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TECHNICAL PRODUCT DESIGN [1]

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TECHNICAL PRODUCT DESIGN

Pekka Paavola

Technical product design is the planning and designing of a product and its parts in such a way that its serial production will be as rational as possible, that is, at the lowest possible cost. The quality of the product must meet the demands commonly placed on the kind of product in question: the quality must not be too high or too low. Serial production is a manufacturing process in which a large number of one item is fabricated in one batch by performing each operation to all similar members of the product at the same time. 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 can be made in quantities of 5,000 pieces, but expensive managers' desks in batches of, let us say, 50 only. The storage situation at the factory will determine when a given product should again be put under manufacture.

The starting point of a technical product design is the product idea, which may be obtained from a freelance designer, who usually is paid a royalty according to the number of pieces eventually manufactured. The development of the idea to suit serial production calls for highly expert knowledge and experience on the part of the technical designing staff as regards raw materials, construction, machining, surface finishing, and so on. It is particularly important that industrial designers are well familiar with the sizes, dimensions and prices of raw materials, semi-manufactures and supplies available on the market.

7.1 Need of technical product design

Some reasons why technical product design is necessary in the furniture and joinery industries today are mentioned below:

1. To hold a competitive position on the market.

2. Introduction of many new materials on the market, which has resulted in a need to develop new construction types suited to these materials.

3. New production methods and special machines, and increasing avoidance of manual work phases.

4. Increasing degree of automation.

5. Marked increase in export trade (especially from the North European countries).

Even the smallest factories today attempt to carry out systematic product designing or product development, in which every detail in the design and fabrication of a product is thoroughly considered.

7.2 Properties required of a serial product

Modern serial production techniques usually place the following demands upon a product:

1. The product must be suitable for the factory's manufacturing process and allow, for instance, the efficient use of multi-purpose machines (e.g., double-end tenoning machine, edge veneering machine).

2. No manual work should be included (no fitting by hand in the assembly phase).

3. Surface finishing of parts should be possible before

assembly (with curtain coating machine, by dipping).

4. In countries where timber is expensive and labour costs high, solid wood should be substituted as far as possible by various kinds of semi-manufactured materials which will be veneered, covered with plastic sheeting or painted. The level of industry and degree of automation is also an additional factor affecting the appropriate selection of materials.

5. The constructions should as far as possible be collapsible in order to reduce storage and shipping costs, especially in export trade.

6. Similar details should be usable as components in as many parts of a product and in as many products as possible.

7. Dimensions, joints, metal fittings and so on should be standardised as far as possible. Profiles, roundings, etc. should be standardised to suit the supply of machine tools at the factory.

8. Products should be so dimensioned that semi-manufactures available on the market can be used with a minimum of material waste (Fig. 7.1).

9. The forms and joints of a product must be so designed that the machining of each part will be possible by a continuous through-feeding operation (Fig. 7.2). It is a further advantage if several machining operations can be carried out at the same time, as in the four-side moulding machine (Fig. 7.3).

7.3 Raw materials for different constructions

With the introduction of particle boards and many other semi-manufactures, many traditional constructions have been abandoned. The raw materials used today for panel furniture (cabinets, bookcases, etc.) are chiefly particle board and various combina-

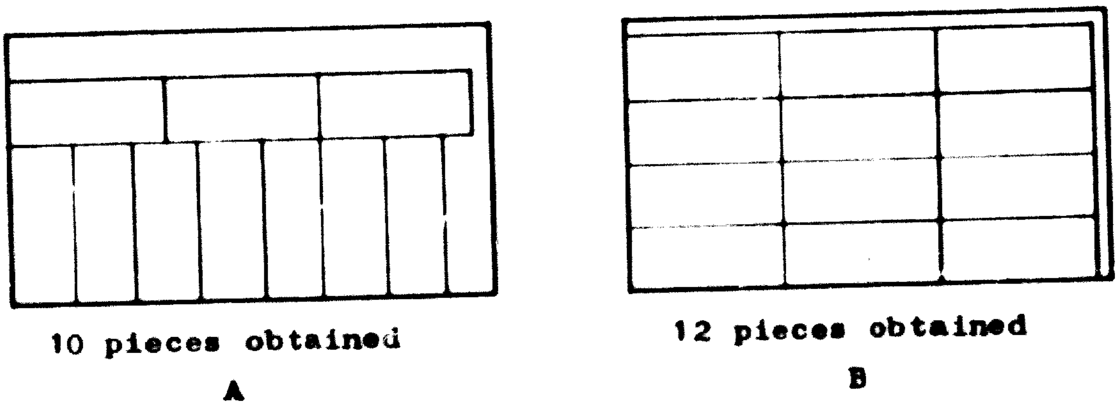


FIG. 7.1

Sawing of panel components from standard size particle board

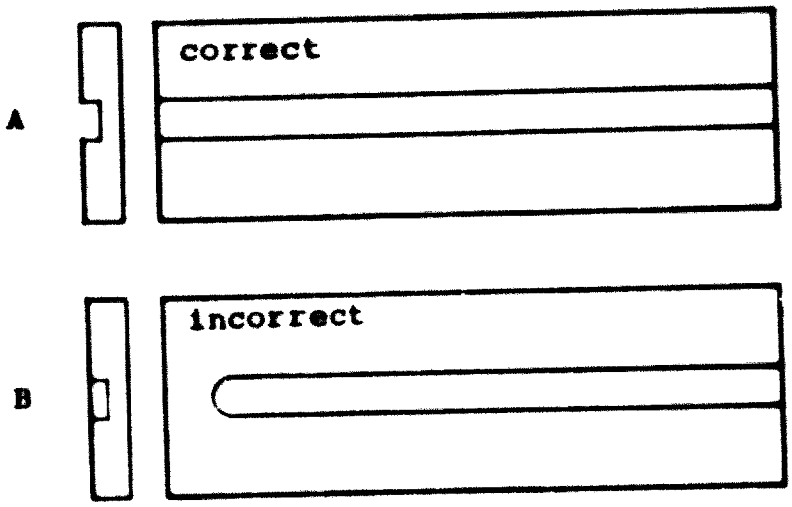


FIG. 7.2

Machining of groove in through-feed operation
A: possible
B: not possible (with standard machines)

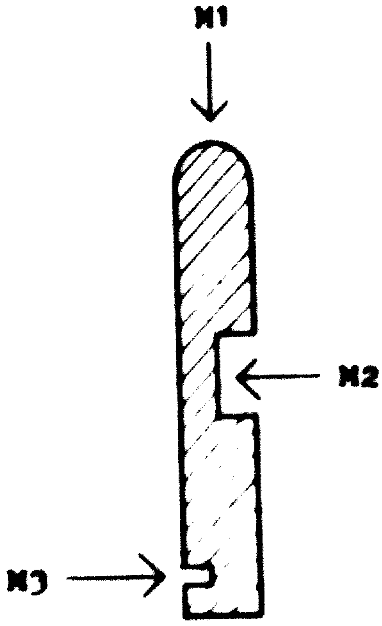


FIG. 7.3

Four-side moulding machine produces final profile including machining phases M_1, M_2 and M_3.

tion boards; solid wood is often used only for chairs, drawers, binding parts and bases.

The following is a brief review of the uses of various raw materials in different constructions and of their characteristics:

1. Furniture members made of one piece of solid wood are seldom more than 100 mm in width. Such furniture members are, e.g., table and chair legs and rails, drawer parts, and other narrow pieces.

2. To reduce costs, solid wood is often veneered. The blindwood can be of low quality provided it is of sufficient strength. If the blindwood pieces are narrow they usually are first glued to form a panel and then planed and veneered. The veneered panel is sawed to the required pieces and the edges are veneered (Fig. 7.4).

3. The most common panel constructions used in furniture manufacture are (Fig. 7.5):

   a) Solid wood panel
   b) Veneered solid wood panel
   c) Veneered particle board
   d) Semi-manufactured board prepared for painting
   e) Panel with frame construction.

   Panel construction a) shrinks and swells across the grain and therefore must be fastened to, e.g., a table base in a manner that allows it to move (buttoning).

   Shrinkage is prevented in panel construction types b), c) and d). The external dimensions of the frame in construction e) are also practically constant.

4. Cell construction (Fig. 7.6) is commonly used in joinery products (doors, kitchen furniture); however, frame and panel construction also is used in doors. In cell construction the corners of frames are stapled (no joints) to keep the frame together during process. The frame is filled with paper honeycomb and covered with fibre board in hydraulic glueing press.

