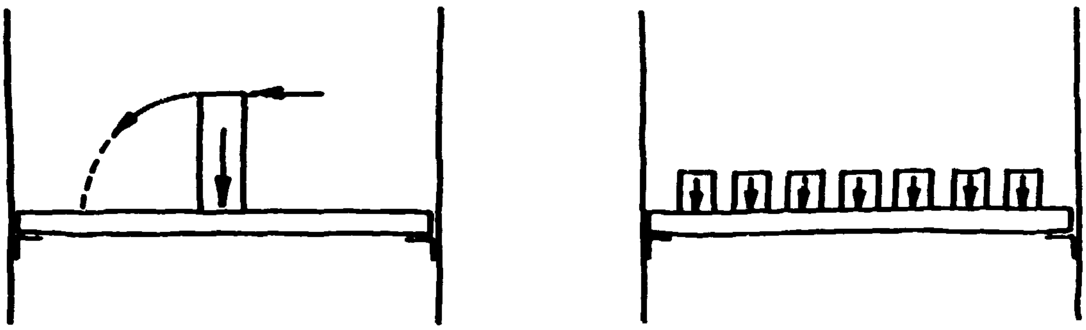


Figure A.36. Loading specifications for testing the rigidity of shelves



A. Central loading

0,6 kg; 1,25 kg; 2,5 kg

B. Evenly distributed load

Load depends on dimension of shelves (average 5 kg/10 cm) deflections are measured after 28 days.

Figure A.37. Loading specifications for testing the solidity of drawers

A. Horizontal movement

B. Tilting of drawer on its guides

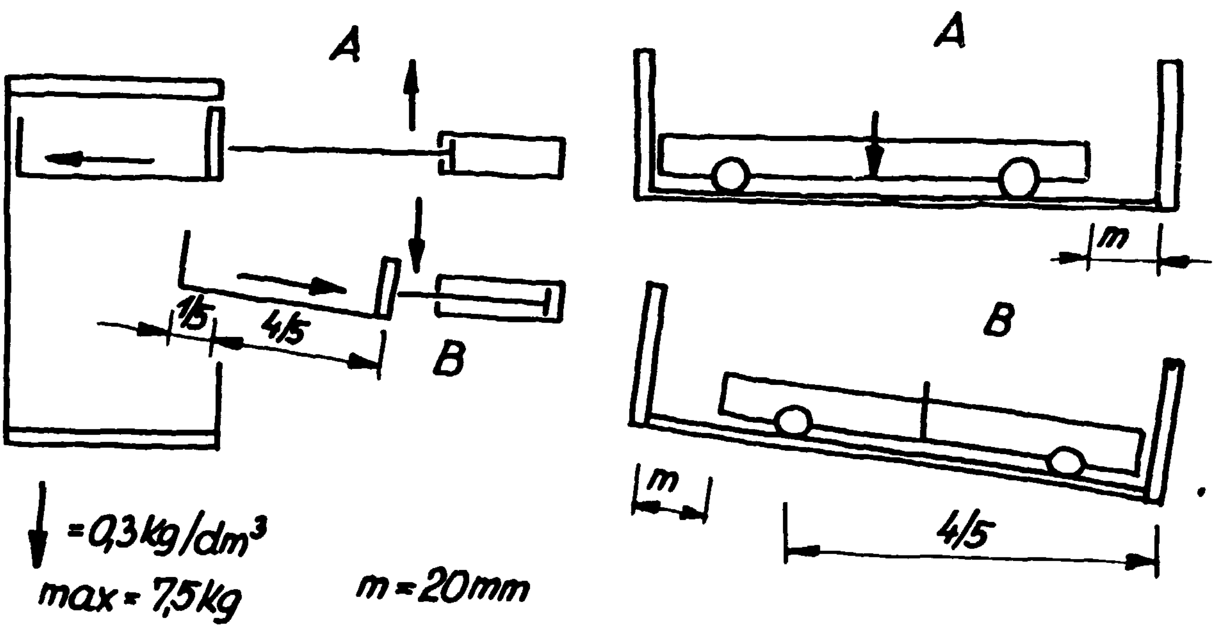


Figure A.38. Loading specifications for testing the stability of chests of drawers (First test: stability if all drawers are pulled out, with no load. Second test: if stable, 5 kg load is applied.)

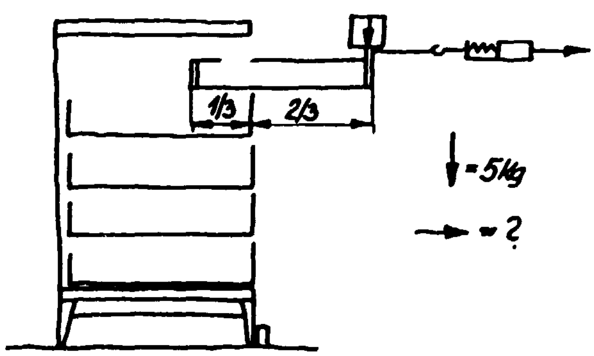
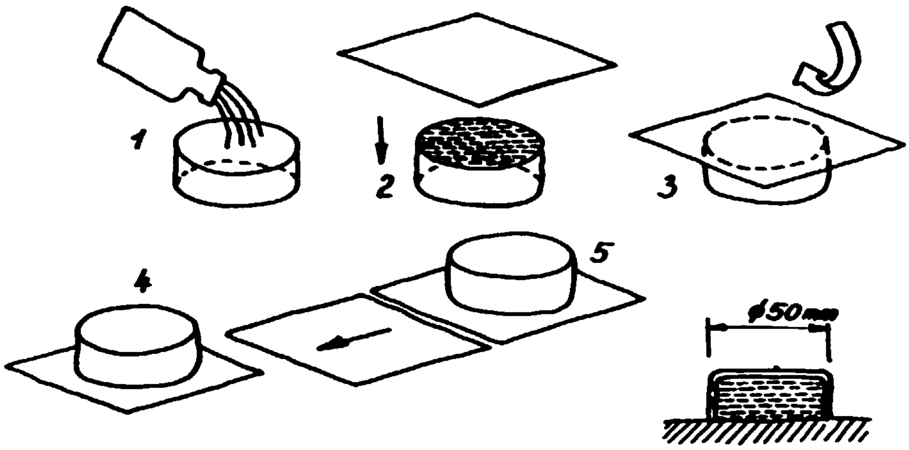


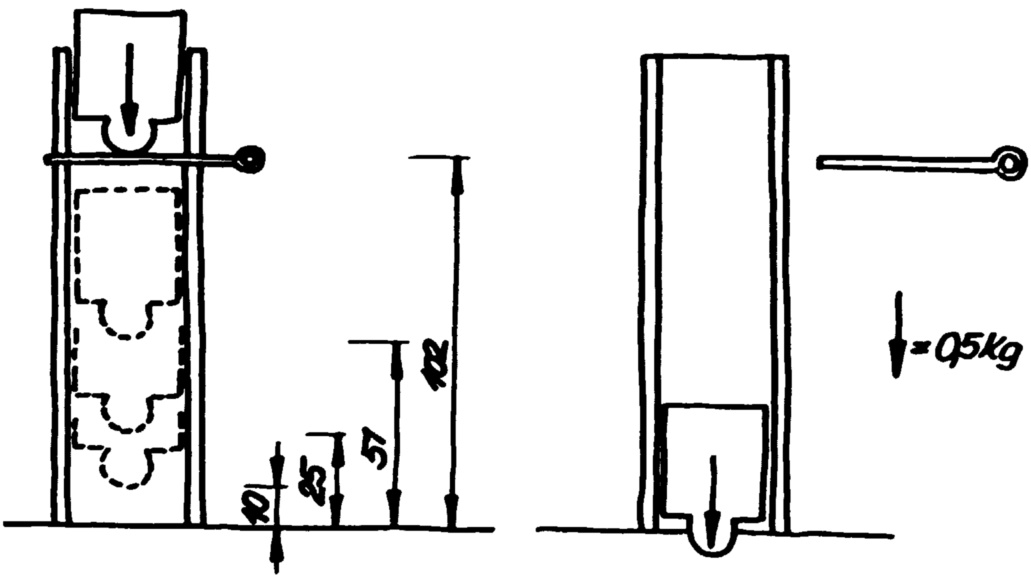
Figure A.39. Test of the effect of liquids on surfaces



Key: 1 Pour the liquid prescribed in the test into a cylindrical glass receptacle with a diameter of 50 mm
2 Place a foil on it
3 Turn upside down so that foil is at the bottom
4 Place both on surface to be tested
5 Slide the foil from under the glass recipient

(The liquid is now in contact with the surface to be tested.)

Figure A.40. Equipment for measuring the resistance of surface to impacts (A 0.5-kg load is dropped from heights increasing from 10 to 102 mm.)



XXXIV. Production management*

Introduction

The ultimate goal of any furniture or joinery business, be it small or large, is to produce goods or services. This is not an easy or simple task because many diverse activities are required to carry out the production function.

At the outset, a manager must be concerned with: determining the kind of wooden products to be sold; deciding whether to buy semi-finished parts or to produce them within the factory; planning, acquiring, laying out and maintaining the physical facilities required for operations; procuring and producing the right quantity of the right items at the right time and at the right cost; controlling the quality and quantity of inventory; and maintaining a workforce. All of these activities make the production management function interesting, challenging and rewarding but also frustrating.

The relationship between production management and other functional areas within a manufacturing environment is presented in figure 456. Inputs are needed from the various sources shown in the figure, and therefore the organizational structure of the manufacturing enterprise, whether small or large, must represent a continuous attempt to co-ordinate and integrate all of the production-related activities of the various functional areas towards the aims of production management. In turn, production management carries out activities of both a technical and an administrative nature that are geared towards the production of goods. These activities can be grouped as follows:

(a) Converting inputs to outputs (products and services);

(b) Planning and controlling work;

(c) Planning, requisition and control of materials.

Converting inputs to outputs

All business organizations produce something, either a product or a service. Production is a mechanism for converting inputs into outputs, and represents the major activity of the business. Among the many outputs are the products produced or the services performed for the customers. Examples of inputs and outputs in a wood-processing firm are shown in figure 457. In reality, production can be defined as the creation of value or wealth by manufacturing goods and providing services. As indicated above, all companies receive inputs and convert them to outputs, and production managers must find efficient ways to do this. Three alternative production systems exist, as described below.

Job order production systems. Small-scale companies manufacture furniture and joinery for customers requesting non-standard products, and goods are manufactured when an order has been placed by a customer. These companies are called "job shops". Seasonal and other variations in demand cause production to vary considerably and tend to result in idle time and varying employment levels. Highly skilled and versatile workers are needed to cope with the wide variety of machining operations. Machines are of the general-purpose type. There is no advance planning, so only a very small amount of money is tied up in raw materials and semi-finished articles.

Batch-production systems. As they develop from craft operations to industrial production, companies often adopt the batch-production system. They produce uniform lines of products in batches. This production system, once established, is repeated at regular intervals. The outputs can be stored because it is unlikely that they will depreciate in value or become obsolete owing to changes in style or intended use. These industries usually have sophisticated machinery and equipment. Production supervisors are machine operators rather than skilled personnel as in job order production systems.

Planned mass-production systems. Large-scale industries at an advanced development stage manufacture intermediate parts that can be interchanged to produce a variety of products in large quantities. Automated machinery lined up and linked with mechanized materials-handling equipment is commonly used.

Craft operations and semi-mechanized plants use the job order and batch systems, while larger industries use the batch and mass-production systems.

In all three systems the processes for transforming inputs to outputs have the following common characteristics:

(a) They are systems of transformation as related to product, place or time;

(b) A sequence of steps or operations is used to convert the inputs into outputs;

(c) Special skills and often tools, machinery or equipment are needed to make the conversion;

(d) There is a time frame in which the work is to be done;

(e) Instructions are given to identify the work to be performed and the units being produced;

(f) Certain quality standards and rates of input and output are set;

(g) There are expectations and errors that must be handled.

*By Sinan Cinar, Kelebek Mobilya, Istanbul, Turkey.

Figure 456. The relationship between production management and other aspects of the manufacturing operation

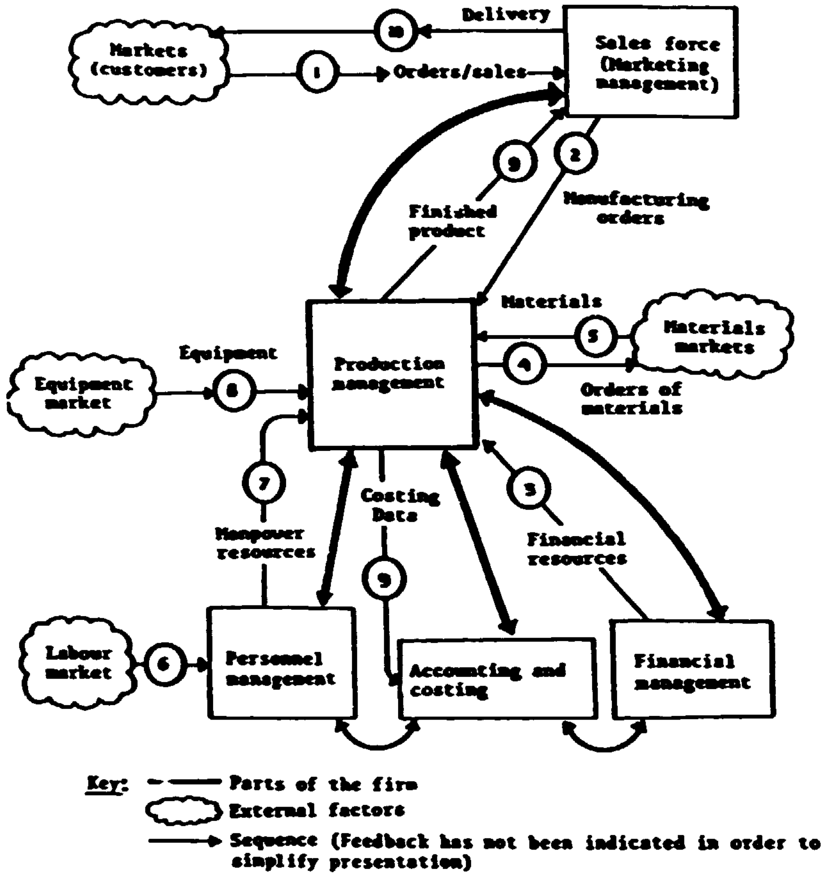
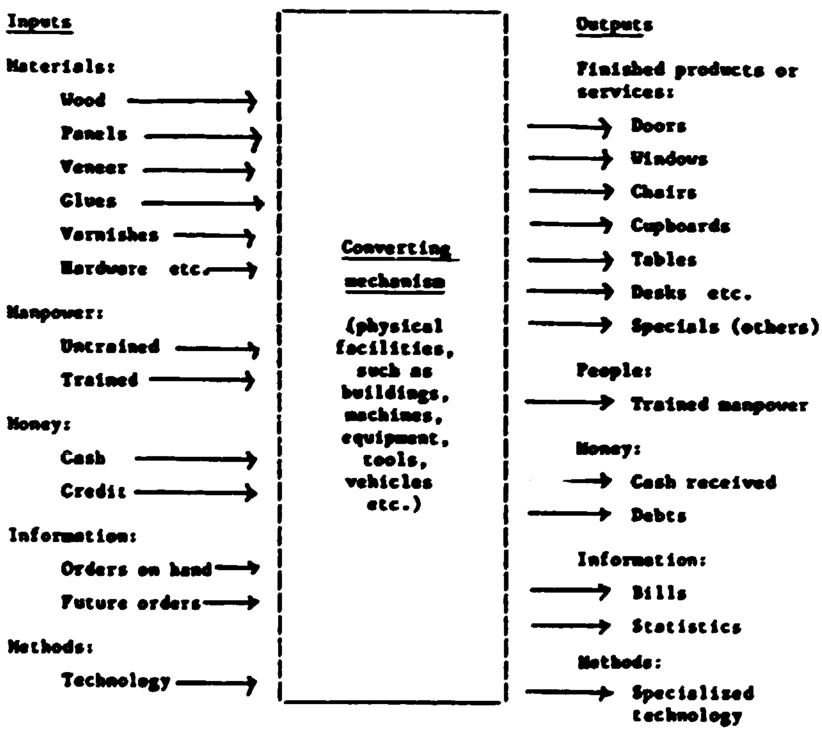


Figure 457. Examples of inputs and outputs in a typical furniture or joinery plant



Planning and controlling work

In all three production systems, planning and control are necessary. The product is usually conceived by a designer, a technologist or, in larger firms, a product development team. These people not only develop the design but also draw up production specifications. The operations to be performed, the machines to be used and the labour, material inputs and skills that are needed are determined for each product or order. The production time is set, and detailed instructions about tools, jigs, quality control procedures etc. are established. This information is used in performing and checking the work to ensure that the output conforms to the specifications.

