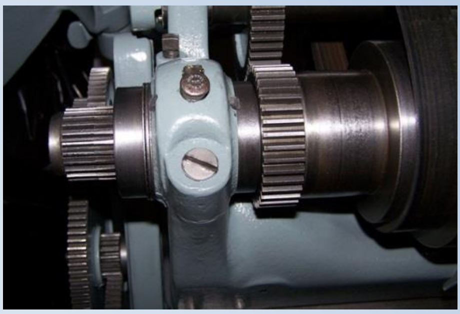
MEM09209A

2013



Detail bearings, seals and other componentry in mechanical drawings.

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Unit Resource Manual

Manufacturing Skills Australia Courses

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Aims of the Competency Unit

This unit covers producing drawings to Australian Standard 1100 or equivalent where the critical dimensions and associated tolerances for components and/or materials are selected from supplier/manufacturers' catalogues using design specifications.

Manual drafting or drawing equipment is used or where a CAD (Computer Aided Design) system is used, Unit MEM09009C (Create 2D drawings using computer aided design system) and/or Unit MEM09010C (Create 3D models using computer aided design system) should also be considered

Unit Hours

72 Hours

Prerequisites:

MEM09002B	Interpret technical drawing
MEM09003B	Prepare basic engineering drawing

Elements and Performance Criteria

1.	Prepare assembly, layout and detail drafting	1.1	Drawings are prepared in plane orthogonal, isometric projection or equivalent including auxiliary views and sections to *Australian Standard 1100*.
		1.2	Layout, assembly and component drawings are prepared from specification.
		1.3	Drawings are dimensioned and labelled using supplied tolerances in accordance with Australian Standard 1100.
		1.4	Drawings are produced to specification in accordance with standard operating procedures.
		1.5	Standard symbols to Australian Standard 1100 or equivalent are used to specify requirements.
2.	Determine component and/or material requirement	***2.1***	***Components and/or materials are selected from supplier/manufacturers' catalogues using design specifications***

Required Skills and Knowledge

Required skills include:

- preparing drawings using appropriate projections and views in accordance with AS1100 or equivalent, see above note in the range statement
- producing layout, assembly and component drawings in conformance with specification
- inserting all relevant dimensions, tolerances and instructions in the drawing
- producing drawings to specification
- appropriately using standard symbols in accordance with AS1100 or equivalent in the drawings produced
- obtaining component specifications in accordance with work place procedures
- reading, interpreting and following information written job instructions, specifications, standard operating procedures, charts, lists, drawings and other applicable reference documents
- planning and sequencing operations
- checking and clarifying task related information
- checking for conformance to specifications
- undertaking numerical operations, geometry and calculations/formulae within the scope of this unit

Required knowledge includes:

- appropriate projection for the drawing purpose
- reasons for selecting the chosen projection
- reasons for including auxiliary views in drawings
- requirements of AS1100 or equivalent with respect to dimensions, tolerances and labels
- procedures for producing component, layout and/or assembly drawings
- drawing specifications
- common symbols used in drawings to AS1100 or equivalent
- design specifications of the component
- appropriate components and materials from supplier/manufacturers' catalogues
- reasons for selecting the chosen components and/or materials
- safe work practices and procedures

Free Software Download Sites

The follow site allows their software to be downloaded, installed and used free of charge.

AutoCAD

www.students.autodesk.com

To download the AutoCAD or any other Autodesk software free of charge, you have to register as a student. Click on **Register** and complete your details on the following screens using your TAFE email address which is shown on your TAFE receipt when paying your fees; you may need to enquire at your TAFE Library or Administration Centre for your password.

Once registered, you can start to download any of 30 programs. Download the version you will be using in class to avoid the problems of opening and saving your drawings as versions.

On downloading the program, make a note of the Product Key and Serial Number which are required to register the software.

The software is licensed for 13 months for educational purposes ONLY. At the end of the licence period the software will not operate however the latest version can then be downloaded and installed on the same, or a new computer.

Lesson Program

Unit *MEM09209A Perform basic engineering drafting* is a 72 hour unit and is divided into the following program. The listed Skill Practice Exercises MUST be successfully completed to the satisfaction of the teacher or facilitator.

Topic	Skill Practice Exercise
Error! Reference source not found.	MEM09209-SP-0101
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Topic 1 – General Tolerance Dimensions:	MEM09209-SP-0301
Topic 2 – Surface Finish Indication	MEM09209-SP-0401
Topic 3 - Geometric Tolerance:	MEM09209-SP-0501
Error! Not a valid result for table.	MEM09209-SP-0601
Topic 5 – Hole & Shaft Basis Systems:	MEM09209-SP-0701
Topic 6 – Plain Bearings:	MEM09209-SP-0801
Topic 7 – Rolling Contact Bearings:	MEM09209-SP-0901
Topic 8 – Bearing Retention:	MEM09209-SP-1001
Topic 9 – O-Rings:	MEM09209-SP-1101
Error! Not a valid result for table.	MEM09209-SP-1201
Topic 11 – Thrust Bearings:	MEM09209-SP-1301
Topic 12 – Bearing Materials:	MEM09209-SP-1401
Topic 13 – Lubrication:	MEM09209-SP-1501
Practice Competency Test	MEM09209-PT-01
Tables	

Contents:

Topic 1 – General Tolerance Dimensions:

Required Skills:

- Add dimensions containing tolerances to a detail drawing.
- Convert Unilateral and Bilateral to Limit of Size.

Required Knowledge:

- Dimensioning techniques to AS1100.
- Basic calculations (addition and subtraction)

Lesson Aim:

The aim of this lesson is to develop the skill of the draftsperson in applying tolerance dimensions to a detail drawing using the tolerances as supplied by the engineer. Specific lessons on the selection and application of tolerances and determining tolerances from charts and tables will be covered in later Topics in this unit.

Tolerance Dimensioning:

Unfortunately, it is impossible to make anything to the exact size as there are always small amounts of variation due to wear of cutting tools, misalignment, or many other reasons. Components can be made very close, even to a few millionths of a millimetre but accuracy is expensive. Exact sizes are not needed, only varying degrees of accuracy according to the functional requirements; a workshop reconditioning engines for motor vehicles would soon be bankrupt if they attempted to make every engine with formula racing car engine accuracy. The engines will be acceptable IF they are made with reasonable differences in the sizes of the engine components. The problem can easily be overcome if a *tolerance* is applied on each dimension.

Tolerance is the total amount a specific dimension is permitted to vary, which is the between maximum and minimum limits. For example, a dimension given as 67.35±0.20 means that may be 67.55mm or 67.15mm or anywhere between these *limit dimensions*. The total amount of variation, or *tolerance*, is 0.40mm therefore it is the function of the detail draftsperson, to specify the allowable error that may be tolerated for a given dimension and still permit the satisfactory performance of the part. Since the cost of manufacturing the part increases with the greater accuracy, the draftsperson will specify as generous a tolerance as possible.

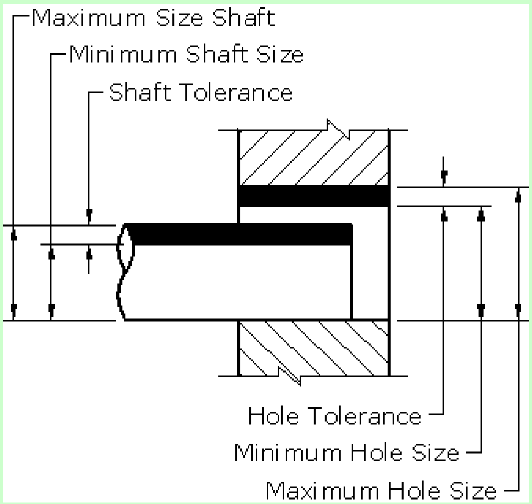


Figure 1.1

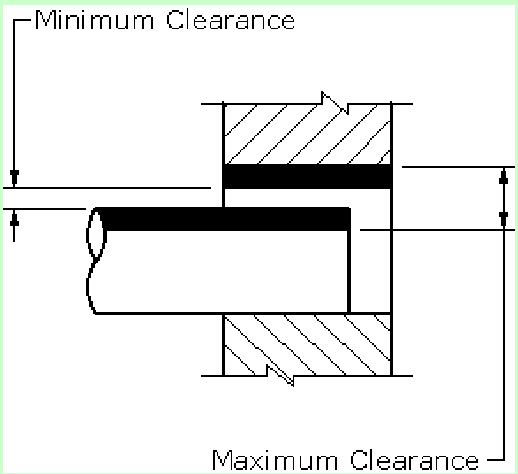


Figure 1.2

Methods of Expressing Tolerance:

There are three methods used to specify tolerance on engineering drawings:

- Unilateral
- Bilateral
- Limit of Size or Direct

Unilateral Tolerance:

A unilateral tolerance is one where the total allowable variation is given in **ONE** direction. The dimension consists of a basic size with a tolerance that is either slightly smaller, or larger. Figure 1.3 shows the nominal size as 50 with the tolerance of 0.5 being applied slightly to make the diameter larger; Figure 1.4 shows the tolerance of 0.5 being applied to make the diameter smaller.

Figure 1.5 and Figure 1.6 have two tolerance values for each dimension however the tolerances are in the one direction, either larger by 0.2 to 0.5 or smaller by 0.1 to 0.5.

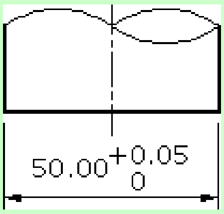


Figure 1.3

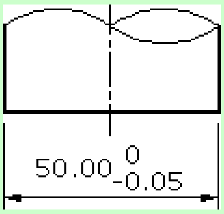


Figure 1.4

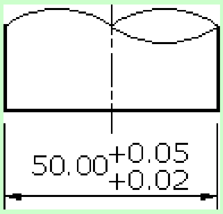


Figure 1.5

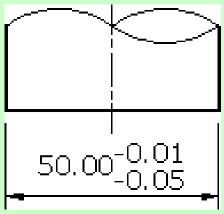


Figure 1.6

Bilateral Tolerance:

A bilateral tolerance is one where the total allowable variation is given in **TWO** directions. The dimension is given as a basic size with a small variation in size that can be either larger or smaller. Bilateral tolerances should generally be equal, but special design considerations may sometimes dictate unequal values.

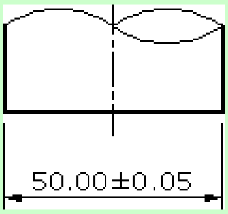


Figure 1.7

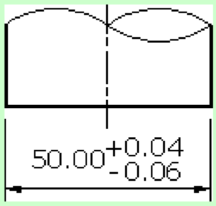


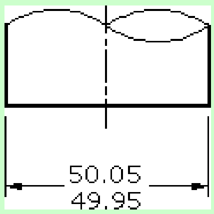
Figure 1.8

Figure 1.7 shows the nominal size as 50 with a tolerance both larger and smaller by 0.05; in Figure 1.8 the same nominal size of 50 is required but the diameter can be larger by 0.04 or smaller by 0.06. Both toleranced dimensions are Bilateral.

Limit of Size:

Limit of size specifies the maximum and permissible sizes that the part can be manufactured.

Limit of Size toleranced dimensions are always placed in the centre of the dimension line with the upper value (maximum size) located above the dimension line and the lower value (minimum size) placed below the dimension line; Unilateral and Bilateral dimensions are always placed above the dimension line. In all cases, the number of decimal places in the tolerance and the preferred size must be the same.



Limit of Size or Direct

AutoCAD Terminology:

AutoCAD uses the terminology "Limits" for Limits of Size, "Deviation" and "Symmetrical", and are applied to a selected Dimension Style.

- The Limit style sets up the tolerance to display the upper and lower sizes. The upper limit is placed above the dimension line while the lower limit is placed below the dimension line.
- A rule for toleranced dimensions requires the number of decimal points in the nominal size and tolerances to be the same; eg. 1, 2, 3 or 4 decimal points.

Toleranced dimensions can be added to a detail drawing produced using AutoCAD using 2 methods:

- Creating a new dimension style (eg. Tolerance); once the dimension has been applied to the view, the upper and lower limits can be modified accordingly.
- Creating several new dimension styles (eg. Tol-1, Tol-2, Tol-3); the toleranced dimension is applied to the view using the correct dimension style. The disadvantage is there could be many dimension styles required.

Fundamentals for Tolerance Selection

Before the engineer can decide on the precision necessary for a particular part and specify the proper fits and tolerances, an understanding on the manufacturing process and the use of the component is required. Many factors such as the length of the engagement, bearing load, speed, lubrication, temperature, humidity and materials must be taken into consideration when selecting the tolerances. In many cases, practical experience is necessary in determining the fit conditions guaranteeing proper performance.

Before being able to select appropriate tolerances, it is essential to know the precision attainable with various machine tools and manufacturing methods; e.g. drilled holes must not have a tolerance applied which is smaller than can be achieved with a drill.

Tolerance for Linear Dimensions:

Toleranced dimensions are applied to a drawing using the same rules as for nominal dimensions with the exception that Limit of Size tolerances MUST be centred each side of the dimension line with the upper (or maximum) tolerance on top of the line and the lower (or minimum tolerance below the dimension line. In the case of Unilateral and Bilateral tolerance dimensions, the nominal size followed by the tolerance is placed above the dimension line.

It is recommended that the aligned method of dimensioning is utilized when placing toleranced dimensions on a drawing as several vertical dimensions require less room and the text does not run into one continuous string.

The preferred method for placing toleranced dimensions is shown in Figure 1.9 where the dimensions are aligned with the feature. Figure 1.10 has the dimensions spaced identical to Figure 1.9 bus as can be seen, the dimension text always horizontal and shown, the text from one dimension overlaps the neighbouring text and cannot be read. The resulting

Figure 1.11 is easily read but the spacing between the dimension line has been increased which could result in insufficient room on a tight-fitting drawing. Figure 1.12 has the dimension lines spaced at the correct distance and the text in each toleranced dimension moved vertically up or down to allow the dimensions to be read with more clarity; moving a vast number of dimension text could lead to excessive drawing time increasing the cost of the drawing.

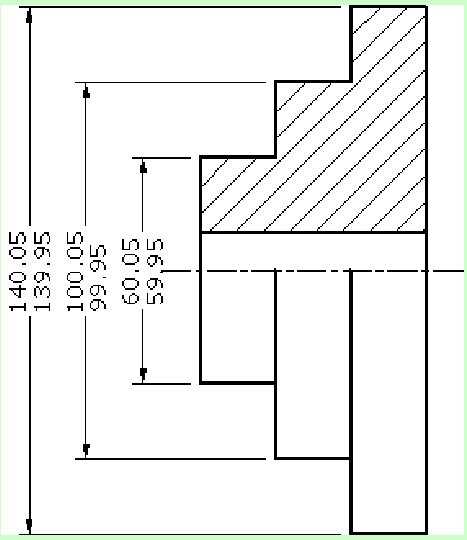


Figure 1.9

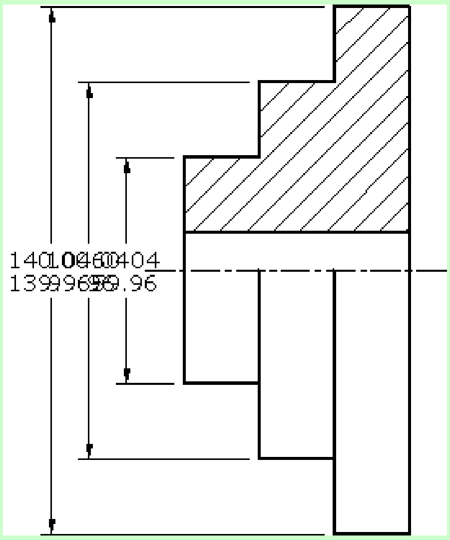


Figure 1.10

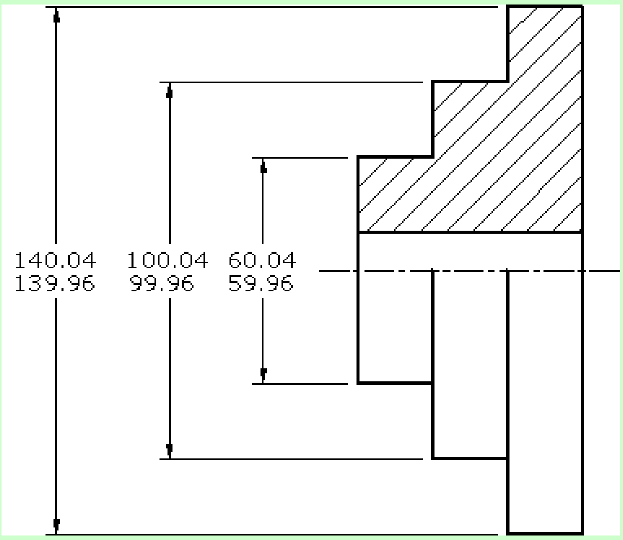


Figure 1.11

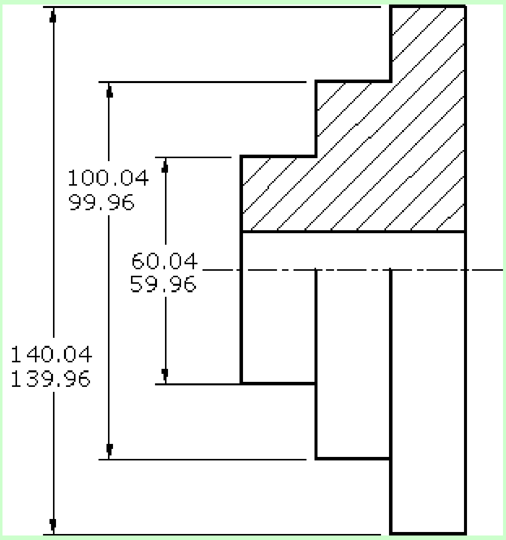


Figure 1.12

The length required to indicate the dimensions and view of Figure 1.9 measures 150 while Figure 1.11 measures 160 and Figure 1.12 measures 130.

Tolerance for Angular Dimensions:

The tolerance on angular dimensions is normally given as bilateral and shown as 74±0.5°. If the tolerance is given in minutes the toleranced dimension is shown as 74±0°15′. If the tolerance is given in seconds it is shown as 74±0′30″.

Tolerance for Holes and Shafts:

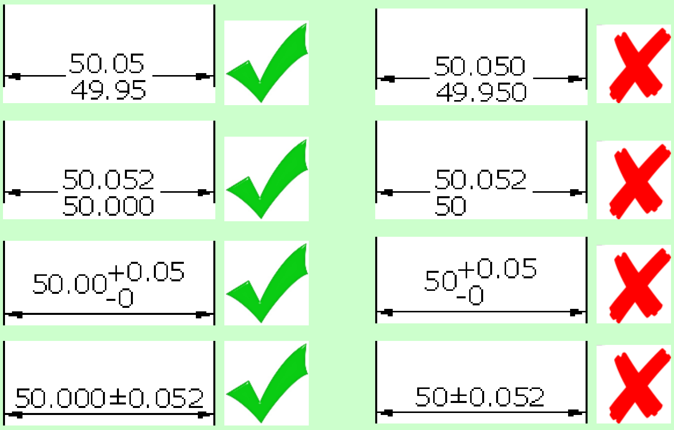
Holes are dimensioned in accordance with AS1100 where the dimension can be placed on a dimension line through the hole/shaft or placed as a leader line with the text horizontal. The leader must touch the edge and point to the centre of the hole/shaft. The diameter symbol appears before the hole/shaft size followed by the dimension text.

Number of Decimal Points:

In Unilateral and bilateral tolerance dimensions, the number of decimal points showing in the nominal size and the tolerance must be the same. In Limit of Size tolerances, the upper and lower values must have the same number of decimal points.

Where the values are calculated with the last decimal place being zero (0) for both the upper and lower values, the zeros can be removed.

Correct Wrong



Convert Unilateral and Bilateral Tolerances to Limit of Size Tolerances:

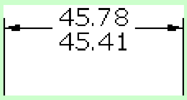
To convert Unilateral and Bilateral Tolerances to Limits of Size, simply add or subtract the given tolerance to the basic size to obtain the maximum and minimum limits.

When adding tolerances too, or subtracting from the nominal dimension, the number of decimal points should be the same to reduce the errors made during mental calculations.

Example:

Convert $45.64^{+0.14}_{-0.23}$ to a Limit of Size

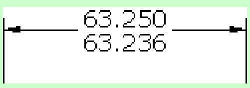
Upper limit = 45.64 + 0.14 *= 45.78*
Lower limit = 45.64 – 0.25 *= 45.41*



Example:

Convert $62.25^{+0}_{-0.015}$ to a Limit of Size

Upper limit = 63.25 + 0 *= 63.25*
Lower limit = 63.250 – 0.014 *= 63.236*



Datum Dimensioning:

Datum dimensions consist of dimensions given from the same lines, centres, points or edges of the surfaces of a part. The leading CAD software packages use the Baseline dimension to create a datum dimension. Most datum dimensioning is given as horizontal and vertical dimensions placed about the extreme left and bottom edges of the part however they can also be hole or feature centrelines or any other notable feature. Datum dimensioning reduces the error resulting from the accumulation of errors.

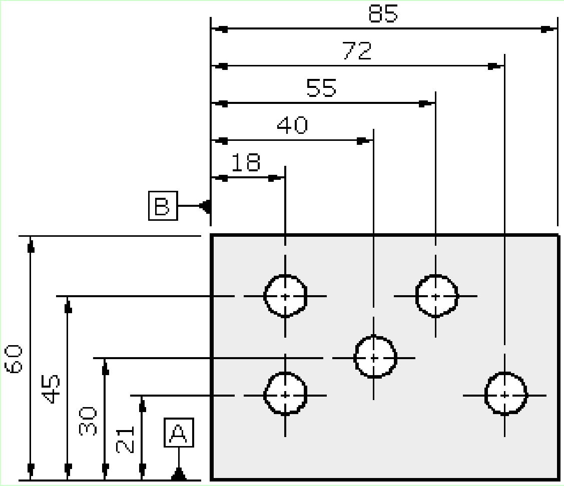


Figure 1.13

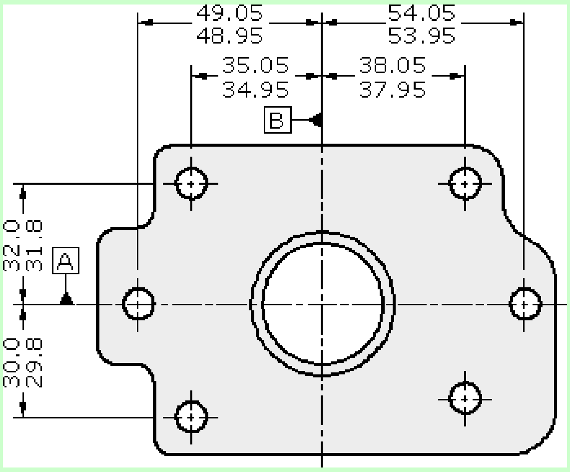


Figure 1.14

In the images above Figure 1.13 use the bottom and left edges for the datum while Figure 1.14 uses the major vertical and horizontal centrelines for the datum.

All dimensions must be spaced at a uniform distance when baseline dimensioning is used on a drawing.

Datum Edges/Surfaces:

Datum edges and surfaces are identified by a solid filled triangle and a designating letter (A, B, C …) centred inside a square bounding box with a line linking the box to the triangle.

The height of the Datum letter is the same height as used throughout the drawing. The height of the Datum box is twice the text height.

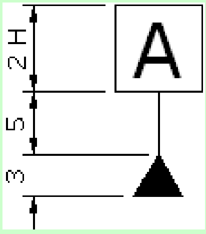


Figure 1.15

Review Questions: MEM09209-RQ-01
Answers are at the rear of the reference book.

1. Define the term "Tolerance".

____

____

2. Name 3 methods of displaying tolerances on drawings giving examples of each method.

   a) ____

   b) ____

   c) ____

3. Convert the following Unilateral and Bilateral tolerances to Limit of Size.

$35.26^{+0.06}_{-0.00}$ ____________ ____________

$56.93^{+0.00}_{-0.05}$ ____________ ____________

$92.91^{+0.16}_{-0.005}$ ____________ ____________

$15.20^{+0.07}_{-0.01}$ ____________ ____________

$86.26^{+0.120}_{+0.115}$ ____________ ____________

$147.25^{+0.105}_{+0.032}$ ____________ ____________

4. If a hole has a maximum diameter of 59.125mm and a minimum diameter of 58.975mm, what is the tolerance?

5. Define the following terminology as applied to tolerancing.
   a) Bilateral Tolerance

   b) Limit of Size

   c) Nominal Size

   d) Basic Dimension

   e) Allowance

6. Name the preferred method of tolerancing.

7. With the limit of size method of tolerancing, the larger limit is written above the line.

(Tick one Box Only).

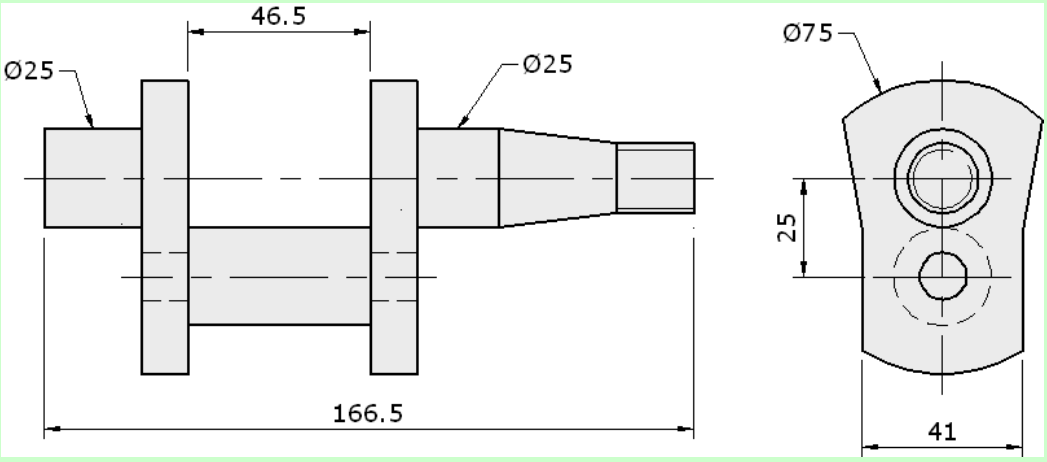
❑ TRUE ❑ FALSE

Skill Practice Exercises:

Skill Practice Exercise MEM09209-SP-0301.

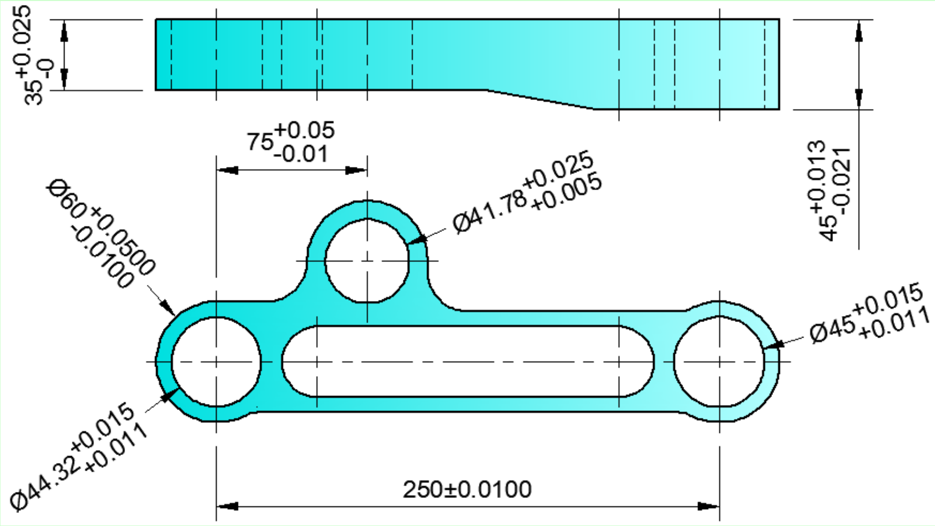
Create a new drawing using the template provided on the network drive called Crankshaft and complete the drawing by adding all dimensions, border and a Title Block. All toleranced dimensions indicated are to be converted and displayed as "Limit of Size" dimensions using the tolerances shown in the following table. Plot the final drawing onto an A3 sheet at an appropriate scale. Save the file as MEM09209-SP-0301.

Dimension	Maximum	Minimum
Ø75	-0.25	-0.105
46.5	+0.09	+0.025
Ø25	+0	-0.05
25	-0.005	-0.012
166.5	+0.25	-0.05
41	+0.15	-0.15



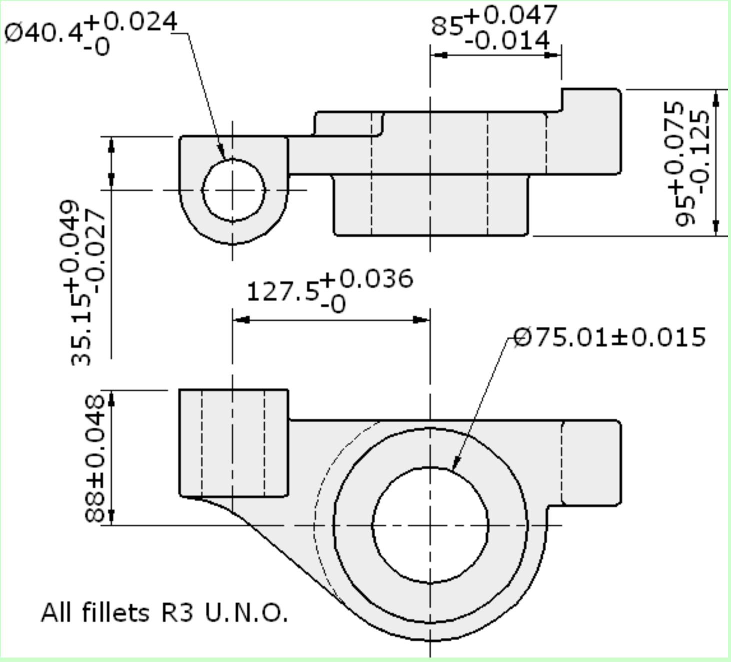
Skill Practice Exercise MEM09209-SP-0302.

Create a new drawing using the template provided on the network drive called Flap Link and complete the drawing by adding all dimensions, border and a Title Block. All toleranced dimensions shown in the Figure below are to be displayed as "Limit of Size" toleranced dimensions. Plot the final drawing onto an A3 sheet at an appropriate scale. Save the file as MEM09209-SP-0302.



Skill Practice Exercise MEM09209-SP-0303.

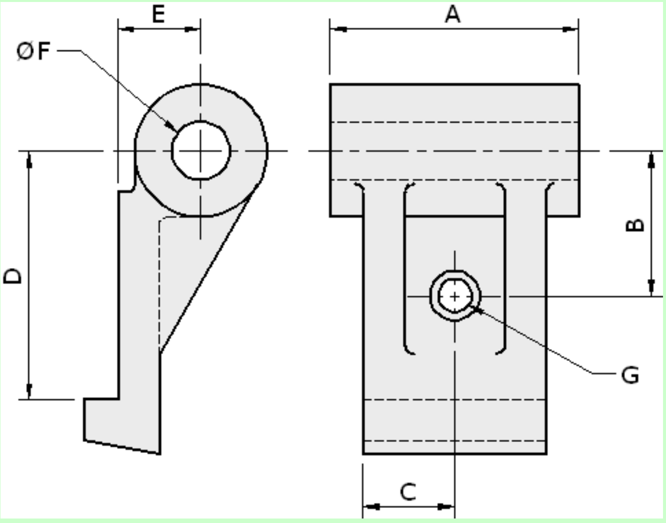
Create a new drawing using the template provided on the network drive called Rocker Arm and complete the drawing by adding all dimensions, border and a Title Block. In creating the details drawings All toleranced dimensions are to be displayed as "Limit of Size". Plot the final drawing onto an A3 sheet at an appropriate scale. Save the file as MEM09209-SP-0303.



Skill Practice Exercise MEM09209-SP-0304.

Create a new drawing using the template provided on the network drive called Hook Bearing and complete the drawing by adding all dimensions, missing features, border and a Title Block. All toleranced dimensions shown in the Figure below are to be displayed as "Limit of Size" toleranced dimensions. Plot the final drawing onto an A3 sheet at an appropriate scale. Save the file as MEM09209-SP-0304.

Dimension	Tolerance
A	±0.05
B	±0.125
C	±0.025
D	+0.035 -0
E	+0 -0.078
F	+0.08 +0.03
G	Drill Ø12.5±.05 Counterbore Ø17x12 deep



Topic 2 – Surface Finish Indication

Required Skills:

- Place surface finish symbols on a detail drawing.
- Place geometric tolerance symbols on a detail drawing.

Required Knowledge:

- Surface roughness.
- Geometric tolerances.

Surface Finish:

Modern development of high-speed machines has resulted in higher loadings and increased speeds of moving parts. To withstand these more severe operating conditions with minimum friction and wear, a particular surface finish is often essential, making it necessary for the designer and detailer to accurately describe the required finish to the trades actively involved in manufacturing the part/s.

All surface finish control starts in the drawing office. The detailer has the responsibility of specifying the correct surface to give the maximum performance and service life at the lowest cost. In selecting the required surface finish for any particular part, the designers base decisions on past experience with similar parts, on field service data, or on engineering tests. Factors such as size and function of the parts, type of loading, speed and direction of movement, operating conditions, physical characteristics of both materials on contact, type and amount of lubricant, contaminants, temperature influence the choice of the surface finish.

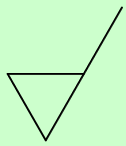
The two principal reasons for specifying surface finish are to:

- Reduce friction.
- Control wear.

Finished Surface Symbols:

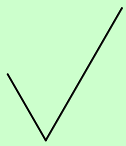
Machining Mandatory:

A machining process MUST prepare any surface indicated by the mandatory-machining symbol. The symbol is used where the surfaces on separate components are mated and/or motion may exist.



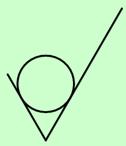
Machining Optional:

The symbol is also referred to as the Basic Symbol. The optional symbol is used where ANY process can be used to achieve the desired surface finish.



Machining Not Permitted:

Where a circle is shown inside the basic symbol, the removal of material is not permitted. The surface is to be left in the as cast or forged condition, as removal is unnecessary and could increase the manufacturing costs.



Proportions of Surface Symbols:

The proportions of the size of the Surface Symbols are given as a direct size of the lettering used to indicate the roughness values as shown in **Error! Reference ource not found.**. The angled lines are drawn at 60º in both directions with the height of the short leg being 1.4 x the height of the lettering and the longer leg being 2.8 x the lettering height.

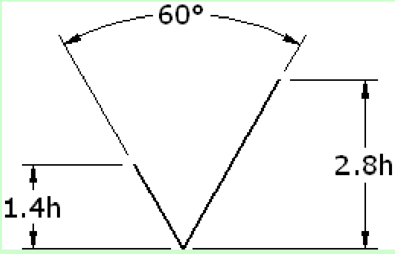


Figure 2.1

Example:

If the lettering height used on the drawing is 3.5mm; the length of each leg would be 1.4mm x 3.5mm. The sizes would be rounded of and drawn at 5mm and 10mm.

Surface Roughness:

The proper functioning and wear life of a part frequently depends upon the smoothness quality of its surfaces. Any surface, despite its apparent smoothness, has minute peaks and valleys, the height of which is termed "*surface roughness*" and which may or may not be superimposed on a more general "*waviness*". The most prominent direction of tool marks is called the "lay"

Figure 2.2 shows a magnified view of the profile of a surface where ALL smooth surfaces consist of peaks and valleys. The roughness (or smoothness) of a surface is given by a measurement called the Roughness Value (Ra) which is the average height of the hills measured from the centre of the profile.

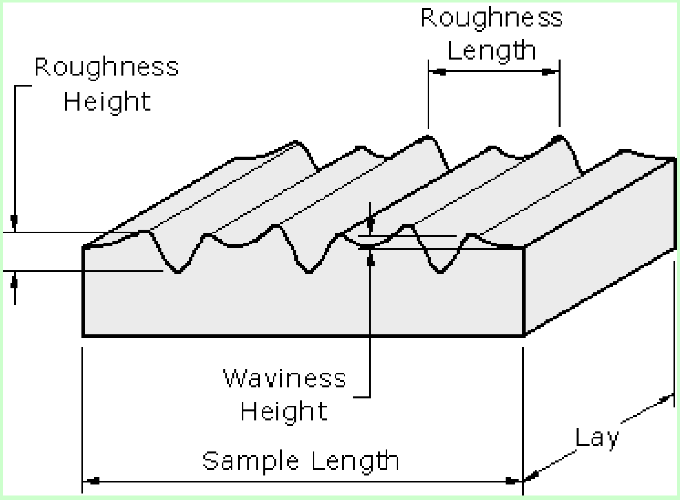


Figure 2.2

The sampling length is the distance over which the surface roughness is measured.

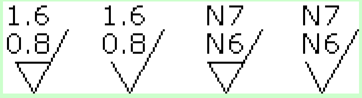
The roughness value can be specified on the surface finish symbol using one of two methods:

- Specifying the roughness height in micrometers – 0.025 μm to 50 μm,
- Specifying a roughness grade number – N1 to N12

Specifying Surface Roughness Value:

The Surface Roughness can be specified as a maximum value, or as a tolerance using maximum and minimum values as shown in Figure 2.3.

Maximum Surface Roughness Only Specified



Maximum and Minimum Surface Roughness Specified

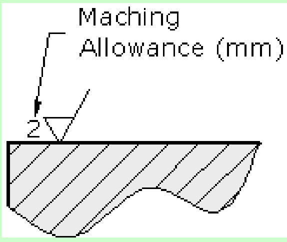
Figure 2.3

Surface Lay Pattern:

The term "lay" refers to the pattern that tool marks leave on the surface of a component and is the direction of the predominant surface pattern produced by those tool marks or grains of the surface ordinarily determined by the production method used. Sometimes it is necessary to specify the lay in a conjunction with special surface finish requirements.

Material Removal Allowance:

When it is desirable to indicate the amount of material to be removed, the amount of material in millimetres is shown to the left of the symbol. Methods of indicating material removal allowance are shown in Figure 2.4.



Means

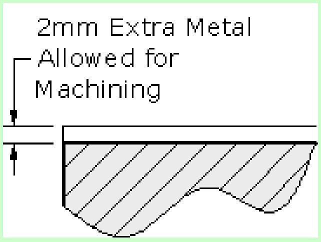
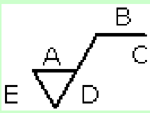


Figure 2.4

Symbol for Special Requirements:

The symbols shown in Figure 2.3 are usually sufficient to specify the surface finish, however, in some circumstances; more comprehensive details need to be specified as indicated in Figure 2.5.



A = Roughness Value
B = Production Method
e.g., Turn, Grind, Ream
C = Sample Length
D = Lay
E = Machining Allowance

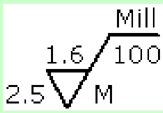


Figure 2.5

Location of Surface Finish Symbols on Drawings:

Surface finish symbols are placed so that they can be read from the bottom or right side of the drawing. To achieve the correct method, the symbol may be applied to leader lines and projection lines that extend from the surfaces on the bottom or right side of the view. Figure 2.6 shows the correct methods for applying the general machining symbols to a drawing while Figure 2.7 shows the incorrect method.

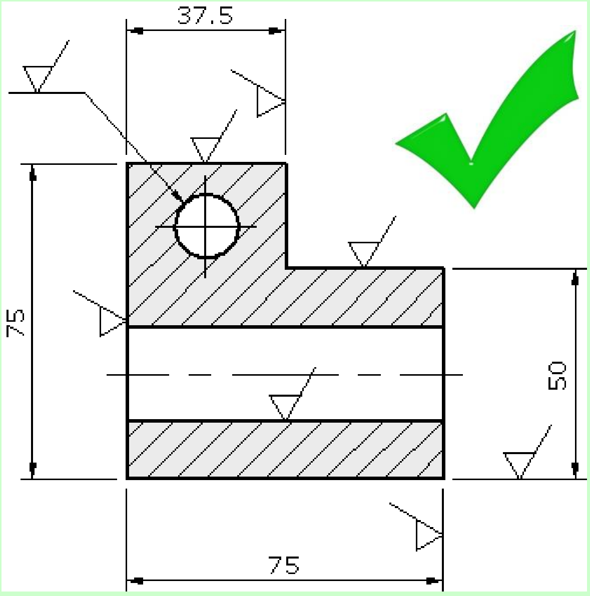


Figure 2.6

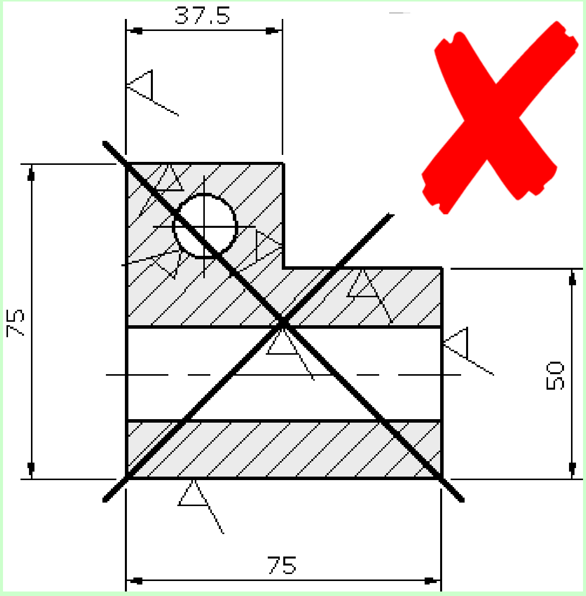


Figure 2.7

Review Questions: MEM09209-RQ-02

1. Sketch and name the 3 basic Surface Finish Symbols.

   ______________ ______________ ______________

2. Name two reasons for specifying surface finish on engineering detail drawings.

   a) ____

   ____

   b) ____

   ____

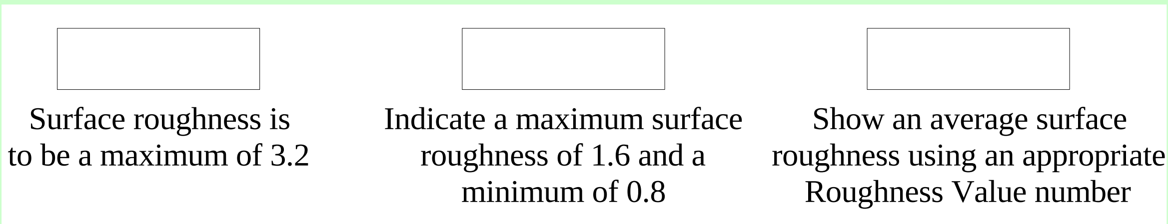
3. Provide a short description of surface roughness.

   ____

   ____

   ____

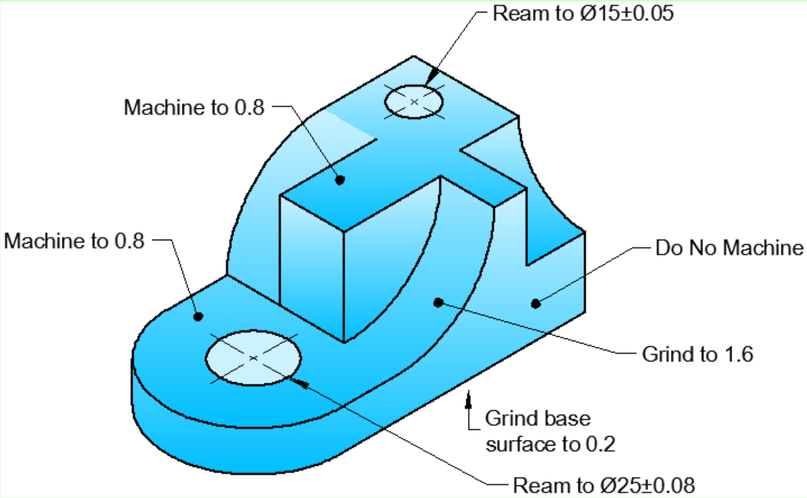
4. Complete the following drawings by adding the surface finish symbols specifying the amount of allowable surface roughness to machine the top surfaces.



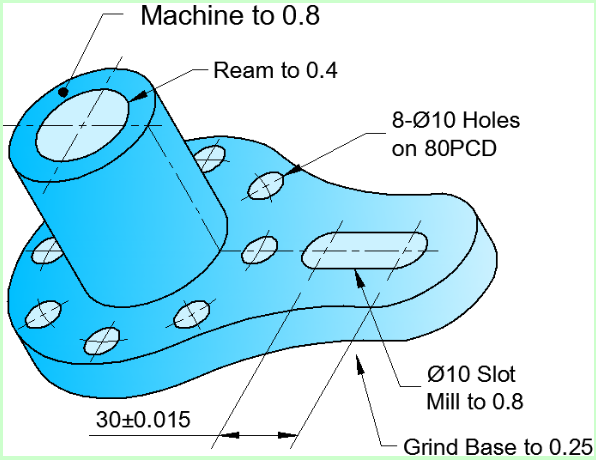
Skill Practice Exercises:

Skill Practice Exercise: MEM09209-SP-0401

Create a new drawing using the template file called Shoe Block provided on the network drive and produce a detail drawing by adding all dimensions, notes and surface finish symbols as shown. Add an A3 drawing sheet and plot the finished drawing. Save the drawing in your work folder as MEM09209-SP-0401.



Skill Practice Exercise: MEM09209-SP-0402



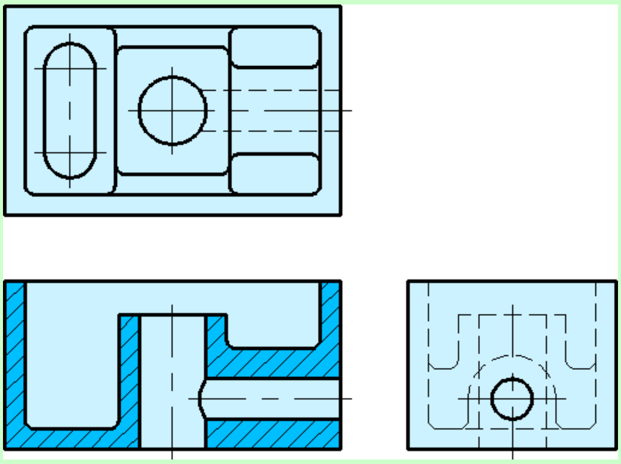
Create a new drawing using the template file called Slotted Guide provided on the network drive and produce a detail drawing by adding all dimensions, notes and surface finish symbols as shown below. Add an A3 drawing sheet and plot the finished drawing. Save the drawing in your work folder as MEM09209-SP-0402.

Skill Practice Exercise: MEM09209-SP-0403

Create a new drawing using the template file called Junction Box provided on the network drive and produce a detail drawing by adding all dimensions, notes and the following surface finish symbols.

- All vertical external surfaces to be machined to 0.8
- All internal surfaces are not to be machined.
- Ø20 Hole to be reamed to ±0.035
- Ø12 Hole to be reamed to ±0.015

Add an A3 drawing sheet and plot the finished drawing. Save the drawing in your work folder as MEM09209-SP-0403.



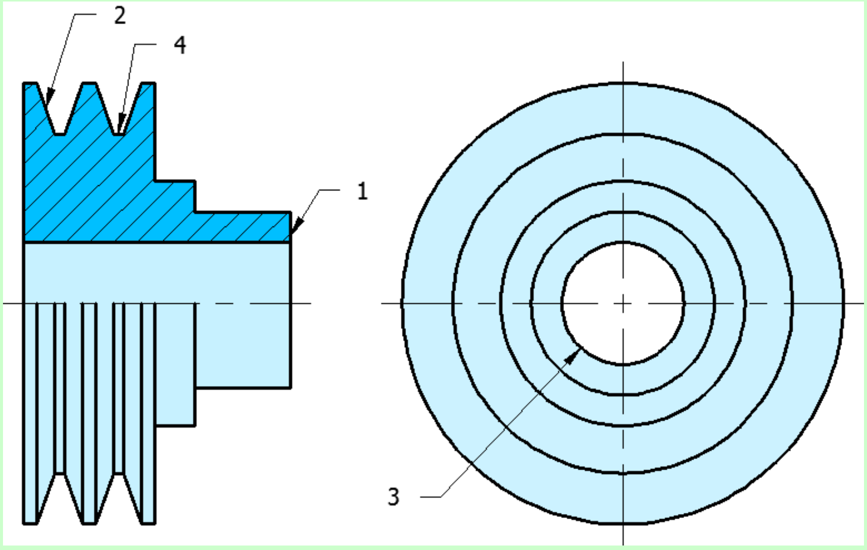
Skill Practice Exercise: MEM09209-SP-0404

Create a new drawing using the template file called 2-Belt Pulley provided on the network drive and produce a detail drawing by adding all dimensions, notes and the following surface finish symbols and tolerances:

1. Machine to 1.6

2. Hone to 0.2
3. Ream to ±0.015 and a finish of 0.2
4. Buff to 0.2

Add an A3 drawing sheet and plot the finished drawing. Save the drawing in your work folder as MEM09209-SP-0404.



Topic 3 - Geometric Tolerance:

Required Skills:

- Place geometric tolerance symbols on a detail drawing in accordance with Engineer's specifications.
- Produce a detail drawing of engineering components indicating Geometric Tolerance where applicable

Required Knowledge:

- Definition of "*Geometric Tolerance*".
- Geometric tolerances.
- Dimensioning techniques

Definition:

Geometric Tolerances states the maximum allowable variations of a form or its position from the perfect geometry implied on the drawing.

Geometric Tolerancing:

The term "*geometric*" refers to various forms as a plane, cylinder, cone, square, hexagon, etc. Theoretically, these are perfect forms, but, because it is impossible to produce perfect forms, it may be necessary to specify the amount of variation permitted. These tolerances specify either the diameter or the width of a tolerance zone within which a surface or the axis of a cylinder or hole must be if the part is to meet the required accuracy for proper function and fit. When tolerances of form are not given on a drawing, it is customary to assume that, regardless of form variations, the part will fit and function satisfactorily.

Tolerances of form and position or location control such as straightness, parallelism, perpendicularity or squareness, flatness, concentricity, roundness, angular displacement, etc. Methods for indicating geometric tolerances by means of *geometric characteristic symbols* are as recommended by AS1100 Part 210. Geometric tolerances should not be added to drawings unless they are specifically required as they may add significantly and unnecessarily to the cost of manufacture.

Symbols for Tolerance of Position and Form:

The symbols indicated in **Error! Reference source not found.** have been adopted by he Australian Standards for inclusion on drawings. The symbols provide an accurate and concise means of specifying *geometric characteristics* and *tolerances* in a minimum of space and save the necessity of including long and confusing notes.

		Characteristic	Symbol
Form Tolerances	Individual Features	Straightness	⏤
		Flatness	⏥
		Roundness; Circularity	○
		Cylindricity	⌭
	Individual or Related Features	Profile of a Line	⌒
		Profile of a Surface	⌓
	Related Features	Angularity	∠
		Perpendicularity (Squareness)	⟂
		Parallelism	∥
Location Tolerances		Position	⌖
		Concentricity	◎
		Symmetry	⌯
Runout Tolerances		Circular	↗
		Total	↗
Supplementary Symbols			
MMC	Maximum Material Condition		Ⓜ
RFS	Regardless of Feature Size		Ⓢ
DIA	Diameter		⌀

Figure 3.1

Basic Dimensional Symbol:

The basic dimension is defined by the enclosing frame symbol, Figure 3.2. The basic dimension (size) is the value used to describe the theoretically exact size, shape, or location of a feature. It is the basis from which permissible variations are established by tolerances on other dimensions.

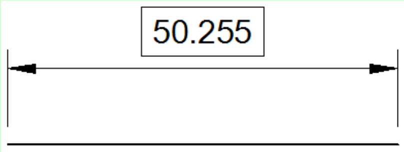


Figure 3.2

Datum Identifying Symbol:

The datum identifying symbol consists of frame containing a reference letter preceded and can be placed directly on a centreline, visible outline or projection line, or above a solid filled triangle as shown in Figure 3.3. A *point*, line plane, cylinder, or other geometric form assumed to be exact for purposes of computation may serve as a datum from which the location or geometric relationship of features of a part may be established.