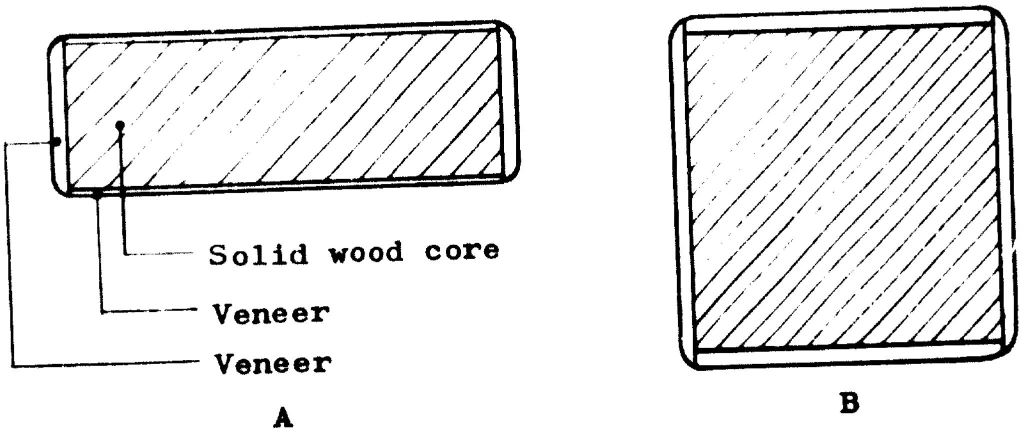


FIG.7.4 Veneered solid wood components

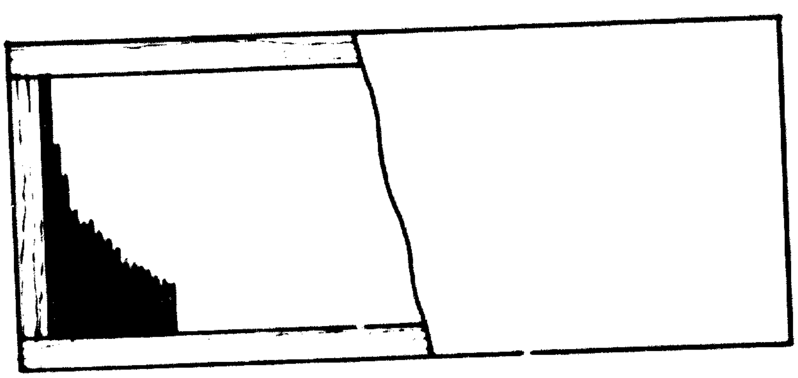


FIG.7.6

Cell construction commonly only used for flush doors and kitchen furniture

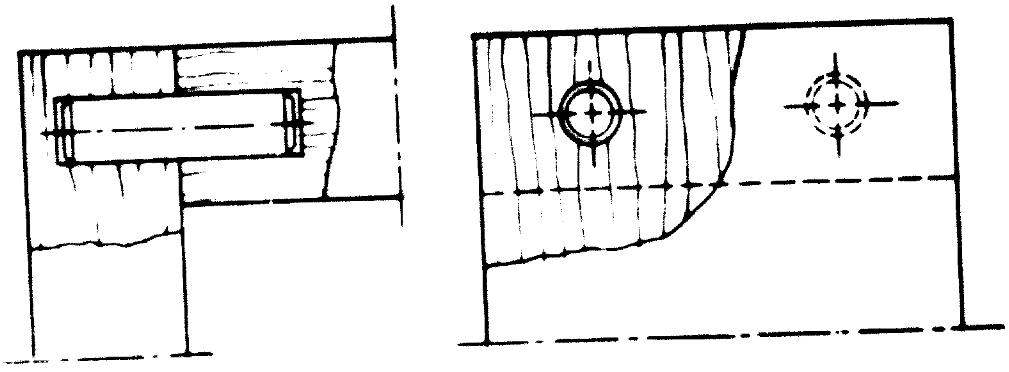


FIG. 7.7

Dowel joint

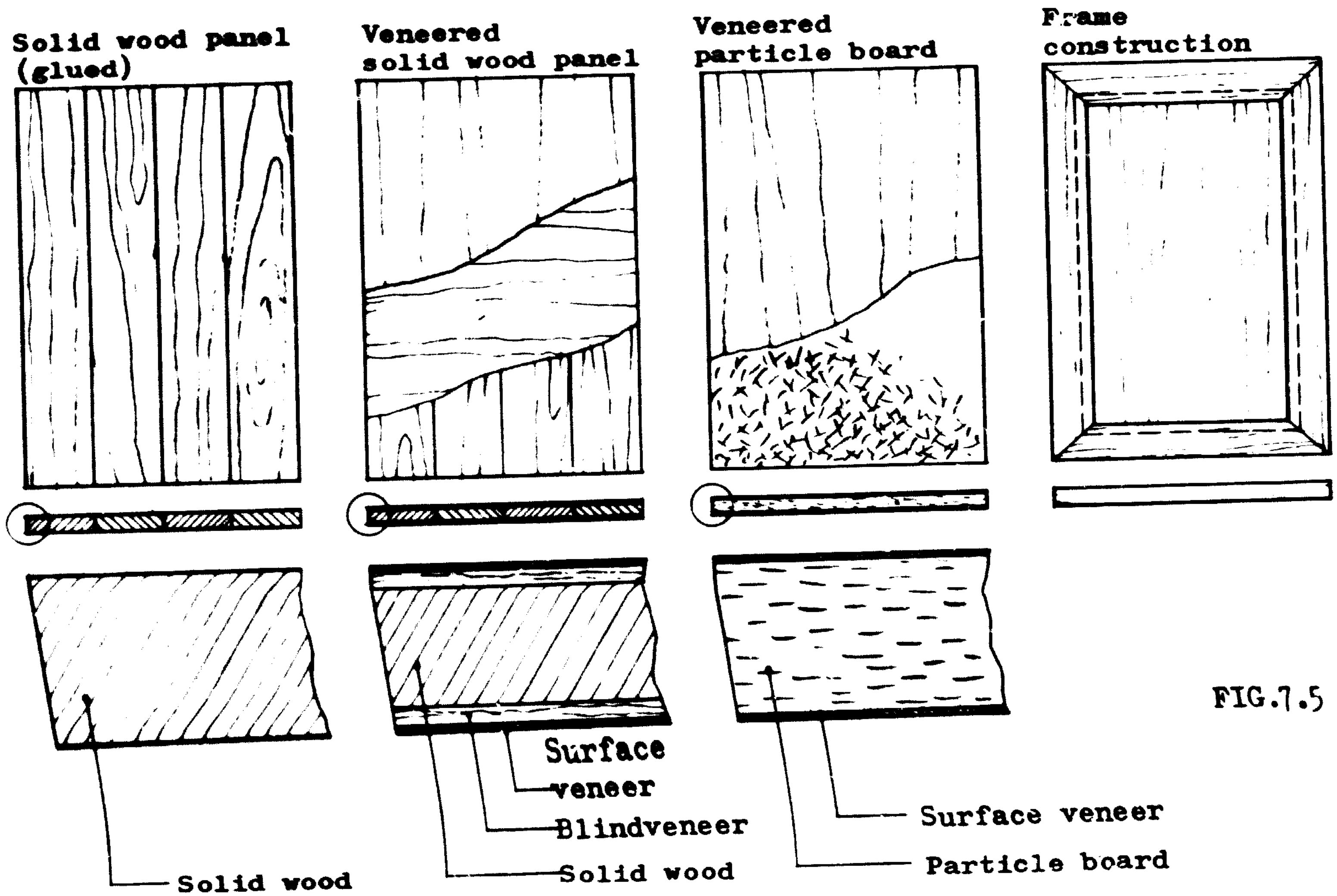


FIG.7.5 Common furniture panel constructions

5. Back panels of cabinets and bottoms of drawers are now usually made of hard or semi-hard fibreboard, which is painted or veneered. Plywood is considerably more expensive.

7.4 **Joints**

The dowel joint (Fig. 7.7 and Table 7.1) has rapidly gained wide use as a general method of joining the structural members of furniture. The principal advantages of the dowel joint are:

1. Machining is simple and accurate with multi-spindle boring machines. The two components of the joint always fit closely together.

2. Driving of dowels is rapidly performed with a special instrument.

3. The joint is easy to assemble.

4. The wood is scarcely weakened by the holes because the fibres are cut over a very small area.

5. Surface finishing can be carried out with a curtain coating machine after boring but before assembly since lacquer flowing into the holes does not affect the gluing.

6. Raw material consumption is reduced by use of waste-wood for dowels.

7. Use of dowel joints contributes to efficient rationalisation as well as to automation.

8. The dowel joint is the joint best suited for particle board construotions.

Of the traditional joints, the following are suited fairly well to modern manufacturing processes (Fig. 7.8).

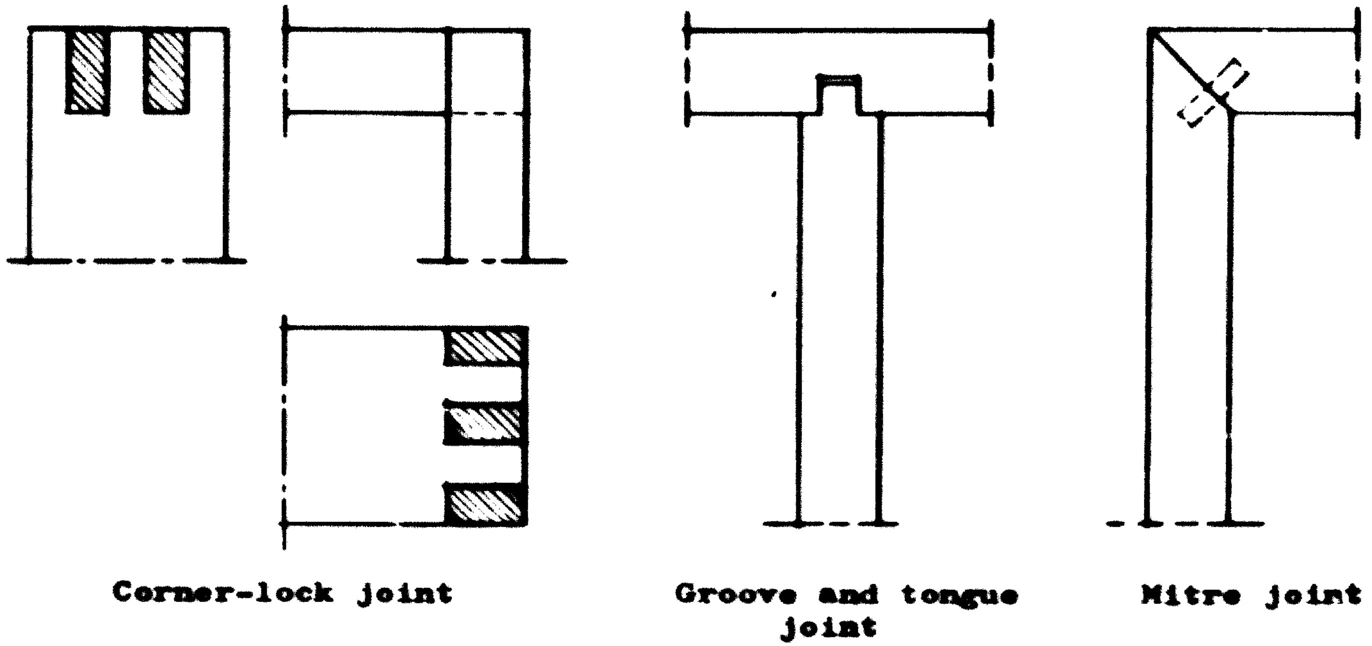


FIG 7.8 Three common joints suitable for modern manufacturing processes.

- Corner-look joint
- Groove-and-tongue joint
- Mitre joint.

The stubtenon joint (table 7.2) is a traditional furniture joint but less used today because it is slower to machine and produces poor surface quality to mortise. The hollow-chisèl mortiser makes rough inside surfaces into the mortise and results in reduced strength of glued joint. Various kinds of metal fasteners (fig. 7.9 and 1.10) are being substituted for glued joints. They have the advantage that the product can be shipped to the customer in knocked-down form and compactly packed. The parts can be easily assembled at destination even without special skill. An additional advantage is that surface finishing is done to the parts in unassembled condition. Type A in fig. 7.9 with cylindrical steel nut implanted in wood (in rail) has excellent strength properties and is therefore well suited for jointing of chair and table legs to rails. The rail is guided by two dowels. Type B with ordinary nuts has not quite as good properties in respect of strength. Type C with nylon nut is suited only for light loads. Type D is a common fasteners for table legs (guiding is not necessary).

To simplify designing and fabrication the joints should be standardised to a few standard joint types. The machining dimension of selected joints must also be standardised. Recommended practical tolerances for joints are shown in Table 7.3.

7.5 Modular dimension principle and element furniture combinations

A module is a basic unit of measurement in an object, all larger dimensions being multiples of the module (fig. 7.11). Pieces of home, office and kitchen furniture - both movable and stationary - are dimensioned today very generally on the modular principle. Basic pieces of furniture manufactured on the modular principle, called element furniture, can be combined by customers into larger units according to their individual needs and tastes. In many element furniture systems the variety of combinations possible is very great.

