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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

FURNITURE AND JOINERY INDUSTRIES FOR DEVELOPING COUNTRIES

UNITED NATIONS

with 09256

CORRIGENDUM
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September 1979

FURNITURE AND JOINERY INDUSTRIES FOR DEVELOPING COUNTRIES

Corrigendum

Page 62, line 6

For easily *read* safely

Page 62, line 10

For advantages *read* disadvantages

Page 63, line 9

For Germany *read* the Federal Republic of Germany

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Vienna

FURNITURE AND JOINERY INDUSTRIES FOR DEVELOPING COUNTRIES

UNITED NATIONS
New York, 1977

ID/108/Rev.1

EXPLANATORY NOTES

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

The monetary unit in Finland is the Finnish mark (Fmk). During the period covered (1971-1975) by the study, the mean value of the Fmk in relation to the United States dollar was $US 1 = 3.88.

The term "billion" signifies a thousand million.

References to tons are to metric tons.

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.

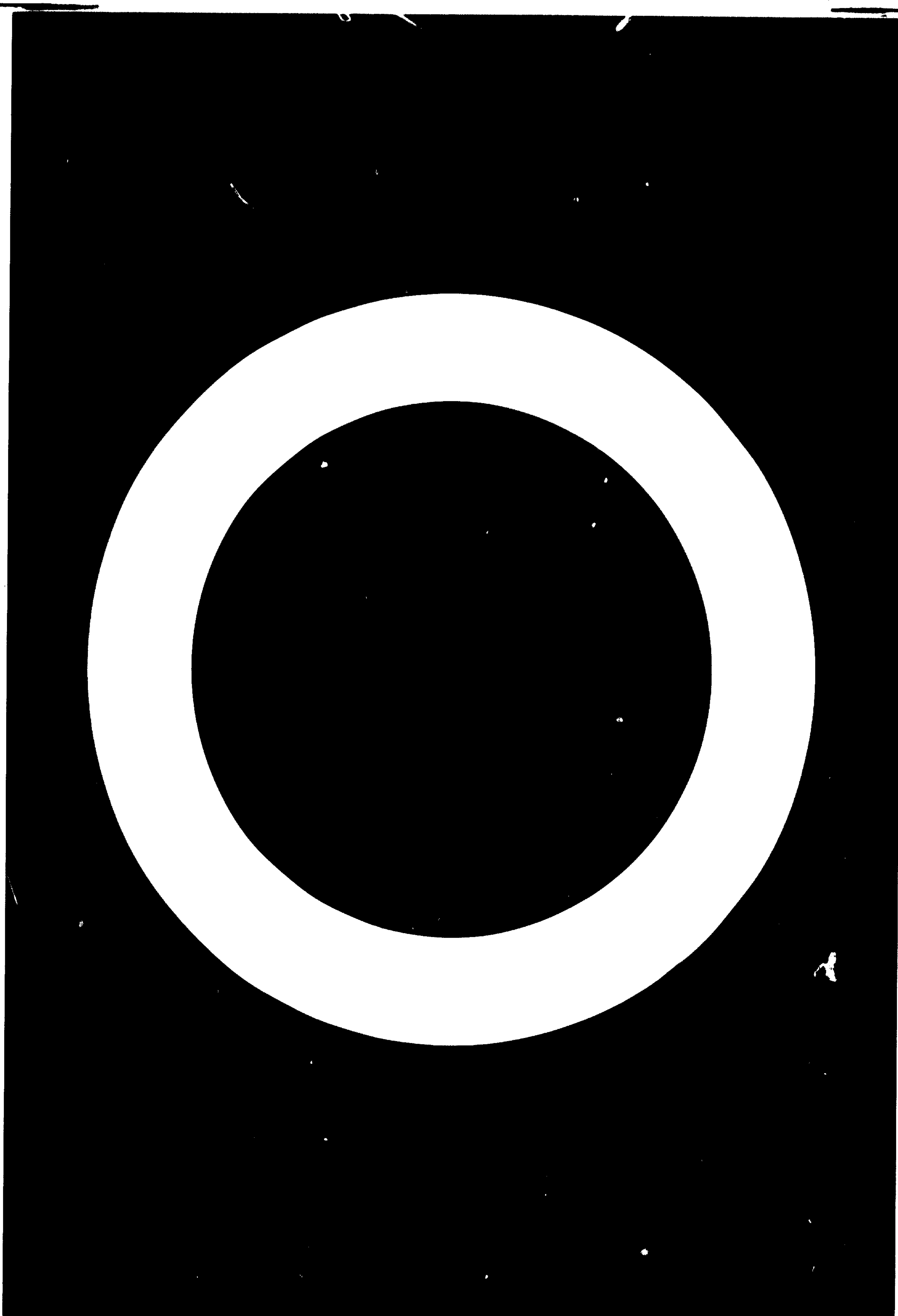
A blank indicates that the item is not applicable.

The following technical abbreviations are used in this publication:

c.i.f.	cost, insurance, freight
cP	centipoise
dB	decibel
f.a.s.	free alongside ship
f.o.b.	free on board
FRP	fibreglass reinforced plastic
FSP	fibre saturation point
ha	hectare
kcal	kilocalorie
kN	kilonewton
kp	kilopond
lbf	pound-force
N	newton (100,000 dynes)
p.s.i.	pounds per square inch
PVAc	polyvinyl acetate
PVC	polyvinyl chloride
r.h.	relative humidity
rm	running metre
μm	micrometre (10^{-6} m)

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

ASTM	American Society for Testing and Materials (United States)
BS	British Standards (United Kingdom)
DIN	Deutsche Industrie-Norm (Federal Republic of Germany)
FEIC	Fédération européenne de l'industrie du contreplaqué
FIRA	Furniture Industry Research Association (United Kingdom)
FPRL	Forest Products Research Laboratory (United Kingdom)
ISO	International Organization for Standardization
NEMA	National Electic Manufacturers' Association of New York
NHLA	National Hardwood Lumber Association (United States)
SIS	Sveriges Standardiseringskommission (Sweden)



Preface

Five 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; the subsequent four were held at Lahti in 1972, 1973, 1974 and 1975.[1] The success of the seminars was largely owing to the hospitality and understanding of the Finnish authorities and of the Finnish furniture industry in providing participants with an invaluable opportunity to learn first hand 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 up-grade their own operations and to establish priorities for such improvement. The seminars were attended by 122 participants from 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. Many of the lectures were illustrated by material that did not lend itself to reproduction in the present form. They were complemented by demonstrations, discussions and visits to medium-sized and small-scale furniture and joinery plants, plywood and blockboard manufacturers and producers of upholstery foams, paints and woodworking machinery as well as to vocational and technical training institutions.

Although these studies constitute a coherent whole, for convenience they have been grouped into three parts.[2] Part one is made up of articles on the materials from which furniture and joinery products are constructed, among them solid wood; composite boards of various kinds and their uses in the furniture and joinery industries; upholstery materials; bonding agents; and the hardware used in assembly and trimming.

Part two deals with processing technology. It includes chapters on furniture design, product development, plant layout, finishing operations, plant automation and machines and tool maintenance.

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 may 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 that may not be wholly applicable to particular developing countries.

The views expressed are those of the individual authors and do not necessarily reflect the views of UNIDO.

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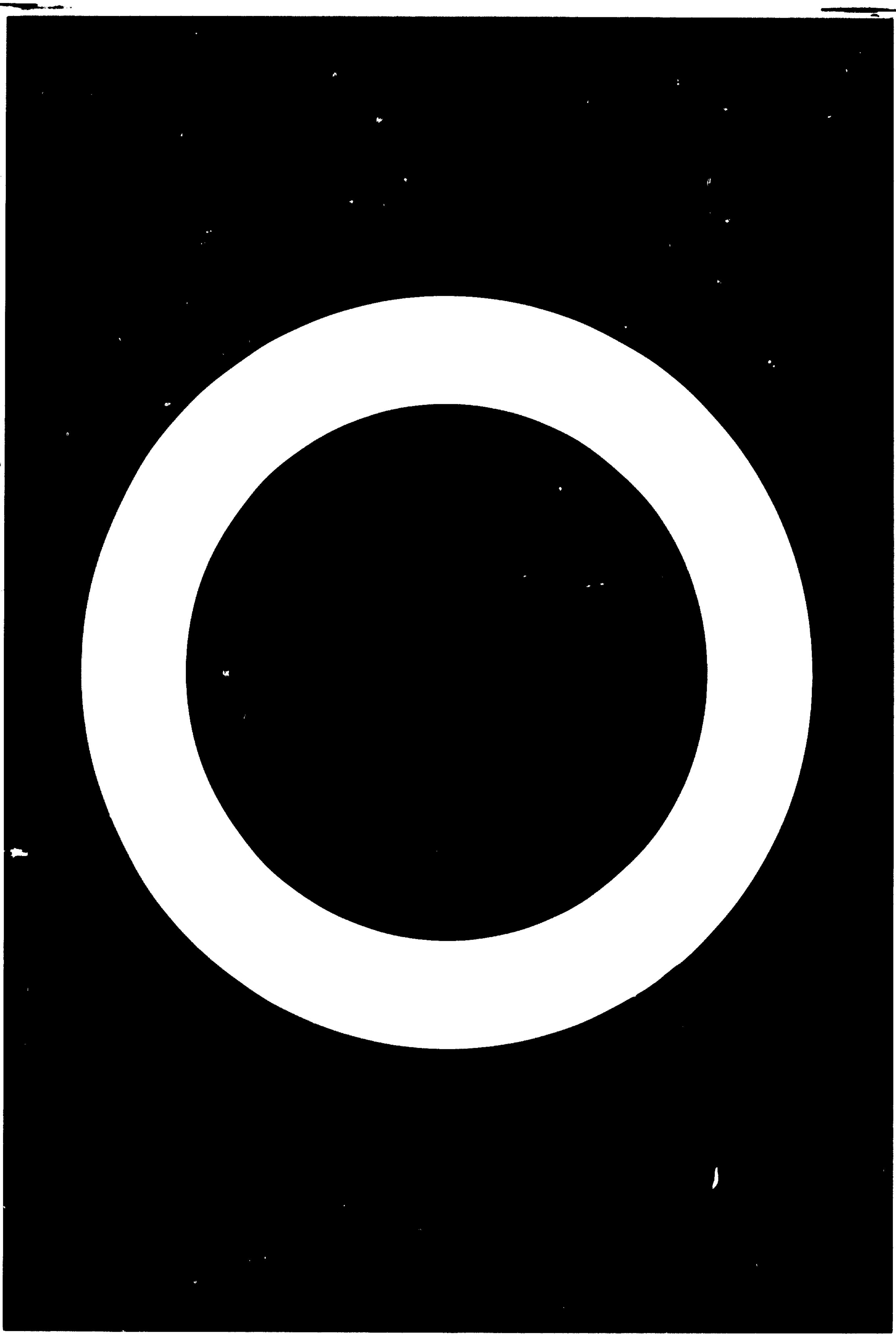
[1] Documents originally prepared for the seminars bore the symbol numbers: for 1971, ID/WG.105/–; for 1972, ID/WG.133/–; for 1973, ID/WG.163/–; for 1974, ID/WG.183/–; and for 1975, ID/WG.209/–.

[2] This publication was issued originally in three separate parts. In this revision the parts are brought together in one volume.



CONTENTS

Part three

MANAGEMENT CONSIDERATIONS

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 these exports is still in the form of logs which are processed into veneers, sawnwood, furniture and joinery products in the developed countries, thus contributing very little to the economies of the exporting countries.

In nearly all developing countries, the 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, design for larger production series, 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 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 of their imports of these products and of the raw material requirements through more rational utilization. If the goals of the Lima Declaration and Plan of Action[1] 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] Adopted by the Second General Conference of the United Nations Industrial Development Organization (UNIDO), Lima, Peru, 12-16 March 1975 (General Assembly resolution 3362 (S-VII)).

Part one

RAW MATERIAL INPUTS

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 are easy to veneer, lacquer and cover with various plastic sheets and foils. 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. A very interesting new method used in the joinery industry is the covering of window components with a layer of plastic.

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]

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 toughness, rigidity and hardness
Grain structure, with homogeneity, colour shade and variations
Drying properties, such as shrinkage, swelling and twisting
Suitability for gluing
Finishing qualities
Bending qualities (reaction to treatment by steam and ammonia)
Workability
Resistance to weathering 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 Indian 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 oils. 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 NHLA-graded lumber. 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 saw-mill or at the furniture factory.

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*By Pekka Paavola, Lahti Technical Institute, Lahti, Finland. (Originally issued as document ID/WG.105/22/Rev.1.)

[1] The examples included in the text are of Finnish birch because a text treating even most of the important tropical species would have been beyond the scope of this presentation. 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.

TABLE I. STANDARD THICKNESSES OF BIRCH BOARDS USED IN THE FINNISH FURNITURE INDUSTRY[a]

Raw thickness		
Millimetres	*Inches*	*After surface and thickness planing millimetres (average)*
19	¾	14
25	1	20
32	1 ¼	26
38	1 ½	32
50	2	44
63	2 ½	56

[a]Average length of boards is 6 metres.

The first phases of work in a furniture factory are kiln-drying, cross-cutting and edging. Figure I 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 previous grading of boards is usually unnecessary. For many parts, however, various kinds of defects are allowed to a certain extent. Because of the high quality requirements of furniture, the amount of waste of material is fairly great, usually 40 to 60 per cent of the used volume of wood. The consumption of raw material can often be reduced by gluing smaller pices side by side when wide components are needed. In furniture manufacture the basis for estimating material consumption is usually the net area of board needed for a certain component. When this area is multiplied by the rough thickness of the board, the so-called net volume is obtained. The gross volume, which is the basis of cost accounting, is obtained by multiplying the net volume by the waste coefficient (averaging 1.6 to 1.8, depending on the kind of wood, size of components and quality requirements). An example is given in figure II.

Figure I. Principle of cross-cutting and edging of boards in the furniture industry

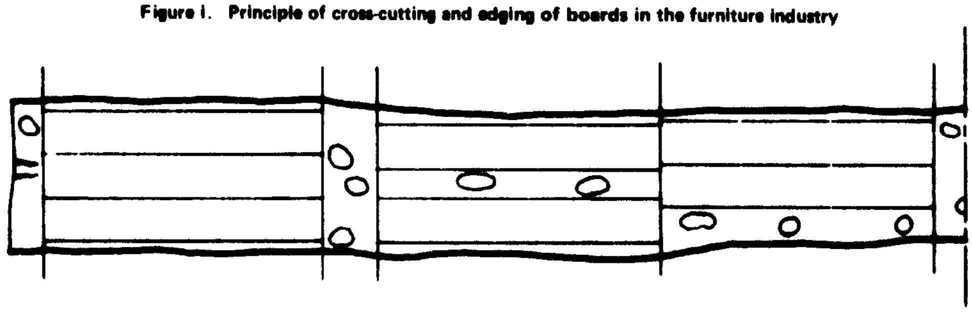
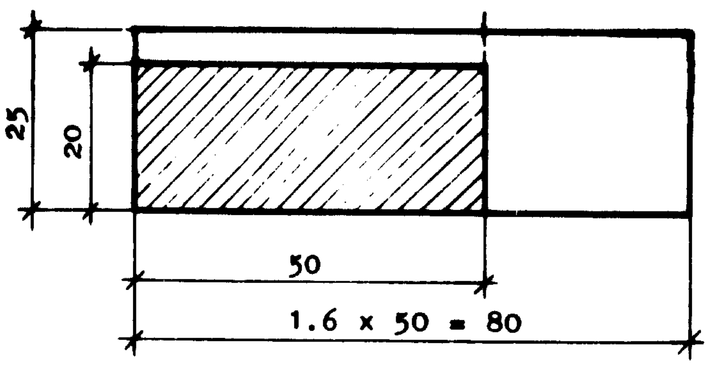


Figure II. Estimation of material consumption



The timber used in the joinery industry is usually edged. Grading before cross-cutting is of little importance because of the way the material is handled. As a conventional method, timber is first kiln-dried, then cross-cut to the required lengths. The worst points of defect are rejected (figure III). Smaller knots are drilled and plugged. A new method is to cross-cut the board at the point of defect (figure IV). The ends are then finger-jointed and glued together to form a continuous profile, which is moulded and trimmed to the needed lengths.

Figure III. Conventional cross-cutting principle in the joinery industry

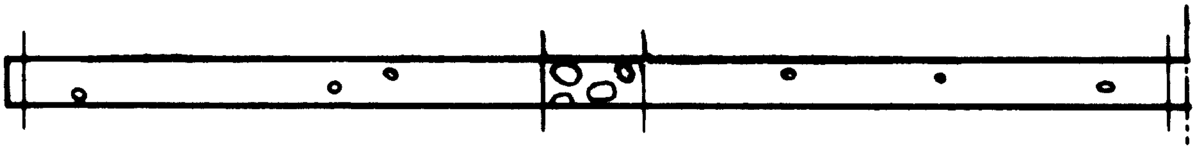
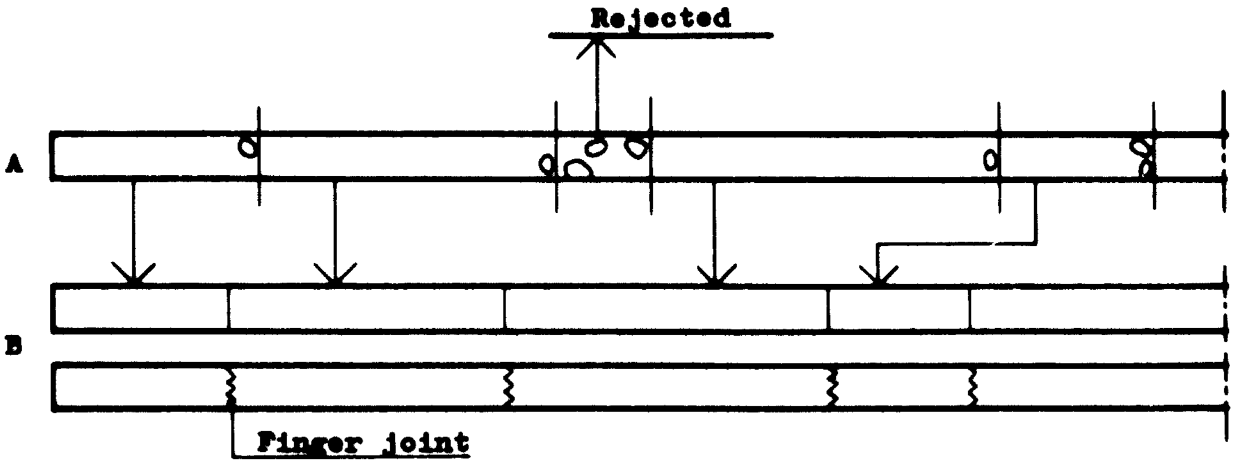


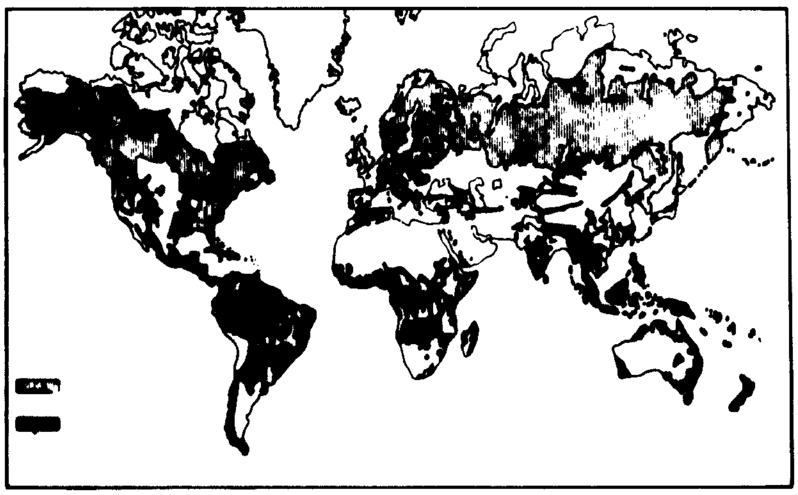
Figure IV. Finger-jointing of timber in the joinery industry



Hardwoods and softwoods

The 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 V. The basic properties of the wood are approximately the same in both classes of trees.

Figure V. Regions of growth of hardwoods and softwoods



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

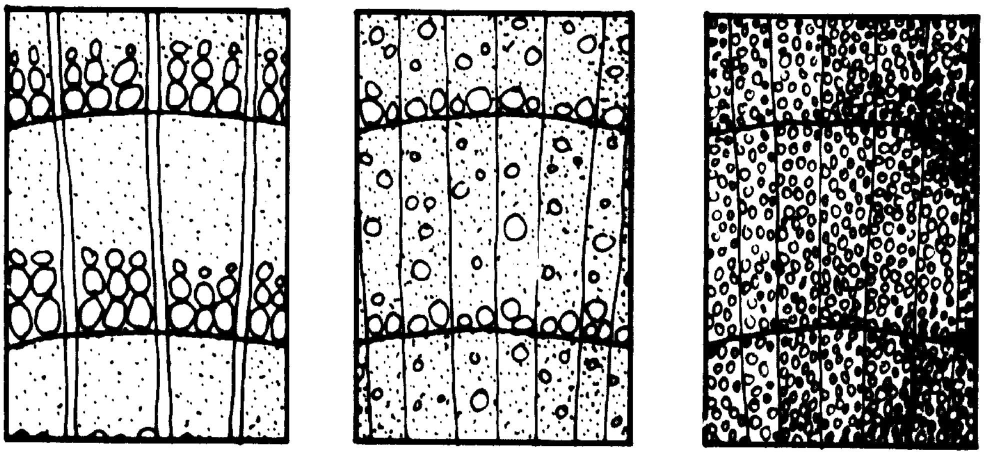
Hardwoods are divided further into three groups:

- 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 (figure VI). 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, its finishing and certain other properties.

Figure VI. The three main hardwood types



Ring porous   Semi-ring porous   Diffuse porous

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, 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.

The grain structure on the surface of a sawn board depends greatly on the direction in which the timber has been sawn. As shown in figure VII, the principal directions of sawing are longitudinal (L), radial (R) and tangential (T).

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. Tangential sawing (plain sawing) yields a more lively figure pattern, but the rays are visible only as cross-sections (figure VIII). 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 of trees there is little or no difference in colour between the heartwood and sapwood.

Figure VII. The principal sawing directions for logs

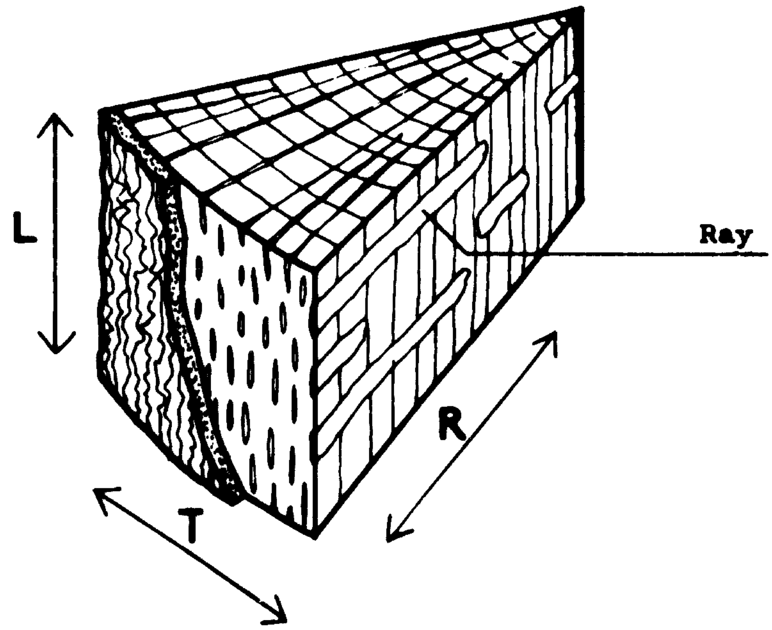
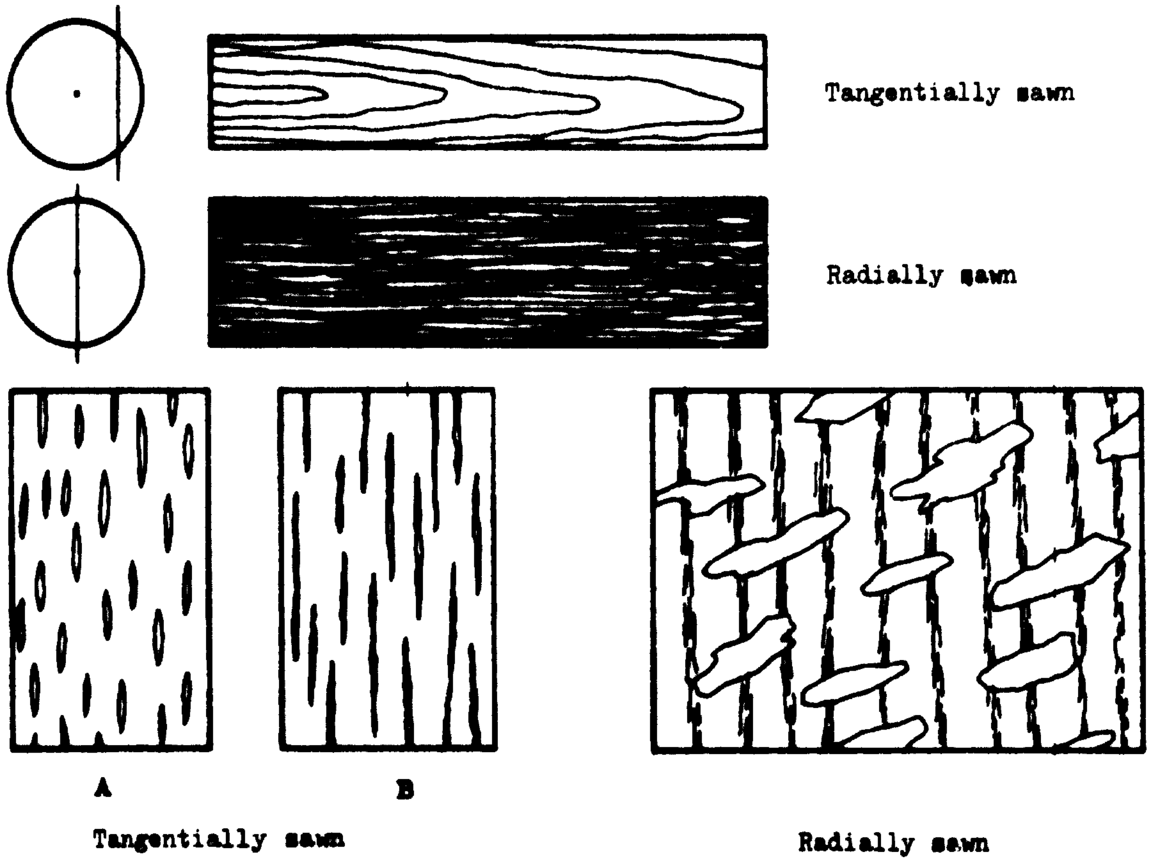


Figure VIII. Effect of sawing direction on figure pattern of wood



The density of a wood is generally considered to be the best criterion of its general characteristics since all species of wood consist of practically 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) The use of 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:

	Example
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	

	Example
Oven-dried specimen is weighed (m_0)	m_0 = 36.2 g
Moisture content (u) is calculated from the following formula:	

$$u = \frac{m_u - m_0}{m_0} = \frac{48.6 - 36.2}{36.2} = \frac{12.4}{36.2} = 0.342 = 34.2\%$$

This method gives a fairly accurate result with the use of an ordinary laboratory balance.

For 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 below 20 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 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 kind of wood. 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 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. 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 tendency to come to a 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.

The equilibrium moisture content of wood depends not only on the relative humidity but also on the temperature of the ambient air. When the service conditions of a wood are known, its equilibrium moisture content can be determined from the values shown in table 2. These values apply to all species of wood with sufficient accuracy for all practical purposes. Some values obtained from table 2 are shown in table 3.

TABLE 2. RELATIVE HUMIDITY (ROMAN TYPE) AND EQUILIBRIUM MOISTURE CONTENT (ITALIC TYPE) VALUES OCCURRING AT VARIOUS DRY-BULB TEMPERATURES AND WET-BULB DEPRESSIONS

Wet-bulb depression

(C°: 1.1 2.2 3.3 4.4 5.6 5.7 7.8 8.9 10 11 12 13 14 15 17 19 21 25)

Temperature dry bulb (C°)	(F°)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	45	50
-1	30	89 / ...	78 / 15.9	67 / 12.9	57 / 10.8	46 / 9.0	36 / 7.4	27 / 5.7	17 / 3.9	6 / 1.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
+2	35	90 / ...	81 / 16.8	72 / 13.9	63 / 11.9	54 / 10.3	45 / 8.8	37 / 7.4	28 / 6.0	19 / 4.5	11 / 2.9	3 / 0.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	40	92 / ...	83 / 17.6	75 / 14.8	68 / 12.9	60 / 11.2	52 / 9.9	46 / 8.6	37 / 7.4	29 / 6.2	22 / 5.0	15 / 3.5	8 / 1.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	45	93 / ...	86 / 18.3	78 / 15.6	72 / 13.7	64 / 12.0	58 / 10.7	51 / 9.5	44 / 8.5	37 / 7.8	31 / 6.6	25 / 5.3	19 / 4.2	13 / 2.9	6 / 1.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	50	93 / ...	86 / 19.0	80 / 16.3	74 / 14.4	68 / 12.7	62 / 11.5	56 / 10.3	50 / 9.4	44 / 8.8	38 / 7.6	32 / 6.7	27 / 5.7	21 / 4.9	16 / 3.9	10 / 2.8	5 / 1.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	55	94 / ...	88 / 19.8	82 / 16.9	76 / 15.1	70 / 13.4	65 / 12.2	60 / 11.0	54 / 10.1	49 / 9.3	44 / 8.4	39 / 7.6	34 / 6.8	28 / 6.0	24 / 5.3	19 / 4.5	14 / 3.6	9 / 2.5	5 / 1.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16	60	94 / ...	89 / 19.9	84 / 17.4	78 / 15.6	73 / 13.9	68 / 12.7	63 / 11.6	58 / 10.7	53 / 9.9	48 / 9.1	43 / 8.3	39 / 7.6	34 / 6.9	30 / 6.3	26 / 5.6	21 / 4.9	17 / 4.1	13 / 3.2	9 / 2.3	5 / 1.3	1 / 0.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	65	95 / ...	90 / 20.3	84 / 17.9	80 / 16.1	75 / 14.4	70 / 13.3	66 / 12.1	61 / 11.2	56 / 10.4	52 / 9.7	48 / 8.9	44 / 8.3	39 / 7.7	36 / 7.1	32 / 6.5	27 / 5.8	24 / 5.2	20 / 4.5	16 / 3.8	13 / 3.0	8 / 2.3	6 / 1.4	2 / 0.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	70	95 / ...	90 / 20.6	86 / 18.2	81 / 16.8	77 / 14.9	72 / 13.7	68 / 12.5	64 / 11.6	59 / 10.9	55 / 10.1	51 / 9.4	48 / 8.8	44 / 8.3	40 / 7.7	36 / 7.2	33 / 6.6	29 / 6.0	25 / 5.5	22 / 4.9	19 / 4.3	15 / 3.7	12 / 2.9	9 / 2.3	6 / 1.8	3 / 0.7	...	...	...	...	...	...	...	...	...	...	...	...
24	75	96 / ...	91 / 20.9	86 / 18.5	82 / 16.8	78 / 15.2	74 / 14.0	70 / 12.9	66 / 12.0	62 / 11.2	58 / 10.5	54 / 9.8	51 / 9.3	47 / 8.7	44 / 8.2	41 / 7.7	37 / 7.2	34 / 6.7	31 / 6.2	28 / 5.6	24 / 5.1	21 / 4.7	18 / 4.1	15 / 3.5	12 / 2.9	10 / 2.3	7 / 1.7	4 / 0.9	1 / 0.2	...	...	...	...	...	...	...	...	...
27	80	96 / ...	91 / 21.0	87 / 18.7	83 / 17.0	79 / 15.8	75 / 14.3	72 / 13.2	68 / 12.3	64 / 11.5	61 / 10.9	57 / 10.1	54 / 9.7	50 / 9.1	47 / 8.5	44 / 8.1	41 / 7.7	38 / 7.2	35 / 6.8	32 / 6.3	29 / 5.8	26 / 5.4	23 / 5.0	20 / 4.5	18 / 4.0	15 / 3.5	12 / 3.0	10 / 2.4	7 / 1.9	5 / 1.1	3 / 0.3	...	...	...	...	...	...	...
29	85	96 / ...	92 / 21.2	88 / 18.8	84 / 17.2	80 / 15.7	76 / 14.8	73 / 13.8	70 / 12.5	66 / 11.8	63 / 11.2	59 / 10.5	56 / 10.0	53 / 9.8	50 / 9.0	47 / 8.5	44 / 8.1	41 / 7.6	38 / 7.2	36 / 6.7	33 / 6.3	30 / 6.0	28 / 5.6	25 / 5.2	23 / 4.8	20 / 4.3	18 / 3.9	15 / 3.4	13 / 3.0	11 / 2.4	9 / 1.7	4 / 0.9	...	...	...	...	...	...
32	90	96 / ...	92 / 21.3	89 / 18.9	85 / 17.3	81 / 15.9	78 / 14.7	74 / 13.7	71 / 12.8	68 / 12.0	65 / 11.4	61 / 10.7	58 / 10.2	55 / 9.7	52 / 9.3	49 / 8.8	47 / 8.4	44 / 8.0	41 / 7.6	39 / 7.2	36 / 6.8	34 / 6.5	31 / 6.1	29 / 5.7	26 / 5.3	24 / 4.9	22 / 4.6	19 / 4.2	17 / 3.8	15 / 3.3	13 / 2.8	9 / 2.1	5 / 1.3	1 / 0.4	...	...	...	...
35	95	96 / ...	92 / 21.3	89 / 19.0	85 / 17.4	82 / 16.1	79 / 14.9	75 / 13.9	72 / 12.9	69 / 12.2	66 / 11.8	63 / 11.0	60 / 10.5	57 / 10.0	55 / 9.6	52 / 9.1	49 / 8.7	46 / 8.2	44 / 7.9	42 / 7.5	39 / 7.1	37 / 6.8	34 / 6.4	32 / 6.1	30 / 5.7	28 / 5.3	26 / 5.1	23 / 4.8	22 / 4.4	20 / 4.0	17 / 3.6	14 / 3.0	10 / 2.3	6 / 1.5	2 / 0.6	...	...	...
38	100	96 / ...	93 / 21.3	89 / 19.0	86 / 17.8	83 / 16.1	80 / 15.0	77 / 13.9	73 / 13.1	70 / 12.4	68 / 11.8	66 / 11.2	62 / 10.6	59 / 10.1	56 / 9.6	54 / 9.2	51 / 8.9	49 / 8.5	46 / 8.1	44 / 7.8	41 / 7.4	39 / 7.0	37 / 6.7	35 / 6.4	33 / 6.1	30 / 5.7	28 / 5.4	26 / 5.2	24 / 4.9	22 / 4.6	21 / 4.2	17 / 3.6	13 / 3.1	10 / 2.4	7 / 1.6	4 / 0.7	...	...
40	105	96 / ...	93 / 21.4	90 / 19.0	87 / 17.5	83 / 16.2	80 / 15.1	77 / 14.0	74 / 13.2	71 / 12.6	68 / 11.9	66 / 11.3	62 / 10.8	60 / 10.3	58 / 9.8	55 / 9.4	53 / 9.0	50 / 8.7	48 / 8.3	46 / 7.9	44 / 7.6	42 / 7.3	40 / 6.9	37 / 6.7	35 / 6.4	33 / 6.1	31 / 5.7	29 / 5.4	27 / 5.2	26 / 4.8	24 / 4.6	20 / 4.2	17 / 3.6	14 / 3.1	11 / 2.4	8 / 1.8	...	...
43	110	97 / ...	93 / 21.4	90 / 19.0	87 / 17.5	84 / 16.2	81 / 15.1	78 / 14.1	75 / 13.3	73 / 12.6	70 / 12.0	67 / 11.4	65 / 10.8	62 / 10.4	60 / 9.9	57 / 9.5	55 / 9.2	52 / 8.6	50 / 8.4	48 / 8.1	46 / 7.7	44 / 7.5	42 / 7.2	40 / 6.8	38 / 6.6	36 / 6.3	34 / 6.0	32 / 5.7	30 / 5.4	28 / 5.2	26 / 4.8	23 / 4.5	20 / 4.0	17 / 3.5	14 / 3.0	11 / 2.5	4 / 1.1	...
46	115	97 / ...	93 / 21.4	90 / 19.0	88 / 17.5	85 / 16.2	82 / 15.1	79 / 14.1	76 / 13.4	74 / 12.7	71 / 12.1	68 / 11.8	66 / 10.9	63 / 10.4	61 / 10.0	58 / 9.6	56 / 9.3	54 / 8.9	52 / 8.6	50 / 8.2	48 / 7.8	46 / 7.6	43 / 7.3	41 / 7.0	40 / 6.7	38 / 6.5	36 / 6.2	34 / 5.9	32 / 5.6	31 / 5.4	29 / 5.2	26 / 4.7	23 / 4.3	20 / 3.9	17 / 3.4	14 / 2.9	8 / 1.7	2 / 0.4
49	120	97 / ...	94 / 21.3	91 / 19.0	88 / 17.4	86 / 16.2	83 / 15.1	80 / 14.1	77 / 13.4	74 / 12.7	72 / 12.1	69 / 11.5	67 / 11.0	64 / 10.5	62 / 10.0	58 / 9.7	60 / 9.4	55 / 9.0	53 / 8.7	51 / 8.3	49 / 7.9	47 / 7.7	45 / 7.4	43 / 7.2	41 / 6.8	40 / 6.6	38 / 6.3	36 / 6.1	34 / 5.8	33 / 5.6	31 / 5.4	28 / 5.0	26 / 4.6	22 / 4.2	19 / 3.7	17 / 3.3	12 / 2.3	9 / 1.1
52	125	97 / ...	94 / 21.2	91 / 18.9	88 / 17.3	86 / 16.1	82 / 15.0	80 / 14.0	77 / 13.4	75 / 12.7	73 / 12.1	70 / 11.8	68 / 11.0	65 / 10.5	63 / 10.0	61 / 9.7	59 / 9.4	57 / 9.0	55 / 8.7	53 / 8.3	51 / 8.0	48 / 7.7	47 / 7.5	45 / 7.2	43 / 7.0	41 / 6.7	39 / 6.5	37 / 6.2	36 / 6.0	35 / 5.8	33 / 5.5	30 / 5.2	27 / 4.8	24 / 4.4	22 / 4.0	19 / 3.6	13 / 2.7	8 / 1.6
54	130	97 / ...	94 / 21.0	91 / 18.8	89 / 17.2	86 / 16.0	83 / 14.9	81 / 14.0	78 / 13.4	76 / 12.7	73 / 12.1	71 / 11.5	69 / 11.0	67 / 10.8	64 / 10.0	63 / 9.7	60 / 9.4	58 / 9.0	56 / 8.7	54 / 8.3	52 / 8.0	50 / 7.8	48 / 7.6	47 / 7.3	45 / 7.0	43 / 6.8	41 / 6.6	40 / 6.4	38 / 6.1	37 / 5.9	35 / 5.6	33 / 5.3	29 / 4.9	26 / 4.6	24 / 4.2	21 / 3.8	13 / 3.0	10 / 2.0
60	140	97 / ...	95 / 20.7	92 / 18.6	89 / 16.9	87 / 15.8	84 / 14.8	82 / 13.9	79 / 13.2	77 / 12.5	75 / 11.9	73 / 11.4	70 / 10.9	68 / 10.4	66 / 10.0	64 / 9.6	63 / 9.4	60 / 9.0	58 / 8.7	56 / 8.4	54 / 8.0	53 / 7.8	51 / 7.6	49 / 7.3	47 / 7.1	46 / 6.9	44 / 6.6	43 / 6.4	41 / 6.2	40 / 6.0	38 / 5.8	35 / 5.4	32 / 5.1	30 / 4.8	27 / 4.4	25 / 4.1	19 / 3.4	14 / 2.6
66	150	98 / ...	95 / 20.2	92 / 18.4	90 / 16.6	87 / 15.4	85 / 14.5	82 / 13.7	80 / 13.0	78 / 12.4	76 / 11.8	74 / 11.2	72 / 10.6	70 / 10.3	68 / 9.9	66 / 9.5	64 / 9.2	62 / 8.9	60 / 8.6	58 / 8.3	57 / 8.0	55 / 7.7	53 / 7.5	51 / 7.3	49 / 7.1	48 / 6.9	46 / 6.7	45 / 6.4	43 / 6.2	42 / 6.0	41 / 5.8	38 / 5.4	36 / 5.2	33 / 4.9	30 / 4.5	28 / 4.2	22 / 3.6	8 / 2.9
71	160	98 / ...	95 / 19.8	93 / 18.1	90 / 16.2	88 / 15.2	85 / 14.2	83 / 13.4	81 / 12.7	79 / 12.1	77 / 11.8	75 / 11.0	73 / 10.6	71 / 10.1	69 / 9.7	67 / 9.4	66 / 9.1	64 / 8.8	62 / 8.5	60 / 8.2	58 / 7.9	57 / 7.7	55 / 7.4	53 / 7.2	52 / 7.0	50 / 6.8	49 / 6.7	47 / 6.4	46 / 6.2	44 / 6.0	43 / 5.8	41 / 5.5	38 / 5.2	35 / 4.9	33 / 4.6	31 / 4.3	26 / 3.7	21 / 3.2
77	170	98 / ...	95 / 19.4	93 / 17.7	91 / 15.8	88 / 14.8	86 / 13.9	84 / 13.2	82 / 12.4	80 / 11.8	78 / 11.3	76 / 10.8	74 / 10.4	72 / 9.9	70 / 9.6	68 / 9.2	67 / 9.0	66 / 8.6	63 / 8.4	62 / 8.0	60 / 7.8	59 / 7.6	57 / 7.3	56 / 7.2	55 / 6.9	53 / 6.7	51 / 6.6	49 / 6.4	48 / 6.2	47 / 6.0	45 / 5.7	43 / 5.5	40 / 5.2	38 / 4.9	35 / 4.6	33 / 4.4	28 / 3.7	24 / 3.2
82	180	98 / ...	95 / 18.9	94 / 17.3	91 / 15.5	89 / 14.8	87 / 13.7	85 / 12.9	83 / 12.2	81 / 11.6	79 / 11.1	77 / 10.6	75 / 10.1	73 / 9.7	72 / 9.4	70 / 9.0	68 / 8.9	67 / 8.4	65 / 8.1	63 / 7.8	62 / 7.6	61 / 7.4	60 / 7.2	57 / 7.0	55 / 6.8	54 / 6.5	52 / 6.4	51 / 6.2	50 / 6.0	48 / 5.9	47 / 5.7	45 / 5.4	42 / 5.2	40 / 4.8	38 / 4.6	35 / 4.4	30 / 3.8	26 / 3.3
88	190	98 / ...	96 / 18.5	94 / 16.9	92 / 15.2	90 / 14.2	88 / 13.4	86 / 12.7	84 / 12.0	82 / 11.4	80 / 10.9	78 / 10.3	76 / 10.0	75 / 9.6	73 / 9.2	71 / 8.9	69 / 8.6	68 / 8.2	66 / 7.9	65 / 7.7	63 / 7.4	62 / 7.2	60 / 7.0	59 / 6.8	57 / 6.6	56 / 6.4	54 / 6.2	53 / 6.0	51 / 5.9	50 / 5.7	49 / 5.5	46 / 5.3	44 / 5.0	42 / 4.8	39 / 4.5	37 / 4.4	32 / 3.8	28 / 3.3
93	200	98 / ...	96 / 18.1	94 / 16.4	92 / 14.9	90 / 14.0	88 / 13.2	86 / 12.4	84 / 11.8	82 / 11.2	80 / 10.8	79 / 10.3	77 / 9.8	76 / 9.4	74 / 9.1	72 / 8.8	70 / 8.4	69 / 8.1	67 / 7.7	66 / 7.5	64 / 7.2	63 / 7.0	61 / 6.9	60 / 6.8	58 / 6.4	57 / 6.2	55 / 6.0	54 / 5.9	53 / 5.7	52 / 5.6	51 / 5.4	48 / 5.2	46 / 4.9	43 / 4.7	41 / 4.5	39 / 4.3	34 / 3.8	30 / 3.3
99	210	98 / ...	96 / 17.7	94 / 16.0	92 / 14.6	90 / 13.8	88 / 13.0	86 / 12.2	85 / 11.7	83 / 11.1	81 / 10.6	79 / 10.0	78 / 9.7	76 / 9.2	75 / 9.0	73 / 8.7	71 / 8.3	70 / 8.0	68 / 7.6	67 / 7.4	66 / 7.1	64 / 6.9	63 / 6.8	61 / 6.6	60 / 6.3	59 / 6.1	57 / 5.9	56 / 5.8	54 / 5.5	53 / 5.4	52 / 5.3	50 / 5.1	47 / 4.8	45 / 4.6	44 / 4.4	41 / 4.2	36 / 3.7	32 / 3.2

Source: United States Department of Agriculture, Forest Service, *Dry Kiln Operator's Manual* by Edmund F. Rasmussen, Agricultural Handbook No. 188 (Washington, DC, Government Printing Office, 1961).

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 (30 per cent).;

(b) The shrinkage in volume (V) of a piece of wood in the moisture area 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 dm^3;

(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 4).

TABLE 3. EQUILIBRIUM MOISTURE CONTENT OF WOOD

Relative humidity of air (percentage)	*Temperature (°C)*	*Equilibrium moisture content of wood (percentage)*
40	20	7.6
	30	7.3
	40	7.0
50	20	9.1
	30	8.8
	40	8.4
60	20	10.8
	30	10.5
	40	10.0
70	20	13.0
	30	12.6
	40	12.1
80	20	16.1
	30	15.7
	40	15.0
90	20	20.8
	30	20.0
	40	19.3
100	20	Fibre
	30	saturation
	40	point = 30%

TABLE 4. WEIGHT AND MAXIMUM SHRINKAGE OF WOOD FROM SOME IMPORTANT TREE SPECIES

Species	*Density at 0% moisture (g/cm^3)*	*Maximum shrinkage[a]* L (percentage)	R	T	V
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)*	0.31	0.2	4.1	6.6	10.9

[a] L = longitudinal, R = radial, T = tangential, V = volume.

The dimensional changes of pieces of wood, resulting from changes in their moisture content, can be calculated rather simply. For example, the answer to the question: How much will a 100-mm-wide mahogany board, cut tangentially to the growth rings, shrink when its moisture content is reduced from 20 per cent to 10 per cent?

Maximum shrinkage T[2]	= 5.1%
Original width (20% moisture)	= 100 mm
Change in moisture content (20% to 10%)	= 10%
FSP	= 30%

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

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

$$= 1.7 \text{ mm}$$

Swelling that results from increase in the moisture content may be calculated in a similar manner.

[2] See table 4.

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 IX);

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

Two alternative principles are therefore followed in constructing furniture and joinery products. Deformations are either allowed to develop freely (figure X), or are totally prevented (figure XI).

Figure IX. Shrinkage deformations in cross-sections

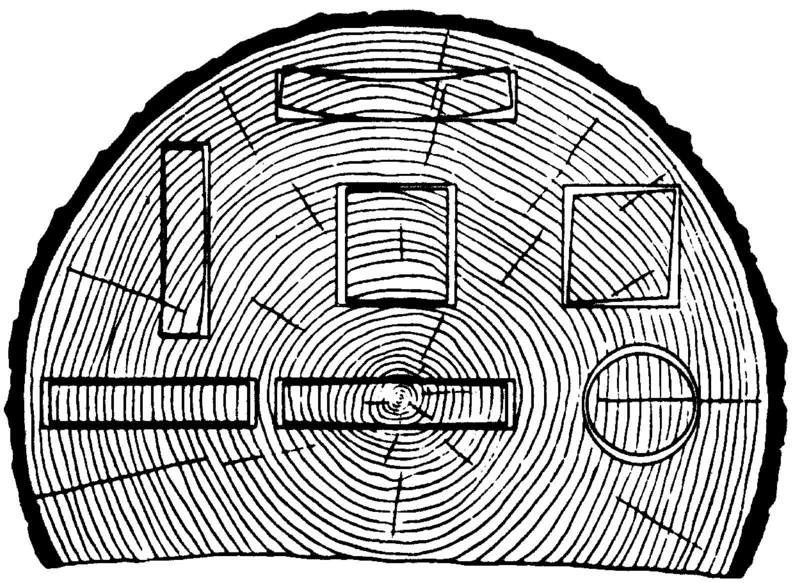


Figure X. Construction allowing deformations to develop freely

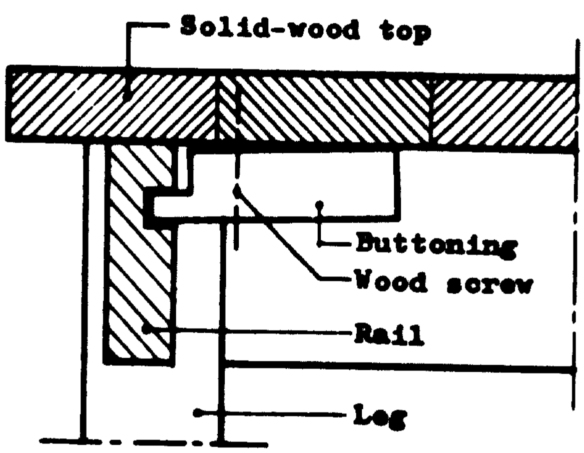
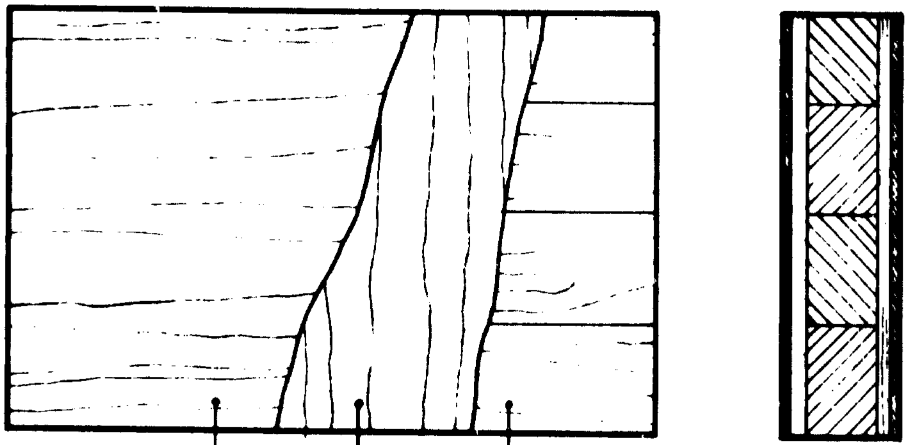


Figure XI. Construction preventing development of deformations



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 now normally done with either fork-lift trucks or tractor-trailer units; the use of narrow-gauge railway arrangements must be 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.

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 equilibrium moisture content. Careful attention to and close control of all phases of the process are necessary for successful drying. Hardwoods, especially thick boards, present particular difficulties in drying. Kiln-drying that is begun too rapidly will harden the surface, resulting in splitting inside the board (figure XII) and warping. The total charge of lumber being dried in a kiln may become unserviceable through careless drying.

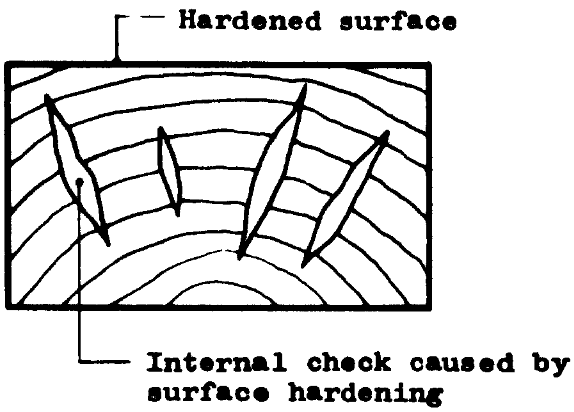
The general practice is to kiln-dry furniture and joinery timber to a slightly lower moisture content than the service conditions demand, counting on a moderate increase in moisture content during the storage and manufacturing periods. This practice is intended to assure uniform distribution of moisture 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.

Table 5 gives a drying schedule suitable for certain hardwood species (azobé, hickory, iroko, mahogany, makoré, oak, ramin, rosewood, sapela, teak, yang). During the drying operation the relative humidity of air in the kiln atmosphere must be maintained at the given value (column 5) until the moisture content of the wood has been lowered to the value given in column 1. The drying process is controlled by test specimens which are frequently taken out of the kiln (through a small hatch) to determine the moisture content. These specimens are naturally sawn from the timber to be dried before loading the kiln.

TABLE 5. KILN-DRYING SCHEDULE SUITABLE FOR CERTAIN HARDWOOD SPECIES

Actual moisture content of wood (percentage)	*Temperature readings in drying kiln*			*Relative humidity of air (percentage)*	*Equilibrium moisture content of wood (percentage)*
	Dry bulb (°C)	*Wet bulb (°C)*	*Difference (°C)*		
From green to 60%	40	38	2	90	19.5
60 to 25	45	42	3	82	15.6
25 to 20	51	46	5	74	12.5
20 to 16	57	49	8	65	10.0
16 to 13	63	52	11	55	8.0
13 to 10	70	54	16	46	6.3
Even up to 8	70	62	8	70	10.0

Figure XII. Effect of surface hardening



Quality standards of sawnwood for furniture manufacture[3]

There are no international quality standards for sawnwood 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 Malaysian 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. The 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 down 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 shall be of good quality.

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

[3] See also part two, chapter XVIII, "Technical product design".

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

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

In hardwoods with specific formation of heartwood, such as oak, teak, mahogany and rosewood, there shall 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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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 advantage 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 which 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 and durability, 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 and resistance and surface characteristics allowing 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 higher cost of solid sawnwood, higher labour costs, and lower quality of sawnwood. 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.

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Prices

Since quality standards have heen 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 material. Thus, the panel manufacturers have horne 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 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 panel use.

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 improvement 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 sides, turned parts and flat pieces to fill standing orders of large furniture makers provide the opportunity to plan and schedule machine and manpower 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 from the exploited timber are sought.

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.

Principal uses of panels in furniture

The need for low-cost, flat, homogeneous, 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 table and desk tops, ends of buffets, commodes and dressers, and 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 places of upholstered furniture, it is now taking on a glamourous role for clear or brightly coloured, stained finishes with no attempt made to hide the plys. Better-quality, primarily hardwood and plywood must therefore be 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.

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 processing and application of hardware shall be carried out properly. Otherwise, consumer acceptance will fall after discouraging attempts to use traditional (wood) techniques. This service has also been extended to include maintenance of the carbide-tipped cutting tools generally recommended for particle board, particularly for the smaller industrial user, and stocking of 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 building industry specifications are concerned with characteristics of weathering, durability, fire, insect and mould resistance and such strength properties as racking resistance, rigidity and impact resistance (specially for doors and partitions). Panels intended for furniture, on the other hand, must be dimensionally accurate and stable, 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 sufficiently 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, the questions of *(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 are difficult to answer in general terms. They depend, *inter alia*, on volume purchased, size of series, 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.

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 right 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 his 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 United Kingdom estimate 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 increased 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 1 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 are widely accepted by the furniture industry. Table 2 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.

[1] For articles on particle board conversion, see Mitlin, Leo, 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 of ***Timber Trades Journal and Woodworking Machinery)***, 4 May 1974, pp. 12-13.

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

TABLE 1. PERCENTAGE OF PANELS USED IN FURNITURE (1964-1965)

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

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

TABLE 2. BREAKDOWN OF MARKET FOR PARTICLE BOARD IN AUSTRALIA, 1972

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 *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 what 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 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 materials are at hand, provided of 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.

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

Wood-based panels are among the main raw materials of 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 etc.

The following table gives the main components in which plywood and blockboard were used in the furniture and joinery industries in the United Kingdom in 1970.

CONSUMPTION OF PLYWOOD AND BLOCKBOARD PANELS IN THE UNITED KINGDOM, 1970

Component	*Share of total consumption of panels (percentage)*	
	Plywood	*Blockboard*
Home and office furniture	15.0	18.0
Frames of upholstered furniture		
Table-tops		
Side panels, plane surfaces, shelves		
Back panels		
Drawer sides and bottoms etc.		
Doors		
Radio and TV cabinets	0.7	0.1
Built-in furniture	12.0	37.9
Sides, ends, shelves, backs of cupboards		
Doors		
Flush doors, exterior doors	3.9	1.5
Share of furniture industries in total consumption	31.6	57.5

*By Antti Vaajoensuu, Jaakko Pöyry and Co., Helsinki, Finland. (Originally issued as document 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).

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 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 which is used in exposed parts and finished with colourless lacquer with no attempt made to hide its ply structure.

Blockboard has also suffered from the 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 situation in the developing countries could be completely different where the prerequisites exist for manufacturing plywood and, above all, where there are 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 the wood technology is on a high level. In these cases plywood and blockboard could be adopted more easily than 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 furniture 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 such an appearance and could be used for demanding purposes. Surface finishing would also be easier.

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 and sliced. Thus, blockboard can be manufactured economically in connexion with a plywood mill and, if possible, also a sawmill or a similar plant. In such cases the raw material for core can be wood which 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 and working endurance;

(g) Other special properties.

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

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

Properties of plywood and blockboard

In furniture the most common plywood used 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 also thinner blockboard, 15-16 mm, and thicker, 22 and 25 mm, are commonly used. Thinner and thicker dimensions than these are 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, so that it makes for light-weight structures which at the same time are strong. Screw-holding capacity is highly 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 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.

What was said about plywood also largely applies to blockboard. Blockboard has the good properties of wood–light weight, durability and workability. It also has the 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.

As regards patterns of use in the developed countries, plywood is used extensively in mobile homes, shelving and do-it-yourself projects. In all, 25 per cent of hardwood plywood production in the United States in 1972 was used for furniture. Some 20 per cent–450 million ft^2–of total softwood plywood was used by home owners for such purposes as shelving (although it is not ideally suited for this), cabinets, furniture and work benches, and 90 per cent of this was do-it-yourself. Altogether, over 6 million families used plywood, mostly sanded and veneered grades, for this end-use. Products made for sale took 490 million ft^2 (3/8 in. basis) in 1972 for furniture, which represented a 69 per cent increase since 1969, largely owing to increased use in upholstered furniture. In the United Kingdom, 112,000 tons of plywood were used in furniture (estimated) in 1973, which was about 14 per cent of wood-based raw materials used in furniture. In Japan, only 13 per cent of plywood was used in furniture compared with 45 per cent and 28 per cent in construction and joinery in 1964 (according to an estimate made by the Tuolumne Corporation for FAO in July 1971).

Conclusion

Large-scale use of panels in furniture and fitments calls for structures 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.

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 exceeded 40 kg 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), the Timber Research and Development Association (TRADA) in the United Kingdom, the National Particleboard Association (NPA) of the United States of America and the Particle Board Guide of the Finnish Particleboard Association.

Definition

Particle board is a rather new industrial product; it was first introduced some 30 years ago in the Federal Republic of Germany and Switzerland. It is a sheet material manufactured from small pieces of wood or other ligno-cellulosic materials (such as chips, flakes, splinters, strands, shreds and shives) agglomerated by use of an organic binder, together with one or more agents such as heat, pressure, humidity and a catalyst.

Boards made from wood wool, wood chips or similar materials, and inorganic binders, e.g. cement, are not classified as particle boards.

Materials

Particles of 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, planer shavings, or chippings 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 by 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 antiswelling agent. Fire retardant, insecticide and fungicide chemicals can also be added in small proportions.

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*By the secretariat of UNIDO. (Originally issued as document ID/WG.209/25.) This chapter contains additionat material excerpted from "The requirements and use of wood-based panels in furniture manufacture" (ID/WG.209/1).

Properties

Particle board has about the same density as sawnwood of the same species but is more homogeneous. It contains no grain direction (although it does have the so-called "machine direction", that is, the direction of the material flow), knots or any other growth faults. Longitudinal swelling owing to moisture is equal in both directions, although it is slighter in comparison with sawnwood 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 compared with birch (*Betula spp.*) are shown in the table.

VALUES FOR A REPRESENTATIVE FINNISH, FLAT-PRESSED PARTICLE BOARD[a] AND FOR SOLID WOOD (FINNISH BIRCH *BETULA SPP*)

Characteristics	*Values for* Particle board	*Values for* Solid wood
	(kp/cm²)	
Bending strength	180-250	1,300-1,600
Tensile strength (direction of plane)	80-120	
(direction of grain)		1,200-1,500
Tensile strength (perpendicular to plane)	3-8	
(perpendicular to grain)		60-80
	(kp/mm)	
Withdrawal resistance of wood screws at surface	6-10	
Withdrawal resistance of wood screws at edge	4-7	

[a]Density = 650 kg/m³.

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 for overlays not to show unevennesses or to avoid "show-through" of particles. Care must he taken not to sand away too much of one surface since the stability of the board may thus he impaired, especially in multilayer boards.

Multilayered boards have heen developed, and even boards with densified edges can he produced, which improve surface and edge qualities with respect to screw-holding and edge-handing, and which allow machining with greatly reduced tear-out and chipping. The most common is a three-layer hoard. Flat-pressed boards are by far the most preferred by the furniture industry while extrusion types are used more in huilding.

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 hoard 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 be developed.

Board formation

The chips are carefully coated with controlled quantities of binder either in a discontinuous batch process or in a continuous system of spraying of chips as they fall through vertical cylinders. In all instances the final moisture content is controlled at about 10 per cent. The coated chips are formed into boards either hy pressing between steel plates (platen-pressed) or by forcing the chips 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 spreading, formation of layers and pressing. The density of the boards depends on many factors including the type of chips and the pressure applied. One way of defining the type of platen-pressed board is hy the structure resulting from the method of spreading the chips. 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 grain direction. The four basic types, which are represented in figure I, are

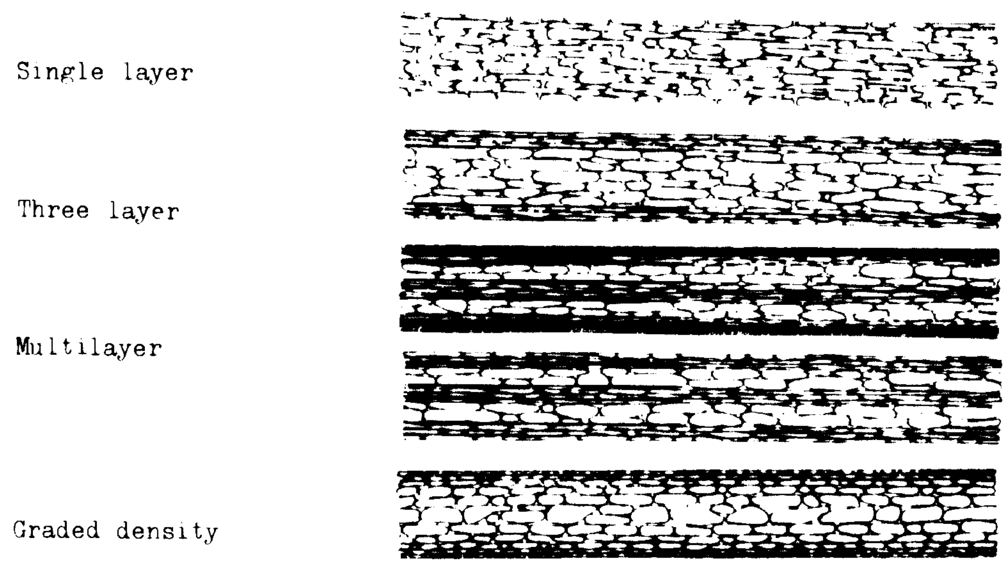
(a) Single-layer, in which the board is formed from chips of the same size or mixture of sizes so that it has a consistent density throughout the thickness;

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

(c) Multilayer, which is similar to the three-layer 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) Grade density is achieved through the method of spreading the chips making it possible to use chips without pre-grading them, the boards are characterized by smooth, high-density surfaces and low-density cores without any abrupt change in chip size. This type has some of the attributes of both the single-layer and three-layer type.

Figure I. 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 of pressing a number of boards at the same time in a multi-daylight press. Alternatively, single boards are 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.

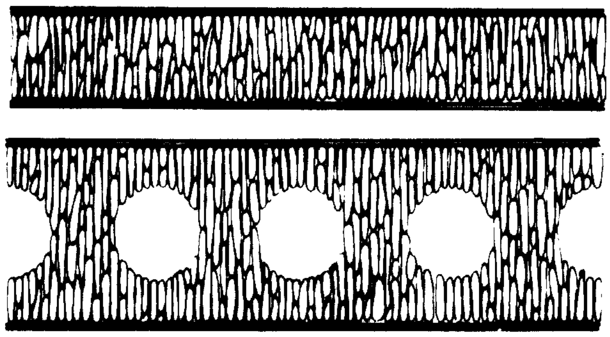
"Mende" thin boards produced on a calender

This is a recently developed method of producing a thin particle board through continuous pressing between heated rollers. It produces a continuous single-layer board which 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

This 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 my means of platen pressing. The chips are fed into a vertical 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 larger thickness 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 which, 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 II.) These boards are not commonly used in furniture but are used mainly as partitions.

Figure II. Extruded particle board



Choice of board sizes

Because of the annual 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 4 X 8 feet, has become larger. In the developing countries it is still common to produce only 4 X 8 ft 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 affect quality of products, thereby adversely affecting 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 nor 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 owing 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 it is not a common process, 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, 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 particle boards are not commonly available.

In general, internal walls, ceilings nad built-in furniture should not be affected by humidity. Situations, however, do arise in some developing countries in the tropics where, because of the open nature of the houses and the habit of frequent washing of the internal surfaces, there is the risk that the board will deteriorate because of its retaining 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, be 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 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 which 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. Different designs of hinges, slides and knock-down fasteners must be available, as well as screws with 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 the locally produced boards has created consumer resistance to this "man-made" product;

(d) Utilizers in the developing countries have not realized that whereas particle board can replace sawnwood, it is not sawnwood (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) Wrong fittings have been used (especially hinges) which worked loose, thus prompting end-users to declare it unsatisfactory;

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

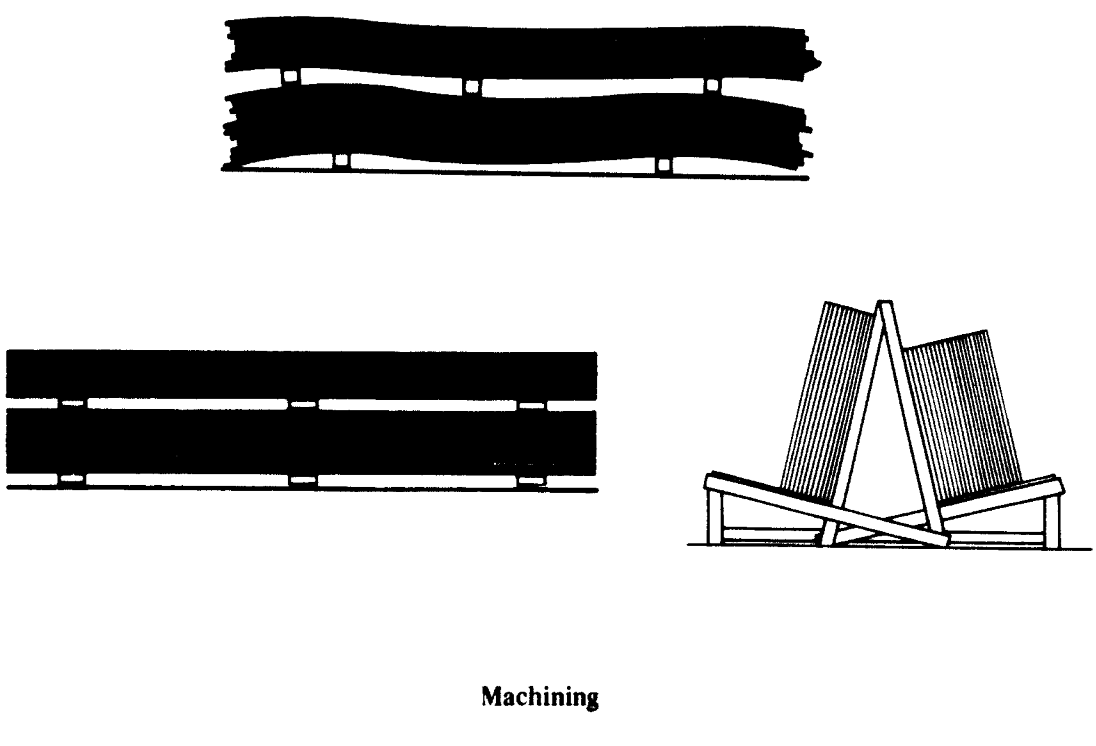
Other end-uses

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 making sure that the board shall be stored 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 III.

Figure III. Above, incorrect, and, below, correct methods for stacking particle board



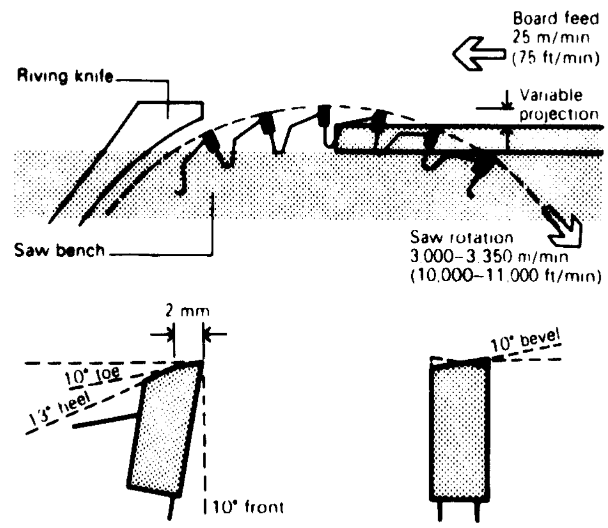
Machining

Particle board can be sawn, routed, spindled, planed or bored. The rate of feed should generally be slower than that used for sawnwood, 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 sawnwood timber are suitable. Saw blades should have a peripheral speed of about 3,000-3,500 m/min (10,000-11,000 ft/min). The angles of teeth are also important; a positive front angle is particularly necessary. Figure IV indicates the recommended details for circular saws.

Figure IV. Sawing method for particle board



Side elevation
tungsten carbide tip

Front elevation

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 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. Projection of the saw above the workpiece should be between about 8 mm and 20 mm.

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 set down the precise details, in general feed speeds should be slower than for sawnwood 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 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 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. Figure V shows a typical machining and folding operation for cabinet sides and top. 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 VI.

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 chips 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 board 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 cleanly 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 cleanly 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 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 VII.

Edge-banding

Particle board may be edged or lipped in a variety of ways (see figure VIII). Edges can be veneered easily to provide a matching finish to the surface. Provided that a clean 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 particle board. While the use of 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.

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 from the bottom of the threading). Dipping the screws into polyvinyl acetate (PVAc) glue before driving improves their withdrawal resistance. (See figure IX.) Furthermore, it is recommended that fittings and structures particularly suited for the purpose should be used as indicated in figure X. As regards the use of hinges, the more modern type

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

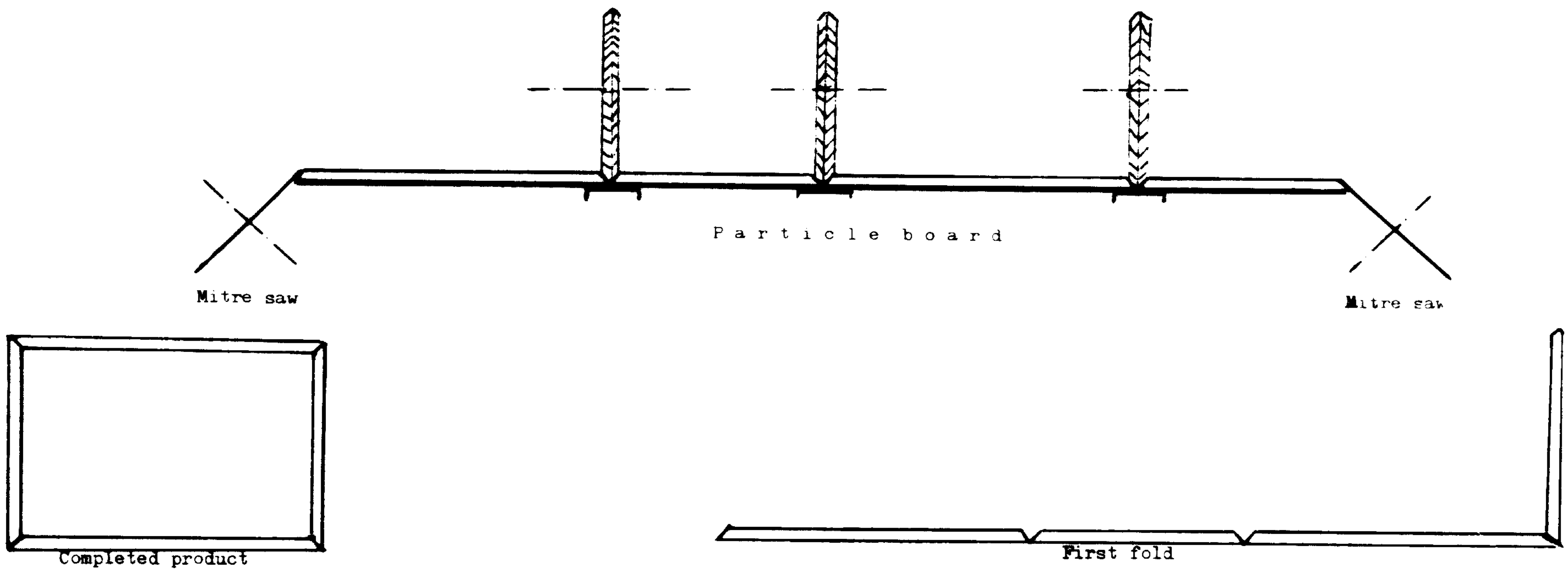
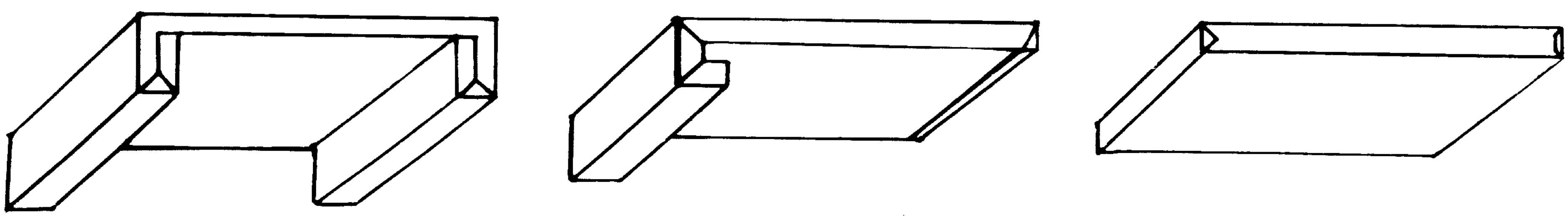
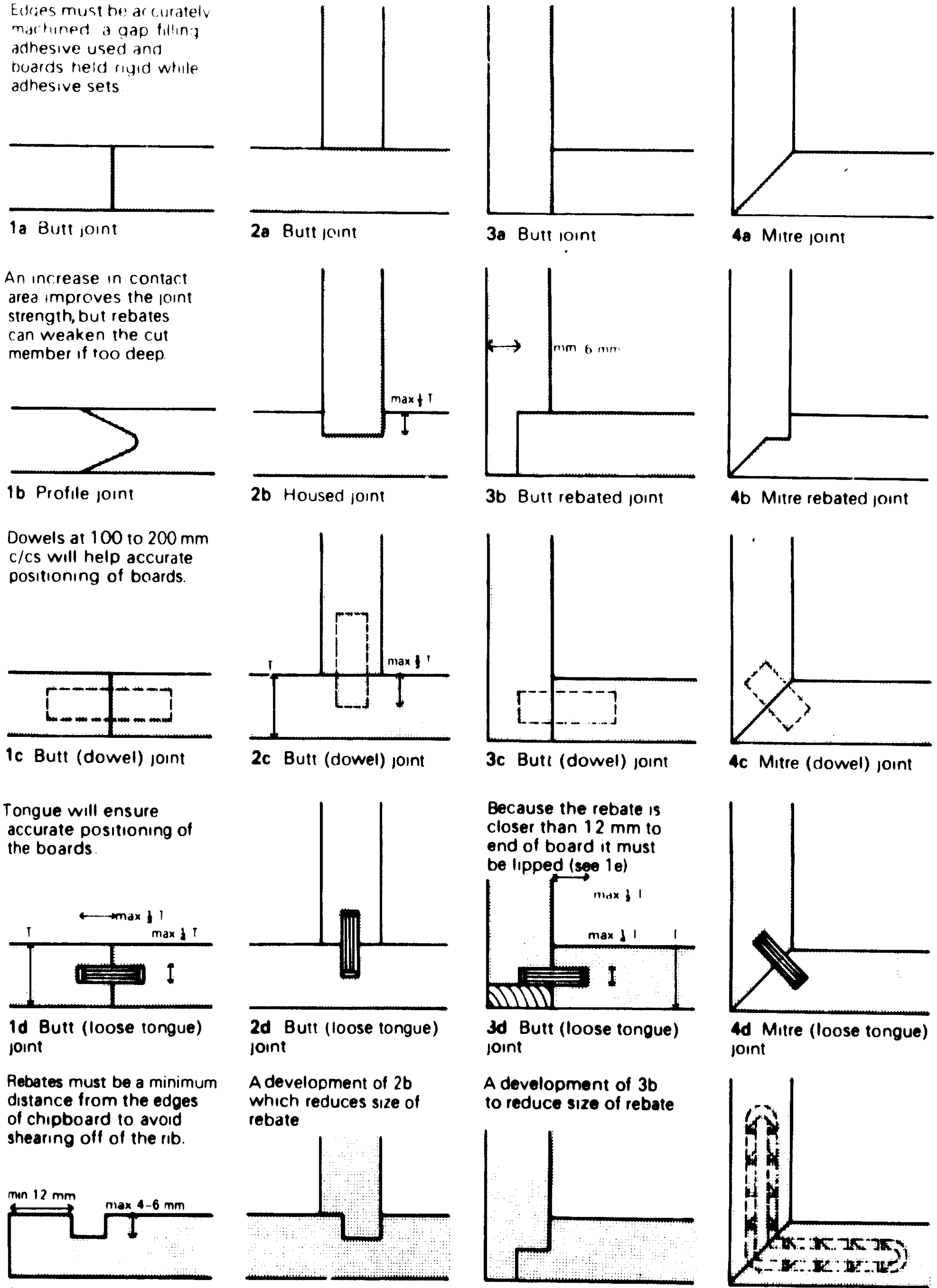


Figure VI. V-grooving for edge folding and doubling



Carcass joints



Edges must be accurately machined, a gap filling adhesive used and boards held rigid while adhesive sets.

1a Butt joint

2a Butt joint

3a Butt joint

4a Mitre joint

An increase in contact area improves the joint strength, but rebates can weaken the cut member if too deep.

1b Profile joint

2b Housed joint

3b Butt rebated joint

4b Mitre rebated joint

Dowels at 100 to 200 mm c/cs will help accurate positioning of boards.

1c Butt (dowel) joint

2c Butt (dowel) joint

3c Butt (dowel) joint

4c Mitre (dowel) joint

Tongue will ensure accurate positioning of the boards.

Because the rebate is closer than 12 mm to end of board it must be lipped (see 1e)

1d Butt (loose tongue) joint

2d Butt (loose tongue) joint

3d Butt (loose tongue) joint

4d Mitre (loose tongue) joint

Rebates must be a minimum distance from the edges of chipboard to avoid shearing off of the rib.

A development of 2b which reduces size of rebate

A development of 3b to reduce size of rebate

1e Edge rebates

2e Rebated housing

3e Butt double-rebated joint

4e Mitre (nylon 'L' dowel) joint

Figure VIII. Edge-banding and lipping

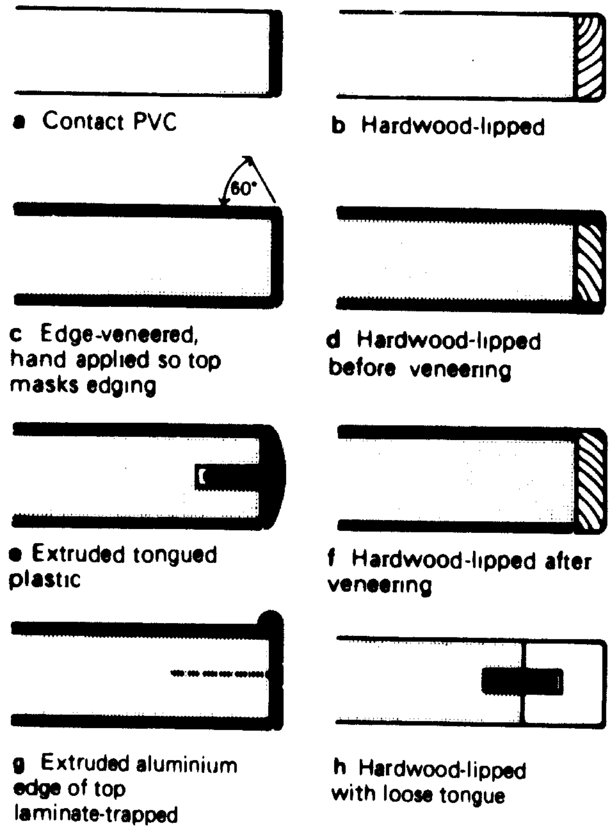
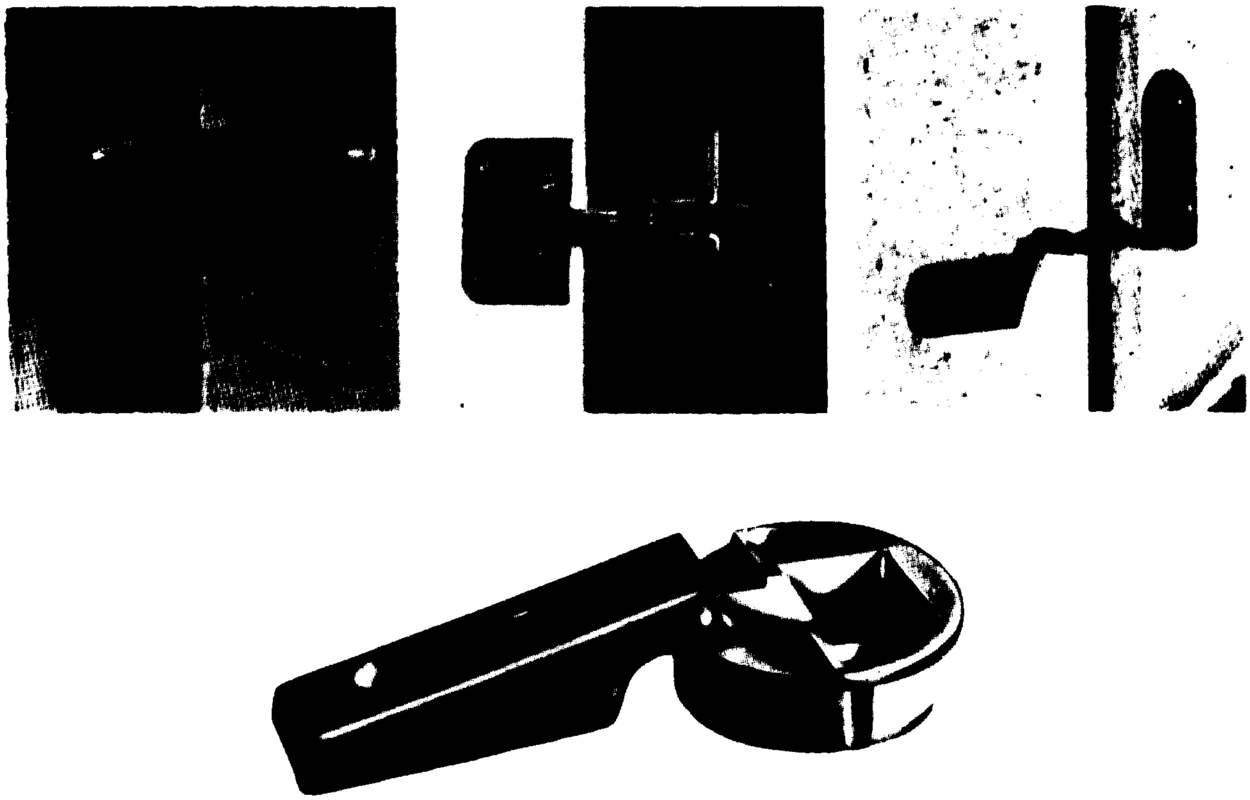


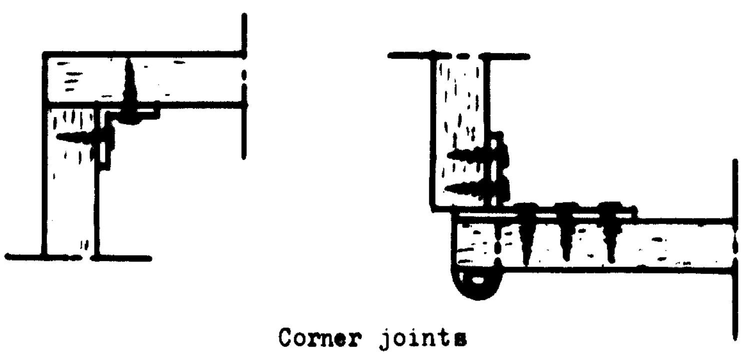
Figure IX. Particle-board screw

requires a bored hole on the door panel, which is very practical because boring is the simplest of all machining methods. The other side of the hinge is fixed with screws directly on the inside surface of the cabinet side panel. Only 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 X).

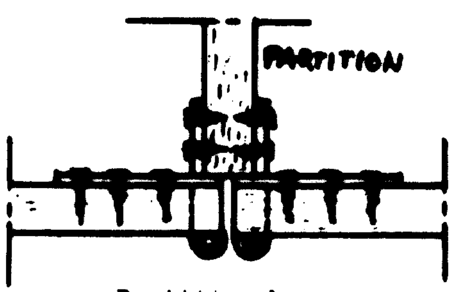
Figure X. Some metallic hardware suitable for use with particle board



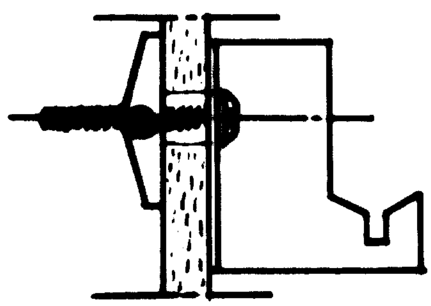
Hinges



Corner joints



Partition braces



Toggle bolt

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.

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Limited distribution.

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Limited distribution.

V. The use of fibre building board in the joinery industry*

In every country, new dwellings are needed and old ones must be kept in good condition and modernized. Stipulating the level of requirements for huildings and furniture is a matter of standardization that ranges beyond national borders. Standardization refers to huildings, dimensions and the choice and correct use of materials. The joinery and furniture industries are important elements of this complex and have become well-automated branches of production.

In most parts of the world, wood is a basic material in the construction of housing and furnishings. Although it is one of the oldest of the traditional materials, its usefulness and use is increasing hecause of its compatibility with plastics. Indeed, hecause of its desirable characteristics, wood is often the model for newly designed plastics. While still commonly used in its natural solid form, wood is now often decomposed and recomposed into new forms. One of the more interesting of these is fihre building board, which is made from fibrous materials such as wood pulp and waste paper. It is widely used in the joinery industry.

Types of fibre building board

The classification of fibre building hoards into different types is based on the method of manufacture, the mode and circumstances of use and the density in kg/m^3. Density forms the basis of the existing international classification of fihre building board. The classification system of the International Organization for Standardization (ISO) is as follows:

Board type	*Density (kg/m³)*	*Thickness (mm)*
Hardboard	>800	2 to 8
Medium board	>350 <800	6 to 30
Softboard	<350	9 to 32

Such a wide density scale guarantees a wide range of use for fibre building board with the possibility of choosing the right type of board for each purpose. In the joinery industry, principally hardboard and medium board are used, i.e. relative density range from 0.65 to 1.20. Softboard is used in the building industry as decorating and insulating board. It is particularly useful in moist places when impreganted with bitumen.

The strength and mechanical properties of some fibre building boards are shown in table 1.

The world fibre building board industry

Fibre building board mills were first built to utilize residues from sawmills and paper mills or to utilize inferior raw materials. This new industry first secured a foothold in the United States of America and in the Scandinavian countries. The production of softboard grew rapidly in the United States, but for a long time the Mason hardboard patent restricted the production of hardboard elsewhere. In Europe the manufacture of hardboard and medium board went ahead rapidly after the introduction of Asplund's new production method in Sweden. Since that time the output of these boards has risen continuously throughout the world. The most recent development in the production of hardboard and medium board is the dry process, which is particularly popular in places where water pollution owing to waste-water from fibreboard production is a serious problem.

Hardboard represented 77 per cent of the total fibre building board production of Finland in 1967. The good properties of medium board, its wide range of thicknesses and densities, and its ability to compete with particle board and plywood for indoor and outdoor use have contributed to the increase in production of this type of board.

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*By Anjal Kaila, Heinolan Faneritehdas Zachariassen and Co., Heinola, Finland. (Originally issued as document ID/WG.105/25/Rev.1.) This chapter contains additional material excerpted from "The requirements and use of wood-based panels in furniture manufacture" (ID/WG.209/1).

TABLE 1. MECHANICAL PROPERTIES OF SOME FIBREBOARDS[a]

Property	Units	Value for structural insulating board	Value for medium board[b]	Value for special densified medium board[c]	Value for high density hardboard[c]	Value for tempered hardboard	Value for special densified hardboard
Density	kg/m³	160-480	529-800	810-848	800-1 280	960-1 280	1 360-1 440
Specific gravity	10³ N/mm²	0.16-0.48	0.53-0.80	0.81-0.85	0.80-1.28	0.96-1.28	1.36-1.44
Modulus of elasticity (bending)	10³N/mm²	0.18-0.89	2.28-3.94	3.10-4.26	2.81-5.62	4.57 7.73	8.79
Modulus of rupture	N/mm²	1.40-5.62	13.36-33.75	28-42	21.1-49.2	29.4-70.3	70.3-87.9
Tensile strength parallel to surface	N/mm²	1.40-3.50	10.0-15.0	18.0-23.0	21.1-42.2	25.3-54.8	55.0
Tensile strength perpendicular to surface	N/mm²	0.07-0.18	0.3-0.6	0.5-0.8	0.7-2.5	1.12-3.16	3.51
Compressive strength parallel to surface	N/mm²		10.0-12.0	14.0-16.0	12.7-42.2	26.0-42.2	186.3
Shear strength (in plane of board)	N/mm²					3.0-5.9	
Shear strength (across plane of board)	N/mm²					19.7-23.9	
24-hour water absorption	Per cent by volume	1-10					
24-hour water absorption	Per cent by weight		9-14	7.5-10	3-30	3-20	0.3-1.2
Thickness swelling (24-hour soaking)	Per cent		2-5	5-6	10-25	8-15	
Linear expansion from 50 to 90 per cent r.h.[d]	Per cent	0.2-0.5	0.2-0.4	0.20-0.30	0.15-0.45	0.15-0.45	
Thermal conductivity at mean temperature of 24°C	Joule cm/cm²/hour/°C	1.40-2.39	2.80-3.89	3.0-4.0	3.89-7.27	3.89-7.78	9.60

Source: Forest Products Laboratory, Madison, Wisconsin, United States of America (1967).

[a]The data presented are general round-figure values accumulated from numerous sources. For more exact figures on specific products, individual manufacturers should be consulted or tests made. The values are for general laboratory conditions of temperature and humidity.

[b]Medium hardboard especially manufactured for siding use and therefore with high moisture resistance.

[c]Medium board for external uses.

[d]Measurements made on material at equilibrium at each condition of room temperature.

World productive capacity

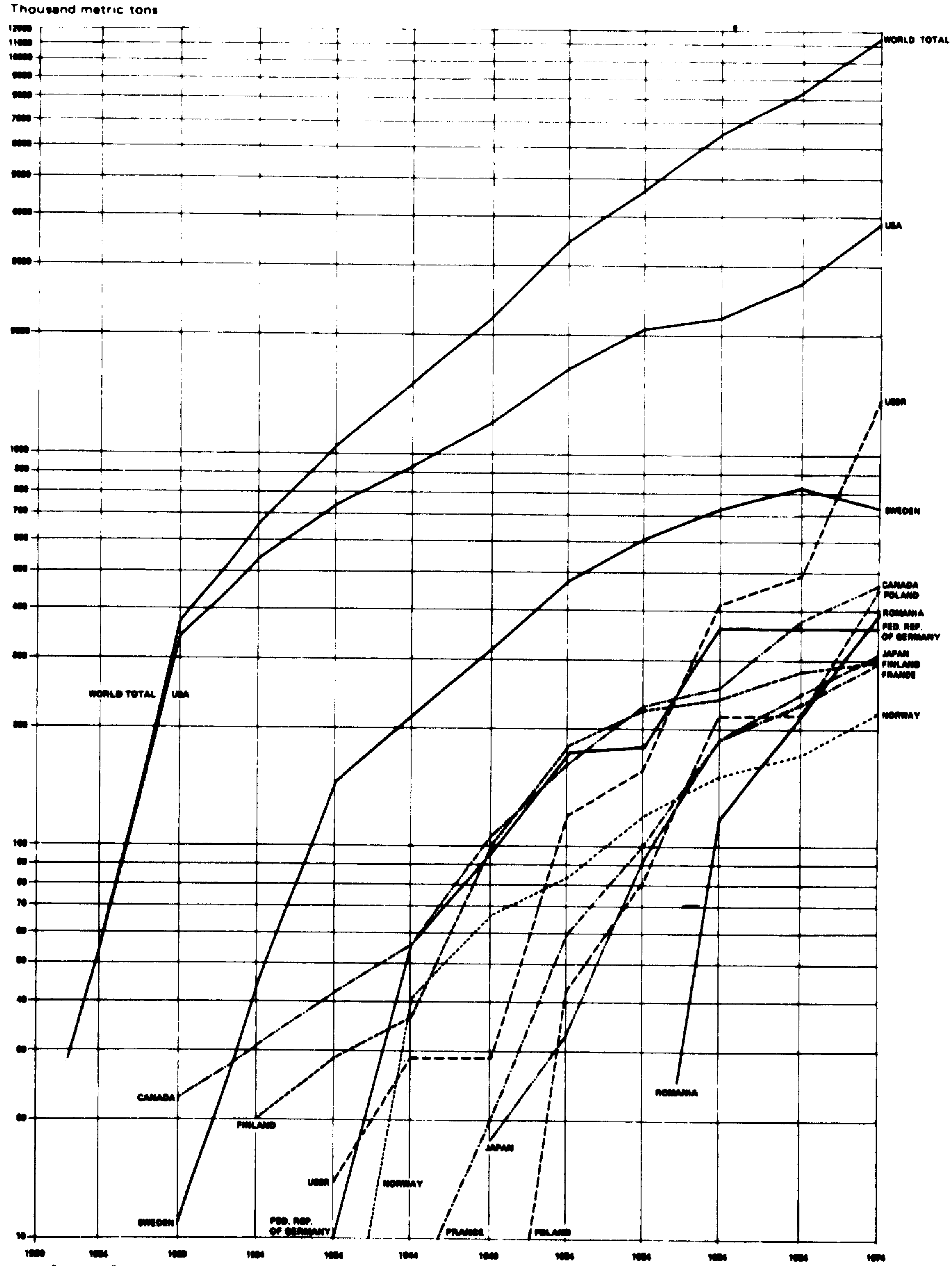
In 1971, world production capacity was approximately 9 million tons, and world forecast for the growth in production for 1970-1980 is 5.2 per cent per annum. The productive capacity in various countries is shown in figure I, and the regional development of capacity of the fibreboard industry between 1934 and 1974 is shown in figure II.

At present, there is unused production capacity both in Europe and in the United States, resulting in stagnation in the growth of the industry. This slump is caused by lack of cheap raw material. In the developing countries, on the other hand, where the fibre building board industry is not yet advanced, it seems probable that where there is a market, available raw material and industrial potential, the industry should be able to grow. The need for foreign currency is one of the main problems hindering the development of forest-based industries, both for the domestic market and for export. In regions where there is overproduction, the industry will have to concentrate on special products and processing.

The total progress of forest-based industries in developing countries has not completely met the demands made on it. In 1967 the Food and Agriculture Organization of the United Nations (FAO) presented a study concerning the world-wide need of investments in forestry and forest-based industries in 1961-1975. In that study $39 billion were ascribed to the expansion of forest-based industries; the share of wooden board-making industry was $3.3 billion, of which the share of developing countries was 22 per cent, that is, $750 million.

Many different factors influence the capability of forest-based industries to compete in the developing countries. Until now, the developing countries have been unable, to any considerable degree, to export the products of their forest-based industries to the industrialized countries, where equivalent raw materials have been available.

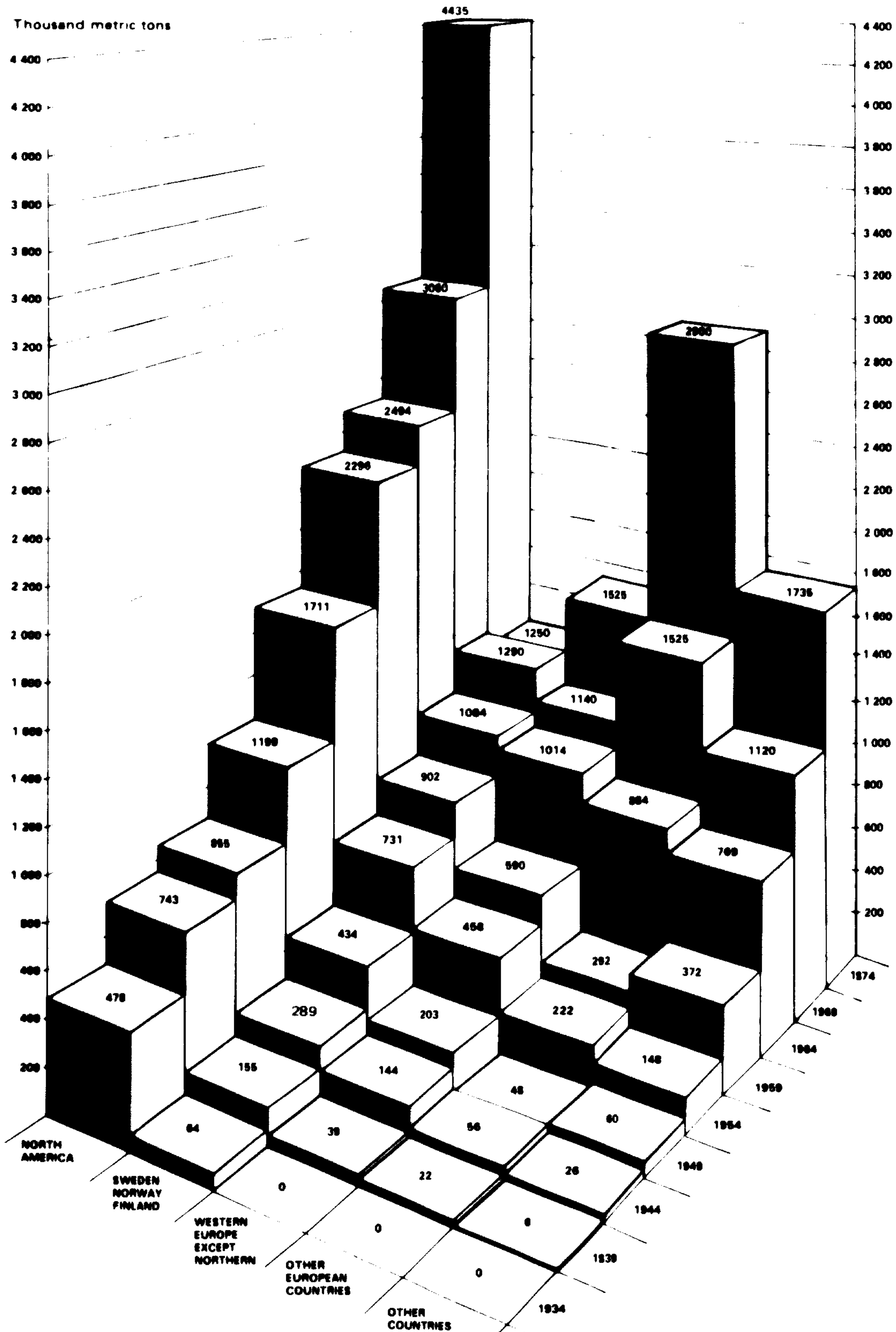
Figure I. Capacity of the fibreboard industry in the world and in selected countries, 1922-1974



Source: Fibreboard Industry and Trade: some statistical data. 13th rev. ed. Stockholm, November 1974. © Copyright Defibrator, 1974. 57 p.

Note: Capacities at end of five-year periods plotted on logarithmic scale. Equal vertical distances denote equal percentage changes.

Figure II Regional development of the capacity of the fibreboard industry, 1934-1974



NORTH AMERICA
CANADA
CUBA
MEXICO
USA

WESTERN EUROPE
AUSTRIA
BELGIUM
DENMARK
FED. REP. OF GERMANY
FRANCE
IRELAND
ITALY
NETHERLANDS
PORTUGAL
SPAIN
SWITZERLAND
UNITED KINGDOM
YUGOSLAVIA

OTHER EUROPEAN COUNTRIES
CZECHOSLOVAKIA
GERMAN DEM. REP.
HUNGARY
POLAND
ROMANIA
USSR

OTHER COUNTRIES IN
AFRICA
ASIA
LATIN AMERICA
and
AUSTRALIA
NEW ZEALAND

Note Capacities at end of five-year periods.

The situation is changing, however, as suitable raw materials are decreasing in the industrialized countries. However, irrespective of the raw material used, the utilization and development of forest resources in the developing countries is hampered by many difficulties, among them:

- Need for greater investment funds (25 to 50 per cent more)
- Need for planning and engineering work
- Difficulties in building, installation and maintenance
- Increased freight charges
- Low production efficiency
- Availability of auxiliary substances
- Problems of power and energy supply
- Marketing efficiency
- Inadequacy of home market and distribution system
- High rates of interest

The share of developing countries in the world production of fibreboard was about 5 per cent in 1967 (see table 2). In all probability the importance of fibreboard is greater in developing countries with limited resources of logs for sawnwood and plywood. The development of large enough markets for fibreboard and particle board to warrant mass production has been a bottle-neck in almost all developing countries. The solution of this problem may still be far in the future; information about resources and well-organized projects are still lacking. As regards the products of forest industries, the developing countries will probably reach self-sufficiency as early as the 1980s when they will start to export to industrialized countries.

TABLE 2. PRODUCTION, EXPORTS AND IMPORTS OF FIBREBOARD, 1957-1967

	Production (million tons)		*Percentage growth*	*Exports (million tons)*		*Percentage growth*	*Imports (million tons)*		*Percentage growth*
	1957	*1967*	*1957-1967*	*1957*	*1967*	*1957-1967*	*1957*	*1967*	*1957-1967*
World	3.42	6.18	6.1	0.62	1.15	16.3	0.53	1.16	8.1
Scandinavian countries	0.74	1.02	3.2	0.44	0.58	2.9	0.00	0.00	
Developing countries	0.10	0.29	10.9	0.00	0.03	20.0	0.07	0.12	5.5
Percentage share of world	3.0	4.7		0.8	2.7		13.2	10.3	

Per capita consumption of fibreboard

The consumption of fibreboard depends primarily on local conditions, climate, level of income, technical production, competing products, customer service, market conditions and research activities. The Nordic countries lead in the consumption of fibre building board, but there has been a glut of this material for some time, largely because of the high consumption of competing products. Figure III shows *per capita* consumption of fibreboard and *per capita* GNP for 1965-1971 in selected countries. Figure IV shows consumption of fibreboard for 1950-1970 and estimated requirements of fibreboard for 1975 by region.

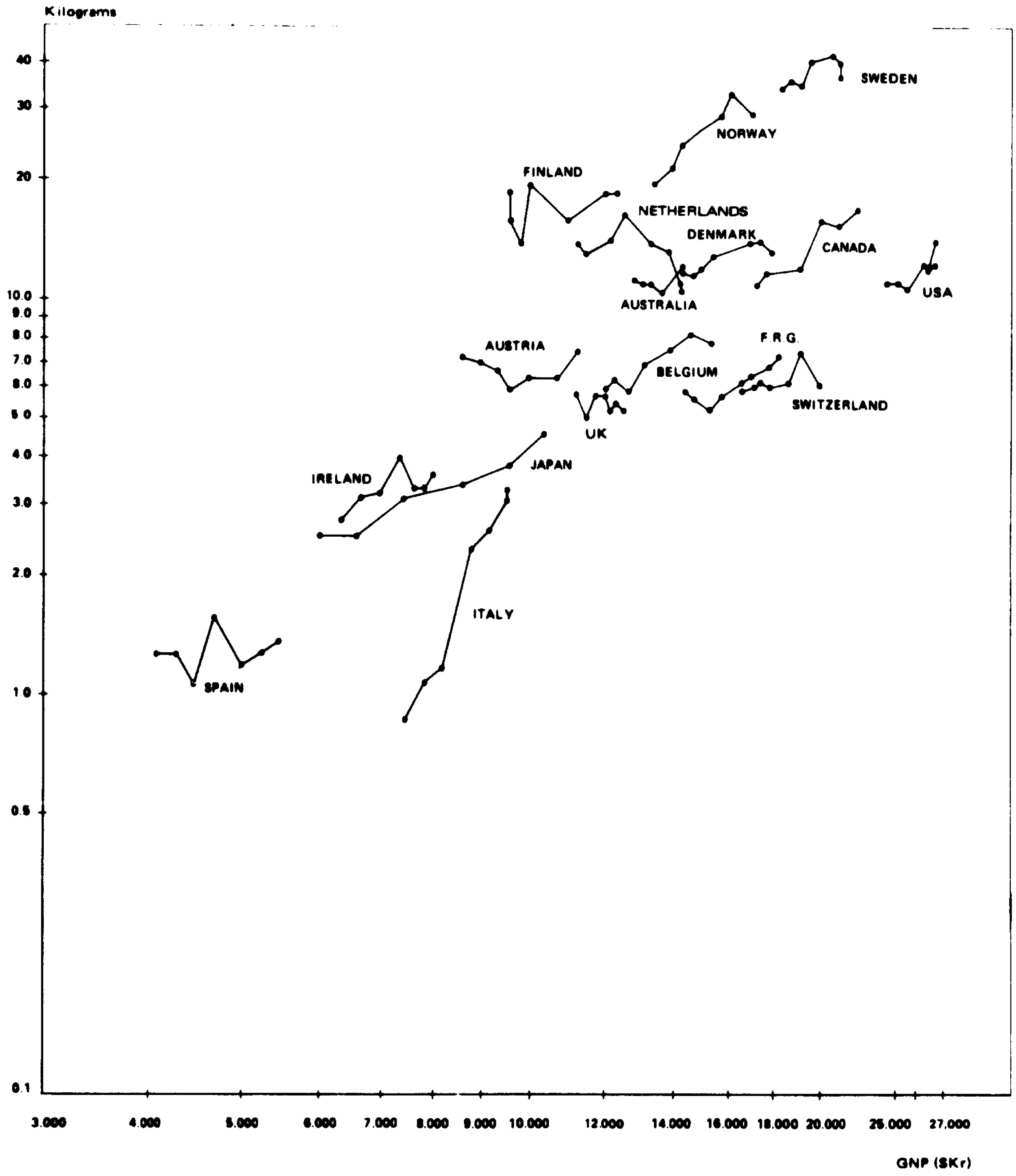
The housing industry is a major consumer of fibreboard in the Nordic countries and it seems likely that a similar correlation between housing construction and board consumption exists in other countries.

Use of fibreboard in the furniture industry

The furniture industry uses primarily medium and hard fibreboard, that is, with specific gravities in the 0.65 to 1.20 range. The greatest demand comes from the building trades; one major use of fibreboard is for kitchen cupboards, backs and floors of furniture and drawer bottoms. Profile-pressed and punched hardboard and medium board are much used by the radio, television and furniture industries, especially as TV tube surrounds and loudspeaker grilles.

Recently the use has grown of double hardboard skins bonded to both sides of solid-wood frames with a supporting centre of light-weight paper cores (as in flush-door construction) for furniture, especially for kitchen and built-in storage furniture, and as doors in large wardrobes.

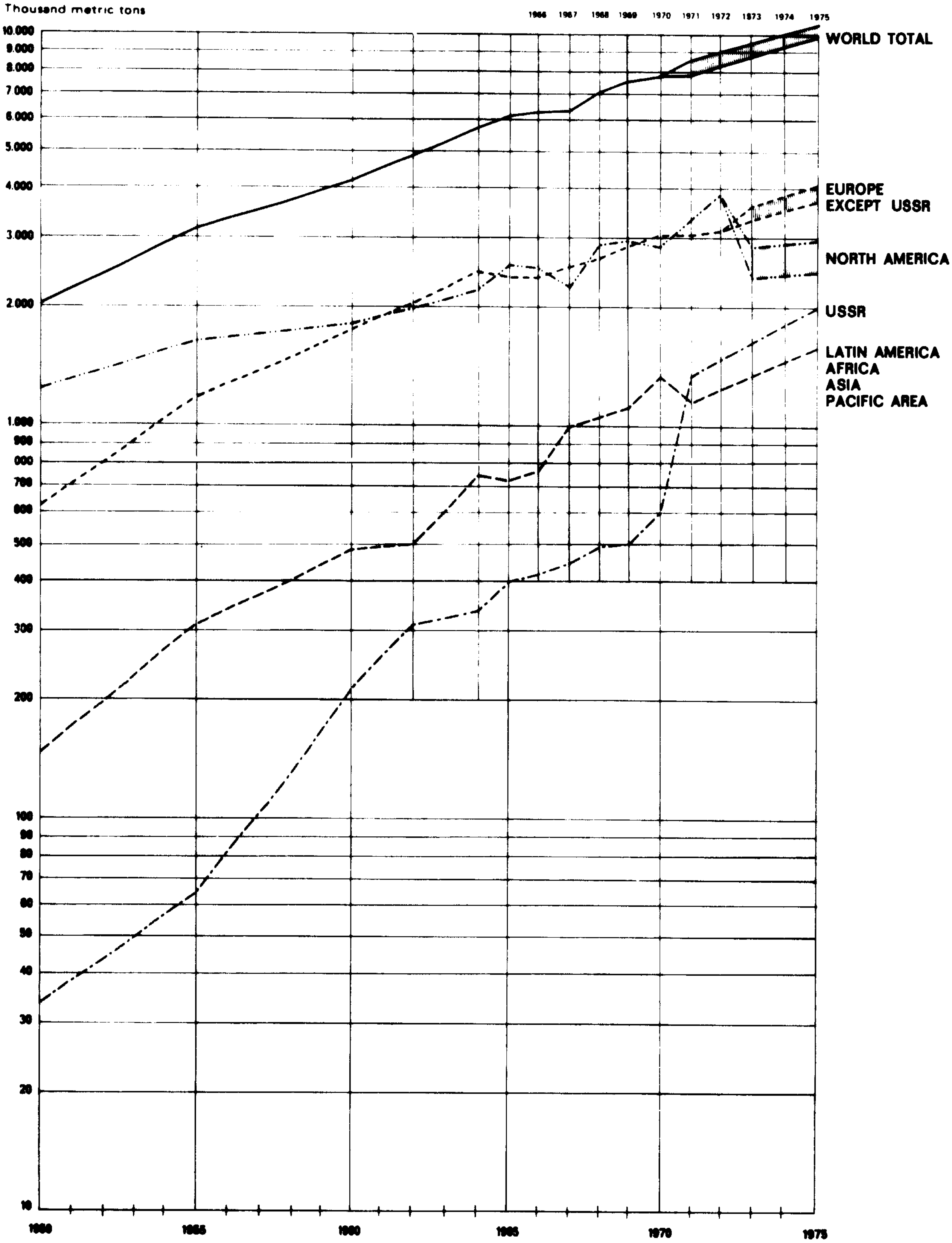
Figure III. Fibreboard consumption *per capita* and GNP *per capita* in selected countries, 1965-1971



Sources: FAO, ECE, *Timber Bulletin for Europe;* FAO, *Production Yearbook, 1969;* FAO, *Production Yearbook, 1971;* OECD, *Main economic indicators* (October 1973).

Note: Per capita GNP at 1971 prices.

Figure IV. Consumption of fibreboard, 1950-1972, and estimated requirements for 1975



Source: FAO.

Note: The higher and lower estimates made are represented by the lines bordering the shaded areas. Equal vertical distances denote equal percentage changes.

Fibreboard may be produced with finely ground particles comprising the surface, so that it is compact and can be sanded to a very smooth finish. It works very little parallel to the surface and when impregnated with a glue or drying oil. Fine sanding followed by painting results in excellent flush-door panels. It can readily be:

- *(a)* Covered with ivory pulp (with groundwood pulp);
- *(b)* Primed (puttied or filled);
- *(c)* Painted or lacquered;
- *(d)* Printed (roller-coated or by silk screen);
- *(e)* Impregnated with monomers and cured by radiation;
- *(f)* Laminated with melamine, urea, phenol, polyester, plastic veneer or polyvinyl chloride (PVC), either soft, hard or semihard.

Types *(a)-(d)* are used commonly for the backs of closets, drawer and bed bottoms, baseboards in cupboards and closets and for the backs of desks, dressers and commodes. It can be produced to a very close tolerance (± 0.2 mm is standard) a very important criterion for furniture manufacturers who order cut-to-size pieces.

Raw materials of fibre building board

The problem of securing raw materials for the fibre building board industry is quantitative and economic rather than technical. Research may lead to a technical process that would utilize any kind of raw material from wood and plant fibre to tree bark. Resins can be used to impart strength to the boards, and various sizing agents are available to make them water resistant. When wood fibres are used, the raw material costs in Europe represent 20 to 40 per cent of the total costs, depending upon the size of the mill and the manufacturing process. The factors that most frequently determine the siting of fibreboard mills are the costs of labour, transport and the handling and storage of raw material, together with those of marketing the end-product.

As regards raw materials, the possibilities of planting fast-growing forests are good. For example, eucalyptus trees, which are very good raw material for hard and semihard fibreboard, can be grown in 6-to-15-year cycles. The annual growth is 10 to 60 m^3. Similar growth rates are also reached by poplar, willow and many tropical hardwoods and pine species with suitable fibre qualities. These can be grown for fibre wood in 12-to-20-year cycles, with annual growth rates of 10 to 40 m^3/ha. With concentrated fields of raw material, the advantage of uniformity of pulp and board qualities is achieved. These facts strongly support the possibilities of forest industry in developing countries.

Methods of producing fibre building board

Fibre building board is of two principal kinds: compressed and non-compressed. The compressed boards are made with either the transport of the fibres by water (the wet and wet-dry processes) or by air (the semi-dry and dry processes). All non-compressed boards are made by a wet process that involves the transport of the fibres by water. In the wet process, the wet lap is gathered by means of water. However, abundant water is not available everywhere or the mill waste-water may pollute the surroundings, in which case the so-called dry process must be used. By these processes hardboard and medium board in thicknesses of 2.0 to 30 mm are manufactured in a density range of 600 to 1,200 kg/m^3.

Non-compressed boards are manufactured by the wet process, and the wet lap is treated by a drying device. The product is softboard in thicknesses of 9 to 32 mm in a density range of 250 to 350 kg/m^3. This board is primarily used as insulation board.

The choice of process depends on the desired product. It may be a board smooth on one or both sides, thin or thick, light or heavy. Thick (> 8 mm) and light board is most economically manufactured by the dry process, whereas it is better to manufacture thin (< 8 mm) and heavy board by the wet process. Both boards have a long-established use in the joinery industry.

A hardboard or medium board with good dimensional stability is obtained with various types of resin and paraffin, according to the quality desired before it is compressed and dried. For use in exceptionally high humidity the board is saturated with a drying oil to which fungi and termite protectives may be added.

Properties of fibre building board

Hardboard should be regarded primarily as a surface material for indoor use, whereas medium board is a joinery and surface material that can be used successfully in moist places as well as out of doors. The manufacture of fibreboard is adjusting to the production of boards for special purposes as well as those for general use. ISO has already progressed far in establishing standards for fibre building board production, such as:

ISO Recommendation R 766: Determination of dimensions of test pieces
ISO Recommendation R 767: Determination of moisture content

ISO Recommendation R 768: Determination of bending strength
ISO Recommendation R 769: Determination of water absorption
ISO Recommendation R 818: Definition. Classification

The manufacture of boards with special properties is becoming predominant. Some of the special varieties are:

(a) Hardboards and medium boards of construction grades, with special qualities such as strength, workability, dimensional stability and fire resistance;

(b) Boards pre-covered with paint, plastic and so on;

(c) Boards of grades suitable for certain elements and constructions;

(d) Boards with dimensions standardized on millimetre or module (M = 100 mm) bases.

The use of hardboard and medium board in the joinery industry[1]

Although the joinery industry is becoming increasingly rationalized, it is still characterized by a high labour input. Its level of efficiency is determined by the size of the production series, and long series imply uniformity of raw material and evenness of quality.

Because of their homogeneity and special properties, hardboard and medium board are well suited to the joinery industry. Some of these properties are common to both types of board, among them surface characteristics, workability, small tolerances, strength properties, "working" and dimensional stability and impact resistance; the specific qualities of medium board include screw-holding characteristics, heat- and sound-insulating qualities and resistance to moisture. These properties are considered individually in the section that follows.

Surface characteristics[2]

In general, the surface of a fibreboard is made up of finely ground and well-glued fibres; it is thus compact and good for sanding, and it adheres well to the base fibres. A good surface of a fibreboard should be smooth, with homogeneous fibres. Paint adhesion should be good and the amount of paint needed should be small (an alkyd paint, sprayed on, should yield a glossy surface with 22 g of paint per square metre—see figure V); or a two-component acid catalyst paint, applied by the curtain-flow technique, should yield a glossy surface with 60 to 80 g of paint per square metre. With a view to sanding, the surface layer should be 0.5 mm thick. The surface should be able to pass a moisture-resistance test (relative humidities of 30 to 65 per cent and 65 to 90 per cent) without the fibres rising or the bottom showing through. The surface fibres should not generate tension in the board.

A special surface quality can be obtained by impregnation with a glue or drying oil; boards of this kind can be sanded finally at the mill. Their consumption of paint is small, and their even surface and quality have made them particularly popular for the manufacture of doors.

Workability

The joinery properties that are most important in fibreboard cannot be expressed in figures, but they are important none the less. First of all, the board should have good edges and surfaces and be slightly brittle but yet tough; in brief, it should be easy to work with ordinary tools. Attempts have been made to express all this numerically, but so far to no avail. These properties are not directly proportional to the specific gravity but rather to the variations in quality that occur in connexion with changes in the properties of the raw material in pulp refining, gluing and heat tempering. On the other hand, the specific gravity being low, the board has better dimensional stability, that is, it warps less easily.

Both hardboard and medium board can be worked easily. They can be sawn, planed, bored, perforated, milled and cut. A good board does not crack, split or become fluffy when being worked by hard metal cutters under normal conditions. Qualities that suit these boards particularly well for the joinery industry are the smoothness of the surface layer and the evenness of the edges even after being worked.

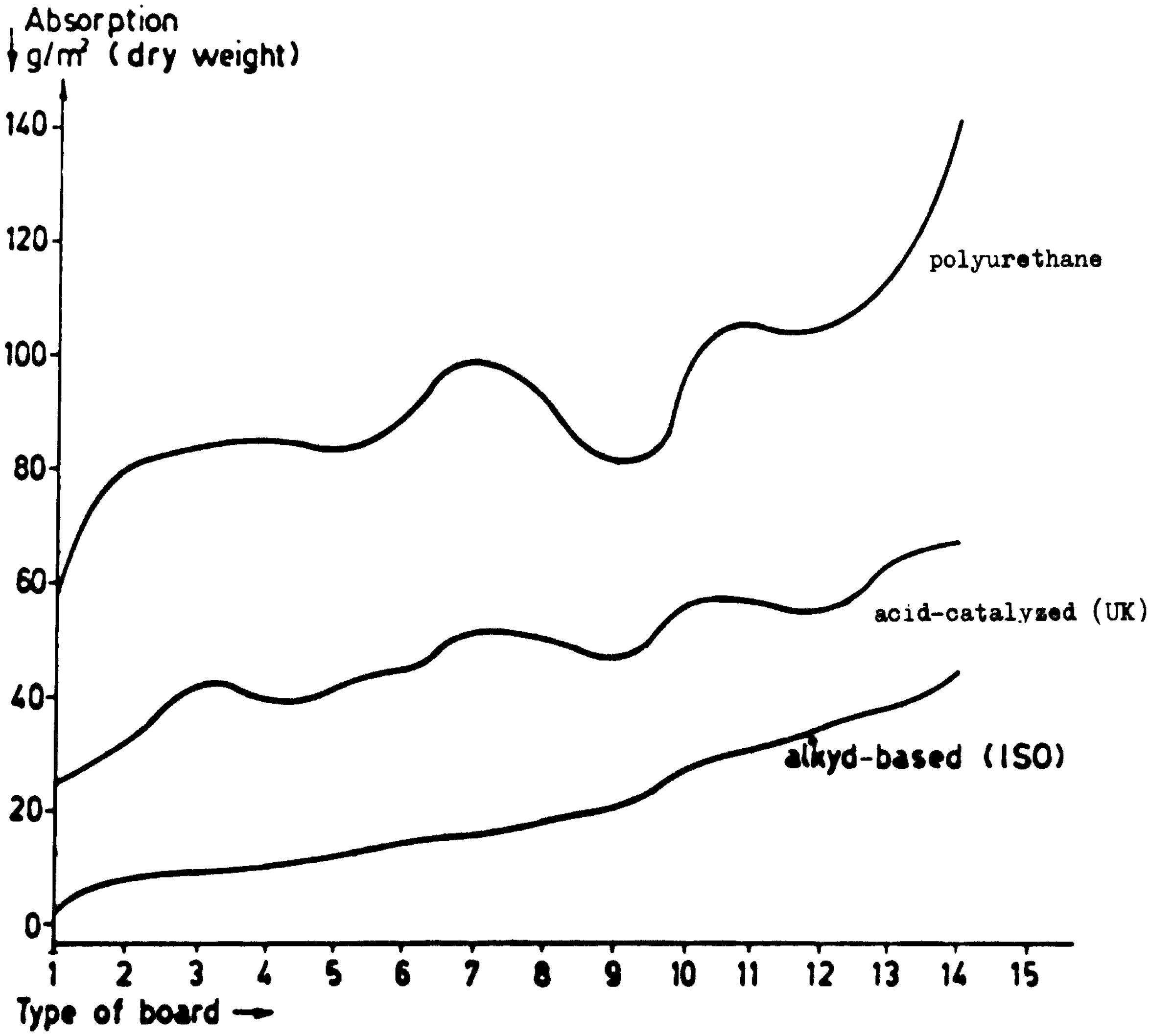
Small tolerances

All medium boards are now calibrated, and at the buyer's request hardboard is calibrated to ± 0.2 mm accuracy. Length and width tolerances, edge straightness and squareness have been standardized. Boards can also be manufactured to an accuracy desired by the buyer.

[1] See also part two, chapter XIX, "Joinery industry technology".

[2] See also chapter VI, "Properties and uses of paper-based decorative plastic laminate board", and part two, chapter XX, "The surface finishing of wood and wooden products".

Figure V. Results of tests of covering ability of three types of paint on 15 representative hardboards from various mills



Strength properties

The strength properties common to hardboard and medium board are, in general, satisfactory for the joinery industry. The rigidity of the board increases with increase in thickness. It is to be noted, however, that fibreboard is a viscoelastic material (figure VI), stretching when subjected to loads of long duration (figure VII). The Forest Products Research Laboratory (FPRL)[3] has reported that the basic bending stress for 4.8-mm hardboard is generally comparable to that for plywood, but that the modulus of elasticity of the former is only from one third to one half of that of the latter.

When boards are covered with hard, shrinking overlays, the tensile strength perpendicular to the surface must be observed, since it may become critical if the board is given a plastic cover that shrinks on one side; a balancing film is therefore necessary. With hardboard, the tensile strength against the surface should be at least 0.8 N/mm². Too low a tensile strength may cause the film to crack and split, as in the case shown in figure VIII.

[3] The name of this organization has been changed to Princes Risborough Laboratory, Building Research Establishment. Its address is Princes Risborough, Bucks, United Kingdom.

Figure VI. Tensile strain of four 3.2-mm hardboards versus loading time. Relative humidity 73 per cent. Linear extrapolations are marked with broken lines

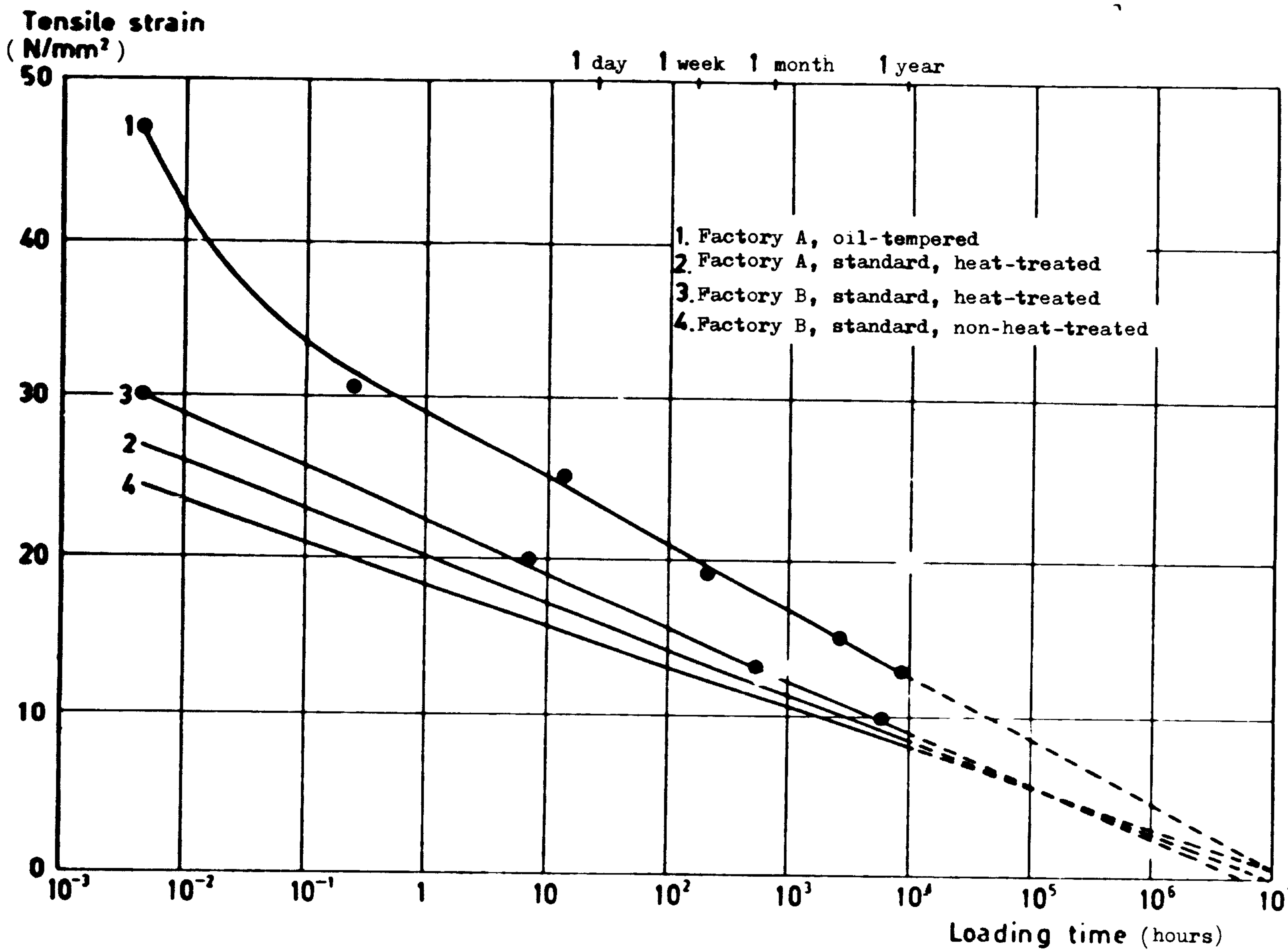


Figure VII. The elongations for an untempered, average (air-dried, 165 C) and a well heat-treated (steam-dried, 205 C) Asplund medium board *versus* loading time

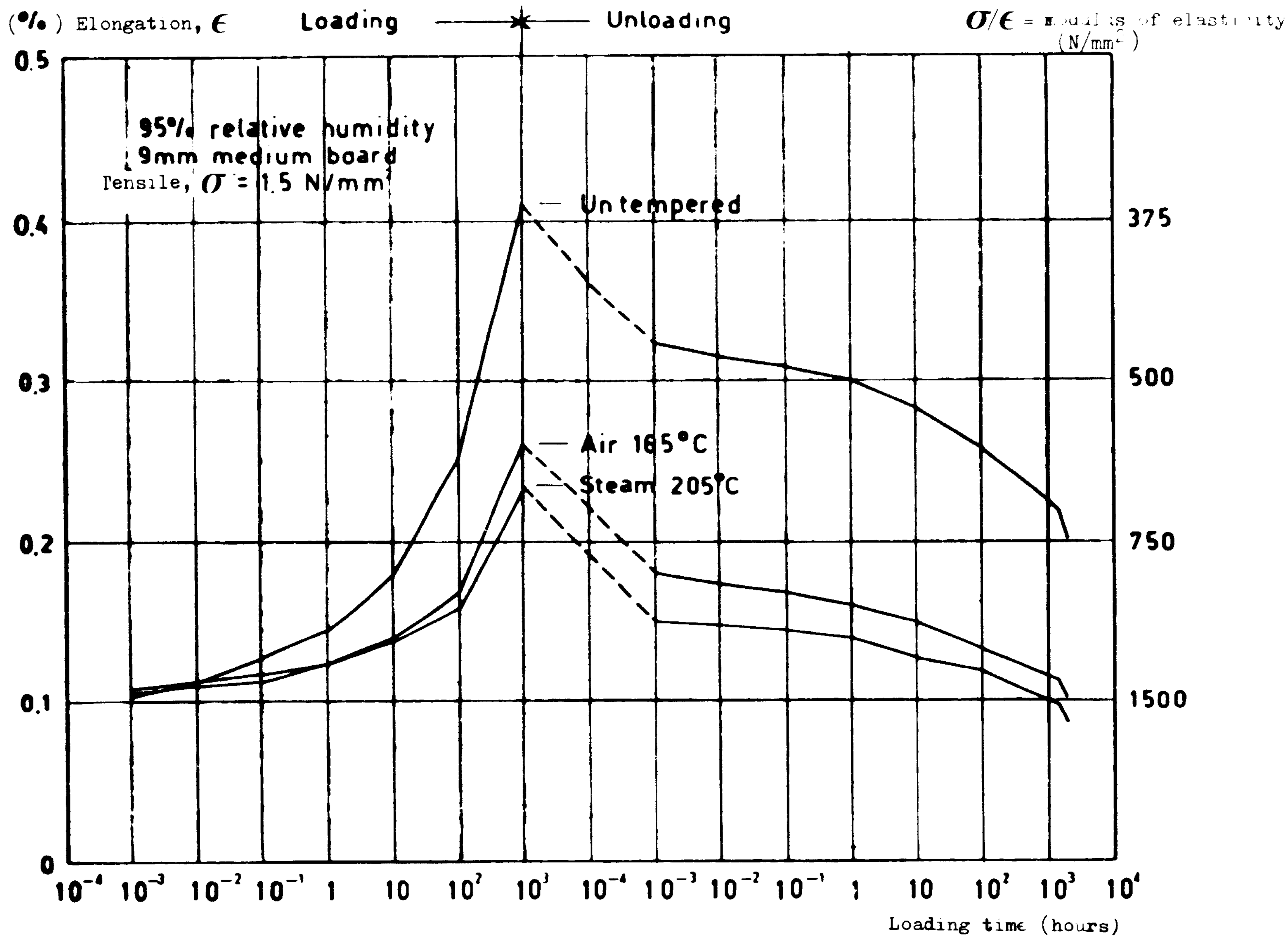
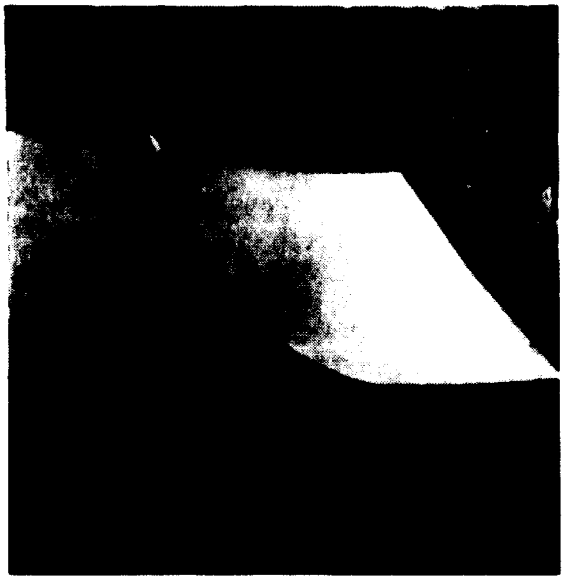


Figure VIII. Cracking and loosening of a melamine-urea resin top layer from its hardboard base because of its poor (< 0.4 N/mm^2) tensile strength perpendicular to the surface



Working and dimensional stability

All wooden boards "work" (move) according to the relative humidity of the ambient air. To a small extent, fibreboards work both lengthwise and crosswise, but more perceptibly in the direction of thickness, where there are tensions derived from compression which strive to be liberated. Such working is permanent or varying according to whether the relative humidity in the place where the board is being used is permanent or variable (figure IX). The lower the equilibrium moisture content of a board, the less it will work.

