Textbook for Vocational Training – Engineering Drawing Metal

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Preliminary remarks

The Textbook Engineering Drawing – Metal – is intended for all trainees of metal–working trades.

Due to the consistent consideration of the unit of theory and practice, the trainee can use it as a guide during theoretical instructions and in practical vocational training.

The grasping of the problems dealt with is facilitated by numerous illustrations and a vivid representation of the subject–matter in a way that is easily understandable.

Each Chapter contains a number of problems and questions for repetition. They are concentrated on the focal points of the subjects of particular importance to metal–working trades and the trainee can take advantage of them for checking his knowledge independently.

In order that the acquisition of knowledge by the trainee can be successfully assisted by the process of practising, the author has prepared problem sheets for each Chapter which are compiled in an Appendix to the book.

Institut für berufliche Entwicklung

1. Introduction into Engineering Drawing

1.1. Tasks and Importance of Engineering Drawings

In any engineering drawing, information of different kinds are stored. Engineering drawing is a graphic language that expresses and conveys ideas enabling the perceiving, understanding and production of technical objects. This shows that the engineering drawing is an important means of communication between men, men and machines and between machines. Today, in all trades and professions, in leisure time and in households, more and more devices, machines and plants are used which are described and operated on the basis of engineering drawings.

In textbooks, periodicals and other publications, engineering drawings also play an important part. For the manufacture of products, engineering drawings have become an indispensable means which actually enables production. For this reason, the subject of "Engineering Drawing" has become part and parcel of vocational training. That is why it has become a necessity to teach the fundamentals of this subject already in elementary schools.

The engineering drawing has a twofold importance:

It is necessary for the user of technical objects in order to carry out operation, maintenance and, to a limited extent, repairs. This is the general importance of the engineering drawing.

It is necessary for the manufacturer of technical objects in order to be in a position to produce them manually and mechanically. This is the special importance of the engineering drawing.

In the various chapters of the present textbook, one enters into particulars especially of this special importance which consists in the fact the expert worker of metal–working and metal–processing trades also needs the engineering drawing to be in a position to produce. This shows that the drawing is turned into a manufacturing programme or production order. In order to meet the requirements of this task, the engineering drawing must contain the data which are shown in Fig. 1.1 and are related to the object of work. In addition it can give information about design and function of the workpiece to be made, of the device and structure or the main component, machine or plant to be produced. The extent of the required data will be determined by the intended use of an engineering drawing.

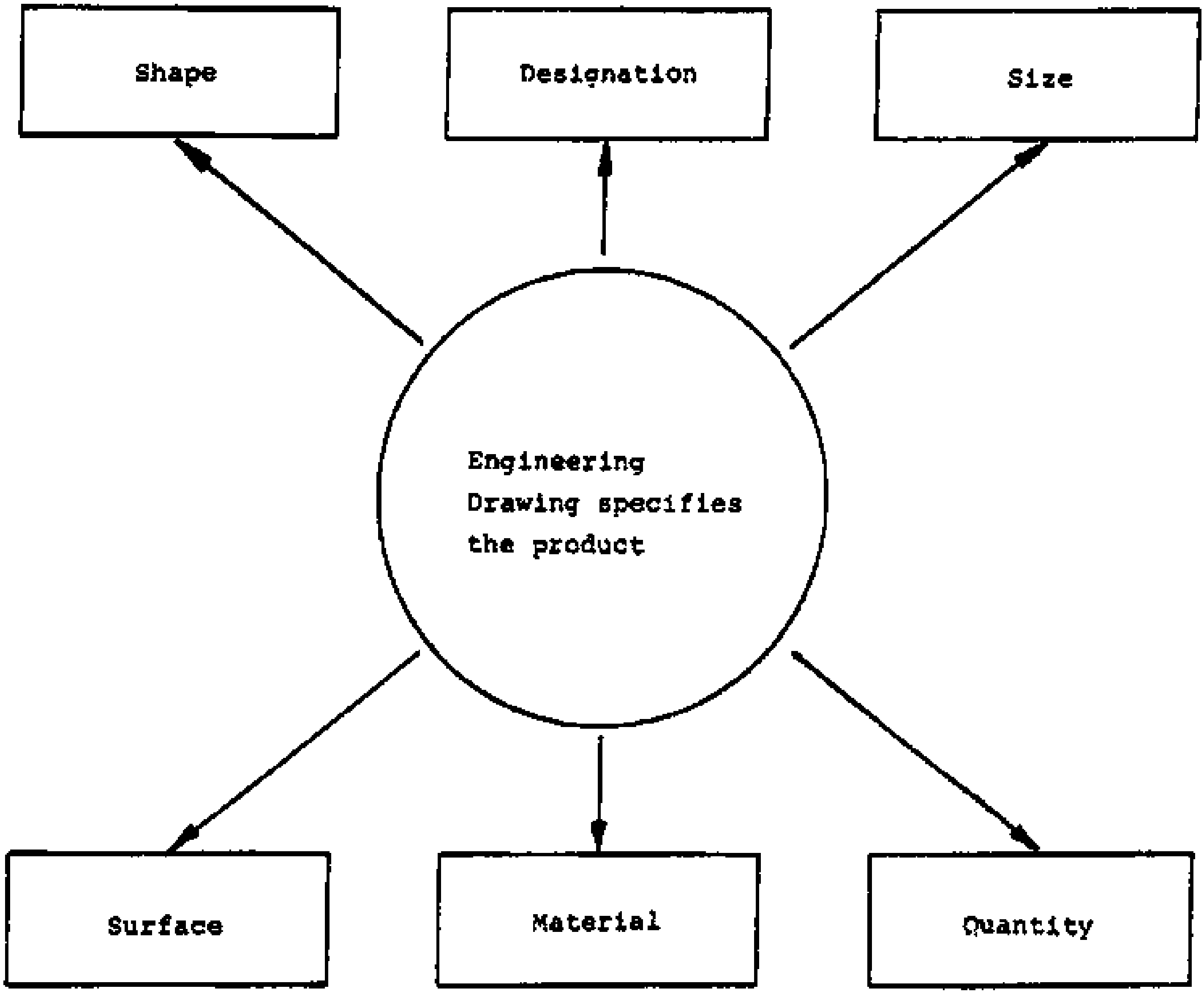


Fig. 1.1. Engineering drawing as a means of communication

It is the task of an engineering drawing to be information store for technical and graphic data and thus to become a means of communication between designer, draughtsman, expert worker and user (see Fig. 1.2).

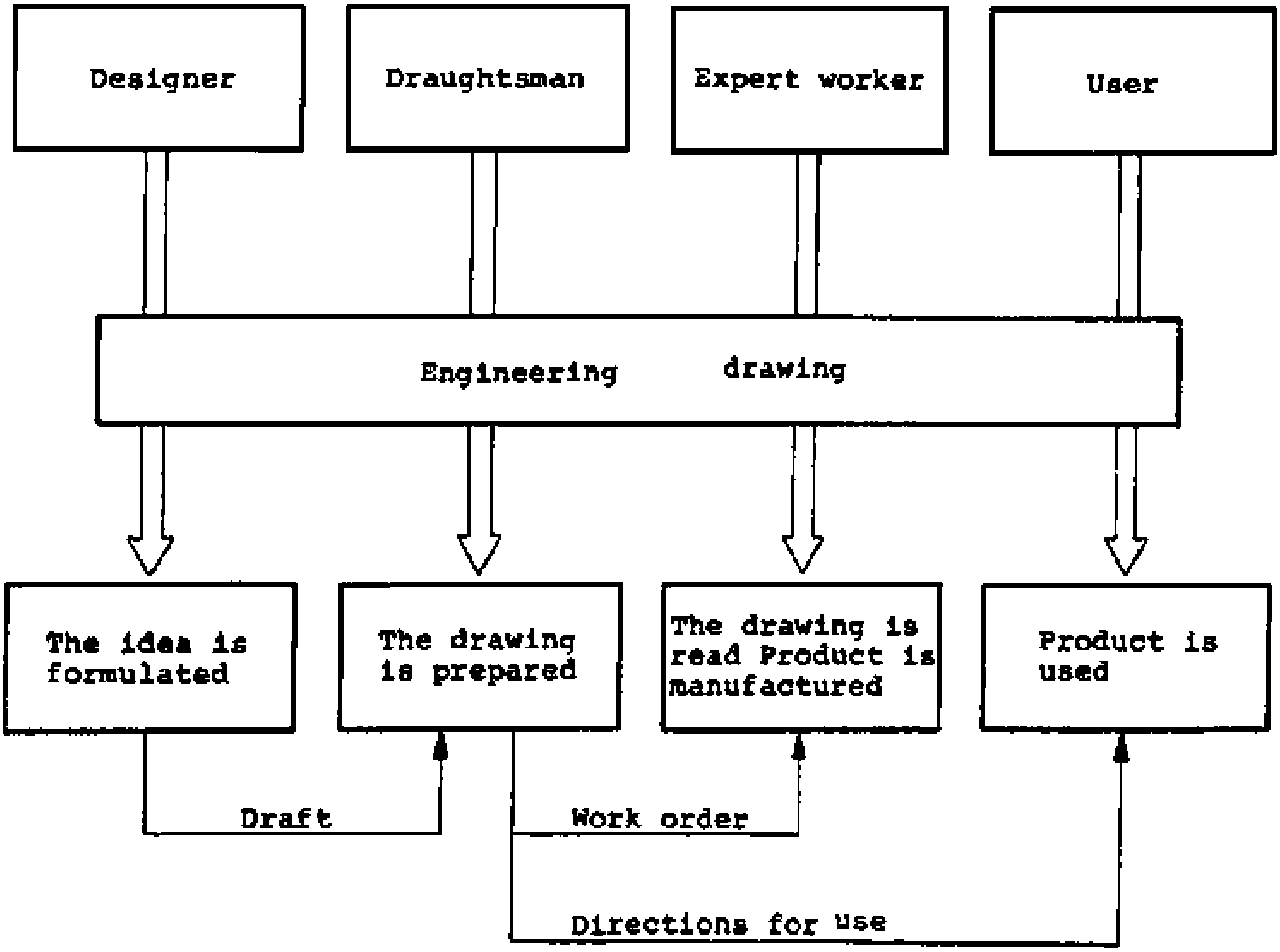


Fig. 1.2. The engineering drawing as the work order

In the form of a draft, a production order, an operating instruction or directions for use, the engineering drawing is always an important technical document without which production planning, preparation and carrying–out as well as organisation and sale of the production would be unthinkable.

In order to meet the requirements of a means of communication, the preparation of engineering drawings must be effected according to standardised or uniform rules. These rules are called standards which represent best solutions which are recommended or made compulsory for the territorial regions in question so that they adopt legal character. For the preparation, carrying–out and checking as well as for teh revision of standards, state institutions are responsible. Today, more and more international unifications are accepted in addition to national standards. These unifications or standards enable a specialisation and cooperation of production and, thus, are instrumental in the promotion and consolidation of the economic relations between countries.

Standards are classified in three main groups (see Fig. 1.3): according to their contents, according to the binding force stated (degree of obligatory conditions) and according to their scope.

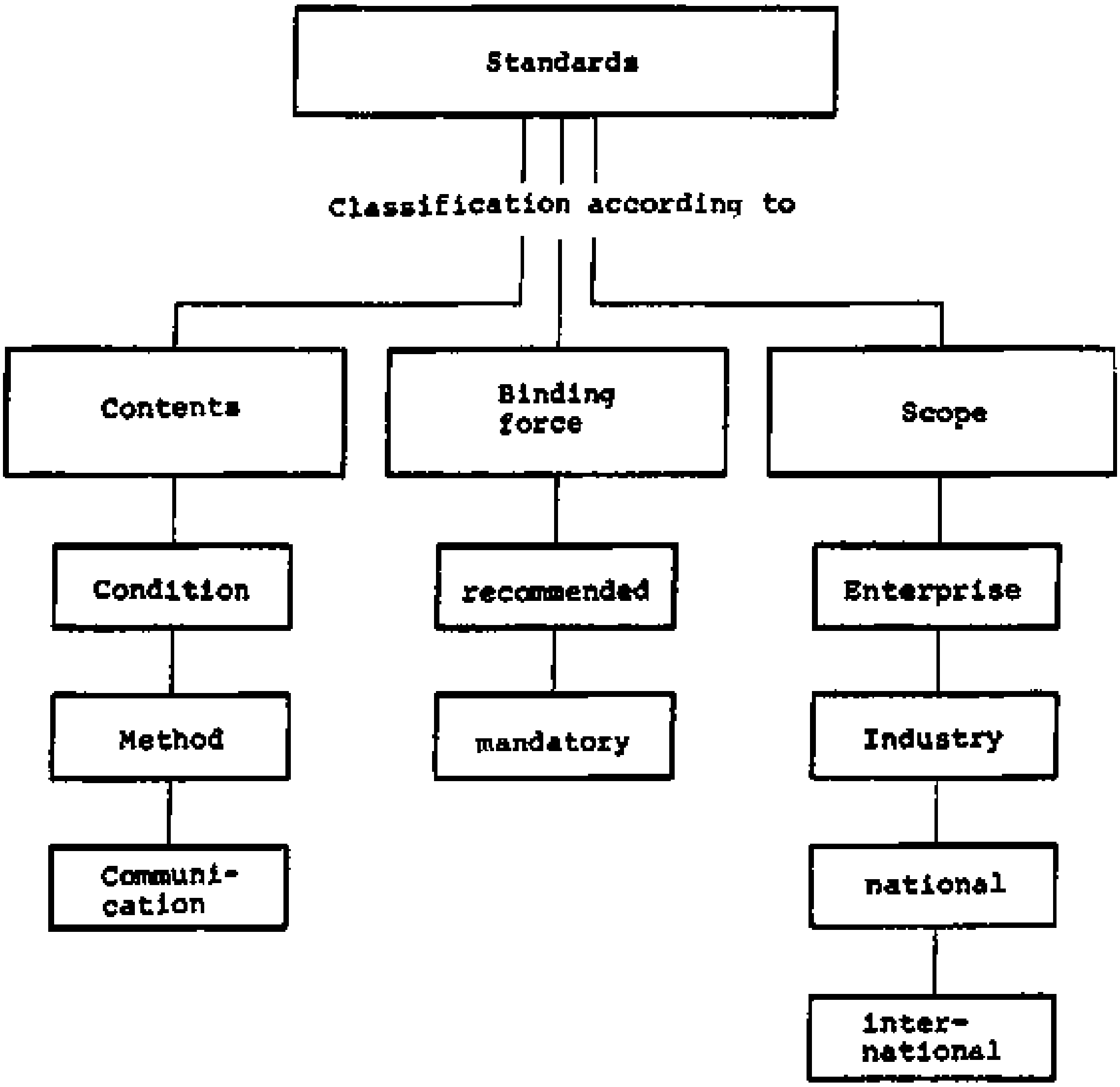


Fig. 1.3. Classification of standards

Condition standards are concerned with dimension, material specifications, surfaces of a product.

Methods standards standardise, for example, manufacturing and testing procedures and storage specification for a product.

Communication standards are prepared in order to standardise, for example, terms and symbols. Symbols play an important part because they facilitate communication on an international level in a much better way than verbal statements. The development of international standards, especially for engineering drawing, is on the increase. For the CMEA–states (CMEA = Council for Mutual Economic Aid), the "Uniform System of Design Documentation" has been created which has supported the socialist economic integration with particular respect to a rationalisation of the preparation, keeping and reproduction of design documents. Standards valid so far have been and will be checked and revised and, provided with comprehensive explanations, introduced into the economies of several countries according to a new systematic representation.

1.2. Types of Drawings

The great number of existing and the continuously increasing number of engineering drawings call for a consistent grouping and coordination of them. The term "engineering drawing" today has become a collective name under which various types of engineering drawings should be subsumed according to agreed criteria. Fig. 1.4. shows a compilation of the usual distinctive features.

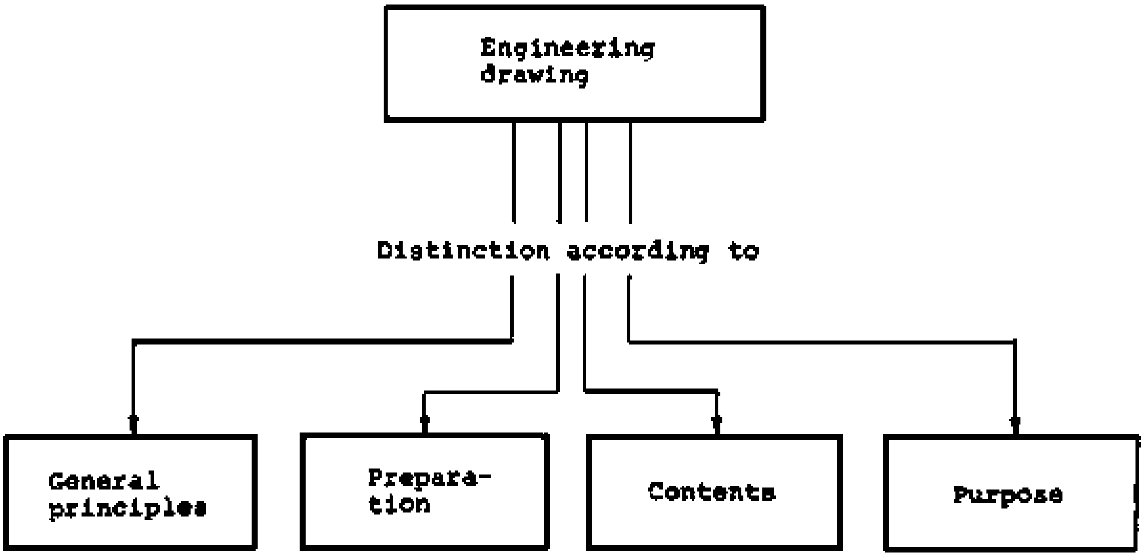


Fig. 1.4. Distinctive features of engineering drawings

1.2.1. Distinction according to General Principles

The sketch

Frequently, sketches are necessary for the preparation of a drawing. In a sketch, first considerations about shape, dimension or function of a technical object are laid down. Further, sketches are a suitable form to give explanations related to the overall drawing so that sketching may be necessary after the drawing. It is also possible to use a sketch as an "aid to memory" in order to acquire technical interrelations and shapes or dimensions as information so that this can be used later (see also Fig. 1.5).

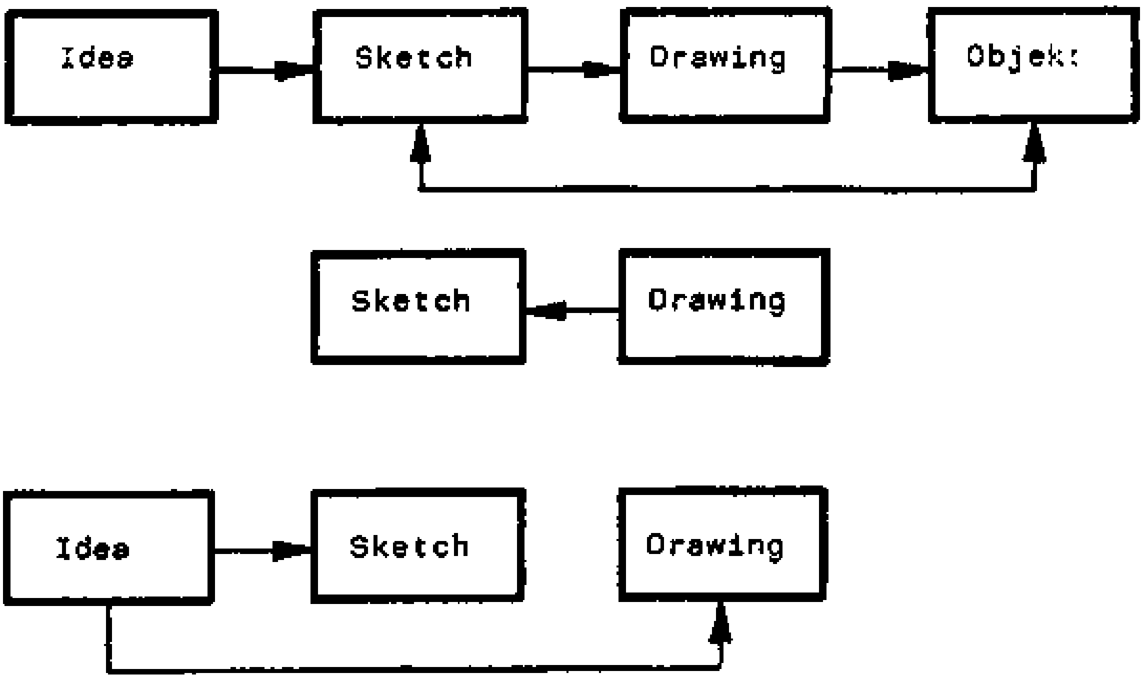


Fig. 1.5. Importance of the sketch

– Usually, a sketch is prepared offhand.

– In sketching, specified basic standards and ratios of size or proportions must be observed although the sketch need not be drawn to scale.

– To facilitate sketching, frequently chequered drawing paper is used.

The drawing

The drawing is the representation of an object (workpiece, tool, plant, building, component layout, etc.) true to scale. Its preparation calls for comprehensive knowledge of the relevant standards and their use and for a developed imaginative faculty enabling the designer to picture a technical object which always has three dimensions (length, width, thickness) but will be represented in two dimensions only.

− A drawing is prepared with the help of drawing equipment (e.g. straight edge, compass, curve).

− For the proportions, a scale must be specified.

− The drawing must conform to accepted standards.

The plan

Plans as generally differentiated from engineering drawings are representations which specify the position of objects or their function. Here are three examples:

− The track plan as a survey of a railway trackage (see Fig. 1.6).

− They layout plan or site plan showing the arrangement of machines in a hall (see Fig. 1.7).

− The plan of a network of pipes giving a survey of installed pipe lines (see Fig. 1.8).

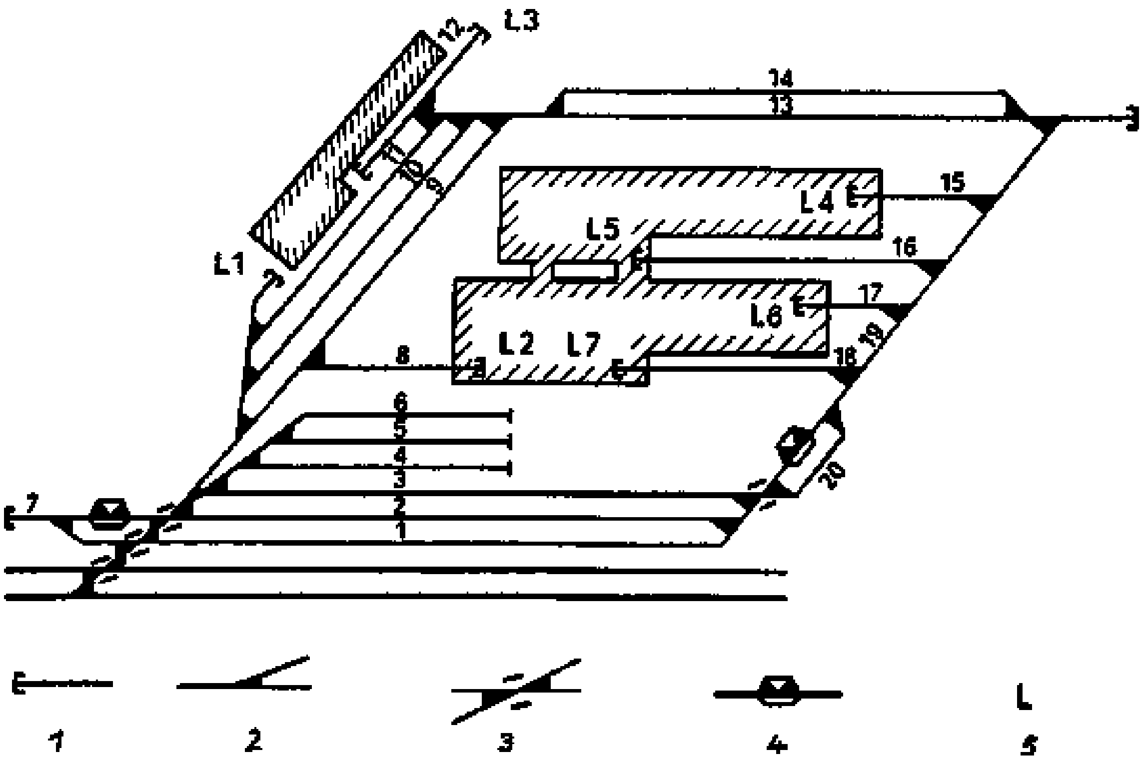


Fig. 1.6. Track plan

1 Bumping post, 2 Simple switch, 3 Double−slip points, 4 Railway balance, 5 Loading station

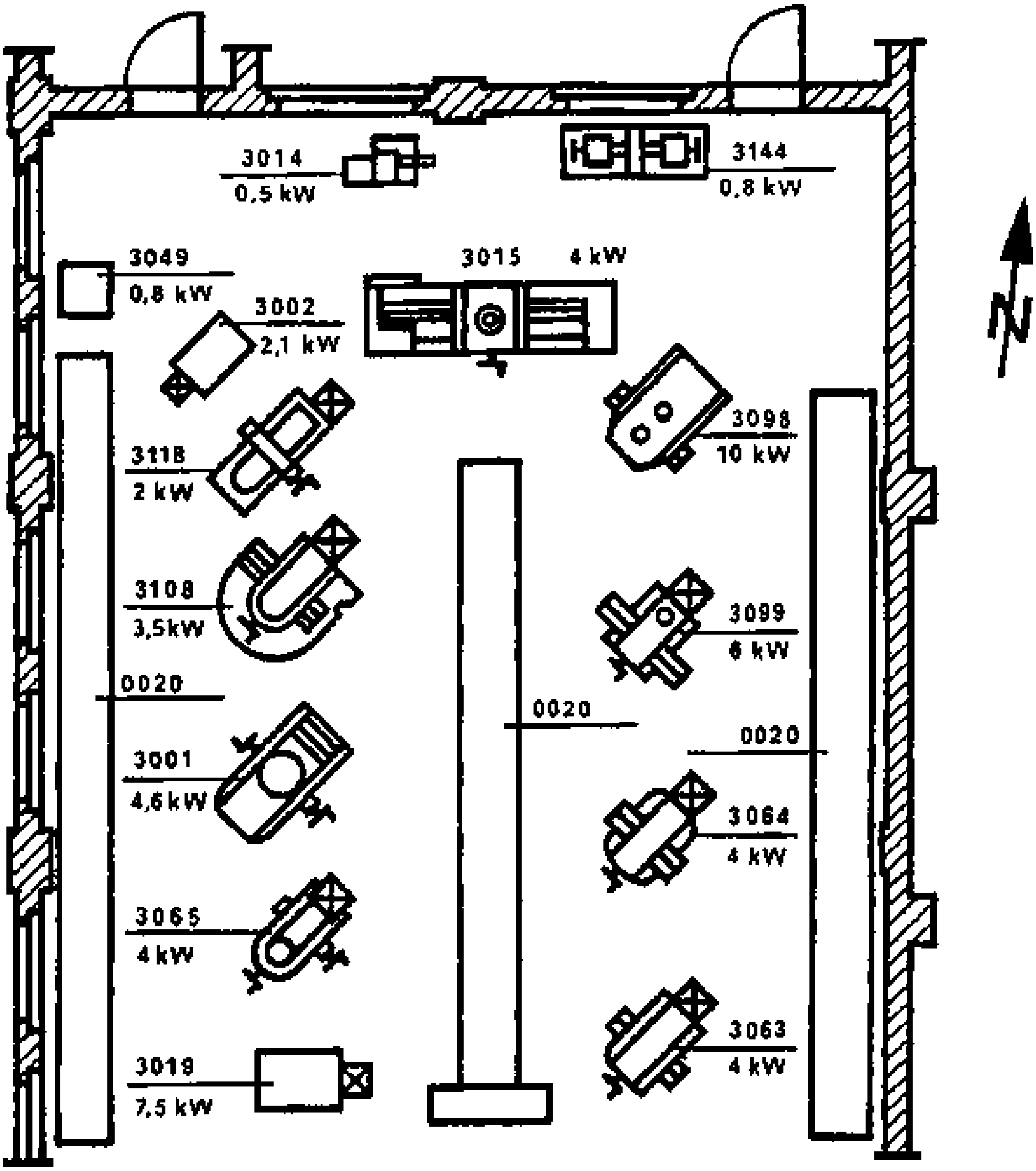


Fig. 1.7. Layout plan

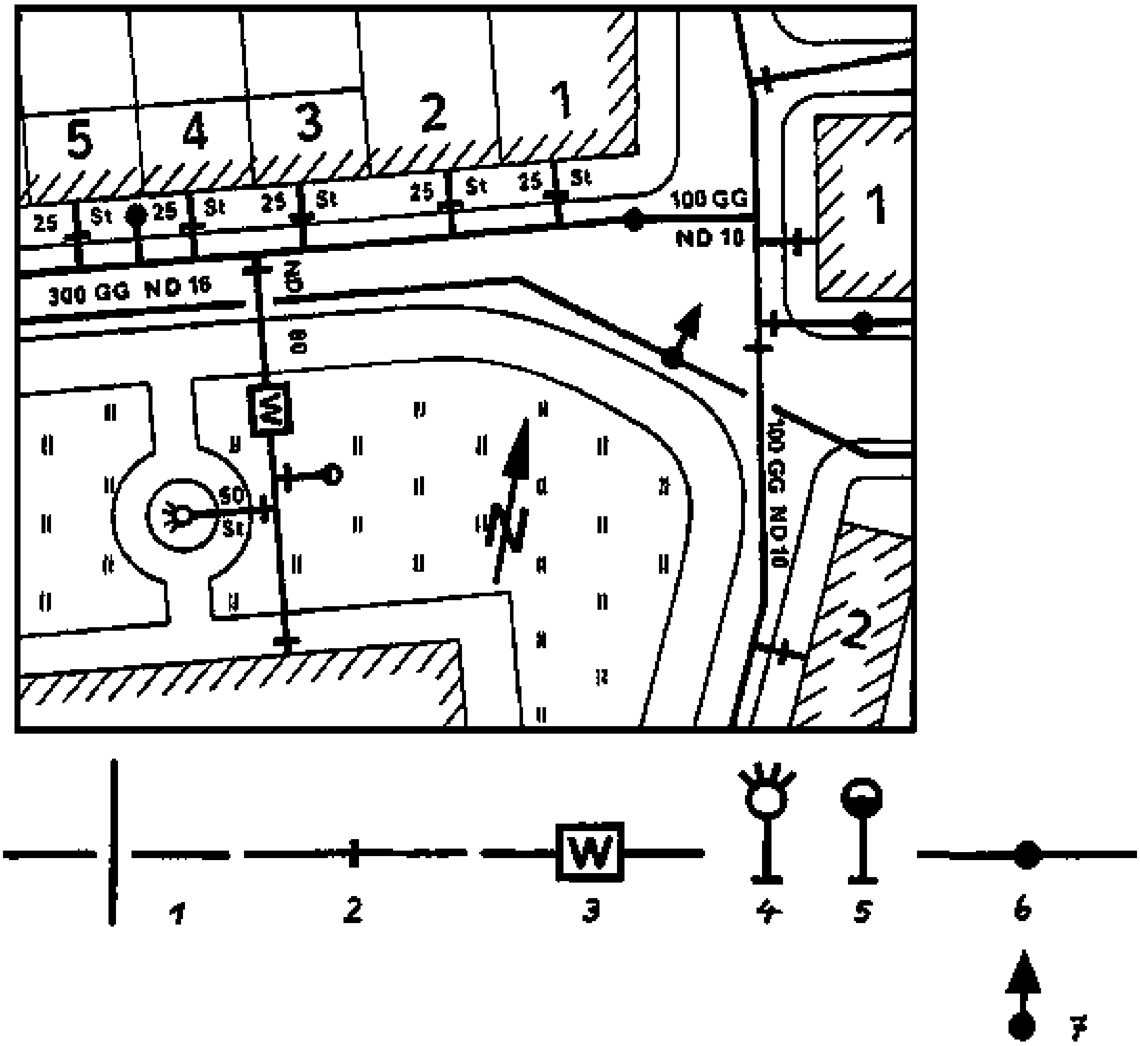


Fig. 1.8. Plan of a network of pipes

1 Crossing of lines, 2 Shut−off valve, 3 Water counter equipment, 4 Fountain, 5 Garden hydrant, 6 Underground hydrant 7 Overground hydrant

1.2.2. Distinction according to the Preparation

When a drawing or sketch is made for the first time, then it is an original. For the preparation, a lead pencil, fibre pencil or ink can be used. Originals are kept particularly carefully and are subjected to certain safety regulations. In most cases, in practice the original is not used but a copy. The reproduction of copies is effected either according to the heliographic printing process or the photographic process.

Copies can also be produced by printing.

The most widely known method of reproducing engineering drawings is the heliographic printing process. In this process, the original drawing, which must be on transparent paper, is placed on light−sensitive tracing paper and exposed to a light source of high intensity. The light destroys the light−sensitive film while the outlines, lines and signs which were drawn on the original remain. In a dry process, ammonia vapours, to which the exposed tracing is subjected, are instrumental in developing and copying.

Besides the heliographic printing process, photographing should be mentioned which gains in importance especially in association with technical modeling. The xerographic process, in which opaque paper can be used for the original, is subsumed under the heading of the photographic process. Examples of the conventional printing process are the stencil printing, the small offset printing and the embossed printing processes which will not be explained in detail here. Fig. 1.9 gives a survey of the reproduction of originals of drawings differentiated according to the kind of process of reproduction used.

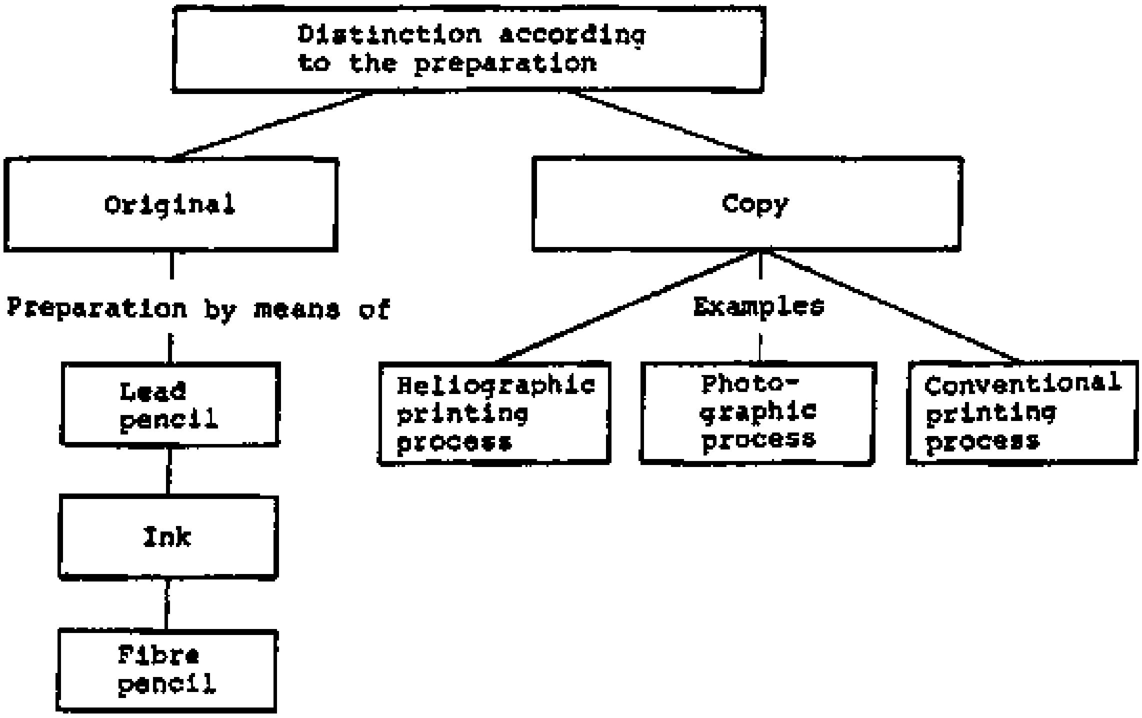


Fig. 1.9. Original drawing and copy

1.2.3. Distinction according to the Content

An overall drawing is given when a machine, a plant, a device or a structure is represented in the assembled state. This definition also includes representations of complete processes and plans.

It is common practice to number the overall drawings with consecutive numbers which are also allotted to the individual components or objects (see also Fig. 1.19.2).

A group drawing is defined as a representation of a sub−assembly or a main component which is part of finished product and which is composed of two or more parts. The group drawing contains details of assembling and of the type of connection between the individual parts.

Individual parts are represented in a detail drawing. This form of a drawing contains data of size and shape and gives information about working and machining. It is the basis of the manufacture and checking of the technical object to be made and, therefore, must be concise and subject to but one. Interpretation. The dimensions must conform to the sequence of operations in manufacture (see Fig. 1.19.3).

Sometimes it is necessary to prepare a representation of the interaction of individual elements which is defined as a schematic representation. In this representation, the individual parts are shown in a simplified (schematic) form. It includes, for example, gearing layouts and plans for the characterisation of a power flow.

1.2.4. Distinction according to the Purpose

The intended use determines the type, the contents and the preparation of an engineering drawing. A distinction is made between:

– Draft drawings and design drawings which are required for the preparation of production, for calculating and as a basis for planning.

– Manufacturing drawings as a basis for the production of a product.

– Operating instructions, maintenance and repair plans which facilitate the proper use, care and repair of technical objects.

If the drawing is intended for explanations for the user, particularly vivid and clear illustrations have to be presented.

Further examples are order drawings (for explanations regarding the order, for inquiries and complaints), approval, foundation, packing, forwarding and revision drawings. The latter must be provided with the dimensions important for revision (acceptance). These examples do not constitute the full list of drawings.

<u>Repetition</u>

1. What is the special importance of an engineering drawing?

2. Explain the term “standard”.

3. Determine the difference between condition standards, methods standards and communication standards.

4. What is the difference between a drawing and a sketch?

5. Declare the possibilities for reproducing originals.

1.3. The Drawing Sheet

1.3.1. Sheet Sizes

The sheet sizes to be used in engineering drawing are determined by the standards for format series. A distinction is made between:

Format series A	– e.g. for drawing sheets, post cards, filing cards, exercise–books
Format series B and C	– e.g. filing cards, envelopes, folders, packing cardboard

The following explanations concern the format series A. The size of the initial format for drawing sheets is 841 mm × 1189 mm and is designated by A0. The format has an area of 1 m^2. The next smaller sheet size (A1) is obtained by dividing into halves of the initial format so that the basic formats A1, A2, A3, A4 and A5 are brought about (see Fig. 1.10).

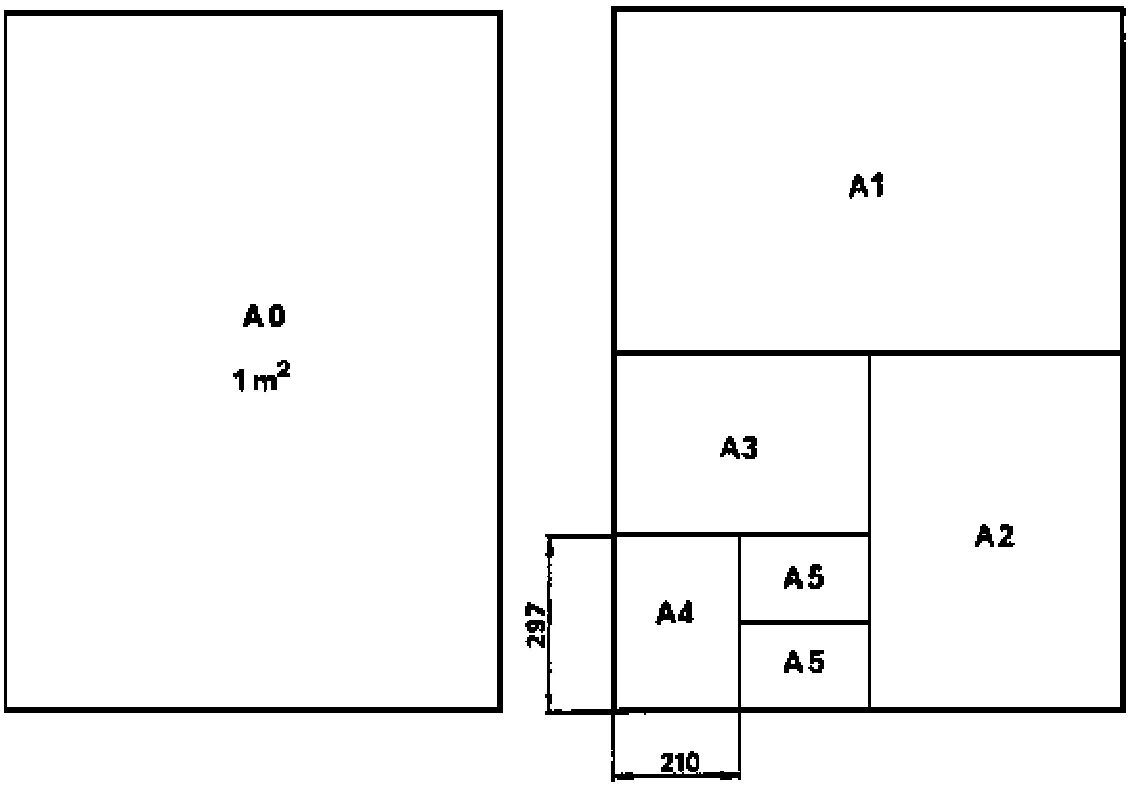


Fig. 1.10. Basic formats

The format sizes obtained in this way can be designated by the symbol (A0 – A5) or by a 2–digit, 3–digit or 4–digit number. The short designation of the format by numbers is shown in Fig. 1.11 in the right upper corner.

Thus the size of the formats

1.10 (spoken one – ten)	is 297 mm × 2102 mm
75 (spoken seventy–five)	is 2081 mm × 1051 mm
12 (spoken twelve)	is 297 mm × 420 mm

If one of the two numbers is 9, then it must be separated from the second number by a point.

The numbers selected for the individual formats are in the following relation:

The starting format is always A4 with the

vertical value	297 mm = 1 unit (factor 1) and the
horizontal value	210 mm = 1 unit (factor 1)

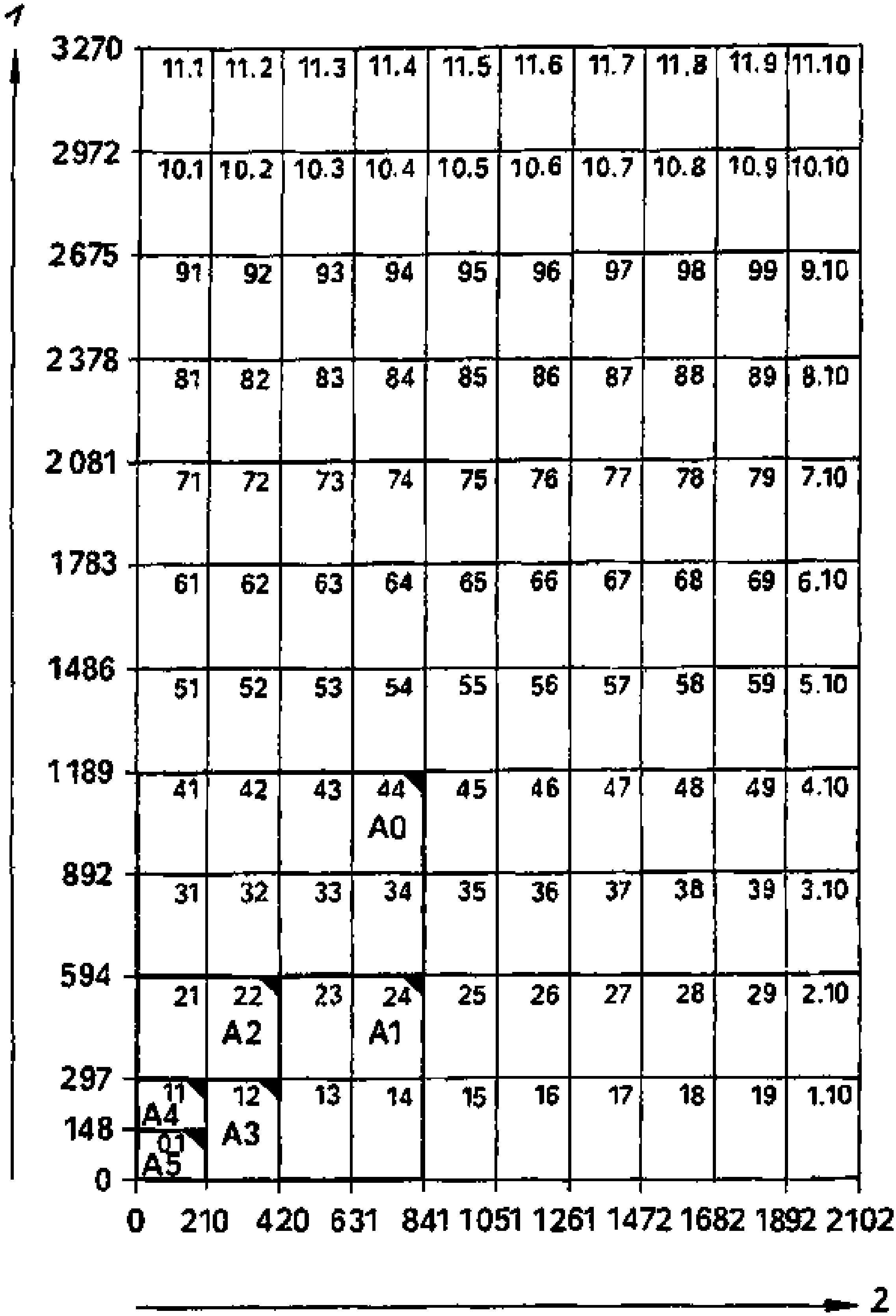


Fig. 1.11. Short designations of formats

1 Vertical values in mm
2 Horizontal values in mm
3 Main formats in mm
4 Symbol
5 Format

3	4

5		
44	1189 × 841	A 0
24	594 × 841	A 1
22	594 × 420	A 2
12	297 × 420	A 3
11	297 × 210	A 4
01	148 × 210	A 5

The first number of the short designation indicates the factor of the multiple of the vertical value (297 mm).

The second number of the short designation indicates the factor of the multiple of the horizontal value (210 mm) (see Fig. 1.12).

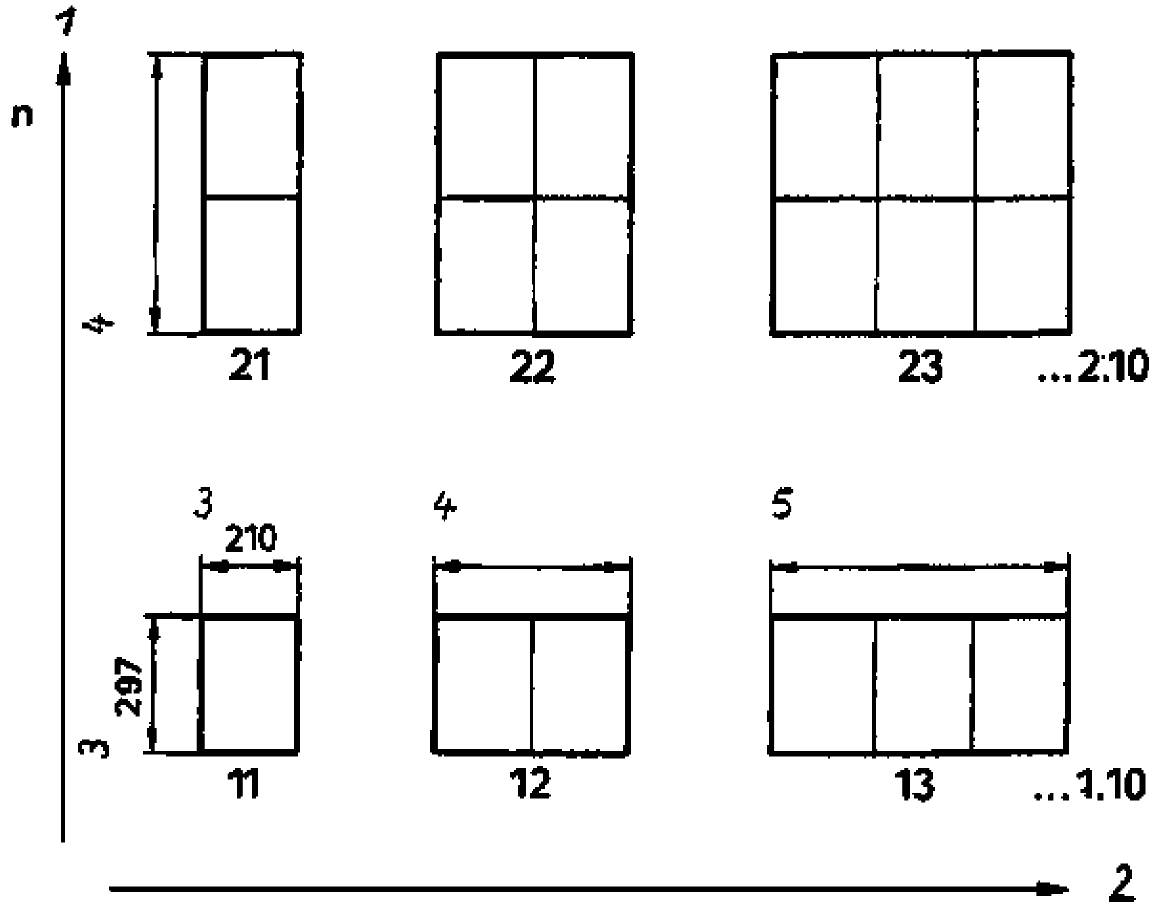


Fig. 1.12 Rule of format formation

1 Vertical value
2 Horizontal value
3 One unit
4 Two units,
5 Three units

Due to the designation of the format size with the help of numbers it is possible to mark sizes which deviate from the main formats (A0 – A5). For example, this may be necessary for the representation of towers and bridges where the vertical or horizontal extension must be considerably larger than the second dimension involved.

1.3.2. Division and Position of the Sheet

The division of a drawing sheet of size A4 (11) is shown in Fig. 1.13. Thus any drawing sheet is provided with

– one filing margin	(with A4 = 20 mm)
– three protective margins	(with A4 = each 5 mm)
– one title block	(185 × 25 mm)

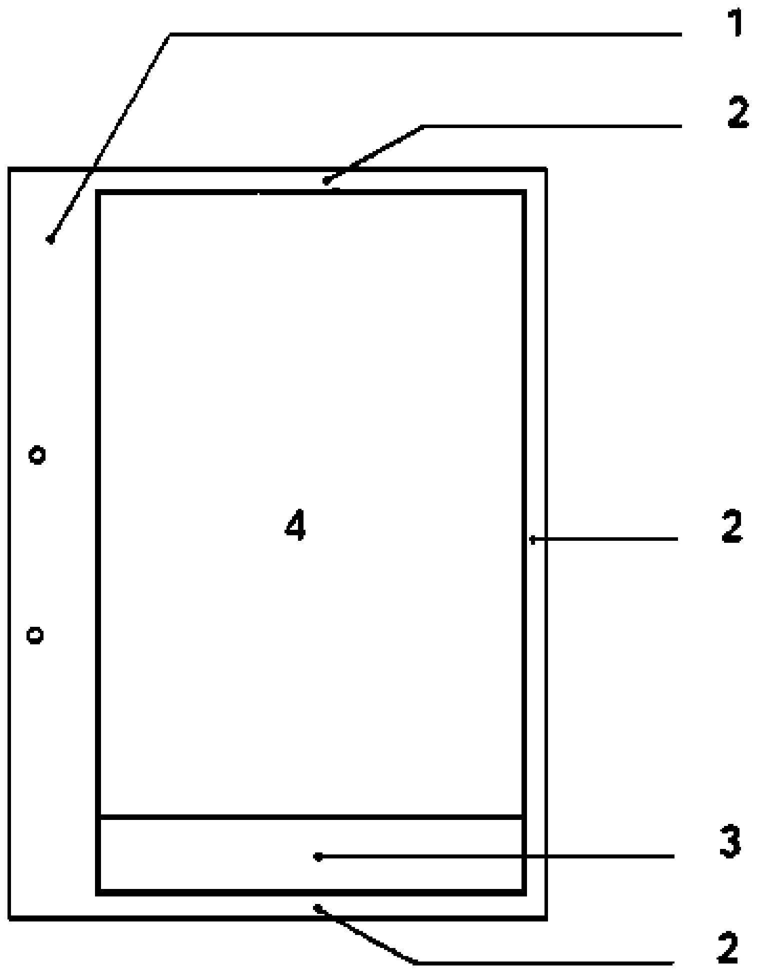


Fig. 1.13. Division of the sheet

1 Filing margin
2 Protective margin
3 Title block
4 Drawing area

The remaining area is the drawing area.

The possible position of the sheet of the main formats is shown in Fig. 1.14.

Fig. 1.14. Position of the sheet (possibilities)

Abbreviated designations or symbols of the main formats	**Arrangement**

		Upright size	Broad–size
A0	44	———	•
A1	24	•	•
A2	22	•	•
A3	12	•	•
A4	11	•	———

The format A4 mostly used in schools is mainly of the upright size. If the broadside is exceptionally required, then the filing margin is on top. The position of the title block is not changed. Depending on the position of the sheet, the readability of the dimensional numbers must be taken into consideration (see Fig. 1.15.).

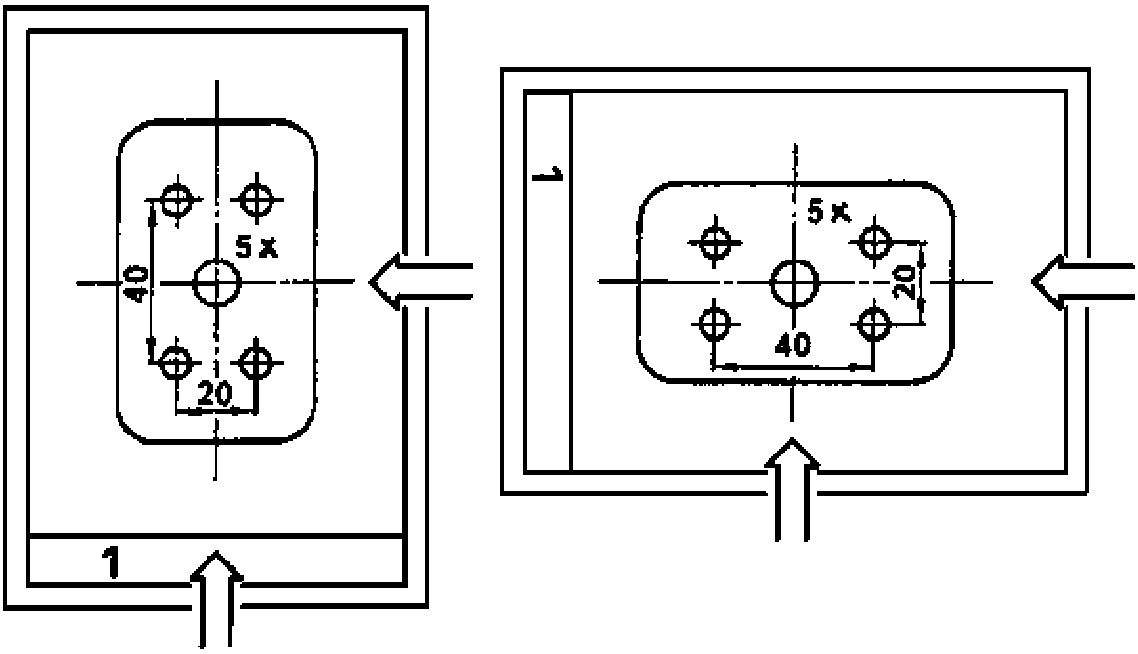


Fig. 1.15. Position of the sheet (readability)

1 Title block, × 5 thick

1.3.3. Title Block and List of Parts

Any engineering drawing contains a title block (see Fig. 1.16.).

The title block provides space for

– the designation of the represented object,
– the scale selected,
– the enterprise (or educational institution) where the drawing has been prepared
– the day when it has been finished
– the date of testing
– the registration number.

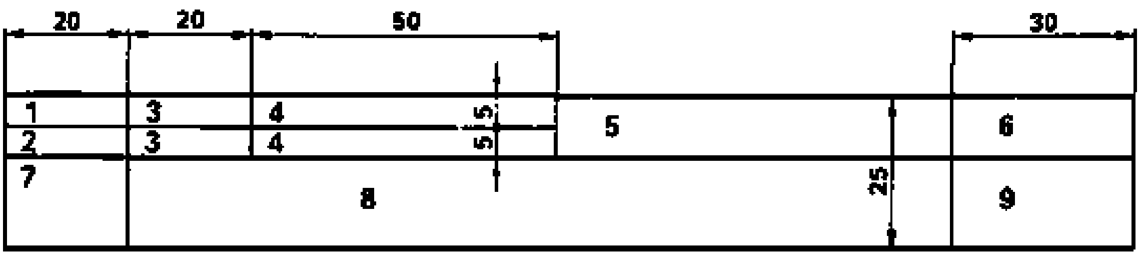


Fig. 1.16. Title block, simplified for drawings

1 Drawn by: 2 Approved by: 3 Date, 4 Name, 5 Name of the institution or enterprise, 6 Form, course, workshop etc., 7 Scale, 8 Description, 9 Sheet number

All data entered (excluding the signature of the draughtsman and testers) have to be made in standard lettering.

A simplified title block for sketches is shown in Fig. 1.17. (for use in schools).

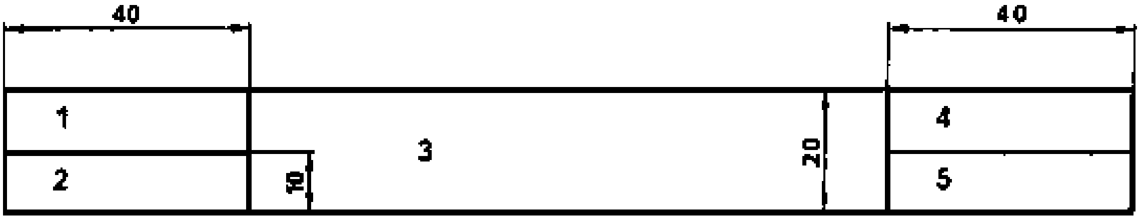


Fig. 1.17. Title block, simplified for sketches

1 Name, 2 Date, 3 Description, 4 Form, course, workshop etc., 5 Sheet number

The complete title block used for drawings in factories is shown in Fig. 1.18.

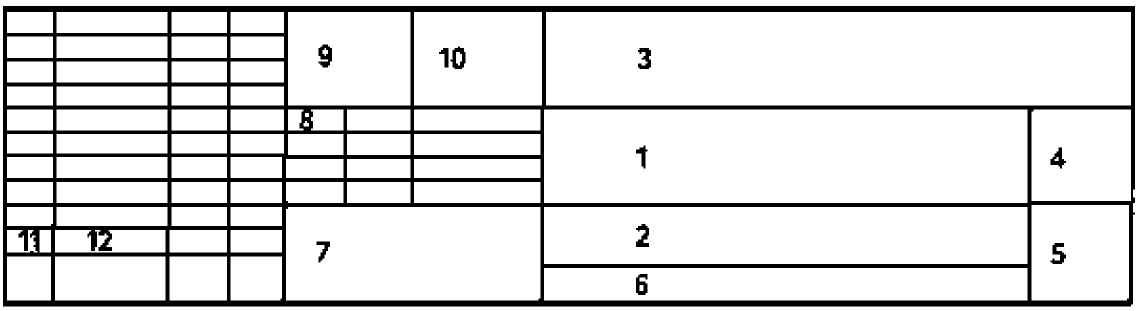


Fig. 1.18. Title block, complete for manufacturing the product

1 Description, 2 Drawing number, 3 Semi−finished products/Material, 4 Scale, 5 Registration No., 6 Substitute, 7 Enterprise, Institution, 8 Drawn by/Checked by/Standard/ Date/Name, 9 Tolerances, 10 Weight or other data 11 Amendment letters, 12 Number of amendment information, 13 Date, 14 Name

To facilitate the preparation of engineering drawings, drawing sheets (cardboard and transparent paper) are used where the title block is printed on.

The list of parts contains all individual parts and standard components required for the manufacture of a product or an assembly. The list of parts is arranged above the title block or is attached as a supplement when the number of parts is large. In this case, the parts are entered from top to bottom otherwise from bottom to top as is shown in Fig. 1.19.c Standard components which are not shown in the drawing (such as screws, washers, springs, rivets and the like) are also entered into the list of parts. In the column “dimensions” (also “raw dimensions”) references are given to DIN−sheets (German industrial standard sheets) which give details of these parts.

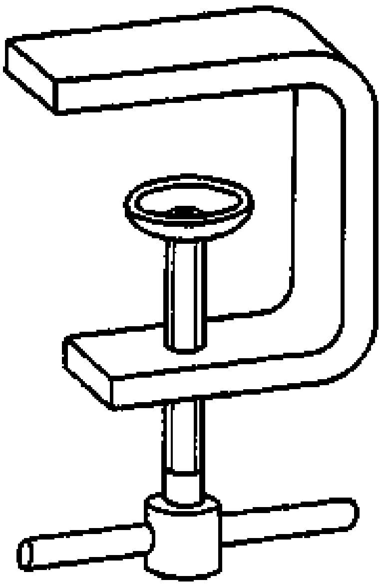


Fig. 1.19.a. Screw clamp, perspective representation

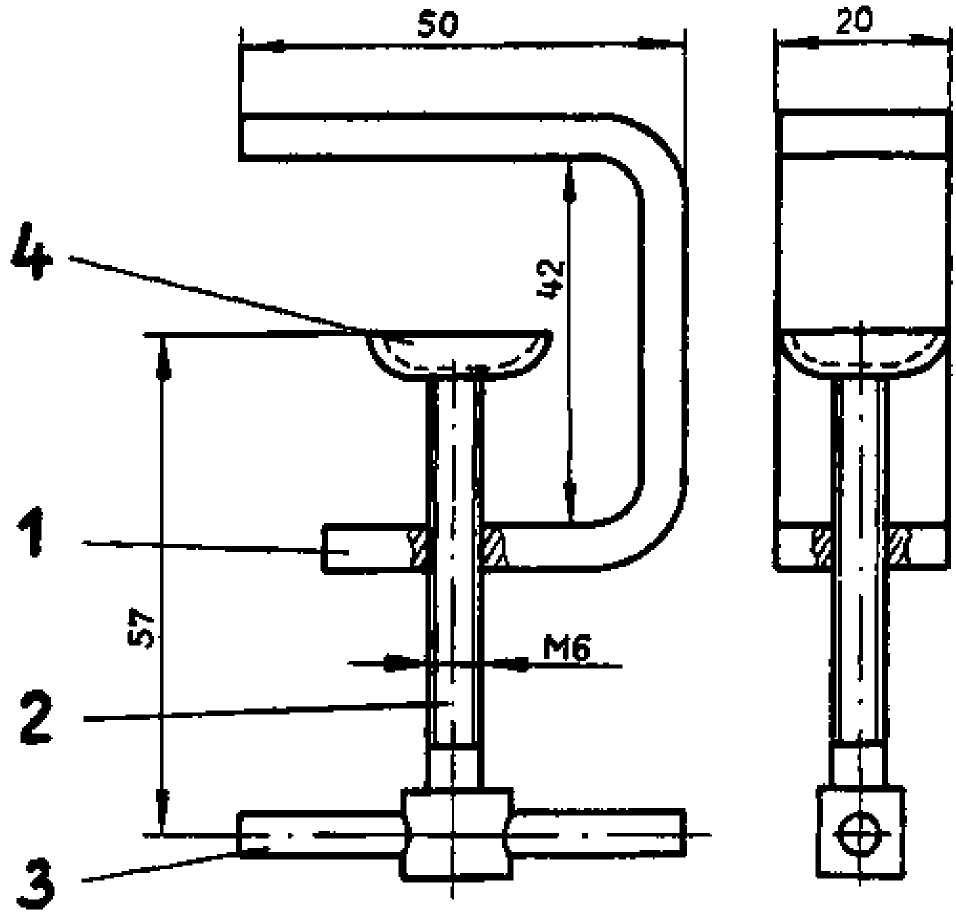
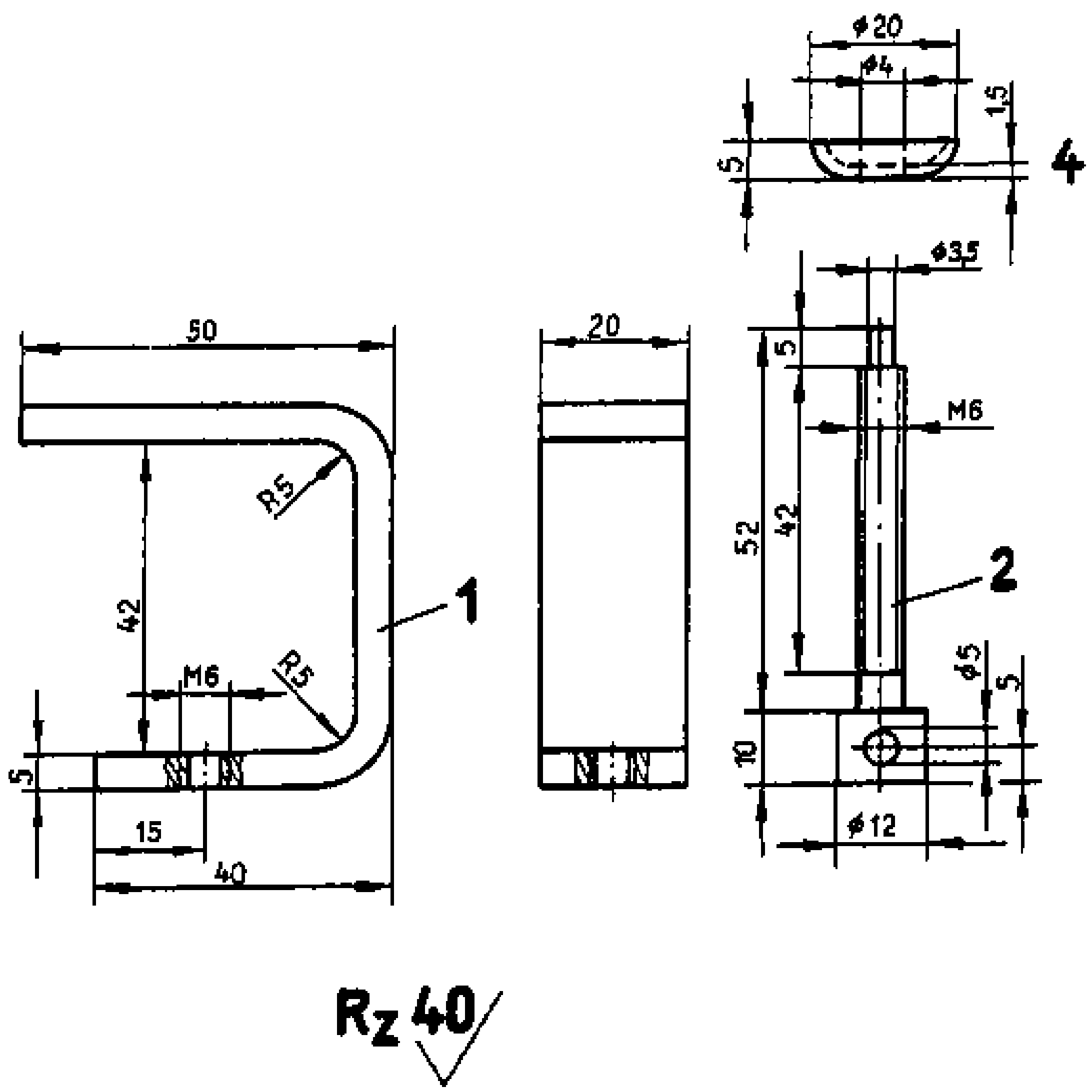


Fig. 1.19.b. Screw clamp, overall drawing

1 Bow
2 Threaded bolt
3 Fulcrum pin
4 Washer



A

1		4		
1		3		
1		2		
1		1		
1	2	3	4	5

Fig. 1.19.c. Screw clamp, detail drawing

1 Quantity, 2 Description or designation, 3 Part, 4 Material, 5 Dimensions

A	1 Washer	4 St 38u−2	plate 1.5 ×	22
	1 Fulcrum pin	3 St 38u−2	A5 DIN 900	
	1 Threaded bolt	2 St 38u−2	Rd 12 × 62	
	1 Bow	1 St 38u−2	F1 20 × 5 × 146	

Repetition

1. Tell possibilities of designating drawing formats.

2. Explain the format designation 24 and give the appropriate symbol.

3. What are the data which must be contained in a title block?

4. When is the preparation of a list of parts necessary?

1.4. Lettering of Drawings

1.4.1. The Inclined Letters

The necessary communication between draughtsman, manufacturer and user requires a uniform lettering. For this purpose, two styles of letters are available, the vertical letters and the inclined letters; the letter must be written at an angle of 75°. For the lettering of drawings in the course of the vocational training of expert workers, the inclined letters are recommended. The forms of letters for the alphabet and for the numbers are shown in Fig. 1.20.

Starting size for the size of letters is the nominal height (h). It depends on the selected format of the drawing sheet and determins all of the further dimensions of the individual letters such as height of letters, line spacing, width of strokes of letters (see Fig. 1.21.).

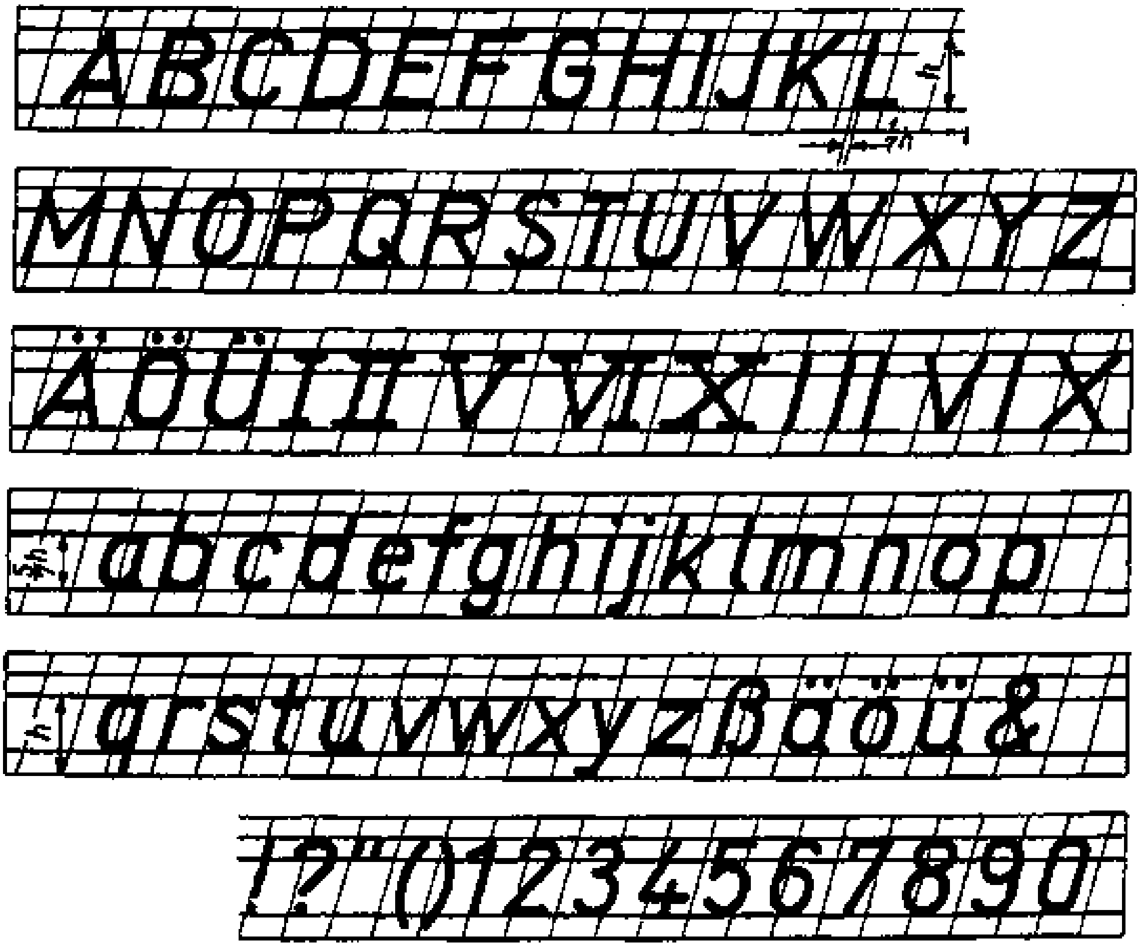


Fig. 1.20. Inclined letters (alphabet)

1	h	3	5	8	10	12	16	20
2		~2,2	~3,6	5,5	7	8,5	11,5	14,5
3		~4,3	~8	12,5	15,5	19	25	31,5
4		~		1		2		3

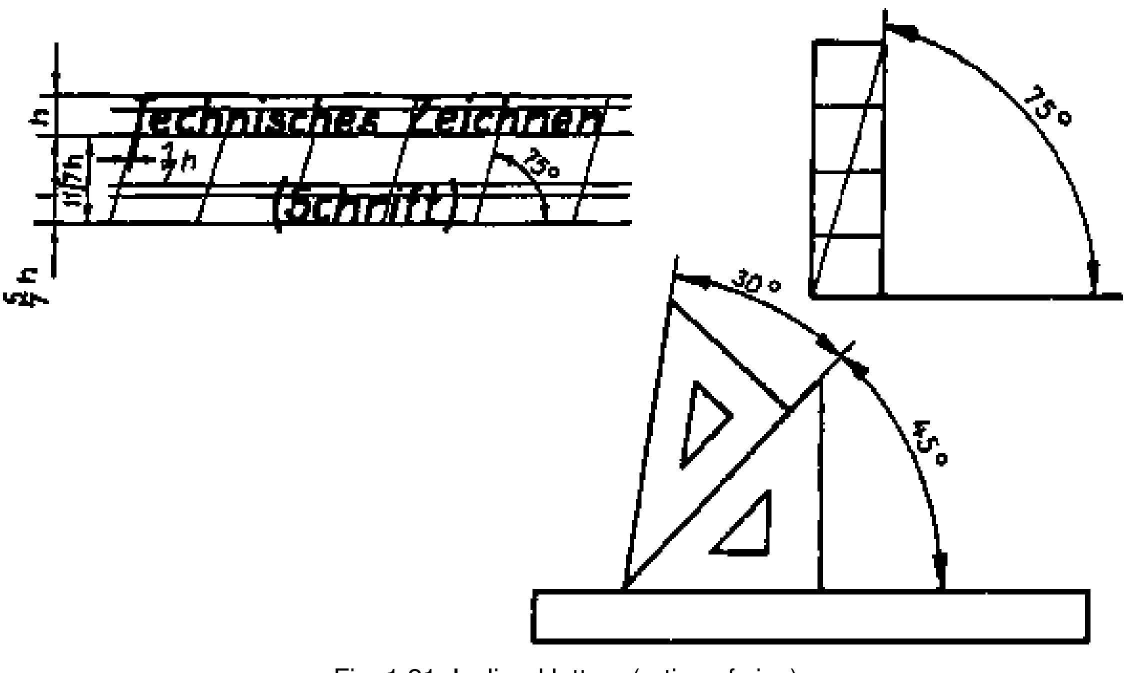


Fig. 1.21. Inclined letters (ratios of size)

1 Height of capital letters
2 Height of lower−case letters
3 Line spacing
4 Width of strokes of letters

The following nominal heights can be selected (dimensions in mm): 2; 3; 4; 5; 6; 8; 10; 12; 16; 20; 25.

When writing the letters, care must be taken that the correct sequence of strokes is applied. The sequence of writing which is most advisable is shown in Fig. 1.22.

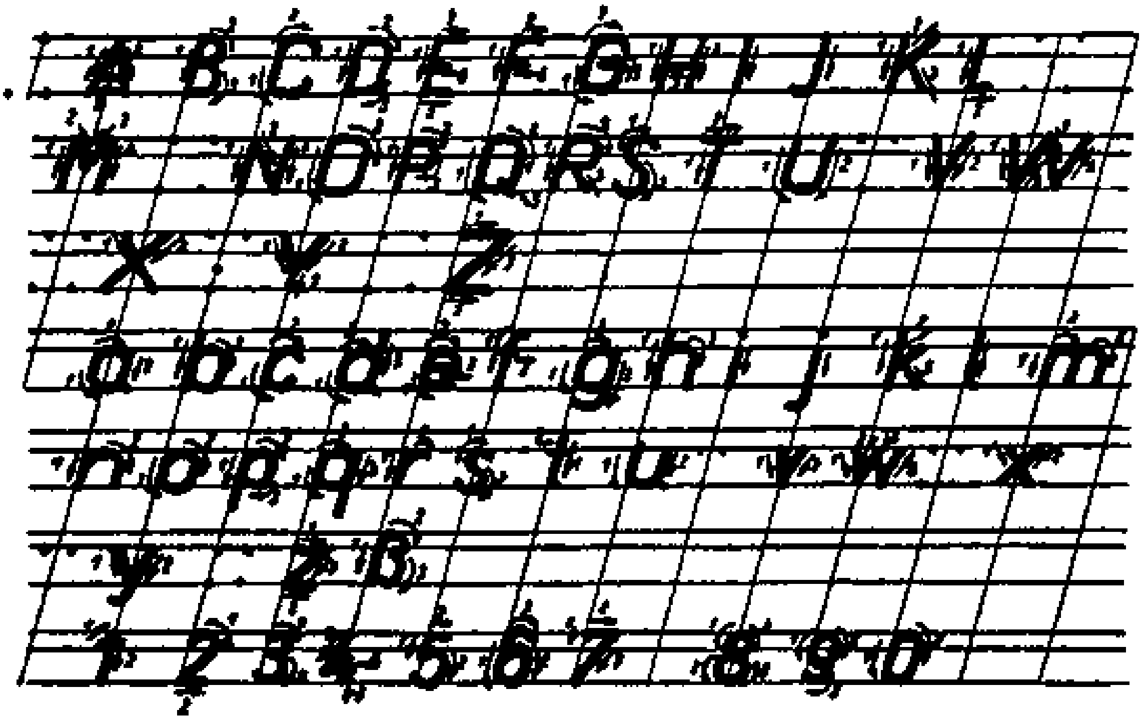


Fig. 1.22. Sequence of writing letters

The learning of the adequate forms of lettering is only possible by consistent practising. It is recommendable to keep the following in mind before starting the practising of lettering:

− The possible nominal heights (h) are specified and obligatory. They apply to all numbers, capital letters and lower−case letters consisting of three parts known as bodies, ascenders and descenders (e.g. h, t, g, p).

− The stroke width of any letter is dependent on the nominal size h and is 1/7 h.

− The height of lower−case letters without ascenders and descenders is 5/7 h (e.g. e, o, u).

− The spacing of letter should be 1/7 h to 2/7 h.

− The letters are written at an angle of 75°.

Practising lettering is to be performed by means of a soft lead pencil. The figs. 1.23. to 1.27. provided for this purpose must be completed in such a manner that each line is filled with maximum 12 letters (see pages 36−40).

F F E E

T T

H H

A A Ä Ä

V V

N N

Z Z

W W

M M

X X

Y Y

K K

Fig. 1.23. Capital letters with straight elements

O

O Q

O Q

C

C

C

G

G

G

D

D

D

P

P

P

R

R

R

B

B

B

U

U Ü

U Ü

S

S

S

ZEIT

ZEIT

SCHNITT

SCHNITT

Fig. 1.24. Capital letters with curves

j

l t

f

r

k

n

h

m

u ü

c e

o ö

a ä

Fig. 1.25. Lower−case letters

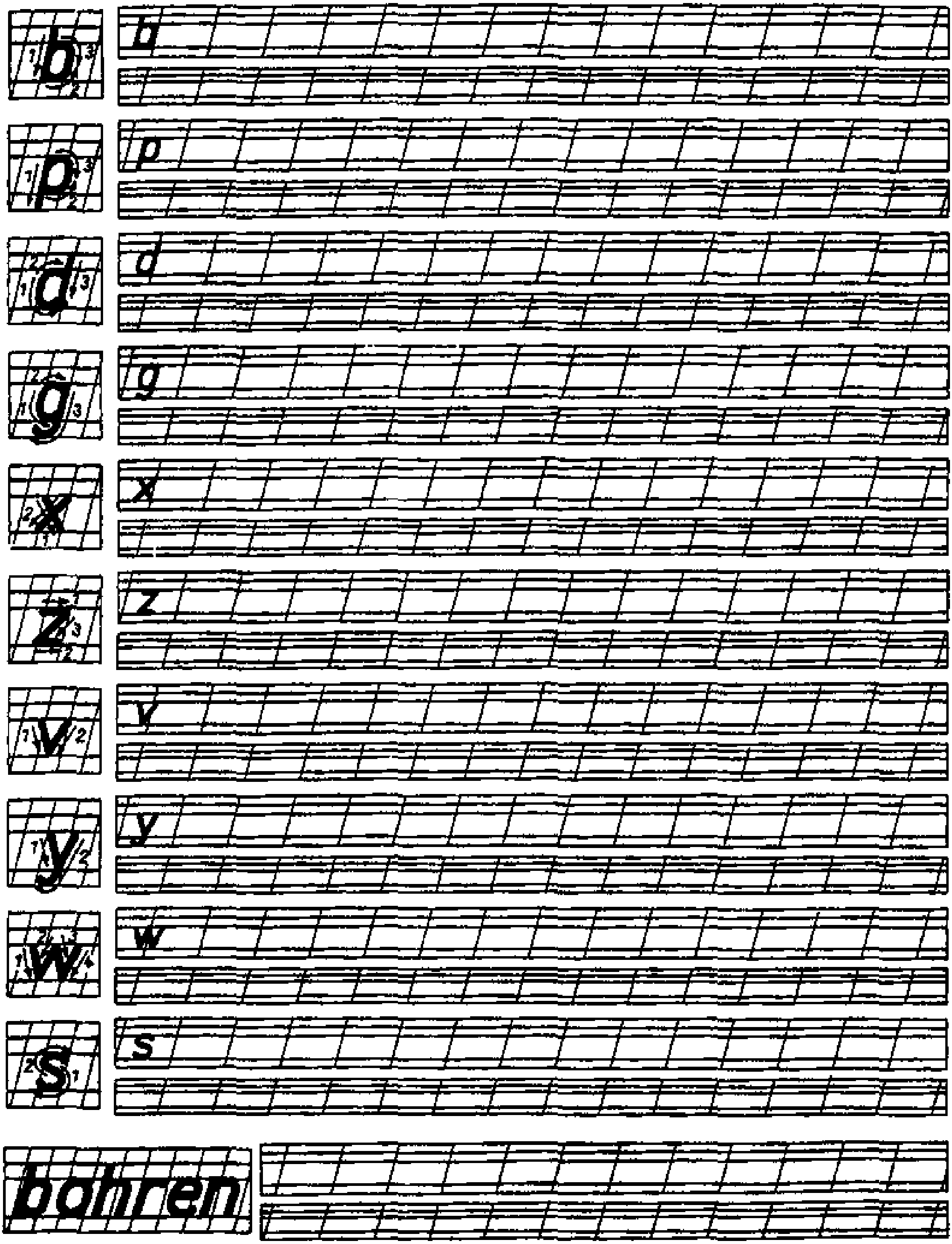


Fig. 1.26. Lower−case letters

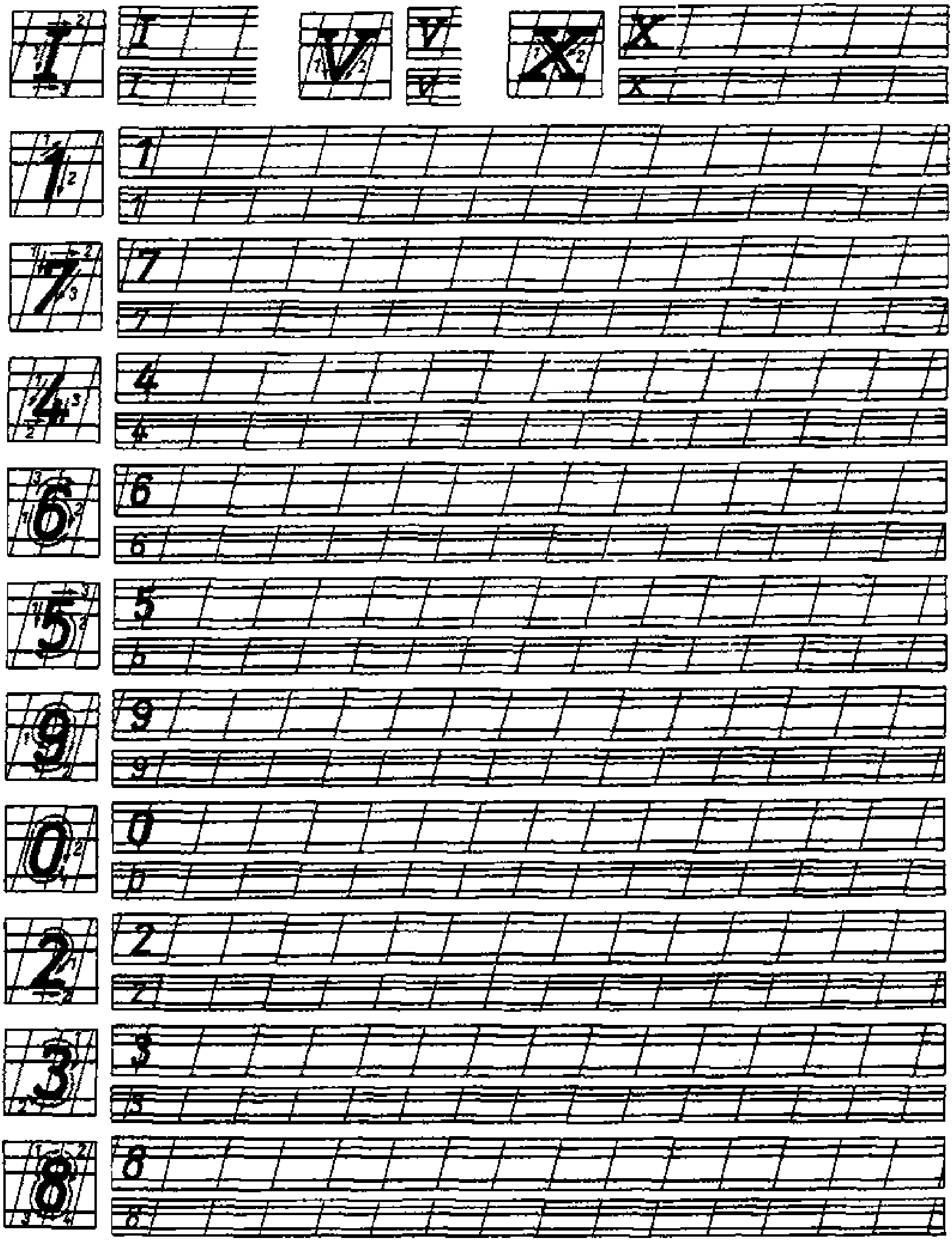


Fig. 1.27. Numerals

Repetition

1. What is the stroke width for writing letters with a nominal night of 10 mm?

2. What determines the nominal height of letters to be selected?

1.4.2. The Vertical Middle Size Lettering

Besides the inclined letter described in full detail, it is possible to select a vertical middle size of lettering. Besides the deviation with respect to the form of a few letters, the following data have to be observed in the use of this style of lettering:

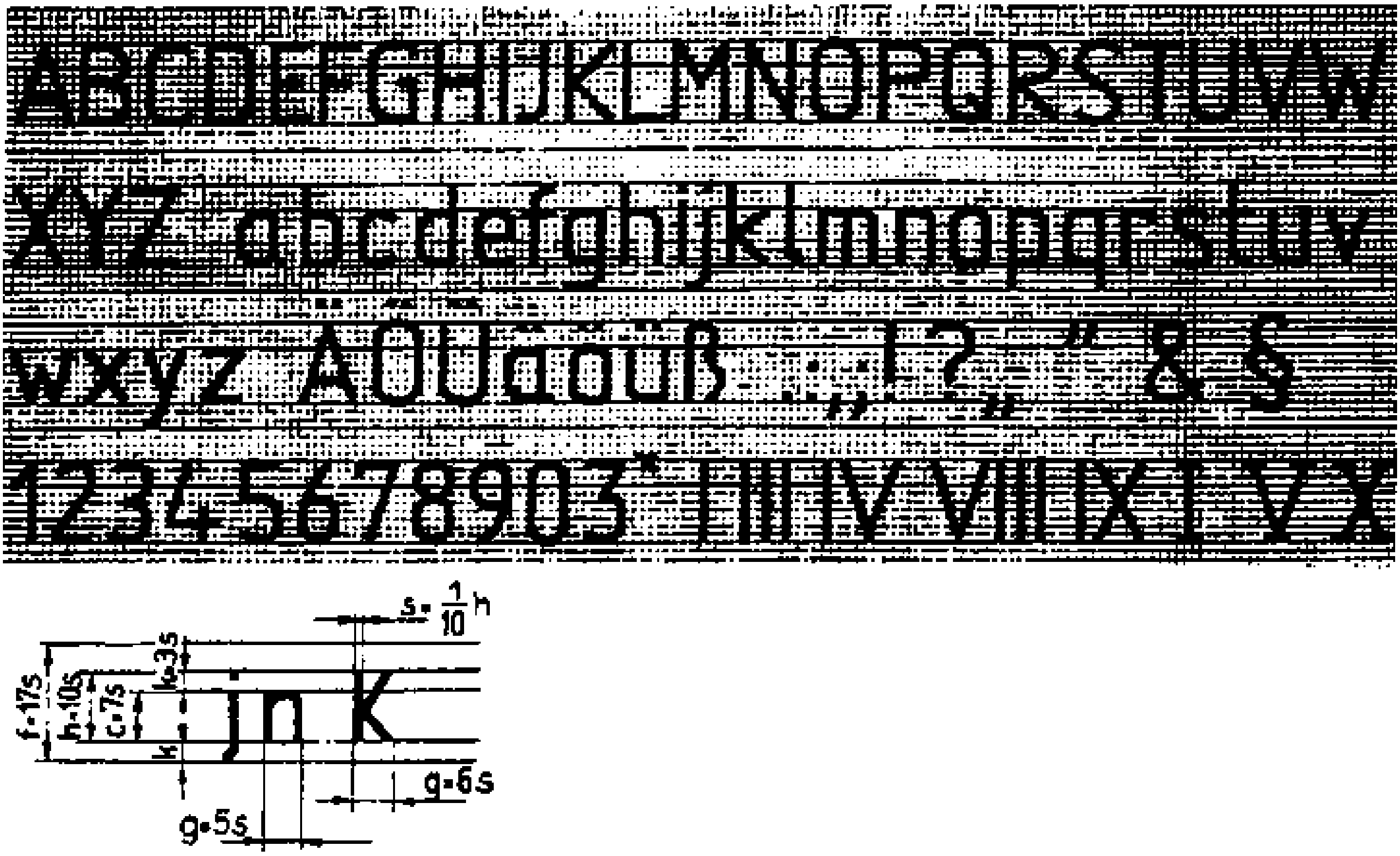


Fig. 1.28. Middle size letters, vertical (alphabet)

h nominal letter height, s stroke width, c height of the lower−case letters, b width of letter

Letter	Term	Size	Explanation
h	nominal height		height measured at right angles to the base line of the lines
s	width of stroke		depending on the nominal height
c	height of the small letters	7 s	is determined by the relationship to the nominal height
b	letter width	5 s	most of the small letters
		6 s	most of the capital letters

1.5. Types of Lines and Groups of Lines

1.5.1. Types of Lines

In engineering drawing, the following types of lines are used:

Designation	Description	Example (see Fig. 1.29.)
Thick solid line	continuous line with a regular form	(1)
Thin solid line	– ditto –	(2)
Dashed line	interrupted line with elements of regular form in repetition	(3)
Dash–and–dot line	interrupted line with different elements repeated	(4)
Free–hand line	continuous line of irregular form	(5)

Figure 1.29. shows the following uses

(1) for visible edges
(2) for dimension lines, extension lines, leaders and sectioning
(3) for invisible edges, phantom lines
(4) for centre lines
(5) for break lines

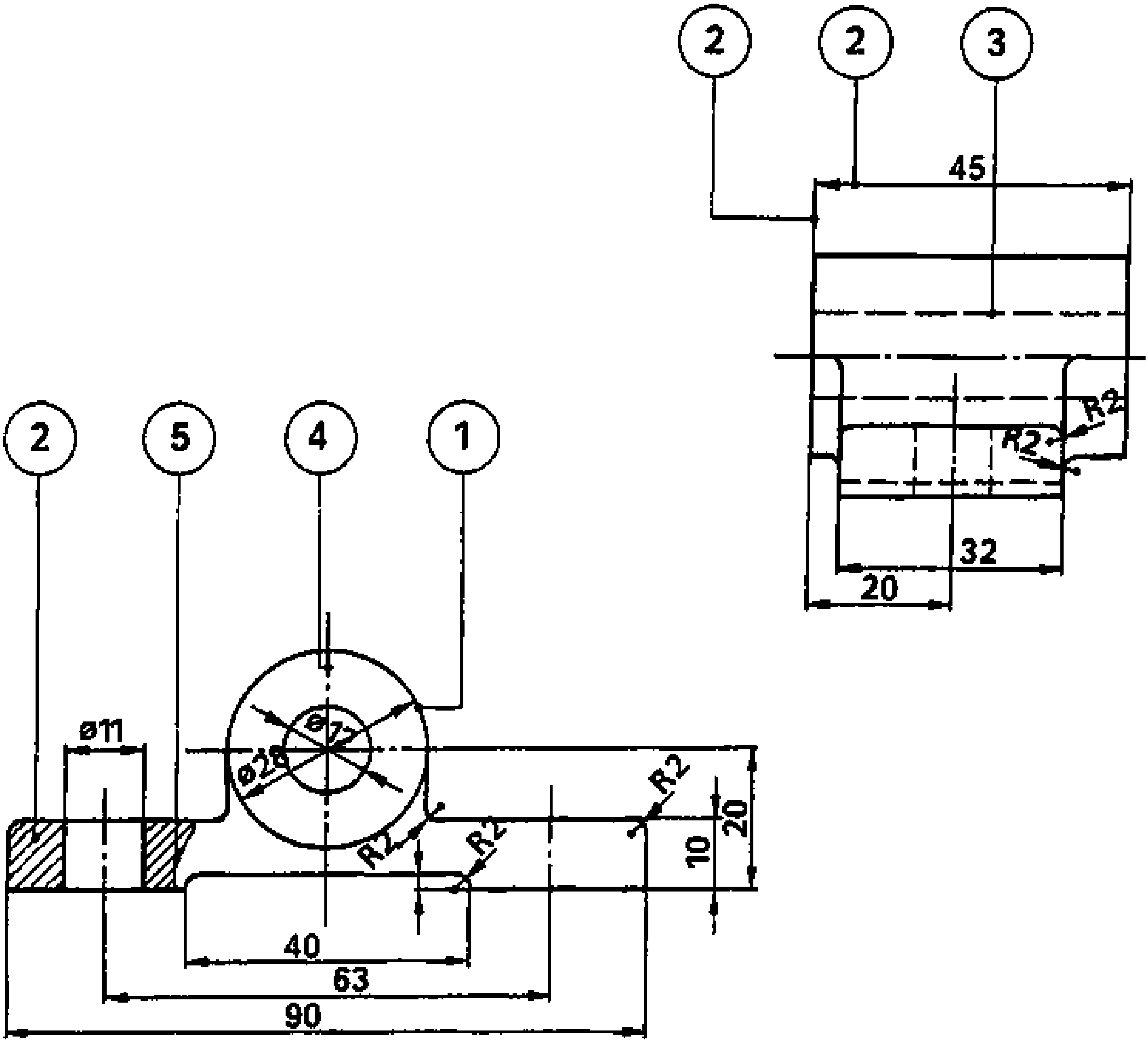


Fig. 1.29. Types of lines

1.5.2. Groups of Lines

Each drawing should contain only line types of one line group. Fig. 1.30. shows the groups of lines that can be selected.

Fig. 1.30. The drawing of lines, groups of lines

Types of lines	How lines have	Groups of lines			
		0,3	**0,5**	**0,8**	**1,2**
Thick solid line		0,3	0,5	0,8	1,2
Thin solid line		0,1	0,2	0,3	0,4
dashed line		0,2	0,3	0,4	0,6
Dash–and–dot line		0,1	0,2	0,3	0,4
Freehand line		0,1	0,2	0,3	0,4

1.5.3. The Drawing of Interrupted Lines

– The length of dashes, the size of dots and the spacings in interrupted lines should be practically uniform.

– The lines must start with a dash and end in a dash (see Fig. 1.31.).

– The lines must cross with dashes (see Fig. 1.32.).

Fig. 1.31. Drawing a line

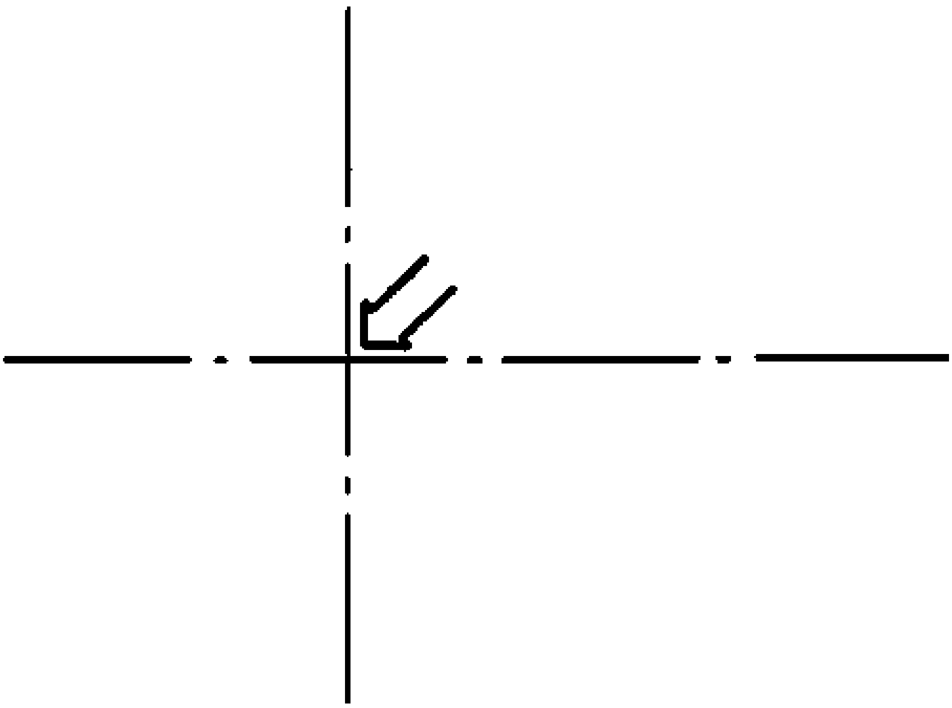


Fig. 1.32. Drawing a line

– The elements of lines of the same type running parallel must be drawn in a staggered manner (see Fig. 1.33.).

– The lines must contact each other with dashes even if curves have to be represented (see Fig. 1.34.).

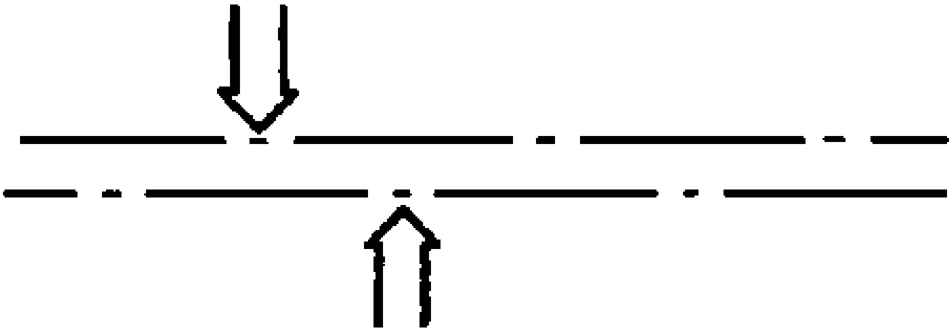


Fig. 1.33. Drawing a line

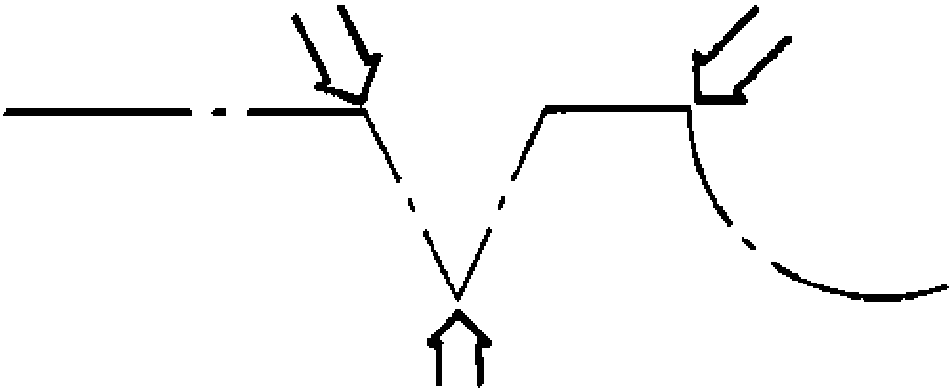


Fig. 1.34. Drawing a line

– Instead of points or dots in a dash–and–dot line, short dashes having a length of up to 3 s (3 × the width of the line).

Repetition

1. Describe the types of lines to be used in engineering drawing.

2. What is the purpose of a dashed line?

3. What is the ratio between the thick and the thin solid line related to the width of lines?

4. Describe the difference between a thin solid line and a free–hand line?

1.6. Scales

A drawing is made so that the object is shown

– in its full or natural size,
– in its reduced size (e.g. vehicles, machines, plants, bridges)
– in its enlarged size (e.g. elements of the optical industry).

Thus, scale is defined as the ratio of a distance in the drawing to the length of the respective distance in its natural size. Hence, the scale of reduction is a scale where the length of a distance in the drawing is smaller than the length of the same distance in its natural size.

The scale of enlargement is a scale where the length of a distance in the drawing is larger than the respective length of the distance in its natural size.

From this follows:

size of representation = size of object × scale

The scale for the preparation of engineering drawings are shown in Fig. 1.35.

Fig. 1.35. Scales, main series

	50:1	*10^n:1*		
Scale of enlargement	*5:1*	*10:1*	*20:1*	In the title block, the main scale must be indicated.
			2:1	
Natural size		*1:1*		
	1:2			
Scale of reduction	*1:20*	*1:10*	*1:5*	In case of a scale deviating from that of the representation in the drawing.
	1:200	*1:100*	*1:50*	
	1:(2·10^n)	*1:10^n*	*1:(5·10^n)*	

Irrespective of the size of representation which results from the selected scale, the dimension to be entered in the drawing must be that which corresponds to the natural size.

Repetition

1. Determine the size of representation in the following Table:

Size of object	5	1000	0.8
Scale	5 : 1	1 : 20	50 : 1
Size of representation			

2. Give examples of your workshop where objects have to be represented in a scale of reduction.

1.7. Basic Geometric Constructions

In engineering drawing, frequently problems have to be solved which call for the knowledge of the method, or systematic procedure, to be used for preparing basic constructions. At the same time, the performance of such tasks develops the skills in handling drawing tools (compasses and dividers, triangles, rulers, templates) and promotes logical thinking.

1.7.1. Basic Problems

Problem 1:

A given segment of a line AB must be bisected!

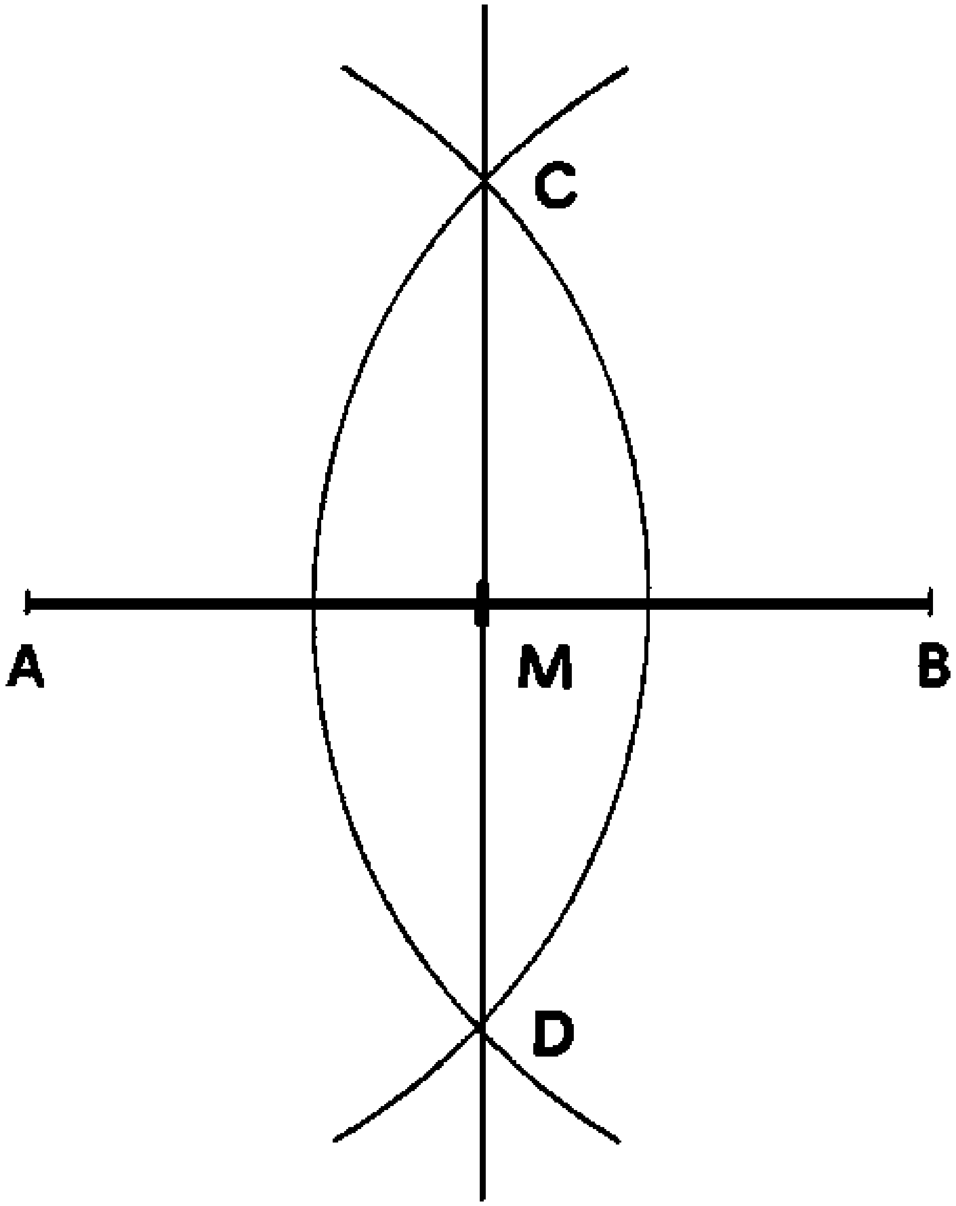


Fig. 1.36. Bisecting a line segment

Solution:

Draw arcs using B as the centre with the compass set so that its opening is practically .

Draw arcs using B as the centre with the compass set as above.

Connect the intersection (C and D) by a line.

The connecting line bisects AB in point M.

Problem 2:

Bisect a given angle!

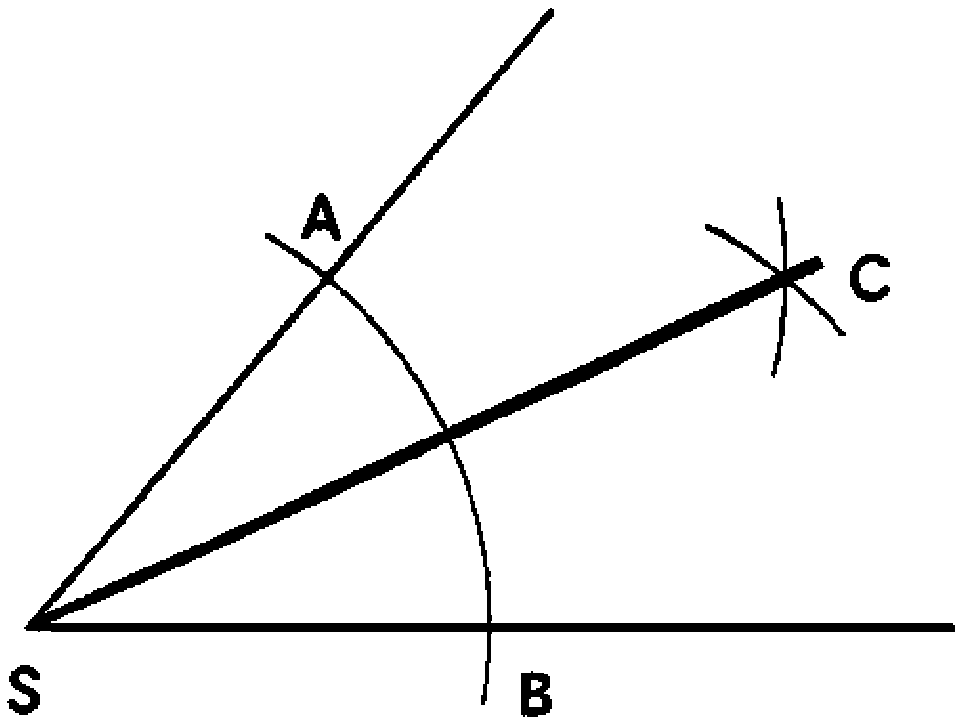


Fig. 1.37. Bisecting an angle

Solution:

Draw an arc with S as the centre, thus A and B are obtained.

Draw any arcs with A and B as the centres which intersect in C

The connecting line C – S bisects the angle.

Problem 3:

Draw a line perpendicular to the line AB in A!

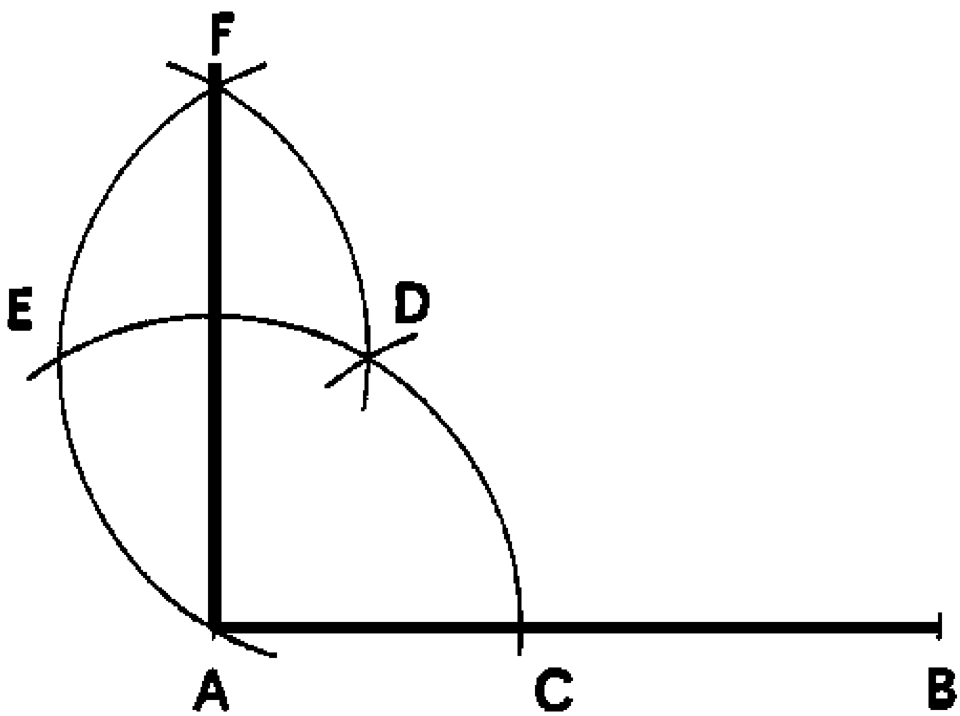


Fig. 1.38. Drawing a line perpendicular to a given line

Solution:

With the compass set to any radius draw

an arc about A as centre, thus C,
an arc about C as centre, thus D,
an arc about D as centre, thus E,
an arc about E as centre, thus F,
connecting line F to A is the perpendicular.

Problem 4:

A given line is to be divided into 5 equal parts!

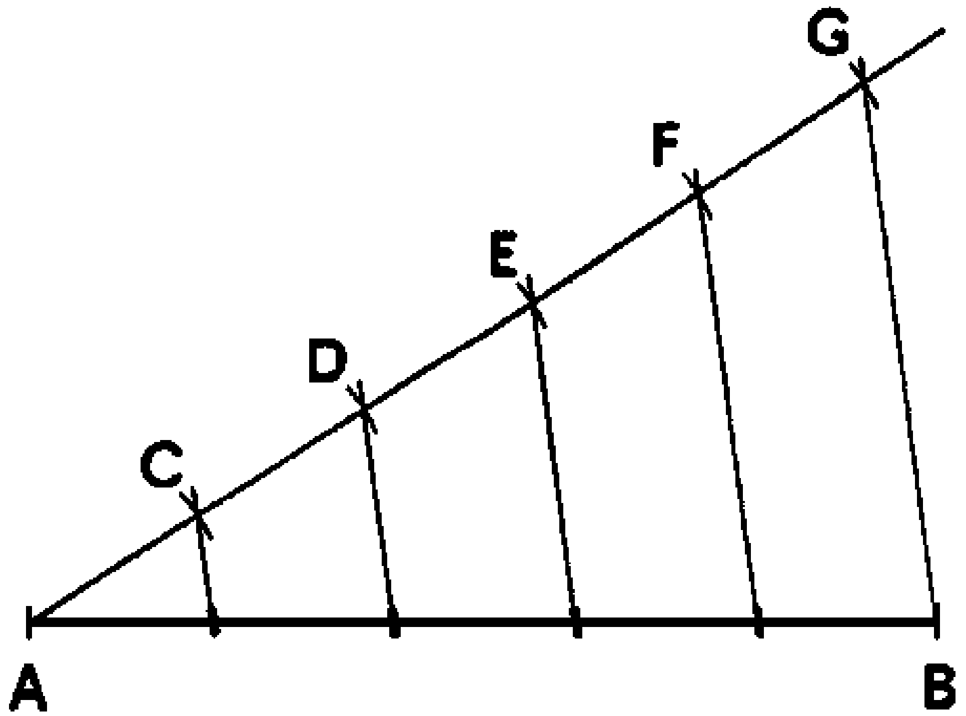


Fig. 1.39. Dividing a line into equal parts

Solution:

From A of this line draw a second line at any convenient angle and lay off 5 equal spaces (points C – G).
Connect G with B; Draw parallel lines to GB.

Problem 5:

Determine the centre of a circle!

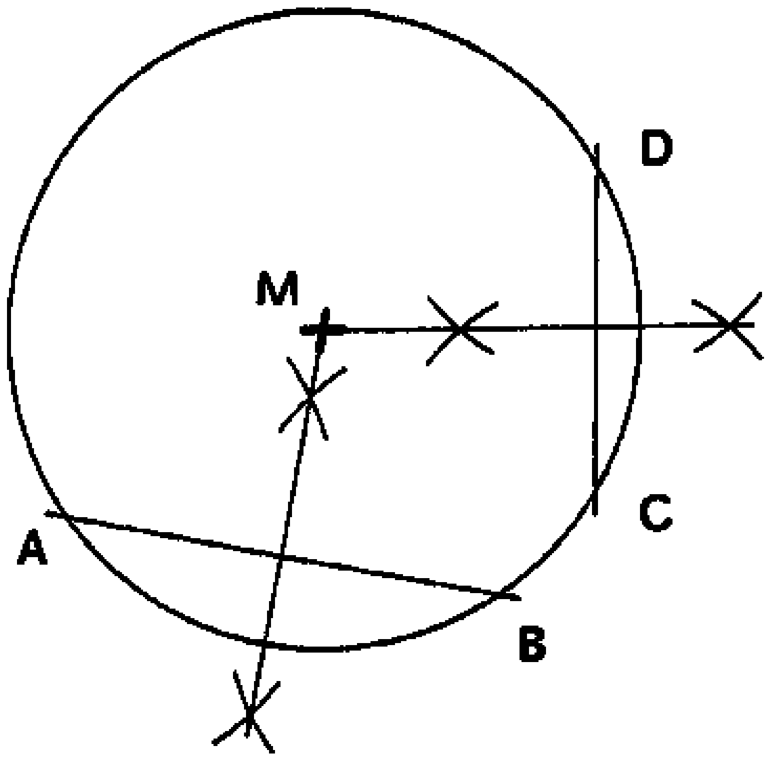


Fig. 1.40. Determining the centre of a circle

Solution:

Draw any two chords AB and CD.

Draw lines perpendicular to the two chords.

The intersection of these two perpendiculars is the centre (M) of the circle.

1.7.2. Regular Polygons

Problem 6:

Hexagon

Given: distance across corners “e”.

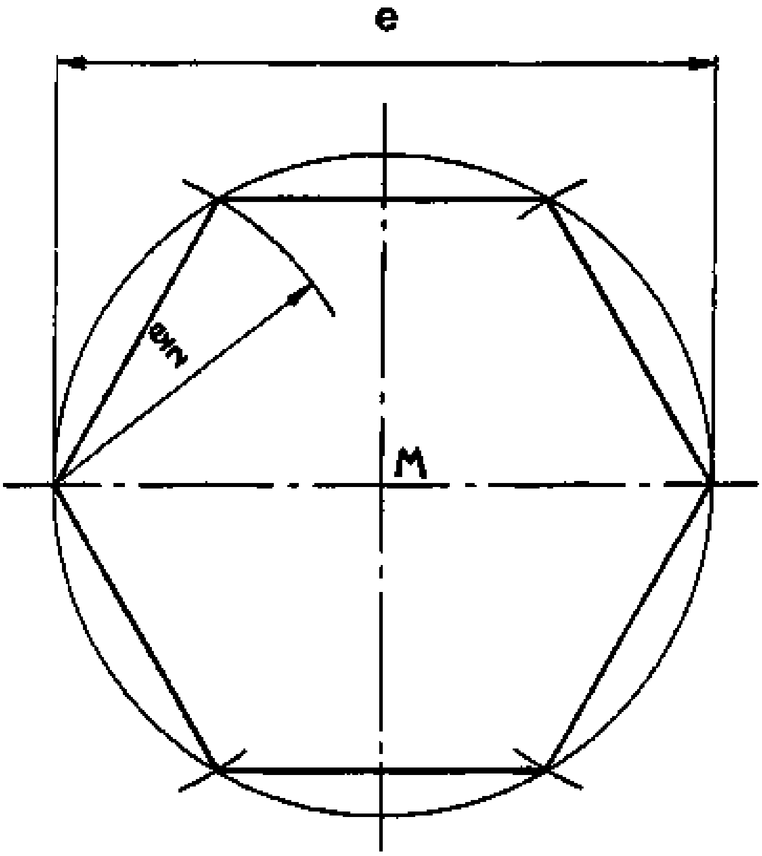


Fig. 1.41. Drawing a regular hexagon

Solution:

Draw the vertical and horizontal centre lines.

Draw circular arc with M as the centre and the compass set to .

With the compass set to draw arcs intersecting the circle.

Problem 7: Pentagon

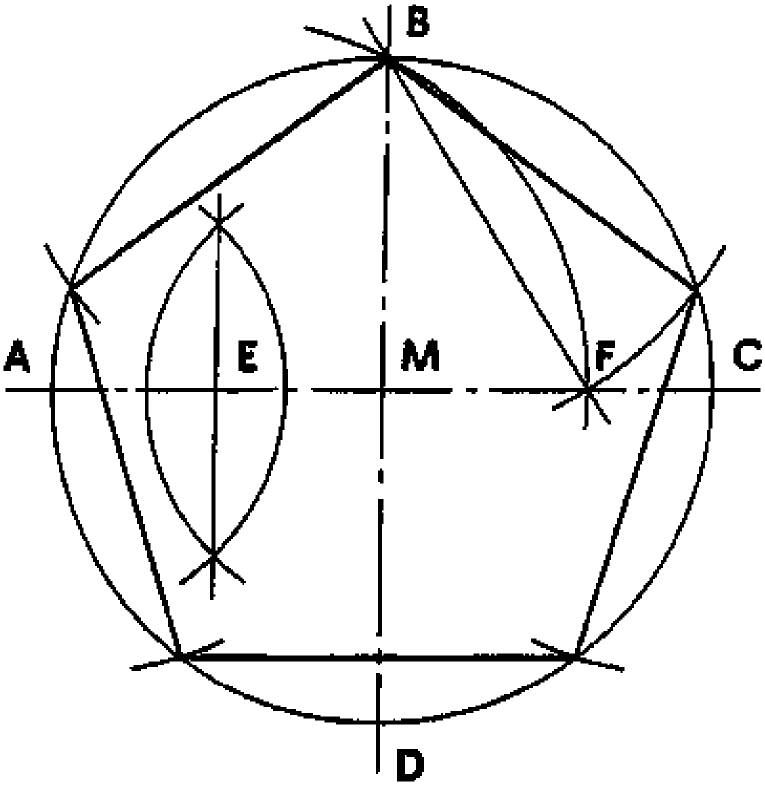


Fig. 1.42. Drawing a regular pentagon

Solution:

Draw the vertical and horizontal centre lines.

Draw circular arc with M as the centre (thus obtaining A, B, C, D).

Bisect line segment MA (thus obtaining E); Draw arc with the radius EB and with E as the centre (thus obtaining F).

BF is the length of one side of the pentagon.

Problem 8:

Square (standing on a corner)

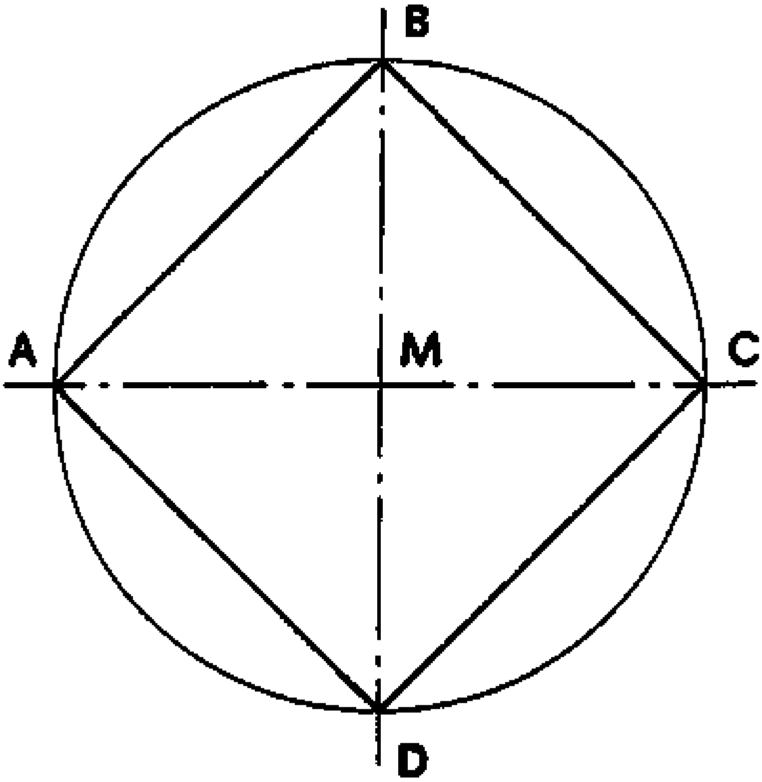


Fig. 1.43. Drawing a square standing on a corner

Solution:

Draw the vertical and horizontal centre lines.

Draw circle with M as the centre, thus obtaining A, B, C and D.

Connect the intersections.

Problem 9:

Square (standing on a flat)

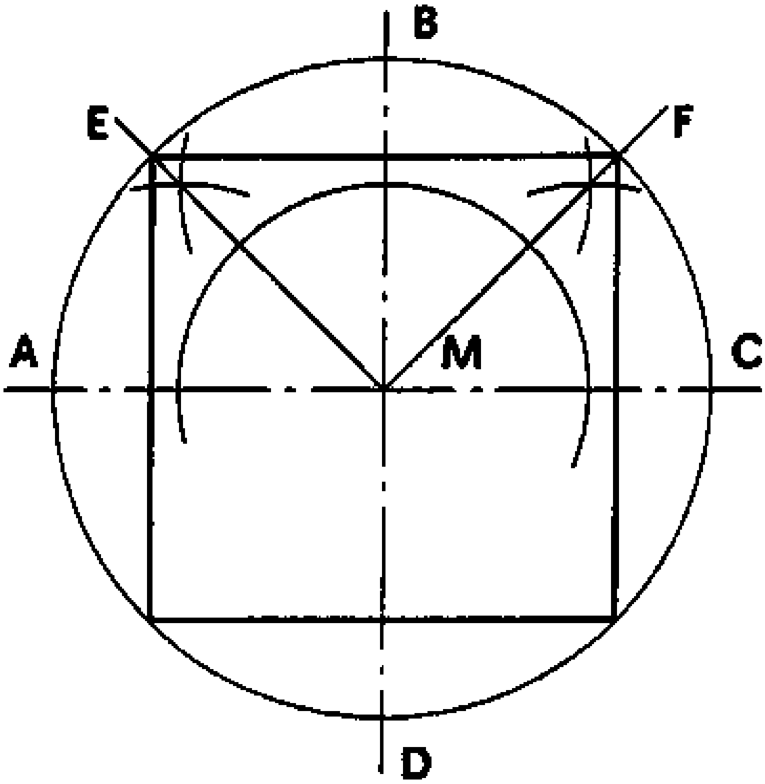


Fig. 1.44. Drawing a square standing on a flat

Solution:

Draw the vertical and horizontal centre lines.

Draw circle with M as the centre, thus obtaining A, B, C and D.

Bisect the angle AMB, thus obtaining E.

Bisect the angle CMB, thus obtaining F.

EF is a flat side of the square.

Connect the points and mark off the distances on the circle.

Problem 10:

Ellipse

Given: Major axis AB, Minor axis CD

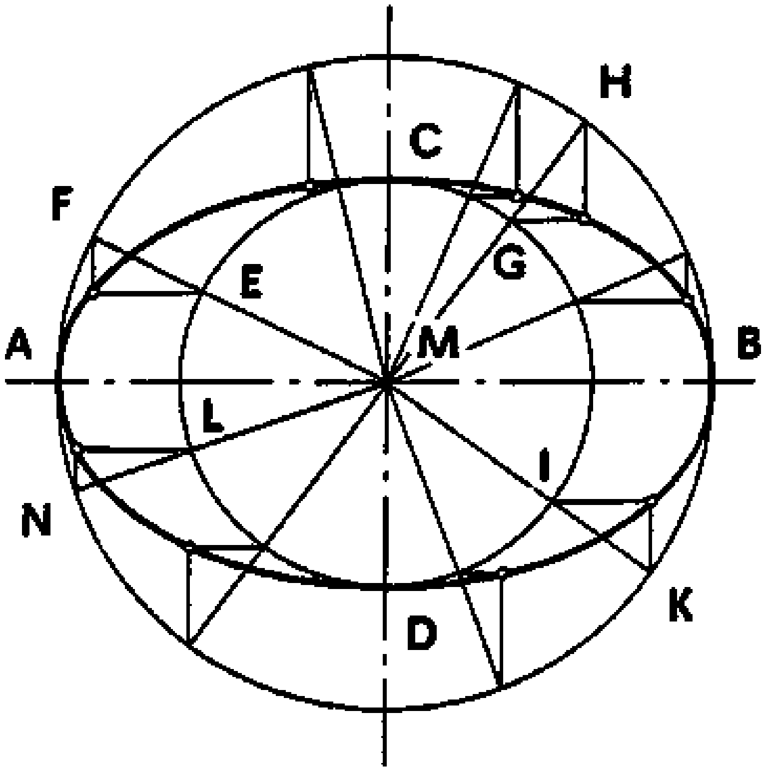


Fig. 1.45. Drawing an ellipse

Solution:

Draw the major axis and the minor axis, thus also obtaining, A, B, C, D and M.

Draw a circle with M as the centre and the radius equal to the major axis.

Draw a circle with M as the centre and the radius equal to the minor axis. Draw any number of radii from M.

Mark off the points on the outer circle (F, H, K, N).

Mark off the points on the inner circle (E, G, I, L).

Draw further radii (without letter in the illustration).

Draw lines parallel to major axis through points provided by the intersections.

Draw lines parallel to the minor axis through points provided by intersections.

The intersections of the vertical and horizontal lines provide points of the ellipse.

1.7.3. Circular Arc Connections

Problem 11:

Construct the tangents to a circle having a diameter of 40 mm!

The tangents have to pass through the common intersection A.

The distance AM is 55 mm.

Connect A with B and A with C. AB and AC are the tangents.

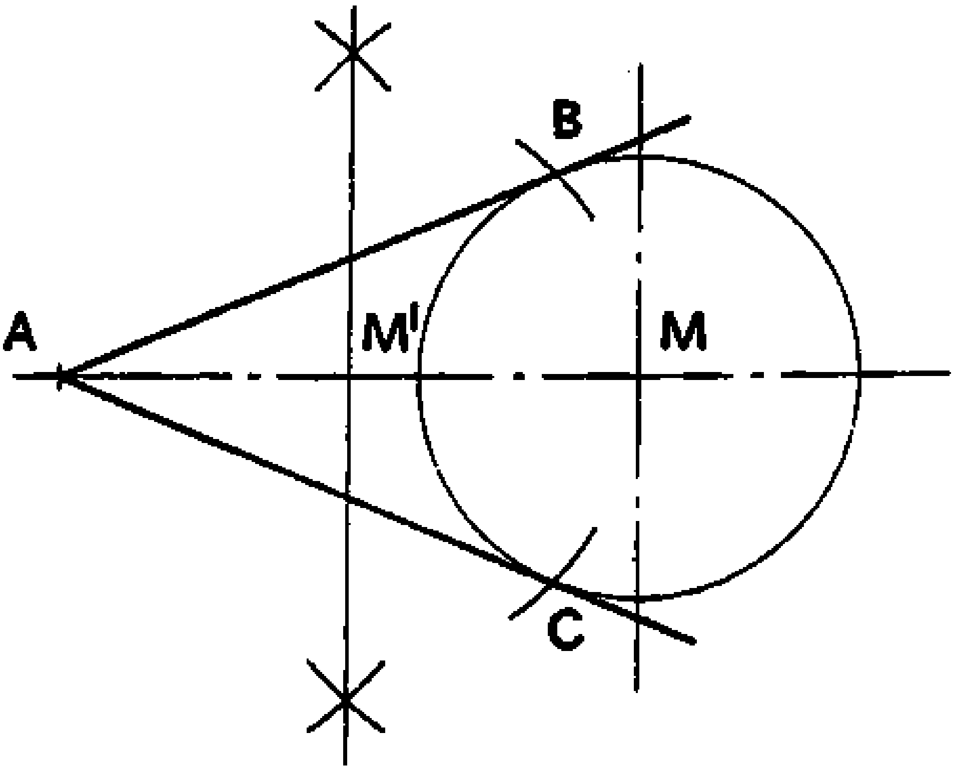


Fig. 1.46. Tangents to a circle

Solution:

Find the centre M.

Draw circle with M as the centre and a radius of 20 mm.

Find A (AM = 55 mm).

AM Bisect AM, thus obtaining M' (AM' =).

Draw arcs with M' as the centre and AM' as the radius, thus obtaining B and C.

Problem 12:

The two legs of a right angle have to be connected by a circular arc with a radius of 30 mm.

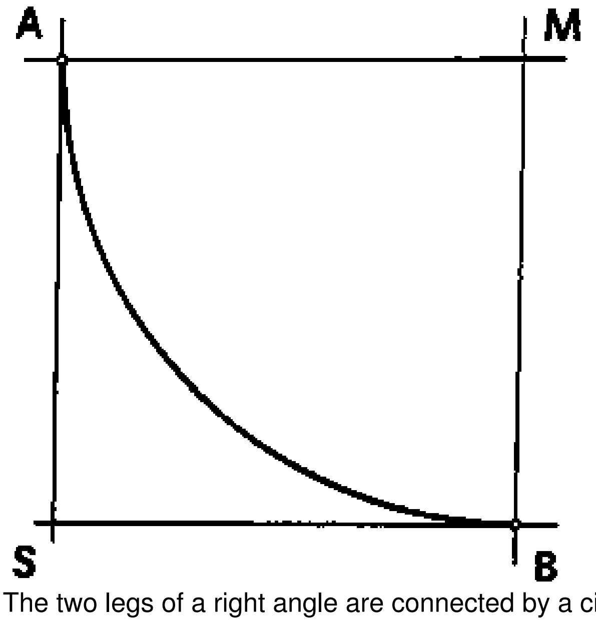


Fig. 1.47. The two legs of a right angle are connected by a circular arc

Solution:

Draw a right angle, thus obtaining S.

Draw two parallels within the angle at a distance of 30 mm in any case.

The intersection of the parallels is the centre M.

The perpendiculars (AM and BM) are the points of connection.

Problem 13:

The two legs of an angle of 120° have to be connected by a circular arc with a radius of 36 mm.

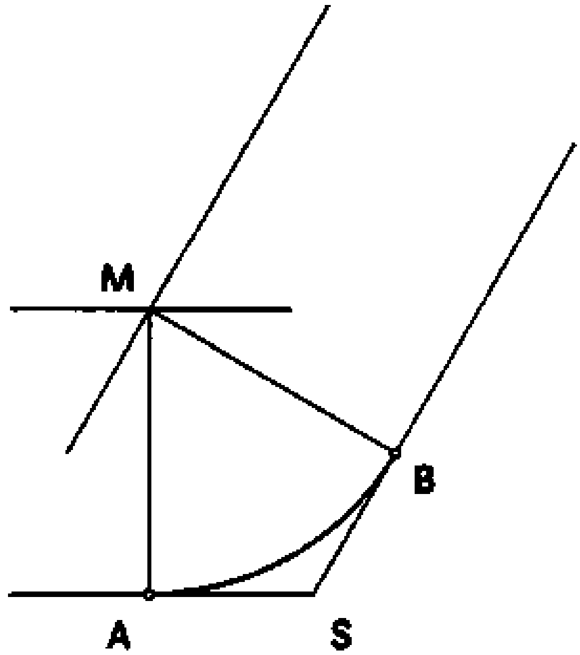


Fig. 1.48. The two legs of any angle are connected by a circular arc

Solution:

Draw the angle (90° + 30°!), thus obtaining S.

Draw two parallels at a distance of 36 mm each, thus obtaining M.

The perpendiculars (AM and BM) are the points of connection.

Problem 14:

Two adjacent circles have the following diameters:

d_1 = 50 mm
d_2 = 30 mm

The distance between their centres is 70 mm. The two circles have to be connected with a transition radius (R_{tr}) of 25 mm!

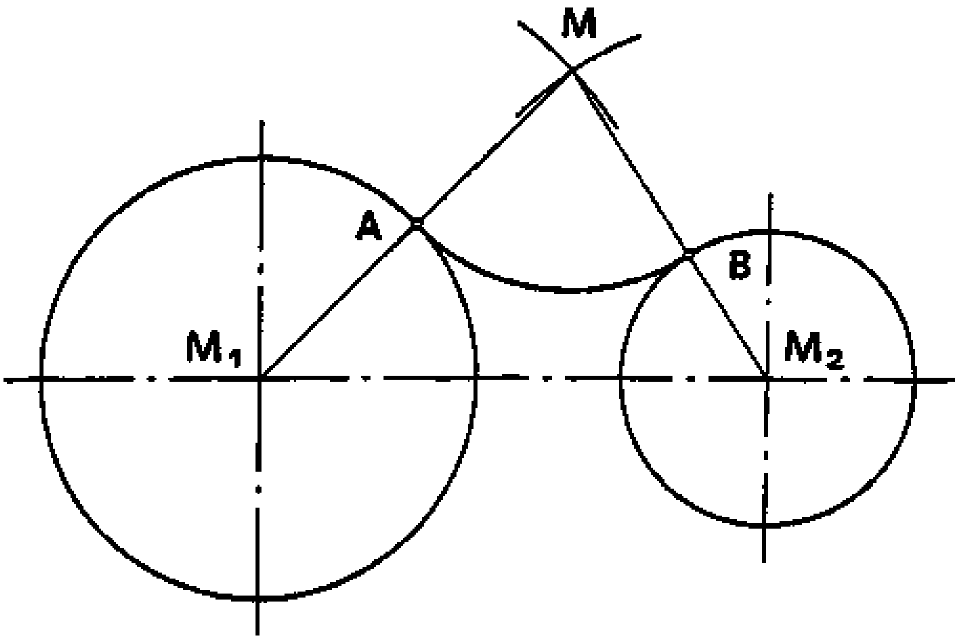


Fig. 1.49. Transition radius, two adjacent circles

Solution:

Draw the two circles, thus obtaining M_1 and M_2.

Draw a circular arc with M_1 as the centre and the radius of $R_1 + R_{tr}$ (30 mm + 25 mm).

Draw a circular arc with M_2 as the centre and the radius of $R_2 + R_{tr}$ (15 mm + 25 mm).

The intersection is M.

Connect M with M_1 and M_2, thus obtaining A and B.

A and B are the points of connection.

Problem 15:

Two circles, an inner circle and an outer circle, have to be connected by a circular arc. The circles have the following diameters:

outer circle = d_1 = 60 mm, inner circle = d_2 = 25 mm

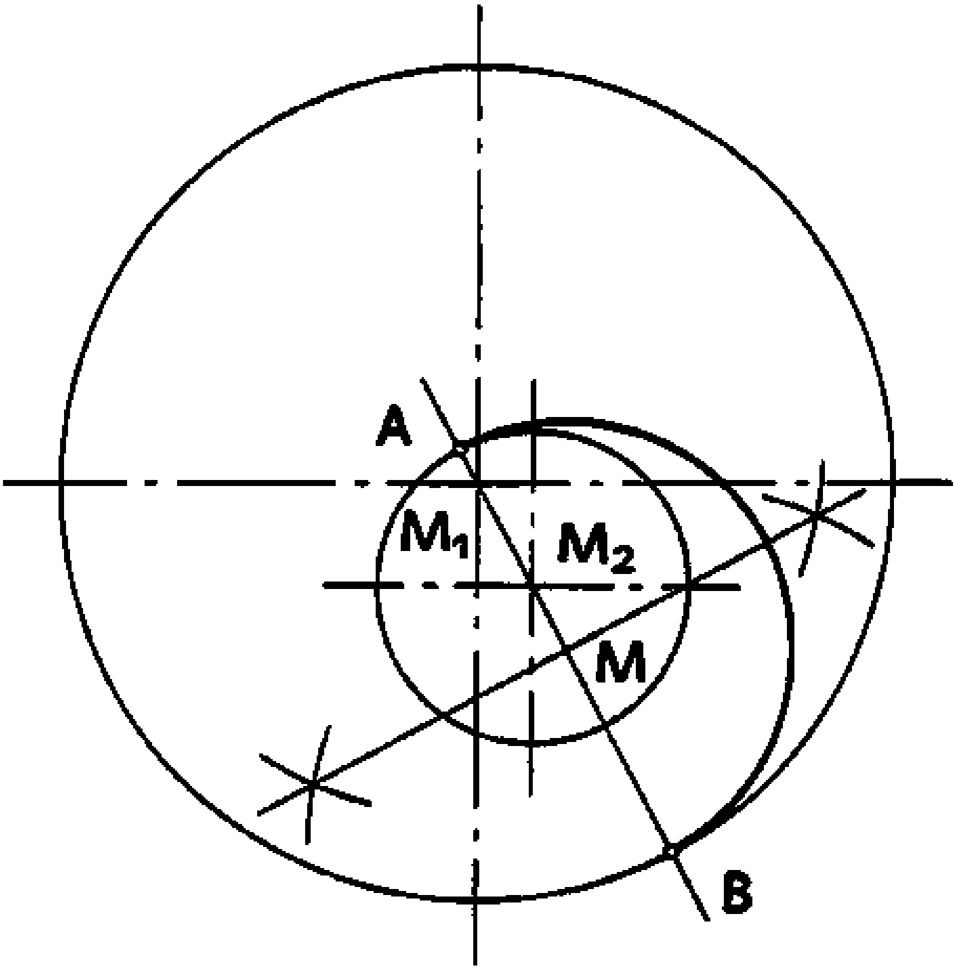


Fig. 1.50. Transition radius, two circles one inside the other

Solution:

Draw the two circles, thus obtaining M_1 and M_2.