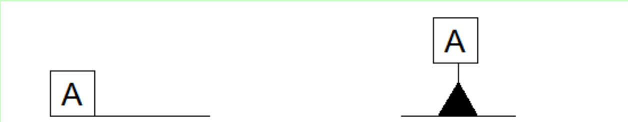


Figure 3.3

Supplementary Symbols:

The symbols for the MMC (the minimum hole diameter or the maximum shaft diameter) and the RFS (the tolerance applies to any of the feature within its size tolerance and/or the actual size of a datum feature) are indicated in Figure 3.4. The abbreviations MMC and RFS can be used in notes. The diameter symbol is used instead of the abbreviation DIA and precedes the specified tolerance in a feature control symbol Figure 3.5.

DIA	***Diameter***	***Ø***
MMC	***Maximum Material Condition***	Ⓜ
RFS	***Regardless of Feature Size***	Ⓢ

Figure 3.4

Combined Symbols:

Individual symbols, reference letters, required tolerances; etc. may be combined in a single frame Figure 3.5. A position or form tolerance is given by a feature control symbol made up of a frame about the appropriate geometric symbol plus the allowable tolerance with a vertical line separating the symbol and tolerance. Where needed, the tolerance should be preceded by the symbol for diameter and followed by the symbol for MMC or RFS. A tolerance of position or form related to a datum is so indicated in the feature control symbol by placing the datum reference letter following either the geometric characteristic symbol or the tolerance. Vertical lines separate the entries, and, where applicable, the datum reference letter entry includes the symbol for MMC or RFS.

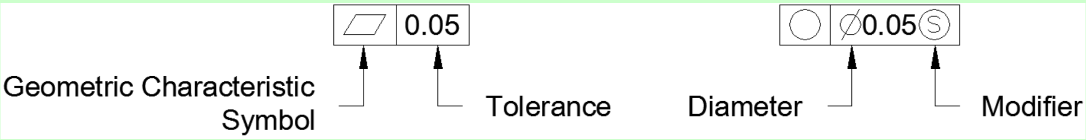


Figure 3.5

Explanation of Characteristic Symbols:

Straightness Tolerance:

A straightness tolerance specifies a tolerance zone within which as axis or all points of the considered element must lie. Straightness is a condition where an element of a surface or an axis is a straight line.z

E

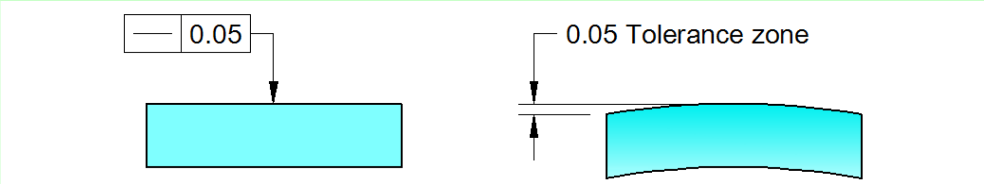


Figure 3.6

Flatness Tolerance:

A flatness tolerance specifies a tolerance zone defined by two parallel planes within which the surface must lie. Flatness is the condition of a surface having all elements in one plane.

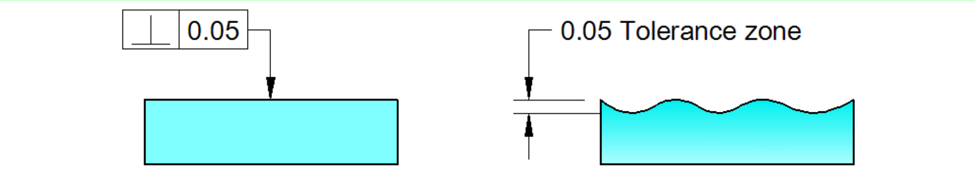


Figure 3.7

Roundness (Circularity) Tolerance:

A roundness tolerance specifies a tolerance zone bounded by two concentric circles within each circular element of the surface must lie. Roundness is a condition of a surface of revolution where, for a cone or cylinder, all points of the surface intersected by any plane perpendicular to a common axis are equidistant from that axis. For a sphere, all points of the surface intersected by any plane passing through a common centre are equidistant from that centre.

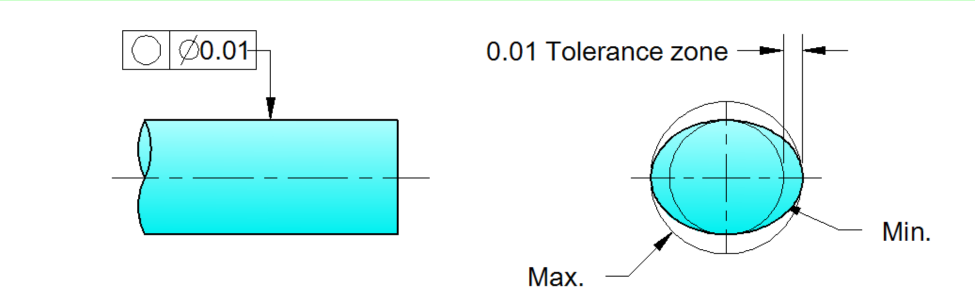


Figure 3.8

Cylindricity Tolerance:

Cylindricity is the condition of the surface that forms a cylinder where the surface elements in cross sections parallel to the axis are straight and parallel and in cross sections, perpendicular to the axis are parallel.

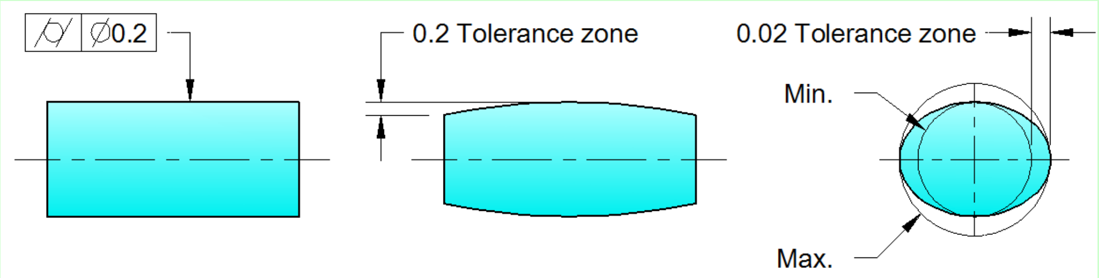


Figure 3.9

Profile of a Line Tolerance:

A profile of a line tolerance may be directed to a line of any length or shape. With profile of a line tolerance, datums may be used in some circumstances but would not be used when the only requirement is the profile shape.

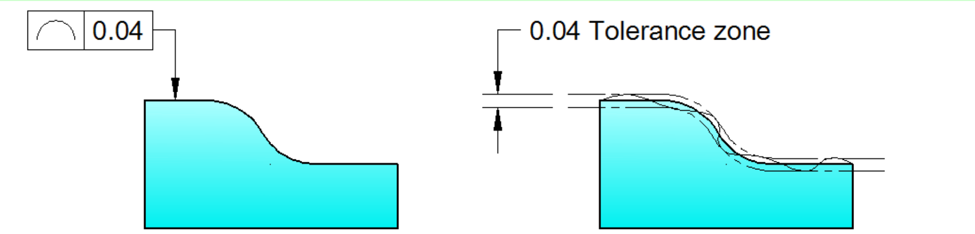


Figure 3.10

Profile of a Surface Tolerance:

The profile of a surface tolerance indicates a tolerance zone having the same basic surface, with a uniform width equal to the specified tolerance within which the entire surface must lie.

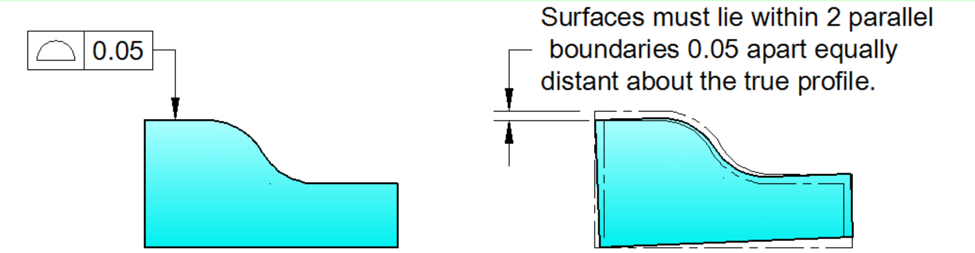


Figure 3.11

Angularity Tolerance:

An angularity tolerance specifies a tolerance zone defined by two parallel planes at the specified basic angle (other than 90°) from a datum plane or axis within which the surface or the axis of the feature must lie.

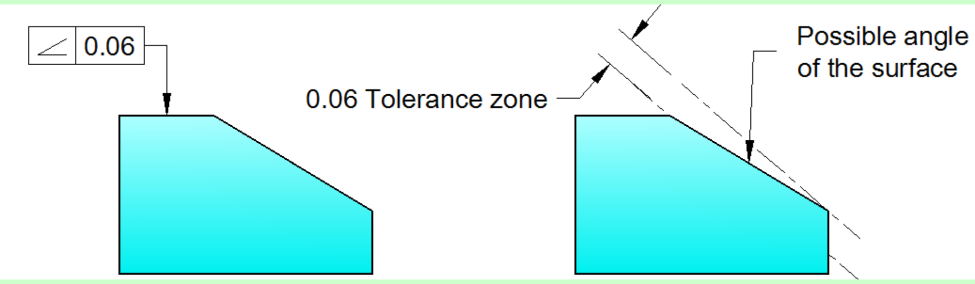


Figure 3.12

Parallelism Tolerance:

Parallelism is the condition of a surface equidistant at all points from a datum plane or an axis equidistant along its length from a datum axis or plane.

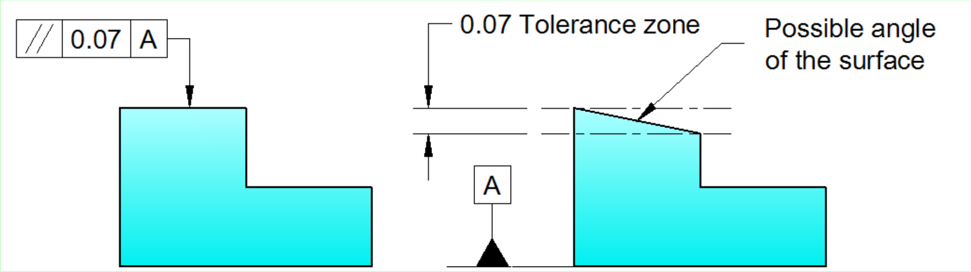


Figure 3.13

Perpendicularity Tolerance:

Perpendicularity is a condition of a surface, medium plane, or axis at 90° to a datum plane or axis.

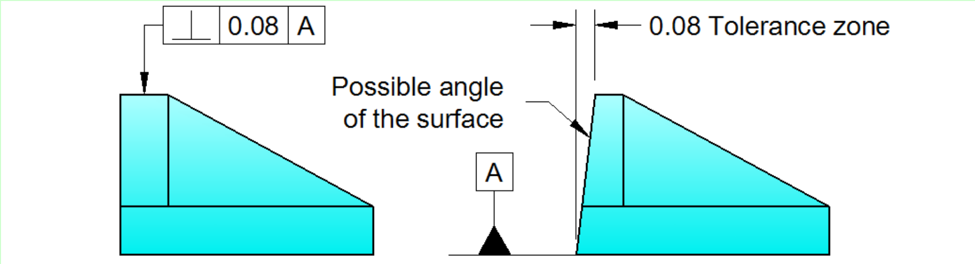


Figure 3.14

Concentricity Tolerance:

Concentricity is the condition in which two or more features such as circles, spheres, cylinders, cones or hexagons share a common centre or axis. An example is a hole passing through the centre of a shaft.

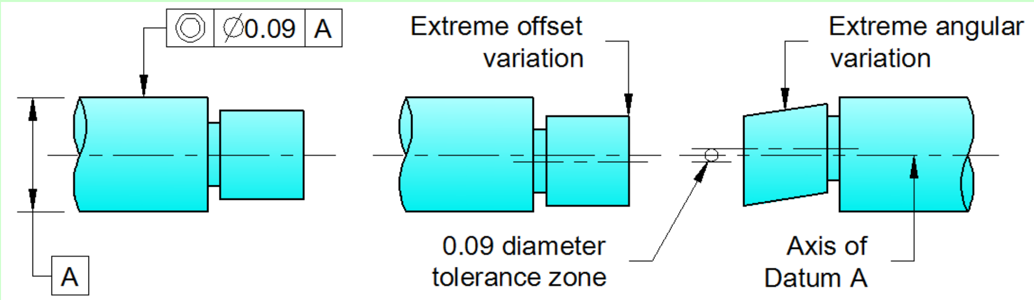
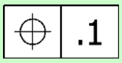


Figure 3.15

Placing the Symbols Using AutoCAD:



The Geometric Tolerance dialog box is located in the Dimension panel of the Annotate tab. The Dimension panel must be expanded and then the Geometric Tolerance button can be selected. On selecting the Geometric Tolerance button, the Geometric Tolerance dialog box is displayed.

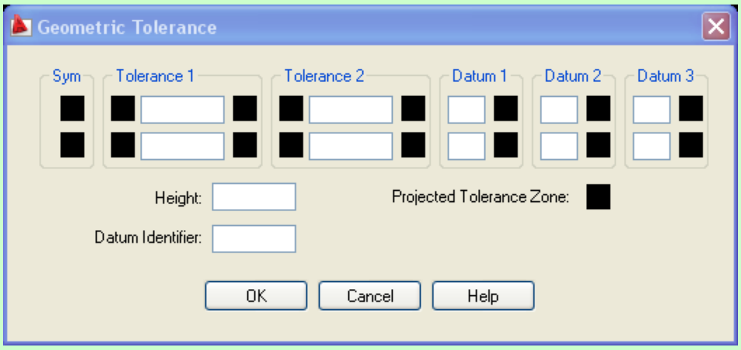


Figure 3.16

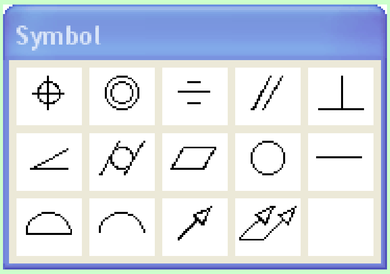


Figure 3.17

Clicking within the boxes below “Sym” displays the Symbol dialog box. An explanation of the symbols is shown in Figure 3.17. Left clicking on any of the symbols displays that symbol in the Sym box of the Geometric Tolerance dialog box. If a symbol is to be removed from the Sym box, the blank box in the bottom right corner is selected.

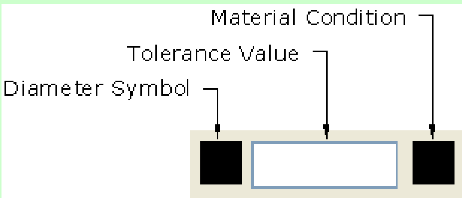


Figure 3.18

Clicking on the left box under Tolerance 1 and Tolerance 2 displays or hides the diameter Ø symbol. The actual value of the tolerance is typed into the box between the Diameter symbol and the Material Condition boxes.

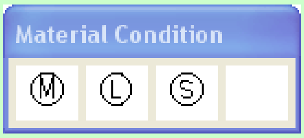


Figure 3.19

Clicking on the Material Condition box displays the Material Condition dialog box and refers to a feature of size containing the maximum or least amount of material, yet remaining within its tolerance zone.

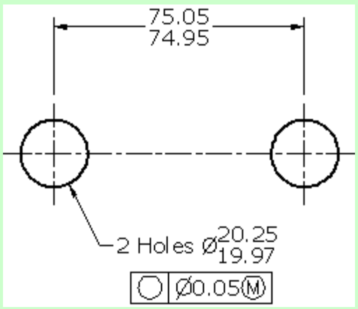


Figure 3.20

Once the geometric tolerance has been setup, clicking the OK box exits the command and allows the operator to position the information on the drawing at the end of a leader line or attached to a notation.

Review Questions: MEM09209-RQ-03

1. *In less than 3 lines, describe the term "Geometric Tolerancing".*

____

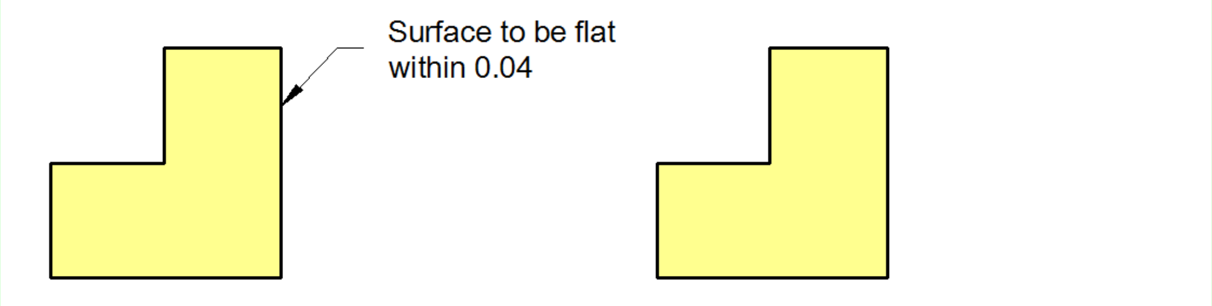
____

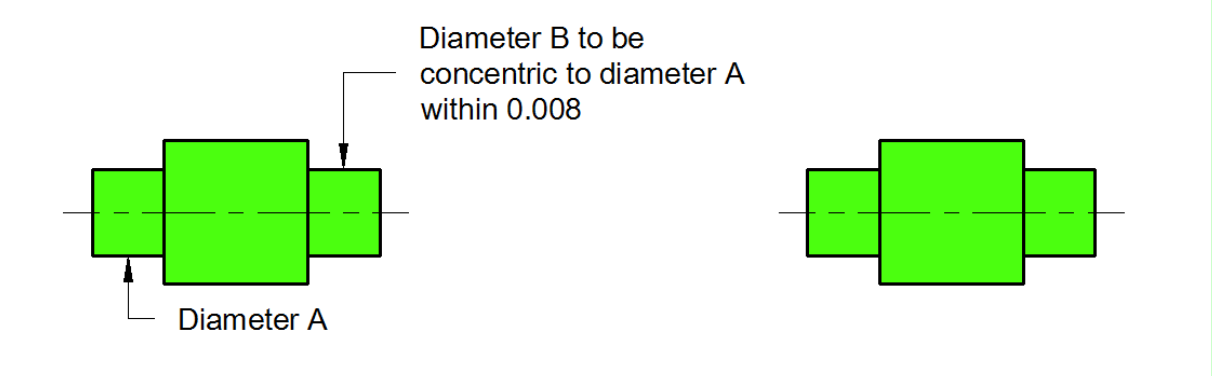
____

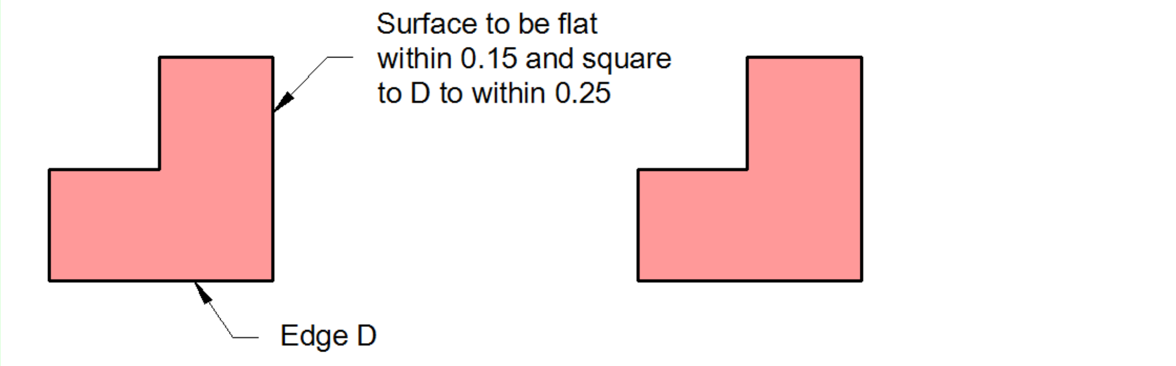
2. *Complete the following table by adding the missing information:*

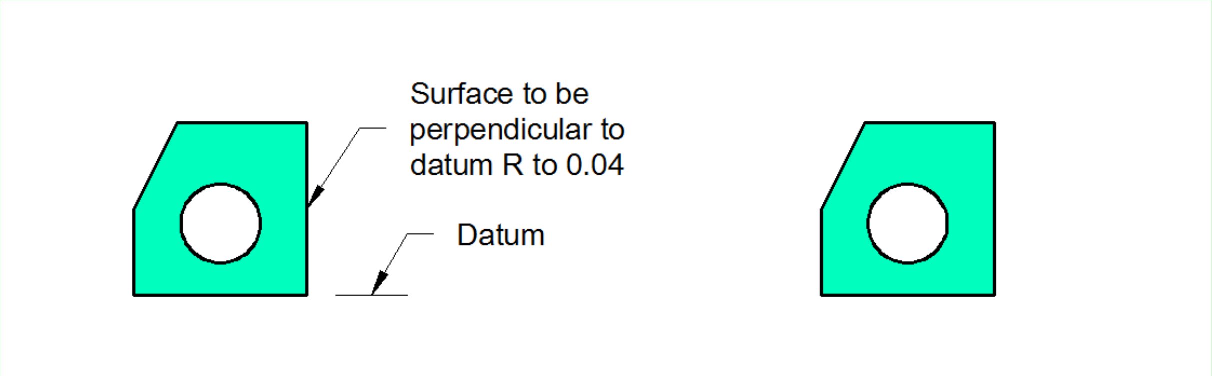
Straightness	
	⏥
Roundness; Circularity	
	⌭
Profile of a Line	
	⌓
Angularity	
	⊥
Parallelism	//
	◎
Circular	
Maximum Material Condition	
Regardless of Feature Size	
Diameter	

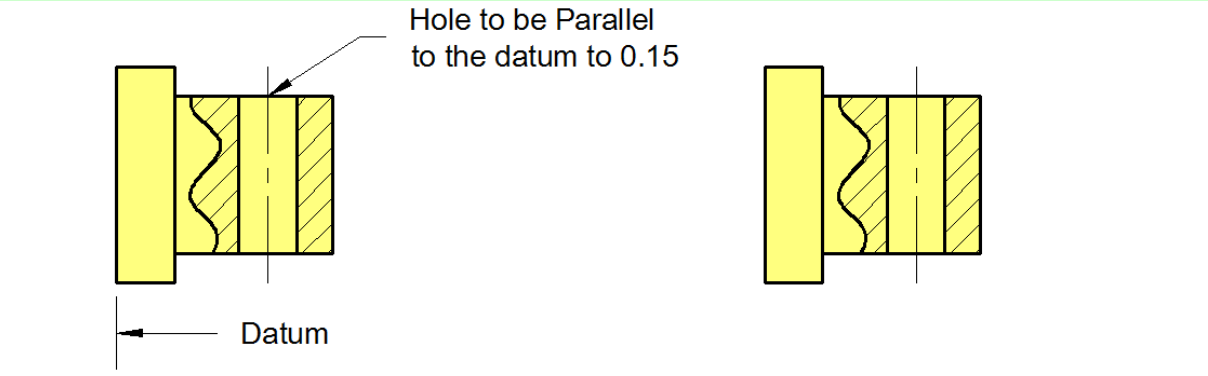
3. *Note the required geometric tolerance on the blank images provided.*

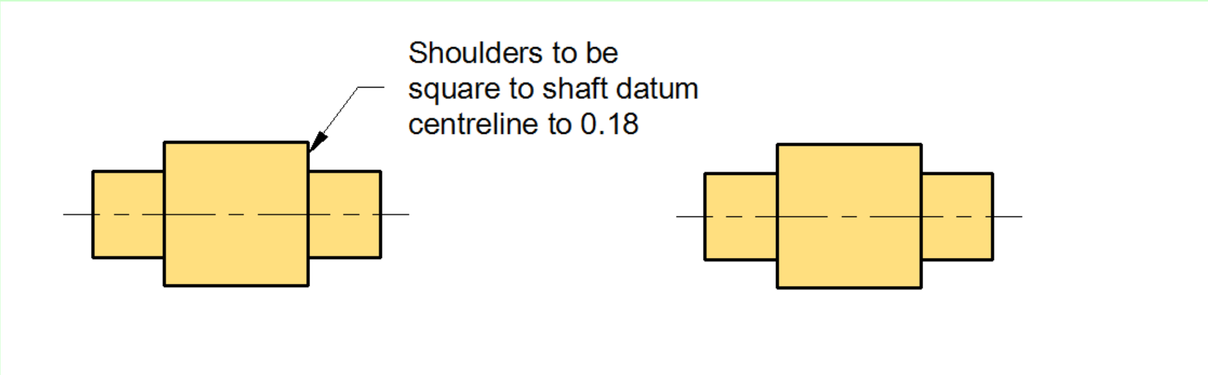

Surface to be flat
within 0.04

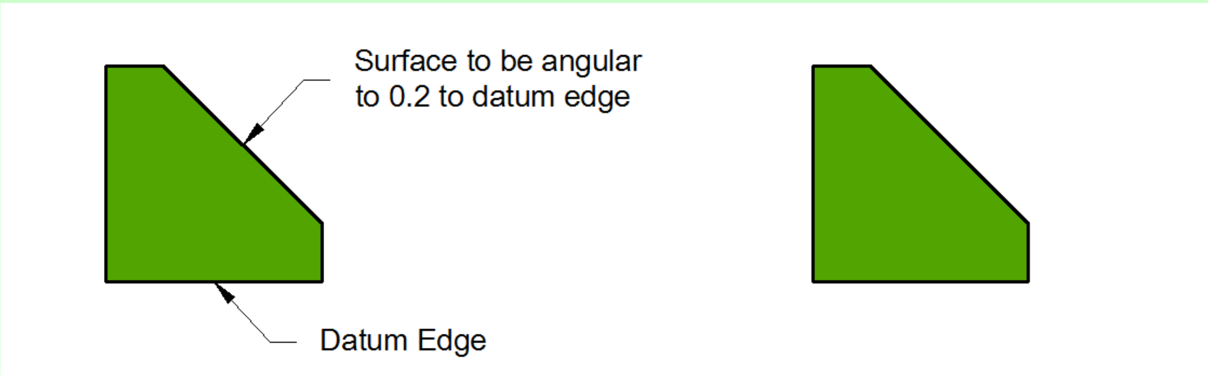

Diameter B to be
concentric to diameter A
within 0.008
Diameter A


Surface to be flat
within 0.15 and square
to D to within 0.25
Edge D


Surface to be
perpendicular to
datum R to 0.04
Datum


Hole to be Parallel
to the datum to 0.15
Datum


Shoulders to be
square to shaft datum
centreline to 0.18


Surface to be angular
to 0.2 to datum edge
Datum Edge

Skill Practice Exercises

Skill Practice Exercise MEM09209-SP-0301

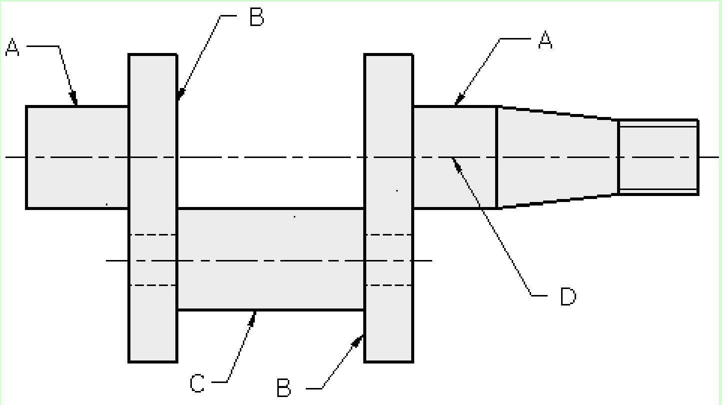
Open drawing MEM09209-SP-0301 and add the surface finish and geometric tolerances symbols in accordance with the following notes.

A Grind the surface to a roughness of 0.4; the shaft is to be round to within 0.04 and concentric to each other.

B Machine the surface to a roughness of 1.6, a flatness of 0.5 and perpendicular to the datum to within 0.01.

C Grind the surface to a roughness of 0.4; the shaft is to be round to within 0.04 and parallel to the datum to 0.025.

D Datum



Save the drawing in your work area as MEM09209-SP-0301.

Skill Practice Exercise MEM09209-SP-0302

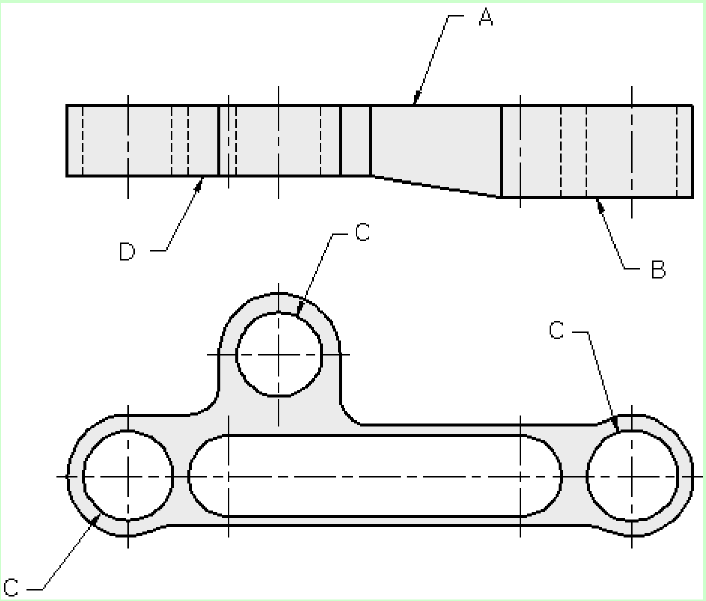
Open drawing MEM09209-SP-0302 and add the surface finish and geometric tolerances symbols in accordance with the following notes.

A Hone the datum surface to a roughness of 0.2, a flatness of 0.1 and perpendicular to the datum to 0.08.

B Hone surface to a roughness of 0.2, a flatness of 0.1 and parallel to surface A to within 0.5.

C Ream the holes to a roughness of 0.1 and perpendicular to surface A to 0.04.

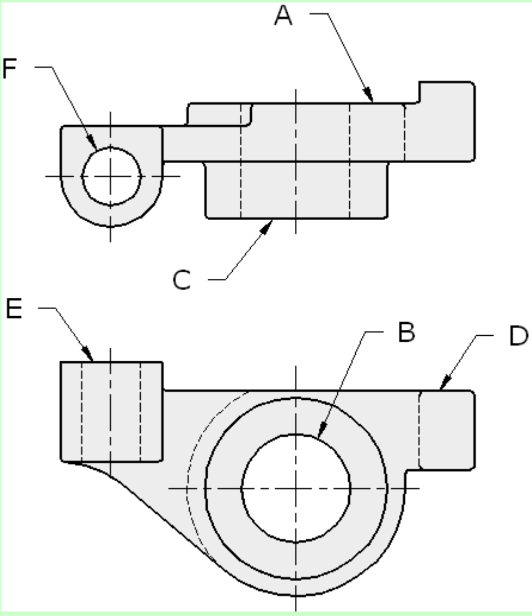
D Hone surface to a roughness of 0.2.



Save the drawing in your work area as MEM09209-SP-0302.

Skill Practice Exercise MEM09209-SP-0303

Open drawing MEM09209-SP-0303 and add the surface finish and geometric tolerances symbols in accordance with the following notes.



A Datum surface is machined to a roughness 0.2 and straightness of 0.05.

B Bore hole B to a roughness of 0.4, circular and perpendicular to datum A to 0.2.

C Surface to be a roughness of 1.6 and a flatness of 0.8.

D Datum surface is machined to a roughness 0.2 and straightness of 0.1.

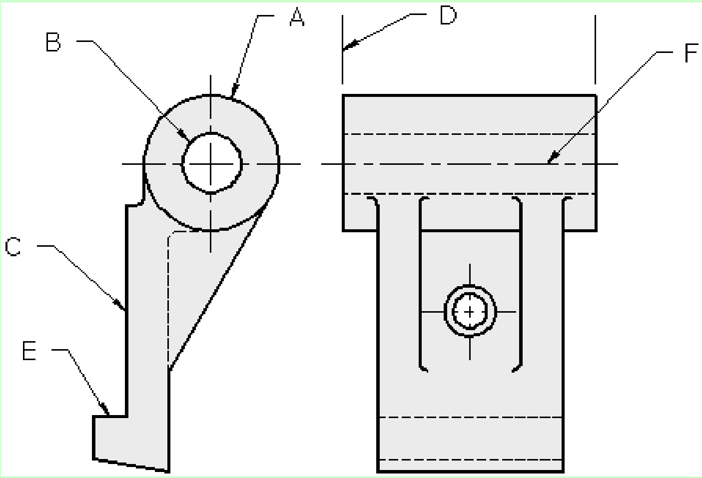
E Surface to be machined to a roughness of 3.2 and parallel to datum D.

F Ream hole to 0.4 and perpendicular to datum D to 0.05.

Save the drawing in your work area as MEM09209-SP-0303.

Skill Practice Exercise MEM09209-SP-0304

Open drawing MEM09209-SP-0304 and add the surface finish and geometric tolerances symbols in accordance with the following notes.



A Surface is not to be machined.

B Hole B to be reamed to roughness of 0.8 and circular to 0.2.

C Surface to be a roughness of 1.6 and a flatness of 0.8.

D Surfaces to be a roughness of 0.1 and perpendicular to the datum TO 0.2.

E Surface to be a roughness of 3.2 and perpendicular to within 0.15 of surface C.

F Datum

Save the drawing in your work area as MEM09209-SP-0304.

Topic 4 – Keys, Keyways & Keyseats:

Required Skills:

- Use standard tables to select a key size to suit a specified shaft.
- Use standard tables to determine the shaft and hub tolerances dimensions for square and rectangular keys.
- Produce a detail drawing of engineering components containing keyed shaft and hubs and apply toleranced dimensions for the key.

Required Knowledge:

- The difference between a *"Key"*, *"Keyseat"* and *"Keyway"*.
- Name the various types of key used in engineering applications.
- List the types of fit used for keys and keyways.

Keys & Keyways:

Keys are used to provide positive drive between cylindrical elements such as gears and pulleys on their shafts. A key is a piece of metal that is placed in a groove called the "key seat", cut in a shaft. The key extends above the shaft and fits into a "keyway" cut into the hub. After assembly, the key locks the 2 parts together so that one cannot rotate without the other thereby providing positive drive.

Rectangular Key

Rectangular keys consist of a piece of rectangular or square shaped section bar with chamfered edges that have a slight taper to assist fitting. The keys are located in rectangular slots or keyways that have been milled in the shaft to a depth of approximately half that of the key. A corresponding keyway is machined in the bore of the part to be keyed to the shaft.

Gib Head

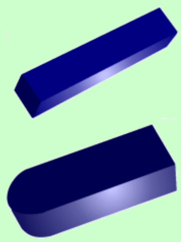
The Gib head key is used at the end of a shaft and is tapered to give a rigid fixing when hammered into place. A head is provided to assist removal of the key.

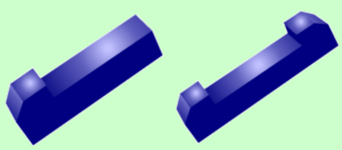
Woodruff Key

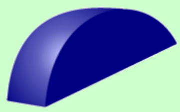
The Woodruff keys are used on tapered shafts and can be tilted for easy assembly. The keys are semi-circular segment discs that fit into recesses of the same diameter.

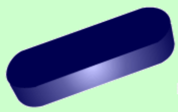
Pratt and Whitney Key (Feather Key)

The Pratt and Whitney key is similar to the rectangular key but has radius ends and fits into a keyway of the same shape on the shaft. The keyway in the hub is open at one or both ends.









Rectangular Keys	Gib Head Keys	Woodruff Key	Pratt & Whitney Key

Round Key

The round key provides a cheap method of keying and requires only a hole to be drilled (parallel to the axis of the shaft) which is half in the hub and half in the shaft. The key is a length of stock bright bar or a taper pin.

Saddle Key

The saddle key consists of a rectangular keyway is cut into the hub allowing only a small portion of the key to extend into the bore while the shaft is flattened in way of the key. The saddle key is intended for use on light duty applications only.

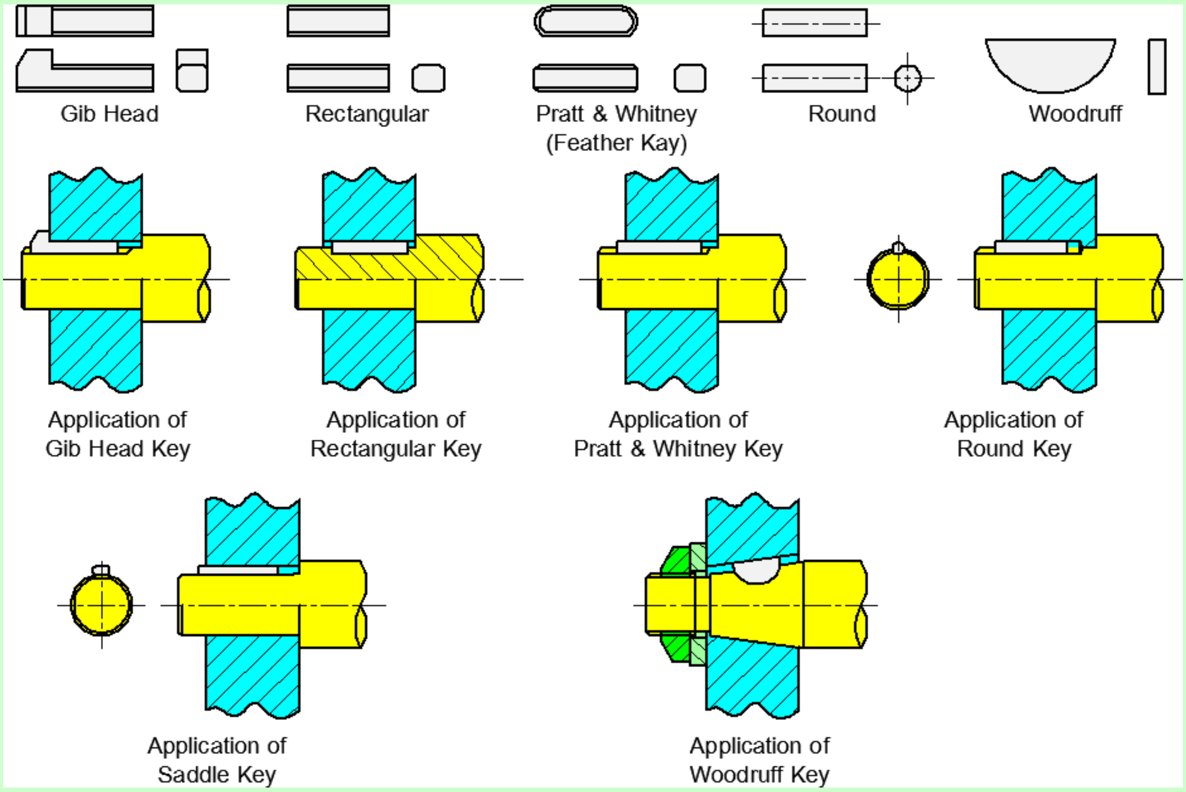


Figure 4.1

Dimensions and Tolerances for Keyways:

The dimensions required for manufacturing a keyway in a shaft and hub are shown in Figure 4.2. Note that the depth of the keyway cannot be directly measured therefore the depth of the keyway is given from the opposite side of the shaft or hub.

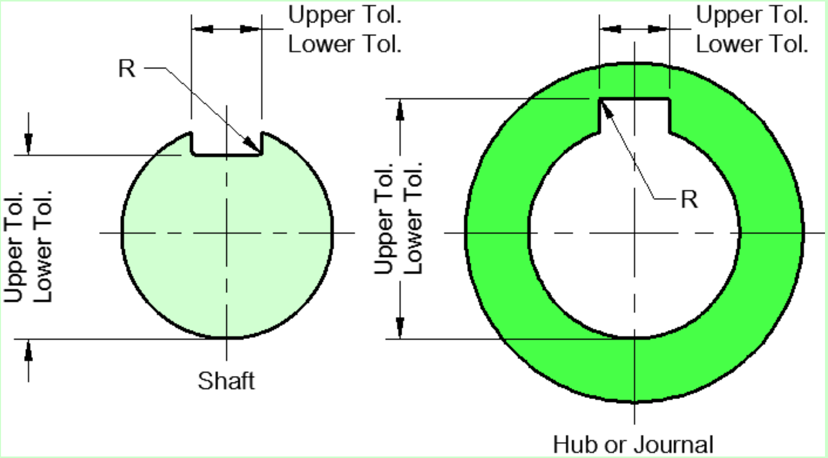


Figure 4.2

Types of Fit:

Australian Standard AS1111 (BS 4235 Part 1: 1972) specifies four classes of fit between keys and keyways. Free, Normal and Close fits apply to standard size keys; Interference fits apply to special oversize keys only.

Free

The free fit is used where the hub is required to slide over the key in use; ie the keyway in the hub is smaller than the key.

Normal

The normal fit is used where the key is to be inserted in the keyway with the minimum of fitting and is used for mass-produced items. The normal fit is usually used to specify fit on drawings unless otherwise indicated.

Close

The close fit is used where an accurate fit is required. The type of fit requires the key to be fitted and sometimes a selection of components will need to be made so that the fits match.

Interference

The interference fit is used where the possibility of play between the shaft and the hub cannot be permitted.

Selecting the Key Size:

Refer to

Table 21 – Dimensions and Tolerances for Keyways to determine the required sizes of keyways.

The size of the key to be used is determined by the diameter of the shaft. Columns 1 and 2 of

Table 21 list a range of diameter sizes. Column 3 lists the key to be used for the shaft size range.

Example 4-1:

Determine the size of a key to suit a shaft size of 32 mm diameter.

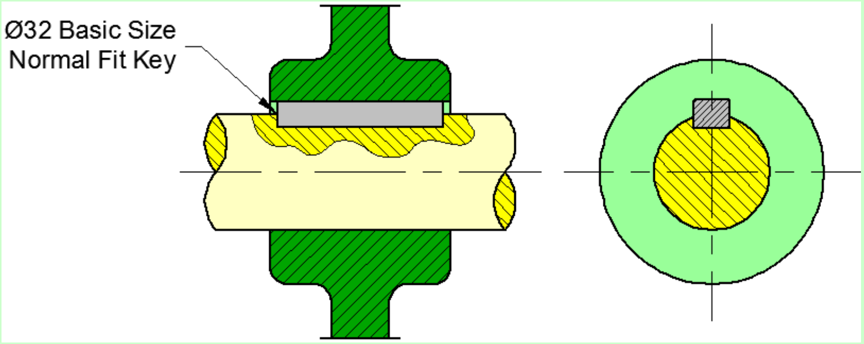


Figure 4.3

Procedure:

The shaft lies in the 30 mm (Column 1) to 38 mm (Column 2) nominal size range. Reading from Column 3, it can be seen that a 10 mm x 8mm key will be used.

Example 4-2:

Determine the size of a key to suit a shaft size on 110 mm diameter.

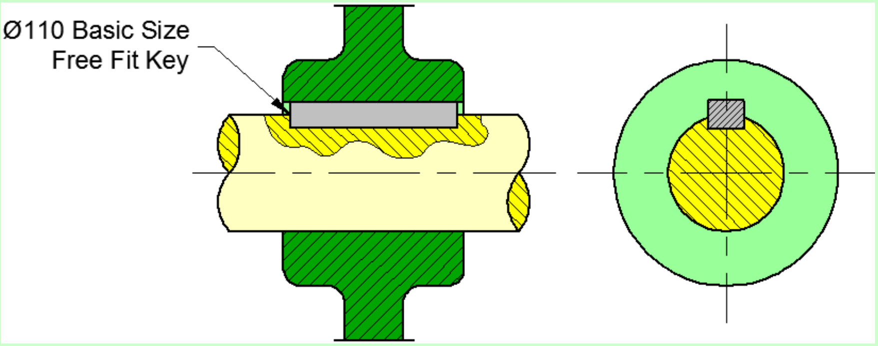


Figure 4.4

Procedure:

Column 2 indicates shaft sizes up to and including those indicated; therefore the shaft lies in the 95 mm to 110 mm range. The size of the key from Column 3 is 28 mm x 16 mm.

Selecting Shaft and Hub Dimensions and Tolerances:

Shaft and Hub Widths

The widths of the keyways in the shaft and hub are determined by locating the tolerances for the designated class of fit to suit the nominal shaft diameter then applying those tolerances to the width of the selected key.

Example 4-3:

Calculate the width of the keyway in the shaft and hub to suit a key on a 32 mm diameter shaft. The key is to be a normal fit in the keyway.

Procedure:

The key as determined is 10 mm x 8 mm. Reading across the line to Columns 7 & 8 (Normal), the tolerances are shown as:

7	8
Shaft	Hub
0 -0.036	+0.018 -0.018

Apply the tolerances to the width:

Shaft -	Maximum	= 10.000 + 0	= 10.000mm
	Minimum	= 10.000 – 0.036	= 9.964mm
Hub -	Maximum	= 10.000 + 0.018	= 10.018mm
	Minimum	= 10.000 – 0.018	= 9.982mm

Example 4-4:

Calculate the width of the keyway in the shaft and hub to suit a key on a 110 mm diameter shaft. The key is to be a free fit in the keyway.

Procedure:

The key as determined is 28 mm x 16 mm. Reading across the line to Columns 5 & 6 (Free), the tolerances are shown as:

5	6
Shaft	Hub
+0.052 0	+0.149 +0.065

Apply the tolerances to the width:

Shaft -	Maximum	= 32.000 + 0.052	= <u>32.052 mm</u>
	Minimum	= 32.000 + 0	= <u>32.000 mm</u>
Hub -	Maximum	= 32.000 + 0.149	= <u>32.149 mm</u>
	Minimum	= 32.000 + 0.065	= <u>32.065 mm</u>

Shaft and Hub Depths

The depth of the keyway is determined by reading the depths and tolerances from Columns 10 to 13 and applying them to the following formula:

Shaft = Nominal Shaft Diameter – (Depth-Column 10 and Tolerance-Column 11)

Hub = Nominal Shaft Diameter + (Depth-Column 1 and Tolerance-Column 13)

Example 4-5:

Calculate the depth of the keyway in the shaft and hub to suit a key on a 32mm diameter shaft.

Procedure:

The key as determined is 10 mm x 8 mm. Reading across the line to Columns 10 & 11, to determine the depth of the shaft; the tolerances are shown as:

10	11
Nominal	Tolerance
5	+0.2 0

Apply the tolerances to determine the shaft depth:

Shaft -	Maximum	= 32.00 – (5.000 + 0.2)	= <u>26.80 mm</u>
	Minimum	= 32.00 – (5.000 + 0)	= <u>27.00 mm</u>

Now read across the line to Columns 12 & 13, to determine the depth of the hub; the tolerances are shown as:

12	13
Nominal	Tolerance
3.3	+0.2 0

Apply the tolerances to determine the hub depth:

Hub - Maximum = 32.000 + (3.3 + 0.2) = 35.2 mm

Minimum = 32.000 + (3.3 + 0) = 35.0 mm

Example 4-6:

Calculate the depth of the keyway in the shaft and hub to suit a key on a 110 mm diameter shaft.

Procedure:

The key as determined is 28 mm x 16 mm. Reading across the line to Columns 10 & 11, to determine the depth of the shaft; the tolerances are shown as:

10	11
Nominal	Tolerance.
10	+0.2 0

Apply the tolerances to determine the shaft depth:

Shaft - Maximum = 110.00 – (10.000 + 0.2) = 99.80 mm

Minimum = 110.00 – (10.000 + 0) = 100.00 mm

Now read across the line to Columns 12 & 13, to determine the depth of the hub; the tolerances are shown as:

12	13
Nominal	Tolerance
6.4	+0.2 0

Apply the tolerances to determine the hub depth:

Hub - Maximum = 110.000 + (6.4 + 0.2) = 116.6 mm

Minimum = 110.000 + (6.4 + 0) = 116.4 mm

Select the Keyway Corner Radius:

The maximum and minimum radii for the corners of the keyway on the shaft and hub are determined by reading across to Columns 14 and 15.

Example 4-7:

Determine the radii of the keyway in the shaft and hub to suit a key on a 32 mm diameter shaft.

Procedure:

Reading across the line to Columns 14 & 15, to determine the radii of the shaft and hub:

14	15
Maximum	Minimum
0.40	0.25

Apply the radii to the drawing:

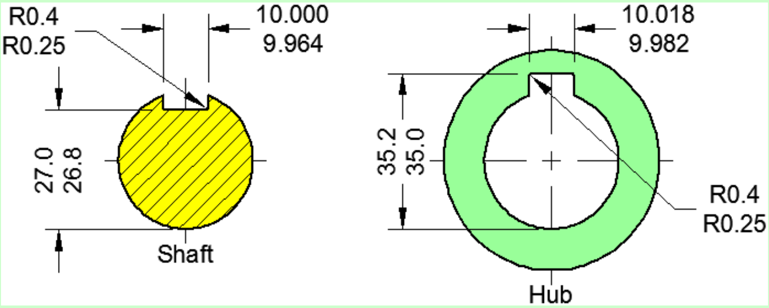


Figure 4.5

Example 4-8:

Calculate the depth of the keyway in the shaft and hub to suit a key on a 110 mm diameter shaft.

Procedure:

Reading across the line to Columns 14 & 15, to determine the radii of the shaft and hub:

14	15
Maximum	Minimum
0.60	0.40

Apply the radii to the drawing:

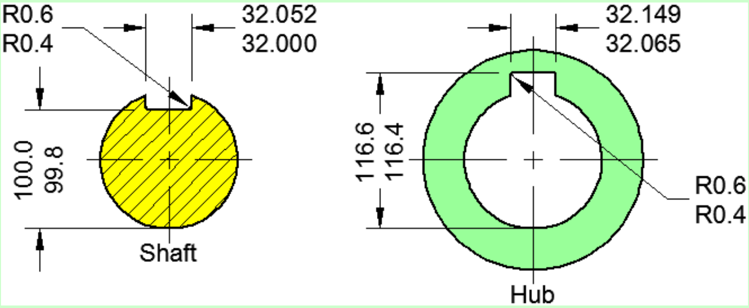


Figure 4.6

Review Questions: MEM09209-RQ-04

1. Define the following terminology:

Key

____

____

Keyway

____

____

Interference Fit

____

____

2. Name 4 types of key used in engineering applications.

a) ______________________________________

b) ______________________________________

c) ______________________________________

d) ______________________________________

3. List the 3 types of fit used for keys and keyways.

a) ______________________________________

b) ______________________________________

c) ______________________________________

4. Use the Dimensions and Tolerances for Keyways Tables to select a key size to suit a 64 mm diameter shaft.

____

5. Use the Dimensions and Tolerances for Keyways Tables to determine the tolerance dimensions for the width of the keyway and keyseat of the shaft and hub to suit a 95 mm diameter shaft with a normal class of fit.

Maximum Shaft

____

Minimum Shaft

____

Maximum Hub____

Minimum Hub

____

6. What factor determines whether the key is rectangular or square in section?

____

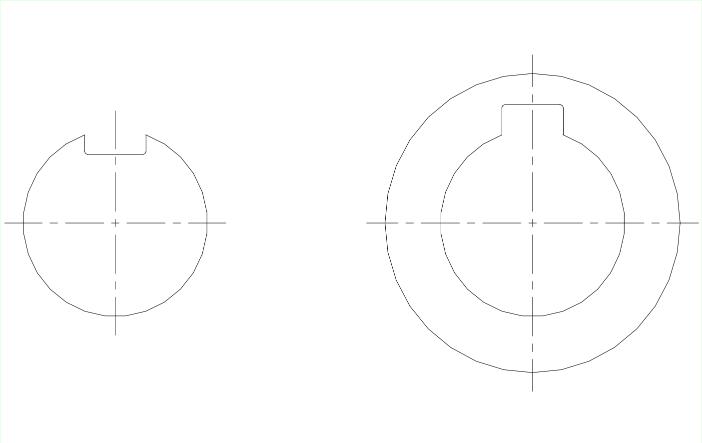
____

7. Does the key require to be toleranced when producing a detail drawing?

(Tick one Box Only).

