AEROSPACE INFORMATION REPORT	**AIR1594™**	**REV. C**
	Issued 1981-08 Revised 2010-07 Reaffirmed 2015-11 Superseding AIR1594B	

Plain Bearing Selection for Landing Gear Applications

RATIONALE

AIR1594C has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE

This document is intended to give advisory information for the selection of plain bearings and bearing materials most suitable for aircraft landing gear applications. Information included herein was derived from bearing tests and service experience/reports. Airframe/landing gear manufacturers, commercial airlines, the U.S. Air Force and Naval Air Systems Command provided input for the document.

Information is given on bearing installation methods and fits that have given satisfactory performance and service life.

Base metal corrosion is a major cause of problems in bearing installations for landing gears. Therefore, methods of corrosion prevention are discussed.

Effort is directed toward minimizing maintenance and maximizing life expectancy of landing gear bearings. Lubricated and self-lubricating bearings are also discussed.

There are wide ranges of bearing load and motion requirements for applications in aircraft landing gears. For this reason, it is the responsibility of the designer to select that information which pertains to the particular application.

Anti-friction bearings, defined as rolling element bearings generally used in wheel and live axle applications, will not be discussed in this document.

Landing gear shock strut bearing design and selection criteria are covered in AIR5883 and, therefore, are not discussed in detail in this document.

1.1 Purpose

This document is to be used as a general reference for the aerospace community.

2. REFERENCES

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AMS4533 Copper-Beryllium Alloy, Bars and Rods 98Cu - 1.9Be Solution and Precipitation Heat Treated (TF00, formerly AT)

AMS4534 Copper-Beryllium Alloy, Bars and Rods 98Cu - 1.9Be Solution Heat Treated, Cold Worked, and Precipitation Heat Treated (TH04, formerly HT)

AMS4535 Copper-Beryllium Alloy, Mechanical Tubing 98Cu - 1.9Be Solution and Precipitation Heat Treated (TF00, formerly AT)

AMS4590 Extrusions, Nickel-Aluminum Bronze, Martensitic, 78.5Cu - 10.5Al - 5.1Ni - 4.8Fe, Quenched and Tempered (TQ50)

AMS4596 Copper Nickel Tin Alloy, Bars, Rods, and Tubes, 77Cu - 15Ni - 8Sn Solution Annealed and Spinodal Hardened (TX00)

AMS4597 Copper-Nickel-Tin Alloy, Bars and Rods 77Cu - 15Ni - 8Sn Solution Annealed, Cold Finished and Spinodal Hardened (TX TS)

AMS4640 Aluminum Bronze, Bars, Rods, Shapes, Tubes, and Forgings 81.5Cu - 10.0Al - 4.8Ni - 3.0Fe Drawn and Stress Relieved (HR50) or Temper Annealed (TQ50)

AMS4880 Aluminum Bronze Alloy, Centrifugal and Continuous-Cast Castings 81.5Cu - 10.3Al - 5.0Ni - 2.8Fe Quench Hardened and Temper Annealed (TQ50)

AMS4881 Nickel-Aluminum-Bronze, Martensitic, Sand and Centrifugal Castings 78Cu - 11Al - 5.1Ni - 4.8Fe Quench Hardened and Temper Annealed

AMS5643 Steel, Corrosion-Resistant, Bars, Wire, Forgings, Tubing, and Rings, 16CR - 4.0Ni - 0.30Cb - 4.0Cu Solution Heat Treated, Precipitation Hardenable

AS14101 Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, Narrow, Grooved Race, -65 to +325 °F

AS14102 Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, Wide, Chamfered Race, -65 to +325 °F

AS14103 Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, Wide, Grooved Race, -65 to +325 °F

AS14104 Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, Narrow, Chamfered Race, -65 to +325 °F

AS21230 Bearing, Plain, Self-Aligning, Grooved Outer Ringer TFE Lined, Wide

AS81820 Bearings, Plain, Self-Aligning, Self-Lubricating, Low Speed Oscillation

AS81934 Bearings, Sleeve, Plain and Flanged, Self-Lubricating

AS81934/1 Bearing, Sleeve, Plain, Self-Lubricating, -65 °F to 325 °F

AS81934/2 Bearing, Sleeve, Flanged, Self-Lubricating, -65 °F to 325 °F

AS81935 Bearings, Plain, Rod End, Self-Aligning, Self-Lubricating, General Specification For

AS81936 Bearings, Plain, Self-Aligning, (Cu-Be Ball, CRES Race), General Specification For

AIR5883 Landing Gears Shock Strut Bearing Selection

ARP5935 Use of HVOF Thermal Spray Coatings for Hard Chrome Replacement in Landing Gear Applications

2.2 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI B4.1 Preferred Limits and Fits for Cylindrical Parts

2.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 15428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 1417 Standard Practice for Liquid Penetrant Testing

