2. DRAFTING

• Drafting was previously a set of techniques (using compasses, angles, T-squares, etc.) for creating drawings that could be understood and used in manufacturing.

• More recently drafting is focusing less on techniques and more on conventions, because of CAD systems.

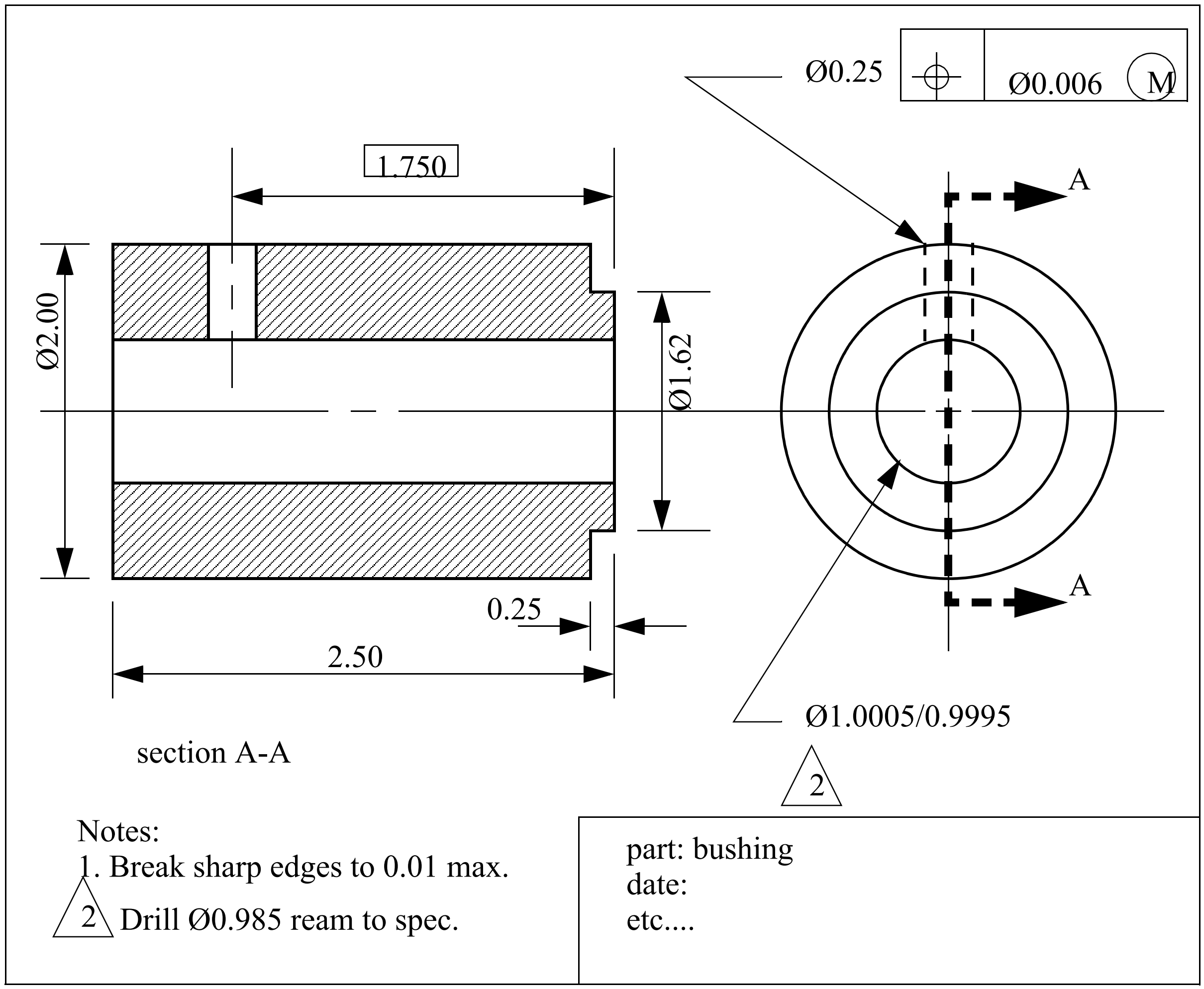
• The conventions of drafting are very important because they allow us to define parts in a way that they will be understood by any engineer, machinist, technologist, etc.

2.1 CONVENTIONAL DRAFTING

• The purpose of drafting is to present technical ideas in precise and concise forms.

• A properly drafted drawing should be understood by any engineer.

• A sample of a drafted drawing is given below.



2.1.1 Manual Drafting

• This is the use of drafting boards, pencils, pens, and a number of specialized tools for drafting. While this method is still very popular, the techniques used in manual drafting are quickly being displaced by CAD (Computer Aided Design) systems.

• I will not cover some of the manual drawing topics list below, but more information on them appears in a large number of drafting books.
   - lettering
   - hand sketching
   - drawing ellipses
   - etc

2.1.2 Turning Three Dimensions Into Two (Multi View Drawings)

• The problem with drafting is that the paper is flat, while the object drawn is not.

• To get around this we can develop a number of views to work with.
  - Front View
  - Top View (Plan View)
  - Right Side View
  - Left Side View

• This method of developing views is known as Orthographic projection

• This method eliminates the perspective distortion in real vision, thus making it easier for technical depiction.

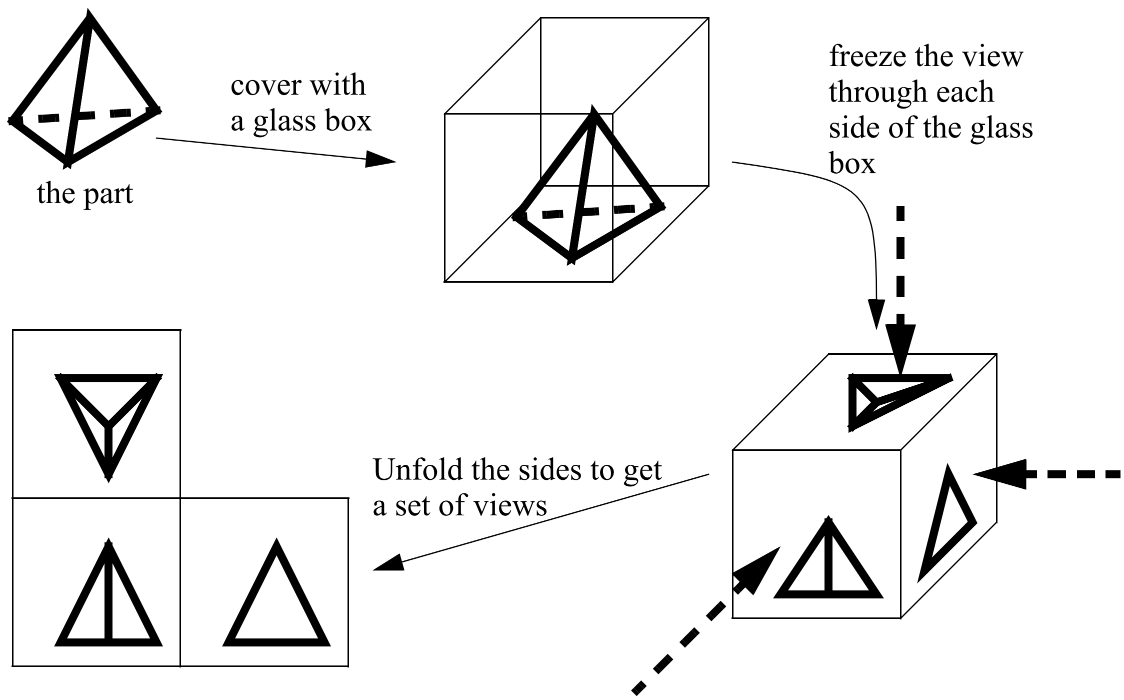
• In this method, object faces that are parallel to the viewing plane are shown as actual size, but objects that are not parallel are foreshortened.

• The number of views used is a function of the geometry. For a simple object such as a washer, only one view is needed. A more complicated object, such as a piston, would require at least two views.

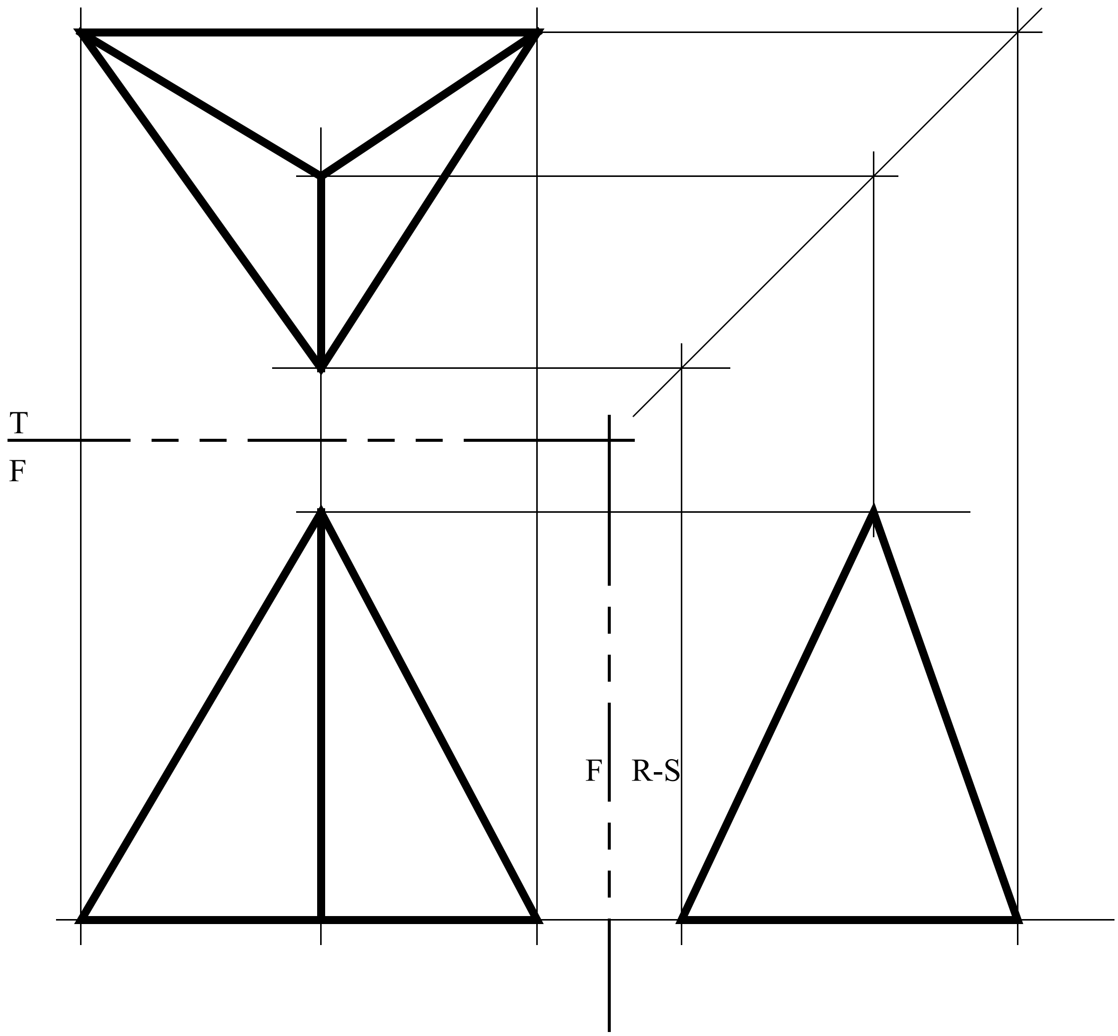
2.1.2.1 - The Glass Box

• The views are developed as if a glass box was placed over the object. The view from each direction was frozen, and when the box is unfolded, the resulting views are seen.

• Imaging the case below of a small tetrahedron (a three pointed triangle),

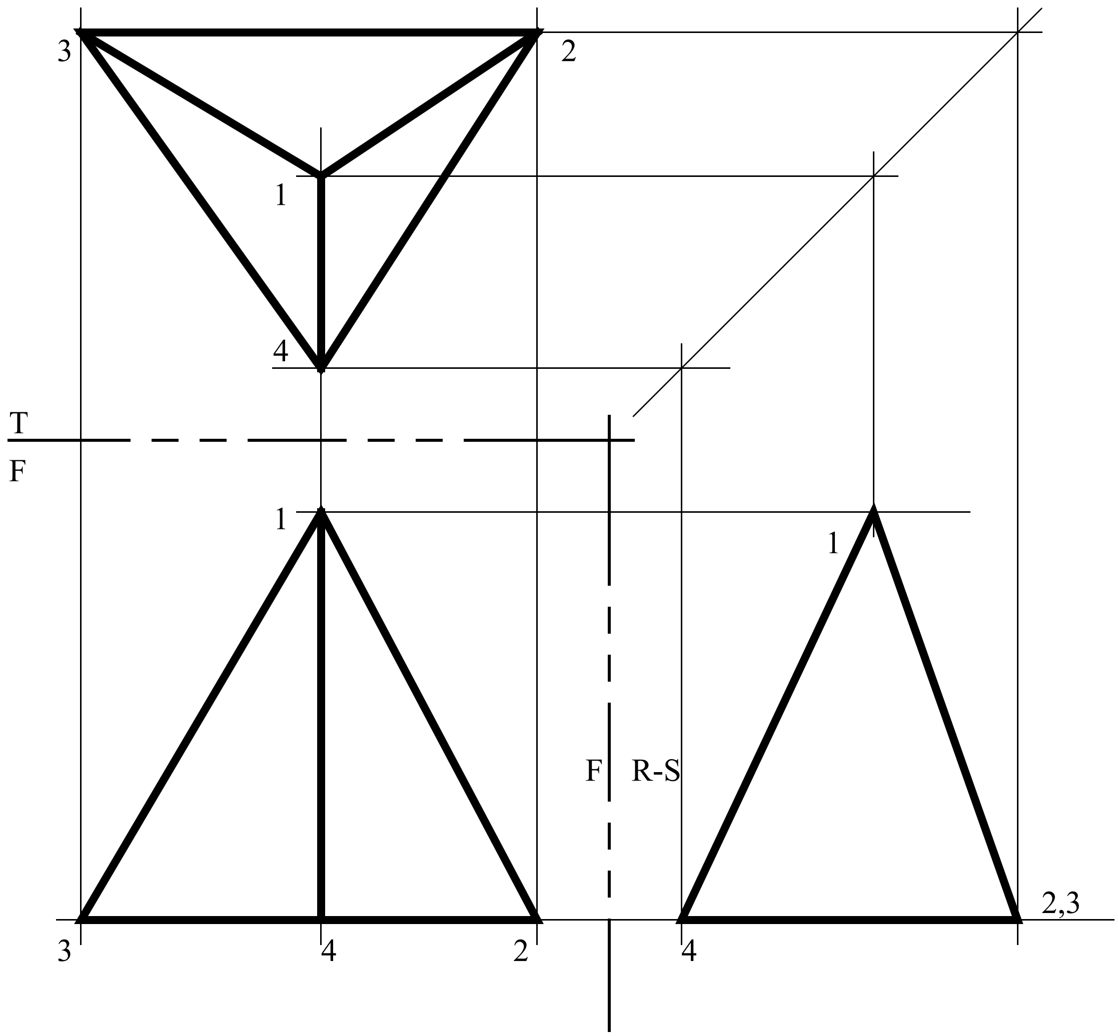


• The drawings are layed out with certain conventions. The example above is continued below for illustration, In the figure extra construction lines are added to show how the drawings in the different views are related.Note that the top view is related to the side view using a 45° line. These properties are a result of the ‘glass box’ concept. The folding lines are often shown on drawings (they have two dashes and one long). Also note that in the figure shown below, the points in the top view will be the same distance from the folding line as they are in the side view.