Connect the centres and extend to the circles, thus obtaining A and B.

Bisect AB, thus obtaining M as the centre for the circular arc.

Problem 16:

Two adjacent circles have to be connected by a tangent.

Their diameters are:

d_1 = 80 mm
d_2 = 34 mm

The distance between the centres of the two circles is 85 mm.

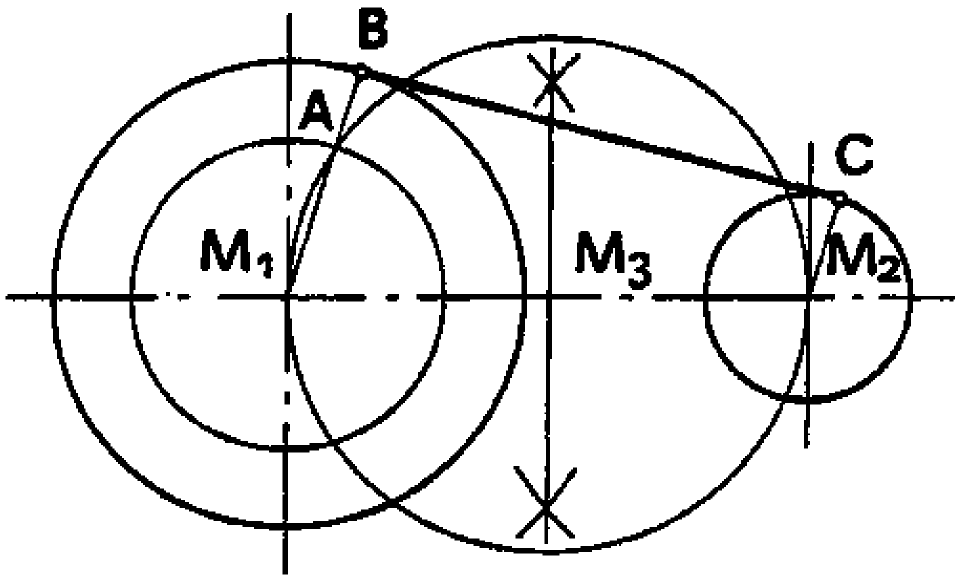


Fig. 1.51. Tangents to two circles

Solution:

Draw the two circles, thus obtaining M_1 and M_2

(M_1 M_2 = 85 mm).

Draw circle with the centre M_1 and the radius of $R_1 - R_2$ (40 mm − 17 mm).

Bisect M_1 M_2. Thus obtaining M_3.

Draw a circle with M_3 as the centre and M_1M_3 as the radius, thus obtaining A.

Extend M_1A over A, thus obtaining B.

Draw a parallel through M_2 to M_1B, thus obtaining C BC is the tangent.

2. Perspective Representation of Simple Workpieces

2.1. Preliminary Remarks

Since all objects are three−dimensional, whereas their images are plane (i.e. two−dimensional) − because they are represented on surfaces −, the illustrations and representations of technical and other objects can only produce an impression that is similar to the true object.

Therefore, a difference is made between vivid and less vivid images of real objects. The more vivid a picture is, the more difficult its representation on drawings or, in other words, its graphic representation. In drawing, the representation of the object is simplified. Therefore, one of the most important tasks in engineering drawing is the systematic development of spatial visualisation.

For this reason, you should try − in any example given below − to derive an imagination of the object to be represented and, in this way, of the procedure of representing. In addition, you should produce models of the object to be represented by means of wooden rods, plasticine, paper and other materials!

For the graphic representation of technical objects, different methods of representation are used.

The recognisability of shape and size of a technical object (machine, structure, pipe line and the like) largely depends on the manner of its illustration.

Since, up to now, there is no method of representation which meets the requirements of vividness, dimensional accuracy and compliance with standards to the same degree, different methods of representation are used.

The perspective representation helps to produce a good spatial visualisation of the object represented in only one illustration.

2.2. Standardised Perspectives (Projections)

2.2.1. Isometric Projection (Isometry)

Isometry (Greek isos = equal; metric = a standard of measurement)

The essence of isometric projection is indicated by the term. The part of the word “iso” is derived from the Greek “isos” which means equality. In the isometric projection this is expressed by the equality of the side relations and angle relations. All edges of the body represented appear unshortened. That is to say, the side relationship of a : b : c = 1 : 1 : 1 and the angles ? = ? = 30°; in other words, a perspective representation is isometric when all dimensions are represented in the same drawing scale (Fig. 2.1.).

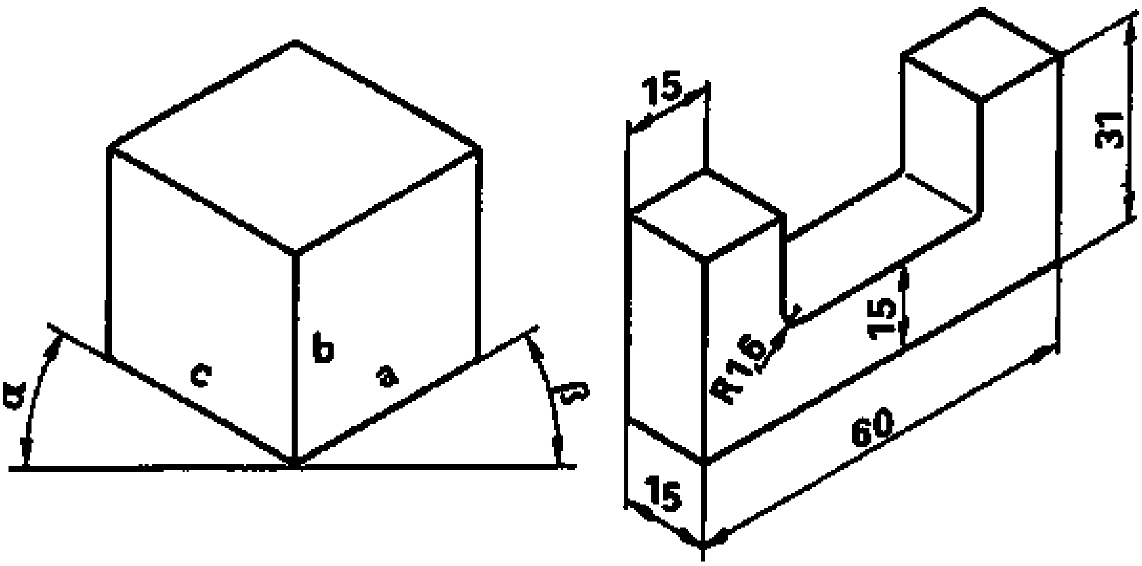


Fig. 2.1. Isometric projection

When placing a cube on a corner (see Fig. 2.1.) so that the two lower body edges form an angle of 45 and further tilting this body until the diagonal through the body is horizontal, then the representation will be isometric. The body edges a and c and all body edges running parallel to them will then form an angle of 30° on either side to the horizontal.

> The isometric projection is used when in all three planes (views; axes) essential things have to be shown clearly.

2.2.2. Dimetric Projection (Dimetry)

Dimetry (Latin: di = two; Metric = a standard of measurement) In dimetric representation, the side relationship a : b : c = 1 : 1 : 0.5 and the angle have a magnitude of ? = 41° and ? = 7°. The angle of 41° usually is drawn at the left–hand side because the side view is frequently drawn from the left (Fig. 2.2.).

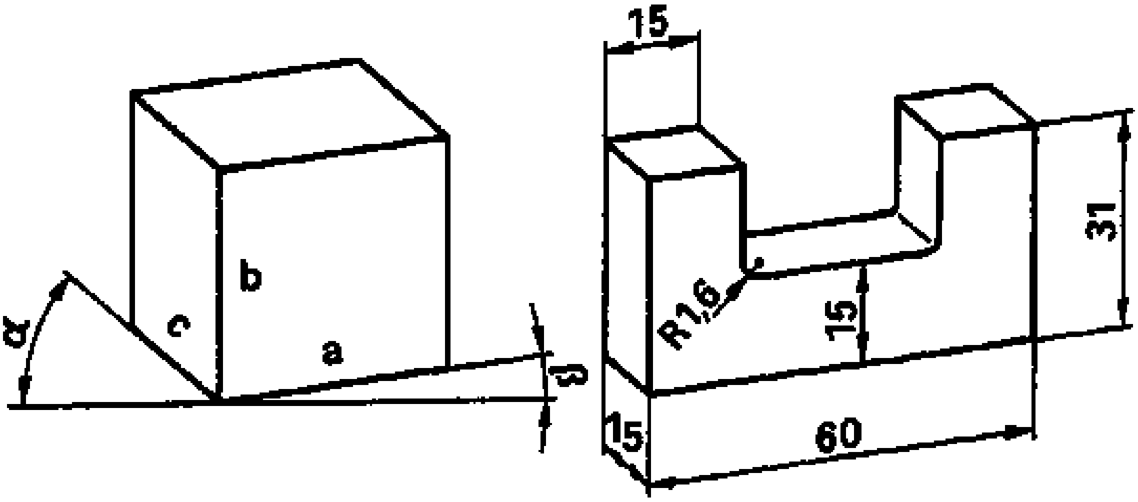


Fig. 2.2. Dimetric projection

The stated side and angular relations are brought about when the object in top view is turned through 20°. The view from the left is also tipped through 20°. By projection of the body edges, one obtains the lateral angles of ? = 7°10' and ? = 41°25'.

The values obtained in this way have to be rounded off.

Dimetry is used for representations where the main view (view from the front) is designed to show the most essential details (see Fig. 2.2.).

2.2.3. Frontal−dimetric Projection

The perspective picture of the technical object is produced on a plane surface which is located vertically and at a parallel distance from and behind the object and on which the parallel projection rays are incident obliquely from the side and from top.

It can be compared with a body shade produced by the rays of the sun on the surface of the earth.

All surfaces of the object retain in this perspective their natural shape and size. All edges receding to the depth are represented at an angle of 45° and shortened by half.

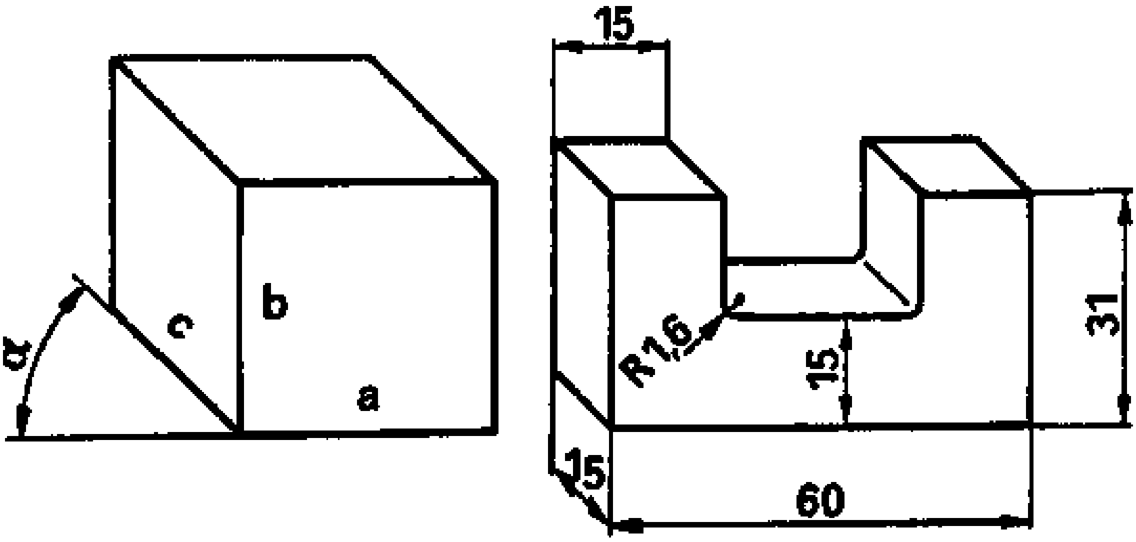


Fig. 2.3. Frontal−dimetric projection

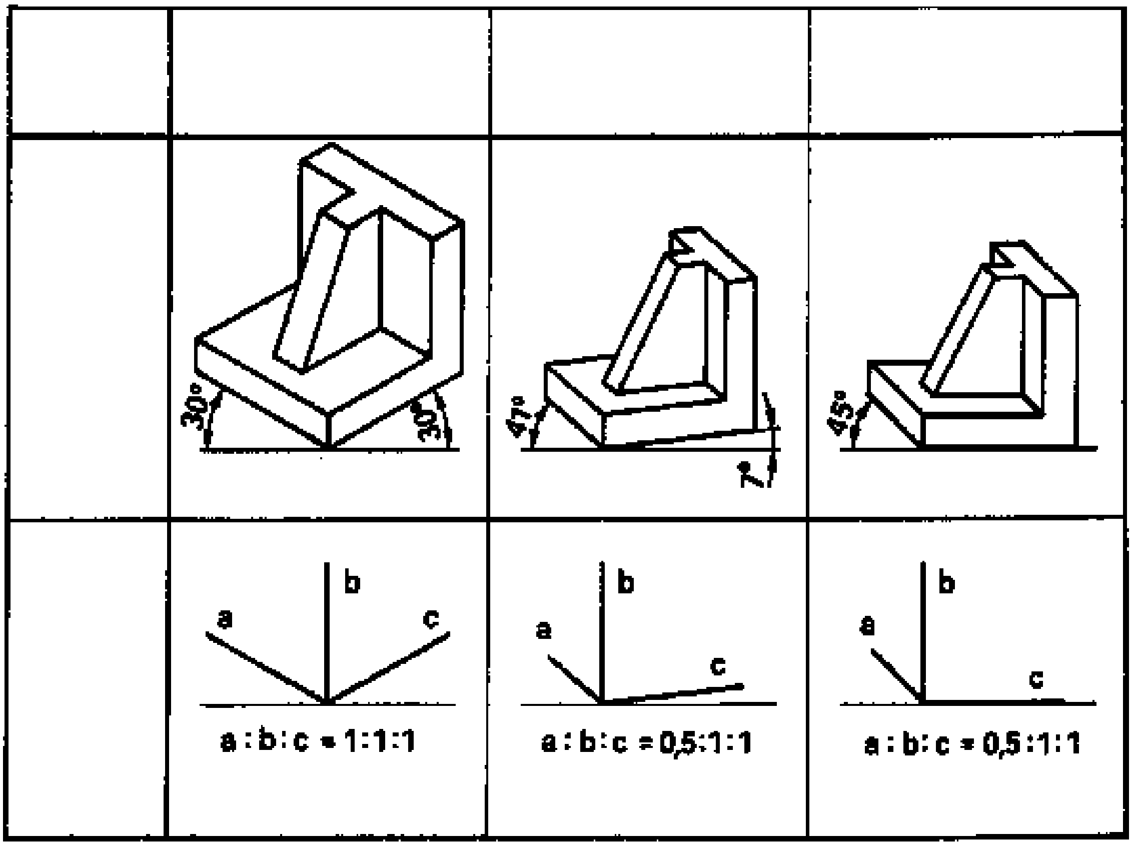


Fig. 2.4. Survey of the types of projection

That is to say, the side relations correspond to those of the dimetry. However, the frontal–dimetric projections can be drawn more easily as the dimetry. Therefore, it is used for blackboard pictures, on illustrative plates and for operating instructions (see Fig. 2.3.).

<u>Repetition</u>

1. What are the differences between isometry, dimetry and frontal–dimetric projection with respect to:

   – relationship between axes,
   – angles,
   – use?

Quote examples from the present textbook.

2. Explain the development of the isometric projection.

3. Construct the frontal–dimetric projection of a cuboid and of a hexagonal prism.

2.3. Dimensioning of Perspective Workpieces

– The extension lines are indicative of the body edges and must be shown as such.

– The extension lines run parallel to the body edges; the angles of isometry, dimetry and frontal–dimetric projection have to be observed.

– The dimension figures must be entered above the dimension line in the respective plane.

– The extension lines and dimension lines must be applied where they most clearly show the shape of the object to be represented.

– The representation itself should be kept free from the dimensional entries, that is to say, within the illustration the number of dimensions should be kept as small as possible.

In this respect pay attention to the illustrations 2.5., 2.6. and 2.7. and to the readability of the dimension figures!

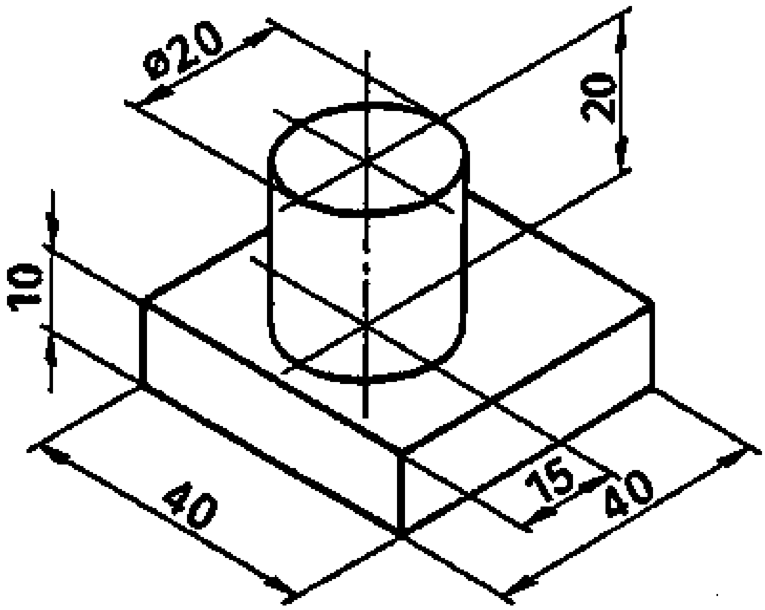


Fig. 2.5. Example 1 of dimensioning (isometry)

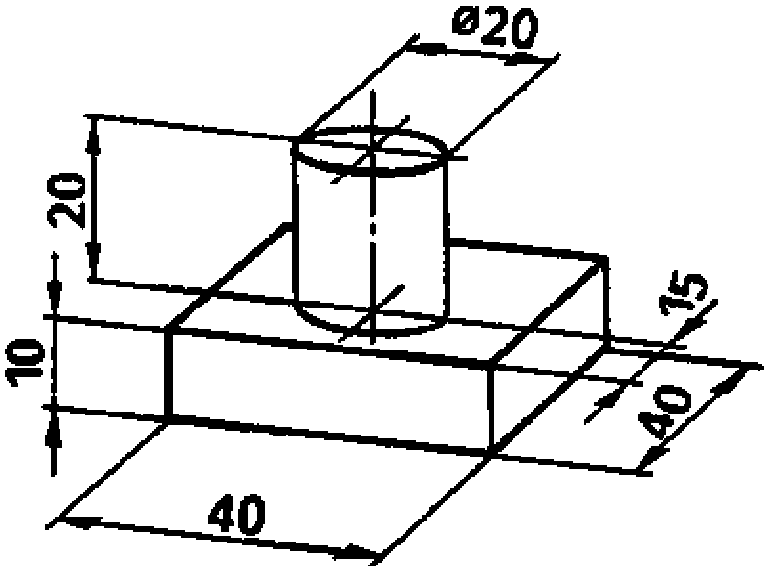


Fig. 2.6. Example 2 of dimensioning (dimetry)

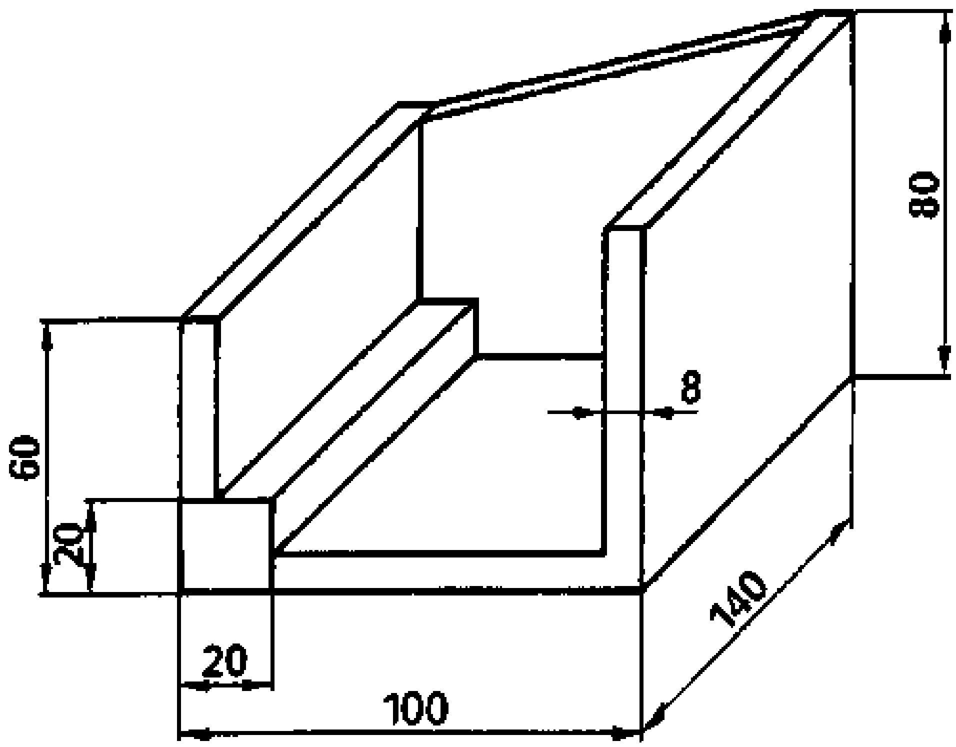


Fig. 2.7. Example 3 of dimensioning (frontal perspective)

2.4. Perspective Representation of a Circle (Fig. 2.8.)

Approximate construction for circles in planes B and C−dimetry

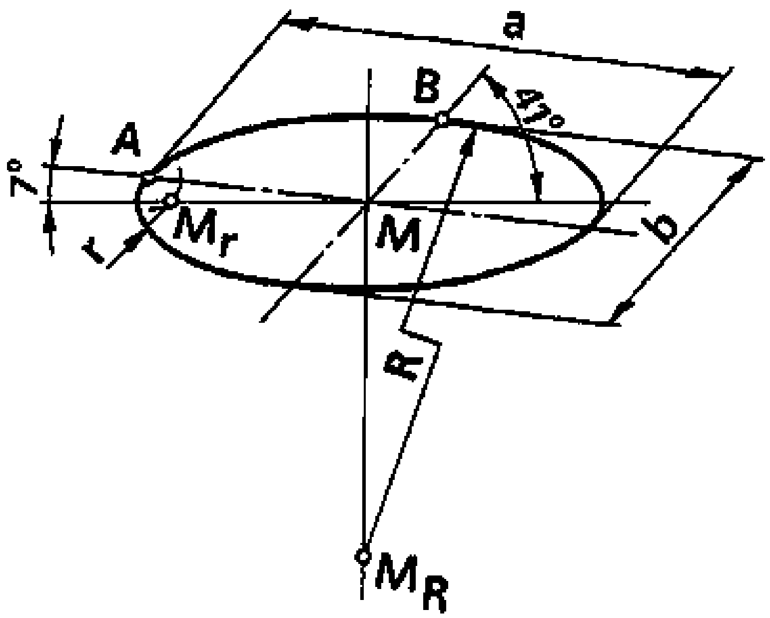


Fig. 2.8. Approximate construction of a circle for dimetry

Solution:

Draw the rectangular system of coordinates.

Mark off 7°/41°

Mark the circle diameter (a and b) on 7°/41° − system of coordinates.

Mark the points A and B on 7°/41° − system of coordinates.

Calculate the radii, R = 1.5a r =.

Draw a circular arc with A as the centre and radius r (intersects horizontal axis in M_r).

Draw a circular arc with M_r as the centre and r as the radius.

Draw a circular arc with B as the centre and R as the radius (intersects vertical axis in M_R).

Draw a circular arc with M_R as the centre and R as the radius.

Coordinate the ellipse radii.

(Pay attention to the practical examples given in Fig. 2.9.).

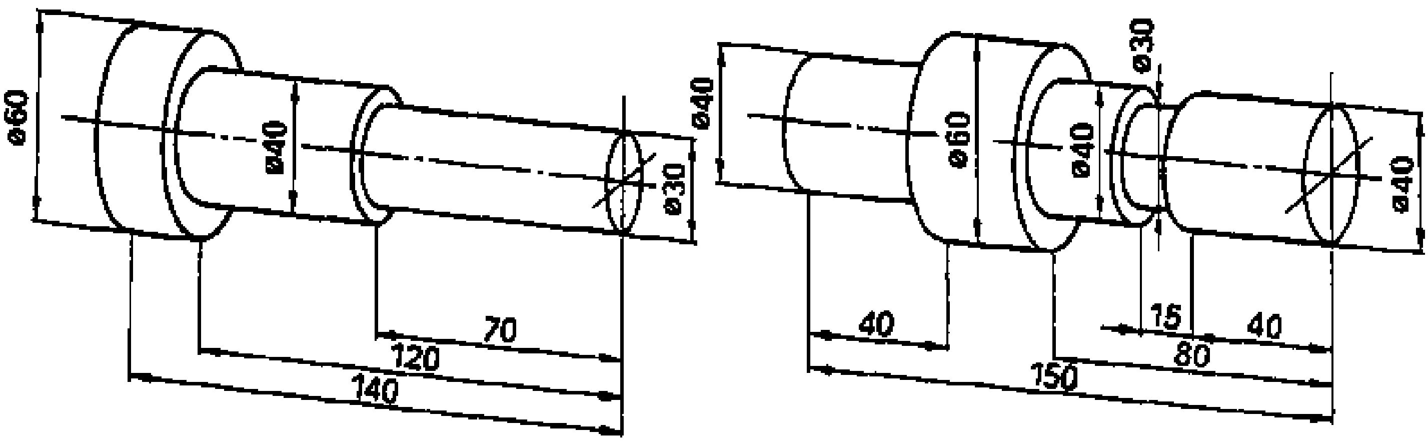


Fig. 2.9. Representation of cylindric objects (dimetry)

2.5. Principles of the Perspective Representation of Simple Workpieces

– Body edges which are parallel at the technical object are represented as parallel lines.

– In the representation, one starts from the envelope of the figur (i.e. the outside shape of the geometric object).

– At first all lines running parallel to each other are constructed and the intersections to partial shapes are determined.

– Auxiliary lines no longer required are removed by erasing step by step in order to obtain a clear picture of the final shape.

– The systematic development of the final shape can be effected by the “dismantling procedure”.

For this purpose, the following steps have to be observed:

– Drawing the enveloping figur (geometric basic body),
– Drawing in the partial shapes (thin solid lines),
– Removal of unnecessary auxiliary lines by erasing,
– Re–drawing of the visible body edges (thick solid lines),
– Always trace lines running parallel to each other (saving time and better quality),
– Re–drawing of oblique body edges,
– Dimensioning (if required).

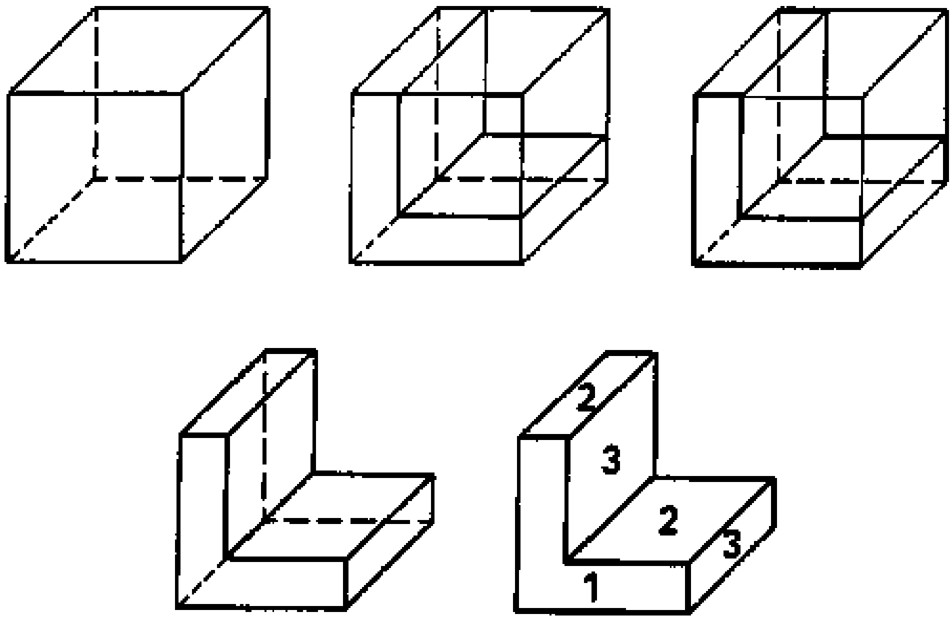


Fig. 2.10. Sequence of steps for the frontal–dimetric representation

2.6. Representation of Workpieces in Perspective from Different Station Points

It is possible to draw technical objects in different positions in order to ensure better recognisability of the partial shapes (see Fig. 2.11.). The following example shows a simple angle in 4 possible positions (viewed from different station points) of the frontal–dimetric projection.

In a similar way, various station points can also be used for the isometric and dimetric projections.

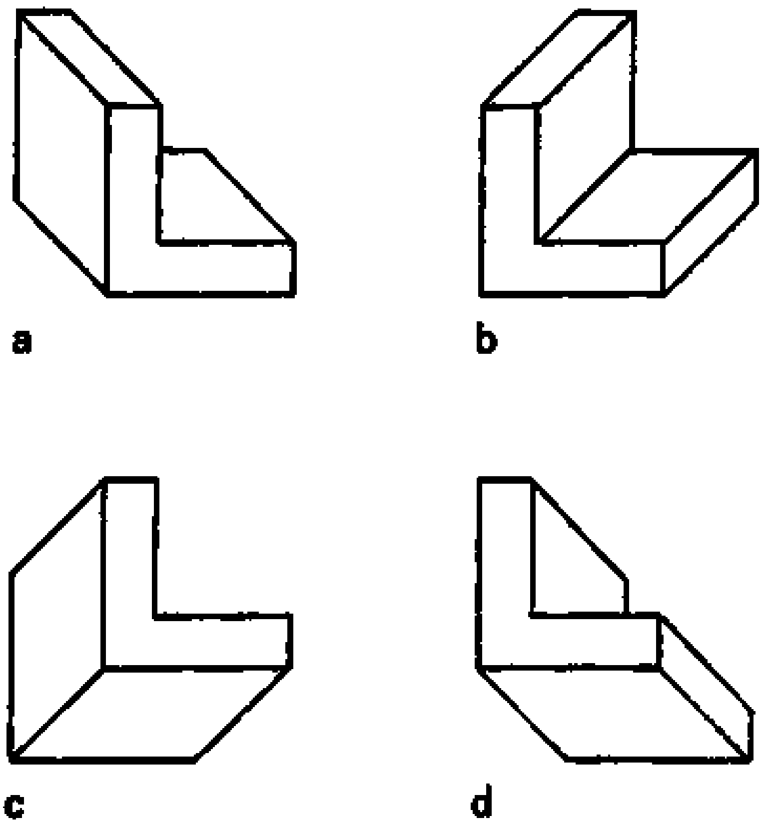


Fig. 2.11. Viewing directions (frontal–dimetric representation)

Viewing directions:

1 front–top–left
2 front–top–right

3 front−bottom−left
4 front−bottom−right

3. Representation of Workpieces in Right−angle Parallel Projection

3.1. Development and Number of Views

The name <u>"right−angle or orthographic parallel projection"</u> means that the object is viewed at right angle and is projected with parallel visual rays on a plane of projection (see Fig. 3.1.).

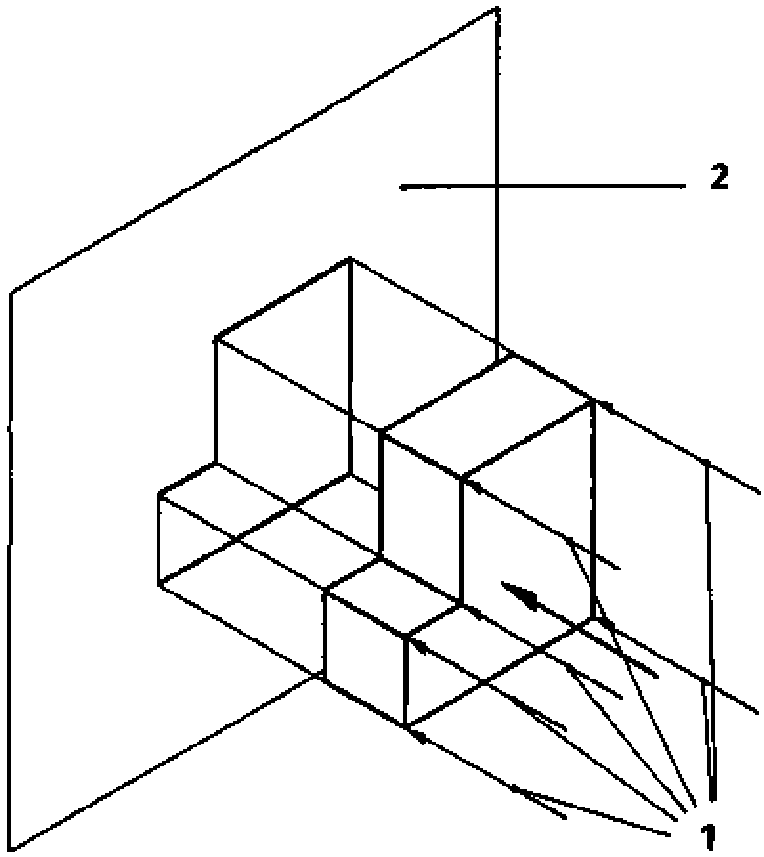


Fig. 3.1. 1 Visual rays, 2 Plane of projection

This representation in various views is less vivid than the perspective representation (see Chapter 2) but it can be prepared considerably more conveniently; therefore it is the most widely used method of representation in production. This also means that working with engineering drawings of this type calls for greater expert knowledge.

As to the number of views, a distinction is made between the possible views and the necessary views!

There are 6 possible views which are brought about in the following way: The object is positioned in front of an imaginare plane and turned through 90° for each view. The visible edges are represented on the plane (see Fig. 3.2.).

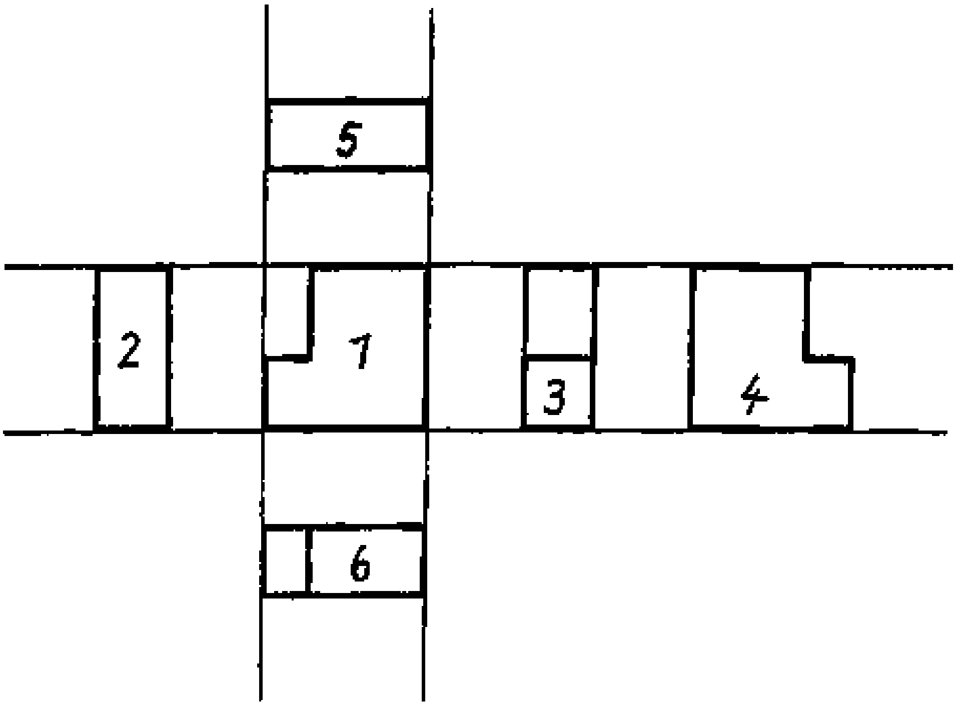


Fig. 3.2. Figure

1 Front view
2 Right side view
3 Left side view
4 Rear view
5 Bottom view
6 Top view

The views are named as follows:

F – Front view or main view
Sl – Side view from the left or left side view
T – Top view
R – Rear view
Sr – Side view from the right or right side view
B – Bottom view

The development of the 6 views can also be explained in another way. One starts from the consideration that the observer changes his station point always by 90 and represents what he sees on a plane (see Fig. 3.3.). The same arrangement of views is obtained as in Fig. 3.2. The letters given are the abbreviations of the views as shown above.

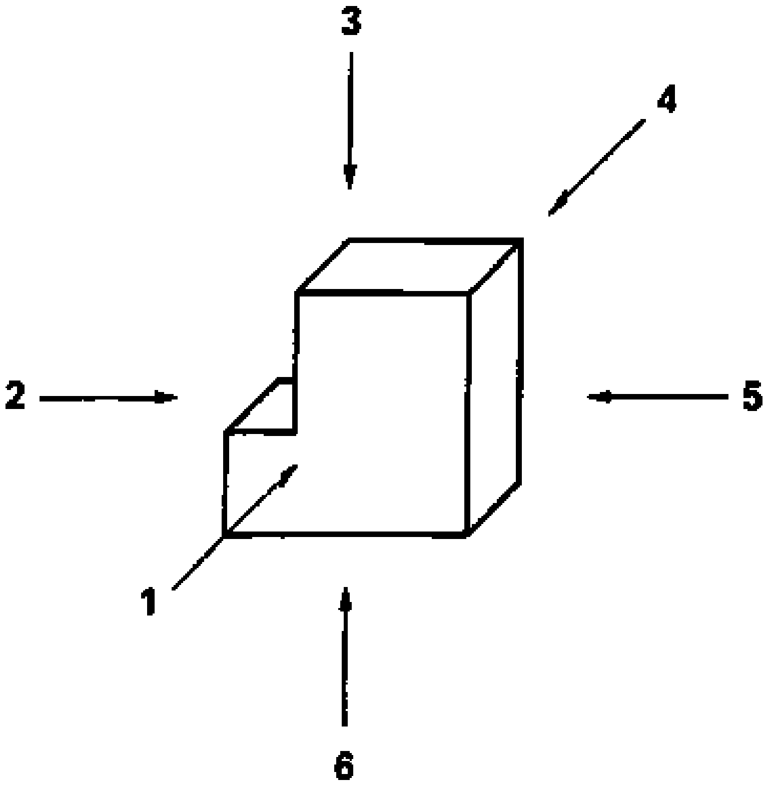


Fig. 3.3. Figure

1 Front view
2 Right side view
3 Left side view
4 Rear view
5 Bottom view
6 Top view

For the representation in orthographic parallel projection (views), the following rules should be observed:

– As front view that view should be selected which is most instructive for the shape of the workpiece. That is why the front view is also called main view.

– The arrangement of the views must comply with the projection! That is to say, Sr, F, S1 and R are on a horizontal line while B, F and T are on a vertical line as is shown in Fig. 3.4.

– The spacings between the views should be of equal size. In this way, the visualisation of the object as a three–dimensional object is facilitated for the observer (once more see Fig. 3.4.).

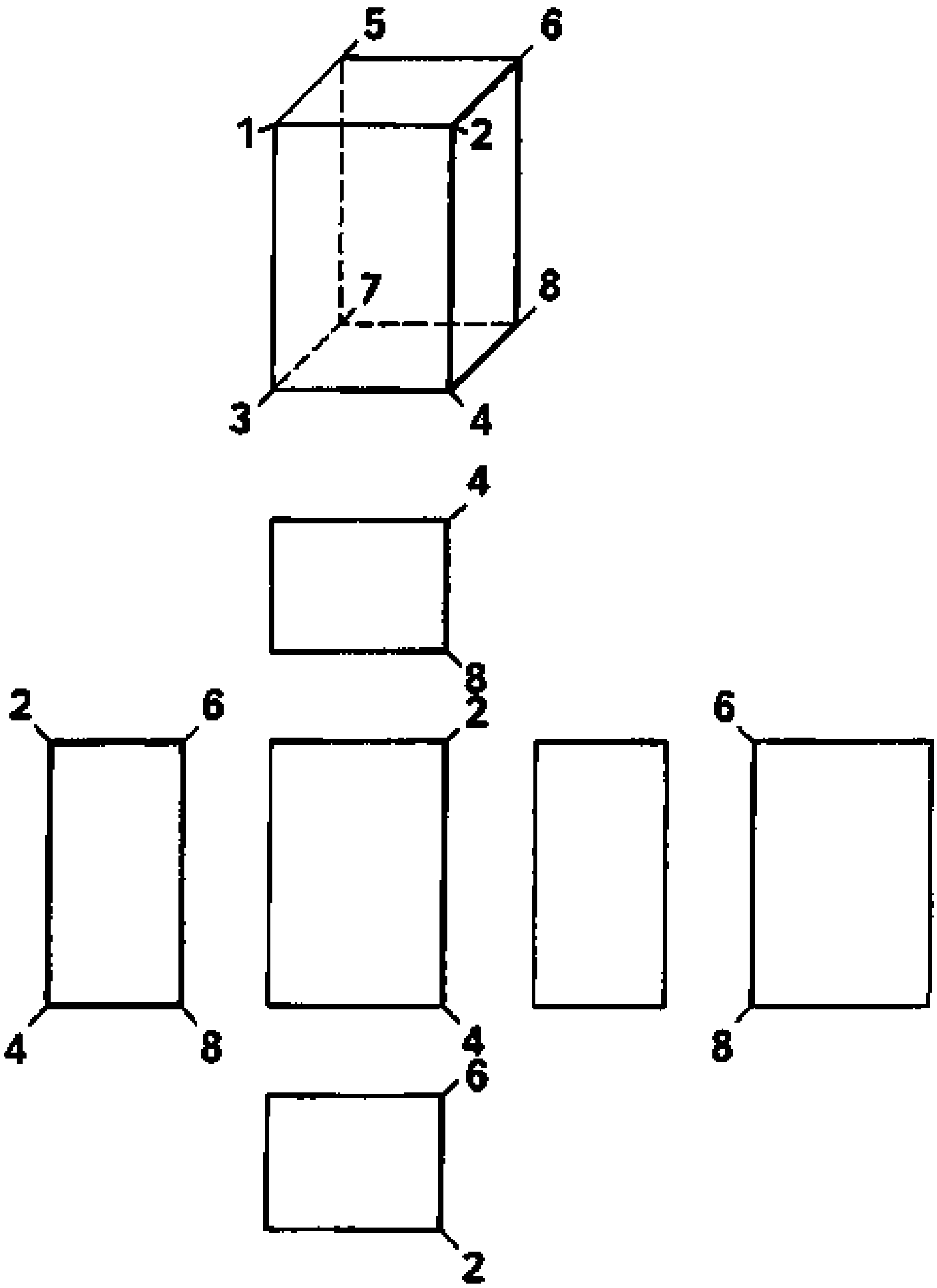


Fig. 3.4. Figure

Repetition

1. What means the term “right−angle or orthographic parallel projections”?

2. Explain the development of the 6 possible views.

3. Explain the abbreviations in Fig. 3.2.

4. Complete the designation of the corners in Fig. 3.4.

5. What are the reasons for the determination of a view as the front views?

6. Determine a corner of the front view in Fig. 3.2. with E and mark this corner in the other views (hidden – E in parantheses).

3.2. Representation of Flat Workpieces in a View

In practice it is mostly not necessary to show all six views for the clear representation of a workpiece or component so that it is subject to but one interpretation. The views necessary for the complete representation have to be drawn. All objects have three dimensions (length, width, thickness). For this reason, two view are the minimum number of the necessary views. Due to the interduction of an additional indication in the form of a “word” for the thickness, one view can be omitted (see Fig. 3.5.).

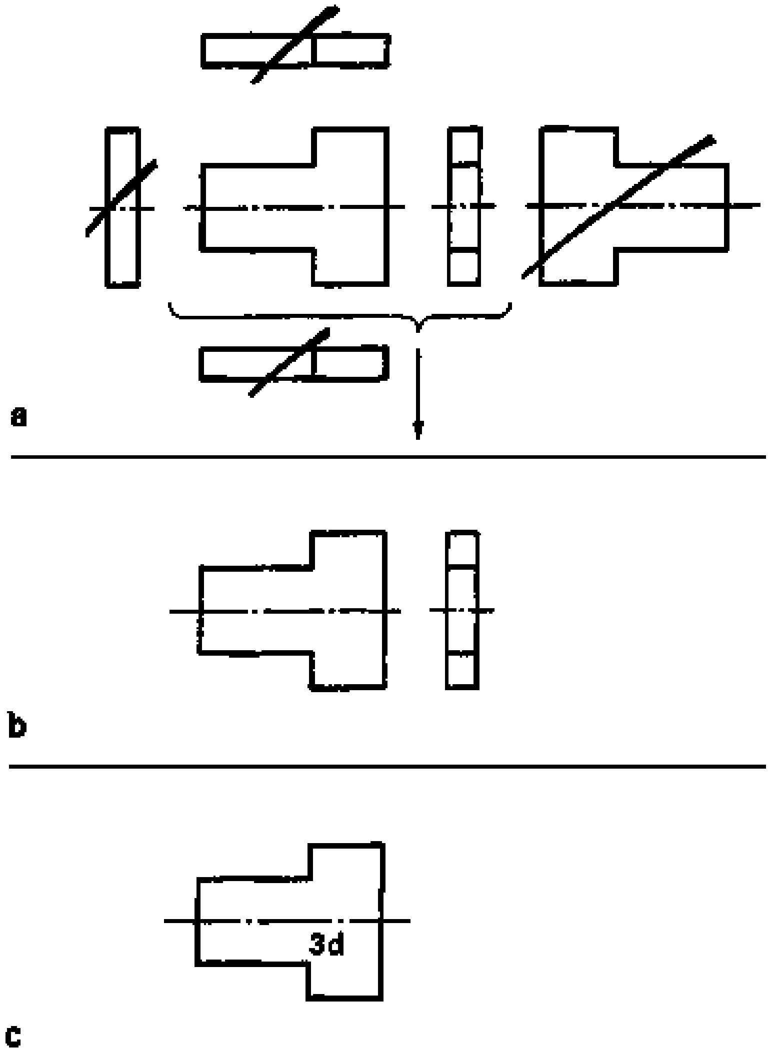


Fig. 3.5. Figure

1 Unnecessary views
2 Necessary views without verbal indication of thickness
3 One view when the thickness is stated, × 3 thick.

For the representation of flat workpieces with a small thickness, one view will suffice when the thickness is indicated in the form of a “word”. This view is always the front view.

The thickness can be entered in the drawing in two ways:

– If there is sufficient room in the front view, the thickness is given at a prominent point within the outlines (see Fig. 3.6.).

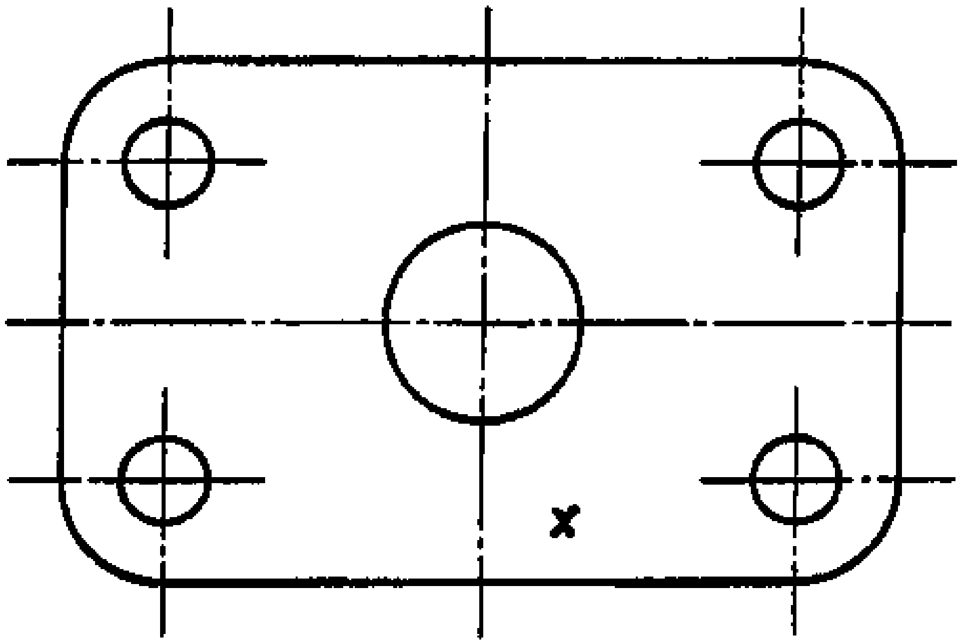


Fig. 3.6. × 3 thick

– If the front view does not provide sufficient room, the thickness is indicated close by the view. A so–called leader or reference line (thin solid line) connects the view and the lettering. Inside the view, this line is provided with a point (see Fig. 3.7.).

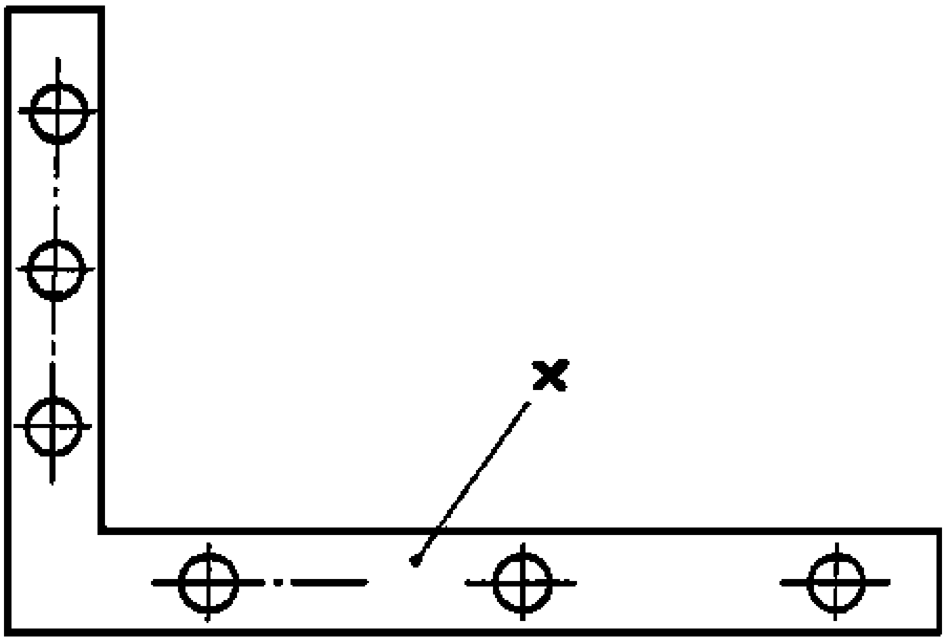


Fig. 3.7. × 2 thick

In both cases, the thickness measure is given in millimetres but without the indication of the unit of measurement in front of the word "thickness".

Centre lines are important auxiliary means for the marking of symmetric shapes. They are imaginary lines!

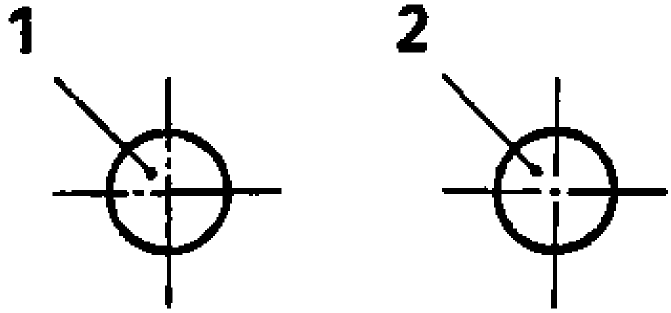
As the examples given in the illustrations 3.5. and 3.7. show, this is even used for flat workpieces. Centre lines are of particular importance for the representation of cylindrical, taper, spherical and similar shapes of workpieces.

– The centre line is drawn as a dash–and–dot line (see Chapter 1). In the place of a dot, a short

dashy can be drawn. Length of dashes and spacings should be uniform (a).

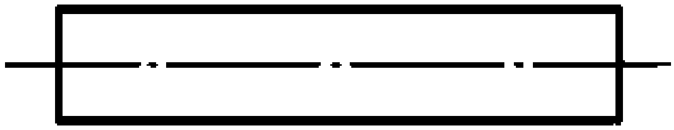
– The centre line must start and end with a dash (a to e).

– Centre lines must cross each other with dashes. When crossing body edges, dashes in the centre line should be used whenever possible. (b), 1 correct, 2 wrong



b

– Start and end of the centre line are shortly extended over the symmetric form. (c)

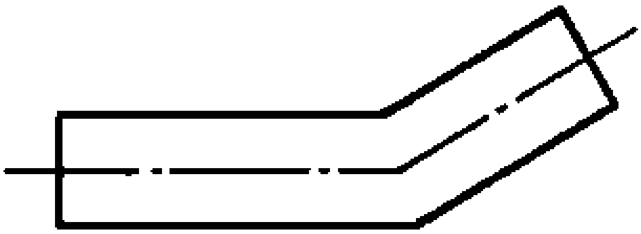


c

– In case of small shapes, the centre line may take the form of a thin solid line. (d)

d

– When changing the direction, two dashes must contact each other at the corner. (e)

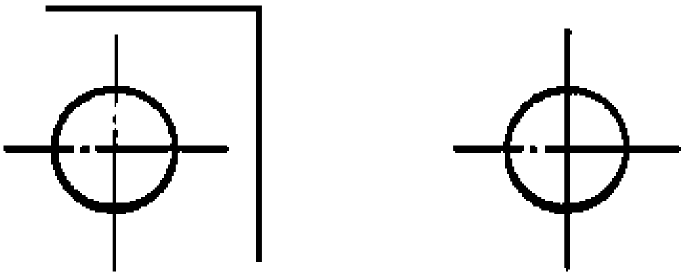


e

– Centre lines must not be drawn through from one view into the other as in Fig. 3.5.

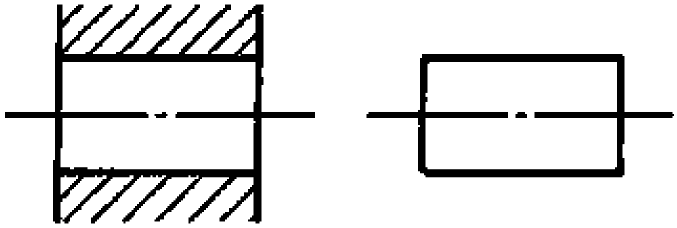
Use:

– As symmetry lines of circles for drill–holes and cylindrical, tapered, spherical and similar solid bodies. (a)



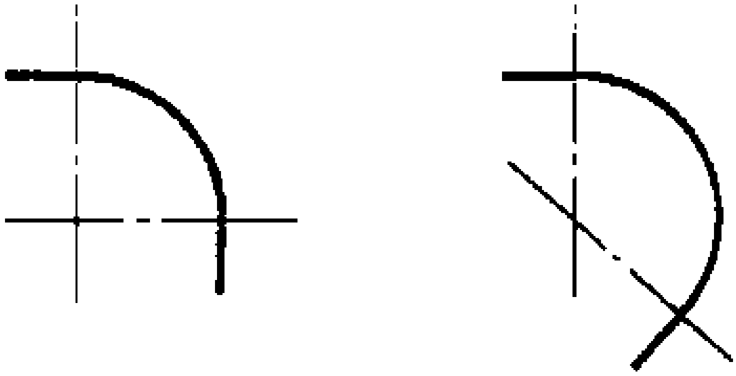
a

– As symmetry line of cylindrical, tapered, spherical and similar hollow and solid bodies without representation of circles. (b)

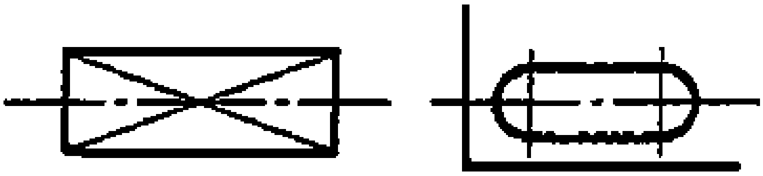


b

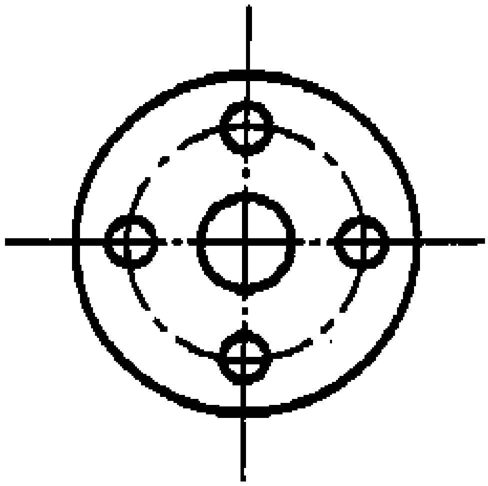
– As a boundary line for curvatures. (c)



– As symmetry line for prismatic shapes and partial shapes. (d)



– As hole circle. (e)



e

In almost any of these functions, the centre line can also serve as dimension line.

Repetition

1. Describe the shape of workpieces for the representation of which only one view is required.

2. What is the procedure enabling the representation of work–pieces clearly in one view so that it is subject to but one interpretation?

3. Explain two possibilities of indicating the thickness in the representation in one view.

4. Quote at least three different fields of application of the dash–and–dot line!

3.3. Representation of Workpieces in Two Views

3.3.1. Principles

For shapes of workpieces which in the third dimension (in thickness) show changes in sections, at least two views are required for the definite representation. The workpiece shown in Fig. 3.8. would not be represented definitely by one view and a statement of the thickness. It calls for two views because of the stepping (shaped in Fig. 3.9.).

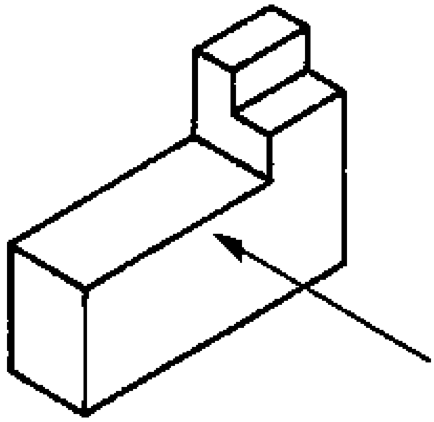


Fig. 3.8. Figure

whose cross−section can only be identified clearly in the side view. Selecting the top view as the second view would be not sensible because in this view the cross−section of the stepping cannot be seen.

For the representation in two views, it is advisable to represent

– the front view and the left side view or
– the front view and the top view.

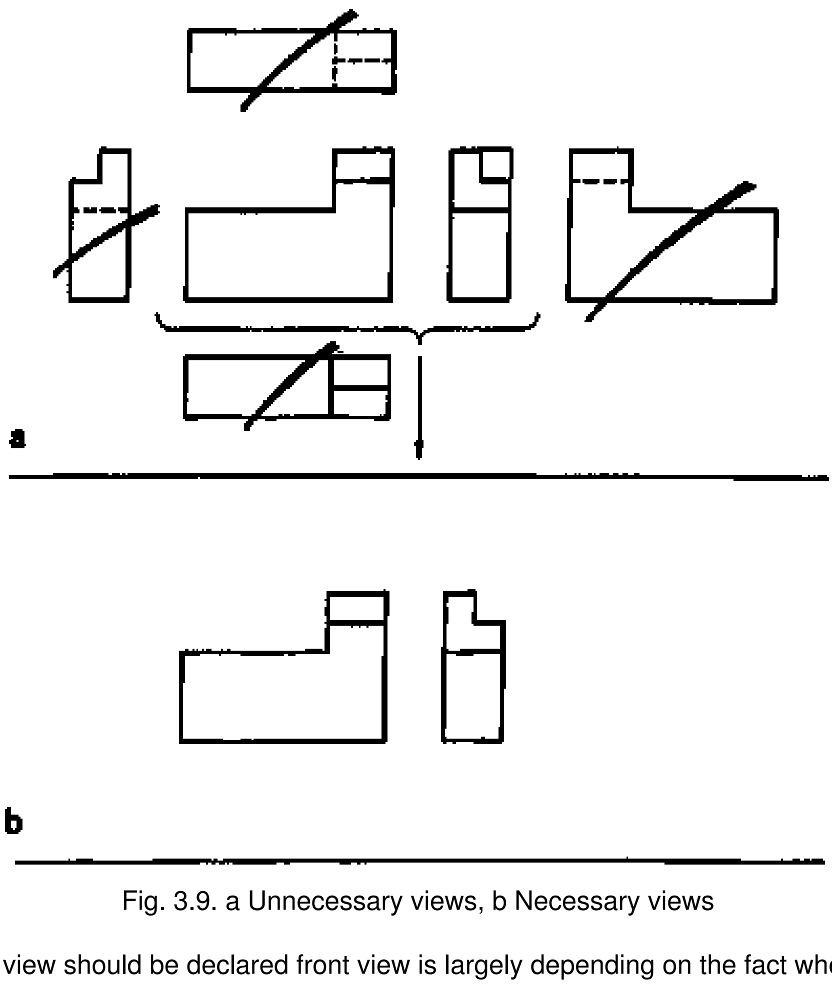


Fig. 3.9. a Unnecessary views, b Necessary views

The decision which view should be declared front view is largely depending on the fact where the shapes, which have not yet been clearly included in the front view, are best recognisable. This especially applies to cuts, break−throughs and the like because the thickness is recognisable both in the side view and in the top view.

3.3.2. Examples

An example of the representation in front view and left side view is given in Fig. 3.10, The selection of the front view is clear. It shows the typical shape of the workpiece. Because of the two steps in the side view it must be selected as shown.

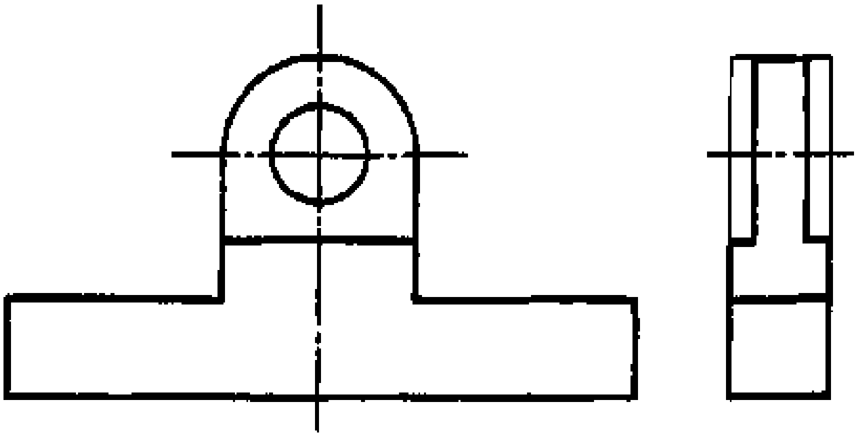


Fig. 3.10.

Another example for the representation of the front view and top view is given in Fig. 3.11. The selection of the front view is obviously clear. It shows the typical shape of the workpiece. Because of the two radii, the top view must be selected as the second view. In the side view, they would not be visible.

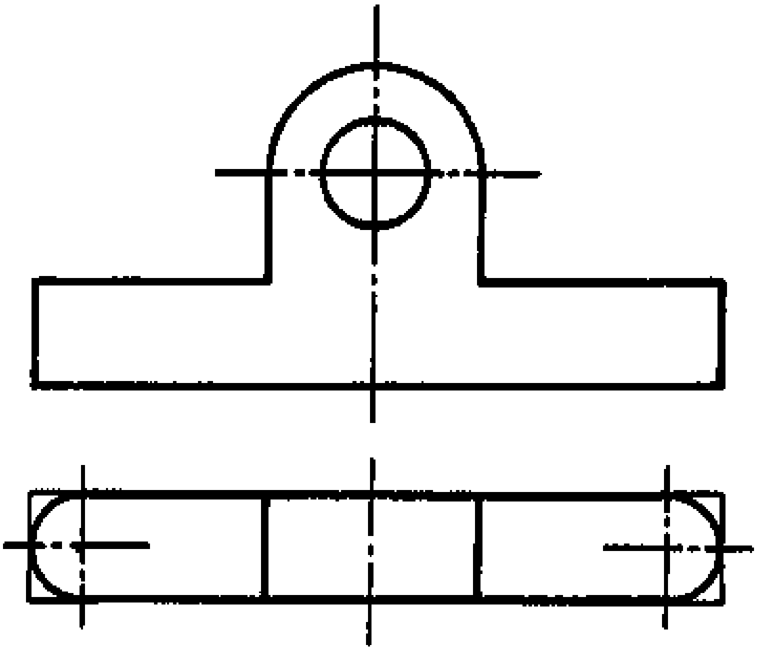


Fig. 3.11.

3.3.3. Hidden Edges

In general, hidden edges are not represented! If it is necessary to show them, then they are drawn in the form of medium−size dashed lines (see Chapter 1).

Rules:

− Dashed lines consist of short dashes of equal length and equal spaces.

– Dashed lines start and end with a dash.

– When dashed lines form a corner, the latter must be drawn with dwo dashes (see Fig. 3.12.).

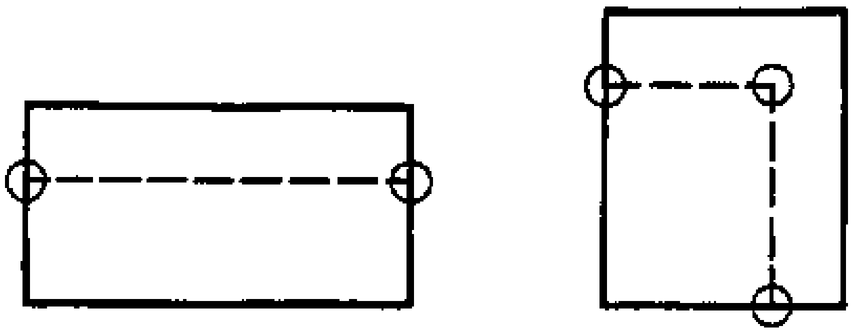


Fig. 3.12.

Hidden edges of an object are represented:

– when they are necessary for the understanding of certain shapes without confusing the representation (Fig. 3.13.).

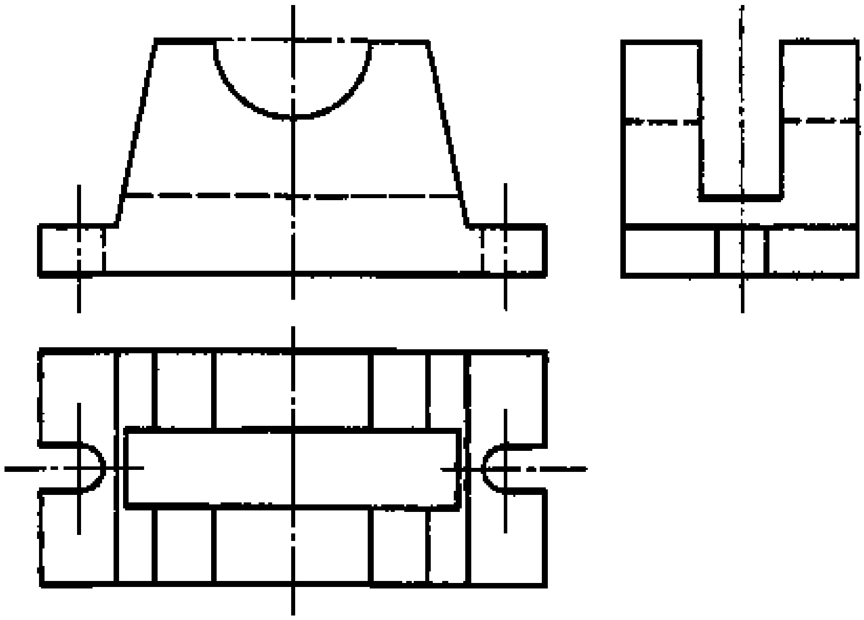


Fig. 3.13.

– when they are necessary to demonstrate the assembly (Fig. 3.14.).

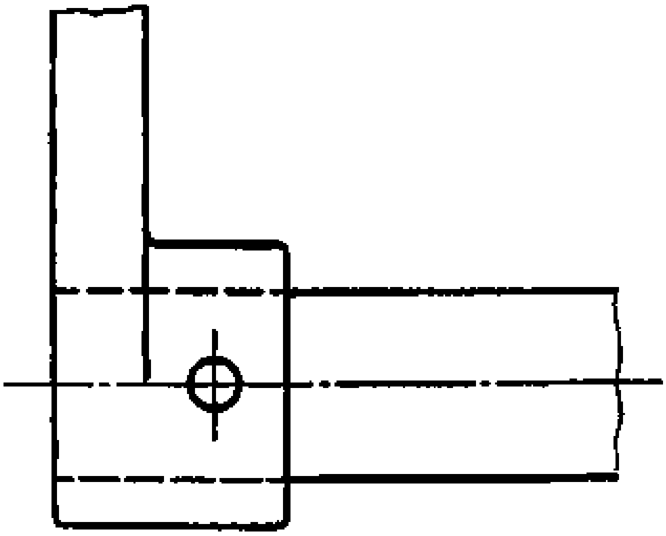


Fig. 3.14.

– when views can be omitted, i.e. drawing work can be saved as is shown in Fig. 3.15.

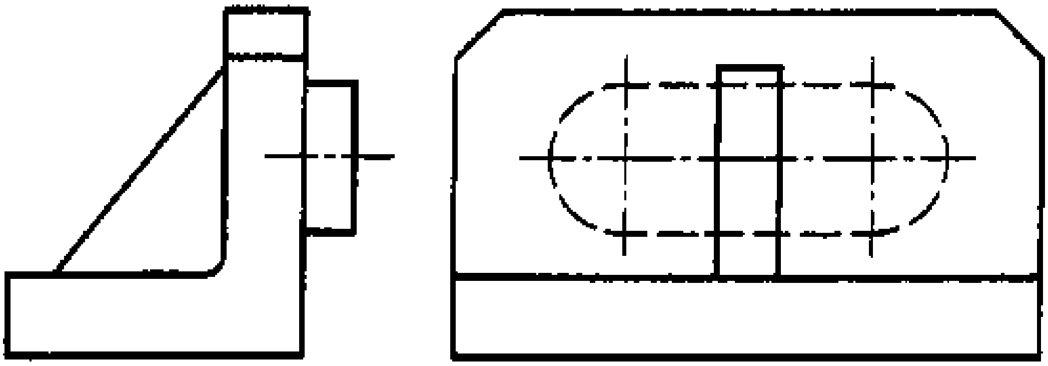


Fig. 3.15.

Repetition

1. Quote the reasons why the representation of a workpiece in at least two views is necessary.

2. What are the views that are primarily used for the representation in two views?

3. In which cases have hidden edges to be represented?

3.4. Representation of Workpieces in Three Views

3.4.1. Principles

The representation of workpieces in three views is necessary when in less views not all of the partial shapes can be seen clearly so that they are subject to but one interpretation. The angular form shown in Fig. 3.16. calls for three views. As the front view, the view in the direction of A must be selected because the angular shape is the typical shape of this workpiece. The width of the workpiece and the partial shapes of radius and drill–hole at the vertical leg can be seen in the left side view (B). But this not clearly shows the shape of the horizontal leg. Therefore, the top view is necessary (c) which is shown in Fig. 3.17.

The representation in three views usually is effected in the front view, the side view and the top view.

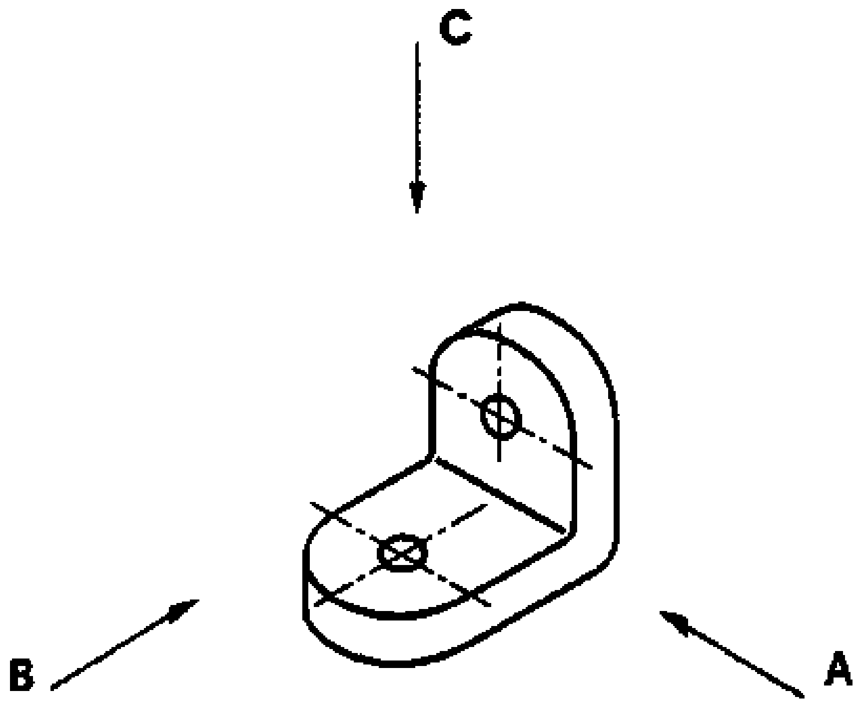


Fig. 3.16.

3.4.2. Further Examples for the Representation of Workpieces in Three Views

The shape of certain workpieces may be so that other views than those of the regular case have to be shown together with the front view.

There are three possibilities which are shown in Fig. 3.18.

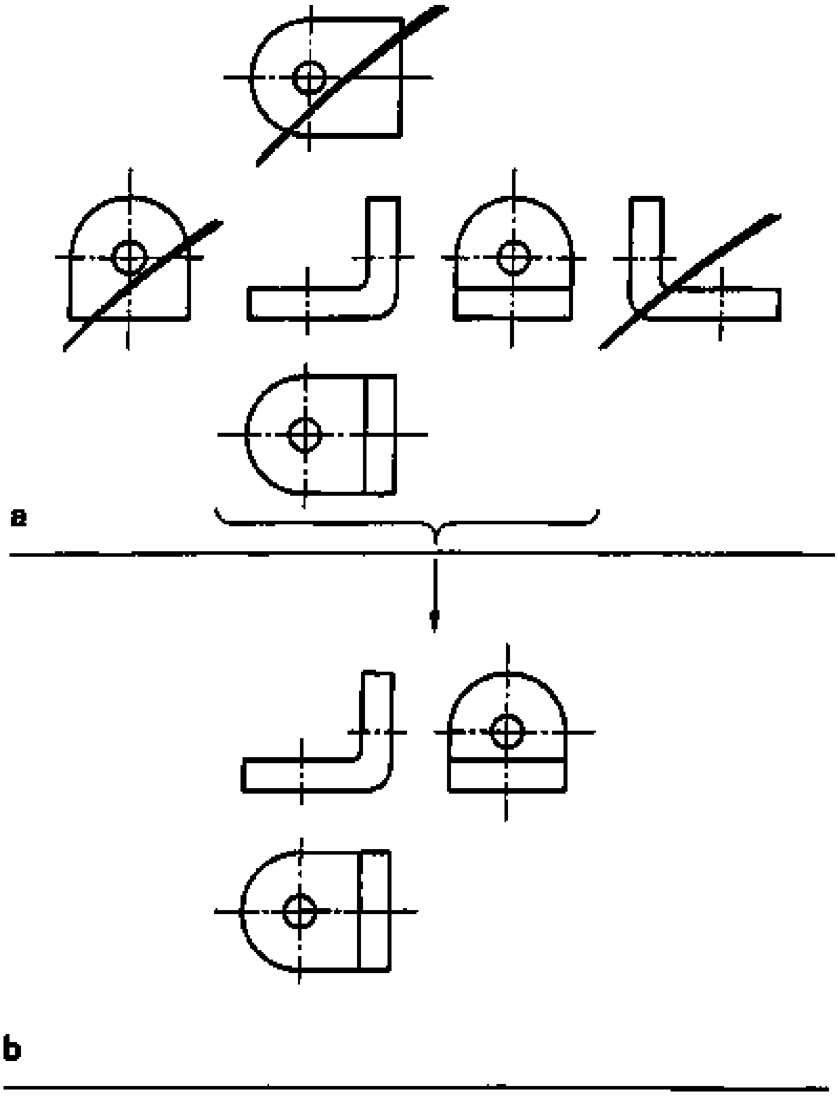


Fig. 3.17. a Unnecessary views, b Necessary views

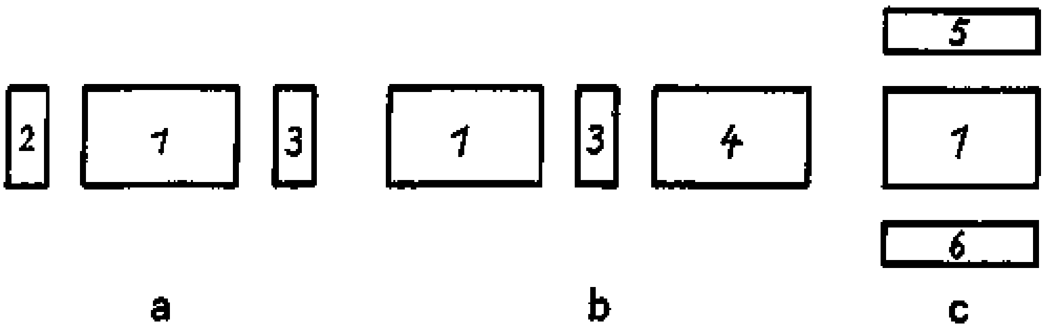


Fig. 3.18.

1 Front view, 2 Right side view, 3 Left side view, 4 Rear view, 5 Bottom view, 6 Top view

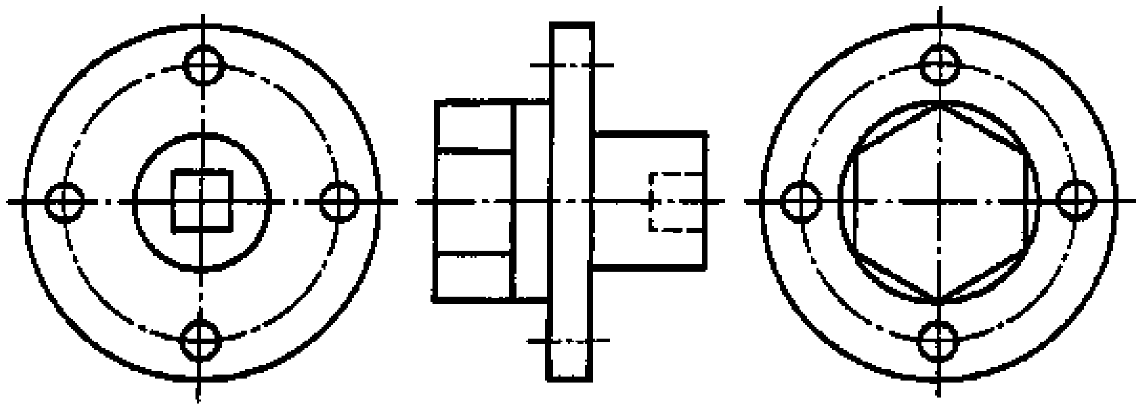


Fig. 3.19.

An example of the first possibility is given in Fig. 3.19. The two side views show essential partial shapes which cannot be represented so clearly in any otherway.

Fig. 3.20. shows the second possibility where an arrangement according to the third possibility is also imaginable. In this case the bent shape of the plate had to be arranged horizontally as front view and the top view and bottom view would be added.

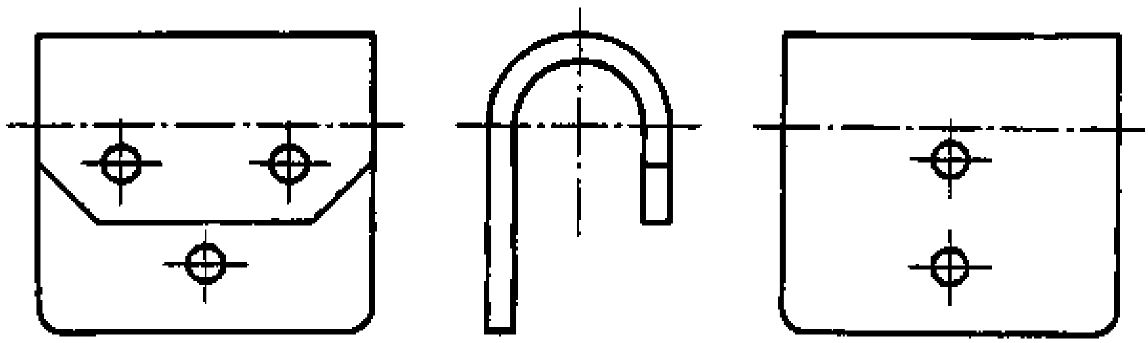


Fig. 3.20.

The third possibility is shown in Fig. 3.21. It is also possible to represent this workpiece vertically in the front view together with the two side views. There are, however, essential reasons for the horizontal arrangement which are dealt with in Section 3.6.

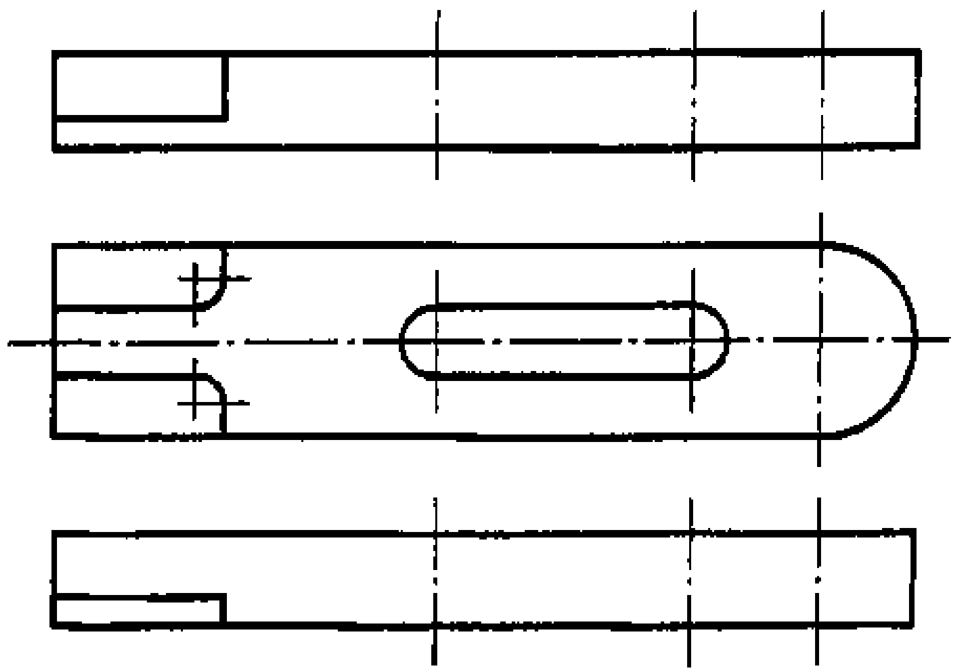


Fig. 3.21.

Repetition

1. Which shapes of workpieces call for a representation in three views?

2. Quote the usual and the possible views which are used for the three−view representation.

3.5. Representation of Workpieces in More Than Three Views

In a few cases, the shape of the workpiece calls for more than three views in order to ensure a representation which is subject to but one interpretation. This applies to bent sheet−metal parts of intricate shape, to parts of housings which have to accommodate other parts from several sides, and to assembly drawings of various devices. The following Figs. 3.22. to 3.24. show a typical example each.

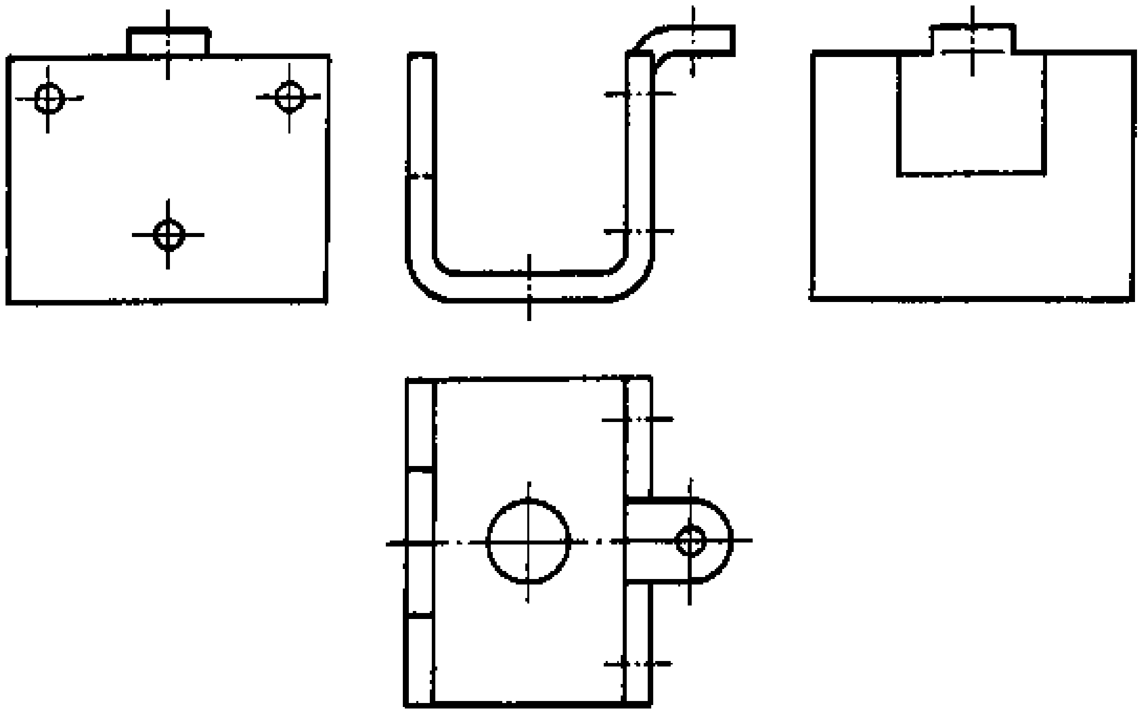


Fig. 3.22. Holding plate in four views

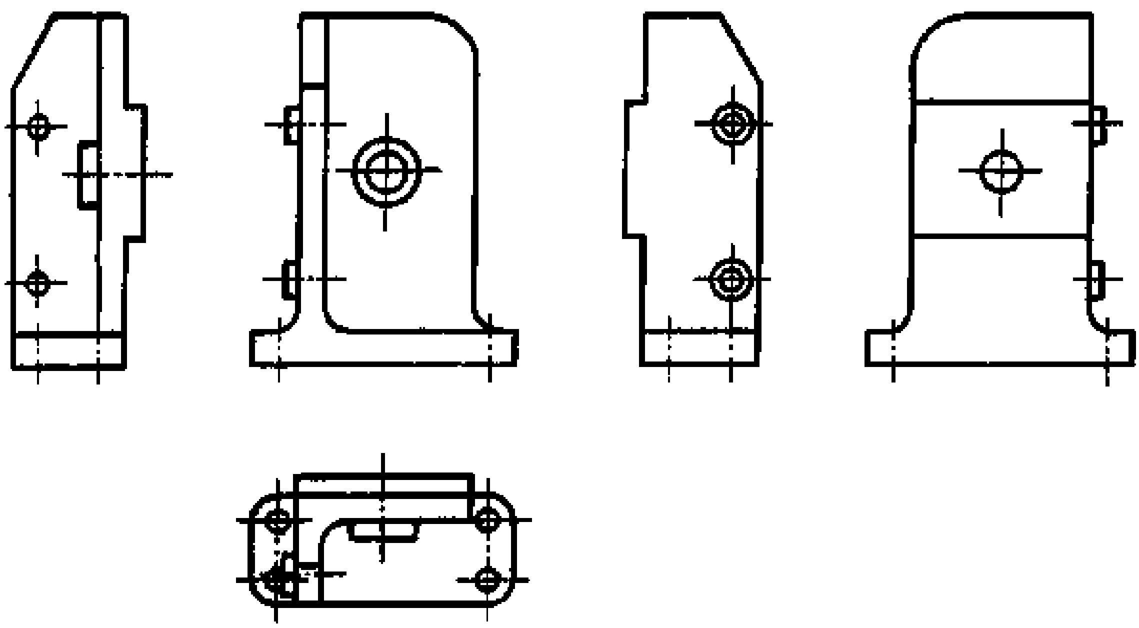


Fig. 3.23. Cast−iron casing in five views

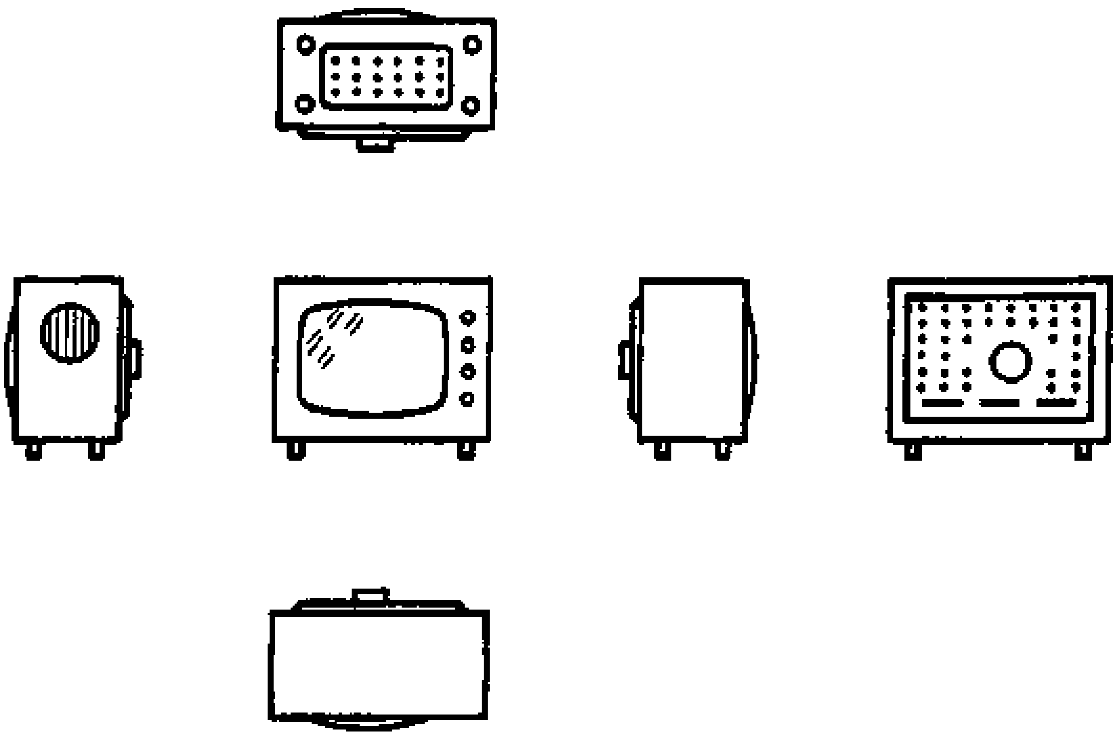


Fig. 3.24. Television set in six views

3.6. Workpiece Position

In order to visualise better the technical representation of a workpiece, it is advisable to observe certain rules for the position of the workpiece on the drawing sheet when preparing the engineering drawing. Usually, workpieces are located in the manufacturing position or in the position of use on the drawing sheet.

From this, the following possibilities result:

– Individual parts with a clear manufacturing position are drawn in this position. This applies to parts to be turned in a lathe, parts to be milled and parts to be planed as is shown in Figs. 3.25. to 3.27.

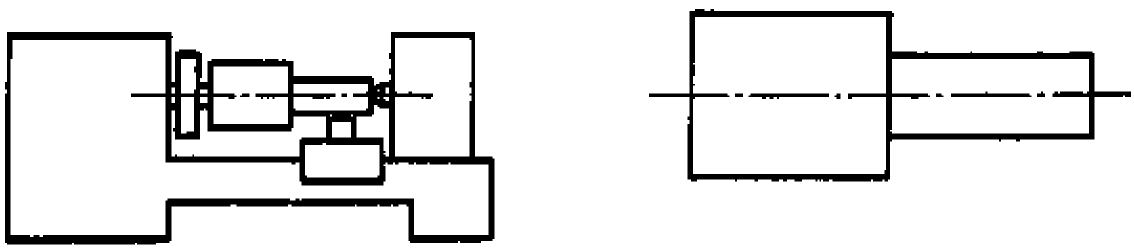


Fig. 3.25. Horizontal machining position (part to be turned)

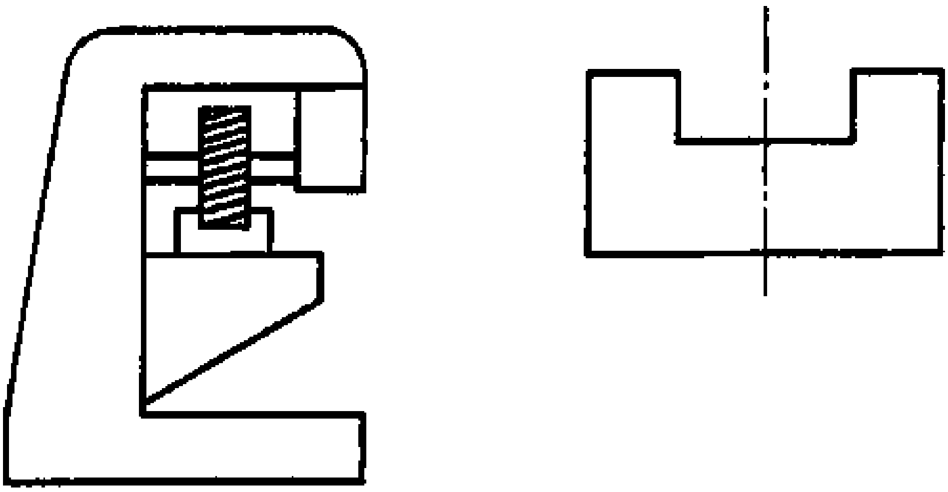


Fig. 3.26. Vertical machining position (part to be milled)

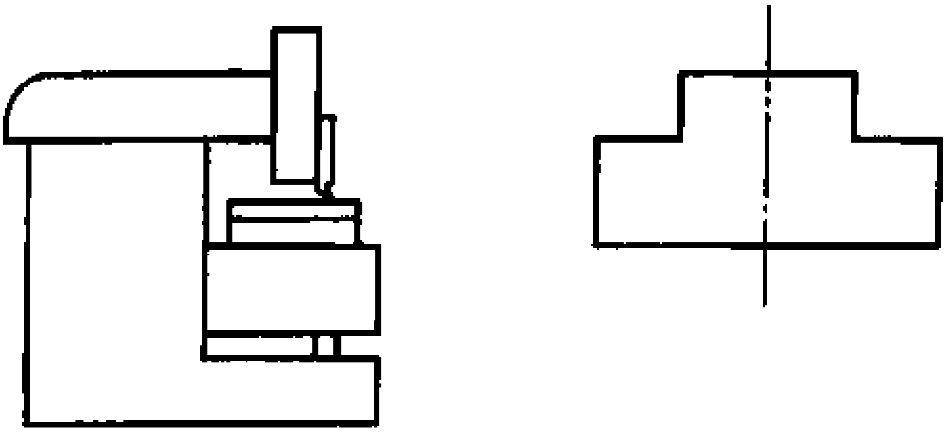


Fig. 3.27. Vertical machining position (part to be planed)

– Individual parts where the manufacturing position cannot be clearly defined but which have a preferential position of use are drawn in this position of use. This, for example, applies to castings and parts to be formed shown in Figs. 3.28. and 3.29.

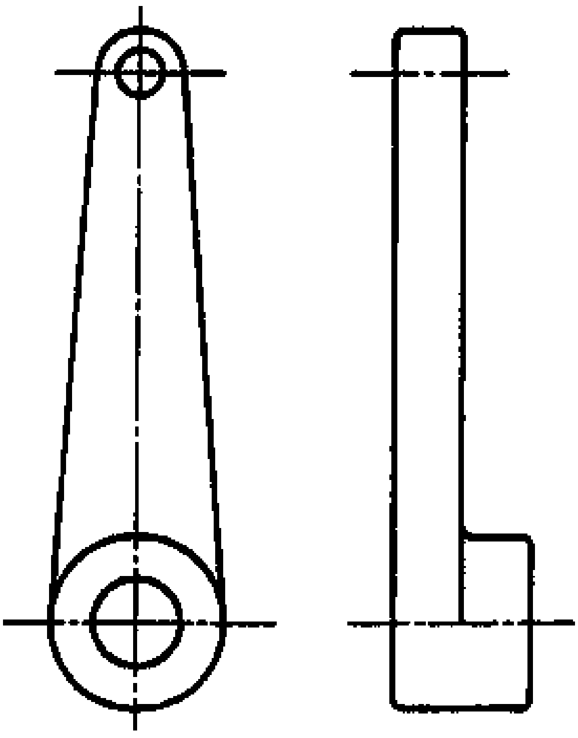


Fig. 3.28. Casting (lever) in position of use

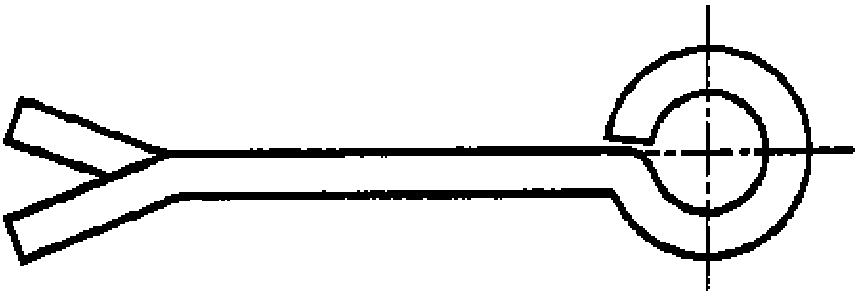


Fig. 3.29. Bent part in position of use

– Individual parts with an oblique position of use are drawn vertically or horizontally as is shown in Fig. 3.30.

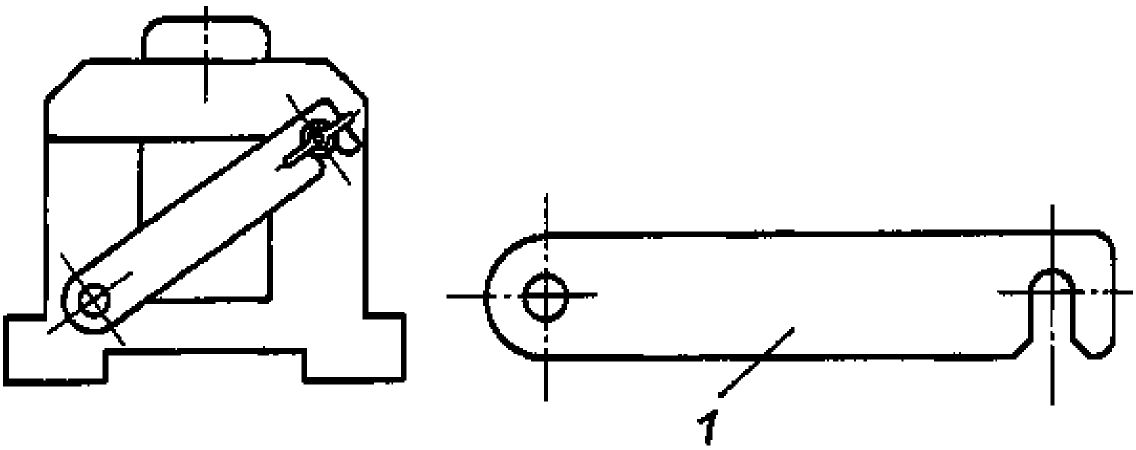


Fig. 3.30. Lock of a fixture in oblique position of use

1 Position on the drawing sheet

– For individual parts where the manufacturing position or the position of use is insignificant or cannot be determined clearly, the arrangement on the drawing sheet is governed exclusively by points of view of drawing techniques. Thus, the plate jig shown in Fig. 3.31. is represented in the main view where the drill–holes are exposed to the eye although it is made and used in the horizontal position.

The rule that the most informative view is to be selected as the front view has priority over the arrangement according to manufacture or use! (see Fig. 3.31.)

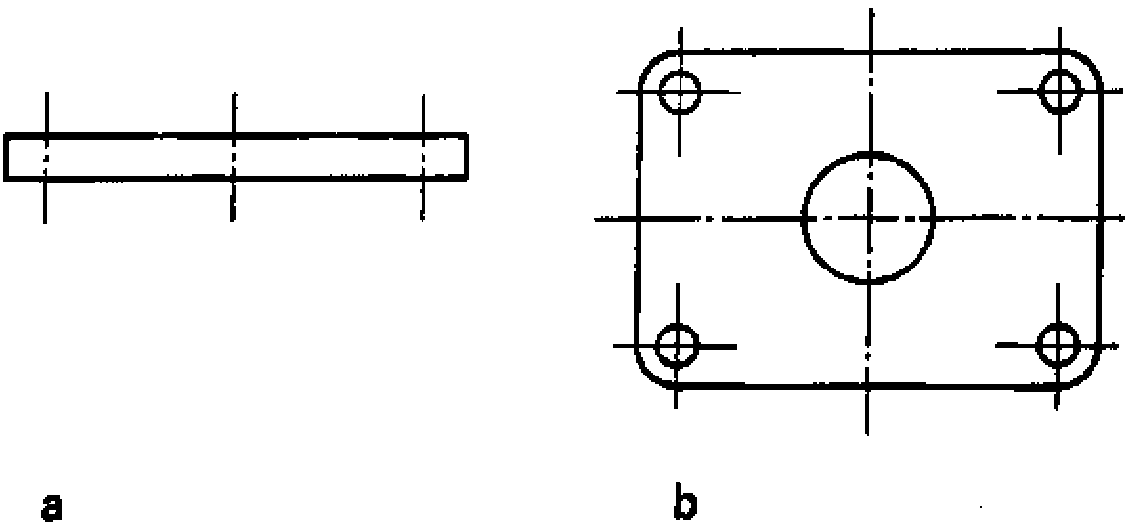


Fig. 3.31. Plate jig

a Machining position and position of use, b Engineering drawing

– Overall plants and assemblies are represented in the position of use or in the main position of use. Examples are given in Figs. 3.24., 3.25. to 3.27.

Repetition

1. Explain the terms "manufacturing position" and "position of use" of a workpiece.

2. In what way have manufacturing position and position of use to be taken into consideration in the representation of a workpiece?

4. Representation and Dimensioning of Simple Workpieces with Prismatic and Cylindrical Basic Shape

4.1. Basic Elements of Dimensioning

In order that a technical object can be manufactured so that it fulfils its function, its drawing must be clearly and completely dimensioned.

The dimensions always refer to the final condition of the drawn part.

Points of view for dimensioning are: the fabrication, the function and in many case also the testing of the part. Linear measures are entered in millimetres but without the statement of the unit of measure. In exceptional cases, the unit of measure must be entered.

Angular measures must be provided with the unit of measure of degree (°).

For dimensioning a drawing, four basic elements are used (see Fig. 4.1.):

the dimension line,
the extension line,
the arrowhead,
the dimension figure.

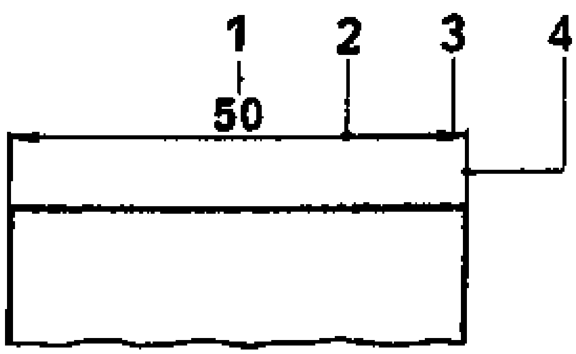


Fig. 4.1.

1 Dimension figure
2 Dimension line
3 Arrowhead
4 Extension line

4.1.1. Dimension lines

The dimension line is a thin solid line which indicates the dimension:

– directly between the body edges where the true shape appears (Fig. 4.2.) or
– outside of the object parallel to the dimension (Fig. 4.3.).

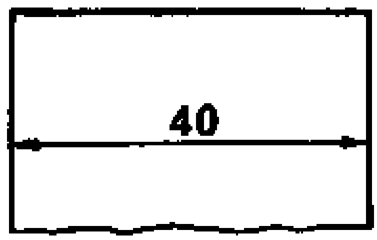


Fig. 4.2.

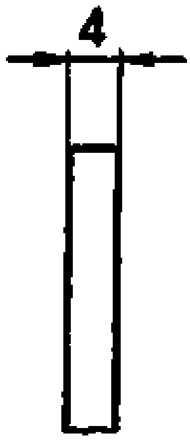


Fig. 4.3.

This indirect arrangement of the dimension line is frequently used because the clearness of the drawing is improved. Body edges and centre lines must not be used as dimension lines!

The distance of the dimension line from the body edge should be at least 8 mm, the distance between dimension lines should be at least 6 mm (see Fig. 4.4.).

Dimension lines must not cross each other.

For the statement of angular measures and arc measures, the dimension line has the form of an arc is shown in Fig. 4.5.

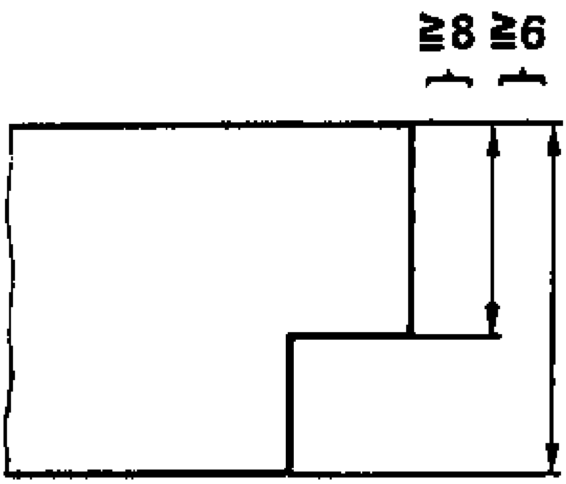


Fig. 4.4.

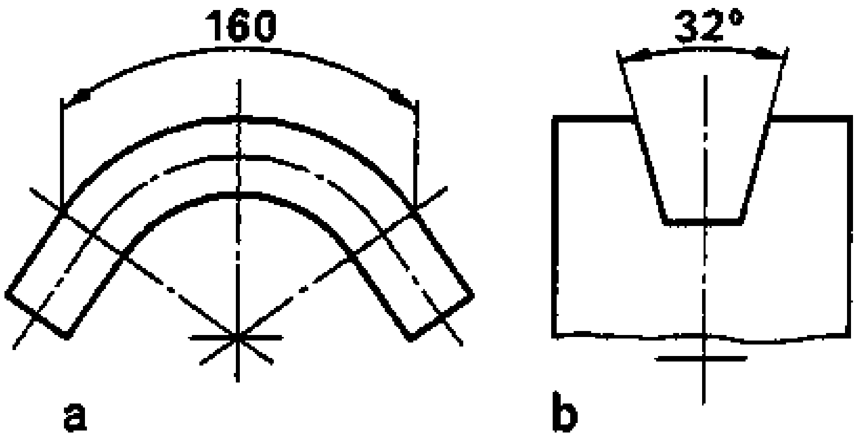


Fig. 4.5.

a Circular measure,
b Angle measure

4.1.2. Extension lines

Extension lines are thin solid lines. With the help of these lines, dimension lines are arranged outside the represented object. We start from the body edges at right angle to the dimension line – with a few exceptions, e.g. circular measure, and extend the line 1 mm to 2 mm beyond the dimension line (see Fig. 4.6. and 4.7.). Extension lines should be drawn so they will not cross one another.

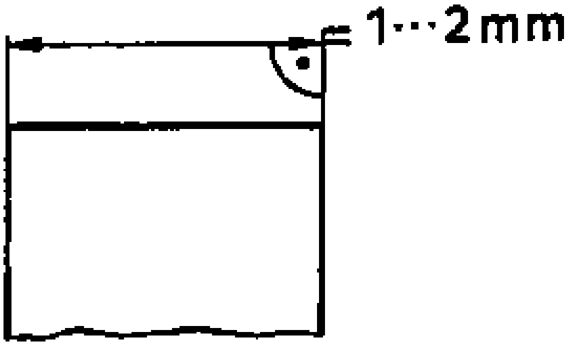


Fig. 4.6.

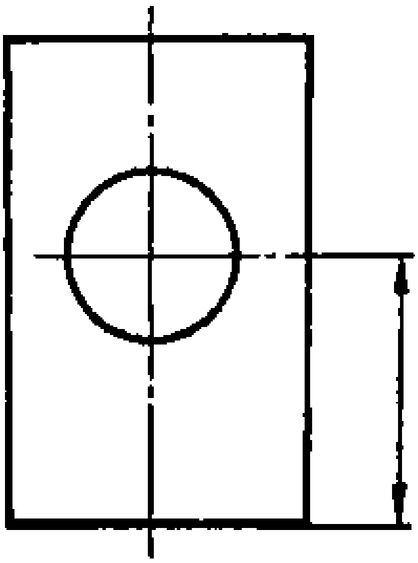


Fig. 4.7.

They must not be drawn out of two views for a dimension. It is not allowed to draw it from one view through the other, when centre lines are used as extension lines, they must be drawn as thin solid lines beyond the representation (Fig. 4.7.). To improve readability, the extension line may form an angle of 60° with the dimension line in exceptional cases, as is shown in Fig. 4.8.

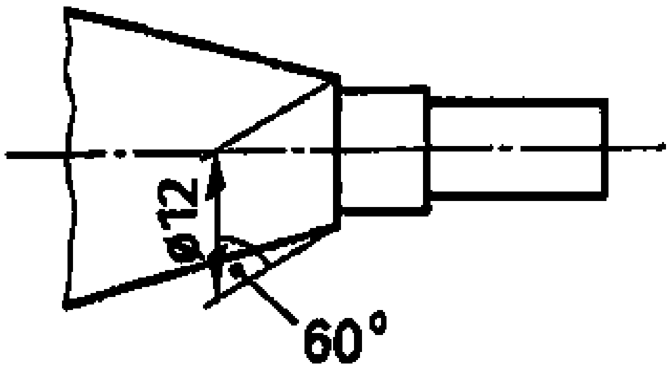


Fig. 4.8.

4.1.3. Arrowheads

The arrowheads terminate dimension lines and their points limit the dimension. The length of the arrowhead is approximately fife times the line width of the body edge. The legs of the arrowhead form an angle of about 15°. The solid type arrowhead should be preferred as shown in Fig. 4.9. when room is limited, a dot may be used instead of the arrowhead as is shown in Fig. 4.10.

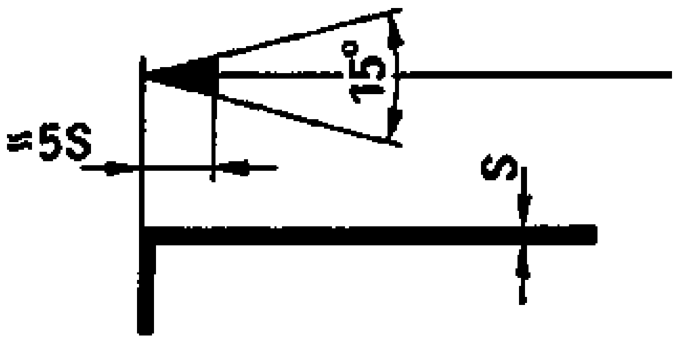


Fig. 4.9.

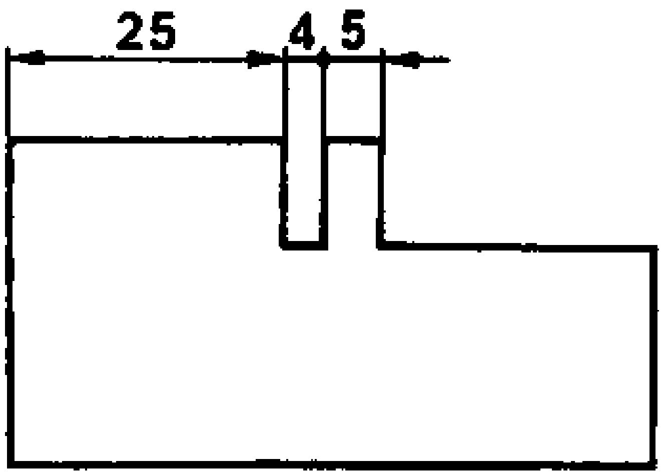


Fig. 4.10.

For radii (see in Section 4.2.), the limitation of the dimension is effected by an arrowhead and the indication of the centre (see Fig. 4.11.).

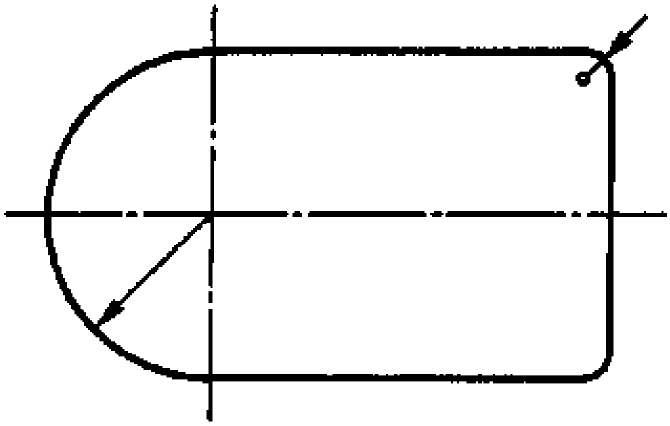


Fig. 4.11.

4.1.4. Dimension Figures

The dimension figure indicates the size to be observed by the manufacturer, The dimension figures have to be shown on drawings in the specified style lettering so clearly that they can be interpreted in only one way.

These figures have a uniform size of at least 3 mm in height and must not be separated by lines or crossed by them. The dimension figure is always located at a short distance above the dimension line.

Usually it is placed in the centre of the dimension line. If, in case of very small dimensions, room is very limited, the dimension figure is located laterally above the arrowhead as is shown in Fig. 4.12.

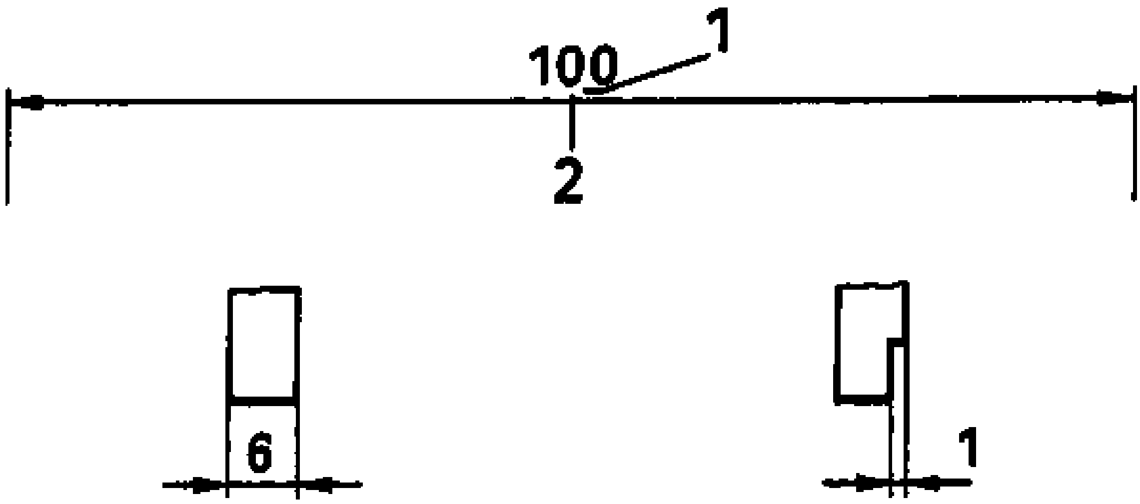


Fig. 4.12.

When several parallel dimension lines are required, stagger the dimension figures or numerals (see Fig. 4.13.) because this will improve readability.

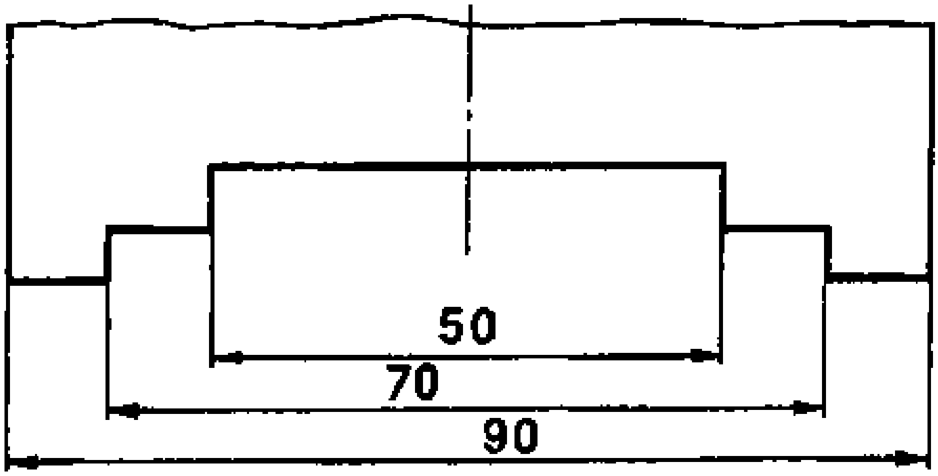


Fig. 4.13.

All dimension figures are placed so that they can be read from the bottom and right–hand edge of the drawing in the usual position of use of the latter. Readability from the bottom is the main reading direction of dimensions (see Fig. 4.14.).

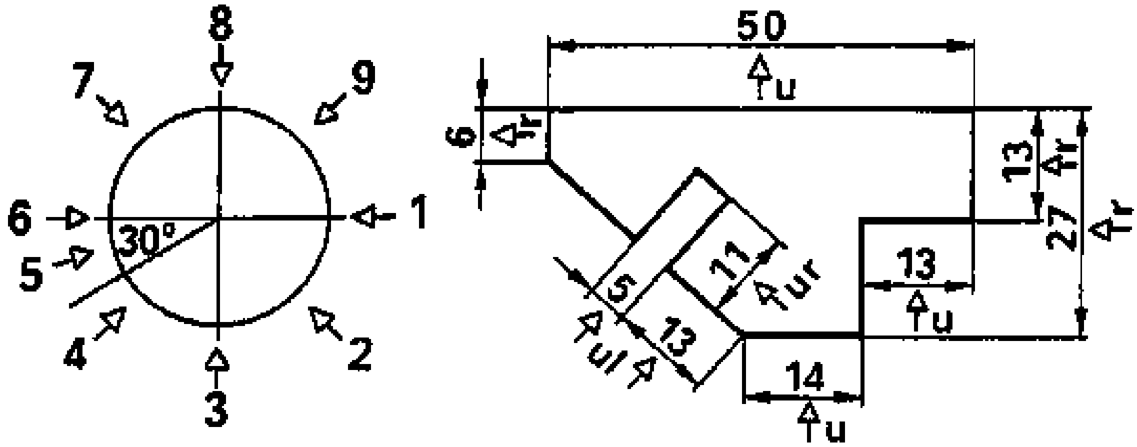


Fig. 4.14. Readability of the dimension figures

Readable from: 1 the right, 2 bottom right, 3 bottom, 4 bottom left, 5 bottom left at an angle of 30° should be avoided, 6 the left, 7 top left, 8 top, 9 top right

Centre lines and shade lines, also known as section lines, are interrupted (Chapter 5) for the dimension figure as is shown in Fig. 4.15.

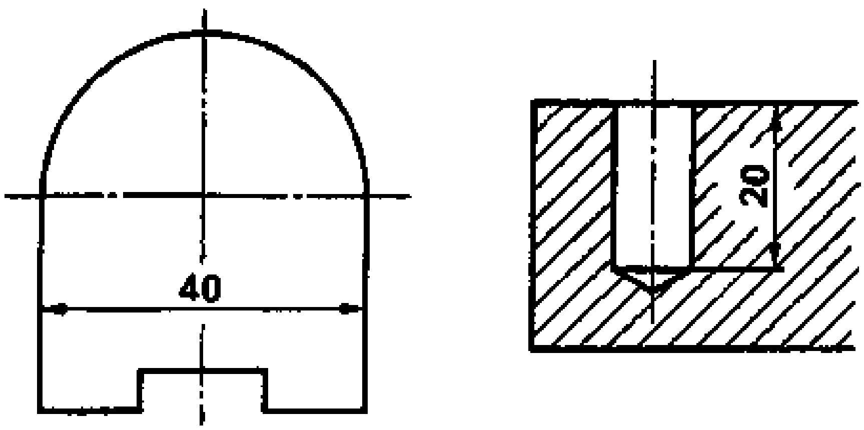


Fig. 4.15.

An arbitrary use of dimension figures in designing would entail considerable economic disadvantages in manufacture and testing. An irresponsible number of tools and gauges had to be kept. In order to avoid this, preferred dimensions are specified for dimensional figures.

Preferred dimensions are defined as a decimal–geometrically stepped series of numerals which permits the necessary variety in designing and which is shown in Fig. 4.16.

Fig. 4.16. Preferred numbers, selection

1		1,2		1,6		2		2,5		3		4		5		6		8	
10	11	12	14	16	18	20	22	25	28	32	36	40	45	50	55	60	70	80	90
100	110	125	140	160	180	200	220	250	280	320	360	400	450	500	550	630	710	800	900

Repetition

1. Quote the basic elements of dimensioning.

2. What is the type of line to which dimension lines and extension lines are added?

3. What are the distances to be observed between dimension line and body edge or between parallel dimension lines?

4. Describe the shape of the arrowhead used in dimensioning.

5. Explain the rules for the location of the dimension figures in a drawing.

4.2. Special Elements of Dimensioning

The term "special elements of dimension" was introduced to distinguish these elements from the basic elements. But the former are very frequently used in engineering drawing. Usually, these special elements are additions indicating shapes which help to perceive the shape more easily and rapidly. In certain cases less views are required and labour can be saved in drawing.

4.2.1. Diameter Sign

Any diameter dimension of a cylindrical shape is provided with a diameter symbol in front of the dimension figure.

This sign is a circle having a diameter of 5/7 h and a stroke inclined by 75° which is drawn through the centre of this circle and has a height h that is specified.

The diameter sign is located about the centre of the height of the dimension figure (see Fig. 4.17.).

When the shape of the circle is readily perceivable and the dimension is entered in or at the circle, then the diameter sign is an additional indication of the shape in question (see Fig. 4.18.).

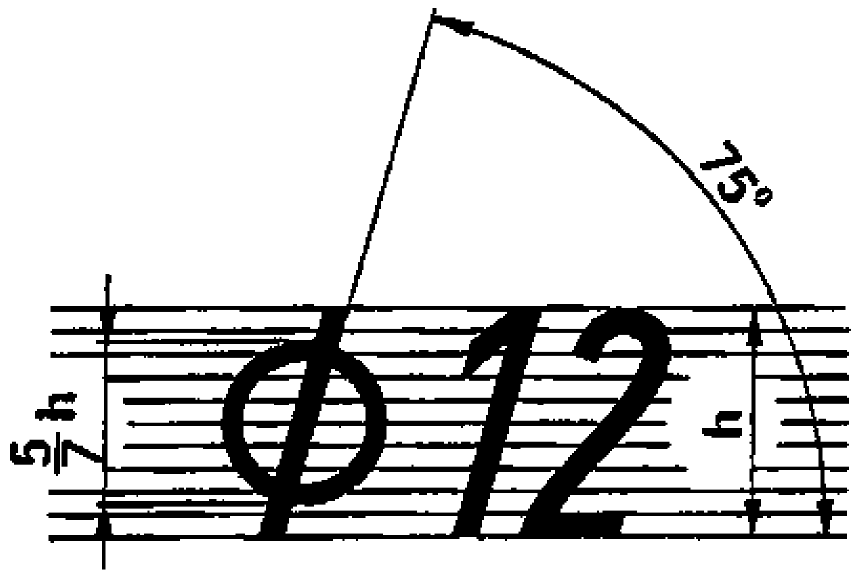


Fig. 4.17.

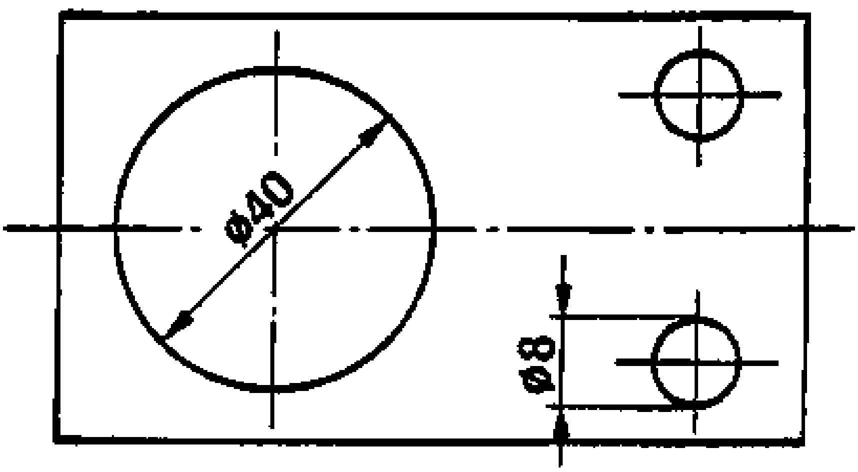


Fig. 4.18.

When the circular shape is incomplete, dimensioning may be effected in the manner shown in Fig. 4.19.

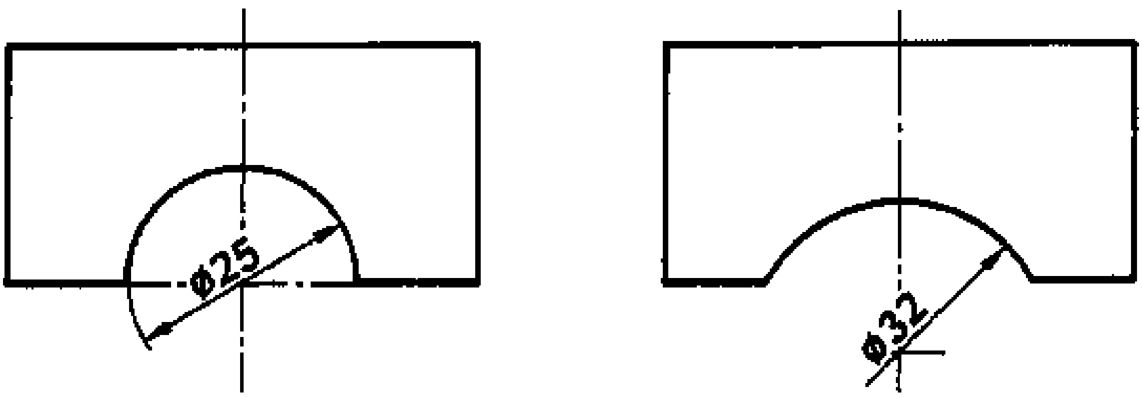


Fig. 4.19.

If the circular shape cannot be perceived readily, it is not necessary to drawn another view because the diameter sign indicates exhaustively the cylindrical shape (see Fig. 4.20.).

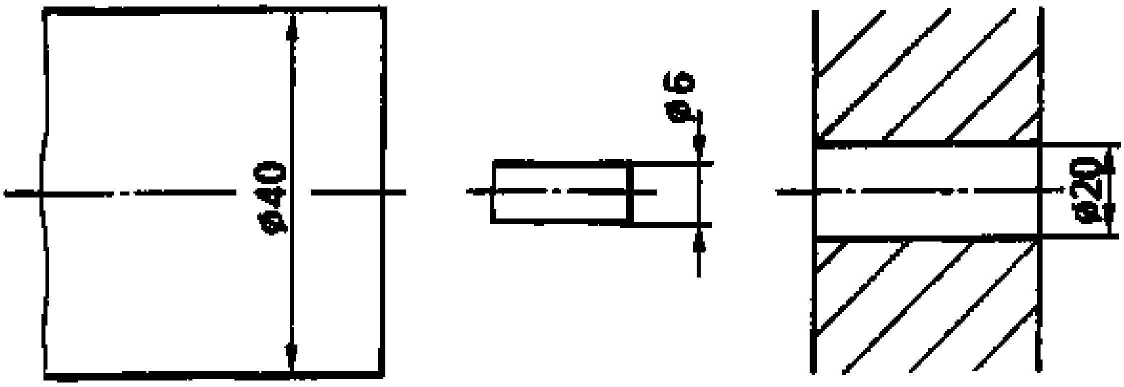


Fig. 4.20.

In case of lack of room or for reasons of a simplification of drawing, the diameter dimension may be placed outside the view with the help of a reference line or leader. The leader starts with a dot as is shown in Fig. 4.21.

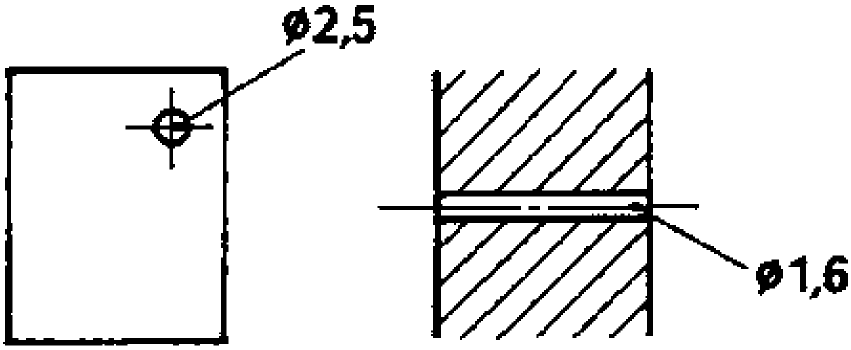


Fig. 4.21.

Repetition

1. In which cases is the diameter sign used?

2. Explain the shape and position of the diameter sign.

4.2.2. Square Sign and Diagonal Cross

The square sign indicates a square shape.

The square sign is placed in front of the dimension figure. It is a square having a side length of 5/7 h and is located in the centre of the height of the dimension figure (see Fig. 4.22.).

Fig. 4.22.

With the help of the square sign, one view can be omitted as is shown in Fig. 4.23.

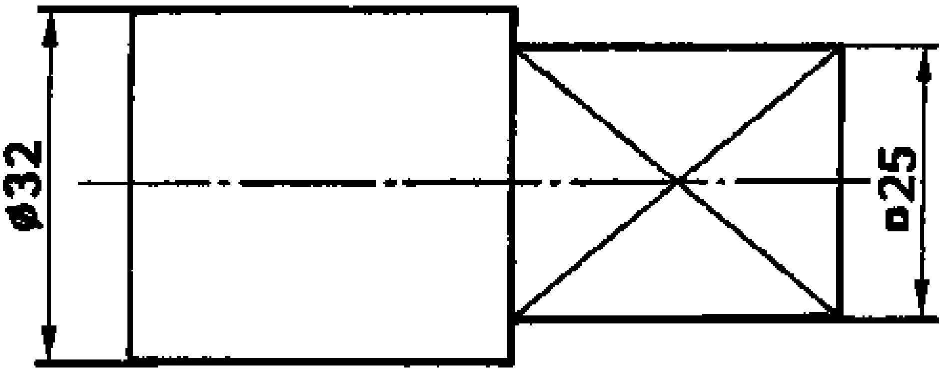


Fig. 4.23.

If it is necessary to show several views, the perceivable square section is dimensioned without an additional square sign by means of two dimensions as is shown in Fig. 4.24.

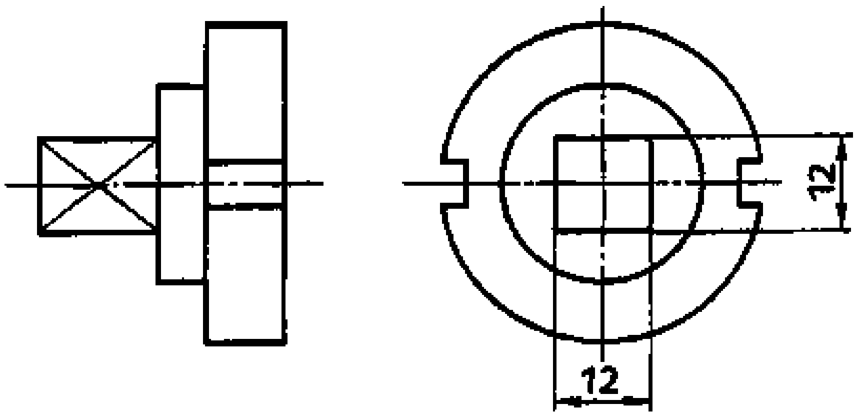


Fig. 4.24.

The Figs. 4.23. and 4.24. show how an additional indication of shape is given in the form of a diagonal cross (thin solid lines).

Plane surfaces which serve as key surfaces are marked by a diagonal cross. This also applies to square pyramidal shapes.

See also Figs. 4.23., 4.24. and 4.25.

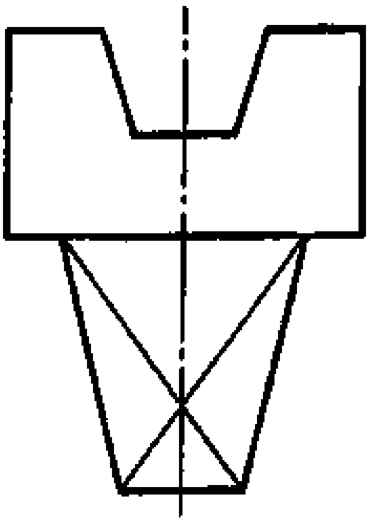


Fig. 4.25.

The diagonal cross must be shown when a representation is given in one view (Fig. 4.23.)! It may be used when an object is represented in several views to increase visualisation (Fig. 4.24.).

In a representation of standardised screws with hexagonal heads, the diagonal cross is not drawn!

Repetition

1. Explain form and position of the square sign.

2. Tell the cases when the square sign is to be used.

3. What is the indication given by the diagonal cross?

4.2.3. Width Over Flats

Width over flats is defined as the distance across two parallel flats of a nut or screw for the application of a wrench.

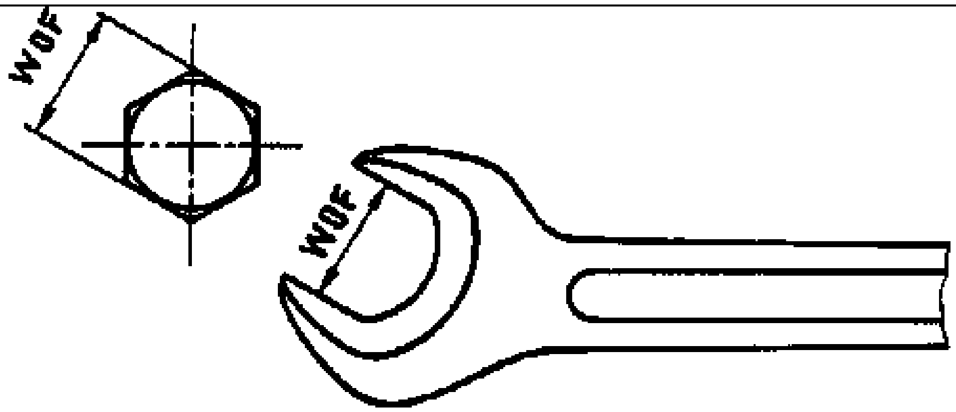


Fig. 4.26. Width over flats (WOF)

For a simplified dimensioning of the width over flats, the letters WoF may be put in front of the dimension figure. A leader with a dot at the beginning starts at the flat and extends to the dimension figure. When WoF is indicated, a view can be omitted! The surface is provided with a diagonal cross as is shown in Fig. 4.27. The abbreviation WoF must be defined, however, for the reader of the drawing.

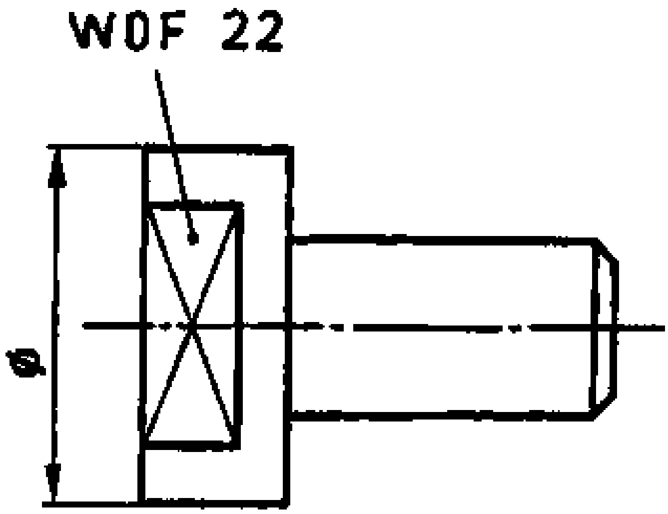


Fig. 4.27. Width over flats “22” (WOF 22)

Repetition

1. What means the abbreviation WoF in front of a dimension line and what are the advantages of its use?

4.2.4. Radius Sign

Radiusing on workpieces is a frequently used procedure. Frequently this is due to the machining operation. For example, the manufacturing processes casting, forging and bending call for round corners. In addition, parts with radii are more convenient in use and the risk of hurts is reduced.

Before the dimension figure, an R is written! R means radius. The dimension line of the radius numeral is provided with an arrowhead at the circular arc. (An alternate method specified in standards of various countries is writing the R behind the dimension figure.)

The arrowhead for dimensioning should be drawn from inside to the arc. When room is lacking, the arrowhead may be placed from outside to the circular arc. In this case, the dimension line is drawn through to the centre (see Fig. 4.28.).

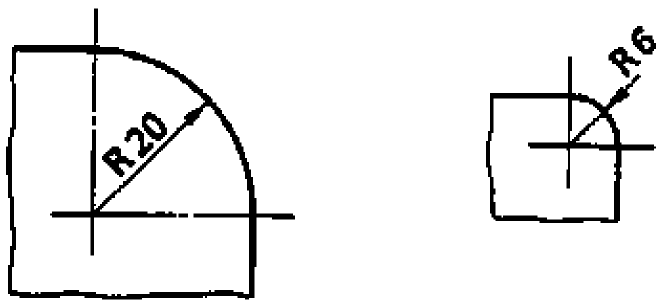


Fig. 4.28.

– Radius dimensions with indication of the centre: The centre may be indicated in the way shown in Fig. 4.29.

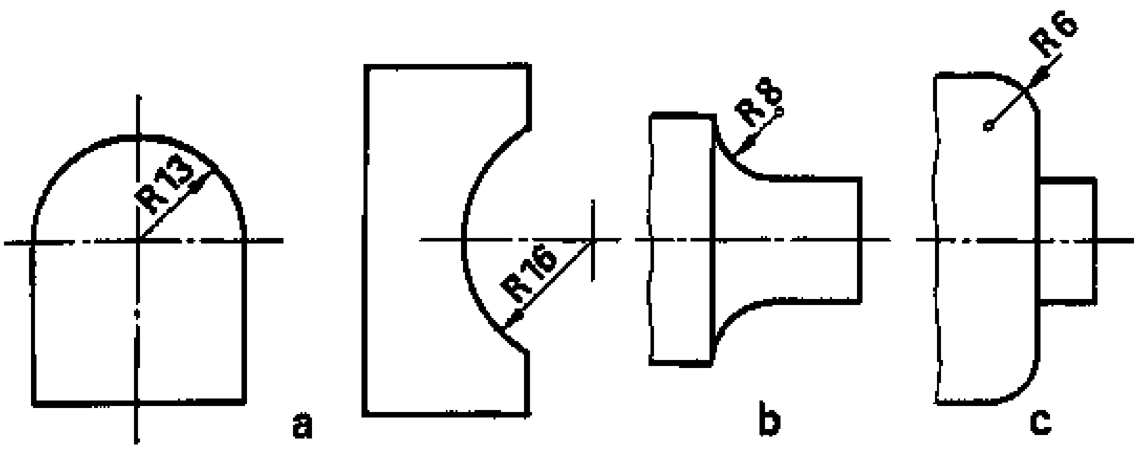


Fig. 4.29.

a Centre line cross, b Circle, c Point

If several radii have a common centre, then a small auxiliary circular arc is drawn about this centre where the dimension lines end (see Fig. 4.20.).

