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ROYAL CANADIAN AIR FORCE

TECHNICAL FACTS

ANTI - FRICTION BEARINGS

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

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TECHNICAL FACTS ANTI - FRICTION BEARINGS

GENERAL

1 It is imperative that all who handle ball and roller bearings be acquainted with Technical Facts which have been compiled in the following data. In order to properly inspect and maintain anti-friction bearings, one must be familiar with the various types of loads and functions to which the bearings are subjected. The following information contains the basic fundamentals of bearing principals which are essential in properly analyzing important and significant bearing characteristics.

THE PURPOSE OF ANTI-FRICTION BEARINGS

2 With high operating speeds employed in most all aircraft machinery, it is very important to maintain as little friction in the component parts of mechanism as possible in order to have maximum operating range, maximum speed and maximum life. This is the reason for ball and roller bearings. As shown in Fig. 1, it can be seen the ease with which a man can roll a ball in comparison with how he can push a block. Such an example reveals that a bearing in operation allows machinery to rotate with maximum efficiency and reduces friction element to a minimum. A good bearing, therefore, will function with the least amount of resistance. Bearings mounted incorrectly, bearings worn badly, and unfavorable operating conditions reduce the efficiency of the bearing and overcome its original purpose. In reality, unfavorable conditions in bearings and their mounting change rolling friction to sliding friction.

BEARING LOADS

3 By referring to Fig. 2, note that there are three basic loads involved in the study of ball and roller bearings - Radial Loads, Thrust Loads and Angular Loads. The radial load is at right angles to the shaft and is principally designed to carry the heavy vertical loads that are imposed on the ball bearing. The anti-friction bearings in the journal box on a train coach illustrates to a great extent the nature of the radial load. A ball bearing must be large enough to withstand the load imposed and at the same time permit a free rotation of the moving component parts. The size of bearing, the size and number of balls, the raceways, the bearing construction and many other factors determine whether or not the machine will perform satisfactorily. Thrust loads may be considered in the same light, but these loads operate in a line parallel to the shaft as shown in Fig. 2. These loads are due to gear drives, tilting operation, lateral movement of machine and many other factors involved in modern design. It is very important that thrust loads be understood for often times a bearing will be strong enough to carry the radial loads, but not strong enough to carry the heavy thrust loads. The combination of the radial and thrust loads form the angular load as shown in Fig. 2. The angular load is a resultant load due to the radial and thrust loads imposed on the design. It is not infrequent to have the resultant load change many times during one single operation. For instance, when an aircraft is in flight every position throws a new resultant on the bearing and there is an uncontrollable change. This is the reason that all bearings must be carefully designed for specific equipment. A bearing must have the quality of absorbing the changes in resultant load and because of this characteristic there is incorporated a radial and lateral looseness in bearings. This play is pre-determined for each application and is very important since it can either give a short or long life span to the bearing.

(a) It is very important to distribute an angular load properly in the bearing itself and a careful study should always be made as to how and where within the bearing the loads will be imposed. Most ball bearings operate on a three point contact and with such a condition all the component parts of the bearing become very important. The reason for this is that some time during the course of operation one of the parts will be carrying the maximum load. If the part is not strong enough to do the work individually, it will break down and the result will be a bearing failure.

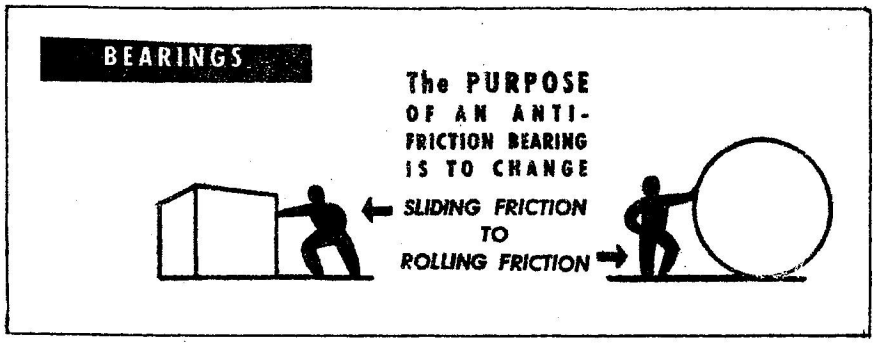

Figure 1 The Purpose of an Anti-Friction Bearing is to Change Sliding Friction to Rolling Friction

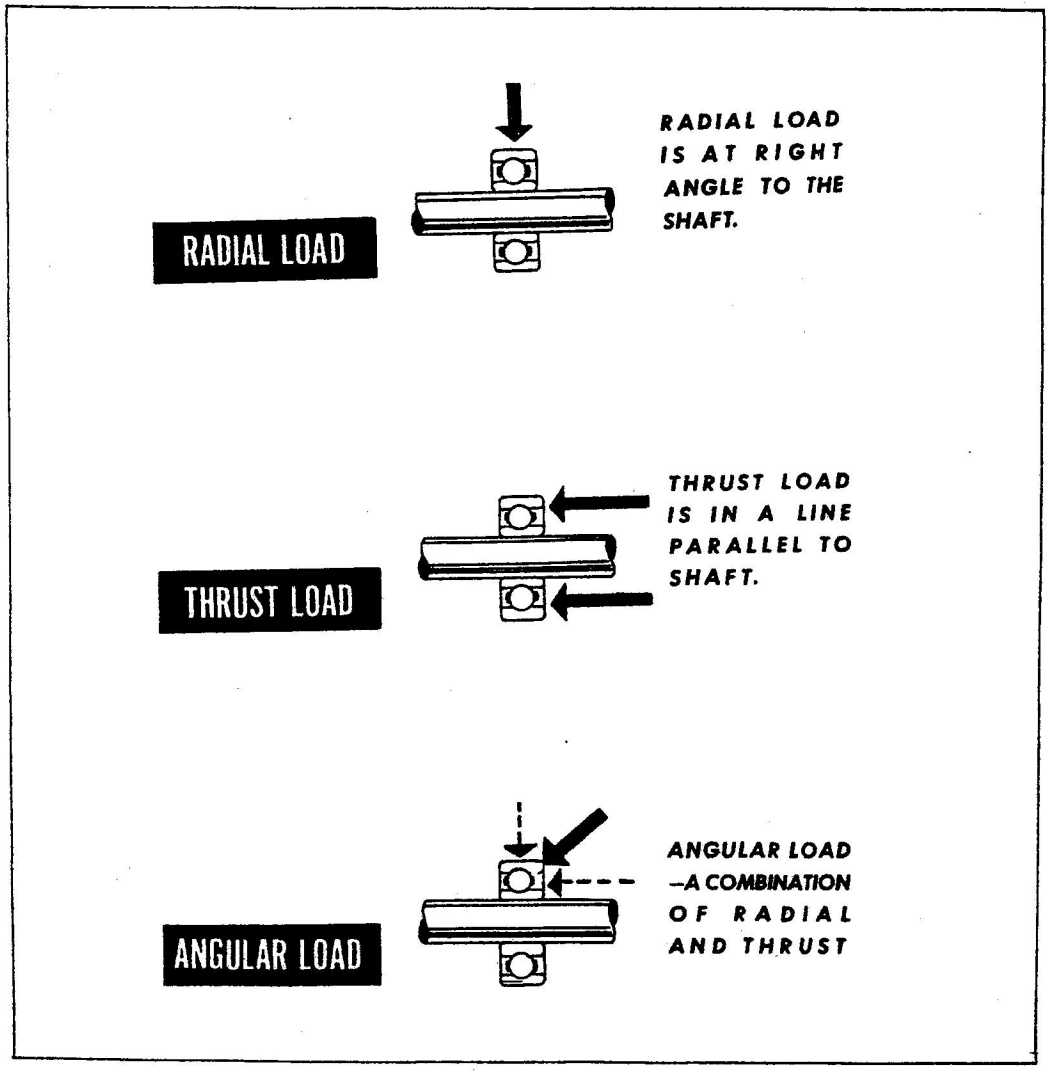

Figure 2 Radial Load is at Right Angle to the Shaft. Thrust Load is in a Line Parallel to Shaft Angular Load-A Combination of Radial and Thrust