Production planning

The starting point for a production plan is the conversion of a market forecast or a customer order into a sales plan. But before the sales plan can be finalized, the plant's production capacity must be checked. The best sales plan from a marketing point of view may not be the best plan for the company as a whole: it may require too much overtime, too much idle time or a combination of the two. The optimum plan from a production standpoint would allow for a constant level of production of one product with the optimal use of workers and machines, with inputs arriving as they are needed and outputs taken by the customers as soon as they are completed. This would be the ideal situation which the manager should try to achieve.

Demands for goods and services vary from one period to another; some fluctuations are seasonal, and can be foreseen, but other, unexpected, factors can also influence demand. These fluctuations may not present a major problem for companies using a job-order production system. Companies with batch- or mass-production systems must try to have goods available upon demand, however, which requires careful planning.

Planning starts with a plan for a longer period of time and proceeds to the detailed day-to-day operations. In production planning, the longer period might be one full year, which is broken down into months. However, there are other production plans that match the characteristics of the production system, the orders and the market, for example:

(a) Producing according to the customers' orders. Under this production plan, output and sales volumes are the same. The inventory of finished goods can be kept at zero or at a constant minimum level. However, such production requires full plant capacity during certain times of the year, and the plant can be relatively idle during the rest of the year. Workers are hired or laid off depending on the season, which is expensive for the factory and a source of hardship for the production workers;

(b) Producing at a constant level equal to the average monthly demand for the year. Inventories thus increase when the volume of demand is lower than the production volume and decrease when the demand is higher. From the production point of view this type of production planning is ideal because:

(i) There is a constant level of personnel and therefore a minimum of hiring and layoff costs;

(ii) The paperwork needed to run the production system is reduced;

(iii) The production capacity could be designed so that it is always fully utilized (especially if the plant specializes in a limited range of products);

(c) Producing complementary products, which balances out increases and decreases in the volume of demand for individual products. This might be done by producing and selling garden and occasional chairs, tables and settees in the summer and concentrating on dining rooms etc. in winter. If the same machines and skills can be used in producing both sets of products and if the volumes produced (expressed in utilization times) and sold can be balanced, the sales and production forces will be kept functioning at a constant rate all year round;

(d) Subcontracting a portion of production that is in excess of installed capacity for some of the operations. A company can manufacture most of the parts itself during slack periods and subcontract operations that would create bottle-necks to other manufacturers during peak periods;

(e) Deciding not to expand production to meet demand. Orders in excess of the existing production capacity would then be turned down. Although this would mean a loss in sales, in many instances the cost of expanding capacity or overtime exceeds the benefits of added sales.

A simplified production planning scheme for a small furniture manufacturing firm is shown in figure 458.

Scheduling

The purpose of proper scheduling is to keep costs down, keep machines and people busy and assure that products are delivered on time.

When orders are received from customers, they are either filled from existing inventories or sent to production. Most manufacturers keep an inventory of standard articles in order to give quick service. They are produced at times when the plant would otherwise be idle. Articles are produced: on a pre-planned schedule; when the inventory reaches a predetermined minimum; or when orders are received for quantities that are not available from inventory.

Schedules set the estimated times needed to produce specified items. A company that produces the same units continuously will have much better records, which will allow it to estimate production times more accurately and thus plan realistically.

Time schedules are especially important in areas where bottle-necks are likely to occur. Therefore, the production planning and control department must control the schedule and, if necessary, revise the time standards by taking into account feedback data from the shop floor. Details on establishing standard times are dealt with in a UNIDO publication, *Production Management of Small and Medium Furniture Manufacturing Firms in Developing Countries* (ID/300), chapter VI. A simplified version of how to establish standard times is shown in figure 459.

Figure 458. Simplified production planning scheme for a small furniture manufacturing firm

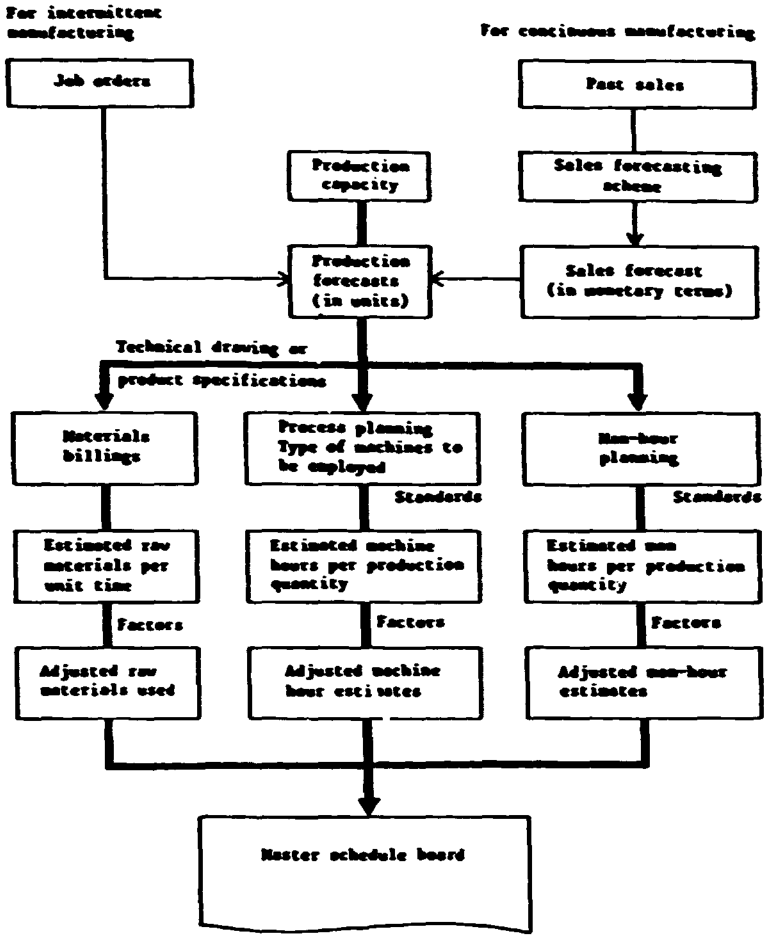


Figure 459. Establishing the standard time for a simple manual job

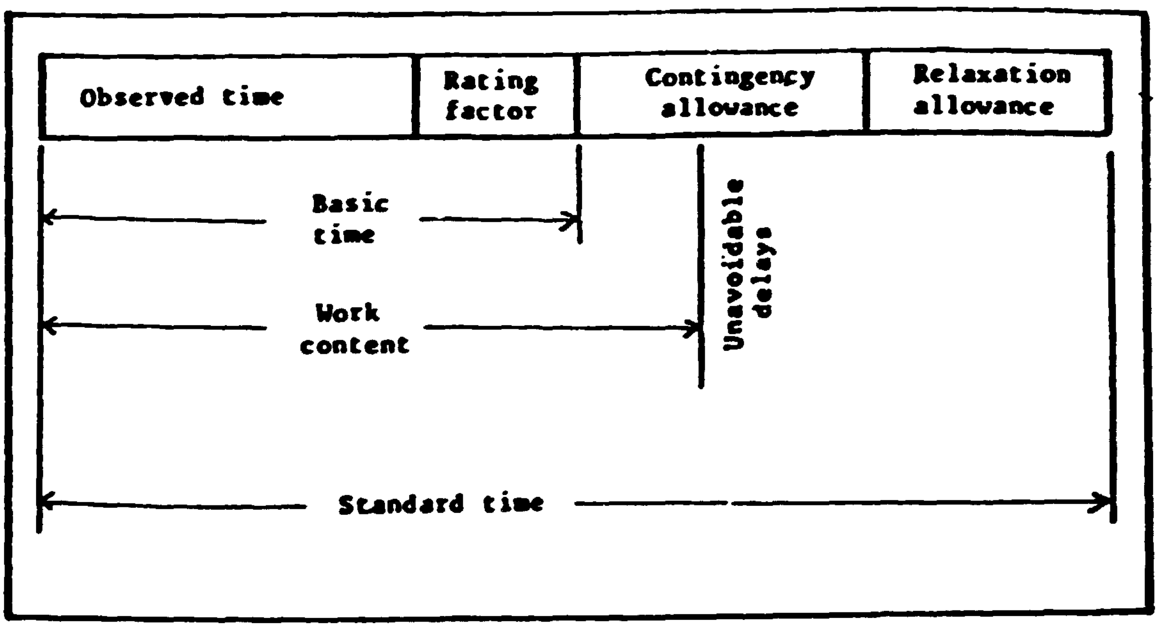
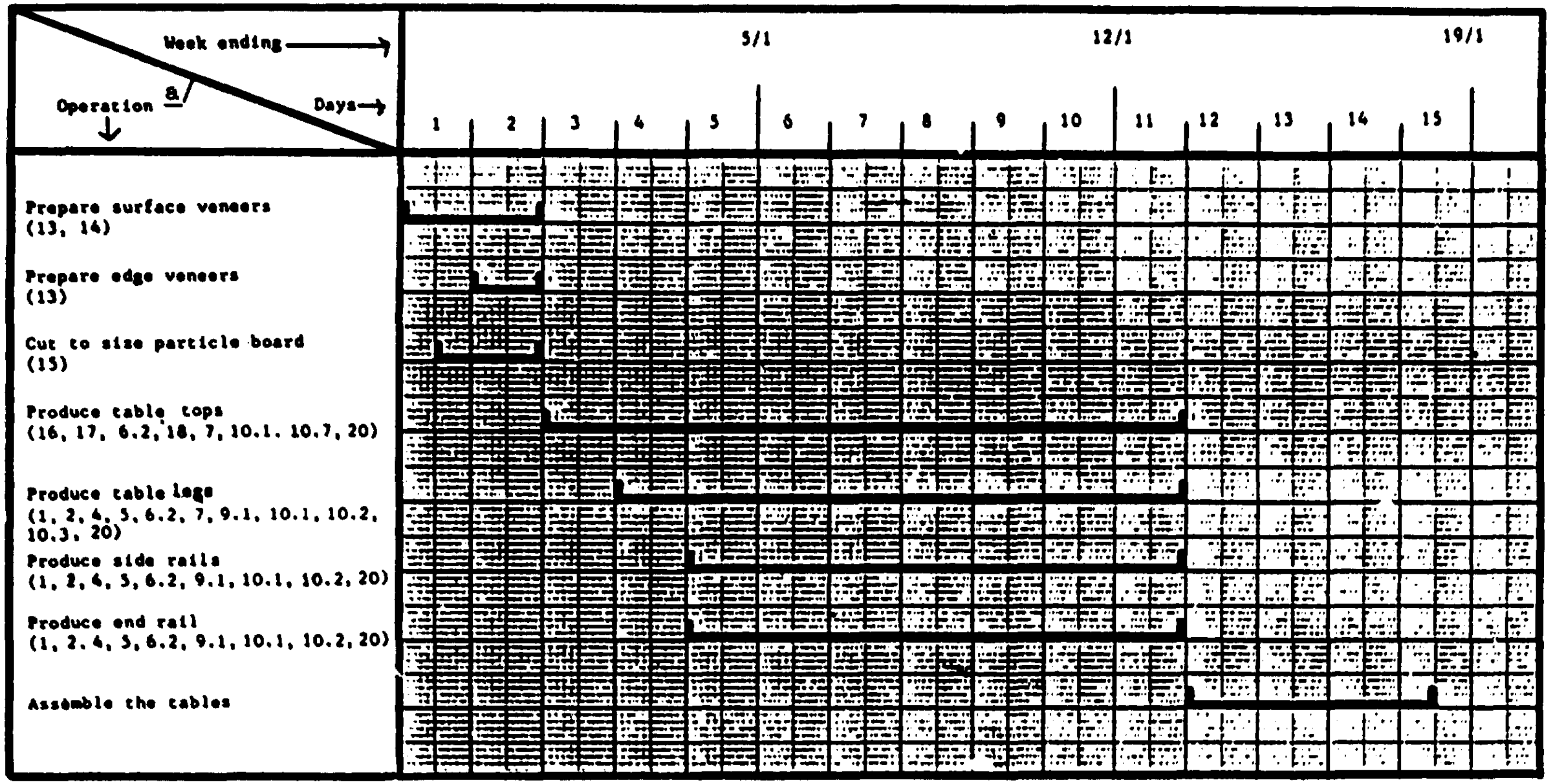


Figure 460. A simple Gantt chart used as an aid for scheduling 50 tables



a/ Numbers in parenthesis refer to the machine or device, as follows:

1. Cross-cut saw
2. Edging saw
3. Band saw
4. Surface planer
5. Thickness planer
6.1. Single-blade saw bench
6.2. Double-blade trimming saw
7. Vertical-spindle moulder
8. Router
9.1. Multi-spindle boring machine
9.2. Single-spindle boring machine
10.1. Horizontal belt-sanding machine
10.2. Vertical belt-sanding machine
10.3. Form sanding machine
11. Glue spreader
12. Solid-wood panel glue press
13. Veneer saw
14. Veneer jointer
15. Panel saw
16. Glue spreader
17. Hydraulic veneering press
18. Edge veneering

Plants employing job order production systems must schedule each incoming order. There are several ways of doing this:

(a) Incoming orders are handed over to production in sequence. The orders are processed on a first-come-first-served basis;

(b) Orders are scheduled according to the priorities;

(c) Orders are scheduled using either methods (a) or (b) for each operation;

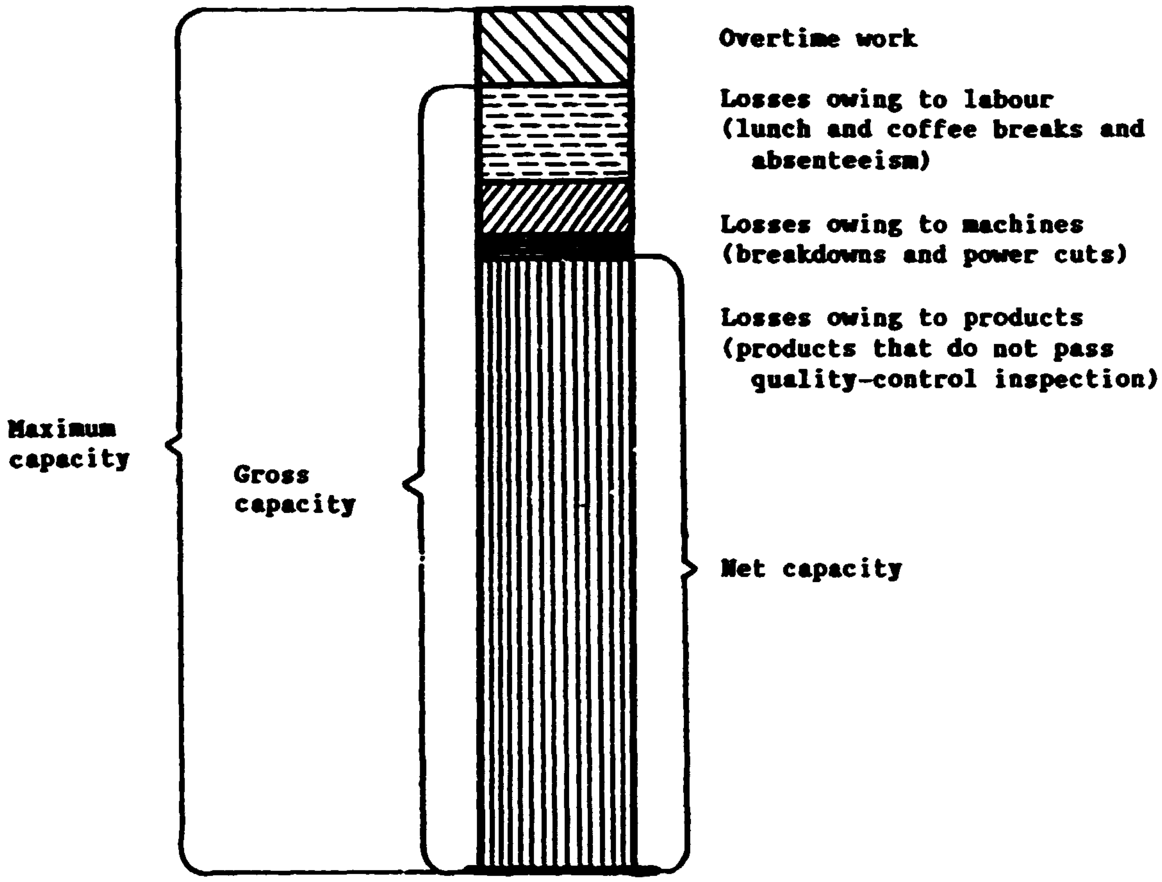
(d) Scheduling is done according to a pre-set time for each order;

(e) Similar orders are grouped together and articles are processed in batches.

When orders are scheduled an effort should be made to keep the inventory as small as practicable. Production should be started early in a long sequence of operations for a part that is to be assembled to a part that can be produced in a short period of time (i.e., production should be calculated backwards). In such instances, a Gantt chart is very useful (figure 460).

Once production orders are scheduled, the through-put time of each article must be planned by allocating the machines for each job operation. This is called "machine loading". To plan loading properly, the net available plant capacity must be known. This may be obtained by subtracting all losses from the theoretical gross capacity as shown in figure 461.