❑ YES ❑ NO

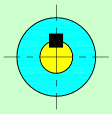
8. Complete the drawing of the shaft and hub shown by calculating and including the toleranced dimensions. Basic size = 32.5 mm with a normal fit.



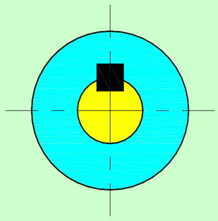
Skill Practice Exercises

Skill Practice Exercise: MEM09209-SP-0601

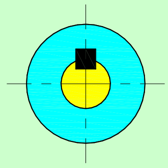
Reproduce the following drawing on two A3 sheets using the scales shown then adding the toleranced dimensions for the keyways and keyseats. Insert an A3 sheet on the drawings and save the drawing in your work area as MEM09209-SP-0601.



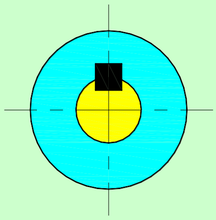
Scale 2:1
Shaft Ø12.5
Collar Ø25
Normal Key



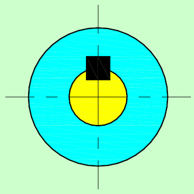
Scale 1:1
Shaft Ø50
Collar Ø75
Close Fit



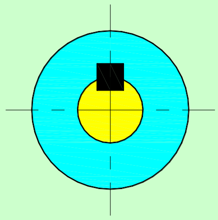
Scale 1:5
Shaft Ø165
Collar Ø225
Free Fit



Scale 1:1
Shaft Ø64
Collar Ø90
Free Fit



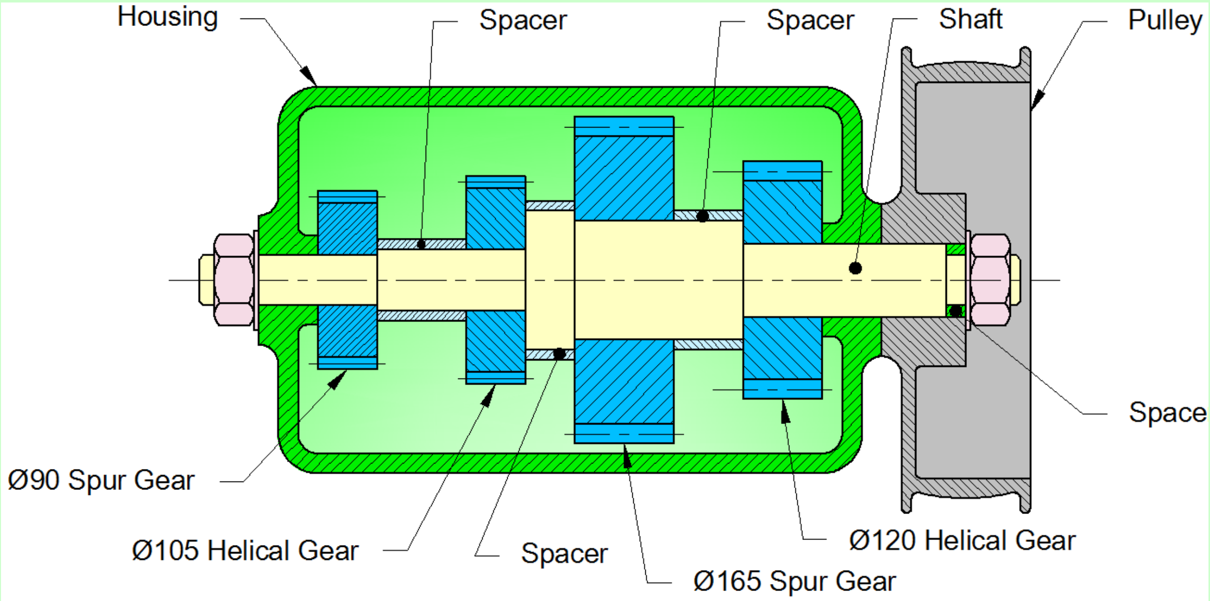
Scale 1:1
Shaft Ø38.25
Collar Ø75
Normal Fit



Scale 1:2
Shaft Ø110
Collar Ø150
Close Fit

Skill Practice Exercise: MEM09209-SP-0602

1. Create a new drawing using the template drawing called Gearbox and complete the assembly by adding keyways to the shaft and gears.
2. Produce an assembly drawing of the Gearbox including a Parts List and cross-referencing.
3. Produce separate detail drawings of the shaft and the various gears showing details of the keyseat and keyway to suit a normal fit.
4. Indicate that all mating flat surfaces are to be milled to 1.6 and all curved surfaces ground to 0.4. Holes are to be reamed to 0.1.
5. All flat mating flat surfaces are to be perpendicular to the datum centreline to 0.05 and a flatness of 0.1. All holes and curved surfaces are to be concentric to the datum to 0.02 and straight to within 0.08.
6. Insert an A3 sheet to all drawings and submit to your teacher for correction.
7. Save the drawing as MEM09209-SP-0602.

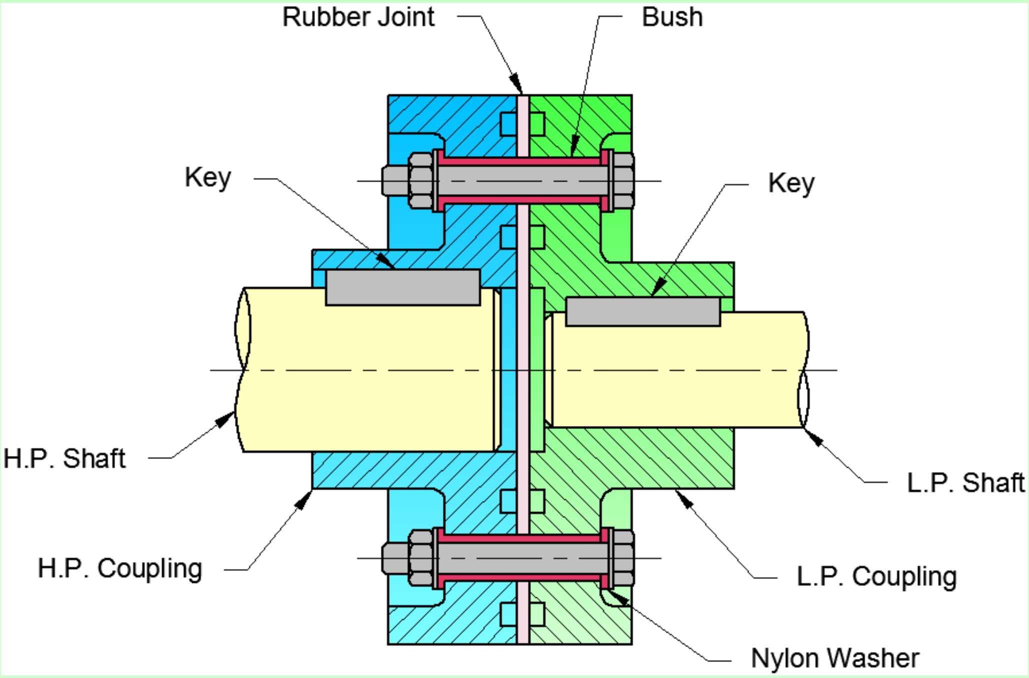


The shape of the Housing is circular. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Materials are: Housing – Cast Iron, Shaft – Stainless Steel, Gears – Mild Steel, Pulley – Cast Iron, Spacers – Brass, Fastenings – Commercial.

Skill Practice Exercise: MEM09209-SP-0603

1. Create a new drawing using the template drawing called Flexible Coupling and complete the assembly by adding keyways to the shafts and couplings.
2. Produce an assembly drawing of the Flexible Coupling including a Parts List and cross-referencing.
3. Produce separate detail drawings of the shaft, the HP and LP Couplings showing details of the keyseat and keyway to suit a close fit.
4. Indicate that all mating flat surfaces are to be milled to 3.2 while all curved surfaces are machined to 0.8. Holes are to be reamed to 0.05.
5. All flat mating flat surfaces are to be perpendicular to the datum centreline to 0.05 and a flatness of 0.1. All holes and curved surfaces are to be concentric to the datum to 0.02 and straight to within 0.08.
6. Insert an A3 sheet to all drawings and submit to your teacher for correction.
7. Save the drawing as MEM09209-SP-0603.



The coupling is circular in shape and fastened using 6 machine screws/bolts equally spaced on the PCD. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Materials are: HP & LP Coupling – Mild Steel, Shafts – Stainless Steel, Bushes – Nylon, Keys – Mild Steel, Flexible Disc – Rubber.

Topic 5 – Hole & Shaft Basis Systems:

Required Skills:

- Use the Hole Basis and Shaft Basis System Tables to determine the maximum and minimum dimensions of a hole and shaft.
- Produce a detail drawing of engineering components using the tables to specify toleranced dimensions of holes and shafts

Required Knowledge:

- The 2 of Basis Systems for assigning tolerances to shafts and holes.
- Conversion of toleranced dimensions.
- Application of toleranced dimensions.

Hole Basis System:

The Hole Basis System, is a system of fits in which the different clearances and interferences are obtained in associating various shafts with a single hole.

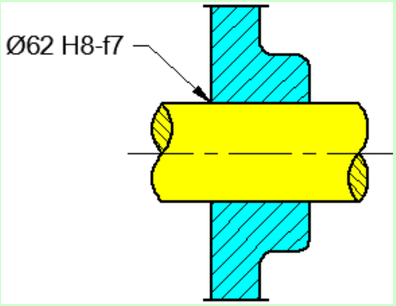
In the Hole basis system, the hole is kept with the basic size as one of its limits. The shaft is then varied above or below the basic size to provide the fit required. The reason for preferring this system is that it is easy to drill or ream a standard size hole. The mating shaft can then be turned oversize or undersized as required. The alternative would be to have standard size shafts and non-standard holes, which is more difficult and costly.

To determine the toleranced dimensions for holes and shafts,

Table 17 - Hole Basis System must be referred to.

Example 5-1:

Determine the upper and lower values of a shaft and hub with a basic hole size of Ø62 mm and a fit of H8-f7.



Procedure:

Refer to

1. Table 17 - Hole Basis System.
2. Locate the row where the diameter of the shaft lies – between 50 & 65.
3. Locate the columns containing the fit H8-f7.
4. Read the tolerances in the box intersecting the selected row and column.

   H8 = +46 & 0 f7 = -30 & -60

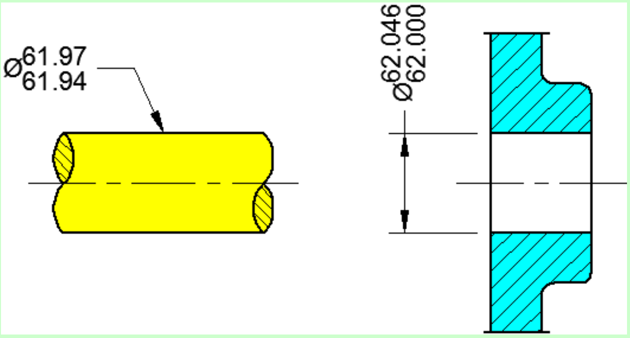
   The sizes are in micrometres (1/1000th mm)
5. Calculate the upper and lower values of the hole - H8:

   Upper = 62.000 + 0.046 = 62.046 mm

   Lower = 62.000 + 0.000 = 62.000 mm
6. Calculate the upper and lower values of the shaft – f7:

   Lower = 62.000 – 0.060 = 61.940 mm

   Upper = 62.000 – 0.030 = 61.970 mm
7. Apply the tolerance dimensions to the detail drawing.



Shaft Basis System:

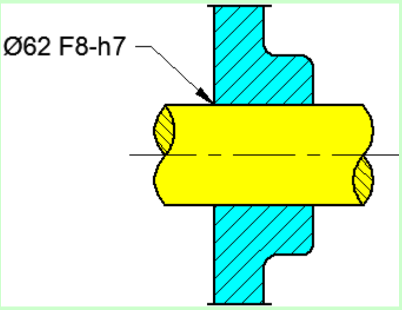
The Basic Shaft System is a system of fits in which the design size of the shaft is the basic size and the allowance applies to the hole.

The shaft basis system of fits complements the hole basis system. With the shaft basis system, the shaft is kept at a standard size and the hole size varied above or below the standard size to provide the required fit. The shaft basis system has advantages where a number of components have to be fitted onto one shaft. It is particularly suitable where standard ground steel bar is used for the shaft.

To determine the toleranced dimensions for holes and shafts, Table 18 – Shaft Basis System must be referred to.

Example 5-2:

Determine the upper and lower values of a shaft and hub with a basic shaft size of Ø62 mm and a fit of F8-h7.



Procedure:

1. Refer to Table 18 – Shaft Basis System.
2. Locate the row where the diameter of the shaft lies – between 50 & 65.
3. Locate the columns containing the fit F8-h7.
4. Read the tolerances in the box intersecting the selected row and column.

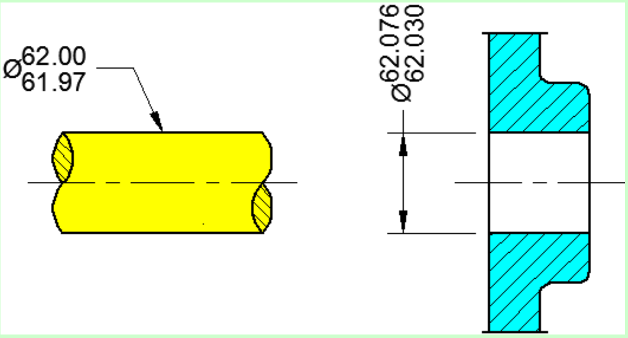
   F8 = +76 & +30 f7 = 0 & -30
5. The sizes are in micrometres (1/1000th mm)
6. Calculate the upper and lower values of the hole - F8:

   Upper = 62.000 + 0.076 = 62.076 mm

   Lower = 62.000 + 0.030 = 62.030 mm
7. Calculate the upper and lower values of the shaft – h7:

   Lower = 62.000 – 0 = 62.000 mm

   Upper = 62.000 – 0.030 = 61.970 mm
8. Apply the tolerance dimensions to the detail drawing.



Note:

Although both the Hole and Shaft Basis Systems are equivalent in the view of their functional properties, the Hole Basis System is preferably used.

Classification of Fits:

The table below indicates that switching the letters in the fit makes the conversion from hole to shaft basis. (Note that the hole fit always has the capital letter.) There is only one exception to the rule and that is where H9-d10 converts to D10-h9 for a loose running fit.

Clearance Fit:

A Clearance fit is a fit that always enables a clearance between the hole and shaft in the coupling. The lower limit size of the hole is greater or at least equal to the upper limit size of the shaft.

H11/a11, H11/c11, H11/c9, H11/d11, A11/h11, C11/h11, D11/h11

Fits with great clearances with parts having great tolerances. Use: Pivots, latches, fits of parts exposed to corrosive effects, contamination with dust and thermal or mechanical deformations.

H9/C9, H9/d10, H9/d9, H8/d9, H8/d8, D10/h9, D9/h9, D9/h8

Running fits with greater clearances without any special requirements for accuracy of guiding shafts.

Use: Multiple fits of shafts of production and piston machines, parts rotating very rarely or only swinging.

H9/e9, H8/e8, H7/e7, E9/h9, E8/h8, E8/h7

Running fits with greater clearances without any special requirements for fit accuracy.
Use: Fits of long shafts, e.g. in agricultural machines, bearings of pumps, fans and piston machines.

H9/f8, H8/f8, H8/f7, H7/f7, F8/h7, F8/h6

Running fits with smaller clearances with general requirements for fit accuracy.
Use: Main fits of machine tools. General fits of shafts, regulator bearings, machine tool spindles, sliding rods.

H8/g7, H7/g6, G7/h6

Running fits with very small clearances for accurate guiding of shafts. Without any noticeable clearance after assembly.

Use: Parts of machine tools, sliding gears and clutch disks, crankshaft journals, pistons of hydraulic machines, rods sliding in bearings, grinding machine spindles.

H11/h11, H11/h9

Slipping fits of parts with great tolerances. The parts can easily be slid one into the other and turn.
Use: Easily demountable parts, distance rings, parts of machines fixed to shafts using pins, bolts, rivets or welds.

H8/h9, H8/h8, H8/h7, H7/h6

Sliding fits with very small clearances for precise guiding and centring of parts. Mounting by sliding on without use of any great force, after lubrication the parts can be turned and slid by hand.
Use: Precise guiding of machines and preparations, exchangeable wheels, roller guides.

Transition Fit:
A Trancisi0on fit is a fit where (depending on the actual sizes of the hole and shaft) both clearance and interference may occur in the coupling. Tolerance zones of the hole and shaft partly or completely interfere.

H8/j7, H7/js6, H7/j6, J7/h6

Tight fits with small clearances or negligible interference. The parts can be assembled or disassembled manually.

Use: Easily dismountable fits of hubs of gears, pulleys and bushings, retaining rings, frequently removed bearing bushings.

H8/k7, H7/k6, K8/h7, K7/h6

Similar fits with small clearances or small interferences. The parts can be assembled or disassembled without great force using a rubber mallet.
Use: Demountable fits of hubs of gears and pulleys, manual wheels, clutches, brake disks.

H8/p7, H8/m7, H8/n7, H7/m6, H7/n6, M8/h6, N8/h7, N7/h6

Fixed fits with negligible clearances or small interferences. Mounting of fits using pressing and light force.

Use: Fixed plugs, driven bushings, armatures of electric motors on shafts, gear rims, flushed bolts.

Interference Fit:

An Interference fit is a fit always ensuring some interference between the hole and shaft in the coupling. The upper limit size of the hole is smaller or at least equal to the lower limit size of the shaft.

H8/r7, H7/p6, H7/r6, P7/h6, R7/h6

Pressed fits with guaranteed interference. Assembly of the parts can be carried out using cold pressing.
Use: Hubs of clutch disks, bearing bushings.

H8/s7, H8/t7, H7/s6, H7/t6, S7/h6, T7/h6

Pressed fits with medium interference. Assembly of parts using hot pressing. Assembly using cold pressing only with use of large forces.
Use: Permanent coupling of gears with shafts, bearing bushings.

H8/u8, H8/u7, H8/x8, H7/u6, U8/h7, U7/h6

Pressed fits with big interferences. Assembly using pressing and great forces under different temperatures of the parts.
Use: permanent couplings of gears with shafts, flanges.

Fit	Hole Basis Specification	Shaft Basis Specification
Loose Clearance	H11 - c11	C11 – h11
Loose Running	H9 – d10	D10 – h9
Easy Running	H9 - e9	E9 – h9
Normal Running	H8 – f7	F8 – h7
Precision Running	H7 – g6	G7 – h6
Average Location	H7 – h6	H7 – h6
Light Push	H7 – k6	K7 - h6
Heavy Push	H7 – n6	N7 – h6
Press (Ferrous)	H7 – p6	P7 - h6
Press (Non Ferrous)	H7 – s6	S7 - h6

Review Questions: MEM09209-RQ-05

1. Why would a Shaft Basis System be used in preference to a Hole Basis System?

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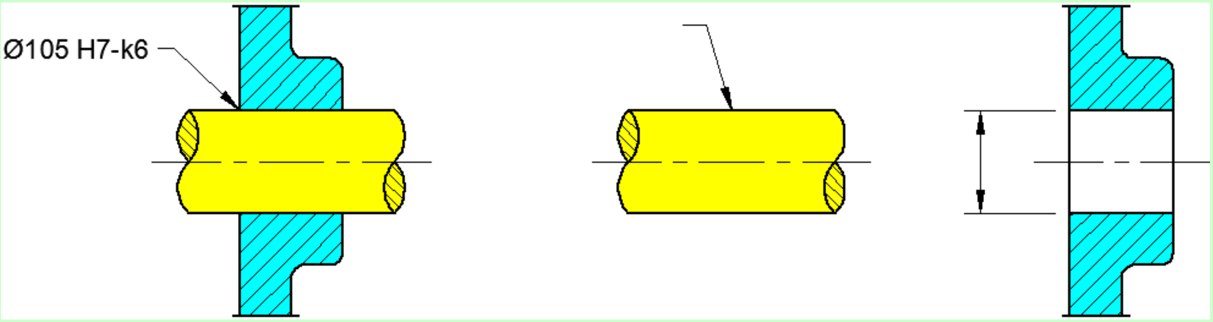
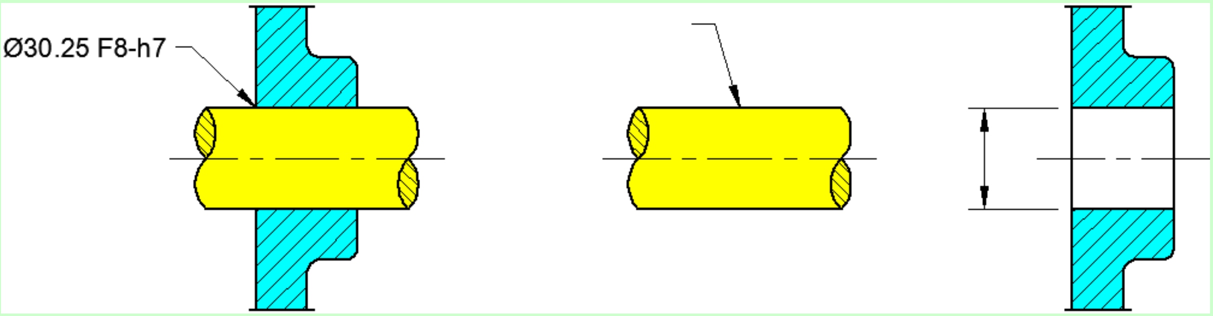
2. Calculate the missing dimensions of the shaft and hub by using the Hole Basis System Table. Complete the drawing by including the toleranced dimensions.



3. Calculate the missing dimensions of the shaft and hub by using the Shaft Basis System Table. Complete the drawing by including the toleranced dimensions.



4. What are the units of tolerance listed in the Hole and Shaft Basis tables?

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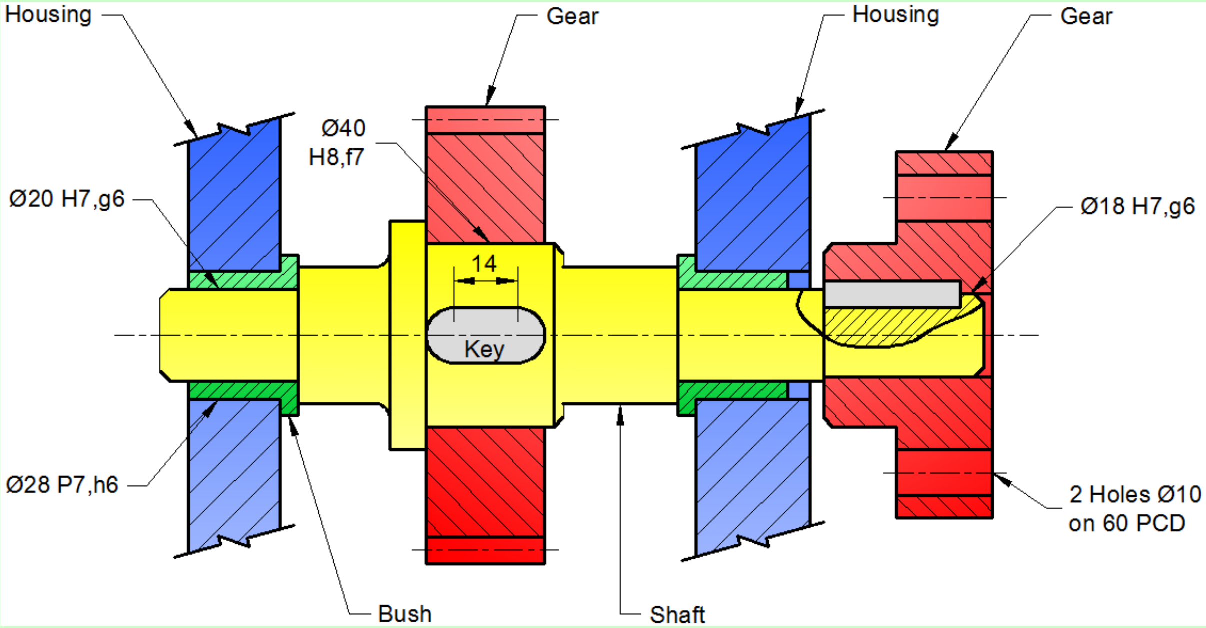
Skill Practice Exercises

Skill Practice Exercise: MEM09209-SP-0501

1. Create a new drawing using the template drawing called Drive Shaft.
2. Produce an assembly drawing of the Flexible Coupling including a Parts List and cross-referencing.
3. Produce separate detail drawings of the Shaft, Gear and Bushes showing details for the keyseats and keyways to suit a normal fit.
4. Indicate that all mating flat surfaces are to be milled to 1.6 while all curved surfaces are machined to 0.4. Holes are to be reamed to 0.02.
5. All flat mating flat surfaces are to be perpendicular to the datum centreline to 0.025 and a flatness of 0.15. All holes and curved surfaces are to be concentric to the datum to 0.08 and straight to within 0.12.
6. Insert an A3 sheet to all drawings and submit to your teacher for correction.
7. Save the drawing as MEM09209-SP-0501.



The Housing can be assumed to be circular. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Materials: Shaft –Mild Steel; Bushes – Brass; Keys – Commercial; Gears – Mild Steel

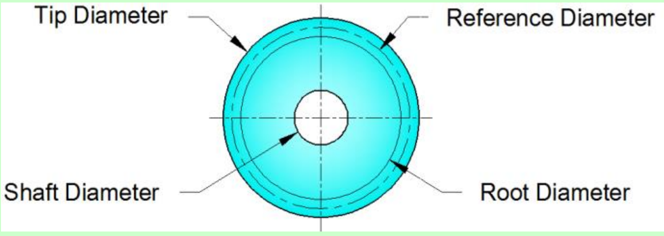
Gear Representation:

Tip Diameter – 0.5 Visible Outline

Shaft Diameter – 0.5 Visible Outline

Reference Diameter – 0.25 Centreline

Root Diameter – 0.25 Visible Outline

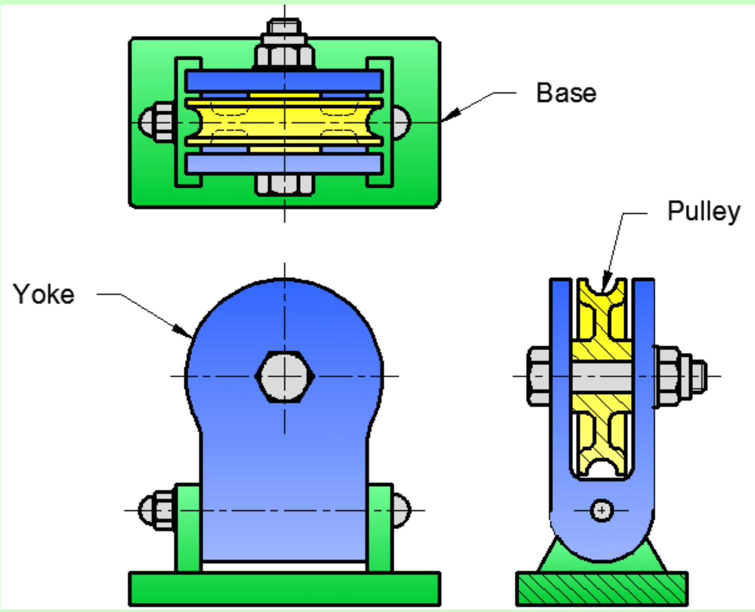


Skill Practice Exercise: MEM09209-SP-0502

1. Create a new drawing using the template drawing called Bench Pulley.
2. Produce an assembly drawing of the Bench Pulley including a Parts List and cross-referencing.
3. Produce separate detail drawings of the Yoke, Pulley and Base.
4. Assign toleranced dimensions to suit the following:

Pulley to Yoke	H11-c11
Yoke to Base	H9-d10

5. Indicate that all mating flat surfaces are to be machined to 0.8 while all mating curved surfaces are ground to 0.2. Holes are to be reamed to 0.05.
6. All flat mating flat surfaces are to be perpendicular to the datum centreline to 0.025 and a flatness of 0.15. All holes and curved surfaces are to be concentric to the datum to 0.08 and straight to within 0.12.
7. Insert an A3 sheet to all drawings and submit to your teacher for correction.
8. Save the drawing as MEM09209-SP-0502.



All toleranced dimensions are to be placed on the drawing as Limit of Size.

Materials: Base – Cast Iron; Yoke – Mild Steel; Pulley – Bronze; Fastenings – Commercial.

Topic 6 – Plain Bearings:

Required Skills:

- Produce assembly and detail drawings of components containing plain bearings.
- Prepare detail drawings of components mating with bearings.

Required Knowledge:

- Classifications of bearings.
- The use and applications of bearings in engineering.
- Materials used in the manufacture of bearings.

Bearings:

Bearings are used to reduce friction and wear, or constrict and restrain motion of mechanical components. Shafts are supported by bearings and form an integral part of power transmission. The shafts are designed to enable the bearings to be lubricated and adjusted so that only the minimal amount of work is expended in overcoming frictional resistance to motion. The relationship between the size of the shaft and bearing is arranged to allow a "running fit". A lubricant is used to reduce the amount of undue heating that could lead to the seizure of the moving parts through expansion.

Bearings can be dated to 1100BC where friction was reduced by inserting rollers between the object and the surface over which it was to be moved. The Egyptians, Assyrians and Babylonians used rollers to move enormous stones for their pyramids, monuments and palaces.

Classification of Bearings:

Shaft bearings may be *journal bearings* (the term 'journal' refers to the shaft) that takes the radial (perpendicular to the shaft) forces, or *thrust bearings* which take axial (parallel to the shaft) forces. There are two main classifications of journal and thrust bearings: *sliding contact* are plain sleeves and *rolling contact,* which consist of rollers or balls.

Sliding Contact Bearings:

Sliding Contact type bearings are commonly known as *Plain Bearings* and work with or without lubrication. Plain bearings incorporate fundamentally all types other than rolling contact bearings and are often referred to as *sleeve bearings* or *thrust bearings*, terms that designate whether the bearing is loaded axially or radially. There are 4 types of Sliding Contact Bearings; Plain Journal or Sleeve Bearing, Pedestal Bearing, Footstep Thrust Bearing and the Plain Thrust Bearing. Sliding contact bearings are relatively simple and hence inexpensive. They are compact, lightweight, simple to repair or replace and have high load-carrying capacity. However, if operating in dry conditions plain bearings may wear faster and have higher friction than rolling bearings. A common plain bearing design is to use a hardened and polished steel shaft and a soft bronze bushing. The design allows for the softer metal to be worn away and periodically changed during regular maintenance.

Plain Journal or Sleeve Bearings:

A typical Plain Bearing is made from two sleeves or a solid bush. Plain bearings may carry loads in one of several ways depending on their operating conditions, load, relative surface speed (shaft to journal), clearance within the bearing, quality and quantity of lubricant and temperature (affecting viscosity). If full-film conditions apply, the bearings load is carried solely by a film of fluid lubricant, there being no contact between the two bearing surfaces.

Plain bearings are cylindrical or ring shaped bearings designed to carry radial loads. The term sleeve and journal are used more or less synonymously since sleeve refers to the general configuration while the journal pertains to any portion of a shaft supported by the bearing. In another sense, the term journal may be reserved for two-piece bearings used to support the journals of an engine crankshaft.

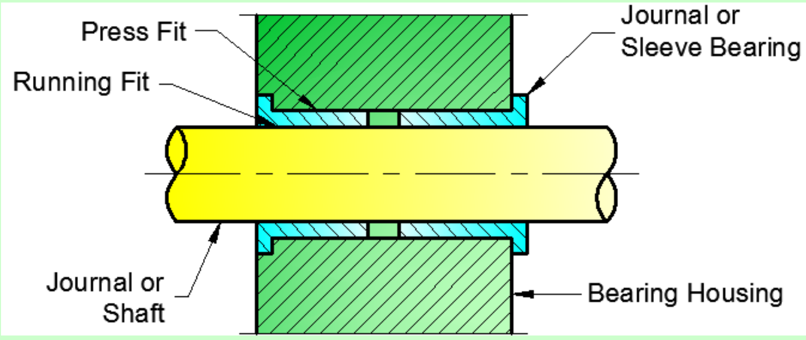
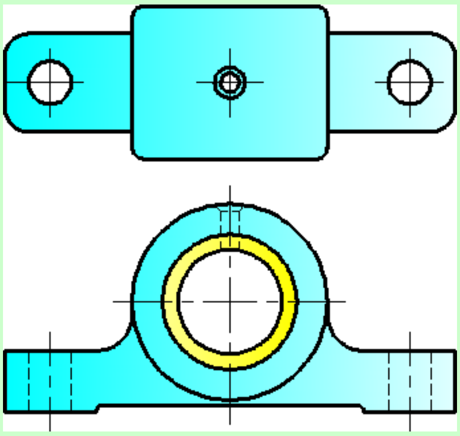


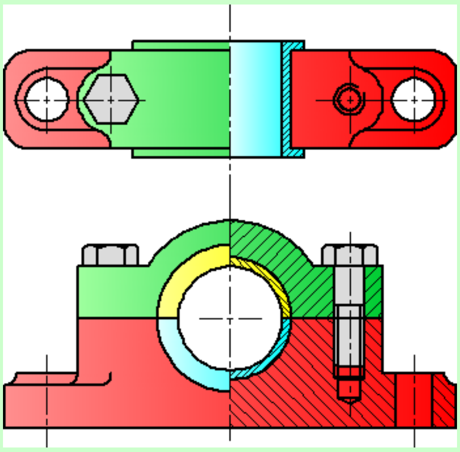
Figure 6.1

Pedestal Bearing:

The pedestal bearing can be mounted in a support bolted to a flat surface and is known as a pedestal and may be a casting, forging or weldment. The pedestal is sometimes split at the centreline of the shaft and the bush made in two pieces called *bushes* or *shells*.



Simple Pedestal Bearing



Split or Halved Pedestal Bearing

Figure 6.2

Plain or Journal Bearings are used in many applications and have the following advantages: -

1. Small outside diameter as compared to rolling element bearings.
2. Quietness of operation.
3. Good capacity to absorb shock loading.
4. Will take oscillating motion.
5. Low cost.

Hydrostatic

In a hydrostatic bearing the load is carried by fluid pressure generated outside the bearing. Fluid is pumped under pressure into the bearing, therefore the bearing will operate whether static or rotating

Hydrodynamic

In a hydrodynamic bearing a fluid is drawn into the region between the moving parts of the bearing by the virtue of its adhesion to the surfaces of the bearing and its viscosity and due to the shape of the bearing surfaces a pressure is generated within the fluid which keeps the bearing surfaces separated. The separating film is only generated when the there is relative motion in the bearing, i.e. when the shaft is rotating.

Boundary Lubrication

If the working fluid in a bearing adheres to or "wets" the bearing surfaces then some load may be carried. Boundary lubrication will apply at low speeds but as the speed increases some degree of hydrodynamic lubrication will be needed.

Dry Bearing

Dry bearings operate without a significant fluid film to separate the moving surfaces therefore low friction materials, or materials impregnated with a lubricant, must be used.

Footstep Thrust Bearing:

The Footstep Thrust Bearing is used for the lower end of a vertical shaft. A bush takes the horizontal load and a hardened steel pad takes the weight of the shaft or any thrust.

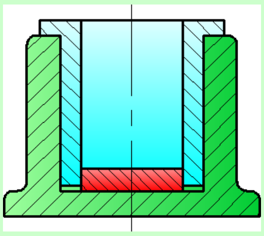


Figure 6.3

Plain Thrust Bearing:

The Plain Thrust Bearing consists of a flat ring or brass, bronze, etc., taking the axial thrust on a shaft via a collar.

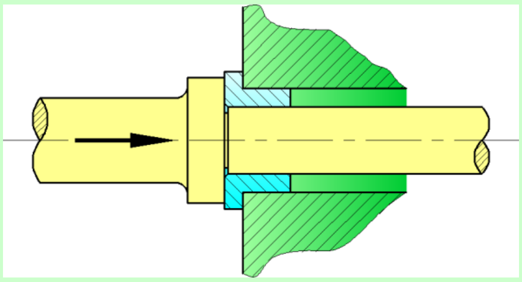


Figure 6.4

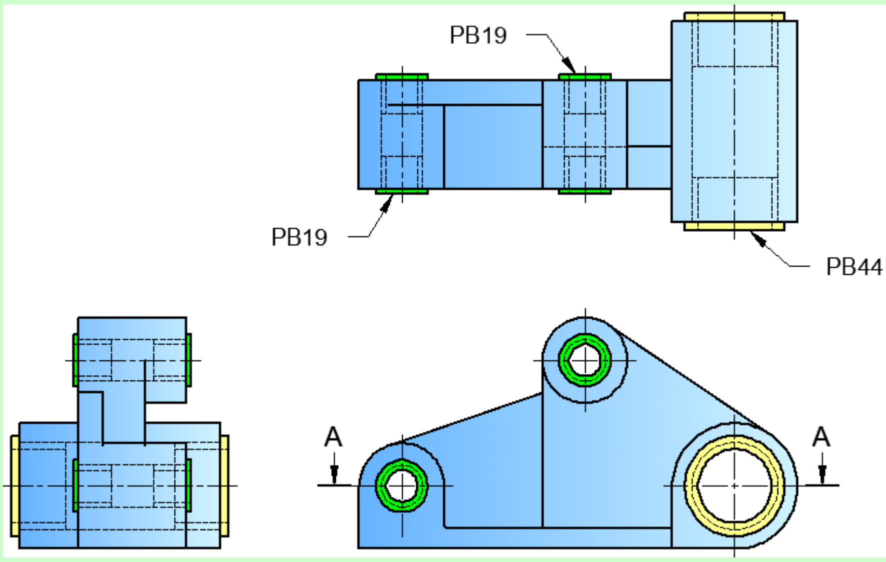
Plummer Block | Dry Bearing | Sleeve

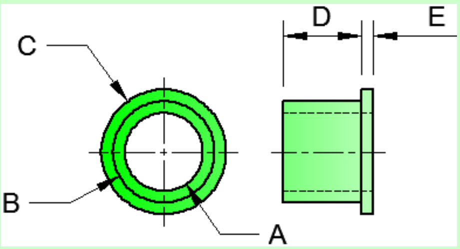
Figure 6.5

Skill Practice Exercises

Skill Practice Exercise: MEM09209-SP-0601

1. Create a new drawing using the template drawing called Compound Link.
2. Produce an assembly drawing of the Compound Link including a Parts List and cross-referencing.
3. Produce separate detail drawings of the Compound Link and Bushes. The Compound Link is to include a sectional view along the cutting plane shown in the following diagram.
4. Assign toleranced dimensions to suit H7-h6 fits:
5. Indicate that all mating flat surfaces are to be machined to 3.2 while all mating curved surfaces are ground to 0.15. Holes are to be reamed to 0.5.
6. All flat mating flat surfaces are to be perpendicular to the datum centreline to 0.025 and a flatness of 0.15. All holes and curved surfaces are to be concentric to the datum to 0.08 and straight to within 0.12.
7. Insert an A3 sheet to all drawings and submit to your teacher for correction.
8. Save the drawing as MEM09209-SP-0601.





Plain Bearing Proportions

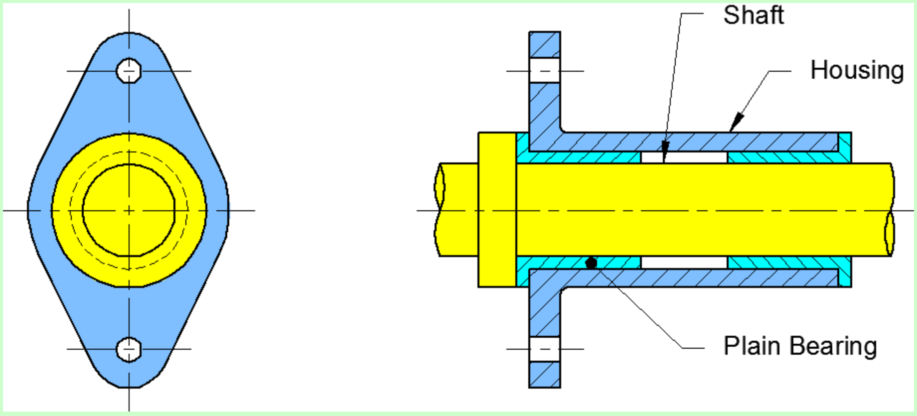
	A	B	C	D	E
PB19	19	25	31	20	3
PB44	44	52	60	27	5

All toleranced dimensions are to be placed on the drawing as Limit of Size.

Materials: Compound Link – Cast Iron; Bushes - Brass.

Skill Practice Exercise: MEM09209-SP-0602

1. Create a new drawing using the template drawing called Gland Bearing.
2. Produce an assembly drawing of the Gland Bearing including a Parts List and cross-referencing.
3. Produce separate detail drawings of the Housing and Bushes. The drawings are to include a sectional view along the cutting plane.
4. Assign toleranced dimensions to suit G7-h6 between the Bearings, Shaft and Housing.
5. Indicate that all mating flat surfaces are to be machined to 6.4 while all mating curved surfaces are ground to 1.6. Holes are to be reamed to 0.4.
6. All flat mating flat surfaces are to be perpendicular to the datum centreline to 0.02 and a flatness of 0.1. All holes and curved surfaces are to be concentric to the datum to 0.1 and straight to within 0.15.
7. Insert an A3 sheet to all drawings and submit to your teacher for correction.
8. Save the drawing as MEM09209-SP-0602.



All toleranced dimensions are to be placed on the drawing as Limit of Size.

Materials: Shaft – Mild Steel; Housing – Mild Steel; Bushes - Brass.

Topic 7 – Rolling Contact Bearings:

Required Skills:

- Apply symbols of rolling contact bearings to detail drawings.
- Select appropriate rolling contact bearing from manufacturer's specifications and catalogues.
- Produce assembly drawings containing rolling contact bearings.
- Produce detail drawings of components required to fit a rolling contact bearing.
- Produce detail drawings for retaining rolling contact bearings.

Required Knowledge:

- Identify, draw the symbol and list the applications of 8 types of rolling contact bearings**.**
- Name the materials used in the manufacture of rolling contact bearings.
- List the different methods of retaining bearings in position.

Rolling Contact Bearings:

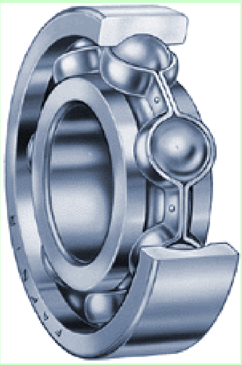
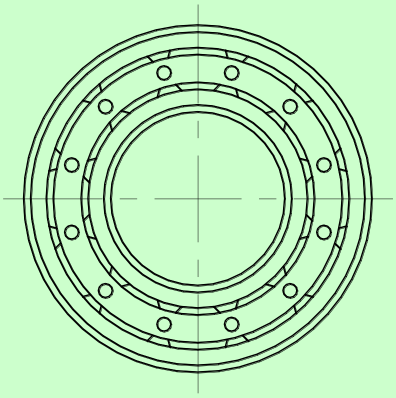
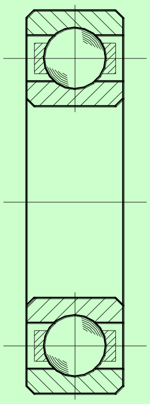
Rolling Contact Bearings cover a large range of bearings in which hardened steel balls or rollers run between housings (or races) on the shaft and the fixed member. Roller contact type bearings are often termed *anti-friction bearings* because of their extremely low frictional resistance, especially at low speeds. Ball and roller bearings, although more complicated than plain bearings, compare favourably in price when made in large quantities. There are 3 types of Rolling Contact Bearings; Ball Bearings, Roller Bearings and Thrust Bearings.

Ball Bearings:

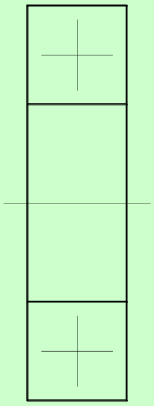
Ball bearings use spheres or balls contained between inner and outer cases. The balls can be manufactured cheaper than roller type bearings. Ball bearings can support both radial (perpendicular to the shaft) and axial (parallel to the shaft) loads. And offer lower friction than rollers. Ball bearings can operate when the bearing races are misaligned. Ball bearings consist of Single Row Deep Groove Ball Bearings, Double Row Deep Groove Ball Bearings, Self-Aligning Bearings and Angular Contact Bearings.

Single Row Deep Groove Ball Bearings

Single row deep groove ball bearings are particularly versatile, simple in design, non-separable, suitable for high and even very high speeds and are robust in operation, requiring little maintenance. Deep raceway grooves and the close conformity between the raceway grooves and the balls enable deep groove ball bearings to accommodate axial loads in both directions, in addition to radial loads, even at high speeds. Single row deep groove ball bearings are the most widely used bearing type.

Single Row Ball Bearing

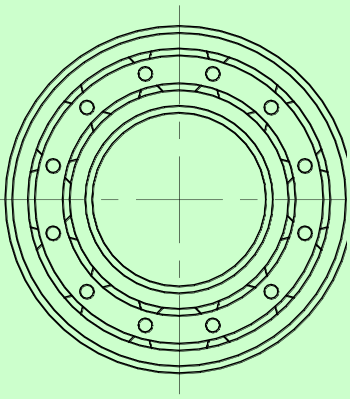
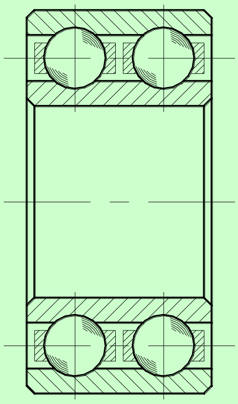


Single Row Ball Bearing Symbol

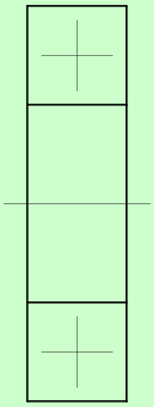
Refer to Table 3 – Deep Groove Ball Bearings for dimensions.

Double Row Deep Groove Ball Bearings:

Double row deep groove ball bearings correspond in design to single row deep groove ball bearings; they have deep uninterrupted raceways and high conformity between balls and raceways. Double row deep groove ball bearings can carry axial loads acting in both directions in addition to radial loads. Double row deep groove ball bearings are suitable for bearing arrangements where the load carrying capacity of a single row bearing is inadequate. For the same outside and bore diameters, double row deep groove ball bearings are slightly wider and have considerably higher load carrying capacity than single row bearings in the 62 and 63 series.

Double Row Ball Bearing

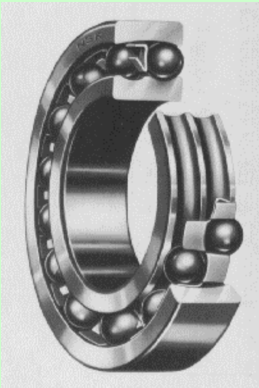


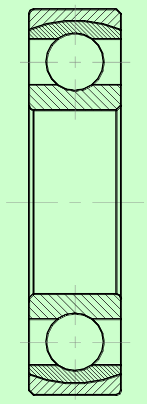
Double Row Ball Bearing Symbol

Refer to Table 4 – Self Aligning Ball Bearings for dimensions.

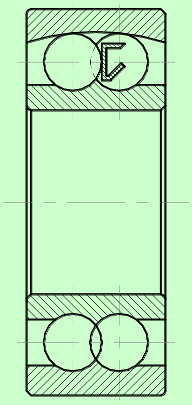
Self-aligning Bearing:

The elf-aligning bearing normally has double rows of balls however they are available in single rows of balls and a common concave spherical raceway in the outer ring. The bearing is consequently self-aligning and insensitive to angular misalignments of the shaft relative to the housing. It is particularly suitable for applications where considerable shaft deflections or misalignments are to be expected. Additionally, the bearing has the lowest friction of rolling bearings, which enables it to run cool even at high speeds.

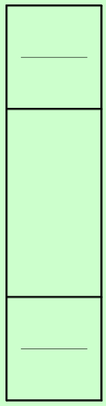




Single Row



Double Row

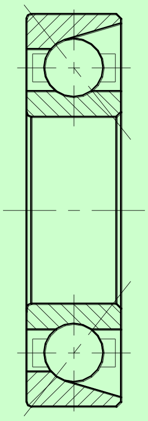


Self-aligning Bearing Symbol

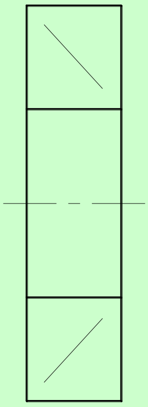
Angular Contact Bearing:

Angular contact bearings have raceways in the inner and outer rings that are displaced with respect to each other in the direction of the bearing axis; meaning they are designed to accommodate combined loads, i.e. simultaneously acting radial and axial loads.

The axial load carrying capacity of angular contact bearings increases with increasing contact angle. The contact angle is defined as the angle between the line joining the points of contact of the ball and the raceways of the radial plane, along which the load is transmitted from one raceway to another, and a line perpendicular to the bearing axis.



Angular Contact Bearing



Angular Contact Bearing Symbol

Refer to Table 5 - Angular Contact Ball Bearing for dimensions.

Determining Bearing Sizes:

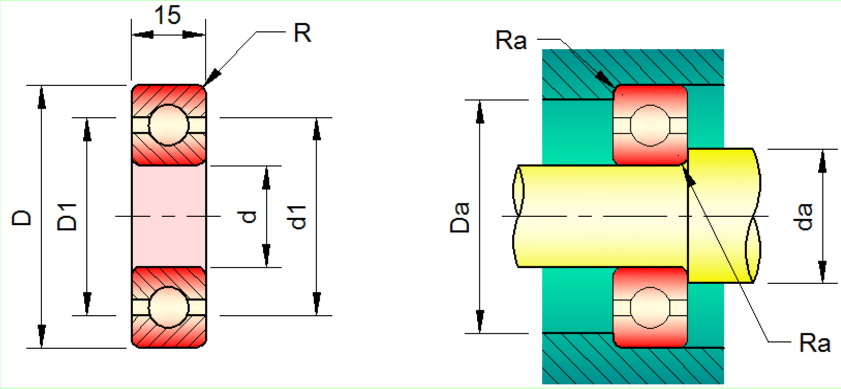
The sizes of bearings can be obtained using the applicable table and are read in a similar manner. The table is used to determine the outside diameter (D), shaft diameter (d), width (B) and designation number (eg. 6203). The shoulder dimensions for the bearing to fit against are given in the last three columns.

Example 7-1:

Using the following excerpt from Figure 7.1 – Deep Groove Ball Bearing Table, determine the designation number and width for a bearing to fit over a Ø35 mm shaft and inside a journal of Ø80 mm.

Procedure:

Look down the first column of principle dimensions (d) and locate the 35; it can be seen that the outside diameters in column 2 can be 47,62,72,80 or 100. Reading across the 80 row, the third column indicates the thickness (B) as 21 mm and in the designation column, the bearing number is 6307; the shoulder radius (r) is 1.5 mm.