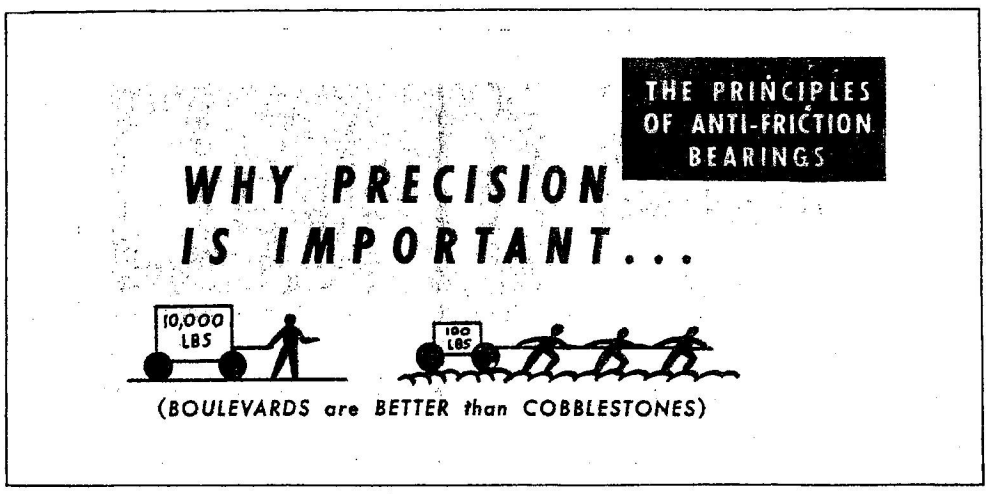

Figure 3 Why Precision is Important

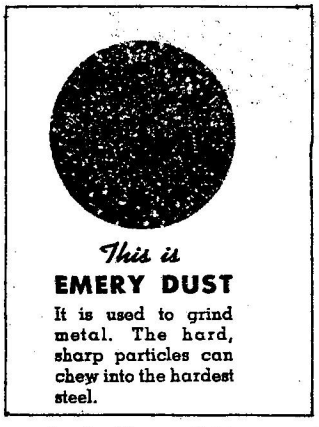

Figure 4 Action of Emery Dust on Ball Bearings

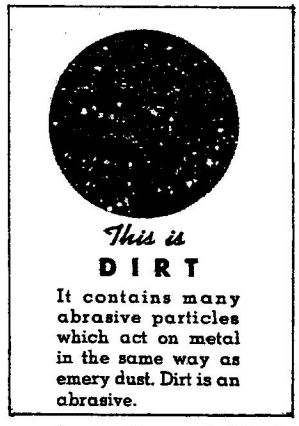

Figure 5 Action of Dirt on Ball Bearings

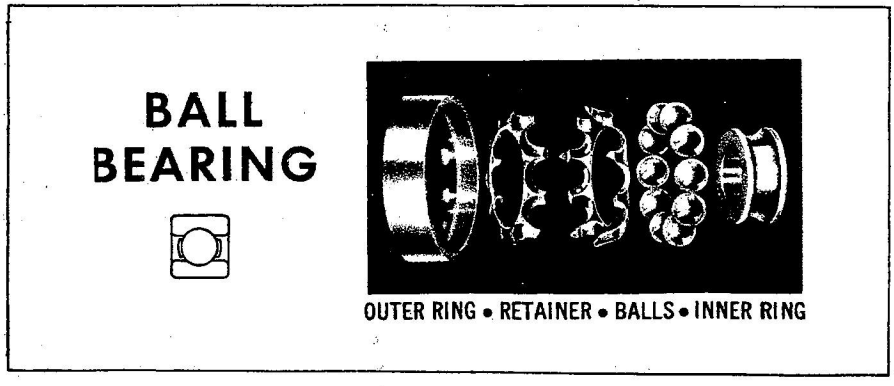

Figure 6 Ball Bearing-Outer Ring-Retainer-Balls-Inner Ring

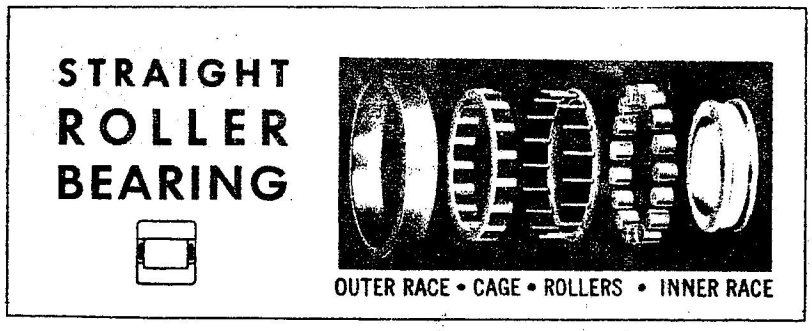

Figure 7 Straight Roller Bearing - Outer Race Cage-Rollers-Inner Races

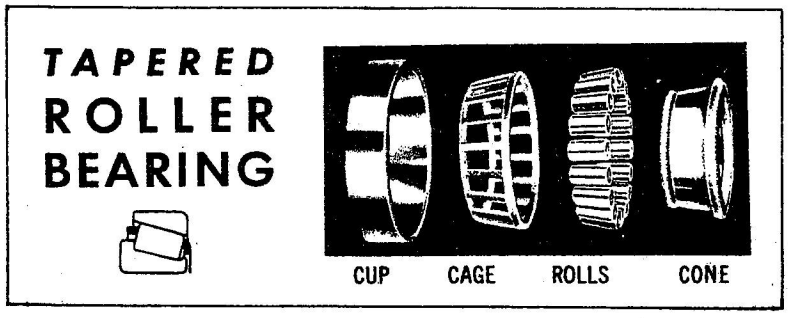

Figure 8 Tapered Roller Bearings - Cup-Cage-Rolls-Cone

WHY PRECISION IS IMPORTANT

See Fig. 3

4 From the illustration, it can be noted that it is easier to ride on a boulevard than it is to ride on cobblestones. For this reason, it is important that all bearings have as fine a raceway as possible and that no obstructions get in the way of the ball or roller in operation. Such obstructions can be defined as dirt, foreign matter, pits or flakes on the raceway and many other common causes of bearing failure.

(a) The rollers, balls and raceways of modern anti-friction bearings are among the finest and most accurate surfaces that are possible to produce. To make a modern bearing, accuracy to a few ten thousandths of an inch is required for most operations. Unless raceways are perfectly round and all exactly of the same size, a bearing is not only rough running but it wears out quickly.