• The layout of the drawings is done by convention. In this drawing the right side view is to the right of the front view. If this drawing observed european standards, the right side view would be on the left hand side.

• A useful method for keeping the large number of points in a drawing sorted is to number them. For example,



• The view that is selected as the front is arbitrary, but it should
- be a natural front to the object.
- be the most important view
- appear stable
- chosen to minimize hidden lines in other views
- contain most of the detail

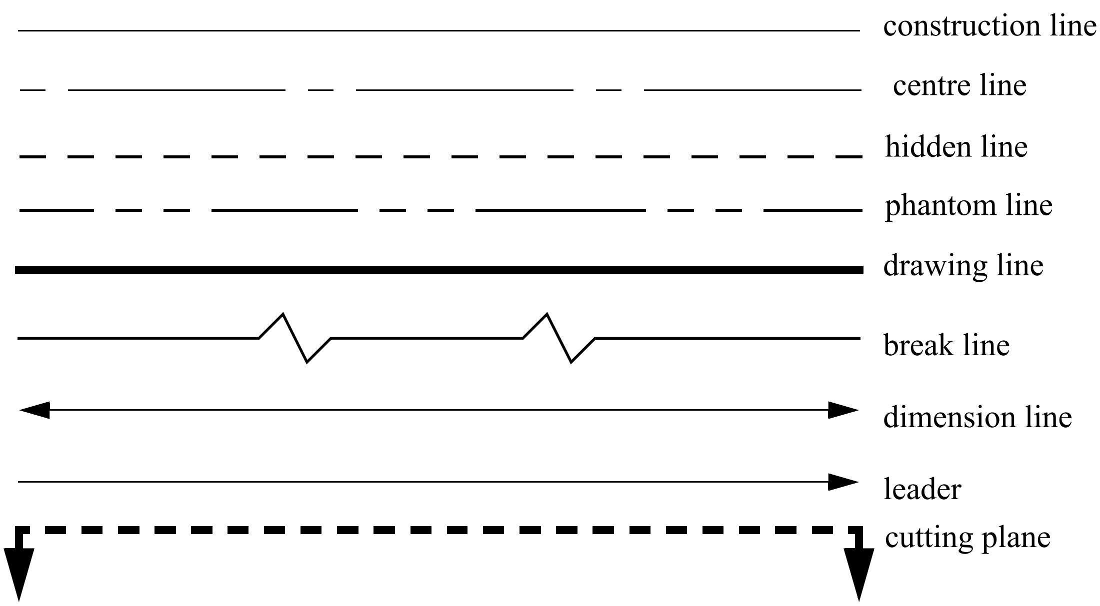
2.1.3 Lines

• The number of lines on drawings will become confusing, therefore this calls for some method for differentiating between lines.

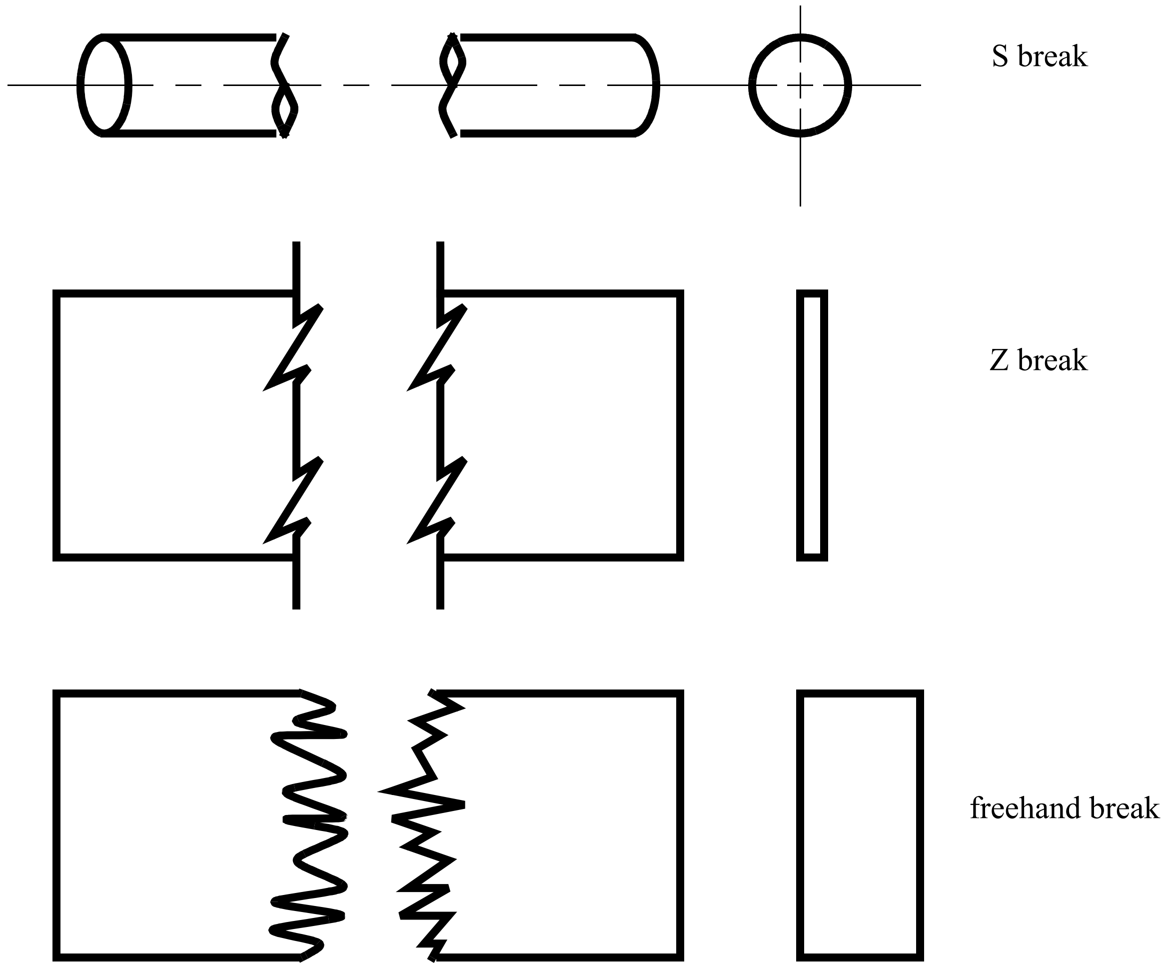
• Hidden lines are dashed lines used to show lines that not visible.

• Centre lines are used to show the axis of rotation for an object surface. These lines have long/ short dashes.

• Construction lines are drawn on to help locate final drawing lines. These lines are so light that they are often not even erased when the drawing is complete.

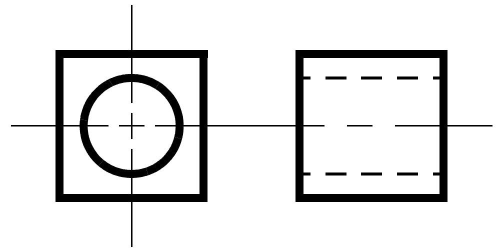


• Some objects have disproportionate dimensions. As a result, it may be necessary to 'break' them to show any reasonable level of detail. There are three types of breaks commonly used,
- S breaks - for round objects
- Z breaks - for thin long/wide objects
- freehand breaks - for long rectangular objects

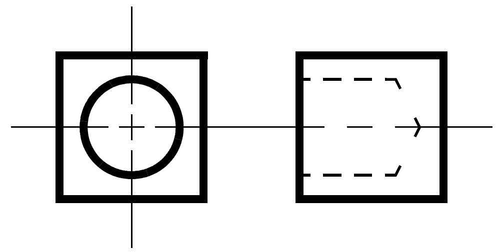


2.1.4 Holes

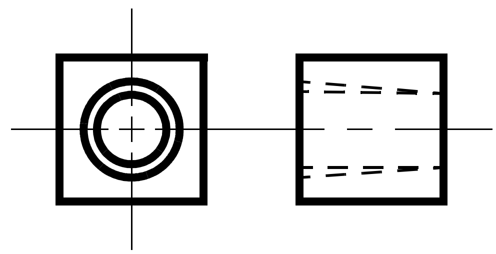
• There are a number of holes commonly depicted in drawings, Through Holes - these are cut all the way through an object



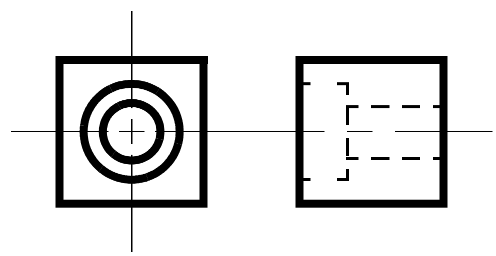
Blind Holes - these holes stop part way through an object



