SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
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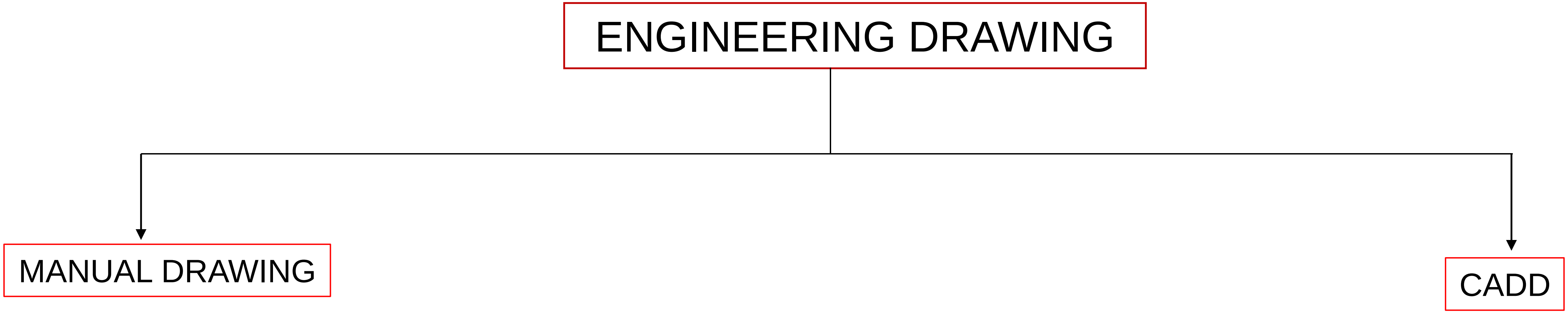
MACHINE DRAWING

(SMEA1304)

- ✓ Drawing is a Graphical representation of an object.
- ✓ Engineering Drawing – A drawing of an object that contains all information like actual shape and size, manufacturing methods, etc., required for its construction.
- ✓ No construction / manufacturing of any engineering objects is possible without engineering drawing.
- ✓ Engineering drawing is a two dimensional representation of three dimensional objects.
- ✓ Engineering drawing is called the universal language of Engineers.



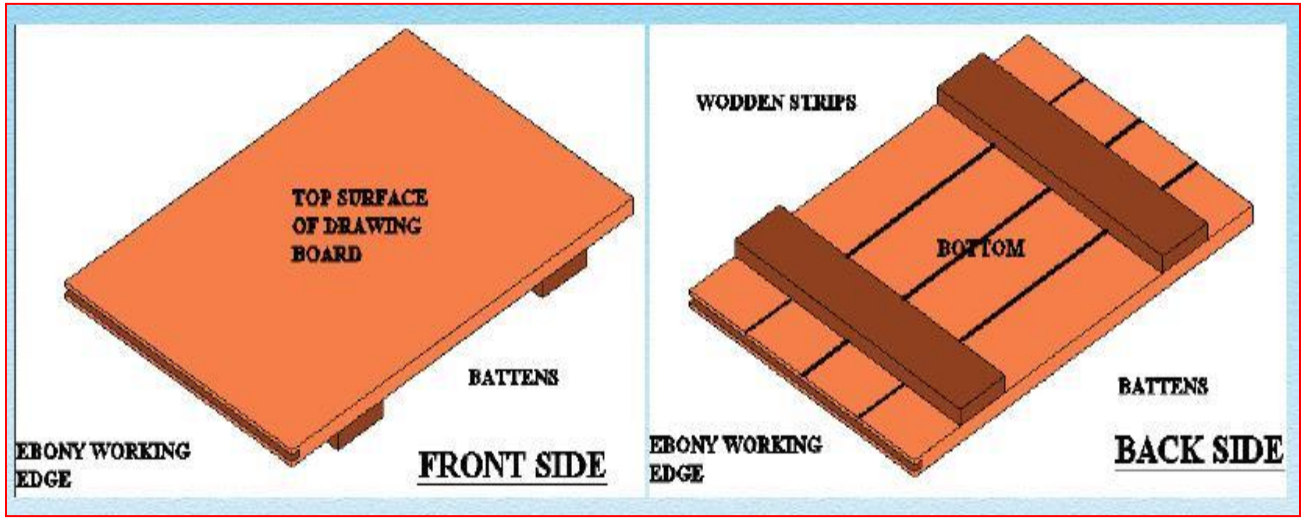
- Computer has a major impact on the methods used to design and create technical drawings.
- Design and drafting on computer are cheap and less time consuming.

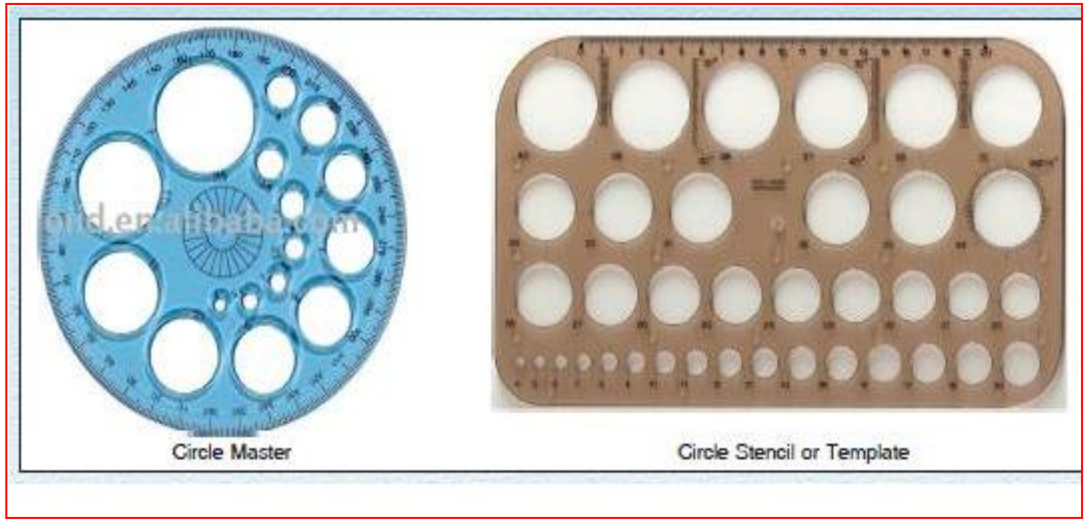
NEED TO STUDY ENGINEERING GRAPHICS

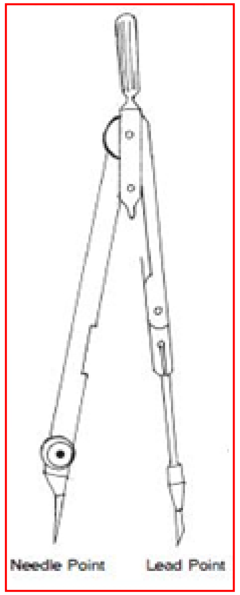
- ✓ To develop the ability to produce simple engineering drawing and sketches based on current practice.
- ✓ To develop the skills to read manufacturing and construction drawings used in industry.
- ✓ To develop a working knowledge of the layout of plant and equipment.
- ✓ To develop skills in abstracting information from calculation sheets and schematic diagrams to produce working drawings for manufacturers, installers and fabricators.
- ✓ Applications are : building drawing for civil engineers, machine drawing for mechanical engineers, circuit diagrams for electrical and electronics engineers, computer graphics for one and all.

DRAFTING EQUIPMENTS

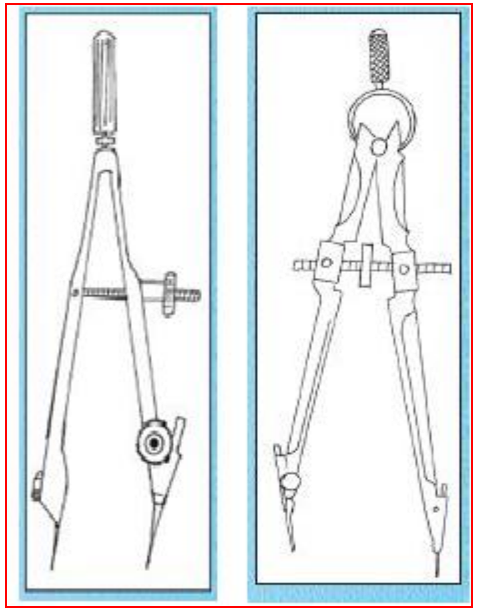
- ✓ DRAWING BOARD
- ✓ MINI DRAFTER
- ✓ DRAWING SHEET
- ✓ PENCILS (H, HB, 2H etc.,)
- ✓ NON DUST RUBBER
- ✓ SCALES
- ✓ INSTRUMENT BOX
- ✓ SET SQUARES (30°, 45°, 60° etc..)
- ✓ DRAWING BOARD CLIPS, CLAMPS, PINS, CELLO TAPE
- ✓ PROTRACTOR / PRO CIRCLE / CIRCLE MASTER
- ✓ PENCIL SHARPENER
- ✓ SMALL PAPER KNIFE or STITCHING THREAD etc.,



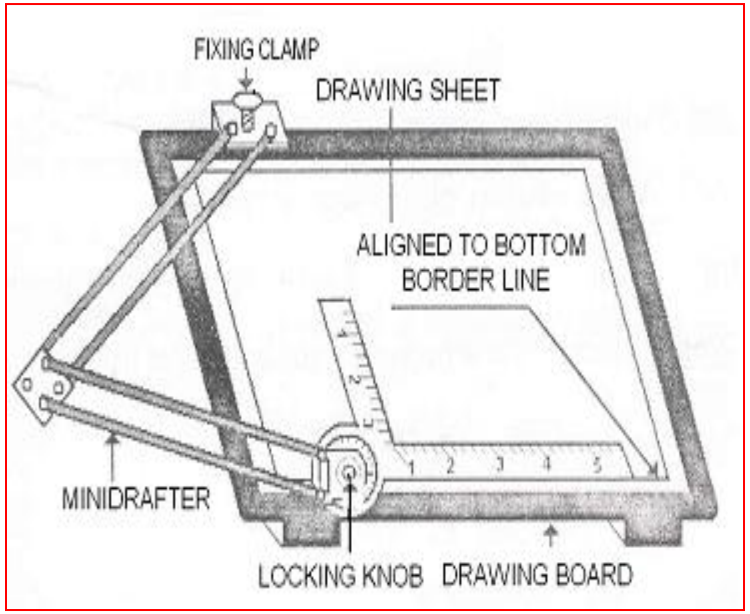


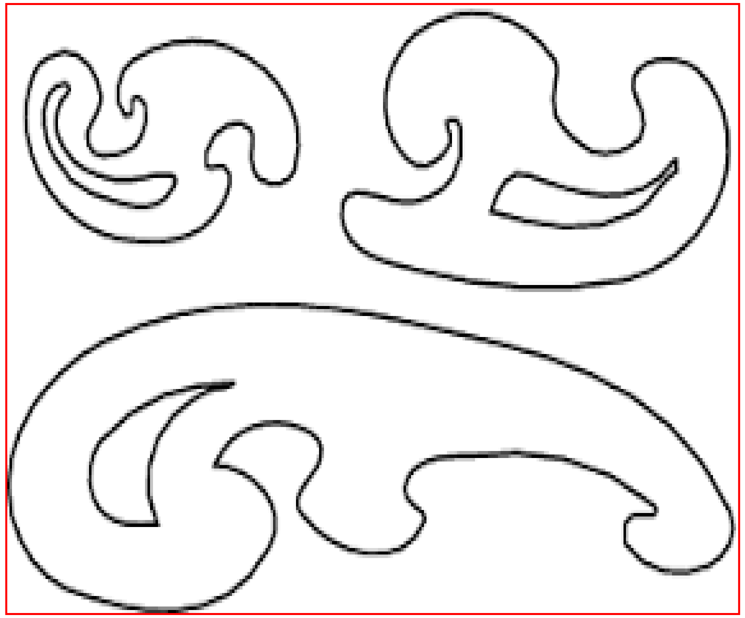


LARGE



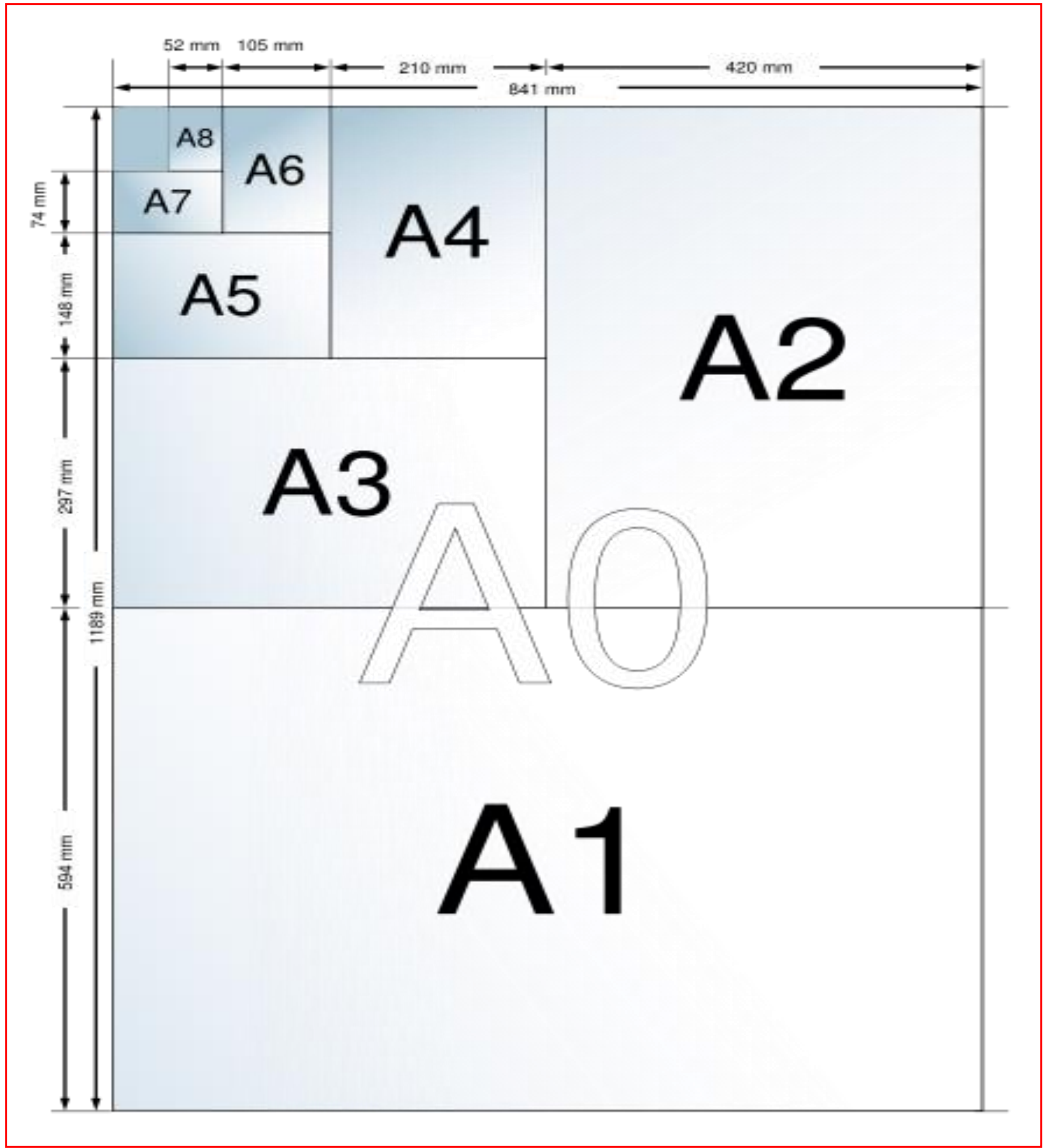
BOW COMPASS





PAPER SIZES

A Series Formats (mm)	
A0	841 × 1189
A1	594 × 841
A2	420 × 594
A3	297 × 420
A4	210 × 297
A5	148 × 210
A6	105 × 148
A7	74 × 105



TITLE BLOCK

✓ The title block should lie within the drawing space at the bottom right hand comer of the sheet.

The title block should contain the following information:

1. Title of the drawing

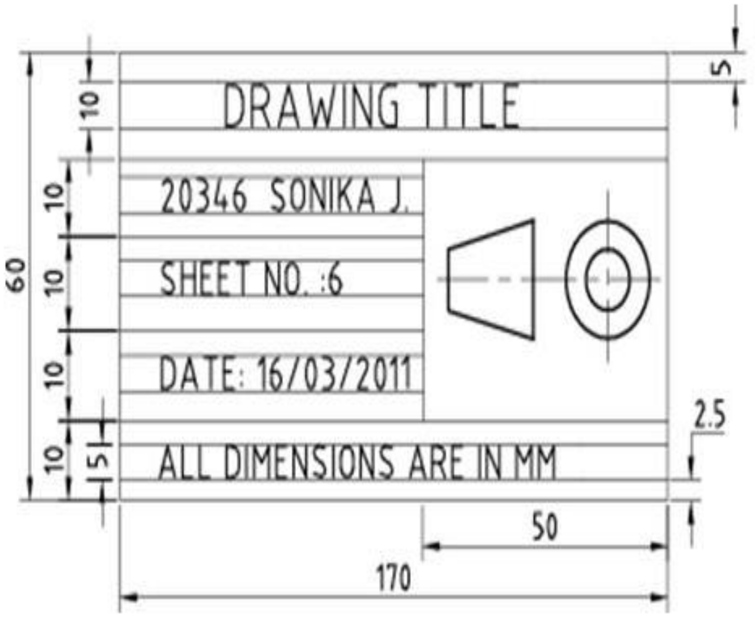
2. Drawing plate number

3. Scale chosen

4. Symbol denoting the angle of projection

5. Name of the firm and

6. Initials of staff who have designed, checked and approved.

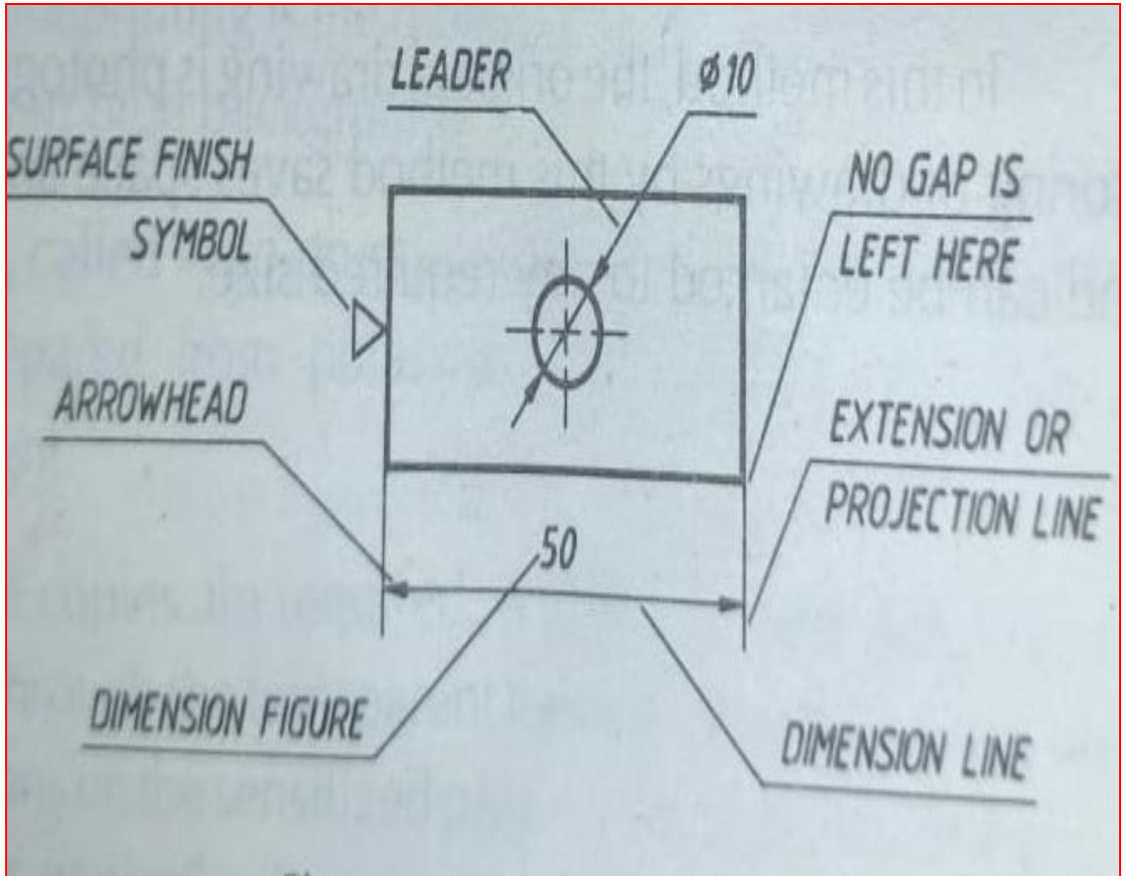


TYPES OF LINES AND THEIR APPLICATIONS

Line description and Representation	Applications
Continuous narrow line B	Dimension lines, Extension lines
	Leader lines, Reference lines
	Short centre lines
	Projection lines
	Hatching
	Construction lines, Guide lines
	Outlines of revolved sections
	Imaginary lines of intersection
Continuous narrow freehand line C	Preferably manually represented termination of partial or interrupted views, cuts and sections, if the limit is not a line of symmetry or a center line [a].
Continuous narrow line with zigzags A	Preferably mechanically represented termination of partial or interrupted views, cuts and sections, if the limit is not a line of symmetry or a center line[a].
Continuous wide line	Visible edges, visible outlines
	Main representations in diagrams, maps, flow charts
Dashed narrow line D	Hidden edges
	Hidden outlines
Long-dashed dotted narrow line E	Center lines / Axes, Lines of symmetry
	Cutting planes (Line 04.2 at ends and changes of direction)
Long-dashed dotted wide line F	Cutting planes at the ends and changes of direction outlines of visible parts situated in front of cutting plane

DIMENSIONING

➢ It is nothing but indicating on a drawing, the size of the object and other details essential for its construction and function, using lines, numerals, symbols, notes, etc.,



Elements of Dimensioning

PRINCIPLES OF DIMENSIONING

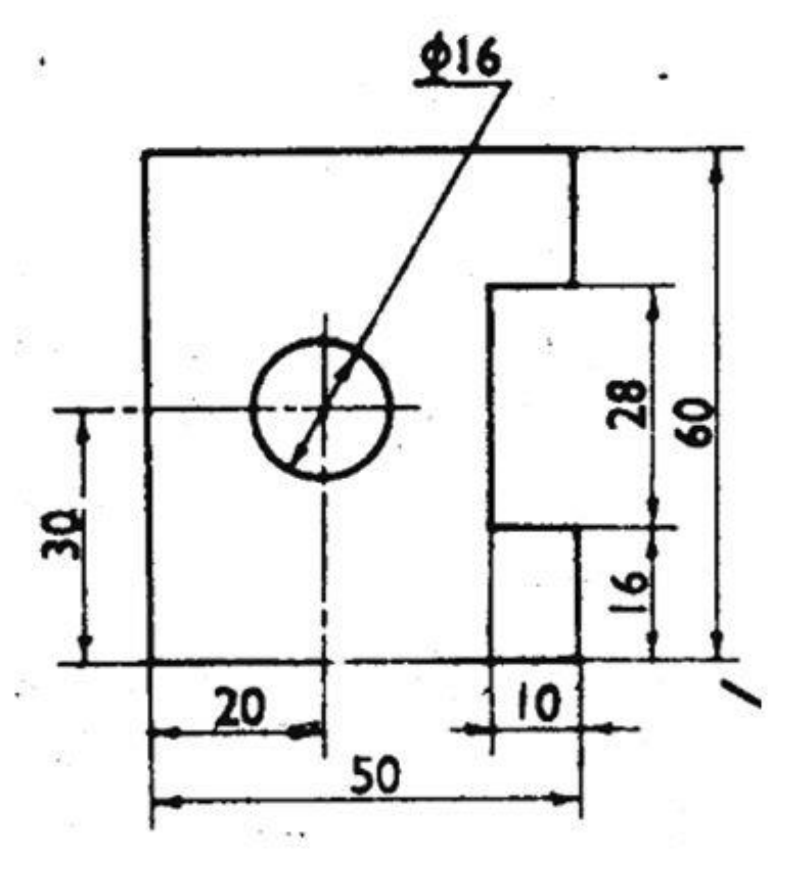
✓ All dimensional information necessary to describe a component clearly and completely shall be written directly on a drawing.

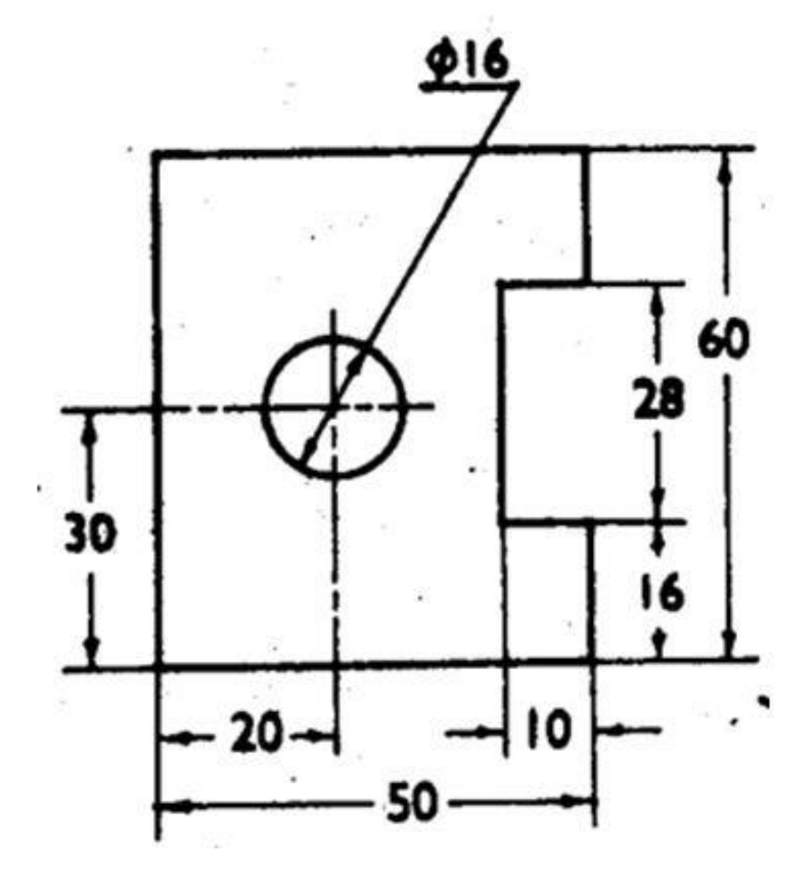
✓ Each feature shall be dimensioned once only on a drawing, i.e., dimension marked in one view need not be repeated in another view.

✓ Dimensions should be expressed millimeters only, without showing the unit symbol (mm).

✓As far as possible dimensions should be placed outside the view .

SYSTEMS OF DIMENSIONING





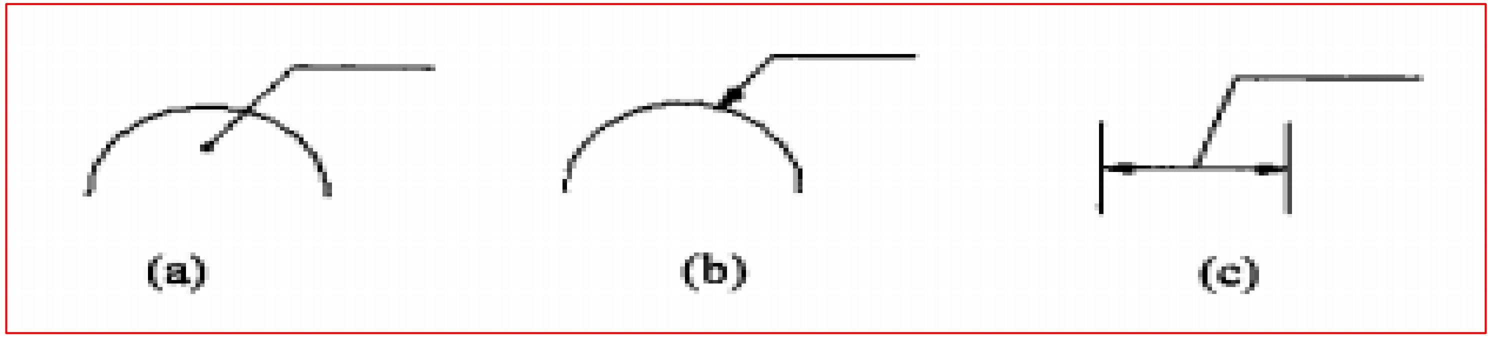
ALIGNED SYSTEM

UNIDIRECTIONAL SYSTEM

LEADER OR POINTER LINE

✓ A leader line is a thin or continuous line of TYPE Breferring to a feature (object, outline, dimension).

✓ Leader lines may be drawn at 30°, ***45°***, 60° to horizontal.



SCALES

- ✓ A scale is defined as the ratio of the linear dimensions of the object as represented in a drawing to the actual dimensions of the same.
- ✓ Representative Fraction(RF) = DL/OL = Drawing Length/Original Length

CATEGORY	RF	SCALES						
Enlargement Scales	RF>1	2:1	5:1	10:1	20:1	50:1		
Reduction Scales		1:2	1:5	1:10	1:20	1:50	1:100	1:200
	RF<1	1:500	1:1000	1:2000	1:5000	1:10000		
Full Scale	RF=1	1:1						

SMEA1101 ENGINEERING GRAPHICS

UNIT 1 LETTERING, DIMENSIONING AND GEOMETRICAL CONSTRUCTION

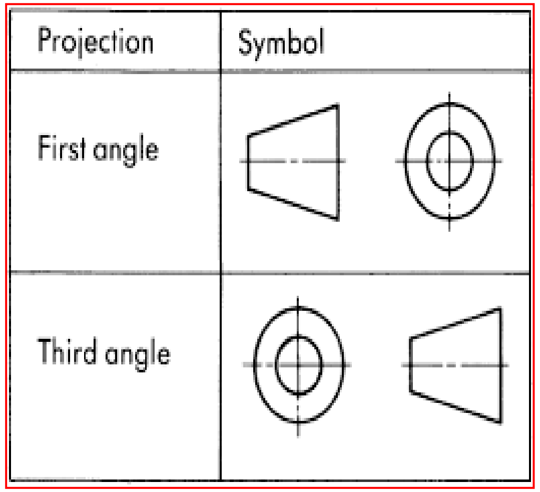
UNIT 2 ORTHOGRAPHIC PROJECTION

UNIT 3 SECTION OF SOLIDS

UNIT 4 DEVELOPMENT OF SURFACES

UNIT 5 ISOMETRIC PROJECTION

Quadrant	Position of the point	Front view or elevation	Top view or plan
I	Above the HP In front of the VP	Above the xy line	Below the xy line
II	Above the HP Behind the VP	Above the xy line	Above the xy line
III	Below the HP Behind the VP	Below the xy line	Above the xy line
IV	Below the HP In front of the VP	Below the xy line	Below the xy line



MACHINE DRAWING

(SMEA1304)

SMEA1304 MACHINE DRAWING

L	T	P	Credits	Total Marks
1	0	4	3	100

COURSE OBJECTIVES

- ❖ To understand and apply national standards while drawing machine components based on BIS.
- ❖ To understand the conventions, abbreviations and symbols to be followed by Engineers for making assembly drawings.
- ❖ To make the students to understand sectioning, concept of limits, fits and tolerances used for component design.
- ❖ To understand surface texture, riveted joints, welded joints and keys.
- ❖ To know various thread forms and its engineering applications.
- ❖ To make the students learn to draw the assembly, orthographic and sectional views of various machine components and to interpret the assembly drawing.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1: Identify the national standards related to the machine drawing based on BIS and applying the standards.

CO2: Analyze limits and tolerances for assembly and evaluate to choose appropriate fits for the assembly.

CO3: Understand and apply surface finish and welding symbols.

CO4: Assemble machine components through drawings.

CO5: Interpret the machine components and conventions used in the drawing.

CO6: Interpret the components such as fasteners, riveted joints, welded joints and keys.

TEXT / REFERENCE BOOKS

1. Engineering drawing practice for schools and colleges, SP 46 - 1988.

(http://web.iitd.ac.in/~achawla/public_html/201/lectures/sp46.pdf)

2. **Gopalakrishnan, K.R., Machine Drawing**, Subhas Publications, 16th Edition, 2008.

3. Bhatt, N.D., Machine Drawing, Charotar Publishing House, 48th Edition, 2013.

4. Brian Griffiths, “Engineering Drawing for Manufacture”, Kogan Page Science, 2003.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Maximum Marks: 100 **Exam Duration: 3 Hrs**

PART A: Questions from sections 1 - 6 (Each section 10 marks) 60 Marks

PART B: One question from section 7 with no choice

(Assembly Drawing) 40 Marks

1. CONVENTIONS, ABBREVIATIONS AND SYMBOLS

Conventional representation of shaft, hollow shaft, bar - Conventional representation of common machine elements such as threads, slotted head, bearings, straight and diamond knurling, holes on a linear and circular pitch, helical spring, leaf spring - Conventional representation of metals, glass, packing and insulating materials, liquids, concrete and wood - Conventional representation of screw, rivet and pin in section. Abbreviations for iron, carbon steel, alloy steel - Abbreviations for across corners, across flats, assembly, bearing, center of gravity, counterbore, countersunk, insulation, left hand, right hand, nominal, pitch circle diameter, tolerance, undercut.

2. SECTIONAL VIEWS

Full section, half section, partial or local section, revolved or superimposed section, removed section, successive section, parts that are not sectioned.

3. LIMITS, FITS AND TOLERANCES

Definitions: Limits, Fits and Tolerances - Upper limit, lower limit, tolerance, deviation, upper deviation, lower deviation, tolerance zone - Standard tolerance grades - Computation of IT tolerance using formulae and tables - Fundamental deviation - Computation of fundamental deviation - System of fits - Clearance fit - Interference fit - Transition fit - Problems on clearance and interference fit on shaft and hole basis system.

4. SURFACE TEXTURE

Nominal surface - Roughness - Waviness - Lay - Sampling length - Indication of surface roughness by roughness values, roughness grade number, roughness symbols - Indication of surface roughness by surface texture symbol with all the characteristics.

5. THREADED FASTENERS AND ITS APPLICATIONS

Screw thread terminology - Basic forms of screw threads - Standard forms of V threads - Basic form of square threads -Modified forms of square threads - Basic knuckle thread - Standard form of knuckle thread Conventional representation of internal V thread and external V thread - Square thread - Designation of threads - Empirical proportions of hexagon and square head bolt and nut.

6. RIVETED JOINTS, WELDED JOINTS AND KEYS

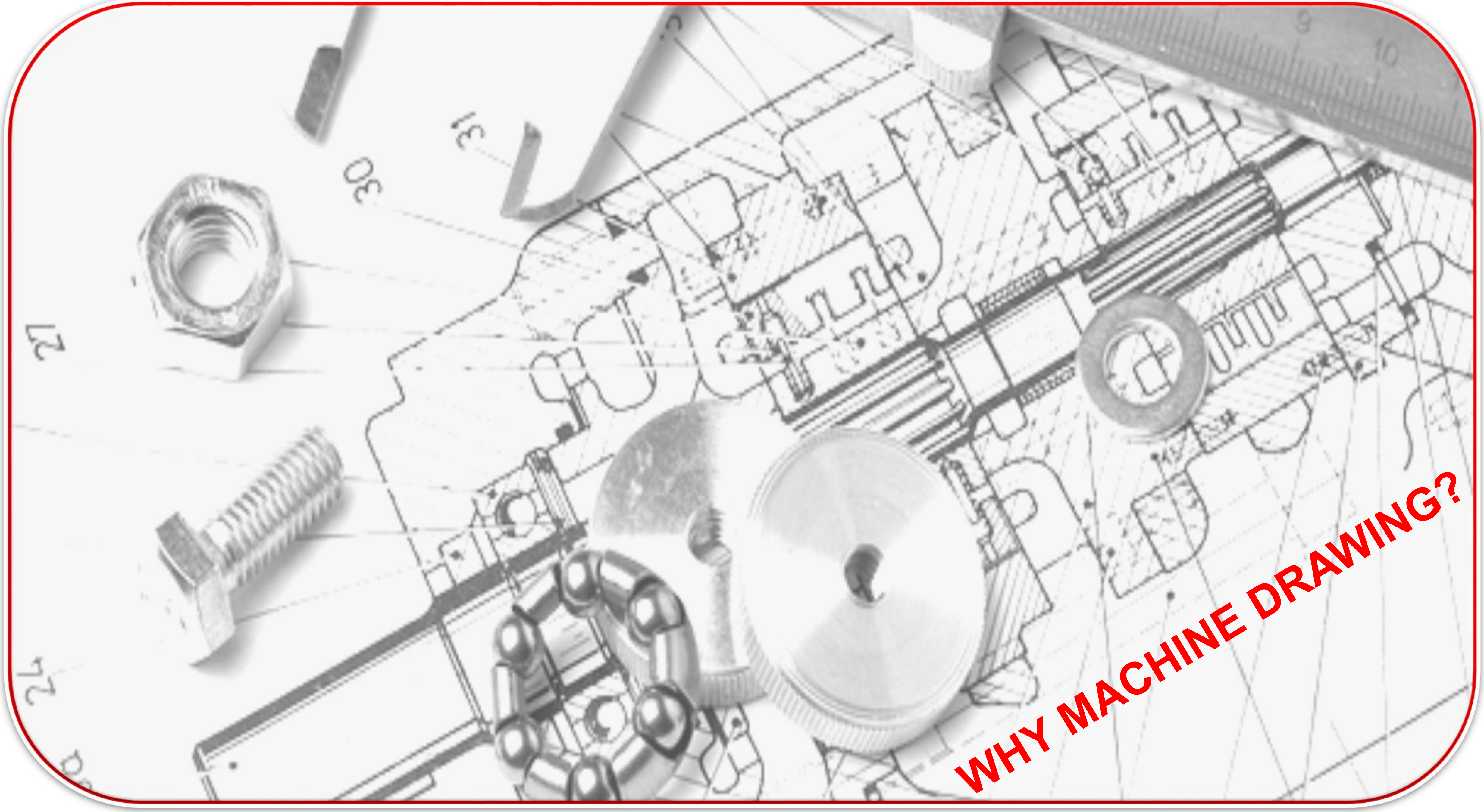
Application of riveted joints - Difference between a bolt and a rivet - Disadvantages of riveted joints - Types of riveted joints - Empirical proportions of riveted joints - Types of welded joints - Symbolic representation of weld - Elementary weld symbols - Keys - Application of keys.

7. ASSEMBLY DRAWING (USING MINI-DRAFTER) FOR THE FOLLOWING WITH PART DRAWINGS GIVEN

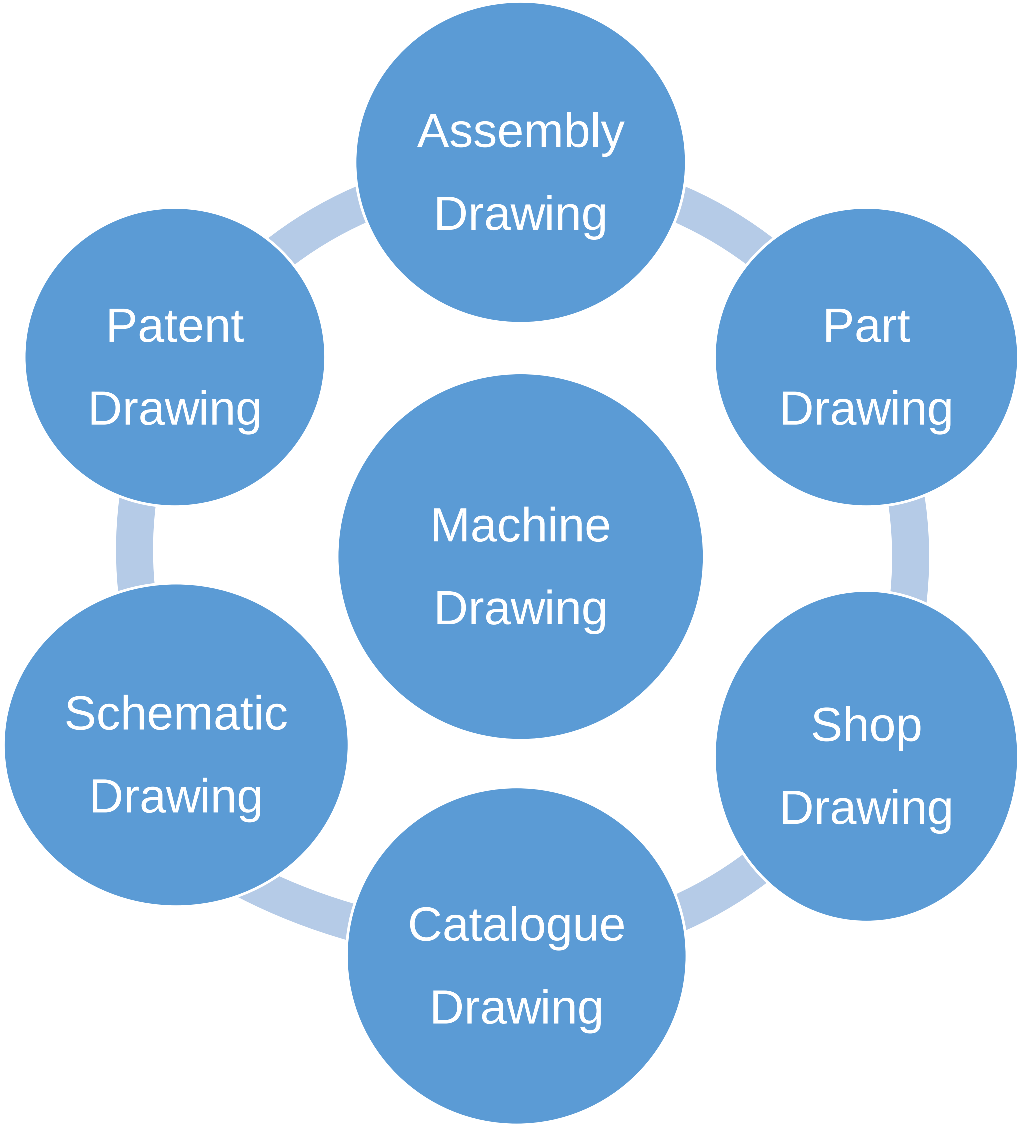
Preparation of assembled views from exploded views for the following components: Cotter joint with sleeve, screw jack, snug type pedestal bearing, swivel bearing, tail stock.

UNIT 1

CONVENTIONS, ABBREVIATIONS AND SYMBOLS


WHY MACHINE DRAWING?

- ❖ Machine drawing is a pictorial representation of machine or machine components or the part of a product which provides outline/inline detail of a product including how it is going to manufacture with certain rules.
- ❖ The machining symbols, tolerances, bill of material, dimensions etc are notified in that drawing.
- ❖ Machine drawing is the way of communication between you and the worker/designer/customer/manufacturer/engineer to get the desirable outcome in an efficient way.
- ❖ The relative position of the different components and to make assembly drawing are also specified.
- ❖ IS: 696—1972 is the BIS Code for Machine Drawing.


Assembly Drawing
Patent Drawing
Part Drawing
Machine Drawing
Schematic Drawing
Shop Drawing
Catalogue Drawing

(a) **Assembly Drawing** - An assembly drawing shows all the complete drawing of a given machine indicating the relative positions of various components assembled together.

(b) **Part Drawing** - A part drawing shows the number of views of each single part of a machine to facilitate its manufacturing. It should give all the dimensions, limits, tolerances and special finishing; if any.

(c) **Shop Drawing** - A shop drawing includes the part drawing, subassembly and the complete assembly of a product for manufacturing.

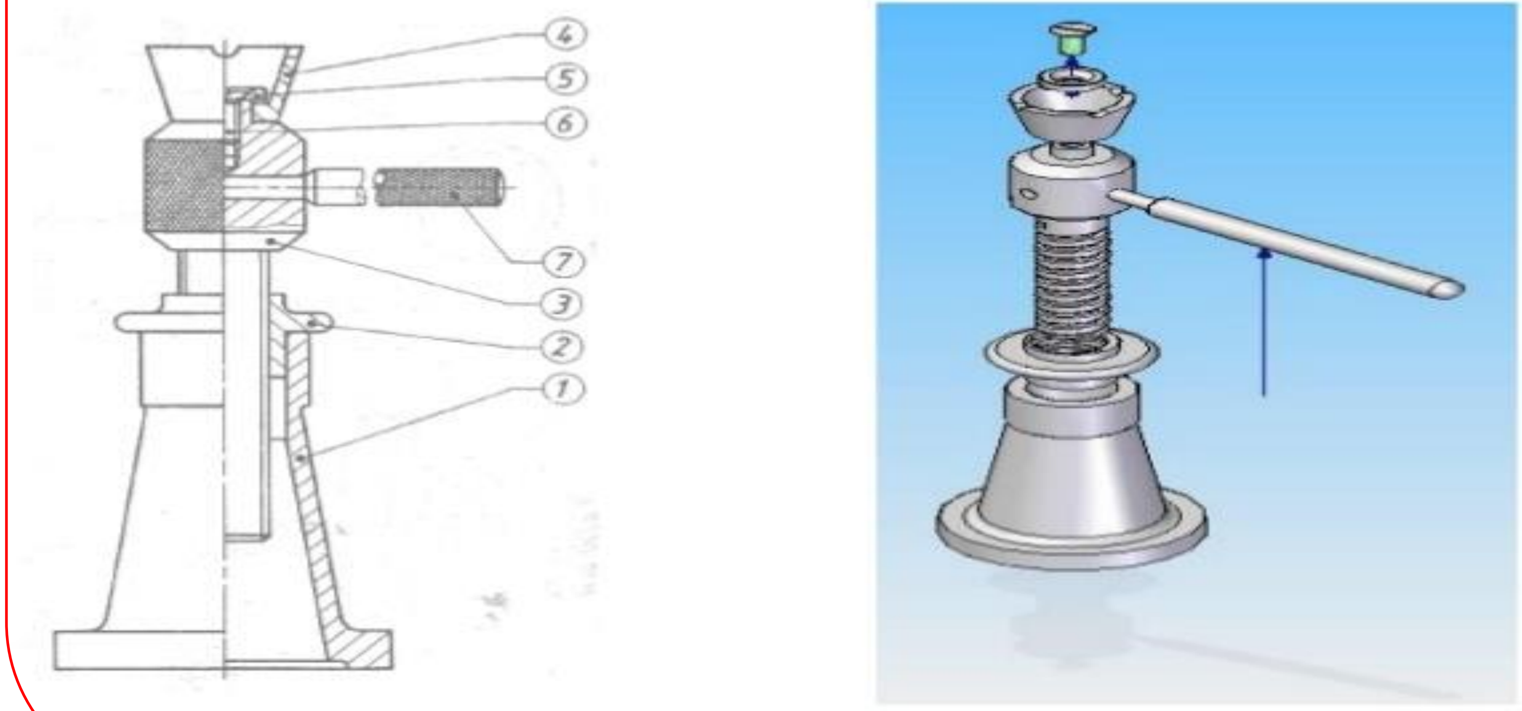
(d) **Catalogue Drawing** - A catalogue drawing shows only the outlines of an assembly drawing for illustration purpose.

(e) **Schematic Drawing** - A schematic drawing is the simplified illustration of a machine or system, replacing all the elements by their respective conventional representations, to understand the principle of operation.

(f) **Patent Drawing** - A patent drawing gives the correct and complete features of a new technology or innovation adopted for a machine or system. The drawings are pictorial in nature and self — explanatory but not useful for production purposes.

(a) Assembly Drawing - An assembly drawing shows all the complete drawing of a given machine indicating the relative positions of various components assembled together.

Screw Jack



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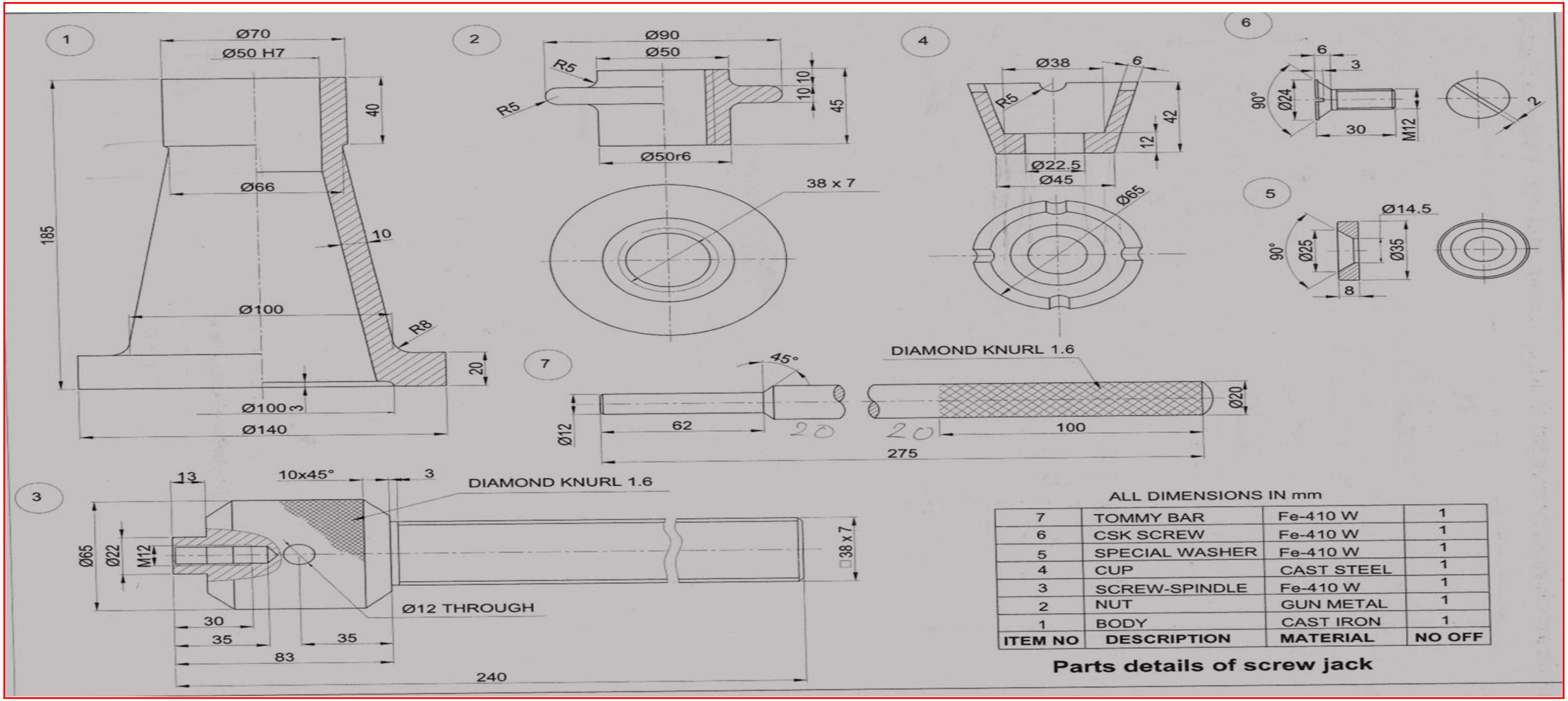
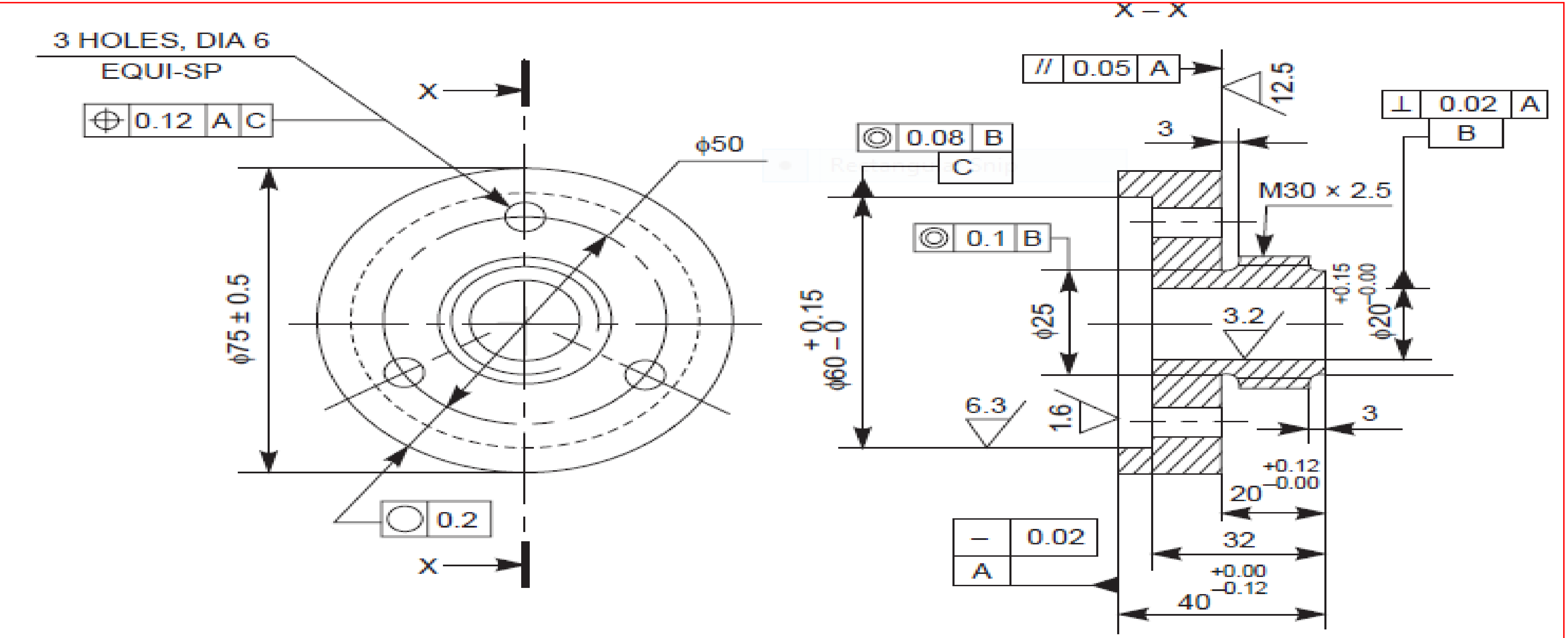


ITEM NO	DESCRIPTION	MATERIAL	NO OFF
7	TOMMY BAR	Fe-410 W	1
6	CSK SCREW	Fe-410 W	1
5	SPECIAL WASHER	Fe-410 W	1
4	CUP	CAST STEEL	1
3	SCREW-SPINDLE	Fe-410 W	1
2	NUT	GUN METAL	1
1	BODY	CAST IRON	1

Parts details of screw jack

Part Drawing - A part drawing shows the number of views of each single part of a machine to facilitate its manufacturing. It should give all the dimensions, limits,tolerances and special finishing; if any.