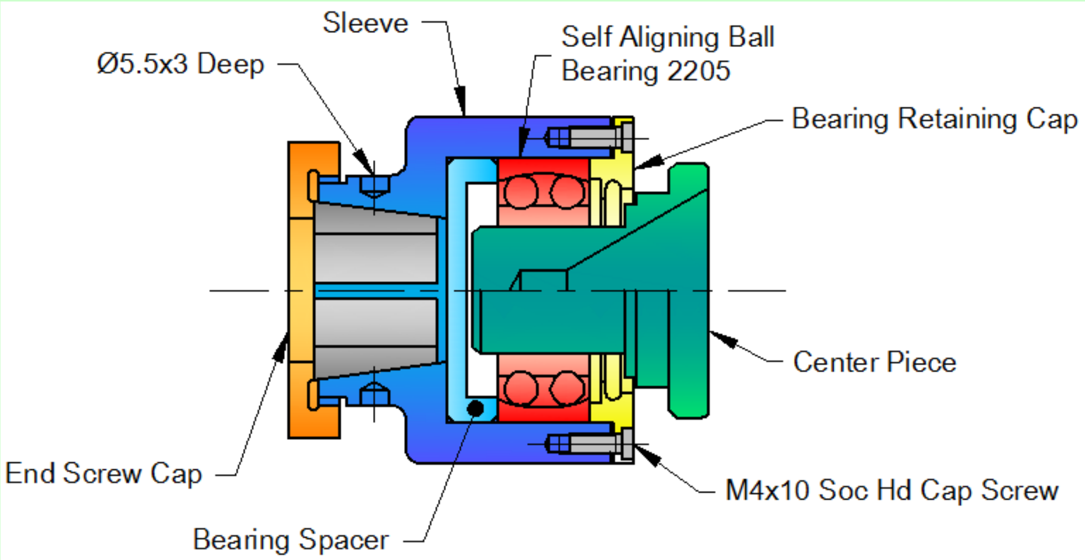
Principal Dimensions			Basic Load Settings		Limit Speeds		Mass	Designation	Dimensions				Abutment and Fillet Dimensions		
					Lubrication				mm				mm		
d	D	B	C	C_o	Grease	Oil			d_1	D_1	D_2	r min	d_a min	D_a max	r_a max
mm			N		R/min		Kg		mm				mm		
30	52	7	3120	2080	15000	18000	0.026	61806	33.8	38.2	-	0.3	32	40	0.3
	55	9	11200	5850	12000	15000	0.085	16006	38	47.3	-	0.3	32	53	0.3
	55	13	13300	6800	12000	15000	0.12	6006	38.2	47.1	49	1	35	50	1
	62	16	19500	10000	10000	13000	0.20	6206	40.3	52.1	54.1	1	35	57	1
	72	19	28100	14600	9000	11000	0.35	6306	44.6	59.9	61.9	1.1	36.5	65.5	1
	90	23	43600	24000	8500	10000	0.74	6406	50.3	70.7	-	1.5	38	82	1.5
35	47	7	4030	3000	13000	16000	0.030	61807	38.8	43.2	-	0.3	37	45	0.3
	62	9	12400	6950	10000	13000	0.11	16007	44	53.3	-	0.3	37	60	0.3
	62	14	15900	8500	10000	13000	0.16	6007	43.7	53.6	55.7	1	40	57	1
	72	17	25500	13700	9000	11000	0.29	6207	46.9	60.6	62.7	1.1	41.5	65.5	1
	80	21	33200	18000	8500	10000	0.46	6307	49.5	66.1	69.2	1.5	43	72	1.5
	100	25	55300	31000	7000	8500	0.95	6407	57.4	80.6	-	1.5	43	92	1.5
40	52	7	4160	3350	11000	14000	0.034	61808	43.8	48.2	-	0.3	42	50	0.3
	68	9	13300	7800	9500	12000	0.13	16008	49.4	57	-	0.3	42	66	0.3
	68	15	16800	9300	9500	12000	0.19	6008	49.2	59.1	61.1	1	45	63	1
	80	18	30700	16600	8500	10000	0.37	6208	52.6	67.9	69.8	1.1	46.5	73.5	1
	90	23	41000	22400	7500	9000	0.63	6308	56.1	74.7	77.7	1.5	48	82	1.5
	110	27	63700	36500	6700	8000	1.25	6408	62.8	88	-	2	49	101	2

Figure 7.1 – Deep Groove Ball Bearing Table

Skill Practice Exercise:

Skill Practice Exercise: MEM09209-SP-0701

1. Create a new drawing using the template drawing called Cup Center Assembly and complete the assembly by adding the hatching and bearing where shown.
2. Produce an assembly drawing of the Cup Center Assembly including a Parts List and cross-referencing.
3. Produce separate detail drawings of the Centre Piece and Sleeve. One of the views of the Centre Piece and Sleeve is to include a full or half sectional view along the cutting plane.
4. Assign toleranced dimensions to suit P7-h6 between the fit between the bearing, Sleeve and Center Piece.
5. All cylindrical surfaces for the bearings are to be reamed to a finish of 0.25, be concentric to the datum centreline to 0.05 and roundness to 0.8.
6. All straight mating surfaces are to be milled to 0.4 and perpendicular to the centreline to 0.5.
7. Insert an A3 sheet to all drawings and submit to your teacher for correction.
8. Save the drawing as MEM09209-SP-0701.

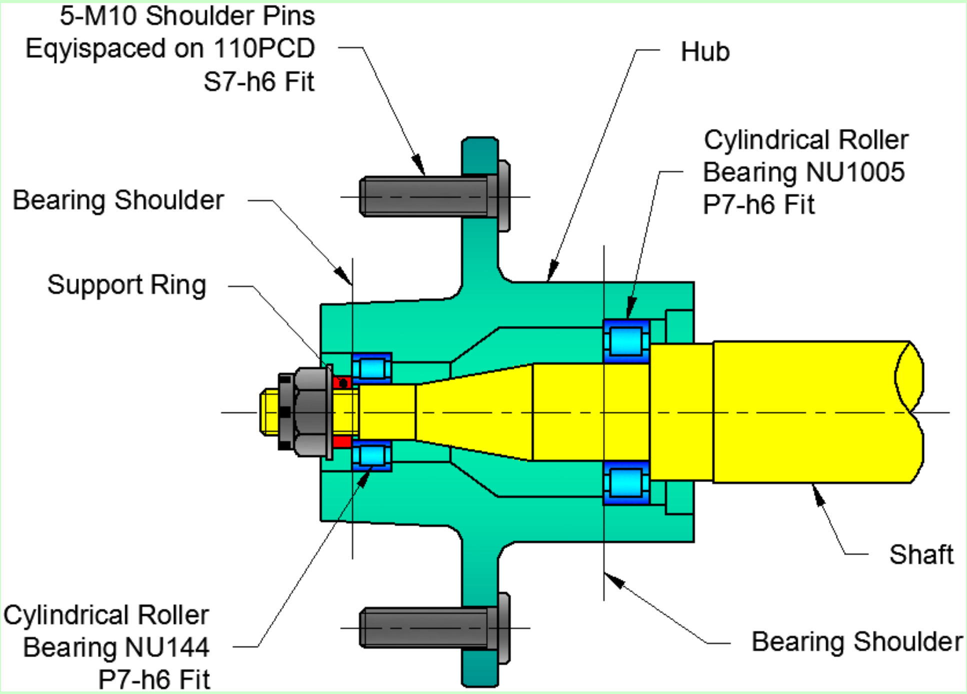


The coupling is circular in shape and fastened using 6 machine screws/bolts equally spaced on the PCD. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Materials: Centre Piece – Mild Steel; Sleeve – Mild Steel; Bearing Spacer – Brass; Rearing Retaining Cap – Mild Steel; End Screw Cap – Mild Steel; Fasteners and Bearing – Commercial.

Skill Practice Exercise: MEM09209-SP-0702

1. Create a new drawing using the template drawing called Wheel Hub and complete the assembly by adding the hatching and bearing where shown.
2. Produce an assembly drawing of the Wheel Hub including a Parts List and cross-referencing.
3. Produce separate detail drawings of the Hub. One of the views of the Centre Piece and Sleeve is to include a full sectional view along a cutting plane.
4. All cylindrical surfaces for the bearings are to be reamed to a finish of 0.8, be concentric to the datum centreline to 0.05 and roundness to 0.02.
5. All straight mating surfaces are to be milled to 0.4 and perpendicular to the centreline to 0.1.
6. Insert an A3 sheet to all drawings and submit to your teacher for correction.
7. Save the drawing as MEM09209-SP-0702.



The coupling is circular in shape. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: Hub – Cast Iron; Shaft – Mild Steel; Support Ring – Bronze; Fasteners & Bearings – Commercial.

Topic 8 – Bearing Retention:

Required Skills:

- Produce assembly drawings containing bearing retainers.
- Produce detail drawings of components requiring bearing retention.

Required Knowledge:

- Methods of retaining bearings in position.
- Reading circlip tables.
- Application of toleranced dimensions.

Retention of Bearings:

When fixing a bearing in position on a shaft or in a hub, journal or housing, there are many instances where the interference fit alone is not enough to hold the bearing in place. The bearing must be fixed in place by various methods so they do not move axially when placed under load. The most common method of fixing bearings in place is to hold the ring end face against the shoulder of the shaft or housing abutment by means of snap rings, circlips, bolts or screws.

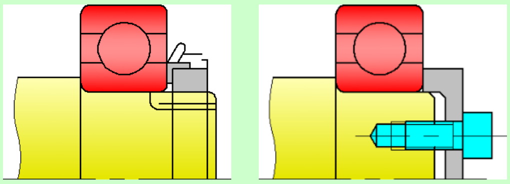


Figure 8.1

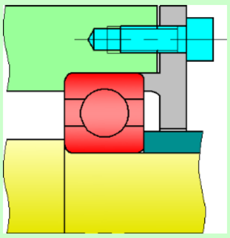


Figure 8.2

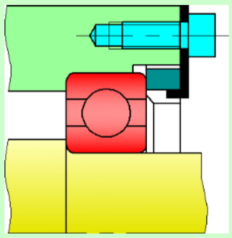


Figure 8.3

Figure 8.1 illustrates inner ring clamping methods, while Figure 8.2 and Figure 8.3 show outer ring clamping methods.

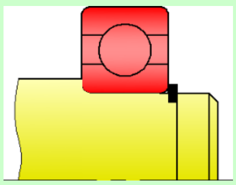


Figure 8.4

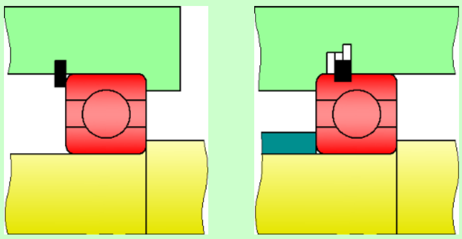


Figure 8.5

Figure 8.4 and Figure 8.5 show the use of snap ring/circlip methods which makes the construction and assembly extremely simple.

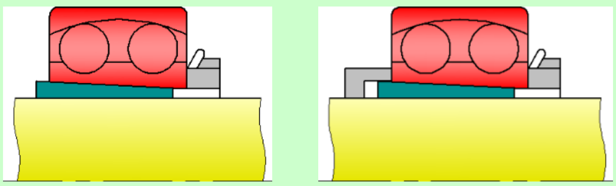


Figure 8.6

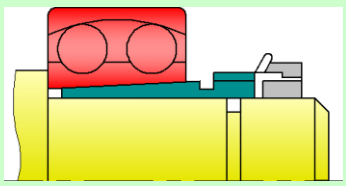


Figure 8.7

For bearings with tapered bores, examples of the use of adapters are shown in Figure 8.6. When fitting bearings on non-stepped shafts, fixing the bearing axially depends on the friction between the sleeve and the shaft. Figure 8.7 shows the use of withdrawal sleeves and clamping with nuts or end-plates on shaft ends.

For installing tapered bore bearings directly on tapered shafts, the bearing is held in place by a split ring inserted in the groove provided in the shaft, and tightened on the shaft by the split ring nut as shown in Figure 8.8.

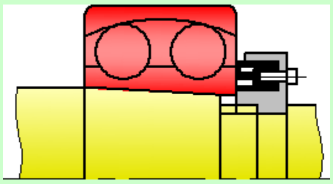


Figure 8.8

Bearing Retaining Cap (Outer Ring Clamping)

A Bearing Retaining Cap can consist of a variety of shapes depending on the design and application of the Housing, Cap and Bearing. Figure 8.2 shows the bearing being retained by a Retaining Cap. It is essential a gap of 0.5mm to 1.0mm exists between the Housing and the Bearing Retaining Cap to allow *Pre-load* to be applied to the bearing using a tension spanner; the gap can be filled with very thin sheets of metal called *shims* which can be removed or replaced when required.

The base of the Bearing Retaining Cap presses against the Outer (or Inner) Race of the bearing to ensure the correct pressure or torque is maintained on the bearing and cannot move axially. Great care must be taken in designing the Retaining Cap that the base does not overhang the inner dimension of the outer race to prevent any possibility of foreign matter jamming the bearing. Care must also be taken when designing the shoulder of the Shaft to ensure the race remains free.

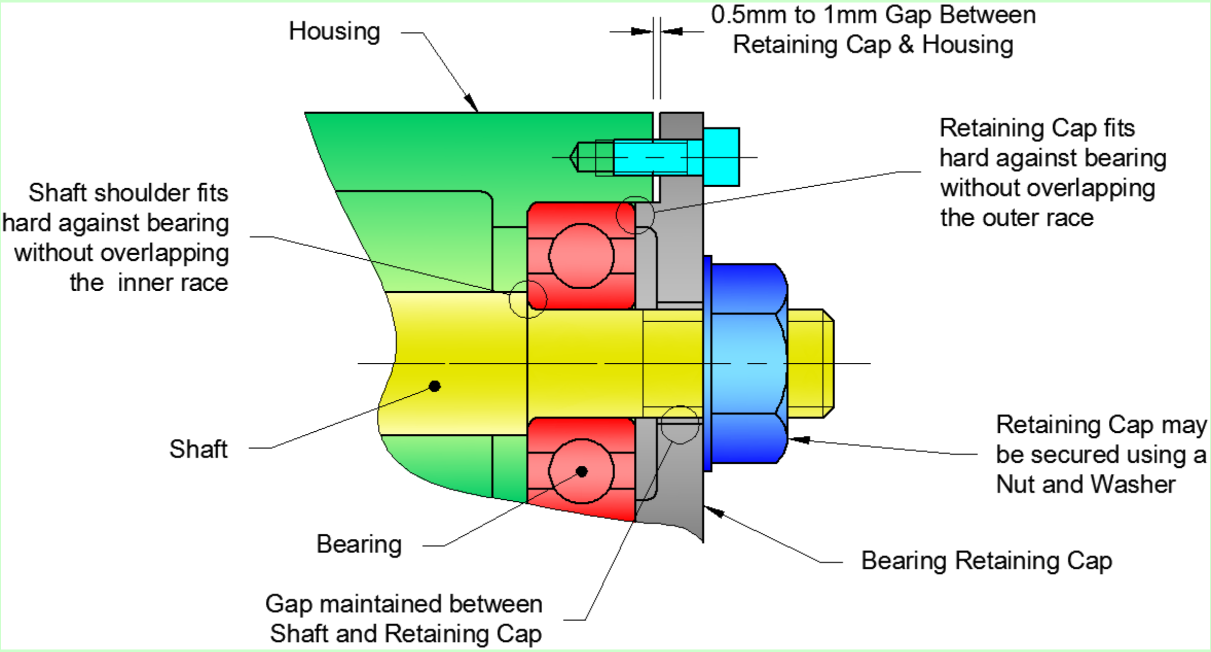


Figure 8.9

The gap between the bearing race and the underside of the cap's inner surface is normally a minimum of 3 mm with a 3 mm fillet.

The fastenings securing the Retaining Cap into place can be Machine Screws or Cap Screws and can be counterbored flush with the surface of screwed against the surface.

Circlips:

Circlips are a cost saving alternative to fastenings such as machined collars on shafts or washer and pin assemblies but still offer the same benefits of a single fastening mechanism by reducing material waste and the number of components. Modern assembly allow for many variations to the basic Internal and External types which were developed out of the special needs of the consumer for various strength and design characteristics.

Basic Types:

The basic types of classic circlips and retaining rings include:

- Internal Circlip – designed to fit over a shaft.
- External Circlip – designed to fit inside a housing, journal or hub.
- Inverted Circlip – have a small radial height; they simultaneously transfer axial forces and serve as a radial guidance.
- Increased Abutment Ring – have equally distributed lugs around the circumference and are suitable for covered applications.

Radial Assembly:

The radial types of circlips and retaining rings include:

- Crescent Ring – Have a large clasp angle.
- 'E' Clips – Used for radially assembled circlips on shafts. The groove is gripped by 3 tabs.

Compensating Axial Play:

- Bevelled Circlip – the bevelled circlips are similar to the basic types, however, they offer more application possibilities due to the bevel 15° bevel which allows the ring to wedge itself between the groove and the retained part until it can go no farther, effectively "locking" everything in place.

Snap Rings

- Snap Ring – snap rings fit over shafts. The inner edges have a radius applied to the edge for fixing of roller bearings with a groove and outer ring.

Push-on Fix/Grip:

- Grip Ring - High clamping force for a play-free retention on shafts without a groove; they are easily removable, self-locking grip rings.
- Heavy Push-on Fix – Strengthened version of the toothed clip, transmitting relatively high axial forces.
- Toothed Clip – The clips are concentric in design with a small radial height for use against softer materials.

Plain Wire:

- Plain Wire Ring – Round cross section wire rings, cold worked spring steel. Especially suited for semi-circular grooves with covering.
- Special Wire Ring – fit over shafts.

Internal Circlip

External Circlip

External Inverted Circlip

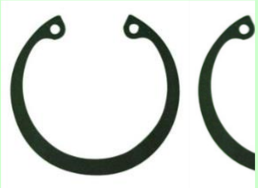
Internal Inverted Circlip


External Increased Abutment Ring


Internal Increased Abutment Ring


Crescent Ring

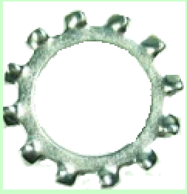

E-Clip


Bevelled Circlip


Snap Ring


Grip Ring


Heavy Duty Push-on Fix


Toothed Clip


Plain Wire Ring


Special Wire Rings

All circlips are inserted and removed using special long-nosed pliers

Display of Circlips on an Assembly Drawing:

As most circlips are very narrow with respect to the shaft diameter, and hidden line will display as a continuous line in the view. All circlips can be solid filled so they are readily identifiable on a drawing. Circlips are not included on a detail drawing, only the grooves.

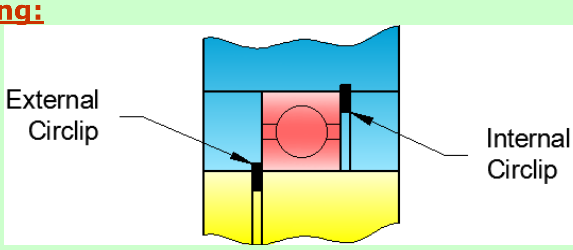


Figure 8.10

Circlip Grooves:

The dimensions for each circlip groove must be

shaft or bore diameter. Tables

Table 1 – Internal Circlips is used to determine the groves for shafts while Table 2 – External Circlips. The dimension in each column correlates to the lettered dimensi9on in the diagrams shown in Figure 8.11 for Internal Circlips and Figure 8.12 for External Circlips.

The same method is used for reading the two tables in determining the required dimensions.

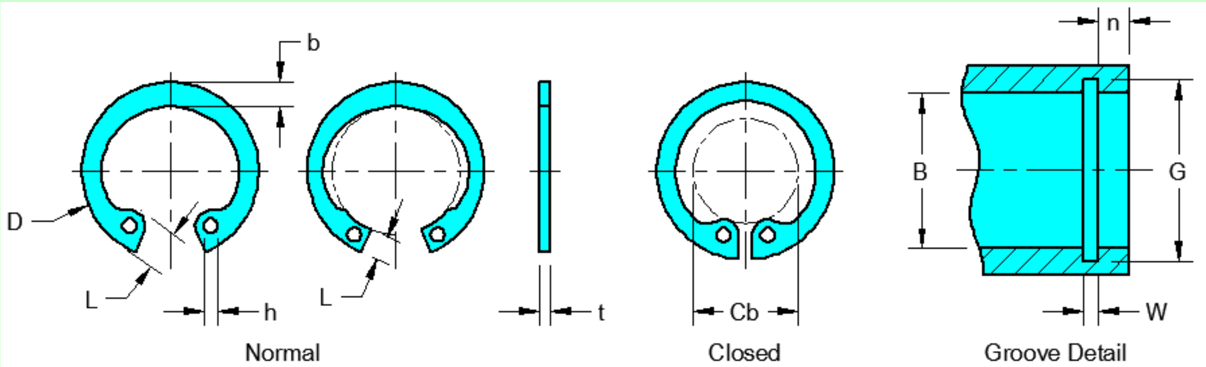


Figure 8.11

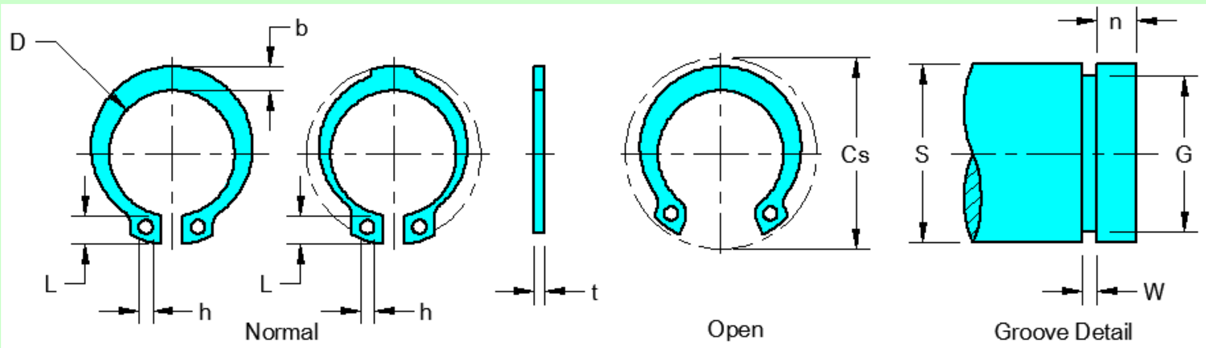


Figure 8.12

Example 10-1:

Create a detail of a circlip groove to suit a Ø108 housing.

Procedure:

Study Figure 8.11 to determine the data required

Refer to Tables

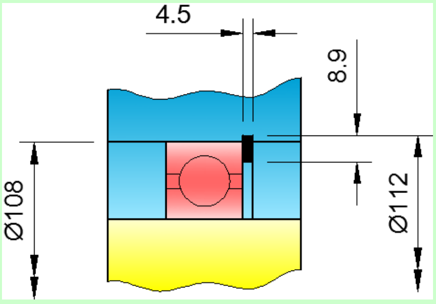
- Table 1 – Internal Circlips to determine the sizes.
- Figure 8.11 shows the dimensions required are 'B' for the groove diameter, 'W' for the groove width, 'b' for the thickness of the circlip.

Refer to the Tables

- Table 1 – Internal Circlips and look down the first column labelled *Bore B* until the size 108 is displayed.

Most sizes over 170mm are without lugs. Measurements in mm & kN															Code No
Bore B	Circlip Dimensions									Groove Dimensions					
	t	Tol	D	Tol	Cb	b	L	h	Fr kN	G	Tol	W	n	Fr kN	
102	4		108		82	8.5	9.5	3.5	439	106		4.15	6	108.8	INT1020
105	4		112		85	8.7	9.5	3.5	436	109		4.15	6	112	INT1050
108	4		115	1.3 -0.54	88	8.9	9.5	3.5	419	112	0.54 0	4.15	6	115	INT1080
110	4		117		88.2	9	10.4	3.5	415	114		4.15	6	117	INT1100
112	4		119		90	9.1	10.5	3.5	418	116		4.15	6	119	INT1120

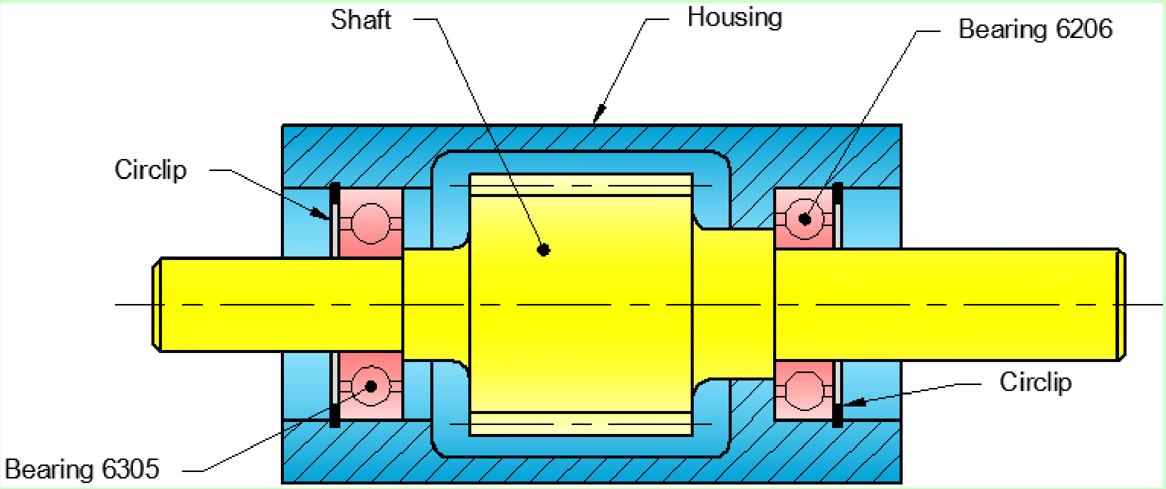
- Read across the row and note dimension 'G' is 112, 'W' is 4.15 and 'b' is 8.9.
- The groove can now be drawn on the assembly or detail drawing.
- When producing the detail drawing, applicable tolerances can be applied as required.



Skill Practice Exercises:

Skill Practice Exercise: MEM09209-SP-0801

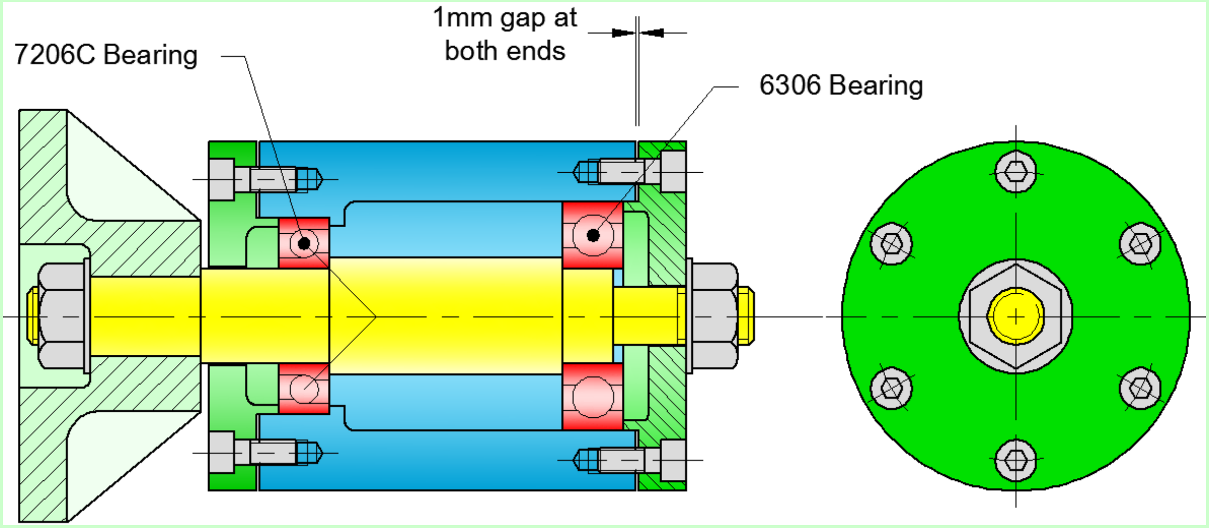
1. Create a new drawing using the template called Gear Housing located on the network drive. Complete the assembly by adding the bearings, circlips and completing the shaft and housing where shown.
2. Use the Tables to determine the size of each circlip groove.
3. Produce an assembly drawing of the Gear Housing including a parts list and cross referencing.
4. Create detail drawings of the Housing and the Shaft applying toleranced dimensions to suit S7-h6 fits between the Housing, Shaft and bearings. One of the views is to include a full or half sectional view along the cutting plane
5. All cylindrical surfaces for the bearings are to be reamed to a finish of 0.2, be concentric to the datum centreline to 0.025 and roundness to 0.05.
6. All straight mating surfaces are to be milled to 0.4 and perpendicular to the centreline to 0.1.
7. Provide appropriate normal fitting 60 mm long keys to both ends of the shaft.
8. Insert an A3 sheet on both drawings and save the drawing in your work area as MEM09209-SP-0801 before plotting the finished drawings.



The Housing is circular in shape. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Skill Practice Exercise: MEM09209-SP-0802

1. Create a new drawing using the template called Roller Bearing Idler Pulley located on the network drive and complete the assembly by adding the bearings and hatching where required.
2. Add a Bearing Retaining Cap to suit the Shaft, Bearing and Housing.
3. Produce an assembly drawing of the Roller Bearing Idler Pulley complete with a Parts List, cross-referencing and overall dimensions.
4. Produce a detail drawing of the Housing assigning the appropriate toleranced dimensions to take the bearings assuming a S7-h6 fit between the bearing and housing. One of the views is to include a full or half sectional view along the cutting plane.
5. All cylindrical surfaces for the bearings are to be reamed to a finish of 0.15, be concentric to the datum centreline to 0.05 and roundness of 0.025. All straight mating surfaces are to be ground to 0.8 and perpendicular to the centreline to 0.15.
6. Insert an A3 sheet on both drawings and save the drawing in your work area as MEM09209-SP-0802 before plotting the finished drawings.



The assembly is circular in shape and fastened using 6 machine screws/bolts equally spaced on the PCD at each end. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Topic 9 – O-Rings:

Required Skills:

- Produce an assembly drawing and indicate O-rings using the correct symbols.
- Produce a detail drawing of engineering components containing grooves for O-rings.

Required Knowledge:

- Purpose for using seals in engineering applications.
- Conditions for using O-rings in engineering applications.
- Use tables to determine dimensions for detailing O-ring grooves.
- Application of toleranced dimensions.

Seals: O-Rings:

The "O" ring is the simplest form of seals. It is a synthetic rubber ring of solid circular cross-section and made in a wide variety of ring and cross-section diameters. "O" rings are suitable for static sealing e.g., pipe joints, cylinder end covers and valve spindles. Although designed primarily for static situations, O-rings can be used for low speed dynamic sealing of pistons and piston rods in hydraulic and pneumatic cylinders.

O-ring seals fall into 2 application categories; Static and Dynamic. Static seals exist when there is no relative motion between the mating surfaces being sealed. Dynamic Seals function in an environment where the mating surfaces are in reciprocating (alternating direction of motion), rotary (turning) or oscillating (vibrating) motion to each other. Static seals can sustain greater range of tolerances, rougher surface finishes and higher pressure limits. The types of static O-ring seals are: Static Radial Seal, Static Axial (Face) Seal, Static Seals with Dovetail Grooves, Static Crush Seals and Straight Thread Fitting Seals.

All grooves for O-Rings can be determined using Table 16 – O-Rings.

Static Seals:

Static seals exist where there is no relative motion between the mating surfaces being sealed. There are four types of static seals; Static Radial, Static Axial, Dovetail Grooves and Crush.

Static Radial Seal

Static radial seals are formed when squeeze (compression) is applied to the inside diameter (I.D.) and outside diameter (O.D.) of the O-ring. Cap and plug type configurations commonly utilize radial seals. An example of a static radial O-ring seal for a male gland is shown in Figure 9.1 while a static radial O-ring seal for a female gland is shown in Figure 9.2.

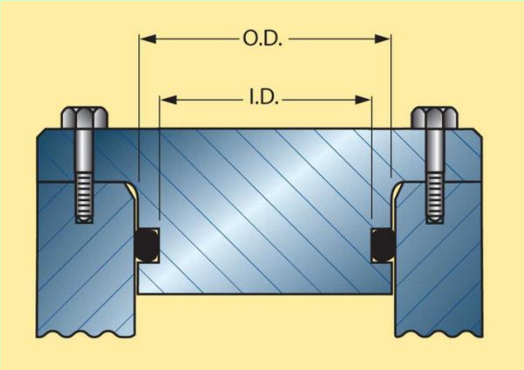


Figure 9.1

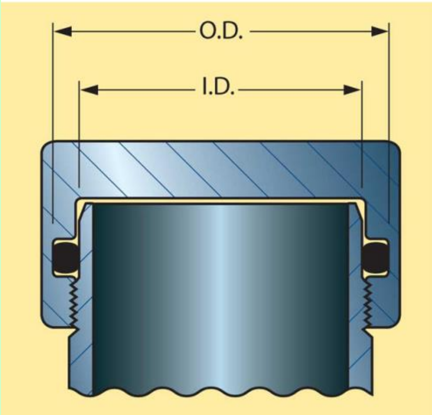


Figure 9.2

Static Axial (Face) Seal

Static axial seals (also known as face seals) are formed when squeeze is applied to the top and bottom surfaces of the O-ring. Axial seals are most often used in face (flange) type designs where an O-ring seats against the groove's low-pressure side. A static axial O-ring seal (internal pressure) is shown in Figure 9.3 and a static axial O-ring seal (external pressure) is shown in Figure 9.4.

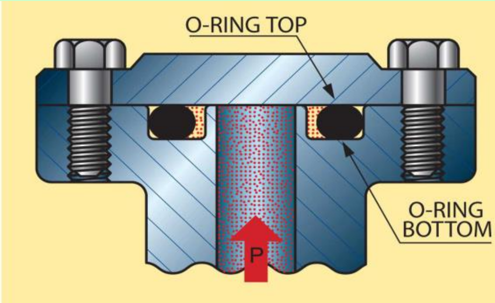


Figure 9.3

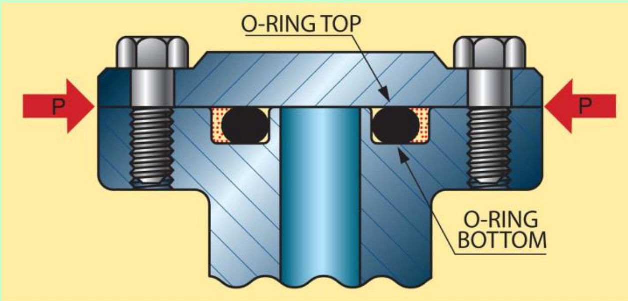


Figure 9.4

Static Seals with Dovetail Grooves

Dovetails are face type designs that have been customized to form static seals by structurally immobilizing the O-ring within the gland. Dovetails are more expensive and difficult to design and install than the other types of static seals. A dovetail seal is shown in Figure 9.5.

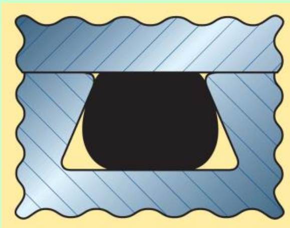


Figure 9.5

Static Crush Seals

Static crush seals use a male cover with a machined 45° angle to "crush" an O-ring into the corner of a triangular gland. Because the resulting distortion to the O-ring is permanent, it cannot be reused later. An example of a static crush seal is shown in Figure 9.6.

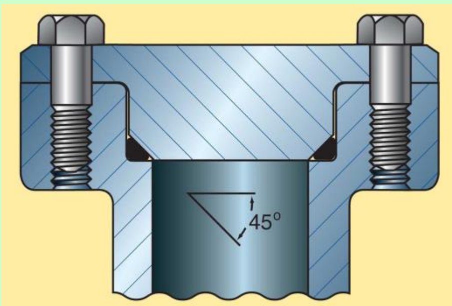


Figure 9.6

Dynamic Seals:

In contrast to static seals, dynamic seals exist where there is relative motion between the mating surfaces being sealed. In most instances, the dimensional variations inherent in dynamic seals make them more difficult to design and more expensive to construct than static seals. Nevertheless, dynamic O-ring seals are indispensable to a wide variety of applications.

Reciprocating Seals:

Reciprocating seals involve relative reciprocating motion along the shaft axis between the inner and outer elements. In reciprocating seal applications, the O-ring slides or rocks back and forth within its gland with the reciprocating motion.

Reciprocating seals are most often seen in cylinders and linear actuators. Some examples of reciprocating O-ring seals are shown in Figure 9.7 and Figure 9.8.

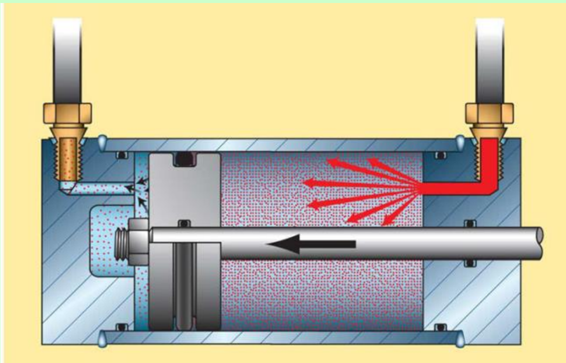


Figure 9.7

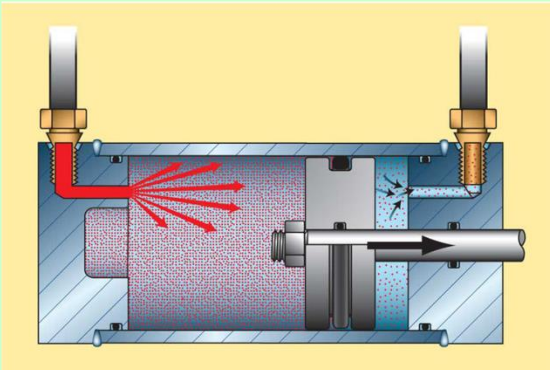


Figure 9.8

Floating Pneumatic Piston Seals:

Floating pneumatic piston seals are reciprocating in nature, but the way in which the seals are affected is unique. Normal reciprocating designs rely on the O-ring being stretched over a piston and then squeezed radially (on the inside diameter, or I.D., and the outside diameter, or O.D.).

In floating O-ring designs, however, there is no radial squeeze on the seal's cross-section. The O-ring's O.D. is larger than the cylinder bore diameter. Peripheral squeeze is applied to the O.D. as the O-ring is installed into the bore. Incoming air pressure forces the O-ring against the groove wall, and a seal is affected as shown in Figure 9.9.

Floating designs offer a number of advantages, including greatly reduced breakout friction and longer seal life. Floating pneumatic piston seals are suited for applications in which the air pressure does not exceed 29 kPa. Floating O-rings are NOT suitable as rod seals.

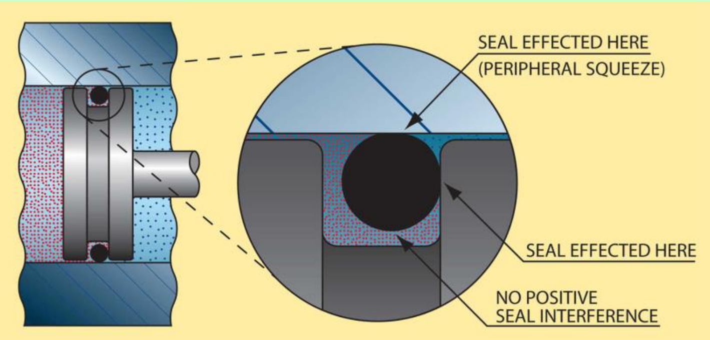


Figure 9.9

Rotary Seals:

Rotary seals involve motion between a shaft and housing. Typical rotary seals include motor shafts and wheels on a fixed axle. Installation of a rotary O-ring seal is shown in Figure 9.10. Most manufacturers recommend lip type shaft seals for most rotary applications; several applications can exist where an O-ring will provide an effective rotary seal.

O-ring seals are NOT recommended for rotary applications under the following conditions:

- Pressures exceeding 116 kPa.
- Temperatures lower than -40° C (-40° F) or higher than 107° C (225° F).
- Surface speeds exceeding 180 meters per minute.

When an elastomer is stretched and heated, it will contract; this is called the *Gough-Joule effect* and is an important design consideration in a rotary application because if an O-ring is installed in a stretched condition, frictional heat will cause the O-ring to contract onto the shaft and may cause the O-ring to seize the rotating shaft so that the dynamic interface becomes the O-ring O.D. and the groove I.D.; the contraction will also cause more frictional heat, further exacerbating the situation and causing premature failure of the O-ring.

Most rotary O-ring seals are designed so that the free O-ring I.D. is larger than the shaft onto which it fits. The gland I.D. is smaller than the free O-ring O.D. so that when it is placed into the gland, the O-ring is peripherally squeezed, and the I.D. is reduced so that a positive interference exists between the O-ring I.D. and the shaft. Because the O-ring is not in a stretched condition, it will not build up heat, seize the shaft, and rotate in the groove.

Rotary seals (such as the one shown in Figure 9.11) do not dissipate heat as well as reciprocating seals do, so provisions must be made to keep heat build-up to a minimum.

- The housing I.D. should not be used as a bearing surface.
- Bearings should be provided to ensure that the shaft runout does not exceed 0.05 mm TIR.
- The O-ring groove should be located away from the bearing and close to the lubricating fluid.
- The housing length should be 8 to 10 times the O-ring cross-section to provide for better heat transfer.

To prevent extrusion of the O-ring, the clearance gap (extrusion gap) should not be more than 0.125 mm per side. If pressures greater than 116kPa are encountered, it is recommended that an 80 durometre O-ring be used.

The minimum hardness for the section of shaft that comes into contact with the O-rings is Rockwell C30. To prevent excessive wear, scratches, nicks, and handling damage, a hardness of Rockwell C45 is recommended. A shaft finish of 0.01 mm to 0.02 mm is recommended, and plunge grinding with no machine lead is the preferred finishing method. The shaft ends should be chamfered with a 15/30° chamfer to prevent installation damage.

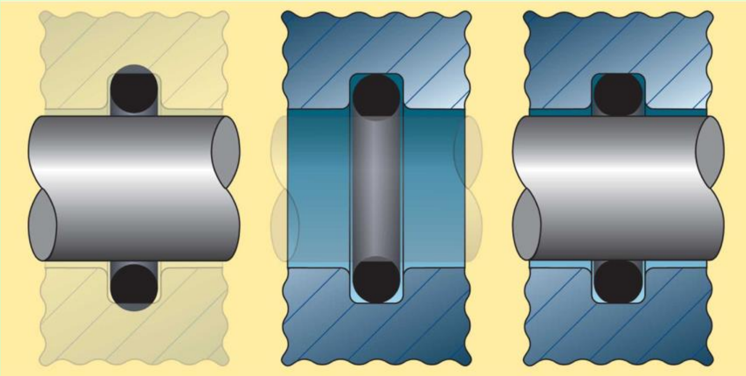


Figure 9.10

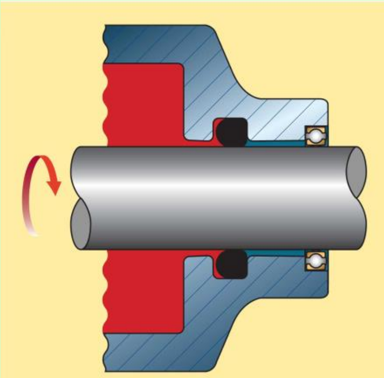


Figure 9.11

Oscillating Seals:

Oscillating seals are commonly used in faucet valves. In oscillating applications, the shaft or housing rotates back and forth through a limited number of turns around the axis of the shaft. An oscillating O-ring seal is shown in Figure 9.12.

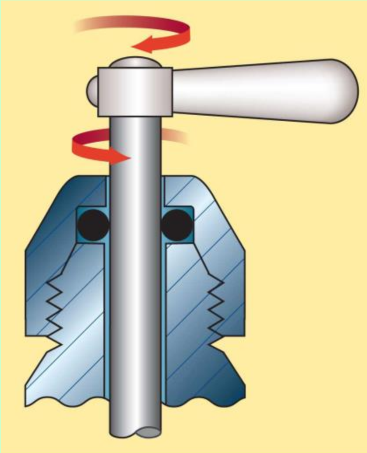


Figure 9.12

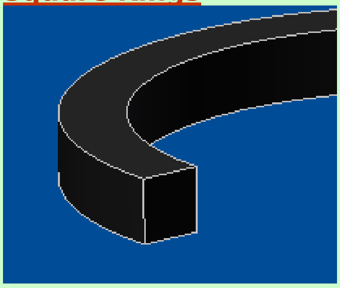
Other Cross Sectional Options:

Although O-rings are ideal for a wide variety of applications, they are not suitable for all situations.

Lobed Seals (X-rings)

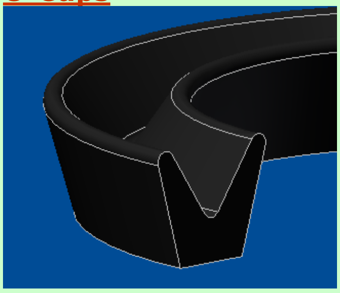
Lobed seals are also known as X-rings and have the advantage of doubling the number of sealing surfaces found on the traditional O-rings. Lobed seals require less compression than O-rings which make them suitable for the use in dynamic situations. Due to their design, lobed seals provide improved sealing ability and are more resistant to twisting.

Square Rings



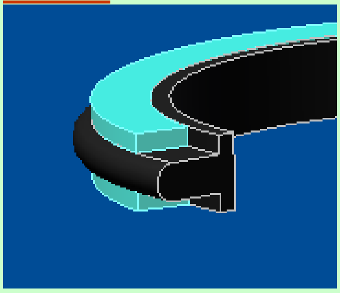
Square rings are circular sealing devices that utilize a square rather than circular cross-section. Square rings do not seal as well as O-rings because the circular cross-section allows for more concentrated loading.

U-Cups



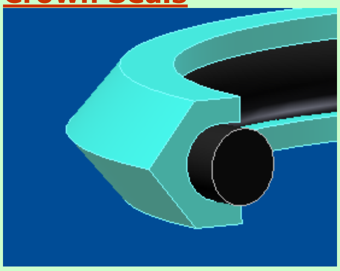
U-cups can be used in static and dynamic applications. Due to the pressure-actuated lip they operate with lower break-out () and running friction. U-cups can be used in a dynamic application, however they are unidirectional and 2 seals are required for bidirectional sealing.

T-seals



T-rings are T-shaped in cross section and are used with back rings on the sides. The T shape adds stability and is resistant to spiral failure than O-rings.

Crown Seals

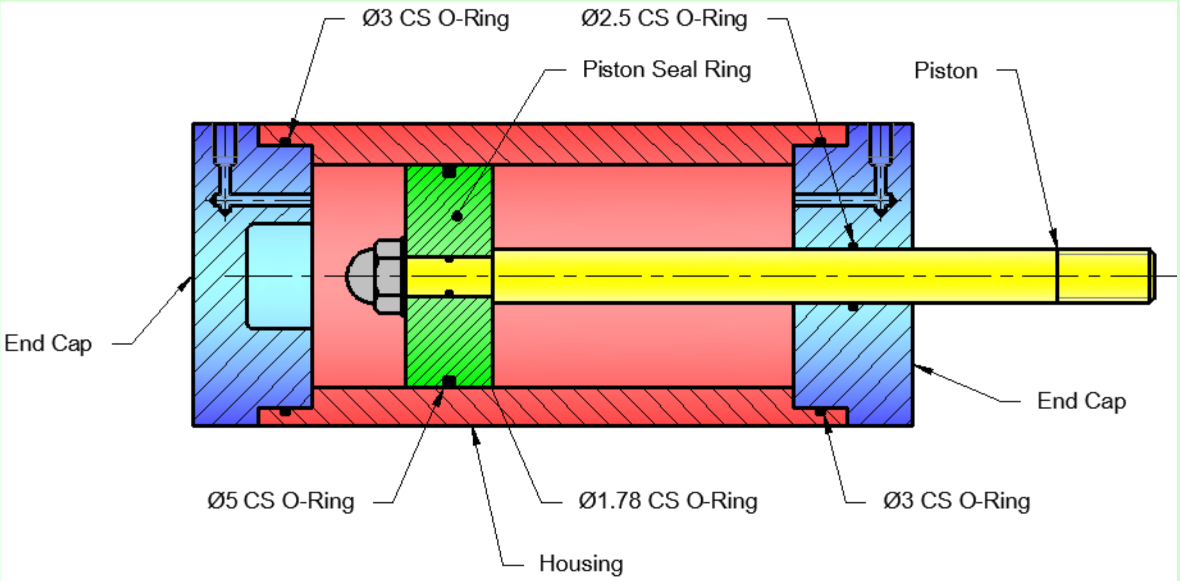


The Crown seal is comprised of the outer crown and an inner O-ring. The tougher outer crown reduces wear and enables the seal to operate under low temperature and low pressure conditions.

Skill Practice Exercises

Skill Practice Exercise: MEM09209-SP-0901

1. Using the template file provided on the network drive called Hydraulic Actuator, complete the assembly by adding grooves for O-Rings where indicated.
2. Produce an assembly drawing of the Hydraulic Actuator including a Parts List and cross-referencing.
3. Produce detail drawings of the Piston, Housing, End Caps and Piston Seal Ring assigning details for the O-Ring grooves. One of the views is to include a full or half sectional view along the cutting plane.
4. Assign Limit of Size dimensions a G7/h6 fit between mating surfaces.
5. Indicate that all mating surfaces are to be bored or machined to a roughness of 0.2. All circular features are to be concentric to the centreline while all vertical surfaces are perpendicular to the centreline to 0.05.
6. Save the completed drawing as MEM09209-SP-0901.
7. End Caps, Housing, Piston and Piston Seal Ring can be considered to be circular in shape.

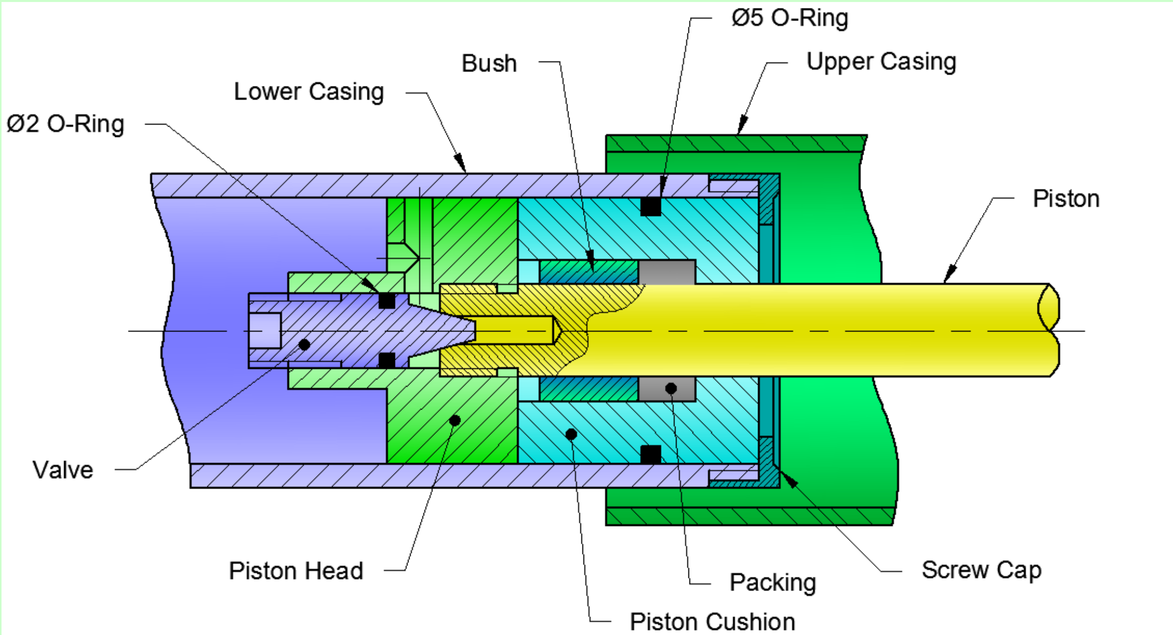


The assembly can be considered circular in shape and fastened using 4 machine screws/bolts equally spaced on the PCD at each end offset at 45° to the centreline. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: End Caps – Aluminium Alloy; Housing – Aluminium Alloy; Shaft – Mild Steel; Piston Seal Ring – Nylon; Fasteners – Commercial; O-Rings – Rubber.

Skill Practice Exercise: MEM09209-SP-0902

1. Create a new drawing using the template file provided on the network drive called Pneumatic Shock Absorber and complete the assembly by adding the missing O-Ring grooves in the centre of the mating parts.
2. Produce an assembly drawing on a standard A3 sheet incorporating a Parts List and cross-referencing.
3. Create detail drawings of the Piston Cushion and the Valve including a detail of the groove assigning the appropriate toleranced dimensions as required. One of the views is to be a full or half sectional view along the cutting plane.
4. Assign Limit of Size dimensions a H7/h6 fit between mating surfaces of the Piston Head and the Upper Casing and N7/h6 fit between the Shaft and Bush.
5. Indicate that all mating surfaces are to be bored or machined to a roughness of N3.
6. All circular features are to be concentric to the datum centreline to within 0.025 and roundness to 0.015 while all vertical surfaces are perpendicular to the centreline to 0.05.
7. Insert standard A3 sheets and save the drawing in your work area as MEM09209-SP-0902



The coupling is circular in shape. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: Lower Casing – Mild Steel; Upper Casing – Mild Steel; Screw Cap – Mild Steel; Piston Head – Mild Steel; Piston Cushion – Mild Steel; Valve – Mild Steel; Piston Stainless Steel; Bush – Brass; Packing – Felt.