Tapered Holes -



Counterbored Holes -

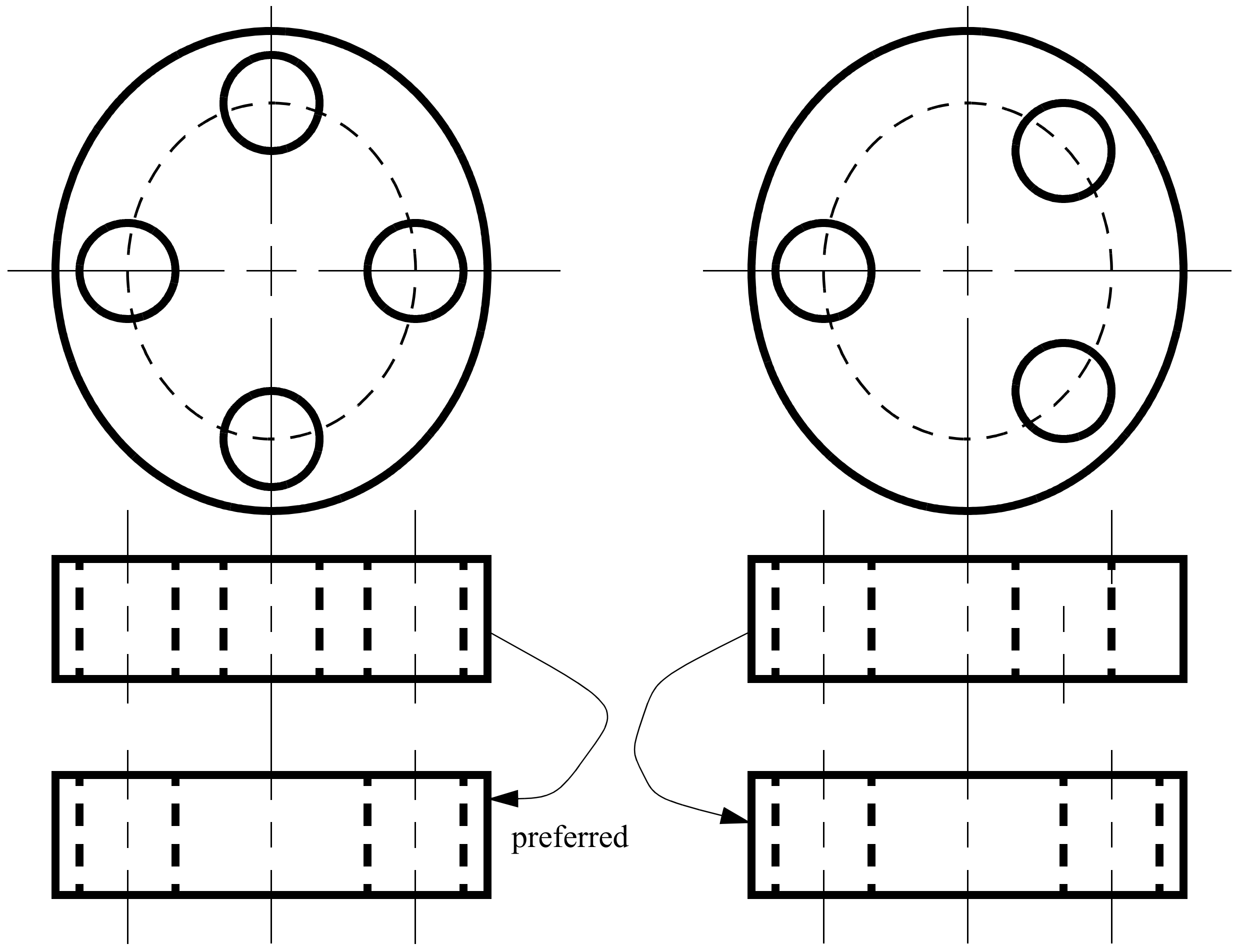


2.1.5 Special Cases

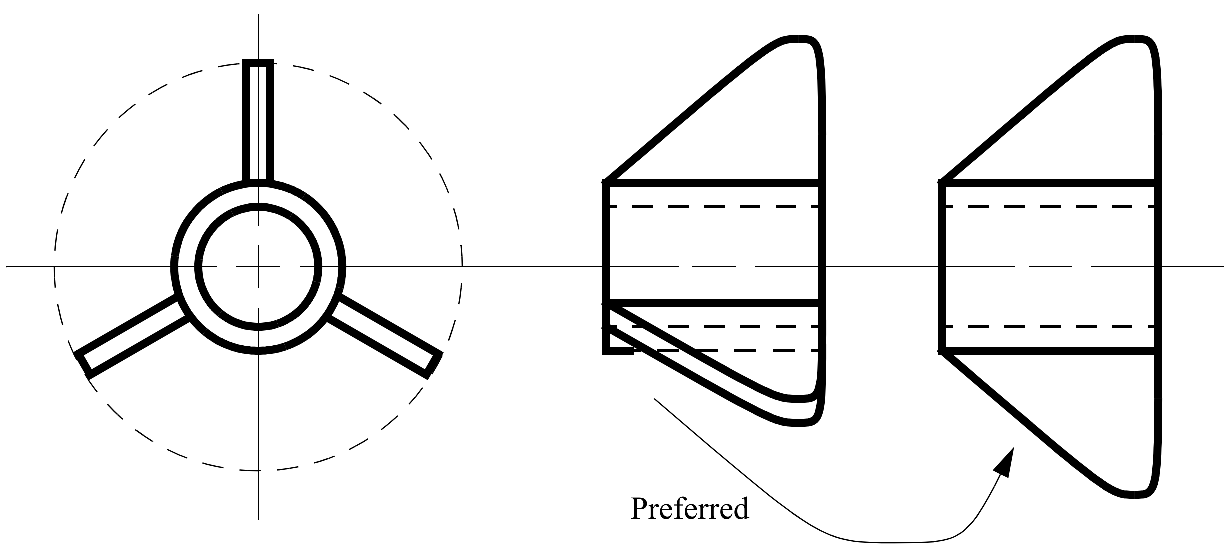
2.1.5.1 - Aligned Features

- Aligned features - in some cases, features are revolved, and shown at a consistent radial distance, but not necessarily in the correct position.

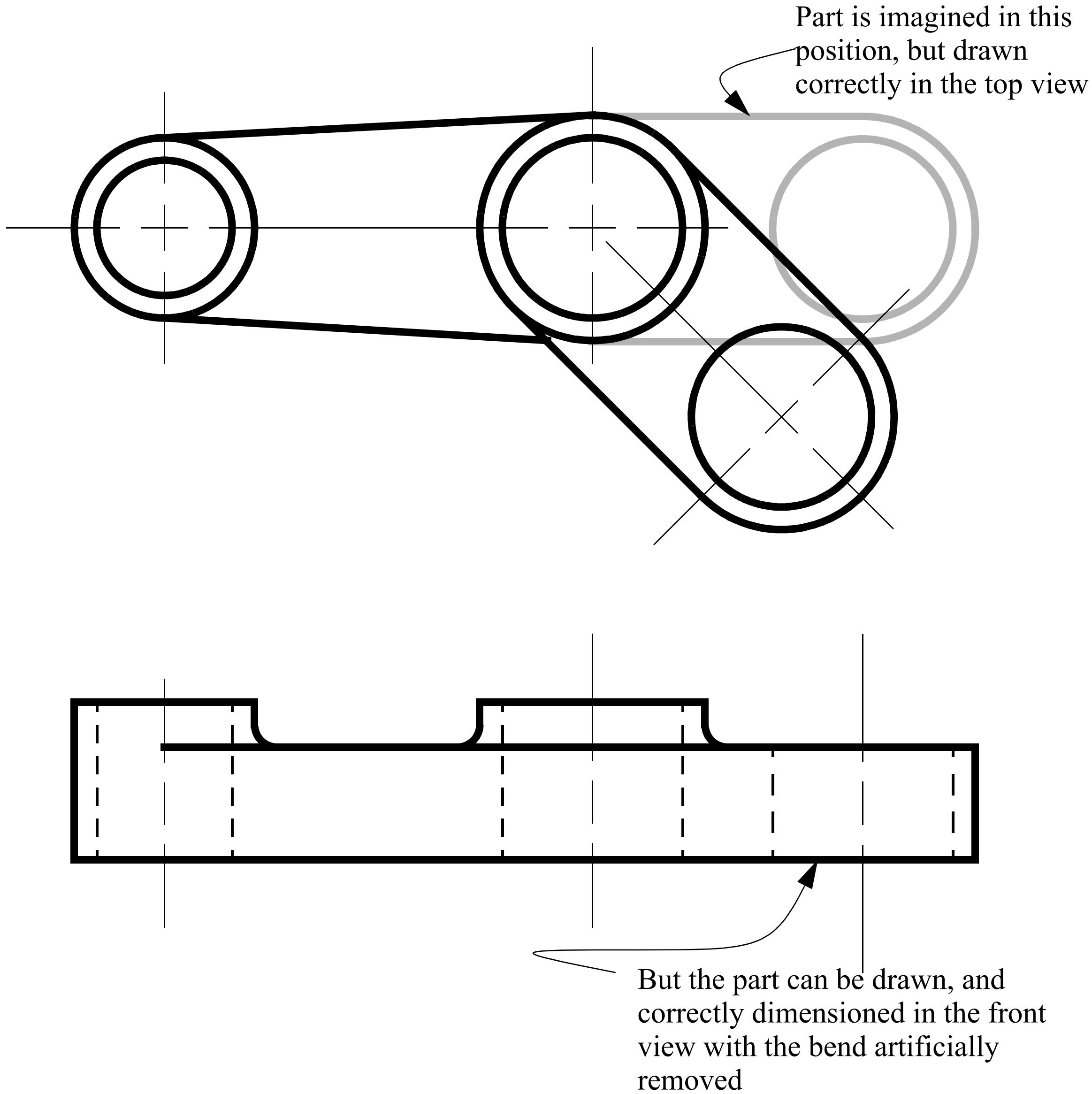
- Holes are commonly rotated to simplify views



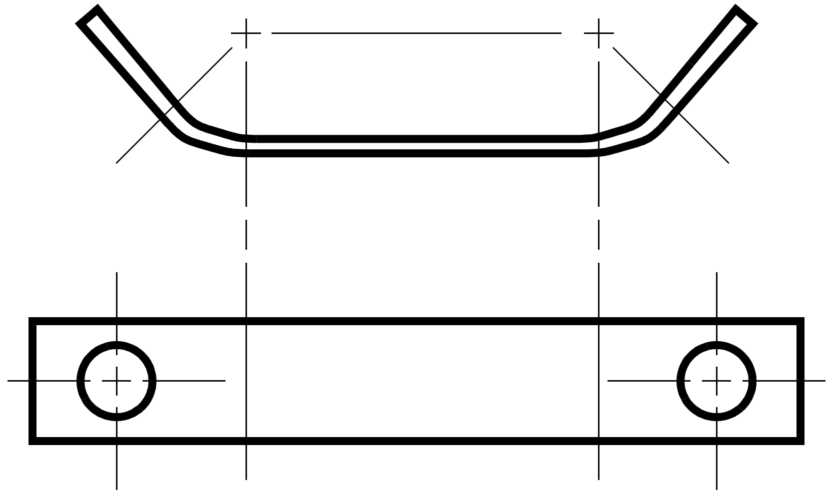
• Ribs and wings are commonly rotated to simplify views



• Large features on parts may be rotated to simplify views. small features, such as slots may also be rotated between views for clarity.



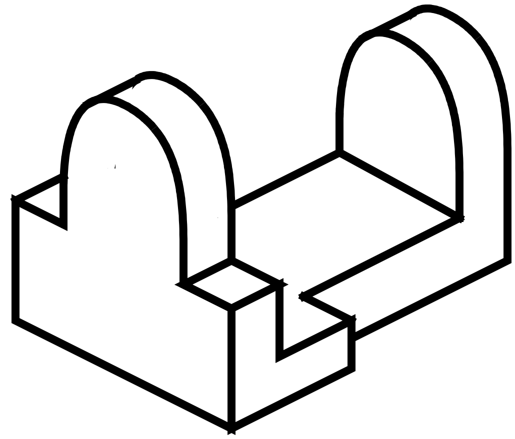
• Sheet metal parts start out flat, but are deformed to new useful shapes. Therefore it is common to draw sheet metal parts in the deformed, and the undeformed state.

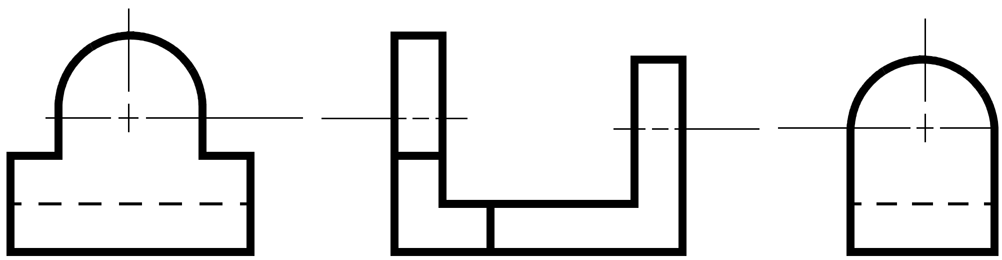


2.1.5.2 - Incomplete Views

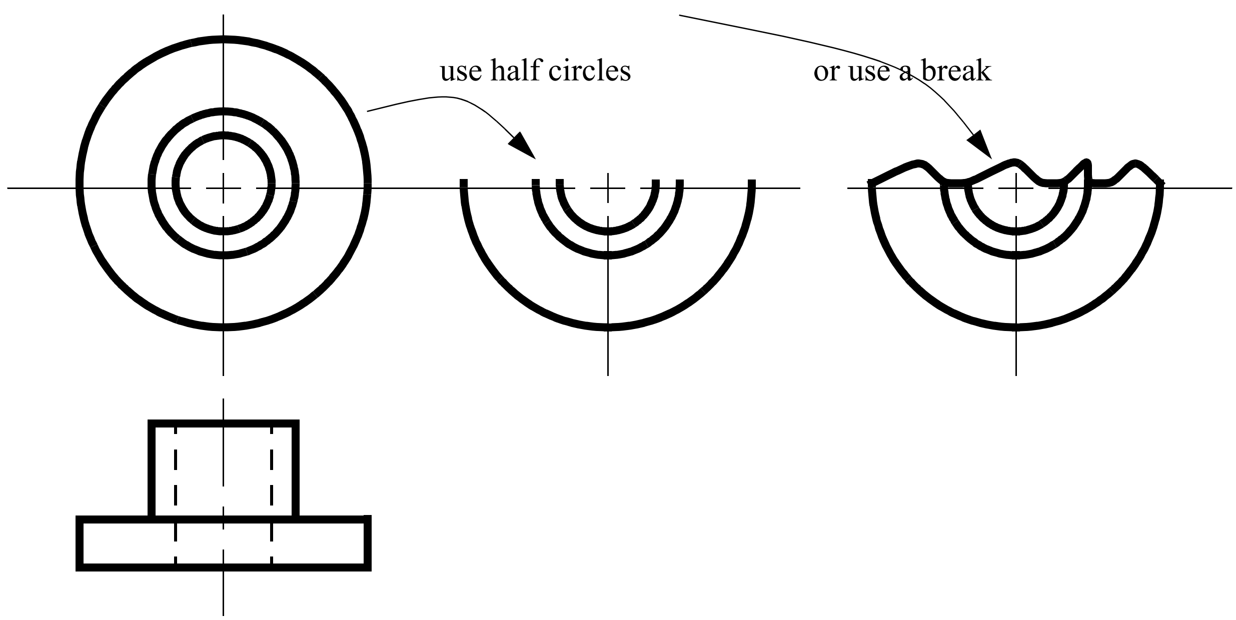
- Incomplete views - certain details can be omitted to simplify the view. This method produces drawings that are not correct, but they are commonly used in practice.

- Some views will end up having an excessive number of hidden lines. To combat this problem, we may sometimes just leave them out.





• Large radial/cylindrical parts are often cropped to save space. But, enough is shown to make the remainder of the geometry obvious.



2.1.6 Section Views

• when there are complicated internal features, they may be hard to identify in normal views with hidden lines. A view with some of the part "cut away" can make the internal features very easy to see, these are called section views.