Figure 461. Calculation of plant capacity



Information flow

Information regarding orders received and plans made based on these orders must, in one way or another, be communicated to those doing the work. Each worker must know what and how many items are to be produced, when and where to produce them and how to perform the job satisfactorily. This is usually done by means of written instructions complemented by oral explanations. Examples of the most important written instructions are as follows:

(a) Parts list, which contains information on every single identical part that is to be produced, such as code number, specifications of the material, rough and final dimensions, type of surface finish etc. It is easy to follow if a separate parts list is prepared for each kind of material, such as particle board, plywood, hardboard, veneer, textile etc. (figure 462);

(b) Cutting plans, which give information on the cutting patterns of the panels, calculated so as to minimize waste (figure 83, chapter XVII);

Figure 462. Parts List

PARTS LIST												
Product:												
Pcs.	Item	Wood, particle board etc.					Blind veneer		Surface veneer, Plastic laminates etc.			Remarks
		Final dimension			Material	Quality	Material	Thickness	Material		Thickness	
		Length	Width	Thickness					Face	Reverse		

(c) Part progress/transfer tickets, which accompany the batches or pallets through all the production stage. Such information as the job number, type of product and routing instructions are written on the ticket (figure 463);

(d) Machine loading ticket, which gives the machine loading schedule for each operation. This ticket can be displayed on a loading board and is used for advance planning as well as for current allocation and control. It shows at a glance the overall production situation;

Figure 463. Parts progress and transfer sheet

		DIMENSIONS (mm)						SCHEDULE week	
Job No: 001	Quantity: 50	1210 L	810 W	19 T	1195 L	795 W	20 T	1	3
Component: Top panel	of: 50	GROSS			NET			Start	Finish
....	Initials: S.C.								
Article: Table									
....	Date: 17/04/85								

Operator No.	Job centre	QUANTITY Received	Scrap	Good	Operator's initials	Date	Remarks
1	15.0	55	1	54		02/01/85	
2	16.0	54	-	54)		03/01/85	
3	17.0	54	-	54)			
4	6.2	54	2	52		04/01/85	
5	18.0	52	-	52		05/01/85	
6	6.2	52	-	52		08/01/85	
7	18.0	52	-	52		08/01/85	
8	7.0	52	-	52		09/01/85	
9	10.2	52	-	52		11/01/85	
10	10.1	52	1	51		11/01/85	
11	20.0*	51	1	50		12/01/85	

Inspector: X, Y, Z	Stores	Cost accounts
Date:	Store keeper's initials:	Accountant's initials: ....
Quantity passed: 50	Quantity received: 50	Cost per one: ....
		Date: ....

*Surface finishing department.

(e) Material requisition sheet, which enables the purchasing department to buy or allocate materials and make them available to the shop at the right time. It also serves as a voucher for stock control (figure 464).

Figure 464. Materials requisition sheet

MATERIALS REQUISITION

Date ____________ Requisition No. ____________

For ____________ Product order No. ____________

Department

Requested by ____________

Stores No.	Quantity requested	Description	Quantity issued	Unit cost	Total cost

Received by: ____________ Date: ____________

(f) Job and rate sheet, which contains instructions for the production supervisor and the individual operator. On completion of the job, the card goes first to the progress control as a progress report and then to the wages office as a basis for wage calculation. Thereafter it serves as an accounting document for cost analysis and post-operation calculations (figure 465);

(g) Special forms, which can be devised according to the individual needs of each company or for specific products and processes.

The paperwork should be reduced to a minimum at all times.

Production control

Even if both the production plans and the work carried out are excellent, there is a need for control. If effective control is not exercised over the operations, the process is likely to fail sooner or later. The following functions should be controlled:

Quantity
Quality
Time

It is essential that any variation from a plan must be reported and that corrective action should be taken.

Before introducing a control system, the following steps should be taken:

(a) Setting standards;

(b) Measuring actual performance;

(c) Comparing performance with standards;

(d) Making corrections when needed.

Materials planning, requisition and control

One of the main prerequisites for complying with delivery times is that the proper materials must be available in the right quantity, of the right quality, at the right time and at the right price. A company's success will partly depend on skill and luck in finding and acquiring adequate supplies of all the material inputs. For production management to succeed, the planning and controlling of materials, inventories, ordering points, sources of supply, materials rece[illegible] storing and handling must be efficient and effe[illegible]

Figure 465. Job and rate sheet

Job No.: 001	Quantity: 50
Component: Top panel	of 50
Article: Table	Initials: SC
	Date: 17/04/85

DIMENSIONS (mm)						SCHEDULED Day	
1210	810	19	1195	795	20	04/01/85	04/01/85
L	W	J	L	W	J	Start	Finish
Gross			Net				

Operation No.	Job centre	Description of operation	Standard time Hrs.	Standard time Mins.	Per
4	6.2	Trim the long edges of the veneered table top to final dimensions using TCT sawblades 250 mm diameter on machine No. 6.2.	–	4.5	1

Received	Finished
54	52

Actual time Hrs.	Actual time Mins.
3	33

Time earnings	Rate
25'	
Bonus earnings	**Rate**

Operator	Production Control Dept.	Wages Office	Cost accounting
Initials:	Remarks:	Calculated benefit:	Cost:
Date:			

The stock of materials, parts, goods and supplies represents a large investment. The purpose of stock is to make it possible to disconnect one segment of a process from another, so that work on each segment can be carried out at an optimum level of performance. Stocks are kept at various places in the plant and at different stages of production. Stocks consist of:

- Purchased materials, parts and products
- Goods in process or between operations
- Finished goods at the factory, warehouse or store
- Spare parts for machines and facilities
- Tools, cutters and auxiliary materials
- Supplies for the office, shop or factory

Although each of these types of stock performs basically the same function, some of them represent a much greater investment, cause more serious trouble if the items are not in stock and are more costly to restock than others. An "ABC" system can be used to rate stock items according to importance; management can then devote more time to ordering items that are expensive or that are needed in large volumes. Special consideration should also be paid to optimum inventory levels, the intervals between orders and the quantities of orders.

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XXXV. Computer applications in the furniture and joinery industries*

Introduction

The development of computers dates back to the 1940s. The first true electronic computer, codenamed "ENIAC", was developed in 1946. This computer weighed about 30 tonnes and was housed in a building that was two storeys high and had a 1,400 m² floor space.

Today, a micro-computer, a so-called personal computer about the size of a small stereo music set and costing about $1,000, can in fact add and subtract 20 times faster than the original ENIAC computer did 40 years ago. With this in mind, it can be said that the computer industry was the fastest developing industrial sector in this 40-year period.

The so-called computer revolution started with the introduction of micro-computers early in 1975. Before this time, computers had been used almost exclusively by large business organizations such as banks and insurance companies and by government departments in industrialized countries. Today, this has changed, and people can buy computers for home use.

The extent of the use of computers in different industries varies widely. Computers are generally used less in the wood-processing industry than in other industries. In most developing countries the furniture and joinery industries may not yet have started using computers, which is unfortunate. Managers in the woodworking industries are faced daily with many problems associated with operation, management and raw-material supplies. Therefore, in most cases, a small but powerful micro-computer would be an effective tool in woodworking industries. Specific areas in which a computer could be used would be production planning, work preparation, production control, the optimization of panel cutting, planning and controlling maintenance and accounting.

The use of (micro-) computers in general and specific areas will no doubt lead to competitiveness, reduced labour costs, increased productivity, reduced clerical expansion, improved customer service, increased profits owing to more accurate cost accounting, reduced stock levels owing to closer stock control and enhanced management efficiency owing to a more efficient reporting system.

There is still some confusion among people working in the wood-processing industry regarding what is possible and what is not, how much effort is required and how much risk is involved. This confusion seems to be one of the main reasons why micro-computers have not been used extensively in developing countries.

*By Sinan Cinar, Kelebek Mobilya, Istanbul, Turkey.

The following topics will be covered in the present chapter to acquaint the reader with some basic knowledge about computers:

- Hardware concepts
- Software concepts
- Programming languages
- Specific areas of application for the furniture and joinery industries

Hardware concepts

Computer categories

Hardware is the physical part of a computer system. The capacity of a computer system has a direct relation to the nature of its hardware. Computers are classified into three categories, according to the characteristics of their hardware, as follows:

Mainframe computers. A mainframe computer is a large one. It costs at least several hundreds of thousands of dollars and requires a staff of operators, programmers and system analysts.

Mini-computers. A mini-computer is smaller than a mainframe computer and less costly, but it is still a very powerful device. A mini-computer system normally requires only a small staff.

Micro-computers. A micro-computer is smaller and much cheaper than the other two. It normally requires only one operator, often the so-called owner-user.

Elements of a computer system

The hardware consists of the following elements:

- Central processing unit
- Input device
- Storage device
- Output device

These elements make up a computer system (figure 466). It is important to distinguish between a computer system and a piece of hardware that might be sold as a computer.

Each element that makes up the computer system has its own features and characteristics, which are explained below.

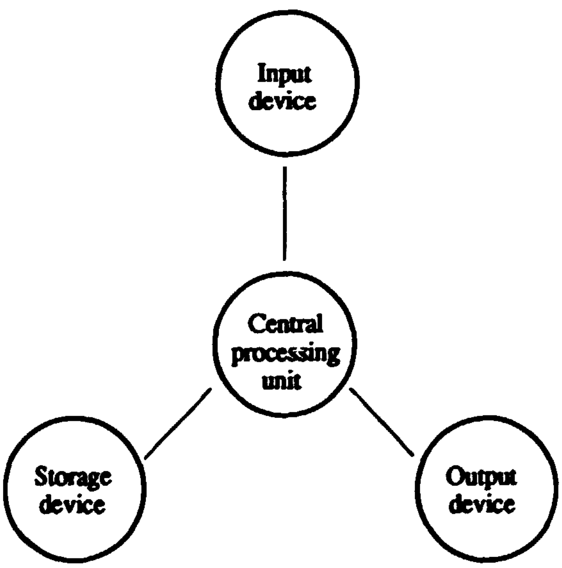
Central processing unit (CPU). The CPU contains the integrated circuit that directs the flow of information within the computer and does the actual computing. It has two kinds of memories: read only memory (ROM) and random access memory (RAM). ROM contains the programs that are built into the computer by the manufacturer. RAM, however, is far more important for the user. The amount of RAM usually defines the computer's maximum capacity to receive information and process it. The CPU of a micro-computer with integrated double floppy-disk drive is shown in figure 467a.

Input device. In a micro-computer system, the input devices include the keyboard on which the operator types, reels of magnetic tape and magnetic disks, or so-called floppy disks. A micro-computer can only be given directions through one of these input devices. A typewriter-type keyboard is shown in figure 467b.

Output device. The most common output devices are screens (figure 467c), printers and plotters. However, magnetic tapes and floppy disks can also be used as output devices. A dot-matrix printer is shown in figure 468.

Storage device. There are two kinds of storage, external and internal. External storage devices include magnetic diskettes and magnetic tapes where data files are kept. On the other hand, internal storage is the computer's memory. A 5-1/4" floppy disk is shown in figure 469.

Figure 466. The computer system



Software concepts

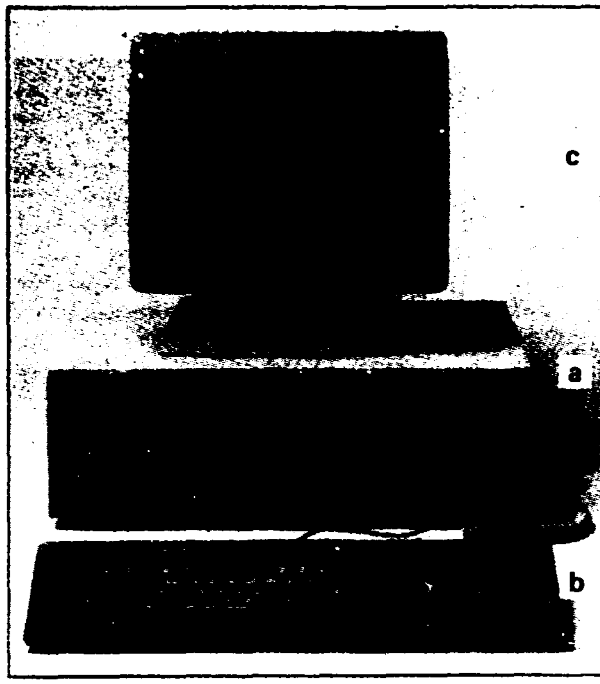
Computers are incapable of doing anything unless instructed to do so by a human being. The set of instructions that a computer will follow to solve a problem is called a "computer program". The programs that the computer needs in order to function are known as "software".

Computer software is an essential complement to computer hardware and is grouped into two categories:

Operating systems. Operating systems are designed to control the execution of other programmes and utilize the hardware efficiently.

Applications software. Applications software or programs are designed to use the capabilities of the computer to solve specific user-oriented problems.

Figure 467. Compact micro-computer system



Key: a CPU with built in floppy disk drives
b Keyboard
c Screen

Figure 468. Dot-matrix printer

Programming languages

Human language is different from computer language. Neither humans nor computers can communicate without the use of an intermediate language. These intermediate languages are known as "programming languages". Although many different programming languages exist, the most widely used ones are the following:

FORTRAN. One of the oldest languages used for scientific programming.

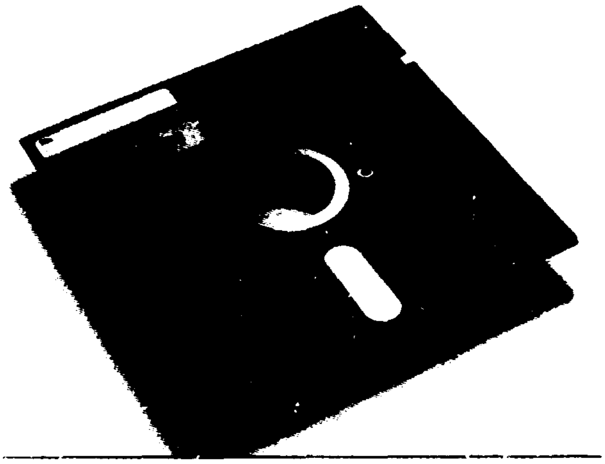
COBOL. A business-oriented programming language that was first introduced in the 1950s.

PL/1. A general-purpose and versatile programming language that is designed to be used for all types of tasks.

BASIC. A simple, conversational and interactive programming language used for general-purpose programs.

RPG. A programming language used for simple programs requiring printed reports as an output.

Figure 469. 5-1/4" floppy disk



Applications in the furniture and joinery industries

At present, both general-purpose as well as specialized software programs have been developed for many sectors of the furniture and joinery industries (household furniture, kitchen furniture, office furniture and doors and windows).

Many hardware manufacturers have developed general-purpose programs for manufacturing industries that can be adapted to the individual sectors. However, these may not meet the exact needs of a specific industry. In view of this, some suppliers and consulting firms have also developed specific software programs for the woodworking industry. An order-processing and production-planning program developed specifically for the furniture industries is presented as a flow chart in figure 470.

A general description of such programs and the application areas are explained below in very general terms.

Production planning

Items of furniture can be produced for stock or for a specific order. In either case, once the size of the batch has been decided for each type of surface, veneer or wood species, certain information can be fed into the computer: the quantity of each part (or component) for each type of surface and species of veneer or wood; the quantity of each type of hardware and fittings; and the quantity of other material inputs (figure 471). These quantities are compared with the stocks on hand to obtain the actual number of parts or components to be produced, and, if necessary, a quantified list of materials to be procured is made. Standard production times, standard material costs, total work-hours required and standard costs of items are obtained as advance information or for further planning.