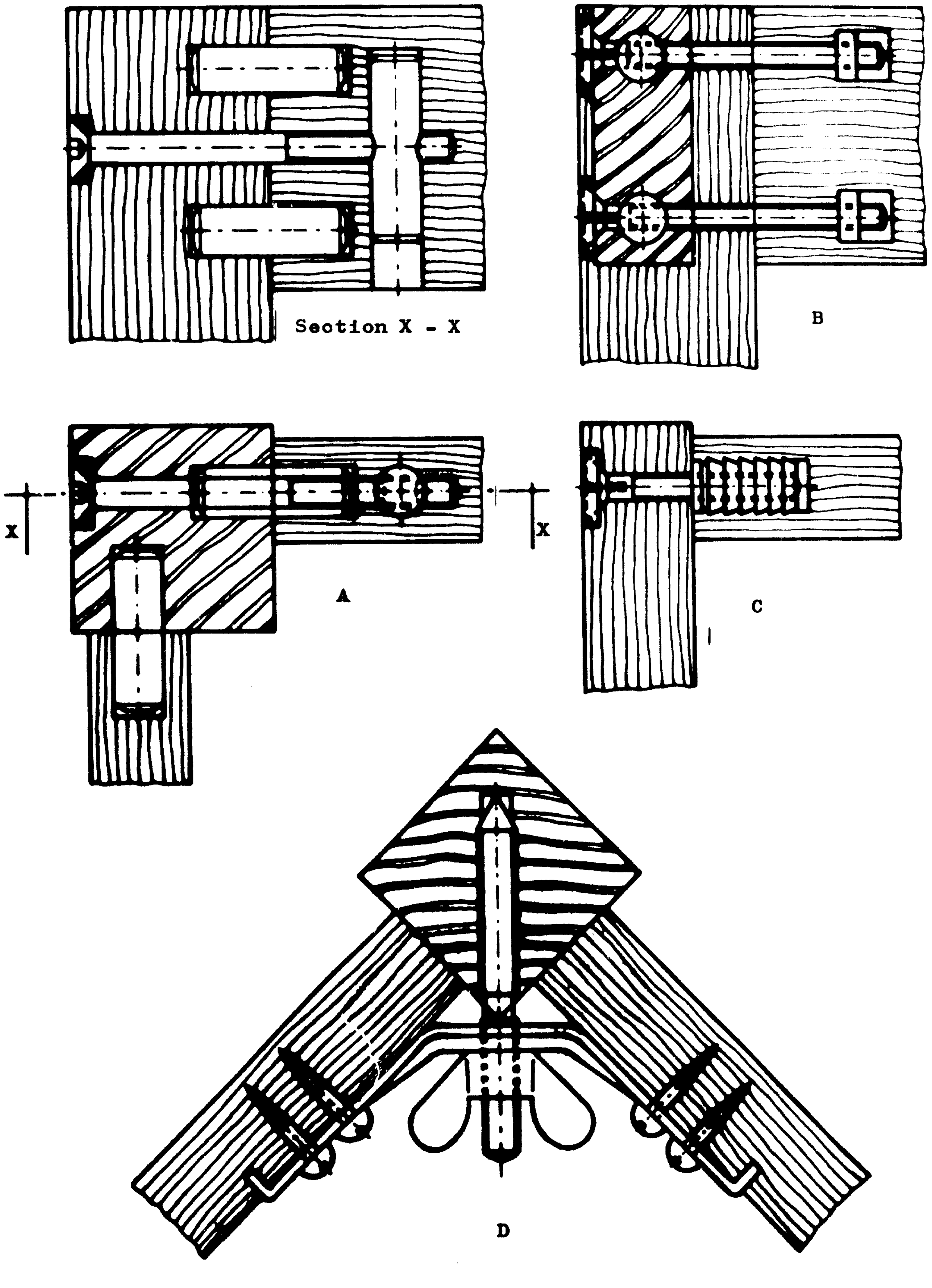


Fig. 7.9 Various metal fasteners.