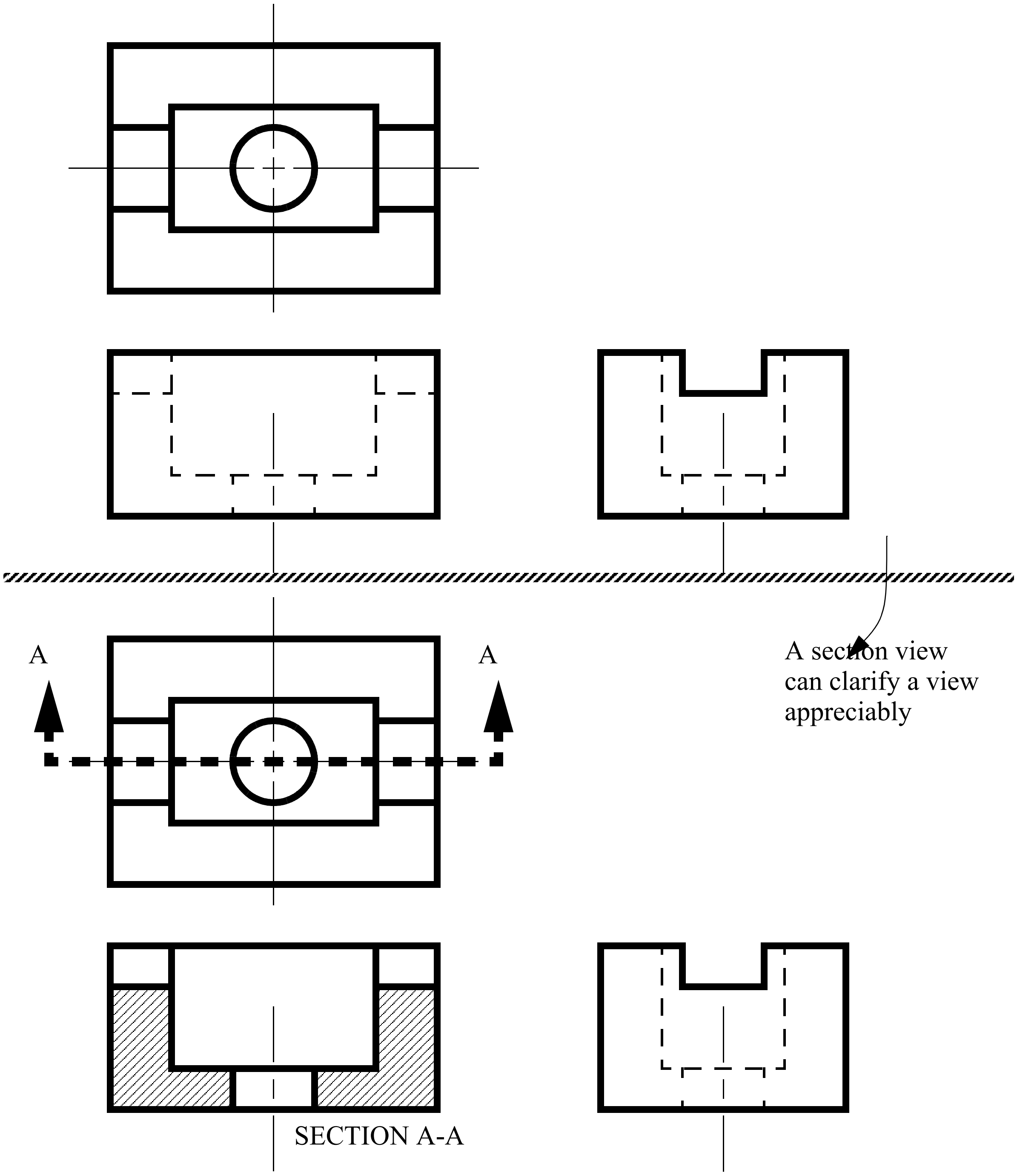
• In these views hidden lines are generally not used, except for clarity in some cases.

• The cutting plane for the section is,
  - shown with thick black dashed lines.
  - has arrows at the end of the line to indicate the view direction
  - has letters placed beside the arrow heads. These will identify the section
  - does not have to be a straight line

• sections can be lined to indicate,
  - when the section plane slices through material
  - two methods for representing materials. First, use 45° lines, and refer to material in title block. If there are multiple materials, lines at 30° and 60° may be used for example. Second, use a conventional set of fill lines to represent the different types of materials.

2.1.6.1 - Full Sections

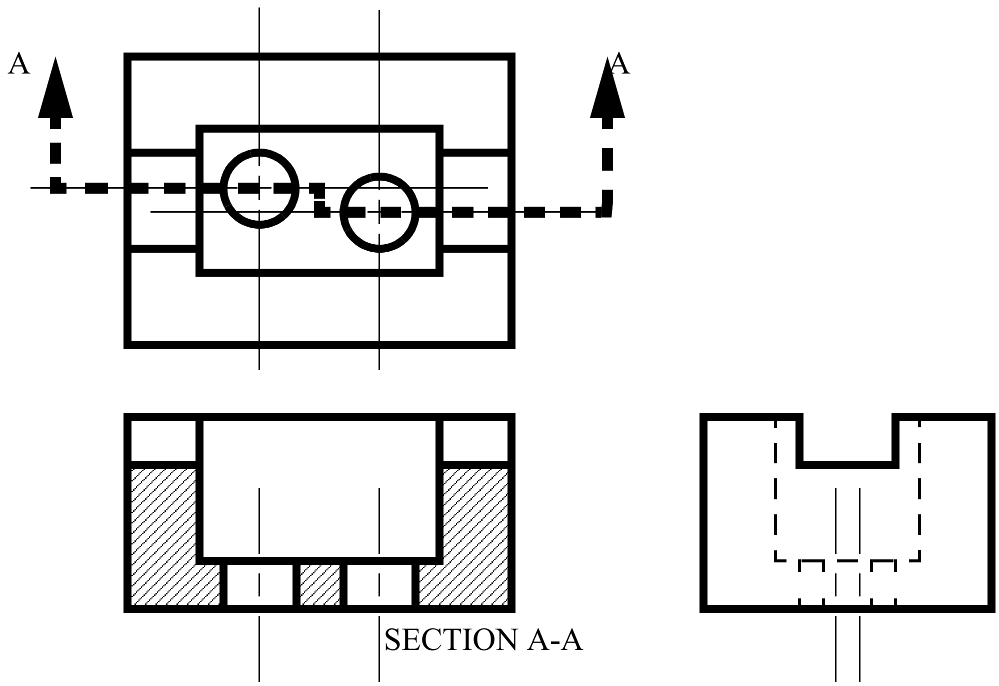
• Full sections - generally a straight section line cuts through a part to give a complete view of the inside. This section typically replaces one of the views that is confusing.



2.1.6.2 - Offset Section

• Full sections will experience difficulties when the features do not lie along a single line.

• We can use a section line that is turned to cut through features. This view can be used to replace one of the principle views.

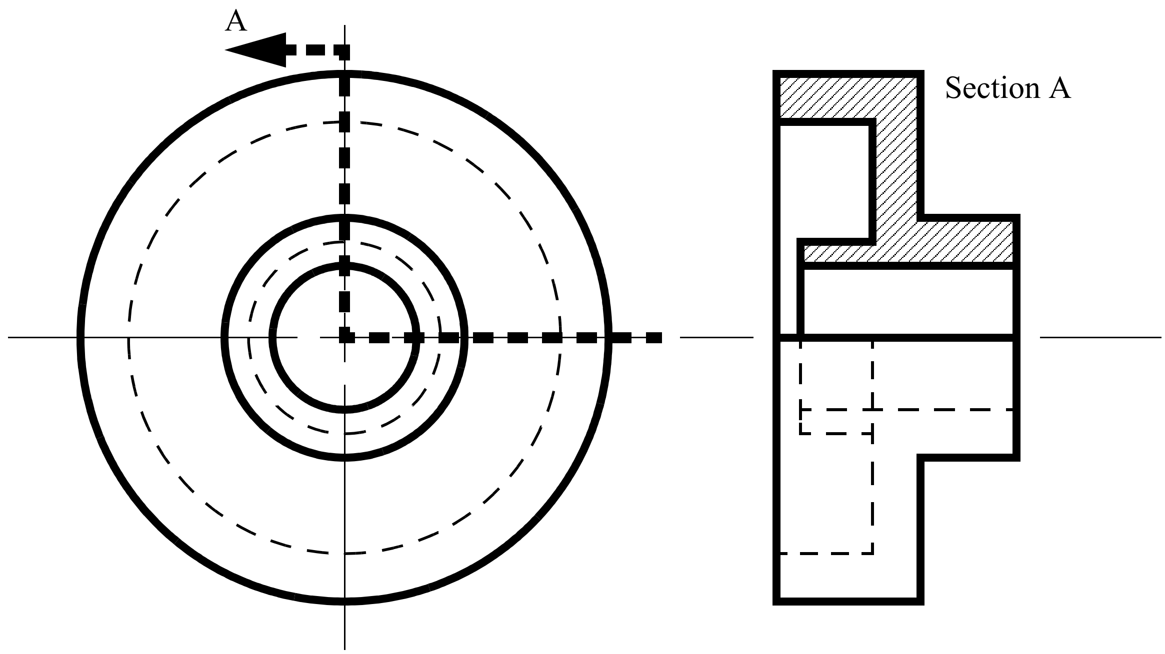


2.1.6.3 - Half Section

• In some cases it is better to illustrate internal features with both a section, and a full view. In this case we can cut away only part (a quarter) of the object, and draw a view that is half normal, half section.

• this method is well suited to symmetrical parts, with the section starting at the axis of symmetry

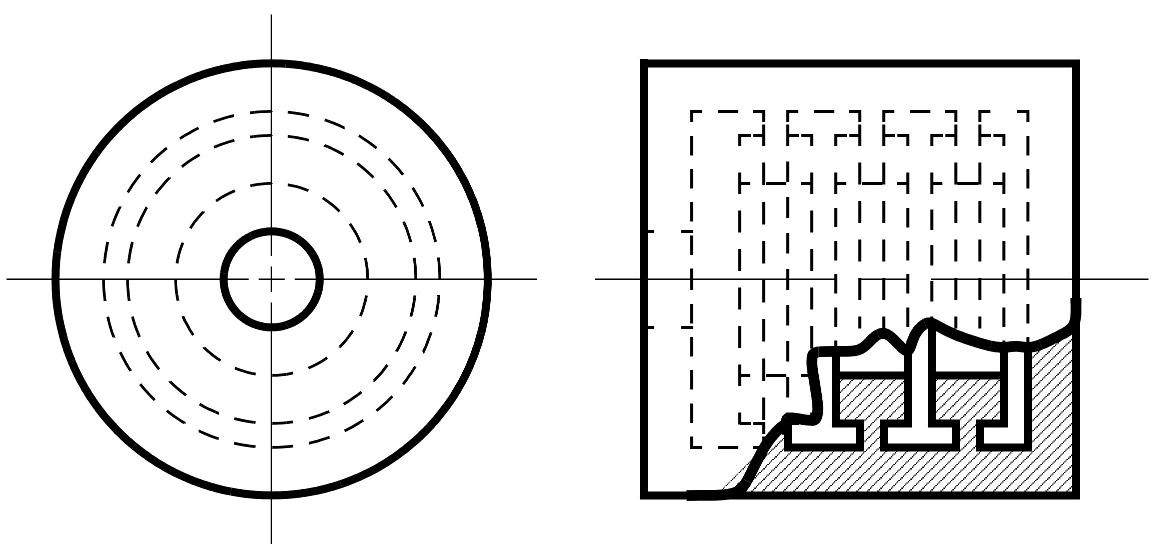
• Take note that the section line here only has one arrow head, but the direction must be observed



2.1.6.4 - Cut Away Sections

• Instead of doing large scale sections, we can cut away a very specific region of interest.

• In this case a break line is used, and the cutting plane lines used in other cases are not applicable.



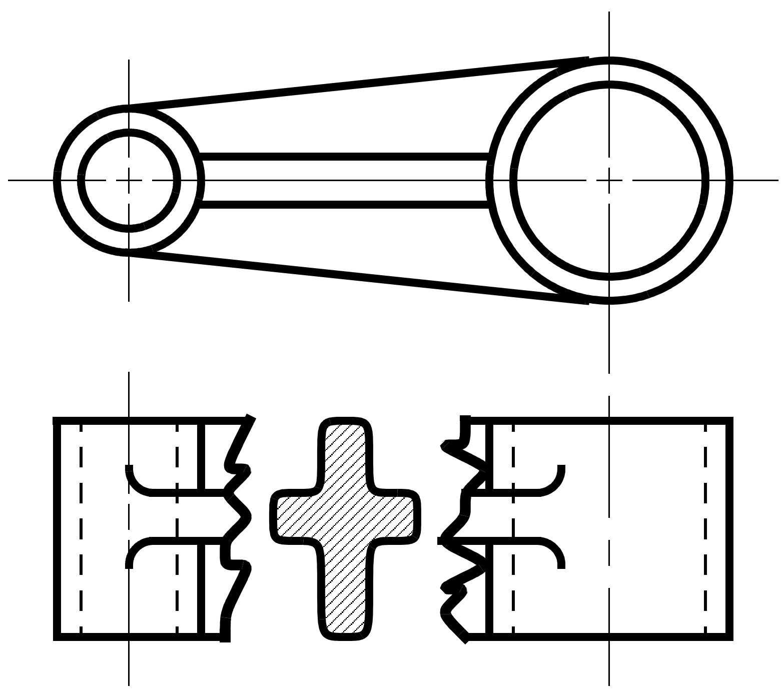
2.1.6.5 - Revolved Section

• When we have transition pieces, such as ribs, or airplane wings, we will want to show the shape, but this is not easy with conventional views, In this case we can break out a section.

• The basic procedure is to
  1. select a characteristic section, and draw cut lines to either side.
  2. in between the breaks, draw a section that is rotated 90° so that it is obvious on the drawing.

• This method is useful when space is at a premium

• The cutting plane line is not used with this technique



2.1.6.6 - Removed Section

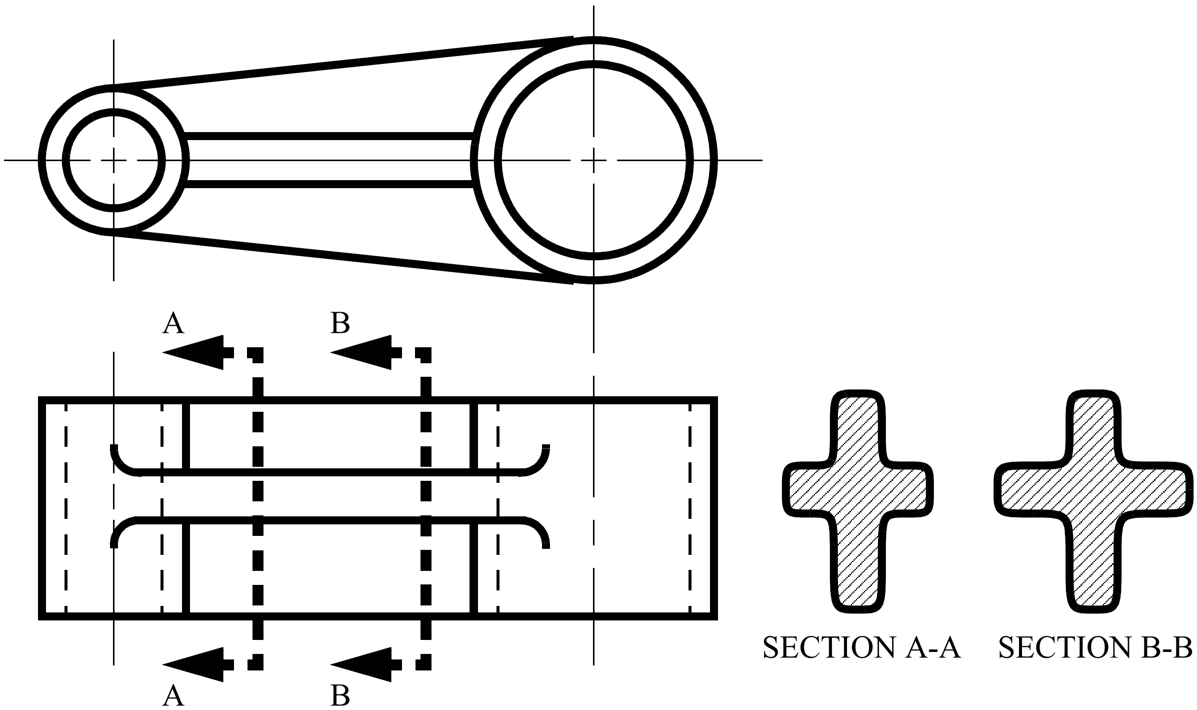
• this is a more exact alternative to the revolved section method.