Work preparation

Orders received should be translated by production management into the working language of the shop-floor so that workers, machine operators and supervisors can perform their jobs. This involves the printing of the following information in a predetermined format:

Parts lists (figure 472)
Job and rate sheets
Machine-loading tickets
Part progress/transfer tickets (figure 473)
Optimized panel-cutting plans

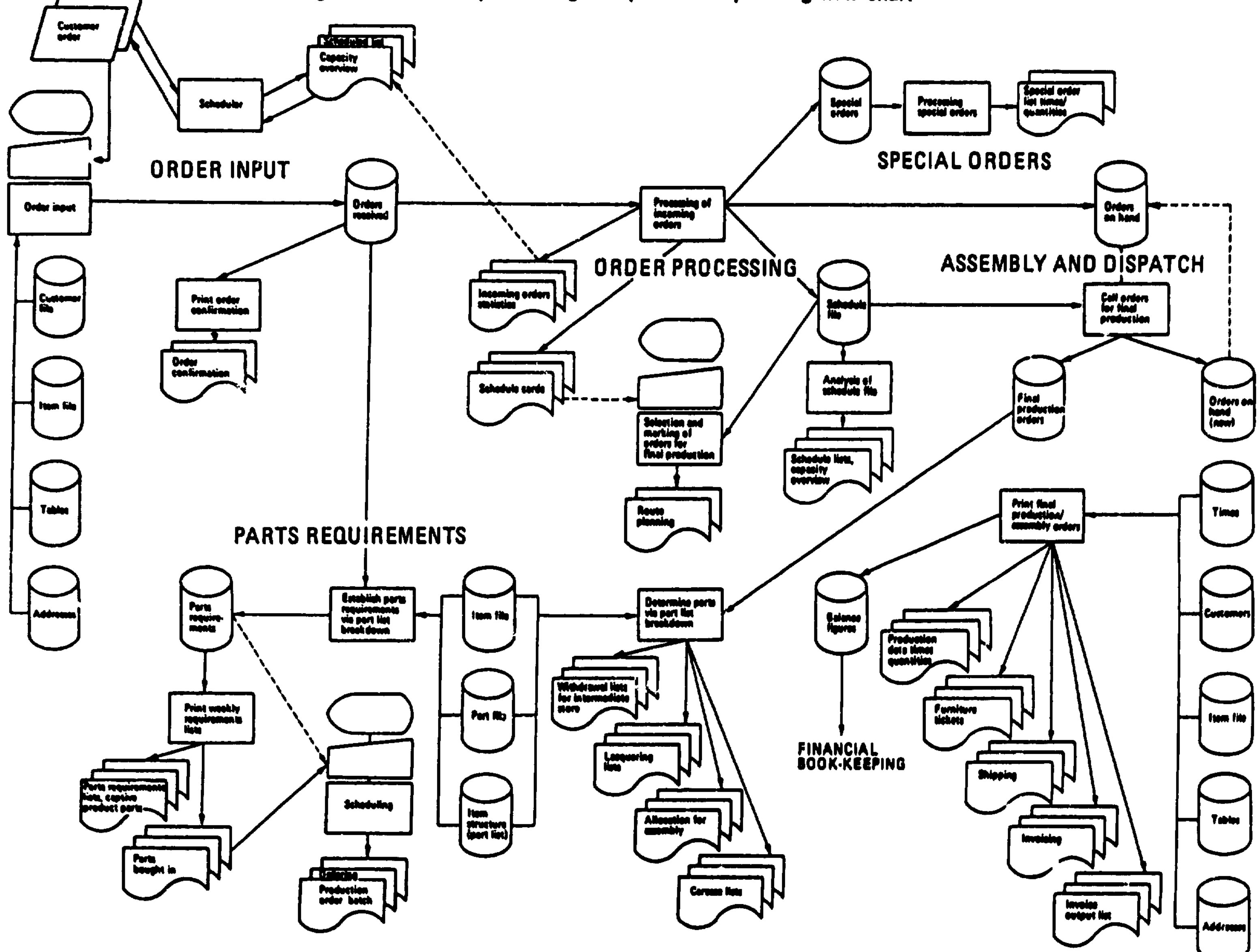
Optimizing panel cutting and printing the cutting plans is a specialized field in itself. The essential software is an optimization program that involves advanced mathematics and an understanding of basic cutting terminology. Appropriate cutting terminology as used on a cutting plan is shown in figure 474. Once the lists of the required wood-based panels and components (parts) have been prepared giving the type of panel and the grade, thickness, dimensions and quantity of each component, the computer is fed with a panel-cutting list (figure 475). Based on this information input, the computer optimizes and prints out a cutting plan (figure 476). The software also enables the computer to print out a summary of the number of boards used, the number of components or parts cut, the waste factor for each cutting plan (figure 477) and cutting times for capacity calculation (figure 478).

Production control

Using computers, production quantities and times can be controlled accurately. At the production-planning stage, quantities of components and materials are calculated and stored on a floppy disk or a magnetic tape. When manufactured components and procured materials are placed in the finished goods or material stores, the quantity of each incoming item, with its identification code number, is entered into the computer, and hence under- or over-production or procurement is automatically controlled, stocks are minimized, the inventory is controlled and timely purchases can be made.

Time control is almost the same as quantity control. The calculated standard times for each and every production item are stored in the computer. When the actual time is entered, the time difference is obtained instantly.

Figure 470. Order-processing and production-planning flow chart



Source: Unternehmensberatung Gerhard Schuler Pfalzgrafenweiler.

Figure 471. Breakdown of an item into parts and material inputs

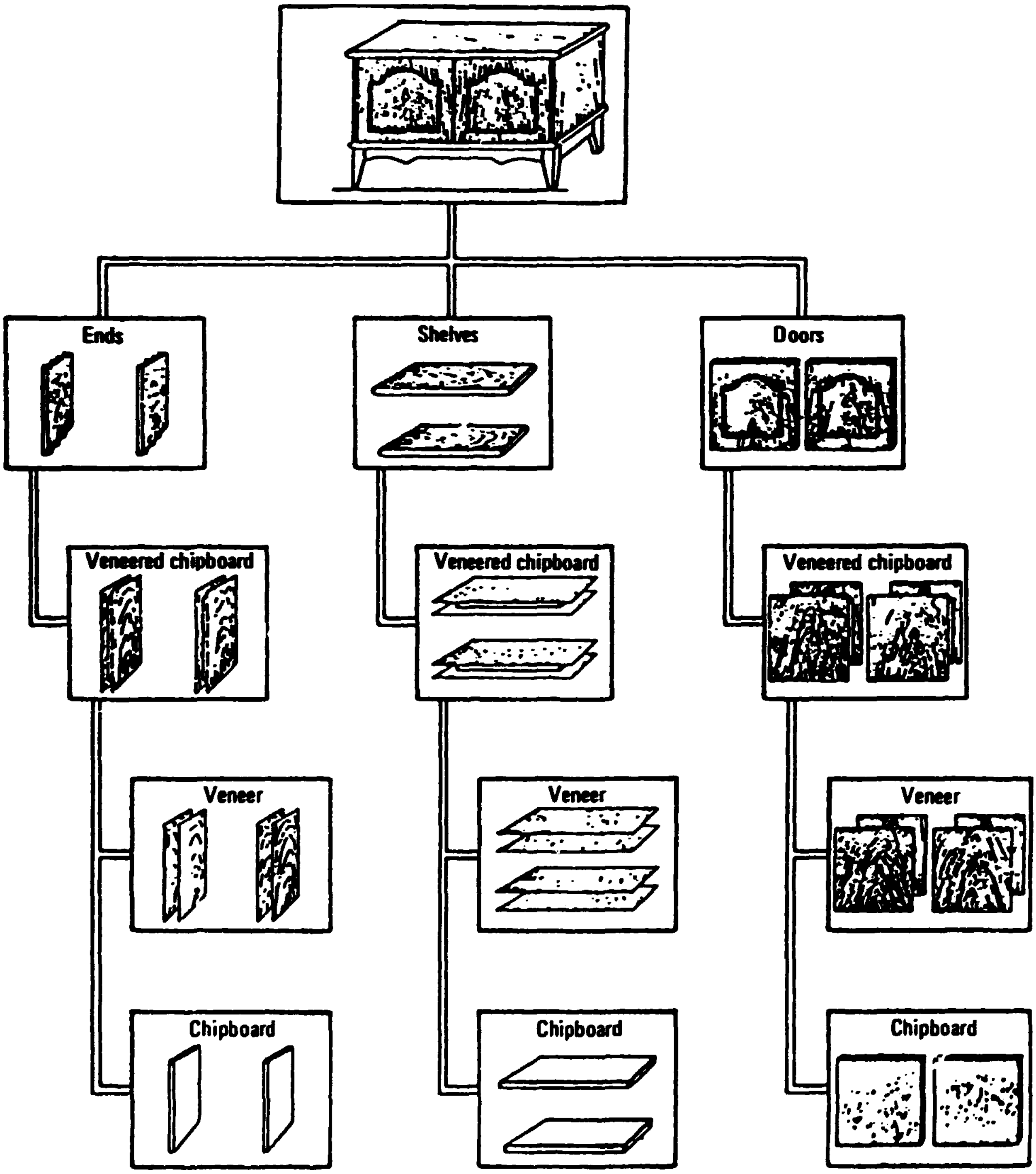
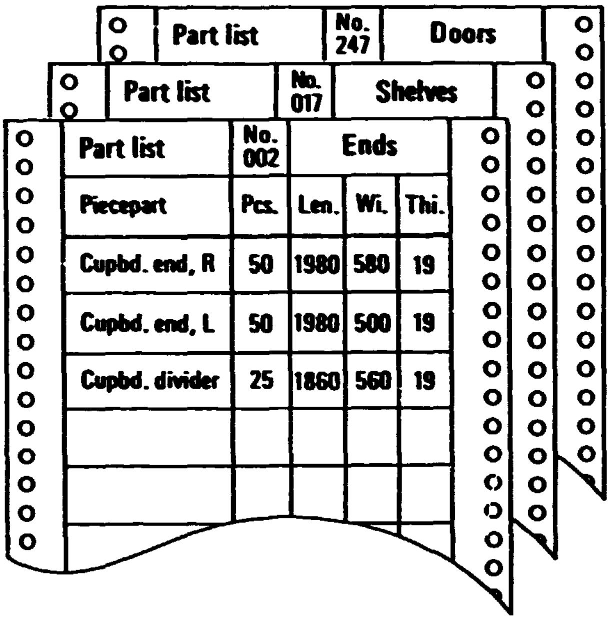
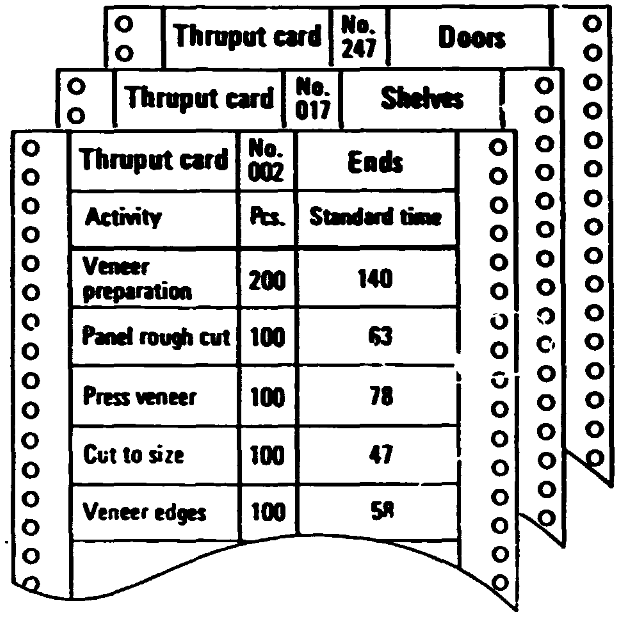


Figure 472. A computer-printed parts list



Source: Unternehmensberatung Gerhard Schuler Pfalzgrafenweiler.

Figure 473. A part-progress (thruput) ticket



Source: Unternehmensberatung Gerhard Schuler Pfalzgrafenweiler.

Figure 474. Cutting terminology as used on a cutting plant (The numbers refer to the proposed order of cuts. Cuts 19, 20, 21 and 22 can be cut on a bench saw.)

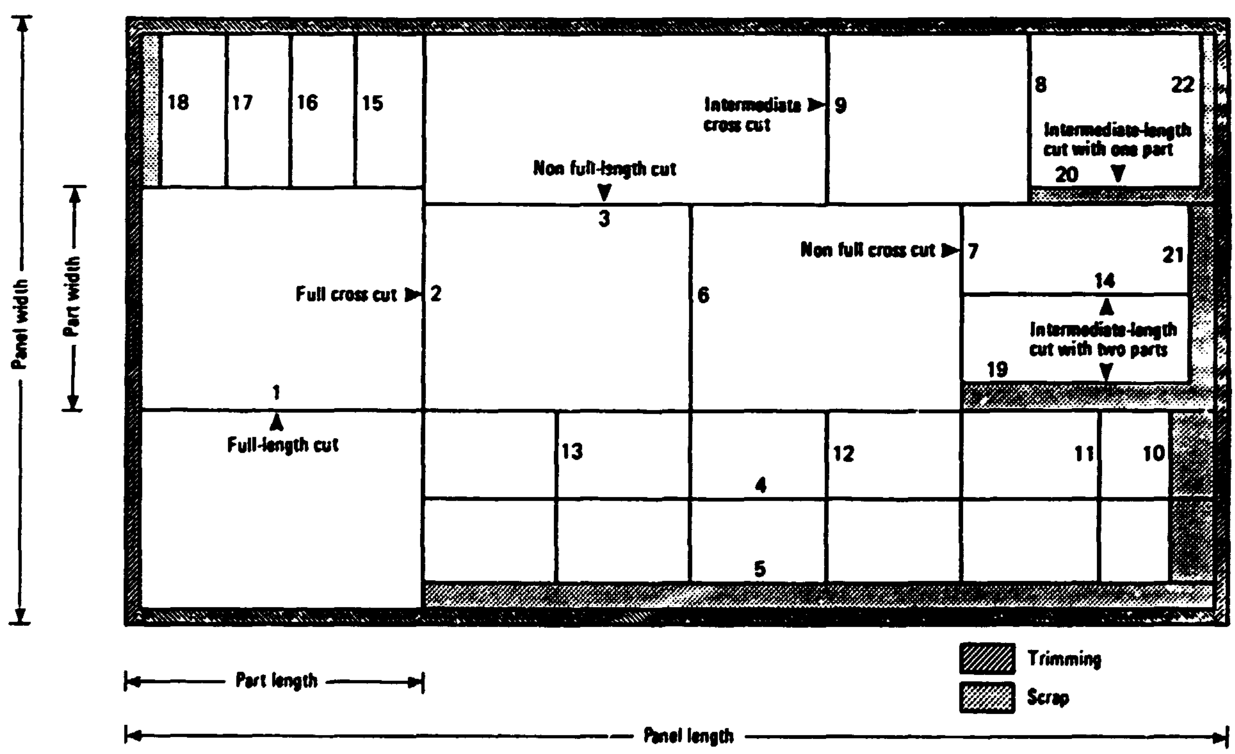


Figure 475. Panel-cutting list

PANEL CUTTING LIST

MATERIAL: MEL

NO.	PANEL DESCRIPTION	PROCESSING LENGTH	PROCESSING WIDTH	QUANTITY REQD	QUANTITY OVER	QUANTITY UNDER	ROTATE (Y/N)
1.	BOTTOM	1200	300	1	0	0	Y
2.	SIDE	1000	250	2	0	0	Y
3.	FRONT	300	600	6	0	0	Y
4.	BACK	800	540	2	0	0	Y
5.	TABLE	640	375	8	0	0	Y
6.	DRAWER	710	300	2	0	0	Y
7.	SIDE 2	1000	630	1	0	0	Y
8.	TOP	1220	1000	1	0	0	Y
9.	SHELF	1900	1000	2	0	0	Y
10.	MIRROR	540	400	14	0	0	Y
11.	FRONT	810	250	5	0	0	Y
12.	LID	300	300	2	0	0	Y
13.	BOTTOM 2	1760	300	1	0	0	Y
14.	DRAWER 2	1770	250	4	0	0	Y

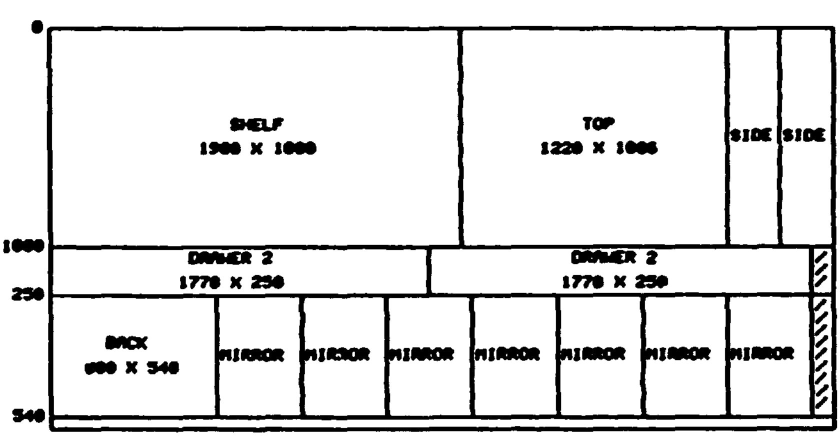
AVAILABLE BOARDS

1.	MEL 1	3660	1830	25
2.	MEL 2	2440	1220	12

Figure 476. Optimized panel-cutting plan

BOARDS REQUIRED: 1
BOARD SIZE: 3660 X 1830 X 16MM
MATERIAL: MEL

WASTE: 3.71 %



SAW KERF: 4.4MM TRIMS - LENGTH (4 & 4) - WIDTH (4 & 4)

PANEL	CODE	LENGTH	WIDTH	REQD	CUT	LEFT
2	SIDE	1000	250	2	2	0C
4	BACK	800	540	2	1	1
8	TOP	1220	1000	1	1	0C
9	SHELF	1900	1000	2	1	1
10	MIRROR	540	400	14	7	7
14	DRAWER 2	1770	250	4	2	2

Stock control

Stock control can be carried out using any general-purpose stock control program. Information regarding the current status of ordered or purchased materials, work in progress, finished goods, spare parts, tools, cutters and supplies for offices and workshops can be obtained instantly.