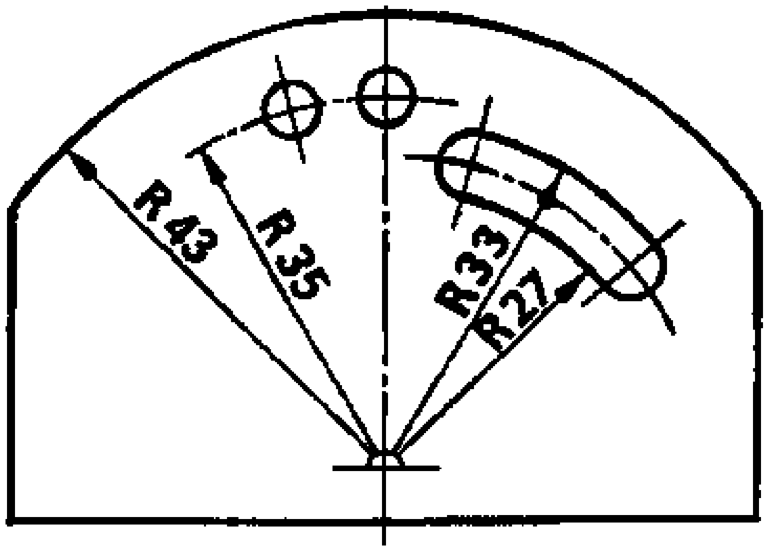


Fig. 4.30.

In certain cases there is the necessity of dimensioning the position of the centre of a very large radius. This is the case when this centre is located beyond the drawing sheet or in another view. It is “fetched” by a double 90° – kink of the dimension line. That part of the dimension line which carries the arrowhead points in its extension to the true centre and is provided with the dimension figure (see Fig. 4.31.).

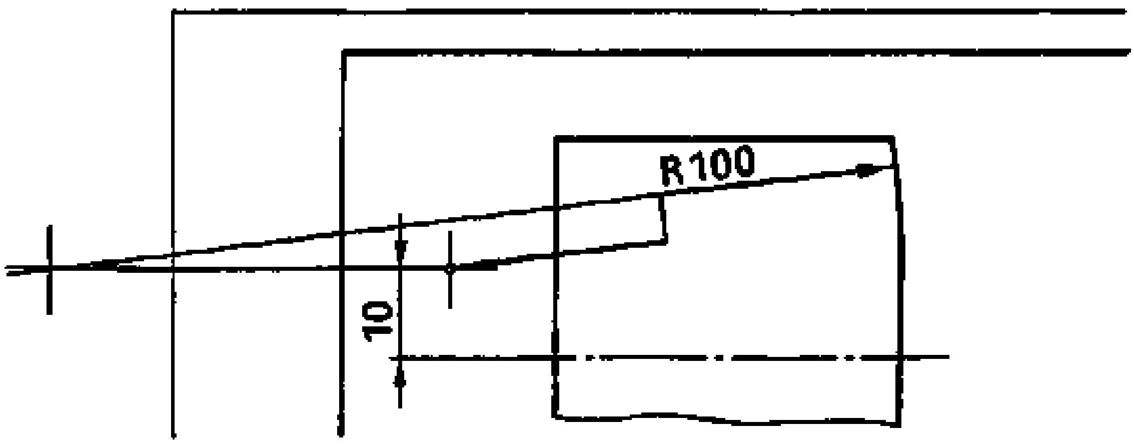


Fig. 4.31.

– Radius dimensioning without indication of the centre: When room is lacking, only very small radii may be drawn without centre (Fig. 4.32.). For castings and forgings having a great number of the same radii, a general indication is allowed.

For very large radii whose centre location cannot be dimensioned in the way shown in Fig. 4.31., the dimension lines must be drawn shortened (Fig. 4.33.).

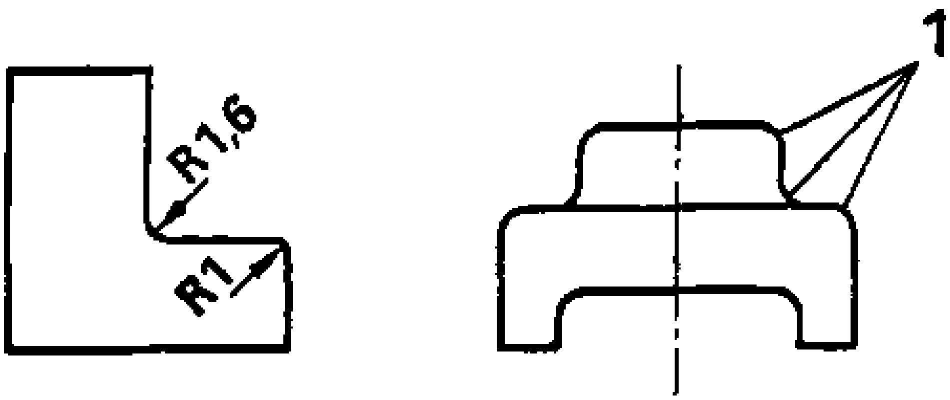


Fig. 4.32.

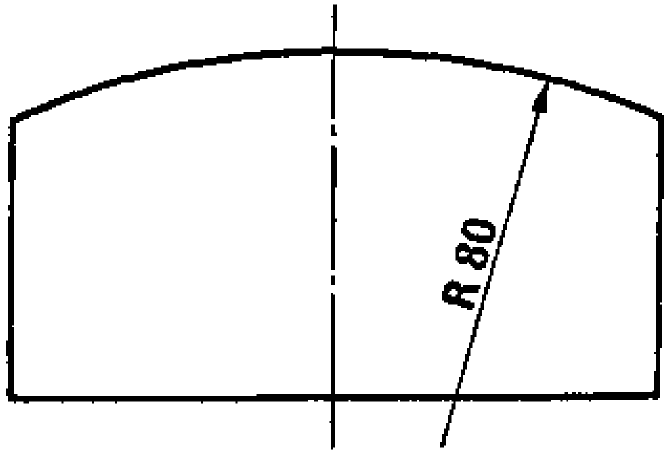


Fig. 4.33.

for all radii R is equal to 2.5.

Repetition

1. How are all of the radius dimensions to be indicated?

2. Describe the possibilities of marking the centres of radii.

3. What is the dimensioning rule for very large radii whose centres are beyond the drawing sheet?

4.2.5. Dimensioning Spheres

For spherical shapes, the dimension of the diameter or of the radius is provided with the word “sphere” (Fig. 4.34.) having the same height as the dimension numerals in front of the latter.

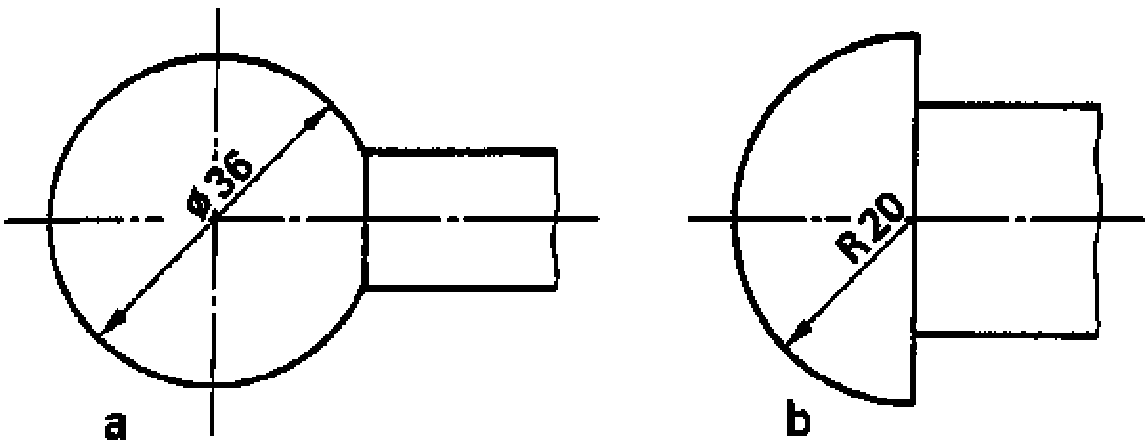


Fig. 4.34.

× shere 60 in dia./shere radius 20

Lentil heads on screw, bolt or pin ends which, considered geometrically, are spherical segments (Fig. 4.35.) are not dimensioned. If they have a special function, they have to be dimensioned with a radius dimension without the addition “sphere”.

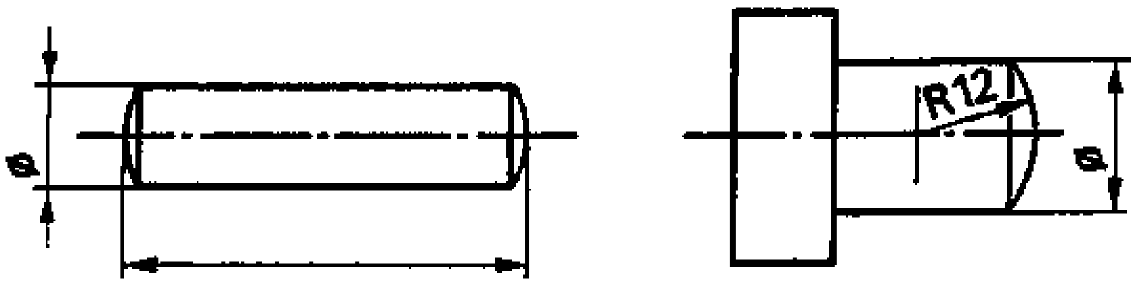


Fig. 4.35.

4.2.6. Dimensioning Angles

Surfaces in an inclined position with respect to each other can be dimensioned in different ways in accordance with their function.

Usually, the angle is dimensioned with a circular dimension line and a dimension figure with addition of the sign of degrees (Fig. 4.36.). The extension lines correspond to the legs of the angle.

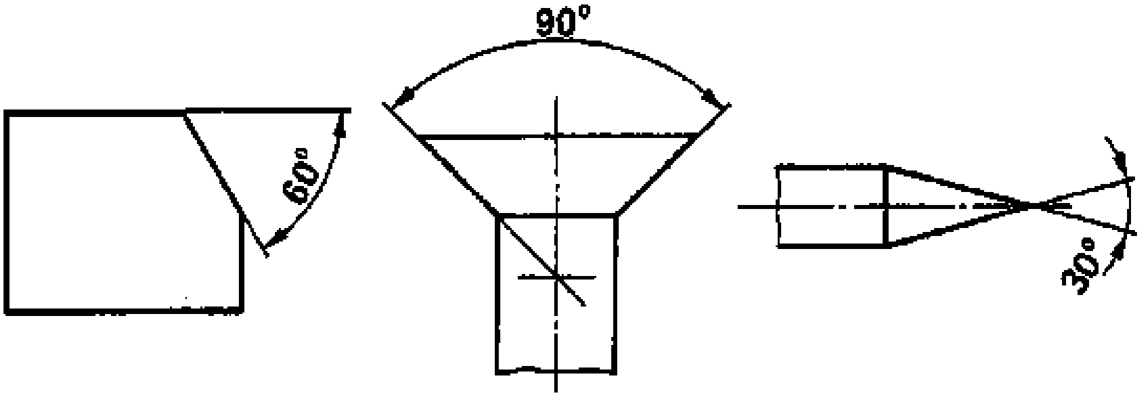


Fig. 4.36.

Tapers or bevels can also be dimensioned:

- by a ratio (see Section 4.2.7.)
- by the statement of a percentage (see Fig. 4.45.)
- by linear measures (Fig. 4.37.)

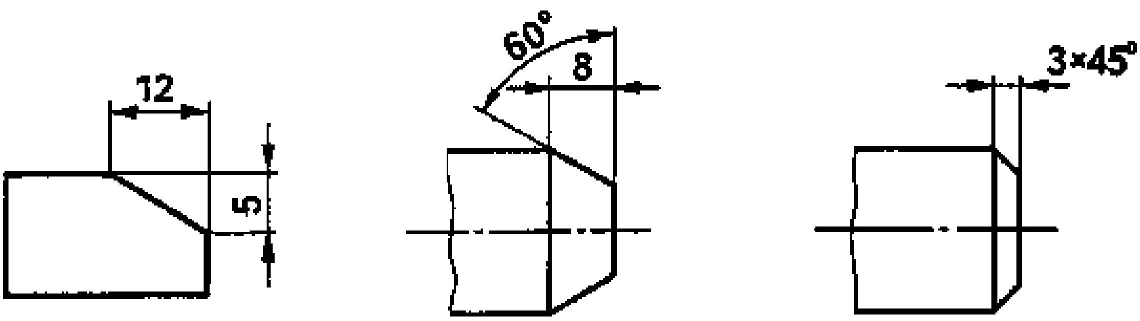


Fig. 4.37.

3 × 45° only applies to 45°–chamfers

Repetition

1. How is the shape of a sphere perceived in a drawing?

2. Describe the ways of dimensioning angles.

4.2.7. Taper, Pyramid, Inclination

Taper, pyramidal and wedge shapes are in practice frequently used for establishing connections. Examples are the connection of a drill with the drill spindle by means or taper shanks or the keyed joint between shaft and hubs for fastening gears and V−belt pulleys.

The usual shapes (Fig. 4.38) are the frustum of a cone, the square frustum of a pyramid and the taper in one direction only.

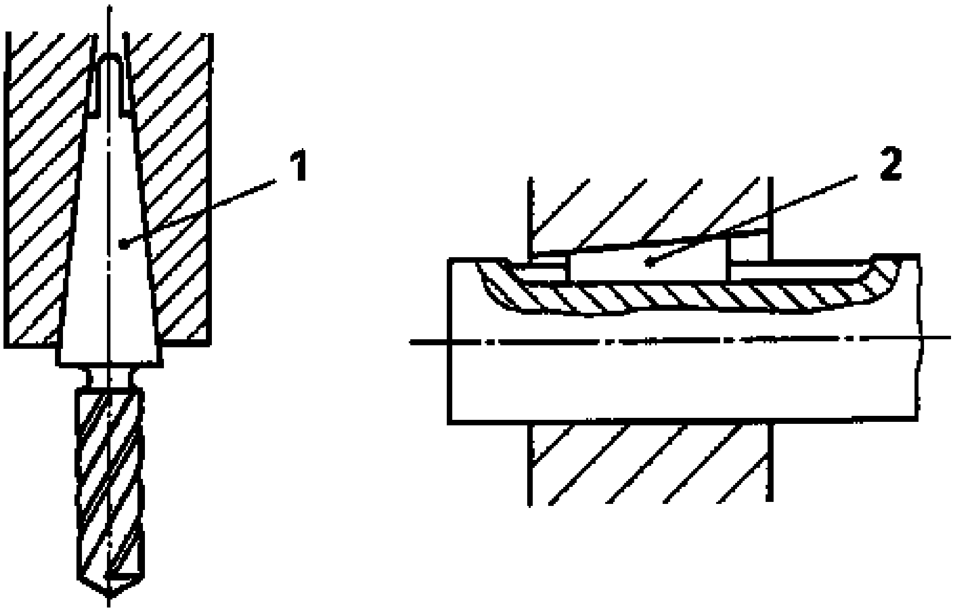


Fig. 4.38.

1 Frustum of a cone as drill shank
2 Taper in one direction only

<u>Taper</u>

For dimensioning a conical shape, also known as taper in practice, overdimensioning is allowed in contrast to other regulations.

The following items are stated (Fig. 4.39.):

major diameter D
minor diameter d
length of cone 1
half angle of cone ?/2 (setting angle for lathe)
ratio of taper 1 : k

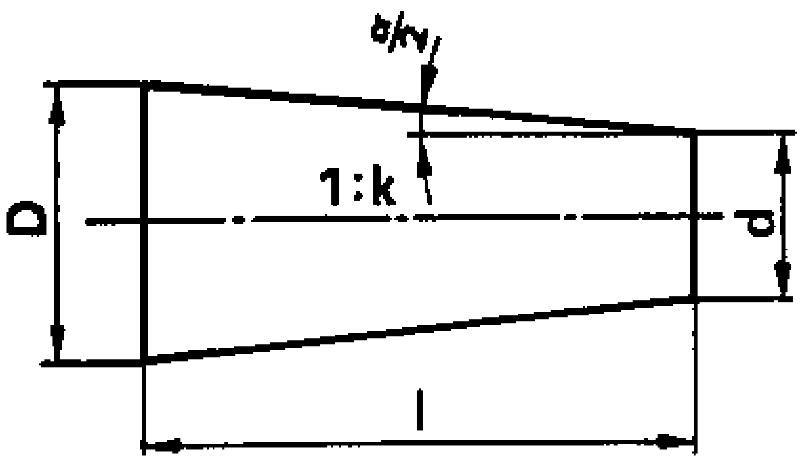


Fig. 4.39.

The calculation of the ratio of taper is carried out according to .

It is entered in the drawing parallel to the centre line.

Applications are shown in Fig. 4.40.

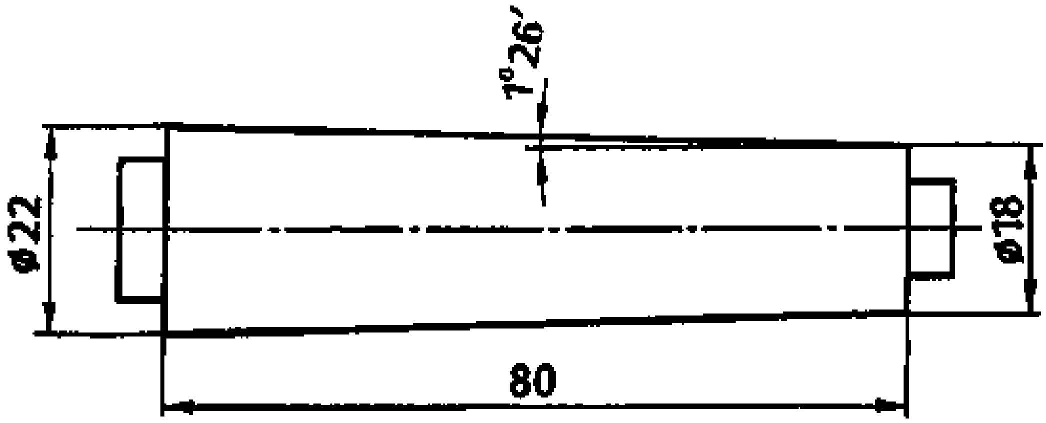


Fig. 4.40. Example of data to be entered in the drawing for a cone

On the calculation:

The quantity k in 1 : k indicates the length where the difference between the diameters is equal to 1. The half angle of cone is looked up in Tables. It is calculated according to the tangent function (see Fig. 4.39.). A few frequently used ratios of taper:

Designation	?/2	Application
taper 1 : 50	34'	taper pins
taper 1 : 20	1°26'	tool shanks
taper 1 : 10	2°52'	coupling bolts
taper 1 : 3.43	8°18'	cutter arbor
taper 1 : 0.866	30°	packings, centrings

Pyramid

The dimensioning of pins and holes having the shape of a frustam of a pyramid is carried out in a way similar to that used for tapers.

Here, no angle must be given! The ratio of the side length difference to the length is called ratio of reduction.

The calculation of the ratio of reduction (see Fig. 4.41.) is carried out according to . It is entered in the drawing parallel to the centre line.

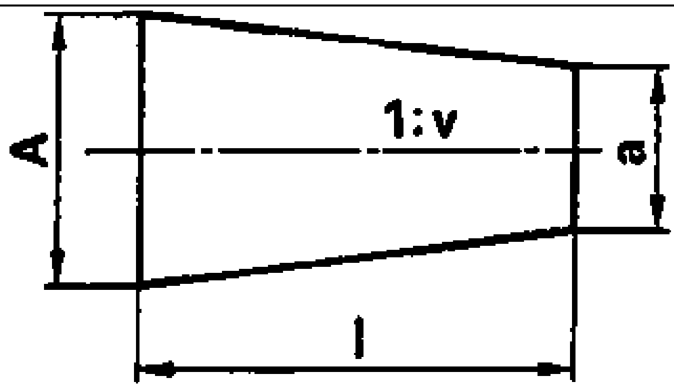


Fig. 4.41.

The quantity v in 1:v designates the length where the side length difference is 1 (see Fig. 4.42.).

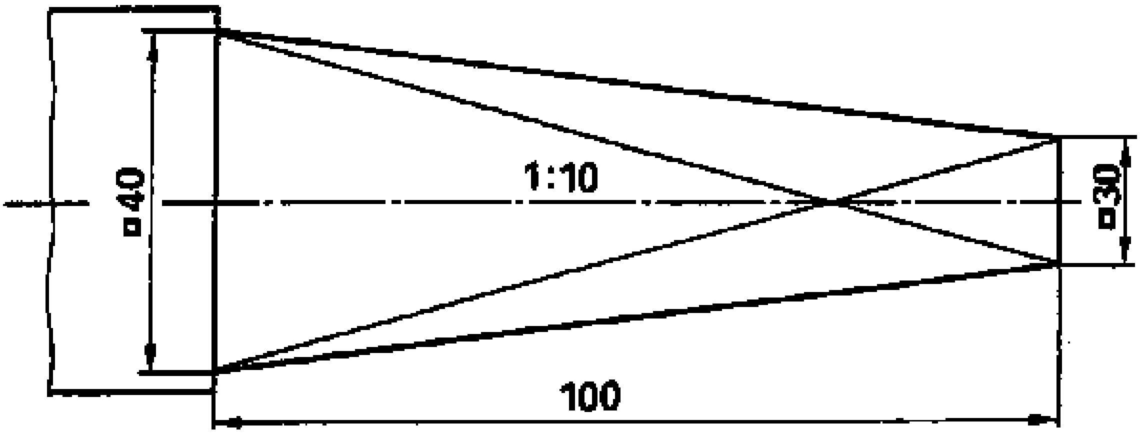


Fig. 4.42. Example of data to be entered in the drawing for taper

<u>Inclination</u>

The dimensioning of the wedge shape is carried out by entering in the drawing of the two heights and the length and by stating the ratio of inclination. This is the ratio of the height difference to the length as shown in Fig. 4.43.

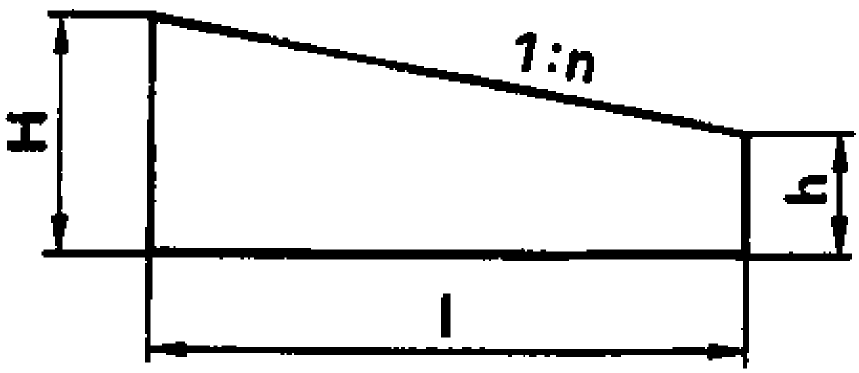


Fig. 4.43.

The calculation of the ratio of inclination is carried out according to . It is entered into the drawing parallel to the centre line.

The quantity n in 1 : n indicates the length where the height difference is 1 (Fig. 4.44.). For castings, forgings and rolled products, the statement of inclination can be in % (Fig. 4.45.).

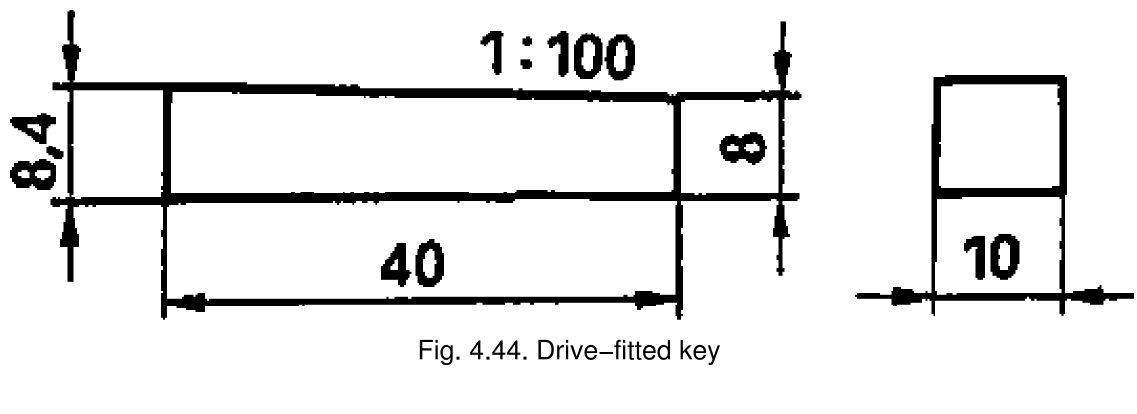


Fig. 4.44. Drive−fitted key

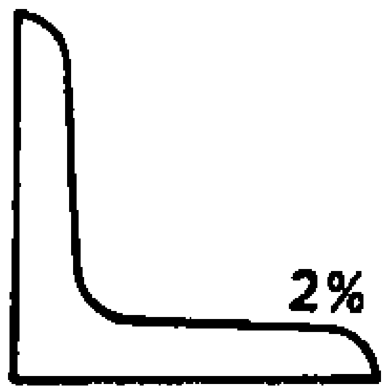


Fig. 4.45.

Repetition

1. Explain the statements in drawings: taper 1 : 50/inclination 1 : 100/reduction 1 : 25

2. Which dimensions belong to the complete dimensioning of a taper?

3. From the following data, determine H of a wedge: 1 : n = 1 : 40/1 = 120 mm/h = 15 mm!

4.3. Entering Dimensions in Drawings

4.3.1. Arrangement of the Dimensions

– Show each dimension only once!

– Do not show dimensions at hidden edges of the object!

– Enter external dimensions in any case (see Fig. 4.50.)!

– Show dimensions which belong together at one and the same site, i.e. where the partial shape to be dimensioned is represented most clearly! (Fig. 4.46.).

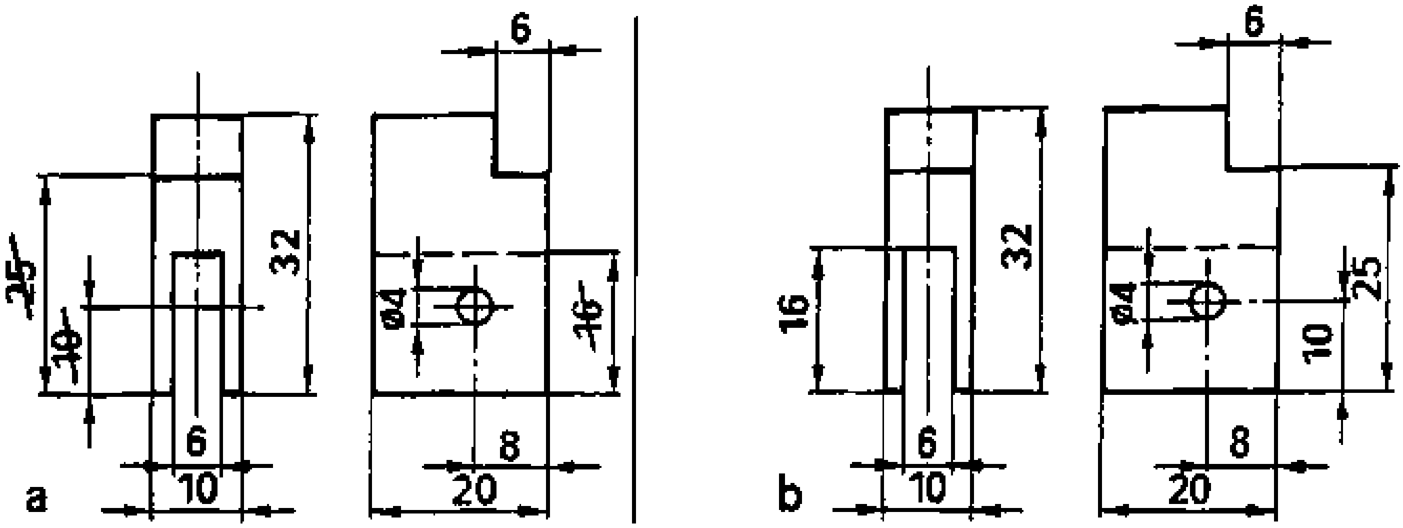


Fig. 4.46. a wrong, b correct

– All dimensions can be classified in two categories:

– Dimensions of the size of a partial shape or of the basic shape (initial shape)

– Positional dimensions (dimensions of distances and spacings) of a partial shape (Fig. 4.47.).

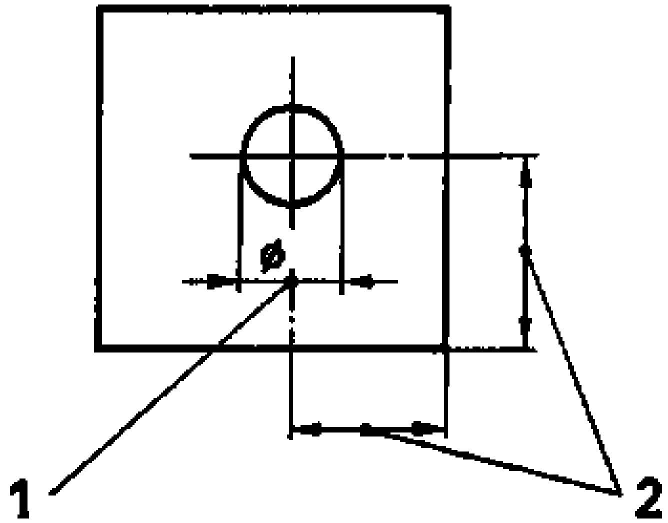


Fig. 4.47.

1 – dimension of size
2 – positional dimension

This grouping into dimensions of size and dimensions of position facilitates both the reading of drawings and the independent dimensioning.

– Entering dimensions in drawings is largely governed by points of view of manufacture and function (see Section 4.3.2.).

4.3.2. Reference Systems for Dimensioning

The final condition of the workpiece to which the dimensions refer can be achieved by differend methods of manufacture. Since dimensioning is also governed by the production, there may be different ways of dimensioning the same workpiece correctly, depending on the method of manufacture. Analogously, this also applies to the influence of the function on the way of dimensioning.

As starting lines for dimensioning, such lines are selected which are essential for manufacture and for the function. These lines are called reference lines.

Reference lines are starting lines for dimensioning. They are determined by manufacture or the function. The dimensions are related to these lines.

Frequently, the following items are selected as reference lines:

Supporting surfaces, contact surfaces, symmetry lines of the objects and symmetry lines of partial shapes.

In practice, usually manufacturing and functional points of view must be observed for dimensioning the drawing of an object. Thus, in Fig. 4.48., the reference lines characterise both contact surfaces (function) and the starting surfaces for manufacture (see also Figs. 4.48., 4.49. and 4.50.).

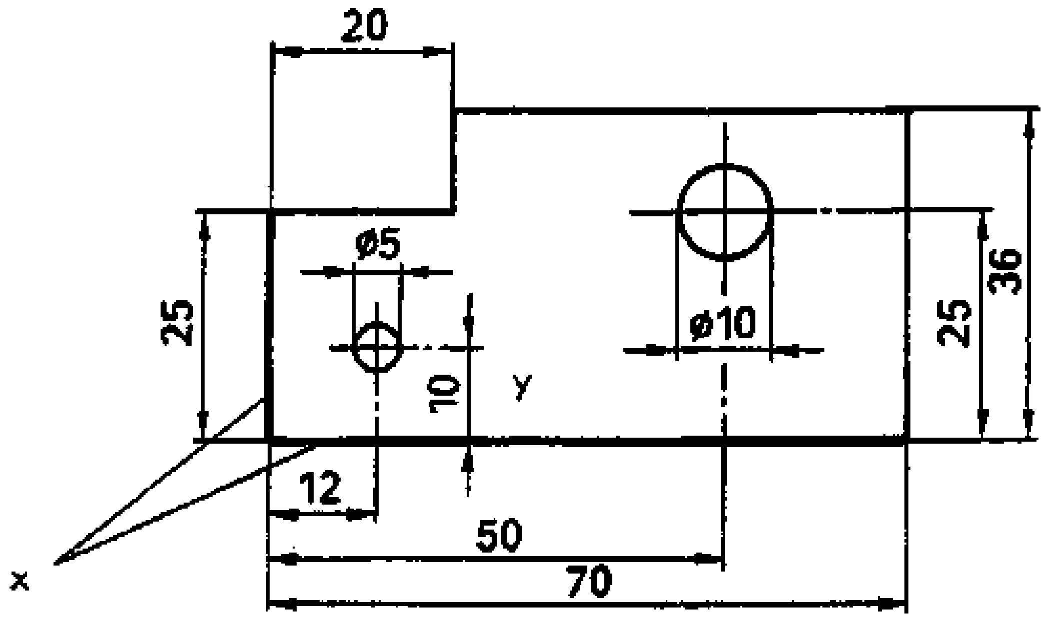


Fig. 4.48. Two surfaces as dimensional reference lines

x Dimensional reference lines, y 2 thick

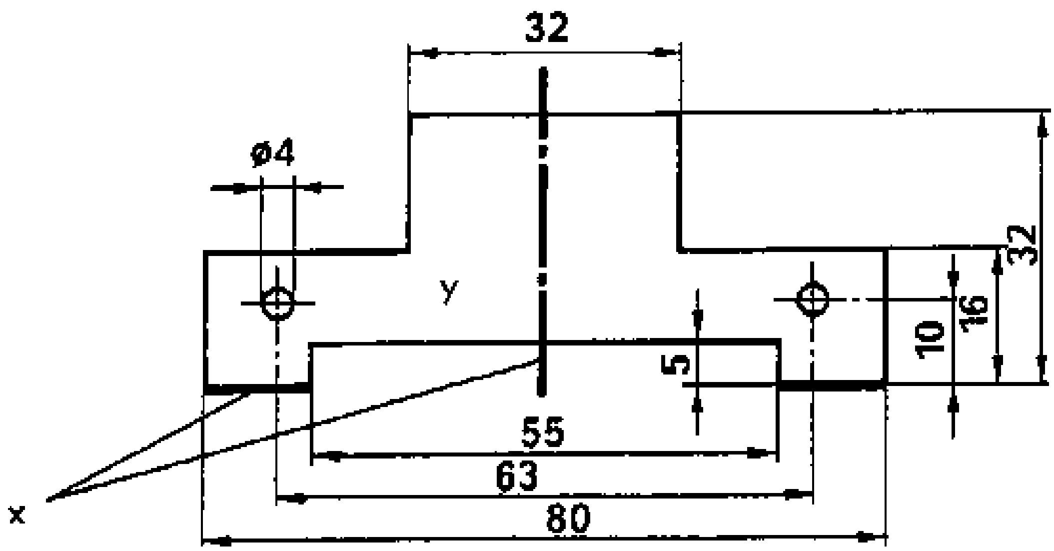


Fig. 4.49. A surface and the line of symmetry as dimensional reference line

x Dimensional reference lines, y 3 thick

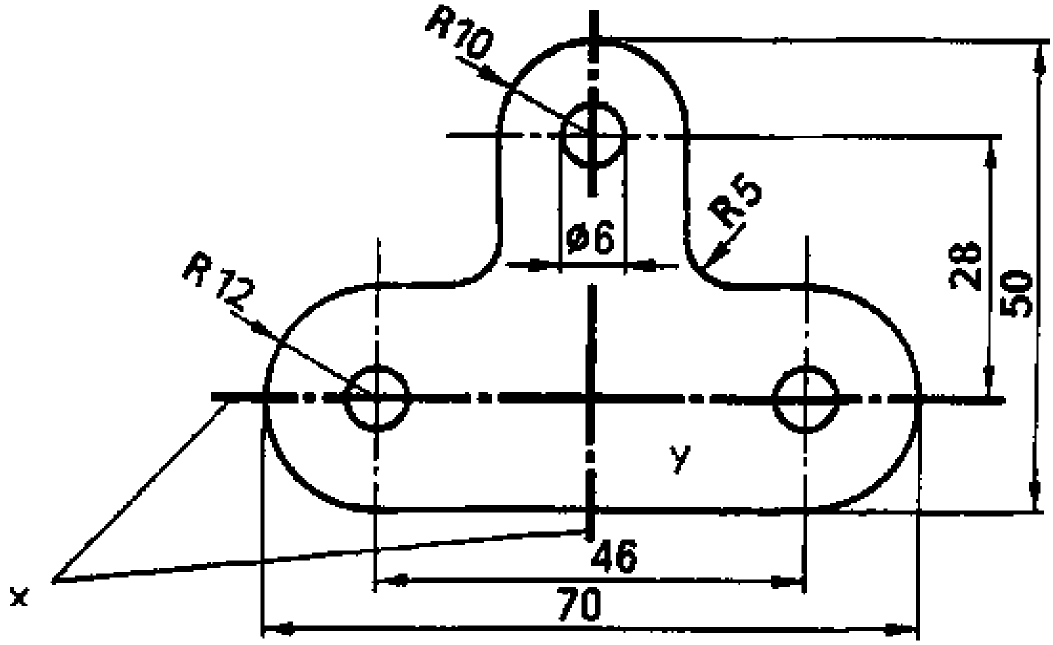


Fig. 4.50. Two lines of symmetry as dimensional reference lines

x Dimensional reference lines y 1 thick

For objects whose shape calls for at least two views, sometimes three reference lines must be established (Fig. 4.55.). The designer will lay down the dimensions in such a way that the component will properly function with other parts after mounting. The drawing which is submitted to the manufacturer contains the dimensions according to the conditions of manufacturing engineering.

<u>Example 1</u>

Figure 4.51. and Figure 4.52.

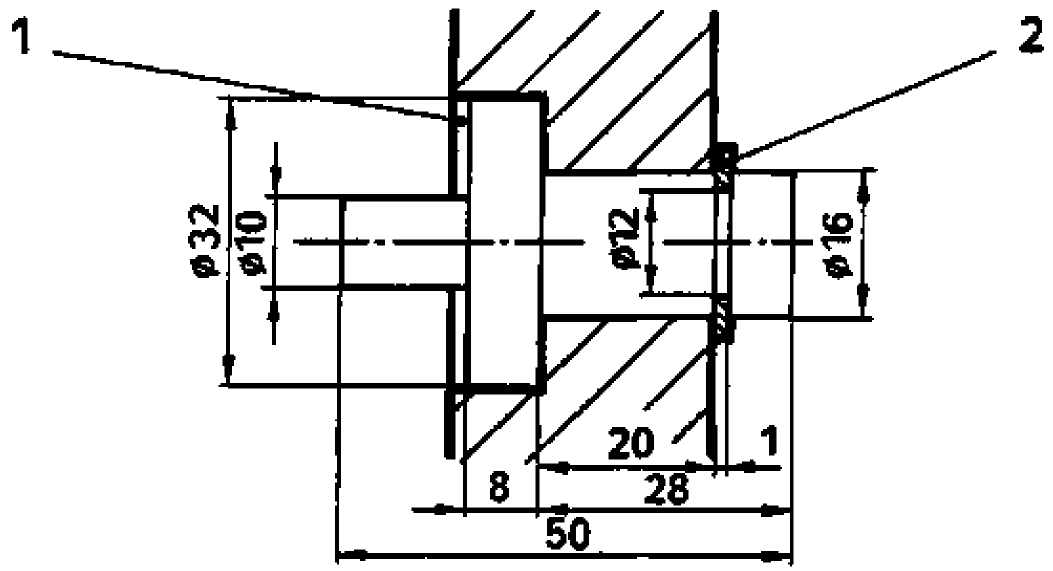


Fig. 4.51. Dimensioning according to functional and technological points of view

1 Recessing
2 Gap

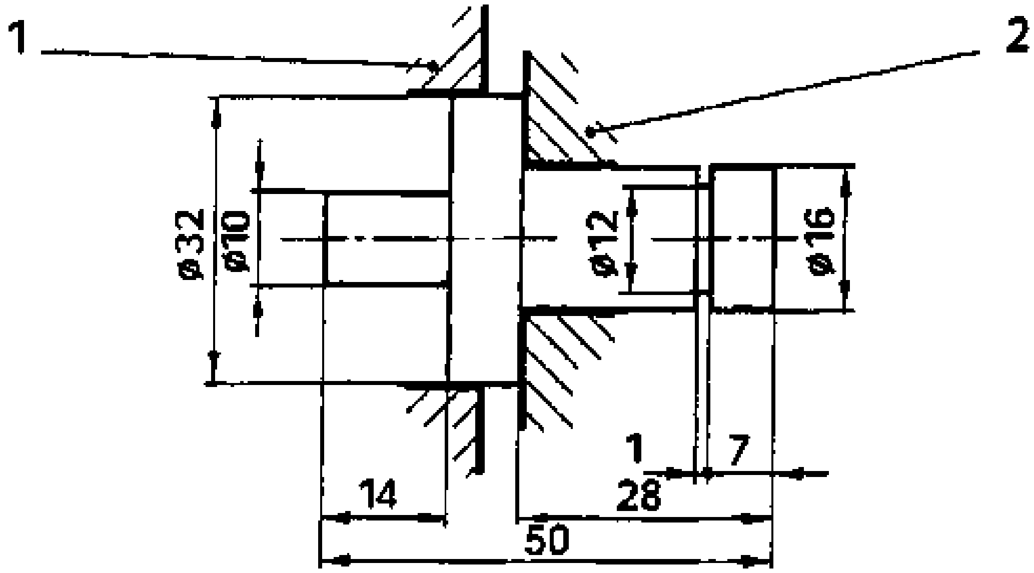


Fig. 4.52. Dimensioning according to technological points of view

1 Mounting in lathe for tooling the right−hand side
2 Mounting in lathe for turning the journal having a diameter of 20 and a length of 14

<u>Example 2</u>

Figure 4.53. and Figure 4.54.

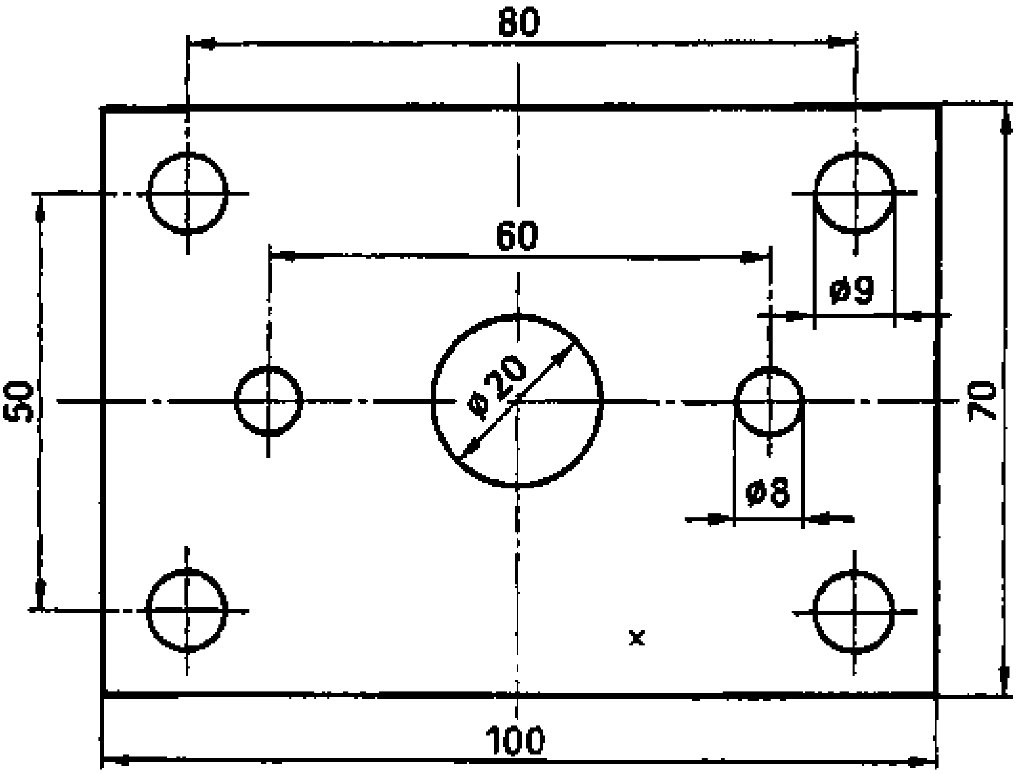


Fig. 4.53. Drawing for scribing and drilling with drilling machine

x 4 thick

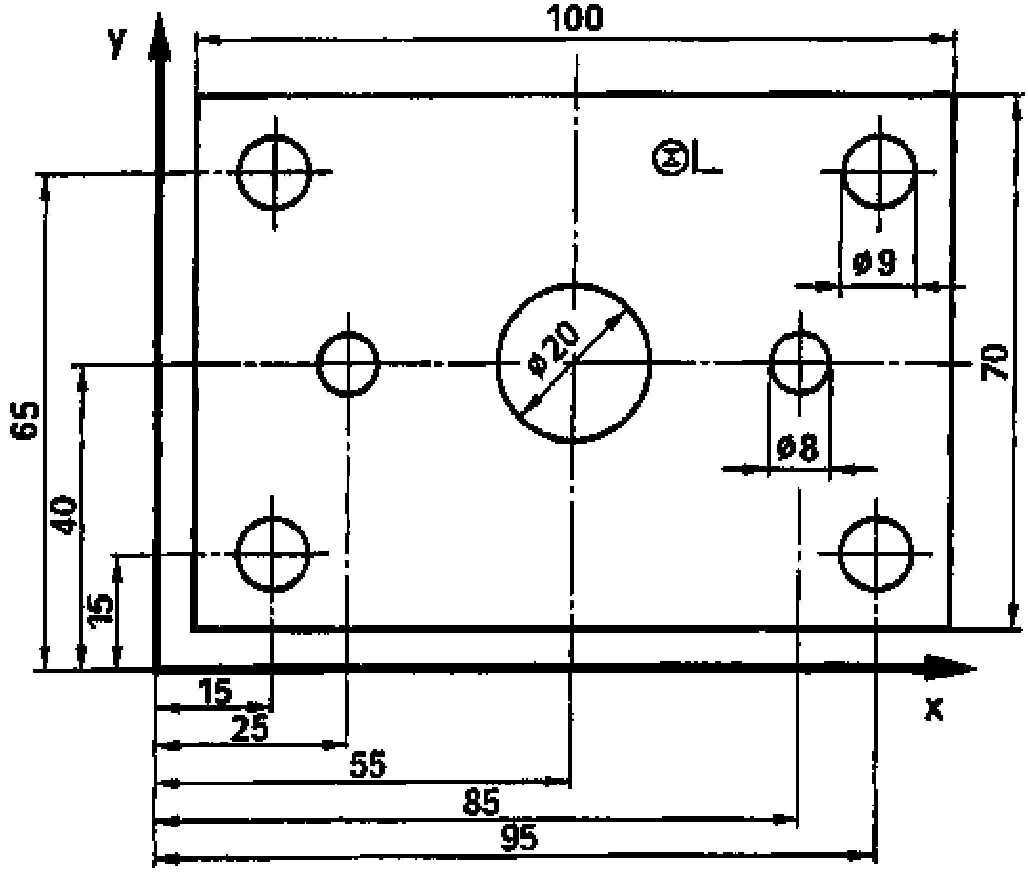


Fig. 4.54. Drawing for boring by means of a boring mill (dimensioning by coordinates)

4 thick, x/y dimensional reference lines (x abscissa, y ordinate)

4.3.3. Succession of Dimensioning

The succession of the individual steps of dimensioning is dependent on the sequence of operations. In the sequence of operations, one partial shape is produced at a time. These partial shapes are determined by dimensions of size and dimensions of position. Although the dimensions are required in manufacture in the sequence of basic shape/partial shape 1/ partial shape 2/ etc., it is more expedient from the drawing point of view to enter them in the inverse order! In this way, the room for the dimensions can be observed better – that is to say, the smaller dimensions are located closer by the object, the larger dimensions are located a larger distance away from it (cf. Figs. 4.55. and 4.56.).

Repetition

1. On the basis of Figs. 4.46. (right) and 4.55. show dimensions which have to be entered in the drawing together in one and the same view.

Substantiate this!

2. What are reference lines?

3. What are the points of view that govern the specification of reference lines for dimensioning a workpiece representation?

4. Determine the reference lines for dimensioning in Figs. 4.46. (right–hand side), 4.53. and 4.55.

5. Determine the dimensions of size and of position of the partial shapes and of the basic shape in Figs. 4.49. and 4.52.

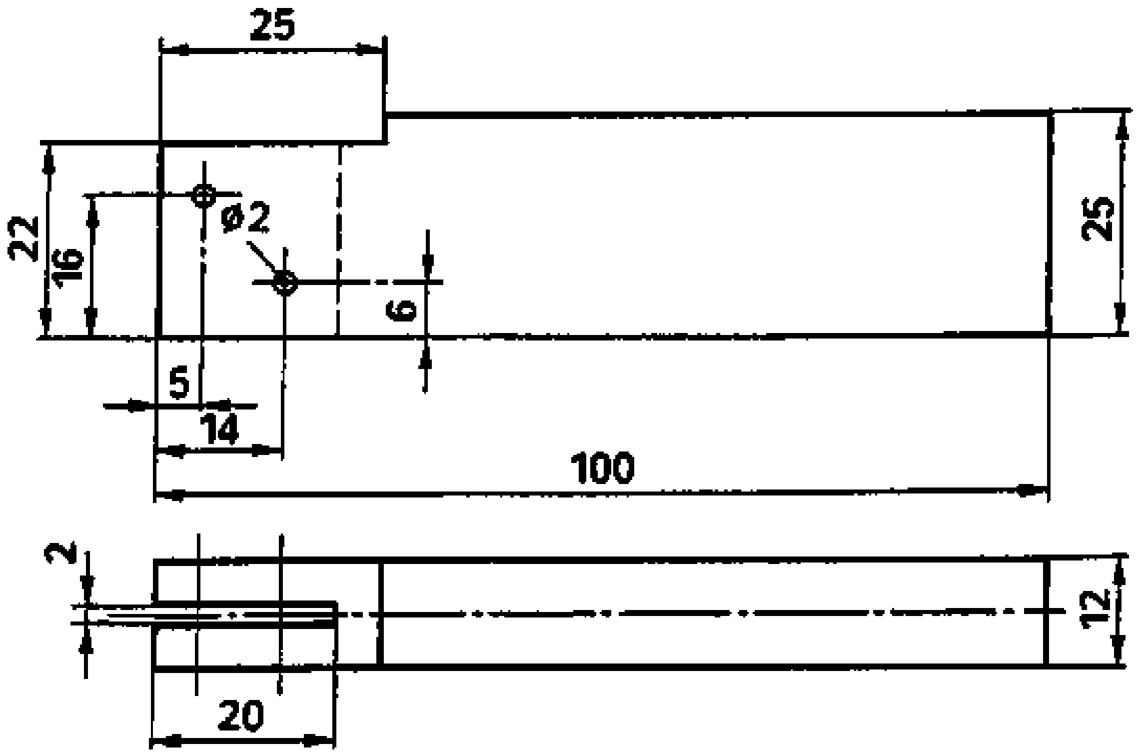


Fig. 4.55. Main part of a try square

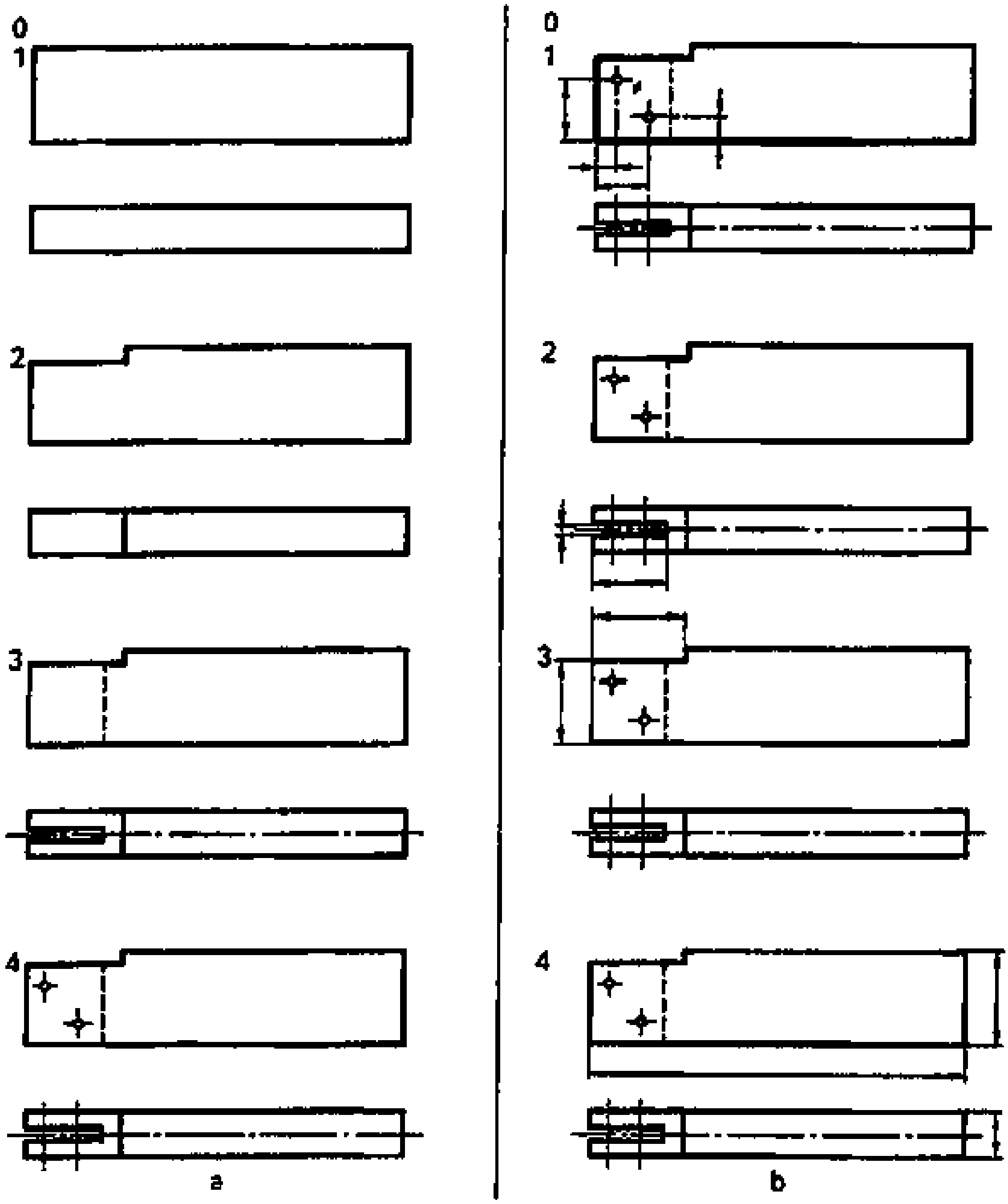


Fig. 4.56.

a Sequence of operations:

0. Providing reference surfaces for the basic shape
1. Producing the basic shape
2. Milling the shoulder
3. Milling the slot
4. Harking the holes and drilling the holes

b Sequence of entering the dimensions:

0. Providing dimensional reference lines according to procedure of manufacturing and/or function
1. Dimensions of size of the holes to be drilled and positional dimensions of the holes to be drilled
2. Dimensions of size of the slot (positional dimensions are omitted)
3. Dimensions of size of the shoulder (positional dimensions are omitted)
4. Dimensions of size of the basic shape

4.3.4. Locating Holes

In workpieces with may holes close by each other at the same distance, a comprehensive dimensioning would be very time−consuming and less informative (Fig. 4.57.).

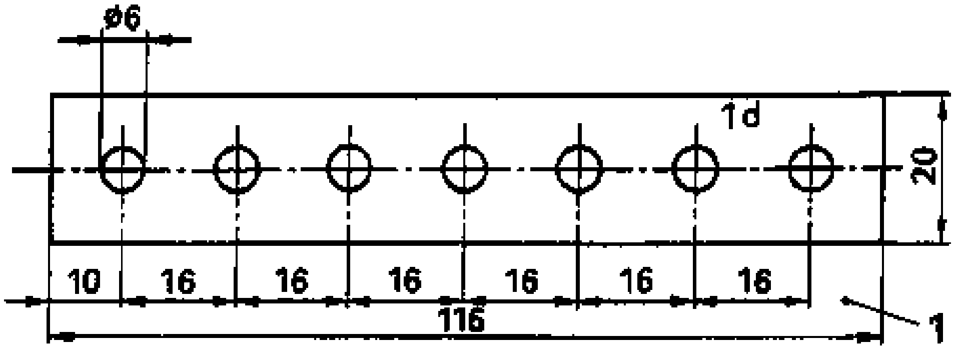


Fig. 4.57. 1 to be kept free

If this manner of dimensioning is required for certain reasons, then the dimensioning chain must not be closed!

Closed dimensioning chains should be avoided!

The dimensioning chains for the equal location of holes usually are represented in a simplified manner, as is shown in Figs. 4.53. to 4.61.

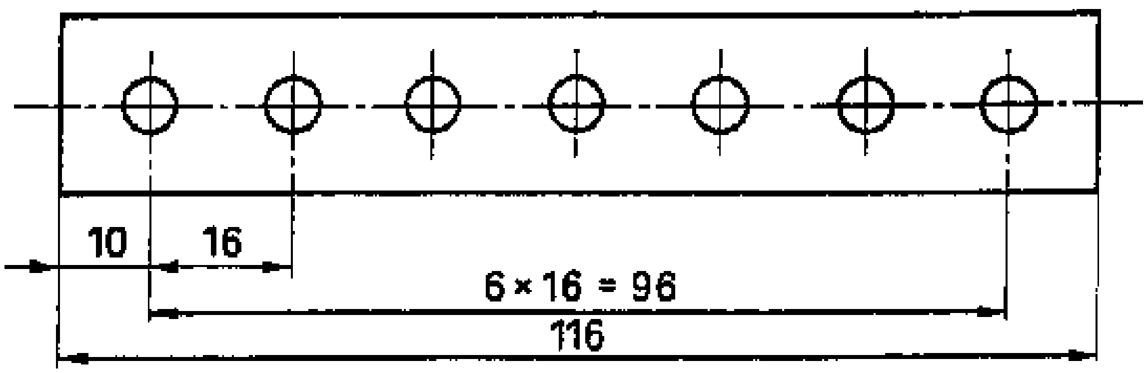


Fig. 4.58.

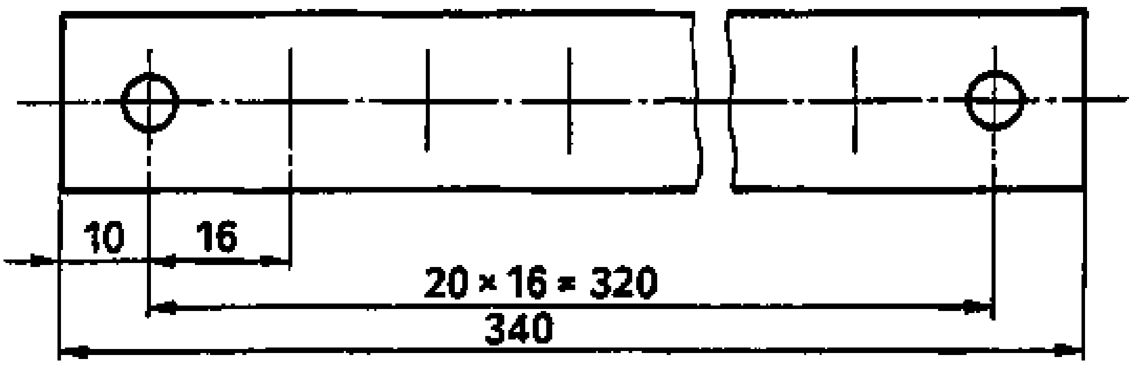


Fig. 4.59. Workpiece with uniform spacings of many holes

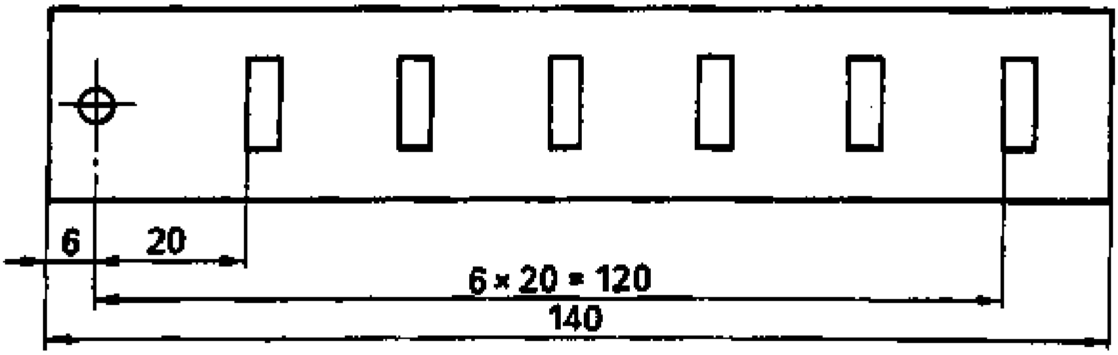


Fig. 4.60. Rectangular openings, dimensioned from edge to edge

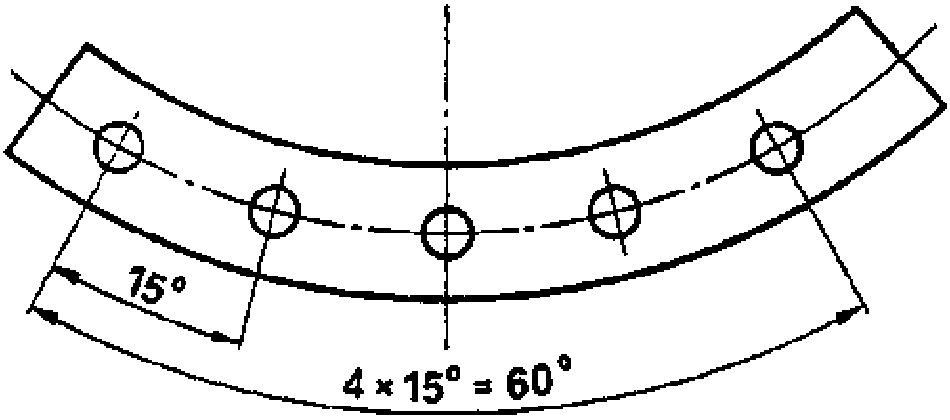


Fig. 4.61. Spacings between holes given in the form of angular measures

If holes are located at the same spacing on a pitch circle, then the angular measure for the distance need not be given (Fig. 4.62.). The indication of one angular measure will suffice (Fig. 4.63.). When the locating is clear and subject to but one interpretation, it will suffice to represent one hole fully while the other holes are only specified in their position (Fig. 4.63.).

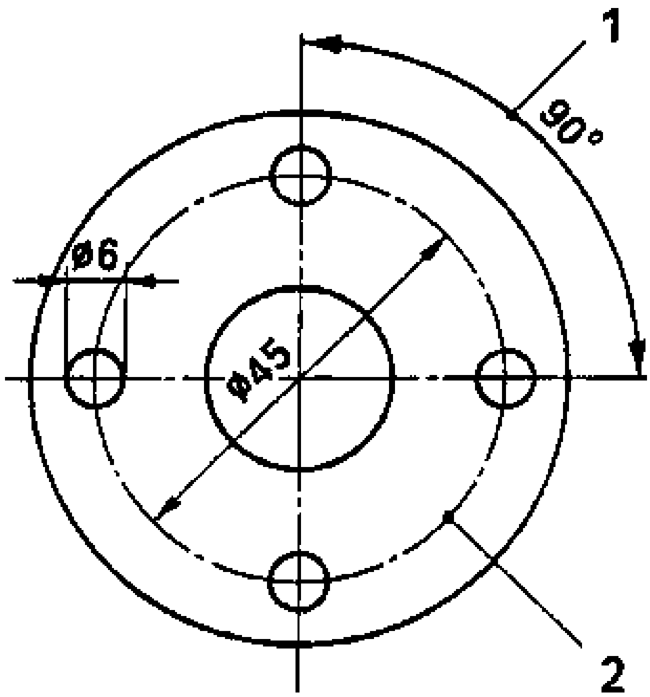


Fig. 4.62. Four holes an a hole (or index) circle

1 Index circle,
2 This dimension need not be given

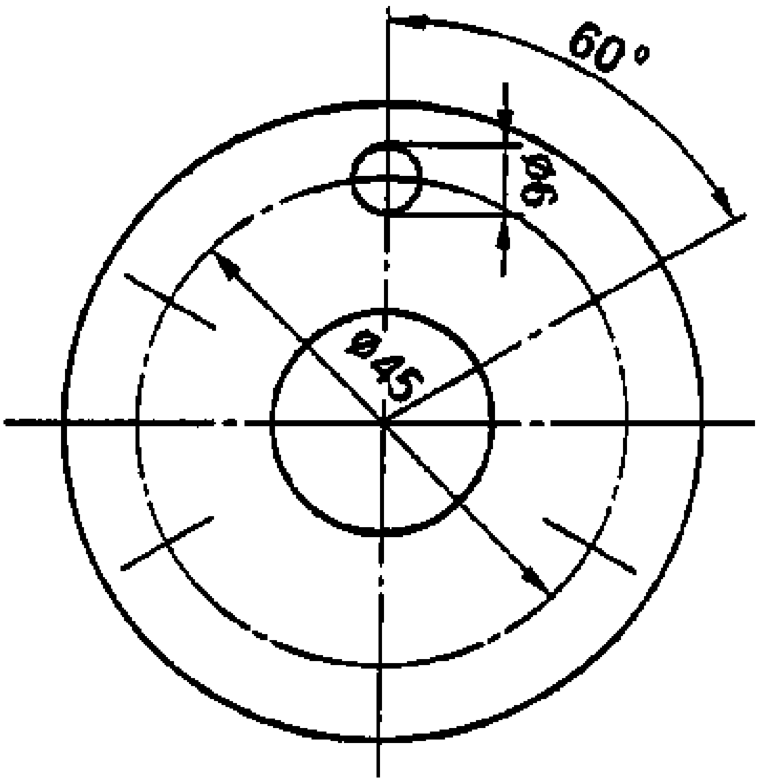
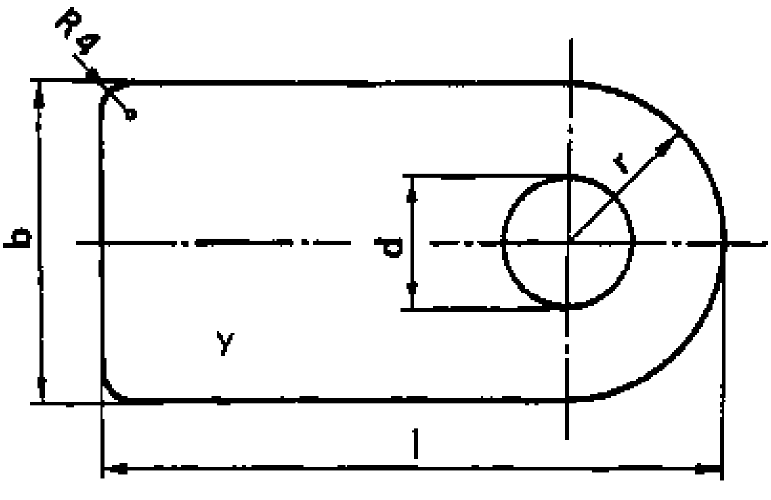


Fig. 4.63. Six holes on a hole circle

4.3.5. Sort Drawing

In order to achieve a rational method of representation for parts of the same shape but different dimensions, the part is drawn only once and is provided with dimension letters instead of dimension figures. The dimension figures for the sorts in question are given in a Table (Fig. 4.64.).



x	l	b	d	r
A	40	20	8	10
B	63	32	12	16
C	80	40	16	20

Fig. 4.64. Drawing of grades

x grade, y 2 thick

4.4. Dimensional Variations I

It is not possible and not necessary to adhere strictly to the dimensions specified in the manufacture of workpieces.

It would be uneconomical to observe the dimensions specified in a drawing as strictly as possible. Now, how strictly should the dimension figure given in a drawing be observed?

The accuracy of the dimension to be observed in the manufacture is clearly given with the dimension figure. Each dimension figure includes an information about the tolerance (Fig. 4.65.).

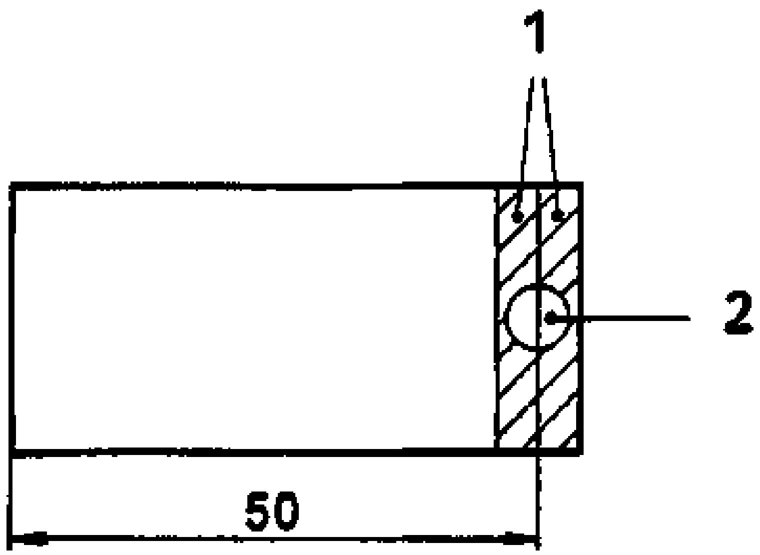


Fig. 4.65.

1 deviation
2 tolerance

Tolerance is the allowable deviation from the specified dimension (nominal size)! It is the difference between the upper and lower limits between which a size must be held; hence, upper and lower deviations.

The tolerance is not arbitrary. It is governed by the function of the object and specified by the designer accordingly. He has to take his decision according to the economical principle:

Select the deviations as coarse as possible and as fine as necessary!

Depending on the requirements, the tolerance can be specified according to three possibilities:

– Dimensions without specification of a tolerance – for purposes of insignificant requirements (the allowable deviations are given in Tables)

– Dimensions where deviations are given in numerals – for purposes of medium requirements

– Dimensions with a coded indication of the deviations (letter–numeral–system) – for purposes of higher requirements, e.g. for fits (this field will be dealt with in Chapter 7).

4.4.1. Dimensions without Specification of a Tolerance

Dimensions which are not subject to special functional requirements are not provided with any statement for allowed deviations in the drawing. This is a simplification! The deviations applicable to this case are given in Tables. Every designer must know, for example, that, when giving the dimension of 50, he specifies that this dimension has to be observed between the values of 49.7 and 50.3. Every user of the engineering drawing in question must also know this. This way of statement of tolerances must not be used for dimensions from which other dimensions are dependent (assembly dimensions, dimensions of assembled parts).

When using dimensions without the specification of tolerances, an indication is given in the title block of the drawing (Fig. 4.66.).

Fig. 4.66. Permissible dimensional variations for dimensions without tolerance specifications

X							
>0,5	>6	>30	>120	>315	>1000	>2000	>4000

bis 6	bis 30	bis 120	bis 315	bis 1000	bis 2000	bis 4000	
±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3

x Nominal size range

Repetition

1. What is tolerance when manufacturing workpieces?

2. For what reasons, tolerance specifications are required?

3. Considering Fig. 4.6.7., as certain the dimensions which are the limits, the upper and the lower limits, which have to be observed in the manufacture of this object?

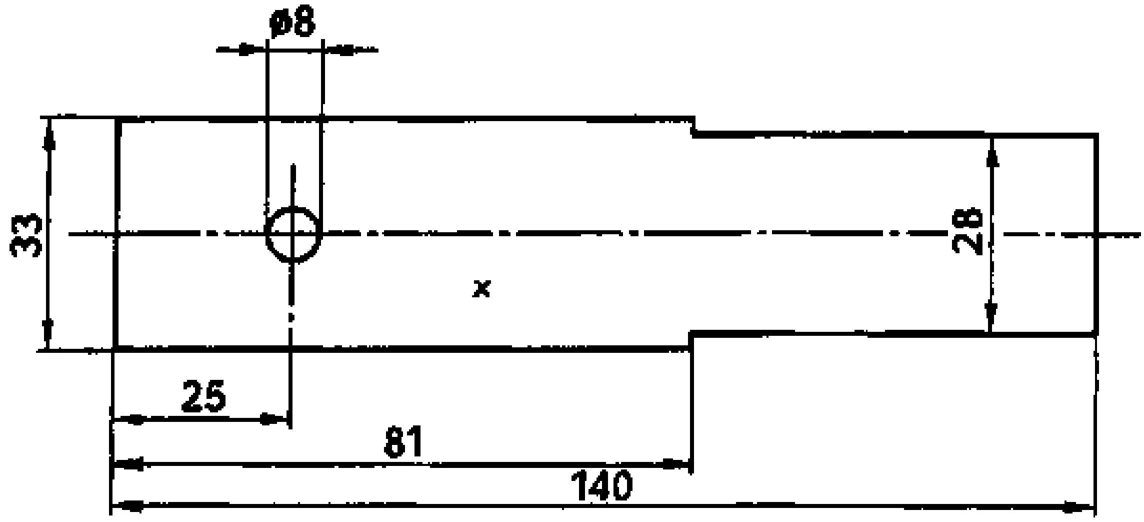


Fig. 4.67.

x 3 thick

1 Design dimension
2 Upper deviation
3 Lower deviation

1	2	3
3	3,1	
8		7,8

4.4.2. Dimensions where Deviations are Given in Numerals

In cases where objects or shapes or their parts in conjunction with other parts have to fulfil certain functions, the dimensional variations are given directly in the form of numerals.

The dimensional deviations are always written with a sign. The upper deviation is written behind the dimension figure and raised while.

The lower deviation is written behind the dimension figure deep (Fig. 4.68.).

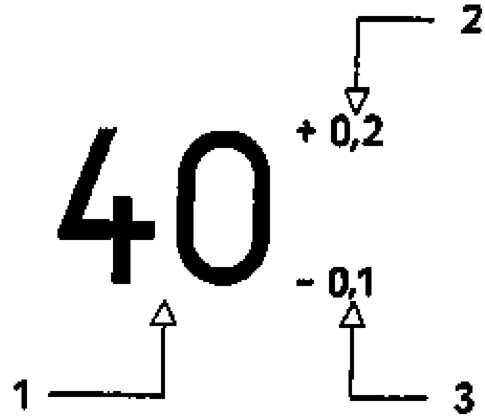


Fig. 4.68.

1 Nominal size
2 Upper deviation
3 Lower deviation

The dimensional variations have a height of 0.7 dimension figure height. But they are not smaller than 2 mm.

The complete representation of the basic terms of tolerance are given in Fig. 4.69.

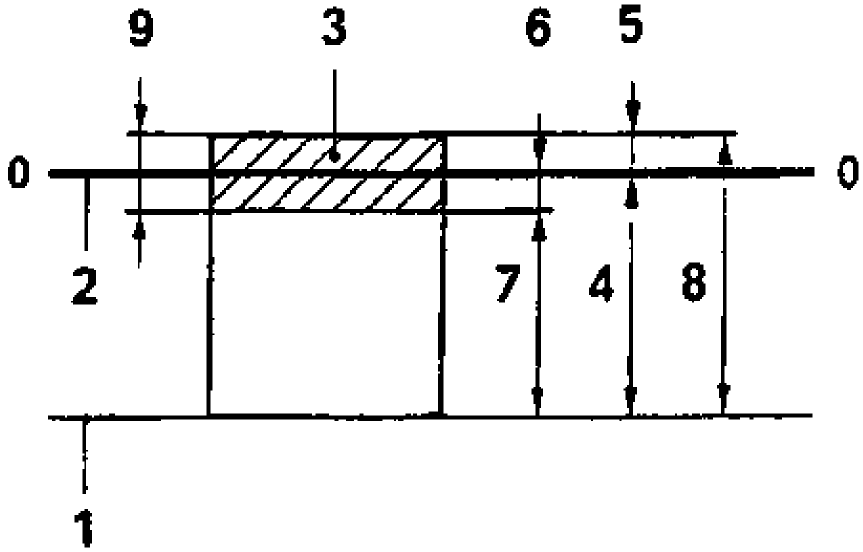


Fig. 4.69. Basic terms of tolerance specification

1 Reference line, 2 Zero line, 3
Tolerance zone

4 Nominal size	N
5 upper deviation	UD = MS − N
6 lower deviation	LD = SS − N
7 smallest size	SS = N + LD
8 maximum size	MS = N + UD
9 tolerance	T = MS − SS
9	T = UD − LD

– The zero line is the reference line for the dimensional variations which corresponds to the basic size.

– The tolerance zone is the field which illustrates the difference between maximum limit and minimum limit. It shows the magnitude of the tolerance and its position with respect to the zero line.

There are five possibilities of the position of the tolerance zone with respect to the zero line which are given in Fig. 4.70.

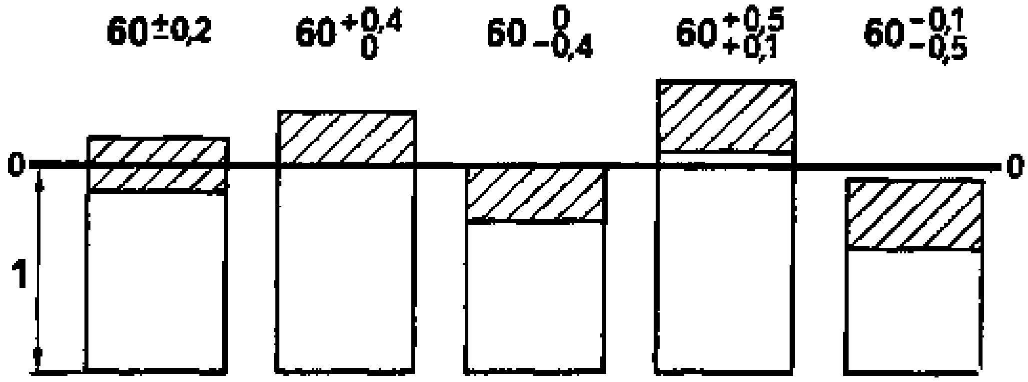


Fig. 4.70. Possibilities of the location of the tolerance zone with respect to the zero line

The extreme positions or plus–plus and minus–minus can only be understood in connection with the solution of the problem of fits (see Chapter 7).

When manufacture is the main point of view for entering the dimensional variations (the requirements regarding the function are significant), then the following rule bolds:

– Give the tolerances in manufacturing direction! That is to say:

external dimensions which become smaller during machining are provided with a negative deviation,

external dimensions which become larger during the working process are provided with a positive deviation (see Fig. 4.71.).

If, in manufacture, the basic size is to be achieved – it is the next limit –, then the tolerance zone remains to be the reserve for the permissible “inaccuracy”.

Fig. 4.72. shows two examples for the way of entering of dimensional variations in drawings according to points of view of manufacture.

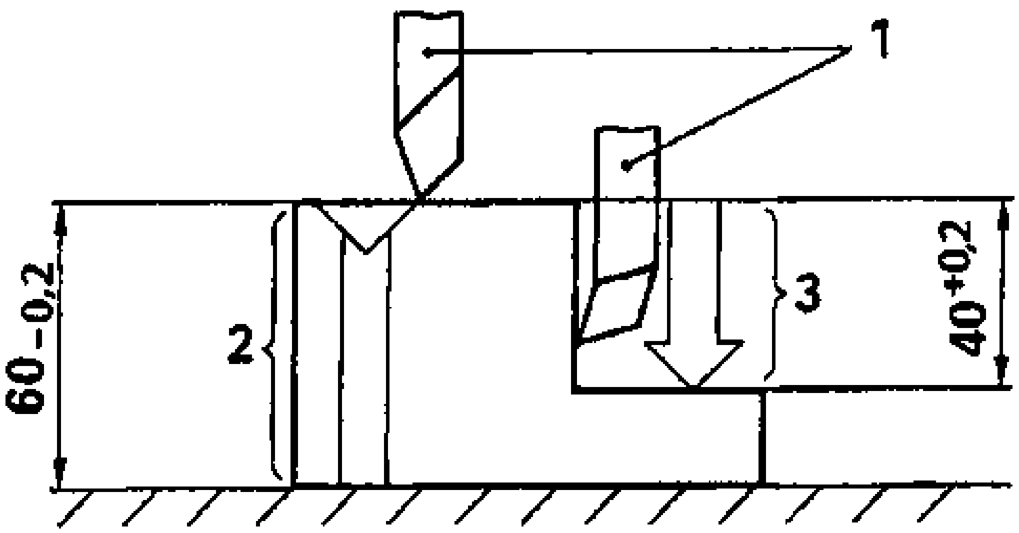


Fig. 4.71.

1 Planing tool
2 External dimension becomes smaller during machining

3 Internal dimension becomes larger during machining

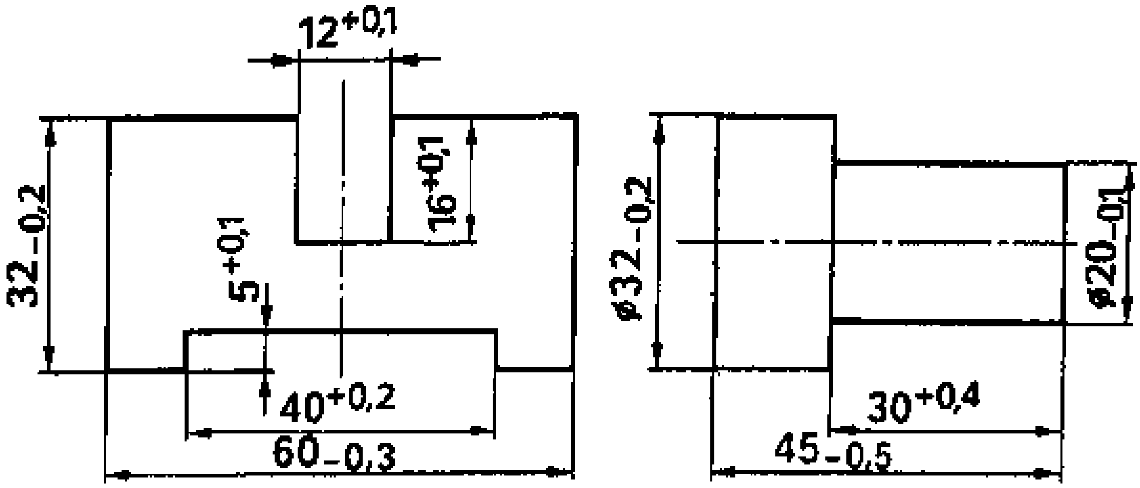


Fig. 4.72. Part to be milled and part to be turned in a lathe

The same rule is applicable to the dimensioning of angles between two surfaces (see Fig. 4,73.).

Distances are indicated by the ± tolerance (Fig. 4.74.).

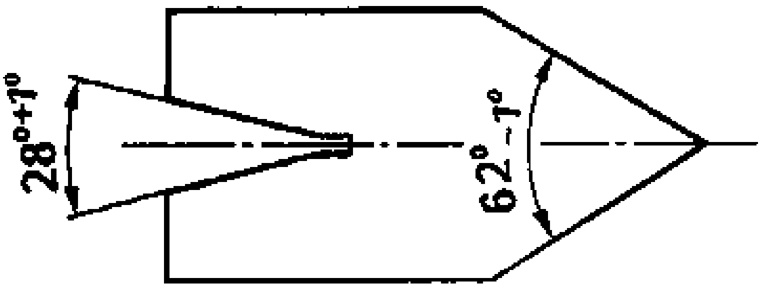


Fig. 4.73.

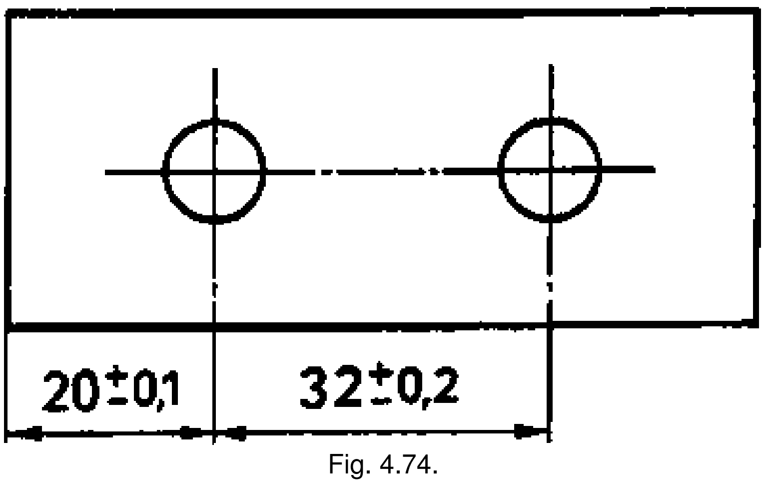


Fig. 4.74.

This also applies to distances which are specified by angular dimensions (Fig. 4.75.).

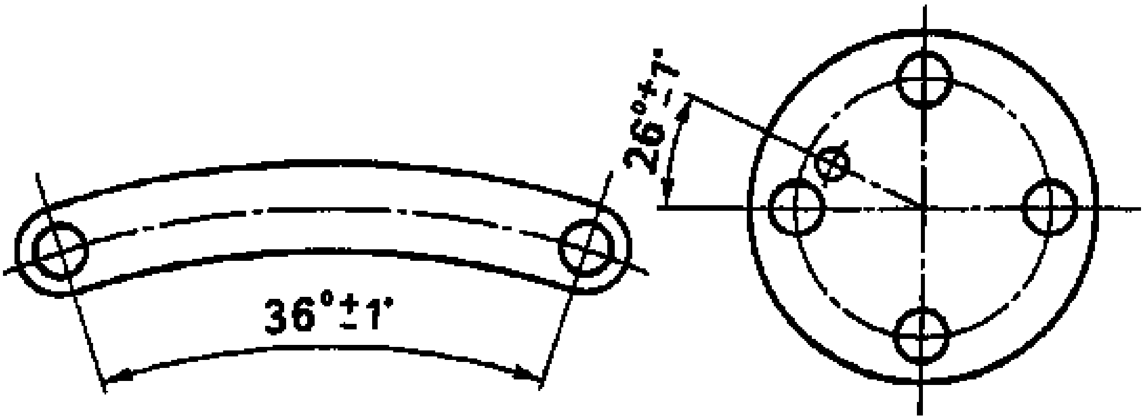


Fig. 4.75.

When the function is the main point of view of entering dimensional variations in a drawing, then the reference plane is decisive for the kind of dimensional variations (Fig. 4.76.).

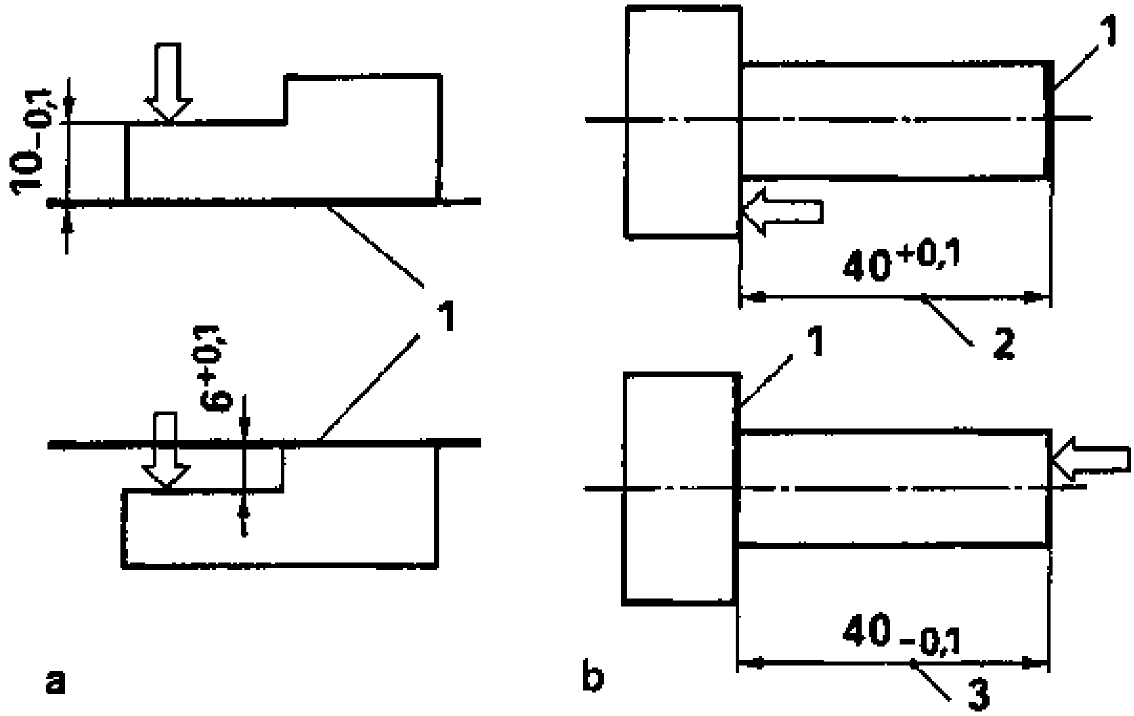


Fig. 4.76. Dependence of the statement of dimensional variations on the function (plane of reference)

a Example 1, b Example 2, 1 Plane of reference, 2 Internal dimension, 3 External dimension

Repetition

1. Determine the six basic sizes of the tolerance specification according to Fig. 4.67. for the dimension 24.3

2. Determine the six basic sizes for any four dimensions shown in Fig. 4.72. and in Fig. 4.75.

3. Give reasons for the signs of the dimensional variations shown at the part to be turned in a lathe in Fig. 4.72.!

5. Sectional Views

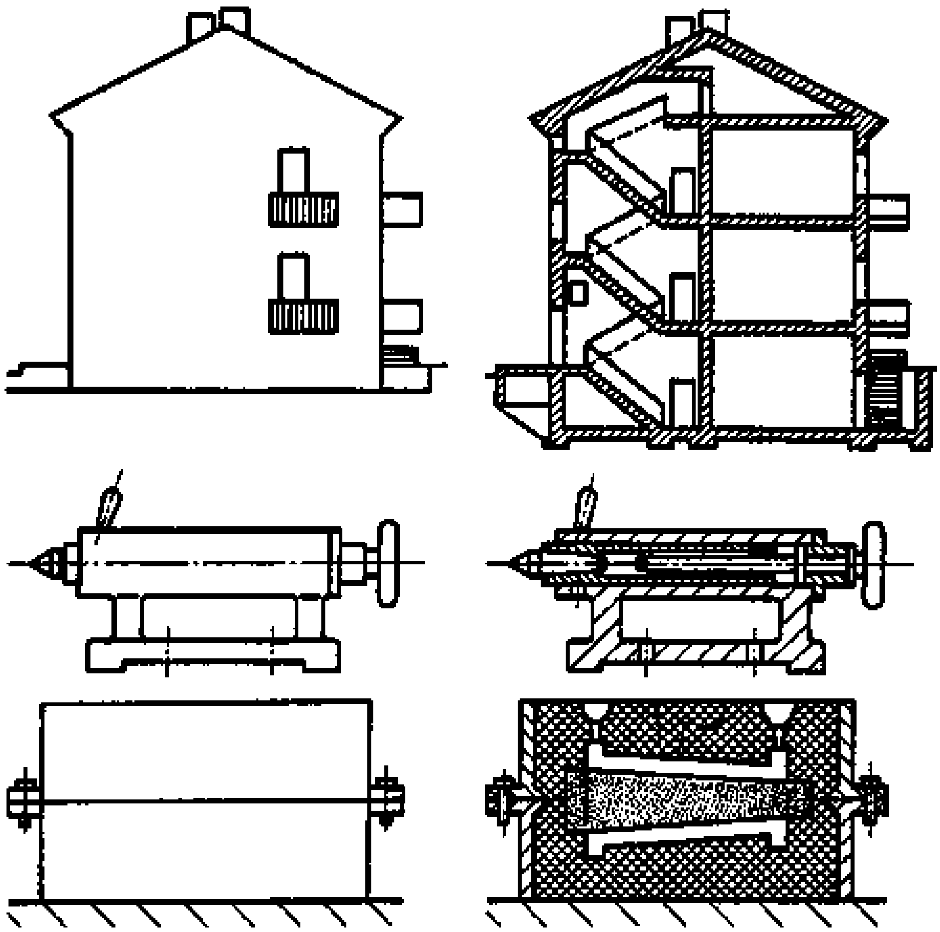
5.1. Introduction into the Process of Drawing Sectional Views

5.1.1. Function of Sectional Views and Basic Terms

An engineering drawing has the function of showing shape and size of an object clearly and completely. In certain cases, however, the representation in views is not sufficient. Many objects have internal shapes which are so complicated in nature that it is virtually impossible to show their true shape without employing numerous confusing hidden lines (Fig. 5.1.).

Fig. 5.1.

View | Representation of the intersection



The solution of the problem is the use of one or more sectional views: One imagines the object cut by passing a cutting plane through it so that the internal shape is revealed.

The purpose of a sectional view is to show the internal shape of an object. In this way, the dimensions of the internal shape can be applied to visible edges.

By passing a cutting plane (e.g. a saw or a knife) that portion of the object is removed which obstructs the view into the interior.

The edges which become visible due to the cut have to be represented as thick solid lines, as is shown in Fig. 5.2.

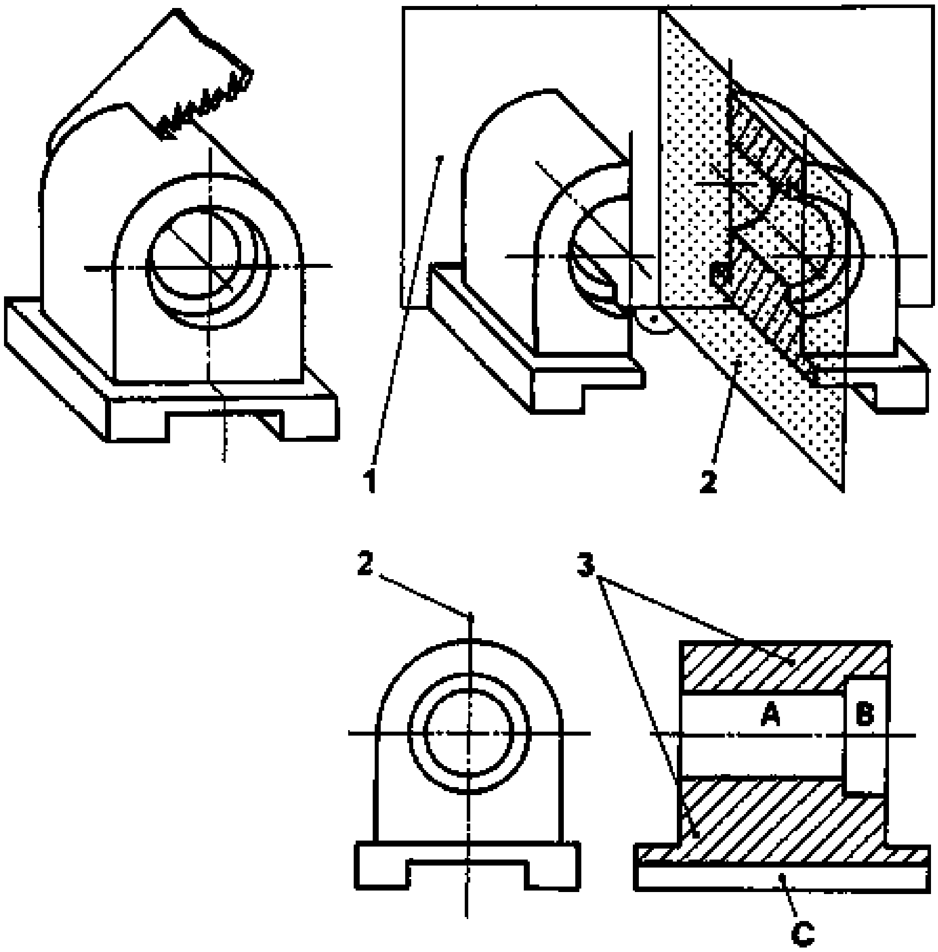


Fig. 5.2.

1 Drawing plane
2 Cutting plane
3 Shading

To clearly define the surfaces of a section, the cut areas have to be marked by a hachure!

The areas which become visible because of the cut (A, B, C) and which are located behind the cutting plane are not shaded.

A cut is the imaginary dividing of an object by a cutting plane at right angle to the drawing plane.

5.1.2. Identification of the Cut Areas

The hachure by which the cut areas are represented is represented by parallel thin solid lines. They are drawn at 45° to the axis or to the main outline of the object.

To differentiate between various objects, the hachure can be varied with respect to the direction of shading and the width of hachure, as is shown in Figs. 5.3. and 5.4.

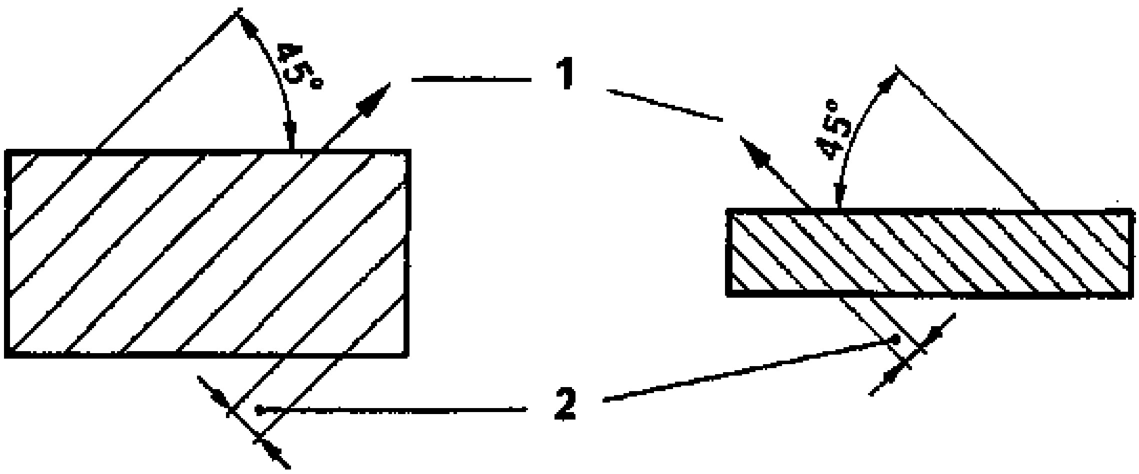


Fig. 5.3.

1 Direction of shading, 2 Spacing of shading lines

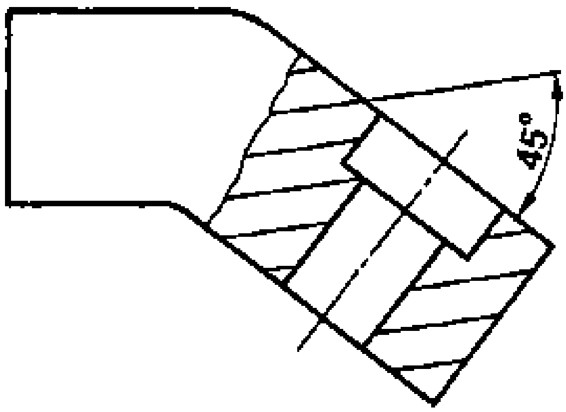


Fig. 5.4.

Rules:

– large cut areas are identified by wide−space hachure,

– small cut areas are identified by small−spaced hachure (Fig. 5.3.) – but

the cut areas of one and the same parts must be shaded in the same way (Fig. 5.5.).

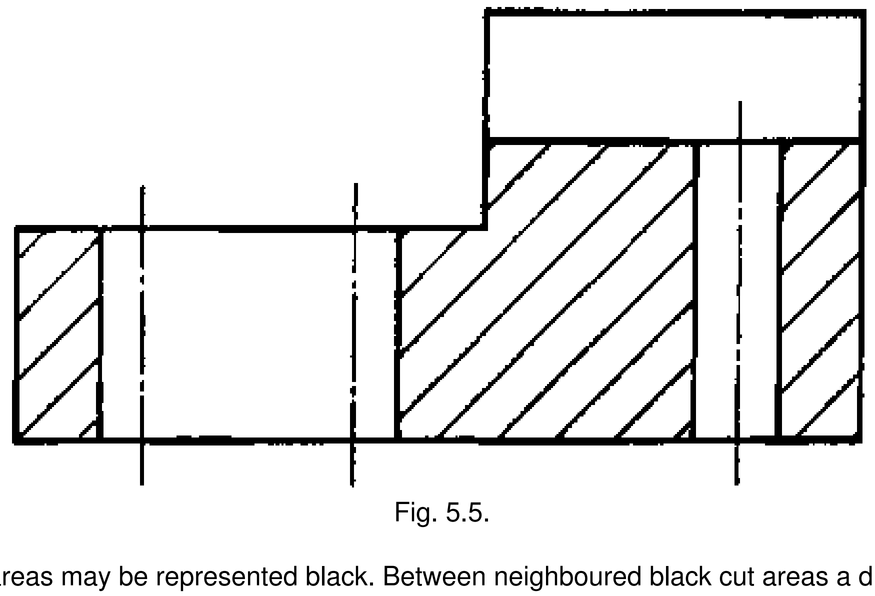


Fig. 5.5.

Very narrow cut areas may be represented black. Between neighboured black cut areas a distance must be observed as is shown in Fig. 5.6.

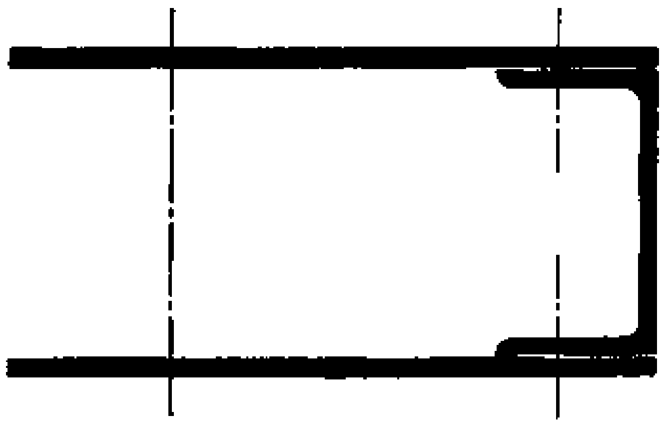


Fig. 5.6.

In assembly drawings, for two adjacent parts different directions of shading are selected (see Fig. 5.7.). For surfaces contacting each other and having the same direction of hachure, shading of different spacing of the lines should be used (see Fig. 5.8.).

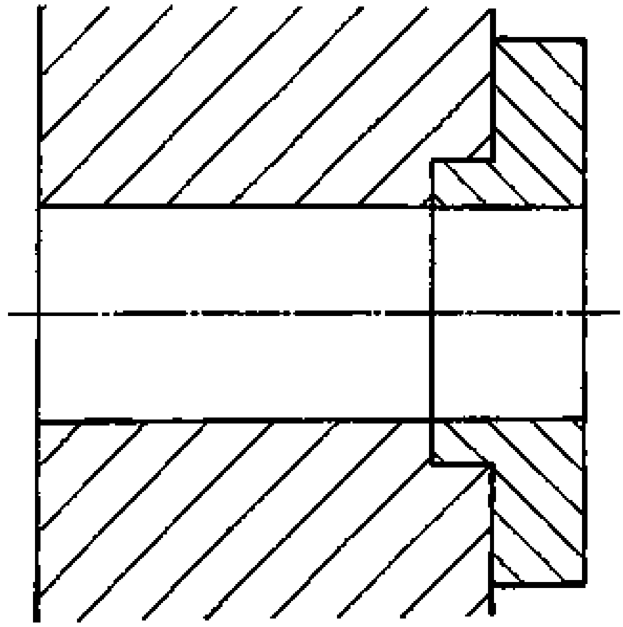


Fig. 5.7.

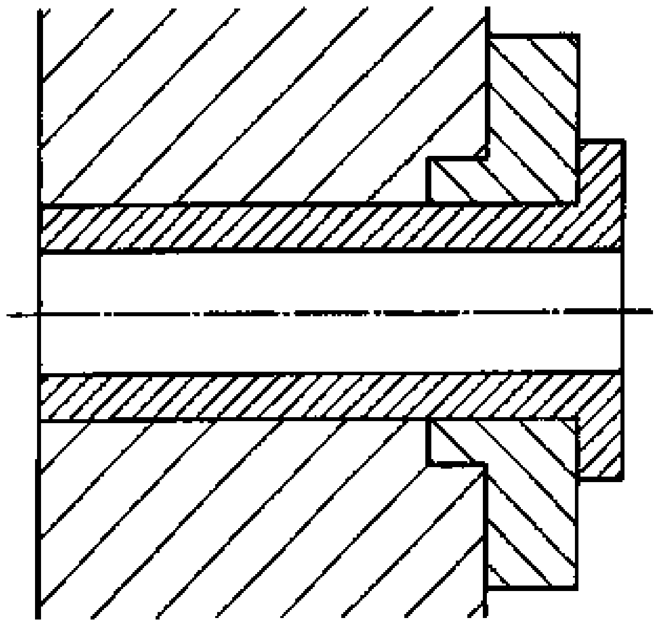
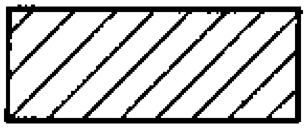
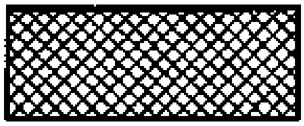
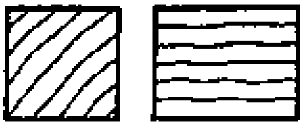
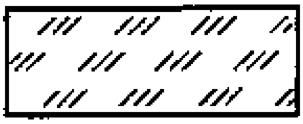
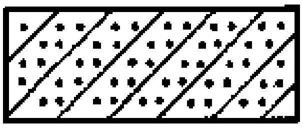
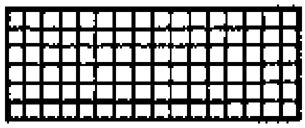
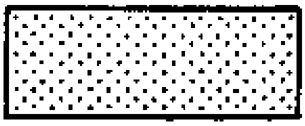
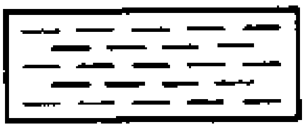
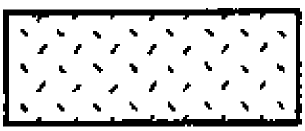


Fig. 5.8.

Shading with thin solid lines at an angle of 45 is the general hachure which is used irrespective of the material. In assembly drawings, shading can be used which is indicative of the material. In this way, the drawing becomes more clearly. The function of the parts can thus be perceived more conveniently and rapidly. The hachure, also known as section lining, which indicates the material cannot, however, exactly specify the material as it is defined in the list of parts. Fig. 5.9. shows a selection of section linings for materials.

Fig. 5.9.

Material	Shading characterising the material
Metal	
Plastics, rubber, felt, leather, filler, material	
Wood (cross−grained wood, other wood)	
Glass and the like	
Reinforced concrete	
electrical windings	
Sintered materials	
Liquids	
Porcelain, marble, slate	

Repetition

1. Quote the two important reasons for the use of sectional views!

2. What is the common characteristic of all sections of an object?

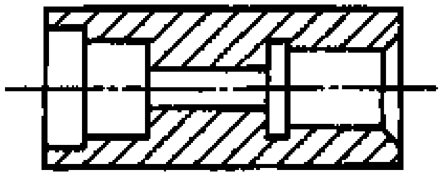
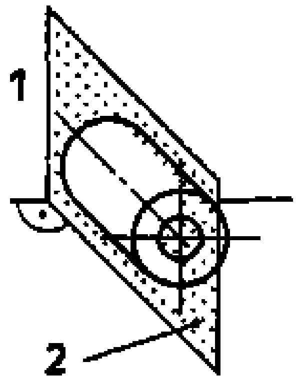
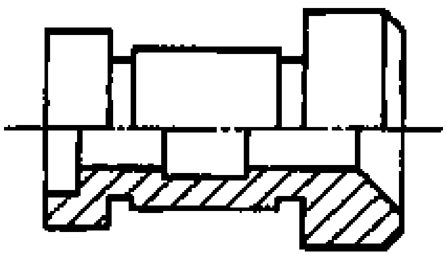
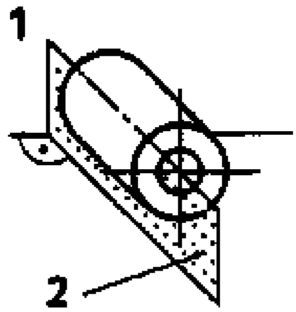
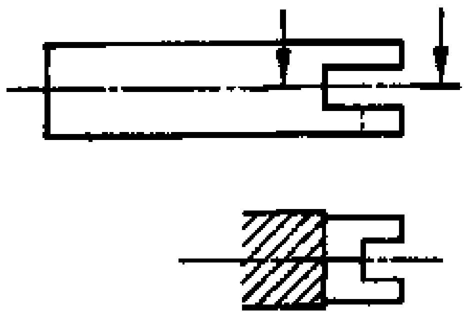
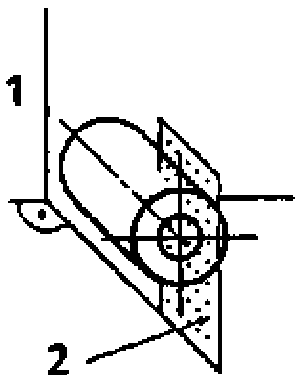
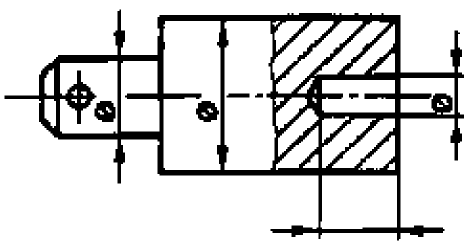
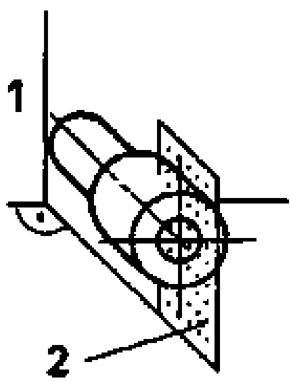
3. What is the angle and the type of line used for the representation of hachures in general?

5.1.3. Survey of the Types of Sectional Views

The following illustration (Fig. 5.10.) shows the possible sectional views, their development and applications.

Fig. 5.10.

1 Drawing plane, 2 Cutting plane

Type of section	Explanations	Applications	Principle
Full sectional view	Objects with intricate internal shapes. Symmetric or non–symmetric or prismatic or cylindrical.		
Half section	Objects with intricate internal and external shapes; usually symmetric, prismatic or cylindrical		
Partial section	An internal partial shape is to be made visible but a full section is not necessary. It would not show more. Cutting line indicated by arrows.		
Broken–out section	This section is used to show only a desired feature of the object. A full section is not necessary or not permitted (shafts, pins, rivets). The view must be shown completely because of other features of the object.		

5.2. Full Sectional Views

5.2.1. Information about the Full Section Representations

A full section is the imaginary division of an object by an unlimited cutting plane.

It is used when the full section of an object is to be revealed (Fig. 5.11.).

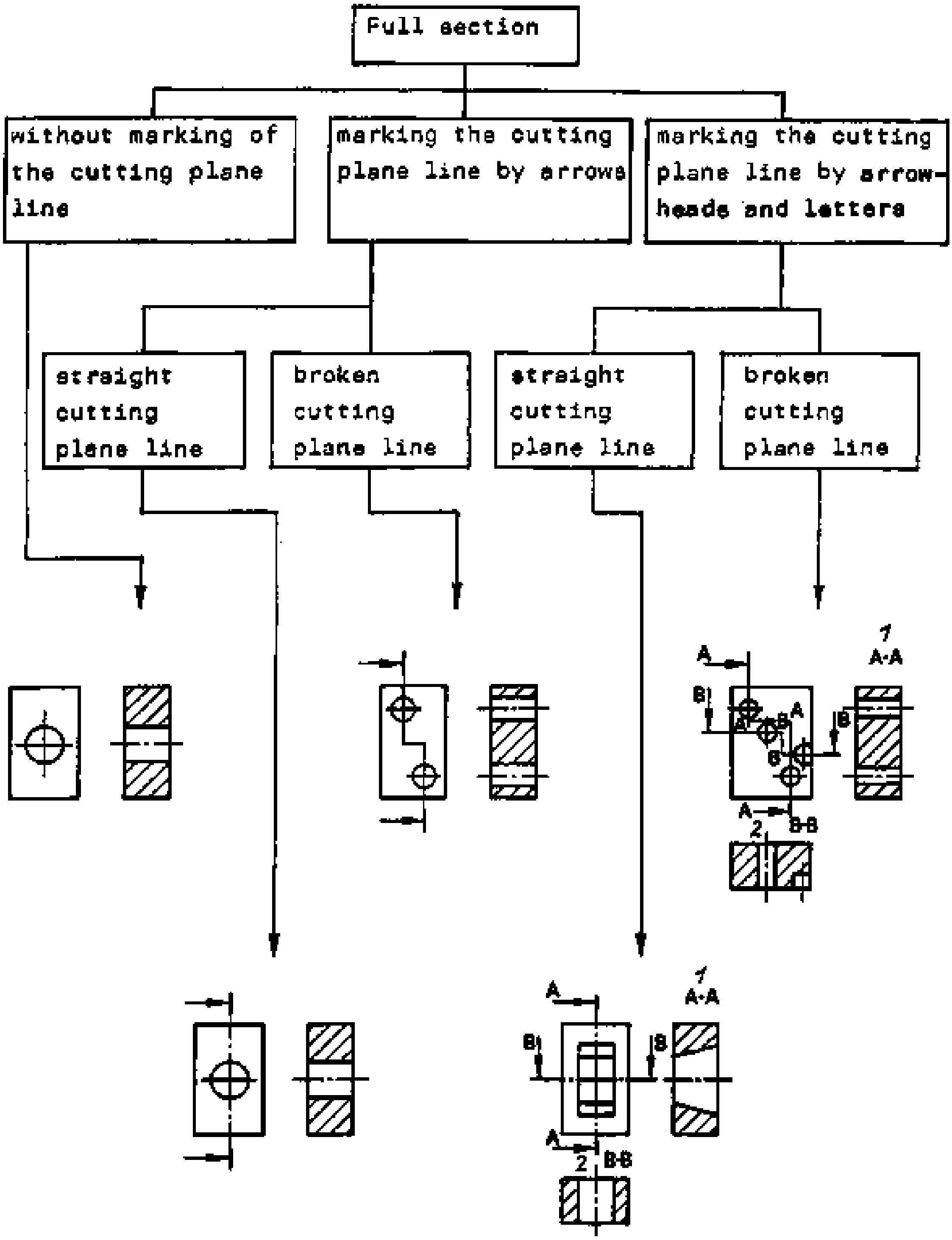


Fig. 5.11.

1 Section A–A, 2 Section B–B

5.2.2. Full Sections without Marking of the Cutting Plane Line

The cutting plane need not be shown when this line is clear and subject to but one interpretation. This is the case when the cutting plane passes through the centre line (symmetry section). Marking is also not necessary when the plane of cutting is clearly identifiable from the view from which the section has been developed (Figs. 5.13. to 5.16.). This also applies to the fact when the cross−section is directly drawn into the view (Fig. 5.17.).

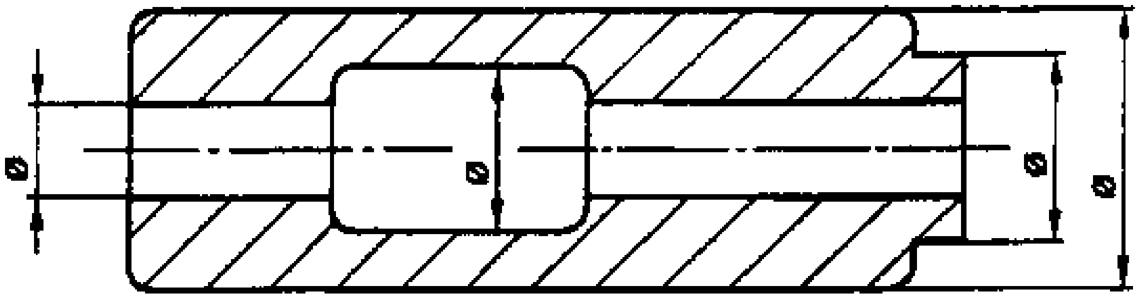


Fig. 5.12.

For full sections without marking the cutting plane line, there are the following possibilities:

Full section (without further views) (Fig. 5.12.).

The shape of the sleeve is clearly visible even with a second view. It is cylindrical. This is indicated by the diameter sign. With this, the cutting plane line is clearly visible − it is through the centre line.

<u>Representation in general view and full section (Fig. 5.13.).</u>

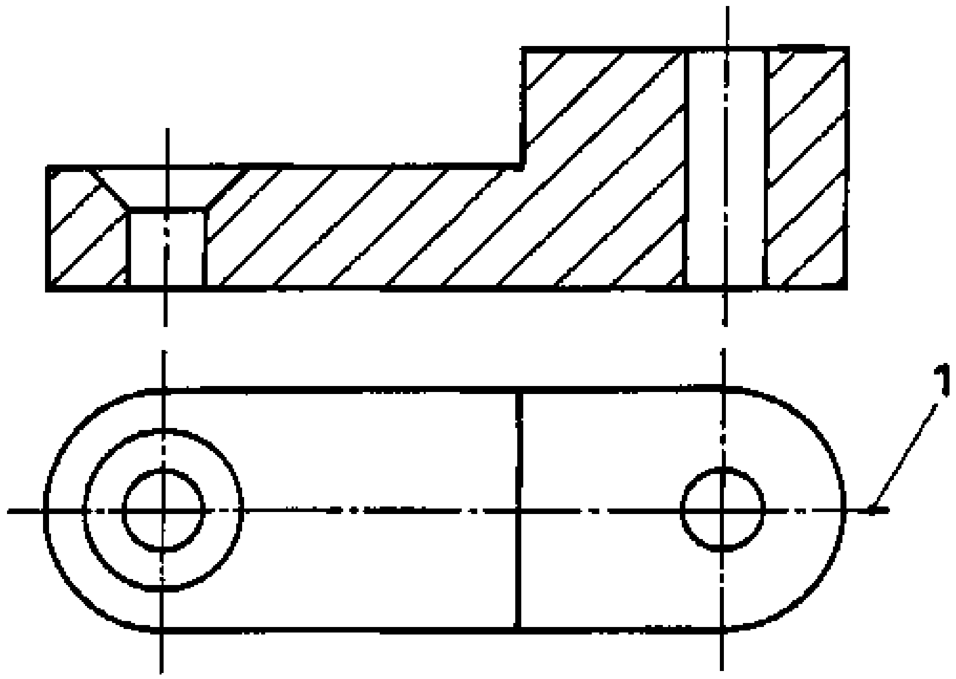


Fig. 5.13.

1 Cutting plane line

The cutting plane line cannot be interpreted as passing through the centre of the object.

<u>Representation in general view and in two sections (Fig. 5.14.).</u>

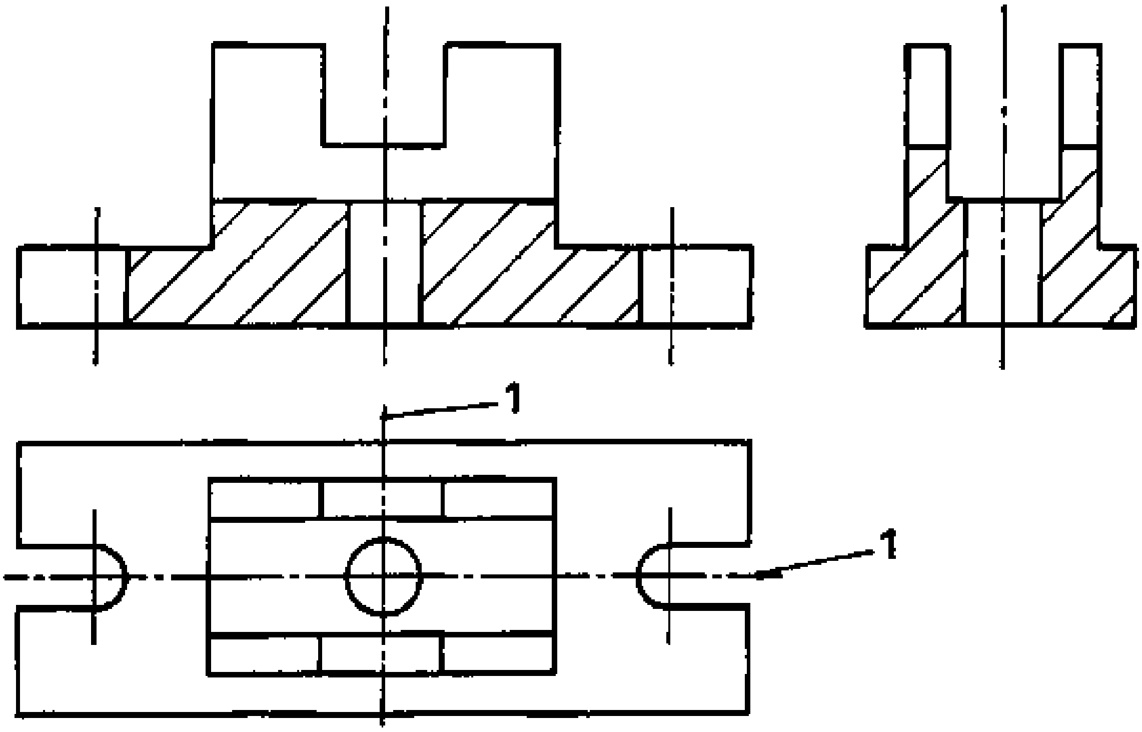


Fig. 5.14.

1 Cutting plane line

The cutting plane clearly passes through the central axes. Also, for the bolts represented (Fig. 5.15.). the line of the cutting plane of the two full sections is clear.

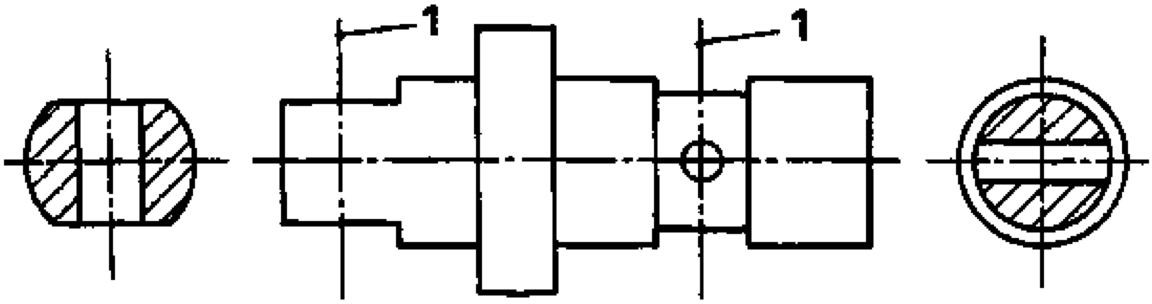


Fig. 5.15.

1 Cutting plane line

Representation in two full sections (Fig. 5.16.)

From one full section, a second can be derived. This must be represented in such a way as if the initial section was drawn in a view.

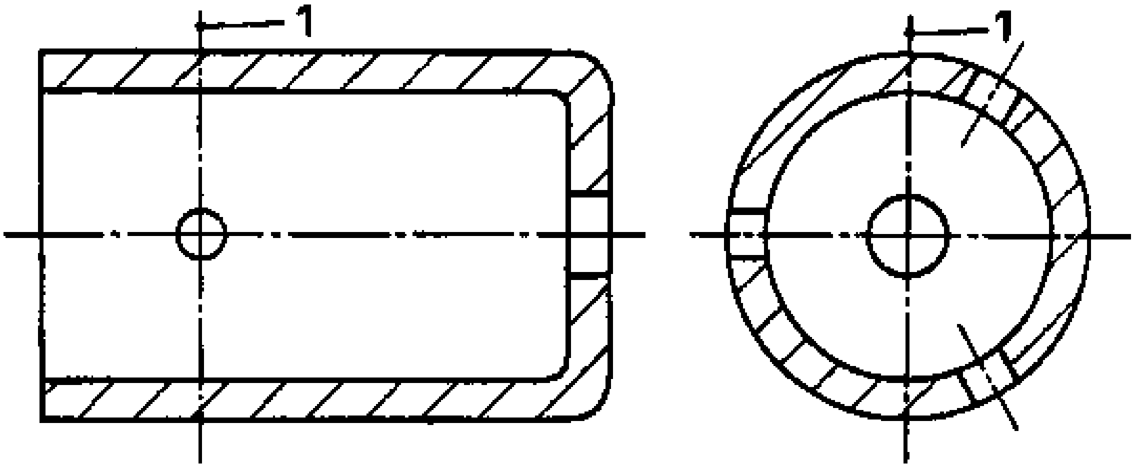


Fig. 5.16.

1 Cutting plane line

Representation of the cross−section within a view (Fig. 5.17.)

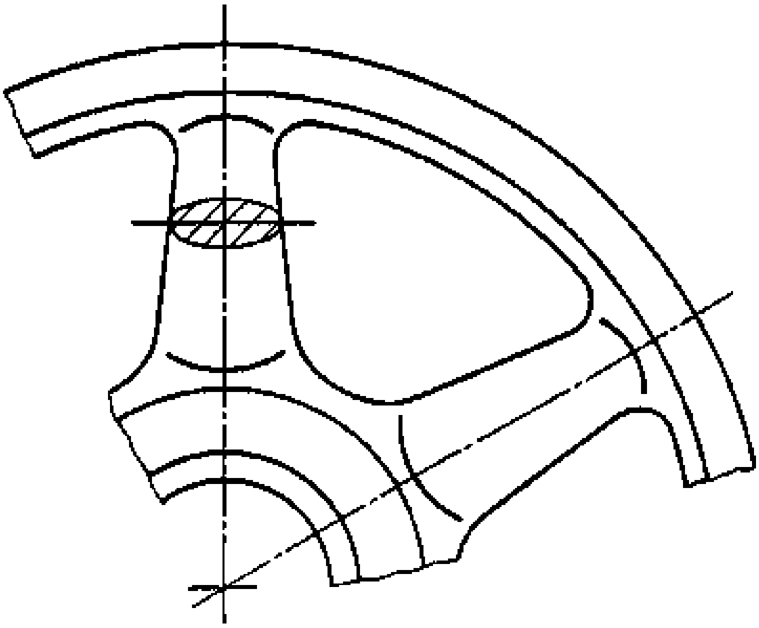


Fig. 5.17.

For ribs, spokes and the like, the cross−section can be indicated directly at the point for which it hilds (Fig. 5.18.).

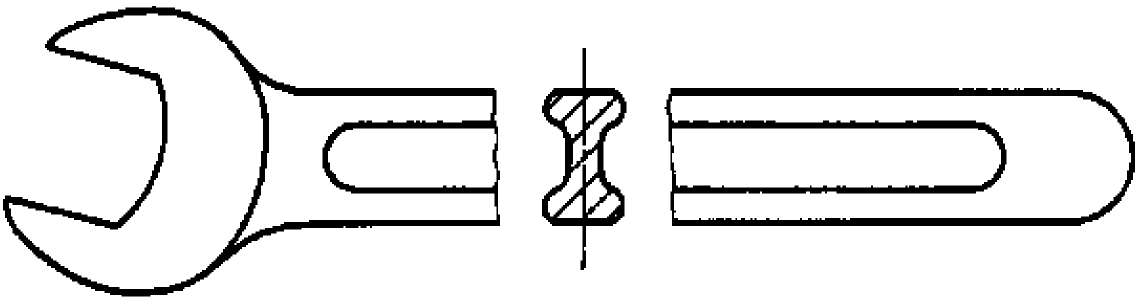


Fig. 5.18.

When the section is interrupted for certain purposes, then this must be indicated by thick lines of the contour.

Repetition

1. In what case of the sectional view is the indication of the cutting plane line not necessary?

2. Explain the rational representation of sectional views.

5.2.3. Full Section with Marking of the Cutting Plane Line by Arrowheads

When the location of the cutting plane is not clear, then it is marked.

The imagined cutting plane is drawn in the form of a dash−and−dot line which projects beyond the contour of the object (see Fig. 5.19.).

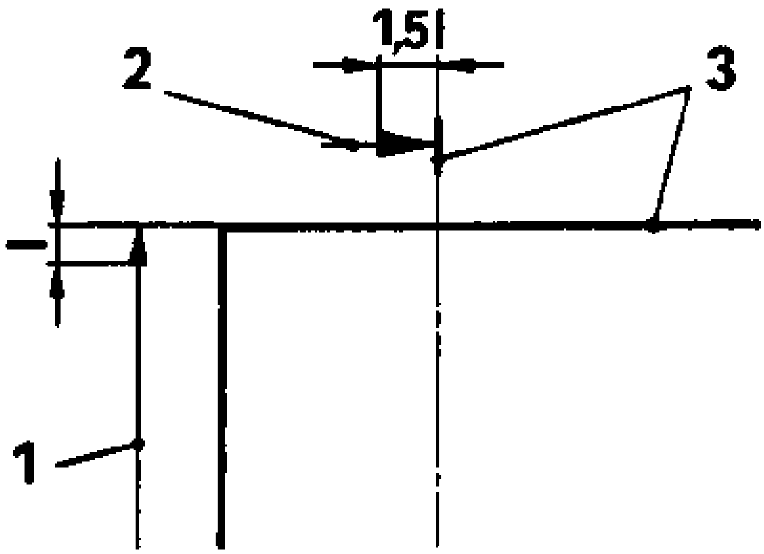


Fig. 5.19.

1 Centre

The ends of this centre line are drawn thick. An arrowhead is put on the centre of the thickened ends which point in the direction of sight. The size of these arrowheads is about 1.5 times that of the arrowheads of dimension lines in the drawing.

For full sections with marking the cutting plane by arrowheads, there are the following possibilities:

Cutting plane located in a straight line
Offset cutting plane line

This is illustrated by the Figs. 5.20. to 5.22.

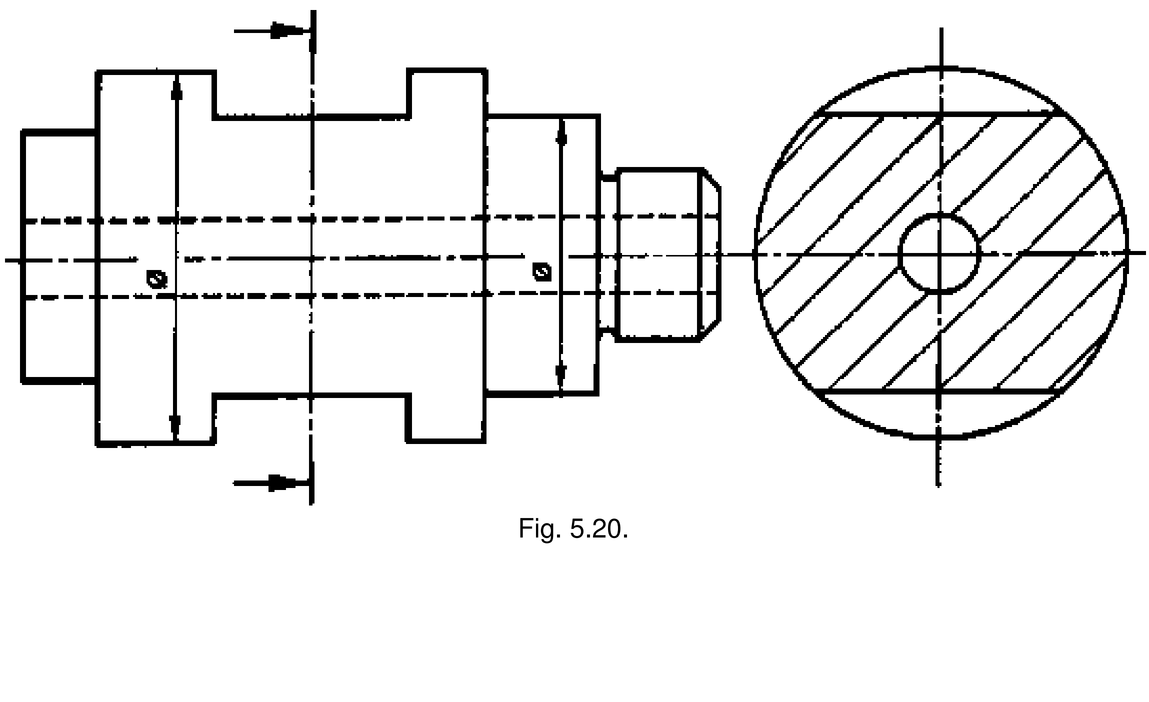


Fig. 5.20.

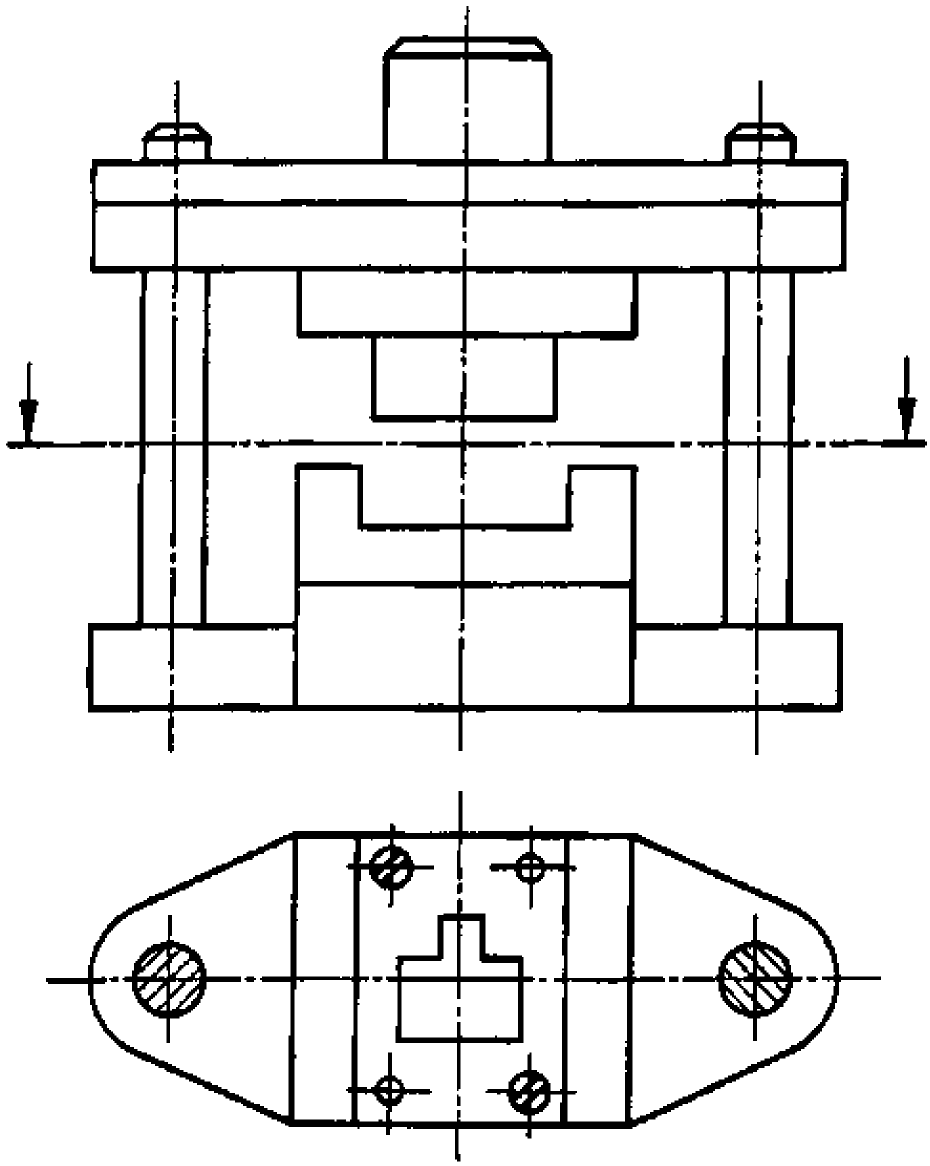


Fig. 5.21.

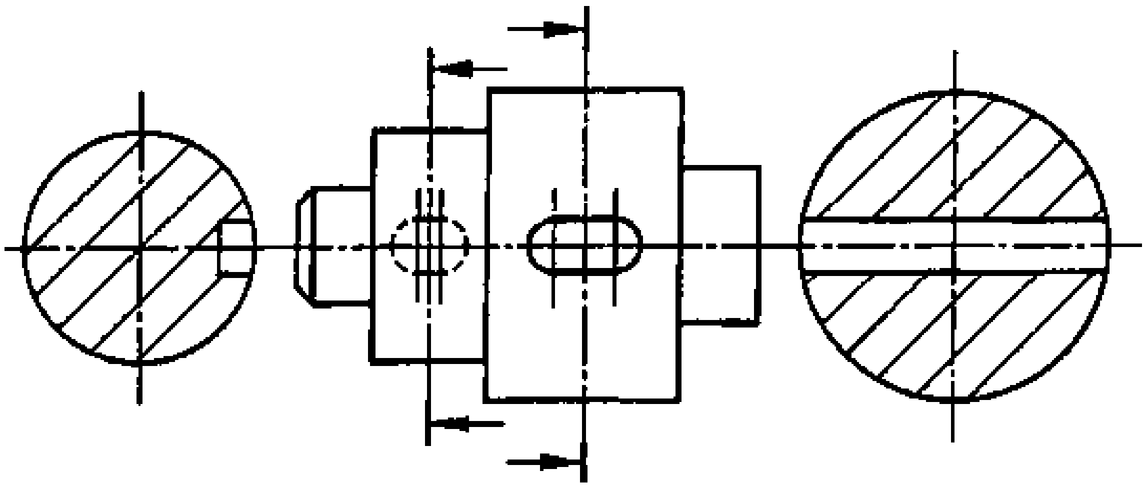


Fig. 5.22.

When using the offset cutting plane line, one sectional view covers internal shapes which are located in various planes. The change in direction of the cutting plane line is indicated by thickening the angle.

All parts of the section are represented in such a way as if they would be located in one plane. The angles do not result in visible edges (imaginary dividing as shown in Fig. 5.23.). The section is turned into one plane and then projected. This is necessary in order to avoid distortions (Fig. 5.24.). The arrowhead pointing in the direction of sight is also here perpendicular to the cutting plane. The angle of twist is not given.

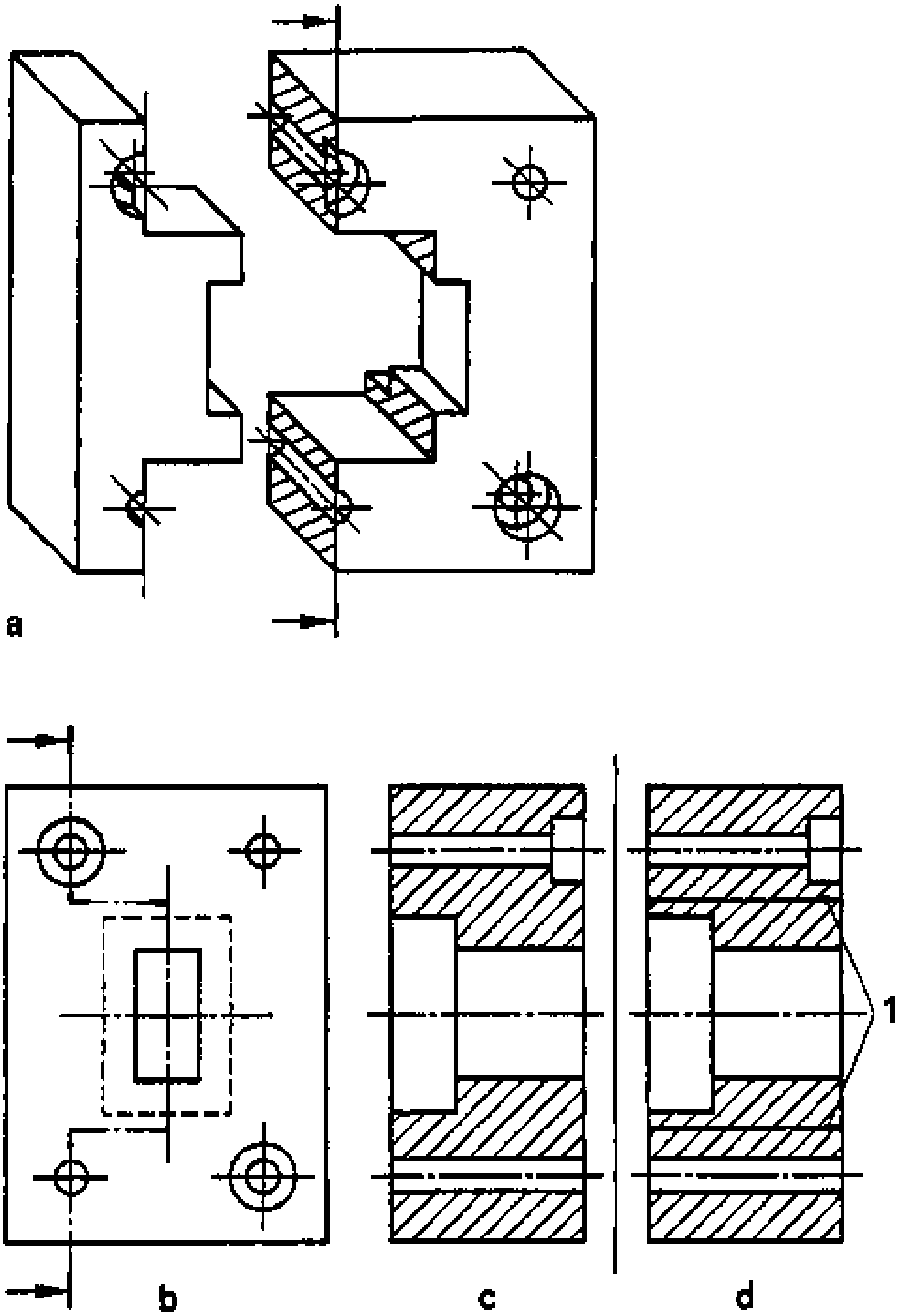


Fig. 5.23.