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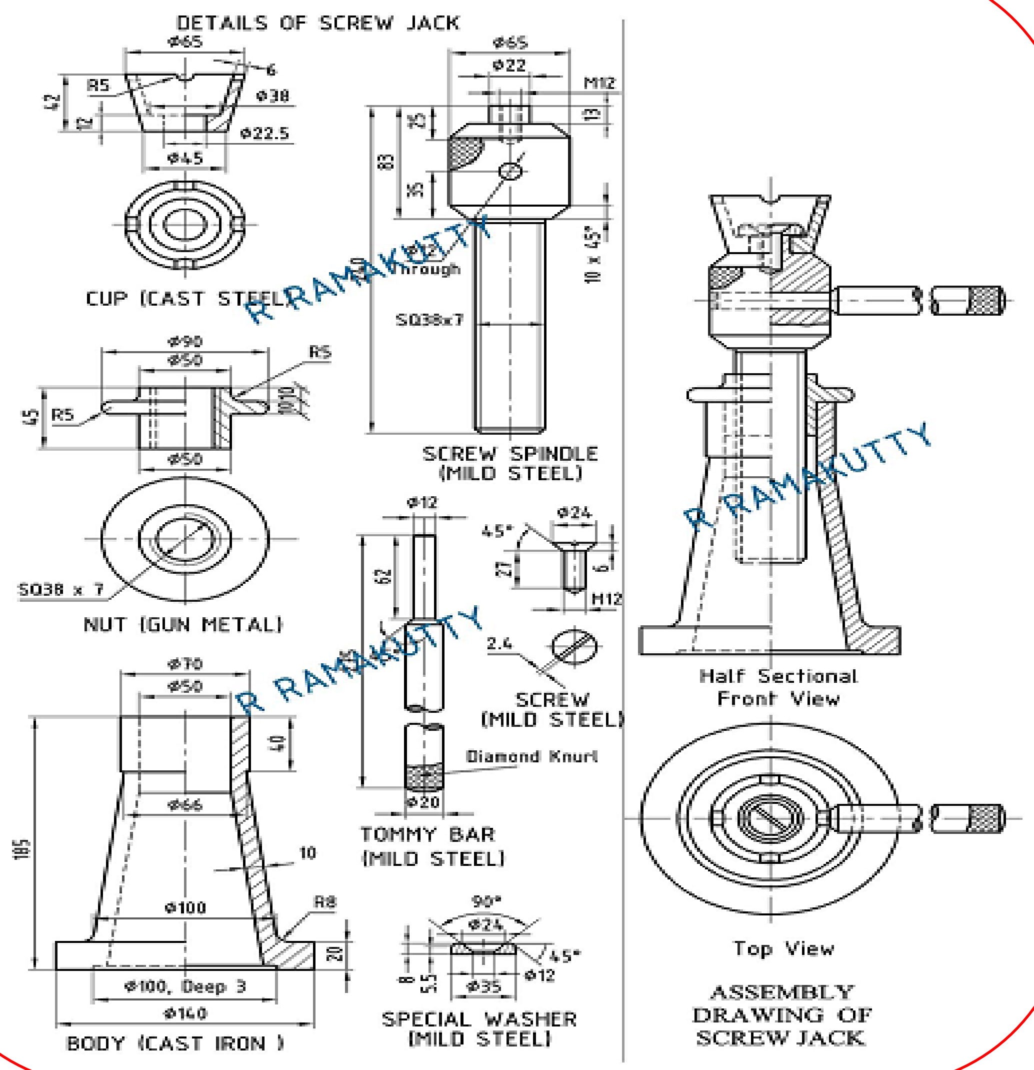

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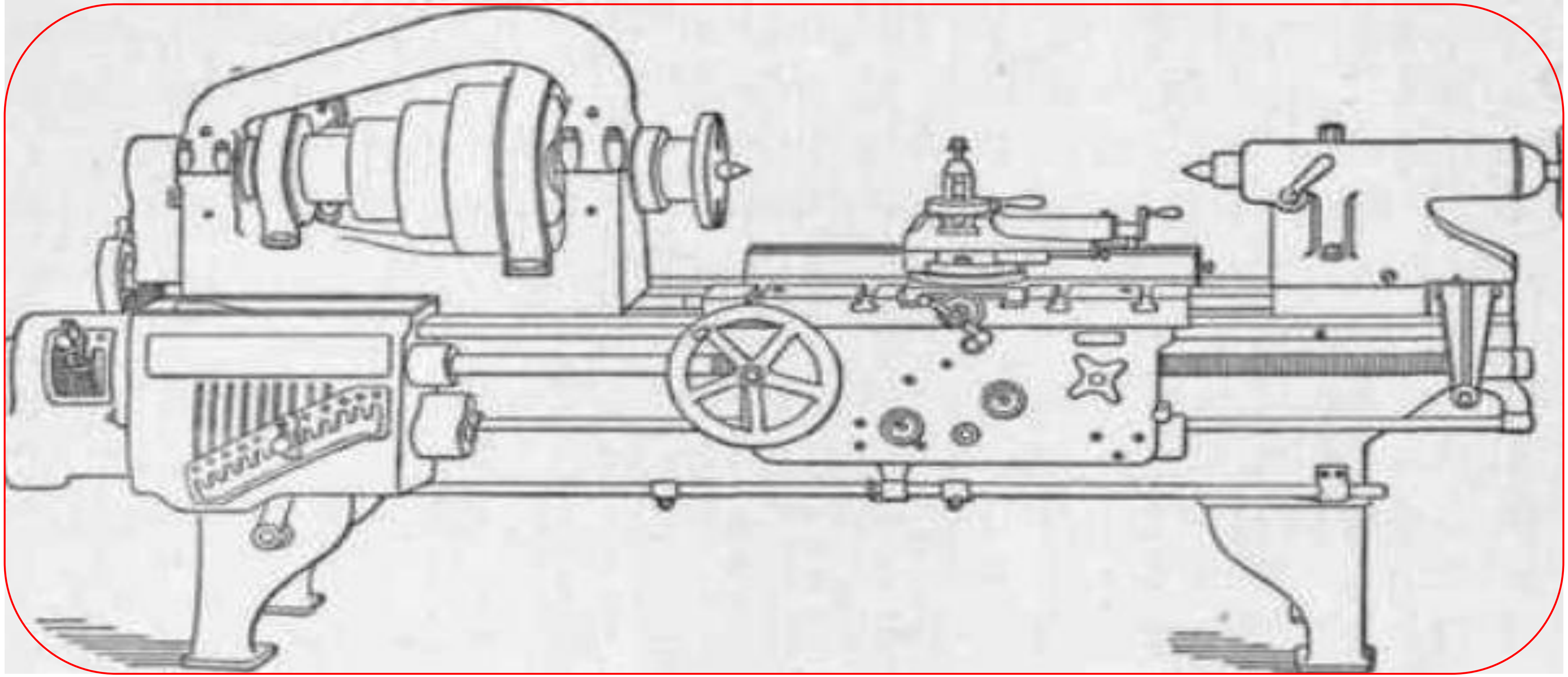

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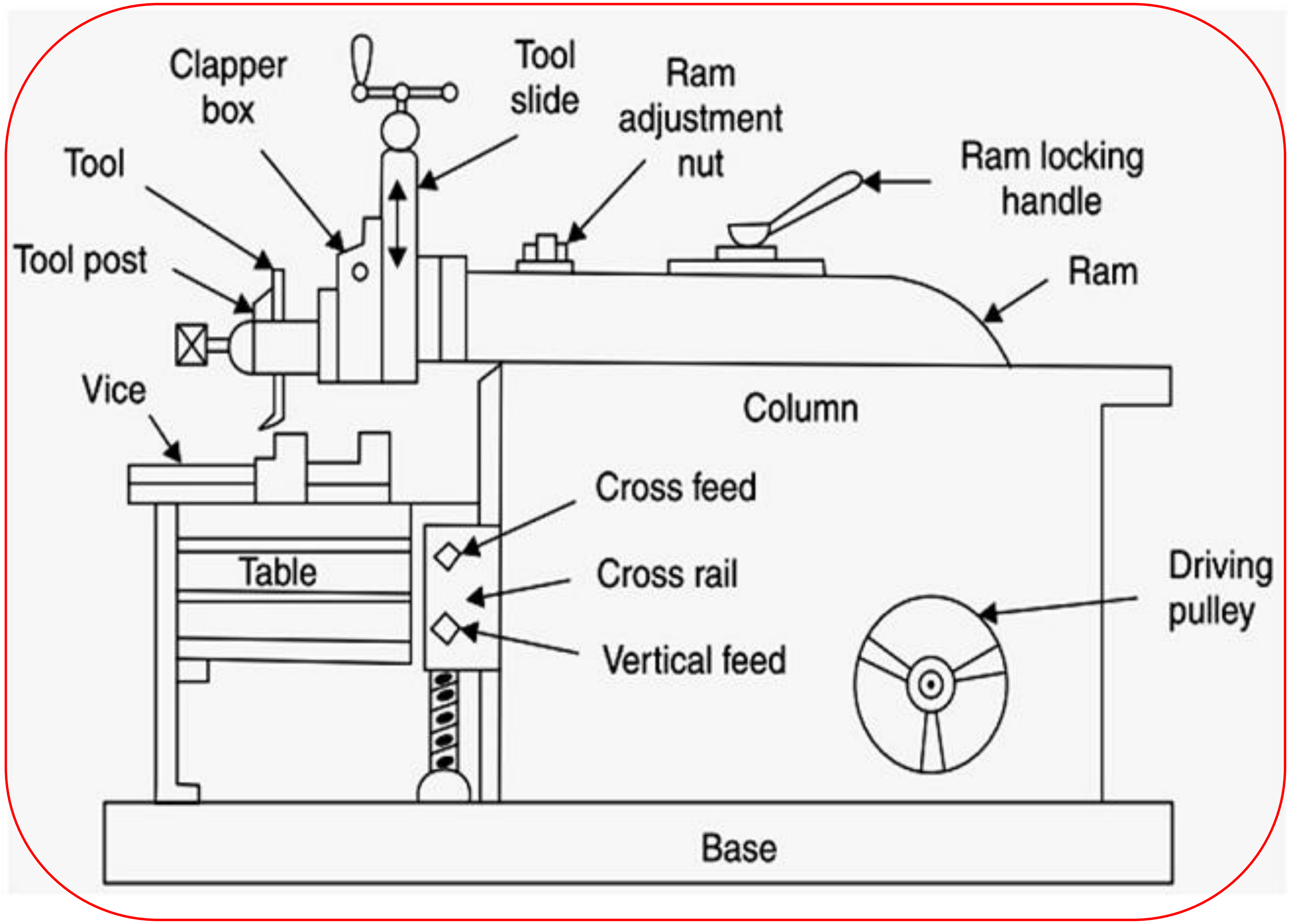

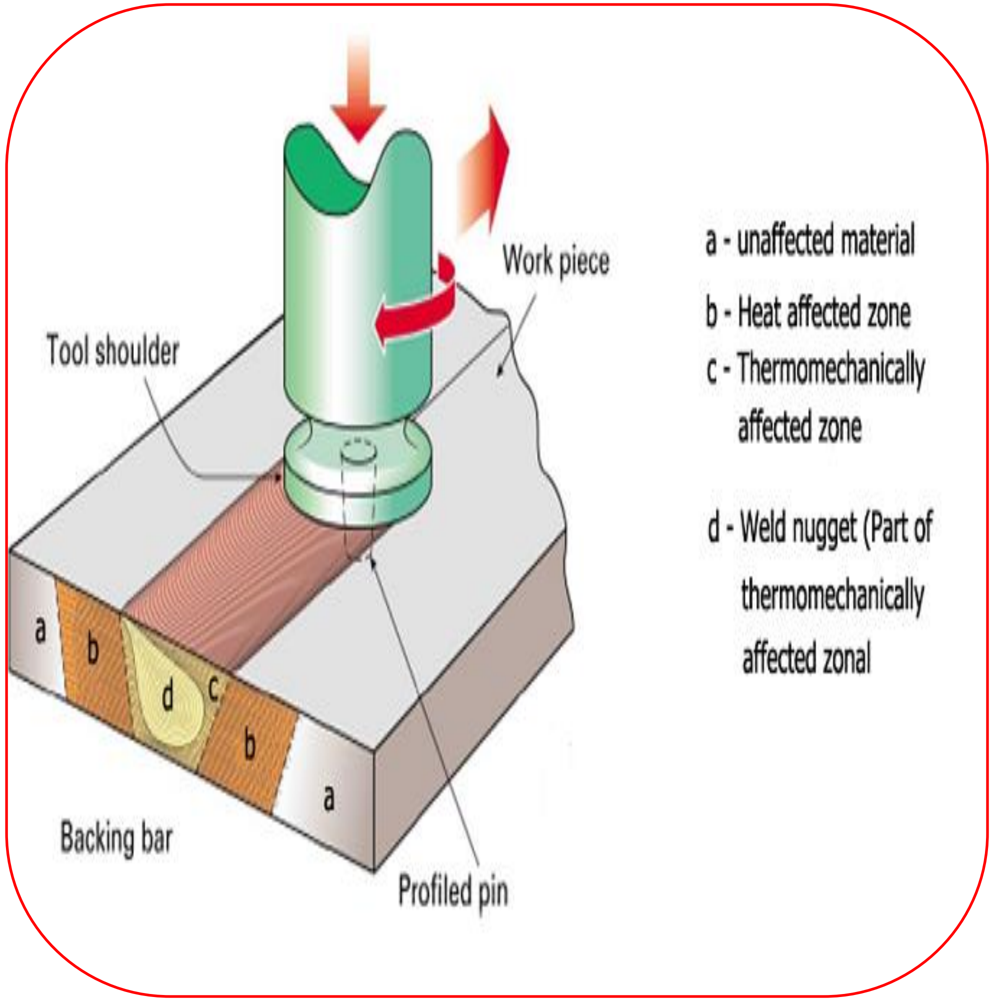

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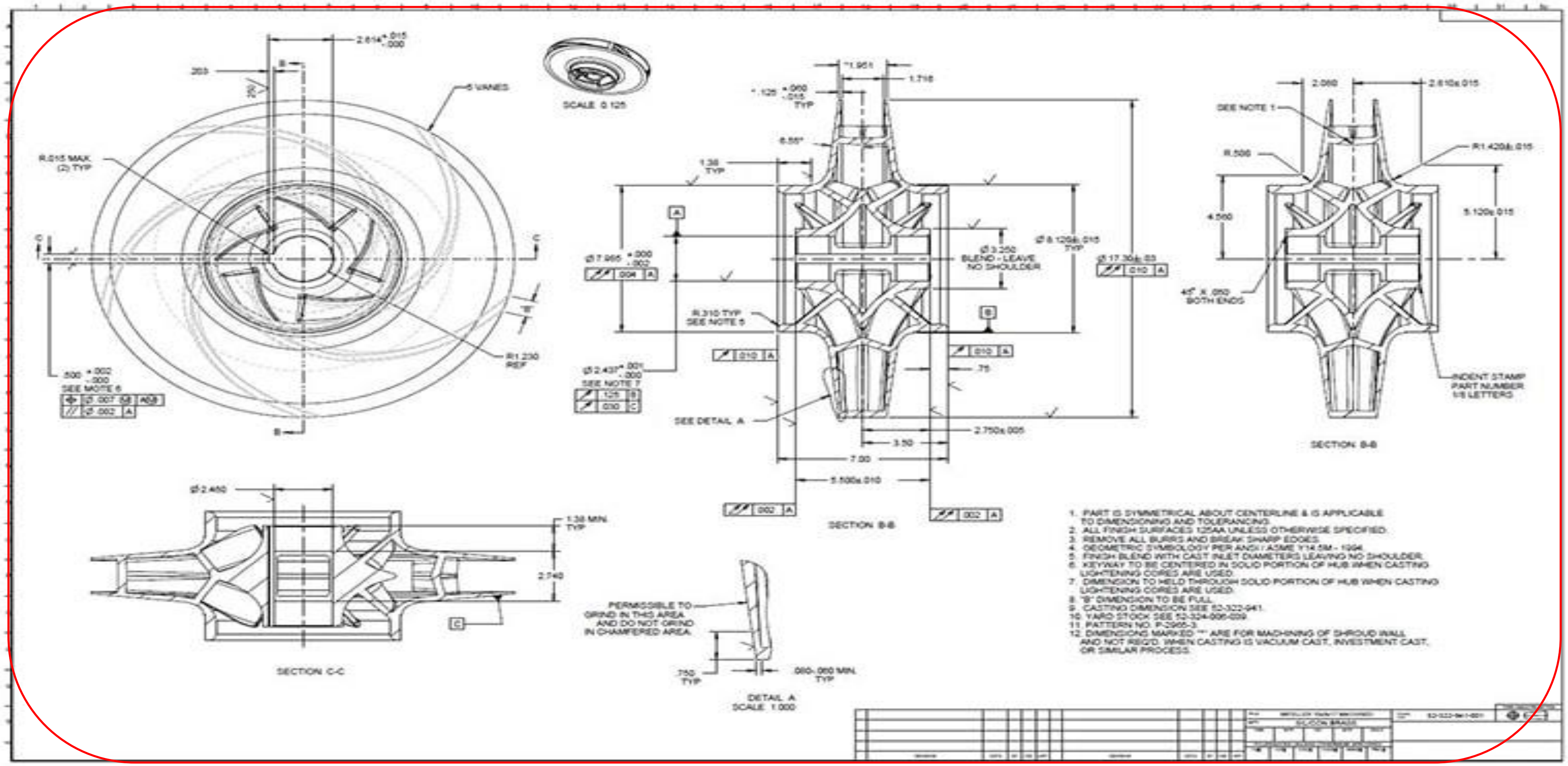

1. CONVENTIONS, ABBREVIATIONS AND SYMBOLS

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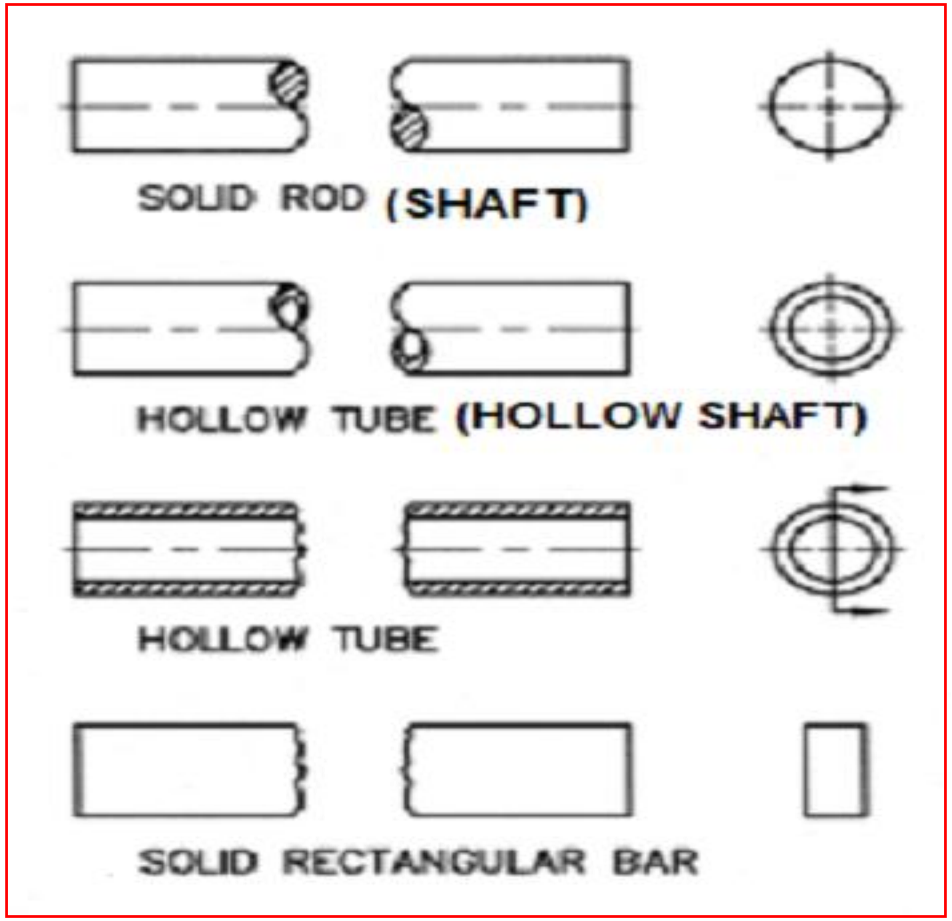
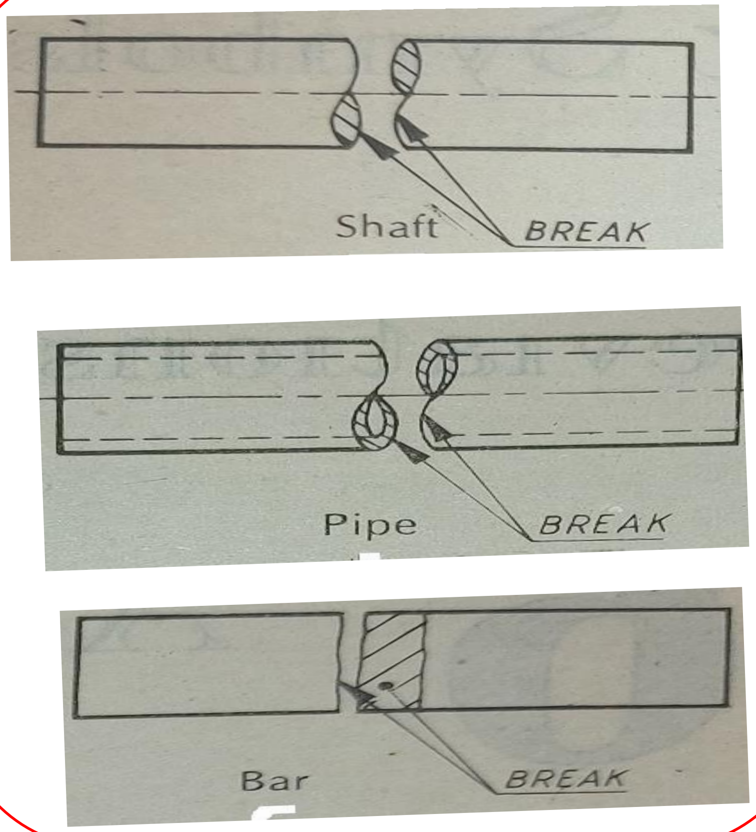
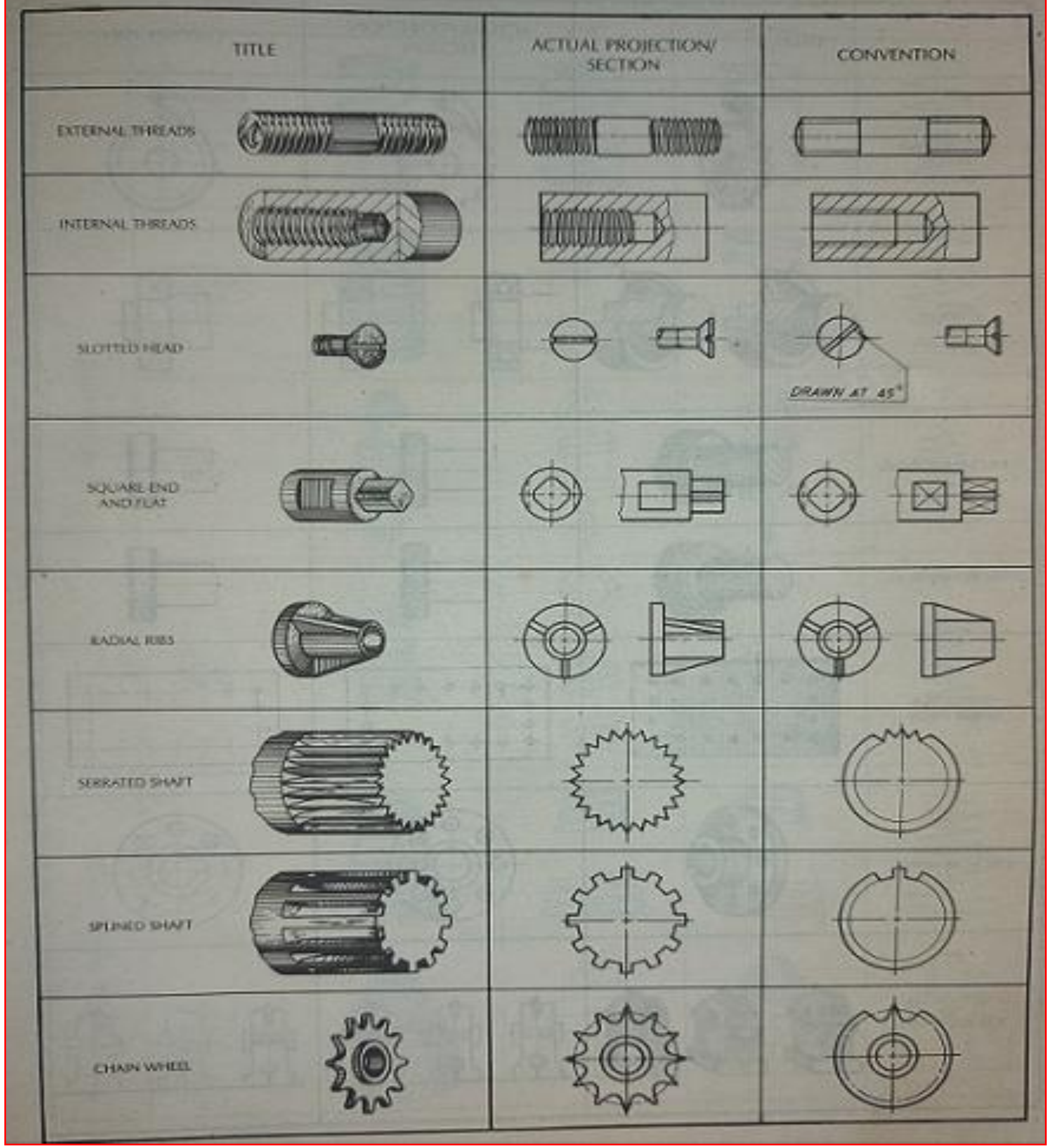
CONVENTIONS, ABBREVIATIONS AND SYMBOLS

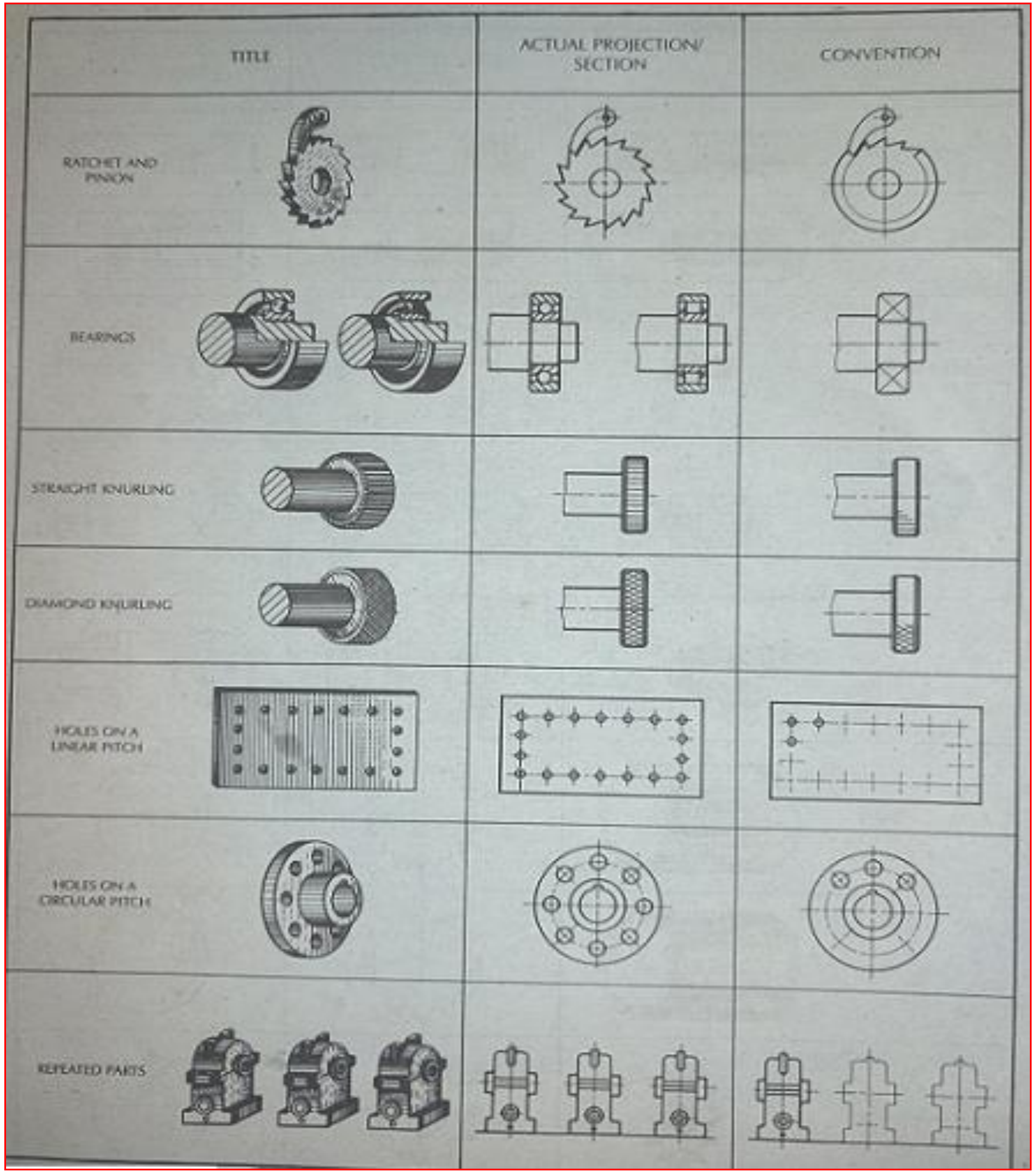
CONVENTIONS: When the complete drawing of a machine component involves a lot of time or space, it may be drawn in conventional form to represent the actual machine component.

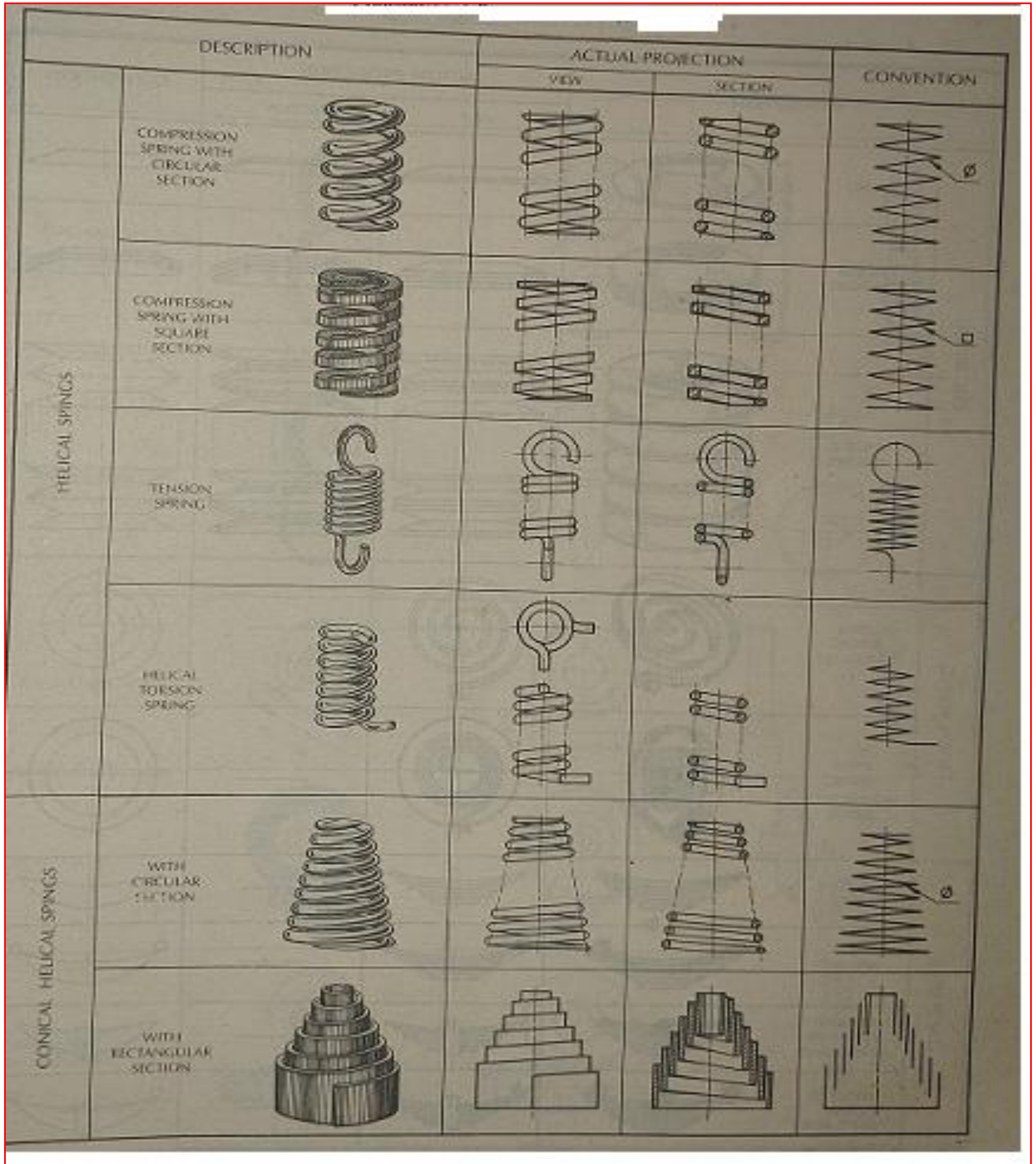


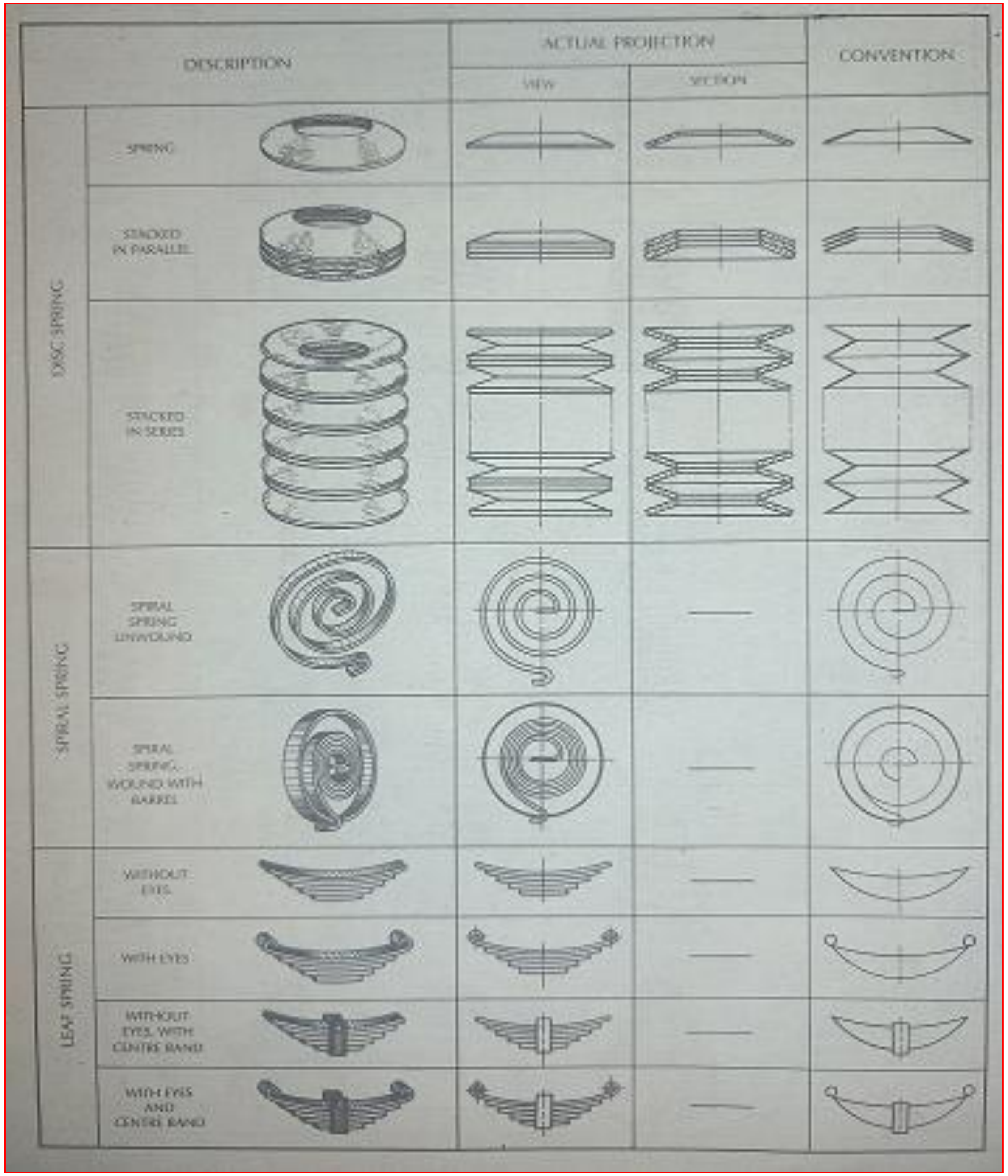


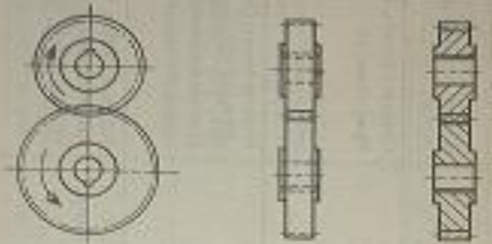
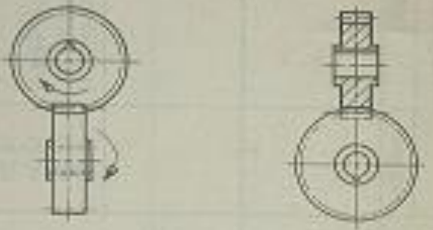
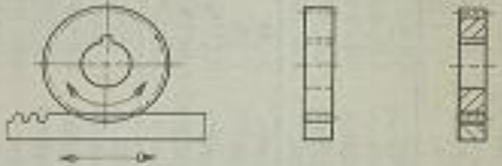
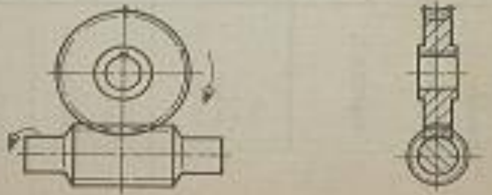
Conventional Representation of Common Machine Elements






DESCRIPTION
ACTUAL PROJECTION
VIEW
SECTION
CONVENTION
HELICAL SPINGS
COMPRESSION SPRING WITH CIRCULAR SECTION
COMPRESSION SPRING WITH SQUARE SECTION
TENSION SPRING
HELICAL TORSION SPRING
CONICAL HELICAL SPINGS
WITH CIRCULAR SECTION
WITH RECTANGULAR SECTION


DESCRIPTION
ACTUAL PROJECTION
VIEW
SECTION
CONVENTION
DISC SPRING
SPRING
STACKED IN PARALLEL
STACKED IN SERIES
SPIRAL SPRING
SPIRAL SPRING UNWOUND
SPIRAL SPRING WOUND WITH BARREL
LEAF SPRING
WITHOUT EYES
WITH EYES
WITHOUT EYES, WITH CENTRE BAND
WITH EYES AND CENTRE BAND

TITLE		CONVENTIONAL REPRESENTATION
SPUR/HELICAL GEARS		
SCREW GEARS		
RACK AND PINION		
BEVEL GEARS		
WORM AND WORM WHEEL		

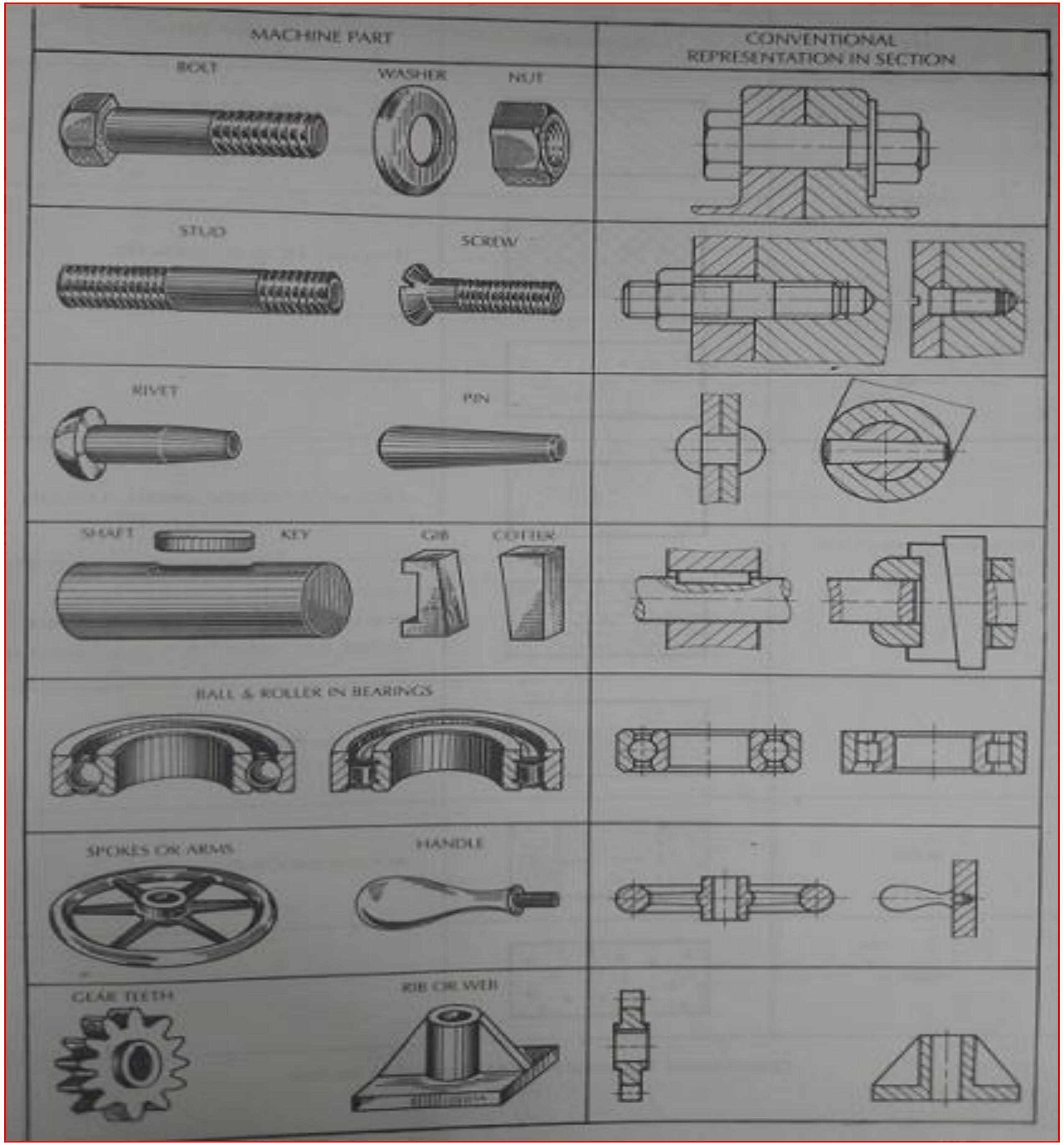
TYPE	CONVENTION	MATERIALS
METALS		STEEL, CAST IRON, COPPER AND ITS ALLOYS, ALUMINIUM AND ITS ALLOYS, ETC
		LEAD, ZINC, TIN, WHITE-METAL, ETC
GLASS		GLASS
PACKING AND INSULATING MATERIALS		PORCELAIN, STONEWARE, MARBLE, SLATE, ETC
		ASBESTOS, FIBRE, FELT, SYNTHETIC RESIN PRODUCTS, PAPER, CORK, LINOLEUM, RUBBER, LEATHER, WAX, INSULATING & FILLING MATERIALS
LIQUIDS		WATER, OIL, PETROL, KEROSENE, ETC
WOOD		WOOD, PLYWOOD, ETC
CONCRETE		

Abbreviations for use in Engineering Drawing
SP : 46 - 1988

Term	Abbreviation	Term	Abbreviaiton
Across corners	A/C	Long	LG
Across flats	A/F	Machine/Machinery	M/C
Alternation	ALT	Manufacture/ing	MFG
Approved	APPD	Material	MATL
Approximate	APPROX	Maximum	max.
Arrangement	ARRGT	Mechanical	MECH
Assembly	ASSY	Minimum	min.
Auxiliary	AUX	Miscellaneous	MISC
Bearing	BRG	Modification	MOD
Cast Iron	CI	Nominal	NOM
Centres	CRS	North	N
Centre Line	CL	Number	NO.
Centre of Gravity	CG	Opposite	OPP
Centre to Centre	C/C	Outside diameter	OD
Chamfered	CHMED	Pitch circle diameter	PCD
Checked	CHKD	Quantity	QTY
Cheese Head	CH HD	Radius (in a note)	RAD
Continued	CONTD	Reference	REF
Constant	CONST	Required	REQD
Counterbore	C'BORE	Righthand	RH
Countersunk	CSK	Round	RD
Countersunk head	CSK HD	Screw Screwed	SCR
Cylinder/Cylindrical	CYL	Serial Number	SL NO.
Diameter (in a note)	DIA	Sheet	SH
Dimension	DIM	Sketch	SK
Drawing	DRG	South	S
East	E	Specification	SPEC
Etcetera	etc	Spotface	SF
External	EXT	Standard	STD
Figure	FIG	Symmetrical (in a note)	SYM
General	GEN	Temperature (in a note)	TEMP
Ground Level	GL	Thick	THK
Hexagon/Hexagonal	HEX	Thread (in a note)	THD
Horizontal	HORZ	Through (in a note)	THRU
Hydraulic	HYD	Tolerance	TOL
Head	HD	Typical	TYP
Indian Standard	IS	Undercut (in a note)	U/C
Inspection / ed	INSP	Weight	WT
Inside diameter	ID	West	W
Insulation	INSUL	With reference to/ With respect to (in a note)	WRT
Internal	INT		
Left Hand	LH		

Abbreviations for Rolled Sections
IS : INDIAN STANDARD

Type of Rolled Section	Abbreviations	Type of Rolled Section	Abbreviations
Round bar, Steel	ISRO	Channel Junior, Steel	ISJC
Square bar, Steel	ISSQ	Channel Light, Steel	ISLC
Flat, Steel	ISF	Channel Medium Weight, Steel	ISMC
Strip, Steel	ISST	Tee Bar, Normal, Steel	ISNT
Equal Angle, Steel	ISA	Tee Bar, Deep Legged, Steel	ISDT
Unequal Angle, Steel	ISA	Tee Bar, Light Weight, Steel	ISLT
Beam, Junior, Steel	ISJB	Tee Bar, Slit H Section, Steel	ISHT
Beam, Light Weight, Steel	ISLB	T-Section, Aluminium	ISALT
Beam, Medium Weight, Steel	ISMB	Equal Angle, Aluminium	ISALA
Beam, Wide Flange, Steel	ISWB	Beam Section, Aluminium	ISALB
Beam, H, Steel	ISHB	Channel Section, Aluminium	ISALC


MACHINE PART
CONVENTIONAL REPRESENTATION IN SECTION
BOLT
WASHER
NUT
STUD
SCREW
RIVET
PIN
SHAFT
KEY
GIB
COTTER
BALL & ROLLER IN BEARINGS
SPOKES OR ARMS
HANDLE
GEAR TEETH
RIB OR WEB

UNIT 2

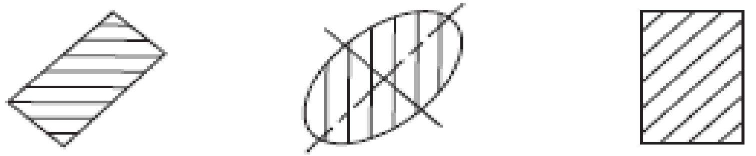
SECTIONAL VIEWS

2. SECTIONAL VIEWS

Full section, half section, partial or local section, revolved or superimposed section, removed section, successive section, parts that are not sectioned.

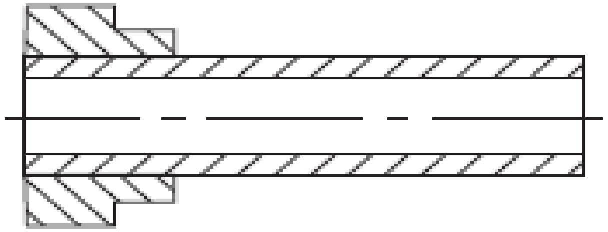
Purpose of section: To show the inner details of a machine component, the object is imagined to be cut by a cutting plane and the section is viewed after the removal of cut portion.

- ✓ Hatching is generally used to show areas of sections.
- ✓ Hatching is done as continuous thin lines at an angle, preferably 45°, to the principal outlines.

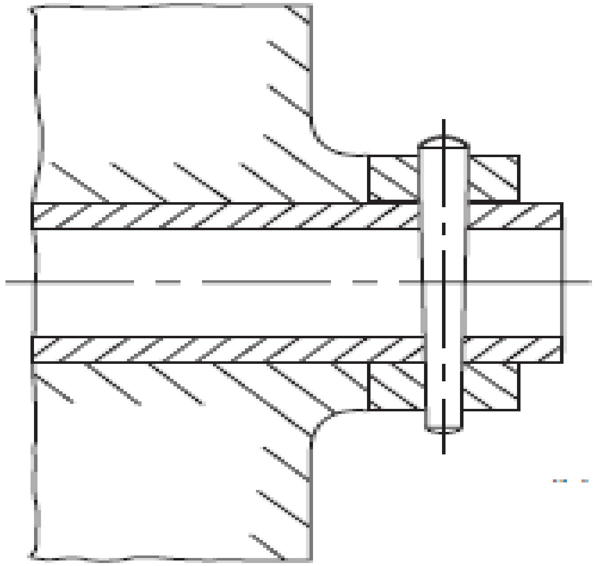


✓ Separate areas of a section of the same component shall be hatched in an identical manner.

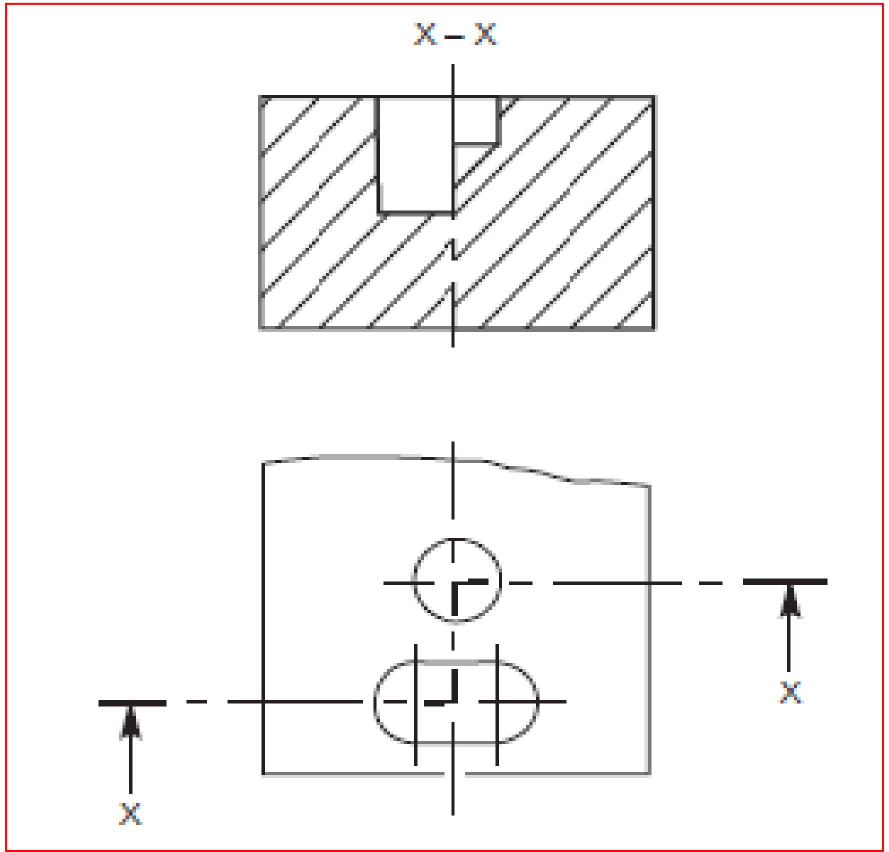
✓ The hatching of adjacent components shall be carried out with different directions or spacing.



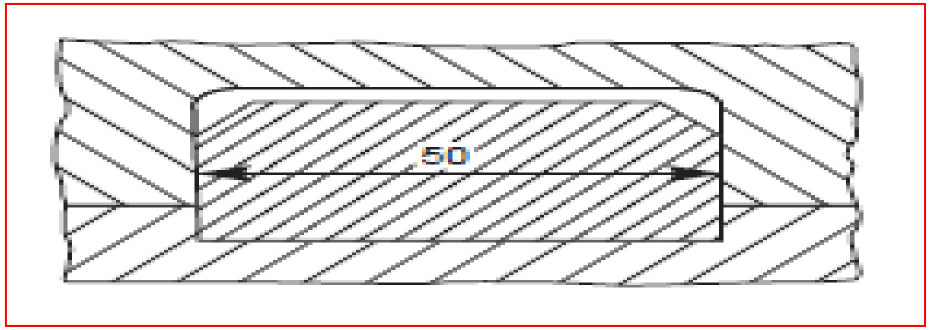
In case of large areas, the hatching may be limited to a zone, following the contour of the hatched area.



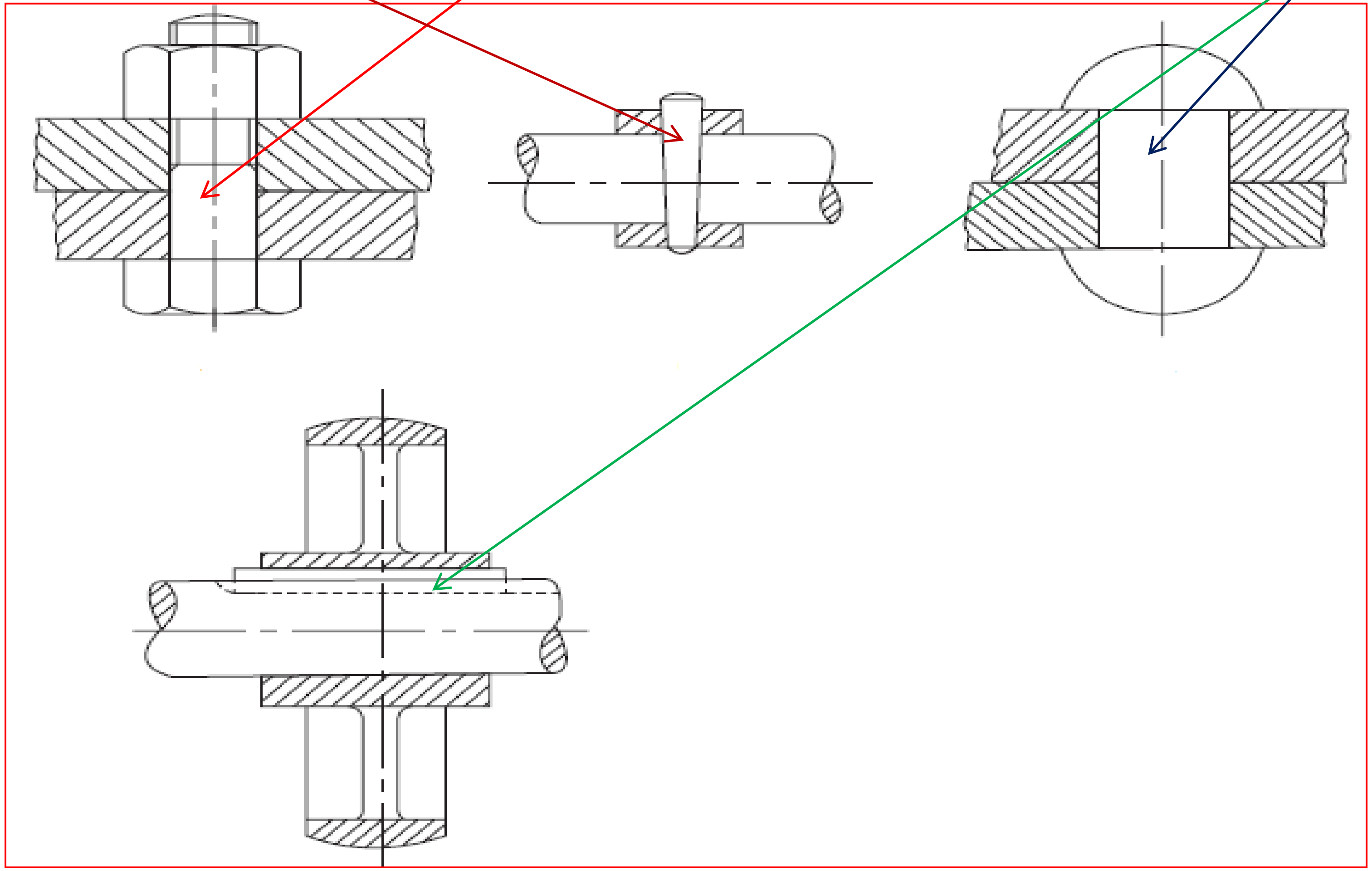
Where sections of the same part in parallel planes are shown side by side, the hatching shall be identical, but may be off-set along the dividing line between the sections



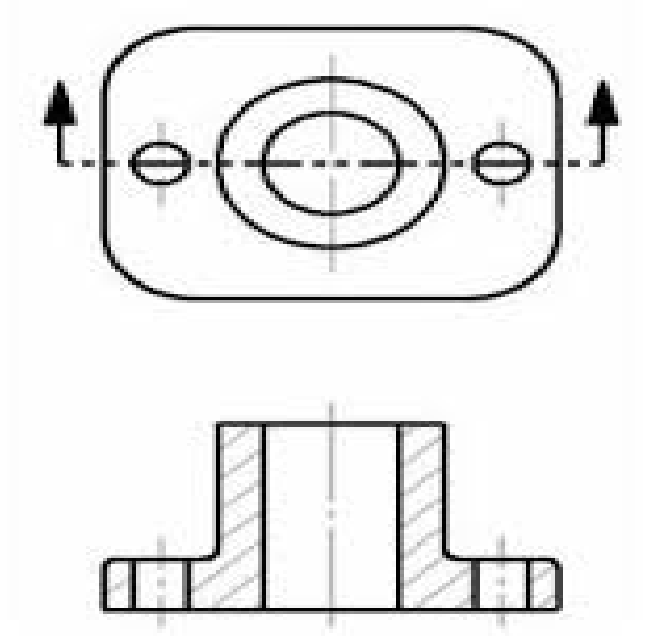
Hatching should be interrupted when it is not possible to place inscriptions outside the hatched area



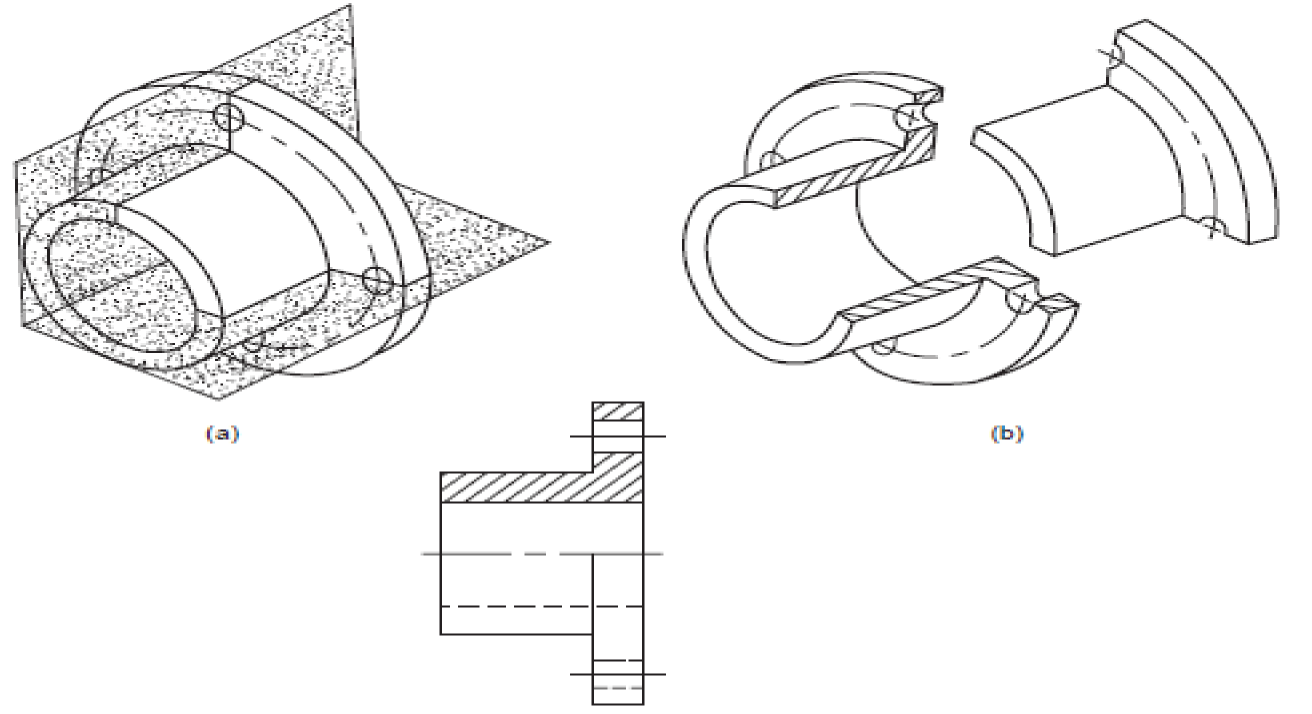
Machine parts not sectioned: In principle: shafts, handles, bolts, studs, screws, washers, nuts, rivets, keys, pins, gib, cotters, webs, stiffening ribs, spokes, arms, teeth of gears, bearings etc., are not cut in longitudinal sections and therefore should not be hatched.



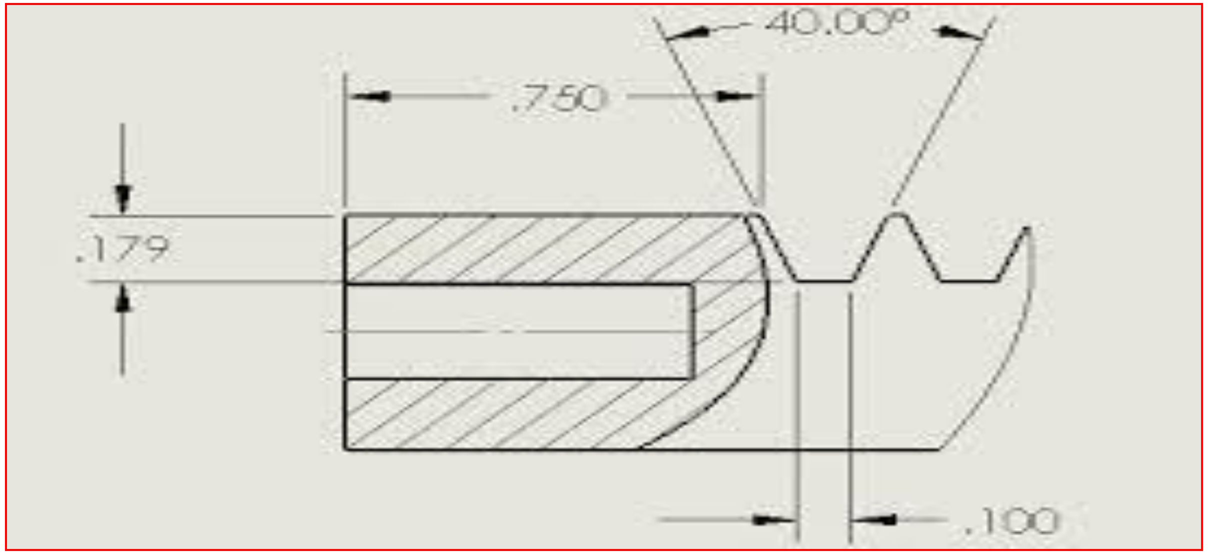
- ✓ **Full Section:** A sectional view obtained by assuming that the object is completely cut by a plane is called a **full section** or **sectional view**.
- ✓ It may be noted that, in order to obtain a sectional view, only one half of the object is imagined to be removed.
- ✓ Further, in a sectional view, the portions of the object that have been cut by the plane are represented by hatching.
- ✓ The view should also contain the visible parts behind the cutting plane.



- ✓ **Half Section:** A half sectional view is preferred for symmetrical objects.
- ✓ For a half section, the cutting plane removes only one quarter of an object.
- ✓ To obtain an half sectional view, the object is cut by two imaginary planes at right angles to each other, so as to pass through two mutually perpendicular centre lines of the object.
- ✓ In this, only one half of the object is shown in section while its other half will be shown as unsectioned.