WHY DIRT IS DANGEROUS

5 From Figs. 4 and 5, you will note the actual picture of emery dust and dirt on the raceway of a ball bearing.

(a) When foreign matter enters bearing, it immediately begins to cause excess wear on the microscopic smoothness of working surfaces. Once wear starts, fragments of metal, spalled off, speed up wear and presently, the surfaces of the races and balls are destroyed. If the bearing is kept absolutely clean, it will last almost indefinitely. A CLEAN BEARING DOES NOT WEAR. Dirt is the most common cause of bearing failure and the principal cause of wear.

BASIC PARTS OF AN ANTI-FRICTION BEARING

6 In Fig. 6, all of the component parts of bearing are removed and the individual parts are identified. Although there are many different types of ball bearings, yet the nomenclature of the individual parts remains the same and it is imperative that in the maintenance of bearings that all have the same idea about what retainer is and where it is placed in the complete bearing. The same condition applies to the other component parts of the bearing. The individual function of each part is self-explanatory. In Figs. 7 and 8, tapered roller bearing and straight roller bearings are broken down in the same manner. Note that for the most part the nomenclature is the same, but here the actual implication is more effective. When referring to a cage in a roller bearing, the part is immediately indentified, whereas if reference is made to a cage in a ball bearing there is considerable confusion and no one really under-

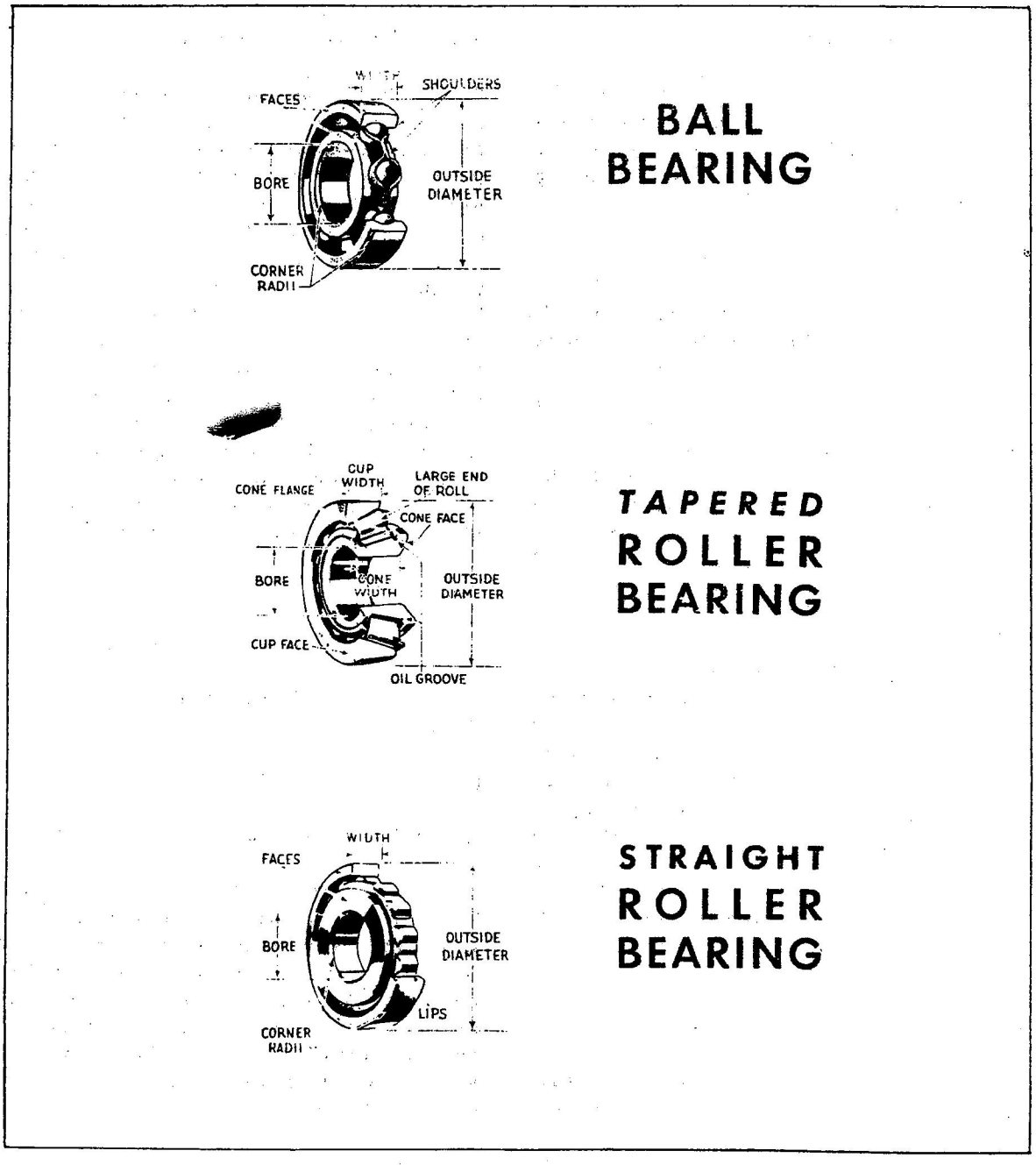

Figure 9 Ball Bearing - Tapered Roller Bearing Straight Roller Bearing

stands just what reference is made to. Personnel concerned in bearings should immediately acquaint themselves with this information.

TERMS AND NAMES - BEARING NOMENCLATURE

7 Fig. 9 gives a very vivid picture of the various references that can be made to parts of a bearing. It is imperative when reference is made to some component part of a bearing that correct terminology is used.

LOAD TRANSMISSION THROUGH BALL AND ROLLER BEARINGS, See Figs. 10 to 17

8 These diagrams illustrate how the load is transmitted through the moving parts of the bearing. Although the arrows are shown going in one direction, it can easily be seen that the load can pass in either direction. That is, a load on the housing can be transmitted to the shaft and a load on the shaft can be transmitted to the housing. Bearings seldom operate in actual service under pure thrust or pure radial load; most loads are combinations of the two.

(a) This picture of bearing load now becomes slightly complicated, as it is obvious how important it is to adjust the machinery and bearing to withstand the many complicated loads imposed. The actual flow of stress runs through the bearing as illustrated and it becomes obvious that proper installation and handling as well as a great amount of engineering all contribute to a near perfect operating ball or roller bearing. The following chart reveals the nature or load carrying capacity of various types of bearings by comparison:

Type	Thrust capacity is equal to the following part of the radial rating	Radial Rating
Single Row	75%	100%
Angular Contact	200%	100%
Double Row	100%	100%
Self-Aligning	10%	100%

(b) It is very easy to calculate by means of established formulae the nature of the complicated loads and just how much load can be imposed on a bearing in actual operation.

TYPES OF BEARINGS

Single Row Deep Groove, Fig. 18

9 This is the most popular type of single row bearing and is most flexible as to use. It contains as many balls as can be inserted by the Conrad Assembly method shown in the diagram. The inner ring is pushed to one side to permit insertion of the balls after which the rings are centered and the balls equally spaced around the rings by retainer. The line through the points of contact between the balls and the raceways is perpendicular to the shaft. It can carry high thrust loads because there is no filling notch and the grooves are deep. Radial capacity of this bearing is approximately 75% to 80% of radial capacity of maximum type single row bearings. The deep groove type is better suited to take a small amount of misalignment than the maximum type.

Applications

(a) Moderate radial loads.

(b) Moderate thrust loads in either direction.

(c) High speeds.