Form stability means resistance to stresses that tend to buckle the board when the relative humidity is extremely high, that is, around 90 per cent. If the board is fastened or supported at its long edges, high humidity will cause a swelling unrelated to the thickness of the board. Conversely, low humidity may lead to cracking because of shrinkage.

Fibreboard that has been correctly heat-treated and moistened works so little that it is satisfactory for the joinery industry, but in the building industry, where fibreboard is used outdoors, working is allowed for constructive means (figure X).

Impact resistance

In certain constructions, such as honeycomb sandwich doors, the impact resistance of fibreboard is important. The surface of fibreboard used for this purpose should withstand dynamic strain as long as the product is used. In the hard-body impact test, the panels are supported horizontally by 15-mm-wide strips along both of the 900-mm edges and along the bottom 600-mm edge. The upper edge is not supported. A 50-mm steel ball weighing 520 g is dropped from a point 735 mm above the panel surface; its energy at the moment of impact is 3.75 joules, as required by the draft standard (figure XI). Immediately after impact, the imprint depth is measured, using a dial gauge instrument (figure XII).

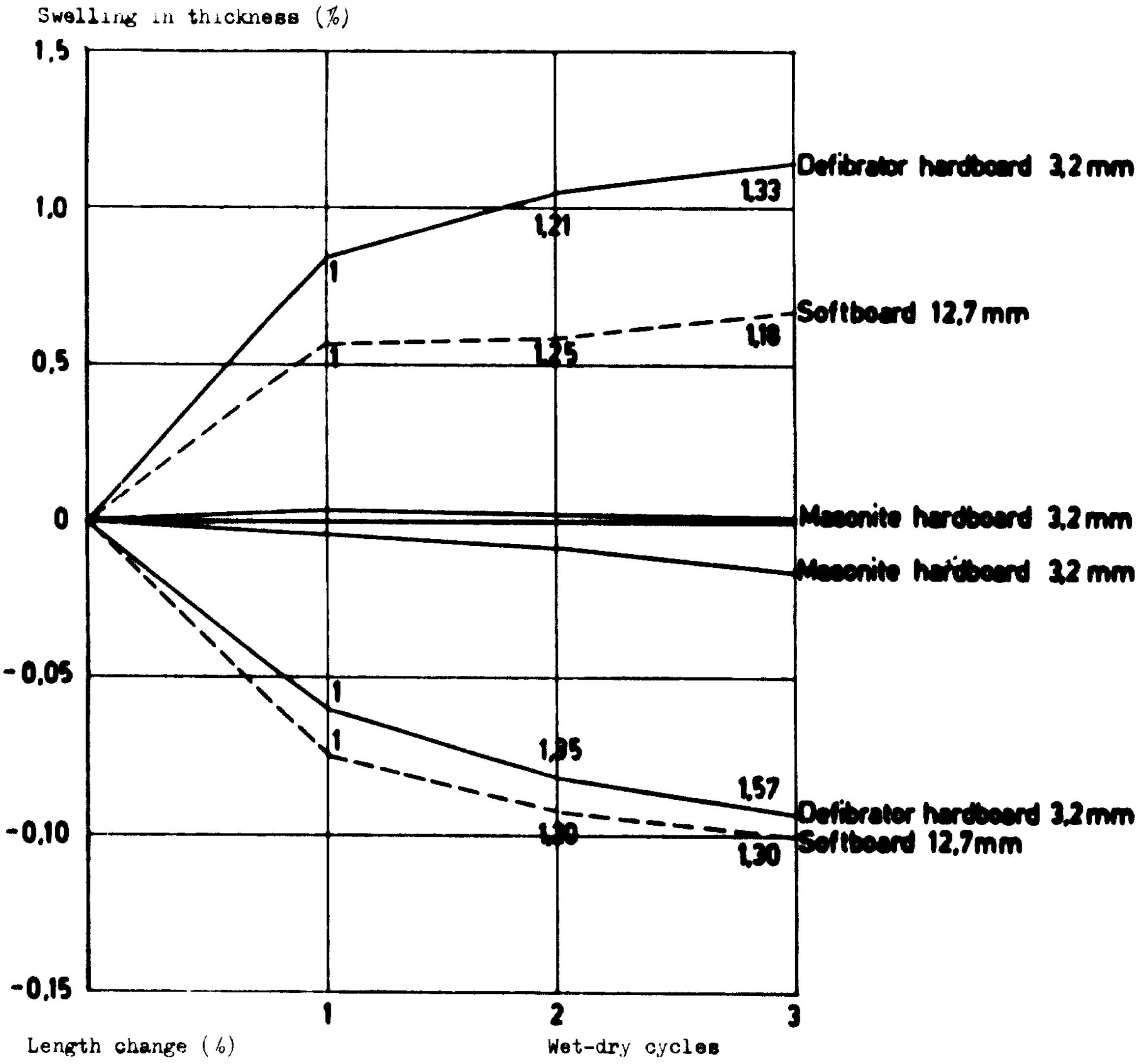
Screw-holding characteristics

Driving screws into the edge of even thick medium board is not advisable. Side framings are generally used when attaching hinges to the surface of the board (see figure X).

Heat and sound insulation

Medium board can be used in constructions where a moderate heat and sound insulation is required. Softboard fulfils the maximum requirements in this respect.

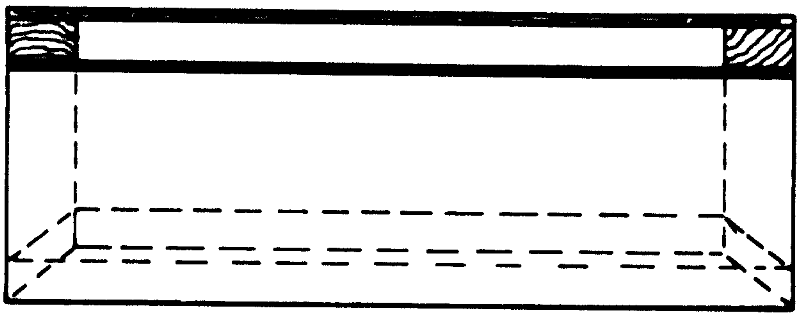
Figure IX. Measurement of permanent change in thickness and length (permanent dimensional change equilibrium—PDCE) in six types of fibreboard after 0 to 3 wet-dry cycles at relative humidities from 32 to 90 per cent. The hardboards are heat-treated



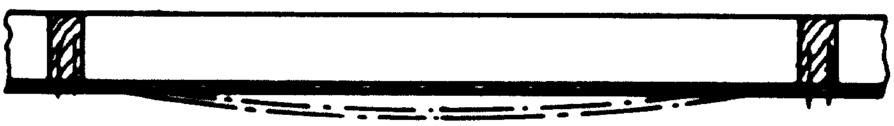
Resistance to moisture

Fibreboard contains no water-soluble additives. When manufactured in temperatures above 200°C, the separate fibres as well as the whole board is more or less "killed" against moisture movements. Chemical additives are used in the fibre building board industry to counterbalance differences in the raw material and methods of manufacture and also to give the product certain desired properties. The moisture content of board sheets will adjust to the conditions of the ambient air. The hygroscopicity of the boards is of great importance when they are under different stresses of short or long duration; this characteristic can be decreased by timely heat treatment, which reduces the humidity equilibrium and dimensional changes in the board. Owing to its porosity, medium board can absorb and emit moisture without altering its dimensions to any noteworthy degree.

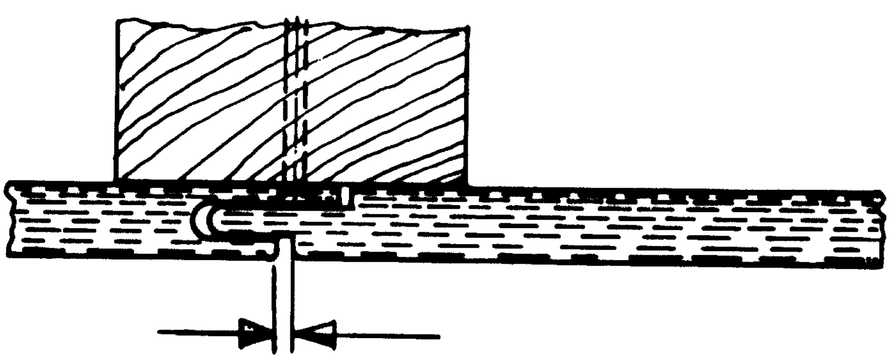
Figure X. Construction details for the support of fibreboard elements



(a) Side framings of a door



(b) Supporting at the sides



(c) Constructive joint

Figure XI. The effect of impact energy on the depth of the imprint on a 52-mm hardboard-skin sandwich panel with an E mesh (38-mm) cardboard core

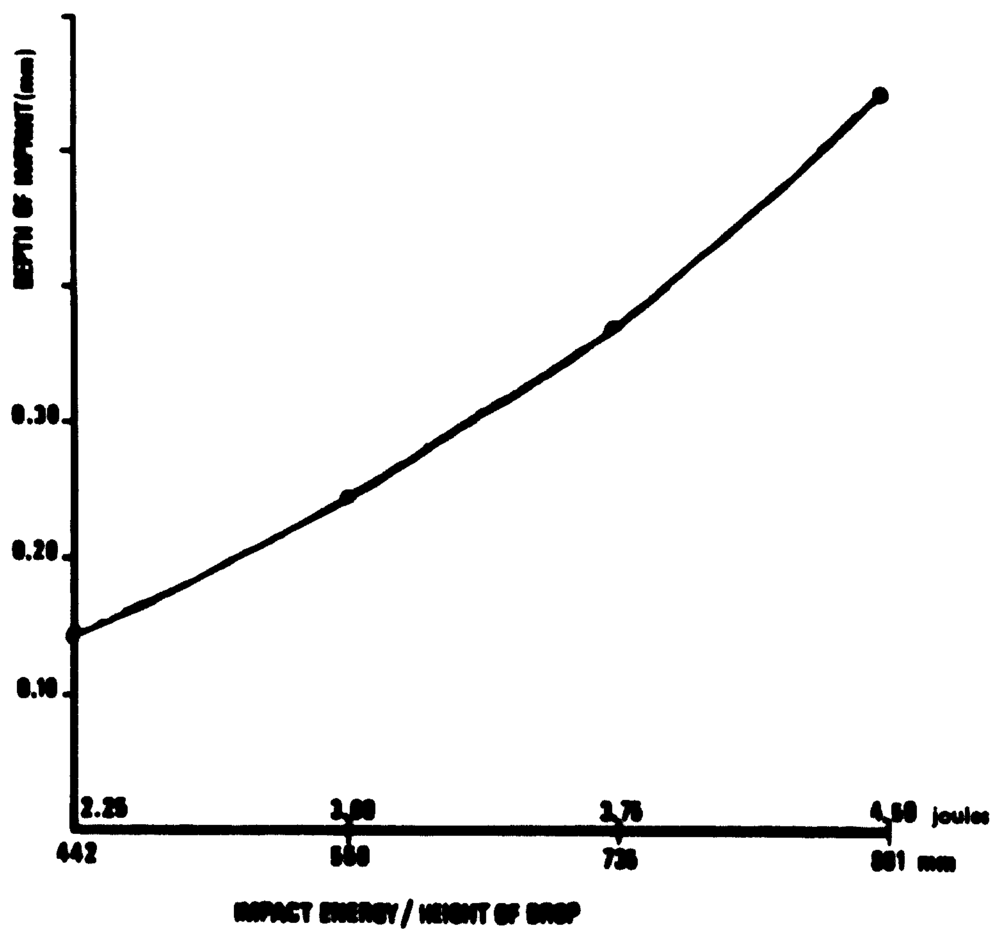
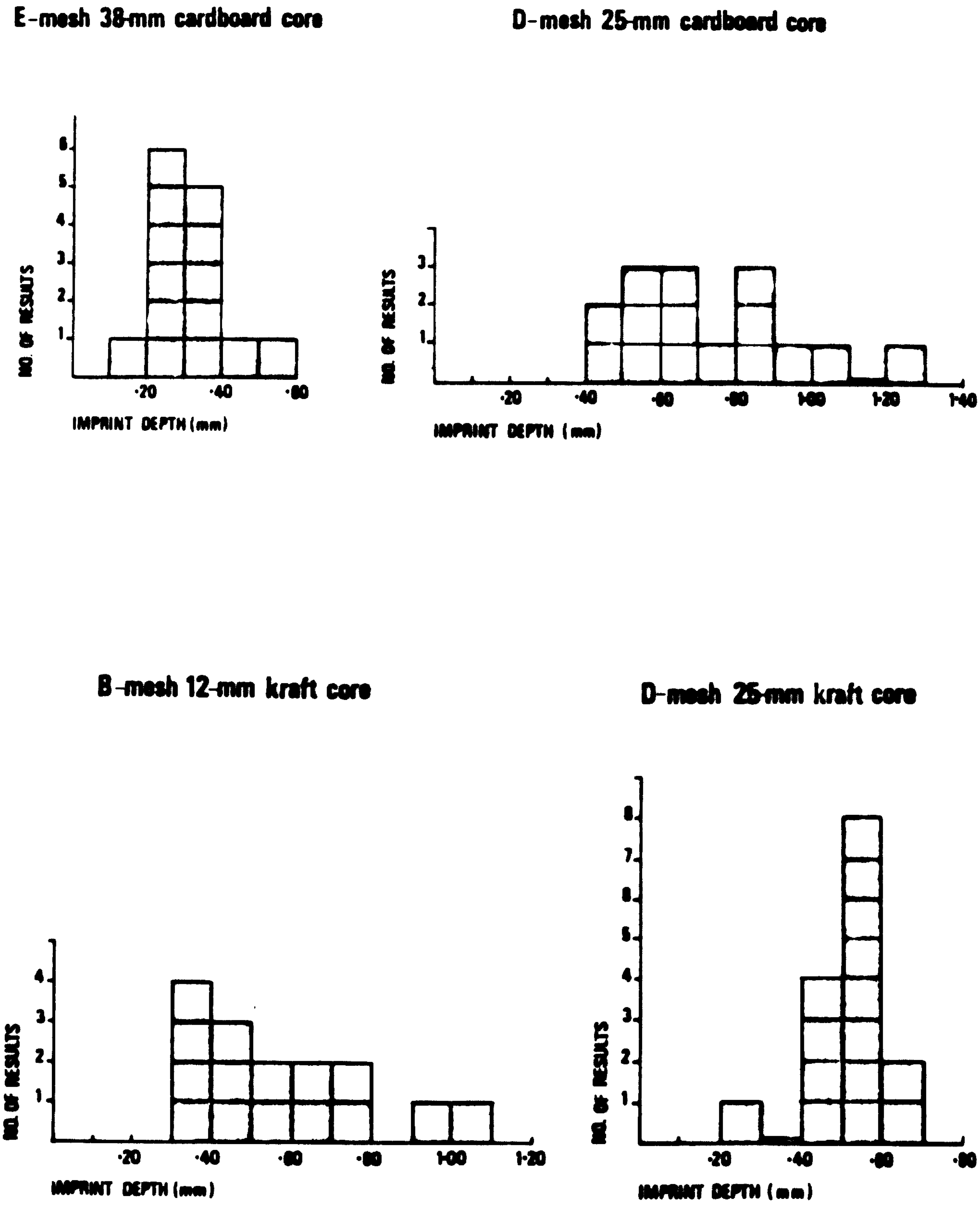


Figure XII. Distribution of imprint depth results with four representative hardboard-skin sandwich panels



Basic elements in the joinery industry

Generally, the joinery industry uses four basic elements in construction (figure XIII). They are:

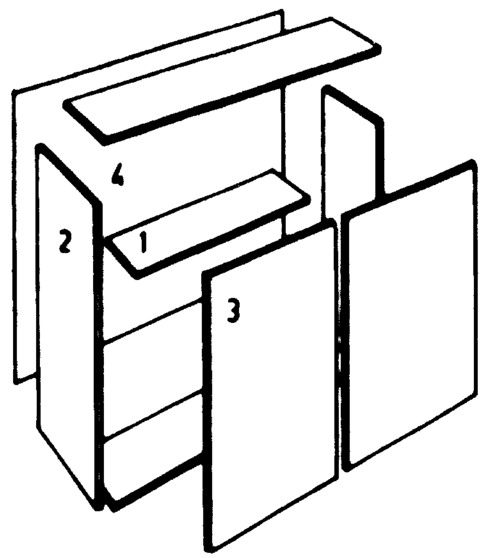
(a) Bearing elements (ceilings, floors, bottoms and shelves), which require great bending strength and a high modulus of elasticity, at least in the outer surfaces of the construction;

(b) Supporting elements (side walls), which should have adequate bucking and bending strengths;

(c) Free-standing elements (light partition walls, doors), which demand high stability of form and dimensions and offer the possibility of being attached at their edges. High impact resistance and low density are also desirable;

(d) Covering elements (external and internal wall coatings, painted or printed sheets, back walls), which should be thin but with density high enough to permit sufficient bending strength.

Figure XIII. Fundamental building and furniture elements

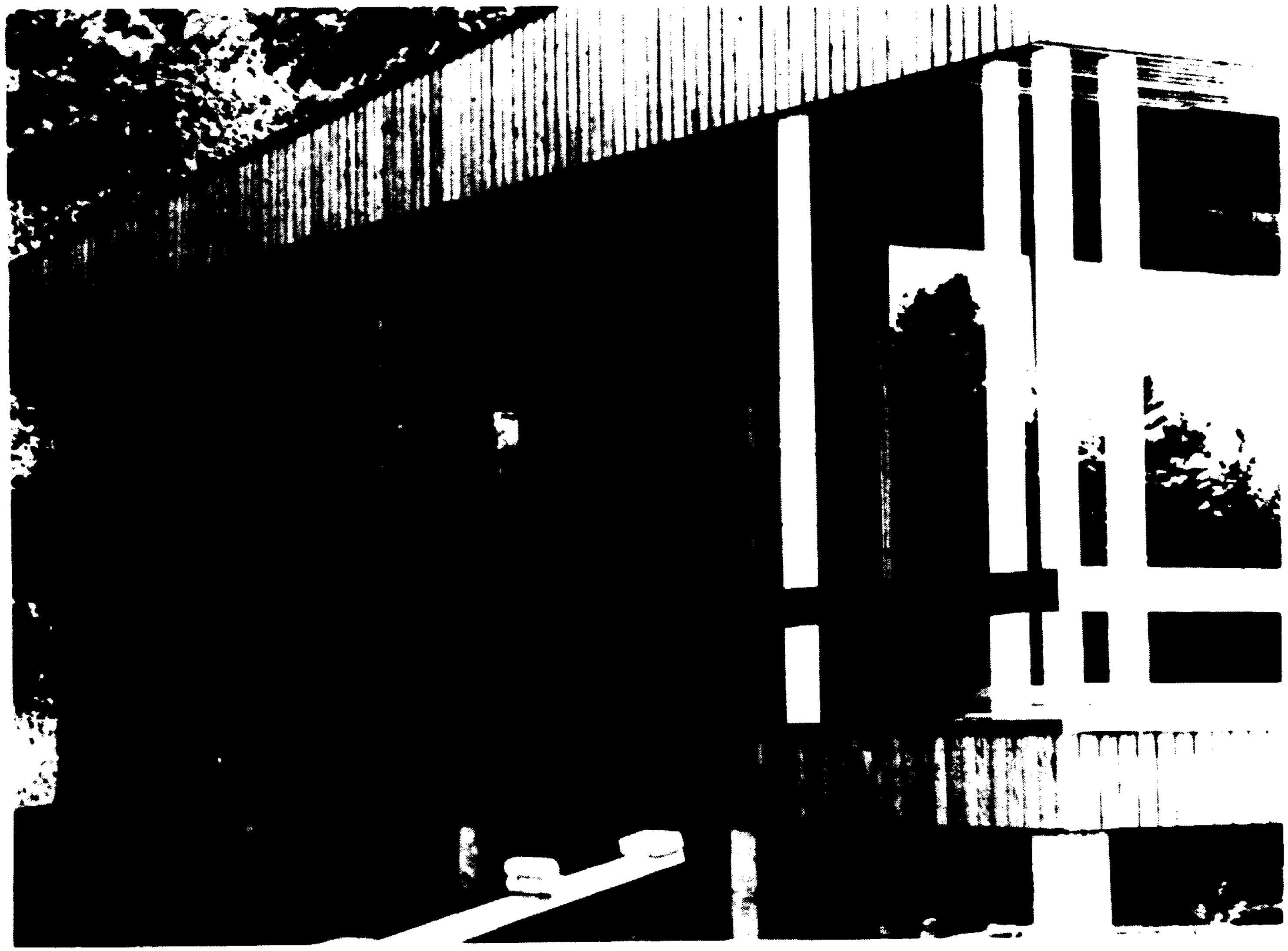


Key: (1) Bearing element
(2) Supporting element
(3) Free-standing element
(4) Covering element

Hardboard is well adapted for items *(c)* and *(d)* when the product, such as a door, is manufactured as a honeycombed construction. Thick, heavy medium board, smooth on one side or on both sides, can be used especially in the building industry for *(a)*, *(b)* and *(c)* as both indoor and outdoor covering, painted or otherwise covered. Vertical or horizontal panels 10 to 12 mm thick are particularly popular for external use (figure XIV). In the building industry, softboard is suitable for item *(d)*.

The mechanical and physical properties of the above-mentioned elements can be determined scientifically, and boards can be manufactured that will fulfil the technical requirements particular to the end-use. In this way, the most economical solution can be reached and boards of too good or too poor quality are not used. At the same time, the assortment of qualities remains as small as possible.

Figure XIV. Horizontal 10-mm medium board (800 kg/m³) used as exterior panels in a modern house



Surface and appearance of the joinery product

Products from the cabinet-making industry should have two essential characteristics: attractiveness of appearance surface and colour which is often a matter of taste, and a surface quality suited to the chemical-physical properties of the product and with its intended use. Specifically, requirements are:

(a) That the outer surface of bearing elements should be attractive and stand hard mechanical and chemical wear;

(b) That the outer surface of supporting elements should he attractive, stable to light and to some extent washahle and resistant to moisture;

(c) That the surface of free-standing elements should be of first-class quality, stability to light and appearance;

(d) That the surface of covering elements should he well adapted to the environment in which they are to be used;

(e) That, in general, joinery products should have hard surfaces that are stable to wear, impact, heat and light and that give a hygienic general impression.

The use of processed hardboard and medium board in the joinery industry

Standard hardhoard is a cheap material and it must also be processed at a low cost; otherwise it would be more profitable to use more expensive material.

The surface of fibreboard is even, compact and smooth, and it works little parallel to the surface. Furthermore, it can be covered hy many modern techniques, such as:

Covering with ivory pulp (white ground-wood pulp)
Priming (puttying or filling)
Painting and lacquering
Printing by roller coater or silk screen

Lamination (for architectural and construction use and for industrial applications)

Extrusion covering
Form pressing
Profile pressing
Radiation-chemical covering (impregnated with monomers and then cured by radiation)

The timher resources may he used more fully improving the surfaces of structurally adequate material that is unattractive and difficult to finish, thus making them suitable for premium products. This can be done by applying an overlay to serve as a finish or even as a decoration. However, the costs of applying overlays must be low enough to be economic. Such overlays have opened new markets for fihreboard panels, which may be tailored for various end-uses. Improvements in production equipment include the automatic detection and correction of defects in a continuous-line operation.

The most common uses of ivory-faced hardboard in the joinery industry are for the backs of closets and the bottoms of drawers and beds.

Primed (filled) board is easily painted and surfaces can be made smooth. It can be used readily as baseboard in cuphoards and closets.

Hardhoard and medium board, ready painted with polyester or alkyd paint, are normal commercial joinery products, primarily designed for different furnishings and wall coverings. Printed and painted hardboard is much used as walls, furniture and fixture backs. The patterns are conventional, fantastic and wood-imitation. They may be varied without raising the cost greatly. They can be applied inexpensively by modern silk-screen printing techniques.

Architectural and construction surface lamination is done with thermosetting melamine, urea, phenol, polyester, plastic veneer or PVC films that are soft (plasticized), hard and semi-hard (unplasticized). The resin-treated fibre overlays are of three kinds: high density, medium density and special.

Semi-hard internal panels, covered with soft PVC film or fabric at the mill, is a useful product for internal wall covering. Hard plastic, 0.5 mm thick, is used to cover vertical surfaces in rooms and in furniture, and 0.7-mm-thick hard plastic is used in kitchen equipment and in drawers where great impact resistance is not needed. In places where the surface of hardboard or medium board is exposed to great wear, impact or rough handling, 1.5-mm-thick plastic overlay is used.

The industrial lamination application may increase strength, stiffness, wearing, impact and weather resistance. The overlays may be of fibreglass reinforced plastic (FRP) or metal. The most common procedure is a wet application with FRP/board composite, and hot- and cold-setting adhesives are covered with metal overlays. Cold-setting glues have the advantage of avoiding most of the dimensional stability problems encountered in the hot pressing of materials with dissimilar thermal expansion properties.

Medium board and frames made from it are covered by extrusion, in which case the board is coated with hard thermoplastics. Drawers and other parts of furniture can be covered in this way with 0.5- to 0.7-mm-thick PVC film. This board-film compound is, for example, cheaper than if the corresponding parts were made from solid beech or from PVC pre-formed to follow profiles. The pastic covering affords good humidity insulation and increases the bending strength of the core hy about 30 per cent. The Federal Republic of Germany is a great user of covered fibrehoard, 6 million m^2 of faced hardboard was manufactured there in 1969 and most of this was used by the joinery and television industries.

Hardboard (thickness 2 to 3.5 mm) can be hot-pressed, wet or dry, into various shapes if it is first heated for 5 seconds at ahout 400°C and then rapidly cooled to normal temperature. This treatment does not decrease its strength to any significant degree. Various form-pressing techniques for hardboard are much used in the United States, where 50,000 tons of form-pressed hardboard are manufactured per year for the furniture and automobile industries, primarily to he used as core material in car seats and car walls.

Profile-pressed and punched hardboard and medium board are commonly used by the radio, television and furniture industries. Thick, dry-processed medium hoard, specific gravity 0.6, is easy to mill, and products made from it are good.

Fibreboard may be impregnated with chemicals and then cured by radiation. While this technique is still being developed, new fields of application in the joinery industry are anticipated.

The present use of hardhoard and medium board in the joinery industry may be summarized as follows:

(a) Kitchen equipment and cupboards are widely standardized, so that external dimensions of different units are the same, irrespective of manufacturer. These dimensions are such that different parts of the equipment can be cut from standard boards with very little waste. Joinery firms can also order their boards in standard dimensions that are most favourable from the price standpoint;

(b) In the manufacture of kitchen equipment, there is no tendency to substitute plastics for fibreboard. On the contrary, a return to the good old cosy kitchen is noticeable;

(c) Series in the joinery industry are long, and very close attention to costs is typical. Thus, in finishing, although good results achieved by a single coating are already common, this is possible only by using a densely surfaced hardboard:

(d) Work carried out in the United Kingdom by FPRL[4] in cored panels revealed the superiority of the paper-honeycomb core in the door performance test for hard-body impact resistance;

(e) Work was completed at FPRL on tests in the structural properties of hardboard. It now seems reasonable to claim that 4.8-mm tempered hardboard can be used for structural tasks demanding good shear strength and bending qualities. In this respect, it compares favourably with 6.4-mm plywood. Some limitations of its use may exist because of its low modulus of elasticity, particularly under conditions of bending deflection, e.g. structural flooring;

(f) A FPRL report on the racking strength of timber for wall units shows that a slightly better performance over-all was obtained with a panel sheathed in 6.4-mm tempered hardboard and 9-mm panel board when compared with a similar panel made with 12-mm sheathing-grade Douglas fir plywood (figure XV);

(g) Thick (6- to 20-mm) medium board with density from 600 to 800 kg/m^3 is very suitable for joinery purposes and can he produced specially for outdoor uses in the building industry. The most rapid manufacturing system is the dry method. Thin (3.2-mm) hardboard for doors and cupboards is usually made by the wet process. Figure XVI gives a broad picture of the costs of different methods and of the production capacity when using a 4-ft by 24-ft press. The number of openings of the press finally determines the production capacity.

A new constructional grade (K) of standard, oil-tempered and medium hardboards is described in table 3. The figures are separated into two groups according to the requirements of two different environments.

Basic stresses are derived by applying a safety factor to the minimum stress values, as shown in table 3, to take account of such matters as rate and duration of loading, accidental overload, and size and shape of the test specimen. For timber and plywood in bending and shear, a value of 2.25 has become acceptable. For hardboard an over-all factor of safety of 3 is recommended by FPRL. A value of 2.66 has been suggested by Lundgren in Sweden for building regulation purposes. Figure XVII shows allowable working loads and spans for nine different beams of wood-hardboard with webs of oil-tempered hardboard.

The status of fibre building board materials as a whole should benefit from their acceptance as stress-bearing components. It is obvious that a whole new range of structural applications of both hardboard, medium board and insulating board is now becoming possible.

Fibre huilding board is the most logical and competitive way of using timber in sheet form. It also serves to provide woodworking firms with good and economical materials for the building, joinery and furniture industries.

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[4] See foot-note 3.

TABLE 3. PERMISSIBLE STRESSES FOR THREE VARIETIES OF A NEW (K) GRADE OF NORMAL CONSTRUCTIONAL HARDBOARD IN ENVIRONMENTAL GROUPS I AND II[a]

(N/mm^2)

		Type of stress							
		Tension		*Compression*		*Shear*			
Type of board	*Bending (//)*	*(//)*	*(⊥)*	*(//)*	*(⊥)*	*(layer)*	*(panel)*	*E modulus (//)*	*G modulus (panel shear)*
Group I									
Oil-tempered	11	6	0.2	6	5	0.4	4	3 500	1 800
Standard	7	5	0.15	4	5	0.3	3	1 700	830
Medium grade	3	1		1	1	0.05	1	880	440
Group II									
Oil-tempered	5	3	0.08	2	5	0.3	2	1 800	880
Standard	3	2	0.05	1	5	0.2	1.3	880	440
Medium grade	1	0.8		0.4	0.5	0.4	0.6	340	200

Source: A. Lundgren, ***Träskivor som byggnadmaterial***, Nykoping, 1967.

[a]Group I, most structural elements in heated buildings with relative humidity below 75 per cent; Group II, most structures in temporarily heated, ventilated buildings with relative humidity as high as 95 per cent. Symbols: // = parallel to face grain; ⊥ = perpendicular to face grain.

Figure XV. Comparative racking forces and deflections with various sheathing materials at a vertical load of 22.3 kN (5000 lbf)

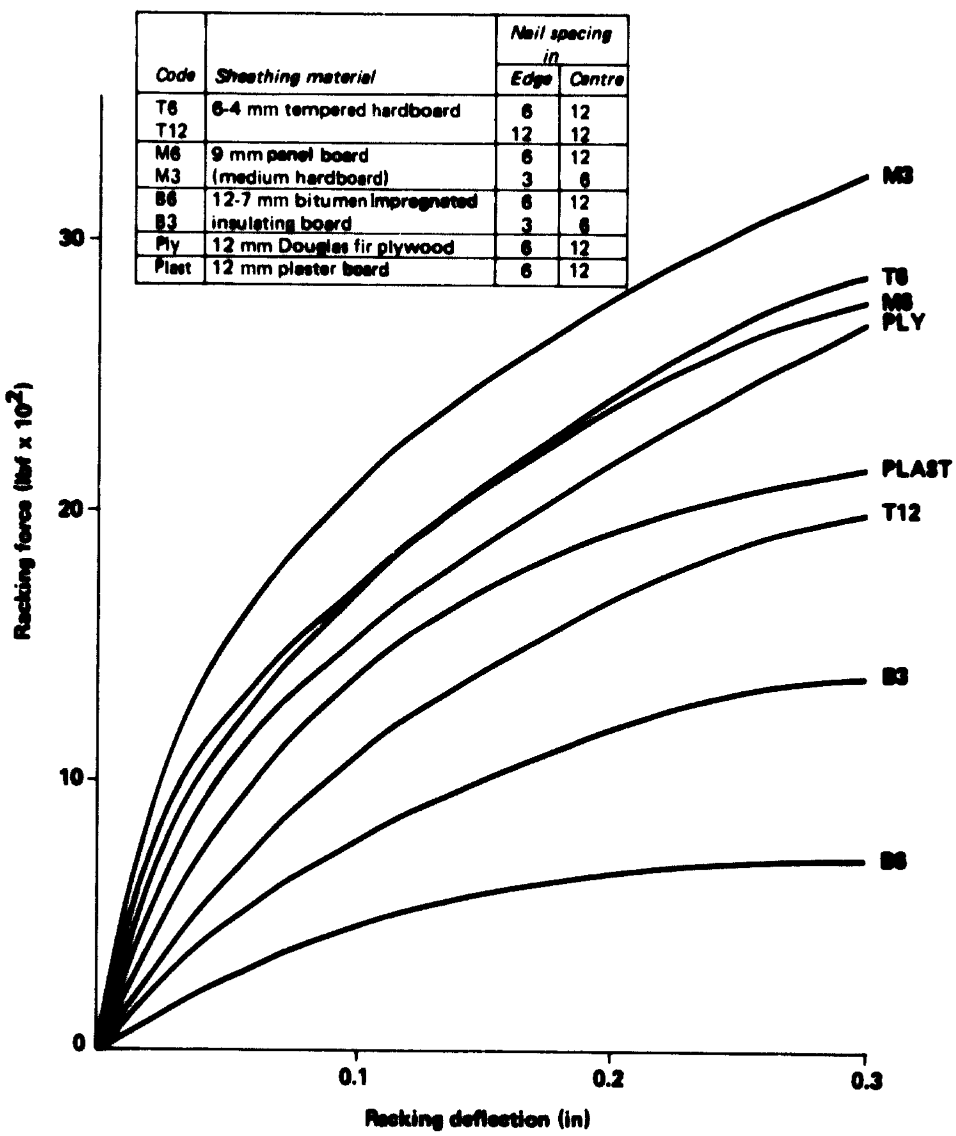


Figure XVI. Investment costs for three different systems for producing a 12-mm medium board: 1, wet method, 27,000 tons/year; 2, dry method, phenol gluing, 50,000 tons/year; 3, dry method, urea gluing, 90,000 tons/year

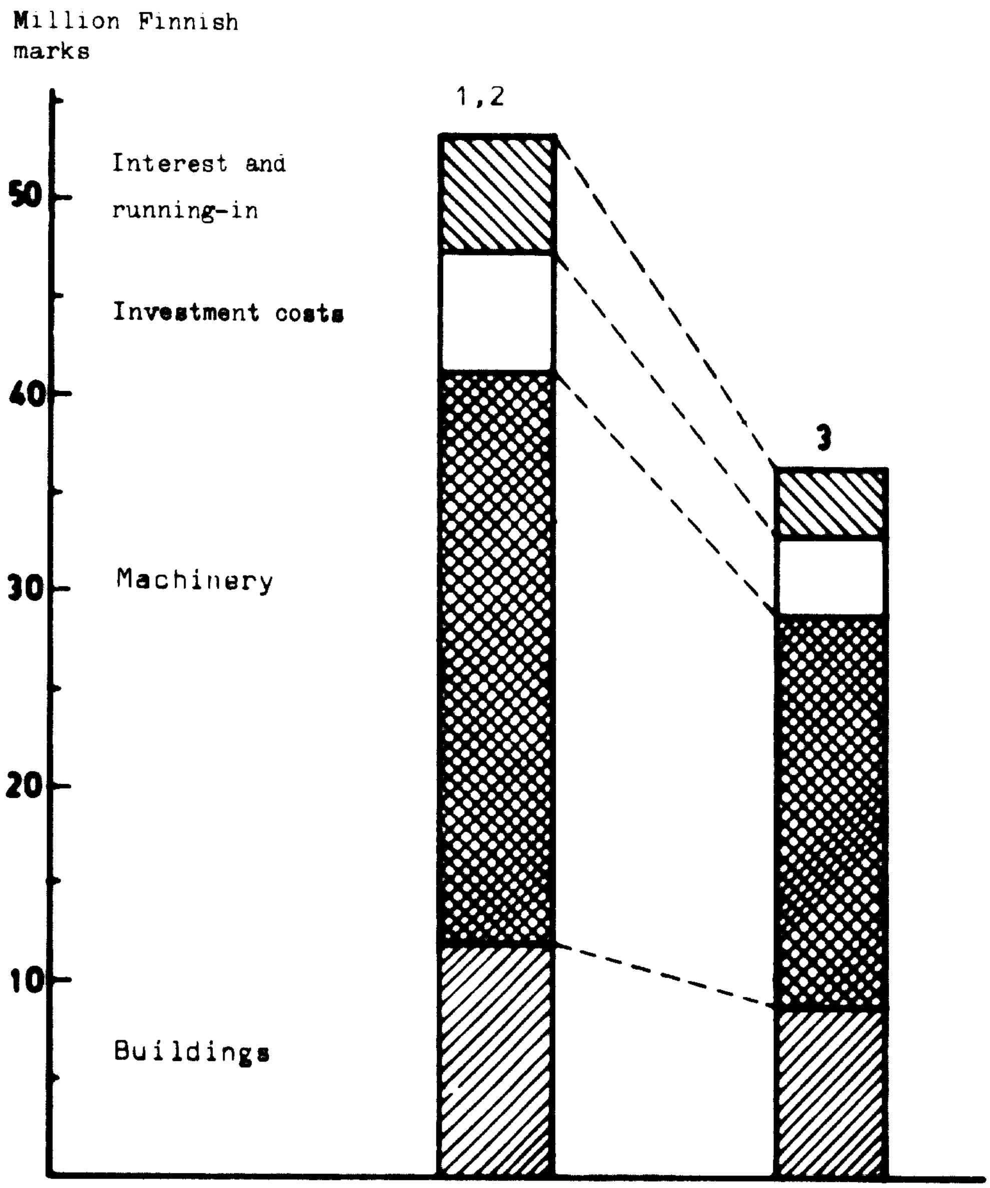
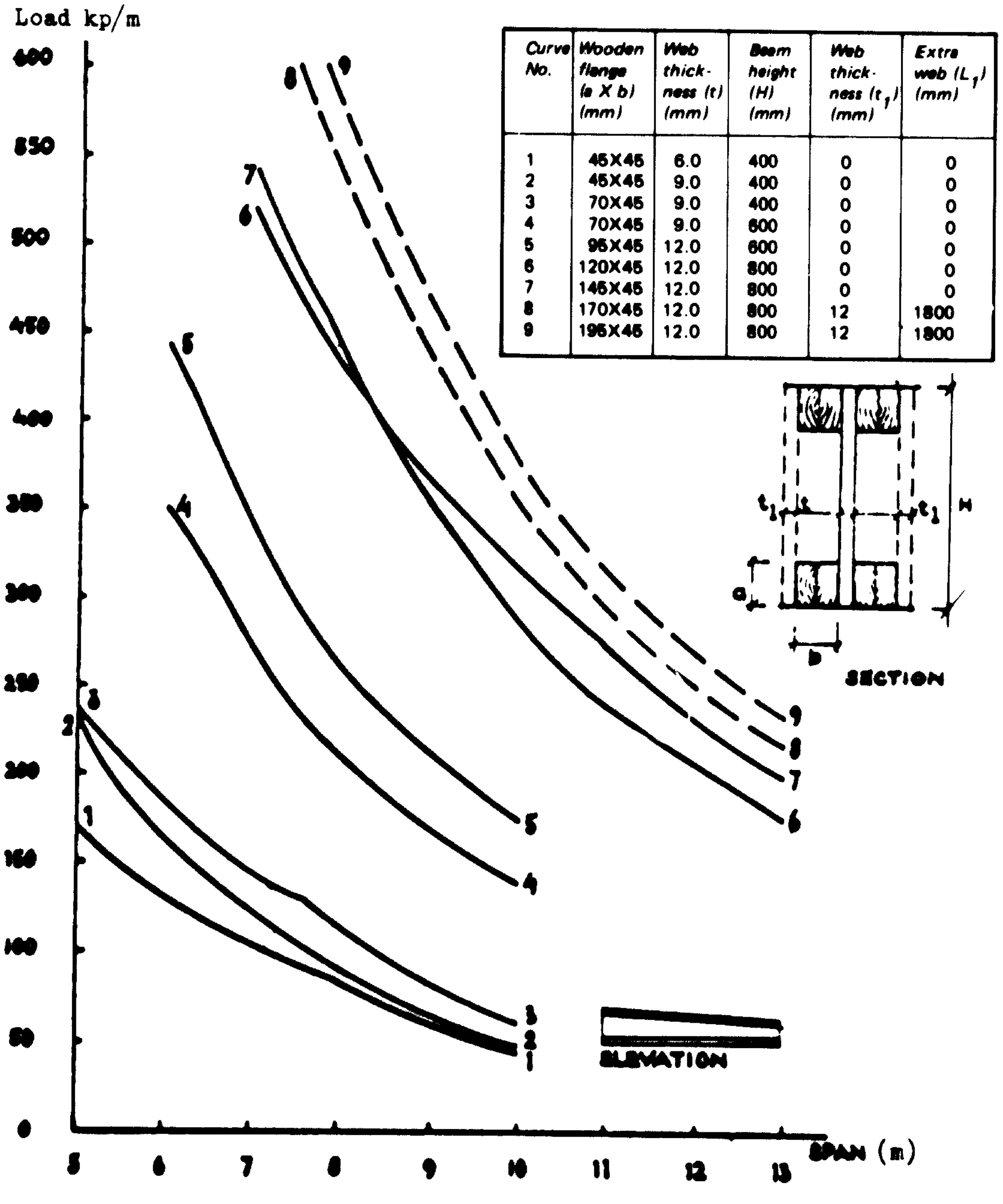


Figure XVII. Working loads and spans for nine different beams of wood-hardboard with webs of oil-tempered hardboard. Environmental group II

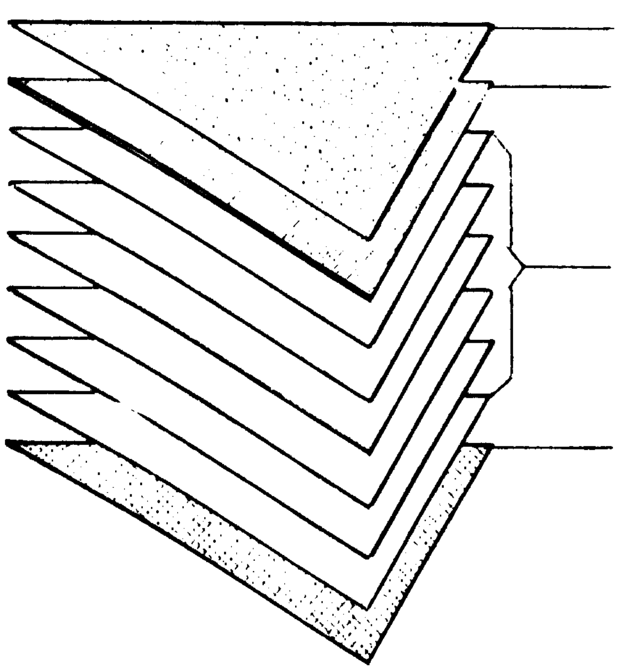


Curve No.	Wooden flange (a X b) (mm)	Web thick-ness (t) (mm)	Beam height (H) (mm)	Web thick-ness (t_1) (mm)	Extra web (L_1) (mm)
1	45X45	6.0	400	0	0
2	45X45	9.0	400	0	0
3	70X45	9.0	400	0	0
4	70X45	9.0	600	0	0
5	95X45	12.0	600	0	0
6	120X45	12.0	800	0	0
7	145X45	12.0	800	0	0
8	170X45	12.0	800	12	1800
9	195X45	12.0	800	12	1800

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

At present many plastic materials are used as interior linings, such as imitation leather, plastic-covered textiles, plastic films, and to a large extent laminate boards. 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/cm^2, 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 I).

Figure I. The construction of laminate board



Decorative laminate boards with 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 of America, Resopal in the Federal Republic of Germany, Perstorp in Sweden and IKI-board in Finland. World production is over 200 million m^2 per year (2,000 million ft^2 per year).

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

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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 cafés; this use has since been extended to 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 m^2 of decorative laminate is needed for one deluxe cruiser. Decorative laminates have recently been introduced also for exterior wall coverings, but the experience in their usability for this purpose is as yet insufficient. Gre t demands are made on laminate's resistance to light in these cases. Laminate for exterior walls usually has large patterns and is about 3 mm thick.

There are few modifications of laminate b ards; three could be mentioned:

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

In principle, postforming 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. In these boards certain substances are added to the resin or paper which 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/cm^2 must be used to avoid compressing the particle 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 th me 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 appearance of laminate board depends on the decor paper and surface finish. As mentioned, 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 foot), 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 their 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 get an individual pattern in the collection.

Unicoloured decor papers are already thoroughly coloured in the production stage. The result is that it is not worth while to manufacture small quantities of some colour that is separately chosen.

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 either glossy, semimat or mat. Recently, marketing has started of so-called three-dimensional surfaces. Perhaps the most popular of them is the wood-grain imitation with porous finish which produces 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.

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 board of 50 mm (2 in.) thickness. The thinnest qualities 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 qualities in large sheets; they are inclined to break and crack and thus the result is no cheaper than if thicker boards were used. Boards between 1.6 and 1.0 mm are used mainly for horizontal surfaces. Thin qualities (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 when unicoloured boards are concerned. As a result, the hardness and simultaneous 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 245 cm (4 ft and 6 ft); the usual dimensions are 125 X 245 cm (4 X 8 ft) and 125 X 305 cm

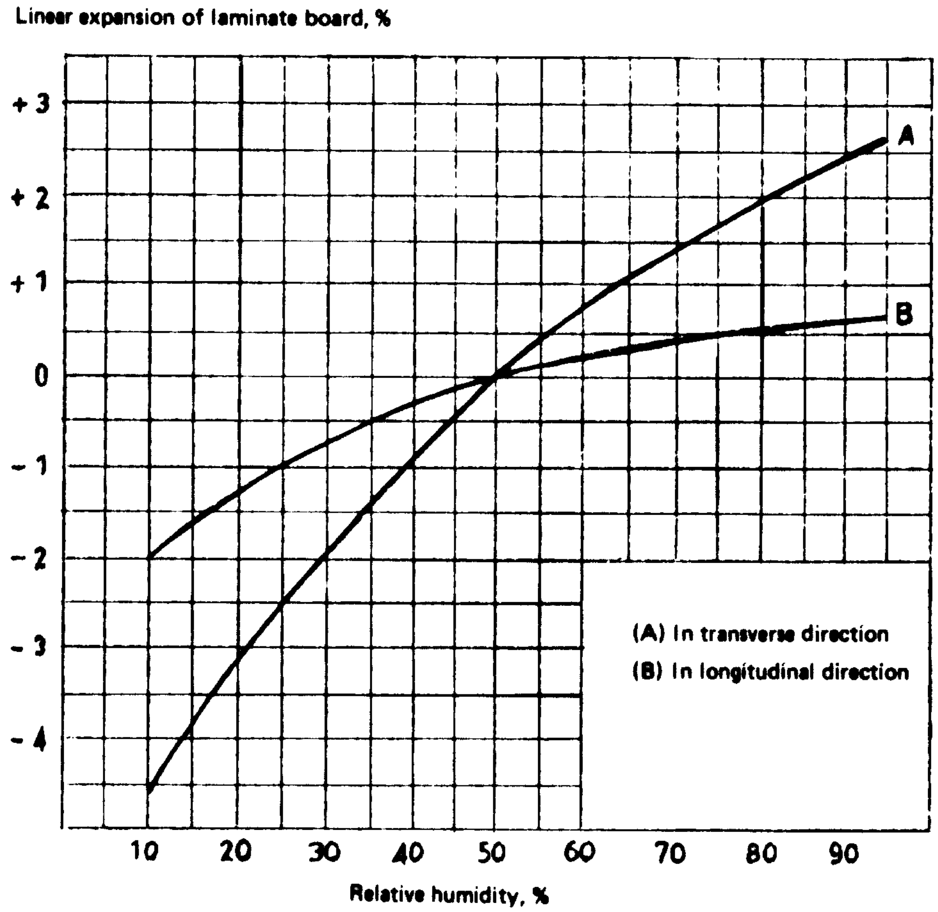
(4 X 10 ft). By far the most common width is between 122 and 127 cm; two kitchen table widths may be obtained from it. Because the product is sold cut to certain sizes, and not for example in rolls, waste occurs both in longitudinal and transverse directions.

The most common types of laminates and their properties

Decorative laminate is very resistant to wear abrasion. Another important advantage is that it tolerates a temperature over 100°C (212°F). A kettle filled with boiling water can easily 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 owing to the melamine resin which is hard and transparent. In boards for horizontal surfaces, this property is increased by an overlay with particularly high resin content.

Decorative laminate also has certain advantages 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 part 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, and in dry circumstances 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 II). For example, if the laminate is taken from cold and moist storage, glued on chipboard and later kept in dry circumstances, it will shrink; however, when glued it only stretches and causes heavy tension. If the chipboard 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.

Figure II. Dimensional stability of laminate board



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 crosswise and 0.3 per cent in the longitudinal direction; if this is prevented, a corresponding tension will exist. The same difference also appears in 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.

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 Germany, British Standards (BS) and Sveriges Standardiseringskommission (SIS) in Scandinavia.

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

COMPARATIVE LIST OF STANDARDS FOR DECORATIVE PLASTIC LAMINATE BOARDS

Test element	*NEMA*	*SIS*	*DIN*	*BS*
Abrasion resistance	LD 1-2.01			
Resistance to boiling water	LD 1-2.02	R 70 50 02	53799	3794
Resistance to high temperature	LD 1-2.03	24 58 03	53799	
Resistance to burning cigarettes	LD 1-2.04		53799	
Stain resistance	LD 1-2.05	24 58 05	53799	
Resistance to light	LD 1-2.06	24 58 05	53799	
Wetting resistance	LD 1-2.07	24 58 01		2782
Dimensional stability	LD 1-2.08	24 58 06	53799	
Flexural strength	LD 1-2.09			3794
Modulus of elasticity	LD 1-2.09			3794
Deflection at rupture	LD 1-2.09			3794
Inspection for appearance	LD 1-2.10		53455	3794
Tensile strength	LD 1-2.14			
Impact strength	LD 1-2.15			
Scratch resistance by pencils		18 41 87		
Water vapour transmission			53122	
Thermal expansion				
Thermal conductivity				

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

Normal decorative laminates with melamine surface 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 decorative laminates. If the board is long, and warping is fully prevented, both sides must have identical laminates with melamine surface glued to them.

Finally, so-called postforming 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 postforming 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)	$0.11 \times 10^{-4}/°C$
Thermal expansion (crosswise)	$0.14 \times 10^{-4}/°C$
Heat conductivity	0.208 W/m°C sec

The mechanical characteristics of counter-boards are somewhat lower for modulus of elasticity, but otherwise have the same properties as decorative laminates.

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 postforming laminates, the best qualities can be bent to the radius of about 4 to 5 cm; a radius of about 10 cm can usually be obtained easily.

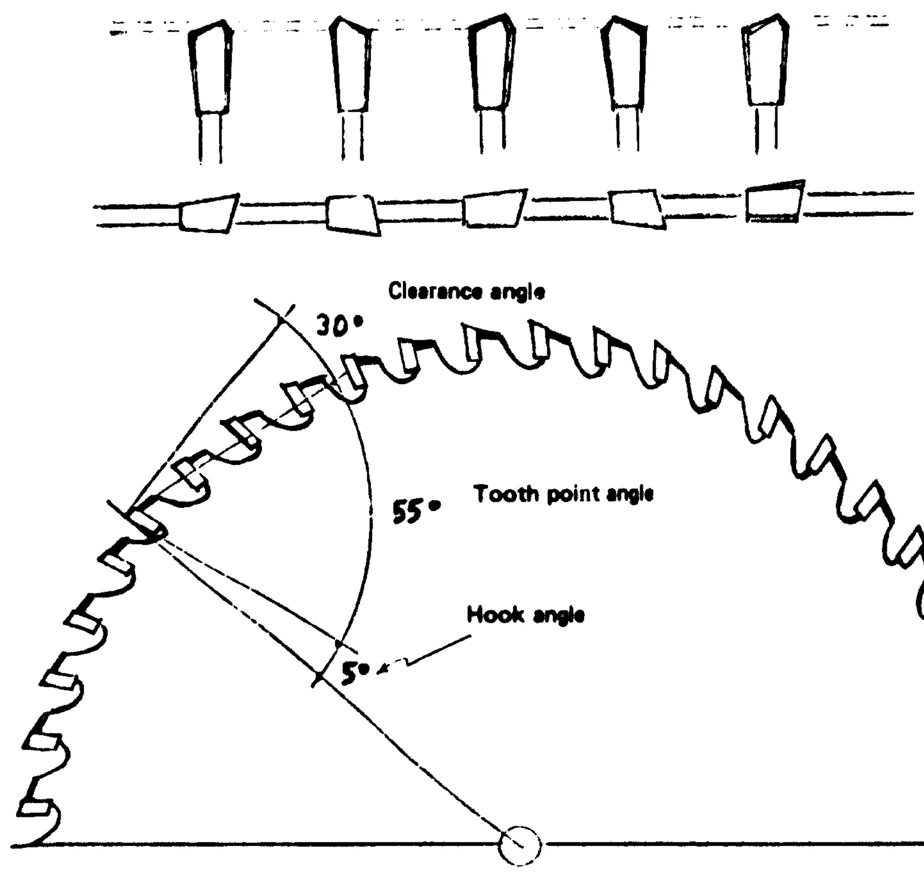
So-called melamine plastics are very resistant to all chemicals, and generally the laminate surface resists all chemicals that are used in the household, hospitals and institutions, with the exception of some easily staining organic colourants which may leave a spot difficult to clean on the surface.

Machinir' and gluing of laminates in the furniture industry

As a general rule, the majority of machines used in joinery production are suitable for the machining of laminate hoard. Nevertheless, for constant use it is advisable to provide machines with tungsten-carbide bits, since their lasting sharpness improves the finishing of hoard edges and speeds up the manufacturing process. When laminate hoards are sawn into sizes corresponding to those of the base material, the hoard 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 III).

Figure III. A blade recommended for cutting laminate board

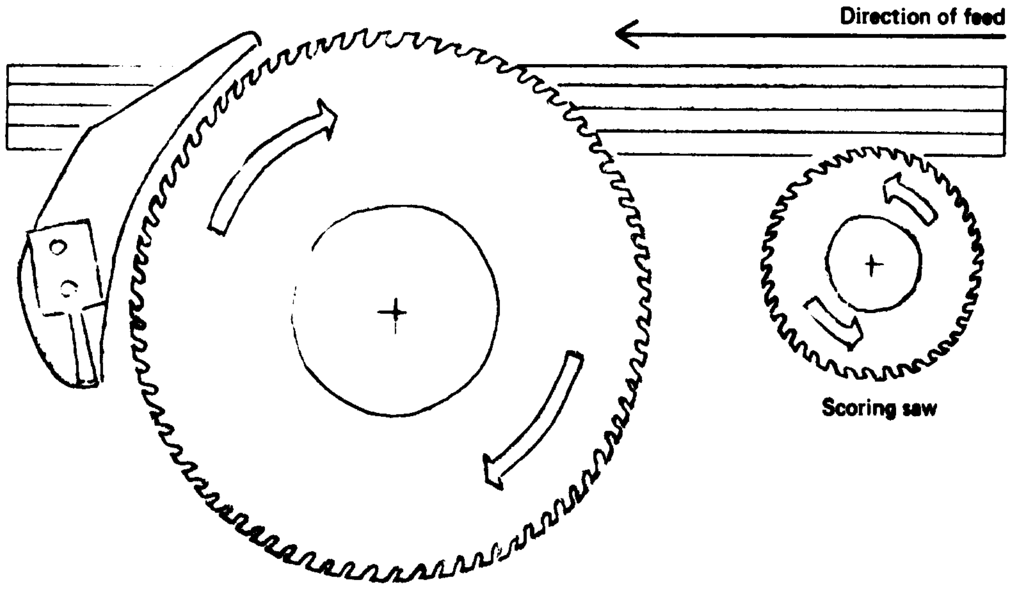


The purpose of machining laminates before gluing is usually to cut them to suitable sizes for gluing and installation. Tungsten-carbide bits with rim speed of 50 to 60 m/sec are used for sawing, with a feed speed of 0.2 to 0.3 m/sec. Laminate boards can also be cut in the same way as glass, by incising 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 revolutions (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. In this case one tooth cuts about 20 to 50 µm of the material.

When a decorative laminate is laminated on both sides of the core (e.g. particle board) and 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 IV. When sawing several laminate boards at one time–3 to 5 boards–only the undermost board need be scored, but strong pressure has to be used to bind the boards firmly together during the sawing.

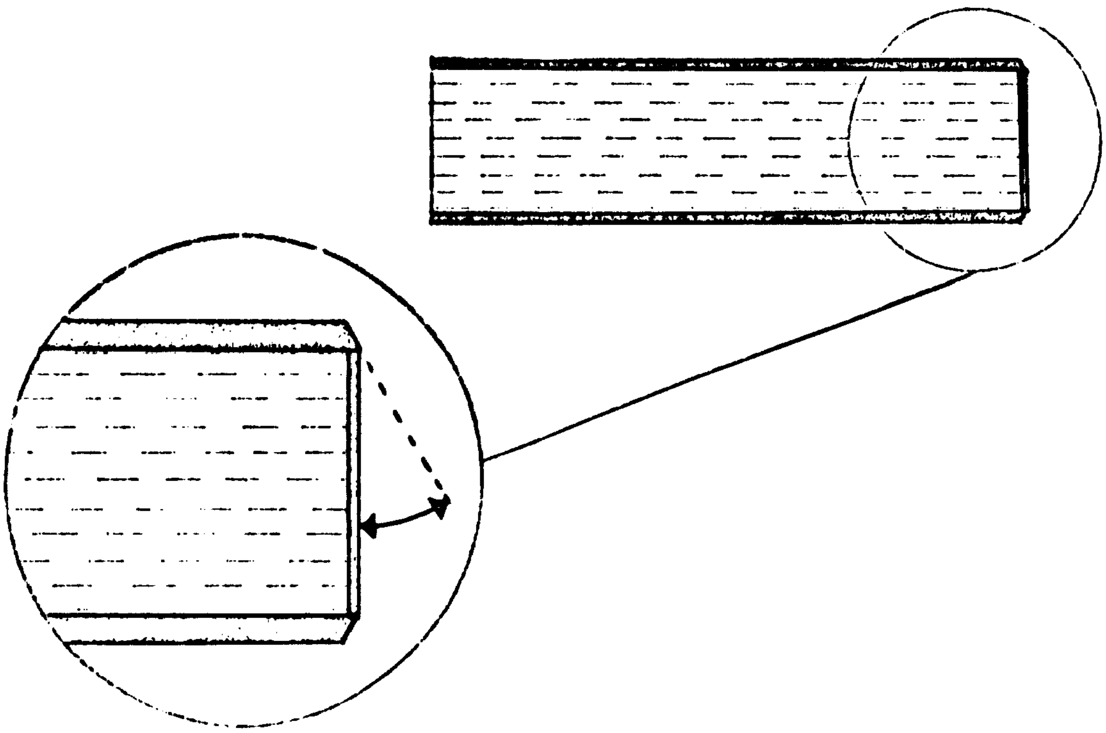
Figure IV. Sawing a board laminated on both sides with scoring saw



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

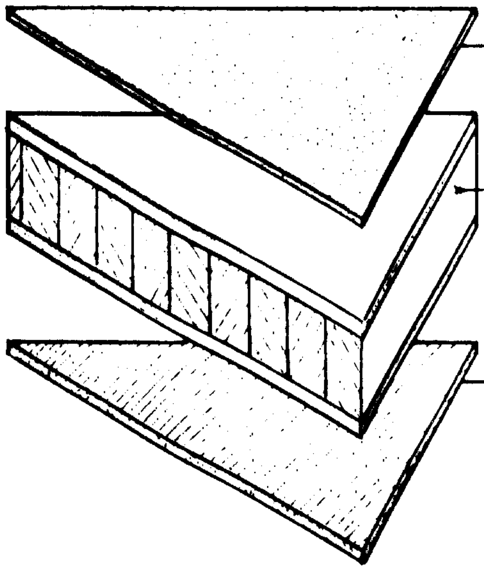
About 500 to 1,000 rm of laminate boards can be cut with the present tungsten-carbide bits before resharpening. Figure III gives the shape of a blade profile known to be very durable.

Figure V. The edge of laminate boards should always be machined or rounded in a machine or filed by hand



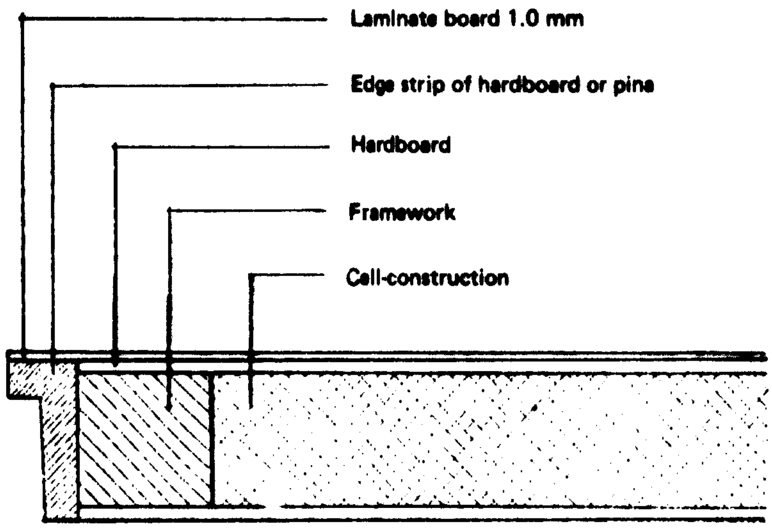
Laminate board is fixed by gluing on the framework which is usually of wooden board, such as particle board, block- or laminboard, and plywood. Metal and stone bases may also be considered (figures VI and VII).

Figure VI. Laminate counter-board



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

Figure VII. Cross-section of a door



There are general rules for the application of wood glues such as urea-formaldehyde glue, PVAc, those 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 tnermal 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.

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

The glue is generally spread on both sides of the core material at the same time, e.g. particle board, so that the amount of glue is about 120 to 140 g/m^2. 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.

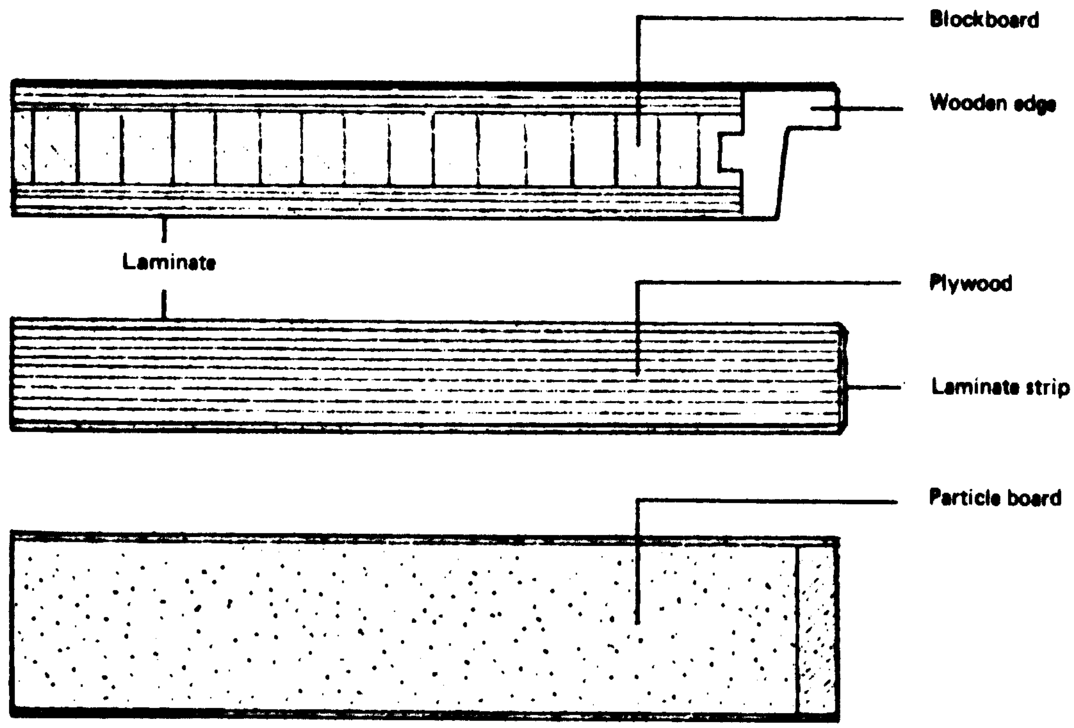
After the glue is spread, laminates are placed on the core and set into the gluing press. As a rule up to 50 boards can be pressed at one time. Then, however, care should be taken that the compression strength is about 3 to 4 kp/cm^2 to compensate for warping etc. A sufficient pressing time is about 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 VIII and V).

Figure VIII. Core materials and edge forms



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, ships and trains.

In handling laminates the most usual error occurs when insufficient care is taken of the moisture content. In figure II 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.

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

Bonding 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 his 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 I 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;

(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 connexion with light insulating materials such as hardened 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.

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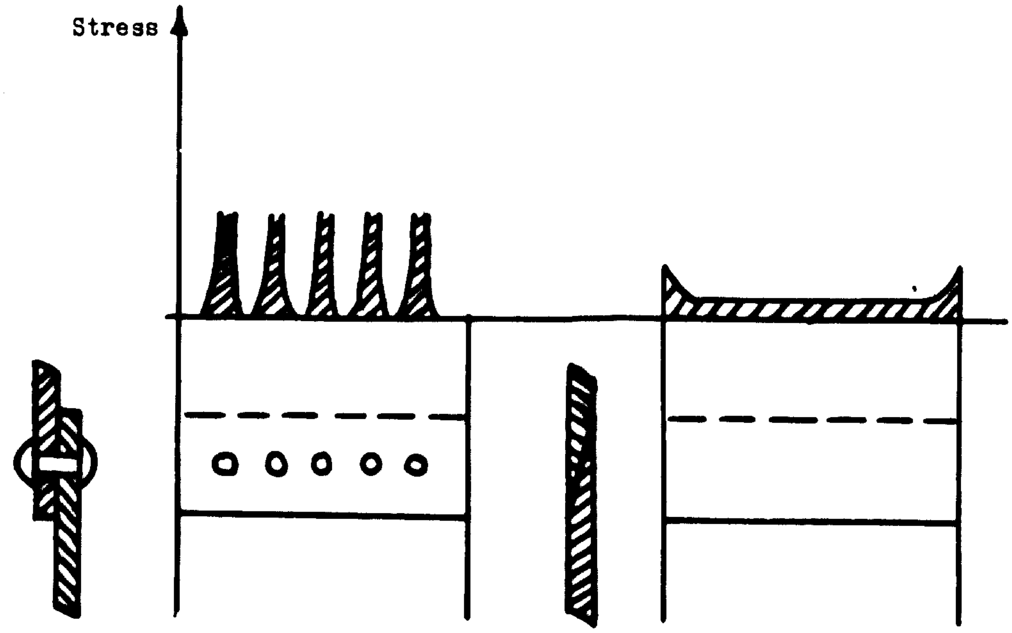
Figure I. Comparison of the distribution of stresses in a riveted joint and a glued joint



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 ability to withstand varying loads are impaired. The temperature value of 250°C (480°F) is to 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;

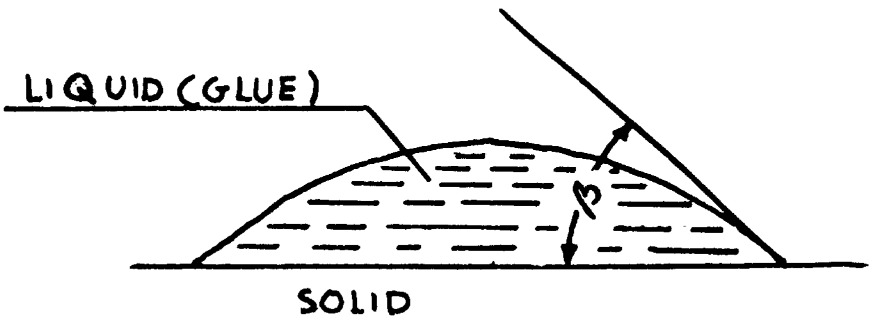
(e) Gluing requires great care during the process and continuous control (suitable proportion of components of the glue; viscosity and acidity of the component parts and of the mixture; amount of dry substance in the mixture; amount of glue spread and the smoothness of the layer; the time interval during 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 (3×10^{-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 II gives some concepts connected with gluing.

Figure II. The spreading of glue: the object is to minimize contact angle β



β = contact angle, this may vary between 0 and 180° (theoretical ultimate values)

β = 0°: complete spreading

β = 180°: zero spreading

Aim in the spreading of glue: minimize β.

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 kinds of wood differ considerably, and even the same species varies 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 wood (such as its moisture content).

Light, porous wood takes up too much thin glue; thus thicker glues must be used with them. Resins and oils make adhesion more difficult, as in gluing teak. 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.

The gluing of heavy and light woods 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 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 (15 kp/cm², 213 lbf/in.²) than for medium-density hardwoods (20 kp/cm², 284 lbf/in.²). In the case of Finnish woods, 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.

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.). Polyvinyl acetate (PVAc) glue has in many cases superseded dextrin glue.

Cellulose glues. These are of two main types: cellulose ethers (methyl-cellulose) 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 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 micro-organisms. Resistance to moisture can be increased through the use 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 connexion 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 air-tight 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) 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 soybean. Soybean glue is much used in Japan and in the United States. Its properties are comparable with those of casein and albumin 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.

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 half-way. 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 which have in common a reaction with formaldehyde. These are the two phenolic (phenol-formaldehyde 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 = 18 kp/cm^2 (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 which has been impregnated with sulphuric 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, so that 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 this 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 multistage 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 = 8 to 20 kp/cm^2 (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 = 1 to 3 kp/cm^2 (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. These are water-soluble materials suitable for paste-type glues; they are used in the same way as PVAc;

(b) Polyethylene glues. These 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 (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 plates, for instance in the furniture industry.

(c) Polyisobutylene (butylene rubber);

(d) Polystyrol glues (Buna S rubber). Both of them give a very firm and tough joint.

(e) PVC glues. These 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. From 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 = 3 to 8 kp/cm^2 (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 this case 12 hours. Hot setting is achieved with phthalic acid anhydride, for instance. If the temperature is elevated to above 220°C, 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 with 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, 5 kp/cm^2 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 1 and 2.

TABLE 1. PROPERTIES OF GLUES
(Average values no special materials)

A. Protein glues	*Glutin*[a]	*Casein*[b]	*Albumen*	*Soybean*
General properties				
Trade form	Sheet, pearl, powder, solution	Powder	Powder, solution	Powder
Shelf-life	Dry several years Solution 1 year	6 month 2 years	1 year (powder)	1 year
Colour	From yellowish to brown	Light yellow	Dark brown	Light yellow
Hygiene	Not dangerous	Not dangerous	Not dangerous (bad-smelling)	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	½ to 2		3 to 12
hot (minutes)	10 to 15		5 + 1/mm[c]	
Pressure (kp/cm^2)	2 to 8	5 to 12	8 to 14	8 to 16
Temperature (°C)	20 to 100	20	90 to 120	20
Maturing time (hours)	12 to 72	20 to 24		48

TABLE 1 *(continued)*

4 *Protein glues*	*Glutin*[a]	*Casein*[b]	*Albumen*	*Soybean*
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
Hygiene	Irritation of skin and respiratory tract	Irritation of skin and respiratory tract	Not dangerous
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	
Pressing time: cold (hours)		½ to 10	
hot (minutes)	3 + 1.25/mm (125°C)		6 + 1/mm[c] (140°C)
Pressure (kp/cm²)	12 to 20	2 to 10	10 to 20
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
Hygiene	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

C Plastic glues polycondensates II	Resorcinol-formaldehyde	Urea-formaldehyde[h]	Melamine-formaldehyde
Technical properties (continued)			
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) hot (minutes)	10 5 (80°C)	 1½ + ½/mm	 4 + 1/mm[c] (120°C)
Pressure (kp/cm²)	2 to 10	6 to 18	5 to 20
Temperature (°C)	20 to 80	110 to 140	90 to 140
Maturing time (hours)	24	48 to 72	
Seam properties			
Water resistance	1	2 to 3	1
Weather resistance, temperate tropical	1 1	2 2	1 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

D. Plastic glues – polymers[i]	PVAc[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
Hygiene	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)	1½ to 24			¼
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) hot (minutes)	½ to 2 3 to 7 (50°C)	 1 to 3 seconds		
Pressure (kp/cm²)			⅕ to ⅓	½
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 tropical	3 2	1 1	1	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

TABLE 1 (continued)

F Plastic glues polyadditives[i]	Epoxy[l]	Polyurethane[m]
General properties		
Trade form	Mixture of liquids, pastelike	Mixture of liquids, lump
Shelf-life (months)	12	6 to 9
Colour	Brownish	Dark brown
Hygiene	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)	½	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 (kp/cm²)	2 to 12	3 to 8
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
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 circumstances

(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 20 to 40 kp/cm². The value becomes higher if pressures from 5 to 10 kp/cm² are used.

[l]Epoxy glues lose about 10 per cent of their strength under continuous loading for more than 1 year.

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

TABLE 2. GLUES USED IN FINLAND (1972)

Group of glues	*Share of total use (percentage)*	*Price relative to urea (by weight)*
Protein	3	1.5
Urea	60	1.0
Phenol	20	1.5
Resorcinol	2	12 to 15
Melamine	2	5 to 8
PVAc	10	6 to 10
Contact glues	2	15 to 20
Other plastic glues	1	

The gluing process

The manufacturer usually provides instructions for the use of his products. 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 (minutes)*	*Glue B (hours)*
15	70	40
20	40	24
25	25	15
30	15	10

Glue A is for cold gluing, glue B is for 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 multilayer press is used, all of its openings should close at the same time.

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 meter;

(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 ‹ ıng 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 higher than that for non-treated wood is recommended. Boron-containing preservatives 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 15 kp/m². 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 gluing time for cold setting is 30 minutes, but for hot setting it can be over 24 hours. The pressure needed varies between 2 and 16 kp/m² for liquid glues and is around 20 kp/m² for film glues. The setting time for cold-setting types ranges from 30 minutes to 4 hours, and for hot setting (temperature range: 105°C 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 too thin or moist a veneer, too thin a glue or too slow a hardener. 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. In 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 10 kp/m², 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°C to 150°C temperature and at a pressure of 20 kp/m². 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 pressing time is 2 to 6 hours. The moisture content can be over 20 per cent. 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°C to 40°C.

A grave fault may happen 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 contingent of pheno‹ ‹ is maximum 30 per cent.

Epoxy glues are used specially in cases where wood is fastened to metals. These glues are the strongest ‹ ‹ost 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 ‹ r even by spraying. The faces can be pressed together when the glue is dry. For more demanding tasks a pressure of 5 kp/m² is recommended. If hot presses are used the temperature should be at least 60°C. The maximum permitted ambient temperatures are from 60°C 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 are traditional upholstery materials. They have many advantages over other materials in this application since their possibilities of design and colour are nearly unlimited. Uncoated textiles are permeable by air and moisture, and they transfer heat. The typical surface of a textile fabric is soft and attractive. Textiles are elastic, that is, they tend to recover their original length after stretching. This property is important in upholstery fabrics.

On the other hand, many types of upholstery textiles have less resistance to abrasion than synthetic leather or other materials, and they lower resistance to soiling and are more difficult to clean than synthetic leather. Woven cloth is often unsuitable for the rational mass production of upholstery because it is not homogeneous in all directions.

Price is usually the determining factor in the choice of materials. The manufacture of textile fabrics includes spinning, weaving, dyeing and finishing and each of these stages consists of several processes. High manufacturing cost is the reason for the relatively higher price levels of textiles than of other upholstery materials, which usually are manufactured by one or two processes. Upholstery textiles are suitable for hand-weaving because such fabrics are heavy and made of coarse yarns. The share of knitted and non-woven fabrics in the textile industry is presently increasing. In the future, the price levels of upholstery fabrics manufactured by these methods will decrease.

The fibres used for upholstery textiles have changed over the past 20 to 30 years. While wool was once the main raw material, it is now used only for costly materials. At present, wool is used primarily in blends with other fibres and especially with regenerated cellulosics (rayons), the usual mixture being 50 per cent wool and 50 per cent cellulosic. The addition of 10 to 15 per cent synthetic fibre, usually polyamide, in wool-rayon blends increases the strength Such mixtures are easy to dye in either piece or yarn form, and it is possible to attain the required colour-fastness. Wool-rayon blends are now the main raw materials for upholstery textiles in Scandinavia. In these blends the good properties of wool—softness and resistance to abrasion and soiling—are partly maintained. The cellulosic component lowers the cost of the raw material since its price is about 30 per cent of that of wool. Wool and cellulosics absorb moisture, which gives antistatic properties to fabrics made from them. Furthermore, cellulosics are less resistant to soiling than either wool or synthetic fibres. Wool-rayon blends can be given finishing treatments to improve their properties. Anti-soiling, water-repellent, flame-resistant and antiseptic treatments are also possible, but they are normally requested only in upholstery fabrics for special purposes, such as those for offices, hospitals and ships.

Cotton and its blends with synthetic fibres are widely used for upholstery fabrics. The price of raw material and the weight of the fabric determine the product price. Compared with that of wool, the price of cotton is about 30 per cent and that of synthetic fibres from 60 to 70 per cent. Cotton fabrics are usually piece-dyed or printed. Resin treatment and coated finishes are common in cotton upholstery fabrics to increase their wearing properties.

The use of synthetic fibre has been increasing in every textile field. In 1969, the consumption of synthetic fibres was 21 per cent of total world fibre production, and the prediction for 1980 is 39 per cent.

The principal synthetic fibres for upholstery textiles are polyamide, polyacrylic, polyester and polypropylene. The best-known polyamide fibres are nylon, Antron and Perlon. These and the other polyamides have good abrasion resistance, are easily dyed and have good fastness properties. Antron, a textured polyamide filament yarn, is a widely used material for upholstery fabrics. By blending polyamide yarns with different dye affinities, it is possible to achieve multicolour effects in piece dyeing.

Dralon, Orlon and Exlan are polyacrylic fibres that are widely used in Europe. Such polyacrylics have a soft handle, but their abrasion resistance is lower than that of polyamides. Polyacrylics are used in modern upholstery fabrics with velvet and stretch qualities. With polyacrylics, it is possible to achieve bright shades with good fastness properties. Anionic and cationic dyeable polyacrylic fibres are now available, making it possible to obtain two-colour effects of quite different shades with a single dye-bath.

At present, polyesters are not used extensively for upholstery fabrics even though their wearing properties are good. The dyeing of polyester is difficult, and the fibre needs thermosetting finishing treatment. In the future, however, textured polyester yarns will probably be one of the usual raw materials in knitted upholstery fabrics.

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The use of polypropylene fibres, also called "olefins", as raw material for upholstery fabrics is increasing. They are widely used in carpet manufacturing. Olefin fibres have good abrasion resistance and high breaking strength, their handle is soft, and their price is lower than that of other synthetic fibres. Their difficult dyeability has restricted their use mainly to carpet manufacturing. For many years coloured olefins were available only as bulk-dyed material. Today olefin fibres have a 2 to 4 per cent share in upholstery fabrics, but estimates indicate a great increase in the near future.

The properties primarily required for upholstery textiles are good resistance to abrasion and pilling and good colour-fastness to light. The breaking strength gives a good idea of the wearing properties. The weave must be tight enough to prevent slippage of yarns in the seams. The fastness of colour against rubbing, perspiration, water and cleaning must be good. The fabric must also have some elasticity and stretchability for covering.

In a modern textile mill all fabrics are tested before production to make sure that they fulfil the requirements for an upholstery fabric.

The standard methods for testing the wearing and colour-fastness properties of textiles have been published by the American Society for Testing and Materials (ASTM).

There are many types of abraser for determining abrasion resistance. Their principle is the same: a weighted sample is rubbed against a piece of sandpaper. Note is taken of the number of rubbing cycles until the sample has worn through. Tests with a Stoll abraser show that the minimum range for upholstery fabrics is 1,200 to 1,500 cycles. In these tests the weight of the load used is 1 kg and the fineness of the sandpaper is zero. The abrasion resistance for fabrics made of synthetic fibres is about 4,000 to 5,000 cycles, and for coated fabrics about 12,000 to 14,000 cycles.

Colour-fastness is tested according to the standard method in Zenotester or Fadeometer. The sample is exposed to light for 200 hours. The result is compared to a sample scale consisting of eight different standard samples. The number of the standard showing a change similar to that of the sample is noted. The requirement of fastness to light for upholstery fabrics is 6 on this scale.

The required value for wet-fastness properties of colour is 4 on the standard scale; this means that a light staining of white test fabric is allowed. The minimum value for breaking strength of a sample measuring 200 mm in length and 50 mm in width is 45 kg.

Pilling resistance gives a good indication of the wearing propeities of upholstery fabrics. The test is carried out in a rotating box in which four samples of the tested material wound on rubber tubes rotate and rub each other for 10 hours. The number of small fibre balls, or "neps", on the fabric surface is noted. The pilling effect occurs in fabrics in which fibres with a low and a high breaking strength are blended, such as blends of rayon or wool with synthetics.

The quality control of new products and production is very important in textile manufacturing, especially when the product is made of several raw materials and many shades of colour and fabrics.

Glass fibres, already widely used in drapery fabrics, are being tested for use in upholstery fabrics as well. As these fibres have very good abrasion resistance and do not burn, they are well suited for use in upholstery.

Stretch fabrics for upholstery are available commercially and their share of the market is expected to increase. In the United States these fabrics at present constitute at least 10 to 15 per cent of the total production of upholstery fabrics.

One of the most conspicuous changes in textile manufacturing has been the growth of the knitting sector. It is 10 to 20 times faster to produce a fabric by knitting than by weaving. The increased production of knitted fabrics will bring new products at lower prices to the upholstery industry. With the help of coating and coining processes, it is possible to give knitted textiles qualities that make them suitable for upholstering. Broader use of needling and tufting techniques in upholstery fabrics is also foreseen.

The manufacturing of non-woven textiles has increased considerably. The production speed of such techniques is high, comparable to that of synthetic leather. Non-woven fabrics have the appearance and softness of traditional textiles and patterns may be printed on them. With biconjugate nylon as the raw material, it is possible to produce a non-woven fabric with good wearing properties without using any binding substances. Biconjugate nylon yarn has a core of nylon 6 and its fibre surface is nylon 66. In heat treatment the surface layer of nylon 66 melts and binds the fibres. Non-woven products are suitable for mass production in the upholstery industry; they are easy to cut and do not fray.

IX. Plastic foams used in the furniture industry*

Since the mouldability of polymers in their plastic stage was discovered, this field has developed rapidly and a great variety of new plastics has been created. In the late 1930s the expansion of polymers by gases began. Although this technique permits almost every polymer to be foamed, only a few have achieved commercial importance.

While it is possible to froth polymers by whipping them with air and curing the foam, they are generally foamed with inert gases. Use is also made of carbon dioxide or nitrogen peroxide, which is formed by chemical reaction or by the decomposition of suitable chemical compounds. Solvents with low boiling points are also used as gas sources. Foamed polymers may be cured with closed (intact) or with open (ruptured) walls. As a rule, foams with closed cells are rigid and those with open cells are flexible.

Flexible foam

The flexible (open-cell) foams already have a well-established market. Their yearly consumption in the industrialized countries is between 1.0 and 1.2 kg *per capita* and growing at a rate of 8 to 14 per cent. Of this amount, the furniture industry absorbs 40 to 50 per cent for upholstery purposes, exclusive of bedding.

The flexible foams of greatest commercial importance are polyurethane, PVC and latex foams. In Finland polyurethane accounts for 90 per cent of all flexible foam. It has two main components: a polyol and an isocyanate. They are combined into a thermosetting resin and foamed at the same time. Depending on the polyol chosen, the resulting plastic is called polyether, polyester or high-resilient polyurethane foam.

Since polyurethane foams are thermosetting resins, they may be used over a wide temperature range. Polyether and high-resilient foams are little affected by chemical or oxidative attacks; they swell in many solvents but are not damaged by them. Polyester is not attacked by dry-cleaning agents but may hydrolyze in warm, moist conditions. All polyurethane foams are easy to glue.

PVC foam is thermophastic. It is inferior in all upholstery characteristics to polyurethane and latex foams but is easy to weld by high-frequency radiation. It therefore has a certain usefulness, especially in connexion with PVC film, which cannot be glued.

Latex foam is a good upholstery material if it is properly protected against oxidation. However, its share of the market has declined rapidly, both for commercial reasons and because of its lack of self-extinguishing characteristics.

Standards

In general, foams are examined in accordance with national standards such as ASTM, DIN, BS and SIS. Testing methods are similar but results are not always comparable. Some representative tests are described below.

Density. The volume weight of a foam is proportional to the amount of material that will bear the upholstery load. In polyurethane, the volume weight may be given as "bun" density or core density. In bun density the skin is included. For slab stock, the core density of polyurethane foam lies about 2 kg/m^3 below the bun density. A tolerance of ± 1.5 kg/m^3 in core density is normally allowed.

Load-bearing characteristics. Indentation hardness is a measure for the load-bearing properties of a foam. Recommendations H 19 and H 56 made by Technical Committee 45 of ISO (ISO/TC 45) characterize deflection under load. The test is carried out using special equipment for several indentations; the loads for 25, 40 and 65 per cent deflections are usually reported (see figure I). Hardness is almost independent of density and has very little influence on durability.

A useful figure for comparing different foams is obtained by dividing the load of 65 per cent indentation by the load at 25 per cent deflection. This gives a measure of comfort since users want a foam with both softness and a high load-bearing capacity, that is, rapidly decreasing hardness below 30 per cent indentation but increasing hardness above that level.

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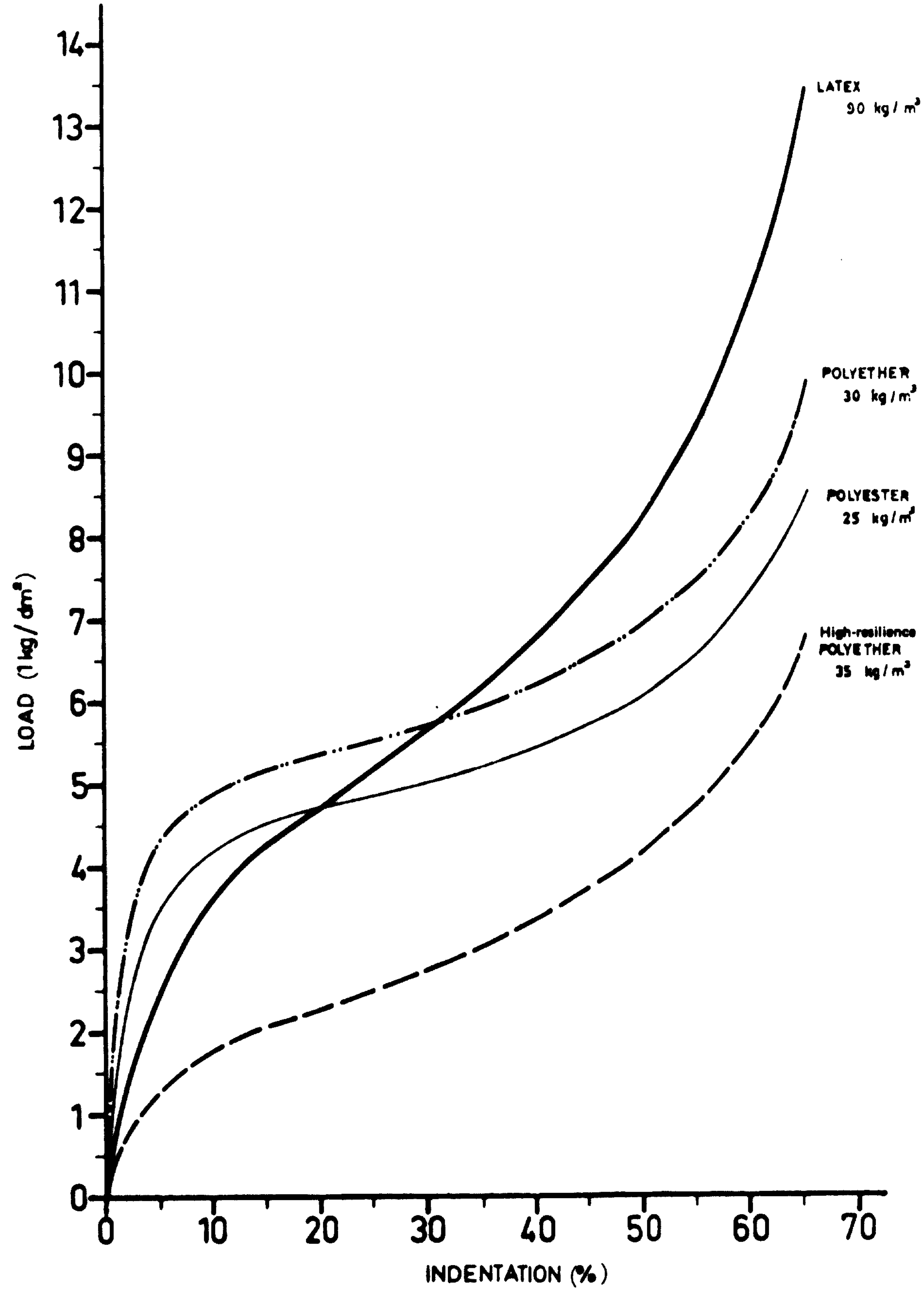
Figure I. Hardness characteristics of some plastic foams



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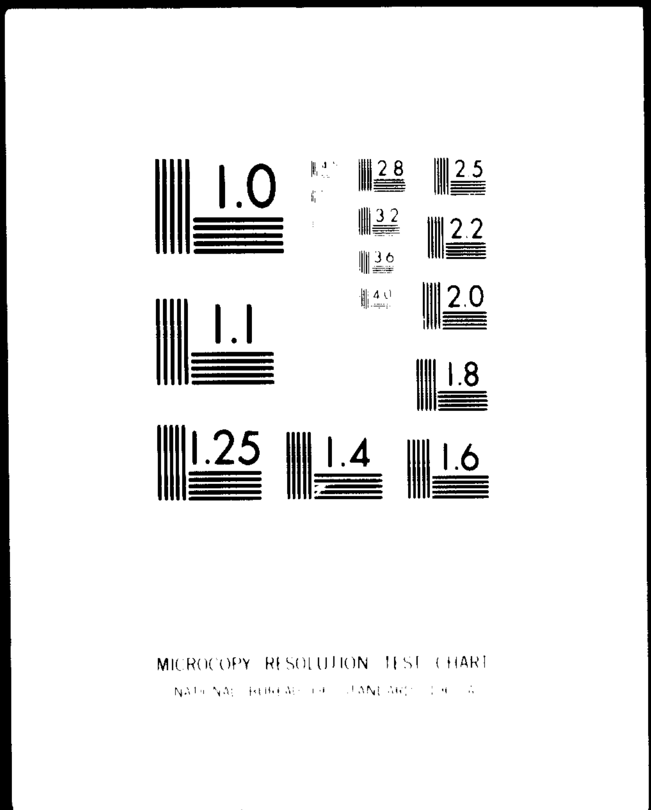

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Permanent set. In a simple way, the permanent set gives an important figure for the actual quality of a foam, that is, its degree of cure. The test is described in detail in preliminary recommendation H 81 made by ISO/TC 45. A specimen is simply compressed by either 50, 70, or 90 per cent for 22 hours at 70°C, and the permanent loss in thickness is measured. With 70 per cent compression a good foam should not lose (permanently) more than 10 per cent, but in some cases a 15 per cent loss is acceptable.

Tensile strength and elongation at break are measured in accordance with ASTM D1564.

Tear strength may be measured by ASTM D1564.

Steam ageing, which shows degradation in humid conditions, may be measured by ASTM D1564.

The flexing test is usually carried out to 250,000 cycles (ASTM D1564). The loss of indentation hardness caused by the flexing gives a figure for one of the principal weaknesses of polyurethane foam.

The breathability test (DIN 52213) gives figures for the amount of closed cells in a flexible foam. Comfort demands high breathability.

The self-extinguishing test (ASTM D1692) is needed when a certain fire resistance is required.

The ball-rebound test (ASTM D1564) gives the resilience of foams.

Rigid foams

Rigid foams are used for thermal insulation, for structural purposes and for packaging. Those used for insulation and packaging have densities of 12 to 40 kg/m^3; structural foams are used in densities from 40 kg/m^3 upwards. The most common rigid foams are:

- Rigid polyurethane foam
- Expanded polystyrene
- Duromer-type polyurethane foams
- Structural polystyrene and similar plastics
- Structural polyolefins

All rigid foams have closed cells. Of the types mentioned above, only polyurethane is a thermosetting resin, the others are thermoplastic. Rigid polyurethane and expanded polystyrene are used in furniture in densities from 40 to 80 kg/m^3. Owing to the low density of these materials, relatively thick walls as well as inserts for bolts, screws and nails are needed. Gluing to polyurethane is easy, but polystyrene requires very carefully chosen glues.

The duromers are used for decorative details and structural purposes. They have a tight skin and a blown core. The over-all density of the duromers is 200 to 600 kg/m^3.

A new development in the plastics field is the use in structural applications of familiar thermoplastic resins lightly expanded by gases. The advantages of structural polystyrene and polyolefin foams lie in the production technique, which permits mass production of large items such as chairs and furniture parts.

Equipment

Plastic foams are made by continuous methods as well as by batchwise moulding. Continuously foamed plastics 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. (For trial purposes, the components can be hand-mixed.) In moulding, mixing equipment with maximum capacities below 60 kg/min. is used. The mould-filling time must not exceed 5 to 10 seconds, depending on the formula. Most flexible foam is produced as slab stock by continuous foaming; it is later cut by band knives or, less often, by oscillation knives.

Expanded polystyrene is either foamed continuously by extruding equipment or moulded by special moulding machines. The denser structural polystyrenes and polyolefins are moulded on especially designed injection-moulding machines.

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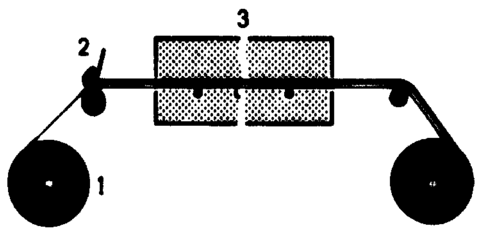
X. The use of synthetic leathers as upholstery materials*

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 cloth whose yarn counts, density etc. depend on the end-use of the product. Artificial leathers made from PVC-coated fabric are the most widely used, although polyurethane-coated fabrics are very competitive and their use is increasing. The base cloth of polyurethane artificial leathers is always napped to some extent. There are also foils, which 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 is not good, and when thicker than the minimum their handle is poor. Foils are used only for chairs that are very hard and cheap.

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 I. Most of the so-called compact coatings are applied in this way. In recent years, however, the so-called transfer method has been gaining ground. In this system 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. Figure II illustrates the process and its apparatus, called a tandem spreading machine. This method is used in the manufacture of expanded-PVC synthetic leathers and in most of the compact-coated polyurethane leathers.

Figure I. Spreading machine for direct coating



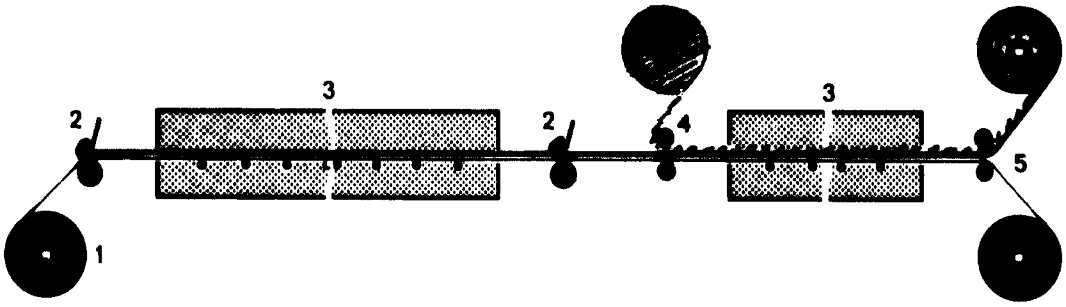
Key: (1) Base cloth
(2) Spreading
(3) Heating oven

There are also machines for printing, lacquering and embossing that are used to make the product look more like real leather. (It should be understood 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.

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

Figure II. Tandem spreading machine for transfer coating



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

Their colours must have good light-fastness; they must change in sunlight very little if at all. In the ISO scale, the value 6 is good and the value 8 excellent. There must be no migration of pigments; that is, they must not work up to the surface. Migration can be observed by wiping with a white cloth, which picks up any loose particles. Bronzing is detected in the same way. In this case the plastic surface has, as the name indicates, a metallic, bronzed appearance. The wet-fastness of colour can be tested by wiping the surface with a wet cloth.

Synthetic leathers resist most of the usual chemicals. However, the effect of adhesives is of great interest to the furniture industry. Although they are discussed in detail elsewhere in this publication,[1] the following facts should be mentioned here.

When dry, wood glues have no effect on synthetic leathers. When wet, however, glues with high acidity or those containing strong PVAc solvent or sulphur can cause discolouring. On the other hand, one of the most popular glues, PVAc dispersion, can be used even for gluing synthetic leather directly to wood with no risk. PVC is sensitive to strong solvents such as thinners. Gasoline (petrol), fats and oils all have a harmful effect on PVC. Polyurethane can resist chemicals much better.

In the 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 air humidity, the hydrolysis property must be taken into account. For this, a laboratory test is made under conditions of 100 per cent relative humidity with a temperature of +70°C. The test lasts for seven days and the plastic must in no case 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 the artificial leather must not have cracked. This test is usually carried out according to the test method of Polyurethan-Gesellschaft Lemförde mbH & Co, Osnabrück, Federal Republic of Germany.

A phenomenon 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 the PVC-fabric synthetic leathers and naturally concern the plastic itself. The base cloth must in some cases be impregnated to resist mildew and bacteria.

One of the more important mechanical characteristics of PVC products is the handle associated with stiffness or 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

[1] See also chapter VII, "The use of glues and other adhesives in furniture and joinery".

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.

A better material is made with expanded PVC, in which 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 the handle. The following table gives the property specifications of the base cloth and of finished synthetic leathers.

PROPERTY SPECIFICATIONS OF THE BASE CLOTH AND OF FINISHED SYNTHETIC LEATHERS[a]

Quality		*HK 45*	*TK 60*	*L*	*NL*	*NV*
Base cloth				*Napped*	*Napped*	*Napped*
Yarn tex No./threads/cm						
	warp	38/25	Knitted	28/27	28/26	Knitted
	weft	38/24	cotton	52/31	52/21	nylon
Weight g/m²		210	135	250	185	125
Width cm		135	140	145	130	145
Tensile strength	warp/weft, kp/5 cm	70/45	16/8	58/88	49/51	25/56
Elongation	warp/weft, per cent	12/21	76/170	7/27	7/26	80/70
Tear strength	warp/weft, kp	1.8/1.6	1.1/	1.8/2.0	3.4/2.9	1.9/1.9
Coating		PVC compressed	PVC expanded	PU	PU	PU
Weight g/m²		430	600	80	80-90	100
Total thickness mm		0.7	1.4	0.85	0.7	0.7
Tensile strength	warp/weft, kp/5 cm	82/62	35/17	45/83	45/42	29/59
Elongation	warp/weft, per cent	12/44	32/190	7/28	6.5/30	70/82
Tear strength	warp/weft, kp	1.9/1.8	1.8/2.4	2.1/2.0	3.4/2.9	1.7/2.0
Cold flexibility	°C	42	33			
Abrasion	revolutions	>5000	>8000	3000	>3000	5000

[a] HK 45, TK 60 etc. are the code numbers of upholstery materials produced by Oy Finlayson-Forssa Ab, Forssa, Finland.

Some polyurethane synthetic leathers are porous and others are not. Porosity can easily be tested with cigarette smoke, as follows. Smoke is inhaled and a test sample is pressed tightly against the lips. If the exhaled smoke passes through the test piece, it shows that the piece is porous or perforated.

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 half-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-Forssa AB Plastics Works the specified elongations are as follows: in the warp direction, 35 to 70 per cent, and in the weft direction, 50 to 100 per cent. As shown in the table, the upholstery quality NV is the best.

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; the 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.

Detailed tests of upholstery materials made by the Furniture Industry Research Association (FIRA), Stevenage, Herts, 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.

The different types of plastic materials have different possibilities. Compact PVC may be used as upholstery material for very cheap furniture 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 furniture in public buildings and for domestic furniture. Its share of the market is about 80 per cent.

The share of the market of polyurethane materials is only about 10 per cent at present but it is expected to increase. Since this material looks so much like leather, it will probably be widely used for domestic furniture in the near future.

Prices always change, but given a hypothetical price for compact PVC of 1, the price of expanded PVC would be about 1.5 to 2 and that of polyurethane from 2.5 to 3.

XI. Hardware and metal fittings*

Wood has traditionally been the primary material in the furniture industry. Although iron and stone have been used for making such articles as benches and chairs, the combined use of metal and wood is rather new. Serious attempts in this direction began in England in the 1850s. Helena Hayward's book *World Furniture* is recommended to those interested in the historical development of furniture making.[1]

The development of metallurgy contributed to the successful combination of steel and wood. The trend received further impetus from the architectural school known as "Functionalism", so that from roughly 1920 onwards the use of metal and wood in the same piece of furniture has become increasingly common.

In this chapter hardware and metal fittings are considered separately. The discussion of hardware is divided into hardware used in furniture making and hardware used in the joinery industry.

Hardware

In Finnish usage, hardware, and especially building hardware, includes a wide range of products, such as levers, door-handles, locks, hinges, doorbells, espagnolettes, door-stops and curtain-rail brackets.

Materials

Brass is very common in hardware. It is used in sheet, profile and pressure-cast forms. The usual brass alloy consists of about 63 per cent copper and 37 per cent zinc.

Another important zinc alloy is Mazak (Zamak), which consists of 3.5 to 4 per cent aluminium, 0.5 to 1.0 per cent copper, 0.3 to 0.8 per cent magnesium, and a maximum of 0.1 per cent each of manganese, iron, lead, cadmium and tin, the balance being zinc. It is used in pressure-cast articles and is very popular because its cost is about two thirds that of brass. In good conditions, it can be used in the same ways as brass. Mazak is always chromium-plated.

Prior to the introduction of Mazak, aluminium was widely used because of its relatively low cost. At present, however, its importance as a hardware material is decreasing except in low-cost items. It is still used in sheets, profiles and pressure castings.

Steel is used mainly in sheets, out of which certain articles are pressed.

Finishes

Finishing is an essential part of hardware production because it determines the final appearance of the article and protects its base material against corrosion and wear. Finishes are either mechanical (such as painting and polishing), electrochemical (chromium and nickel plating) or chemical (anodizing and oxidizing).

Polishing. Most hardware is polished before the final finishing to remove possible scratches caused by prior work phases, but polishing itself can also be the final finishing, as with brass and aluminium articles. Polishing is done with rough brushes that give the article a dull surface.

Painting. This is usually done electrostatically, principally to provide a decorative finish because the corrosion resistance and durability of such coatings are not good. However, the use of painting is supported by the ease with which it can be done, the many alternatives it provides and possibilities for retouching, and the availability of the new plastic-component paints.

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*By Seppo Aho, Joutjärvi Oy, Lahti, Finland. (Originally issued as document ID/WG.105/36/Rev.1.)

[1] London, Hamlyn, 1969.

Plating with chromium. Chromium plating is the most important galvanostegic finish. It gives good corrosion resistance, durability against mechanical wear and a choice of several different surfaces, of which three bright, satin and black are used in Finland. Chromium is usually applied to steel, Mazak and brass.

According to the standards used in the Finnish hardware industry, the application consists of two layers of copper, one or two of nickel and, finally, one of chromium, the layer thicknesses being 8 to 10 microns (μm) of copper, 16 μm of nickel and 0.2 μm of chromium. If a black chromium finish is desired, an additional black layer is put on.

Nickel plating and copper plating are done in the same way, that is, electrolytically but without the chromium layers.

Anodizing. Aluminium can be treated electrolytically so that its surface is made porous by oxidation. Certain pigments are impregnated into the pores which, when closed, produce a decorative coloured surface that may be used in places where mechanical wear is slight.

Oxidizing. Brass can be oxidized in various ways to give it a decorative dark surface.

Hot-dipping. Steel hardware can be coated mechanically by dipping it into molten metal; the resulting thick layer resists corrosion very well. While zinc and aluminium are the most common covering metals, copper and brass may also be used.

Qualities required of materials and finishes

When choosing hardware, several points must be taken into consideration. For example, in the open air of an industrial site or near the sea, brass hardware must be used, whereas in clean air and indoors Mazak and steel hardware can be used. Likewise, in articles such as door-handles that are subject to heavy wear, chromium plating is preferable while painting or zinc plating is suitable for more sheltered places such as mortised locks and espagnolettes.

Appearances sometimes call for certain finishes; in Finland, for example, it is customary to combine polished or brushed brass with such coloured woods as teak and mahogany.

Metal fittings

The subject of metal fittings will be considered from the furniture industry's point of view since the building sector usually has special requirements. The most important items are thus the legs, arms and backs of chairs, tables and table legs, and the bodies of chairs and sofas.

Materials

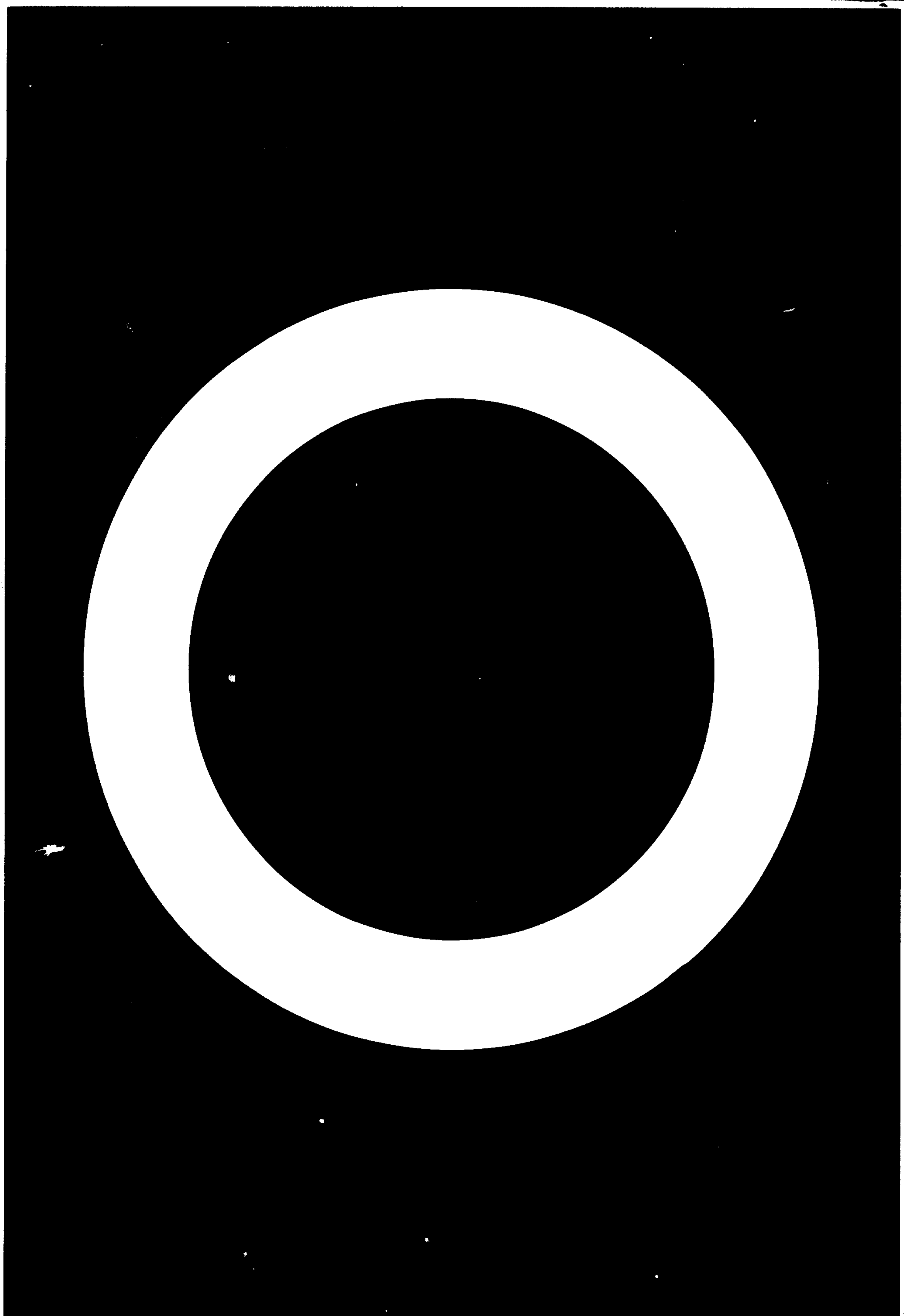
The material most used by the furniture industry is tubular steel, the profile of which may be round, square, oval, flat-pressed or some combination of these. Aluminium and brass are used as tubes and profiles, as are parts pressed or cast from aluminium, brass or steel sheet. Some other alloys are used to a lesser extent.

Finishes

The finish of metal fittings is at least as essential as that of hardware and, considering the design of metal fittings, perhaps even more so. The most common finish is chromium plating with bright or satin chromium, but almost as important is painting, since new paints and methods now permit the production of more resistant surfaces.

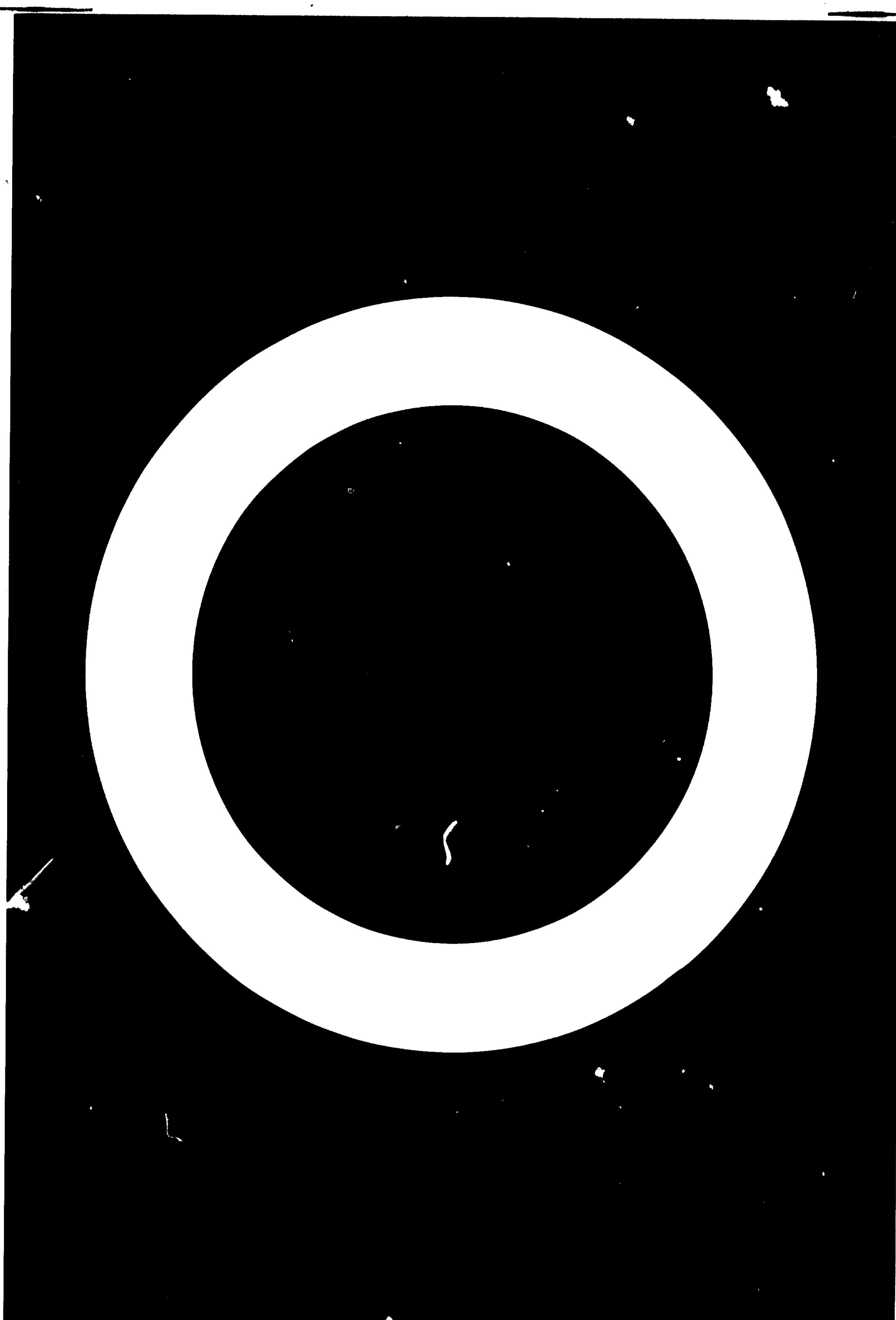
Future prospects

New raw materials are constantly being tested. At the moment, glass fibre and various plastics offer the best possibilities. Plastics have made a debut in the hardware industry in levers and door-handles, light hinges, pulls and the like, and both glass fibre and plastic are being used in furniture bodies and upholstery. A promising new material is asbestos cement, which has been used as a raw material in various chairs and benches.



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 the 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.

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 the 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 sift them.

Positive aspects

A developing country's own system of design education will guarantee the future needs of its industry. The tightening competition in world markets is raising design standards, and products with the exotic touch that only designers familiar with tradition can give increase the possibilities of a country's penetrating foreign markets. Consumers are becoming more and more critical of design when selecting goods.

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".

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

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.

Overseas education

All these factors considered, sending talented young people overseas 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 such training could be selected through competitive examination or through the two-week selection courses mentioned above.

Positive aspects

As with local training, overseas training 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.

The professional level of designers trained overseas 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 at first hand the competition. It is therefore very important that student designers use their college vacations to gain experience in modern industry.

Upon completion of overseas training, 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 overseas education 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 work and its success on the market are his 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 overseas education 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. For example, the successful co-operation between a designer from Thailand and a European furniture company is of considerable international significance in the future field.

Positive aspects

The importation of designers makes possible the creation of new salable 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

Initially, a designer from an industrialized country will have difficulty understanding local working methods. His attempts to become accustomed to them may take a long time and impair his interest in local design development. Furthermore, if local salaries are appreciably lower than those in his own country, he may return home more quickly.

If a foreign designer's income is paid on a royalty basis, mass production of his designs must be on a very large scale if he is to earn as much as he could in his own country, local factory prices being much lower than in industrialized countries. If it is a question of only a few years' contract work, his remuneration may barely cover his 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 quality of his 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 salable 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 with the new demands and with the narrowing distance between international and local designs.

Negative aspects

The value of imported plans and designs may decline if long distances and lack of personal contact cause the designer to lose interest, especially if his 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 his own 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 quality 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 actual but in terms of its normally short-lived influence 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 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, designer meetings etc. 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.

XIII. Service conditions of furniture designers in Scandinavian countries*

The working circumstances of 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 perquisites 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 may occasionally design furniture, but this cannot be considered his profession.

Furthermore, the mobility of furniture designers, in Finland at least, is very high, so that their distribution over the three categories changes constantly. There is also the question of who can be considered a full-time, professional designer. There may be as few as 40 active, full-time furniture designers in Finland, although this number is only about 23 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 a designer's point of view the first arrangement has the important advantage of giving him independence; if he receives an advance against his royalties, he may be able to devote considerable time to a given design. Moreover, if he is working with several different firms, the end of a working relation with one of them will not be catastrophic; he will have lost only part of his income and will be free to establish new working relations. The disadvantages are that he must pay all of the development costs and bear all of the risks before his design is sold if it ever is! 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, the designer still enjoys a large measure of independence, and the employing firm pays part of the development costs. On the other hand, since the designer's total share is still felt to be too small, his share of the risk is considered to be proportionately too large.

In the third system, with a larger royalty and smaller fee, the designer still maintains much of his 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 the designer is that he gets his money at once. On the other hand, he 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 a free-lance designer signs a fixed-term contract to produce a certain amount of work within a given time for a set remuneration, he has given up his independence for the duration of the contract. This disadvantage may be offset, however, by the possibility of conducting research free from immediate financial pressure.

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*By Ahti Taskinen, Lahti, Finland. (Originally issued as document ID/WG.105/47.)

Thus far, salary-and-royalty arrangements with furniture producers have not been known 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 to the designer is continuity of income. Even if he changes employers or becomes a free-lance designer, he will continue to draw income from his earlier work. He can also give precedence to his own ideas over those of his 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 designer's point of view, is that the salary may be too small.

Designers on straight salary

When a designer receives a fixed salary and perhaps some perquisites 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 designer is satisfactory. When it is terminated, however, he retains no rights in, or income from, his earlier work.

Working place and time

Free-lance designers

The free-lance designer normally works in his own studio and at his own pace. However, his income tends to fluctuate with changes in his productivity, the state of the market, changes in fashion and so on. Moreover, he may have difficulty in maintaining contact with his sources of commissions, and he runs the risk of losing familiarity with the production methods of his clients. Another consideration is that difficulties may arise when the working rhythms of the designer and the producer differ widely.

Designers on straight salary

Designers who are salaried, with or without royalties, 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 lose contact with the outer world and become 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, the designer must use his 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 commissioning

Free-lance designers

A free-lance designer normally receives his commissions direct from a producer. He maintains his independence and need not limit himself 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 a free-lance designer accepts commissions from several different producers, it becomes easier for him 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 such a long-term, continuing relation does not develop, his contacts with sources of commissions will be incidental and short-lived, and he will find himself taking all of the risks.

The free-lance designer must thus concentrate on a few producers and become dependent upon them to some degree. He must often guess at the real requirements of a client, since the latter may be reluctant to give him information that might be of value to a competitor. Perhaps his principal disadvantage is that he does not participate in the decision-making process; the acceptance or rejection of his designs is entirely in the hands of the client. Also, for reasons of cost, producers are often reluctant to accept from a free-lance designer a design that might be expected to become a fast seller; the fee and/or royalty would be too great. Work of this kind is usually assigned to a salaried designer.

Designers on straight salary

A designer who works for a salary, with or without royalties, normally works on a commission basis. He is usually part of the development team of a producer and participates 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, the designer has 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. He will have to follow the development plan of his employer and may well find himself involved in routine or distasteful tasks which he will find 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 a designer. He sees and works with the same people year after year and comes to resemble them, since he knows their opinions, attitudes and reactions in advance. Furthermore he runs the risk of becoming entangled in the various intrigues that are found in most large organizations.

Connexions with consumers, retailers and factory agents

Free-lance designers

When a free-lance designer is in contact with several manufacturers he can get a wide range of information. He can thus see things from a broader perspective than a designer who is tied to one enterprise, and he can try to look at things from the point of view of the consumer.

On the other hand, his actual contacts with consumers are usually rather slight and the information he receives is generally out-dated. Since he cannot conduct surveys of consumers, retail salesmen or factory representatives, he has no current information about what is being sold and where and why.

Designers on straight salary

Designers who are in an employee relation to an enterprise have good possibilities for contact with consumers. Also, information becomes available directly from the market. Nevertheless, some of this information will be unreliable because of loss of detail and the time necessary for passing it from consumer to retail salesman to retail manager to factory representative to sales manager and, finally, to the designer. In any case much of the 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.

Free-lance designers

If a free-lance designer conducts research and development work of his own, he can base his designs on it and offer them to the enterprise he considers most capable of making good use of them. If the offer is turned down, he may approach other enterprises with the same ideas. In actual practice, however, the free-lance designer does 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. 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 that he would prefer 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 value, connoting something connected with the arts in general and with sculpture in particular. When a Finn hears the word he understands that aesthetics as well as engineering are involved. 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 Ltd plant in Finland, for example, is also materials oriented in that its primary raw material is Finnish birch, birch being plentiful in Finland. When metal, glass fibre and plastics are used, the employment 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, until it is established that their use would be advantageous in furniture production.

Product development at Asko Ltd comprises all four of the factors mentioned above: marketing design, materials and production. Representatives from these phases of the work form a body called the Product Development Committee. This Committee meets once a week and also includes representatives of the production and marketing divisions, and retailing and exporting personnel. The manager of the woodworking factory chairs these meetings and is responsible for the continued existence of the Committee. He 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 work. The chairman oversees the work of the entire Committee.

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 through experiment over the years and is subject to modification. It can change at any time when and if a situation arises in which a different organization would be considered preferable. The operation 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 to whom the Committee may turn to request a design. The designers are entirely independent from Asko. This is important because it enables the firm to get designs that the marketing or production people could not conceive of. The designers are specialists in their fields, but they are not necessarily specialists in design, 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 and shape and costing so much, and the designer tries to solve the problem. He may feel entirely free to create whatever he thinks that people might buy; he may then present his 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 steadied 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

*By Asko Karttunen, Asko Ltd, Lahti, Finland. (Originally issued as document ID/WG.105/44.)

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 the 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, his 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 operation of the Product Development Committee to have the data from 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 attractive 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, no advance on royalties or additional allowances. The designer thus shares the risk. Elsewhere in Europe, and especially in Italy and France, it is customary that the designer be paid something before he starts work and a royalty after that. This system has not been adopted at Asko Ltd in order to keep the designer free from pressure.

XV. 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, 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, semimanufactures and supplies available on the market.

The need for technical product design

Some of the important reasons for technical product design in the furniture and joinery industries are the following:

- The necessity of maintaining a competitive position on the market;
- The need to develop new forms of construction suited to the many new materials that have been introduced;
- The impact of new production methods and special machines, and the concomitant decrease in manual labour;
- The increasing importance of automation;
- The marked increase in export trade, especially from the northern European countries.

Today, even the smallest factories attempt to carry out systematic product design or 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 following characteristics of a product:

(a) The product must be suitable for the manufacturing process of the plant in question and permit the efficient use of multipurpose machines (for example, double-end tenoning machines and edge-veneering 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 he replaced as far as possible by various kinds of semimanufactured 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;

*By Pekka Paavola, Lahti Technical Institute, Lahti, Finland. (Originally issued as document ID/WG.105/30/Rev.1.)

(e) The constructions should, to the extent possible, be collapsible to reduce storage and shipping costs, especially in export trade;

(f) Similar details should be usable as components in as many parts 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 supply of machine tools at a factory;

(h) Products should be dimensioned in such a way that semimanufactures available on the market can be used with a minimum of waste (figure I);

(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 II). 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 III).

Figure I. Sawing panel components from a standard-sized particle board to minimize waste

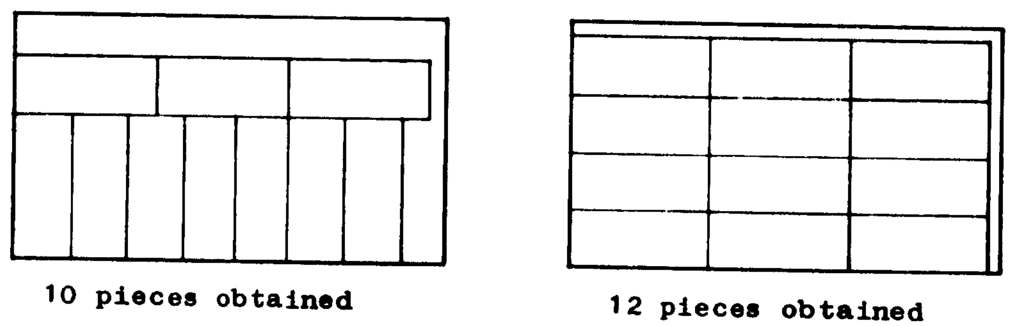


Figure II. Machining grooves in a through-feed operation: (a) possible with standard machines; (b) not possible with standard machines

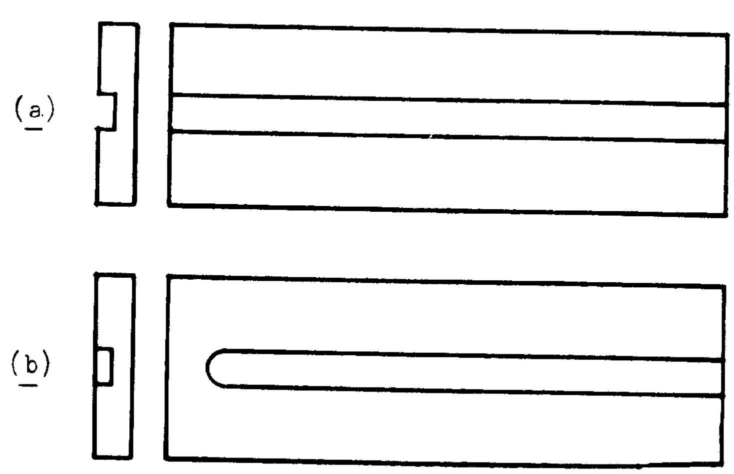
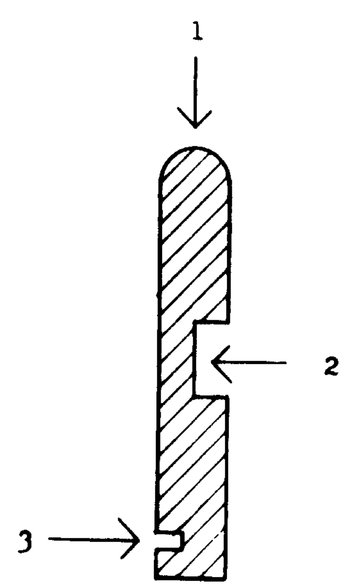


Figure III. A final profile, including three machining phases, produced by a four-side moulding machine



Raw materials for different constructions

With the introduction of particle board and other semimanufactures, many traditional constructions 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.