ASTM E 1444 Standard Practice for Magnetic Particle Testing

2.4 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-B-8942 Bearings, Plain, TFE Lined, Self-Aligning

MIL-B-8943 Bearings, Journal, Plain and Flanged, TFE Lined

MIL-PRF-16173 Corrosion Preventative Compound, Solvent Cutback, Cold - Application

MIL-PRF-23827 Grease, Aircraft and Instrument, Gear and Actuator Screw

MIL-PRF-32014 Grease, Water Resistant, High Speed, Aircraft and Missile

MIL-PRF-81322 Grease, Aircraft, General Purpose, Wide Temperature Range

MIL-PRF-81733 Sealing and Coating Compound, Corrosion Inhibitive

MMPDS Metallic Materials Properties Development and Standardization

2.5 Definitions

A landing gear bearing is a component which, when installed between two or more landing gear structural members having relative motion, can perform the following functions:

a. Transmit loads between those members (moving or stationary).

b. Control the friction coefficient of the joint.

c. Control the wear of the joint.

d. Protect the primary component - act as a sacrificial part.

3. PLAIN BEARING CONFIGURATIONS

Plain bearings are those bearings whose interface motions are sliding actions between two parallel surfaces. Bearings falling within this classification can carry radial and/or thrust loads and accommodate motion. The bearing configurations most widely used in landing gear applications are journal, spherical, and thrust. These bearings can be lubricated or self-lubricating configurations.

3.1 Journal Bearings (Bushings)

This configuration consists of a cylindrical shell (with or without a flange) installed in a housing in conjunction with a mating pin or bolt. These bearings are used in pinned joints of landing gear mechanisms and structures. They can be highly loaded when there is no joint rotation and less loaded when oscillatory motion is present such as during landing gear retraction and extension. Axially sliding sleeve journals are used in shock struts and hydraulic actuators. Figure 1 is an example of a typical landing gear journal bearing illustrating both a plain and flanged bearing on the same diagram.

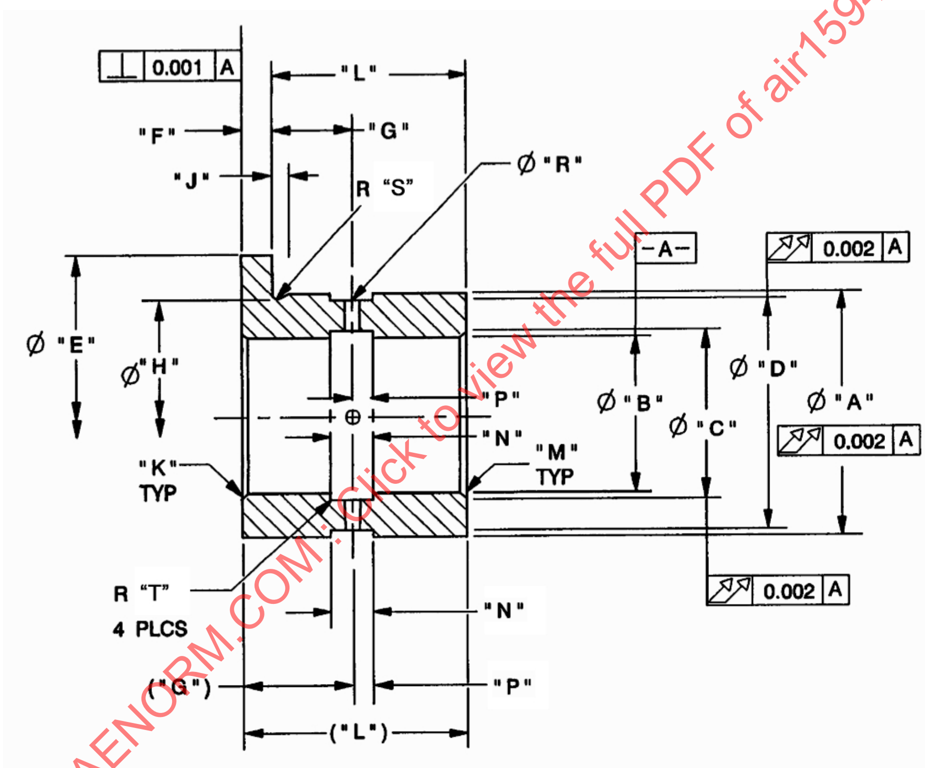

FIGURE 1 - TYPICAL LANDING GEAR JOURNAL BEARING

3.2 Spherical Bearings

This bearing configuration is an integral unit in which a spherically shaped (ball) inner race is free to rotate and misalign within the confines of the outer race. The spherical interface will provide for misalignment of joined members and allow for rotary motion. The design will function under both radial and thrust loads. It is desirable for the rotary motion to take place between the ball and the outer race of the bearing (lower bearing stress) to avoid galling of the mating pin. To this end, the most common installation, the ball side faces (or bushing sleeve at the ball center) are clamped to the mating pin. The ball may be greased or lined with a low friction material.