Figure 477. Summary list

SUMMARY

MATERIAL MEL

PATTERN NUMBER	RUN QTY	BOARD LENGTH	BOARD WIDTH	WASTE %
1	1	3660	1830	3.71
2	1	3660	1830	4.32
3	1	3660	1830	9.76

CUTTING	M2	M3
BOARDS USED	20.09	.3214
PANELS CUT	18.90	.3024
WASTE	1.191	.0190
WASTE %	5.929	

BOARDS USED	LENGTH	WIDTH
3	3660	1830

Figure 478. Cutting times

CUTTING TIMES

MATERIAL MEL

SINGLE SAW

PATT NO	NO CYCLE	O/L CUT	RIP CUT	CROSS CUT	TIME PER CYCLE	TOTAL TIME
1	1	0	4	17	00-07-00	00-07-00
2	1	1	0	15	00-09-07	00-09-07
3	1	0	5	27	00-13-34	00-13-34

Maintenance management

There is specialized computer software to cope with almost every aspect of maintenance. These programs are usually modular in character and can be adapted to any industry. A typical system, which is simple to operate, has the following functions: Servicing schedules; Inspection schedules; Work-order preparation; Maintenance reports.

XXXVI. Marketing and export trade*

Basic concepts and considerations in marketing

The two basic functions of any business enterprise have often been defined as making and selling, or, in other words, production and marketing. By the same token, the effectiveness of a firm depends on its ability to complete through creativity, on the one hand, and on its skill in marketing a product or service, on the other. These prerequisites should be understood as complementary to each other and not as supplementary.

Marketing consists of the creation of markets and the satisfaction of customers through the distribution of goods and services. It includes the business activities that are required to develop and transfer goods and services from production to consumption. The American Marketing Association has defined marketing as "the performance of business activities that direct the flow of goods and services from producer to consumer or user". As an alternative to this condensed definition, marketing could be defined on the basis of the crucial functions involved, in which case the definition might read as follows: "Marketing is the performance of all business activities required to develop, promote and distribute products and services to satisfy the existing and potential demand of customers". However, no matter which of the numerous definitions of marketing is used, the main elements remain the creation or identification of customer wants and the distribution of goods and services to satisfy these wants.

It must be emphasized that, although modern marketing techniques have been developed in the industrially advanced countries and are based on their competitive conditions, modern marketing will become more important and applicable also in the developing countries for three principal reasons. First, in many developing countries the competition within industries is getting keener, and at the same time different kinds of consumer goods compete for a limited purchasing power. Secondly, domestic firms must compete against foreign companies that operate or sell in developing countries using modern marketing methods. Thirdly, although economic development increases business opportunities, many marketers believe that marketing can make an essential contribution to economic development and that marketing orientation, planning and implementation should therefore be given sufficient weight.

Marketing activities

Marketing functions or activities have been classified under various headings in different contexts. Since it is thus largely a matter of choice, the following presentation of marketing activities is based on the structural classification used in *Creating a Market*, published by the International Labour Organisation (ILO). Some of the most common divergences in definitions are dealt with at the end of this chapter.

Market research

Market or marketing research is the systematic collection and analysis of marketing information. It includes various types of research, among them market and sales analysis, which is a study of the size, location and characteristics of markets. Sales is concerned with consumer attitudes, motives and preferences.

Before starting the production of a new item, management should obtain information on the potential market, its size and location, competitors, expected market share and sales volume, customers' needs and preferences etc. The same information requirements apply to existing products if the sales volume or market share is to be increased. Some of the basic market information may be obtained from statistics, previous studies, publications, journals and similar sources. The data on customers' wishes and preferences and on competition may to some extent be gathered through a company's own sales personnel and retailers. Consumer surveys such as personal interviews, mail questionnaires and motivational research are more difficult to conduct without expert help. Instead, product tests in which new items are given to selected customers, or test marketing in which a new product is actually offered for sale in certain locations only, may be used for studying customers. It must be emphasized that the use of outside market research experts normally gives the best results, but it is very costly and always leaves some problems that must be resolved by subjective decisions.

Product planning

Product planning is the process of developing new products and modifying or abandoning existing ones to meet customer needs and to utilize fully the capabilities of an enterprise. The ultimate aim of product planning is to develop a product that sells; therefore attention must be paid to marketing in addition to research and engineering. In fact, in marketing-minded companies, product planning is based largely on analysis of market requirements and future opportunities. An evaluation of the effects of technology and technological change on market needs and competitive conditions is also necessary. Especially in the case of small companies and markets, new product development is dependent mainly on the suitability of a company's existing technical and marketing experience.

Product modification is any physical alteration of an existing product or its packaging. It may become necessary because of new technological developments, competitive

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conditions, changes in customers' needs and preferences and so on. The most important product-modification strategies are quality improvement through better materials and engineering; feature improvement to achieve increased user benefits, real or imaginary; and style improvement to achieve better aesthetic appeal.

Compared with new product development and product modification, the importance of product elimination is often neglected. For this reason, many marginal or losing products may consume considerable resources that could be employed productively elsewhere; such a situation reduces the profitability of an enterprise and its ability to take advantage of new opportunities. To avoid losses or financial setbacks, an enterprise should have a periodic product-review system, in particular for products that yield less than average returns.

With regard to product planning there are two basic marketing strategies: product differentiation and market segmentation. Product differentiation is a method of controlling the demand for a product by advertising or promoting real or imaginary differences between it and competitors' products. It is basically a strategy to establish the market position of a firm and counter balance existing or potential price competition; in fact, the prices of differentiated products tend to exceed the average level. Market segmentation, on the other hand, is a way of viewing a heterogeneous market as a number of smaller homogeneous markets resulting from differing product preferences among important market segments. Moreover, market segmentation often relies on the substantial use of advertising and sales promotion in order to inform special markets of the availability of products meeting their needs. Successful marketing generally requires careful application of both product strategies.

Pricing

Pricing is the process of determining the price of a product on the basis of type of product, customer demand, costs, competition and company objectives. In most cases the starting point in developing a price is the character of the product, that is, its physical and market qualities, its production aspects, its degree of differentiation and whether it is new or established. In the case of durable consumer goods, there is normally some leeway for price differentials between competing products. For so-called shopping goods, this depends largely on the use of brands, special features, styling and the like, whereas for speciality goods considerable variations in pricing are possible. As noted above, differentiated products generally command somewhat higher prices. Product differentiation gives the best results when a company's product has a distinctive advantage over competing ones, but even if this is not the case, differentiation can be developed in other aspects of sale, such as delivery terms, service and credit conditions.

The pricing of a new product depends on whether it is completely new or similar to existing products. In the latter case the price is determined by the price range of the existing substitutes, while in the former situation there are two basic pricing approaches: market skimming and market penetration. The first of these refers to setting a high price accompanied by considerable promotional expenditures during the early phases of market development, followed by lower prices during later phases; the other consists of setting a relatively low price in order to stimulate the growth of the market and to capture a large share of it in the early stages.

In practice, there are basically three different pricing policies: cost-oriented, demand-oriented and competition-oriented. In cost-oriented pricing, an enterprise sets its prices largely or wholly on the basis of its costs. The most common methods are mark-up or cost-plus pricing, in which the price is determined by adding a fixed percentage to the unit cost, and target pricing, in which the price is determined on the basis of a specified target rate of return on the investment required for the product. Demand-oriented pricing is based on differences in the intensity of demand; in other words, a high price is charged when or where demand is intense, and a low one when or where demand is weak, even though unit costs may be the same in both cases. A common form of demand-oriented pricing is price discrimination, in which a particular product is sold at two or more prices. Price discrimination may take various forms, depending on whether its basis is the customer, the version of the product, the place or the time. Competition-oriented pricing is a policy of setting prices chiefly on the basis of what competitors charge and not on the basis of either costs or demand. The most common type is so-called going-rate or imitative pricing, in which an enterprise tries to keep its price at the average level of the industry. Especially in fairly homogeneous product markets or in cases of close substitutes, an enterprise should take the competitive prices as a starting point for its price decisions, and costs should be regarded as setting the lower limits to prices. Even in the case of product differentiation, the presumably higher price must be set in some realistic and feasible relation to competitive non-differentiated products.

If a firm wishes to change its established price, it must consider carefully its customers' and competitors' possible reactions. The probable reaction of customers may be expressed in terms of price elasticity of demand, whereas competitors' reactions depend largely on the market structure and the degree of product homogeneity. If, on the other hand, a price change is initiated by a competitor, an enterprise must try to understand the competitor's intent and the likely duration of the change. In general, price as a competitive weapon can be dangerous to its user unless the firm has a distinct cost advantage. In many cases of competition, other marketing techniques, such as product differentiation, advertising, sales promotion, improved distribution and the like, may be more appropriate.

Advertising

Advertising may be defined as any paid form of impersonal presentation and promotion of ideas, goods or services by an identified sponsor through mass media such as newspapers and magazines, radio and television, motion pictures, posters, signs and billboards, direct mail, catalogues, leaflets etc. The purpose of advertising is to induce potential buyers to respond more favourably to whatever a particular enterprise is offering. This is attempted by providing information to customers, by arousing their interest, by trying to influence their desires and buying decisions and by giving real or emotional reasons for preferring the product in question. These tactics in turn usually involve finding various points at which the product may be distinguished to advantage from competitive ones. When successful, such efforts partially protect the product from direct price competition. An important factor in this respect is a brand or trade mark. By means of advertising and other promotional methods, a company should try to create preferences and loyalties to the name of the company or brand name of the product rather than merely to the product.

The most important elements in planning an advertising programme are the size of the advertising budget, the selection of media, the message design, the timing of advertisement and the measurement of effectiveness. The size of the advertising budget may be determined in a number of ways:

(a) According to what a company can afford;

(b) As a regular percentage of the company's sales;

(c) By relating it to competitors' expenditures;

(d) By defining the cost of accomplishing specified communication goals, which actually amounts to estimating marginal revenues and the costs of specified advertising projects.

The selection of media must be based on the following factors: availability, geographical range, the media habits of the target audience or population segment, the nature of the product and the cost of different media. The effectiveness of advertising depends largely on the development of good message content and presentation, which are the elements of message design. These aspects are influenced by local characteristics, and they should therefore be preceded by marketing research covering the buying process and buyer motives, attitudes and behaviour. The timing of advertising should be determined on the basis of a product's nature, target customers, competition, distribution channels and other marketing factors. For example, when introducing a new product, a company may try to create brand preference by advertising heavily in the initial phase and less later on, or in the case of some special product, instead of repetition it may try to reach most of the people known to be interested, in which case the advertising effort would be distributed fairly evenly over a period of time. One of the most difficult tasks related to advertising is measuring its effectiveness. Nevertheless, a continuous effort should be made to evaluate: *(a)* the likely communication effect, that is, the effect of advertising on buyers' knowledge, feelings and decisions; and *(b)* the likely sales effect, that is, the effect of individual advertisements on sales.

Sales promotion

Sales promotion consists of those marketing activities, other than personal selling, advertising and publicity, that stimulate consumer purchasing and dealer effectiveness. Some of the most common techniques are displays, shows and exhibitions, demonstrations, samples, premiums, contests, manuals and other promotional literature and special customer service. In contrast to advertising, sales promotion involves unrepetitive, one-time communications efforts and is mostly accomplished by bringing the selling message to the actual point of sale. It is a direct method of influencing the customers and can therefore stimulate demand more quickly than advertising. Furthermore, it can be applied more easily to particular market segments or areas.

The satisfactory selection of various methods of sales promotion requires the continuous study of the market and the competitive situation. As there are no fixed rules, the company should experiment with different methods used in various combinations. The extent to which sales promotion is necessary depends on the company's other promotional efforts, advertising, personal selling and publicity. By its nature, sales promotion is a fairly close substitute for advertising, and therefore any factors that restrict the use of advertising normally increase the relative importance of sales promotion.

As stated in the definition, sales promotion also refers to stimulating dealer effectiveness. This may be achieved partly by applying some of the aforementioned general techniques to dealers but also through financial inducements such as allowances and extensions of credit, training and consultation, good co-operation and personal relations etc.

Distribution

Distribution is the marketing activity that covers all aspects of the movement and flow of goods and services from the producer to the consumer or user. A channel of distribution is the set of marketing intermediaries, agents and wholesale and retail dealers through which goods and services are marketed.

Manufacturers can develop their own marketing channels by owning and operating the intermediate and retail facilities, by selecting firms already operating in the distributive structure or by using a combination of both of these methods. The selection of a marketing channel or a combination of them depends mainly on the following factors:

(a) Customer characteristics (their number, geographical distribution, purchasing patterns and susceptibility to different selling methods);

(b) The nature of the product (bulk, degree of standardization, service requirements and unit value);

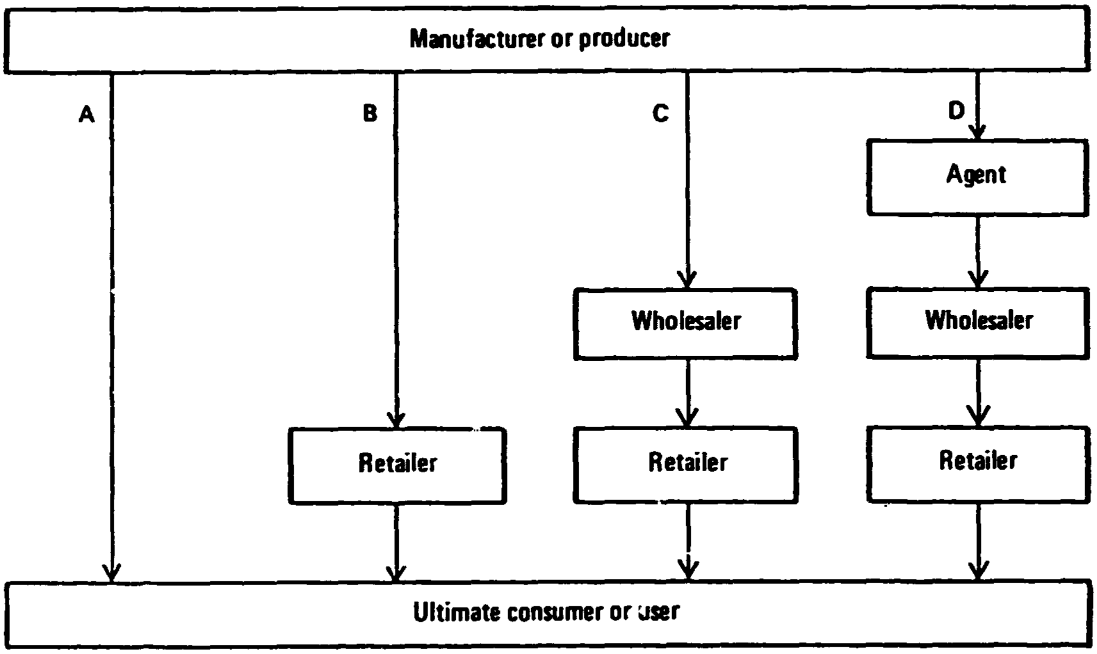
(c) The characteristics of intermediaries (the strength and weaknesses of different types of middlemen in handling various tasks);

(d) The structure of channels used by competitors (either as a target or as an example to be avoided);

(e) The characteristics of the enterprise itself (its size, financial strength, product line, past channel experience and over-all marketing policies).

The basic options of distribution channels available to a manufacturer are shown in figure 479, in which option A is the case of direct selling, which may be done through the manufacturer's own retail outlets, by door-to-door sales personnel or through direct contacts to large customers such as Governments or institutions. Option B is common when a producer sells in quantity to such retailers as department stores, chain stores or mail-order houses. Option C is a channel typically followed by manufacturers of mass consumption goods, and option D is an example of a channel where the service of a middleman, such as a sales agent, is used for the initial dispersion of goods.

Figure 479. Distribution channels available to a manufacturer



In practice, however, the selection of alternative channels is more complicated; a manufacturer often uses different channels at different times, for different products, in different markets. The problem of selecting the most satisfactory channel of distribution for a product is complex, and each situation must be analysed individually. After the major feasible possibilities of channels are examined in detail, each of them must be evaluated according to economic, control and adaptive criteria; economic criteria are sales, costs and profits; control criteria are possible sources of channel conflict; and adaptive criteria are the firm's flexibility with regard to new competitive and distributive challenges. After determining its basic channel structure, the enterprise must find or select intermediaries through whom to work. It must also motivate intermediaries through special incentives and supervision in addition to normal trade relations. Furthermore, it must periodically evaluate their performance against their past sales, other intermediaries' sales and possibly sales quotas.

Personal selling

Personal selling may be defined as an oral presentation to one or more prospective purchasers for the purpose of making sales. Basically, the selling process consists of making the customer aware of the product, developing customer comprehension of the offer, convincing the customer that the product can satisfy his or her needs and persuading the customer to make the actual purchase.

The sales staff can be very important in selling. A company should therefore decide exactly what it is trying to accomplish through direct selling to make the best use of sales staff. It must determine the size and organization of its sales force; this is often done on the basis of estimated productivity by territory or the feasible work load of sales personnel. The organizational lines are carefully planned on the basis of territory, products or customers. Personal selling involves the following managerial tasks: recruiting and selecting sales staff, training, motivating and supervising them, paying them and periodically evaluating their performance.