Single Row Maximum Type, Fig. 19

10 In order to obtain high radial capacity, this bearing has the maximum number of balls which can be introduced and still leave space for a retainer. This requires that a notch be cut in one side of both races through which the extra balls are inserted. Since this notch cuts away a part of the side of the raceway, it is not suitable for high thrust loads, nor is it suitable for pure thrust loads.

Applications

(a) Heavy radial loads.

(b) Moderate thrust loads in either direction.

(c) Moderate speeds.

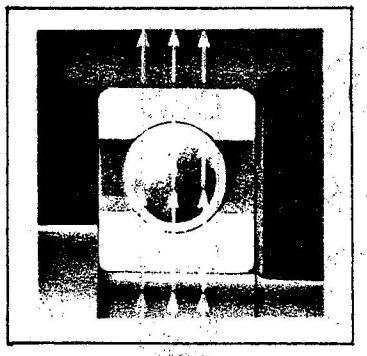

Figure 10 Radial Load

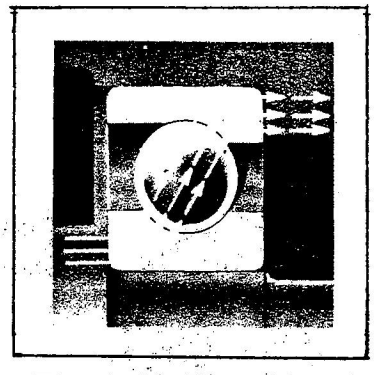

Figure 11 Thrust Load

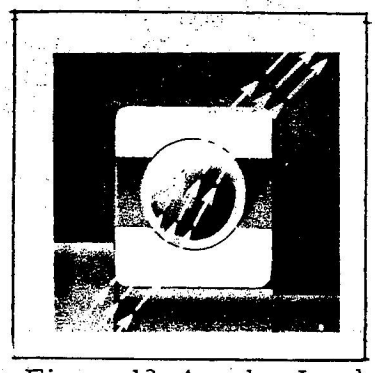

Figure 12 Angular Load

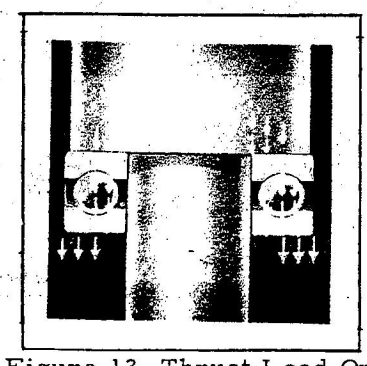

Figure 13 Thrust Load Only

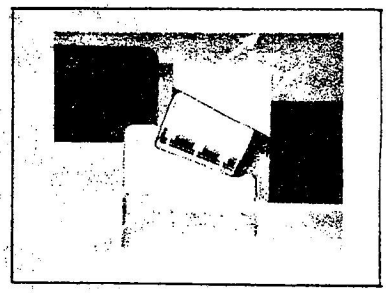

Figure 14 Angular Load

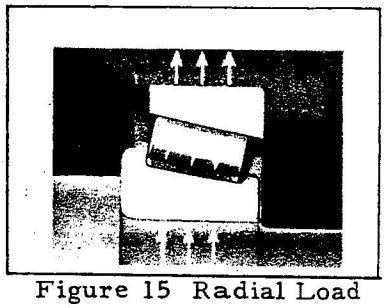

Figure 15 Radial Load

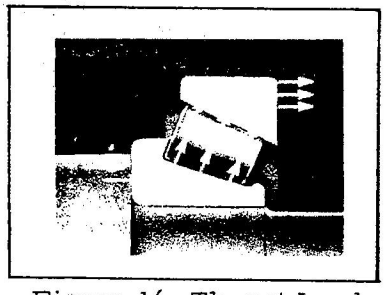

Figure 16 Thrust Load

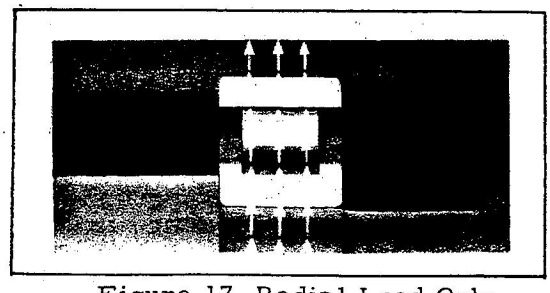

Figure 17 Radial Load Only

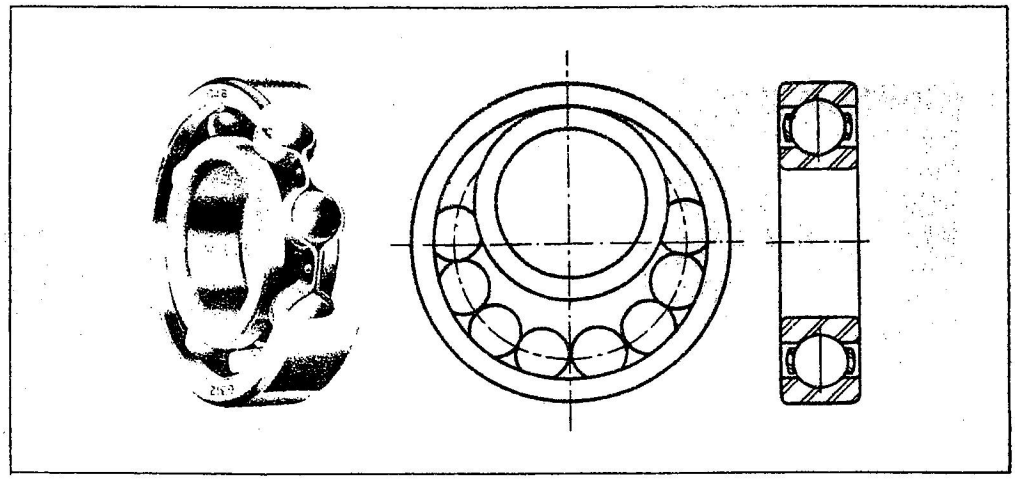

Figure 18 Conrad Assembly

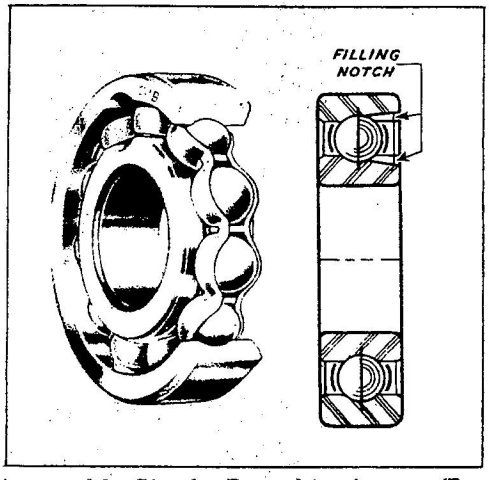

Figure 19 Single Row Maximum Type

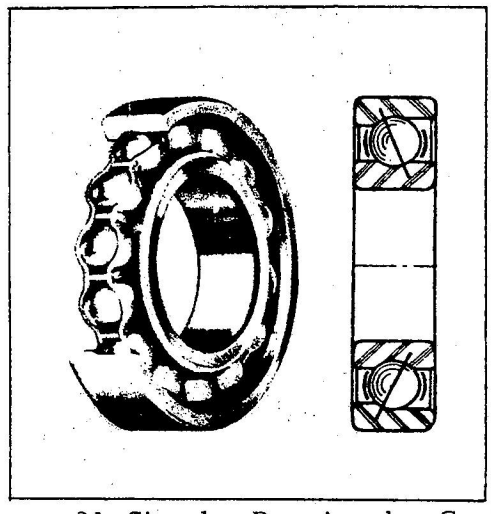

Figure 21 Singular Row Angular Contact

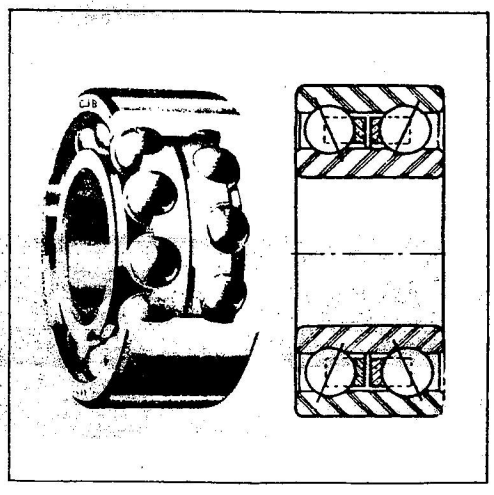

Figure 20 Double Row

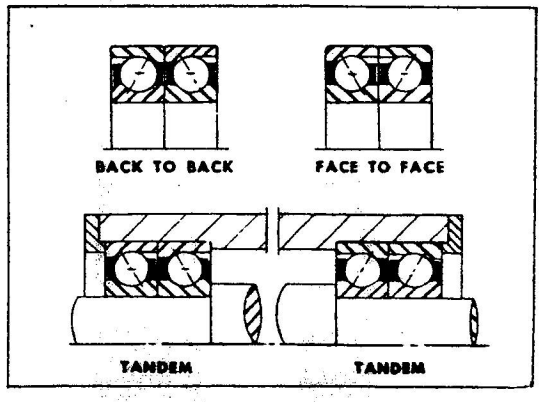

Figure 22 Duplex Bearings

Double Row, Fig.20

11 Both inner and outer rings have two grooves and the ball contact is at an angle similar to the angular contact type bearing. A double row bearing is slightly narrower than a pair of single row bearings and has slightly less capacity than two single row bearings. The thrust capacity is equal to the radial capacity.

Applications

(a) Heavy radial loads.

(b) Heavy thrust loads in either direction.

(c) Great axial rigidity.

(d) Great radial rigidity.

(e) Moderate speeds.

Single Row Angular Contact, Fig.21

12 The outer race has a deep shoulder on side and a shallow shoulder on the other instead of a notch so a maximum number of balls can be introduced when the outer race is expanded by heat. The ball contact is at an angle so the bearing can carry a high thrust load in one direction but none in the other. It is useful where thrust is all one way and radial load is heavy. It is usually mounted with another angular contact bearing at the other end of the shaft in opposition, also see duples, below.

Applications

(a) Heavy radial loads when combined with heavy thrust loads.

(b) Heavy thrust loads in one direction.

(c) Great rigidity.

(d) Used where adjustment is necessary.

(e) High speeds.

Duplex Bearings, Fig.22

13 A matched pair of angular contact bearings mounted face to face, back to back or in tandem to give minimum of shaft deflection and axial movement as in a machine tool spindle.

Applications

(a) Heavy radial loads.

(b) Heavy thrust in either direction.

(c) Extreme axial rigidity.

(d) Great radial rigidity.

(e) High Speed - Bearings of this type are often preloaded. That is to say that the bearings are designed to have a load imposed on them before they actually go into the application. The purpose is to allow the bearing to perform at its maximum efficiency which happens to be in a certain range after that predetermined load is imposed.

Self-Aligning Bearings, Fig.23