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 blindwood may be of low quality provided it is sufficiently strong. If the blindwood 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 IV;

(c) Cell construction (figure V) 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;

Figure IV. Veneered solid-wood components

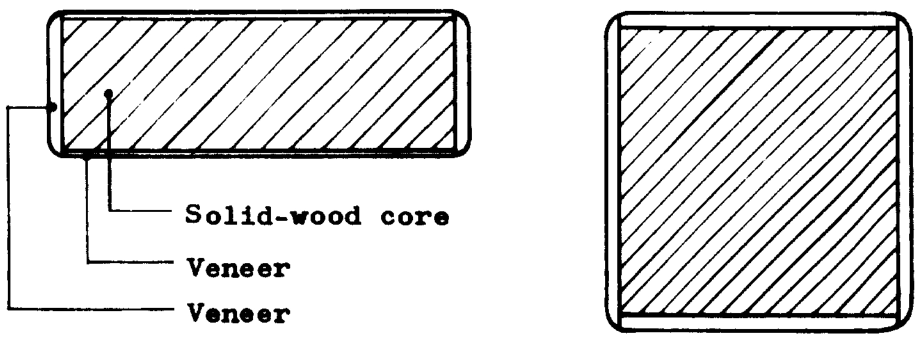
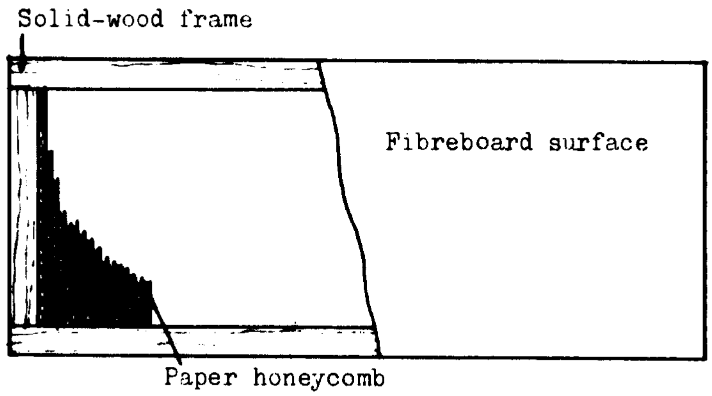


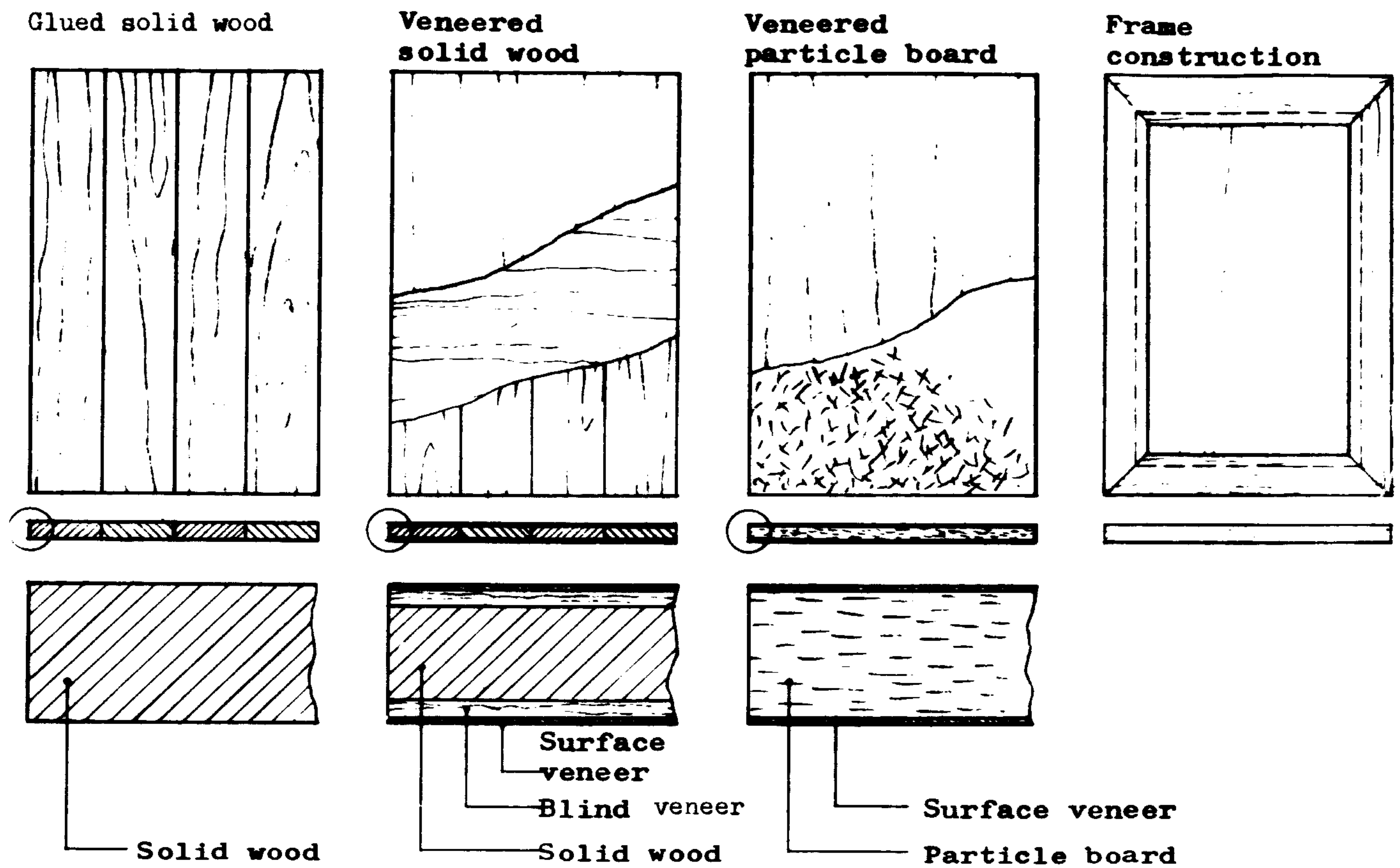
Figure V. Cell construction commonly used for flush doors and kitchen furniture



(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 VI. 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;

(e) Back panels of cabinets and bottoms of drawers are usually made of hard or semihard fibreboard, painted or veneered. Plywood is considerably more expensive.

Figure VI. Four common furniture panel constructions



Joints

The dowel joint (figure VII) 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 multispindle boring machines; the two components of the joint always fit closely;

(b) Dowels are driven rapidly with a special instrument;

(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 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 use of wastewood 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.

Of the traditional joints, the following are fairly well suited to modern manufacturing processes: the corner-lock joint, the tongue-and-groove joint and the mitre joint (see figure VIII).

The stub-tenon joint (figure IX) is a traditional furniture joint but is less used today because its machining is time-consuming and, owing to the rough inside surfaces made by the hollow-chisel mortiser, the strength of the glued joint is reduced. Various kinds of metal fasteners (figures X and XI) are being substituted for glued joints. They have the advantage that the product can be shipped to the customer in knocked-down form, packed compactly. The parts can be easily assembled at the destination even without special skill. An additional advantage is that surface finishing is done to the unassembled parts. Type A in figuie XI with a cylindrical steel nut implanted in wood (in the rail) has excellent strength and is therefore well suited for jointing chair and table legs to rails. The rail is guided by two dowels. Type B with ordinary nuts is not quite as strong. Type C with a nylon nut is suited only for light loads. Type D is a common fastener for table legs (guiding is not necessary).

To simplify design and fabrication, the joints should be standardized to a few types. The machining dimensions of selected joints should also be standardized. The recommended practical tolerances for mortise and tenon joints are shown in table 1.

TABLE 1. LOWER AND UPPER LIMITS OF MORTISE AND TENON DIMENSIONS

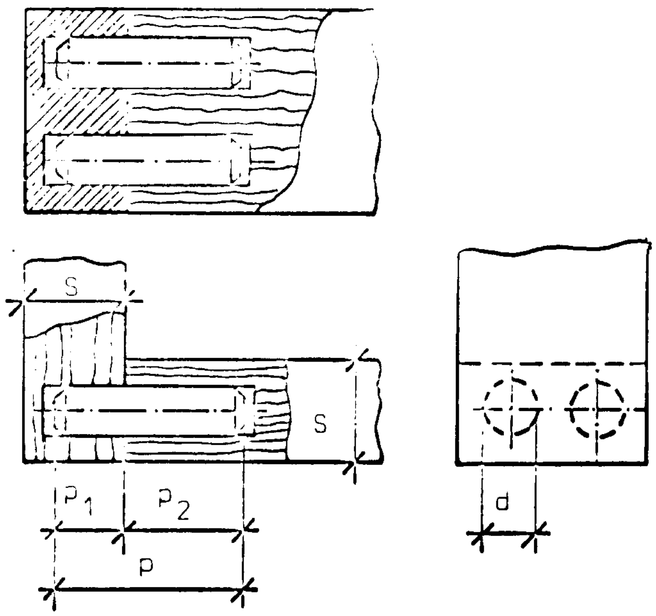
(Nominal dimension of joint is 8 mm)

Hardness of wood	*Boring of mortise (mm)*	*Dowel or tenon (mm)*
Soft (pine, spruce)	+ 0.05 0.0	+ 0.3 + 0.2
Semihard (birch, beech)	+ 0.05 0.0	+ 0.2 + 0.1
Hard (oak, teak)	+ 0.05 0.0	+ 0.1 + 0.0
Very hard (rosewood, wenge)	+ 0.05 - 0.0	+ 0.0 - 0.1

The modular dimension principle and element-furniture combinations

A module is a basic unit of measurement, all larger dimensions being multiples of it (figure XII). Today much home, office and kitchen furniture, both movable and stationary, is dimensioned on the modular principle. Basic pieces of furniture manufactured on the modular principle, called element furniture, may be combined by customers into larger units according to their individual needs and tastes. A great variety of combinations is possible in many element-furniture systems.

Figure VII. The dimensioning of a dowel joint used as a corner joint



Millimetres

S	d	p	p_1	p_2
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

Figure VIII. Three traditional joints suitable for modern furniture-manufacturing processes: (a) corner-lock joint, (b) tongue-and-groove joint and (c) mitre joint

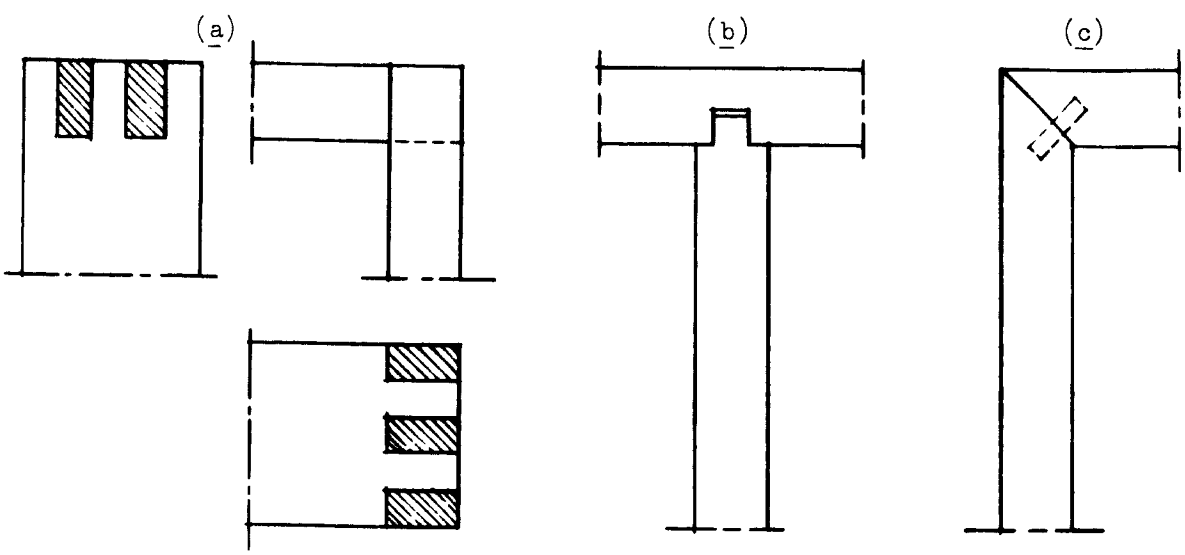
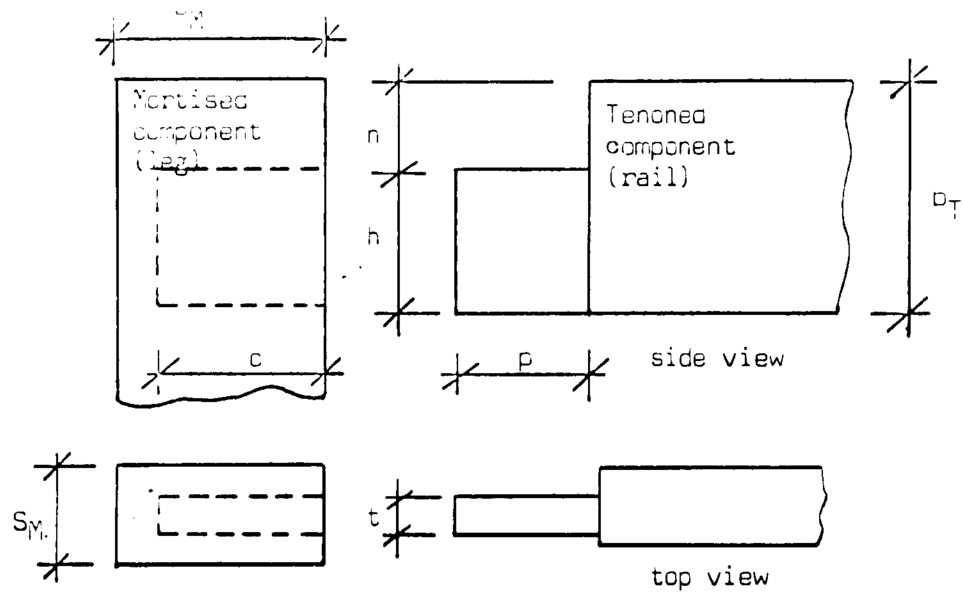


Figure IX. The dimensioning of a stub-tenon joint.
The tenon must be as long as possible and machined about 0.2 mm thicker than the mortise



Millimetres	
S_M	t
6	3
8	4
11	5
14	6
17	8
20	8
26	10
32	14
36	16
44	20
50	23
56	26

c = p + (2 to 5) mm

Millimetres		
b_T	h	n
14	8	6
17	10	7
20	12	8
26	16	10
32	20	12
38	22	16
44	26	18
50	30	20
56	34	22
60	36	24
70	42	28
80	48	32
100	60	40
120	72	48

Figure X. Some fasteners used in furniture construction: cylindrical steel nut embedded in the wood, ordinary nuts, nylon nut, common fastener for table legs (no guiding necessary)

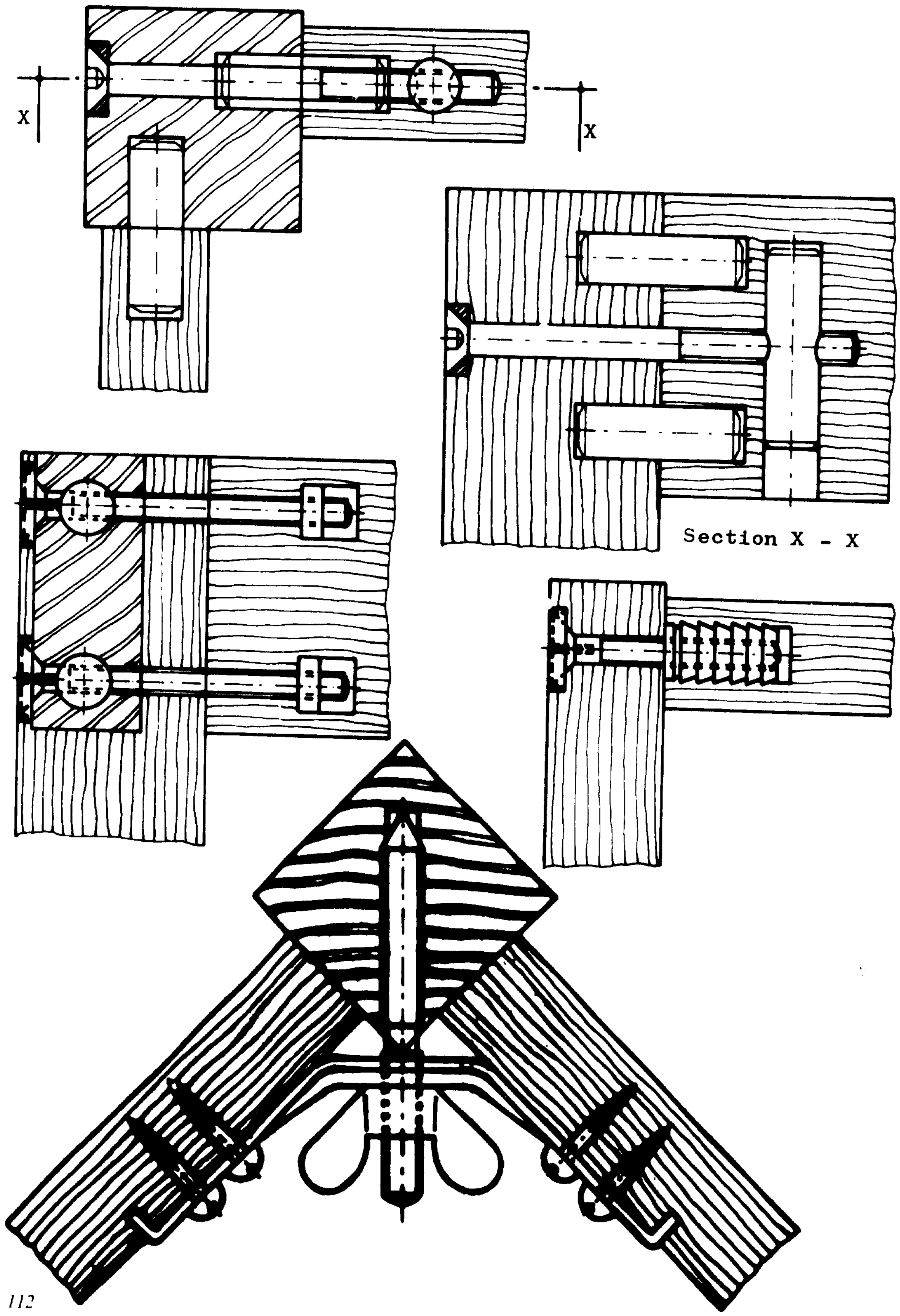


Figure XI. Dimensions of some metal fasteners used in furniture production

(M3, M6 etc. refer to standard metric threads)

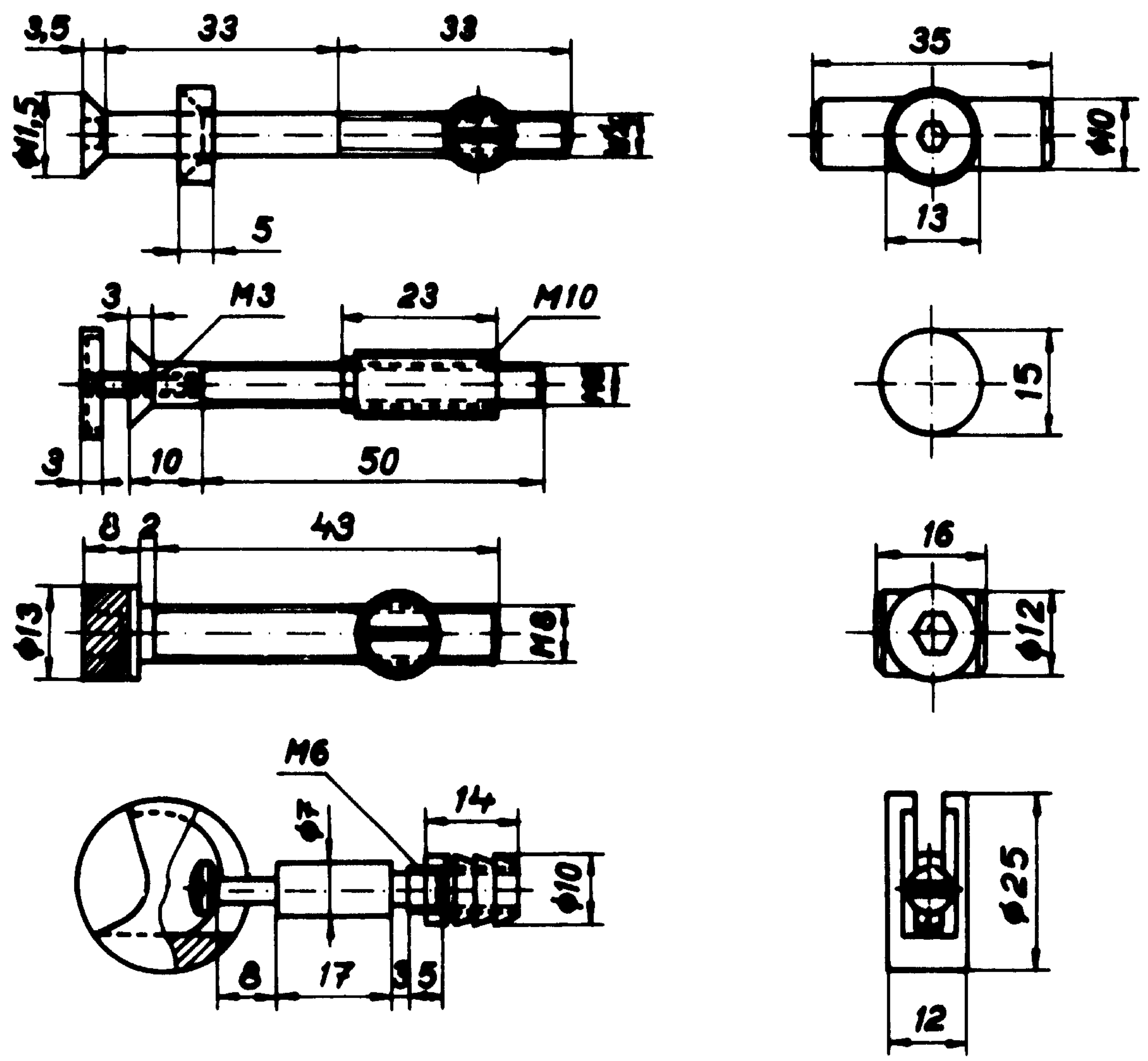


Figure XI *(continued)*

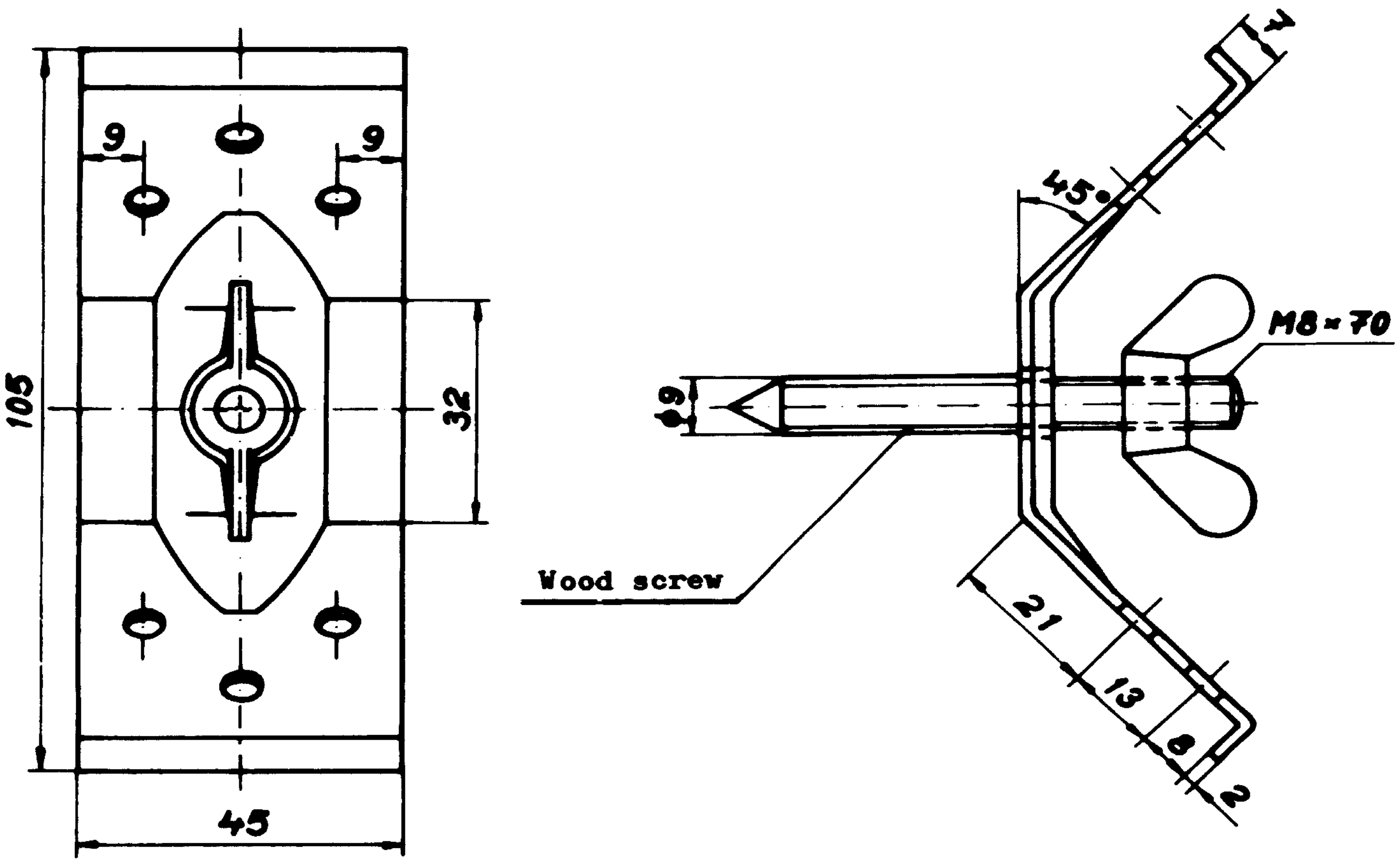
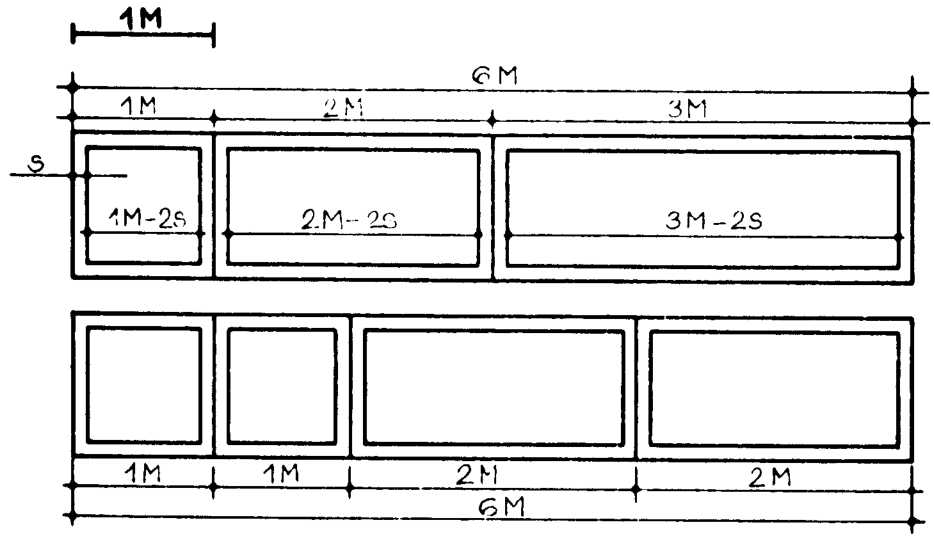


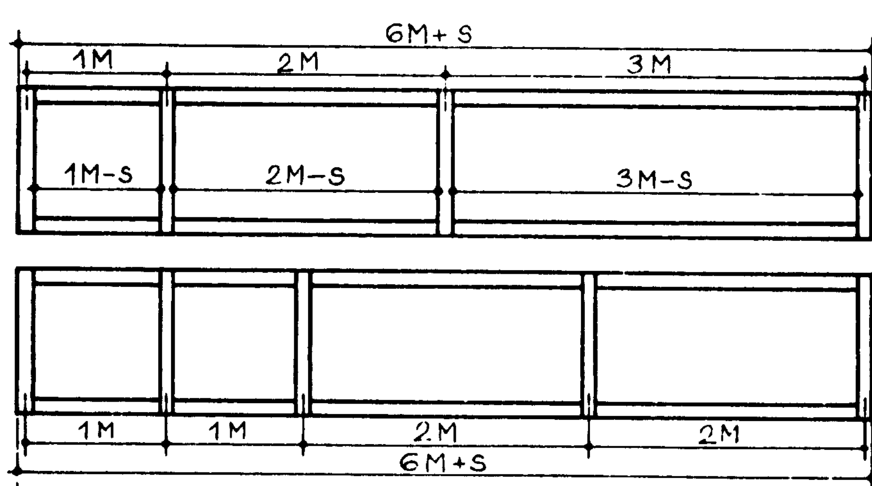
Figure XII. Some commonly used ways of expressing width combinations, showing the importance of the inclusion or exclusion of the side pieces in the calculation of space requirements

(M = module, s = side piece)

(a) Modular design using outside measurements



(b) Modular design using centre-to-centre measurements



(c) Modular design using inside measurements (abutted components)

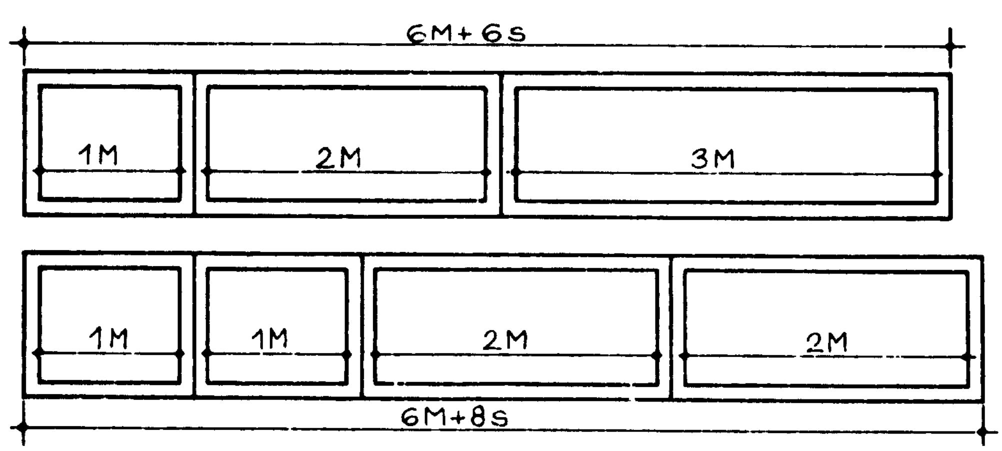
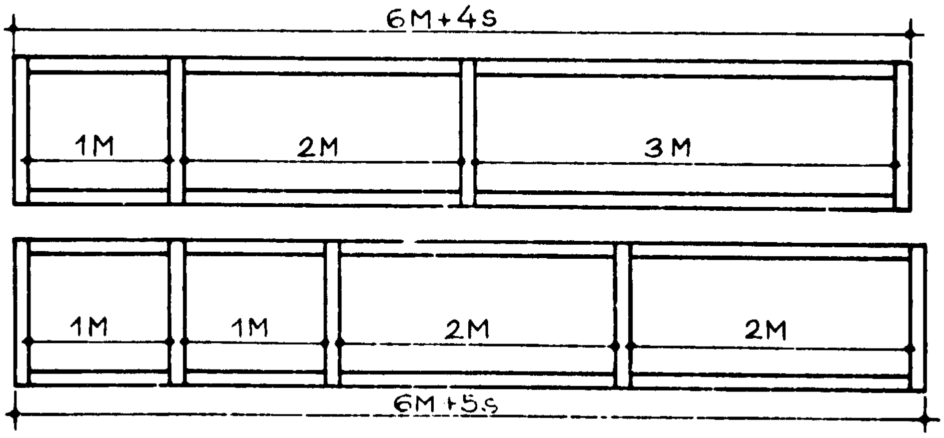


Figure XII *(continued)*

(d) Modular design using inside measurements (one component)



Concealing dimensional inaccuracies by structural means

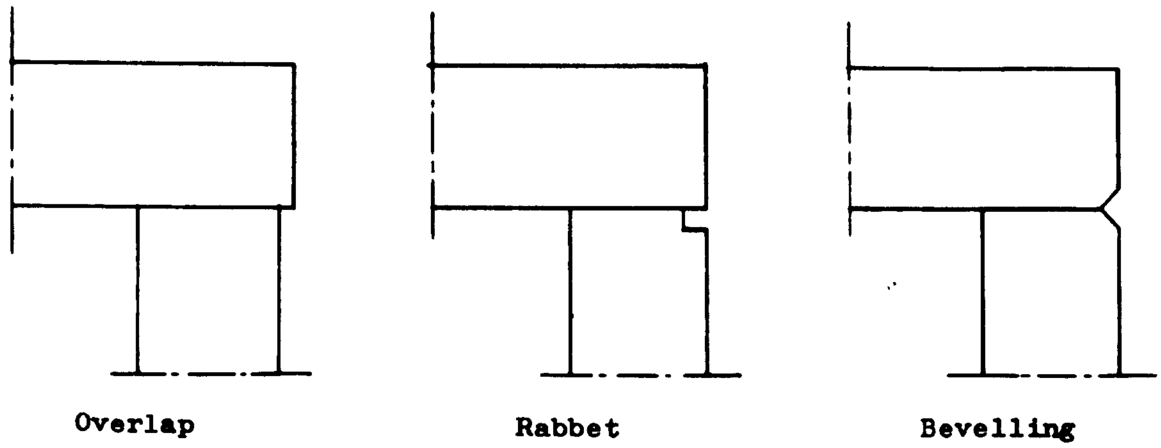
Inaccuracies resulting from dimensional deviations in raw materials, such as variations in the thickness of particle board and inaccurate machining, may be rendered inconspicuous and practically invisible to the naked eye by appropriate constructional designing. At the same time, hand-fitting in the assembly phase is avoided. Structural means of this kind include overlap of one component and rabbeting or bevelling at the line of joining (figure XIII).

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.

Drawings and dimensions

The drawings used in the furniture and joinery industries are of two principal types: full-scale drawings and drawings to scale. Their characteristics, advantages and limitations are described below.

Figure XIII. Structural means of concealing dimensional inaccuracies



Full-scale drawings (1 : 1 scale)

(a) Dimensions are taken by measuring the workpiece against the full-sized drawing when the machine is being set up for machining operations;

(b) No dimensions are indicated on the drawing;

(c) The accuracy of manufacture is poor;

(d) In general, 1 : 1 drawings are not suited for modern serial production. They are useful, however, in presenting the dimensions of curved and complicated details of chair members, profiles and the like.

Drawings to scale

(a) For each member of the product, a complete drawing is made according to a given scale (1 : 2.5, 1 : 5, 1 : 10, details 1 : 1);

(b) Section drawings of details (in scale 1 : 1) are often highly illustrative;

(c) The most advanced development method is to draw each original part-drawing on a separate standard sheet (size A4) which is easy to file and to copy with modern copying devices. Copies are then sent to the respective points in the factory;

(d) The dimensional figures on the drawings are decisive, not the measures obtained from the drawing with a scale ruler;

(e) Only the dimensional figures need to be changed if alterations in dimensions are necessary;

(f) An assembly drawing is made of the complete product, showing the position of members;

(g) Joint types may be indicated on the drawings by appropriate abbreviations and symbols.

In figure XIV, a simple product is presented with one assembly drawing and four part-drawings (one of each member). The drawings are also marked for veneer quality (II, IV) and grain direction (↲).

Prototypes

Before serial production of an object is started, it is necessary to make a prototype in order to avoid costly mistakes in the manufacturing phase. The main points in prototype making are:

(a) The prototype must be similar in all respects (jointing etc.) to the intended serial product so as to bring out any defects in construction or fabrication;

(b) The prototype is used to examine and test the properties dimensions, strength, rigidity, appearance of the product in service.

Organization of technical product planning

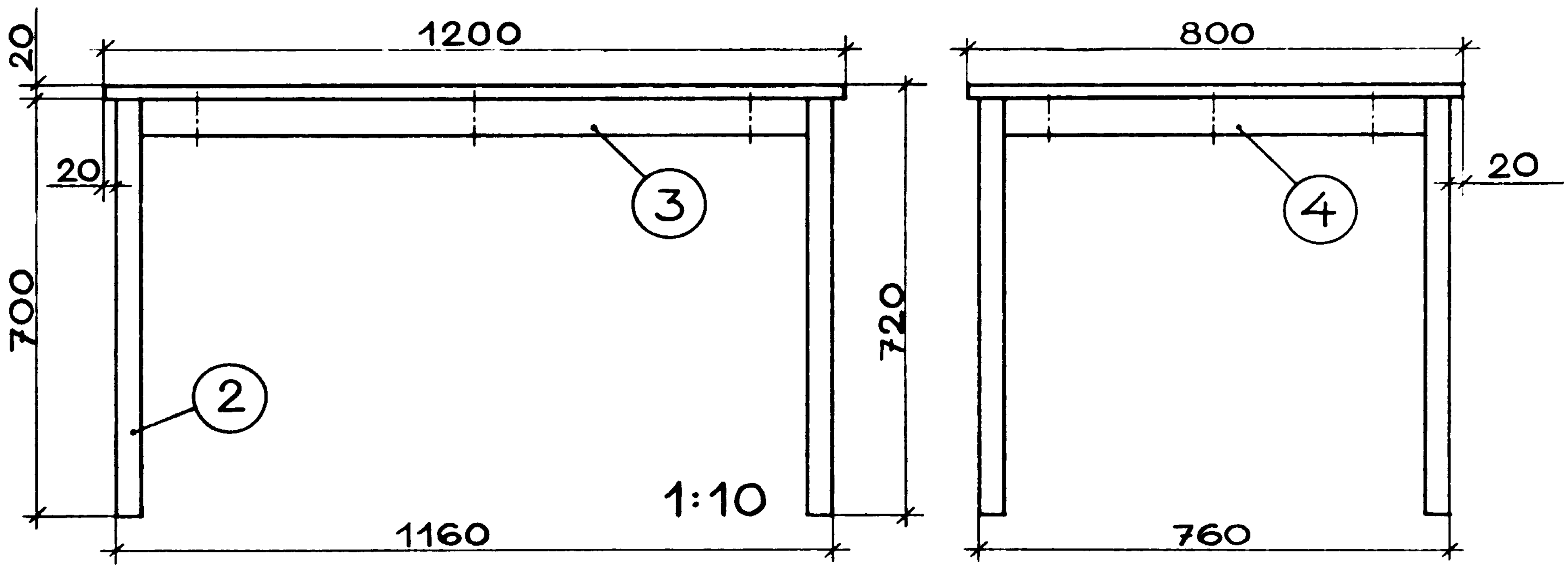
It is customary for a product designer with training in applied art to create an idea and submit it to a factory. The appropriate persons on the factory staff develop a technical plan for the product and make a prototype which is submitted to critical examination and altered until the object is either considered ready for production or is rejected. The phases of product development from idea to manufacture are shown schematically in figure XV.

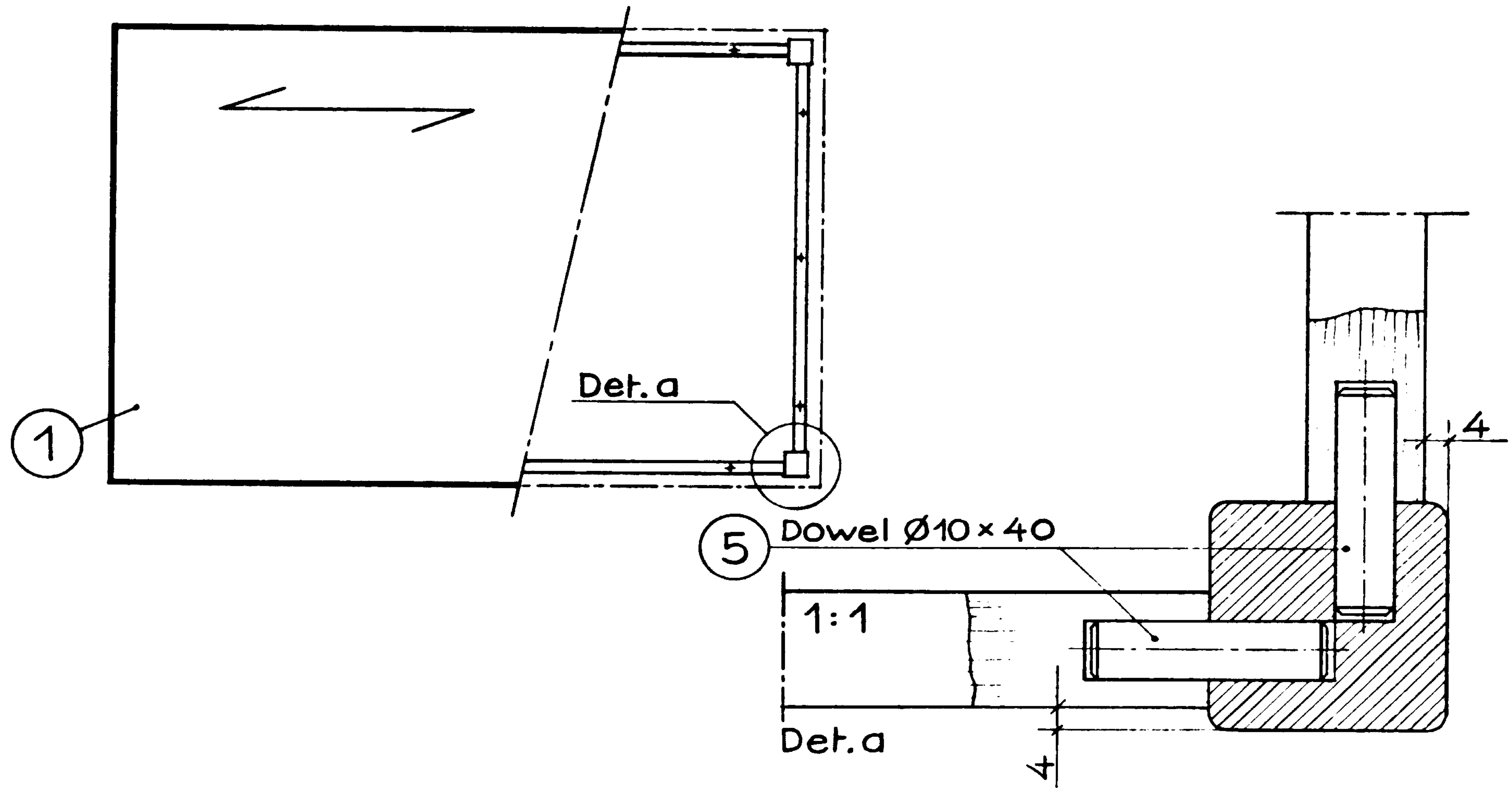
It is more efficient to carry out product planning with a team because product development is greatly facilitated when the various aspects of technical production can be taken into consideration throughout the planning process.

Production design

Production design is one of the preliminary steps to be taken before starting manufacture. Careful production design makes possible the economic utilization of raw materials as well as the most efficient utilization of a plant's production capacity. The principal task of a production design department is to compile two kinds of lists: *(a)* lists

Figure XIV. Assembly drawing of a simple table

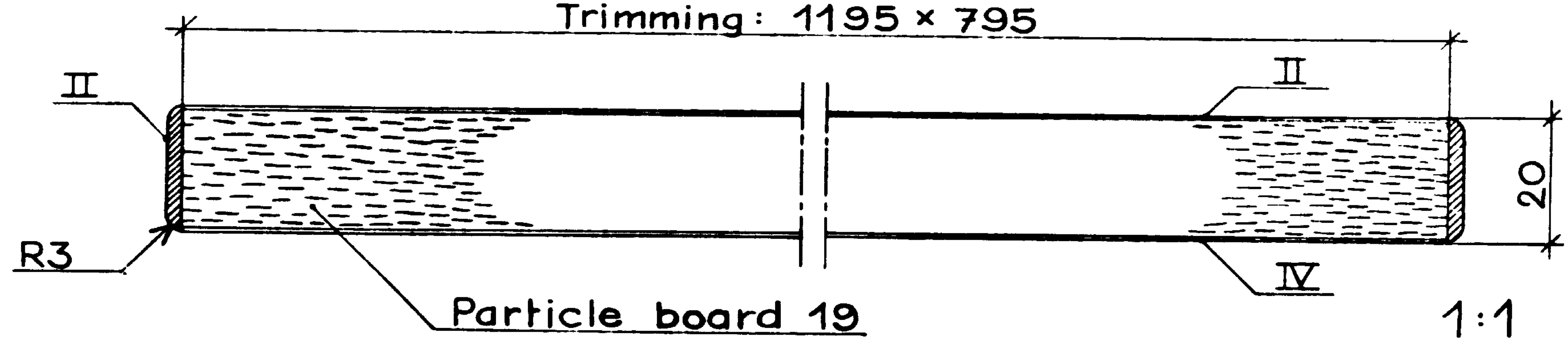


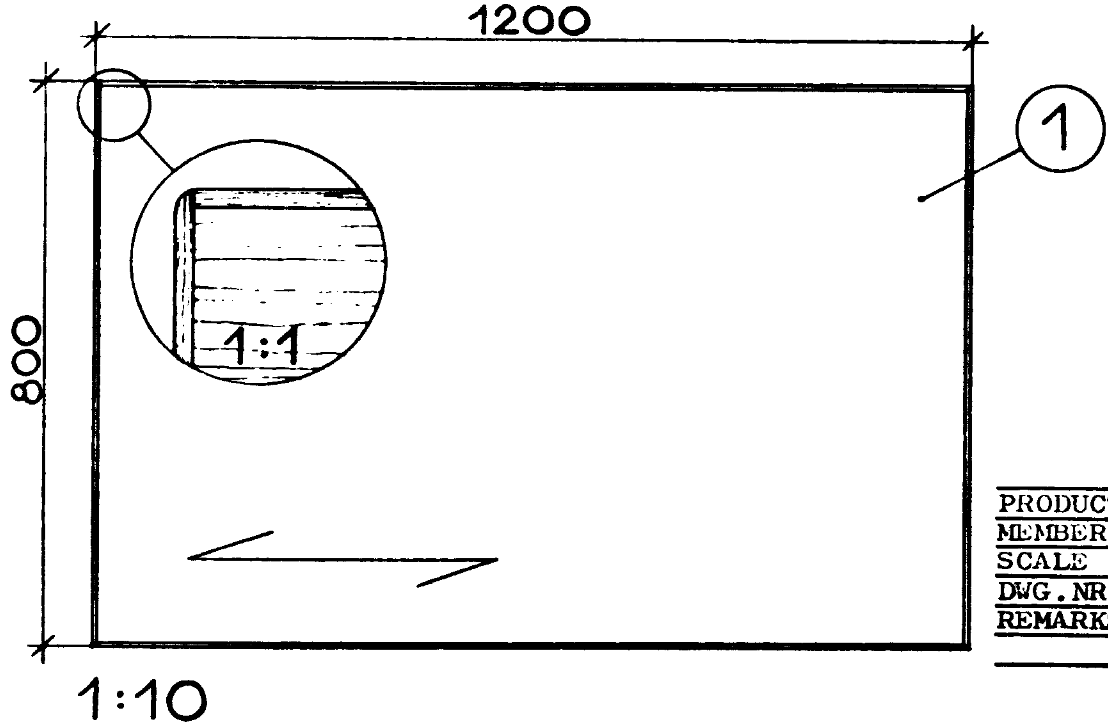


PRODUCT:	Table		
MEMBER :	Assembly drawing		
SCALE :	1:10 1:1		DATE:
DWG.NR.:		DRAWN:	CHANGED:
REMARKS:			

Figure XIV *(continued)*

(a) Part-drawing 1

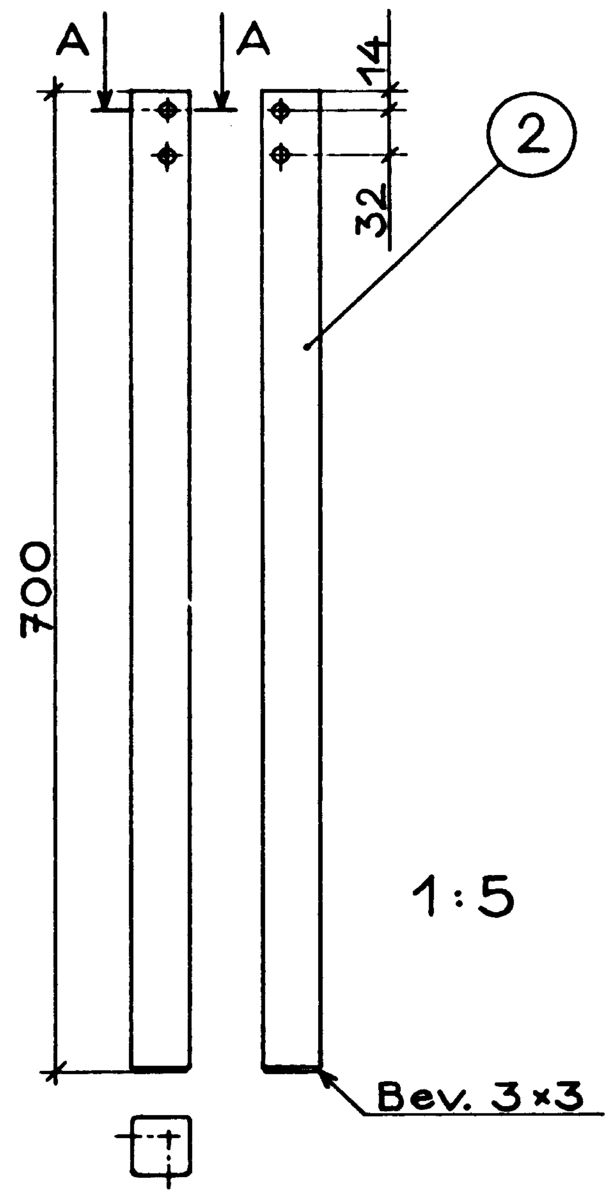


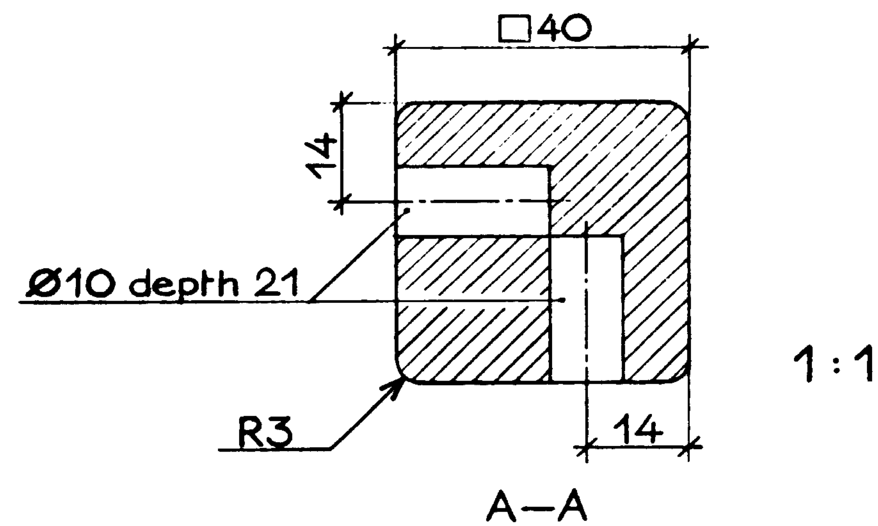


Veneer	Thickness	
	Raw	Sanded
Surface	0.7	0.5
Edge	2.8	2.5

PRODUCT:	Table		
MEMBER :	Top panel (1)		
SCALE :	1:10 1:1		DATE:
DWG.NR.:		DRAWN:	
REMARKS:			

(b) **Part drawing 2**

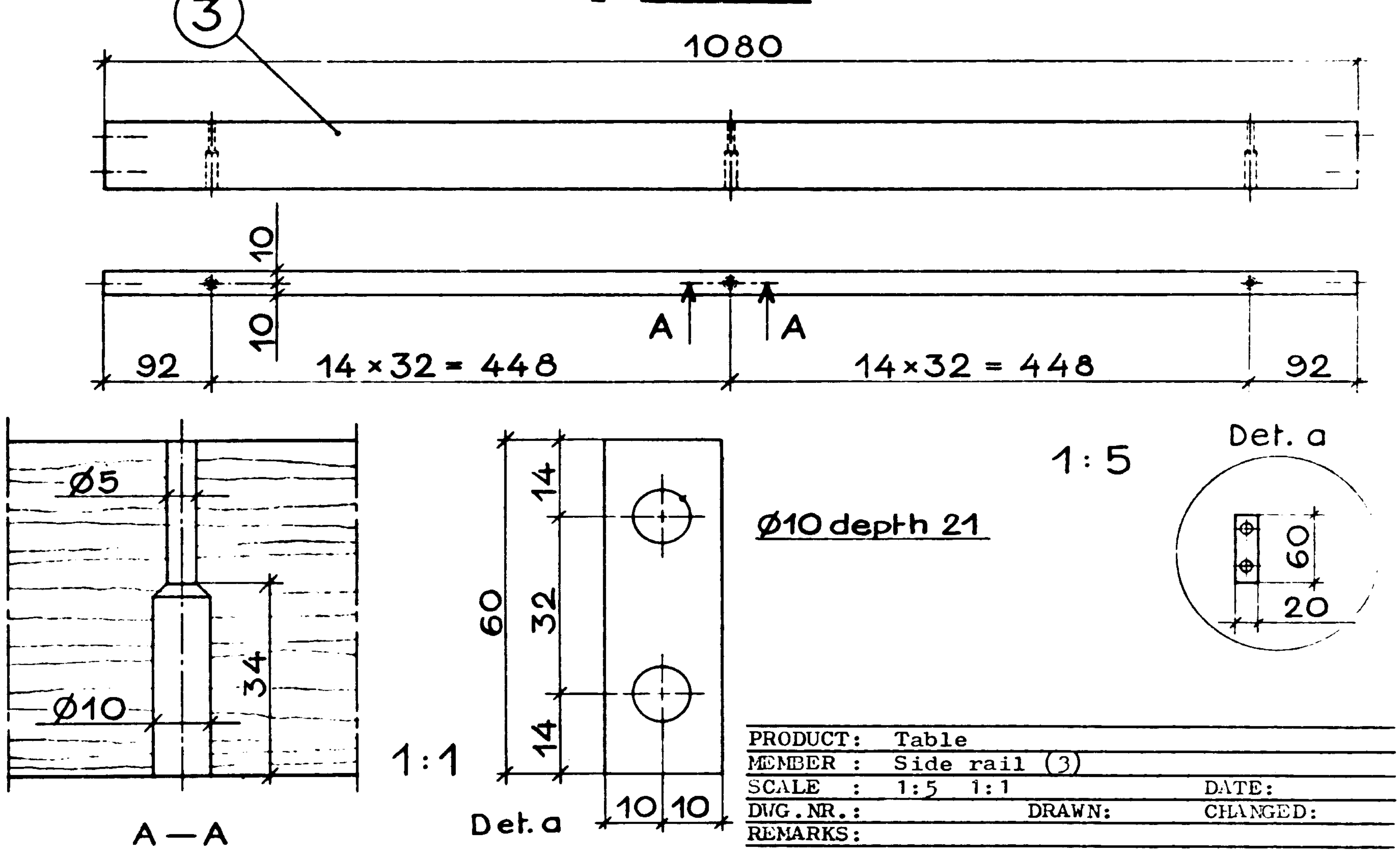




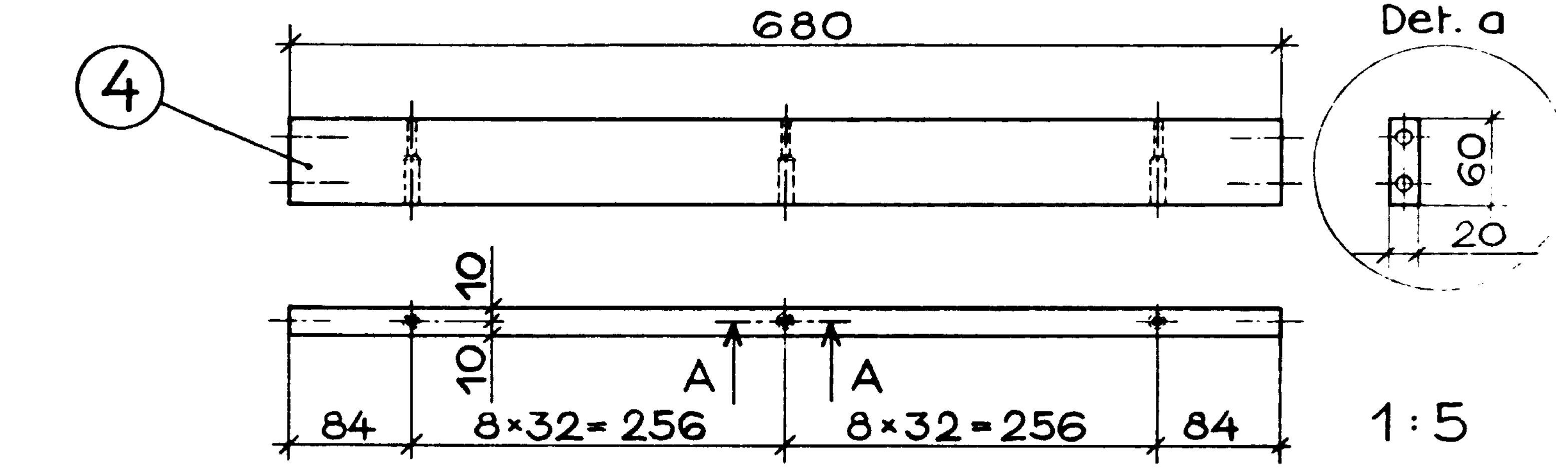
PRODUCT:	Table		
MEMBER :	Leg (2)		
SCALE :	1:5 1:1		DATE:
DWG.NR.:		DRAWN:	CHANGED:
REMARKS:			

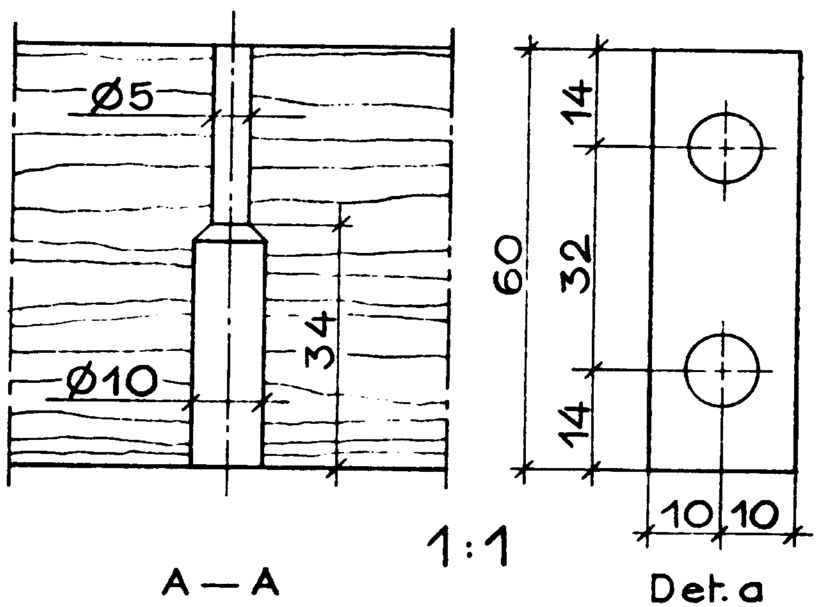
Figure XIV *(continued)*

(c) **Part-drawing 3**



(d) **Part-drawing 4**

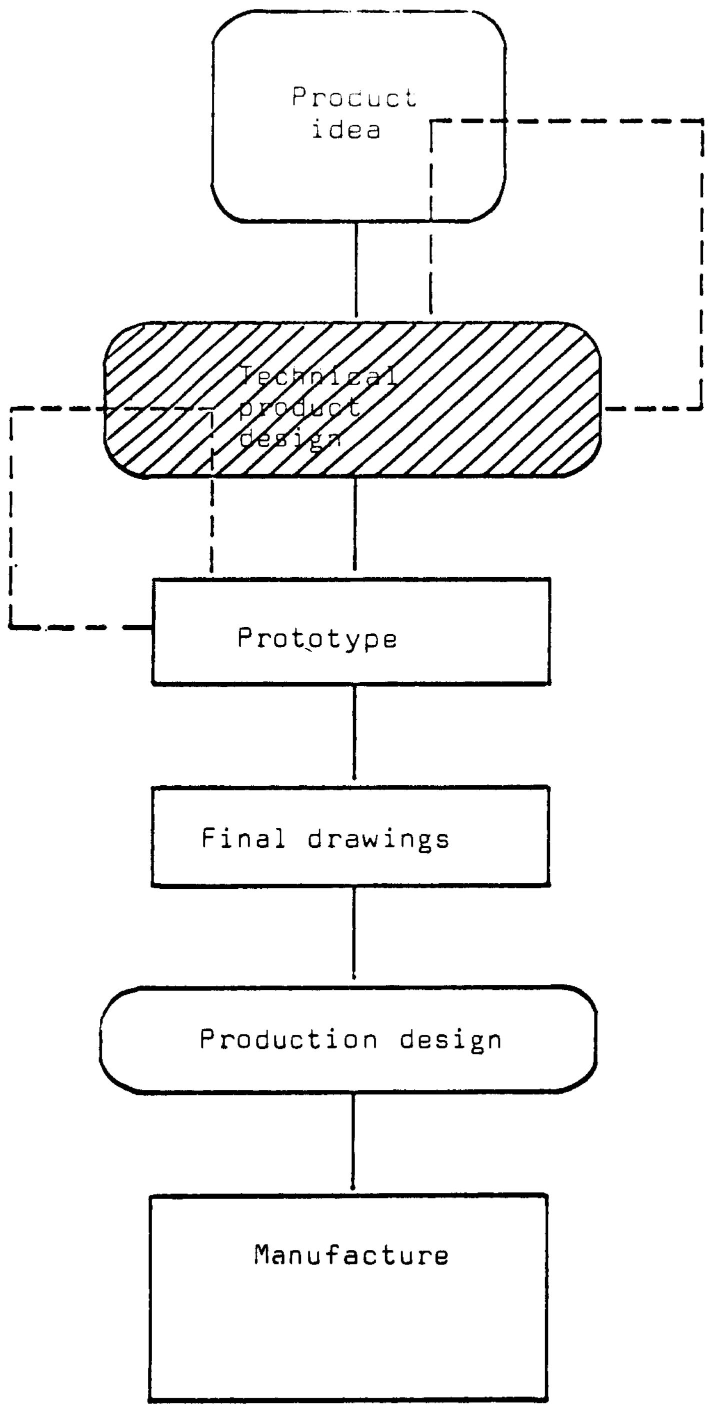




Ø10 depth 21

PRODUCT:	Table		
MEMBER :	End rail (4)		
SCALE :	1:5 1:1		DATE:
DWG.NR.:		DRAWN:	CHANGED:
REMARKS:			

Figure XV. Schematic representation of the phases of product development



of all raw materials and requisites and of dimensions and number of necessary pieces (piece-lists for cross-cutting and edging, for cutting veneer, particle board etc.); and *(b)* operation lists (separate lists for each work phase) for machining, assembling, surface finishing and other phases. The lists follow on cards the production lot through all manufacturing phases. The operation lists give the following information:

(a) The machines and other equipment to be used, listed in the order required by the work phases. Machines and other equipment are indicated by code numbers. The capacities of some basic woodworking machines are shown in table 2;

(b) Details on each manufacturing phase (special tools, grit number of sanding belt to be used etc.);

(c) Completed and uncompleted work phases. Every phase is marked on the card when completed.

TABLE 2. 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 mortising machines	1 400 to 1 900
Horizontal-belt sanding machine	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.

Production control is also concerned with timing the production so that each production lot is completed according to schedule. This is of prime importance as far as a factory's competitive ability is concerned. The following points should be taken into consideration when dealing with production capacity:

(a) The production capacity of a furniture plant using separate detached basic machines and equipment is determined by the so-called bottle-neck (figure XVI);

(b) The production capacity of machines can be raised only in steps, that is as multiples of single machines (figure XVII).

The following means are used to remove bottle-necks in production:

Procuring additional machines
Procuring more efficient machines
Hiring more competent personnel
Working overtime
Working in shifts
Subcontracting some of the work

The removal of a production bottle-neck usually means that a new one will appear elsewhere in the line.

Factors affecting production design

The most important factors affecting production design are:

The availability of machines and equipment
Size of the production lot
Quality desired
Availability of raw materials and requisites
Professional skill of the labour force

Figure XVIII shows the connexion between production design and the manufacturing process.

Figure XVI. Graphic representation of the formation of a bottle-neck in a production line

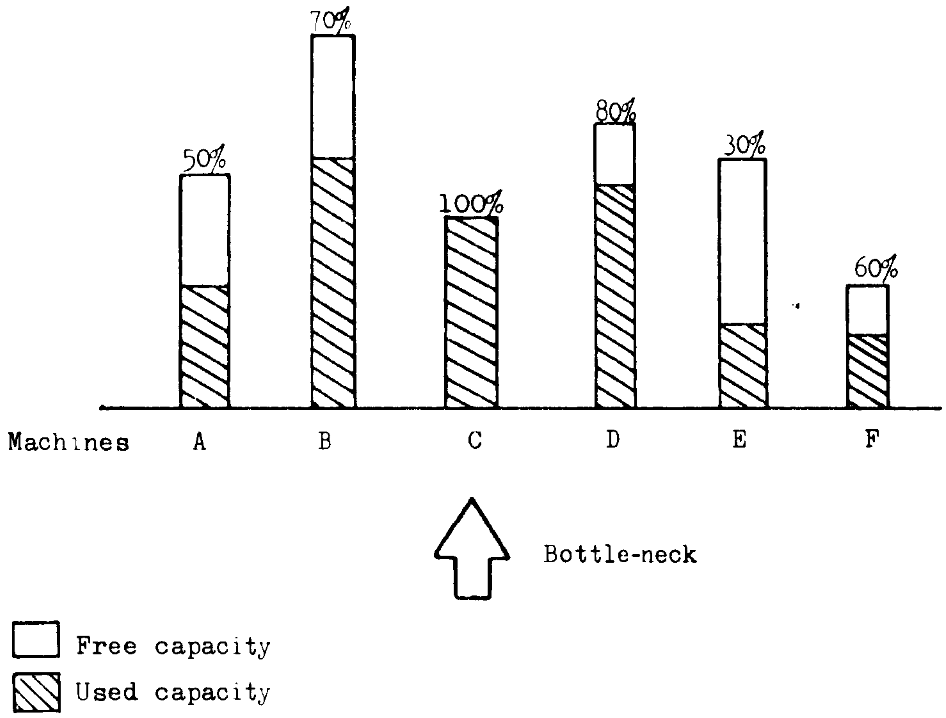


Figure XVII. Graphic representation of the fact that the capacity of a machine line can be increased only as a multiple of the capacities of individual machines

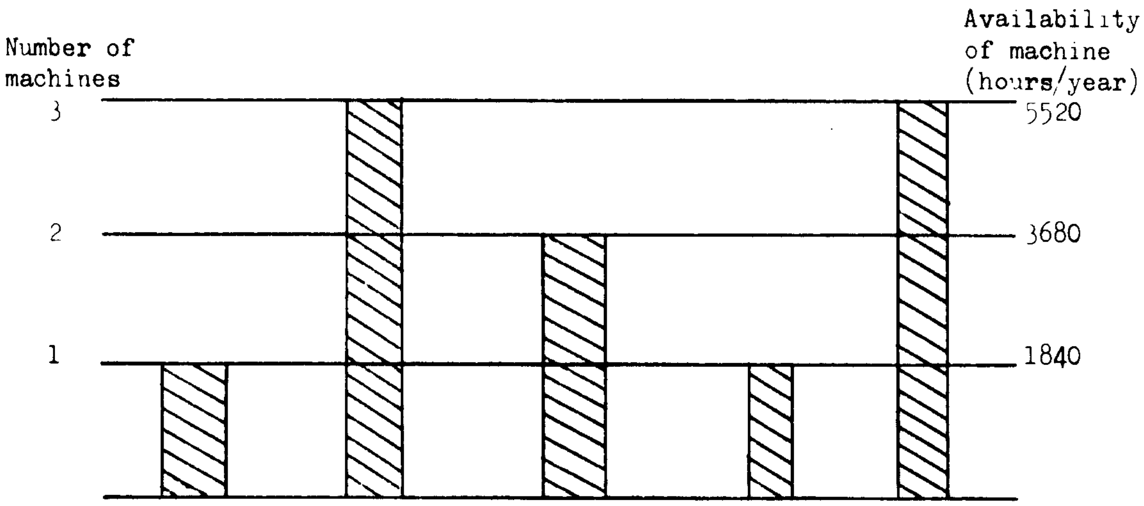
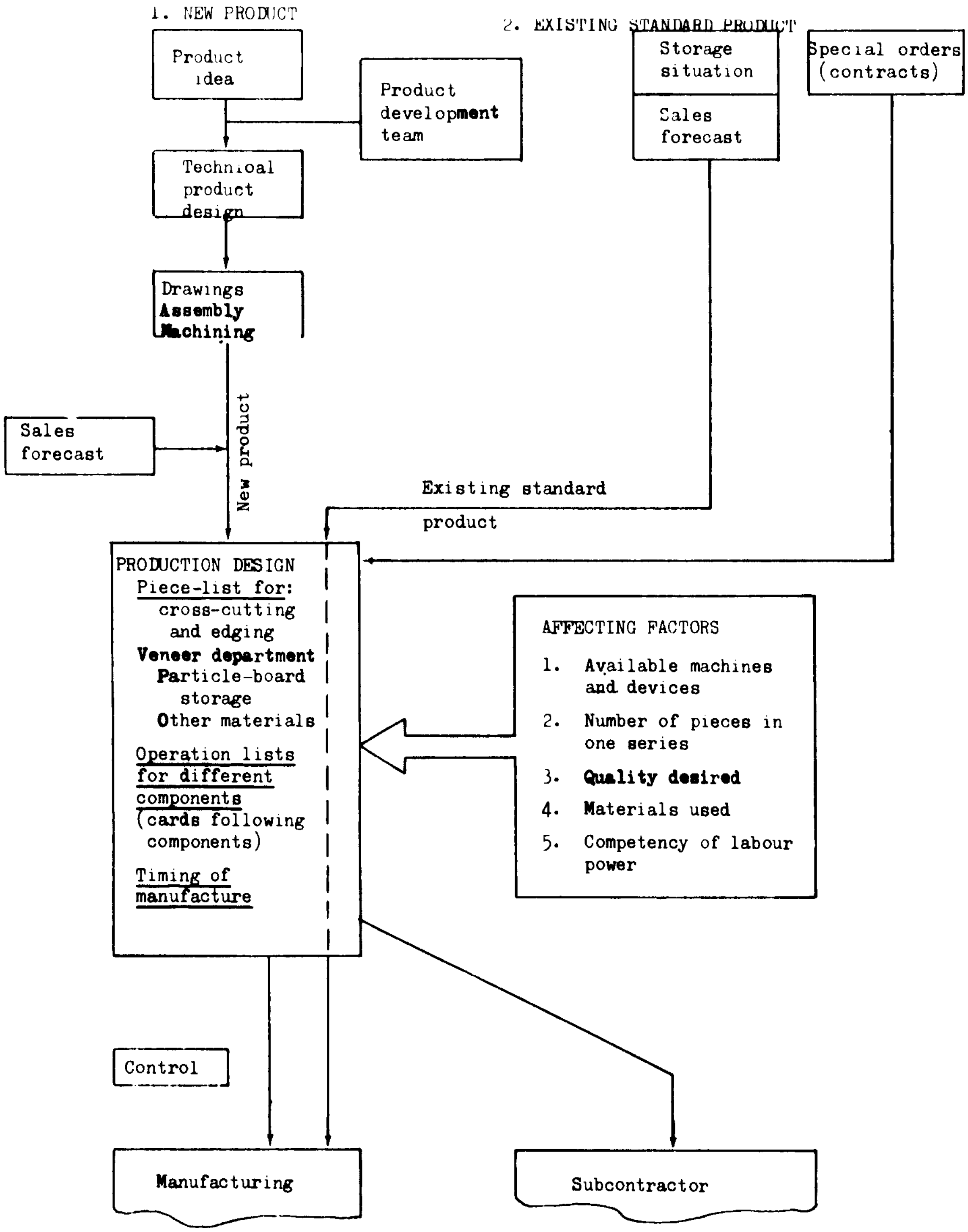


Figure XVIII. Schematic representation of the position of production design in the furniture-production process



XVI. Project planning in the furniture and joinery industries*

General principles of investment studies

An investment decision is generally the result of an investigative chain that involves many studies and decisions at different levels. At the outset, there will appear to be several equally promising alternatives. To identify the most promising and to permit more detailed investigations, a system must be found for eliminating the weaker project alternatives as early as possible. Figure I shows the principle of an investigative chain that eliminates weaker alternatives. The chain has three phases: project identification, the pre-feasibility study and the feasibility study. Each phase is followed by a decision to stop or to continue investigations.

The purpose of an investigative chain is to direct the research potential primarily towards those objectives that would first affect the feasibility of the various project alternatives. By using this method, both money and resources can be saved, and it is likely that the best alternative will be chosen for further consideration. In the case of a large, export-oriented concern such as a pulp and paper mill, a thorough study is necessary.

This chapter deals with project planning, that is, with the part of the investigative chain that has already been completed, the results of which have indicated that the furniture and joinery industries are promising project alternatives.

Pre-feasibility study

The purpose of the pre-feasibility study is to present the technical and economic conditions of projects identified in earlier studies prepared by the furniture and joinery industries. The contents of a typical study of this kind are presented in the annex to this chapter. The economic evaluation of alternative projects is based on a detailed market projection, a reasonably complete raw material inventory and a description of the production programme and processes. The economic calculations provide a basis for establishing priorities between the alternatives identified for the projected mills, indicating their approximate profitability. The economic risks involved in the execution of the projects are indicated through sensitivity analyses.

Market survey

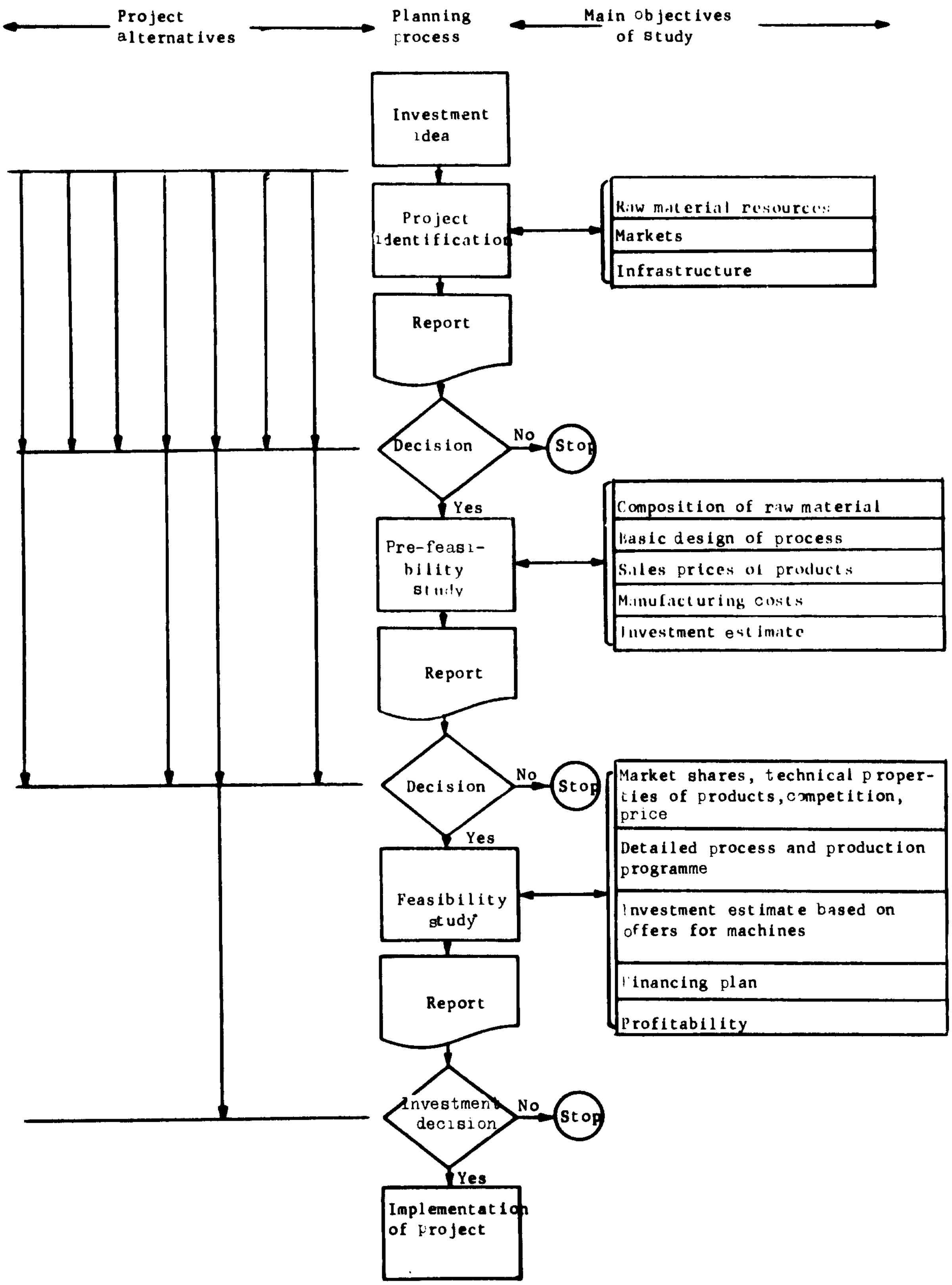
The market survey should include a description of the historical development of production, trade and consumption in the furniture and joinery industries. On the basis of this material, a projection is made concerning domestic demand, future production and foreign trade. Depending on supply and demand, selected export markets are covered. The analysis includes such factors as prices, quantities and grades as well as incentives and barriers to foreign trade. The assessment of the competitive strength of the project is the most critical task of the survey. The survey should give a complete breakdown of the prospective markets of the projected mill, stating total sales to each area, sales prices, market shares and competitive position. The value of the project to the national economy should be pointed out in quantitative terms (export earnings/import substitution) since this consideration will be important when seeking financing.

Raw material resources

If properly made, the resource inventory will be reasonably complete; at least the total volume will not be subject to change. Frequently the results of special investigations related to raw material availability (for example, present consumption) are also accessible. Similarly, the availability of veneer and wood-based panels must be

*By Antero Liusvaara, Jaakko Pöyry and Co., Consulting Engineers, Helsinki, Finland. (Originally issued as document ID/WG.105/40.)

Figure I. Schematic representation of the selection of project alternatives during investment studies



carefully investigated. (Above all, attention should be paid to the possibilities of using smaller and shorter pieces of wood.) The results of this survey will serve as a basis for decisions concerning the possibilities of raw material utilization and the possible location of the contemplated industrial units. The salient factors determining or limiting the supply of raw materials should be presented and evaluated in fairly great detail.

Technical description

Mill site study. No more than two or three mill sites should be considered. The relevant site factors should be subjected to a closer examination than that given in preliminary studies. The purpose of the current study is to provide a basis for a technical and an economic comparison of the sites. The latter comparison requires an estimation of the unit prices of raw materials, power and services. The effect of the transportation of wood raw materials on the selection of the final mill site is also considered. The maximum loads and capacities of transportation elements, such as road connexions, ports and existing equipment, are evaluated in order to calculate the unit costs of transportation. Furthermore, it is necessary to make suggestions as to how the investment costs for infrastructure, such as roads and community development, should be shared by the company and the Government.

Production programme and process description. This section is intended to provide all the technical information required for the establishment of priorities between alternative projects and thus to serve as a basis for a feasibility study. The programmes should constitute a rational synthesis of the information already compiled. Types of mills, end-products and capacities are specified. Block diagrams, process flow sheets, lists of major equipment, and general and departmental layouts are presented. A brief written description is called for to tie the elements together and to give the reader, who may be a potential investor, a clear concept of the process and the production lines. It is understood that only the key items of the process are studied and that the scope is just adequate for a comparative economic analysis. The production programme should define, in addition to the production rates of intermediate and end-products and their specifications, the operating ratios of the various production lines during the first years of operation. As an example, the process flow in a joinery factory is shown schematically in figure II.

Economic calculations

Investment requirements. On the basis of the technical description, the investment requirements by department or function are determined, taking into account regional factors (coefficients or data collected for the project). Investment estimates are usually based on cost data obtained from the records, and sometimes specifications for the main machinery may be given. The purpose of the estimates is to determine the total investment requirements of the plant at a given cost level. If necessary the investment requirements are spread over a number of periods or divided into different groups for depreciation purposes. Furthermore, the assumptions regarding financing are considered.

Production costs. Annual production costs are calculated on the basis of the production programme and the process planned. Raw materials, packing materials and the costs of energy and fuel are then taken into account as variables; wages, maintenance and administration are treated as fixed costs.

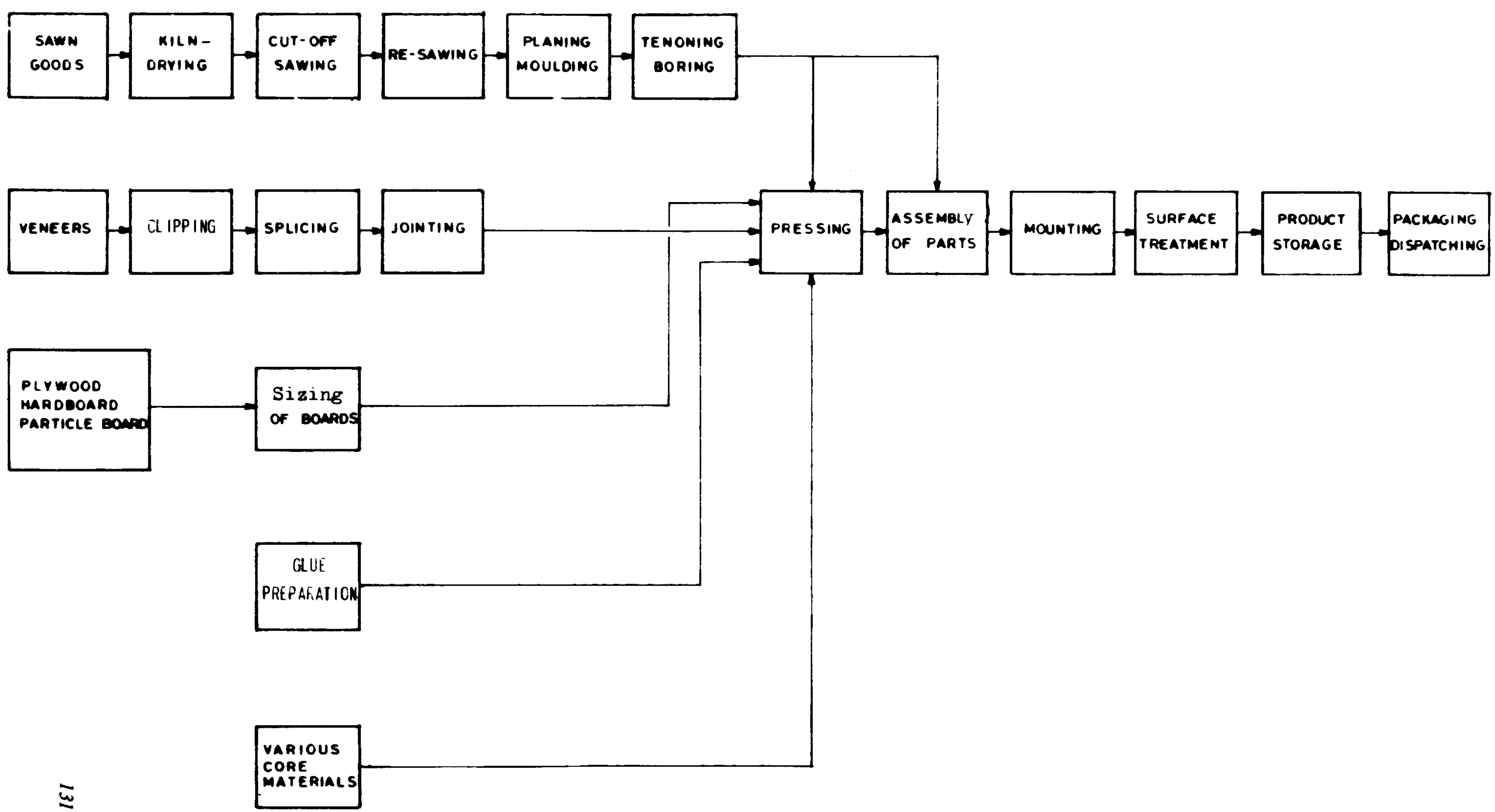
Profitability calculation and financial statements. Profitability is calculated by means of the discounted cash-flow method. Thus the economic life of a project is usually considered to be 15 years and the annual earnings are calculated for this period. The discounted cash-flow rate is determined before and after taxes, both on total capital invested and on equity. A sensitivity analysis is carried out to assess the most critical determinants of profitability.

Planning of project financing

The financing plan is an integral part of the economic evaluation of a project. It should be completed before an investment decision is taken; the schedule for the execution of the project should be available in making such a decision. While the investment estimate indicates the need for funds, the financing plan shows where funds may be acquired. There are two aspects of planning financing: quantity and time. For example, a project showing good profitability may, in the early stages, indicate a negative cash flow; in other words, liquidity is not guaranteed and the project may fail. Since liquidity must be guaranteed in all situations, great attention should be paid to the planning.

Experience plays a large role in financial planning. All factors affecting financing should be carefully weighed. Experience shows that excessive optimism a great danger in developing countries may lead to situations in which either the funds are exhausted when the project is only half completed or the completed project has no working capital. Industrial projects for developing regions must be not only technically sound, but also economically secure. In addition, they should yield early profits for both the investor and the economy.

Figure II. Schematic diagram of process flow in a joinery factory



Feasibility study

A feasibility study should contain all the information required for making an investment decision. Consequently, its report should convince potential investors that the project is technically, economically and financially viable and, if necessary, that the investment climate of the country concerned satisfies potential foreign participants.

At this stage the comparison of feasible alternatives has already been carried out and only one basic solution is proposed. Since the work is performed with specific investors in mind, their concepts of the project should also be taken into account. In principle, the structure of a feasibility study follows that of a pre-feasibility study, the difference being the depth of the presentation. Consequently, both studies include the same elements.

Execution of the project

On the basis of the information contained in the feasibility study, an investment decision is made, after which the execution of the project proper can be planned. This phase generally starts with a list of the work necessary. It should be emphasized that successful execution of the project requires as accurate a description as possible of the various work phases. On the basis of this description, a time schedule for the whole project is prepared with the various work groups programmed in chronological order. The total time schedule is thereafter divided into sections according to the block diagram of the mill, and these sections are in turn divided and subdivided into smaller and smaller sections and tasks. The more specific the time schedule is at an early stage, the easier the supervision of the execution of the project will be and the fewer the number of costly delays. In working out a schedule for the execution of a project of such magnitude as a furniture or joinery plant, the Project Evaluation and Review Technique (PERT) network should be used. Great attention should already have been paid in the early stages of the project to the so-called critical times, that is, to the amounts of time required for executing specific work sections. If the time exceeds the schedule, it may delay the entire project. A typical project work model is presented in figure III.

In machine procurement, the investor may use various procedures, depending on the know-how available. The easiest way is normally to order total delivery, but this is not always the soundest approach, either economically or technically. If the investor himself has sufficient technical and economic know-how or, failing that, uses the services of a consultant, he can purchase the machinery item by item, acquiring the best and most suitable machines from various sources.

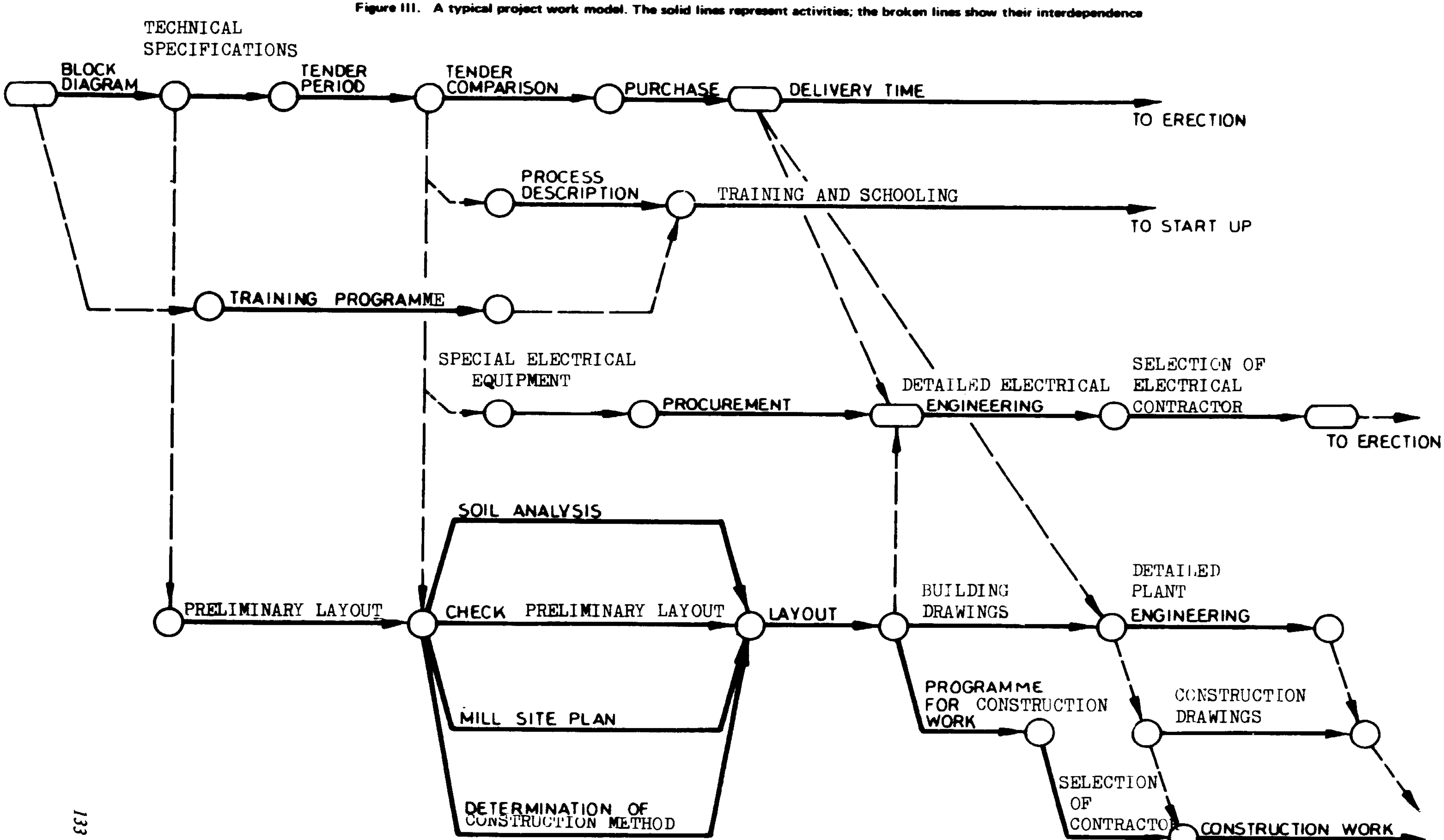
For planning, machine procurement and the like, the plant should be divided into departments according to production. Such departments in a furniture and joinery plant include:

- Mill site area
- Reception and intermediate storage of sawn goods
- Drying of sawn goods
- Woodworking department
- Pressing department
- Assembly and mounting department
- Surface-treatment department
- Product storage and dispatch department
- Power generation
- Electrical equipment and instrumentation
- Heating, water, air-conditioning and compressed-air systems
- Social facilities
- Knife-grinding and maintenance space

If the work required to execute the project is examined, it can be seen that the various steps may be placed in chronological order, although some of the activities are simultaneous and their duration varies. The following list is a chronological presentation of the basic information given in a feasibility study:

- Soil analyses
- Technical specification of machines and equipment needed for the process
- Preparation of tender requisitions and their submission to vendors
- Preliminary block diagrams
- Final mill-site drawing
- Specification of construction methods for plant buildings
- Comparison of tenders for machines and equipment, and negotiations with vendors concerning technical and commercial details of tenders
- Commencement of electrical and instrumentation layouts
- Preliminary investment budget
- Final preparation of block diagrams and preparation of construction cost estimate

Figure III. A typical project work model. The solid lines represent activities; the broken lines show their interdependence



Purchase of main machinery and equipment
Process description and preparation of department layouts
Preparation of specifications for building subcontracts
Checking of cost estimates for buildings
Start of construction

After this, the technical details are checked during the construction phase.

In addition to the actual technical engineering, plans for hiring personnel and, if necessary, for their training must be initiated from the very start of the project. The training period should end when the erection phase begins, so that the employees may participate in the mill's erection together with the representatives of the machine suppliers. Thus they can acquire quickly and efficiently the special knowledge of the work, machines and equipment that they will need when the mill goes into operation.

When the plant buildings have been completed, the erection of machinery and general installation of electrical, water, heating and air-conditioning systems for the plant building are started. The installation of a compressed-air system and of sprinkler and other fire-protection equipment is also begun. When the machinery is nearly erected, the installation of electrical and compressed-air lines for the machines and of chip- and dust-extraction systems can be started.

When the erection phase has been completed, a mechanical trial run and adjustment of the machinery and equipment is carried out at the mill. Next, a trial run with raw materials is made, followed by the gradual start of actual production.

Annex

CONTENTS OF A TYPICAL PRE-FEASIBILITY STUDY

1. OBJECTIVES AND SCOPE OF STUDY
   - 1.1 Terms of reference
   - 1.2 Justification of project
2. SUMMARY
   - 2.1 Conclusions
     - 2.1.1 Suitability of fibrous raw material resources
     - 2.1.2 Production programme and processes proposed
     - 2.1.3 Economic aspects (markets and marketing, investment requirements and profitability, analysis of risk)
   - 2.2 Recommendations
   - 2.3 Time schedule for project implementation (Mini-PERT)
3. CULTURAL, POLITICAL AND ECONOMIC BACKGROUND
   - 3.1 Geography, climate, population
   - 3.2 Education, social institutions
   - 3.3 Political system
   - 3.4 Economy
     - 3.4.1 Structure and growth
     - 3.4.2 Foreign trade
     - 3.4.3 Economic integration
     - 3.4.4 Development policies and trends
4. MARKETS
   - 4.1 Projected domestic demand and market structure
     - 4.1.1 Quantities, grades, prices
     - 4.1.2 Competitive situation and market structure
     - 4.1.3 Import substitution
   - 4.2 Export markets
     - 4.2.1 Quantities, grades, prices
     - 4.2.2 Incentives and barriers
     - 4.2.3 Export earnings
5. RAW MATERIAL RESOURCES
   - 5.1 Forest resources
     - 5.1.1 Natural forests
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   - 5.3 Logging and transport of timber

6. TECHNICAL DESCRIPTION

6.1 Mill sites

6.2 Production programme and process description

6.2.1 Programme

6.2.2 Mill descriptions

6.2.3 Materials handling at the mill

6.2.4 Heat and power, water and effluent disposal

6.2.5 Personnel requirements and training

7. ECONOMIC CALCULATIONS

7.1 Investment requirements

7.2 Production costs

7.3 Profitability and sensitivity analysis, cash-flow statement

7.4 Financing, budget and pro-forma balance sheets

7.5 Economic evaluation

8. LEGAL ASPECTS

XVII. 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
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

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;

*By Pekka Paavola, Lahti Technical Institute, Lahti, Finland. (Originally issued as document ID/WG.133/27.)

(c) In addition to solid wood or timber, plastics and metals as well as many wood-based senimanufactures such as plywood 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:

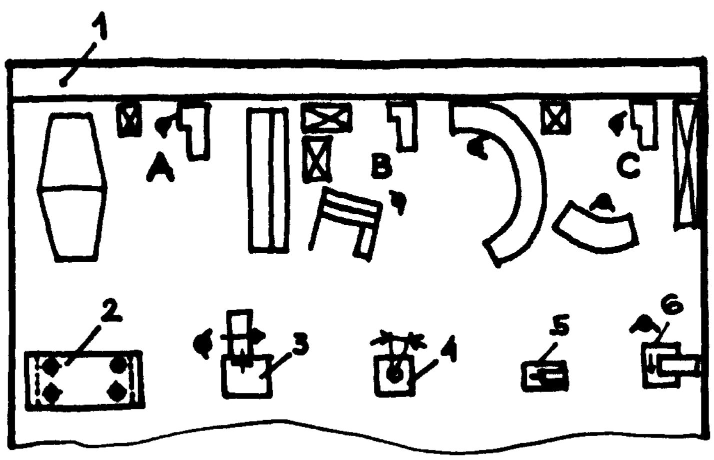
Stationary working places, as in the manufacture of fixtures (figure I)
Arrangement according to manufacturing method, for example basic wood-working machines in the furniture industry (figure II)
Production lines (figure III): *(a)* a line of separate working stations (e.g. machines) placed according to successive work stages; *(b)* a conveyor-belt line such as in furniture assembly; or *(c)* semi-automated or automated production lines. (Sequential automation is common in the furniture and joinery industries.)

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 over-all capacity of the equipment will be increased and second, 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.[1]

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 (see chapter XV, table 2). In an automated line, however, the capacity is the same throughout.

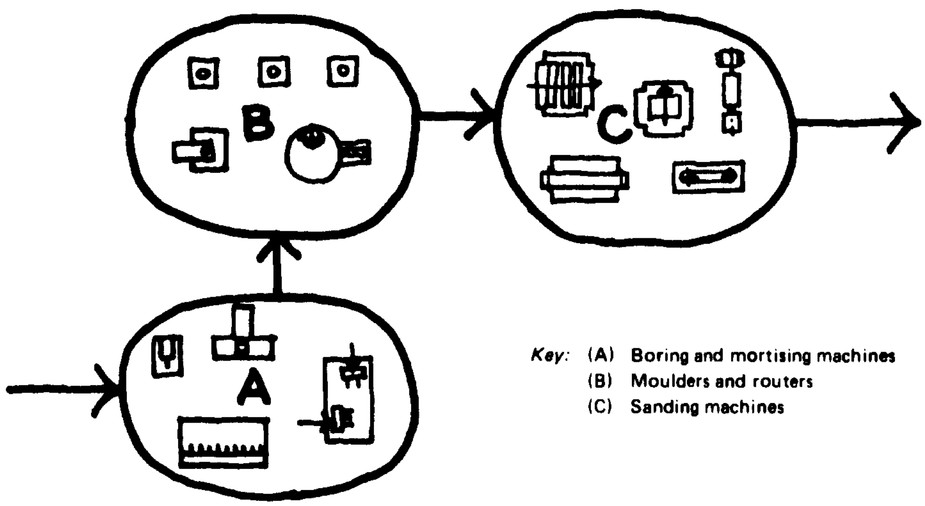
Figure I. Production with stationary working places



Key: (1) Drafting and plan table
(2) Single-opening press
(3) Circular saw with feed table
(4) Vertical-spindle moulder with tilting table
(5) Horizontal boring machine
(6) Band-saw
(A) Boring and mortising machines
(B) Moulders and routers
(C) Sanding machines

[1] See the final section on production design of chapter XV, "Technical product design".

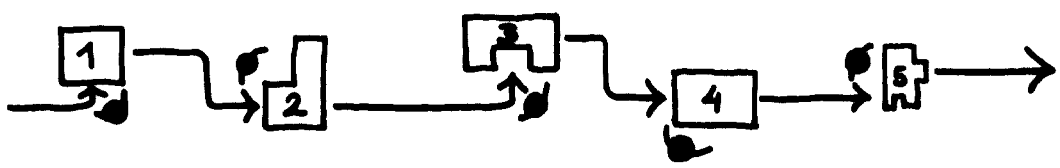
Figure II. Production arranged according to manufacturing methods



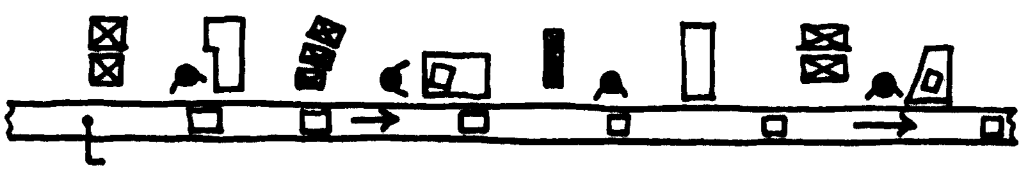
Key: (A) Boring and mortising machines
(B) Moulders and routers
(C) Sanding machines

Figure III. Production lines

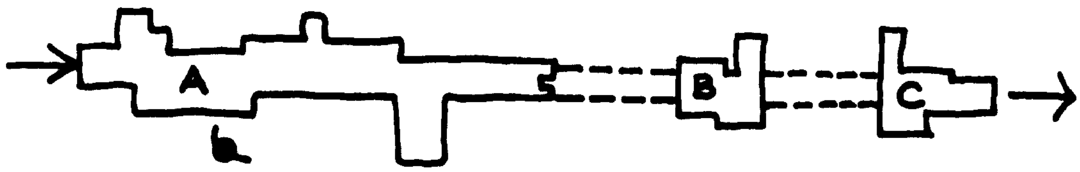
(a)



(b)



(c)



Key: (a) A line of separate work stations, such as machines, placed according to successive work stages
(b) Flow-line production with a conveyor belt or slide bench
(c) Automated or semi-automated production line. Note that one operator controls machines A, B and C

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 IV).

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 of factory equipment and fixtures such as transportation pallets, storage shelves, work-benches and tool cabinets)
Operation process charts, machine operation charts, schemes and drawings (figures V and VI)
Scale models (figure VII)

The practice of plant layout

It is advisable to begin layout planning by drawing up, on 1-mm graph paper, a floor plan of the plant building showing the walls, pillars and other construction details that impose limits. (The usual scale of such building drawings is 1 : 50.) Next, the machines, equipment, conveyors, passages, storage areas etc. are placed. This is best done with the aid of scale models of the various items; these may be cut from fibreboard covered with 1-mm graph paper or from coloured cardboard. If necessary three-dimensional models may be carved from a soft wood such as balsa or from polystyrene foam.

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 components made from semimanufactured boards)

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
Tenoning machines
Mortising and boring machines
Vertical-spindle moulders and routers
Sanding machines
Veneering machines

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 in the joinery industry. The conveyors used in surface-finishing shops are usually of a spec[illegible] type and thus unsuited to other stages of production. The modern tendency, especially in the furniture industry [illegible]s to do surface finishing before assembly.

Load transportation (on pallets) must be a continuous one-way direction in factory passages. Opposing and crossing traffic must be avoided (figure VIII).

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)

Further storage facilities are needed for the following items:

Kiln-dried timber
Veneers
Semimanufactured boards, plywood, plastic laminates etc.
Glues
Fittings and hardware, sanding materials etc.
Packing materials

Figure IV. Five patterns of production flow

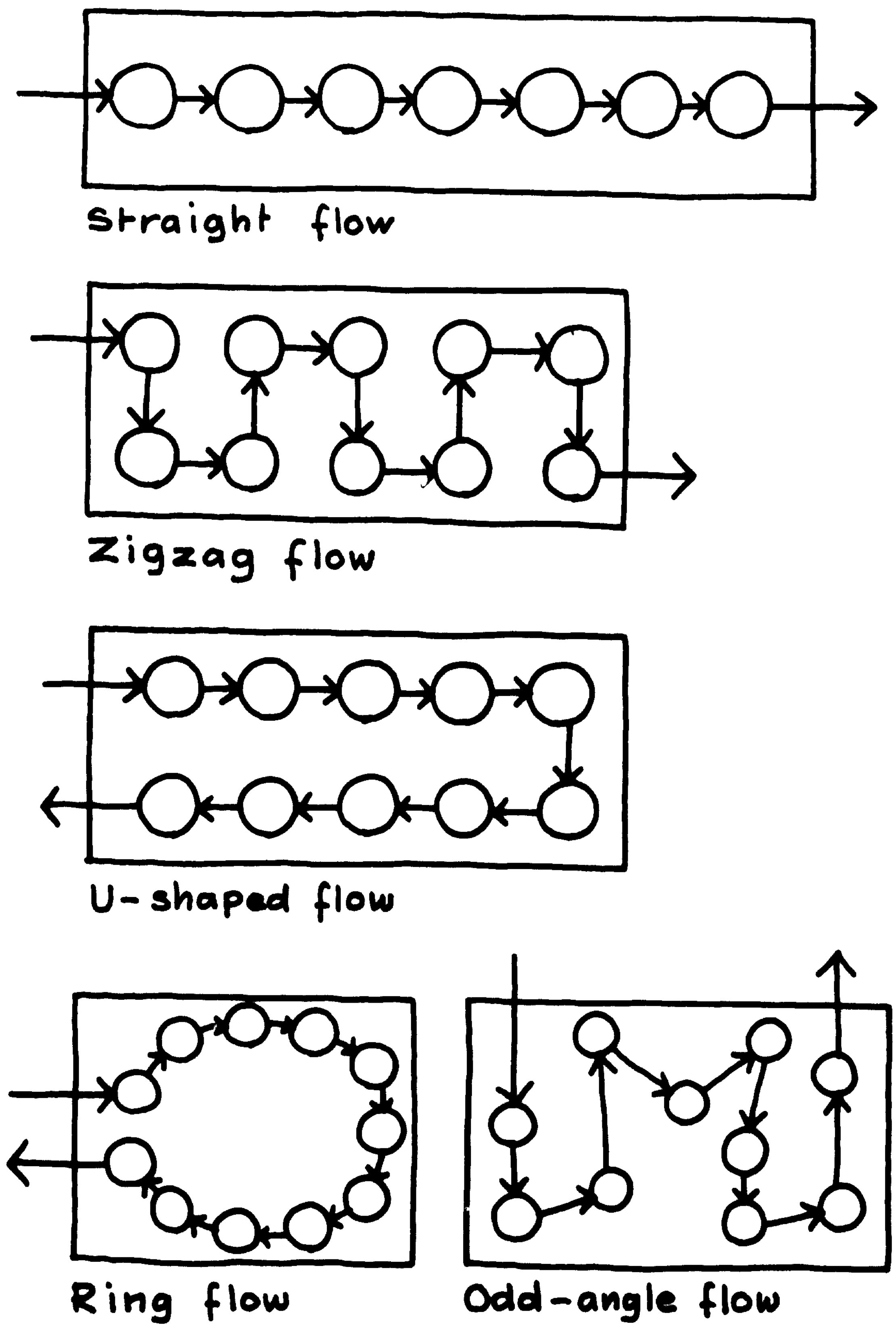


Figure V. A typical machine operation chart

(Operations refer to the production of the table shown in figure XIV, chapter XV)

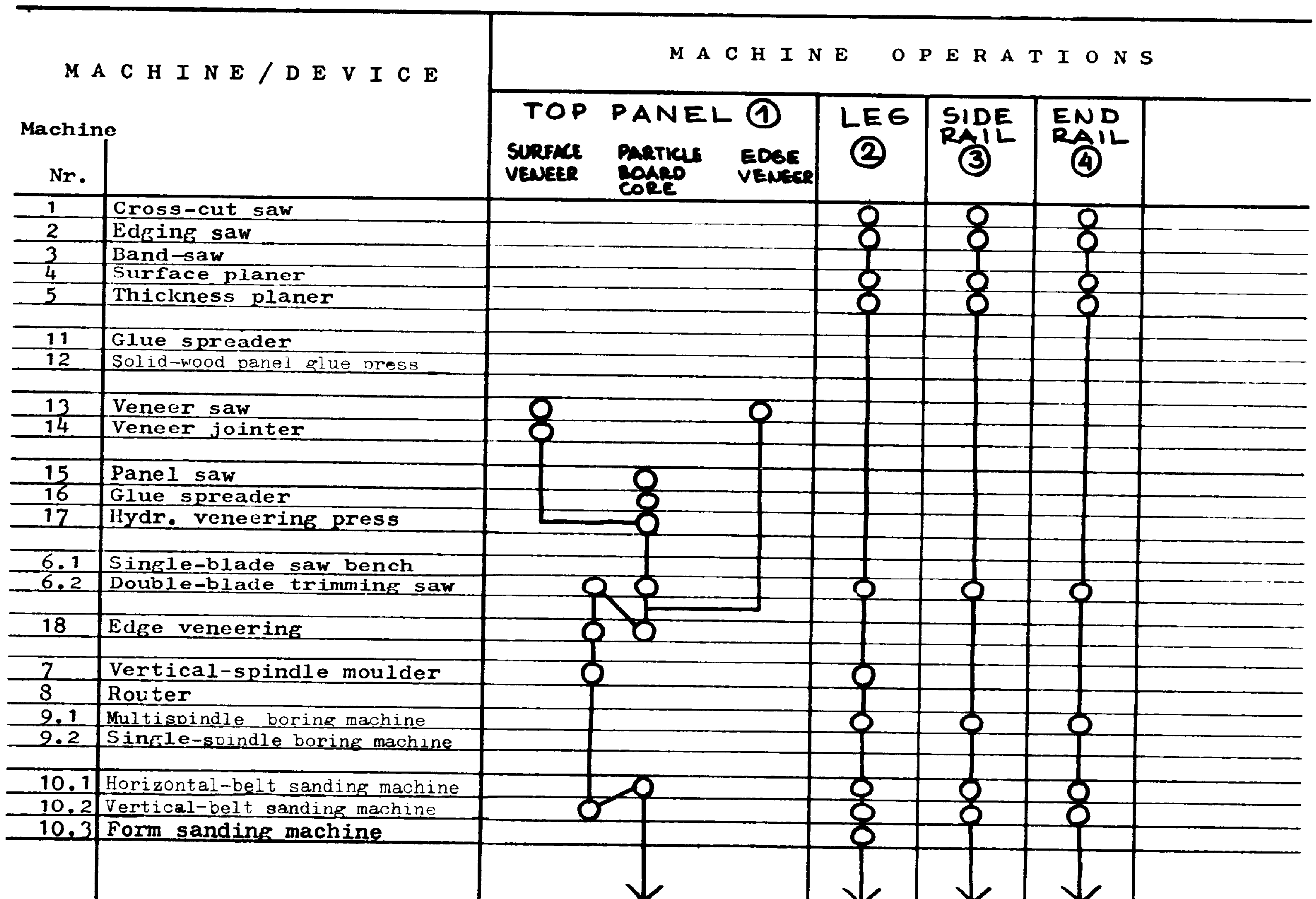


Figure VI. Typical drawings for the machining section of a small furniture factory

(The numbers shown are the machine numbers given in figure V)

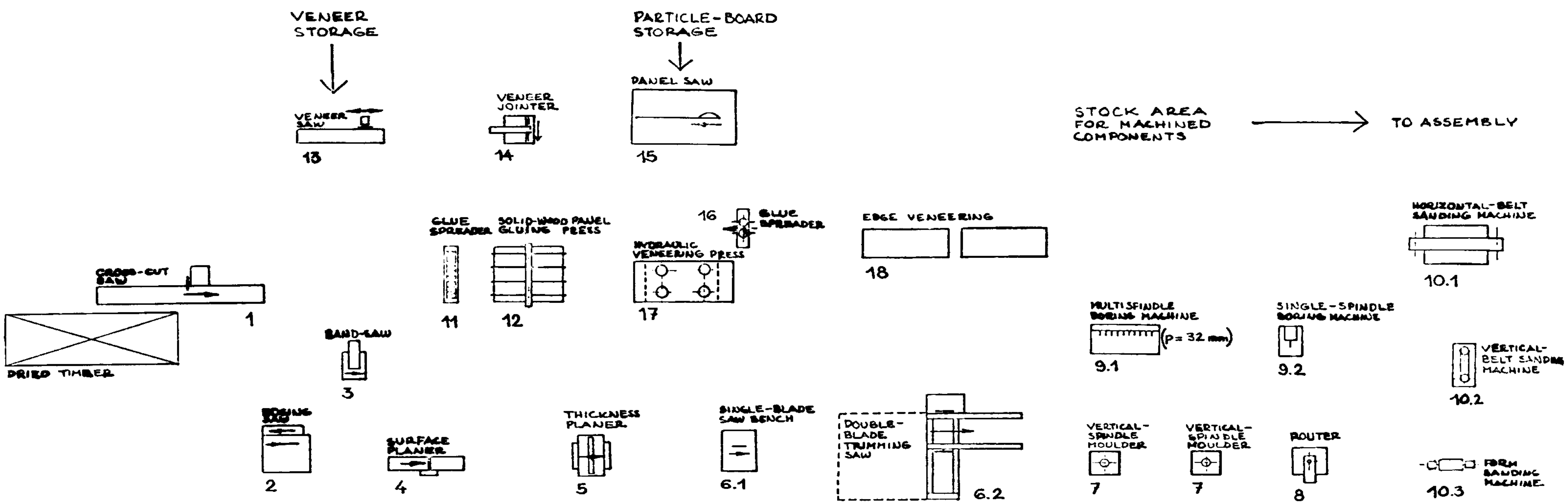


Figure VII. Scale models (1:100) of some typical woodworking machines

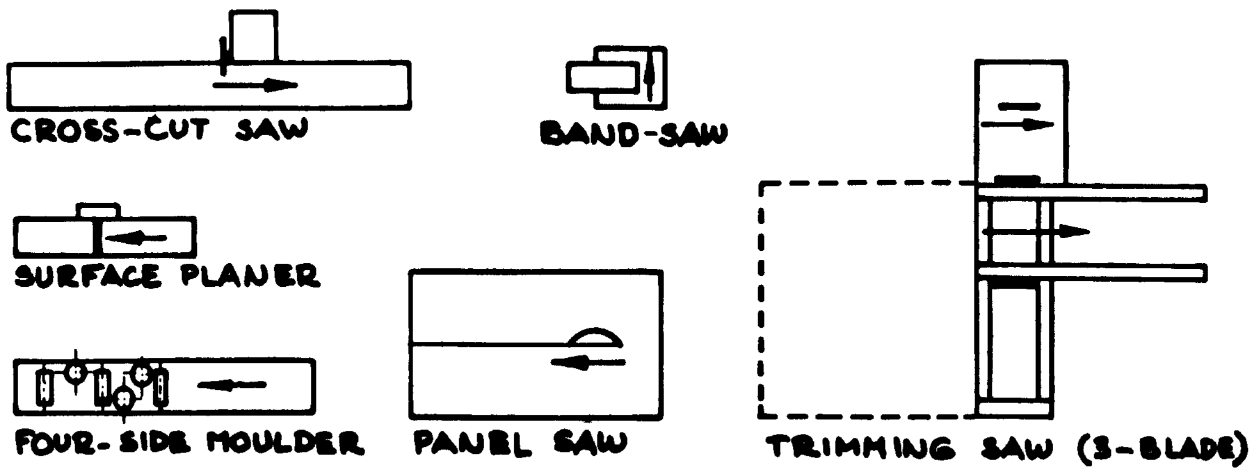
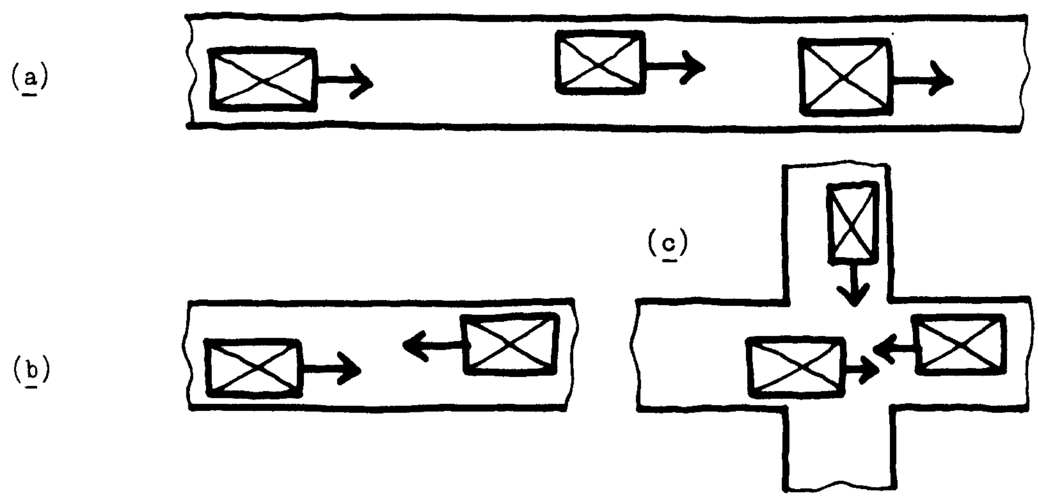


Figure VIII. Pallet transportation in factory passages

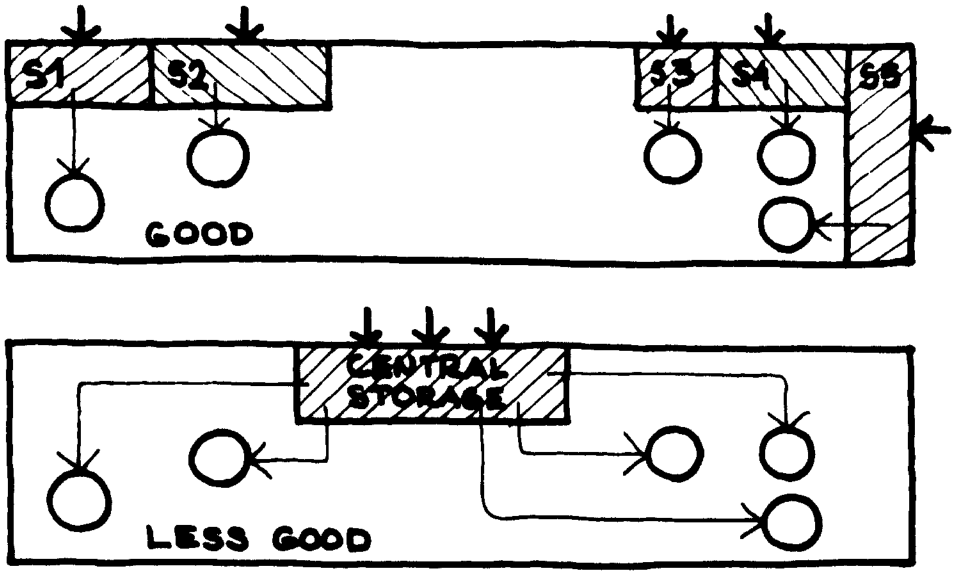


Key: (a) One-way traffic flow
(b) Opposing traffic
(c) Crossing traffic

The storage areas must be easily accessible from the factory side by workers and from outside by motor 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 IX).

Electrical installations and pipe networks 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.

Figure IX. Location of storage areas. The dispersed areas shown above are preferable to the single central area shown below



The factory building

The principal characteristics of modern factory buildings in the furniture and joinery industries are the following:

(a) The buildings are on one level. This avoidance of vertical transportation permits cheaper foundations and facilitates future enlargements;

(b) The buildings are rectangular in form. In large buildings, natural illumination through skylights is possible. 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 enlargements are taken into consideration from the outset.

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 enlargements will be possible. It is advantageous if the starting point of production can be maintained in spite of enlargements;

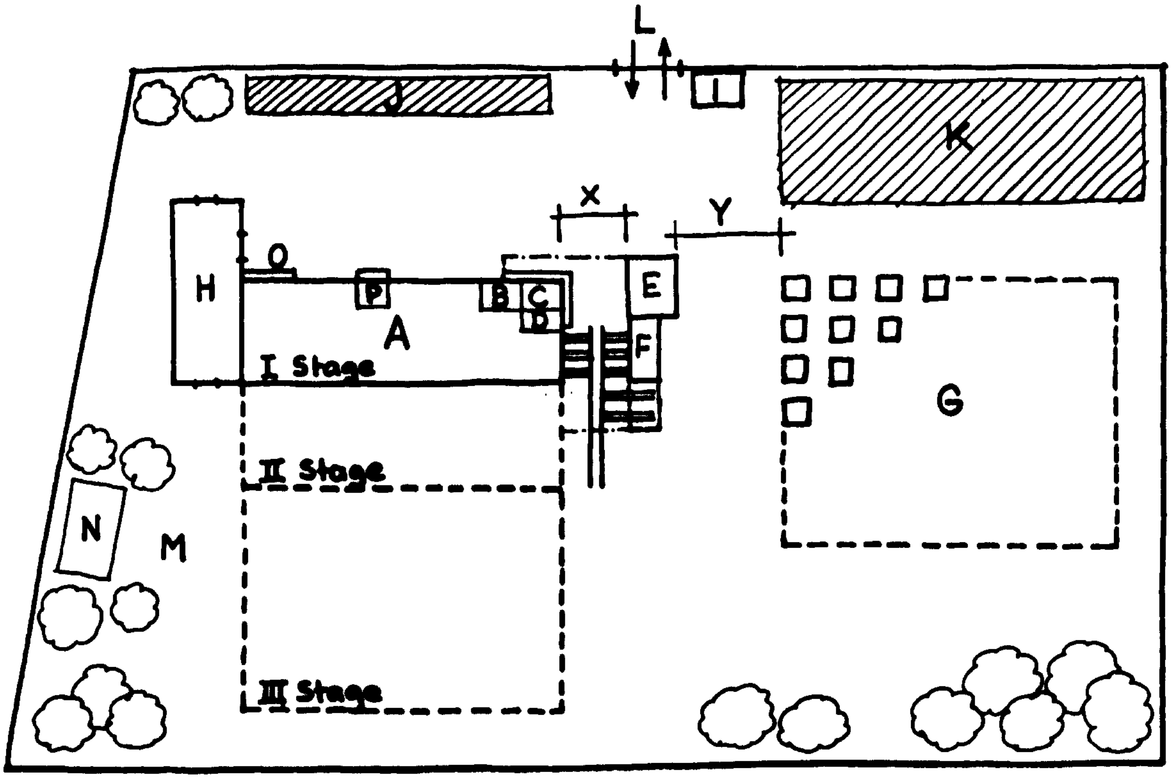
(b) Placing the timber yard and outer storage areas so as to minimize transportation problems;

(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.

A good example of factory layout is presented in figure X.

Figure X. A well-planned factory area



Key:
(A) Factory building
(B) Panel storage
(C) Veneer storage
(D) Storage area for kiln-dried timber
(E) Boiler house
(F) Drying kilns
(G) Timber-storage yard
(H) Office building
(I) Gate-keeper's booth
(J) Parking for office staff and visitors
(K) Parking for workers
(L) Factory gate
(M) Lawn
(N) Recreation field
(O) Loading dock for finished products
(P) Storage for fittings, hardware etc.
(X) Permissible distance between heating plant and factory
(Y) Permissible distance between heating plant and timber storage
I Stage, original building
II Stage and III Stage, space for successive expansions of the factory

XVIII. Furniture technology*

Special features of the furniture industry

The products of the furniture industry represent the highest degree of refinement 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 northern Europe, the demand for furniture is seasonal. Furthermore, furniture sales are considerahly affected hy 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 very popular.

The greatest production problem in most furniture factories is, however, the wide assortment of items. In many cases the different kinds of work-pieces 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. In this case, furniture plants hecome assembly operations.

Mode of production

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 I);

(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 he used to a limited extent only (assemhly, surface finishing) because of the great variety of items produced.

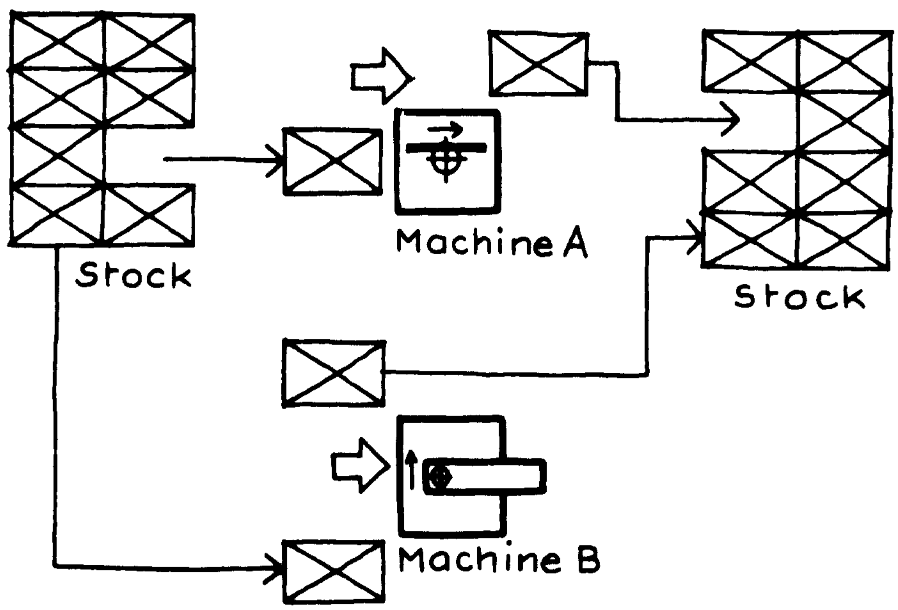
The manufacture of furniture as a continuous process is, of course, possihle in principle, using a fixed production line without stock areas. It would, however, require a large expansion of the market. In any case, a clear trend towards extended use of machine lines and automated production can he noted 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.

*By Pekka Paavola, Lahti Technical Institute, Lahti, Finland. (Originally issued as document ID/WG.105/35/Rev.1.)

Figure I. Stock areas between different stages of manufacture



The advantages of high 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 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) Gauges and templates are used to control the dimensions during machining (figure II);

(d) Jigs are used in machining and assembly whenever possible (figure III).

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.

The arrangement of phases of work in machining

The order of machining phases in furniture manufacture is generally that indicated in figure IV.

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;

(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;

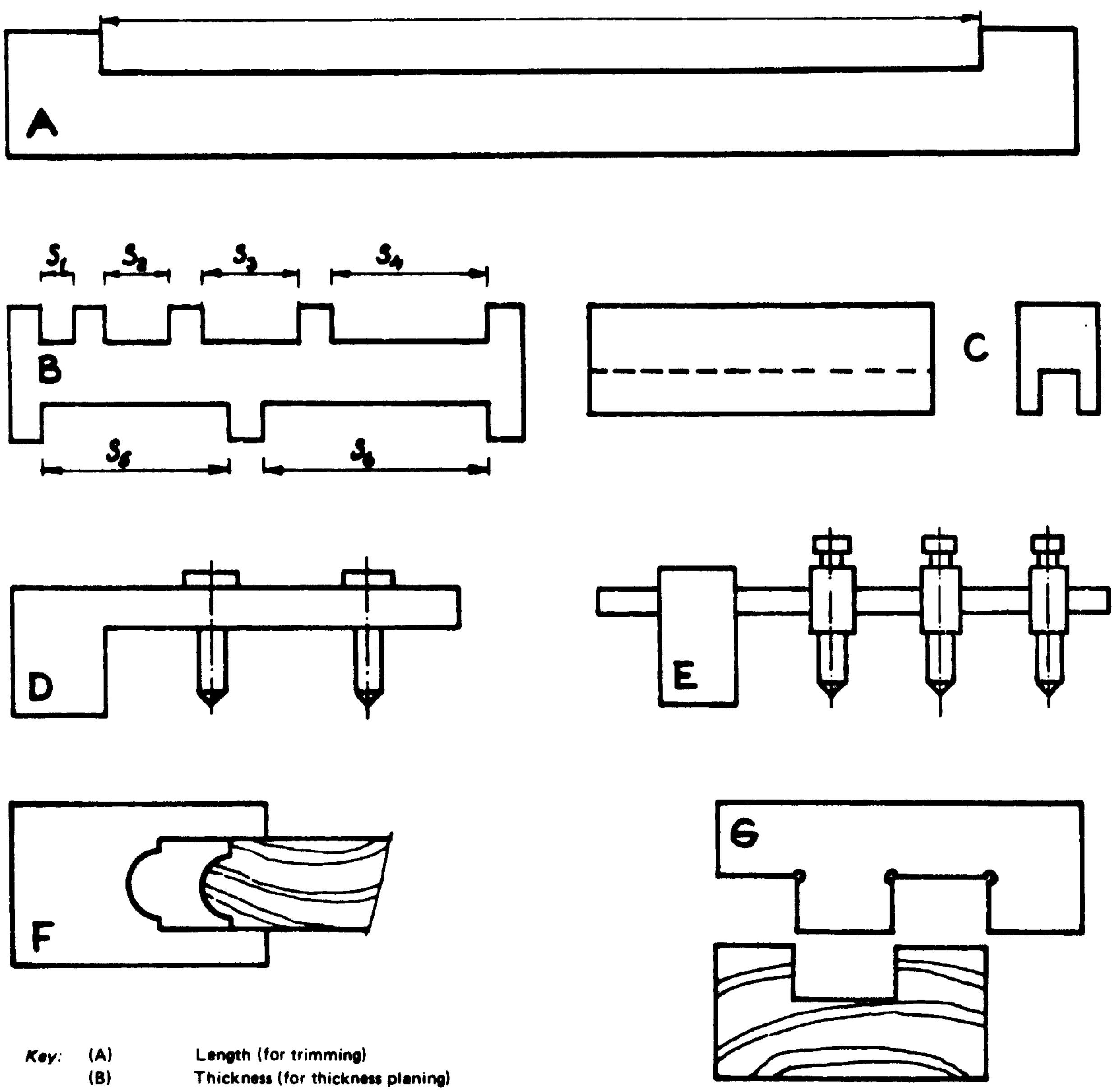
(e) The choice of feed speed strongly affects the quality of the finish;

(f) Automatic feed attachments (figure V) 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.