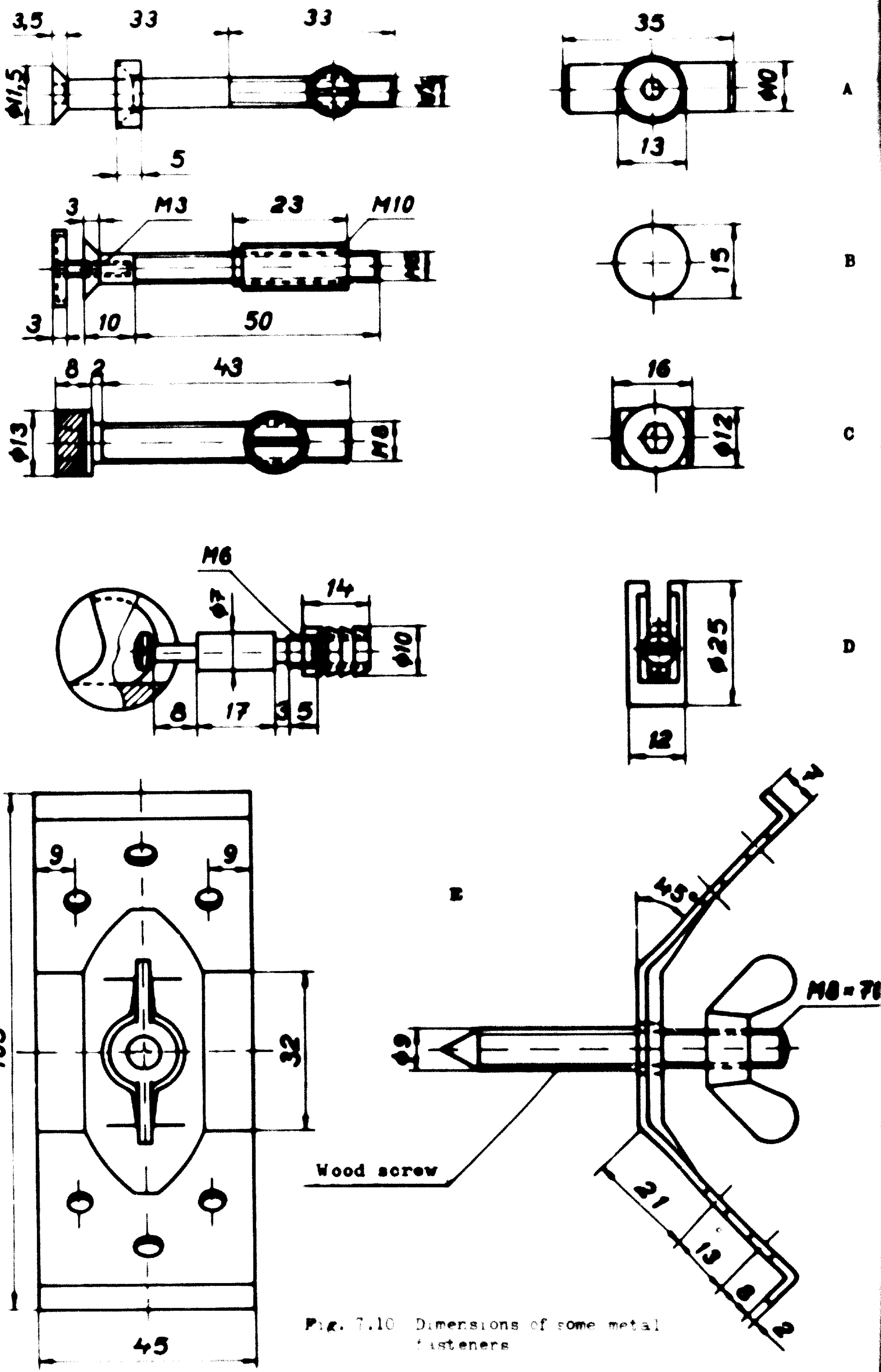


Fig. 7.10 Dimensions of some metal fasteners

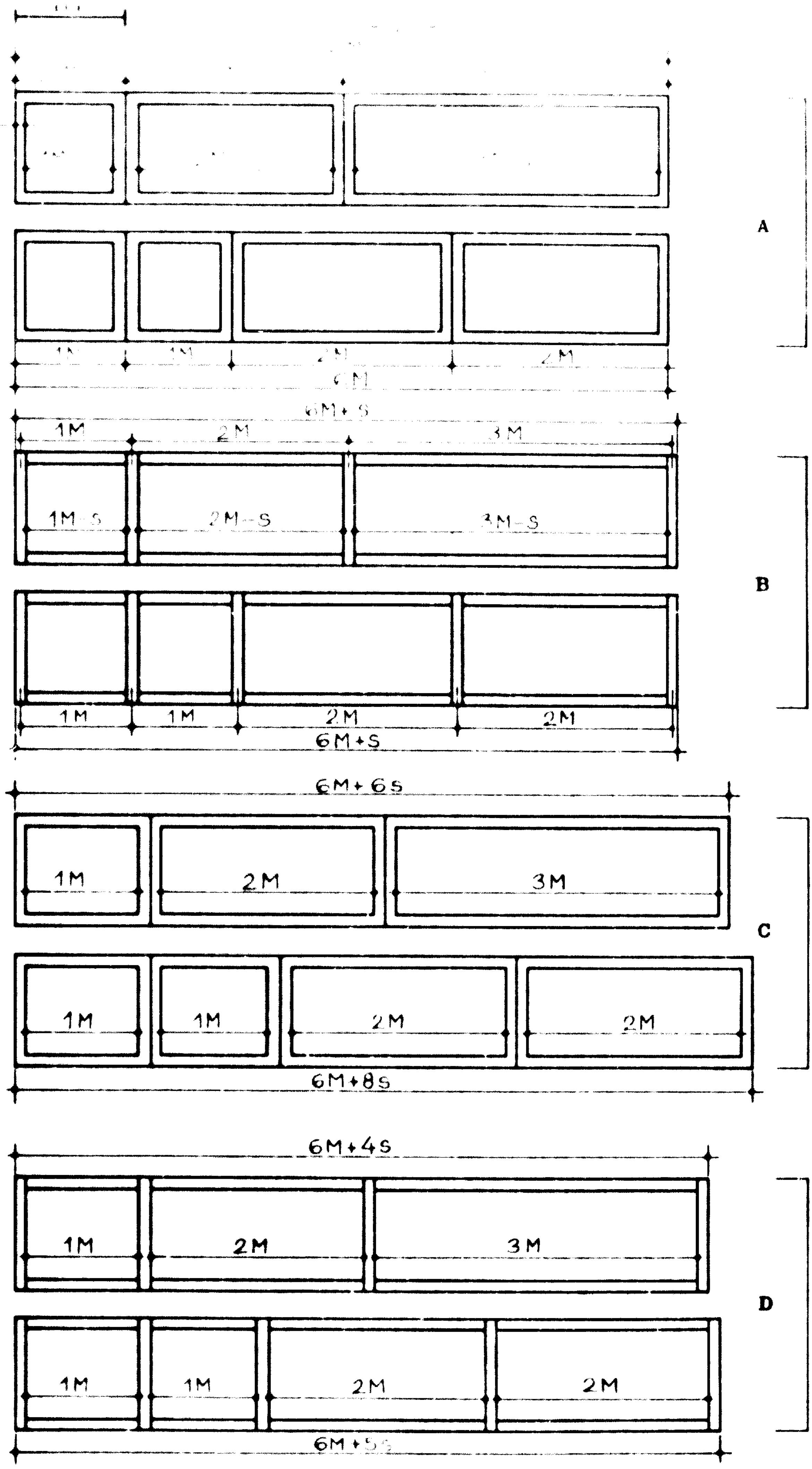


Fig. 7.11 Various modular principles

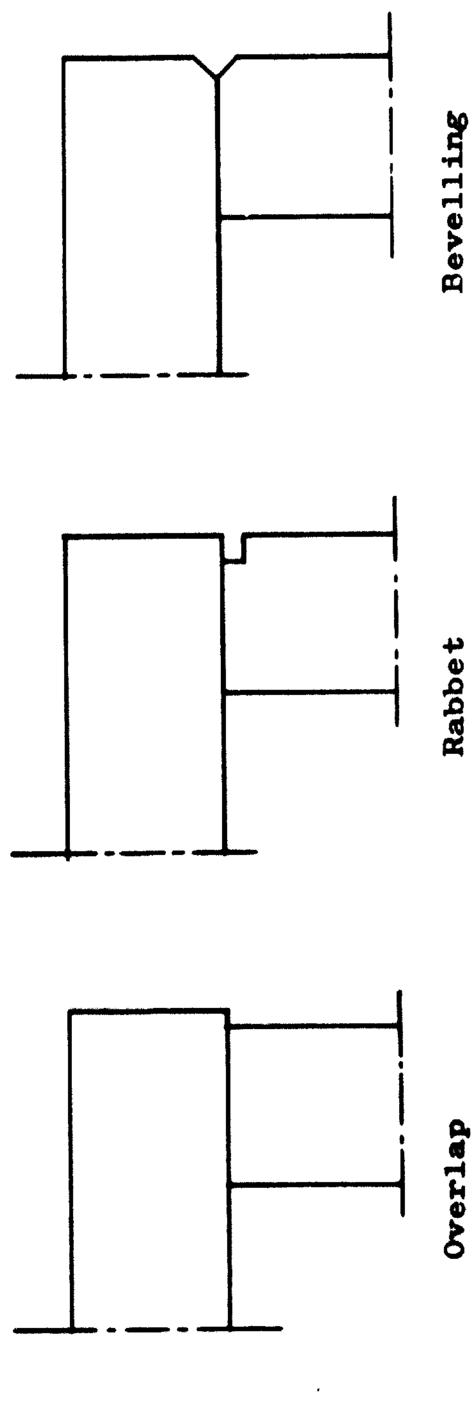


FIG.7.12

Structural means of concealing dimensional inaccuracies

7.6 Concealing of dimensional inaccuracies by structural means

Inaccuracies due to dimensional deviations in raw materials, such as variations in particle board thickness, inaccurate machining, etc., can be rendered inconspicuous and practically invisible to the eye by appropriate constructional designing. At the same time, hand fitting in the assembly phase will be avoided. Structural means of this kind are (fig. 7.12):

- Overlap of one component
- Rabbet or bevelling at line of joining.

In veneered particle board products it is possible to use only overlap because of the thin surface-veneer, whereas rabbet and bevelling are particularly suitable in solid wood constructions.

7.7 Drawings and dimensions

The drawings used in the furniture and joinery industries are of two principal types:

Full-scale drawings (1:1 scale)

1. The dimensions are taken by measuring the work-piece against the full-size drawing when the machine is being set up for the machining operations.

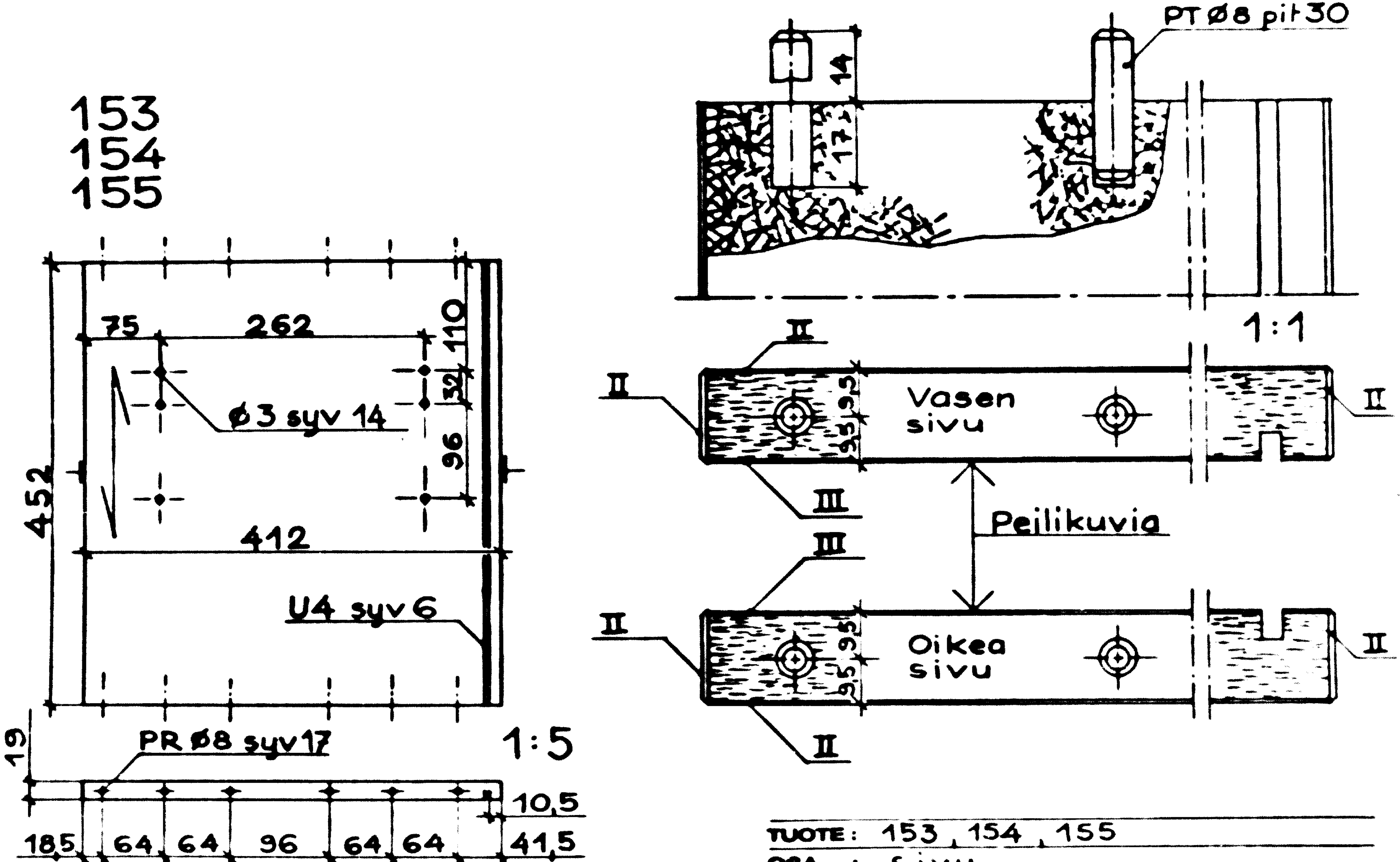
2. No dimensions are indicated on the drawing.

3. Accuracy of manufacture is poor.

4. 1:1 drawings are not suited for modern serial production in general; however, they are useful in presenting the dimensions of, e.g., curved and complicated details of chair members, profiles, etc.

Drawings to scale

1. 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).



TUOTE:	153, 154, 155
OSA:	Sivu
SUHDE:	1:5 1:1 — PVM: 21 5 71
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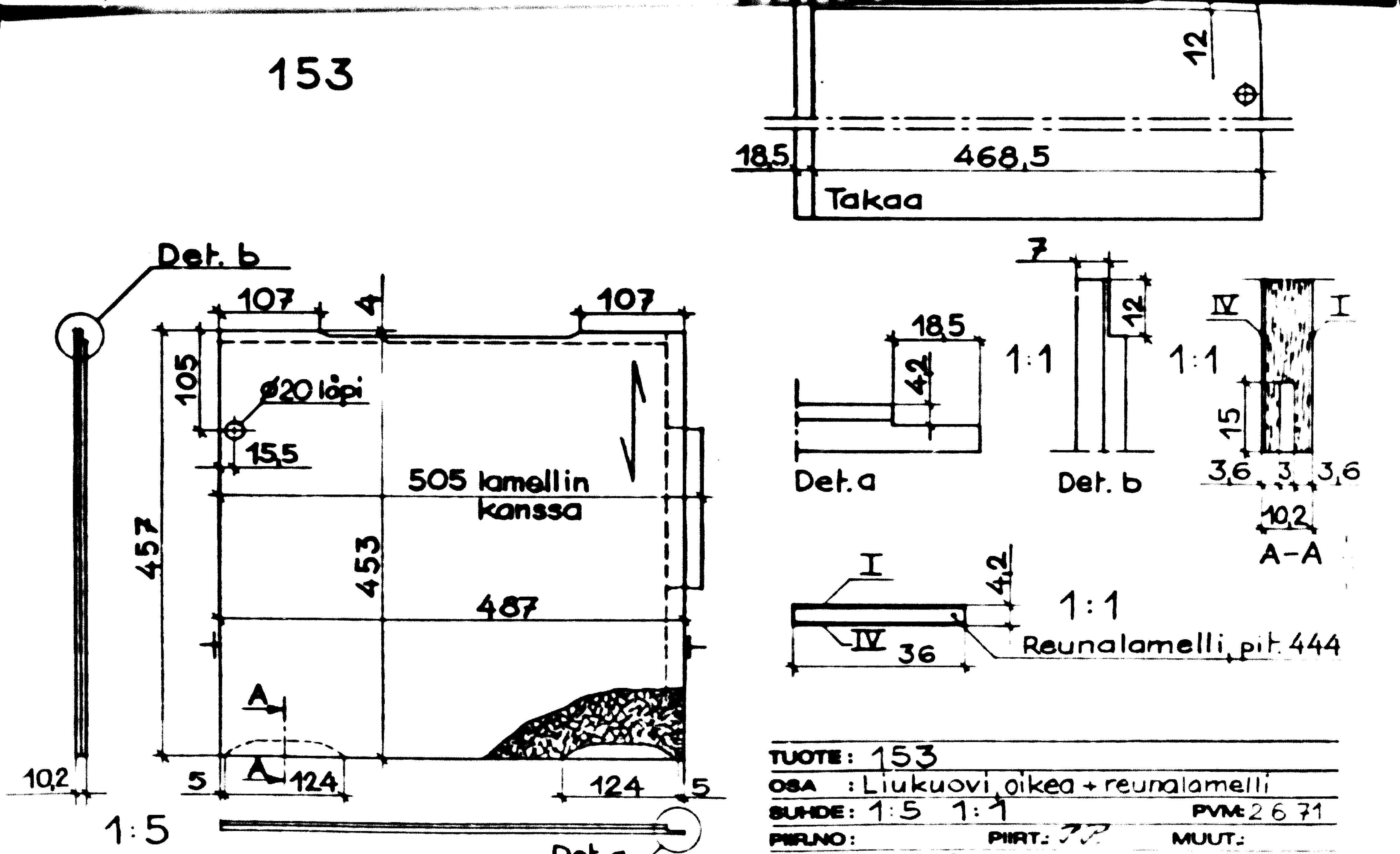
Scale drawing for one member of product (end panel of filing cabinet)

cabinet)



Scale drawing for one member of product
(right-hand sliding door of filing cabinet)

Fig. 7.