14 The inner ring has two raceways similar to a double row bearing. The outer ring has a spherical inner surface so the balls and inner race can pivot about the centre of the bearing. This lets the balls choose a path on the outer race to compensate for misalignment between shaft and housing.

Applications

(a) Where shaft or housing may run out of line.

(b) Moderate radial loads.

(c) Very light thrust loads in either direction

(d) Moderate speeds.

Thrust Bearings, Fig.24

15 The races resemble flat washers with a groove for the balls on one face. They handle maximum thrust loads but in one direction only. This bearing has no radial capacity. They are made both with and without retainers.

Applications

(a) Maximum thrust in one direction.

(b) Absolute axial rigidity in one direction.

(c) Moderate speeds.

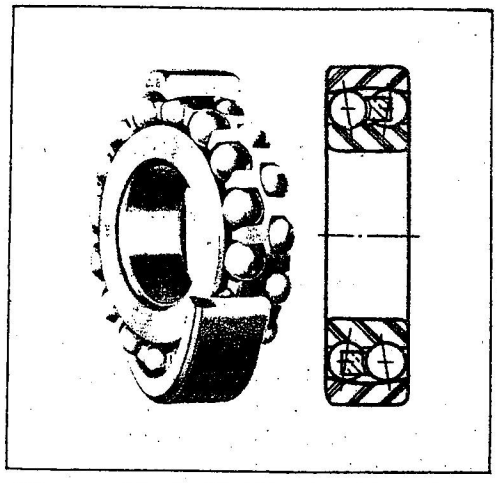

Figure 23 Self-Aligning Bearing

Grease Plate Bearings, Fig. 25

16 The following bearings might be called accessory types. They consist of standard types to which special devices have been applied to control lubrication, assist in mounting, etc. There are many variations of standard bearing types for special purposes and unusual uses but the types shown here represent those in most general use.

(a) A thin metal plate is swaged into a groove in the outer ring and runs with close clearance in a recess on the inner ring. A plate can be furnished on one or both sides (not positive seal). Double row bearings can be furnished with single or double plate. A single row bearing with one or two grease plates is the same width as a standard single row bearing, but the double row bearing with a grease plate is wider than a standard double row bearing.

Applications

(b) The following applications apply:

(1) Excludes large particles of foreign matter.

(2) Retains grease in bearing.

(3) Reduces the flow of lubricant through bearing.

Felt Seal, Fig. 26

17 A felt seal carried between two washers which are fixed in the outer ring rubs in a recess in the inner ring. This gives a more positive seal than with plates alone but it adds to the width of the bearing. Seals may be used on one side or on both sides as desired or with a grease plate on one side.

Applications

(a) When a grease plate is not adequate to retain the lubricant.

(b) Where a grease plate is not adequate to exclude dirt.

Snap Ring, Fig. 27

18 A split ring is snapped into a groove in the outer ring and serves to position the bearing in the housing. Obviously, it can carry only light thrust loads but it eliminates the need for machining a shoulder in the housing and makes assembly easy. Applicable to many types of bearings and is often used in combination with a single grease plate for automotive applications such as in the transmission.

Applications

(a) When it is desirable to eliminate the shoulder in the housing for simplicity of manufacture.

BALL BEARING NUMBERS, Figs. 28, 29 and 30

19 The principal types of ball bearings have long been made to international standards with respect to the external dimensions. Bores, ODs and sometimes widths are made to metric dimensions and thus they are not measured in even divisions of an inch but instead in millimeters.

(a) The bearing number is printed clearly on the outside of the box in which it is placed so that it will not be necessary to remove the oiled wrapping and expose the bearing to dirt. On the bearing itself the number is stamped on the faces of the races.