• With this method a break is not used, but a cutting plane line is. The sections are then drawn at some other location on the page.

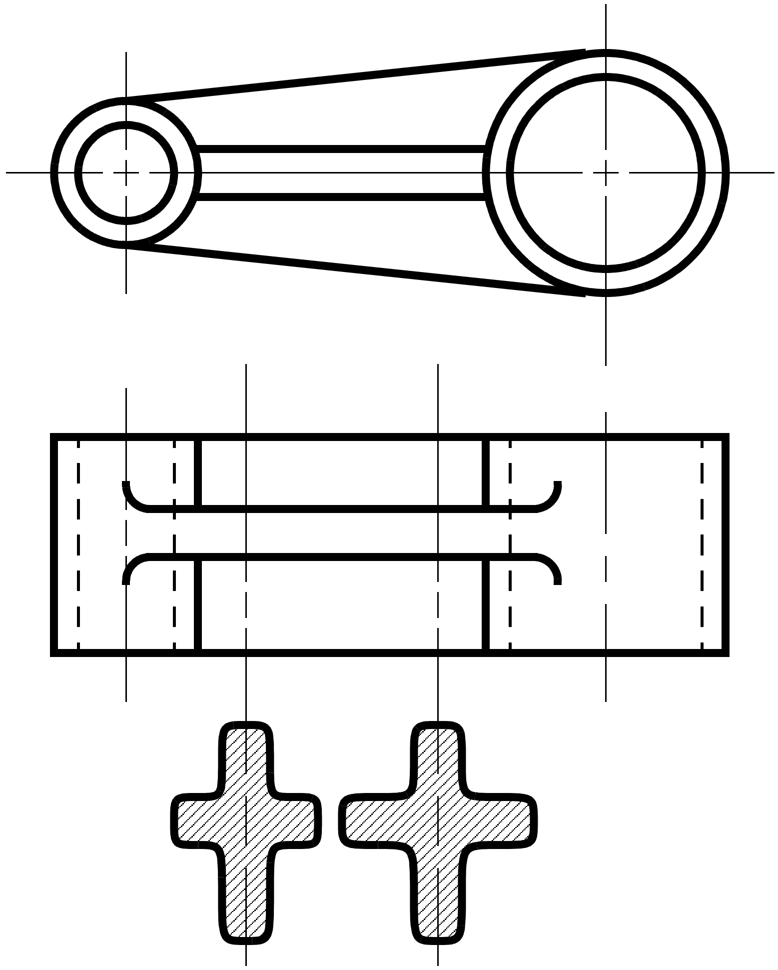
• The only features shown are the features of the section.

• labels such as A-A, B-B, etc are used to avoid ambiguity.

• these views are often placed at a distance and arranged in the same order as the sections.



• These section may also be shown using lines extended from the object

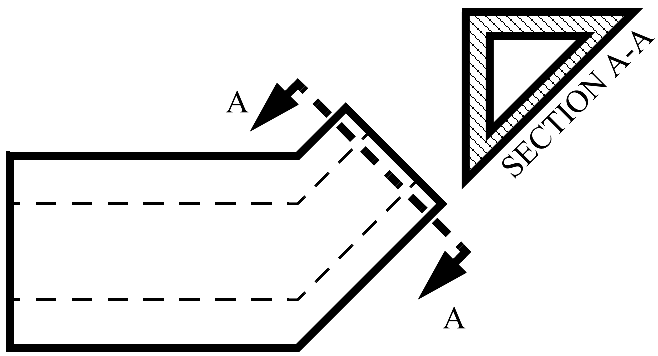


• modified scales may also be used with appropriate notation

2.1.6.7 - Auxiliary Section

• A section can be done that does not lie in one of the primary planes.

• This done as a normal section

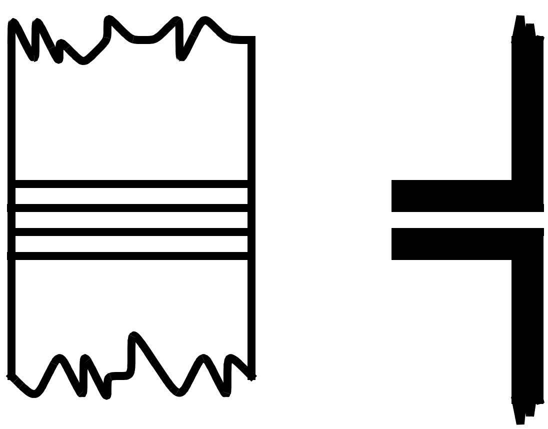


2.1.6.8 - Thin Wall Section

• This method is used for assemblies of thin materials, such as sheet metal.

• This illustrates how the pieces butt up against each other.

• The sections are filled with black, but a small space is left between the piece to indicate the assembled faces (operations such as crimping, spot welding, etc are used for these)

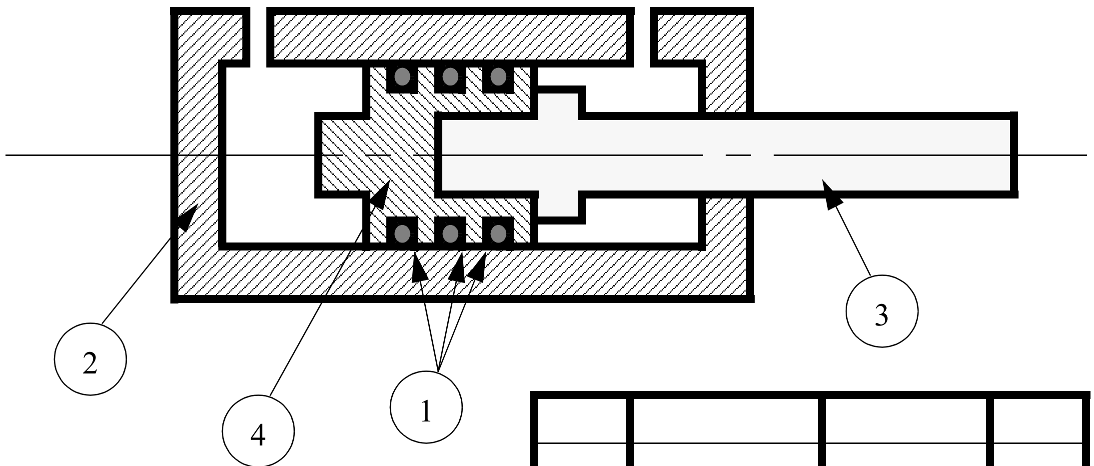


2.1.6.9 - Assembly Section

• When placing parts together we want to verify that they will match, and that they can be assembled. We also want to provide assistance to the assembler. To do this a cut away assembly drawing can be used.

• There are a number of elements present in these diagrams,

- two or more parts
- a parts list with numbered items
- generally section views are used, and oriented along the main assembly axis



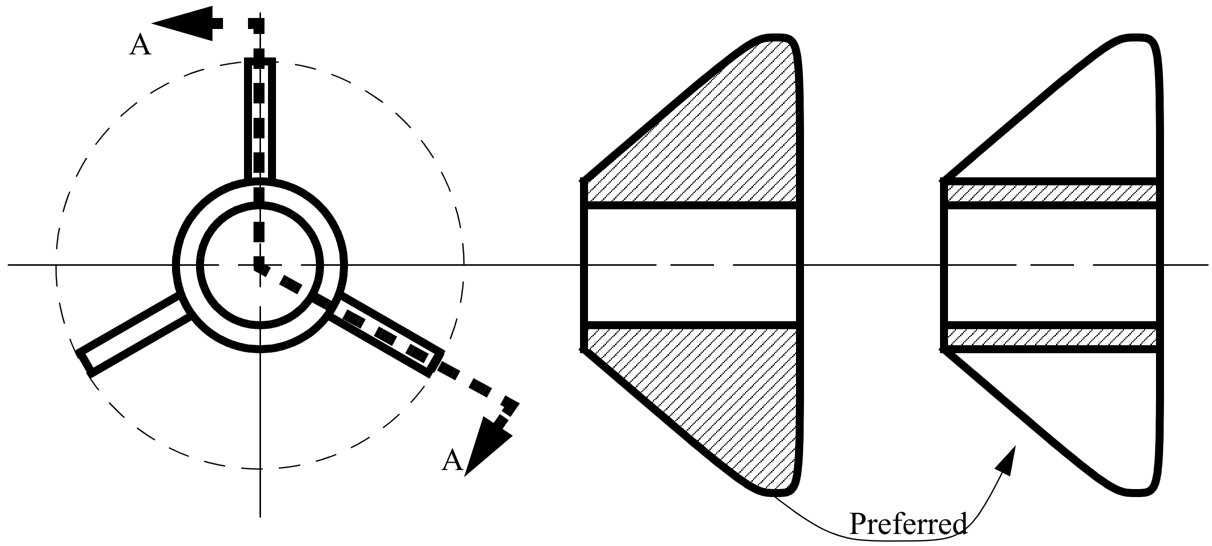
ref #	description	part #	qty.
4	piston	M8765	1
3	rod	M87101	1
2	chamber	M8734	1
1	o-rings	P8703	3

2.1.6.10 - Special Cases

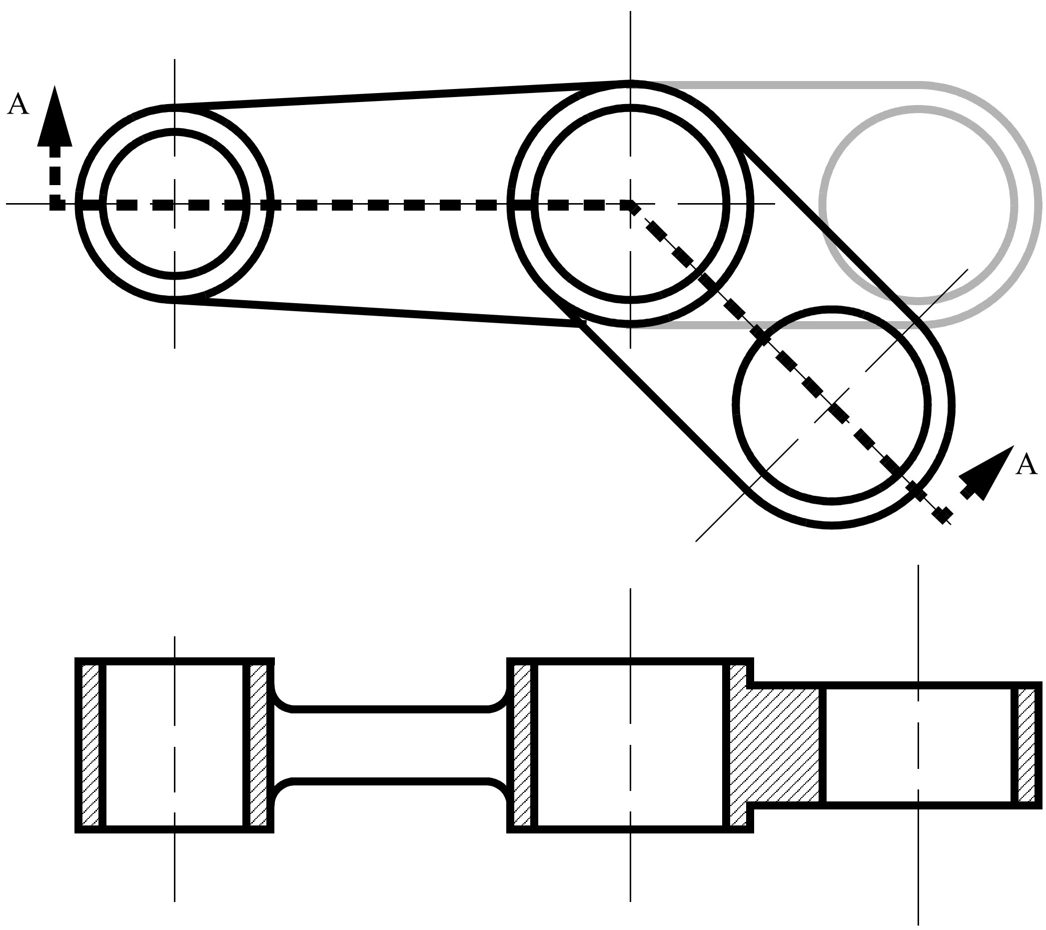
• Because sections are to clarify confusing features on diagrams, they are sometimes not theoretically correct.

• A few of the cases that are considered when working with sections are,

1. cutting lines may intersect ribs, but they may be drawn offset somewhat to clarify the rib geometry.



2. sections may be aligned to clarify the views

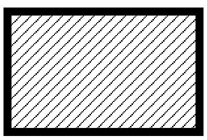


3. If a cutting plane cuts through intersecting features, the less important feature may be omitted for clarity, or to save time. For example, two rounds that intersect at an angle other than 90° would have an unusual shape, if one is not drawn, the section becomes much easier to do.

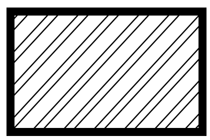
2.1.6.11 - Fill Patterns

• Sections can be filled with a number of patterns to indicate different materials

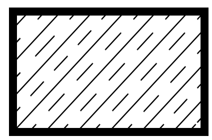
• This was a common technique in the past. Some examples are given below.