1 wrong

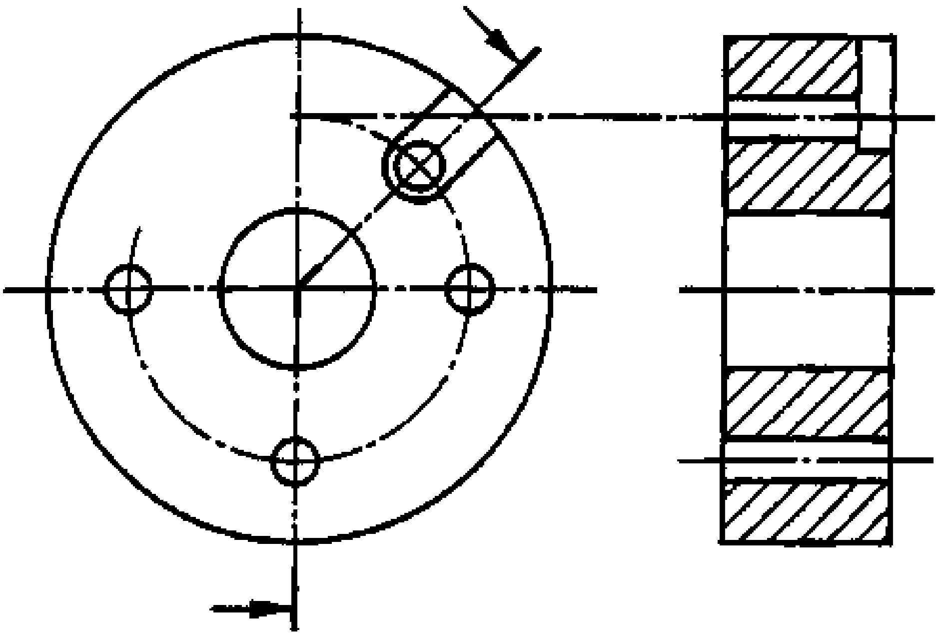


Fig. 5.24.

<u>Repetition</u>

1. What are the reasons for marking the cutting plane line by arrowheads?

2. What are the advantages associated with the offset cutting plane line?

3. How is the offset cutting plane line marked?

5.2.4. Full Section with Marking the Cutting Plane Line by Arrowheads and Letters

When several full sections are necessary in one drawing and when misinterpretation will be possible, marking by arrowheads alone will not suffice.

The various sections are distinguished by letters. One uses capital letters of the beginning of the alphabet. Each cutting plane line receives a letter. These letters are located close by the arrowheads and their size is twice that of the dimension figures.

The letters must be written so that they can be read from below!

The letters used to identify the sections are such as Section A – A, Section B – B, etc.

There are two possibilities which are shown in Figs. 5.25. to 5.27.

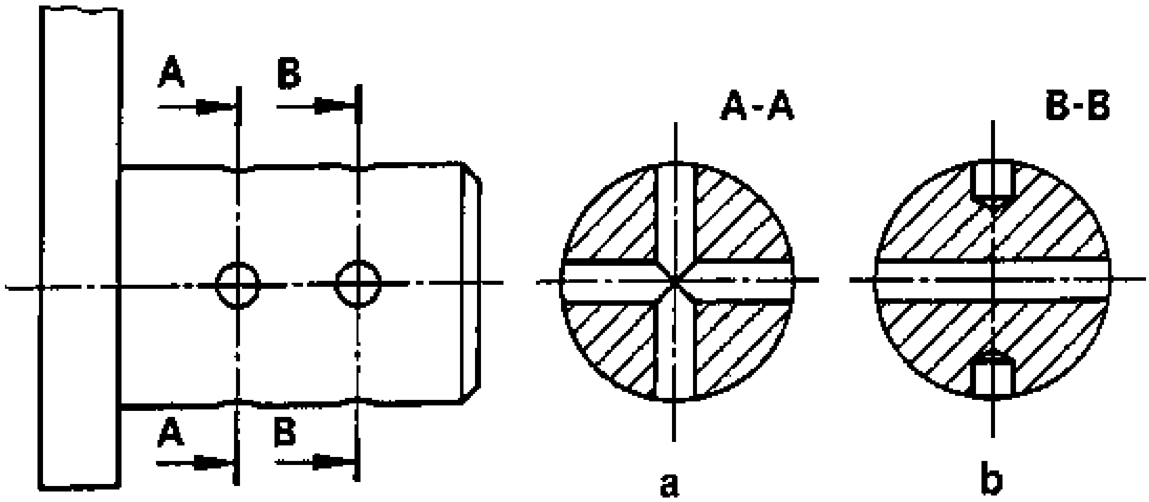


Fig. 5.25.

a Section A–A, b Section B–B

Straight cutting plane line

In a simplified manner, one cross–section can be shown without edges behind it (e.g. Section A – A, right–hand side, Fig. 5.26.).

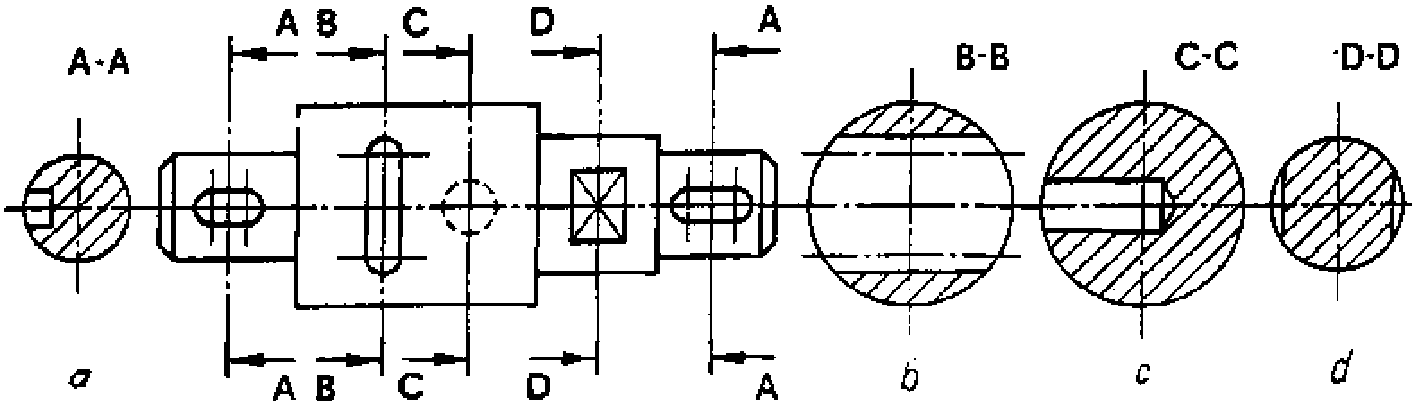


Fig. 5.26.

a Section A–A, b Section B–B, c Section C–C, d Section D–D

Offset cutting plane line

This marking must be used when the part has several interior shapes or unsymmetrical arrangement which are not located in a straight line so that straight sections are useless.

The letters are used to identify clearly the individual sections.

The letters at the angles where the direction of the line changes are only written when they are indispensable for clarity. They are written so that they can be read from below (Fig. 5.27.).

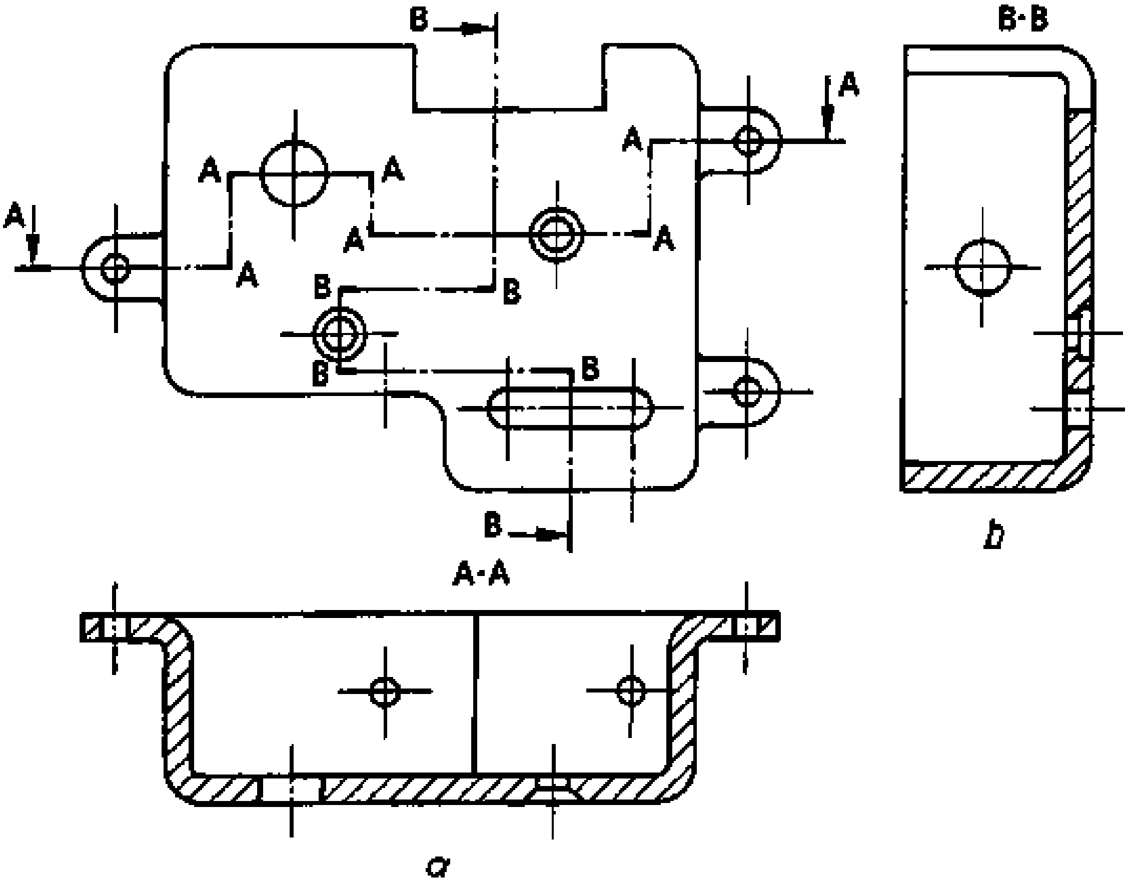


Fig. 5.27.

a Section A–A, b Section B–B

<u>Repetition</u>

1. When must the cutting plane line be marked in addition to the arrowheads by letters?

2. Explain the manner of marking by letters in greater detail (location, size and number of letters, designation of the sections)!

5.3. Half Sections

5.3.1. Use of Half Sections

Objects having several exterior and interior shapes call for representation in view and section. When these objects are symmetrical, the external view and the section can be combined in a half section.

Consequently, one view can be omitted.

The half section enables the rational representation of symmetrical objects with diversified exterior and interior shapes. The half section is the imaginary separation of an object by a cutting plane which extends to the centre line (Fig. 5.28.).

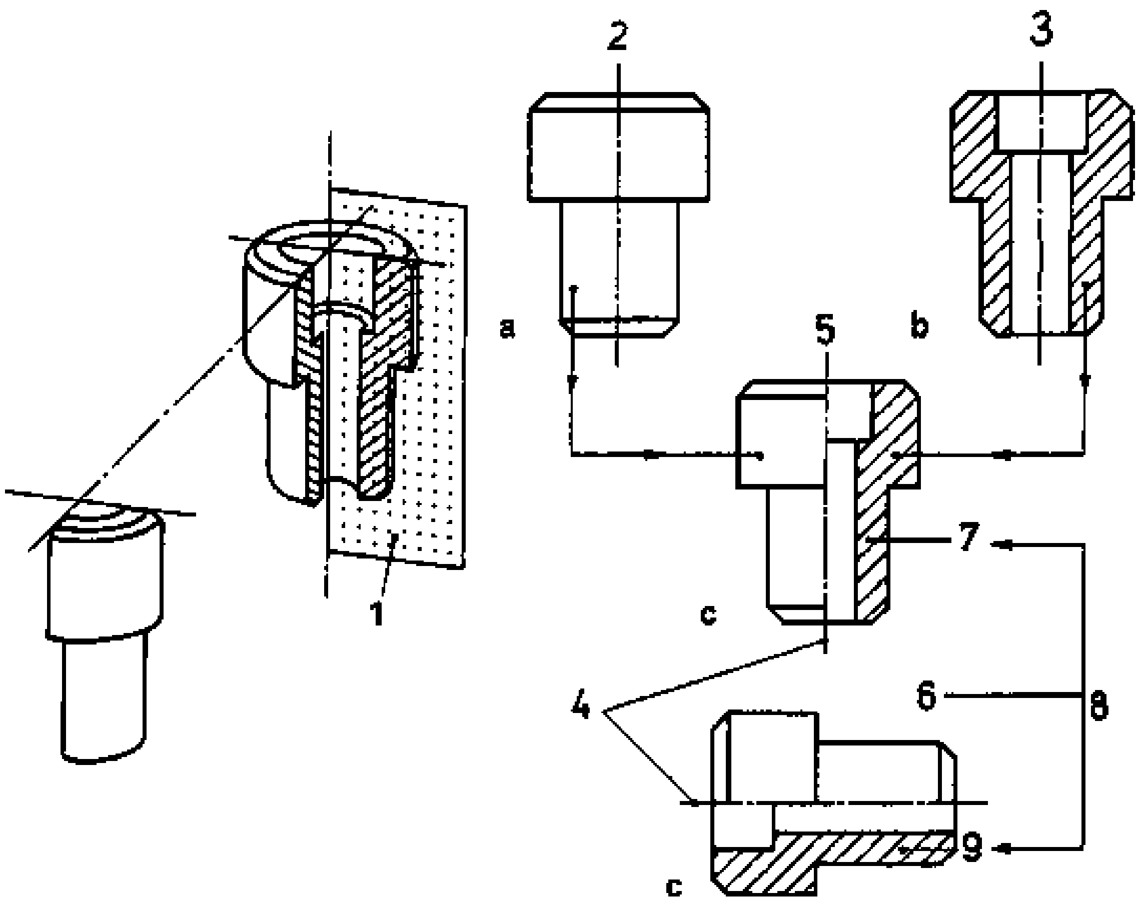


Fig. 5.28.

1 Cutting plane, 2 View, 3 Full section, 4 Separating line 5 Half section, 6 Location or the half section, 7 Right, 8 or 9 bottom

5.3.2. Rules for Half Section Representation

– The sectioned half must be arranged at the right–hand side when the centre line is vertical (Fig. 5.29.)

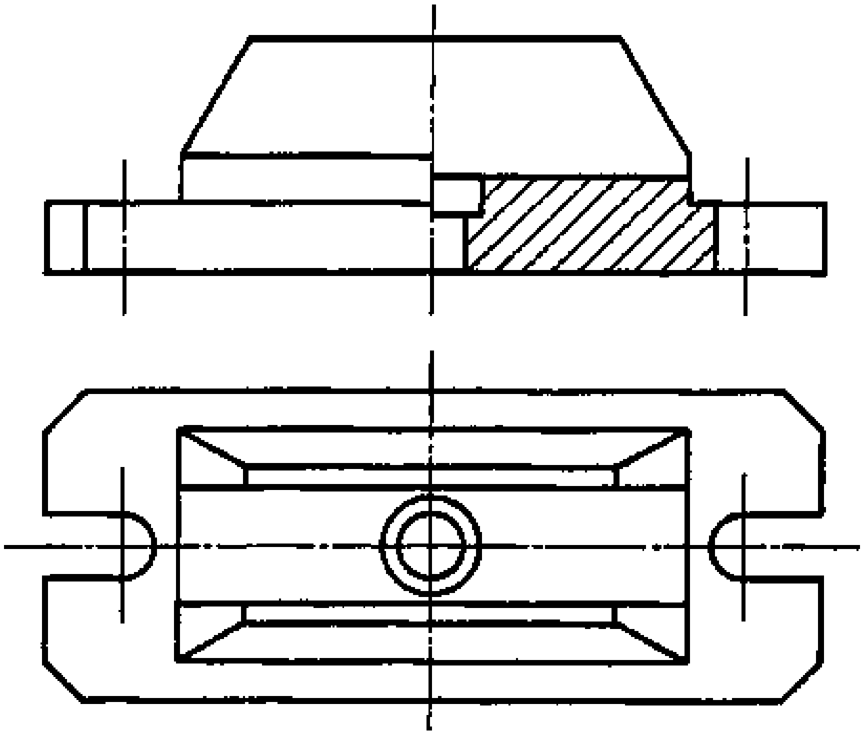


Fig. 5.29.

at the bottom when the centre line is horizontal (Fig. 5.30.)!

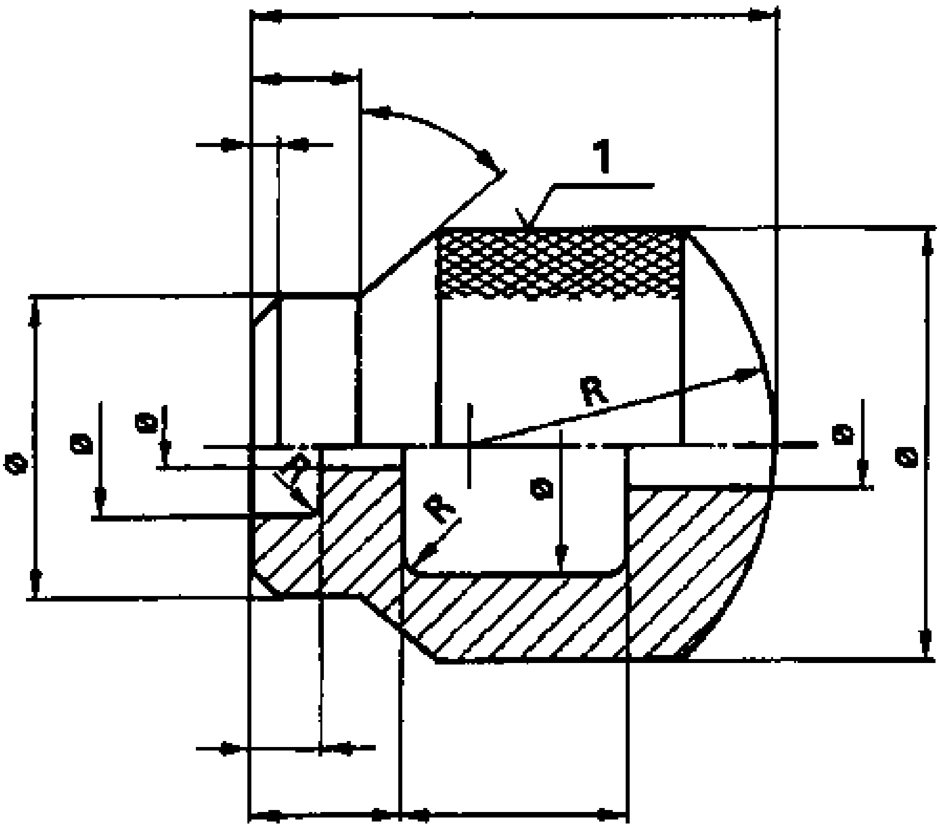


Fig. 5.30.

1 knurl, 1.2

– The centre line is the separating line between exterior view and half section. This separating line must be drawn as a body edge!

– In the half of the exterior view, no dashed lines for hidden body edges have to be drawn!

– Dimension lines for interior shapes which are represented only half are provided with only one arrowhead (Fig. 5.30.)!

– To improve clearness, the interior linear measures are applied to the half section while the exterior linear measures are applied to the half of the exterior view!

Repetition

1. Define the representation of half section.

2. Quote the possibilities of use of a half section.

3. What is the advantage of the sectional view?

4. What are the rules for the arrangement of the sectioned half?

5. Explain how dimension have to be entered in the drawing of a half section.

5.4. Parts in the Cutting Plane Which are not Cut

A sectional view has to reveal the interior shape. In assembled components, the interesting detail is the point where connecting parts are arranged or where shafts, axles, journals, bolts, rolling elements and the like are arranged. Usually, these parts have no internal shapes. Therefore, they are represented in the non−cut form (see Figs. 5.31., 5.32. and 5.33.).

Ribs, spokes, arms, bracings and the like must not be represented in sectional views otherwise a wrong idea of the shape of the object would be produced.

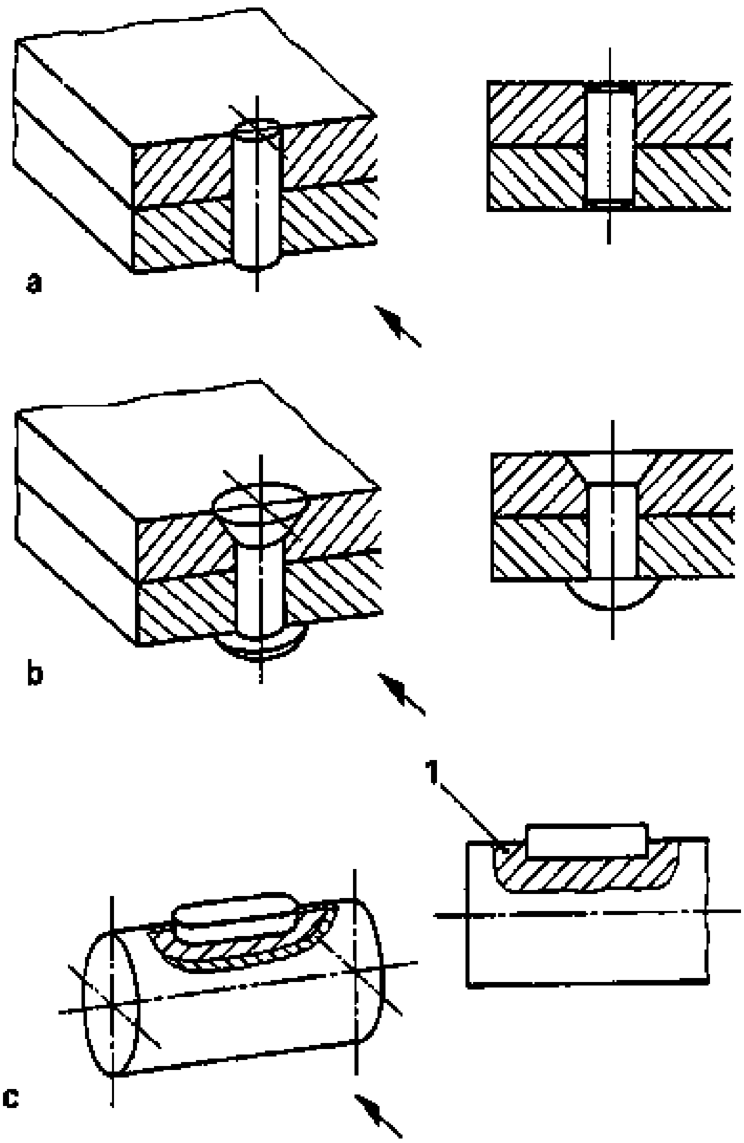


Fig. 5.31.

a Pin connection
b Rivet joint
c Spring connection
d Shaft broken open

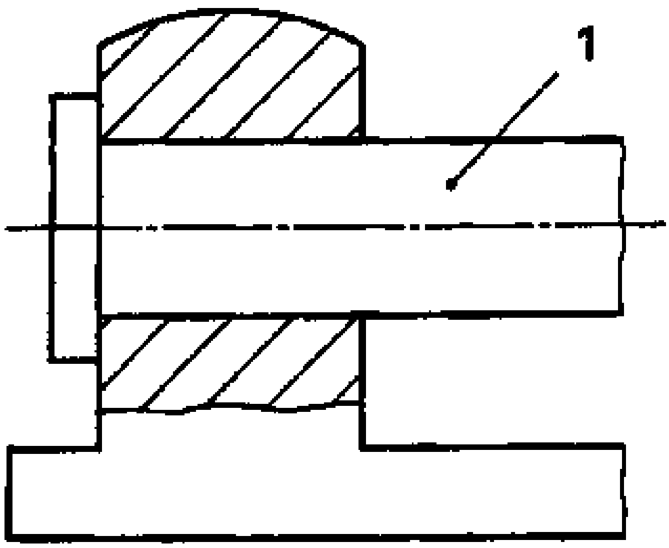


Fig. 5.32.

1 Shaft, non−cut

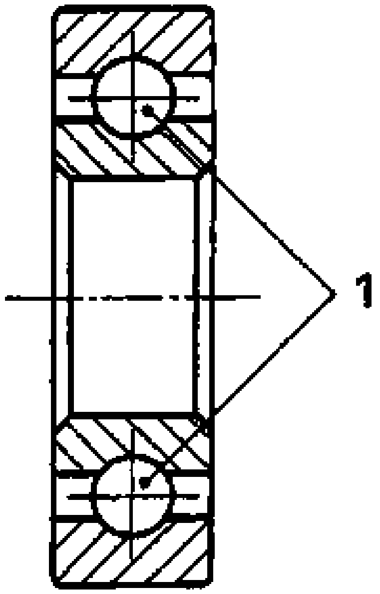


Fig. 5.33.

1 Rolling element (ball) not cut

5.4.1. Connecting Parts

Once more consider Fig. 5.31.

5.4.2. Shafts, Axles, Journals, Rolling Elements

The same rules which have been explained in connection with Figs. 5.31. to 5.33. also apply to the representation in half sections.

5.4.3. Ribs, Spoken and Arms

Such bracing and supporting elements as ribs, spokes and arms − when they are located in the cutting plane − have to be treated in the same way as the connecting elements and the shafts. The Figs. 5.34. and 5.35. show that in this way the shape is more clearly represented.

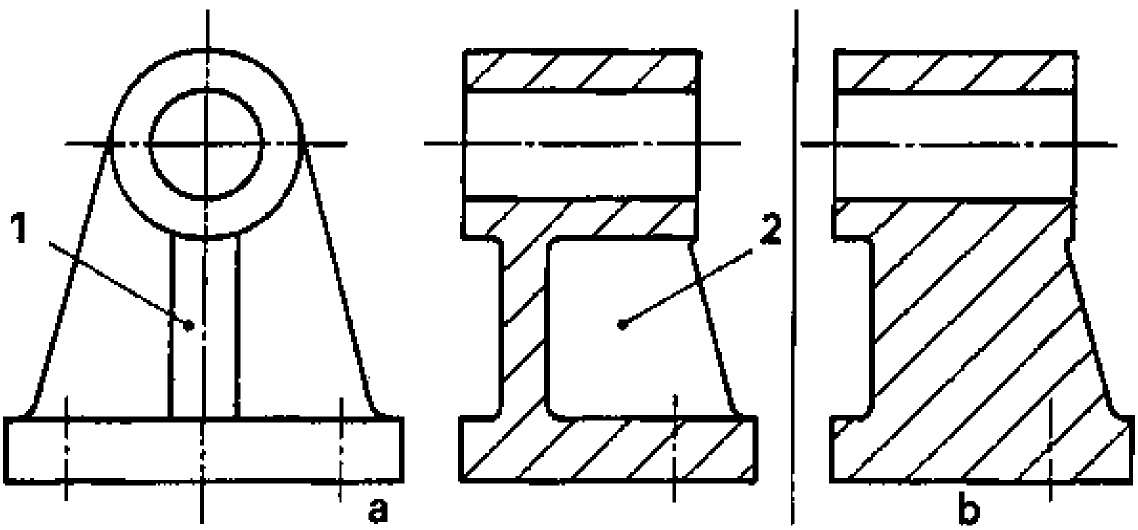


Fig. 5.34.

1 Rib, 2 Rib not cut, b wrong representation

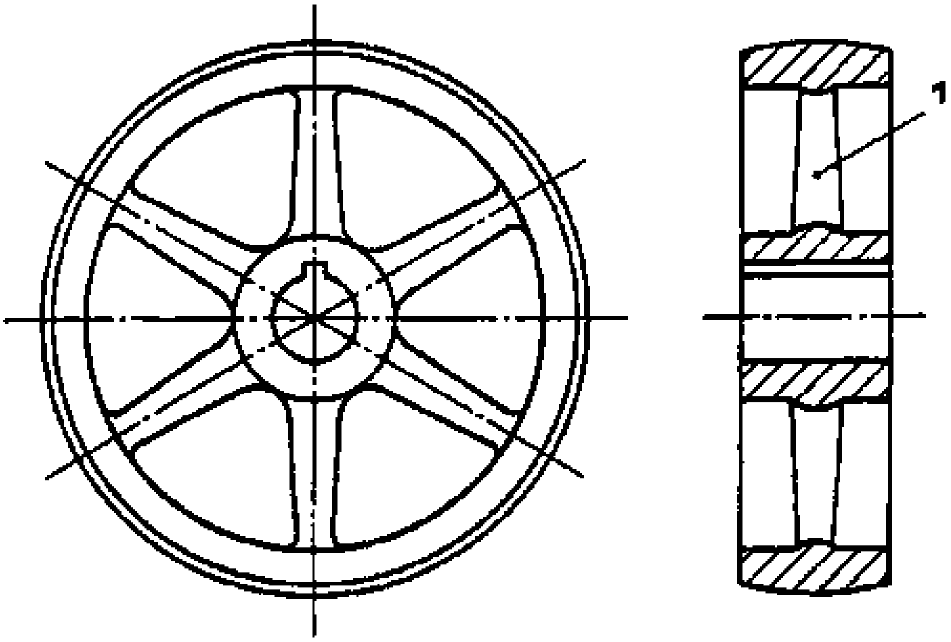


Fig. 5.35.

1 Spoke not cut

<u>Repetition</u>

1. Give examples of parts which in sectional views of assembly drawing must not be cut although they are located in the cutting plane.

2. Explain the reasons for the non−sectioned representation of certain parts in a sectional view!

3. Explain the imagined cutting plane line when spokes, ribs or the like are located in the cutting plane!

6. Thread Representation and Thread Dimensioning

In practice, many problems are solved with the help of components and machine parts which have the shape of a thread. Above all, these are:

- problems of fastening (connecting) parts and
- problems of moving (transporting) parts.

A distinction is made between fastening screw threads and threads for the transmission of motion (see Fig. 6.1.).

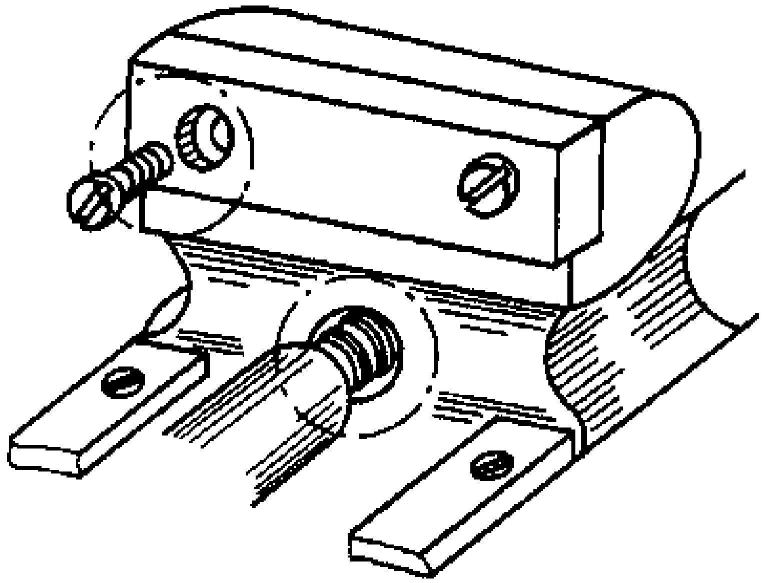


Fig. 6.1.

Fastening screw and screw for transmitting motions

In any technical problem which is solved with threaded parts, external threads and internal threads (also known as male and female threads) are involved. An external thread or internal thread alone is meaningless.

6.1. Thread Representation

The simplified representation, on grounds of economy and ease of rendering, is the most commonly used method for showing screw threads on drawings.

Irrespective of the different thread profiles in use, a uniforme symbol is used for thread representation as is shown in Fig. 6.2.

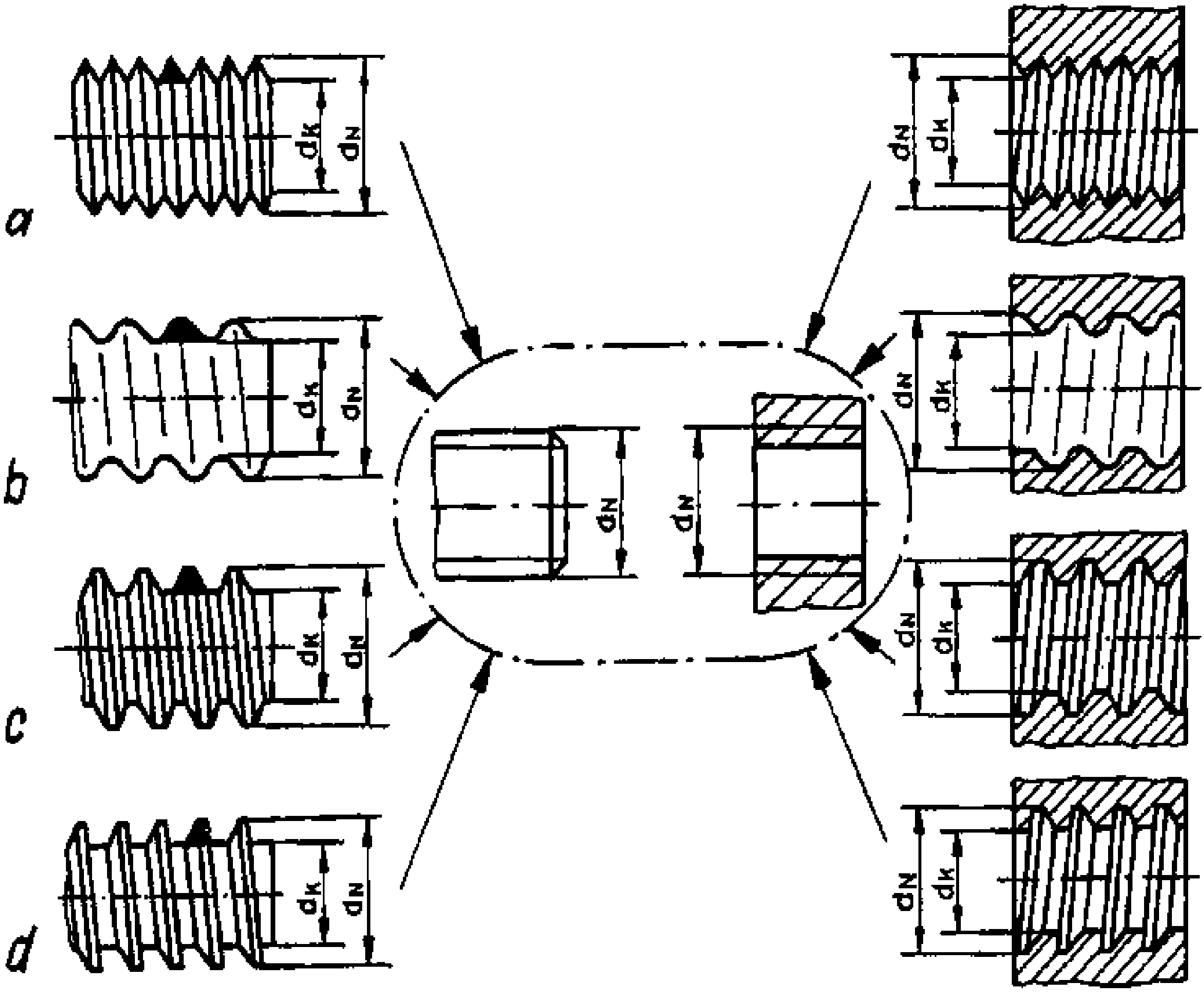


Fig. 6.2. Standardised symbol for screw thread representation

a Sharp thread, b Knuckle thread, c Acme thread, d Saw−tooth thread, d_N Nominal diameter, d_K Core diameter

The development of the thread symbol (thick and thin solid lines) can be explained on the basis of thread production. A distinction is made between

− external thread and
− internal thread (Figs. 6.3. and 6.4.).

In thread representation, at first the produced shape is shown by thick solid lines. In external threads, this is the nominal diameter and in internal threads the core diameter.

Thin lines characterise:

− the core diameter of the external thread and the nominal diameter of the internal thread in sections.

− In the direction of sight of the thread axis, the diameters symbolised by thin solid lines are shown as three−quarter circles.

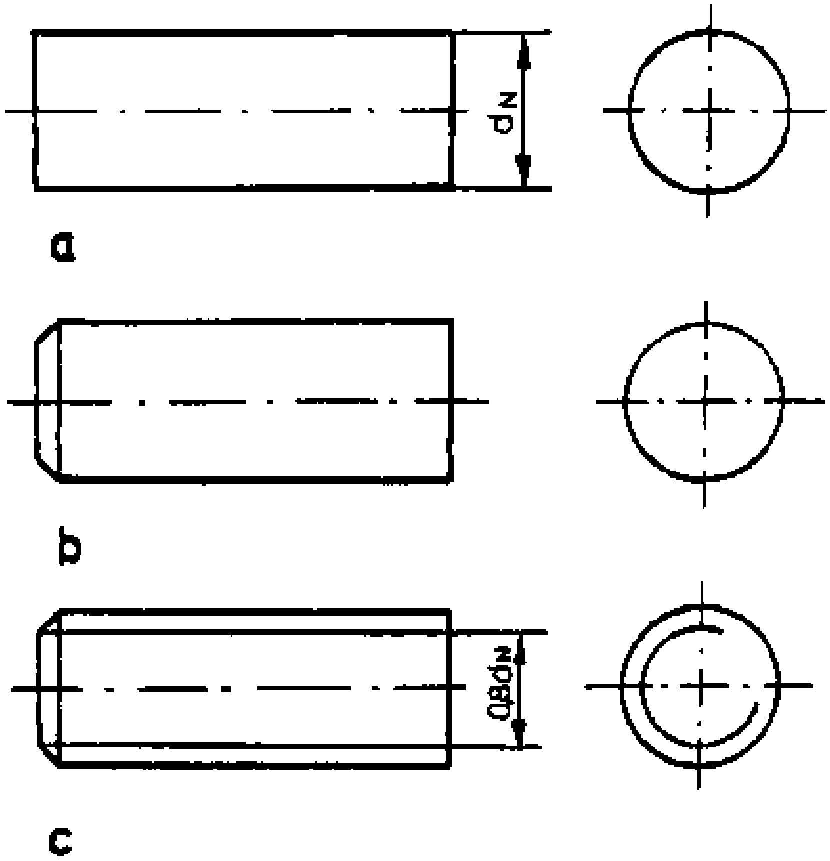


Fig. 6.3. External thread

a Bolt for thread to be produced
b Chamfer for start of cut (not drawn for threads)
c Thread is machined.

Core diameter:

– thin solid line
– inside view, three–quarter circle
– $d_k = 0.8\ d_N$ in drawings

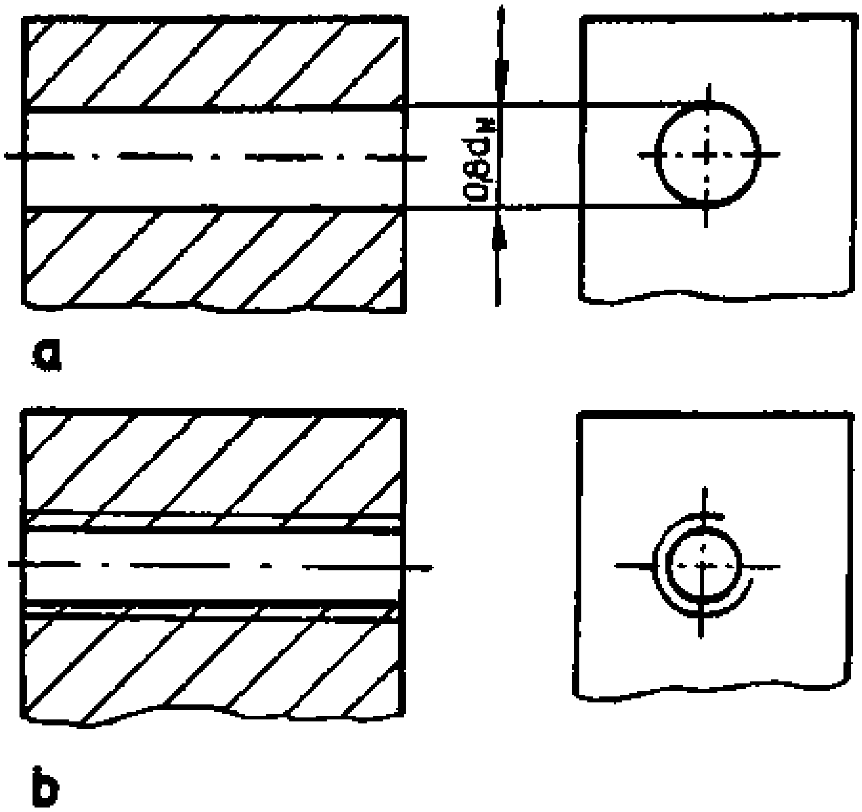


Fig. 6.4. Internal thread

a Hole for thread to be produced $d_k = 0.8\ d_N$ countersink for start of cut is not drawn

b Thread is machined. Nominal diameter:

- thin solid line
- in side view, three–quarter circle

<u>Repetition</u>

1. Explain the type of lines used for showing the thread dimensions.

2. What is the dimension of the core diameters to be drawn for M6, M32 and M48 threads?

6.2. Thread Dimensioning

For the clear dimensional definition of a screw thread, two dimensions are required:

- the nominal diameter and
- the thread length.

For through threads, the thread length is equal to the material thickness (Fig. 6.4.). For all other cases, the following has been specified:

The thread limitation is a thick solid line (see Fig. 6.5.).

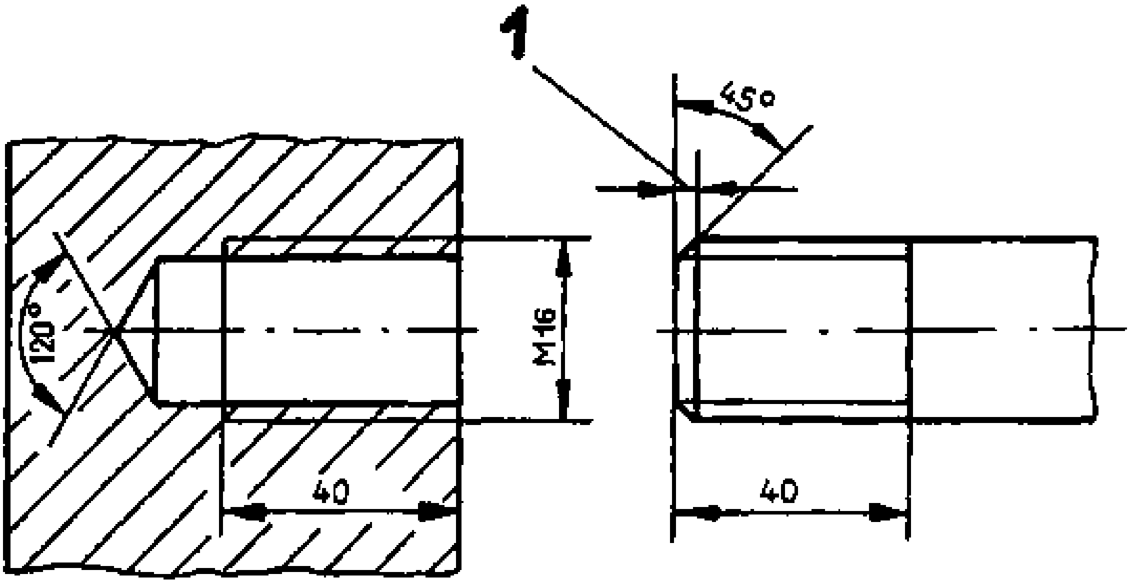


Fig. 6.5. Thread limitation

1 Depth of thread, graphically

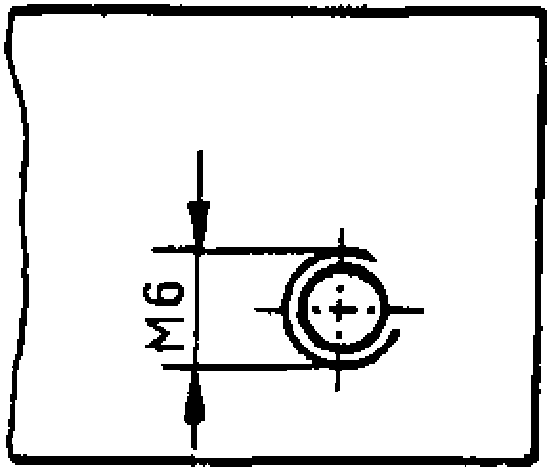


Fig. 6.6. Dimensioning of a circle in screw thread representation

The thread end is included in the thread length (chamfer or round tip). When representing threads in sectional views, the hachure is up to the core diameter. When it is necessary to dimension the circular form, then the nominal diameter is to be shown in the way given in Fig. 6.6.

Although the symbol for all types of thread simplifies the representation considerably, it fails to show, however, differences with respect to profile, pitch, direction and number of threads. These data are given by the designation of screw threads.

To facilitate understanding, the term “pitch” is explained first:

The pitch P is the distance between two adjacent threads, as is shown in Fig. 6.7.

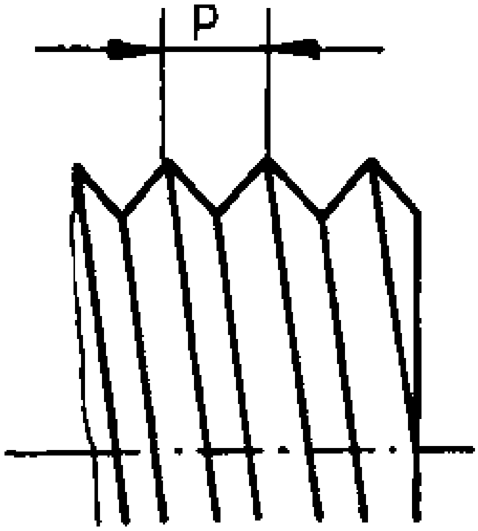
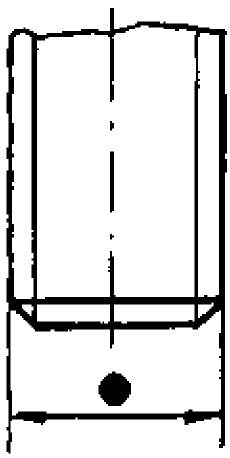


Fig. 6.7. Representation of the pitch of a thread P

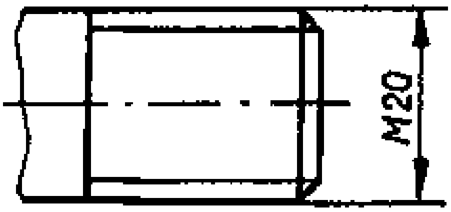
The following Table shows examples of dimensioning different types of screw threads (Fig. 6.8.).

Fig. 6.8.

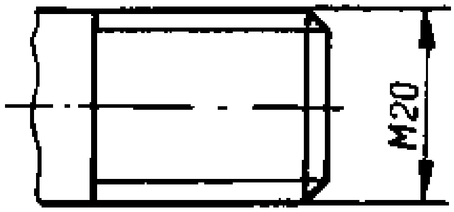
	Example of designation	Explanation	Remarks
	M 16	Metric thread − nominal diameter d_N in mm	V−profile, thread for fastening
	M 20×2	Metric fine pitch thread−d_N in mm pitch P in mm	Pitch smaller than that of a normal thread
	Tr 80×10	Acme thread d_N in mm, P in mm	Thread for transmitting motions
	S 32×6	Saw−tooth thread d_N in mm, P in mm	Thread for transmitting motions
	Rd	Knuckle thread d_N in mm, P in inches	Thread for fastening
		Whitworth thread d_N in inches	1 inch = 25.4 mm
	R3”	Whitworth pipe thread−internal diameter of the pipe in inches	External diameter (external) is larger! Here 87.9 mm

All screw threads without further data are right−hand threads. For left−hand threads, the word “left” is written behind the designation.

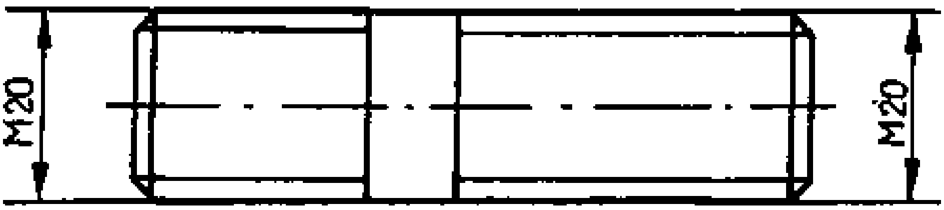
When both types or threads are present in one object, the right−hand thread must also be marked additionally, as is shown in Fig. 6.9, For multi−start (multi−threaded) screw threads (Fig. 6.10.), the number of threads must be stated in parantheses.



a



b



c

Fig. 6.9. Right−hand and left−hand threads

a Right−hand thread
b Left−hand thread
c Right−hand and left−hand thread in one object

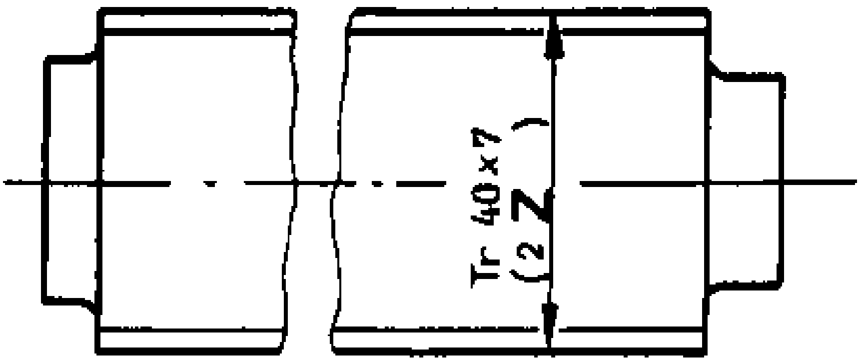


Fig. 6.10. Multi−start thread

A simplified statement of dimensions is to be used when the representation in the drawing of the screw thread is smaller than 5 mm or labor is to be saved in drawing (see Fig. 6.11.).

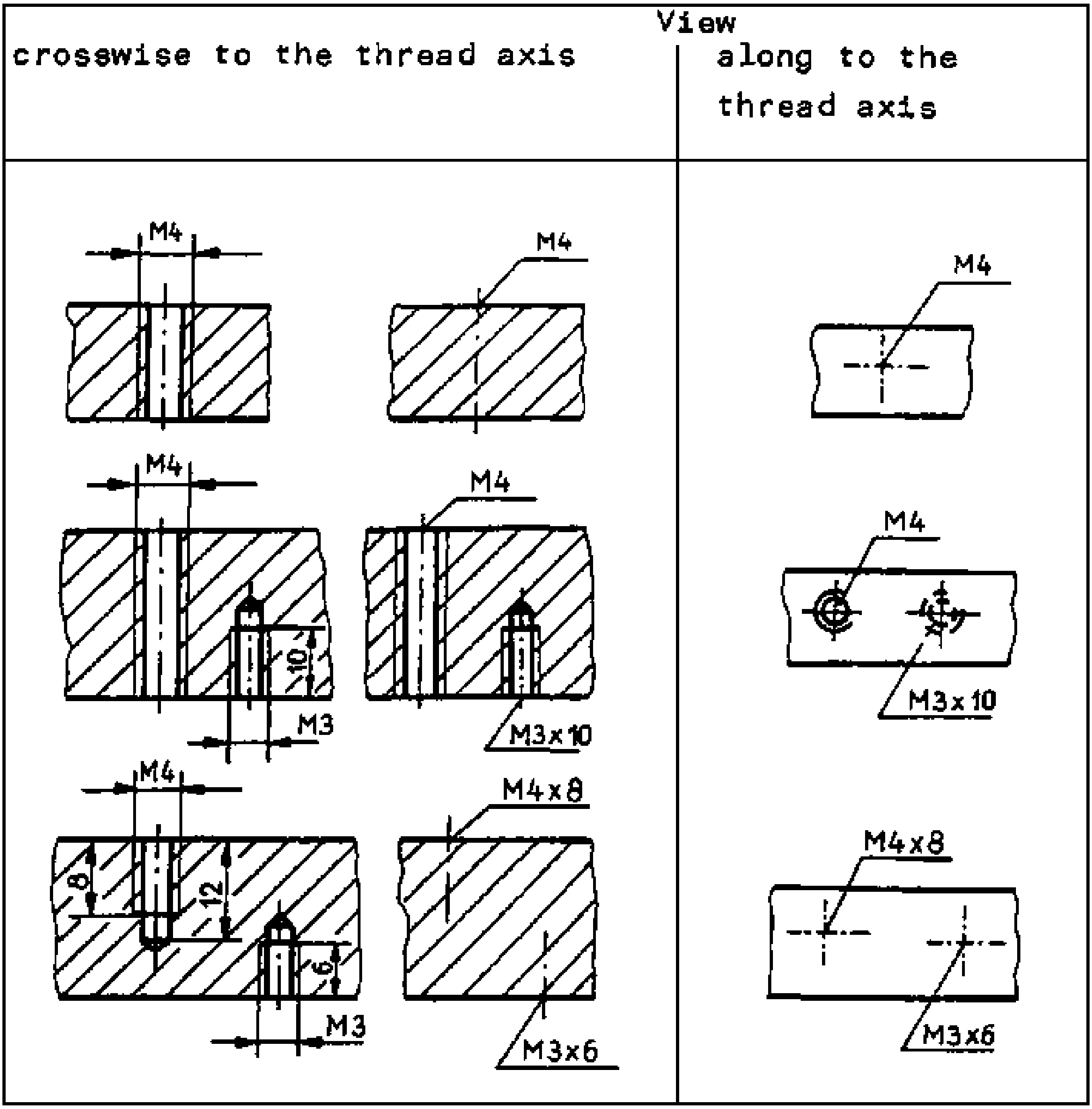


Fig. 6.11. Simplified statement of dimensions

<u>Repetition</u>

1. Which dimensions belong to a complete representation of a screw thread?

2. Explain the term “pitch”.

3. Explain the thread designations M40, M16 × 1, Tr 22 × 5 and S 70 × 10.

6.3. Representation of Screwed Parts

In the representation of two parts which are connected by screw threads, the external thread covers the internal thread (see Fig. 6.12.). Further information about the representation of connections is given in Chapter 9.

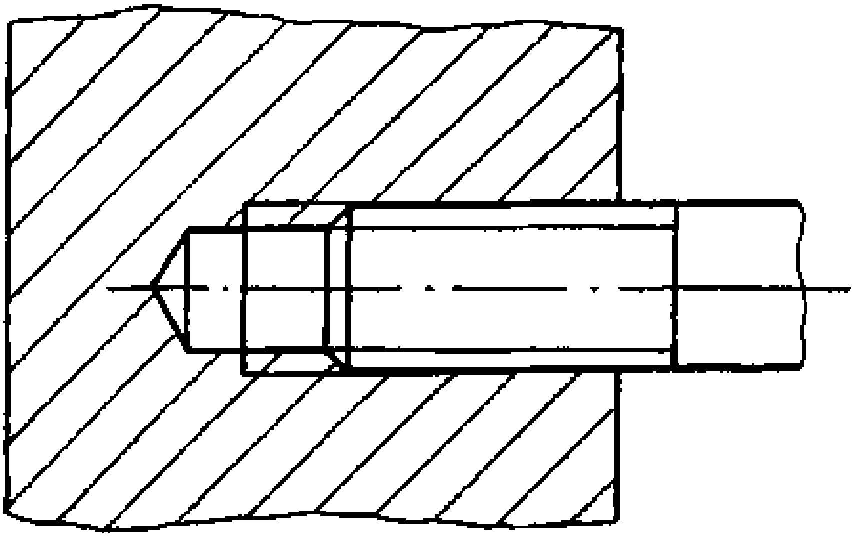
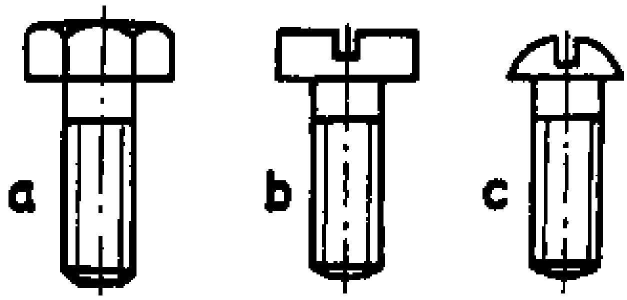
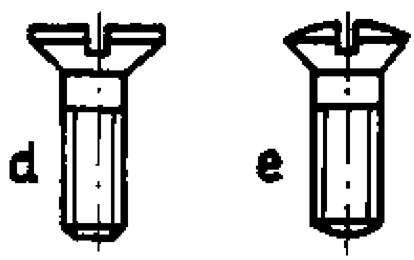
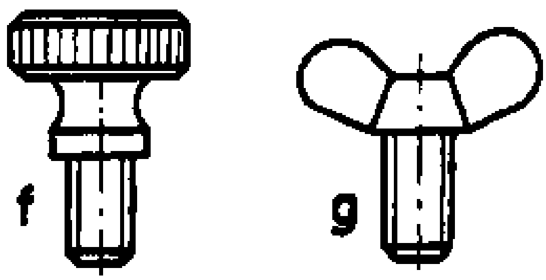


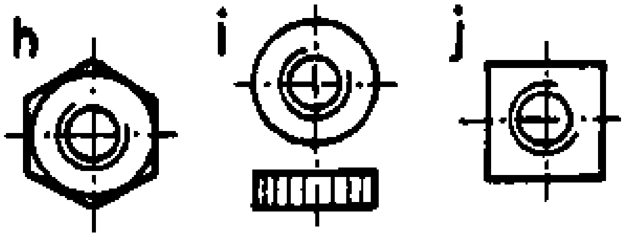
Fig. 6.12. Representation of two parts which are connected by threads

6.4. Bolts and Nuts

In assembly drawings, bolts and nuts must be represented in order that the expert worker who uses the drawing for his assembling work correctly assembles these connecting parts, In the representation, specified dimensions must be observed, namely, for bolts and nuts and for corresponding counterbores and through holes (see Chapter 9).

Fig. 6.13. Screws, bolts and nuts

Cap screws	a Hexagonhead screw b Fillister head screw c Round head screw	
Countersunk screws	d Flat head e Oval head	
Special screws	f Knurled screw g Thumb screw	

Nuts	h Hexagon nut i Knurled nut j Square nut	

Usually, screws and bolts are termed according to the shape of their heads (see Fig. 6.13.).

6.4.1. Hexagon−head Bolts and Hexagon Nuts

In a detailed representation, the chamfer edges are also drawn. They are shown as circular arcs (Fig. 6.14.). In a simplified representation, the chamfer is not shown. This method of representation will usually suffice (Fig. 6.15.). To improve clearness, the detailed representation is used (Fig. 6.16.).

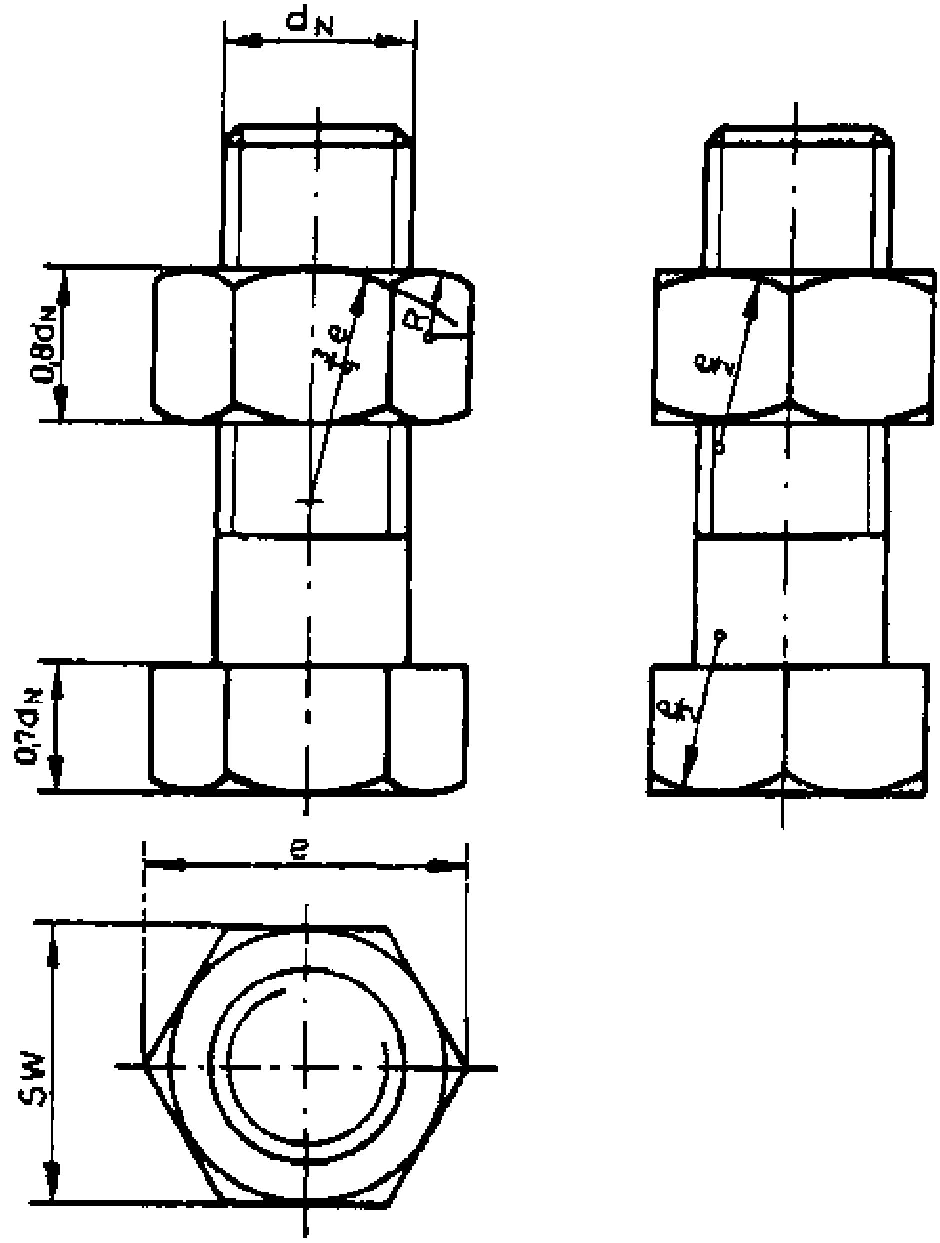


Fig. 6.14. Representation of hexagon−head screws and hexagon nuts with chamfer edges.

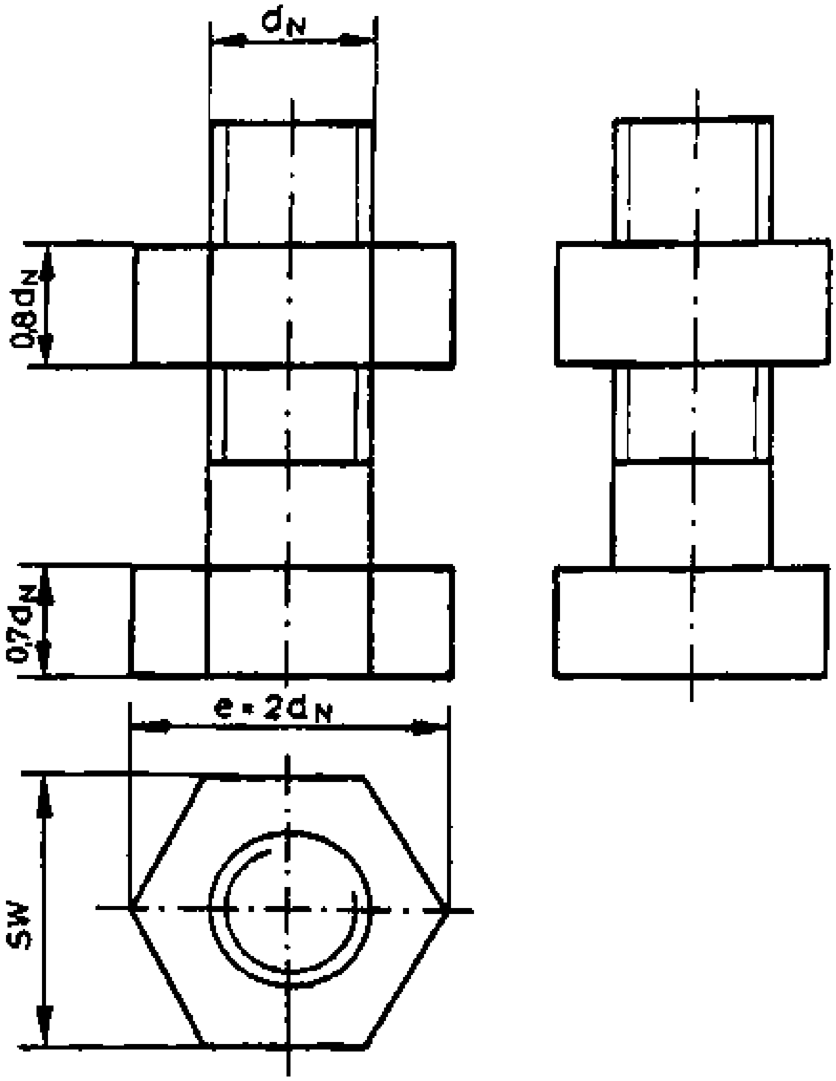
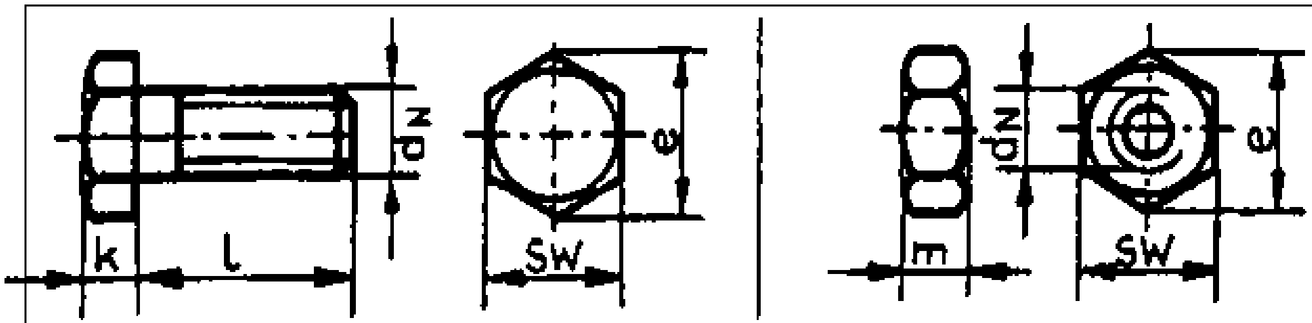


Fig. 6.15. Simplified representation of hexagon−head screws and hexagon nuts

Fig. 6.16. Designation of hexagon−head screws and hexagon nuts



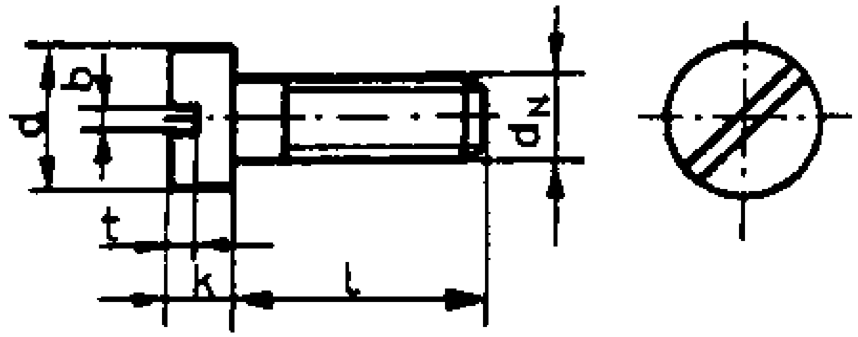
	d_N							
	M5	**M6**	**M8**	**M10**	**M12**	**M16**	**M20**	**M24**
e*	9	11	14	19	21	26	33	40
SW	8	10	13	17	19	24	30	36
k	3,5	4	5,5	7	8	10	13	15
m	4	5	6,5	8	9,5	13	16	19
l	$3d_N$ ... $15d_N$							

1 Example of designating a screw where 1 = 40: Hexagon−head screw M 10 × 40, 2 Dimensions

6.4.2. Fillister−head Screw

See Fig. 6.17.

Figure 6.17. Designation of fillister head screws



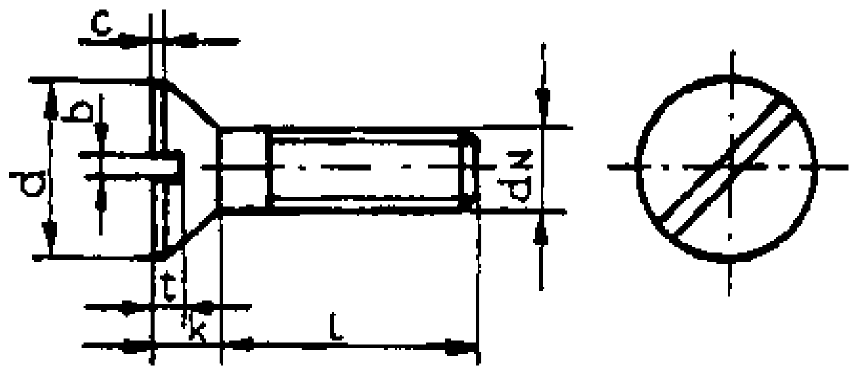
	d_N							
	M2	**M2,5**	**M3**	**M4**	**M5**	**M6**	**M8**	**M10**
d	3,8	4,5	5,5	7	8,5	10	13	16
k	1,3	1,6	2	2,6	3,3	3,9	5	6
b	0,5	0,6	0,8	1	1,2	1,6	2	2,5
t	0,7	0,8	1,1	1,4	1,7	2	2,5	3
l	1,2 d_N ... 5d_N							

1 Example of designating a screw where 1 = 16: Fillister head screw M6 × 16
2 Dimensions

6.4.3. Countersunk Screws

See Fig. 6.18.

Fig. 6.18. Designation of countersunk screws



	d_N							
	2	**2,5**	**3**	**4**	**5**	**6**	**8**	**10**
d	3,8	4,7	5,6	7,4	9,2	11	14,5	18

k	1,2	1,5	1,65	2,2	2,5	3	4	5
b	0,5	0,6	0,8	1	1,2	1,6	2	2,5
t	0,5	0,6	0,8	1	1,2	1,4	1,8	2,3
c	0,2	0,2	0,2	0,2	03	0,3	0,4	0,5
l	$2d_N$ bis $10d_N$							

1 Example of designating a screw where 1 = 20: Countersunk screw M5 × 20
2 Dimensions

Repetition

1. Determine the basic dimension according to Table and for the simplified representation of hexagon−head bolts and hexagon nuts of the dimensions M6, M12 and M20.

2. Determine the dimensions of a fillister−head screw M12 × 50.

3. Determine the dimensions of a hexagon−head screw M6 × 18.

7. Surface Finish Harks and Production Specifications

7.1. General Remarks

Besides the data regarding shape and size of a drawn object, the engineering drawing must give information about the required surface finish. Due to the selection of different manufacturing methods, the surfaces can be raw or machined or produced by other methods. It is not possible to produce a surface without any flaw. Irrespective of the manufacturing method (see Fig. 7.1.), a drawing must contain data about the required quality of the surface finish.

Fig. 7.1. Methods of manufacture

Original forming	casting powder pressing etc.
Forming	extrusion forging etc.
Separating	cutting turning grinding etc.
Joining	welding wedging riveting etc.
Coating	painting galvanising etc.
Heat treatment	hardening glowing etc.

The quality of the surface comprises a certain regularity such as a certain smoothness, as is shown in Fig. 7.2.

The degree of the surface quality exerts a high influence on the function and quality of the workpiece.

Fig. 7.2. Surface quality

Pictorial indication of surfaces of different quality	Degree of uniformity	Degree of smoothness
	imperfect	imperfect
	good	imperfect
	imperfect	good
	good	good

The surface quality is largely determined by the irregularities of the surface of a workpiece, namely, the magnitude of the “roughness height” R_h(or depth R_t). The roughness height is the difference between the points A and B of a reference distance 1 (see Fig. 7.3.).

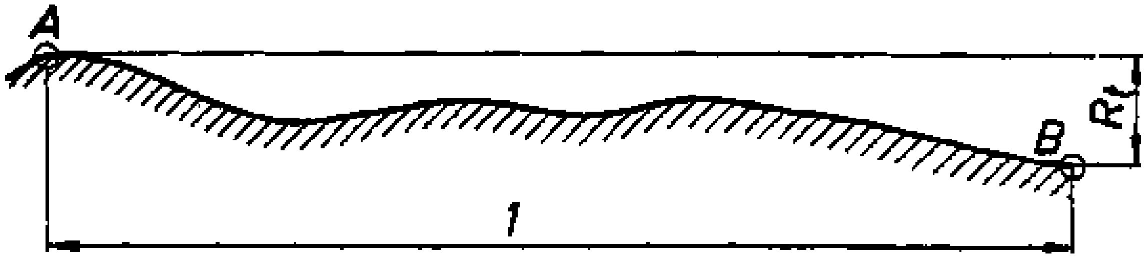


Fig. 7.3. Peak−to−valley height R_t

1 Reference distance

When specifying the quality of the surface, the principle holds: “As fine as necessary, not so fine as possible.”

Frequently, produced parts require an additional surface treatment for the protection against contamination and atmospheric influences. In many cases, the surface should show a pleasing appearance. For these purposes, a further special marking is required which will be explained in Section 7.3.

Repetition

1. Quoting an example, explain the necessity of data specifying the surface quality in an engineering drawing.

2. How do you define quality of a surface?

7.2. Marking of Shaped Surfaces

7.2.1. Surfaces with a Qualitative Marking

The surface of shaped objects is characterised in engineering drawings according to two points of view:

− which quality of the surface is required with respect to the degree of uniformity and smoothness (e.g. “good”, “less good”.)?

− which is the degree of surface quality required of the object? This is specified quantitatively in ?m as the “roughness height” (or peak−to−valley height) which can be measured. When stating the roughness height, information is given about how good the shaped surface has to be (see also Section: Surfaces with a Quantitative Marking).

For the qualitative marking, symbols are used. They always indicate the final condition of the surface finish and are applied to the edges and surfaces in question. The points of the equilateral triangles and as symbols point to the surface to be machined or treated in any other way. An indication of the manufacturing method to be employed is not given. The meaning of the specified symbols is shown in Fig. 7.4.

Fig. 7.4. Qualitative marking of the surfaces

Surface marking	Sign	Requirements for the surface
none		Surfaces for which the evenness and smoothness is not specified are not provided with a surface marking; e.g. cast, pressed or rolled parts which are not machined externally.
Wave line		Surfaces which have to be more regular and of a better appearance, e.g. by forging, casting and smooth rolling.
one triangle		Surfaces which have to be finished in such a way that traces of working may be visible, e.g. turning in a lathe, milling, drilling.
two triangles		Surfaces where the traces of working should scarcely be visible, e.g. precision turning.
three triangles		Surfaces where no traces of working must be visible with the naked eye, e.g. fine grinding.

Due to the demands on quality which become more and more exacting on national and international markets, the above explained quality designations no longer meet the manufacturing and control requirements.

The development of the international surface measuring technology calls for the transition from the qualitative to the quantitative surface finish marking.

International standards specify to give only quantitative statements in engineering drawings by means of dimensional figures (surface roughness values). In order to be in a position to understand older drawings, textbooks and standards, surface finish marks of qualitative character have been explained here briefly.

When new engineering drawings are prepared, the surfaces are provided with data about the roughness!

7.2.2. Surfaces with a Quantitative Marking

Data regarding the surface roughness

Surface roughnesses are only specified when this is required for functional or technical reasons. Data of surface roughnesses are always given in connection with standardised basic symbols (see Fig. 7.5.). These basic symbols include all necessary statements (see Fig. 7.6.); at the long leg of the check mark, an extension bar can be applied on which the manufacturing method may be given, as is shown in Fig. 7.7.

Fig. 7.5. Surfaces with a quantitative marking

Basic symbol	Application	Examples
	When the manufacturing process is optional	casting, extruding, planing
	When the surface roughness is specified by stock removal	turning in a lathe, milling, grinding
	When a manufacturing process other than stock removal is specified for the surface roughness	rolling, drawing

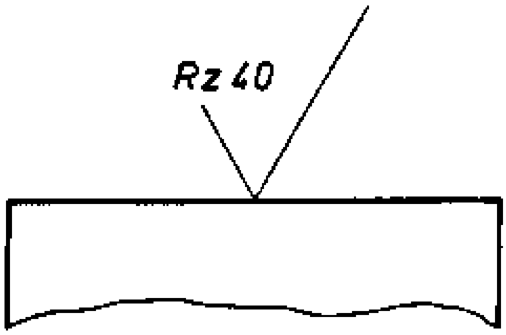


Fig. 7.6. Example

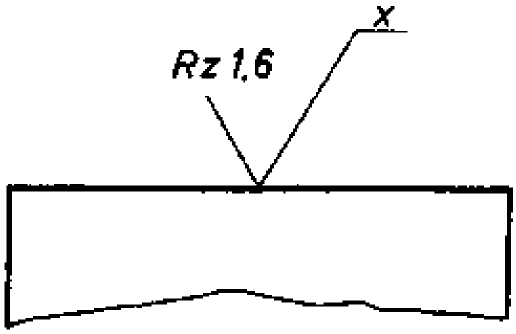


Fig. 7.7. Example

x polished

When using symbols, first and foremost the basic symbol in the form of the check mark should be used which leaves the manufacturing method to the discretion of the producer.

In practice, instead of the roughness depth R_t (once more see Fig. 7.3.), the mean roughness depth R_z is stated, as is shown in Figs. 7.6. and 7.7. (in some international standards, the roughness depth is called roughness height).

The mean roughness depth R_z is the mean distance between the five highest and five deepest points within the reference distance 1 (see Fig. 7.8.).

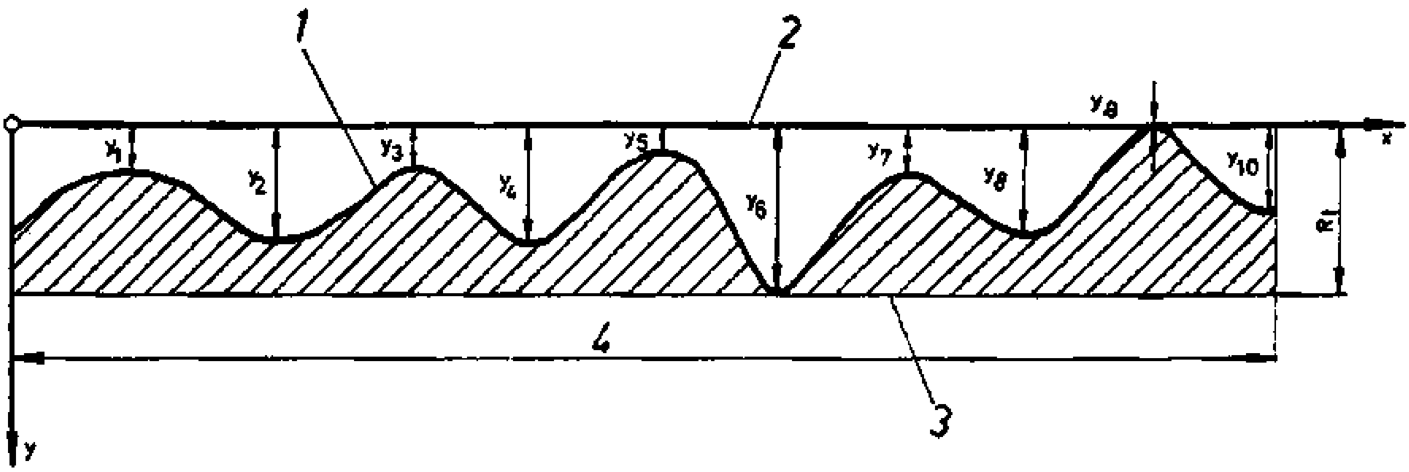


Fig. 7.8. Determination of the mean peak−to−valley height R_Z

1 Actual profile, 2 Reference profile, 3 Basic profile, 4 Reference distance

The mean roughness R_z ist standardised and depends on the selected manufacturing method.

Fig. 7.9. illustrates in a few selected examples the roughnesses which can be achieved under normal technological conditions.

Fig. 7.9. Examples for the mean peak–to–valley height R_z

Manufacturing process		**R_z (in ?m)**
Planing	(rough) (fine)	40 ... 100 10 ... 40
Milling	(rough) (fine)	25 ... 100 1.6 ... 10
Turning	(rough) (fine)	25 ... 100 1 ... 10
	(normal)	2.5 ... 10
Grinding	(fine)	0.16... 2.5

Increments of the mean roughness

Fig. 7.10. Increments of the mean roughness

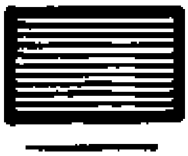
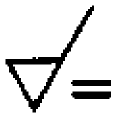
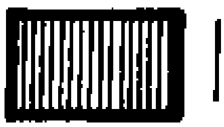
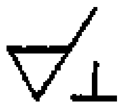
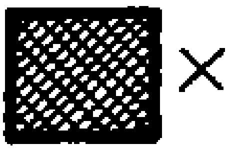
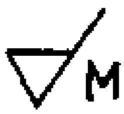
0.05	0.1	0.2	0.4	0.8	1.6	3.2	6.3	10	20	40	160	320

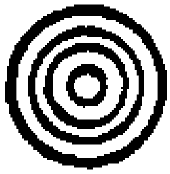
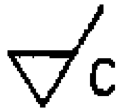
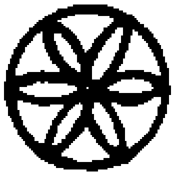
The numerical value in ?m must be given behind the abbreviation of the roughness characteristic (R_z). The entered numerical value is the maximum permissible value of the respective roughness characteristic (e.g. R_z 40 in Fig. 7.6.).

Statement of the course taken by the working traces

When workpieces are subjected to cutting, depending on the machining process used, different surface patterns are produced by the traces of machining which may be of importance to the function of the object. If required, standardised symbols have to be added to the basic symbol, e.g.  = for the identification of the course of the traces also known as direction of lay (see Fig. 7.11.).

Fig. 7.11. Marking of the direction of lay

Symbol	**Direction of lay**	**Marking the lay or traces**	**to be entered into the drawing**
=	parallel to the marked surface		
⊥	vertical to the marked surface		
X	crossed or inclined to the marked surface		
M	in various directions		

C	approximately circular to the marked surface		
R	approximately radial to the marked surface		

Indication of the reference distance

In exceptional cases, the standardised reference distance (once more compare with Fig. 7.8.) can be indicated in a numerical value in mm, as is shown in Fig. 7.12.

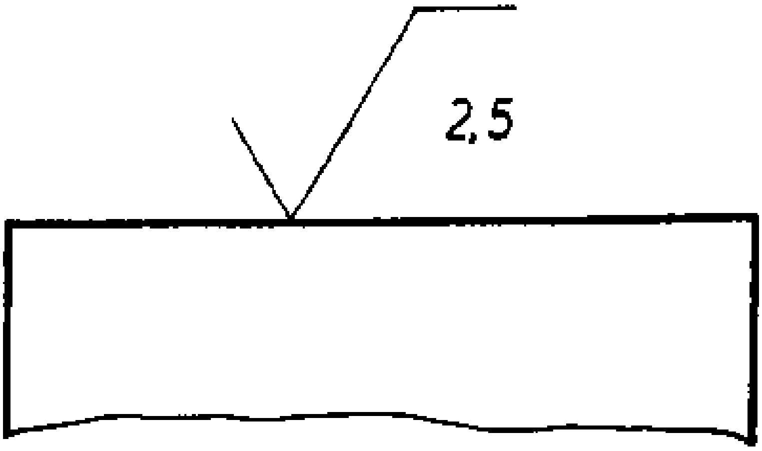


Fig. 7.12. Example

Drawing the symbol

Shape and size of the symbols (see Fig. 7.13.) must be drawn with thin solid lines while the selected nominal height of the lettering is decisive for the size of the symbol.

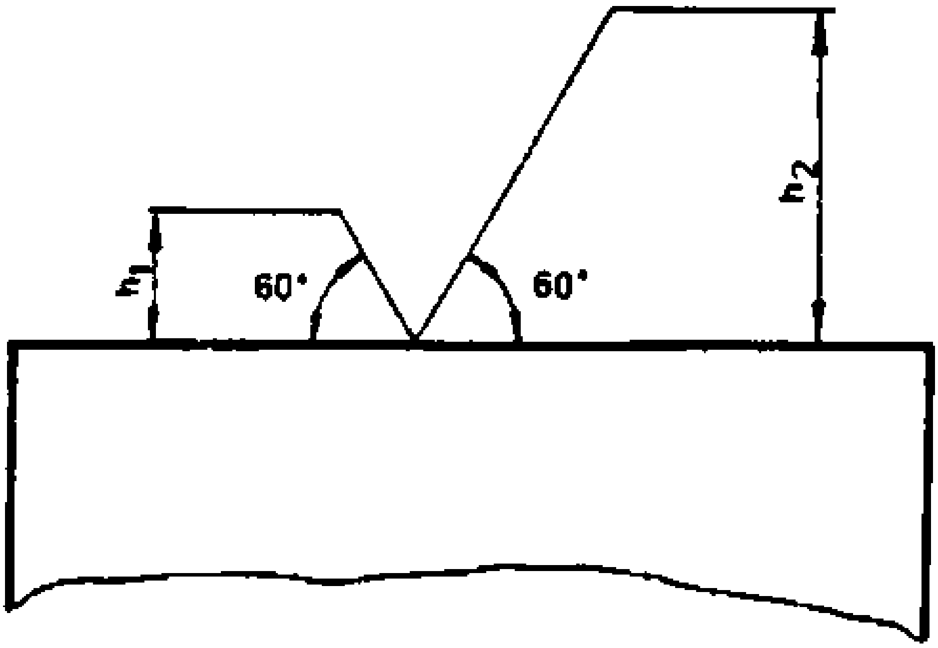


Fig. 7.13. Nominal height of the symbol

h_1 ? 1.5 × nominal height of the letters
h_2 ? 3 × nominal height of the letters

A horizontal extension bar should be added to the basic symbol (Fig. 7.14.) if it is required.

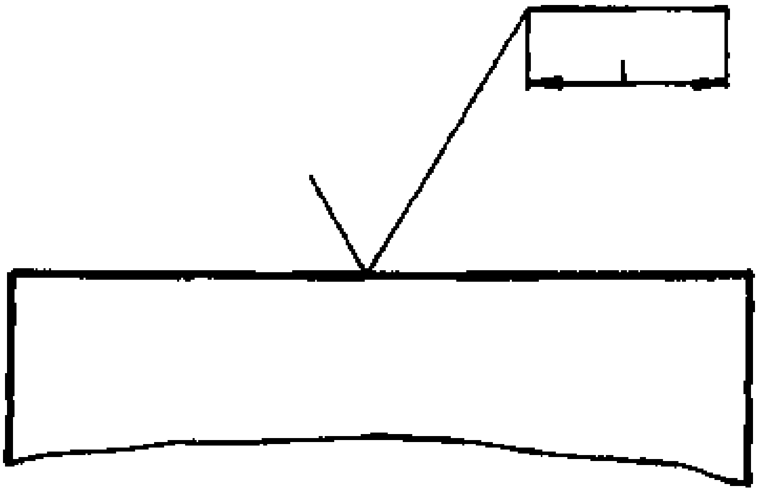


Fig. 7.14. Horizontal extension bar at the basic symbol

1 ? h_2, h_1 and h_2 as given in Fig. 7.13.

Examples of marking the surface roughness

– Surface roughness equal all over

For parts with a surface roughness that is equal all over, a symbol has to be entered above the title block having twice the height of the letters (see Fig. 7.15.).

– Parts having several surfaces with the same surface roughness

For parts having their greater number of surfaces with the same surface roughness, proceed in the way shown in Fig. 7.15.

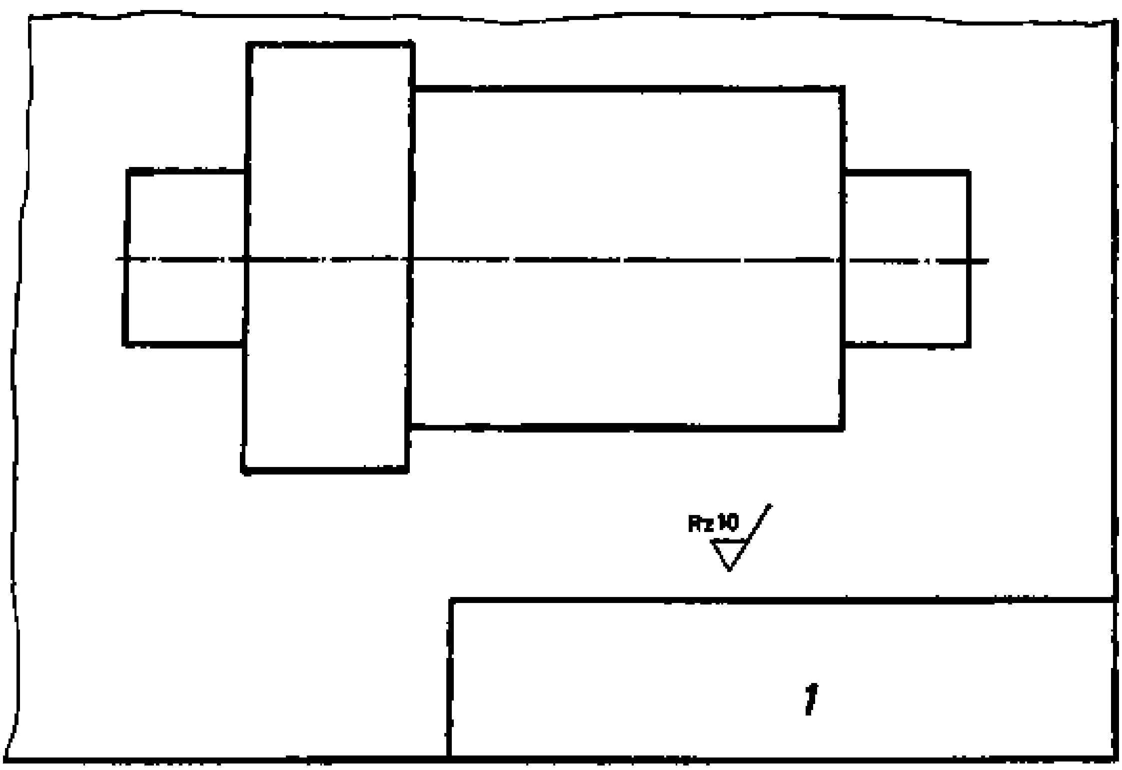


Fig. 7.15. Equal surface roughness

1 Title block

In addition, surfaces with a different roughness have to be marked individually (see Fig. 7.16.). As an indication to these surfaces, the basic symbol must be entered in parantheses without statement of the dimensional figure in the same size as the common symbol () behind the common symbol, e.g. R_Z .

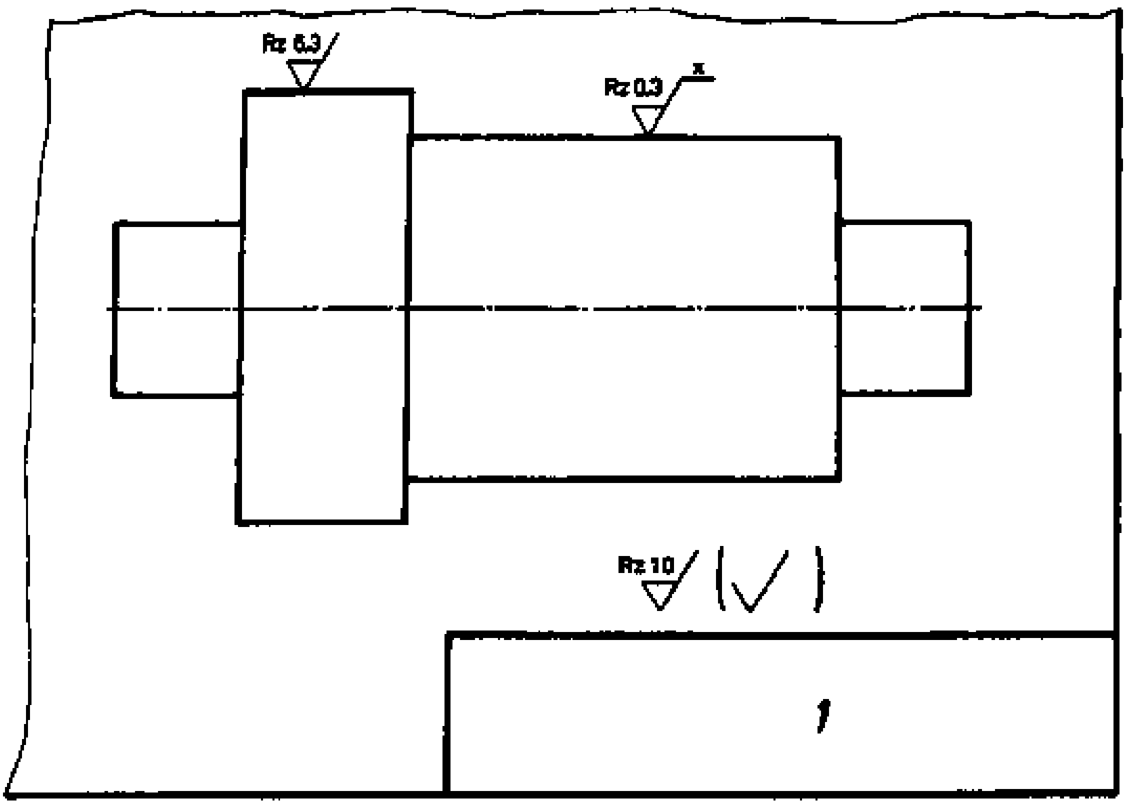


Fig. 7.16. A few surfaces have a different surface roughness

x to be ground
1 Title block

– Rotationally symmetrical parts

For rotationally symmetrical parts, the symbols for the circumferential surface have to be applied to the generatrix or, if room is lacking, to the extension line (see Fig. 7.17.).

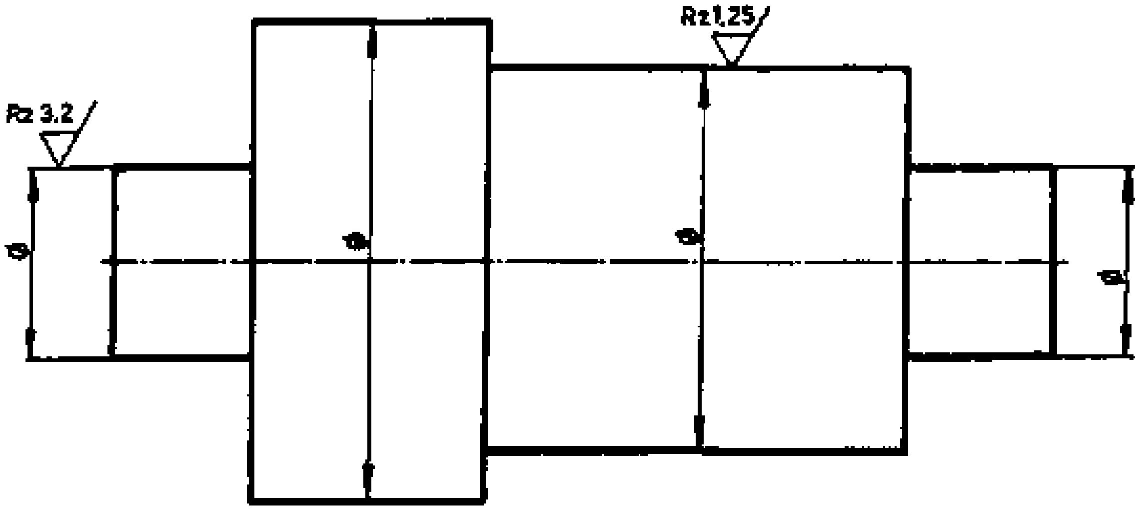


Fig. 7.17. Example

– Parts with surfaces having different surface roughnesses The symbols can be entered in the drawing on the surfaces to be marked, on the extension line or on the leaders. The arrowheads point to the surfaces in question. For each of the surfaces to be marked, only one symbol should be applied. The data at the symbol must be entered in such a way that they can be read from below or from the right, as is shown in Fig. 7.18.

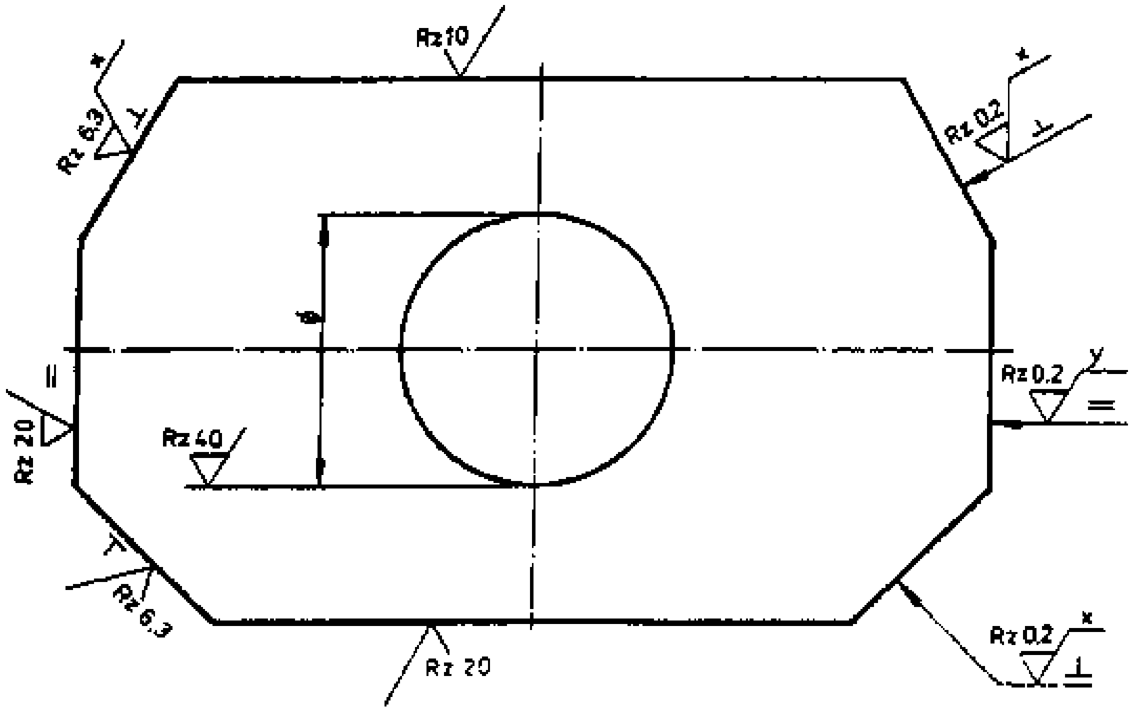


Fig. 7.18. Parts having different surface finish

x plished, y lapped

– Symmetrical parts

For symmetrical parts with the same surface roughness on either side, the symbols should be applied only on one side (see Fig. 7.19.).

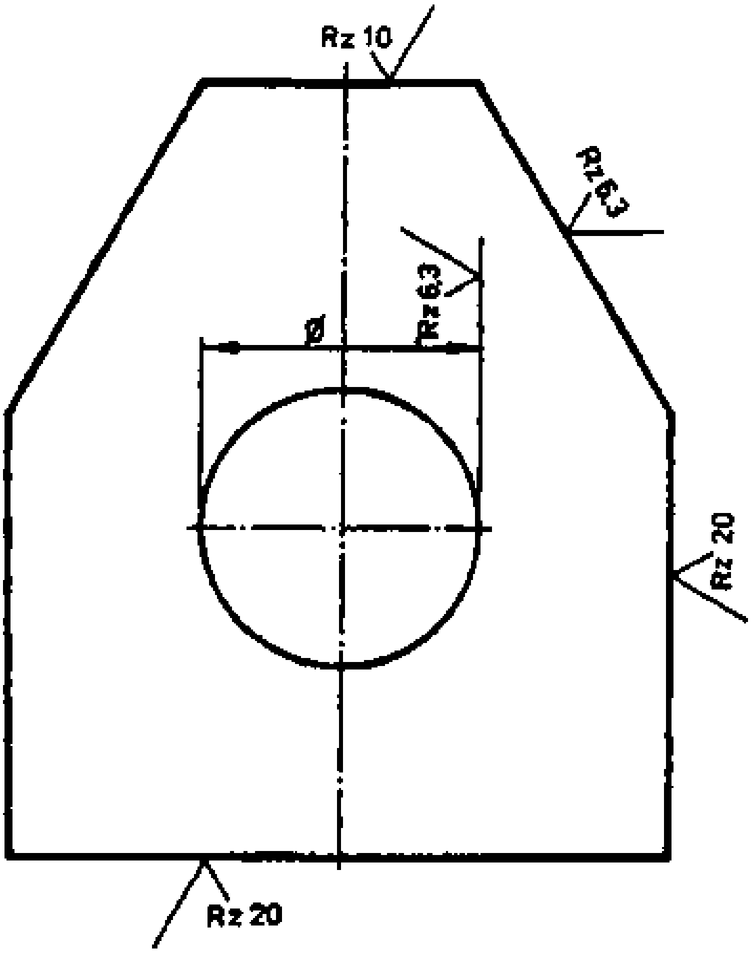


Fig. 7.19. Example

– Adjacent surfaces of the same roughness

Several adjacent surfaces having the same surface roughness may be marked by a common symbol with the help of reference lines or leaders, as is shown in Fig. 7.20.

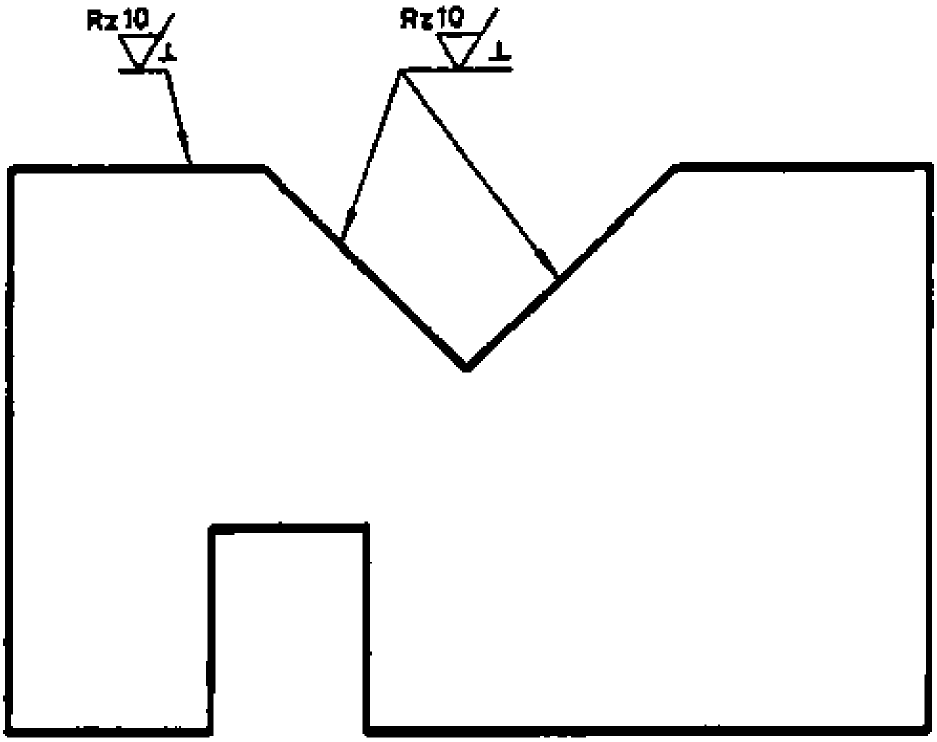


Fig. 7.20. Example

– Surface roughness of screw threads

The symbol for the surface roughness must be applied to the nominal diameter of the thread (see Fig. 7.21.).

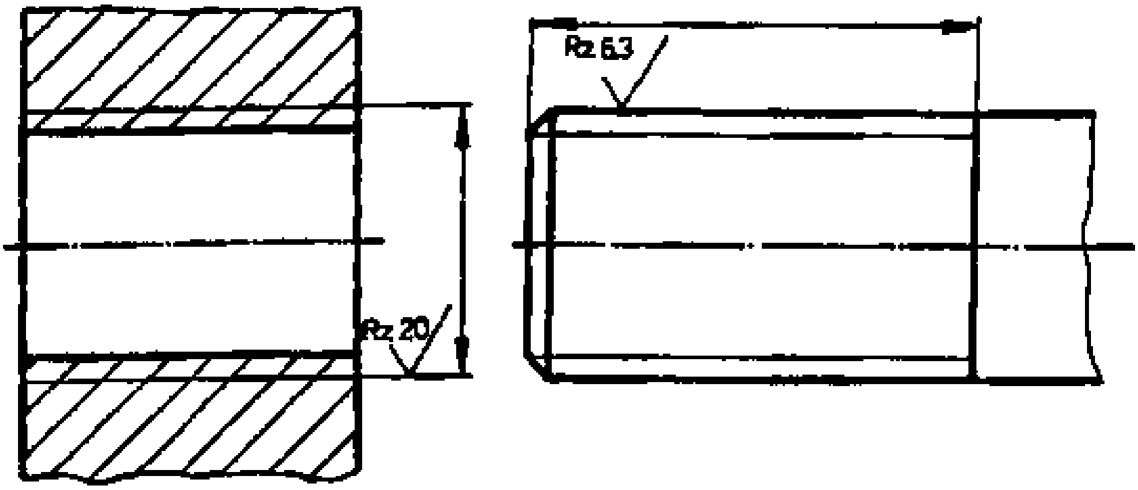


Fig. 7.21. Example

– Application of the symbol for the state of delivery

Surfaces which are not worked but left as in the state of delivery have to be marked by the symbol with circle without indication of the roughness characteristic (see Fig. 7.22.) and the numerical value.

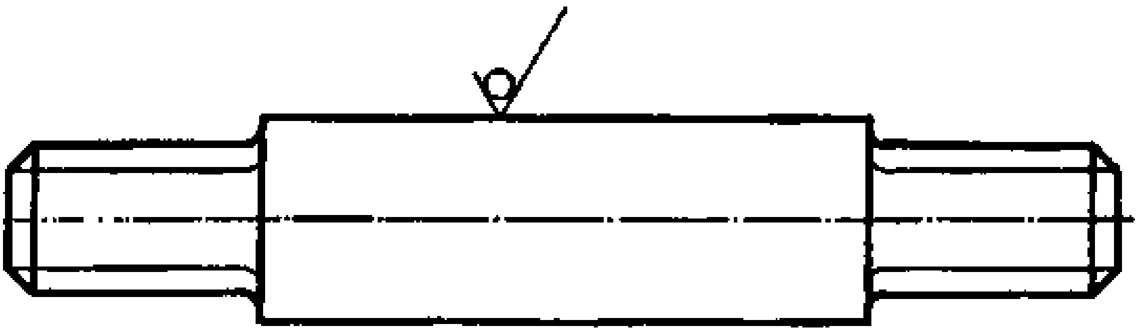


Fig. 7.22. Example

7.2.3. Surfaces Used to Improve the Grip

In order to improve the grip of operating parts such as control levers, disks, adjusting knobs or to facilitate the handling of tools and measuring instruments, e.g. bushing and plug gauges, their surfaces are roughened. Depending on the structure of the surface, a distinction is made between straight knurl and diamond knurl (see Figs. 7.23. and 7.24.). The magnitude of the spacing t is dependent on the diameter d and the width b, as is shown in Fig. 7.25.

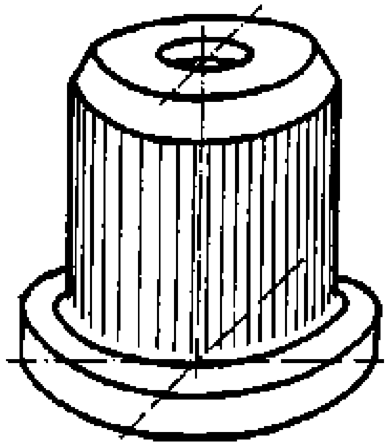


Fig. 7.23. Surface provided with a straight knurl

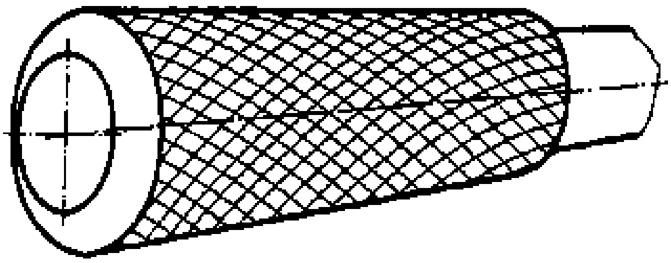
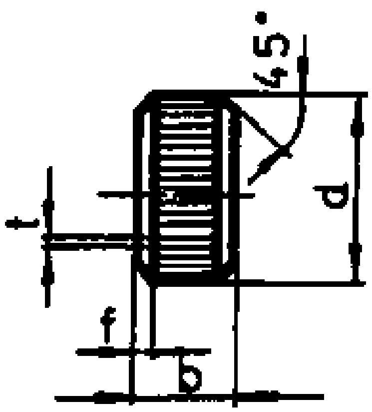
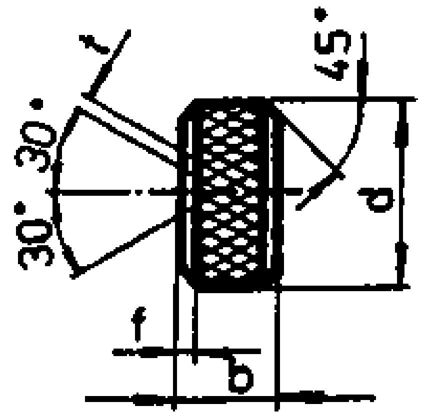


Fig. 7.24. Surface provided with a diamond knurl

Fig. 7.25. Data regarding straight and diamond knurling

	Diameter d mm	**Width b mm**	**Pitch t mm**	**Chamfer f mm**	**Use**
	up to 8	2	0.5	0.4	
 straight knurl	over 8 to 16	3	0.6	0.5	for sure gripping of objects in one direction, e.g. with respect to rotary motion
	over 1.6 to 32	4	0.8	0.8	
	up to 8	2	0.6	0.5	
	over 8 to 16	3	0.8	0.8	for sure gripping of objects in two directions, e.g. with respect to rotary and sliding motions

 diamond knurl					
	over 16 to 32	4	1.0	1.0	

Width b is a minimum value and may be exceeded

Marking is effected for straight knurls with thin parallel solid lines and for diamond knurls with thin crossing solid lines at an angle for 30°. The indication of the spacing is given with the help of a leader and the designation “straight knurl” or “diamond knurl” (see Figs. 7.26. and 7.27.).

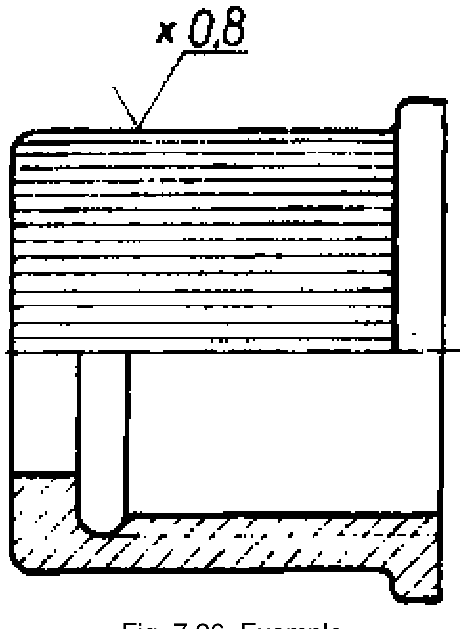


Fig. 7.26. Example

x straight knurl 0.8

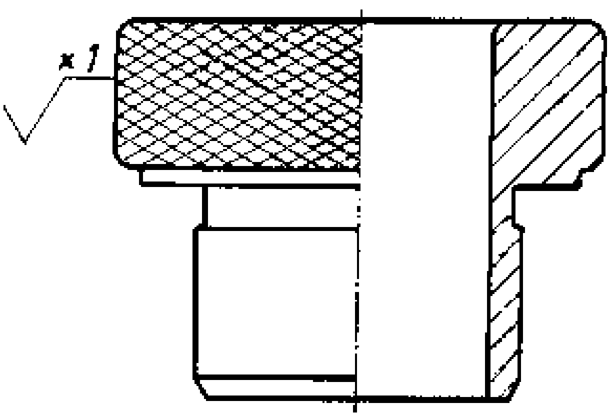


Fig. 7.27.

x diamond knurl 1

In case of larger surfaces, it is allowed to give only a limited indication of the straight or diamond knurl to save drawing time in the way shown in Fig. 7.28.

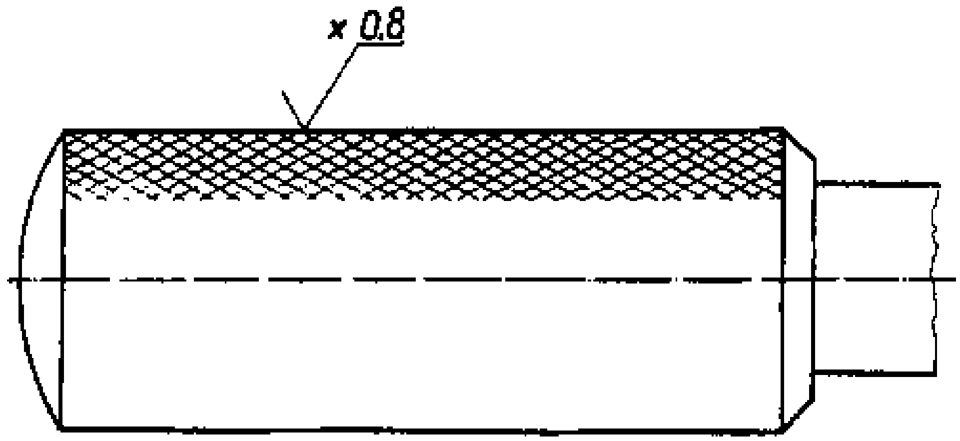


Fig. 7.28. Example

x diamond knurl 0.8

Repetition

1. What do you understand by roughness depth and mean roughness depth?

2. Why is the quantitative marking only used in engineering drawings today?

3. Why are surfaces roughened by straight knurls or diamond knurls?

4. Quote an example each for workpieces with straight and with diamond knurls.

5. What means the marking knurl 0.5?

7.3. Marking of Treated Surfaces

The data given in a drawing regarding the quality of the surface finish of a workpiece frequently are insufficient because machined or formed surfaces often have to be subjected to an additional treatment in order to protect them from corrosion, to improve their appearance or to change the properties of the material. This surface treatment can be indicated in engineering drawings

– by words with leaders, as shown in Fig. 7.29. or
– by characteristic lines, as is shown in Fig. 7.30.

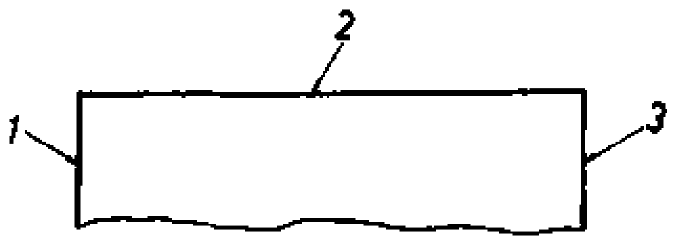


Fig. 7.29. Example

1 chromium–plated
2 painted–grey
3 dull polish

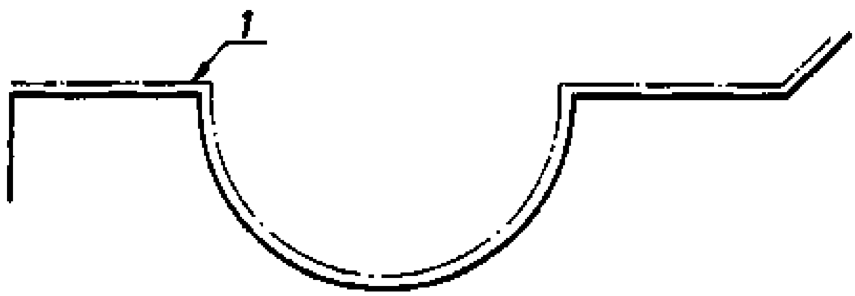


Fig. 7.30. Example

1 burnished

These statements are related to the final or finished state (e.g. burnished, chromium−plated, etc.). General designations such as painted will not suffice for special cases and have to include specifications with respect to kind of varnish, colour and coat thickness. If necessary, data regarding the pre−treatment of the surface have to be given in order to ensure the proper adhesion of the coat to be applied.

<u>Examples for marking treated surfaces</u>

− The same treatment all over

When the surface of a part is coated completely and uniformly, a common designation must be entered above the title block, see Fig. 7.31.

− Partial or different coating

The coating of the surface must be indicated by a leader, as is shown in Fig. 7.29.

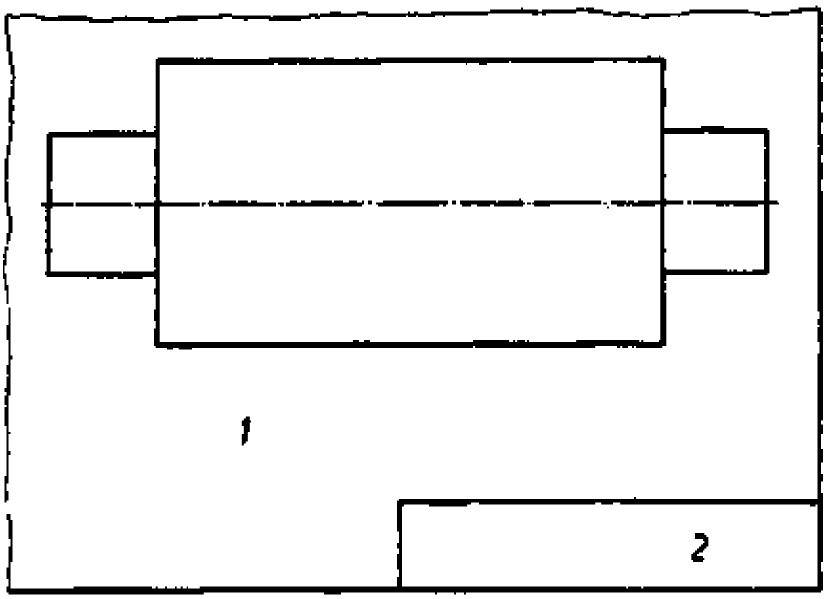


Fig. 7.31. Surface treated on all sides in the same way

1 nickel−plated, 2 title block

It is permissible to combine the statement of the coating with the statement of the surface roughness if this is necessary for the function of the surface. In this case, the basic symbol for optional manufacturing methods is to be used (see Fig. 7.32.).

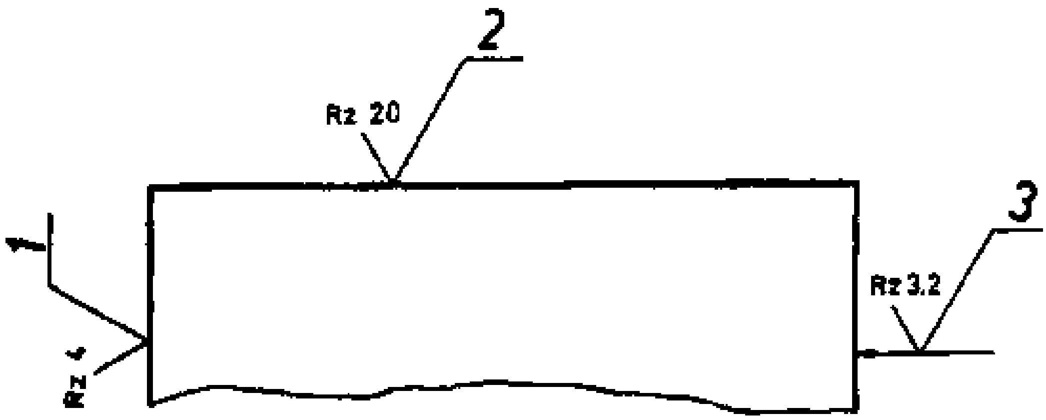


Fig. 7.32. Example

1 chromium−plated
2 nickel−plated
3 chromium−plated

In the case of intricate contours, a thick characteristic line (dash−and−dot line) is to be applied immediately above the surface to be coated, as is shown in Fig. 7.30.

For rotationally symmetrical parts, the characteristic line is to be drawn up to the centre line or along all contours (see Fig. 7.33.).

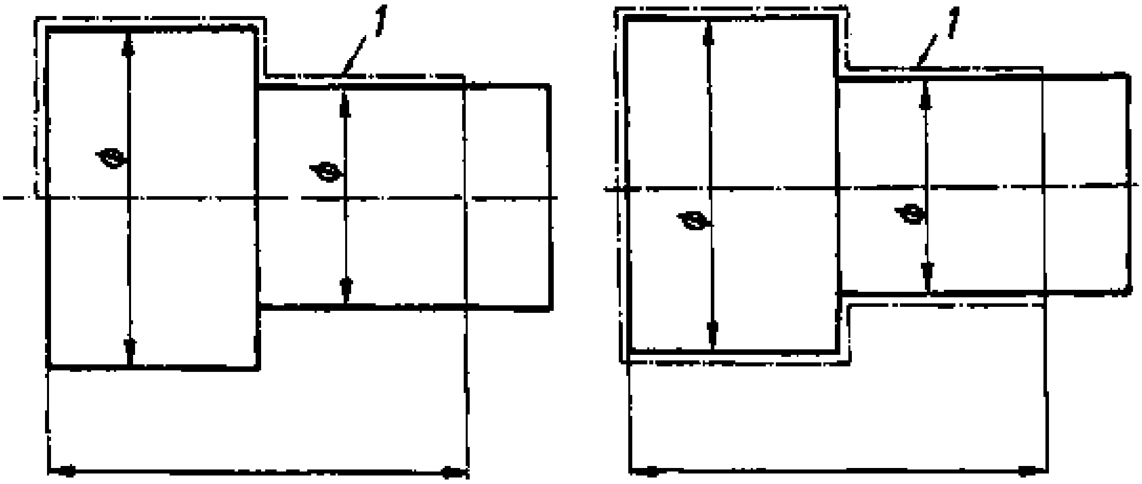


Fig. 7.33. Example

1 hardened

<u>Repetition</u>

1. What is a treated surface? Quote examples of industrial practice.

2. What are the possibilities for marking treated surfaces?

8. Dimensional Variations II

8.1. Importance and Necessity of the Determination of Suitable Tolerances

In the manufacture of single parts, the expert worker relies on the dimensions specified in the drawing. However, it is neither possible to produce parts with absolute accuracy nor to measure them with this accuracy. In addition, an exact observance of the dimension is never required. Therefore, it is necessary to give the producer a certain allowance or certain limits within which the actual dimension (I) may vary. This “allowance” is called tolerance (ISA tolerance). A tolerance is the amount of variation permitted in size and location; thus, it expresses the inaccuracy of the work that is allowed. The greater the tolerance, the quicker the object can be produced. The smaller the tolerance, the more time is required and the more expensive the product will become. Rejects may−occur quickly. Therefore, the following requirement holds:

Determine tolerances that are as coarse as possible but as fine as necessary!

For modern engineering, the determination of tolerances is indispensable and of great importance to national and international trade. The production of replacement parts and their interchangeability in machines can be carried out without time−consuming mating operations. Thus, it becomes possible that sub−contracting factories produce certain parts or components, e.g. motor−vehicle engines, which can be mounted or used as replacement unit by assembly enterprises without any difficulty. The specification of tolerances is the basis of interchangeability and establishes the pre−conditions of “fits”.

Repetition

1. What is the determination of tolerances of dimensions?

2. Substantiate the necessity of the specification of tolerances.

8.2. Determination of Tolerances by Symbols Designating Fits

8.2.1. Basic Terms of the Determination of Tolerances

For the manufacture of a workpiece, the manufacturer must know the limits within which the actual size may vary. A limit indicates the largest permissible dimension (G) or the smallest permissible dimension (K), the difference between these limits is represented by the tolerance IT. Then we have as an algebraic formula:

IT = G − K.

The largest dimension is the greater one and the smallest dimension is the smaller one of the two limits of size. The Figs. 8.1. and 8.2. show that a distinction is made between external dimension and internal dimension, and the shaded area − called tolerance zone − is a half of the tolerance. The actual size may be within these limits. Therefore, the dimensions G and K are also called limits of size.

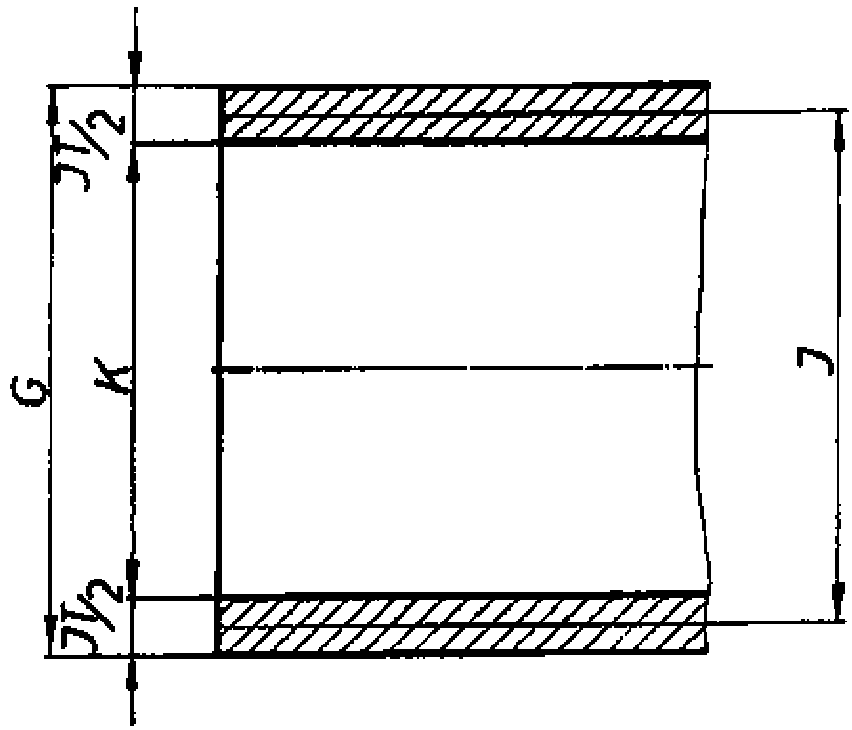


Fig. 8.1. External dimensions (shaft)

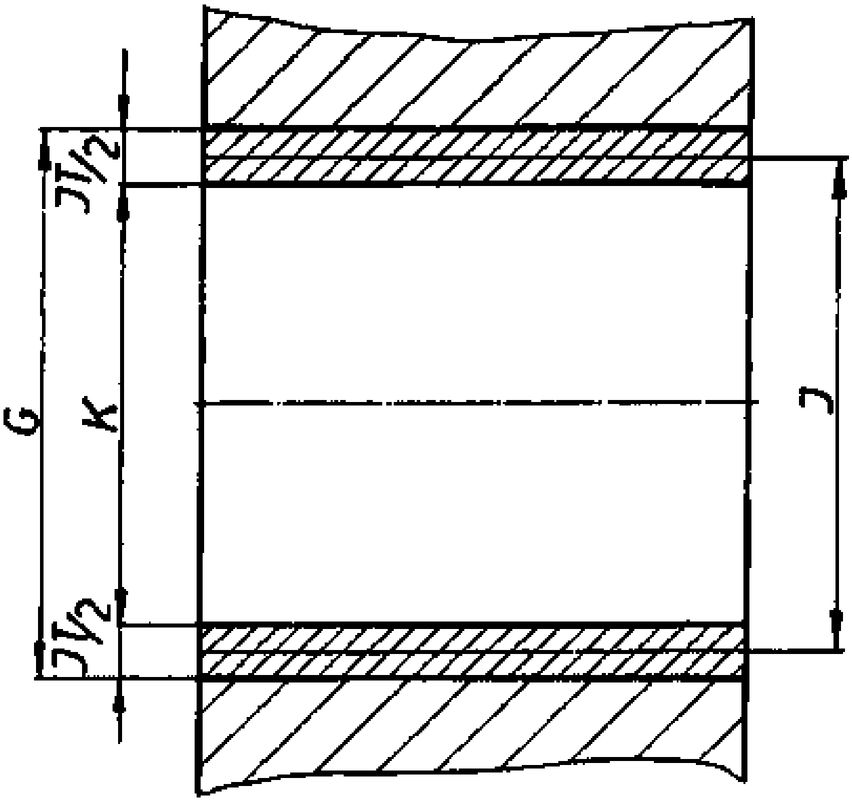


Fig. 8.2. Internal dimensions (hole)

In order to simplify the drawings and to further explain the location of the tolerance zone, the latter is represented enlarged and only on one side for drill−holes, shafts and the like while the symmetry is neglected (see Figs. 8.3. and 8.4.).

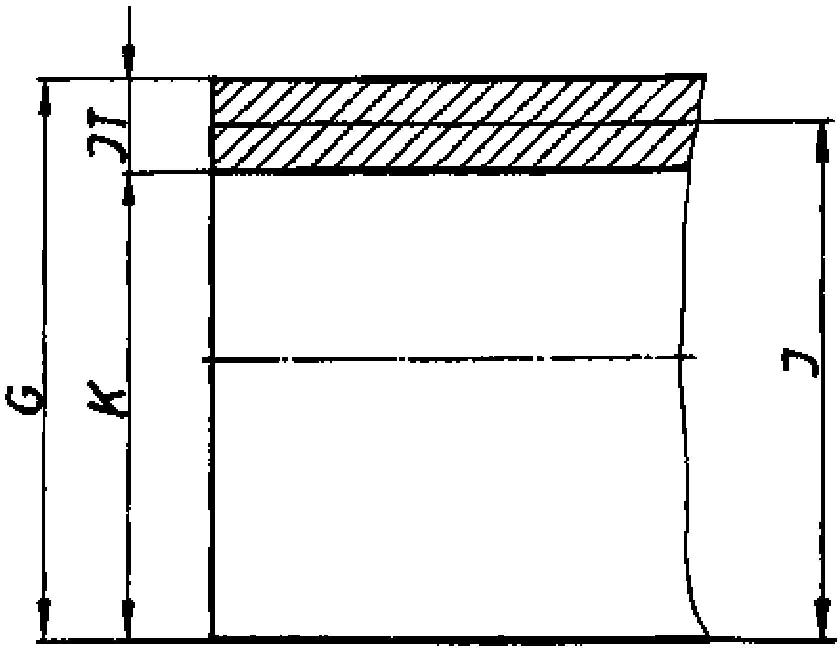


Fig. 8.3. Tolerance representation at one side − external dimension

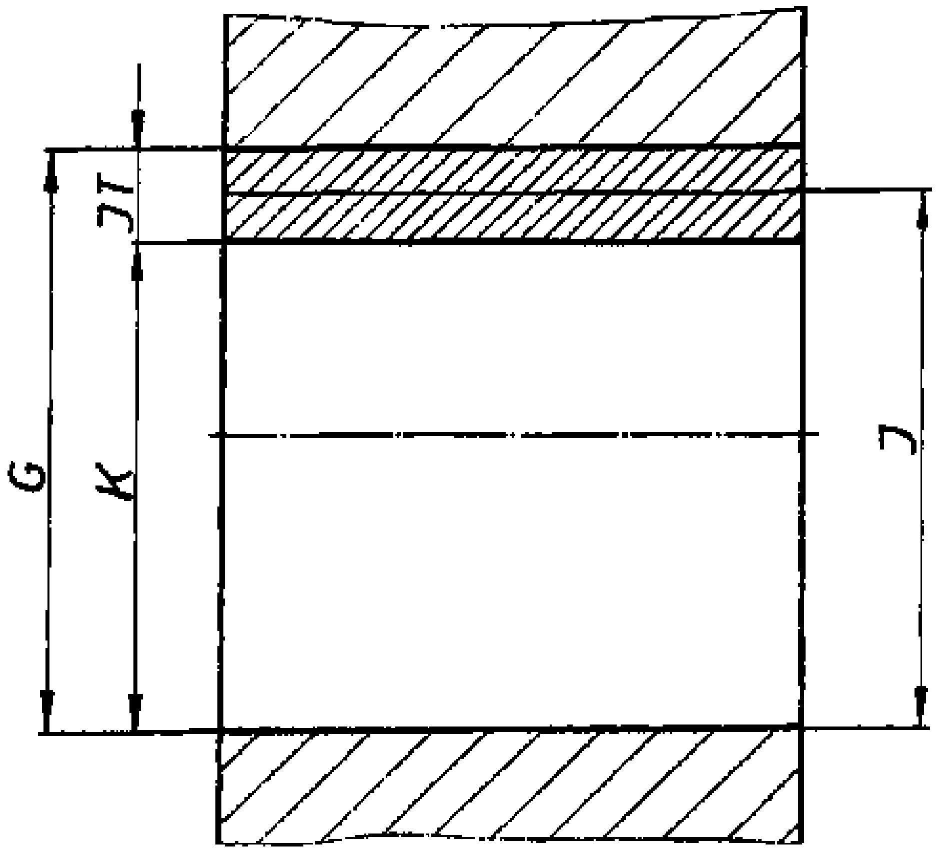


Fig. 8.4. Tolerance representation at one side – internal dimension

Nominal size and dimensional variations

For the manufacture of an object, the indication of the limits in an engineering drawing would be sufficient in order to specify the tolerance, e.g. G = 40.2 and K = 39.9 This way of dimensioning in a drawing is in contradiction to the efforts of standardisation because preferred standardised numerals have to be selected (e.g. 40). Therefore the limits are indicated as variations from numerals which are included in a range of standardised preferred figures. These latter figures are called nominal size or nominal dimension (N). In the above example, N = 40. The differences between the limits (a limit is the extreme permissible dimension resulting from the application of a tolerance) and the nominal size are called dimensional variations or amounts of variation or, in short, deviation.

They are related to the zero line (0) which is determined by the nominal size (see Figs. 8.5. and 8.6.).

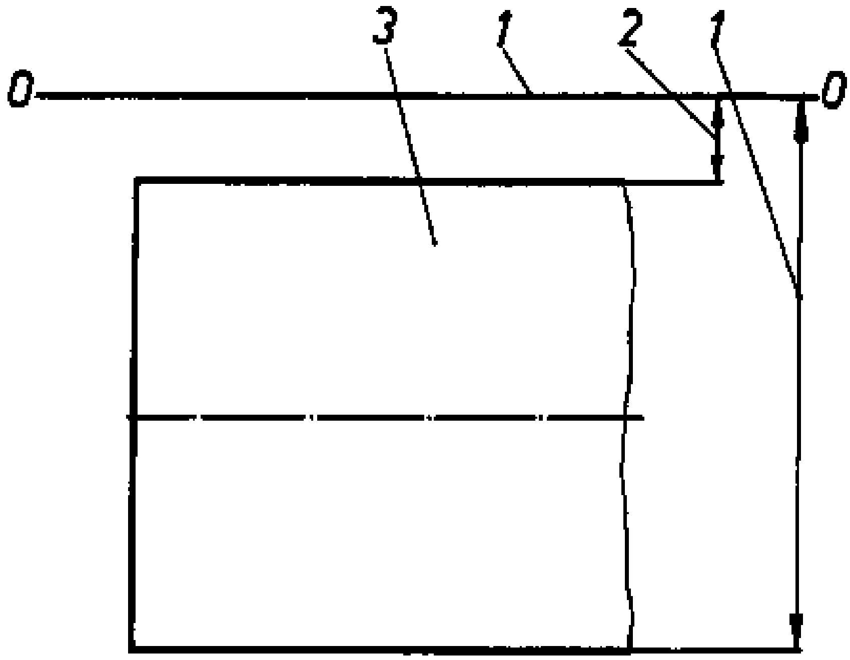


Fig. 8.5. Entry of the deviation – shaft

1 zero line
2 deviation
3 shaft

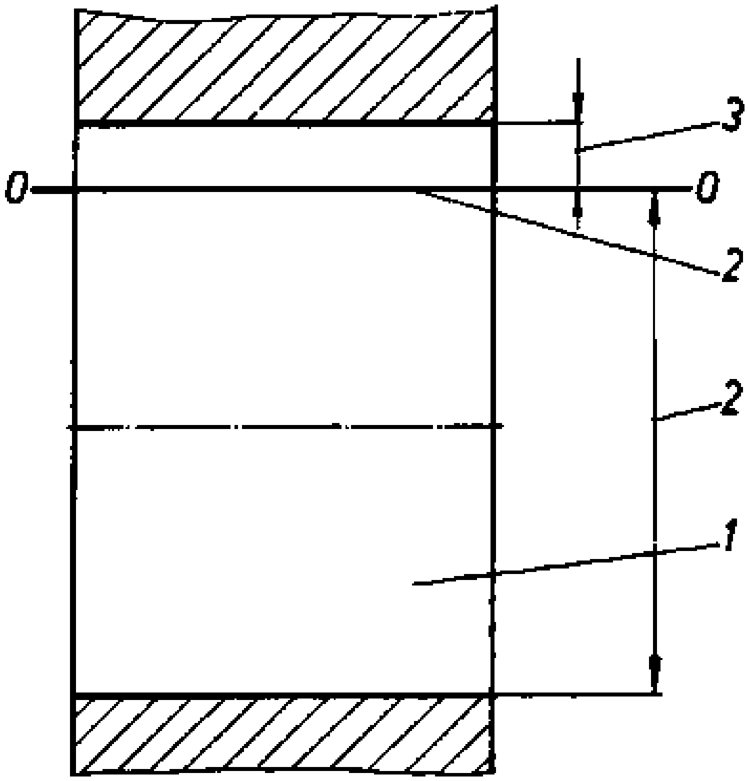


Fig. 8.6. Entry of the deviation – hole

1 hole
2 zero line
3 deviation

Below, the terms “shaft” and “hole” not only refer to parts with round cross–section but also to elements of single parts of another shape (e.g. to such which are bounded by parallel planes). Since for the proper manufacture of an object two limits are required, we have two dimensional variations each for the shaft and the hole, namely:

– upper deviation = difference between largest dimension and nominal size (Fig. 8.7.)