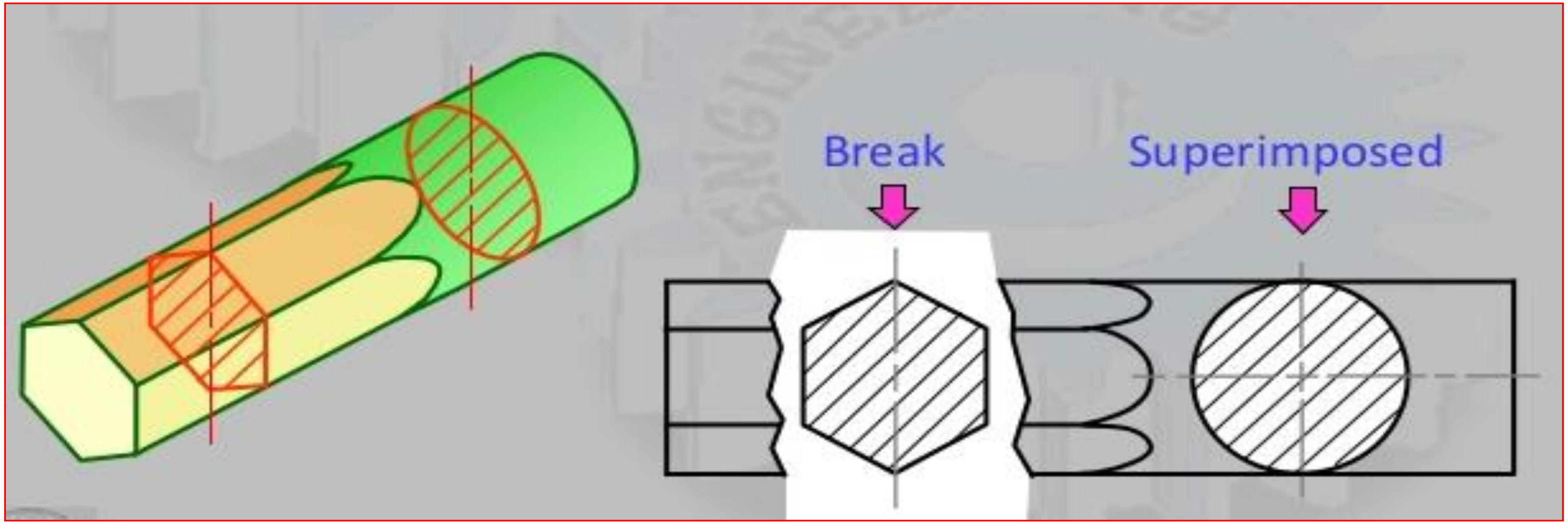


- ✓ **Partial or Local Section:** Sometimes it may be required to expose only a small portion of the interior of the object. In such cases, instead of showing either a full section or half section, local or partial section is taken.
- ✓ To draw a local section, the object is imagined as broken partially to expose the required detail and the break is indicated by a continuous thin wavy line..



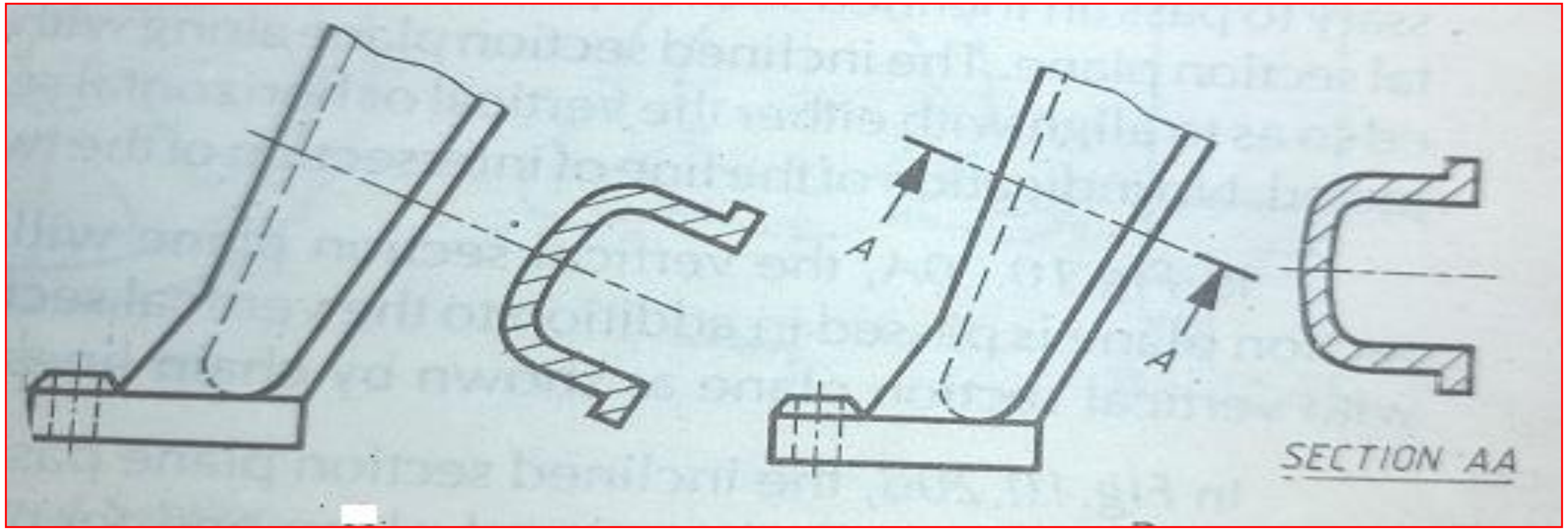
✓ **Revolved or Superimposed section:** The true shape of external surfaces of some objects like structural members, spokes of wheels, arms, handles etc., may be shown without an additional view by means of revolved sections.

✓ A revolved section is obtained by passing a section plane through the part perpendicular to the centre line or axis and then the section plane with the cross section lying on it is revolved through 90 degrees so as to superimpose the cross section on the exterior view.



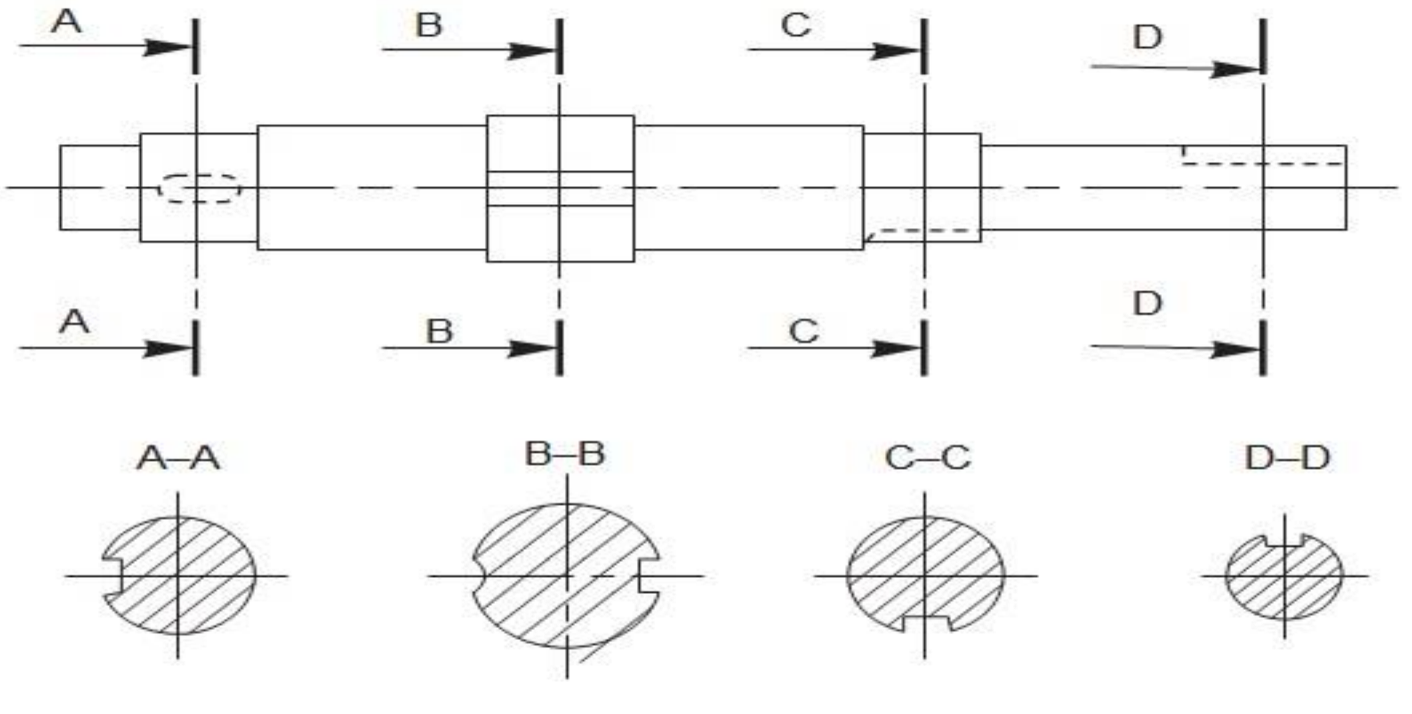
✓ **Removed section:** This is similar to the revolved section except that the sectional view is removed from the actual view and drawn separately either, near to and connected with the view by a chain line or in a different position and identified by the designation.

✓ The removed sections are preferred to revolved sections in cases where superimposed cross section is not desirable.



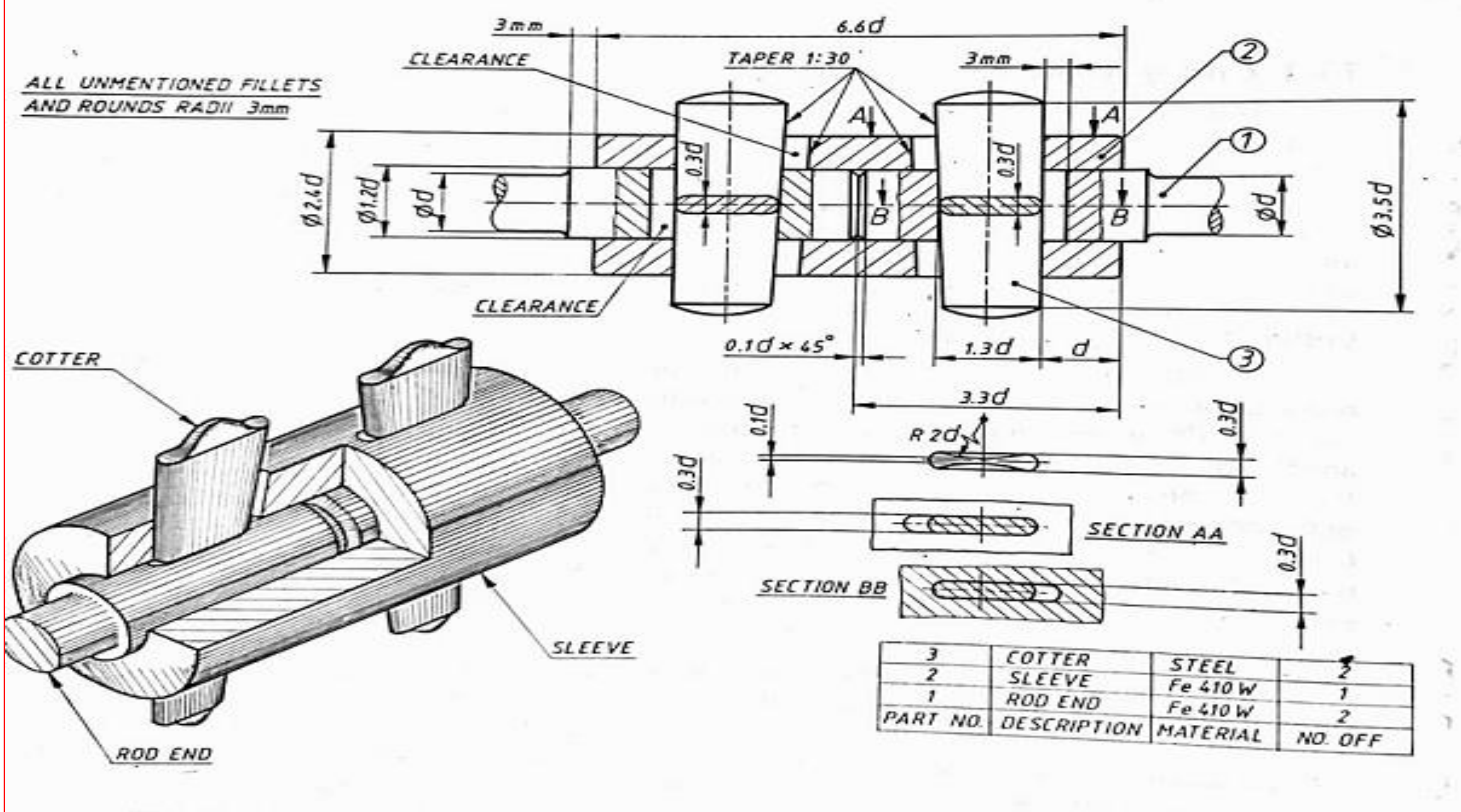
✓ **Successive section:** Successive sections are similar to the removed sections. A series of parallel section planes are passes successively at different positions of a long shaft of different diameters so as to expose the details such as keyways, slots, holes etc., on the cross sections as shown below.

✓ The removed sections are preferred to revolved sections in cases where superimposed cross section is not desirable.



Successive sections

IDENTIFY THE DIFFERENT SECTIONS IN THE ASSEMBLY SHOWN



3	COTTER	STEEL	2
2	SLEEVE	Fe 410 W	1
1	ROD END	Fe 410 W	2
PART NO.	DESCRIPTION	MATERIAL	NO. OFF

Assembly of Cotter Joint with Sleeve

UNIT 3

LIMITS, FITS AND TOLERANCES

3. LIMITS, FITS AND TOLERANCES

Definitions: Limits, Fits and Tolerances - Upper limit, lower limit, tolerance, deviation, upper deviation, lower deviation, tolerance zone - Standard tolerance grades - Computation of IT tolerance using formulae and tables - Fundamental deviation - Computation of fundamental deviation - System of fits - Clearance fit - Interference fit - Transition fit - Problems on clearance and interference fit on shaft and hole basis system.

✓ **What is a machine?**

✓ A machine is an ***assembly*** of many parts such as bolts, nuts, screws, bearings, gears, chains, couplings etc.,.

✓ These are **standard parts** of any machine and the remaining parts are specially designed for that particular machine.

✓ **Standard parts** are commercially available in the market in standard sizes and manufactured by **mass production.**

✓ Designed parts are manufactured as per the design specifications.

✓ If the machines are required in large numbers, then even the design parts are manufactured by mass production.

✓ The parts produced by mass production must be ***interchangeable***.

BOLTS - BATCH A

NUTS - BATCH B

✓ ***Interchangeable*: A part picked at random must fit properly with its counterpart also picked randomly, and both of them must satisfy functionally.

✓ It is highly impossible to manufacture large number of identical parts accurately to the specified exact size economically due to the inherent limitations in men, material and machines.

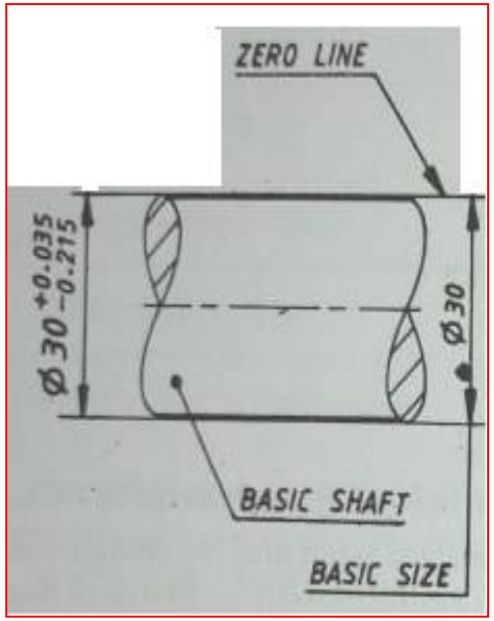
✓ The cost of manufacture will be higher since greater care and skill is required while machining the part very close to the **basic size**.

✓ Therefore, it is inevitable to tolerate variations in the basic size so that the actual machined sizes may lie within the specified limits of variations.

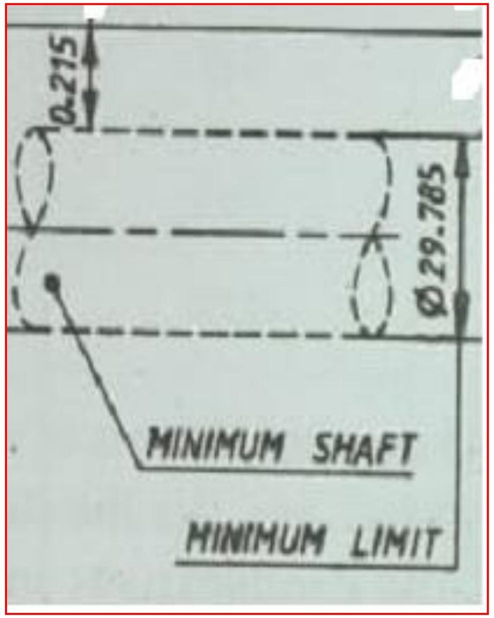
✓ The amount of variation permitted for a basic size is called **tolerance**.

✓ The maximum and minimum permissible sizes within which the actual machined size lies are called **limits**.

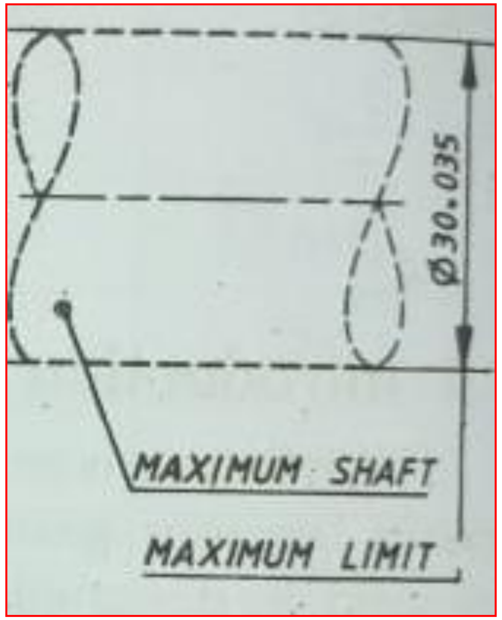
✓ The functional relationship between the two adjacent parts achieved by the specified tolerances is called **fit**.



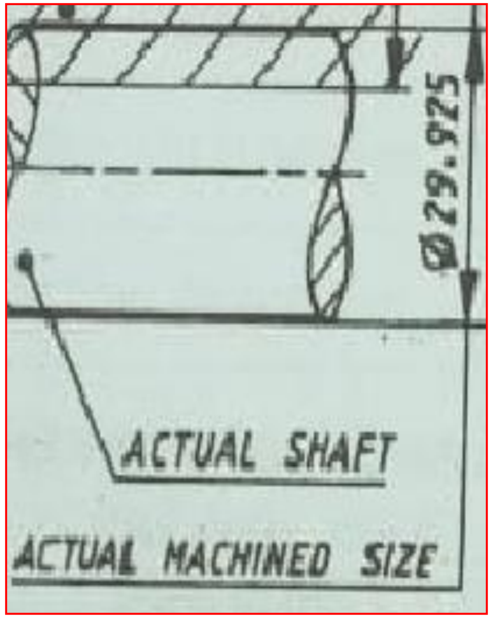
BASIC SHAFT



MINIMUM SHAFT

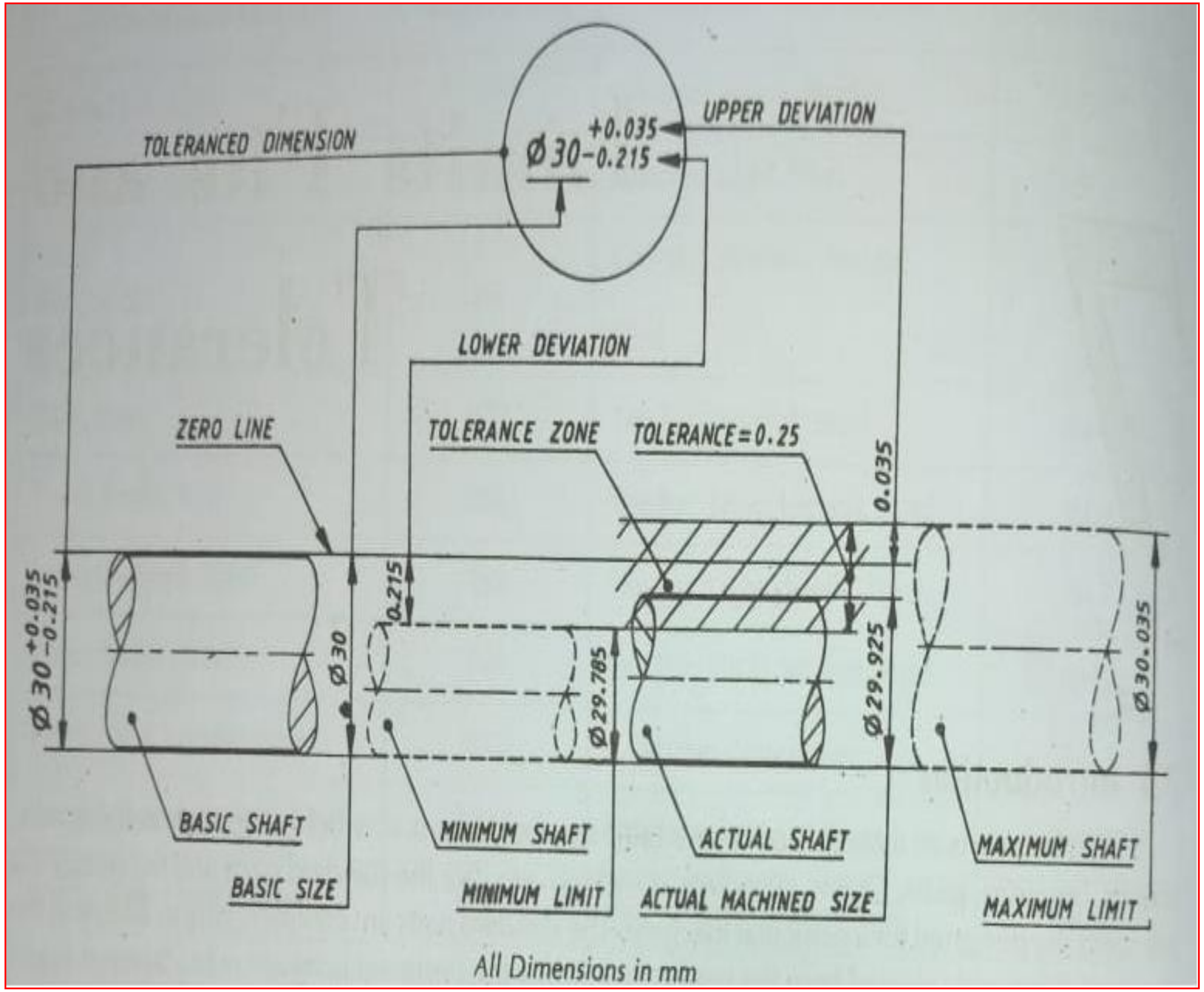


MAXIMUM SHAFT



ACTUAL SHAFT

- ✓ **Basic size:** Theoretical size of a part derived from the design. The tolerances are always specified to the basic size.
- ✓ The dimension 30 mm is the basic size.
- ✓ **Actual size:** Size actually obtained by the machining. The actual size of the shaft is ϕ29.925 mm.
- ✓ **Zero line:** Since the deviations are measured from the basic size, to indicate the deviations graphically: the basic shaft, the minimum shaft, the actual shaft and the maximum shaft are aligned at the bottom and a straight line, called zero line is drawn. Deviations above this line will be positive and below this line will be negative.



✓ **Limits:** Two extreme permissible sizes between which the actual size lies.

✓ **Maximum limit**: Maximum permissible size for a given basic size. From the fig, the maximum limit is ϕ30+0.035 = ϕ30.035 mm.

✓ **Minimum limit**: Minimum permissible size for a given basic size. From the fig, the minimum limit is ϕ30-0.215 = ϕ29.785 mm.

✓ **Tolerance:** Amount of variation permitted to a basic size.

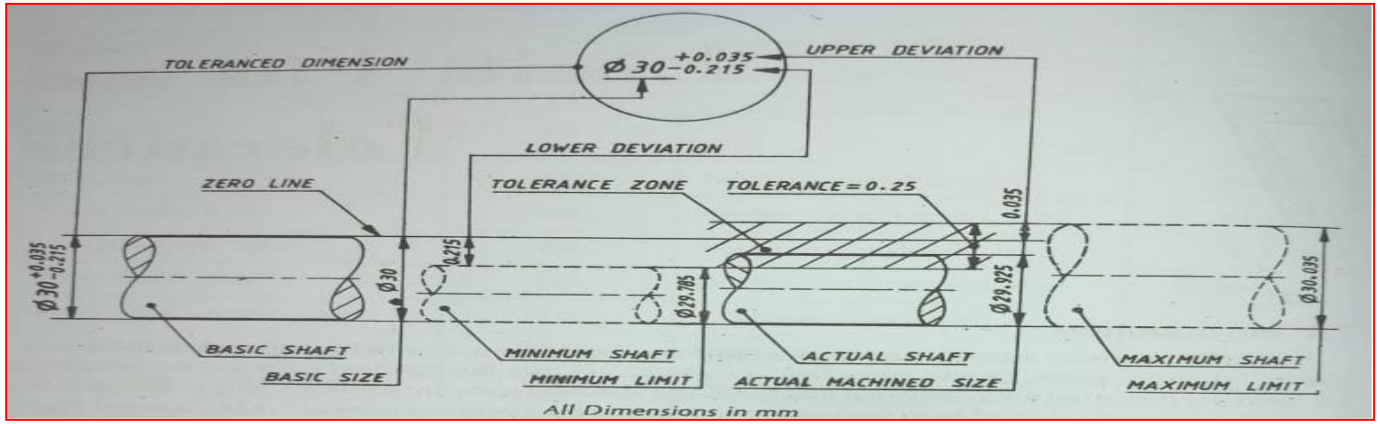
It is the **difference between the maximum and minimum limits of a basic size.**

From the fig., the tolerance is = ϕ30.035- ϕ29.785 = 0.25 mm.

✓ **Deviation:** It is the difference between the limit sizes (either maximum or minimum) and the corresponding basic size.

✓ **Upper Deviation**: Algebraic difference between the maximum limit and the basic size = ϕ30.035-ϕ30 = 0.035 mm.

✓ **Lower Deviation**: Algebraic difference between the minimum limit and the basic size = ϕ29.785-ϕ30 = -0.215 mm.



✓ **Actual Deviation**: Algebraic difference between the actual measured size and the basic size = ϕ29.925-ϕ30 = -0.075 mm.

✓ **Tolerance zone:** It is the zone bounded by the upper and lower limits of the basic size, shown hatched.

TOLERANCES

✓ Tolerance on a basic size is obtained based on its performance.

✓ To achieve the required tolerance, the **manufacturing process** has to be selected.

✓ This manufacturing process should be capable of accomplishing the specified tolerance **economically.**

✓ The various manufacturing processes ranging from the **fine gauge manufacture** to the **coarse manufacturing** process such as sand casting, are classified by **BIS (Bureau of Indian Standards)** into **sixteen grades**, numbering from **1 to 16**.

✓ The tolerance is expressed in **micron(micrometer)**.

✓ Note: **1 MICRON = 0.001 mm = 10^{-6} m**.

Degree of Accuracy Expected of Manufacturing Process

PROCESS	Grad No
Slip blocks, Reference gauges	1
High quality gauges, Plug gauges	2
Good quality gauges, Gap gauges	3
Gauges, fits of extreme precision by lapping	4
Ball bearing, machine lapping, diamond or fine boring, fine grinding	5
Grinding, fine honing	6
High quality turning, broaching, honing	7
Centre lathe turning and boring, reaming, capstun or automatic in good condition	8
Worn capstun or automatic; horizontal or vertical boring machines	9
Milling, slotting, planing, metal rolling or extrusion	10
Drilling, rough turning or boring, precision tube drawing	11
Light press work, tube drawing	12
Press work, tube rolling	13
Die casting or moulding; rubber moulding	14
Stamping	15
Sand casting, flame cutting	16

Recommendations for Selection of Tolerance Grades

Manufacturing Processes	Grade of Tolerance	
	Difficult to achieve	Can be easily achieved
Lapping		4 & 5
Honing	4	5
Cylindrical & Centreless Grinding	5	6, 7, 8 & 9
Surface Grinding - Peripheral	5	6, 7, 8 & 9
Surface Grinding on Face	6	7, 8 & 9
Diamond Boring	5	6 & 7
Boring	6	7, 8 & 9
Broaching	6.	7, 8, & 9
Reaming	6	7, 8, 9 & 11
Turning	7 & 8	9, 10, 11 & 12
Face Milling - Peripheral Milling	9	10, 11 & 12
Keyway Milling		9, 10 & 11
Planing	8	9, 10, 11 & 12
Pre-drilling	10	11
Drilling with Fixture	10	11 & 12

STANDARD TOLERANCE GRADES RECOMMENDED BY BIS

BASIC SIZE	BIS	GRADES	TABLE NO	TOTAL NO OF GRADES
Upto 500 mm	IS: 919-1963	IT01, IT0, IT1, IT2......IT16	7.3	18
Above 500 mm and upto 3150 mm	IS: 2101-1962	IT6......IT16	7.4	11

✓ The symbol IT indicates the recommended standard tolerance grades.

TABLE 7.3

Fundamental Tolerances of Grades 01, 0 & 1 to 16 For Sizes upto 500 mm

All Dimensions in mm

DIAMETER STEPS IN mm	VALUES OF TOLERANCES IN MICRONS (1 MICRON = 0.001 mm)																	
	TOLERANCE GRADES																	
	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14*	15*	16*
TO AND INC 3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250	400	600
OVER 3 TO AND INC 6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
OVER 6 TO AND INC 10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900
OVER 10 TO AND INC 18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
OVER 18 TO AND INC 30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
OVER 30 TO AND INC 50	0.6	1	1.5	2.5	4	7	11	16	25	39	62	100	160	250	390	620	1000	1600
OVER 50 TO AND INC 80	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
OVER 80 TO AND INC 120	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
OVER 120 TO AND INC 180	1.2	2	3.5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
OVER 180 TO AND INC 250	2	3	4.5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
OVER 250 TO AND INC 315	2.5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
OVER 315 TO AND INC 400	3	5	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3600
OVER 400 TO AND INC 500	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000

TABLE 7.3

FUNDAMENTAL TOLERANCES OF GRADES 01, 0 & 1 to 16 FOR SIZES UPTO 500 mm

TABLE 7.4

Fundamental Tolerances of Grades 6 to 16 for Sizes Above 500 mm and Upto 3150 mm

All Dimensions in mm

DIAMETER STEPS IN mm		GRADES										
		6	7	8	9	10	11	12	13	14	15	16
OVER	TO	VALUES IN μ										
500	630	44	70	110	175	280	440	700	1100	1750	2800	4400
630	800	50	80	125	200	320	500	800	1250	2000	3200	5000
800	1000	56	90	140	230	360	560	900	1400	2300	3600	5600
1000	1250	66	105	165	260	420	660	1050	1650	2600	4200	6600
1250	1600	78	125	195	310	500	780	1250	1950	3100	5000	7800
1600	2000	92	150	230	370	600	920	1500	2300	3700	6000	9200
2000	2500	110	175	280	440	700	1100	1750	2800	4400	7000	11000
2500	3150	135	210	330	540	860	1350	2100	3300	5400	8600	13500

TABLE 7.4

FUNDAMENTAL TOLERANCES OF GRADES 6 to 16 FOR SIZES UPTO 500 mm

COMPUTATION OF IT TOLERANCE FOR SIZES UPTO 500 mm

TABLE 7.8

Recommended Diameter Steps

All Dimensions in mm

For Sizes upto 500 mm													
Above	-	3	6	10	18	30	50	80	120	180	250	315	400
Upto	3	6	10	18	30	50	80	120	180	250	315	400	500

For Sizes above 500 mm & upto 3150 mm								
Above	500	630	800	1000	1250	1600	2000	2500
Upto	630	800	1000	1250	1600	2000	2500	3150

TABLE 7.5

Formulae for IT Tolerances for Sizes upto 500mm

GRADE	TOLERANCE VALUES μ
IT 01	$i = 0.3 + 0.008D^*$
IT 0	$i = 0.5 + 0.012D^*$
IT 1	$i = 0.8 + 0.020D^*$
IT 2 to IT 4	To be obtained from Table 7.3
IT 5 to IT 16	$i^* = 0.45\sqrt[3]{D^*} + 0.001D^*$

+ Substitute i values in Relative Magnitude Values given in Table 7.6

TABLE 7.6

Relative Magnitude of IT Tolerances for Grades 5 to 16 in terms of Tolerance Unit *i* for Sizes Upto 500 mm

GRADE	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
TOLERANCE VALUES	7 *i*	10 *i*	16 *i*	25 *i*	40 *i*	64 *i*	100 *i*	160 *i*	250 *i*	400 *i*	640 *i*	1000 *i*

TABLE 7.9

Rules for Rounding off Tolerance Values

Values in Microns	Above	5	45	60	100	200	300	560	600	800	1000	2000
	Upto	45	60	100	200	300	560	600	800	1000	2000	
Rounded in Multiples of	For standard tolerance for grade 11 and finer	1	1	1	5	10	10					

HOW TO COMPUTE THE IT TOLERANCE FOR SIZES UPTO 500 mm

1. Calculate the **'Geometric Mean of the extreme diameters of each step (D)'** using **Table 7.8**

   where **D = √(product of the diameter steps)** in mm.

2. Use **Table 7.5** to find tolerance unit '**i**' for the corresponding given GRADE, in microns.
3. Use **Table 7.6** to find the relative magnitude of IT tolerance for the given IT grade, in microns.
4. Use **Table 7.9** to round off the above value.
5. Verify the obtained answer using **Table 7.3**.

Q: Compute the IT tolerance of diameter 40 mm of tolerance grade 5.

Soln:

- ✓ *1. Calculate the* ***'Geometric Mean of the extreme diameters of each step (D)'*** *using* ***Table 7.8***

  where ***D = √(product of the diameter steps)*** *in mm.*

  The given diameter 40 mm lies in the diameter step 30 mm and 50 mm.

  Hence, D = √(30x50) = 38.73 mm.

- ✓ *2. Use* ***Table 7.5*** *to find tolerance unit '**i**' for the corresponding given GRADE, in microns.*

  For the tolerance grade IT5, $i = 0.45\sqrt[3]{D} + 0.001D = 0.45\sqrt[3]{38.73} + 0.001(38.73) = 0.45x3.38 + 0.03873$ = 1.5225+0.03873 = 1.56123 microns.

- ✓ 3. Use **Table 7.6** to find the relative magnitude of IT tolerance, in microns.

  Magnitude of IT tolerance = 7i = 7x1.56123 = 10.92861 microns.

- ✓ 4. Use **Table 7.9** to round off the above value.

  Rounding off to the nearest 1 and hence: Magnitude of IT tolerance = 11 microns.

- ✓ 5. Verify the obtained answer using **Table 7.3, Page 59 of KRG**.

  The value of fundamental IT tolerance corresponding to grade 5 and diameter 40 mm is 11 microns. This verifies the answer computed above.

HOW TO COMPUTE THE IT TOLERANCE FOR SIZES ABOVE 500 mm UPTO 3150 mm

1. Calculate the **'Geometric Mean of the extreme diameters of each step (D)'** using **Table 7.8**

   where **D = √(product of the diameter steps)** in mm.

2. Use the empirical formla to find tolerance unit '**i**', ***i* = *0.004D+2.1*** in microns.
3. Use **Table 7.7** to find the relative magnitude of IT tolerance for the given IT grade, in microns.
4. Use **Table 7.9** to round off the above value.
5. Verify the obtained answer using **Table 7.4**.

TABLE 7.8

Recommended Diameter Steps

All Dimensions in mm

For Sizes upto 500 mm													
Above	-	3	6	10	18	30	50	80	120	180	250	315	400
Upto	3	6	10	18	30	50	80	120	180	250	315	400	500

For Sizes above 500 mm & upto 3150 mm								
Above	500	630	800	1000	1250	1600	2000	2500
Upto	630	800	1000	1250	1600	2000	2500	3150

TABLE 7.7

Relative Magnitude of IT Tolerances for Grades 6 to 16 in terms of Tolerance Unit *i* for sizes Above 500 mm and Upto 3150 mm

GRADE	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
TOLERANCE VALUES	10 *i*	16 *i*	25 *i*	40 *i*	64 *i*	100 *i*	160 *i*	250 *i*	400 *i*	640 *i*	1000 *i*

Q: Compute the IT tolerance of diameter 700 mm of tolerance grade 9.

Soln:

- ✓ *1. Calculate the* ***'Geometric Mean of the extreme diameters of each step (D)'*** *using* ***Table 7.8***

  where ***D = √(product of the diameter steps)*** *in mm.*

  The given diameter 700 mm lies in the diameter step 630 mm and 800 mm.

  Hence, D = √(630x800) = 709.93 mm.

- ✓ *2. Use the empirical formla to find tolerance unit '**i**',* ***i = 0.004D+2.1*** *in microns.*

  i = (0.004x709.93)+2.1 = 4.9397 microns.

- ✓ 3. Use **Table 7.7** to find the relative magnitude of IT tolerance, in microns.

  Magnitude of IT tolerance = 40i = 40x4.9397 = 197.58 microns.

- ✓ 4. Use **Table 7.9** to round off the above value.

  Rounding off to the nearest 5 and hence: Magnitude of IT tolerance = 200 microns.

- ✓ 5. Verify the obtained answer using **Table 7.4, Page 59/60 of KRG**.

  The value of fundamental IT tolerance corresponding to grade 9 and diameter 700 mm is 200 microns. This verifies the answer computed above.

FUNDAMENTAL DEVIATION

- ✓ **Fundamental Deviation:** The upper or lower deviation that is chosen to specify the position of the tolerance zone.
- ✓ For both the hole and shaft, the fundamental deviations are indicated by ***letter symbols***.
- ✓ Fundamental deviations for the **holes** indicated by: **UPPER CASE(CAPITAL) LETTERS**.
- ✓ Fundamental deviations for the **shafts** indicated by: **LOWER CASE LETTERS**.
- ✓ BIS recommended 25 types of fundamental deviations for the holes and shafts of basic sizes *less than 500 mm* (IS:919-1963).
- ✓ For holes: A B C D E F G H Js J K M N P R S T U V X Y Z ZA ZB ZC **(Refer Table 7.10/Page 64 & 65)**.
- ✓ For shafts: a b c d e f g h js j k m n p r s t u v x y z za zb zc **(Refer Table 7.11/Page 66 & 67)**.

- ✓ BIS recommended 14 types of fundamental deviations for the holes and shafts of basic sizes above 500 mm & up to 3150 mm.
- ✓ For holes: D E F G H Js K M N P R S T U.
- ✓ For shafts: d e f g h js k m n p r s t u.

✓ The symbols used for the fundamental deviations for the shafts and holes are as follows:

	HOLES	SHAFTS
✓ Upper Deviation (E'cart Superior)	**ES**	**es**
✓ Lower Deviation (E'cart Inferior)	**EI**	**ei**

- ✓ **For shafts: es = ei + IT**
- ✓ **For holes: ES = EI + IT**

FUNDAMENTAL DEVIATIONS FOR SHAFTS OF a to zc

Table 2 — Numerical values of the fundamental deviations of shafts

Basic size mm		Fundamental deviation values														
		Upper deviation *es*														
		All standard tolerance grades												IT5 and IT6	IT7	IT8
Above	Up to and including	a[1]	b[1]	c	cd	d	e	ef	f	fg	g	h	js[2]	j	j	j
—	3[1]	− 270	− 140	− 60	− 34	− 20	− 14	− 10	− 6	− 4	− 2	0	Deviations = $\pm \frac{IT_n}{2}$, where *n* is the IT value number	− 2	− 4	− 6
3	6	− 270	− 140	− 70	− 46	− 30	− 20	− 14	− 10	− 6	− 4	0		− 2	− 4	
6	10	− 280	− 150	− 80	− 56	− 40	− 25	− 18	− 13	− 8	− 5	0		− 2	− 5	
10	14	− 290	− 150	− 95		− 50	− 32		− 16		− 6	0		− 3	− 6	
14	18															
18	24	− 300	− 160	− 110		− 65	− 40		− 20		− 7	0		− 4	− 8	
24	30															
30	40	− 310	− 170	− 120		− 80	− 50		− 25		− 9	0		− 5	− 10	
40	50	− 320	− 180	− 130												
50	65	− 340	− 190	− 140		− 100	− 60		− 30		− 10	0		− 7	− 12	
65	80	− 360	− 200	− 150												
80	100	− 380	− 220	− 170		− 120	− 72		− 36		− 12	0		− 9	− 15	
100	120	− 410	− 240	− 180												
120	140	− 460	− 260	− 200		− 145	− 85		− 43		− 14	0		− 11	− 18	
140	160	− 520	− 280	− 210												
160	180	− 580	− 310	− 230												
180	200	− 660	− 340	− 240		− 170	− 100		− 50		− 15	0		− 13	− 21	
200	225	− 740	− 380	− 260												
225	250	− 820	− 420	− 280												
250	280	− 920	− 480	− 300		− 190	− 110		− 56		− 17	0		− 16	− 26	
280	315	− 1 050	− 540	− 330												
315	355	− 1 200	− 600	− 360		− 210	− 125		− 62		− 18	0		− 18	− 28	
355	400	− 1 350	− 680	− 400												
400	450	− 1 500	− 760	− 440		− 230	− 135		− 68		− 20	0		− 20	− 32	
450	500	− 1 650	− 840	− 480												
500	560					− 260	− 145		− 76		− 22	0				
560	630															
630	710					− 290	− 160		− 80		− 24	0				
710	800															
800	900					− 320	− 170		− 86		− 26	0				
900	1 000															
1 000	1 120					− 350	− 195		− 98		− 28	0				
1 120	1 250															
1 250	1 400					− 390	− 220		− 110		− 30	0				
1 400	1 600															
1 600	1 800					− 430	− 240		− 120		− 32	0				
1 800	2 000															
2 000	2 240					− 480	− 260		− 130		− 34	0				
2 240	2 500															
2 500	2 800					− 520	− 290		− 145		− 38	0				
2 800	3 150															

1) Fundamental deviations a and b shall not be used for basic sizes less than or equal to 1 mm.

2) For tolerance classes js7 to js11, if the IT value number, *n*, is an odd number, this may be rounded to the even number immediately below, so that the resulting deviations, i.e. $\pm \frac{IT_n}{2}$, can be expressed in whole micrometres.

IS 919 (Part 1) : 1993
ISO 286 - 1 : 1988

Fundamental deviation values in micrometres

Basic size mm		deviation values															
		Lower deviation *ei*															
		IT4 to IT7	Up to IT3 (incl.) and above IT7	All standard tolerance grades													
Above	Up to and including	k	k	m	n	p	r	s	t	u	v	x	y	z	za	zb	zc
—	3	0	0	+ 2	+ 4	+ 6	+ 10	+ 14		+ 18		+ 20		+ 26	+ 32	+ 40	+ 60
3	6	+ 1	0	+ 4	+ 8	+ 12	+ 15	+ 19		+ 23		+ 28		+ 35	+ 42	+ 50	+ 80
6	10	+ 1	0	+ 6	+ 10	+ 15	+ 19	+ 23		+ 28		+ 34		+ 42	+ 52	+ 67	+ 97
10	14	+ 1	0	+ 7	+ 12	+ 18	+ 23	+ 28		+ 33		+ 40		+ 50	+ 64	+ 90	+ 130
14	18										+ 39	+ 45		+ 60	+ 77	+ 108	+ 150
18	24	+ 2	0	+ 8	+ 15	+ 22	+ 28	+ 35		+ 41	+ 47	+ 54	+ 63	+ 73	+ 98	+ 136	+ 188
24	30								+ 41	+ 48	+ 55	+ 64	+ 75	+ 88	+ 118	+ 160	+ 218
30	40	+ 2	0	+ 9	+ 17	+ 26	+ 34	+ 43	+ 48	+ 60	+ 68	+ 80	+ 94	+ 112	+ 148	+ 200	+ 274
40	50								+ 54	+ 70	+ 81	+ 97	+ 114	+ 136	+ 180	+ 242	+ 325
50	65	+ 2	0	+ 11	+ 20	+ 32	+ 41	+ 53	+ 66	+ 87	+ 102	+ 122	+ 144	+ 172	+ 226	+ 300	+ 405
65	80						+ 43	+ 59	+ 75	+ 102	+ 120	+ 146	+ 174	+ 210	+ 274	+ 360	+ 480
80	100	+ 3	0	+ 13	+ 23	+ 37	+ 51	+ 71	+ 91	+ 124	+ 146	+ 178	+ 214	+ 258	+ 335	+ 445	+ 585
100	120						+ 54	+ 79	+ 104	+ 144	+ 172	+ 210	+ 254	+ 310	+ 400	+ 525	+ 690
120	140	+ 3	0	+ 15	+ 27	+ 43	+ 63	+ 92	+ 122	+ 170	+ 202	+ 248	+ 300	+ 365	+ 470	+ 620	+ 800
140	160						+ 65	+ 100	+ 134	+ 190	+ 228	+ 280	+ 340	+ 415	+ 535	+ 700	+ 900
160	180						+ 68	+ 108	+ 146	+ 210	+ 252	+ 310	+ 380	+ 465	+ 600	+ 780	+ 1 000
180	200	+ 4	0	+ 17	+ 31	+ 50	+ 77	+ 122	+ 166	+ 236	+ 284	+ 350	+ 425	+ 520	+ 670	+ 880	+ 1 150
200	225						+ 80	+ 130	+ 180	+ 258	+ 310	+ 385	+ 470	+ 575	+ 740	+ 960	+ 1 250
225	250						+ 84	+ 140	+ 196	+ 284	+ 340	+ 425	+ 520	+ 640	+ 820	+ 1 050	+ 1 350
250	280	+ 4	0	+ 20	+ 34	+ 56	+ 94	+ 158	+ 218	+ 315	+ 385	+ 475	+ 580	+ 710	+ 920	+ 1 200	+ 1 550
280	315						+ 98	+ 170	+ 240	+ 350	+ 425	+ 525	+ 650	+ 790	+ 1 000	+ 1 300	+ 1 700
315	355	+ 4	0	+ 21	+ 37	+ 62	+ 108	+ 190	+ 268	+ 390	+ 475	+ 590	+ 730	+ 900	+ 1 150	+ 1 500	+ 1 900
355	400						+ 114	+ 208	+ 294	+ 435	+ 530	+ 660	+ 820	+ 1 000	+ 1 300	+ 1 650	+ 2 100
400	450	+ 5	0	+ 23	+ 40	+ 68	+ 126	+ 232	+ 330	+ 490	+ 595	+ 740	+ 920	+ 1 100	+ 1 450	+ 1 850	+ 2 400
450	500						+ 132	+ 252	+ 360	+ 540	+ 660	+ 820	+ 1 000	+ 1 250	+ 1 600	+ 2 100	+ 2 600
500	560	0	0	+ 26	+ 44	+ 78	+ 150	+ 280	+ 400	+ 600							
560	630						+ 155	+ 310	+ 450	+ 660							
630	710	0	0	+ 30	+ 50	+ 88	+ 175	+ 340	+ 500	+ 740							
710	800						+ 185	+ 380	+ 560	+ 840							
800	900	0	0	+ 34	+ 56	+ 100	+ 210	+ 430	+ 620	+ 940							
900	1 000						+ 220	+ 470	+ 680	+ 1 050							
1 000	1 120	0	0	+ 40	+ 66	+ 120	+ 250	+ 520	+ 780	+ 1 150							
1 120	1 250						+ 260	+ 580	+ 840	+ 1 300							
1 250	1 400	0	0	+ 48	+ 78	+ 140	+ 300	+ 640	+ 960	+ 1 450							
1 400	1 600						+ 330	+ 720	+ 1 050	+ 1 600							
1 600	1 800	0	0	+ 58	+ 92	+ 170	+ 370	+ 820	+ 1 200	+ 1 850							
1 800	2 000						+ 400	+ 920	+ 1 350	+ 2 000							
2 000	2 240	0	0	+ 68	+ 110	+ 195	+ 440	+ 1 000	+ 1 500	+ 2 300							
2 240	2 500						+ 460	+ 1 100	+ 1 650	+ 2 500							
2 500	2 800	0	0	+ 76	+ 135	+ 240	+ 550	+ 1 250	+ 1 900	+ 2 900							
2 800	3 150						+ 580	+ 1 400	+ 2 100	+ 3 200							

FUNDAMENTAL DEVIATIONS FOR HOLES OF A to ZC

Table 3 — Numerical values of the fundamental deviations of holes

Fundamental deviation values in micrometres

Basic size mm: Above	Up to and including	Lower deviation EI (All standard tolerance grades): A[1]	B[1]	C	CD	D	E	EF	F	FG	G	H	JS[2]	Upper deviation ES: J IT6	J IT7	J IT8	K[3] Up to IT8 (incl.)	K Above IT8	M[3,4] Up to IT8 (incl.)	M Above IT8
–	3[1,5]	+270	+140	+60	+34	+20	+14	+10	+6	+4	+2	0	Deviations = ± ITn/2, where n is the IT value number	+2	+4	+6	0	0	-2	-2
3	6	+270	+140	+70	+46	+30	+20	+14	+10	+6	+4	0		+5	+6	+10	-1 + Δ		-4 + Δ	-4
6	10	+280	+150	+80	+56	+40	+25	+18	+13	+8	+5	0		+5	+8	+12	-1 + Δ		-6 + Δ	-6
10	14	+290	+150	+95		+50	+32		+16		+6	0		+6	+10	+15	-1 + Δ		-7 + Δ	-7
14	18																			
18	24	+300	+160	+110		+65	+40		+20		+7	0		+8	+12	+20	-2 + Δ		-8 + Δ	-8
24	30																			
30	40	+310	+170	+120		+80	+50		+25		+9	0		+10	+14	+24	-2 + Δ		-9 + Δ	-9
40	50	+320	+180	+130																
50	65	+340	+190	+140		+100	+60		+30		+10	0		+13	+18	+28	-2 + Δ		-11 + Δ	-11
65	80	+360	+200	+150																
80	100	+380	+220	+170		+120	+72		+36		+12	0		+16	+22	+34	-3 + Δ		-13 + Δ	-13
100	120	+410	+240	+180																
120	140	+460	+260	+200		+145	+85		+43		+14	0		+18	+26	+41	-3 + Δ		-15 + Δ	-15
140	160	+520	+280	+210																
160	180	+580	+310	+230																
180	200	+660	+340	+240		+170	+100		+50		+15	0		+22	+30	+47	-4 + Δ		-17 + Δ	-17
200	225	+740	+380	+260																
225	250	+820	+420	+280																
250	280	+920	+480	+300		+190	+110		+56		+17	0		+25	+36	+55	-4 + Δ		-20 + Δ	-20
280	315	+1 050	+540	+330																
315	355	+1 200	+600	+360		+210	+125		+62		+18	0		+29	+39	+60	-4 + Δ		-21 + Δ	-21
355	400	+1 350	+680	+400																
400	450	+1 500	+760	+440		+230	+135		+68		+20	0		+33	+43	+66	-5 + Δ		-23 + Δ	-23
450	500	+1 650	+840	+480																
500	560					+260	+145		+76		+22	0					0		-26	
560	630																			
630	710					+290	+160		+80		+24	0					0		-30	
710	800																			
800	900					+320	+170		+86		+26	0					0		-34	
900	1 000																			
1 000	1 120					+350	+195		+98		+28	0					0		-40	
1 120	1 250																			
1 250	1 400					+390	+220		+110		+30	0					0		-48	
1 400	1 600																			
1 600	1 800					+430	+240		+120		+32	0					0		-58	
1 800	2 000																			
2 000	2 240					+480	+260		+130		+34	0					0		-68	
2 240	2 500																			
2 500	2 800					+520	+290		+145		+38	0					0		-76	
2 800	3 150																			

Basic size mm: Above	Up to and including	Upper deviation ES: N[3,5] Up to IT8 (incl.)	N Above IT8	P to ZC[3] Up to IT7 (incl.)	P	R	S	T	U	V	X	Y	Z	ZA	ZB	ZC	Values for Δ: IT3	IT4	IT5	IT6	IT7	IT8
–	3	-4	-4	Values as for standard tolerance grades above IT7 increased by Δ	-6	-10	-14		-18		-20		-26	-32	-40	-60	0	0	0	0	0	0
3	6	-8 + Δ	0		-12	-15	-19		-23		-28		-35	-42	-50	-80	1	1,5	1	3	4	6
6	10	-10 + Δ	0		-15	-19	-23		-28		-34		-42	-52	-67	-97	1	1,5	2	3	6	7
10	14	-12 + Δ	0		-18	-23	-28		-33		-40		-50	-64	-90	-130	1	2	3	3	7	9
14	18									-39	-45		-60	-77	-108	-150						
18	24	-15 + Δ	0		-22	-28	-35		-41	-47	-54	-63	-73	-98	-136	-188	1,5	2	3	4	8	12
24	30							-41	-48	-55	-64	-75	-88	-118	-160	-218						
30	40	-17 + Δ	0		-26	-34	-43	-48	-60	-68	-80	-94	-112	-148	-200	-274	1,5	3	4	5	9	14
40	50							-54	-70	-81	-97	-114	-136	-180	-242	-325						
50	65	-20 + Δ	0		-32	-41	-53	-66	-87	-102	-122	-144	-172	-226	-300	-405	2	3	5	6	11	16
65	80					-43	-59	-75	-102	-120	-146	-174	-210	-274	-360	-480						
80	100	-23 + Δ	0		-37	-51	-71	-91	-124	-146	-178	-214	-258	-335	-445	-585	2	4	5	7	13	19
100	120					-54	-79	-104	-144	-172	-210	-254	-310	-400	-525	-690						
120	140	-27 + Δ	0		-43	-63	-92	-122	-170	-202	-248	-300	-365	-470	-620	-800	3	4	6	7	15	23
140	160					-65	-100	-134	-190	-228	-280	-340	-415	-535	-700	-900						
160	180					-68	-108	-146	-210	-252	-310	-380	-465	-600	-780	-1 000						
180	200	-31 + Δ	0		-50	-77	-122	-166	-236	-284	-350	-425	-520	-670	-880	-1 150	3	4	6	9	17	26
200	225					-80	-130	-180	-258	-310	-385	-470	-575	-740	-960	-1 250						
225	250					-84	-140	-196	-284	-340	-425	-520	-640	-820	-1 050	-1 350						
250	280	-34 + Δ	0		-56	-94	-158	-218	-315	-385	-475	-580	-710	-920	-1 200	-1 550	4	4	7	9	20	29
280	315					-98	-170	-240	-350	-425	-525	-650	-790	-1 000	-1 300	-1 700						
315	355	-37 + Δ	0		-62	-108	-190	-268	-390	-475	-590	-730	-900	-1 150	-1 500	-1 900	4	5	7	11	21	32
355	400					-114	-208	-294	-435	-530	-660	-820	-1 000	-1 300	-1 650	-2 100						
400	450	-40 + Δ	0		-68	-126	-232	-330	-490	-595	-740	-920	-1 100	-1 450	-1 850	-2 400	5	5	7	13	23	34
450	500					-132	-252	-360	-540	-660	-820	-1 000	-1 250	-1 600	-2 100	-2 600						
500	560	-44			-78	-150	-280	-400	-600													
560	630					-155	-310	-450	-660													
630	710	-50			-88	-175	-340	-500	-740													
710	800					-185	-380	-560	-840													
800	900	-56			-100	-210	-430	-620	-940													
900	1 000					-220	-470	-680	-1 050													
1 000	1 120	-66			-120	-250	-520	-780	-1 150													
1 120	1 250					-260	-580	-840	-1 300													
1 250	1 400	-78			-140	-300	-640	-960	-1 450													
1 400	1 600					-330	-720	-1 050	-1 600													
1 600	1 800	-92			-170	-370	-820	-1 200	-1 850													
1 800	2 000					-400	-920	-1 350	-2 000													
2 000	2 240	-110			-195	-440	-1 000	-1 500	-2 300													
2 240	2 500					-460	-1 100	-1 650	-2 500													
2 500	2 800	-135			-240	-550	-1 250	-1 900	-2 900													
2 800	3 150					-580	-1 400	-2 100	-3 200													

1) Fundamental deviations A and B shall not be used for basic sizes less than or equal to 1 mm.

2) For tolerance classes JS7 to JS11, if the IT value number, n, is an odd number, this may be rounded to the even number immediately below, so that the resulting deviations, i.e. ± ITn/2, can be expressed in whole micrometres.

3) For determining the values K, M and N for standard tolerance grades up to IT8 (incl.) and deviations P to ZC for standard tolerance grades up to IT7 (incl.), take the Δ values from the columns on the right.

3) (concl.) *Examples:*

K7 in the range 18 to 30 mm: Δ = 8 µm, therefore ES = -2 + 8 = +6 µm

S6 in the range 18 to 30 mm: Δ = 4 µm, therefore ES = -35 + 4 = -31 µm

4) Special cases: for tolerance class M6 in the range from 250 to 315 mm, ES = -9 µm (instead of -11 µm).

5) Fundamental deviation N for standard tolerance grades above IT8 shall not be used for basic sizes less than or equal to 1 mm.

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ISO 286-1 : 1988

TABLE 7.10

Fundamental Deviations for Shafts of Types a to zc of Sizes Upto 500 mm

FUNDAMENTAL DEVIATIONS IN MICRONS (1 MICRON = 0.001mm)															
DIAMETER STEPS IN mm		UPPER DEVIATION (es)								js**	LOWER DEVIATIONS (ei)				
		a*	b*	c	d	e	f	g	h		j			k	
OVER	TO	ALL GRADES									5,6	7	8	4 to 7	≤3 >7
-	3*	-270	-140	-60	-20	-14	-6	-2	0	DEVIATIONS = $\pm \frac{IT}{2}$	-2	-4	6	0	0
3	6	-270	-140	-70	-30	-20	-10	-4	0		-2	-4		+1	0
6	10	-280	-150	-80	-40	-25	-13	-5	0		-2	-5		+1	0
10	14	-290	-150	-95	-50	-32	-16	-6	0		-3	-6		+1	0
14	18														
18	24	-300	-160	-110	-65	-40	-20	-7	0		-4	-8		+2	0
24	30														
30	40	-310	-170	-120	-80	-50	-25	-9	0		-5	-10		+2	0
40	50	-320	-180	-130											
50	65	-340	-190	-140	-100	-60	-30	-10	0		-7	-12		+2	0
65	80	-360	-200	-150											
80	100	-380	-220	-170	-120	-72	-36	-12	0		-9	-15		+3	0
100	120	-410	-240	-180											
120	140	-460	-260	-200	-145	-85	-43	-14	*0		-11	-18		+3	0
140	160	-520	-280	-210											
160	180	-580	-310	-230											
180	200	-660	-340	-240	-170	-100	-50	-15	0		-13	-21		+4	0
200	225	-740	-380	-260											
225	250	-820	-420	-280											
250	280	-920	-480	-300	-190	-110	-56	-17	0		-16	-26		+4	0
280	315	-1050	-540	-330											
315	355	-1200	-600	-360	-210	-125	-62	-18	0		-18	-28		+4	0
355	400	-1350	-680	-400											
400	450	-1500	-760	-440	-230	-135	-68	-20	0		-20	-32		+5	0
450	500	-1650	-840	-480											

* The deviations of shafts of types a and b are not provided for diameters upto 1 mm

** For types js in the particular Grades 7 to 11, the two symmetrical deviation $\pm \frac{IT}{2}$ may possibly rounded if the IT value in microns is odd value, by replacing it by the even value immediately below.