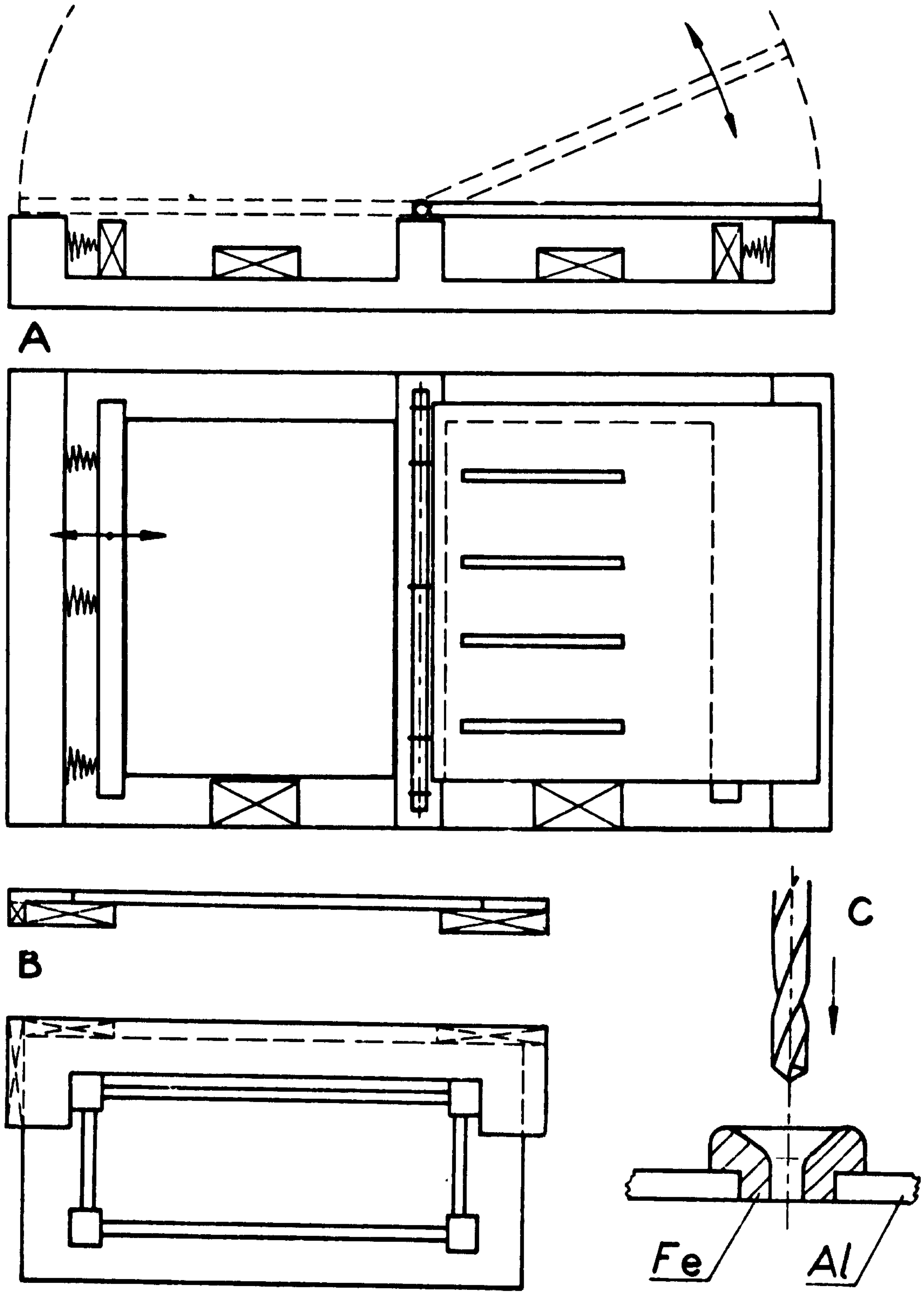
Some of the most important machining phases and their special features are treated briefly below.

Figure II. Gauges and templates for various measuring purposes



Key:
(A) Length (for trimming)
(B) Thickness (for thickness planing)
(C) Thickness (of tongue etc.)
(D) and (E) Dowel-joint pitch
(F) and (G) Profiles

Figure III. Three jigs used in furniture machining and assembly



Key: (A) Jig for wooden assembly of drawer-supporting strips by staple gun on the inside surfaces of the left and right panels of the drawer unit

(B) Assembly jig for fixing a cabinet base

(C) Detail of a boring jig

Figure IV. The order of machining phases in a furniture factory

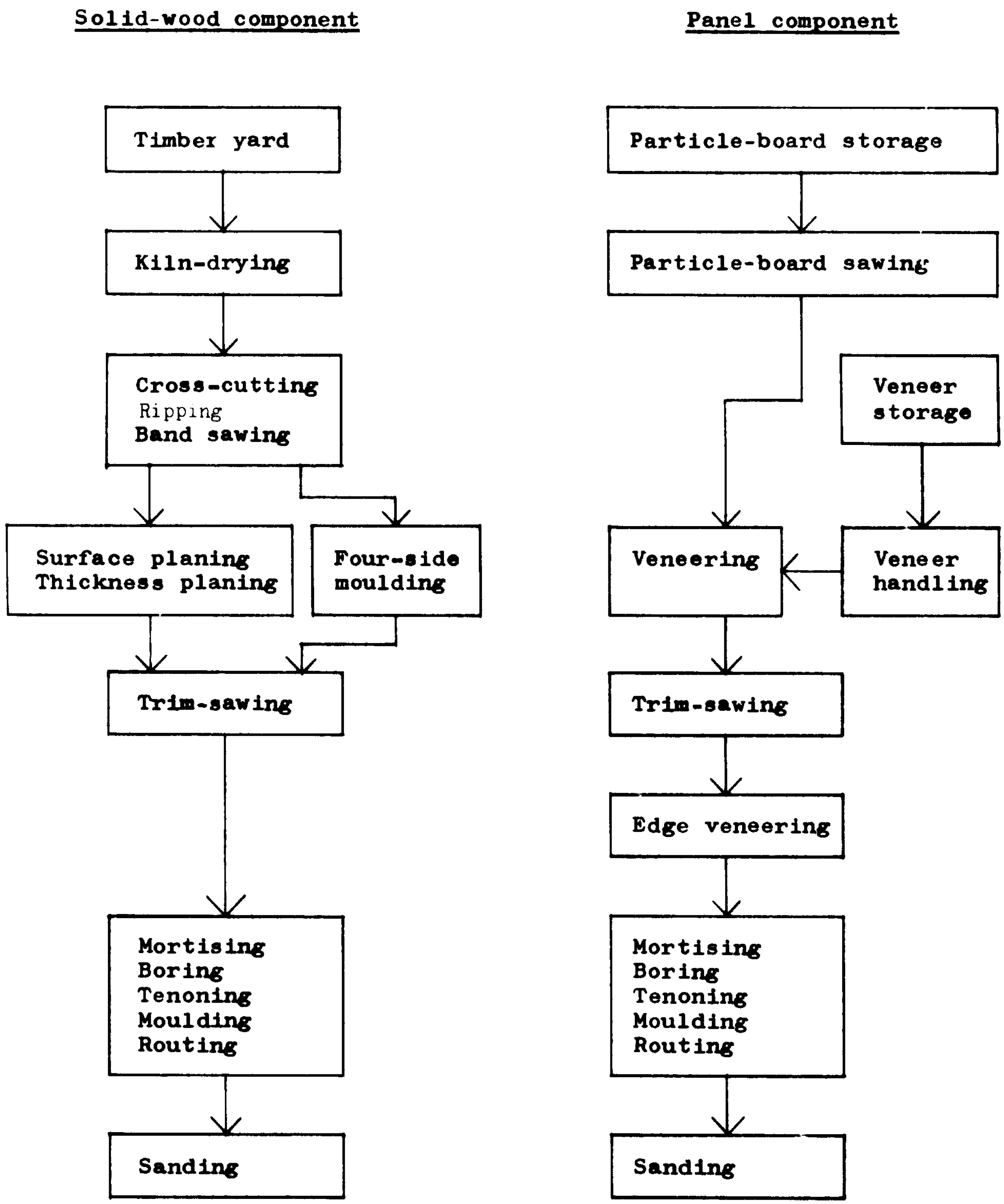
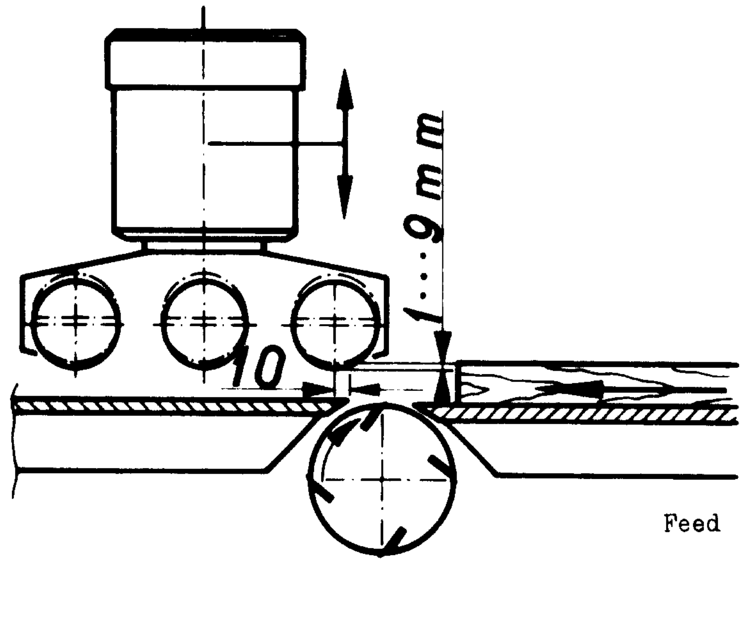


Figure V. Placement of an automatic feeding attachment for a surface-planing machine



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 VI). The operator must possess a good working skill in order to achieve small material losses (usually 5 to 20 per cent). The cutting margin varies between 10 and 50 mm, depending on the length of the pieces.

Cut material is usually transported for ripping on pallets but a rotating circular sorting table or other methods can also be used (figure VII). The ripping saw usually cuts from above and is provided with a feed chain and a return belt conveyor. The position of the blade is made visible on the surface of the board by means of a shadow-line device (figure VIII). The cross-cutting and ripping are done according to a piece-list; other raw materials needed may be marked on the same list (figure IX).

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.

Figure VI. Timber wagon on a lift table (pneumatic or hydraulic)

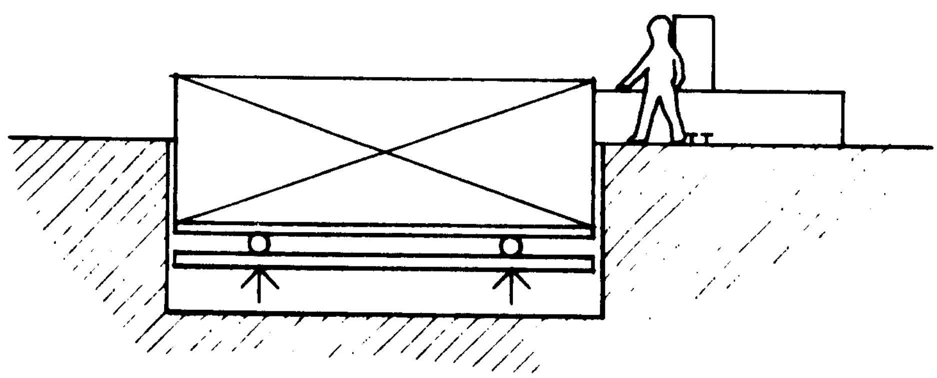
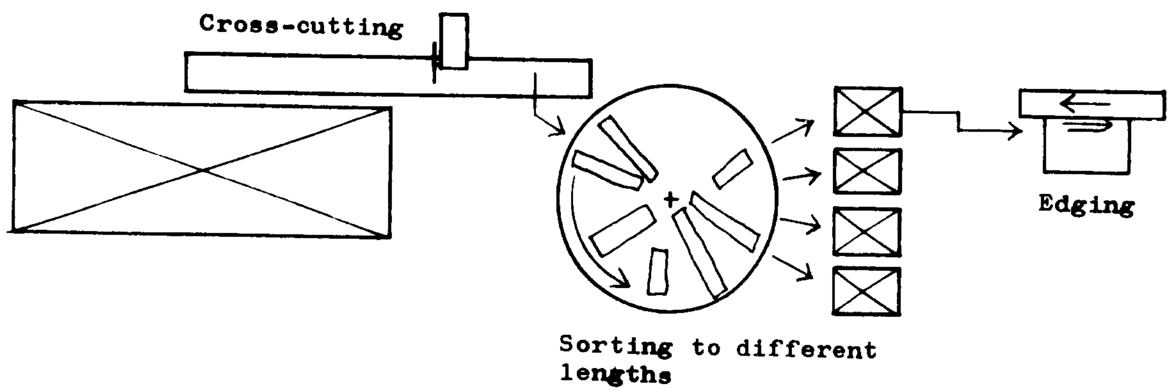


Figure VII. A rotating circular sorting table between the cross-cutting and edging phases



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 V).

When more complicated profiles are machined, a four-side moulder is efficient provided the scale of production is large enough. In the furniture industry such machines have a long front table for planing the undersides of boards.

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 X) 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 VIII. Edging saw with a shadow-line device

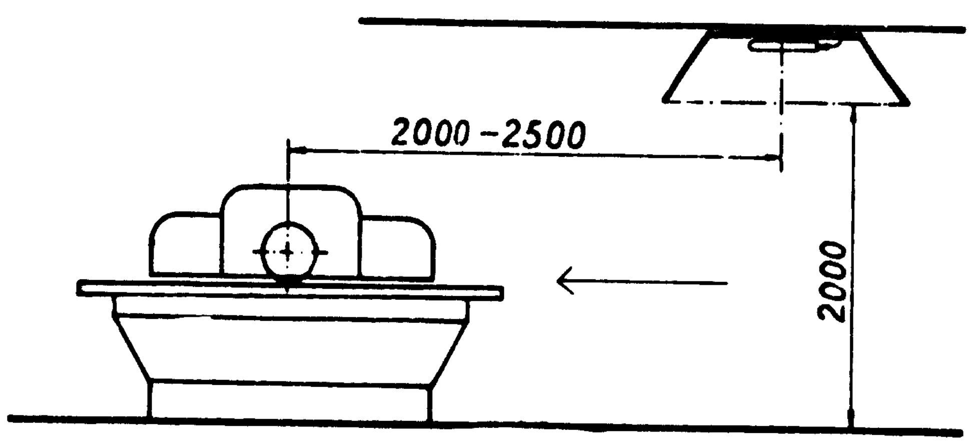


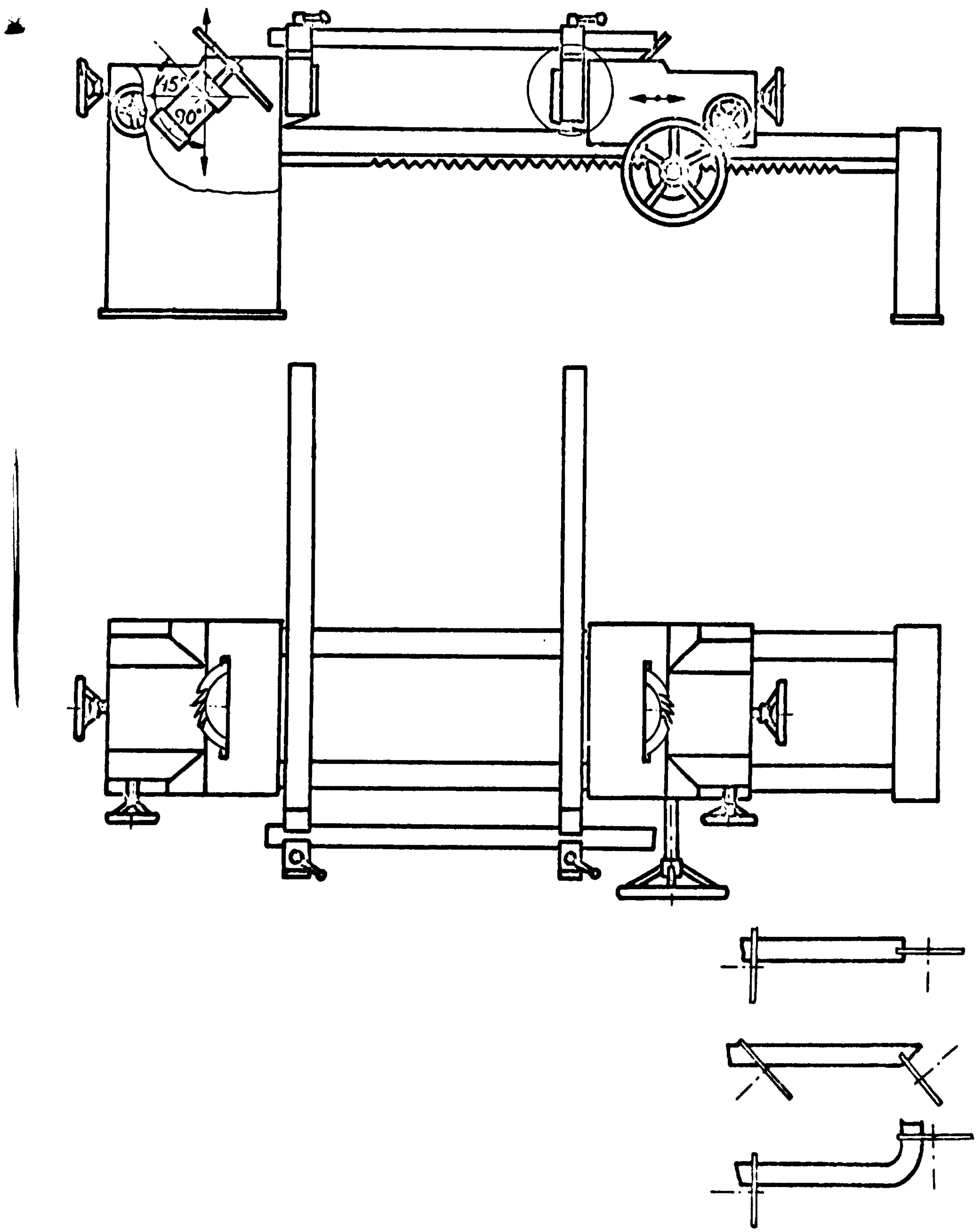
Figure IX. Piece-list for cross-cutting and ripping

PIECE-LIST

Product:

Pcs.	Item	Wood, particle board etc.					Blindveneer		Surface veneer Plastic laminates etc.			Remarks
		Final dimension			Material	Quality	Material	Thickness	Material		Thickness	
		Length	Width	Thickness					Face	Reverse		

Figure X. Side and top views of a double-bladed trimming saw with tilting blades (possible cuts are shown at lower right)



Mortising and boring

The mortises needed in furniture joints may be turned out with hollow-chisel, chain, slot and oscillating mortisers or with a dowel-hole boring machine (figure XI).

Hollow-chisel mortising is the traditional way of making holes. Because the machine is hand fed, its efficiency is low; the method is therefore poorly suited to modern production.

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 and hollow-chisel mortisers make rectangular holes. 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 is usually done with multispindle boring machines with a normal standard pitch of 32 mm (figure XII). For boring narrow parts of chairs, drawers etc., special spindle heads with fixed or adjustable spindle centres are used (figure XIII).

Tenoning

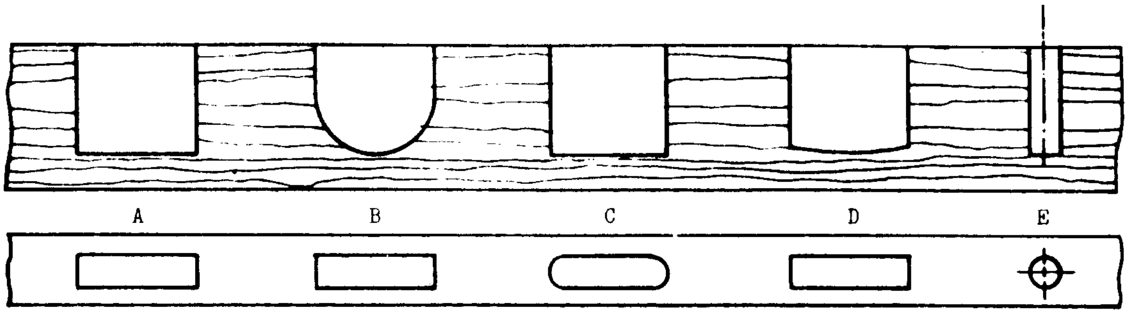
For machining corner-locks, tongue-and-groove boards and stub-tenon joints, any of the following machines may be used: a vertical-spindle moulder with a special attachment, a single-end tenoner or a double-end tenoner. The tenoners are provided with many tool heads, and they always trim the piece to be machined by length with the aid of circular blades (figures XIV and XV).

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 through the machine. The machine can be programmed to make various cut-outs and other complicated phases of machining.

Vertical-spindle moulding

The vertical-spindle moulder (figure XVI) is one of the most versatile machines 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 template. 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 connexion with the careless use of a vertical-spindle moulder.)

Figure XI. Mortises produced by five different machines



Key: (A) Hollow chisel
(B) Chain
(C) Slot
(D) Oscillating
(E) Dowel

Figure XII. A multispindle boring machine. The detail drawing shows the construction of a spindle head with a standard pitch

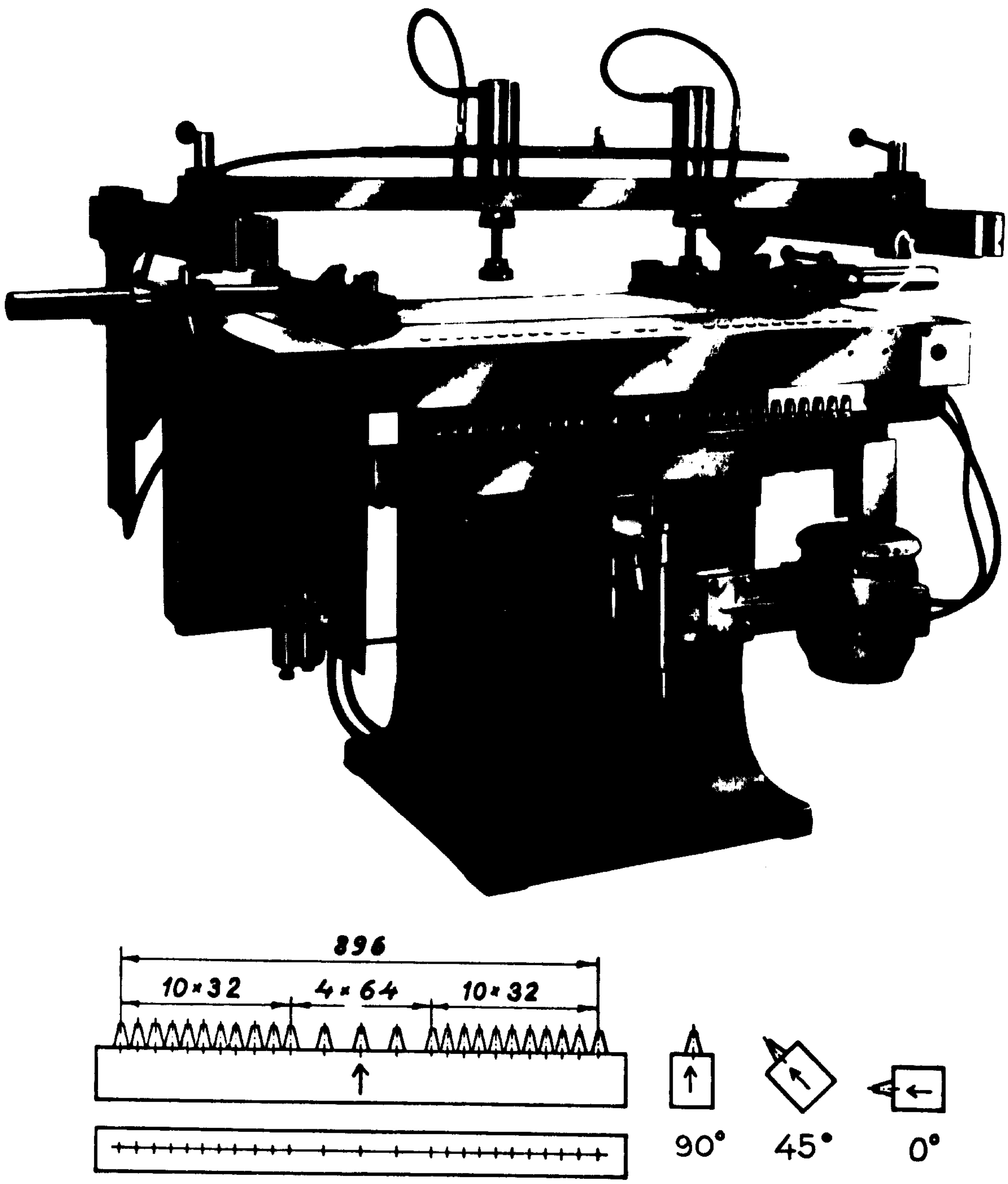
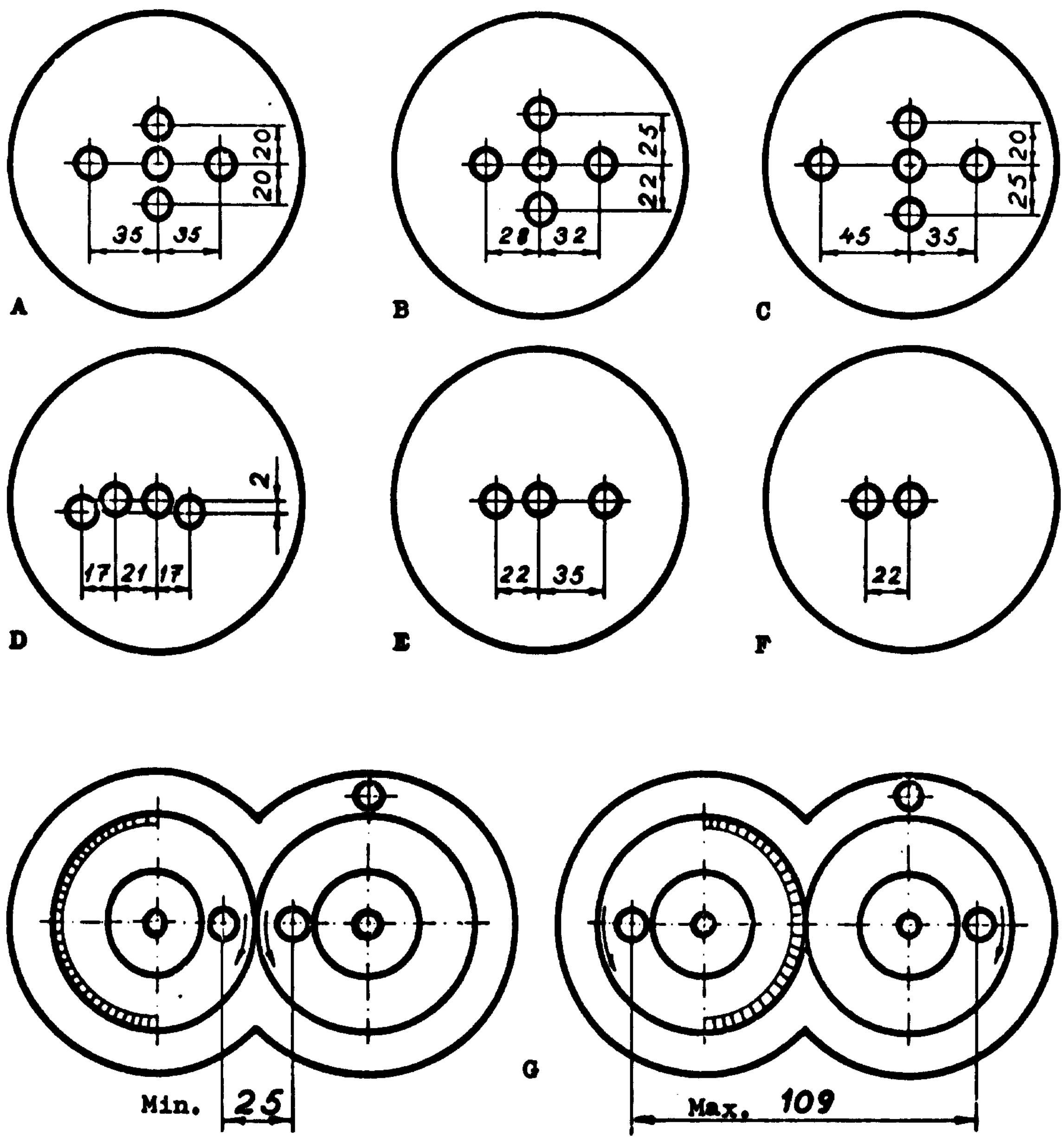
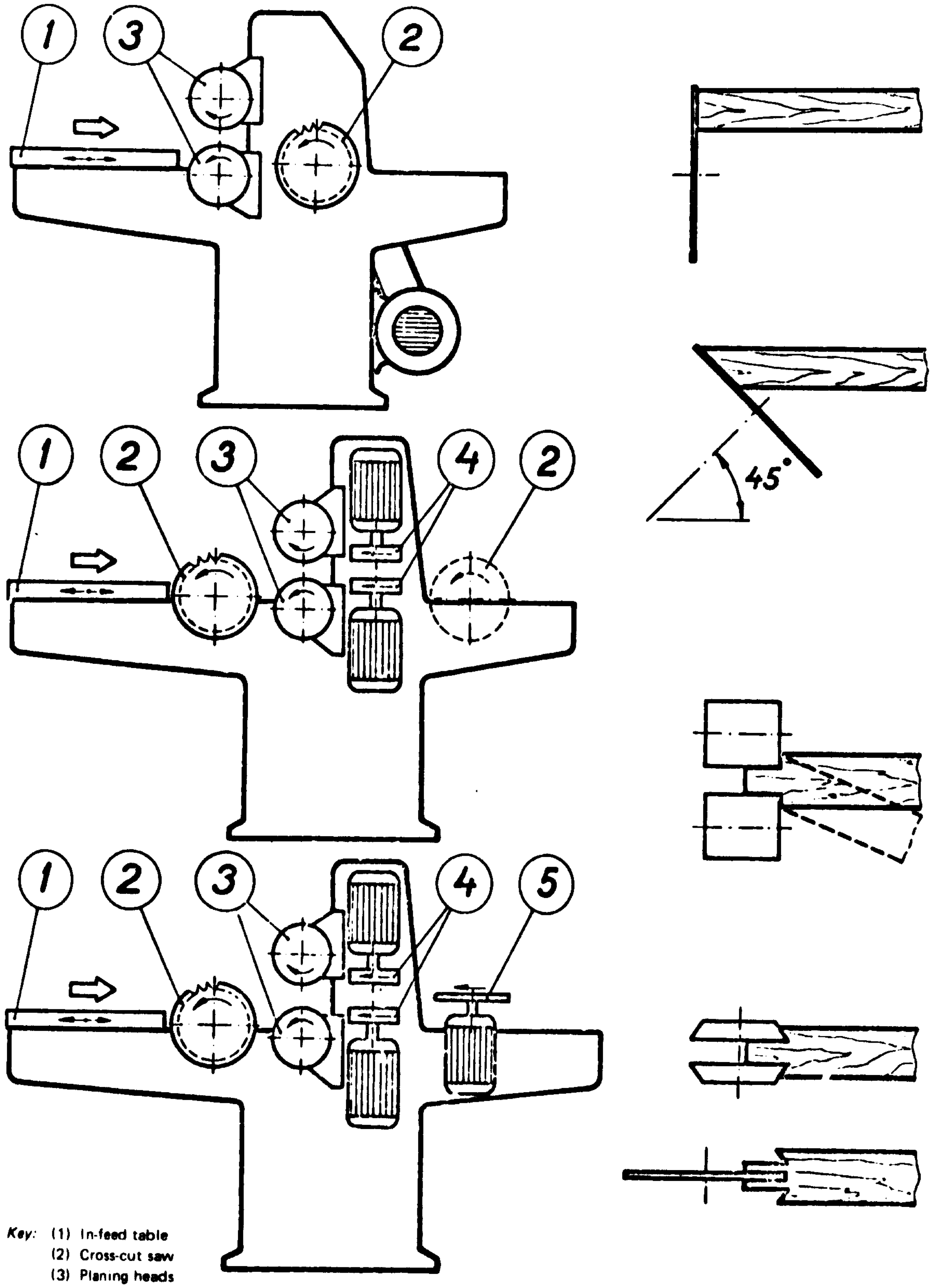


Figure XIII. Spindle heads for boring narrow furniture parts



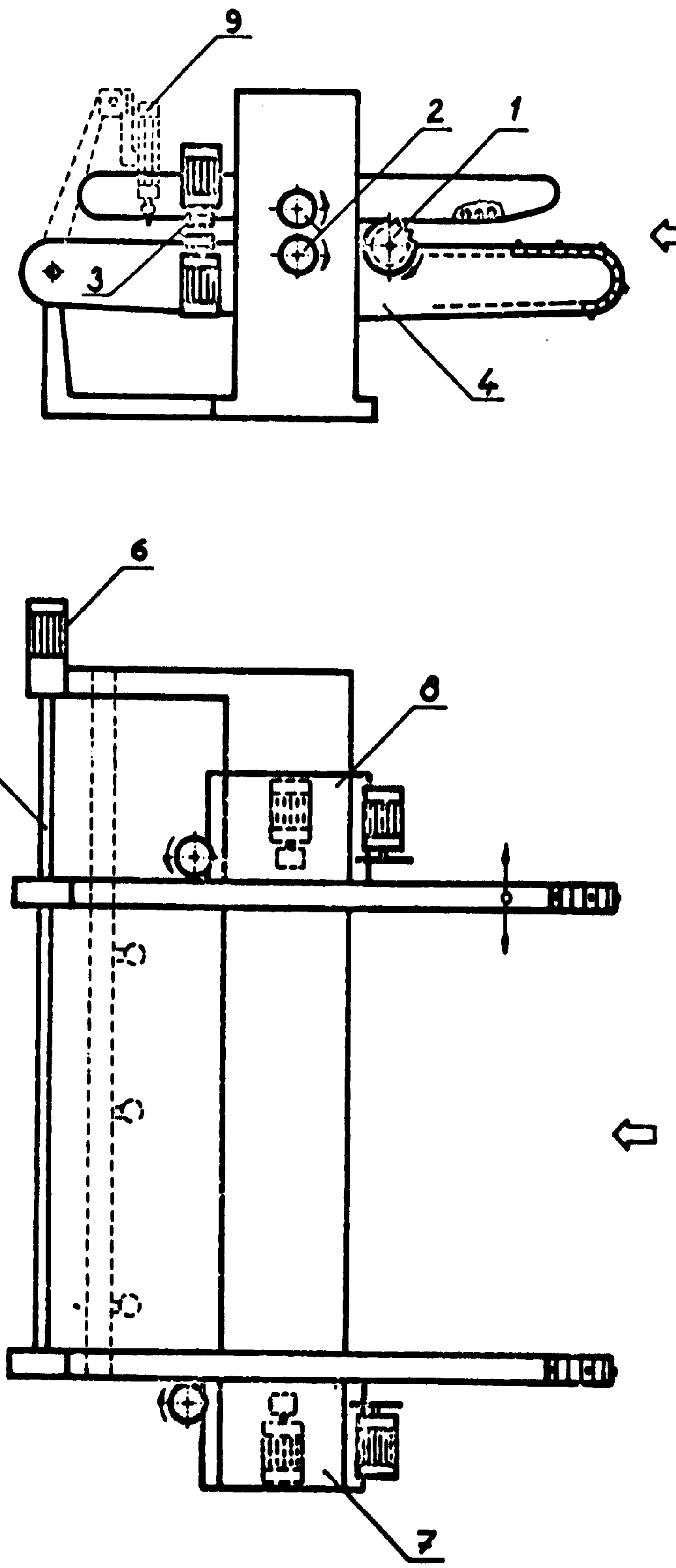
Key: (A)–(F) With fixed spindle centres
(G) With adjustable spindle centres

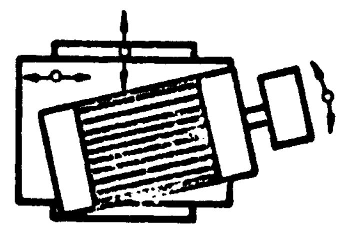
Figure XIV. Three types of single-end tenoners



Key: (1) In-feed table
(2) Cross-cut saw
(3) Planing heads
(4) Coping heads
(5) Grooving disc

Figure XV. A double-end tenoning machine

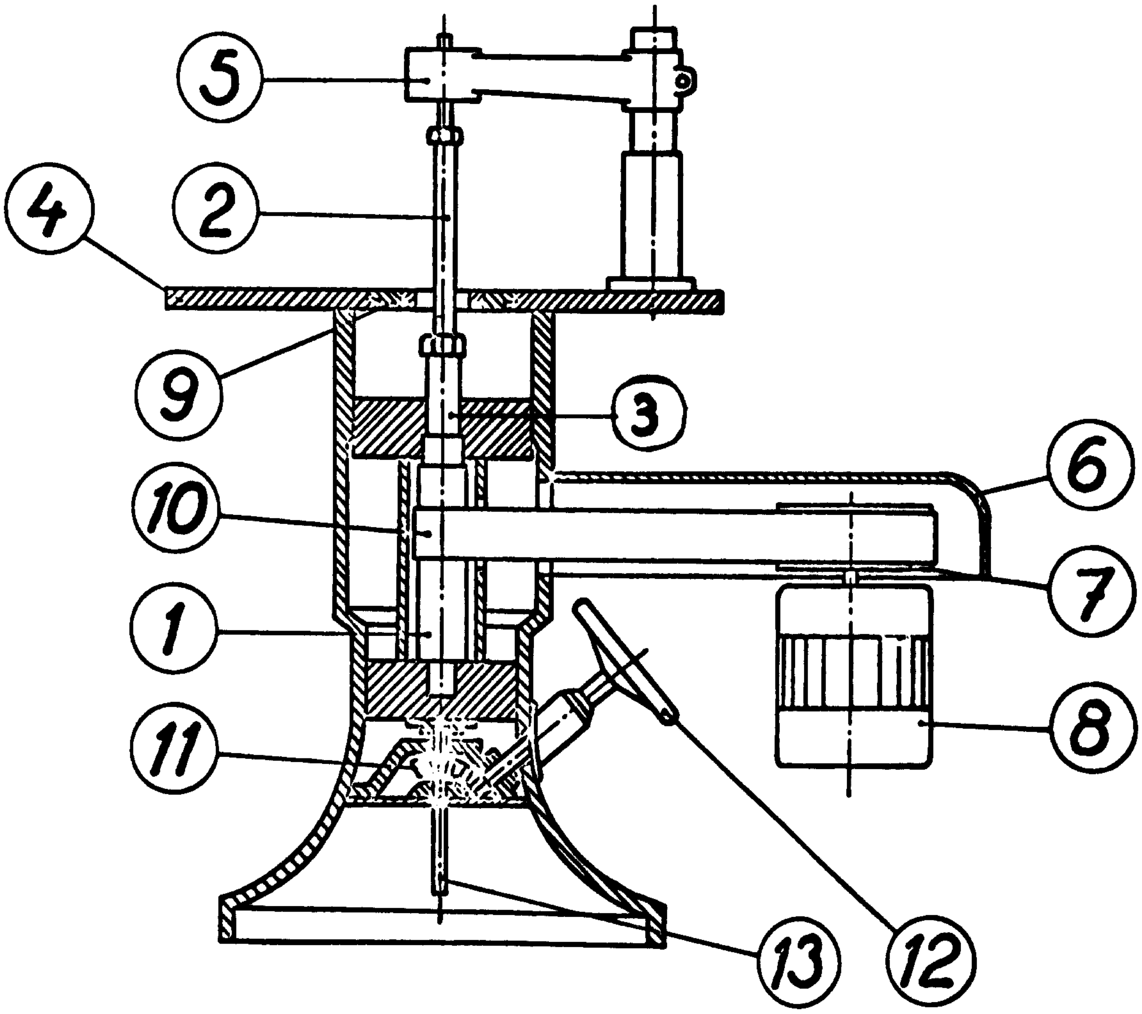




Key:

- (1) Trim saw
- (2) Moulding heads (horizontal)
- (3) Moulding heads (vertical)
- (4) Feed chain
- (5) Width adjusting bar
- (6) Adjustment motor
- (7), (8) Moulding heads (horizontal)
- (9) Drill or router

Figure XVI. A vertical-spindle moulder



Key:
(1) Spindle axis (and pulley shaft)
(2) Loose spindle
(3) Spindle unit
(4) Table
(5) Top counter bearing
(6) Drive hood
(7) Drive pulley
(8) Motor
(9) Ring set
(10) Pulley belt
(11) Adjustment gear for height
(12) Adjustment wheel
(13) Threaded height–Adjustment shaft

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 are used especially for sanding the edges and sides of assembled drawers. Horizontal-belt machines are chiefly used for sanding veneered boards. 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 boards. The construction principle for one such machine is shown in figure XVII.

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 through-sanding 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 XVIII. The pieces are joined with glued tape or with a zigzag machine. The tape must be sanded away after veneering, but the plastic thread used in the zigzag machine melts and is left underneath the veneer.

Urea glue is used to secure the veneer, and the pressing is done at a high temperature (100° to 120°C) with a multiplaten hydraulic press. Recently, the type of press shown in figure XIX has become more common. The boards are fed to the press by means of a moving steel band. For edge veneering, devices with pneumatic cylinders or fire-hose pressure units are used (figures XX and XXI). The pressure of the compressed air in the network of a factory is usually 6 to 8 kp/cm^2. In large factories, use of edge-veneering machines (figure XXII) is already widespread. Some of these machines have several additional working units. Small factories use portable machines, as shown in figure XXIII.

Formerly, assembly was always the next phase after machining. Today, however, it is usual to try to complete surface finishing before assembly whenever possible. To do this, a curtain-coating machine may be used advantageously. The two main phases of assembly are detail 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 hand pump)
- Dowel-driving machines
- Staple guns
- Mechanical screwdrivers
- Assembly jigs (see figure III)
- Frame and carcass clamps (figure XXIV)

As noted previously, manual fitting in assembly 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 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 XVII. Operating scheme of one type of wide-belt sanding machine

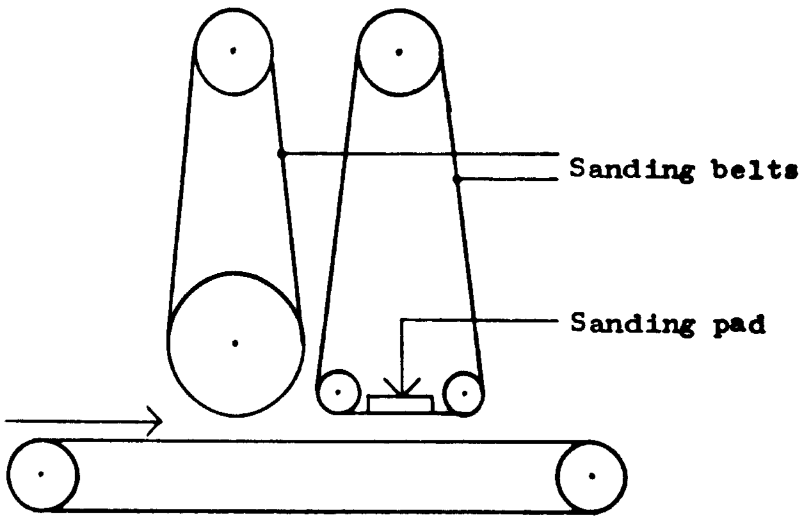


Figure XVIII. The placement of veneer sheets

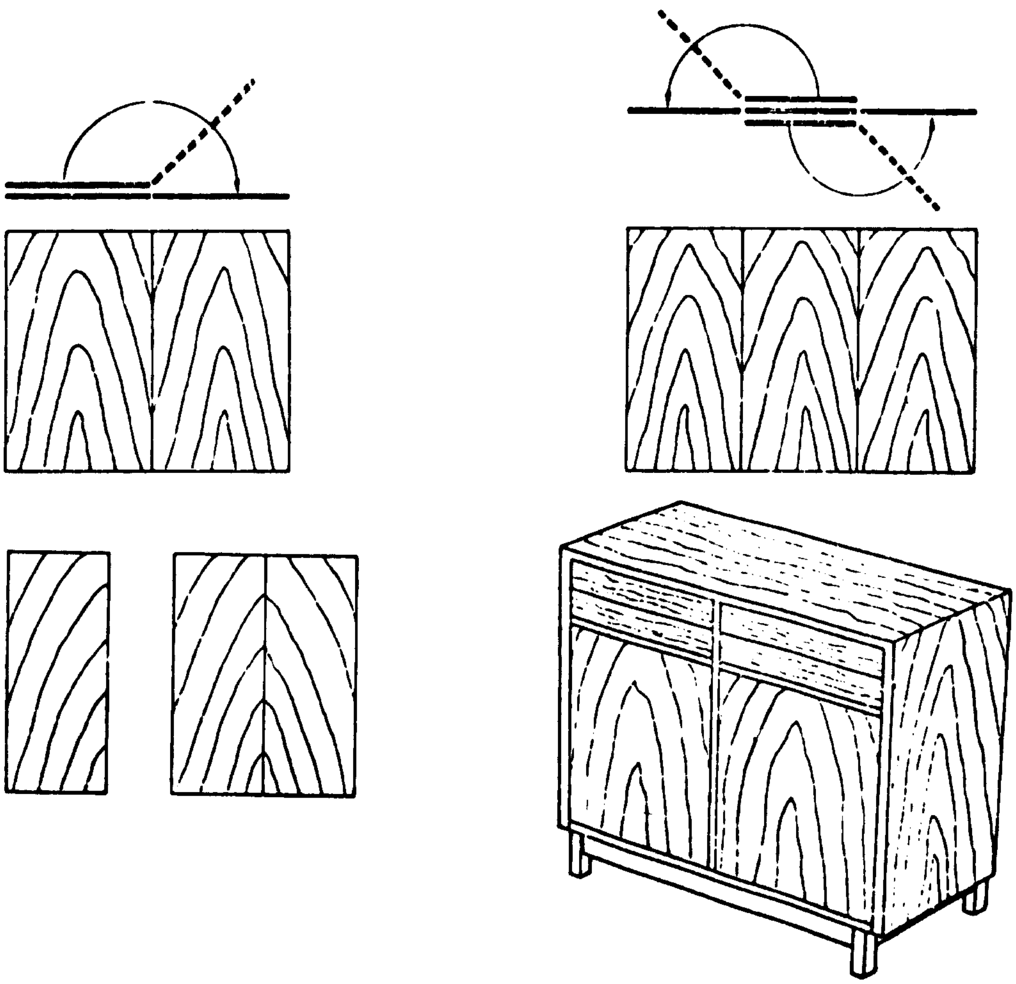


Figure XIX. A hydraulic veneering press with a steel band-feed conveyor

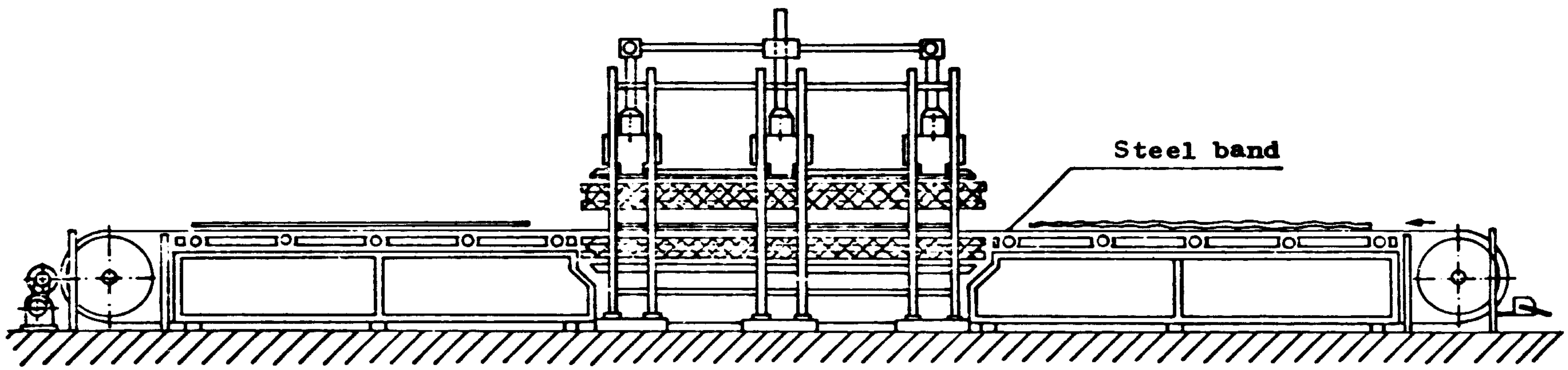


Figure XX. Principle of the fire-hose pressure unit

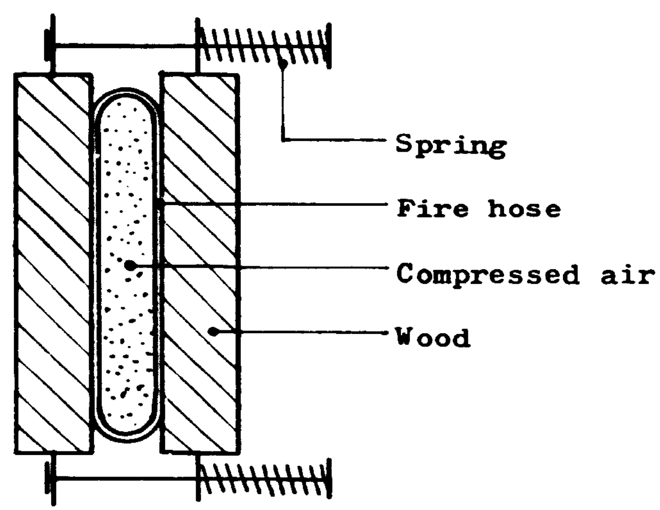


Figure XXI. Set-up for edge veneering, using a fire-hose pressure unit

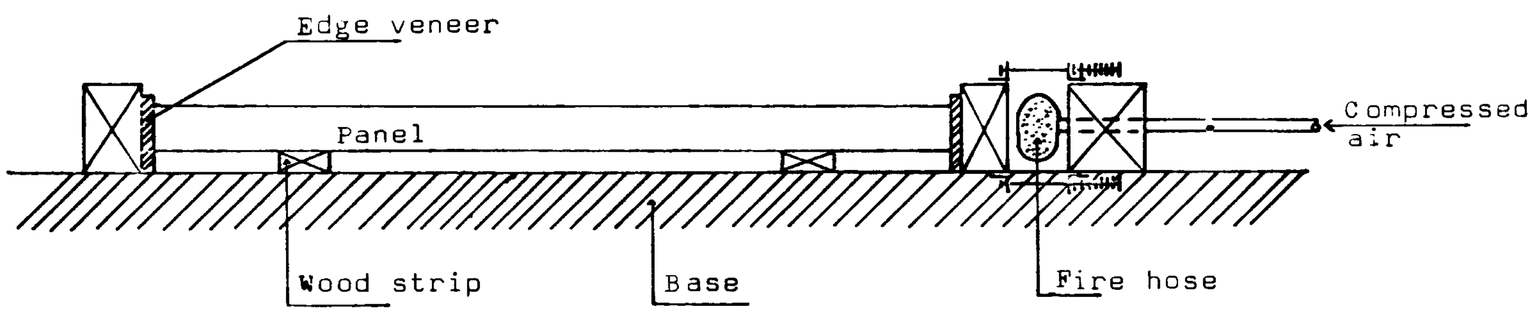


Figure XXII. Principle of automatic veneering machine with additional working units (seen from above). The machine uses thermoplastic glue

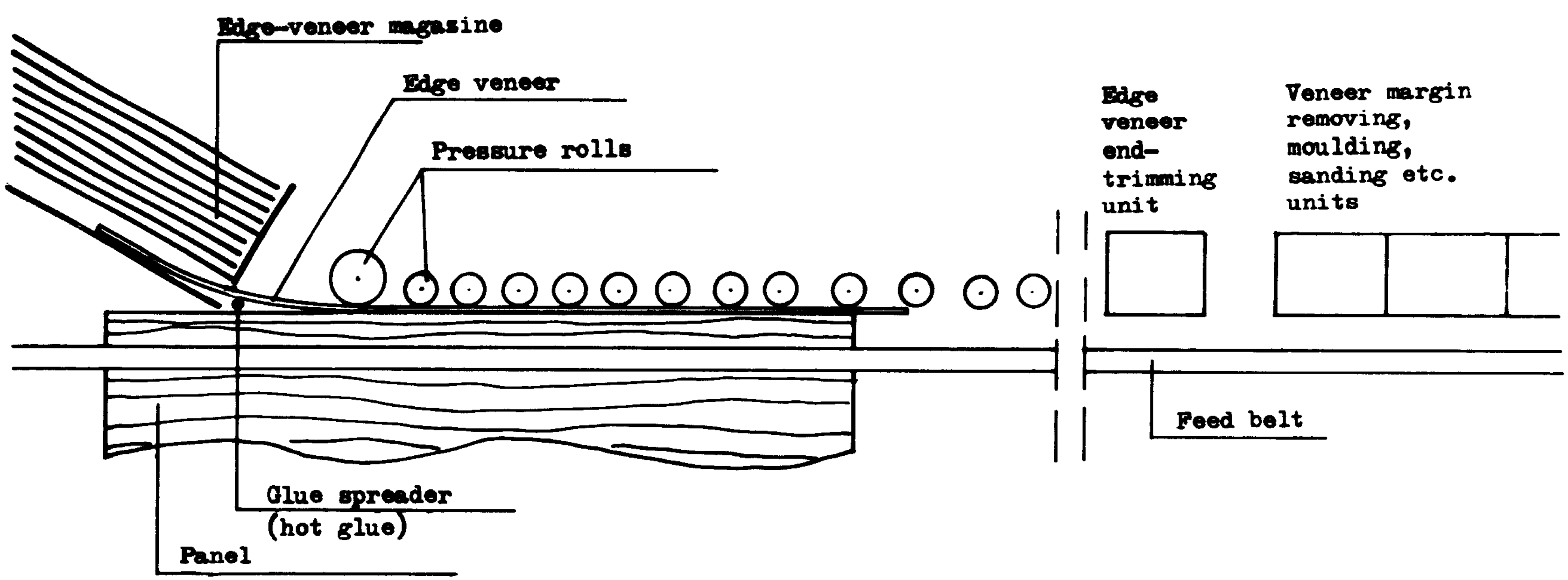


Figure XXIII. A hand-guided machine for sawing the margins of edge-veneer work: A and B are guiding surfaces

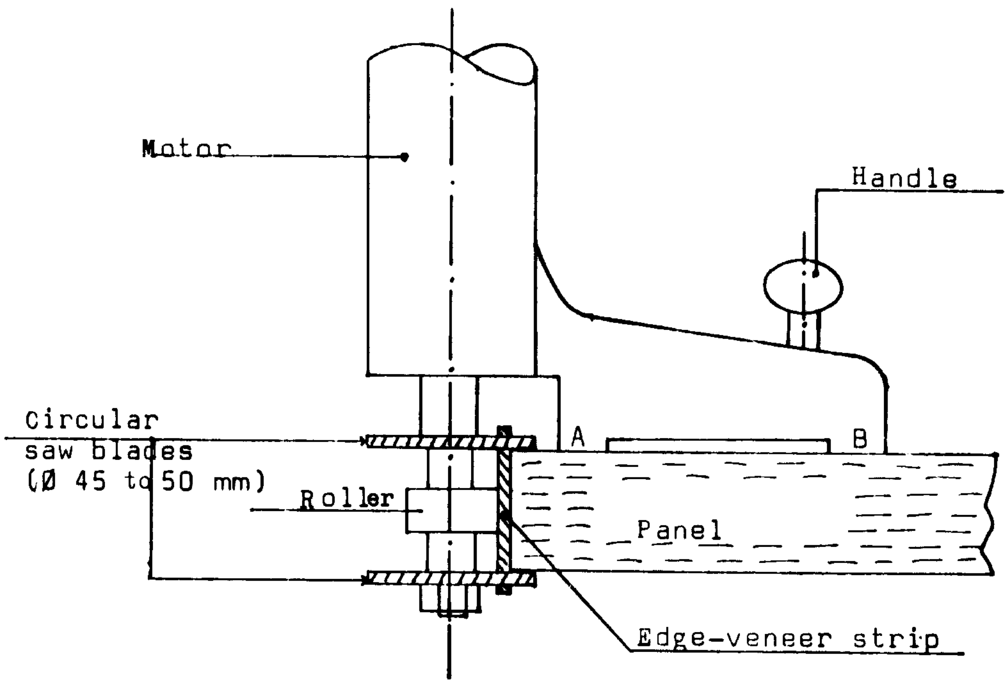
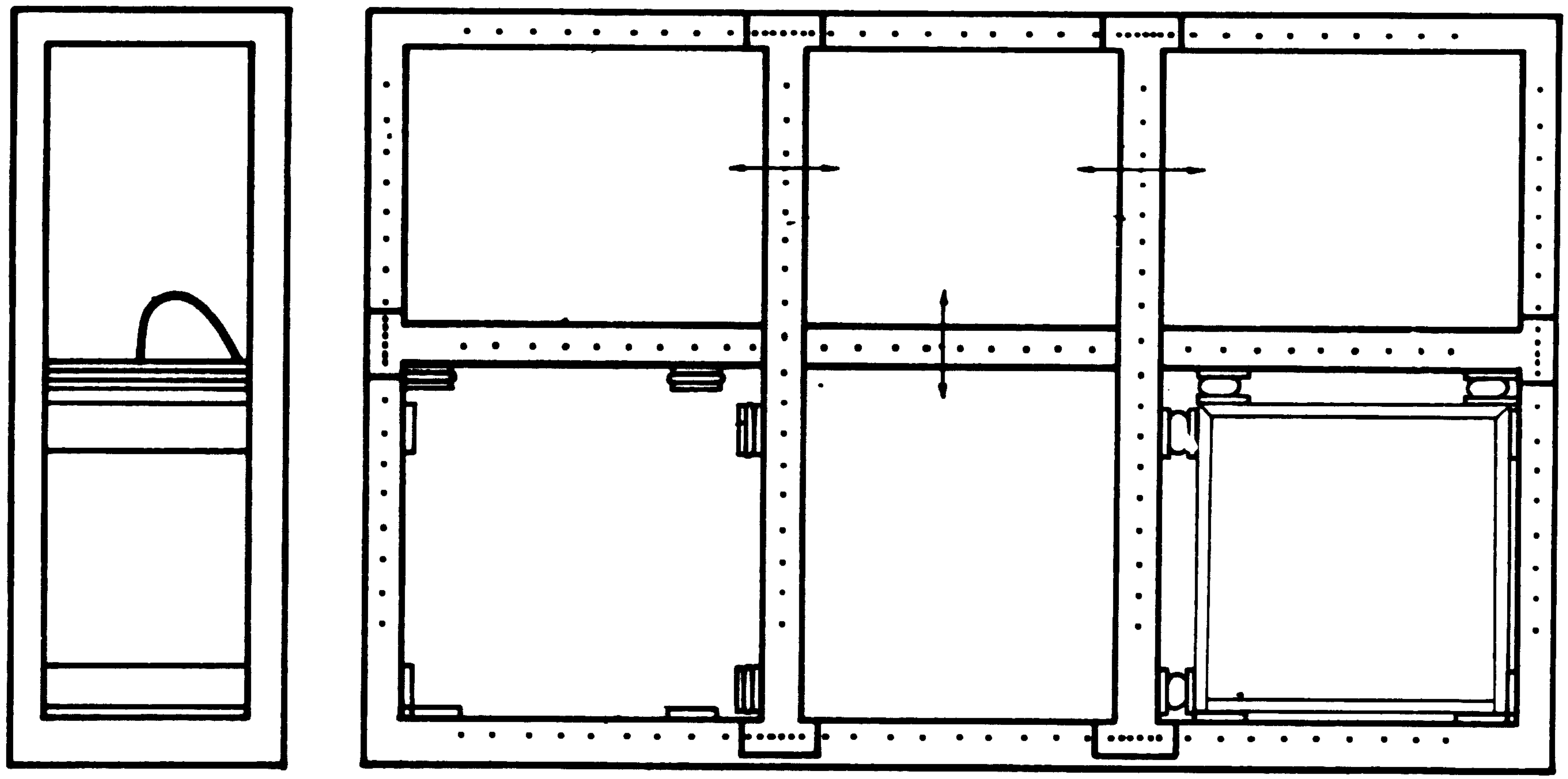


Figure XXIV. Carcass clamp with fire-hose pressure units. Two cabinets can be assembled at one time with this arrangement



XIX. Joinery technology*

Module dimensioning of joinery products

In 1960 the module department of the Nordic Building Regulations Committee (NKB)[1] formulated a system of standards called the module system for the building industry. The International Organization for Standardization (ISO) used these standards as the basis for a system of international recommendations, and the Finnish Standardization Commission (Suomen Standardisoimislautakunta) in Helsinki developed them for joinery products.

The starting point in the module dimensioning of joinery products is that their joining dimensions must be compatible with those of the module system for the building industry. The basic module *(M)* of this dimensioning system is M = 1 dm = 100 mm. The joining dimensions of the products are integral multiples of the basic module $n \times M$, in which n = 3.

This chapter is restricted to three principal groups of joinery products: doors, windows, and kitchen furniture and closets. They have long been made in a range of standard sizes at various factories. The latest Finnish standards are considered separately in connexion with each of these groups of products and in the annex to this chapter. Quality regulations and structural data are considered together with standard dimensioning.

Structure of doors

The Finnish standards for several kinds of doors, both flush (not rebated) and rebated, are reproduced in the annex. The structural requirements for flush doors are given in standard RT 210.82. Their components are the frame, the filling and the surface boards.

The main purpose of the surface boards is to give the door the desired appearance but, together with the filling, they also have a decisive influence on the rigidity of the structure. If the door is to remain straight in use, its structure must be symmetrical, and this requirement makes notable demands on the covering boards, which must be homogeneous both in thickness and in quality. Generally, covering boards are of hard fibreboard or plywood, which answer this purpose quite well. Doors for more exacting use are often veneered with oak, okoumé, teak or pine.

The filling and the framework of the door form the base on which the covering boards are glued. The framework may be made either of solid wood or of thin sheets or pieces glued together. Pieces are usually glued together by means of automatic finger-jointing machines. In this case, timber of quite low quality can be used by cutting away its faults and joining the suitable pieces. Earlier, framework pieces were 4 in. (10 cm) wide, and the corners were strengthened with corner-locks or dowel joints. Gradually, the framework has become narrower and is now only 10 to 50 mm wide. Its pieces are joined only with staples, which facilitates the assembly phase. With the narrowing of the framework, however, it has become necessary to use special additional pieces for installing the lock and hinges so that fastening screws can be fixed in solid wood.

The filling of flush doors used to be solid wood, but block filling has become more common. The distance between the blocks varies greatly, depending on how even a surface is required. The blocks may be of solid wood, plywood, or porous or hard fibreboard. They may also be used to form grids in order to obtain better filling than

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[1] The common standardization organization of the Scandinavian countries. Questions connected with it are dealt with by the following governmental offices and organizations: Boligministeriet, Denmark; Sisäasiainministeriö, Finland; Kommunalog Arbeidsdepartmentet, Norway; Statens Planverk, Sweden.

with blocks set in only one direction. At present, paper-honeycomb fillings, the best known of which are Dufolite and Wellite fillings, are used almost exclusively.

Paper-honeycomb fillings are formed of sections. The compression strength of the filling may be regulated by changing the size of the sections and the thickness of the paper. Paper fillings are inexpensive and provide the product with an even surface, great bending strength, straightness and light weight.

A separate group among flush doors consists of fireproof and sound-insulating doors. These differ from ordinary flush doors only in their filling. Wooden doors for dwellings belong to groups C 15 and C 30 in their degree of resistance to fire. The numbers 15 and 30 indicate the fire resistance of the doors in minutes. A burning test is performed in a vertical oven of a fire laboratory according to a standard burning curve in which the temperature reaches 730°C 15 minutes and 850°C 30 minutes after the oven is lit. The door must stand the heat without burning through. The smoke formation and surface temperature on the unexposed side are also examined.

If the inner structure of the fireproof doors is of solid wood, a door 40 mm thick withstands burning for 15 minutes. The same result may be obtained using a particle-board structure or expanded cork as filling. In fire group C 30, the structure must be stronger. The required fire resistance is obtained by using asbestos or some other special material.

Sound insulation is required mainly in doors for hotel rooms, doors for patient and examination rooms in hospitals, classroom doors for schools and the outer doors of dwellings.

Sound-insulation requirements are 25 or 30 decibels (dB) depending on the use. Degrees of insulation are obtained by increasing the weight of the door with thicker surface boards or with a multilayer structure whose inside is often soft and sound absorbing. Particular attention must then be paid to the packing between the door and the frame. (This is also true for fire doors.)

Windows and glazed doors

While space does not permit detailed discussion of the construction of windows and glazed doors, the subject is well covered in some of the Finnish standards in the annex to this chapter (see in particular standard RT 210.81).

Kitchen furniture

Kitchen furniture is divided into three categories according to types of cupboards:

(a) Wall cupboards, whose standard widths are 400 and 500 mm or integral multiples of these dimensions. Their depth is 290 mm and their heights are 1,160, 680 and 480 mm;

(b) Table cupboards, with widths of 400 and 500 mm or integral multiples of these; the depth is 790 mm and height 820 mm which, when the table-top (30 mm) is added, gives a total height of 850 mm;

(c) Closets, with widths of 500 and 600 mm, depth of 590 mm and heights of 2,380 and 1,900 mm, plus a separate upper cupboard (480 mm).

The main raw materials of kitchen furniture are particle board, plywood, hard or semihard fibreboard, and solid pine in joints and framework. Structural boards are often made, using the honeycomb construction discussed above in connexion with flush doors; the quality regulations are basically the same as the corresponding ones for doors.

Main raw materials used in the manufacture of windows, doors and furniture

The timber used in Finland is generally pine, which is quite suitable for manufacturing joinery products. For visible surfaces, unsorted top-grade (u/s) or export-quality wood is generally used. The faults allowed in the timber are given in standards RT 210.81 and RT 210.82.

The use of fir has been studied recently, and it has been used to some extent, e.g. in door-frames. Some manufacturers also use birch in certain parts of kitchen furniture.

Other raw materials include hard and semihard fibreboard, plywood, hardboard, blockboard and various species of import hardwoods.

Among the other manufacturing materials needed are glues, paints, fittings and screws.

Special features of manufacturing in the joinery products industry

Finger-jointed timber

The joinery industry has begun to use finger-jointed timber in increasing amounts. This has become possible because waste in cutting is being reduced and timber of lower quality is being used. Finger jointing is usually done with kiln-dried timber that is driven through a rip and cross saw and possibly also through a surface planer to a finger-jointed machine. After jointing, it is cut again to the required length. The strength of the joint is determined by the length of the fingers, so that finger-jointed timber can be processed for almost any use.

Along with the development of the timber-lengthening technique, edge gluing has also become important; indeed, it is even necessary in some products. Edge-glued timber does not twist nearly as much as solid pieces, which is an important factor in the manufacture of structures such as door-frames. In general, door-frames wider than 5 in. (6.25 cm) must be made of edge-glued timber. This is because wider pieces, when cut from the trees of small diameter available today, contain a mixture of radial and tangential grain directions that can cause differential shrinking.

Automatic production lines

The continuous rise in production costs has increased the importance of economy in the use of raw materials and labour. The resulting tendency towards greater and more rationalized serial production has also accelerated the introduction of automatic machines and machine lines. An example is the automatic door-manufacturing line of a Finnish producer. In this arrangement the door goes automatically from the press through double-end tenoning, surface sanding, edge sanding and the installation of fittings. After these phases the doors are stacked and then, if necessary, sent to another automatic line where all the phases of surface finishing are performed automatically, including base painting and sanding and finishing on both sides. Similar examples may be found in window and furniture manufacturing.

Furniture manufacture is more complicated owing to the wider range of products. However, the newest furniture factories have also advanced considerably in their assembling phases. It is now common to use assembling presses, from which the items go to a conveyor where doors are fixed and inside fittings installed. Painting is done before assembly because it is easier to paint parts than a whole. Furthermore, the use of assembling presses has brought about changes in types of jointing, the type best suited for presses being the dowel joint.

Materials and performance of finishing

Surface finishing is treated elsewhere in this publication,[2] so that only a few points need be mentioned here. The demands made on finished surfaces depend on personal taste, the surroundings of the article and other factors connected with its use.

As a base for surface finishing, solid wood, veneer, plywood, hardboard or particle board may be used. The final appearance of the surface depends on the quality of the board; good results cannot be obtained on a poor base. If the base is uneven, it must be sanded and filled before finishing.

Furniture parts and doors are usually painted with curtain-coating machines that contain preliminary heating and drying ovens and a cooling area. The newest lines also have sanding machines with brush equipment as well as a return rail for the pieces with its own turning equipment.

[2] See chapter XX, "The surface finishing of wood and wooden products".

Windows are painted with spraying-painting equipment either as parts or assembled. The temperatures of drying ovens are low so that when softwood is used the resin will not boil out of the wood and spoil the painted surface. Paints used in windows differ from door and furniture paints in that they must be sufficiently resilient to resist weather. The paints used are usually based on alkyd, amine and urea resins, which act as cementing agents. Nitro-cellulose, urethane or polyester resins are the most common cementing-agent varnishes. All paints and varnishes are highly flammable, so that equipment must be designed with particular attention to safety.

It is worth mentioning that, instead of paint, plastic profiles are now often used to coat door-frames and windows. In this case no painting is necessary, and timber of a lower quality may be used under the plastic covering.

Marketing joinery products

In Finland there are two principal outlets for joinery products: sales by tender to building companies and sales through retail organizations to small-scale consumers.

The first outlet is by far the larger and works as follows: a building company sends an inquiry to several manufacturers of the joinery product in question and decides the purchase after severe competitive evaluation in terms of price and quality. Some manufacturers operate entirely in this field of marketing and manufacture no products for stock at all. Their competitive position is enhanced owing to their flexibility and ability to offer better prices when a special product, that is, one of non-standard size, finish or fitting, is desired. Furthermore they have no inventory or interest costs. On the other hand, they may not have the benefits of longer manufacturing series that standard products assure.

The strongest retail dealers are the builders' department stores that have appeared in recent years. They have the great advantages of their specialized staff and stock. Hardware stores have traditionally been retail outlets. They do not, however, hold products in stock but act as agents of manufacturers, receiving an agreed commission for their sales. Larger Finnish companies also have district representatives throughout the country who generally sell from stock on a commission basis.

Traditionally, manufacturers operated alone with their own sales organizations, but the increased competition that forced them into product rationalization has also led to the formation of joint sales organizations by several factories. An example in Finland is Sovi Oy, the sales organization of three door factories. It divides its orders according to an agreed principle by which each member company manufactures the products best suited to its processing capability.

The degree of manufacture of joinery products has changed considerably during the past few years. Kitchen furniture is now delivered almost completely finished and sometimes comes fixed to the walls, at least in new buildings. Increasingly, doors and windows are delivered already painted, provided with fittings and glazed. Building companies have found that this saves costs and, in the case of prefabricated articles, it results in better quality than would be possible if the products were made on the site in poor conditions with deficient machines and equipment. Thus, the time-table for completing buildings is accelerated and capital interest costs and labour are saved.

Annex

REPRESENTATIVE FINNISH JOINERY STANDARDS[a]

RT 210.81	Wooden windows and outside doors, quality
RT 210.82	Wooden flush doors, quality
RT 860.22	Windows, wood, installation
RT 860.23	Windows, wood, fittings
RT 861.42	Windows, wood, opening inward, double casement
RT 861.46	Windows, wood, opening inward, coupled casements
RT 862.46	Windows, wood, opening inward, coupled casements
RT 870.22	Door, wood, fixing and fittings
RT 871.05	Doors for dwellings, standard sizes
RT 871.21	Wooden doors for dwellings, not rebated door-leaf
RT 871.22	Wooden doors for dwellings, rebated door-leaf

Suomen Standardisoimisliitto Finlands Standardiseringskommission

WOODEN WINDOWS AND OUTSIDE DOORS, quality

SFS 2455
SfB A
UDK 674.21
Page 1 (3)

Lumber defects	RT 210.7	
Wooden flush doors, quality	RT 210.82	SFS 2456
Wooden storage units, quality	RT 210.83	SFS 2457
Boardings, selection of character and quality	RT 216.01	
Industrial finishing of joinery products	RT 148.032	

1 CONTENTS

11 This standard gives quality provisions for windows and glazed doors as well as for outside and other panelled doors.

12 The standard includes provisions for the materials used the construction of windows and glazed doors as well as for outside and other panelled doors, their manufacture, accuracy of form and appearance of the surfaces 'in the white'.

2 NOTATION

Notation: Manufacturing degree of the product and quality grade (type of timber) and the RT number of this standard.
E.g. in the white 1 pine, RT 210.81
E.g. painted 2, RT 210.81

3 QUALITY GRADES

The products are classified special grade, varnishing grade and painting grade. In classification a 'main face' principle is applied. This means that other than main face surfaces (e.g. surfaces seen only occasionally) may, in the case of the special grade and the varnishing grade be of the next lower grade, unless otherwise specified.

31 Special grade, notation E

This class comprises products, which meet high requirements and to which the timber has been chosen with particular care. These products are usually intented to be finished with varnish. The sort of timber should be specified in the order.

In grade E the frames are of grade 1.

32 Varnishing grade, notation 1

This is the normal quality grade for products intended to finished with varnish. The sort of timber should be specified in the order.

33 Painting grade, notation 2

This quality grade comprises conifer products meant to be painted.

4 PROVISIONS FOR THE MATERIALS

41 Timber

.1 Quality

The basis of grading softwood is the u/s quality given in the grading rules of export timber with the limitations given later.

For foreign hardwood the provisions in appendix 2 will be applied.

.2 Heading joints

The joints have to be finger joints or alternating butt joints. The length of an alternating butt joint may be at the most one third of the width of the lengthened piece, however not more than 50 mm. No visible heading joints are allowed for special grade and varnishing grade.

.3 Defects. Plugging.

Wane is not permitted in surfaces exposed to view. The knots have to be distributed evenly and they are not permitted in places where they might affect the strength of the timber. The plugs shall be of the same species of wood and the direction of their grains shall be the same as in the surrounding wood to which they shall be firmly fastened. The plugs are considered sound knots and their sizes shall be taken into consideration at grading.

In products used in humid surroundings plugging ought to be avoided.

42 Plywood

Plywood shall as to quality, dimensioning and property comply with the requirements of SFS standards.

43 Block- and laminboards

Block- and laminboards shall suit the purpose as to quality and structure.

Boards for use, as main faces should on both sides of the board have 1 + 1 veneers glued at right angles to each other and so that the grain direction of the veneer adjacent to the core is running at right-angles to the grain of the core.

Boards with one or two parallel surface veneers on both sides, whose grain direction is running at right-angles to the grain direction of the core may be used for main faces only when they are faced with cross-wise glued veneer, laminated plastics sheet, plastics fabric or the like.

44 Particle board

Particle board has to be a LA/A board and comply with the requirements of standard SFS 0.IV.2.

45 Wood fibre boards

.1 Hardboard should have a density of not less than 850 kg/m^3.

.2 Medium hardboard should have a density of not less than 700 kg/m^3.

46 Face veneer

Facing veneer has to be sliced, except birch, which may be rotary cut.

Sliced veneer shall meet the requirements set in appendix 2.

Rotary cut veneer has to meet the requirements set in SFS standards.

47 Laminated plastics sheet

Laminated plastics sheet has to meet the requirements given in appendix 3.

48 Fittings

The manufacturer shall indicate in his offer the fittings he has used.

49 ~~Degree of dryness~~

The timber has to be artifically dried. The moisture content calculated from dry weight shall not exceed 12 % during the manufacturing and delivery phases

The moisture content also constitutes the basis for judging the accuracy of size and form.

5 PRODUCT SPECIFICATIONS

51 General

The productsand their parts have to be manufactured and assembled with care and skill. All timber joints which are known to be good and suit the appearance of the quality grade in question are allowed.

Joints in boards are not allowed. In veneers joints are not allowed across the grains.

Adhesives should comply with the requirements of the use of the product and should resist moisture and micro-organisms.

52 Accuracy of form

Testing methods for accuracy of form, see appendix 1.

The provisions concerning accuracy of form refer to the moment of delivery, to the guarantee period inspection and to a dryness degree of the timber of 10...12 %.

The continuity of the properties of the products implies that they are stored and handled on the site according to the general specifications for construction works, RYL 1960, RT 140.1/B, para. B.671 and B.673.

.1 Accuracy of angles (squareness)

at delivery	at guarantee period inspection
1 mm	1 mm

.2 Planeness of surface (dish or/and twist)

at delivery	at guarantee period inspection
4 mm	5 mm

These figures imply that the temperatures and moisture conditions are the same in the spaces on both sides of the door.

.3 Evenness of surface

	at delivery	at guarantee period inspection
with a 200 mm ruler	0,2 mm	0,3 mm

53 Panels ($\leqq 0{,}5\ m^2$)[1])

Quality and minimum thickness

	special grade	varnishing grade	painting grade
Plywood, face veneer rotary cut	9 mm A1(A)	9 mm I(B)	9 mm II(S)
Timber	15 mm	15 mm	15 mm
Hardboard	not permitted	not permitted	2...3 layers glued, 9mm in all

[1]) If the size of the panel is bigger than the given size, the thickness should be correspondingly increased.

54 Matchboards

In accordance with RT 216.0.

55 Defects permitted in surfaces exposed to view

	special grade	varnishing grade	painting grade
.1 Window casements (42 mm x 42 mm)[1])			
Sound knots or plugs pieces/m	not permitted	2p.10mm 3p. pin knots	2p.20mm 2p.15mm and pin knots
Checks	not permitted	not permitted	small patched ones permitted
Blue stain	not permitted	not permitted	permitted as miscolouring
.2 Casement bars and linings			
Sound knots or plugs pieces/m	not permitted	pin knots	pin knots
Checks	not permitted	not permitted	small patched ones permitted
Blue stain	not permitted	not permitted	permitted as miscolouring
.3 Casements of glazed doors (42 mm x 104 mm)[1])			
Sound knots or plugs pieces/m	not permitted	1p.20mm 2p.10mm and pin knots	2p.30mm 3p.20mm and pin knots
Checks	not permitted	not permitted	small patched ones permitted
Blue stain	not permitted	not permitted	permitted as miscolouring
.4 Stiles and rails of outside and panelled doors (40 mm x 93 mm)[1])			
Sound knots or plugs pieces/m	not permitted	1p.20mm 2p.10mm and pin knots	2p.30mm 3p.20mm and pin knots
Checks	not permitted	not permitted	small patched ones permitted
Blue stain	not permitted	not permitted	permitted as miscolouring
.5 Frames (42 mm x 118 mm)[1])			
Sound knots or plugs pieces/m		1p.20mm 3p.15mm and pin knots	2p.35mm 3p.25mm and pin knots
Checks		not permitted	small patched ones permitted
Blue stain		not permitted	permitted as miscolouring

[1]) If sizes are smaller or greater than the given, knots are permitted correspondingly less or more.

56 Finishing of surfaces 'in the white'

.1 As to special grade products all main faces should be very carefully finished. There should be no glue accumulations which might make finishing difficult or cause colour defects. Defects due to manufacture may not be seen.

.2 As to varnishing grade products main faces have to be carefully finished. There should be no glue accumulations, which might make finishing difficult or cause colour defects. Minor defects due to manufacture are allowed only in places not well adapted to machine grinding, like surfaces only a little or occasionally exposed to view.

.3 As to painting grade products main faces should be finished. No glue accumulations are allowed, which might make surface finishing difficult. Minor defects due to manufacture are allowed only in surfaces which are only a little or occasionally exposed to view.

6 MANUFACTURING DEGREE

Windows, glazed doors, outside and other panelled doors are delivered in the white, varnished or painted.

Varnishing and painting should be done according to RT 148.032.

If the products are required finished in some other way this should be indicated separately as well as the materials and the methods used.

APPENDIX 1

Testing methods for accuracy of form

1 Accuracy of angles (squareness)

Squareness is measured with a square at diagonally opposite corners. The measuring points have to be situated 500 mm from the corners or at a distance corresponding the width if the width is less than 500 mm. Deviation is given in millimetres with the accuracy of 0,1 mm.

2 Planeness of surface (dish and/or twist)

Dish of a surface is measured on the concave side with a ruler, which is as long as the surface, along the diagonals and all edges. The greatest measured grade is decisive. The deviation is given in millimetres with an accuracy of 1 mm. Twist is measured by placing the surface on a level plane so that three corners touch the plane. The distance of the fourth corner from the plane gives the twist of the surface to be measured.

The deviation is given in millimetres with an accuracy of 1 mm.

3 Evenness of surface

Evenness of surface is measured with a ruler which is 200 mm long by setting it in arbitrary directions on the surface to be measured and using a special measuring device to measure the checks.

The deviation is given in millimetres with the accuracy of 0,1 mm.

APPENDIX 2

Quality requirements for foreign hardwood surfaces

1 General

Foreign hardwoods are imported species (e.g. oak, teak, mahogany etc.).

These provisions are also adapted to veneers cut of domestic species.

Provisions have been given for special grade and varnishing grade products.

2 Veneer

Veneer has to be sliced and the thickness should be the minimum of 0,6 mm. The joints of the veneer have to fit perfectly and the veneers have to be jointed so that a uniform pattern typical of the veneer in question is achieved.

.1 Special grade

The veneer should be typical of the species in question, free from defects and altogether homogeneous both as to colour and structure. Inserts are not allowed.

.2 Varnishing grade

The veneer should be typical of the species in question. Slight defects in colour and some other imperfections which do not disturb the general impression are allowed. A small amount of knots smaller than 5 mm (bird's eye) are permissible. Defects which sometimes appear in veneer such as surface wood of different colours, blisters, decay etc, are not allowed. Small corrections like patchings done carefully so that they fit in with the surrounding veneer as to colour and structure are allowed.

3 Converted timber

The thickness of boards used for facing should be the minimum of 5 mm.

.1 Special grade

The timber should be typical of the species in question and the faces should be free from defects and altogether homogeneous as to colour and structure. Patches are not allowed.

.2 Varnishing grade

The timber should be typical of the species in question. Small defects allowed in main faces. Knots smaller than 7 mm are allowed to some extent. Surface wood of different colours and other imperfections sometimes appearing in timber are not allowed. Sole plugs, which are carefully made and fit in with the colour of the wood and are smaller than 15 mm are allowed. The plugs have to be of the same species and the grains of the plug shall run in the same direction as the grains of the surrounding wood, in which it should be tightly fixed.

APPENDIX 3

Quality requirements for laminated plastics sheet

1 Coating of desks

The coating of desks should be paper-backed laminated plastics sheet. Its thickness is the minimum of 1,4±0,1 mm and it has to meet the following requirements:
Wearing strength: NEMA LD 1-3.03/64 A
Impact strength: NEMA LD 1-3.03/64 K
Appearance: NEMA LD 1-3.03/64 J
Changes due to moisture: NEMA LD 1-3.03/64 H
Heat resistance: SIS 245803 (NEMA LD 1-2.03/64). At testing no trace allowed on a matt surface, a glossy surface may lose some lustre.
Durability in boiling water: SIS R 705002 (NEMA LD 1-2.02/64), no trace allowed on the surface.
Influence of chemicals: SIS 245805 (NEMA LD 1-2.05/64), the grade has to be 3. The grades are 1, 2 and 3, of which 3 is the best.
Light resistance: SIS 245804 (NEMA LD 1-2.06/64), the grade has to be the minimum of 5. Grades are 1...8, of which 8 is the best.
Water absorption: SIS 245801 (NEMA LD 1-2.07/64), the absorption may not be higher than the maximum of 500 mg/25 cm^2 for sheets 1,4 mm thick. For thicker sheets the maximum of 10 % of the mass.

2 Coating of vertical surfaces

The coating of vertical surfaces such as door leaves should be paper-backed laminated plastics sheet, the thickness of which is the minimum of 0,8 ± 0,1 mm which has to meet the following requirements:
Wearing strength: NEMA LD 1-4.03/64 A
Impact strength: NEMA LD 1-4.03/64 G
Appearance: NEMA LD 1-4.03/64 E
Changes due to moisture: NEMA LD 1-4.03/64 D
Influence of chemicals: SIS 245805 (NEMA LD 1-2.05/64). The grade has to be 3. Grades are 1, 2 and 3, of which 3 is the best.
Light resistance: SIS 245804 (NEMA LD 1-2.06/64). The grade has to be the minimum of 5. Grades are 1...8, of which 8 is the best.

Water absorption: SIS 245801 (NEMA LD 1-2.07/64), for sheets which are 0,8 mm thick the absorption may be the maximum of 350 mg/25 cm^2, for thicker sheets the maximum of 12 % of the mass.

3 Coating of shelves

The thickness of laminated plastics sheet used for coating of shelves has to be the minimum of 0,8±0,1 mm and the coating has to meet the following requirements:
Wearing strength: NEMA LD 1-4.03/64 A
Impact strength: NEMA LD 1-4.03/64 G
Influence of chemicals: SIS 245805 (NEMA LD 1-2.05/64). The grade has to be 3. Grades are 1, 2 and 3, of which 3 is the best.

4 Other laminated plastics sheet

Sheets may also be fabric-backed or other laminated plastics sheet if it meets all the requirements of the previously mentioned standards SIS and NEMA. The manufacturer has to indicate the thickness and type of laminated plastics sheet in his offer.

Suomen Standardisoimislautakunta Finlands Standardiseringskommission

WOODEN FLUSH DOORS, quality

SFS 2456
SfB A
UDK 674.21
Page 1 (3)

Lumber defects	RT 210.7	
Wooden windows and outside doors, quality	RT 210.81	SFS 2455
Wooden storage units, quality	RT 210.83	SFS 2457
Boardings, selection of character and quality	RT 216.01	
Industrial finishing of joinery products	RT 148.032	

1 CONTENTS

11 This standard gives quality provisions for flush doors

12 The standard includes provisions for the material used, the construction, the manufacture of doors and the accuracy of form as well as for the appearance of the surface 'in the white'.

2 NOTATION

Notation Manufacturing degree of the product and quality grade (type of timber) and the RT number of this standard.
E.g. in the white 1 pine, RT 210.82
E.g. painted 2, RT 210.82.

3 QUALITY GRADES

The products are classified special grade, varnishing grade and painting grade. In classification a 'main face' principle is applied. This means that other than main face surfaces (e.g. surfaces seen only occasionally) may, in the case of the special grade and the varnishing grade be of the next lower grade, unless otherwise specified.

31 Special grade, notation E

This class comprises products, which meet high requirements and to which the timber has been chosen with particular care. These products are usually intented to be finished with varnish.

In grade E the frames are of grade 1.

32 Varnishing grade, notation 1

This is the normal quality grade for products intended to be finished with varnish.

The sort of timber for frame, lippings of door leaf and face veneer have to be specified in the order.

33 Painting grade, notation 2

This quality grade comprises products meant to be painted

4 PROVISIONS FOR THE MATERIALS

41 Timber

.1 Quality

The basis of grading softwood is the u/s quality given in the grading rules of export timber with the limitations given later

For foreign hardwood the provisions in appendix 2 will be applied

.2 Heading joints

The joints have to be finger joints or alternating butt joints. The length of an alternating butt joint may be at the most one third of the width of the lengthened piece, however not more than 50 mm. No visible heading joints are allowed for special grade and varnishing grade

.3 Defects Plugging

Wane is not permitted in surfaces exposed to view. The knots have to be distributed evently and they are not permitted in places where they might affect the strength of the timber. The plugs shall be of the same species of wood and the direction of their grains shall be the same as in the surrounding wood to which they shall be firmly fastened. The plugs are considered sound knots and their sizes shall be taken into consideration at grading.

In products used in humid surroundings plugging ought to be avoided.

42 Plywood

Plywood shall as to quality, dimensioning and property comply with the requirements of SFS standards

43 Block- and laminboards

Block- and laminboards shall suit the purpose as to quality and structure.

Boards for use as main faces should on both sides of the board have 1 + 1 veneers glued at right angles to each other and so that the grain direction of the veneer adjacent to the core is running at right angles to the grain of the core.

Boards with one or two parallel surface veneers on both sides, whose grain direction is running at right-angles to the grain direction of the core may be used for main faces only when they are faced with crosswise glued veneer, laminated plastics sheet, plastics fabric or the like.

44 Particle board

Particle board has to be a LA/A board and comply with the requirements of standard SFS O IV 2

45 Wood fibre boards

.1 Hardboard should have a density of not less than 850 kg/m^3

.2 Medium hardboard should have a density of not less than 700 kg/m^3

46 Face veneer

Facing veneer has to be sliced, except birch which may be rotary cut.

Sliced veneer shall meet the requirements set in appendix 2.

Rotary cut veneer has to meet the requirements set in SFS standards.

47 Laminate plastics sheet

Laminate plastics sheet has to meet the requirements given in appendix 3.

48 Fittings

The manufacturer shall indicate in his offer the fittings he has used.

49 Degree of dryness

The timber has to be artifically dried. The moisture content calculated from dry weight shall not exceed 10 % during the manufacturing and delivery phases.

The moisture content also constitutes the basis for judging the accuracy of size and form.

5 PRODUCT SPECIFICATIONS

51 Genera'

The produ nd their parts have to be manufactured and assembled with care and skill. All timber joints which are known to be good and suit the appearance of the quality grade in question are allowed.

The faces should be plywood, which is at least 2,7 mm thick, hardboard, which is at least 3,2 mm thick, or other board of corresponding thickness. The facing boards should be fixed by gluing to the core.

Joints in boards are not allowed. In veneers joints are not allowed across the grains.

If the inner structure is not suitable to fixing, of fittings, inside wood blocks should be provided or the 'stiles' should be dimensioned according to the fittings.

Adhesives should comply with the requirements of the use of the product and should resist moisture and micro organisms.

If the products are located in spaces which are continuously humid, this has to be indicated in the offer.

52 Accuracy form

Testing methods for accuracy of form, see appendix 1.

The provisions concerning accuracy of form refer to the moment of delivery, to the guarantee period inspection and to a dryness degree of the timber of 8...10 %.

The continuity of the properties of the products implies that they are stored and handled on the site according to the general specifications for construction works, RYL 1960, RT 140.1/B, para. B 671 and B 673.

.1 Accuracy of angles (squareness)

at delivery	at guarantee period inspection
1 mm	1 mm

.2 Planeness of surface (dish or/and twist)

at delivery	at guarantee period inspection
3 mm	4 mm

These figures imply that the temperatures and moisture conditions are the same in the spaces on both sides of the door.

.3 Evenness of surface

	at delivery	at guarantee period inspection
with a 200 mm ruler	0,2 mm	0,3 mm

53 Face veneer

	special grade	varnishing grade	painting grade
Rotary cut	AI(A)	I(B)	II(S)
Sliced, see appendix 2			

54 Defects allowed in surfaces exposed to view

	special grade	varnishing grade	painting grade
.1 Visible parts of door leaf frame and lippings thickness of doors = 40 mm			
Sound knots or plugs pieces/m not allowed	not allowed	1 p. 10 mm and pin knots	2 p. 20 mm 2 p. 15 mm and pin knots
Checks	not allowed	not allowed	small patched ones allowed
Blue stain	not allowed	not allowed	allowed as miscolouring
.2 Frames (42 mm x 93 mm)[1]			
Sound knots or plugs pieces/m		1 p. 20 mm 3 p. 10 mm and pin knots	2 p. 30 mm 3 p. 20 mm and pin knots
Checks		not allowed	small patched ones allowed
Blue stain		not allowed	allowed as miscolouring

55 Finishing of surfaces 'in the white'

.1 As to special grade products all main faces should be very carefully finished. There should be no glue accumulations which might make finishing difficult or cause colour defects. Defects due to manufacture may not be seen.

.2 As to varnishing grade products main faces have to be carefully finished. There should be no glue accumulations, which might make finishing difficult or cause colour defects. Minor defects due to manufacture are allowed only in places which are not well adapted to machine grinding, like surfaces only a little or occasionally exposed to view.

.3 As to painting grade products main faces should be finished. No glue accumulations are allowed, which might make surface finishing difficult. Minor defects due to manufacture are allowed only in surfaces which are only a little or occasionally exposed to view.

6 MANUFACTURING DEGREE

Doors are delivered in the white, varnished or painted. Varnishing and painting should be done according to RT 148.032.

If the products are required finished in some other way this should be indicated separately as well as the materials and the methods to be used.

1) If the sizes are smaller or greater than the given, knots are permitted correspondingly less or more.

APPENDIX 1

Testing methods for accuracy of form

1 Accuracy of angles (squareness)

Squareness is measured with a square at diagonally opposite corners. The measuring points have to be situated 500 mm from the corners or at a distance corresponding the width if the width is less than 500 mm. Deviation is given in millimetres with the accuracy of 0,1 mm.

2 Planeness of surface (dish and/or twist)

Dish of a surface is measured on the concave side with a ruler, which is as long as the surface, along the diagonals and all edges. The greatest measured grade is decisive. The deviation is given in millimetres with an accuracy of 1 mm. Twist is measured by placing the surface on a level plane so that three corners touch the plane. The distance of the fourth corner from the plane gives the twist of the surface to be measured.

The deviation is given in millimetres with an accuracy of 1 mm.

3 Evenness of surface

Evenness of surface is measured with a ruler which is 200 mm long by setting it in arbitrary directions on the surface to be measured and using a special measuring device to measure the checks.

The deviation is given in millimetres with the accuracy of 0.1 mm.

APPENDIX 2

Quality requirements for foreign hardwood surfaces

1 General

Foreign hardwoods are imported species (e.g. oak, teak, mahogany etc.).

These provisions are also adapted to veneers cut of domestic species.

Provisions have been given for special grade and varnishing grade products.

2 Veneer

Veneer has to be sliced and the thickness should be the minimum of 0,6 mm. The joints of the veneer have to fit perfectly and the veneers have to be jointed so that a uniform pattern typical of the veneer in question is achieved.

.1 Special grade

The veneer should be typical of the species in question, free from defects and altogether homogeneous both as to colour and structure. Inserts are not allowed.

2 Varnishing grade

The veneer should be typical of the species in question. Slight defects in colour and some other imperfections which do not disturb the general impression are allowed. A small amount of knnts smaller than 5 mm (bird's eye) are permissible. Defects which sometimes appear in veneer such as surface wood of different cnlours, blisters, decay etc. are not allowed. Small corrections like patchings done carefully so that they fit in with the surrnunding veneer as to colour and structure are allowed.

3 Converted timber

The thickness of boards used for facing should be the minimum of 5 mm.

1 Special grade

The timber should be typical of the species in question and the faces should be free from defects and altogether homogeneous as to colour and structure. Patches are not allowed.

2 Varnishing grade

The timber should be typical of the species in question. Small defects allowed in main faces. Knots smaller than 7 mm are allowed to some extent. Surface wood of different colours and other imperfections sometimes appearing in timber are not allowed. Sole plugs, which are carefully made and fit in with the colour of the wood and are smaller than 15 mm are allowed. The plugs have to be of the same species and the grains of the plug shall run in the same direction as the grains of the surrounding wood, in which it should be tightly fixed.

APPENDIX 3

Quality requirements for laminated plastics sheet

1 Coating of desks

The coating of desks should be paper-backed laminated plastics sheet. Its thickness is the minimum of 1,4 ± 0,1 mm and it has to meet the following requirements
Wearing strength: NEMA LD 1-3.03/64 A
Impact strength: NEMA LD 1-3.03/64 K
Appearance: NEMA LD 1-3.03/64 J
Changes due to moisture: NEMA LD 1-3.03/64 H
Heat resistance: SIS 245803 (NEMA LD 1-2.03/64). At testing no trace allowed on a matt surface, a glossy surface may lose some lustre.
Durability in boiling water: SIS R 705002 (NEMA LD 1-2.02/64), no trace allowed on the surface.
Influence of chemicals: SIS 245805 (NEMA LD 1-2.05/64), the grade has to be 3. The grades are 1, 2 and 3, of which 3 is the best.
Light resistance: SIS 245804 (NEMA LD 1-2.06/64), the grade has to be the minimum of 5. Grades are 1...8, of which 8 is the best.
Water absorption: SIS 245801 (NEMA LD 1-2.07/64), the absorption may not be higher than the maximum of 500 mg/25 cm² for sheets 1,4 mm thick. For thicker sheets the maximum of 10 % of the mass.

2 Coating of vertical surfaces

The coating of vertical surfaces such as door leaves should be paper-backed laminated plastics sheet, the thickness of which is the minimum of 0,8 ± 0,1 mm which has to meet the following requirements:
Wearing strength: NEMA LD 1-4.03/64 A
Impact strength: NEMA LD 1-4.03/64 G
Appearance: NEMA LD 1-4.03/64 E
Changes due to moisture: NEMA LD 1-4.03/64 D
Influence of chemicals: SIS 245805 (NEMA LD 1-2.05/64). The grade has to be 3. Grades are 1, 2 and 3, of which 3 is the best.
Light resistance: SIS 245804 (NEMA LD 1-2.06/64). The grade has to be the minimum of 5. Grades are 1...8, of which 8 is the best.

Water absorption: SIS 245801 (NEMA LD 1-2.07/64), for sheets which are 0,8 mm thick the absorption may be the maximum of 350 mg/25 cm², for thicker sheets the maximum of 12 % of the mass.

3 Coating of shelves

The thickness of laminated plastics sheet used for coating of shelves has to be the minimum of 0,8 ± 0,1 mm and the coating has to meet the following requirements:
Wearing strength: NEMA LD 1-4.03/64 A
Impact strength: NEMA LD 1-4.03/64 G
Influence of chemicals: SIS 245805 (NEMA LD 1-2.05/64). The grade has to be 3. Grades are 1, 2 and 3, of which 3 is the best.

4 Other laminated plastics sheet

Sheets may also be fabric-backed or other laminated plastics sheet if it meets all the requirements of the previously mentioned standards SIS and NEMA. The manufacturer has to indicate the thickness and type of laminated plastics sheet in his offer.

WINDOW, WOOD, INSTALLATION

1970 **RT 860.22E**
SfS X(31)
UDK 69.028.21 674
Page 1 (2)

Window, wood, fittings RT 860 23

0 GENERAL

01 This RT-sheet describes the number and location of fixing points of frames of wooden windows.

02 The frame of the window is always fixed by the jambs. Window frames, whose nominal width is ≥ 12 dm, are fixed also by their head and sill. See point 12.

1 NUMBER AND LOCATION OF FIXING POINTS

11 Number and location of fixing points in the jambs, fig. 2...5.

The distances are measured from the corner of the rebates, of the frame, fig 1.

Fig. 1

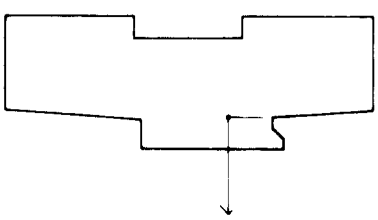
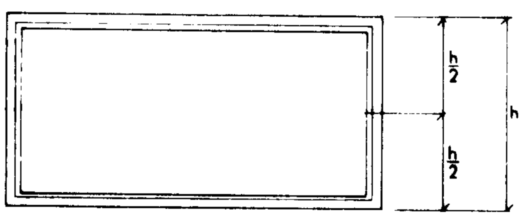
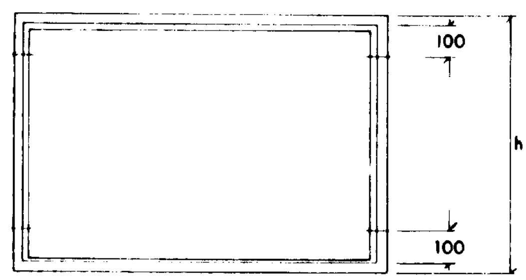


Fig. 2



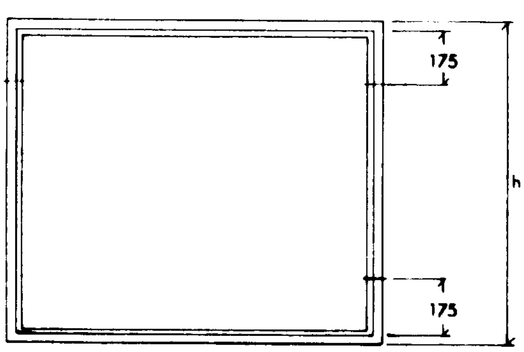
h < 8 dm

Fig. 3



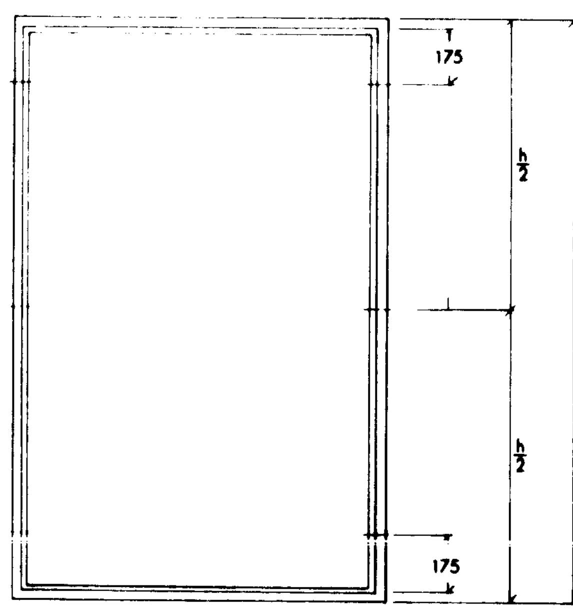
h = 8 dm

Fig. 4



8 dm < h ≤ 16 dm

Fig. 5



h > 16 dm

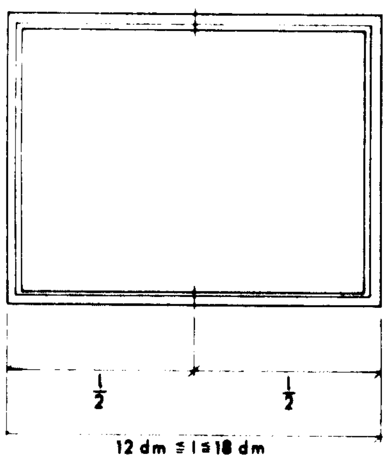


Fig. 6

12 Number and location of fixing points in the head and sill members of the frame, fig. 6 and 7. The distances are measured inside rebates.

When the nominal width of frame is < 12 dm no fixing by head and sill members is necessary.

13 Location of fixing points in the direction of depth is shown in fig. 8.

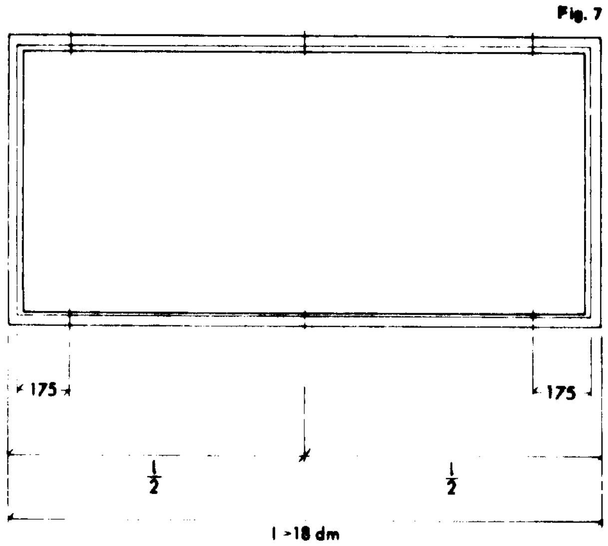


Fig. 7

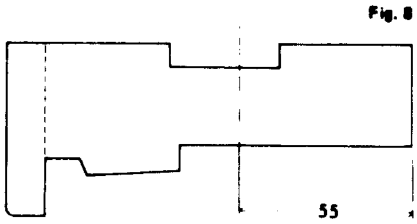
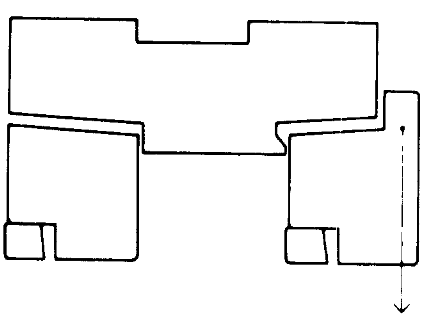


Fig. 8

Windows in group RT 861...
Window, wood, installation RT 860.22

Fig. 1



0 GENERAL

This RT-sheet includes the position of hinges and the number and position of closure and coupling fittings in wood windows.

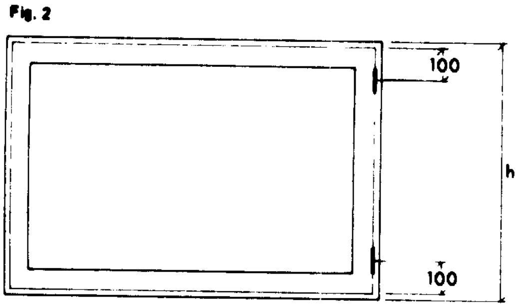
1 POSITION OF HINGES

The centre of hinges is measured from the corner of the inner casement, see fig. 1.
Number of hinges, see group RT 861...
Hinges of coupled windows
Coupling hinges should be placed near the bearing hinges. The strength of the casement must not be lessened. There should be 1 mm distance between coupled casements.

11 Hinges of side hung windows

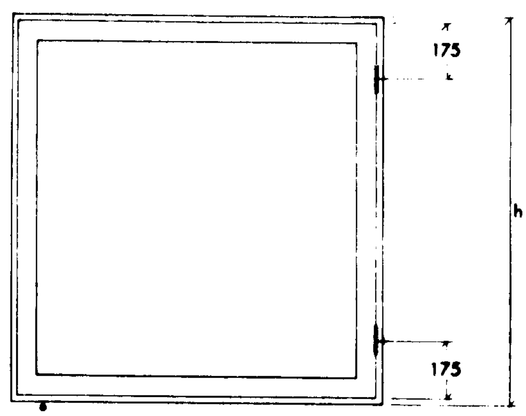
111 Side hung windows with two hinges, fig. 2 and 3.

Fig. 2



h ≤ 8 dm

Fig. 3



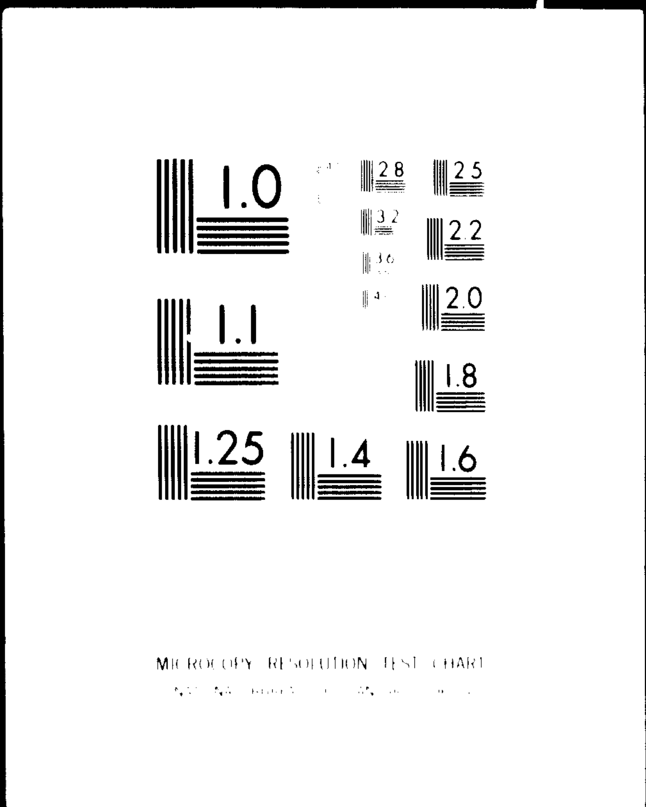
h > 8 dm

C-210

80.06.24

3 OF 5

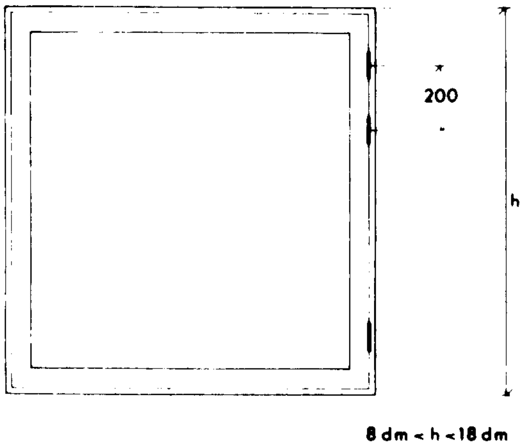
09256



24x

C

Fig. 4



112 Side hung windows with three hinges, fig. 4 and 5.

12 Hinges of top hung windows

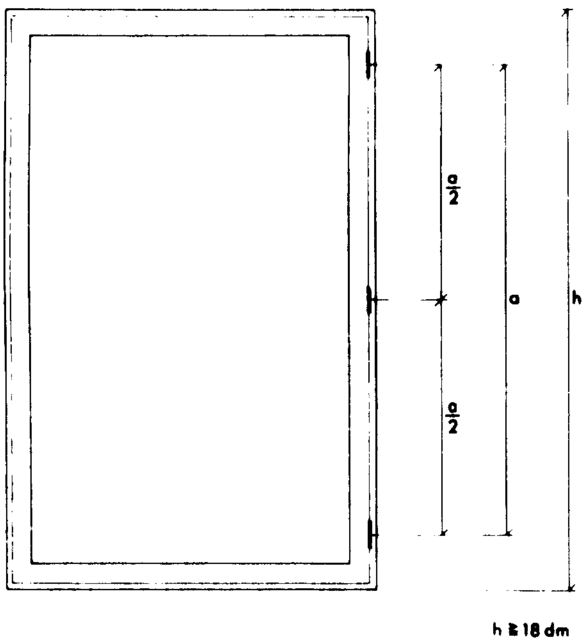
121 Top hung windows with two hinges, fig. 6 and 7.

122 Top hung windows with three hinges, fig. 8.

13 Hinges of bottom hung windows

The hinges of bottom hung windows are fixed to the bottom member at places corresponding to the position of the hinges of top hung windows.

Fig. 5



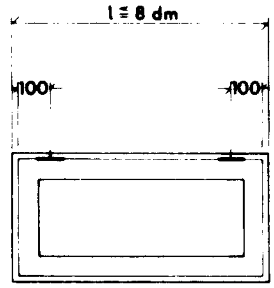


Fig. 6

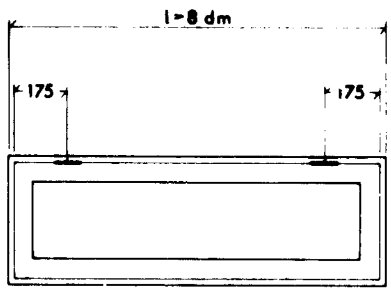


Fig. 7

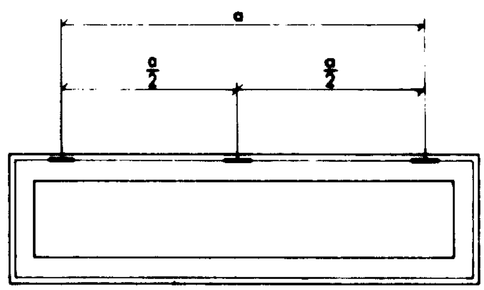


Fig. 8

Fig. 9

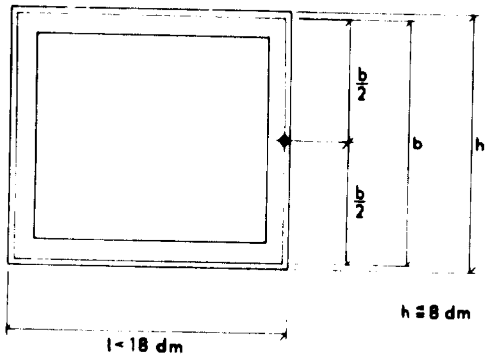


Fig. 10

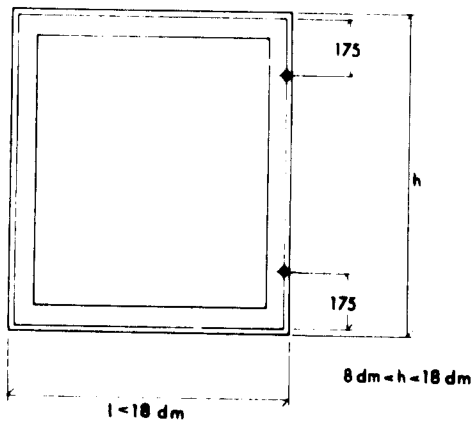
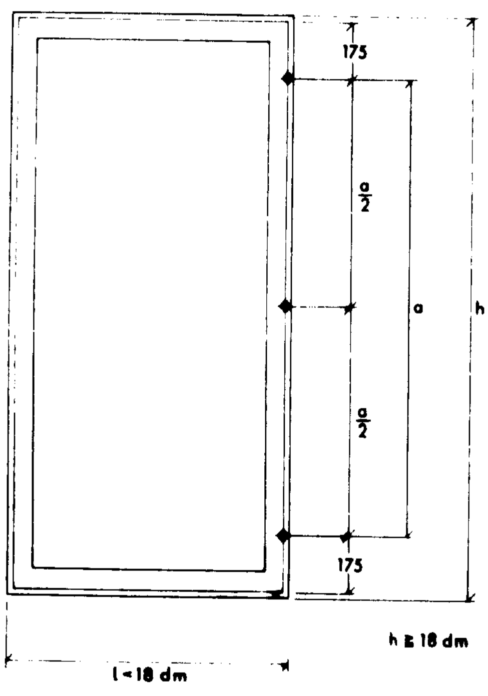


Fig. 11



2 NUMBER AND POSITION OF CATCHES AND ESPAGNOLETTES

The position of the centre of the hole for catch handle is measured from the corner of the inner casement, see fig. 1.

21 Catches of side hung windows, figures 9, 10 and 11.

If the nominal width of a side hung window is ≧ 18 dm, there should be one catch in the middle of both the top and the bottom members in addition to the catches in the stile.

211 Meeting stiles

Meeting stiles casements should have espagnolettes with both side and end fastenings.

The number and position of the side fastenings of espagnolettes is the same as the number and position of the separate catches in windows of corresponding height. The handle of espagnolettes is in the centre of the stile, when the nominal height of the window is ≦ 14 dm, and 600 mm from the bottom corner of the casement when the nominal height is > 14 dm.

212 Ventlights provided with doors

One catch with permanent handle is enough for a ventlight door, whose nominal height is ≦ 8 dm.

If the nominal height is > 8 dm, espagnolettes are used. The espagnolettes should have side fastenings. For the number and position of fastenings and the position of handles, see point 211.

22 Catches of top hung windows, fig. 12, 13 and 14.

23 Catches of bottom hung windows

The catches of bottom hung windows are fixed in top and bottom members to such places as correspond to the position of the catches of top hung windows.

Fig. 12

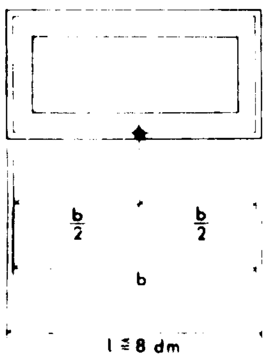


Fig. 13

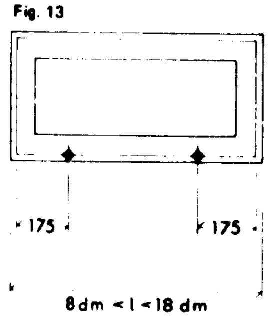
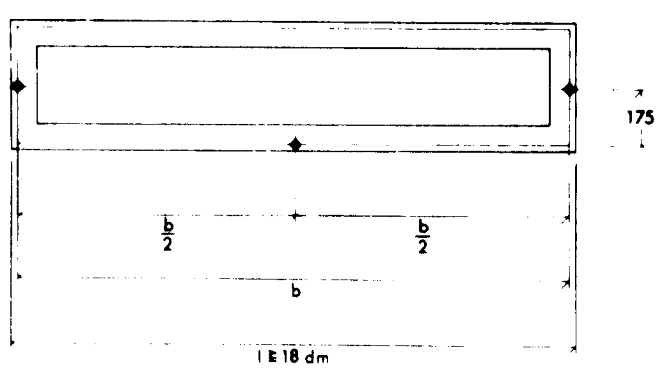


Fig. 14



3 NUMBER AND POSITION OF COUPLING FITTINGS

In coupled windows should have as many coupling fittings as there are catches, however the minimum of 2. The coupling fittings are positioned near the catches. The strength of the casement must remain the same. There should be 1 mm distance between the coupled casements.

WINDOWS, WOOD, OPENING INWARD, DOUBLE CASEMENT

SFS/RT 861.42E

SfB X(31)
UDK 69.028.21.674
Page 1 (8)

Windows, nomenclature SFS/RT 860.00
Wooden windows and outside doors, quality SFS/RT 210.81

1 Contents

11 This SFS/RT standard includes modular wood windows with inwards opening double casements.

12 The standard gives the outer sizes of the frame, the size of the frame and the casement members, and the clearances as well as the standard sizes, glazing rebate sizes, and sizes of panes and hinges of one-light windows designed according to a horisontal module of 3M.

2 Notation

The nominal sizes of the standard windows is given in dm, width x height.
Notation: name of window, nominal size and the number of this standard.
E.g. One-light window 15 x 12 SFS/RT 861.42.
Manufacturing degree and quality class according to standard SFS/RT 210.81 has to be mentioned with the order.

3 Dimensioning basis

Basic module M = 1 dm = 100 mm.
The co-ordinating sizes of the windows are modular sizes, integer multiples of the basic module. Dimensioning implies that the moisture content of the timber calculated from dry weight is ≦ 12 %.

4 Dimensioning

The principle of dimensioning is given in fig. 1.

41 The outer sizes of the frames are 10 ± 2 mm smaller than the corresponding co-ordinating sizes the windows. Figure 1.

42 Glazing rebate sizes of one-light windows are 156 ± 1 mm smaller than the corresponding co-ordinating sizes of the windows. Figure 1.

43 The basic sizes of the panes of one-light windows are 160 mm smaller than the corresponding co-ordinating sizes of the windows.

44 Sizes of profiles, see figures.

45 Sizes of clearances are valid for unfinished windows provided with fittings.

Clearance	Outer casement	Inner casement
at the hanging stile	2 mm	2 mm
at the closing stile	3...4 mm	3...4 mm
at the top rail	2,5...3,5 mm	2,5...3,5 mm
at the bottom rail	3,5...4,5 mm	3...4 mm

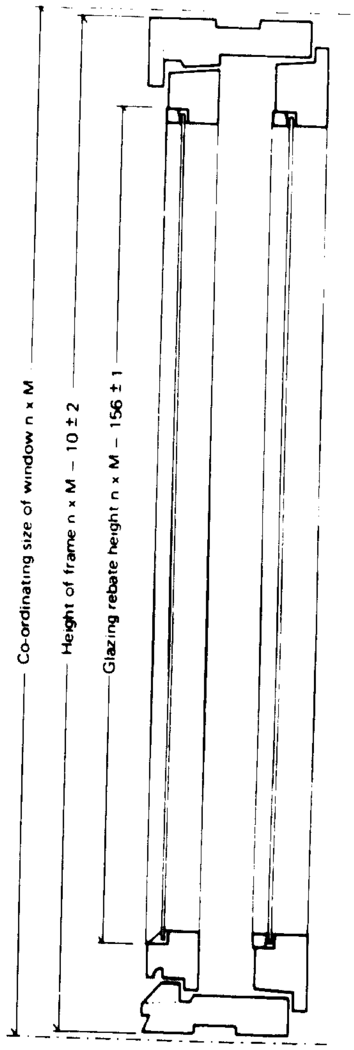
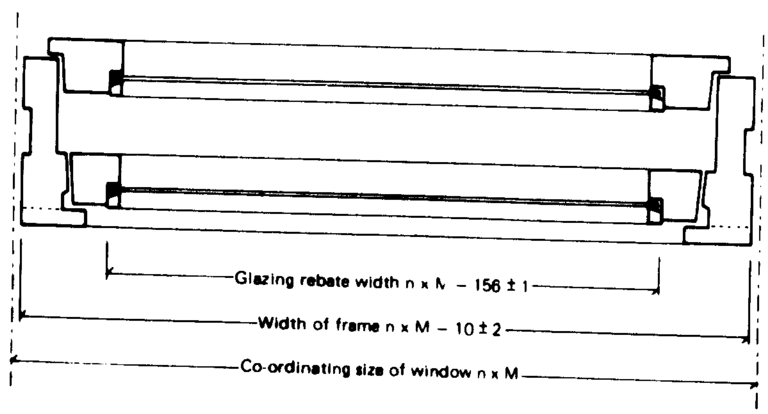
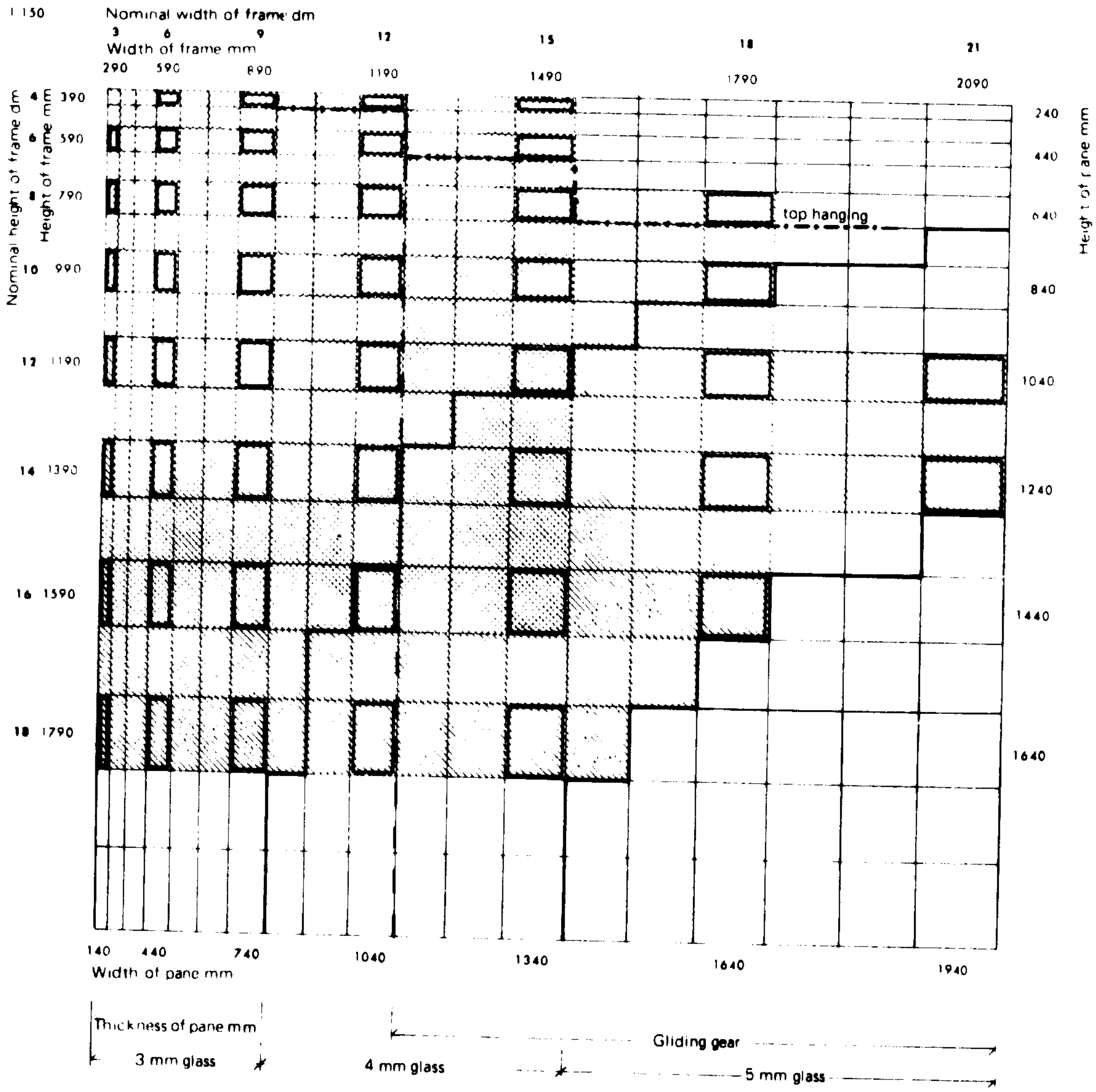


Fig. 1
M = 100 mm
n is an integer number ≧ 3



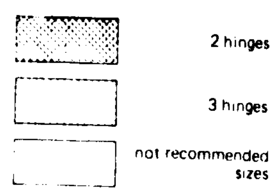
5 Standard sizes of one-light windows

In the table the hatched area includes the recommended sizes of one-light windows. The standard sizes that as to their width are based on the module 3M are shown as framed squares. The nominal sizes of the standard windows as well as the basic overall sizes are given along the top and left edges of the table. The corresponding glass sizes are given along the bottom and right edges. The thickness of the glass is given at the bottom of the table and as a black dividing line on the table itself. The number of hinges is shown by different hatching and dimensions for top hanging above the dot and dash line. A dash line shows the area within which side hung windows shall be provided with a gliding gear.



6 Combined windows

Window rows of two or more lights can be formed by joining together one-light windows. These types of windows and glazed doors are joined together as shown in fig. 2.