Topic 10 – Seals:

Required Skills:

- Produce an assembly drawing and indicate the appropriate seal using the correct symbols.
- Use manufacturer's charts, specifications and catalogues to determine the sizes of seal grooves.

Required Knowledge:

- Purpose of different mechanical seals.
- The names of various mechanical seals.
- Materials used in the production of mechanical seals.
- Advantages and disadvantages of the various mechanical seals.
- Application of toleranced dimensions.

Seals:

Seals are used as the name implies, to prevent lubricants from leaking out, or through bearings, or to prevent foreign particles, dust, grit, and corrosive liquids including water from getting onto the surface of the bearing or mixing with the lubricant. In the case of anti-friction bearings, ALL foreign matter causes a rapid breakdown of the balls, rollers and raceways. Seals are made in various designs and of different materials, depending on the type of service required as shown in Figure 10.1.

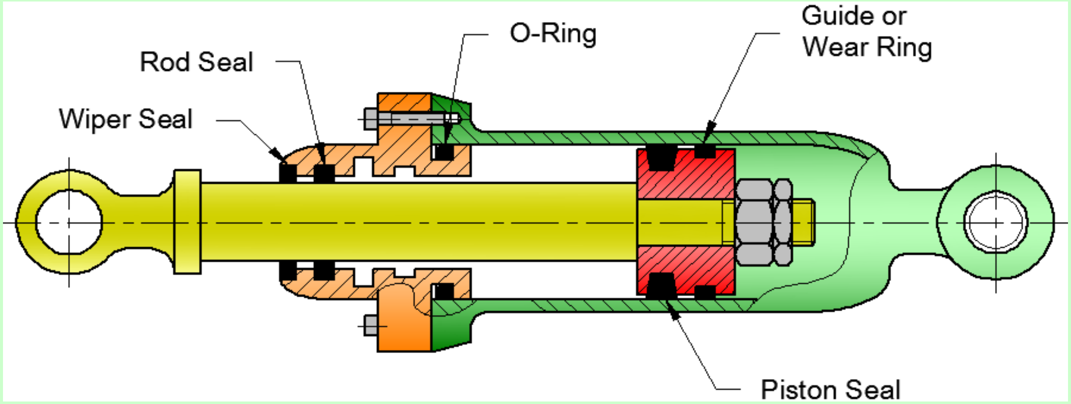


Figure 10.1

Factors to consider are:

- Impervious to the type of lubricant used.
- Temperature of operation.
- Frictional wear.
- Resistance to chemical or acid solutions with which it may come in contact.

Types of Seals:

Felt Seal:

Felt seals consist of a felt material encased in a steel shell. Felt seals are used in light applications to exclude dust and grit, and can be used at shaft speeds of 305 m/sec and temperatures to 49°C. Felt is a built up fabric made by interlocking fibres through a suitable combination of mechanical work, chemical action, moisture and heat without spinning, weaving or knitting. It may consist of one or more classes of fibres – wool, reprocessed wool, or reused wool – which are used alone or combined with animal, vegetable and synthetic fibres. Felt has long been used as an important material for sealing purposes. The main advantages are, oil absorption, filtration, resiliency, low friction, polishing action and cost.

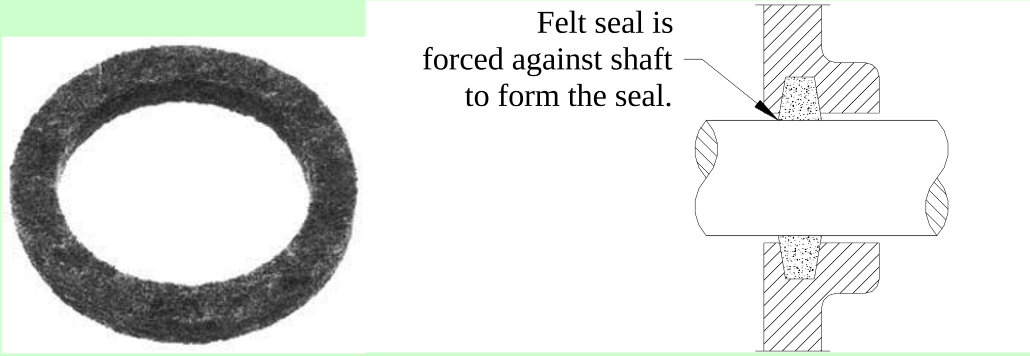


Figure 10.2 Felt Seal

Labyrinth Seal:

A Labyrinth Seal is a type of seal in which there is no contact between the seal and the moving part. This is important where there may be side movement of a shaft relative to the fixed part. It is inevitable however that some leakage must occur. Labyrinth seals consist of a series of restrictions formed by projections on the shaft or casing and form a complicated irregular shape with many passages to prevent the escape of the lubricant. There is no fixed design for a labyrinth seal.

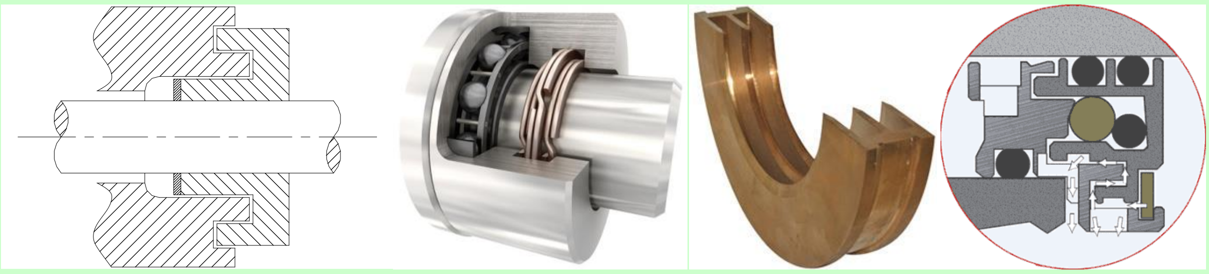


Figure 10.3 Labyrinth Seals

Radial Lip Seal:

Radial lip seals have rubber seal set inside a ground steel case and retained by a garter spring. The element of the seal (rubber etc.) can be varied to suit the application. The purpose of the radial lip seal is to exclude foreign matter or the retention of lubricants, depending on the direction in which they are installed.

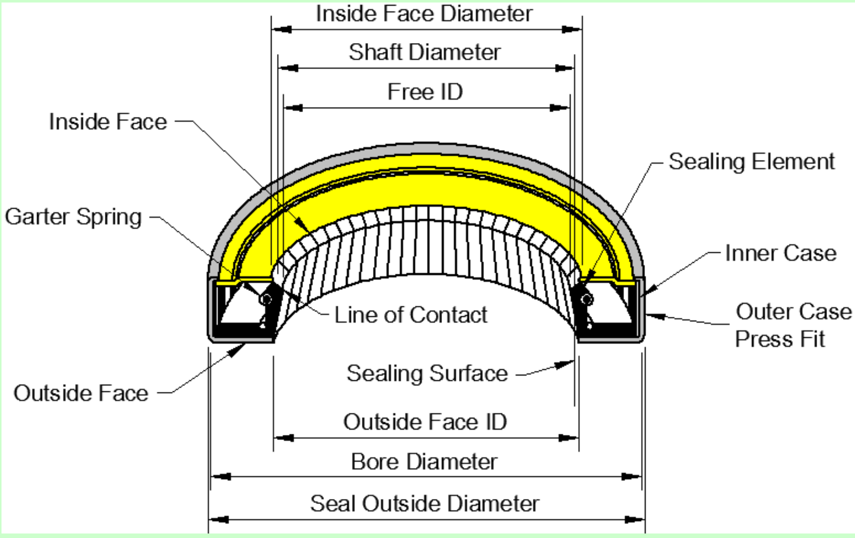


Figure 10.4 Radial Lip Seal

Rod Wiper Seal:
Contamination particles in the hydraulic system are the most common cause for breakdowns and short service life of seals. A majority of the contaminating particles reaches the system on the rod; the wiper seal's task is to prevent this.

The wiper seal is the most undervalued seal type in the hydraulic cylinder in relation to its important function. The choice of wiper seal should, however, be founded on as carefully drawn-up requirement specifications as the choice of piston and rod seals. The surrounding environment and service conditions must be taken into special consideration.

The wiper seal must be designed not only to fit the rod (dynamic function) but also to seal in the housing (static function).


Figure 10.5 Rod Wiper Seals

Rod Seal:
The rod seal is the seal in the hydraulic cylinder with the most demanding requirement specifications. In addition to normal wear and aging, this seal is directly affected by changes on the rod’s surface.

The rod seal is often the decisive factor for the function of the hydraulic cylinder in its entirety. Leakage through the rod seal can in some cases cause accidents and environmental damages; therefore, it is of significant importance to make the correct choice of rod seal and not the least, to be familiar with the properties of other existing seal types.

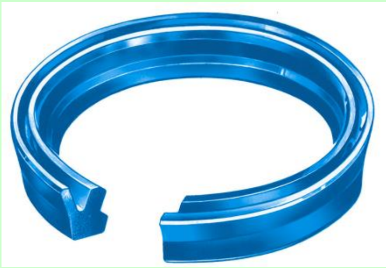


Figure 10.6 Rod Seal

Piston Seal:
The basic demand on piston seals as well as on rod seals for hydraulic cylinders under the operating conditions for which they have been chosen, is to maintain a high level of

sealing performance during their service life. The overall demands on both these function-determining main seals in the hydraulic cylinder are meanwhile very different in many respects. In this section, we feature both single- and double-acting piston seals.

The choice of the type of piston seal is to a great extent decided by the way in which the cylinder operates. For a cylinder which is exclusively single-acting, it is always best to choose the type of seal designed to provide optimum sealing qualities for single-acting functions, with, for instance, the thinnest possible lubrication film that can pass through the contact area between the seal and the cylinder tube surface.

The best sealing capacity of a double-acting cylinder is achieved by choosing a double-acting seal. A piston design where two single-acting seals on the piston for a double-acting cylinder are used can easily give rise to a breakdown. The reason is that a very high pressure can be trapped between the seals.

Figure 10.7 Piston Seal

Piston seals, both single- and double-acting, can be designed for and used with integrated or separate back-up rings and guide rings. The ultimate choice must be based on the operating conditions of the cylinder.

Guide Rings and Strips:

The task of guide rings and guide strips of plastic materials is to guide the piston in the cylinder bore and the rod in the cylinder head in a working hydraulic cylinder as well as to withstand arising side loads and prevent metallic contact between these axially mobile parts. Plastic guides have been used instead of metallic guides for several years now which has resulted in a considerably longer service life for hydraulic cylinders. Plastic materials work more smoothly against the cylinder tube and the sealing surface of the rod, although contamination particles often are included in the hydraulic oil.

Metal guides are only slightly deformed also at heavy loads which imply that the force is concentrated to small areas. The speed in a hydraulic cylinder is also very low from a guide function point of view which results in an insufficient lubrication; this condition in combination with the presence of contamination particles result in a rapid wear of the metal guide, the cylinder tube and the rod surface.

Figure 10.8

Split Ring Seal:

Split rings are used for a large number of seal applications. Expanding split rings (piston rings) are used in compressors, pumps and internal combustion engines. Applications for straight cut and seal joint rings are common in industrial and aerospace hydraulic and pneumatic cylinders (linear actuators) where the ruggedness of piston rings is advantageous and where various degrees of leakage can be tolerated. The rings are made of cast iron or steel, are rectangular in cross-section and fit into grooves of the same shape in the piston. The ring is cut so that it springs out against the cylinder wall to ensure a good seal. A typical petrol engine piston has two compression rings for gas sealing and an oil scraper ring that prevents oil from entering the combustion chamber.

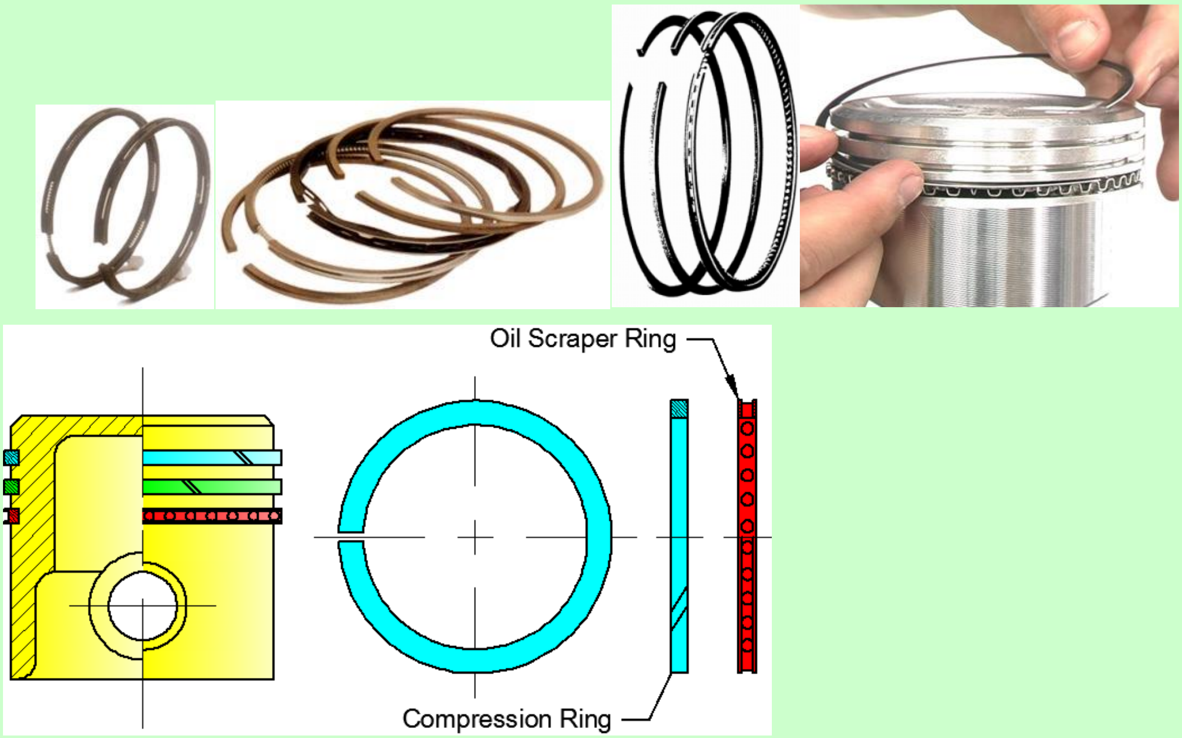


Figure 10.9 Split Ring Seal

Stuffing Box (Gland)

A Stuffing Box or Gland, is a recess in a casing (surrounding a shaft) containing sealing material, or *gland packing*, which is compressed by means of an adjustable ring to prevent leakage along the shaft. The ring is often termed a *gland ring* or simply a *gland*. The packing in a stuffing box consists of a spiral or several rings of woven cotton or hemp impregnated with grease and graphite to reduce friction.

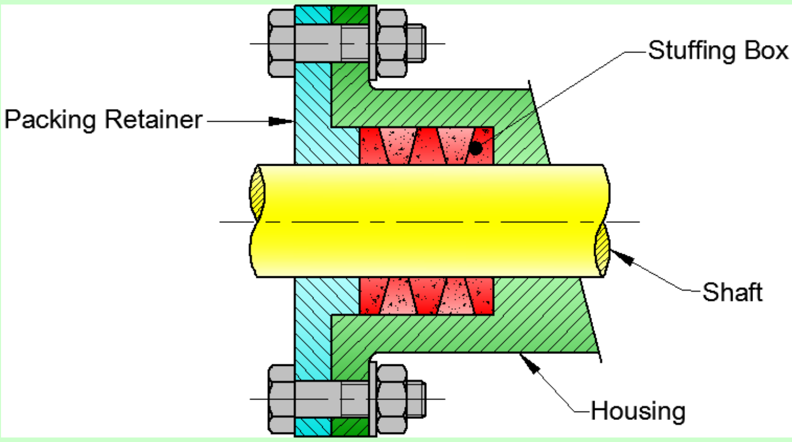


Figure 10.10 Stuffing Box

Seal Materials:

Seal Face:

- Bronze, Carbon, Glass Filled PTFE, Moulded Plastic and Tungsten Carbide.

Casing:

- Bronze, Brass, Monel, Chrome Steel and Stainless Steel

Elastomers:

- A range of many various polymers having the elastic properties of natural rubber including Buna, Viton ®, Neoprene, Teflon® and Asbestos.

Seal Seats:

- Bronze, Cast Iron, Ceramic, Silicon Carbide and Tungsten Carbide.

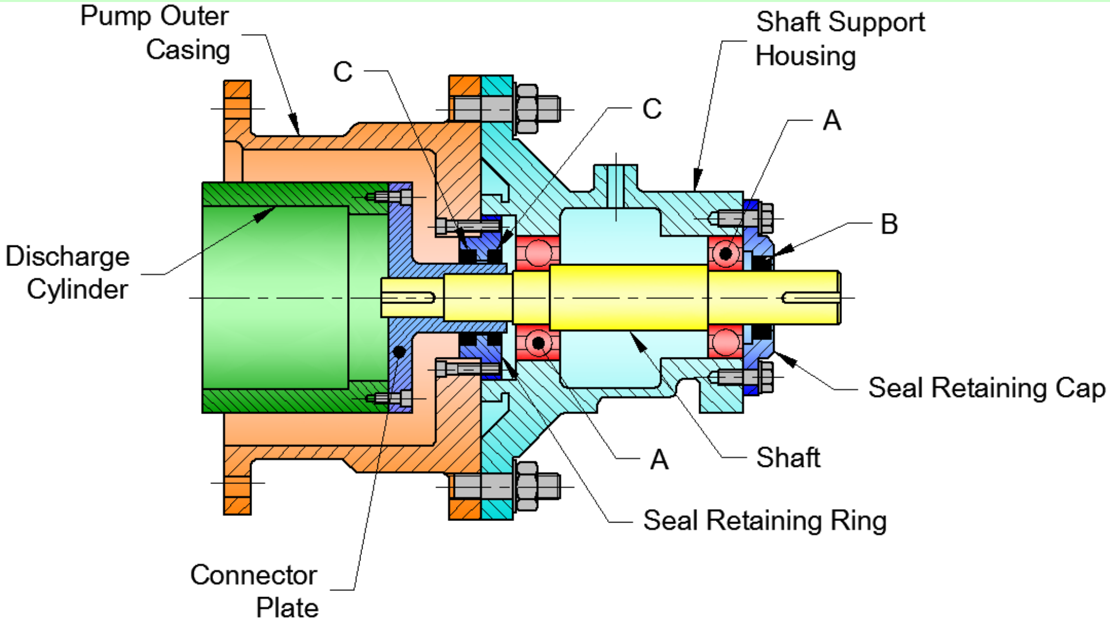
Springs:

- Monel, Stainless Steel and Spring Steel.

Skill Practice Exercises

Skill Practice Exercise: MEM09209-SP-1001

1. Create a new drawing using the template file provided on the network drive called Nuclear Pump and complete the assembly by adding the bearings and seals as shown below.
2. Produce an assembly drawing of the Nuclear Pump including a Parts List and cross-referencing.
3. Produce detail drawings of the Seal Retaining Cap and Seal Retaining Ring including the appropriate toleranced dimensions as required. One of the views is to be a full or half sectional view along the cutting plane.
4. All cylindrical surfaces for the bearings are to be reamed to a finish of 0.4, be concentric to the datum centreline to 0.035 and roundness of 0.08.
5. All straight mating surfaces are to be milled to 1.6 and perpendicular to the centreline to 0.05.
6. Insert standard A3 sheets and save the drawing in your work area as MEM09209-SP-1001 before plotting.



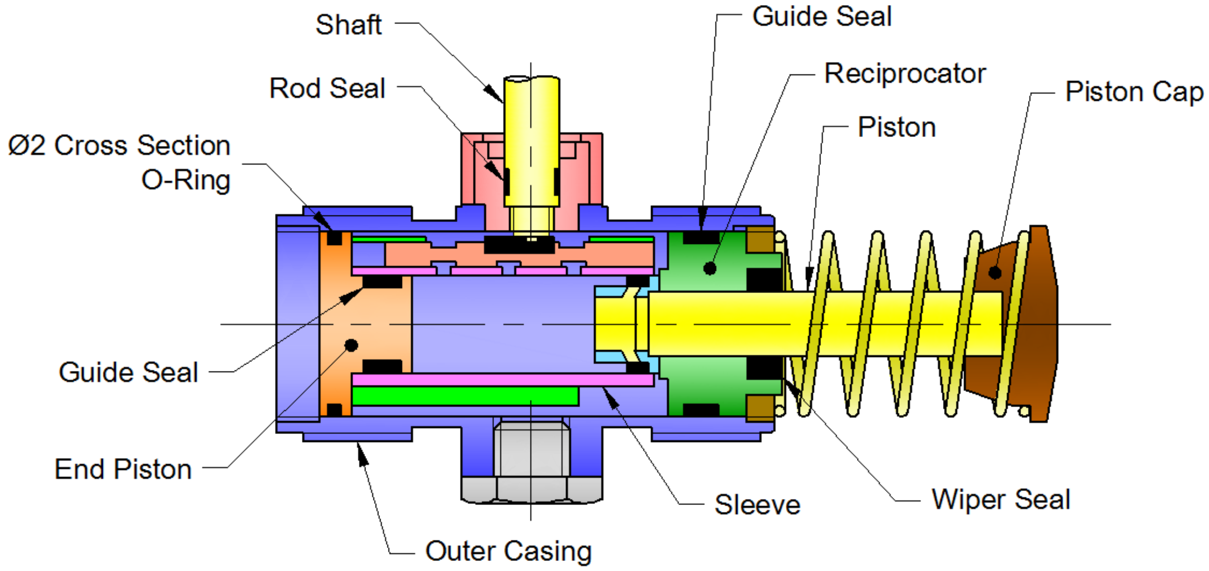
Item	Description	Quantity
A	Cylindrical Roller Bearing - NU 2204	2
B	Radial Lip Seal – Steel Cased	1
C	Radial Lip Seal – Steel Cased	2

The assembly can be considered circular in shape and fastened using 8 studs equally spaced on the PCD. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: Pump Outer Casing – Cast Iron; Shaft Support Housing – Cast Iron; Shaft – Mild Steel; Bearing Retaining Caps – Mild Steel; Connector Plate – Mild Steel; Discharge Cylinder – Mild Steel; Fasteners, Bearings and Seals - Commercial.

Skill Practice Exercise: MEM09209-SP-1002

1. Create a new drawing using the template file provided on the network drive called Shock Absorber and complete the assembly by adding the seals as shown below.
2. Produce an assembly drawing of the Shock Absorber including a Parts List and cross-referencing.
3. Produce detail drawings of the End Piston and Reciprocator including the appropriate toleranced dimensions as required. One of the views is to be a full or half sectional view along the cutting plane.
4. All cylindrical surfaces for the bearings are to be reamed to a finish of 0.15, be concentric to the datum centreline to 0.05 and roundness to 0.8.
5. All flat mating surfaces are to be milled to 0.8 and perpendicular to the centreline to 0.15 with a flatness of 0.03.
6. Insert standard A3 sheets and save the drawing in your work area as MEM09209-SP-1002 before plotting.



The assembly can be considered circular. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: Outer Casing – Brass; End Piston – Nylon; Sleeve – Brass; Reciprocator – Nylon; Spring – Stainless Steel; Piston – Stainless Steel; Shaft – Mild Steel; Piston Cap – Nylon; Seals – Rubber.

Topic 11 – Thrust Bearings:

Required Skills:

- Produce assembly drawings containing thrust bearings.
- Produce detail drawings of components requiring thrust bearings.

Required Knowledge:

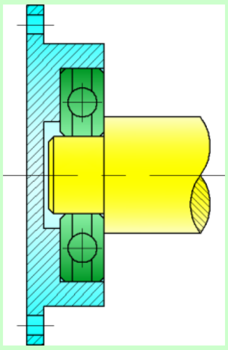
- Identify the symbol and list the applications of the various types of thrust bearings.
- Extract data from trust bearing tables.

Thrust Bearings:

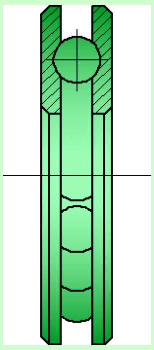
A thrust bearing is a type of rotary bearing that permits rotation between parts but are designed to support high axial (parallel to the shaft) loads. Thrust bearings are available in the following types: Ball Thrust Bearings, Tapered Roller Bearings, Self-Aligning Thrust Bearing and Fluid Bearings.

Ball Thrust Bearings:

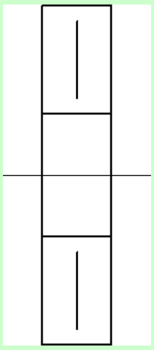
Ball Thrust Bearings contain balls that are mounted in a cage and run between the faces of two annular rings, and these may be used to take the weight of a vertical shaft in a footstep bearing. The object of thrust bearings is to support thrust and axial loads. The basic single rigid row type has a shallow grooved track in each washer. The load is taken axially in one direction only and has a limited speed range. The double ball type will take thrust in both directions



Ball Thrust Bearing Assembly



Ball Thrust Bearing



Symbol

Single Direction Thrust Ball Bearings:

A single direction thrust ball bearings consist of a shaft washer, a housing washer and a ball and cage thrust assembly. The bearings are separable so that mounting is simple as the washers and the ball and cage assembly can be mounted separately.

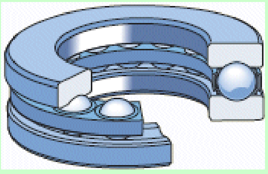


Figure 11.1

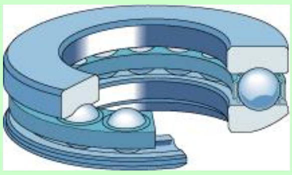


Figure 11.2

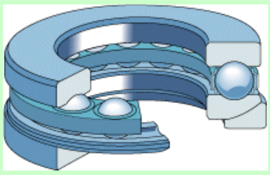


Figure 11.3

Smaller sizes are available with either a flat seating surface on the housing washer (Figure 11.1) or a spherical seating surface (Figure 11.2). Bearings with a spherical housing washer can be used together with a spherical seating washer (Figure 11.3) to compensate for misalignment between the support surface in the housing and the shaft. Single direction thrust ball bearings, as their name suggests, can accommodate axial loads in one direction and thus locate a shaft axially in one direction and must not be subjected to any radial load.

Double Direction Thrust Ball Bearings:

A double direction thrust ball bearings consist of one shaft washer, two housing washers and two ball and cage thrust assemblies. The bearings are separable so that mounting is simple. The various parts can be mounted separately. The housing washers and ball and cage thrust assemblies are identical to those of the single direction bearings.

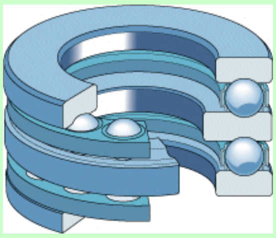


Figure 11.4

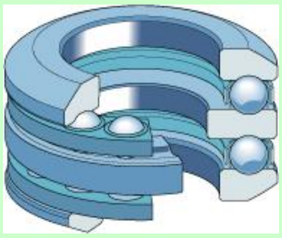


Figure 11.5

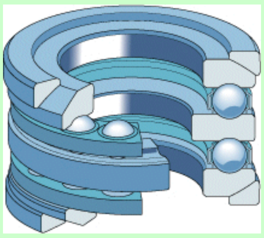


Figure 11.6

Smaller bearings are available with either a flat seating surface on the housing washers (Figure 11.4) or with a spherical seating surface (Figure 11.5). Bearings with sphered housing washers can be used together with sphered seating washers (Figure 11.6) to compensate for misalignment between the housing and shaft. Double direction thrust ball bearings can accommodate axial loads acting in both directions and can thus serve to axially locate a shaft in both directions. They must not be subjected to radial load.

Cylindrical Roller Thrust Bearings

Cylindrical roller thrust bearings are suitable for arrangements that have to support heavy axial loads. Furthermore, they are relatively insensitive to shock loads, are very stiff and require little axial space. As standard they are available as single direction bearings and can only accommodate axial loads acting in one direction.

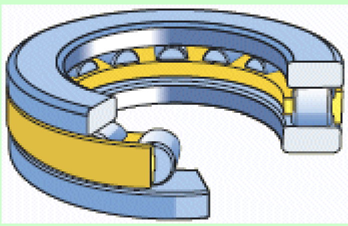


Figure 11.7

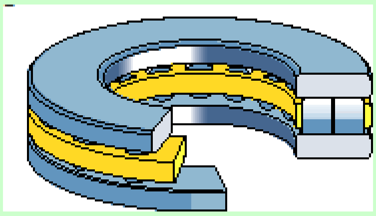
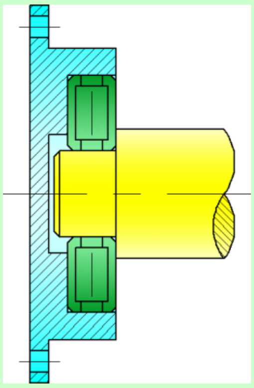


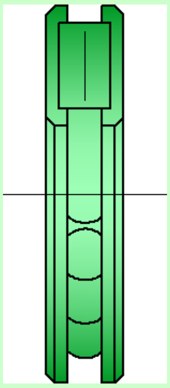
Figure 11.8

Cylindrical roller thrust bearings are simple in form and design and are produced in single row (Figure 11.7) and double row (Figure 11.8) designs. The cylindrical surface of the rollers is slightly relieved towards the ends. The resulting contact profile virtually eliminates damaging edge stresses. The bearings are of separable design; the individual components can be mounted separately.

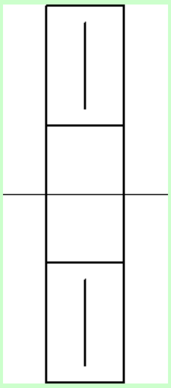




Roller Thrust Bearing Assembly



Roller Thrust Bearing



Symbol

Taper Roller Thrust Bearings

Taper roller thrust bearings enable axially very compact bearing arrangements to be produced which can carry very heavy axial loads, are insensitive to shock loads and are stiff. Manufacturers produce single direction taper roller thrust bearings (Figure 11.9) and double direction taper roller thrust bearings (Figure 11.10). The screw-down bearings (Figure 11.11) constitute a special design of single direction taper roller thrust bearing and have a full complement of rollers. They are used for rolling mill screw-down arrangements.

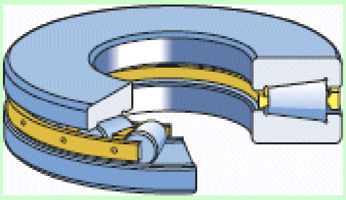


Figure 11.9

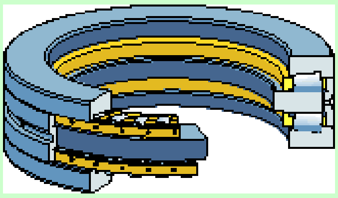


Figure 11.10

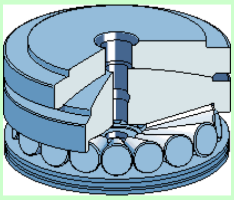
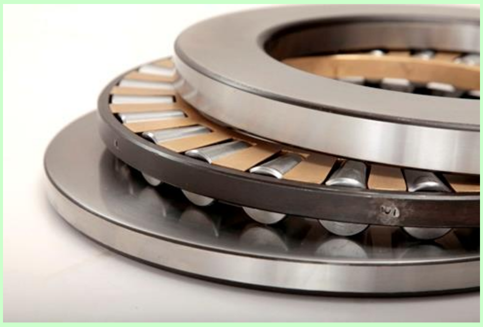
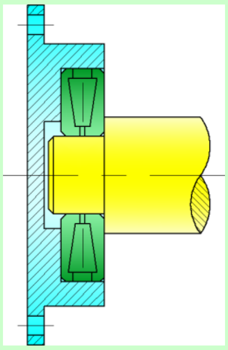
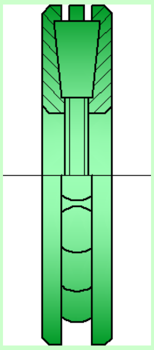


Figure 11.11

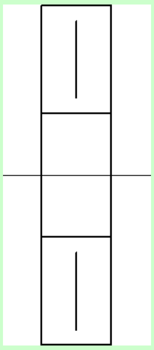
Taper roller thrust bearings are produced with the logarithmic contact profile between raceways and rollers to guarantee optimum stress distribution in the bearing, thus enhancing bearing life. Taper roller thrust bearings with cage are of separable design so that the two washers and the roller and cage thrust assembly can be mounted separately and easily. The full complement screw-down bearings are held together by special retaining components and, to simplify handling, the washers have threaded holes for eye bolts.

Taper Roller Thrust Bearing Assembly



Taper Roller Thrust Bearing



Symbol

Spherical Roller Thrust Bearings

In spherical roller thrust bearings the load is transmitted from one raceway to the other at an angle to the bearing axis (Figure 11.12). The bearings are therefore suitable to accommodate radial loads in addition to simultaneously acting axial loads. Another important characteristic of spherical roller thrust bearings is their self-aligning capability. This makes the bearings insensitive to shaft deflection and misalignment of the shaft relative to the housing.

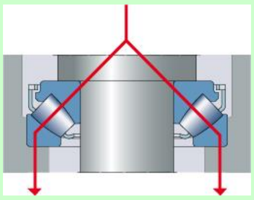


Figure 11.12

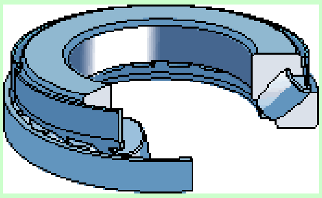


Figure 11.13

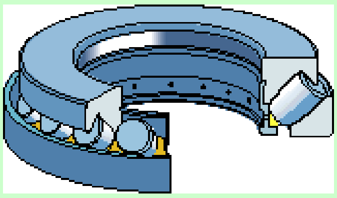
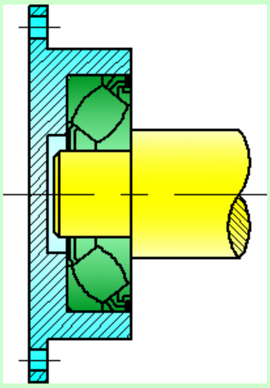
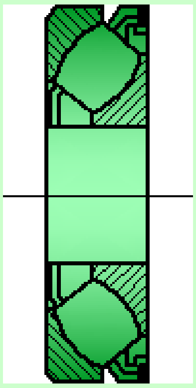


Figure 11.14

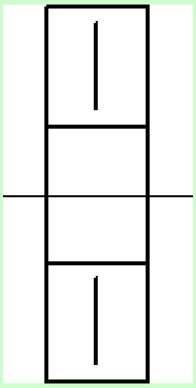
Spherical roller thrust bearings incorporate a large number of asymmetrical rollers and have specially designed raceways with an optimum conformity. They can therefore support very heavy axial loads and permit relatively high speed operation. Spherical roller thrust bearings are produced in two designs depending on the size and series. Bearings up to and including size 68 identified by the designation suffix E have a pressed steel window-type cage which, with the rollers, forms a non-separable assembly with the shaft washer (Figure 11.13). All other bearings have a machined brass or steel cage which is guided by a sleeve held in the shaft washer bore (Figure 11.14). The shaft washer and cage with rollers form a non-separable unit.



Spherical Roller Thrust Bearing Assembly



Spherical Roller Thrust Bearing



Symbol

Needle Roller Thrust Bearings Thrust Bearing

Needle roller thrust bearings can support heavy axial loads, are insensitive to shock loads and provide stiff bearing arrangements which require a minimum of axial space. They are single direction bearings and can only accommodate axial loads acting in one direction. Particularly compact bearing arrangements can be made, taking up no more space than a conventional thrust washer, if the faces of adjacent machine components can serve as raceways for a needle roller and cage thrust assembly. For applications where adjacent components cannot serve as raceways, the assemblies can also be combined with washers of various designs.

Because of all the possible combinations, all bearing components must be ordered separately.

Angular Contact Thrust Bearing

The Angular contact thrust ball bearings were originally designed to support the rotary tables of drilling rigs but are also suitable for other applications where high load carrying capacity, high axial stiffness and low friction torque are important. In contrast to conventional thrust ball bearings, angular contact thrust ball bearings can accommodate radial loads in addition to axial loads and are able to operate at high speeds.

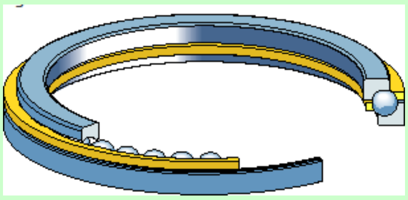


Figure 11.15

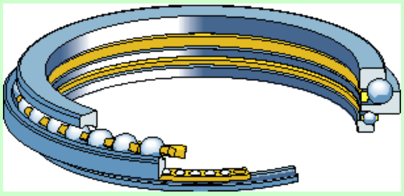


Figure 11.16

Single Direction Angular Contact Thrust Ball Bearings

Single direction angular contact ball bearings (Figure 11.15) are able to take up axial loads acting in one direction. They are of separable design, i.e. the washers and ball and cage assembly can be mounted individually. In the main application area for these bearings – rotary tables – two bearings are always adjusted against each other. The second bearing has to carry the weight of the drill when it is stationary and has a higher load carrying capacity than the first bearing.

Double Direction Angular Contact Thrust Ball Bearings

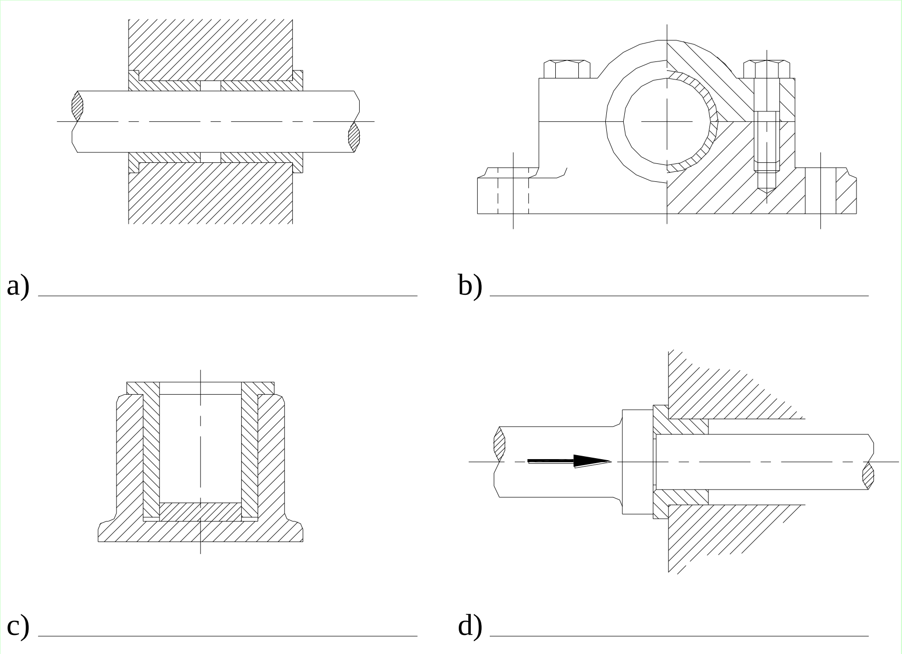
In bearings of the double direction design (Figure 11.16), the upper bearing with the higher load carrying capacity and the smaller bearing which locates in the opposite direction are combined together to form a unit. These bearings have low height and can accommodate axial loads acting in both directions as well as moment loads. A single bearing can therefore be used to support rotating machine components in relation to stationary components. These double direction bearings are also of separable design.

Fluid Thrust Bearing:

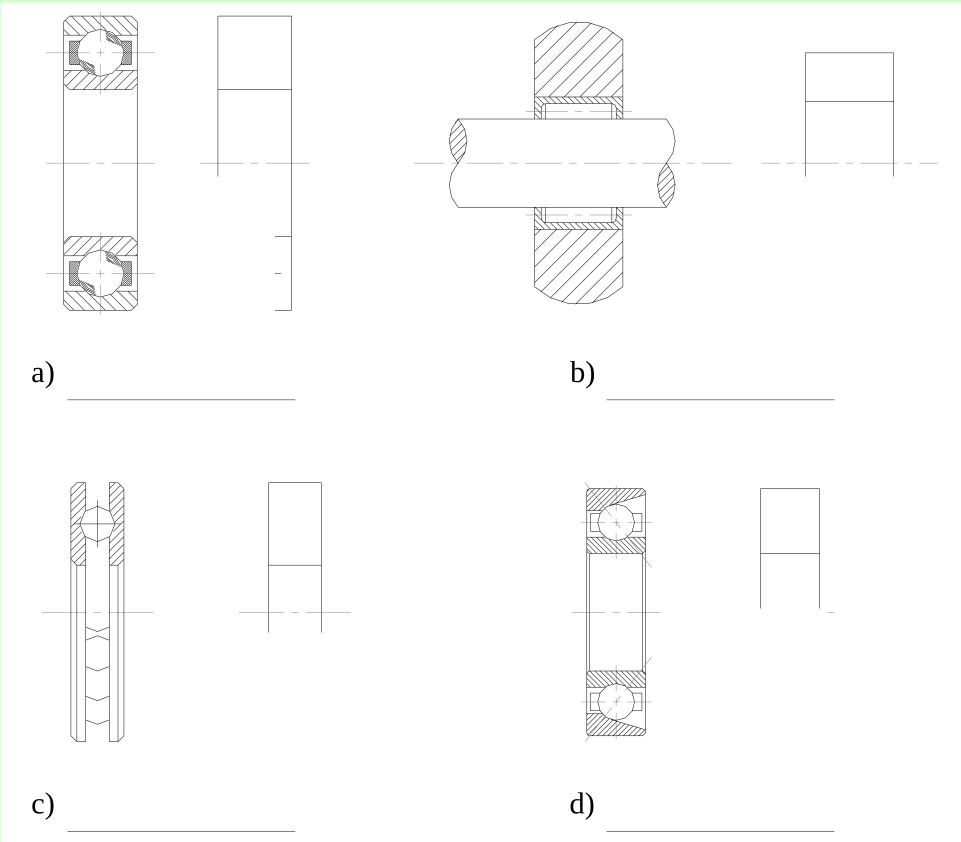
Fluid thrust bearings support the axial loads on a thin layer of pressurised liquid providing relatively low drag. Fluid thrust bearings contain a number of sector or wedge shaped pads arranged in a circle about the shaft and are free to pivot. The wedge shaped regions of fluid inside the bearing between the pads and the rotating disk, which supports the applied thrust and eliminate metal on metal contact.

Review Questions: MEM09209-RQ-06

1. Describe the term *"Bearing"* and list its applications in engineering.
2. List 2 classifications of frequently used engineering bearings.
3. Identify the following sliding contact bearings.



4. Identify and complete the symbol of the following different t rolling contact bearings.

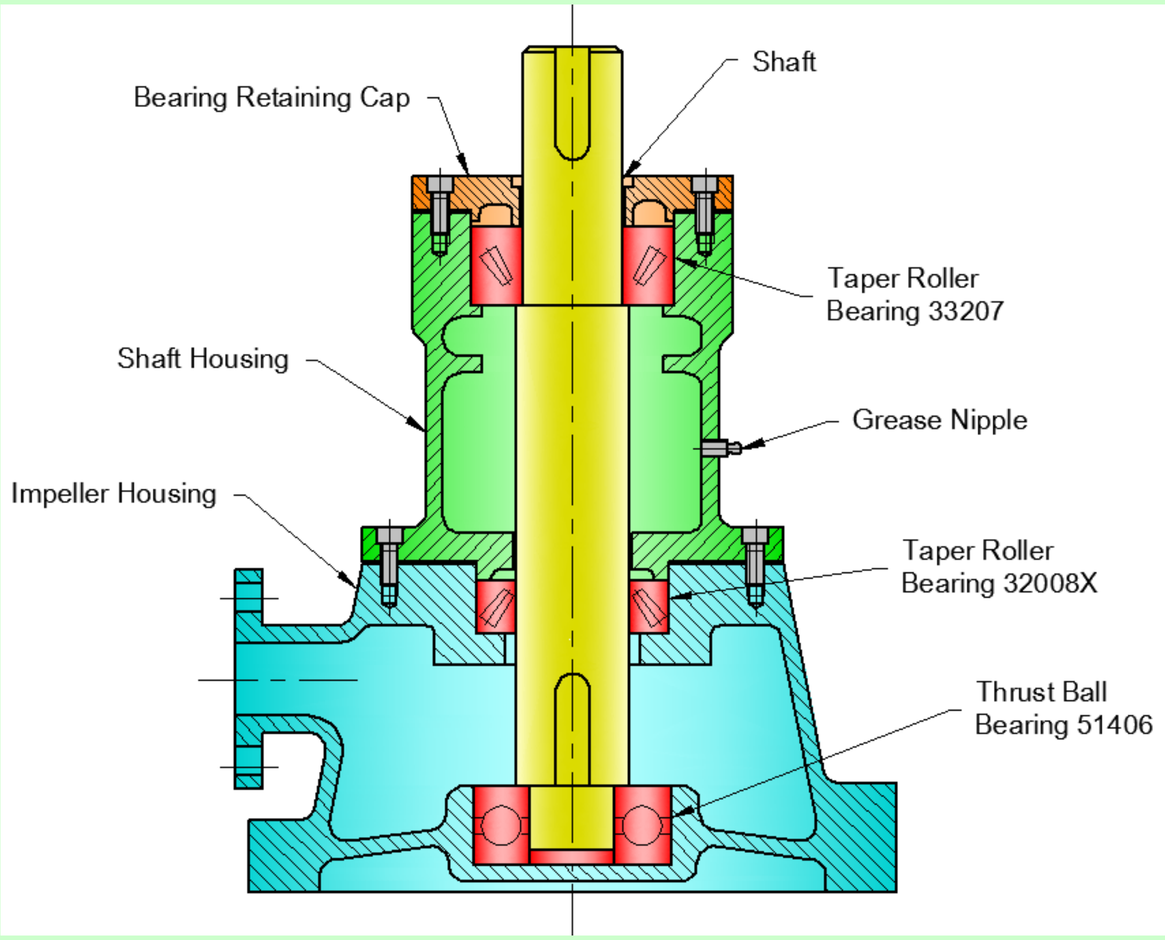


5. Name three materials used in the manufacture of bearings for industrial application.
6. List three different methods of retaining bearings in position.

Skill Practice Exercises:

Skill Practice Exercise: MEM09209-SP-1101

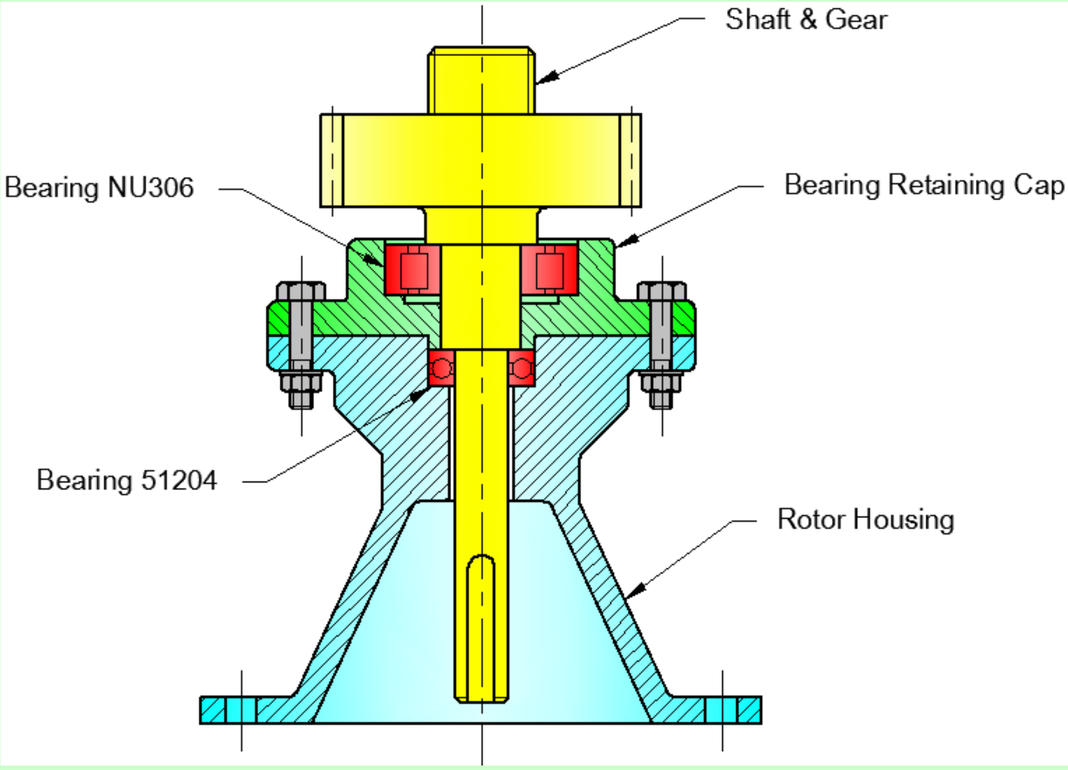
1. Create a new drawing using the template called MF Overhung Oil Handling Pump located on the network drive and complete the assembly by adding the bearings, keyseats and hatching where required. Provide a Bearing Retaining Cap to suit the Shaft, Bearing and Shaft Housing.
2. Produce an assembly drawing of the MF Overhung Oil Handling Pump including a Parts List and cross-referencing.
3. Produce detail drawings of the Shaft Housing, Bearing Retaining Cap and Shaft assigning the appropriate toleranced dimensions to take the bearings with the following fit classifications:
    - S7-h6 fit between the Bearing and Shaft Housing,
    - C11-h11 fit between the Shaft and the Bearings,
    - H7-h6 fit between the Bearing Retaining Cap and the Shaft Housing,
    - H7-g6 fit between the Bearing Housing and the Main Pump Body.
4. All mating surfaces are to be machined to a surface finish of 0.2. Circular surfaces are to be concentric to the datum centreline to 0.05 with a roundness of 0.1 while all flat surfaces are to be perpendicular to 0.05 and flatness to 0.02.
5. Provide an appropriate keyseats in the shaft.
6. Insert an A3 sheet on all drawings and save the drawing in your work area as MEM09209-SP-1101.



Material: Impeller Housing – Cast Iron; Shaft Housing – Cast Iron; Shaft – Mild Steel; Bearing Retaining Cap – Mild Steel; Bearings & Fasteners – Commercial.

Skill Practice Exercise: MEM09209-SP-1102

1. Create a new drawing using the template called Cylinder Head Rotor located on the network drive and complete the assembly by adding the bearings where shown and modifying the Rotor Housing and Bearing Retaining Cap as required.
2. Produce an assembly drawing of the Cylinder Head Rotor including a Parts List and cross-referencing.
3. Produce drawings of the Rotor Housing and Bearing Retaining Cap assigning the appropriate toleranced dimensions to take the bearings assuming a D10-h9 fit for Bearing 51204 and a H7-h6 fit for Bearing NU306. The Rotor Housing is circular in shape.
4. All cylindrical surfaces for the bearings are to be reamed to a finish of 0.2, be concentric to the datum centreline to 0.025 and roundness to 0.05. All straight mating surfaces are to be milled to 0.4 and perpendicular to the centreline to 0.1.
5. Provide an appropriate keyseat in the shaft.
6. Insert an A3 sheet on both drawings and save the drawing in your work area as MEM09209-SP-1102



The assembly is circular in shape. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: Rotor Housing – Cast Iron; Bearing Retaining Cap – Mild Steel; Shaft & Gear – Mild Steel; Bearings & Fasteners – Commercial.

Topic 12 – Bearing Materials:

Required Skills:

- Select suitable bearing materials to an application.