(Continued)

TABLE 7.10

FUNDAMENTAL DEVIATIONS FOR SHAFTS OF a to zc FOR SIZES UPTO 500 mm

TABLE 7.10
(CONTINUED)
Fundamental Deviations for Shafts of a to zc of Sizes Upto 500 mm

FUNDAMENTAL DEVIATIONS IN MICRONS														(1 MICRON = 0.001 mm)	
		LOWER DEVIATIONS (ei)													
DIAMETER STEPS IN mm		m	n	p	r	s	t	u	v	x	y	z	za	zb	zc
		ALL GRADES													
OVER	TO														
-	3	+2	+4	+6	+10	+14		+18		+20		+26	+32	+40	+60
3	6	+4	+8	+12	+15	+19		+23		+28		+35	+42	+50	+80
6	10	+6	+10	+15	+19	+23		+28		+34		+42	+52	+67	+97
10	14	+7	+12	+18	+23	+28		+33		+40		+50	+64	+90	+130
14	18								+39	+45		+60	+77	+108	+150
18	24	+8	+15	+22	+28	+35		+41	+47	+54	+63	+73	+98	+136	+188
24	30						+41	+48	+55	+64	+75	+88	+118	+160	+218
30	40	+9	+17	+26	+34	+43	+48	+60	+68	+80	+94	+112	+148	+200	+274
40	50						+54	+70	+81	+97	+114	+136	+180	+242	+325
50	65	+11	+20	+32	+41	+53	+66	+87	+102	+122	+144	+172	+226	+300	+405
65	80				+43	+59	+75	+102	+120	+146	+174	+210	+274	+360	+480
80	100	+13	+23	+37	+51	+71	+91	+124	+146	+178	+214	+258	+335	+445	+585
100	120				+54	+79	+104	+144	+172	+210	+254	+310	+400	+525	+690
120	140	+15	+27	+43	+63	+92	+122	+170	+202	+248	+300	+365	+470	+620	+800
140	160				+65	+100	+134	+190	+228	+280	+340	+415	+535	+700	+900
160	180				+68	+108	+146	+210	+252	+310	+380	+465	+600	+780	+1000
180	200	+17	+31	+50	+77	+122	+166	+236	+284	+350	+425	+520	+670	+880	+1150
200	225				+80	+130	+180	+258	+310	+385	+470	+575	+740	+960	+1250
225	250				+84	+140	+196	+284	+340	+425	+520	+640	+820	+1050	+1350
250	280	+20	+34	+56	+94	+158	+218	+315	+385	+475	+580	+710	+920	+1200	+1550
280	315				+98	+170	+240	+350	+425	+525	+650	+790	+1000	+1300	+1700
315	355	+21	+37	+62	+108	+190	+268	+390	+475	+590	+730	+900	+1150	+1500	+1900
355	400				+114	+208	+294	+435	+530	+660	+820	+1000	+1300	+1650	+2100
400	450	+23	+40	+68	+126	+232	+330	+490	+595	+740	+920	+1100	+1450	+1850	+2400
450	500				+132	+252	+360	+540	+660	+820	+1000	+1250	+1600	+2100	+2600

TABLE 7.10

FUNDAMENTAL DEVIATIONS FOR SHAFTS OF a to zc FOR SIZES UPTO 500 mm

TABLE 7.11

Fundamental Deviation For Holes of Types A to ZC for Sizes upto 500 mm

FUNDAMENTAL DEVIATIONS IN MICRONS (1 MICRON = 0.001 mm)

DIAMETER STEPS IN mm		LOWER DEVIATIONS (EI)									UPPER DEVIATIONS (ES)									
		A*	B*	C	D	E	F	G	H	Js**	J			K		M		N		P to ZC
OVER	TO	ALL GRADES									6	7	8	≤8	>8	≤8***	>8	≤8	>8*	≤7
-	3*	+270	+140	+60	+20	+14	+6	+2	0	DEVIATIONS = ± IT/2	+2	+4	+6	0	0	-2	-2	-4	-4	SAME DEVIATION AS FOR GRADES > 7 INCREASED BY Δ
3	6	+270	+140	+70	+30	+20	+10	+4	0		+5	+6	+10	-1+Δ		-4+Δ	-4	-8+Δ	0	
6	10	+280	+150	+80	+40	+25	+13	+5	0		+5	+8	+12	-1+Δ		-6+Δ	-6	-10+Δ	0	
10	14	+290	+150	+95	+50	+32	+16	+6	0		+6	+10	+15	-1+Δ		-7+Δ	-7	-12+Δ	0	
14	18																			
18	24	+300	+160	+110	+65	+40	+20	+7	0		+8	+12	+20	-2+Δ		-8+Δ	-8	-15+Δ	0	
24	30																			
30	40	+310	+170	+120	+80	+50	+25	+9	0		+10	+14	+24	-2+Δ		-9+Δ	-9	-17+Δ	0	
40	50	+320	+180	+130																
50	65	+340	+190	+140	+100	+60	+30	+10	0		+13	+18	+28	-2+Δ		-11+Δ	-11	-20+Δ	0	
65	80	+360	+200	+150																
80	100	+380	+220	+170	+120	+72	+36	+12	0		+16	+22	+34	-3+Δ		-13+Δ	-13	-23+Δ	0	
100	120	+410	+240	+180																
120	140	+460	+260	+200	+145	+85	+43	+14	0		+18	+26	+41	-3+Δ		-15+Δ	-15	-27+Δ	0	
140	160	+520	+280	+210																
160	180	+580	+310	+230																
180	200	+660	+340	+240	+170	+100	+50	+15	0		+22	+30	+47	-4+Δ		-17+Δ	-17	-31+Δ	0	
200	225	+740	+380	+260																
225	250	+820	+420	+280																
250	280	+920	+480	+300	+190	+110	+56	+17	0		+25	+36	+55	-4+Δ		-20+Δ	-20	-34+Δ	0	
280	315	+1050	+540	+330																
315	355	+1200	+600	+360	+210	+125	+62	+18	0		+29	+39	+60	-4+Δ		-21+Δ	-21	-37+Δ	0	
355	400	+1350	+680	+400																
400	450	+1500	+760	+440	+230	+135	+68	+20	0		+33	+43	+66	-5+Δ		-23+Δ	-23	-40+Δ	0	
450	500	+1650	+840	+480																

* The deviation of holes of types A and B in all grades > 8 are not provided for diameters upto 1 mm.

(Continued)

** For the hole of type Js in the grades 7 and 11, the two symmetrical deviations $\pm \frac{IT}{2}$ may possibly rounded. If the IT value in microns is an odd value by replacing it by the even value immediately below. Special case : For the hole M6, ES = —9 from 250 to 315 (instead of — 11)

TABLE 7.11 FUNDAMENTAL DEVIATIONS FOR HOLES OF A to ZC FOR SIZES UPTO 500 mm

TABLE 7.11
(CONTINUED)

Fundamental Deviations for Holes of Types A to ZC for Sizes upto 500 mm

FUNDAMENTAL DEVIATIONS IN MICRONS														(1 MICRON = 0.001 mm)					
DIAMETER STEPS IN mm		UPPER DEVIATIONS (ES)												△ IN MICRONS*					
		P	R	S	T	U	V	X	Y	Z	ZA	ZB	ZC						
OVER	TO	> 7												3	4	5	6	7	8
-	3	-6	-10	-14		-18		-20		-26	-32	-40	-60	△ = 0					
3	6	-12	-15	-19		-23		-28		-35	-42	-50	-80	1	1.5	1	3	4	6
6	10	-15	-19	-23		-28		-34		-42	-52	-67	-97	1	1.5	2	3	6	7
10	14	-18	-23	-28		-33		-40		-50	-64	-90	-130	1	2	3	3	7	9
14	18						-39	-45		-60	-77	-109	-150						
18	24	-22	-28	-35		-41	-47	-54	-63	-73	-98	-136	-188	1.5	2	3	4	8	12
24	30				-41	-48	-55	-64	-75	-88	-118	-160	-218						
30	40	-26	-34	-43	-48	-60	-68	-80	-94	-112	-148	-200	-274	1.5	3	4	5	9	14
40	50				-54	-70	-81	-97	-114	-136	-180	-242	-325						
50	65	-32	-41	-53	-66	-87	-102	-122	-144	-172	-226	-300	-405	2	3	5	6	11	16
65	80		-43	-59	-75	-102	-120	-146	-174	-210	-274	-360	-480						
80	100	-37	-51	-71	-91	-124	-146	-178	-214	-258	-335	-445	-585	2	4	5	7	13	19
100	120		-54	-79	-104	-144	-172	-210	-254	-310	-400	-525	-690						
120	140	-43	-63	-92	-122	-170	-202	-248	-300	-365	-470	-620	-800	3	4	6	7	15	23
140	160		-65	-100	-134	-190	-228	-280	-340	-415	-535	-700	-900						
160	180		-68	-108	-146	-210	-252	-310	-380	-465	-600	-780	-1000						
180	200	-50	-77	-122	-166	-236	-284	-350	-425	-520	-670	-880	-1150	3	4	6	9	17	26
200	225		-80	-130	-180	-258	-310	-385	-470	-575	-740	-960	-1250						
225	250		-84	-140	-196	-284	-340	-425	-520	-640	-820	-1050	-1350						
250	280	-56	-94	-158	-218	-315	-385	-475	-580	-710	-920	-1200	-1550	4	4	7	9	20	29
280	315		-98	-170	-240	-350	-425	-525	-650	-790	-1000	-1300	-1700						
315	355	-62	-108	190	-268	-390	-475	-590	-730	-900	-1150	-1500	-1900	4	5	7	11	21	32
355	400		-114	-208	-294	-435	-530	-660	-820	-1000	-1300	-1650	-2100						
400	450	-68	-126	-232	-330	-490	-595	-740	-920	-1100	-1450	-1850	-2400	5	5	7	13	23	34
450	500		-132	-252	-360	-540	-660	-820	-1000	-1250	-1600	-2000	-2600						

* In determing K, M, N, upto grade 8 and P to Zc upto grade 7 (given in Page 66) take the values from the columns on the righ:
Example : For p7 from diameters 18 to 30 mm, —8. hence ES= —14.

TABLE 7.11

FUNDAMENTAL DEVIATIONS FOR HOLES OF A to ZC FOR SIZES UPTO 500 mm

- ✓ How to indicate 'tolerance size?'
- ✓ 50g7 ⟶ value ***50*** indicates ***basic size in mm***, ***g*** indicates the ***tolerance zone for the shaft*** and ***7*** indicates the ***tolerance grade***.
- ✓ 50D6 ⟶ value ***50*** indicates ***basic size in mm***, ***D*** indicates the ***tolerance zone for the HOLE*** and ***6*** indicates the ***tolerance grade***.

HOW TO COMPUTE THE FUNDAMENTAL DEVIATION FOR HOLE?

Q: Compute the fundamental deviations for a circular hole of 35 mm diameter finished to H7 tolerance (Φ35H7).

Magnitude of the fundamental IT tolerance

- Directly from the Table 7.3
- Using the empirical formula given in Table 7.5 and Table 7.6

Soln:

- ✓ *1.* From **Table 7.8**, Page 61, 35 mm lies in the diameter steps between 30 mm and 50 mm. Hence, D = √(30x50) = 38.73 mm.
- ✓ *2. Use **Table 7.5** to find tolerance unit '**i**' for the corresponding given GRADE 7, in microns.*

For the tolerance grade IT7, i = 1.5225+0.03873 = 1.56123 microns.

- ✓ 3. Use **Table 7.6**, Magnitude of IT tolerance = 16i = 16x1.56123 = 24.979 microns.
- ✓ 4. Use **Table 7.9** to round off the above value.

  Rounding off to the nearest 1 and hence: Magnitude of IT tolerance, **IT = 25 microns = 0.025 mm**.
- ✓ 5. Verify the obtained answer using **Table 7.3, Page 59 of KRG**.

  The value of fundamental IT tolerance corresponding to grade 7 and diameter 35 mm is 25 microns. This verifies the answer computed above.
- ✓ 6. Using **Table 7.11**, **Page 66**,either the lower or upper deviation is obtained.

  Corresponding to the basic size of 35 mm and tolerance zone H, we found that lower deviation, EI, is zero.
- ✓ 7. Wkt: ES = EI + IT

  ES = 0 + 0.025 mm.
- ✓ 8. The numerical equivalent of tolerance dimension, **Φ35H7 =** $\phi\, 35\, H7 = \phi\, 35^{+0.025}_{\;0}$

Soln:

✓ *1.* From **Table 7.8**, Page 61, 35 mm lies in the diameter steps between 30 mm and 50 mm. Hence, D = √(30x50) = 38.73 mm.

TABLE 7.8

Recommended Diameter Steps

All Dimensions in mm

For Sizes upto 500 mm													
Above	-	3	6	10	18	30	50	80	120	180	250	315	400
Upto	3	6	10	18	30	50	80	120	180	250	315	400	500

For Sizes above 500 mm & upto 3150 mm								
Above	500	630	800	1000	1250	1600	2000	2500
Upto	630	800	1000	1250	1600	2000	2500	3150

✓ *2. Use* ***Table 7.5*** *to find tolerance unit '**i**' for the corresponding given GRADE 7, in microns.*

For the tolerance grade IT7, i = 1.5225+0.03873 = 1.56123 microns.

$$i = 0.45\sqrt[3]{D} + 0.001D = 0.45\sqrt[3]{38.73} + 0.001(38.73) = 0.45x3.38 + 0.03873$$

TABLE 7.5

Formulae for IT Tolerances for Sizes upto 500mm

GRADE	TOLERANCE VALUES μ
IT 01	i = 0.3 + 0.008D*
IT 0	i = 0.5 + 0.012D*
IT 1	i = 0.8 + 0.020D*
IT 2 to IT 4	To be obtained from Table 7.3
IT 5 to IT 16	$i^* = 0.45\sqrt[3]{D^*} + 0.001D^*$

+ Substitute i values in Relative Magnitude Values given in Table 7.6

- ✓ 3. Use **Table 7.6**, Magnitude of IT tolerance for IT7 = 16i = 16x1.56123 = 24.979 microns.

TABLE 7.6
Relative Magnitude of IT Tolerances for Grades 5 to 16 in terms of Tolerance Unit *i* for Sizes Upto 500 mm

GRADE	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
TOLERANCE VALUES	7 *i*	10 *i*	16 *i*	25 *i*	40 *i*	64 *i*	100 *i*	160 *i*	250 *i*	400 *i*	640 *i*	1000 *i*

- ✓ 4. Use **Table 7.9** to round off the above value.
- ✓ Rounding off to the nearest 1 and hence: Magnitude of IT tolerance, **IT = 25 microns = 0.025 mm**.

TABLE 7.9
Rules for Rounding off Tolerance Values

Values in Microns	Above	5	45	60	100	200	300	560	600	800	1000	2000
	Upto	45	60	100	200	300	560	600	800	1000	2000	
Rounded in Multiples of	For standard tolerance for grade 11 and finer	1	1	1	5	10	10					

- ✓ 5. Verify the obtained answer using **Table 7.3, Page 59 of KRG**.

  The value of fundamental IT tolerance corresponding to grade 7 and diameter 35 mm is 25 microns. This verifies the answer computed above.

- ✓ 6. Using **Table 7.11**, **Page 66**,either the lower or upper deviation is obtained.

  Corresponding to the basic size of 35 mm and tolerance zone H, we found that lower deviation, EI, is zero.

TABLE 7.11

Fundamental Deviation For Holes of Types A to ZC for Sizes upto 500 mm

FUNDAMENTAL DEVIATIONS IN MICRONS																				(1 MICRON = 0.001 mm)
DIAMETER STEPS IN mm		LOWER DEVIATIONS (EI)									UPPER DEVIATIONS (ES)									
		A*	B*	C	D	E	F	G	H	Js**	J			K		M		N		P to ZC
OVER	TO	ALL GRADES									6	7	8	≤8	>8	≤8***	>8	≤8	>8*	≤7
-	3*	+270	+140	+60	+20	+14	+6	+2	0	DEVIATIONS = $\pm \frac{IT}{2}$	+2	+4	+6	0	0	-2	-2	-4	-4	SAME DEVIATION AS FOR GRADES > 7 INCREASED BY Δ
3	6	+270	+140	+70	+30	+20	+10	+4	0		+5	+6	+10	-1+Δ		-4+Δ	-4	-8+Δ	0	
6	10	+280	+150	+80	+40	+25	+13	+5	0		+5	+8	+12	-1+Δ		-6+Δ	-6	-10+Δ	0	
10	14	+290	+150	+95	+50	+32	+16	+6	0		+6	+10	+15	-1+Δ		-7+Δ	-7	-12+Δ	0	
14	18																			
18	24	+300	+160	+110	+65	+40	+20	+7	0		+8	+12	+20	-2+Δ		-8+Δ	-8	-15+Δ	0	
24	30																			
30	40	+310	+170	+120	+80	+50	+25	+9	0		+10	+14	+24	-2+Δ		-9+Δ	-9	-17+Δ	0	
40	50	+320	+180	+130																
50	65	+340	+190	+140	+100	+60	+30	+10	0		+13	+18	+28	-2+Δ		-11+Δ	-11	-20+Δ	0	
65	80	+360	+200	+150																
80	100	+380	+220	+170	+120	+72	+36	+12	0		+16	+22	+34	-3+Δ		-13+Δ	-13	-23+Δ	0	
100	120	+410	+240	+180																
120	140	+460	+260	+200	+145	+85	+43	+14	0		+18	+26	+41	-3+Δ		-15+Δ	-15	-27+Δ	0	
140	160	+520	+280	+210																
160	180	+580	+310	+230																
180	200	+660	+340	+240	+170	+100	+50	+15	0		+22	+30	+47	-4+Δ		-17+Δ	-17	-31+Δ	0	
200	225	+740	+380	+260																
225	250	+820	+420	+280																
250	280	+920	+480	+300	+190	+110	+56	+17	0		+25	+36	+55	-4+Δ		-20+Δ	-20	-34+Δ	0	
280	315	+1050	+540	+330																
315	355	+1200	+600	+360	+210	+125	+62	+18	0		+29	+39	+60	-4+Δ		-21+Δ	-21	-37+Δ	0	
355	400	+1350	+680	+400																
400	450	+1500	+760	+440	+230	+135	+68	+20	0		+33	+43	+66	-5+Δ		-23+Δ	-23	-40+Δ	0	
450	500	+1650	+840	+480																

* The deviation of holes of types A and B in all grades > 8 are not provided for diameters upto 1 mm. *(Continued)*

** For the hole of type Js in the grades 7 and 11, the two symmetrical deviations $\pm \frac{IT}{2}$ may possibly rounded. If the IT value in microns is an odd value by replacing it by the even value immediately below. Special case : For the hole M6, ES = —9 from 250 to 315 (instead of — 11)

- ✓ 7. Wkt: ES = EI + IT

  ES = 0 + 0.025 mm.

- ✓ 8. The numerical equivalent of tolerance dimension, **Φ35H7 =** $\phi 35\ H7 = \phi 35^{+0.025}_{\ \ 0}$

HOW TO COMPUTE THE FUNDAMENTAL DEVIATION FOR shaft?

Q: Compute the fundamental deviations for a circular shaft of 60 mm diameter finished to g6 tolerance (Φ60g6).

Soln:

✓ *1.* From **Table 7.8**, Page 61, 60 mm lies in the diameter steps between 50 mm and 80 mm. Hence, D = √(50x80) = 63.24 mm.

TABLE 7.8
Recommended Diameter Steps
All Dimensions in mm

For Sizes upto 500 mm													
Above	-	3	6	10	18	30	50	80	120	180	250	315	400
Upto	3	6	10	18	30	50	80	120	180	250	315	400	500

For Sizes above 500 mm & upto 3150 mm								
Above	500	630	800	1000	1250	1600	2000	2500
Upto	630	800	1000	1250	1600	2000	2500	3150

✓ *2. Use **Table 7.5** to find tolerance unit '**i**' for the corresponding given GRADE 6, in microns.*

For the tolerance grade IT6, i = 1.7929+0.06324 = 1.856139 microns.

$$i = 0.45\sqrt[3]{D} + 0.001D = 0.45\sqrt[3]{63.24} + 0.001(63.24)$$
$$= 1.7929 + 0.06324 = 1.856139 microns$$

TABLE 7.5
Formulae for IT Tolerances for Sizes upto 500mm

GRADE	TOLERANCE VALUES μ
IT 01	i = 0.3 + 0.008D*
IT 0	i = 0.5 + 0.012D*
IT 1	i = 0.8 + 0.020D*
IT 2 to IT 4	To be obtained from Table 7.3
IT 5 to IT 16	i* = 0.45 $\sqrt[3]{D^*}$ + 0.001D*

+ Substitute i values in Relative Magnitude Values given in Table 7.6

✓ 3. Use **Table 7.6**, Magnitude of IT tolerance for IT6 = 10i = 10x1.856139 = 18.56139 microns.

TABLE 7.6

Relative Magnitude of IT Tolerances for Grades 5 to 16 in terms of Tolerance Unit *i* for Sizes Upto 500 mm

GRADE	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
TOLERANCE VALUES	7 *i*	10 *i*	16 *i*	25 *i*	40 *i*	64 *i*	100 *i*	160 *i*	250 *i*	400 *i*	640 *i*	1000 *i*

✓ 4. Use **Table 7.9** to round off the above value.

✓ Rounding off to the nearest 1 and hence: Magnitude of IT tolerance, **IT = 19 microns = 0.019 mm**.

TABLE 7.9

Rules for Rounding off Tolerance Values

Values in Microns	Above	5	45	60	100	200	300	560	600	800	1000	2000
	Upto	45	60	100	200	300	560	600	800	1000	2000	
Rounded in Multiples of	For standard tolerance for grade 11 and finer	1	1	1	5	10	10					

✓ 5. Verify the obtained answer using **Table 7.3, Page 59 of KRG**.

The value of fundamental IT tolerance corresponding to grade 6 and diameter 60 mm is 19 microns. This verifies the answer computed above.

✓ 6. Using **Table 7.10**, **Page 64**, either the lower or upper deviation is obtained.

Corresponding to the basic size of 60 mm and tolerance zone g, we found that upper deviation, es, is -10 microns = -0.010 mm.

TABLE 7.10

Fundamental Deviations for Shafts of Types a to zc of Sizes Upto 500 mm

FUNDAMENTAL DEVIATIONS IN MICRONS											(1 MICRON = 0.001mm)				
DIAMETER STEPS IN mm		UPPER DEVIATION (es)								js**	LOWER DEVIATIONS (ei)				
		a*	b*	c	d	e	f	g	h		j			k	
OVER	TO	ALL GRADES									5,6	7	8	4 to 7	≤3 >7
-	3*	-270	-140	-60	-20	-14	-6	-2	0	DEVIATIONS = $\pm \frac{IT}{2}$	-2	-4	6	0	0
3	6	-270	-140	-70	-30	-20	-10	-4	0		-2	-4		+1	0
6	10	-280	-150	-80	-40	-25	-13	-5	0		-2	-5		+1	0
10	14	-290	-150	-95	-50	-32	-16	-6	0		-3	-6		+1	0
14	18														
18	24	-300	-160	-110	-65	-40	-20	-7	0		-4	-8		+2	0
24	30														
30	40	-310	-170	-120	-80	-50	-25	-9	0		-5	-10		+2	0
40	50	-320	-180	-130											
50	65	-340	-190	-140	-100	-60	-30	-10	0		-7	-12		+2	0
65	80	-360	-200	-150											
80	100	-380	-220	-170	-120	-72	-36	-12	0		-9	-15		+3	0
100	120	-410	-240	-180											
120	140	-460	-260	-200	-145	-85	-43	-14	0		-11	-18		+3	0
140	160	-520	-280	-210											
160	180	-580	-310	-230											
180	200	-660	-340	-240	-170	-100	-50	-15	0		-13	-21		+4	0
200	225	-740	-380	-260											
225	250	-820	-420	-280											
250	280	-920	-480	-300	-190	-110	-56	-17	0		-16	-26		+4	0
280	315	-1050	-540	-330											
315	355	-1200	-600	-360	-210	-125	-62	-18	0		-18	-28		+4	0
355	400	-1350	-680	-400											
400	450	-1500	-760	-440	-230	-135	-68	-20	0		-20	-32		+5	0
450	500	-1650	-840	-480											

* The deviations of shafts of types a and b are not provided for diameters upto 1 mm

** For types js in the particular Grades 7 to 11, the two symmetrical deviation $\pm \frac{IT}{2}$ may possibly rounded if the IT value in microns is odd value, by replacing it by the even value immediately below.

(Continued)

- ✓ 7. Wkt: es = ei + IT

  -0.010 = ei + 0.019 mm

  ei = -0.010-0.019 = -0.029 mm

- ✓ 8. The numerical equivalent of tolerance dimension, **Φ60g6 :** $\phi 60\ g6 = \phi\ 60^{-.0010}_{-0.029}$

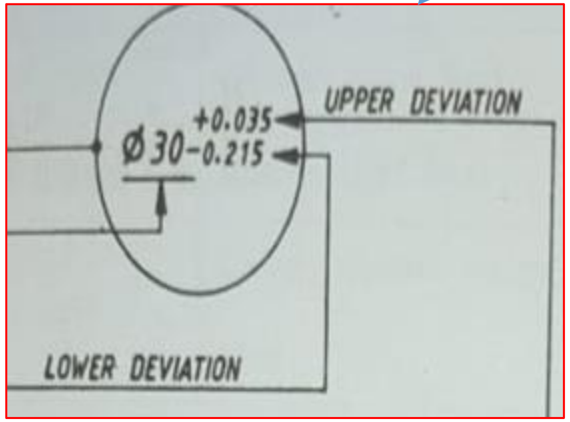
METHODS OF INDICATING TOLERANCES ON DRAWING

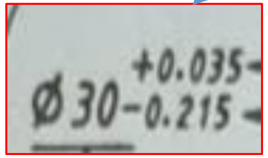
✓ **Rules to be followed while indicating tolerance:**

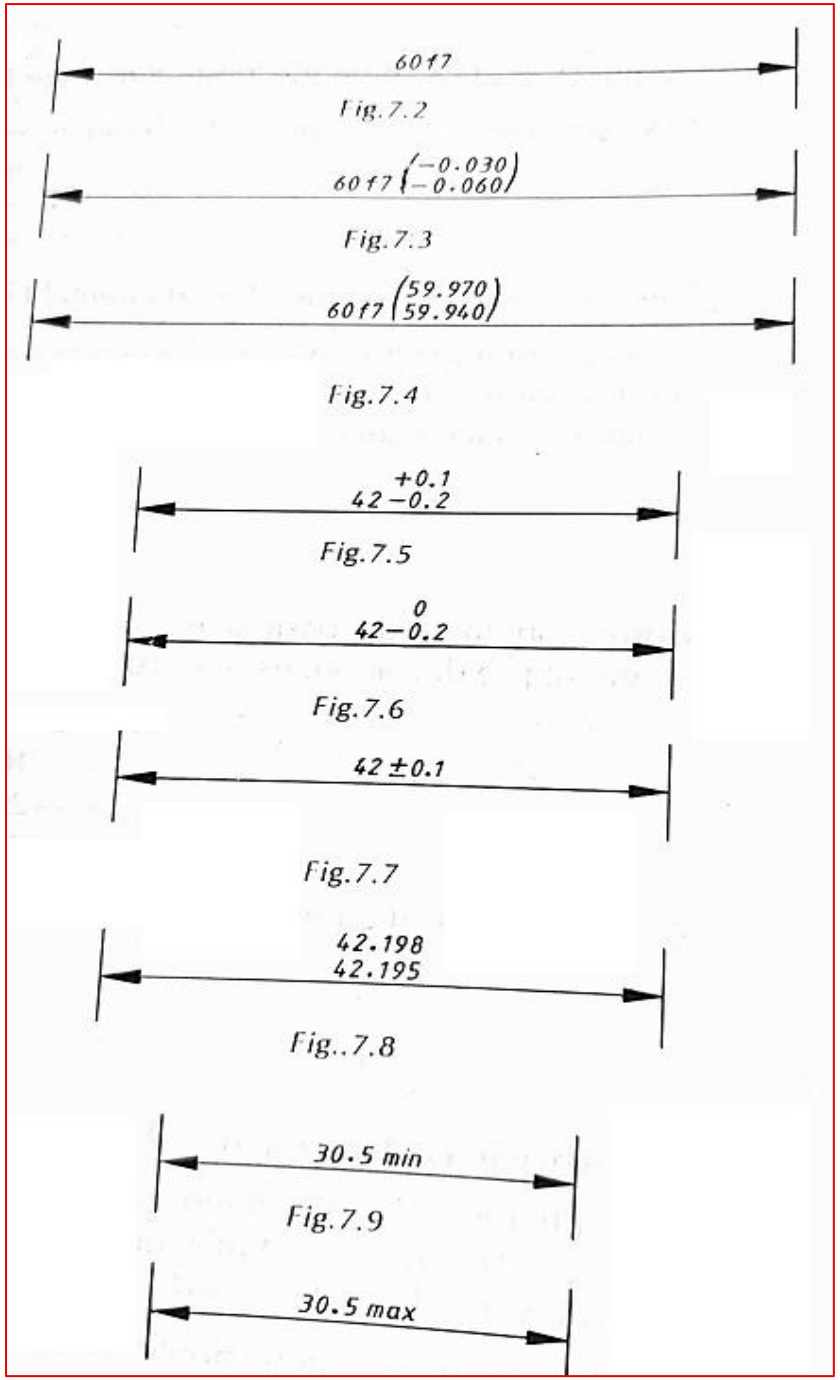
1. The upper deviation should always be written above the lower deviation irrespective of whether it is a shaft or a hole.

2. Both the deviations are expressed to the same number of decimal places, except the cases where the deviation in one direction is nil.

3. When tolerances are uniform on all the individual dimensions, instead of indicating the tolerances on each of the dimensions, a general note assigning the uniform tolerances should be stated, for eg., TOLERANCE ON DIMENSION ±0.5. This saves the drafting time and simplifies the drawing.



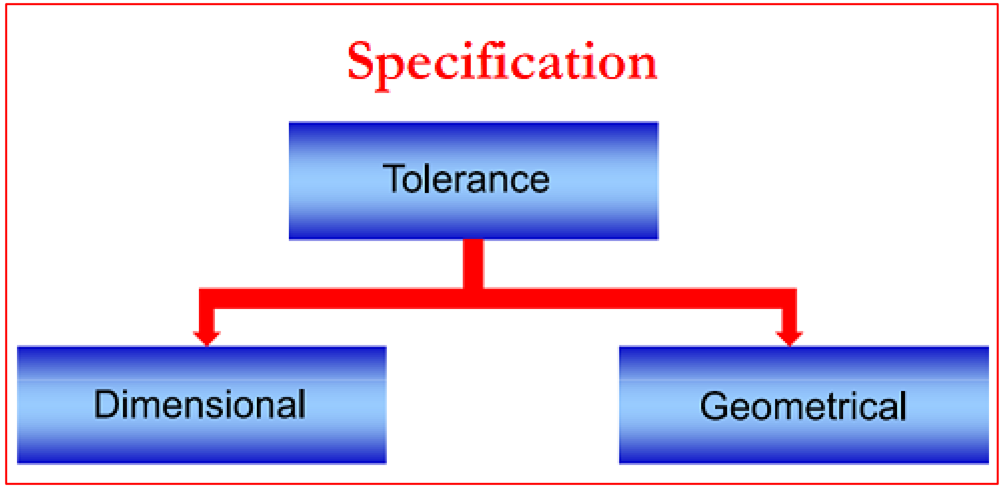


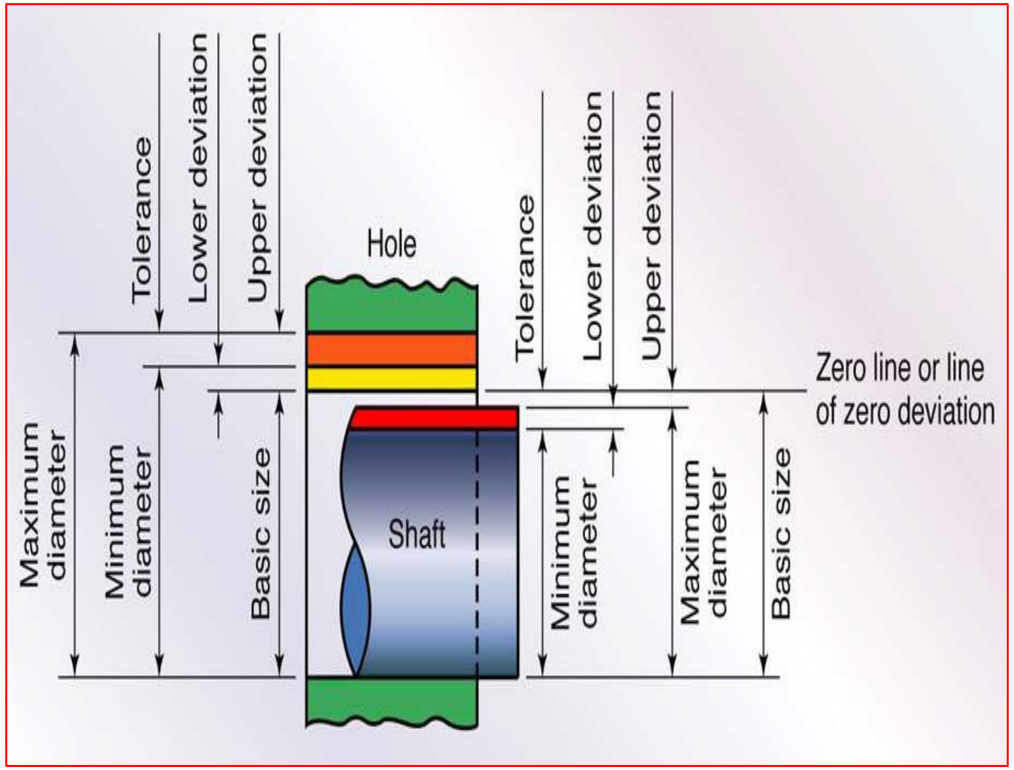


- ✓ Using toleranced symbol
- ✓ Besides toleranced symbol, with the values of deviation
- ✓ Besides toleranced symbol, with the limits of sizes
- ✓ Deviations expressed in ***bilateral system***
- ✓ Deviations expressed in ***unilateral system***, the deviation in one direction will be zero
- ✓ When the upper and lower deviations are equal, the value of the deviation should be indicated once only, preceded by the sign ±
- ✓ Direct indication of tolerance using the limit dimensions

Toleranced dimension with deviations

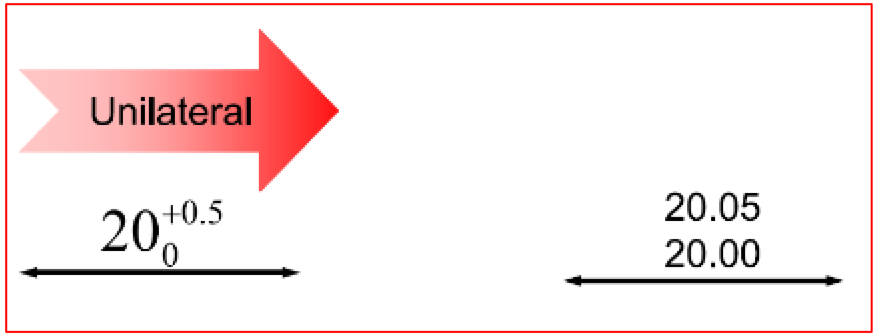
- ✓ If a dimension is to be limited in one direction only, then it must be indicated by adding “min” or “max”.





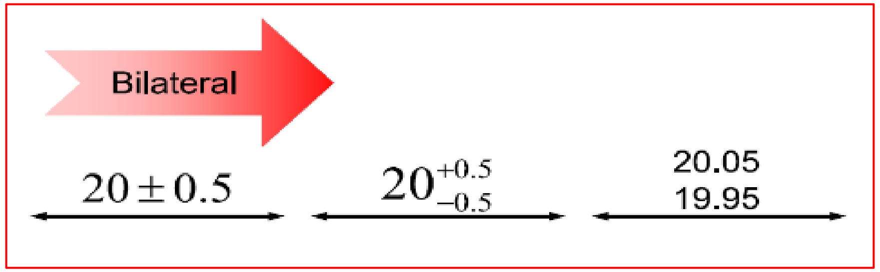
Unilateral Tolerance

In this system, the dimension of a part is allowed to vary only on one side of the basic size, i.e. tolerance lies wholly on one side of the basic size either above or below it.



Bilateral Tolerance

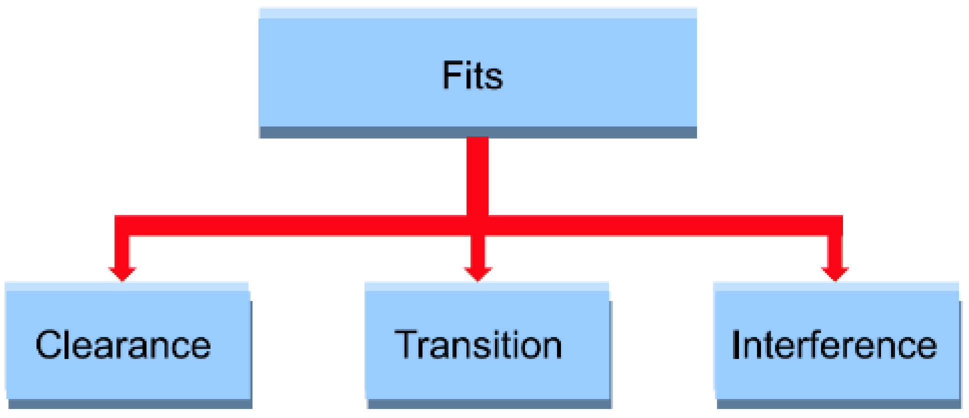
In this system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e. the limits of tolerance lie on either side of the basic size.



FITS

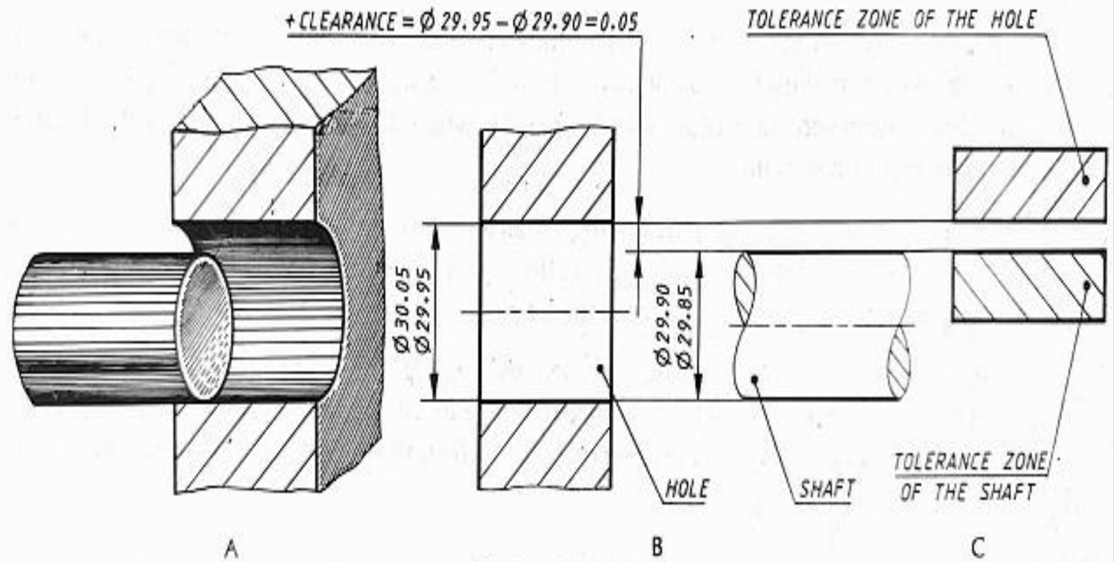
- ✓ The functional relationship between the two adjacent parts achieved by the specified tolerances is called **fit**.
- ✓ It is the relationship existing between the mating surfaces of the parts because of the differences in their dimensions.
- ✓ It may be defined as the degree of tightness and looseness between two mating parts.

- ✓ In general, a **rod of circular section** and a **circular hole** are termed as ***shaft*** and ***hole*** respectively.
- ✓ For the sake of simplicity: even the non circular sections and the space containing or contained by two parallel faces of any part such as, thickness of a key and the width of the keyway or a slot, are also referred as ***shaft*** and ***hole*** respectively.



CLEARANCE FIT

- ✓ In clearance fit, a clearance exists between the shaft and hole.
- ✓ It is defined as the fit established, when a **positive clearance** exists between the hole and the shaft.
- ✓ In this, the **clearance (i.e., positive clearance)** is due to the difference between the dimensions of the ***smallest possible hole*** and the ***largest possible shaft***.
- ✓ Φ29.95-Φ29.90 = 0.05 mm.
- ✓ Fig. C shows the conventional representation of clearance fit.
- ✓ Tolerance zone of the hole **lies above** that of the shaft.
- ✓ Hole > Shaft; Hole-shaft > 0;
- ✓ Allows rotation or sliding between the mating parts.



All Dimensions in mm
Clearance Fit

TYPES OF CLEARANCE FIT

- ✓ **Loose Fit**

It is used between those mating parts where no precision is required. It provides minimum allowance and is used on loose pulleys, agricultural machineries etc.

- ✓ **Running Fit**

For a running fit, the dimension of shaft should be smaller enough to maintain a film of oil for lubrication. It is used in bearing pair etc.,

- ✓ **Slide Fit or Medium Fit**

It is used on those mating parts where great precision is required. It provides medium allowance and is used in tool slides, slide valve, automobile parts, etc.

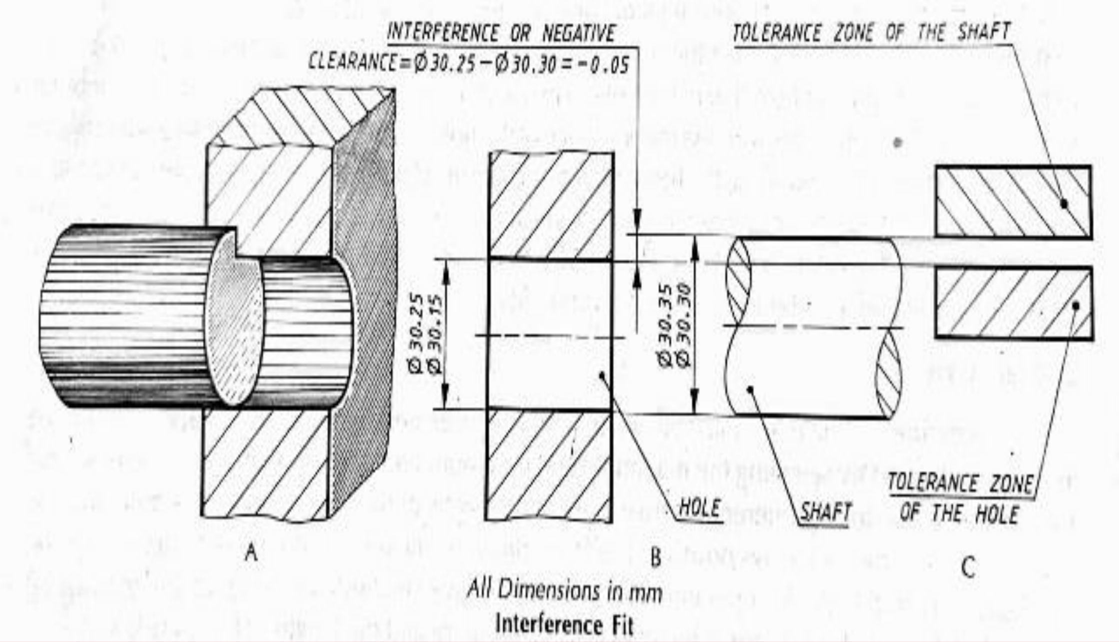
INTERFERENCE FIT

- ✓ In interference fit, a negative clearance exists between the shaft and hole.
- ✓ It is defined as the fit established, when a **negative clearance** exists between the hole and the shaft.
- ✓ In this, the **interference of the surfaces (i.e., negative clearance)** is due to the difference between the dimensions of the ***largest possible hole*** and the ***smallest possible shaft***.
- ✓ Φ30.25-Φ30.30 = -0.05 mm.
- ✓ Fig. C shows the conventional representation of interference fit.
- ✓ Tolerance zone of the hole **lies below** that of the shaft.
- ✓ Hole < Shaft; Hole-shaft < 0;
- ✓ Interference fit is obtained by several methods:

  (a) a shaft may be driven into the hole with a considerable force

  (b) heating the part having the hole in order to increase the diameter of the hole

  (c) cooling the shaft and thus decreasing its diameter.



TYPES OF INTERFERENCE FIT

- ✓ **Shrink Fit or Heavy Force Fit**

It refers to maximum negative allowance. In assembly of the hole and the shaft, the hole is expanded by heating and then rapidly cooled in its position. It is used in fitting of rims etc.,

- ✓ **Medium Force Fit**

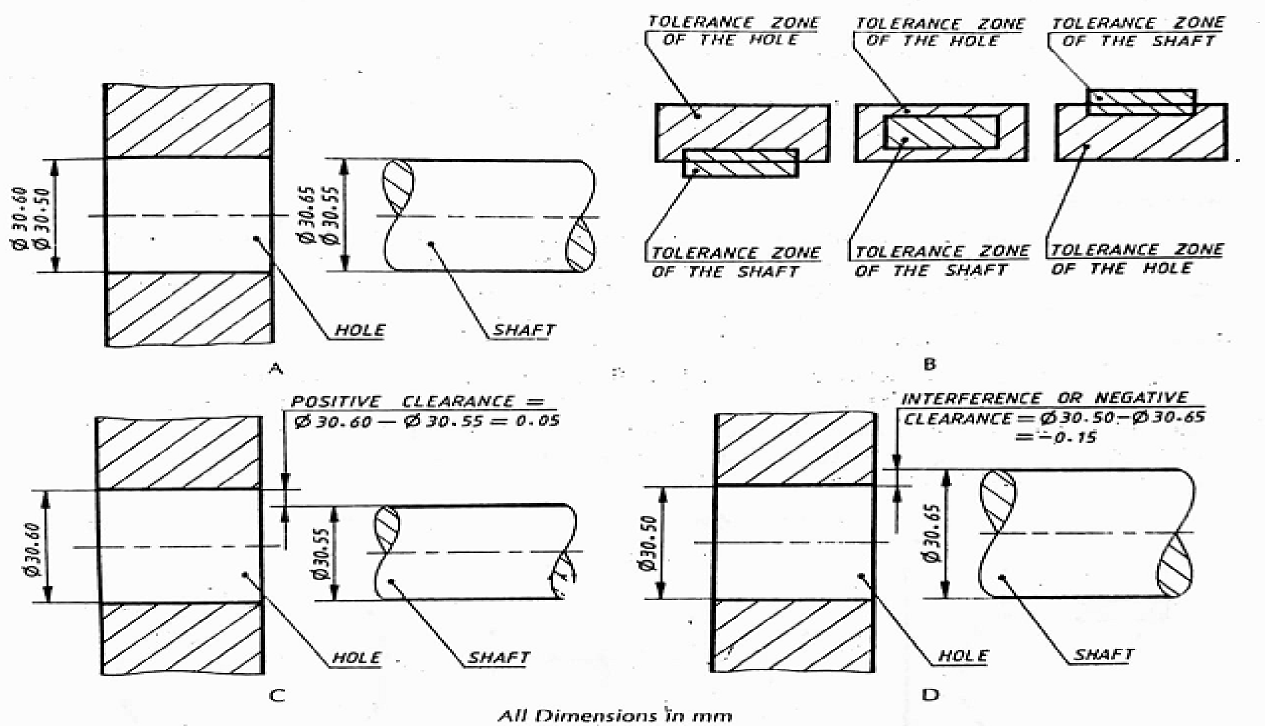
These fits have medium negative allowance. Considerable pressure is required to assemble the hole and the shaft. It is used in car wheels, armature of dynamos etc.,

- ✓ **Tight Fit or Force Fit**

One part can be assembled into the other with a hand hammer or by light pressure. A slight negative allowance exists between two mating parts. It gives a semi permanent fit and is used on a keyed pulley and shaft, rocker arm, etc.,

TRANSITION FIT

- In transition fit, a positive or a negative clearance exists between the shaft and hole.
- It is defined as the fit established, when the dimensions of the hole and the shaft are such that there exists a **positive clearance or** a **negative clearance** when the shaft is fitted into the hole.
- **Positive clearance** when the ***smallest possible shaft*** if fitted into the **largest possible hole**.
- Φ30.60-Φ30.55 = 0.05 mm (Fig. C).
- **Negative clearance** when the ***largest possible shaft*** is fitted into the ***smallest possible hole***.
- Φ30.50-Φ30.65 = -0.15 mm (Fig. D).
- Fig. B shows the conventional representation of interference fit.
- Tolerance zone of the hole and shaft overlap.



Transition Fit

TYPES OF TRANSITION FIT

✓ Push Fit or Snug Fit

It refers to zero allowance and a light pressure is required in assembling the hole and the shaft. The moving parts show least vibration with this type of fit.

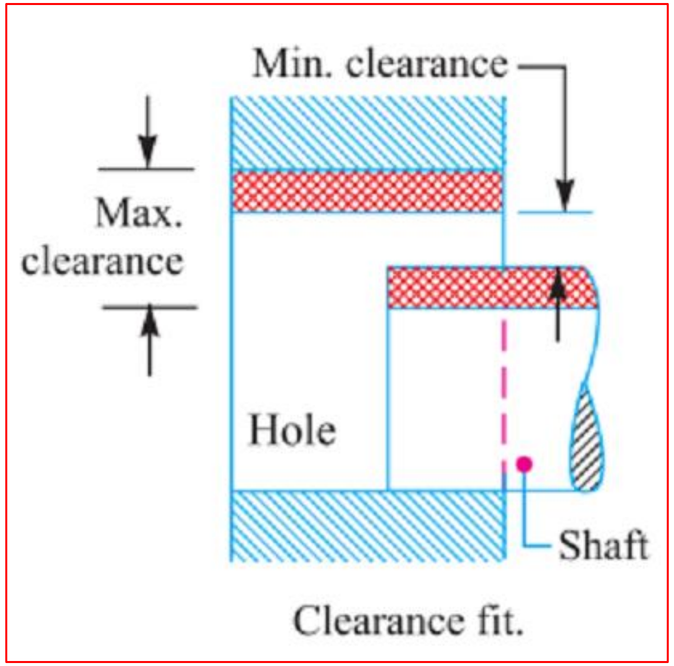
✓ Force Fit or Shrink Fit

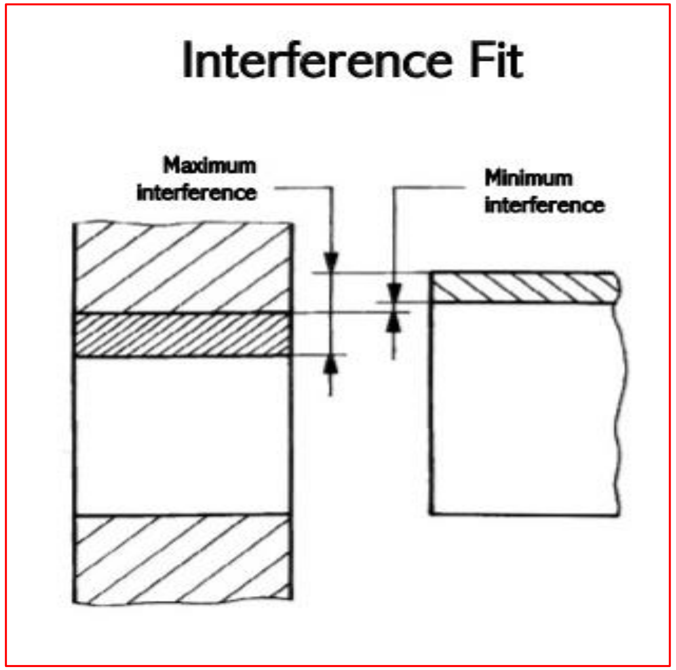
A force fit is used when the two mating parts are to be rigidly fixed so that one cannot move without the other. It either requires high pressure to force the shaft into the hole or the hole to be expanded by heating. It is used in railway wheels, etc.,

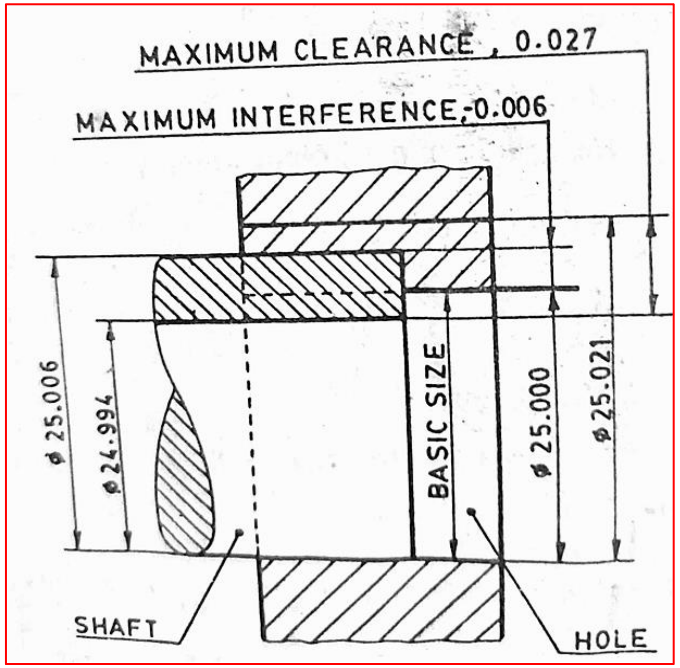
✓ Wringing Fit

A slight negative allowance exists between two mating parts in wringing fit. It requires pressure to force the shaft into the hole and gives a light assembly. It is used in fixing keys, pins, etc.

TYPE OF FIT	HOLE	SHAFT	CLEARANCE
Clearance fit	Smallest possible hole	Largest possible shaft	Positive
Interference fit	Largest possible hole	Smallest possible shaft	Negative
Transition fit	Largest possible hole	Smallest possible shaft	Positive
	Smallest possible hole	Largest possible shaft	Negative





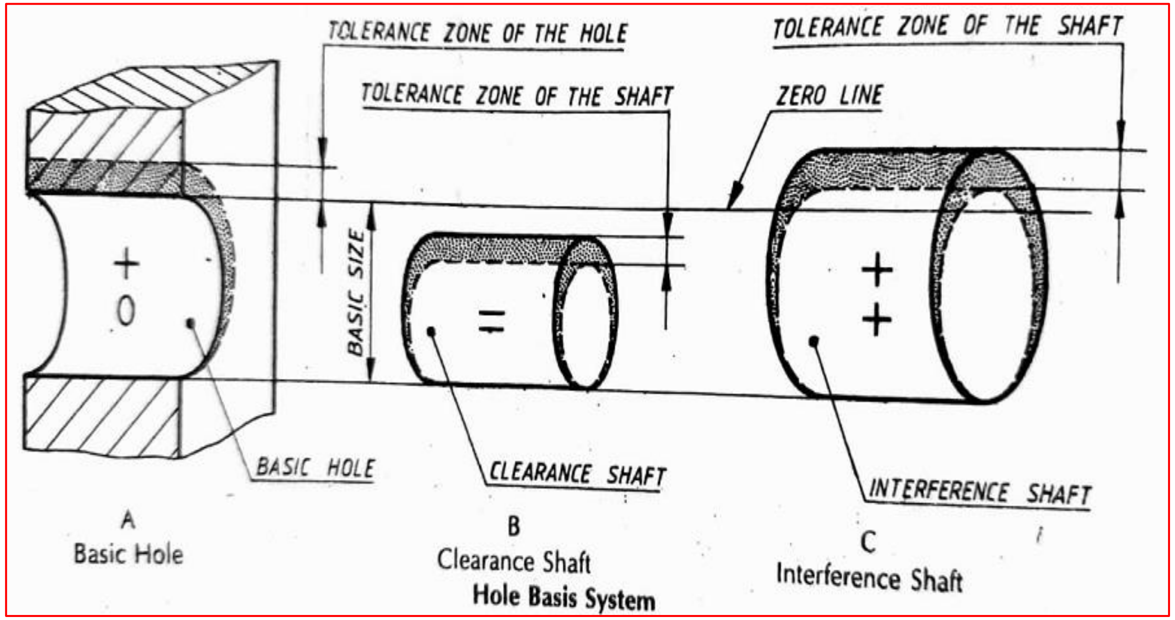


SYSTEM OF FITS

SYSTEM OF FITS	HOLE	SHAFT	RULE
Hole Basis System	Hole size is kept constant	Shaft size is varied to get different types of fits	✓ Lower deviation of hole is zero(EI = 0). ✓ Minimum limit of the hole = Basic size of the hole.
Shaft Basis System	Hole size is varied to get different types of fits	Shaft size is kept constant	✓ Upper deviation of shaft is zero(es = 0). ✓ Maximum limit of the shaft = Basic size of the shaft.
✓ BIS recommends both the systems, but the selection depends on the production methods.			

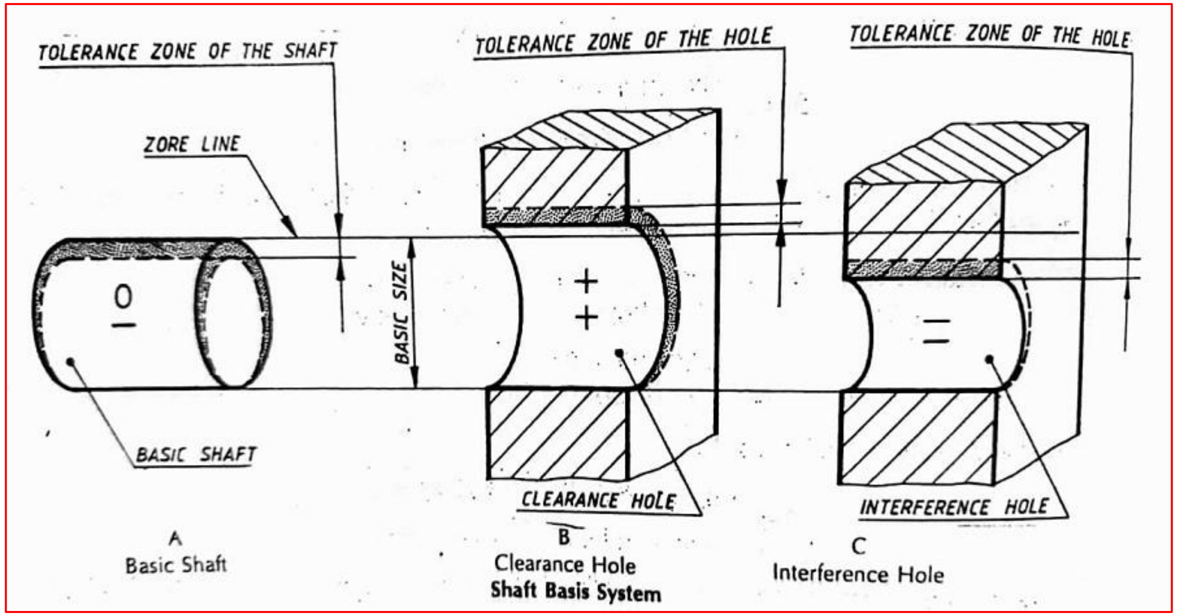
Why hole basis system is preferred?

Hole Basis System



- ✓ Fig. A shows the tolerance zone for the hole having its lower limit equal to the basic size.
- ✓ Zero line is drawn through the lower limit since the lower deviation is zero.
- ✓ Both the limit dimensions of the shaft lie below the zero line for the clearance fit as in Fig. B, while they are above the zero line for the interference fit as in Fig. C.

Shaft Basis System



- ✓ Fig. A shows the tolerance zone for the shaft having its maximum limit equal to the basic size.
- ✓ Zero line is drawn through the upper limit since the upper deviation is zero.
- ✓ Both the limit dimensions of the hole lie above the zero line for the clearance fit as in Fig. B, while they are below the zero line for the interference fit as in Fig. C.

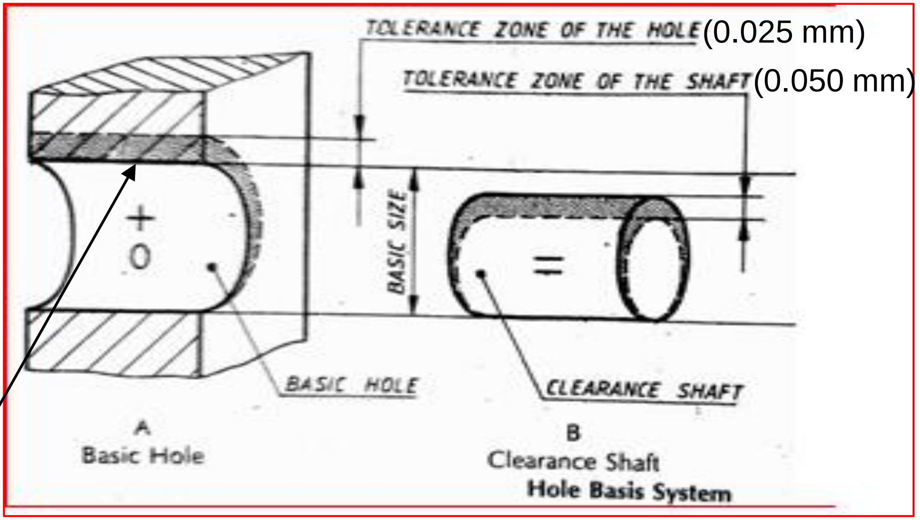
Why hole basis system is preferred?