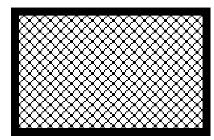
cast iron and malleable iron



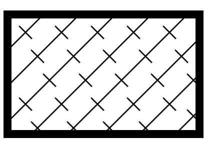
steel and wrought iron



bronze, brass copper



zinc, lead, alloys



aluminum and magnesium and their alloys

2.1.7 Auxiliary Views

• The glass box can also be folded at odd angles. This technique produces views known as Auxiliary views.

• These views are useful when we want to draw a view of a surface that is not normal to one of the primary viewing planes.

• common terms used for this method are true size, and true shape. keep in mind that if a feature does not lie parallel to one of the primary viewing planes, it will appear distorted in every view.

• These views can be constructed from any view in a drawing. typical names for these identify the view that they are drawn from,

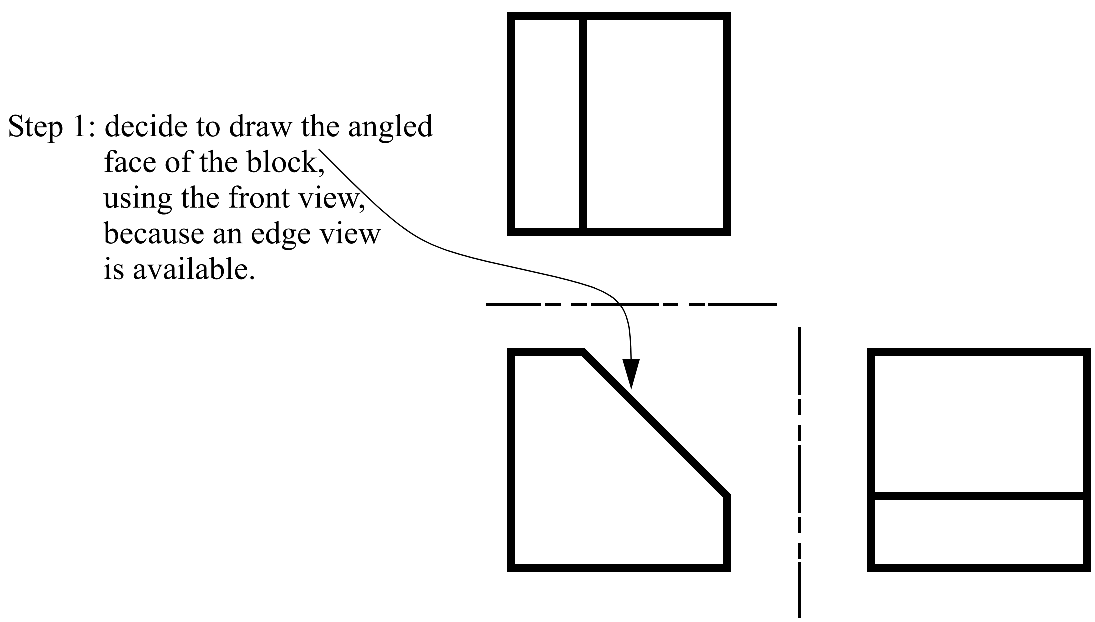
- front auxiliary view
- top auxiliary view
- side auxiliary view

• We can also use auxiliary views to project other views for geometric purposes

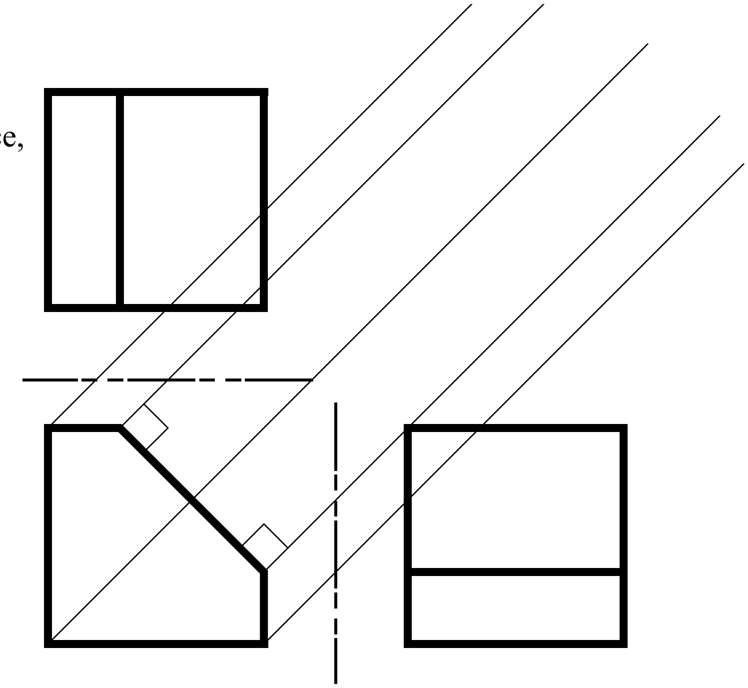
• hidden lines are typically not used in auxiliary views, unless needed for clarity. Also, a number of surfaces are not included because they are distorted, and of little value.

• typically steps followed to construct an auxiliary view,
1. select the face that is to be drawn as i) a true surface, ii) a true length line, iii) an end view of a line.
2. draw construction lines perpendicular to the surface/line/point of interest. This line should go in a direction, and far enough that leaves enough space for the view.
3. draw a folding line at an appropriate distance. This will act as a reference plane.
4. transfer distances from another view. This view will typically be the view adjoining the view that the auxiliary is drawn from.
5. Complete the view.

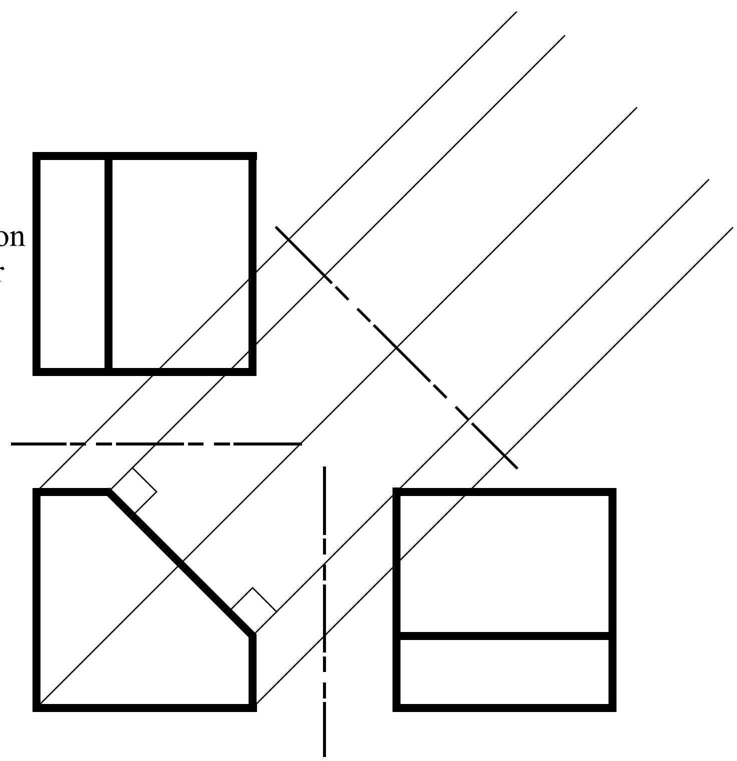
• an example is given below, and all faces are drawn for illustration, but normally only the angled face would be drawn. Because this is the first auxiliary from the drawing, it is called the primary auxiliary view.



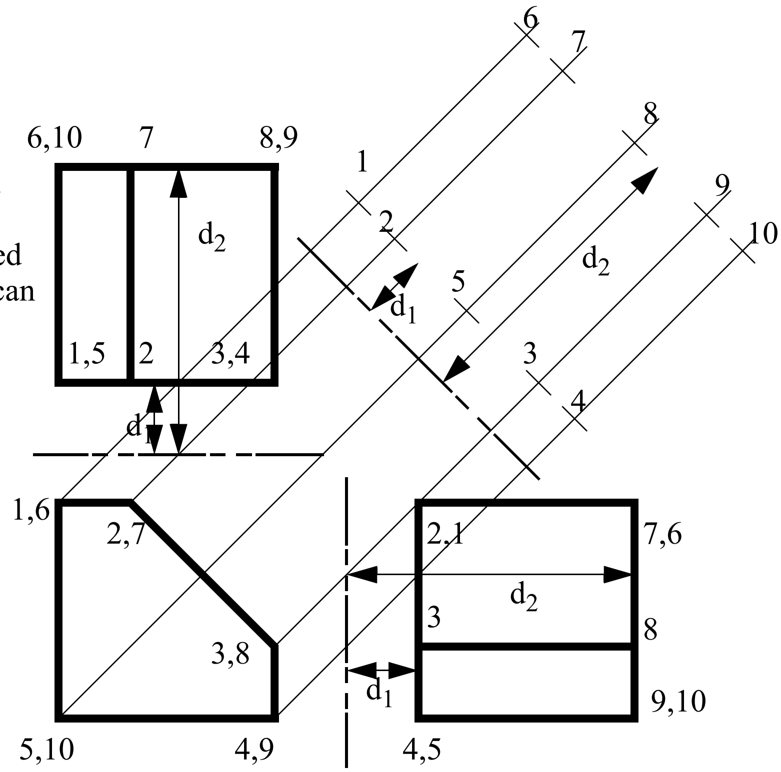
Step 2: draw construction lines perpendicular to the face, the view will be drawn in the open space in the upper right opening.



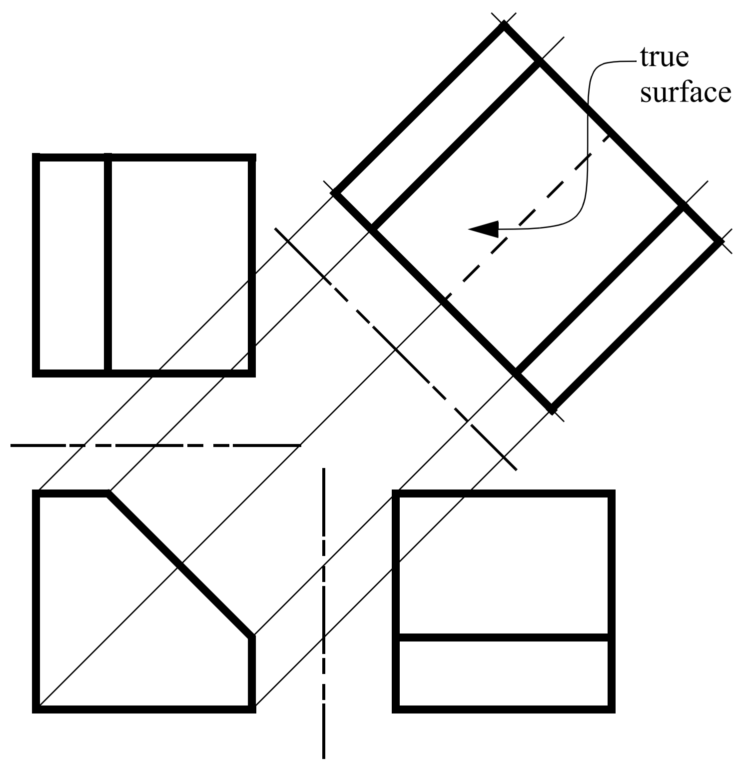
Step 3: draw the fold line in for reference. Just as a visual check, each of the construction lines should be perpendicular



Step 4: Transfer distances to find points in the auxiliary view. Here the points are numbered for the readers benefit. We can transfer the distances either from the top or side view.



Step 5: the view is completed



• There are special drafting techniques for rounded, or curved surfaces, these can be found in any drafting textbook.

2.1.7.1 - Secondary Auxiliary Views

• sometimes it is necessary to make an auxiliary view, using an auxiliary view. When this is done, the first auxiliary is constructed as normal. The second auxiliary is made from the first, but the distances can only be transferred from the first auxiliary for the second auxiliary.

• These views can be needed for a number of purposes, but generally they will be needed when the object does not lie perpendicular, or parallel to any of the viewing planes.

2.1.7.2 - Partial Auxiliary Views

• It is not necessary to draw entire auxiliary views, they can be draw in part, and break lines use.

• This technique allows simplified illustrations of features of interest, without full development of an auxiliary view.

2.1.8 Descriptive Geometry

• The use of drafting to determine geometric properties, such as shortest distances between points and lines.

• These methods can also be used to solve statics (vector) problems, etc.

• These methods use extensions to the methods of auxiliary views that allow curved surface to be considered.

• the basic steps in these methods are,

1. find the true lengths of a line
2. find the end view of a line
3. find the edge view of the surface
4. find the true shape of the surface

• These steps will allow determination of a number of properties,

- points can be projected into other views
- lines can be projected into other views

- the true length of a line can be determined
- a point view of a line can be found
- distances between points and lines can be found
- distances between lines can be found
- distance between a point and plane
- angle between two planes
- edge view of a plane

2.1.9 Isometric Views

• These views are done as a way of realistically drawing objects. This is not correct, as a perspective drawing would be, but it is very good for engineering problems.

• The viewing directions are skewed so that up is still up, but straight back now goes to the left and back, and right goes to the right and back. Both of the moved axis are drawn at 30° to the horizontal.

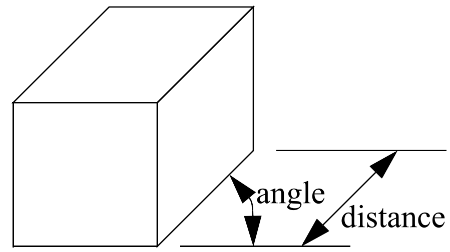
• The values measured off these views will be accurate when measured along the axis.

2.1.10 Special Techniques

• There are a number of special techniques of interest when doing manual drafting, but of declining interest in view of modern CAD systems. A list of these techniques are given below, and are described in good detail in most drafting books,

- drawing ellipses
    - drawing with circles
    - drawing with revolution
    - drawing with four centres
- isometric drawing
    - using 30°/60° angles
    - using special paper
- Oblique views
    - cavalier (45°, with full depth size)
    - cabinet (0-90°, with half depth size)
    - general (0-90°, with between half and full depth size)

a unit cube is shown for illustration



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2.2 NOTATIONS

• Typically these are a number of notations added to drawings to describe features, or explain operations.