2. Section drawings of details (in scale 1:1) are often very illustrative.

3. The latest 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 (e.g. Xerox type); copies are then sent to the respective points in the factory (fig. 7.13 and 7.14).

4. The dimension figures on the drawings are decisive, not the measures obtained with a scale ruler from the drawing.

5. Only the dimension figures need to be changed in case alterations in dimensions are necessary.

6. An assembly drawing is made of the complete product, showing the position of members.

7. Joint types can be indicated on the drawings by appropriate abbreviations and symbols.

In the drawing series of figures 7.15...7.19 a simple product is presented with one assembly drawing and four part-drawings (one of each member). The drawings are also provided with markings for veneer quality (II,IV) and grain direction (⟷).

7.8 Prototype

Before the serial production of any objects 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:

1. The prototype must be similar in all respects to the intended serial product (similar joints, etc.) in order to bring out any defects in construction or fabrication.

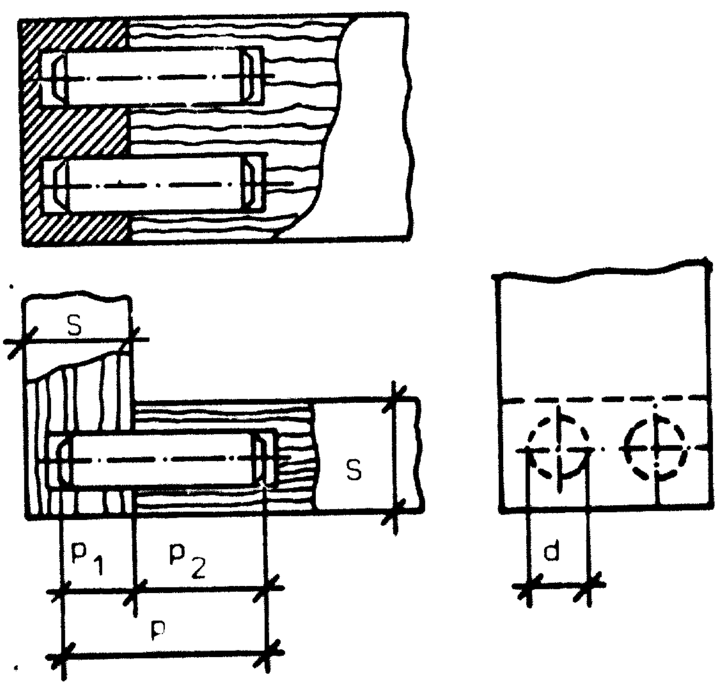
2. The prototype is used to examine and test the properties of the product in service, its dimensions, strength and rigidity, appearance, etc.

7.9 Organisation of technical product planning

It is customary that a product designer with training in applied art create the idea and submit it to a factory. The appropriate persons on the factory staff develop the technical plan of the product and make a prototype which is submitted to critical examination and altered until the object is considered ready for production or is rejected. The phases of the whole of product development from idea to **manufacture** are shown with a scheme in FIG. 7.20.

A more efficient way would be to carry out product planning as team work. Product development is greatly facilitated when the various aspects of technical production can be taken into consideration throughout the planning process.

Table 7.1. Dimensioning of dowel joints (as corner joint).

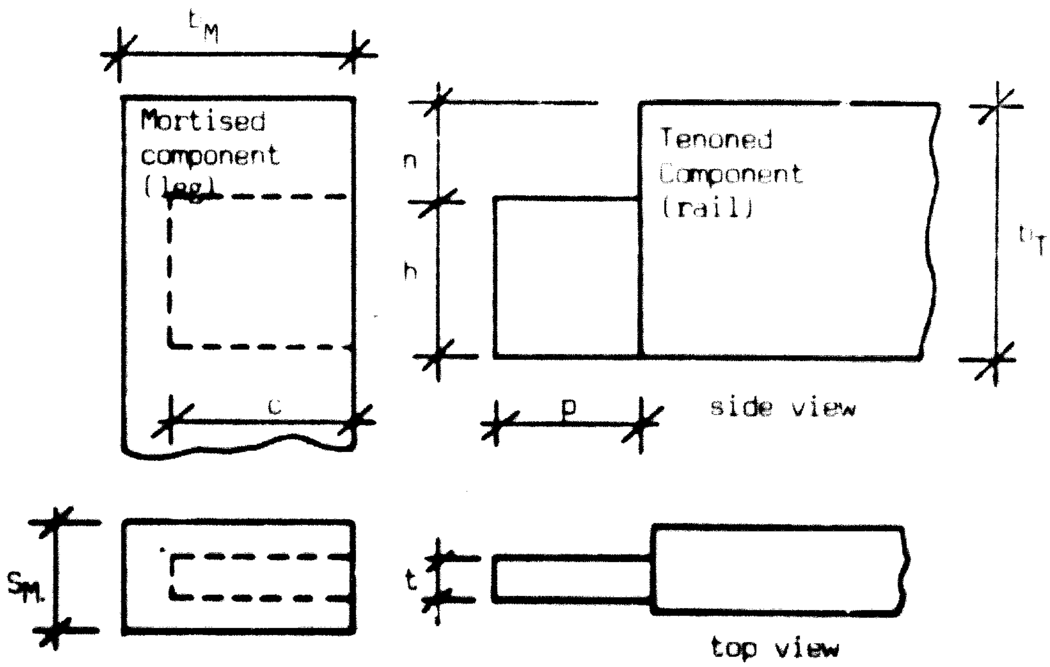


Millimetres

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

(Example of dowel pitch in fig. 7.13)

Table 7.2. Dimensioning of stub tenon joints



Millimetres	
S_M	t
6	3
8	4
11	5
14	6
17	8
20	8
26	10
32	14
38	16
44	20
50	23
56	26

$c = p + (2...5)$ 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

Tenon should be as long as possible.

Tenon must be machined about 0.2 mm thicker than mortise.

Table 7.3 Tolerances for joints

Hardness of wood	Boring or mortise	Dowell or tenon
Soft (Pine, spruce)	+ 0,05 - 0,0	+ 0,3 + 0,2
Semi Hard (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

EXAMPLE

Lower and upper limits of mortise and tenon dimensions

Hardness of wood in question : semi-hard

Nominal dimension of joint : 8 mm

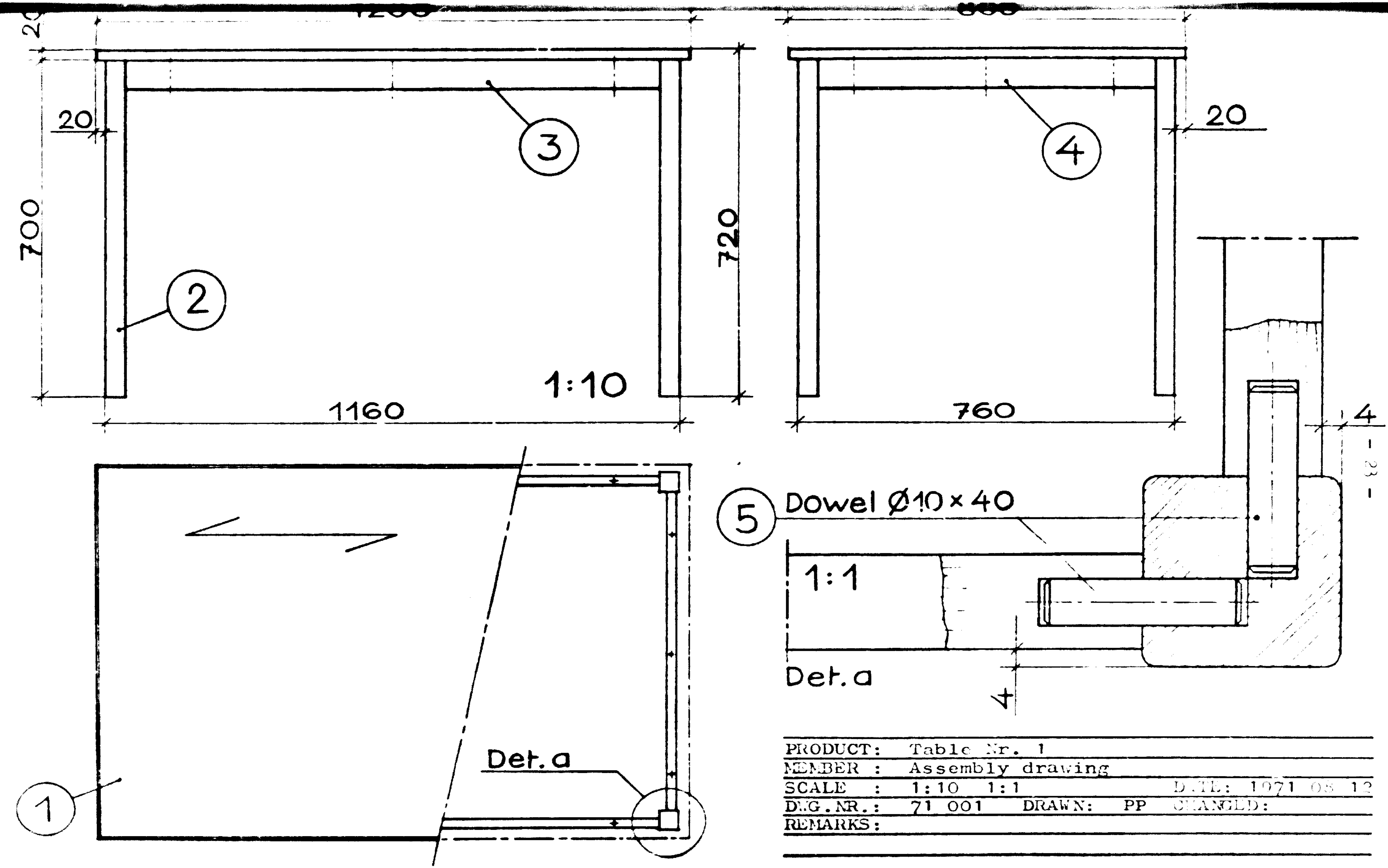
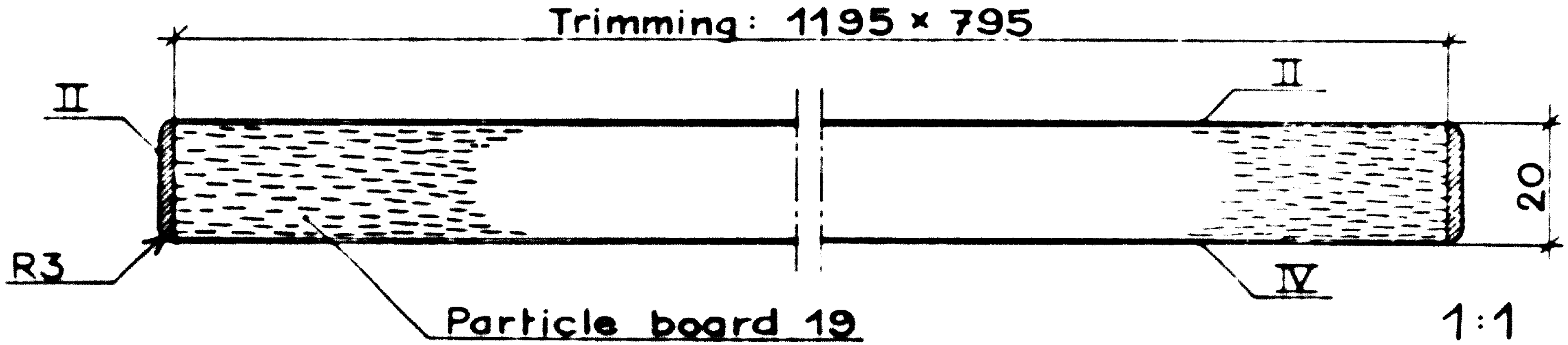
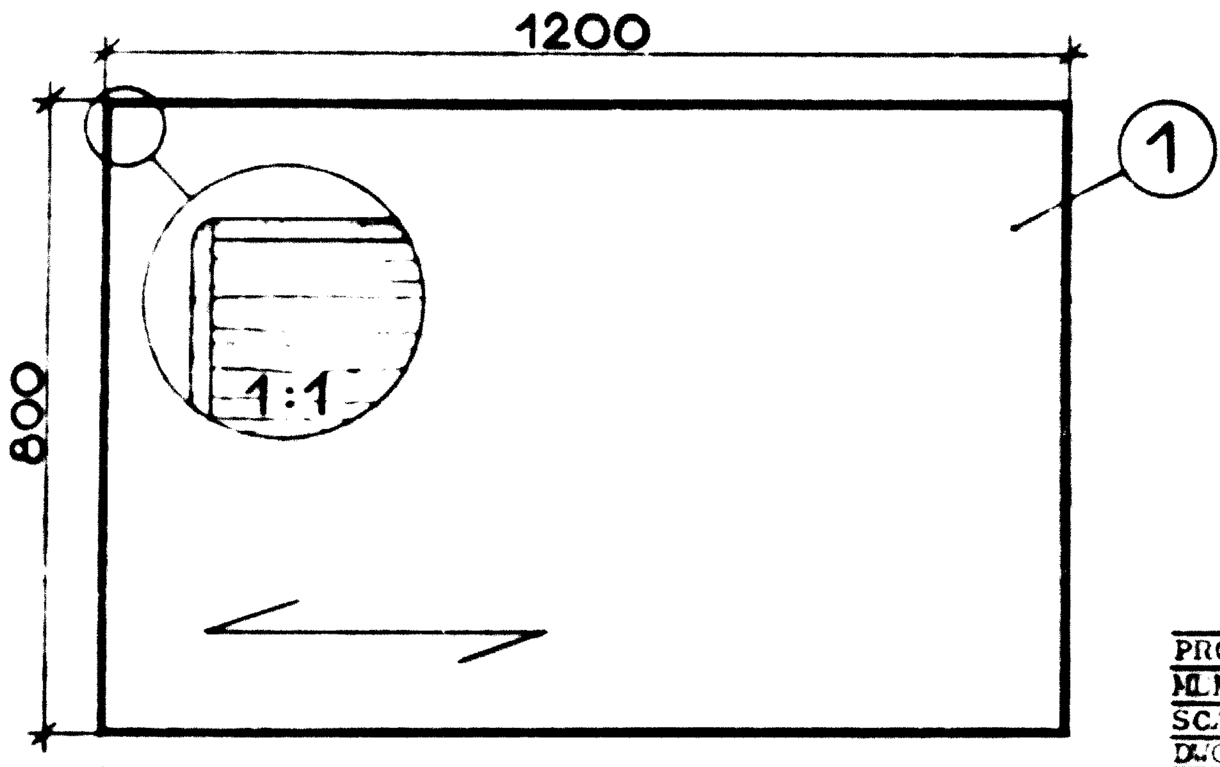