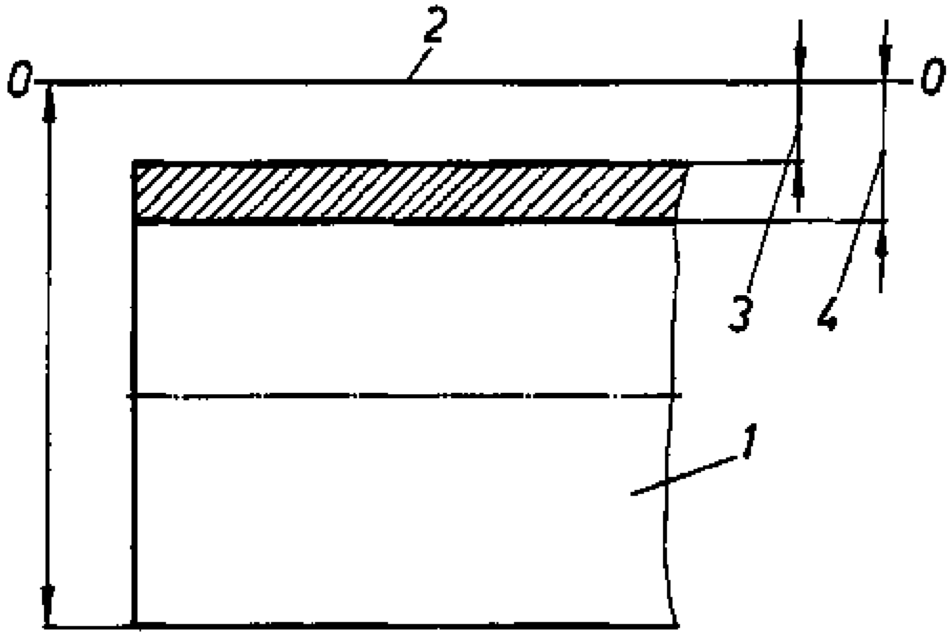


Fig. 8.7. Deviations for shafts

1 shaft
2 zero line
3 upper deviation
4 lower deviation

– lower deviation = difference between smallest dimension and nominal size (Fig. 8.8.)

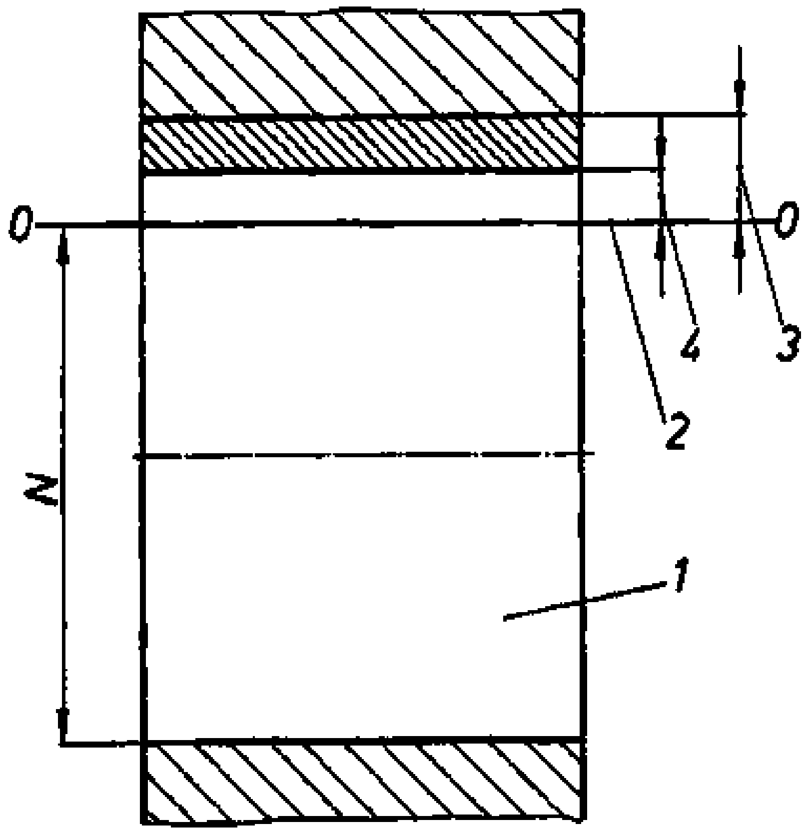


Fig. 8.8. Deviations for holes

1 hole
2 zero line

3 upper deviation
4 lower deviation

The upper deviation specifies the difference between largest dimension and nominal size while the lower deviation specifies the difference between smallest dimension and nominal size.

In order to simplify the designation of the dimensional variations and to make a distinction between the deviations regarding hole and shaft, the following has been accepted internationally:

– upper deviation of the hole
es;
– upper deviation of the shaft
es;
– lower deviation of the hole
ei;
– lower deviation of the shaft
ei;

The capital letters indicate the dimensional variations or deviations of the hole, the small letters those of the shaft. With a formula, the dimensional variations and limits can be expressed as follows:

hole – deviations	hole – limits
ES = G – N or by rearranging	G = N + ES
EI = K – N the formula:	K = N + EI
shaft – deviations	
es = G – N	G = N + es
ei = K – N	K = N + ei

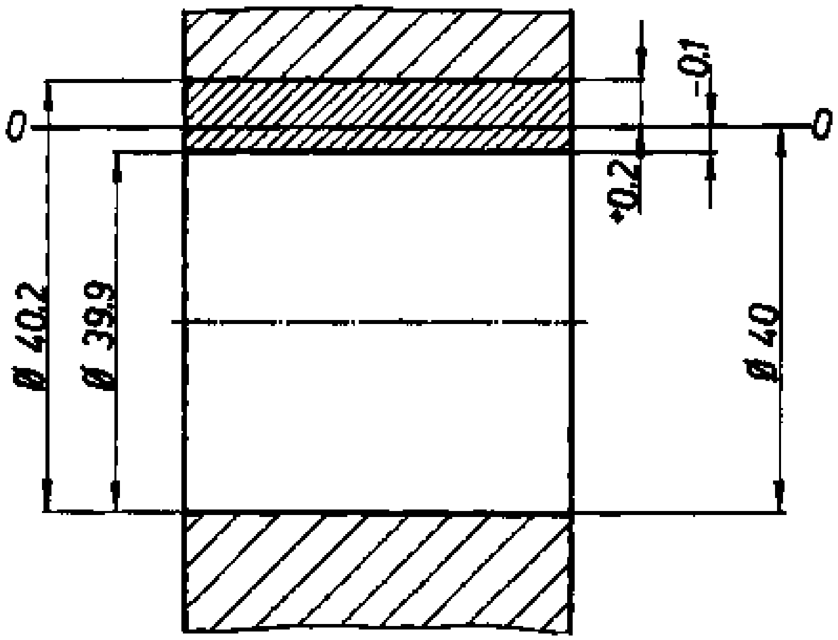


Fig. 8.9. Numerical examples of deviations and limits (hole)

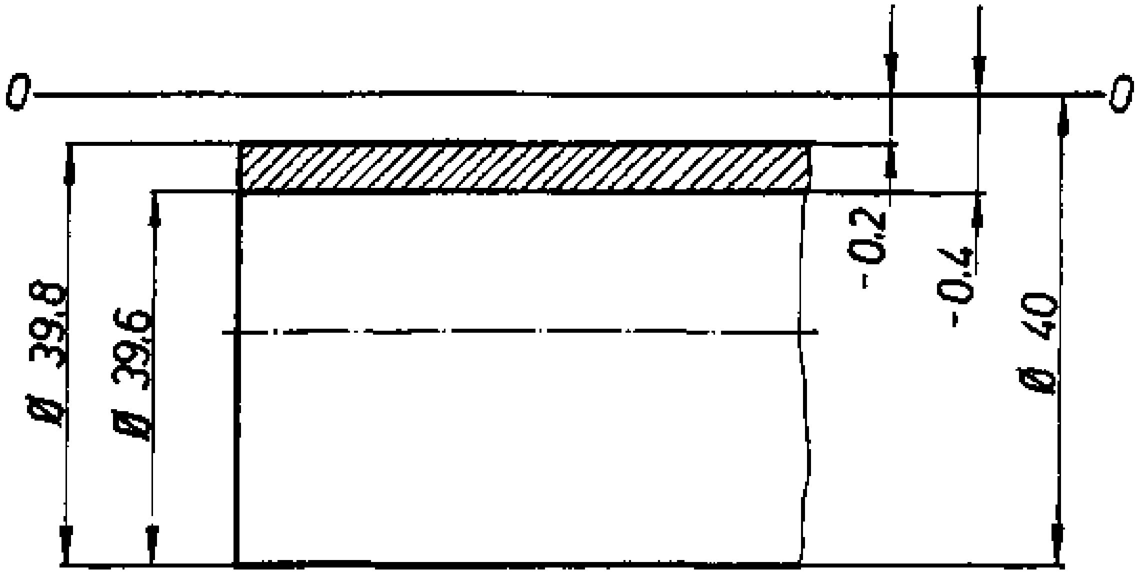


Fig. 8.10. Numerical examples of deviations and limits (shaft)

According to Figs. 0.9. and 8.10., by substituting numerals, we obtain the following:

hole:	shaft:
upper deviation	upper deviation
ES = G – N	es = G – N
= 40.2 mm – 40 mm	= 39.8 mm – 40 mm
<u>ES = + 0.2 mm</u>	<u>es = – 0.2 mm</u>
lower deviation	lower deviation
EI = K – N	ei = K – N
= 39.9 mm – 40 mm	= 39.5 mm – 40 mm
<u>EI = – 0.1 mm</u>	<u>ei = – 0.4 mm</u>

<u>Location of the tolerance zones</u>

Both the numerical examples and the illustrations 3.9. and 8.10. show that the dimensional variations are positive (+) (i.e. above the zero line) and negative (–) (below the zero line). According to algebraic laws, dimensional variations may have numerical values which are

– positive in both cases or

– negative in both cases or

– different, that is to say, the upper deviation has a positive value while the lower deviation has a negative one,

depending on the fact what are the values of the largest and the smallest dimension with respect to the nominal size. It is possible that one of the two dimensional variations has the value of zero.

Figs. 8.9. and 8.10. show that, for a graphical representation of the dimensional variations, the location of the tolerance zones with respect to the zero line is of importance only. Therefore, the simplified representation will be used below in order to demonstrate the different locations of the tolerance zone with respect to the zero line (see Figs. 8.11. and 8.12.).

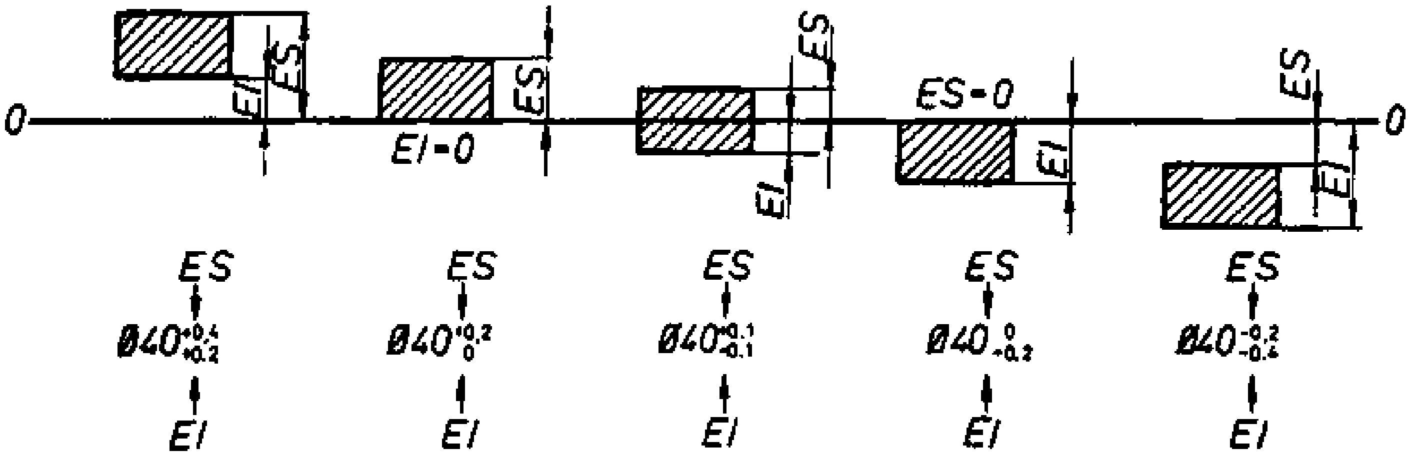


Fig. 8.11. Location of the tolerance zones with respect to the zero line (hole)

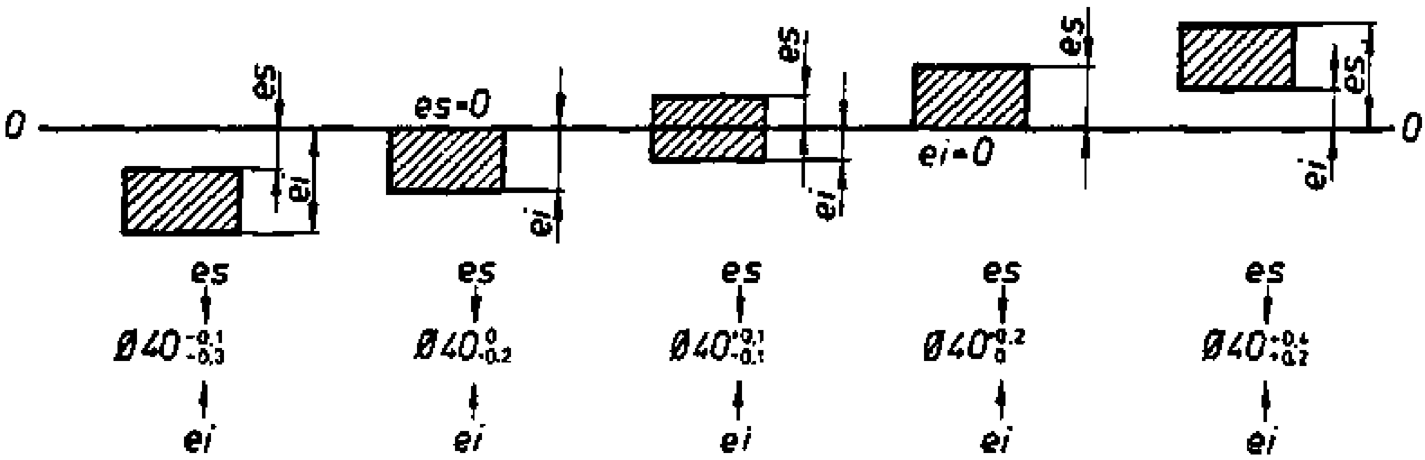


Fig. 8.12. Location of the tolerance zones with respect to the zero line (shaft)

The magnitude of the tolerance is by given the difference between the two limits. The location of the tolerance with respect to the zero line results from the positive and negative signs and the amount of the variations.

Manner of writing tolerances

The tolerances of linear measures must be indicated in drawings by entering the two deviations in small letters immediately after the nominal size. The high limit is placed above the low limit and the respective signs must be given, e.g. . This does not indicate whether or not the deviations are those of the shaft or of the hole; for this, special regulations are required which are explained in section 7.2.2. Deviations or limits are usually given with the same number of digits, in millimetre without indication of the unit of measure, e.g. . In Tables or books of Tables, the dimentional variations usually can be read in ?m.

Deviations of zero, need not be given with the number of digits of the other deviations and without sign, e.g. . It is permissible to omit the statement of zero, e.g. $40_{0.025}$; Ø$35^{+0.2}$.

Numerically equal deviations with different signs are given only once behind the nominal size, e.g. 20 ± 0.02 (see Fig. 8.13.).

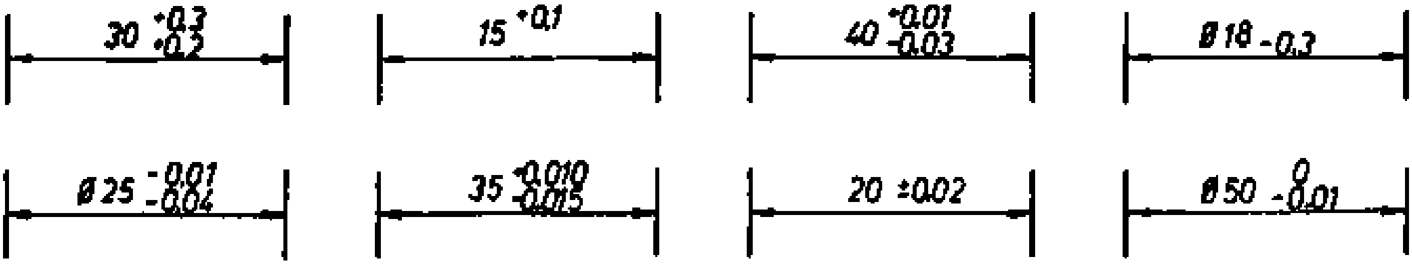


Fig. 8.13. Entry of deviational variations

8.2.2. Entering the Tolerance by Symbols Designating Fits

Frequently, the room available for entering the dimensional variations in drawings is insufficient or errors are made in the transfer of measures. The numerical statements of tolerances also present difficulties to the recognition of the fit, e.g. that between shaft and hole, and in the tabulation of dimensional variations. In order to avoid these disadvantages, internationally accepted symbols have been introduced. They indicate the location and magnitude of the tolerance zones for certain nominal dimension ranges (linear measure) and are applied to internal and external dimensions. The symbols consist of a letter and a numeral, e.g. H 7, k 6.

> The letter indicates the location of the tolerance zone with respect to the zero line. The numeral specifies the magnitude of the tolerance zone.

For the identification of the location of the zone of tolerance, letters of the alphabet are used. To avoid misinterpretations and confusion with other letters and numerals (in addition, they are not included in all languages), the following letters are omitted:

I, L, O, Q, W, i, l, o, q, w.

> The capital letters are used for the tolerance zones of holes, the small letters for the tolerance zones of shafts.

The two letters Js and js indicate the symmetrical position of the tolerance zone so that equal deviations are given which are designated by the sign ±. In order to explain the use of the letters (Figs. 8.14. to 8.17.), the tolerance zones are represented in the same size because, in this case, their location with respect to the zero line is of importance.

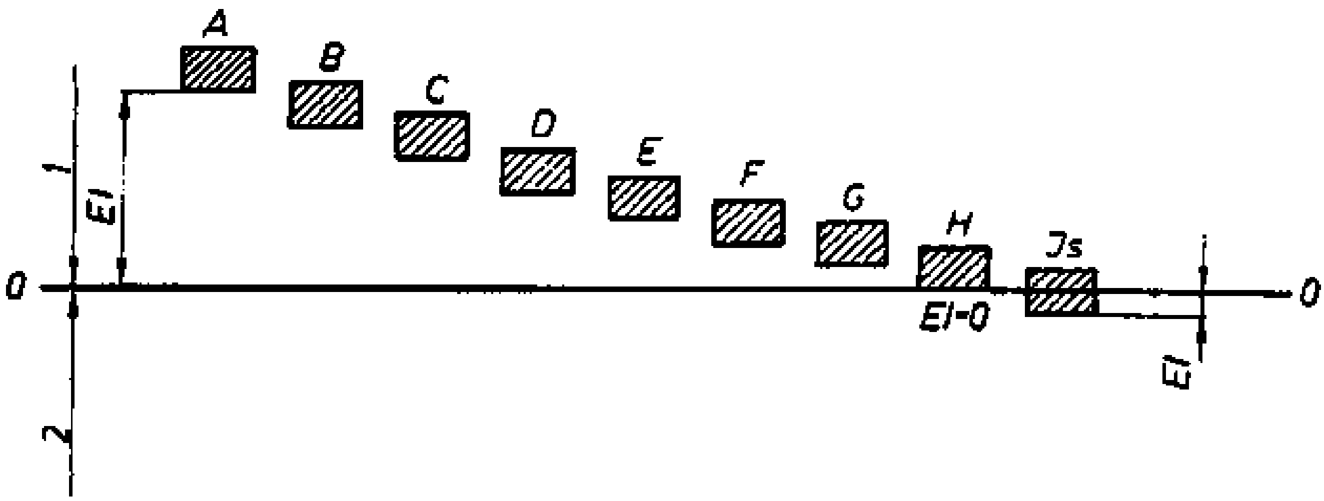


Fig. 8.14. Location of the tolerance zones between A and Js (hole)

1 positive deviations, 2 negative deviations

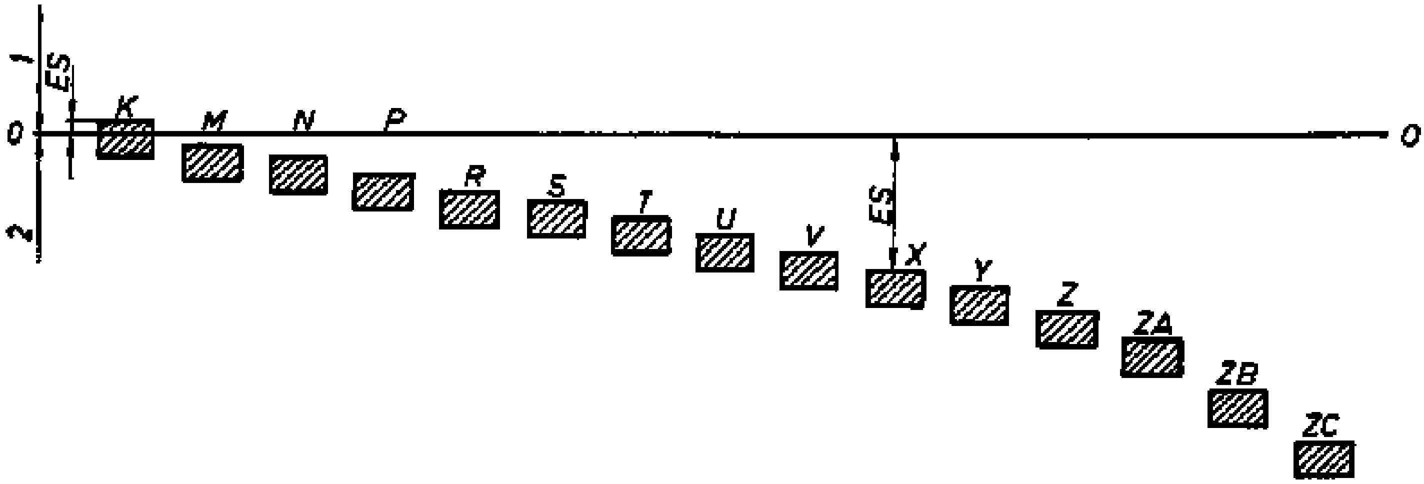


Fig. 8.15. Location of the tolerance zones between K and ZC (hole)

1 positive deviations, 2 negative deviations

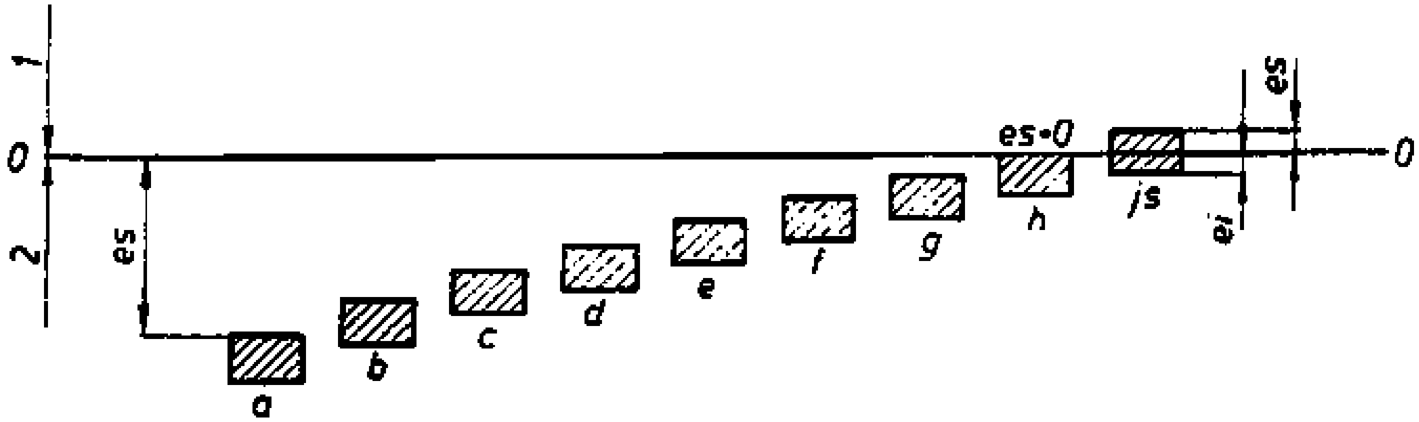


Fig. 8.16. Location of the tolerance zones between a to js (shaft)

1 positive deviations, 2 negative deviations

The tolerance zones A to H are above the zero line, and A is farthest away from this line.

All dimensional variations (ES and EI) are positive except those for the letter H. As the lower deviation, it always has the value of zero.

The tolerance zone of Js is placed symmetrically on the zero line.

Within the range of letters from K to ZC, the deviations are below the zero line, that is to say, in the negative range. Exceptions are represented by K and M while the upper limit, depending on the magnitude of the nominal size and of the tolerance zone, may be above the zero line. Fig. 8.15. shows that the upper limit (negative) becomes the greater, the more it approaches the letters ZC.

When considering the location of the tolerance zones from A to ZC, we find two extreme cases:

– Tolerance zone A is far above the zero line. The diameter of the hole is increased.
– Tolerance zone ZC is far below the zero line. The diameter of the hole is decreased.

The tolerance zones a to h are below the zero line while a is farthest away from the zero line. All deviations are negative except for the letter h, it always has the value of zero as the upper deviation ei.

The tolerance zone of js is always located symmetrically about the zero line.

In the letter range from k to zc, the deviations are generally above the zero line, i.e. within the positive range (Fig. 8.17.). The latter illustration shows that the lower deviation (positive) becomes the greater, the more it approaches the letters zc.

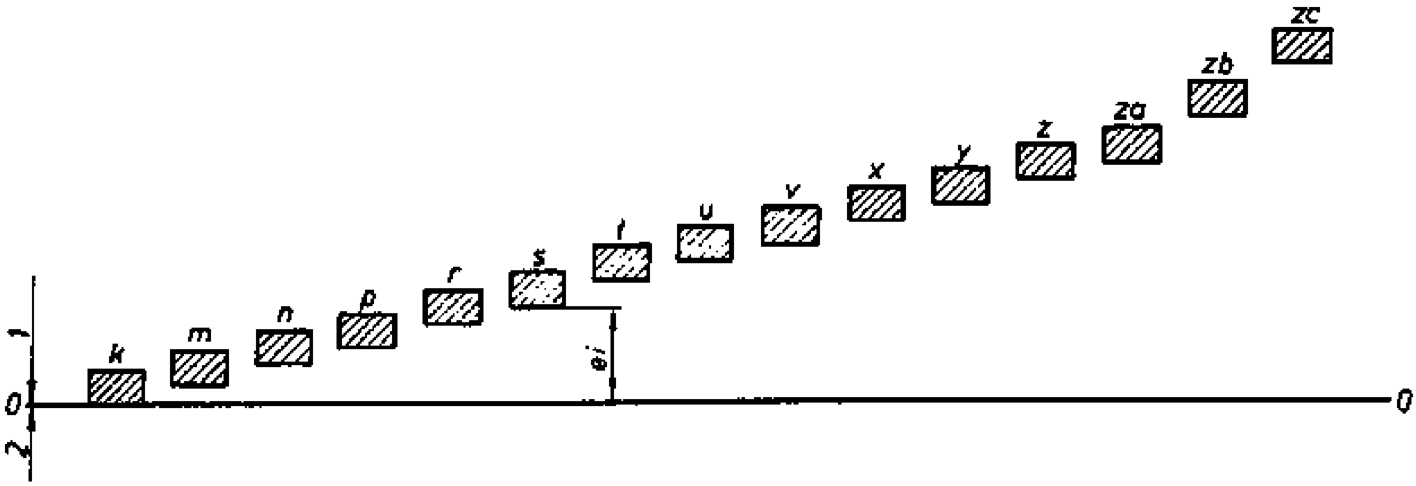


Fig. 8.17. Location of the tolerance zones between k to zc (shaft)

1 positive deviations, 2 negative deviations

When considering the location of the tolerance zones from a to zc, we again can observe two extreme cases:

– Tolerance zone a is far below the zero line. The shaft diameter is decreasing.
– The tolerance zone zc is far above the zero line. The shaft diameter is increasing.

The marking of the magnitude of the tolerance zone is effected by symbols which must indicate both the location of the tolerance zone and its magnitude. For this purpose, 19 figures are used, namely, 0.1; 0 and 1 to 17, and it should be noted that the magnitude of the tolerance increases with increasing number, as is clearly shown in 8.18.

A small numeral means a small tolerance, a large numeral naturally a large tolerance. For this measure of accuracy, expressed by a numeral, one has chosen the term of quality. This means:

The smaller the tolerance, the smaller the quality number and, hence, the tolerance zone.

The stepping of the qualities is effected by means of mathematical formulas, taking into consideration nominal size ranges. Explanations and examples of the use of formulas are not given here. The Table shows that, with a constant quality and increasing dimensional range, the tolerances become greater. This means that the magnitude of the nominal size is the basis of the tolerance magnitude. In Fig. 8.19., the magnitudes of the tolerances for the nominal size range from 18 to 30 mm is represented as a supplement to Fig. 8.18.

Fig. 8.18. Magnitude of tolerances in ?m

Quality		**0,1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**17**
	up to 3	0,3	0,5	0,8	1,2	2	3	4	6	1000
	over 3 up to 6	0,4	0,6	1	1,5	2,5	4	5	8	1200
	over 6 up to 10	0,4	0,6	1	1,5	2,5	4	6	9	1500
Measuring range in mm	over 10 up to 18	0,5	0,8	1,2	2	3	5	8	11	1800
	over 18 up to 30	0,6	1	1,5	2,5	4	6	9	13	2100

	Values in ?m									
	over 400 up to 500	4	6	8	10	15	20	27	40	6300

Note: For dimensions up to 1 mm, the qualities 14 to 17 are not used

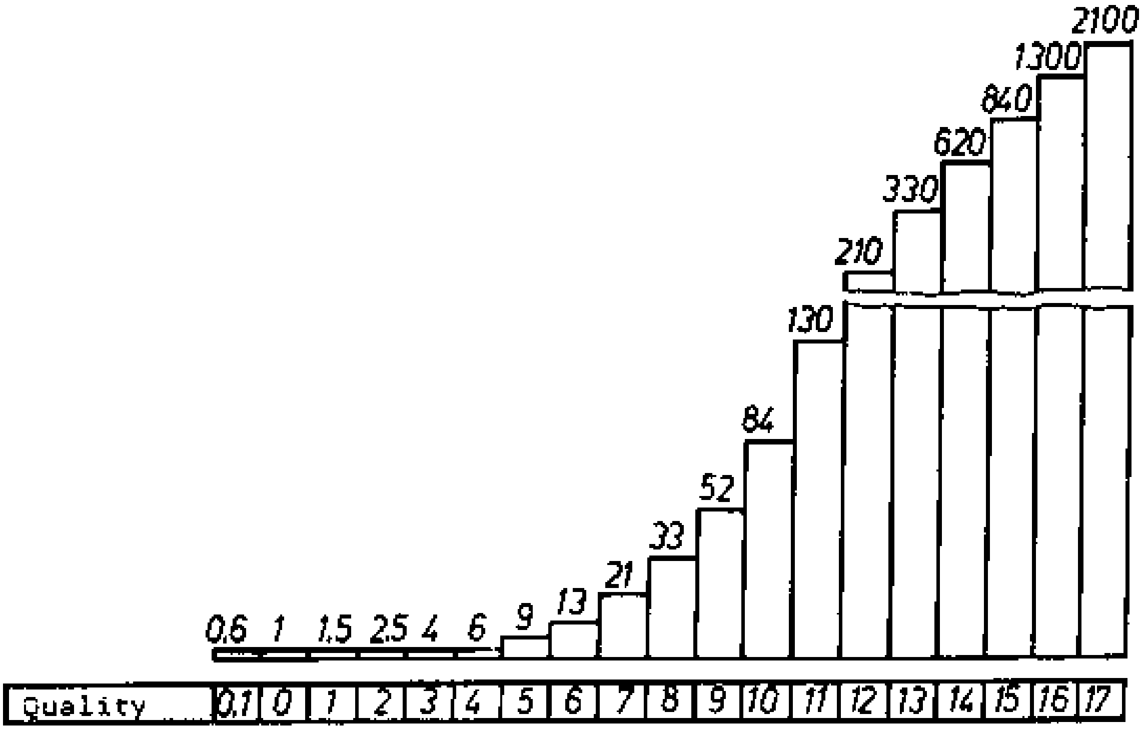


Fig. 8.19. Tolerance magnitudes for the nominal range of measures from 18 to 30 mm

8.2.3. Determination of Tolerances with the Help of Tables

Within the tolerance system, there are many possibilities of forming tolerance zones. The Figs. 8.14. to 8.17, show, for hole and shaft tolerance zones, 24 different positions each with respect to the zero line. Further, according to Fig. 8.18., 19 different qualities (tolerance magnitudes) of the shaft or hole can be selected for each range of nominal size. Many of these tolerance zones are practically useless, e.g. A0 1 or zc 17, because they have extremely high values and are not used in manufacture. By means of international standards, a selected series of tolerance zones has been established in the form of Tables which meet the national and international requirements of the industry. In the selected series – it applies to holes and shafts – preferred tolerance zones have been marked in order to narrow down the possibilities of combination and to save costs for measuring means for checking the limits. The Figs. 8.20. and 8.21. show standard abstracts of basic dimensional variations, i.e. without taking into consideration the various nominal size ranges; the notes having the following meaning:

1. ^{x} tolerance zones which usually are not intended for fits
2. preferred tolerance zones

Quality	a	d	e	f	g	h	js	k	m	n	p	r	z
						Basic deviations							
0,1						h01^{x}	Js01^{x}						
5					g5	h5	js5	k5	m5	n5	p5	r5	
6				f6	g6	h6	js6	k6	m6	n6	p6	r6	
7			e7	f7		h7	js7	k7	m7	n7			
8		d8	e8	f8		h8	js8^{x}						z8
9		d9	e9	f9		h9	js9^{x}						
17						h17^{x}	js17^{x}						

Fig. 8.20. Preferred series for tolerance zones of shafts

In practice, books of Tables are used where – taking into consideration nominal size range, location of the tolerance zone with respect to the zero line, and magnitude of the quality – the mathematically determined dimensional deviations, usually expressed in ?m, are compiled. Figs. 8.22. and 8.23. show an abstract of Table for quality 6 of shaft tolerance zones and of quality 7 for hole tolerance zones.

Quality	A	D	E	F	G	H	Js	K	M	N	P	R	Z
						Basic deviations							
0,1						H01^{x}	Js01^{x}						
5					G5	H5	Js5	K5	M5	N5			
6					G6	H6	Js6	K6	M6	N6	P6		
7				F7	G7	H7	Js7	K7	M7	N7	P7	R7	
8		D8	E8	F8		H8	Js8	K8	M8	N8			
9		D9	E9	F9		H9	Js9^{x}						
17						H17^{x}	Js17^{x}						

Fig. 8.21. Preferred series for tolerance zones of holes

Fig. 8.22. Dimensional variations of shaft tolerances of quality 6

Dimensional range mm	Tolerance zones										
	f6	g6	h6	js6	k6	m6	n6	p6	r6	s6	t6
	Nominal deviations; ?m										
From 1 up to 3	–6 –12	–2 –8	0 –6	+3,0 –3,0	+6 0	+8 +2	+10 +4	+12 +6	+16 +10	+20 +14	–
over 3 up to 6	–10 –13	–4 –12	0 –8	+4,0 –4,0	+9 +1	+12 +4	+16 +8	+20 +12	+23 +15	+27 +19	–
over 18 up to 24	–20	–7	0	+6,5	+15	+21	+28	+35	+41	+48	–

over 24 up to 30	–33	–20	–13	–6,5	+2	+8	+15	+22	+28	+28	+54 +41
over 30 up to 40	–25	–9	0	+8,0	+18	+25	+33	+42	+50	+59	+64 +48
over 40 up to 50	–41	–25	–16	–8,0	+2	+9	+17	+26	+34	+43	+70 +54
over 400 up to 450	–68	–20	0	+20,0	+45	+63	+80	+108	+166 +126	+272 +232	+370 +330
over 450 up to 500	–108	–60	–40	–20,0	+5	+23	+40	+68	+172 +132	+292 +252	+400 +360

Example 1:

What means the dimension Ø 20 g 6?

Solution:

Ø 20 = nominal size

g 6 according to Table: upper deviation of shaft (es) = 7 ?m

lower deviation of shaft (ei) = 20 ?m

The two deviations are below the zero line.

The largest dimension G is: G = N + es

= 20.0 + (–0.007)

= 20.0 – 0.007

G = Ø 19.993 mm

The smallest dimension K is: K = N + ei

= 20.0 + (–0.020)

= 20.0 – 0.020

K = Ø 19.980 mm

The magnitude of the tolerance, hence, is:

IT = G – K = 19.993 mm – 19.980 mm

IT = 0.013 mm

IT = 13 ?m

When finding the difference between es and ei, one again obtains the tolerance IT = es – ei = – 7 ?m – (–20 ?m)

= – 7 ?m + 20 ?m

IT = 13 ?m

Example 2:

What means the dimension Ø 25 H 7?

Solution:

Ø 25 = nominal size

H 7 according to Table: upper deviation of hole (ES) = + 21 ?m

lower deviation of the hole (EI) = 0

The upper deviation is above the zero line, the lower deviation is on the zero line

The largest dimension G is:	G = N + ES
	= 25.0 + (+0.021)
	= 25.0 + 0.021
	G = Ø 25.021 mm
The smallest dimension K is:	K = N + EI
	K = 25.0 + (0)
	K = 0 25.0 mm
The magnitude of the tolerance is given by:	IT = G – K = 25.021 – 25.0
	IT = 0.021 mm
	IT = 21 ?m
When finding the difference between E5 and EI, one again will obtain the tolerance	IT = ES – EI = + 21 ?m – (0)
	IT = 21 ?m

Figures 8.22. and 8.23. demonstrate:

Within the same range of nominal size, the tolerance of the same quality is constant.

Repetition

1. What do you understand by limits and tolerance zone?

2. Explain the terms "upper deviation and lower deviation" and use the appertaining designations!

3. What is the importance and meaning of the capital and small letters for the designation of tolerances?

4. What do you understand by "quality" and by means of what symbol is it defined?

5. Explain the dimensions Ø 20 k 6 and Ø 35 N 7!!

Fig. 8.23. Dimensional variations of hole tolerances of quality 7

	Tolerance zones										
Dimensional range mm	**F7**	**G7**	**H7**	**Is7**	**K7**	**M7**	**N7**	**P7**	**R7**	**S7**	**T7**
	Nominal deviations; ?m										
From 1	+16	+12	+10	+5	0	–2	–4	–6	–10	–14	–
up to 3	+6	+2	0	–5	–10	–12	–14	–16	–20	–24	–
over 3	+22	+16	+12	+6	+3	0	–4	–8	–11	–15	–
up to 6	+10	+4	0	–6	–9	–12	–16	–20	–23	–27	–
over 18 up to 24	+41	+28	+21	+10	+6	0	–7	–14	–20	–27	–

over 24 up to 30	+20	+7	0	–10	–15	–21	–28	–35	–41	–48	–33 –54
over 30 up to 40	+50	+34	+25	+12	+7	0	–8	–17	–25	–34	–39 –64
over 40 up to 50	+25	+9	0	–12	–18	–25	–33	–42	–50	–59	–45 –70
over 400 up to 450	+131	+83	+63	+31	+18	0	–17	–45	–103 –166	–209 –272	–307 –370
over 450 up to 500	+68	+20	+0	–31	–45	–63	–80	–108	–109 –172	–229 –292	–337 –400

8.3. Fits

8.3.1. Basic Terms and System of Fits

Observance of tolerances is necessary when parts are assembled and, as mating parts, have to fulfil a certain function. When a shaft and a drill–hole are considered mating parts, different possibilities may occur depending on the location and magnitude of the tolerance zone. When assembling parts for which tolerances have been determined, variations of the play or clearance occur which cause good or less good running qualities. The tolerances specified for the parts can also be such that they have an allowance for interference so that they cannot move. Besides these two extreme cases, there are transition fits where a clearance or an interference may be involved. Therefore, a distinction is made between clearance fit, transition fit and interference fit. (See Fig. 8.24.). The clearance fit is also known as sliding and running fit and the interference fit as force and shrink fit.

Clearance fit

For this fit, the hole is larger than the shaft and the tolerance is such that clearance is given in both cases (Sg = maximum clearance; S_k = minimum clearance). There are two limiting values (extreme cases) within which the clearance must be. Fig. 8.25. demonstrates the location of the tolerance zones of hole and shaft with respect to the zero line.

Example:

bore Ø 40 H 7; shaft Ø 40 g 6.

Determine the kind of fit!

Solution:

With the help of Figs. 8.22. and 8.23., the appertaining dimensional variations and limits are compiled into a Table of dimensional variations or deviations for exercising according to Fig. 8.26. and with the given formulas for the maximum and minimum clearance, the latter are determined. In both cases, the values must be positive, i.e. a clearance must be given.

If in one case or the two extreme cases negative values occur, then an interference is given (see Section on interference fit).

In both cases, the limits are positive. A clearance fit is given within the limits of

maximum clearance = + 50 ?m and
minimum clearance = + 9 ?m

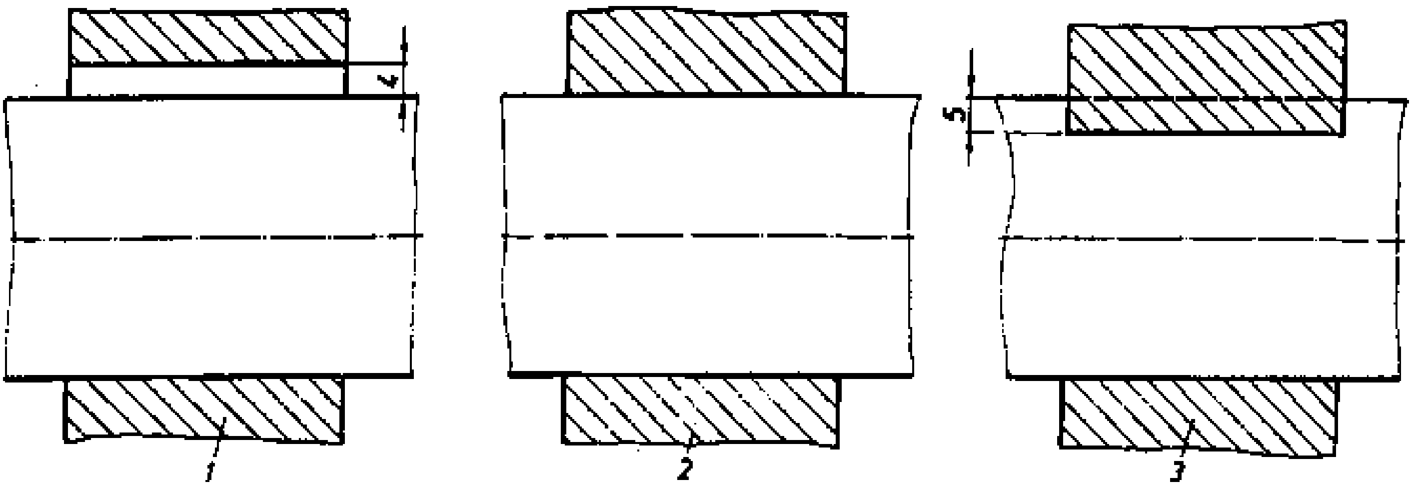


Fig. 8.24. Types of fits (survey)

1 Clearance fit, 2 Transition fit, 3 Interference fit
4 Clearance, (also known as allowance for fit)
5 Allowance for interference

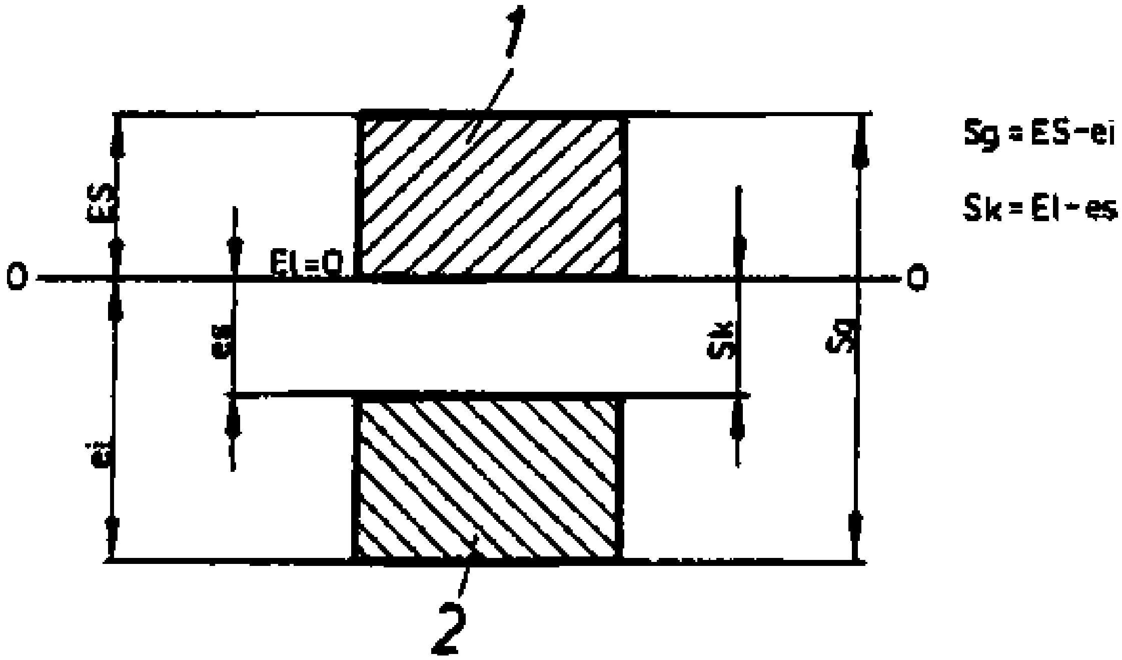


Fig. 8.25. Clearance fit

1 Hole, 2 Shaft

Fig. 8.26. Table of deviations for clearance fit

Fit, designation	Deviations in ?m	Limits in mm
40 H 7	+ 25	40.025
	0	40.0
40 g 6	– 9	39.991
	– 25	39.975

Sg = ES – ei = + 25 – (–25)

= + 25 + 25 = + 50 ?m

Sg = + 50 ?m

Sk = EI – es = 0 – (–9)

= 0 + 9 = + 9 ?m

Sk = + 9 ?m

Interference fit

In an interference fit, the shaft is larger than the hole and in both cases the tolerance has an allowance for interference (U_g = maximum allowance for interference, U_k = minimum allowance for interference). The two limiting values (extreme cases) are negative within which the interference must be. In Fig. 8.27., the location of the tolerance fields of hole and shaft to the zero line is shown.

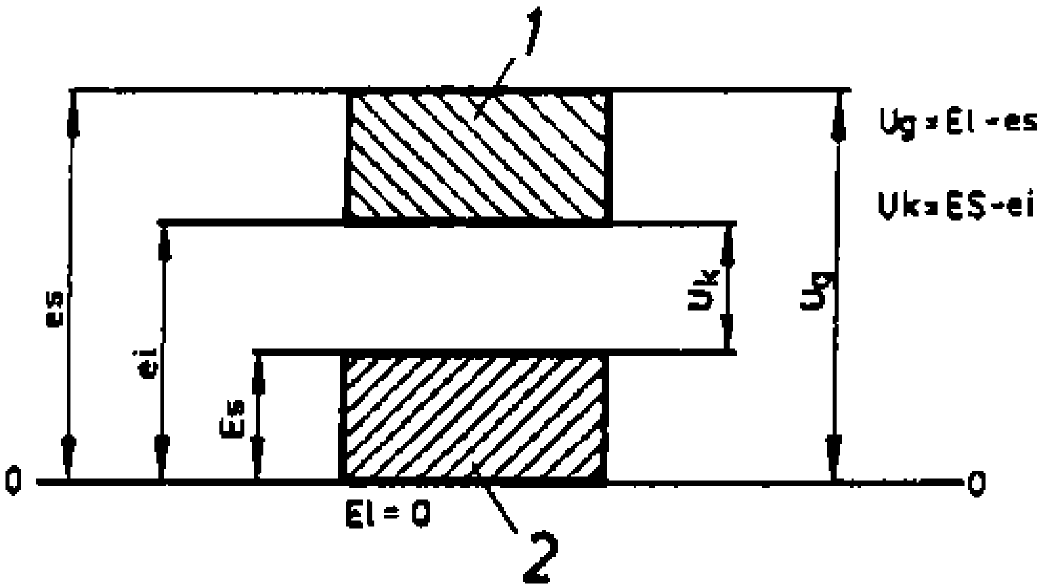


Fig. 8.27. Interference fit

1 Shaft, 2 Hole

Example:

hole Ø 40 H 7; shaft Ø 40 r 6.

Determine the kind of fit!

Solution:

With the help of Figs. 8.22. and 8.23., the appertaining dimensional variations and limits are again compiled into a Table of dimensional variations or deviations and, using the relevant formulas, the maximum and minimum interference are determined. See Fig. 8.28.

Fig. 8.28. Table of deviations for interference fit

Fit, designation	**Deviations in ?m**	**Limits in mm**
40 H7	+ 25	40.025
	0	40.0
40 r 6	+ 50	40.050

	+ 34	40.034

Ug = EI – es = 0 – (+50)

= 0 – 50= – 50 ?m

Ug = – 50 ?m

Uk = ES – ei = + 25 – (+34)

= + 25 – 34 = – 9 ?m

Uk = – 9 ?m

In both cases, the limits are negative. An interference fit is given within the limits of

maximum interference allowance = – 50 ?m
minimum interference allowance = – 9 ?m

Transition fit

In a transition fit, in an extreme case the hole may be larger or smaller than the shaft so that both a clearance fit and an interference fit may be obtained. That is why this kind of fit is called transition fit. One limit is provided with a positive sign with the maximum clearance Sg while the other limit is negative with the maximum allowance for interference Ug. Fig. 8.29. shows that the two tolerance zones overlap.

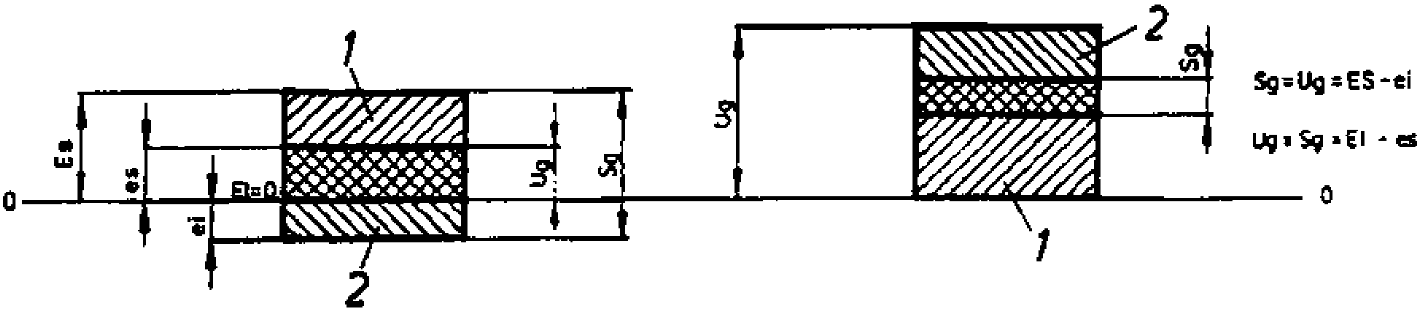


Fig. 8.29. Transition fit, 1 Hole, 2 Shaft

Example:

Hole Ø 40 H7; shaft Ø 40 n6.

Determine the kind of fit!

Solution:

Chose the pertinent dimensional variations from the Figs. 8.22. and 8.23. and compile the Table of deviations. Determine clearance and interference. In one case, the limit is positive so that a clearance fit is given while the limit in the other case is negative so that an interference fit is given (Fig. 8.30.). A transition fit is given within the limits of

maximum clearance = + 8 ?m
maximum allowance for interference = – 33 ?m

Fig. 8.30. Table of deviations for transition fit

Fit, designation	Deviations in ?m	Limits in mm
40 H7	+ 25	40.025

	0	40.0
40 n6	+ 33	40.033
	+ 17	40.017

Sg = Ug = Es – ei

= + 25 – (+17) = 25 – 17

Sg = + 8 ?m

Ug = Sg = EI – es

= 0 – (+33) =0 – 33

Ug = – 33 ?m

8.3.2. Basic Hole and Basic Shaft

In Section 8.2.2. it has been pointed out that a restriction of the tolerance zones has been effected by the establishment of selected series or preferred series. In order to ensure that for the different fits the zones of tolerance are not specified arbitrarily for internal and external cylindrical surfaces, two systems have been developed by mating hole and shaft which comply with the requirements of the industry. These are the basic hole system and the basic shaft system. The advantages of these systems are

– reduction of the number of tools and measuring instruments required;

– quick recognition of the kind of fit (clearance fit, transition fit or interference fit).

Depending on the kind of production, an enterprise chooses one of the two systems. Both systems together are not used.

Basic hole system

In the basic hole system, the hole diameter having the same nominal dimension is equal to the same basic size for all fits. The specified tolerance (quality) must be taken into consideration. The hole may be larger by this tolerance.

The basic hole is always designated by the letter H together with a quality number to be selected, e.g. H6; H7; H8; H9.

With this, the lower deviation of the hole is always zero (see Section 8.2.2.) and the smallest dimension is equal to the nominal dimension. The appertaining shaft is machined in accordance with the requirements of the purpose of the fit. If the shaft is to fit tightly in the hole, letters should be selected of the range from m to z (depending on the quality). If running or sliding of the shaft is desired, the small letters from a to h may be used (see Fig. 8.31.).

Further, Fig. 8.31. shows:

In the basic hole system, the kind of fit is determined by the shaft tolerance zone.

For example, in the nominal size range from 18 to 30 mm, the mating of the dimensions

corresponds to a clearance fit

corresponds to a transition fit

corresponds to an interference fit

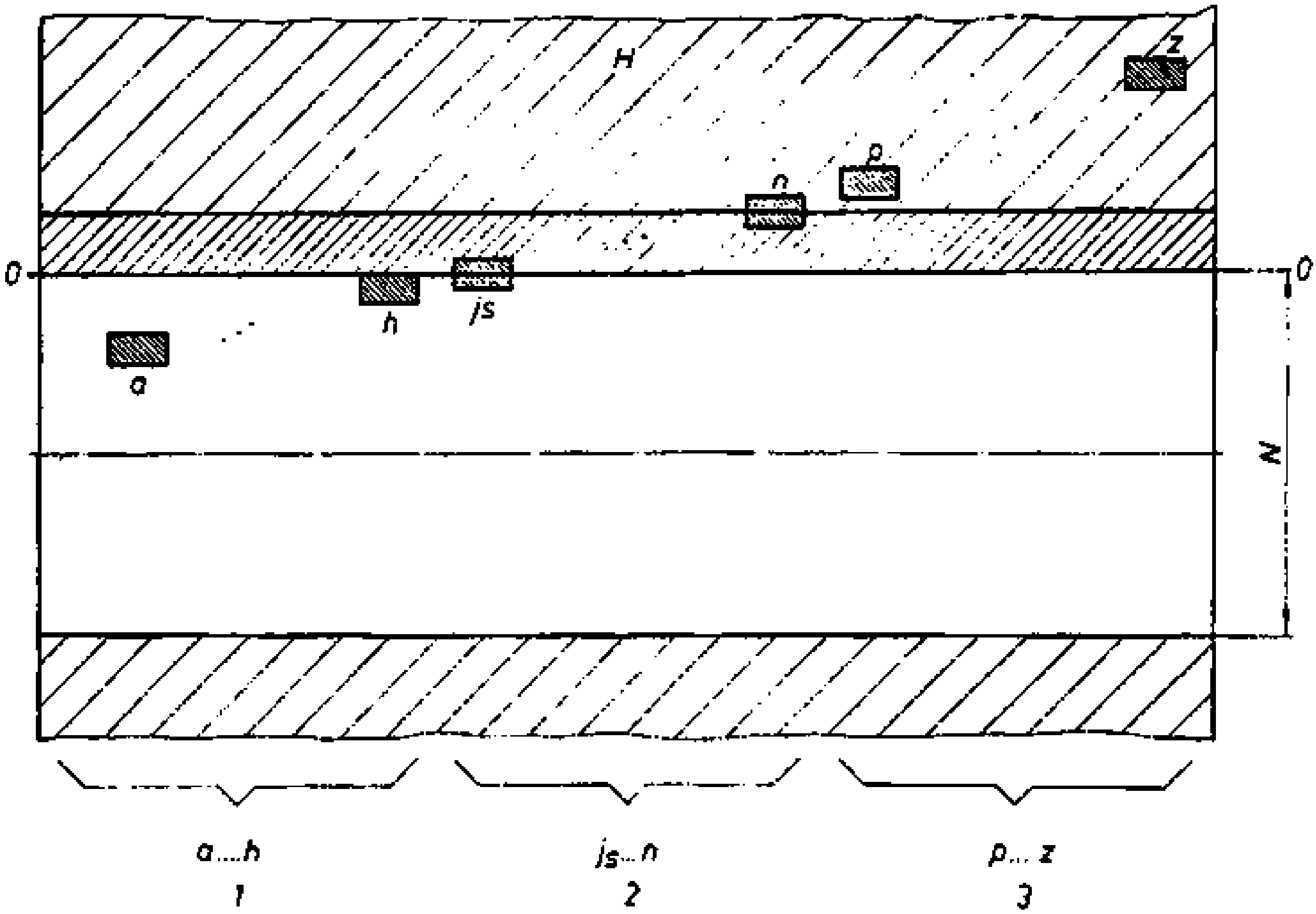


Fig. 8.31. Basic hole

1 Clearance fit, 2 Transition fit, 3 Interference fit

Basic shaft system

In the basic shaft system, the shaft diameter having the same nominal dimension is equal to the same basic size for all fit. The specified tolerance (quality) must be taken into consideration. The shaft may be smaller by this tolerance.

The basic shaft is always designated by the letter h together with a quality number to be selected, e.g. h 6, h 7, h 8.

With this, the upper deviation of the shaft is always equal to *zero* (see Section 8.2.2.) and the nominal size is equal to the largest dimension. Magnitude and location of the tolerance zone of the appertaining hole is different with respect to the zero line, depending on the kind of fit to be produced. In Fig. 8,32., the ranges (location of the tolerance) are specified within which clearance fit, transition fit or interference fit can be established by reasonable mating the standardised dimensions.

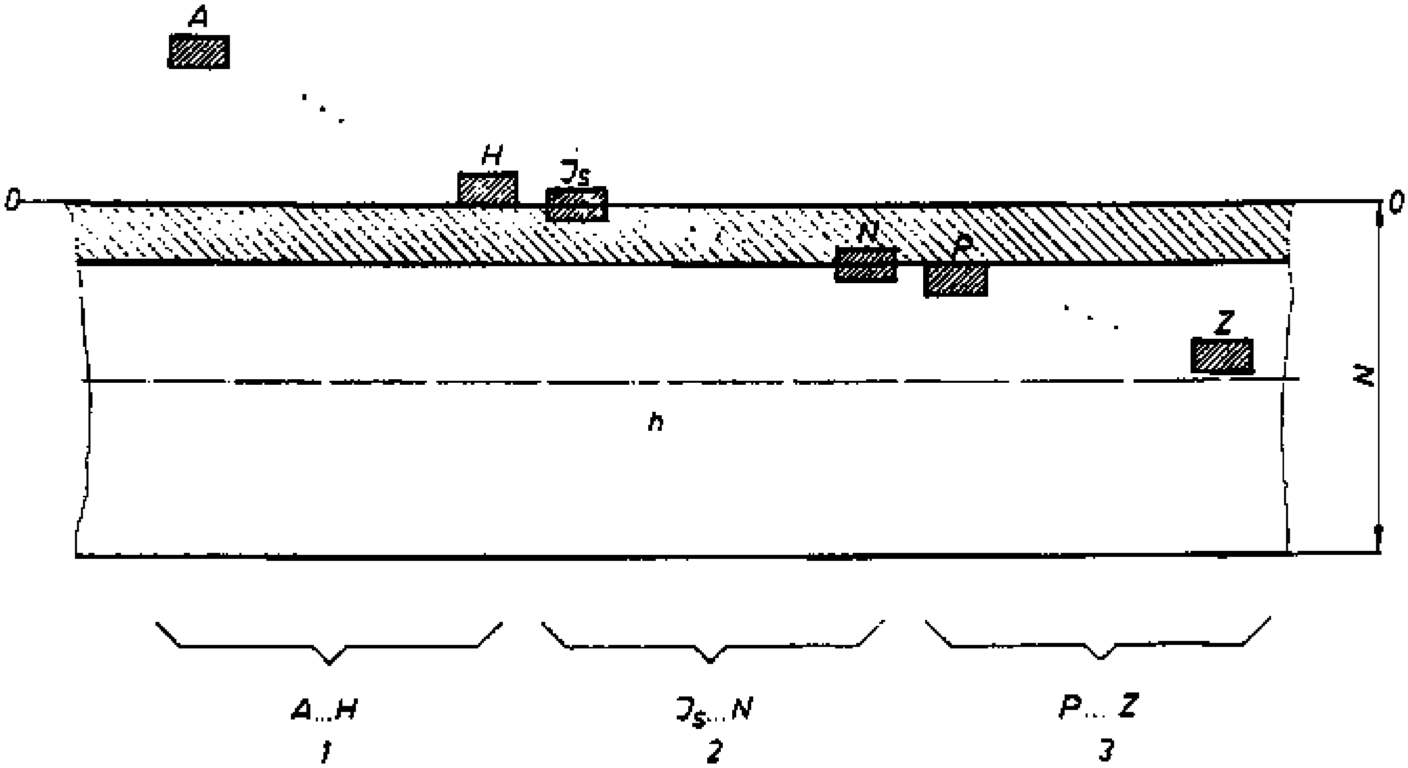


Fig. 8.32. Basic shaft

1 Clearance fit, 2 Transition fit, 3 Interference fit

Further, Fig. 8.32. shows:

In the basic shaft system, the kind of fit is determined by hole tolerance field.

For example, in the nominal size range from 18 to 30 mm, the mating of the dimensions

corresponds to a clearance fit,

corresponds to a transition fit.

corresponds to an interference fit.

Use of the Basic Hole System and Basic Shaft System

In practice, both systems are used. The basic hole system is primarily used in general machine building for the manufacture of larger and smaller numbers of parts because the fit dimensions for shafts can be reached more easily, for example, by grinding. The prime costs for drilling tools are thus reduced. The system of basic hole is used in 90 per cent of all cases.

Enterprises which have to tool many thoroughly smooth shafts primarily use the basic shaft system, for example, enterprises manufacturing textile machines, agricultural machines, construction machinery and hoisting gear.

8.3.3. Entering Fits into Engineering Drawings

The symbols of the tolerance zones have to be placed after the nominal **size** with the same letter height, irrespective of shaft and hole, as is shown in Fig. 8.33.

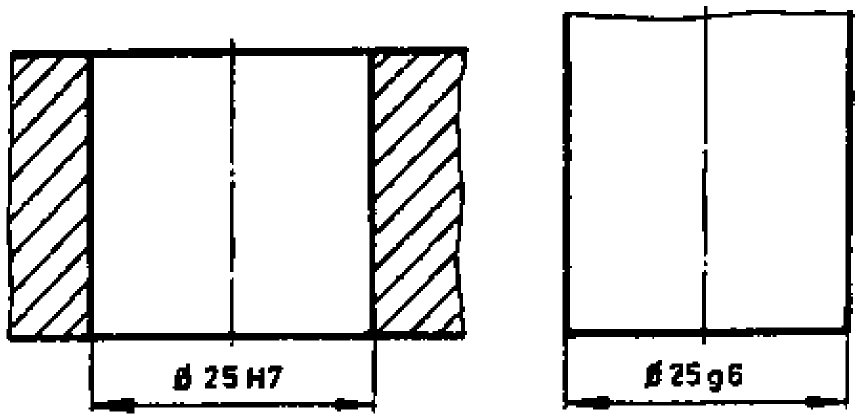


Fig. 8.33. Entry of designations of fits in detail drawings indicating the dimensions of fits

Deviations of assembled parts are shown in the drawing according to Fig. 8.34. as fractions with a horizontal or oblique fractional line, in the numerator the symbol of the tolerance zone of the hole and in the denominator the symbol of the tolerance zone of the shaft. (See Fig. 8.34.)

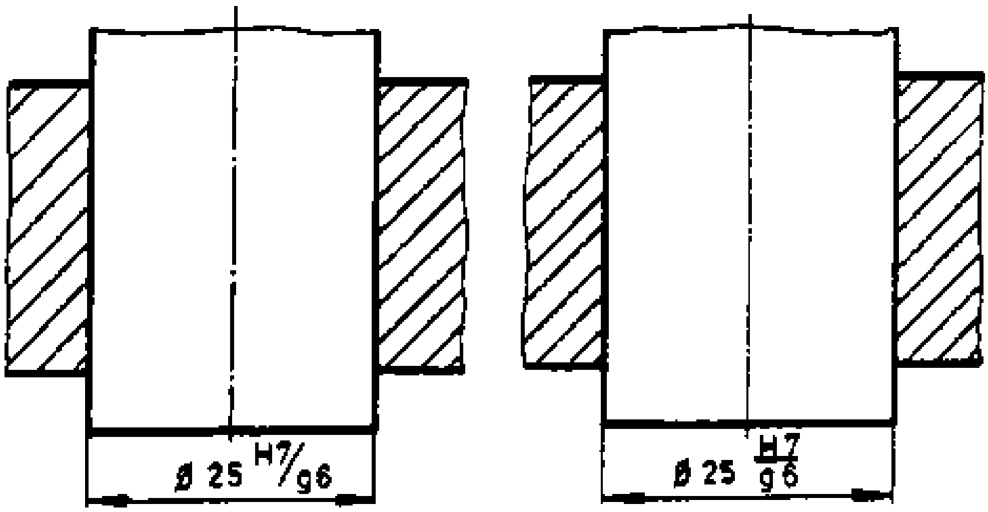


Fig. 8.34. Entry of abbreviated designations of fits indicating their dimensions in assembly drawings

Instead of the symbols, the fraction of the rated deviations are used in assembly drawings. In this case, the numerator shows the deviations of the hole and the denominator the deviations of the shaft (see Fig. 8.35.).

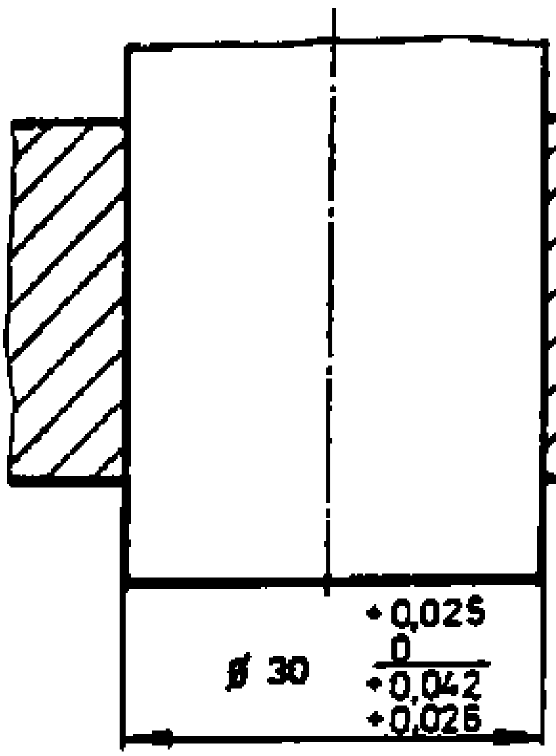


Fig. 8.35. Entry of dimensions of fits in assembly drawings by nominal deviations

Further, it is possible, by a double entry of the nominal size, to place the deviations for the hole above and for the shaft below the dimension line. Before the nominal size it must be indicated for which part the deviations are intended. Fig. 8.36. shows two possibilities.

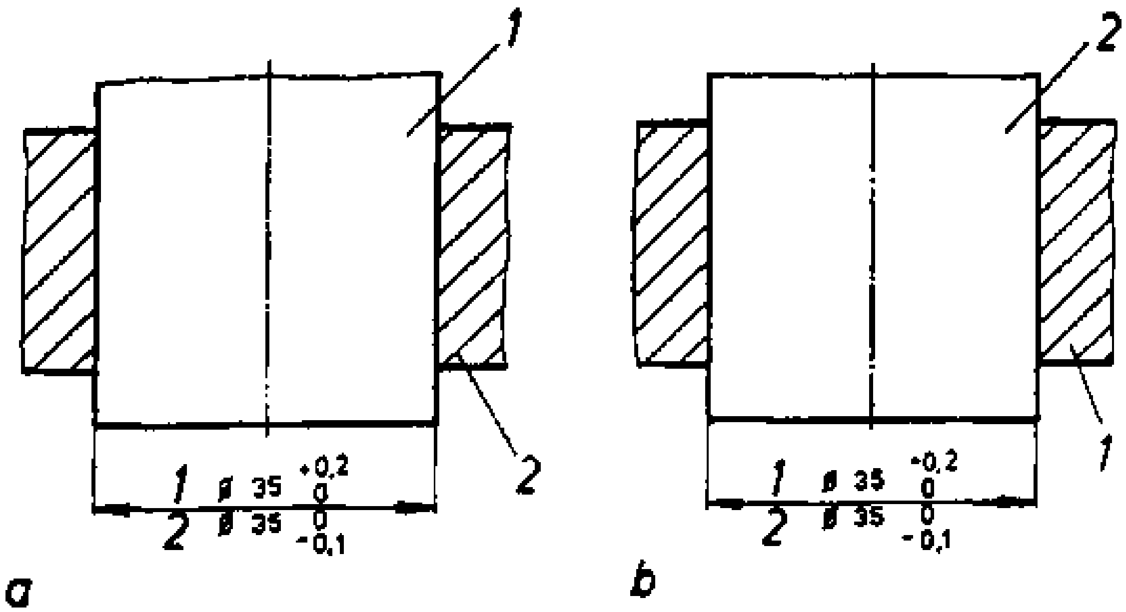


Fig. 8.36. Entry of dimensions of fits in assembly drawings by indicating their numerical value and nominal deviations

a) Part 1, Part 2, b) Hole (1), Shaft (2)

Repetition

1. What do you understand by mating parts or parts to be mated?

2. Explain the use of clearance, interference and transition fits, taking advantage of examples of practice.

3. Quote advantages of the basic hole system and the basic shaft system.

4. How is the statement of the fit dimensions identified with respect to the specification of the basic hole or basic shaft to be used for manufacture?

5. Explain the statement of the fit dimensions:

9. Representation of Assembled Parts

9.1. General Application

In the first Chapter, the different types of drawings and the relevant fundamentals have been explained. Compare the detailed statements given in this Chapter with the following Sections.

The assembly drawing shows complete assembly arrangement, devices, machines, installations, appliances and the like. This type of drawing never shows single parts. For the assembly worker, it is of particular importance that these drawings provide dimensions and statements which he requires for assembling. Data of this kind are, for example, numbering and denominations and descriptions of the single parts to be assembled. For this, the following rules are given which will be explained in connection with the coupling shown in Fig. 9.1.

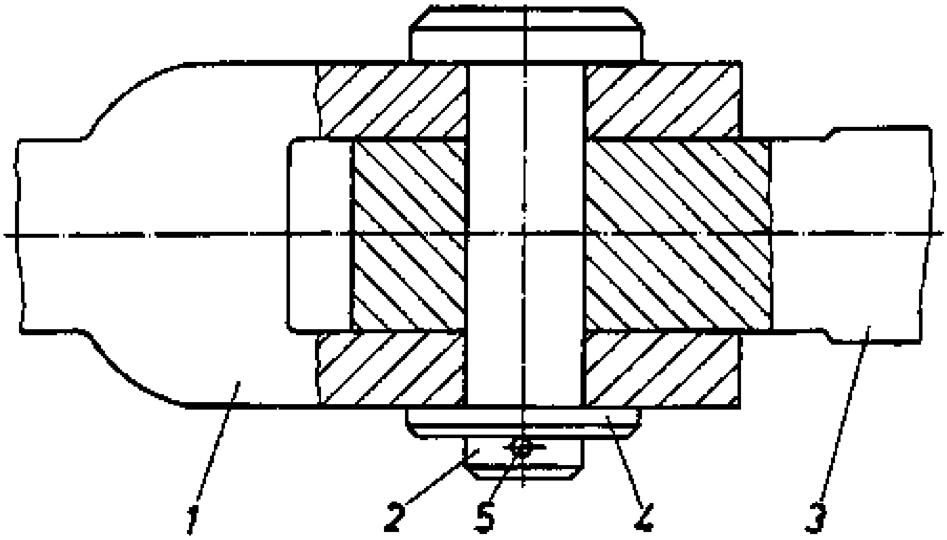


Fig. 9.1. Assembly drawing of a coupling

1 Fork
2 Bolt
3 Rod
4 Washer
5 Split pin

The individual parts of the assembled coupling are marked by numerals. These numerals correspond to the number of the different single parts required and are called serial numbers. The shown non−controllable coupling consists of five different single parts. The serial numbers are written in a height that is double that of the dimension figures. Consequently, they are conspicuous and can be recognised conveniently. Usually, leaders are used to write them close by the drawing of the parts represented. If room is available, they may be written inside the drawing of the part. The leaders, also known as reference lines, are thin solid lines which must be drawn in such a manner that confusion with body edges or neighbouring lines is not possible. The end of the leader inside the drawing of the part is provided with a small dot. It is clearer when the serial numbers are placed on the same level, vertically or horizontally. If this is not possible, then it is more convenient for the assembly worker when the numbers can be read clockwise.

When several equal parts are included in one sub−assembly, the serial number is entered only once in the drawing. In the following illustration, three plates are connected with two equal pins (Fig. 9.2.).

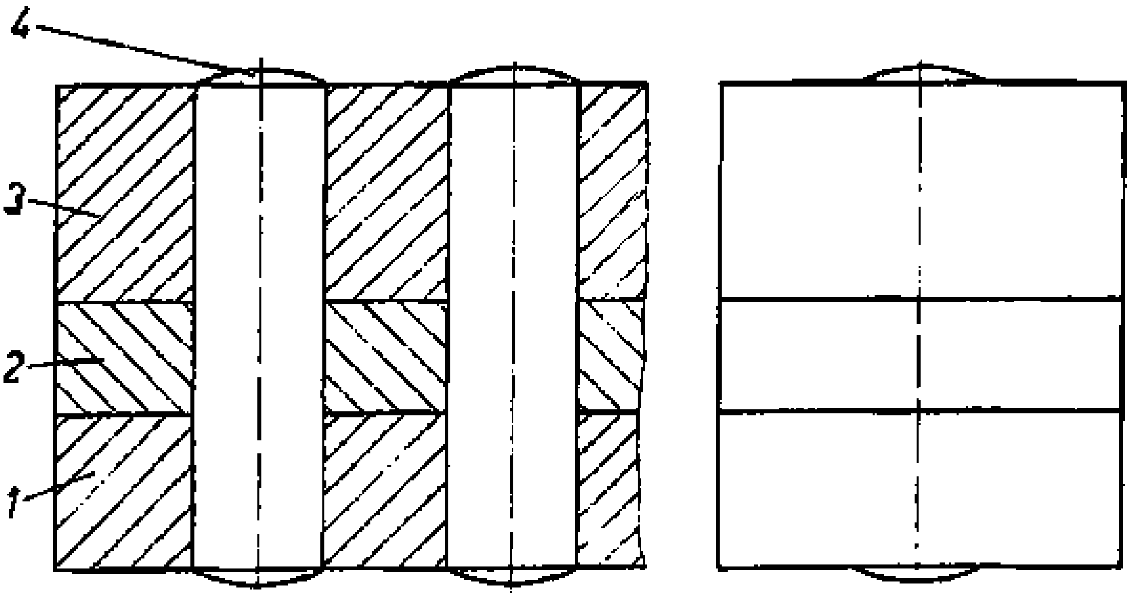


Fig. 9.2. Assembly drawing of a pin connection

1 Plate 1, 2 Plate 2, 3 Plate 3, 4 Pin

Here, only one pin is provided with the serial number, in this case part number four. The list of parts appertaining to the drawing – which will be explained in the following Section – would show that two pins of the same type are required, when these pins would differ in shape, diameter, length or material, each pin had to be provided with a separate serial number.

Repetition

1. The coupling shown in Fig. 9.1. consists of the five single parts bolt, fork, washer, split pin and rod. Provide these parts with serial numbers.

2. In Fig. 9.1. change the position of the parts numbers 1 and 3 in such a way that they are beyond the drawing of the parts with the help of leaders. Solve this problem by preparing a sketch.

3. What is the sectional view of the front representation given in Fig. 9.2.?

4. Why are the two pins (part 4) shown in Fig. 9.2. not shaded although they are in the cutting plane?

5. Give reasons for the different kind of shading in Fig. 9.2.

6. Sketch the 4 different single parts shown in Fig. 9.2. and apply the dimensions required for manufacture (only dimension lines and arrowheads).

7. How would the assembly drawing have to be changed in the same illustration as above, when the diameter of one pin had a value of 10 mm and the other pin of 8 mm while the length of the pins remained constant?

For assembling, it is also of particular importance to perceive immediately how certain parts have to be mated. It is an advantage of the assembly drawing that the fit, more–precisely the kind of fit, of the individual parts is clearly shown. When parts are shown how they have to be mated, the nominal dimensions and the deviations are written one above the other. For this purpose, two dimension lines are drawn. The dimension of the fit for the external part (a) is written above the dimension of the fit for the internal part. Before the dimensions, the word external part or internal part is placed, see Fig. 9.3.

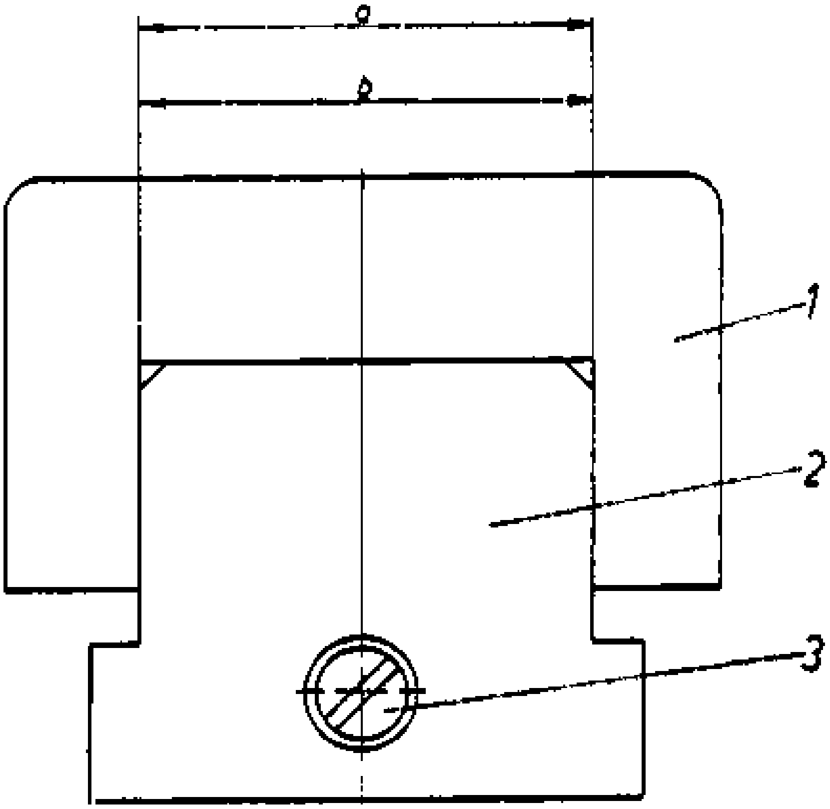


Fig. 9.3. Word indication with two dimension lines

a = external part =
b = internal part = $25_{-0.02}$

1 External part
2 Internal part
3 Screw

Similar conditions apply to cylindrical fits, e.g. when a shaft is mounted in a bearing bush. Here, the word “hole” or “shaft” is placed before the dimension of the fit. If, for each part, only one deviation is entered in the drawing, only one dimension line is required because the other deviation is equal to 0 (zero), as is shown in Fig. 9.4.

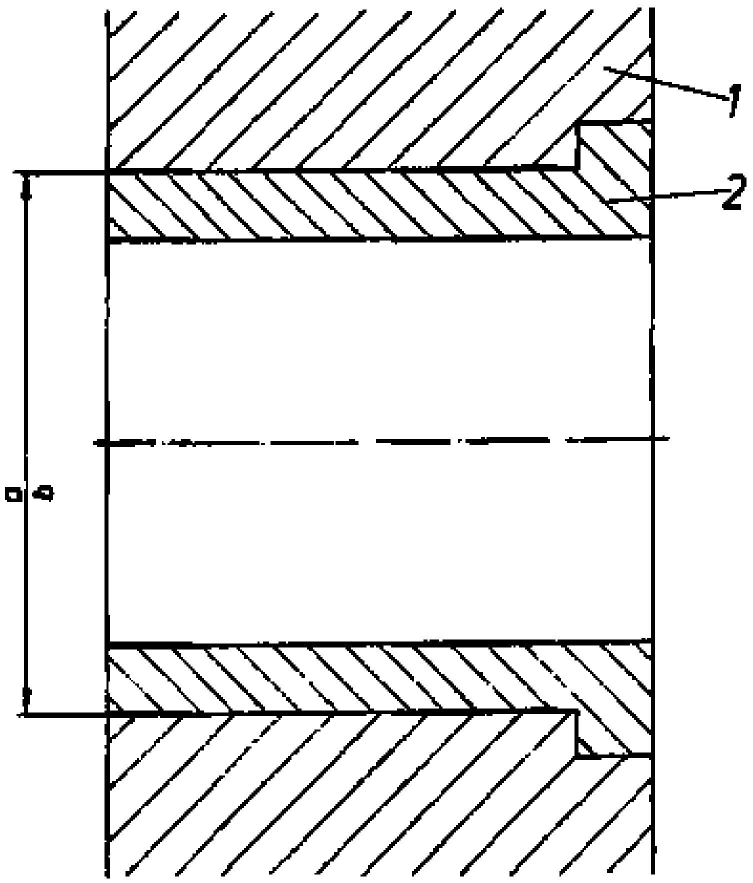


Fig. 9.4. Word indication with one dimension line

a = bore−hole = Ø $30^{+0.2}$
b = shaft = Ø $30_{-0.1}$

1 Hole
2 Bearing bushing

The fit for the assembled parts can also be designated by placing the serial number before the dimensions of the fit. The examples shown in Figs. 9.5. and 9.6. demonstrate this possibility for circular fits including the variants with one or with two dimension lines.

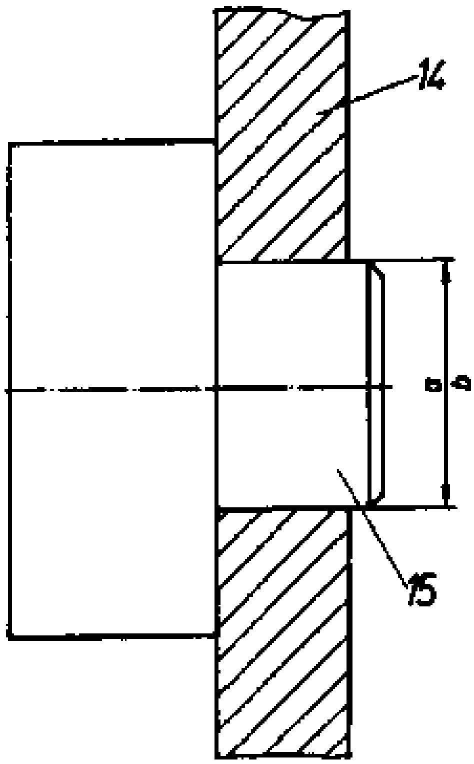


Fig. 9.5. Word indication with one dimension line and part number statement

a = part 14 = Ø $16^{+0.15}$
b = part 15 = Ø $16_{-0.10}$

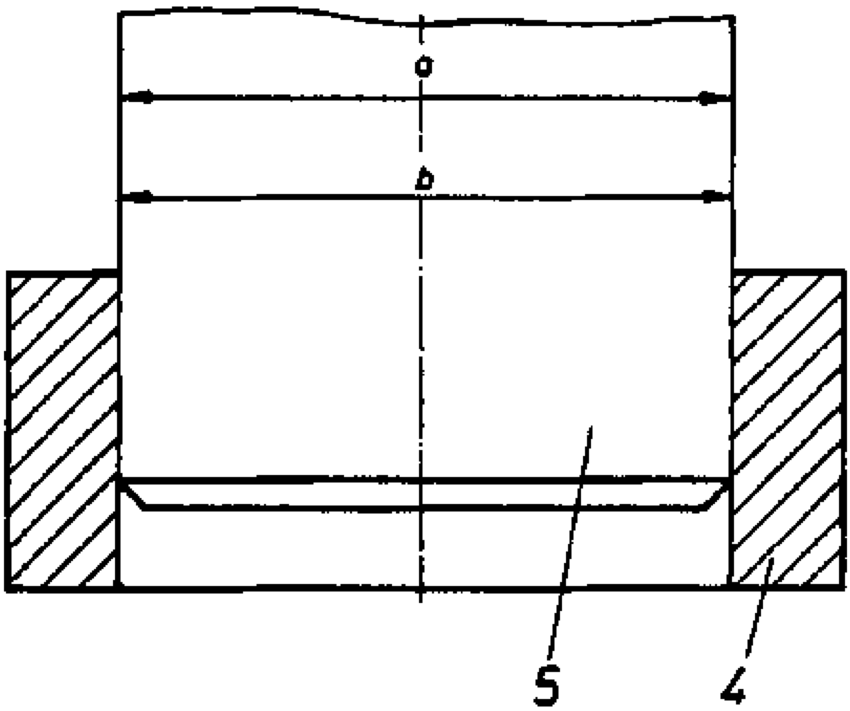


Fig. 9.6. Word indication with two dimension lines and part number statement

a = part 4 = Ø $60^{+0.09}$
b = part 5 = Ø

If symbols designating fits are used, these symbols both for the hole and for the shaft are written on a nominal size. These symbols, consisting of a combination of letter and numeral, are placed behind the nominal dimension. The capital letters and numbers are placed above the small letters and numbers. The selection of these fit statements is effected with a view to ensuring good reading of standardised fits and avoiding misinterpretations. The following illustration, Fig. 9.7., shows a plain bearing and a shaft before assembling with the dimensions required for manufacture and the assembly drawing. The designation of the bearing bush mounted with interference fit and that of the shaft mounted with clearance are clearly perceptible.

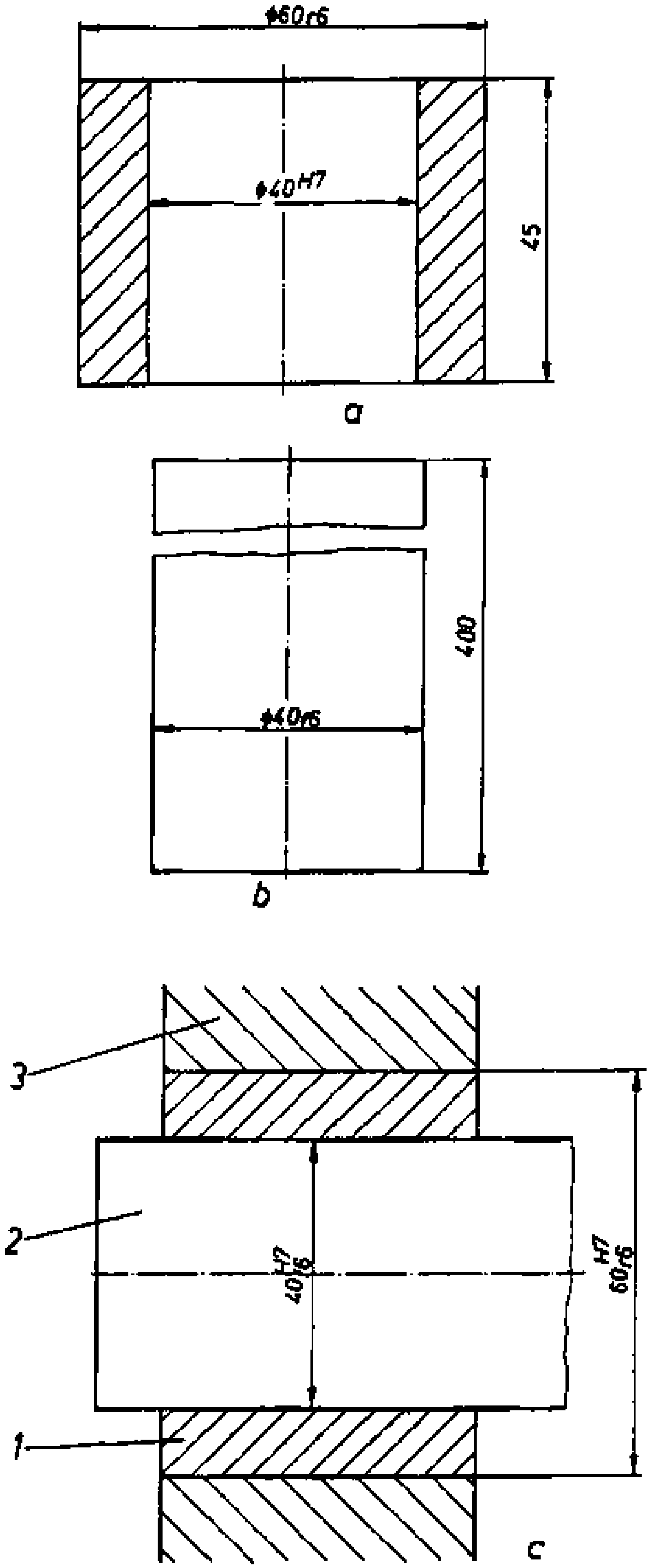


Fig. 9.7. Statement of abbreviated designations of fits

a = single part sliding bearing (1)
b = single part shaft (2)
c = indication of fit in the mounted condition
3 = hole

Dimensioning of the various single parts is omitted in the assembly drawing. For this purpose, detail drawings are prepared which are required for the manufacutre of the parts. Here, all dimensions and statements for manufacture must be given. Consequently, the assembly drawing is clearly arranged and offers readily information about the parts to be assembled.

An exception are assembly dimensions which are absolutely necessary for assembling, for the function or the use of the component. For the plat of a drill jig (Fig. 9.8.), for example, the correct distance between centres of the drill bushings in the mounted condition is such an assembly dimension.

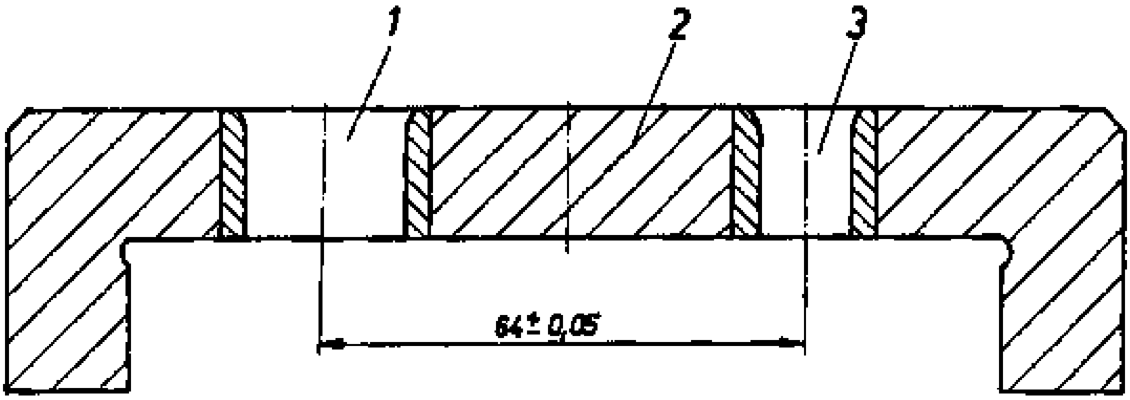


Fig. 9.8. Entry of assembly dimensions in the drawing

1 Jig bushing, 2 Plate jig, 3 Jig bushing

Assembly drawings show the position of the individual parts in the mounted state. The serial numbers of the various single parts, the fits of important parts and necessary assembly and connection dimensions are entered in these drawings.

Repetition

1. Give reasons why in assembly drawing the individual parts are not dimensioned completely.

2. What information can you gather from assembly drawings?

3. In the Figs. 9.3. to 9.8. examples of data designating fits in assembly drawings are given. Determine the external part and the internal part (maximum dimension, minimum dimension and tolerance)!

4. Describe whether the internal parts represented in Figs. 9.3, to 9.7. are mounted so that they are free to move (clearance fit) or so that they are firmly held (interference fit).

5. Explain how one has to work according to the rules of good workmanship in order to avoid rejects in the examples shown.

9.2. List of Parts

The single parts contained in an assembly drawing such as bolts, screws, nuts, washers and split pins are included in the list of parts and defined. The arrangement of a list of parts is shown in Fig. 9.9.

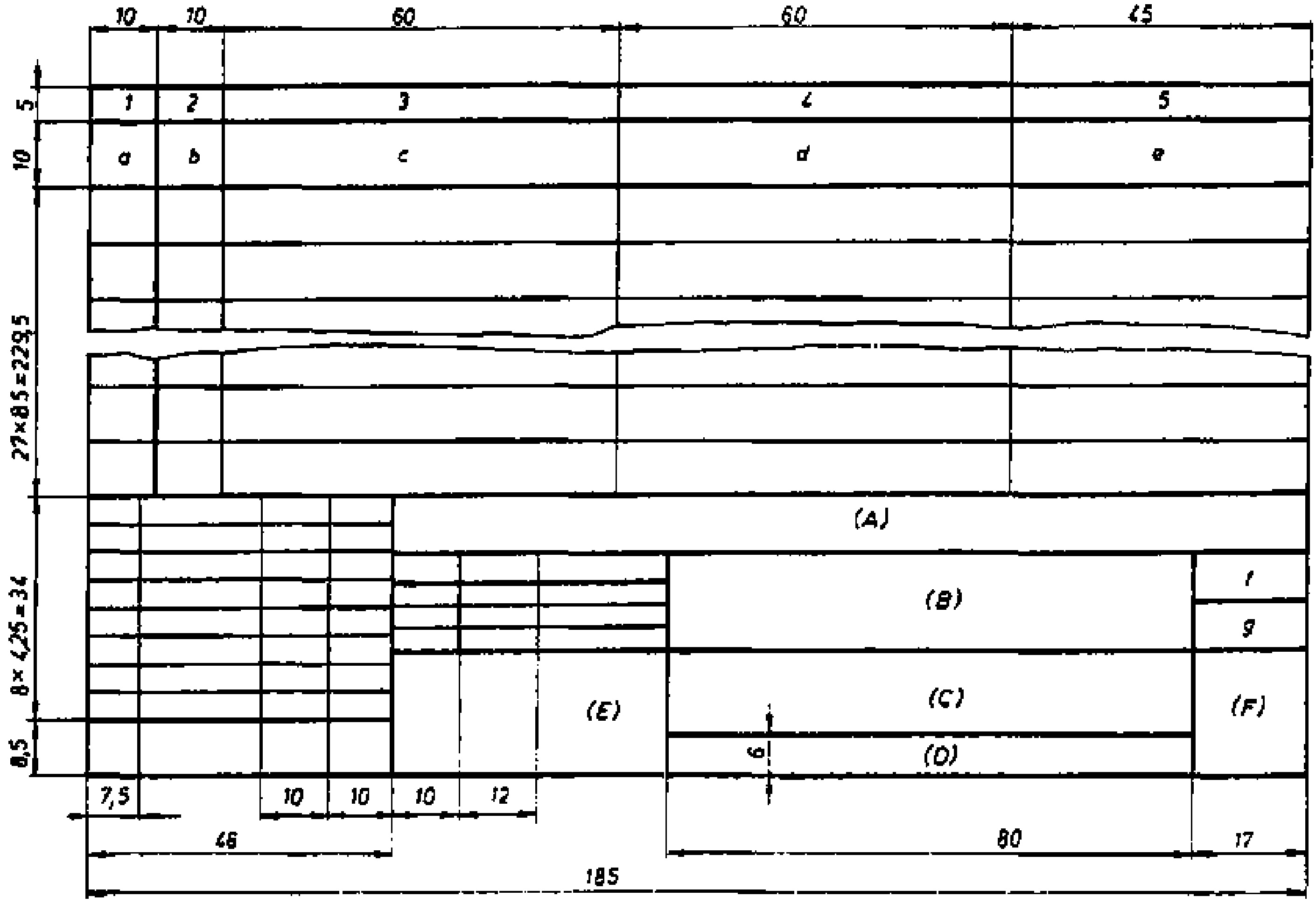


Fig. 9.9. List of parts

a = Item number	(A) = Notes
b = Quantity	(B) = Description, name
c = Description, name	(C) = Number of list of parts
d = Identification No.	(D) = Substitute
e = Remarks	(E) = Enterprise / Institution
f = List consists of ... sheets	(F) = Registration sign
g = Sheet No.	

When reading the data, the following must be taken into consideration: The fields marked by small letters from a to g must be provided with the words indicated in the legend of the above illustration. All fields marked by capital letters from A to F must be filled in accordance with the contents of the drawing and, hence, are always different. All fields not dimensioned correspond to the normal arrangement of the title block. The serial numbers – or item numbers – in column 1 must be in agreement with the data given in the assembly drawing. It is important to know the quantity of the same single part required because for this part, irrespective of the number required, only one serial number or item number is given. The quantity required to be entered in the second column always refers to one mounted unit, one assembly, one machine, etc. The part name or description which must be in keeping with the description in the title block of the detail drawing is to be entered in column 3.

The complete drawing number of the detail drawings is entered in the fourth column headed "identification No." The fifth column "Notes" is intended for further remarks concerning the making available of the parts. In connection with this form of a list of parts, lists with entries concerning the material, semi–finished products, orders and target–dates are required for job planning, depending on the factory organisation. These lists can be glued on the list of parts.

When the assembled unit consists of a large number of single parts, then the above mentioned list of parts must be prepared separately. The top line with the columns number 1 to 5 must be written on top.

The serial numbers of the single parts are entered in the list from top to bottom.

For smaller assemblies, the number of single parts is smaller. The paper required for the rather small list of parts and the separate assembly drawing would be uneconomical and the presence of many documents for a few parts would be troublesome. Therefore, both the assembly drawing and the appertaining list of parts can be drawn on one sheet. This list of parts is arranged directly above the title block. The serial numbers are entered from the bottom to the top.

In this form of a list of parts, the small letters a to e also mean the already printed terms or these terms which have to be entered. The fields marked by the capital letters A to D must be provided with the entries which are in keeping with the drawing and list of parts (see Fig. 9.10.).

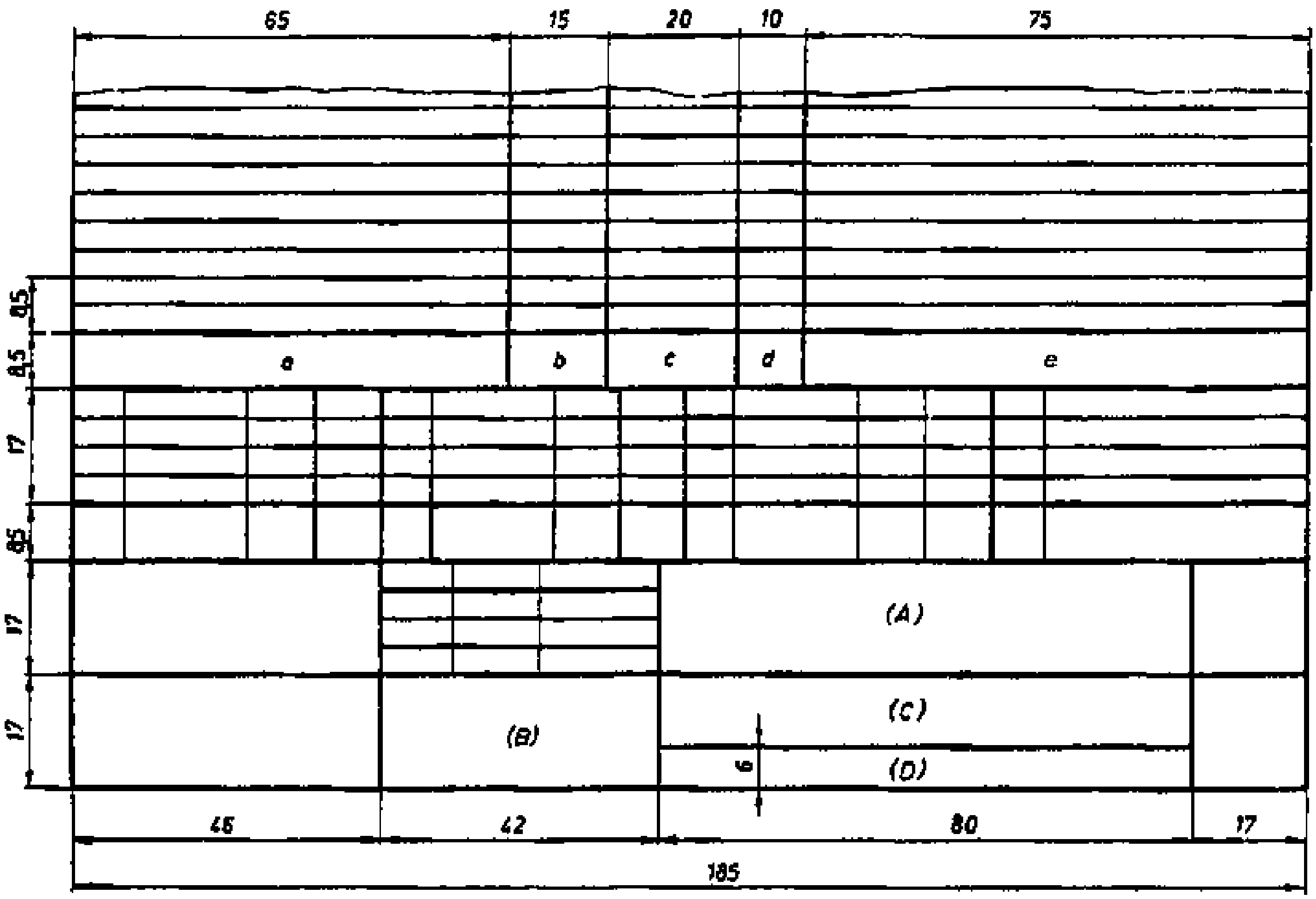


Fig. 9.10. Title block with list of parts

a = Description, name (A) = Description, name

b = Drawing number (B) = Enterprise/Institution

c = Material (C) = Drawing No.

d = Item No. (D) = Substitute

e = Semi–finished product

For instructions and for practising and for drawings other than manufacturing documents, the simplified title block can be used. Here, the list of parts in simplified form is arranged above the title block and the serial numbers – or item numbers – of the single parts are entered starting from bottom. The small letters from a to g again represent terms to be entered, and the capital letters from A to G indicate fields to be filled with data regarding the drawing in question (see Fig. 9.11.).

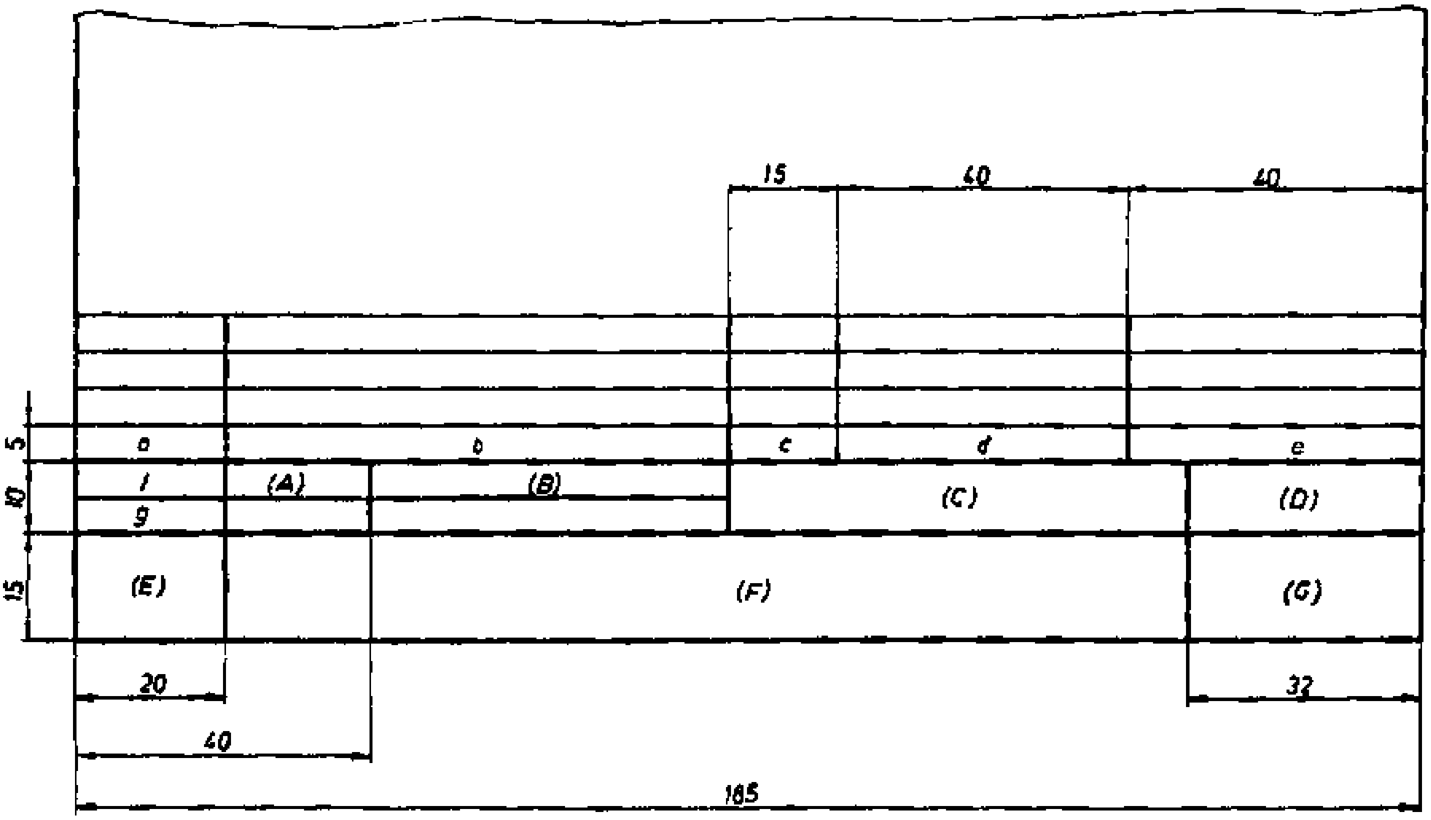


Fig. 9.11. Simplified title block with list of parts

a = Quantity required	(A) = Date
b = Description, Semi–finished products	(B) = Name
c = Item No.	(C) = School / Institution
d = Material	(D) = Form / Course / Field
e = Remarks	(E) = Scale
f = Drawn by	(F) = Description / Name
g = Checked by	(G) = Drawing No.

A list of parts belongs to a complete assembly drawing. The assembly drawing illustrates the different parts while the list of parts gives additional data about the quantity of single parts required, description, number of detail drawings, semi–finished products required, etc.

Repetition

1. Explain why the assembly worker requires a list of parts in addition to the assembly drawing.

2. What information can you derive from an assembly drawing and from a detail drawing?

3. Drawing from your practical experience, give at least five examples where an assembly drawing and the appertaining list of parts are required.

9.3. Examples

The blank of a key shown in Fig. 9.12. is to be made of three parts, namely, handle (1), round bar (2), and key bit (3).

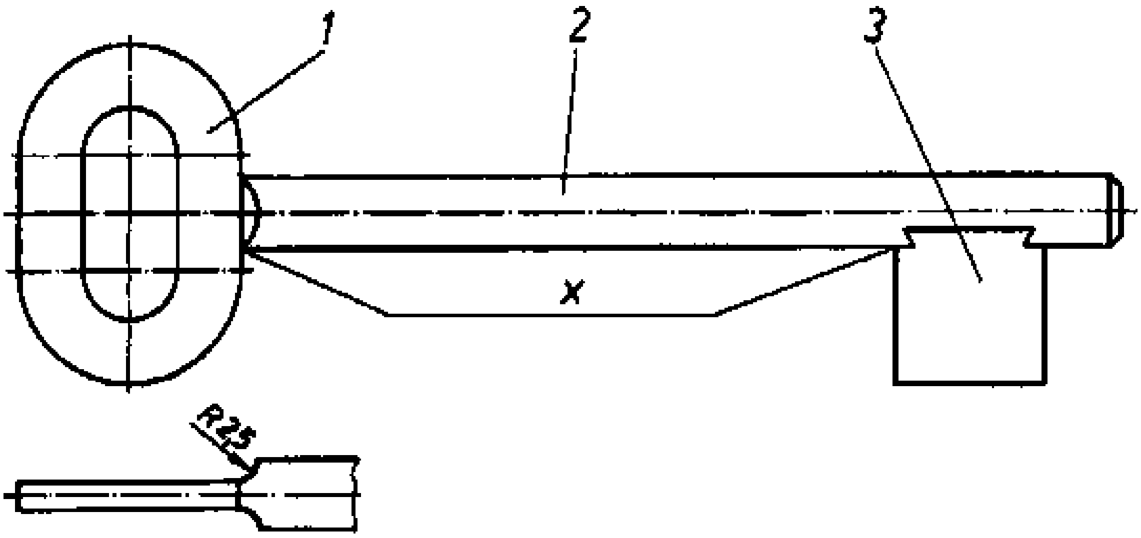


Fig. 9.12. Assembly drawing of a key blank

1 Handle, 2 Round bar, 3 Key bit, x brazed

In the assembly drawing, these three single parts are indicated with the help of leaders and serial numbers applied to the finished component. The handle is fitted into the groove and the key bit into the dovetail groove in the round bar and brazed. Since this is an operation to be done during assembling, the kind of connection must be indicated by adding the word "to be brazed". Between handle and round bar, the soldered seam is to be finished with a radius of 2.5 mm. This radius can only be filed after assembling and brazing. Therefore, it is necessary that for this operation the required dimension is given in the assembly drawing.

For these three single parts, detail drawings are required. It is to be assumed that these parts are made in other departments of the factory and by various expert workers. Then they are transferred to the assembly shop where they are fitted together. During manufacture, a detail drawing, which is sufficiently dimensioned and provided with the required information, must be available in any of the workshops involved. Fig. 9.13. shows the drawings of the three single parts of the blank of the key.

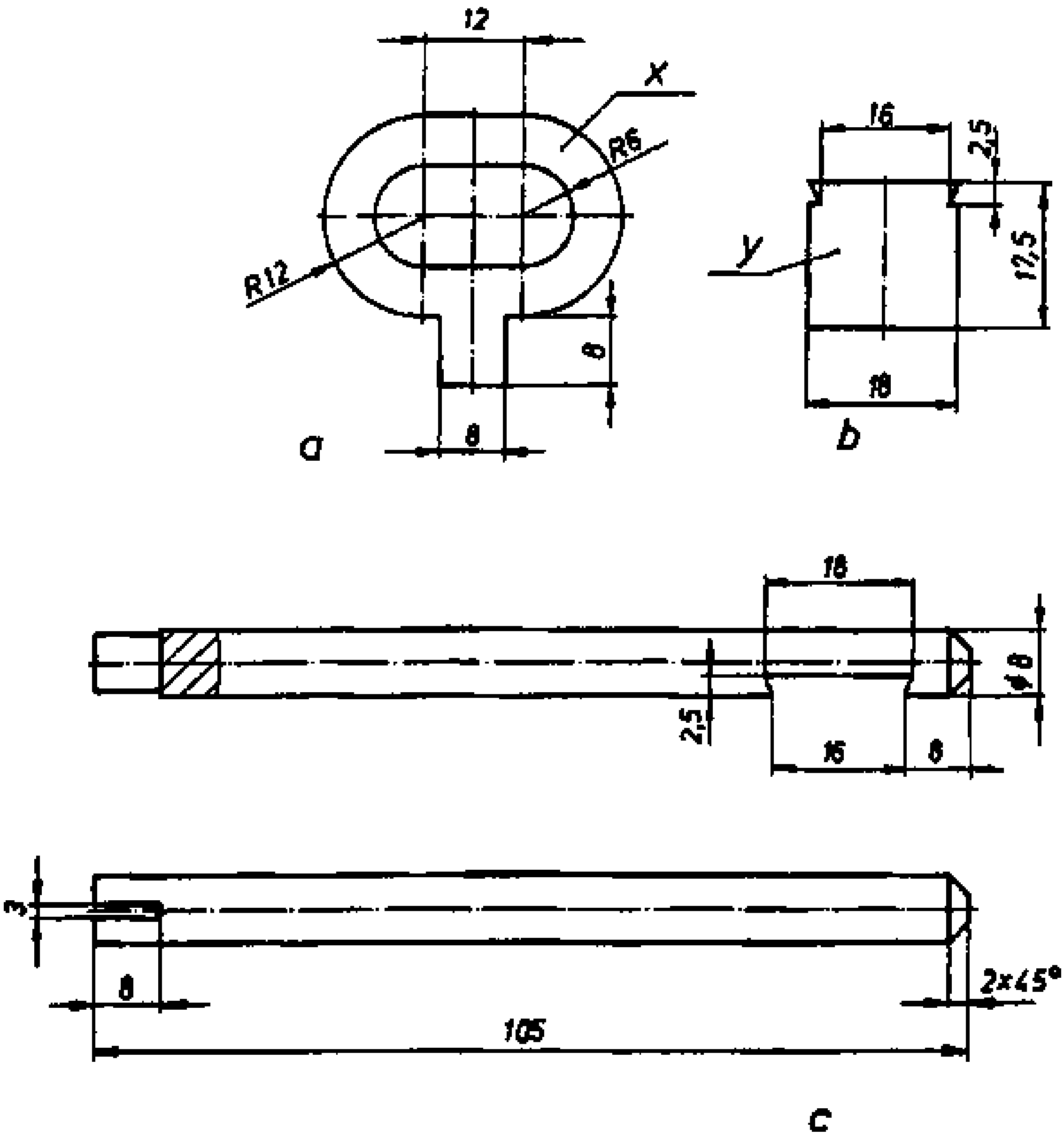


Fig. 9.13. Detail drawings for the blank of a key

a = handle
b = key bit
c = round stock
x = 3 thick
y = 8 thick

For material specification, determination of the dimensions of material and blank, reference to the detail drawings and for other organisational measures of job planning, a list of parts is required for the assembly drawing (see Fig. 9.14.).

1	h ▭ 20x20x8	3	St 38	
1	g ø8x110	2	St 38	
1	f ▭ 40x35x 3	1	St 38	
a	b	c	d	e
	i			

Fig. 9.14. Simplified list of parts for blank of key

a = Quantity required
b = Description, name
c = Item No.
d = Material
e = Remarks
f = Handle
g = Round stock
h = Key bit
i = Blank of key

<u>Repetition</u>

1. Explain the manufacture according to the rules of good workmanship of the three single parts (Fig. 9.14.) including the required tools and measuring instruments.

Grinding wheels serve for the machining of workpieces. They are mounted on the spindles of grinding−wheel spindle heads or of flat grinding or cylindrical grinding machines.

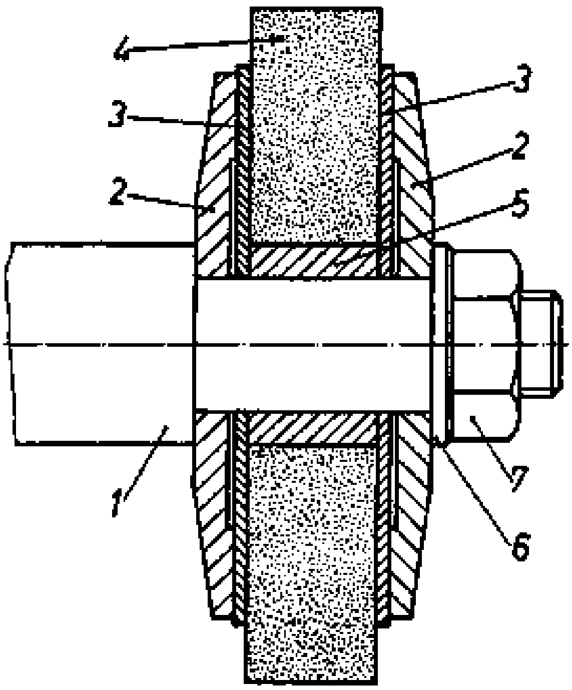


Fig. 9.15. Assembly drawing of a grinding−wheel mount

1 Spindle
2 Flanges

3 Rubber disks
4 Grinding wheel
5 Bushing
6 Washer
7 Hexagon nut

A grinding−wheel mount of this type is shown in Fig. 9.15. in the form of an assembly drawing. The spindle, part 1, carries the grinding wheel, part 4. Since grinding wheels usually are very hard and brittle and grinding is carried out at high rotary speeds, the grinding wheels must be mounted in a special way for reasons of labour safety. For this purpose, the two flanges (part 2) are used which are placed on the right and left of the grinding wheel and retain it in place. In order that the contact pressure does not destroy the wheel, two soft cardboard or rubber disks (part 3) are fitted between flange and wheel. The mounting hole of the grinding wheel is larger than the spindle diameter. In order to ensure that the grinding wheel fits tightly, nevertheless, a bushing is inserted in the hole of the wheel which has a diameter that is adapted to the spindle. This bushing has item number 5. After mounting the grinding wheel with the flanges, the cardboard disks and the bush, the assembly is properly fastened by means of the washer (part 6) and the hexagon nut (part 7). In order that the nut cannot work loose during grinding but is automatically tightened, it is provided with a left−hand thread.

Repetition

1. Explain the different hachures in Fig. 9.15.

2. Prepare a list of parts for Fig. 9.15.

3. Prepare sketches of the single parts of the grinding−wheel mount.

10. Intersections and Developments

10.1. Fundamentals

Parts of machines, apparatures, boilers, transport and storage equipment, frequently show shapes whose representation is difficult (see Fig. 10.1.).

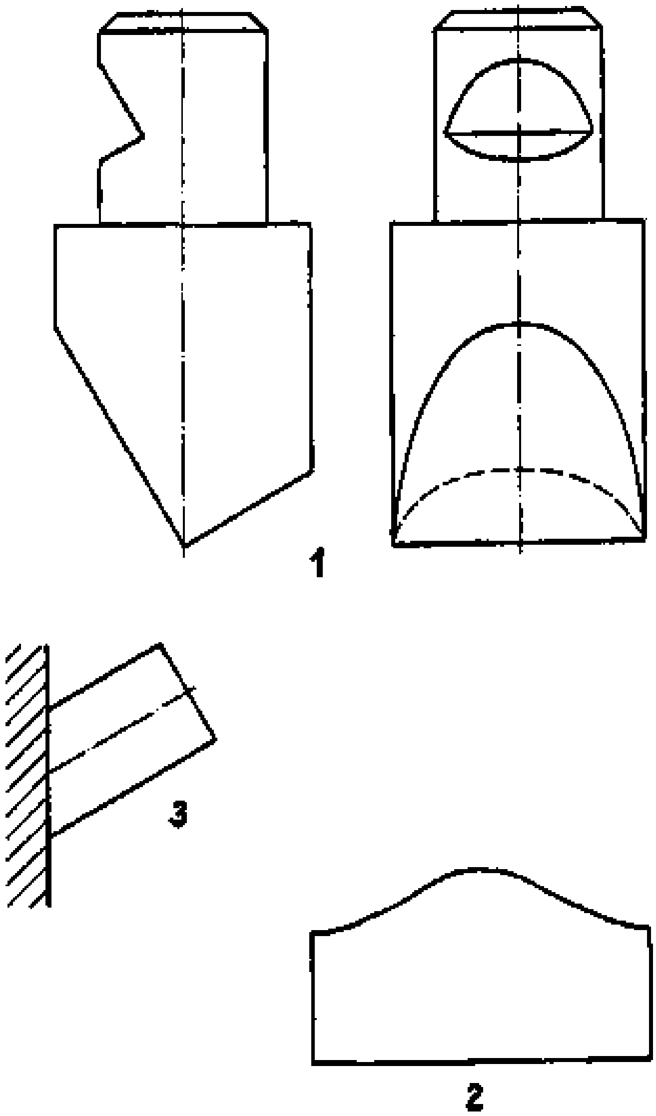


Fig. 10.1.

1 Forming punch
2 Blank
3 Pipe socket

For the drawing of these shapes, special methods of projection drawing are available which facilitate the solution of such problems of representation. These methods are based on the rules of the rectangular parallel projection which has been dealt with in Chapter 3.

Since, in complicated projections, everything depends on the transfer of individual corners, edges and surfaces from one view to the other (see Figs. 10.2. and 10.3.), these problems of representation will be dealt with at first.

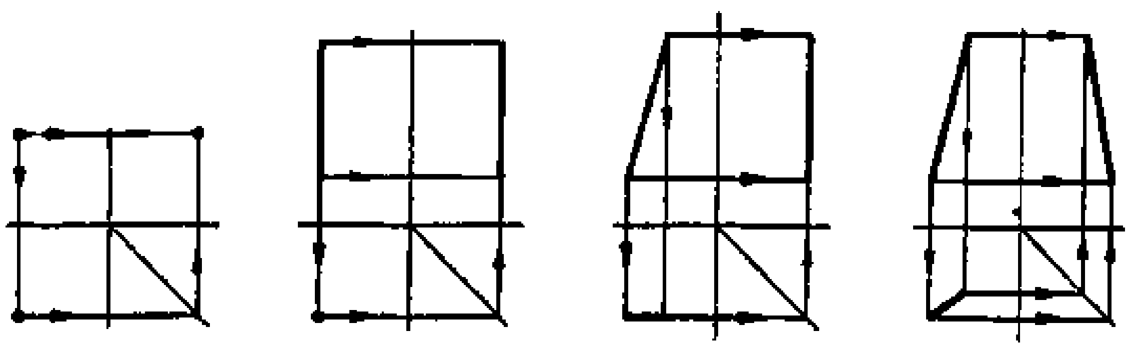


Fig. 10.2. Projection of corner (point) and edge (straight line segment) in three views

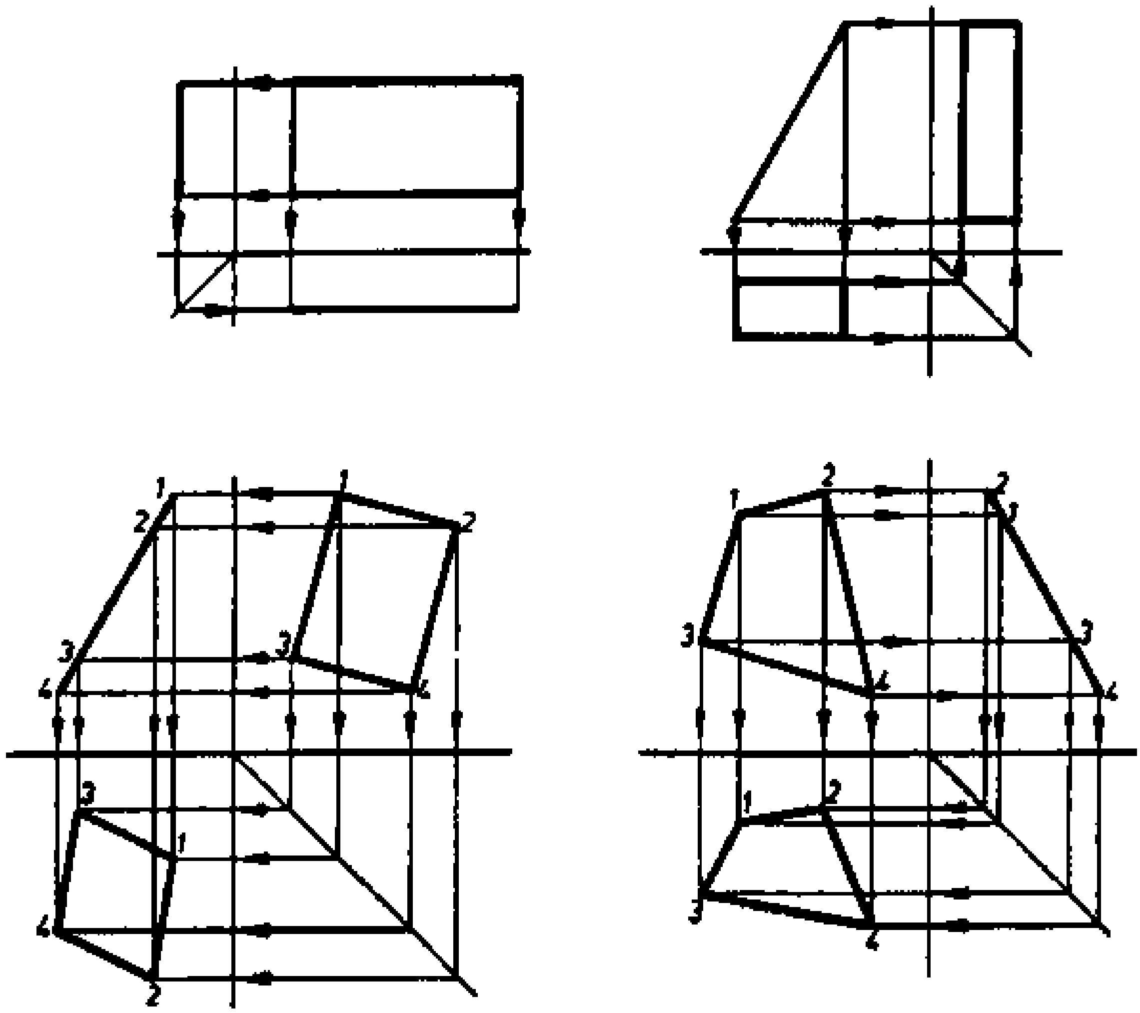


Fig. 10.3. Projection of surfaces in three views

In the Figs. 10.4. and 10.5., the determination of the true size of edges and areas is demonstrated. The principle consists in the fact to turn the edge or surface into a position parallel to drawing plane and then to project it.

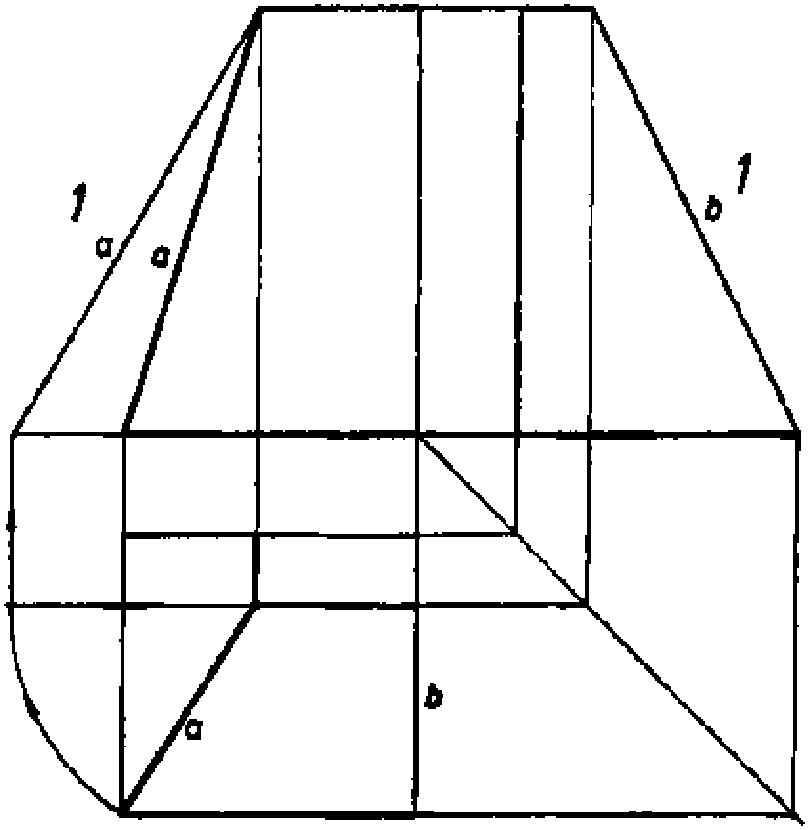


Fig. 10.4. True length of an edge

1 True length

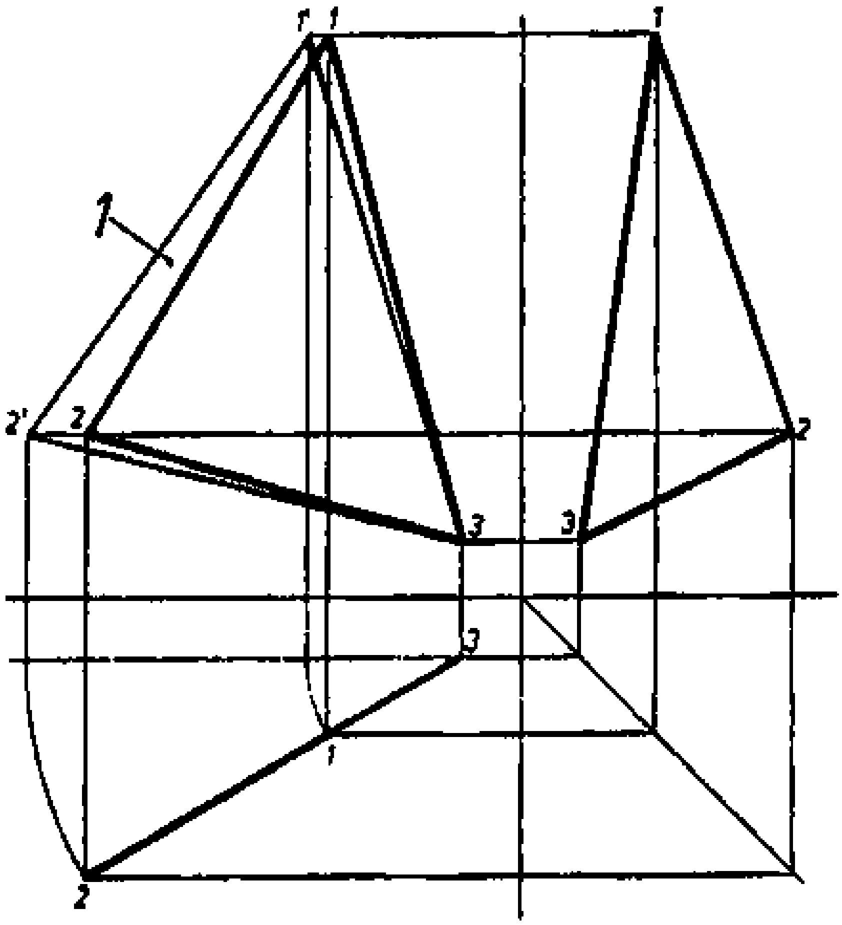


Fig. 10.5. True size of a surface

1 True size

10.2. Intersection

All objects are composed of geometric basic bodies (Figs. 10.6. and 10.8.) or a geometric basic body has been derived from another geometric basic body (Figs. 10.7. and 10.8.). For the hollow shapes, one can imagine the tool or the path of the tool as body.

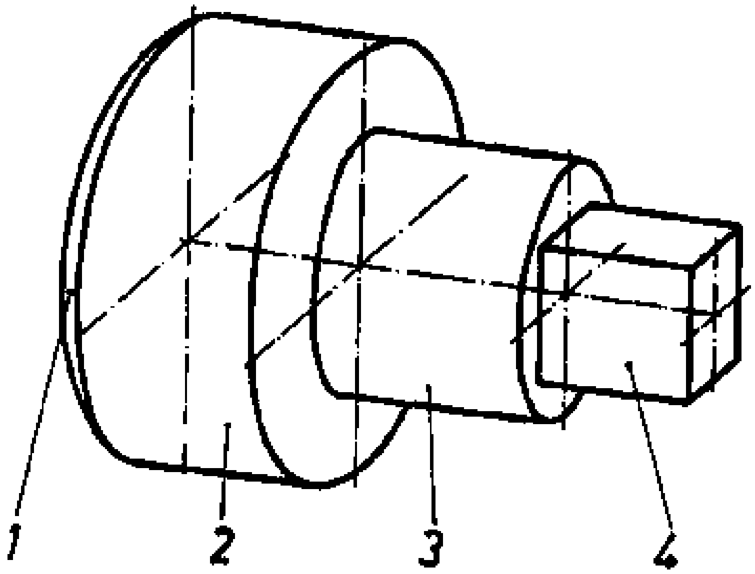


Fig. 10.6.

1 Frustum of a cone
2 Cylinder
3 Cylinder
4 Square prism

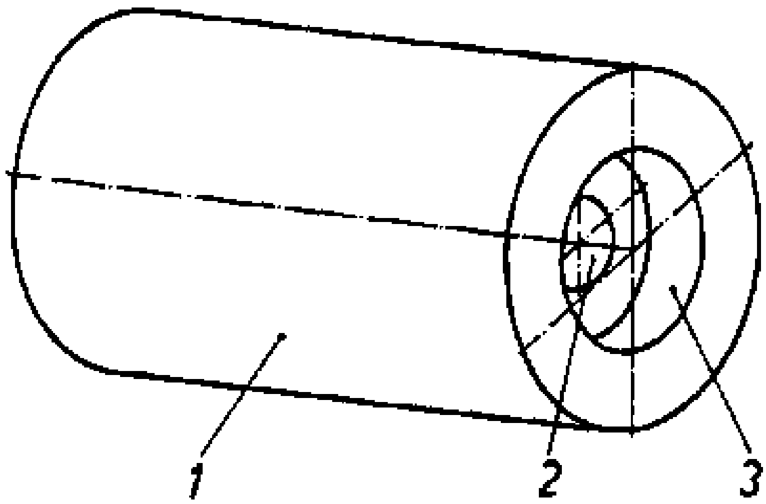


Fig. 10.7.

1 Cylinder
2 Cylinder (hole)
3 Cylinder (counterbore)

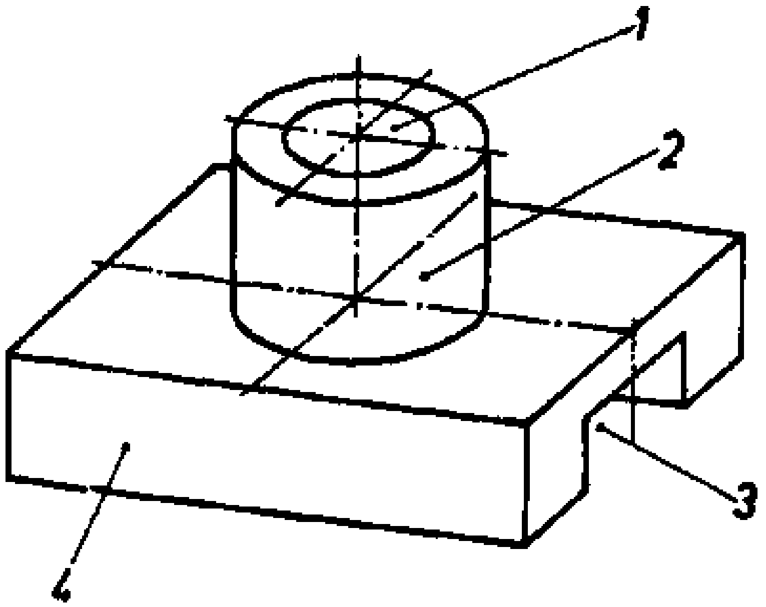


Fig. 10.8. Object of assembled and machined basic bodies

1 Cylinder (hole)
2 Cylinder
3 Square prism (groove)
4 Square prism

The edges produced at the “points of connection” present in many cases no problem to representation, for example, with a common axis of symmetry (Figs. 10.6. and 10.7.) and when a geometric basic body meets a plane surface at right angles (Fig. 10.8.). The red lines are lines of intersection.

Lines of intersection are brought about where the surfaces of intersecting bodies contact each other.

In engineering drawing, one speaks of problems of intersection only when.it becomes necessary to construct the lines of intersection.

This is necessary in the following basic cases which are shown in Fig. 10.9.

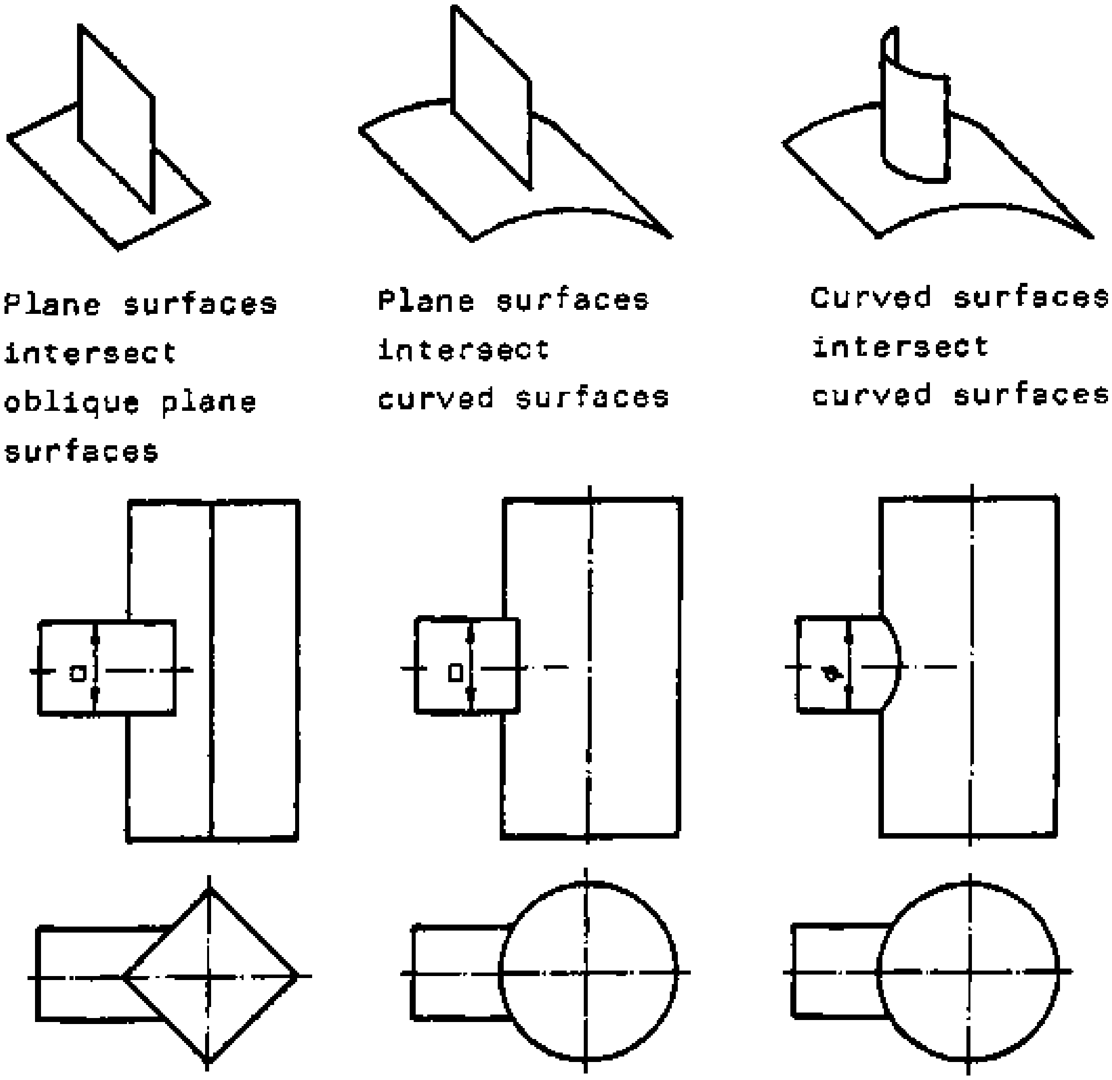


Fig. 10.9.

In all of these three cases, the axis of the intersecting body can be located oblique or staggered with respect to the axis of the intersected body (Fig. 10.10.).

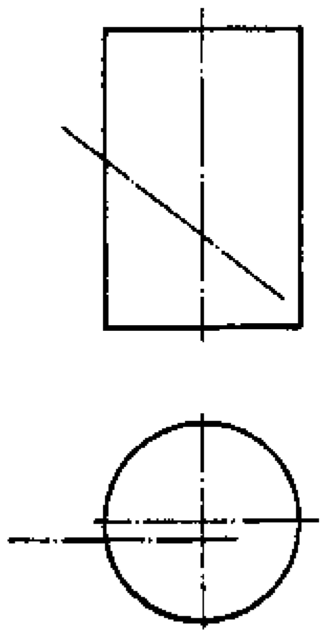


Fig. 10.10. Relative position of the intersecting bodies

An intersection is the arrangement of two bodies where one body partly occupies the room of the other one.

Body sections are intersections of one body by a plane. In practice, this plane is formed by the path of a tool (intersecting body) which is wider than the intersected body (see Fig. 10.11.).