• Some abbreviated terms are given below,

Abrev.	Description
CBORE	counterbore
CSK	countersink
DIA	diameter
HDN	case harden
L	lead
LH	left hand
NC	national course
NF	national fine
P	pitch
R	radius
Rc	Rockwell C hardness
RH	right hand
THD	thread(s)
TIR	total indicated runout
TPI	threads per inch
UNC	unified national course
UNF	unified national fine

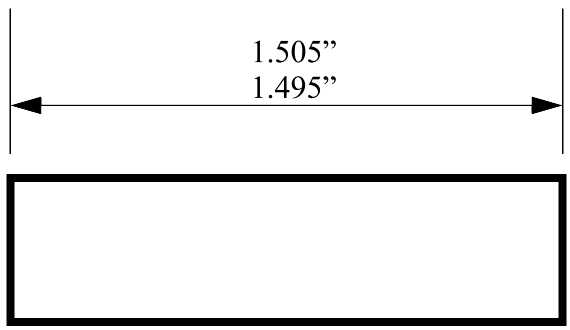
2.2.1 Basic Dimensions and Tolerances

• The size of an object, and the required accuracy can have a significant bearing on the cost

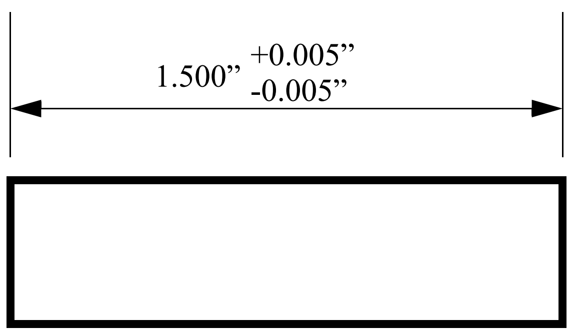
• Unilateral Tolerances

• Bilateral Tolerances

• Limits can be used to exactly define the size boundaries of a feature.



• Tolerances use a nominal dimension and differences.



2.2.2 Geometric Dimensioning and Tolerancing (GD & T)

• Specified in standard ANSI Y14.5 (1983).

• Combines rules and independent symbols in addition to the normal tolerancing symbols

• Allows old style tolerances, but adds new methods that cover geometrical forms.

• Allows easy specifications of datums, etc.

• Advantages of this method are,
  - makes drawings clearer and more ambiguous
  - allows separated features to be related
  - uses symbols instead of words to reduce language translation problems
  - the method helps specify manufacturing and metrology methods

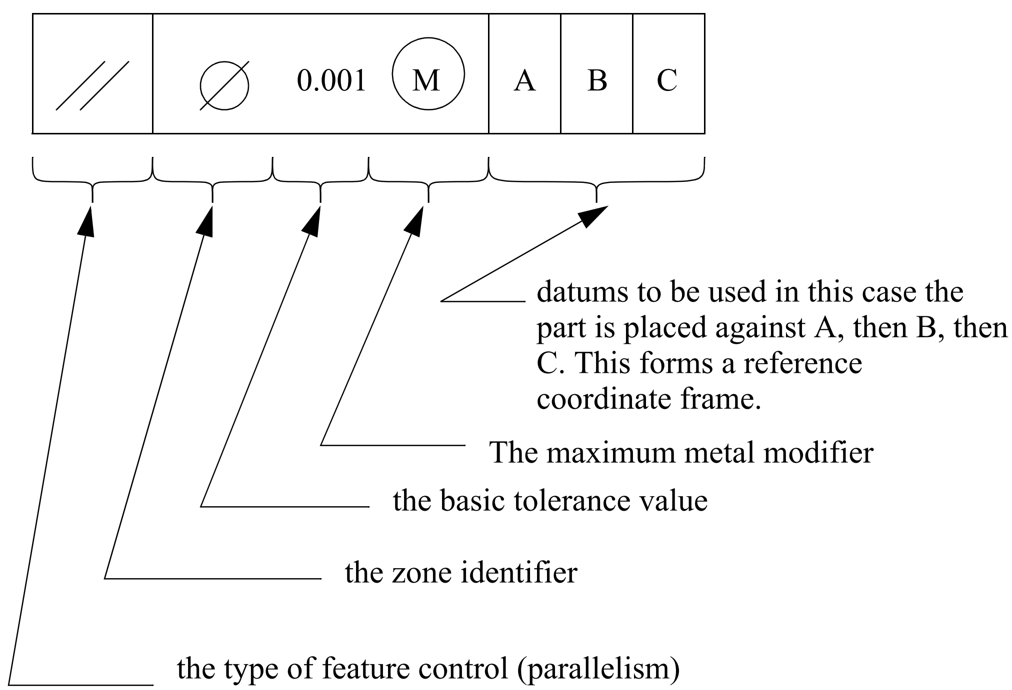
• The main purpose of GD&T is to ensure,
  size - the overall dimensions are as specified
  form - the shapes specified must have the correct geometrical form
  fit - two parts must mate as specified
  function - the product conforms to performance specification

2.2.2.1 - Feature Control Symbols

• The basic of GD&T is the feature control symbol.

• This indicates what the tolerance is, its value, the reference datums, and any modifiers needed.

• An example of a feature control is given below,



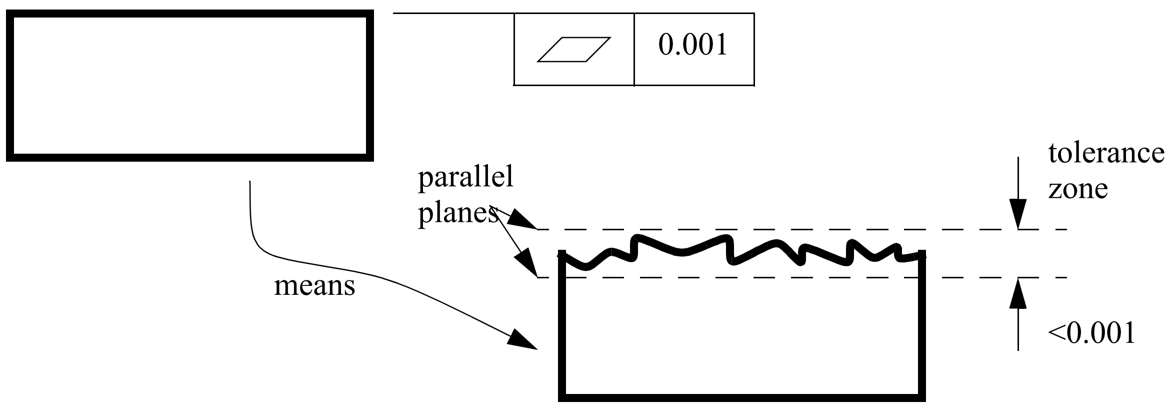
• not all of these symbols/categories will be used on a regular basis, but they provide the designer added flexibility in how they specify tolerances.

2.2.2.2 - Symbols and Meaning

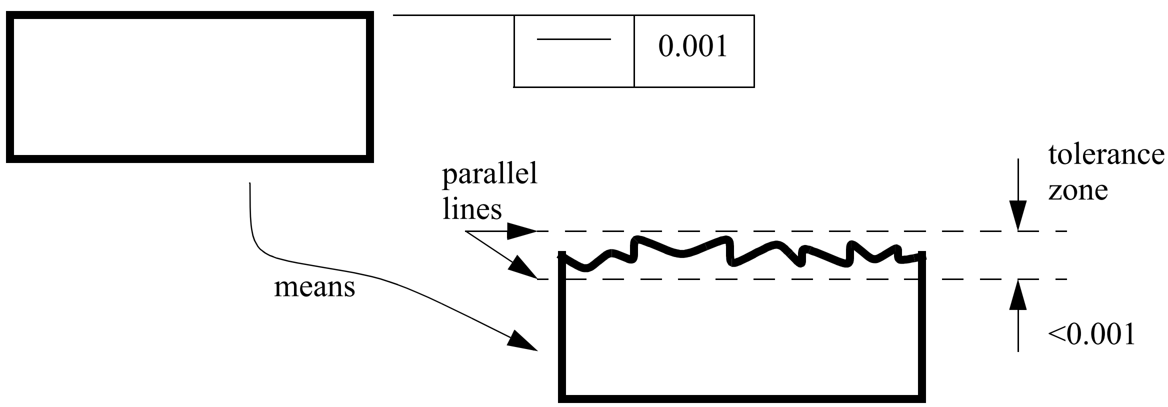
• The basic symbols are shown below,

	tolerance type	characteristic	symbol
individual features	form	straightness	⏤
		flatness	⏥
		circularity	○
		cylindricity	⌭
for individual or related features	profile	profile of a line	⌒
		profile of a surface	⌓
related features	orientation	angularity	∠
		perpendicularity	⊥
		parallelism	∥
	location	position	⌖
		concentricity	◎
	runout	circular runout	↗
		total runout	⌰

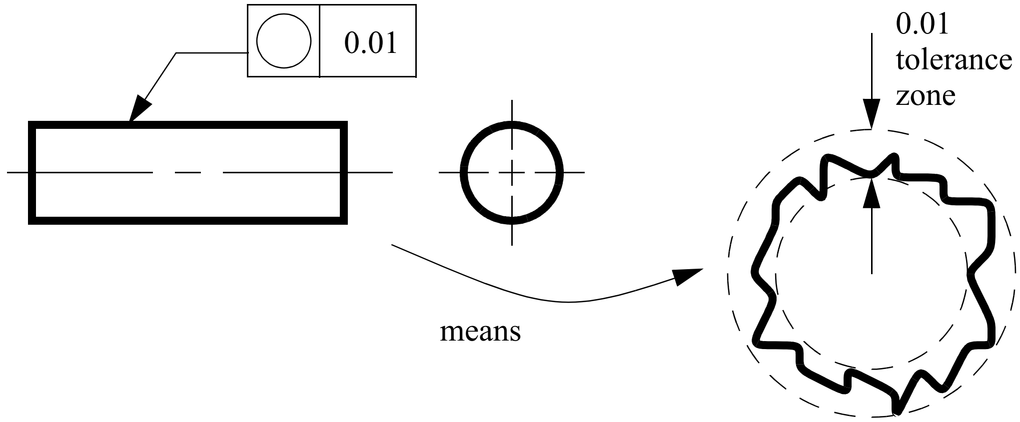
• Flatness - basically, all the surface elements are constrained to lie within two parallel surface places, separated by the tolerance



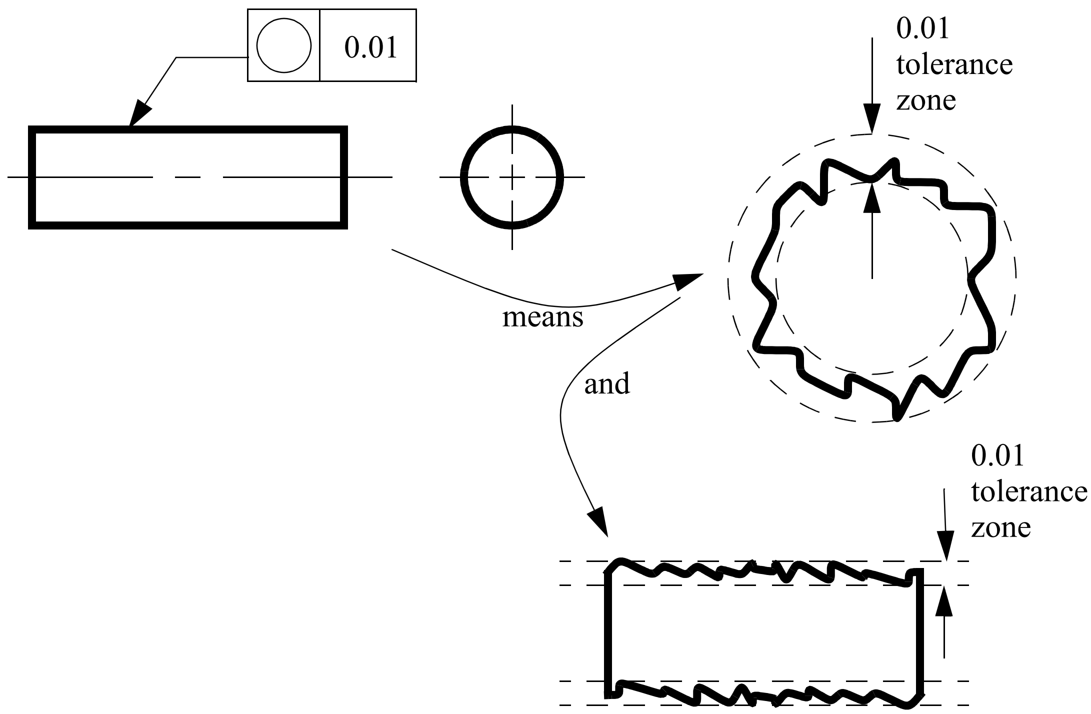
• Straightness - basically, one the surface elements is constrained to lie within two parallel surface places, separated by the tolerance. In effect, this means that if any line across the surface is within two parallel lines, the part is acceptable. This can be tested by running a comparator across the surface (using a reference plane)



• Circularity - all of the points on a cylindrical surface are constrained to lie within two circles. This can be tested with a talyrond.

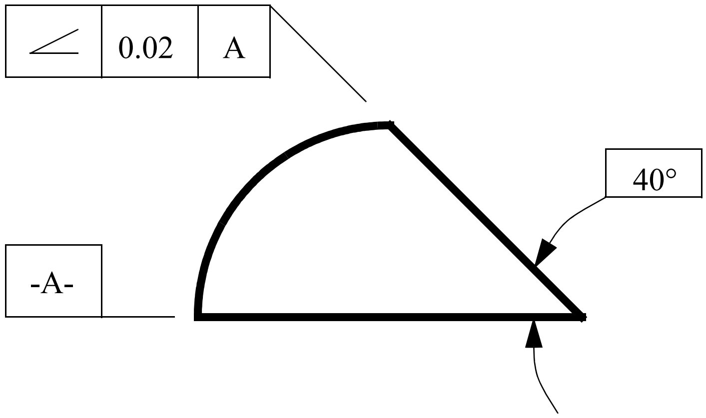


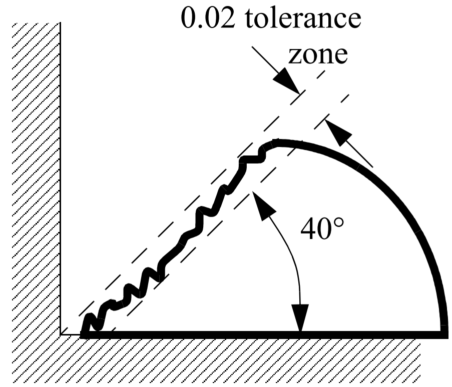
• Cylindricity - an extension to circularity that specifies the tolerance along the cylinder.