- ✓ Generally the holes are produced by drilling, boring, reaming, broaching, etc., whereas shafts are produced by turning.
- ✓ Suppose, if the shaft basis system is used (shaft diameter kept constant), then for different types of fits, holes of different sizes are required which in turn requires tools of different types and sizes.
- ✓ If, instead, if the hole basis system is used (hole diameter kept constant), then there will be reduction in production costs as only one tool is required to produce the hole and also the shaft can be machined to any desired size with single tool.
- ✓ Hence, hole basis system is preferred over shaft basis system in most of the industry.

- ✓ However, shaft basis system is preferred when a single shaft has to mate with holes of different sizes to give different sizes to give different kinds of fits, such as in the mating of a gudgeon pin both with the piston and connecting rod; outer rings of antifriction bearings with various bores in housings etc.,

Clearance fit on hole basis system

Compute the limit dimensions for **clearance fit** on the **hole basis system** for a basic size of 20 mm diameter with a minimum clearance of 0.100 mm, tolerance on the hole 0.025 mm and tolerance on the shaft 0.050 mm.



Given: Hole Basis System; Basic size of hole = 20 mm; Minimum clearance = 0.100 mm; Tolerance on the hole = 0.025 mm; Tolerance on the shaft = 0.050 mm

Computation:

- ✓ Minm Clearance = Minm hole – Maxm shaft
- ✓ Maxm Clearance = Maxm hole – Minm shaft

- ✓ Lower deviation of hole is zero(EI = 0)

In the hole basis system:

Minimum limit of the hole = Basic size of the hole = 20 mm

Maximum limit of the hole = Minimum limit of the hole + Tolerance on the hole = Φ20.000+0.025 = Φ20.025 mm.

Maximum limit of the shaft = Minimum limit of the hole – Minimum clearance = Φ20.000-0.100 = Φ19.900 mm.

Minimum limit of the shaft = Maximum limit of the shaft – Tolerance on the shaft = Φ19.900-0.050 = Φ19.850 mm.

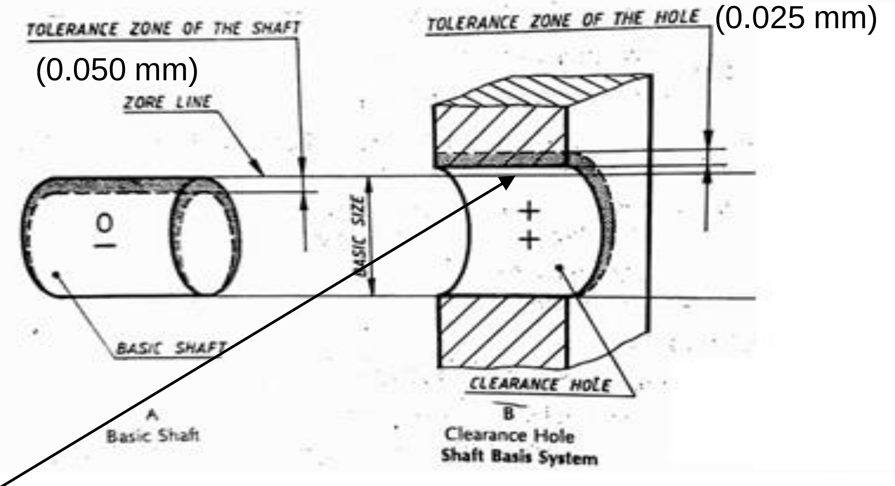
Thus,

Limits of the shaft are: $Shaft^{Maximum\ limit\ =\ \varphi 19.900\ mm}_{Minimum\ limit\ =\ \varphi 19.850\ mm}$

Limits of the hole are: $Hole^{Maximum\ limt\ =\ \varphi 20.025\ mm}_{Minimum\ limit\ =\ \varphi 20.000\ mm}$

Clearance fit on shaft basis system

Compute the limit dimensions for **clearance fit** on the **shaft basis system** for a basic size of 20 mm diameter with a minimum clearance of 0.100 mm, tolerance on the hole 0.025 mm and tolerance on the shaft 0.050 mm.



Given: Shaft Basis System; Basic size of shaft = 20 mm; Minimum clearance = 0.100 mm; Tolerance on the hole = 0.025 mm; Tolerance on the shaft = 0.050 mm

Computation:

In the shaft basis system:

- ✓ Minm Clearance = Minm hole – Maxm shaft
- ✓ Maxm Clearance = Maxm hole – Minm shaft

✓ Upper deviation of shaft is zero(es = 0)

Maximum limit of the shaft = Basic size of the shaft = 20 mm

Minimum limit of the shaft = Maximum limit of the shaft - Tolerance on the shaft = Φ20.000-0.050 = Φ19.950 mm.

Minimum limit of the hole = Maximum limit of the shaft + Minimum clearance = Φ20.000+0.100 = Φ20.100 mm.

Maximum limit of the hole = Minimum limit of the hole + Tolerance on the hole = Φ20.100+0.025 = Φ20.125 mm.

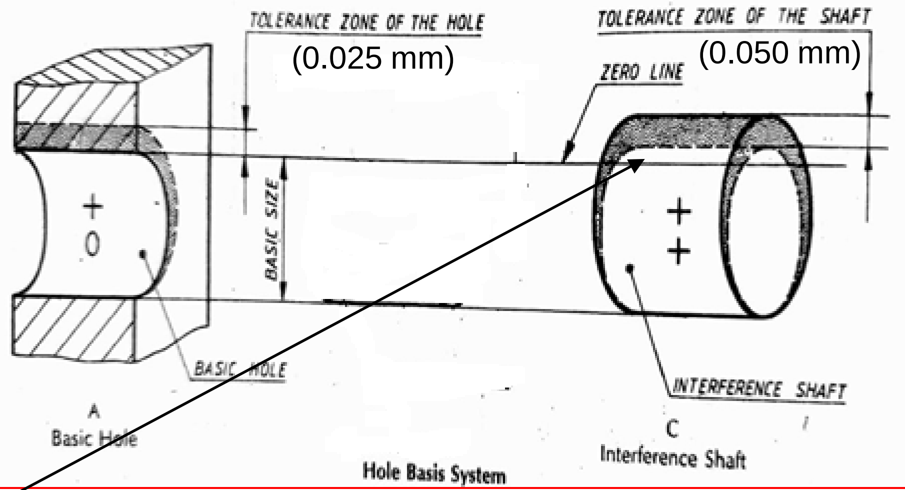
Thus,

Limits of the shaft are: $Shaft_{Minimum\ limit\ =\ \varphi 19.950\ mm}^{Maximum\ limit\ =\ \varphi 20.000\ mm}$

Limits of the hole are: $Hole_{Minimum\ limit\ =\ \varphi 20.100\ mm}^{Maximum\ limit\ =\ \varphi 20.125\ mm}$

Interference fit on hole basis system

Compute the limit dimensions for **interference fit** on the **hole basis system** for a basic size of 20 mm diameter with a negative clearance or maximum interference of 0.100 mm, tolerance on the hole 0.025 mm and tolerance on the shaft 0.050 mm.



Given: Hole Basis System; Basic size of hole = 20 mm; Negative clearance = -0.100 mm(Maximum interference); Tolerance on the hole = 0.025 mm; Tolerance on the shaft = 0.050 mm.

Computation:

- ✓ Maximum interference = Minm hole – Maxm shaft
- ✓ Minimum interference = Maxm hole – Minm shaft

- ✓ Lower deviation of hole is zero(EI = 0)

In the hole basis system:

Minimum limit of the hole = Basic size of the hole = 20 mm.

Maximum limit of the hole = Minimum limit of the hole + Tolerance on the hole = Φ20.000+0.025 = Φ20.025 mm.

Maximum limit of the shaft = Minimum limit of the hole – Maximum interference = Φ20.000- (-0.100) = Φ20.100 mm.

Minimum limit of the shaft = Maximum limit of the shaft – Tolerance on the shaft = Φ20.100-0.050 = Φ20.050 mm.

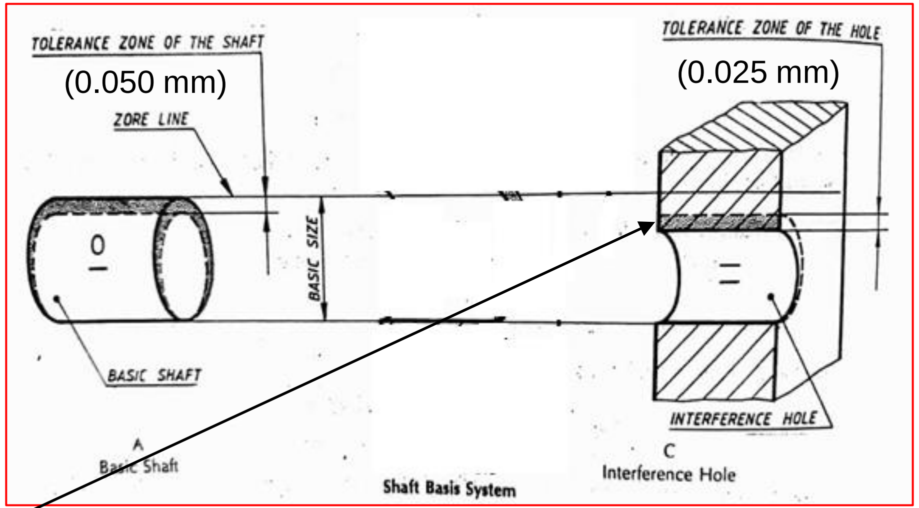
Thus,

Limits of the shaft are: $Shaft^{Maximum\ limit = \varphi 20.100\ mm}_{Minimum\ limit\ = \varphi 20.050\ mm}$

Limits of the hole are: $Hole^{Maximum\ limt = \varphi 20.025\ mm}_{Minimum\ limit = \varphi 20.000\ mm}$

Interference fit on shaft basis system

Compute the limit dimensions for **interference fit** on the **shaft basis system** for a basic size of 20 mm diameter with a negative clearance or maximum interference of 0.100 mm, tolerance on the hole 0.025 mm and tolerance on the shaft 0.050 mm.

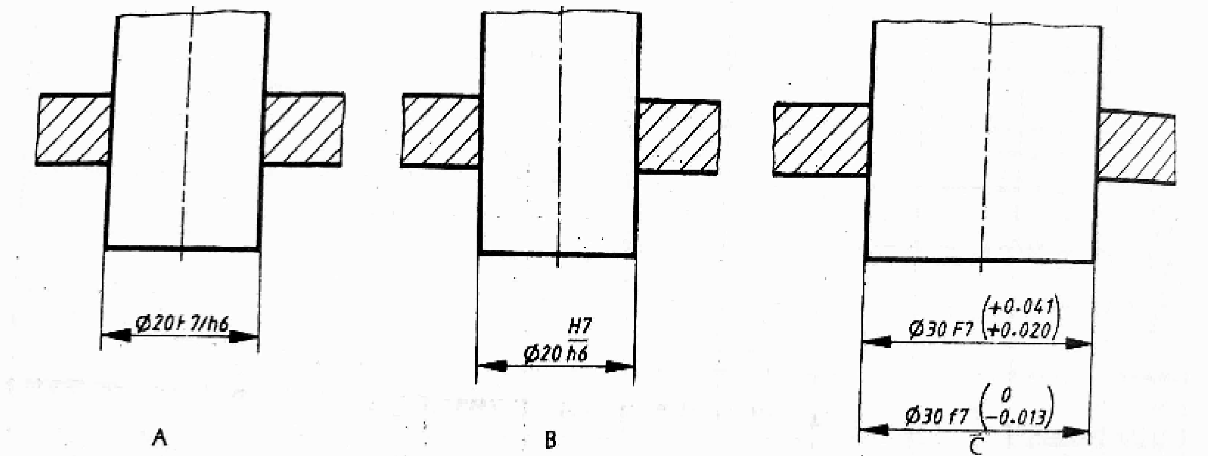


Given: Shaft Basis System; Basic size of shaft = 20 mm; Negative clearance = -0.100 mm(Maximum interference); Tolerance on the hole = 0.025 mm; Tolerance on the shaft = 0.050 mm

- ✓ Maximum interference = Minm hole – Maxm shaft
- ✓ Minimum interference = Maxm hole – Minm shaft

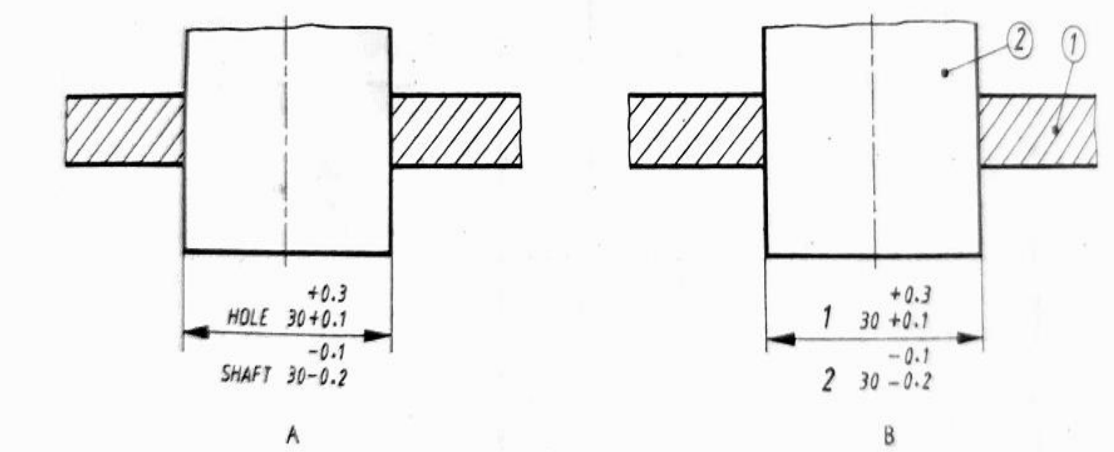
- ✓ Upper deviation of shaft is zero(es = 0)

METHODS OF INDICATING *FITS*



Indication of Fits by Letter and Grade Symbols

- ✓ Tolerance symbol of the hole must be placed before that of the shaft as in A.
- ✓ Tolerance symbol of the hole must be placed above that of the shaft as in B.
- ✓ When it is necessary to specify the numerical values of the deviations, they should be written in brackets as in C.



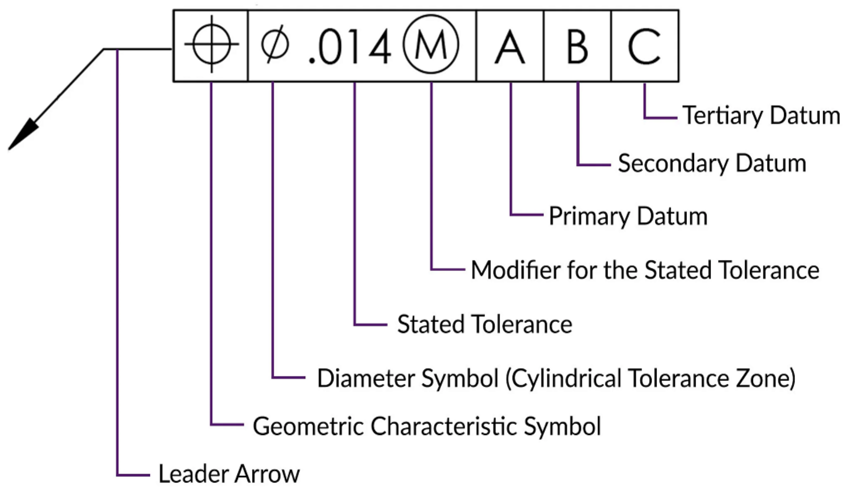
Indicating of fits by Numerical Values

- ✓ The dimensions of each of the components of the assembled parts should be preceded by the name as in A or item reference as in B.
- ✓ In both the cases, the dimension for the hole must be placed above that of the shaft.

Geometrical Tolerance

- ✓ The tolerances for the sizes, called linear tolerances, are specified only to ensure that the actual manufacturing sizes are well within the acceptable limits.
- ✓ A shaft may have its diameter well within the specified limits of size, but may not be truly circular.
- ✓ Similarly, a square slot may not have its surfaces exactly perpendicular or a hole may not have its center correctly located.
- ✓ Thus it necessitates to specify the permissible deviations not only for its sizes but also for the geometrical variations in the form of surfaces and the variations for their locations.
- ✓ The geometry variations are called **form variation** and the location variations are called **position variation**.
- ✓ Specifying of the permissible variations for both form and position using symbols and letters is called **geometrical tolerancing**.

Feature Control Frame



SYMBOL	GEOMETRIC CHARACTERISTIC	TOLERANCE TYPE	CONTROL SUMMARY
⏥	FLATNESS	FORM (NO RELATION BETWEEN FEATURES)	CONTROLS FORM (SHAPE) OF SURFACES AND CAN ALSO CONTROL FORM OF AN AXIS OR MEDIAN PLANE DATUM REFERENCE IS NOT ALLOWED
⏤	STRAIGHTNESS		
⌭	CYLINDRICITY		
○	CIRCULARITY (ROUNDNESS)		
⊥	PERPENDICULARITY	ORIENTATION (NO RELATION BETWEEN FEATURES)	CONTROLS ORIENTATION (TILT) OF SURFACES, AXES, OR MEDIAN PLANES FOR SIZE AND NON-SIZE FEATURES DATUM REFERENCE REQUIRED
//	PARALLELISM		
∠	ANGULARITY		
⌖	POSITION	LOCATION	LOCATES CENTER POINTS, AXES, AND MEDIAN PLANES FOR SIZE FEATURES ALSO CONTROLS ORIENTATION
⌓	PROFILE OF A SURFACE		LOCATES SURFACES ALSO CONTROLS SIZE, FORM, AND ORIENTATION OF SURFACES BASED ON DATUM REFERENCE
⌒	PROFILE OF A LINE		
⌰	TOTAL RUNOUT	RUNOUT	CONTROLS SURFACE COAXIALITY ALSO CONTROLS FORM AND ORIENTATION OF SURFACES
↗	CIRCULAR RUNOUT		
◎	CONCENTRICITY	LOCATION (DERIVED MEDIAN POINTS)	LOCATES DERIVED MEDIAN POINTS OF A FEATURE *NOT COMMON...CONSIDER USING POSITION, RUNOUT, OR PROFILE*
⌯	SYMMETRY		

UNIT 4

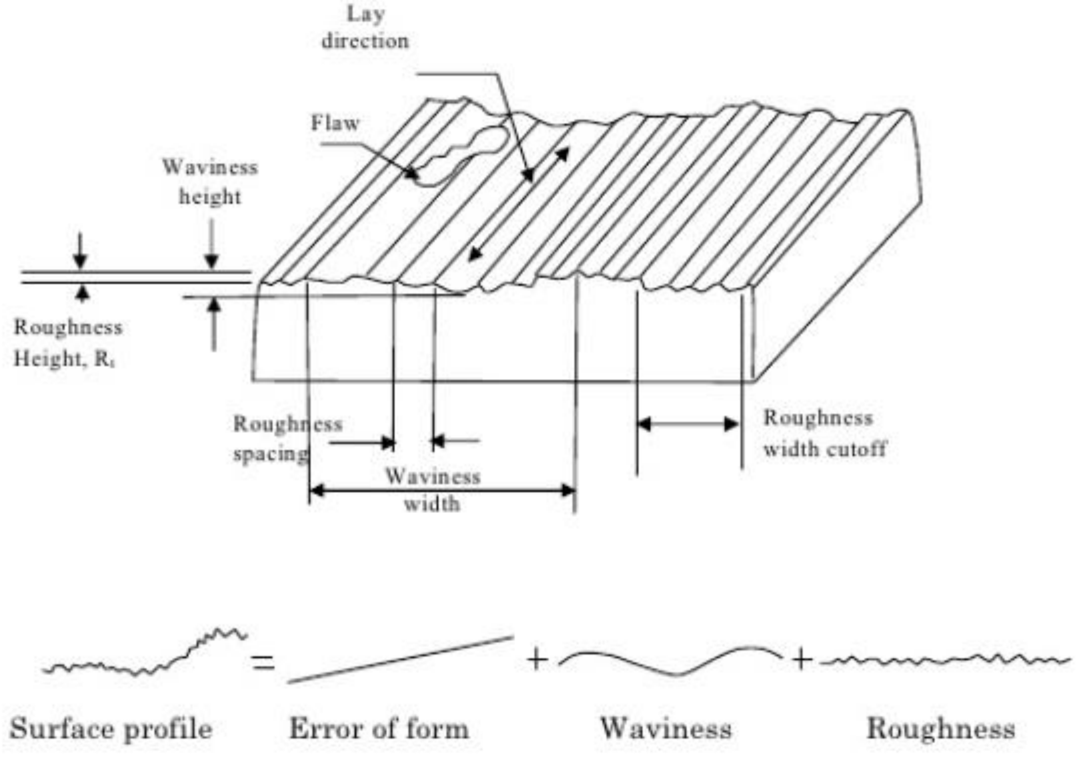
SURFACE TEXTURE

4. SURFACE TEXTURE

Nominal surface - Roughness - Waviness - Lay - Sampling length - Indication of surface roughness by roughness values, roughness grade number, roughness symbols - Indication of surface roughness by surface texture symbol with all the characteristics.

- ✓ **SURFACE TEXTURE** – It is defined as a degree of finish conveyed to the machinist by a system of symbols devised by a Standards Association, e.g., ASA – American Standards Association; BS – British Standards; BIS – Bureau of Indian Standards etc.,
- ✓ These symbols provide a standard system of determining and indicating surface finish.
- ✓ Unit for surface finish: micrometer(μm).
- ✓ Modern technology demands improved surface finish to ensure proper functioning and long life of machine parts.
- ✓ Piston, bearings, and gears depend to a great extent on a good surface finish for proper functioning.
- ✓ Finer finishes often require additional operation, such as *lapping* or *honing*.
- ✓ Higher or finer finishes result in *higher production costs*.
- ✓ Finer finishes are not always required on parts.
- ✓ To prevent over-finishing a part, the desired finish is indicated on the shop drawing.

SURFACE TEXTURE TERMS AND DEFINITIONS

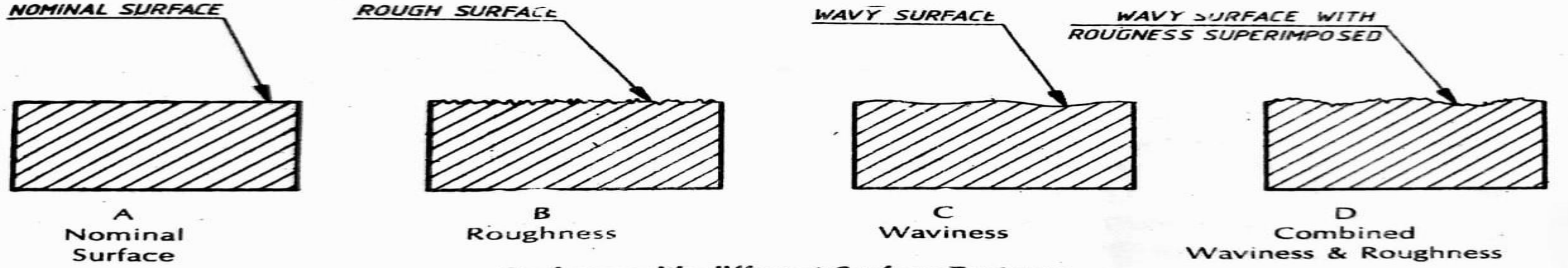


NOMINAL SURFACE (Fig. A)

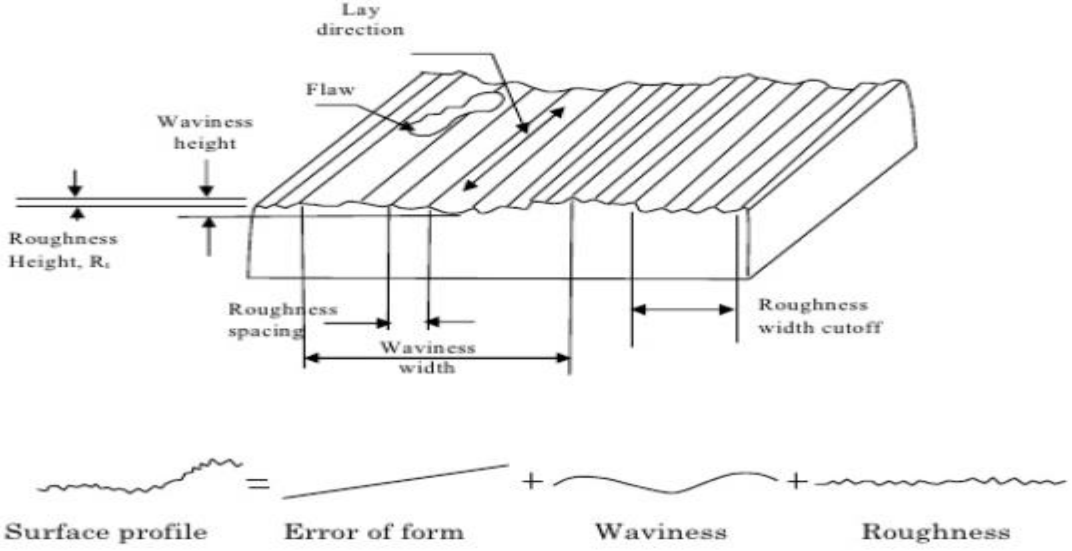
- ✓ The surface of an object is its exterior boundary.
- ✓ Nominal surface is a surface that has been finished by any one of the machining processes contains numerous small peaks and valleys that deviate from the geometrically perfect surface.

FLAWS

- ✓ Flaws or defects are random irregularities, such as scratches, cracks, holes, depression, seams, tears or inclusions.
- ✓ These defects can be caused during machining or production processes such as moulding, drawing, forging etc.,
- ✓ For eg., holes caused by air bubbles during casting, crack and tears by forging and drawing process.



Surfaces with different Surface Textures



LAY

- ✓ Lay or directionality, is the direction of predominant surface pattern caused by the machining process and it is usually visible to the naked eye.
- ✓ The direction of lay is determined by the production method employed.

ROUGHNESS (Fig. B)

- ✓ It is defined as the closely spaced, irregular deviation on a scale smaller than that of waviness.
- ✓ It is the micro irregularity of a surface produced by cutting tool or the abrasive grain action and the machine feed.
- ✓ Roughness may be superimposed on waviness.

ROUGHNESS HEIGHT

- ✓ Roughness height is the deviation to the centreline in *micrometres*.

ROUGHNESS WIDTH

- ✓ Roughness width is the distance between successive roughness peaks parallel to the nominal surface in *millimetres*.

WAVINESS (Fig. C)

- ✓ Waviness is a recurrent deviation from a flat surface much like the waves on the surface of water.
- ✓ It is the surface undulations of larger magnitudes.
- ✓ Waviness can be caused by:

  1. deflection of tools, dies or the work piece.
  2. force or temperature sufficient to cause warping
  3. uneven lubrication
  4. vibrations
  5. any periodic mechanical or thermal variations on the system during machining operations.

SAMPLING OR CUT-OFF LENGTH

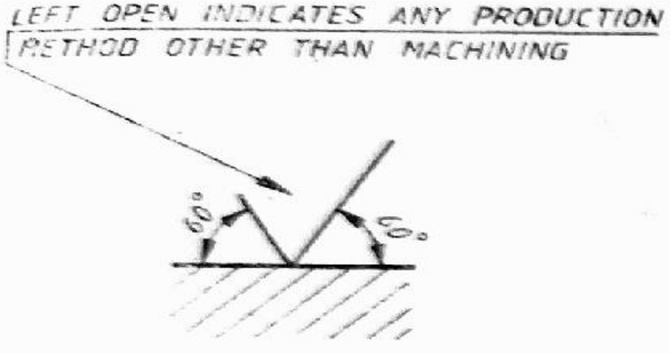
- ✓ It is a particular length of the profile decided for the evaluation of the surface irregularities on any chosen portion of the machined surface.
- ✓ The sampling length is selected depending upon the type of machining process.
- ✓ It is recommended to choose smaller value for the finer grade and the larger value for the coarser grade for a given machining process when more than one values are given.

Sampling Length for Different Manufacturing Processes

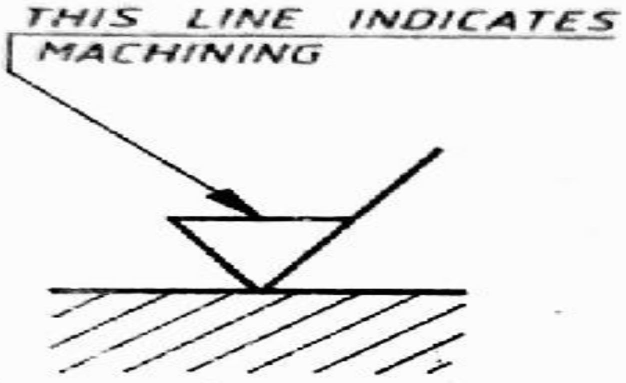
All Dimensions in mm

Type of Surfaces	Manufacturing Process	Sampling Lengths					
Machined Surfaces	Milling	....	0.8	2.5	8	10	....
	Boring	....	0.8	2.5	8	10	....
	Turning	....	0.8	2.5	....	....	....
	Grinding	0.25	0.8	2.5	....	....	....
	Planing	....	....	2.5	8	10	25
	Shaping	....	0.8	2.5	8	10	....
	Reaming	....	0.8	2.5	....	....	....
	Broaching	....	0.8	....	....	....	....
	Diamond Boring	0.25	0.8	....	....	....	....
	Diamond Turning	0.25	0.8	....	....	....	....
	Honing	0.25	0.8	....	....	....	....
	Lapping	0.25	0.8	....	....	....	....
	Super-finishing	0.25	0.8	....	....	....	....
	Buffing	....	0.8	2.5	....	....	....
	Polishing	....	0.8	2.5	....	....	....
	Spark Machining	....	0.8	....	....	....	....
Non-Machined Surfaces	Burnishing	....	0.8	2.5	....	....	....
	Drawing	....	0.8	2.5	....	....	....
	Extrusion	....	0.8	2.5	....	....	....
	Moulding	....	0.8	2.5	....	....	....
	Electro Polishing	....	0.8	2.5	....	....	....

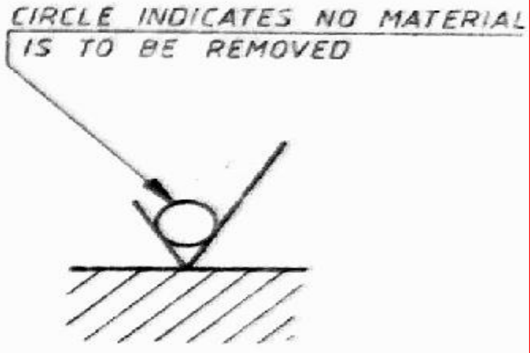
SYMBOLS FOR INDICATING SURFACE TEXTURE



A
Basic symbol for Surface Texture by any Production Process other than Machining

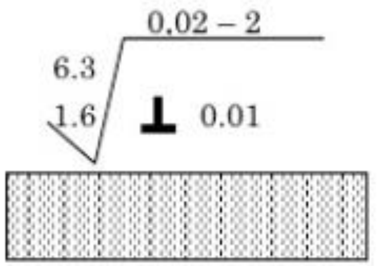


B
Symbol for Surface Texture By Machining Process



C
Symbol for Surface Texture without the Removal of Material

STANDARD SYMBOLS TO DESCRIBE SURFACE TEXTURE/FINISH



A sample of a surface texture/finish designation

Symbols' definition:

0.02	–	Maximum waviness height (mm)
2	-	Maximum waviness width (mm)
6.3	-	Maximum roughness height (μm)
1.6	-	Minimum roughness height (μm)
0.01	-	Maximum roughness width (mm)
⊥	-	Lay symbol (Lay perpendicular to the line representing the surface to which the symbol is applied)

✓ Sometimes, the roughness number is used as a substitute for the roughness value, for eg., N7 is equal to 1.6 μm.

✓ The surface roughness may be indicated in the basis symbol by

1. **Roughness value in micrometre**
2. **Roughness grade numbers**
3. **Triangle symbol**

BIS recommends the first two types for indicating the surface roughness.

Roughness number and value

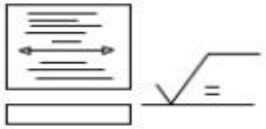
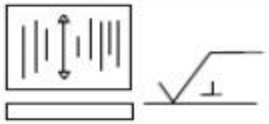
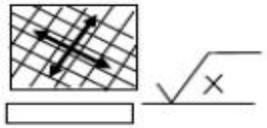
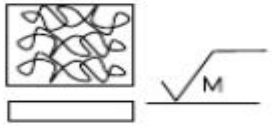
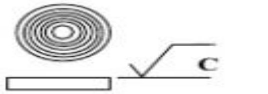
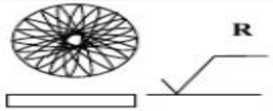
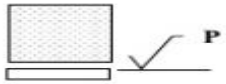
μm	50	25	12.5	6.3	3.2	1.6	0.8	0.4	0.2	0.1	0.05	0.025
Roughness number	N12	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1

Average surface roughness produced by standard machining processes

PROCESS	MICROINCHES	MICROMETERS
Turning	100 - 250	2.5 - 6.3
Drilling	100 - 200	2.5 - 5.1
Reaming	50 - 150	1.3 - 3.8
Grinding	20 - 100	0.5 - 2.5
Honing	5 - 20	0.13 - 0.5
Lapping	1 - 10	0.025 - 0.254

SYMBOLS FOR SURFACE ROUGHNESS

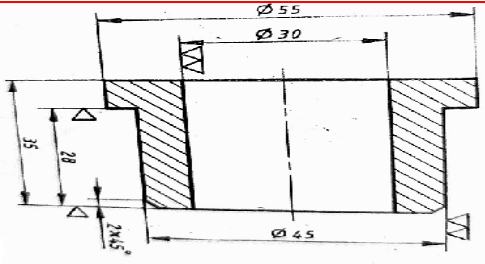
The following symbols indicate the direction of the lay

Lay Symbol	Interpretation	Examples
=	Lay parallel to the line representing the surface to which the symbol is applied	
⊥	Lay perpendicular to the line representing the surface to which the symbol is applied.	
X	Lay angular and both direction to line representing the surface to which symbol is applied	
M	Lay multidirectional	
C	Lay approximately circular relative to the centre of the surface to which the symbol is applied	
R	Lay approximately radial relative to the centre of the surface to which the symbol is applied	
P	Pitted, protuberant, porous, or particulate non-directional lay	

Standard lay symbols for engineering surfaces

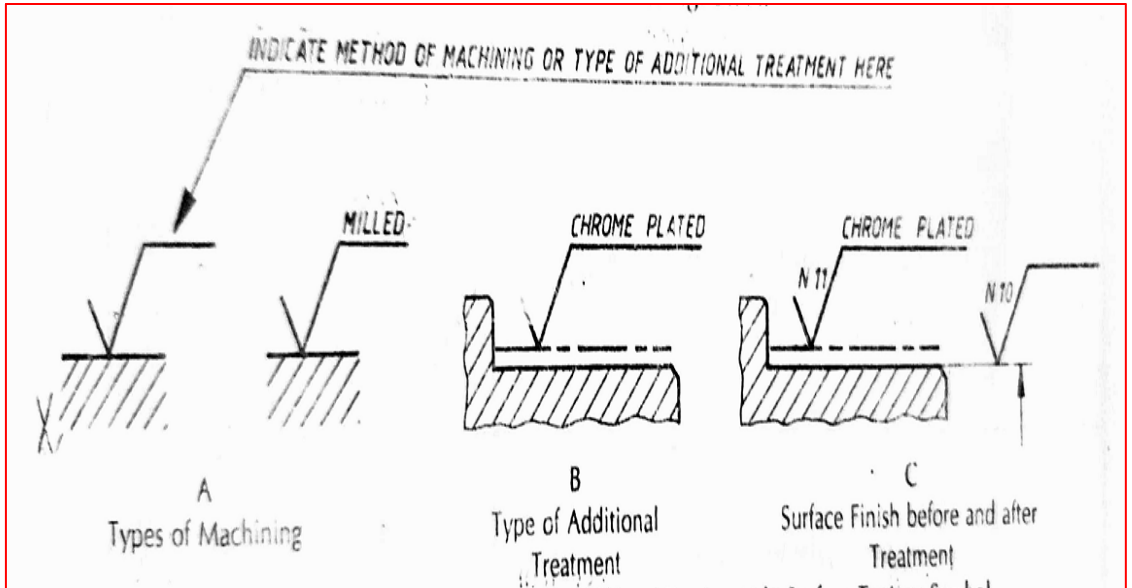
Surface Roughness, Value Grades and Symbols

Roughness Values Ra µm	Roughness Grade Number	Roughness Symbols
50	N 12	∼
25 12.5	N11 N10	▽
6.3 3.2 1.6	N9 N8 N7	▽▽
0.8 0.4 0.2	N6 N5 N4	▽▽▽
0.1 0.05 0,025	N3 N2 N1	▽▽▽▽



~ Unless Othewise Specified

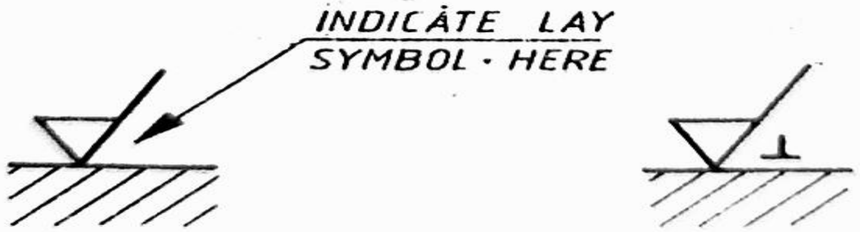
Indication of Surface Roughness by Symbol



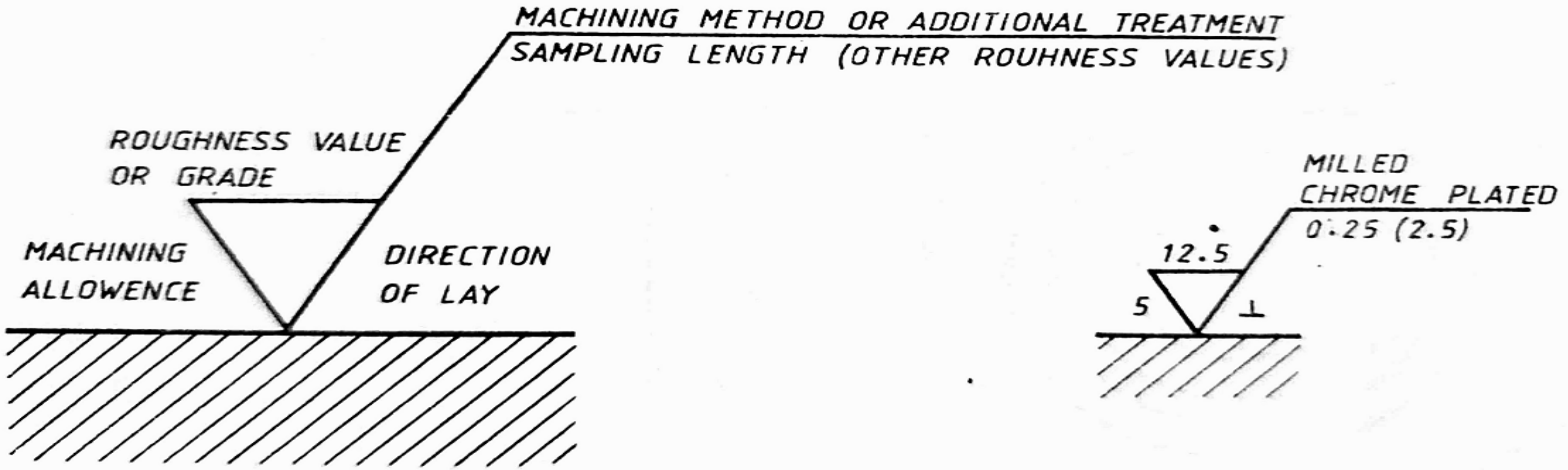
Indication of Type of Machining and Additional Treatment in Surface Texture Symbol

Indication of Sampling Length

Fig 8.8



Indication of Lay



Surface Texture with all the Characteristics

UNIT 5

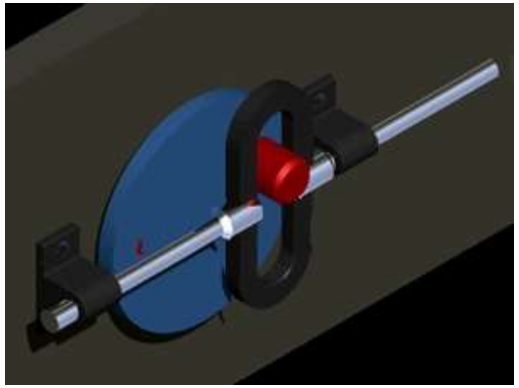
THREADED FASTENERS AND ITS APPLICATIONS

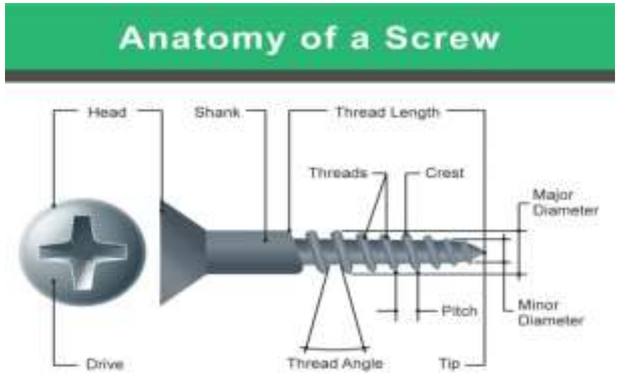
5. THREADED FASTENERS AND ITS APPLICATIONS

Screw thread terminology - Basic forms of screw threads - Standard forms of V threads - Basic form of square threads -Modified forms of square threads - Basic knuckle thread - Standard form of knuckle thread Conventional representation of internal V thread and external V thread - Square thread - Designation of threads - Empirical proportions of hexagon and square head bolt and nut.

Screw

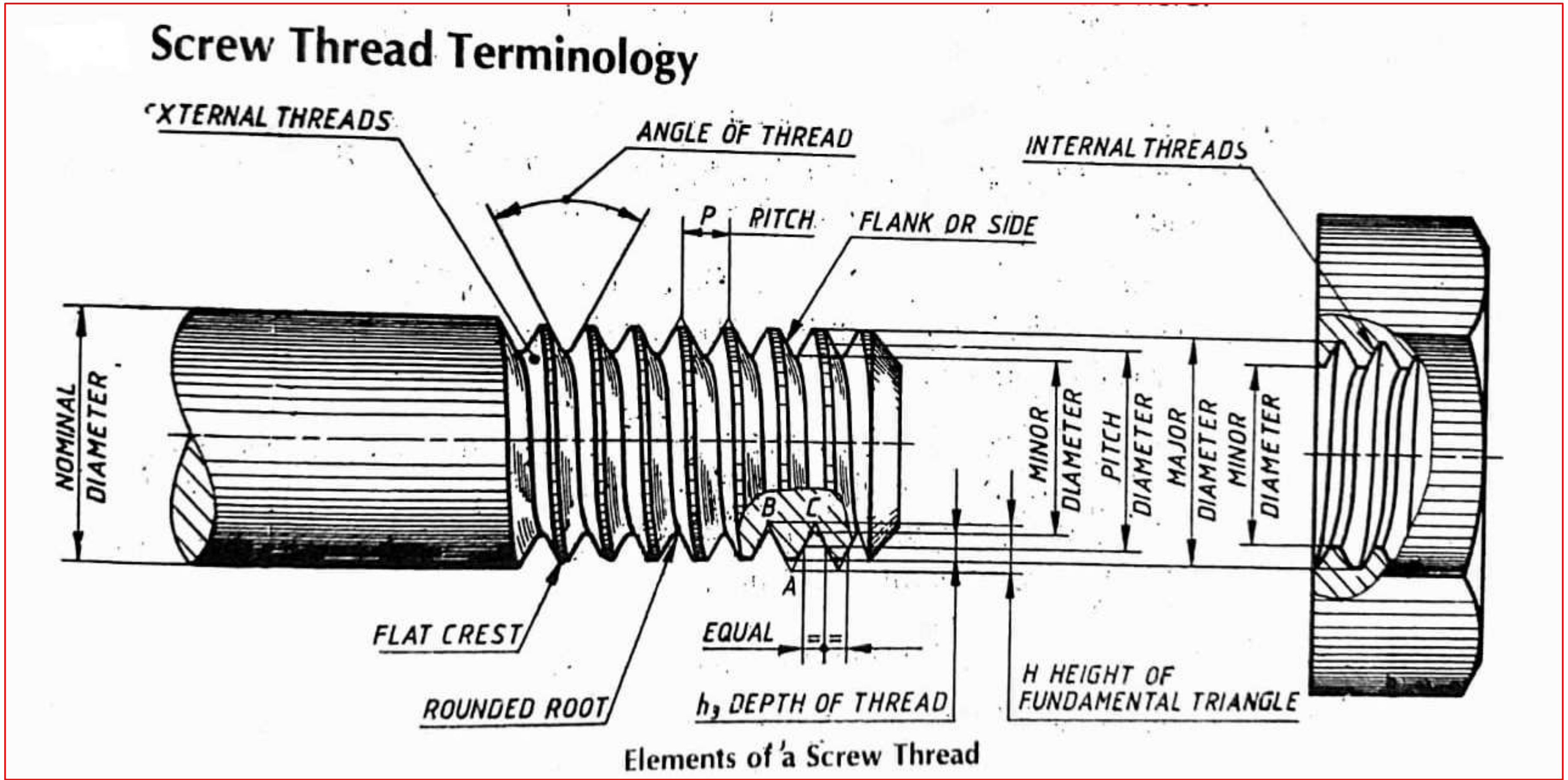
- ✓ Screw is a cylindrical rod with a helical groove cut on it.
- ✓ Screw transforms the input motion of rotation into output motion of translation.





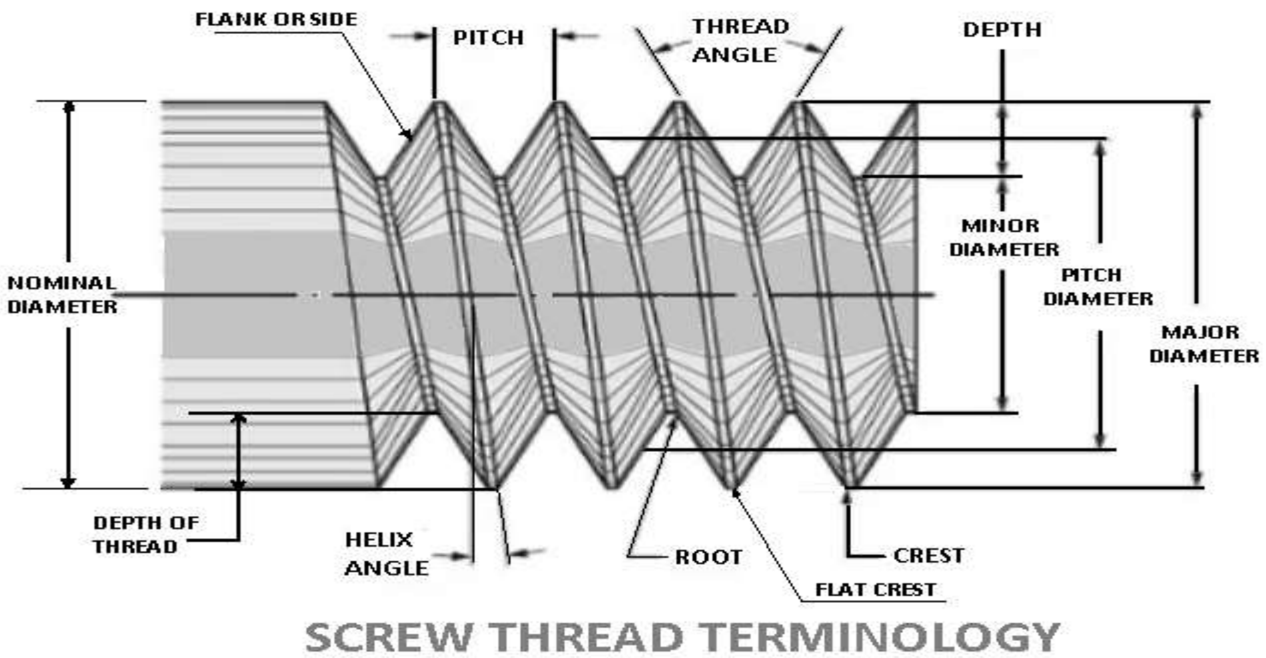
- ✓ Screw thread is a temporary fastener.
- ✓ A screw thread is a continuous helical ridge formed by cutting a helical groove on a cylindrical or conical shank.

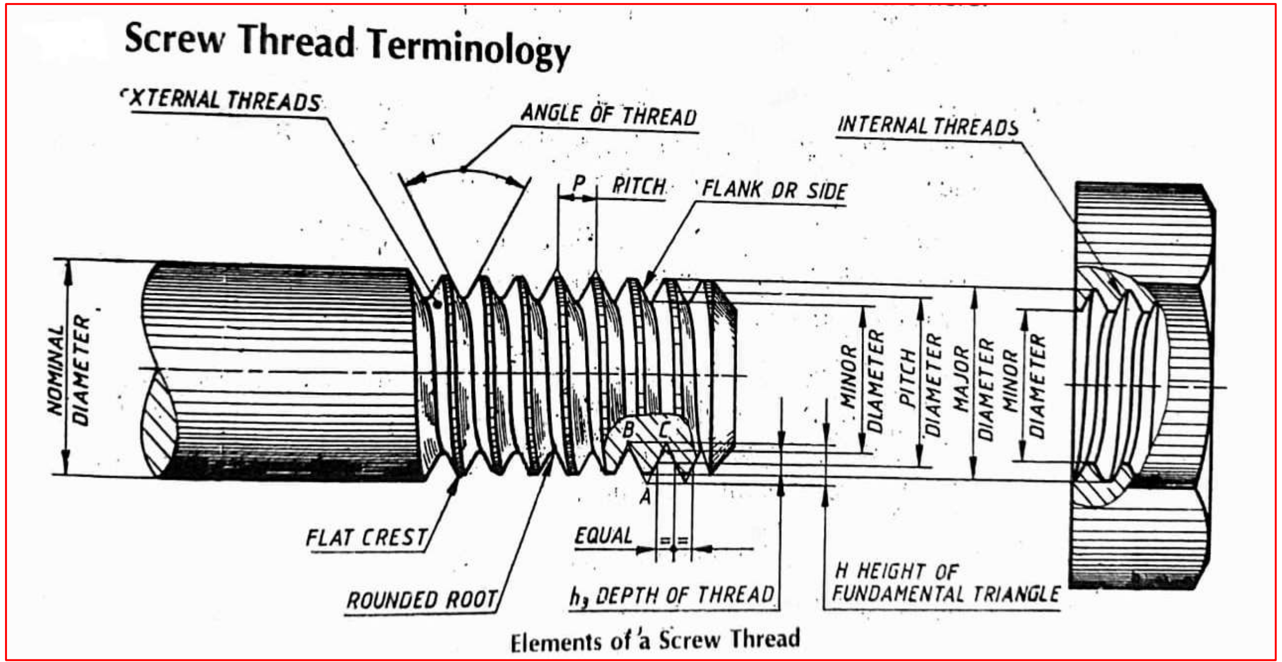
- ✓ Screw threads are used
  1. to fasten the parts together.
  2. to transmit motion and power.
- ✓ To perform the above functions, threads of different profiles are used.



- ✓ External thread is the thread cut on the outer surface of rod.
- ✓ Internal thread is the thread cut on the inner surface of a hole.

- ✓ Root – It is the bottom portion of the surface of a thread, either flat or rounded which joins the sides of the adjacent threads.
- ✓ Crest – It is the top portion of the surface of a thread, either flat or rounded which joins the sides of the same thread.
- ✓ Flank or side – It is the surface of a thread that connects the crest with the root and also it offers the surface contact with its counterpart.
- ✓ Angle of the thread – It is the angle included between the sides of the two adjacent threads.
- ✓ Depth of the thread – It is the distance between the crest and the root of a thread which is measured normal to the axis. It is designated as h_3.





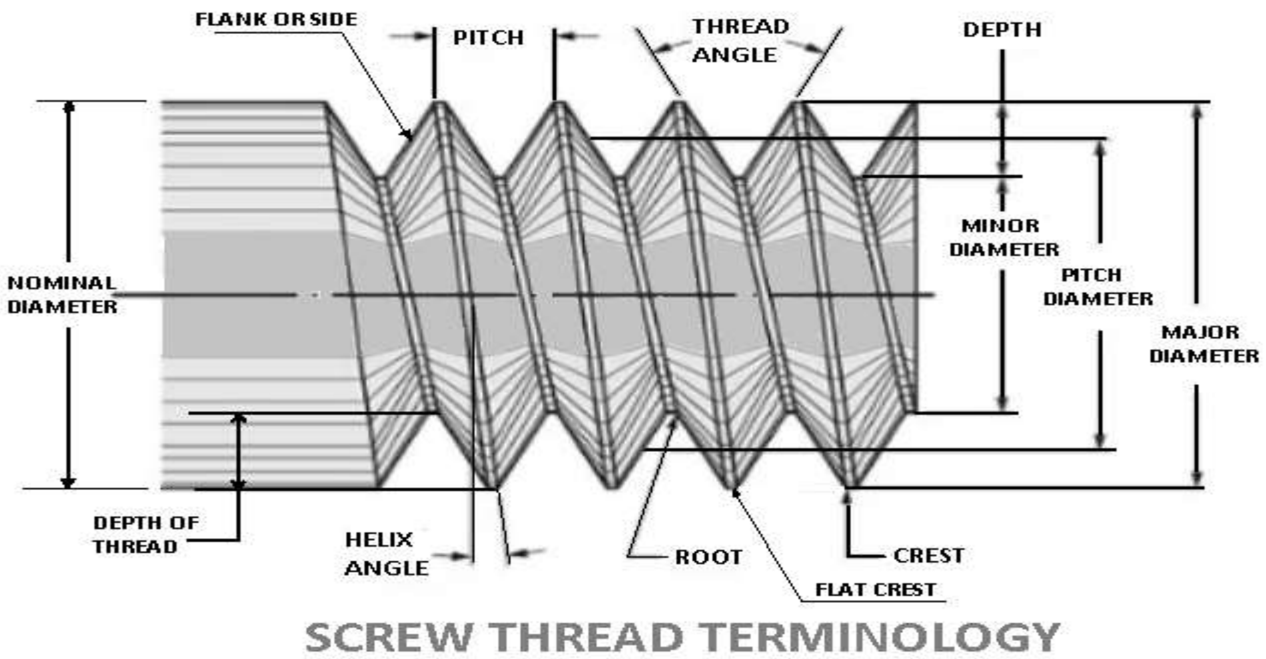
- ✓ Nominal diameter – It is the diameter of the cylindrical rod on which the threads are cut. **This diameter specifies the size of the screw.**
- ✓ Major diameter – It is the diameter of an imaginary coaxial cylinder which bounds the **crests of an external thread** or **the roots of an internal thread**.

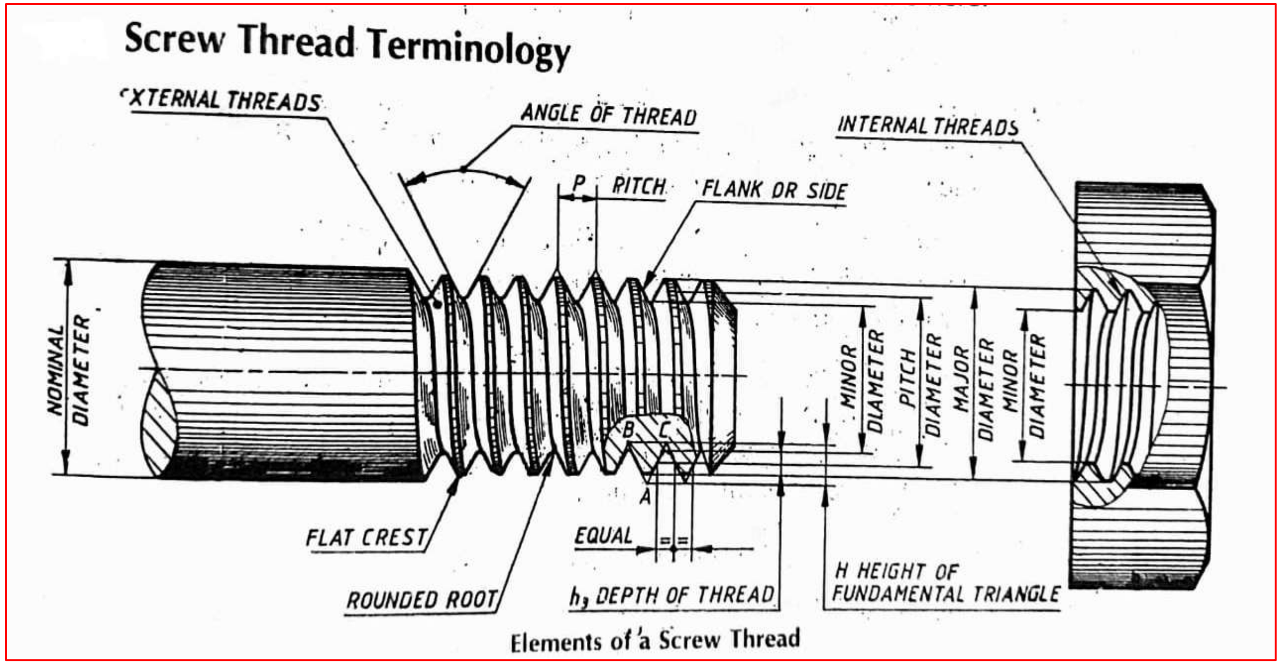
  D – Major diameter of internal thread.

  d – Major diameter of external thread.
- ✓ Minor or core or root diameter - It is the diameter of an imaginary coaxial cylinder which bounds the **roots of an external thread** or **the crests of an internal thread**.

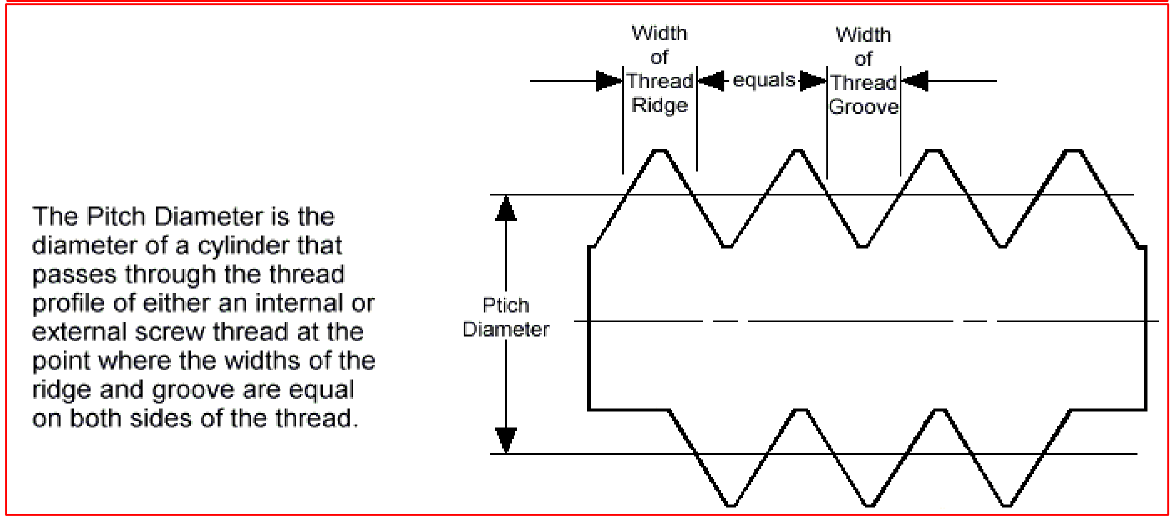
  D_l – Minor diameter of internal thread.

  d_3 – Minor diameter of external thread.