(b) The last two digits identify the bore size, Fig. 28. The accompanying table lists standard bore numbers and the corresponding bore dimensions. From "04" on up the bores increase in 5 mm. steps, and the bore can be determined by multiplying the bore number by 5

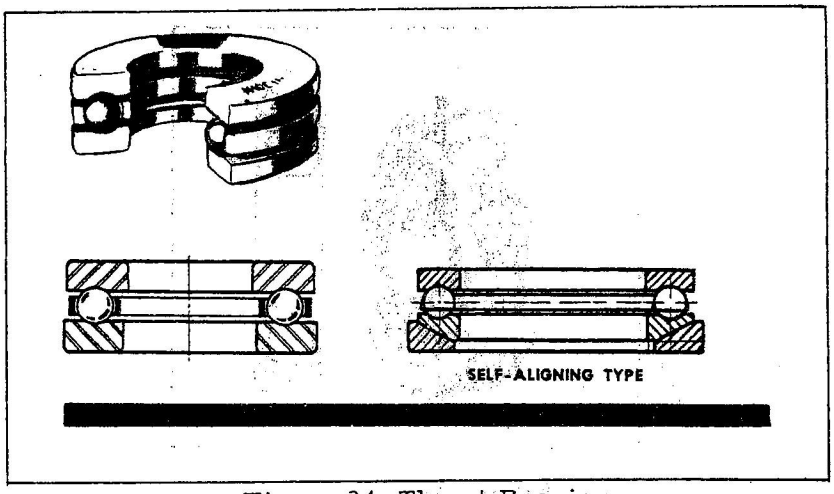

Figure 24 Thrust Bearing

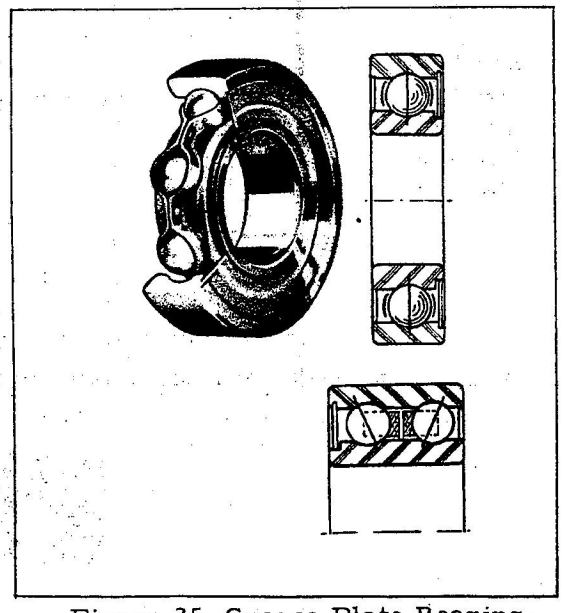

Figure 25 Grease Plate Bearing

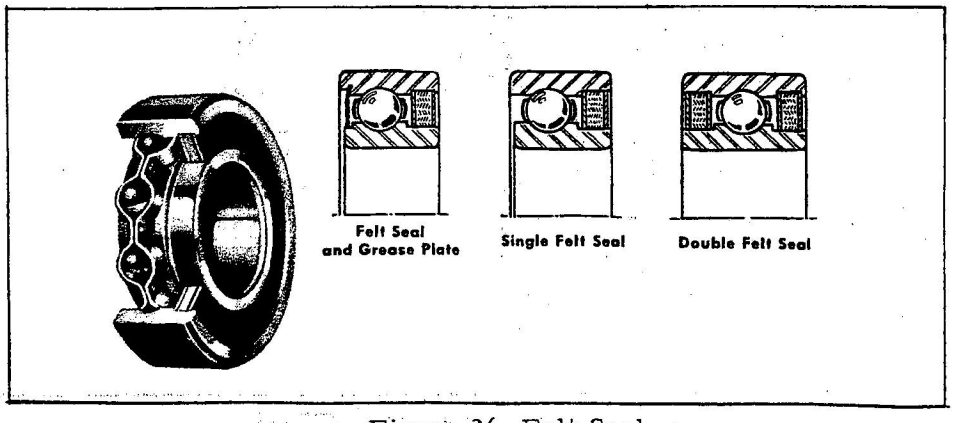

Figure 26 Felt Seal

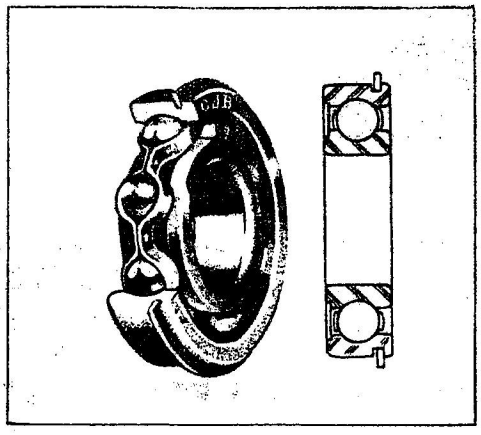

Figure 27 Snap Ring

09

THIS PART OF THE NUMBER INDICATES BORE SIZE

Bore Number	Bore Diameter Millimeters	Bore Diameter in Inches
0	10	.3937
1	12	.4724
2	15	.5906
3	17	.6693
4	20	.7874
5	25	.9843
6	30	1.1811
7	35	1.3780
8	40	1.5748
9	45	1.7717
10	50	1.9685
11	55	2.1654
12	60	2.3622
13	65	2.5591
14	70	2.7559
15	75	2.9528
16	80	3.1496
17	85	3.3465
18	90	3.5433
19	95	3.7402
20	100	3.9370
21	105	4.1339
22	110	4.3307