Publicity

Publicity may be defined as impersonal stimulation of demand for a product or service through its favourable exposure in communications media as part of news or entertainment, without payment by the sponsor. In practice, publicity may take the form of news releases, published articles, general booklets, pamphlets etc. Publicity is important because people tend to be more influenced by a news item or other official-looking information than by direct advertising. Consequently, many companies use publicity to some extent to supplement their advertising and selling efforts.

Management in marketing

The first and most vital principle of marketing management is customer or market orientation; in other words, the customer is the key to a firm's survival and growth. Secondly, there must be a company philosophy and full commitment and an active approach towards marketing. Thirdly, the marketing function must be integrated, that is, all decisions of an enterprise, including those concerning organization, production, communications, finance and distribution, must take into account all marketing elements and factors influencing the marketing effort. Finally, the marketing effort must be planned and evaluated continuously.

The main tasks of marketing management consist of assessing marketing opportunities, planning and programming marketing efforts, organizing marketing activity and controlling marketing effort.

Assessing marketing opportunity

The assessment of marketing opportunity involves identifying a company's mission and goals and analysing profit potentials to determine the markets in which the company may try to achieve its objectives. In practice, it is essentially a problem of identifying existing and potential customers. The process should be continuous in order to facilitate dynamic marketing and production operations, identify new challenges and problems facing the company and take advantage of changing market opportunities.

The assessment of marketing opportunity, which should be the determining factor in company activities, must be based on an analysis of the firm's present market position, resources, characteristics and capabilities.

Planning and programming marketing effort

Marketing planning calls for the establishment of objectives, the formulation of strategies and the development of concrete programmes; basically, it consists of anticipating possible problems and considering alternative solutions to them.

The main components of the marketing planning process may be classified under four consecutive phases. The first, the situation analysis and identification of problems and opportunities, covers a firm's actual business, product lines, markets, organization, channels of distribution, competition, technological change and profits. The second phase, the determination of specific goals or objectives, concentrates on a firm's desired business, product and marketing mix, market share and profits or return on investment. The third, the development of marketing strategies, refers to the generation of many different types of strategies, on the one hand, and to the selection of more promising strategies, on the other. A marketing strategy is composed of two parts: *(a)* the definition of market targets, including the types of customers a firm wants to reach; and *(b)* the composition of a marketing mix that combines the manpower and other resources and inputs needed in marketing programmes, such elements as product planning, pricing, branding, advertising, sales promotion, personal selling, physical handling, channels of distribution and servicing. The last phase in the marketing planning process is the evaluation and adjustment of plans, which calls for the establishment of objective performance standards, which in turn determine the necessary control activities and the need for any adjustments.

The programming of marketing effort consists of two major functions: the development of schedules for each element in the plan and the establishment of the necessary procedures. It should be noted that marketing planning and programming, if carried out in detail, also provide a built-in control device.

Organizing for marketing activity

In principle, the framework for organization and planning is provided by the goals of an enterprise. Traditionally, organization was dominated by production or financial orientation, as shown in figure 480.

As the marketing concept developed, sales have been gradually removed from the jurisdiction of the production manager and made separate. Since this situation has tended to engender conflicts between the logic of customer satisfaction and that of cost minimization, marketing-minded companies have applied the modern marketing concept of centralizing the responsibility for the total marketing task under one executive who establishes, co-ordinates and integrates all factors necessary to achieve marketing goals (see figure 481).

Although there are differing opinions, from a market-oriented company's point of view it is obvious that the marketing executive must be at a high level in the organization where participation in all areas of business policy related to the marketing objectives of the firm is possible.

Controlling the marketing effort

In practice, an enterprise may apply many different types of controls to keep marketing effort keyed to areas of profitable opportunity. The basic forms are managerial controls, financial and cost controls and leadership controls. Managerial controls are based on clear-cut plans, standards of performance, operational procedures and policies established by the management. Financial and cost controls in marketing often consist of distribution cost accounting and cost analysis by function and product. In making forecasts and setting quotas, both managerial and fiscal controls are commonly used. Leadership control, under which the two other controls are integrated, is exercised through the organization and motivation of individuals and groups. The objective of this type of control is to motivate individuals to achieve and exceed predetermined organizational and individual goals.

All effective control systems must include four common elements. The first is the definition of goals and standards that must be understood and accepted by the persons involved and stated numerically if possible. The establishment of numerical standards usually implies a range of tolerable deviations. The second element involves the development of a programme for achieving these goals, that is, a detailed plan of how available resources should be used over a specific period. The third element involves the measurement of results, whereby actual performance is checked against desired performance on the basis of various types of information, both external and internal. Depending on circumstances, the comparisons are made either continuously, as through daily field reports, or intermittently, as through quarterly reports. The fourth element is a control system involving making adjustments in goals, programmes or both, if the goals are not being achieved.

Figure 480. Traditional organization of a manufacturing company

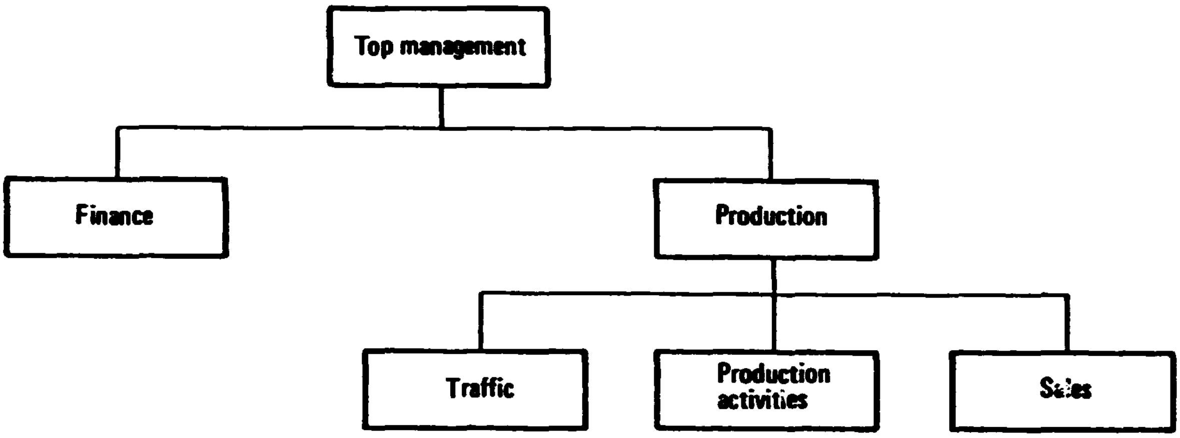
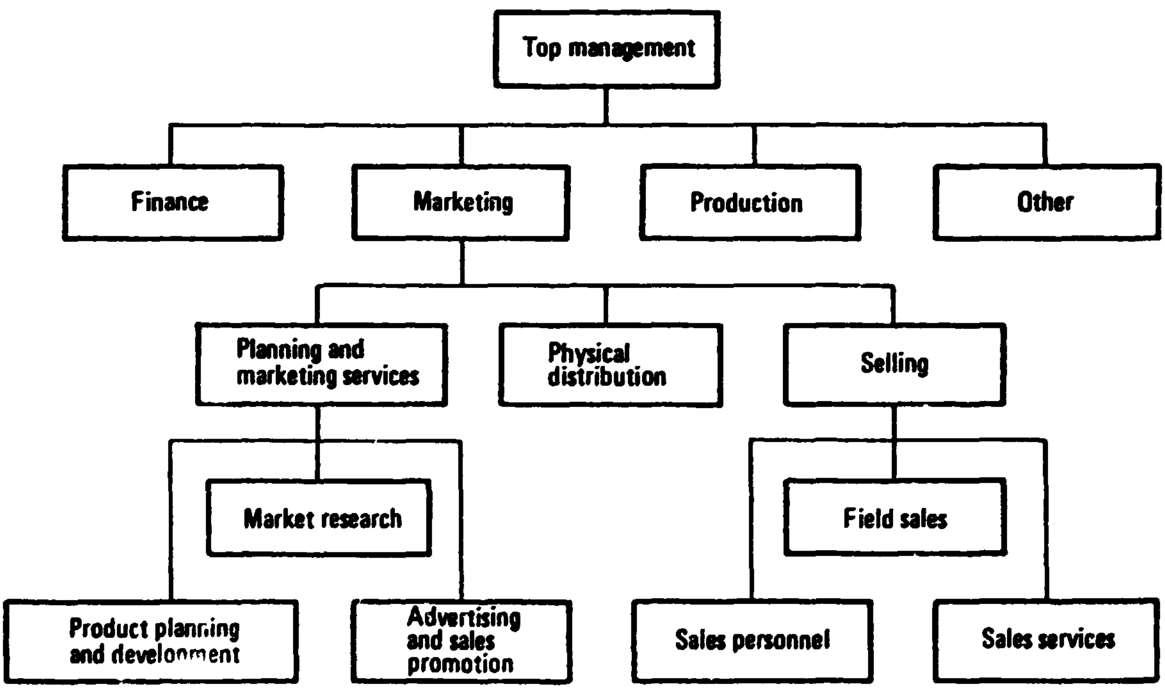


Figure 481. Organization of a marketing-oriented company



Fundamentals of export trade

There are many basic reasons why a country may want to stimulate export trade; some typical examples are an abundance of natural resources, the necessity of paying for imports, balance-of-payments problems, national welfare and profits from exports. From the viewpoint of an individual enterprise, however, considerations regarding export trade are essentially different.

Advantages of export trade

For a new or potential exporter, the advantages may be direct or indirect. Direct advantages include the creation of a larger market, increased and even mass production, specialization and concentration in production, more rapid inventory turnover and more sales revenue, better chances for balancing seasonal differentials and possibilities for limiting risks caused by changes in local demand. There may also be indirect advantages. For example, increased exports may bring about changes in the technical and managerial structure of an enterprise through competition, contacts and so on; the technical developments and tendencies in foreign countries that an export company must follow will make it more competitive domestically. Furthermore, export trade often tends to improve co-operation between domestic companies through rationalization, specialization and the like. Another important factor is that a well-known and successful exporter has a better image in the home market and may gain access to more long-term credits, both domestic and foreign.

Study of export potential

The first step in studying export potential is to determine the position of an enterprise in the home market, the general trends within the industry and present exports, if any. The position of the enterprise must be analysed as regards the existing market share, development trends, the financial position and the availability of adequate financial resources. The second step is the study of production, that is, of the suitability of products for export, possible patents or other protections, production capacity and planning capacity for technical modifications.

The next factor is pricing. In general, the price of a product is fixed by the price level of existing competitors or substitutes, and the cost price must be calculated for comparison with this figure. In export pricing, however, special features should be taken into account. In the case of export products, the domestic sales tax is normally deductible, because taxes and duties are deductible that are paid on imported raw materials and accessories. All domestic selling expenses should also be deducted from export prices. In practice, one of the most common methods of determining the lowest acceptable export price is the so-called break-even analysis, in which the price must cover at least all variable costs and then, if possible, make some unit contribution to fixed costs. Important factors in export trade are the specific costs caused by exporting, which may consist of such necessities as market research, advertising, product modification, better packaging, staff travel etc. These costs often cannot be assigned to any particular sale and should therefore be spread over a period of time.

The last step in studying export potential is to determine the range and scope of the different tools of marketing available to a company. Basically they are the same as those considered above in the discussion of marketing activities, but in export trade they must be adjusted to local conditions in foreign countries, which will increase costs substantially. Moreover, the competition is likely to be keener, and for these reasons a potential exporter should co-operate closely with domestic or foreign representatives and, most importantly, with other exporters. When planning to export, a firm must bear in mind that export trade is a long-term activity taking years to learn and that profits are often not made immediately. On the other hand, an exporter is required to comply with agreements and commitments and to have knowledge of export trade, terms and procedures.

The export process

Establishing contact with foreign markets

Occasionally a firm may receive inquiries from foreign representatives or importers leading to actual sales later. More often, however, the export process must be initiated by the potential exporter. One way to do this is to carry out market research, which also clarifies available distribution channels and their costs. However, such studies tend to be very costly, and their findings may be speculative and useful for only a short period, so that this activity can normally be engaged in only by larger enterprises. Another way of gaining a foothold in foreign markets is to take part in trade fairs and exhibitions, which can serve both as a means of establishing contacts and as actual selling situations. Even this type of participation is rather costly and can best be accomplished through co-operation between many smaller firms.

From the point of view of a small enterprise, the best way of initiating the export process may be to get in touch with either importers or their intermediaries, directly by letter or through sales representatives. The choice of appropriate channels will depend on such circumstances as the type of product, the size of the enterprise, local (foreign) purchasing habits and the price of the product.

The channels of distribution in export trade may be divided into two basic groups: those in the home country and those abroad. In the former case the principal intermediaries are export agents and export firms, although occasionally some of their tasks are handled by wholesalers and department stores. The main difference between an export agent and export firm is that the former sells for and on the account of a manufacturer, while the latter buys a product, sells it on its own account and also assumes all of the risks.

In foreign countries, the distribution channels consist typically of export agents (normally located in third countries), import agents and firms, wholesale firms, department stores, retail stores and brokers; all of these are generally involved in selling. Sometimes it may be possible to sell directly to industries and institutions, occasionally even through a local manufacturer if the products complement each other. Owing to the high costs involved, the establishment of a sales organization is usually realistic only for large enterprises with very profitable products or for many small companies working in close co-operation.

In export trade there are often many types of supporting activities at different levels that are of vital importance for relatively small exporters. If governmental export organizations or financial arrangements exist, they should be utilized. On the other hand, there may be foreign trade associations and industrial federations that can furnish valuable information or support. Export activities may to some extent be promoted through chambers of commerce and local banks that have international operations and through the official commercial representatives and trade attachés of foreign countries. Unfortunately, these institutions may be limited in number.

However, important possibilities for individual exporters are export and sales associations and export groups and pools based on voluntary co-operation. Associations may be formed either to cover a product range or a region; their main activity is often concentrated on promotional aspects, such as establishing business connections and arranging exhibitions and joint advertising, but they may also engage in market research and even selling. Export groups and pools, on the other hand, are based on smaller groups in which small manufacturers of different but supplementary products obtain marketing information in a joint effort, using the same channels of distribution and hiring joint personnel. In the light of the prevailing keen competition in international markets, some form of co-operation between small enterprises is necessary for increased exports or even for any exports at all.

Essential information

The basic export trade information of an exporter should consist of a reasonably thorough knowledge of terms of delivery and payment. If an export agent or firm is used, a company does not normally have to apply these terms in practice. In other cases, however, it must be familiar with delivery clauses such as f.a.s., f.o.b. and c.i.f. and with their effects on pricing and actual export measures and with methods of payment including letters of credit, documents against cash or acceptance and pre-payment. Even though an exporter does not handle these functions, it would be useful to have some idea of foreign currency controls and rates of exchange as well as of various shipping documents, such as bills of lading, insurance certificates, commercial and consular invoices and certificates of origin.

One task of increasing significance in export trade is to obtain credit information before selecting a partner in a foreign country. This information is normally provided by local banks that carry on international operations. An exporter should also become familiar with the existing foreign trade agreements of countries to which export is envisaged, as well as with potential regulations concerning patents and trade-mark registrations. Last but not least, an exporter should know how to find business contacts abroad. One possibility of doing this is through the supporting organizations mentioned above, but there are also many other sources, such as special international publications and reference books for different lines of business, foreign trade directories and local professional journals.

Finally, it should be emphasized that export trade is a very difficult and demanding activity that must be based on effective domestic operations. On the other hand, once a firm is in a position to begin exporting, it may find the experience very interesting, challenging and profitable in the long run.

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XXXVII. Export market surveys*

Manufacturers who intend to enter foreign markets are handicapped in many ways; they have no experience of the markets, they may be unable to discuss with prospective clients in a common language and they may not have made a cost analysis to determine a real price for exports. Many specific difficulties are encountered in the export of furniture and joinery products, such as the lack of appropriate manufacturing tradition in the factory of the exporter and the absence of a tradition in using furniture; such factors may make potential importers hesitate to place an order.

Marketing is a strategy of presenting a product. It is based on research on the needs of people and on the ways of satisfying these needs. It entails developing a system for transforming such ways into concrete services and products that can be produced at an economic price, and it concerns the manufacture, distribution, description, selling and consumption of the product.

The clients are the people living within a manufacturer's market area. There may be a well-defined market, such as a country, but within this area the market segment must be pinpointed. Manufacturers cannot think in chairs only, but must know if these are to be modern or traditional (that is, what is modern and what is traditional for the people they wish to reach). Should the chairs be soft, hard, rigid, collapsible, cheap and sold in dozens to each buyer? Manufacturers must know the reasons behind the order or the purchase decision and be able to predict the purchase far enough in advance so that production can be planned without difficulties up to the time of shipment. All possible questions must be pre-solved and accounted for in manufacturers' offers.

From a general market survey, manufacturers can learn what people used to think some years ago; most market surveys deal only with the present. What is needed is information about the present, past and future market.