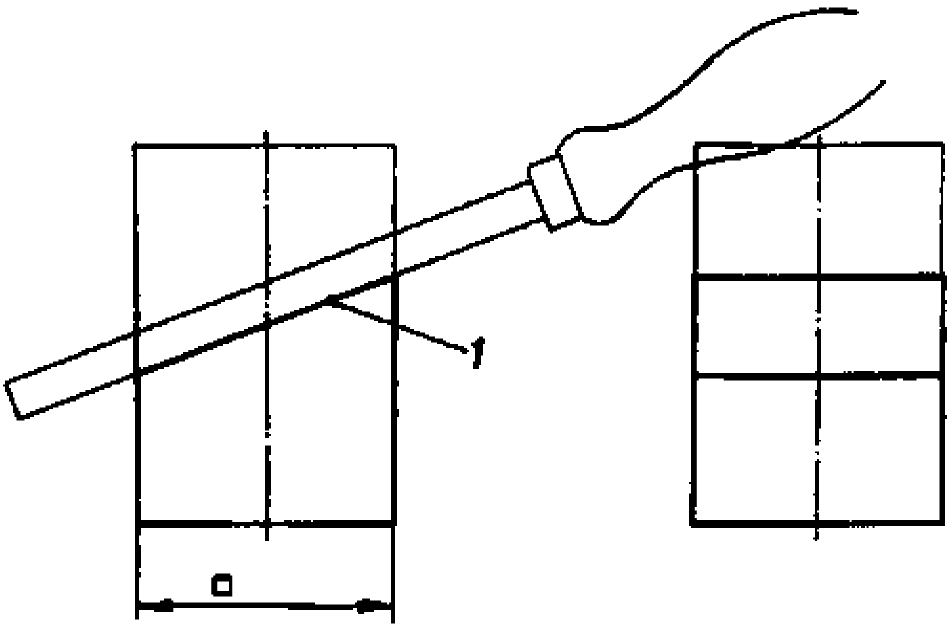


Fig. 10.11.

1 Plane

<u>Repetition</u>

1. At which sites of objects do lines of intersection occur?

2. What is meant by an intersection?

3. Give reasons for the fact that body sections belong to intersections.

4. Quote the three kinds of problems of intersection!

10.2.1. Plane Surfaces Intersect Oblique Plane Surfaces

In most cases, the projection of the point of intersection of the edges into the other view will suffice.

As an auxiliary line, a line is drawn from the corner of the front view at an angle of 45° (Fig. 10.12.).

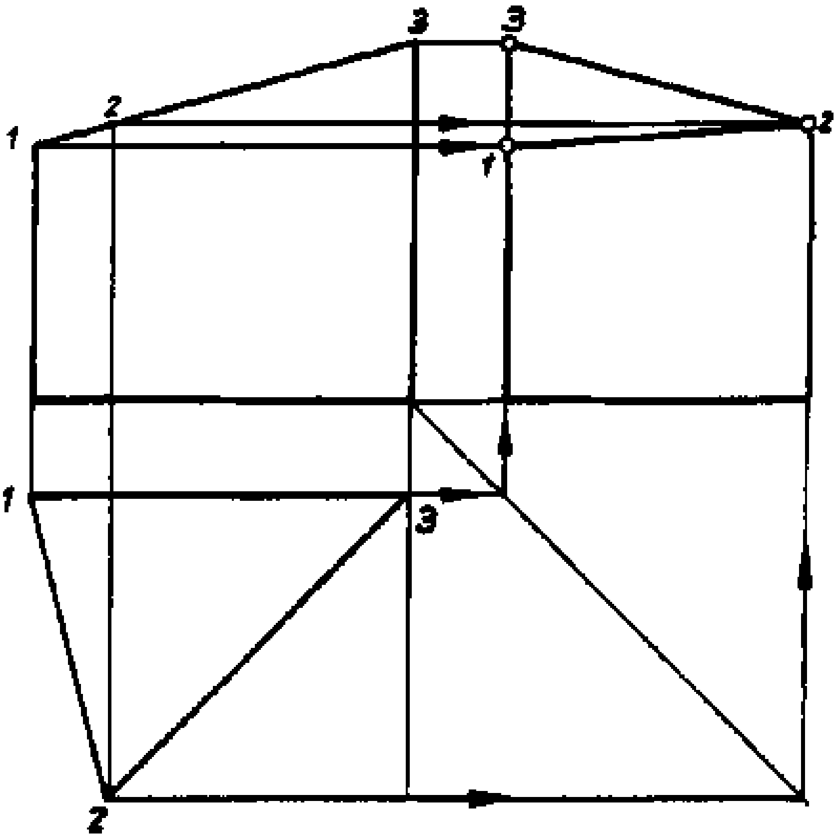


Fig. 10.12. Oblique cut through a triangular prism

It is a condition that the distances between the views are equal. In symmetrical parts, this auxiliary line runs through the point of intersection of the centre lines of the left side view and the top view (see Fig. 10.13.).

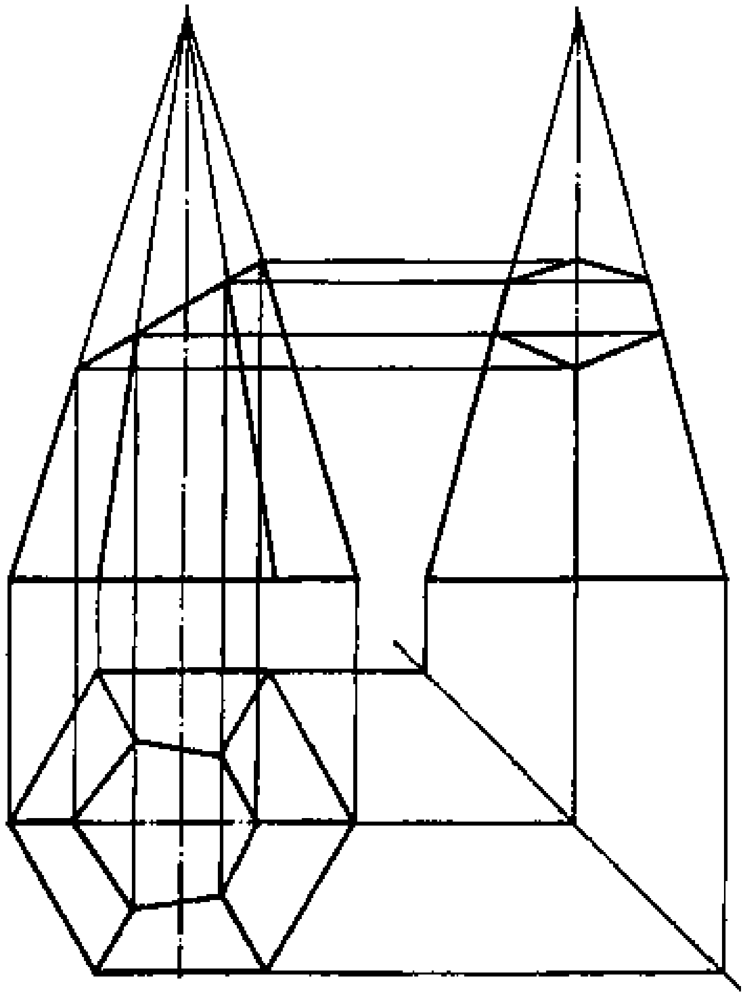


Fig. 10.13. Oblique cut through a hexagonal pyramid

The construction of the lines of intersection in the intersection of two flat bodies is carried out in the same way as in body sections. (See Fig. 10.14.).

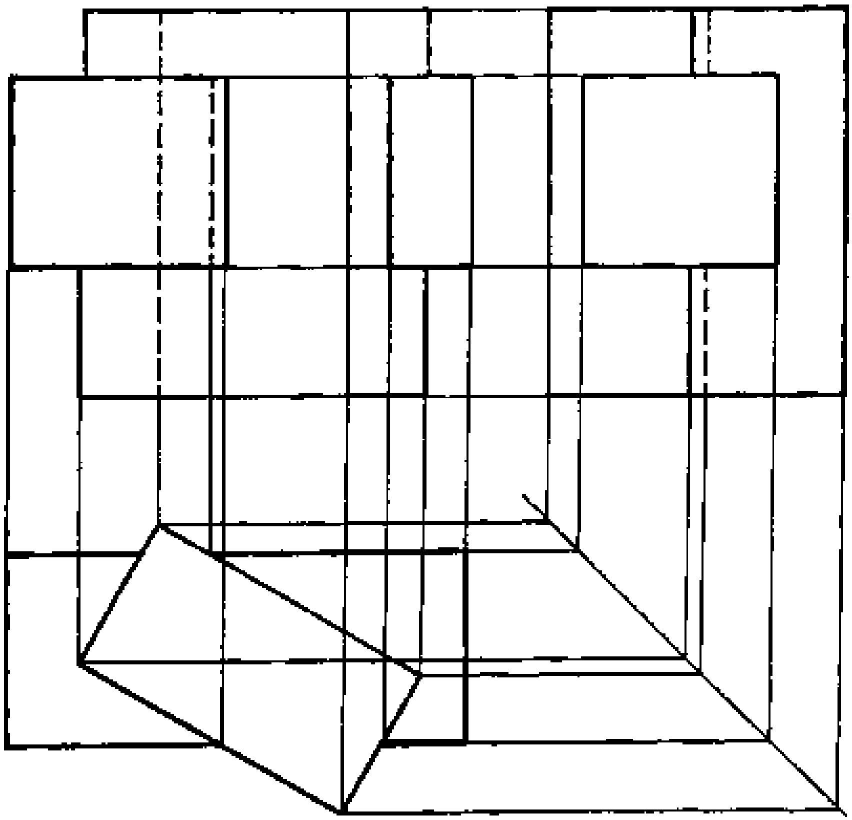


Fig. 10.14. Intersection square prism – rectangular prism (right–angled)

10.2.2. Plane Surfaces Intersect Curved Surfaces

In practice, curved surfaces usually are the areas of the surfaces of cylinders, cones and spheres. Since the circular cross–sections of these bodies (as polygons with an infinite number of corners) do not show any prominent points, auxiliary sections are made.

By means of the method auxiliary sections, curve points can be constructed for intersections.

The more auxiliary sections are made, the more precise the curve will be. On the other hand, a few points will suffice in order to draw the intersection as accurate as necessary. In the manner represented in Fig. 10.15., the same problems have to be solved at quite different objects (Fig. 10.16.).

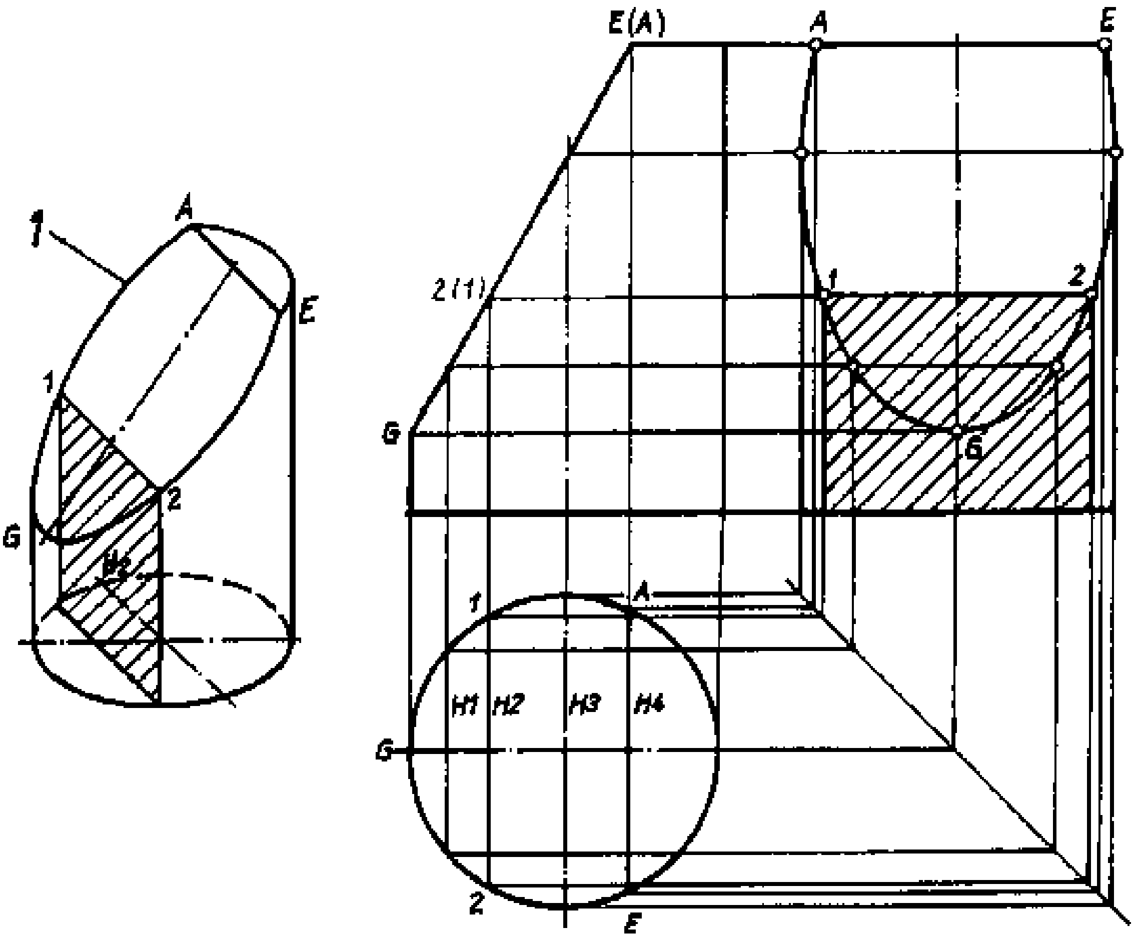


Fig. 10.15. Oblique cut through a cylinder

1 Ellipse, A Starting point of the curve, E End point of the curve, G Apex of the curve, H Auxiliary sections

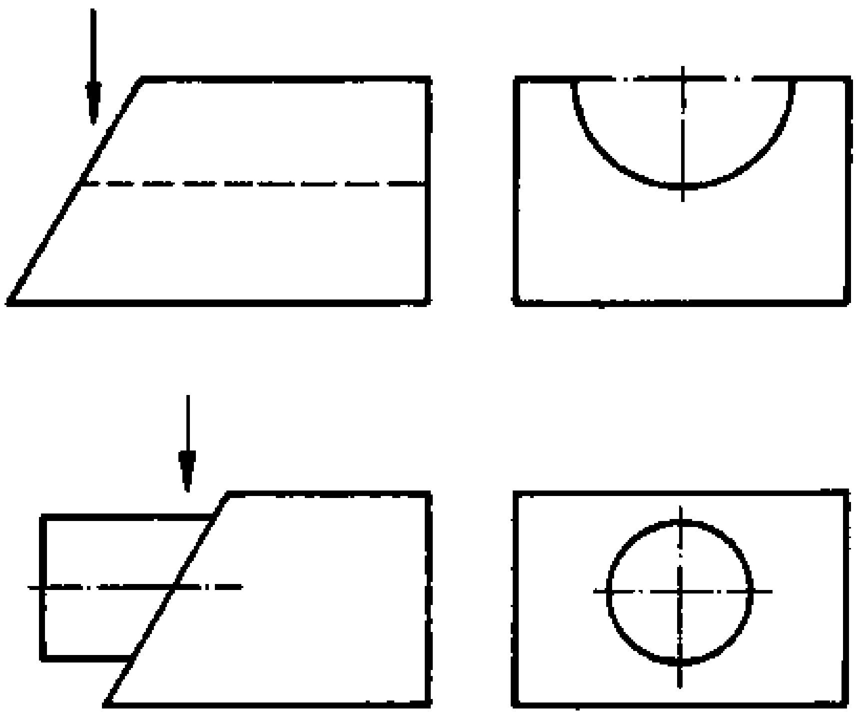


Fig. 10.16.

In body sections through a cone, there are four principal cases which are demonstrated in Fig. 10.17.:

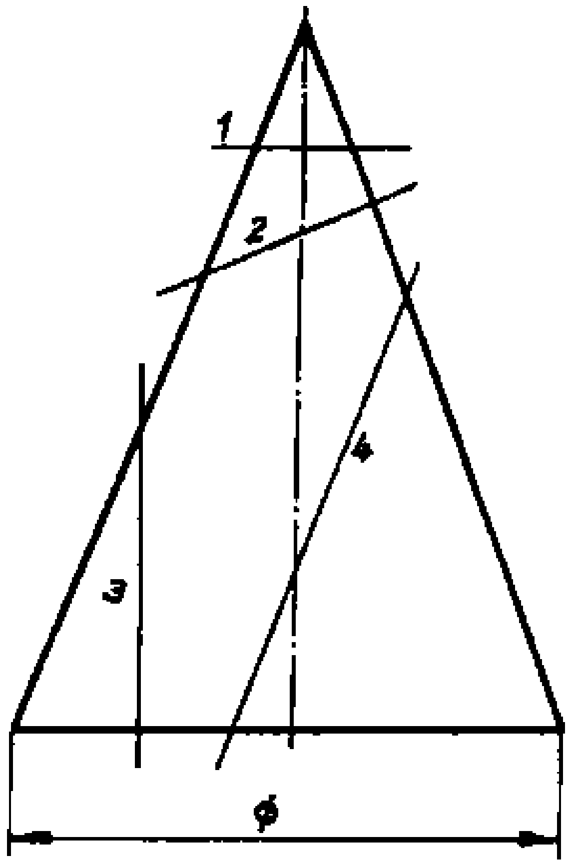


Fig. 10.17.

1 Circle
2 Ellipse
3 Hyperbola
4 Parabola

The plane passes through the cone parallel to the base surface (circle).

The plane passes through the cone in an oblique manner (ellipse).

The plane passes through the cone parallel to the centre axis (hyperbola).

The plane passes through the cone parallel to the element of the cone (parabola).

The first case does not require any special method of solution. The three other cases can be solved by the construction of auxiliary sections. Fig. 10.18. shows the solution of the problem 3 of intersection (hyperbola).

The intersection of a prismatic body by a cylindrical body is shown in Fig. 10.19. A very simple example has been selected which frequently occurs in practice. Since the rectangular cut is symmetrical and parallel to the area of the cylindrical surface, one auxiliary section or the transfer of the points of intersection will suffice.

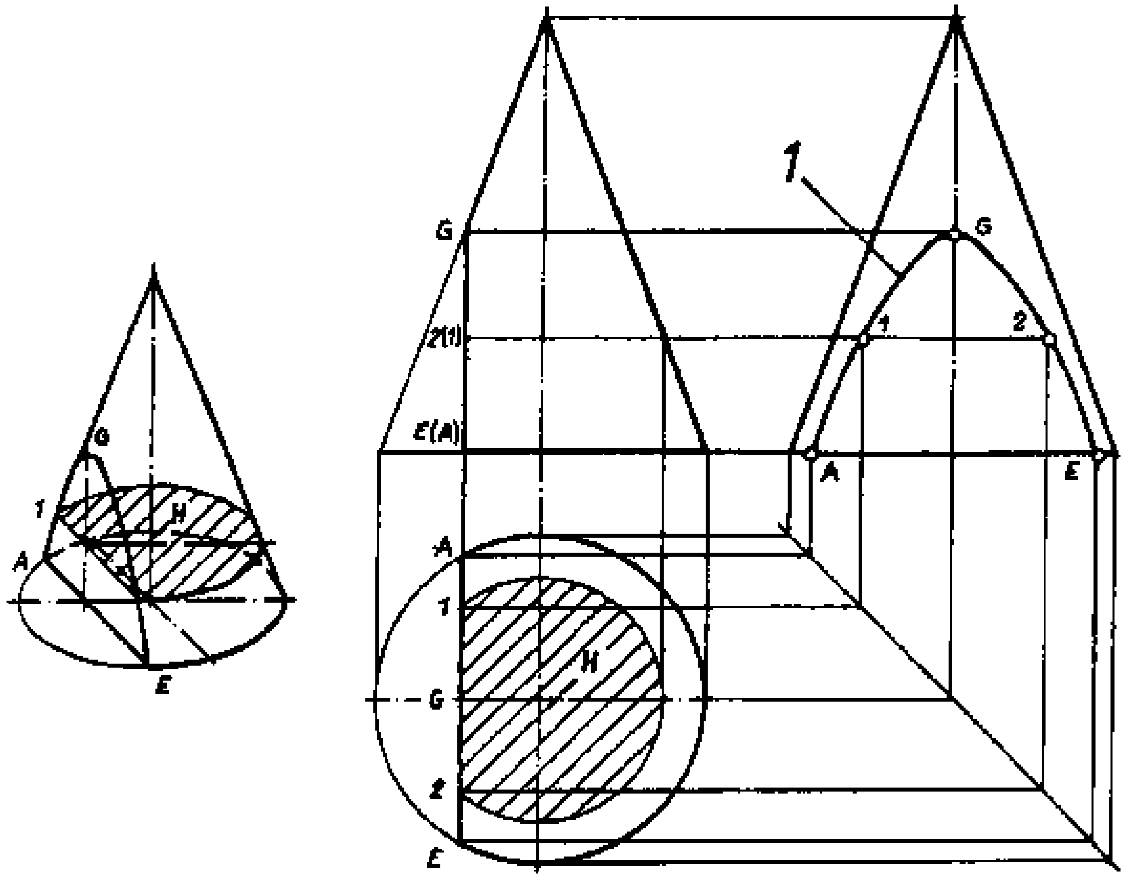


Fig. 10.18. Plane intersects cone parallel to the central axis

H Auxiliary cut, 1 Hyperbola

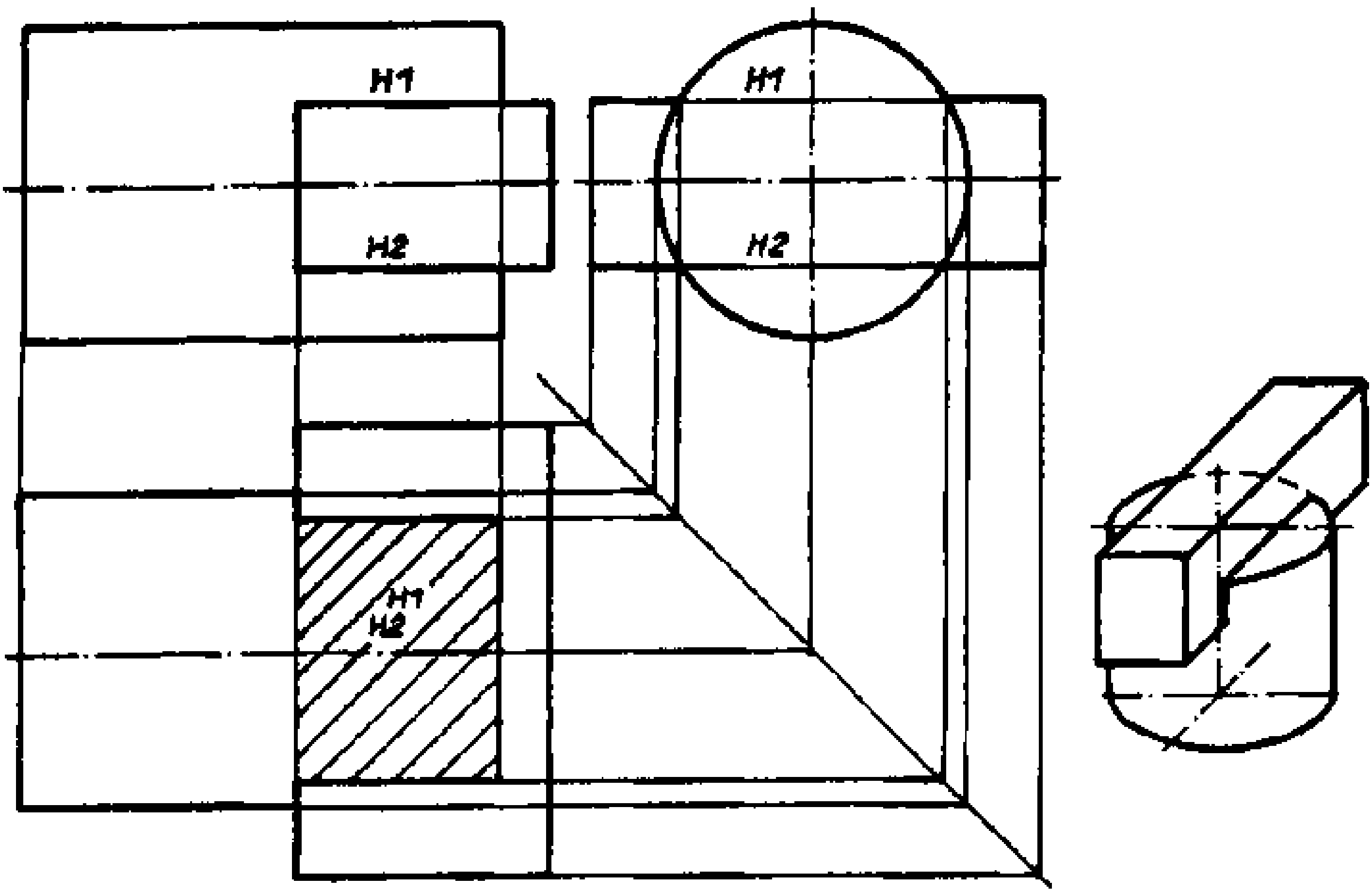


Fig. 10.19. Prismatic body intersects cylindrical body

Repetition

1. Explain the procedure for the determination of the curve points in the intersection of curved surfaces by plane surfaces.

2. Explain the different positions of the intersection planes in cutting a cone and the relative designations of the curves.

10.2.3. Curved Surfaces Intersect Curved Surfaces

These problems on intersection are also solved with the help of the auxiliary section method.

Most frequently, intersections of cylinders occur (Fig. 10.20.). In many cases, the establishment of starting point, end point and apex of the curve will suffice. These three points are connected with the help of a circular template or a French curve. In case of smaller diameters (see Fig. 10.20.), this curve can be neglected.

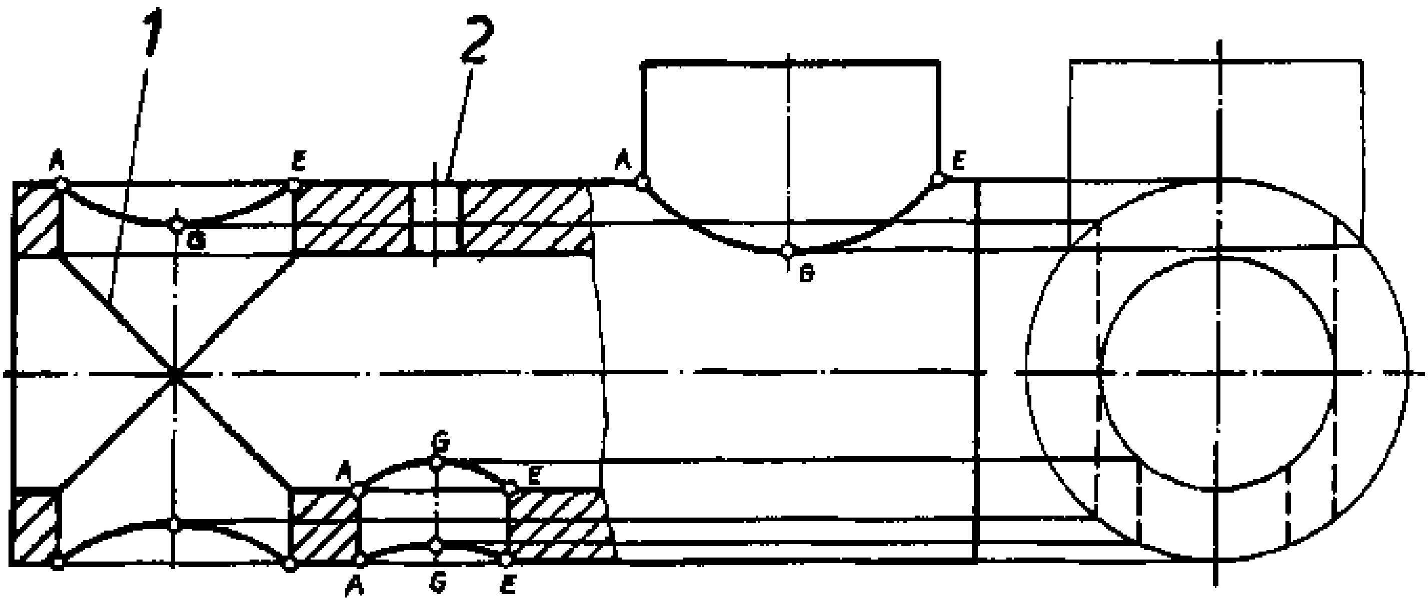


Fig. 10.20. Cylinders intersect cylinders (right–angled)

1 With the same diameters, 2 Curve neglected

When constructing with the help of auxiliary sections, the latter are located within the range between A/E and G in order to get further curve points, as is shown in Fig. 10.21.

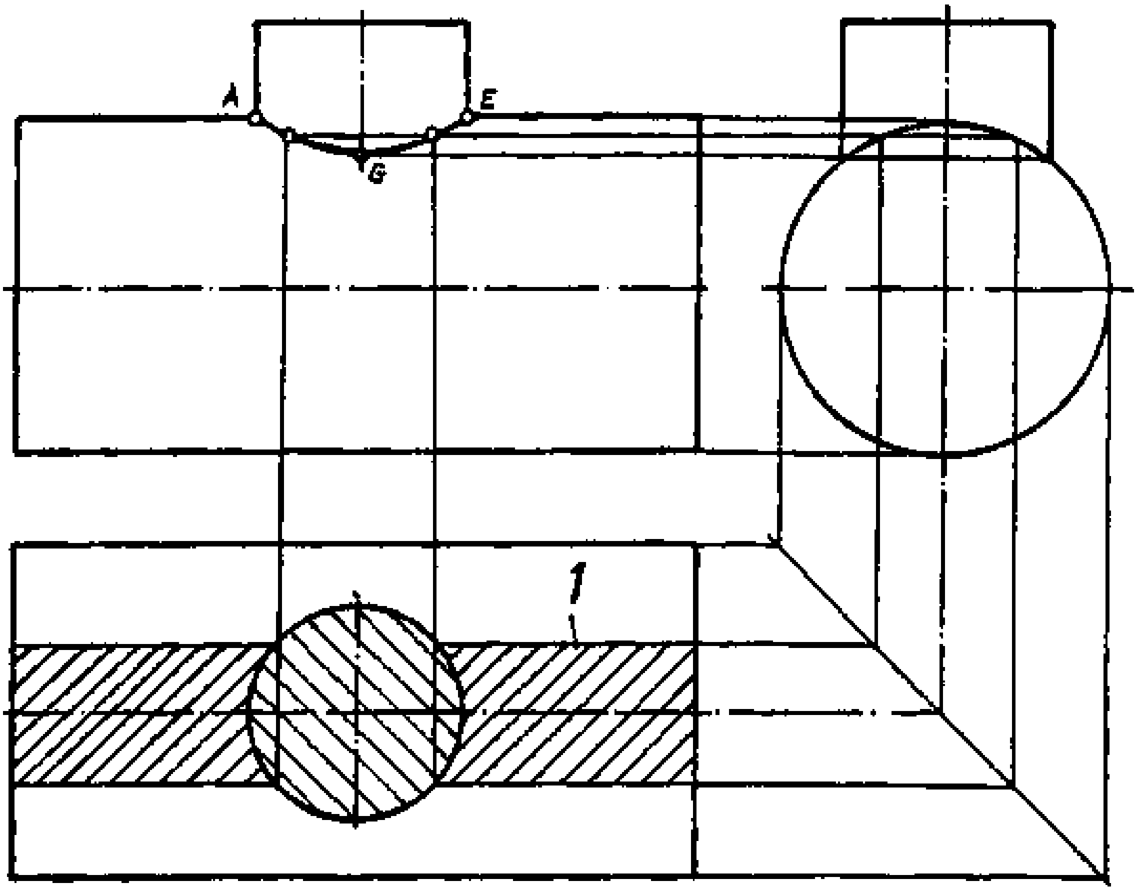


Fig. 10.21. 1 Auxiliary section

A simple method for the determination of the points of lines of intersection is the method of spherical section. It can only be used when the axis of the two intersecting bodies are in one plane. By means of this method, the lines of intersection (see Fig. 10.22.) can be determined in one view.

The centre lines are caused to intersect in M. This is the centre of the auxiliary spherical circles.

From the points of intersection S of the spherical circle with the contours of the two bodies, lines are drawn to the axes at right angles. The points of intersection of these lines (Fig. 10.23.) are the points of the curve of intersection.

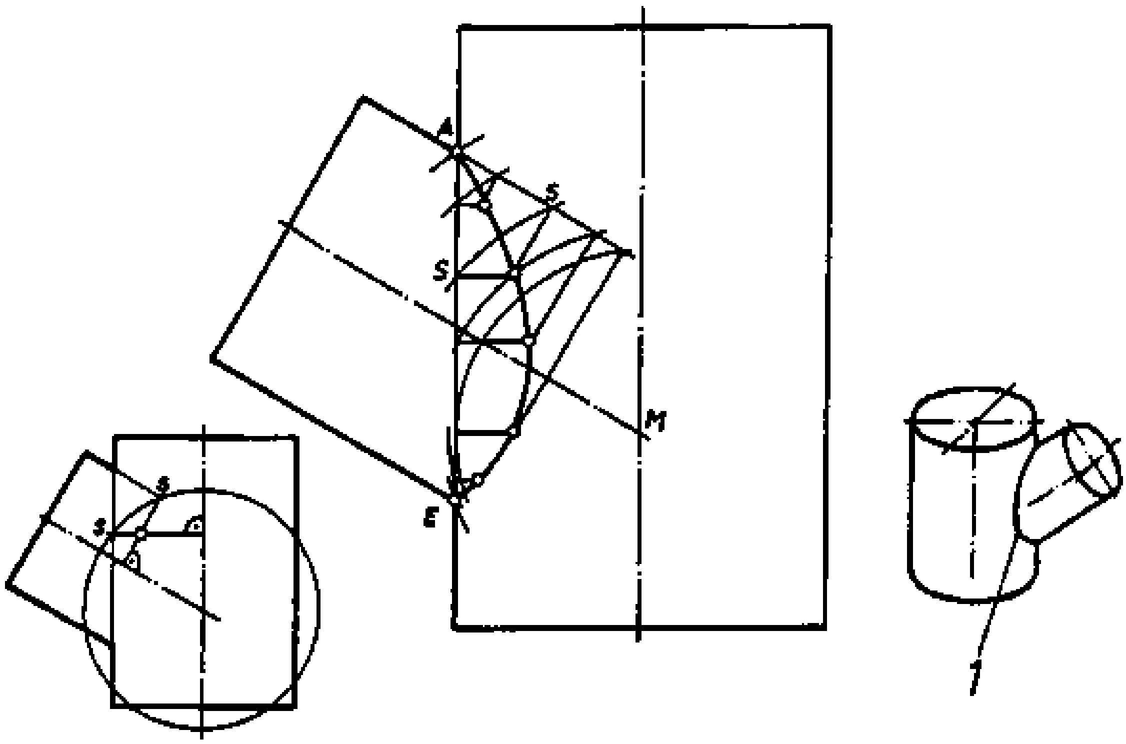


Fig. 10.22. Cylinder intersects cylinder (obliquely)

1 Flanged socket

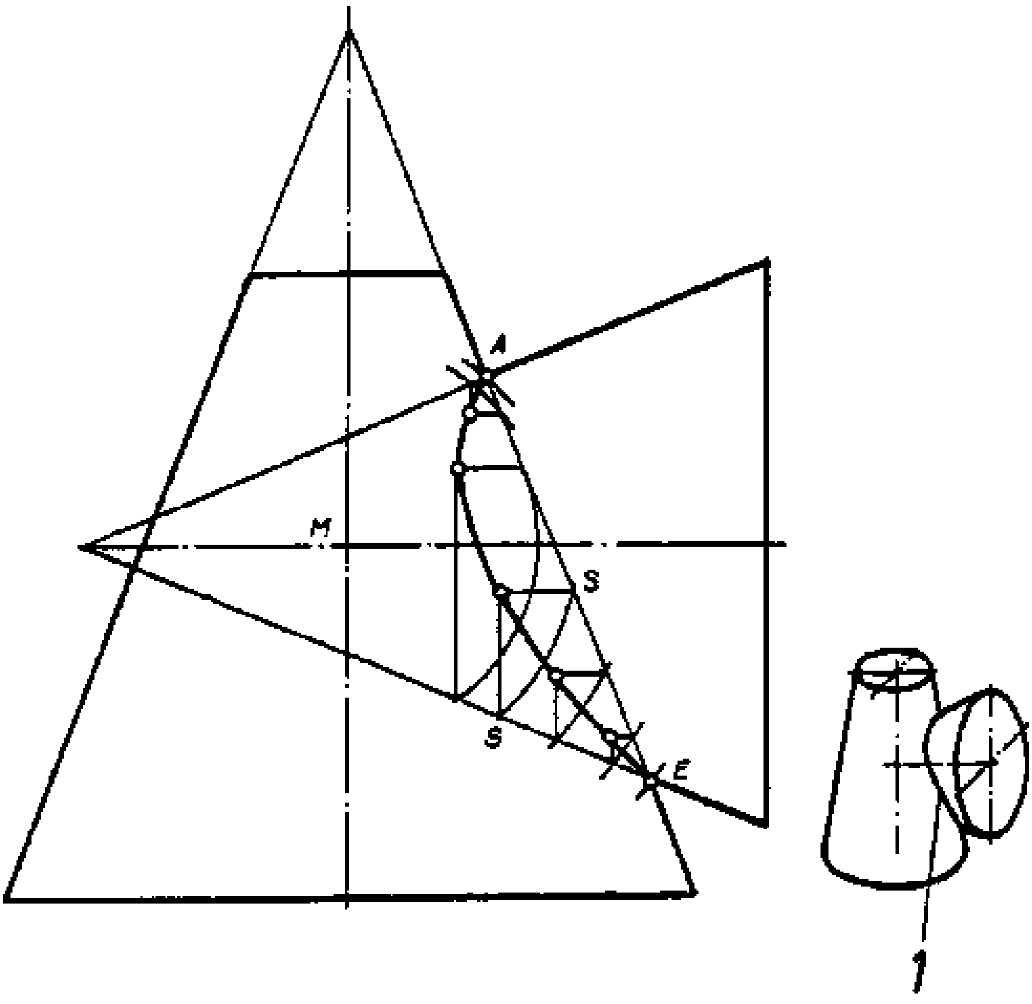


Fig. 10.23. Cone intersects cone (right−angled)

1 Funnel attachment

Repetition

1. Explain the simplified procedure for the determination of a curve of intersection in a case where cylindrical bodies intersect with cylindrical at right angles.

2. Explain the conditions for the application of the spherical section method and its advantages.

10.3. Developments

A development is the representation of the surface of a body. A surface which can be rolled out or unfolded without distortion is said to be developable. Any object composed of single−curved surfaces is developable. In practice, only the outer surface of a body or the wall of a hollow body is represented in this manner. This is necessary, to provide sheet blanks for the production of containers, pipes, panelling and the like. In packaging industry developments are of great importance. When transferring the drawing to sheets or plates and for cutting the latter, the deformation of them during bending must be taken into account. The developments should be separated along a short edge in order that only a short weld is necessary.

10.3.1. Development of Prismatic Objects

The development of prismatic objects is shown in the Figs. 10.24. and 10.25.

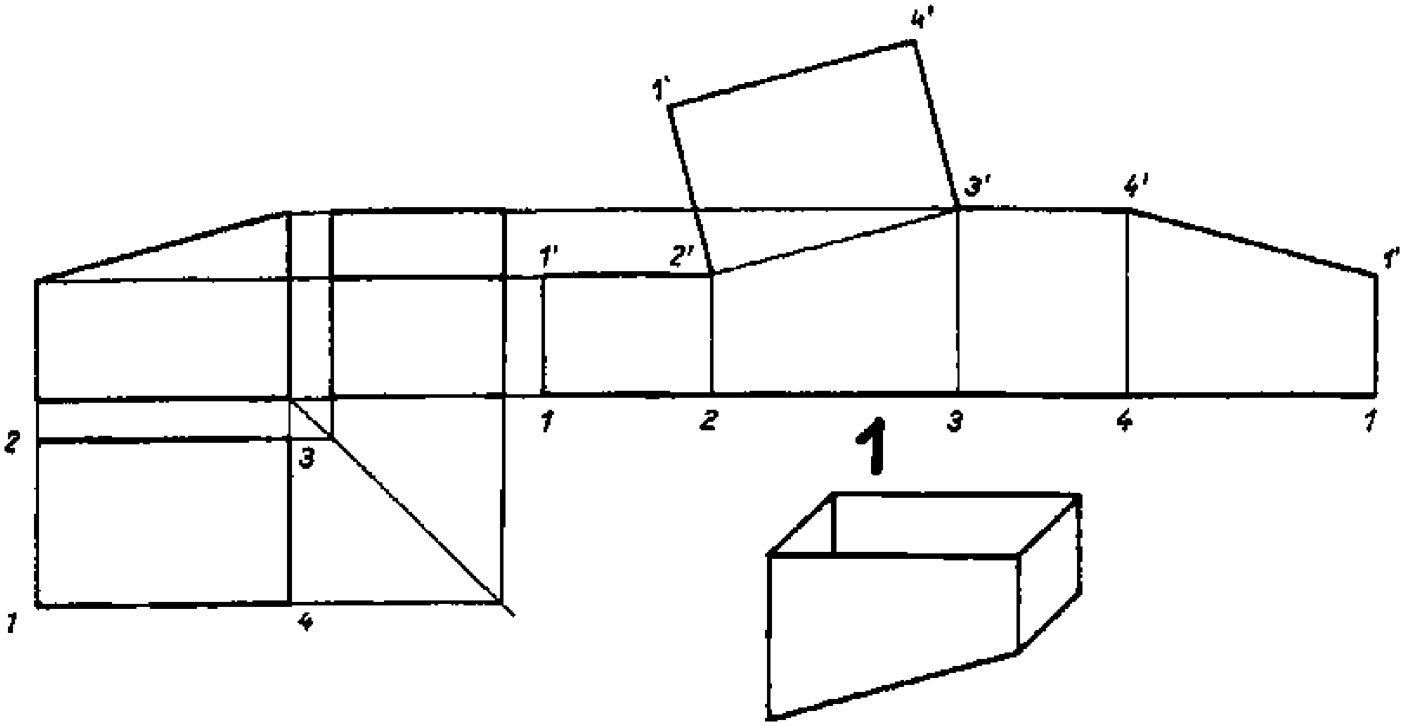


Fig. 10.24. Protective enclosure

1 Development without base surface

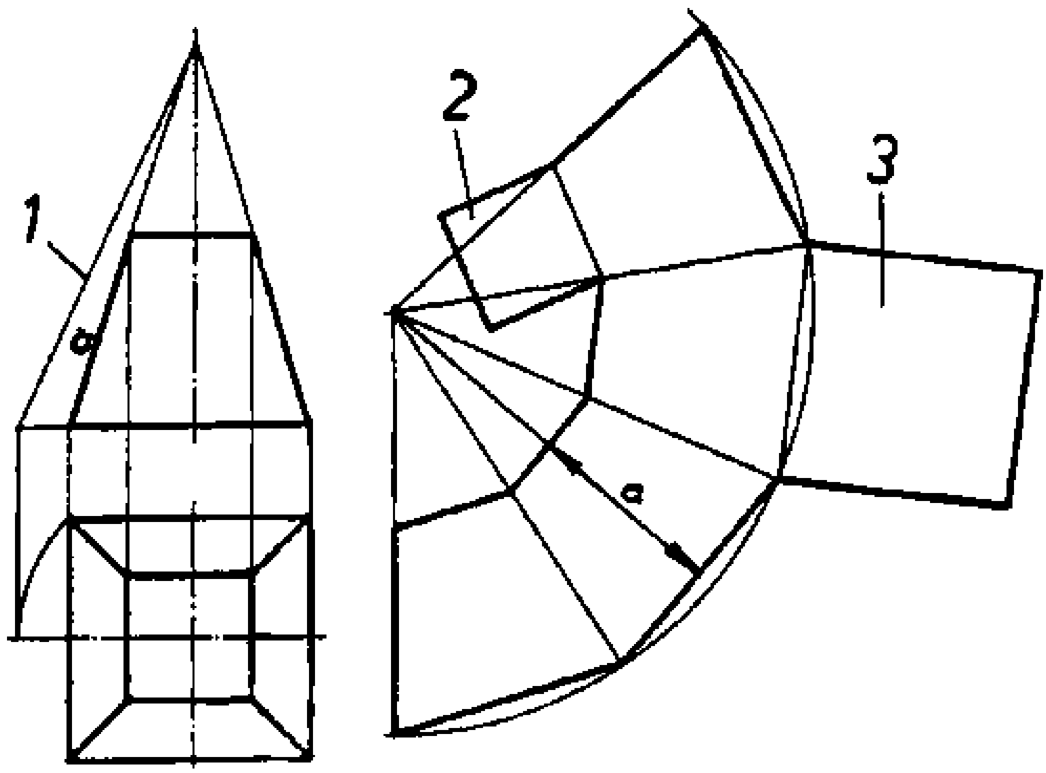


Fig. 10.25. Frustum of a pyramid

1 True length
2 Cover surface
3 Base surface

10.3.2. Development of Cylindrical Objects

For the solution of such problems of development, a certain number of points is determined on the generatrix of the cylindrical object. In these points, the length of the generatrix, which results from the main view, is transferred to the development. This method is known as the generatrix method, and it represents the same procedure as the method of auxiliary section in Section intersections.

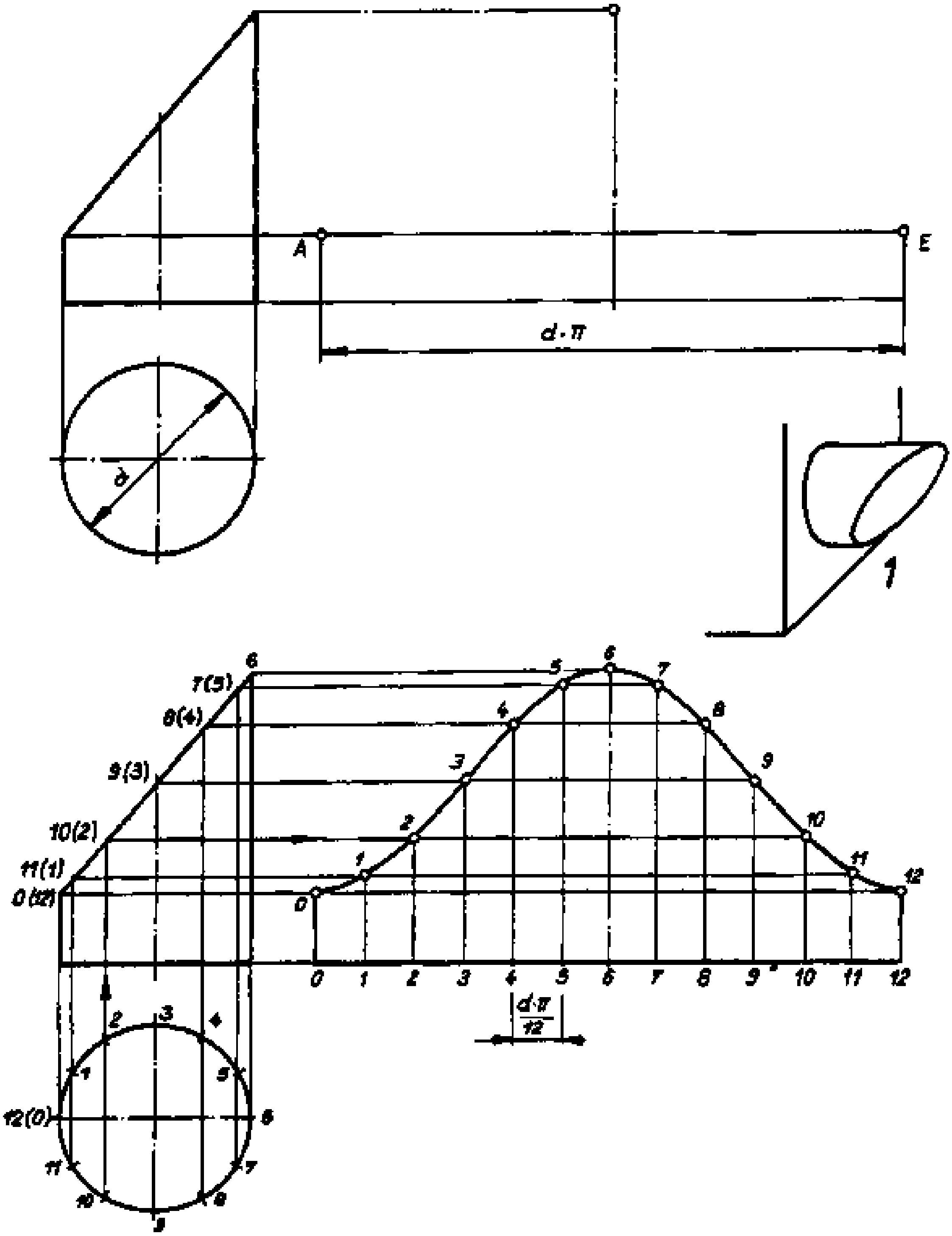


Fig. 10.26. Chamfered cylinder

1 Pipe socket

In the generatrix method, the points of a developed curve of intersection are determined by transferring the lengths of a certain number of generatrices to the development (see Fig. 10.26.).

10.3.3. Development of Conical Objects

For the development of the container having the shape of a frustum of a cone shown in Fig. 10.27., the determination of the angle ? is required. The following idea is at the bottom of the calculation:

Angle ? is to the angle of 360° as the circumference of the base area of the frustum of the cone d . ? is to the total circumference 2s . ?.

? : 360° = (d . ?) : (2s . ?)
? . 2s . ? = 360° . d . ?

With this the construction of the development is started. The further procedure is shown in Fig. 10.27.

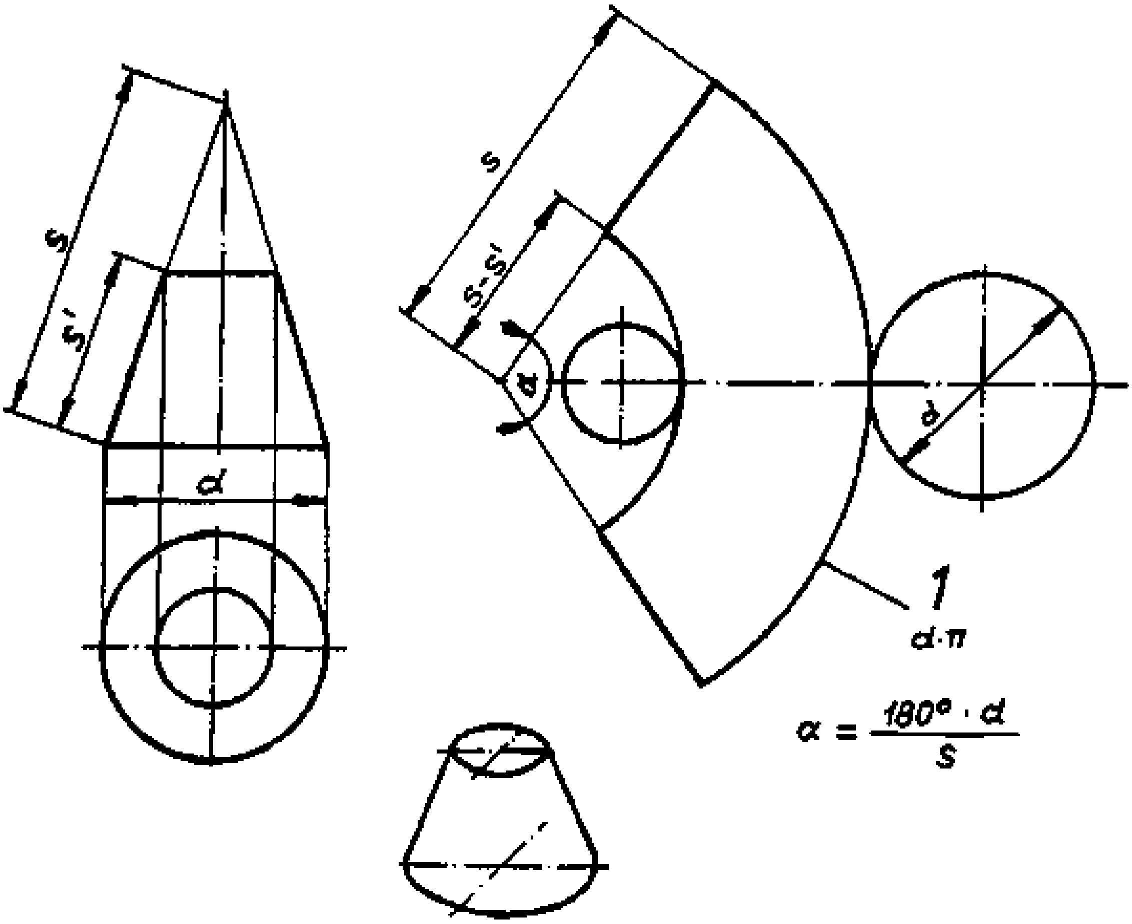


Fig. 10.27. Frustum of a cone

1 Circumference = d . ?

10.3.4. Development of Two Objects Intersecting Each Other

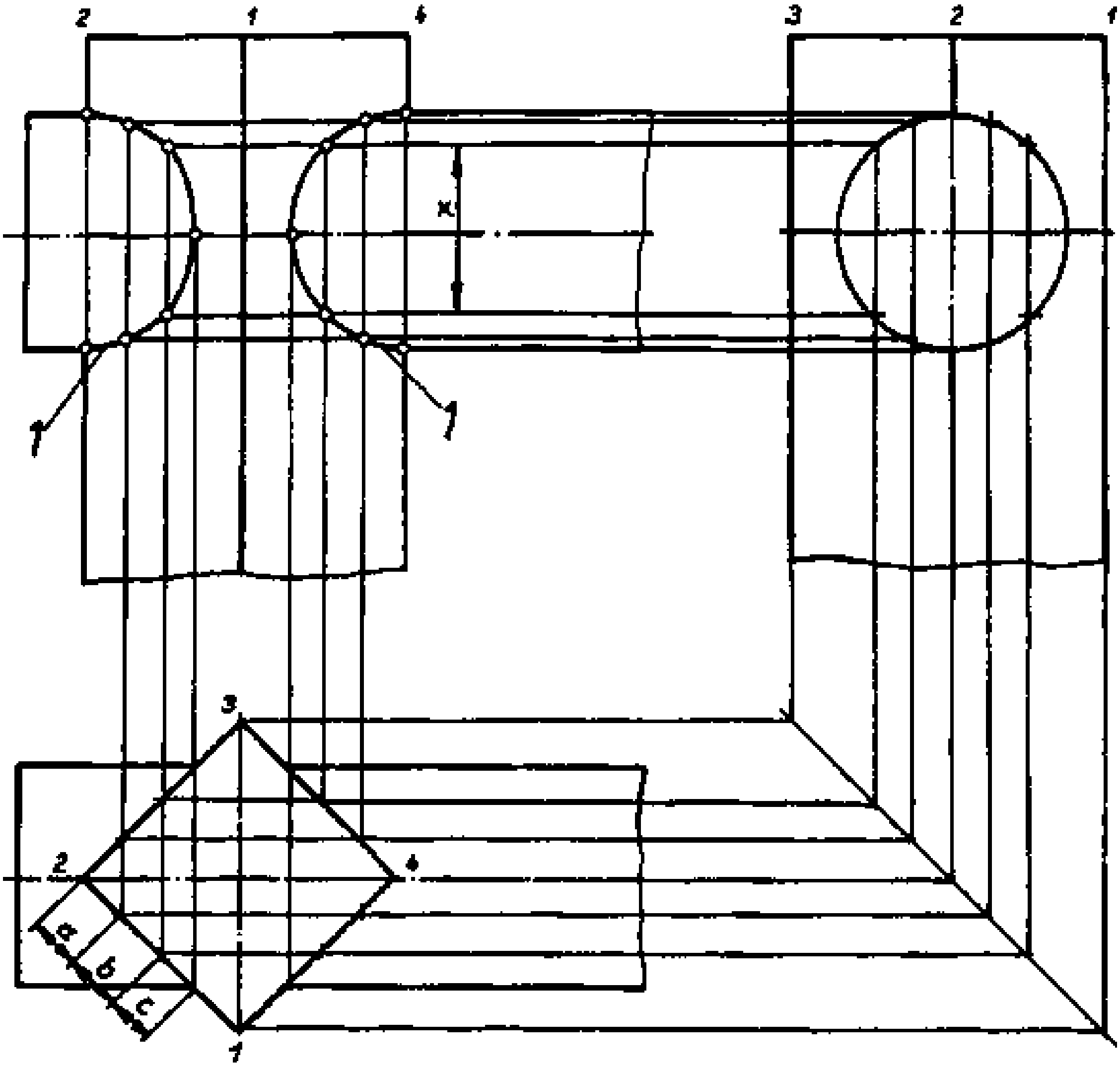


Fig. 10.28. shows the solution of this problem.

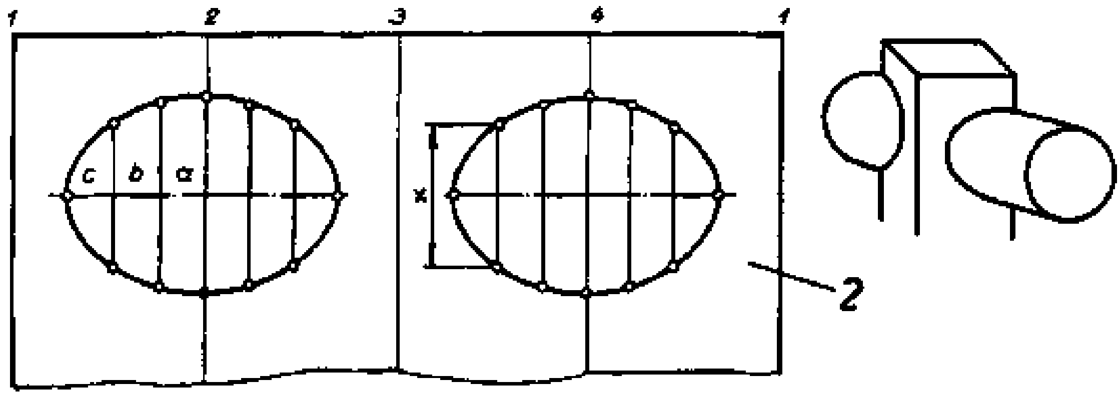


Fig. 10.28. Prism with cylinder

1 Semicircles since section below 45°
2 Development of the square column

Repetition

1. Explain the use of developments in practice.

2. What is the method used for the construction of the development of cylindrical parts? Explain the principle.

3. Consider how to proceed in the construction of the development of a cone with a sloping top. Look at Fig. 10.26. which demonstrates the use of the generatrix method.

11. Gear Elements and Gear Diagrams

In designing and producing machines, the transfer and change of rotary motions are a principal task. For this purpose, shafts, couplings, clutches and gears are used. Gears are used to transfer power and motion from one point to another. They also provide a mean of regulating the amount of power and speed to be transmitted, or of altering the direction of motion. The rotary motion of shafts is enabled by bearings.

11.1. Symbolic Representation of Gear Elements

11.1.1. Shafts

For the representation of shafts, only their contours are drawn. As line of symmetry, the centre line (dash−and−dot line) is drawn.

The shaft ends are called journals. These journals are produced by a reduction of the cross−section (e.g. by turning in a lathe). By the journals, a better mounting of shafts in bearings is ensured.

In order to reduce the time required for drawing, shafts are represented in a simplified manner on drawings. The symbol of shafts in engineering drawings is a thick solid line, as is shown in Fig. 11.1.

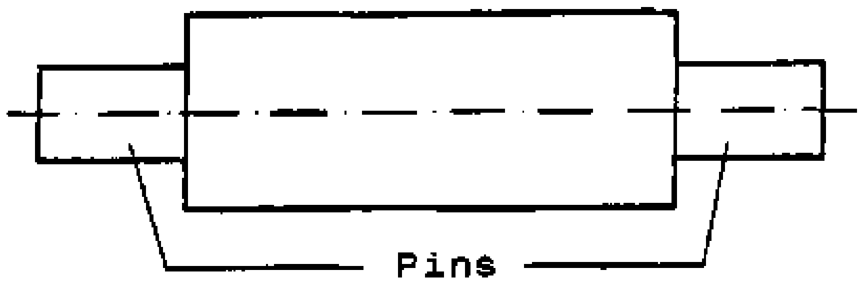


Fig. 11.1. A Engineering drawing

Fig. 11.1. 8 Symbol

A distinction is made between pivot journals and supporting journals. Pivot journals − which comprise faced end journals, neck collar journals or taper journals − are loaded radially (see Fig. 11.2.).

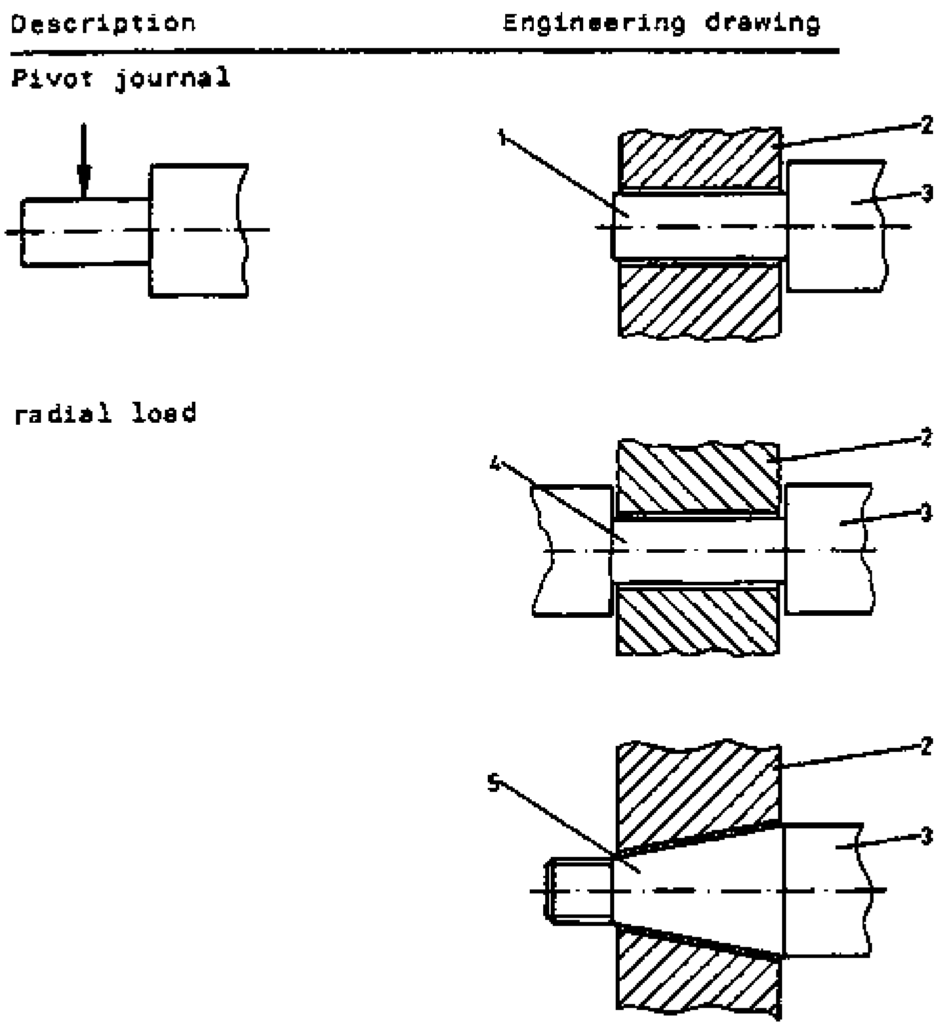


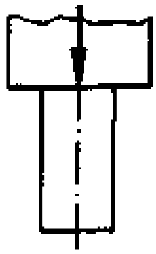
Fig. 11.2. Pivot journal

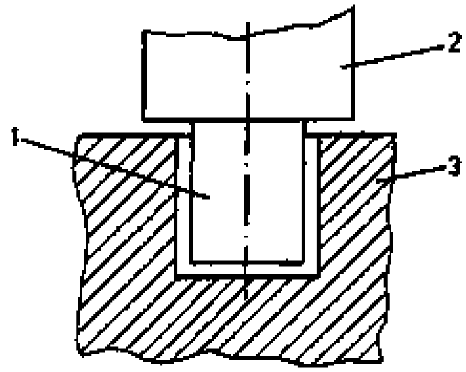
1 End journal, 2 Bearing, 3 Shaft, 4 Neck collar journal 5 Taper journal

The supporting journals are also known as footstep. They are loaded in axial direction. The spherical supporting journal takes force radially and axially because of the spherical shape of the journal (see Fig. 11.3.).

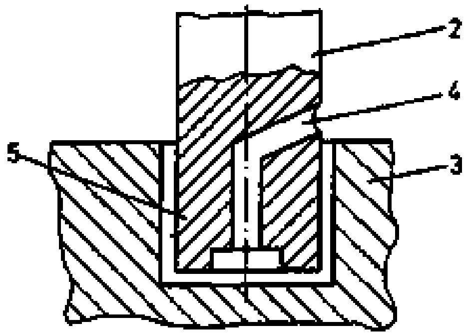
Description | **Engineering drawing**

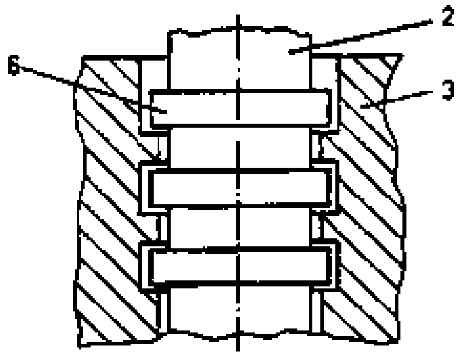
Supporting journal





axial load





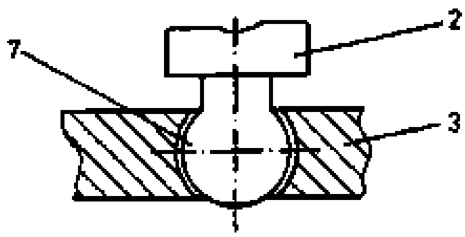


Fig. 11.3. Supporting journal

1 Solid supporting journal, 2 Shaft, 3 Bearing, 4 Oil hole, 5 Ring journal, 6 Thrust journal, 7 Ball journal or spherical journal

11.1.2. Bearings

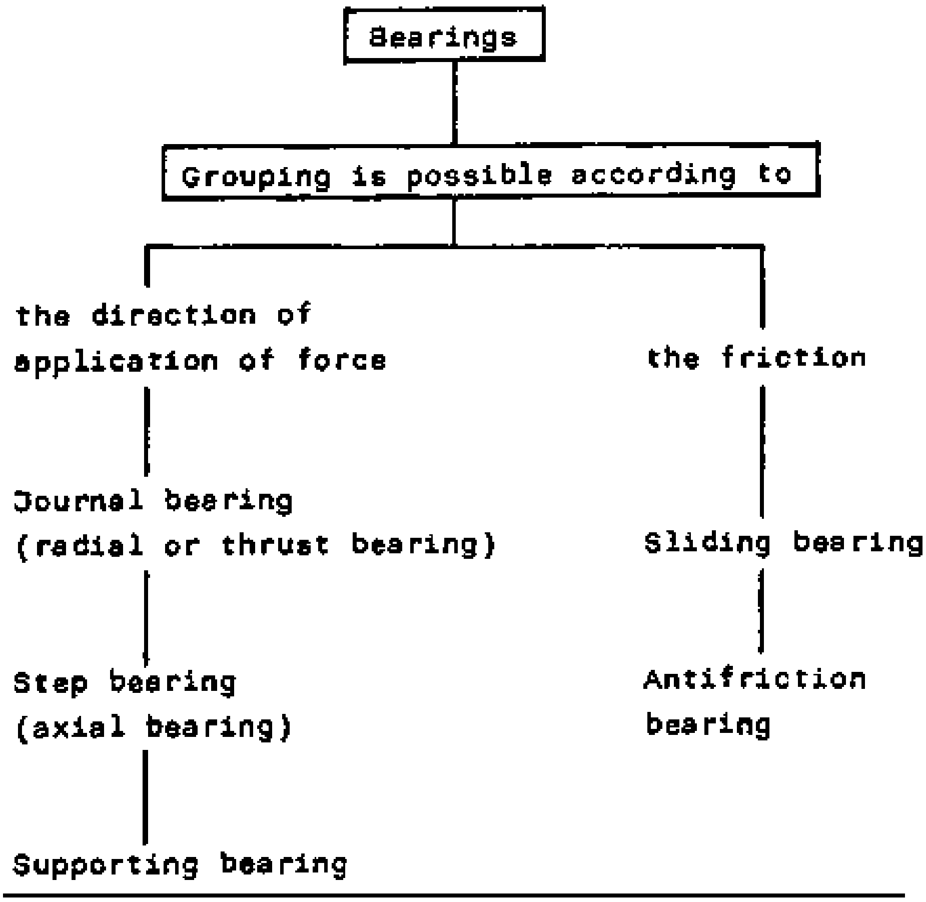


Fig. 11.4. Bearings (survey)

The bearings are represented in drawings by symbols. Plain bearings are represented by two short and thick solid lines parallel to the shaft. Antifriction bearings are represented by small circles or rectangles depending on their shape.

Bearings (Fig. 11.4.) accommodate the journals of shafts and have to transmit forces. They enable the rotary motion of shafts and guide them in radial or axial direction. Plain bearings, also known as sliding bearings, consist of a bearing housing, a bearing bush or bearing sheels and a lubricating device housing, a bearing bush or bearing sheels and a lubricating device (see Fig. 11.5.). The latter serves for the supply of grease or oil for the lubrication of the bearings.

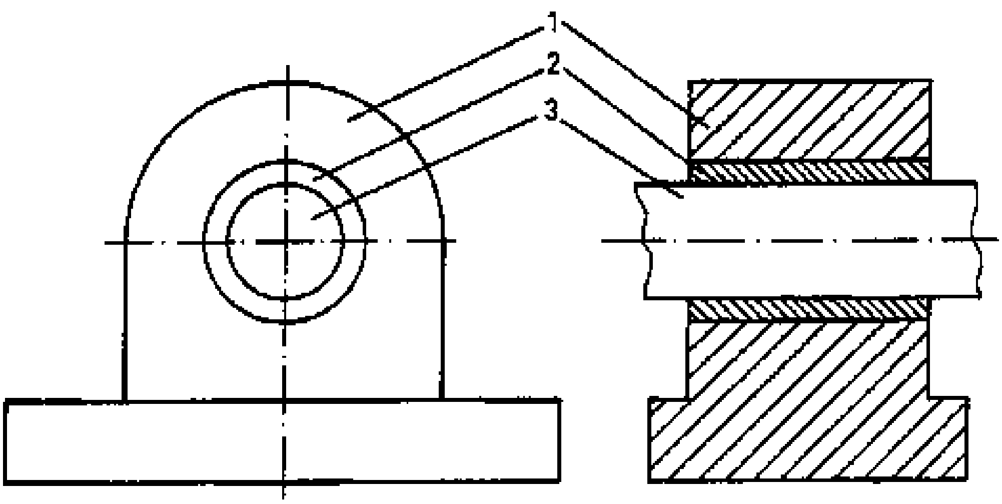


Fig. 11.5. Non−split bearing housing

1 Bearing housing
2 Bush
3 Shaft

Non−split bearing housings may have a bearing bush without collar, with one collar or with two collars. Split bearing housings consist of a lower part, the cap and the bearing shells (Fig. 11.6.).

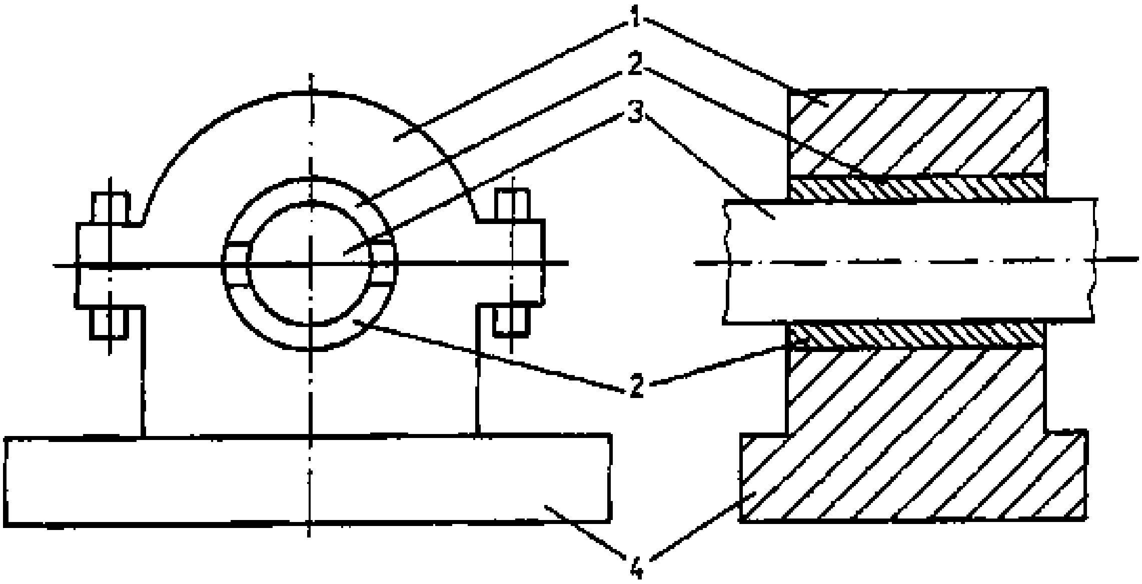


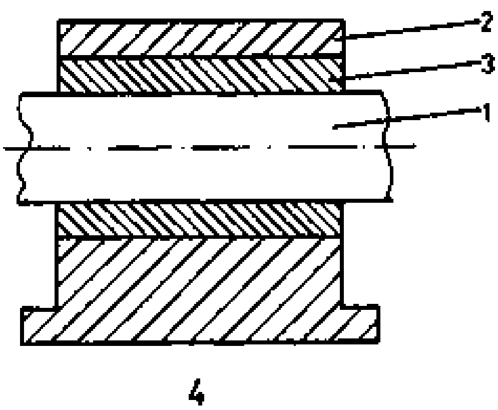
Fig. 11.6. Split bearing housing

1 Cap, 2 Bearing shell, 3 Shaft, 4 Lower part

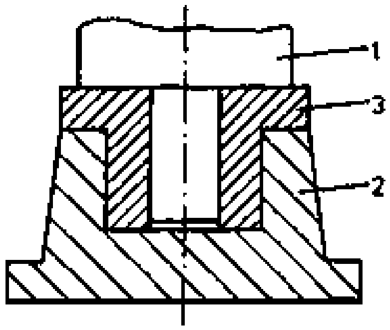
In engineering drawings, plain bearings are frequently represented symbolically, (The shaft as a thick solid line.) Parallel to the shaft, two short thick solid lines are drawn. When using bearing bushes with collar, the latter is drawn across the shaft symbol in the form of a short thick solid line, as is shown in Fig. 11.7.

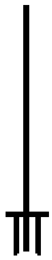
Fig. 11.7. Sliding bearings

Engineering drawing



Symbol





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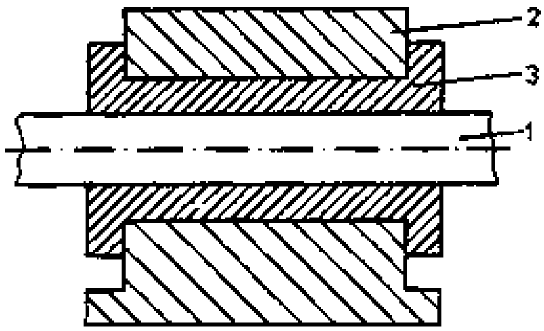
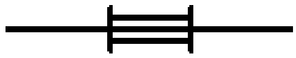




6

1 Shaft,
2 Bearing housing,
3 Bearing bush,
3_2 Bearing bush with collar,
3_3 Bearing bush with two collars,
4 Journal bearing,
5 Step bearing,
6 Supporting bearing

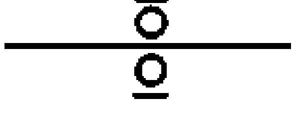
In antifriction bearings, the rolling members take the rolling friction. These members can be spherical (ball bearing), cylindrical (cylindrical roller bearing), needle−like (needle bearing) or barrel like (barrel−type roller bearing), and they are located between the internal ring and the external ring. The two rings are also called races.

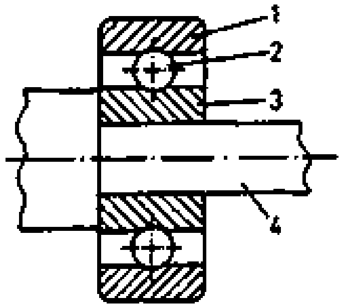
Antifriction bearings are represented in a full section. In the symbolic representation (Fig. 11.8.), small circles (for the balls) or small rectangles (for the cylindrical rolling members) are drawn.

For designating in the list of parts, the word “radial” may be omitted while “axial” must always be written.

Fig. 11.8. Antifriction bearings

Engineering drawing Symbol





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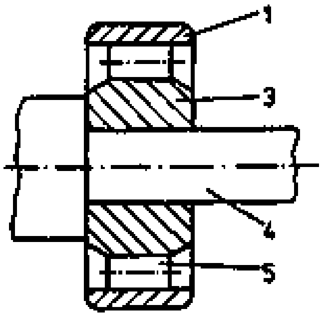

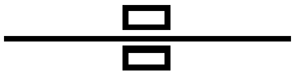

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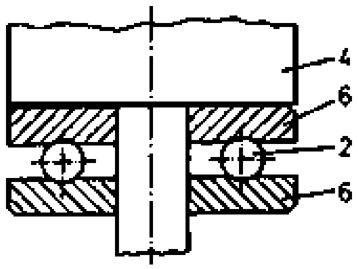
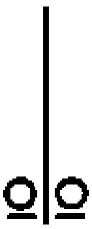




9

1 External ring,
2 Ball,
3 Internal ring,
4 Shaft,
5 Roller
6 Body of the race,
7 (Radial) grooved ball bearing,
8 (Radial) cylindrical roller bearing,
9 Axial grooved ball bearing

11.1.3. Couplings and Clutches

Couplings and clutches are represented in engineering drawings in a simplified form or by a symbol.

Couplings and clutches connect two shaft ends and enable or interrupt a flow of energy. For conducting the mechanical flow of energy, different types of couplings and clutches can be used. Below, a few of them will be dealt with (with respect to their representation in drawings) and their complete representation is omitted, here. A distinction is made between the way of connecting the halves of the couplings or clutches.

There are

- positive and
- non−positive connections.

In the following Table (Fig. 11.9.), only those couplings and clutches are mentioned which are explained below. When a permanent connection of two shaft ends is to be established, permanent couplings are used. These may be, for example, pin couplings (Fig. 11.10.).

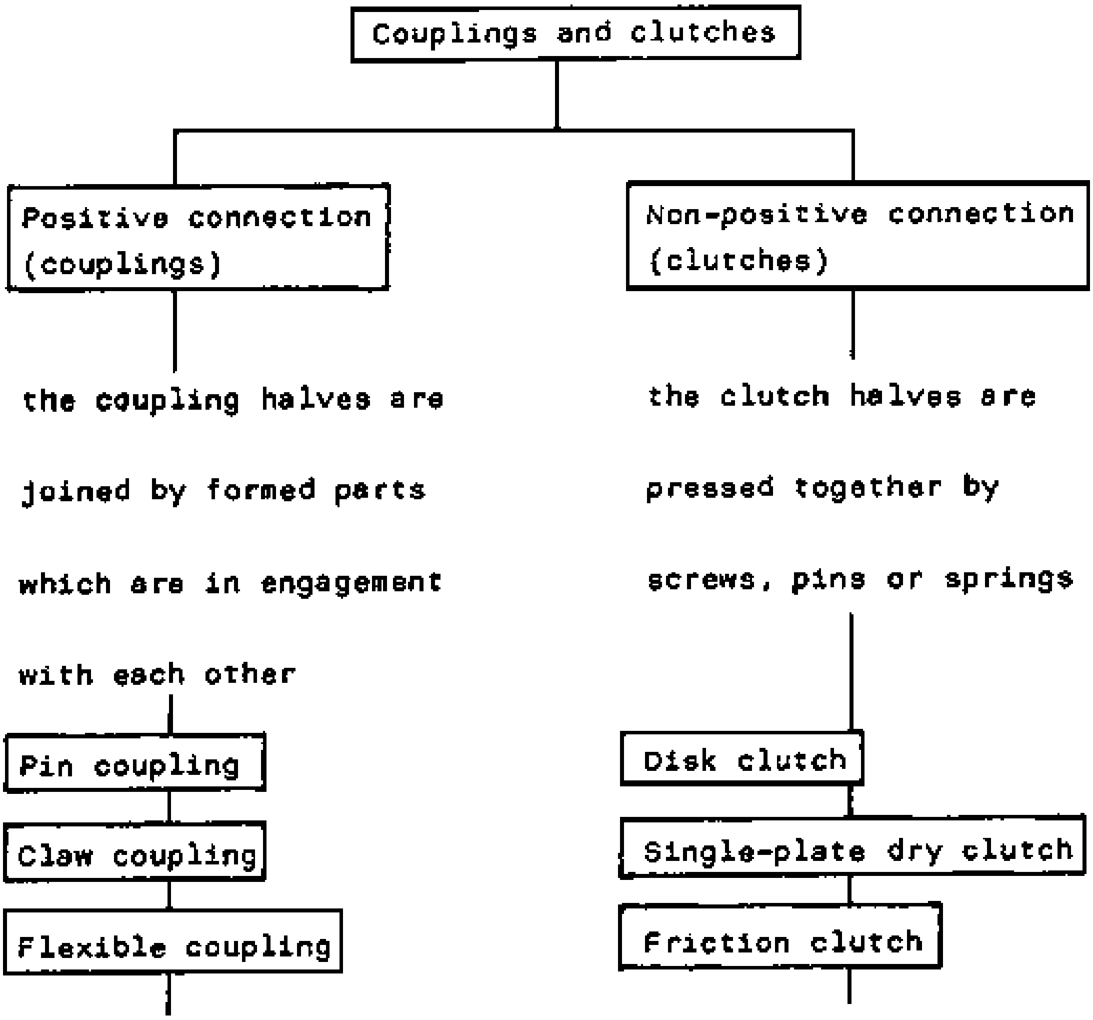
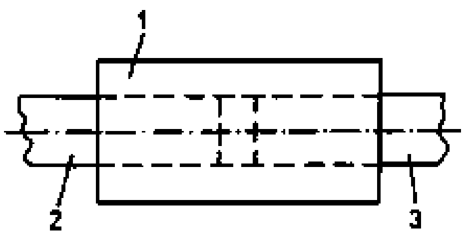


Fig. 11.9. Couplings and clutches (survey)

Fig. 11.10. Pin coupling

Engineering drawing (simplified representation)



Symbol

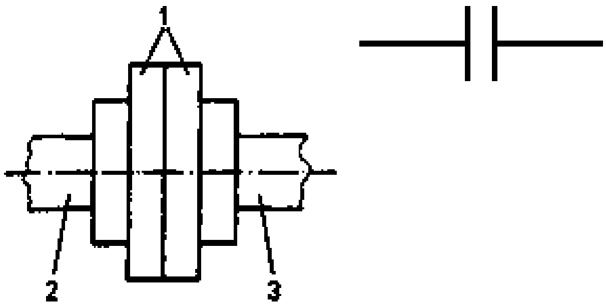
1 Hollow cylinder,
2 Shaft I,
3 Shaft II

The pin coupling, also known as sleeve coupling, consists of a hollow cylinder which is fastened to the shaft ends by means of pins, bolts or keys. The fastenings are not shown in a drawing.

The disk coupling (Fig. 11.11.) is also a rigid permanent coupling. It consists of two coupling disks which are firmly pressed together by screws.

Fig. 11.11. Disk clutch

Engineering drawing (simplified representation) | Symbol

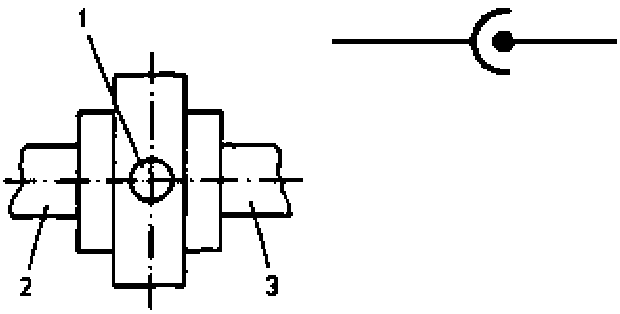


1 Clutch disks,
2 Shaft I,
3 Shaft II

Small deviations from direction and position of shafts are neutralised by the use of movable permanent couplings. This angular motion is achieved by means of elastic fabric disk couplings. Universal joint couplings are also particularly suitable for this purpose (see Fig. 11.12.).

Fig. 11.12. Flexible coupling

Engineering drawing (simplified representation) | Symbol



1 Universal joint,
2 Shaft I,
3 Shaft II

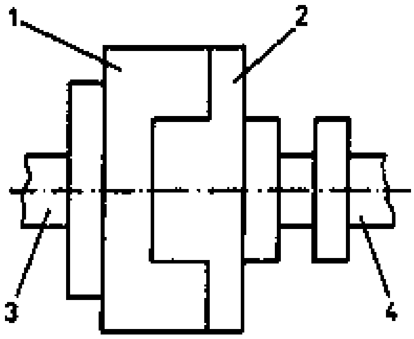
For an interruption of the energy flow, controllable clutches are used, A distinction is made between:

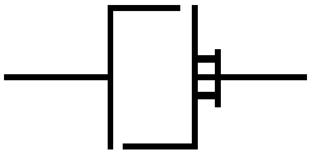
- clutches that can be operated when they are stationary or synchronised,
- clutches that can be operated at any speed,
- self−controlling clutches.

A clutch that can only be operated when the machine is stationary is the claw clutch (Fig. 11.13.). The halves of the clutch are connected by means of shaped parts engaged with each other (A and B, see Fig. 11.13.).

Fig. 11.13. Claw coupling

Engineering drawing (simplified representation) | Symbol





1 Formed part A,
2 Formed part B,
3 Shaft I,
4 Shaft II

Of the clutches which can be operated at any speed and of self−controlling clutches, the single−plate dry clutch and the friction clutch will be dealt with below (it is also known as safety clutch adjusted to slip at a predetermined torque). As has already been said, the positive couplings usually are permanent couplings, some of them can be operated when the machine is stationary. Non−positive clutches, i.e. loose clutches, can be operated in any operational state.

11.2. Belt Drive

For the representation of a belt drive, the belt pulleys and the belt are drawn.

In the driving pulley and in the driven pulley, the sense of rotation is indicated by an arrowhead with circular arrow.

If larger distances between driving and driven shafts have to be bridged, traction mechanisms are used. Of this group, the belt drives will be explained here. They serve for the transmission of torques.

The speed can be varied and the sense of rotation reversed. According to the shape of the section of the means of traction, a distinction is made between flat belt drive and V−belt drive. Below, an explanation will be given of the flat belt drive; there are the open and the crossed belt−drive. In the open belt−drive, the sense of rotation of driving and driven belt−pulleys is the same. By the crossed belt−drive, the sense of rotation is reversed.

In the graphic representation (Fig. 11.14.), the belt pulleys and the belt are drawn. The flat belt which actually has a sag is represented by a straight, thick solid line. An arrowhead indicates the direction of the tight side. Further, the sense of rotation is indicated.

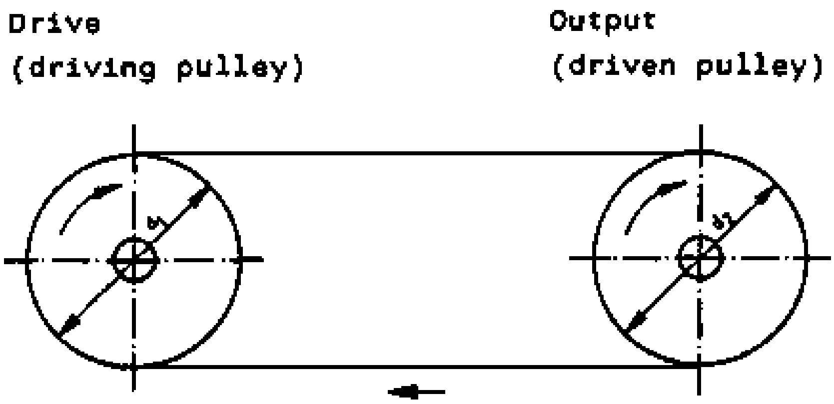


Fig. 11.14. Open belt−drive

d_1 = diameter of the driving pulley
d_2 = diameter of the driving pulley

By the use of belt pulleys of the same size, the same speed of drive and driven side is achieved. This condition ($d_1 = d_2$) is shown in Fig. 11.14.

The change of the sense of rotation is shown in Fig. 11.15. Frequently, the pulleys are drawn without shaft.

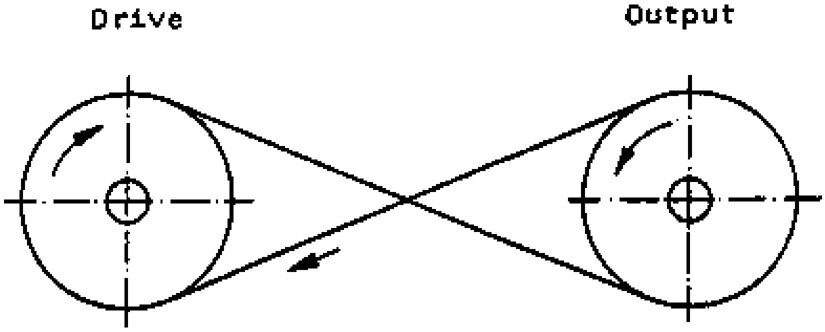


Fig. 11.15. Crossed belt drive

When the driving pulley has a diameter that is larger than that of the driven pulley (Fig. 11.16.), the speed is changed (d_1>d_2).

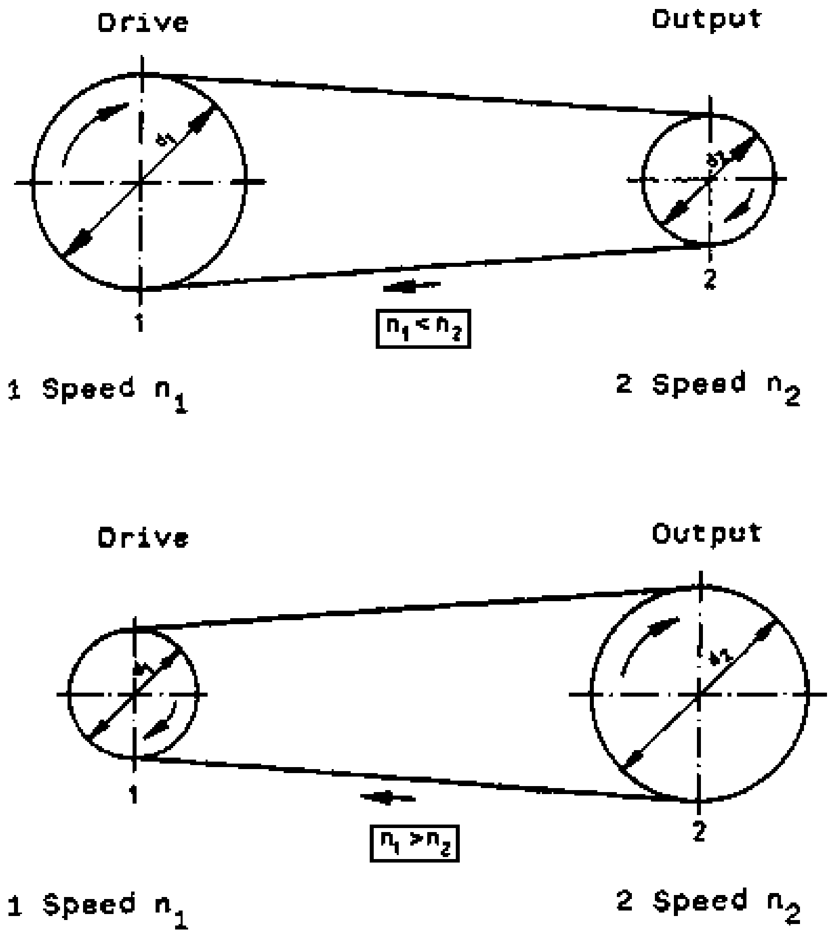


Fig. 11.16.

When the drive is a belt pulley with a diameter that is smaller than that of the driven pulley, the speed is reduced (d_1<d_2).

11.3. Friction–gear Drive

In engineering drawings, the geometric shape of the friction gears is drawn. For shafts and bearings, the specified symbols are used.

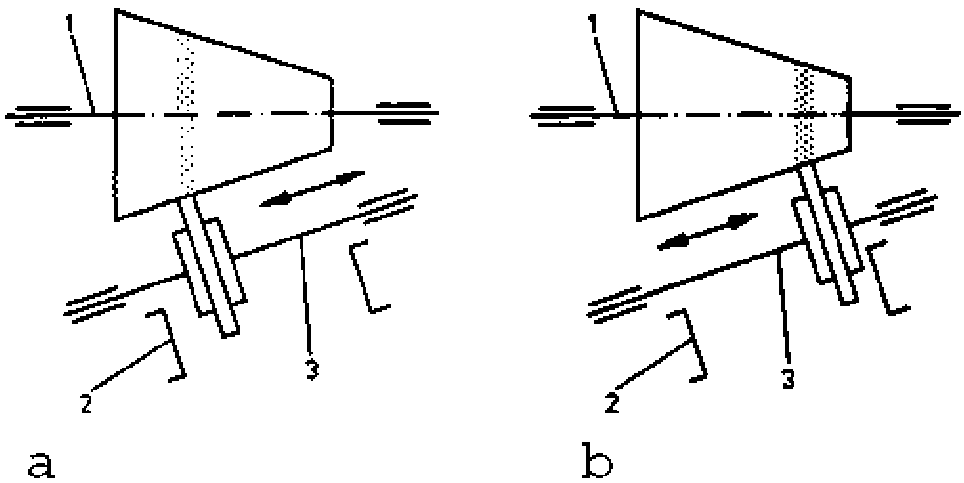


Fig. 11.17. Friction−gear drive

1 Driving shaft with taper,

2 Stop,

3 Driving shaft with adjustable rubber roller

a e.g. control position a): large cone diameter

small speed of the driven shaft

b e.g. control position b): small cone diameter

high speed of the driven shaft

Power transmission in the friction−gear drive is achieved by pressing together driving gear and driven gear. The contact pressure and the particular condition of the friction surfaces ensure power transmission by friction at the point of contact. This is called a non−positive connection. In Fig. 11.17., the point of contact of the cone with the rubber roller is marked by a red line. By means of the friction−gear drive, infinitely variable transmission is possible.

Besides friction−gear drives with taper disks, there are such with spherical or cylindrical friction members.

11.4. Toothed−wheel Gearing

For toothed−wheel gearings, simplified or symbolic representations are preferred in engineering drawings. Frequently, only the pitch diameters of the gears are drawn (as a dash−and−dot line).

Shafts, bearings, couplings or clutches and the gear casings are also represented symbolically.

Toothed−wheel gearings have to fulfil the following tasks:

− transfer of the rotary motion,
− transfer of the rotary motion and variation of the speed
− transfer of the rotary motion, variation of the speed and of the sense of rotation.

Depending on the location of the shafts, a distinction is made between the following kinds:

− spur−gear drive	(on parallel axes)
− bevel−gear drive	(shafts arranged at angles)

– worm–gear drive (shafts are crossed)

– helical–gear drive (shafts are crossing)

In these four types of toothed–wheel gearings, the rotary motion is achieved by a positive connection of the gears. The teeth of one gear mesh with those of the other gear. The curved surfaces where the teeth contact each other during the rotary motion of the gears are called tooth flanks. There is a non–jerky transfer from one tooth to the other. Due to this rolling motion, a slipless power transmission is ensured.

11.4.1. Representation of Gears

In engineering drawings, gears or toothed wheels are represented in a simplified manner. Because of the curved tooth flanks, they have been drawn clearly, see example of the straight spur gears.

The meshing of the teeth of two spur gears is shown in Fig. 11.18. The parts are not drawn completely, only a segment of each gear is shown.

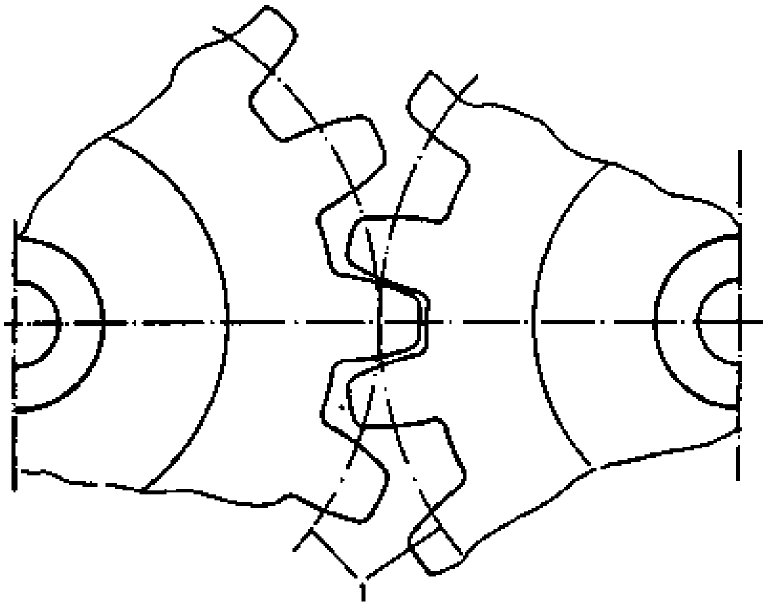


Fig. 11.18. Meshing of two spur gears

1 Pitch circle diameter

For the representation of gears, special designations are specified which are explained with the help of a perspective drawing showing a straight spur gear. The data are restricted to dimensions required for the preparation of an engineering drawing (see Fig. 11.19.).

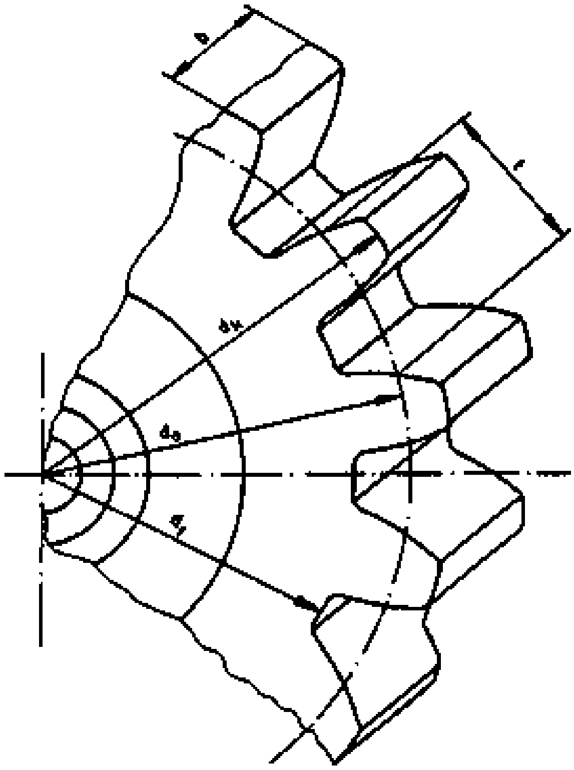


Fig. 11.19. Designation for the representation of a spur gear

d_k S addendum circle diameter

d_o pitch circle diameter

d_f diameter of the root circle

b tooth width

t pitch

z number of teeth } see Fig. 11.21.

m module } see Fig. 11.21.

Further designations of a toothed wheel are not explained here because the specified quantities will suffice normally. A Table, shown in Fig. 11.20., defines some of the designations which are of particular importance.

Fig. 11.20.

Description	Symbol	Representation in drawing	Remarks
addendum circle	d_k		drawn as a continuous (imaginary) thick solid line
pitch circle	d_o		imaginary line in the centre between addendum circle and root circle, drawn as a dashed line
root circle	d_f		as continuous (imaginary) dashed line, drawn
			as a thick solid line in the sectional view
tooth	b	none	is stated as a dimension
width			figure for the tooth width
pitch	t	none	dimension figure for the calculation of the module consists of a tooth thicknes plus one gap width

number of teeth	z	none	number of teeth of one gear
module	m	none	ratio for the calculation of the pitch circle

11.4.2. Dimensioning

Fig. 11.21. shows how a toothed wheel has to be dimensioned. This is a complete dimensioning procedure as required for two views. The shape of the tooth is not specified. Frequently, a sectional view will suffice.

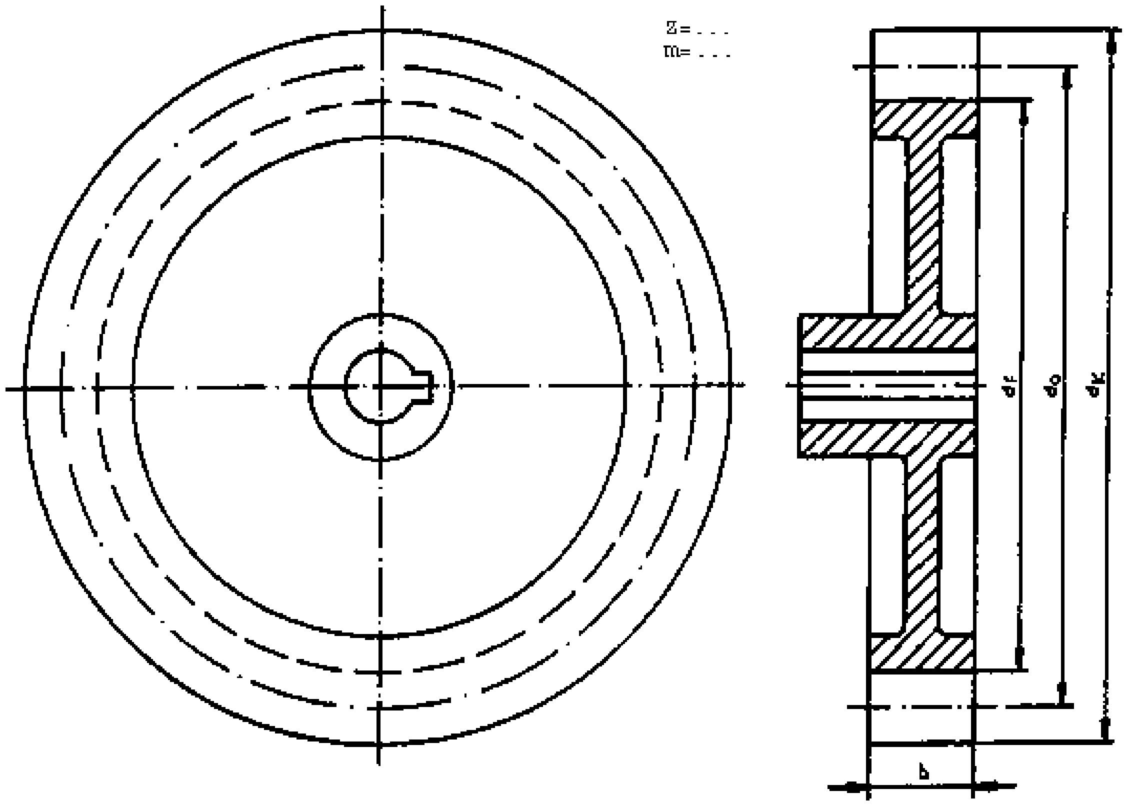


Fig. 11.21. Dimensioning the spur gear

z = number of teeth,
m = module

The dimensions refer to the following quantities:

- addendum circle diameter (d_k)
- pitch circle diameter (d_0)
- diameter of the root circle (d_f)
- tooth width (b)

In addition, data are given on

- number of teeth (z)
- module (m)

Module is a ratio. It is the ratio of the division t (in mm) to ?, hence, . For the calculation of the pitch circle diameter we have:

pitch circle diameter = module times number of teeth

$$d_o = m \cdot z$$

For the indication of the surface finish of tooth flanks, which are not shown in the engineering drawing, surface signs are applied to the pitch circle line. For small gears, this can be achieved with the help of leaders.

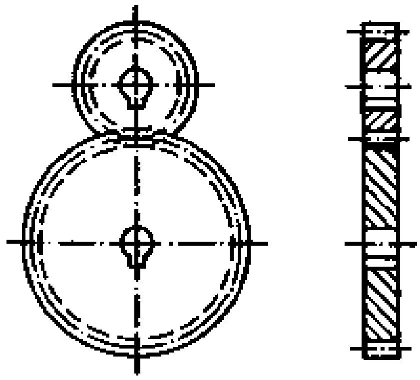
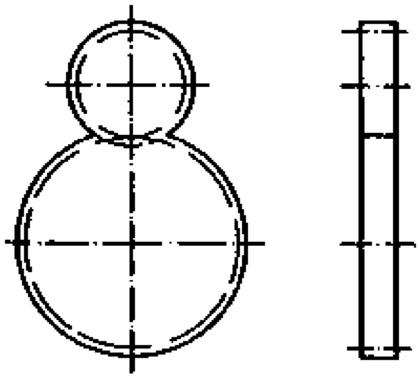
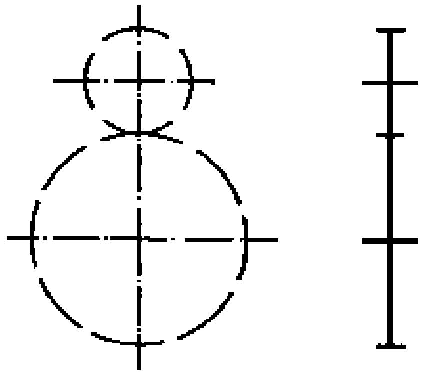
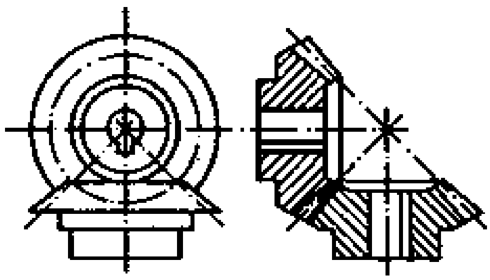
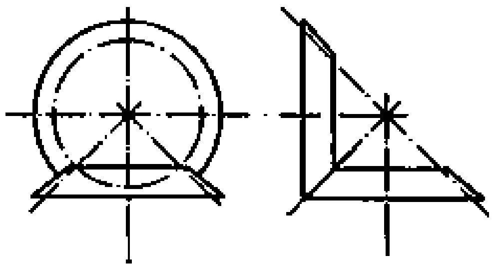
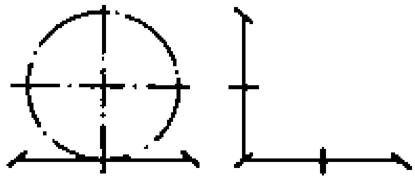
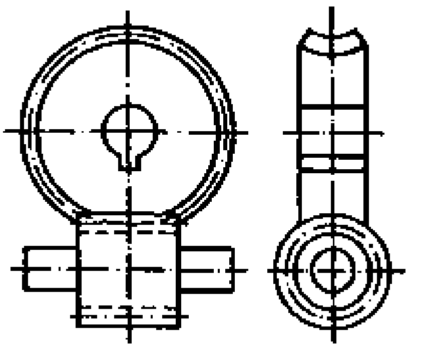
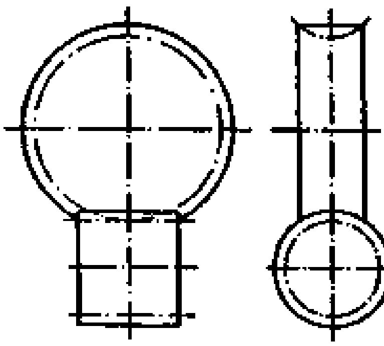
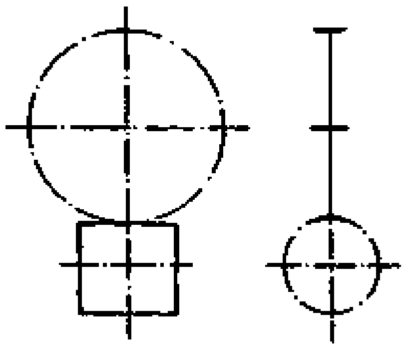
11.4.3. Representation of Gear Mechanisms

For the complete representation of gear mechanisms, a time−consuming drawing procedure would be necessary. Therefore, the following possibilities of representation can be selected:

detailed representation	for detail drawings
simplified representation	for the indication of positions in assembly drawings
symbolic representation	for gear diagrams

In the symbolic representation (Fig. 11.22.), additionally, the fastening of one toothed wheel on a shaft must be indicated. There are four possibilities which are demonstrated in Fig. 11.23.

Fig. 11.22. Representation of gears

Detailed representation	Simplified representation	Symbolic representation
Addendum, pitch and foot circles have to be drawn	Addendum and pitch circles have to be drawn	Only the pitch circles have to be drawn
Spur gears on parallel axes		
		
Bevel−wheel train		
		
Worm−wheel drive		
		

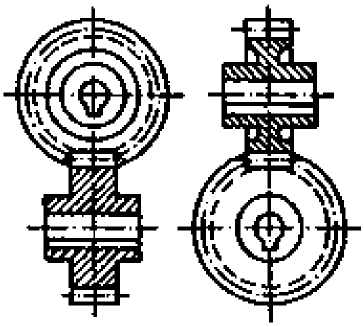
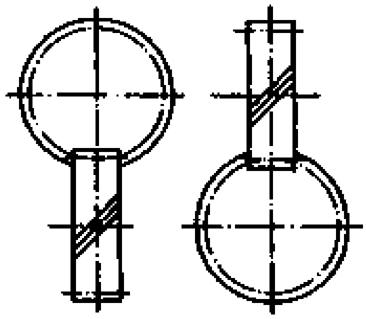
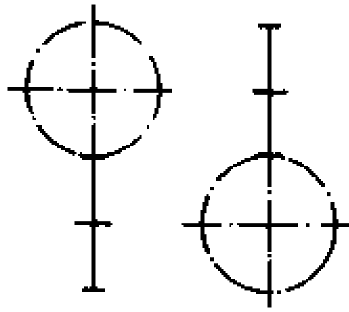
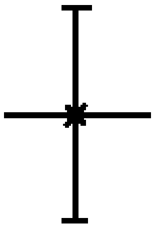
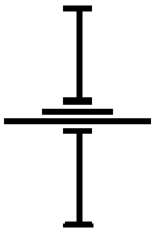
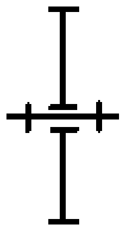
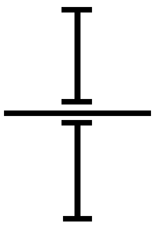
Helical–gear mechanism		
		

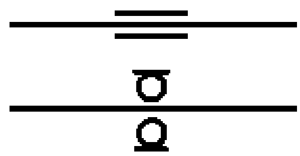
Fig. 11.23.

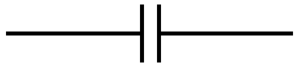
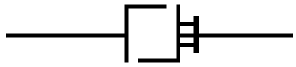
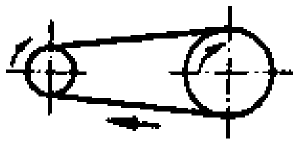
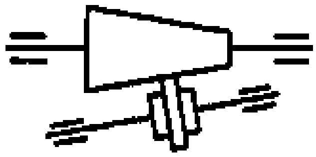
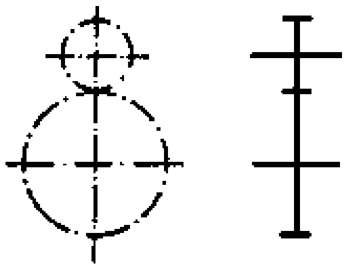
Symbol	Explanation
	Axially firm on the shaft
	Cannot be turned on the shaft, can be displaced axially
	Can be turned on the shaft, cannot be displaced axially
	Can be turned on the shaft and axially displaces

11.5. Summary

In Fig. 11.24., the essential statements given in the preceding Sections are compiled in a Table.

Fig. 11.24.

Description	Function	Symbol
Shaft	transmits torque	
Bearing	mounting of shafts by sliding bearing or antifriction bearing	

Clutch coupling	connection of shafts, rigid (pin coupling)	
	rigid (disk coupling)	
	controllable (claw coupling, clutch)	
	flexible (flexible coupling)	
Belt drives	transmission of rotary motion when the distance between shafts is larger (non−positive, frictional)	
Friction−gear drive	transmission of rotary motion by frictional force (non−positive, frictional)	
Toothed−gear drive	transmission of rotary motion by meshing gear teeth, change of speed and sense of rotation possible (positive)	

11.6. Reading and Representation of Simple Gear Diagrams

Gear diagrams – also known as gearing schematics – show type, position and function of the parts of a gearing mechanism used. For this purpose, symbols are used. The gear casing is represented by a thick solid line. Data regarding the driving and output speeds are applied to the shafts in question by arrowheads and abbreviations (N_{An} or n_{Ab}, this means speed of the drive or speed of the output and, in English, may be written n_{dr} or n_{output}). The gears are marked by consecutive numbers (e.g. Z_1, Z_2 ...). The shafts are marked by Roman numerals).

In gear diagrams, the interaction of the gear parts is shown. The example of a simple spur gear mechanism (Fig. 11.25.) shows the variation of the speed (Z_1>Z_2).

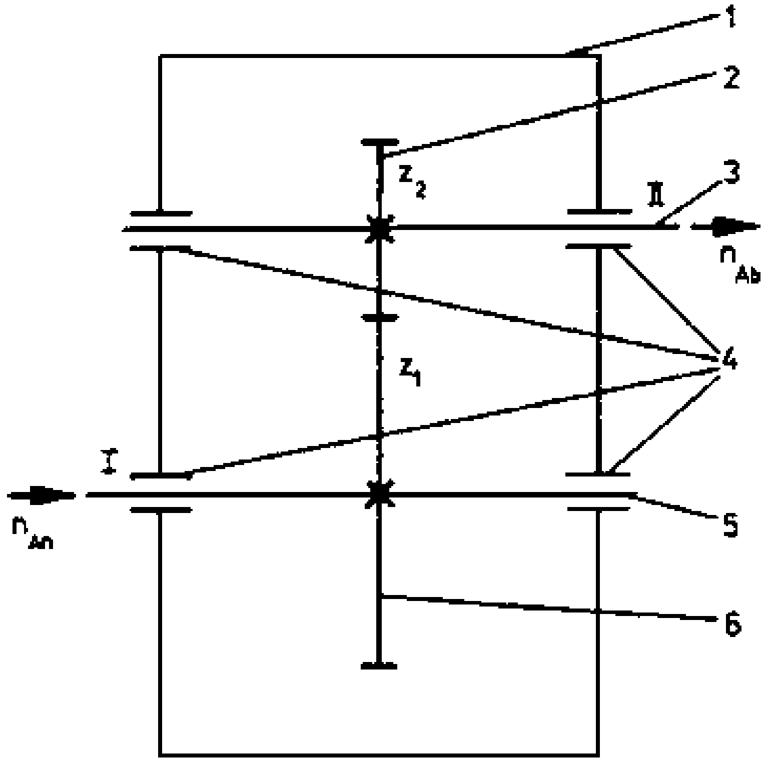


Fig. 11.25. Spur gears on parallel axes

1 Gear casing
2 Spur gear (Z_2)
3 Driven shaft (II)
4 Sliding bearing
5 Driving shaft (I)
6 Spur gear (Z_1)

To facilitate grasping, the components used in this gear diagram are provided with the relevant terms. Normally, these terms are not entered in the drawing.

Figure 11.26. illustrates a speed−changing mechanism for two speeds. Besides the designation of the shafts by Roman numerals, the indication of the possible rotational speeds is required for speed−changing mechanisms. This is effected by Arabic numerals.

For example, a gear mechanism with two shafts and two speeds: speed−changing mechanism II / 2.

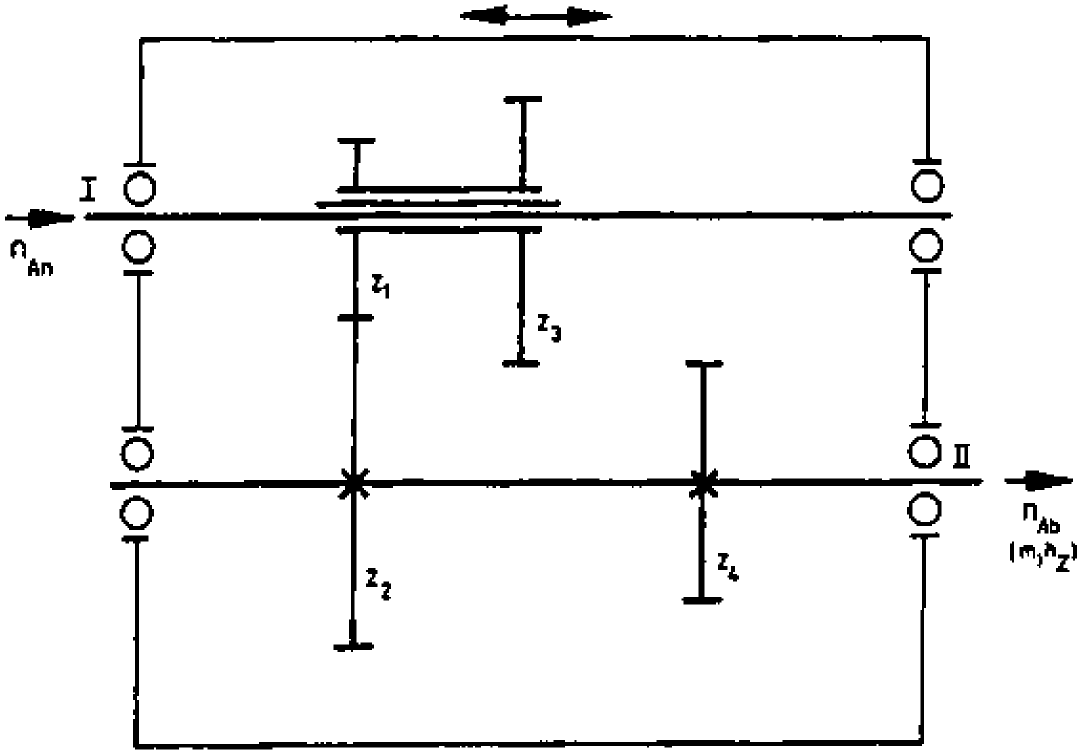


Fig. 11.26. Speed–changing mechanism II/2

On the drive shaft (I), a pair of gears comprising two spur gears (Z_1 and Z_3) is arranged. This block of gears cannot be turned on the shaft because of the incorporation of an engagement device (sliding key) but it is axially movable. The shifting of the gears can be achieved by means of a shifting fork and is indicated by a double arrowhead above the gear casing.

12. Structural Steel Elements

12.1. Sections

In steel construction, structures are erected in many designs of the material steel. This includes, for example, steel bridges. Bridges are built for bridging railways, roads and rivers. Structural building frames of steel are used for the erection of buildings, railway–stations and factories. Cranes and dredger excavators are products of conveying engineering made of steel. Further, transmission–line towers and other towers are made of steel. Railways, motorcars and ships are also among the products of steelwork. The production of tanks, containers and pipe–lines of steel and structures of hydraulic engineering are further fields of steel construction; the latter field includes weirs, gates and embankments for the prevention of floods.

In steel works, the parts are rolled which are required for the erection of steel structures. These are sections and sheets and plates. They are delivered in different shapes and dimensions by the manufacturer.

The sections are used either as individual sections or composite sections made up of individual sections. The sections have a centre of gravity which may be located within or beyond the material. Related to this centre of gravity, the gravity axis is drawn as the centre axis into the section. The location of centres of gravity and gravity axes can be looked up in Tables. Below, a few sections are discussed which are used for beams and supports in light–weight steel construction. Fig. 12.1. shows the perspective representation of an isosceles and non–isosceles angle steel. Viewed from the front, the blackened section is only seen. The outline of this section is selected as side view in drawing: this shape is used as the symbol for the section. The isosceles angle section is indicated by and the non–isosceles angle section by **L**.

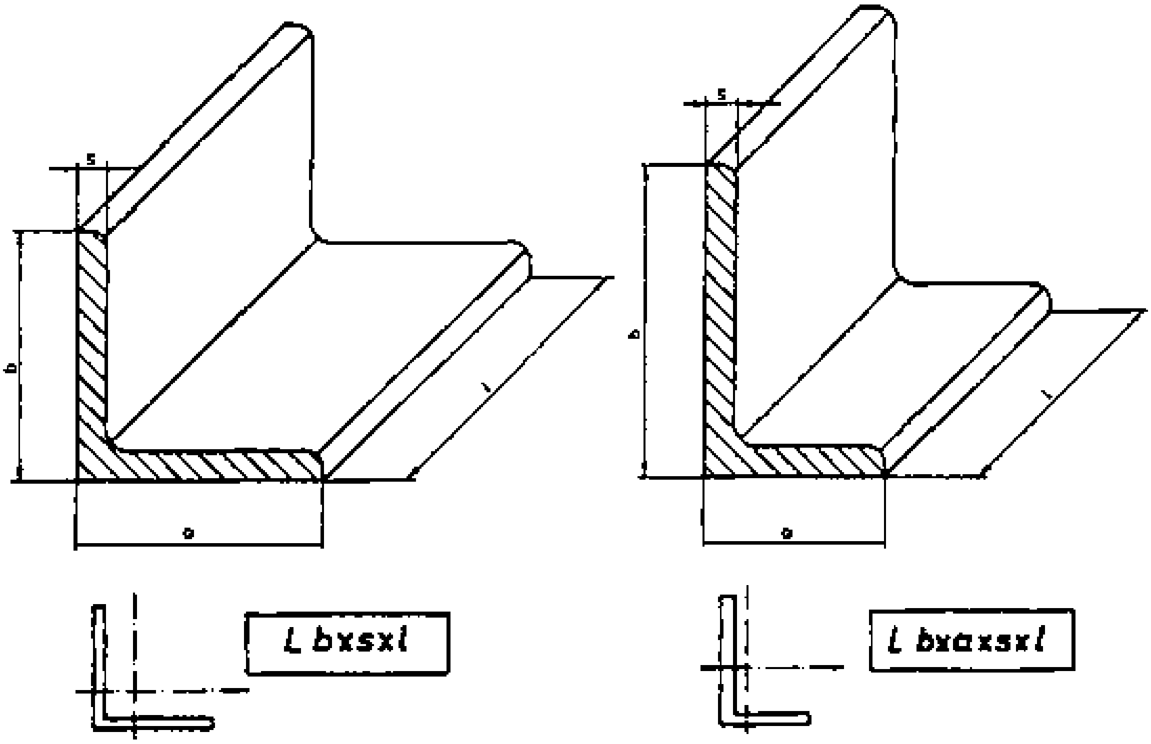


Fig. 12.1. Isosceles and non–isosceles angle steel

a = small leg width,
b = large leg width,
s = leg thickness
l = length of profile or section

For defining the section, the dimensions in millimetres are written behind the symbols and connected by the symbol × (i.e. times). Since, in the isosceles angle steel, the two legs (b) are of equal length, only one width of the leg is given. To increase strength and loadability, the transitions of sections are rounded, the dimensions of the radii are given in Tables.

Isosceles angle steel:

leg width (b) × leg thickness (s) × length

Non–isosceles angle steel:

large leg width (b) × small leg width (a) × leg thickness (s) × length

Examples:

50×4×1000 means isosceles angle steel, the width of the two legs is 50 mm, the leg thickness is 4 mm and the section has a length of 1000 mm.

80×50×8×2000 means non–isosceles angle steel, width of the large leg is 80 mm, width of the small leg is 50 mm, thickness of the leg is 8 mm, and length of the section is 2000 mm.

Repetition

1. Explain the following designations of sections:

75×7×1500 mm; 200×125×14×3000; 32×20×3×1750!

2. Prepare a sketch of these sections in perspective.

If Tables are not available, the radii may be estimated.

For the T–steel sections and double T–steel sections (see Fig. 12.2.) it also holds that, viewed from the front, they have to be specified with their typical main dimensions. These are the height of the section and the length.

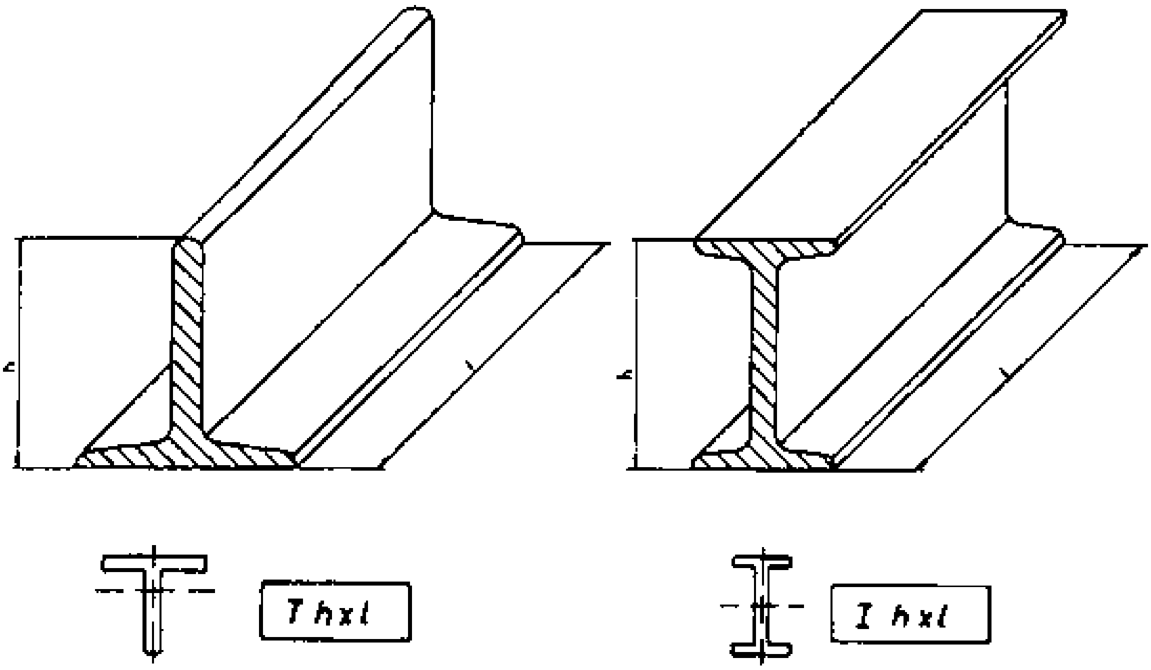


Fig. 12.2. T–steel and double T–steel

h = height of profile,
l = length of profile

<u>T–steel:</u>	T height of the section (h) × length (l)
double T–steel:	I height of the section (h) × length (l)

Examples:

T 40×1000	means a T–section having the height of 40 mm and a length of section of 1000 mm.
I 300×2000	means double T–steel with a height of 300 mm and a length of 2000 mm.

Problems:

1. Explain the following specifications of sections: T 60×1250, I 100×1800, T 100×1800.

2. Sketch these sections in two views.

3. Tell where you have seen or worked during your training angles, T– and double T–sections.

Other sections are shown in Fig. 12.3., namely, the –section (rolled steel channel) and the zee section.

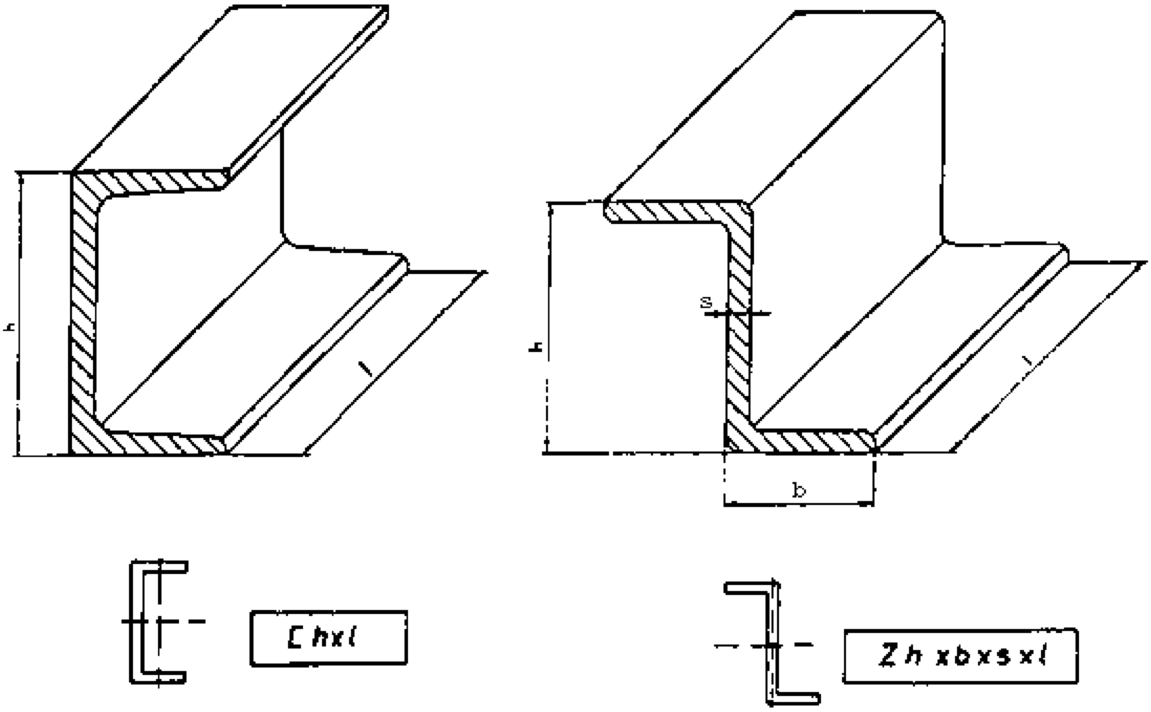


Fig. 12.3. −steel and zee−steel (or zed−steel)

h = height of section or web,
b = width of flange,
s = wall thickness,
l = length of section or profile

The typical dimension of the −section is its height. For the determination of the zee−steel (also known as zed−steel), several data are required in order that its shape is clearly understood.

−section:	height of section (h)	×	length
zed−section:	height of section (h)	×	width of flange (b)
	× wall thickness (s)	×	length (l)

Examples:

50×2000	means a steel channel of −section having a height of 50 mm and a length of 2000 mm.
zee 32×20×2	means zee−section steel having a height of section or web of 32 mm. The width of flange is 20 mm and the wall has a thickness of 2 mm. In this example, only the cross−section is given but not the length.

Repetition

1. How should the designation be changed when the zed−section should have a length of 3000 mm?

2. Of this section, prepare a drawing in two views, scale 1:1.

3. Explain the following abbreviated designations: 330×6645, zee 16×10×1, 5×2000.

4. Explain the designation of a channel section having the symbol the height of section is 180 mm and the length 4 mm.

Besides the sections discussed above, plates and flat steels are required in steel construction. When placing the rectangular outline as symbol before the given main dimensions, namely, width, thickness and length, then shape and size can easily be recognised. As compared to flat steel, plates and sheets of metal have a thickness which is much smaller than the width. These plates or sheets are usually delivered in specified sizes (compare Fig. 12.4.).

Flat steel, plate: width × thickness × length

Examples:

80×10×2000 means flat steel having a width of 80 mm, a thickness of 10 mm and a length of 2000 mm.

600×3×850 means plate having a thickness of 3 mm, a width of 600 mm and a length of 850 mm.

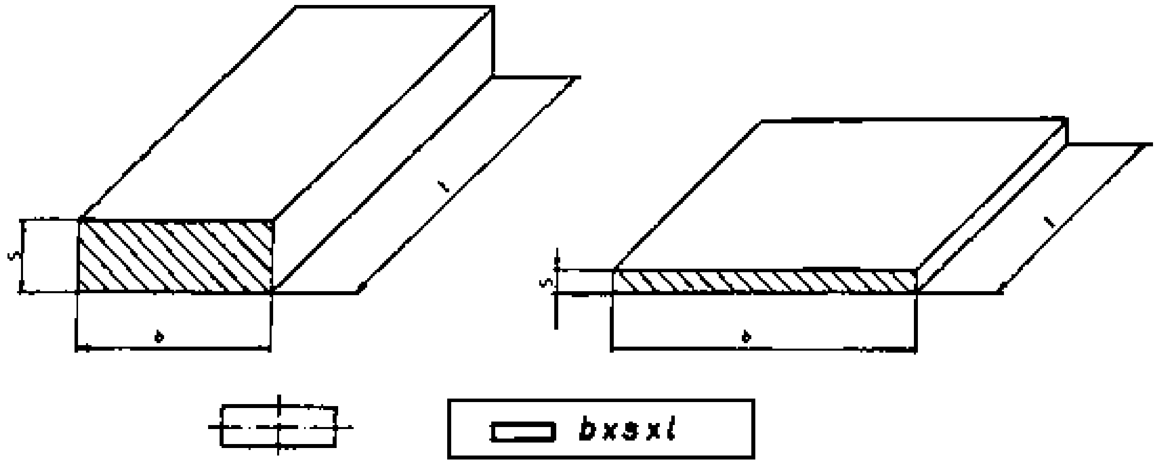


Fig. 12.4. Flat steel and plate

b = width,
s = thickness,
l = length

The abbreviated designation for sections are entered into the drawing in longitudinal direction, this means parallel to the gravity axis**,** either on or beside the section in its front view. Another view is not required because misinterpretations are not possible due to the statement of the section. When cross−sections are made up of several individual sections, then their number must be placed before the symbol of the section, e.g. 2 120×4265 or, in case of four isosceles angle sections, 4 120×10×5500 (see Fig. 12.5.).

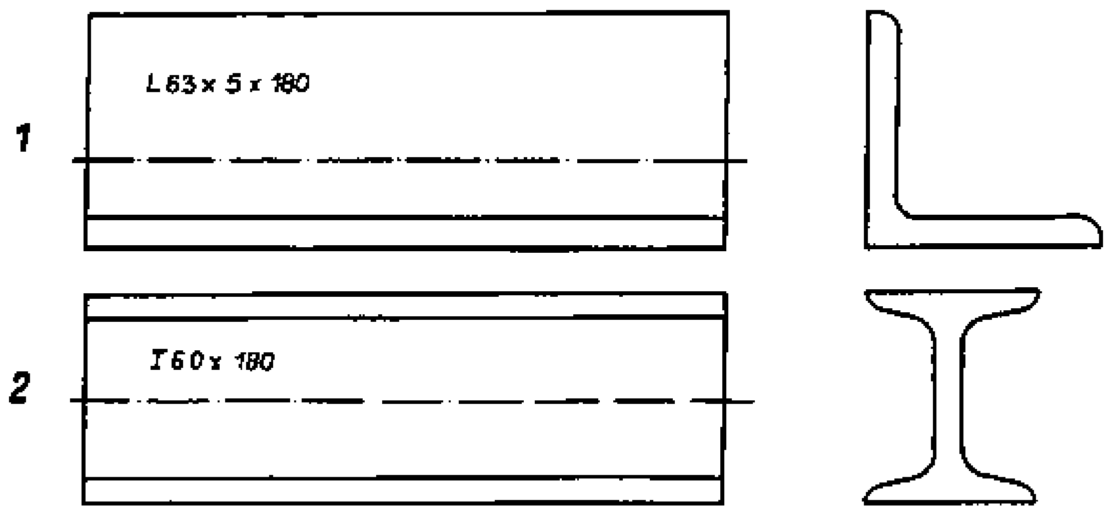


Fig. 12.5.1. Examples of indicating sections in drawings

1 = single section with symbol on the section
2 = single section with symbol above the section

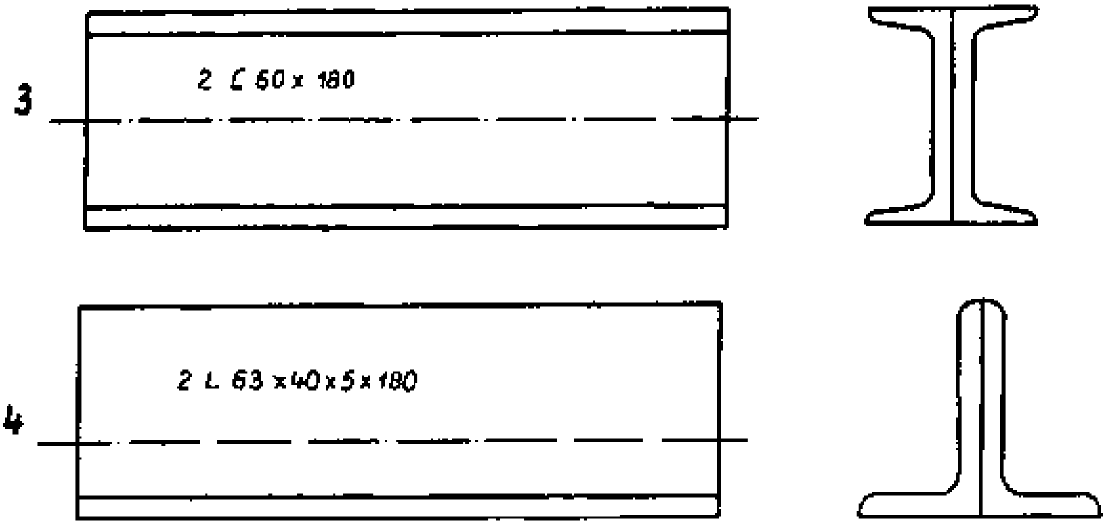


Fig. 12.5.2. Examples of indicating sections in drawings

3 = Composite section made up of two single sections
4 = composite section made up of two single sections

Narrow areas of cut are not shaded but fully blackened, when several blackened areas are adjacent to each other, the joint must be indicated and light gaps (Fig. 12.6.) are permissible which have to be located on the left and on top. When the areas of cut are sufficiently large, then the rules for drawing given in Chapters “Sectional Views” and “Representation of Assembled Parts” have to be used.

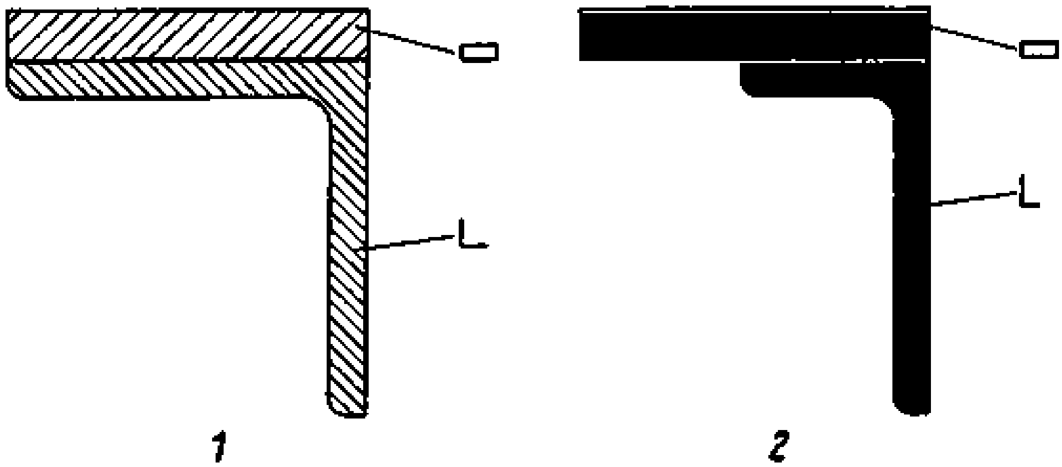


Fig. 12.6. Possibilities of sectional views

1 Representation when the cross−section is sufficiently large
2 Representation of narrow cut areas

Repetition:

1. Describe where steel constructions are required.

2. What types of steel sections are frequently used?

3. Explain the following designations of sections: 45×28×4×2000, T 70×1550, I 22×4855, 200×10×1800. Change these data in such a way that the lengths are 3500 mm in each case.

4. Prepare sketches of these sections in two views and enter the designations of the sections into these sketches.

5. What may be the appearance of the composite section 4 <<L>> 80×8? (Several solutions are possible)

6. Consider why cross−sections are made up of individual sections, and prepare a sketch of a few examples of this from your practical activities.

12.2. Joining and Types of Joints

12.2.1. Riveted Joints

In steel construction, permanent and detachable joints between the sections and plates are established by rivets. Holes are drilled into the parts to be joined. Before fitting, the rivet, consisting of the die head and the shank, is heated to bright red. Then it is put into the rivet hole and treated in such a way that the projecting shank is shaped into the so−called driven head. The glowing rivet shank is upset in this way, filling the whole rivet hole. The rivet hole always is 1 mm larger than the shank diameter of the undriven raw rivet.