Figure 28 Ball Bearing Numbers

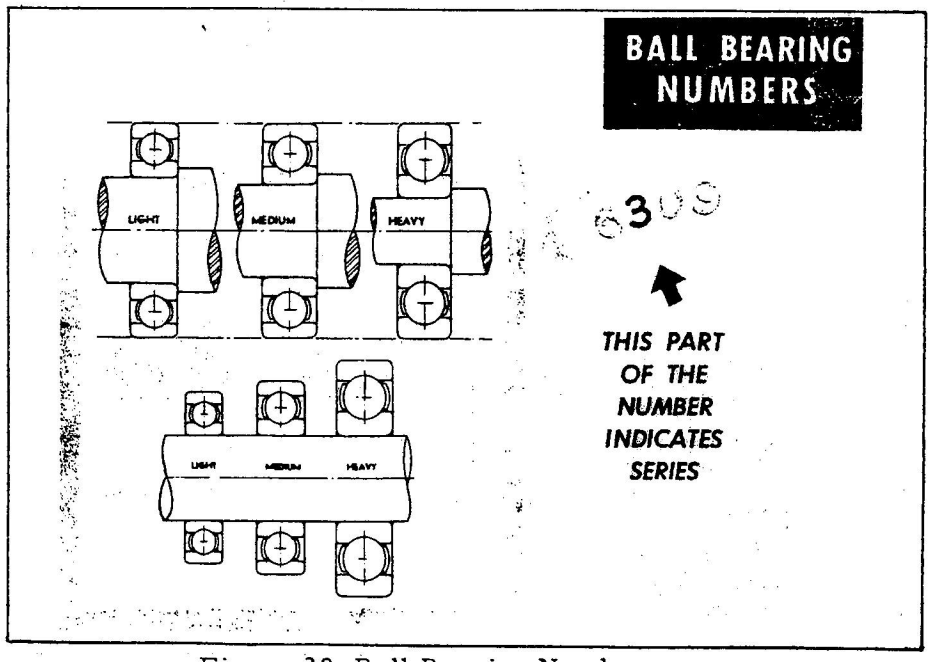

Figure 29 Ball Bearing Numbers

BALL BEARING EQUIVALENT LIST

Type	CJB Ahlberg	Norma Hoffmann	Fafnir	New Departure	S. K. F.
SINGLE ROW Deep Groove Type	6200 6300 6400	200 300 400	200-K 300-K 400-K	3200 3300 3400	6200 6300 6400
SINGLE ROW Maximum Ball Type	M-6200 M-6300 M-6400	MT-200 MT-300 MT-400	200-W 300-W 400-W	1200 1300 1400	
SINGLE ROW with Grease Seal	6200-G 6300-G 6400-G	200-P 300-P	200-WD 200-KD 300-WD 300-KD 400-WD 400-KD	7200 7500 7300 7600	6200-Z 6300-Z 6400-Z
SINGLE ROW with Snap Ring	6200-K 6300-K 6400-K	4200 4300	200-G 300-G 400-G	41200 43200 43500 41300 43300 43600	6200-NR 6300-NR
SINGLE ROW with Grease Seal and Snap Ring	6200-KG 6300-KG 6400-KG	4200-P 4300-P	200-DG 300-DG	47200 47500 47300 47600	6200-ZNR 6300-ZNR
SINGLE ROW Angular Contact	7200 7300 7400	100-AC 300-AC 500-AC	7200 7300 7400	0200 20200 0300 20300 0400 20400	7200 7300 7400
DOUBLE ROW	5200 5300 5400		5200 8200 5300 8300 5400 8400	200 5200 300 5300 400 5400	5200 5800 5300 5900 5400
DOUBLE ROW with Grease Seal	5200-G 5300-G 5400-G		5200-D 5300-D 5400-D	5500 5600 5700	75300
FRONT WHEEL Complete	1, 2, 3, etc.		10001, 10002, etc.	909001, 909002, 909003, etc.	909001, 909002, etc.
FRONT WHEEL Cone Cup Retainer	501, etc. 601, etc. 701, etc.		10501, etc. 10601, etc. 10701, etc.	909501, etc. 909601, etc. 909701, etc.	909501, etc. 909601, etc. 909701, etc.
SELF ALIGNING	1200 1300 400 2200 2300 1400	U-100 U-300 U-500 U-100-W U-300-W	L-200 L-300 L-400 L-6200 L-6300		1200 1300 400 2200 2300 1400
SELF ALIGNING Adapter Type	1500 1600	UT-100 UT-300	L-5500 L-6600		1500 1200-K 1600 1300-K
SELF ALIGNING Extended Cone	EC-13, etc.				X-13, etc. 1-71200, etc. 1-71500, etc.
SINGLE ROW Tapered Bore	6200-T 6300-T		5500-A 6600-A		6600

Type	M. R. C.	S. R. B.	Gurney	Strom	Federal	CJB Ahlberg
SINGLE ROW Deep Groove Type			200-C 300-C 400-C	200 300 400	1200 1300 1400	6200 6300 6400
SINGLE ROW Maximum Ball Type	200 300 400	200 300 400	200-R 300-R 400-R	200-M 300-M 400-M	1200-M 1300-M 1400-M	M-6200 M-6300 M-6400
SINGLE ROW with Grease Seal	200-F 300-F 400-F				1200-F 1300-F 1400-F	6200-G 6300-G 6400-G
SINGLE ROW with Snap Ring	200-G 300-G 400-G				1200-G 1300-G 1400-G	6200-K 6300-K 6400-K
SINGLE ROW with Grease Seal and Snap Ring	200-FG 300-FG 400-FG				1200-GF 1300-GF	6200-KG 6300-KG 6400-KG
SINGLE ROW Angular Contact	200-R 7200 300-R, 7300 400-R 7400		200-RT 300-RT 400-RT	5200 5300 5400	7200 7300 7400	7200 7300 7400
DOUBLE ROW	5200 5300 5400	200-D 300-D 400-D	200-D 5200-R 300-D 5300-R 400-D 5400-R	1200 5200-A 1300 5300-A 1400 5400-A	5200 5300 5400	5200 5300 5400
DOUBLE ROW with Grease Seal	5200-F 5300-F 5400-F				5200-F 5300-F 5400-F	5200-G 5300-G 5400-G
FRONT WHEEL Complete	1, 2, 3, etc.				F-001, etc.	1, 2, 3, etc.
FRONT WHEEL Cone Cup Retainer	501, etc. 601, etc. 701, etc.				F-501, etc. F-601, etc. F-701, etc.	501, etc. 601, etc. 701, etc.
SELF ALIGNING					1200-SA 1300-SA 1400-SA 2200-SA 2300-SA	1200 1300 400 2200 2300 1400
SELF ALIGNING Adapter Type					1500-X 1600-X	1500 1600
SELF ALIGNING Extended Cone						EC-13, etc.
SINGLE ROW Tapered Bore	200-X 300-X				1200-X 1300-X	6200-T 6300-T