Methods of market study and research

In marketing, there are four basic considerations: product, price, promotion and distribution. In a market study tangential factors should be included such as demand, competition and institutional factors (e.g. laws and customs duties). Two possible forms of presentation are the general survey and a study specially designed according to previously defined needs.

A suggested table of contents for a market study would be:

Definition of the market (area, individuals etc.)
Government regulations concerning imports to the country
Other institutional factors
Competition, including import statistics
Types of competition
Demand, including possible forecasting and definition for products
Distribution systems
Promotion systems
Pricing
Recommendations

Other information that should be included in a study would be: the aim of the study; for whom it has been prepared; by whom and how it was carried out; and the date of the study and the preparation. It should also contain, as appendices, detailed tables, bibliography used and further studies, detailed theoretical matters and their degree of accuracy, a list of people interviewed (if possible) and other relevant original documentation.

Collecting data

Before starting to collect information it is a good idea to look first for the answers already at hand, in the firm's own business correspondence or among friends, to save money and time. Trade associations, government agencies, international bodies, magazines and newspapers may also prove valuable sources. Checking these for ready answers, or so-called desk research, is necessary to the success of field research.

Besides the written and verbal information, basic numerical data should be sought. These statistics are commonly available on the general foreign trade of industrialized countries but are more scanty and less reliable from areas with less-sophisticated statistical services. If quantitative goals are measured against such figures, the local manufacturer may be able to re-assess and recast the goals and questions of the enterprise.

For more detailed and personal knowledge and exchange of information, for example, exporters in Finland have created an informal luncheon club in Helsinki where experts are invited to give topical presentations. The list of members with addresses is frequently distributed. On this basis many difficulties have been solved and information has been shared and increased.

Useful guidelines for collecting and preparing information are:

(a) Make a good plan for the study, starting with an analysis of the present situation and defining the difficulties and ways of overcoming these difficulties. Summarize the results and compare them with the enterprise's realistic possibilities. Then decide whether to entrust the study to an outside expert;

(b) Define the market. If the enterprise is supplying nuclear-power stations, the market is very limited but well-

*By Reino Routamo, market research expert, Helsinki, Finland. Originally issued as ID/WG.209/16.

known and scattered geographically all over the world. If cheap, ordinary tables are to be manufactured, concentrate on geographically limited areas and study their tastes, needs etc.;

(c) Time is an important element. The present is transparent and easy to understand; the future is more unpredictable but will include the enterprise's activity with its results in terms of competition and change of patterns. The present will not develop to the future without certain changes. Research should narrow down the options.

Usually, the most important data needed for making decisions are not available in the form of statistics or similar written documentation. Normally, some field research is necessary.

The easiest way to acquire new information is, if it is known that a manufacturer wants to sell to a certain buyer, to ask that buyer for an opinion. There may even be many buyers for a product; the manufacturer knows them, it is easy to ask them all. It is another matter if there are many potential and unknown buyers; the seller must then use other methods of research.

An elementary way to reach many buyers is to participate in a fair where they will be gathered and thus have the product tested and gain an idea of the competition. Participation in fairs is expensive, however—much more expensive than is commonly believed—and must be well prepared for. In preparation it is useful to visit the fair as an observer and note how it operates. It is inadvisable to have too many objectives in participating in a fair, however, such as product testing, selling, nominating a distributor etc. Favourable results may be achieved only after several attempts.

Ways of testing the product

If there is no suitable fair, there are three different methods of having the product tested by the public: the omnibus and the Gallup type of interview and different panels.

In an omnibus interview a number of people are asked certain questions, in the street or called upon at random in their homes or offices. The answers are taken to represent the general view of this public. For this kind of interviewing, however, only simple questions may be asked such as "Which of these two colours do you prefer?" Some control questions may be included that will indicate the relationship of the sample group being questioned to the population as a whole. Such questions may concern age and occupation. If the sample should deviate greatly from the statistical medium, showing that only 10 per cent of manual workers have been reached instead of the statistical 35 per cent, an attempt should be made to increase the number of workers in the sample. An omnibus interview may also be carried out among a previously selected group, such as traders, visitors to a fair, students or users of a certain post office.

In a Gallup type of interview the people are selected personally for the sample before the interview, so that the sample represents the statistical medium of the population of a certain area. Reliable information on the inhabitants of the area is therefore needed. This kind of an interview is usually only possible by enlisting the help of specialized agencies. The great benefit of a Gallup interview is that good coverage is obtained with a relatively small sample. More complicated questions may be used since this interview must, by definition, be carried out on appointment at the homes of those questioned.

For the different panels a sample is selected to keep accurate account of its behaviour in certain respects, such as the daily purchases of housewives or an engineer's maintenance record of certain machinery.

A manufacturer may poll all potential clients, such as those building nuclear-power stations or the 20 wholesalers of furniture in the area of interest. But even if everyone is approached, the answers could be wrong, the questions wrongly understood and the deductions based on the results incorrect. People are unpredictable and often unaware of their own wishes or interests.

Besides such special interviews, the normal observations should be made at fairs or in the streets of a city. This kind of research is rapid and cheap, although subjective and influenced by the qualifications and prejudices of the observers.

Fortune telling

A market study merely tells something about the past on which the present is based. A decision must also be based on some foreknowledge of the future.

The usual way to forecast is to extrapolate from the known facts. If in three succeeding years the statistics show an annual increase of population, it may be assumed that the population will increase in the fourth year. This can then be checked by investigating the factors causing the change in population, such as birth and death rates, standards of living, health effects and wars. The most common trap of statistical forecasting is to believe in the figures themselves; the trend must be borne out by logic and common sense.

One quite useful device for forecasting is to find out the "leader" for the area, i.e. does an area follow the pattern of change of a more advanced area, as Finland has followed Sweden or the Federal Republic of Germany has followed the United States of America. With precaution it may be assumed that the situation in the "follower" country is likely to be the same as that in the "leader" country a number of years later. The period of lapse in commercial change in the two cases indicated is two to five years.

For estimating future sales of furniture, facts may be collected such as birth and marriage rates and construction and standard-of-living figures and related to the statistics on furniture sales to predict the sales of furniture in the following year.

One specific form of questionnaire for determining furniture sales is used frequently in many developed countries; its purpose is to determine the intentions of the population for spending money. People are asked annually what they would do with an extra income of one month. Changes in these results may show a future consumption pattern. This kind of questionnaire could be useful in the less developed countries and would benefit the planning in these countries.

Some precautions

Finally, it is well to be aware of sources of misinformation, such as the wrong planning of an investigation, an incorrect or misleading interpretation of the results and unreliable answers such as those influenced by bad will towards rivals, goodwill towards friends or the answers of people trying to please.

Some precautions should always be taken, for example more money might be spent for the research than was previously estimated and the researchers should be instructed to check their information thoroughly.

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XXXVIII. Safety at work in the furniture and joinery industries*

Introduction

This chapter is based on a study prepared by ILO as a background paper for the First Consultation on Wood and Wood Products held at Helsinki in September 1983. It covers primarily carpentry, joinery and furniture making. A broad outline is given on how to deal with the major occupational safety and health problems in a practical way under conditions prevailing in developing countries.

Recent information compiled for a number of major countries has indeed shown that the rates of incidence and frequency of injuries in the wood industries are on the whole about two times higher than the average rates for all industrial activities. Accidents are also as a rule much more serious in the wood and wood-processing industries than the average for all activities.

It appears that sawmilling, wood construction and carpentry are the most hazardous branches and furniture making the least hazardous branch of the wood and wood-processing industries.

Practical problems and solutions

Safety problems

In the industrialized countries, a large number of different machines are used for carpentry and joinery and for furniture making. Technology is advancing rapidly, requiring continuous efforts to keep in line with safety requirements. In the developing countries, the same advanced technology is applied in large-scale enterprises, but most furniture is still made by artisans working with a few basic hand tools. The complexity of this situation does not permit a detailed discussion of safety problems in the context of this chapter. For this reason, the emphasis will be put on some selected common areas where safety problems are particularly important.

Plant layout, materials handling and housekeeping

As can be seen from statistics, a large proportion of accidents are caused by falls, stepping on or knocking into various objects, being struck by falling objects and handling goods. Of the different work phases, transport is particularly accident prone.

In order to keep hazards in materials transport and handling under control, work and storage areas, as well as the succession of work operations and work flow, must be well-designed, and an adequate standard of order and cleanliness must be maintained. Where such conditions exist there will not only be low rates of accidents but also a high level of productivity.

Materials transport and handling tend to be problems, especially when smaller enterprises are gradually expanding and when space is limited. It is most important to ensure that there is enough space for workers and for vehicles to move freely. It may be necessary to move to a new working site rather than continuing to work under hazardous conditions on the old one.

Flooring should be even, non-slippery and free from obstacles. Offcuts, shavings and sawdust must be cleared away regularly. Ladders, stairways, railings and working platforms must be kept in adequate condition to avoid falls, which may result in severe injuries.

Where the plant layout is inappropriate, it is often possible, through simple adjustments, to remove the safety hazards. Good housekeeping requires little extra time but can save a lot of unproductive delays. Few, if any, special investments are needed to comply with basic safety demands. Managers and supervisors must be safety-conscious and play an active role in the instruction and motivation of workers, however. A large number of accidents, including fatalities, can thus be avoided.

When establishing new wood industries, especially larger industrial complexes, plant layout should be carefully studied and adapted to local conditions and requirements instead of relying blindly on standard blue-prints for turn-key factories.

No matter whether the work is done in a small or large woodworking plant, a considerable amount of time and effort is spent on moving and storing bulky and heavy material. The handling of sawn wood, finished products or waste must be carried out with just as much care and proper equipment when it is done manually as when it is done mechanically. Unless tools, equipment and machines for transport, such as turning hooks, levers, simple carts, lorries, forklift trucks, cranes, chain conveyors and rail systems, are in adequate condition and handled skillfully, a great deal of trouble can be expected in maintaining reasonable standards of productivity and safety.

Woodworking machines

Woodworking machines are one of the most dangerous types of machines in industry. Accident statistics from different industrialized countries show quite clearly that in spite of the increasing variety of special machines, the majority of injuries caused by woodworking machines occur on a few basic machines, namely circular saws, planers and spindle moulders. To this may be added, especially because of the conditions in developing countries, band saws.

All machines must be provided with adequate guards for moving or projecting parts. According to ILO Convention

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No. 119 and Recommendation No. 118 on the guarding of machinery, the manufacturer, vendor or person letting out a machine on hire must ensure that dangerous parts of machines are fitted with appropriate guards; the employer must make sure that machines are used in that condition; and workers must not be permitted to operate machines that are not properly guarded. Furthermore measures must be taken to enforce these provisions.

In the case of developing countries, care must be taken to ensure that machines supplied from industrialized countries are equipped with guards according to the safety standards of the country of origin. Tenders for new machines should specify that dangerous machine parts must be adequately guarded.

Several developing countries are already manufacturing woodworking machines. They must make sure that safety requirements are fully considered at the design stage and that new machines are tested with respect to safety by a competent authority before being released for commercial production.

Machine guarding is of the greatest importance in relation to saws and cutter heads, which additionally must always be kept sharp, must be firmly fixed and must not exceed the prescribed speed.

Circular saws. When working with circular saws, accidents are frequently caused because of contact between the hand and the saw and because of the kick-back of wood, both resulting in bruises, scratches, the penetration of splinters, cuts and even amputations. The operation of circular saws without proper guards inevitably leads, in the course of time, to serious accidents. Circular saws used for rip sawing (length sawing) must be fitted with adjustable hood guards covering as much as possible of the saw blade above the table and with additional guards covering the saw blade below the table to prevent accidental touching of the saw. To avoid kick-back, circular saws must furthermore be fitted with adjustable riving knives, the height and thickness of which as well as the distance from the saw blade must correspond to narrowly defined limits.[1] The guide fence must be parallel to the saw blade. Jamming of wood between the saw blade and the guide fence can be prevented by an adjustable intermediate guide fence. A further means of protection are push sticks. Correctly applying all these protective implements obviously requires a skilled and adequately instructed operator.

A large variety of circular saws are used for cross cutting; pendulum saws mounted above the saw bench are the most common type. They must be equipped with a self-adjusting guard covering the saw blade, a counterweight that returns the saw after cross cutting to a safe position behind the guide fence, a device to limit the travel of the saw beyond the saw bench and a start-and-stop switch within easy reach of the operator. The saw should be operated from the side.

Band saws. Bench-type band saws are commonly used by cabinet makers. In some developing countries, they are also employed for breaking down small-size and short logs. Such saws require complete guarding of the upper and lower band wheel. In addition, an adjustable top guide that can be lowered to the height of the timber to be cut is needed. A brake should be available to stop the saw blade after switching off the power. Saw blades must frequently be checked for defects such as cracks or inadequate joints.

Planers and thicknessers. Of the different planing machines, hand-fed surface planers are the most dangerous and probably the most widely used in developing countries. They should be fitted with securely fixed cylindrical cutters. To prevent contact with the hand, the cutter block must be guarded by an adjustable bridge-type guard. Various designs are in use, but telescopic guides that provide protection on both sides of the fence guide are particularly good.

Thicknessers have the advantage that the cutter block can be completely enclosed, which also facilitates extraction of dust and shavings. Wood passes below the cutter block and is fed by powered rollers, which should be released automatically in case the plank jams. As protection against kick-back, a sectionalized system of rollers or teeth should reach over the whole in-feed side.

Spindle moulders. Spindle moulders are used to shape wood edges to many different patterns. Special care is required to avoid contact with this high-speed working tool, particularly under conditions that do not allow the cutter to be guarded completely.

The cutter should be surrounded by an enclosure that should preferably be combined with an exhaust-ventilation system for wood dust, chips and shavings.

If the wood is passed along a straight fence guide, mechanical devices should be fitted to hold it down on the table and against the guide while at the same time providing protection against kick-back. Jigs should be employed when the use of such holding devices is not applicable, as in the case of irregularly shaped work pieces. Jigs may also serve as a template for the finished product. After cutting off power, spindle moulders should be stopped by a brake.

Other woodworking machines. There are also many other types of woodworking machines, which are needed for steaming, drying, sawing, boring, turning, bending, bonding, pressing, sanding, coating, nailing etc. Detailed safety instructions and regulations have been issued by manufacturers and competent national authorities in technologically advanced countries on the installation and operation of such machines, and these should always be observed when introducing machines in developing countries.

The best way to improve the prevailing safety situation, however, is by ensuring that the more widely used basic machines correspond as closely as possible to the safety requirements discussed above.

Other safety problems

Fire. In all wood and wood-processing industries fire is an ever-present danger when wood waste is accumulated and when large quantities of wood materials and products are stored. Fire not only endangers human lives but also destroys industrial premises and may deprive workers of

[1] See chapter XXIX.

their jobs for long periods of time. More than most other industries, the wood and wood-processing industries must be concerned with minimizing the fire risk and being well prepared to efficiently suppress outbreaks of fire.

The smaller the wood particles, the higher the fire risk. Wood dust, shavings and chips are particularly hazardous materials. If wood dust accumulates on engines and impairs their cooling systems, there may be a fire risk owing to overheating. Furthermore, sawdust, shavings etc. tend to self-ignite owing to internal heating. The regular disposal of wood waste is therefore of crucial importance, as are precautions and restrictions concerning the use of open fire, welding equipment, smoking, the handling of highly inflammable chemicals etc.

Fire-fighting equipment must be kept ready for use in convenient places, and workers should know how to handle it in case of a fire alarm. Periodic checks of equipment, the responsibilities of employees in fire fighting and co-operation with outside fire brigades must be clearly planned. Small workshops may only need to keep sand and water in accessible places, whereas larger ones may require motor pumps, chemical fire extinguishers and a specially trained internal fire-fighting crew.

Electrical shock. Faulty electrical equipment may produce electrical shocks, which can harm workers, or cause fires or explosions. Electrically powered woodworking machines must therefore comply with prevailing national standards. Installation and repair must be done by qualified electricians. Wiring and cables should never be allowed to become worn.

Special attention is required in the case of portable electrical machines such as drills, saws and sanders. They must be properly earthed. Cables should be placed in safe places, e.g. they should be put between two boards or suspended over supports.

Repairs and maintenance. There is a considerable risk of accident when the repair and maintenance of machines is carried out by unqualified personnel and with unsuitable equipment. Knowledgeable operators, experienced mechanics and the availability of proper tools are the best means of protection against such risks, which tend to be under-estimated. Before dismantling and taking guards off a machine for maintenance, the power must be shut off and the switch must be locked to avoid the danger of setting the machine into motion accidentally.

A special problem arises when maintaining and sharpening saws and cutters by means of special grinding machines. The hazards in this activity are caused by the handling of sharp tools, by filings flying off and by breaking grindstones. The screening of grindstones, the use of transport frames for circular saws and the application of personal protective equipment such as goggles, aprons and gloves are the most important precautions.

Occupational health problems

The major occupational health hazards leading to occupational diseases are described below.

Wood dust

Dust is produced when working with wood, particularly in furniture and cabinet making. Dust in high concentrations may impair the workers' health and may furthermore provoke explosions and increase the risk of fire. A distinction must be made between inert wood dust and dust from toxic wood.