In steel construction, mainly the button−head rivet is used. Its typical shape before and after driving and its most important dimensions are shown in Fig. 12.7.

When the projecting die head and driven head are obstructing, then countersunk−head rivets are used. They are flush with the surface. The values of the various dimensions are dependent on the raw rivet diameters and compiled in Tables. Fig. 12.8, shows a fitted countersunk−head rivet.

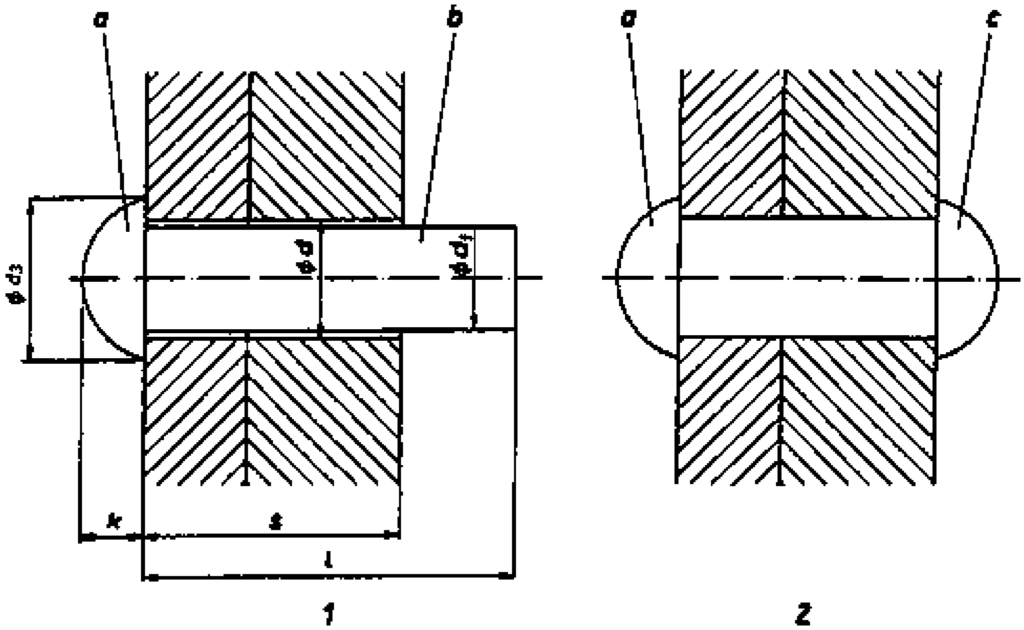


Fig. 12.7. Button−head rivet, raw and driven

1 = inserted raw rivet,
2 = driven rivet,
a = die head
b = shank,
c = driven head,
d = hole diameter,
d_1 = diameter of raw rivet (raw rivet is defined as the rivet before driving)
d_2 = head diameter of the die head and the driven head
k = height of the die head and the driven head
l = length of the shaft of the rivet before driving
s = clamping length (thickness of the parts to be joined)

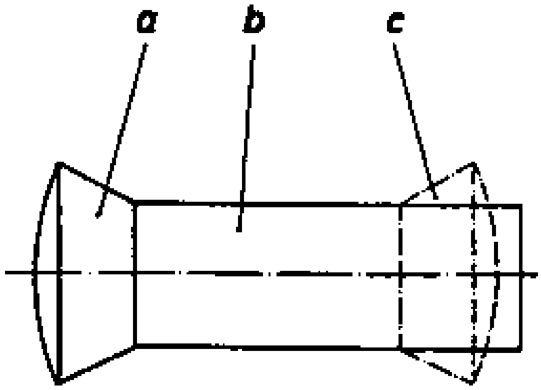


Fig. 12.8. Countersunk−head rivet

a = die head is to be countersunk
b = shank
c = driven head to be countersunk

The parts to be joined can be connected in various ways. When the parts are put one upon the other and are then riveted, the joint is called overlapping riveted joint. When the ends of the parts are abutting, then additional cover plates must be used for the riveted joint. In this case, the established joint is called double−strap riveted butt joint or riveted butt joint with cover plates on each side (Fig. 12.9.).

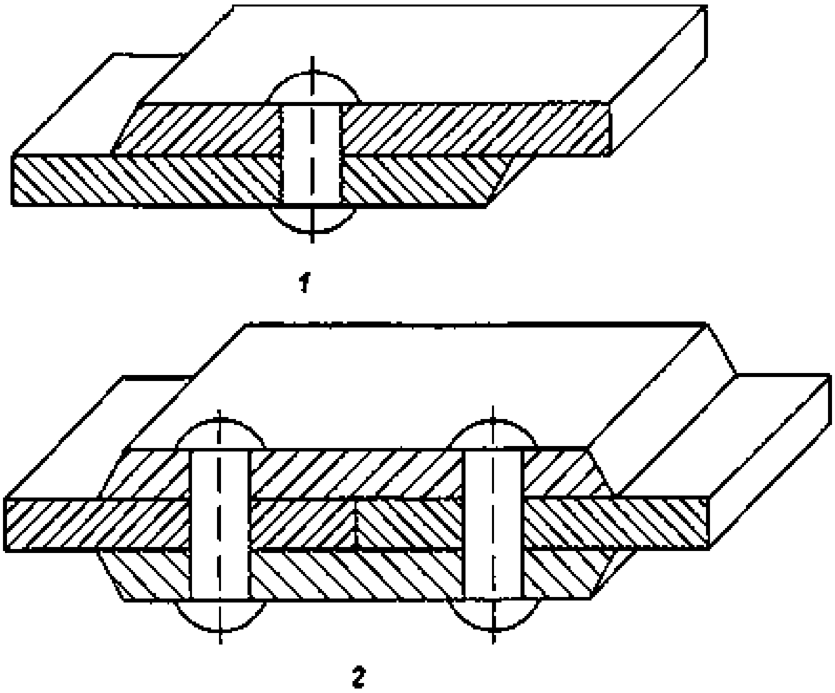


Fig. 12.9. Types of rivet joints

1 = overlapping riveted joint
2 = double−strap riveted butt joint

<u>Repetition:</u>

1. Explain the basic rules of the representation of sectional views, using Fig. 12.7.

2. Why has the button−head rivet shown in Fig. 12.7. not been shaped although it is in the cutting plane?

3. Quote examples where rivet joints occur.

4. According to the example given in Fig. 12.8., prepare sketches of a countersunk−head riveted joint raw and driven

Steel structures usually are drawn at a reduced scale.

To save time for drawing and to facilitate clear recognition of connections in drawings, rivets used in steel construction are represented by symbols, as is shown in Fig. 12.10.

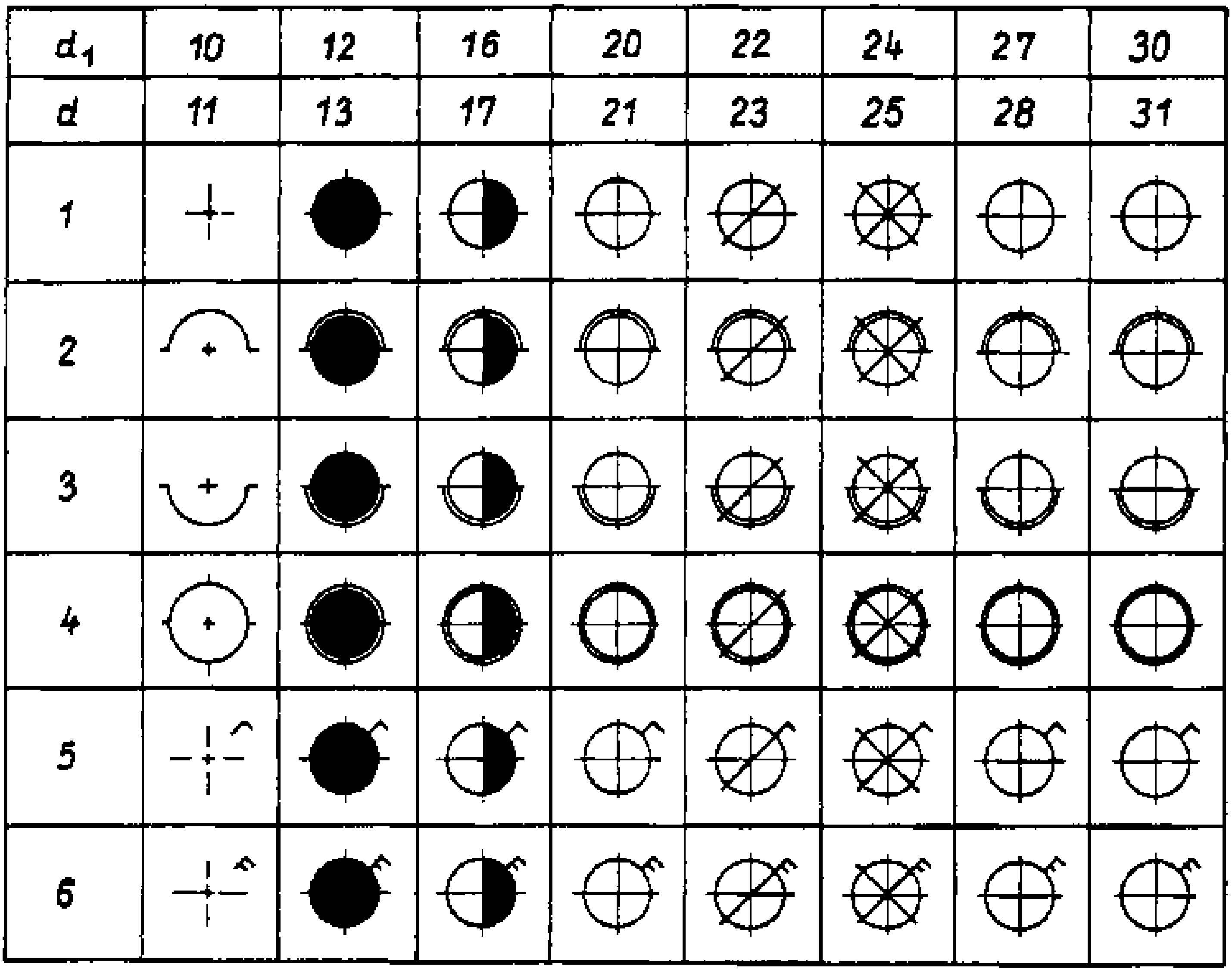


Fig. 12.10. Symbols for rivets

d_1 = diameter of rivet before driving,
d = rivet hole diameter
1 = button−heads on both sides,
2 = rivet countersunk on top
3 = rivet countersunk on the bottom,
4 = rivet countersunk on both sides,
5 = rivet is driven at the site
6 = rivet holes are drilled at the construction site

The symbols of rivets shown in Fig. 12.10. give information about the shape of the rivet (button−head rivet, countersunk−head rivet), about the diameters of raw rivet (i.e. the rivet before driving) and the diameter of the rivet hole, about the place of rivet shaping and the place of rivet hole drilling (workshop or construction site).

– In the first column, the diameter of the raw rivet is given, from d_1 = 10 mm up to 30 mm; these are the sizes which can be delivered.

– In the second column, the appertaining rivet hole diameter can be read. It is always for 1 mm larger than the diameter of the rivet before driving.

– In the third column, the symbols of the button−head rivets are drawn, they change in dependence on the diameter of the rivet before driving. For the rivet diameters of 27 mm and

30 mm, the rivet hole diameters required, i.e. 28 mm and 31 mm, respectively, is written in the form of a numerical value on the top left of the symbol.

– In the fourth, fifth and sixth columns, the symbols of the countersunk–head rivets are given with an indication if they have to be applied on each side, to be countersunk from top only or from bottom only.

– In the seventh and eighth columns, information is given about where the rivet is driven at the construction site and if the rivet hole has to be drilled at the construction site also.

In a drawing of a scale of up to 1:5, for the symbol the size of the rivet hole diameter (d) is drawn, when the scale is smaller, the rivet hole diameter (d_1) is drawn for better readability.

The reference diameter for the location of the symbols always is the section diameter; for oblique sections, the symbols have to be entered into the drawing according to the rules of dimensioning. In the side view only a thin solid line is drawn as the symbol and projects beyond the cross–section of the parts to be joined. A few examples are given in Figs. 12.11. and 12.12.

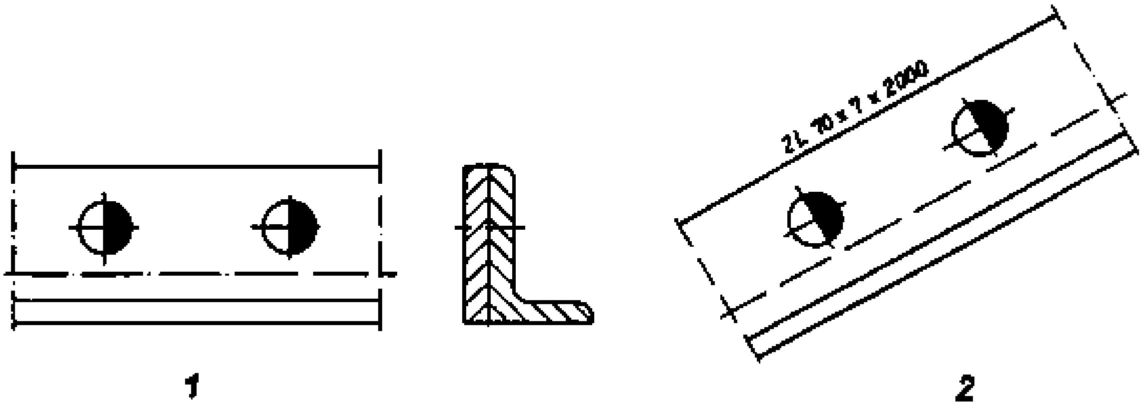


Fig. 12.11. Rivet joint with two rivets (16 mm in diameter)

1 A plate and an angle section are riveted together
2 Double angle rivet joint, oblique

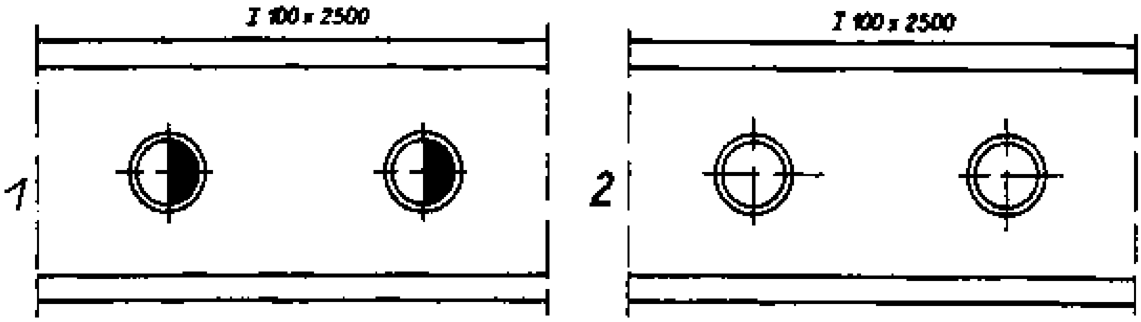


Fig. 12.12. Rivets countersunk on both sides

1 = Diameter of rivet before driving 16 mm
2 = Diameter of rivet before driving 20 mm

Repetition:

1. Using the Table given in Fig. 12.10., explain the rivet symbols shown in Figs. 12.11. and 12.12.

2. Draw the symbols of the following rivets:

Button–head rivet 12 mm, countersunk–head rivet 12 mm countersunk from top, button–head rivet d_1 = 10 mm, button–head rivet 20 mm to be driven at the construction site, and rivet to be countersunk from below of d_1 = 30 mm.

3. When have numerical values to be applied to the symbols?

Depending on the size of the parts to be joined together and the steel sections used, the parts can be riveted together in different ways. The arrangement of the rivets is shown in Fig. 12.13.

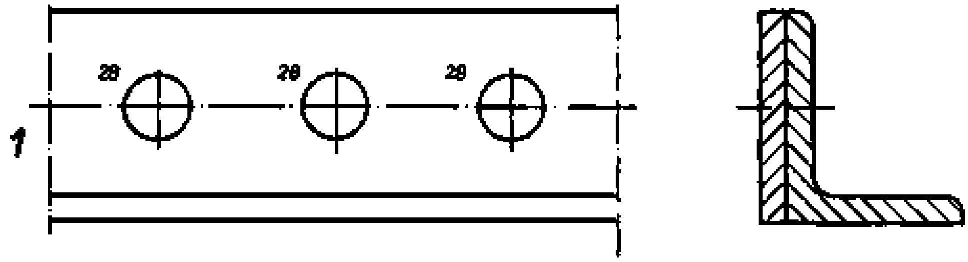


Fig. 12.13.1. Examples of riveted joints

1 = Single−row riveted joints

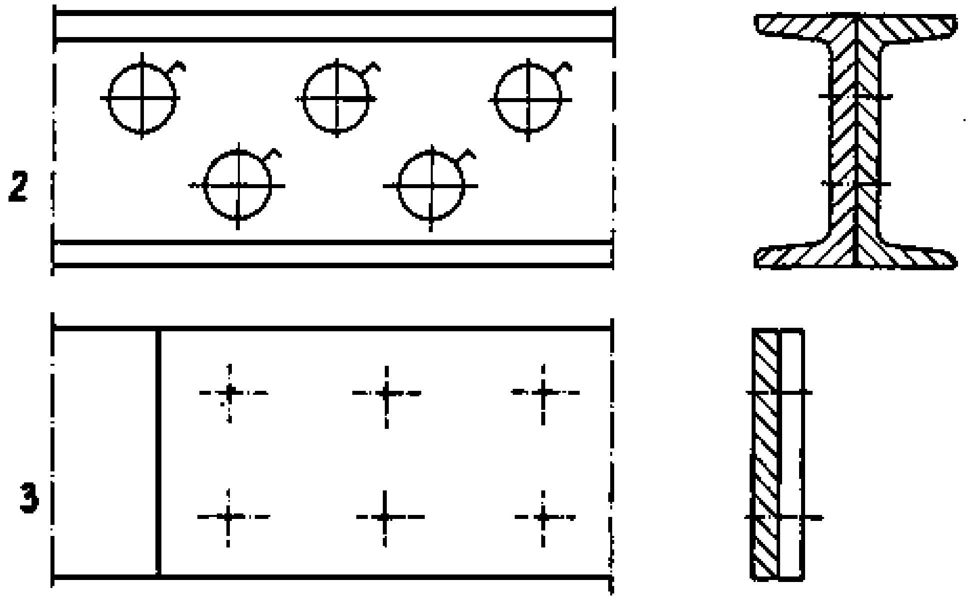


Fig. 12.13.2. Examples of riveted joints

2 = Two−row joint, rivets are staggered
3 = Two−row joint, parallel arrangement of the rivets

Repetition: Solve the problem sheet No, 48.!

12.2.2. Bolted Joints

In steel construction, detachable connections are frequently required. The assembled structure or component can be disassembled into the individual parts without the necessity of destroying the elements or parts of the connection. For this purpose, screws and bolts with nuts are used. After loosening the connection, they can be used further whereas in case of riveted joints the rivet must be drilled out, the die head and driven head must be chiselled off or ground off, hence, destroyed. Generally, hexagon−head bolts are used in steel construction.

For minor purposes, bolts without fit are used. Their general feature is that the shank or external thread diameter d_1 is smaller than the hole diameter (d). Consequently, the bolt (Fig. 12.14.) can easily be inserted into the hole. It is shown that a complete bolted joint consists of the hexagon−head bolt, a suitable hexagon nut and, between nut and part to be joined, a washer. As in riveted joints, the hole diameter in the parts to be joined and in the washer is always for 1 mm larger than the shank and external thread diameter.

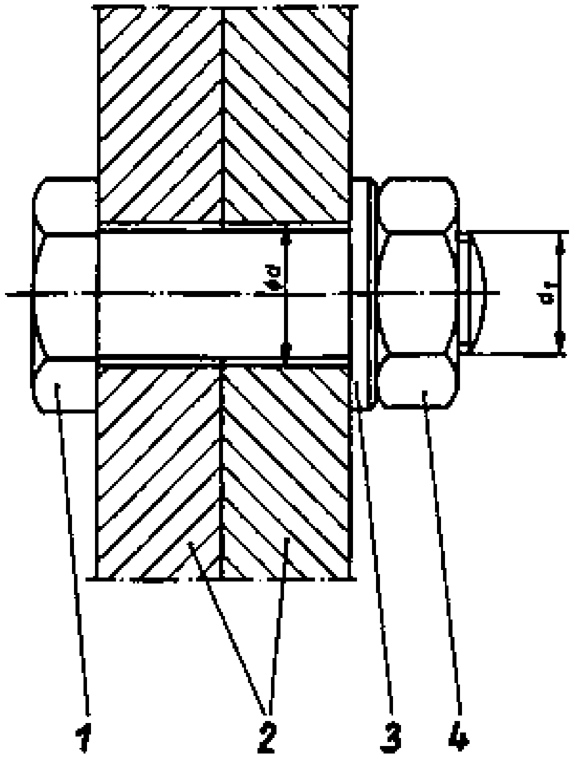


Fig. 12.14. Bolt for which a fit is not specified

1 = bolt
2 = parts to be joined

Repetition:

1. Explain the thread designations M 10, M 16, and M 30.

2. How large have the hole diameters in the parts to be connected and in the washers for the examples mentioned in problem 1 to be?

3. Explain the representation of the thread in Fig. 12.14.

For joints subjected to high stresses, the precision bolt, also known as fitting bolt, is used. In this case, the diameters of hole and shank are of the same size. The bolt shank completely fills the hole. Therefore, the bolt hole is reamed to the diameter (d) before assembling and then the bolt is fitted. Precision−bolt connections (Fig. 12.15.) have the same carrying capacity as rivet joints.

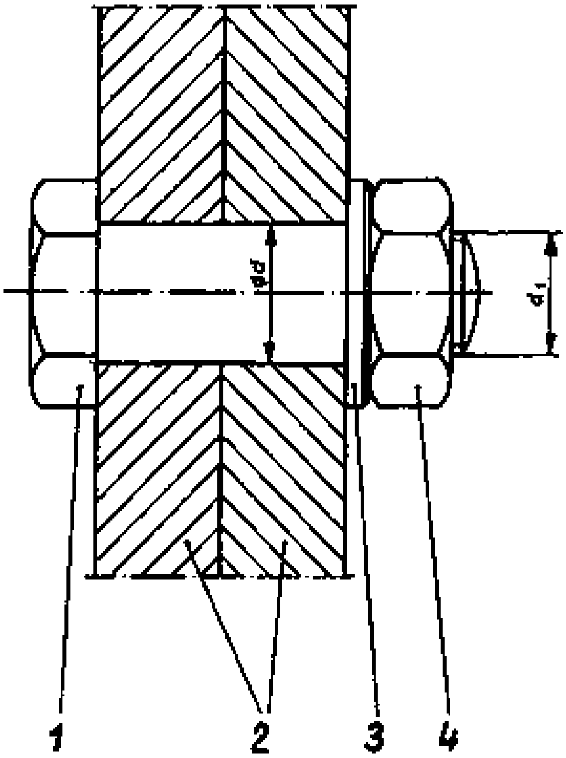


Fig. 12.15. Precision bolt or fitting bolt

3 = washer
4 = nut

The illustration shows that the bolt shank is offset. The threaded portion having the diameter (d_1) follows the shank to be fitted in (d). The threaded portion is for 1 mm smaller than the shank and hole diameter.

To save time for drawing and for greater clarity of the drawing symbols are used for bolts in steel construction, as is shown in Fig. 12.16.

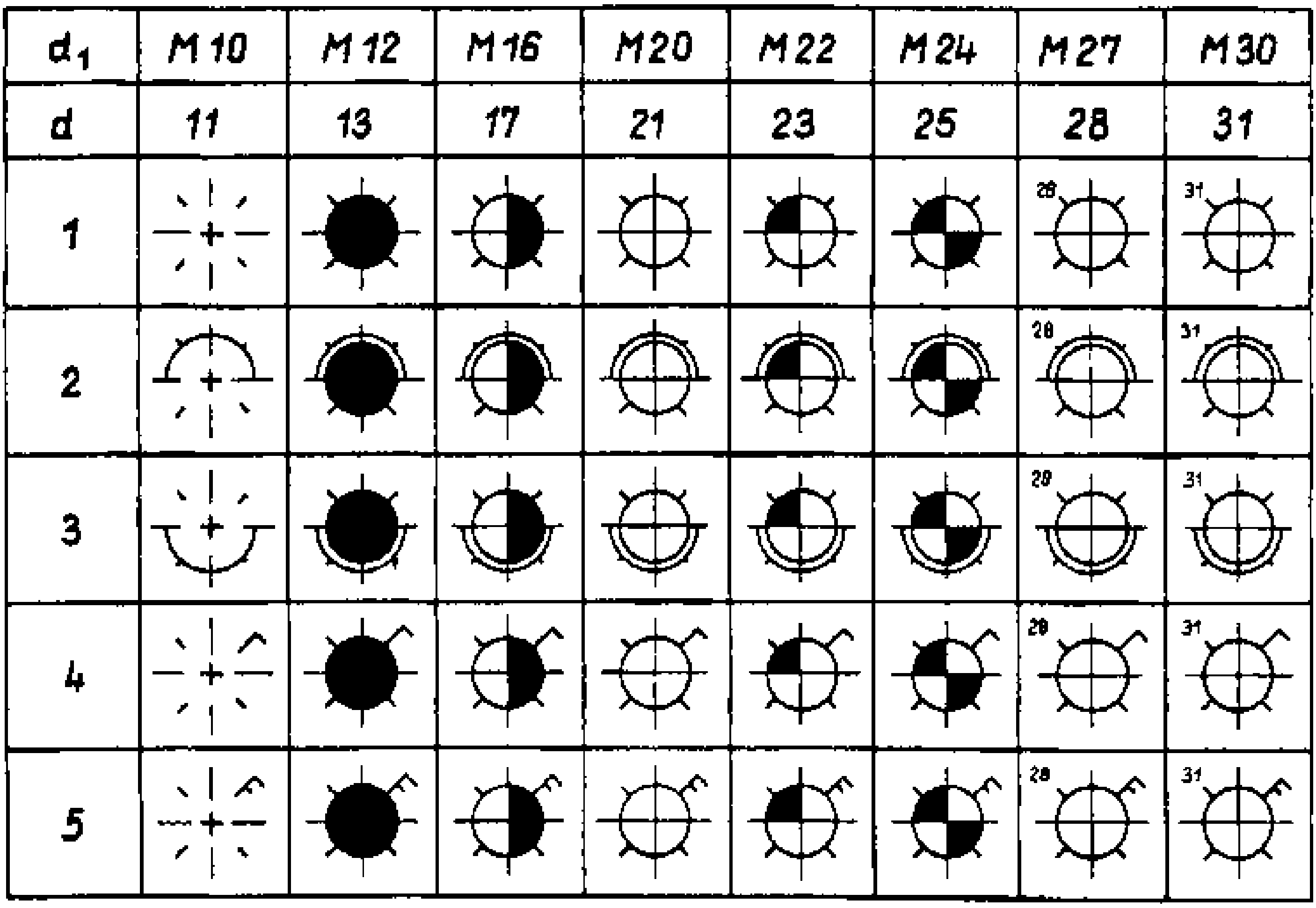


Fig. 12.16. Symbols for screws

d_1 = thread diameter of the bolt,
d = hole diameter
1 = bolts with a normal through hole,
2 = bolts countersunk on top,
3 = bolts countersunk on the bottom,
4 = bolts are fitted at the construction site,
5 = bolt holes are drilled at the construction site

– In the 1st line, the thread diameter with the respective abbreviated designation is shown.

– In the 2nd line, the size of the hole for the thread is indicated.

– In the 3rd line, the symbol are represented. They are changed with the thread diameters in question. For the bolts M27 and M30 and all sizes of threads not included in the Table, the same symbol is used and the respective hole diameter, in these two examples 28 and 31, is added to the symbol on top to the left.

– In the 4th and 5th lines, bolts countersunk from top and bolts countersunk from below are shown. They are flush with the surface.

– In the 6th and 7th lines it is indicated whether or not the bolts have to be fitted at the construction site and whether or not the bolt holes have to be drilled at the construction site.

For the location and size of the symbols the same is to be observed as has already been said with respect to rivets. A few examples are given in Figs. 12.17. and 12.18.

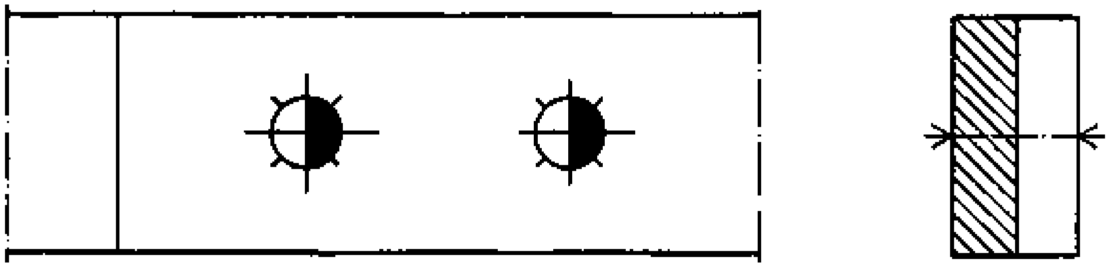


Fig. 12.17. Bolted joint with two M16 bolts

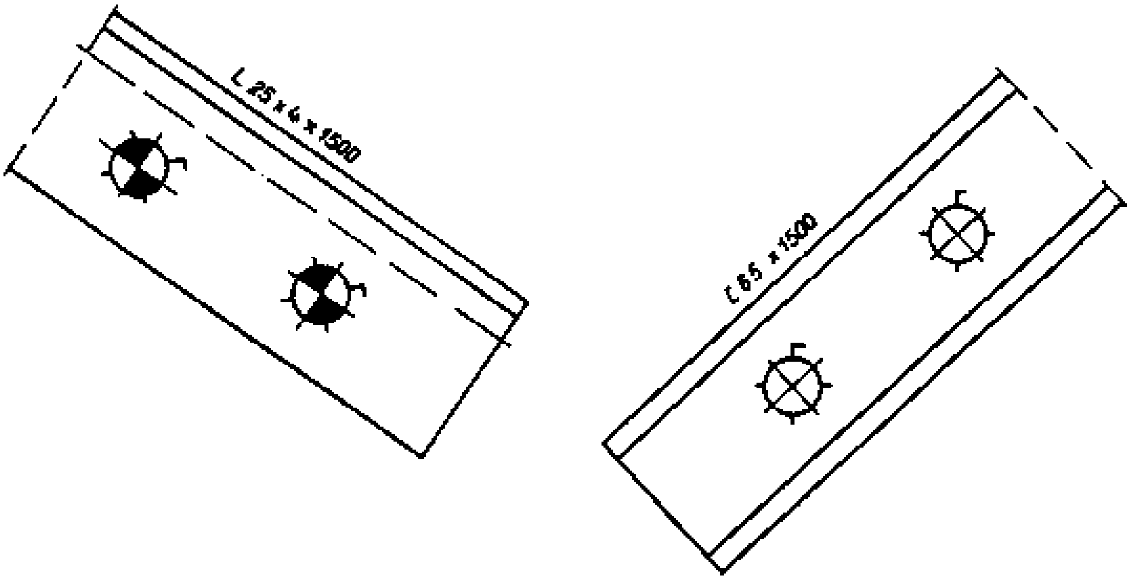
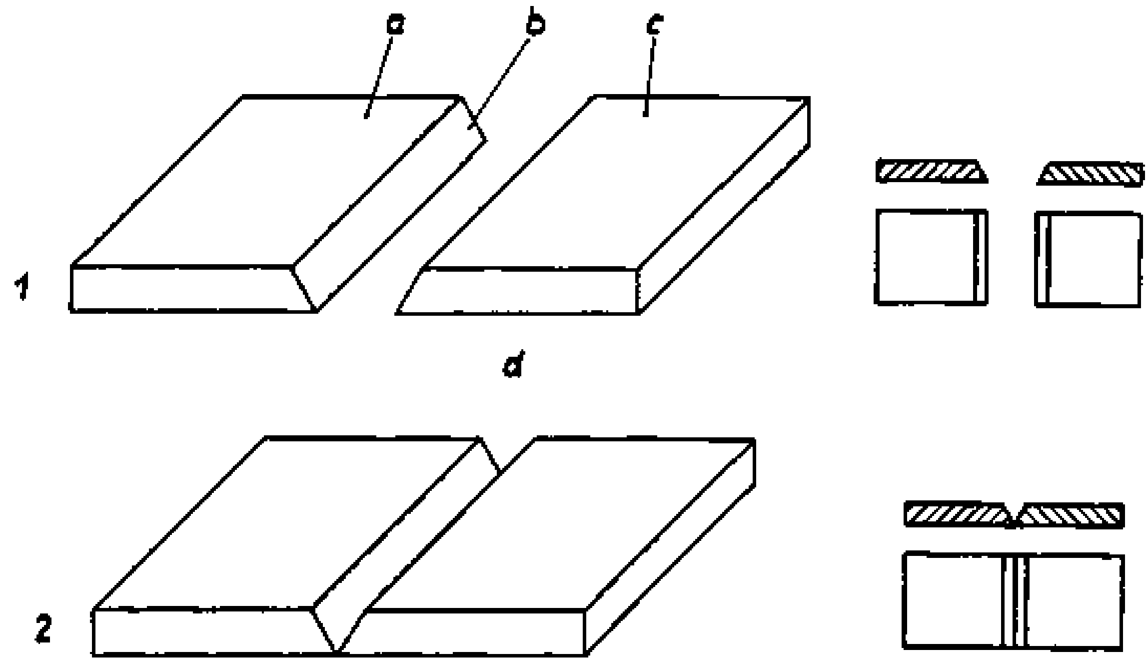
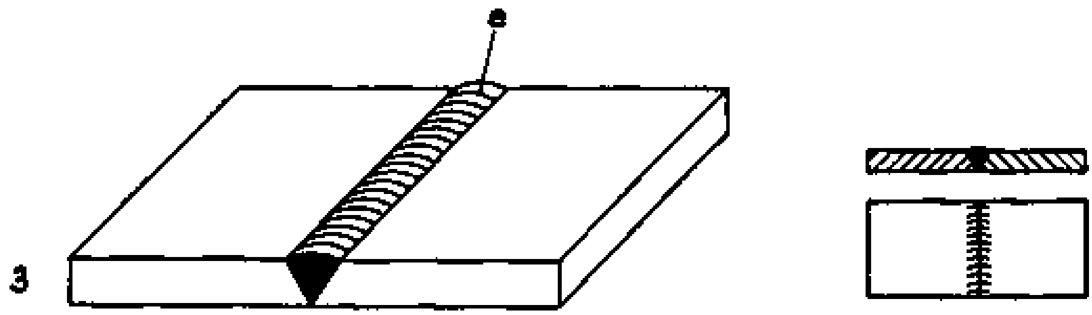


Fig. 12.18. Examples of bolts to be fitted at the construction site

1 = bolts M 24,
2 = bolts M 20

Fig. 12.19. Operational steps in the production of a weld seam

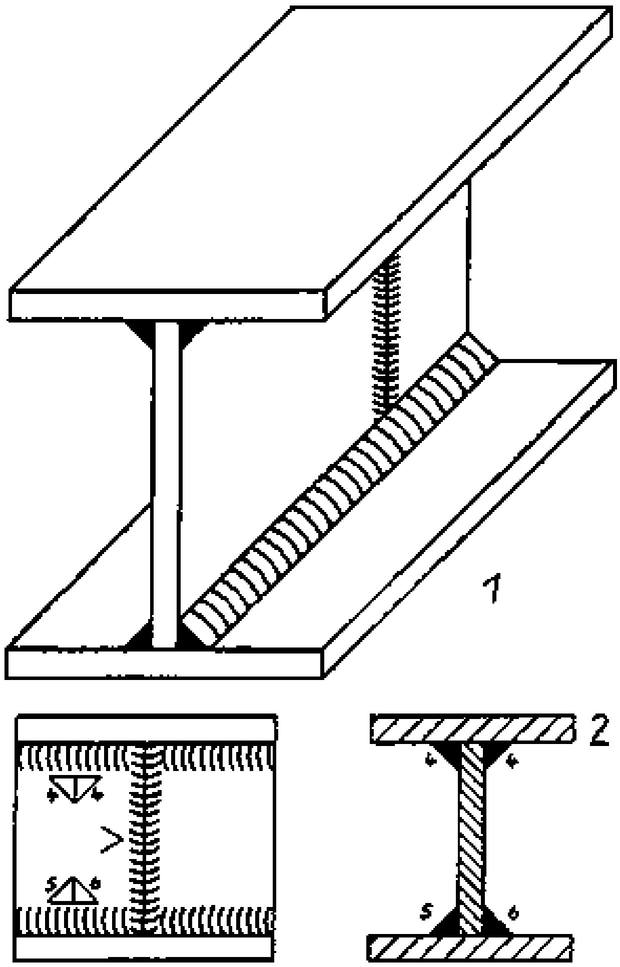


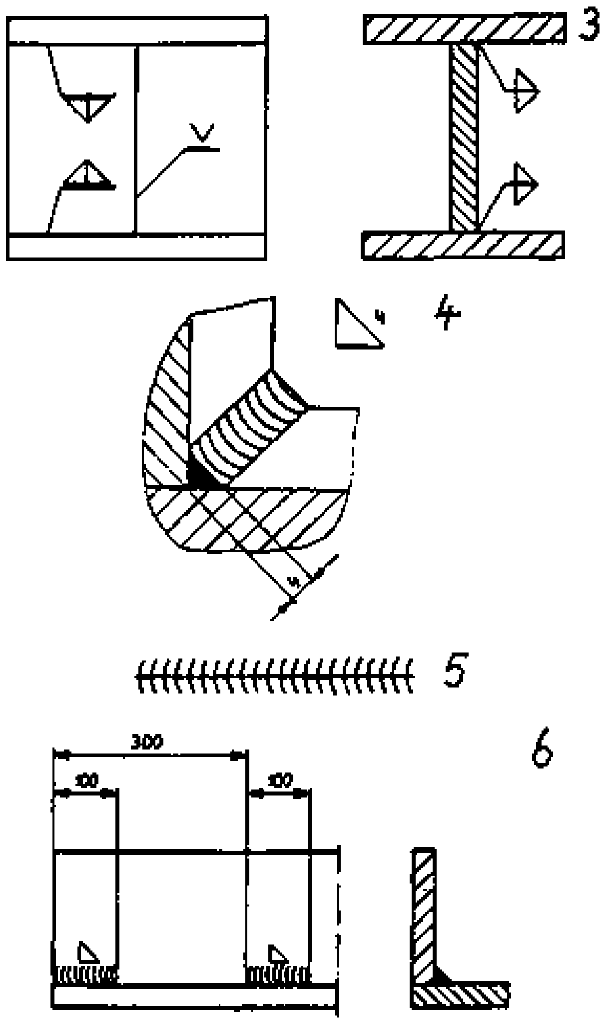


1 = prepared individual parts,
2 = position required for welding,
3 = welded parts,
a = single part 1,
b = area of groove,
c = single part 2,
d = groove,
3 = weld seam

In the pictorial representation of welds, the weld beads should be drawn as bead ripples to indicate the course of the weld. Each weld bead is provided with a certain symbol. This symbol is entered above the weld beads. In the sectional view, the actual form of the seam becomes visible and is fully blackened. All of the necessary welding dimensions are shown only once, either in the main view or in the section. In the following illustration (Fig. 12.20.) it is demonstrated how a fillet weld seam should be dimensioned (thickness = 4 mm).

Fig. 12.20. Pictorial and symbolic representation of weld seams





1 = perspective,
2 = pictorial representation,
3 = symbolic representation,
4 = statement of thickness of fillet weld
5 = through weld,
6 = interrupted weld

When thicknesses of the welds are different, then the two fillet weld thicknesses must be specified. For this purpose, the thickness numerals are applied to the long side of the symbolic triangle. If the weld is interrupted, the weld in the drawing is also shown in an interrupted representation and dimensioned accordingly.

Repetition:

1. Determine the symbols given in Figs. 12.17. and 12.18. according to Table 12.16., check and explain the symbols.

2. Draw, in front view and side view, the symbols for M16, M12 countersunk from top; M24 to be fitted at the construction site; and M30 with the bolt holes to be drilled at the construction site.

3. Draw the symbols for a button–head rivet having a diameter of 16 mm and for a bolt M16 in two views. Compare these two views.

4. Solve the problem sheet No. 49.

12.2.3. Welded Connections

Besides riveting and bolting, welding is frequently used in steel construction. The welding of joints or connections usually is effected by the fusion arc welding process which can be carried out by hand or by machine. An advantage of this process is the reduction of mass so that the structure becomes lighter. The individual parts are firmly joined together and can be subjected to high stresses. The joining can be effected rapidly and in a simple manner. Broken parts can be rapidly welded and then again be subjected to the full load. It must be taken into consideration that due to the great heat to which the parts are exposed distortion of them can occur. Before the production of a welded connection, the parts involved must be prepared, in other words, a certain form of groove must be prepared. The weld seam is deposited in this groove in one or more passes. Since there are many forms of welds, the respective grooves must be prepared carefully.

In Fig. 12.19., steps in the production of a weld are shown in perspective and in two views (V−type weld).

Forms, positions and sizes of the welds must be clearly visible in the views and sectional views. For this purpose, the pictorial and the symbolic representations are used.

In the symbolic representation of the weld bead, the form of the weld is not drawn true to scale and the ripple is not shown. In the main view and in the sectional view, the weld is only represented as a line (thick solid line) and, with the help of leaders, provided with symbols and the weld thickness and weld length in numerals.

Weld seams are drawn pictorially and symbolically. The pictorial representation is preferred for the sectional view and the symbolic representation for the main view.

Repetition:

1. Explain the composite section represented in Fig. 12.20. How does it differ from a respective individual section?

2. Name the distinguishing features between the pictorial and the symbolic representation of weld seams.

3. Why have different directions of shading been used in Figs. 12.19. and 12.20.?

4. Draw the welded joint shown in Fig. 12.19. symbolically in two views!

The forms of weld seams include butt−welded seams, edge welds and fillet welds. The specified form must be taken into consideration in the preparation of the groove in the parts to be welded together and must be indicated in the drawing. When the parts to be connected are in one and the same plane, i.e. they are abutting, butt welds have to be produced. The most important types, their symbols and the possibilities of their pictorial and symbolic representations are shown in Fig. 12.21.

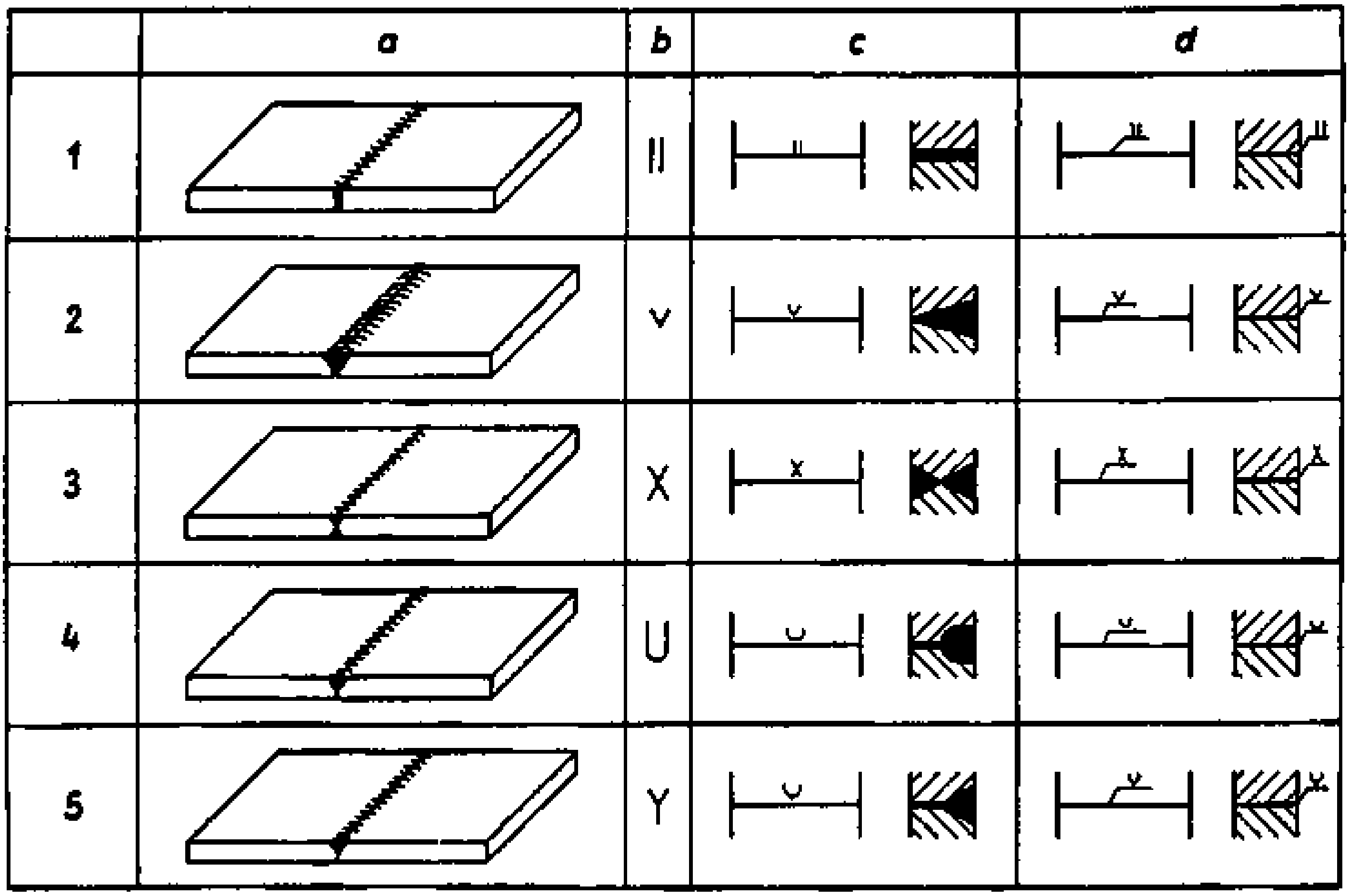


Fig. 12.21. Butt welds

1 I–weld,
2 V–weld,
3 double V–weld,
4 U–butt weld,
5 Y–weld
a perspective,
b symbol used,
c pictorial representation
d symbolic representation

When part arranged in parallel which have to be connected at their faces, then one speaks of edge welds. Usually, two types are used. Their symbols, their pictorial and symbolic representations in drawings are shown in Fig. 12.22.

Frequently, parts have to be welded at an angle of 90° or any other angle. This can be achieved by a **fillet** weld. If a fillet weld is to be produced on two sides, then it is called twin fillet weld. In Fig. 12.23., their symbols, their pictorial and symbolic representations are explained.

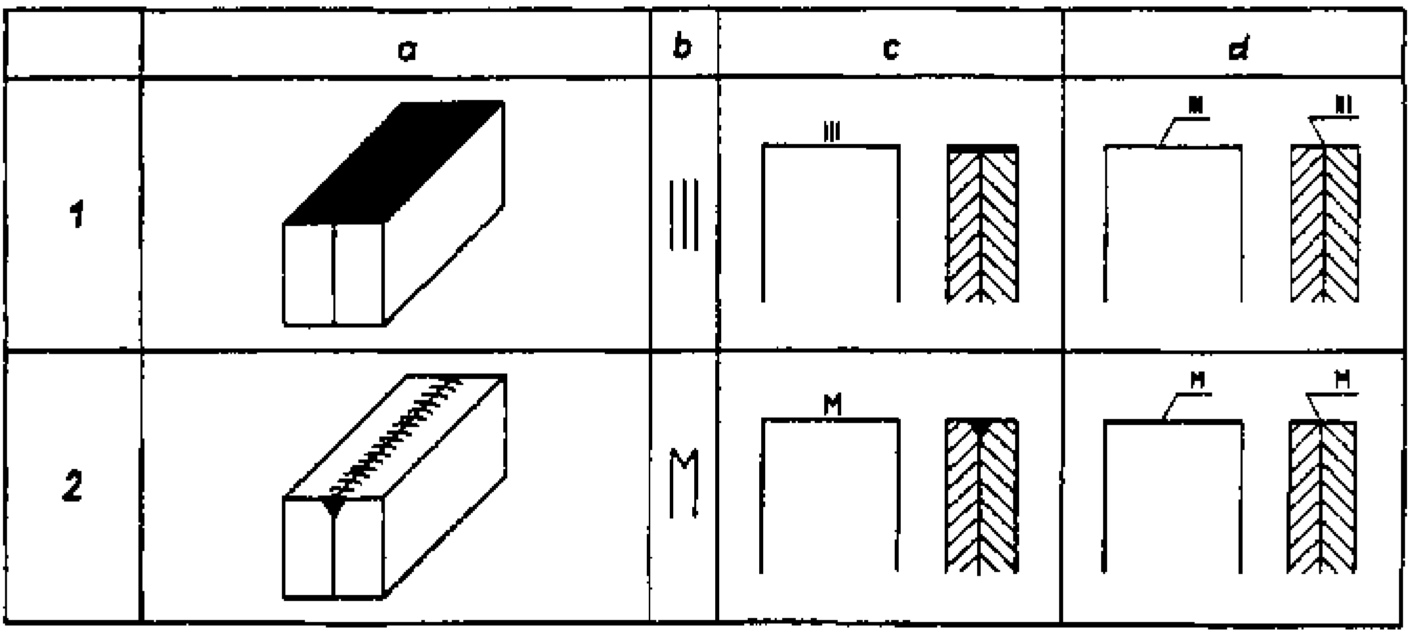


Fig. 12.22. Edge welds

1 edge joint weld,
2 edge groove weld
a perspective,
b symbol used,
c pictorial representation
d symbolic representation

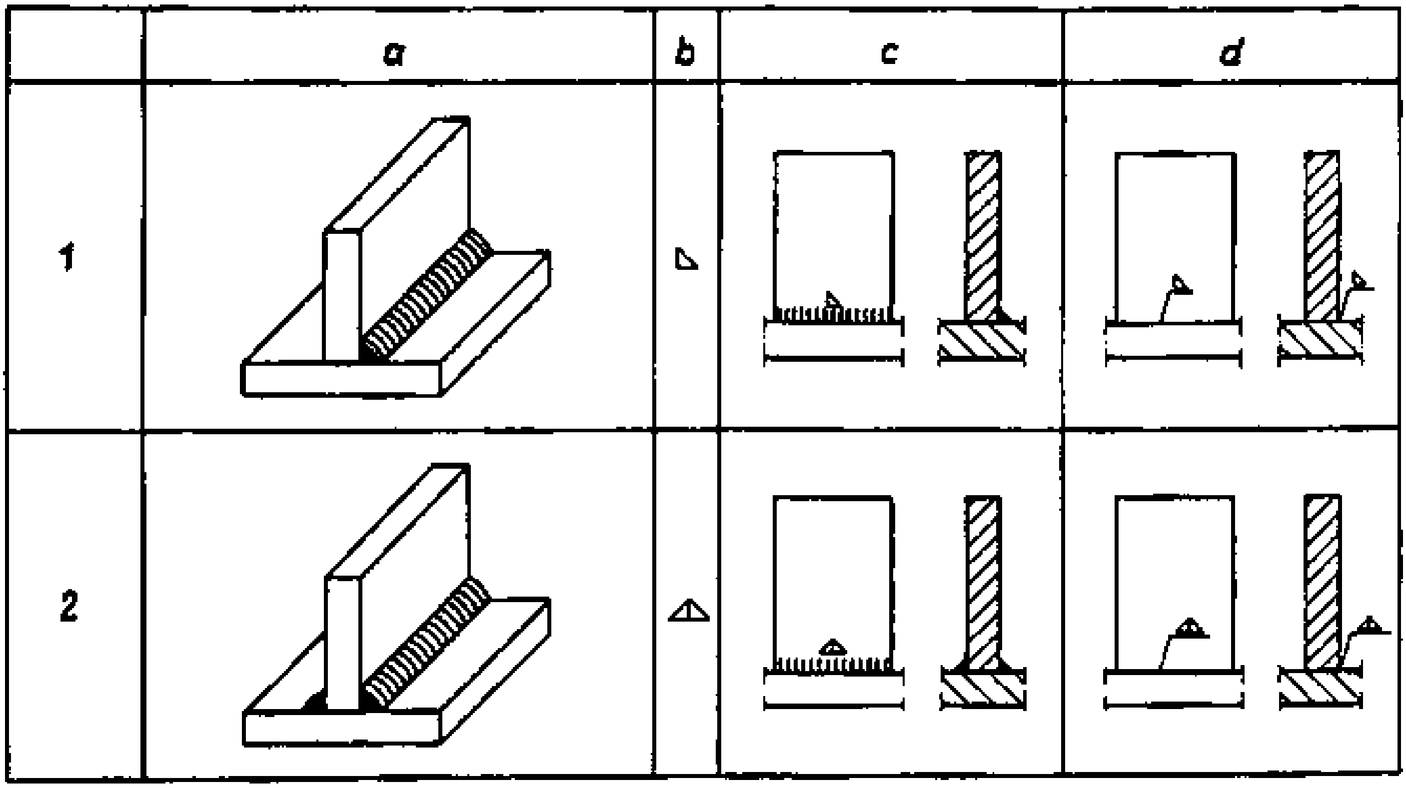


Fig. 12.23. Fillet welds

1 fillet weld,
2 twin fillet weld
a perspective,
b symbol used,

c pictorial representation
d symbolic representation

Repetition:

1. Explain the symbols and simplified representations of the welded section shown in Fig. 12.20.

2. Draw the front view symbolically and the side view as a full sectional view when two flat steels 200×35×1000 have to be connected as follows:

– as I weld (square butt weld), V−type weld and X−weld (double−Vee butt weld) with size 200×35×2000,

– edge weld with size 200×70×1000,

– as isosceles angle section (fillet weld)

– as −section (twin fillet weld).

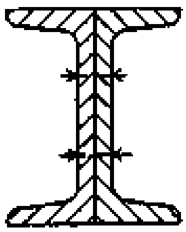
3. Solve the problem sheet No. 50.

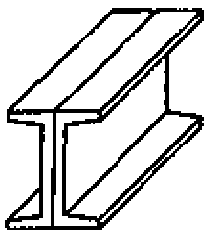
12.3. Examples of Structural Units and Design Problems in Steel Construction

12.3.1. Tension Ties

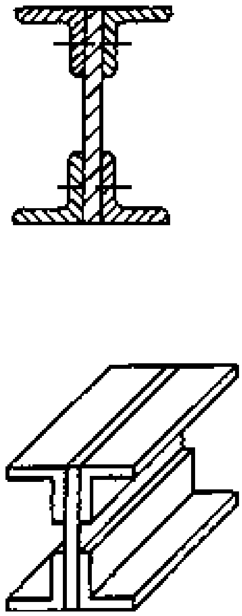
When structural parts in steelwork are subjected to tension, tension ties are used. Usually, these are tension ties in framework or tie rods in framing systems. Tension ties can consist of a single section or a cross−section which is made up of several single sections. Composite cross−sections can be riveted, bolted or welded. Flat steel and plates are not suited as single section because they may easily bend during the construction of the structural member or structure. Tension tie sections must be quite simple and, above all, symmetrical. Due to the use of composite sections, it is possible to produce desired cross−sections in workshops of the enterprise which cannot be produced by the steel works and rolling mill or only at high costs. In Fig. 12.24. a few selected designs of tension ties are shown.

Fig. 12.24. Tension tie sections

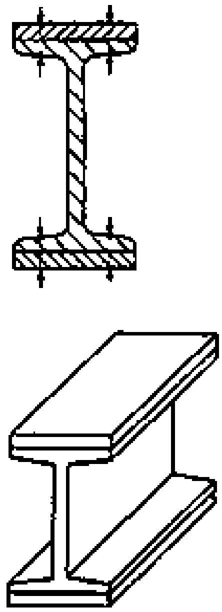




a



b



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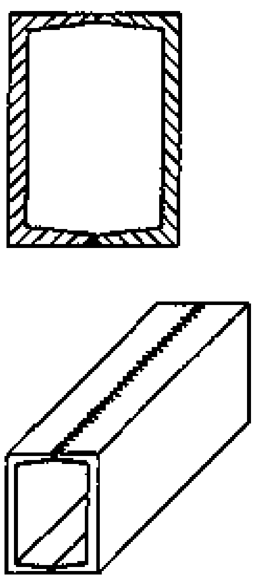

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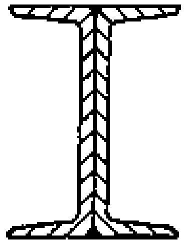

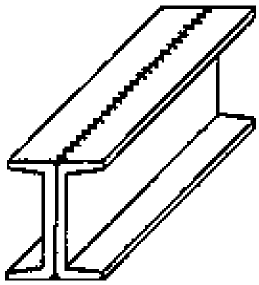

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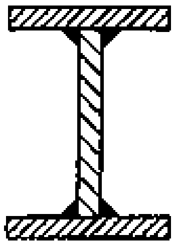
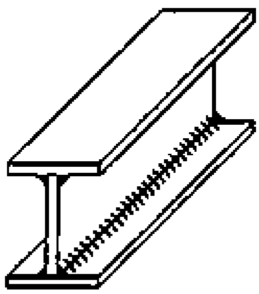




f

a = bolted section of two individual sections
b = riveted section of four individual sections
c = reinforced single section
d = welded box section
e = section welded of two individual sections
f = I–section welded of flat steel parts

Repetition:

1. Explain the types of connections or joints represented in examples a to f of the above illustration.

2. Draw the front view of all 6 examples (select a diameter of 16 mm for both bolts and rivets).

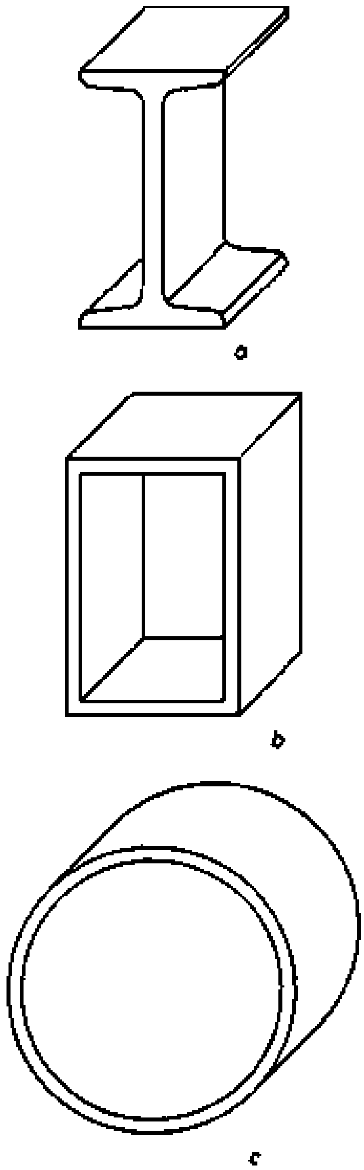
3. Prepare sketches showing for each of these tension ties the necessary single sections in perspective and repeat the abbreviated designations for the latter.

4. Sketch a possibility to produce the box section d by a bolted or riveted connection.

12.3.2. Designs of Compression Bars or Members

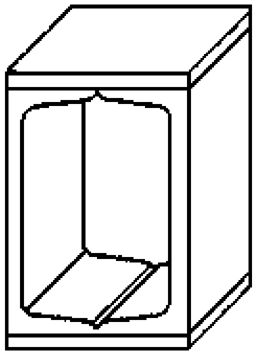
When structural parts have to transmit compressive forces in steel construction, then they are called compression bars or compression members. They must have certain geometric shapes in order that they cannot buckle under load. Single sections and cross−sections composed of various sections are used. In any case, they must be resistant to buckling. The selected examples (Fig. 12.25.) only show the position of the sections with respect to each other but not the type of connection.

Fig. 12.25. Compression bars or members

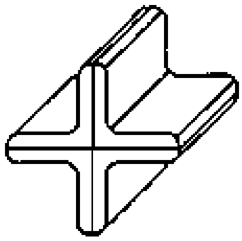


a = I−section,
b = box section,
c = round section

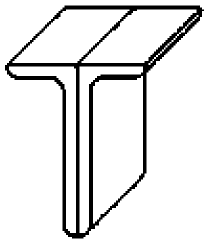
Fig. 12.25. Compression bars or members



d



e



f

d = composite, reinforced box section,
e = composite four−angle section,
f = composite double−angle section

<u>Repetition:</u>

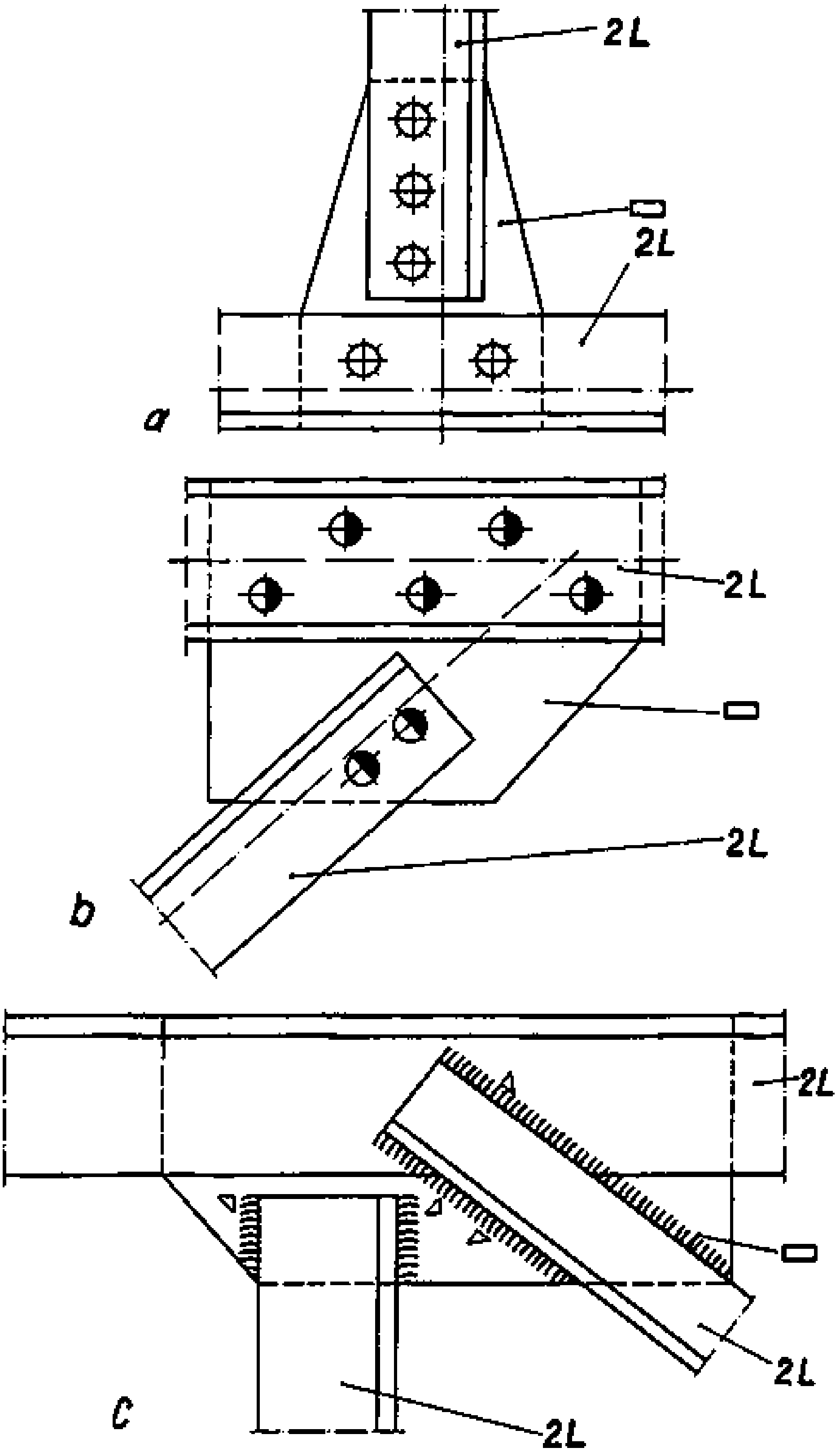
1. Draw the six compression bars shown in perspective in front view and in side view.

2. These cross−section can be rolled of one piece or riveted, bolted or welded of several single sections. Sketch for each example another solution.

12.3.3. Gusset Plates and Butt Joints

The tension ties and compression members are connected with each other in the nodal or junction points, i.e. points of connection of ties and members. This connection frequently is established by gusset plates. With the help of these plates, several sections which meet each other at certain angles can be joined by riveting, bolting or welding. The gusset plates can be represented on drawings in true size. It is possible and rational to use the drawing as a pattern for flame−cutting the shape of the gusset plate out of the steel plate so that marking by means of a scriber is omitted and time saved. Below follow three examples of gusset plate constructions Fig. 12.26.).

Fig. 12.26. Gusset plates



a = bolted gusset plate
b = riveted gusset plate
c = welded gusset plate

Repetition:

1. Explain the symbols of the connections and sections represented in Fig. 12.26.!

2. For the riveted and bolted gusset plate, prepare a sketch showing a possibility of producing a welded construction!

3. Replace the welded representation by a riveted one!

4. Prepare a sketch showing the three gusset plates as single parts!

Frequently, ties and bars must be connected at their abutting ends to obtain greater lengths (see Fig. 12.27.). In this case, the webs are provided with cover plates (2) and further cover plates (1) are mounted on the flanges. This ensures a firm connection of the butt joint which can be subjected to the specified loads. Rivets, bolts and weld seams are used as the connecting elements. An example of the butt joint of a tension tie in a riveted version is shown in Fig. 12.27.

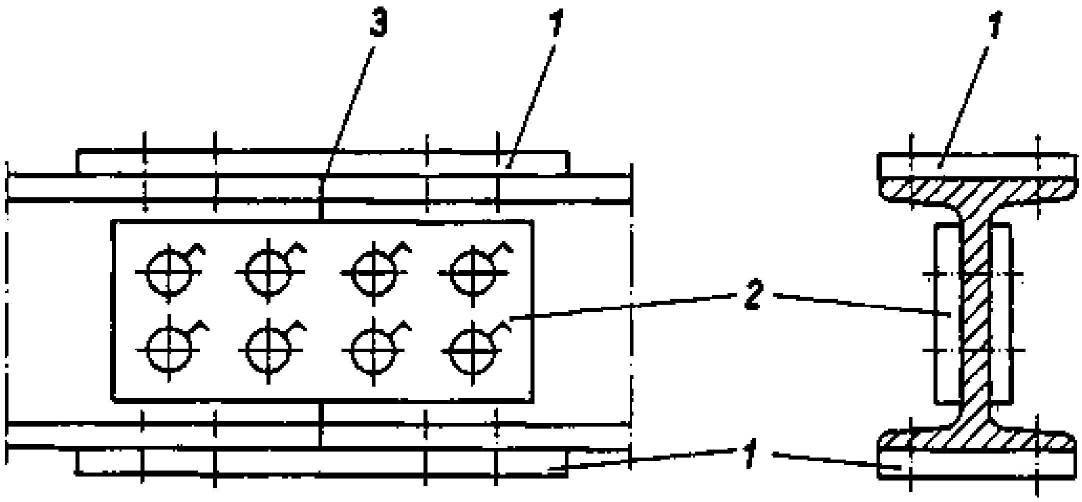


Fig. 12.27. Riveted butt joint of tension ties

1 = cover plate on top,
2 = cover plate on web,
3 = butt joint

Repetition:

1. Sketch the cover plates (Fig. 12.27.) on the flanges and the cover plates on the webs with the rivet holes.

2. Explain the symbols of the rivets and those of the sections.

3. Prepare a sketch of the tension tie connection in the welded version! The front view should be represented symbolically and the side view pictorially as a section.

4. What are the symbols to be used when the butt joint has to be established by means of bolts and the bolt diameter should be equal to the rivet diameter?

12.3.4. Rigid Beams and Stabilisations

Besides tension ties and compression members, rod–type structural elements, which are subject to deflection by the forces involved, are used in steel construction. These rigid beams must be stable in their shape and size to that effect that they withstand the specified stresses. In case of small spans, rolled steel sections are used. A few of these sections have been dealt with in Section 12.1. Applications of these rigid beams are, for example, longitudinal members and cross beams in steel bridge construction, beams for smaller hoisting gear, and ceiling beams for buildings. When higher forces are involved, the rolled single sections frequently are too weak. This also applies to large spans. Therefore, new sections are made up of individual elements and plates.

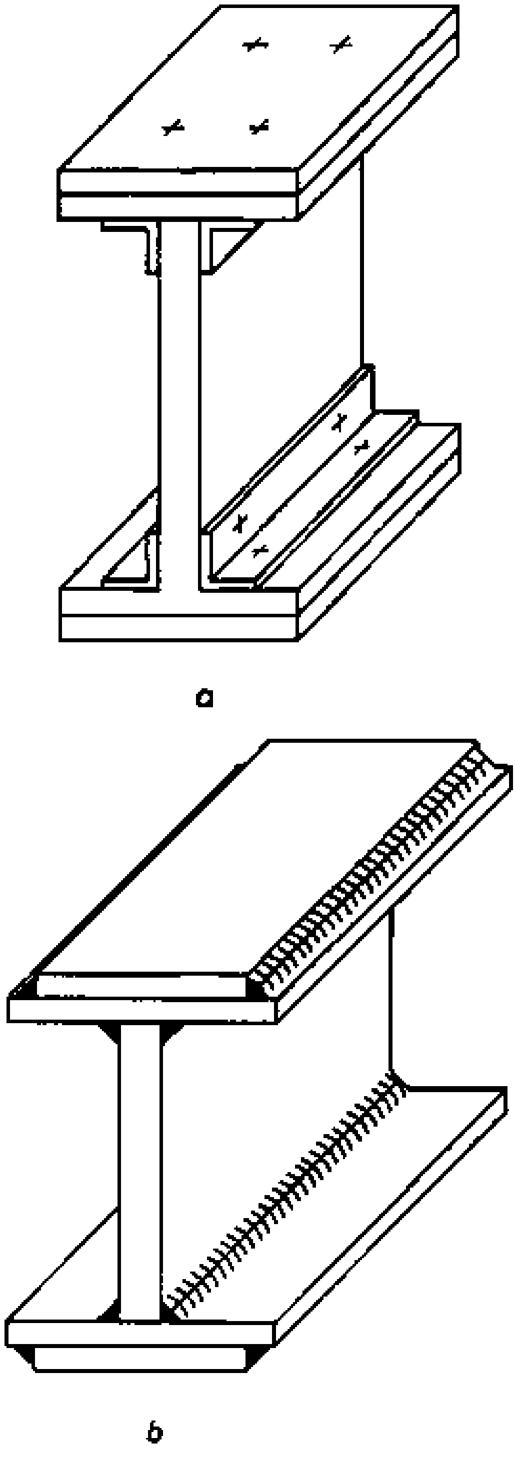
Connections have to be established by rivets and welding processes. These composite sections are used as main beams for steel constructions.

According to the forces to be taken up, rod–shaped sections are grouped in tension ties – which are subjected to tension –, compression members – which are subjected to pressure –, and rigid beams – which are subjected to deflection.

A few of the composite rigid beam types in riveted and welded versions are shown in Fig. 12.28.

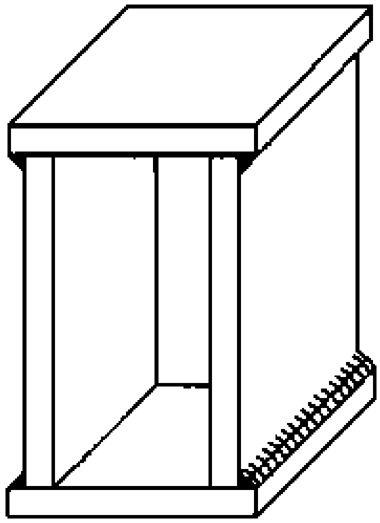
Sections are stabilised by chords of which frequently several are used for one beam; as a consequence, the sections can withstand higher loads without changing their gravity axis and deflecting. For butt joints of rigid beams – similar to the example given in Fig. 12.27. – the webs are provided with cover plates and chords are mounted. A stabilisation of a rigid beam butt joint is shown in Fig. 12.29. It is clearly shown that the chord in this case is one part.

Fig. 12.28. Composite rigid beam



a

b



c

a = riveted steel plate girder
b = welded steel plate girder
c = welded box section beam

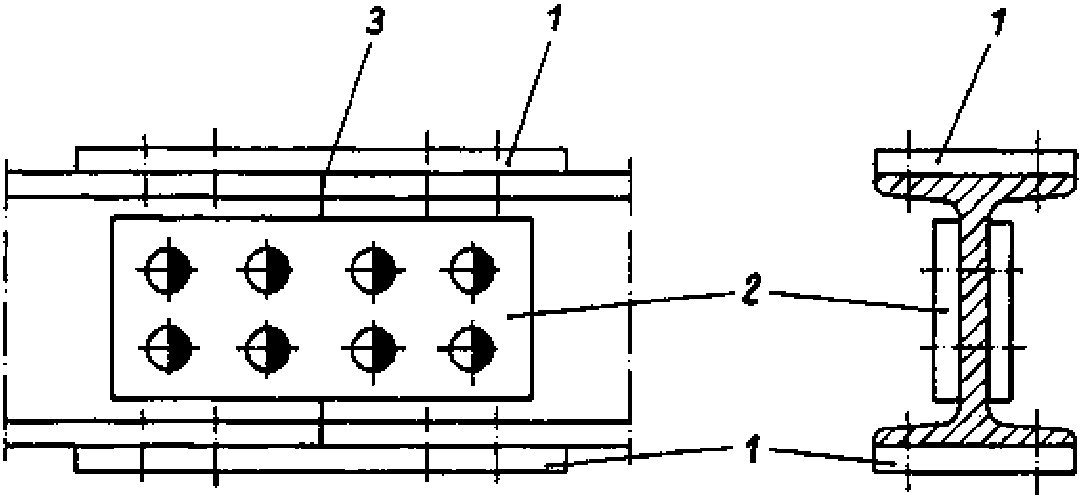


Fig. 12.29. Riveted butt joint of rigid beams

1 = top cover plate (chord plate),
2 = cover plate
3 = butt joint

12.3.5. Beam Connections

Rigid beams are incorporated in steel constructions. In contrast to gusset plates for supporting tension ties and compression members, rigid beams are fastened by means of rigid−beam connections. These are frequently simple angular straps. Widely used are rivets and bolts for connecting. It is possible that both types of fasteners are used in one beam connection. Such a combined arrangement including a supporting angle (1) and two angular straps (4), partly bolted and partly riveted, is shown in Fig. 12.30.

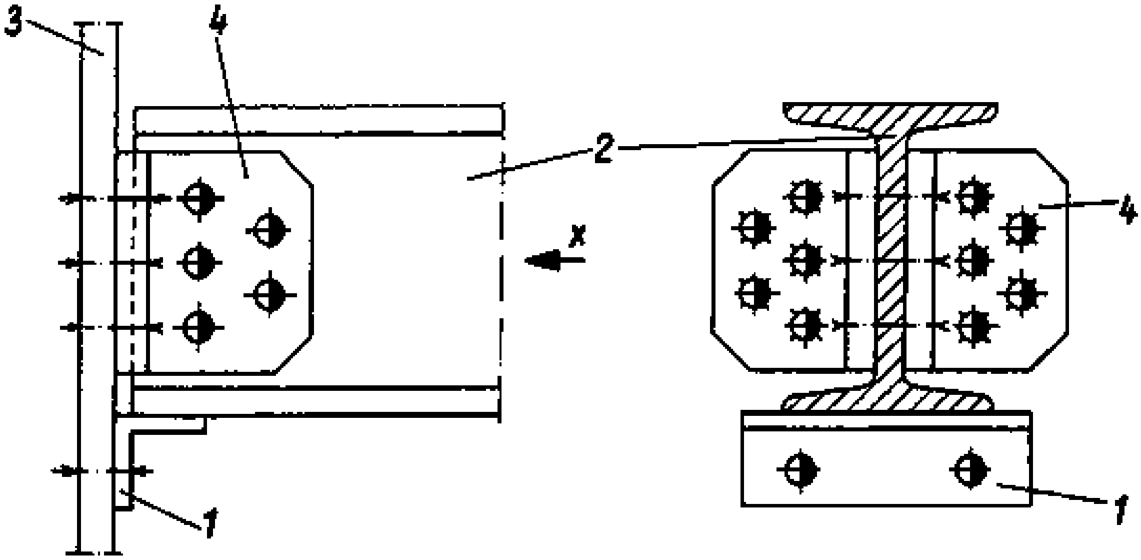


Fig. 12.30. Beam connection

1 = supporting angle (riveted),
2 = I–beam,
3 = connecting part
4 = angular, straps (riveted to the rigid beam, bolted to the connecting part)

Repetition:

1. Describe compression members, tension ties and rigid beams' according to load, shape and connections.

2. Explain the symbols and simplified designations and the individual parts or the beam connection shown in Fig. 12.30.

3. Prepare a sketch of the individual parts 1 (supporting angle) and 4 (connecting angles) shown in the above illustration and state the hole diameters.

4. Consider Figs. 12.27. and 12.29.! What are the differences?

12.3.6. Columns and Frame Corners

Forces acting vertically can be taken up by columns. These columns transmit the compressive forces from adjacent structural units to the foundations. The columns must have an adequate section in order that they do not buckle. For anchoring to the foundation, a foot plate (5) is welded to the column (see Fig. 12.31.). In order to increase the contact area for the beam to be carried, a top plate (3) is welded to the upper end of the column. A stone bolt (6) is used to connect the column of the foundation.

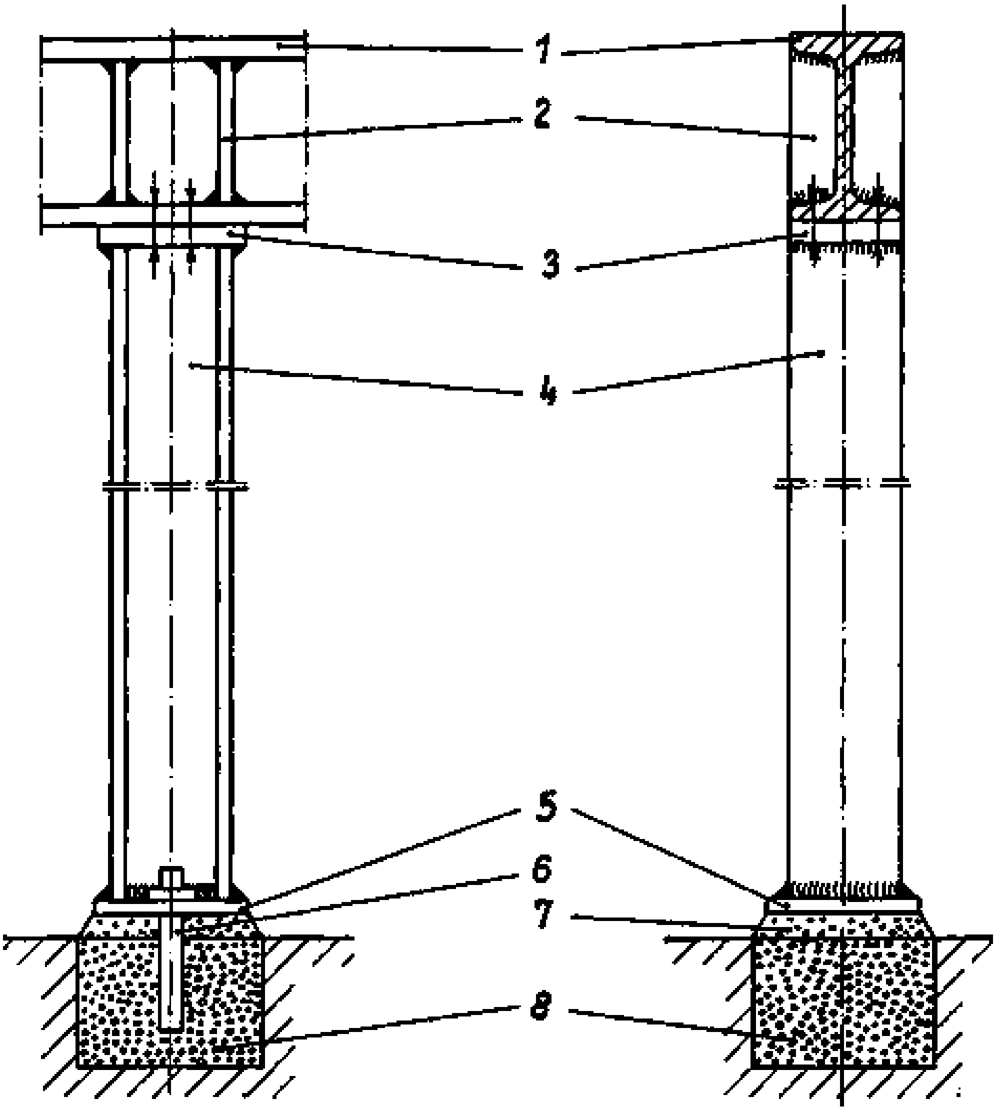


Fig. 12.31. Column (basic construction)

1 = beam to be supported,
2 = stiffening plates,
3 = head plate,
4 = column shaft,
5 = foot plate,
6 = stone bolt
7 = mortar bed,
8 = foundation

The beam to be carried is provided with stiffening plates within the area where it contacts the column. This is a rigid design.

But columns can also be made in an articulated form. This is the case in bridges where thermal expansion must be taken into consideration. When high forces are involved, both the column head and the column foot must be siffened. Small columns can be embedded in concrete directly.

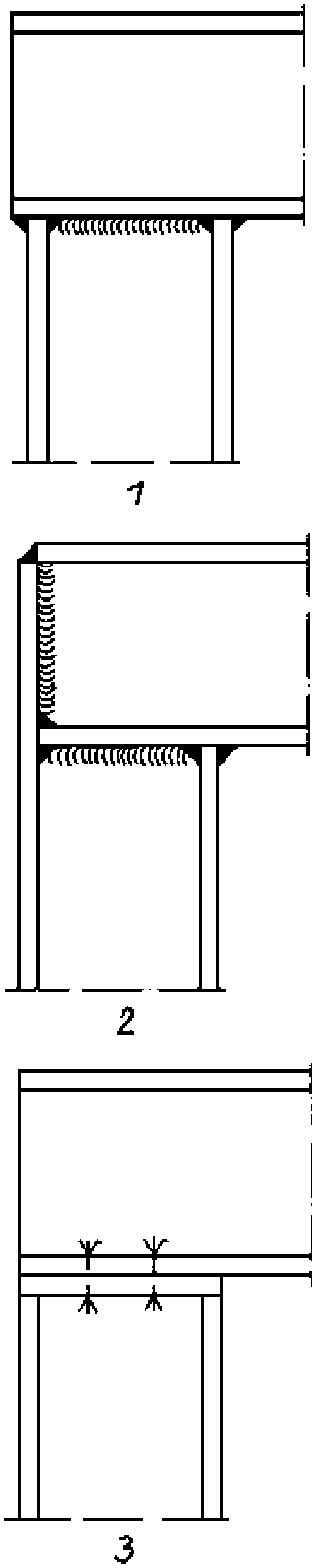
Columns transmit compressive forces from beams and rods to foundations.

In hall and steel skeleton structures, frequently framework, is incorporated. For this purpose, beams and columns are connected in such a way that forces acting on this arrangement cannot widen and distort this connection. Since these connections have the appearance of corners of frames, they are called frame corners.

Frame corners are rigid connections of beam and rods or bars with columns.

Framework usually is provided with welded and bolted connections (see Fig. 12.32.).

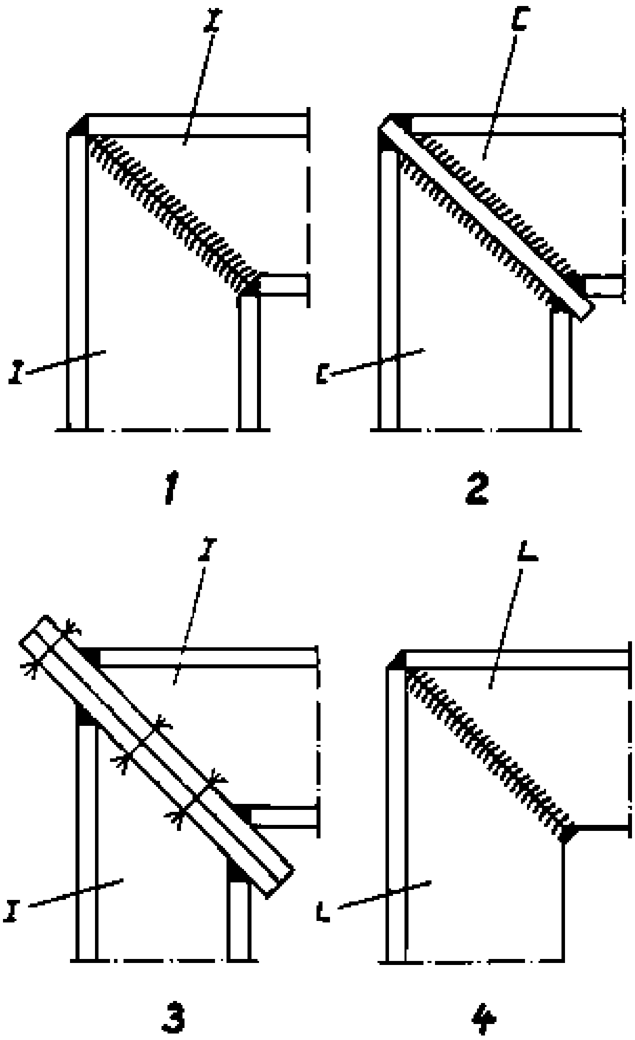
Fig. 12.32. Frame corner with beams in place



1 = welded frame corner,
2 = welded frame corner,
3 = frame corner bolted at the construction site

Another type of connection is the mitred joint. It can be used when beam and column have the same section. The ends of both members are cut at an angle of 45 and then joined. This construction (see Fig. 12.33.) is simple and is used for static loading. The sections prepared by mitre cutting are connected either directly or by means of contact plates. The mitred joints are welded, bolted or connected by combining welding and bolting.

Fig. 12.33. Frame corner with mitred joint



1 = welded corner of I–sections
2 = welded corner with contact plate
3 = corner bolted at the construction site with welded–on contact plates
4 = frame corner welded of L–sections

Repetition:

1. What are the functions of columns and frame corners?

2. Explain the welded joints pictorially represented in Figs. 12.31. to 12.33.

3. Sketch the symbolically presented views of the frame corners.

4. What is the reason for the use of contact plates in the frame corners with mitred joint?

5. Why have the mortar bed shown in Fig. 12.31. and the foundation not been shaded?

6. Explain the task of the stone bolt shown in Fig. 12.31.

7. Explain how columns and frame corners have to be mounted in order to prevent accidents.

8. Solve the problem sheet No. 51.

12.4. Drawings in Steel Construction

12.4.1. Working Drawing

The working drawing is, according to its content, the overall drawing and, according to its purpose, the assembly drawing. The working drawing contains obligatory data for the production and the assembly of steel structures. All of the essential data, i.e. dimensions, sections and clear information about the connections, must be provided. For the sections, abbreviated designations, and for the bolts, rivets and weld seams, the respective symbols are used.

The complete representation of the entire structure, the structural units and the individual parts requires that, besides the necessary views, one or more sectional views have to be drawn. Especially the connections of the sections and plates have to be provided with comprehensive information. This cannot be given in clear drawings and dimensions cannot be provided because of the reduced scale of the drawings of structures. Therefore, these points are represented as details. Because of the size of the parts in steel construction., the details can be drawn in the scales 1:1, 1:2 or 1:5. The scale selected is added to the word “detail” at the point in the drawing where the detail is represented.

Gusset plates can be drawn as patterns in original or true size. When gusset plates are located in the cutting plane, then they are not represented in the cut state, this also applies to standardised parts.

A precondition of the preparation of a working drawing is the design drawing. It contains the essential main dimensions. Details are only given when connections to other, already existing, steel structures are necessary.

The working drawing can be prepared as a drawn or a sketched representation. The sketch is the simplified form of a working drawing. Shapes, rivet and bolt spacings are represented in outline or approximately by freehand sketching. Working drawings in the form of signs and symbols have to be made in the scales of 1:10, 1:15 or 1:20. The example of a gusset plate (shown in Fig. 12.34.) with the appertaining rods illustrates a working drawing in steel construction.

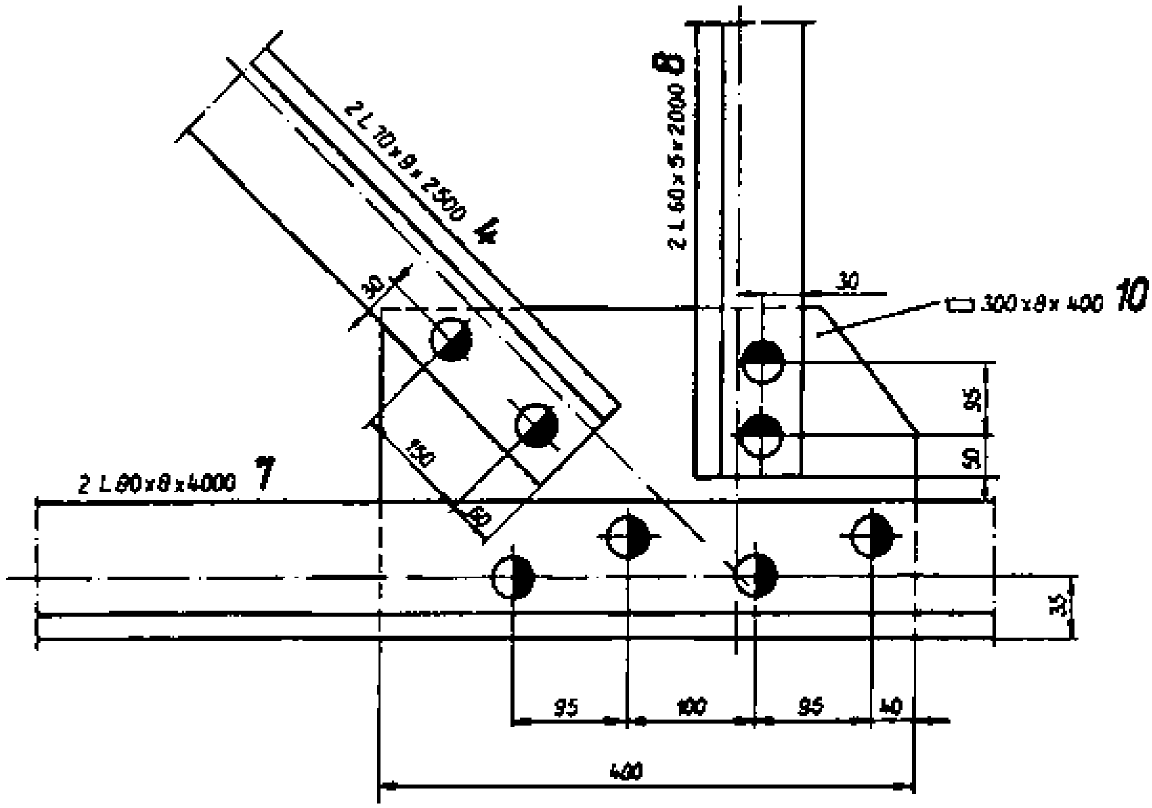


Fig. 12.34. Example of a working drawing

The working drawing in steel construction is the complete representation of a construction with all dimensions, symbols and data for manufacture and assembly.

Repetition:

1. With the help of Section 1.2. “Types of Drawings”, explain the terms of drawing, sketch, overall drawing and assembly drawing.

2. What are the types of drawings contained in the problem sheets No. 48 to No. 51?

3. Enumerate the data which must be contained in a working drawing in order to ensure the production and assembly of the parts or of the construction.

4. Explain the single parts of the gusset plate design shown in Fig. 12.34. and the symbols.

5. Prepare sketches of the single parts with two views for each part.

6. Dimension the single parts! The holes have been drilled in the workshop and, thus, must also be dimensioned.

12.4.2. System Drawings

It is common practice in steel construction to draw the constructions for a certain information in the form of a system. This method of representation provides a clear survey. To simplify the work of drawing and to ensure recognition of the dimensions of mounted sub–assemblies, only the system lines, i.e. the location of the gravity lines, are drawn as thick solid lines.

In the system drawing, the dimension figures are written directly on the system line without the use of dimension lines, extension lines and arrowheads. As a basic rule, the numbers must be readable from the front and from the right. For oblique rods, the numerals are entered in accordance with the dimensioning of angles.

Sections, connecting elements and joints are not represented. Instead, the lengths of the assembly arid the total dimensions of the structure are given clearly for rapid reading. System drawings are drawn in the scales of 1:50, 1:100, 1:200 or 1:500. An example for this way of representing is the part of a framework shown in Fig. 12.35.

System drawings are simplified representations of the structural units of a steel structure. Lengths and total dimensions are written directly on the system lines.

In frameworks, the rods can be arranged in the form of a triangle; this triangular component is a structural unit.

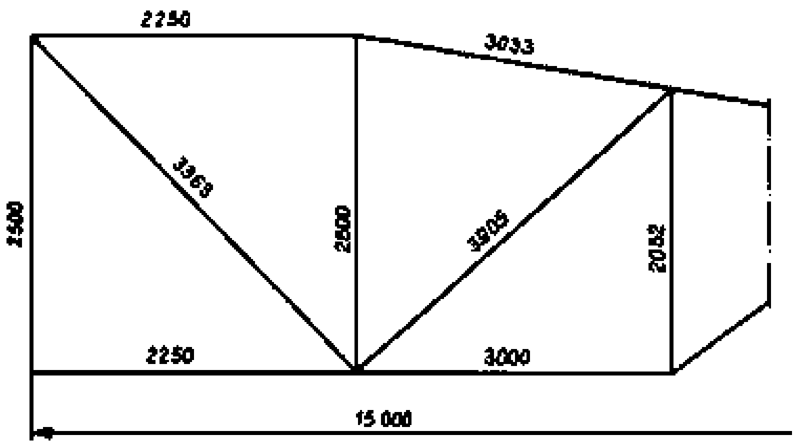


Fig. 12.35. Example of a system drawing

In the working drawing, the system size must be easily perceivable in the multitude of parts and dimensions. For entering the system dimensions, a triangle of thin solid lines is drawn; this is a special case of the system drawing. This system triangle may be drawn not to scale (Fig. 12.36.).

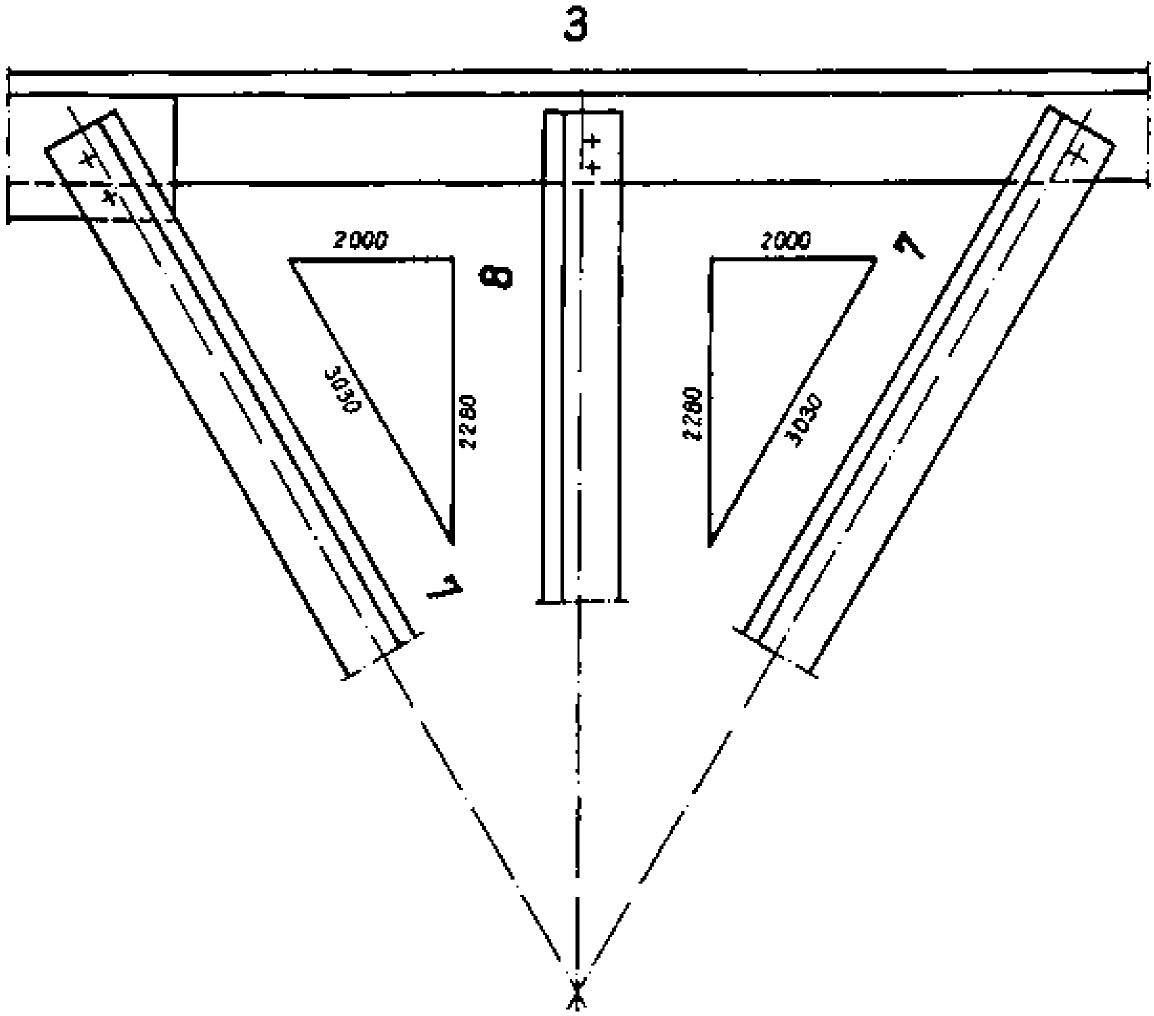


Fig. 12.36. Representation of a system triangle inside the structural unit

If space permits, this triangle should be arranged unside the structural unit. The system dimensions are written directly on the sides of the triangle without dimension arrowheads.

The part numbers are derived from numbering the single parts. The numbers of the single parts, twice as high as the other dimension figures, are placed behind the section designations. Parts of the same size and the same section have one and the same number, the quantity is given in the list of parts. This applies to part No. 7 shown in Fig. 12.36.

Repetition:

1. Explain the sections shown in Fig. 12.36.

2. Substantiate why the lengths of the system triangle deviate from the rod lengths.

3. How are single parts marked in drawings of steel construction?

12.4.3. Altitude Drawings

In scaffolds, in buildings and other steel structures, the altitude i.e. the elevation of the object in question above ground, must be stated. The various levels are indicated by leaders. An isosceles triangle, fully blackened, is placed on the leaders or reference lines (Fig. 12.37.), and the distance to ground is stated in millimetres. The ground is equal to the altitude zero. On the opposite side of the object drawn, the altitude above sea–level is indicated in metres with three decimal places, practically as an extension of the zero line. Depth specifications of the foundation are entered into the drawing with negative sign related to the zero line.

Altitude indications serve for the arrangement of floor, scaffold and foundation levels related to ground. The respective signs must be added.

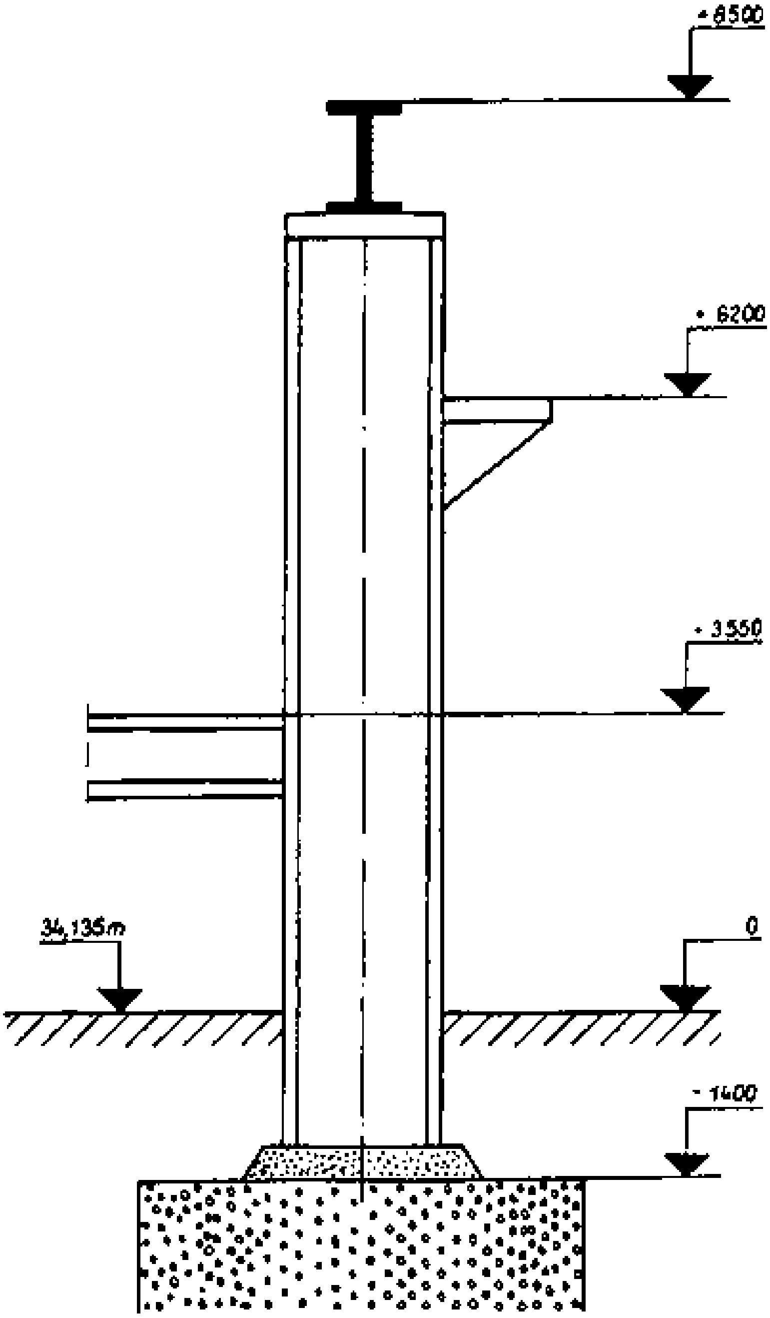


Fig. 12.37. Example of an altitude drawing

12.4.4. Axes and Rows

Steel structures frequently consist of very many beams, rods and columns. In order to specify their relative locations clearly and in order to be in a position to recognise them immediately in sectional representations, steel structures are divided into axes and rows (see Fig. 12.38.). Axes are system lines which pass through the length of the steel structure. They are provided with capital letters inscribed in a circle. Rows run across the axes at a certain angle that is determined by the construction.

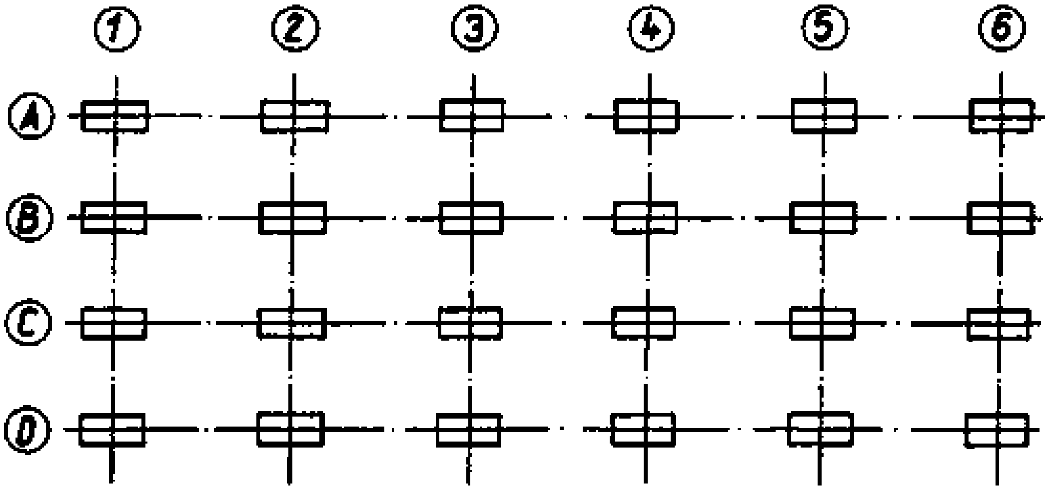


Fig. 12.38. Marking of axes and rows

These system lines are marked by numerals in a circle. Thus, each point of the construction can be clearly defined.

Axes and rows are system lines of a steel structure and serve for the arrangement of individual components or structural units. They are marked by letters and numerals inscribed in circles.

Repetition:

1. What are the data that can be derived from an altitude drawing?

2. Why is it necessary to indicate the position of the ground level related to the sea–level?

3. Explain the importance and meaning of the marking of axes and rows.

4. Explain the representation of the foundation in Fig. 12.37.

5. Solve the problem sheet No. 52.

13. Fittings and Piping

13.1. Importance

Piping in general is defined as:

– pipes and their connections in the form of pipe elements
– adapting pieces
– fittings
– carrying and supporting constructions.

In general, pipe lines are used for conducting liquids, vapours and gases. The transport of solid matter with the help of piping increasingly gains in importance. In addition to its function as means of conveyance, piping can be vessel for chemical and physical processes. Piping is used in all industries, in water supply and in plumbing of houses.

13.2. Pipe Fittings

Pipe fittings are components of pipe–line installations. They are designed to block and regulate the flow of various media at all pressures and temperatures involved, to secure the piping against excessive pressures and to control certain processes. The most widely used fittings are:

– valves
– slide valves

– cocks
– flap valves

They are distinguished by the shape of the closing body (check member) and its motion and position in the flow of the medium.

13.2.1. Valves

In valves, the checking member or shut–off device has the shape of a cone. Opening and closing is effected by lifting and lowering the checking member, that is to say, the checking member acts in or against the flow in the manner shown in Figs. 13.1. and 13.2. In the open position, the checking member, also known as blocking member, remains in the flow and the medium flows about it. Thus, valves have a high flow resistance. Passage is possible only in one direction and is indicated by an arrowhead at the housing (see Fig. 13.3.).

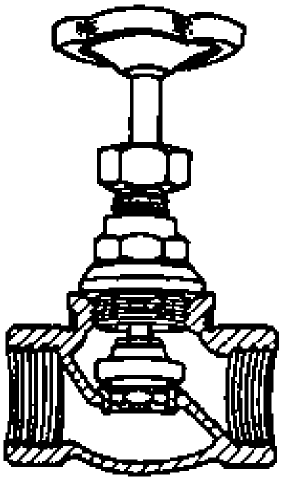


Fig. 13.1. Straight–way shut–off valve, closed (full section)

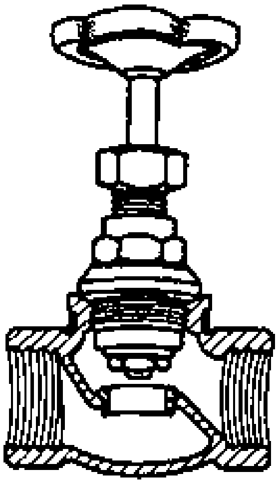


Fig. 13.2. Straight–way shut–off valve, open (full–section)

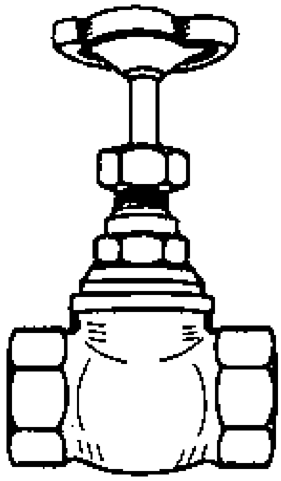


Fig. 13.3. Straight–way shut–off valve (general view)

Valves have the following advantages:

– simple design and low manufacturing costs
– they ensure proper sealing, even at high temperatures and pressures
– they are readily serviceable for control and throttling functions
– they close rapidly
– they are subjected to wear at their seats to a low degree
– when damaged at the seat, they can be easily regenerated by grinding.

Safety valves are used in water, steam or gas pipes as a protection against excessive rise in pressure. They open automatically when the preset pressure is exceeded and allow sufficient amounts of the flow medium to escape into the open (usually through discharge lines) until the pressure has dropped to the allowed value. Fig. 13.4. shows the sectional view of a safety valve.

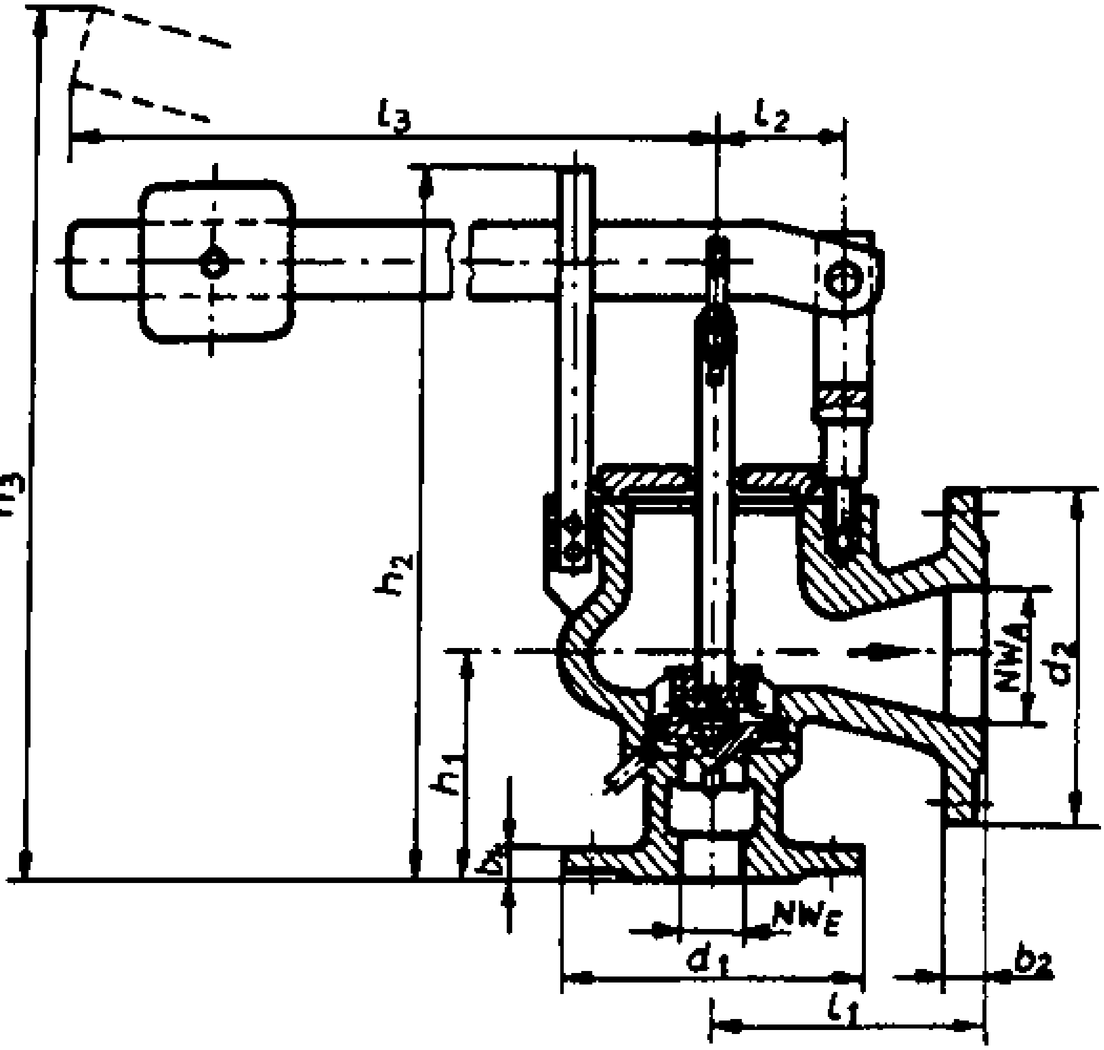


Fig. 13.4. Full−stroke safety valve with lever and mass load

Non−return valves (Fig. 13.5.) prevent the medium from flowing back. When the flow passes in the specified direction, they are opened. Usually, non−return valves are provided with an additional closing spring arranged above the cone. Due to flow reversal, they close without bouncing of the cone so that they can be used for any mounting position.

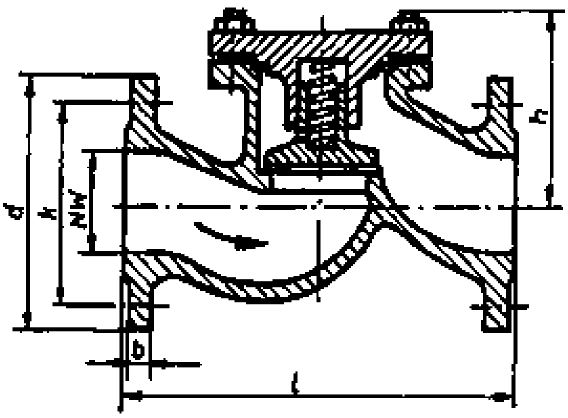


Fig. 13.5. Non−return valve (sectional view)

13.2.2. Slide Valves

In slide valves, the checking member, also known as shut−off device, is pushed across the flow direction into the cross−section of the pipe (Fig. 13.6.). Slide valves are mainly used for pipe sizes over 40 mm. They are installed in gas and water piping, heating lines and large water piping. Slide valves can block the flow or release it fully, intermediate positions are not allowed (so−called throttling positions). Since sealing surfaces are arranged on either side of the checking member, flow in both directions is possible. Flow losses are low.

Fig. 13.7. shows the full sectional view of a slide valve.

Fig. 13.6. Slide valve (half section)

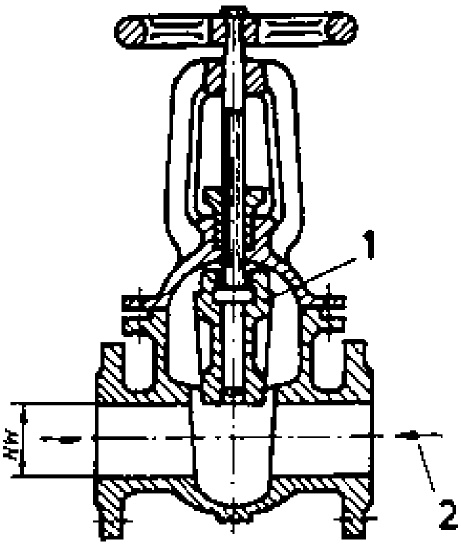


Fig. 13.7. Slide valve (sectional view)

1 shut−off device
2 flowing out from both sides is permissible

13.2.3. Cocks

Cocks lend themselves to rapid opening and closing by turning the shut−off device (taper plug) (Fig. 13.8.). Cocks are installed in air, gas and oil pipes. By a quarter of a revolution, they can change over to one or several pipes (three−way cock). Disadvantages are the large friction surfaces of the taper plug, the high wear associated with this and the difficulty of actuating large cocks. Due to the short change−over actions, cocks are of advantage to the chemical industry.

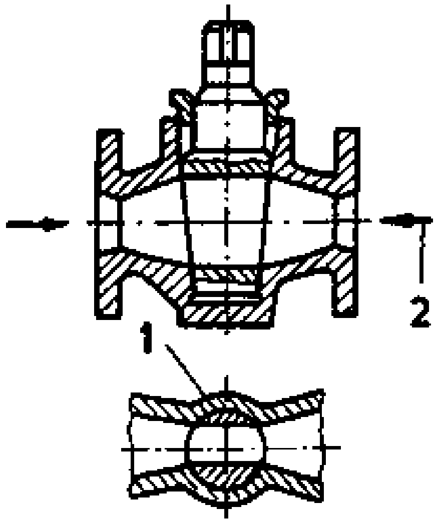


Fig. 13.8. Cock (sectional drawing in two views)

1 shut−off device
2 flowing out from two sides is permissible

13.2.4. Flap Valves

The shut−off device acts as a flap in the direction of flow. As compared to the other above mentioned pipe fittings, flap valves (see Fig. 13.9.) call for the smallest mounting space. For cold water, good blocking action is achieved by means of a rubber packing. Flap valves prevent the medium from flowing back into the piping.

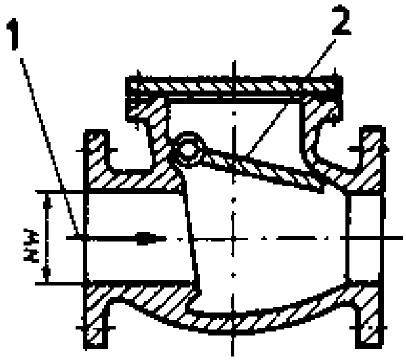


Fig. 13.9. Flap valve (sectional view)

1 flow direction
2 shut−off device

Repetition:

1. What are the differences between valves, slide valves, cocks and flap valves?

2. What are the functions of pipe fittings?

3. When reading the illustration given in Fig. 13.7. you should observe:

− the direction of shading of various components
− the lines of edges
− parts which must not be cut
− the representation of internal and external threads.

13.3. Symbols for Pipe Lines

Piping, fittings and other components of pipe installation are, unlike other technical objects, not fully represented with all essential and minor details in drawings. Such a representation would be very time−consuming, unclear and hence, uneconomical. For the representation of pipe lines in drawings, the components and assemblies involved are very simplified in the form of symbols. These symbols give information about type and design of the parts to be installed and about their arrangement in accordance with their function. A distinction is made between symbols for:

– piping (Fig. 13.10.)
– pipe accessories (Fig. 13.11.)
– connections (Fig. 13.12.)
– length−compensation devices (Fig. 13.13.)
– holders (Fig. 13.14.)
– shut−off devices (Figs. 13.15. to 13.19.)
– safety devices (Fig. 13.20.)

Fig. 13.10. Symbols for pipe lines

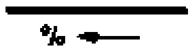
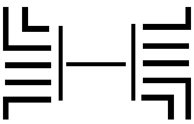
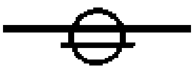
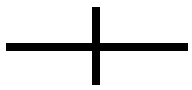
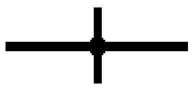
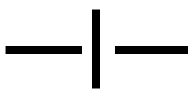
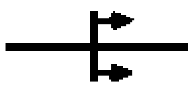
Symbol	Description	Remarks
	basic line with statement of the gradient	Basic lines can be drawn with additional data.
	basic line with statement of the direction of flow	The additions must be explained on the plan. The main line is represented by the thickest line.
	combination of lines running parallel	
	movable line	
	line with secondary pipe and heat protection	
	line heated by jacket	To be marked at least at the beginning and end of the pipe line
	line heated by shells	
	control pulse line	
	crossing of two lines without connection	
	crossing of two lines with connection	
	branch	The branch is smaller or equal in size to the main two−way pipe
	pipe passes vertically downward	Symbols for two−dimensional representation of pipe lines
	pipe passes vertically upward	
	crossing of two lines without connection	Marking of the line located at the front
	supply limit	

Fig. 13.11. Symbols for pipe accessories

Symbol	Description	Remarks

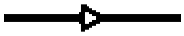
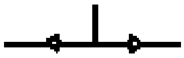
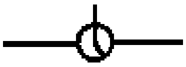
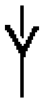
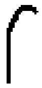
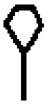
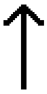
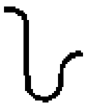
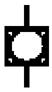
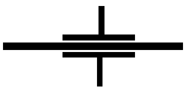
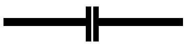
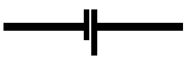
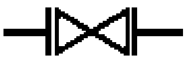
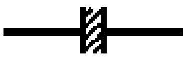
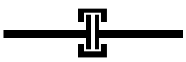
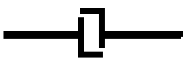
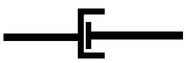
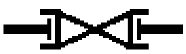
	reduction or expansion of the pipe	
	T–piece	Only for high–pressure piping with a nominal diameter larger than 100
	nozzle injection into the pipe line	
	draining funnel	
	blowing off over roof	
	silencer	
	exhaust	
	rain–hood	
	siphon pressureless draining	
	flow sight–glass	
	passage through a wall	

Fig. 13.12. Symbols for pipe line connections

Symbol	Description	Remarks
	flange connection	
	plug disk	
	flanged fitting	
	pipe end with blank flange	
	insulating flange	
	clamp connection	Detachable connections
	coupling	
	bolted connection	
	fitting bolted in place	
	detachable sleeve connection	
	pipe end with dummy cap	

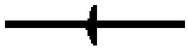
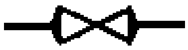
	fitting in sleeves	
	welded joint, butt weld	Non–detachable connections
	welded sleeve joint	
	fitting welded in	
	pipe end with dummy cap or bottom	

Fig. 13.13. Symbols of length compensation devices

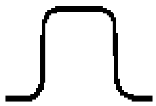
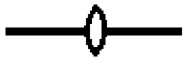
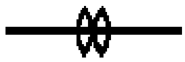
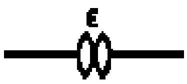
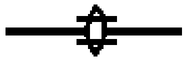
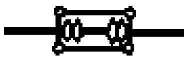
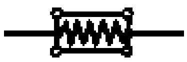
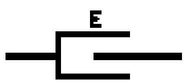
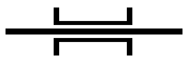
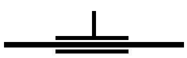
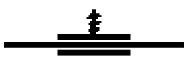
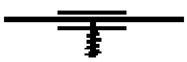
Symbol	Description	Remarks
	U–bend expansion pipe	
	corrugated–pipe axial compensating device, single–wave	The **number of waves** can be represented by a picture or by writing the numeral over the symbol
	corrugated–pipe axial compensating device, having two or more waves	
	corrugated–pipe axial compensating device with relief	
	corrugated–pipe axial compensating device with internal anchorage	
	corrugated–pipe and joint compensating device	
	metal–hose and joint compensating device	
	expansion gland compensation not relieved	
	expansion gland compensation relieved	

Fig. 13.14. Symbols of holders

Symbol	Description	Remarks
	slide bearing without guide	
	slide bearing with guide	
	slide bearing, rolling without guide	
	slide bearing, rolling with guide	
	suspension	
	springy suspension	
	springy support	
	fixed point, general	

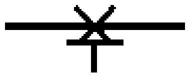
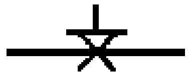
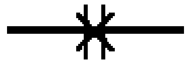
	fixed point, standing	
	fixed point, suspended	
	fixed point in pipe axis; sliding across the pipe axis	

Fig. 13.15. Symbols of shut−off devices in general and additional signs for actuating the shut−off devices

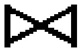
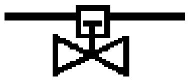
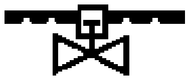
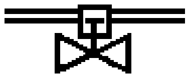
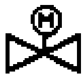
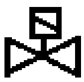
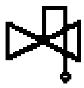
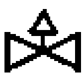
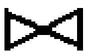
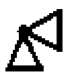
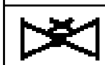
Symbol	Description	Remarks
	shut−off device, general	
	fitting with piston drive	
	hydraulic drive	
	compressed−air drive	
	oil−drive	
		
	fitting with motor drive fitting with magnet drive	The additional signs must be placed on the fitting in question. Additional signs can also be used in combination.
	fitting with float actuation	
	fitting with diaphragm actuation	
	hand drive	
	falling−hammer drive	
	floor−mounted column	
	liquid lock	

Fig. 13.16. Symbols of valves

Symbol	Description	Remarks
	straight−way valve	
	angle−body valve	
	valve with throttle cone	
	valve with nozzle cone	

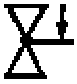
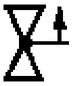
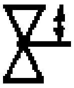
	two–way valve	
	ventilation valve	
	escape valve	
	respiration valve	
	pressure reducing valve	small triangle = higher pressure
	straight–way/non return valve cannot be shutt–off	Back–flow prevention in the direction of the point of the black triangle
	angle–body non–return valve	Non–return valves that can be shut–off have to be completed by adding the symbol “hand drive”
	foot valve	

Fig. 13.17. Symbols of slide valves

Symbol	Description	Remarks
	slide valve	
	slide valve with by–pass	

Fig. 13.18. Symbols of cocks

Symbol	Description	Remarks
	straight–way cock	
	angle–body cock	
	three–way cock	

Fig. 13.19. Symbols of flap valves

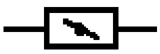
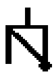
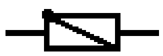
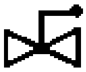
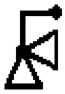
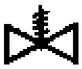
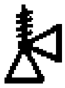
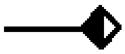
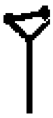
Symbol	Description	Remarks
	sealing flap	
	throttle flap	
	foot flap	
	non–return flap	
	condensate draining–off flap	

Fig. 13.20. Symbols of safety devices

Symbol	Description	Remarks

	weight−loaded safety straight−way valve	
	weight−loaded safety angle−body valve	
	spring−loaded safety straight−way valve	
	spring−loaded safety angle−body valve	
	quick−acting valve	
	automatic steam−pipe isolating valve	
	bursting pane	
	explosion flap	

13.4. Sanitary Details

Sanitary installations form a complex of details. Sanitary details, however, should not be defined as all single parts which belong to an installation.

Sanitary details are sanitary assemblies having a special function such as washing, bathing, shower−bath and WC−installations.

Sanitary details are the synthesis of sanitary fittings, piping and fitments taking the relevant standards into consideration. They must be made and tested according to technical rules and regulations.

13.4.1. Sanitary Details for Water Supply

Figs. 13.21. and 13.22. show examples of sanitary details for water supply.

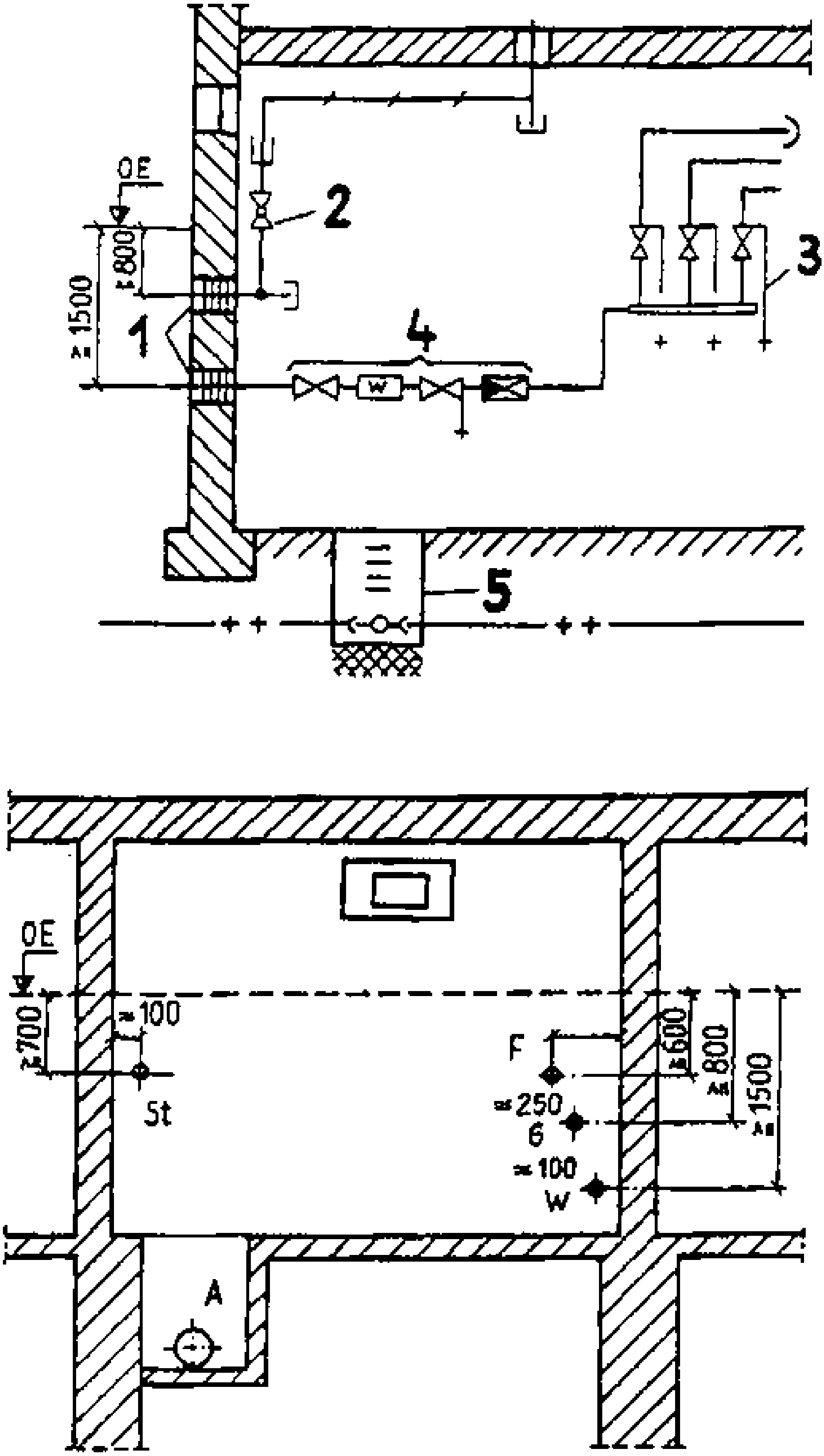


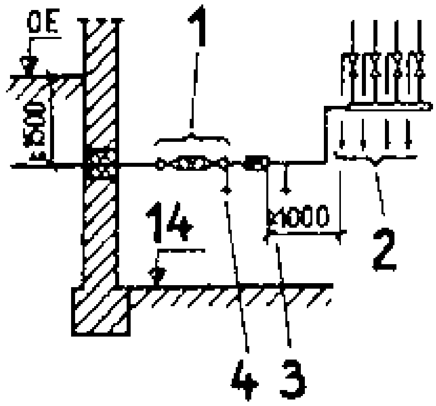
Fig. 13.21. Water supply (house installation room: detail)

St power supply cable
F telephone cable
G gas main
W water pipe
A waste pipe

OE ground

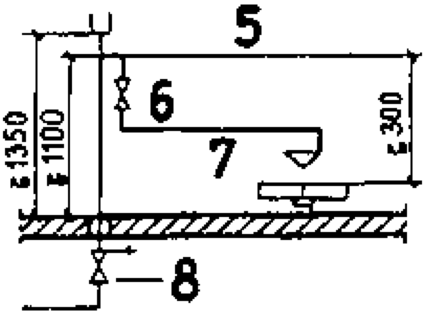
1 gas−tight
2 main shut−off device
3 distributor
4 water meter
5 revision duct

Fig. 13.22. Water supply − haus connection for cold water



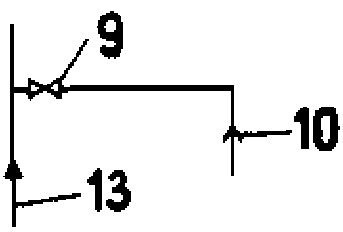
House connection for cold water with distributor

= 1000 mm distance between distributor and metering device
= 1500 mm below ground level

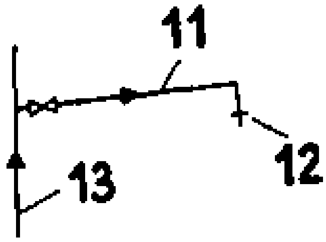


Line closed by sleeve with stopper 1300 to 1350 mm above ground level. The lines for the various floors are provided with shut−off valve. Each riser line is provided with a shut−off valve.

Branch at least 1100 mm above floor and at least 100 mm above highest waste water level.



Each connection for a valve tap should have a minimum width of 20 mm and be so arranged that it can be shut−off individually. Valve taps should have a rising main each so that other pressure−dependent devices cannot be influenced.



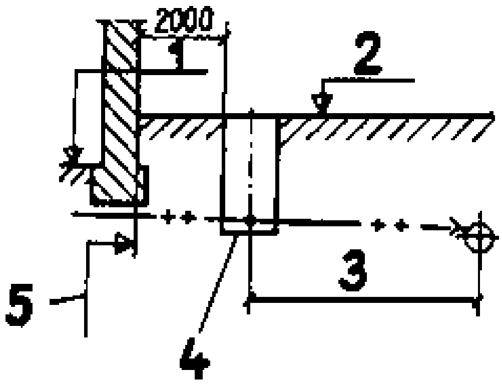
All lines must be installed straight and with gradient to the tapping point. Minimum nominal diameter: rising main 20, branch line 15

1 meter,
2 discharge of lines,
3 drainage,
4 check valve
5 branch above waste water level,
6 shut−off valve for drainage
7 highest waste water level,
8 line shut−off valve if there is no distributor,
9 shut−off valve for valve tap,
10 valve tap
11 incline to tapping point,
12 tapping valve,
13 rising main
14 top of cellar floor

13.4.2. Sanitary Details for Drainage

Due to their function, other technical conditions are given for drainage systems as for water supply installations and gas supply installations. Figs. 13.23. and 13.24. offer a survey of a few essential sanitary details for drainage.

Fig. 13.23. Drainage (down pipe, connection line, ground line)



Termination duct

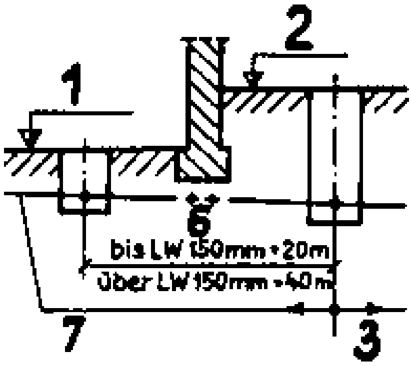
Connecting duct from the public road duct to the first revision duct

Gradient

The pipes must be installed straight without change in gradient

not flatter than I = 1 : 100

not steeper than

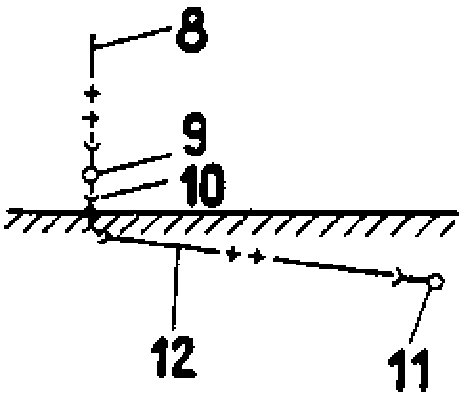


Ground line

The line is installed

• embedded in the earth
• in the cellar free below the cellar ceiling or in front of the wall

It conducts the water from the connection line, down pipe and secondary ground lines to the connecting duct.



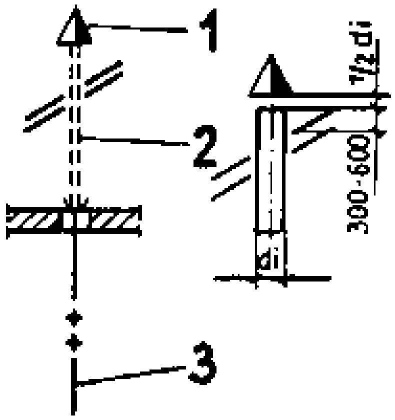
Connection of the down pipe

to the ground line via cleaning device, transition piece and from cast−iron or PVC to earthenware pipes.

Further connections: secondary ground line, main ground line, connecting duct − public road duct

1 cellar floor,
2 ground floor,
3 connection duct,
4 first revision duct on the premises,
5 building line,
6 distance up to inside diameter of 150 mm = 20 m over inside diameter of 150 mm = 40 m
7 ground line,
8 down pipe,
9 cleaning device,
10 transition piece,
11 main ground line,
12 secondary ground line

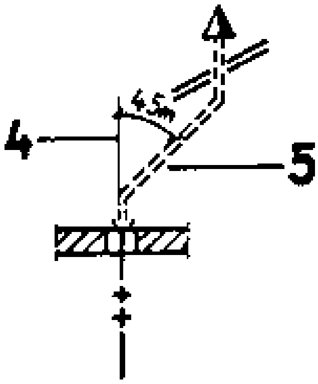
Fig. 13.24. Drainage (breather lines)



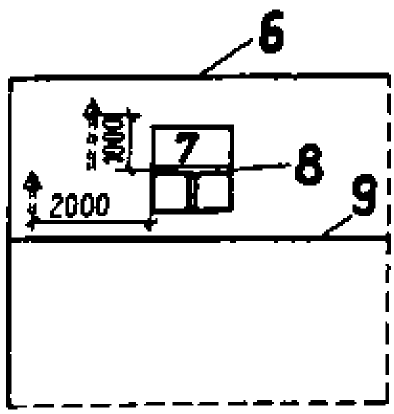
The ground line must be ventilated.

The outlet of the breather line must be installed 300 to 600 mm above the roof because of snow accumulations, depending on the climatic conditions.

The distance of the hood from the pipe end is half the inside diameter.



Breather lines must be installed vertically and without bends. When breather lines must be drawn, they must not be below 45°. The angle may be 45, when the pipe material is resistant to corrosion, e.g. PVC.



The escaping sewer gases must not molest neighbouring recreation or day rooms. Outlets must be installed at least 1000 mm above the lintel. If this is not possible, the outlet must be located laterally at a distance of at least 2000 mm.

1 vapour hood,
2 breather line,
3 down pipe,
4 vertical,
5 drawn breather line,
6 roof ridge,
7 bay,

8 lintel,
9 eaves

Repetition:

1. With the help of the symbols, determine the function and interaction of the individual components given in Figs. 13.21. and 13.22.

2. What should be observed especially in the room where connections are made to houses?

3. What is the function of ventilation lines?

Problem sheets No. 1 to 52 (appendix)

Textbooks for Vocational Training

Supplement to the textbook “Engineering drawing”

worksheets

Institut für berufliche Entwicklung

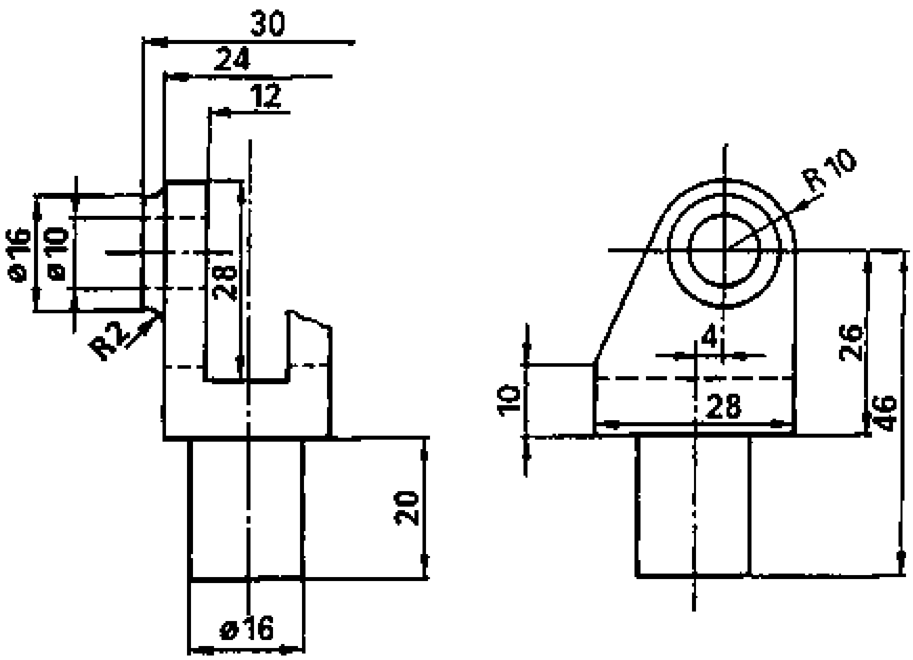
1. Bisect an angle of 135° on a drawing.

2. Divide the given line segment AB into 13 equal sections.

3. Draw a regular hexagon whose side length is equal to 30 mm.

	Problem sheet			1

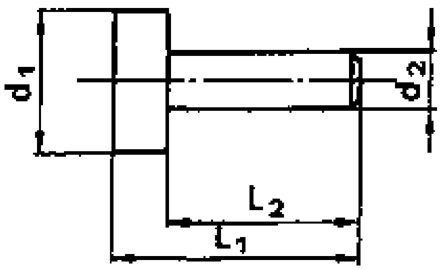
1. Mark the types of lines used in the drawing by numbers and coordinate them with the terms.