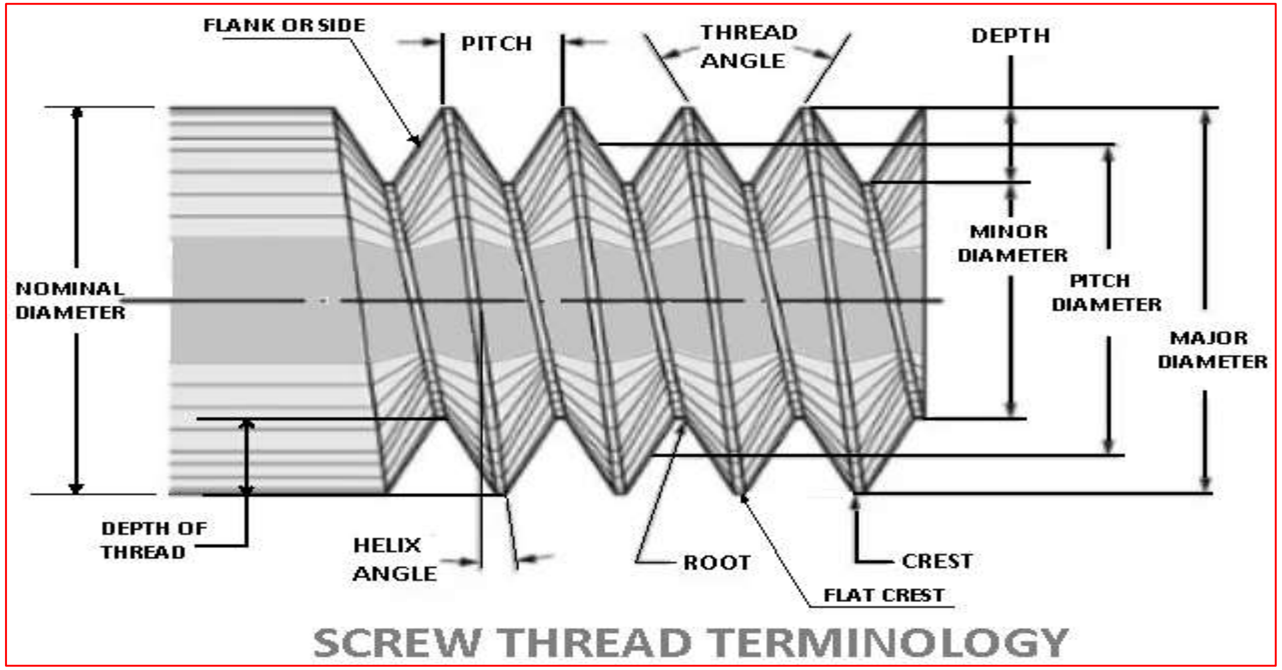


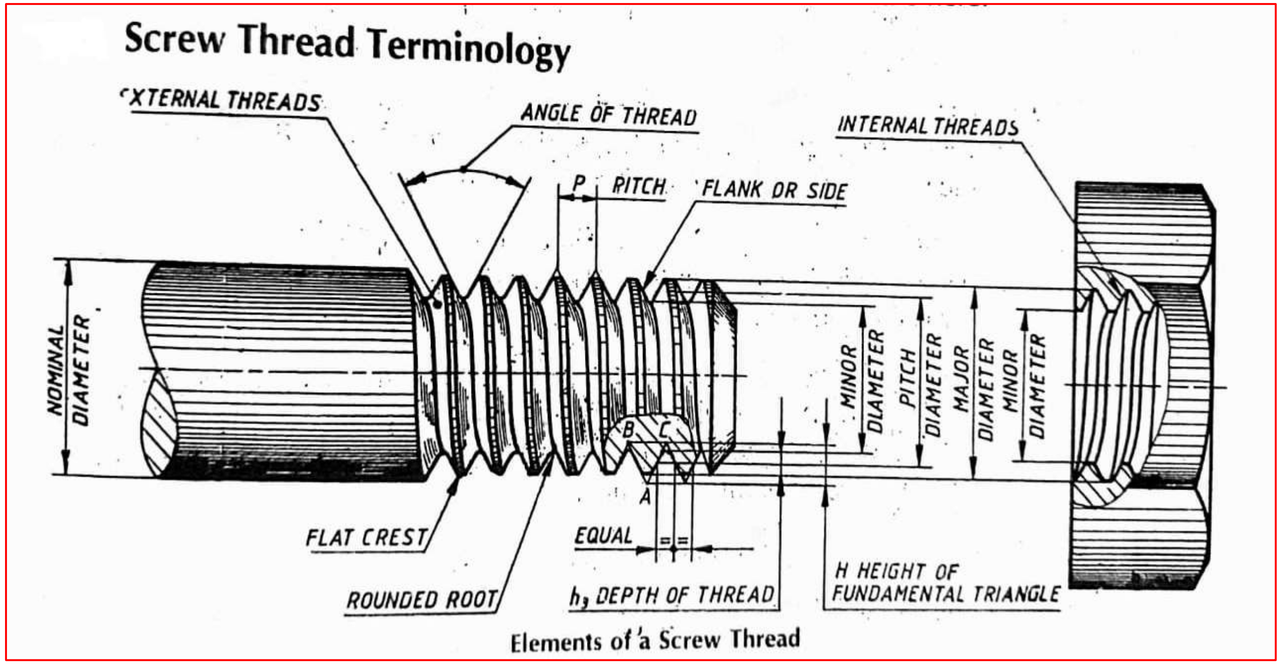


- ✓ Pitch Diameter - It is the diameter of the thread at which an imaginary coaxial cylinder that can be passed so as to cut the thread so that the width of the cut thread will be equal to the width of the groove.



- ✓ Height of the fundamental triangle, H – The imaginary equilateral triangle, ABC, which bounds a V-thread.





✓ Pitch – It is the distance from a point on a screw thread to a corresponding point on the next thread, measured parallel to the axis.

It may be indicated as the distance from crest to crest or from root to root, **but the former is the convention**.

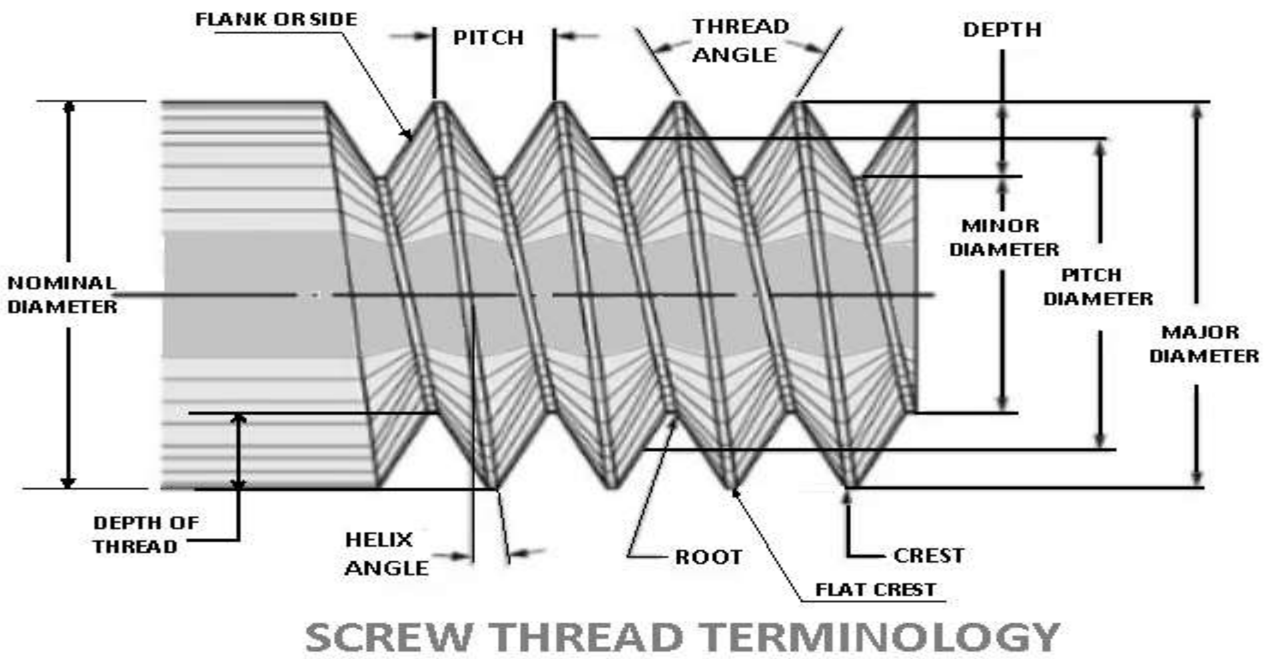
✓ Lead – It is the axial distance advanced by a nut for its one full turn over a threaded rod.

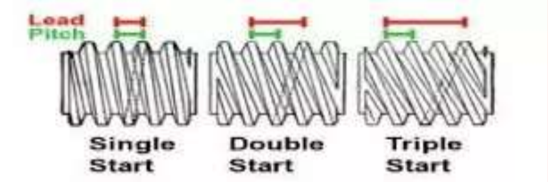
For single start thread: Lead = pitch

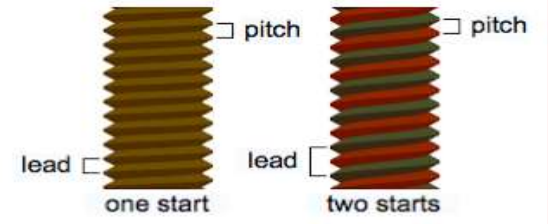
For double start thread: Lead = 2 x pitch

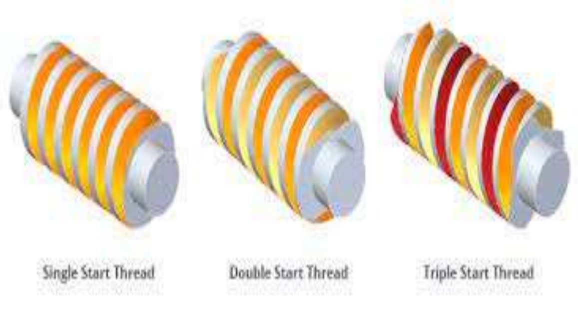
For triple start thread: Lead = 3 x pitch

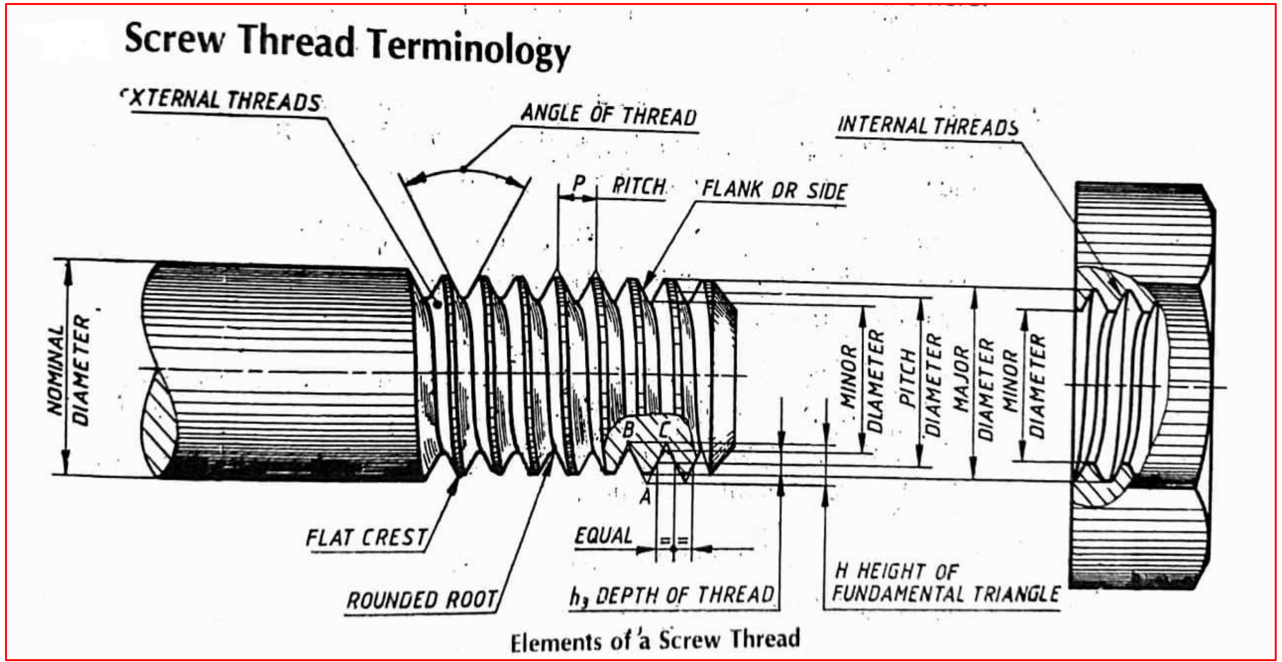
✓ Also, Lead = no of starts x pitch











BASIC PROFILES OF SCREW THREADS

Fastening Device

- Triangular profile known as V thread

Power Transmission Element

- Square thread

Basic Forms of V Threads

1. Whitworth Thread – British Standard
2. Sellers Thread – Earlier American Standard
3. Unified Thread – ISO Thread – Indian Standard

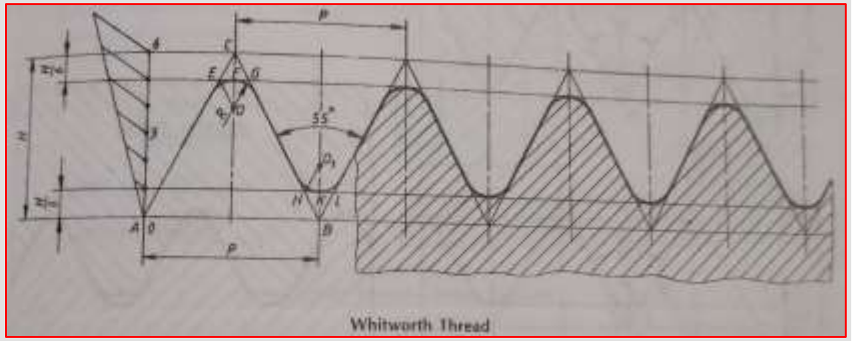
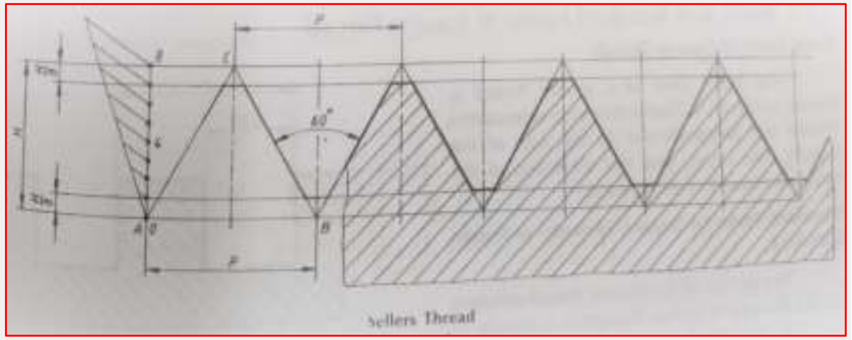
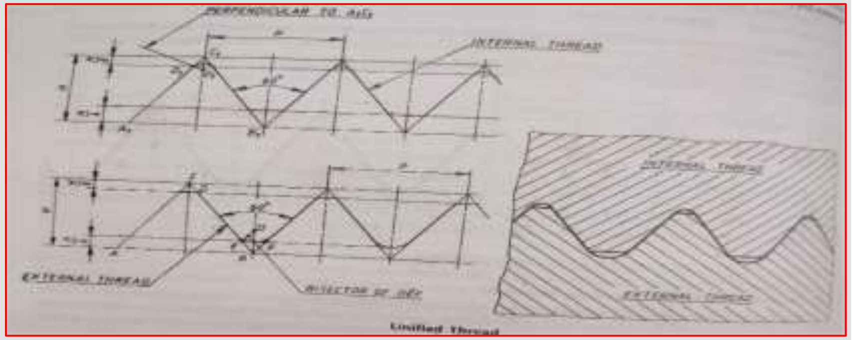
Basic Form of Square Thread

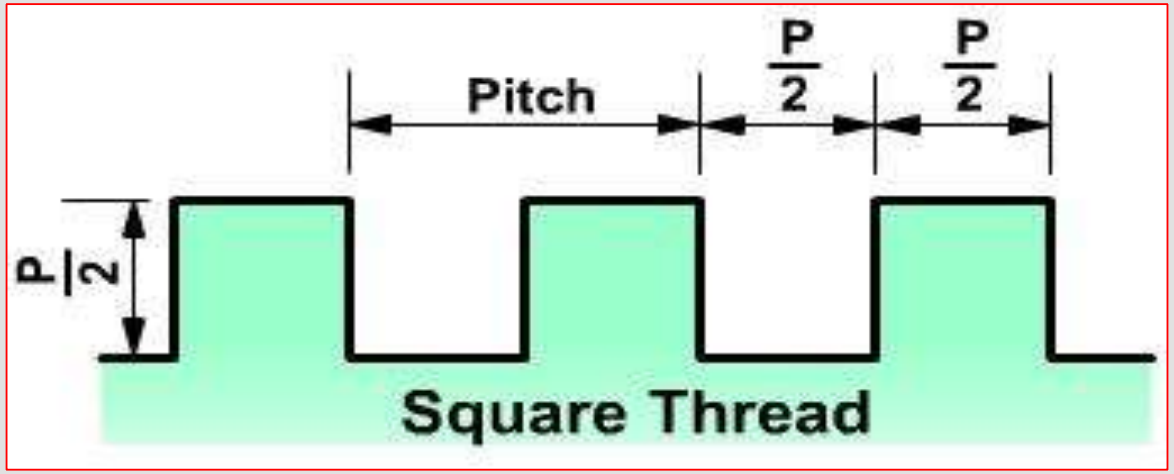
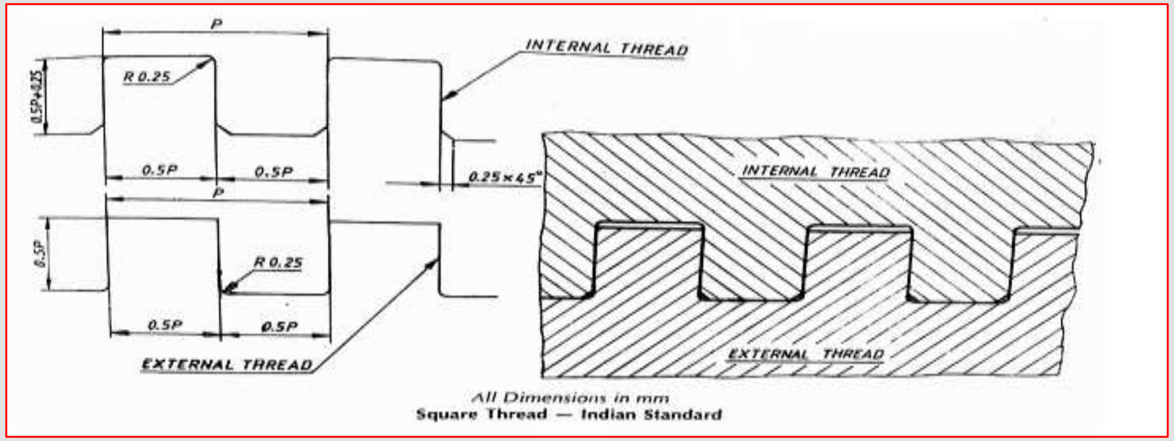
Indian Standard

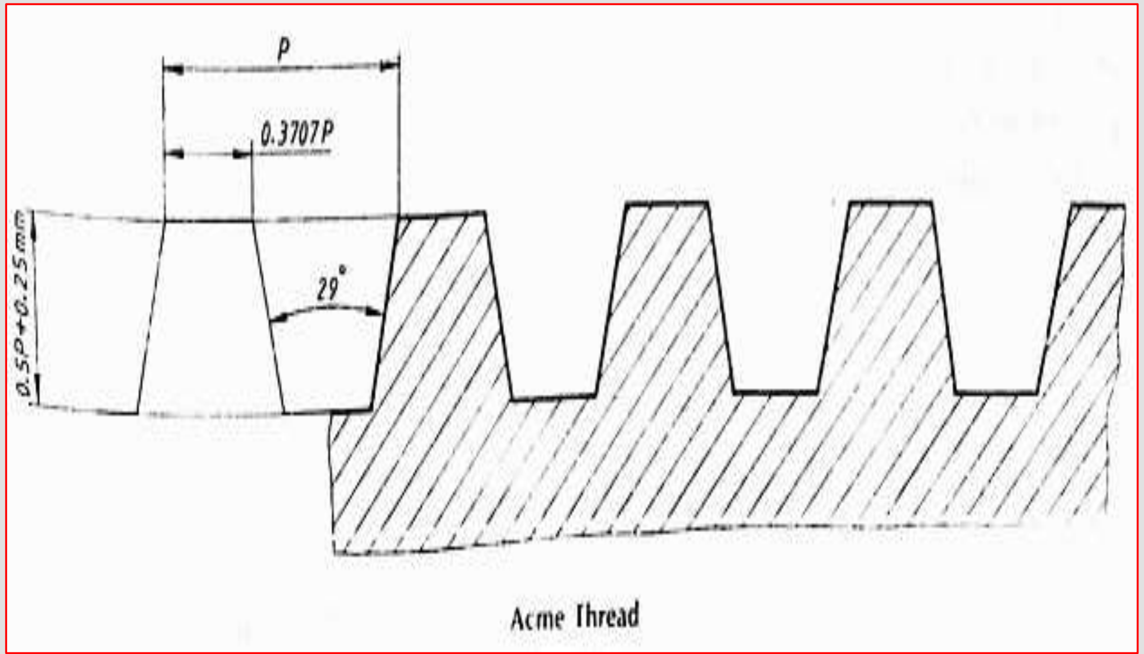
Modified Forms of Square Threads

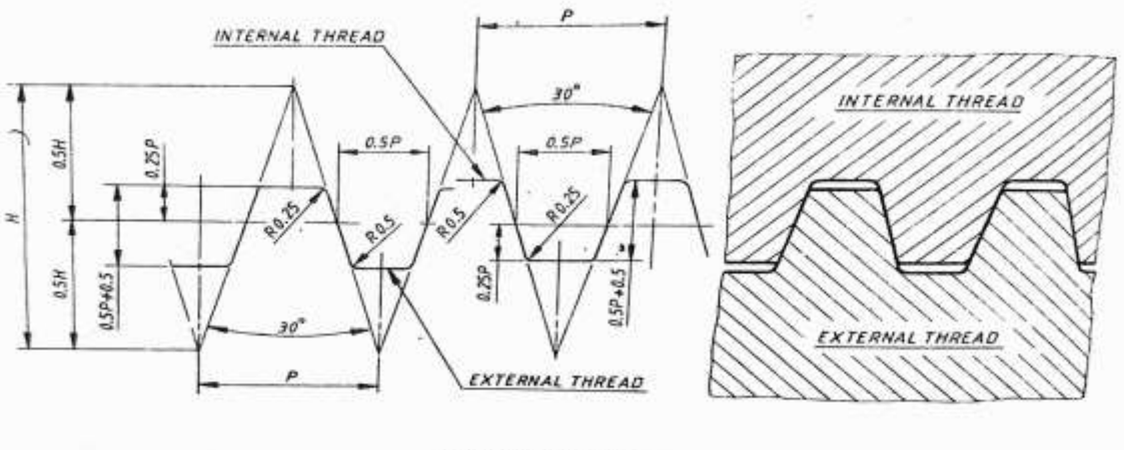
1. ACME Thread
2. Traphezoidal Thread – Indian Standard substitute for ACME Thread
3. Buttress Thread
4. Saw Tooth Thread - Indian Standard substitute for Buttress Thread
5. Basic Knuckle Thread

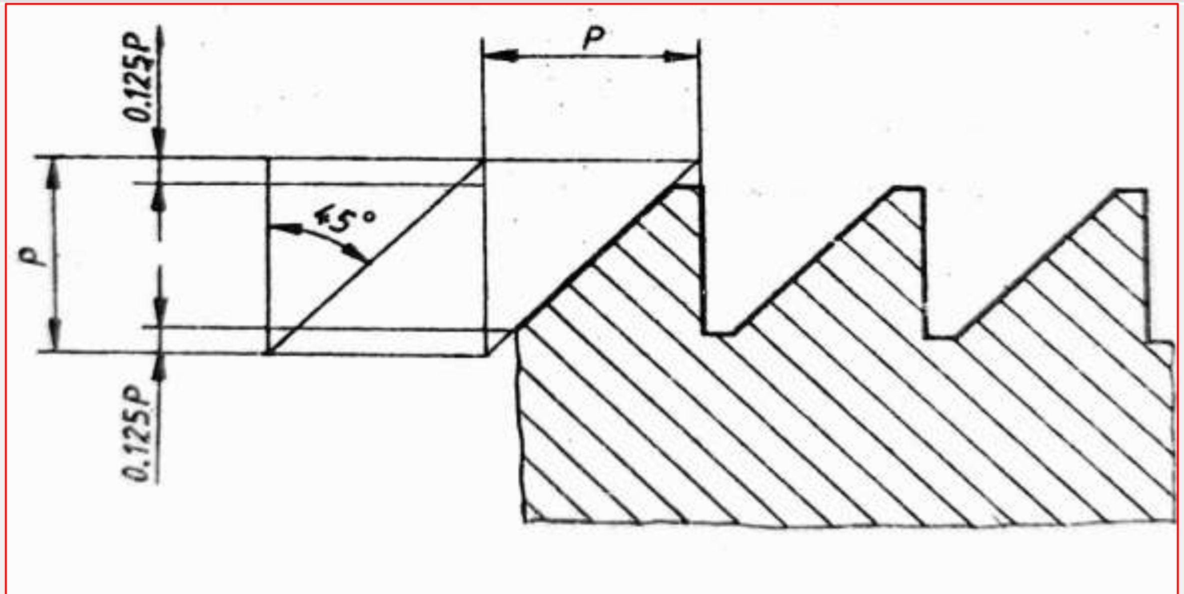
   Standard Form of Knuckle Thread

Basic Profile	Basic Forms	Abbreviation	Thread Angle	
	Whitworth Thread – British Standard	BSW	55º	
V Thread	Sellers Thread – Earlier American Standard		60º	
	Unified Thread – ISO Thread – Indian Standard		60º	

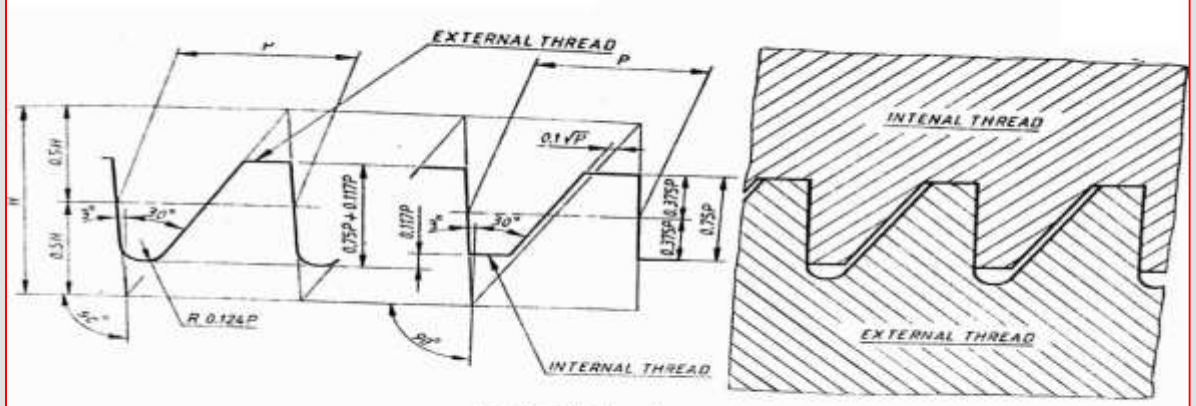
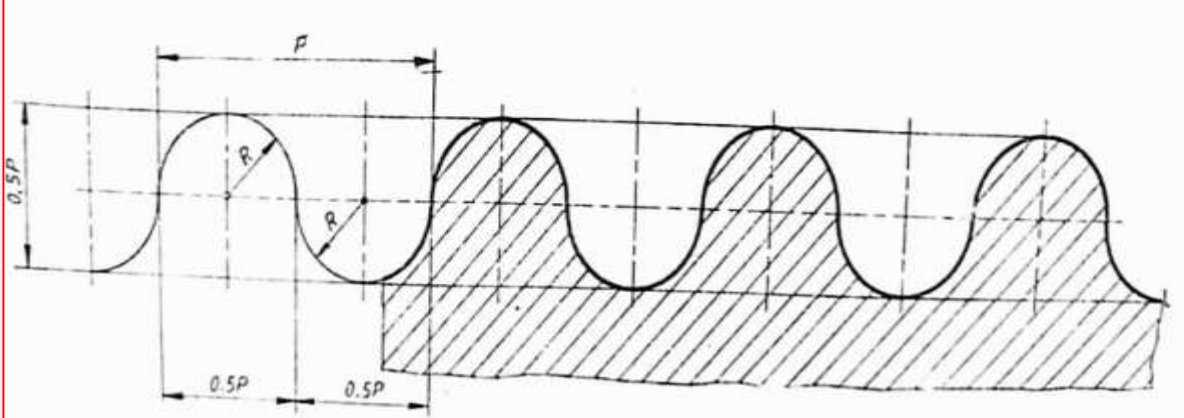
Basic Profile	Basic Forms	Thread Angle	
Basic Form of Square Thread	✓ Indian Standard ✓ The flank or the sides of the this thread are perpendicular to the axis of the thread. ✓ The **depth** and **thickness** of the thread is **equal to half the pitch.** ✓ Depth of internal thread = 0.5P + 0.25 mm	90º	 

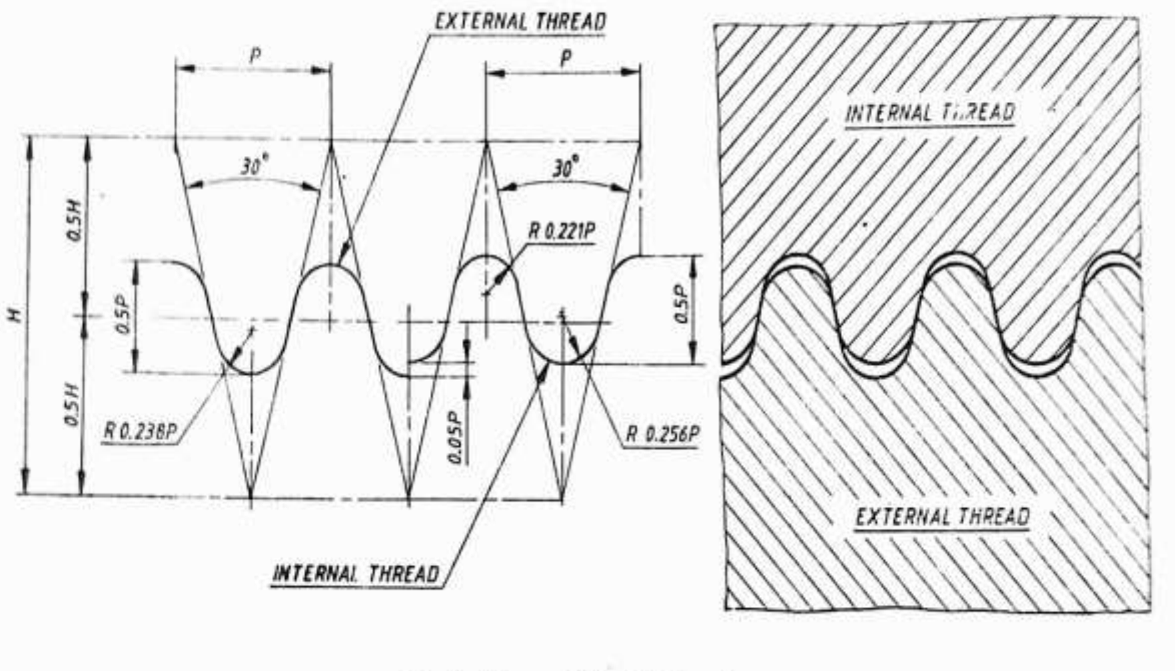
Basic Profile	Basic Forms	Thread Angle	
Modified Forms of Square Threads	✓ ACME Thread - Unlike the square thread it is easier to cut and is stronger at the root. - The inclined sides of the thread facilitate quick and easy engagement and disengagement (Eg., split nut of the lead screw of lathe). **Application:** Power screws like brake screws, jack screws and on the valve operating screws for axial power transmission.	29º	

<table>
<tr><th>Basic Profile</th><th>Basic Forms</th><th>Thread Angle</th><th></th></tr>
<tr><td rowspan="2">Modified Forms of Square Threads</td><td>✓ Trapezoidal Thread
✓ Indian standard substitute for ACME Thread
✓ Trapezoidal Thread is designated as: Tr 40 x 7
40 – Nominal Diameter
7 – Pitch</td><td>30º</td><td>

All Dimensions in mm
Trapezoidal Thread</td></tr>
<tr><td>✓ Buttress Thread
- Combination of square and V threads, combining the advantages of the square thread like ability to transmit power and low frictional resistance with the strength of the V thread.
Application: For transmitting unidirectional load in screw press,</td><td>45º
vices and breech locks of guns to resist the recoil.</td><td>

Buttress Thread</td></tr>
</table>

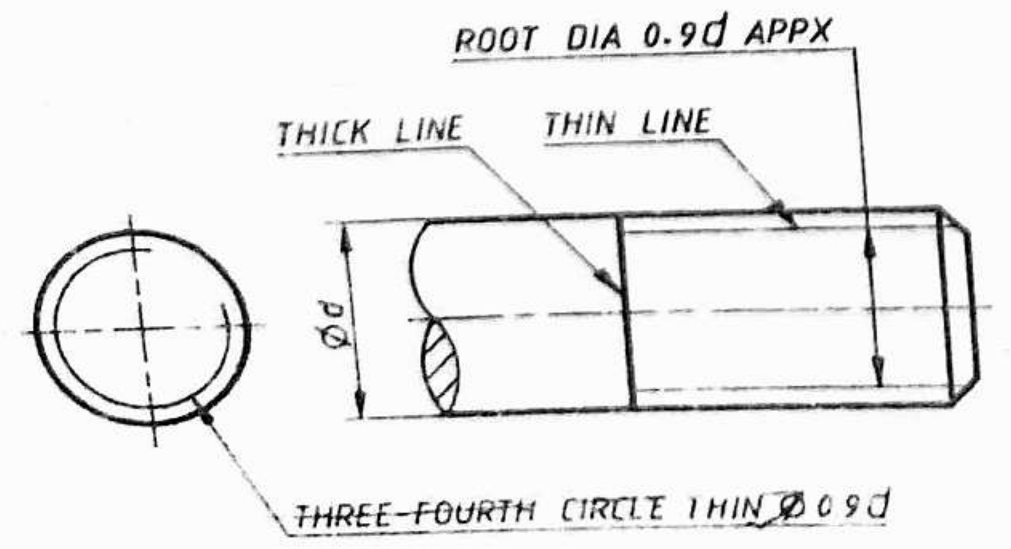
Basic Profile	Basic Forms	Thread Angle	
Modified Forms of Square Threads	✓ Saw Tooth Thread ✓ Indian standard substitute for Buttress Thread. ✓ ISO thread profile adopted by BIS in preference to Buttress thread.	30º	 Saw Tooth Thread
	✓ Basic Knuckle Thread ✓ Sharp corners of the square thread which are liable for damage are rounded off. **Advantage:** It can be rolled in a sheet metal or cast so as to have shallow depths which makes its use on electric bulbs and sockets, bottle tops, etc., **Application:** Used where heavy wear and rough use is expected as in railway carriage for coupling screw.		 Basic Knuckle Thread

Basic Profile	Basic Forms	Thread Angle	
Modified Forms of Square Threads	✓ Standard Form of Knuckle Thread ✓ ISO thread profile adopted by BIS in preference to the basic knuckle thread. ✓ Knuckle Thread is designated as: K 10 x 2.54 10 – Nominal Diameter 2.54 – Pitch	30º	

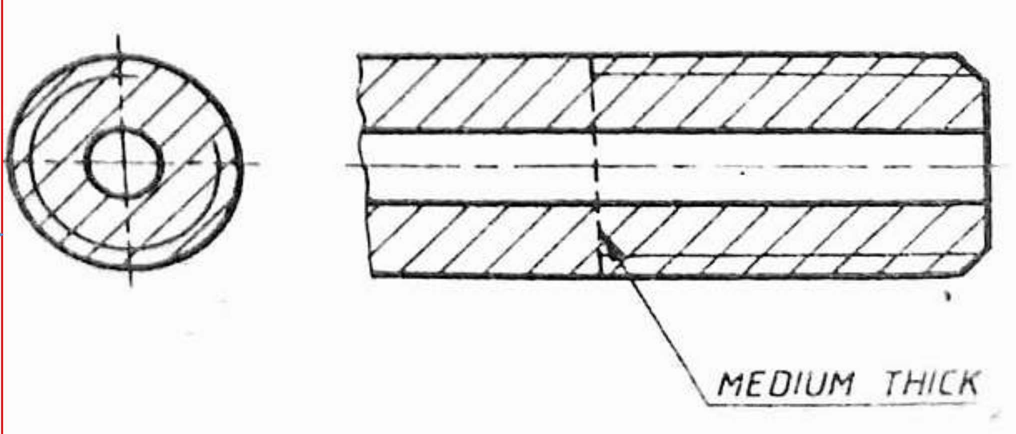
Standard Form of Knuckle Thread

CONVENTIONAL REPRESENTATION OF V PROFILE THREADS – EXTERNAL THREAD

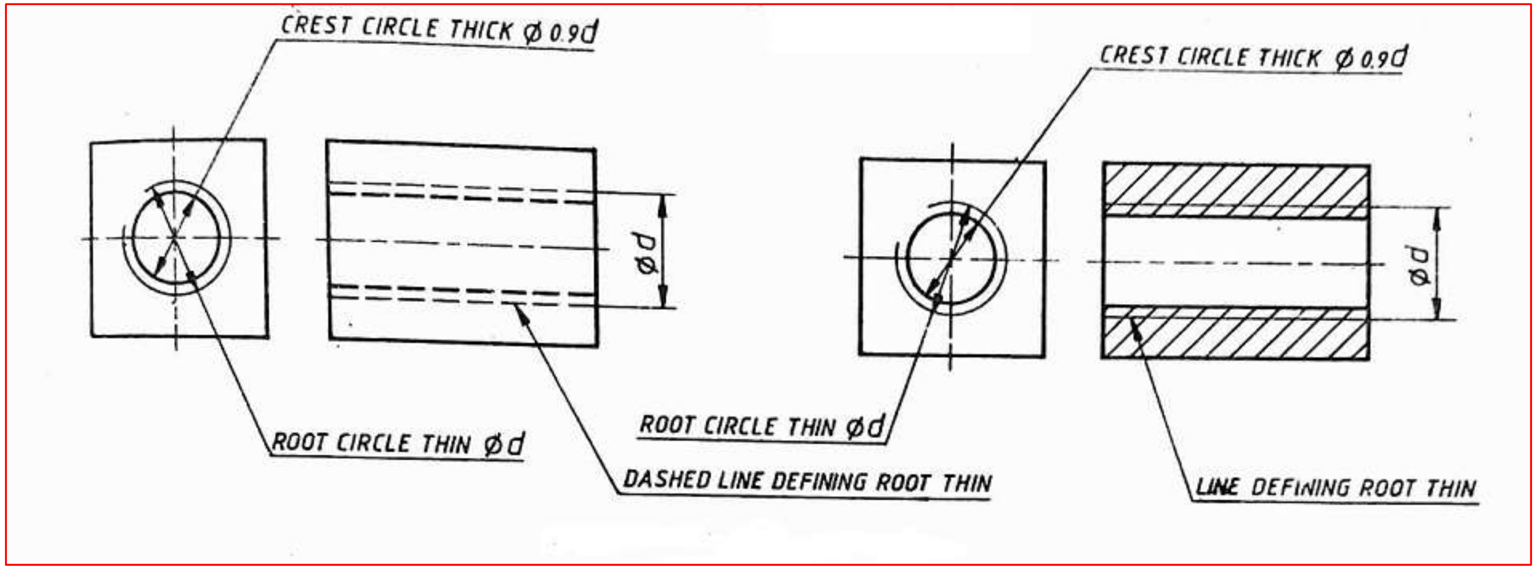
- ✓ The external v threads are represented by two thin continuous lines on the non-circular view, and by a thin complete circle for about three fourth of its circumference on the circular view.
- ✓ The thin lines must be drawn at a distance equal to 0.9xdiameter of the rod.



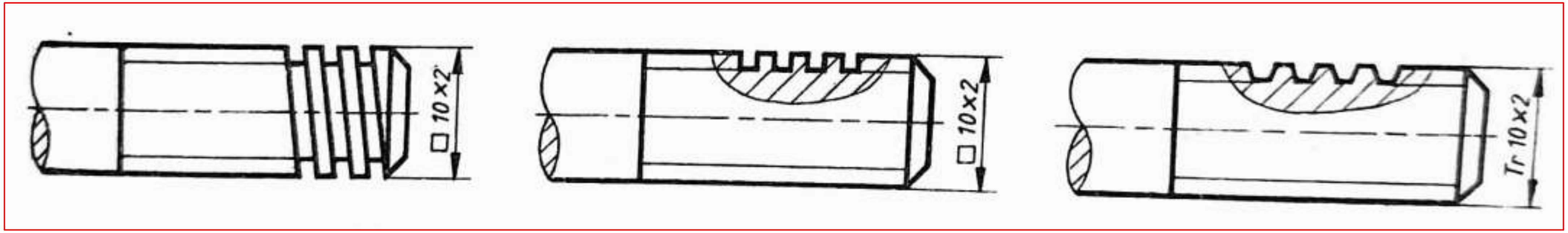
- ✓ When the externally added parts are to be shown in section, the thin lines and incomplete thin circle representing the root diameter must be drawn on the hatched area.



CONVENTIONAL REPRESENTATION OF V PROFILE THREADS – INTERNAL THREAD



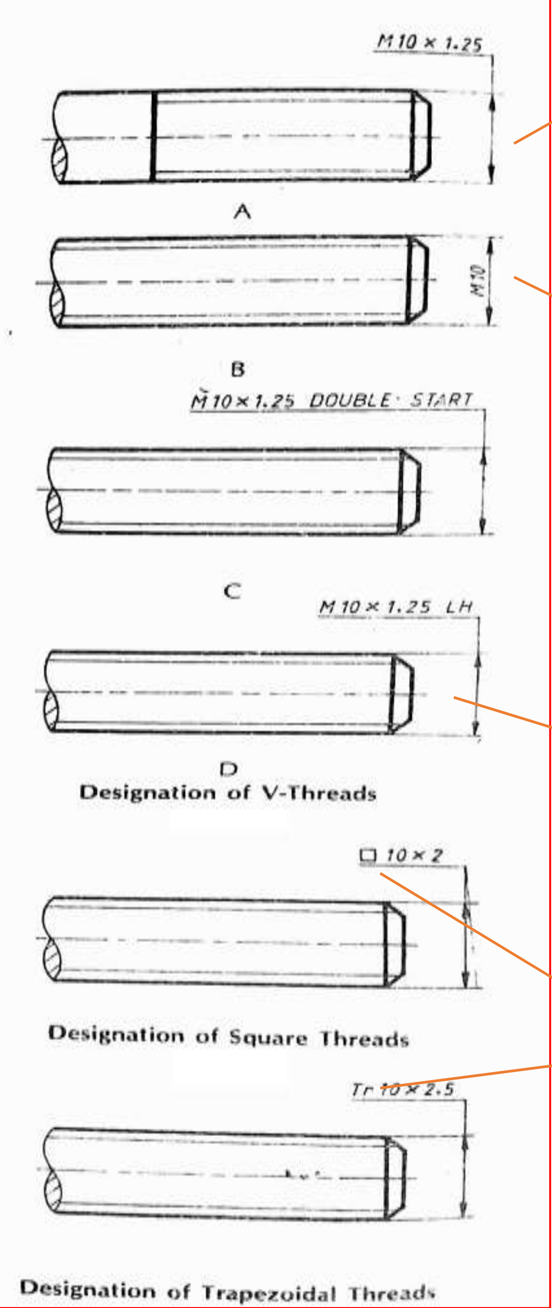
CONVENTIONAL REPRESENTATION OF SQUARE & OTHER FORMS OF THREADS



- ✓ The form of thread should be indicated as above in the case of square thread profile.

DESIGNATION OF THREADS

- ✓ Threads are designated by indicating: **the type of thread, the major diameter and the pitch.**



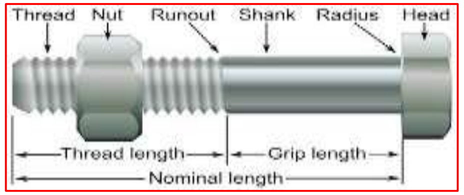
- ✓ V-threads of ISO profile are designated by the letter M followed by major diameter and pitch as M10x1.25; **M** representing **Metric Thread**; 10 – Major Diameter; 1.25 – Pitch;

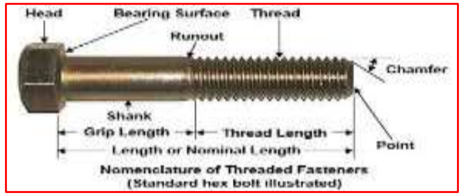
- ✓ V-threads designated without indicating the pitch; it means the threads are cut with *coarse pitch,* whose values is to obtained from the relevant Indian Standard Codes.

- ✓ Multi-start threads are designated by specifying the number of starts.

- ✓ Screw threads are always considered as right hand unless otherwise specified.
- ✓ When left hand threads are used, the abbreviation LH must be used.

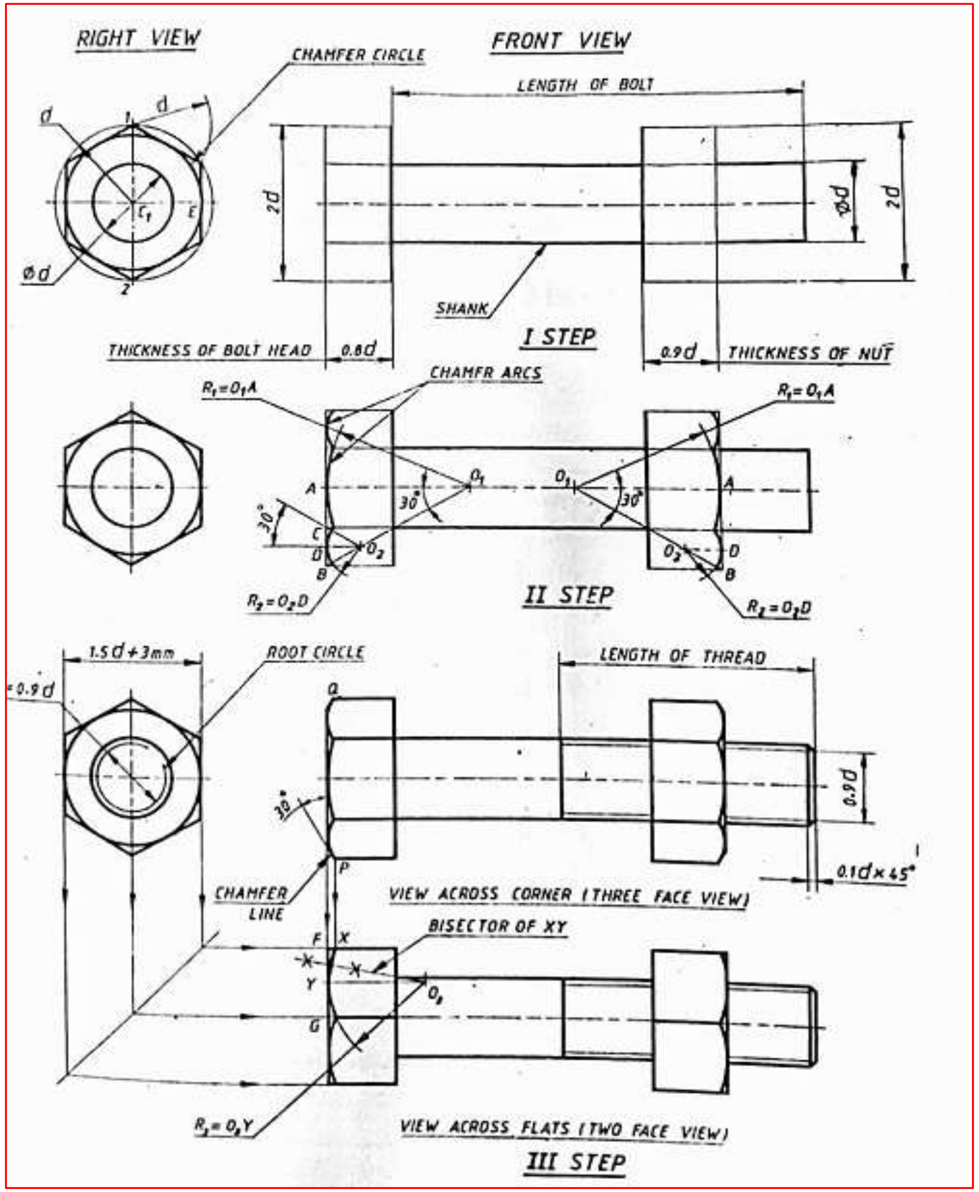
- ✓ Square threads are designated by the □ symbol.
- ✓ Trapezoidal threads are designated by the letters Tr.





EMPIRICAL PROPORTIONS OF HEXAGON AND SQUARE HEAD BOLT & NUT

DETAIL	PROPORTIONS
Nominal Diameter	d = Size of bolt or Nut, mm
Width Across Flats	S = 1.5d + 3 mm
Width Across Corners	e = 2d
Thickness of Bolt Head	k = 0.8 d
Thickness of Nut	m = 0.9 d
Root Diameter	d_1 = d – (2 x Depth of thread) or = d – (4 x Thickness of lines) or = 0.9 d (approximate)
Length of Bolt	l = As specified
Thread Length	b = 2d + 6 mm (for l < 150 mm) = 2d + 12 mm (for l > 150 mm)
Radius of Bolt End	r = d (for spherical ends)
Chamfer of Bolt End	Z = Depth of thread x 45° or = 0.1 d (Approximate)
Chamfer Angle of Bolt Head & Nut	30°



EMPIRICAL PROPORTIONS OF HEXAGON AND SQUARE HEAD BOLT & NUT

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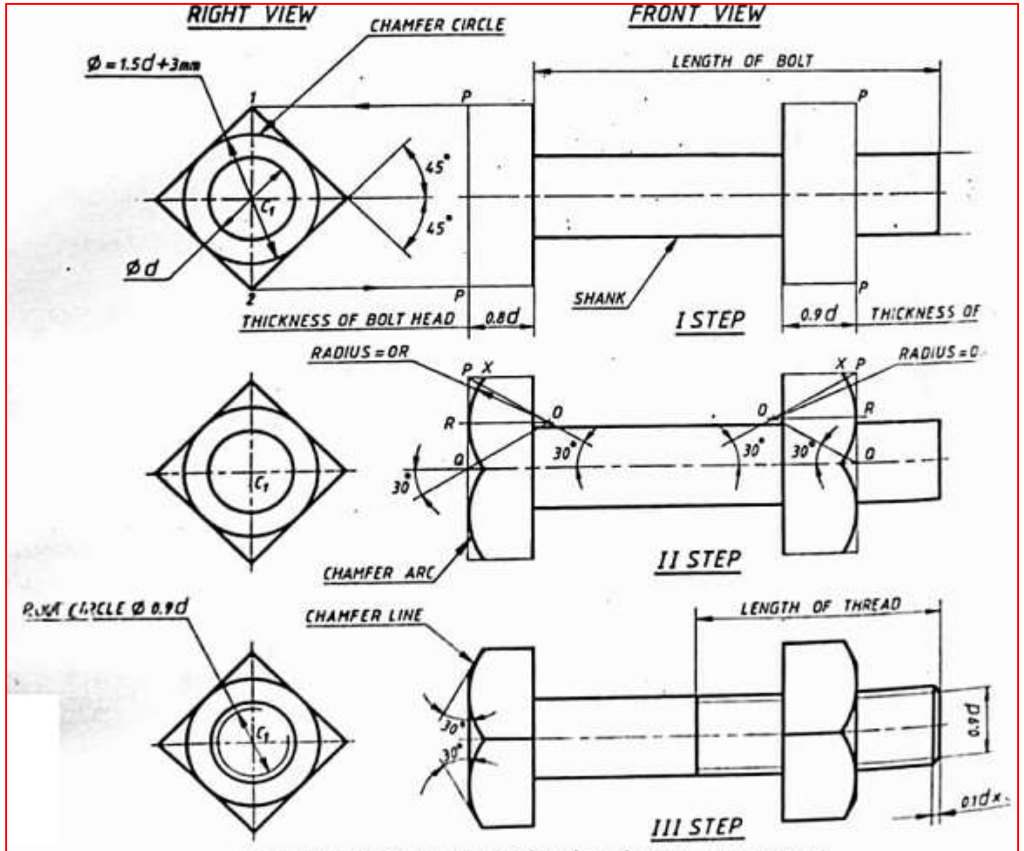
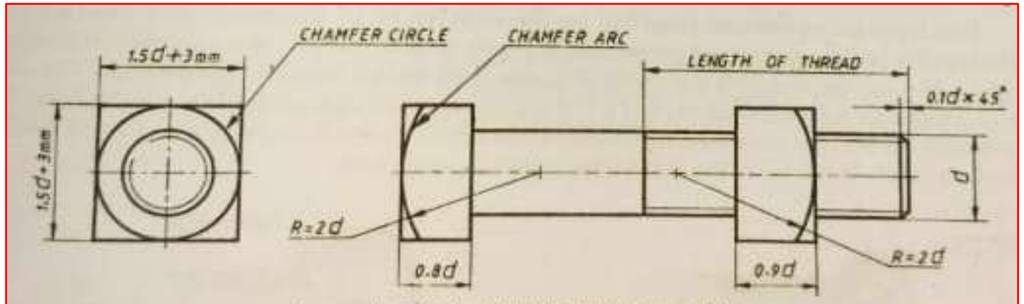
Width Across Corners	e = 2d
Thickness of Bolt Head	k = 0.8 d
Thickness of Nut	m = 0.9 d
Root Diameter	d_1 = d – (2 x Depth of thread) or = d – (4 x Thickness of lines) or = 0.9 d (approximate)
Length of Bolt	l = As specified
Thread Length	b = 2d + 6 mm (for l < 150 mm) = 2d + 12 mm (for l > 150 mm)
Radius of Bolt End	r = d (for spherical ends)
Chamfer of Bolt End	Z = Depth of thread x 45° or = 0.1 d (Approximate)
Chamfer Angle of Bolt Head & Nut	30°



Steps in Drawing Square Head Bolt and Nut in View Across Corners



Square Head Bolt and Nut in View Across Flats

UNIT 6

RIVETED JOINTS, WELDED JOINTS AND KEYS

6. RIVETED JOINTS, WELDED JOINTS AND KEYS

Application of riveted joints - Difference between a bolt and a rivet - Disadvantages of riveted joints - Types of riveted joints - Empirical proportions of riveted joints - Types of welded joints - Symbolic representation of weld - Elementary weld symbols - Keys - Application of keys.

FASTENERS

- ✓ A fastener is a hardware device that mechanically joins or affixes two or more objects together.
- ✓ It is defined as a hardware which can be easily installed and removed with hand tool or power tool.
- ✓ Fasteners have only one intended function which is to clamp two parts together.
- ✓ Fasteners are not meant to position parts relative to one another.
- ✓ They are also not meant to function as pivots, axles and fulcrums.
- ✓ Common fasteners include screws, bolts, nuts, keys and rivets.
- ✓ Male fasteners – Hexagonal headed bolt, slotted head bolt, countersunk head bolt, square headed bolt, round head bolt etc.,
- ✓ Female fasteners – Hexagonal nuts, lock nuts, square headed nuts etc.,

- ✓ The most widely mechanical property associated with standard threaded fasteners is tensile strength.
- ✓ Over 90 % of all fasteners are made of carbon steel.

Temporary fasteners

- Removable – which permits the parts to be readily disconnected without damaging the fastener – Nuts and Bolts
- semi-permanent type where the parts can be disconnected, but some damage usually occurs to the fastener – Cotter pin, Keys.

Permanent fasteners

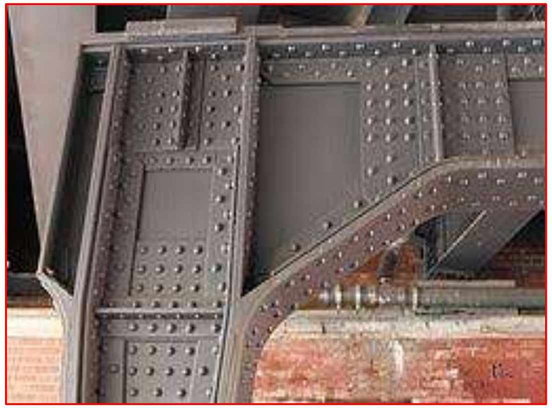
- Permanent type where the parts are never be disassembled – Rivets, welded joints

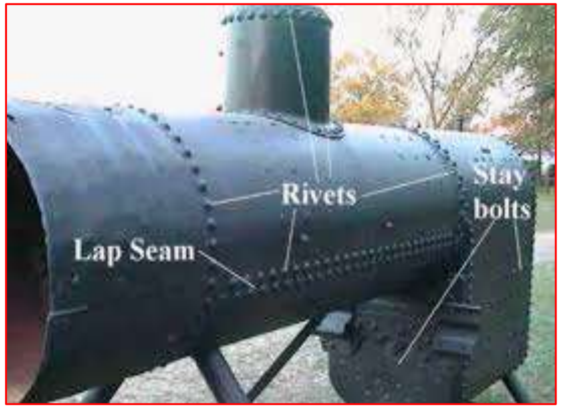
RIVETS AND RIVETED JOINTS

✓ A **riveted joint** is **permanent type of fastener** used to join the metal plates or rolled steel sections together.

Applications:

- Used in structural works such as bridges and roof trusses,
- Used in the construction of pressure vessels such as storage tanks, boilers etc.,





✓ **What is advantages of riveted joints over welded joints?**

- Although welded joints are best suited to several of these applications than the riveted joints, however, riveted joints are ideal in cases where the joints will be subjected to pronounced vibrating loads.

- ✓ Riveted joints are also used when a non-metallic plate and a metallic plate are to be connected together.
- ✓ They are also used when the joints are not subjected to heating while joining as in welding, which may cause *warping* and *tempering* of the finished surfaces of the joints.

Warping - make or become bent or twisted out of shape, typically as a result of the effects of heat.

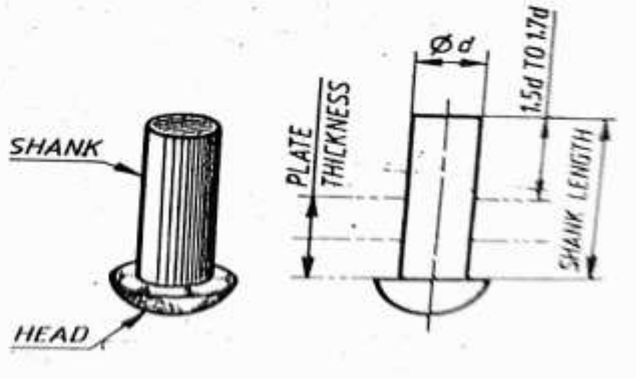
Tempering – increases ductility thereby decreasing the brittleness.