Required Knowledge:

- Materials used in the manufacture of metal bearings.
- Materials used in the manufacture of non-metal bearings

Plain Bearing Materials

Metallic surfaces sliding together under load have a tendency to adhere causing tearing or scoring of surfaces, heat generation results and finally seizure. This factor is of primary importance in all bearing design. To counter this problem the designer's aim is to use materials with suitable lubricants to minimise this effect. A bearing material should, if possible provide the following characteristics:

- Have a good resistance to wear, fatigue and corrosion
- Have sufficient strength to support the load
- Have a fairly high melting point- to reduce the tendency for creep in use
- Have suitable thermal properties to enable heat to be conducted away
- As metal to metal contact will be unavoidable in service the material should be selected to minimise seizure, fretting, scoring and welding
- The bearing should be tolerant to dirt and foreign matter- e.g. soft surface
- Should be tolerant to misalignment
- Should be compatible to lubricant used- e.g. should not corrode if water is used

Metal Bearings

Porous bearings of sintered metals, usually plain or leaded bronze or iron are moulded to shape under pressure and this process results in a sponge like structure with from 10-35% of the metal volume as voids. This allows for impregnating with oil or graphite. In operation the oil feeds through the interconnecting pores to the bearing surface. The overall loss of oil is low although from time to time the bearing has to be re-impregnated.

Methods available for continuously fed oil to porous bearing use force feeding or very simple wick feeds. Porous bearings are very useful in locations with limited access and /or where regular lubrication or engineered lubrication systems are difficult to implement. Porous bearings i.e. Oilite bearings, which are porous bronze or iron alloy impregnated with an oil lubricant, are widely used throughout industry.

Aluminium bronze bearings

Bearings great strength can be produced using iron, silicon, and nickel as alloying elements. The have excellent shock, wear and corrosion resistance. Their strength is retained at elevated temperatures so they can be used in equipment operating above 260°C. This alloy however has poor compatibility, poor embedding properties and poor conformability and so is best suited to heavy duty low speed applications with good lubrication.

Aluminium Based materials

These materials were developed as an improvement on the white metal and copper based alloys and to provide bearings that carry high loads. Special features are their good resistance to corrosion, high thermal conductivity and high fatigue strength, high thermal conductivity and high fatigue strength but they have the disadvantages of only moderate embedding properties, poor compatibility and high coefficients of thermal expansion. If used as solid unbacked bearings this type of alloy is usually too weak to maintain an interference fit and too hard to run satisfactorily against an unhardened shaft. As a bearing material unalloyed aluminium has a tendency to seize to a steel mating surface. It was found that a 20% of tin added to the aluminium improved seizure resistance and that cold working and annealing helped to prevent brittleness. The difference in coefficients between aluminium and steel necessitates work hardening the bearing before use to prevent loosening in service.

Cadmium Alloys

These alloys have greater high temperature lives and a greater resistance to fatigue than whitemetal bearings but are more subject to corrosion which can be overcome by plating with indium. Cadmium has a low affinity for steel and so does not seize easily. Cadmium materials are not widely used because of their high cost.

Cast Iron

Cast iron is an inexpensive bearing material for operation under relatively light loads. Grey cast iron is widely used for machine tool beds due to its damping characteristics. The presence of graphite in the iron improves running properties. The bearing surface is often machined directly into the cast iron structure. Generous lubrication and large clearances are necessary to avoid scoring. A speed of 0.8 m / s and a pressure of no greater than 3.5 MPa are the maximum duty for cast iron bearings. Because of poor conformability it is essential that the bearings have good alignment and freedom from contamination.

Copper Based Alloys

Copper based alloys are considerably harder and strong, have better high temperature characteristics, have greater resistance but poorer anti- scoring properties than the white metals. There are four main classes of these alloys.

Copper Lead Alloys

Copper lead bearings contain 20% to 40% lead. Copper lead alloy bearings have less resistance to seizure than the white metal but more than twice the fatigue resistance even at high loads and temperatures. Hardened journals or lead-tin or lead indium plating of the bearing surface can help to reduce the wear. Copper lead alloy bearings are used in heavy duty bearings that carry moderate loads in high speed applications

Leaded Bronze Alloys

These combine good compatibility characteristics with excellent coating and easy machining properties and have good structural properties and high load capacity. These are inexpensive and are useful as a single material without the need for a separate overlay or steel backing.

Silver

Silver bearings are highly resistant to fatigue but their anti-friction qualities are inferior to the whitemetal bearings. A disadvantage is that they become readily welded to the shaft even if the oil film breaks down for only and instant. They also do not possess the embedding properties of other softer bearing metals. Silver bearings are often overlaid with lead and indium or lead and tin, to provide better resistance to seizure. The corrosion resistance, temperature strength ratio and thermal conductivity are all good. Hard shafts are necessary with silver bearings and bearing loads of above 28.0 MPa may be carried at speed of 10 m/s.

Sintered Materials

Sintered metal bearings are made from powdered bronze plain, leaded bronze, iron or stainless steel which, when subjected to high pressure and temperature, forms a porous material. The finished bearings are self-lubricating as the material contains oil impregnated in the pores. Sintered bearings are used where lubrication supply is difficult, infrequent or inadequate.

Steel

As with cast iron, steel bearings required lots of lubrication and generous clearances. Nickel steel bearings are best operated with intermittent loads rather than continuously and using low journal speeds and temperatures less than 40°C.

Tin bronze

These usually contain small percentages of tin and lead to aid machining and small amounts of zinc and nickel are often added to improve strength. They are restricted to low speed applications but will carry heavy loads.

Whitemetals or Babbit Metals

These are typically:

- tin based (88% Sn-Tin, 4% Cu-Copper, 8% Sb-Antimony),
- lead based (80% Pb-Lead, 14% Sb-Antimony, 6% Sn-Tin).

The materials have properties that include hardness combined with ductility, a structure that holds lubricant, little tendency to cause wear to journals, they embed dirt easily and are easily cast. The two types are generally interchangeable but the tin based ones are usually more expensive , have better wear resistance, stand higher loads and are not as brittle and are more corrosion resisting than the lead based bearings.

Non-metal Bearings

Carbon-Graphite

These materials are self-lubricating, stable at temperatures up to 400°C and resistant to attack by chemicals and solvents. Bearings are moulded or machined from solid. The material is used for applications where lubrication with grease of oil is not practical. In some cases metal alloys may be added to the composition to carbon-graphite alloy to improve the compressive strength. Graphite is too weak for use by itself therefore; tiny graphite flakes are generally bonded with carbon or thermosetting resins.

Cermets

Certain hard carbides such as pressed and sintered titanium carbide or tungsten carbides in a cobalt matrix can be used for high temperature applications for sliding components in nuclear reactors and for other difficult duties. The cermet is very rigid, highly resistant to corrosion and capable of taking a fine finish. Cermets have poor conformability, poor impact resistance, are difficult to machine and are expensive. The outstanding property of cermets is the resistance to wear.

Jewels

Jewel baring are usually made of sapphire or hard borosilicate glass and are used in low torque instruments and control devices where low coefficient of friction, non-magnetic properties and long life are required.

Plastics

The wide use of plastic bearings results from their freedom from corrosion, quiet operation, availability in shapes and their good compatibility. Plastic bearings need little lubrication and water can often be used for lubrication. Plastics are often resistant to most chemicals including acids.

- Phenolics or polyester resins reinforced with cotton fabric, asbestos, and glass fibre are widely used and are very strong - up to 300Mpa in yield strength in compression; they can be water lubricated and are useful where good electrical insulation is needed. The thermal conductivity is low so the heat generated by friction cannot easily be transmitted away through the bearing. As a result heavier loaded bearings must have a feed of cooling or lubricating fluid to remove the heat..
- Nylon bearings are very satisfactory for light loads at high speeds. Nylon has low friction characteristics and can be used with no lubrication. It is quiet in operation, wears at a low rate when lubricated, is easily moulded and is inexpensive..
- PTFE has and exceptionally low coefficient of friction, is self-lubricating and is resistant the most chemicals and operates at temperatures of up to 250 deg.C. However it has poor mechanical properties has low thermal conductivity and has high coefficient of thermal expansion. In its pure form it

is only useful at low speeds and loads. The mechanical properties of PTFE can be improved by filling with glass fibre. PTFE is often made into a composite in porous metals such as bronze or steel which results in a low friction material with good mechanical properties. A widely used bearing design is based on porous bronze filled with a PTFE/lead mixture supported by a steel backing strip. PTFE filled with glass fibre and graphite or other inert materials are very popular in mechanical and civil engineering.

Rubber

Natural rubber, and some synthetic types such as butatiene, acrynitrile, can be used as bearings materials where resilience is needed with water as a lubricant. The bearings usually consist of a fluted lining to a metal shell so that the shaft is carried on a series of rubber strips running the length of the bearing. A flow of water is provided to cool the bearing and to flush through any dirt collecting in the channels between the rubber bearing strips; this type of bearing is used in marine applications and may be loaded up to specific pressures of 0,4 Mpa.

Timber

Timber bearings can be manufactured from special hardwood (lignum vitae has an inherent oiliness which makes it practically self-lubricating) have been used for large low pressure, low speed bearings. The hardwoods absorb oil and grease and so little attention is needed for maintenance; they do not score or seize their shaft but due to uneven expansion and contraction large clearances are required. Timber is seldom used in modern manufacture but would be used in historical renovations.

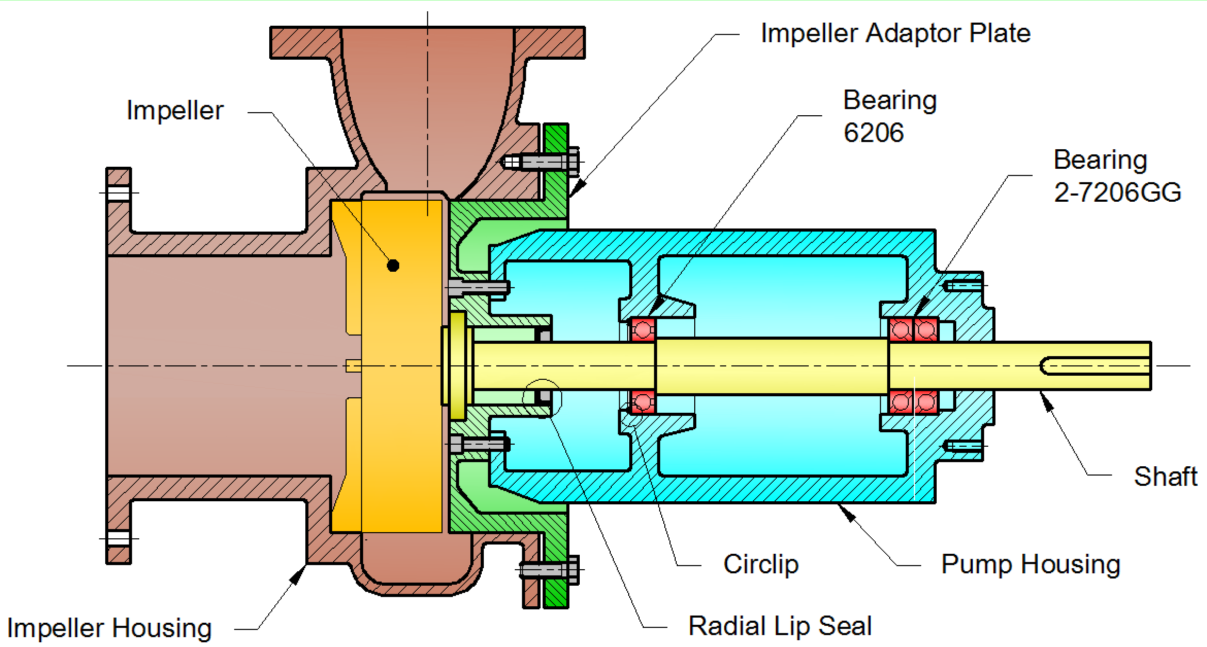
Teflon:

Teflon is part of the plastic family but has an exceptionally low coefficient of friction, high resistance to chemicals, operates through a wide temperature range and is self-lubricating.

Skill Practice Exercises

Skill Practice Exercise: MEM09209-SP-1201

1. Create a new drawing using the template called Chopper Pump and complete the assembly by adding the bearings, circlip, shaft keyway and hatching where required.
2. Produce an assembly drawing of the Chopper Pump including a Parts List and cross-referencing.
3. Produce detail drawings of the Pump Housing and Shaft assigning the appropriate toleranced dimensions assuming a N7-h6 fit between the 6206 Bearing and Bearing Housing and a F8-h7 fit between the 2-7206GG Bearing and the Bearing Housing.
4. All flat mating surfaces are to be milled to a surface finish of 0.8 and circular surfaces reamed or lathe machined to 0.2. Circular surfaces are to be concentric to the datum centreline to 0.08 with a roundness of 0.2 while all flat surfaces are to be perpendicular to 0.025 and flatness to 0.06.
5. Provide an appropriate keyseat in the shaft.
6. Insert an A3 sheet on the drawings and save the file in your work area as MEM09209-SP-1201 prior to plotting.

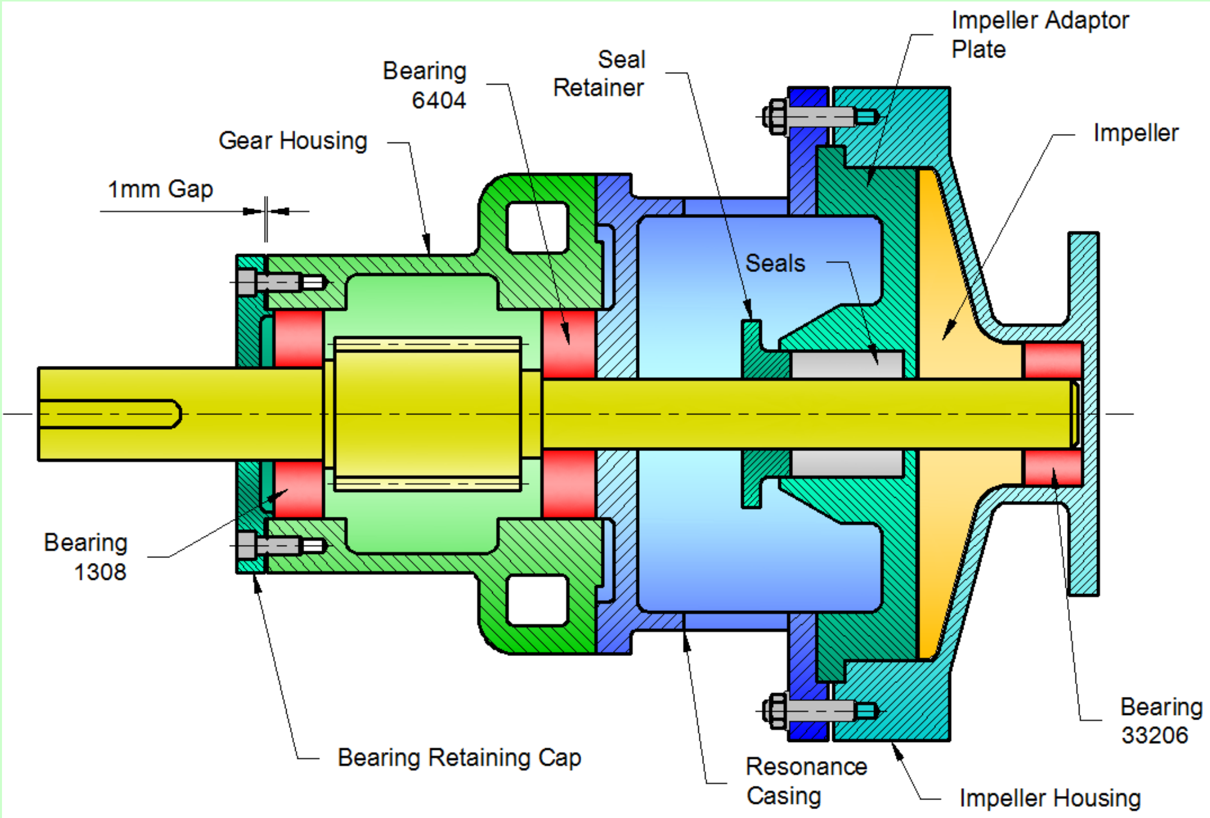


The Pump Housing is circular in shape and fastened using 6 machine screws/bolts equally spaced on the PCD. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: Impeller Housing – Aluminium Alloy; Impeller Adaptor Plate - Aluminium Alloy; Pump Housing - Aluminium Alloy; Impeller – Nylon; Shaft – Stainless Steel; Bearings, Fastenings & Seal – Commercial.

Skill Practice Exercise: MEM09209-SP-1202

1. Create a new drawing using the template called End Suction Pump and complete the assembly by adding the bearings and hatching where required.
2. Add a Bearing Retaining Cap to suit the Shaft, Bearing and Gear Housing.
3. Create detail drawings of the Shaft, Gear Housing and Bearing Retaining Cap assigning the appropriate toleranced dimensions to take the bearings assuming a P7-h6 fit between the Bearing and Housing, a H7-h6 fit between the Shaft and the Bearing Retaining Cap and a H7-h6 fit between the Bearing Retaining Cap and the Bearing Housing.
4. All mating surfaces are to be machined to a surface finish of 0.2. Circular surfaces are to be concentric to the datum centreline to 0.05 with a roundness of 0.1 while all flat surfaces are to be perpendicular to 0.05 and flatness to 0.02.
5. Provide an appropriate keyseat in the shaft.
6. Insert an A3 sheet on both drawings and save the drawing in your work area as MEM09209-SP-1202



The assembly is circular in shape and fastened using 10 studs equally spaced on the PCD. All toleranced dimensions are to be placed on the drawing as Limit of Size.

Material: Gear Housing – Cast Iron; Resonance Casing – Cast Iron; Impellor Housing – Cast Iron; Impeller Adaptor Plate – Mild Steel; Seal Retainer - Mild Steel; Shaft - Mild Steel; Bearing Retaining Cap - Mild Steel; Seals – Felt; Bearings & Fasteners - Commercial.

Topic 13 – Lubrication:

Required Skills:

-

Required Knowledge:

- Purposes for lubricating engineering components.
- Methods of lubricating engineering components.
- Lubrication materials.

Purpose for Lubricating Engineering Components:

The purpose of bearing lubrication is to prevent direct metallic contact between the various rolling and sliding elements. This is accomplished through the formation of a thin oil (or grease) film on the contact surfaces. However, for rolling bearings, lubrication has the following advantages:

- Reduction of friction and wear
- Dissipation of friction heat
- Prolonged bearing life
- Prevention of rust
- Protection against harmful elements

In order to exhibit the effects, a lubrication method that matches service conditions must be selected. In addition to the method to be used, a quality lubricant, the proper amount of lubricant to be used, the bearing and seal must be designed to prevent foreign matter from getting in or lubricant from leaking out.

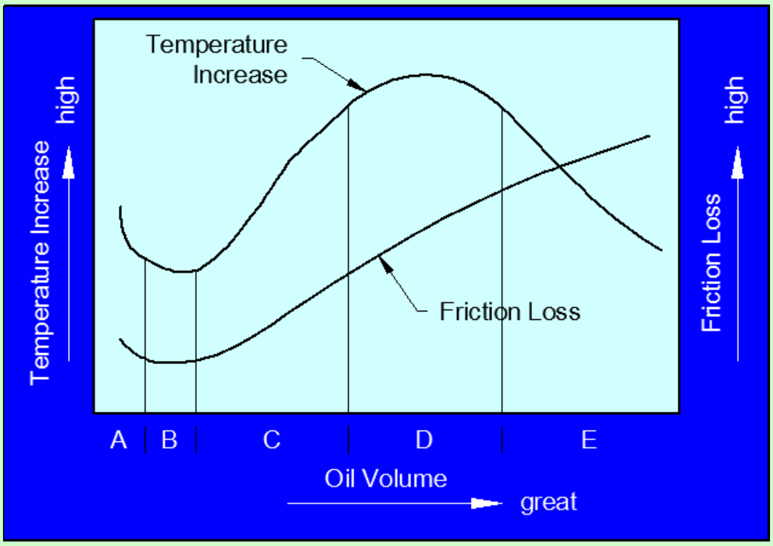


Figure 13.1

Error! Reference source not found. shows the relationship between oil volume, friction loss, and bearing temperature while Figure 13.2 details the characteristics of this relationship.

Range	Characteristics	Lubrication Method
A	When oil volume is extremely low, direct metallic contact occurs in places between the rolling elements and raceway surfaces. Bearing abrasion and seizing occur.	N.A.
B	A thin oil film develops over all surfaces, friction is minimal and bearing temperature is low.	Grease lubrication, oil mist, air-oil lubrication
C	As oil volume increases, heat build-up is balanced by cooling.	Circulating lubrication
D	Regardless of oil volume, temperature increases at a fixed rate.	Circulating lubrication
E	As oil volume increases, cooling predominates and bearing temperature decreases.	Forced circulation lubrication, Oil jet lubrication

Figure 13.2 - Oil Volume, Friction Loss, Bearing Temperature

As friction reduces, lubricants can be considered from two aspects. When a hydrodynamic bearing is started, metal to metal contact occurs. Here, the actual oiliness of the lubricant lowers the coefficient of friction between the two sliding surfaces. In slider bearings operating on full fluid-film lubrication, the lubricant separates the two sliding surfaces completely, and shearing of the lubricant is substituted for sliding friction.

Any system of rolling elements, like ball bearings, should theoretically reduce friction rapidly. If balls and rollers were perfectly smooth and inelastic, friction would be very low. But materials deform and rolling elements slip under load; also, uncaged balls or rollers tend to rub or slide against one another. When a separator or cage is present, the rolling elements slide against it and the cage itself rubs against and gliding flange surfaces. Because of this sliding, lubrication is needed to minimise wear and friction.

Methods of Lubrication:

Lubrication methods, or lubrication technologies, are applied to convey lubricants in certain time intervals and in agreed lubrication quantities in one or several lubrication points. According to the lubrication methods, the lubricant is derived if necessary.

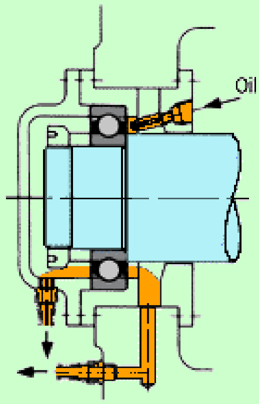
Lubrication methods find their application in the industrial lubrication, but also in many other application fields. Thus lubrication methods have a basic necessity for all kinds of vehicles, small machines, construction machines, agricultural machinery and also for wind turbine technology.

In order to meet the ever growing demands of our highly engineered world, new lubrication methods are constantly developed or the existing lubrication procedures are further developed. Beside the different lubrication methods, play course the different lubricants (lubrication media) a big role.

The constantly growing claims of industry are constantly researching innovative solutions to different lubrication procedures and lubrication technologies.

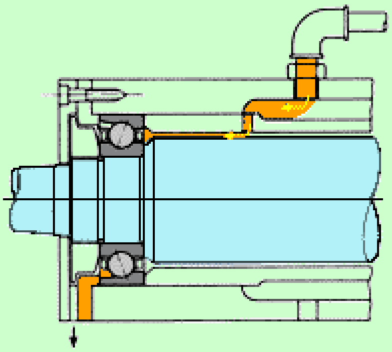
Jet:

Jet lubrication is often used for ultra-high-speed bearings such as the bearings in jet engines. Lubricating oil is sprayed under pressure from one or more nozzles directly into the bearing. The figure shows an example of ordinary jet lubrication. The lubricating oil is sprayed on the inner ring and cage guide face. With high-speed operation, the air surrounding the bearing rotates with it causing the oil to be deflected. The jetting speed of the oil from the nozzle should be more than 20% of the circumferential speed of the inner ring outer surface. More uniform cooling and better temperature distribution are achieved using more nozzles for a given amount of oil. It is desirable for the oil to be forcibly discharged so the agitating resistance of the lubricant can be reduced and the oil can effectively carry away heat.



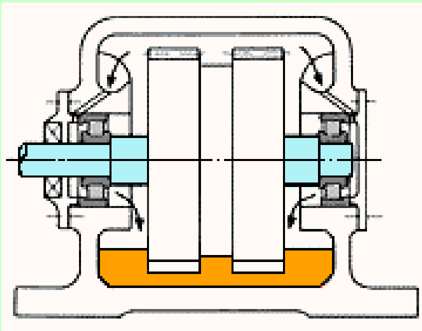
Mist:

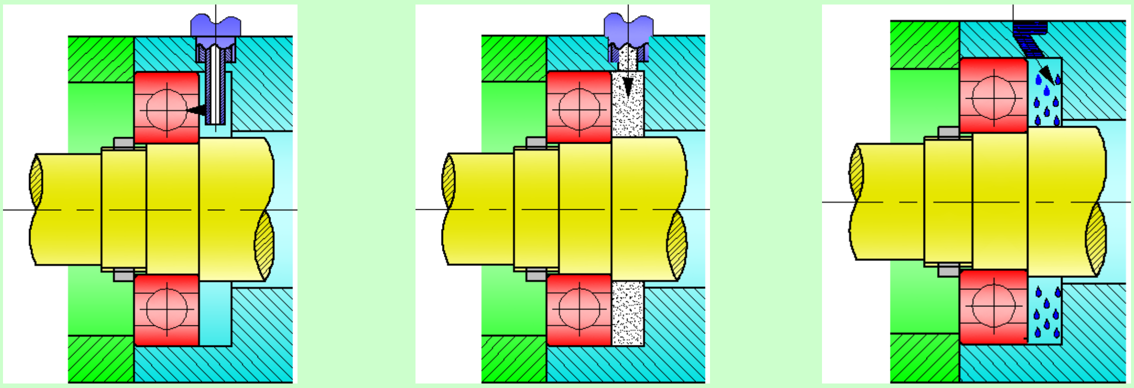
Oil mist systems can also be referred to as "oil fog lubrication" and are an effective system for lubricating and cooling elements that require a limited quantity of fluid in devices by generating a mist of oil that separates the oil particles and distributes them through the components. Due to the small amount of oil flow, contamination in the vicinity of the bearing is low because oil leakage is reduced. The systems are supplied with reservoirs and used with either air supplied from the work place or by self-contained air compressors.



Splash:

Oil can be stored in a sump underneath moving components; as the components start to rotate, they hit the oil causing the oil to splash over all parts, both stationary and moving, and provide lubrication. The splash method has the advantage of the bearings not being immersed in the oil.





Jet Mist Splash

Figure 13.3

Grease Nipple:
Grease nipples are small fittings inserted into holes by screwing or pressing. Grease is forced through the opening in the nipple that has a spring-loaded ball and stops the grease from squirting back out through the opening. The grease is held inside the component and is slowly released by vibration or wear into the working components. Seals are used to assist in retaining grease. Several types of standard grease nipples are available; straight grease nipples, 45° grease nipples and 90° grease nipples.

Straight Grease Nipple

45° Grease Nipple

90° Grease Nipples

Sight Feed Drop Oiler:
Oil is stored in a glass reservoir that allows the operator to observe when the oil is low and needs refilling. A lever in the top of the drop oiler allows the operator to manually lubricate the components.

Screw Down Greaser:
Grease is stored in the reservoir and is forced into the operating components by the operator screwing down the lid of the reservoir.


Sight Feed Drop Oiler


Screw Down Greaser

Wet Lubrication Materials:

Grease:
Grease is a semisolid, combining a fluid lubricant with a thickening agent, usually soap. Soap molecules are attracted to metal surfaces; the long hydrocarbon chain molecule sticks separate the rubbing metal surfaces.

The advantages of grease are:

a) The grease does not flow as readily as oil, so it can be more easily retained in a housing. Since grease is easily contained, leakproof designs are unnecessary.
b) Less maintenance is required. There is no oil level to maintain and regreasing is infrequent.
c) Grease has better sealing capabilities than oil; this asset can assist in keeping dirt and moisture out of the housing.

Oil:
Oils are slippery viscous liquids used to produce a lubricating film between moving machine parts and are manufactured in two forms:

a) Natural – made from crude oil and is chiefly composed of carbon and hydrogen.
b) Synthetic – manufactured oils.

The advantages of oil are:

a) Oil is easier to drain and refill which is important when lubricating intervals are close together. Oil is also easier to control the fill volume in the housing or reservoir.
b) An oil lubricant for a bearing might also be useable at many other points in the machine, even eliminating the need for a second grease type lubricant.
c) Oil is more effective in carrying heat away from bearing and housing surfaces. In addition, oils are available for a greater range of operating speeds and temperatures than greases.
d) Oil readily feeds into all areas of contact and can carry foreign matter, water and the products of wear back to a main reservoir where it is removed from the system by filters.

Other Lubricants:
Animal Fat, Vegetable Oils, Plastics, Air and Gas.

Dry Lubricating Materials:

A bonded dry film lubricant is defined as a dry lubricant dispersed in a continuous matrix of a binder and/or attached to a surface by an adhesive material (or bond).

Bonded dry film lubricants start out as high performance, paint-like coatings consisting of fine particles of lubricating pigments blended with a binder and special additives. After application and proper curing, these lubricants bond to the surface of the ware, and form a solid film, which reduces friction, and greatly increases wear life. Many dry film lubricants also contain special rust inhibitors which offer exceptional corrosion protection in harsh environments.

Dry film lubricants contain special pigments that reduce friction and wear by preventing surface-to-surface contact between mating parts (i.e., a shaft and its bearings). Performance properties vary depending on the specific lubricating pigment used. Some offer excellent lubrication and corrosion protection, while others operate at high temperatures. Some are formulated for use in extreme environments and can withstand nuclear radiation.

PTFE:
Suitable only in very light applications. Mechanically weak material which has a tendency to flow and is seriously affected by high temperatures.

Copper Based alloys
Most common alloys are copper tin, copper lead, phosphor bronze: harder and stronger than whitemetal: can be used un-backed as a solid bearing.

Aluminium Based Alloys:
Running properties not as good as copper based alloys but cheaper.

Sintered Bronze:
Sintered bronze is a porous material which can be impregnated with oil, graphite or PTFE. Not suitable for heavily loaded applications but useful where lubrication is inconvenient.

Dry bearings of the impregnated sintered bronze type are available in stock sizes and these should be used if possible.

Nylon:
Similar to PTFE but slightly harder: used only in very light applications.

Whitemetal:
Usually used as a lining bonded to bronze, steel or cast iron.

Review Questions MEM09209-RQ-07:

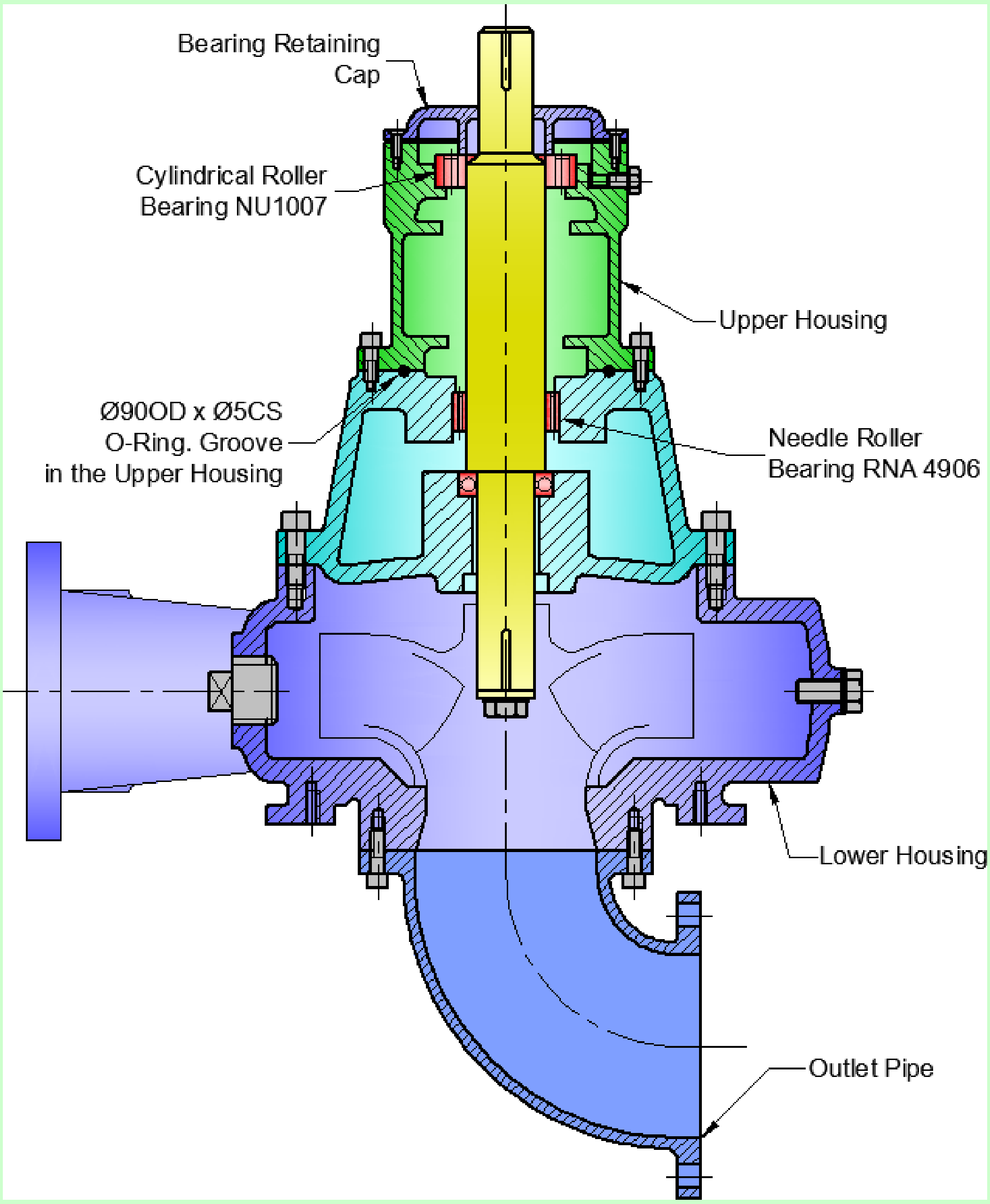
1. List two purposes for lubricating engineering components.
2. List four methods of lubricating engineering components.
3. List four lubrication materials.
4. Provide two advantages of using grease as a lubricant.
5. Provide 2 advantages of using oil as a lubricant.

Skill Practice Exercises

Skill Practice Exercise: MEM09209-SP-1301

- Create a new drawing using the template called Solids Handling Pump and complete the assembly by adding bearings, seal, normal fitting keys and hatching where required.
- Add a Bearing Retaining Cap to suit the Shaft, Bearing and Upper Housing.
- Produce detail drawings of the Upper Housing, Shaft and Bearing Retaining Cap assigning the appropriate toleranced dimensions to take the bearings assuming a S7-h6 fit between the Bearing and Upper Housing, and a C11-h11 fit between the Shaft and the Bearing Retaining Cap.
- All flat surfaces are to be machined to a surface finish of 0.8, holes reamed to 0.4 and circular surfaces ground to 0.2.
- Circular surfaces are to be concentric to the datum centreline to 0.05 with a roundness of 0.1 while all flat surfaces are to be perpendicular to 0.05 and flatness to 0.02.
- Provide an appropriate keyseat in the shaft.
- Insert an A3 sheet on both drawings and save the drawing in your work area as MEM09209-SP-1301 before plotting.
- The assembly is predominantly circular in shape with the components fastened using 6 machine screws/bolts equally spaced on the PCD. All toleranced dimensions are to be placed on the drawing as Limit of Size.

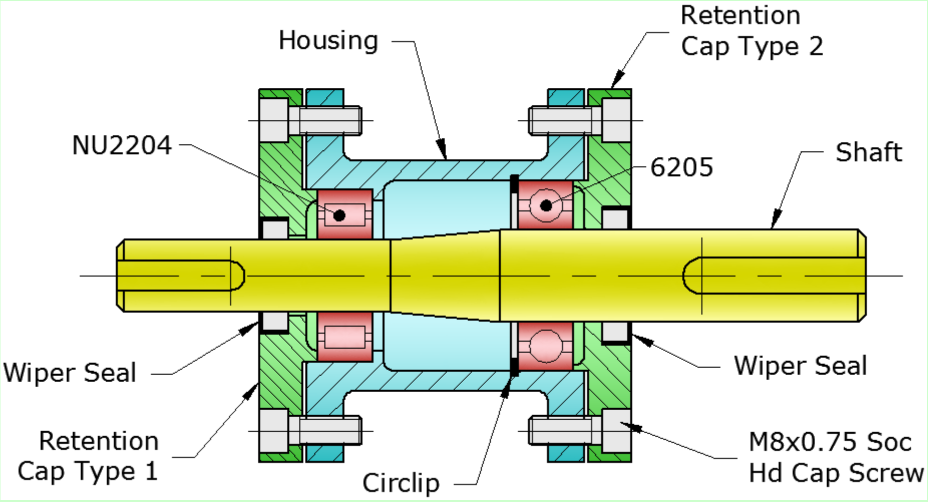
Materials: Upper Housing – Mild Steel; Bearing Casing - Mild Steel; Lower Housing - Mild Steel; Outlet Pipe - Mild Steel; Bearing Retaining Cap - Mild Steel; O-Ring – Rubber; Bearings and Fasteners – Commercial.


Bearing Retaining Cap
Cylindrical Roller Bearing NU1007
Upper Housing
Ø90OD x Ø5CS O-Ring. Groove in the Upper Housing
Needle Roller Bearing RNA 4906
Lower Housing
Outlet Pipe

Practice Competency Test

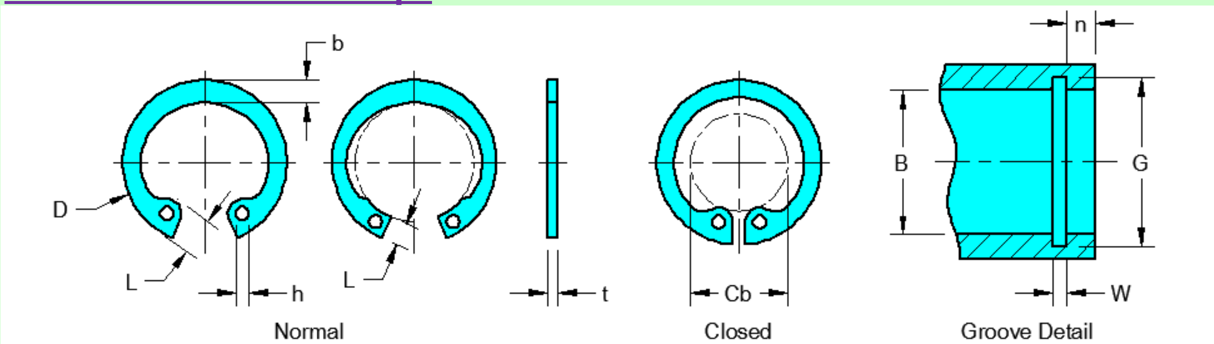
MEM09209-PT-01

1. Create a new drawing using the template called Shaft Support and complete the assembly by adding the Bearings, Seals, Circlips and fastenings where required.
2. Produce an assembly drawing of the Support Shaft Assembly complete with cross-references, overall dimensions and Parts List.
3. Produce detail drawings of the Housing, Retention Caps and Shaft assigning the appropriate toleranced dimensions to take the bearings assuming a P7-h6 fit between the Bearing and Housing and a H7-k6 fit between the Bearing and Shaft.
4. Indicate the length of the Housing to a tolerance of $^{+0.086}_{-0}$
5. For all mating surfaces, select an appropriate machining process to provide a finish of 0.2, a roundness of 0.05 and concentric to the centreline datum to within 0.05.
6. All mating vertical surfaces are to be milled to 0.8, have a flatness of 0.2 and be perpendicular to the datum to within 0.05.
7. Provide a free fitting key at the ends of the Shaft.
8. All toleranced dimensions are to be placed on the drawing as Limit of Size.
9. Insert an A3 sheet on the drawings and save the drawing in your work area as MEM09209-PT-01.



Tables

Table 1 – Internal Circlips

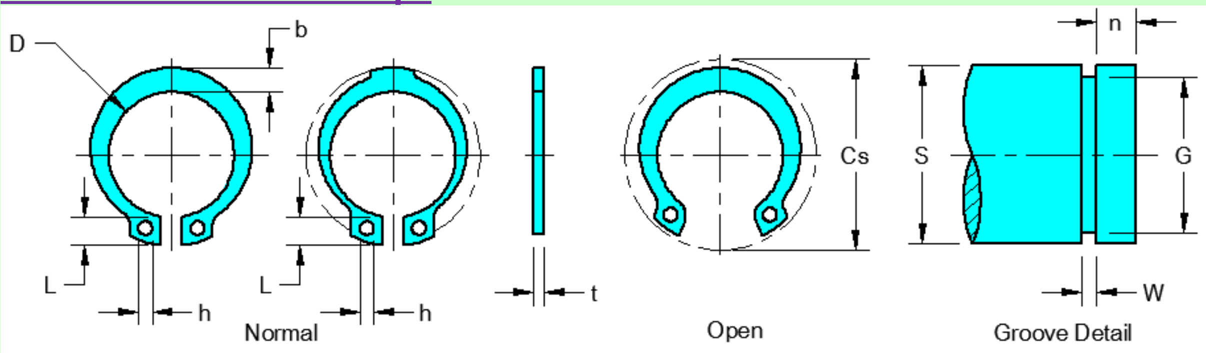


Most sizes over 170mm are without lugs									Measurements are in mm				Code No.
Bore	Circlip Dimensions								Groove Dimensions				
B	t	Tol	d	Tol	Cb	b	L	h	G	Tol	W	n	
8	0.80	+0.00 -0.05	8.7	+0.36 -0.10	3.0	1.1	2.4	1.0	8.4	+0.90 -0.00	0.9	0.6	INT0080
9	0.80		9.8		3.7	1.3	2.5	1.0	9.4		0.9	0.6	INT0090
10	1.00	+0.00 -0.06	10.8		3.3	1.4	3.2	1.2	10.4	+0.11 -0.00	1.0	0.6	INT0100
11	1.00		11.8		4.1	1.5	3.3	1.2	11.4		1.1	0.6	INT0110
12	1.00		13.0		4.9	1.7	3.4	1.5	12.5		1.1	0.8	INT0120
13	1.00		14.1		5.4	1.8	3.6	1.5	13.6		1.1	0.9	INT0130
14	1.00		15.1		6.2	1.9	3.7	1.7	14.6		1.1	0.9	INT0140
15	1.00		16.2		7.2	2.0	3.7	1.7	15.7		1.1	1.2	INT0150
16	1.00		17.3		8.0	2.0	3.8	1.7	16.8		1.1	1.2	INT0160
17	1.00		18.3	+0.42 -0.13	8.8	2.1	3.9	1.7	17.8		1.1	1.5	INT0170
18	1.00		19.5		9.4	2.2	4.1	2.0	19.0	+0.13 -0.00	1.1	1.5	INT0180
19	1.00		20.5		10.4	2.3	4.1	2.0	20.0		1.1	1.5	INT0190
20	1.00		21.5		11.2	2.4	4.2	2.0	21.0		1.1	1.5	INT0200
21	1.00		22.5		12.2	2.5	4.2	2.0	22.0		1.1	1.5	INT0210
22	1.00		26.5		13.2	2.6	4.2	2.0	23.0		1.3	1.5	INT0220
23	1.20		24.6	+0.42 -0.21	14.2	2.5	4.2	2.0	24.1		1.3	1.5	INT0230
24	1.20		25.9		14.8	2.6	4.4	2.0	25.2	-0.21 -0.00	1.3	1.8	INT0240
25	1.20		26.9		15.5	2.7	4.5	2.0	26.2		1.3	1.8	INT0250
26	1.20		27.9		16.1	2.8	4.7	2.0	27.2		1.3	1.8	INT0260
27	1.20		29.1		17.1	2.9	4.7	2.0	28.4		1.3	2.1	INT0270
28	1.20		30.1	+0.50 -0.25	17.9	2.9	4.8	2.0	29.4		1.3	2.1	INT0280
29	1.20		31.1		18.4	3.0	4.8	2.0	30.4	+0.25 -0.00	1.3	2.1	INT0290
30	1.20		32.1		19.9	3.0	4.8	2.0	31.4		1.3	2.1	INT0300
31	1.20		33.4		20.0	3.2	5.2	2.5	32.7		1.3	2.6	INT0310
32	1.20		33.4		20.6	3.2	5.4	2.5	33.7		1.3	2.6	INT0320
33	1.20		35.5		21.6	3.3	5.4	2.5	34.7		1.3	2.6	INT0330
34	1.50		36.5		22.6	3.3	5.4	2.5	35.7		1.6	2.6	INT0340
35	1.50		37.8		23.6	3.4	5.4	2.5	37.0		1.6	3.0	INT0350
36	1.50		38.8		24.6	3.5	5.4	2.5	38.0		1.6	3.0	INT0360

Most sizes over 170mm are without lugs									Measurements are in mm				Code No.
Bore	Circlip Dimensions								Groove Dimensions				
B	t	Tol	d	Tol	Cb	b	L	h	G	Tol	W	n	
37	1.50	+0.00 -0.06	39.8	+0.50 -0.25	25.4	3.6	5.5	2.5	39.0	+0.25 -0.00	1.6	3.0	INT0370
38	1.50		40.8		26.4	3.7	5.5	2.5	40.0		1.6	3.0	INT0380
39	1.50		42.0	+0.90 -0.39	27.2	3.8	5.6	2.5	41.0		1.6	3.0	INT0390
40	1.75		43.5		27.8	3.9	5.8	2.5	42.5		1.8	3.0	INT0400
41	1.75		44.5		28.6	4.0	5.9	2.5	43.5		1.8	3.8	INT0410
42	1.75		45.5		29.6	4.1	5.9	2.5	44.5		1.8	3.8	INT0420
43	1.75		46.5		30.6	4.2	5.9	2.5	45.5		1.8	3.8	INT0430
44	1.75		47.5		31.4	4.2	6.0	2.5	46.5		1.8	3.8	INT0440
45	1.75		48.5		32.0	4.3	6.2	2.5	47.5		1.8	3.8	INT0450
46	1.75		49.5		32.7	4.4	6.3	2.5	48.5		1.8	3.8	INT0460
47	1.75		50.5	+1.10 -0.46	33.5	4.4	6.4	2.5	49.5		1.8	3.8	INT0470
48	1.75		51.5		34.5	4.5	6.4	2.5	50.5	+0.30 -0.00	1.8	3.8	INT0480
50	2.00	+0.00 -0.07	54.2		36.3	4.6	6.5	2.5	53.0		2.15	4.5	INT0500
51	2.00		55.2		37.3	4.7	6.5	2.5	54.0		2.15	4.5	INT0510
52	2.00		56.2		37.9	4.7	6.7	2.5	55.0		2.15	4.5	INT0520
53	2.00		57.2		38.9	4.9	6.7	2.5	56.0		2.15	4.5	INT0530
54	2.00		58.2		39.9	5.0	6.7	2.5	57.0		2.15	4.5	INT0540
55	2.00	+0.00 -0.07	59.2	+1.10 -0.46	40.7	5.0	6.8	2.5	58.0		2.15	4.5	INT0550
56	2.00		60.2		41.7	5.1	6.8	2.5	59.0		2.15	4.5	INT0560
57	2.00		61.2		42.7	5.1	6.8	2.5	60.0		2.15	4.5	INT0570
58	2.00		62.2		43.5	5.2	6.9	2.5	61.0		2.15	4.5	INT0580
60	2.00		64.2		44.7	5.4	7.3	2.5	63.0		2.15	4.5	INT0600
62	2.00		66.2		46.7	5.5	7.3	2.5	65.0		2.15	4.5	INT0620
63	2.00		67.2		47.7	5.6	7.3	2.5	66.0		2.15	4.5	INT0630
64	2.00		68.2		48.2	5.7	7.5	2.5	67.0		2.15	4.5	INT0640
65	2.50		69.2		49.0	5.8	7.6	3.0	68.0		2.65	4.5	INT0650
67	2.50		71.5		50.8	6.0	7.7	3.0	70.0		2.65	4.5	INT0670
68	2.50		72.5		51.6	6.1	7.8	3.0	71.0		2.65	4.5	INT0680
70	2.50		74.5		53.6	6.2	7.8	3.0	73.0		2.65	4.5	INT0700
72	2.50		76.5		55.6	6.4	7.8	3.0	75.0		2.65	4.5	INT0720
75	2.50		79.5		58.6	6.6	7.8	3.0	78.0		2.65	4.5	INT0750
77	2.50		81.5		60.4	6.7	7.9	3.0	80.0		2.65	4.5	INT0770
78	2.50		82.5	+1.30 -0.54	60.1	6.8	8.5	3.0	81.0	+0.35 -0.00	2.65	5.3	INT0780
80	2.50		85.5		62.1	7.0	8.5	3.0	83.5		2.65	5.3	INT0800
82	2.50		87.5		64.1	7.0	8.5	3.0	85.5		2.65	5.3	INT0820
85	3.00	+0.00 -0.08	90.5		66.9	7.2	8.6	3.5	88.5		2.65	5.3	INT0850
87	3.00		92.5		68.9	7.3	8.6	3.5	90.5		3.15	5.3	INT0870
88	3.00		93.5		69.9	7.4	8.6	3.5	91.5		3.15	5.3	INT0880
90	3.00		95.5		71.9	7.6	8.6	3.5	93.5		3.15	5.3	INT0900
92	3.00		97.5		73.7	7.8	8.7	3.5	95.5		3.15	5.3	INT0920

Most sizes over 170mm are without lugs									Measurements are in mm				Code No.
Bore	Circlip Dimensions								Groove Dimensions				
B	t	Tol	d	Tol	Cb	b	L	h	G	Tol	W	n	
95	3.00	+0.00 -0.08	100.5	+1.30 -0.54	76.5	8.1	8.8	3.5	98.5	+0.35 -0.00	3.15	5.3	INT0950
97	3.00		102.5		78.5	8.2	8.8	3.5	100.5		3.15	5.3	INT0970
98	3.00		103.5		79.0	8.3	9.0	3.5	101.5		3.15	5.3	INT0980
100	3.00		105.5		80.6	8.4	9.2	3.5	103.5		3.15	5.3	INT1000
102	4.00	+0.00 -0.10	108.0		82.0	8.5	9.5	3.5	106.0	+0.54 -0.00	4.15	6.0	INT1020
105	4.00		112.0		85.0	8.7	9.5	3.5	109.0		4.15	6.0	INT1050
108	4.00		115.0		88.0	8.9	9.5	3.5	112.0		4.15	6.0	INT1080
110	4.00		117.0		88.2	9.0	10.4	3.5	114.0		4.15	6.0	INT1100
112	4.00		119.0		90.0	9.1	10.5	3.5	116.0		4.15	6.0	INT1120
115	4.00		122.0	+1.50 -0.63	93.0	9.3	10.5	3.5	119.0		4.15	6.0	INT1150
120	4.00		127.0		96.9	9.7	11.0	3.5	124.0	+0.63 -0.00	4.15	6.0	INT1200
125	4.00		132.0		101.9	10.0	11.0	4.00	129.0		4.15	6.0	INT1250
130	4.00		137.0		106.9	10.2	11.0	4.00	134.0		4.15	6.0	INT1300
135	4.00		142.0		111.5	10.5	11.2	4.00	139.0		4.15	6.0	INT1350
140	4.00		147.0		116.5	10.7	11.2	4.00	144.0		4.15	6.0	INT1400
145	4.00		152.0		121.0	10.9	11.4	4.00	149.0		4.15	6.0	INT1450
150	4.00		158.0		124.8	11.2	12.0	4.00	155.0		4.15	7.5	INT1500
155	4.00		164.0		129.8	11.4	12.0	4.00	160.0		4.15	7.5	INT1550
160	4.00		169.0		132.7	11.6	13.0	4.00	165.0		4.15	7.5	INT1600
165	4.00		174.5		137.7	11.8	13.0	4.00	170.0		4.15	7.5	INT1650
170	4.00		179.5		141.6	12.2	13.5	4.00	175.0		4.15	7.5	INT1700
175	4.00		184.5	+1.70 -0.72	146.6	12.7	13.5	4.00	180.0		4.15	7.5	INT1750
180	4.00		189.5		150.2	13.2	14.2	4.00	185.0	+0.72 -0.00	4.15	7.5	INT1800
185	4.00		194.5		155.2	13.7	14.2	4.00	190.5		4.15	7.5	INT1850
190	4.00		199.5		160.2	13.8	14.2	4.00	195.0		4.15	7.5	INT1900
195	4.00		204.5		165.2	13.8	14.2	4.00	200.0		4.15	7.5	INT1950
200	4.00		209.5		170.2	14.0	14.2	4.00	205.0		4.15	7.5	INT2000