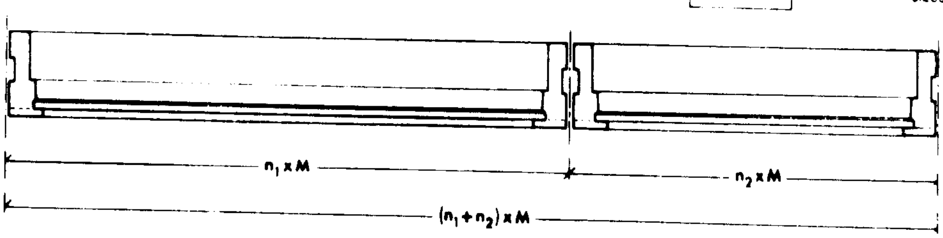
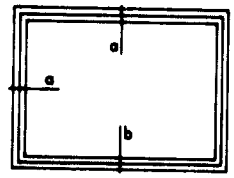
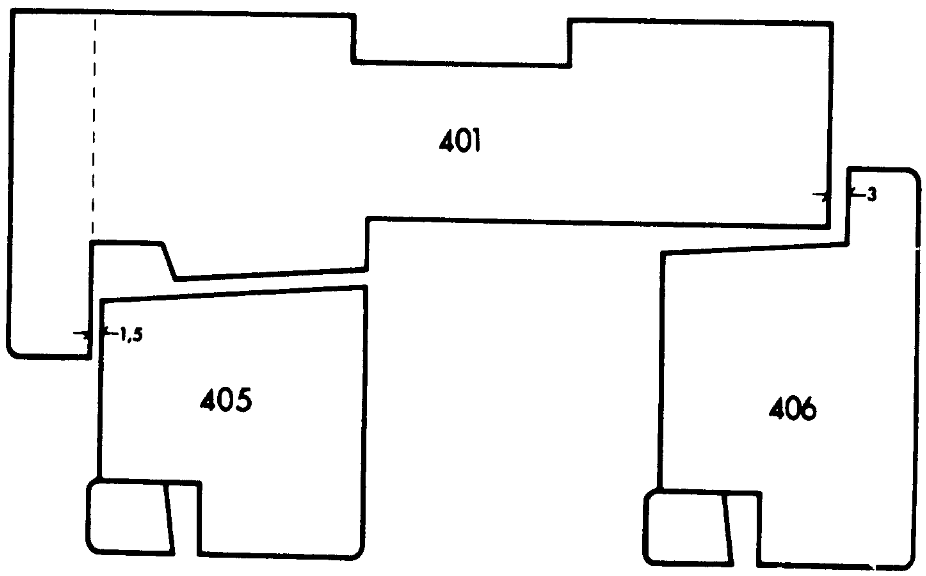
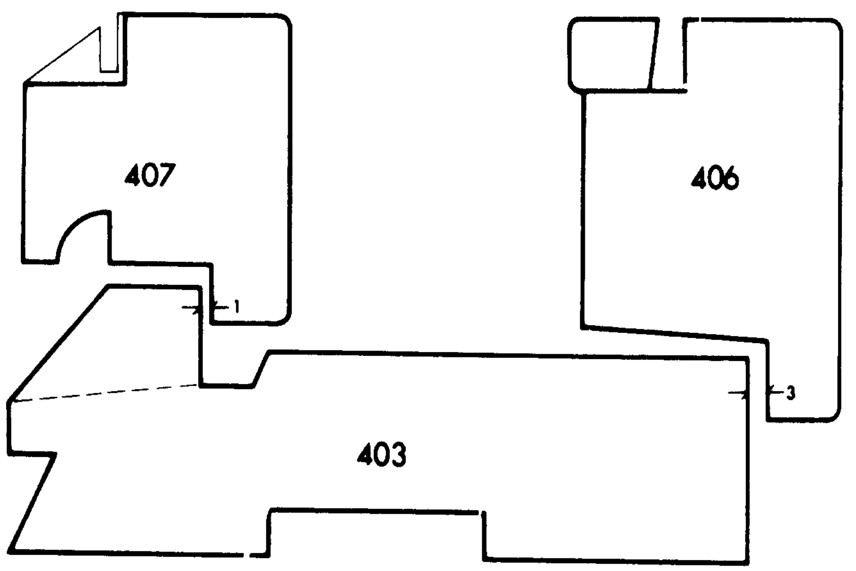


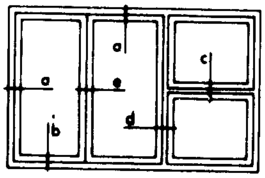
Fig. 2
Modular joining of windows

Fitting of casement members to frame members by one-light windows









Fitting of meeting stiles and of casement members to mullion and transom members

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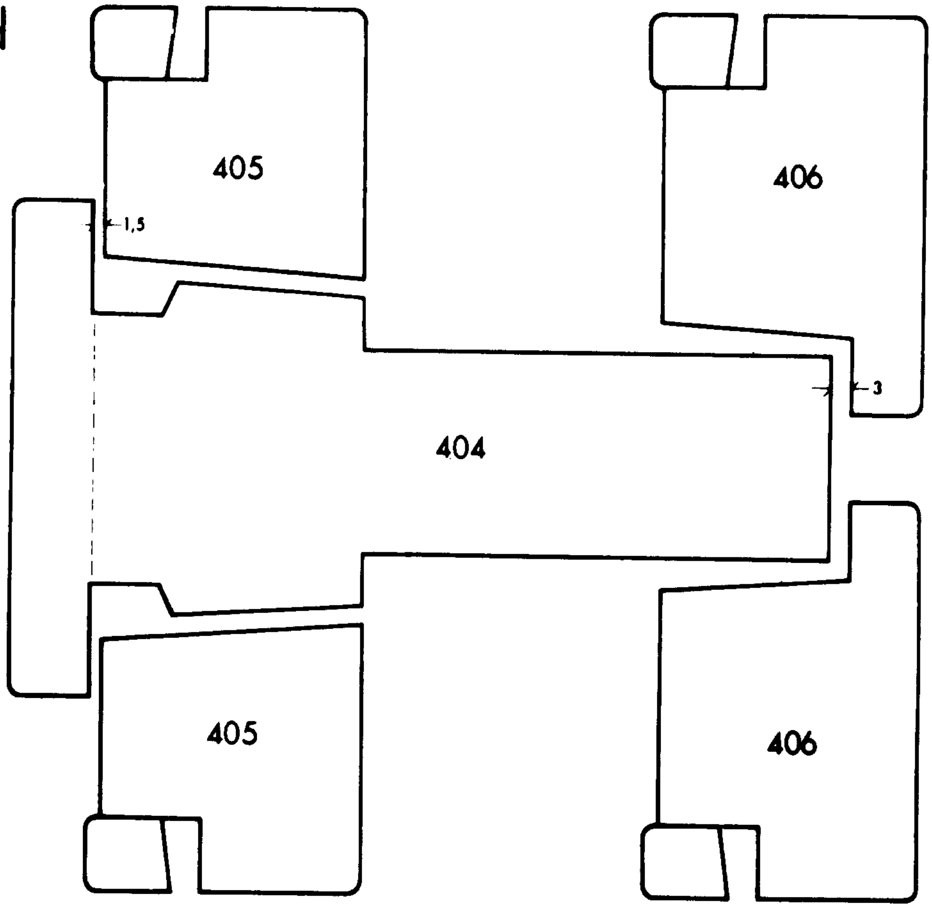

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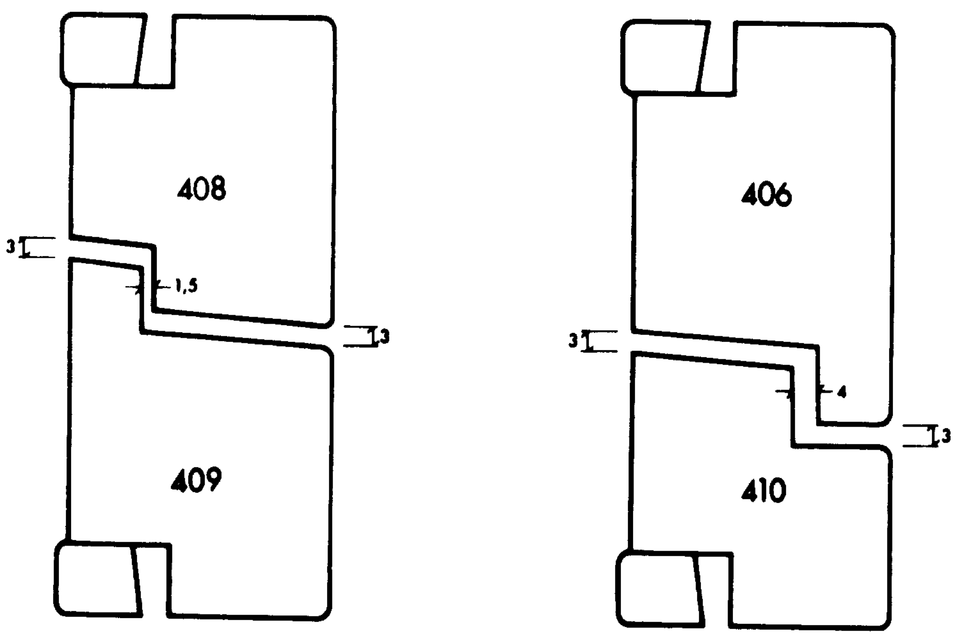

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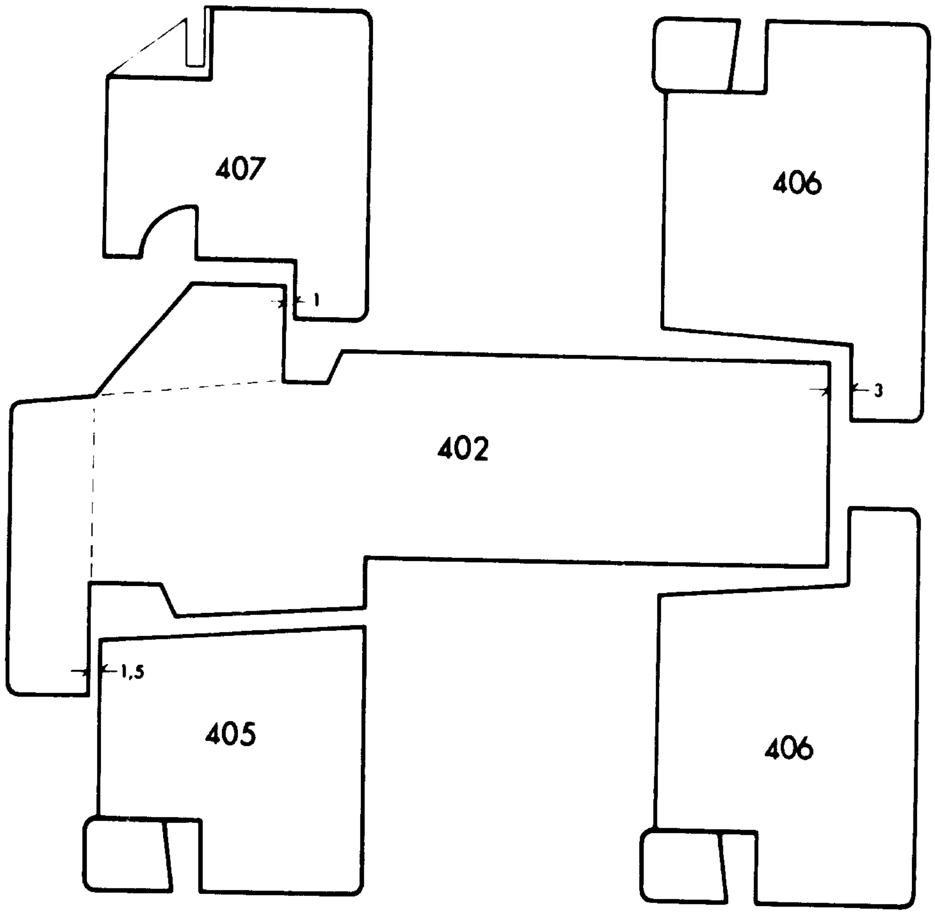
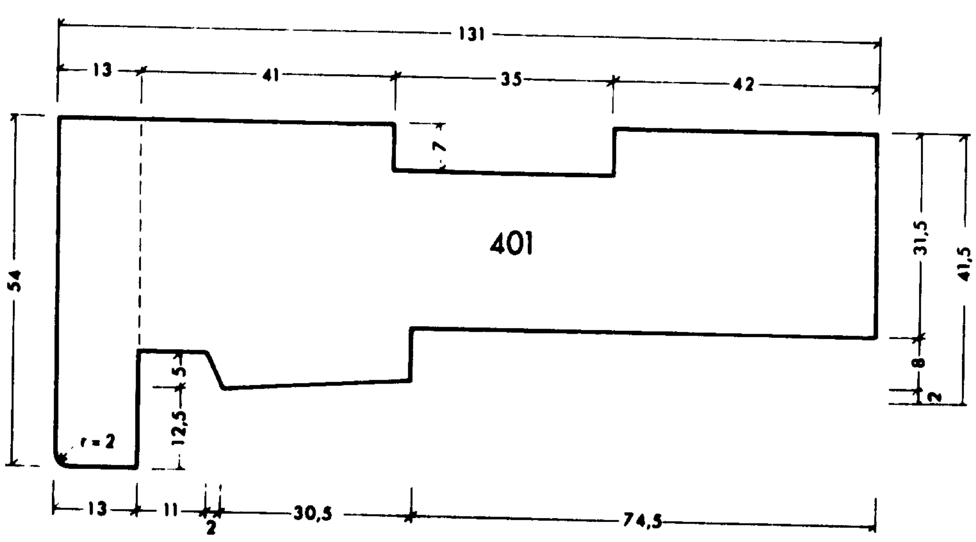
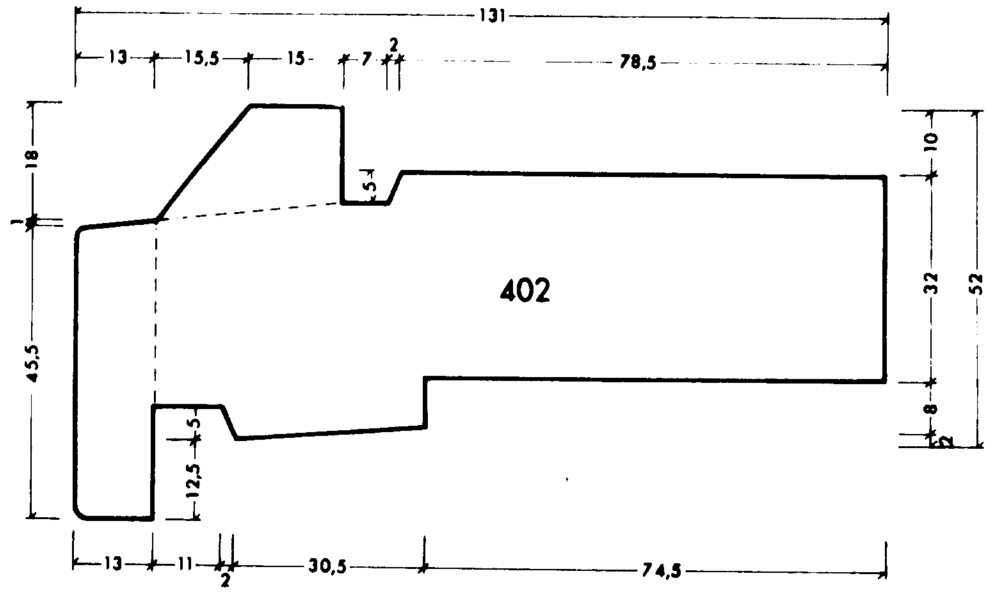


Basic sizes of frame and casement members
Permissible deviations for the main measurements of the members is ± 1 mm

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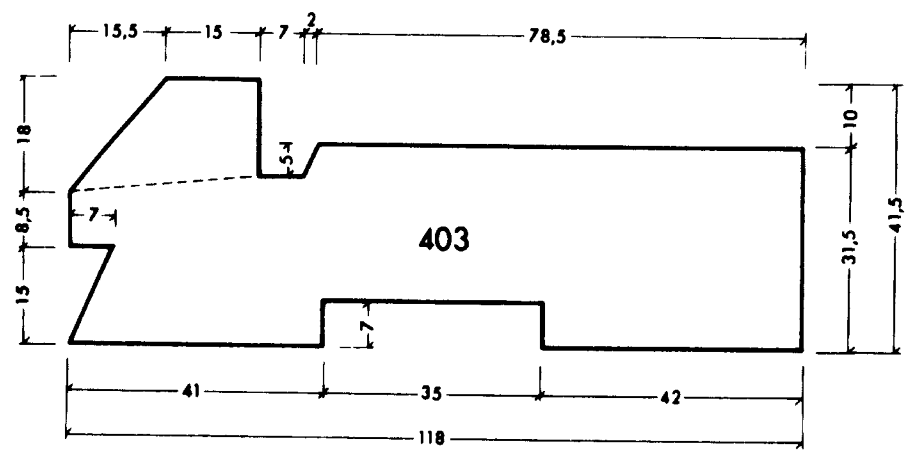
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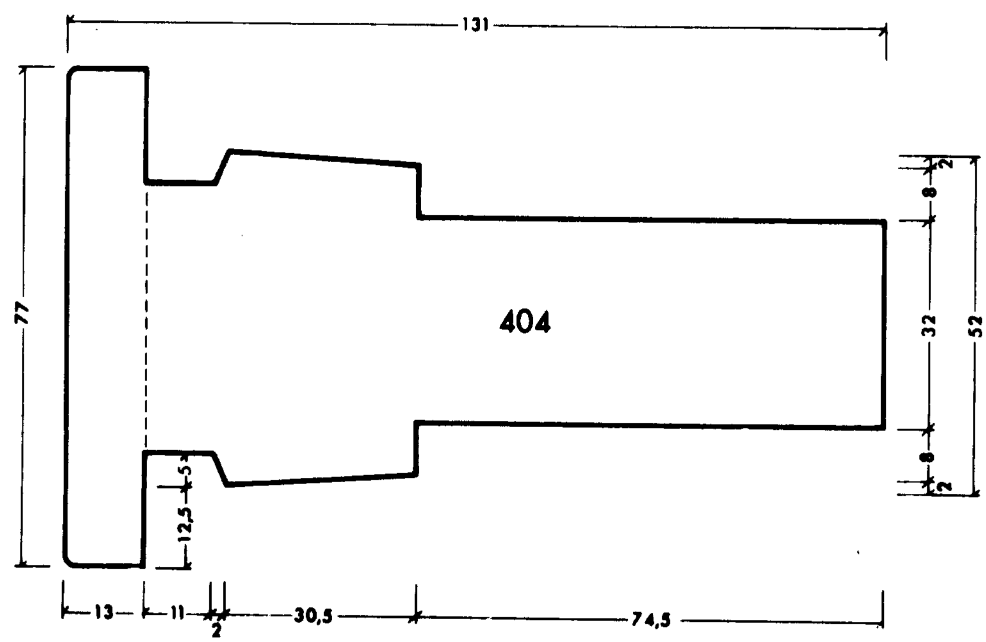
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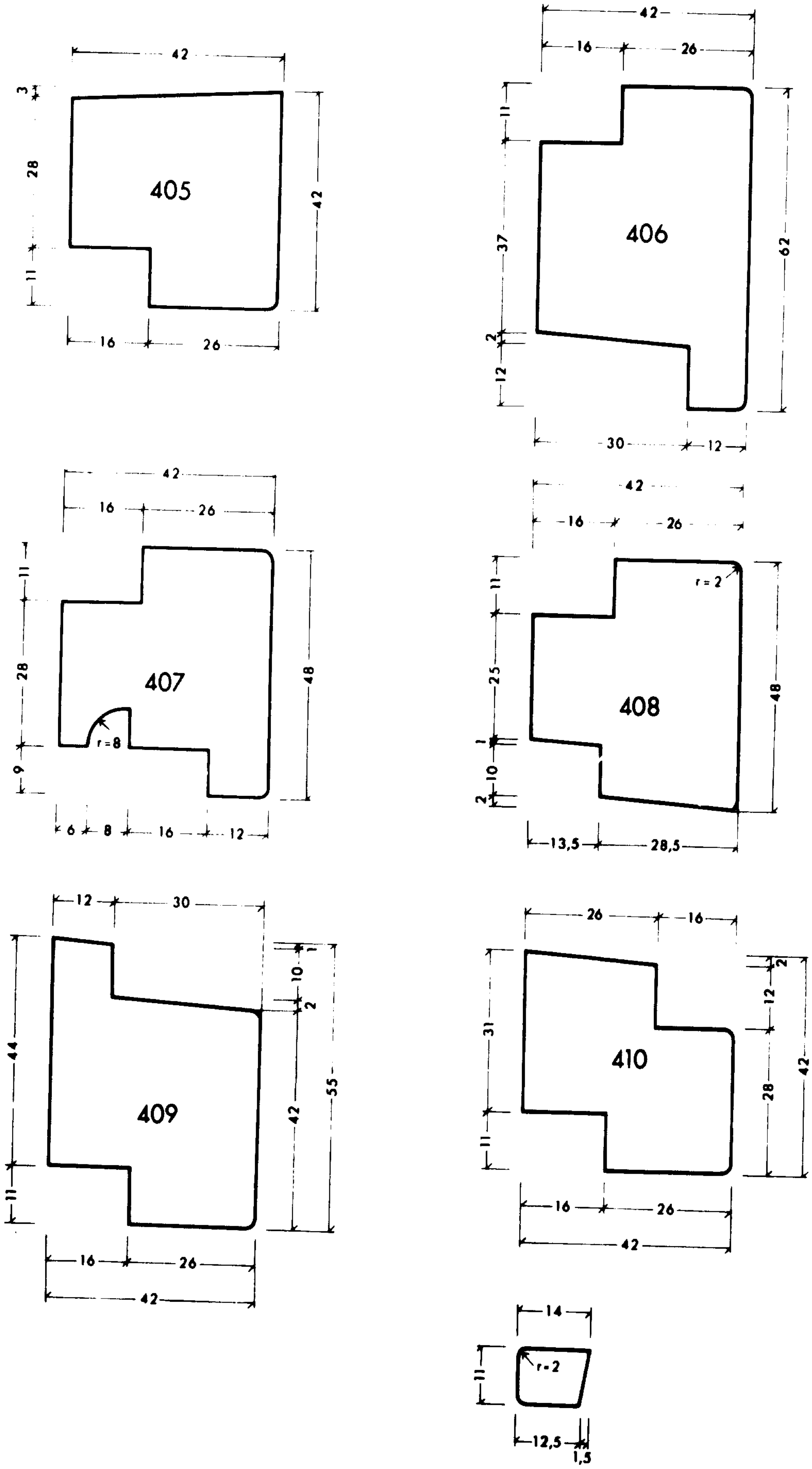
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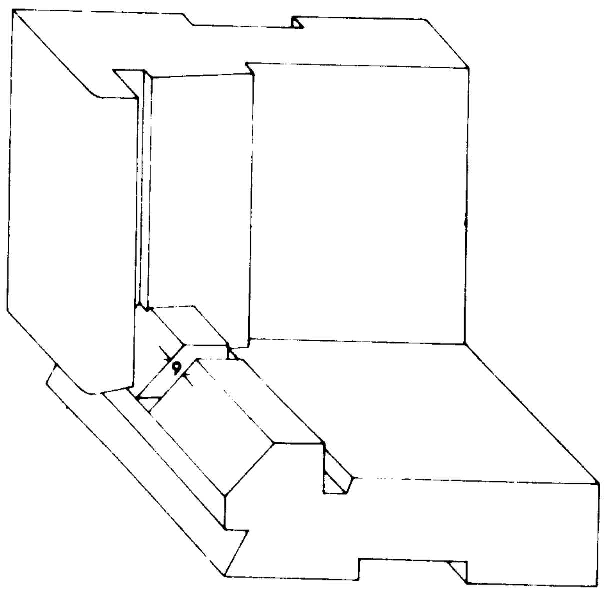
Drainage of frame



Windows, nomenclature		SFS/RT 860 00
Windows	in group	RT 861
Wooden windows and outside doors, quality		SFS/RT 210 81

0 General

01 This RT-sheet includes modular wood windows with inward opening coupled casements

02 The outer sizes of the frame, the sizes of the frame and the casement members and the clearances are given, as well as the standard sizes, glazing rebate sizes and sizes of panes and hinges of one-light windows designed according to a horizontal module of 3M

1 Notation

The nominal sizes of the windows is given in dm, width x height

Notation name of window, nominal size and the number of this RT-sheet

E.g. one-light window 15 x 12 RT 861 46.

Manufacturing degree and quality class according to standard SFS/RT 210.81 have to be indicated in the order.

2 Dimensioning basis

Basic module M = 1 dm = 100 mm

The co-ordinating sizes of windows are modular sizes, integer multiples of the basic module Dimensioning implies that the moisture content of the timber calculated from dry weight is ≦ 12 %

3 Dimensioning

The principle of dimensioning the window is seen in figure 1

31 The outer sizes of frames are 10 ± 2 mm smaller than the corresponding co-ordinating sizes of the windows Figure 1.

32 Glazing rebate sizes of one-light windows are 156 ± 1 mm horizontally and 166 ± 1 vertically Figure 1

33 The basic sizes of the panes of one-light windows are horizontally 160 mm and vertically 170 mm smaller than the corresponding co-ordinating dimensions of the window.

34 Sizes of profiles, see figures

35 Sizes of clearences are valid for unfinished windows provided with fittings.

Clearance	Outer and inner casement
at the hanging stile	2 mm
at the closing stile	3 ...4 mm
at the top rail	2,5...3,5 mm
at the bottom rail	3 ...4 mm

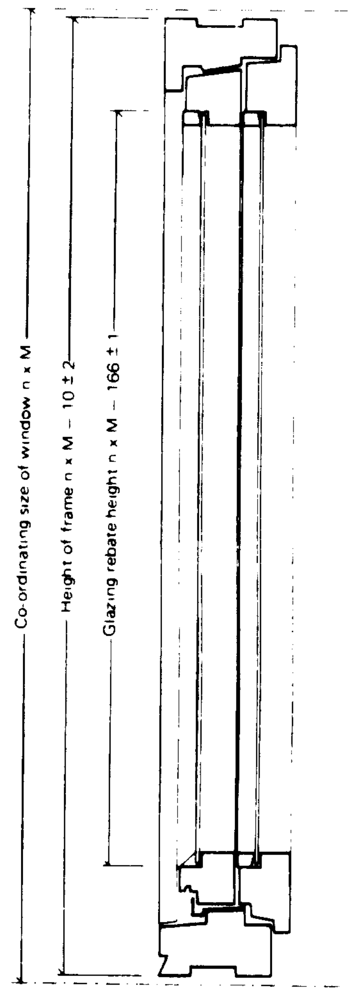
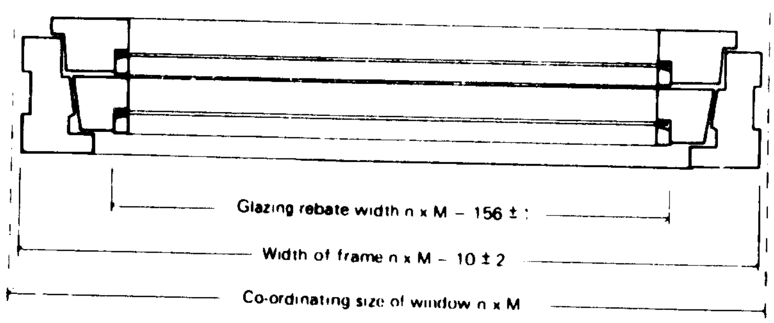
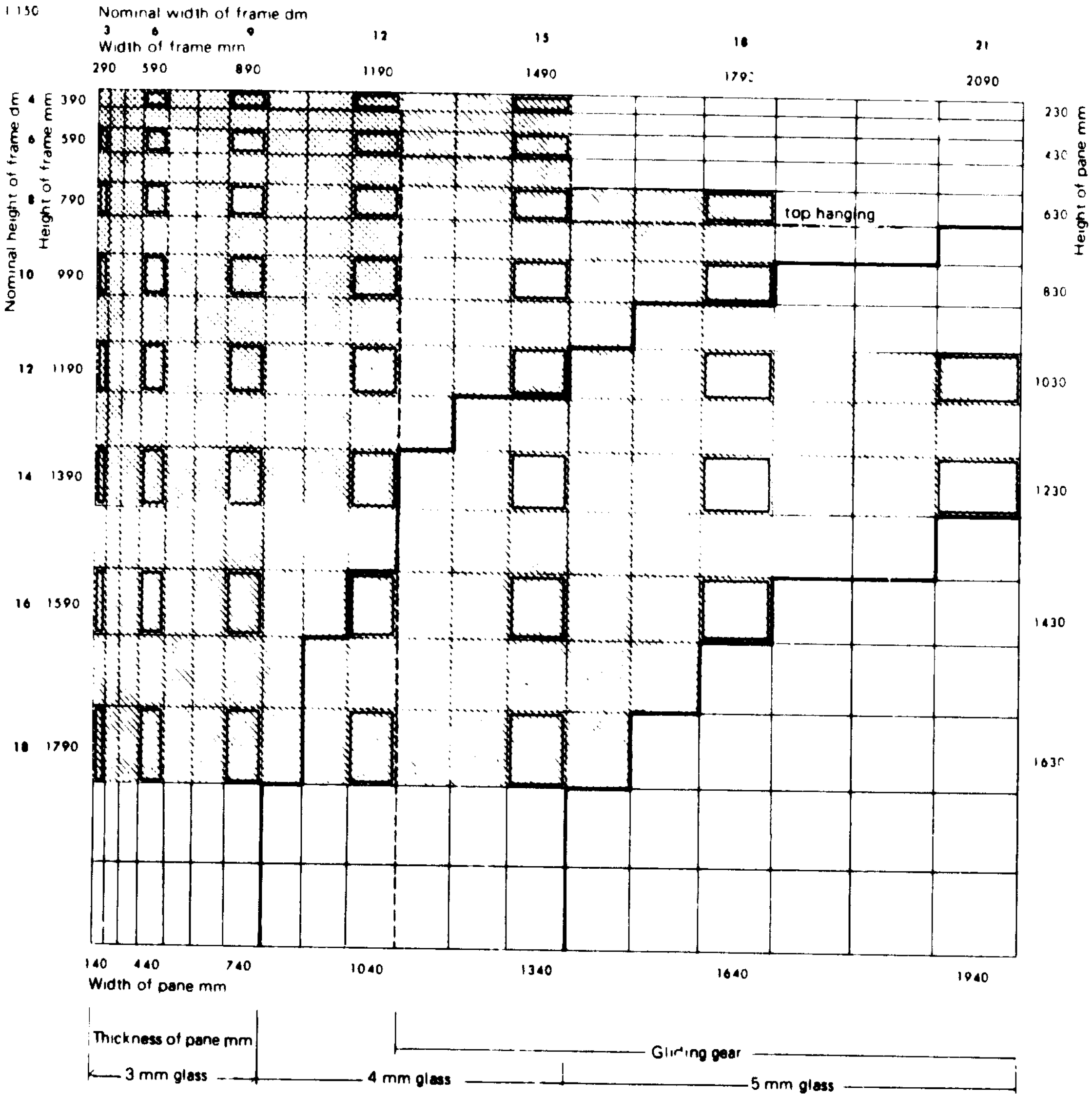


Fig. 1
M = 100 mm
n is an integer number ≧ 3



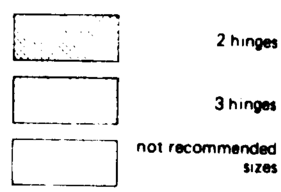
4 Standard sizes of one-light

In the table the hatched area includes the recommended sizes of one light windows. The standard sizes that as to their width are based on the module 3M are shown as framed squares. The nominal sizes of the standard windows as well as the basic overall sizes are given along the top and left edges of the table. The corresponding glass sizes are given along the bottom and rigth edges. The thickness of the glass is given at the bottom of the table and as a black dividing-line on the table itself. The number of hinges is shown by different hatching and dimensions for top hanging above the dot and dash line. A dash line shows the area within which side hung windows shall be provided with a gliding gear.



5 Combined windows

Window rows of two or more lights can be formed by joining together one-light windows. These types of windows and glazed doors are joined together as shown in fig. 2.



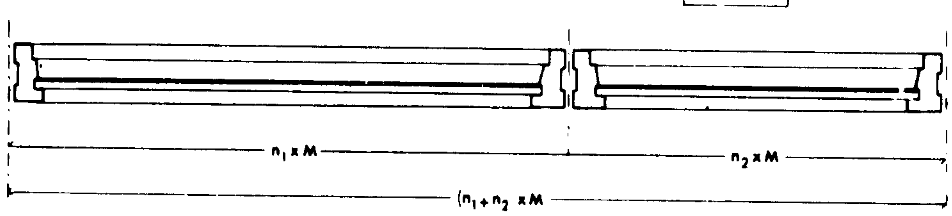
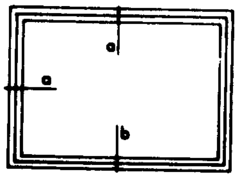
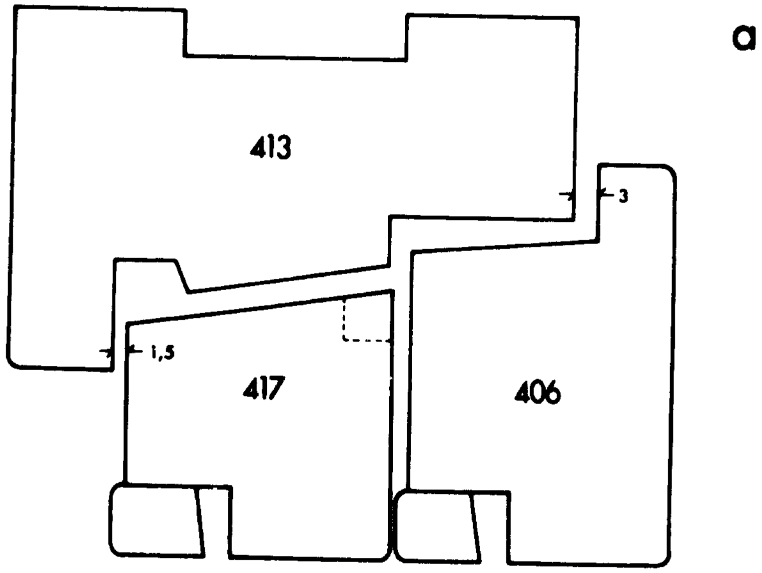
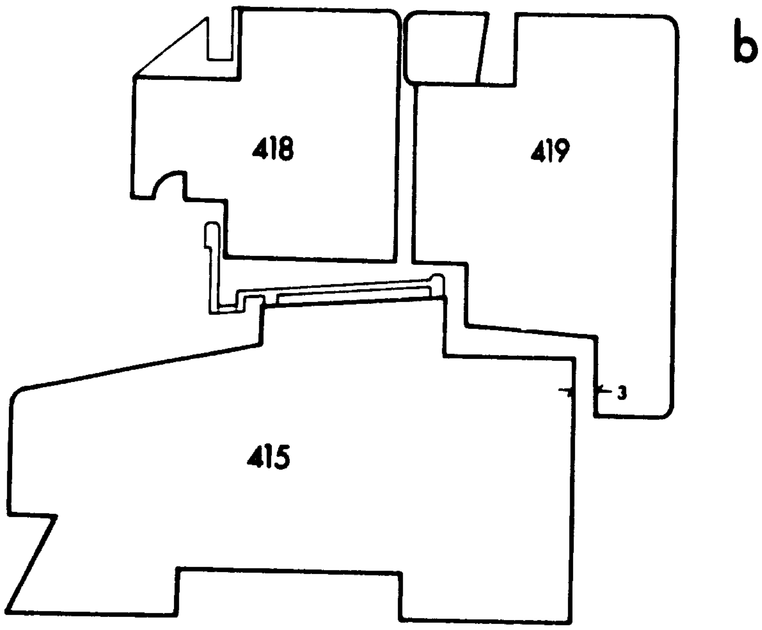


Fig. 2
Modular joining of windows

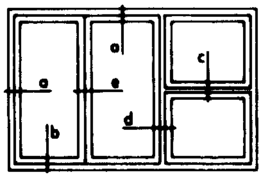
Fitting of casement members to frame members by one-light windows







Fitting of meeting stiles and of casement members to mullion and transommembers



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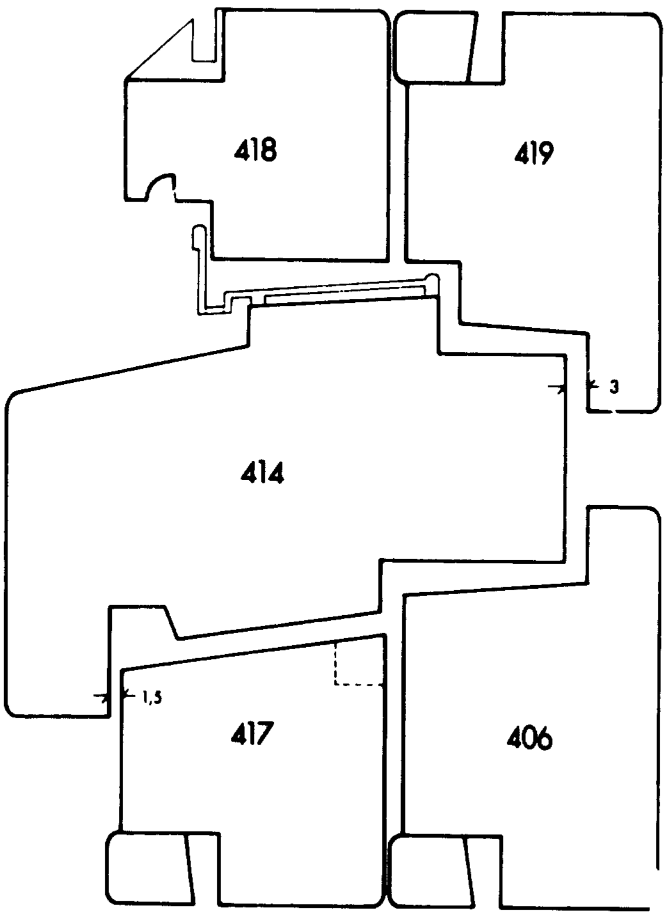

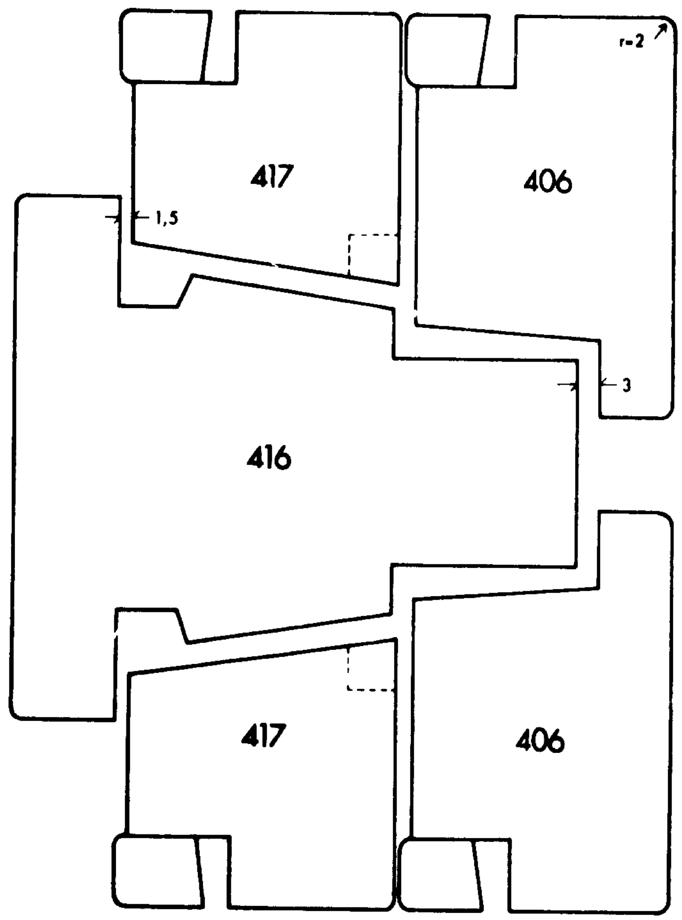

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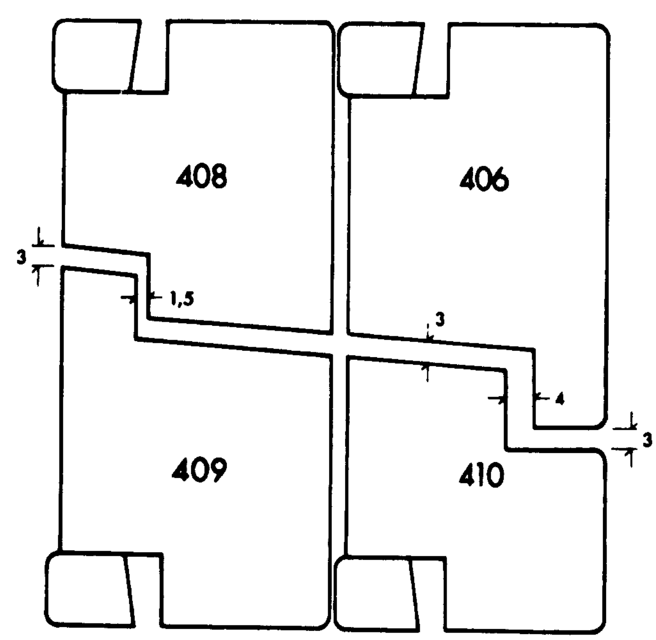

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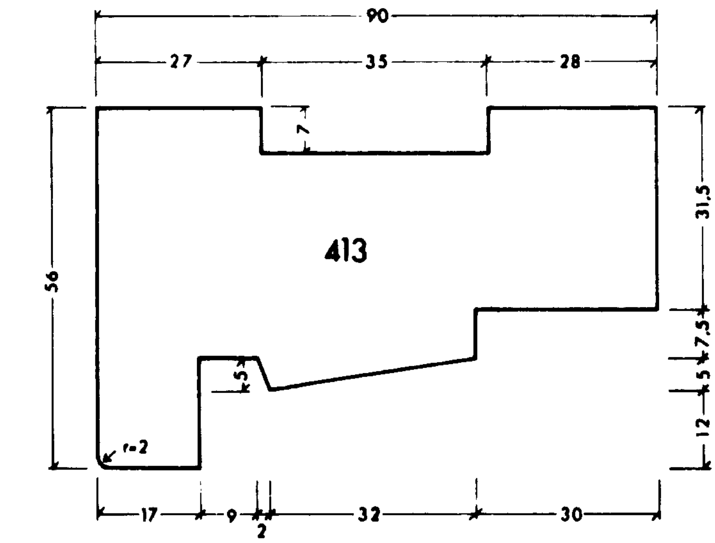
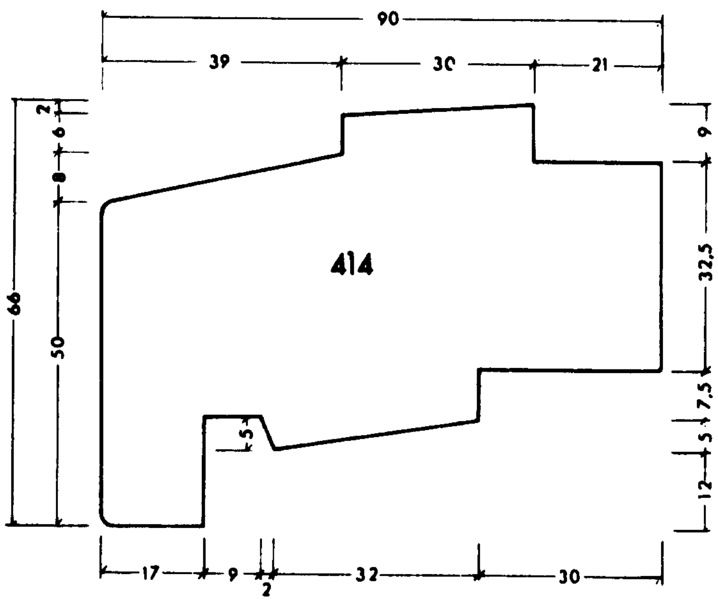
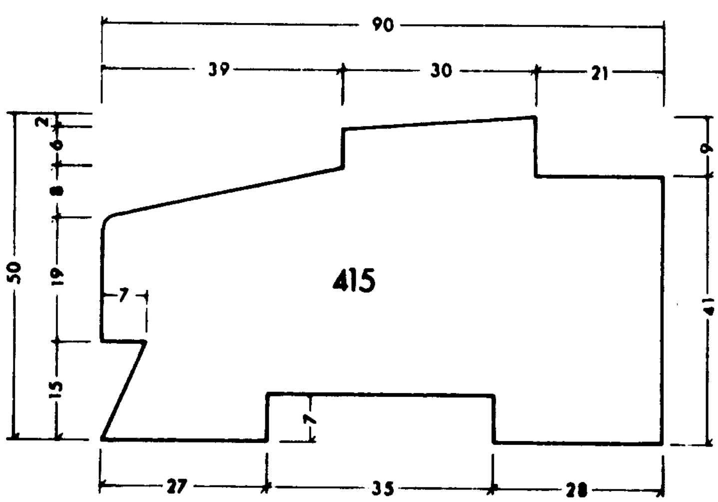
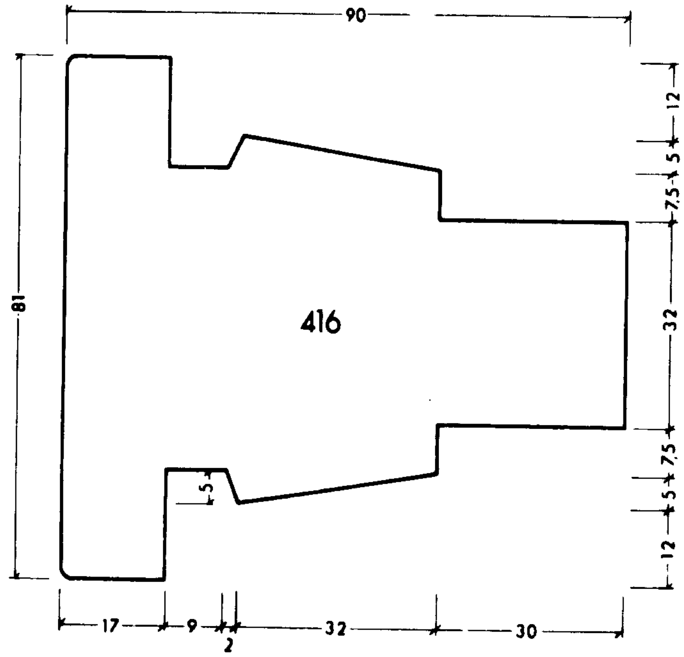
Basic sizes of frame and casement members

Permissible deviations for the main measurements of the members is ± 1 mm





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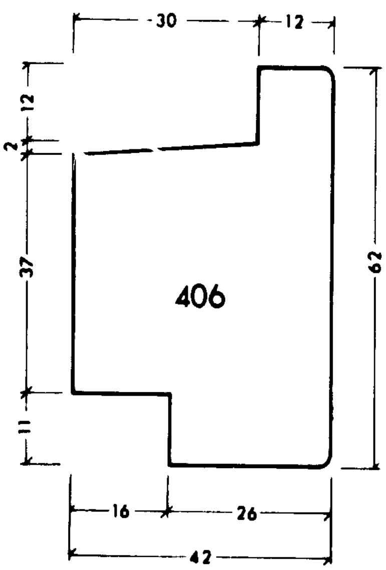
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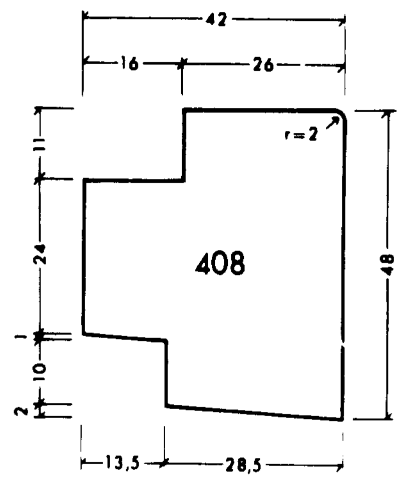
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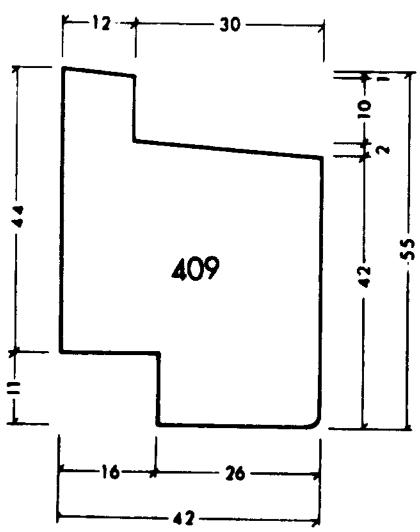
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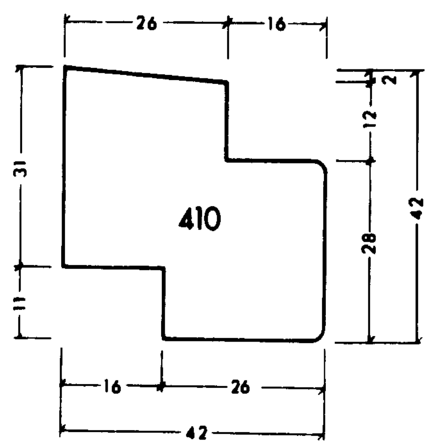
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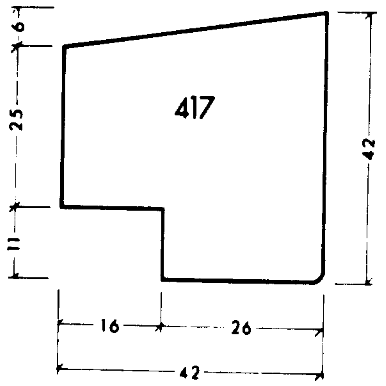
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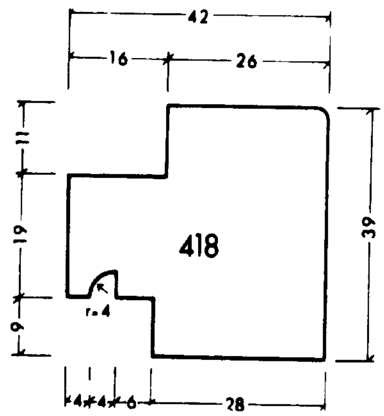
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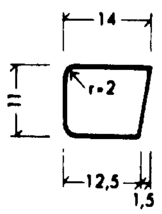
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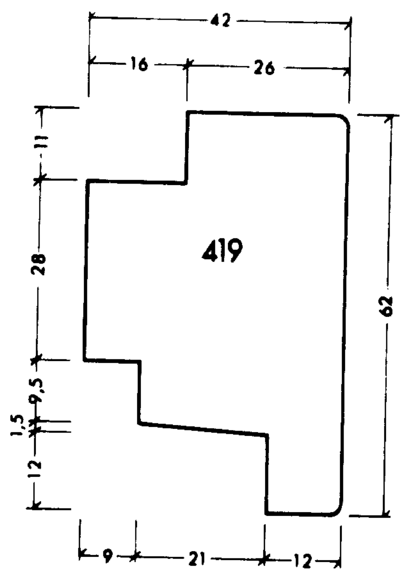
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Glazed doors, nomenclature		RT 862.00
Glazed doors	in group	RT 862...
Wooden windows and outside doors, quality		SFS/RT 210.81
The window for this door is		RT 861 46

01 This RT-sheet describes glazed wood doors, with coupled inward opening casements.

02 The RT-sheet gives the manufacturing sizes of the width of the frame, the frame and casement members, and the clearances of the casements.

1 DIMENSIONING

The dimensioning implies that the moisture content of the timber is not greater than 12 %, calculated from the dry weight.

11 The co-ordinating size of the width of the frame of glazed doors is a modular size 9 x M = 900 mm.
The manufacturing size of the width of the frame is 900 − 10 ± 2 mm = 890 ± 2 mm. Fig. 2.

12 A glazed door adjacent to a window ought to be dimensioned vertically so that the upper members of their frames will be at the same level. A deviation of ± 2 mm is permitted for the vertical manufacturing size.

13 Sizes of cross-sections, see figures.
Normal permissible deviations for the main manufacturing sizes of frame and casement members is ± 1 mm.

14 The sizes of clearances are valid for assembled doors provided with ironmongery but without surface treatment.

Clearance	
at hanging stile	2 mm
at closing stile	3...4 mm
at top rail	2...3 mm
at bottom rail (inner casement)	4...5 mm

15 The thickness of the panes used in glazed door is the minimum of 5 mm.

2 COMBINATING GLAZED DOORS AND WINDOWS

These glazed doors and windows fit to be joined with them are joined together according to fig. 3.

3 APPEARANCE OF DOOR

The sections of the casement members shown on this RT-sheet are designed for glass panels only.

Fig. 1

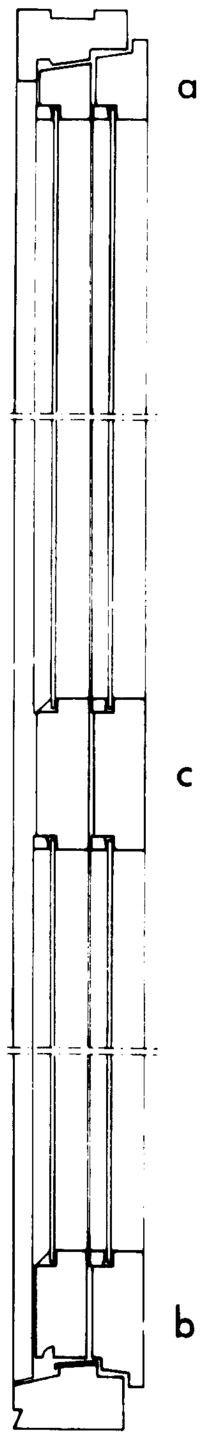


Fig. 2

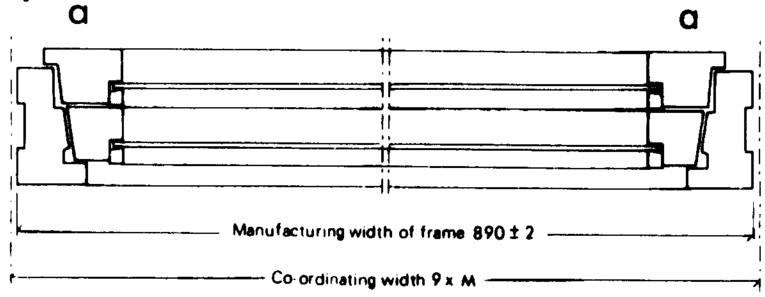
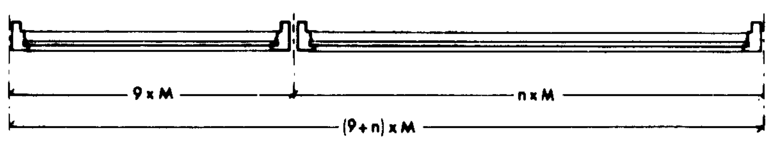


Fig. 3 Modular joining of glazed door and window

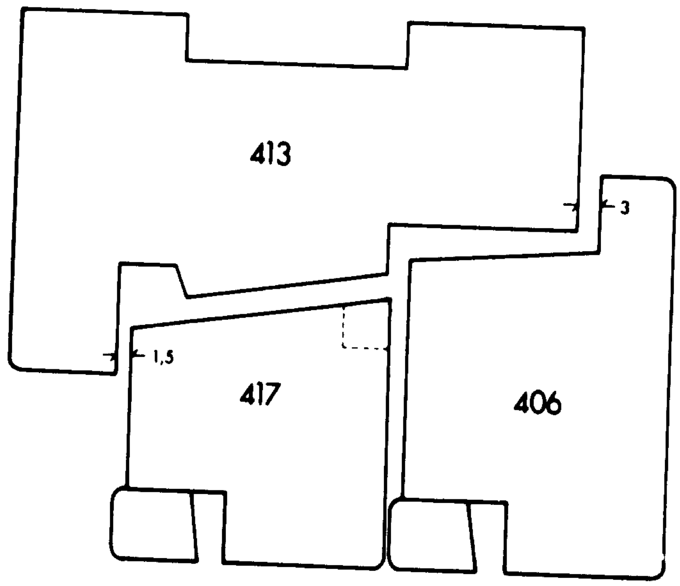


M = 100 mm
n is an integer number ≧ 3

Fitting of frame and casement members

The sill shall be provided with a protective metal section of the type shown in the fig.

a



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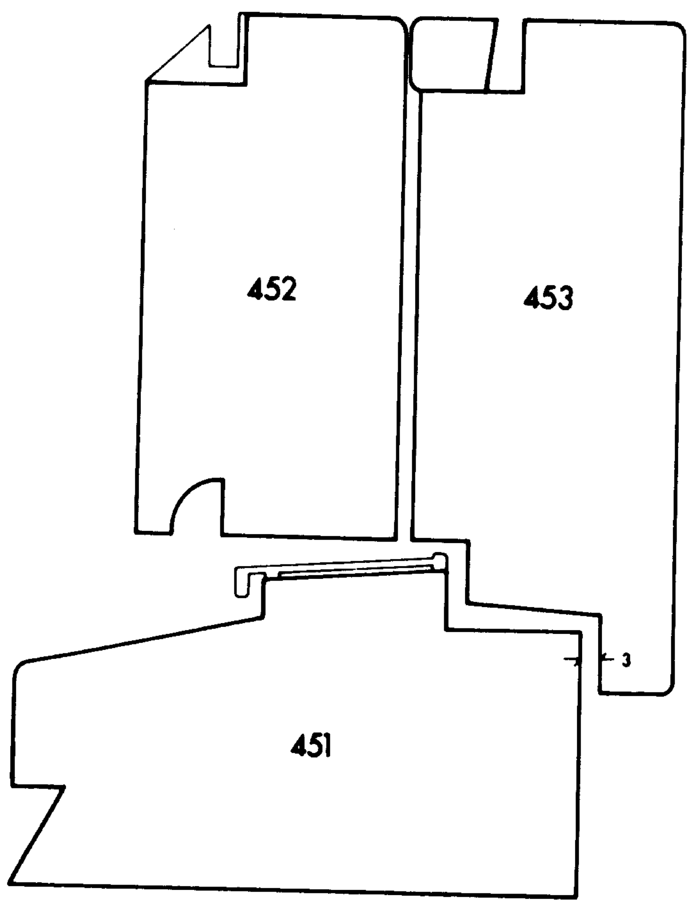

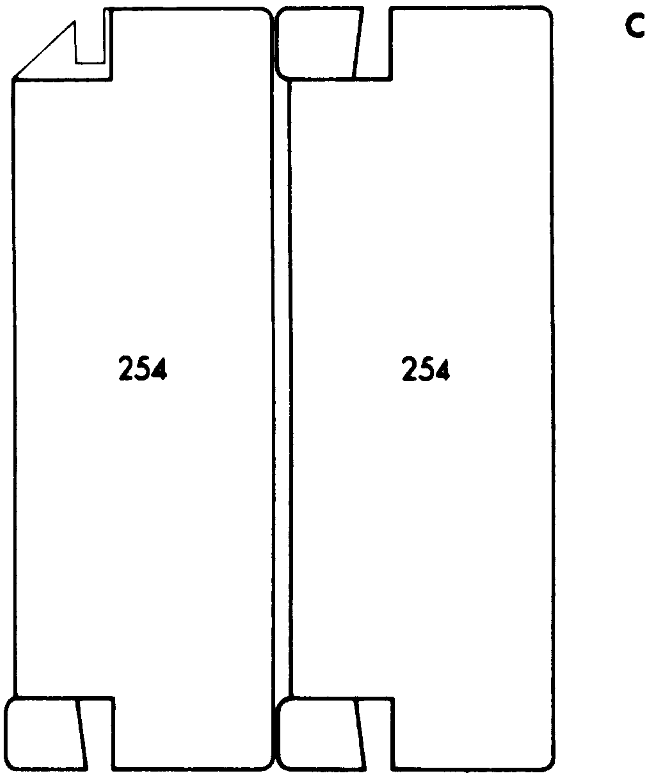
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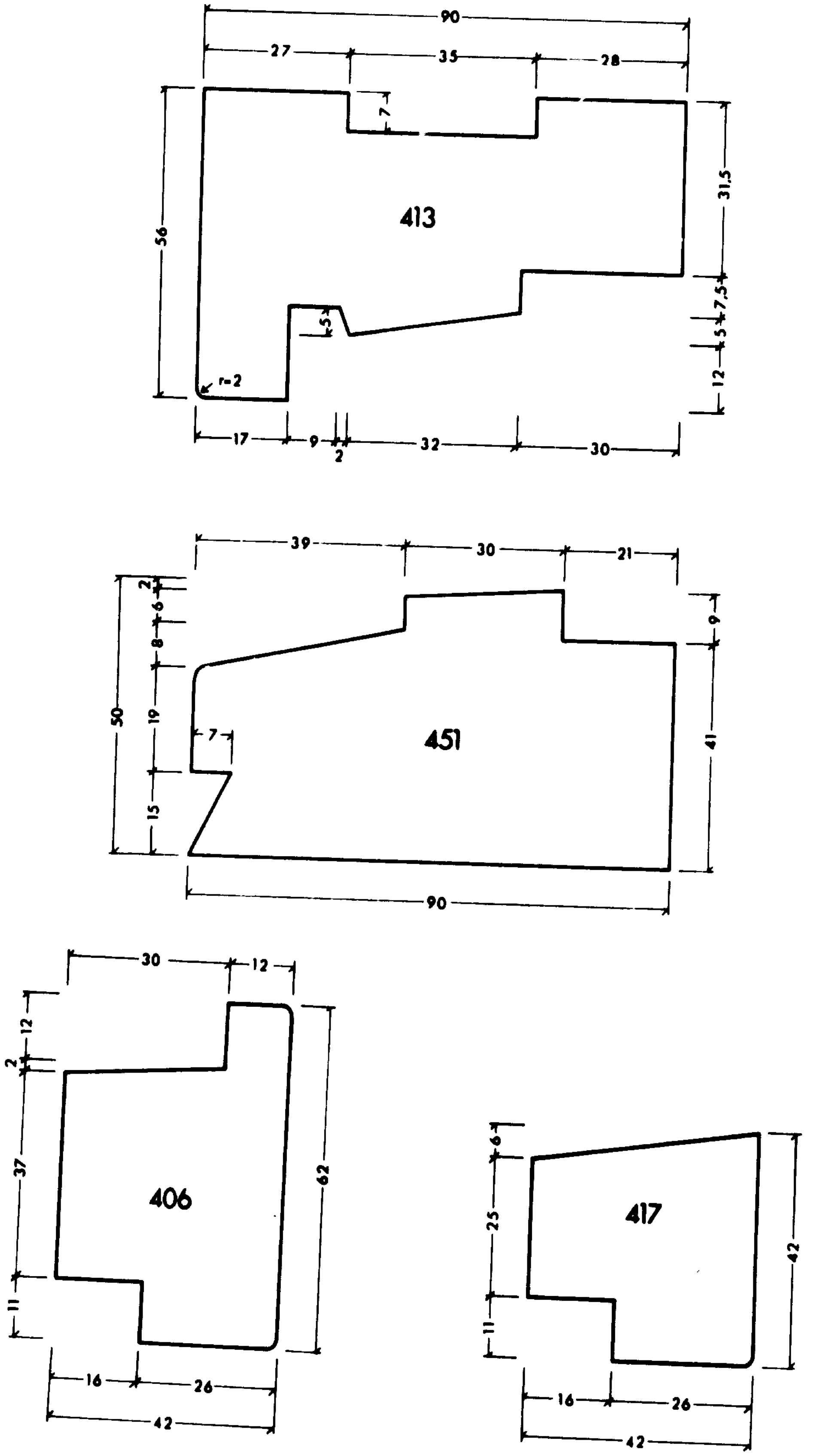
Measures for the dressing of frame



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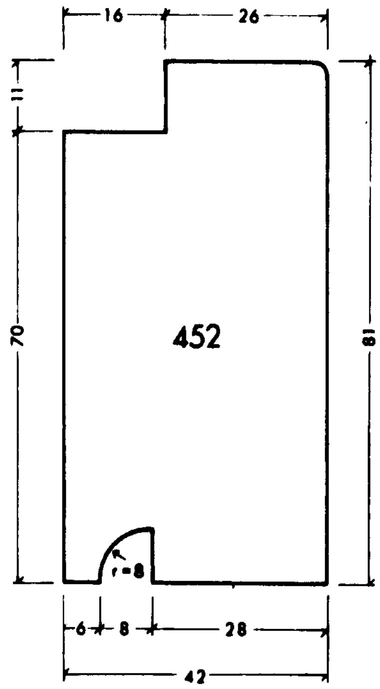
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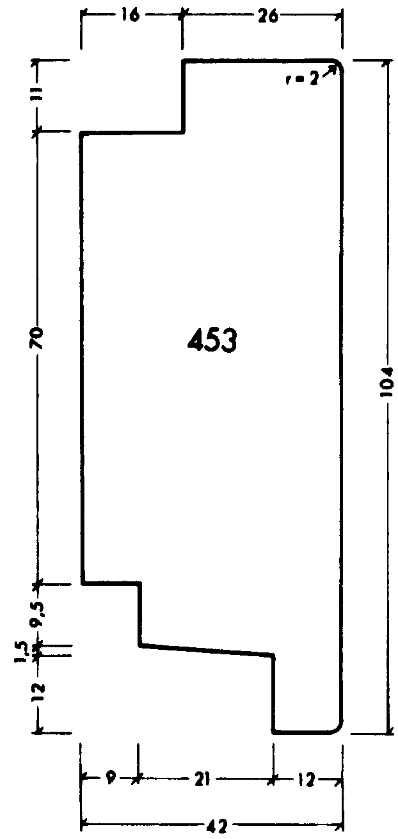
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12
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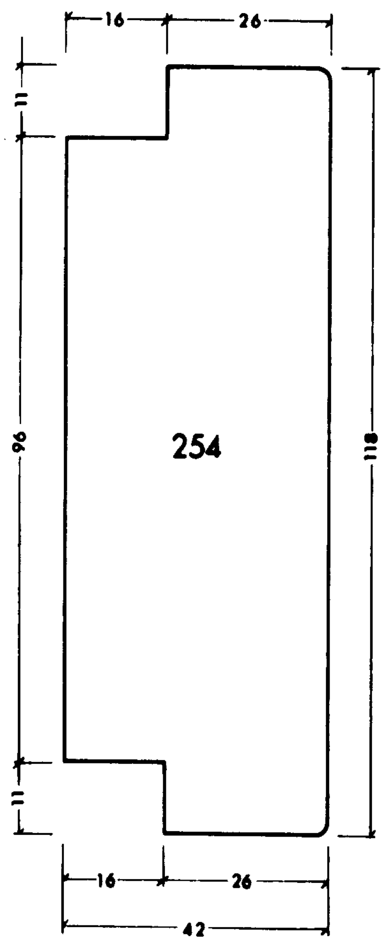
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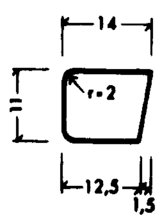
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Suomen Standardisoimisloutakunta Finlands Standardiseringskommission

DOORS FOR DWELLINGS, STANDARD SIZES

SFS 2483
SfB X(32)
UDK 69.028.1
Page 1 (1)

Modular co-ordination for the building industry		RT 038.960
Modular co-ordination, application principles		RT 038.961
Doors nomenclatura		RT 870.00
Doors	in group	RT 87...

1 Contents

This standard comprises the standardized nominal sizes of modular doors for dwellings, offices etc.

2 Co-ordinating dimensions. Notations for door sizes

Door = frame + door leaf
The co-ordinating dimensions of the door determine the connection of the door to the wall. The co-ordinating dimensions of the door height are measured from the finished floor surface.

The co-ordinating dimensions of a modular door are modular sizes, integral multiples of the basic module. The basic module is M = 1 dm = 100 mm.

22 As notations for door sizes, their co-ordinating sizes are used (width and if necessary also height).

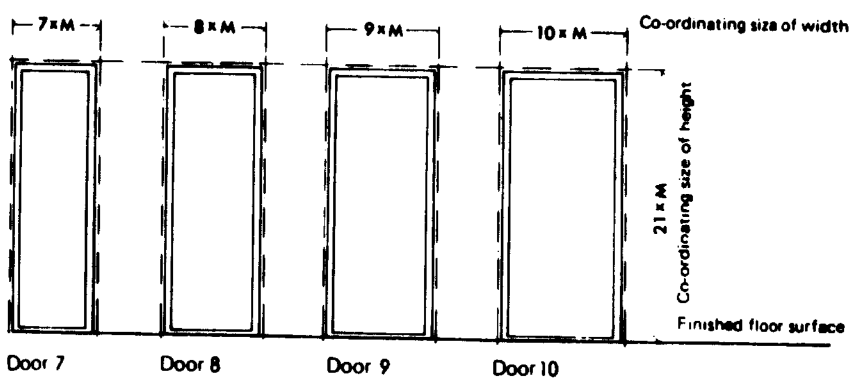
As notations for standard-sized doors for dwellings, offices etc. is adopted the co-cordinating size of the width expressed in decimetres, eg: (door) 9.

A complete notation generally contains several components to express the various qualities of a door.

3 Basic sizes of standard doors

The basic sizes of doors for dwellings are n x M, in which n equals:

width	height
7	21
8	
9	
10	



WOODEN DOORS FOR DWELLINGS, NOT REBATED DOOR LEAF

1969 RT 871.21 E
SfB X(32)
UDK 69.028.1 [illegible]
Page 1 (3)

Doors, [illegible]		RT 870.00
Doors for dwellings, standard sizes		RT 871.05
Doors	in group	RT 87
Wooden windows and outside doors, quality		RT 210.81
Wooden flush doors, quality		RT 210.82

1 CONTENTS

11 This RT-sheet describes standard size wooden doors with not rebated edges for dwellings, offices etc.

12 The outer sizes of the frame, the sizes of the frame members, the sizes of the door leaves and the clearances are given.

2 NOTATION

21 Notation for doors

Name of door, size of door (see RT 871.05), depth of frame (in mm), indication if sill not required, the number of this RT-sheet.

eg. Flush door 9/92 RT 871.21
Panelled door 8/92 without sill RT 871.21

Quality class according to standard RT 210.81 or RT 210.82 and manufacturing degree have to be mentioned in the order.

22 Notation for frames and door leaves when ordered separately

Notation for frame: frame, size of door, depth of frame, if sill not required indication thereof, number of this RT-sheet.

eg. Frame 9/92 without sill RT 871.21
Frame 7/68 RT 871.21

Quality class according to standard RT 210.81 or RT 210.82 and manufacturing degree have to be mentioned in the order.

Notation for door leaf: door leaf, size of door, number of this RT-sheet.

eg. Flush door leaf 9/RT 871.21
Leaf for panelled door 8/RT 871.21

Quality class according to standard RT 210.81 or RT 210.82 and manufacturing degree have to be mentioned in the order.

3 DIMENSIONING

Co-ordinating sizes of doors, see RT 871.05.

31 Manufacturing sizes of door frames are 10 ± 2 mm smaller than the corresponding co-ordinating size.

32 Sizes of frame members, see figures.

33 Manufacturing sizes of door leaves, see figures.

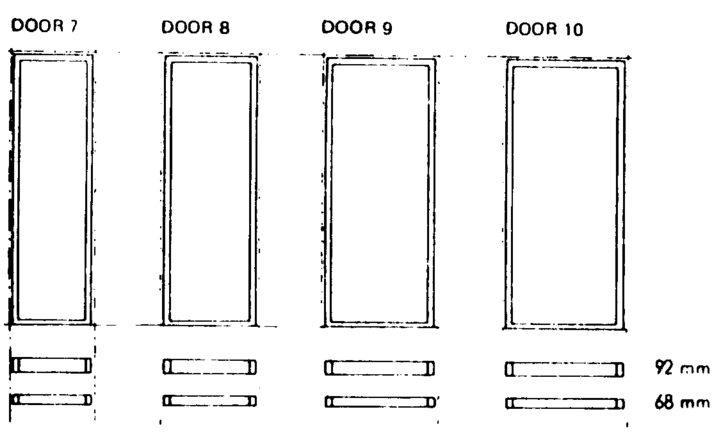
34 Door clearances are valid for assembled doors fitted with ironmongery, but without surface treatment.

Clearance	
at jambs totalling	2...6 mm
at heads	1...3 mm
at sills	2...4 mm

35 Dimensioning implies that the moisture content of timber figured of dry weight is ≦ 10 % for flush doors and ≦ 12 % for panelled doors.

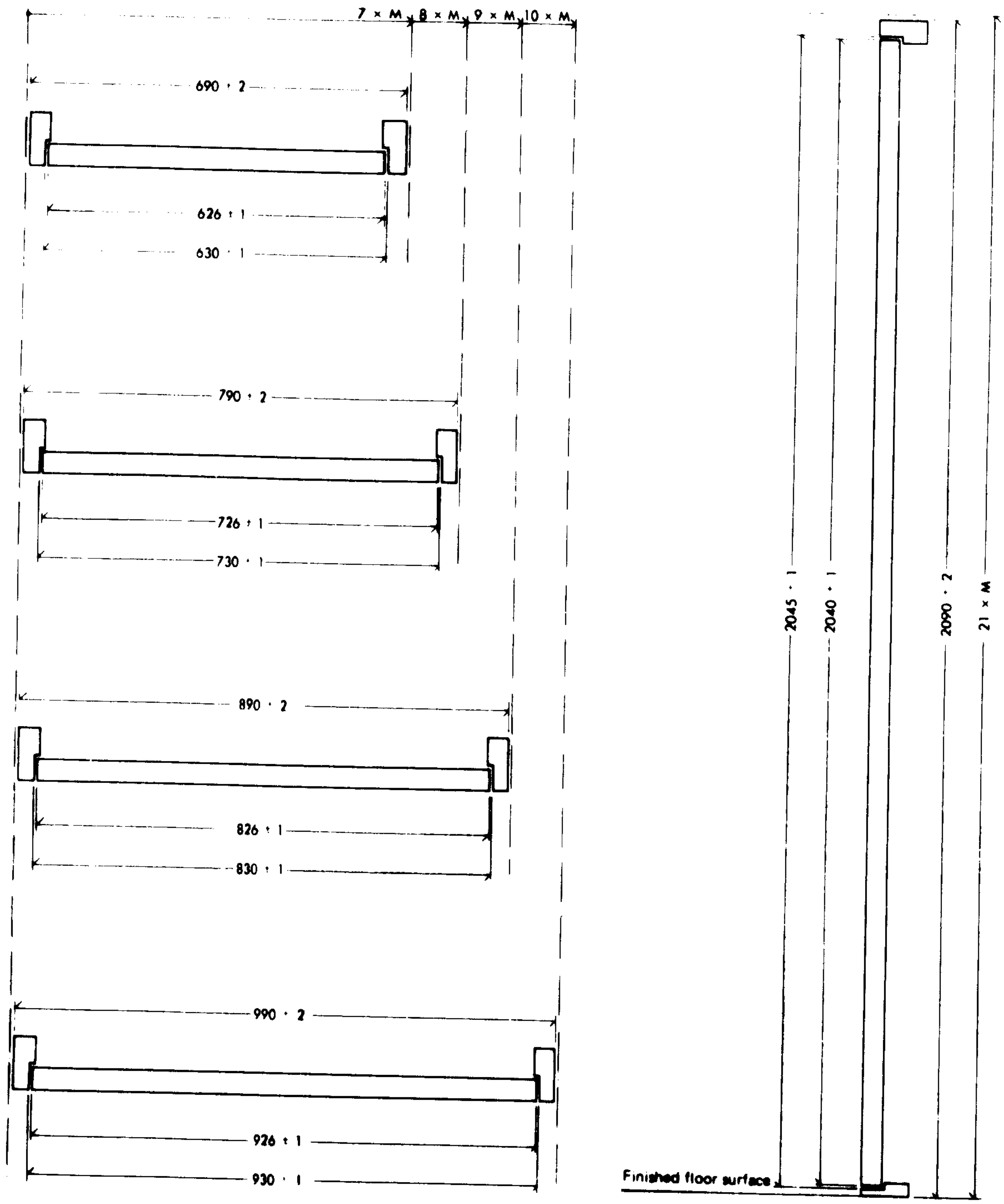
4 SILL

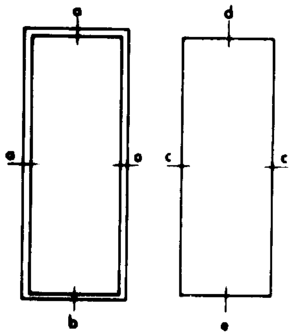
The sill for standard doors is loose. It may also be left out, in which case this must be mentioned in the order.



Door 7/92
Frame 7/92
Door leaf 7

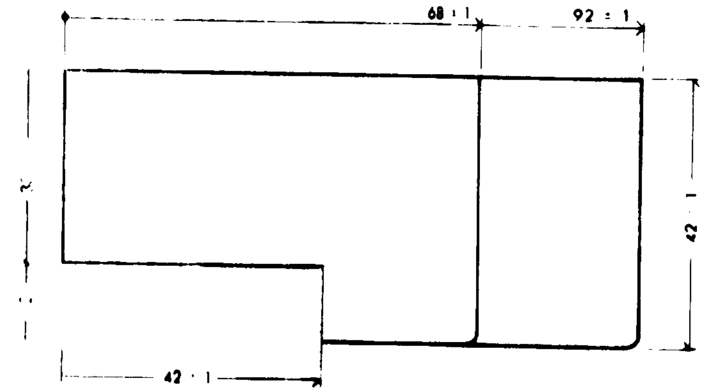
Manufacturing sizes of doors





Sizes of frame members
and of door leaf edges

a



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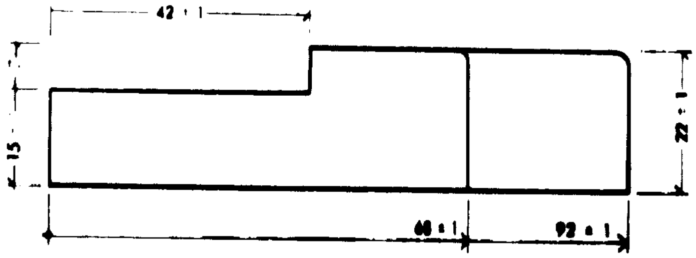

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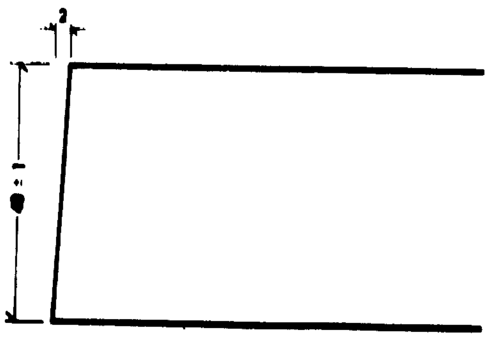

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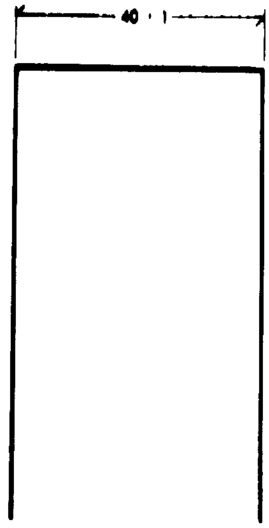


Doors for dwellings, standard sizes RT 871.05

0 GENERAL

01 This RT sheet indicates the number and position of fixing points for door frames and the position of fittings.

1 NUMBER AND POSITION OF FIXING POINTS

11 Position of fixing points in the jambs, fig. 1.

The places of fixing points are measured from the surface of finished floor. A door fitted with two hinges should be fixed at the lowest and the two topmost points of fixing, a door with three hinges at each point of the jambs.

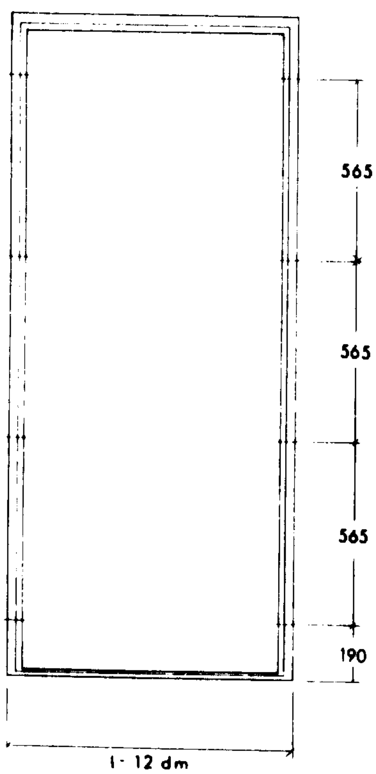


Fig. 1

12 Position of fixing points in the head member

If the nominal width of the frame is over 12 dm, there will be one fixing point at the middle of the head.

13 Position of fixing points in the direction of depth of frame, see fig. 2, 3 and 4.

For all frames, whose depth is ≥ 118 mm, the fixing points are at the middle of the depth.

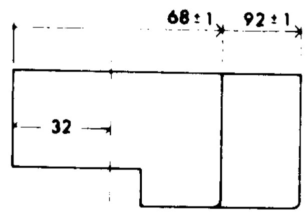


Fig. 2

Frames of not rebated door

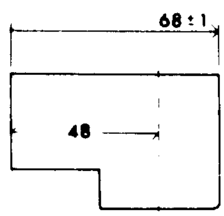


Fig. 3

Frame of rebated door

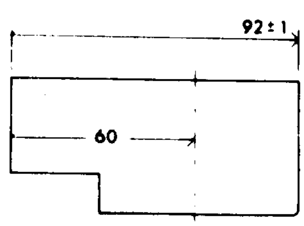


Fig. 4

Frame of rebated door

2 NUMBER AND POSITION OF FITTINGS

Number of hinges, see RT 140.1/X, para. X(32)i.15.

21 Position of hinges, see fig. 5.

22 Position of lock

The lock should be positioned so that the centre of the hole for the pin of the handle is 1020 mm from the bottom of the door leaf, see fig. 5.

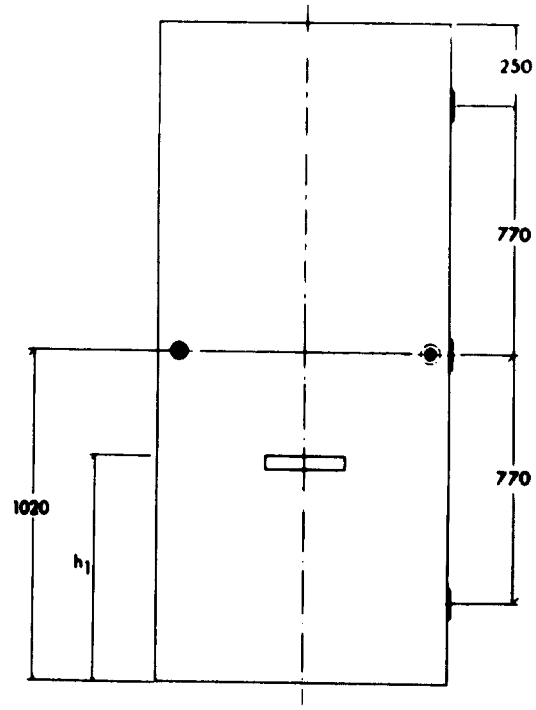
If the centre of the handle and the key hole are symmetrically placed in relation to the horisontal central line of the lock case, the lock can be positioned so that this central line is 1020 mm from the bottom of the door leaf.

23 Position of letterplate, fig. 5.

24 Position of doorbell

The doorbell should be placed symmetrically in relation to the lock.

Fig. 5



650 mm ≦ h_1 ≦ 800 mm

Doors nomenclature		RT 870.00
Doors for dwellings, standard sizes		RT 871.05
Doors	in group	RT 87
Wooden windows and outside doors, quality		RT 210.81
Wooden flush doors, quality		RT 210.82

1 CONTENTS

11 This RT-sheet describes standard wooden doors for dwellings, offices etc, with rebated door leaf.

12 The outer sizes of the frame, the sizes of the frame members, the sizes of the door leaf and the clearances are given.

2 NOTATION

21 Notation for doors

Name of door, size of door (see RT 871.05), depth of frame (in mm), if sill not required indication thereof, the number of this RT sheet.

eg: Flush door 9/92 RT 871.22
Panelled door 8/92 without sill RT 871.22

Quality class according to standard RT 210.81 or RT 210.82 and manufacturing degree have to be mentioned in the order.

22 Notation for frames and door leaves when ordered separately

Notation for frame: frame, size of door, depth of frame, if sill not required indication thereof, number of this RT-sheet.

eg: Frame 9/92 without sill RT 871.22
Frame 7/68 RT 871.22

Quality class according to standard RT 210.81 or RT 210.82 and manufacturing degree have to be mentioned in the order.

Notation for door leaf: door leaf, size of door, number of this RT-sheet.

eg: Flush door leaf 9/RT 871.22
Leaf for panelled door 8/RT 871.22

Quality class according to standard RT 210.81 or RT 210.82 and manufacturing degree have to be mentioned in the order.

3 DIMENSIONING

Co-ordinating sizes of doors, see RT 871.05

31 Manufacturing sizes of door frames are 10 ± 2 mm smaller than the corresponding co-ordinating size.

32 Sizes of frame members, see figures.

33 Manufacturing sizes of door leaves, see figures.

34 Door clearances are valid for assembled doors fitted with ironmongery, but without surface treatment.

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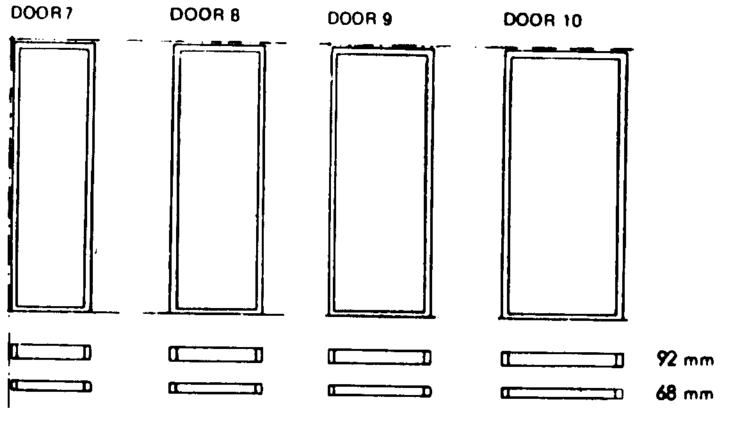
at sills	2...4 mm

35 Dimensioning implies that the moisture content of timber figured of dry weight is ≦ 10 % for flush doors and ≦ 12 % for panelled doors.

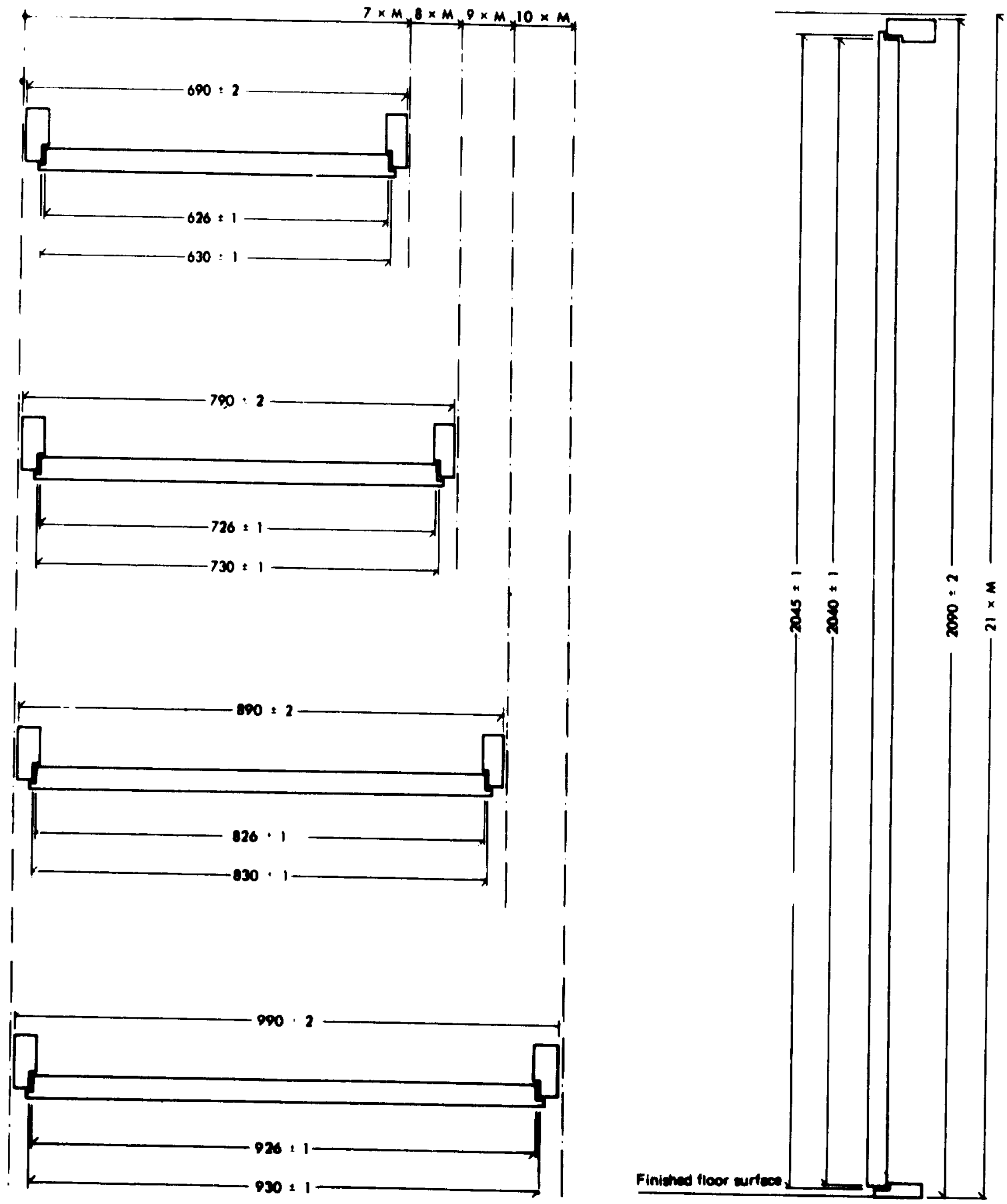
4 SILL

The sill for standard doors is loose. It can also be left out, in which case this must be mentioned in the order.

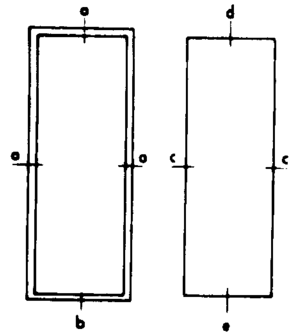


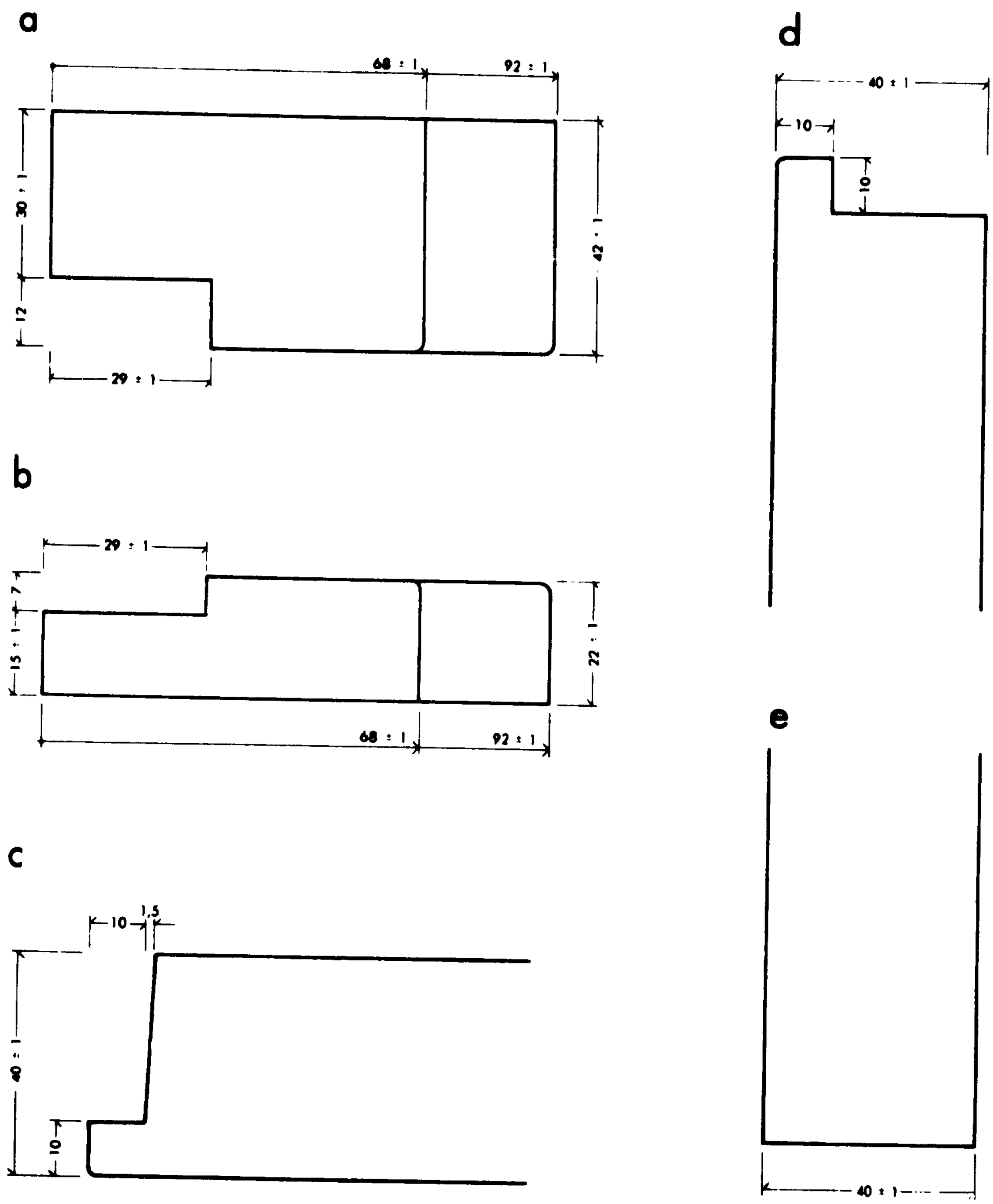
Door 7/92
Frame 7/92
Door leaf 7

Manufacturing sizes of doors



Sizes of frame members
and of door leaf edges





XX. Surface finishing of wood and wooden products*

A multiplicity of materials is 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. If he does not, it will be difficult if not impossible for him to select the proper finishing material. In doubtful cases he should check with his suppliers.

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, spruce, oak and birch. Many tropical species, such as mahogany and teak, 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-catalyzed lacquers are useful for this purpose. After the priming the final finish can be done with urethane or alkyd lacquers.

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*By P. A. Biström, Tikkurilan Väritehtaat, Tikkurila, Finland. (Originally issued as document ID/WG.105/32/Rev.1.)

[1] See part one, chapter I, "Solid wood as raw material for the furniture and joinery industries".

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.

Patching

Before applying any finish, all nail holes, open joints, twig holes etc. should be filled with a non-shrinking plastic wood. They should be filled slightly more than full and the surface should be sanded smooth when the filler has dried. If commercial plastic wood is unavailable, it can be made as follows. A piece of the same species to be filled is scraped to make as fine a powder as possible, then mixed with a binder such as nitro-cellulose lacquer. If a surface is to be finished with a pigmented material, any type of filler may be used provided that it can withstand the solvents in the finishing system. Polyester putties of a softer type as well as high-pigmented one-component putties are used in Finland for this purpose. After the primer has been applied, it is advisable to look over the items again and put in some more filler, if need be.

Bleaching and staining

Although wood is bleached chemically in some countries, this is not done in Finland because it is very difficult 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 water-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 some 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, the 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 ultraviolet (UV) radiation; drying time in special ovens is only 15 to 30 seconds. One can achieve an excellent finish with only one application on such surfaces. Acid-catalyzed paints are normally used.

Hardboards may also be pre-coated with UV polyester putties, but the usual modern practice is to use pre-coating with an acid-catalyzed primer and then an acid-catalyzed 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 discussed below.

The acid-catalyzed system

This sytem includes the following steps:

Holes are filled with alkyd putty. Coating is done with an acid-catalyzed primer, 80 to 120 g/m^2
Sanding
Smoothing with alkyd putty
Sanding
Top-coating with an acid-catalyzed finish paint, 80 to 120 g/m^2

The primer is applied with a spray gun or curtain-coating machine. After drying at room temperature for at least two hours (or for a shorter time at higher temperatures) the boards are sanded by machine. If defects remain in the surface after sanding, they are filled manually with alkyd putty. This material dries fast when applied in thin coats, permitting repairs to be sanded within a few minutes. The final coat is applied to the boards with a curtain-coating machine or a spray gun.

Kitchen furniture is sprayed with an air or airless gun after assembly. Inside surfaces, shelves and outside surfaces that are not seen are normally not puttied. Inside surfaces may be given a single coat of the primer or, better, the final coating material.

Reinforced acid-catalyzed system

For a high-quality finish on furniture and doors for kitchen furniture, the surface may again be levelled with putty and a second top coat applied.

Acid-catalyzed system using UV putty

This system has three steps: application of UV polyester putty (80 to 120 g/m^2, depending on the quality of the blockboard), sanding, and top-coating with an acid-catalyzed paint (80 to 120 g/m^2). It should be noted that the use of UV putty is possible only on wood-based panels.

Polyester system

This is also a three-step system: application of UV polyester putty (80 to 120 g/m^2, depending on the quality of the blockboard), sanding, and top-coating with polyester paint.

Dipping method for small components

An easy method for finishing furniture components such as cabinet legs is to dip them in paints based on nitro-cellulose, alkyds or alkyd/melamine (acid-catalyzed). With the last-mentioned type of paint it must be borne in mind that the pot-life of the mixed paint is only 8 to 12 hours, so that the size of the batch to be dipped must be big enough to justify the mixing of a paint bath.

Systems for unpigmented finishing

Some procedures for lacquering furniture, kitchen cabinets, doors etc. are described below.

Lacquers for light-coloured woods

With light-coloured woods, when it is desired to keep the surface as light as possible, the following procedure is advisable. First, a primer lacquer should be applied that will keep the wood light and will not wet the surface too much; it should also contain a preservative against UV radiation. Next, the piece should be given a light sanding. For the top coat, either the same lacquer is applied or a normal acid-catalyzed lacquer (mat or glossy).

Lacquers for dark woods

Dark woods and stained light woods should be coated with an acid-catalyzed primer lacquer, sanded and then finished with an acid-catalyzed top lacquer. Although water-based stains are still used, the present practice is to use a coloured solution mixed into the primer lacquer before application. In this way both staining and priming are done in one operation. The pigment is dissolved in a solvent with excellent light-fastness.

Teak

Teak should be given two coats of a thinned acid-catalyzed lacquer.

Rosewood

This wood must be primed with a special primer lacquer; normal lacquers usually take on a greenish colour. The top coat should be an acid-catalyzed lacquer.

Window frames made from coniferous woods

Wood preservative system

Treatment is with a clear wood preservative based on linseed oil. The best application method is dipping. One or two coats of a coloured wood preservative may be applied later.

Alkyd system

Pre-treatment is the same as above. Holes are filled with an alkyd putty. (Putty should not be used on the outsides 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-catalyzed 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-catalyzed primer, and the article is smoothed with alkyd putty, sanded and finally given a top coat of acid-catalyzed finish paint. The acid-catalyzed paints should be of a psecial quality, so that they can withstand "living" in the frames. The acid-catalyzed 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-catalyzed 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-catalyzed 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-catalyzed 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-catalyzed products can withstand a dry heat of 100°C. Because they do not burn easily, shipyards are using boards finished with acid-catalyzed materials for the interiors of vessels. Metal surfaces may be finished with acid-catalyzed 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, gelation of its contents will soon occur. This is caused by the isocyanate reacting with the hydroxyl in the water.

Polyesters

These finishing materials were mentioned above in connexion with the surface coatings for indoor furniture. They are little used in Finland and then mostly in some smaller series such as tables and television receiver cabinets. They consist of two components and must be mixed before use. The pot-life of normal polyester products for air spray is only a few minutes, making them difficult to use. With forced heating they can be used in a curtain-coating machine by employing another hardener composition to give a longer pot-life to the mixture. There is also special air-spray equipment on the market in which the components are mixed together in the spray gun immediately before the paint leaves the gun.

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 (0.5 to 1.5 kp/cm^2) through a hose to the gun and atomized by air at 2.5 to 4 kg/cm^2. 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 should be 8 to 10 per cent, and the grounding contacts should not be too far apart (50 to 60 cm). This method has advantages on 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 or drying of paints is being considered, several manufacturers should be consulted before a decision is made.

In many factories, drying of applied finishes such as acid-catalyzed paints is accelerated by high-temperature ovens. With modern equipment, curing time can be reduced to about 40 to 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 temperature because the resin is forced out. For such species, drying temperatures of 50° to 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 the table.

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	1.3-6.7	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.

Over-all 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.

XXI. Surface finishing of furniture and joinery in small plants*

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. Cleaning a dirty wooden surface is laborious. The purpose of surface finishing is also to protect 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, semiglossy, semimat and mat.

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

The method of production is as follows:

(a) Wood dust is scraped off or sanded from the end of a piece of 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.

(b) It is recommended that the same species of wood be used as that of the surface to be repaired.

(c) The binding material used can be a nitro-cellulose or alkyd carbamide, also known as alkyd (formaldehyde) lacquer, both of which have a fairly short setting time, but other lacquers may also be used.

(d) 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 connexion with the coating.

(e) Wood putty is generally applied on secondary objects only.

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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°C to 80°C. A usual concentration of this so-called basic solution is 50 g/litre. The final shades 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 penetration and adhesion of the stain 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 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

This is the newest available stain, 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 intensity.

Properties and use:

(a) Surface drying is very fast;

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

(c) It is partially waterproof;

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

(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 of instruments (violins, guitars);

(g) It is suitable for restoration of old furniture where the surface bas 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 m²/litre of coating area is obtained.

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

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

Drying time at 20°C is

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

Main properties:

(a) It is glossy and mat.

(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-carbamide lacquers (two-component lacquers)

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

Application is by spraying, with a brush, immersion or drum lacquering. For spraying, 18 to 20 seconds DIN 4 at 20°C is correct viscosity; for application with a brush, about 24 seconds DIN 4 at 20°C.

Depending on the method of application, a coated area of 15 to 20 m^2/litre is obtained.

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

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

Drying time at 20°C:

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

Main properties:

(a) It is glossy and mat;

(b) It dries through evaporation and oxidation;

(c) Owing to its 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.

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

One-component catalyst lacquers contain a hardener which 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 leaving th with an unfinished look is often used (it does not wet the surface). The light colour of the wood can a 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 fibre glass in car bodies, boats etc. Later it became a 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 and either contain a hardener or one may be added afterwards. The coating obtained in this way is resistant to chemicals and mechanical wear. These lacquers are used in kitchen and bathroom furniture, also on boats.

Factors affecting the choice of lacquers are:

- The wood material used in the object
- Requirements of the lacquer
- Available surface-finishing materials
- Available equipment
- Method used in surface finishing
- Conditions for surface finishing
- Workers' skill and experience

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 glue spreading out of 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 either with wood putty (lacquer and wood dust), dissolved shellac lacquer, or 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 choice of plugging veneer and the plugging itself must be done 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. Addition of 2 to 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 I.

Final sanding

Final sanding is done with sharp and fine sanding paper 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.

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 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. 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 mm to 15 mm) and it should have a wide base and become narrower towards the points (see figure II). 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 handle. The brushes and pots for cellulose lacquer stay in good condition when stored in a tin container (figure III) 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 IV) for levelling the lacquered surface and a dusting brush and a piece of chamois, or something similar, to remove the dust.

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:

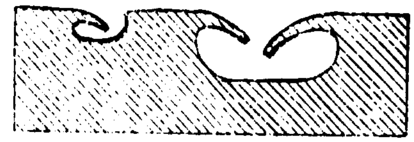
(a) The surfaces to be lacquered are preferably set horizontally so that light is reflected from the lacquered surface (see figure V);

Figure I. Effect of moistening herdwood surface before lecquering

Lacquering unmoistened wood

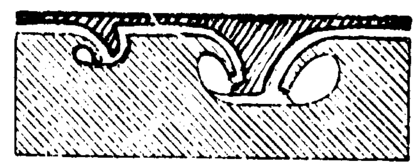
The magnified pores have collapsed from their original round shape. The broken upper edge of the pores has sunk in.

Unmoistened wood



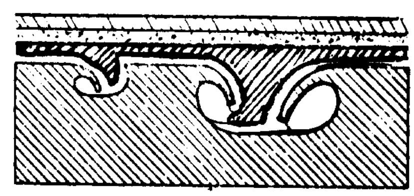
In prime coating with brush, spray gun or some other means the pore edges sink even further, preventing the lacquer from entaring the pores completely. If wood filler is used—as in the figure—evan that cannot fill the pore bottoms.

Wood with prime coating and filling



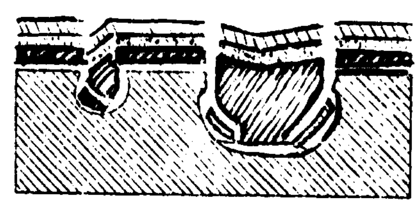
Actual surface lacquars fill the surface, laaving the pores hollow.

Lacquared wood



Becausa the wood later "lives", tha pores tend to return to thair original round shape. Tensions davelop in tha lacquer film, and these can rasult in longitudinal cracks.

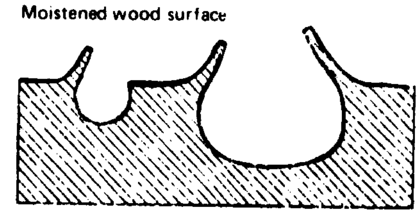
Cracked wood



Lacquering moistened wood

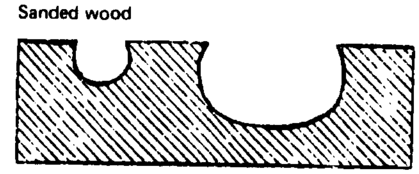
The wood surface has bean moistened with water at 60° to 70°C using a sponge. The wood surface swells fast and the pores return to their original shape. The pores open and the surface becomes rough.

Moistened wood surface



Moistened wood surface has baen sanded and the pores have opaned. A rotating sanding wheal has been used with semihard basa and 220 sanding paper. The sanding dust has been carefully removed from the pores in the longitudinal direction.

Sanded wood



In lacquering, the poras fill up to the bottom and the lacquering bacomas durable.

Lacquered wood

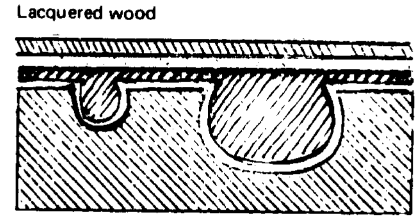


Figure II. Lacquering brush

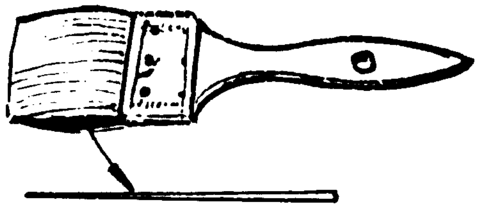


Figure III. Container for brush storage

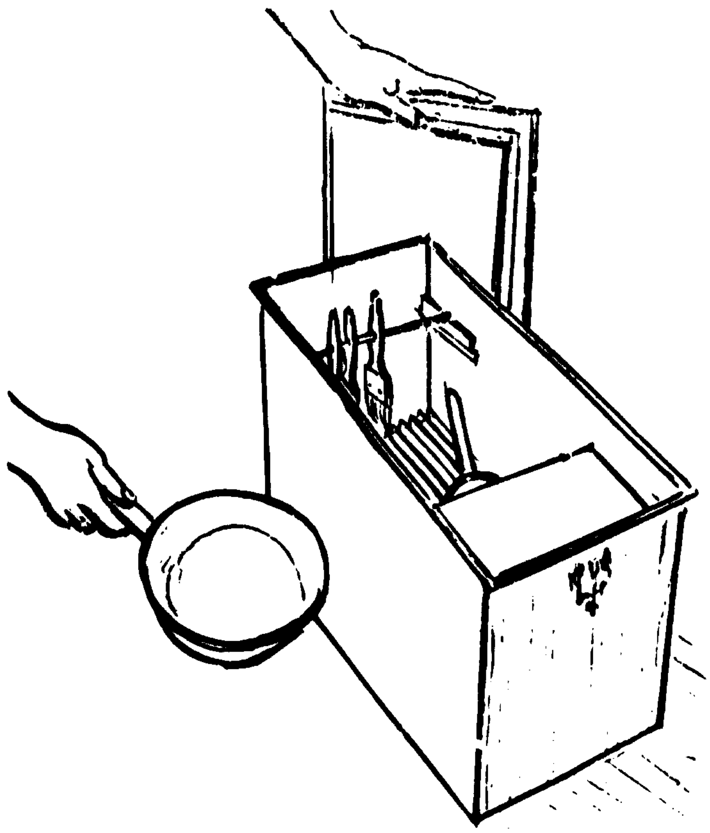


Figure IV. Screping plate

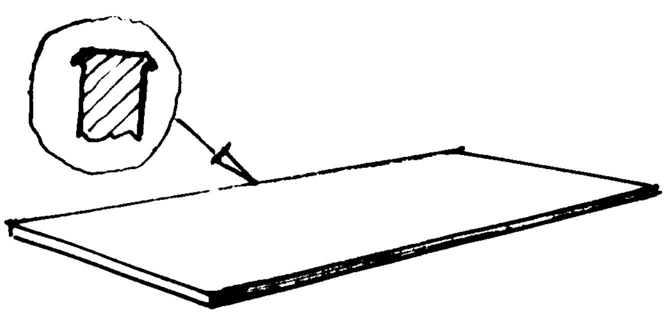
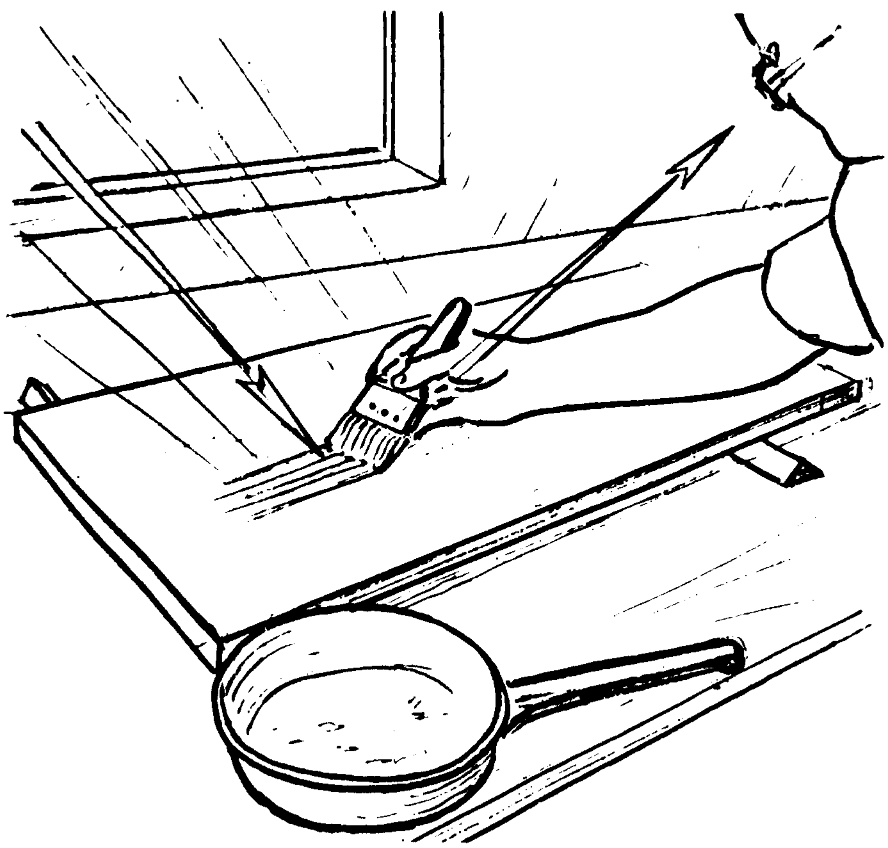


Figure V. Reflection of light from the lacquered surface and holding the brush



(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 V);

(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;

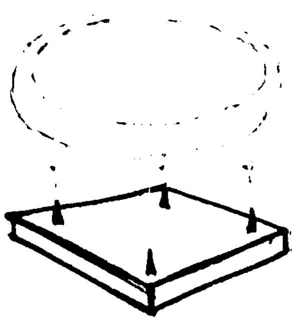
(l) The surfaces must be allowed to dry sufficiently before they can be turned onto their own base, an exception being a case in which a special spiked lacquering and drying base can be used (see figure VI);

(m) Between the coatings the surface is 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 to 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 VI. 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 larger container (see figure III). 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 closet provided with fans, particularly in the case of spray lacquering (see figures VII and VIII). This prevents the spreading of lacquer particles and fumes 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.

Spraying equipment

Electric spray gun. An electric spray gun (see figure IX) is a piece of equipment supplying a high-pressure spray without a compressor, 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 cyclic wave current as a result of a vacuum being created and ejects at a high pressure (100 impulses per second are obtained from 50-cycle alternating current).

Technical data

Weight: about 1 kg
Capacity: 170 to 320 g of paint per minute
Power: 35 to 60 W (consumption)

This type of spray gun is suitable for small-scale production, repair shops etc. These guns must not be used in areas where a danger of explosion exists.

Figure VII. Spraying closet provided with dry filter

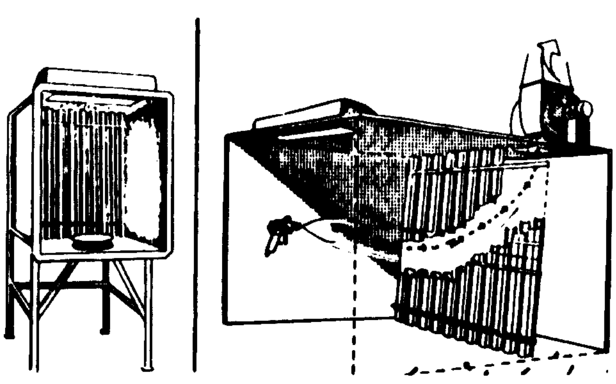


Figure VIII. Spraying closet provided with water curtain

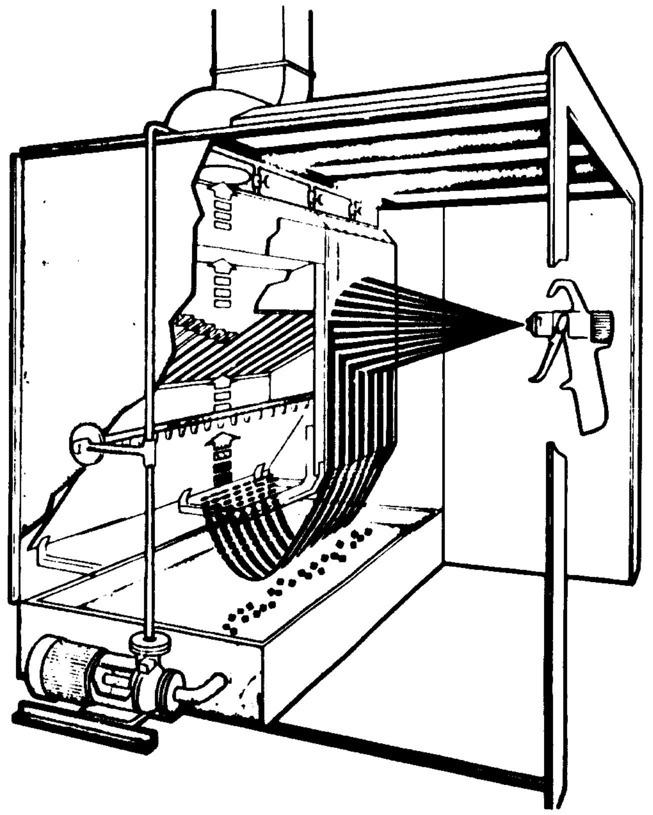
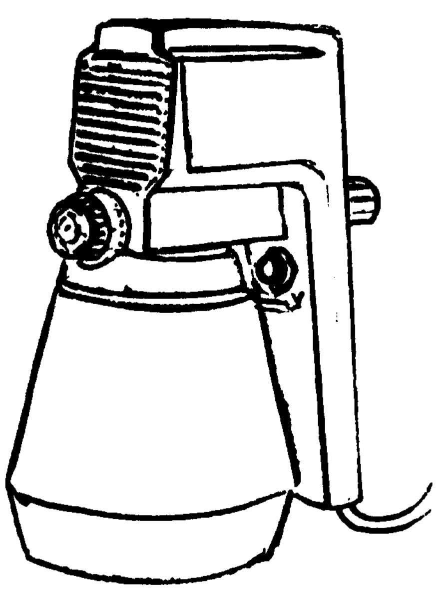


Figure IX. Electric spray gun



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.

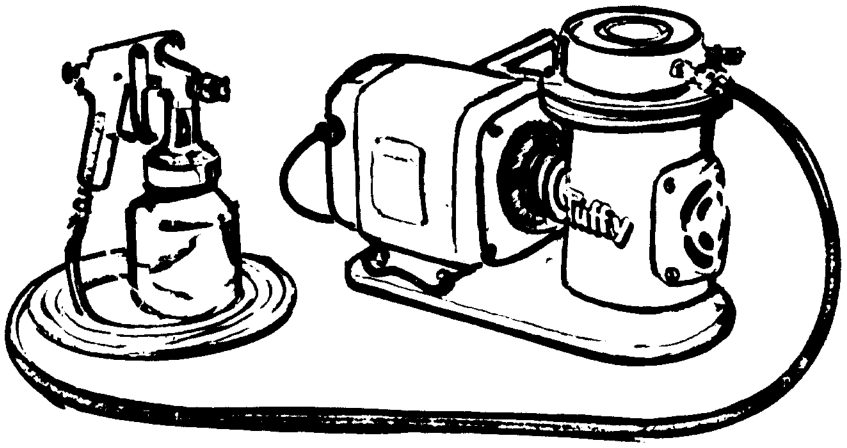
Light pneumatic spraying device. The compressor used is a small film or piston compressor (see figure X). The spray guns usually operate on low pressure and are either suction or pressure fed. The lacquer can be fed from a container attached to the head or from a separate container through pipes. The 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.

Technical data

Weight (including compressor) 15 to 30 kg
Compressor with monophase electric motor under 0.5 kW
Pressure in continuous operation: 2 to 2.8 kg/cm^2
Capacity: 8 litres per minute of free air at pressure of 2 kg/cm^2

A pneumatic spraying device is suitable for small-scale production, repair shops etc., which have no separate compressor and where a spray gun with high capacity is not required.

Figure X. Light spraying device



Fixed spraying device. Fixed spraying devices (see figure XI) 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:

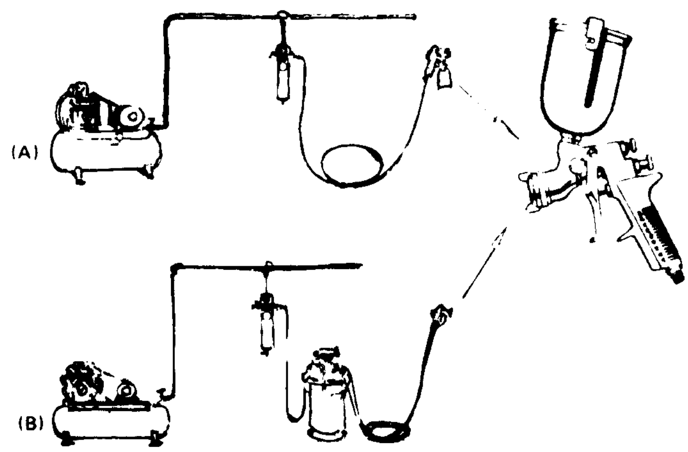
Spray gun
Compressor
Pressure chamber
Pressurized material container
Air line
Pipes for transport of material to be sprayed
Pressure-reducing valve provided with water extractor, air filter and pressure gauge

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 to 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 XI. Fixed spraying device

(A) Container mounted on gun (B) Large separate container



Instructions for spraying

There are spray head combinations (spray head and needle valve) available for each spray gun (see figure XII). The choice depends on the type of spray gun, material to be sprayed and operating pressure. Rough rules to follow are:

(a) That the tinner the material to be sprayed and the lower the operation pressure, the smaller the size of the spray head;

(b) That spray-head sizes suitable for lacquering have diameters of 0.4 to 0.5 mm for electric spray guns, and of 1 to 1.4 mm for suction and pressure-fed spray guns (see table next page);

(c) That in suction feed an external-mix gun is best for fast-drying catalyst and cellulose lacquers (see figure XIII).

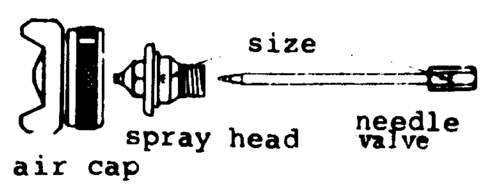
Determining the lacquer viscosity

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 XIV). The viscosity is measured in seconds. The better known viscosity meters have 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 evaporating material. The viscosities for cellulose and catalyst lacquers are about the same: 18 to 20 seconds using DIN cup No. 4.

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 to 400 kN/m^2, depending on the lacquer viscosity.

Figure XII. Spray head components



Spray materials	Spray model[b]	Spray head combination[b]	Feed	Spray head size (mm)	Air intake (litre/min) (pressure kg/cm²)		
Thin		74-FX	P	1,07	285–3,5	330–4,2	395–5,3
Water	P-MBC-510	704-FX	P	1,07	285–2,1	350–2,8	420–3,5
Stain	P-JGA-502	705-FX	P	1,07	205–1,4	230–1,8	260–2,1
Solvents	P-AGA-502	2-FX	P	1,07	225–2,1	275–2,8	330–3,5
Thinner	P-AGB-501	203-FX	P	1,07	200–2,1	240–2,8	285–3,5
Fixer	P-AGA-517	36-FX	P	1,07	190–2,1	235–2,8	285–3,5
	P-AGB-504	58-FX	P & I	1,07	145–2,1	180–2,8	215–3,5
		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 mallit	84-FF	P & I	1,40	90–2,1	110–2,8	130–3,5
	QGA-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
Lacquers		160-FZ	P	1,19	540–3,5	615–4,2	695–4,9
Cellulose paints		181-FF	P	1,40	465–3,5	540–4,2	610–4,9
Synthetic paints		181-FZ	P	1,19	465–3,5	540–4,2	610–4,9
Varnish		765-FF	P	1,40	415–3,5	545–4,9	675–6,3
Thin glues	P-MBC-510	765-FX	P	1,07	415–3,5	545–4,9	675–6,3
Fillers	P-JGA-502	74-FF	P	1,40	285–3,5	330–4,2	395–5,3
	P-AGA-502	74-FX	P	1,07	285–3,5	330–4,2	395–5,3
	P-AGB-501	704-FF	P	1,40	285–2,1	350–2,8	420–3,5
	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
		491-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
		54–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
		45-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
	P-JGA-502-A	78-FX	P	1,07	505–3,5	615–4,2	670–4,9
	P-AGA-502	78-FZ	P	1,19	505–3,5	615–4,2	670–4,9
	P-AGB-501	770-FZ	P	1,19	480–3,5	560–4,2	635–4,9
		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
	P-EGA-502	395-E	P & I	1,78	70–2,1	–	–
		390-F	P & I	1,04	65–2,1	–	–
		124-F	P & I	1,04	40–2,1	–	–
	P-CGA Kaikki mallit	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
	QGA-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, USA.
[a]This table has been included to give an idea of the range of products available.
[b]Numbers refer to DeVilbiss products.

Figure XIII. External-mix spray gun

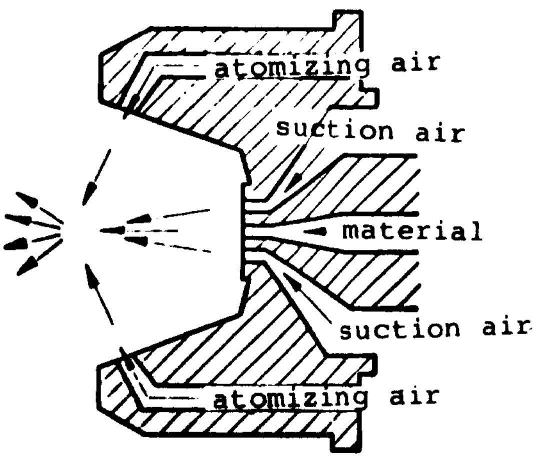
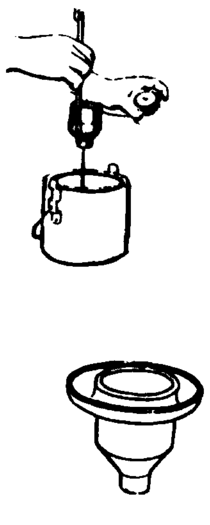


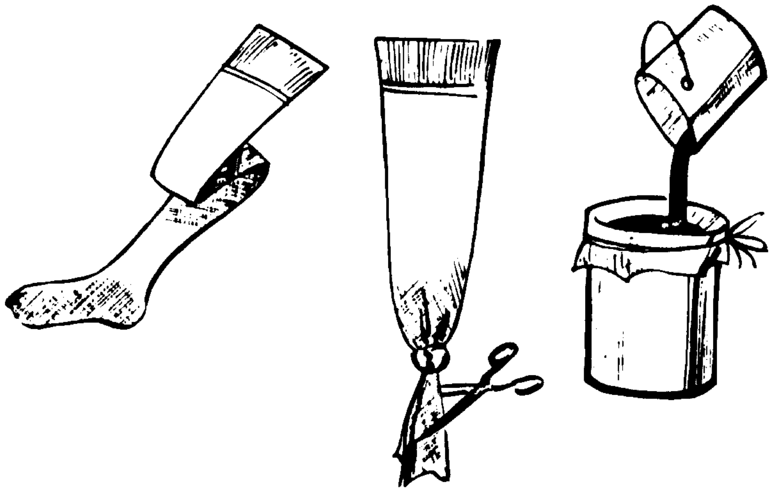
Figure XIV. Measuring viscosity



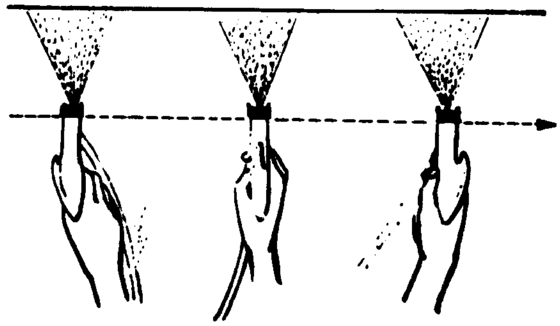
Spraying techniques

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 familiar with the regulation of the spray gun and he must be able to find out possible disturbances and their causes as well as to eliminate them. Some instructions on techniques and problems connected with spraying are indicated in figures XV-XXI.

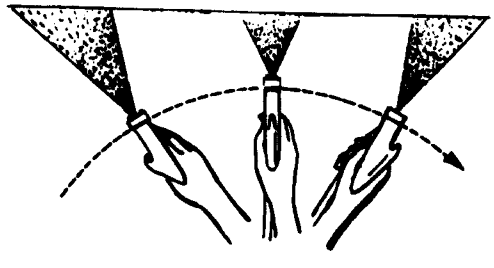
Figure XV. Techniques of spraying paint



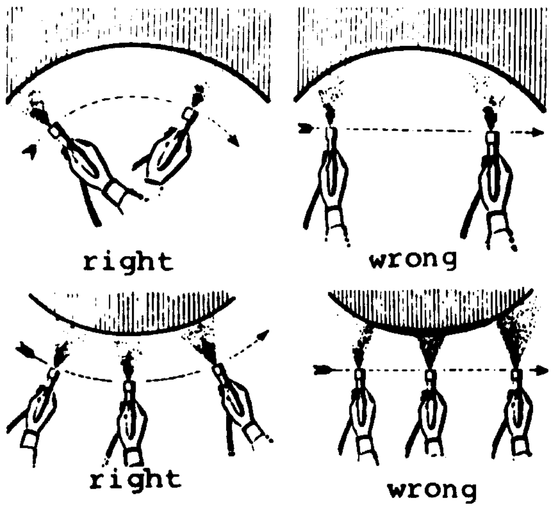
(a) Use of nylon stocking for screening paint



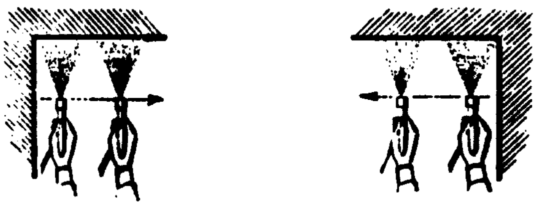
(b) Correct pointing of spray gun for level surface



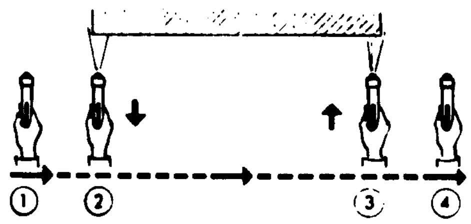
(c) Wrong pointing of gun for level surface. The gun is turned so that the surface becomes uneven and paint is atomized at the edges.



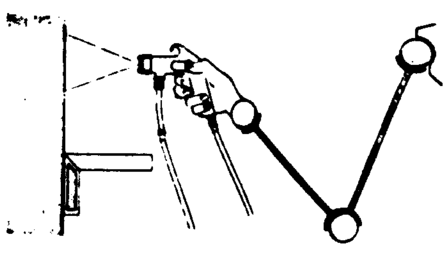
(d) Spraying curved surfaces. The figures on the right show wrong pointing of the gun. On the left the pointing is correct.



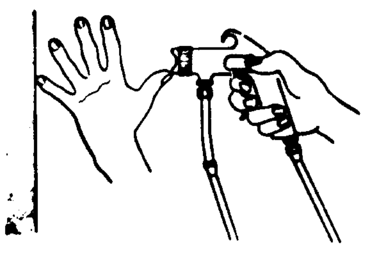
(e) Correct pointing of gun at corners



(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.

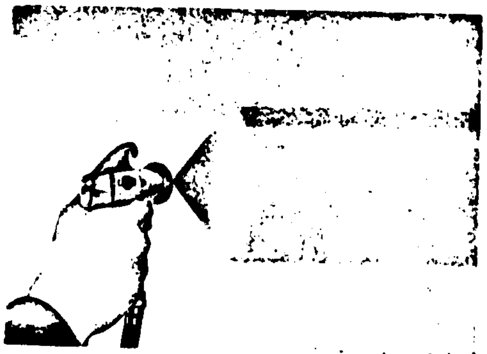


(g) The paint is sprayed with long even strokes. The arm must not be held rigidly, but all joints must move and in this manner the gun can be pointed straight, which is essential to achieve an even surface.

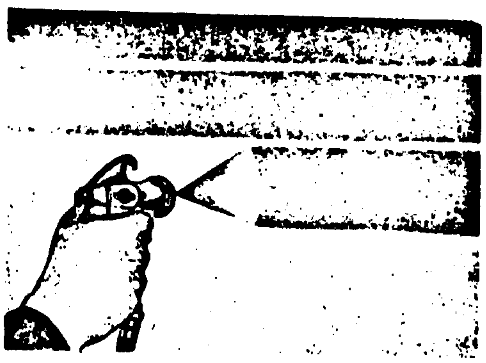


(h) The gun is moved with an even speed across the surface. The distance between the surface and gun must remain constant at between 15 and 25 cm.

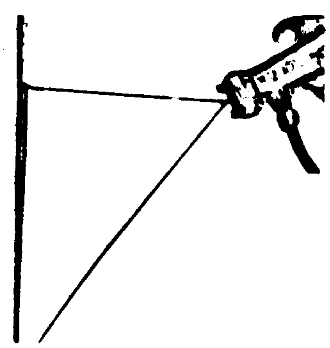
(i) The direction of the movement should not be changed during spraying; otherwise the surface spread valve will change at the turning point.