Disadvantages of riveted joints are:

1. More metal is removed while making the holes which weakens the working cross sections along the line of centers of the rivet holes.
2. Weight of the rivets increase the weight of the riveted members.

DIFFERENCE BETWEEN A BOLT AND A RIVET

- ✓ Although the shape of the rivet is similar to that of a bolt, unlike the bolts, its shank end is not threaded.
- ✓ Rivet is used as a permanent fastener to withstand shear forces acting perpendicular to its axis.
- ✓ Bolt is used as a temporary fastener to withstand axial tensile forces.



Rivet

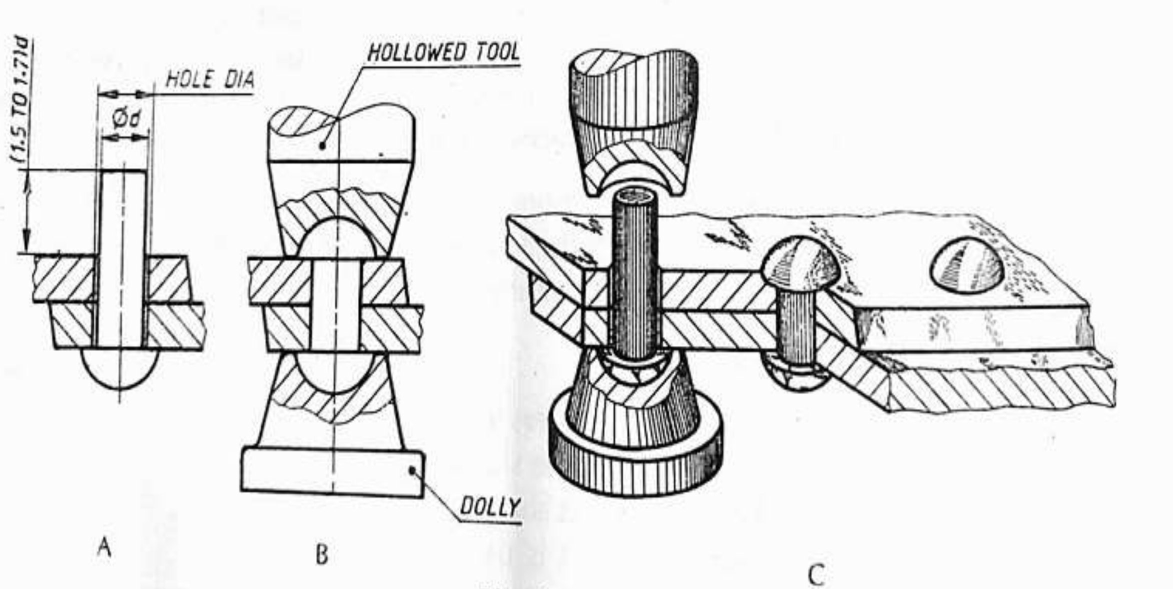
RIVETS

- ✓ A rivet is a round rod made of mild steel or non-ferrous materials such as Cu, Al etc., with a head, of any one of the shapes shown below, formed at one end and a tail end being slightly tapered.
- ✓ The length of the shank of the rivet must be sufficient enough to accommodate the connecting plates and also provide enough material for forming a head at its shank end.
- ✓ Length of shank of the rivet = sum of thickness of connecting plates + (1.5 to 1.7)(diameter of the rivet).
- ✓ i.e., $l = \Sigma t + (1.5 \text{ to } 1.7)d$.

- ✓ Riveting – It is the process of forming a well shaped concentric head from the projection portion of the shank end of the rivet inserted in the holes previously drilled in the plates to be fastened, without allowing it to develop an initial stress so that it can take up the working shear load.
- ✓ The riveting process involves:

  - Making the holes in the plates

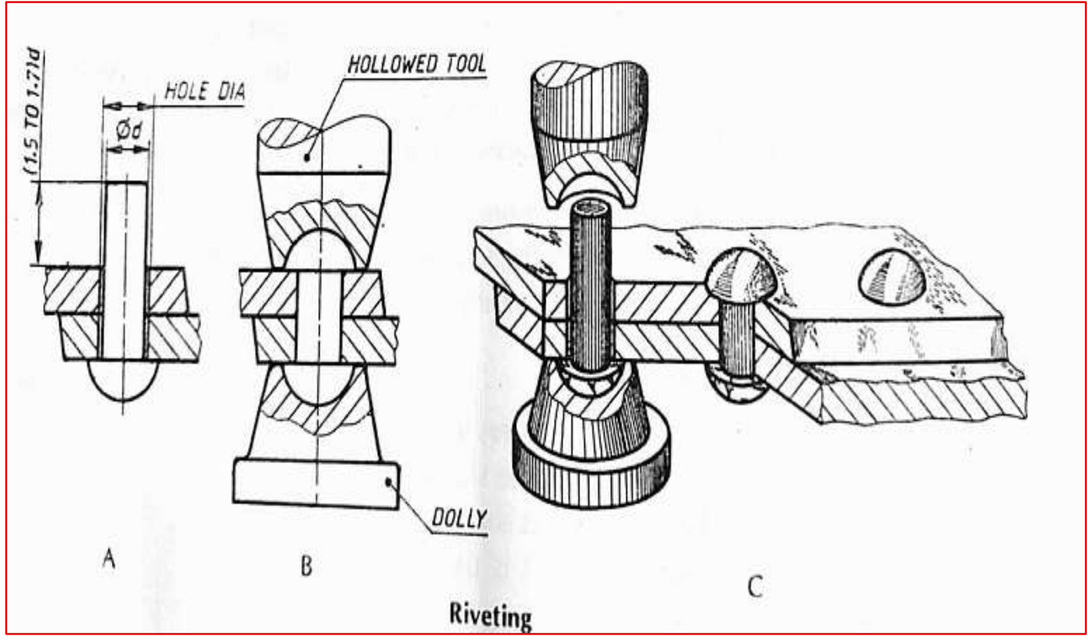
  - Formation of the rivet head.



Riveting

RIVETING

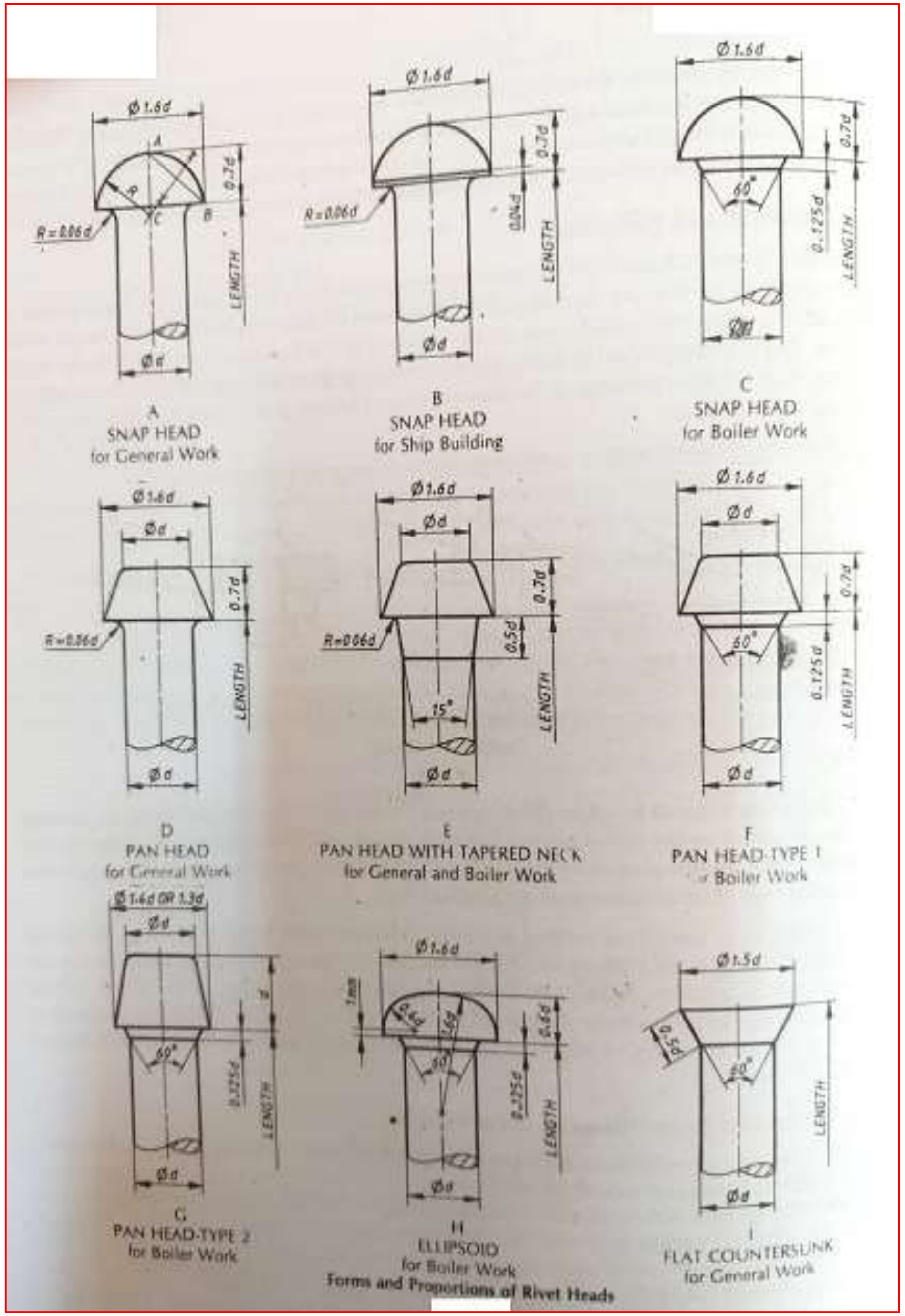
- ✓ The holes drilled in the plates have to be slightly larger than the diameter of the rivet as shown, so that the rivet shank fills the hole after forming the rivet head.
- ✓ For general purposes, the rivet hole will be 1.5 to 2 mm greater than the diameter of the rivet.
- ✓ For boiler work, the rivet hole will be 1 to 2 mm greater than the diameter of the rivet.
- ✓ After making the holes, the rivets heated earlier in a furnace are inserted in the holes.
- ✓ The head of the rivet is pressed against the bearing plate by a supporting aid called 'dolly', while the tail end is hammered or squeezed and then using a hollowed tool having a recess of the same shape of the rivet head, the required head is formed.

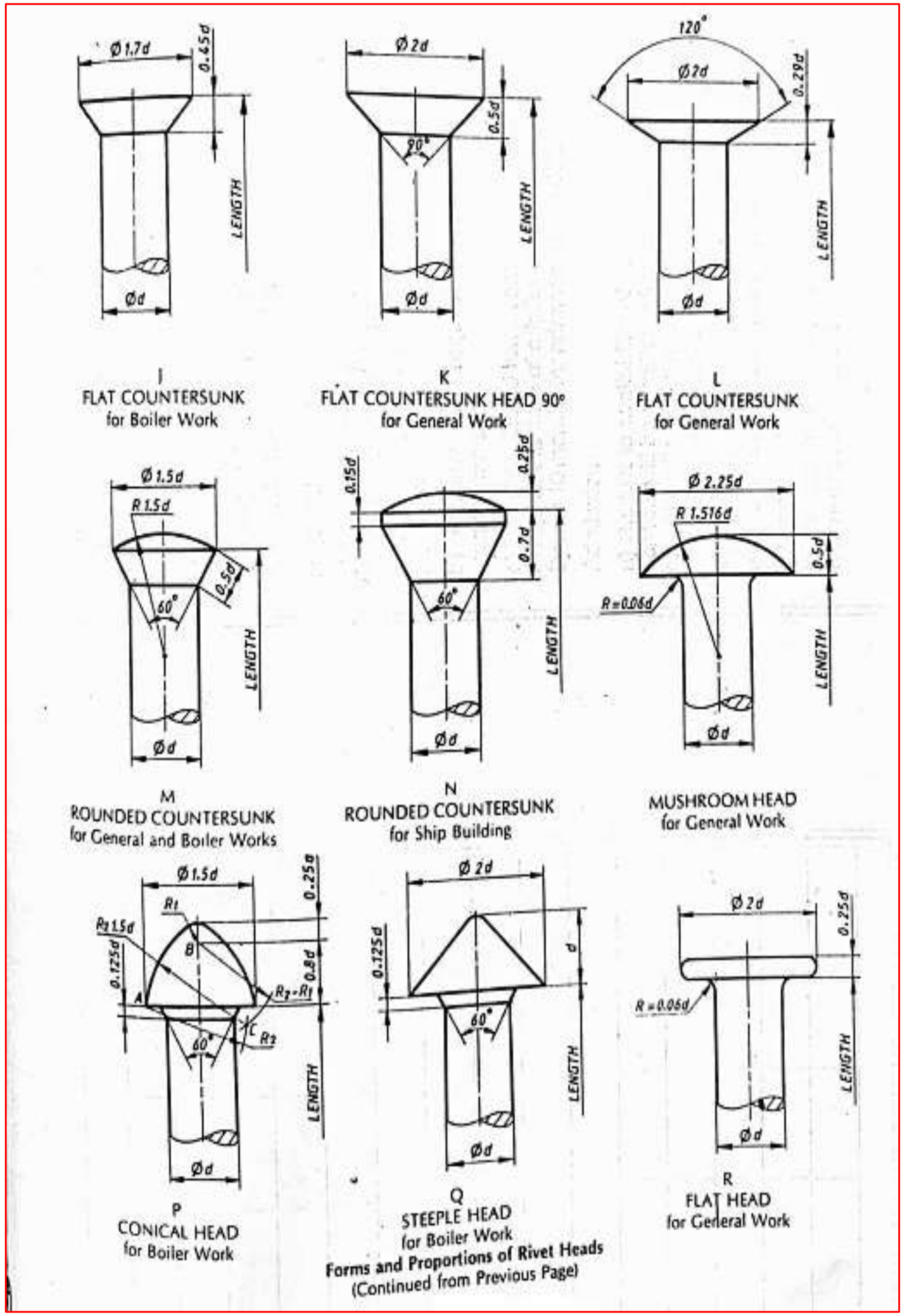


Pneumatic riveting gun for industrial riveting.

FORMS & PROPORTIONS OF RIVET HEADS

- ✓ Various forms of rivet heads for use in general engineering work and boiler work as recommended by BIS are shown.
- ✓ The different proportions of these rivet heads are given in terms of nominal diameter, d, of the rivet.
- ✓ For general purpose: Diameter of rivet head is below 12 mm :- IS: 2155-1962.
- ✓ For diameters between 12 and 48 mm :- IS: 1929-1961.
- ✓ For boiler work :- IS: 1928-1961.
- ✓ For ship building :- IS: 4732-1968.

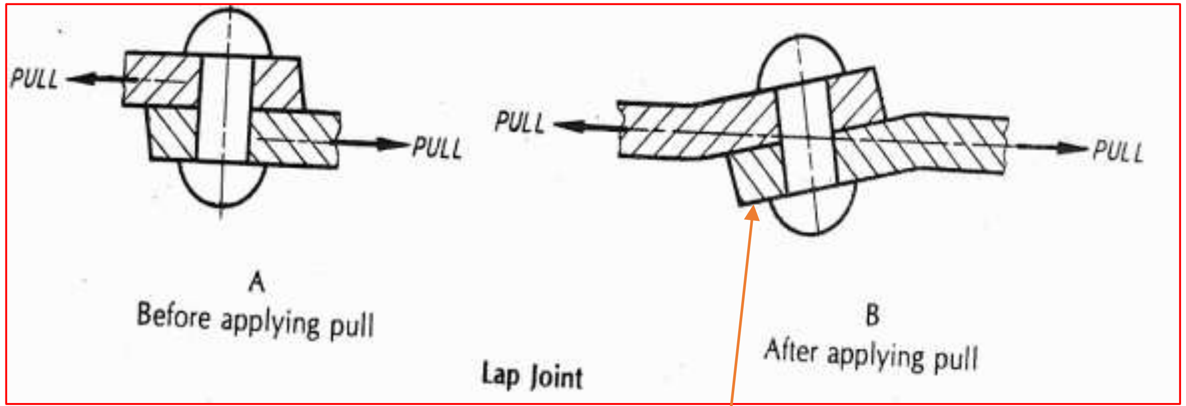




TYPES OF RIVETED JOINTS

✓ LAP JOINTS

- The simplest way to connect two plates by riveting, is to overlap them over a short distance along their edges and drill a row of holes through both of them in the overlapped portion and a joint is made by riveting.

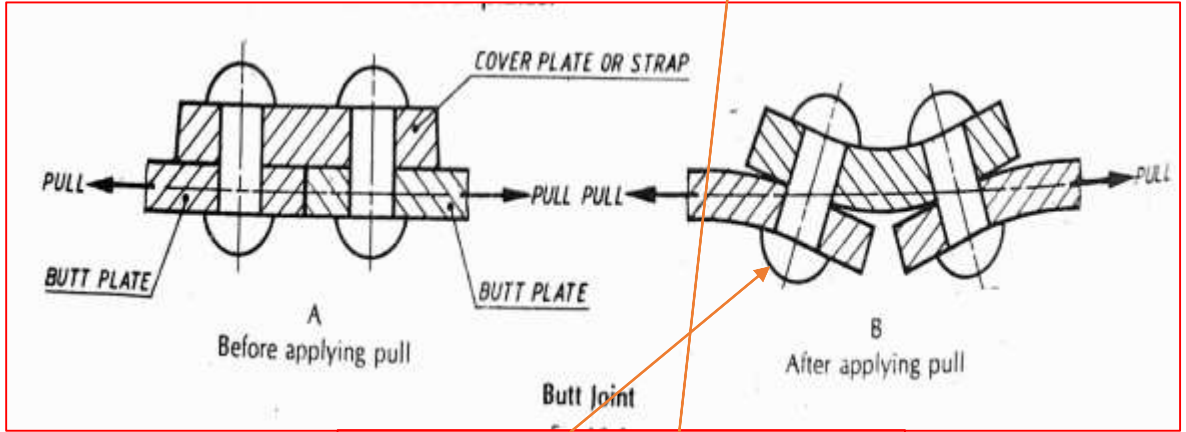


✓ BUTT JOINTS

- When the plates are subjected to heavy loads, the connecting plates are placed in alignment so as to butt each other and a cover plate called *strap* is placed over the joint between them and riveted to hold both the plates together.

- In a butt joint, the load is transferred from one of the butt plates to the cover plate and then from the cover plate to the other butt plate.

- With this kind of arrangement, the rivets will be subjected to ***shear forces*** for which they are designed.



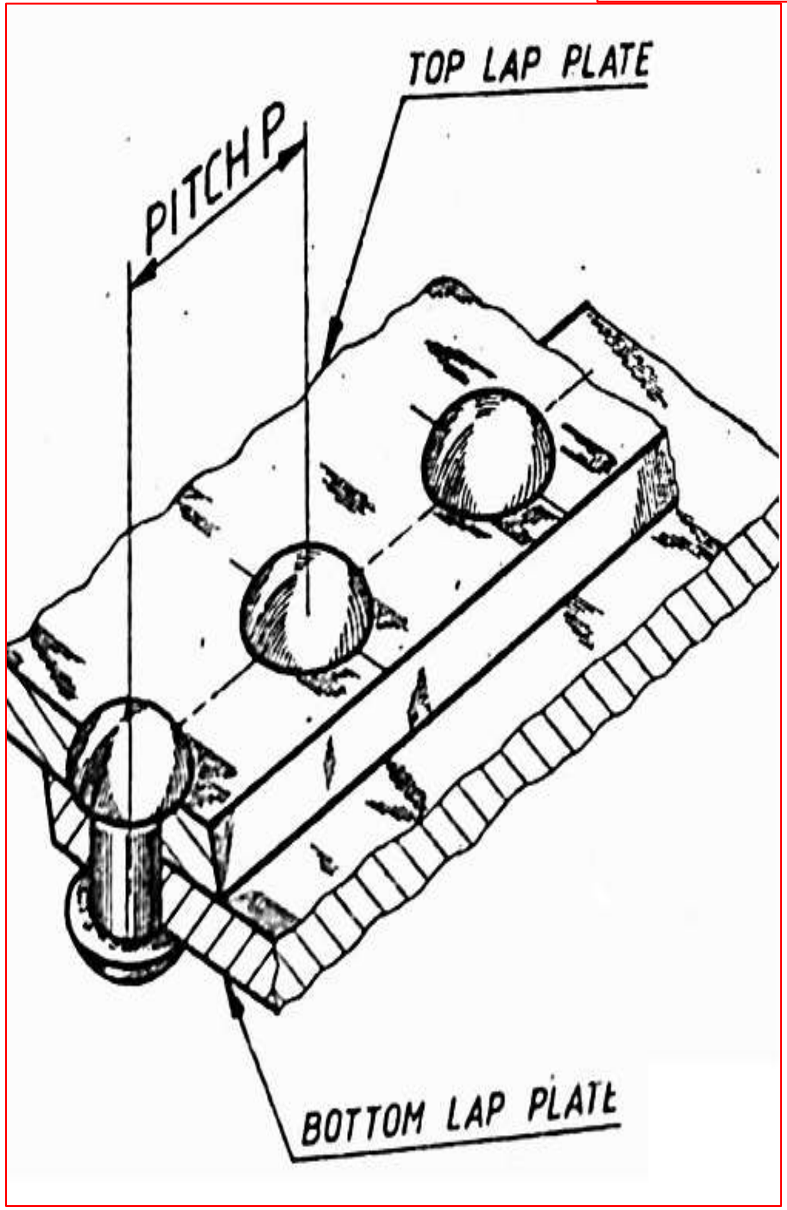
Butt joint with single strap/cover

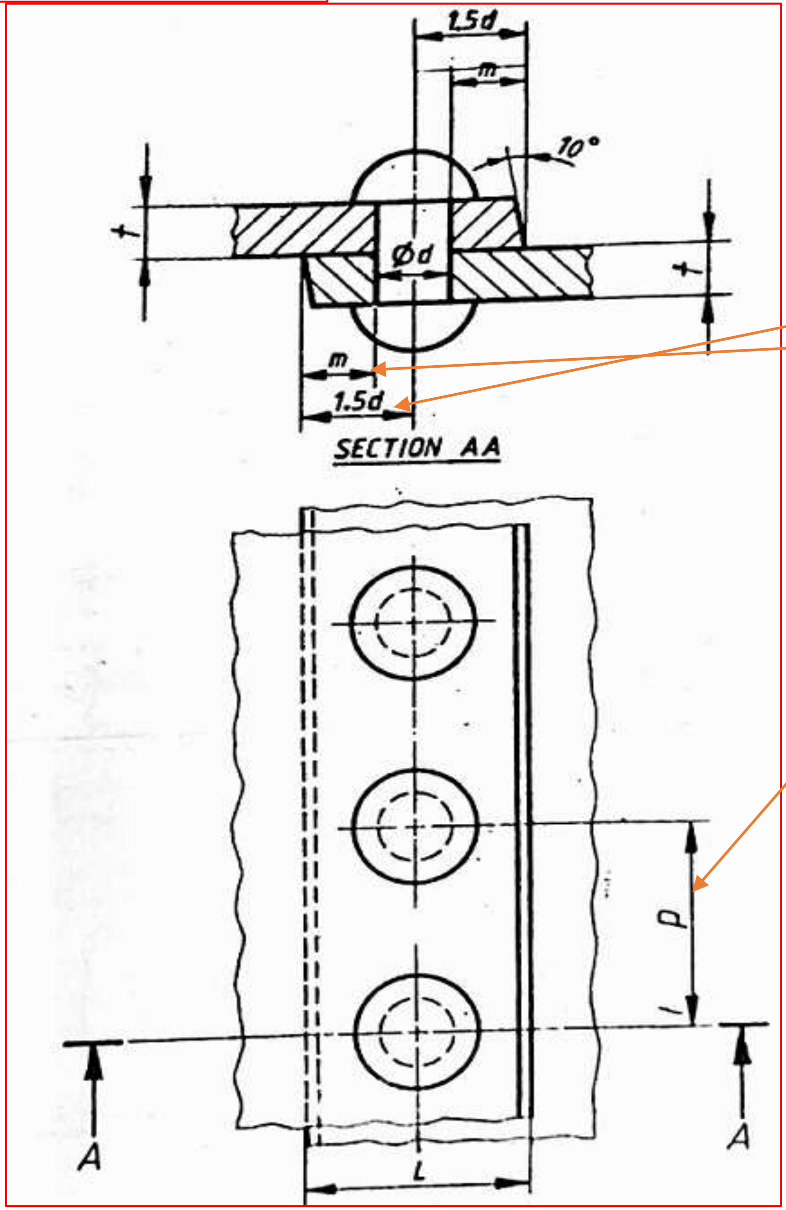
Buckling occurs due to this pull

Butt joint with single strap is also subjected to buckling which can be avoided by placing one more cover at the bottom.

DIFFERENT TYPES OF LAP JOINTS

SINGLE RIVETED LAP JOINT





Empirical Proportions for Riveted Joints
All Dimensions in mm

Sl. No.	Particulars	Empirical Formulae
1.	Diameter of Rivet	d = 6√t
2.	Longitudinal Pitch	p = 3d
3.	Distance of Centre of the Rivet from edge of the Plate	= 1.5d
4.	Margin	m = d
5.	Transverse Pitch	p_t = 0.6p for Chain Riveting p_t = 0.8p for Zig-zag Riveting
6.	Thickness of Straps or Cover Plates (i) Single Cover Plates (ii) Double Cover Plates	 t_1 = 1.125t t_2 = 0.7 to 0.8t

The approximate values of the rivet diameter d for different values of thickness of plates t may also be obtained from Table 12.2.

Table 12.2
Approximate values of Rivet Diameter
All Dimensions in mm

Thickness of plates t	8	9	10	11	12	14	16	18	20	22	25
Diameter of Rivet d	17	18	19	20	21	22	24	26	27	28	30

- When only one row of rivets are used to make a lap joint, then it is called *single riveted lap joint*.

DOUBLE RIVETED LAP JOINT

- ✓ When the lapping width of the plates is more, one row of rivets may not be sufficient to withstand the shearing load and prevent the buckling of the lapping plates.
- ✓ In such cases, to prevent the buckling of the lapping plates, one more row of rivets are used. It is called *double riveted lap joint*.
- ✓ If three rows of rivets are used to make a joint, then it is called *treble riveted lap joint*.
- ✓ When more than one row of rivets are used, the rivets are arranged in

(a) chain formation (chain riveting)

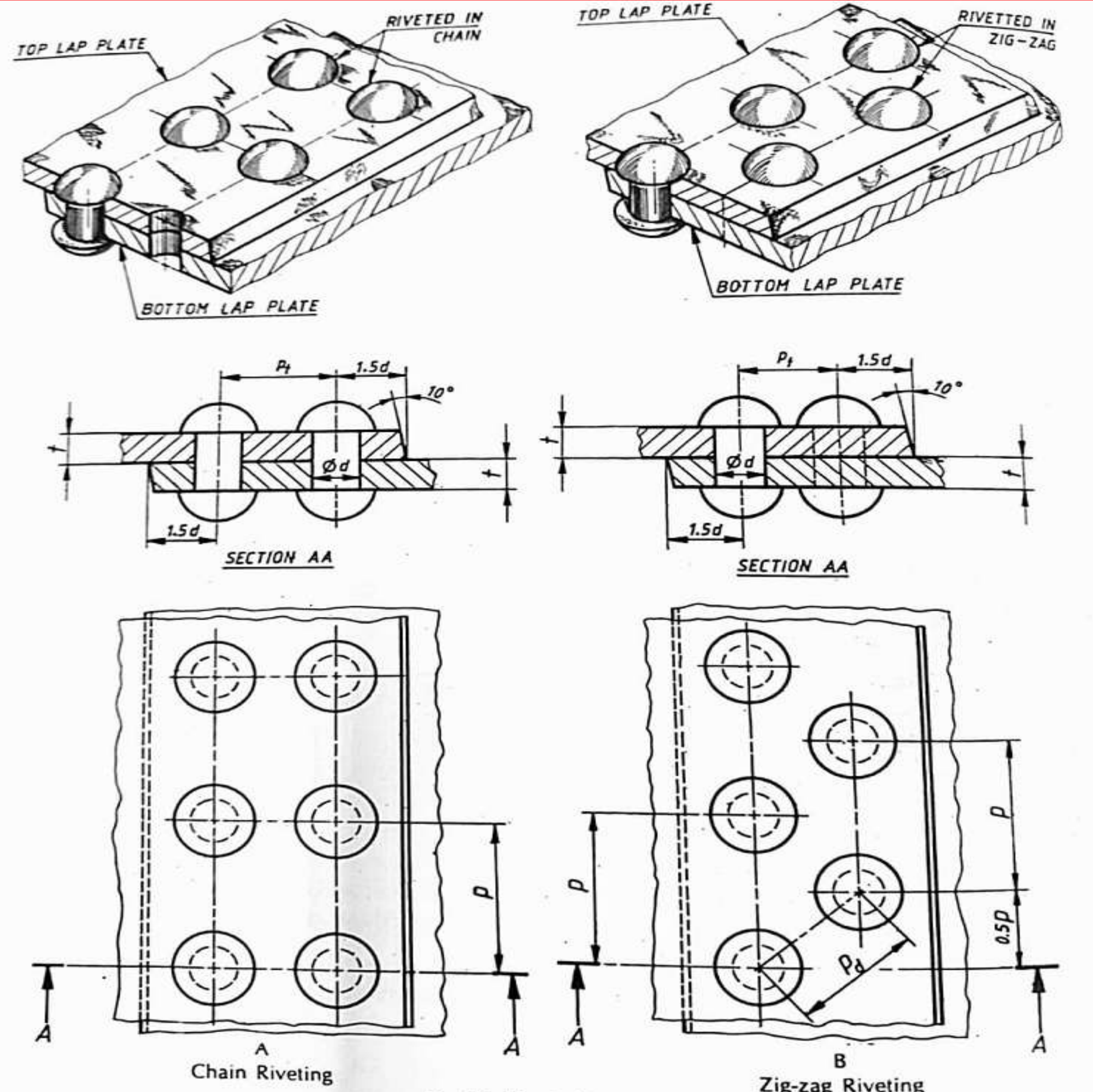
- rivets in the adjoining rows are placed directly opposite to each other.
- generally used in the **structural work**.

Adv: Greater number of rivets can be provided per meter length than zig-zag which reduces the bearing pressure on the rivets.

(b) zig-zag formation (zig-zag riveting)

- rivets in the adjoining rows are staggered to place the rivets **in between** those of the previous row.
- generally used in the **boiler construction**.

DOUBLE RIVETED LAP JOINT



Double Riveted Lap Joint

Empirical Proportions for Riveted Joints

All Dimensions in mm

Sl. No.	Particulars	Empirical Formulae
1.	Diameter of Rivet	$d = 6\sqrt{t}$
2.	Longitudinal Pitch	$p = 3d$
3.	Distance of Centre of the Rivet from edge of the Plate	$= 1.5d$
4.	Margin	$m = d$
5.	Transverse Pitch	$p_t = 0.6p$ for Chain Riveting $p_t = 0.8p$ for Zig-zag Riveting
6.	Thickness of Straps or Cover Plates (i) Single Cover Plates (ii) Double Cover Plates	 $t_1 = 1.125t$ $t_2 = 0.7$ to $0.8t$

The approximate values of the rivet diameter d for different values of thickness of plates t may also be obtained from Table 12.2.

Table 12.2

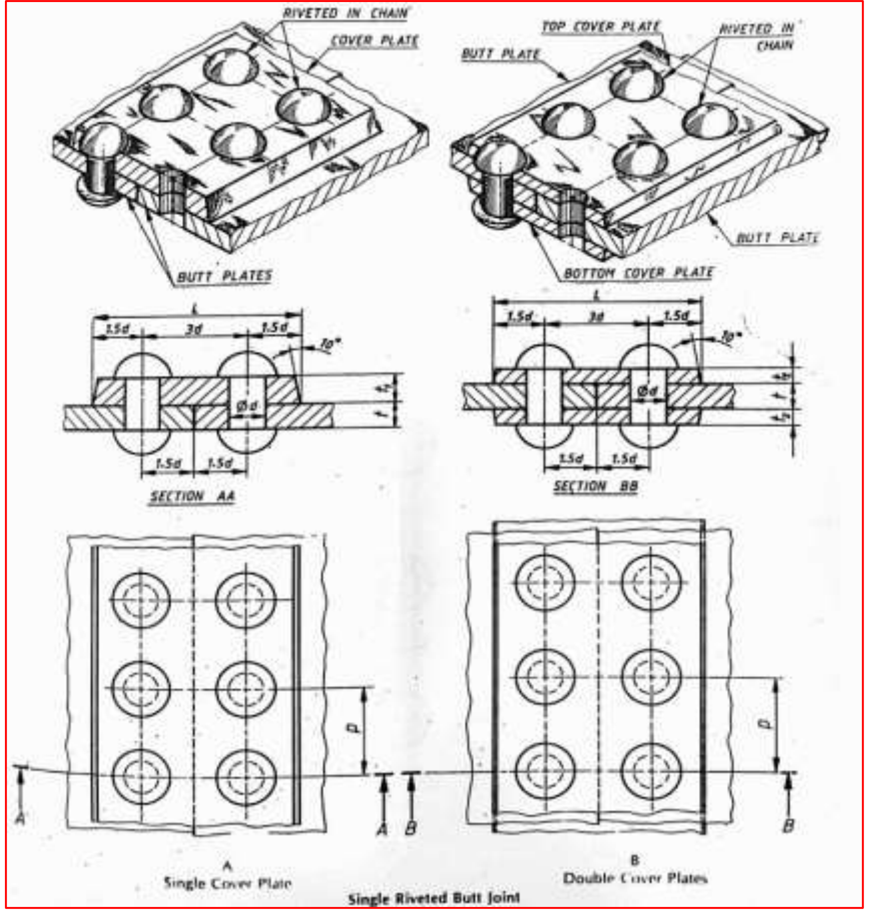
Approximate values of Rivet Diameter

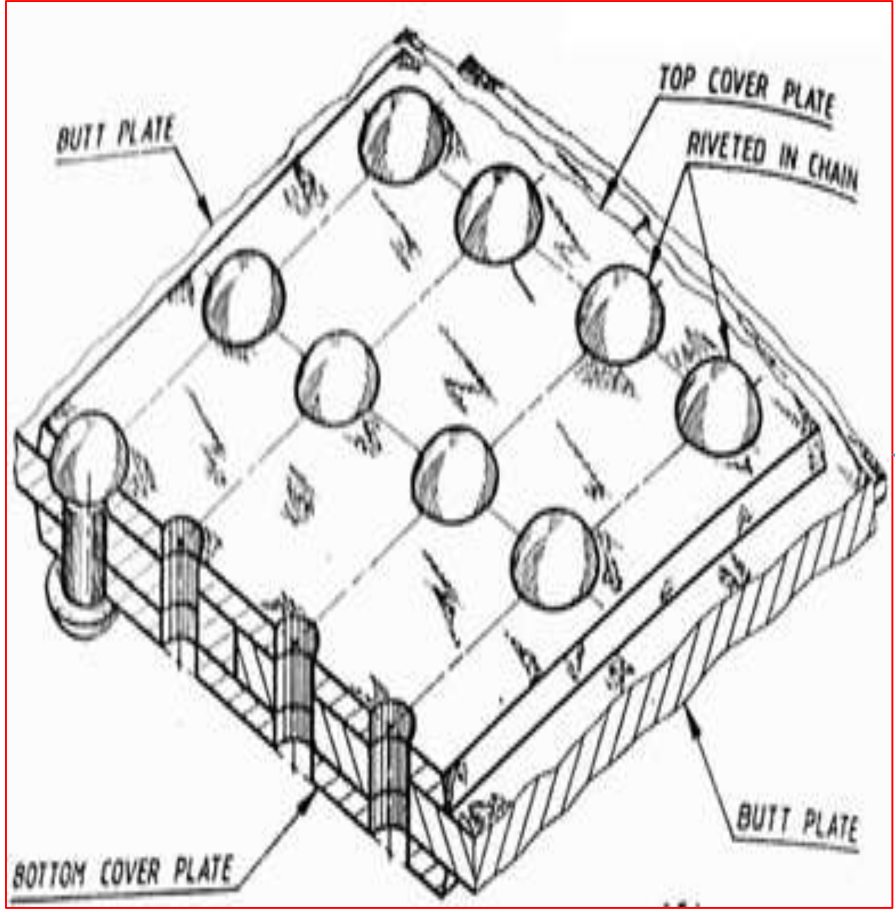
All Dimensions in mm

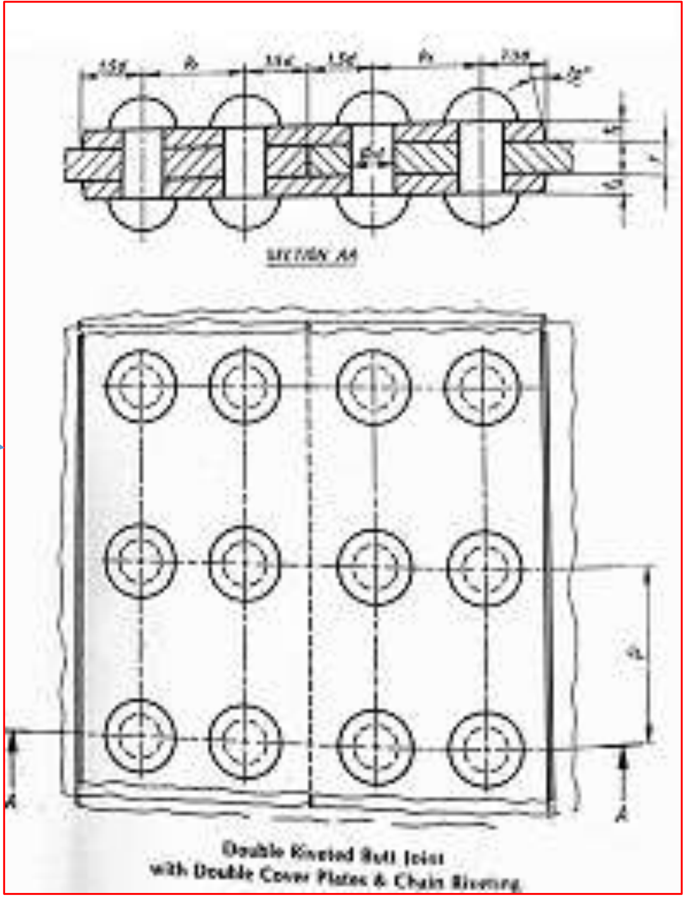
Thickness of plates t	8	9	10	11	12	14	16	18	20	22	25
Diameter of Rivet d	17	18	19	20	21	22	24	26	27	28	30

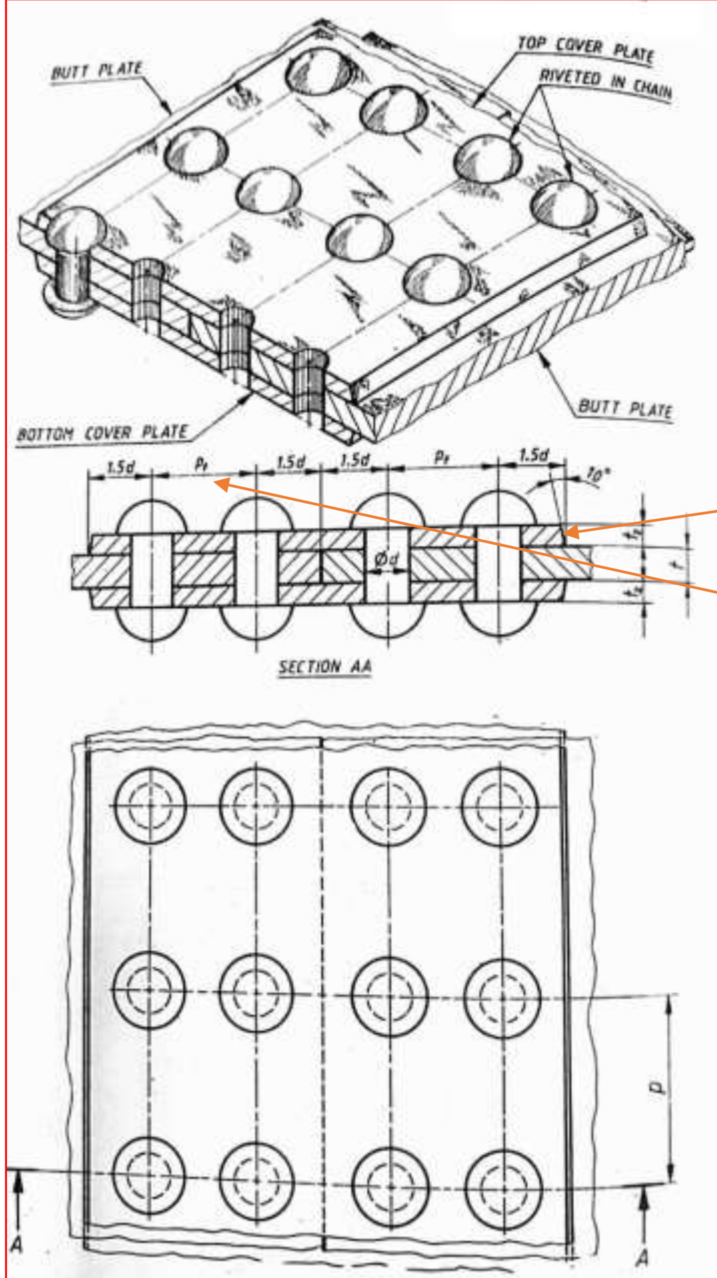
DIFFERENT TYPES OF BUTT JOINTS - SINGLE RIVETED BUTT JOINT

- ✓ Although two rows of rivets are used to make a simple butt joint, since each of the butt plates are connected to the cover plates by only one row of rivets, the joint is called *single riveted butt joint with double cover plates*.
- ✓ If the two rows of rivets are used for each of the butt plates, then the joint is called *double riveted butt joint with double cover plates*.
- ✓ If three rows of rivets are used for each of the butt plates, then the joint is called *treble riveted butt joint with double cover plates*.
- ✓ The rows of rivets in double and treble riveted butt joints will be arranged in chain or zig-zag form.

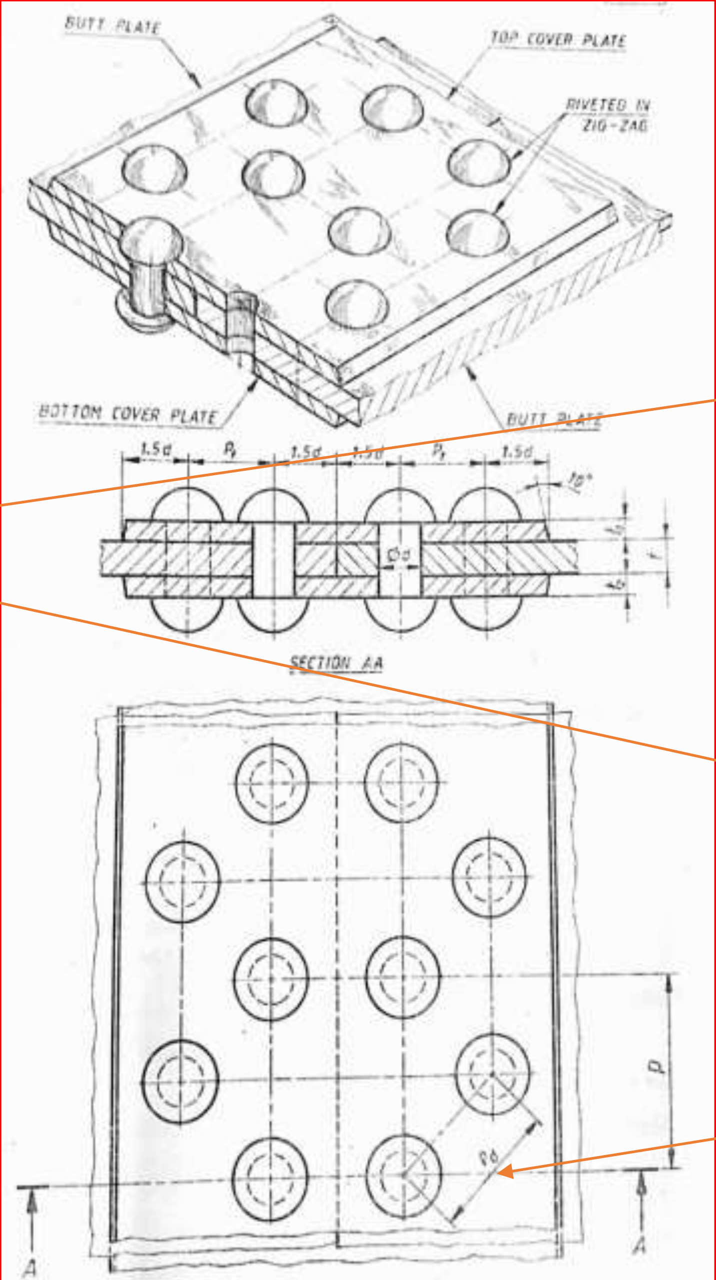








Double Riveted Butt Joint
with Double Cover Plates & Chain Riveting



Double Riveted Butt Joint
with Double Cover Plates & Zig-zag Riveting

TERMINOLOGY USED IN RIVETED JOINTS

✓ Longitudinal pitch, p

- It is the distance from the center of one rivet to the center of next rivet in the same row measured parallel to the **caulking edge** of the plate.

✓ Margin, m

- It is the distance between the edge of the plate and the nearest rivet hole.
- margin = diameter of the rivet.
- since m = d, the distance between the center of the rivet and the caulked edge of the plate will always be equal to 1.5d.

✓ Transverse pitch, p_t

- It is the perpendicular distance between the rows of rivets. It is called **row pitch**.

✓ Diagonal pitch, p_d

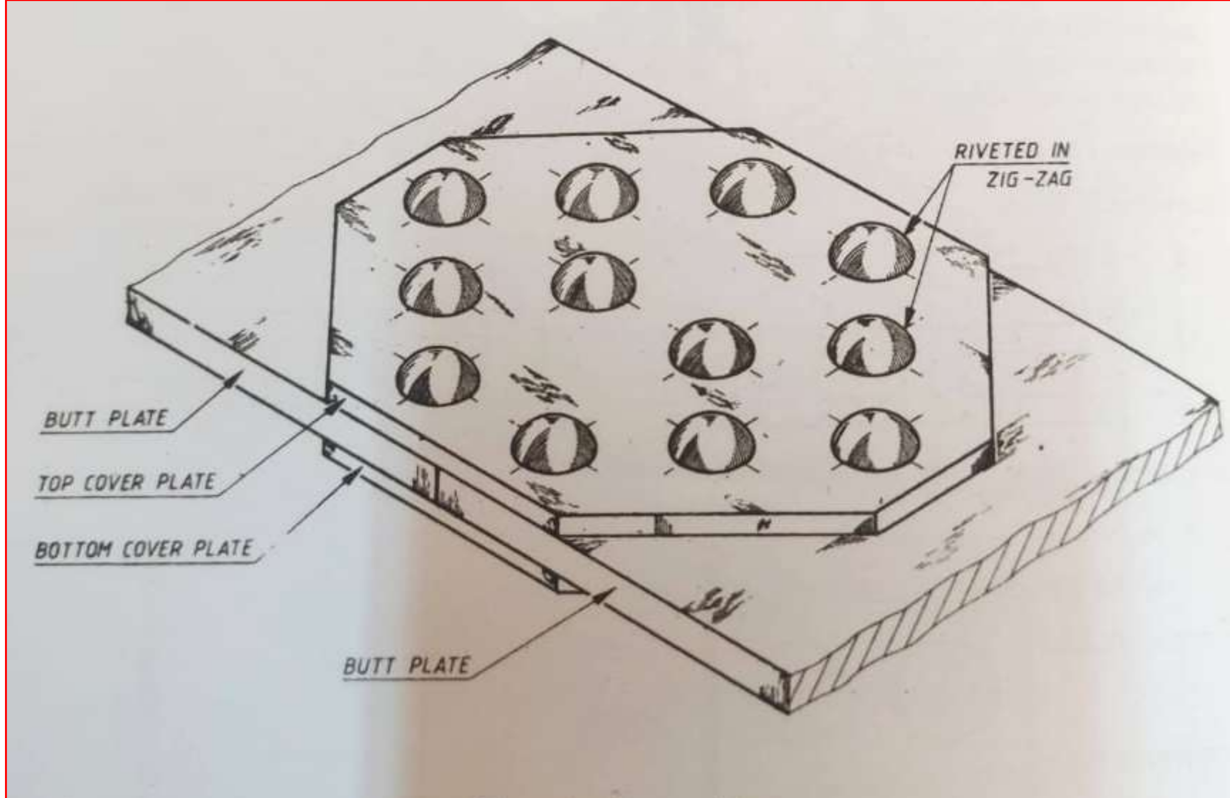
- It is the distance from the center of a rivet in a row to the center of the next rivet in the adjoining row.

DIAMOND OR LOZENZE JOINT

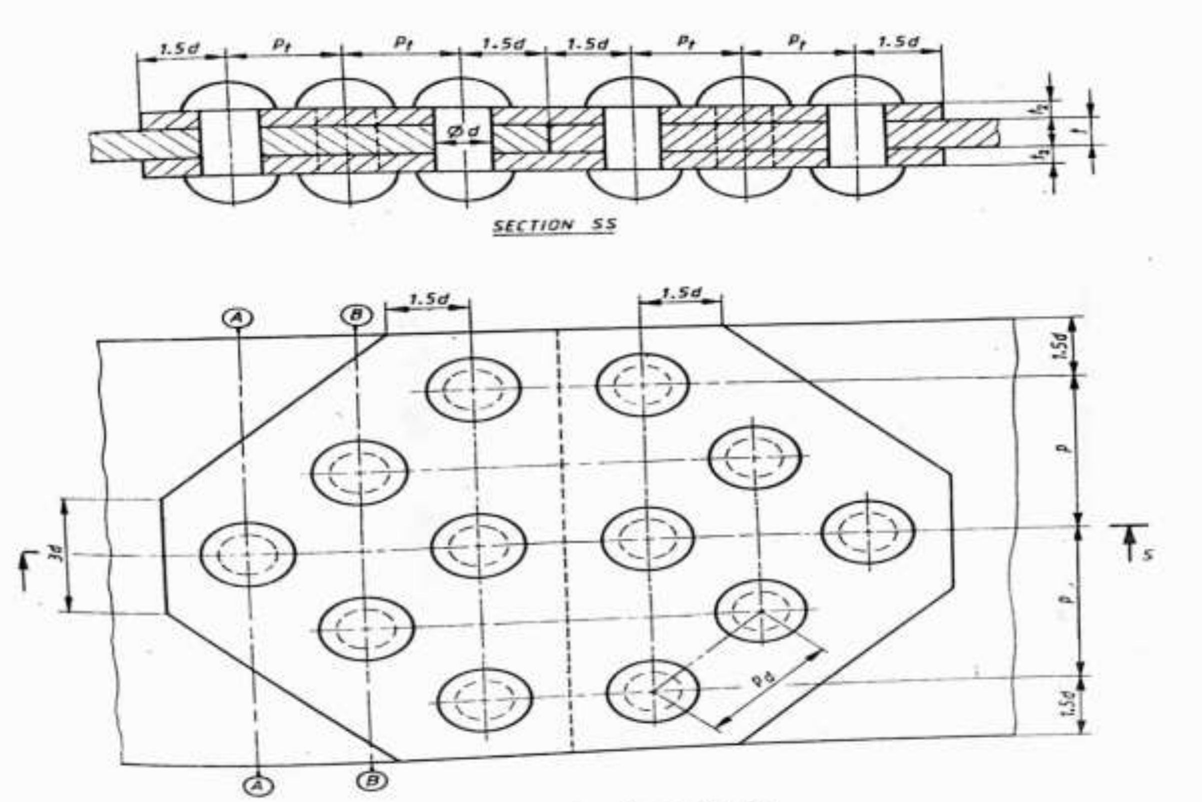
- ✓ This is a particular kind of butt joint with single or double cover plates in which the rivets will be arranged as shown.
- ✓ This arrangement of rivets provides the most efficient joint as along the section AA, the plate is weakened due to only one rivet hole.
- ✓ Along the section BB, the plate is weakened due to two rivet holes, but before the plate can fail on this section, the rivet on AA must also fail in shear. Therefore the joint is stronger on BB.

Application:

- To connect tie bars in bridges and roof structural works.



Diamond or Lozenze Joint



Diamond or Lozenze Joint

WELDED JOINTS

- ✓ Welding is a process of fastening metal parts together permanently.
- ✓ Both ferrous (steel, CI, ferrous alloys) and non-ferrous metals (Br, Cu, Al) can be joined by welding.

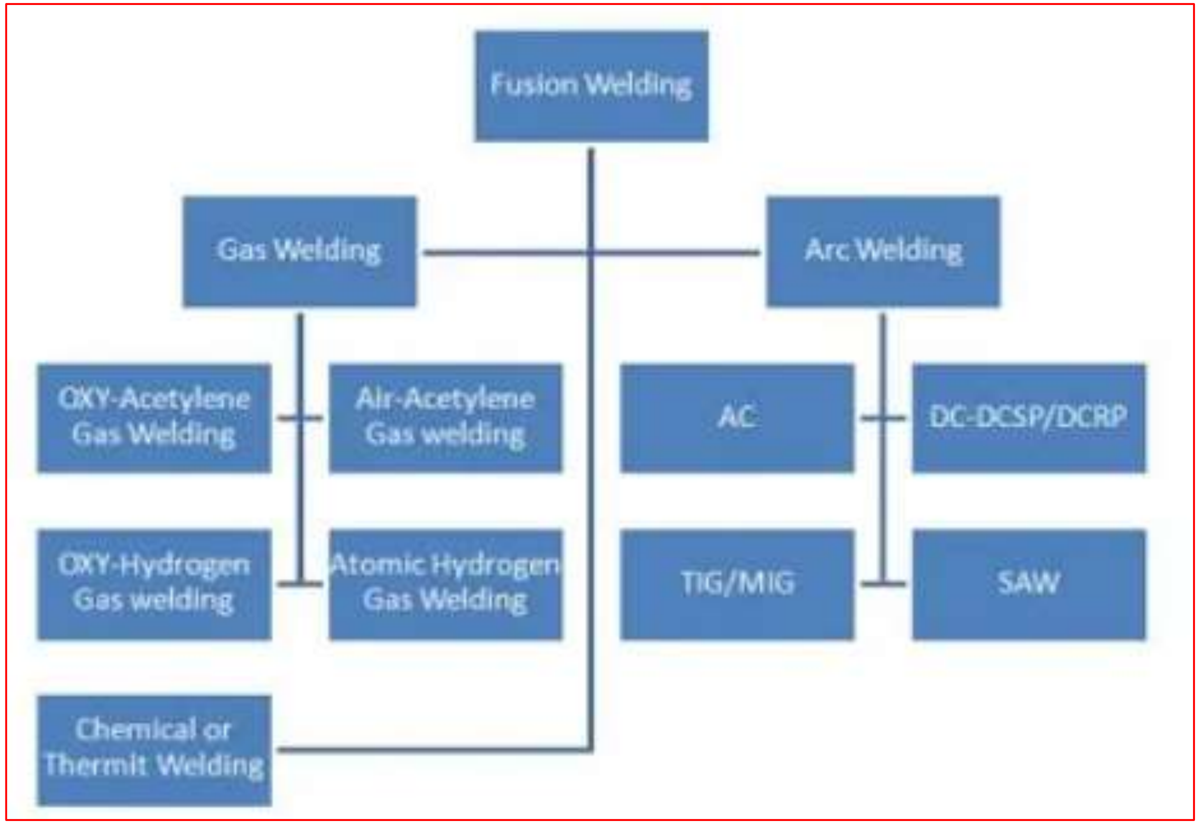
Pressure welding or forge welding

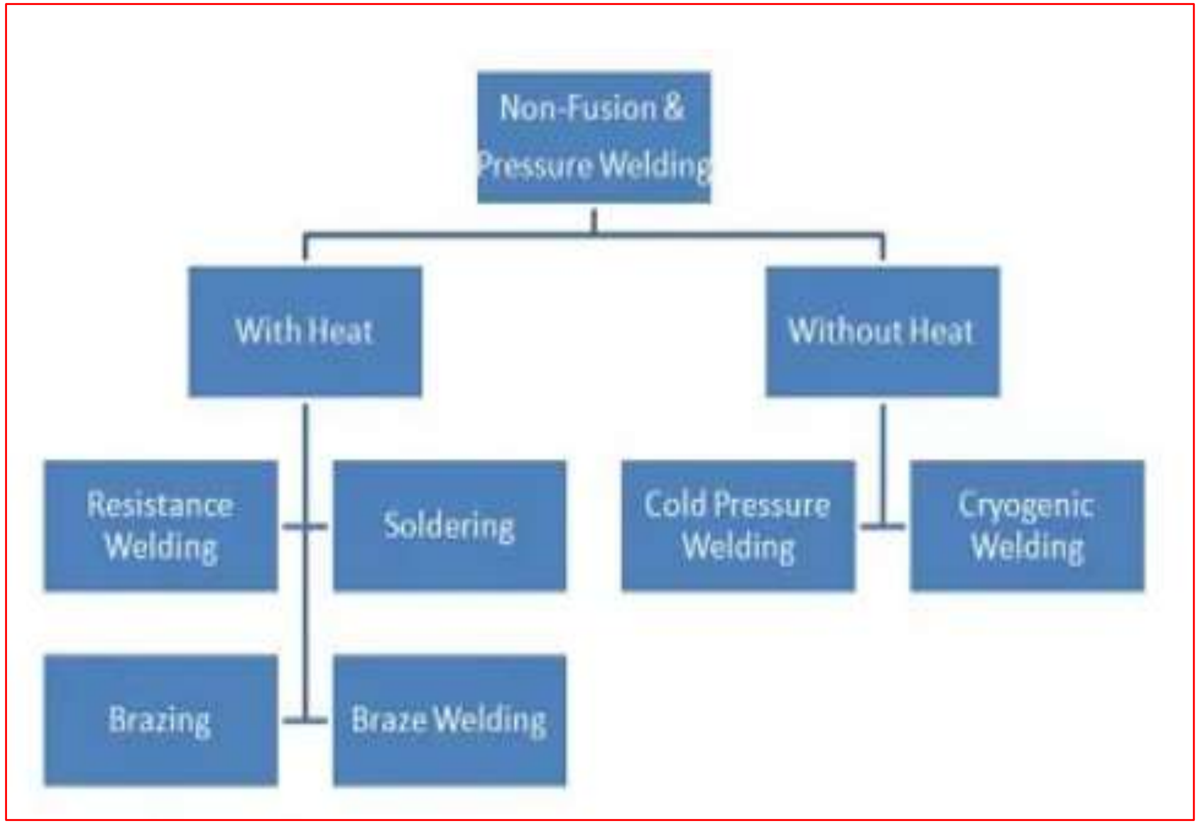
- Two parts around the joints are heated to the plastic state and then joined together by applying the external pressure.
- WI and low carbon steels can be pressure welded.