FIG. 7.15. Assembly drawing

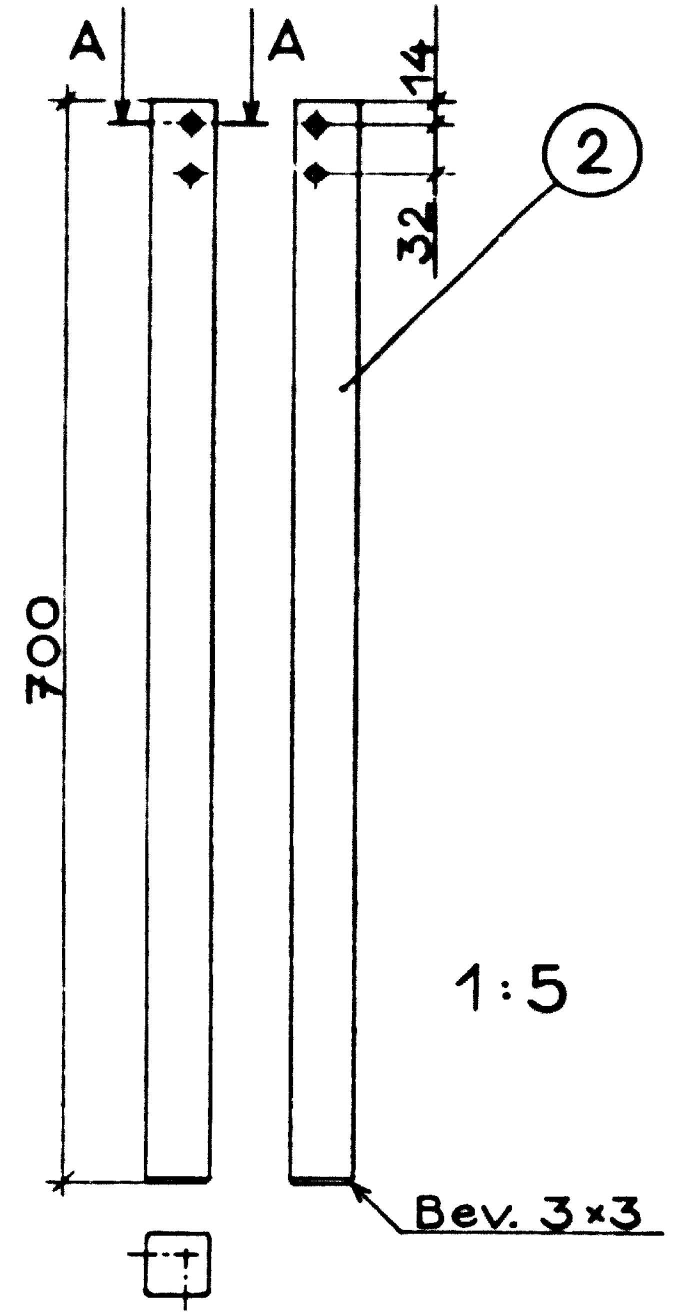


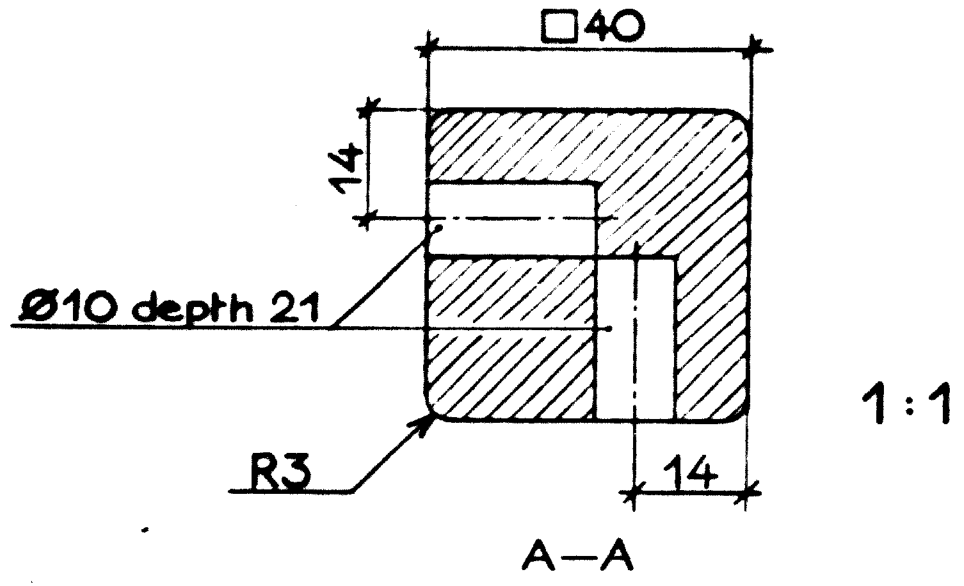


Veneer	Thickness	
	Raw	Sanded
Surface	0.7	0.5
Edge	2.8	2.5

PRODUCT:	Table Nr. 1		
NUMBER :	Top panel (1)		
SCALE :	1:10 1:1		DATE: 1971 08 12
DWG.NR.:	71 002	DRAWN: PP	CHANGED:
REMARKS:			