Table 2 – External Circlips

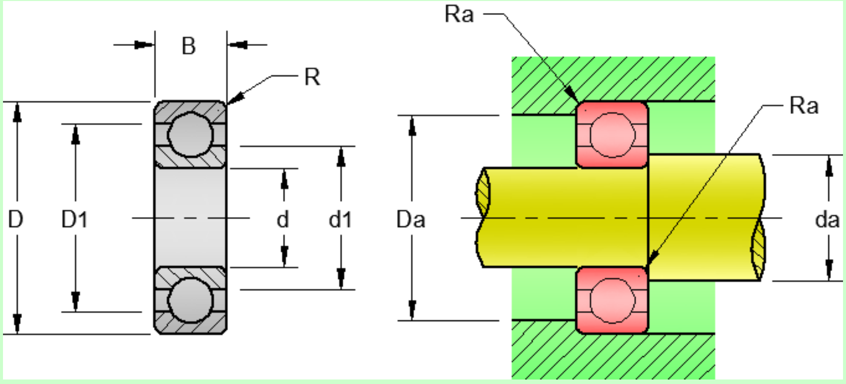


Most sizes over 170mm are without lugs									Measurements are in mm				Code No.
Shaft	Circlip Dimensions								Groove Dimensions				
	t	Tol	d	Tol	Cs	b	L	h	G	Tol	W	n	
3	0.40	+0.00 -0.05	2.7	+0.04 -0.15	7.0	0.8	1.9	1.0	2.8	+0.00 -0.04	0.5	0.3	EXT0030
4	0.40		3.7		8.6	0.9	2.2	1.0	3.8	+0.00 - 0.048	0.5	0.3	EXT0040
5	0.60		4.7		10.3	1.1	2.5	1.0	4.8		0.7	0.3	EXT0050
6	0.70		5.6		11.7	1.3	2.7	1.2	5.7		0.8	0.5	EXT0060
7	0.80		6.5	+0.06 -0.18	13.5	1.4	3.1	1.2	6.7	+0.00 -0.06	0.9	0.5	EXT0070
8	0.80		7.4		14.7	1.5	3.2	1.2	7.6		1.1	0.6	EXT0080
9	0.80	+0.00 -0.06	8.4		16.0	1.7	3.3	1.2	8.6		1.1	0.6	EXT0090
10	1.00		9.3	+0.10 -0.36	17.0	1.8	3.3	1.5	9.6		1.1	0.6	EXT0100
11	1.00		10.2		18.0	1.8	3.3	1.5	10.5	+0.00 -0.11	1.1	0.8	EXT0110
12	1.00		11.0		19.0	1.8	3.3	1.7	11.5		1.1	0.8	EXT0120
13	1.00		11.9		20.2	2.0	3.4	1.7	12.4		1.1	0.9	EXT0130
14	1.00		12.9		21.4	2.1	3.5	1.7	13.4		1.1	0.9	EXT0140
15	1.00		13.8		22.6	2.2	3.6	1.7	14.3		1.1	1.1	EXT0150
16	1.00		14.7		23.8	2.2	3.7	1.7	15.2		1.1	1.2	EXT0160
17	1.00		15.7		25.0	2.3	3.8	1.7	16.2		1.1	1.2	EXT0170
18	1.00		16.5		26.2	2.4	3.9	2.0	17.0		1.3	1.5	EXT0180
19	1.00		17.5		27.2	2.5	3.9	2.0	18.0		1.3	1.5	EXT0190
20	1.00		18.5	+0.13 -0.42	28.4	2.6	4.0	2.0	19.0	+0.00 -0.21	1.3	1.5	EXT0200
21	1.00		19.5		29.6	2.7	4.0	2.0	20.0		1.3	1.5	EXT0210
22	1.00		20.5		30.8	2.8	4.2	2.0	21.0		1.3	1.5	EXT0220
23	1.20		21.5		32.0	2.9	4.3	2.0	22.0		1.3	1.5	EXT0230
24	1.20		22.2	+0.21 -0.42	33.2	3.0	4.4	2.0	22.9		1.3	1.7	EXT0240
25	1.20		23.2		34.2	3.0	4.4	2.0	23.9		1.3	1.7	EXT0250
26	1.20		24.2		35.5	3.1	4.5	2.0	24.9		1.3	1.7	EXT0260
27	1.20		24.9		36.7	3.1	4.6	2.0	25.6		1.3	2.1	EXT0270
28	1.20		25.9		37.9	3.2	4.7	2.0	26.6		1.6	2.1	EXT0280

Shaft	Most sizes over 170mm are without lugs								Measurements are in mm				Code No.
	Circlip Dimensions								Groove Dimensions				
	t	Tol	d	Tol	Cs	b	L	h	G	Tol	W	n	
29	1.20	+0.00 -0.06	26.9	+0.21 -0.42	39.1	3.4	4.8	2.0	27.6	+0.00 -0.21	1.6	2.1	EXT0290
30	1.20		27.9		40.5	3.5	5.0	2.0	28.6		1.6	2.1	EXT0300
31	1.20		28.6		41.5	3.5	5.0	2.5	29.3		1.6	2.6	EXT0310
32	1.20		29.6	+0.25 -0.50	43.0	3.6	5.2	2.5	30.3	+0.00 -0.25	1.6	2.6	EXT0320
33	1.20		30.5		44.0	3.7	5.2	2.5	31.3		1.6	2.6	EXT0330
34	1.50		31.5		45.5	3.8	5.4	2.5	32.3		1.6	2.6	EXT0340
35	1.50		32.2		46.8	3.9	5.6	2.5	33.0		1.6	3.0	EXT0350
36	1.50		33.2		47.8	4.0	5.6	2.5	34.0		1.85	3.0	EXT0360
37	1.50		34.2		49.0	4.1	5.7	2.5	35.0		1.85	3.0	EX370T0
38	1.50		35.2		50.2	4.2	5.8	2.5	36.0		1.85	3.0	EXT0380
39	1.50		36.0		51.4	4.3	5.9	2.5	37.0		1.85	3.8	EXT0390
40	1.75		36.5		52.6	4.4	6.0	2.5	37.5		1.85	3.8	EXT0400
41	1.75		37.5		54.1	4.5	6.2	2.5	38.5		1.85	3.8	EXT0410
42	1.75		38.5	+0.39 -0.90	55.7	4.5	6.5	2.5	39.5		1.85	3.8	EXT0420
43	1.75		39.5		56.7	4.6	6.6	2.5	40.5		1.85	3.8	EXT0430
44	1.75		40.5		57.9	4.6	6.7	2.5	41.5		1.85	3.8	EXT0440
45	1.75		41.5		59.1	4.7	6.7	2.5	42.5		1.85	3.8	EXT0450
46	1.75		42.5		60.1	4.8	6.8	2.5	43.5		1.85	3.8	EXT0460
47	1.75		43.5		61.3	4.9	6.9	2.5	44.5		1.85	3.8	EXT0470
48	1.75		44.5		62.5	5.0	6.9	2.5	45.5		1.85	3.8	EXT0480
50	2.00	+0.00 -0.07	45.8		64.5	5.1	6.9	2.5	47.0		2.15	4.5	EXT0500
51	2.00		46.8		65.7	5.2	7.0	2.5	48.0		2.15	4.5	EXT0510
52	2.00		47.8		66.7	5.2	7.0	2.5	49.0		2.15	4.5	EXT0520
53	2.00		48.8		68.0	5.3	7.1	2.5	50.0		2.15	4.5	EXT0530
54	2.00		49.8	+0.46 -1.10	69.0	5.3	7.1	2.5	51.0	+0.00 -0.30	2.15	4.5	EXT0540
55	2.00		50.8		70.2	5.4	7.2	2.5	52.0		2.15	4.5	EXT0550
56	2.00		51.8		71.6	5.5	7.3	2.5	53.0		2.15	4.5	EXT0560
57	2.00		52.8		72.4	5.5	7.3	2.5	54.0		2.15	4.5	EXT0570
58	2.00		53.8		73.6	5.6	7.3	2.5	55.0		2.15	4.5	EXT0580
60	2.00	+0.00 -0.07	55.8	+0.46 -1.10	75.6	5.8	7.4	2.5	57.0	+0.00 -0.30	2.15	4.5	EXT0600
62	2.00		57.8		77.8	6.0	7.5	2.5	59.0		2.15	4.5	EXT0620
63	2.00		58.8		79.0	6.2	7.6	2.5	60.0		2.15	4.5	EXT0630
65	2.50		62.5		81.4	6.3	7.8	3.0	62.0		2.65	4.5	EXT0650
67	2.50		63.5		83.6	6.4	7.9	3.0	64.0		2.65	4.5	EXT0670
68	2.50		63.5		84.4	6.5	8.0	3.0	65.0		2.65	4.5	EXT0680
70	2.00		65.5		87.0	6.6	8.1	3.0	67.0		2.65	4.5	EXT0700
72	2.00		67.5		89.2	6.8	8.2	3.0	69.0		2.65	4.5	EXT0720
75	2.00		70.5		92.7	7.0	8.4	3.0	72.0		2.65	4.5	EXT0750
77	2.00		72.5		94.9	7.2	8.5	3.0	74.0		2.65	4.5	EXT0770
78	2.50		73.5		96.1	7.3	8.6	3.0	75.0		2.65	4.5	EXT0780

Most sizes over 170mm are without lugs									Measurements are in mm				Code No.
Shaft	Circlip Dimensions								Groove Dimensions				
	t	Tol	d	Tol	Cs	b	L	h	G	Tol	W	n	
80	2.50	+0.00 -0.07	74.5	+0.46 -1.10	98.1	7.4	8.6	3.0	76.5	+0.00 -0.30	2.65	5.3	EXT0800
82	3.00		76.5		100.3	7.6	8.7	3.0	78.5		2.65	5.3	EXT0820
85	3.00	+0.00 -0.08	79.5		100.3	7.8	8.7	3.5	81.5	+0.00 -0.35	3.15	5.3	EXT0850
87	3.00		81.5	+0.54 -1.30	105.5	7.9	8.8	3.5	83.5		3.15	5.3	EXT0870
88	3.00		82.5		106.5	8.0	8.8	3.5	84.5		3.15	5.3	EXT0880
90	3.00		84.5		108.5	8.2	8.8	3.5	86.5		3.15	5.3	EXT0900
92	3.00		86.5		111.0	8.4	9.0	3.5	88.5		3.15	5.3	EXT0920
95	3.00		89.5		114.8	8.6	9.4	3.5	91.5		3.15	5.3	EXT0950
97	3.00		91.5		116.8	8.8	9.4	3.5	93.5		3.15	5.3	EXT0970
98	3.00		92.5		118.0	9.0	9.5	3.5	94.5		3.15	5.3	EXT0980
100	3.00		94.5		120.2	9.0	9.6	3.5	96.5		3.15	5.3	EXT1000
102	4.00	+0.00 -0.10	95.0		122.4	9.2	9.7	3.5	98.0	+0.00 -0.54	4.15	6.0	EXT1020
105	4.00		98.0		125.8	9.3	9.9	3.5	101.0		4.15	6.0	EXT1050
108	4.00		101.0		129.0	9.5	10.0	3.5	104.0		4.15	6.0	EXT1080
110	4.00		103.0		131.2	9.6	10.1	3.5	106.0		4.15	6.0	EXT1100
112	4.00		105.0		133.7	9.7	10.3	3.5	108.0		4.15	6.0	EXT1120
115	4.00		108.0		133.7	9.8	10.6	3.5	111.0		4.15	6.0	EXT1150
120	4.00		113.0		143.1	10.2	11.0	3.5	116.0		4.15	6.0	EXT1200
125	4.00		118.0		149.0	10.4	11.4	4.0	121.0	+0.00 -0.63	4.15	6.0	EXT1250
130	4.00		123.0	+0.63 -1.50	154.4	10.7	11.6	4.0	126.0		4.15	6.0	EXT1300
135	4.00		128.0		159.8	11.0	11.8	4.0	131.0		4.15	6.0	EXT1350
140	4.00		133.0		165.2	11.2	12.0	4.0	136.0		4.15	6.0	EXT1400
145	4.00		138.0		170.6	11.5	12.2	4.0	141.0		4.15	6.0	EXT1450
150	4.00		142.0		177.3	11.8	13.0	4.0	145.0		4.15	6.0	EXT1500
155	4.00		146.0		182.3	12.0	13.0	4.0	150.0		4.15	7.5	EXT1550
160	4.00		151.0		188.0	12.2	13.3	4.0	155.0		4.15	7.5	EXT1600
165	4.00		155.5		193.4	12.5	13.5	4.0	160.0		4.15	7.5	EXT1650
170	4.00		160.5		198.4	12.9	13.5	4.0	165.0		4.15	7.5	EXT1700
175	4.00		165.5		203.4	12.9	13.5	4.0	170.0		4.15	7.5	EXT1750
180	4.00		170.5		210.0	14.0	14.2	4.0	175.0		4.15	7.5	EXT1800
185	4.00		175.5		215.0	14.0	14.2	4.0	180.0		4.15	7.5	EXT1850

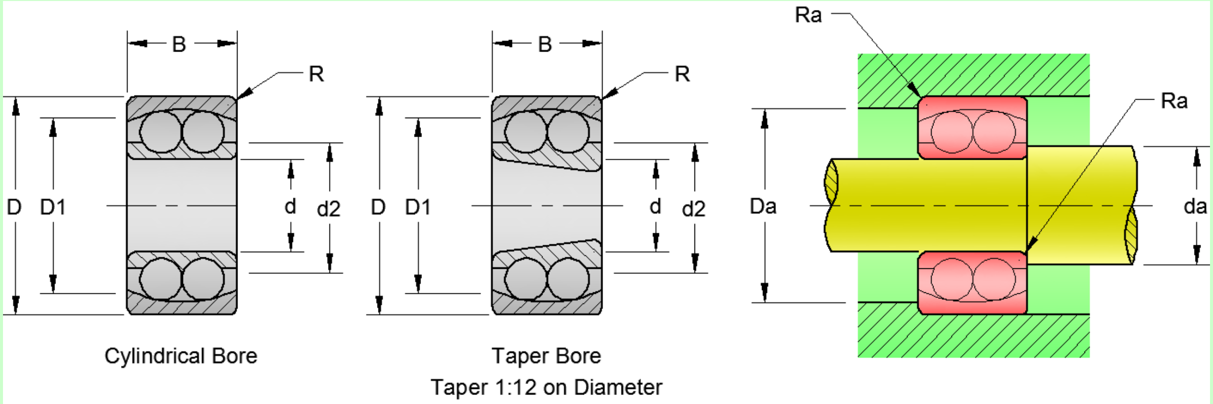
Table 3 – Deep Groove Ball Bearings



Principal Dimensions			Mass	Part No.	Dimensions			Abutment & Fillet Dimensions		
mm			kg		mm			mm		
d	D	B			d1	D1	r	da	Da max	Ra Max
17	26	5	0.0082	61803	20.2	23.2	0.3	19	24	0.3
	35	8	0.032	16003	22.8	29.5	0.3	19	33	0.3
	35	10	0.039	6003	22.8	29.5	0.3	19	33	0.3
	40	12	0.065	6203	2402	32.9	0.6	21	36	0.6
	47	14	0.12	6303	26.5	37.6	1	22	42	1
	62	17	0.27	6403	32.4	47.4	1.1	23.5	55.5	1
20	32	7	0.018	61804	24	28.3	0.3	22	30	0.3
	42	8	0.050	16004	27.2	34.6	0.3	22	40	0.3
	42	12	0.069	6004	27.2	35.1	0.6	24	38	0.6
	47	14	0.11	6204	28.5	38.7	1	25	42	1
	52	15	0.14	6304	30.3	42.1	1.1	26.5	45.5	1
	72	19	0.40	6404	37.1	55.6	1.1	26.5	65.5	1
25	37	7	0.022	61805	29	33	0.3	27	35	0.3
	47	8	0.060	16005	33.3	40.7	0.3	27	45	0.3
	47	12	0.080	6005	32	40.3	0.6	29	43	0.6
	52	15	0.13	6205	34	44.2	1	30	47	1
	62	17	0.23	6305	36.6	50.9	1.1	31.5	55.5	1
	80	21	0.53	6405	45.4	63.8	1.5	33	72	1.5
30	52	7	0.026	61806	33.8	38.2	0.3	32	40	0.3
	55	9	0.085	16006	38	47.3	0.3	32	53	0.3
	55	13	0.12	6006	38.2	47.1	1	35	50	1
	62	16	0.20	6206	40.3	52.1	1	35	57	1
	72	19	0.35	6306	44.6	59.9	1.1	36.5	65.5	1
	90	23	0.74	6406	50.3	70.7	1.5	38	82	1.5

35	47	7	0.030	61807	38.8	43.2	0.3	37	45	0.3
	62	9	0.11	16007	44	53.3	0.3	37	60	0.3
	62	14	0.16	6007	43.7	53.6	1	40	57	1
	72	17	0.29	6207	46.9	60.6	1.1	41.5	65.5	1
	80	21	0.46	6307	49.5	66.1	1.5	43	72	1.5
	100	25	0.95	6407	57.4	80.6	1.5	43	92	1.5
40	52	7	0.034	61808	43.8	48.2	0.3	42	50	0.3
	68	9	0.13	16008	49.4	57	0.3	42	66	0.3
	68	15	0.19	6008	49.2	59.1	1	45	63	1
	80	18	0.37	6208	52.6	67.9	1.1	46.5	73.5	1
	90	23	0.63	6308	56.1	74.7	1.5	48	82	1.5

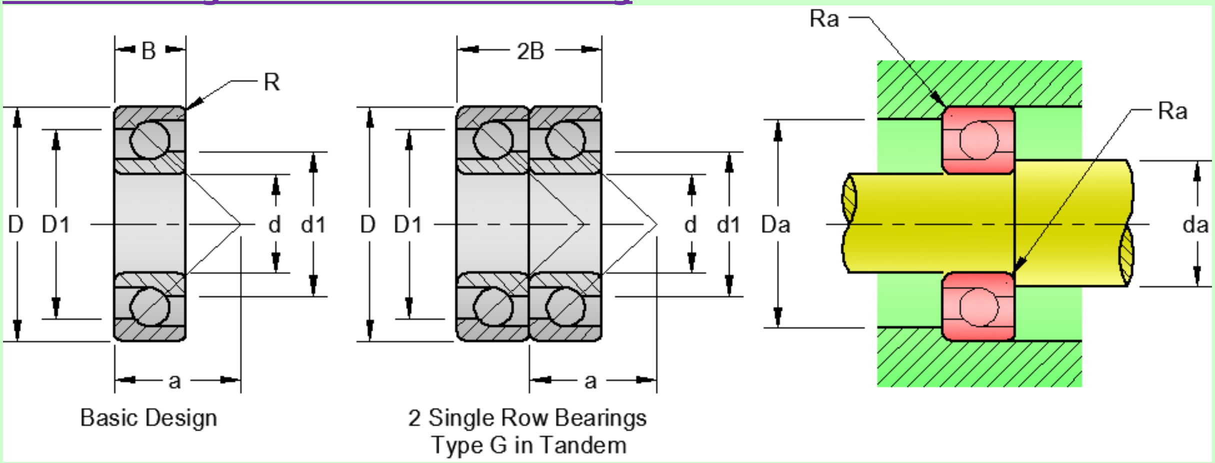
Table 4 – Self Aligning Ball Bearings



Boundary Dimensions			Mass	Part Number		Dimensions			Abutment & Fillet Dimensions		
d	D	B		Cyl. Bore	Taper Bore	d2	D1	R Min	da Min	Da max	Ra max
mm			kg			mm			mm		
17	40	12	0.16	1203	-	24.2	33.7	1	21	36	0.6
	40	16	0.19	2203	-	23.5	34.3	1	21	36	0.6
	47	14	0.29	1303	-	26.4	38.3	1.5	22	42	1
	47	19	0.35	2303	-	25.8	39.4	1.5	22	42	1
20	47	14	0.26	1204	-	28.9	39.1	1.5	25	42	1
	47	18	0.31	2204	-	28.0	40.4	1.5	25	42	1
	52	15	0.35	1304	-	31.3	43.6	2	26.5	45.5	1
	52	21	0.46	2304	-	28.8	43.7	2	26.5	45.5	1
25	52	15	0.31	1205	1205K	33.1	44.9	1.5	30	47	1
	52	18	0.35	2205	2205K	33.0	44.7	1.5	30	47	1
	62	17	0.57	1305	1305K	37.8	52.5	2	31.5	55.5	1
	62	24	0.75	2305	2305K	35.2	52.5	2	31.5	55.5	1
30	62	16	0.48	1206	1206K	40.1	53.2	1.5	35	57	1
	62	20	0.57	2206	2206K	40.0	53.0	1.5	35	57	1
	72	19	0.86	1306	1306K	44.9	60.9	2	36.5	65.5	1
	72	27	1.10	2306	2306K	41.7	60.9	2	36.5	65.5	1

Boundary Dimensions			Mass	Part Number		Dimensions			Abutment & Fillet Dimensions		
d	D	B		Cyl. Bore	Taper Bore	d2	D1	R Min	da Min	Da max	Ra max
mm			kg			mm			mm		
35	72	17	0.71	1207	1207K	47.5	60.7	2	41.5	65.5	1
	72	23	0.88	2207	2207K	46.0	62.2	2	41.5	65.5	1
	80	21	1.10	1307	1307K	51.5	69.5	2.5	43	72	1.5
	80	31	1.50	2307	2307K	46.5	68.4	2.5	43	72	1.5
40	80	18	0.93	1208	1208K	53.6	68.8	2	46.5	73.5	1
	80	23	1.10	2208	2208K	52.4	68.8	2	46.5	73.5	1
	90	23	1.60	1308	1308K	57.5	76.8	2.5	48	82	1.5
	90	33	2.05	2308	2308K	53.5	76.8	2.5	48	82	1.5

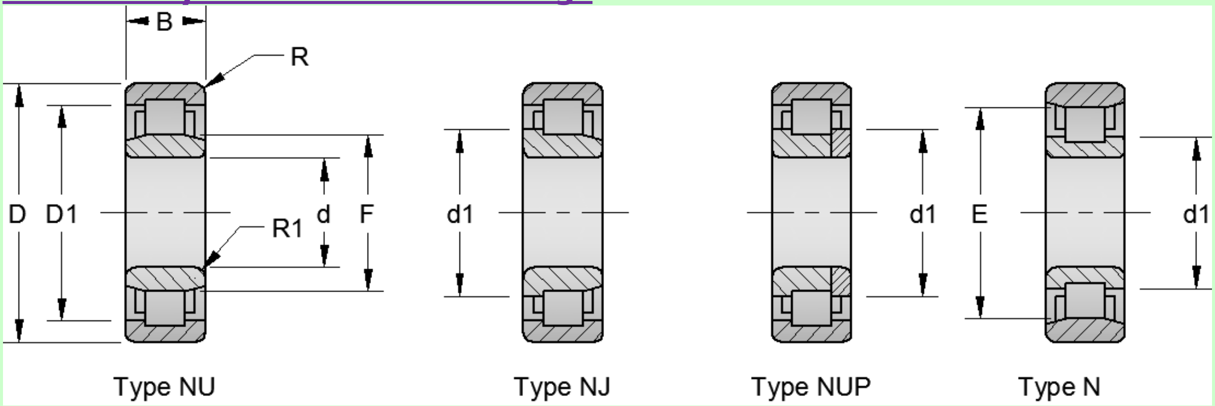
Table 5 - Angular Contact Ball Bearing



Principal Dimensions			Mass	Part No.	Dimensions				Abutment & Fillet Dimensions		
D	d	B			d1	D1	R	a	da	Da max	Ra max
mm			kg		mm				mm		
20	42	12	0.33	7004 C	26.9	35.1	1	10	25	37	0.6
	42	24	0.68	2 x 7004 CG	26.9	35.1	1	10	25	37	0.6
	47	14	0.48	7204 C	29.1	38.7	1.5	12	26	41	1
	47	14	0.58	7204 B	30.7	36.7	1.5	21	26	41	1
	47	28	0.97	2 x 7204 CG	29.1	38.7	1.5	12	26	41	1
	47	28	1.08	2 x 7024 BG	30.7	36.7	1.5	21	26	41	1
	52	15	0.73	304 B	32.7	39.9	2	23	27	45	1
	52	30	1.45	2 x 7304 BG	32.7	39.9	2	23	27	45	1
25	47	12	0.40	7005 C	31.9	40.1	1	11	30	42	0.6
	47	24	0.77	2 x 7005 CG	31.9	40.1	1	11	30	42	0.6
	52	15	0.57	7205 C	34.1	43.7	1.5	13	31	46	1
	52	15	0.68	7205 B	36.3	42.3	1.5	24	31	46	1
	52	30	1.17	2 x 7205 CG	34.1	43.7	1.5	13	31	46	1
	52	30	1.36	2 x 7205 BG	36.3	42.3	1.5	24	31	46	1
	62	17	1.17	7205 B	39.6	48	2	27	32	55	1
	62	34	2.31	2 x 7305 BG	39.6	48	2	27	32	55	1

Principal Dimensions			Mass	Part No.	Dimensions				Abutment & Fillet Dimensions		
D	d	B			d1	D1	R	a	da	Da max	Ra max
mm			kg		mm				mm		
30	55	13	0.57	7006 C	38.1	46.9	1.5	12	36	49	1
	55	26	1.17	2 x 7006 CG	38.1	46.9	1.5	12	36	49	1
	62	16	0.92	7206 C	40.3	51.7	1.5	14	36	56	1
	62	16	1.01	7206 B	42.7	49.9	1.5	27	36	56	1
	62	32	1.85	2 x 7206 CG	40.3	51.7	1.5	14	36	56	1
	62	32	2.05	2 x 7206 BG	42.7	49.9	1.5	27	36	56	1
	72	19	1.74	7306 B	47.7	57	2	31	37	65	1
	72	38	3.52	2 x 7306 BG	47.7	57	2	31	37	65	1
35	62	14	0.77	7007 C	43.7	53.3	1.5	14	41	56	1
	62	28	1.56	2 x 7007 CG	43.7	53.3	1.5	14	41	56	1
	72	17	1.32	7207 C	47	60	2	16	42	65	1
	72	17	1.45	7207 B	49.6	58	2	31	42	65	1
	72	34	2.64	2 x 7207 CG	47	60	2	16	42	65	1
	72	34	2.86	2 x 7207 BG	49.6	58	2	31	42	65	1
	80	21	2.31	7307 B	52.8	63	2.5	35	44	71	1
	80	42	4.62	2 x 7307 BG	52.8	63	2.5	35	44	71	1

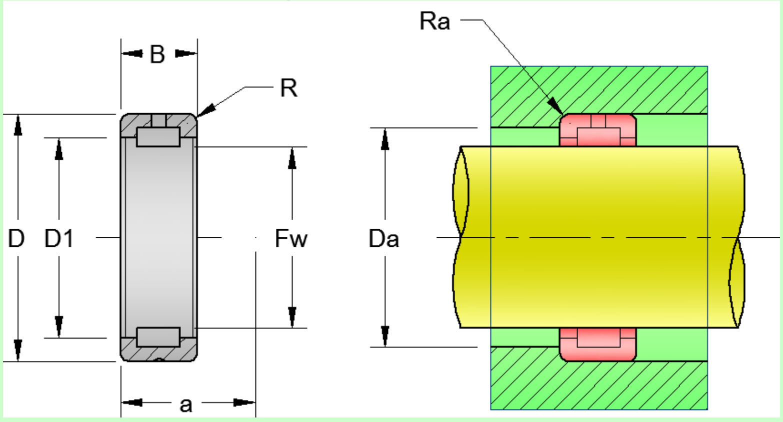
Table 6 - Cylindrical Roller Bearings



Principal Dimensions				Part Number				Dimensions					
d	D	B	kg	NU	NJ	NUP	N	d1	D1	E	F	R	R1
mm													
12	22	8	0.11	NU 1204 E	-	-	-	-	18.6	19.5	13.5	0.5	0.25
e	22	10	0.13	NU 124	NJ 124	NUP 124	N 124	14	18.6	19.5	13.5	0.5	0.25
	28	12	0.16	-	NJ 124 E	NUP 1204 E	-	17.8	23.7	25	16	0.5	0.25
	30	12	0.18	NU 1204	NJ 1204	-	N 1204	19.1	25.4	27	17	0.5	0.25
14	28	8	0.15	NU 1404 E	-	-	-	-	23.7	25	17	0.5	0.25
	30	10	0.18	NU 144	NJ 144	NUP 144	N 144	19.1	25.4	27	18.5	0.5	0.25
	36	12	0.22	-	NJ 1404 E	NUP 1404 E	-	22.9	30.4	32	22	0.5	0.25
	37	12	0.24	NU 1404	NJ 1404	-	N 1404	23.6	31.2	33	23	0.5	0.25
16	30	8	0.19	NU 1604 E	-	-	-	-	25.4	27	18	0.5	0.25
	32	10	0.22	NU 1604	NJ 164	NUP 164	N 164	20.4	27.0	28.5	19.5	0.5	0.25
	36	10	0.25	-	NJ 1604 E	NUP 1604 E	-	22.9	30.4	32	22	0.5	0.25
	36	12	0.29	NU 164	NJ 1604	-	N 1604	22.9	30.4	32	22	0.5	0.25
18	32	10	0.28	NU 1804	-	-	-	-	27.0	28.5	19.5	0.5	0.25
	36	10	0.32	NU 1804 E	NJ 184	NUP 184	N 184	22.9	30.4	32	20	0.5	0.25
	40	12	0.40	-	NJ 1804 E	NUP 1804 E	-	25.5	33.8	37.5	24.5	0.5	0.25
	40	13	0.41	NU 184	NJ 1804	-	N 1804	25.5	33.8	37.5	24.5	0.5	0.25
20	42	14	0.44	NU 2004 E	-	-	-	-	35.5	37.5	25.5	1	0.5
	47	14	0.53	NU 204	NJ 204	NUP 204	N 204	30	37.3	40	27	1.5	1
	47	14	0.53	-	NJ 204 E	NUP 204 E	-	29.7	38.8	41.5	26.5	1.5	1
	47	18	0.68	NU 2204	NJ 2204	-	-	30	37.3	40	27	1.5	1
	47	18	0.72	-	NJ 2204 E	-	-	29.7	38.8	41.5	26.5	1.5	1
	52	15	0.72	NU 304	NJ 304	NUP 304	N 304	31.8	40.5	44.5	28.5	2	1
	52	15	0.77	NU 304 E	NJ 304 E	-	-	31.2	42.4	45.5	27.5	2	1
	52	21	1.01	NU 2304	NJ 2304	NUP 2304	-	31.8	40.5	44.5	28.5	2	1
	52	21	1.01	NU 2304 E	NJ 2304 E	NUP 2304 E	-	31.2	42.4	45.5	27.5	2	1

Principal Dimensions				Part Number				Dimensions					
d	D	B	kg	NU	NJ	NUP	N	d1	D1	E	F	R	R1
mm													
25	47	12	0.42	NU 1005	-	-	-	-	38.8	41.5	30.5	1	0.5
	52	15	0.64	NU 205	NJ 205	NUP 205	N 205	35	42.3	45	32	1.5	1
	52	15	0.68	NU 205 E	NJ 205 E	NUP 205 E	-	34.7	43.8	46.5	31.5	1.5	1
	52	18	0.77	NU2205	NJ 2205	NUP 2205	-	35	42.3	45	32	1.5	1
	52	18	0.81	NU 2205 E	NJ 2205 E	NUP 2205 E	-	34.7	43.8	46.5	31.5	1.5	1
	62	17	1.17	NU 305	NJ 305	NUP 305	N 305	39	48.7	53	35	2	2
	62	17	1.21	NU 305 E	NJ 305 E	NUP 305 E	-	38.2	50.7	54	34	2	2
	62	24	1.65	NU 2305	NJ 2305	NUP 2305	-	39	48.7	53	35	2	2
	62	24	1.69	NU 2305 E	NJ 2305 E	NUP 2305 E	-	38.2	50.7	54	34	2	2
30	55	13	0.57	NU 1006	-	-	-	-	45.6	48.5	36.5	1.5	0.8
	62	16	0.97	NU 206	NJ 206	NUP 206	N 206	41.8	49.8	53.5	38.5	1.5	1
	62	16	1.01	NU 206 E	NJ 206 E	NUP 206 E	-	41.2	51.9	55.5	37.5	1.5	1
	62	20	1.25	NU 2206	NJ 2206	NUP 2206	-	41.8	49.8	53.5	38.5	1.5	1
	62	20	1.32	NU 2206 E	NJ 2206 E	NUP 2206 E	-	41.2	52.5	55.5	37.5	1.5	1
	72	19	1.74	NU 306	NJ 306	NUP 306	N 306	45.9	57.4	62	42	2	2
	72	19	1.80	NU 306 E	NJ 306 E	NUP 306 E	-	44.9	58.9	62.5	40.5	2	2
	72	27	2.42	NU 2306	NJ 2306	NUP 2306	-	45.9	57.4	62	42	2	2
	72	27	2.53	NU 2306 E	NJ 2306 E	NUP 2306 E	-	45.1	58.9	62.5	40.5	2	2
	90	23	3.63	NU 406	NJ 306	NUP 306	-	50.5	66.6	73	45	2.5	2.5
35	62	14	0.88	NU 1007	-	-	-	-	51.8	55	42	1.5	0.8
	62	17	1.01	NU 2007 E	-	-	-	-	54.1	56.5	41.5	1.5	0.8
	72	17	1.41	NU 207	NJ 207	NUP 207	N 207	47.6	57.5	61.8	43.8	2	1
	72	17	1.50	NU 207 E	NJ 207 E	NUP 207 E	-	48.3	60.7	64	44	2	1
	72	23	1.94	NU 2207	NJ 2207	NUP 2207	-	47.6	57.5	61.8	43.8	2	1
	72	23	1.98	NU 2207 E	NJ 2207 E	NUP 2207 E	-	48.3	60.7	64	44	2	1
	80	21	3.30	NU 307	NJ 307	NUP 307	N 307	50.8	63.2	68.2	46.2	2.5	2
	80	21	2.42	NU 307 E	NJ 307 E	NUP 307 E	-	51	66.3	70.2	46.2	2.5	2
	80	31	3.41	NU 2307	NJ 2307	NUP 2307	-	50.8	63.2	68.2	46.2	2.5	2
	80	31	3.52	NU 2307 E	NJ 2307 E	NUP 2307 E	-	51	66.3	70.2	46.2	2.5	2
	100	25	4.84	NU 407	NJ 407	NUP 407	-	59	76	83	53	2.5	2.5

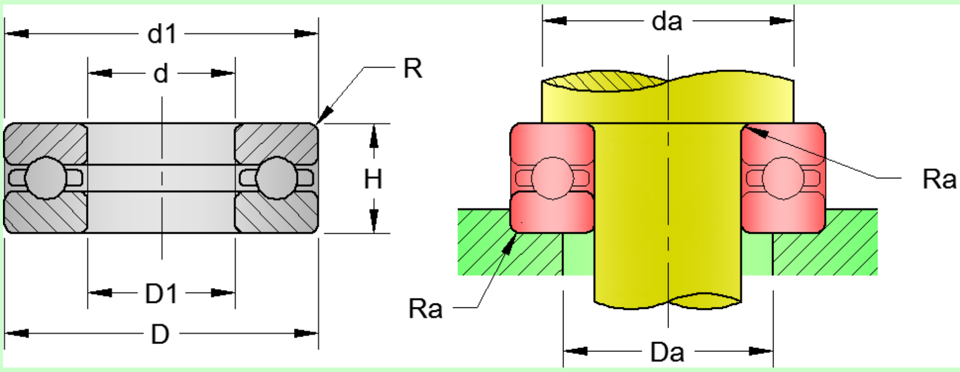
Table 7 - Needle Roller Bearings



Boundary Dimensions			Mass	Part No.	Dimensions		Abutment and Fillet Dimensions	
Fw	D	B			D_1	r min	D_a max	r_a max
mm			kg		mm			
20	28	13	0.051	RNA 4902	23.4	0.5	26	0.3
	28	16	0.066	RNA 202816	23.4	0.5	26	0.3
	28	20	0.084	RNA202820	23.4	0.5	26	0.3
21	29	16	0.071	RNA212916	23.4	0.5	27	0.3
	29	20	0.088	RNA212920	23.4	0.5	27	0.3
22	30	13	0.055	RNA4903	24.5	0.5	28	0.3
	30	16	0.073	RNA223016	24.5	0.5	28	0.3
	30	20	0.090	RNA223020	24.5	0.5	28	0.3
24	32	16	0.077	RNA243216	27.4	0.5	30	0.3
	32	20	0.099	RNA243220	27.4	0.5	30	0.3
25	33	16	0.082	RNA253316	28.4	0.5	31	0.3
	33	20	0.10	RNA253320	28.4	0.5	31	0.3
	37	17	0.13	RNA4904	30.5	0.5	35	0.3
26	34	16	0.086	RNA263416	29.4	0.5	32	0.3
	34	20	0.11	RNA263420	29.4	0.5	32	0.3
28	37	20	0.13	RNA283720	32	0.5	35	0.3
	37	30	0.19	RNA283730	32	0.5	35	0.3
	39	17	0.13	RNA49/22	33.5	0.5	37	0.3
29	38	20	0.13	RNA 293820	33	0.5	36	0.3
	38	30	0.20	RNA 293830	33	0.5	36	0.3
30	40	20	0.16	RNA 304020	34	0.5	38	0.3
	40	30	0.24	RNA 304030	34	0.5	38	0.3
	42	17	0.16	RNA 4905	35.5	0.5	40	0.3

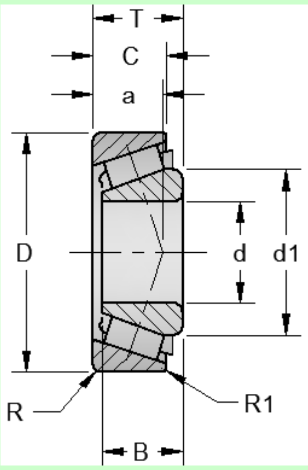
Boundary Dimensions			Mass	Part No.	Dimensions		Abutment and Fillet Dimensions	
Fw	D	B			D_1	r min	D_a max	r_a max
mm			kg		mm			
32	42	20	0.16	RNA 324220	36	0.5	40	0.3
	42	30	0.25	RNA 324230	36	0.5	40	0.3
	45	17	0.19	RNA 49/28	37.5	0.5	43	0.3
35	45	20	0.18	RNA 354520	39	0.5	43	0.3
	45	30	0.27	RNA 354530	39	0.5	43	0.3
	47	17	0.18	RNA 4906	40.5	0.5	45	0.3
37	47	20	0.17	RNA 374720	41	0.5	45	0.3
	47	30	0.24	RNA 374730	41	0.5	45	0.3
38	48	20	0.18	RNA 384820	42	0.5	46	0.3
	48	30	0.26	RNA 384830	42	0.5	46	0.3
40	50	20	0.18	RNA 405020	44	0.5	48	0.3
	50	30	0.26	RNA 405030	44	0.5	48	0.3
	52	20	0.22	RNA 49/32	45.5	0.5	48	0.3

Table 8 – Thrust Ball Bearings



Boundary Dimensions			Mass	Part No.	Dimensions mm			Abutment and Fillet Dimensions mm		
d	D	H			d_1	D_1	R	d_a min	D_a max	R_a max
mm			kg		mm					
17	30	9	0.06	51103	30	18	0.5	25	22	0.3
	35	12	0.12	51203	35	19	1	28	24	0.6
20	35	10	0.09	51104	35	21	0.5	29	26	0.3
	40	14	0.07	51204	40	22	1	32	28	0.6
25	42	11	0.13	51105	42	26	1	35	32	0.6
	47	15	0.26	51205	47	27	1	38	34	0.6
	52	18	0.40	51305	52	27	1.5	41	36	1
30	47	11	0.15	51106	47	32	1	40	37	0.6
	52	16	0.33	51206 X	52	32	1	43	39	0.6
	60	21	0.60	51306	60	32	1.5	48	42	1
	70	28	1.15	51406	70	32	1.5	54	46	1
35	52	12	0.20	51107 X	52	37	1	45	42	0.6
	62	18	0.49	51207	62	37	1.5	51	46	1
	68	24	0.86	51307	68	37	1.5	55	48	1
	80	32	1.75	51407	80	37	2	62	53	1
40	60	13	0.26	51108	60	42	1	52	48	0.6
	68	19	0.60	51208	68	42	1.5	57	51	1
	78	26	1.20	51308	78	42	1.5	63	55	1
	90	36	2.55	51408	90	42	2	70	60	1

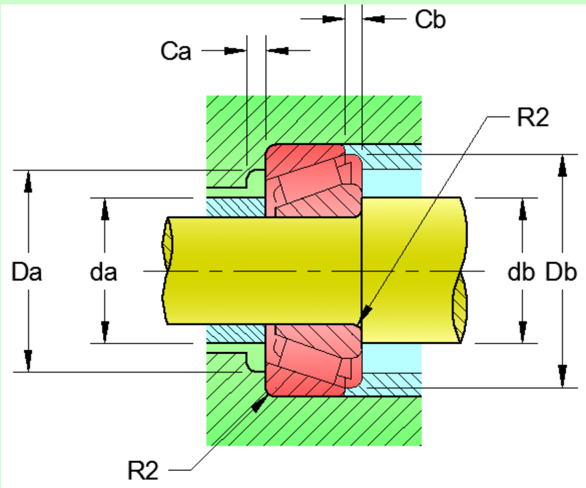
Table 9 – Taper Roller Bearings



Principal Dimensions			Mass	Code No.	Dimensions					
d	D	T			d1	B	C	R min	R1 min	a max
mm			kg		mm				mm	
25	47	15.00	0.24	32005 X	36.5	15	11.5	1	0.3	11
	52	16.25	0.33	30205	37.6	15	13	1.5	0.5	14
	52	19.25	0.42	32205 B	40.2	18	15	1.5	0.5	16
	52	22.00	0.51	33205	39.2	22	18	1.5	0.5	14
	62	18.25	0.57	30305	42	17	15	2	0.8	13
	62	18.25	0.57	31305	46	17	13	2	0.8	20
	62	25.25	0.79	32305	42	24	20	2	0.8	15
28	52	16.00	0.33	320/28 X	40.6	16	12	1.5	0.5	12
	58	20.25	0.55	322/28 B	43.9	19	16	1.5	0.5	17
30	55	17.00	0.37	32006 X	43	17	13	1.5	0.5	13
	62	17.25	0.51	30206	45	16	14	1.5	0.5	14
	62	21.25	0.62	32206	45.5	20	17	1.5	0.5	15
	62	21.25	0.66	32206 B	47.7	20	17	1.5	0.5	18
	62	25.00	0.82	33206	46	25	19.5	1.5	0.5	16
	72	20.75	0.86	30306	49	19	16	2	0.8	15
	72	20.75	0.86	31306	43	19	14	2	0.8	22
	72	28.75	1.20	32306	49	27	23	2	0.8	18
32	58	17.00	0.42	320/32 X	45.6	17	13	1.5	0.5	14
	65	22.25	0.64	322/32 B	50	21	18	1.5	0.5	19

Principal Dimensions			Mass	Code No.	Dimensions					
d	D	T			d1	B	C	R min	R1 min	a max
	mm		kg			mm			mm	
35	62	18.00	0.49	32007 X	49.3	18	14	1.5	0.5	15
	72	18.25	0.71	30207	52	17	15	2	0.8	15
	72	24.25	0.95	32207	52.5	23	19	2	0.8	17
	72	24.25	0.97	32207 B	55.1	23	19	2	0.8	21
	72	28.00	1.25	33207	53.4	28	22	2	0.8	18
	80	22.75	1.15	30307	54.5	21	18	2.5	0.8	16
	80	22.75	1.15	31307	59.6	21	15	2.5	0.8	25
	80	32.75	1.60	32307	54.9	31	25	2.5	0.8	20
	80	32.75	1.65	32307 B	59.6	31	25	2.5	0.8	24
40	68	19.00	0.60	32008 X	54.2	19	14.5	1.5	0.5	15
	80	19.75	0.93	30208	57.5	18	16	2	0.8	16
	80	24.75	1.15	32208	59	23	19	2	0.8	19
	80	24.75	1.15	32208 B	60.3	23	19	2	0.8	22
	80	32.00	1.70	33208	60	32	25	2	0.8	21
	90	25.25	1.60	30308	63.4	23	20	2.5	0.8	19
	90	25.25	1.60	31308	67	23	17	2.5	0.8	28
	90	35.25	2.20	32308	63	33	27	2.5	0.8	23

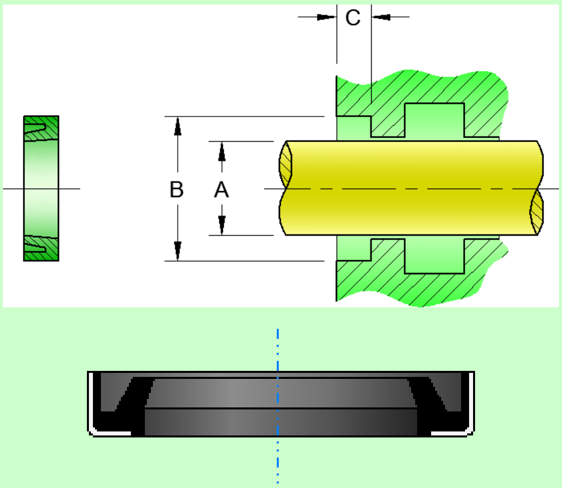
Table 10 – Taper Roller Bearings: Abutment and Fillets



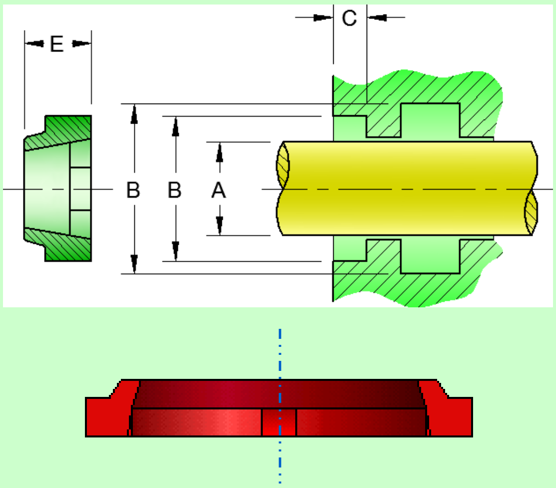
Principal Dimensions			Dimensions							
d	D	T	da max	db min	Da Min	Da min	Db min	Ca min	Cb min	R2 max
mm			mm							
25	47	15	30	30	40	42	44	3	3.5	0.6
	52	16.25	31	31	44	46	48	2	3	1
	52	19.25	30	31	41	46	50	3	4	1
	52	22	30	31	43	46	49	4	4	1
	62	18.25	34	32	54	55	57	2	3	1
	62	18.25	34	32	47	55	59	3	5	1
	62	25.25	33	32	52	55	57	4	5	1
28	52	16	33	34	45	46	49	3	4	1
	58	20.25	33	34	46	52	55	3	4	1
30	55	17	35	36	48	49	52	3	4	1
	62	17.25	37	36	53	56	57	2	3	1
	62	21.25	37	36	52	56	58	3	4	1
	62	21.25	36	36	50	56	60	3	4	1
	62	25	36	36	53	56	59	5	5.5	1
	72	20.75	40	37	62	65	66	3	4.5	1
	72	20.75	40	37	55	65	68	3	6.5	1
	72	28.75	39	37	59	65	66	4	5	1
32	58	17	38	38	50	52	55	3	5	1
	65	22.25	38	38	51	59	63	3	4	1

Principal Dimensions			Dimensions							
d	D	T	da max	db min	Da Min	Da min	Db min	Ca min	Cb min	R2 max
mm			mm							
35	62	18	40	41	54	56	59	4	4	1
	72	18.25	44	42	62	65	67	3	4	1
	72	24.25	43	42	61	65	67	3	3	1
	72	24.25	42	42	56	65	68	3	5	1
	72	28	42	42	61	65	68	5	6	1
	80	22.75	45	44	70	71	74	3	4.5	1.5
	80	22.75	44	44	62	71	76	4	7.5	1.5
	80	32.75	44	44	66	71	74	4	7.5	1.5
	80	32.75	42	44	61	71	76	4	7.5	1.5
40	68	19	46	46	60	62	65	4	4.5	1
	80	19.75	49	47	69	73	74	3	3.5	1
	80	24.75	48	47	68	73	75	3	5.5	1
	80	24.75	48	47	65	73	76	4	5.5	1
	80	32	47	47	67	73	76	5	7	1
	90	25.25	52	49	77	81	82	3	5	1.5
	90	25.25	51	49	71	81	86	4	8	1.5
	90	35.25	50	49	73	81	82	4	8	1.5

Table 11 – Wiper Seals



Metal Cased Wiper

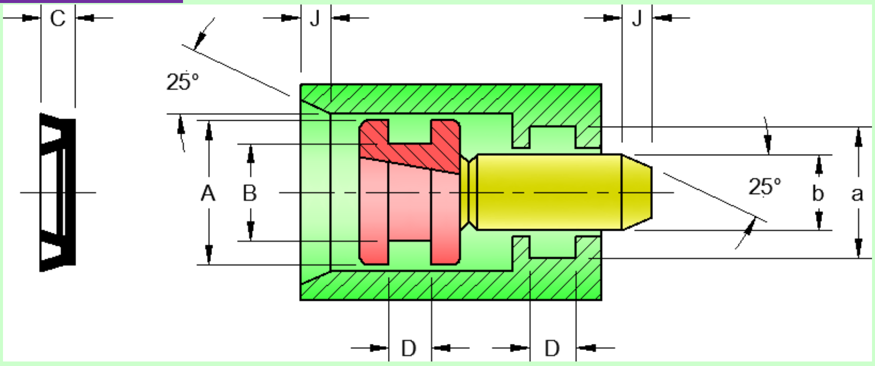


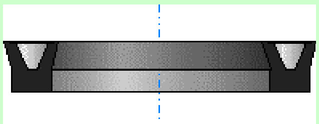
D-Style Rod Wiper

Metal Cased Rod Wiper					D – Style Rod Wiper						
Prod. Code	Ref No.	A	B	C	Prod. Code	Ref No.	A	B	C	D	E
		h10	±0.05	+0.12 -0.00			h10	+0.12 -0.00	+0.15 -0.000	+0.15 -0.000	Nom.
R26000	J0400	8	13	4.15	RD0500	D0500	8	12.45	3.15	10.00	5.33
R26001	J0450	10	16	6.35	RD0625	D0625	10	15.95	3.15	13.50	5.33
R26002	J0500	12	20	6.35	RD0750	D0750	12	18.97	3.15	16.75	5.33
R26003	J0625	15	26	8.15	RD1000	D1000	15	22.14	3.15	19.00	5.33
R26004	J0750	20	32	8.15	RD1250	D1250	20	28.50	4.75	25.25	7.75
R26005	J0875	22	35	8.15	RD1375	D1375	25	34.85	4.75	31.50	7.75
R26006	J1000	25	38	8.15	RD1500	D1500	32	41.20	4.75	38.00	7.75
R26007	J1125	28	42	8.15	RD1625	D1625	35	44.37	4.75	41.15	7.75
R26008	J1250	32	45	8.15	RD1750	D1750	38	47.55	4.75	44.25	7.75
R26009	J1375	35	48	8.15	RD1875	D1875	42	50.72	4.75	47.50	7.75
R26010	J1500	38	50	8.15	RD2000	D2000	45	53.90	4.75	50.50	7.75
R26011	J1625	42	54	8.15	RD2250	D2250	48	57.07	4.75	53.85	7.75
R26012	J1750	45	58	8.15	RD2500	D2500	50	63.42	6.32	59.00	10.03
R26013	J1875	48	60	8.15	RD2750	D2750	58	69.77	6.32	65.50	10.03
R26014	J2000	50	64	8.15	RD3000	D3000	64	76.12	6.32	71.75	10.03
R26015	J2125	54	66	8.15	RD3250	D3250	70	82.47	6.32	78.00	10.03
R26016	J2250	58	70	8.15	RD3500	D3500	75	88.82	6.32	84.50	10.03
R26017	J2375	60	72	8.15	RD3700	D3700	80	95.17	6.32	90.75	10.03