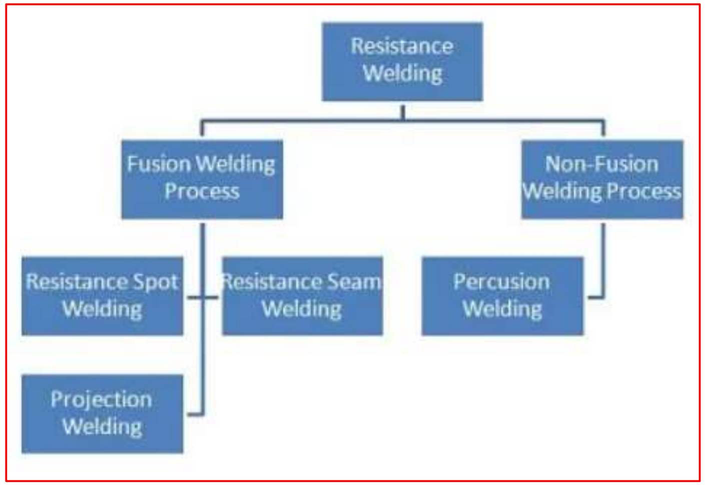
Fusion welding (Eg: Gas welding and arc welding)

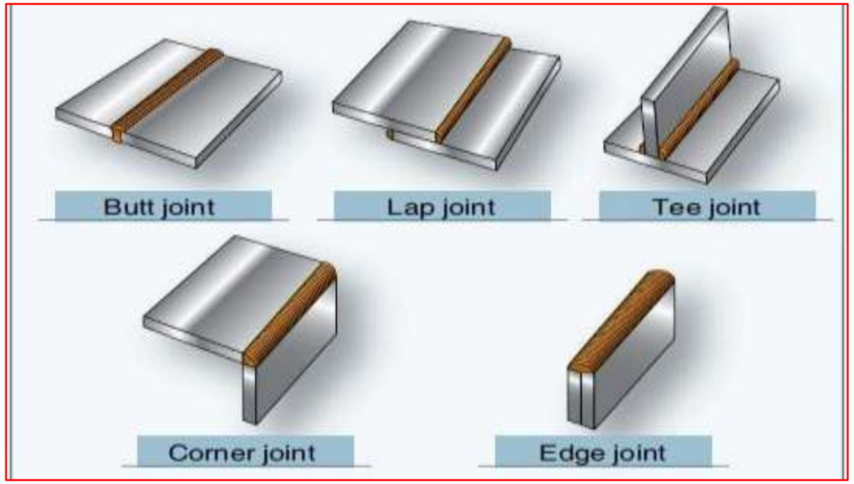
- Parts around the joints are heated to the liquid state and then the ***weld metal*** called ***filler metal*** is added in the molten state to fill the space between the parts being welded which forms the joint when cooled.

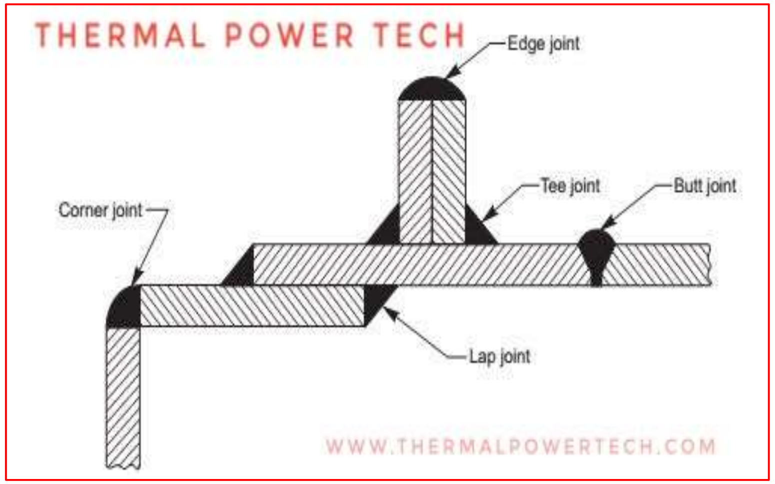
✓ ***Resistance welding*** employs both the pressure welding and fusion welding principles.


Fusion Welding
Gas Welding
Arc Welding
OXY-Acetylene Gas Welding
Air-Acetylene Gas welding
AC
DC-DCSP/DCRP
OXY-Hydrogen Gas welding
Atomic Hydrogen Gas Welding
TIG/MIG
SAW
Chemical or Thermit Welding

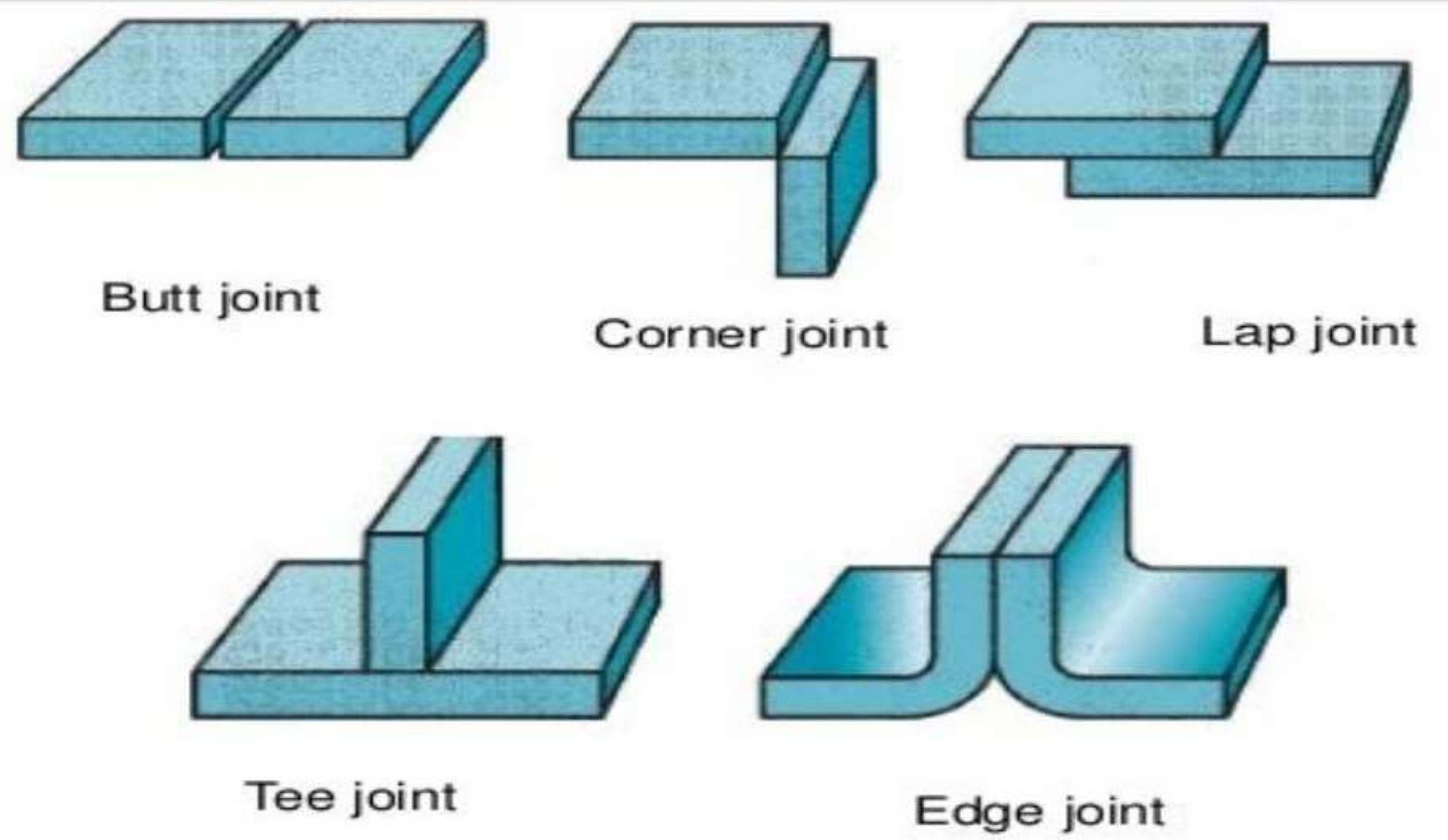

Non-Fusion & Pressure Welding
With Heat
Without Heat
Resistance Welding
Soldering
Cold Pressure Welding
Cryogenic Welding
Brazing
Braze Welding


Resistance Welding
Fusion Welding Process
Non-Fusion Welding Process
Resistance Spot Welding
Resistance Seam Welding
Percusion Welding
Projection Welding


Butt joint
Lap joint
Tee joint
Corner joint
Edge joint

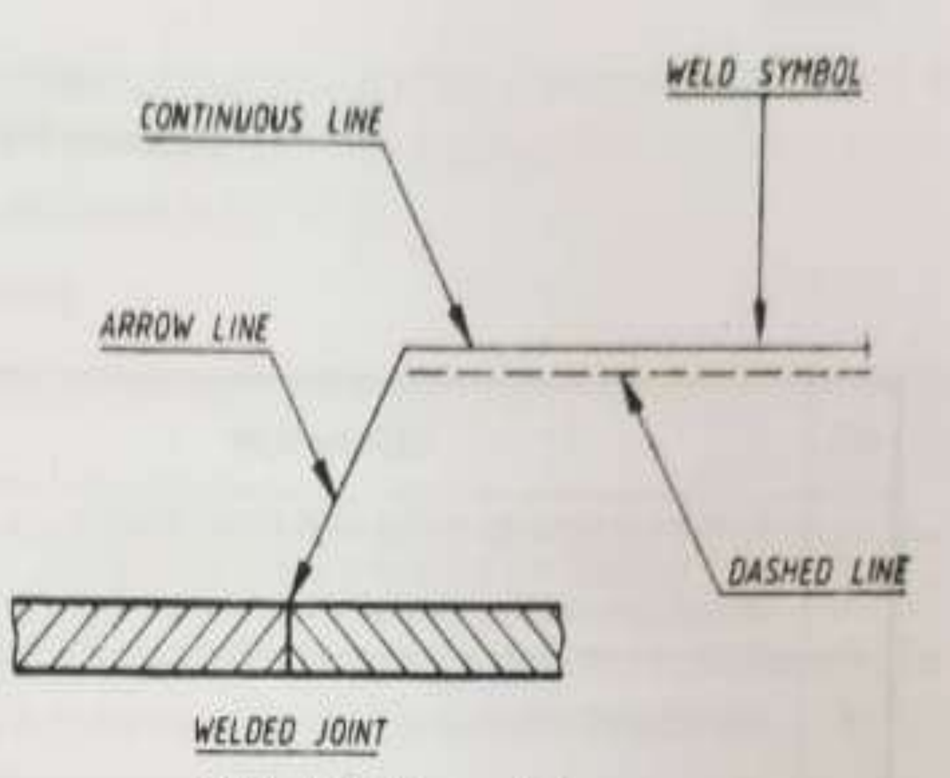

THERMAL POWER TECH
Edge joint
Tee joint
Butt joint
Corner joint
Lap joint
WWW.THERMALPOWERTECH.COM

FIVE BASIC TYPES OF WELDED JOINTS

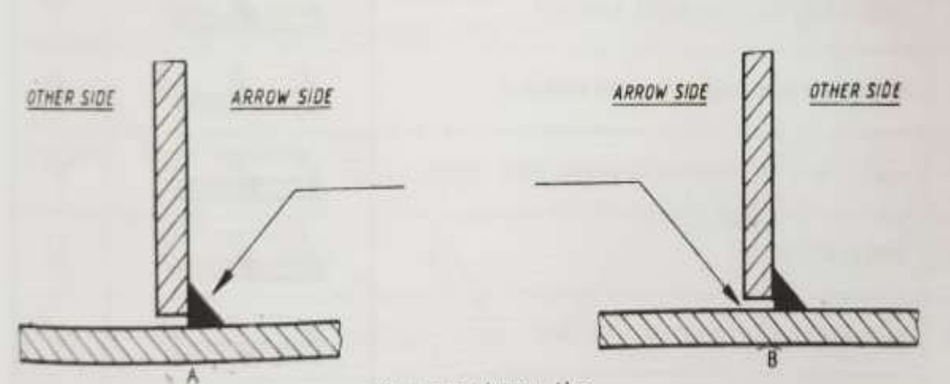


- ✓ Arrow line: Pointing to the point where the weld is to be made.
- ✓ Dual reference line: It consists of two parallel lines: continuous and dashed line.
- ✓ Weld symbol: A basic symbol to specify the type of weld.
- ✓ A supplementary symbol to characterize the shape of the external surface of the weld.
- ✓ Dimension of the weld.

SYMBOLIC REPRESENTATION OF WELD

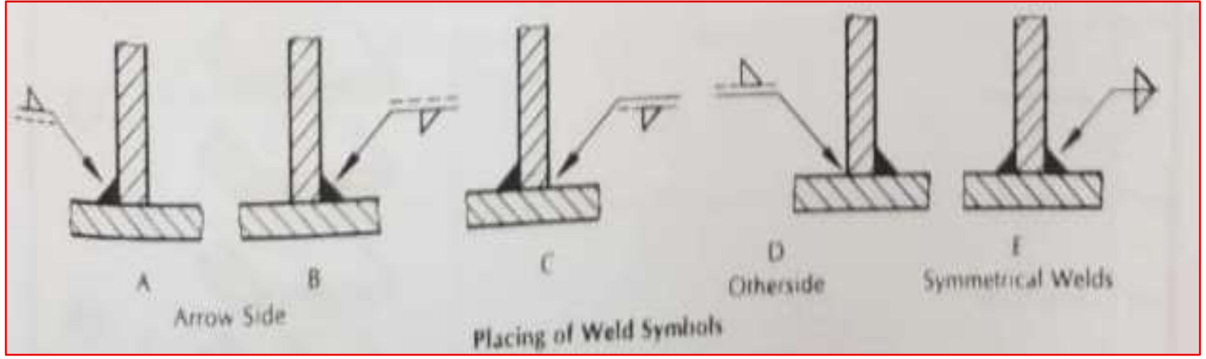


Welded Joint Representation



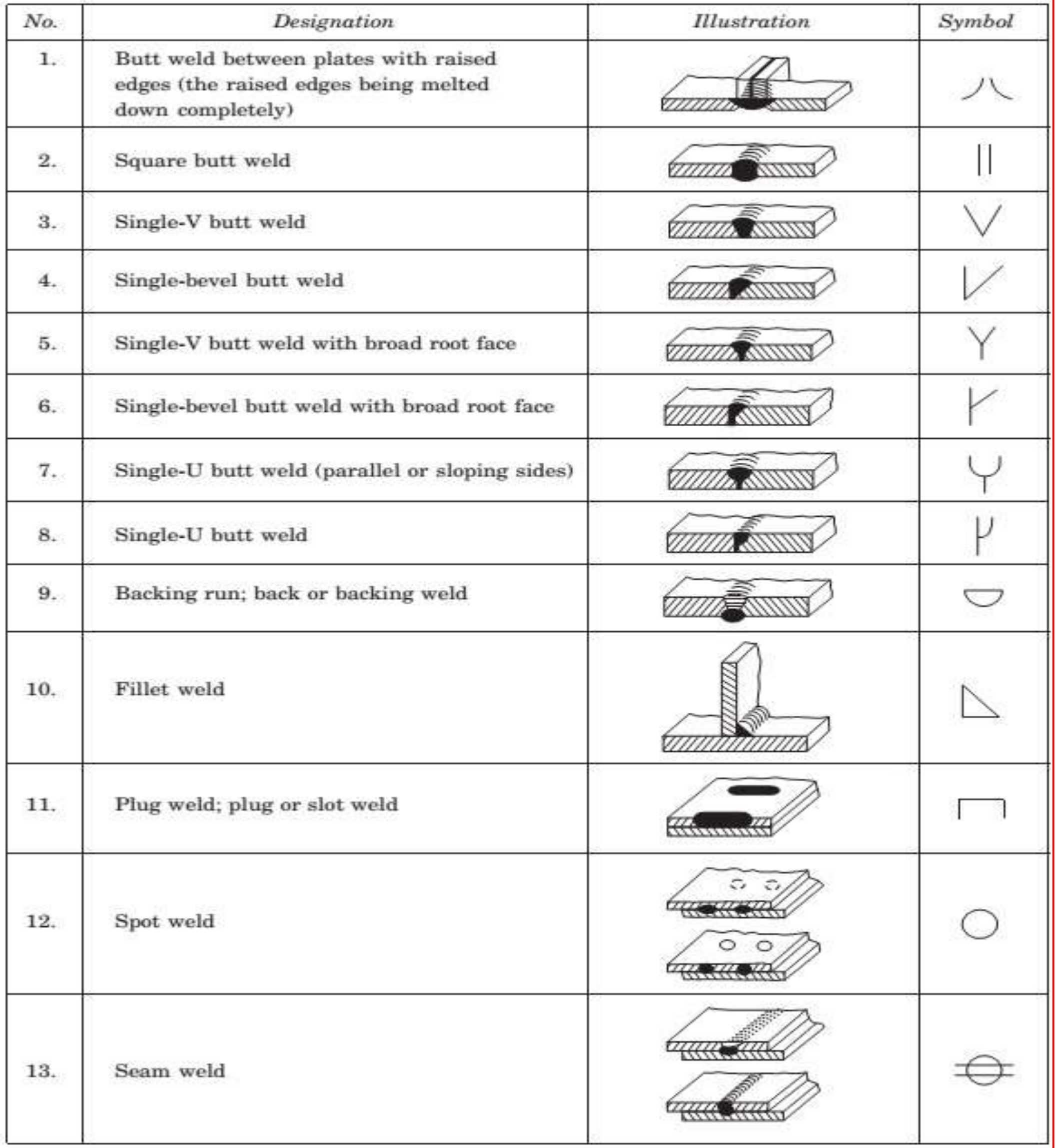
Placement of Arrow Line

SIGNIFICANCE OF REFERENCE LINES AND PLACING OF WELD SYMBOL



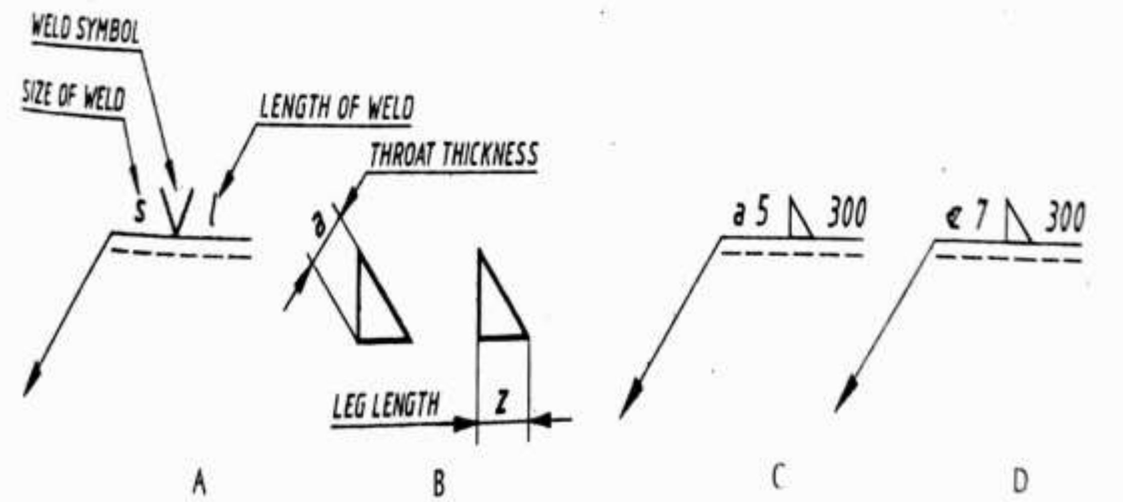
- ✓ Weld symbols may be placed above the reference line as in A and D or below the reference line as in B and C.
- ✓ Weld symbols will be placed on the continuous reference line if the weld is on the arrow side of the joint as in A and B.
- ✓ Weld symbols will be placed on the dashed reference line if the weld is on the other side of the joint as in C and D.
- ✓ For ***symmetrical welds***, the dashed line is omitted and the weld symbols are shown above and beneath the continuous reference line.

ELEMENTARY AND SUPPLEMENTARY WELD SYMBOLS



No.	Designation	Illustration	Symbol
1.	Butt weld between plates with raised edges (the raised edges being melted down completely)		
2.	Square butt weld		
3.	Single-V butt weld		
4.	Single-bevel butt weld		
5.	Single-V butt weld with broad root face		
6.	Single-bevel butt weld with broad root face		
7.	Single-U butt weld (parallel or sloping sides)		
8.	Single-U butt weld		
9.	Backing run; back or backing weld		
10.	Fillet weld		
11.	Plug weld; plug or slot weld		
12.	Spot weld		
13.	Seam weld		

DIMENSIONING OF WELDS



Dimensioning of Welds

Main dimensions required to make a welded joint are:

- ✓ Size of the weld

  - Minimum distance from the surface of the part up to the bottom of the penetration

  - Height of the largest isosceles triangle in the case of fillet welds.

  - Size will be indicated on the left hand side of the weld symbol.

- ✓ Length of the weld

  - Length of the weld will be indicated on the right hand side of the weld symbol.

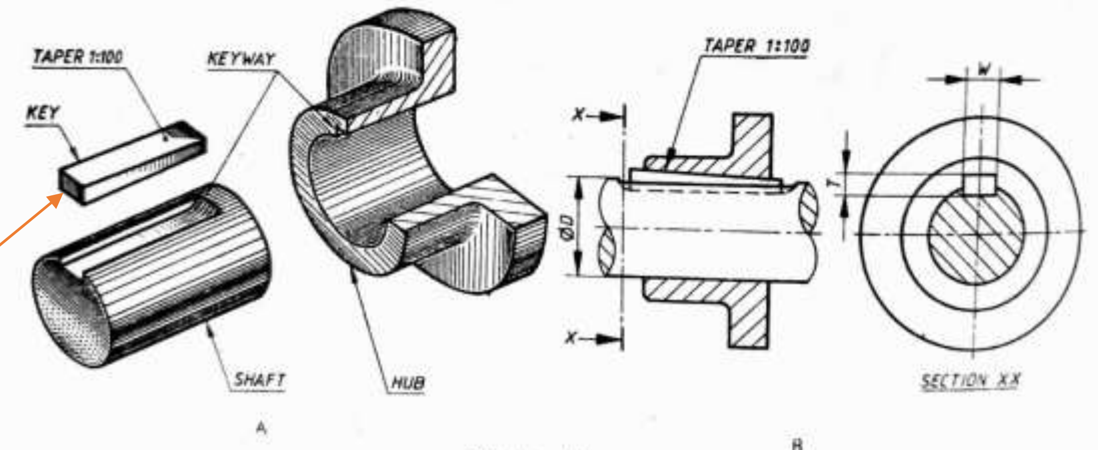
- ✓ For fillet welds, either the throat thickness ‘a’ or the leg length ‘z’ are indicated.
- ✓ In Fig. C: a5 ◺300 means that the weld is a fillet weld of throat thickness 5 mm and length of the weld is 300 mm.
- ✓ In Fig. D: z7 ◺ 300 means that the weld is a fillet weld of leg length 7 mm and length of the weld is 300 mm.

KEYS

- ✓ Keys are temporary fasteners.
- ✓ Keys are used to transmit power from the shaft to the parts to which it is connected.
- ✓ There is no relative rotation between them to effect the transmission from one to the other.
- ✓ Key will be driven such that it sits partly into the shaft and partly into the part mounted on it.
- ✓ To insert the key, *axial grooves*, called *key ways* are cut both in the shaft and the part mounted on it.
- ✓ While transmitting power, the key will be subjected to ***shear*** and ***crushing*** forces.
- ✓ Keys are extensively used to hold pulleys, gears, couplings, clutches, sprockets etc., and the shafts rigidly so that they rotate together.
- ✓ Keys are also used to mount the milling cutters, grinding wheels, etc., on their spindles.

uniform width

and tapering thickness



Key Assembly

TYPES OF KEYS

- ✓ Various types of keys are used for securing the hub of a pulley or a flange or a machine part over a shaft. They are:
- ✓ Sunk key (Taper sunk key, Parallel sunk key)
- ✓ Saddle key (Taper key)
- ✓ Flat key (Taper key)
- ✓ Gib-head key (Taper key)
- ✓ Feather key
- ✓ Peg key (Parallel or Feather key)
- ✓ Single head key (Parallel or Feather key)
- ✓ Double head key (Parallel or Feather key)
- ✓ Spline shaft (Parallel or Feather key)
- ✓ Woodruff key
- ✓ Pin key
- ✓ Cone key

CLASSIFICATION OF KEYS

- ✓ Keys are classified into *two types* namely:

  1. Taper keys

  - Taper key is of rectangular cross section having uniform width and tapering thickness.
  - Taper keys are used to transmit only the torque (turning moment) between the shaft and the hub without any relative rotational and axial motion between them.

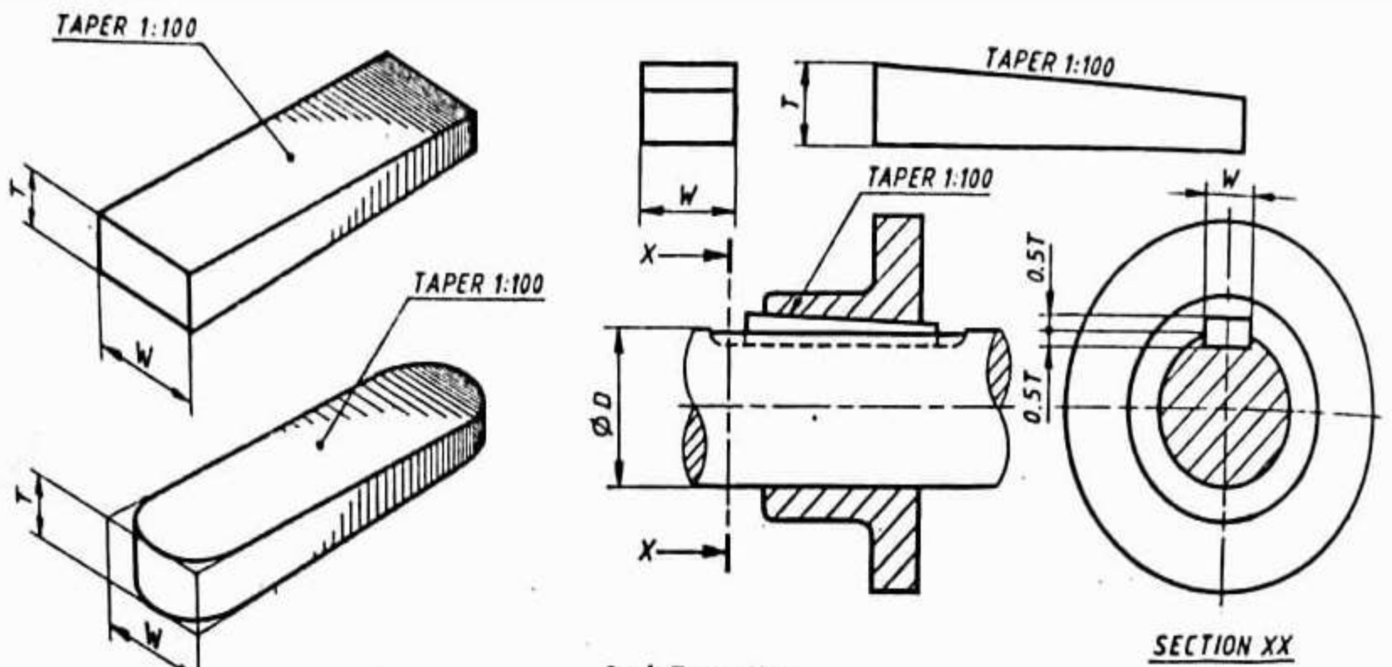
  2. Parallel or feather keys

  - Parallel key is also of rectangular cross section of uniform width and thickness throughout.
  - Parallel keys are used to transmit the turning moment between the shaft and the hub along with the provision to allow a small sliding axial motion between them wherever required.

- ✓ Woodruff key, cone key and pin key are the special purpose keys used for specific applications.

SUNK TAPER KEY

- ✓ It is of rectangular or square cross section of uniform width having its bottom surface straight and top surface tapered.
- ✓ This key is driven between the shaft and the hub with half of its thickness to fit in the flat key way made in the shaft and the other half having the tapered surface to fit in the tapered key way made in the hub.
- ✓ Used to transmit heavy loads.



Sunk Taper Key

If D = diameter of the shaft in mm, W = width of the key and T = thickness of key,

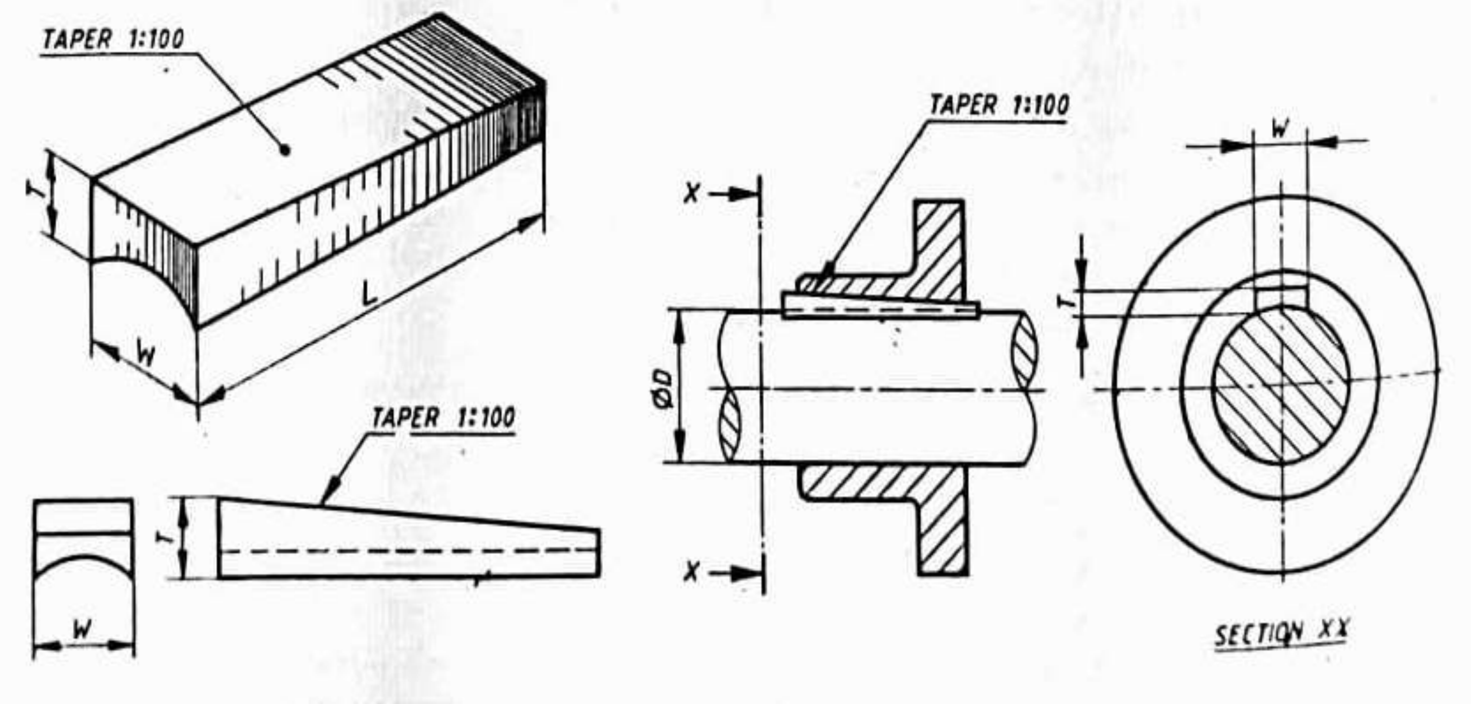
Width of key = 0.25 D + 2 mm

Nominal Thickness = 0.66 W

Standard Taper = 1:100

HOLLOW SADDLE KEY

- ✓ It is of uniform width but tapering in thickness having its upper side flat and the underside hollow so as to sit on a shaft.
- ✓ Since the saddle key holds the shaft and the part mounted on it only by friction, it is not suitable for heavy loads.
- ✓ This key is used when there is frequent alterations in the position of the key on the shaft is expected.



Hollow Saddle Key

If D = diameter of the shaft in mm, W = width of key and T = thickness,

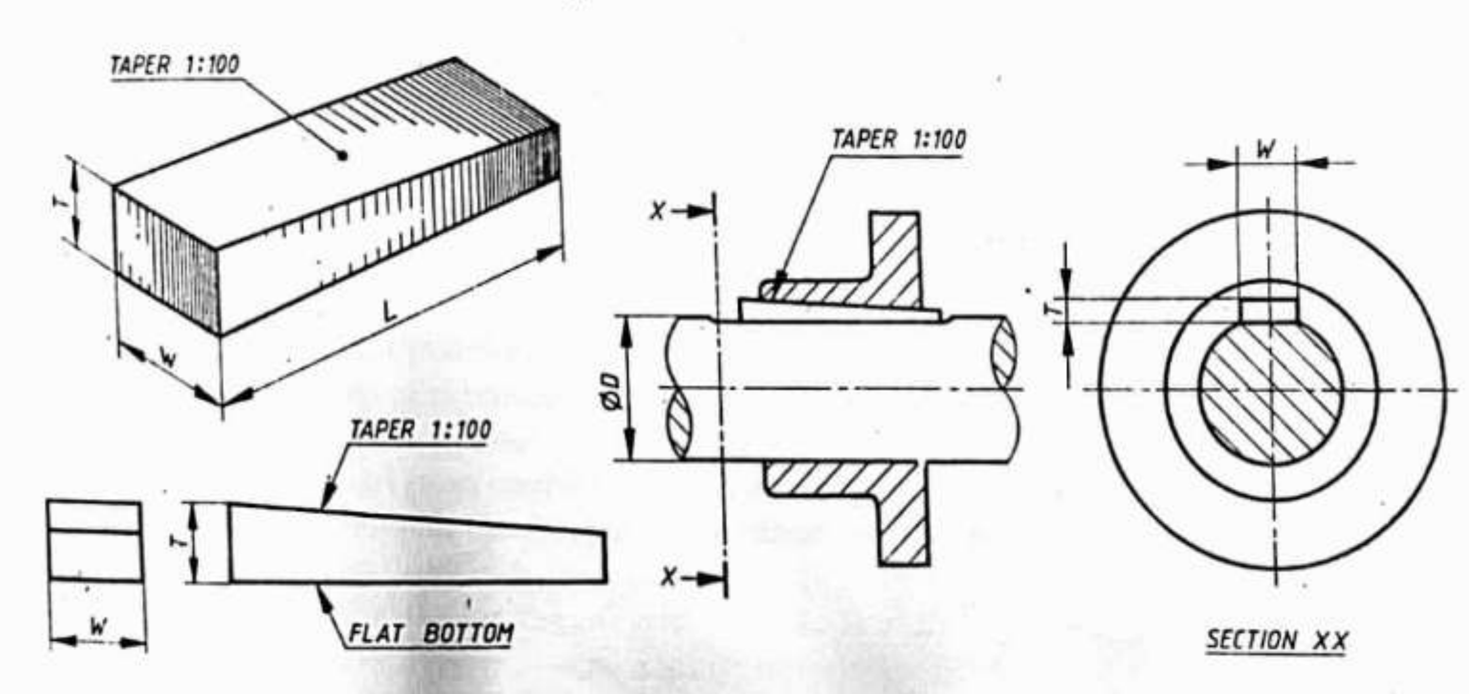
Width of key = 0.25 D + 2 mm

Nominal Thickness = 0.33 W

Standard Taper = 1 : 100

FLAT SADDLE KEY

- ✓ A flat saddle key is similar to a hollow saddle key, except its underneath surface is flat.
- ✓ The key sits over the flat surface formed on the shaft and fits into the key way in the hub.
- ✓ This key is not suitable heavy loads and cannot be used for shafts which frequently change their direction of rotation.



Flat Saddle Key

If D = diameter of the shaft in mm, W = width of key and T = thickness,

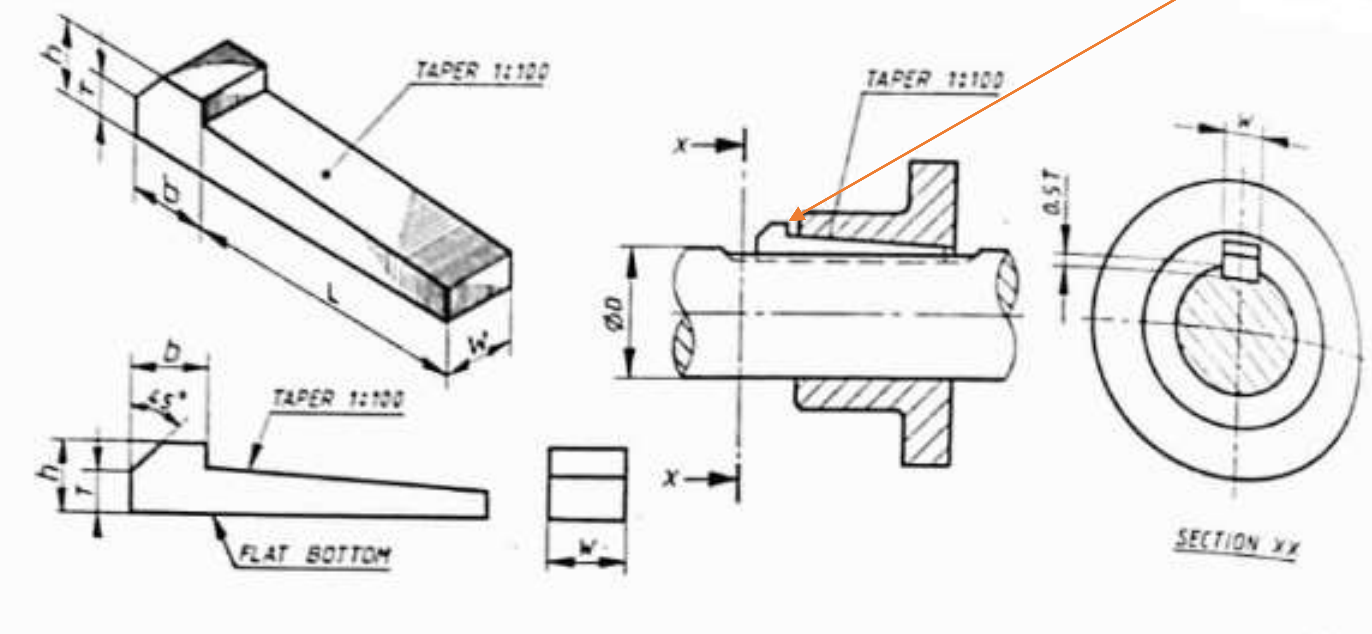
Width of key = 0.25 D + 2 mm

Nominal Thickness = 0.33 W

Standard Taper = 1 : 100

GIB-HEAD KEY

- ✓ When a tapered sunk key is used, it can be removed by striking at its exposed thin end.
- ✓ If this end is not accessible, a head called *gib* is provided integral with the sunk taper key at its thicker end.
- ✓ When a gib-head is to be removed, a *wedge* is forced vertically in the gap between the head of the key and the vertical face of the hub.



Gib - head Key

If D = diameter of the shaft in mm, W = width of the key, T = thickness of key, h = height of the head, b = width of the head.

Width of key = 0.25 D + 2 mm

Nominal Thickness = 0.66 W

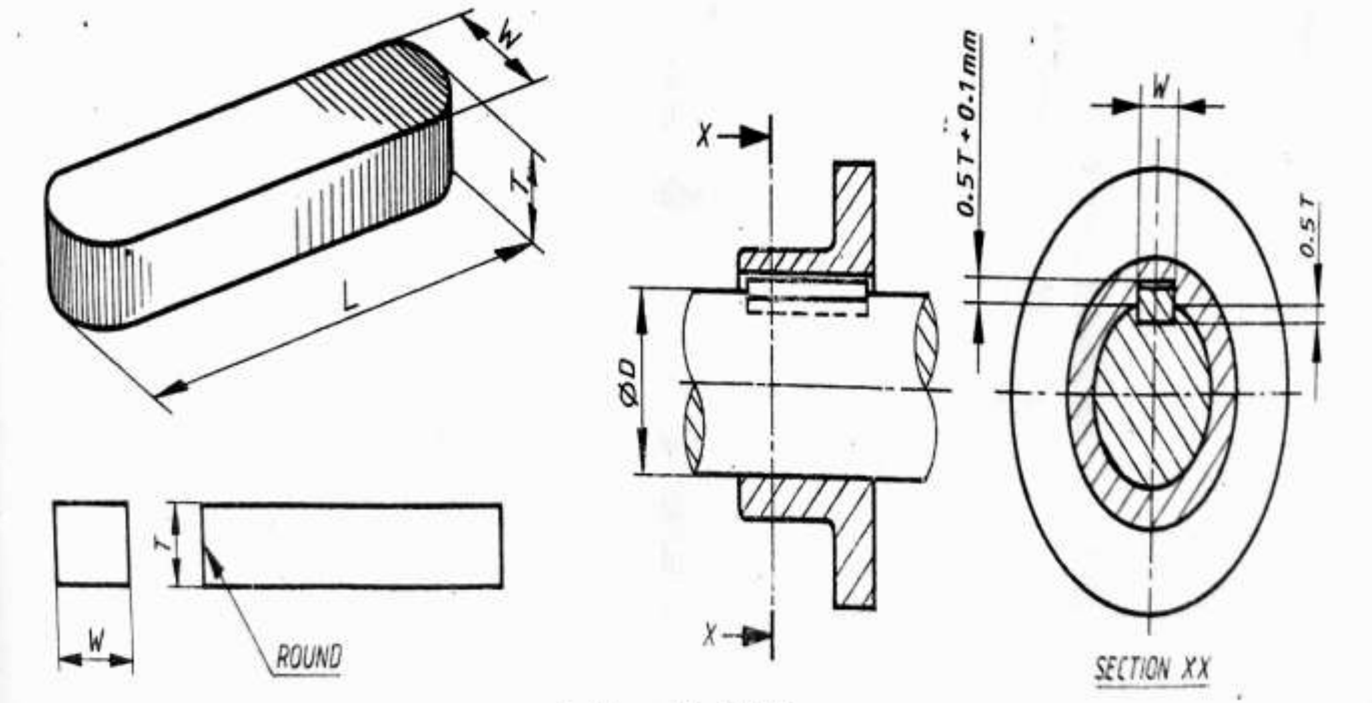
Standard Taper = 1 : 100

Height of Gib-head = 1.75 T

Width of Gib-head = 1.5 T

FEATHER KEY OR PARALLEL KEY

- ✓ A feather key or a parallel key permits an *axial sliding movement* for the wheel over a shaft when both of them are rotating together.
- ✓ This kind of arrangement is required in several power transmission applications like gear boxes, loose pulleys, clutches, universal coupling and flexible types of coupling.
- ✓ In a gear box, any one of the driven gears have to moved axially over the driven shaft so as to engage with the driving gear to obtain different speeds.



Feather or Parallel Key

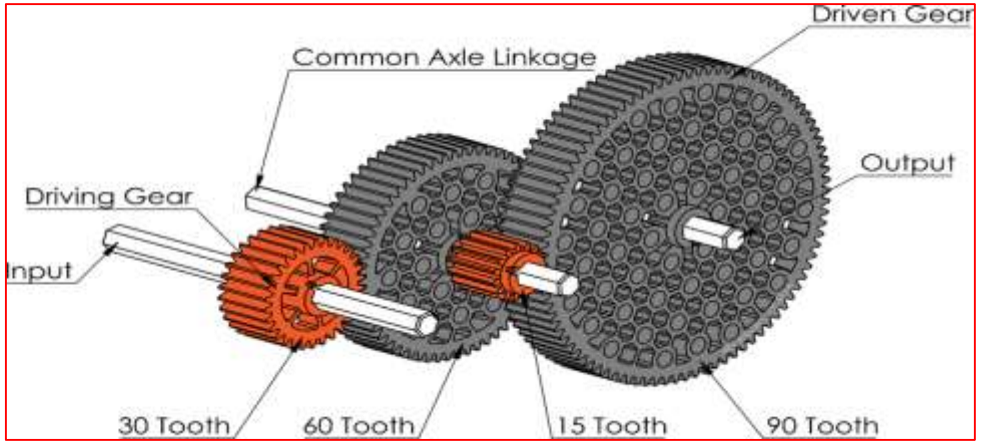
If D = diameter of the shaft in mm,

W = width of the key, and

T = thickness of key,

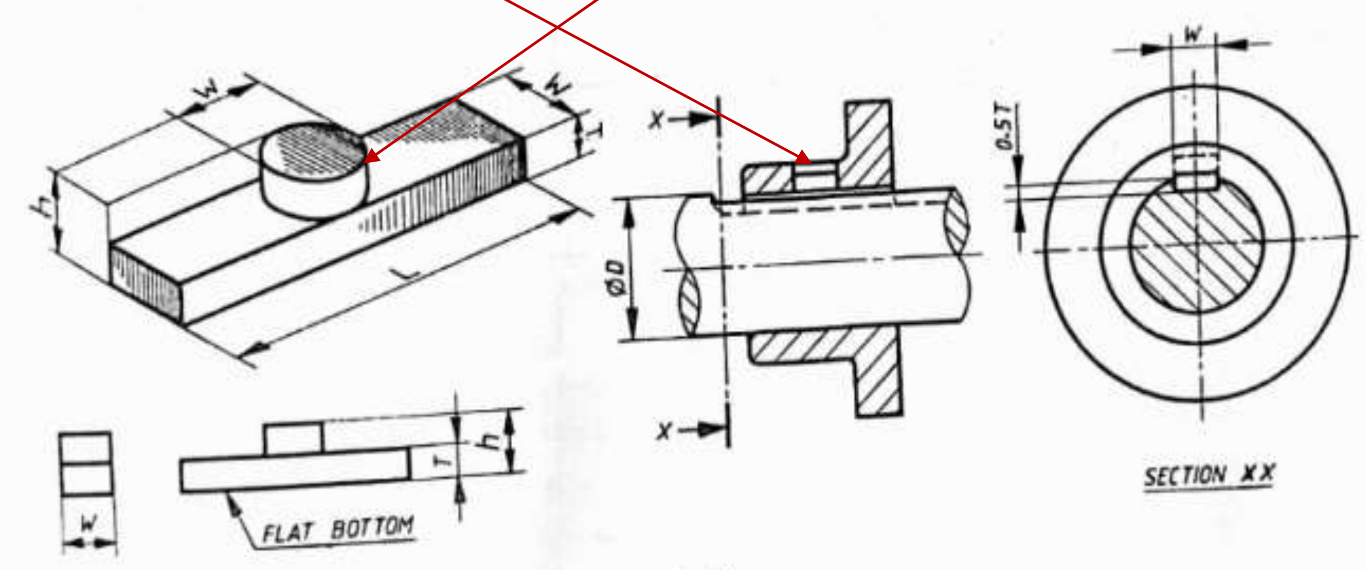
Width of key = 0.25 D + 2 mm

Nominal Thickness = 0.66 W



PEG KEY

- ✓ A peg key is a *feather* type of key having a peg provided in the center of the top face of the key.
- ✓ The peg fits in the hole drilled in the key way in the hub.
- ✓ The key is a sliding fit in the key way of the shaft.



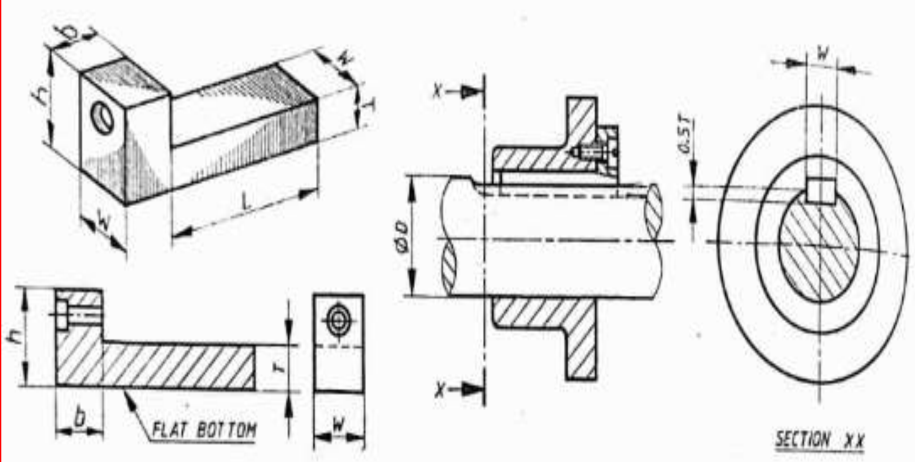
Peg Key

If D = diameter of the shaft in mm,
W = width of the key,
T = thickness of key,
h = thickness of peg,

Width of key = 0.25 D + 2 mm
Thickness of Peg = 0.5 T
Nominal Thickness = 0.66 W

SINGLE HEAD KEY

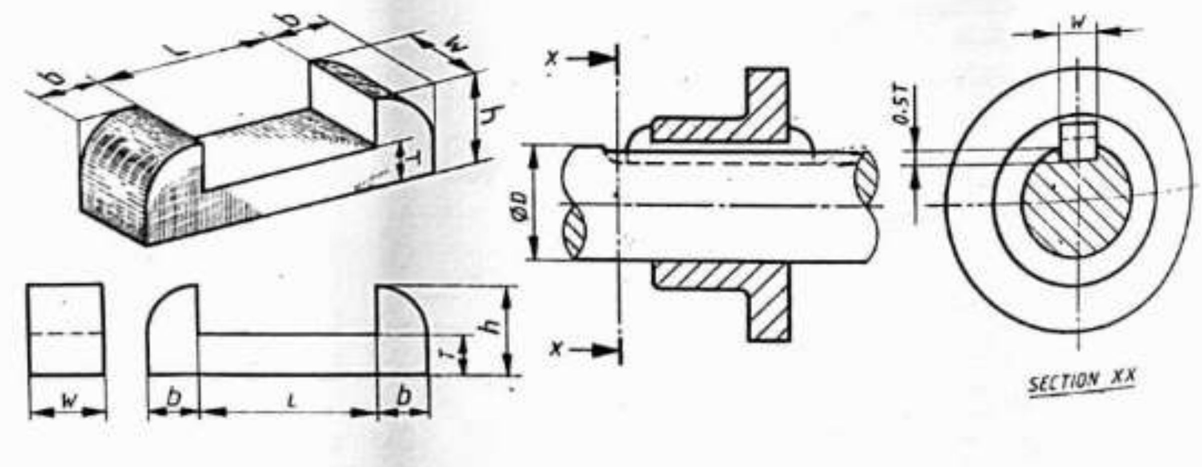
- ✓ A single head key is a *feather* key provided with a gib-head at one of its ends.
- ✓ The key is connected to the hub by a screw.
- ✓ The key is a sliding fit in the shaft.



Single Head Key

DOUBLE HEAD KEY

- ✓ A double head key is a *feather* key having integral gib-head at its ends.
- ✓ It fits tight in the hub and slides along with it in the key way in the shaft.
- ✓ The key is a sliding fit in the shaft.



Double Head key

If D = diameter of the shaft in mm, T = thickness of key, h = height of the head, b = width of the head.

Width of key = 0.25 D + 2 mm	Height of the head = 1.75 T
Nominal Thickness = 0.66 W	Width of the head = 1.5 T

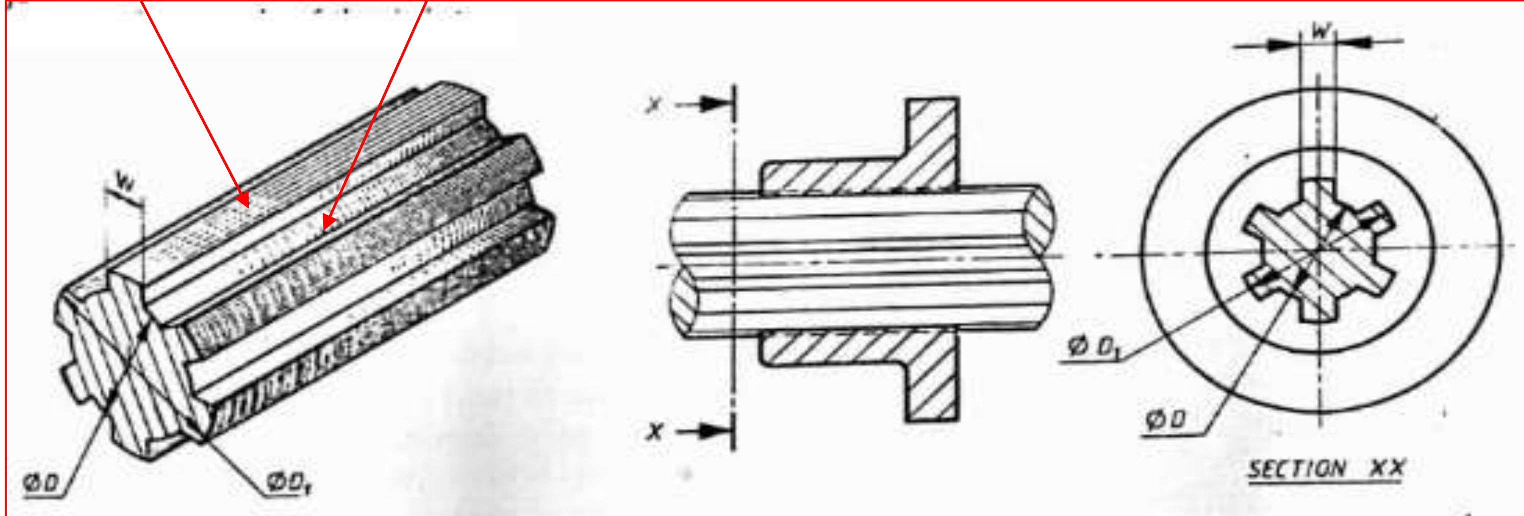
SPLINE SHAFT

- ✓ A spline shaft has a series of lengthwise rectangular grooves extending for a small portion of its length leaving an equal number of feathers in between them.
- ✓ These feathers engage with the corresponding recesses provided in the hub.
- ✓ **Advantages of spline shaft**

  - transmission of heavier loads.

  - accurate centering of hub.

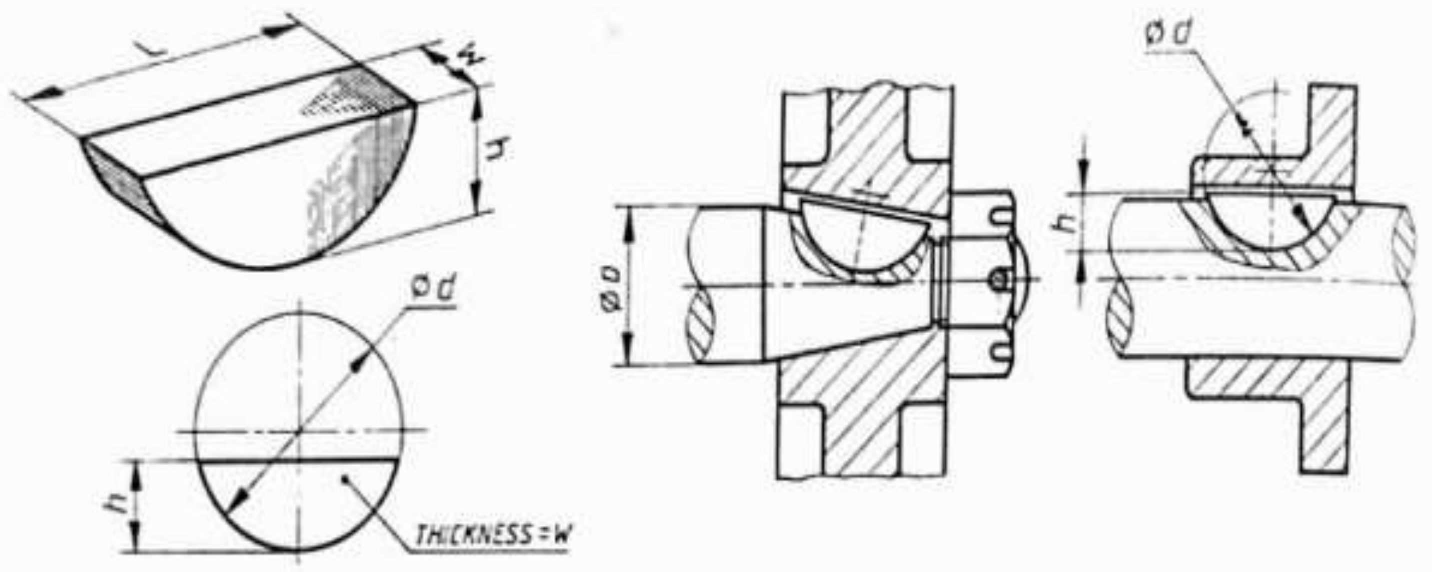
  - increased strength of the joint.



Spline Shaft

WOODRUFF KEY

- ✓ Used in light classes of work for holding the hub over the shaft so as to prevent it from slipping.
- ✓ It is not designed to withstand shear force.
- ✓ It has a uniformly thick curved-base of shape somewhat less than a semicircle.
- ✓ It fits into a similarly shaped key way in the tapered shaft or the spindle.



Woodruff Key

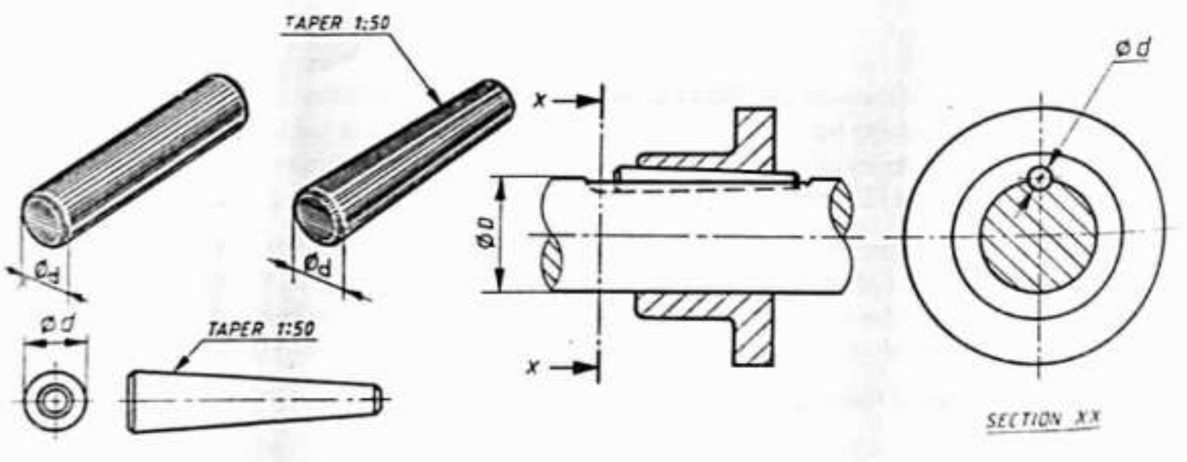
Width of key – 0.25 D

Diameter of key – 4 W

Height of key – 1.75 W

PIN KEY

- ✓ A pin key is either a plain or tapered rod driven in the hole partly drilled in the shaft and partly in the hub.
- ✓ Used generally to hold small toothed wheels, hand wheels, levers, etc., on the spindles to prevent them from slipping.
- ✓ It is also used with shrunk-on wheel hub.



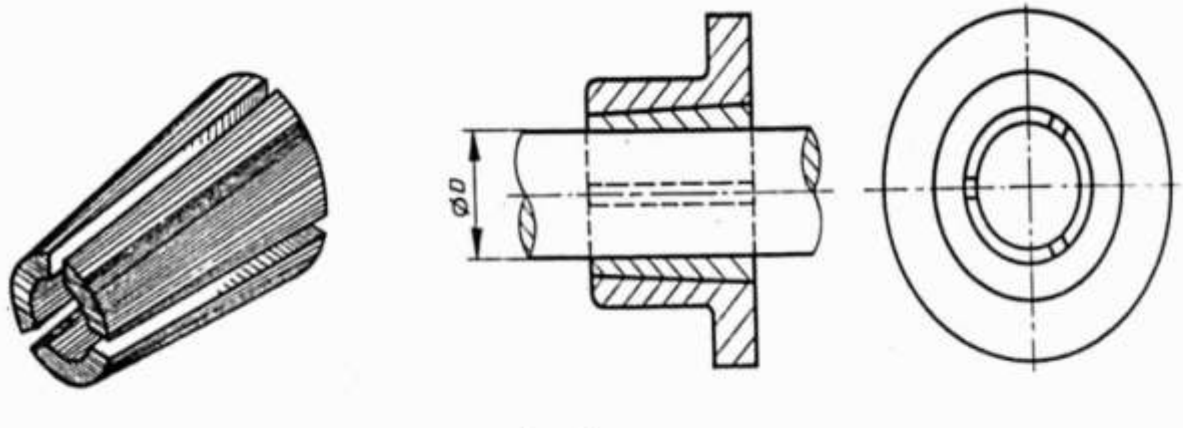
Pin Key

If D = diameter of the shaft, d = diameter of the pin,

Diameter of Pin = 0.2 D Taper 1 : 50

CONE KEY

- ✓ A cone key consists of three segments of a hollow conical bush.
- ✓ The hub of the pulley will have a tapered bore to suit that of the cone key.
- ✓ The segments of the cone key are driven between the shaft and the hub so as to hold them from slipping by the friction grip.
- ✓ Used when pulleys having holes larger than the shaft are to be mounted on them.



Cone Key