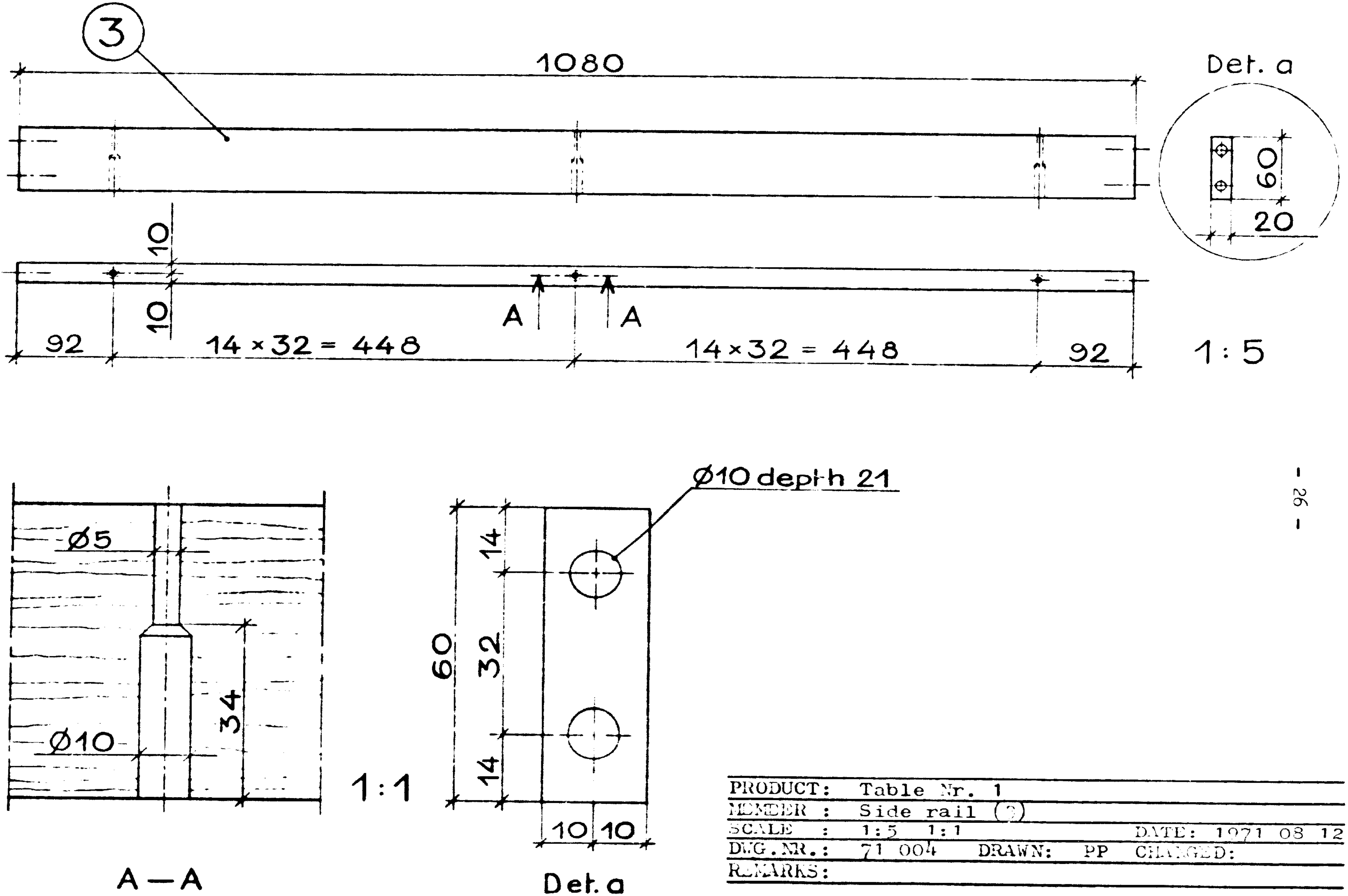
FIG. 7.16. Assembly drawing





PRODUCT:	Table Nr. 1					
MEMBER :	Leg (2)					
SCALE :	1:5 1:1				DATE:	1971 08 12
DWG.NR.:	71 003	DRAWN:	PP		CHANGED:	
REMARKS:						

FIG. 7.17. Assembly drawing



PRODUCT:	Table Nr. 1
MEMBER :	Side rail (3)
SCALE :	1:5 1:1 DATE: 1971 08 12
DWG.NR.:	71 004 DRAWN: PP CHANGED:
REMARKS:	

FIG. 7.18. Assembly drawing

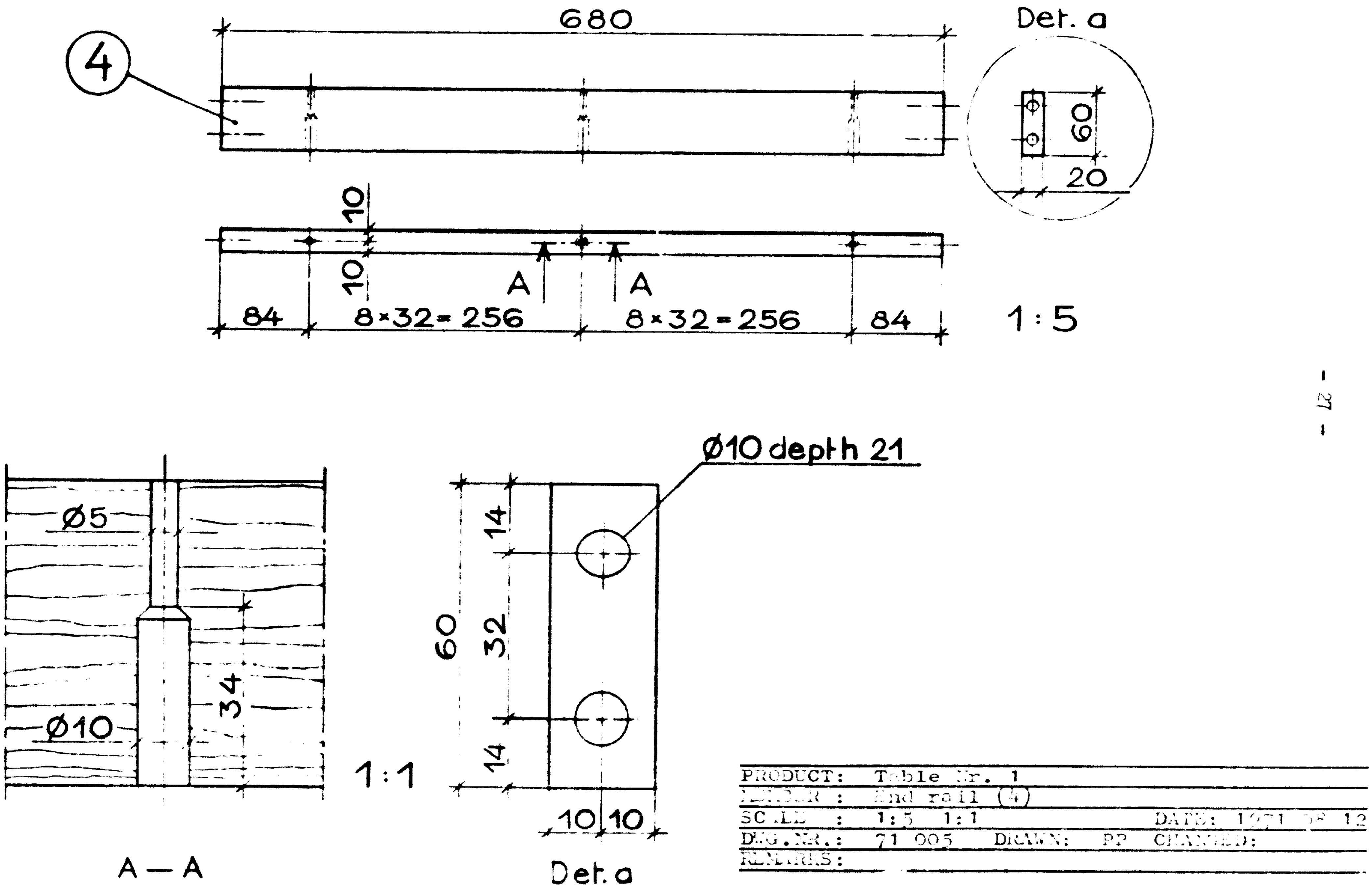


FIG. 7.19 Assembly drawing

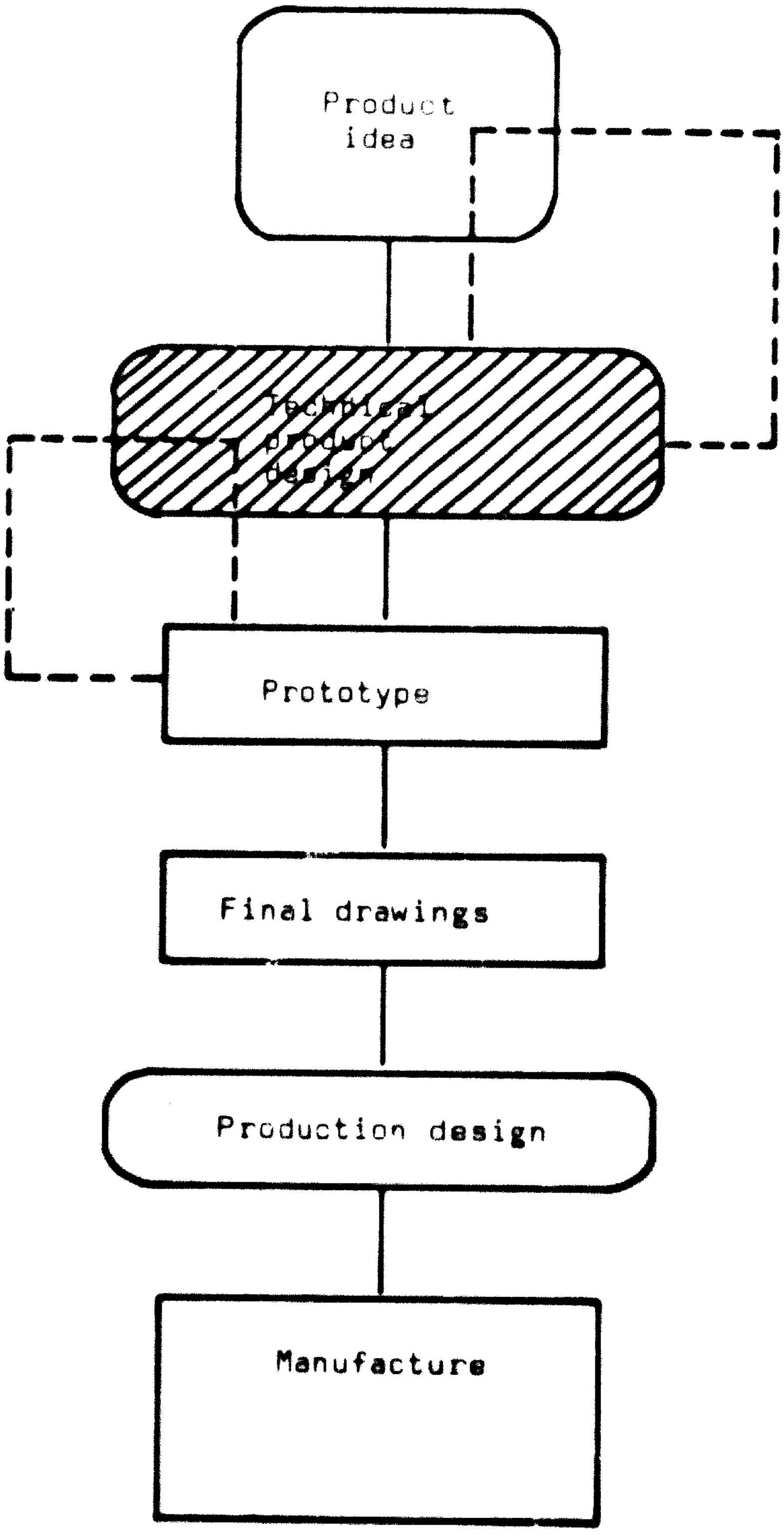


Fig. 7.20.

Process of product development

7.10 Production design is one of the preliminary steps to be taken before starting manufacture. By means of careful production design one achieves an economic utilization of raw materials we well as the most efficient utilization of the production capacity of a plant.

7.11 Purposes of production design

Production design has the following principal tasks:

1. Drawing up lists of all raw materials and requisites, and of dimensions and numbers of necessary pieces (piece lists for cross-cutting and edging, for cutting veneer and particle board etc.)

2. Drawing up operation lists (lists of work phases) of all machining, assembling, surface finishing and other phases for each different part separately. The lists follow in card form the production lot through all manufacturing phases. The operation lists give the following information:

- the machines and other equipment to be used, listed in the order required by the work phases, **and indicated by code numbers.**

- details of each manufacturing phase (special tools, number of sanding belt to be used etc.)
- completed and uncompleted work phases. Every phase is marked on the card when completed.

3. Timing of the production so that the production lot is completed according to schedule. This is of prime importance from the point of view of competitive ability of the factory. The following points should be taken in**to consideration when** dealing with production capacity:

- The production capacity of a furniture plant using separate detached basic machines and equipment is determined by the so called bottleneck (fig. 7.21)

- The production capacity of machines can be raised in steps only (fig. 7.22)

- The means used to remove bottlenecks in production are the following:

- procuring of additional machines
- procuring of more efficient machines
- hiring of more competent personnel
- doing **over time work**
- doing work partly in shifts
- using sub-contractors

- Removing a bottleneck means that one gets a new bottleneck at another spot.