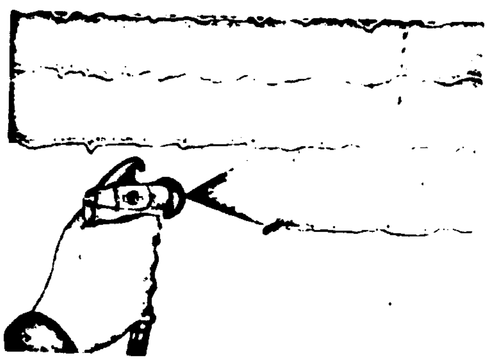
(j) The sprayed coatings must not overlap too much.



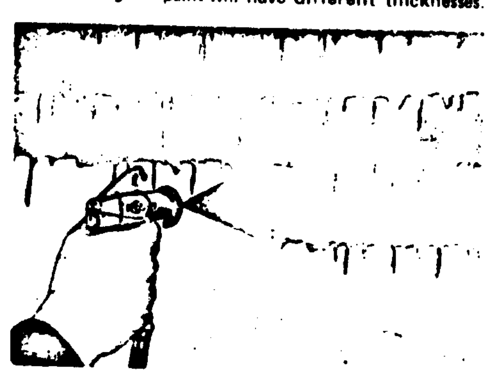
(k) Unless the sprayings cover each other the surface becomes striped.



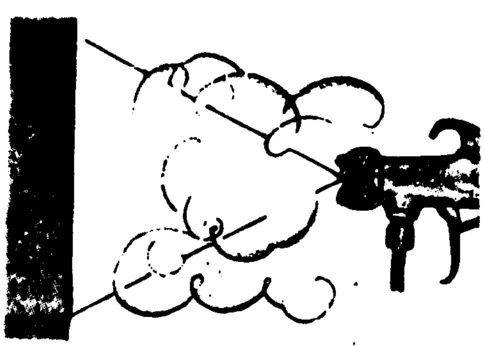
(l) The gun should not be held diagonally or the coatings of paint will have different thicknesses.



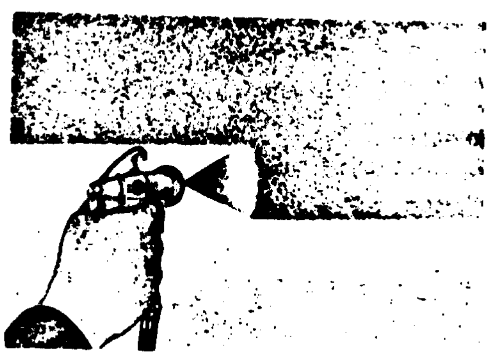
(m) Too much and too thick a paint will settle in folds.



(n) Too much and too thin a paint will run.

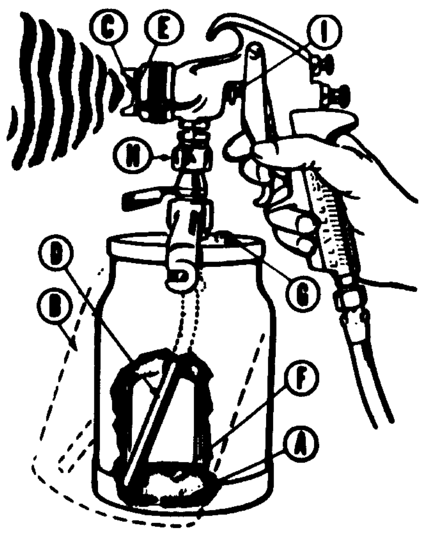


(o) The pressure should not be too high or the surface will be like the peel of an orange.



(p) The distance between the surface and the gun must not be too great or the paint will dry on its way.

Figure XVI. Possible reasons for uneven spray



If the colour sprayed is uneven the defect could be owing 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

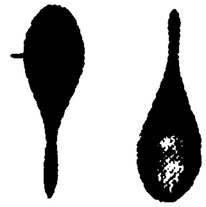
When using a suction container also, defects could be because:

(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

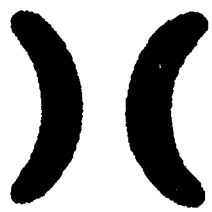
Difficulty also arises if the colour tube reaches the container bottom.

Source: DeVilbiss Company, Toledo, Ohio, USA.

Figure XVII. 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 pettern turning to the left or right could be: blocked sida opening of tha air cep, left or right; or a partly blocked spray head.

(c) The raason for the pattern spreading in the middle could be: too nerrow e spray; too low a pressure or peint is too thick; too smell en eir cep with prassure feed; or too lerge e spray head.

(d) If the pattern narrows in the middle, the reeson could be wrong pressure. Make the sprey narrower or add pressure. Regulating the pressure increeses the emount of colour but the spray movements must be speeded up.

Source: DeVilbiss Company, Toledo, Ohio, USA.

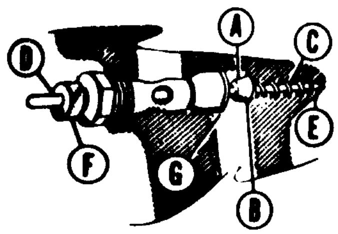
Locating the faults of points *(a)* and *(b)*. Turn the air nozzle half a revolution and spray. If the pattern has turned the same amount, the fault is in the air cap. If, however, the spray head is blocked, careful cleaning is necessary.

Locating the faults of points (c) *and* (d). If the pressure of atomizing air or pressure of colour 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 XVIII.

Figure XVIII. Right spray pattern

Source: DeVilbiss Company, Toledo, Ohio, USA.

Figure XIX. Paint leak through the air cap

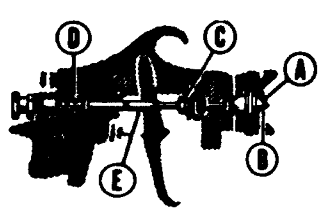


The reasons for a leak through the air cap could be:

(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

Source: DeVilbiss Company, Toledo, Ohio, USA.

Figure XX. Paint leak through the needle valve seal

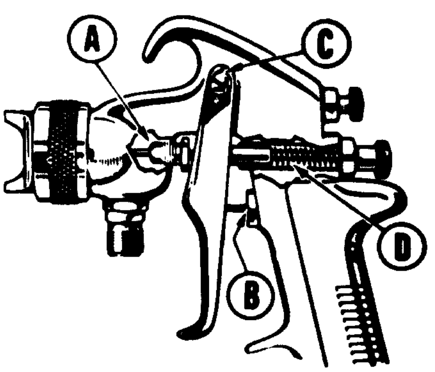


If the paint leaks through the tightening nut of the needle valve seal, the reason might be:

(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 XXI. Greasing the spray gun



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.

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.

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 XXII;

(d) Protective masks of the type shown in figure XXIII should be worn when lacquering indoors.

Cleaning the spray gun (figure XXIV)

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.

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 removed from the container before opening the lid.

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.

Figure XXII. Suitably ventilated spraying booth

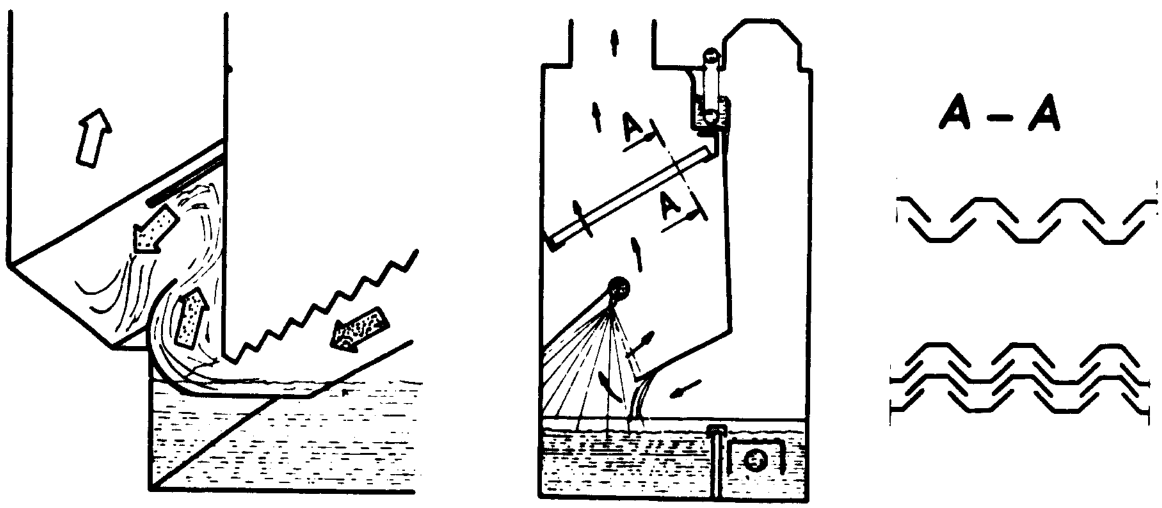
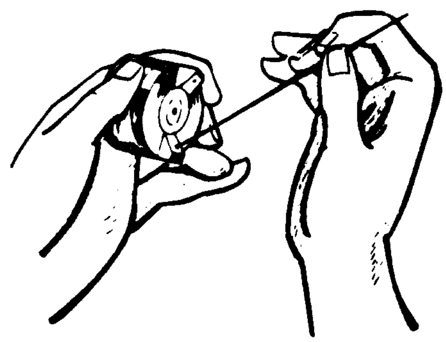
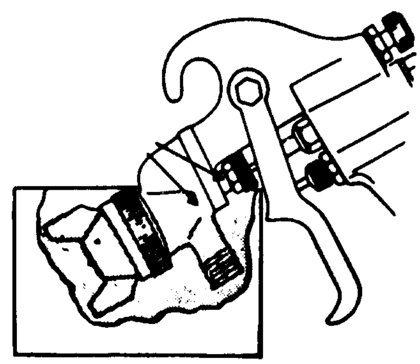


Figure XXIII. Protective masks

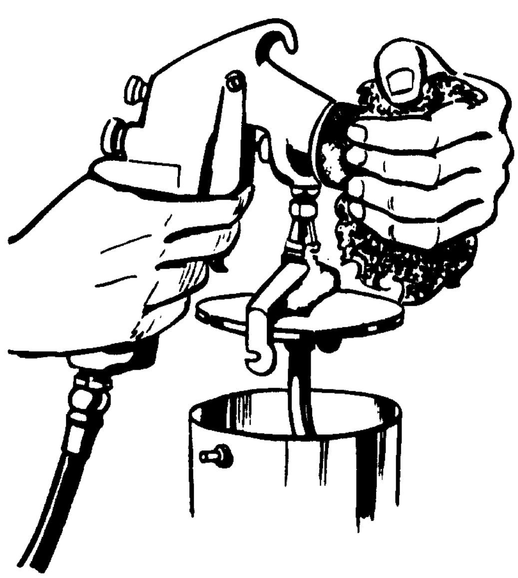
Figure XXIV. Cleaning the spray gun



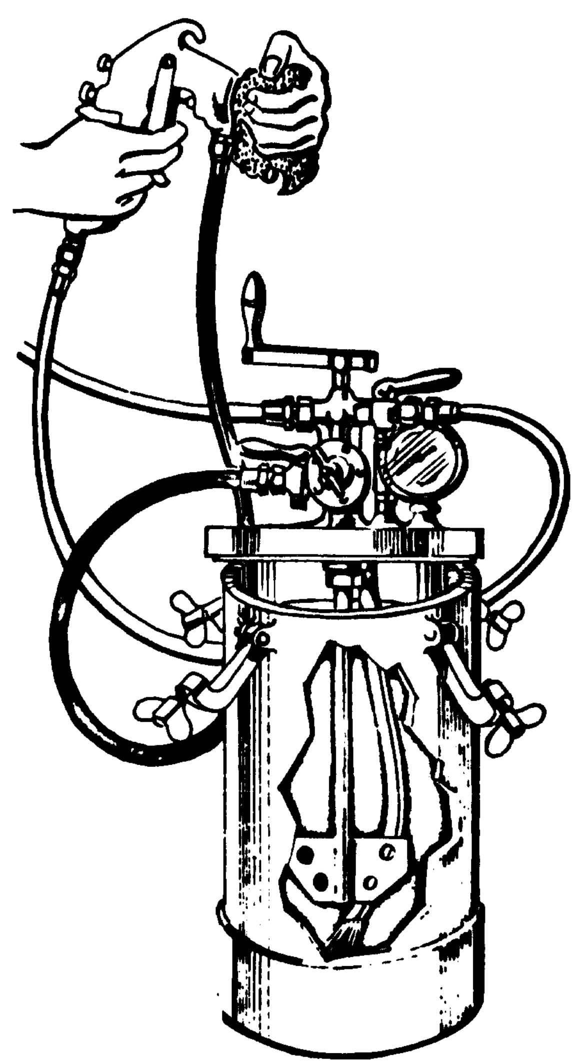
(a) Cleaning side openings



(b) Upper limit of thinner must not rise above the seal



(c) Cleaning spray gun with suction-feed container

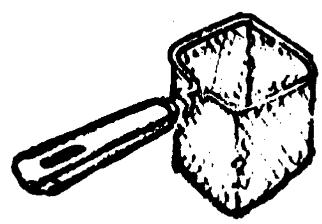


(d) Cleaning the pressure system

Immersion lacquering

If immersion only is used in lacquering, good final results in surface finishing require special equipment which ensures an adjustable rate of lift of the item from the lacquer, of 2.5 to 10 cm/min. Lacquer viscosity and temperature must be carefully controlled. Simple protective lacquering with thin lacquer can he applied manually so that the objects are immersed one by one, or several at one time. Small objects can he 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 XXV) 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 ohjects 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.

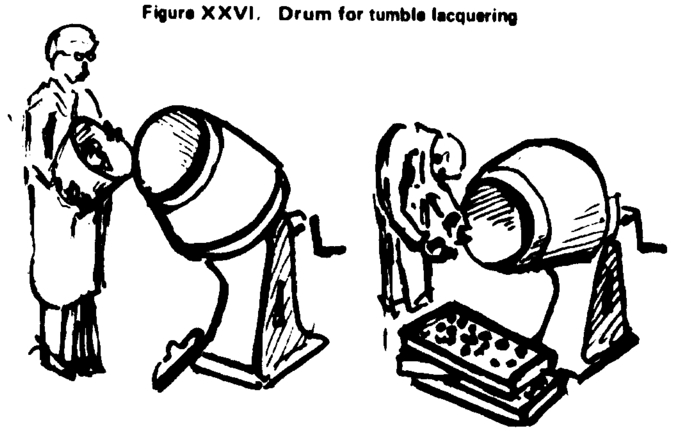
Figure XXV. Large wire sieve



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 and can be tilted to an angle of 45° (see figure XXVI).

Figure XXVI. Drum for tumble lacquering



There are two different ways of drum lacquering:

(a) Ahout two thirds of the drum is filled and 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 suitahle for this type of lacquering, since lacquer that has dried in the drum can he removed with thinner.

Drying techniques

The drying process for cellulose lacquer is based on the evaporation of the thinner material. Drying lacquer catalyst 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

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 (see figure XXVII *(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)*.

Post-treatment processes

If a mat lacquer surface is required, it can be obtained either by using mat lacquer or rendering a glossy lacquer surface mat. 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 the sanding is performed with a soft cloth with sanding support in the direction of the grain. After sanding, the surface must be cleaned with lacquer, petrol or another solvent which removes the grease but does not dissolve the lacquer.

In wood with rough grains mat lacquer gives a more attractive surface, since even the bottoms of the pores become mat. 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

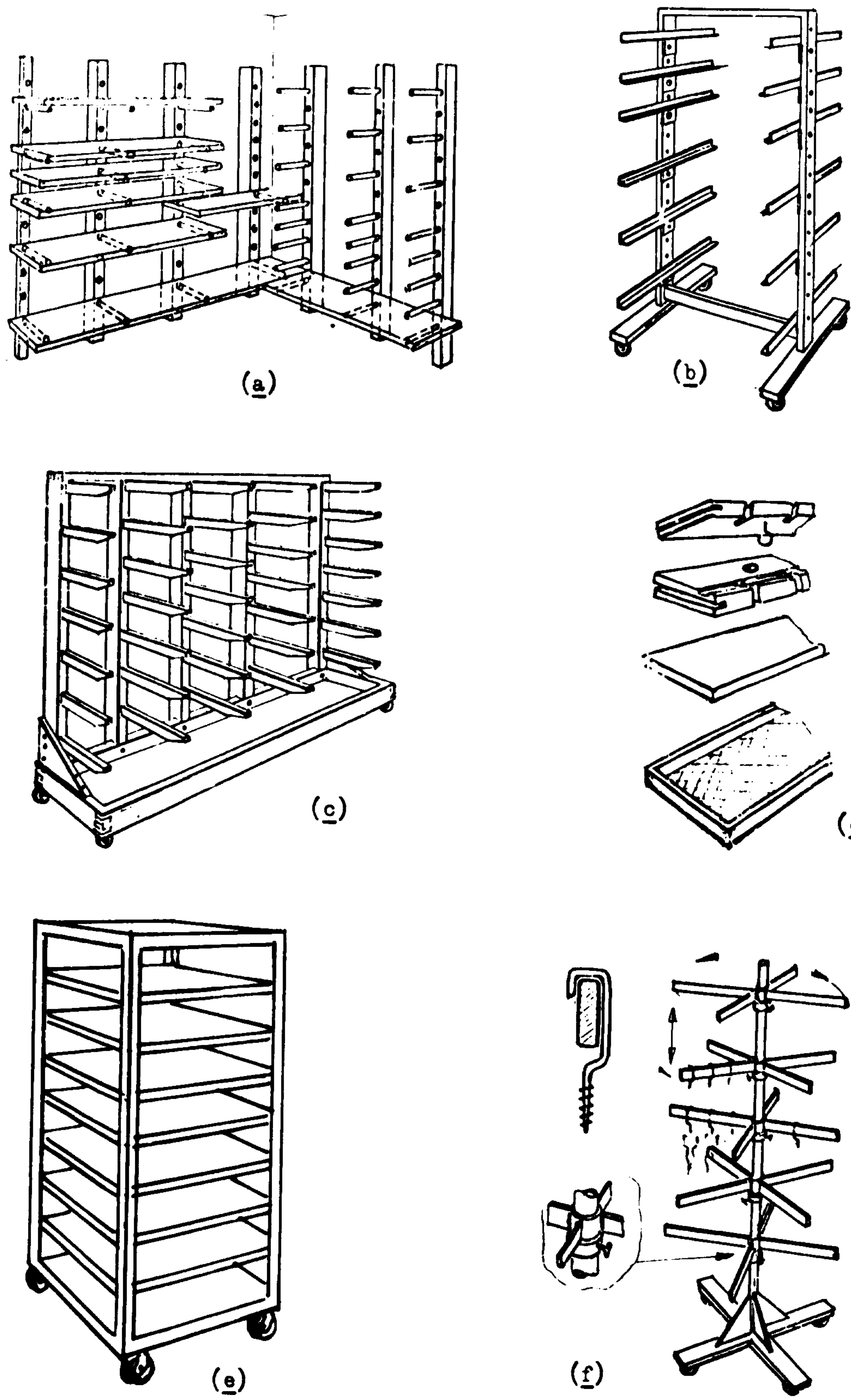
Flow

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 or alcohol is more suitable than ordinary water-soluble stain. Colour adhesion can be improved with light sanding.

Figure XXVII. Drying stands and shelves



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., which 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 which does not damage the colour and the surface of the wood. A scraper made of hardwood, plastic or bone can be used. Also a dull scraping plate is suitable. Catalyst lacquers are removed mechanically. Before lacquering, the surfaces are sanded and worn or damaged stained points are repaired.

XXII. Potential for low-cost automation in the woodworking industries*

Since the concept of low-cost automation is new to many developing countries, this chapter is designed to provide some general outlines on why and how to automate. The term low-cost automation has two connotations: *(a)* automation to achieve low production costs, and *(b)* automation at low cost.

Why automate?

Before considering how to set up automatic operations, it should first be determined why and in which cases it would be advisable.

In the furniture and woodworking industries every manufacturer encounters production difficulties at some time. These are solved in one way or another but not always economically or altogether satisfactorily. If there is enough very skilled staff at the manufacturer's disposal, he can manufacture parts with complicated shapes or cross-sections. A skilled joiner or upholsterer can, perhaps after some experimenting, develop a method for producing the desired result as regards shape and accuracy, but such a method all too often presupposes great skill, ability to concentrate and, above all, a disproportionately large expenditure of time.

It is difficult to recruit skilled joiners in sufficient number for industrial production, and their wages are higher than those of normally efficient but unskilled workers. Thus, in the furniture and woodworking industries, the machines and methods used must be automated to a degree that would permit both the use of unskilled labour and the production of articles of good quality.

When planning low-cost automation in the assembly of products made in parts, it is absolutely necessary to manufacture each part so accurately that no finishing will be necessary during mounting. Conversely, some complicated shapes may be impossible to make without automation if all of the pieces produced are to be identical and thus fulfil the requirements for assembly by mass-production methods.

One result of low-cost automation is the avoidance of human error; even the most careful operator cannot always concentrate so intensely that no mistakes occur. Human fallibility may result in an excessive number of faulty parts, with consequent difficulties at the assembly stage.

Perhaps still more important in estimating the value of automation is the fact that it reduces the number of accidents, thus reducing injuries to workers and damage to tools and machines. Controlled power feed of tools and materials not only increases cutter or tool life, since the applied loads remain constant, but also makes possible consistent machining quality. The smooth and rapid flow of materials in automation ensures maximum output.

Materials feeding often begins rather far from the machine, in which case the material must be brought to it quickly and fed to it with no reduction in machining speed. With automation, these speeds can be set to the ideal values, and all movements can be programmed to occur in the proper order.

While it is often appropriate to put the material into the jig by hand, fixing the workpiece in the jig automatically is more efficient, saves time and reduces strain on the operator.

Particularly worthy of consideration is the way in which the operator receives the material. If he must reach for every workpiece or even leave his station to bring new loads from a distance, low-cost automation should be considered. The coupling of two or more machines with mechanical conveyors is the correct method for saving factory floor space by eliminating unnecessary intermediate storage. Such coupling normally requires that the outputs of the machines in question be about the same, but it is possible to couple two slow machines with one with about double their speed.

The removal of material from the machine or from the jig can often be done advantageously by low-cost automation. Here again, time saving and work safety are the prime considerations.

Because of the influence of the quality of machined components on the quality, marketability and selling price of the final product, automation should be developed to the extent that the operator will have time to control quality and, if necessary, to remove defective pieces. In this manner the number of acceptable pieces will be

*By Juha Haakana, Enve Oy, Lahti, Finland. (Originally issued as document ID/WG.105/45.)

sufficient without the need to stock many reserve pieces, and defective material will not take up space in intermediate storage. If the operator has time to control continuously the dimensions of the machined pieces, he will be able to note in good time when the tools need sharpening or readjustment, thus preventing variations in quality and precision. If there is no automatic conveyor, labour costs can also be reduced by giving the operator time to stack machined pieces on pallets.

Degrees of automation

In any case, the appropriate degree of automation must be determined carefully. When the costs of supplying, mounting and using the automatic device are known and the savings in labour costs have been estimated, it is possible to calculate whether the investment will be profitable. There are certainly many arguments for automation, such as the improved and uniform quality of machined pieces, savings in tools and skilled labour and avoidance of accidents. These considerations are difficult to translate into monetary terms, but they greatly influence the decision.

On the other hand, caution is always advisable; complete automation should be postponed until all favourable and unfavourable results have been carefully analysed. The start should be made in operations in which a reduction of costs or other savings can be achieved.

The effect of automation on the workers is another important consideration. If machining a piece of material is so completely automatic that the operator must only see that everything happens normally, he will soon become bored with his task and get no satisfaction from it. Craftsmen with years of experience may have difficulties in learning the industrial pattern of thinking. For instance, a joiner on a building site who equips windows or doors with fittings may be quite satisfied with completing twice as many as before, even if automation should make possible a tenfold increase without undue exertion. The inculcation of positive attitudes in regard to automation on workers and their supervisors is therefore highly important.

How to automate

The basic rules for low-cost automation are the following:

(a) The component machines must be cheap, standard types that are simple, flexible and easy to set up and maintain;

(b) Systems must be easy to build around one machine and to modify later without waste of time or money.

The most commonly used automatic operations are:

(a) Transferring material into the machine;

(b) Clamping material into the operating condition;

(c) Feeding material into the operating machine;

(d) Taking processed material from the machine;

(e) Stacking processed material;

(f) Transferring material back to the operator for refeeding.

In many cases it is possible to build closed-control loops to ensure that all movements happen at the right moment and in the proper order. It should always be borne in mind that good maintenance of the automatic devices is needed to guarantee the anticipated results.

Many kinds of experimental automatic components and systems are available. Some machines have built-in automatic controls; others must be equipped with them. In some cases the machines, such as double-end tenoners, have many working heads. The prices of these machines and their setting costs are too high in relation to the length of the production series in small-scale production. When information about possibilities and standard equipment for low-cost automation is needed, the easiest and cheapest way to get it may be to contact the manufacturers or sellers, who are often willing technical help. However, to reap the full benefit of the flexibility of such automatic components, it is very advantageous to have on the plant staff a person with extensive theoretical knowledge of, and practical experience with, electrical, hydraulic and pneumatic systems because these three categories or combinations of them embrace all standard equipment for automation.

The most usual elements of pneumatic equipment are the following:

Cylinders for movements in one direction (pushing, pulling, pressing and the like), depending on mechanical arrangements
Rotary actuators to effect torsional actions
Valves and other devices for regulating the above-mentioned devices

In principle, the same kinds of components are used in hydraulic systems as in pneumatic ones. However, it is easier to achieve accurately regulated speeds and more force with a smaller cylinder hydraulically than pneumatically. Conversely, a hydraulic system is in many cases more expensive than a pneumatic one, particularly when compressed air is already available.

A typical example of pneumatic equipment installed to operate a router is presented in the circuit diagram of figure I. Compressed air is fed from the mains through a shut-off valve (1) and filter-reducing valve-lubricator unit (2). When the foot pedal in connexion with the valve (3) is free, the router head (9) is in the upper position and the clamp (12) is opened by the spring in the cylinder (4). The table-moving cylinder (8) is held in plunger-out position by the spring-return valve (6). When the operator presses the foot pedal, the cylinder (4) closes the clamp to hold the material in the right position on the table (11) while the router head is moving down

Figure I. Diagram of a pneumatic circuit for a router

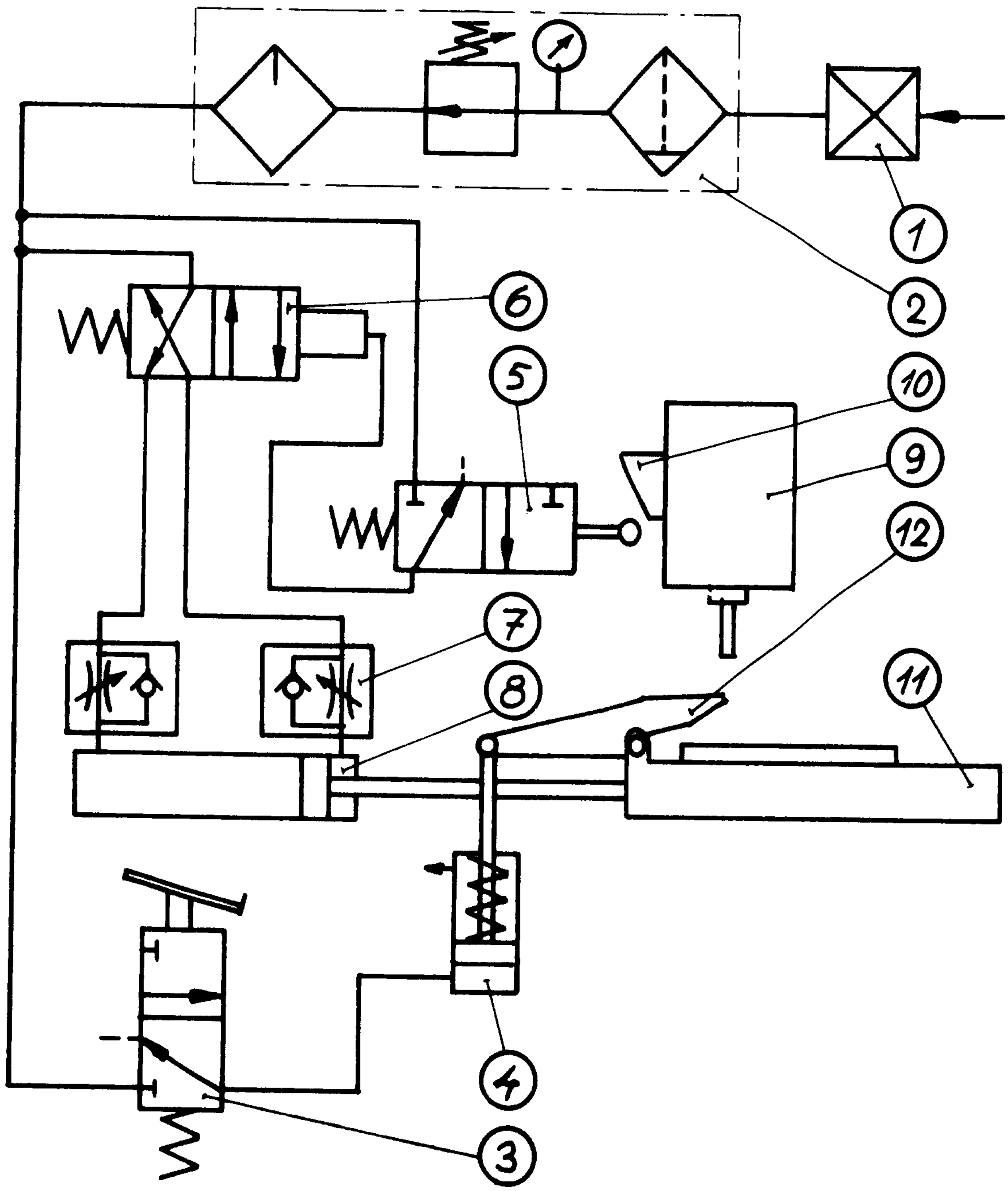
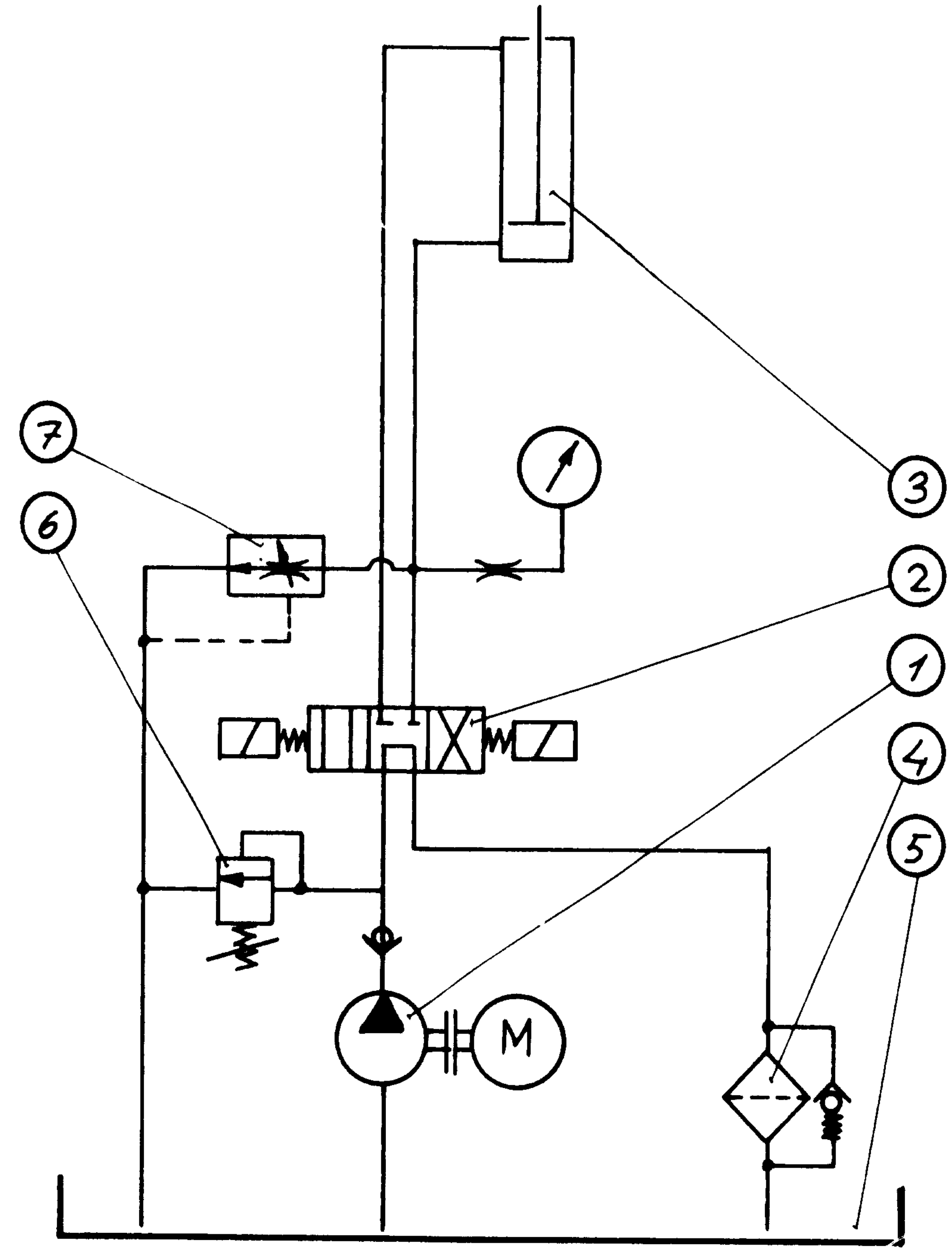


Figure II. Diagram of hydraulic circuit for cylinder operation

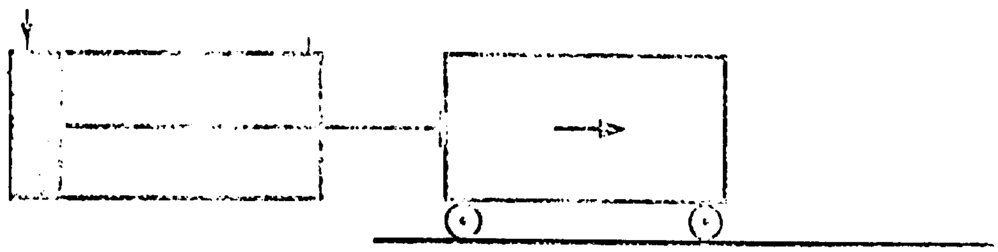


When the router head is at the proper height, the adjustable cam (10) on it strikes a roller-operated spring-return valve (5), which sends a mains air signal to reverse the valve (6). The double-acting cylinder (8) pulls the table with the clamped material past the cutter. The speed of the table movement is controlled by the one-way restrictors (7). The table travel is limited by adjustable mechanical stops.

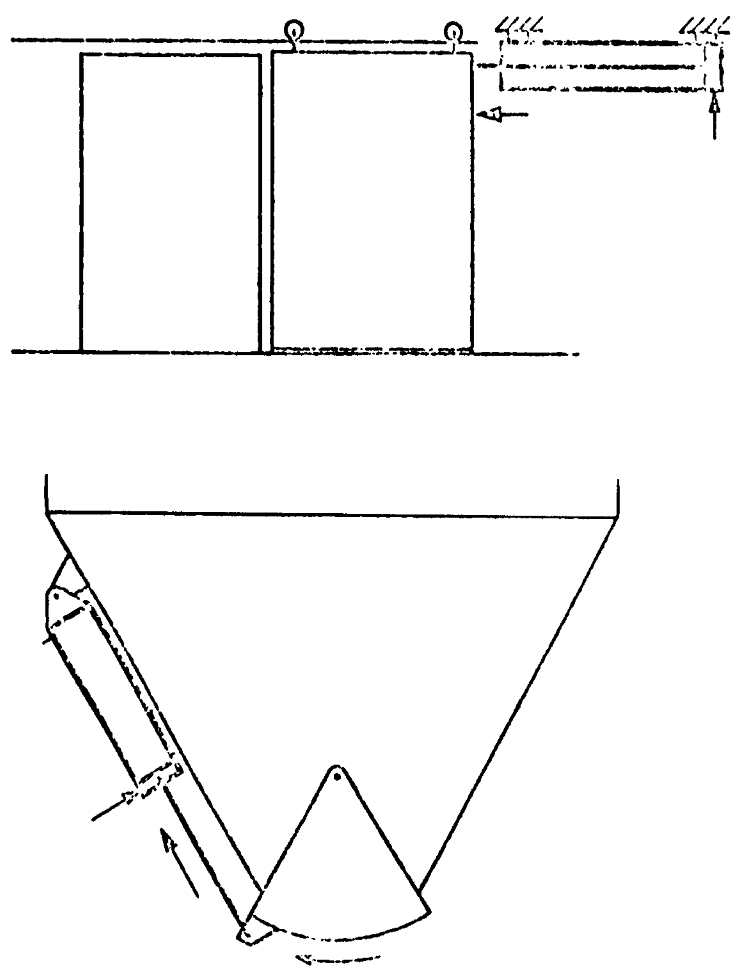
Figure II shows a basic circuit diagram for the operation of a hydraulic cylinder. Pressure for the system is imparted by the motor (M) to a pump (1). When the valve (2) is over to the left, the cylinder (3) pulls at full speed according to the pump capacity. The return oil flows freely through the filter (4) to the oil container (5). The relief valve (6) protects the pump against a too high counterpressure. When the valve (2) is over to the right, the cylinder (3) pushes, controlled by the adjustable flow-control valve (7).

Some applications of pneumatic circuitry are presented in annex I, some simplified symbols of hydraulic and pneumatic circuitry in annex II and some symbols for control mechanisms in annex III.

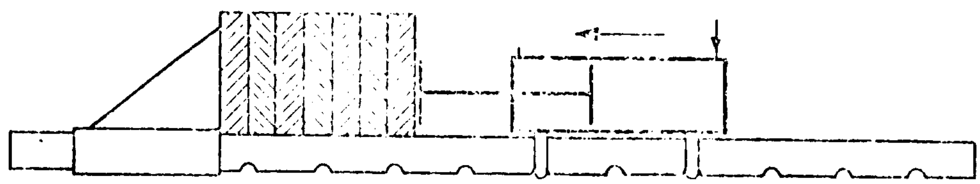
SOME APPLICATIONS OF PNEUMATIC CIRCUITRY

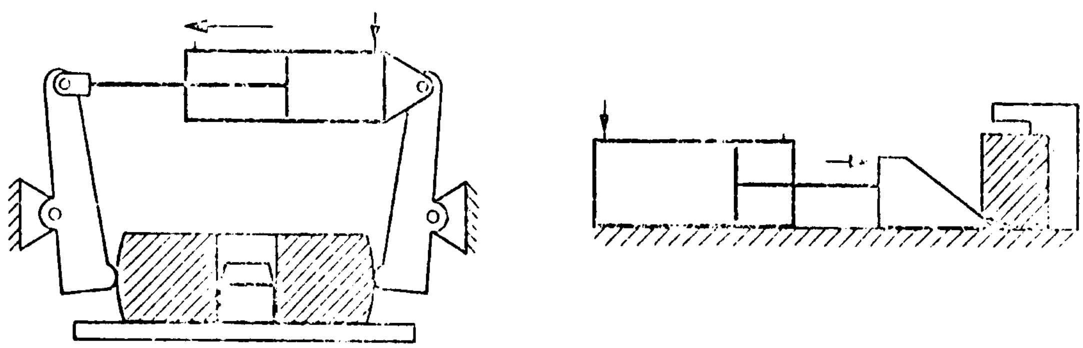


Pushing

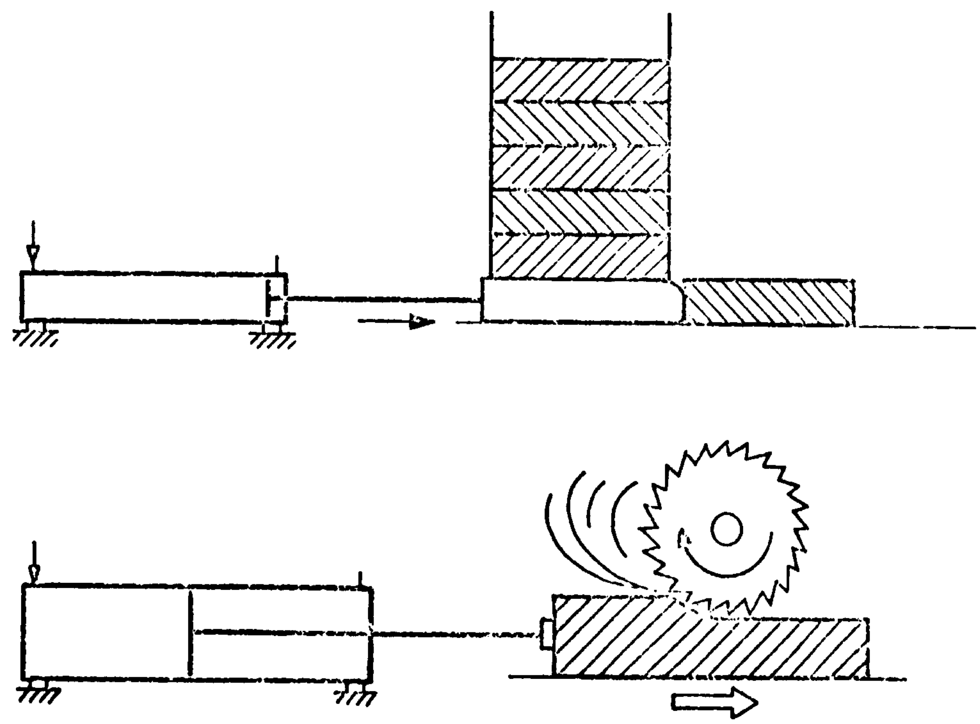


Opening and closing (doors, shutters and the like)

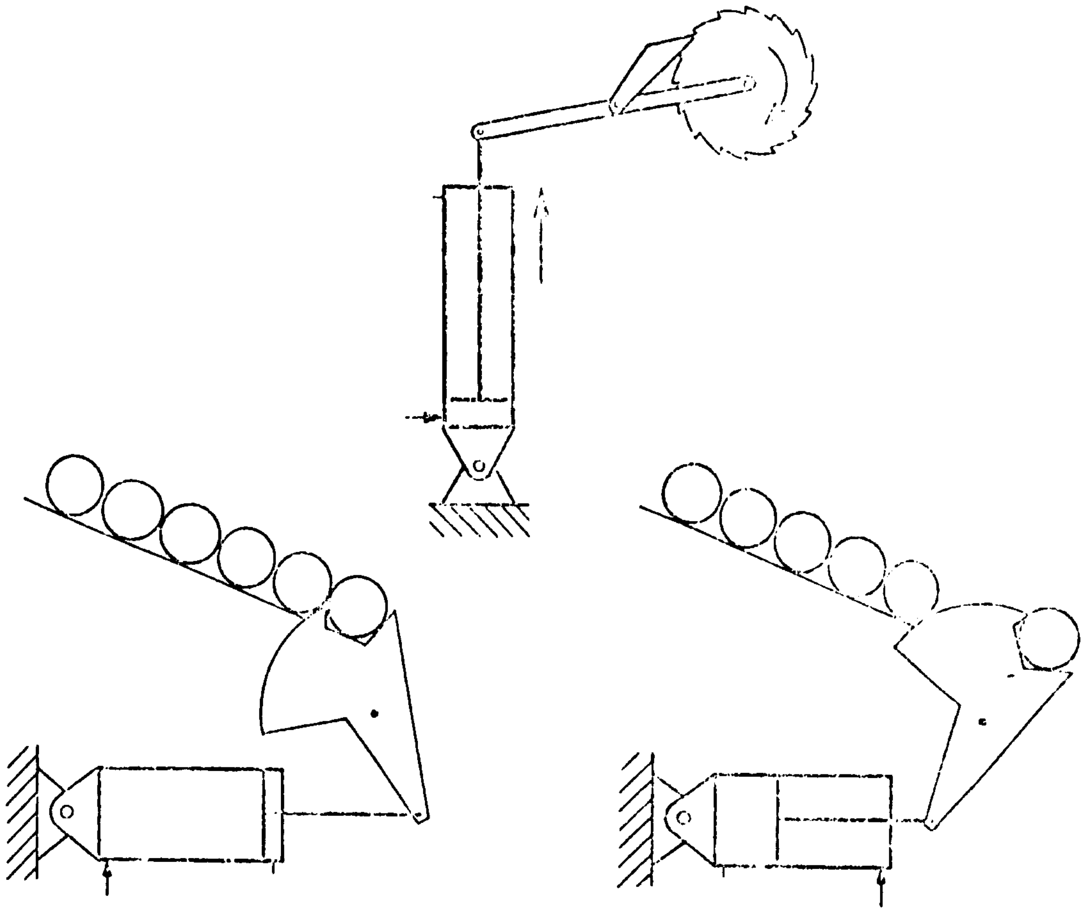




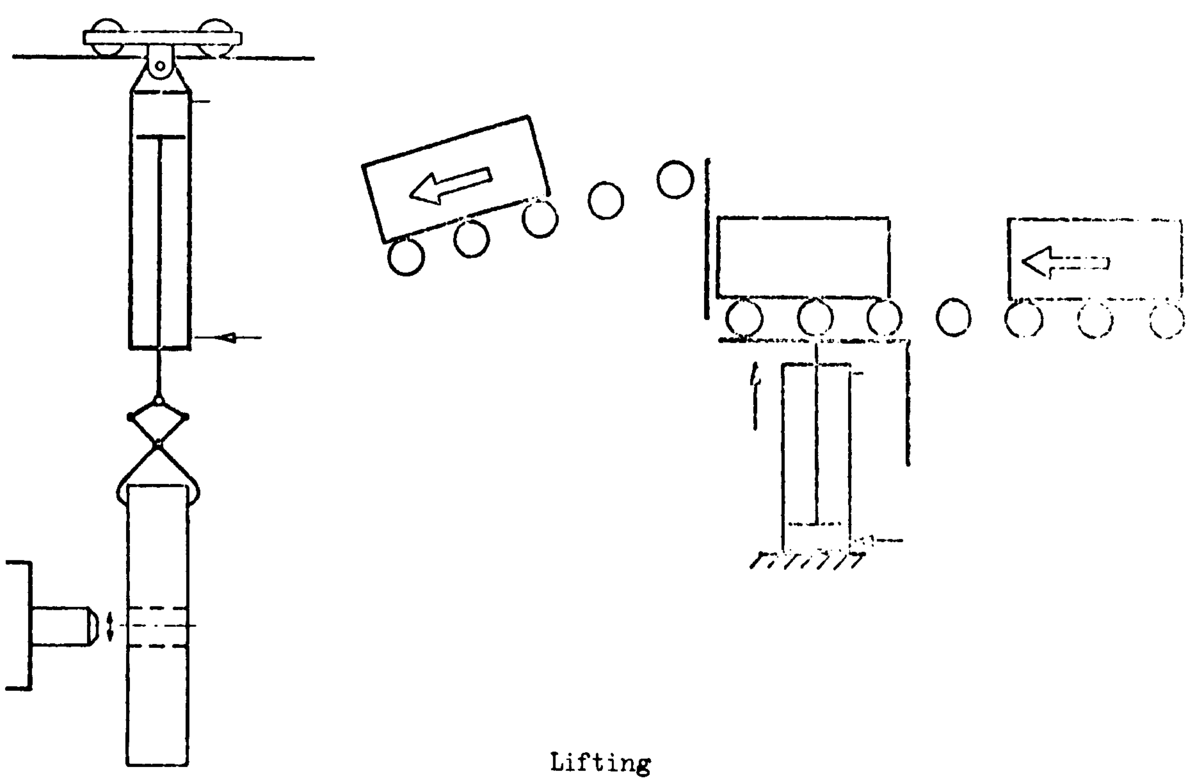
Clamping



Feeding



Indexing



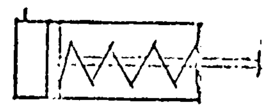
Lifting

Annex II

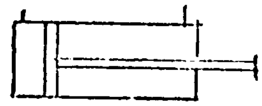
SOME SIMPLIFIED SYMBOLS OF HYDRAULIC AND PNEUMATIC CIRCUITRY[a]

CYLINDERS

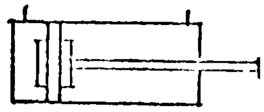
Single-acting cylinder
(Return stroke by return spring)



Double-acting cylinder
(The fluid operates in both directions)

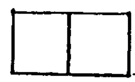


Cylinder with cushion

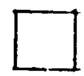


CONTROL VALVES

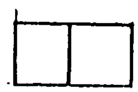
Directional control valves



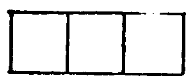
Several service positions
each shown by a square



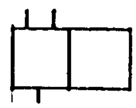
With two positions



With three positions

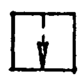


External flow lines

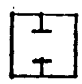


Internal flow paths

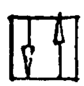
1 Path



2 Ports closed

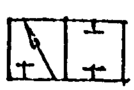


2 Paths



2 Paths, one port closed

2/2 Directional control valve



3/2 Directional control valve

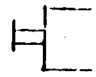
5/2 Directional control valve

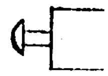
[a]Provisional recommendation RP 3 of the European Oil Hydraulic and Pneumatic Committee (CETOP), Frankfurt am Main, Federal Republic of Germany.

Annex III

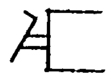
SOME SIMPLIFIED SYMBOLS FOR CONTROL MECHANISMS[a]

Manual control

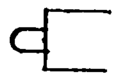
Without indication of method 

By push-button 

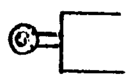
By lever 

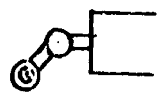
By pedal 

Mechanical control

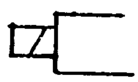
By plunger 

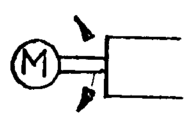
By spring 

By roller 

By roller trip 

Electrical control

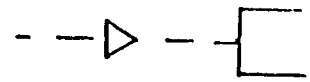
By solenoid 

By motor 

[a]See annex II, note [a].

Pressure control

Direct control



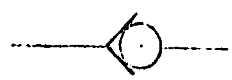
Indirect control

Combined control

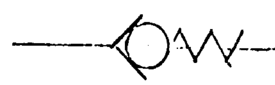
By solenoid and pilot valve

Check valve

Without back pressure

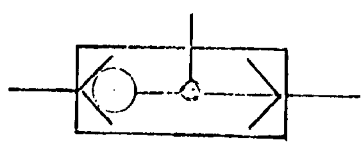


With back pressure



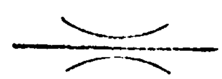
Shuttle valve

The inlet under pressure is connected to the outlet and the other inlet is closed

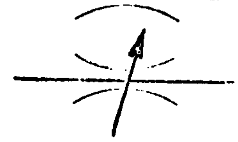


Flow-control valve

Without control

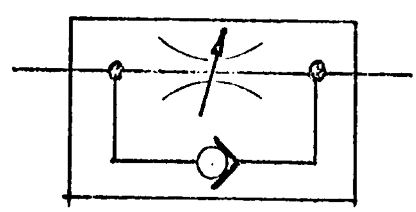


With manual control

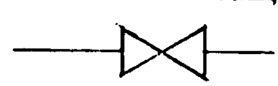


One-way restrictor

Valve allows free flow in one direction and restricted flow in the other.



Shut-off valve



Flow line

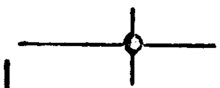
Working and return lines

Pilot control line

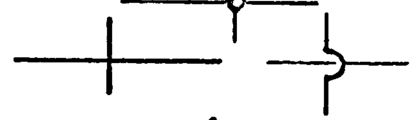
Drain line

Flexible pipe

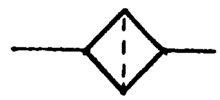
Line junction



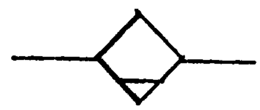
Crossing lines (not connected)



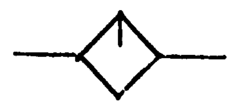
Filter or strainer



Water trap

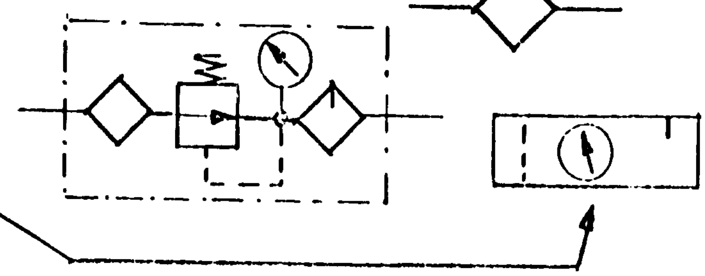


Lubricator



Maintenance unit

(Simplified)



XXIII. Low-cost automation systems*

Definitions[1]

Manual work is the first stage of production, in which various manually operated tools may be used.

Mechanization is a stage in which the major part of the work is performed by a machine. It is also the first stage of a further development of production in which the worker's simple motions are replaced by machines.

Automation is a more advanced stage of production in which a large number of the worker's motions are replaced by special equipment and components.

Low-cost automation involves mechanization and automation. One may also speak of a "degree of automation", meaning a low degree of automation.

An impulse means the initial signal, order or control of operation, actually starting the operation.

A feedback system is used to evaluate the results and to correct the control of the machine, if required, on the basis of the results.

Significance of automation

The main consideration in the use of automation is human and economic: a human being should not be used as a machine to do simple, heavy or fast work because machines perform this work more economically.

There are several advantages to automation:

(a) Work becomes lighter;

(b) Precision of the work is improved

(c) Quality of the work is improved

(d) Machines last longer

(e) Tools last longer

(f) Speed of the work increases

(g) Monotony of the work decreases

(h) Work motivation is increased

Many of these advantages are obtained even at a low level of automation. It is particularly important to realize that automation does not mean only advanced, sophisticated and expensive systems, but frequently advantages are obtained even with simple means.

A machine is tireless and therefore can operate with great precision beyond the point at which human beings tire.

Means of automation

Mechanical devices are some of the oldest means of automation. For example, in steam engines the speed has for a long time been controlled with centrifugal force; moving levers have also been used for a long time. Because of their cumbersome and wearing nature, large size and other reasons, the use of mechanical devices is continuously decreasing, however.

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*By Osmo Moilanen, Lahti Technical Institute, Lahti, Finland. (Originally issued a document ID/WG.163/27.)

[1] For further details and standard symbols, see UNIDO "Low-cost automation for the furniture and joinery industry" (ID/154), April 1976.

Electric devices have been used ever since electricity was invented and their use is increasing, particularly in advanced automation.

Electronics has made possible the automating even of demanding systems.

Pneumatic devices are inexpensive means at the low and middle level of automation and are now very popular in industry. This chapter concentrates almost solely on pneumatics.

Hydraulic devices operate on the same principle as pneumatic devices, except that the fluid allows high pressures so that high powers are obtained with small devices. The fact that the fluid cannot become compact results in precise motions. This quality is often of great importance in working and machining.

Pneumatics

Compressed air is frequently used in automation for the following reasons:

(a) It provides a simple way of obtaining both a rotating and a linear movement;

(b) Speed control is simple;

(c) Use of air involves no danger;

(d) Air can stand high temperatures;

(e) Air is compatible with all chemicals and humidity;

(f) Leaks are neither harmful nor dangerous;

(g) Compressed-air devices are simple, often inexpensive, and it is possible to make them oneself;

(h) The principle of operation is not difficult to comprehend;

(i) It does not require the continuous use of highly paid, specialized workers who are often difficult to find;

(j) The power obtained through compressed-air systems of automation is sufficient;

(k) Compressed air is elastic and, therefore, does not easily break the devices;

(l) It can be used in both demanding and simple jobs.

Compressors

A compressor is a device that compresses air to a desired pressure.

In small compressors the air is compressed in one stage. In medium-sized compressors the type generally used in industry--the air is compressed in two stages with a cooling stage between to obtain greater efficiency.

The most commonly used pressure varies from 6-10 bar.[2]

The temperature of the air rises to approximately 200°C in one-stage compression and to approximately 100°C in two-stage compression.

During compression the humidity in the air is also compressed and, when cooled, it is condensed to water. This causes a great deal of trouble and it is therefore necessary to plan for continuous removal of water from the compressed-air network.

In a warm climate with high humidity there is a tendency for excessive water to be developed in compressed air. The water causes operational disturbances, corrosion and wear.

Piston compressors. In a piston compressor the piston draws the air into the cylinder and compresses it to the desired pressure. The inlet and outlet of air are controlled by valves. The efficiency of a piston compressor is good, and high pressures even up to 1,000 bar can be obtained with it. Because of the back-and-forth motion the machine vibrates, and partly for this reason it has lost some of its popularity during the past few years.

Vane compressors. Vane compressors are provided with a rotor with eccentric bearings. The rotor has slots in which the vanes can move freely. The volume of air between the vanes changes, and thus the air can be compressed. Efficiency is satisfactory. The machine is vibrationless and has become increasingly popular. A pressure of approximately 10 bar can be obtained with it.

Screw compressors. The screw compressor is the newest type of compressor and is still relatively little used. In it the air is compressed between two screws. The machine is vibrationless and produces air without pulsation. The pressure is approximately 10 bar. It can be used only for medium-sized and large compressors, preferably over 2 m^3/min.

[2] One standard atmosphere = 0.98679 bars.

Pneumatic centre

The following requirements should be observed in operating a pneumatic centre:

(a) It should be located in the centre of consumption, where there is a supply of clean air, where there is easy maintenance and service, in a sufficiently spacious place;

(b) Erection for piston compressors should be on the ground; for others there are no special requirements;

(c) Air intake should be from a dust-free place, and it must be protected from rain and dust particles;

(d) Air intake is filtered before its arrival in the compressor;

(e) Air is cooled for water removal and for air or water cooling;

(f) Air receivers should be pressure-resistant steel receivers with a volume of approximately 1/5 of the production of the compressor per minute. Their location should preferably be in a shady place outdoors;

(g) Air should be very dry if required for low-pressure automatics and for instrumentation;

(h) Oil filter is necessary if excessive oils are used in the compressor;

(i) A water trap is necessary to ensure that only the minimum amount of water shall get into the pipe system.

Pipe system

A linear form is suitable only for very limited use when the main line is short.

A ring is the most common form and should be used. Large systems can be divided into several rings.

Exact dimensioning is difficult and therefore diagrams based on experience are used.

The system is manufactured by welding steel pipes and by brazing copper pipes.

Installation should be on an inclined surface, with a slope of 1 : 100 in the air intake direction so that the water can be removed.

Water traps spaced 30-50 m from each other are recommended for water removal.

The air intake from the pipe system must be dry and clean and it should contain some oil in order to prevent wearing of the devices. There are always humidity and dirt particles in the system which cause corrosion. Therefore, the following instructions must be observed for the air intake:

(a) The air should be taken from the top, when necessary for the air intake;

(b) The air should be taken through a so-called maintenance unit.

The maintenance unit usually consists of four parts:

(a) A filter which is frequently a sintered filter to clean the air;

(b) A pressure-reducing valve which reduces the higher network pressure to operation pressure;

(c) A pressure gauge for pressure control;

(d) A lubricator which mixes a small amount of oil with the air.

Cylinders

Cylinders are the muscles which perform the work of automatics. The construction features of a cylinder are as follows:

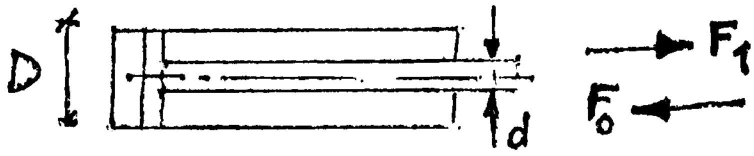
Ends: aluminium or brass, with or without cushions
Cover: aluminium, copper or brass
Piston: seal, piston rod
Size: diameter = 300 mm to 500 mm
length = 400 mm to 4,000 mm

The operation can be:

(a) Single-acting, in which the air operates in one direction only and the return stroke is done e.g. by a return spring;

(b) Double-acting, in which the air operates in both directions; this is the most common cylinder type.

The power obtained with a cylinder can be calculated from the following equations:



$$F_1 \approx 0.8 \times 3.14 \times \frac{D^2}{4} \times P$$

$$F_0 \approx 0.8 \times 3.14 \times \frac{D^2 - d^2}{4} \times P$$

Where:

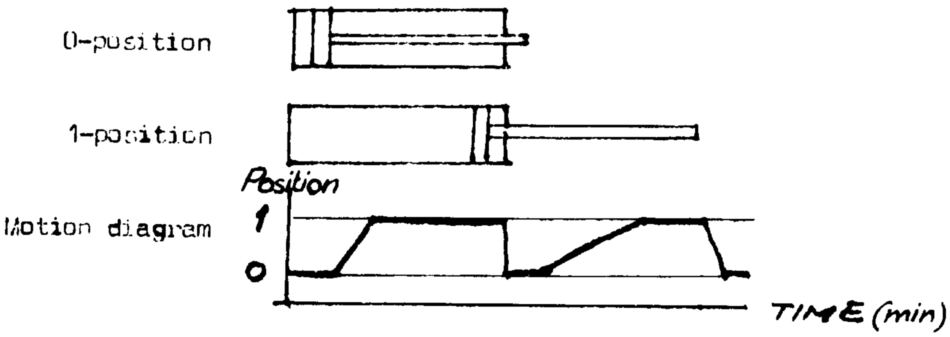
F_1 = power at 1-position
F_0 = power at 0-position
D = diameter of the piston
d = diameter of the piston rod
P = pressure

The cylinder uses air from the network.

$V = K \times n \times A \times s \times P/P_0$

K = 1 for single-acting cylinders
K = 2 for double-acting cylinders
n = number of strokes per minute
A = cylinder area = $3.14 \times D^2/4$
S = length of stroke
P = network pressure
P_0 = pressure of the outside air ≈ 1 bar

Positions of the cylinder are given below.

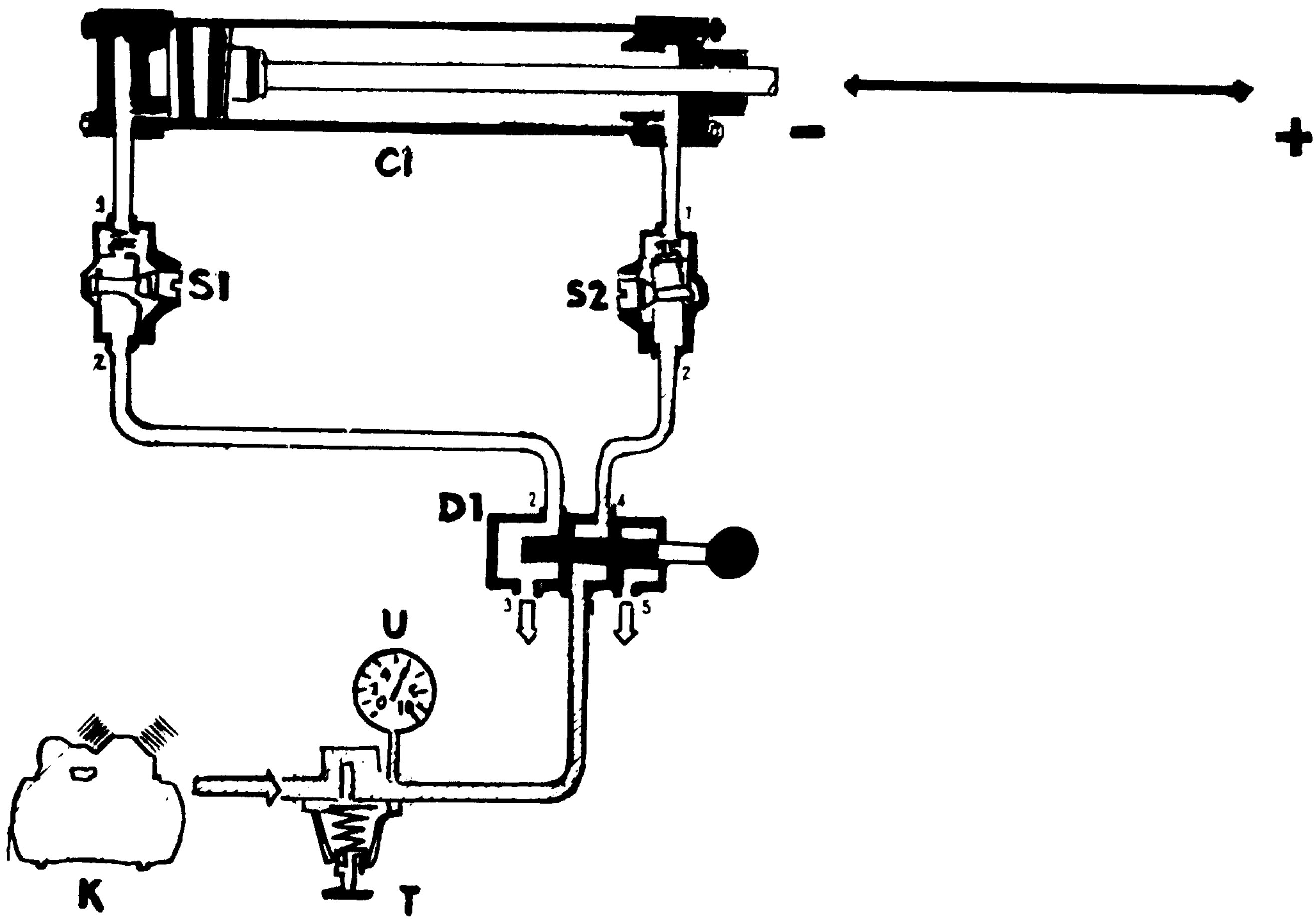


Examples

Seven examples of basic pneumatic circuits (figures I-VII) are shown in the following pages, along with detailed descriptions of their operations.[3] Figure VIII gives the scale for pressure decrease in the pipeline.

[3]For standard symbols of hydraulic and pneumatic circuits, see chapter XXII, annexes I, II and III. See also UNIDO, "Low-cost automation for the furniture and joinery industry" (ID/154), annex I.

Figure I. Pneumatic circuit 1



Key:
C1 Double-acting cylinder, with cushion at both ends
D1 5/2-velve, manual control, bistable function (5/2-velve = 5 ports/2 position-valve)
S1, S2 One-way throttle velve
T Pressure regulator
U Pressure gauge
K Compressor

Function (figure I)

Figure I indicates the three basic methods of controlling a pneumatic cylinder, namely:

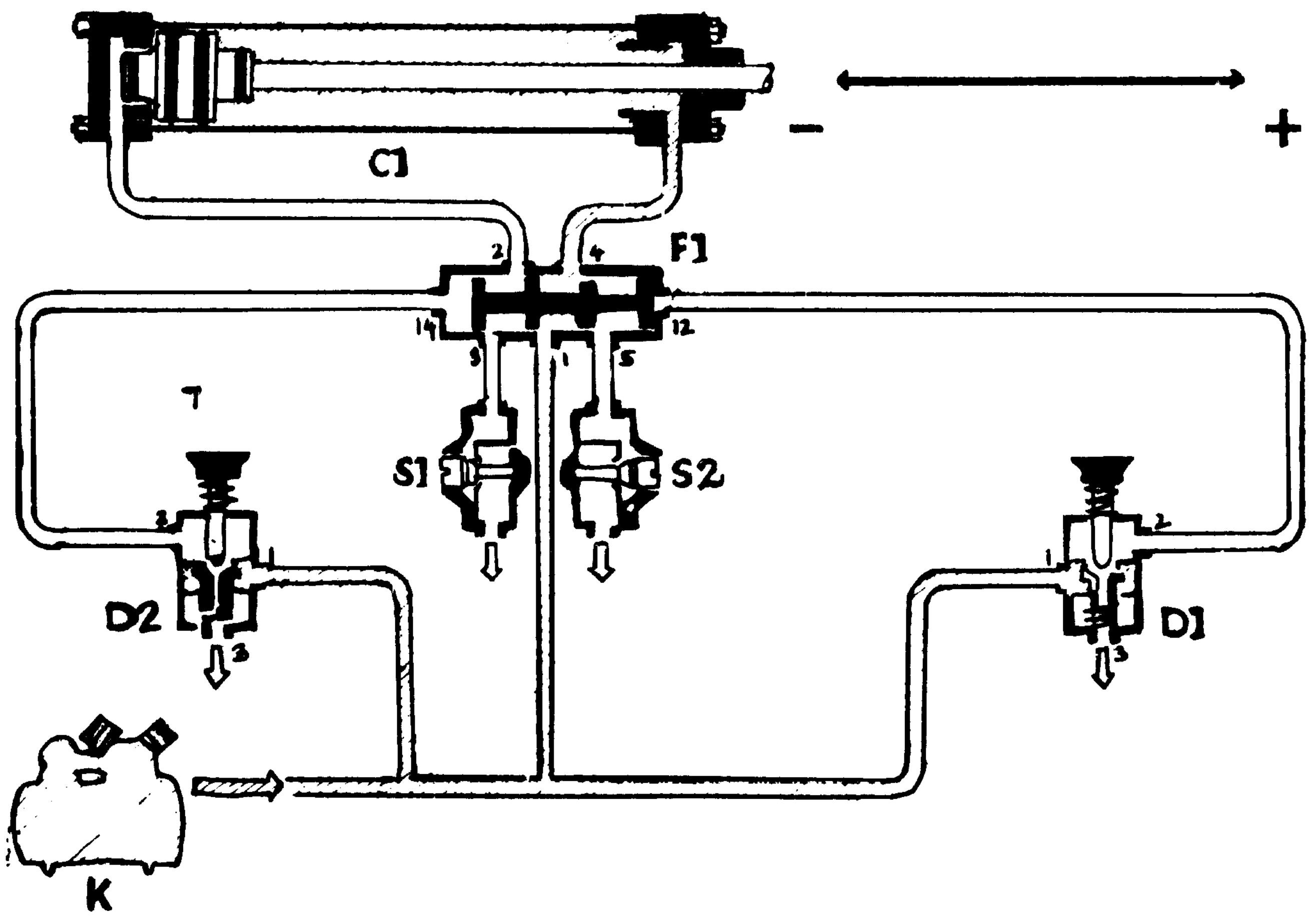
(a) The direction of the piston movement, by the directional control valve D1;

(b) The piston speed, by means of the flow control one-way throttle valves S1 and S2;

(c) The piston force, which is adjusted with the pressure regulator T.

Compressed air is obtained from the compressor K, the pressure of which usually oscillates around 7 bar. The pressure regulator T is set at a working pressure suitable for the cylinder, e.g. 6 bar is read on the pressure gauge U. In the initial position the cylinder thus has a pressure of 6 bar on the piston-rod end, i.e. the minus chamber. When the slide in the valve D1 is switched over, connexion between inlet and outlet 2, and also between outlet 4 and exhaust 5, is obtained. The plus chamber of the cylinder C1 is thereby pressurized; simultaneously, the compressed air in the minus chamber is evacuated to the atmosphere, with a flow determined by the one-way throttle valve S2. The piston and the piston rod in the cylinder C1 then move in the plus direction with a speed that is also determined by S2. When the slide in the valve D1 is reset to its initial position, connexion between inlet 1 and outlet 4, and also

Figure 11. Pneumatic circuit 2



Key: C1 Double-acting cylinder
D1, D2 3/2-valve, push-button control, monostable
F1 5/2-valve, pneumatic control, bistable
S1, S2 Throttle valves
K Compressor

Note: The directional control valve D1 can alternately be provided with spring return and has in such a case a monostable function. In addition, the valve can have various control devices, manual or mechanical, such as handle, foot pedal, plunger, roller lever etc.

between outlet 2 and exhaust 3, is obtained, whereby the piston in cylinder C1 moves in the minus direction with a speed that is governed by the one-way throttle valve S1.

The piston speed in a cylinder is actually governed by the following three factors:

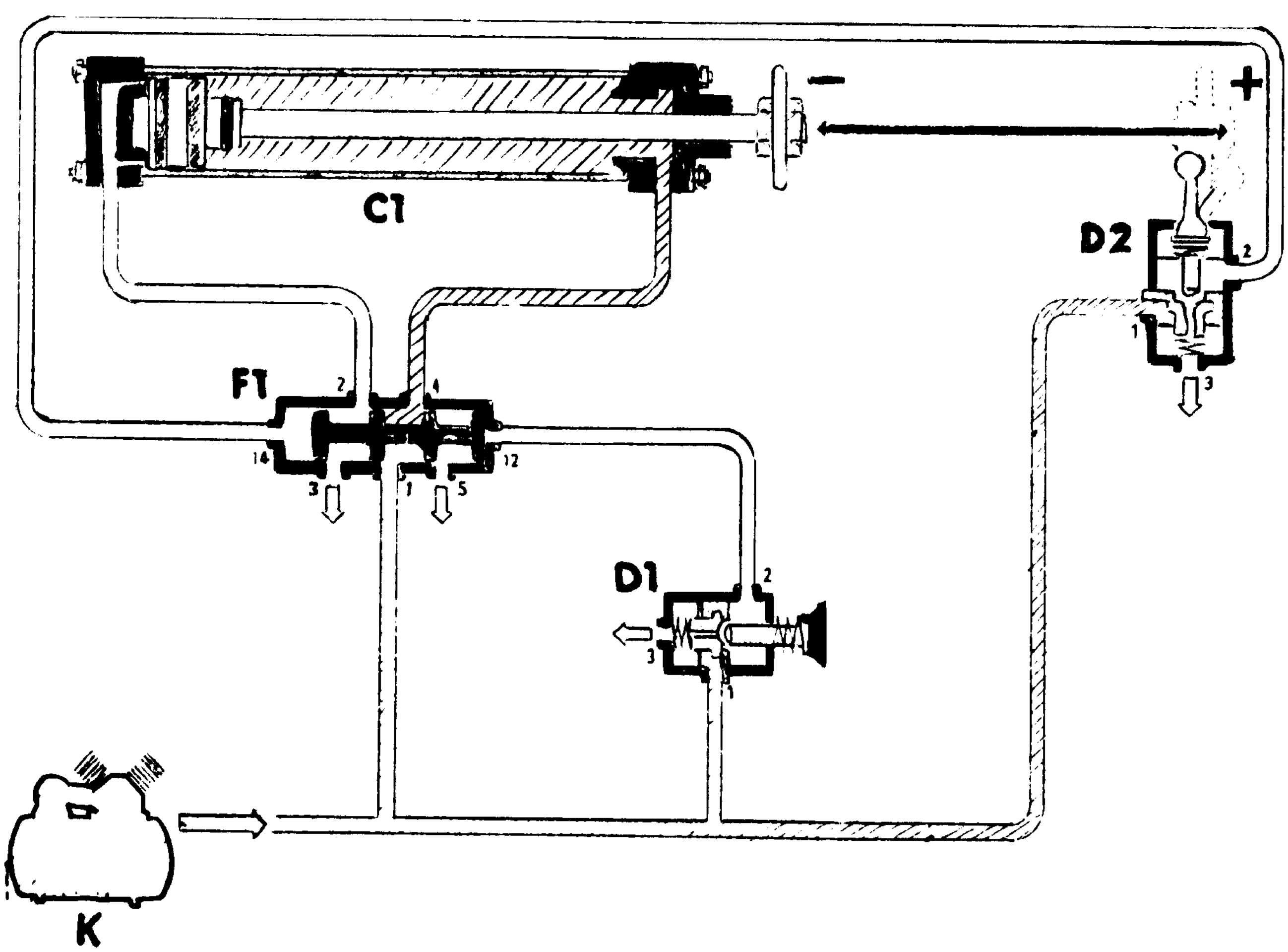
1. *The motive pressure.* This is the pressure that moves the piston forward. The motive pressure is governed partly by the pressure regulator T, and partly by the dimension of the valves and the piping. The motive pressure is always lower than the static pressure which is read on the gauge U when the piston is resting in one end position. This pressure difference is also defined as pressure drop and is a condition for fluid power transmission.

2. *The back pressure.* This is the pressure in front of the piston which is governed by throttling the exhaust air, in this case by means of one-way throttle valves S1 and S2. The built-in non-return valve is to give free flow in the opposite direction. The motive pressure can thus flow into the cylinder unrestricted.

3. *The load.* The load refers to the actual work the cylinder has to do, plus friction losses in the guidings and seals.

Most double-acting cylinders are provided with built-in cushioning in their end positions, which means that the piston speed is effectively damped immediately before its end position and its impact is thus decreased on the end cover of the cylinder. The cushioning effect is usually adjustable from the outside.

Figure III. Pneumatic circuit 3



Key: C1 Double-acting cylinder
D1 3/2-valve, push-button control, monostable
D2 3/2-valve, roller control, monostable
F1 5/2-valve, pneumatic control, bistable
K Compressor

Function (figure II)

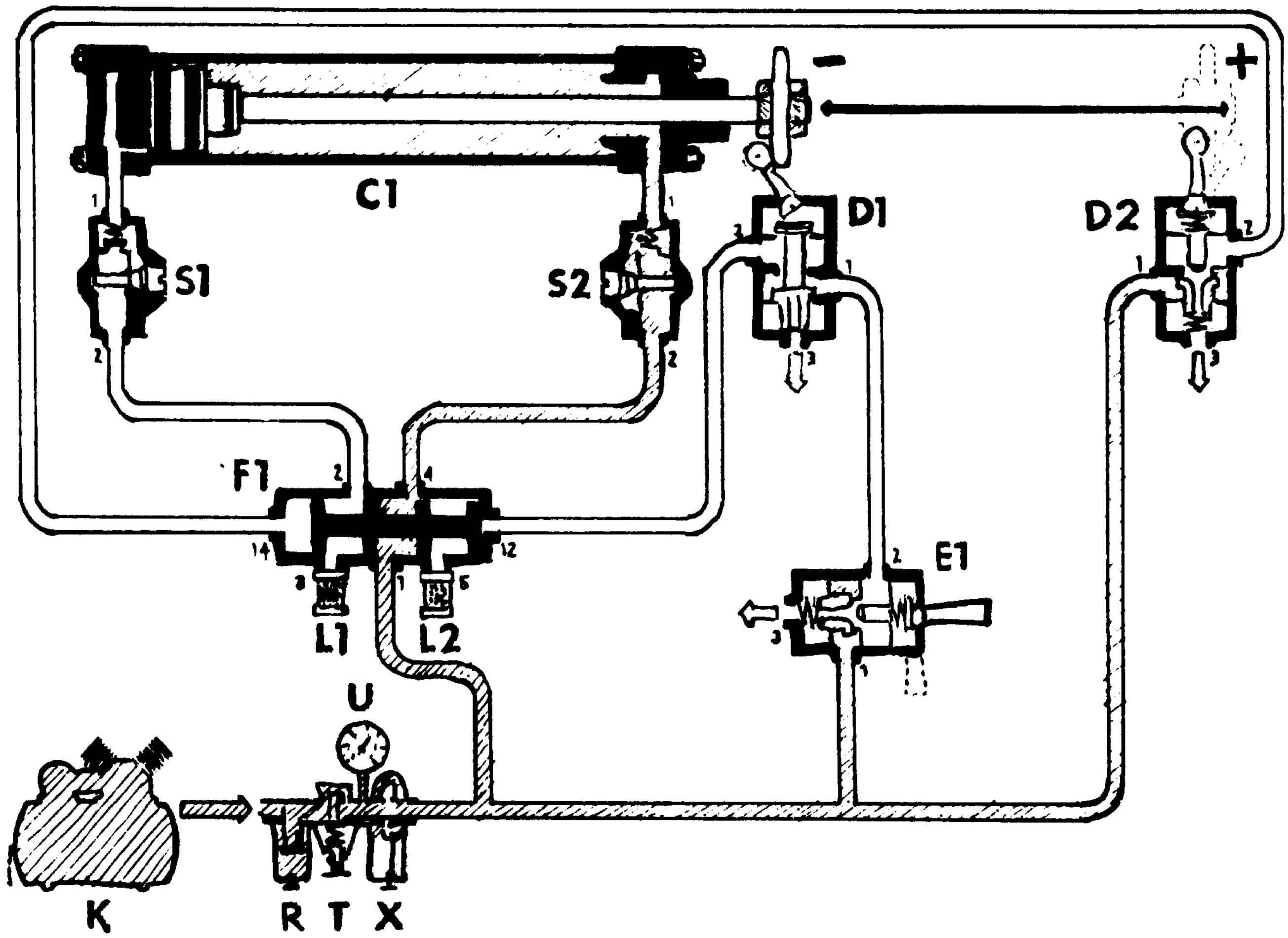
In the initial position the valves D1, D2 and F1 have air supplied to their inlet ports. As there is a connexion between inlet 1 and outlet 4 through valve F1, the cylinder C1 has its minus chamber pressurized.

When the push-button of the valve D1 is depressed, a connexion between port 1 and 2 is obtained, the control port 12 of F1 is pressurized and the valve slide is switched over. Thereby connexion between inlet 1 and outlet 2, as well as between outlet 4 and exhaust 5, is obtained. The piston in the cylinder C1 moves in a plus direction with a speed which is controlled by the throttle valve, S2.

As soon as the slide in F1 has changed over, the valve D1 can be released and the control air between F1 and D1 is evacuated through exhaust port 3 at valve D1. As the valve F1 is bistable, the slide stays in its new position and the piston in C1 carries on to its plus position and stops there. When the push-button valve D2 is depressed, the slide in valve F1 is reset and the piston in cylinder C1 returns to its minus position with a speed controlled by the throttle valve, S1.

In order to be able to reset the slide in valve F1 by depressing the push-button of D2, the push-button of D1 must be released simultaneously; otherwise the signal from D1 will block the switching of the slide. The same is of course valid in reverse; when the slide in F1 is to be changed over by a signal from D1, the push-button of D2 has to be released.

Figure IV. Pneumatic circuit 4



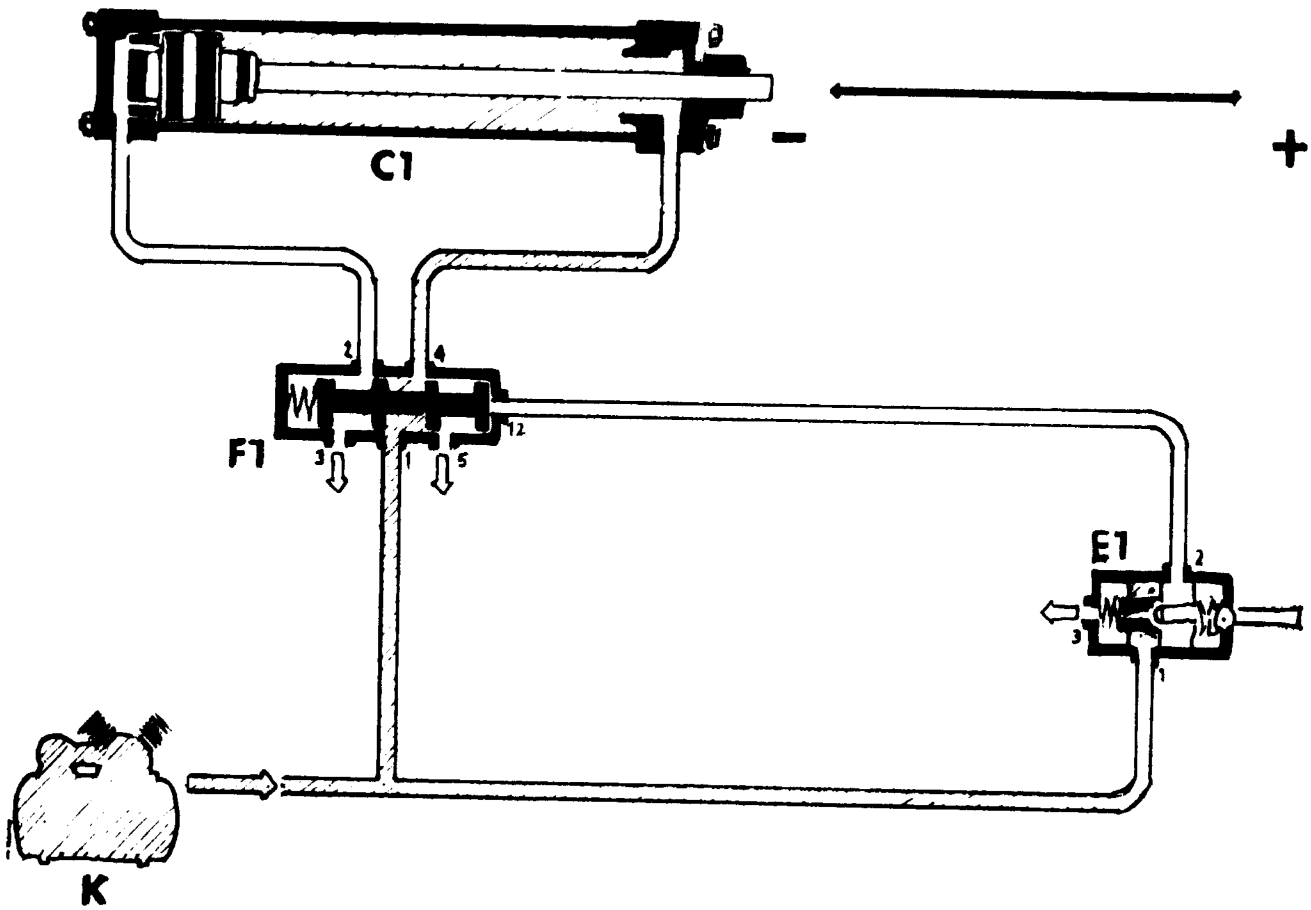
Key:	C1	Double-acting cylinder
	D1, D2	3/2-valva, roller control, monostabla
	E1	3/2-valve, handle control, bistabla
	F1	5/2-valve, pneumatic control, bistabla
	L1, L2	Silencer
	S1, S2	One-way throttle valve
	R	Air filte:
	T	Prassure regulator
	U	Prassura gauge
	X	Lubricator
	K	Compressor

The piston speed here is controlled by means of throttle valves fitted into the exhaust ports of the main valve F1. To be able to adjust the piston speed individually in both motion directions, the main valve has to be equipped with two exhaust ports.

Function (figure III)

When the push-button of valve D1 is depressed, F1 changes over (i.e. the slide in the valve) and the piston in the cylinder C1 moves in the plus direction. When the piston rod end reaches the valve D2 and actuates it, F1 is reset and C1 retracts (i.e. the piston in the cylinder C1 moves in the minus direction). To make it possible for valve D2 to reset F1, the push-button of valve D1 has to be released earlier. Usually, the valve D2 is located so that it is actuated only when the piston in the cylinder has completed the total length of stroke, but if required the stroke length can be shortened by locating the valve D2 closer to the cylinder.

Figure V. Pneumatic circuit 5



Key: C1 Double-acting cylinder
E1 3/2-valve, handle control, monostable
F1 5/2-valve, pneumatic control, monostable
K Compressor

Function (figure IV)

In the starting position the valves D2, E1 and F1 have air supply from the compressor, and thus the minus chamber of cylinder C1 is pressurized. When the valve E1 is changed over, air passes to D1, and as D1 is actuated F1 changes over and the cylinder C1 goes in the plus direction with a speed controlled by the one-way throttle valve, S2.

When the piston rod actuates the valve D2, F1 is reset and the cylinder moves in the minus direction with a speed controlled by S1. In the minus position D1 is actuated again, which causes the cylinder C1 to move positively; then D2 once again causes a negative motion and so on.

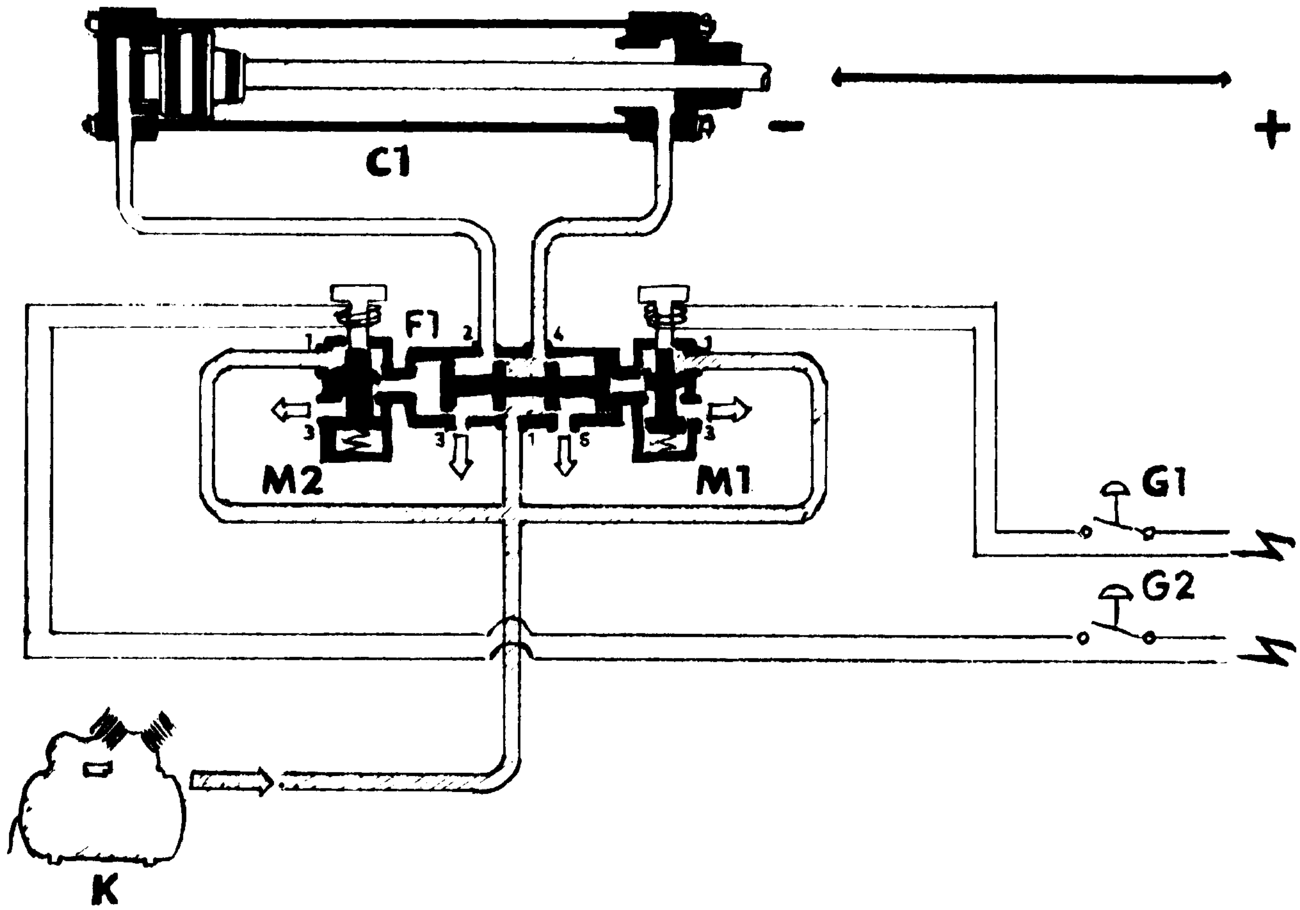
The cylinder C1 is thus working continuously forward and reverse as long as the valve E1 remains in "starting position" and the air supply is sufficient. If the valve E1 is reset to "stop position", the cylinder C1 will just complete a started cycle and then stop in the minus position. The plus position of the cylinder can of course also be chosen as the initial position, which is obtained if the valve E1 is located on the supply line to D2 instead of D1.

The two silencers, L1 and L2, are to decrease the noise from the exhaust air.

The pressure regulator, T, keeps a constant air pressure, which can be read at the pressure gauge, U.

The lubricator, X, finally injects a lubricant in the form of a micro-oil fog into the compressed air and thus to the moving parts of the components.

Figure VI. Pneumatic circuit 6



Key: C1 Double-acting cylinder
F1 5/2-valve, pneumatic control, bistable
M1, M2 3/2-valve, solenoid control, monostable
G1, G2 Electric push-button switches
K Compressor

Function (figure V)

When the valve E1 is actuated, the valve F1 receives control air and changes over, and the cylinder C1 goes in the plus direction. As soon as E1 is released, the control chamber of the valve F1 is evacuated, the valve slide is reset by a spring and C1 goes in the minus direction. In this case the valve E1 has to be actuated as long as the plus position is to be kept.

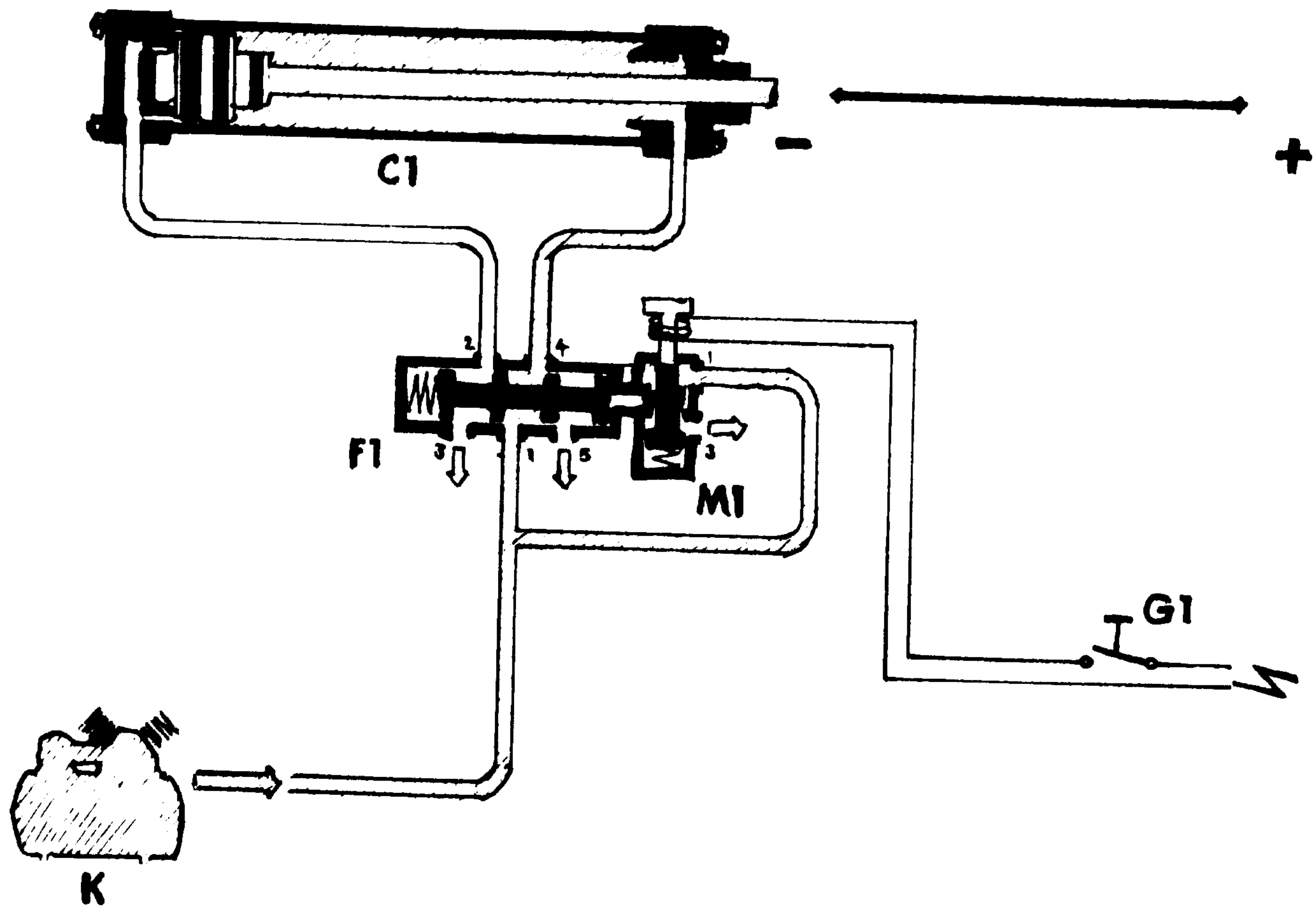
If, instead, the plus position is required as the initial position, the piping between the cylinder and the main valve, F1, is switched over. The valve F1 can alternatively be controlled by a bistable 3/2-valve.

If the cylinder C1 is to operate as single-acting, this may be obtained either by operating the cylinder direct by a 3/2-valve, or by plugging one of the outlet ports on the 5/2-valve.

Function (figure VI)

When the push-button switch G1 is actuated, the solenoid valve M1 changes over, which in its turn means compressed air changes over the main valve F1, and the cylinder C1 makes a plus movement. As soon as G1 is released, the valve M1 is reset.

Figure VII. Pneumatic circuit 7



Key: C1 Double-acting cylinder
F1 5/2-valve, pneumatic control, monostable
M1 3/2-valve, solenoid control, monostable
G1 Electric push-button switch
K Compressor

When, instead, the push-button switch G2 is actuated, M2 changes over, the valve F1 is reset and the cylinder C1 goes in the minus direction. M2 is reset when the push-button G2 is released.

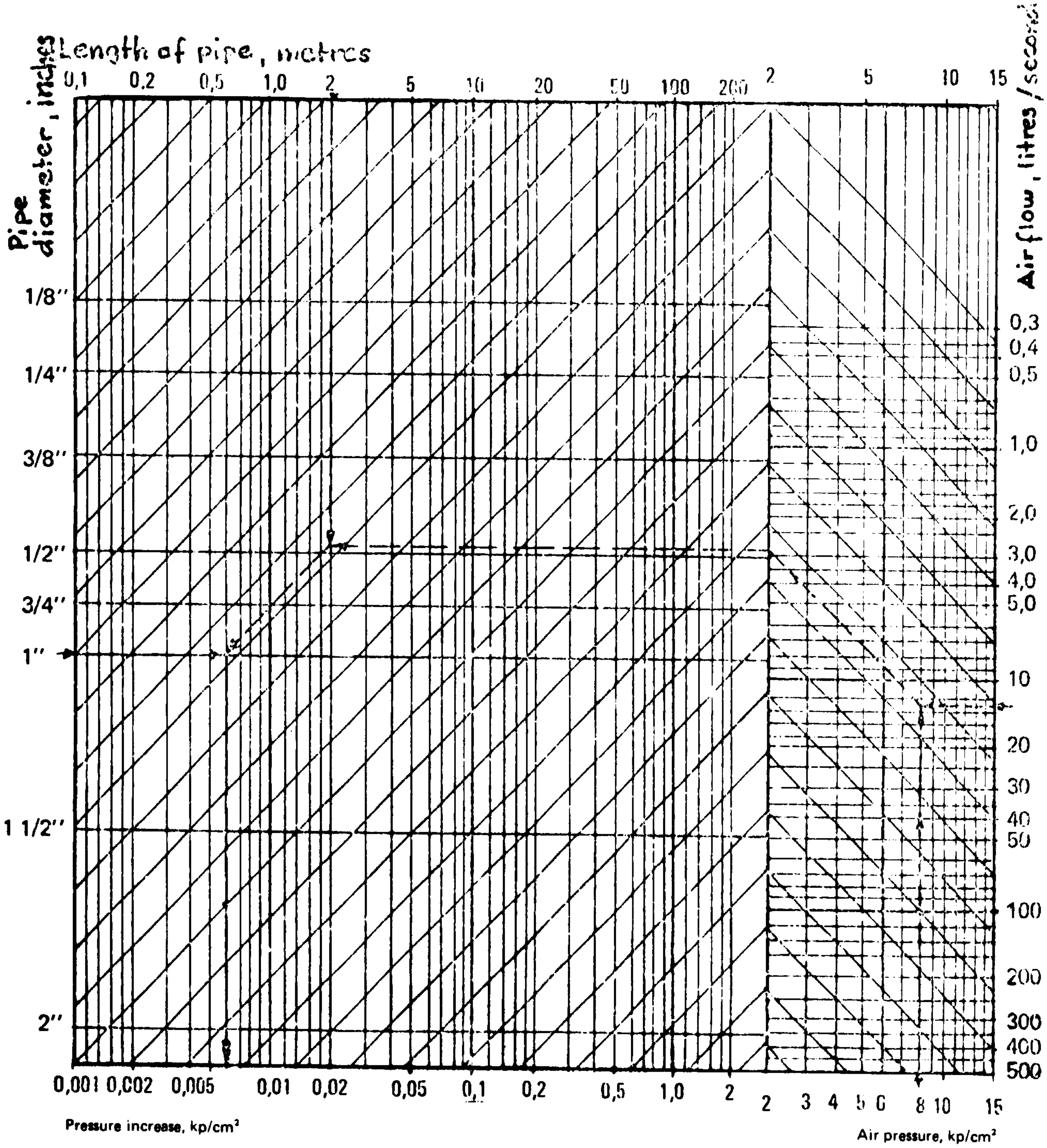
The valves F1, M1 and M2 often form a unit with a common inlet on the main valve, which at the solenoid valves are supplied with air through channels in the main valve.

Function (figure VII)

When the push-button switch G1 is changed over, the solenoid valve M1 will open and pass control air to the main valve, F1. This will cause the valve F1 to change over and the cylinder C1 to make a positive stroke.

When then G1 is reset, M1 is de-energized and reset, the control air to F1 is evacuated and F1 is also reset, after which the cylinder returns to its initial minus position. The valves F1 and M1 are often built together to form one unit with a common inlet situat. 1 on the main valve.

Figure VIII. Pressure decrease in the pipeline



Air-flow scale is valid in atmospheric pressure and a temperature of 20°C

Total pressure decrease in pipeline may not exceed value 0.1 kp/cm²

Example (dot-line in graph)

Values given:	Air pressure: 8 kg/cm² Air flow: 13 l/s Length of pipe: 2 m
Question:	Pressure decrease in 1-inch pipe
Answer:	Graph gives 0.006 kp/cm²

XXIV. Maintenance of machines and equipment*

This chapter is limited to the machines and equipment that perform primary functions in middle-sized and small industrial plants. These functions comprise:

- Maintenance of machines and tools
- Advance service and lubrication
- Erection of new machines and equipment
- Alteration work 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 pl[illegible] it includes several shops or if it deals with several fields of the woodworking industry and not only wi[illegible]ry 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 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 downtime;

(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 big concerns 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

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manufacturers give information on such special repair shops. Annual or other long-term agreements will ensure that the special repair shop shall always have 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 the work machines are bought 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 man, 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 connexion 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 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 supervising 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 additional 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 man goes from year to 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, as for instance, separate departments for preventive maintenance, scrapping and repair, plastics, and instrumentation and automation (possibly even electronic).

In general, within the over-all maintenance organization, there are so-called decentralized and centralized systems. In the former, the maintenance men 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 circumstances such as the nature of the working process, the cost of downtime 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 a paper machine or, in joinery industry, a painting line) are in operation. In such cases it is worth having maintenance workers to control the operation and condition of the equipment.

Nevertheless, the following functions should be centralized:

Planning work
The generation and distribution to production areas of electricity, gas, 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 manpower 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 preferably, 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 numbers of bearings when the machine is disassembled, the numbers of 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 joinery industry, the objects for filing are woodworking machines, presses, conveyors and certain hand tools such as sanders.

The basic card also serves as a 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 joinery industry, 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 electrotechnical data such as motor type, serial number and revolutions per minute need 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 shutdowns;

(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 joinery industry, maintenance should be extended to painting and laminating equipment, rapidly rotating bearings, drive belts, chains and chain wheels.

Before an extensive maintenance programme is begun, the persons concerned should be charged 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
Arrangement of a reliable spare-parts service

Furthermore, it is important that the preventive service group consist of eager and active workers.

The inspection includes two different functions: routine inspection and maintenance, and inspection according to the programme for each particular machine. In joinery and other 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-suction 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 knife shaft bearing which operates at more than 9,000 rev/min for a high-speed machine such as a single-spindle shaper. 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 avoid the damage.

The above listings 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. Correct determination of the inspection period is the basic requirement for a successful programme of preventive maintenance. Too frequent inspection is wasteful of 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.

The 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 joinery industry a knife in poor condition may cause some of these abnormalities, so that the intervals between the replacement of knives in woodworking machines should be observed carefully.

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 producing much 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 thicknesses and protectiveness of grease coatings should be ascertained at the same time.

Preventive engineering

Preventive engineering entails the investigation and selection of raw materials and various protections, 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 constructions, raw materials and protections have been found to be inadequate. Much work is needed 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 lubrication:

(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 accomplished 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)

E = width of the bearing (in millimetres)

To economize on lubrication costs and to ensure reliable lubrication, some larger 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 joinery industry, 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;

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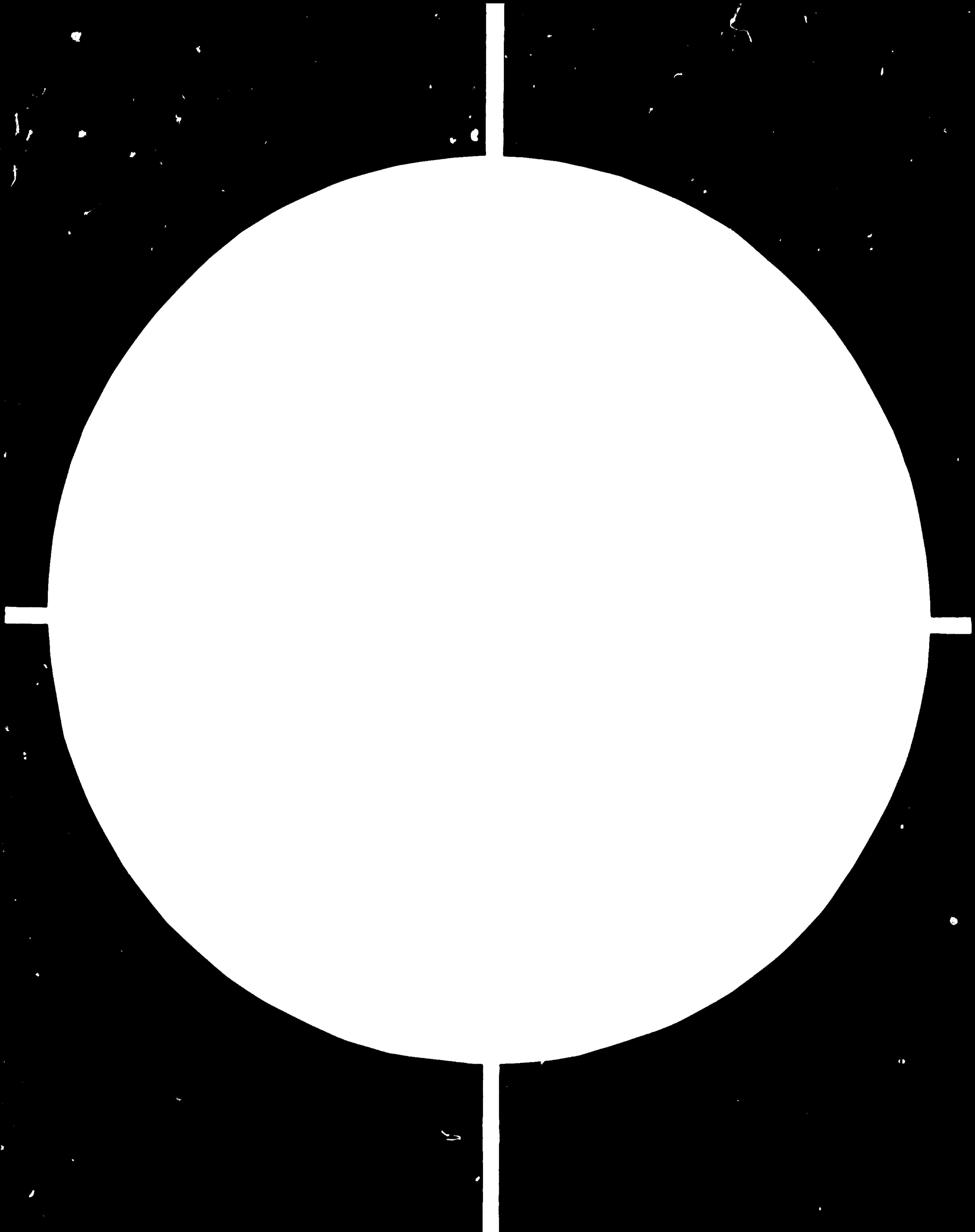

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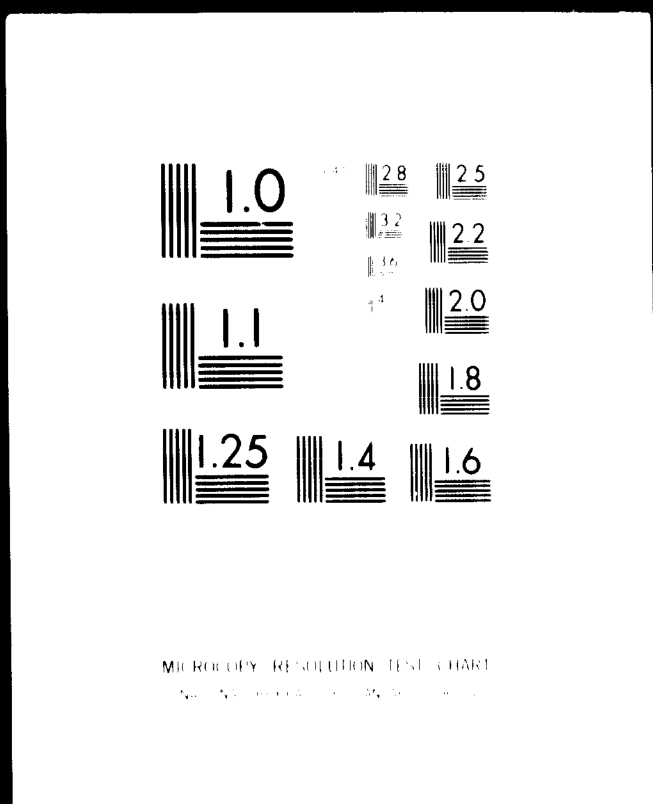
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(e) Use of inhibitors of some reactions involved in corrosion;

(f) Using materials that do not tend to corrode in the given circumstances.

The above listing shows that, in many cases, the corrosion-prevention methods require a considerable knowledge of chemistry. It may also be seen that action on point *(a)* seldom can be undertaken on site; it is usually done by the manufacturer. When the machinery is ordered, however, the purchaser can influence the matter and try to obtain a construction solution suited to the conditions of use.

On the other hand, it is possible to alter conditions according to point *(b)*. The air of the factory hall can be cleaned and dried, and its carbon dioxide content can be reduced. If the problem concerns piping or conduits, flow speeds can be reduced. Ventilation may also be improved.

The protective measures listed in point *(c)* are the most usual and have been in use from early times. With painting, the surface should be cleaned thoroughly, a corrosion-inhibiting primer should be used, and a tight and covering paint should be applied to the surface. Two excellent traditional primers are red lead and zinc yellow. Among the surface paints used are bitumen paints, reaction lacquers and paints, and silicone resin paints.

Among plastic coverings there is a wide range of paints, lacquers, pastes and solutions. They are now used widely and have proved their value in protective and wear-resistant applications.

Rubberizing can be considered for tanks, pipes, conveying rollers, glue rollers and gluing machines in general. Rubberizing should be done only by a fully competent vulcanizer to ensure that the rubber shall hold firmly to the surface to which it is applied.

Boiler masonries, glazing and ceramic coatings should be used only in places subject to very high temperatures.

Metal coatings and platings are not always intended to protect against corrosion but are sometimes used for protection against wear or to give gloss to the object in question. The hot-dipping, spraying and electrolytic methods are the most usual. Zinc, chromium, nickel, aluminium, tin and lead are used as covering layers.

The other methods listed are of little importance in the joinery industry, except in plants where metal furniture parts are used. In the last-mentioned cases, there should be an expert in this line available, so that such parts will be treated correctly and with the right materials.

Finally, so-called provisional protection, which means the use of materials that influence the surrounding air, or the use of protective films, should be mentioned. These protective films are of PVC plastic, which can be torn off. They are first melted, after which the object is dipped into the molten mass (temperature 185°C). The chemicals that influence the surrounding air are called the VPI (Vapour-phase inhibitors), which form a protective gas layer on the object.

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.

The ever-increasing mechanization and automation have also contributed to the capital value of maintenance stock. The increasing costliness of downtime 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, to expedite repairs and reduce downtime, increasing amounts of spare parts and devices for the most essential machines should be held in stock. On the other hand, however, 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 where 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. Furthermore, it is worth while to discuss the necessity of each particular spare part with other users of the machines, especially when these parts are expensive.

Standardization should also be striven for; for instance, all the machines and machine parts, threads, holes and bearings should be in the metric system; measurements in inches 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 that 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 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 below concerns a large, essential electric motor in three-shift operation. Its downtime cost has been calculated at Fmk 200/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 method of choice, and it is therefore economic to keep a complete rotor in reserve.

COMPARATIVE COSTLINESS OF FOUR WAYS OF PERFORMING THE PERIODIC OVERHAUL OF A LARGE ELECTRIC MOTOR

Type of overhaul	*Repair time (hours)*	*Costs (Fmk)*			
		Downtime	*Parts*	*Labour*	*Total*
Complete overhaul	240	48 000		6 000	54 000
Rewinding etc. of rotor	144	28 800	1 000	2 900	32 700
Replacement of rotor	7	1 400	8 000	300	9 700
Replacement of motor	3	600	16 000	100	16 700

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 normally are 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, 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 screws. When the site of the machine has been fixed, cavities for the foundation screws 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 screws 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 this time, a spirit level should be employed to check the horizontal position of the machine.) The screw cavities are then filled with cement grout. When it has hardened, the foundation screws are tightened. At this stage, care should be taken that no tension is created in the machine; in other words the screws must not exert a bending or twisting effect on the frame, which can occur if the machine is not steadily or horizontally placed. 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-evacuation 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 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 working machine. The advantages of such a centralized system are not limited to safety and cleanliness; the waste thus gathered can be used further in particle-board or cellulose mills.

The fitting of such wood-waste ductwork 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. In new plants under planning or construction, it is possible to provide floor channels for this suction network so that the shavings on the floor can be swept into holes to be transported away.

XXV. Maintenance of machine parts*

General points

The machinery of a company 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 a 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 the 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 transportation. The cutter shafts (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 to see if 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 is always 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 after, 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 on. These must be carefully observed.

In general, the manufacturing companies lubricate the bearings of a machine before delivery. The exceptionally high temperature and relative humidity in the developing countries require considerably shorter intervals between services. 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 make of lubrication material is substituted for the one used before, the former material must be thoroughly cleaned away. Mixtures of lubrication materials often result 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 for a longer period; immediate oiling or greasing is necessary. To oil the bearings rotate them 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:

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

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Maintenance of electric machine parts

The 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 otherwise in a way that would prevent the 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

The starting equipment is inspected in connexion 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 work 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 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. They and 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 main currents 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.

For switching on strong currents, contactors filled with transformer oil are used. 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 which will result in its losing its insulation qualities.

The moving connexion 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 listening 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 over-heating 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, remove the fuses of the feed conductor of the electric motor and put up a sign "Men at work" in the distribution centre. Only the person who put up this sign may take it down again.

Only a skilled mechanic may 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:

Rev/min	*Lubrication*
under 1 000	after 2 400 hours in operation
1 500	after 1 200 hours in operation
3 000	after 200 hours in operation
24 000	daily

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 must be used, preferably one recommended by the manufacturer, e.g.:

Mobil Oil	Mobilux grease No. 2
Shell	Alvania grease 2
Esso	Beacon 2
Gulf	Precision grease No. 3

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 conduits must be marked with tape to ensure correct revolution direction.

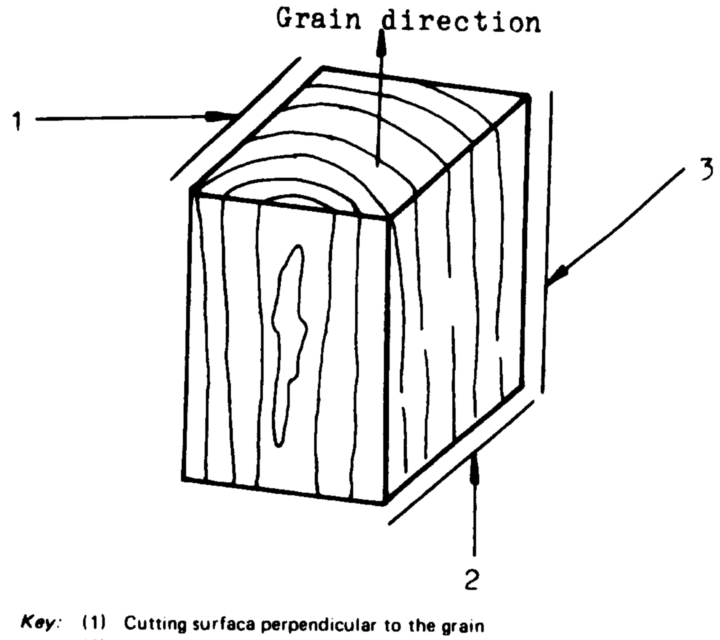
In case of flood or if the motor has become wet, no attempts must be made to start it. It must be disconnected from its conduits and taken apart. The coil must be dried carefully. Trying to start a moist or wet motor will damage the coil.

XXVI. Types of machine tools for woodworking*

When contemplating the manufacture of furniture and joinery products on an industrial scale, the planners must have 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 I, 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 I. 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 II. 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.

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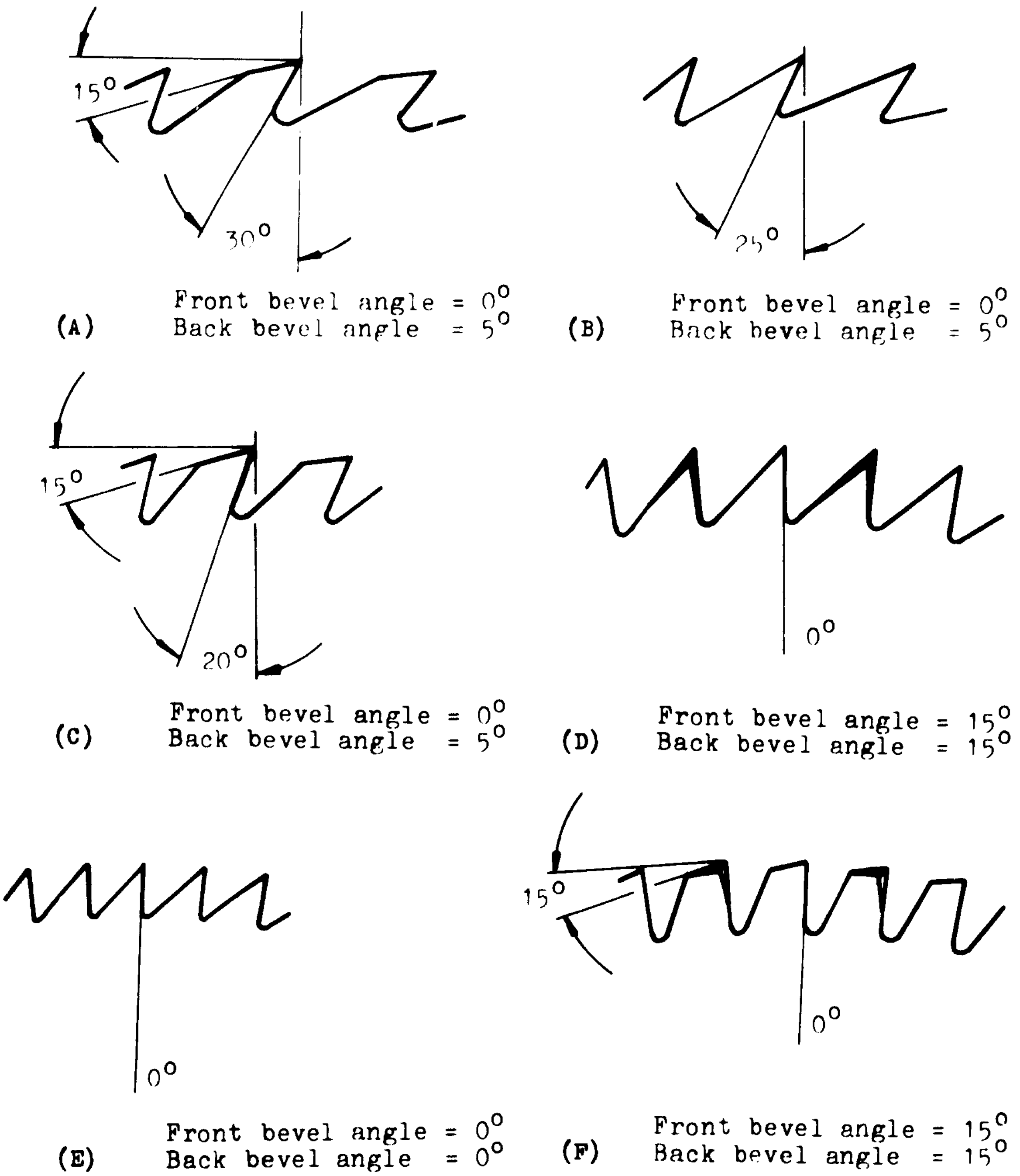
*By Erik Winnlert, Sandviken Jernverks AB, Sandviken, Sweden. (Originally issued as document ID/WG.105/33/Rev.1.)

Figure II. Standard tooth forms and angles for circular saw blades



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/sec. 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 millir e from the straight plane. Hence the importance of tensioning.

Steel qualitites for saws usu have an evrn hardness of approximately 46 R_C with no sizable deviations. For the saw blades to do good work it ecessary that they be filed and set correctly and that correct tooth shape, with suitable angles, be maintained by th ıw filer.

The saw blade is mounted to a shaft which exactly fits its centre hole. The shaft is usually driven by 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 rolls or bands are also used. The sawing of logs with circular saws is cheap as regards machine costs, but the exactness of the sawnwood 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 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 output and reduce manufacturing costs per unit. However, the optimum performance of carbide-tipped blades can be achieved only under certain definite operating conditions.

Cutting speed

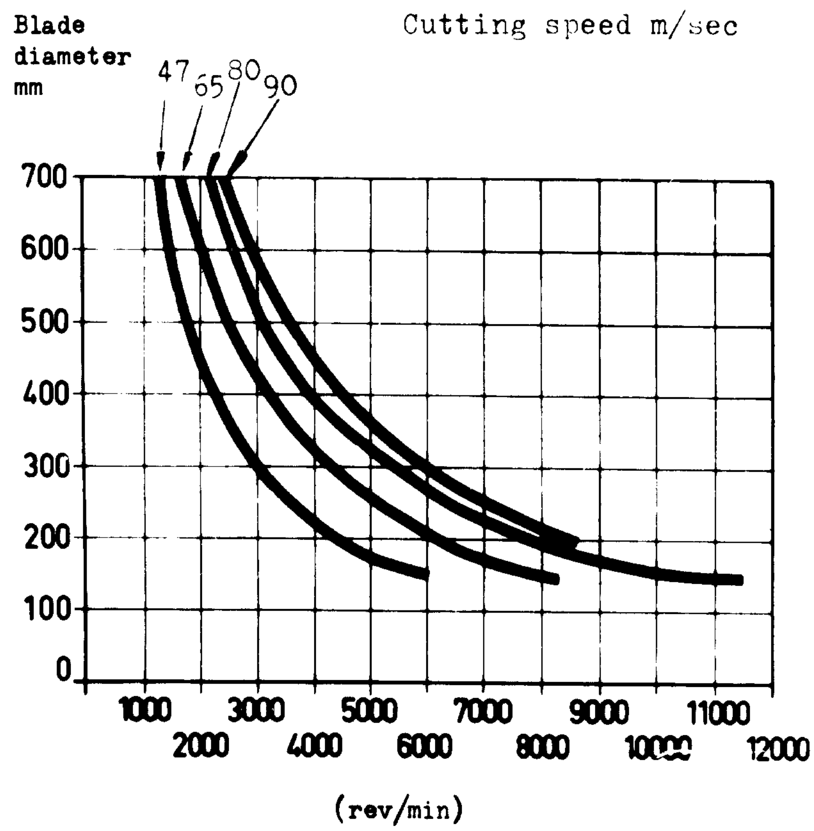
As a rule, machines of older types used in the wood-products industry are not adjustable for different speeds. They frequently have a speed which, with ordinary blades, gives a cutting speed of approximately 47 m/sec. (155 ft/sec, see figure III). When a switch is made to carbide-tipped blades, a smaller diameter can be employed because, with such blades, the diameter reduction will amount to no more than about 5/8 in. (15 mm) during the life of the saw, in other words, 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.

Table 1 gives recommended cutting speeds for various types of material. 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 large feed per tooth, since edge wear is principally dependent on the course of the tooth through the material. If 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 1. CUTTING SPEEDS OF CARBIDE-TIPPED CIRCULAR SAWS IN DIFFERENT MATERIALS

Material	*Cutting speed* *m/sec*	*ft/sec*
Softwood	60-90	200-300
Hardwood	50-70	160-230
Plywood	60-80	200-260
Hardboard	70-90	230-300
Chipboard	60-80	200-260
Veneered board	60-90	200-300

Figure III. Cutting speed (m/sec) as a function of blade speed (rev/min)



Feed speed

The feed per tooth should be between 0.002 and 0.012 in. (0.05 and 0.30 mm), 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 = total feed in m/min

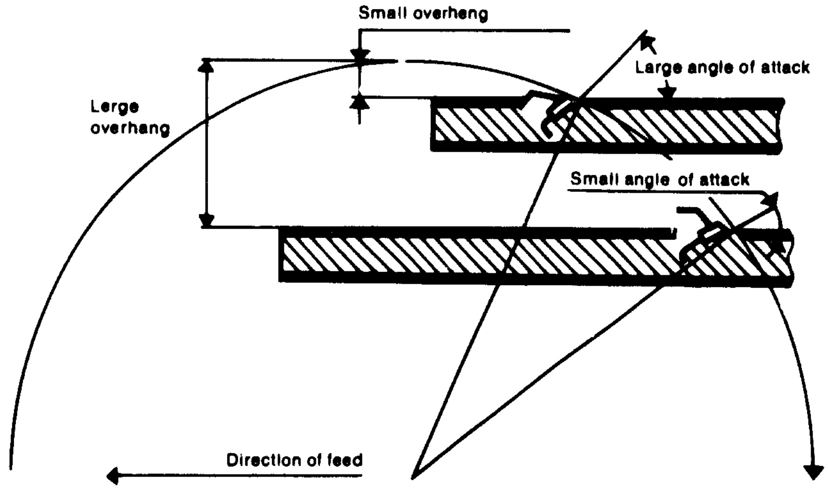
n = rev/min

z = number of teeth working on the section 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 3/8 to 5/8 in. (10 to 15 mm). Figure IV shows how the angle of attack of the tooth against the material varies as the height of the blade is changed. 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 break-through at the underside of the material, while the top face will be better. Reduced overhang, on the other hand, results in break-through 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 IV. Variation of the angle of attack of the tooth against the material



Angles

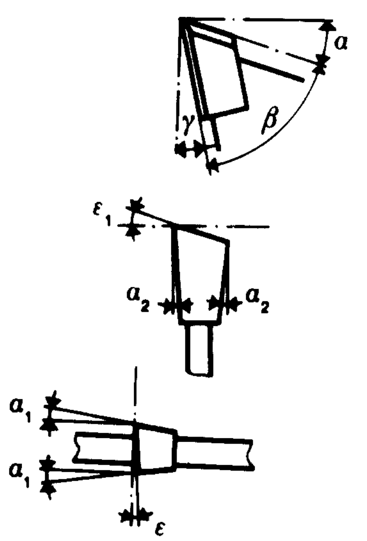
The clearance angle is kept between 10° and 12° (figure V). Thorough studies have shown that increasing the angle above this range will not lead to reduced cutting forces but may well weaken the edge. The tooth-point angle should not be less than 45°, for the sake of strength. The hook is determined 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 II). 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 V. The 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

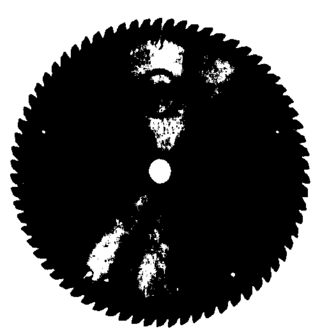
Swedish standards (SIS) governing the dimensions of circular saw blades with carbide tips have recently been established. Swedish standard 2370 contains a dimension schedule comprising diameter series, three tooth-width series and tooth-number series for pitches of 75, 49, 30, 19, 14 and 10 mm. Swedish 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 1/32 to 3/64 in. (1 mm) less than the width of the cutting edge. In other words, the blade has a clearance of about 0.02 in. (0.05 mm).

Blades with extra narrow cutting edges are sometimes made with a clearance of only 0.0182 in. (0.3 mm). It is therefore necessary to pay special attention to the setting-up 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 VI. These slits are found on all close-pitch blades and on those used for continuous sawing.

Figure VI. 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 VII. The arrows indicate the directions in which durability and toughness, respectively, increase. In woodworking, sintered carbides reveal the abrasive-wear known as flank wear, shown in figure VIII.

The grades of sintered carbide falling within group K (see figure VII) 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 VII. ISO grades of sintered carbide

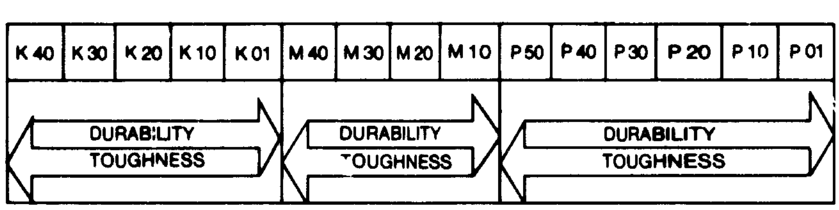


Figure VIII. Typical abrasive wear (flank wear) of a sintered carbide woodworking tool

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 better understanding of the use and care of carbide-tipped blades have resulted in increasingly 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, but a limited number of them are toothed on both sides. 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 joineries and similar wood industries.