Dust from inert wood may give rise to local skin irritation, which is mainly due to mechanical action, depending on the size and the characteristics of the wood particles. This skin irritation is generally situated in folds of skin where the dust may collect or where dust stained clothes may irritate the skin. Inert wood dust may also contain free silica and carries, therefore, a risk of pheumoconiosis. For this reason the concentration of wood dust in the working environment should not exceed a given level.

Certain wood species, mainly tropical ones, are likely to induce biological reactions of various kinds, in particular on the exposed skin and mucosae. The first symptoms are primarily irritating effects, including skin symptoms, in persons working with green wood; in this case the resulting dermatitis is due to the direct action of the wood on the skin. Conjunctival irritation may follow, with inflammation, intense watering of the eyes (lachrymation) and occasionally reactions in the eye tissue (ceratitis). Wood dust may be inhaled and cause irritation of the mucosae of the upper respiratory tract, sometimes with such symptoms as sweating, coughing or hoarseness. Allergic conditions may appear, such as skin disorders (dermatitis, exzema) and asthma. The skin lesions begin with irritation and eruptions on the skin of the hand and face, with severe itching. After a few days these eruptions may give way to vesicules, which crack and form crusts that often become infected. Repeated exposure may lead to a generalized allergic reaction, with lung symptoms such as feelings of bronchial constriction and asthma, sometimes associated with the skin conditions.

Recent epidemiological inquiries have shown that a particular health hazard among cabinet makers is nasal cancer. In the furniture industry, wood is sanded down using belt, disc or orbital sanders. These operations give rise to large quantities of extremely fine wood dust which may prove to be particularly irritating to the respiratory tract. The health hazards that are due to wood and wood dust are generally related to the different types of work. In furniture manufacturing, wood processing, carpentry etc. wood constituents (especially in wood dust, resins, tannins and alkaloids) can cause an irritation of the mucosae of the upper respiratory tract, conjunctivitis, skin allergies, asthma or nasal cancer.

Regulations concerning the exposure of workers to dust have been adopted in a number of countries, the most common value for long-term exposure being 5 mg/m^3.

Efficient dust extraction and collection systems are required on woodworking machines to reduce the hazards caused by dust. Especially in the smaller woodworking establishments of developing countries, much more attention must be paid to this problem. Personal respiratory equipment is needed if adequate dust control cannot be achieved by ventilation. Furthermore, pre-employment and periodic medical examinations are important for workers exposed to dust.

Table 27 contains a list of the principal wood species that have been shown to be toxic; there are undoubtedly a large number of lesser-known tropical species that are also toxic. Attention should be paid to this potential hazard when introducing lesser-known species on a larger scale in the national or international market.

Table 27. Principal wood species with toxic wood

		Symptoms*		
Botanical name	*Common name*	*Dermatitis*	*Mucosal irritation*	*General symptoms*
Thuja standishii	Arbor vitae		X	
Distemonanthus benthamianus	Ayan	X		
Dalbergia melanoxylon	Blackwood African	X		
Gonioma kamassi	Boxwood, Knysna boxwood		X	X
Thuja plicata	Cedar, Western red	(X)	X	
Dalbergia retusa and *Dalbergia* spp.	Cocobolo	X		
Brya ebenus	Cocus	X		
Piptadeniastrum africanum	Dahoma		X	
Diospyros spp.	Ebony	X	X	
Guarea thompsonii and *Guarea* spp.	Guarea		X	
Tabebuia ipe and *Tabebuia* spp.	Ipe (lapacho)	X	X	X
Chlorophora excelsa	Iroko	X	(X)	
Sandoricum indicum	Katon		X	X
Khaya ivorensis and *Khaya* spp.	Mahogany, African	X	(X)	
Swietenia macrophylla and *Swietenia* spp.	Mahogany, American	X		
Tieghemella heckelii	Makoré	X	X	
Mansonia altissima	Mansonia	(X)	X	X
Triplochiton scleroxylon	Obeche	(X)	X	
Nauclea trillesii	Opepe	X	X	
Aspidosperma peroba	Peroba, Pink	X	X	X
Paratecoma peroba	Peroba, White	X	X	
Gonystylus bancanus	Ramin	X		
Dalbergia spp.	Rosewood	X		
Machaerium spp.				
Chloroxylon swietenia	Satinwood, Ceylon	X		
Fagara flava and *Fagara* spp.	Satinwood, West Indian and African	X		
Sequoia sempervirens	Sequoia		X	X
Dysoxylum muelleri	Stavewood		X	X
Tectona grandis	Teak	X		
Frullania etc.	Liverworts and lichens on bark	X		

Source: B. Woods and C. D. Calnan, "Toxic woods", *British Journal of Dermatology*, No. 94, supplement 13 (1976) pp. 1-97.

*Brackets indicate reactions are only suspected.

Chemicals

A large number of harmful chemicals are used in wood preservation and processing. The ILO report on occupational safety, health and welfare in the woodworking industries, published in 1967, contains a detailed list of the nature of such chemicals, their application and their effect upon the worker's health. This list includes 48 chemicals used in timber treatment, 16 glues, 11 varnishes, 11 binders, 27 solvents and diluents and 31 additives. In 1977, ILO published a tabular compilation of values of occupational exposure limits for airborne toxic substances from selected countries. Further relevant information is provided in the monograph No. 25 of the International Agency for Research on Cancer (IARC) on the evaluation of the carcinogenic risk of chemicals to humans in the wood, leather and associated industries (Lyons, 1981), which contains a list of chemicals used in wood and associated industries and includes an evaluation of carcinogenicity.

Some examples of occupational risks caused by chemicals that are more commonly applied in the wood industries are given below.

The use of veneers and laminates with plywood and particle board has increased considerably in recent years, and, consequently, so has the amount and variety of adhesives used in the bonding of wood panels. The two main groups of adhesives are natural glues and synthetic glues. Apart from casein glue, natural glues are seldom used. Great use is made of synthetic adhesives such as those based on formaldehyde and the neoprene adhesives. Any of the synthetic glues may constitute a risk of skin disease or of systemic intoxication, in particular those that release free formaldehyde or organic solvents. Formaldehyde can act through inhalation and transcutaneous absorption.

Exposure to low atmospheric concentrations of formaldehyde causes irritations, especially in the eyes and the upper respiratory tract. When the concentration exceeds 4-5 ppm, discomfort increases rapidly, and a person may experience difficulty in breathing, burning in the eyes, nose and trachea, intense watering of the eyes and severe spasmodic coughing. Inhalation of high concentrations may be fatal. Direct contact with solutions or resins containing formaldehyde may give rise to inflammatory dermatitis. Repeated exposure may lead to allergic reactions, with the appearance of chronic eczema.

Solvents of various kinds are employed for glues, varnishes and paints used in the woodworking industry. Highly toxic solvents such as benzene, tetrachlorethane or carbon tetrachloride have been present, almost completely abandoned. Those more currently used are alcohols, ethers, glycol derivatives, esters, cetones and turpentine. They often have quite an irritant effect on the mucous membrance and skin, which may give rise to contact dermatitis and to localized skin alterations: the skin becomes cracked, chapped and vulnerable to other irritants and sensitizers. Certain solvents may cause allergic reactions and eczematous skin lesions.

Workers handling toxic chemicals in wood preservation and processing should be well instructed about the hazards and the means of protection. Furthermore, they should be provided with adequate washing facilities, specific decontaminants and anti-toxic emergency treatment facilities. Regular medical supervision of exposed workers is also required. Continuing efforts should be made to substitute highly dangerous chemicals by other less harmful ones.

Bursitis (beat elbow, beat hand, beat knee) and tenosynovitis (inflammation of tendons)

Bursitis is an inflammatory condition affecting in particular the elbow and knee joints. It is usually caused by repeated pressure or by repeated jolts to the joint in question.

Tenosynovitis is due to the swelling of the tendon or the surrounding tissues caused by rapid, repetitive movements. The most common form encountered in industry is a tenosynovitis of the hand, wrist or forearm, which reduces the mobility of the fingers and the hand, and movements become very painful. This disease is caused by unsuitable hand tools, painful work posture, jerky movements instead of smooth working action, intense repetitive work after a period of rest etc.

Bursitis and tenosynovitis can be prevented to a large degree by the ergonomic adjustment of tools, the improved design of machines and better working habits.

Noise and vibrations

All woodworking machinery with high-speed cutting tools, such as saws, planers, spindle-moulders etc., produce a considerable amount of high-pitched noise. The intensity and the spectrum of this noise vary from one machine to another, but in general the noise level of the working environment is very high when several machines are in operation. The level of noise may vary owing to the non-continuous operation of certain machines, for instance, the intake of waste in chippers, pneumatic transport systems etc.

Noise may have general and local effects on human beings. The general effects depend, in part, on the individual degree of tolerance and may consist of nervous fatigue, the lowering of the level of attention, gastric troubles etc. The most common and important consequence of prolonged exposure to noise, however, is the impairment of hearing. The raised level of excitement of the sensory cells in the inner ear and therefore a certain degree of hearing loss is reversible within a limited period of time; initially, this impairment disappears after a few hours away from the noisy environment. This is true for a number of years, usually 10 or more, depending on the type of exposure and the spectrum of the noise. The hearing capacity of the worker is normal in the morning and during the weekend, but on work days it is slightly impaired at night. After a certain number of years, however, the time of recovery grows progressively longer, and finally the lesions of the sensory cells become permanent and the hearing loss is no longer reversible.

The hearing impairment is particularly severe in the higher frequency range of sound, i.e. between 3,000 and 6,000 Hz. The clinical characteristic of occupational deafness is said to be bilater. [1] and to show a typical dip in the audiogram at the 4,000 Hz frequency. Workers do not usually become aware of the progression of their deafness until the loss of hearing reaches the spectrum of 500 to 2,000 Hz, which are the usual frequencies for verbal communication. At that stage, the worker is frequently unable to distinguish certain consonants with high frequency components, such as "f" or "s", and may be unable to make out words even though the sound can be heard.

The only effective way to prevent this occupational disease is by reducing the noise level. This is a technical matter and depends on the appropriate design of machinery, as well as on regular maintenance. Cutting tools should be kept well-sharpened and correctly balanced on their spindles, and machines should be fixed on a vibration-dampening base to minimize the amount of noise generated. Progress has been made in noise reduction by modifying cutting tools, by providing machines and machine tools with enclosures lined with sound-dampening material, by placing workers in noise-protected cabins and by the use of ear protectors.

Maximum permissible levels of noise have already been established in a number of countries. In order to adhere to these levels, the working environment must be monitored regularly with well calibrated noise level meters. Certain countries have also prescribed pre-employment and periodical medical examinations with audiometric testing for workers exposed to excessive noise and have recognized hearing impairments that are due to a noisy working environment as a compensable occupational disease.

Further information on the protection of workers against noise and vibration in the working environemnt are found in a special ILO code of practice issued in 1977.

Ergonomics

Ergonomics consists primarily in adapting the working environment to the physiological and psychological capabilities of the worker and in preventing stress and fatigue; it also covers the health aspects of the organization of work. The aim of ergonomics is to maximize the productivity of workers while at the same time protecting their safety and health and providing job satisfaction and fulfilment in line with the economic resources available for achieving an appropriate job design.

Ergonomic studies in the wood and wood-processing industries have been carried out during the past decade primarily in Finland and Sweden, where technology is advanced and the attention paid to working conditions is high.[2]

In developing countries, the scope for applying ergonomic recommendations of this nature may be limited because of simpler technology, economic limitations or lack of skills. Even in the absence of relevant studies, however, there is every reason to assume that basic ergonomic requirements are overlooked almost everywhere.

In many woodworking plants in the developing countries, a large number of jobs consist of physically heavy work which is frequently done by workers in a poor state of health and nutrition under unfavourable climatic conditions. The result is low productivity, many accidents and high rates of absenteeism and turnover of labour. Improvements are required in two respects: on the one hand, a minimum of general health care, adequate nutrition, a supply of safe drinking water and a reasonable pattern of breaks and rest periods is necessary; on the other hand, the physical workload should be minimized to the largest possible extent, especially as regards manual loading, unloading and transport. Since in many cases it will not be economically possible to replace manual handling with mechanical handling, a great deal of attention must be given to improving manual handling by providing efficient tools such as wheelbarrows, manual carts with rubber tyres and manually operated rail systems or by making use of inclined planes and the like. In this context, attention should be paid to the maximum permissible weight to be carried by one worker as specified in ILO convention No. 127 and recommendation No. 128 (1967). Straight-back lifting techniques are also important to reduce the high incidence of strained backs and hernias.

The shape of tools, the design of the work place, and the layout and operation of machines should allow for comfortable work posture. Where possible, the worker should be seated instead of standing during work. Better lighting may be possible by means of simple adjustments. In hot and humid climates, work places should be ventilated to reduce the heat stress.

A good means of adjusting jobs to basic ergonomic requirements is by checking tools, machines or work places using ergonomic check lists. When tools and machines are transferred from industrial to developing countries, they should be adjusted to the extent necessary to local ergonomic requirements.

Basic ergonomics is more a matter of common sense and practical judgement than of scientific study. It is an area where workers can easily be motivated to participate actively and where a lot can be achieved with modest inputs. Furthermore, results of ergonomic improvements are often visible at once or after a short period of time.

General considerations on the prevention of occupational accidents and diseases

Training

The best method of preventing occupational accidents and diseases is to have properly instructed, knowledgeable and skilled personnel. Special training may be required in such matters, and training should be provided at all levels.

In developing countries these requirements are seldom met. Managers may never have been systematically instructed in occupational safety and health problems. Supervisors may tolerate unsafe conditions and acts because management does not care or because they themselves are not knowledgeable in essential safety requirements. New workers may have been shown how to operate a machine by workers using unsafe working habits. To change such a situation is not easy.

Adequate knowledge and skill is particularly required among the supervisors and foremen, machine operators, mechanics and electricians. A special effort must also be made to see that the new entrants in the work-force are adequately instructed before being employed on regular production work.

Training may be provided in industrial training centres, through special courses or on the job. The latter, however, is often an excuse for providing no or only inadequate training if it is not separated from normal production work and carried out by experienced instructors. Safety training and instruction needs to be an ongoing concern and requires refresher and up-dating courses to keep in line with technological developments and progress.

The need for first-aid training should also be mentioned; it is required for the whole work-force and must also be repeated from time to time. (Emphasis should be placed on dealing primarily with types of injuries that most frequently occur and using first aid materials that are normally available on the working site.)

Work clothing and personal protective equipment

Work clothing should correspond to climatic conditions and the requirements of the job. When workers cannot be adequately protected against occupational hazards by other means, they should be provided with suitable personal protective equipment.

Eye protection in the form of goggles or face shields is needed when the eye is exposed to injury from flying particles or dangerous substances, for instance when working with abrasive grinding wheels. If the noise level is above 85 dB (A), hearing protection—ear wool, ear plugs or ear muffs—should be used. Aprons made of leather or

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[2] For information, the proceedings of the International Union of Forestry Research Organizations (IUFRO) Meeting on Ergonomics in Sawmills and Woodworking Industries may be consulted (Stockholm, Arbetarskyddstyrelse, 1975).

other sturdy material provide protection in jobs where workers are exposed to lacerations, splinters and kick-backs.

To protect the hands, gloves may be advisable in certain work places. However, gloves should not be worn in the vicinity of woodworking machines if there is a danger of their being caught and dragged in by fast-revolving machine parts. In such cases, hand pads can afford protection against splinters. Solid footwear with non-slip soles should be worn in all work places.

Respiratory protection is needed where other means are insufficient to reduce exposure to airborne dust, fumes, vapours and gases below the permissible exposure limits. Special care is needed to ensure that respiratory equipment is regularly maintained, cleaned and kept in good condition. When dangerous chemicals are handled, rubber gloves, rubber aprons and rubber boots may be necessary for skin protection.

This list contains only the most important items of personal protective equipment. Mention must also be made of the necessity to provide first-aid kits or boxes in suitable positions near work places, to ensure that their contents meet specified minimum requirements, that they are replenished after use and that they are regularly inspected.

Annex

The following ILO conventions and recommendations are of concern to the woodworking industry:

- Convention No. 119 and recommendation No. 118 (Guarding of machinery, 1963).
- Convention No. 127 and recommendation No. 128 (Maximum permissible weight to be carried by one worker, 1967).
- Convention No. 139 and recommendation No. 147 (Occupational cancer, 1974).
- Convention No. 148 and recommendation No. 156 (Working environment, 1977).
- Convention No. 155 and recommendation No. 164 (Safety and health, 1981).

Furthermore, the ILO Occupational Safety and Health Branch prepared the following publications which may be useful particularly for developing countries as a guide for specific measures in the woodworking industries:

Model Code of Safety Regulations for Industrial Establishments (Geneva, 1949). Revision of the 1954 edition.

Report on Occupational Safety and Health and Welfare in the Woodworking Industries (Geneva, 1967).

Occupational Exposure Limits for Airborne Toxic Substances (Geneva, 1977).

Code of Practice on Protection of Workers against Noise and Vibration in the Working Environment (Geneva, 1977).

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