7.12 Factors affecting production design

The most important factors affecting production design are

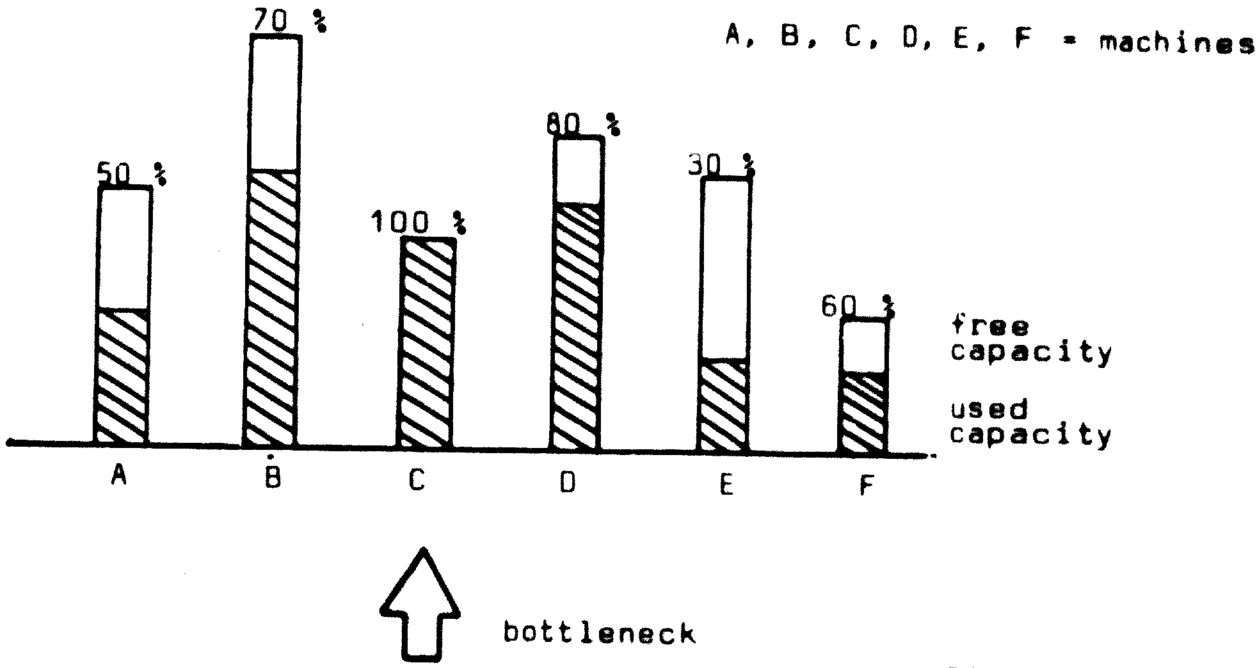
1. Available machines and equipment
2. Size of production lot
3. Intended quality
4. Raw materials and requisites available
5. Profesional skill of the labour force

Fig.7.23 represents the connexion between production design, product design, and manufacturing process.

AVERAGE CAPACITIES OF SOME BASIC WOODWORKING MACHINES

	Cubic metres/year
Cross-cut saw	2300
Edging saw, chain feed	2300
Surface planer	1400
Thickness planer	4,7/mm in width
4-side moulder	2300...4700
Trimming saw, single-blade	1400...1900
Trimming saw, double blade	2800...3700
Band saw	2300...4700
Vertical spindle moulder	700...1400
Router	2300
Chisel mortising machines	1400...1900
Horizontal belt sanding M.	1900...2800

The values are valid in average furniture production where different kinds of furniture are manufactured of solid wood.



Formation of bottleneck Fig. 7.21

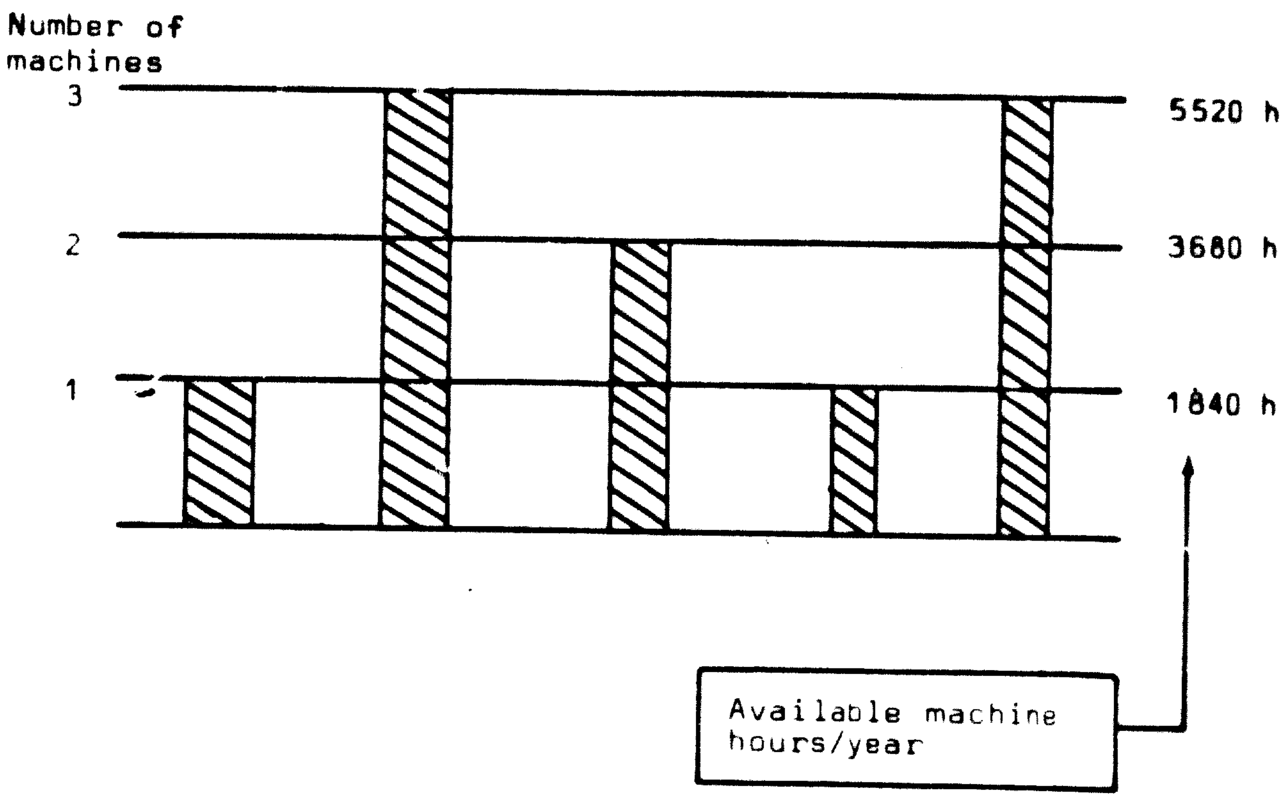


Fig. 7.22 **Capacity of machines can be increased only as multiples of single machines**

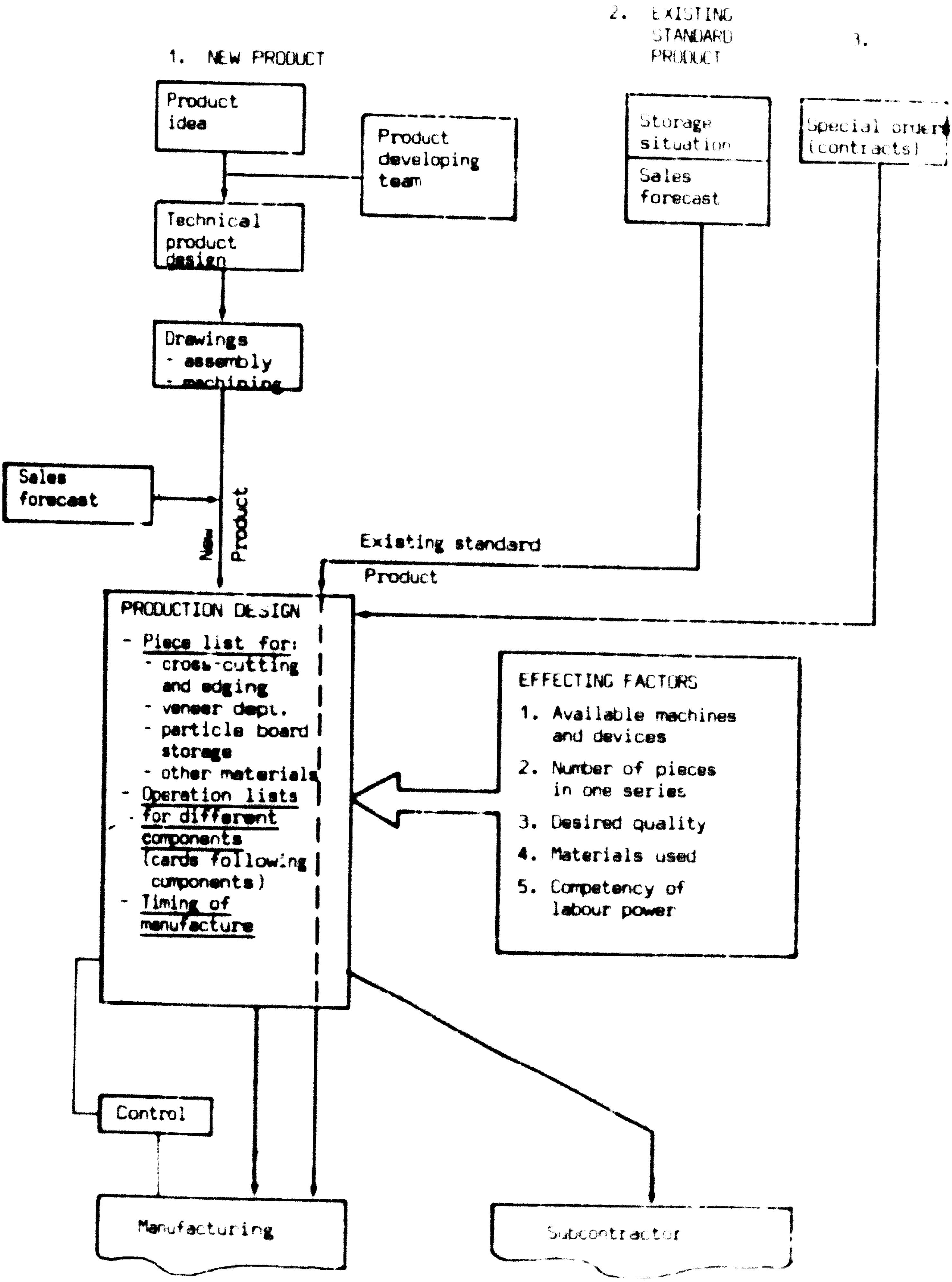


Fig. 7.23

Position of production design in furniture production process

14.6.74