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 rather steady body, around which passes a toothed metal band, the saw blade. 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 pressing 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, cut to size, and 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 makes it easier to cut straight.

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 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 for using good maintenance machines is more noticeable in band-saw mills than in other wood industries.

Machine knives

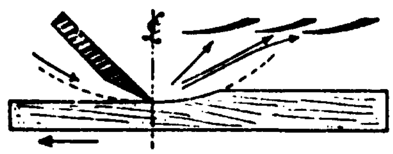
Most machine knives perform either reciprocating or rotary motions on discs, drums, shafts and the like; other knives remain stationary in the machine and the stock (workpiece) performs the necessary reciprocating or rotary motion. There are also single knives and knives that shear in conjunction with 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 IX.

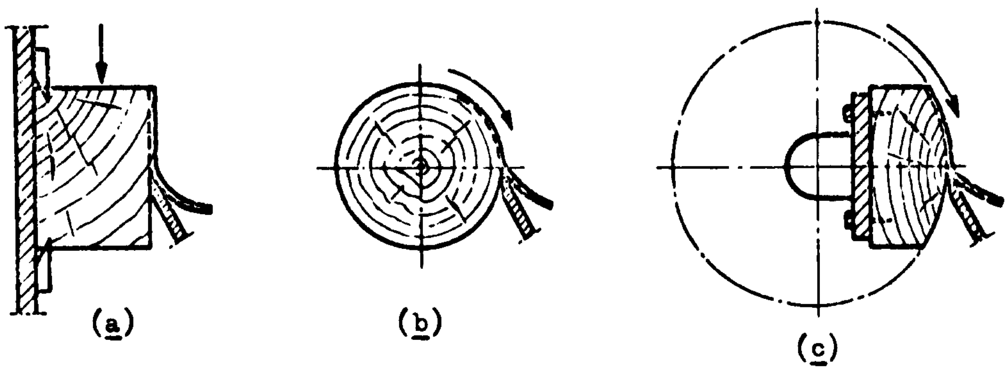
Figure IX. Action of a rotary cutter



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 surface scraper, where the wood is fed across a rigid knife, with a slightly turned edge to remove a thin (about 0.006 in. =about 0.15 mm) shaving. Some examples are shown in figure X.

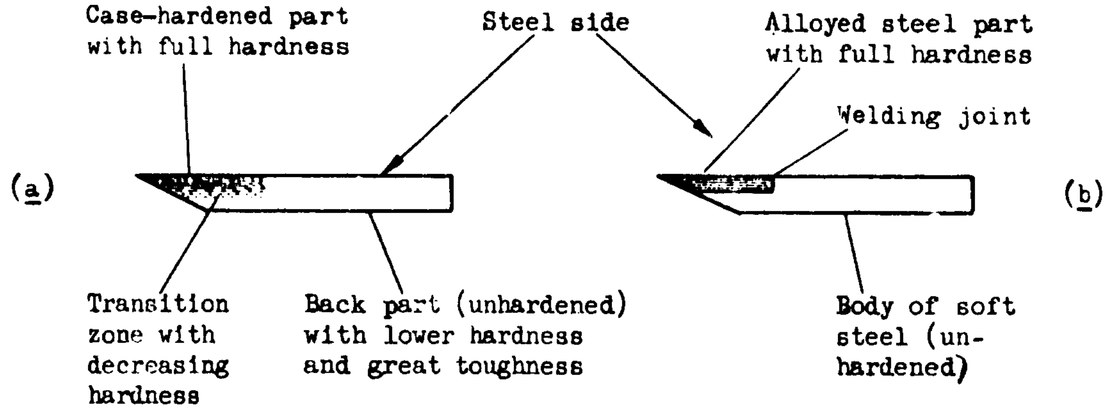
Figure X. Cutting veneers with stationary knives: (a) slicing veneer from a flitch; (b) rotary cutting of veneer from a log or bolt; (c) half-round cutting of veneer from a flitch with a lathe



Chipper knives

Chipper knives are of two kinds: compound and case-hardened (figure XI). 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.

Figure XI. Chipper knives: (a) case-hardened; (b) compound



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.

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 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 normally are 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 probably are adequate for the purpose and most economical in the log run.

This theory is valid only within certain limits. It is self-evident that knives which stay in use longer before regrinding becomes essential, and which 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 (Rockwell scale). Cheap grades of ordinary commercial steel are used to permit the lowest possible prices in order to satisfy the prevailing theory of huyers. 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

During 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.

About two 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 he removed quite frequently and cleaned. Attempts have heen made to solve the problem by painting the bar, but with no great success. However, if the pressure bar is made m 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 ooth 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 be vibrationless and 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 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.

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[1] For more detailed information on the sharpening and maintenance of woodworking tools, see chapters XXVII and XXVIII.

Grinding wheel recommendation

The general rules applying to the selection of hardness and grain size are given below.

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.

Soft wheels. Wheels of looser composition are selected for hard material, larger contact surfaces, smaller cuts and very stable machines.

Roughing and finishing. For roughing, large-grain wheels are used; wheels with a small grain should be employed for finishing.

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.

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 2.

TABLE 2. OPTIMAL CHARACTERISTICS OF GRINDING WHEELS FOR MACHINE KNIVES

Type of knife	*Grain size*	*Hardness*	*Structure*	*Wheel shape*	*Peripheral speed (m/sec)*	*(ft/sec)*
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 2 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 cooled grinding. In addition, the removal of chips is more effective and the working capacity greater than with the 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 (60 to 80 ft/min).

Feed. The feed must be small and should not exceed 0.002 in./stroke (0.05 mm/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.

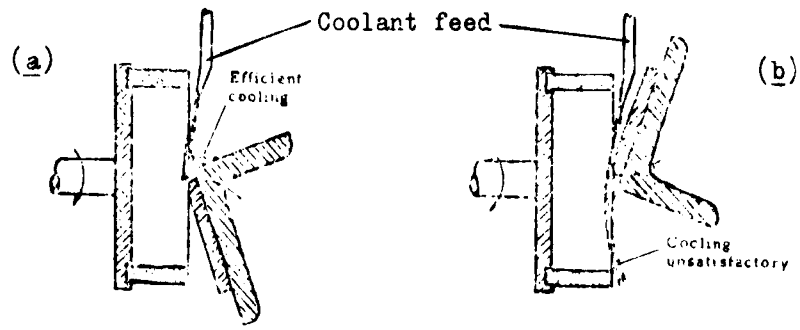
An infallible indication of detrimental heating of the knife is the appearance of the tempering colours. As long as no colours are visible, the steel has not been converted. Tempering begins with a straw (yellow) colour at 250° to 300°C (480° to 570°F) and increases over blue at 300° to 350°C (570° to 660°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 XII). 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.

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 (4½ gallons) at least

Figure XII. Correct (a) and incorrect (b) clamping and coolant feeding when sharpening machine knives



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 (8.8 lb to 22 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 of thumb may serve as a guide for honing the edges of machine knives:

(a) Support the knife 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 XIII);

(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;

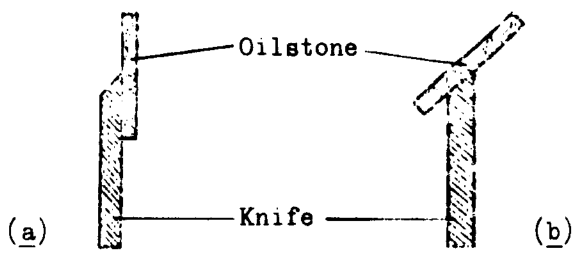
(e) Continue honing in the same way with a finer oilstone;

(f) Finish honing 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 (1/16 in.) from the heel of the bevel;

(g) Examine the edge 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 XIII. Correct application of the oilstone on the hardened side (a) and on the bevel (b) of a machine knife



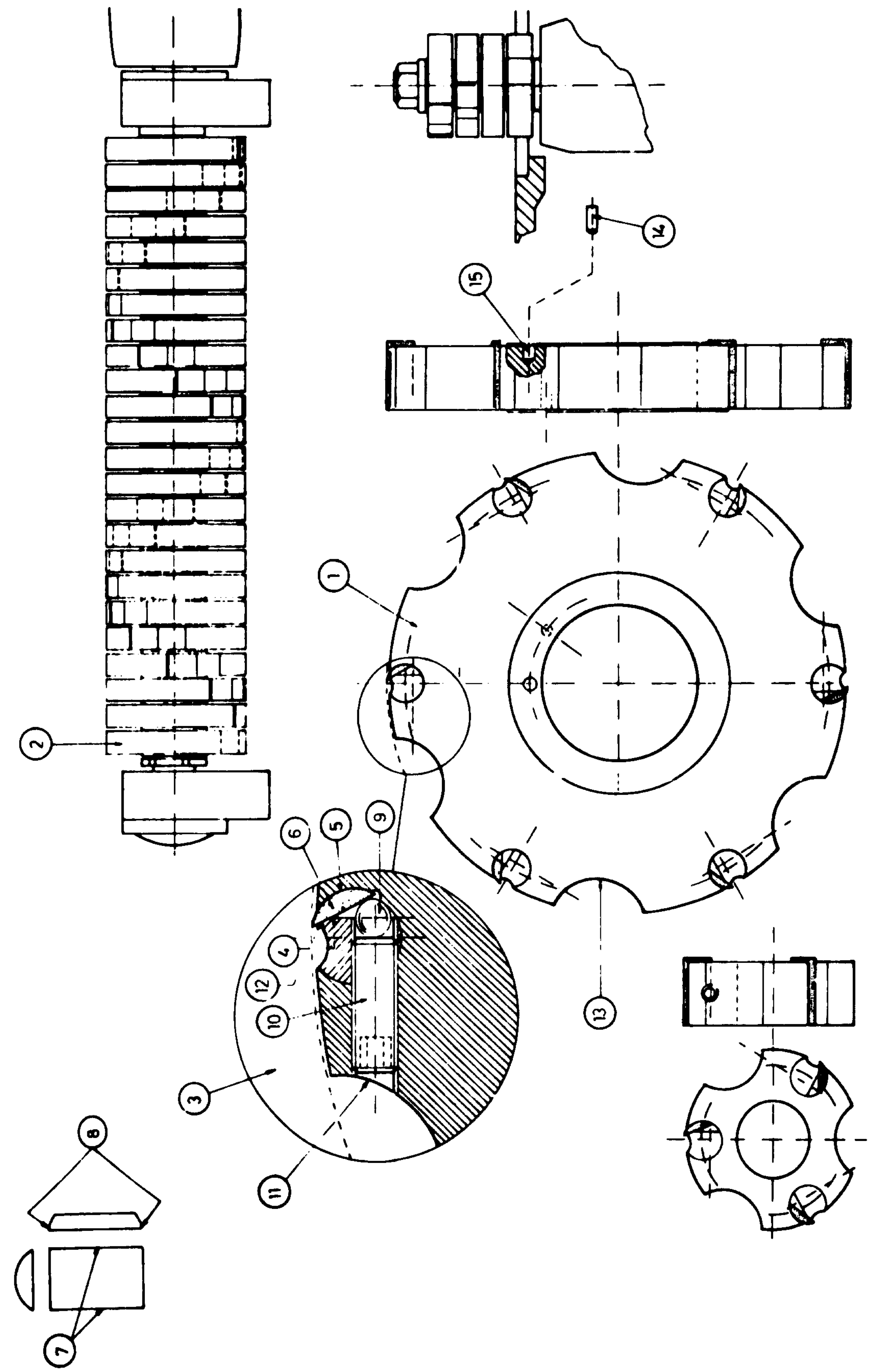
Inserted-tooth cutter

The inserted-tooth cutter is a 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.

The new tool is constructed on the changeable-insert principle so that the insert may be discarded instead of being reground after becoming worn. (see figure XIV.) 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

Figure XIV. Construction of the inserted-tooth cutter



The cutter can be used in all types of multicutting, 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 multitool 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 multitool 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 multitool 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.

XXVII. 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. Further, 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. 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.

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 which 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 I). For example, in edging, a dull circular saw blade may get stuck in the sawing groove and power consumption increases so much that the fuses blow out or the safety relay is released.

Tool life 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 effectively eliminate chipping. 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 (see figure II).

Correct intervals between sharpening are important for the reason mentioned above. Regular and frequent sharpening saves tool material as well as the time of 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.

The most common tools used in the furniture industry

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, 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.

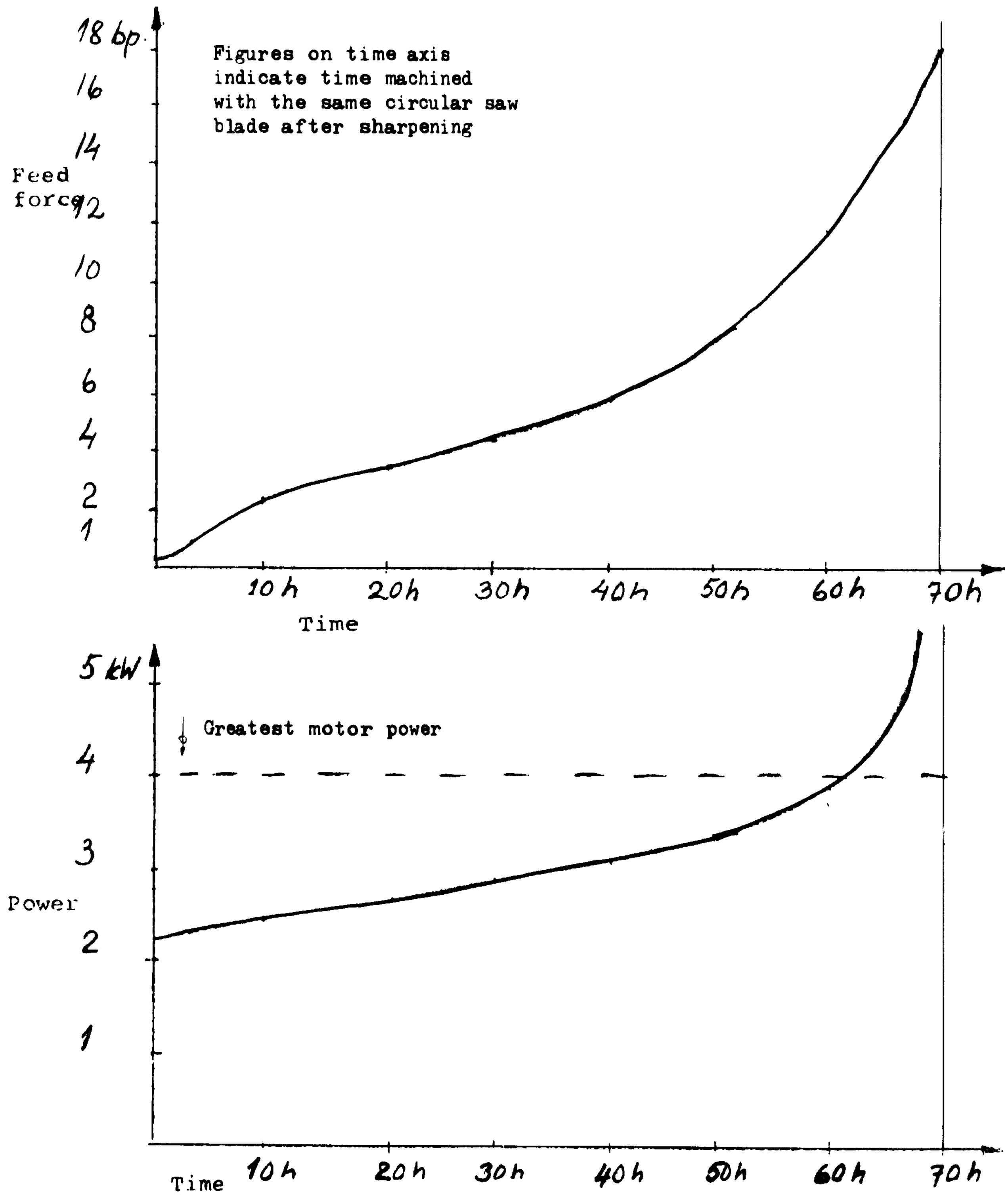
Circular saw blades are chosen according to the material being sawn and the working method, i.e. whether the work entails edging or cross-cutting. Softwoods are sawn best with a wide-pitch circular saw blade (see figure III). Thin material is sawn with a close-pitch blade (see figure IV).

In a machine with a manual feed (e.g. vertical-spindle moulder or circular saw for trimming purposes) a blade equipped with a built-in shock absorber and with the tooth shaped to limit chip thickness is the most suitable (see figure V).

*By Eino Marttinen, Lahti Technical Institute, Lahti, Finland. (Originally issued as document ID/WG.163/26.)

Figure I. Dull tools increase energy consumption

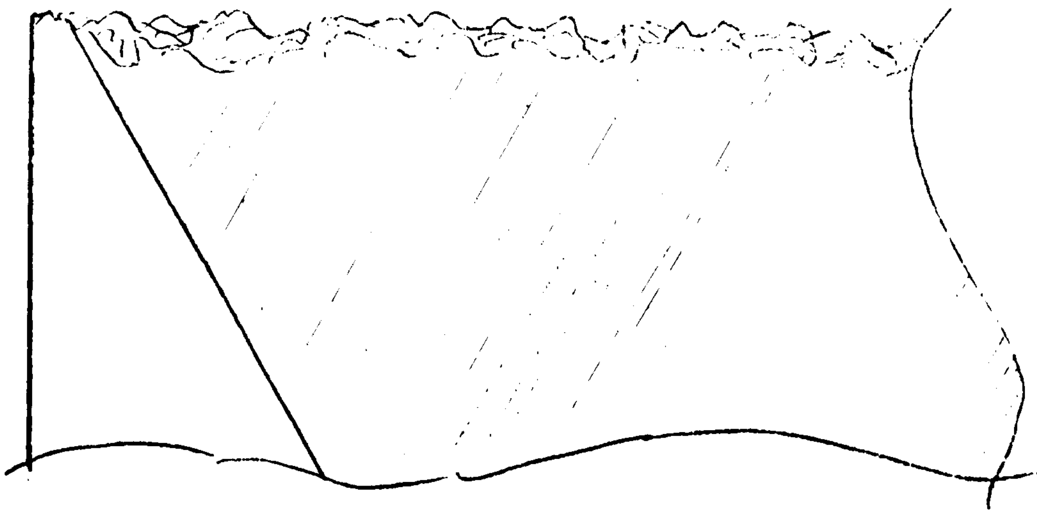
The worker's feed force must be greater if the blade becomes dull.

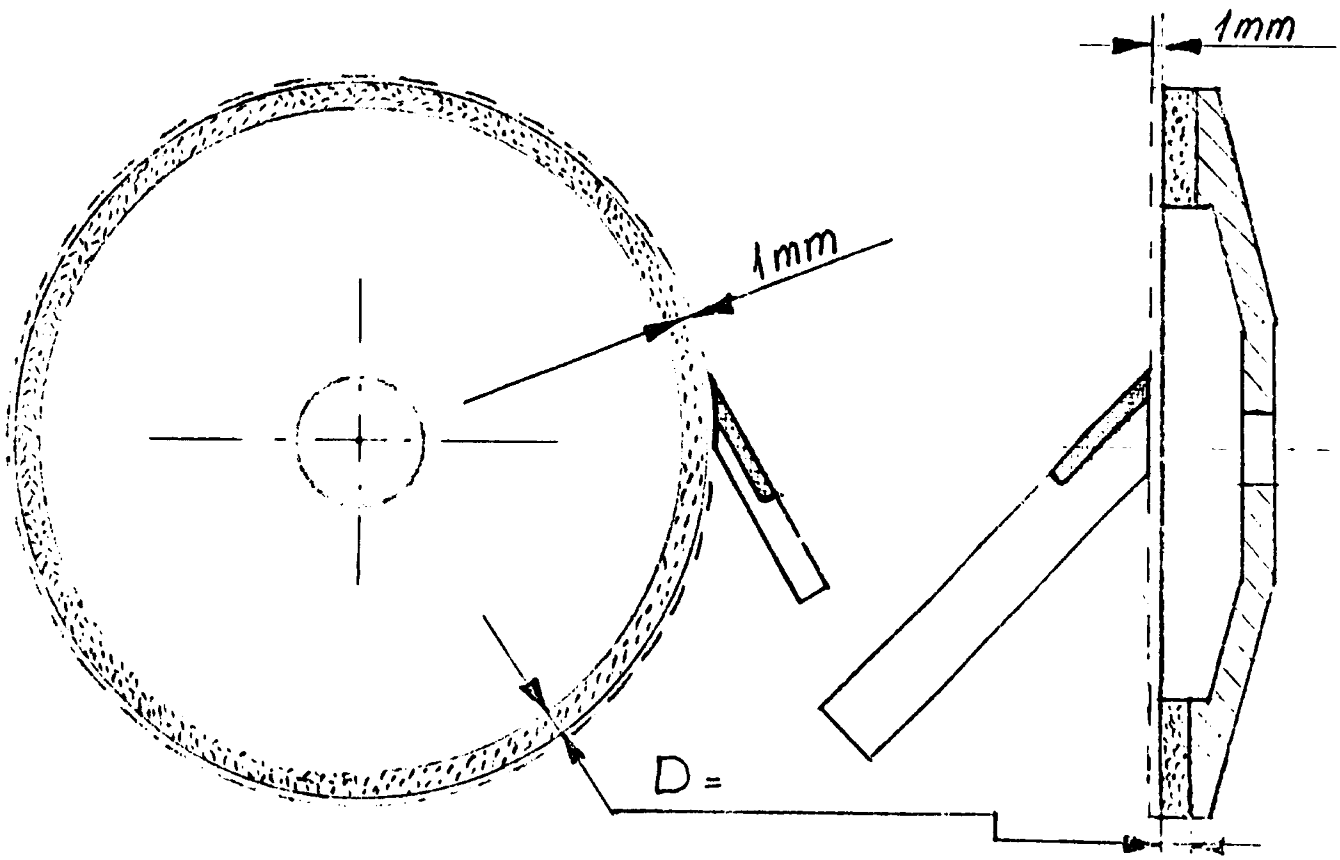


The need for power increases when the circular saw blade becomes dull. When the blade becomes hot it gets stuck and burns the fuses.

Figure II. Regular and frequent sharpening saves tools and wear of grinding wheel

Burnt and broken tool blade which has not been sharpened in time.





Diamond-impregnated part of the wheel costs $70–$100 per mm. Width of diamond part of the wheel decides its price. D = layer of diamond impregnation.

Figure III. Wide-pitch circular saw blade

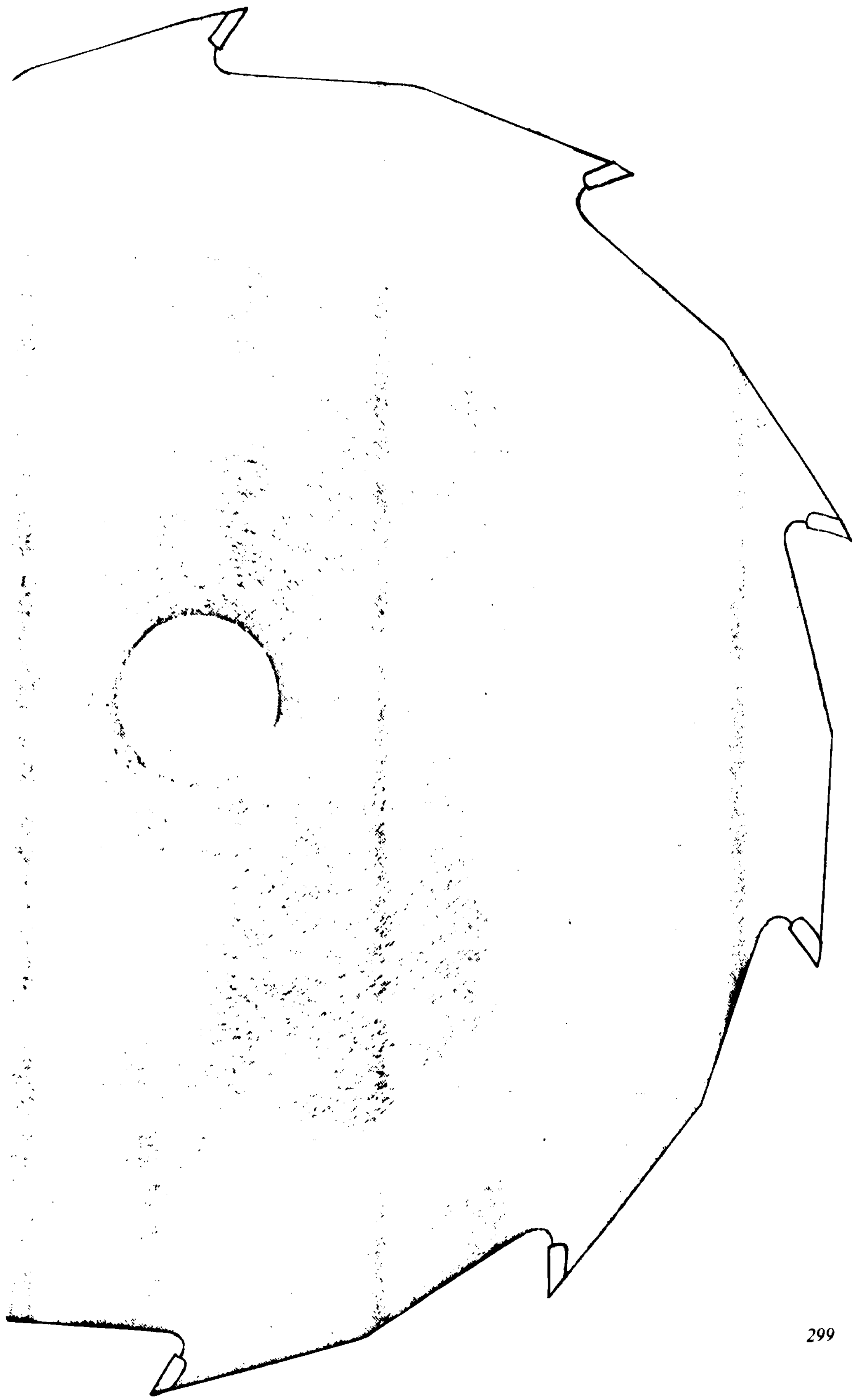


Figure IV. Saw with close-pitch blade for thin material

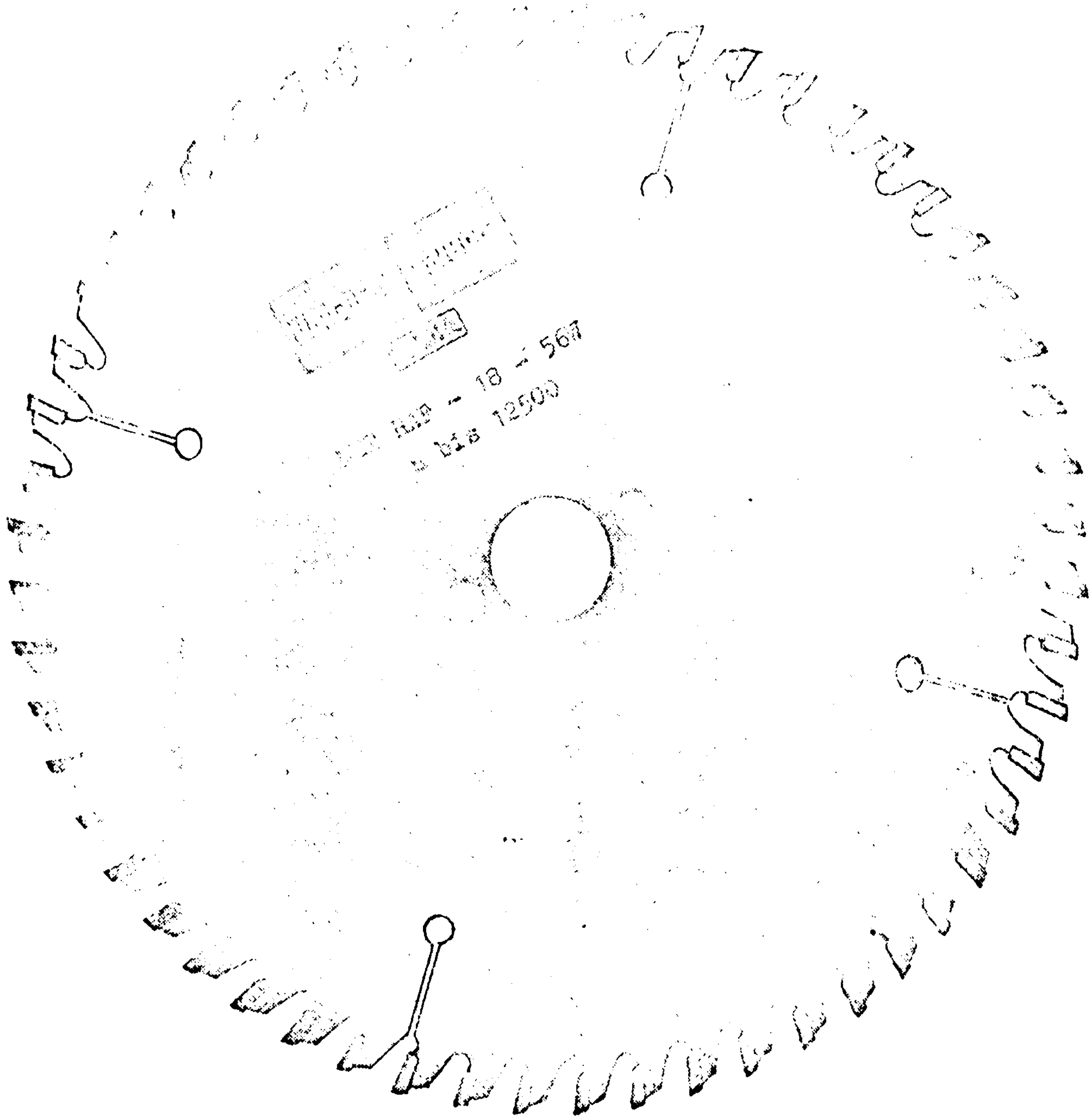
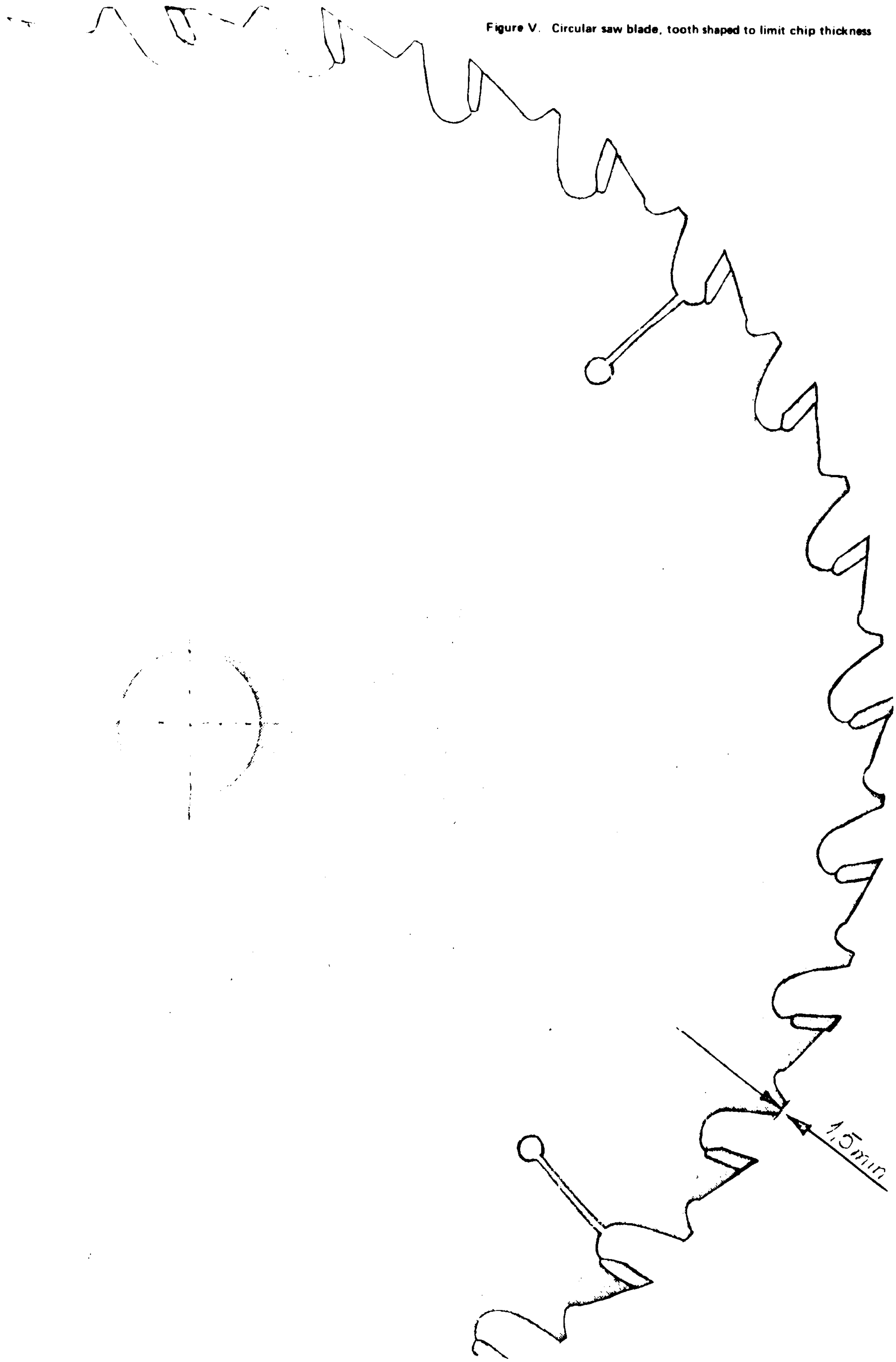


Figure V. Circular saw blade, tooth shaped to limit chip thickness



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 connexion 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 (see figure VI).

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 for cutting very hard woods. Depending on the structure of the circular cutter-block, the knives are 3 or 4 mm thick (see figure VII). 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 VIII).

The purchase price of solid (one-piece) moulding cutters is high; they must be purchased only after careful consideration and should be well maintained (see figure IX). 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.

Borers and mortisers are necessary in making furniture joints. The popular dowel joint is made with a spiral borer (see figure X). A good borer is made of high-speed steel alloy and is suitable for machining hardwoods as well as softwoods.

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 holes 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 (see figure XI).

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. There are also dovetail routers with adjustable knives (see figure XII).

Other types of tools in furniture manufacture are necessary in special cases. Dowels are made with a dowel cutter which comes in various diameters according to the joint (see figure XIII). Lathe knives make up another group also used in furniture manufacture.

The most important sharpening machines and equipment

Simple but versatile standard 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.

These inexpensive machines of light construction are not suitable for carbide-tipped tools. The best way to grind them is to set up a grinding centre in which tools of this type in the whole town or larger area can be sharpened and maintained using special equipment.

Choice of grinding wheel for various purposes

A different grinding wheel must be used for each profile (see figure XIV). 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.

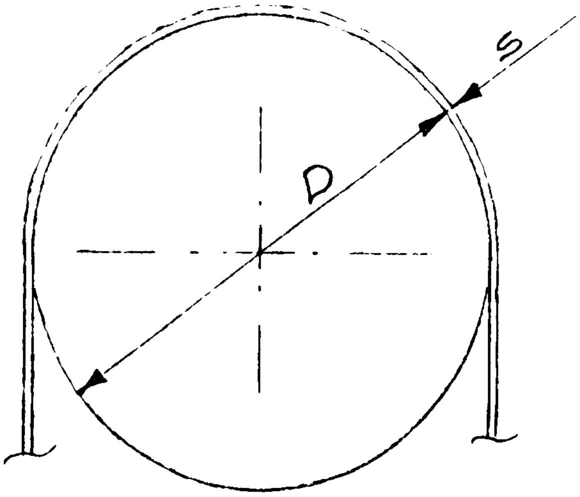
Pre-grinding is done with grinding wheel number 40-60; fine grinding is done with wheel number 100-150.

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.

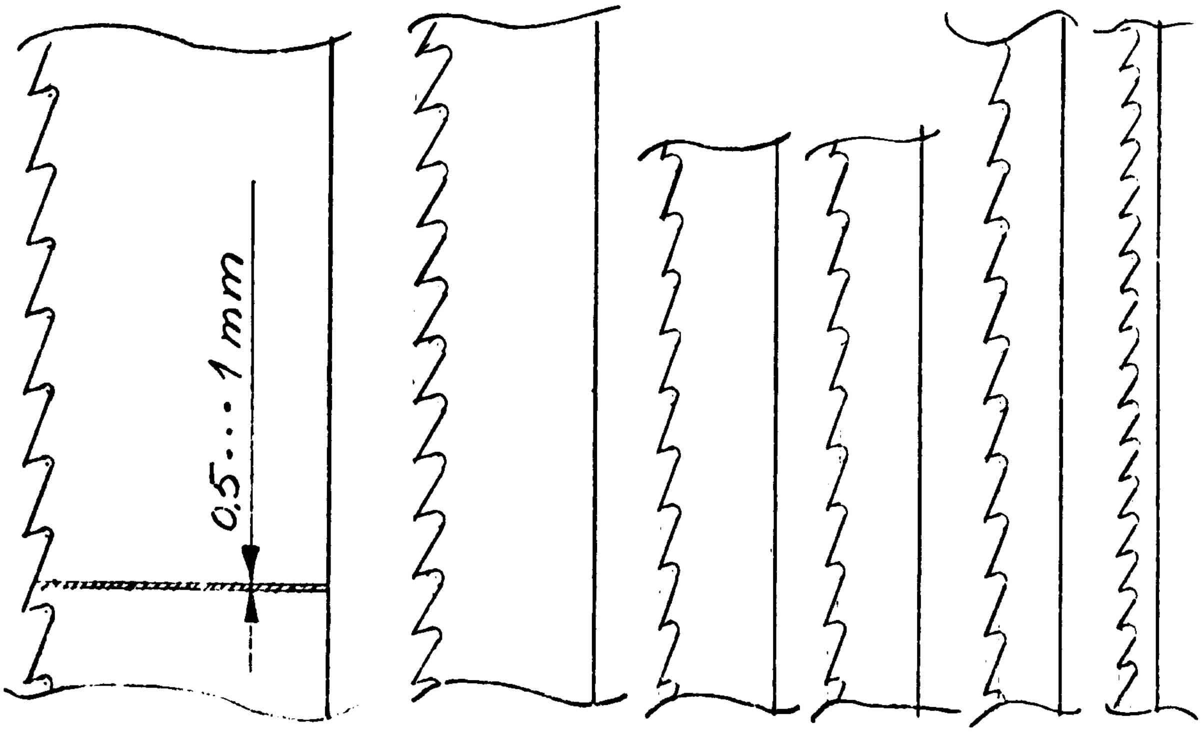
When a dull and worn carbide-tipped tool is ground, three grindings are needed: first, pre-grinding with silicon-carbide SiC wheel; secondly, grinding with diamond-impregnated wheel number 100-150; and thirdly, fine grinding with diamond-impregnated wheel number 220-400. It is important to check that the grinding wheel is not broken before being mounted to the machine and also that the cover is in its proper place.

Figure VI. Band-saw blades

Thinner blade recommended because of bending of the blade. Thicknesses of band-saw blades, 0.5 - 1 mm



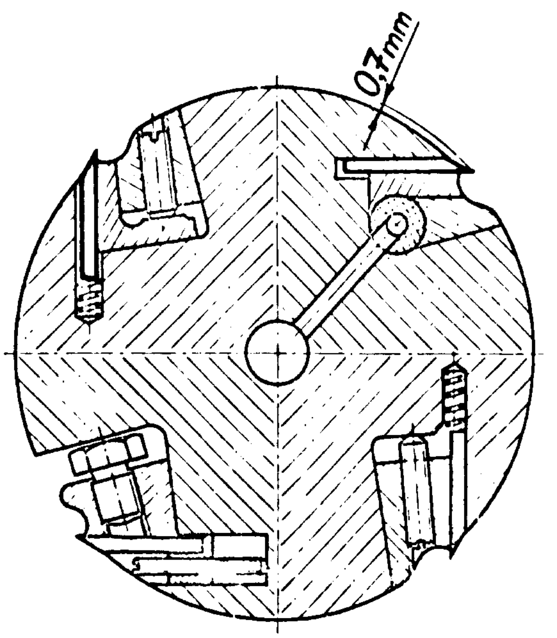
$$S \leq \frac{D}{1000}$$



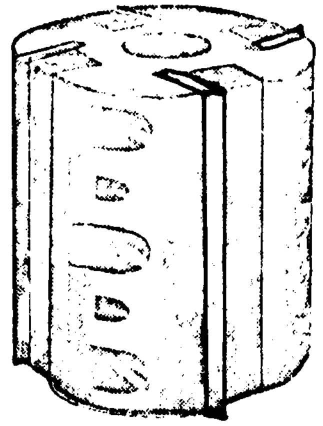
Scale 1:1

Band-saw blades used in furniture work

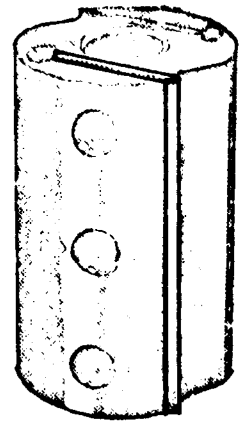
Figure VII. Cutter-blocks



Different ways of mounting circular cutter-blocks

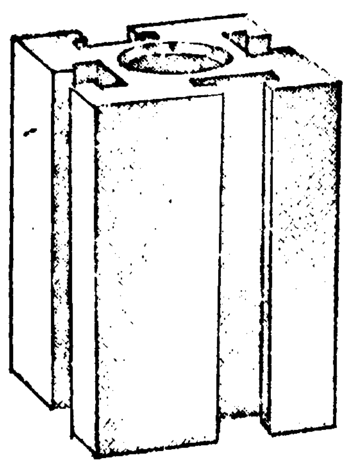


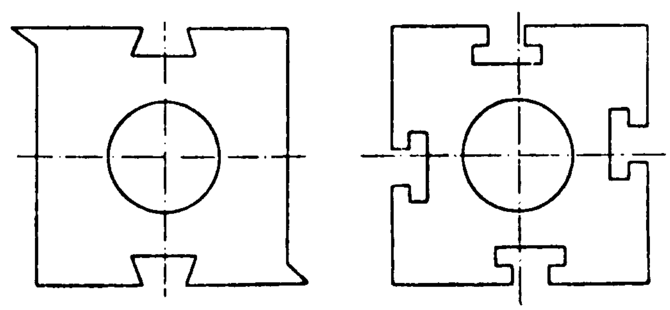
4-knife



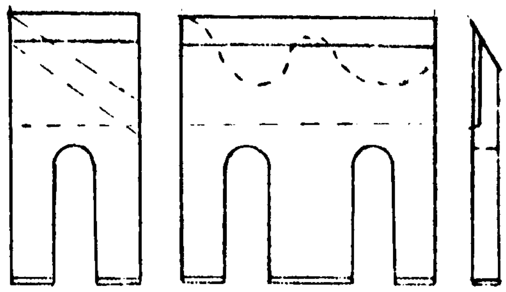
2-knife

(a) Circular cutter-block

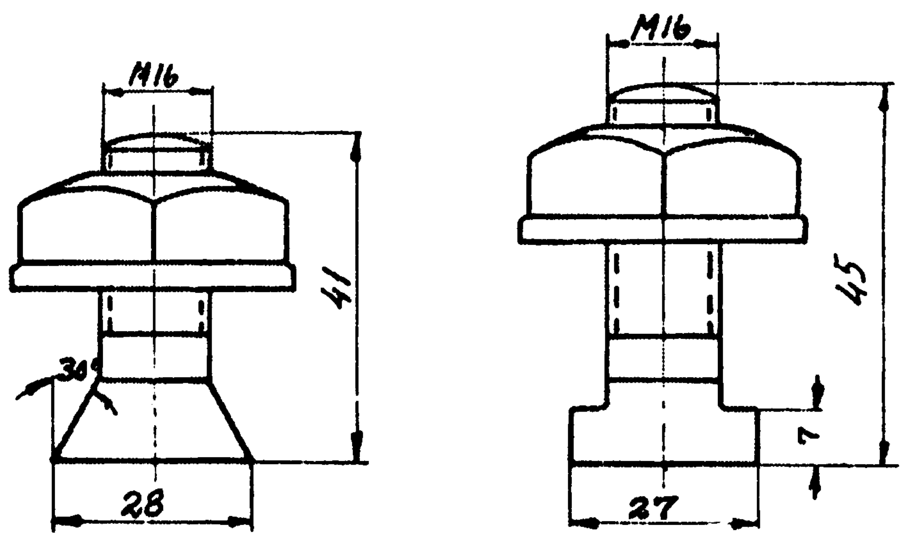




(b) Square cutter-block



(c) Knives for square cutter blocks



(d) Screws and bolts for fixing knives to square bocks

Figure VIII. Circular moulding cutter with profile knives

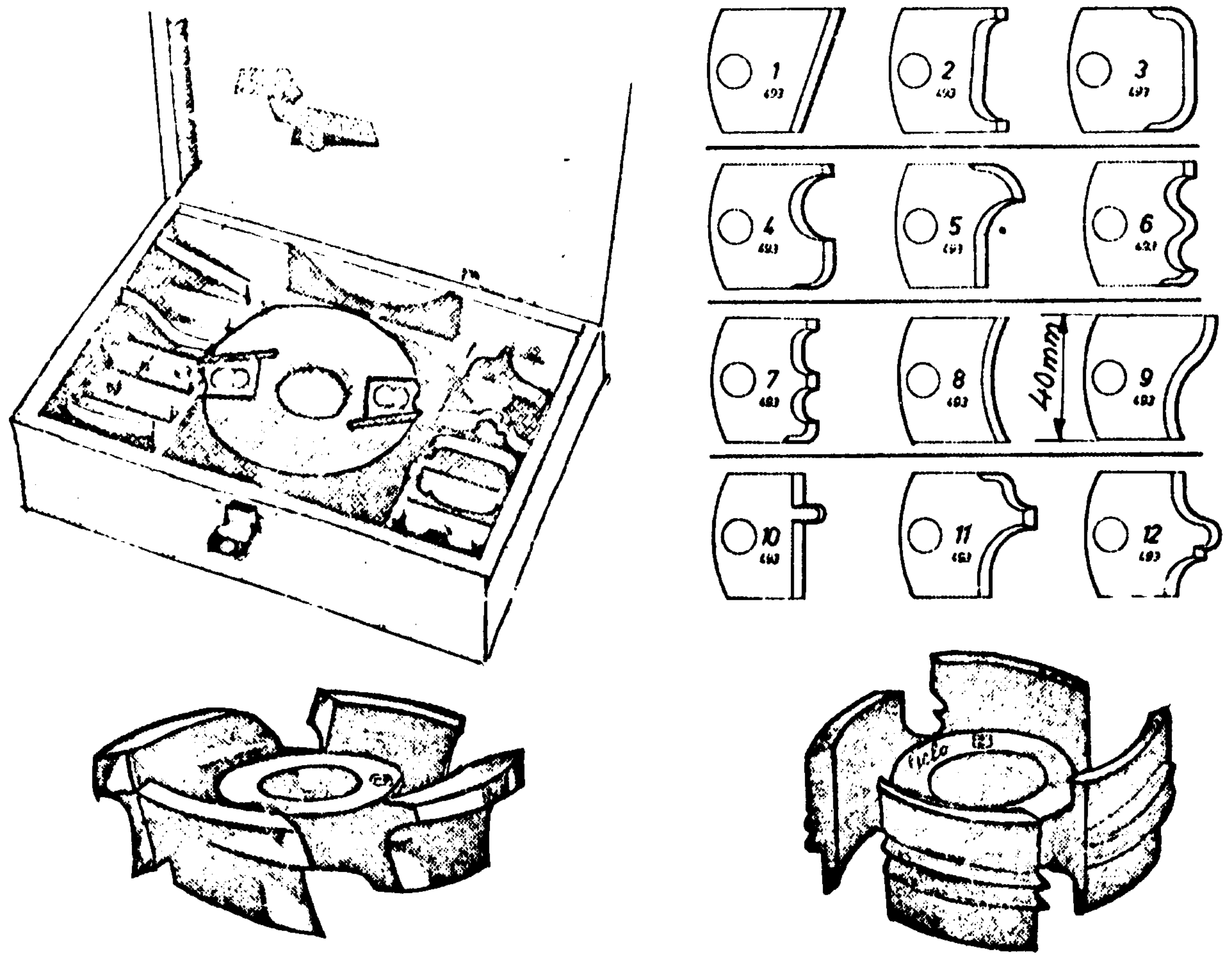


Figure IX. Solid profile cutters for moulding

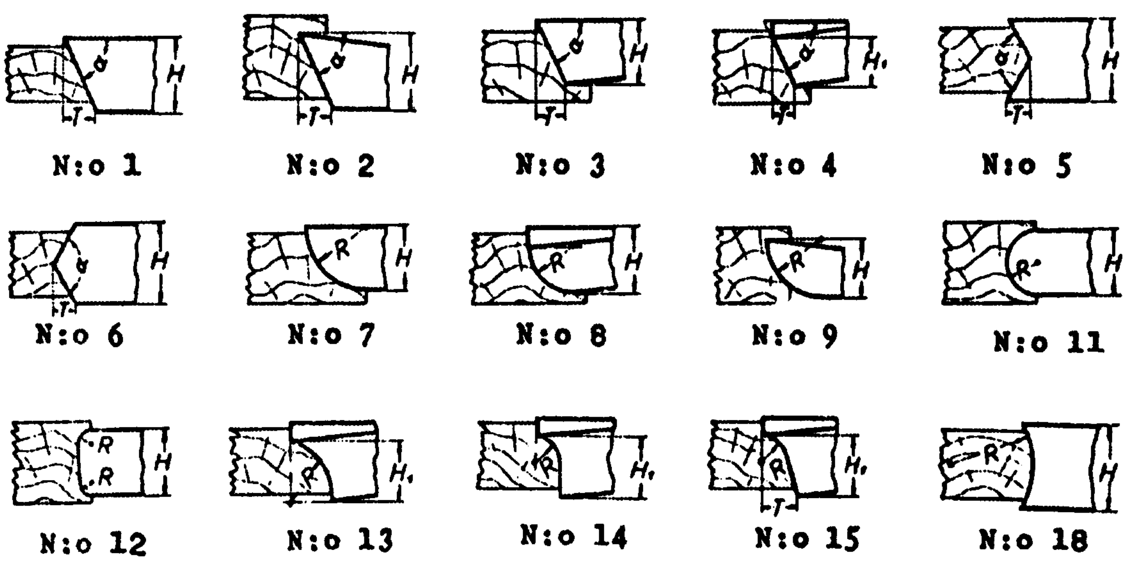
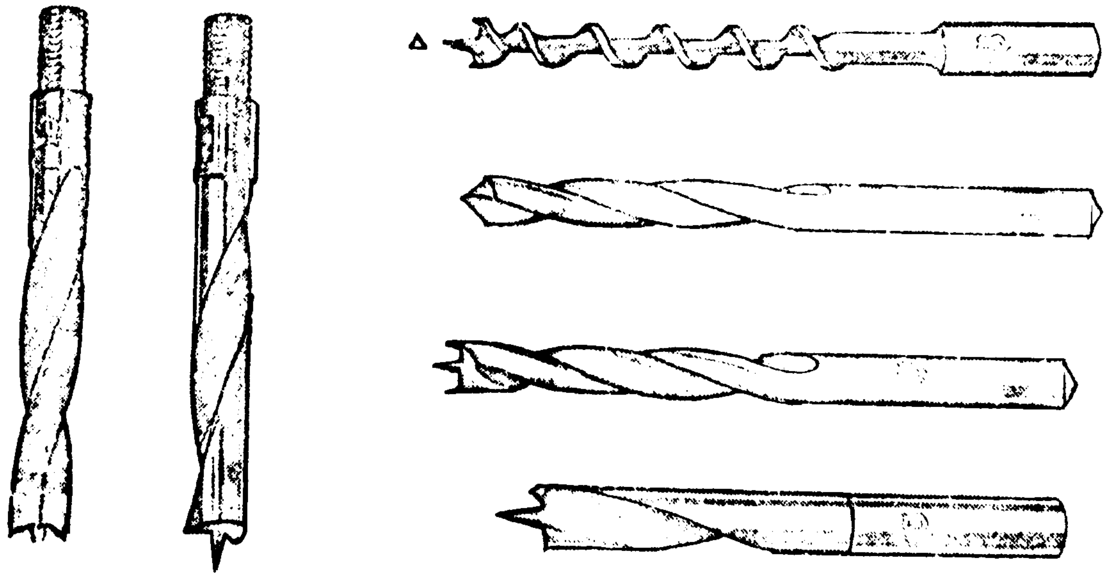
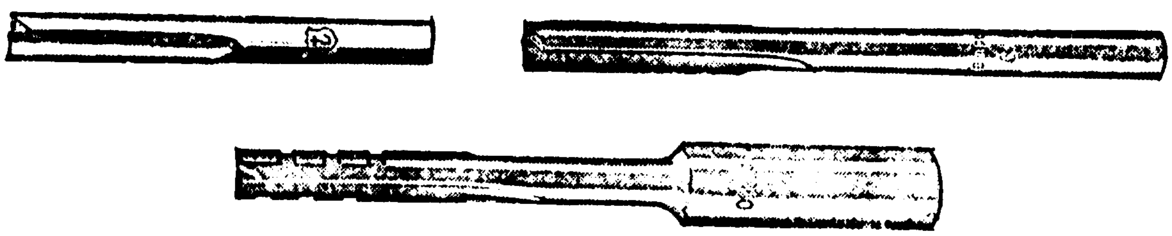


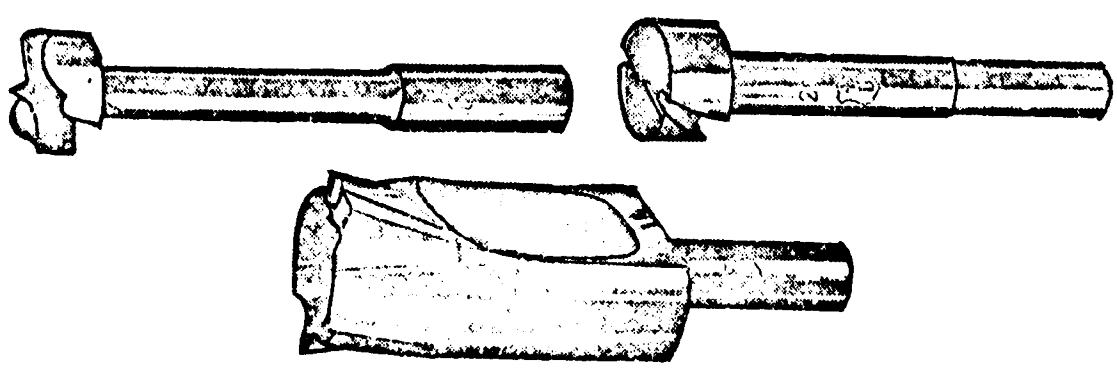
Figure X. Borers



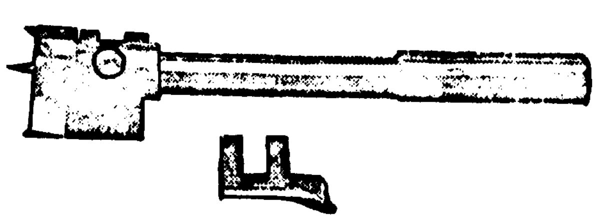
(a) Spiral borers



(b) Slot borers

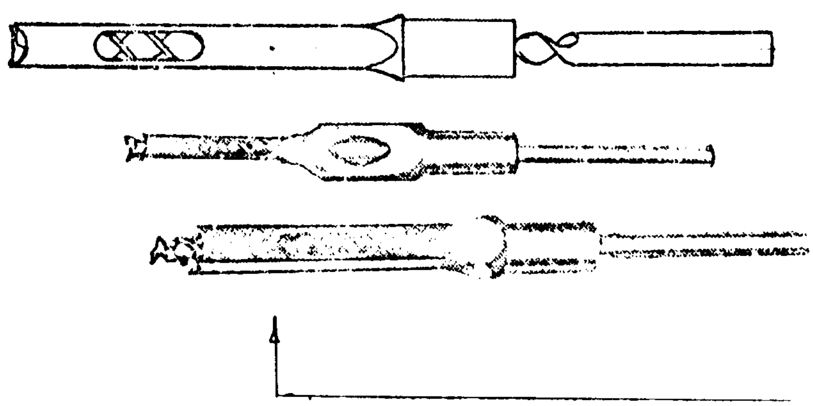


(c) Knot-hole borers

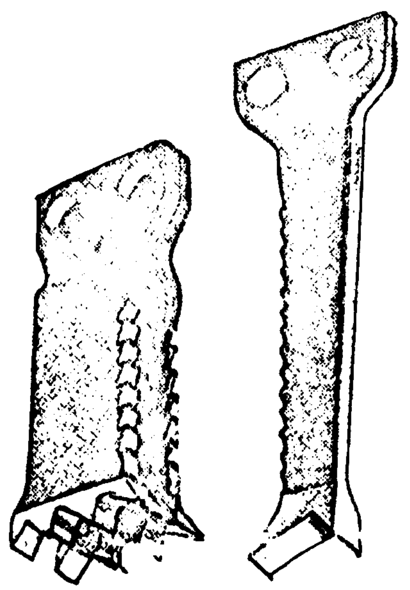


(d) Adjustable borer

Figure XI. Chisels

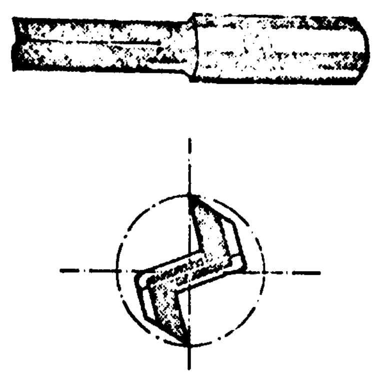


(a) Hollow chisels

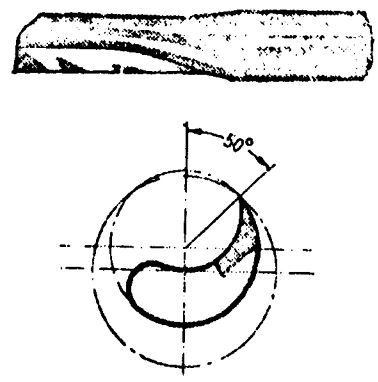


(b) Oscillating mortising chisels

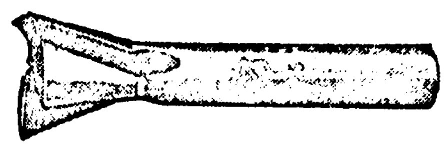
Figure XII. Routing cutters



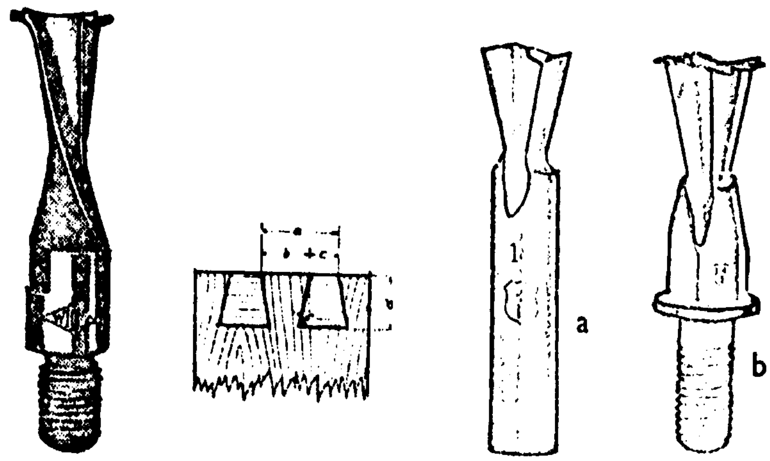
(a) With 2 cutting edges



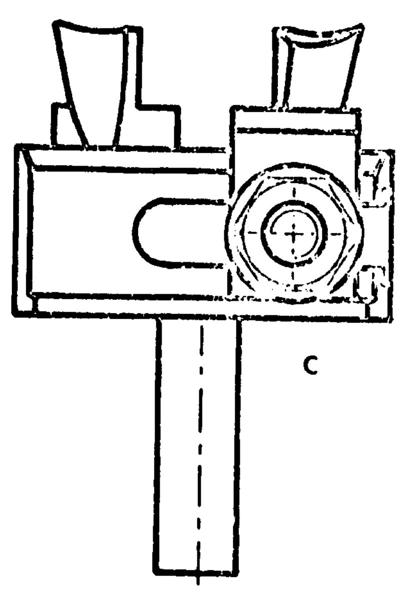
(b) With 1 cutting edge



(c) With 3 cutting edges

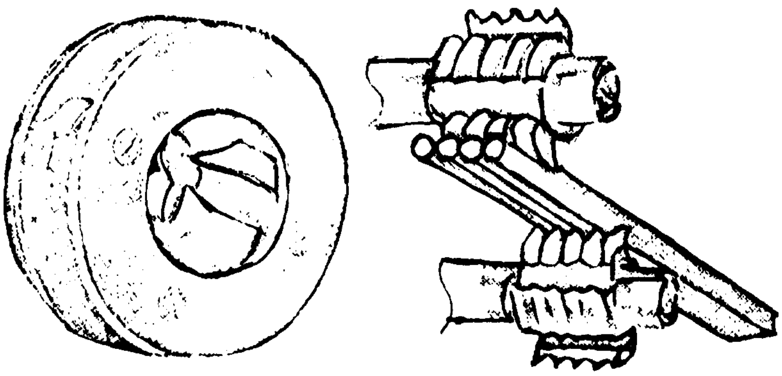


(d) Equipped with spur cutter

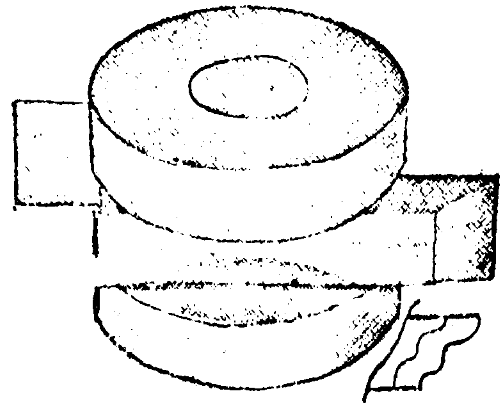


(e) Adjustable groove router

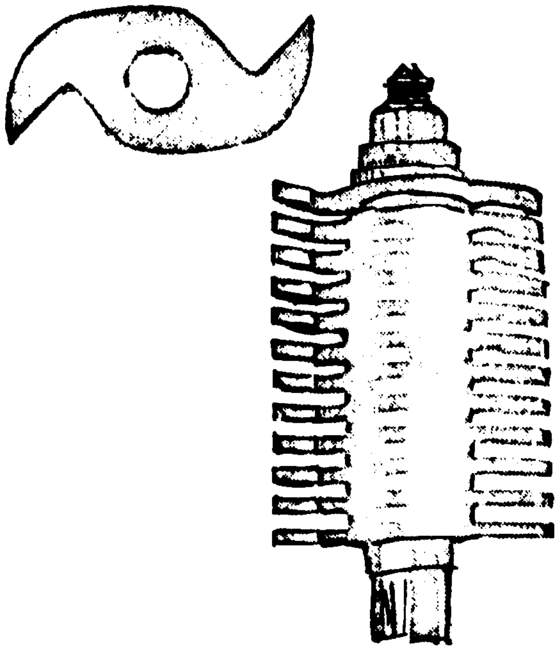
Figure XIII. Various cutters



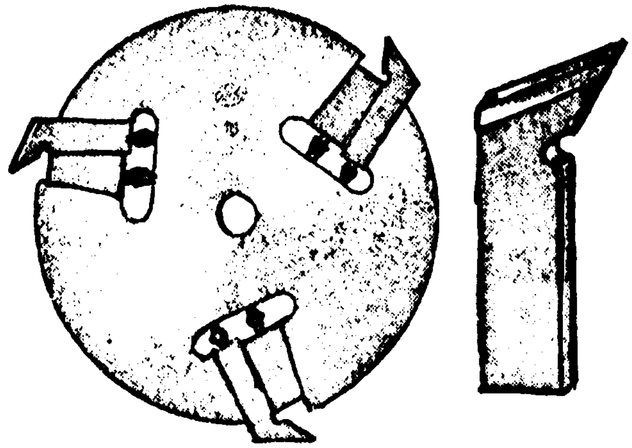
(a) Round profile cutters



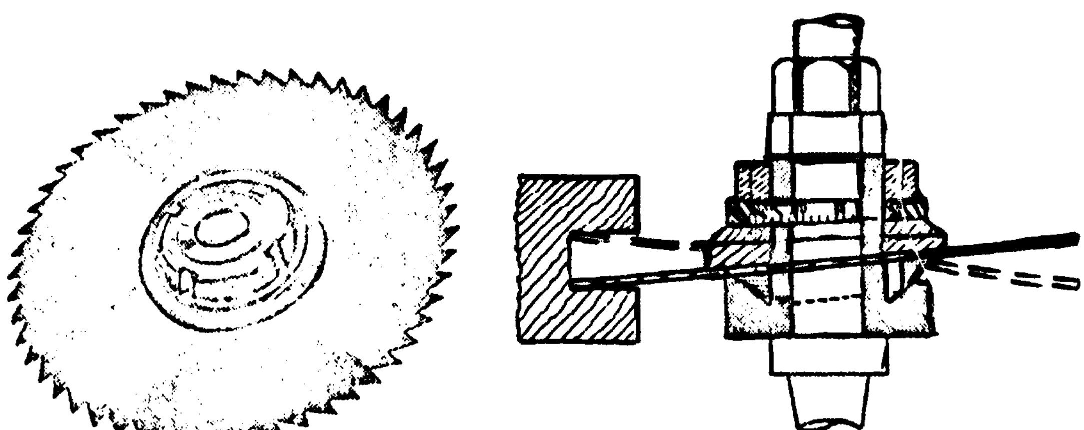
(b) Flange cutter (very dangerous)



(c) S-knives

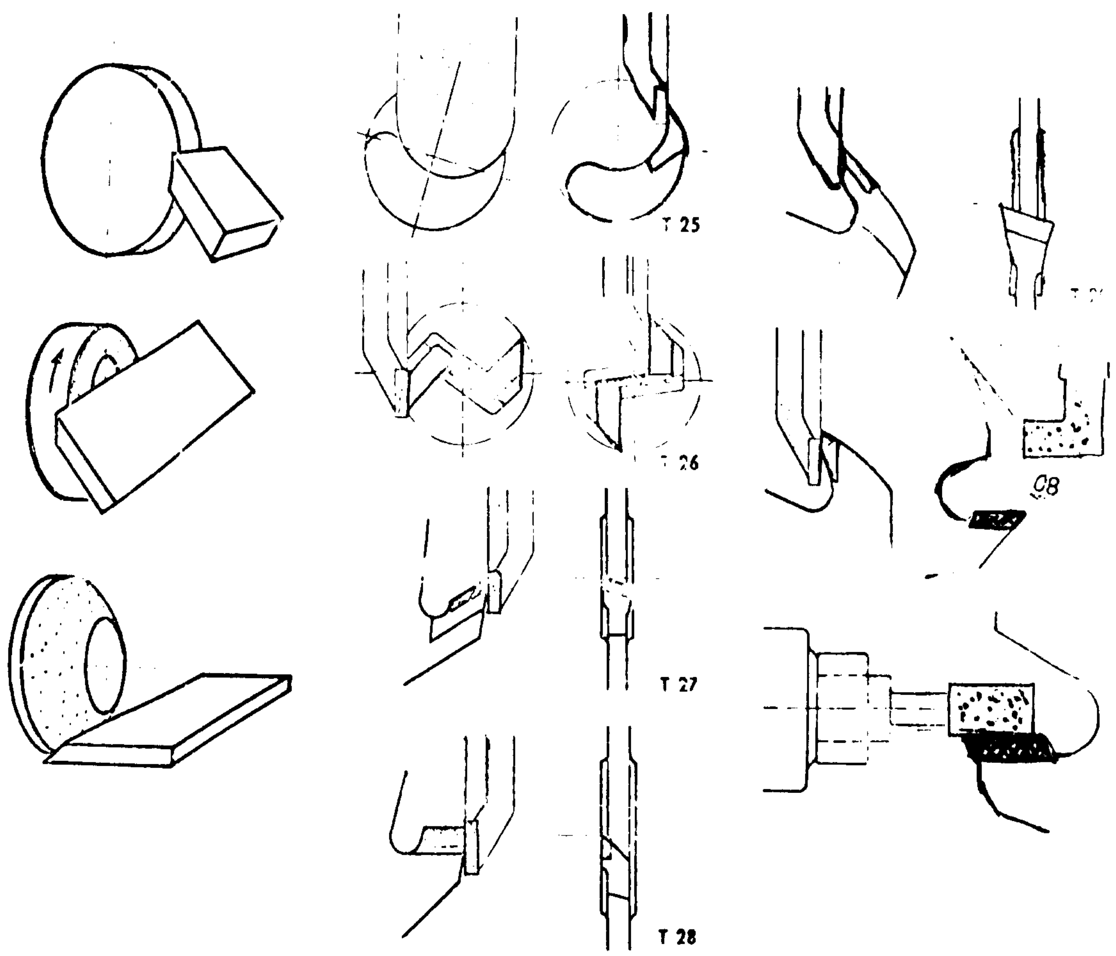


(d) Wheel cutter and knife



(e) "Drunken" saw

Figure XIV. Separate wheel for each profile



Common faults in grinding

The most common fault in grinding is that the cutting edge burns as a result of too rapid single grinding. 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 (see figure XVa). When an attempt is made to grind a very sharp edge, the sharpening angle easily becomes too small and the edge breaks. Level grinding does not make the grinding angle too small. Wet grinding is the best (see figure XVb).

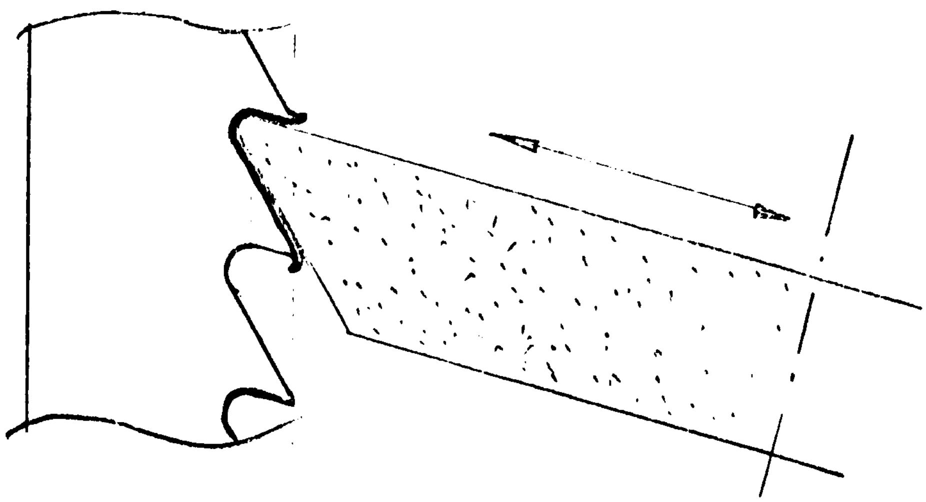
Sharpening angles recommended for different tool materials are:

Carbon steel	35°	for working softwood
Steel alloy	37°	for working softwood
High-speed steel alloy	39°	
Stellite	42°	
Tungsten carbide K 40	45°	
Tungsten carbide K 30	55°	
Tungsten carbide K 20	60°	

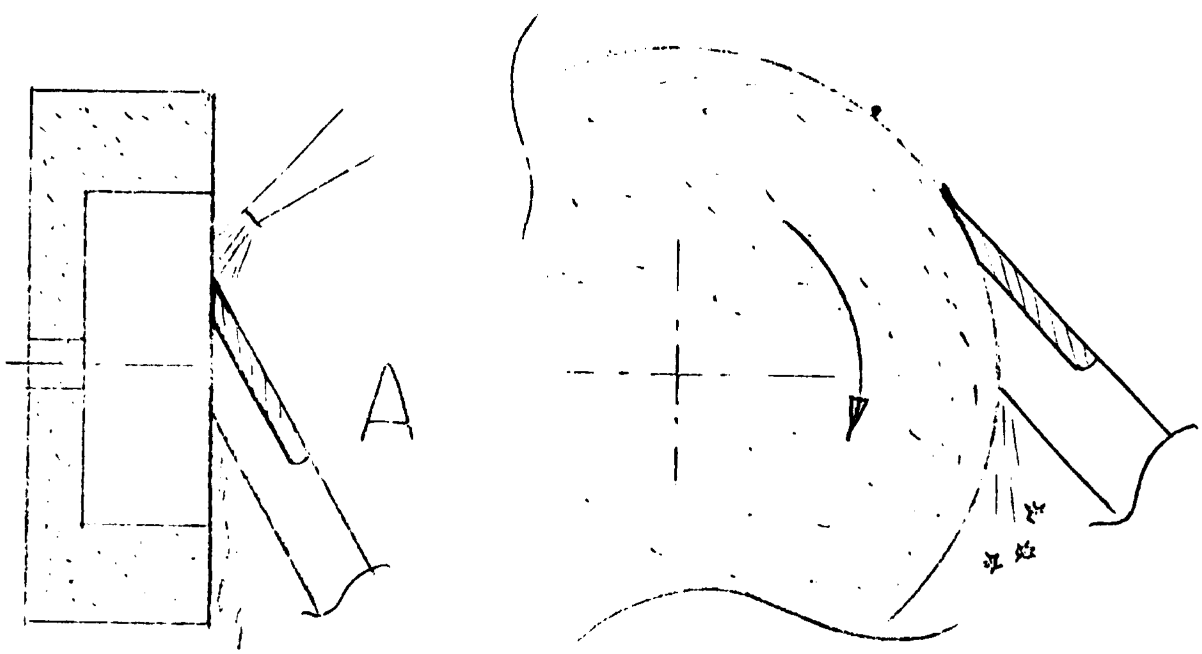
It often occurs in grinding profile cutters that the knife pairs do not have the same form. They may have different weights and a different vibration owing to centrifugal force. Often only one of the knives cuts the correct profile. In that case, the feed rate of the workpiece must be slower or the finish will be uneven.

When solid cutters are ground, a pitch controller must always be used to ensure that the pitch shall remain the same (see figure XVd). In manual grinding the pitch changes easily, with the result that only one edge cuts and the spindle vibrates (see figure XVc). If moulder cutters, borers and mortising tools are sharpened too rapidly the grinding damages the whole tool.

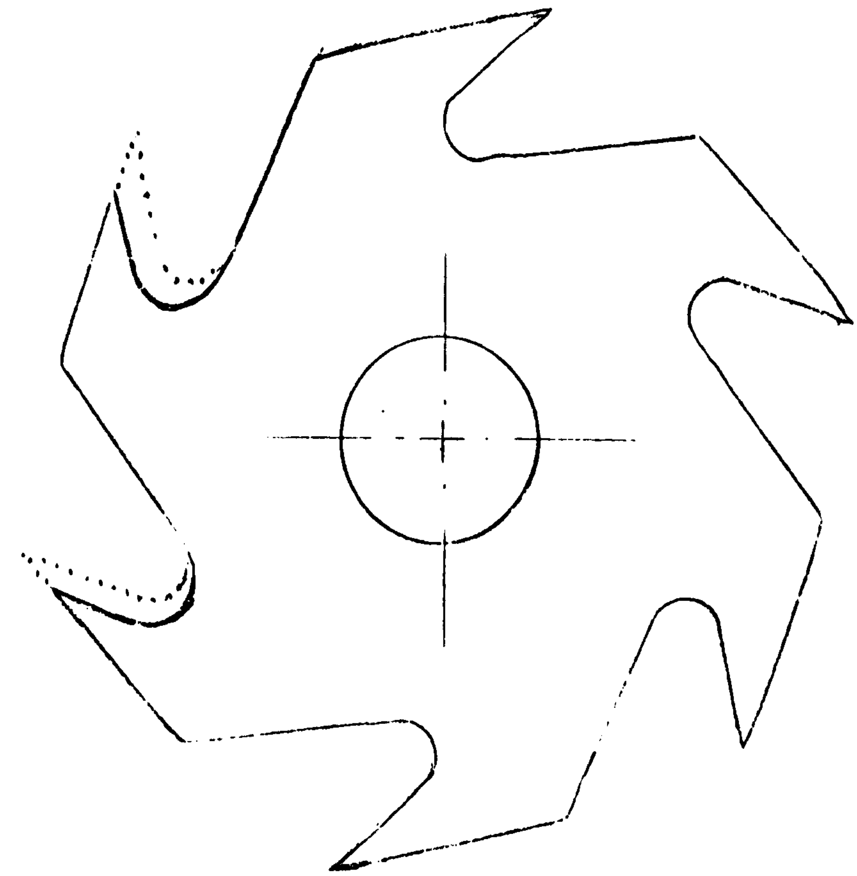
Figure XV. Faulty and correct grinding



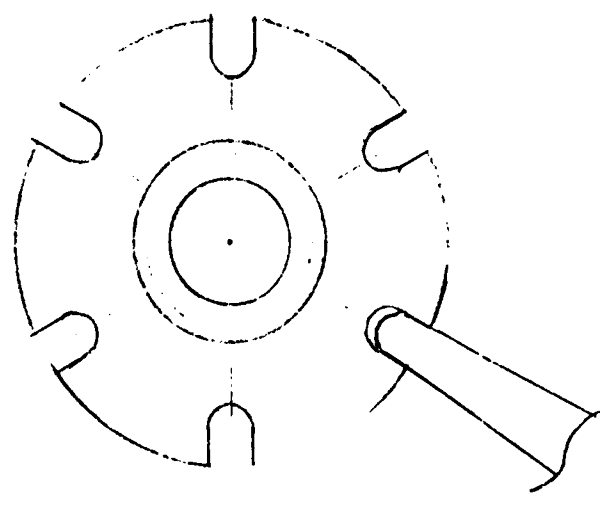
(a) Too fast feed rate in grinding



(b) Level, wet grinding is the best



(c) Result of changing pitch in manual grinding



(d) To correct fault (c), use pitch controller

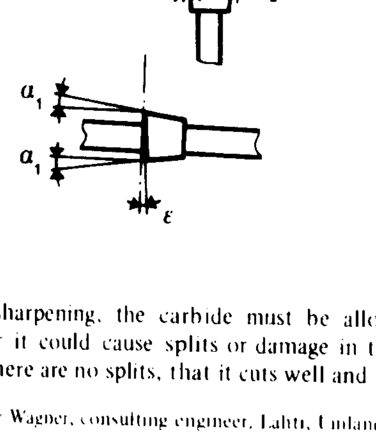
XXVIII. Sharpening carbide-tipped tools for use in working wood and plastic*

Service 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 for economical reasons rather than repaired. 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 I).

Figure I. 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

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.

*By Peter Wagner, consulting engineer, Lahti, Finland. (Originally issued as document ID/WG.209/19.)

Sequence of work phases

1. Cleaning the saw blade
2. Inspection of the general condition
3. Circular grinding of the blade diameter
4. Sharpening of the chipping edge, if necessary
5. Coarse grinding of the back edge
6. Finishing of the back edge
7. 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 II). 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 in correspondence with it. If there are severe cracks in multiteeth saws, the largest of these can be ignored provided that they do not follow one immediately after another, thus, unnecessary reduction of the diameter is avoided and the saw blade's life is not shortened. Carbide tips which 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.

Sharpening the chipping edge

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 III).

The chipping edge is ground lightly, and finished only if necessary. The carbide tip, which is about four times longer than its thickness, 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 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 2/100 mm. When grinding, the cutting edge must not be crossed to prevent it from bending.

Grinding the back edge

When sharpening the clearance angle, the diamond impregnation of the wheel must not touch the basic material of the saw blade. This is possible if the carbide-tipped circular saw blade is directed so that the back angle is 5° wider than the clearance angle at the carbide tip (see figure IV).

Coarse grinding is necessary only when, after the last grinding of the clearance angle (α), there is a bevel larger than 1 mm in the basic material.

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 3/10 mm, so that when finishing the clearance angle, only the carbide tip is sharpened with the diamond-impregnated wheel.

The finishing of the clearance angle has a decisive effect on saw 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 to 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.

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.

Figure 11. Sharpening of a carbide-tipped circular saw

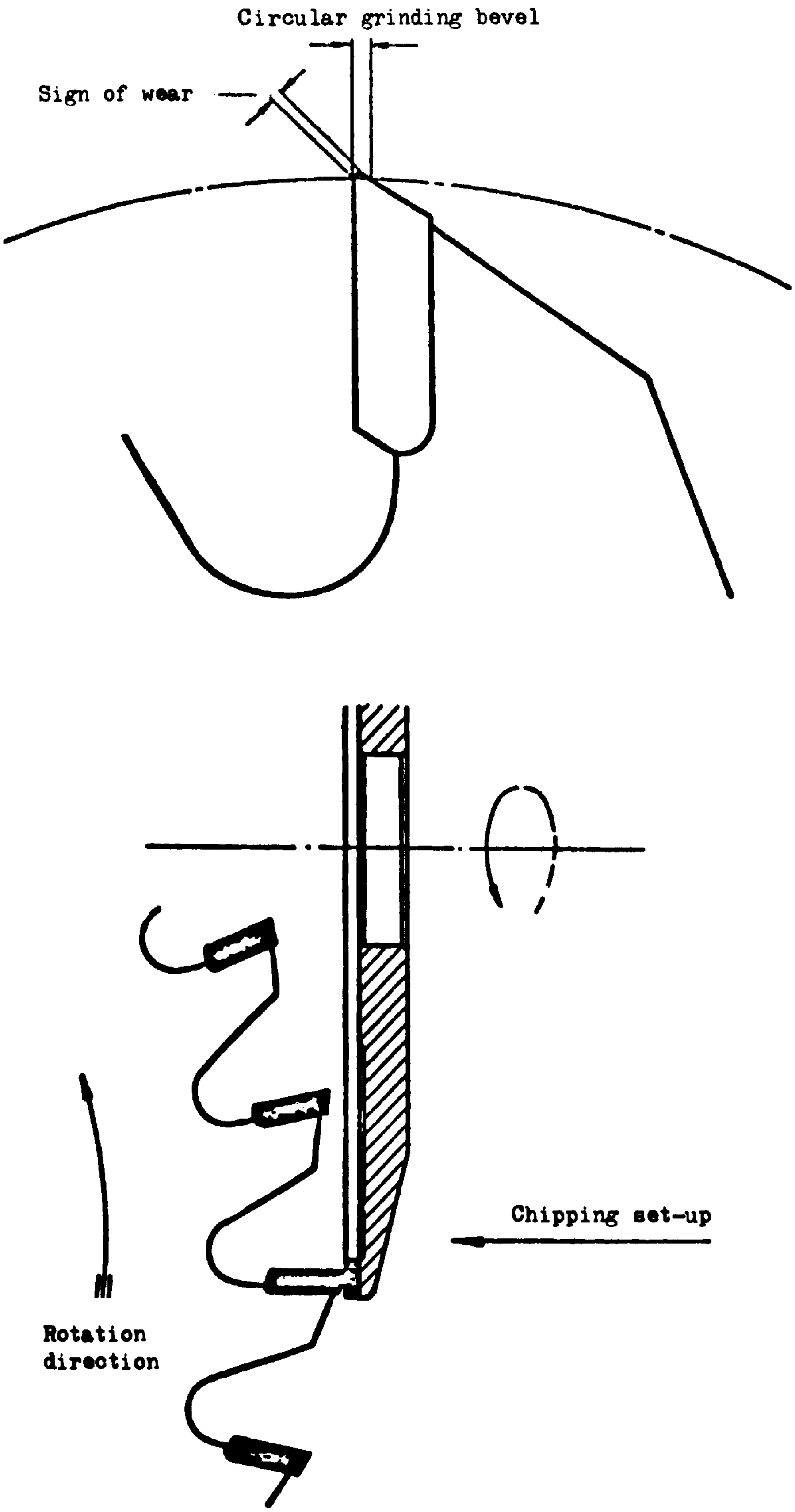
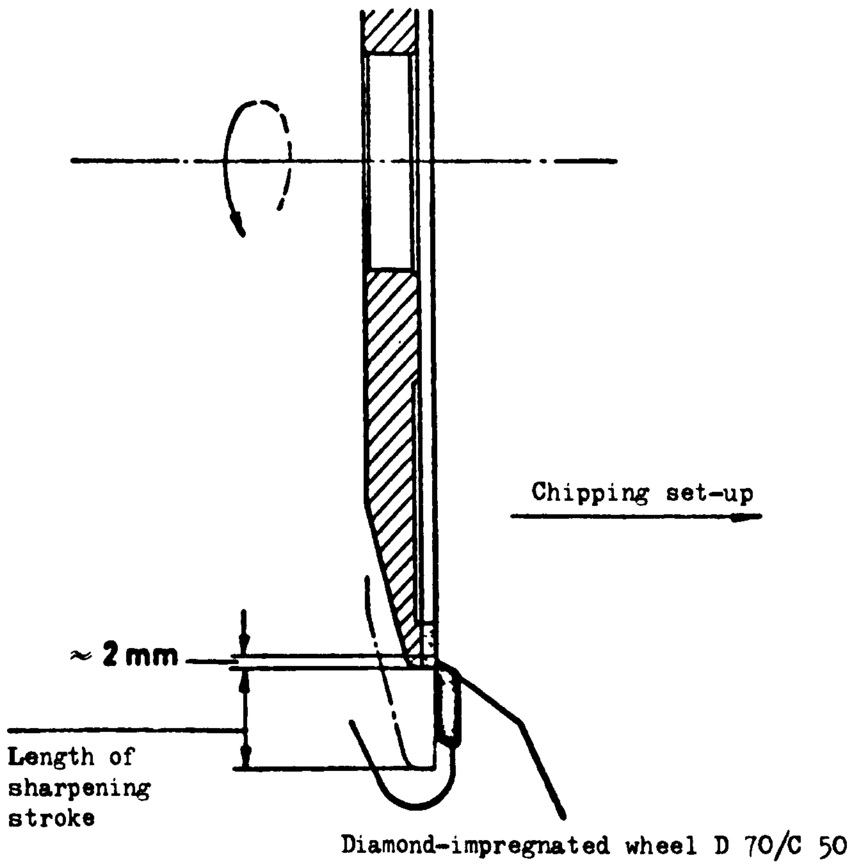


Figure III. Setting for sharpening the chipping edge



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.

Grinding the chipping edge

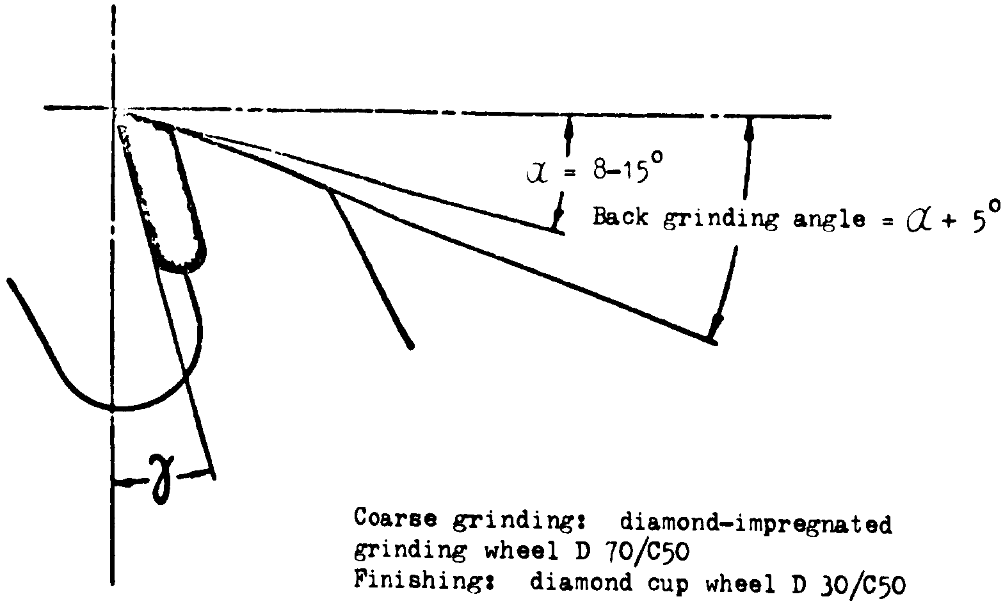
A diamond-impreganted grinding wheel, D 70/C50, is used if coarse grinding is necessary. A diamond cup wheel, D 30/C50, is used for finishing. The cutter with its tightening device is fixed and set to the pitch controller. The pitch controller is turned according to the axial angle so that when the fixing carriage moves, the chipping edge touches the grinding wheel precisely.

Grinding the chipping devices

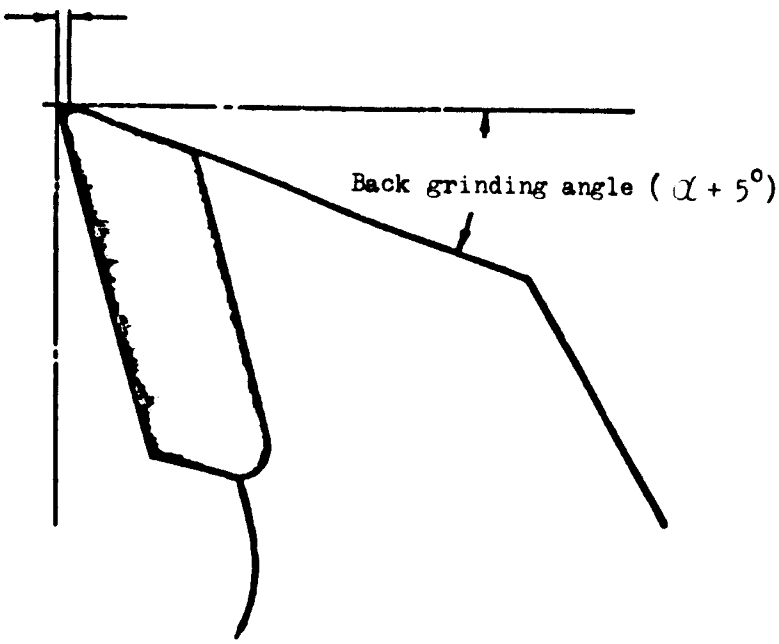
Since the chipping devices made by various manufacturers often differ structurally, it is recommended that the manufacturer's service instructions be observed.

The general instructions for sharpening carbide-tipped circular saws can be applied also to chipping devices. 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.

Figure IV. Setting for sharpening the back edge



Coarse grinding: diamond-impregnated grinding wheel D 70/C50
Finishing: diamond cup wheel D 30/C50



XXIX. Packaging of furniture for export*

Packaging

The packaging methods for protecting and transporting furniture have changed considerably in recent years. In the 1930s furniture dealers were frequently still handicraftsmen. While industry produced furniture, the dealers purchased it unfinished and painted or lacquered and upholstered it before selling it to customers. Today factories are responsible for the entire manufacturing process. Therefore, furniture must be protected for transport and storage. Often the article is delivered to the consumer in a package made at the factory. The packaging of products is one of the most difficult problems encountered in export. A badly designed package and the resulting damage to the product can be disastrous to the trade. When products are sent abroad, their proper packaging is essential.

Damage to furniture

Furniture is expensive and must be handled with care. Repairing damage elsewhere than in the factory where the furniture has been manufactured is difficult, sometimes even impossible, and above all expensive, owing to differences in finishing materials and methods. The more claims that are made for transport damages, the higher the costs are for transport and the more reluctant the manufacturer becomes to ship furniture. Returning products, ordering new ones, waiting for the new delivery and making claims for damage are a strain on the retailer. Thus, damage to furniture concerns three parties: the furniture manufacturer, the owner of the transport company and the dealer. Each has his own problems and responsibilities, although the manufacturer loses most if damage occurs. Transport companies and dealers are not dependent on furniture alone. However, the furniture manufacturer is dependent on them and, consequently, he is responsible for delivering the product undamaged.

Reasons for damage

There are many reasons for damage. Three are dealt with in the following section; they are incompetent handling, defective packaging and the wrong choice of means of transport and storage.

Incompetent handling

The most damage to furniture occurs during transport and storage because of incompetent handling. Usually the lorry drivers or workers in the storerooms have received no training in how to handle furniture. Often they simply cannot afford to handle furniture packages with care; because of their low weight per volume, they are often loaded into trucks or railway cars to full capacity. Furniture packages have always been designed to protect the product in its normal position of use. Packages are often marked to indicate their upper side. Designers and packagers expect the products to be handled in the way indicated by the signs; this, however, does not always happen because of the tendency to use the transport or storage space as economically as possible.

Defective packaging

Considerable damage occurs when products are packaged badly. If the package is too large, the product moves inside it, causing rubbing and other damage. A furniture package must be so tight that the product cannot move in it. Tightness is obtained by filling the inner parts. The package is also defective when too light packaging materials are used. Materials used in domestic transport are not generally strong enough; stronger materials must be used. Most furniture is moved manually. A transport package must be designed so that it is easy to take hold of when moved. If

*By R. Koskenranta and O. Aaltonen, Lahti, Finland. (Originally issued as document ID/WG.209/28.)

the product should travel in a certain position, openings for hands would be helpful. However, some articles are nearly always loaded in a certain position to save space. A rectangular object, if longer than 140 cm, is loaded and stored on its end, hence the ends must be strengthened. The package is also defective if weather hazards are not considered.

Wrong choice of transport means and improper storage

The right mode of transport is not necessarily the most expensive. It is recommended that the best means of transport be chosen first before the cost is reckoned. During the transport there is not as much damage as during loading and unloading, and thus reloading should be minimized, reloading cannot be controlled and therefore the chances of wrong and careless handling are greater. A container going straight to the purchaser may be considered as safe as a full truck-load or railway car. But if other merchandise is transported in the same vehicle and there are reloadings, the risk increases. If it is not possible to arrange a full load to be transported to the customer, it is advisable to arrange one full load destined for one city or at least for one country; this would reduce considerably the risk of damage. In storage high stacks should be avoided. Temperature changes can also damage furniture and in particular severe changes in temperature should be avoided. The storage area should be free from water and water vapour. Part of the products may have been damaged in the factory warehouse. The manufacturer should also pay attention to his own storage. If it can be seen that a package may have been damaged, the product must be checked before being sent further. Many furniture dealers have limited storage areas and this often contributes to further damage.

Function of furniture package

A package that protects the product in all conditions is too expensive to manufacture and use. Thus the purpose of a package is to protect the product during transport and storage in reasonable circumstances against mechanical strain and weather hazards.

The package must protect the product in the following storage conditions: storage indoors and storage outdoors under a roof.

The package must facilitate transport and handling. It must also promote sales of the product through identifying the product and its manufacturer and describing it.

Designing process of furniture package

Package design should be started almost simultaneously with product design. In that way savings may be made in packaging work, storage and transport. The product is protected longer because of a correctly dimensioned and manufactured package. However, in most cases the furniture designer wants individual design requiring individual packages for all products. The package manufacturing industry should be consulted in designing furniture packages.

To obtain efficient package design suited to the purpose, it is important to be familiar with the conditions in which the package will be during transport and storage and other handling. Unlike transport within the home country, in export transport several unknown and rather complicated factors must be considered. The following are some of the more important points that should be considered in package design for export:

Shape, size, weight, structure, quality and price of the product
Destination and route of transport
Mode of transport
Handling of product during transport and storage
Mechanical strain and weather hazards
Packaging standard
Possible use later (secondary use)

The following section deals with different transport means and their effect on packages.

Transport

Railway transport

Railway transport is used frequently since it is an inexpensive and secure means of transport. Experience shows that it requires careful packaging. Special care and skill must be used when loading the car. Fragile objects must not be put under heavy objects. The load must be very tight, since the objects must not move during transport. Reloadings should be avoided since they cannot be controlled.

Container transport

Container transport is used fairly often in furniture export. It usually reduces the need for and costs of packaging. Experience shows that this often is the case, but only if the respective special conditions have been considered. Container transport saves packaging costs most when the container goes directly from the manufacturer to the purchaser without intermediate handling. If the container must be unloaded and the products are packaged more lightly than normally, there may be damage. The problem is not whether to use containers but how to place the packages in them. For example, in a ship's hold the container and the packages in it sway as much as the ship; therefore, packages intended for container transport should not be made light.

Sea transport

Packages during sea transport are exposed to strong mechanical strain and wear. Condensation in the hold and moisture permeation must also be considered when choosing raw materials for the package cover and its inside.

Transport in the company's own trucks

Most furniture factories have their own trucks for the major part of domestic transport. Research and development should be devoted to improving the loading areas so that packages could be made lighter. It may be uneconomical to use the company's own trucks, but it is definitely the surest way.

Packaging materials

Wrapping materials

Corrugated board. At present corrugated board is the most popular raw material for the cover of furniture packages. It is made of two rather thin boards, at least one of which is corrugated.

The main types of corrugated board are:

Single-faced corrugated board (figure I)
Double-faced corrugated board (figure II)
Double-wall corrugated board (figure III)
Triple-wall corrugated board (figure IV)

Single-faced corrugated board is delivered in rolls or sheets. To facilitate packaging, it can be grooved at the back. It is used in packages, and as wrapping, cushions and insulation.

Furniture packages made of single-faced corrugated board are still commonly used, but their use is expected to diminish in the future. Its use in packages for export is rare since its modest appearance makes it unsuitable. It is used mainly to prevent objects from moving in a box, or it can be used as a filler to make the packages tight.

Double-faced corrugated board is mainly used for the manufacture of package boxes and interior fitments. Boxes made of it are used mainly to package furniture for export. It can be used for the manufacture of ready packaging boxes, or if the furniture factory wishes, it may be delivered in sheets cut to the desired dimensions which are used at the factory for the manufacture of packages for export.

Figure I. Corrugated board is increasingly used for packaging furniture. This type is single-faced and is a flexible material used for wrapping

Figure II. Double-faced or single-wall corrugated board is used for lighter packages

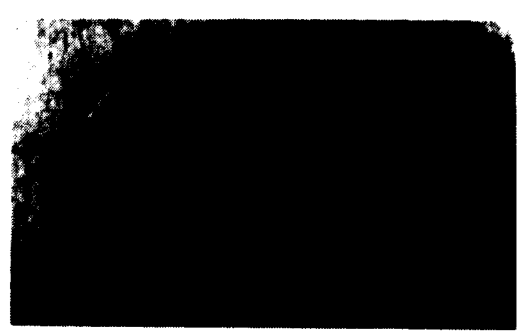


Figure III. Double-wall or double-double corrugated board is used especially for export packages

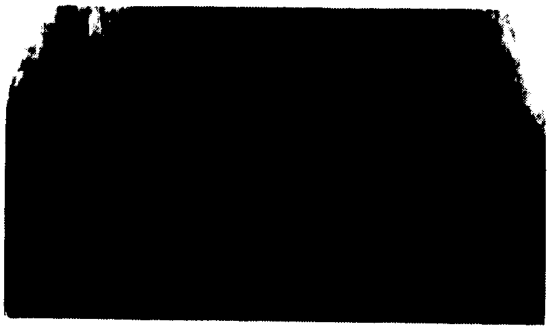
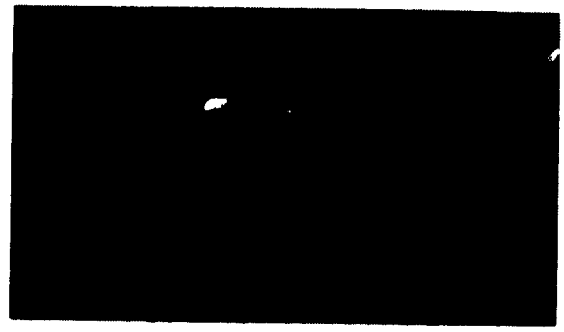


Figure IV. Triple-wall corrugated board is used for very heavy packages



Various factors affect the choice of quality of corrugated board. The most important are:

(a) The mode of transport used by the factory;

(b) Whether the package is intended for domestic or export transport;

(c) Quality and structure of the product.

When choosing the quality of corrugated board it has to be decided whether it is enough to protect the product against impacts and foreign objects, or if the package is able to carry a load on top of it. In other words, is the product's own capacity sufficient or is it so low that the packaging box alone must take a load on top of it, particularly in storage? A heavily built chest is probably strong enough to carry a heavy load, but a bedside table may easily be damaged.

Other packaging materials

In special cases the package can be made of wood, fibreboard or plywood. These are used particularly in export packages, which are delivered (as an example) individually by sea. All three materials can be used in combination if so desired.

Raw materials for the inner package

The following are different raw materials that may be used in combination or alone in making the inner part of the package:

Single-faced corrugated board
Wax paper
Plastic film
Synthetic paper
Kraft paper
Sulphite paper

Corner and edge covers

These are used to restrain impacts and knocks during transport and storage. They protect the most fragile areas and are made of expanded polystyrene (figure V), corrugated board (figures VI and VII) or plastic.

Closing materials and equipment

Materials that can be used alone or in combination to close the package are:

Gummed tape
Self-adhesive tape
Staples and yarn
Plastic strapping
Steel strapping
Glue

Figure V. Protectors made from expanded polystyrene are very popular in the furniture industry. They are supplied in standard shapes and lengths and can be easily cut to the size required

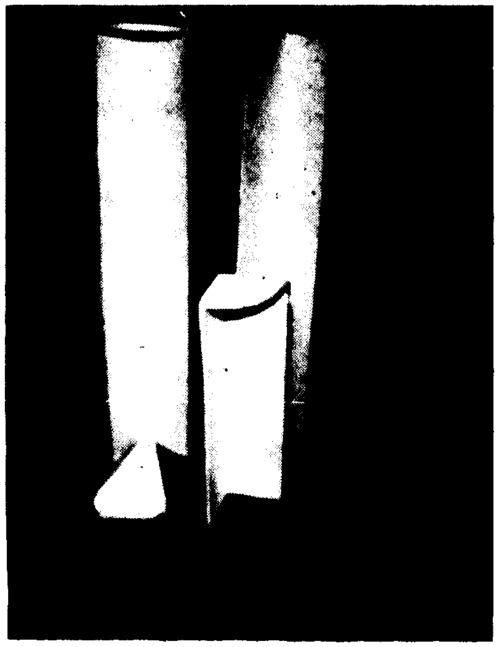


Figure VI. Corrugated board in general provides good possibilities for constructing interior fitments for all kinds of furniture packages

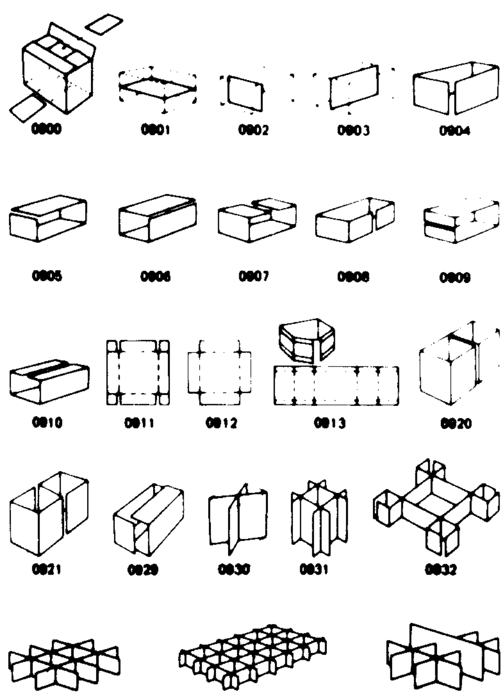
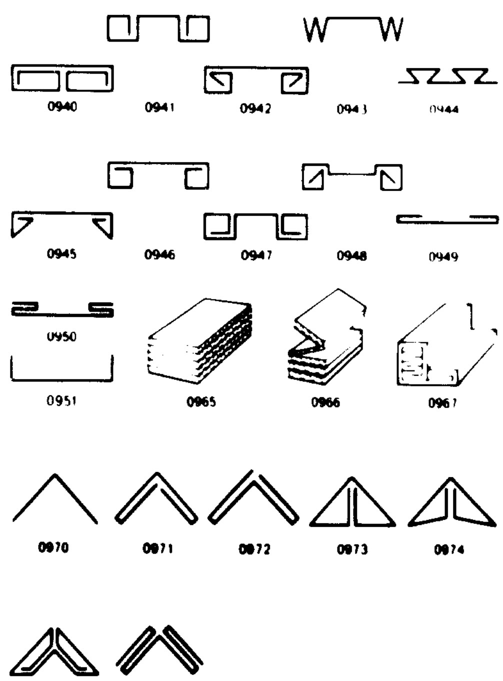


Figure VII. Some applications of corrugated board as corner and edge protectors, pads etc.



Marking materials and equipment

In the final phase the packages are marked; for this, labels and text slips, pens, chalks etc. are needed.

Box packaging of furniture

The basic principles of packaging are:

(a) That there must be some material to prevent rubbing against the surface of the product (figures VIII-XII);

(b) That edges and corners, which can be damaged easily, must be protected separately (figures XIII-XV);

(c) That detachable parts (such as table legs) must be fastened tightly inside the package so that they cannot become loose during transportation and storage (figures XVI-XVIII);

(d) That the product must be packaged in the box so that it cannot move at all (figures XIX and XX);

(e) That the box must be closed carefully.

Closing the box

The strength of the package is also dependent on the correct closing method. A box made of first-class raw materials and of solid construction is worthless if it is not closed so that the closing points are at least as strong as the other parts of the package. A frequent reason for transport damage is failure in the closing point.

The following materials may be used for closing furniture packages:

Gummed tape
Self-adhesive tape
Staples
Strapping
Glue

Closing witn gummed tape is a good method. A box closed with gummed tape is tight and neat, easy to open, and when properly done it strengthens the box. This method, however, requires absolute care and skill. Devices and auxiliary equipment designed especially for this purpose must be used.

The use of adhesive tape in closing can be compared with gummed tape. Its price is higher, but it is easy to use and the auxiliary devices are simple. When using different types of tapes, very strong joints can be obtained.

The use of staples involves a risk owing to the penetration of staples. The method as such is fast, and when properly made the joint is strong. A box closed with staples is not tight, so that moisture and dirt penetrate to the products through the seams. The staples can rub the product or tear the upholstering material.

The packages can be strengthened with strappings, but straps are not recommended for use in closing packages in which the product does not give support to the package.

Figure VIII. The table is wrapped in padded paper

Figure IX. A small cabinet with its polished surface protected by a padded paper wrap

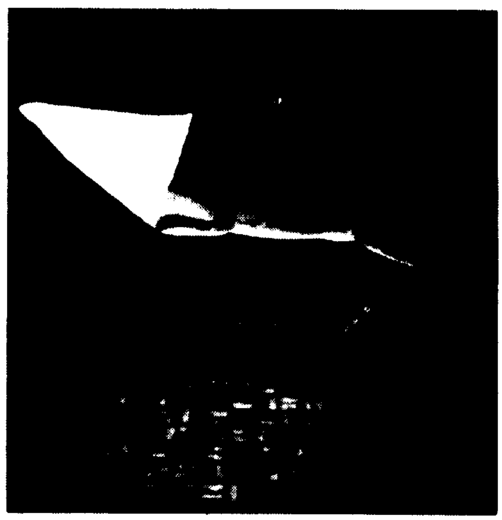


Figure X. To package a small chair, start by protecting the surfaces of the chair with a padded paper wrap

Figure XI. An empty corrugated folder is placed on the seat of the chair

Figure XII. Another chair is placed in an inverted position on top of the first one

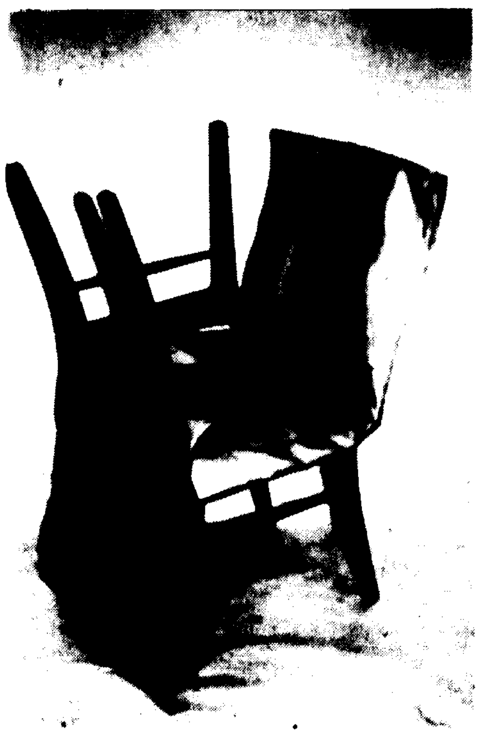


Figure XIII. An example of a pointed cabinet with corner protectors

Figure XIV. This cabinet is first wrapped in a loose plastic film and the protectors fixed in their correct place by strings or tape

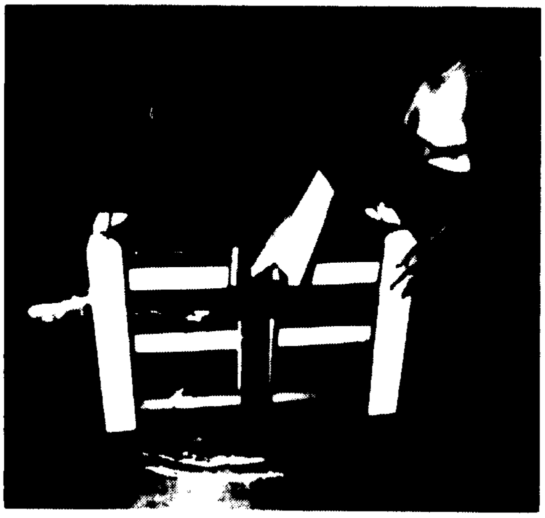


Figure XV. Corner protectors are added

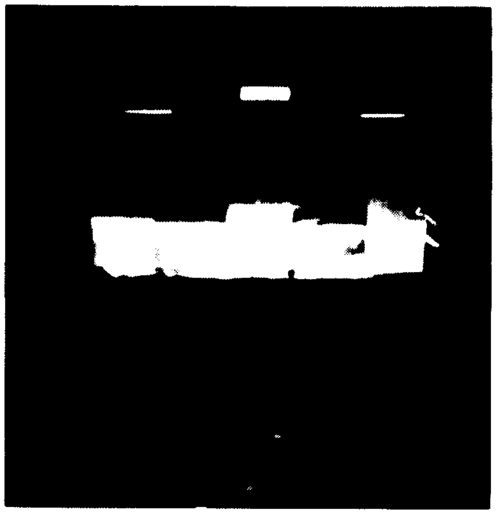


Figure XVI. The legs are removed individually wrapped and secured under the table top

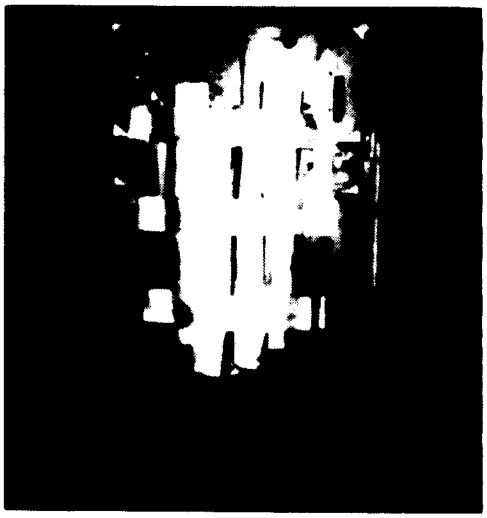


Figure XVII. The legs of the two chairs in the corrugated box are protected by special corrugated interior fitments

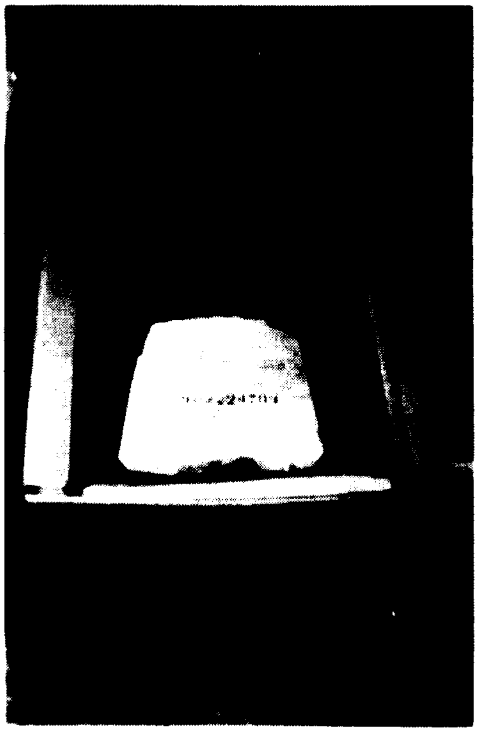


Figure XVIII. The chair legs may be fixed into holes in the inner flaps of the box itself

Figure XIX. The finished package for a dining table

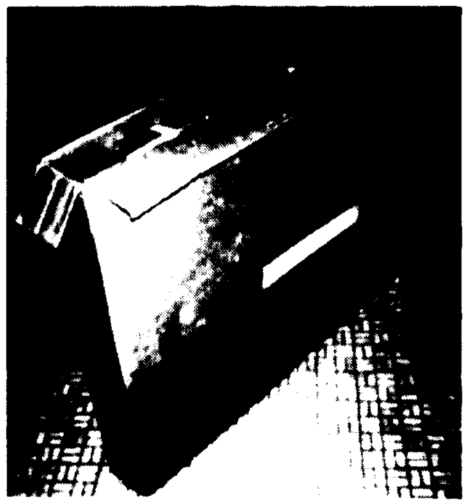
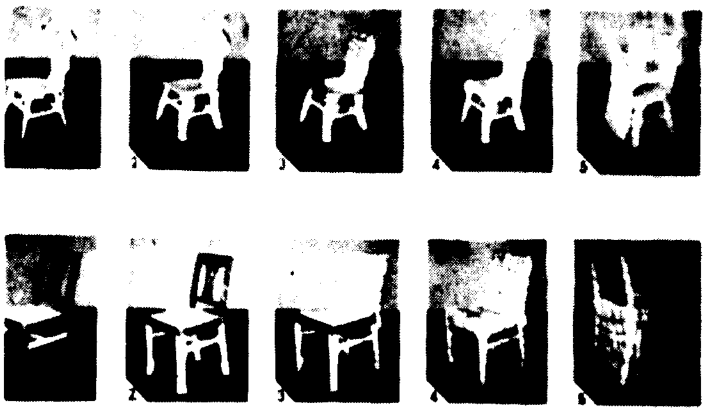
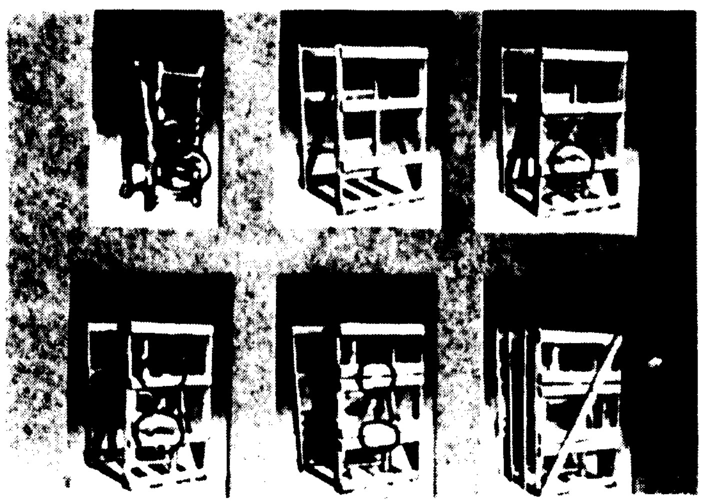


Figure XX. The proper wrapping of furniture is a time-consuming operation. (a)-(b) shows how it should be done

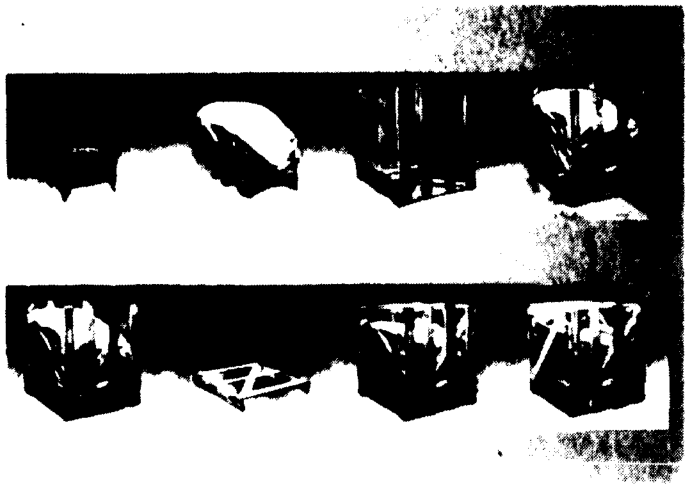


(a) Steps in wrapping two chairs



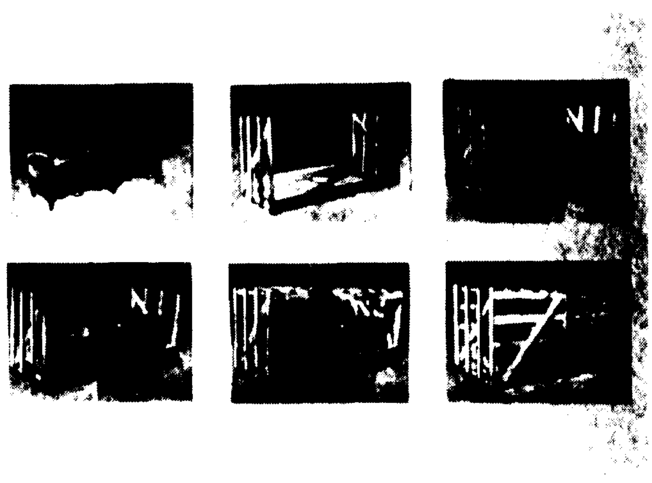
(b) Packaging two chairs

Figure XX *(continued)*



(c) Packaging a lounge chair

(d) Packaging two lounge chairs



(e) Packaging a large-size sofa

Standardization of box packages

The main difficulty in using corrugated board boxes in the furniture industry is the short production series of the factories and their wide product range. Therefore the amounts of boxes of different sizes and shapes ordered are relatively small from the point of view of the box manufacturer. For this reason the furniture factory should standardize packages so that the same box would be suitable for many different products.

Shrink-film package

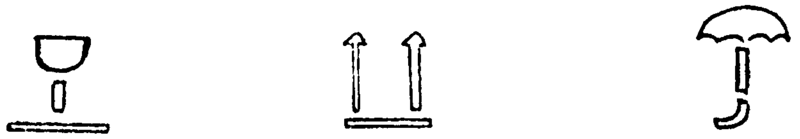
There is no reason to deal here with shrink-film packages in detail since packaging with shrink film requires equipment that is not possible to buy for small factories. Shrink-film packages are not recommended for export packaging except as inner packages for which purpose they are very efficient. The transparency of the package apparently results in more careful handling.

Marking packages

Corrugated-board boxes can be printed either with continuous print or individual design. Individual printing is recommended because it can give necessary information to the receiver, such as name of product, wood species, colour, fabric etc.

Handling instructions and end-use

Handling instructions can also be printed in advance. The signs have been designed so that the symbols indicate the method of handling. The use of signs is supposed to guarantee correct handling in all phases. The symbols are based on the recommendation of ISO. The following signs are the most common handling instructions for furniture packages:



handle with care   this side up   protect from moisture

A general rule about the position of signs is that the person handling the packages should be able to notice them easily.

The handling instructions are part of proper packaging and are very important in preventing damage. They are a prerequisite for claims against the person responsible for careless handling that has caused damage.

Packaging costs

Packaging costs may be grouped as material costs, labour costs, machinery costs and factory area costs.

The costs of machinery and factory area are rather small in the furniture industry, so that cost saving through them is difficult. The main costs are material and labour, which are both significant. The following list indicates the packaging costs of a Finnish furniture factory in which domestic and export packages are compared. The costs are given as percentages of selling prices of the product.

	Packaging costs as percentage of selling prices	
Product	*Domestic*	*Export*
Chair	0.7 to 3.0	2.7 to 10.0
Chair, with arms	0.8 to 1.6	3.0 to 6.0
Table, delivered in parts	0.7 to 4.2	1.9 to 7.5
Cabinet, large	0.7 to 1.1	1.8 to 3.0
Cabinet, small	1.8 to 2.7	5.4 to 8.1
Sofa and two armchairs	0.3 to 1.5	0.8 to 3.7
Approximate average	1.7%	4.5%

As one can see, export packages are a considerable expense. The variation in percentage share in package costs results from the fact that a more expensive product is packaged in a package similar to that of a less expensive product.

Significance of packaging

Packaging as a means of protecting the product is particularly important in transport and product transfer, since that is when the strength of the package is thoroughly tested. A proper package is an important form of service. It speeds the handling of products and guarantees their arrival to the receiver in good condition; it also testifies to the dependableness of the factory.

Correct export package

No single method of packaging may be called the correct one. The article to be packaged and the conditions change even within the factory, not to speak of the variations in articles and conditions in different countries and continents. The principles remain the same: the package has to be suited to the purpose. When it is made, thought must be given to the risks that the article may encounter during transport and storage. Development of packages to suit the different phases of transport requires close co-operation between factory and the people handling the product during transport and storage.

Conclusions

Packaging of furniture, especially for export, is one of the most difficult problems in packaging technology. There are a number of reasons for this:

(a) Furniture is an expensive commodity;

(b) Furniture is very fragile and even small defects caused by damage during transport will make it difficult to sell;

(c) Furniture usually has a large shipping volume and is irregular in shape.

A study on furniture packaging shows three main reasons for damage during transport: inadequate handling, inadequate packaging and inadequate storeroom facilites.

The most important things to remember in packaging furniture are:

(a) A very tight fit in the package in order to prevent any movements of the furniture item inside;

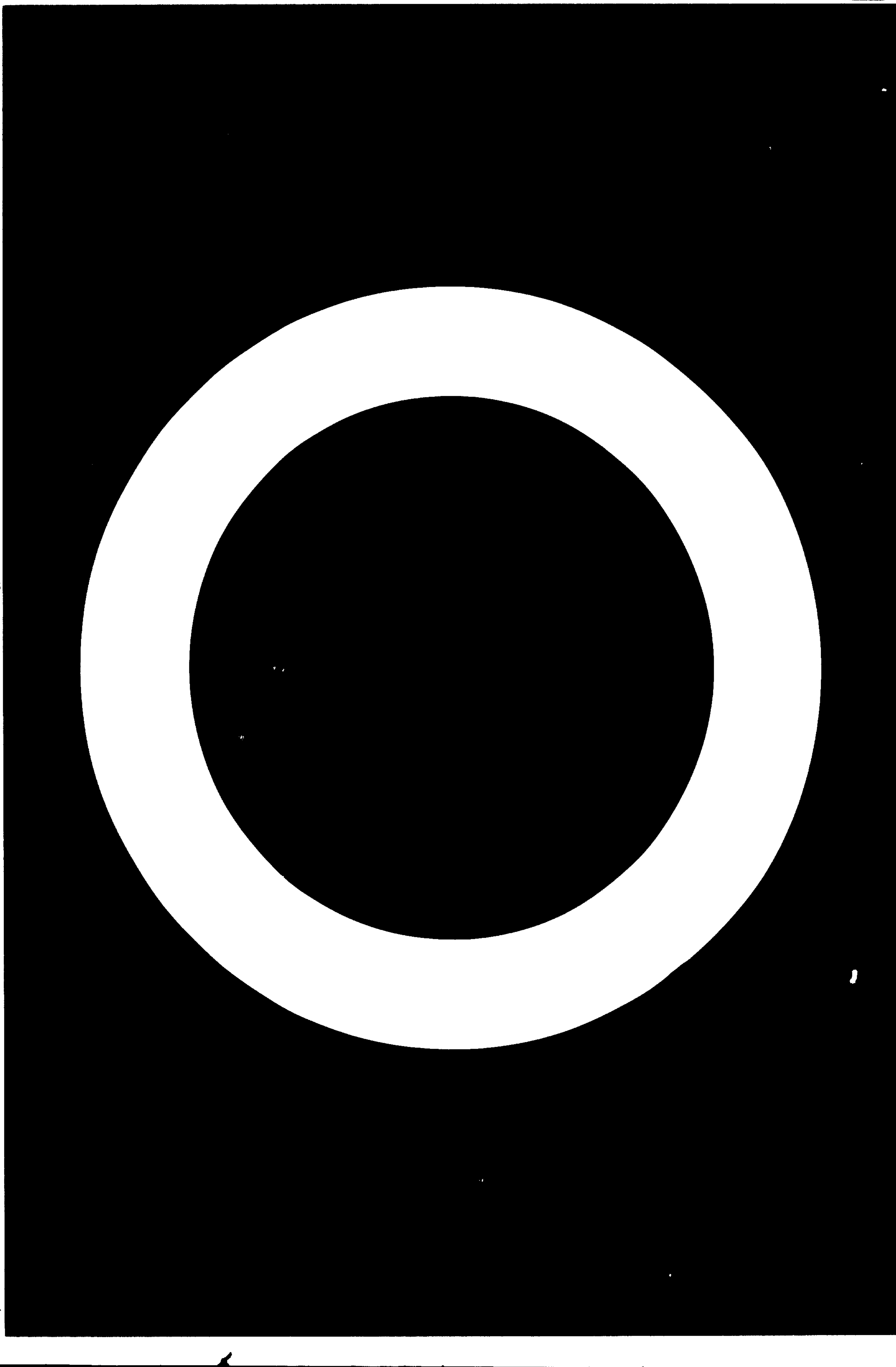
(b) Protection against mechanical shocks by use of cushioning materials, especially to protect edges and corners;

(c) Protection against scuffing or other damage to lacquered or painted surfaces;

(d) Protection against dust and excessive moisture.

Part three

MANAGEMENT CONSIDERATIONS



XXX. Quality control*[1]

The quality of a product determines its usefulness; certain levels of quality correspond to different uses. Quality in general has no absolute value; therefore, only average or relative quality may be considered. Individual pieces are not equal since their qualities differ. This variation usually results from factors connected with raw material and semimanufactured articles, machines, tools and workers' ability. Variation is quite natural and cannot be avoided even in the most careful production.

The variable qualities of a product of the wood industry are, for instance

Measures (length, thickness, breadth)
Condition of the wood (moisture content, number and size of knots, density)
Quality of workmanship (evenness of surface, durability of glued joints, clearances)

Because such variations are more common in woodworking than in many other branches of industry, quality control in the wood industry is relatively complicated and difficult. Production processes in furniture and joinery are divided into many secondary stages, and it is always possible that faults will multiply as the individual items move along the production chain. It is thus not enough to inspect finished products; quality control is necessary throughout all stages of production. It is most important, however, to control production at the beginning of the process. If this is done, economic losses can be avoided because faults will not multiply.

As an example, faulty measurement of length in pre-cutting may be cited. A piece is dried, edged, surfaced and thickness-planed. If it is found to be too short in edge planing it is rejected, transferred to another part of the process or stored for future use. Such errors result in unnecessary work and in increased raw material waste, storage space requirements and difficulties in planning work or repairing products, all of which leads to declining profits.

To summarize, uncontrolled quality gives rise to many difficulties. Among the most important of these is decreased product acceptability leading to rejection of items by consumer and dealer alike, which in turn creates a disposal problem, decreased profitability and a decline in the morale of the work force.

The purpose of quality control is:

(a) To narrow the range of acceptable product variation;
(b) To detect variations in excess of this range;
(c) To work out a system whereby the production process can be followed through its successive stages without unexpected difficulties.

The costs of quality control should, however, be proportional to other costs.

The nature of the production process usually determines the method of quality control. In unit production there are no large series; many different articles are produced randomly, often to order. In this case production volume (and the factory size) is often relatively small, and thus the costs of quality control cannot be very high. Control by sample tests and measurements, normally by a foreman, is suitable for production on this scale. Nevertheless, control must be strict despite its sporadic nature, and it must be repeated at each stage of the work. Simple visual examination, as a general procedure, belongs to this type of control. In addition, measurements must be carried out with appropriate instruments, such as the following:

A linear measure for length, breadth, height and cross-measures (squareness)
A caliper gauge for thickness and breadth
A set of gauges and a ruler for clearances of doors, drawers and the like, and for surface smoothness (a powerful light source is also necessary)
Equipment to check the moisture content of wood (by either the electrical or weighing method)
A wet and dry thermometer and equilibrium curves to determine the humidity of the ambient air

Checking may be done at various times, but it must be done daily. If the foremen are to be responsible for quality control, each of them must be assigned his own special, limited field. However, the best results are achieved when there is a special inspector in charge of quality control.

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*By Jaakko Meriluoto, Lahti Technical Institute, Lahti, Finland. (Originally issued as document ID/WG.133/28.)

[1] For a discussion of specific measures of quality control in the furniture industry, see chapter XXXI.

In either case records must be kept. The best way to ensure that this shall be done is to have a special tabular record that makes it easy to control the situation. The notes make it possible to determine the circumstances of manufacture afterwards; this possibility is important especially if claims concerning performance are made later. The records on quality control are comparable to factory reports on cost calculations and they have a similar value to the factory management.