Metal Cased Rod Wiper				
Prod. Code	Ref No.	A	B	C
		h10	±0.05	+0.12 -0.00
R26018	J2500	64	75	8.15
R26020	J2625	66	80	8.15
R26022	J2750	70	82	8.15
R26024	J3000	75	88	8.15
R26027	J3250	82	98	8.15
R26028	J3500	88	105	8.15
R26029	J4000	100	118	8.15
R26030	J4500	115	130	8.15
R26031	J5000	125	142	8.15

Table 12 – Rod Seals

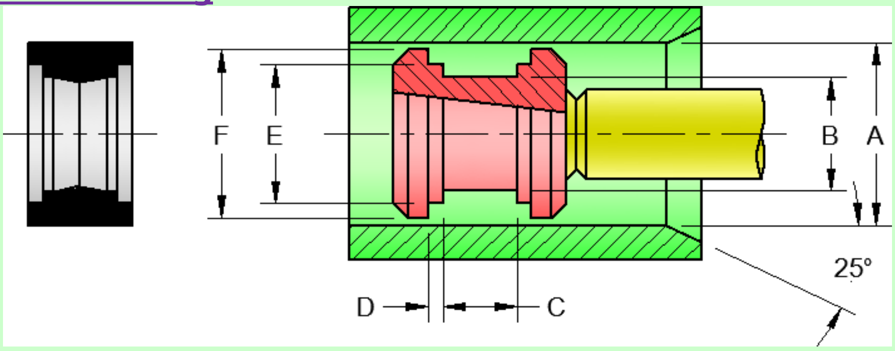


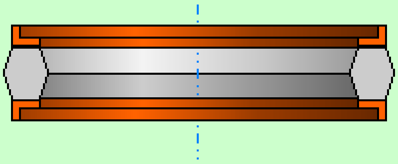


Prod Code	Part No.	A a H10	B b H10	C c Nom.	D +0.25 -0.000
R00274	SU1	8	4	4.76	5.35
R00275	SU2	10	6	4.76	5.35
R00276	SU3	11	7.50	4.76	5.35
R00277	SU4	12	8.50	4.75	5.35
R00278	SU5	13	9.50	4.75	5.35
R00279	SU6	14	10	4.75	5.35
R00280	SU7	15	11	4.75	5.35
R00281	SU8	16	12	6.35	7.00
R00282	SU9	17	13	6.35	7.00
R00283	SU10	18	13.5	6.35	7.00
R00284	SU11	19	14.5	6.35	7.00
R00285	SU12	20	15.5	6.35	7.00
R00286	SU13	22	17.5	6.35	7.00
R00287	SU14	24	18	6.35	7.00
R00288	SU15	25	19	6.35	7.00
R00289	SU16	26	20	6.35	7.00
R00290	SU17	28	22	6.35	7.00
R00291	SU18	30	24	6.35	7.00
R00292	SU19	32	25.5	6.35	7.00
R00293	SU20	34	27.5	6.35	7.00
R00294	SU21	36	29.5	6.35	7.00
R00295	SU22	38	31.5	6.35	7.00
R00296	SU23	40	33	6.35	7.00
R00297	SU24	42	35	6.35	7.00

Prod Code	Part No.	A a H10	B b H10	C c Nom.	D +0.25 -0.000
R00298	SU25	44	37	7.95	9.50
R00299	SU26	46	39	7.95	9.50
R00300	SU27	48	41	7.95	9.50
R00397	SU28	50	42.5	7.95	9.50
R00398	SU29	55	44.5	7.95	9.50
R00399	SU30	60	50	7.95	9.50
R00453	SU31	65	55	7.95	9.50
R00454	SU32	70	65	7.95	9.50
R00455	SU33	75	70	7.95	9.50
R00456	SU34	80	75	7.95	9.50
R00457	SU35	85	80	7.95	9.50
R00458	SU36	90	85	9.55	10.16
R00459	SU37	95	90	9.55	10.16
R00460	SU38	100	95	9.55	10.16

Table 13 – Piston Ring

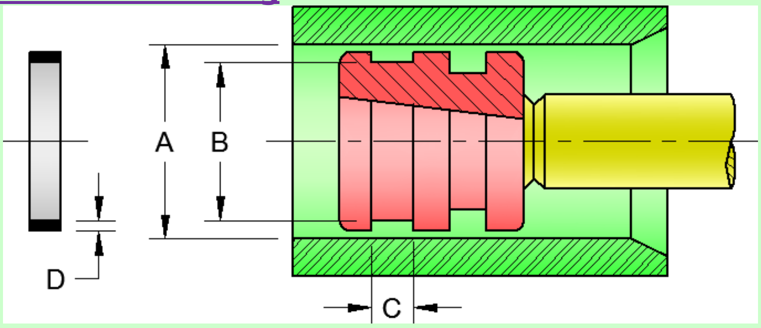




Prof Code	Ref No.	A H9	B h10	C +0.25 -0.00	D +0.00 -0.05	E +0.05 -0.00	F +0.05 -0.05
RZLD01	LD01-WRN	10	8	10	3	7.5	9.5
RZLD02	LD02-WRN	12	9	10	3	9.5	11.5
RZLD03	LD03-WRN	14	10	12	4	11	13.5
RZLD04	LD04-WRN	16	11	12	4	13	15.25
RZLD05	LD05-WRN	18	12	12	4	15	17.25
RZLD06	LD06-WRN	20	13	14	4	17	19.25
RZLD07	LD07-WRN	22	14	14	4	19	21.25
RZLD08	LD08-WRN	24	15	14	6	21	23
RZLD09	LD09-WRN	25	16	14	6	21.5	24
RZLD10	LD10-WRN	26	17	16	6	22.5	25
RZLD11	LD11-WRN	28	18	16	6	24.5	27
RZLD13	LD13-WRN	30	19	16	6	26.5	29
RZLD15	LD15-WRN	32	20	16	6	28.5	30.75
RZLD17	LD17-WRN	38	25	16	8	34	36.75
RZLD19	LD19-WRN	44	28	18	8	39	42.75
RZLD21	LD21-WRN	50	35	18	8	45	48.75
RZLD23	LD23-WRN	60	42	18	8	52	58
RZLD25	LD25-WRN	65	48	18	8	58	63
RZLD27	LD27-WRN	70	50	20	8	62	68
RZLD29	LD29-WRN	75	55	20	8	69	73

Prof Code	Ref No.	A H9	B h10	C +0.25 -0.00	D +0.00 -0.05	E +0.05 -0.00	F +0.05 -0.05
RZLD31	LD31-WRN	80	60	20	8	75	78
RZLD32	LD32-WRN	90	70	20	8	82	88
RZLD34	LD34-WRN	100	80	20	8	94	98
RZLD36	LD36-WRN	120	90	25	10	107	118
RZLD38	LD38-WRN	130	100	25	10	120	128
RZLD40	LD40-WRN	140	120	25	10	132	138
RZLD42	LD42-WRN	150	130	25	10	145	148

Table 14 – Guide or Wear Ring

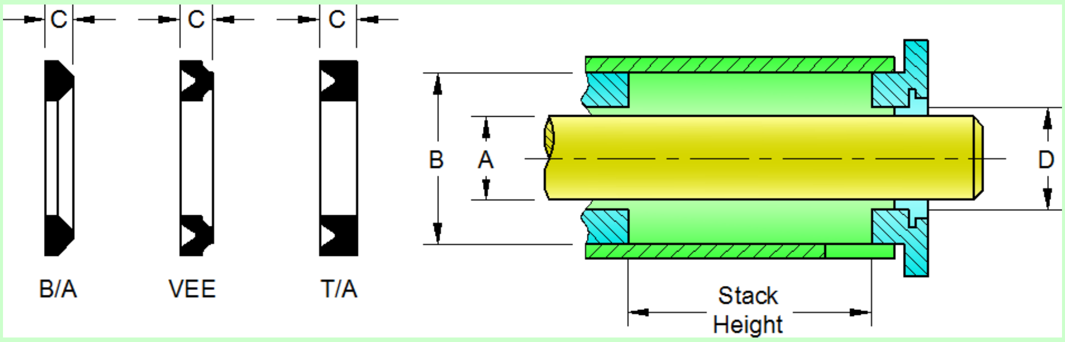


WR/J & JWR Wear Rings

Prod. Code	Reference No.	A H9	B +0.02 -0.02	C +0.25 -0.00	D +0.50 -0.00
R10979	060 WR/J	5	4	4.75	0.50
R10980	065 WR/J	8	6.5	4.75	0.75
R10981	070 WR/J	10	8.5	4.75	0.75
R10982	075 WR/J	12	9.5	4.75	1.25
R10983	080 WR/J	14	11.5	4.75	1.25
R10984	085 WR/J	16	13.5	4.75	1.25
R10985	090 WR/J	18	14	4.75	2.00
R10986	095 WR/J	20	16	4.75	2.00
R10987	098 WR/J	22	18	4.75	2.00
R10988	100 WR/J	25	20	6.35	2.50
R10989	112 WR/J	28	23.5	6.35	2.25
R10990	125 WR/J	30	26	6.35	2.00
R10991	137 WR/J	34	29.5	6.35	2.50
R10992	150 WR/J	38	33	9.53	2.50
R10993	162 WR/J	42	36.5	9.53	2.75
R10994	175 WR/J	44	38.5	9.53	2.75
R10995	187 WR/J	48	42	9.53	3.00
R10996	200 WR/J	50	46	9.53	3.00
R10997	212 WR/J	54	48	9.53	3.00
R10998	225 WR/J	58	52	9.53	3.00
R10999	237 WR/J	60	55	9.53	2.50
R11000	250 WR/J	64	58	9.53	3.00
R11001	262 WR/J	66	61	9.53	2.50
R11002	275 WR/J	70	65	9.53	2.50
R11003	287 WR/J	72	68	9.53	2.50

Prod. Code	Reference No.	A H9	B +0.02 -0.02	C +0.25 -0.00	D +0.50 -0.00
R11004	300 WR/J	75	71	9.53	2.00
R11005	310 WR/J	78	73	9.53	2.50
R11006	312 WR/J	80	74	9.53	3.00
R11007	318 WR/J	82	76	9.53	3.00
R11008	325 WR/J	85	77	9.53	4.00
R11009	350 WR/J	90	83	9.53	3.50
R11010	375 WR/J	92	85	12.70	3.50
R11011	400 WR/J	95	88	12.70	3.50
R11012	425 WR/J	100	92	12.70	4.00
R11013	450 WR/J	102	94	12.70	4.00
R11014	462 WR/J	105	97	12.70	4.00
R11015	475 WR/J	108	100	12.70	4.00
R11016	500 WR/J	110	102	12.70	4.00
R11017	525 WR/J	115	106	12.70	4.50
R11018	550 WR/J	118	109	12.70	4.50
R11019	575 WR/J	120	111	12.70	4.50
R11020	600 WR/J	125	116	12.70	4.50

Table 15 – Vee Packing Seals



Stack Height = B/A + VEE x Number Required + T/A

Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15	Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15
R00100	VEE	10	20	2.20	11.00	R00729	T/A	50	70	12.70	48.25
R00106	T/A	10	20	2.45	11.00	R00535	VEE	50	70	6.35	48.25
R00109	B/A	10	20	2.85	11.00	R00880	B/A	50	70	3.18	48.25
R00205	VEE	12	28	2.75	13.00	R00720	T/A	50	64	6.35	48.25
R00207	T/A	12	28	2.89	13.00	R00536	VEE	52	75	3.96	53.50
R00303	B/A	12	28	3.00	13.00	R00727	T/A	55	70	7.95	56.75
R00305	VEE	15	29	3.47	16.00	R00533	VEE	55	70	3.96	56.75
R00403	T/A	15	29	3.89	16.00	R00878	B/A	55	70	1.60	56.75
R00406	B/A	15	29	3.50	16.00	R00537	VEE	58	72	5.16	56.75
R00501	VEE	18	30	3.96	19.00	R00728	T/A	58	70	6.35	59.80
R00502	VEE	18	30	3.18	19.00	R00534	VEE	58	70	3.28	59.80
R00700	T/A	18	30	6.35	19.00	R06258	B/A	58	72	1.60	59.80
R00850	B/A	20	31	1.60	21.25	R00731	T/A	58	76	9.53	59.80
R00504	VEE	20	31	2.54	21.25	R00732	T/A	58	76	12.70	59.80
R00701	T/A	20	31	4.77	21.25	R00541	VEE	58	76	4.78	59.80
R00503	VEE	22	32	2.39	23.25	R00882	B/A	58	76	1.60	59.80
R00851	B/A	22	32	2.39	23.25	R00883	B/A	58	76	4.78	59.80
R00702	T/A	22	35	6.35	23.25	R00735	T/A	58	76	6.81	59.80
R00505	VEE	22	35	3.18	23.25	R00547	VEE	58	76	3.96	59.80
R00852	B/A	22	35	1.60	23.25	R00886	B/A	58	76	1.60	59.80
R00703	T/A	24	36	6.35	25.15	R00879	B/A	58	70	1.60	59.80
R00506	VEE	24	36	3.18	25.15	R00538	VEE	58	72	3.96	59.80
R00853	B/A	24	36	1.60	25.15	R06246	T/A	58	72	7.92	59.80

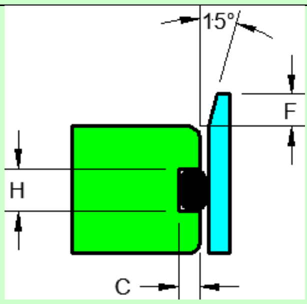
Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15	Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15
R00704	T/A	25	38	6.35	26.20	R00738	T/A	60	80	12.49	61.95
R00507	VEE	25	38	3.18	26.20	R00550	VEE	60	80	5.99	61.95
R00854	B/A	25	38	1.60	26.20	R00551	VEE	60	80	6.48	61.95
R00705	T/A	25	42	7.95	26.20	R00888	B/A	60	80	4.50	61.95
R00508	VEE	25	42	3.96	26.20	R00539	VEE	60	75	2.54	61.95
R00855	B/A	25	42	1.60	26.20	R00543	VEE	60	75	3.96	61.95
R00706	T/A	28	42	6.35	29.25	R00544	VEE	60	75	4.78	61.95
R00509	VEE	28	42	3.18	29.25	R00884	B/A	60	75	4.78	61.95
R00856	B/A	28	42	1.60	29.25	R00891	T/A	60	78	6.10	61.95
R00510	VEE	28	45	3.96	29.25	R00554	VEE	60	78	5.66	61.95
R00513	VEE	30	50	3.96	31.30	R00733	T/A	60	75	7.95	61.95
R00707	T/A	32	45	6.35	31.30	R00542	VEE	60	75	3.96	61.95
R00511	VEE	32	45	3.18	31.30	R00578	B/A	60	75	1.60	61.95
R00857	B/A	32	45	1.60	31.30	R00552	VEE	64	82	4.78	62.25
R27966	B/A	32	45	3.18	31.30	R00889	B/A	64	82	1.60	62.25
R00708	T/A	35	48	6.35	36.45	R00734	T/A	65	78	6.35	66.75
R00512	VEE	35	48	3.18	36.45	R00546	VEE	65	78	3.18	66.75
R00858	B/A	35	48	1.60	36.45	R00885	B/A	65	78	1.60	66.75
R00709	T/A	35	50	7.95	36.45	R00737	T/A	65	80	7.92	66.75
R00514	VEE	35	50	3.96	36.45	R00549	VEE	65	80	3.96	66.75
R00859	B/A	35	50	1.60	36.45	R00887	B/A	65	80	1.60	66.75
R00711	T/A	35	50	7.95	36.45	R00739	T/A	65	82	9.53	66.75
R00516	VEE	35	50	3.19	36.45	R15840	T/A	70	82	7.92	68.15
R00861	B/A	35	50	1.60	36.45	R00553	VEE	70	82	3.18	68.15
R00519	VEE	35	58	5.56	36.45	R00890	B/A	70	82	1.60	68.15
R00710	T/A	38	50	6.35	39.50	R08748	VEE	70	85	3.96	68.15
R00520	VEE	38	58	4.78	36.25	R00740	T/A	70	88	9.53	68.15
R00864	B/A	38	58	1.60	36.25	R00741	T/A	70	88	12.70	68.15
R00515	VEE	38	50	3.18	36.25	R00555	VEE	70	88	4.78	68.15
R00860	B/A	38	50	1.60	36.25	R00891	B/A	70	88	1.60	68.15
R00712	T/A	38	54	7.95	36.25	R00893	B/A	70	88	4.78	68.15
R00713	T/A	38	54	9.53	36.25	R00892	B/A	70	88	4.78	68.15
R00517	VEE	38	54	3.96	36.25	R00558	VEE	70	92	3.96	68.15

Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15	Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15
R00862	B/A	38	54	1.60	36.25	R00743	T/A	70	90	9.53	68.15
R00863	B/A	38	54	3.96	36.25	R00557	VEE	70	90	4.78	68.15
R00714	T/A	38	58	9.53	36.25	R00895	B/A	70	90	1.60	68.15
R00518	VEE	41	58	3.18	39.40	R00560	VEE	72	96	6.35	70.25
R00715	T/A	45	58	6.35	43.20	R00742	T/A	76	88	6.35	74.15
R00521	VEE	45	58	3.18	43.20	R00556	VEE	76	88	3.18	74.15
R00865	B/A	45	58	1.60	43.20	R00894	B/A	76	88	1.60	74.15
R00522	VEE	45	58	3.18	43.20	R00744	T/A	76	92	9.53	74.15
R00716	T/A	45	60	7.95	43.20	R00559	VEE	76	92	4.78	74.15
R00523	VEE	45	60	3.96	43.20	R00896	B/A	79	92	1.60	74.15
R00866	B/A	45	60	1.60	43.20	R00564	VEE	80	102	5.56	78.20
R00717	T/A	45	65	9.53	43.20	R00561	VEE	82	98	3.96	80.25
R00524	VEE	45	65	4.78	43.20	R00745	T/A	80	98	11.13	78.20
R00867	B/A	45	65	1.60	43.20	R00897	B/A	82	98	3.18	78.20
R00724	T/A	45	65	12.70	43.20	R00750	T/A	82	102	8.33	80.25
R00531	VEE	45	65	6.35	43.20	R00749	T/A	82	102	15.88	80.25
R00875	B/A	45	65	1.60	43.20	R00570	VEE	82	102	4.78	80.25
R01296	VEE	45	65	5.99	43.20	R00901	B/A	82	102	1.60	80.25
R00722	T/A	45	65	12.70	43.20	R00563	VEE	82	98	4.37	80.25
R00528	VEE	45	65	4.78	43.20	R00746	T/A	82	102	9.53	80.25
R00873	B/A	45	65	1.60	43.20	R00747	T/A	82	102	12.70	80.25
R00718	T/A	48	65	7.95	46.20	R00565	VEE	82	102	4.78	80.25
R00719	T/A	48	65	9.53	46.20	R00989	B/A	82	102	1.60	80.25
R00525	VEE	48	65	3.96	46.20	R00899	B/A	82	102	4.78	80.25
R00868	B/A	48	65	1.60	46.20	R00587	VEE	82	102	10.30	80.25
R00869	B/A	48	65	3.96	46.20	R00566	VEE	86	102	4.78	84.15
R00721	T/A	48	64	7.37	46.20	R00567	VEE	86	102	3.96	84.15
R00527	VEE	48	64	3.96	46.20	R00568	VEE	86	102	4.78	84.15
R00872	B/A	48	64	1.60	46.20	R00900	B/A	86	102	4.78	84.15
R00526	VEE	50	62	3.18	51.50	R00938	B/A	86	102	1.60	84.15
R00870	B/A	50	62	1.60	51.50	R00748	T/A	88	102	6.35	86.10
R00871	B/A	50	62	3.08	51.50	R00569	VEE	88	102	3.18	86.10
R00796	T/A	50	66	6.35	51.50	R01100	B/A	88	102	4.75	86.10
R00797	T/A	50	66	7.37	51.50	R00752	T/A	88	108	9.53	86.10

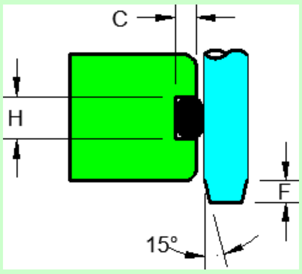
Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15	Product Code	Ref. No.	A H9	B e9	C Nom	D +0.00 -0.15
R00723	T/A	50	66	7.95	51.50	R00573	VEE	88	108	4.78	86.10
R00798	T/A	50	66	9.53	51.50	R00903	B/A	88	108	1.60	86.10
R00529	VEE	50	66	3.96	51.50	R00753	T/A	88	115	12.78	86.10
R00874	B/A	50	66	1.60	51.50	R00754	T/A	88	115	15.88	86.10
R00530	VEE	50	66	4.78	51.50	R00575	VEE	88	115	6.35	86.10
R00725	T/A	50	70	9.53	51.50	R00904	B/A	88	115	1.60	86.10
R00726	T/A	50	70	12.70	51.50	R00905	B/A	88	115	9.53	86.10
R00532	VEE	50	70	4.78	51.50	R00588	VEE	88	124	8.74	86.10
R00876	B/A	50	70	1.60	51.50	R00757	T/A	90	115	12.19	88.00
R00877	B/A	50	70	4.78	51.50	R00578	VEE	90	115	6.35	88.00
R00730	T/A	50	75	12.70	51.50						
R00540	VEE	50	75	6.35	51.50						
R00881	B/A	50	75	1.60	51.50						

Table 16 – O-Rings

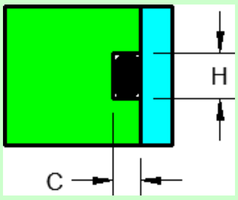
Standard Groove Types for Hydraulic Service



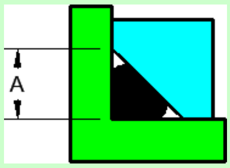
Piston



Gland



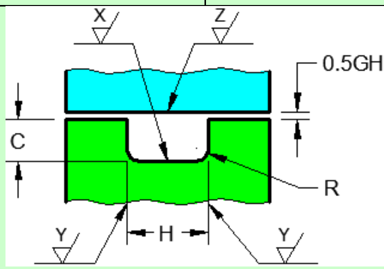
Face (*No BTU Req'd*)



Triangular

Groove Design & Surface Finish

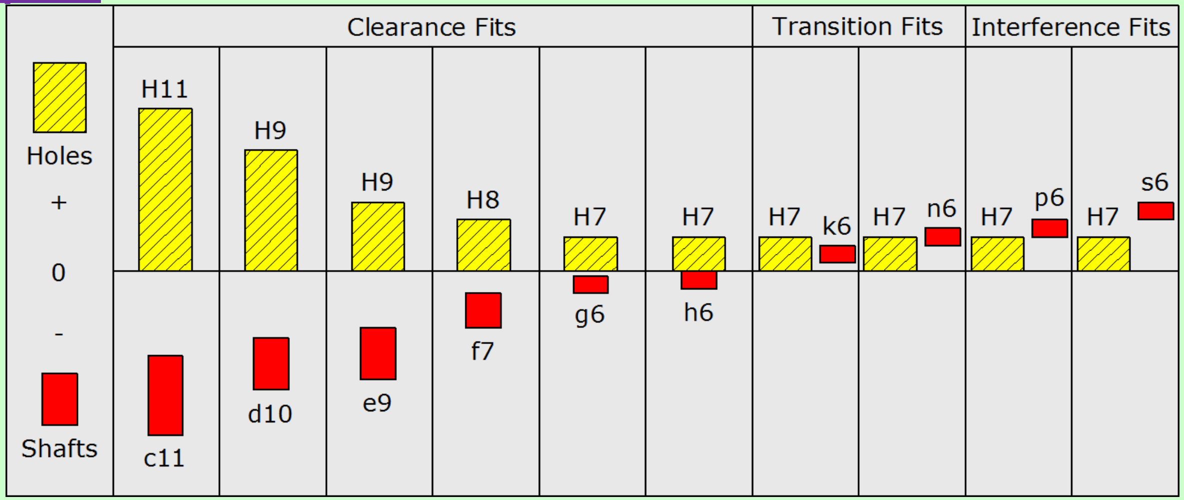
SF	Static			Dynamic					
				BUW's			NO BUW's		
	x	y	z	x	y	z	x	y	z
µm	0.8	1.6	0.8	0.8	1.6	0.4	0.8	0.8	0.4



CS Cross Section		Groove Depth				0.20 H 0.00 Groove Width			A	R	G	F
		Dynamic		Static		No. of BUW's			+0.12 -0.00	Groove Radius	Diam'l Clear	Lead In
mm	Inch	Max	Min	Max	Min	0	1	2		Max	Max	Min
1.00		0.85	0.80									
1.50		1.30	1.25									
1.60		1.38	1.33									
1.78	1/16	1.53	1.47									
1.90		1.64	1.59									
2.00		1.74	1.69									
2.40		2.13	2.07									
2.50		2.23	2.18									
2.62	3/32	2.34	2.25									
3.00		2.71	2.64									
3.10		2.81	2.69									
3.50		3.21	3.09									
3.53	1/8	3.21	3.09									
4.00		3.66	3.54									
5.00		4.60	4.40									
5.33	3/16	4.86	4.70									
5.70		5.28	5.08									
6.00		5.50	5.30									
6.99	1/4	6.31	6.11									
8.40		7.75	7.55									

CS						0.20	H	0.00	A	R	G	F
Cross Section		Groove Depth				Groove Width				Groove Radius	Diam'l Clear	Lead In
		Dynamic		Static		No. of BUW's			+0.12 -0.00			
mm	Inch	Max	Min	Max	Min	0	1	2		Max	Max	Min
1.00		0.85	0.80	0.75	0.70	1.30	-	-	1.40	0.25	0.10	1.00
1.50		1.30	1.25	1.20	1.15	1.95	-	-	2.00	0.25	0.10	1.00
1.60		1.38	1.33	1.28	1.23	2.08	-	-	2.20	0.38	0.10	1.00
1.78	1/16	1.53	1.47	1.38	1.33	2.34	4.10	6.10	2.40	0.38	0.13	1.00
1.90		1.64	1.59	1.53	1.48	2.57	4.10	6.00	2.65	0.38	0.13	1.50
2.00		1.74	1.69	1.60	1.55	2.60	-	-	2.70	0.38	0.13	1.50
2.40		2.13	2.07	1.92	1.87	3.12	4.60	6.00	3.20	0.38	0.13	1.50
2.50		2.23	2.18	2.00	1.95	3.25	-	-	3.40	0.38	0.13	1.50
2.62	3/32	2.34	2.25	2.08	2.03	3.38	4.60	6.50	3.50	0.38	0.13	1.50
3.00		2.71	2.64	2.50	2.30	3.90	5.40	6.80	4.00	0.63	0.13	2.00
3.10		2.81	2.69	2.52	2.32	4.00	5.50	6.90	4.10	0.63	0.13	2.00
3.50		3.21	3.09	2.90	2.70	4.55	6.10	7.50	4.80	0.63	0.13	2.00
3.53	1/8	3.21	3.09	2.90	2.70	4.55	5.50	7.40	4.80	0.63	0.15	2.00
4.00		3.66	3.54	3.30	3.10	5.20	-	-	5.40	0.63	0.15	3.00
5.00		4.60	4.40	4.15	3.85	6.50	-	-	6.70	0.63	0.15	3.00
5.33	3/16	4.86	4.70	4.42	4.12	6.95	7.60	10.20	7.15	0.89	0.15	3.00
5.70		5.28	5.08	4.75	4.45	7.47	9.30	11.10	7.70	0.89	0.15	4.00
6.00		5.50	5.30	4.95	4.65	7.80	-	-	8.00	0.89	0.15	4.00
6.99	1/4	6.31	6.11	5.78	5.45	9.10	10.05	13.50	9.40	0.89	0.17	4.00
8.40		7.75	7.55	6.95	6.65	11.05	13.20	15.40	11.40	0.89	0.17	4.00

Table 17 - Hole Basis System

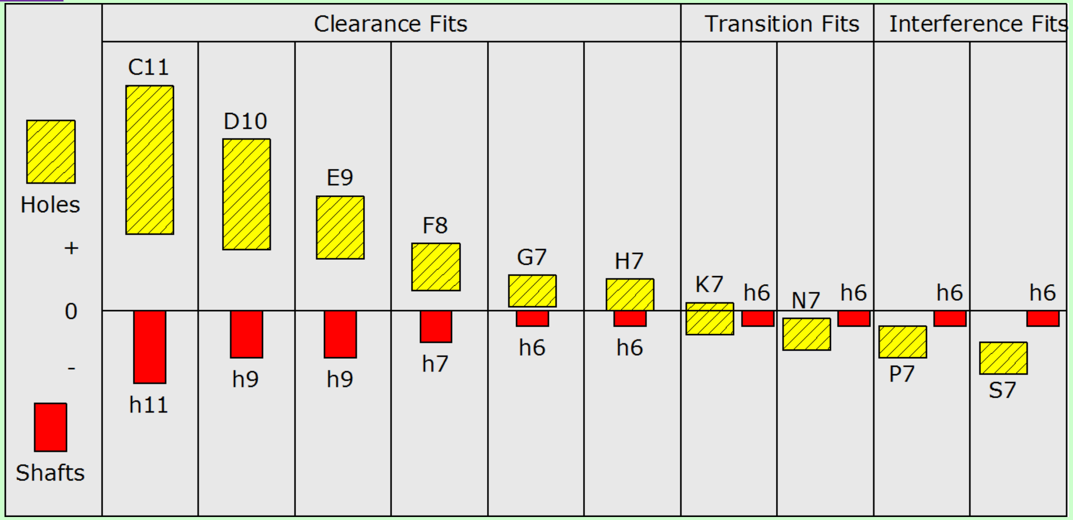


Over	Up to	H11	C11	H9	d10	H9	e9	H8	f7	H7	g6	H7	h6	H7	k6	H7	n6	H7	p6	H7	s6
		+	-	+	-	+	-	+	-	+	-	+	-	+	+	+	+	+	+	+	+
-	3	60	60	25	20	25	14	14	6	10	2	10	0	10	6	10	10	10	12	10	20
		0	120	0	60	0	39	0	16	0	6	0	6	0	0	0	4	0	6	0	14
3	6	75	70	30	30	30	20	18	10	12	4	12	0	12	9	12	16	12	20	12	27
		0	145	0	78	0	50	0	28	0	12	0	8	0	1	0	8	0	12	0	19
6	10	90	80	36	40	36	25	22	13	15	5	15	0	15	10	15	19	15	24	15	32
		0	170	0	98	0	61	0	28	0	14	0	9	0	1	0	10	0	15	0	23
10	18	110	95	43	50	43	32	27	16	18	6	18	0	18	12	18	23	18	29	18	39
		0	205	0	120	0	75	0	34	0	17	0	11	0	1	0	12	0	18	0	28

Over	Up to	H11	C11	H9	d10	H9	e9	H8	f7	H7	g6	H7	h6	H7	k6	H7	n6	H7	p6	H7	s6
		+	-	+	-	+	-	+	-	+	-	+	-	+	+	+	+	+	+	+	+
18	30	130	110	52	65	52	40	33	20	21	7	21	0	21	15	21	28	21	35	21	48
		0	240	0	149	0	92	0	41	0	20	0	13	0	2	0	15	0	22	0	35
30	40		120																		
		160	280	62	80	62	50	39	25	25	9	25	0	25	18	25	33	25	42	25	59
40	50	0	130	0	180	0	112	0	50	0	25	0	16	0	2	0	17	0	26	0	43
			290																		
50	65		140																		72
		190	330	74	100	74	60	46	30	30	10	30	0	30	21	30	39	30	51	30	53
65	80	0	150	0	220	0	134	0	60	0	29	0	19	0	2	0	20	0	32	0	78
			340																		59
80	100		170																		93
		220	390	87	120	87	72	54	36	35	12	35	0	35	26	35	45	35	59	35	71
100	120	0	180	0	260	0	159	0	71	0	34	0	22	0	3	0	23	0	37	0	101
			400																		79
120	140		200																		117
			450																		92
140	160	250	210	100	145	100	84	63	43	40	14	40	0	40	28	40	52	40	68	40	125
		0	460	0	305	0	185	0	83	0	39	0	25	0	3	0	27	0	43	0	100
160	180		230																		133
			480																		108

Over	Up to	H11	C11	H9	d10	H9	e9	H8	f7	H7	g6	H7	h6	H7	k6	H7	n6	H7	p6	H7	s6
		+	-	+	-	+	-	+	-	+	-	+	-	+	+	+	+	+	+	+	+
180	200		240																		151
			530																		122
200	225	290	260	115	170	115	100	72	50	46	14	46	0	46	33	46	60	46	79	46	159
		0	550	0	355	0	215	0	96	0	44	0	29	0	4	0	31	0	50	0	130
225	250		280																		169
			570																		140
250	280		300																		190
		320	620	130	190	130	110	81	56	52	17	52	0	52	36	52	66	52	88	52	158
280	315	0	330	0	400	0	240	0	108	0	49	0	32	0	4	0	34	0	56	0	202
			650																		170
315	355		360																		226
		360	720	140	210	140	125	89	62	57	18	57	0	57	40	57	73	57	98	57	190
355	400	0	400	0	440	0	265	0	119	0	54	0	36	0	0	0	37	0	62	0	244
			760																		208

Table 18 – Shaft Basis System



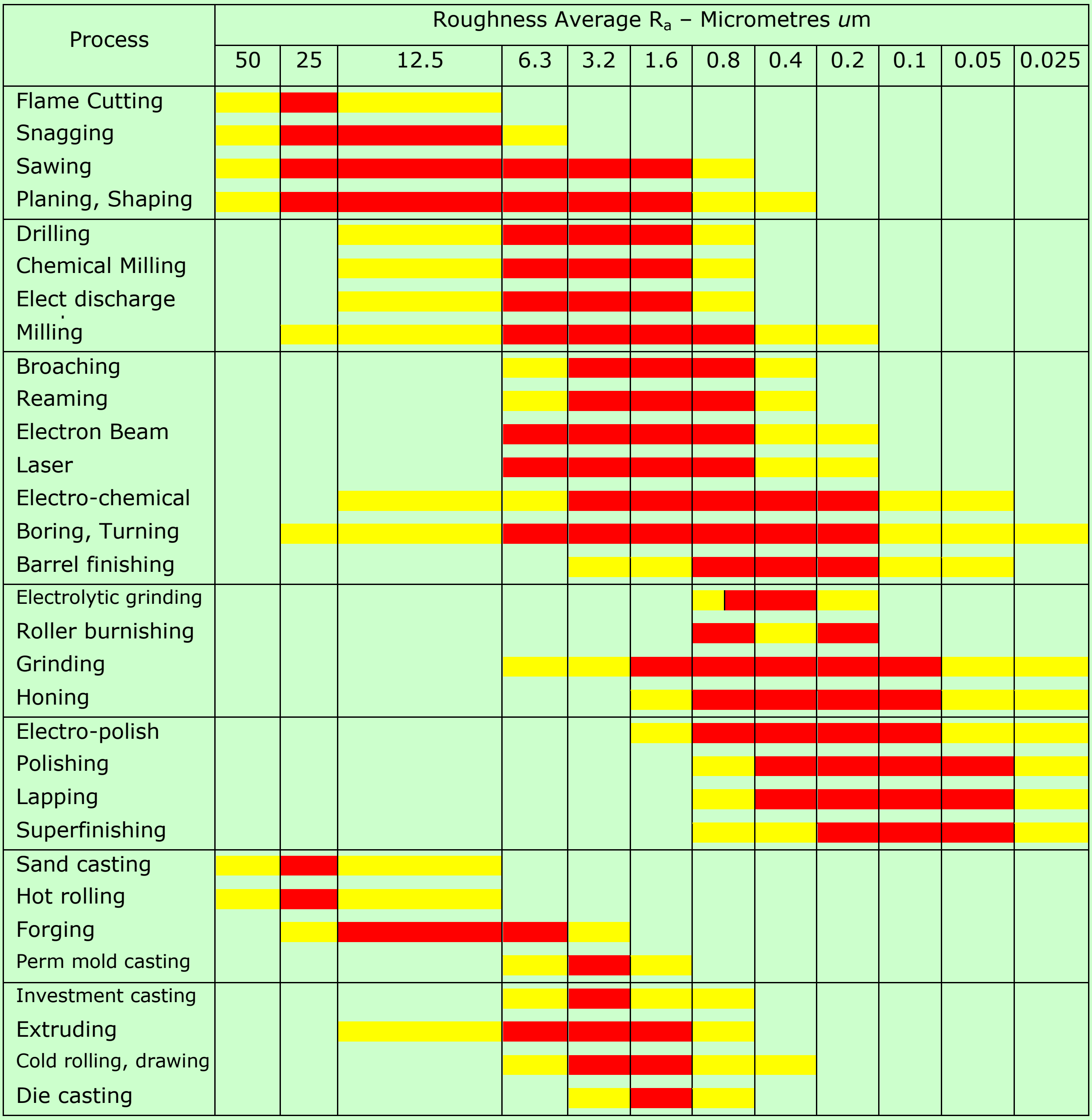
Over	Up to	C11	h11	D10	h9	E9	h9	F8	h7	G7	h6	H7	h6	K7	h6	N7	h6	P7	h6	S7	h6
		+	-	+	-	+	-	+	-	+	-	+	-	+&-	-	-	-	-	-	-	-
-	3	120	0	60	0	39	0	20	0	12	0	10	0	0	0	4	0	6	0	14	0
		60	60	20	25	14	25	6	10	2	6	0	6	-10	6	14	6	16	6	24	6
3	6	145	0	78	0	50	0	28	0	16	0	12	0	3	0	4	0	8	0	15	0
		70	75	30	30	20	30	10	12	4	8	0	8	-9	8	16	8	2	8	27	8
6	10	170	0	98	0	61	0	35	0	20	0	15	0	5	0	4	0	9	0	17	0
		80	90	40	36	25	36	13	15	5	9	0	9	-10	9	19	9	24	9	32	9
10	18	205	0	120	0	75	0	43	0	24	0	18	0	6	0	5	0	11	0	21	0
		95	110	50	43	32	43	16	18	6	11	0	11	-12	11	23	11	29	11	39	11
18	30	240	0	149	0	92	0	53	0	28	0	21	0	6	0	7	0	14	0	27	0
		110	130	65	52	40	52	20	21	7	13	0	13	-15	13	28	13	35	13	48	13

Over	Up to	C11	h11	D10	h9	E9	h9	F8	h7	G7	h6	H7	h6	K7	h6	N7	h6	P7	h6	S7	h6
30	40	280	0																		
		120	160	180	0	112	0	64	0	34	0	25	0	7	0	8	0	17	0	34	0
40	50	290	0	80	62	50	62	25	25	9	16	0	16	-18	16	33	16	42	16	59	16
		130	160																		
50	65	330	0																	42	0
		140	190	220	0	134	0	76	0	40	0	30	0	9	0	9	0	21	0	72	19
65	80	340	0	100	74	60	74	30	30	10	19	0	19	-21	19	39	19	51	19	48	0
		150	190																	78	19
80	100	390	0																	58	0
		170	220	260	0	159	0	90	0	47	0	35	0	10	0	10	0	24	0	93	22
100	120	400	0	120	87	72	87	36	35	12	22	0	22	-25	22	45	22	59	22	66	0
		180	220																	101	22
120	140	450	0																	77	0
		200	250																	117	25
140	160	460	0	305	0	185	0	106	0	54	0	40	0	12	0	12	0	28	0	85	0
		210	250	145	100	85	100	43	40	14	25	0	25	-28	25	52	25	68	25	125	25
160	180	480	0																	93	0
		230	250																	133	25

Over	Up to	C11	h11	D10	h9	E9	h9	F8	h7	G7	h6	H7	h6	K7	h6	N7	h6	P7	h6	S7	h6
180	200	530	0																	105	0
		240	290																	151	29
200	225	550	0	355	0	215	0	122	0	61	0	46	0	13	0	14	0	33	0	113	0
		260	290	170	115	100	115	50	46	15	29	0	29	-33	29	60	29	79	29	159	29
225	250	570	0																	123	0
		280	290																	169	29
250	280	620	0																	138	0
		300	320	400	0	240	0	137	0	62	0	52	0	16	0	14	0	36	0	190	32
280	315	650	0	190	130	110	130	56	52	17	32	0	32	-36	32	66	32	88	32	150	0
		330	320																	202	32
315	355	720	0																	169	0
		360	360	440	0	265	0	151	0	75	0	57	0	17	0	16	0	41	0	226	36
355	400	760	0	210	140	125	140	62	57	18	36	0	36	-40	36	73	36	98	36	187	0
		400	360																	244	36

Table 19 – Typical Surface Roughness Height Application

Roughness Value	Roughness Grade Number	Process and Application
50	N12	
25	N11	A very rough surface produced by lathes, millers and other machine tools using heavy cuts and very coarse feeds. Other processes such as filing, snagging, disc grinding, sand casting and rough forging also produce a texture of this value.
12.5	N10	A very rough coarse surface obtained by sand casting saw cutting, chipping, rough forging, and oxy cutting. Suitable for clearance areas on machinery, jigs and fixtures.
6.3	N9	A coarse production finish obtained by using coarse feeds on lathes, millers, shapers, boring and drilling machines and is acceptable when tool marks have no bearing on performance and quality. The surface can be produced economically and is used on parts where stress requirements, appearance and conditions of operations, and design permit.
3.2	N8	A medium commercial finish easily produced on lathes, milling machines and shapers. The finish is commonly used in general engineering machining operations, which is economical to produce and of reasonable appearance. This is the roughest surface recommended for parts subject to loads, vibration and high stress; it is also permitted for bearing surfaces when motion is slow with light loads.
1.6	N7	A good machine finish that can be maintained on production lathes and milling machines using sharp tools, fine feeds and high cutting speeds. It may be specified for close fits and used for all stress parts except fast rotating shafts, axels and parts subject to severe vibration or extreme tension. It is also suitable for bearing surfaces when motion is slow and loads light.
0.8	N6	A first class machine finish which can be easily produced on cylindrical surface and centerless grinders but requires great care on lathes and milling machines. It is satisfactory for bearings and shafts carrying light loads and running at medium to slow speeds.
0.4	N5	A fine quality surface that can be produced by fine cylindrical grinding, coarse honing, buffing and lapping methods. The finish is specified where smoothness is of primary importance, such as rapidly rotating shaft bearings, heavily loaded bearings and extreme tension members.
0.2	N4	A fine surface produced by honing, lapping and buffing methods. The finish could be specified on precision gauge and instrument work on high speed shafts and bearings. Cost of construction is high.
0.1	N3	Very refined surfaces require this degree of finish that are produced by honing, lapping and buffing methods and are expensive to produce. The finish is specified for surfaces on instrument and gauge work, and where packings and rings must slide across the direction of surface grain such as chrome-plated piston rods where lubrication is not dependable.
0.05	N2	Very smoothly finished surfaces produced by honing, lapping, buffing or super finishing machines. The surfaces may have a satin or highly polished appearance depending on the finishing operation and material. Expensive finishes to produce that are rarely required but can be specified on fine or sensitive instrument parts or other laboratory items and precision gauge blocks.
0.025	N1	Very smoothly finished surfaces produced by honing, lapping, buffing or super finishing machines. The surfaces may have a satin or highly polished appearance depending on the finishing operation and material. Extremely expensive finishes to produce that are rarely required but can be specified on fine or sensitive instrument parts or other laboratory items and precision gauge blocks.



The ranges shown above are typical of the processes listed.

Higher or lower values may be obtained under special conditions.

Key

Average Application

Less frequent application

Table 20 – Lay Symbols

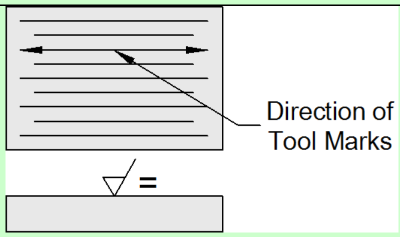
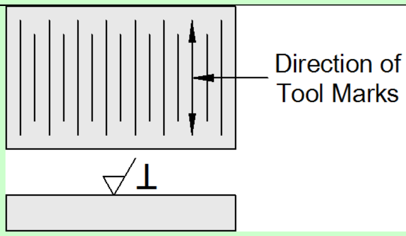
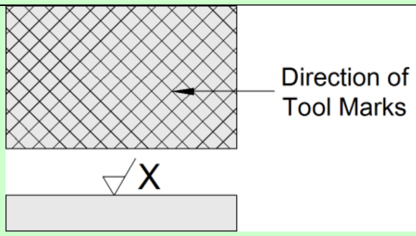
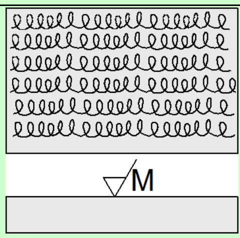
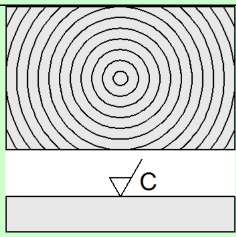
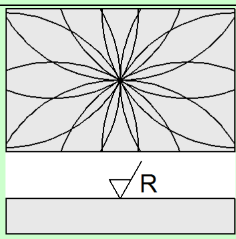
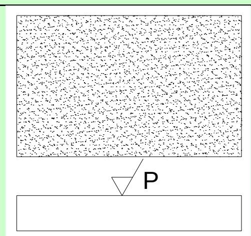
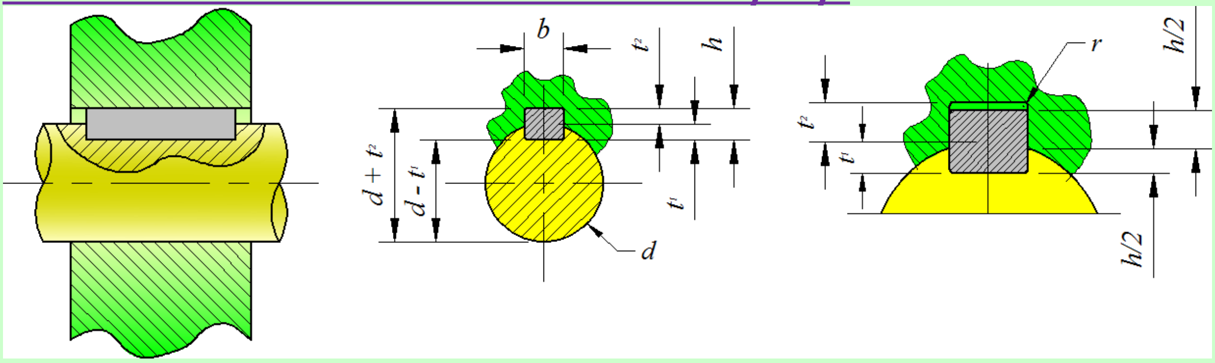
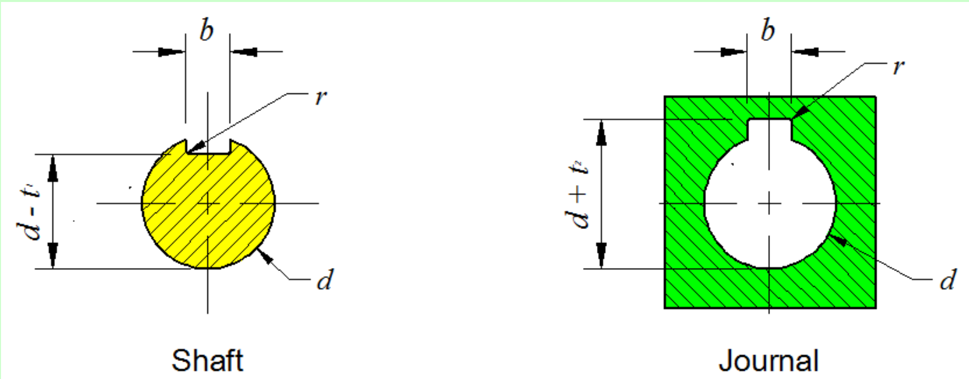
Symbol	Designation	Example
=	Lay parallel to the line representing the surface to which the symbol is applied.	
T	Lay perpendicular to the line representing the surface to which the symbol is applied.	
X	Lay angular in both directions.	
M	Lay multidirectional.	
C	Lay approximately circular relative to the center of the surface to which the symbol is applied.	
R	Lay approximately radial relative to the centre of the surface to which the surface is applied.	
P	Lay nondirectional, pitted or protuberant.	

Table 21 – Dimensions and Tolerances for Keyways





All dimensions are in millimetres

NOTE: The relations between shaft diameter and key section given above are for general applications. The use of smaller key sections is permitted if suitable for the torque transmitted. In cases such as stepped shafts when larger diameters are required, for example to resist bending, and when fans, gears and impellers are fitted with a smaller key than nominal, an unequal disposition of key in shaft with relation to the hub results. Therefore, dimension $d - t_1$ and $d + t_2$ should be recalculated to maintain the *h/2* relationship. The use of larger key sections is not permitted.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Shaft		Key	Keyway											
nom dia see note *d*		Section *b x h* Width x thickness	Tolerance for class of fit						depth				radius	
				free		normal		close	shaft t_1		hub t_2		r	
			nom	shaft (H9)	hub (D10)	shaft (N9)	Hub (J9)*	shaft & Hub (F9)	Nom	Tol	nom	tol	max	min
6	8	2 x 2	2	+0.025	+0.060	-0.004	+0.012	-0.006	1.2		1		0.16	0.08
8	10	3 x 3	3	0	+0.020	-0.029	-0.012	-0.031	1.8		1.4		0.16	0.08
10	12	4 x 4	4	+0.030	+0.078	0	+0.015	-0.012	2.5	+0.1	1.8	+0.1	0.16	0.08
12	17	5 x 5	5	0	+0.030	-0.030	-0.015	-0.042	3	0	2.3	0	0.25	0.16
17	22	6 x 6	6						3.5		2.8		0.25	0.16
22	30	8 x 7	8	+0.036	+0.098	0	+0.018	-0.015	4		3.3		0.25	0.16
30	38	10 x 8	10	0	+0.040	-0.036	-0.018	-0.051	5		3.3		0.40	0.25
38	44	12 x 8	12						5		3.3		0.40	0.25
44	50	14 x 9	14	+0.043	+0.120	0	+0.021	-0.018	5.5		3.8		0.40	0.25
50	58	16 x 10	16	0	+0.050	-0.043	-0.021	-0.061	6	+0.2	4.3	+0.2	0.40	0.25
58	65	18 x 11	18						7	0	4.4	0	0.40	0.25
65	75	20 x 12	20						7.5		4.9		0.60	0.40
75	85	22 x 14	22	+0.052	+0.149	0	+0.026	-0.022	9		5.4		0.60	0.40
85	95	25 x 14	25	0	+0.065	-0.052	-0.026	-0.074	9		5.4		0.60	0.40
95	110	28 x 16	28						10		6.4		0.60	0.40

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Shaft		Key	Keyway											
nom dia see note *d*		Section *b x h* Width x thickness	Tolerance for class of fit						depth				radius	
				free		normal		close	shaft t_1		hub t_2		r	
			nom	shaft (H9)	hub (D10)	shaft (N9)	Hub (J9)*	shaft & Hub (F9)	Nom	Tol	nom	tol	max	min
110	130	32 x 18	32						11		7.4		0.60	0.40
130	150	36 x 20	36	+0.062	+0.180	0	+0.031	-0.026	12		8.4		1.00	0.70
150	170	40 x 22	40	0	+0.080	-0.062	-0.031	-0.088	13		9.4		1.00	0.70
170	200	45 x 25	45						15		10.4		1.00	0.70
200	230	50 x 28	50						17		11.4		1.00	0.70
230	260	56 x 32	56						20	+0.3	12.4	+0.3	1.60	1.20
260	290	63 x 32	63	+0.074	+0.220	0	+0.037	-0.032	20	0	12.4	0	1.60	1.20
290	330	70 x 36	70	0	+0.100	-0.074	-0.037	-0.106	22		14.4		1.60	1.20
330	380	80 x 40	80						25		15.4		2.50	2.00
380	440	90 x 45	90	+0.087	+0.260	0	+0.043	-0.037	28		17.4		2.50	2.00
440	500	100 x 50	100	0	+0.120	-0.087	-0.043	-0.124	31		19.5		2.50	2.00