2. What has to be observed when drawing interrupted lines?

	Problem sheet			2

1. Draw the represented bolt in the scale 5 : 1.



Overall length (L_1) = 20 mm
Length of the shank (L_2) = 12 mm
Maximum diameter (d_1) = 10 mm
Smallest diameter (d_2) = 5 mm

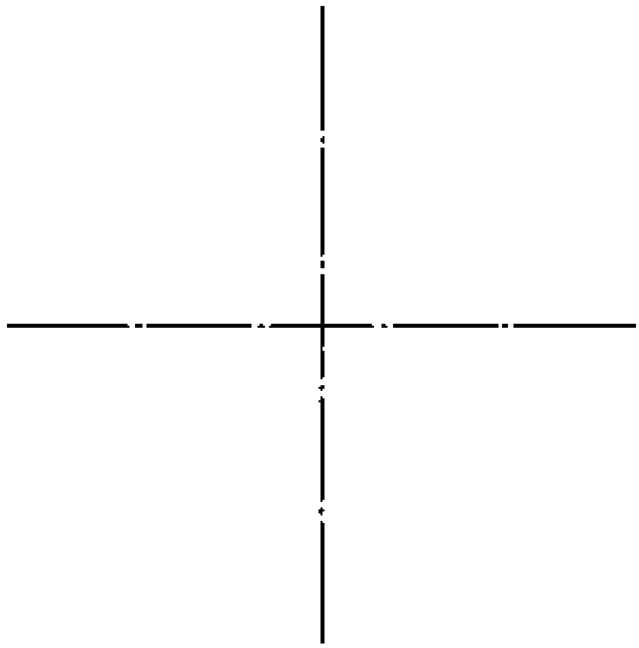
2. Enter the missing values into the following Table!

Size of the object	0,8	12	150	2100	0,15
Scale	50:1	5:1	1:50	1:20	10:1
Size of representation					

	Problem sheet			3

1. Construct a regular octagon.

The radius of the circumcircle is 40 mm.



2. Draw the connection of a circular arc to two circles!

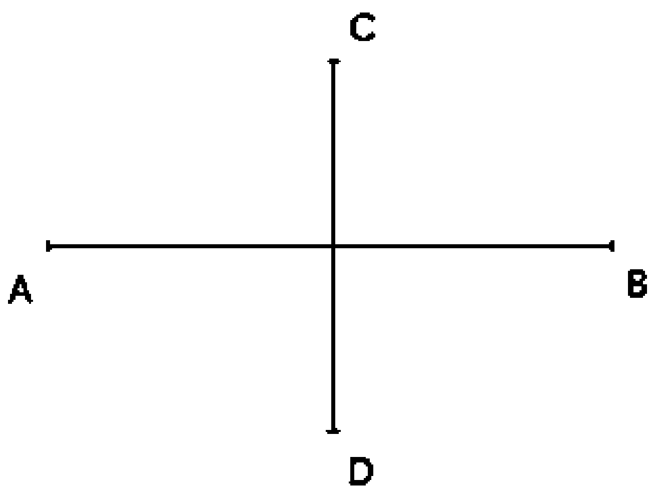
The diameters are 50 mm and 65 mm, the transition radius is 30 mm.

The centre−to−centre distance is 80 mm.

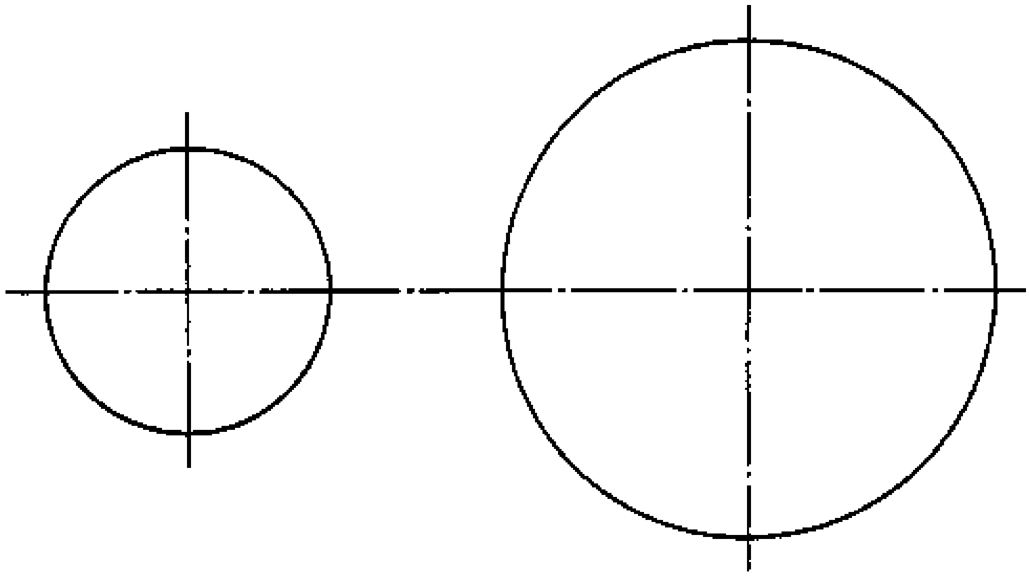
	Problem sheet			4

1. Construct an ellipse.

Given are the major axes AB and CD.

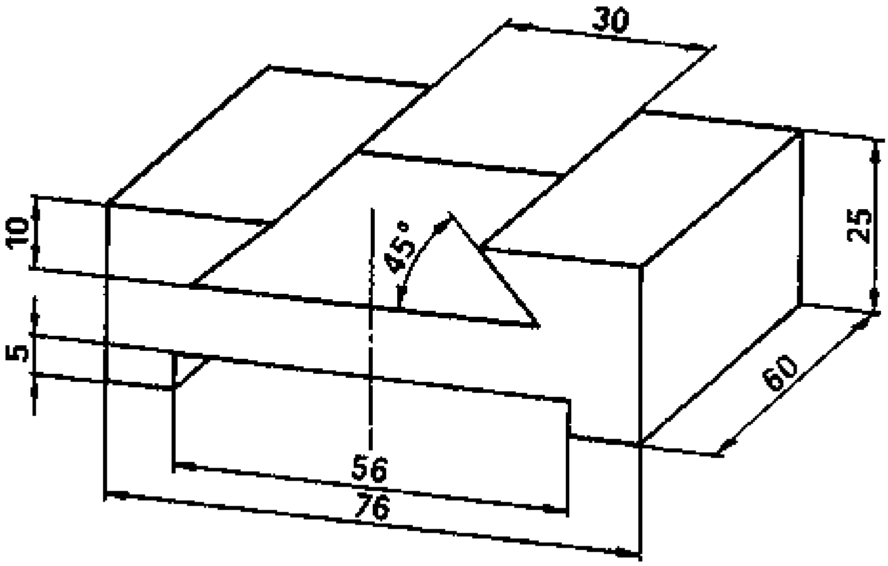


2. Draw tangents to the given circles which have to connect the two circles.



	Problem sheet			5

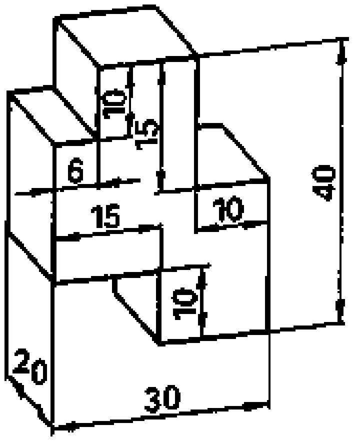
1. For the workpiece represented in dimetry, the isometry has to be drawn in the scale 1 : 1.

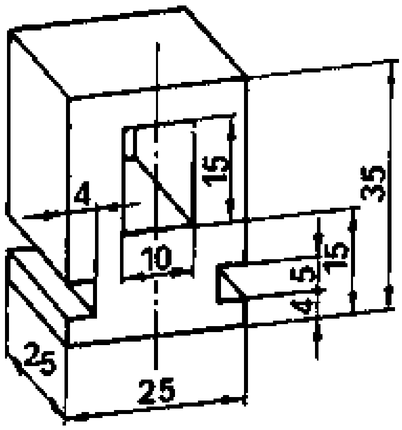


	Problem sheet			6

1. The prismatic objects represented in dimetry have to be sketched in frontal–dimetric projection. Direction of viewing: front–top–right.

The specified dimensions should be approximately doubled in the sketch.



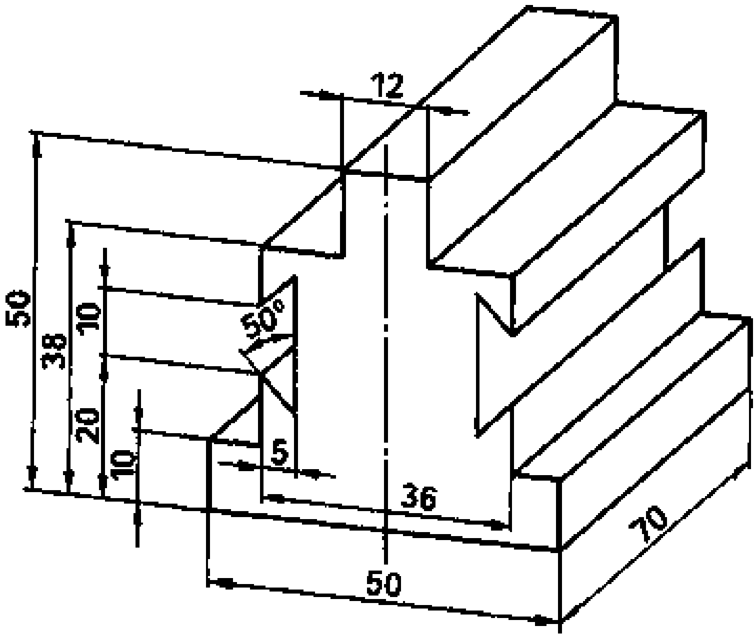


	Problem sheet			7

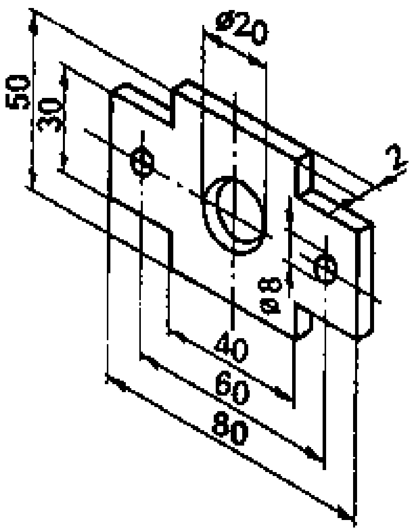
1. Of the represented workpiece, determine

- kind of representation
- viewing direction
- function

2. Draw the isometric projection in the scale of 1 : 1

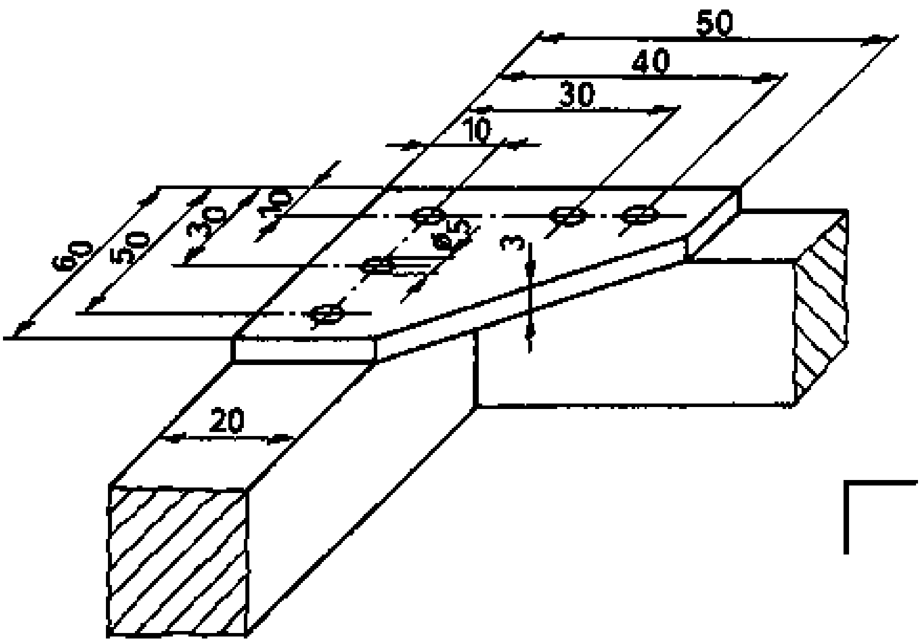


	Problem sheet			8



1. Draw the cover in one view. Enter the thickness into the drawing.

	Problem sheet			9.1

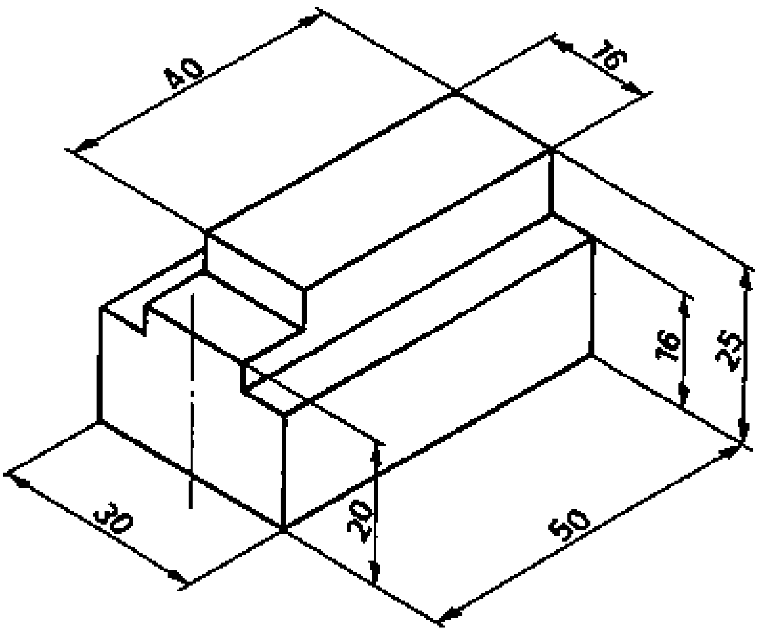


2. Draw the corner plate in one view! Enter the thickness into the drawing!

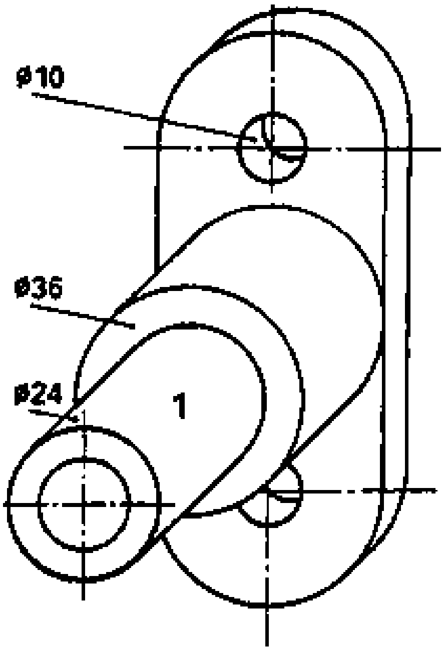
	Problem sheet			9.2

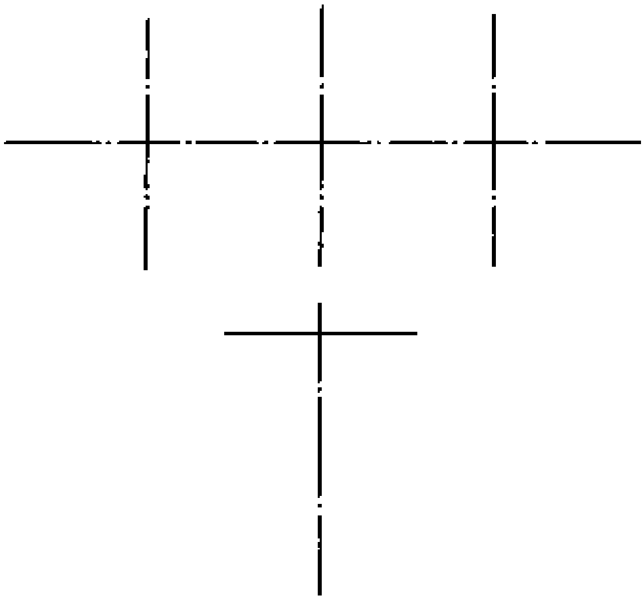
1. Draw the workpiece in two views.

At first determine the viewing direction, i.e. the location of the point of sight for the front view.



	Problem sheet			10.1





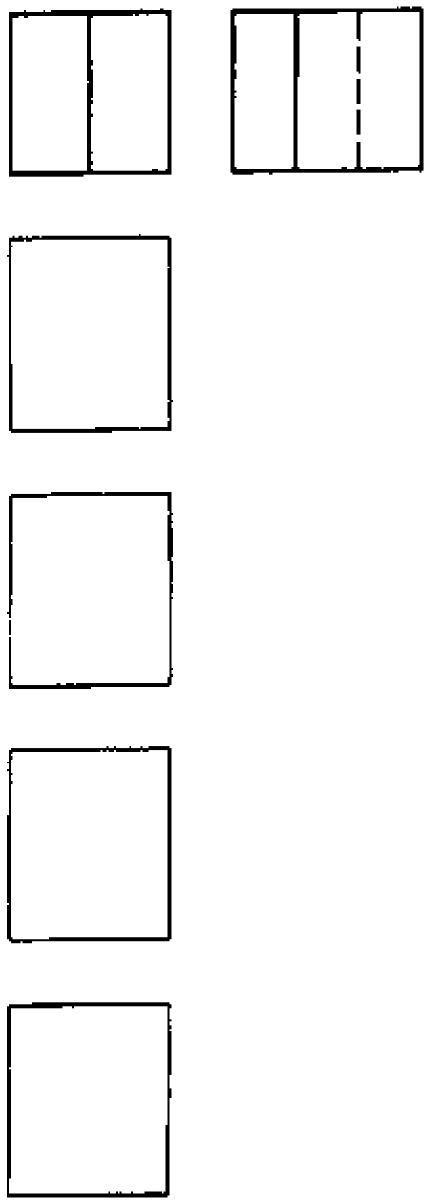
1 pipe

length – 90 mm
height – 36 mm
thickness of the plate – 10 mm

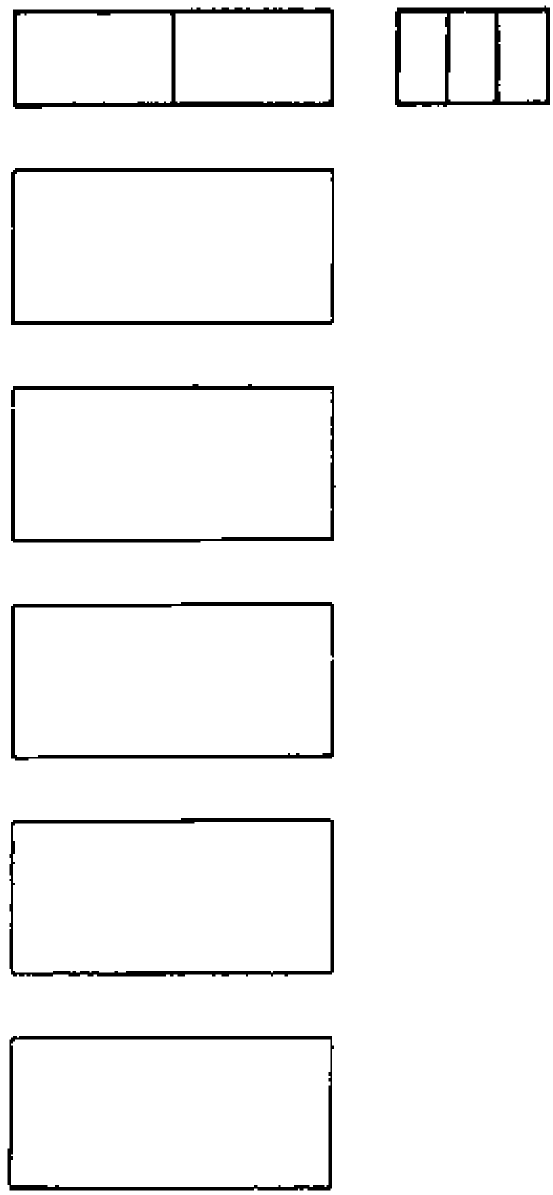
2. The picture shows the bearing for a holding bar (pipe) Draw the bearing (without pipe) – in two views.

	Problem sheet			10.2

1.



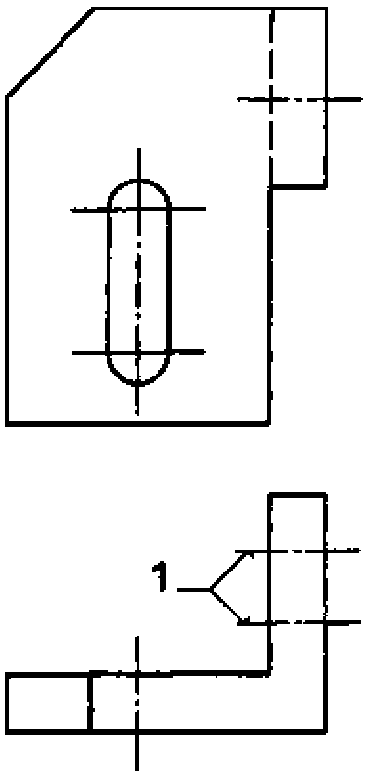
2.



Enter possible top views to the given views.

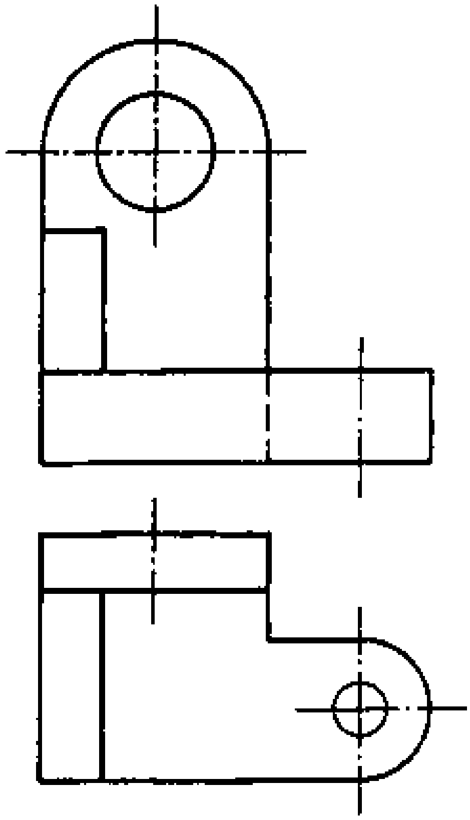
The surfaces of the objects are plane and they are located horizontally, vertically or obliquely.

	Problem sheet			11



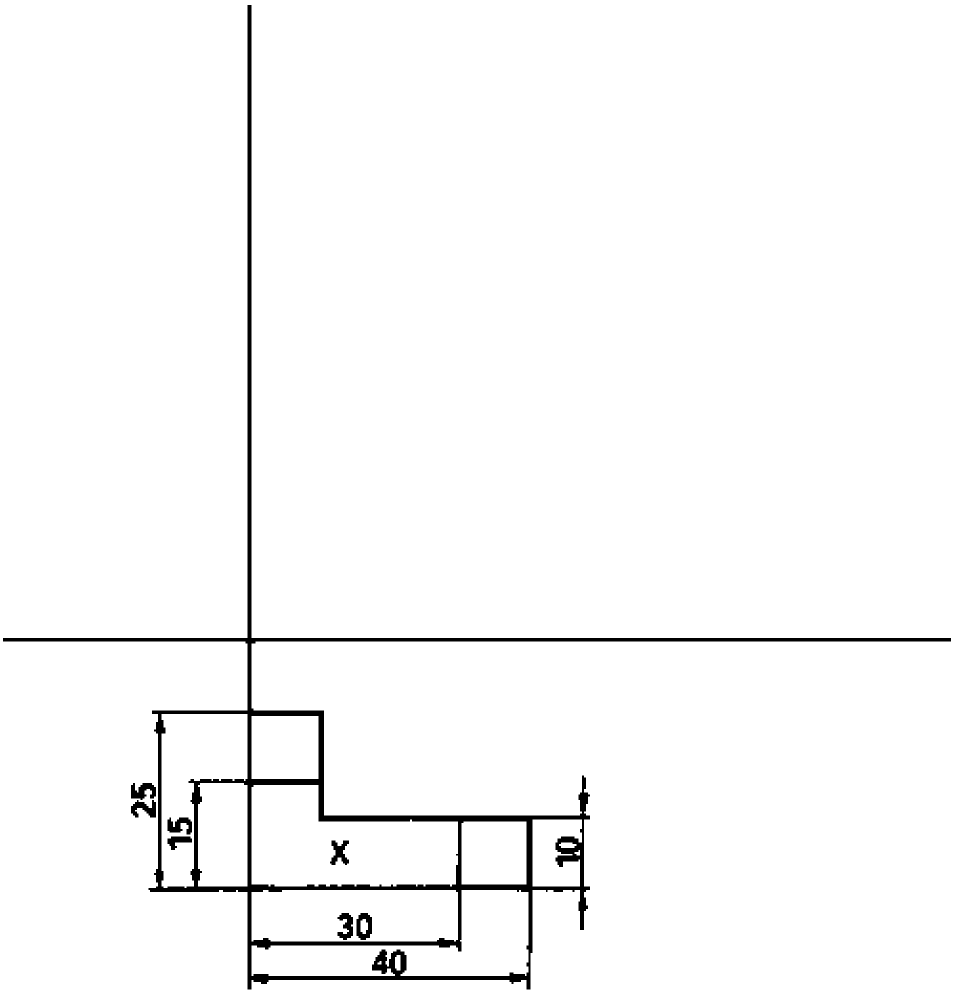
1 two holes having a diameter of 8

1. Add the side view!



2. Add the side view!

	Problem sheet			12



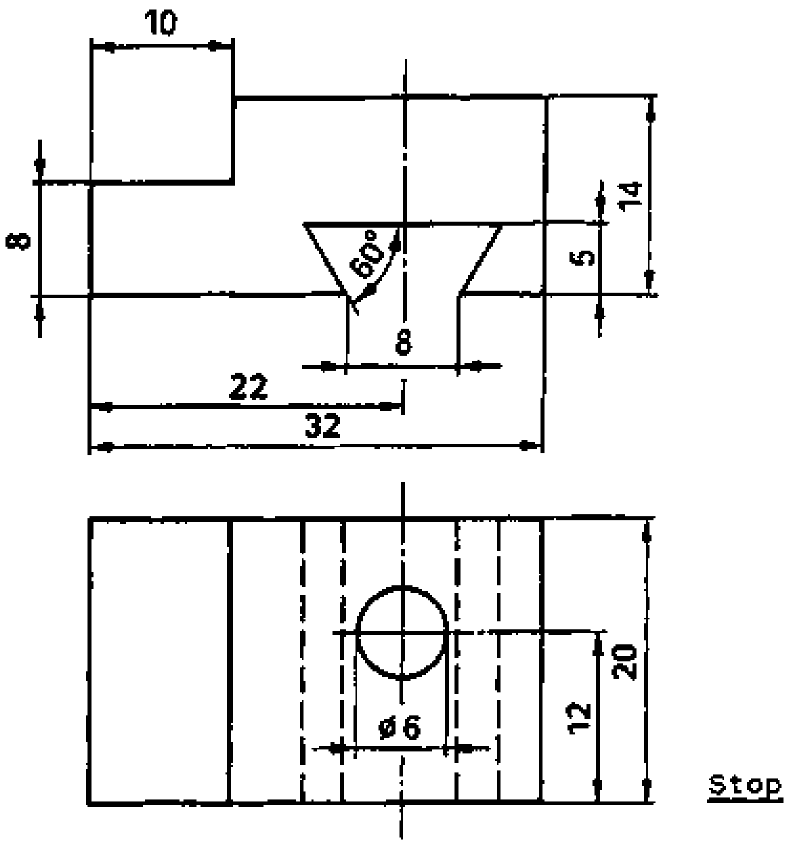
The angle represented in top view is 55 mm high.

The area marked by × is recessed 20 mm deep.

1. Add the missing 5 views.

Hidden edges have to be drawn exceptionally in this case.

	Problem sheet			13



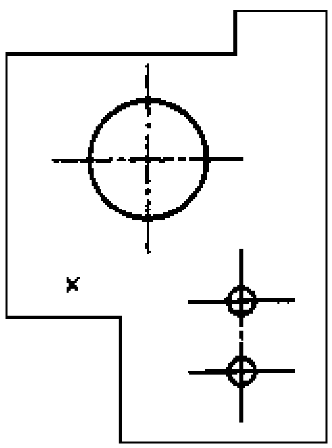
Scale 2:1

1. Determine the dimensions in following order:

1. Size of the hole ....
2. Location of the hole ....
3. Size of the dovetail groove ....
4. Location of the dovetail groove ....
5. Size of the collar ....
6. Location of the collar ....
7. Size of the basic form ....

2. Determine the extension lines.

	Problem sheet			14.1



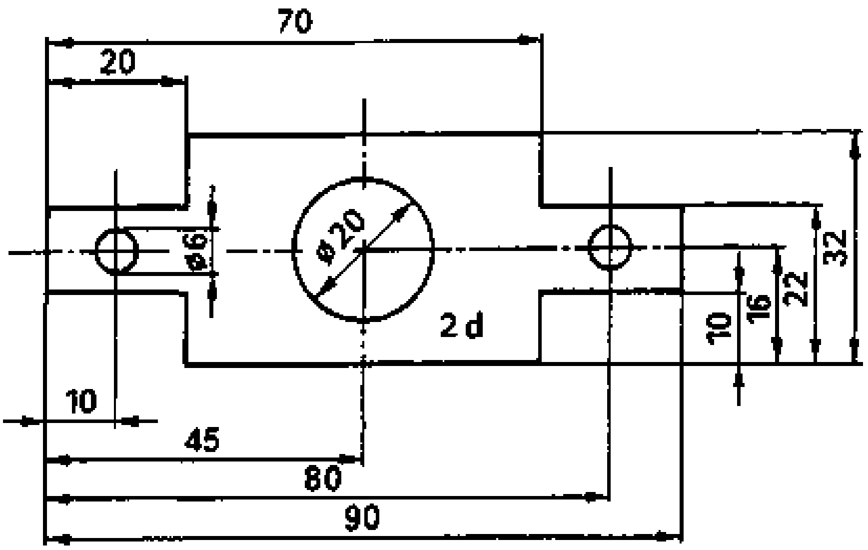
Wall plate
× 3 thick

Scale 1:1

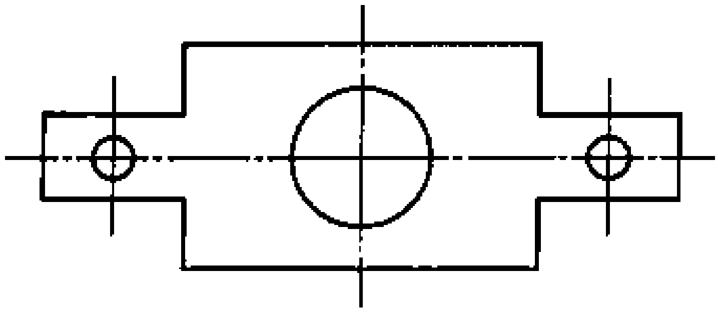
3. Enter the dimensions into the drawing in the following order

1. Size of the large hole ....
2. Location of the large hole ....
3. Size of the small holes ....
4. Location of the small holes ....
5. Size of the upper collar ....
6. Omitted (locations) ....
7. Size of the lower collar ....
8. Locations omitted ....
9. Size of the basic form ....

	Problem sheet		14.2	

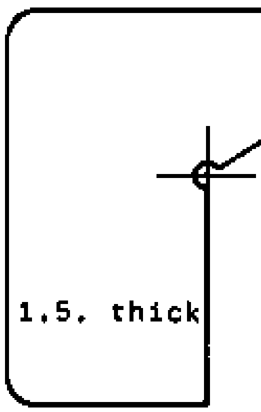


1. Determine the extension lines for the dimensioned representation. Mark the extension lines by a dot.



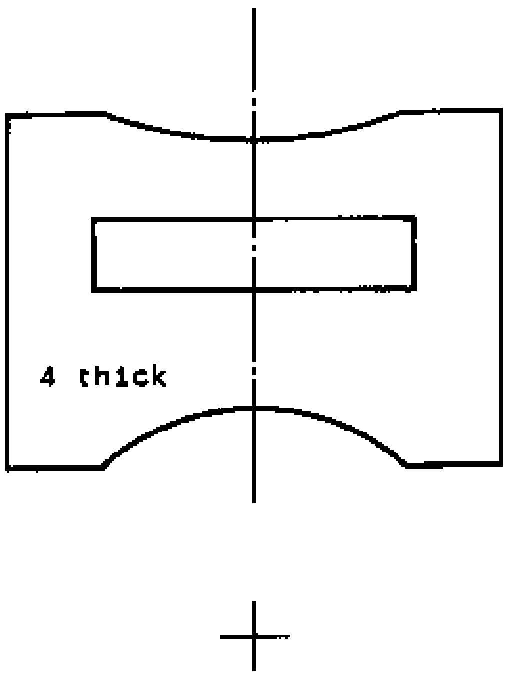
2. Dimension the representation when for functional reasons the two lines of symmetry are specified as extension lines.

	Problem sheet			15



Scale 1:1

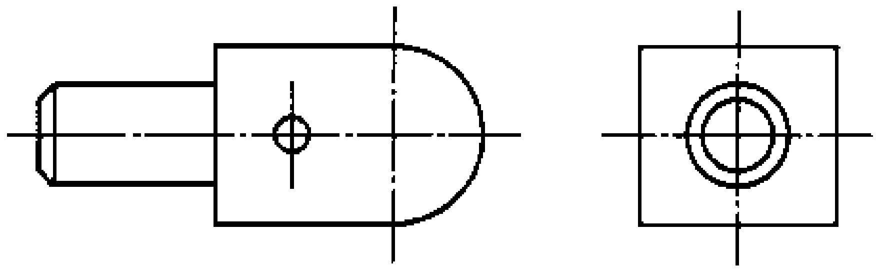
1. Dimension the representation of the angle gauge for the checking of the point angle of 116 of a spiral drill for steel machining.



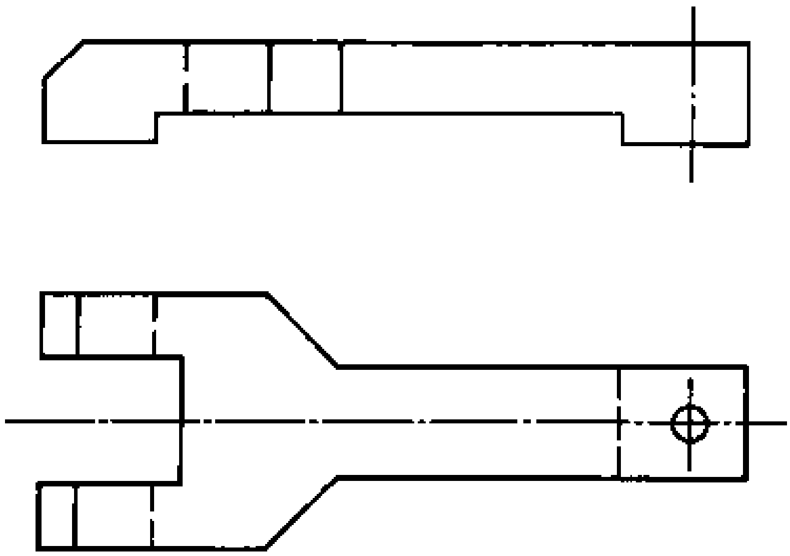
Scale 1:1

2. Dimension the representation of the check plate

	Problem sheet			16



1. Dimension the representation of the bolt

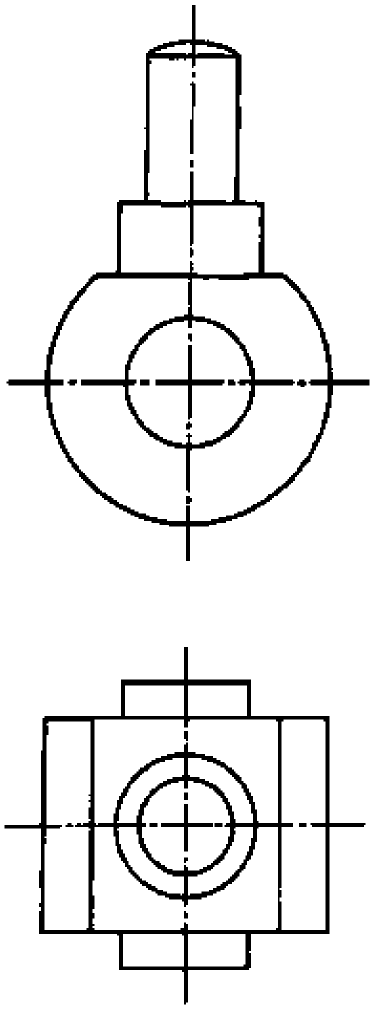


2. Dimension the representation of the wrench!

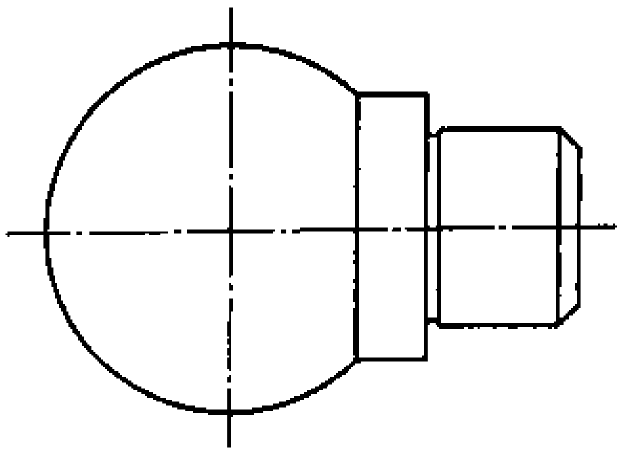
	Problem sheet			17

Draw a bolt of 3 × 16 × 12.4 to the scale of 5 : 1 and dimension it!

	Problem sheet			18

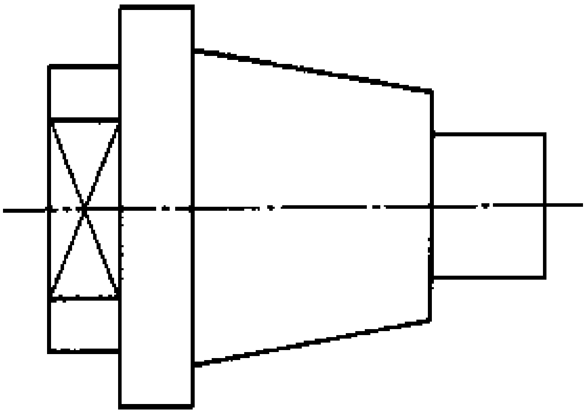


1. Add the view from the left and dimension the representation of the joint.

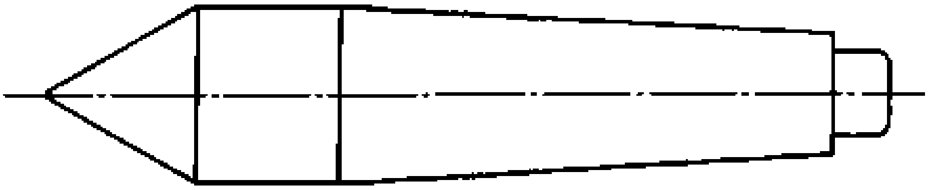


2. Dimension the representation of the ball−head bolt.

	Problem sheet			19



1. Dimension the representation of the taper bolt. The width over flats for spanners is 32 mm.



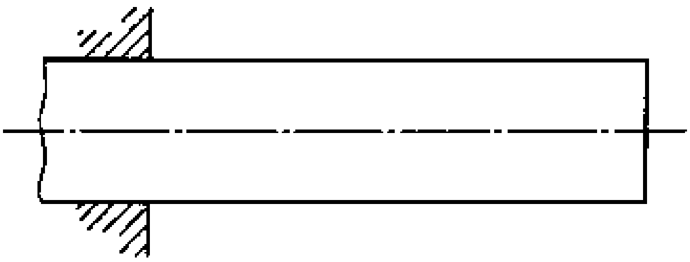
2. The centre is represented in the scale of 1 : 2. Apply the dimensions to the drawing.

	Problem sheet			20

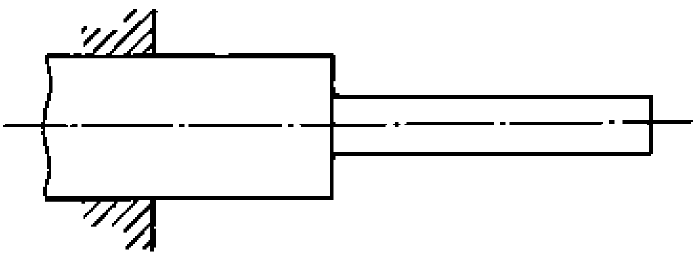
1. Enter the dimensions for the operating steps into the drawing.

2. Prepare a drawing of the intermediate screw thread form to the scale of 2 : 1 and provide with all required dimensions.

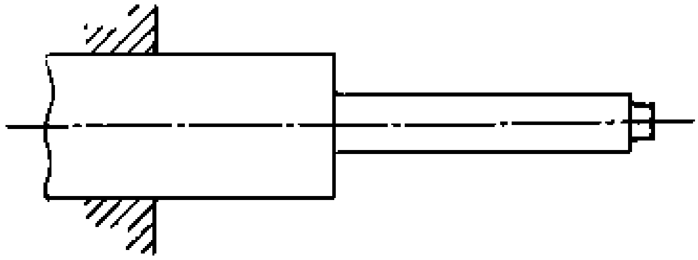
1. Right−hand end face to be surfaced. To be turned in a lathe to the length of 65 mm and diameter of 20 mm.



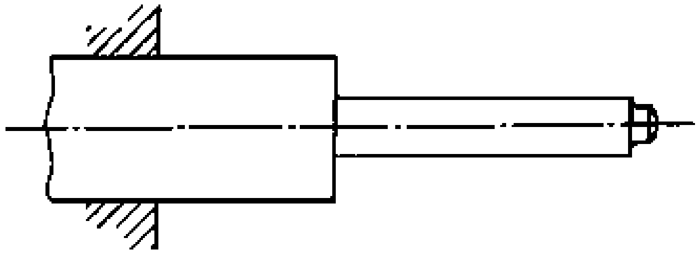
2. Turn pin, dia. 8 mm and length 45 mm. Radius 2 mm.



3. Pin dia. 5 mm, length 3 mm to be turned in a lathe. Radius 0.5 mm.

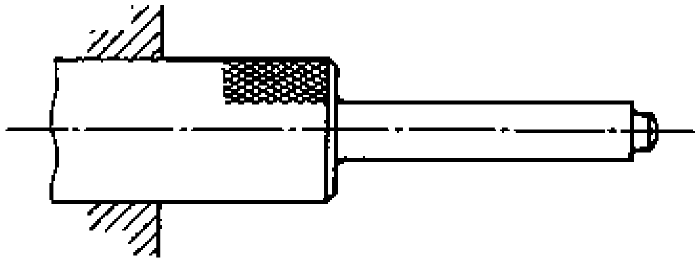


4. Provide pin with a radius of R 5.

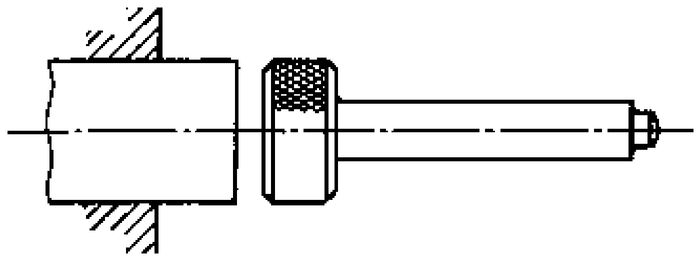


	Problem sheet			21.1

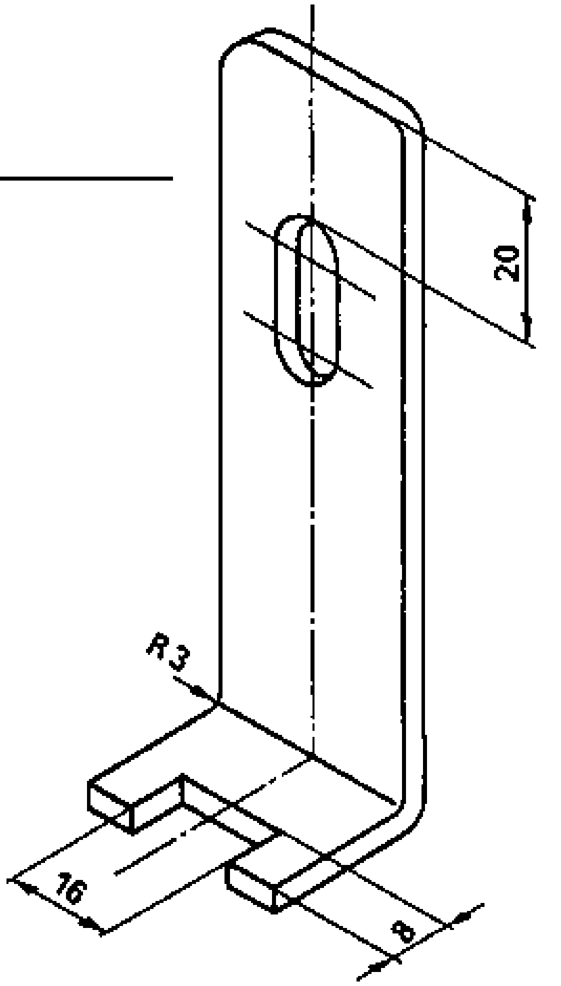
5. Cylinder having a dia. of 20, to be knurled with knurling tool 1. Chamfer 1 wide to be turned at an angle of 45°.



6. Plunging at a length of 55 mm; chamfer 1 wide to be turned at an angle of 45°.
Separating.



	Problem sheet			21.2



The blank holder is to be made of flat steel 30×3!

Long leg	100 mm
short leg	20 mm
radii	4 mm
slot, length	25 mm
slot, width	12 mm

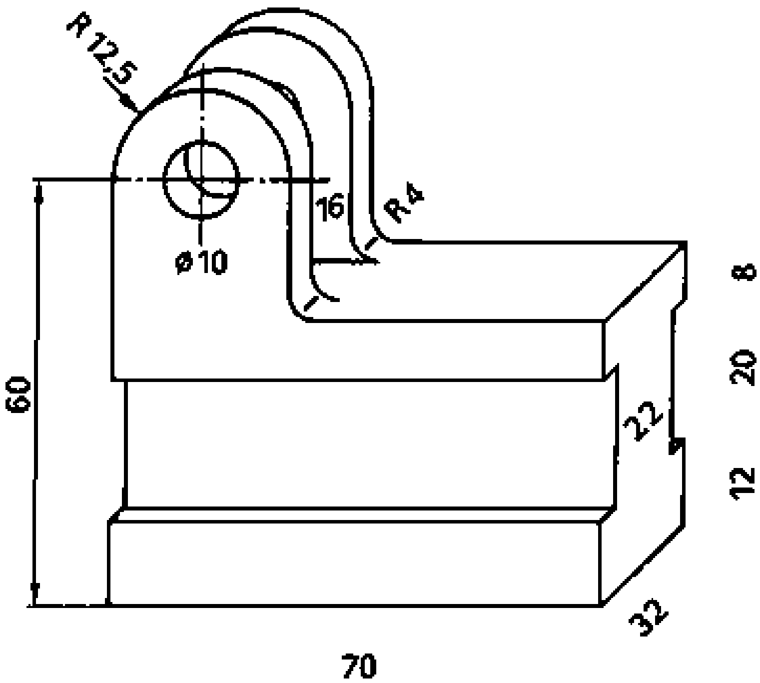
1. Draw the necessary views of the blank holder and dimension the representation.

	Problem sheet			22

Draw the required views of the poppet and enter the necessary dimensions into the drawing.

The numbers given are for information only.

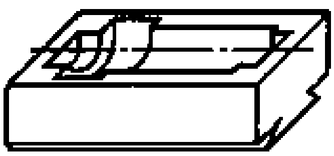
The dimensions of 16, 22 and 20 are subject to the dimensional variations according to the machining method.

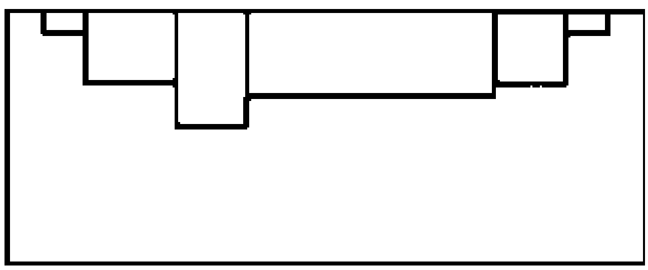


	Problem sheet			23.1

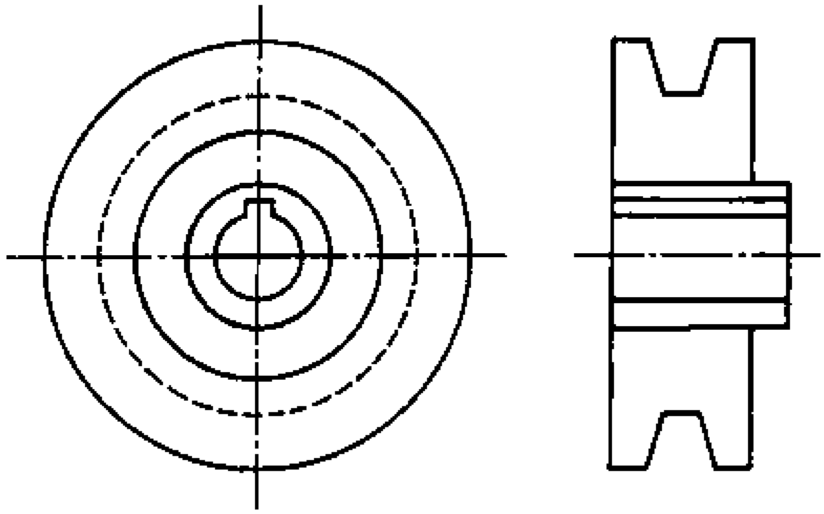
	Problem sheet			23.2

1. Complete the hatching in the representation of the drop−forging die lower part of steel.

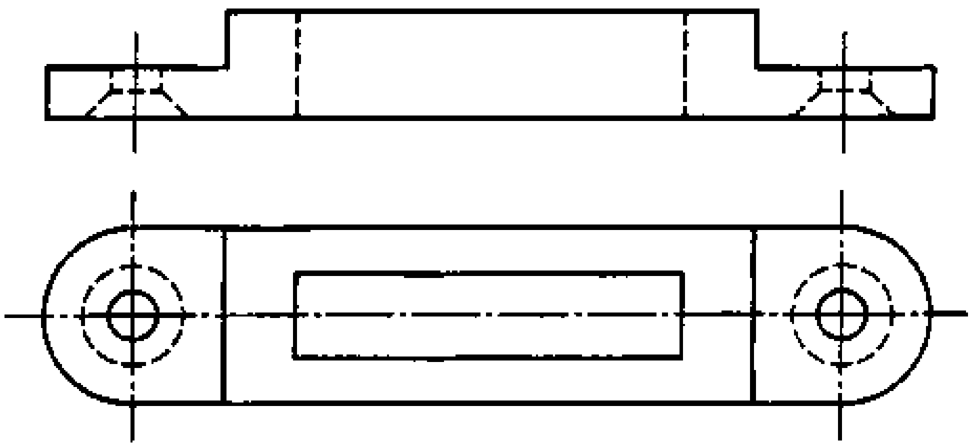




2. Complete the shading of the V−belt made of plastics with steel bushing. Use the shadings identifying the various materials.

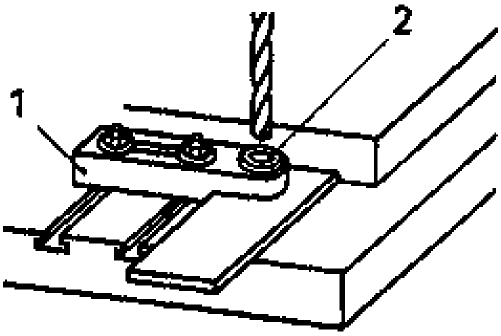


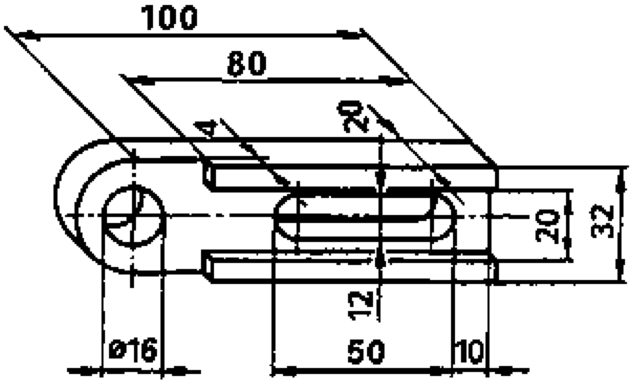
3. Complete the front view of the lathe apron so that a full section is obtained. Using a sheet, indicate the position of the cutting plane in the top view. Apply the necessary dimensions to the workpiece.

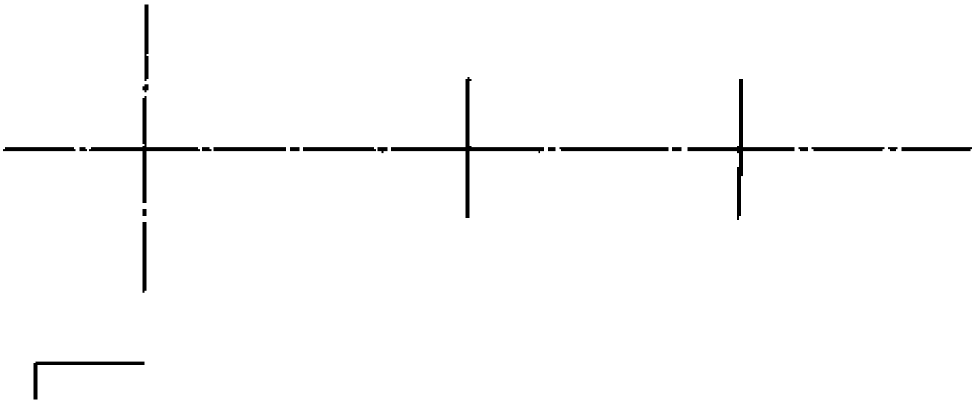


	Problem sheet			24

1. Draw two views of the jig bush carrier (top view in full section).



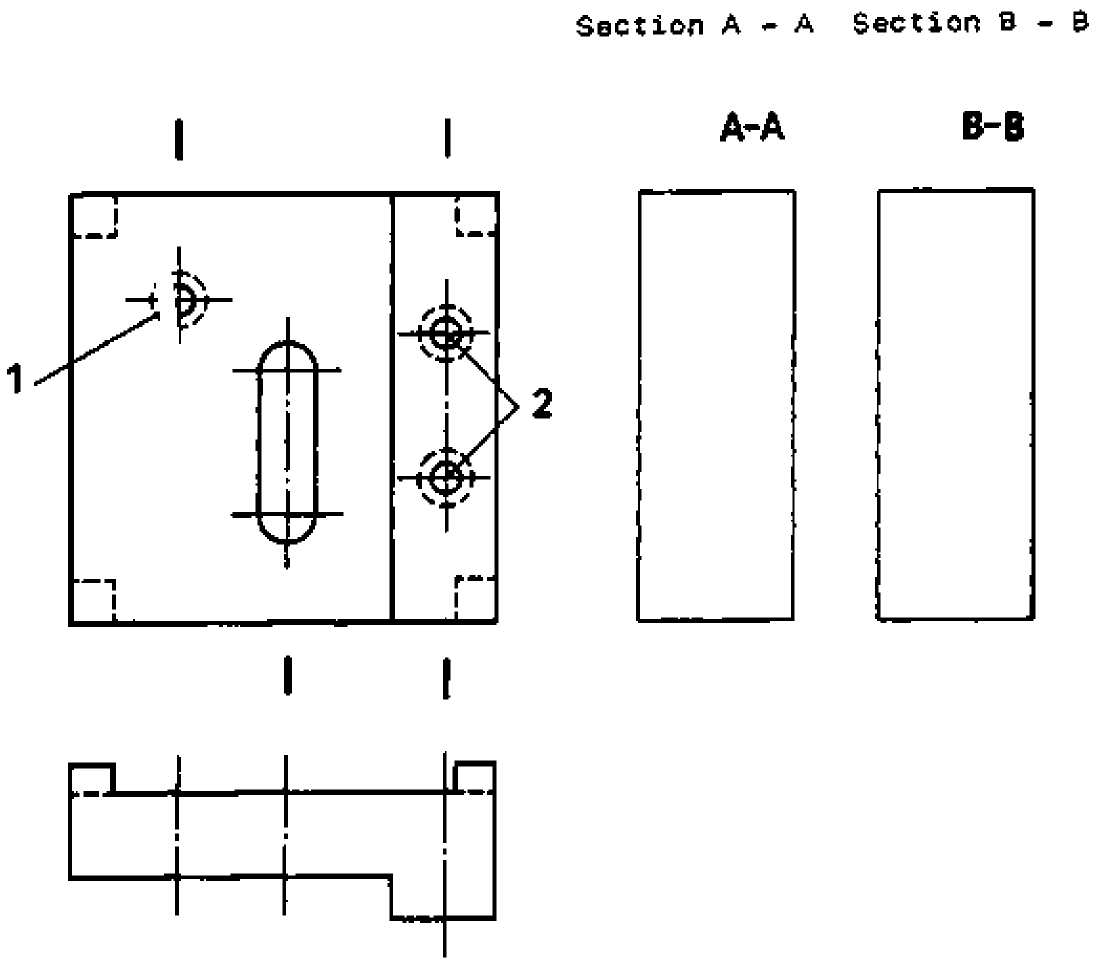




1 Jig bush carrier, 2 Jig bush

	Problem sheet			25.1

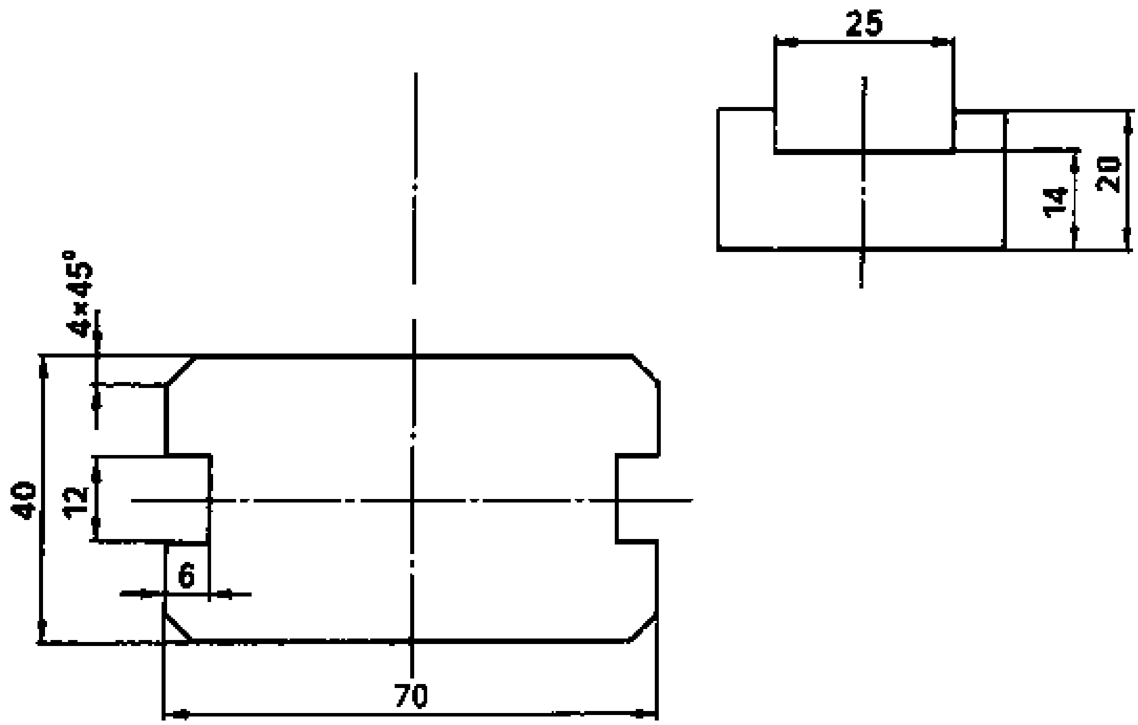
2. The sections A – A and B – B have to be drawn.



	Problem sheet			25.2

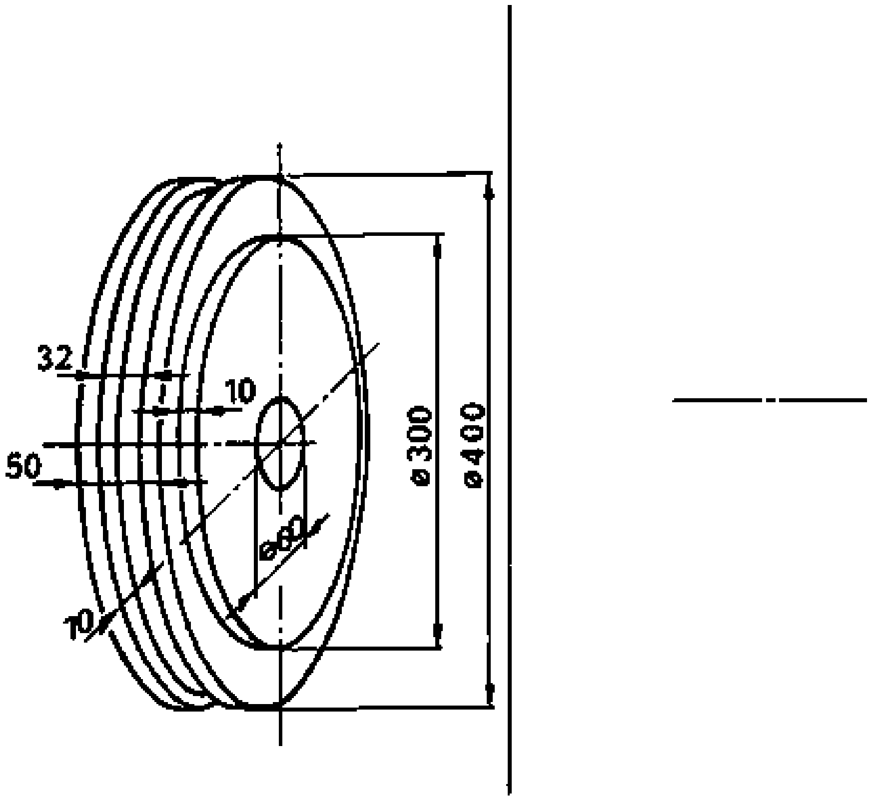
1. The clamping plate is provided with a hole to be drilled through with a diameter of 12 which is countersunk from top to dia. 18 and 6 deep, cylindr. Complete the given views. Draw the front view as a half section.

Add the required dimensions.



	Problem sheet			26.1

2. Prepare a drawing of the blank wheel in the form of a half section. Select an appropriate scale and dimension the drawing.



The through hole having a dia. of 60 is to be countersunk from the left to a dia. of 100 to a depth of 20.

	Problem sheet			26.2

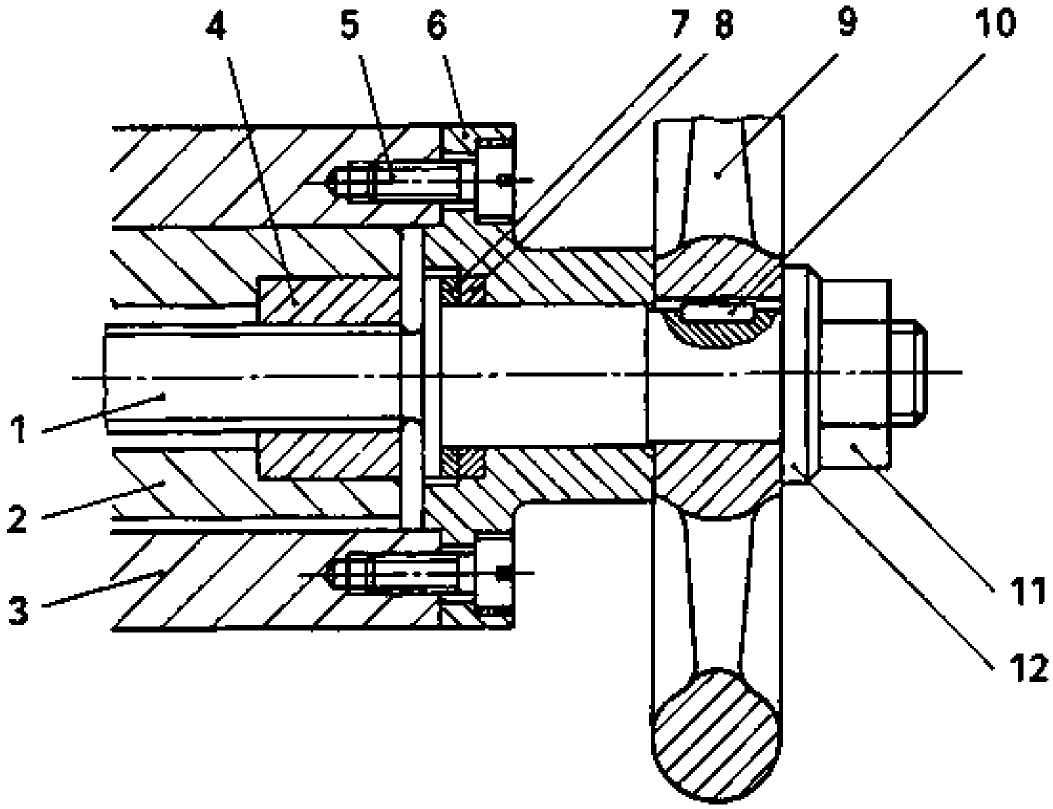
1. What kind of sections have been used for the representation of this sub−assembly?

2. Which parts have been represented in a non−cut condition although they are located in the cutting plane?

3. What is the representation selected for unveiling part 10?

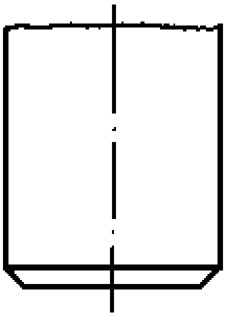
	Problem sheet			27.1

4. Prepare a drawing of part 6 in two views (side view as a half section). Part 6 is connected with part 3 by 4 fillister−head screws (part 5).

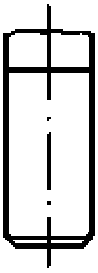


	Problem sheet			27.2

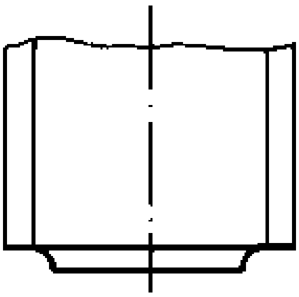
1. Draw and dimension a metric fine screw thread M30×2, length 28.



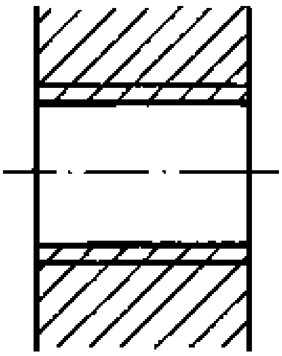
2. Draw and dimension a metric M12 left−hand thread.



3. Acme thread
d_N = 40, P = 7
Two−start − to be provided with dimensions.

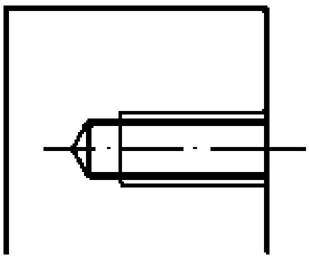


4. Knuckle thread
d_N = (50) (M1:2)
P = 1/6 inch
to be dimensioned.

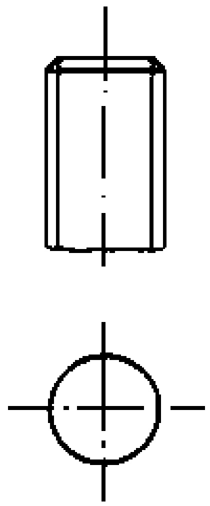


5. Metric thread
d_N = 10
Dimension length and d_N

To be shaded!

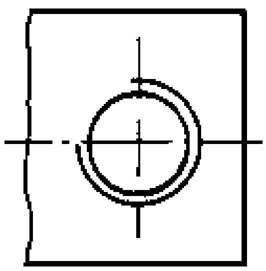


6. Metric thread
$d_N = 16$
Top view to be added.

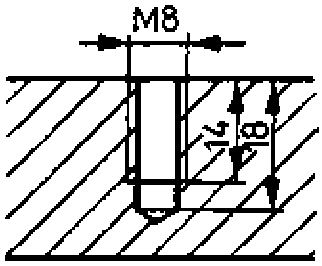


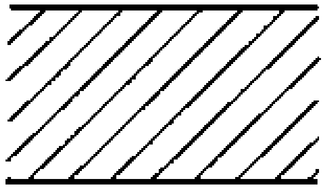
	Problem sheet			28.1

7. Acme thread
d = 18, P = 4
to be dimensioned.

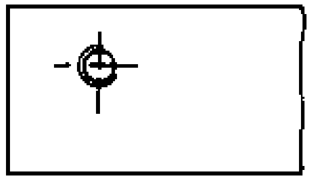


8 . Simplified from below!



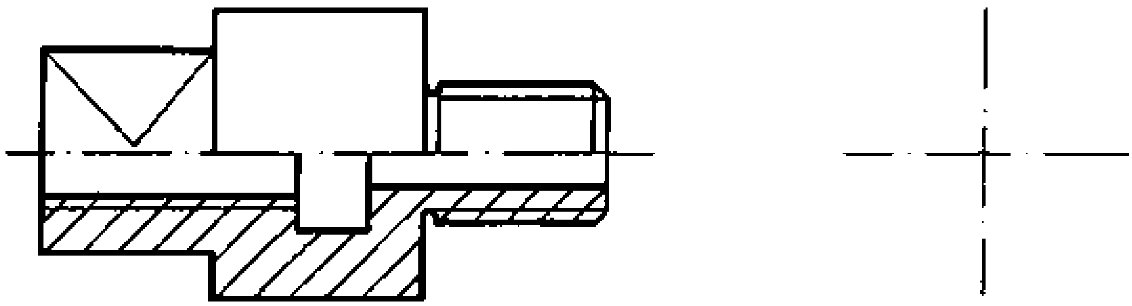


9. M 6 through thread
Simplified dimensioning !

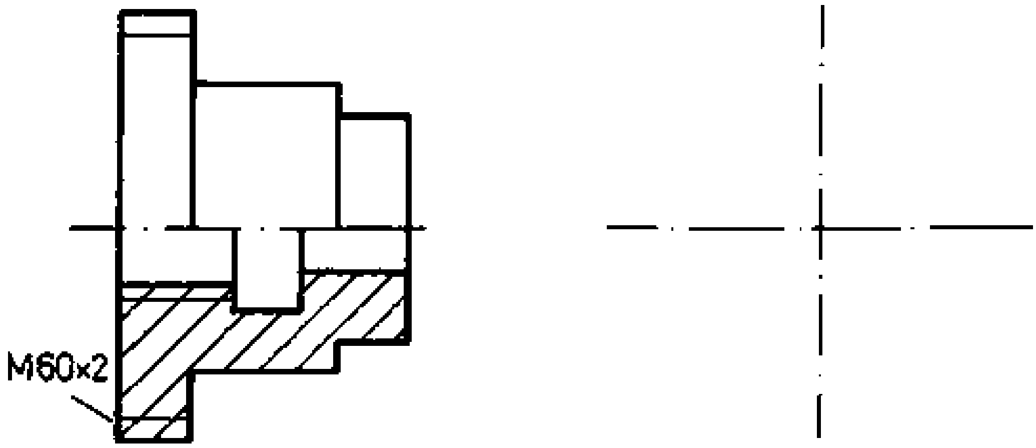


	Problem sheet			28.2

1. Complement the side view and enter the dimensions into the drawing dimensions, cylindrical shapes. (Take the measures)



2. Complement the side view and enter the dimensions into the drawing dimensions, cylindrical shapes. (Take the measures)

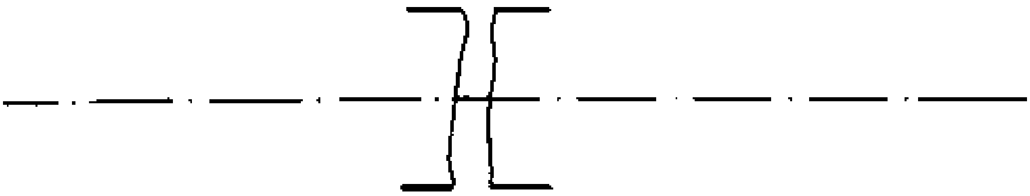


	Problem sheet			29

For the extension of rods of steel, extension parts are used. An extension part has a length of 1 m and a diameter of 25 mm. One end of the part is provided with a threaded pin M 16/32 long In the face of the other end, an internal thread is tapped into which the pin can be fitted (length of thread 35 mm, blind hole having a depth of 40 mm).

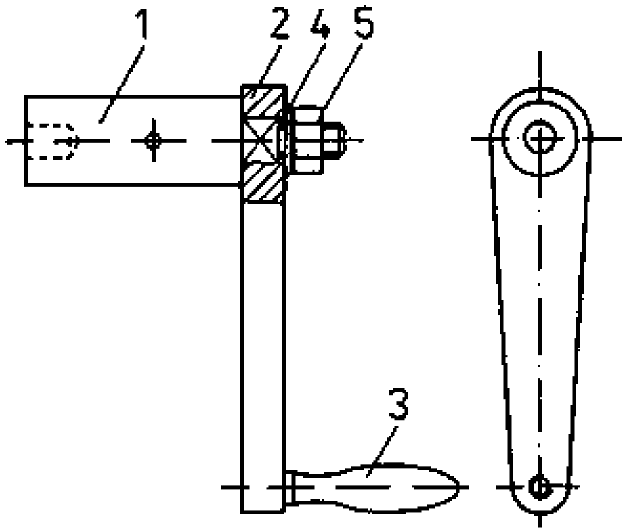
1. Draw the main view of an extension part.
2. Enter the dimensions into this drawing.
3. Indicate the roughness specifications.

The outer cylindrical surface has a roughness of R_z80, all other surfaces of R_z60.



	Problem sheet			30

Prepare a detail drawing of the parts 1 and 2 and provide them with the necessary dimensions.



1	hexagon nut M8	5	St 38b	
1	washer Ø 8.4	4	St 34u	Ø 12×50
1	ball handle	3	St 50	25×10×100
1	lever	2	St 50	Ø 20×75
1	bolt	1	3t 50	
Quantity	Description	Part	Material	Rough size
Drawn by				
Checked by				
Scale 1 : 1		Problem sheet		31

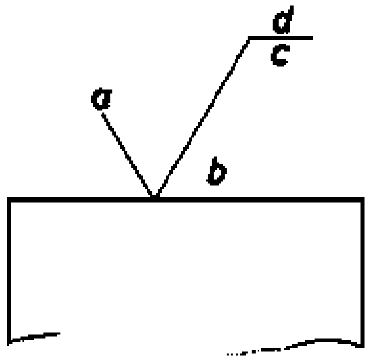
1. What is the definition of the mean roughness R_z ?

2. Enter into the Table the basic symbol together with roughness characteristic and numerical value (?m).

Basic symbol	Basic manufacturing method	Mean surface roughness in mm
	manufacturing method is optional	0.020
	manufacturing method any metal cutting method	0.0063
	any manufacturing method except for metal cutting is specified	0.160

	Problem sheet			32.1

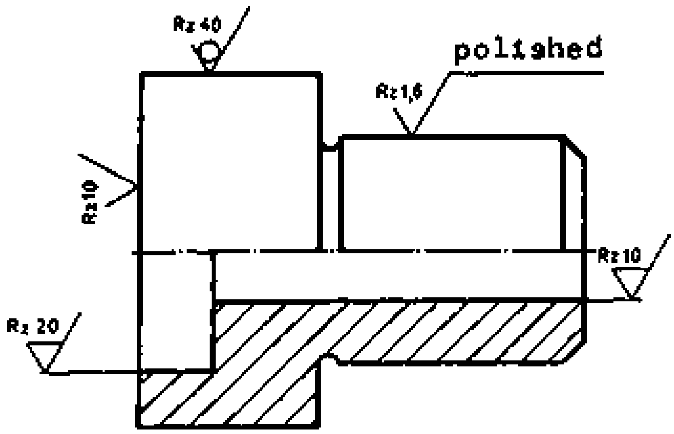
3. Explain the data possible at the symbol



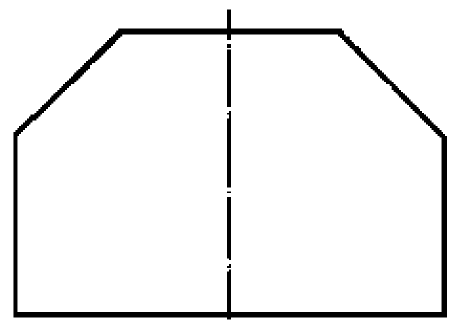
a =
b =
c =
d =

	Problem sheet			32.2

1. Explain the meaning of the dimensions entered.

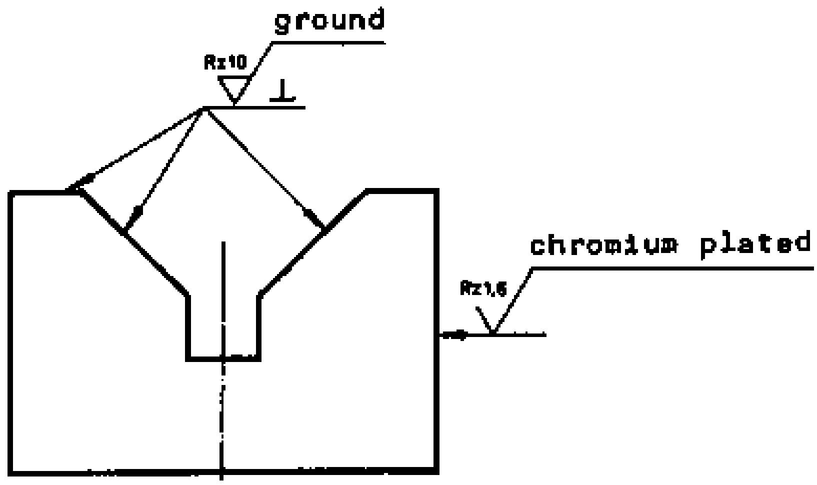


2. In the opposite representation. the following surface roughnesses with optional manufacturing method have to be entered: parallel surfaces R_z 10 inclined surfaces R_z 20, chromium plated

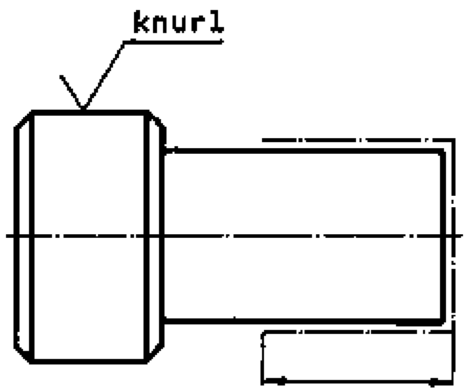


	Problem sheet			33.1

3. Describe the way of dimensioning selected.



4. Complement the representation (knurl) and enter “to be hardened” to the identification line with the help of a leader.



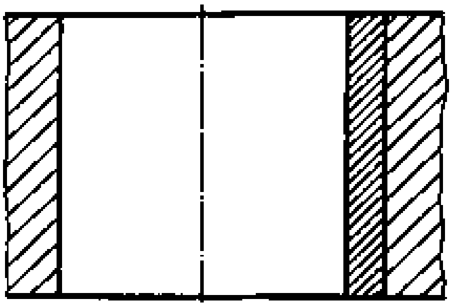
	Problem sheet			33.2

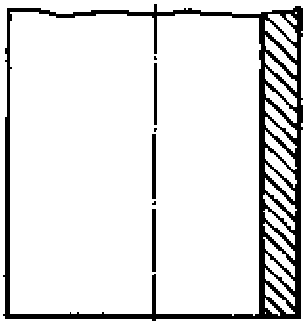
1. Using a practical example, explain the necessity of applying tolerances to dimensions.

2. How do you define the term dimensional variations or, in short, deviations?

3. Dimensional variations may have positive or negative signs or the value of zero. What conclusions do you draw from this?

4. Determine limits and tolerance (nominal size 40 in diameter) and enter them into the Table! Draw the zero line and the required fit dimensions in the drawing.

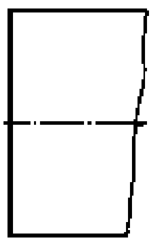
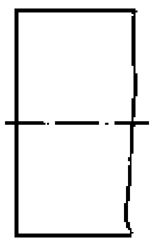
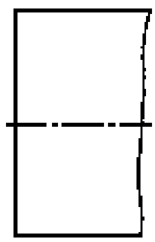
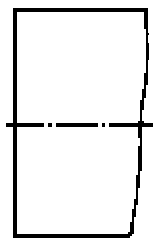
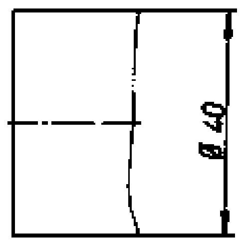




Deviations	G	K	IT
ES + 0,02			
EI 0			
es – 0,01			
ei – 0,04			

	Problem sheet			34.1

5. Sketch the location of the tolerance zones for shafts on the basis of the following data:

Ø 40	+ 0.4;	Ø 40	+ 0.3;	Ø 40	± 0.15;	Ø 40	0;	Ø 40	– 0.1
	+ 0.1		0				–0.3		– 0.4
									

	Problem sheet			34.2

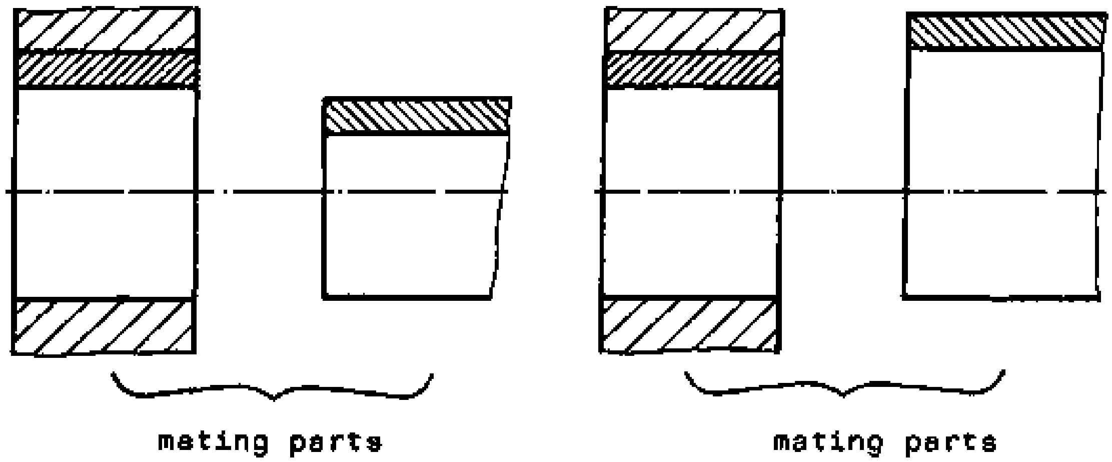
1. When specifying tolerances in drawings, what are the advantages of symbols designating fits over nominal deviations?

2. Explain the use of letters and numerals as symbols designating fits.

3. What are the meanings of the designations Ø 25 K7 and Ø 20 n6?

	Problem sheet			35.1

4. Enter maximum and minimum clearances and largest and smallest allowance for fit into the drawing and explain the terms.

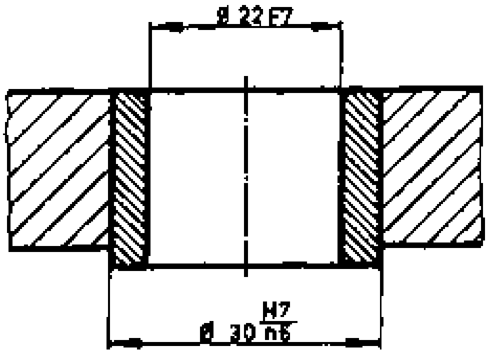


5. Explain the differences between basic hole and basic shaft

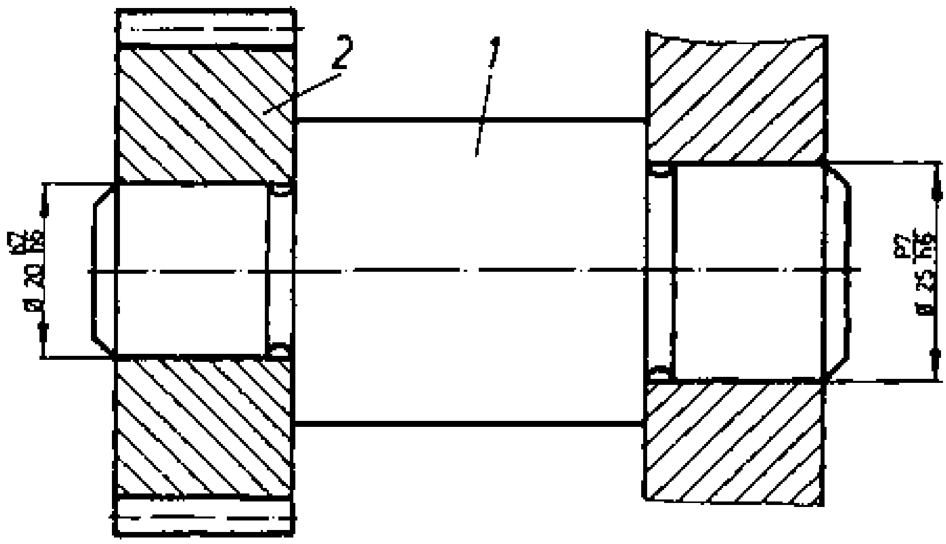
6. what are the letters generally used for basic hole and basic shaft. Give the reasons for this.

	Problem sheet			35.2

1. Prepare a sketch of the jig bush and enter the dimensions of the fit. The fit of the bush must be determined with the help of a Table of deviations.



2. Prepare a sketch of parts 1 and 2. Enter the dimensions of the fit and determine the fits with the help of a Table of deviations.



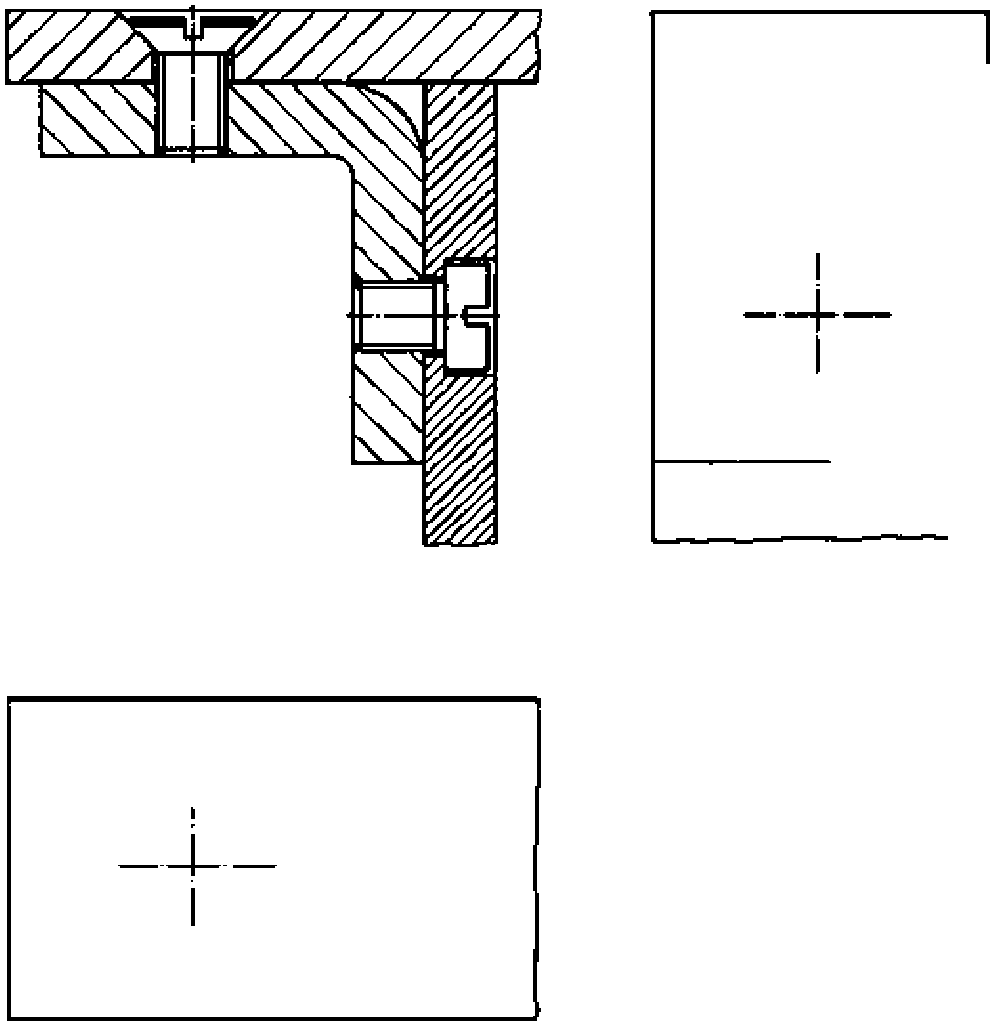
	Problem sheet			36

1. The illustrated bolted connection consists of the parts to be joined “web”, “angle” and “chord plate”. These individual parts are joined by means of a countersunk screw M10×22 and a fillister head screw M10×15.

The three parts have a thickness of 10 mm each. Gather information about the designations of the screws mentioned here.

2. Provide the five parts with a consecutive number and enter them into the drawing.

3. Add the left side view and the top view! (The screw centre points are already indicated by the centre lines.) 4. Prepare a list of parts including all of the necessary data. 5. Prepare a sketch of the five single parts and dimension them.				
	Problem sheet			37.1



	Problem sheet			37.2

A bolt (b) is to be riveted into a plate (a). The detail drawings and the button–head to be driven indicated by a dash–and–dot line are given in order that shape and location of the driven rivet are illustrated.

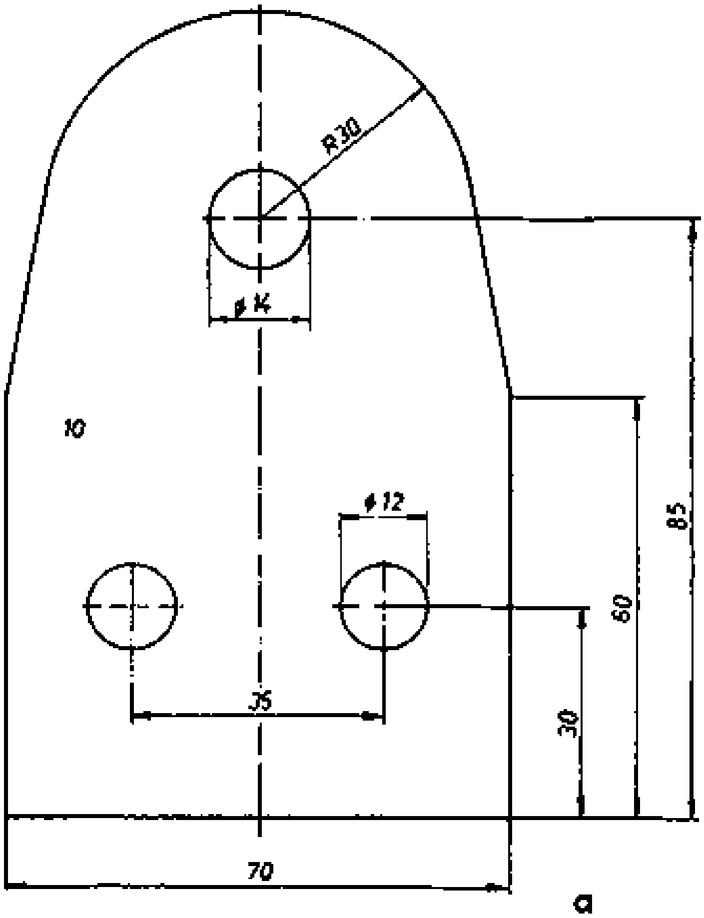
1. Prepare the assembly drawing of the plate with the fitted rivet in front view and left side view.

2. Draw the left side view in full section in such a way that both the bolt and one of the two holes having a diameter of 12 become visible. (Pay attention to the fact that the bolt will not be shaded even if it is located in the cutting plane.)

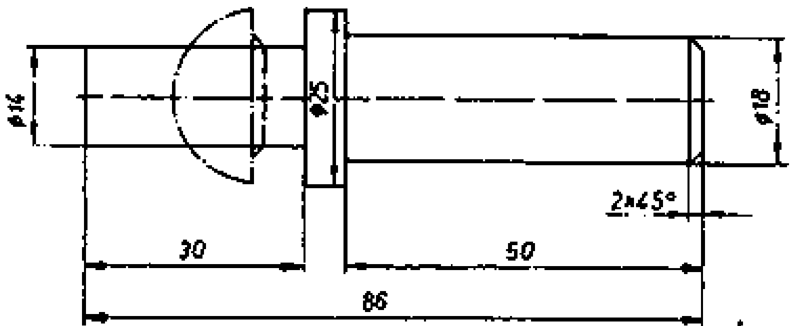
3. Prepare a list of parts (the material is structural steel).

4. Prepare an assembly drawing according to which the bolt is not to be riveted by screwed in.

	Problem sheet			38.1



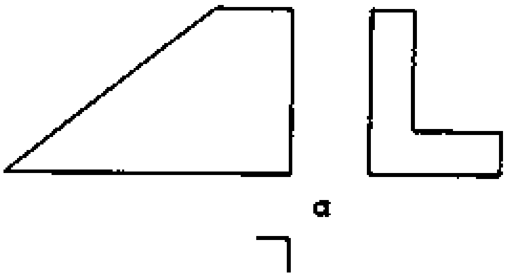
a



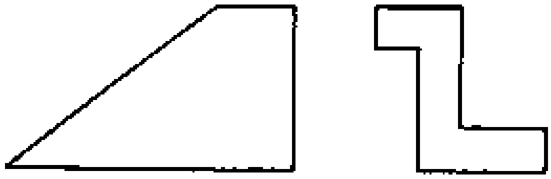
b

	Problem sheet			38.2

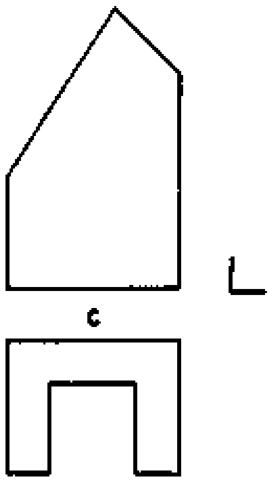
Complete the drawings !



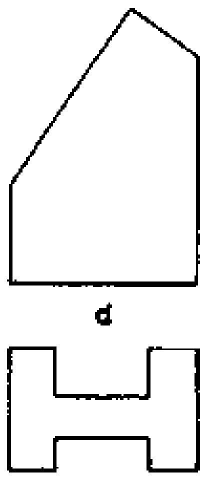
a



b

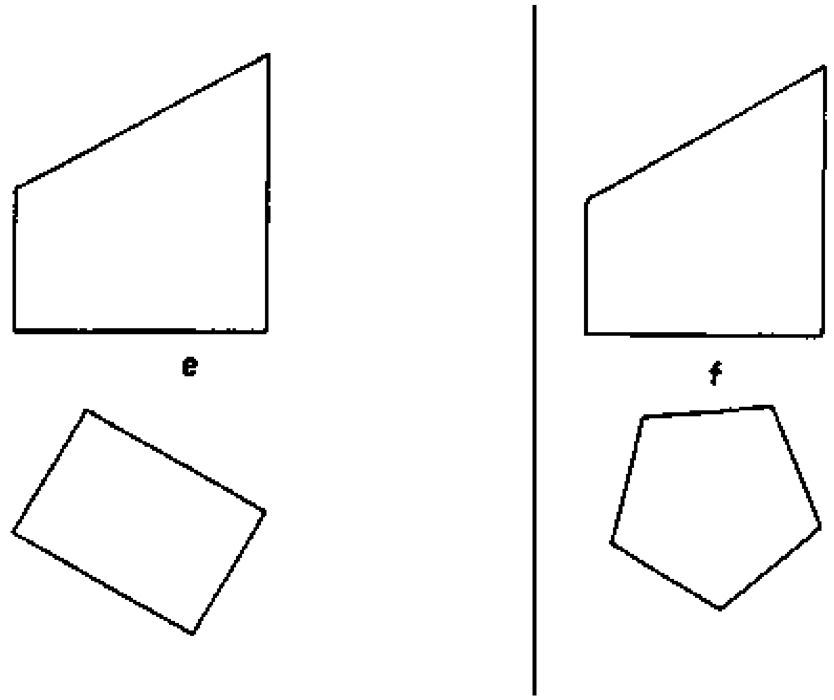


c



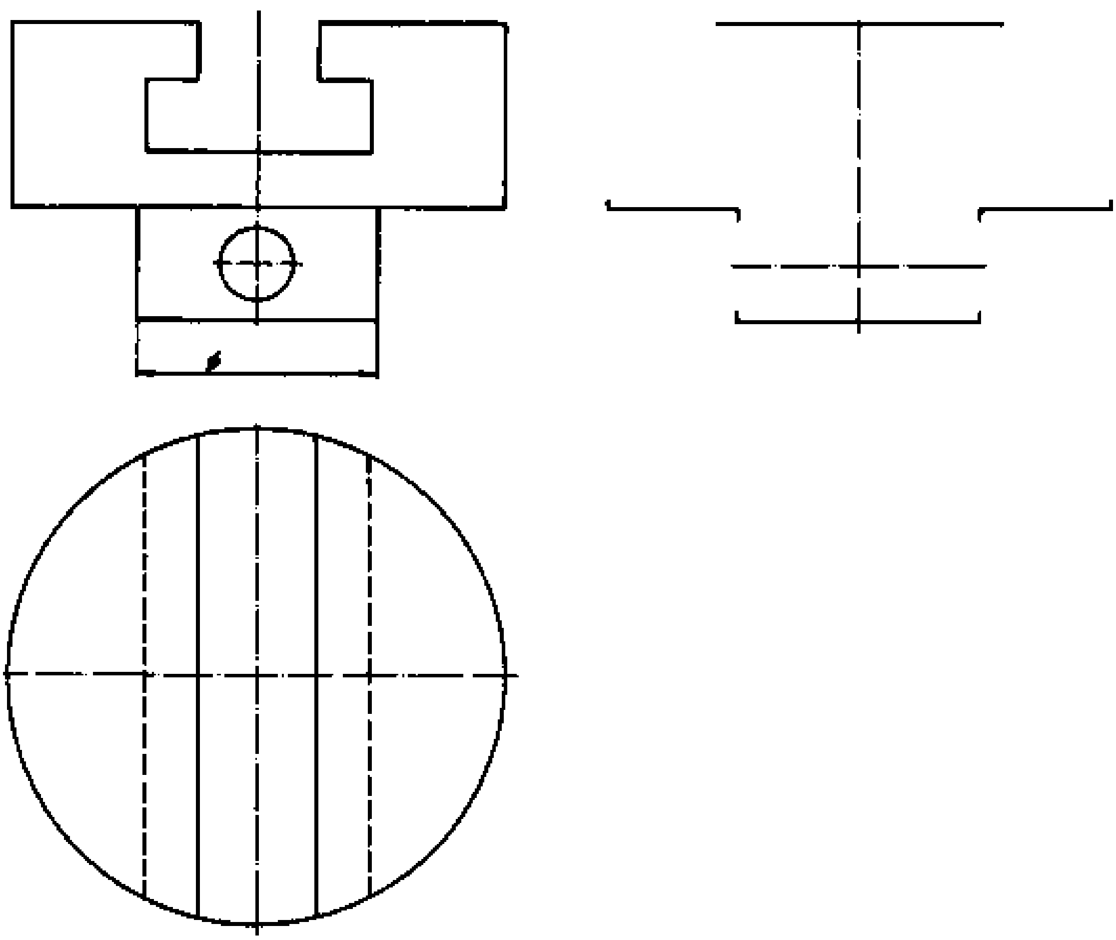
d

	Problem sheet			39.1



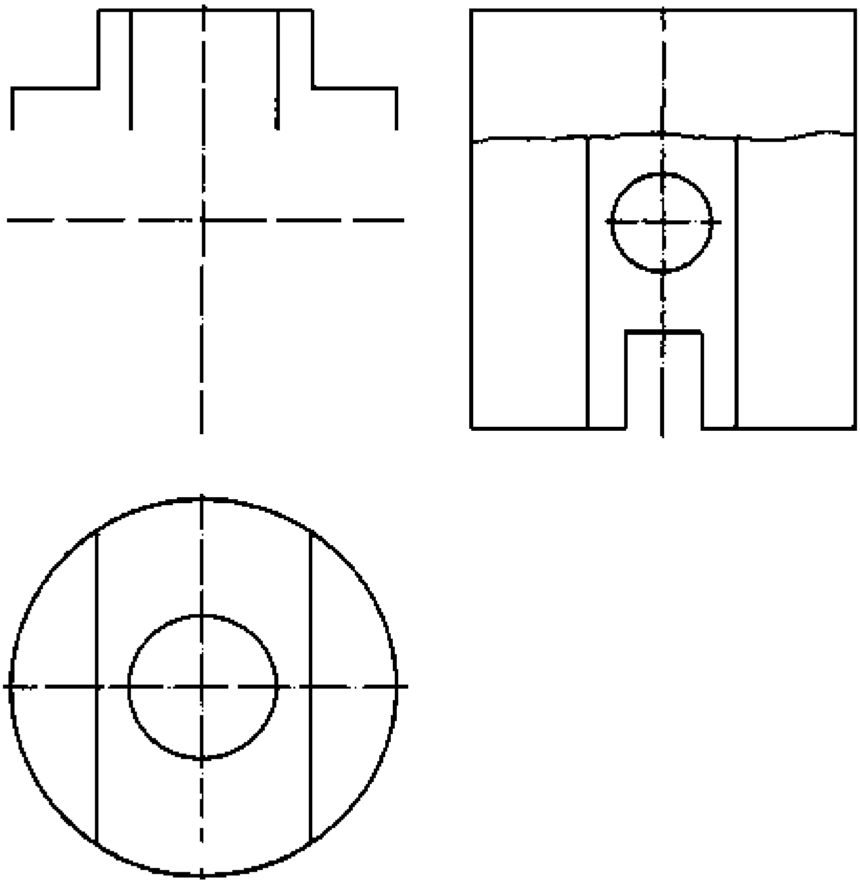
	Problem sheet			39.2

1. Draw the left side view in full section.



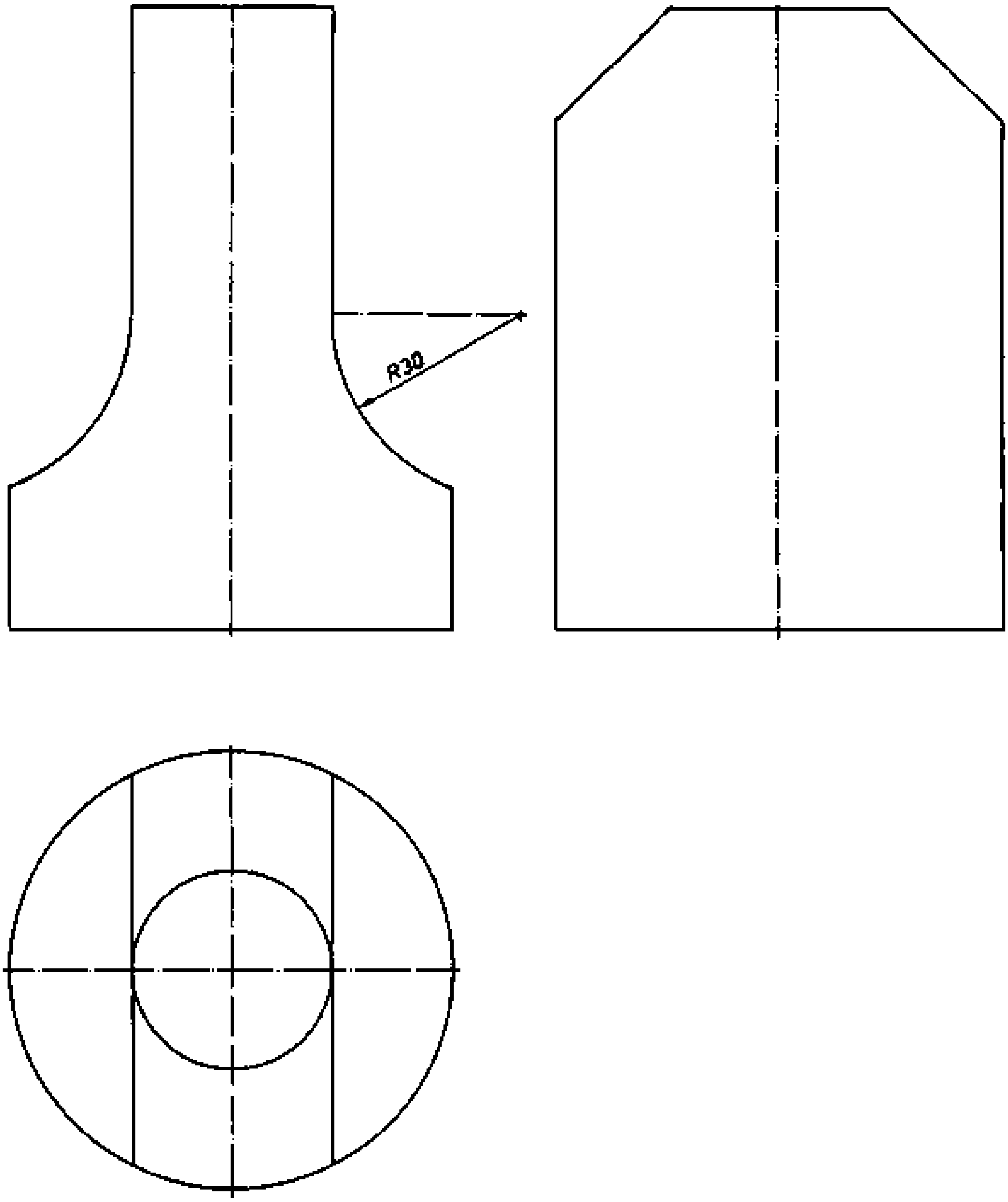
	Problem sheet			40.1

2. Complement the left side view! Draw the main view in full section.



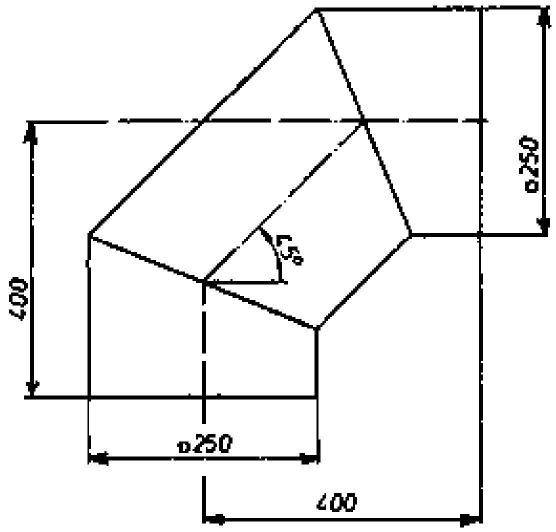
	Problem sheet			40.2

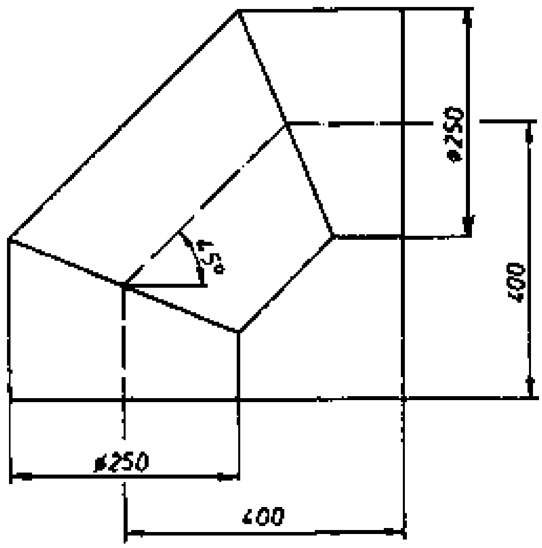
Complete the drawings according to curve patterns, Use the auxiliary Ritter method.

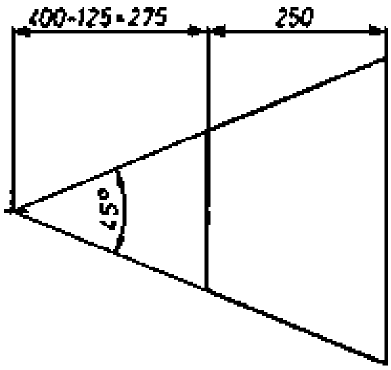


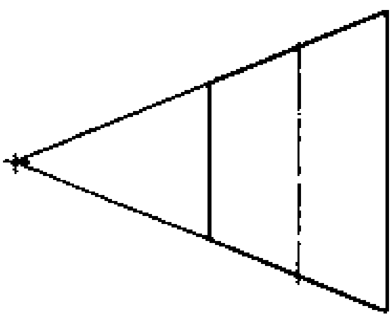
	Problem sheet			41

Construct the development of the two intermediate parts (M 1:10). (First sketch the top view! Next set up the elements! Only project now!)









	Problem sheet			42

1. Complement the following Table:		
Description	Function	Symbol
Shaft		
Sliding bearing Antifriction bearing		
Pin coupling Claw coupling		
2. Answer the questions and draw the symbolic representation:		

Belt drive	Change of the speed?	Change of sense of rotation?	Symbol
Belt pulleys of equal size			
Belt pulleys of different sizes			
Belt pulleys of different sizes and belts crossed			

	Problem sheet			43

1. Explain the term “pitch circle diameter”.

2. Quote the abbreviated form of the term pitch circle diameter:

3. How is the pitch circle diameter represented in engineering drawings?

4. Prepare a detail drawing of a straight-toothed spur gear. Draw and dimension according to the following data:

$d_k = 72$; $d_o = 66$; $d_f = 58.5$; $b = 30$; $m = 3$; $Z = 22$;

in its centre, the spur gear is provided with a hole, diameter 20, which is to be provided with a groove having a width of 6 and a depth of 3 mm.

front view	left side view

	Problem sheet			44

1. Spur gears on parallel axes in a simple arrangement have to be represented in an assembly

drawing in order to indicate their location. Draw the spur gears on parallel axes according to the following data:

distance between the two axes (from shaft centre I to shaft centre II) is 55.5 mm;

gear Z_1 : d_k = 72; d_o = 66; b = 30 and
gear Z_2 : d_k = 51; d_o = 45; b = 30

Simplified representation from the front	from the left

	Problem sheet			45

1. Draw the pair of spur gears on parallel axes of the previous problem sheet in symbolic representation and mark the mounting. The two gears have to be mounted on the shafts axially firm.

Representation from the front	from the left

	Problem sheet			46

1. Tell the difference between a pair of spur gears on parallel axes of simple arrangement and a speed–changing mechanism.

2. Explain the designations used in the gear diagrams "speed–changing mechanism III/9":

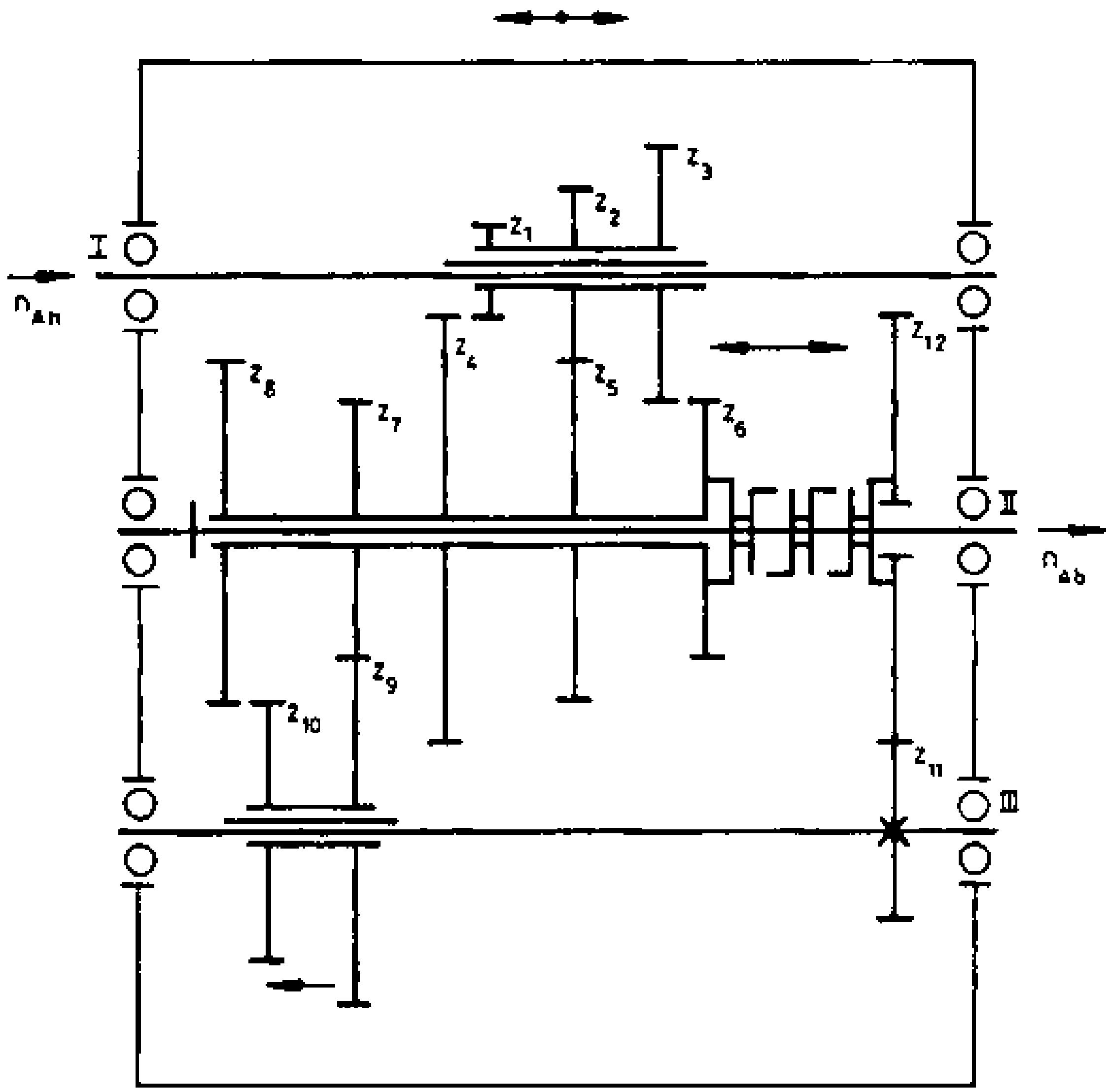
n_{An} =
Z_1 to Z_{12} =

n_{Ab} =

3. How many possible speeds can you read from the gear diagram by

different control positions?				
	Problem sheet			47.1

Speed−changing mechanism HI/9



	Problem sheet			47.2

1. Explain the abbreviated designation of the sections of the parts 1 to 3.

2. Instead of the numbers, enter the designations of the sections into the drawing.

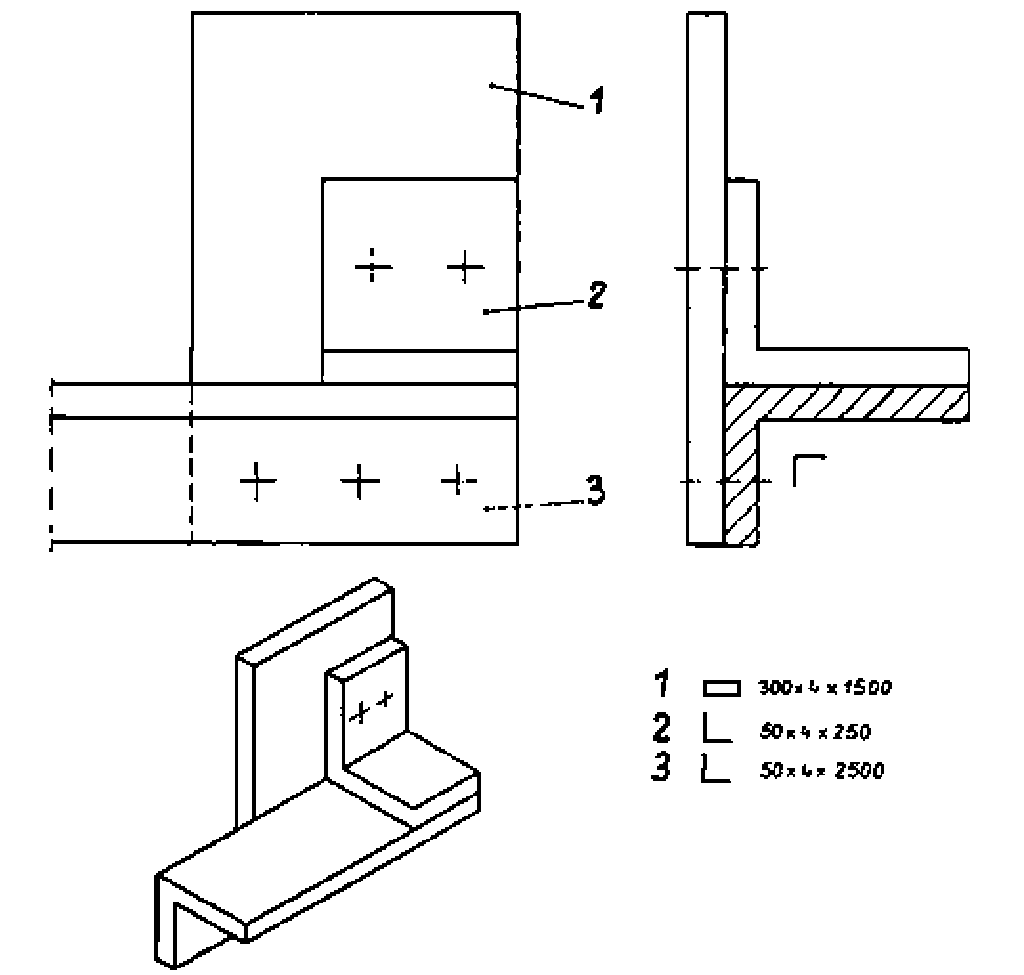
3. Draw button−head rivets having a diameter d = 12 mm before driving into the centres of the front view. Select uniform distances between the rivets.

4. Complement the side view and add the rivet symbols.

5. Draw and dimension the three individual parts with the rivet holes in a scale to be chosen by you.

6. What information in the form of signs has to be given to show that the riveted connection has not to be made in the workshop but at the construction site?

	Problem sheet			48.1



	Problem sheet			48.2

1. Explain the designations of the sections.

2. Draw three bolts M 20 into the centres of the front view. Draw the connection with the help of the symbols.

3. Complement the side view with the bolt symbols.

4. Draw the individual parts with the drilled holes for the bolts in a suitable scale and apply the dimensions to the parts.

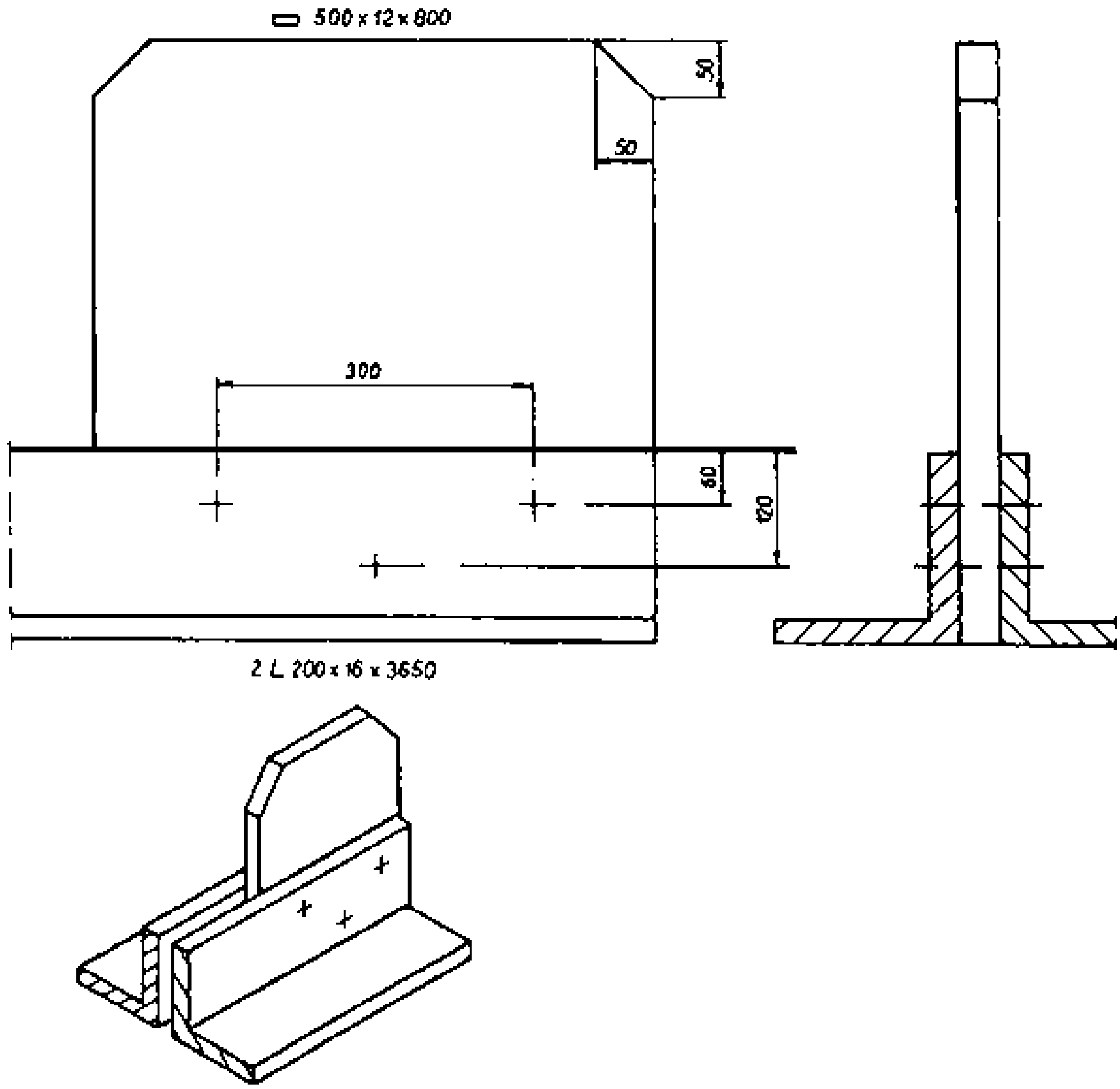
5. Sketch the connection in such a way that, in the place of bolts, three rivets are used having a

diameter of 16 mm before driving.

6. Explain the differences between the bolted and the riveted joint .

7. How have the symbols to be changed when assembling and drilling have to be performed at the construction site?

	Problem sheet			49.1



	Problem sheet			49.2

The perspective representation shows a

−beam which has been welded of two individual sections (4) by a V−seam (d) to the overall length of 6,000 mm. To the end, an angle with stiffening has been welded by a 4−mm thick fillet weld (a). The angle has been made of plates (1, 2). The left−hand weld seam is a 4−mm thick fillet weld (a) while the other three sides are endge−joint single−V groove welds. The angle is reinforced by part (3) and a 4−mm thick twin fillet weld is made.

1. Explain the designations of the sections.

2. Draw the individual parts 1 and 3 and dimension them.

3. Prepare the front view and the side view of the welded angle with stiffening (symbolically).

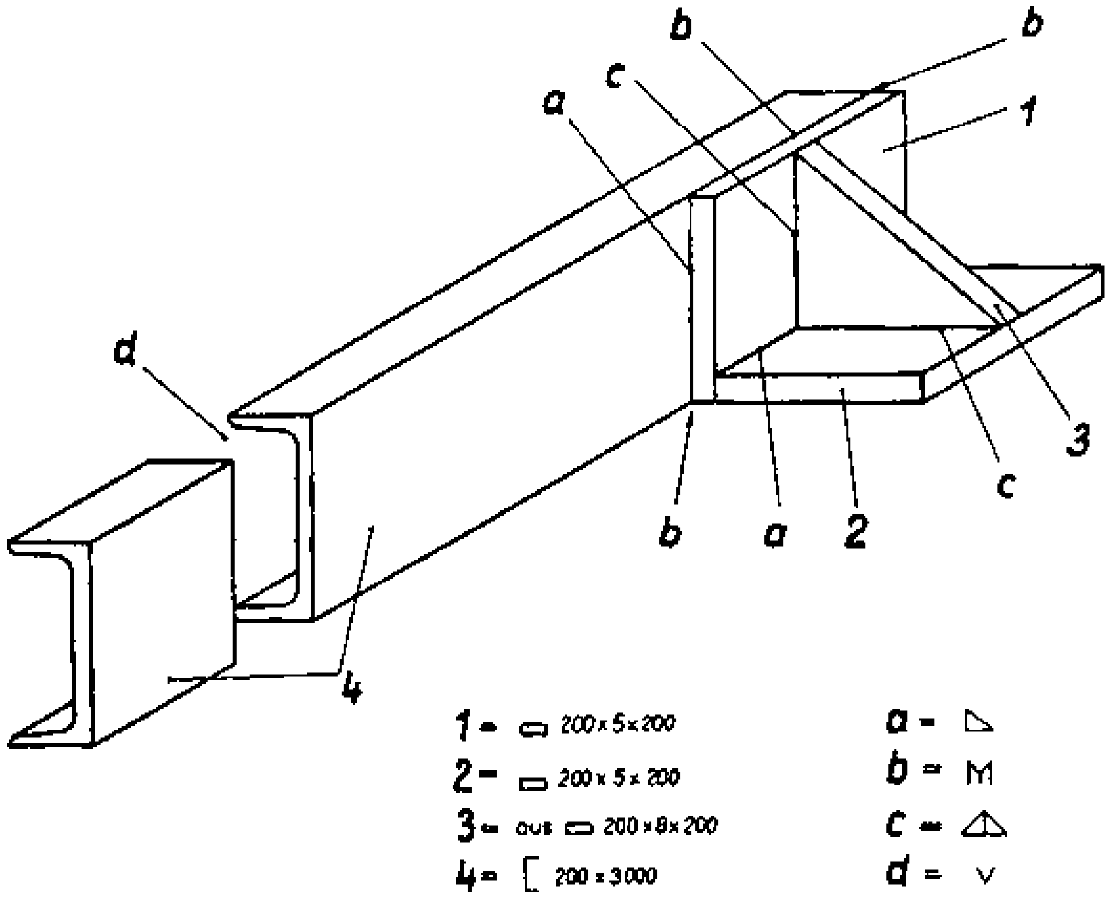
4. Sketch the welded beam without angle in one view (pictorially) and indicate the abbreviated designations of the sections.

5. Prepare a sketch of the complete welded beam element with the angle and all of the welding data and symbols.

6. Prepare a sketch of the construction in such a manner that the angle welded to the −section would be fastened by means of 4 M16 screws or 4 button−head rivets of the same size.

7. Compare the methods of fastening the angle, namely bolting, riveting and welding, according to sequence of operations, durability, interchangeability during repairs and according to the danger of accidents.

	Problem sheet			50.1



	Problem sheet			50.2

By means of the sections and plates represented in perspective, a frame corner is to be welded. The beam (1) is to be placed on a column having box section. The column is welded to a box section of parts (2) and (3) by means of a V–weld.

1. Explain the sections.

2. Prepare a sketch of the individual parts in the necessary views.

3. Prepare a drawing of the welded column in

such a way that the weld seams are clearly visible (pictorially and symbolically).

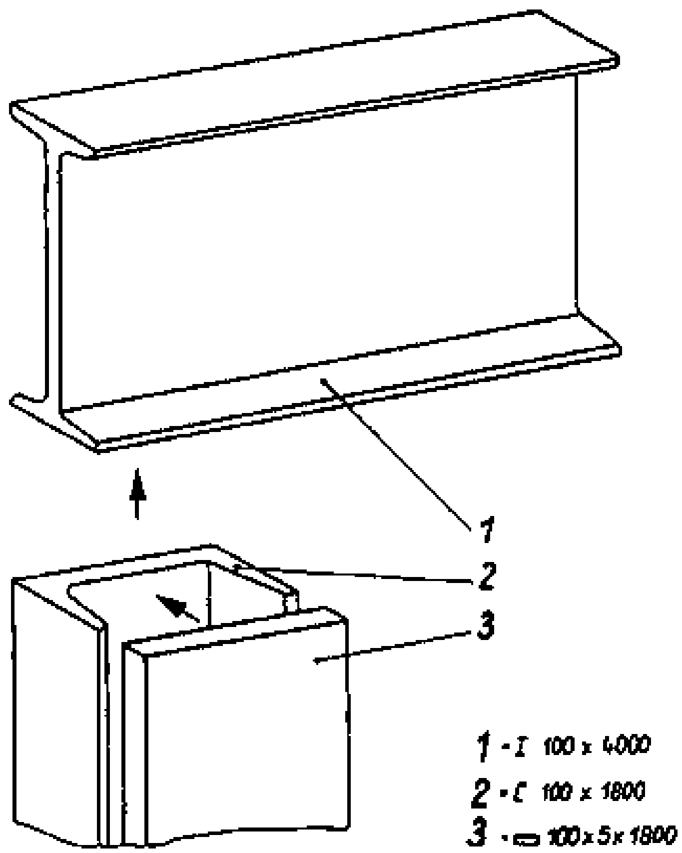
4. Draw the complete welded frame corner.

5. Complement the representation by the use of a top plate and a foot plate. Take into consideration that the foot plate must be larger than the box section of the column because the plate must be provided with two stone bolts! (To find the solution, use Fig. 12.31.)

6. Draw the stiffening plate in the beam within the range of the column contact.

7. Explain the exact sequence of assembling including the required tools and auxiliaries.

	Problem sheet			51.1



	Problem sheet			51.2

The drawings comprise total view and sections of a steel platform construction.

1. Explain the four different drawing types.

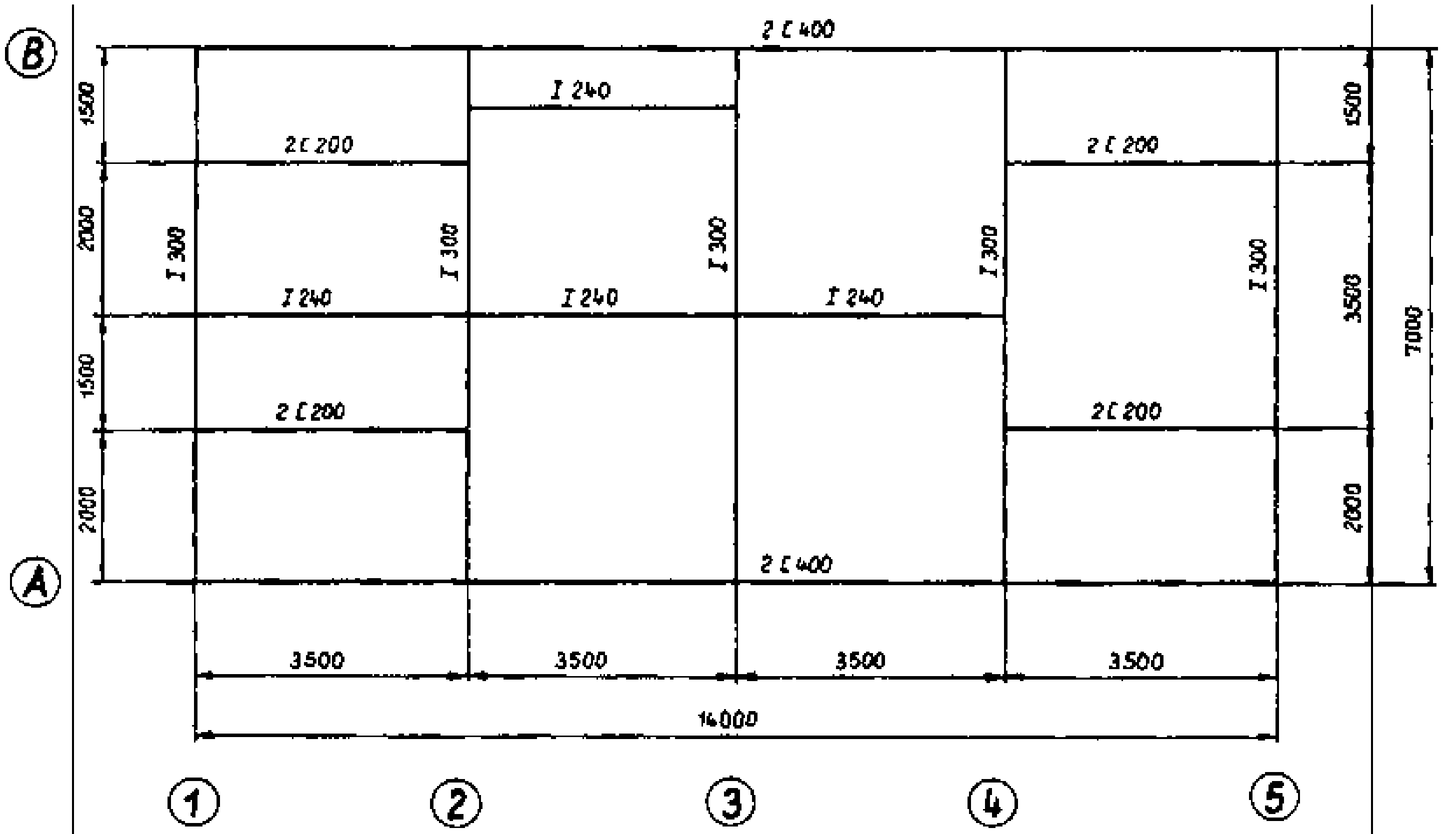
2. Prepare a list of parts for the erection of the components (part number, specifications of sections, quantity required)

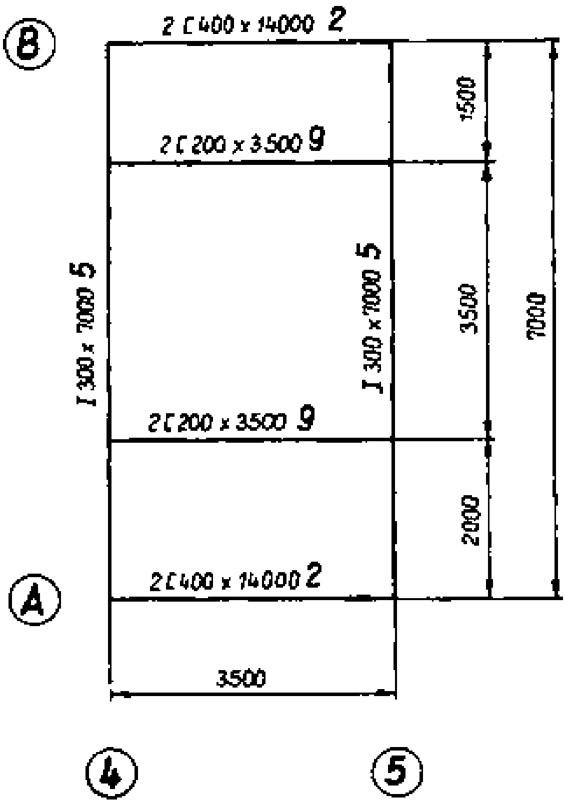
3. How are axes and rows marked?

4. Indicate the altitude levels of the steel platform parts.

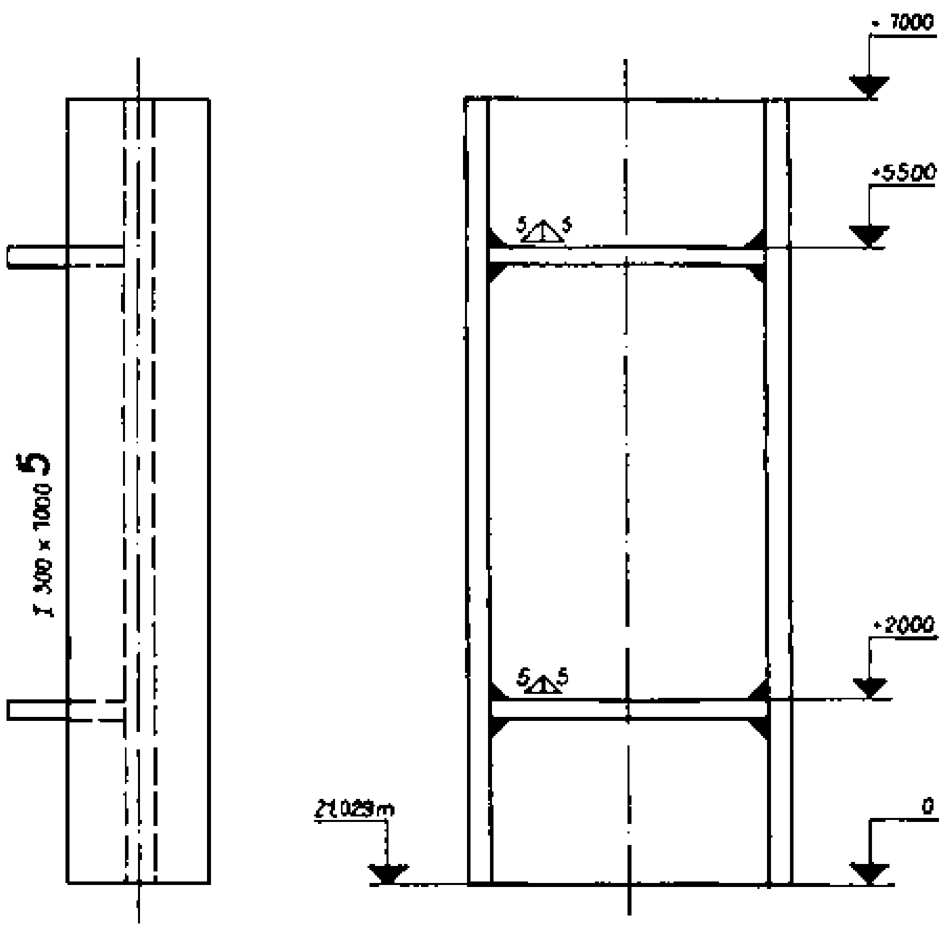
5. Substantiate the representation and dimensioning of the individual parts.

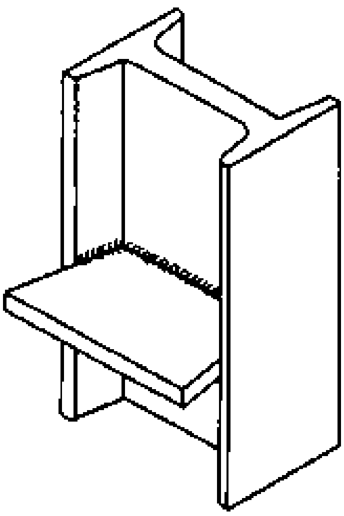
6. Prepare a sketch of the portion between the rows 1 and 2.				
	Problem sheet			52.1

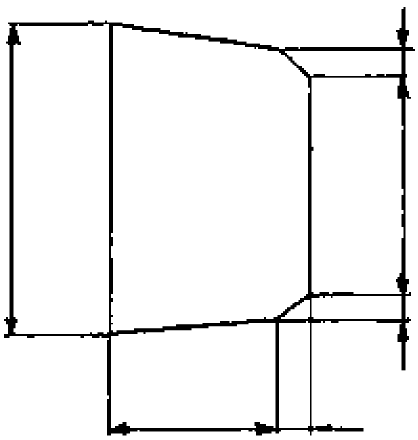




	Problem sheet			52.2







	Problem sheet			52.3