In serial production a relatively limited variety of articles is manufactured in large series. The production plant is usually larger than in the case of unit production and in addition it is more automated.

As unit costs in serial production can be kept relatively low, more money can be invested in quality. Automation and the specialization of human labour increase the importance of quality control because in uncontrolled serial production there is a great danger that the volume of faulty products may become very large before it is noticed.

Serial production may be controlled by using the sample tests mentioned above for custom work, but statistical (mathematical) quality control is more appropriate and effective. Only an expert or skilled craftsman should perform this work. The objects and means of control are the same as in the previous situation. The difference lies in the fact that the schedule of specimen or sample measurements is regular, their number is large and the treatment of mesurement results is mathematical (mainly analysis of test figures). Space does not permit proper discussion here of statistical quality control, but there is a wealth of literature on it. A few representative titles are included in the selected bibliography that follows.

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XXXI. 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 least variation can be attained in individual production in which each part or component can be finished and fitted separately so that the desired standard is finally 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 quality may 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.

Compared with many other branches of industry, there are many reasons for the variation of quality in the wooden furniture industry. Typical variables are the following:

(a) Properties and condition of lumber: moisture content, number and size of knots and other faults, specific gravity, strength properties;

(b) Properties and condition of other raw materials and semi-manufactures: veneer, wood-based panels, plastic parts, fittings;

(c) Dimensional accuracy of machined components: thickness, width, length, joints, forms;

(d) Dimensional accuracy of assembled products: external and internal measures, clearances between moving parts;

(e) Quality of surface finishing: evenness of surface, colour shade, gloss of lacquered surface;

(f) Durability of finished products.

The 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 the use of specially designed simple equipment. As much of this equipment can be self-made in the plant, only 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.

Lumber, for example, is usually bought from outside sawmills and should be checked at the sawmill's lumber yard or in storage at the time the lot is ordered. The same principle applies to veneers. Inspection of the ware on receipt at the factory is usually necessary to make sure that the correct lot has been delivered. All semimanufactures 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 lumber, veneer and wood-based panels.

Inspection of the principal materials usually covers the items indicated briefly below.

*Paper prepared by Pekka J. Paavola, Lahti Technical Institute, Lahti, Finland. (Originally issued as document ID/WG.209/24.)

Lumber or solid wood

Lumber 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 lumber: 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 seasoning (air-drying, kiln-drying) and it requires cutting of test samples. (See later section on "Control of moisture content of solid wood".)

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 light of strong incandescent lamps. Fluorescent lamps are not recommended because of their unsatisfactory spectral properties;

(ii) Uniform quality from batch to batch is of major importance, particularly in 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 in use;

(iv) Pyramid figure is normally allowed to some extent in parts in which the grain direction of veneer will be vertical, e.g. cabinet doors and end panels (figure I);

(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. (figure I);

(c) Thickness and its variations: a micrometer is a suitable measuring instrument;

(d) Evenness of surface: surface should be plane (not wavy) and smooth;

(e) Moisture content:

(i) Handling of veneer necessitates at least 10 to 12 per cent moisture content to avoid splitting. Veneer is too crisp in lower moisture content;

(ii) Ideal moisture content at the moment of veneering with hot press is about 2 per cent lower than moisture content of panel or core wood;

(iii) In case veneer is too moist when gluing, surface checking is to be expected after the panel has attained its final equilibrium moisture content.

Wood-based panels

This group includes particle board, plywood, blockboard and fibreboard. The main objects of inspection are:

(a) Surface quality: its suitability for veneering or painting. Urea-formaldehyde glue requires smooth surface which offers good contact;

(b) Thickness and its variations: 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: 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 later conditions of use.

Glues, lacquers and paints

Glues can be best 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. Ford Cup No. 4 (figure II) having 100 cm^3 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.

Figure I. Veneering according to the pattern of the grain

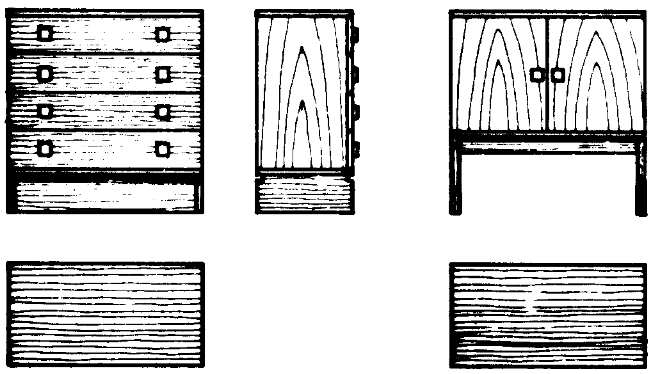
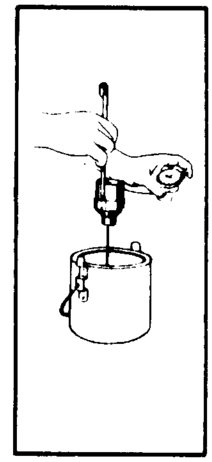


Figure II. Viscosity is measured with a Ford Cup



Control of moisture content of solid wood

The proper moisture content of solid wood to he processed is the primary prerequisite for high-quality products. Wood is a hygroscopic material which 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 graph in figure III gives the average equilihrium moisture content as a function of the relative humidity and temperature of air. These values apply to all species of wood with sufficient accuracy for all practical purposes.

The shrinking and swelling of wood when exposed to variations in moisture are among its most unfavourahle 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 IV. Table I gives the average dimensional change of wood in percentage for certain species when exposed to a 1 per cent change of moisture content. 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.

The ideal moisture content for wood when processed is the equilihrium moisture content of the final conditions of use. From this it follows that the factory climate should have the corresponding relative humidity and temperature. As the time normally needed for all production stages in 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 air in material stores and factory shops is best controlled with a hygrometer giving readings direct in percentages. The meter should be centrally located and fixed, e.g. on a pillar.

Control of moisture content of wood should be done in the following stages:

(a) Whenever possible when buying and ordering a lot of lumber from a sawmill;

(b) When receiving the lot at the furniture factory;

(c) Before kiln-drying; lumber is usually then air-dried;

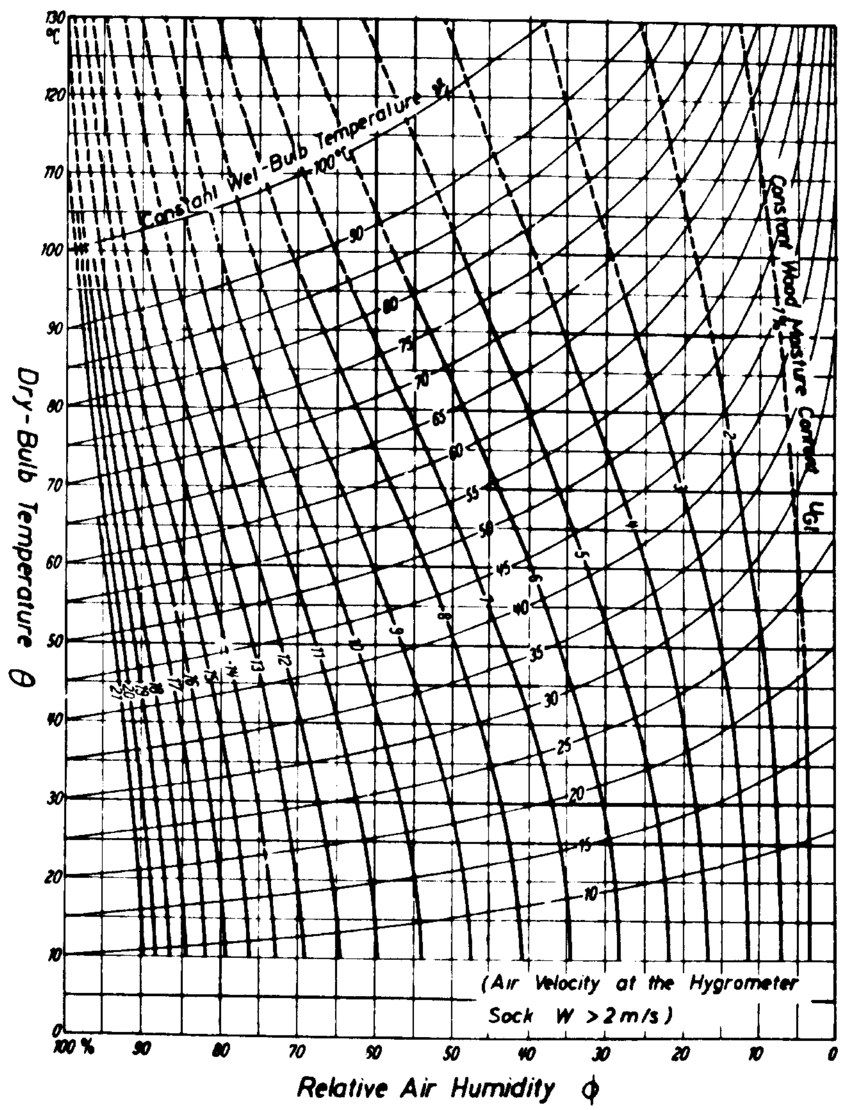
(d) During the kiln-drying process to check that the drying is progressing according to the schedule suitable to the species and thickness in question;

(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.

Figure III. Graph for determination of equilibrium moisture content of wood as a function of relative humidity and temperature of air



Source R Keylwerth 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%)

Moisture content determination

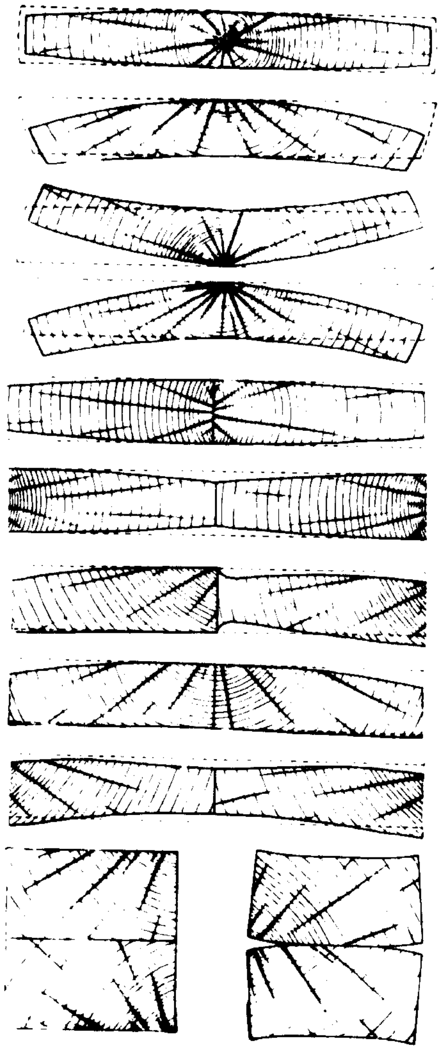
The moisture content of wood is usually determined either by the oven-dry method or by electrical moisture-meters. The oven-dry method is the most exact, but it is slow and requires samples cut from material. Because of its accuracy, however, this method is used as a standard method for moisture determination in kiln-drying. The samples should be sawn from boards according to figure V.

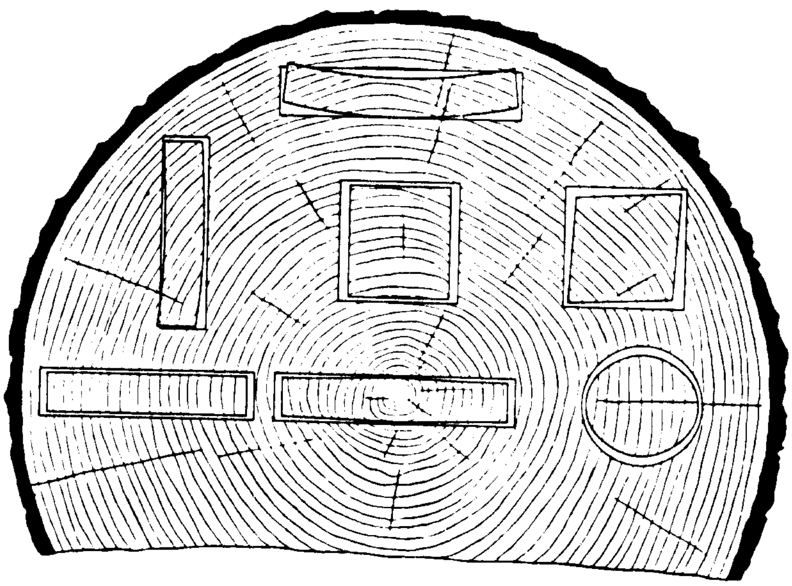
The sample is weighed and then placed in a laboratory oven heated to 103°C ± 2°C and kept there until constant weight is reached. This indicates that all water has been removed from wood. The loss in weight gives the amount of moisture that was in the sample when sawn. The moisture content is calculated 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.

Figure IV. Cross-sections of wood showing deformations from shrinkage





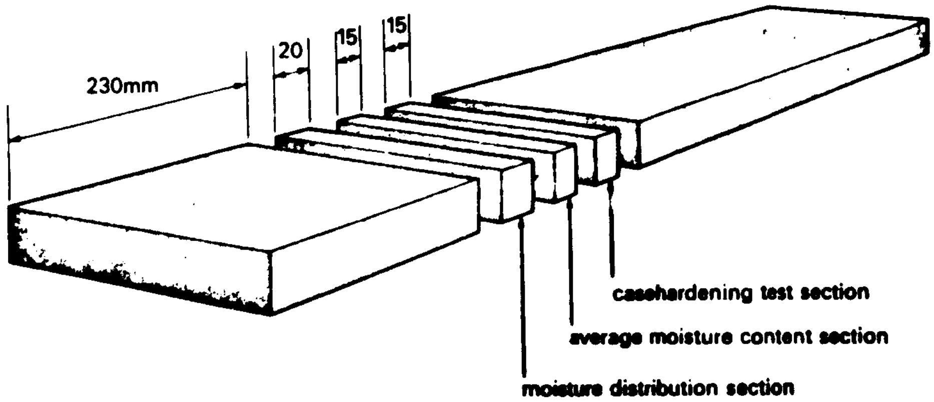
Characteristic shrinkage and distortion of flats, squares, and rounds as affected by the direction of the annual rings. Tangential shrinkage is about twice as great as radial.

TABLE I. SHRINKAGE IN TANGENTIAL AND RADIAL DIRECTION WITH A DECREASE OF WOOD MOISTURE CONTENT BY 1% 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
Hamlock	0.25	0.13	**Lima**	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
Afrormoala	0.32	0.18	**Walnut**	0.30	0.20
Afzelia	0.22	0.11	**Gaboon**	0.24	0.16
Agba	0.20	0.11	**Ramin**	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
Green heart	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

Figure V. Sawing samples for the determination of moisture content

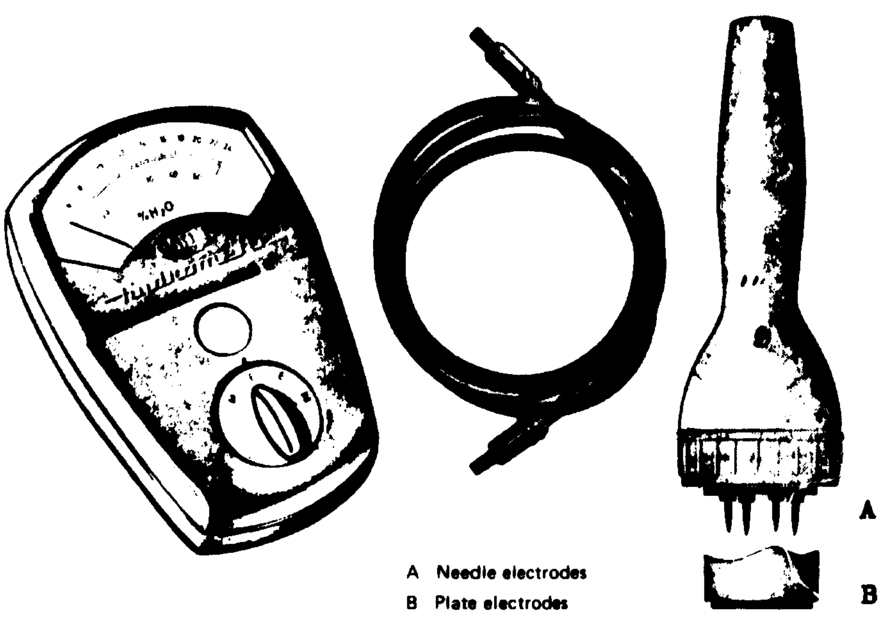


Electrical moisture-meters

The 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 (figure VI), 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 nail-electrodes to different depths, or the value obtained for nails driven to one fifth the thickness should be regarded as representative of the average moisture content of wood.

The electrical moisture-meters can also be used to control the moisture of particle board and fibreboard, providing the necessary corrections are applied. The correction tables needed are usually enclosed in the meter package. Testing of veneer requires plate types of electrodes.

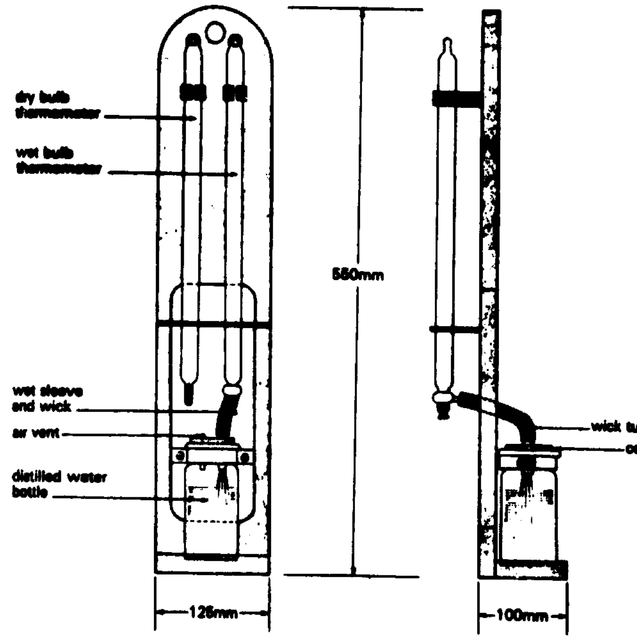
Figure VI. Electrical resistance-type moisture-meter



Moisture control in kiln-drying

The operation of a drying kiln is controlled by the relative humidity of air in the kiln compartment. The relative humidity is measured either with simple wet- and dry-bulb hygrometers (figure VII) or with electrical instruments. The most advanced prefabricated kilns are completely automated and operate according to programmed schedules.

Figure VII. 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 show, 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 moisture content during the manufacturing process. The accuracy with which small details like 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 normally can be bored with 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 equipment. 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 of machines, 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) Number of faulty parts or products decreases;
(f) Higher quality means easier marketing;
(g) Less reclamations from customers.
(h) Profitability becomes better.

Measures in order to achieve high accuracy are:

(a) The machines are regularly serviced according to their working instructions.;
(b) Proper type of tools are used.
(c) Only well-maintained tools are used;
(d) Machines are set up by using high-quality special measuring instruments like micrometer dials and set-up gauges. The set-up made is best checked by test feeds and using nominal measuring gauges;
(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: these include steel tape rulers. Vernier calipers. angle gauges etc. (figure VIII);
(g) The unavoidable variations in measure are concealed by structural means. by already taking them into consideration in the design stage of production (figure IX).
(h) Nominal measure gauges and templates are used to control the dimensions during machining (figure X);
(i) Jigs are used in machining and assembly whenever possible (figure XI);
(j) The machining and assembly shops are adequately illuminated;
(k) The accuracy is continuously controlled by spot tests.

As mentioned before. 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:

Tape rulers with mm-scale
Rigid straight rulers with 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. The most important ordinary measuring instruments are shown in figure VIII.

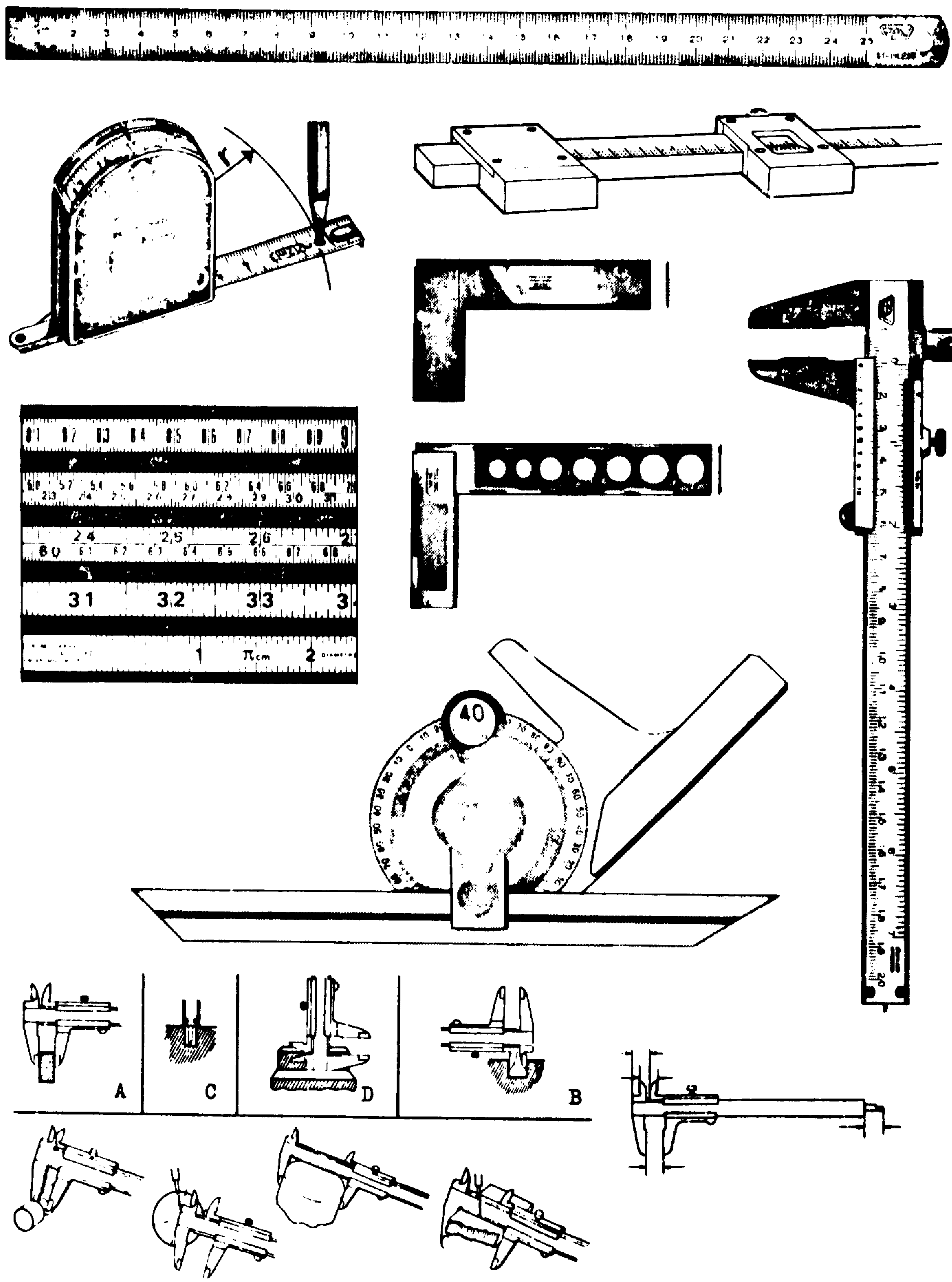
Nominal measure gauges

The set-up of machines and later control of measures in machining can be greatly facilitated by the use of specially constructed nominal measure 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 X. 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

Figure VIII. Ordinary measuring instruments



Source: Teknologisk Institut, Denmark, Department of Wood Technology, "Measuring Instruments".

Figure IX. Structural means of concealing dimensional inaccuracies

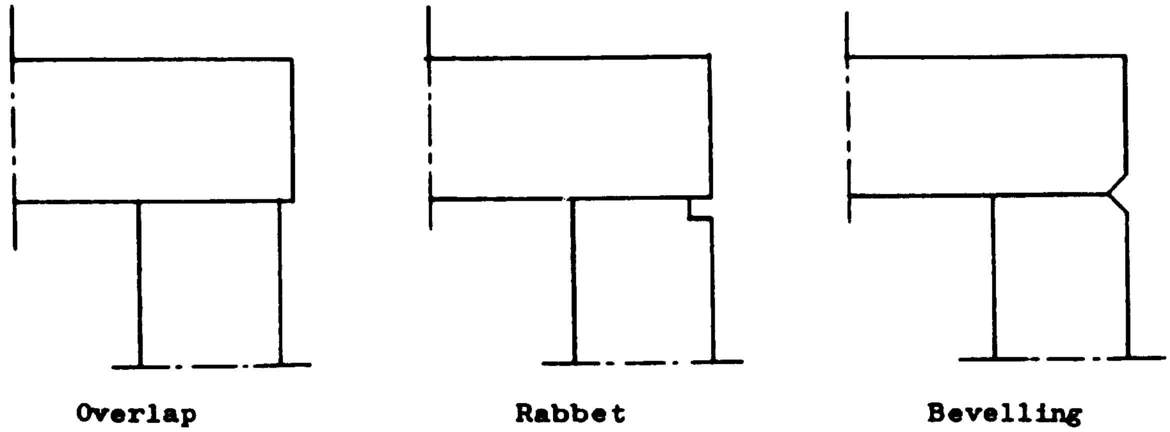


Figure X. Nominal measure gauges

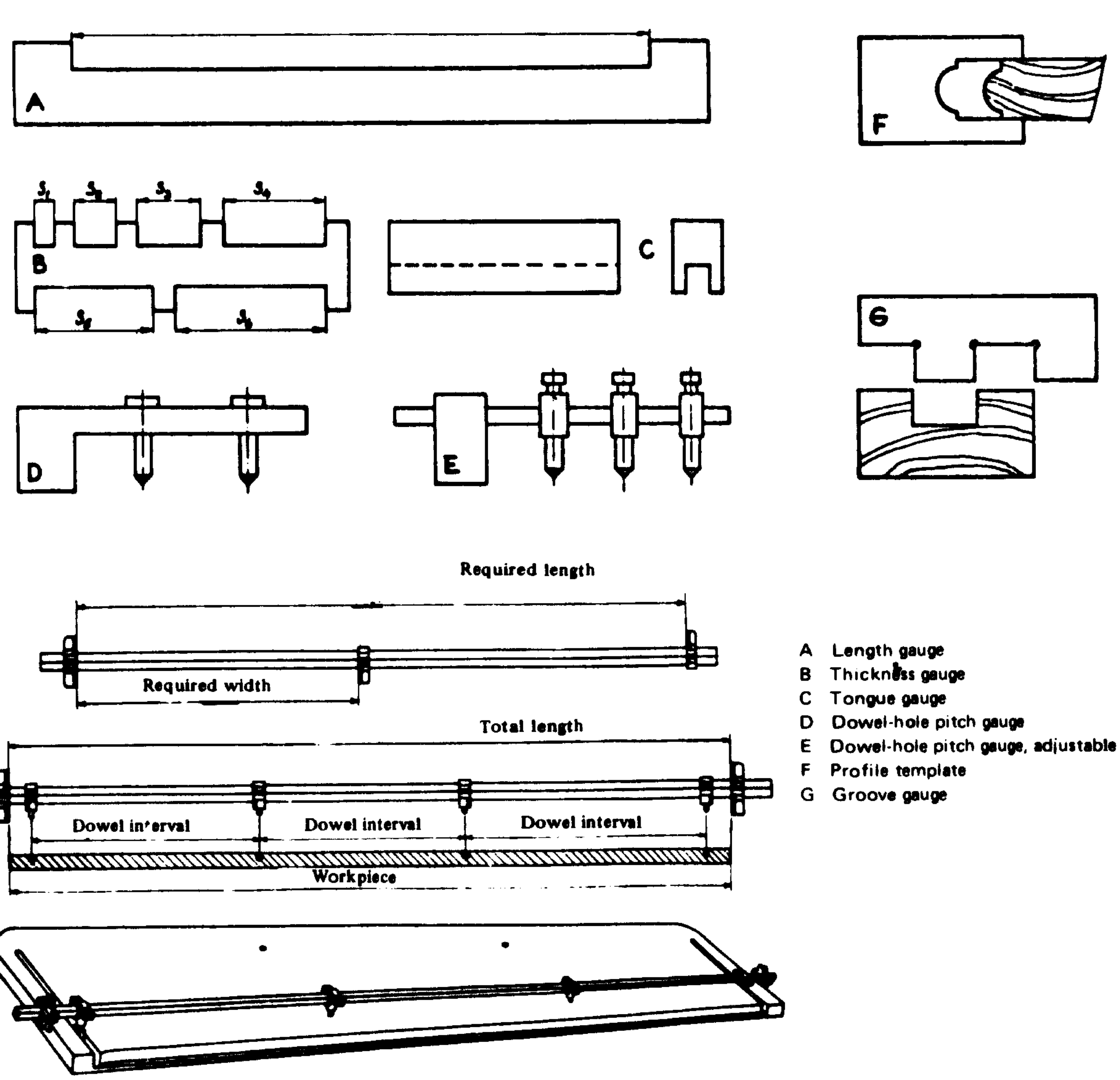
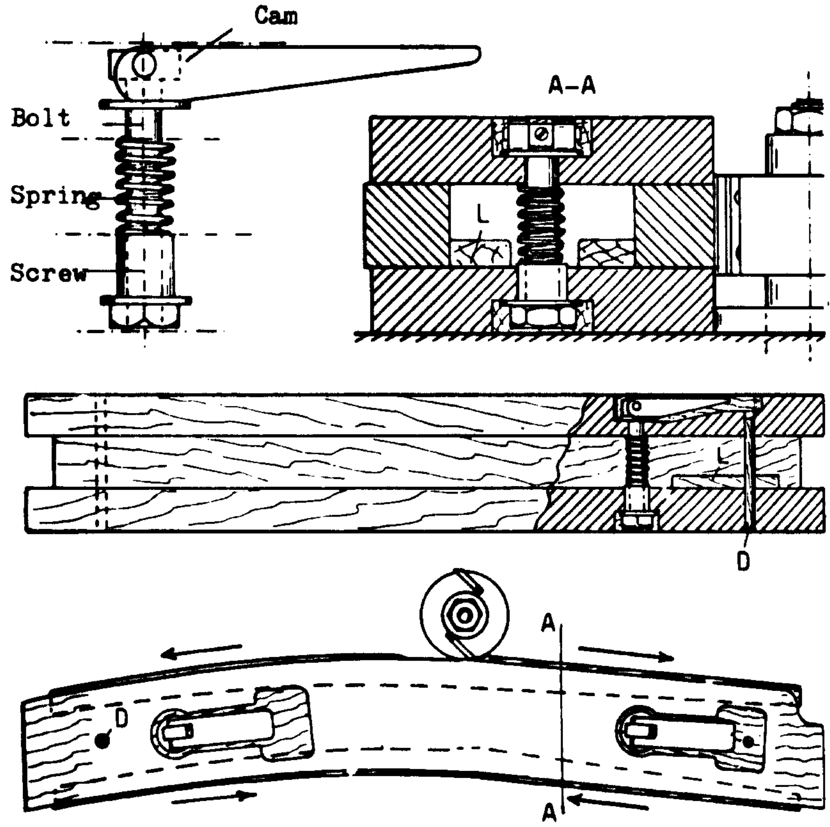
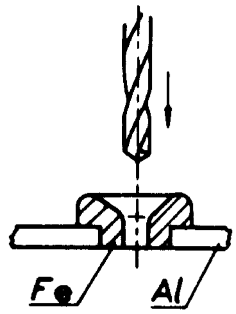


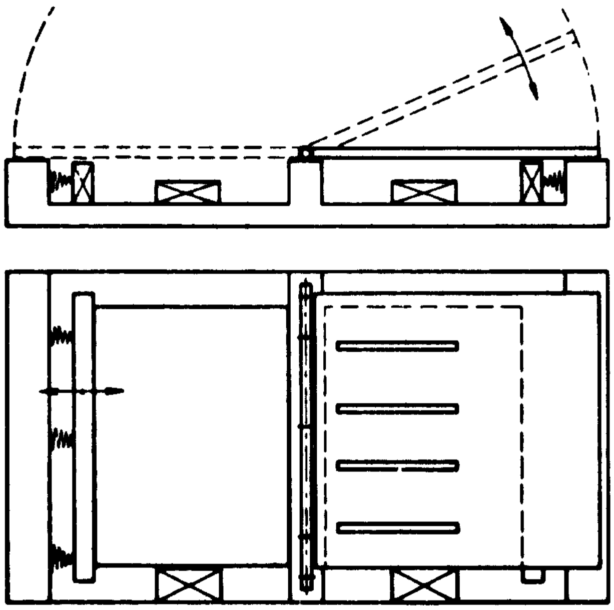
Figure XI. Machining and assembly jigs



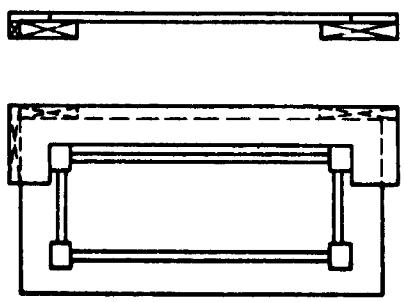
Jig for spindle-moulding of both edges of curved chair leg



Detail of boring jig for hand-held machine



Left- and right-hand stapling jig for drawer sliding strips



Assembly jig for cabinet base

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. 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 width of a panel. If the gauge is made adjustable, it can easily be re-adapted for later measuring purposes. The adjustable types should be constructed of steel. The thickness gauge in figure X is intended for measuring control in thickness planing. The selection of thicknesses it includes represents the standard thicknesses used in the factory. The values are based on standard raw thicknesses of sawnwood, e.g., raw thickness of 25 mm gives a usually finished thickness of 20 mm, 19 mm gives 14 mm etc.

The correct workpiece measure 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 measuring person. Proper use of nominal measure gauges is easily taught to any user. The main advantages of gauges are the following:

(a) There is no risk of misreading;

(b) Machine and equipment set-up is more accurate and rapid than by using ordinary measuring instruments;

(c) Continuous measure control during machining by making frequent spot tests is simple, reliable and rapid;

(d) Measure 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 applied to 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.

By the term "tolerance" is meant 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 XII. 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 set-up of machines.

Tolerance formula for assembly

The 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 of the components.

For example, the height tolerance of the cabinet in figure XIII is thus:

$$t = \sqrt{0.4^2 + 0.3^2 + 0.4^2 + 0.3^2} \text{ mm}$$

$$= \sqrt{0.16 + 0.09 + 0.16 + 0.09} \text{ mm}$$

$$= \sqrt{0.50} \text{ mm}$$

$$= \pm 0.7 \text{ mm}$$

A tolerance system in a furniture factory, if realized as a complete programme, offers numerous advantages. The 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 2. The values are based on strength tests made in laboratory. Corresponding tables can be found in some handbooks of wood technology (e.g., Blankenstein, *Holztechnisches Taschenbuch*). 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 industry.

Figure XII. Tolerance gauges made of metal plate

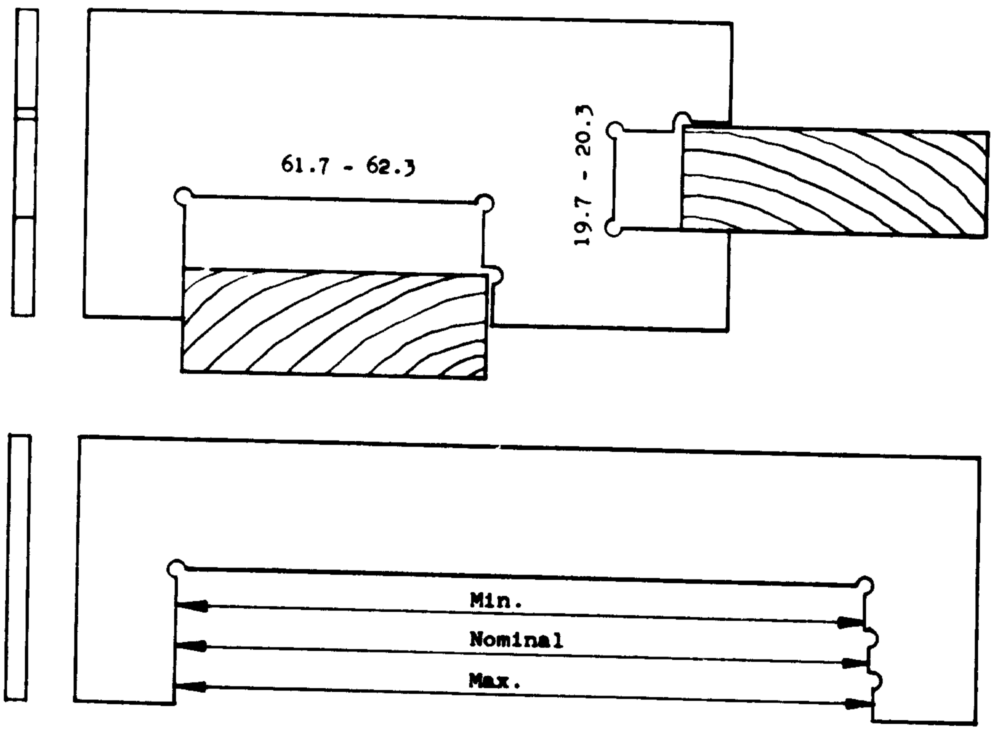


Figure XIII. Tolerances of cabinet components

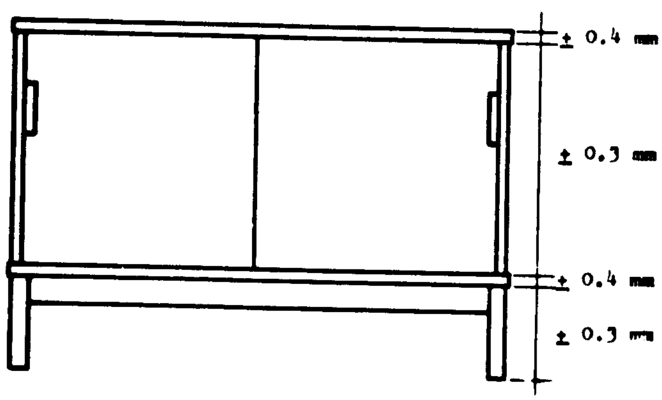


TABLE 2. LOWER AND UPPER LIMITS OF MORTISE AND TENON DIMENSIONS. NOMINAL DIMENSION OF JOINT IS 8 mm.

Hardness of wood		
Soft (pine, spruce)	+ 0.05 − 0.0	+ 0.3 + 0.2
Semihard (birch, beech)	+ 0.05 − 0.0	+ 0.2 + 0.1
Hard (oak, teak)	+ 0.05 − 0.0	+ 0.1 + 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 of parts. The check-up with gauges can be carried out either by the machine operator, assembler or a special inspector.

Continuous quality control by workers

The quality control in a furniture plant must be understood as a continuous activity which should cover all stages of production. Much unnecessary work can be avoided if faulty parts are rejected immediately in the stage when 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 not uncommon mistake is to bring faulty parts through all machining stages even to assembly. The use of a faulty part in assembly results in the rejection or in expensive repairing of a whole product in which all other parts may be of proper quality.

Visual piece-by-piece control

The visual piece-by-piece control is in the first place the responsibility of workers such as machine operators. The foremen and supervisors should therefore emphasize the importance of visual quality control when instructing their subordinates. The control is easier to put in action if the aim and reasons are well explained so that the workers understand what is in question.

Quality control in assembly

The assembly of furniture is usually divided into two substages: parts assembly and final assembly. Parts assembly covers the assembly of drawers, frames, bases, stapling of sliding strips on drawer unit sides etc.; final assembly refers to assembling 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. By the concept "primary measure" is meant a measure that is essential to the proper function of a product or its part. For instance, the sliding strip supports a drawer at the upper edge of the side groove; therefore, the stapling jig must be constructed to give the guidance to this edge. The distance of the strip-ends from the front edge of the side panel is also a primary measure because the end stops the drawer. The thicker lines in figure XIV illustrate the edges to be controlled by a stapling jig.

Control of accuracy in assembly

The accuracy of assembly is best controlled with specially constructed nominal measure or tolerance gauges if a tolerance system is used in the plant. The rectangularity is of major importance for element panel furniture and should be checked by using diagonal measure gauges (figure XV). The parallel run of parts can be checked with gauges or in some cases by the naked eye.

Figure XIV. Side panel of drawer unit with sliding strips. Thick lines indicate edges which are guided by assembly jig

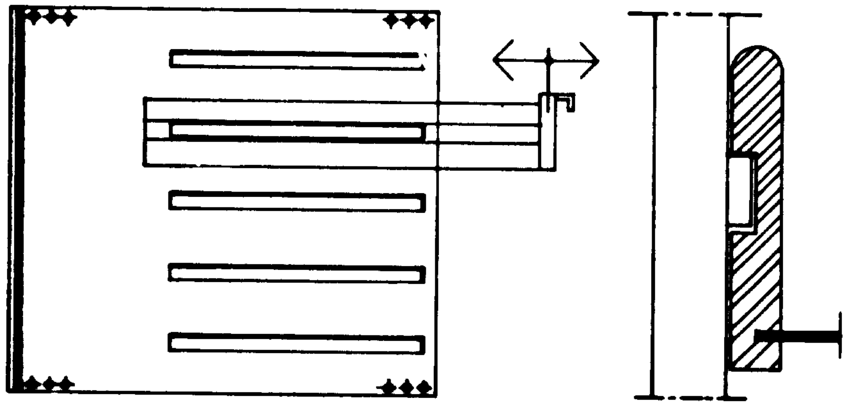
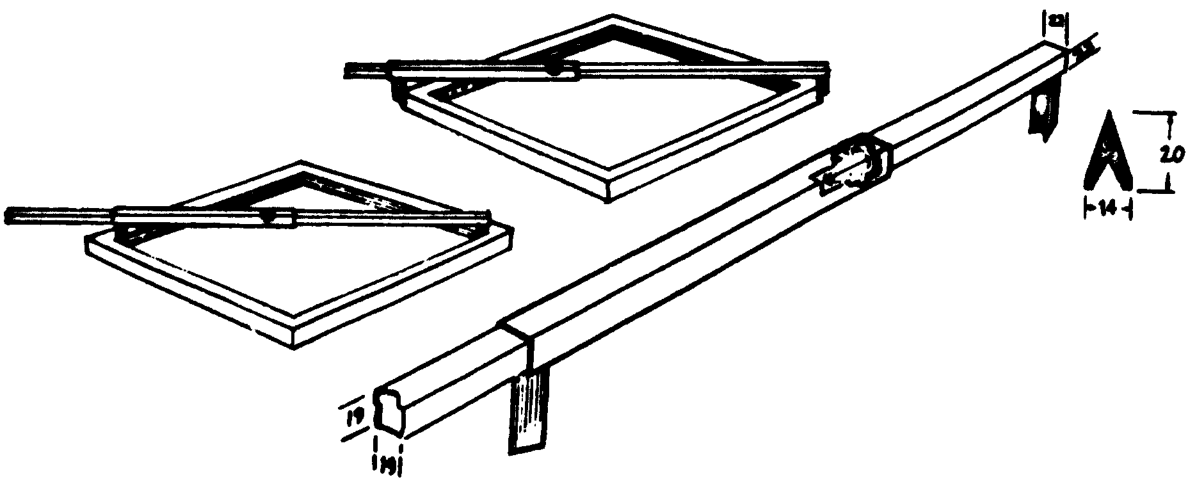


Figure XV. Diagonal measure gauges used for check-up of rectangularity



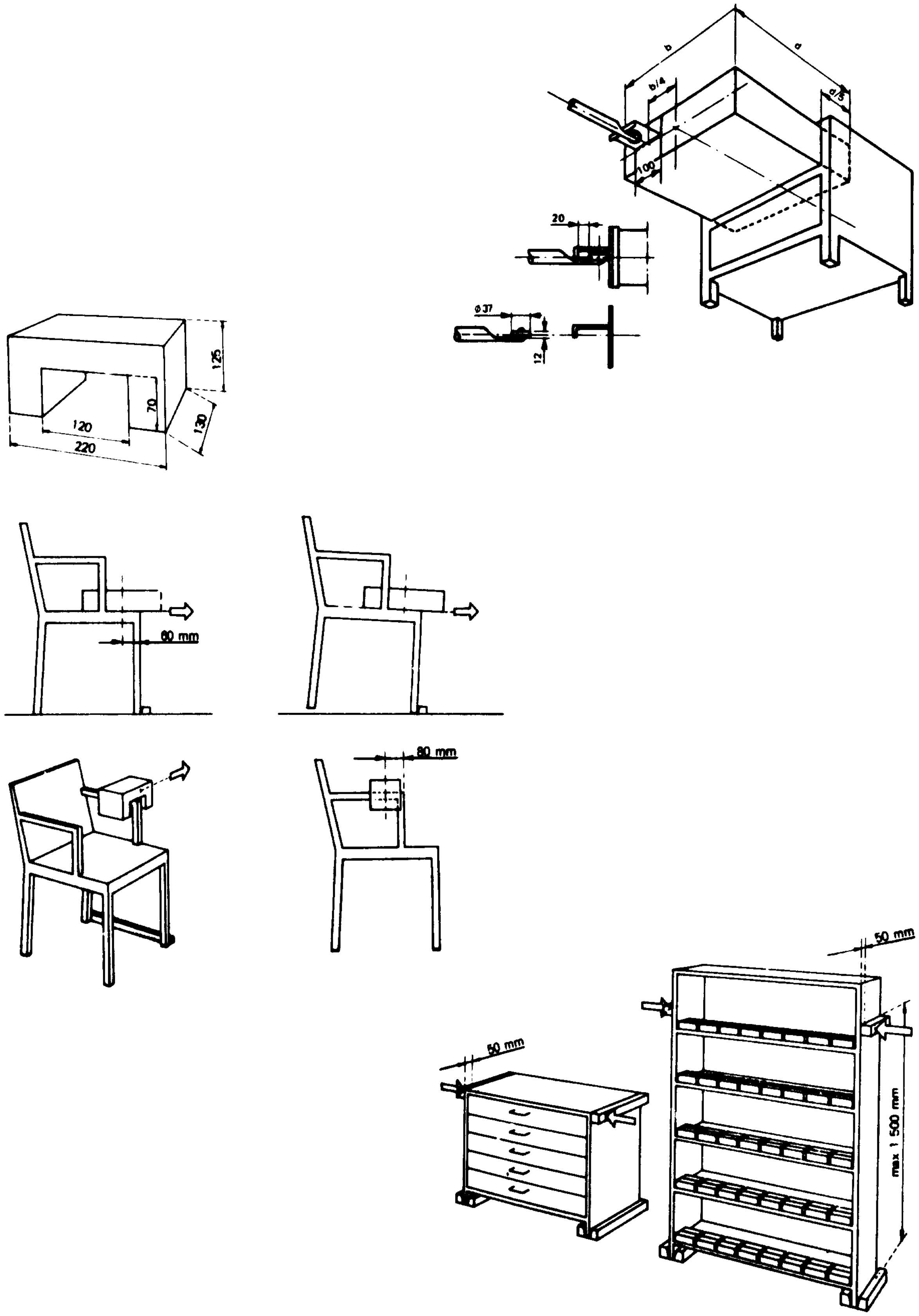
Source: Teknologisk Institut, Department of Wood Technology, "Measuring Instruments".

Quality control in surface finishing and final check

The surface finishing has traditionally been a stage following the assembly. The present tendency is, however, to lacquer or paint the parts and carry out the assembly as the last production stage. 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 aspect of 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.

The check-up is usually done by the naked eye without any instruments.

Figure XVI. Examples of testing arrangements according to Swedish furniture standards



Principal objects of control

The principal objects of control are:

- Evenness of surface
- Gloss of surface
- Colour shade and its evenness in lacquered products
- Visible glue penetrations and remains under surface film
- Quality of edges and corners (through-sanding of veneer becomes visible sometimes only after lacquering)
- Quality of surfaces close to joints

Final check

The final check is always done 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 working of doors, drawers, 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

This task requires particular testing equipment with which a product can be loaded or stressed or in some other way tested, e.g., testing the chemical resistance of the surface finishing. The number of products tested is naturally limited to a few spot tests within a batch of products.

Furniture testing standards

Special testing standards have been developed in some countries. Three examples of testing arrangements according to Swedish furniture standards are shown in figure XVI.

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XXXII. Production management*

The function and objectives of production

Production is a transformation process whereby goods or services are brought into being. It is usually the most complicated function of an enterprise. The problems associated with it are not only technical, but also economic and organizational.

The basic function of production is to make and deliver goods of a desired kind, in the right amount and of the right quality at the right time, all at the lowest possible cost with a minimum of investment.

Quality is the key to the success of a manufacturing enterprise. The quality level must be such that product quality will not be so low that it is uncompetitive or so high that it is too costly.

The second objective of production is to produce the right amount, but the right amount for manufacturing may not be the right amount for sales. Top management must decide whether to sell what is produced or to produce what may be expected to sell.

The third consideration is timing. If production is too early, there may be excessive investment in inventory. On the other hand, if it is too late, there may be a permanent loss of sales and a disposal problem. It is often extremely difficult to produce the right amount at the right time.

The fourth aim is to minimize capital outlay. Production efficiency is generally measured in terms of productivity, which is simply output divided by capacity. Productivity may be raised either by increasing volume with the same basic capacity or by maintaining the same production with reduced capacity.

The cost structure of the enterprise

To develop and rationalize production, the approximate cost structure of the enterprise must be known. In Finnish industries, the averages are as follows:

Cost elements	*Percentage*
Materials (in general purchases)	60
Wages	20
Capital costs, administrative costs etc.	20
	100

What is production management?

Production management may be defined as the principles and procedures, both technological and administrative, for planning and controlling production. Planning is the means used to achieve the four objectives of production. It is an increasingly dynamic function owing to the rapidity of change in the modern world. There is always a shortage of something--capital, capacity, time or know-how so that the best use must be made of the available resources. The planning procedures based on the objectives of production are shown in figure I. The normal sequence of planning procedures for a customer order is shown in figure II.

Prerequisites for planning

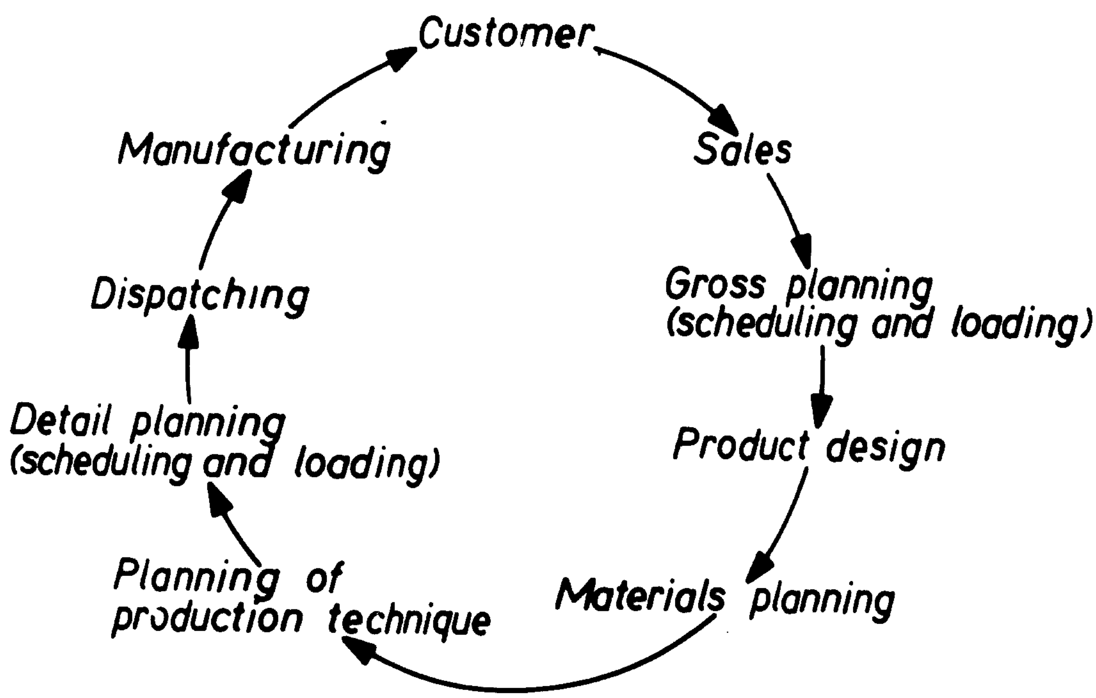
Production is dependent on many other functions of the enterprise. Production management cannot be efficient if the prerequisites for planning are not met. A key element is keeping the product assortment within reasonable limits, since it can easily increase exponentially, thus making production more expensive and planning more difficult. If a new product is suggested, two old ones should be identified to be dropped.

*By Ervi Sirviö, Oy Mec-Rastor Ab, Helsinki, Finland. (Originally issued as document ID/WG.133/24.)

Figure I. Planning procedures based on the objectives of production

OBJECTIVE OF PRODUCTION	PROBLEM	PROCEDURE OF PLANNING
Quality	How to achieve ?	Production technique Processing, routing Methods planning Layout planning Tool design Work study Work measurement
Economy	Minimizing of costs How to produce ? Where to produce?	
Amount	Lot size ?	Production planning Scheduling (gross, detail) Loading (gross, detail) Materials management (inventory control) Dispatching Control, reporting
Point of time	When ?	

Figure II. Planning procedures for a customer order



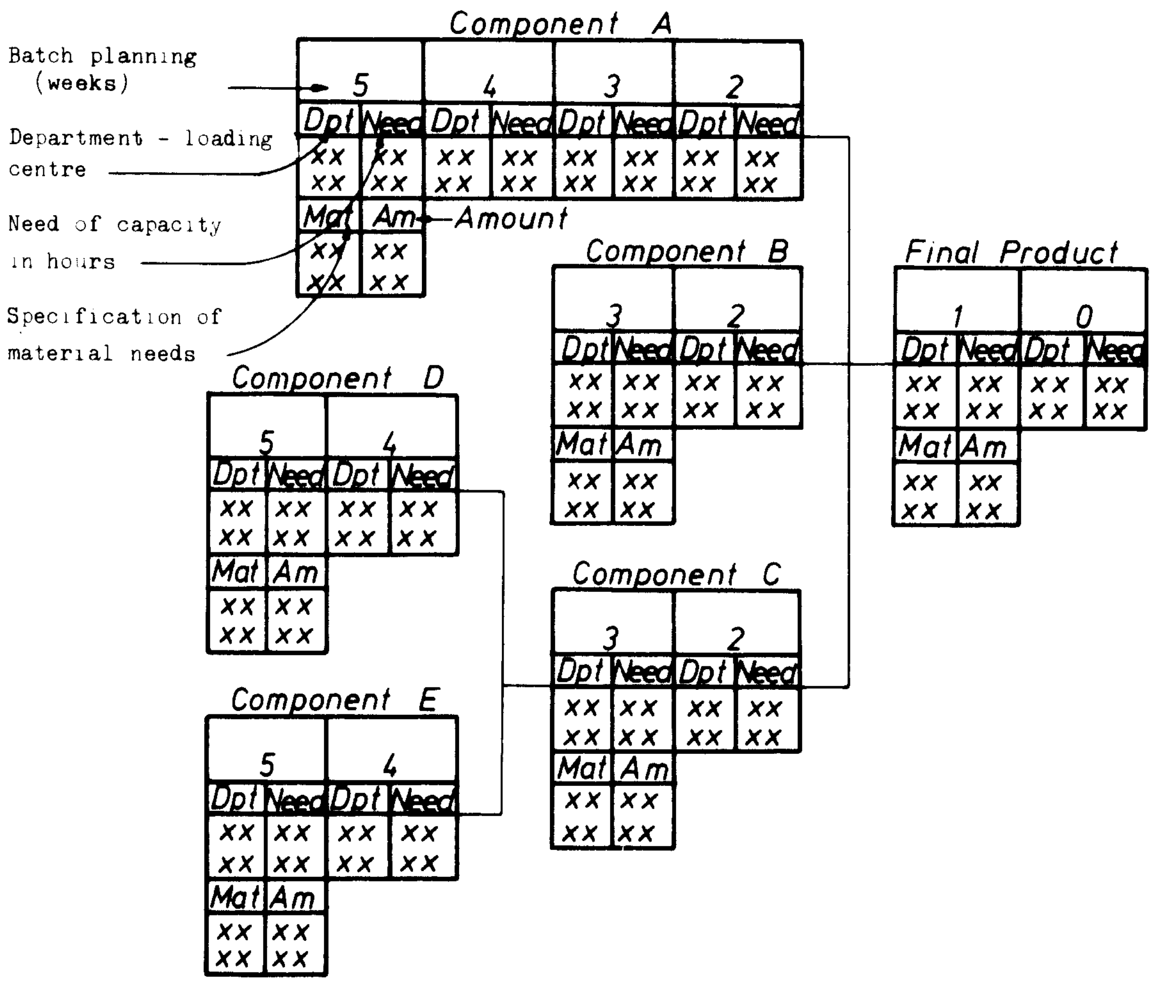
The product itself is the basic consideration, production can be rationalized no further than the product itself. The product must therefore be designed from the production standpoint. The process must begin at the drawing-board, which is where production cost is mainly determined.

Production planning can be no better than the sales programme. This means that detailed sales programmes or forecasts must be made up on a long-term basis. However, the order books of enterprises often include some astonishing things. Even some of the larger firms still perform operations begun years ago in their small-scale handicraft stage. Such small, individual services to old clients are unprofitable in most cases and disturbing to production. To avoid this danger the product list and job policy should be examined from time to time, and management must decide whether it wants to remain a custom shop or grow into an industry.

The procedures of production management

The need for planning and the procedures for it vary in different industries. The situation is most complicated in job-shop production of custom-made products. In batch production of such things as consumer goods, competition is often severe. In this case work study and inventory control are very important. In mass production, as in process industries, the entire production process may have been planned in detail before erection of the plant, in which case no further large-scale planning is needed.

Figure III. A schematic planning model of a product



There are four main objectives of production planning:

(a) To keep output capacity as high as possible. This means that promised times of delivery should be honoured and through-times kept as short as possible;

(b) To keep inventories (stocks and jobs in process) as low as possible;

(c) To utilize production capacity to the fullest possible extent and to keep employment at an even level;

(d) To inform management, sales, purchasing and production supervisors of delivery and capacity reservation (loading) situations to permit correct and prompt decisions and arrangements.

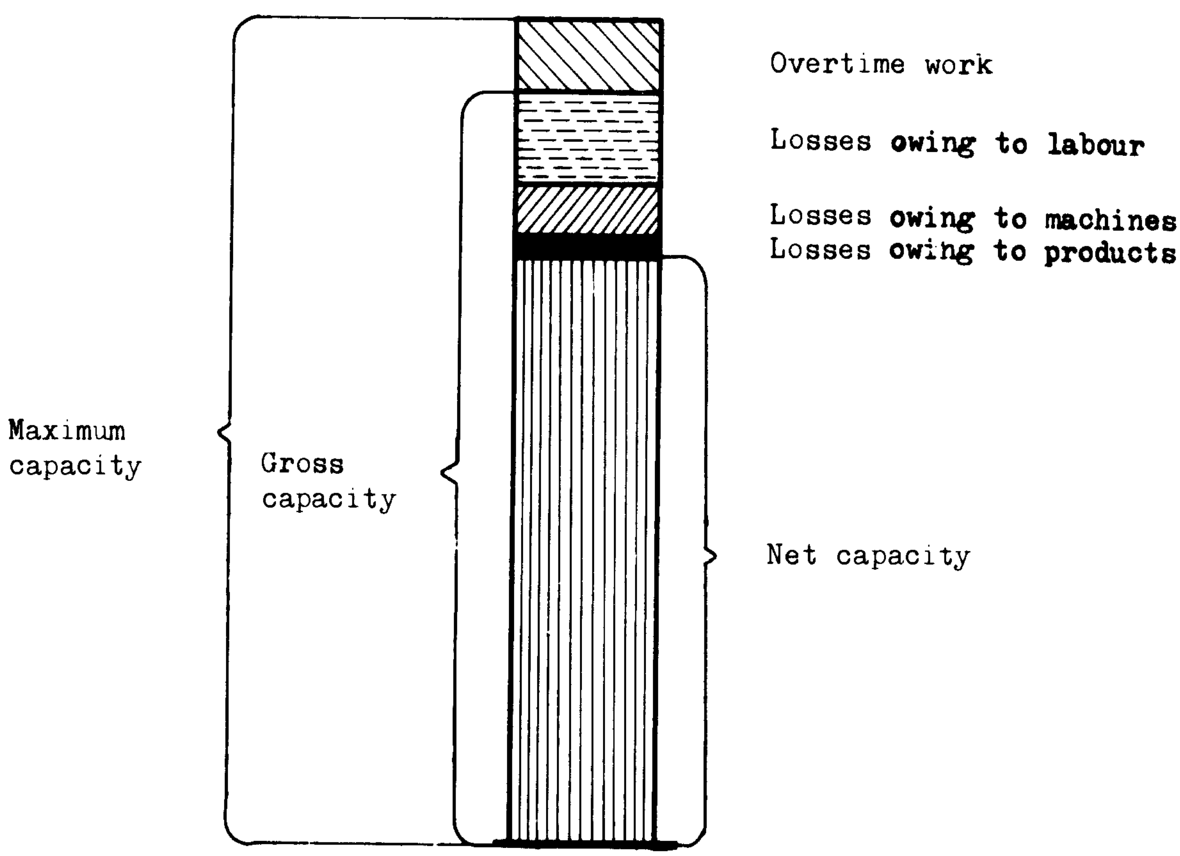
Gross planning is based on sales programmes or on customer orders. It must include all main phases up to the time of delivery. Rough capacity reservation (gross loading) is made at the same time.

Materials planning can be carried out when the preliminary or definite drawings become available. It is important to make material orders or reservations as early as possible and to control delivery times carefully.

Detail planning consists of scheduling and detail loading. It is often helpful to make planning models. Figure III presents a schematic model for a product, including product structure, scheduling, capacity and material needs per operation. Scheduling is always difficult in job-shop production, since waiting times make up about three quarters of the through-time.

To plan loading properly, there must be accurate knowledge of the net available plant capacity. This may be obtained by subtracting all losses from the theoretical gross capacity, as shown in figure IV.[1] There is no general rule for this; each enterprise must make its own calculations.

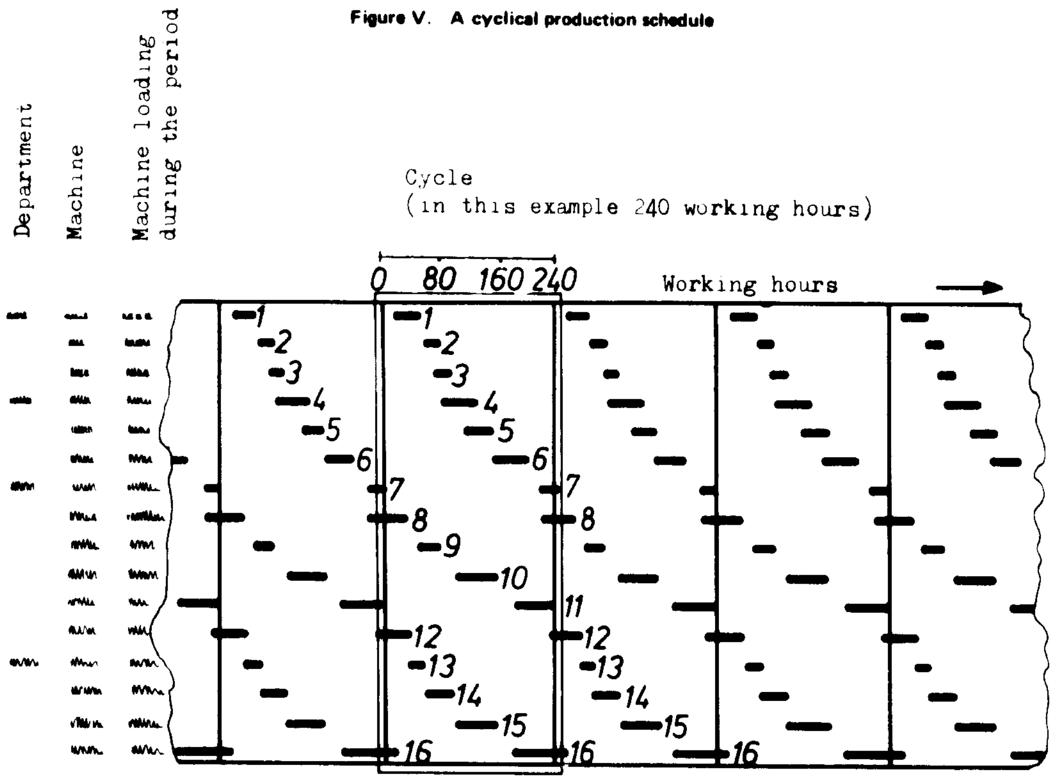
Figure IV. Graphic representation of the calculation of plant capacity



If some products and parts can be produced repetitively, in batches, forced or cyclical schedules are possible. In this case production periods (cycles) do not depend on calendar time but on working hours. A new batch starts at the beginning of every cycle; an example is shown in figure V. Similar cyclical time-tables are used in many other areas such as traffic connexions and schools.

[1] See also part two, chapter XVII, "Plant layout", figure II.

Figure V. A cyclical production schedule



Dispatching is the stage at which the plans are implemented. Here the work flow to and within the plant must be regulated very carefully. If there is close contact between orders and manufacturing, it will be possible to maintain a smooth and rapid production flow. A broad and slow pattern occurs when a production-planning department dispatches all work orders to shop foremen as soon as they are ready. The jobs are badly prepared, but the shop people are satisfied because they get plenty of work and can determine the job sequence themselves. However, the shop will soon be full of uncompleted jobs and the assembly department short of some parts. The result will be long through-times and small output. A narrow and fast pattern occurs when the production-planning department dispatches work orders to the shop well prepared, in the proper sequence and in the volume that the shop can handle at any one time. The shop people are then forced to do the jobs in the proper, planned sequence. The result will be short through-times and an even, broad output flow.

In general, it is useless to give an order if its performance is not checked; there must always be feedback from the shop. Figure VI shows control applied to the production of a single custom-made production. Control must exist on all levels. Figures VII and VIII show how the progress of a single order and of production as a whole can be roughly controlled by curves.

Production technique

The development of production techniques in processing, methods planning, layout planning, tool design, work study and work measurement has been rather slow. Nevertheless, these techniques are being studied and practised almost all over the world. Some extreme results of systematic development work are division of labour, assembly lines and thorough time-and-motion studies with predetermined time standards such as Methods-Time Measurement (MTM), Work Factor system (WF) and Motion-Time Analysis (MTA). It may be asked if the development of this form of work rationalization has gone too far. In industrialized countries signs such as the following indicate that this is the case:

(a) The average educational level of young people is much higher than before;

(b) The labour supply is contracting;

(c) Young people tend to prefer to work in service industries rather than on assembly lines;

(d) The turnover of labour is very high in many industries;

(e) Many labour unions demand regular monthly salaries instead of wages geared to incentives;

(f) Labour is demanding participation in management and more democracy in many work places.

All these signs are challenges to production management.

Figure VI. Diagram of the planning and feedback of an individual custom-made product

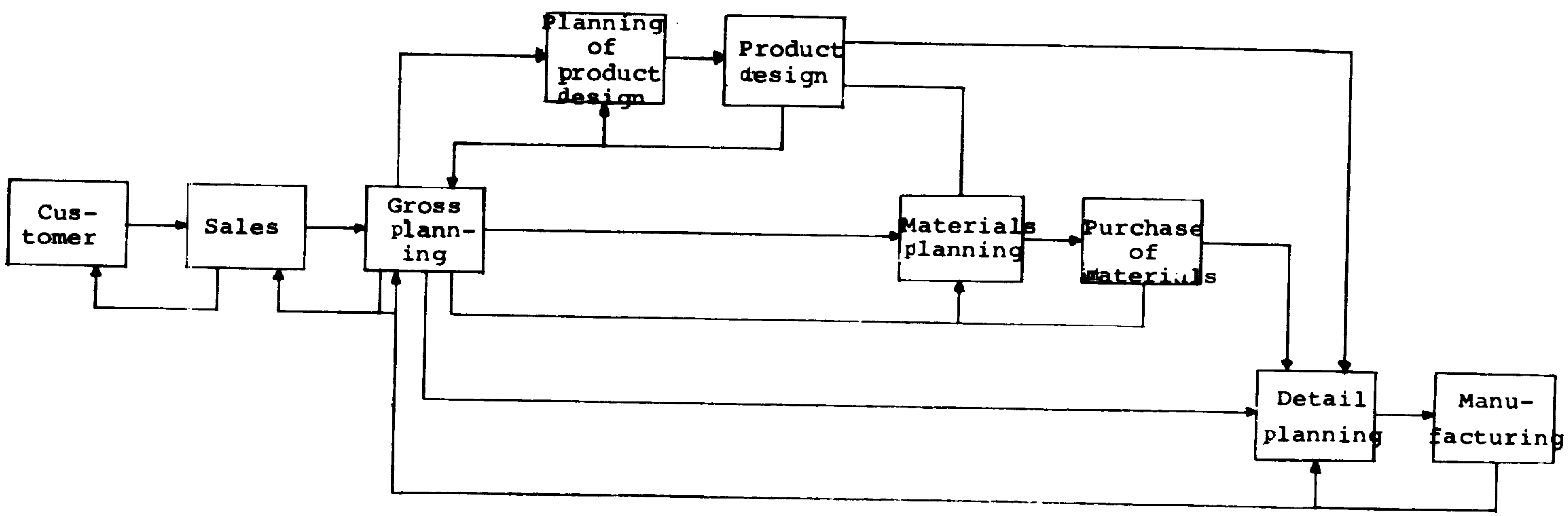


Figure VII. Control curve for an order

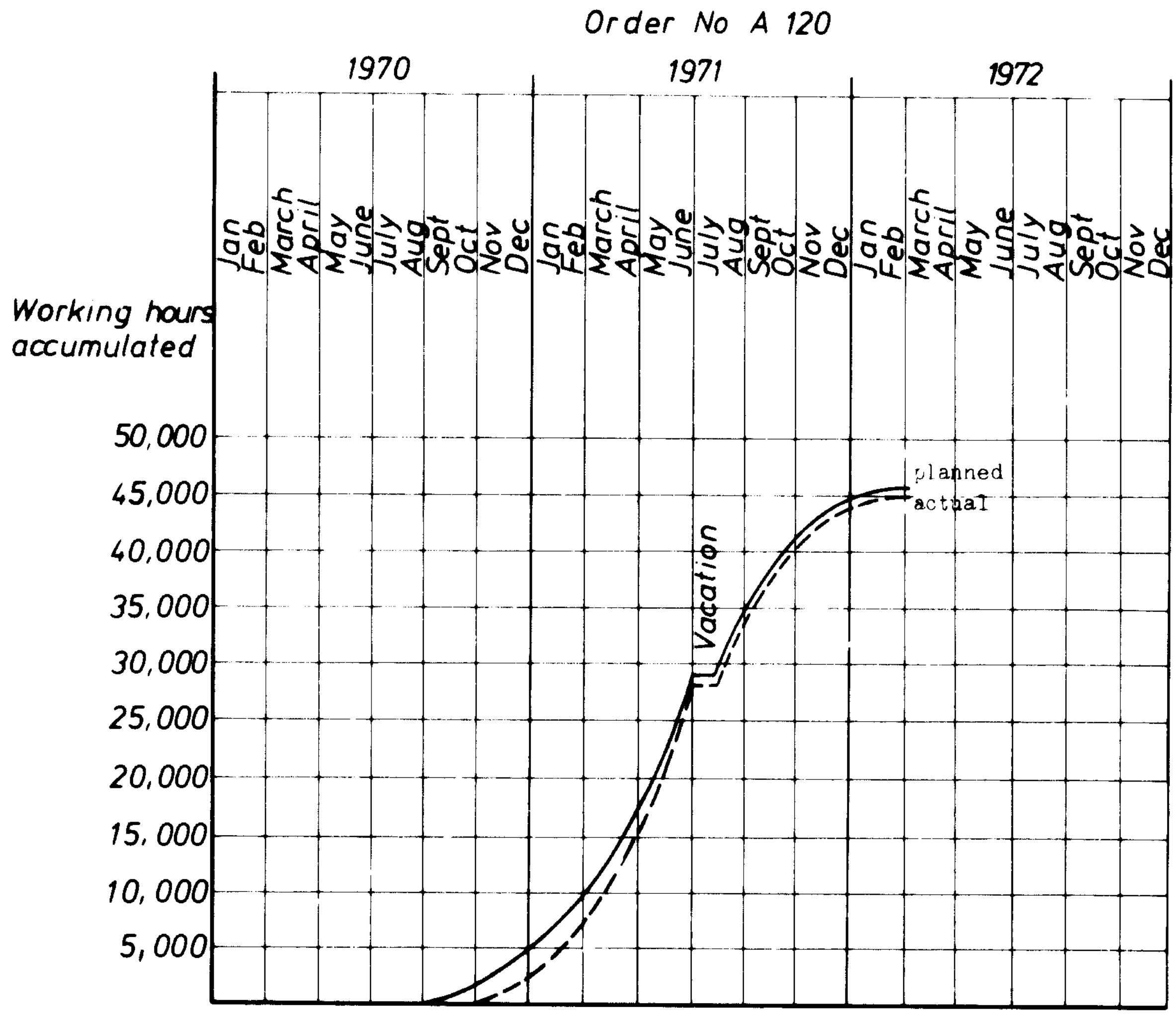
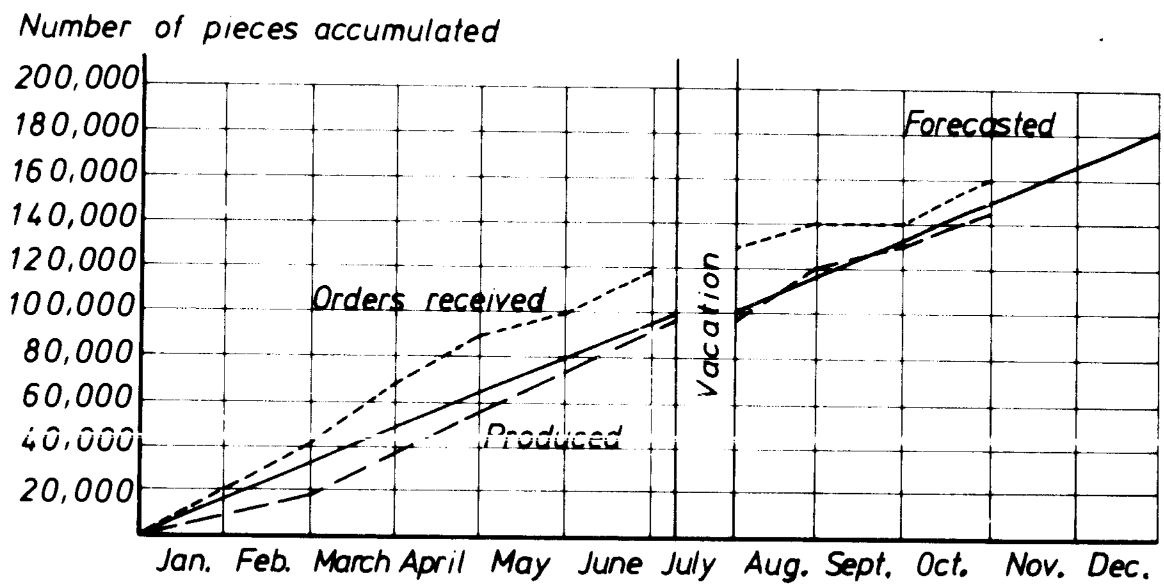


Figure VIII. Follow-up of forecasting, sales and production



The pendulum of work rationalization has apparently reached its extreme position and is swinging back. Job enlargement and enrichment, participation, motivation, ergonomics and human engineering are not only slogans but realities in a growing number of enterprises. Industrial engineering techniques are needed more than ever; the only question is who will use them and how.

Selectivity in production management

It is not always advisable to plan everything with the same accuracy; it is often worth while to remember Pareto's minority principle, according to which there is always a small part in every group that contributes a disproportionately large share of the result. Applications of this principle have been given such names as stratification, volume value, ABC-grouping, the 80/20 rule and the Lorenz diagram. According to these systems the most important elements of the total are identified for selective planning and control, and much work is thus saved by less attention being given to the less important matters. It is often possible to achieve remarkable results by giving priority to selected products and orders. Figure IX shows an application of ABC-grouping in a manufacturing-for-stock system.

The development of production

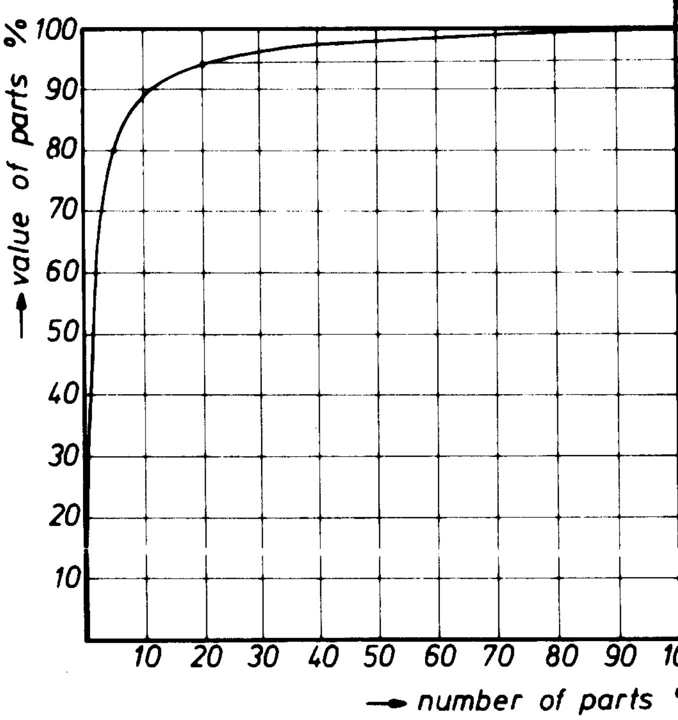
The purpose of production planning is to reduce total cost in time and money. However, planning itself also involves such costs. The problem is thus to determine the point at which investment in planning most effectively reduces production costs. This concept is presented in graphic form in figure X.

Production development does not occur automatically; work that is purposeful and effectively guided is needed to promote it. To begin with, the present level must be determined. An advantageous way of doing this is to use a competitor as a yardstick. Furthermore, good ideas may often be found in different but similar industries.

The second stage is to set objectives for development work These should be at least approximately numerical and as realistic as possible. They may be either short- or long-term and may be divided into successive phases.

The third and final step is to determine how and when to reach the objectives. Subsequent development work should take the form of projects with clear organization and schedules. Such projects are investments, and it is important to calculate and follow up the pay-off time. Figure XI shows a general schedule for a development project of a production-planning system.

Figure IX. ABC-grouping in a manufacturing-for-stock order



The parts				
Group	Number parts	%	Value $	%
C	6,400	80	10,000	5
B	1,200	15	30,000	15
A	400	5	160,000	80
	8,000	100	200,000	100

Figure X. Schematic presentation of the optimization of planning and manufacturing costs

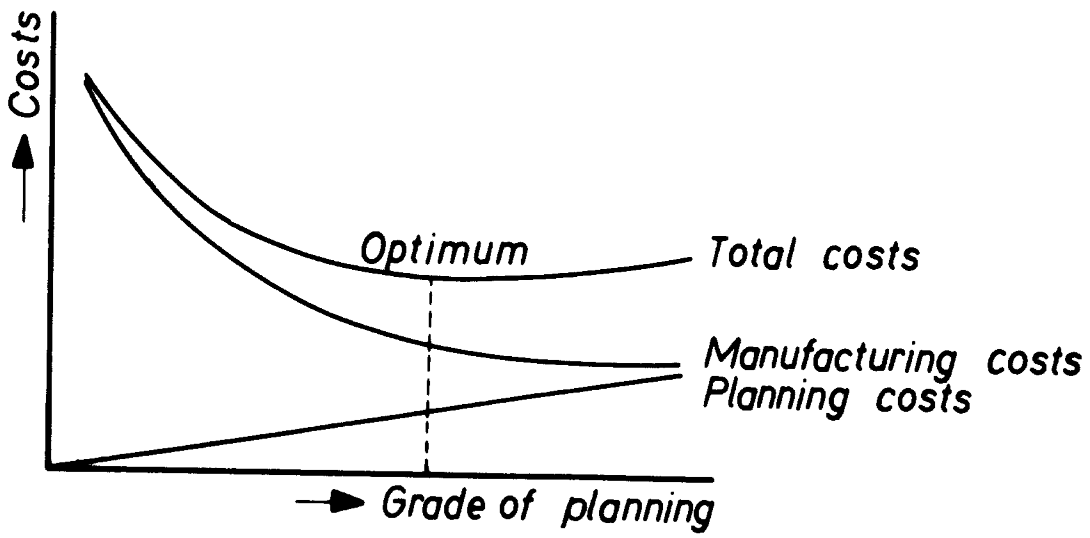
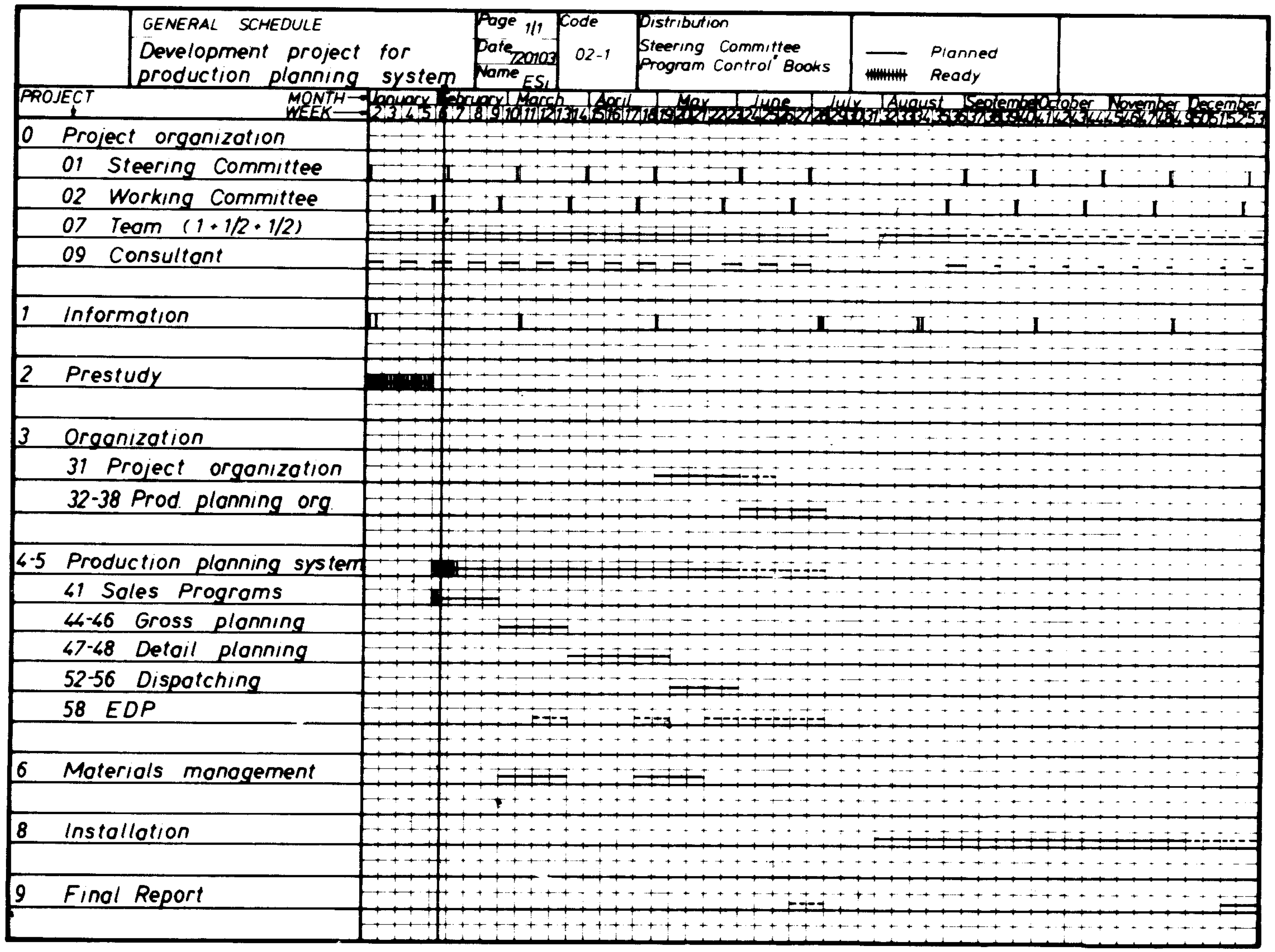


Figure XI. The general schedule for a development project of a production-planning system



XXXIII. 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 compete 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 of *Creating a Market*, published by the International Labour Organisation (ILO).[1] 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 analysis, a study of the size, location and characteristics of markets; 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 salesmen 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

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[1] This work was distributed to the participants in the Seminar (see the bibliography at the end of this chapter).

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, it therefore requires attention to marketing in addition to research and engineering. In fact, in marketing-minded companies, product planning is based largely on an 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 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 specialty 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 product version, 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 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 the offering of a particular enterprise. 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 brand preference and loyalty that refer to the name of the company rather than merely to the product.

The most important elements in planning an advertising programme are the size of the advertising budget, selection of media, message design, timing of advertisement and 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 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.

A manufacturer can develop his 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:

Customer characteristics (their number, geographical distribution, purchasing patterns and susceptibility to different selling methods)

The nature of the product (bulk, degree of standardization, service requirements and unit value)

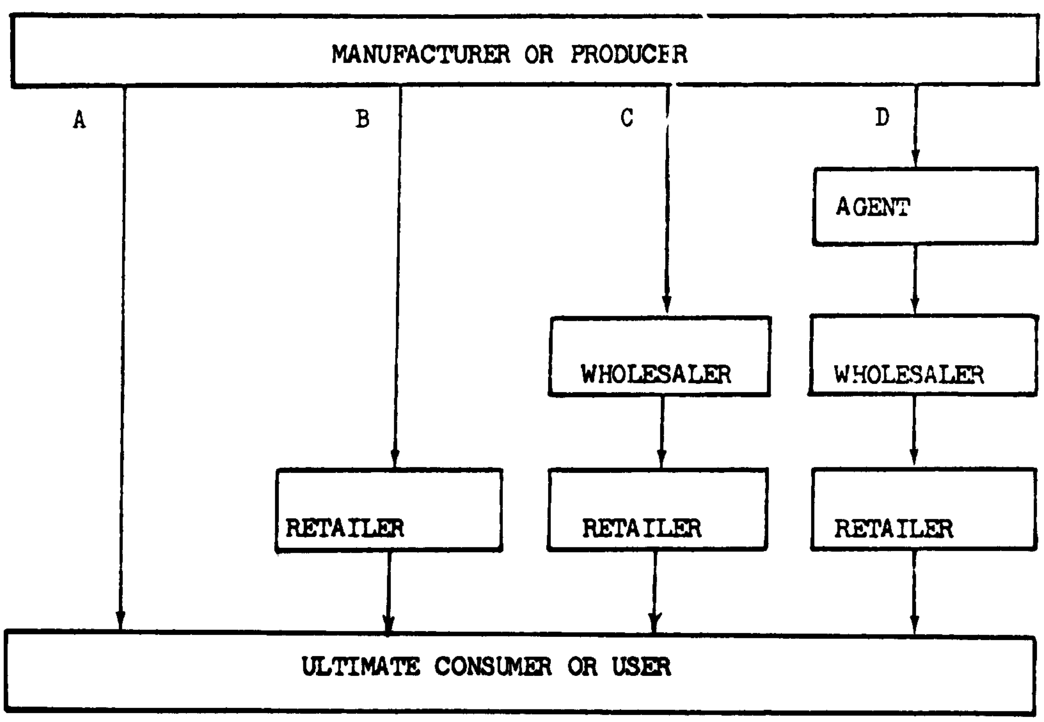
The characteristics of intermediaries (the strengths and weaknesses of different types of middlemen in handling various tasks)

The structure of channels used by competitors (either as a target or as an example to be avoided)

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 I, 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 salesmen 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 and 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 I. 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, of which the first refers to sales, costs and profits, the second to possible sources of channel conflict, and the third to 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.

In addition to effective channels, an important role is played by physical distribution, which covers the actual movement of goods. The functions involved include transportation, warehousing, order handling and inventory control. Physical distribution can be an efficient instrument in stimulating demand. A company may be able to promote sales by offering more service than competitors or by cutting prices through reduced physical distribution costs. Since physical distribution activities are highly interrelated, the choice of the appropriate system must be preceded by an analysis of the total distribution costs associated with different proposed systems. The optimal physical distribution strategy must therefore minimize the cost but also provide a given level of customer service.

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 needs, and persuading him to make the actual purchase.

Salesmen 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 salesmen. 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 salesmen. The organizational lines are carefully planned on the basis of territory, products or customers. Personal selling involves the following managerial tasks: recruiting and selecting salesmen, 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

Principles

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

This function 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 of assessing marketing opportunity should be continuous in order to facilitate dynamic marketing and production operations, identification of new challenges and problems facing the company, and taking 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.

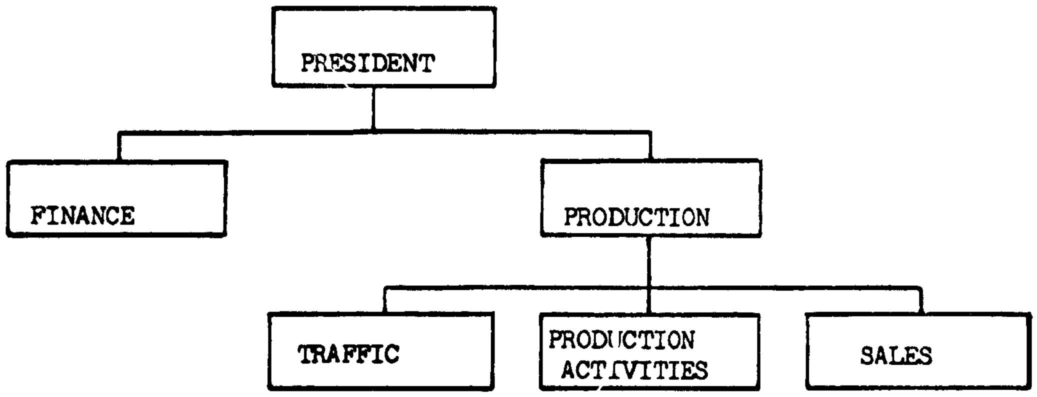
The main components of the marketing planning process may be classified under four consecutive phases. The first, the situation analysis and identification of problems and opportunities, covers a firm's actual business, product lines, markets, organization, channels of distribution, competition, technological change and profits. The second phase, 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, 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 II.

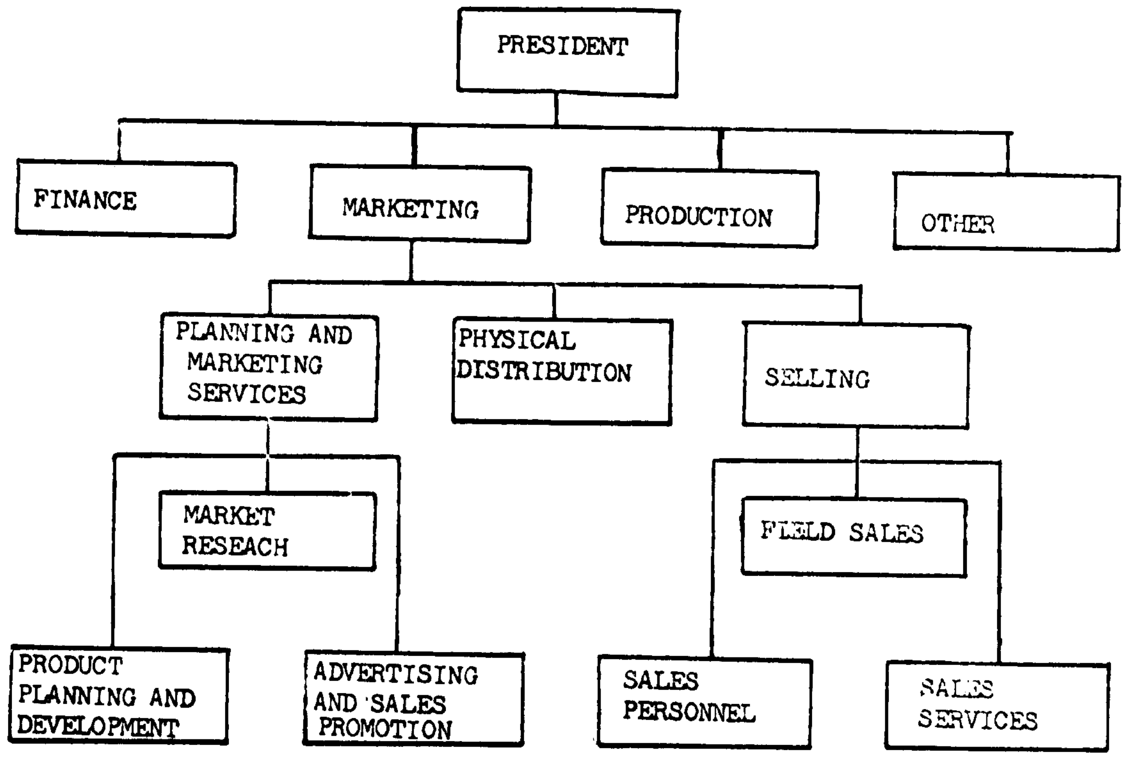
Figure II. Model of traditional organization of a manufacturing company



As the marketing concept has 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 III).

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 so that he can participate in all areas of business policy related to the marketing objectives of the firm.

Figure III. Model of the organization of a marketing-oriented company



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 on 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.

Fundamentals of export trade

There are many basic reasons why a country may want to stimulate export trade; some typical examples are 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 among 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 existing market share, trends of development, financial position and 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, as 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

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 among 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, size of the enterprise, local (foreign) purchasing habits and product price.

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

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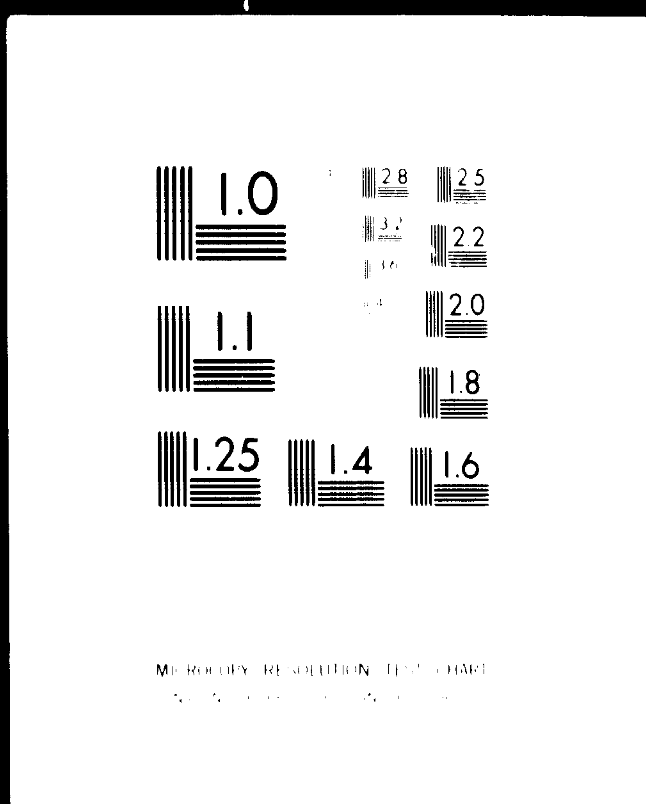
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generally involved in selling. Sometimes it may be possible to sell directly to industries and institutions, occasionally even through a local manufacturer if the products complement each other. Owing to the high costs involved, the establishment of 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 carrying on 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 connexions 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 prepayment. Even though an exporter does not handle these functions, it would be useful for him 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 he envisages exporting, 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 which 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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XXXIV. Export market surveys*

A manufacturer who intends to enter foreign markets is handicapped in many ways; he has no experience of these markets, he may be unable to discuss with prospective clients in a common language, and he may not have a cost-analysis developed 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 of transforming such ways into concrete services and products than 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. The manufacturer 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 he wishes to reach). Should the chairs be soft, hard, rigid, collapsible, cheap and sold in dozens to each buyer? He 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 the manufacturer's offer.

A general market survey tells the manufacturer what people used to think some years ago and what they have achieved; 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: the 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). A general survey or a study specially designed according to previously defined needs are two possible forms of presentation.

Suggested table of contents for a market study

Definition of the market (area, individuals etc.)
Government regulations concerning imports to the country
Other institutional factors
Competition, including import statistics
Ways of competition
Demand, including possible forecasting and definition for products
Distribution systems
Promotion systems
Pricing
Recommendations

When a study is carried out on the initiative of someone, it should also include 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, list of people interviewed (if possible), and other relevant original documentation.

*By Keino Roulamo, market research expert, Helsinki, Finland. (Originally issued as document ID/WG.209/16.)

Collecting data

Before starting to collect information it is well 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 quantitiative goals are measured against such figures, the local manufacturer may be able to re-assess and recast his goals and questions.

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 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 your own realistic possibilities. You may then decide to entrust the study to an outside expert;

(b) Define the market. If you are supplying nuclear-power stations, the market is very limited, but well known and scattered geographically all over the world. If you would like to manufacture cheap, ordinary tables, you should concentrate on geographically limited areas and study their tastes, needs etc.;

(c) Time is an important element. There is a present time and a time in the future; the present is transparent and easy to understand; the future is more unpredictable but will include your own 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 to ask the people who know. If a manufacturer wants to sell to a certain buyer, he may ask for his opinion. There may even be many buyers for his product; if he 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, however, expensive much more expensive than is commonly believed and must be well prepared for. In preparation it is useful to visit the fair previously 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 which will indicate the relation of the sample (the 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. Further 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 of his potential clients, such as those building nuclear 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, if 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. if the area will follow the pattern of change of a more advanced area, as Finland has followed Sweden; or Germany 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. As the factors in this case are available, the sales of furniture in the following year may be predicted.

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 malinformation, such as wrong planning of an investigation, wrong 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, such as spending more money for the research than previously estimated and having the researchers check their information thoroughly.

XXXV. Safety at work and occupational hazards*

Safety promotion at industrial plants

There are two kinds of occupational hazards in industry: accidents and occupational diseases. An occupational accident is an injury occurring at work; occupational diseases are illnesses caused by physical or chemical factors of occupational origin, such as noise, dust or chemicals. Among the consequences of accidents and occupational diseases, which are not fatal, are:

Temporary or permanent, partial or complete loss of working ability of the injured person
Suffering and economic losses to the injured person and his family
Direct and indirect impairment of the operation of the enterprise

In most countries an employer is legally bound to maintain certain minimum safety conditions to prevent accidents and occupational diseases. A well-managed enterprise will not only fulfil these minimum requirements but will also try by all available means to make working conditions as safe as possible. Such voluntary accident prevention is becoming increasingly common as more and more industries realize that the prevention of accidents is not only economically profitable but also a moral obligation of the employer. It is thus usual to speak of three motives for promoting voluntary safety, namely, moral, legal and economic motives.

The degree of safety at work depends on management, on supervisors at all levels and on the workers themselves. While an industrial enterprise with a small staff does not need a special safety organization, every foreman must, in addition to his other duties, concern himself with safety at work. Furthermore, wide co-operation is a condition for effective safety promotion. It is particularly important that workers take part in this operation. The establishment of safety committees that include representatives of management, supervisors and workers can make such co-operation systematic. Safety committees receive and transmit information about safety matters and issue pertinent statements; they should have no executive power nor should they be given the responsibility for safety at work. Such committees have proved useful in industrial plants of all sizes.

The internal safety activities of an industrial establishment must cover a large field of operations. Only some of the most important of these functions can be dealt with here; they are *(a)* statistics and internal accident reports, *(b)* safety inspections and *(c)* training and safety propaganda.

Statistics and internal accident reports

An internal accident report, which the foreman makes after each accident, serves three purposes: it forces him to be aware of every accident that occurs within his jurisdiction, ensures that the management of the department and the factory shall be informed about all accidents and provides a reliable basis for statistics on accidents. Such statistics are an important guide to the necessary safety measures, for they show trends in the frequency and severity of accidents.

Safety inspections

In addition to the safety inspections made by governmental authorities, insurance companies and other external agencies, every industrial establishment should organize its own internal inspection programme directed towards eliminating occupational hazards. A written report of every inspection should be submitted to the management.

*By Kai Lindberg, Institute of Occupational Health, Accident Prevention Department, Helsinki, Finland. (Originally issued as document ID/WG.133/26.)

Training and safety propaganda

There are many ways of conducting an efficient safety training programme and of promoting safety consciousness, among them are meetings, exhibitions, films and rescue displays. These activities are often concentrated into safety campaigns or weeks. Safety competitions have also proved helpful in promoting interest in accident prevention. Posters and pamphlets are commonly used even in small workshops to provide information on safe working methods or merely to promote safety consciousness.

Prevention of occupational hazards in the furniture and joinery industries

In Finland, accident frequency (per million working hours) in various occupational groups is highest in stevedoring (205.0), followed by construction work (109.4), mechanical workshops (102.0), sawmills (95.8), underground work in mines (94.1) and joinery with machines (89.6); accident frequency in joinery without machines is much lower (58.8).

The guarding of machines and the competence of machine operators are the most important factors in curtailing major hazards in the joinery industries, but the prevention of hazards caused by dust, paint and lacquer must also be given attention.

Machines

In assessing the hazards presented by machines and the technical safety measures needed to minimize them, consideration must be given to differences in prudence, professional skill, intelligence, training and attentiveness among the people working at a given machine or in its vicinity. Shortcomings in these qualities are conducive to accidents, which are often attributed to the so-called human factor. Nevertheless, many accidents are also attributable to the dangerous characteristics of machines.

Technical safety devices for machines are intended to minimize human error leading to accidents (it can never be avoided completely). Consequently, the design, construction and installation of every machine (and every part of a machine) must permit work to be done at or near it with minimal risk of accident or disease. The less skilled the workers, the more important this requirement is. In small plants in which the training and professional skill of workers vary widely, the machines must be especially safe.

As already noted, woodworking machinery is inherently dangerous; it should be operated only by skilled and experienced workers. In Finland, persons under the age of 18 years are not permitted to operate it.

In the table below accidents in the joinery industries are classified according to their causes. These data reveal that, on the average, each worker is absent from work 2.7 workdays a year because of an industrial accident. Of these 2.7 lost days, 1.1 are attributable to circular saws, planers and spindle moulders; 0.4 to other woodworking machines; and 1.2 to other reasons. It is apparent that special attention must be paid to woodworking machines of these three kinds. In the following paragraphs specific danger points are indicated.

General. In all woodworking machines, the power transmissions must be completely protected, and each machine must have its own safety switch that cuts off the current when the voltage drops sharply. This switch must be constructed so that the machine does not start again when the power supply is restored. Most woodworking machines must also be equipped with a brake to stop the blade or other moving parts quickly when the power is cut.

TYPICAL ACCIDENTS AND THEIR CONSEQUENCES IN THE FINNISH WOODWORKING INDUSTRY

Causes of accident	*Accidents* Number	*Accidents* Percentage	*Days lost* Number	*Days lost* Percentage	*Number of cases with permanent partial disability*	*Number of days lost per accident*
Circular saws	121	15.0	2 316	14.3	3	19.2
Planers	103	12.8	2 252	13.8	3	21.8
Spindle moulders	64	8.0	2 044	12.6	4	32.0
Total	288	35.8	6 612	40.7	10	23.0
Other woodworking machines	126	15.7	2 276	14.0	2	18.1
Total all woodworking machines	414	51.5	8 888	54.7	12	21.4
Others	390	48.5	7 400	45.3	8	19.0
Total all accidents	804	100	16 288	100	20	20.2

Source Keskinainen yhtio Teollisuusvakuutus (Industrial Mutual Insurance Company), Helsinki, Finland.

Circular saws. Accidents associated with circular saws are caused by touching the saw blade or by kick-backs. In most cases accidents of both types can be prevented by technical measures, although correct working methods are also important.

Most accidents caused by contact with the saw blade occur when the sawyer holds his hand too close to the blade while sawing or when he removes waste from the side of the blade or from beneath it. He may also fall on the blade if he trips or stumbles near it. Most accidents of this kind can be prevented by guarding the blade both above and below the sawing level. The part of the blade below the sawing level can usually be guarded with no inconvenience. The normal underguard is a fixed enclosure, but it should be constructed so that it can be easily removed, either partly or entirely, when the blade is changed. The upper side of the guard should be hinged so that the blade can be changed without removing the whole enclosure (figures I and II).

Figure I. Guards of a rip saw with feed rolls

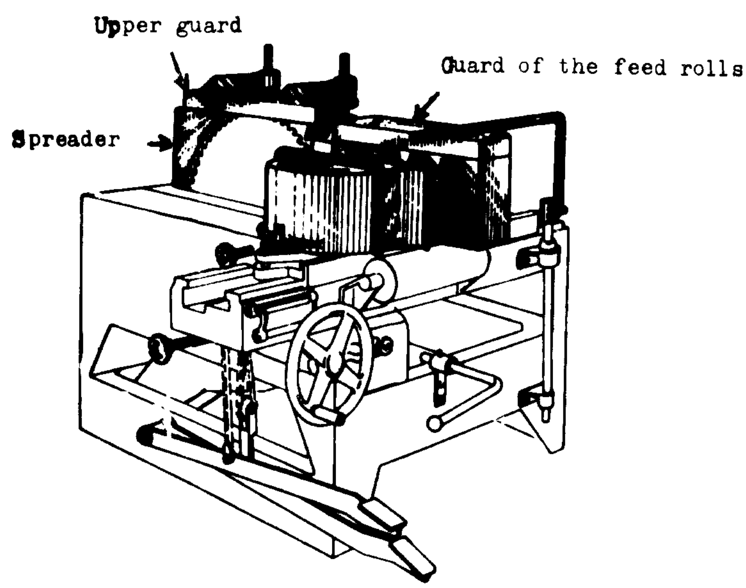
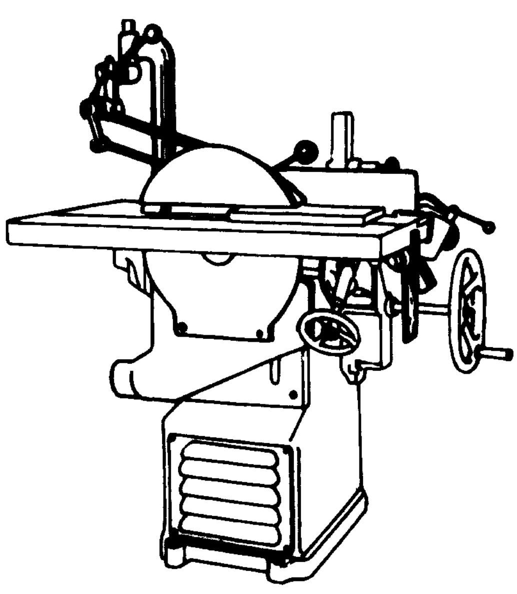


Figure II. Guards of a small rip saw



Kick-backs are a constant danger in the use of circular saws. They may cause serious accidents, so that care must be taken to prevent them. Kick-backs are caused by internal tensions released from the wood during sawing, so that the kerf pinches the turning blade, causing the material to rise to the top of the saw blade and be flung backwards with great force. This happens so quickly that the sawyer has no time to parry the kick-back. (The same thing happens if a board falls on the blade.) To prevent such accidents, every saw that is used for rip-sawing should be equipped with a spreader or at least with double anti-kick-back fingers. A substantial upper guard that is placed low enough is also effective.

Spreaders must be made of steel and must be just thick enough to fill up the kerf and wide enough to be stable. The shape of the spreader knife's leading edge should follow that of the saw blade. The spreader knife should be easily adjustable both vertically and horizontally so that the distance between the knife and the blade will be no more than 3 mm and will extend vertically no more than 5 mm under the top of the biggest blade (figure III).

A rip saw should have an upper guard to prevent the blade from being touched, boards from falling onto it and kick-backs. The upper teeth of the blade must be inside the guard during sawing. The guard must be longer than the diameter of the biggest blade.

In small rip saws that have no feed rolls, the upper guard and the spreader together must cover the whole upper and rear part of the blade. The upper guard must be easily adjustable to the height of the object worked on or it must follow the object during the sawing (figures II and IV). If the saw is equipped with feed rolls, they must be guarded from the front, sides and top. There must be a safety bar in front of the rolls for stopping them (figure I).

A balanced cross-cut saw cutting from underneath must not have a blade that can be lifted with the foot. The handle for lifting should be situated in such a way that the sawyer need not stand in front of the blade where his hand may touch it. In its lowest position the blade must be completely covered. The cross-cut saw lifted from underneath should be balanced so that when the operator releases the handle the blade will drop inside the protective encasement without bouncing.

A cross-cut saw that cuts from above must have a guard that encloses the upper part of the blade. Attached to the front of this guard there must be an additional one that rises and falls by itself according to the thickness of the board to be cut (figure V).

Band-saws. Saws of this kind can be considered safer than circular saws because they present no danger of kick-back. The most important risks when using them are that the hand or another part of the body may touch the blade or power transmissions and that the band blade may break. All moving parts of a band-saw should be completely guarded. Disc wheels are usually considered safer than spoke wheels because spokes can easily cause accidents if pieces of wood or clothing get caught in them. Whichever type of wheel is used, it should be completely enclosed so that the protective casing will prevent a broken saw blade from causing accidents (figure VI).

The blade should be completely covered except at the actual cutting point. Its return side must be encased over its entire length. On the sawing side, the blade must be guarded from the upper wheel to the blade guide with a guard that covers at least the front and outer sides of the blade. This guard should be adjustable so that, regardless of the height of the blade guide, the guard will always cover all of the distance between the wheel and the blade guide. The guard may be attached to the saw guide so that it automatically follows the guide.

Planers. Accidents occurring during planing are usually caused by a knot or some other hard spot in the wood that prevents the work piece from moving on smoothly. When resistance increases too rapidly, the operator cannot react quickly enough and his hand gives way, causing the workpiece to bounce back and his hand to slip into the cutter. Accidents are also caused by holding the workpiece incorrectly. If the operator's grip is weak or unsteady, the slightest shock may cause his hand to slip into the cutter. Moreover, if the operator's hands are placed so that they almost touch the surface of the table, his finger-tips are in danger of being cut off as soon as they reach the cutter.

For safety, it is important that planers be fitted with rounded cutters with gullets for crushing shavings that are as narrow as possible (figure VII). They should also have easy-to-use cutter guards. For safety, the best kind of guard conceals the cutter slit when in use, with the hand gliding over the guard during the planing process. This prevents fingers from slipping into the cutter as a result of a kick-back, as well as accidents caused by incorrect placement of the fingers on the workpiece. Figure VIII shows a good example of this type of safety guard.

Not as effective as those described above but still good and perhaps easier to use are the so-called boomerang guards. In these, the guard always conceals the cutter slit except at the moment of planing when the workpiece pushes the guard aside. Even then only a part of the cutter, no bigger than the width of the piece to be planed, remains uncovered. The guard is pressed against the guide by a counterweight or spring.

Furthermore, planers must always be fitted with a brake that limits the rotating time to 10 to 20 seconds after the power is switched off. They should also have a back guard that covers the part of the cutter behind the guide.

The mechanical feeding device has proved to be by far the best guard for use in planers and in other woodworking machines. It gives complete protection to the cutter and has no characteristics that impede work.

Spindle moulders. These are the most dangerous machines in joinery. Accidents with them are usually caused either by a kick-back or by the fingers of the operator slipping. Because these machines are used in many different ways, it is impossible to devise a general-purpose guard; consequently, a separate protective device must be designed

Figure III. Spreaders for rip saws of various sizes

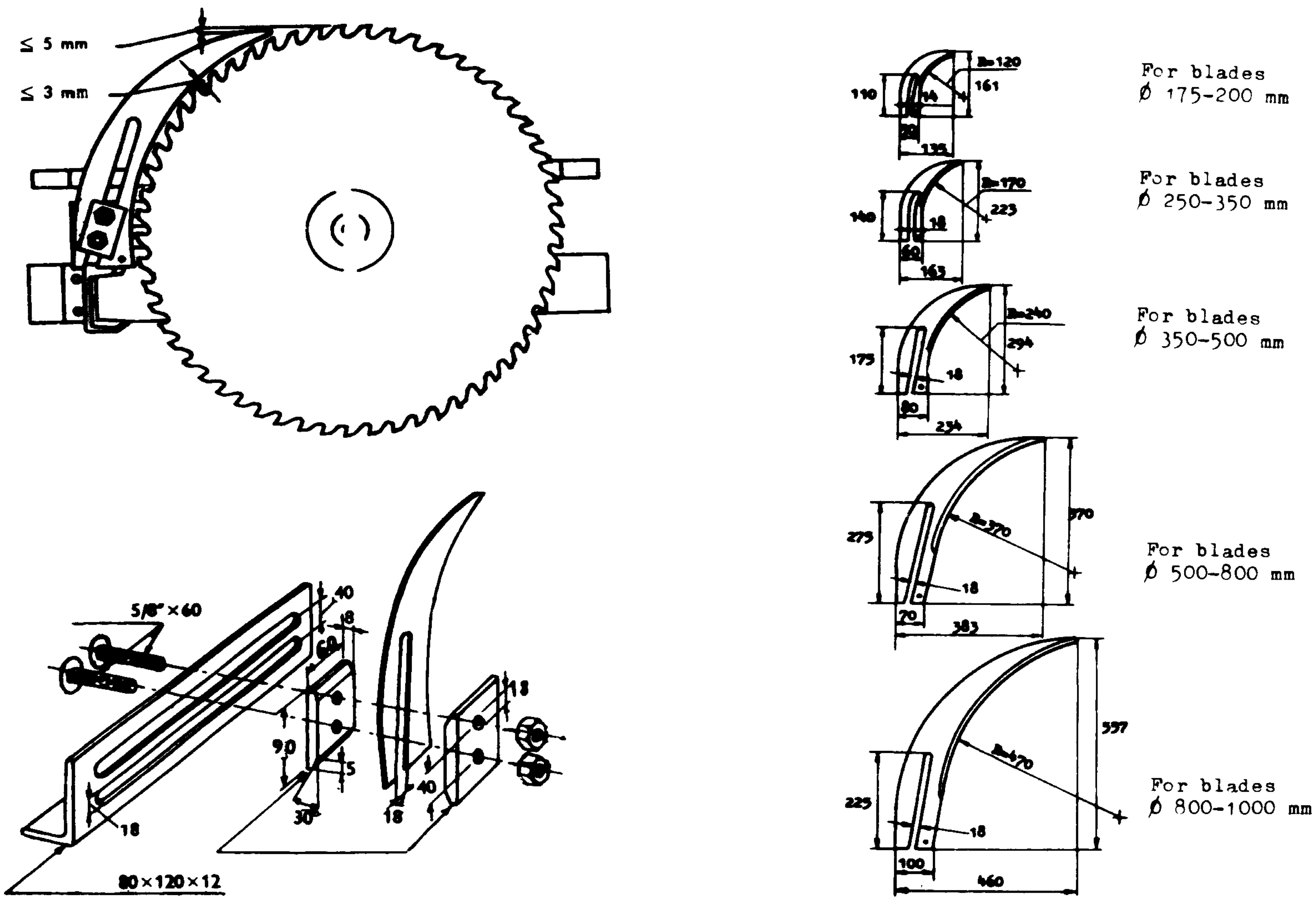


Figure IV. A Swiss-made (SUVA) upper guard for a small rip saw.
This device can be locked into the desired position

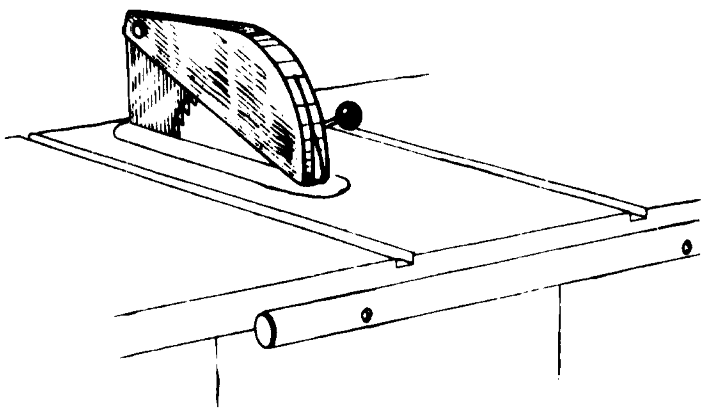


Figure V. Three types of upper guards for cross-cut saws

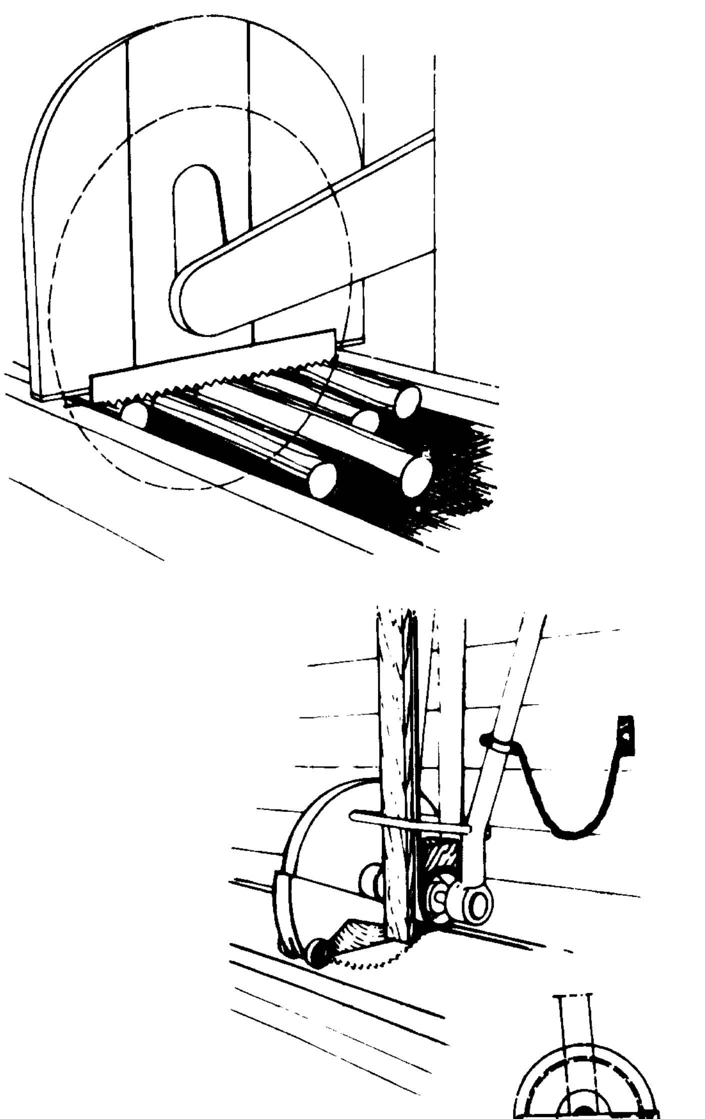


Figure VI. Guards for a band-saw

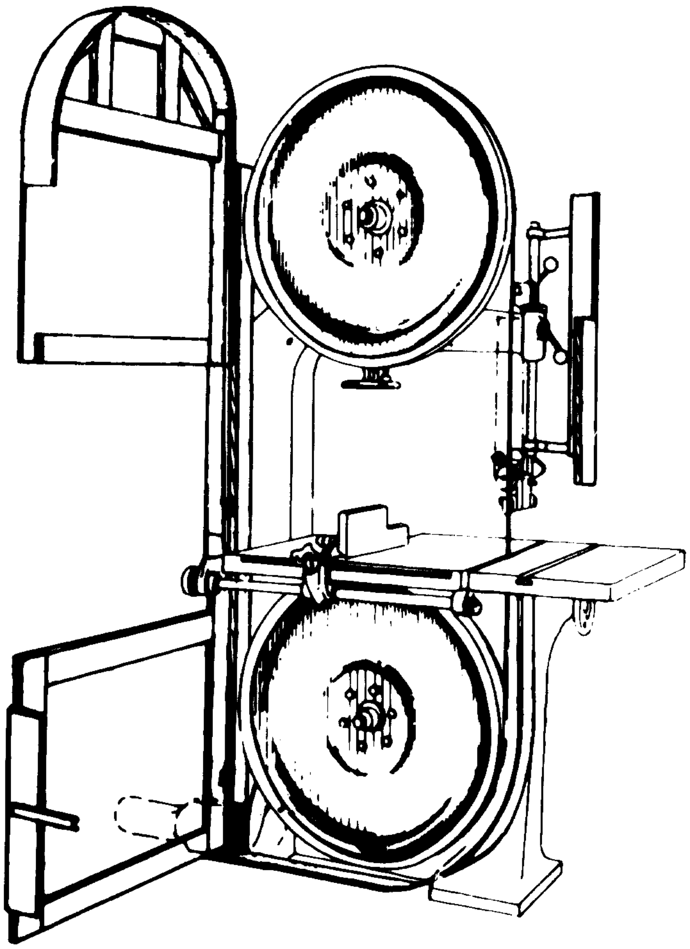


Figure VII. A rounded cutter, with knives. The dimensions A, B and C should be as small as possible. While they should normally not exceed 10.3 mm, 3 mm and 4 mm respectively, the absolute maxima are 13 mm, 4 mm and 6 mm

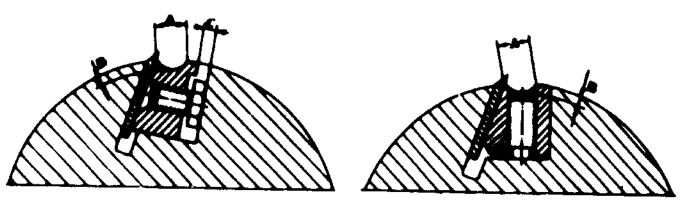
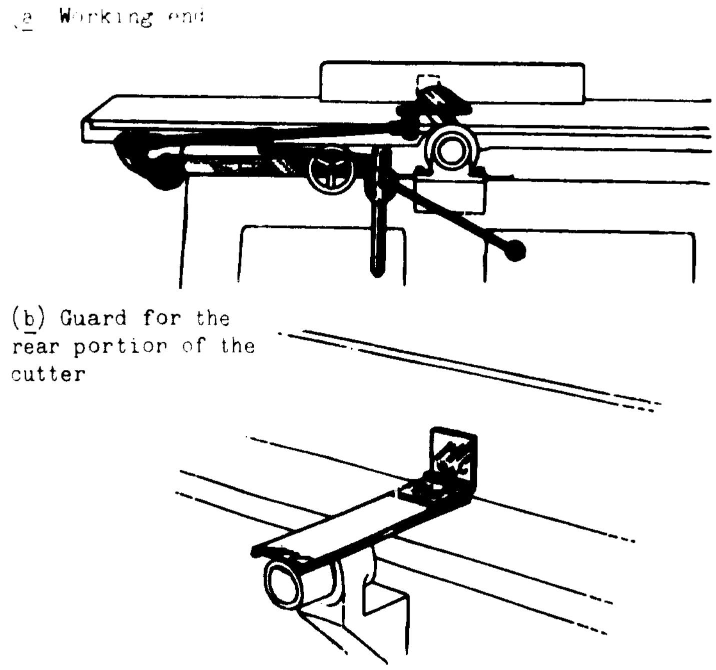


Figure VIII. A Swiss-made guard for a planer



for each use. Figures IX and X show examples of guards that are practical and versatile and applicable to almost all uses of the spindle moulder. It has the disadvantage that the guard requires a separate adjustment for each desired protective position for each working phase; for this reason this otherwise excellent guard has not become popular in Finland. The mechanical feeding device has proved the best and most practical protective device for spindle moulders as it has for other woodworking machinery.

Figure IX. A Swiss-made guard and exhaust-hood for a spindle moulder

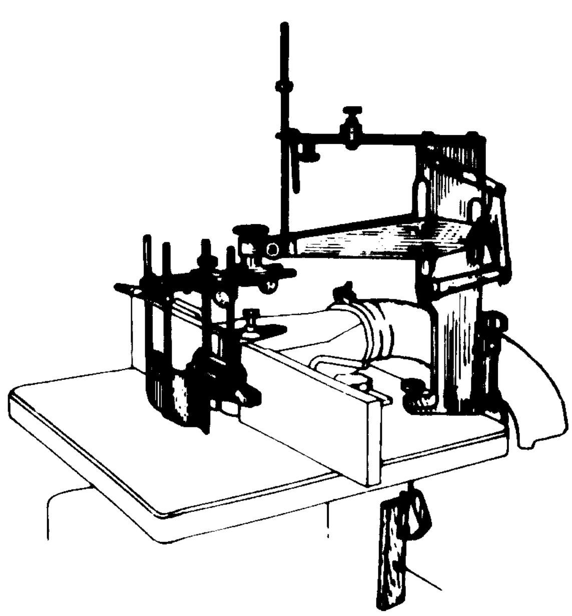
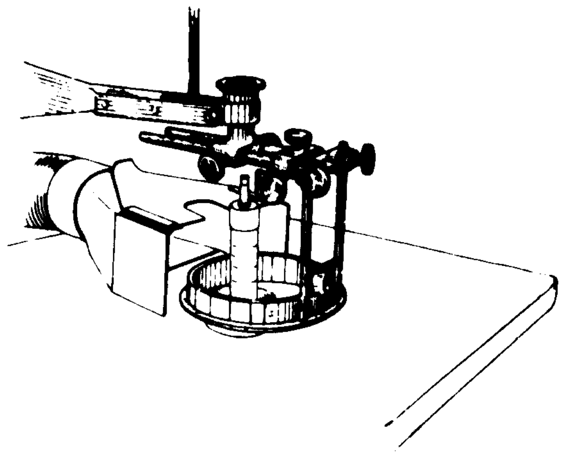


Figure X. A circular guard for a spindle moulder



Dust

The dust produced by woodworking machines should be removed not only because of the danger of explosion and fire but also because the dust of some tropical wood species (for example, teak and mahogany) can cause illnesses such as allergic nasal catarrh, asthma and dermatitis. To remove the dust, each saw must be equipped with a fixed exhaust-hood connected to an exhaust system. In many cases the exhaust-hood may be built together with guards, for example, the underguard of a rip saw. The exhaust system must include a dust precipitator located outside the plant.

Paints and lacquers[1]

The solvents used in many paints and lacquers may cause contact dermatitis and poisoning when inhaled in appreciable amounts. Also, many so-called two-component lacquers and glues contain strong chemicals that can cause dermatitis. Consequently, contact with these materials must be avoided, and special attention must be paid to cleanliness and hygiene at work. Solvents should not be used for washing hands.

The solvents used in most paints and lacquers are also highly combustible. To prevent poisoning and lessen the danger of fire, the shops where paints and lacquers are used must be well ventilated.

No matter how good the ventilation may be, benzol (crude benzene) must never be used as a solvent in painting, lacquering or cleaning because it is highly poisonous. Moreover, some other solvents, notably toluene, may contain benzol in dangerous amounts. The purchasing agent should therefore demand a guarantee that the benzol content of any solvent will not exceed a specified limit. An acceptable maximum would be 3 per cent benzol.

Painting and any other work that entails the handling of materials dangerous to health should be done in a painting booth with enough air exhausted to make the air velocity in the front opening of the booth at least 0.5 m/sec.

Conclusions

In spite of the technical safety measures discussed above, it is obvious that accidents cannot be prevented entirely. Unsafe behaviour and dangerous working methods must be eliminated or corrected. Dangerous acts may result from carelessness, foolhardiness, lack of skill or experience or even from stupidity. On the other hand, the lack of specific instructions or of sufficient training are often reasons for improper working methods. Training and guidance are needed to prevent accidents.

Whether it is a question of technical measures or training, the final responsibility for accident prevention lies with the management. This responsibility does not depend on the size of an enterprise.

[1] See also part two, chapter XX, "The surface finishing of wood and wooden products".

The following studies on various uses of wood have been prepared by the United Nations Industrial Development Organization and some have been issued as United Nations sales publications:

ID/10	*Production Techniques for the Use of Wood in Housing under Conditions prevailing in Developing Countries.* Report of Study Group, Vienna, 17-21 November 1969 United Nations publication, Sales No. 70.II.B.32
ID/61	*Production of Prefabricated Wooden Houses* Keijo N. E. Tiusanen United Nations publication, Sales No. 71.II.B.13
ID/72	*Wood as a Packaging Material in the Developing Countries* B. Hochart United Nations publication, Sales No. 72.II.B.12
ID/79	*Production of Panels from Agricultural Residues.* Report of an Expert Working Group Meeting, Vienna, 14-18 December 1970 United Nations publication, Sales No. 72.II.B.4
ID/133	*Selection of Woodworking Machinery.* Report of a Technical Meeting, Vienna, 19-23 November 1973
ID/154	*Low-cost Automation for the Furniture and Joinery Industry*
ID/180	*Wood Processing for Developing Countries.* Report of a Workshop, Vienna, 3-7 November 1975
UNIDO/LIB/SER.D/4	*UNIDO Guides to Information Sources No. 4: Information Sources on the Furniture and Joinery Industry*
UNIDO/LIB/SER.D/6	*UNIDO Guides to Information Sources No. 6: Information Sources on Industrial Quality Control*
UNIDO/LIB/SER.D/9	*UNIDO Guides to Information Sources No. 9: Information Sources on Building Boards from Wood and other Fibrous Materials*

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