• Concentricity -

• Angularity - requires that all points on a specified feature must form an angle with a datum. This could be measured with a sine bar and a height comparator.

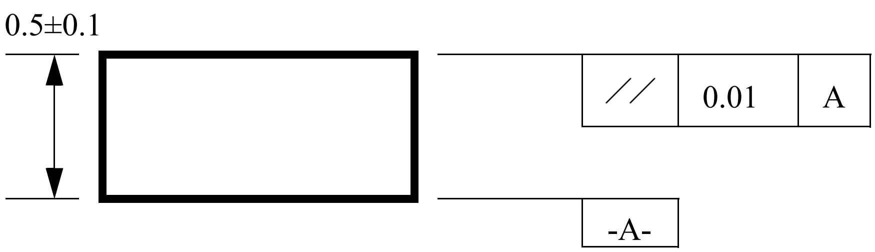


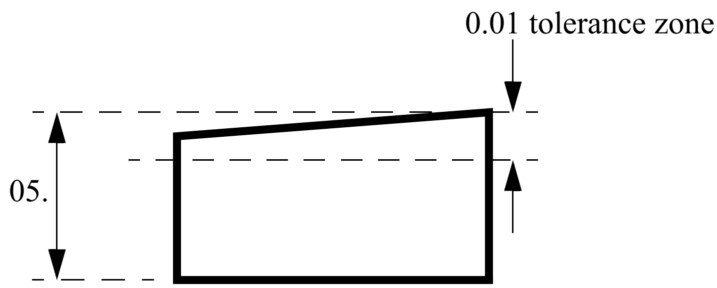


• Perpendicularity - this has the same meaning as angularity, but it is specifically applied to 90• angles. This could be measured with squares and reference plates.

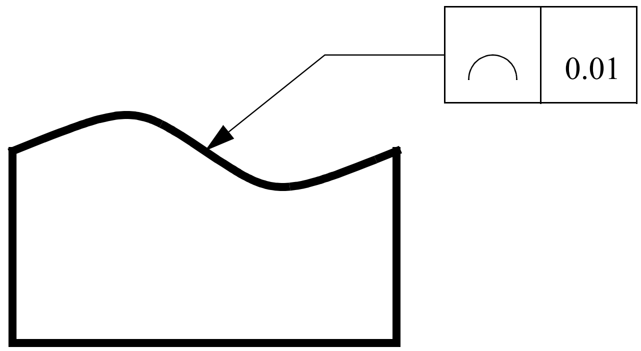
• Symmetry -

• Parallelism - all points on a surface are to be parallel to a given datum, within a specified tolerance

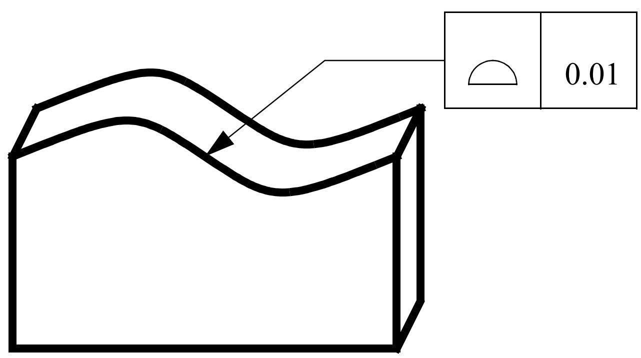


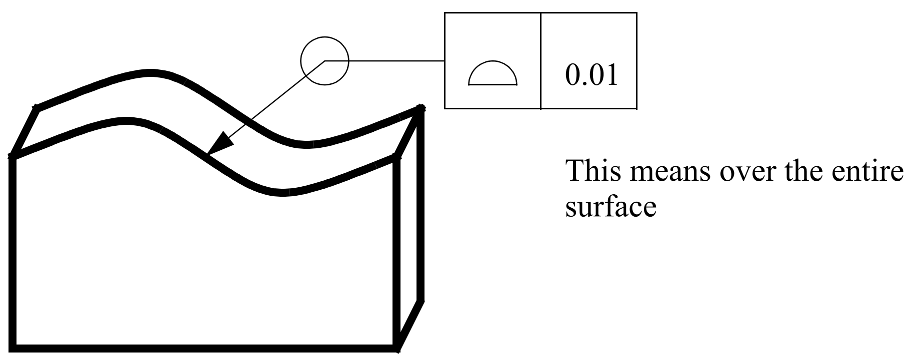


• Line Profile - the amount of deviation that is allowed (typically for irregular lines)

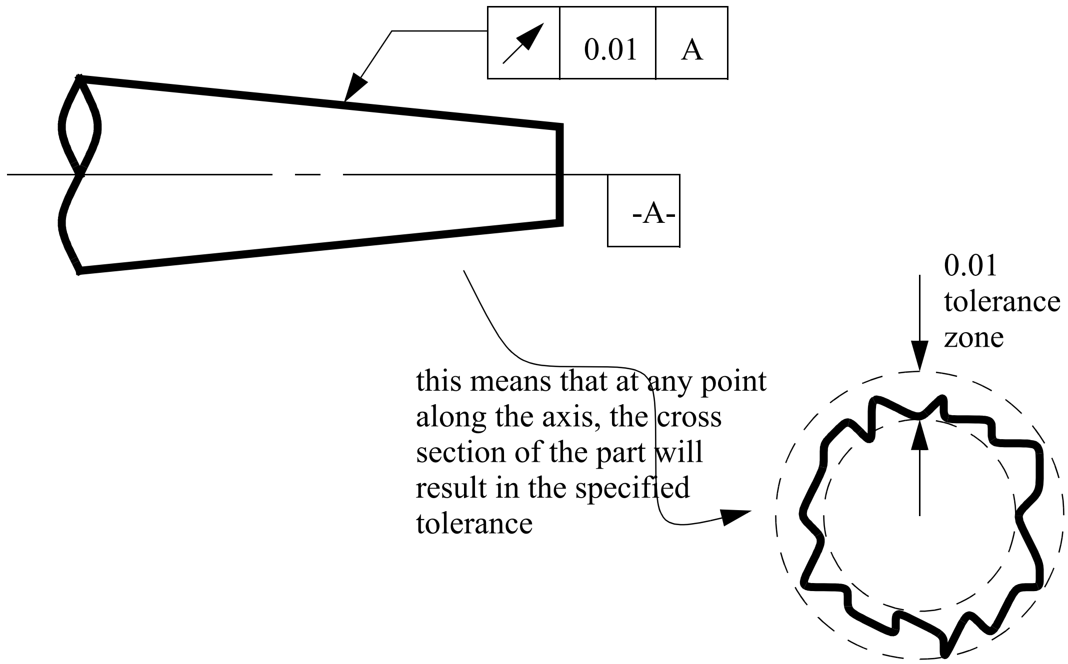


• Surface Profile - the amount of deviation that is allowed for a surface





• Circular Runout - when dealing with a surface of revolution, this determines the amount of deviation allowed from the central axis. This specifically refers to a specific point



• Total Runout - similar to circular runout, but this applies to the entire part. In effect, circular runout uses two circles, whereas total runout uses two surface planes.

2.2.2.3 - Datums

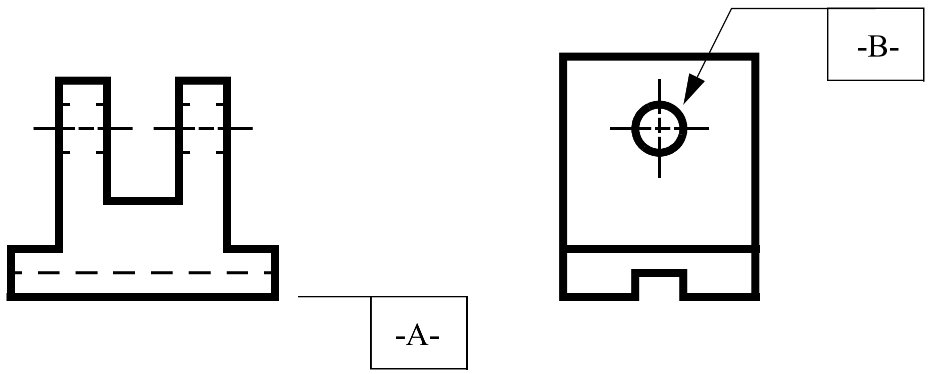
• These are reference features, that other features are to be measured against.

• These can be used when setting up parts, for manufacturing or production

• Typical features used are,
  - axes
  - cylinders
  - planes
  - lines
  - points

• A datum reference frame can be constructed with,
  - three perpendicular planes
  - 3 contact points in the primary plane, 2 in the secondary plane, and 1 in the tertiary

• A datum is specified with a boxed letter with two dashes,



2.2.2.4 - Modifiers

• to overcome shortcomings in symbols, modifiers can be added to change their meanings.

• in particular,

(M) Maximum material condition - the tolerance is at the extreme that would result if too little material was cut off, and the maximum material remains.

(L) Least (Minimum) material condition - the tolerance is at the extreme that would result if too much material was cut off, and the minimum material remains.

(S) Regardless of features size (RFS) - this indicates that the tolerance must be maintained, regardless of variations in this size of the object.

(P) Projected tolerance zone - a tolerance zone can be extended beyond a surface. To do this the basic surface must be specified as a datum.

************ Include an example of tolerances using GD&T

2.3 WORKING DRAWINGS

• The basic skills/topics discussed below lead up to preparing, and understanding a complete set of drawings.

• The purpose of working drawings is to,
  - describe the exact geometry of parts
  - indicate other details associated with drawings (for example, material)
  - show how parts are assembled
  - indicate manufacturing preferences

• generally, the drawing package will include a number of items,
  - a drawing (one a separate sheet with a separate title block) for each part
  - a bill of materials
  - an assembly drawing

• a typical working drawing package will contain,
  - a design layout
  - assembly drawings (and a Bill of Materials)
  - subassembly drawings
  - detailed drawing
  - purchased parts
  - modified purchased parts

2.3.1 Drawing Elements

2.3.1.1 - Title Blocks

• Most of the important details are put in this block. Each block is individualized to a company, but generally they include,
  - company name, and division if applicable
  - machine or department name
  - part name
  - drawing number
  - part number
  - the number of parts required
  - the scale

- drafter name/date
- drawing checker name/date
- material
- tolerances
- finishing details
- units of drawing

• The block is typically located in the bottom right hand corner of the drawing

• The drawing title, and drawing number are commonly printed in large fonts

2.3.1.2 - Drawing Checking

• this is a process whereby a drawing is reviewed for completeness, accuracy, etc.

• modern CAD systems, especially solid modeler should reduce the emphasis on checking the drawings. Some of the main features checked for in manual drawings are,
  - appearance - this can be a large issue for hand drawn work
  - within standards - legal and corporate
  - clarity - all description, dimensions, etc should be well understood
  - completeness - sufficient dimensions, etc should be present for production
  - redundancy - redundant information should be eliminated unless essential
  - manufacturability - the cost and feasibility of production should be considered. are tolerances sufficient/excessive, are other steps sufficient for product life.
  -

2.3.1.3 - Drawing Revisions

• When a drawing has reached production, it is considered final, but changes are frequently made.

• It is very important that drawing changes are dealt with properly. This means,
  - all changes are recorded on the drawing, and new drawings made
  - all old drawing must be collected, or marked void (failure to do this can lead to very expensive mistakes)
  - when a drawing has been changed a number of times, it should be redrafted.

• Computer CAD systems still do not sufficiently deal with problems such as these, and often rely on the previous manual drafting systems to process these updates. But, software is available, and is being developed for product information management (PIM) that will deal with these changes in a manner suitable for CAD.

2.3.1.4 - Bill of Materials (BOM)

• An important list on most drawings is a Bill of Materials, this is a list of all required materials/ parts required to make to part depicted in the drawing.

• This list contains,
  - all part numbers
  - all part names
  - quantity of parts required
  - materials required
  - source

• This is sometimes given on separate sheets, or on the drawing itself

• The typical (but not the only) order for listing parts on a BOM is,
  1. produced in-house
  2. specialty purchase (e.g. roller bearings)
  3. standard purchased hardware (e.g., washers)
  4. bulk items (e.g. lubricants)

2.3.2 Drawing Types

2.3.2.1 - Assembly Drawings

• These are used to specify an assembly with,
  - a drawing of the assembled part

• Hidden lines are typically omitted from these drawings. Details may also be omitted if they have no bearing on the product

• assembly instructions may also be included in these drawings to guide workers

• full section assembly drawings are often used

• dimensions not included unless essential

• Small blow-up bubbles are often used to emphasize details

• The parts can be identified using,

- numbers with arrows and a block list of parts including,
    - quantity
    - part name
    - part source
    - part number
    - reference number
    - drawing number
- arrows and descriptions
    - quantity
    - part name
    - part source
    - part number
    - drawing number

2.3.2.2 - Subassembly Drawings

• these are basically the same as assembly drawings, except that there are components that have already been assembled.

• Modern equipment is complex and is assembled in stages. The final assembly might be something like an automotive body welding shop, whereas a sub-assembly might be the car radio.

2.3.2.3 - Exploded Assembly Drawings

• these are drawings that show each piece separated, and indicates their assembly paths. This can help when determining,
- which part goes where
- the orientation of the part
- the part of approach
- the order of assembly

2.3.2.4 - Detailed Drawings

• These drawings use the techniques discussed earlier in this section to depict, and dimension parts.

************************ INCLUDE A COMPLETE DRAWING PACKAGE TO ILLUSTRATE

2.4 PRACTICE PROBLEMS

2.5 REFERENCES

Ullman, D.G., The Mechanical Design Process, McGraw-Hill, 1997.