Figure 30 Ball Bearing Equivalent List

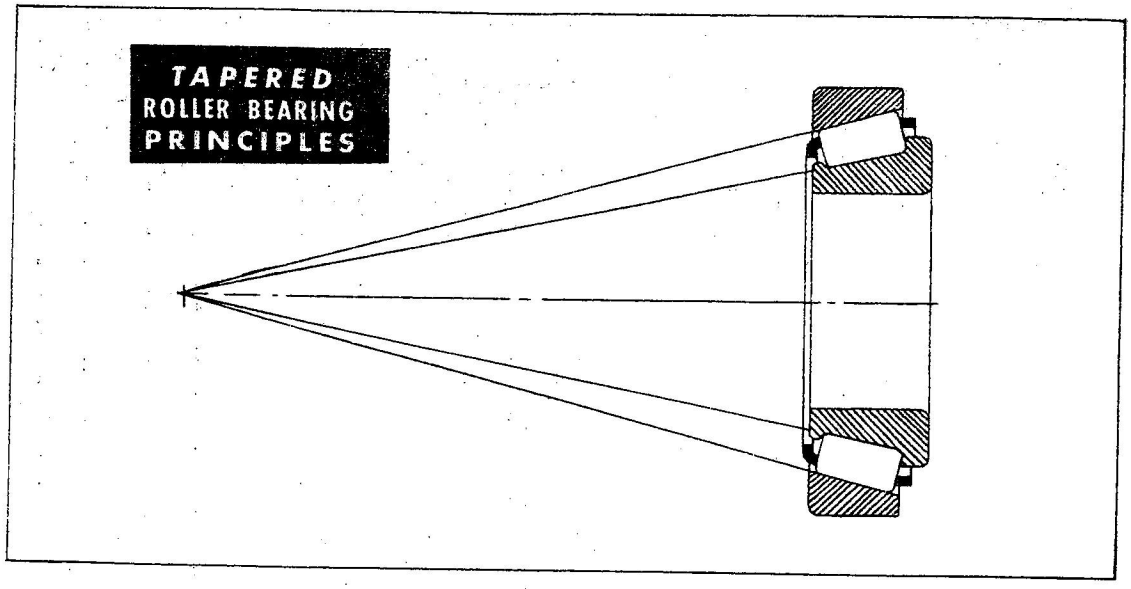

Figure 31 Tapered Roller Bearing Principles

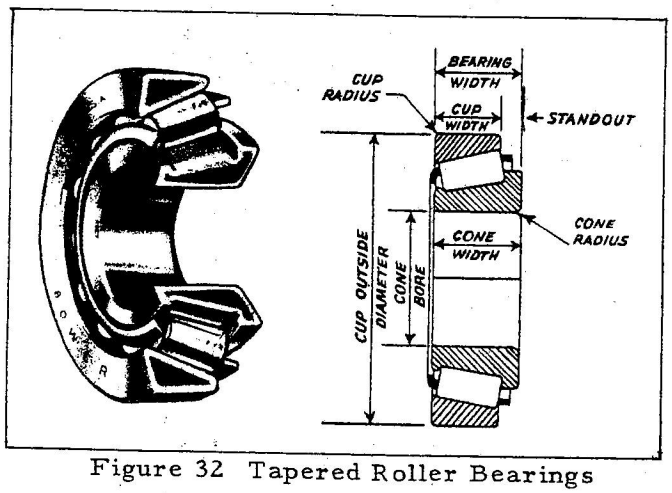

Figure 32 Tapered Roller Bearings

which gives the bore dimension in millimeters. For example, "05" indicates a 25 mm. bore, and "15" a 75 mm. bore, etc. Note that this does not apply to "03" and smaller bearings. The third from the last digit indicates the series to which the bearing belongs, 200 for the Light Series, 300 for the Medium Series and 400 for the Heavy Series, Fig. 29. The illustration shows the comparative proportions of the three series. The proportions are so arranged that three different outside diameters are available for a given shaft size and also, three different shaft sizes are available for a given outside diameter. The above numbering systems are standardized by ball bearing manufacturers, but any additional numbers or letters that may be used are not standardized. See Fig. 30 for a chart of the comparative numbers used by various manufacturers.

TAPERED ROLLER BEARINGS

Figs. 31 and 32

20 The basic principal of the tapered roller bearing is that true rolling motion is obtained by constructing the working surfaces of the cup, cone, and rolls with tapered sections. Notice that lines drawn through the working surfaces between the cone and rolls meet at the same point on the centerline of the bearing and form a cone. The shoulder or flange on the inner race serves to keep the rolls properly aligned.

(a) This tapered construction results in high thrust capacity in one direction only as well as high radial capacity. Also, due to this tapered construction, any radial load creates a thrust reaction which must be taken by another tapered roller bearing mounted in opposition. Therefore, except for very unusual applications tapered roller bearings must always be mounted in pairs.

(b) Tapered roller bearings are divided into groups which are called series and each series is assigned a basic series number. Series numbers have no significance except as a means

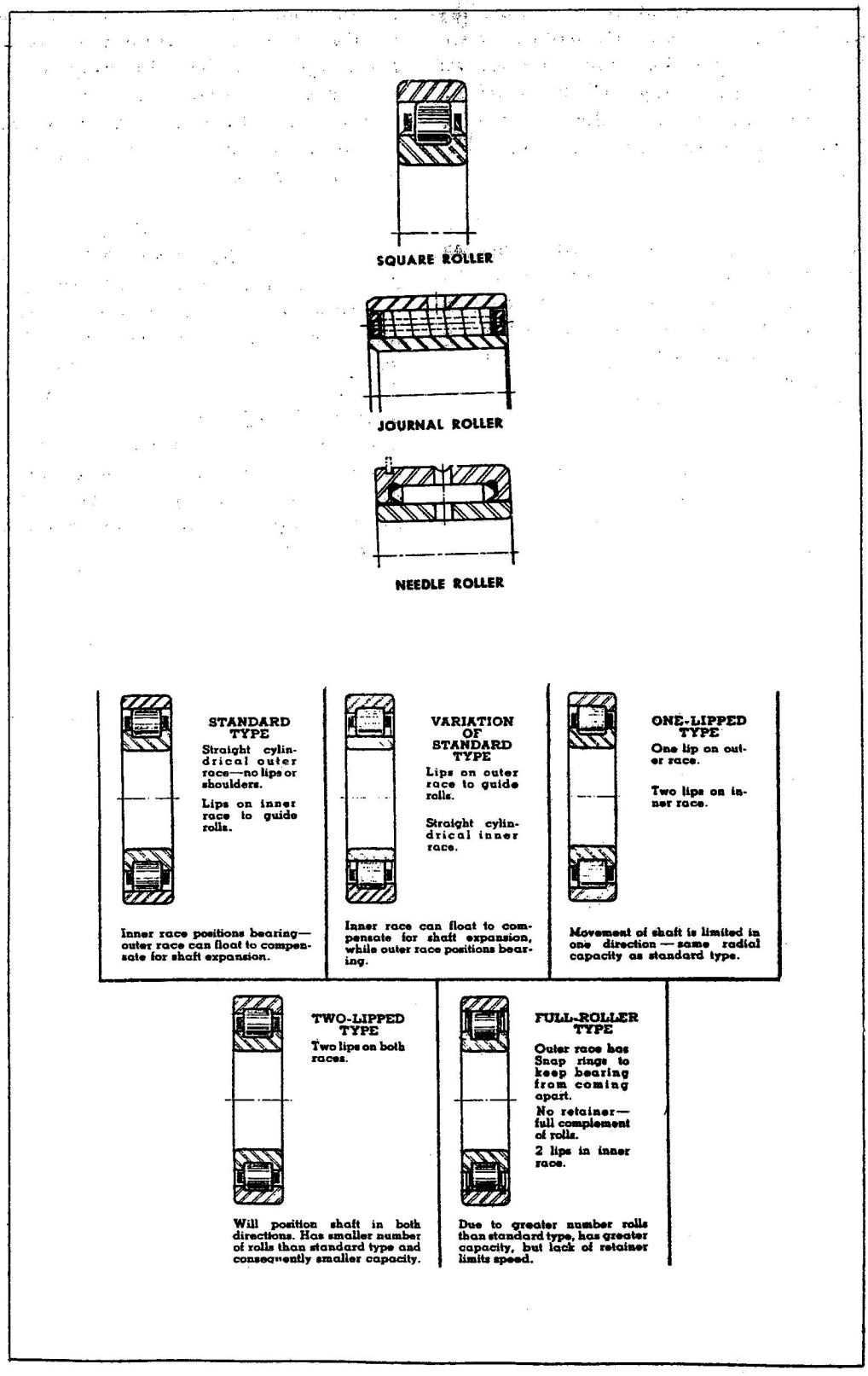

Figure 33 Straight Roller Bearings

of identification. Each size of cup and cone has its own number which is a variation of the basic series number. Each number must be known to identify a complete bearing. All the bearings in any one given series have the same size rolls, the same cage and the same internal construction.

(c) Even though the load capacities within a given series of bearings may be the same, it has been established that the cup of one manufacturer should not be installed with the cone of another manufacturer. Installation must be by matched sets only.

STRAIGHT ROLLER BEARINGS

Fig. 33

21 This group of bearings gets its name from the fact that the bearings are made to metric dimensions the same as ball bearings. Generally, external dimensions are the same as for single row ball bearings and the bearings are interchangeable as far as dimensions are concerned. However, these bearings, as with all straight roller bearings, are suitable for radial loads only.

BALL AND ROLLER BEARING EQUIVALENT LISTS

22 All ball and roller bearings are made according to special predetermined dimensions and therefore are interchangeable providing the same size and typw of bearing is interchanged. By referring to Fig. 30, you will note that the series of major bearing companies are listed and it is simply a matter of reference to interchange one bearing to the other. The last two digits in the bearing number is always the same as it designated the bearing bore in millimeters.