3.3 Thrust Bearings

Thrust bearings, as the name implies, are designed to carry thrust loads. Although they may be a separate bearing, they are frequently integrated into a journal bearing as a flanged face.

4. LANDING GEAR BEARING CONSIDERATION

In the selection of any landing gear bearing or bearing material, the following application parameters must be considered.

a. Environmental conditions including exposure to dirt, water or other contaminants

b. Applied loads (radial, thrust, moment, static, dynamic, and shock)

c. Required service life or service time between overhauls

d. Velocity/duration of relative motion causing frictional heat buildup

e. Lubrication requirements

f. Misalignment possibilities

g. Envelope restrictions

h. Type of application (static, oscillatory, slow motion)

i. Retention methods

j. Position accuracy (radial and axial)

k. Maintenance (must be lubricated, repaired or replaced)

l. Installation (expansion characteristics, allowable looseness, pre-load requirements)

m. Friction, torque (starting and dynamic)

n. Weight

o. Dissimilar materials (provisions for galvanic action)

p. Same materials are avoided for bearings sliding in contact for frictional issues and welding potential

q. Material selection. Similar materials in contact (such as corrosion resistant alloys) are avoided for galling considerations. However, self-lubricating bearings and mating shafts are made from corrosion resistant alloys since there is a lubricating barrier between the mating surfaces.

r. Temperature minimum and maximum

s. Housing material rigidity and stiffness.

t. Running fit per ANSI B4.1.

5. MATERIAL SELECTION FOR LUBRICATED BEARINGS

Based on experience and laboratory testing, the following materials are those used for bearing applications in landing gears (Reference Tables 1 and 2). The mating pin or shaft wear surface, in most cases, is steel with 0.003 in (0.07 mm) minimum chrome plating or tungsten carbide (WC-Co or WC-Co-Cr) coating thickness.

5.1 Journal and Thrust Bearings

There are several materials suitable for lubricated journal bearing use such as aluminum nickel bronze. These journal bearings are often used in conjunction with high strength-chrome plated or WC-Co High Velocity Oxygen Fuel (HVOF) steel pins. Where two journal bearings move relative to one another, aluminum-nickel-bronze is often used in combination with Corrosion Resistant Steel (CRES) or equivalent to prevent galling. It has been shown that coating and finish grinding both mating faces with WC-Co HVOF coatings produces excellent wear properties without galling and allows the use of aluminum nickel bronze for both journal bearings, Also, laboratory tests and service usage indicate that unique journal bearing lubrication grooves improve lubrication properties and minimize wear in service.

5.2 Spherical Bearings

There are several materials suitable for lubricated spherical bearing use such as softer metallic outer races with high strength-chrome plated steel balls. Some materials used are aluminum-nickel-bronze in combination with corrosion resistant steel (CRES) or low alloy steel heat treated to 275 ksi (1896 MPa). Also, laboratory tests and service usage indicate that another satisfactory combination for spherical bearings in the landing gear environment is a copper beryllium ball with a 17-4 PH CRES outer race (Reference AS81936, Be-Cu spherical bearing).

6. WORKING PRESSURES FOR LUBRICATED BEARINGS

6.1 Working Bearing Pressure

The maximum recommended bearing pressures at limit loads generally used for sizing bearings are listed in Table 1. Bearing surface roughness at sliding interfaces is commonly 16 to 32 micro-inch (0.4 to 0.8 micro-meter) Ra. Lower Ra values typically produce less wear in service as long as lubrication retention can be assured. Honing is a commonly used method to achieve superior surface finishes in small bearings. Additional bearing material information is given in Table 2. Aluminum bronze and copper beryllium and similar bearing materials have a higher coefficient of thermal expansion than steel. This characteristic should be considered during the bearing design at limit loads to prevent binding at adverse temperatures. Post installation sizing of the bearing inside diameter is used to ensure adequate bearing to pin clearance.

6.2 Thermal Considerations

Where high velocity and pressure between the bearing surfaces develops frictional heat in excess of 500 °F (260 °C), detrimental impact to landing gear components may occur from frictional burning below a chrome plated journal. In this application, tests have shown that bearings with self-lubricated liners are superior when compared with lubricated metal-to-metal sliding surfaces. Durability of these liners needs to be considered when used where high point loads may exist. The leading and trailing edges of such bearings should be chamfered or beveled to prevent peaking or edge loading. HVOF coatings such as WC-Co and WC-Co-Cr have better thermal properties than chrome and, therefore, may reduce the occurrence of frictional burning issues.

TABLE 1 - BEARING DESIGN GUIDE (LUBRICATED)

		Journal Bearings		Spherical Bearings (2)	
Materials		Aluminum Nickel Bronze	Beryllium Copper	Aluminum Nickel Bronze	Beryllium Copper
		AMS 4640	AMS 4533	AMS 4640	AMS 4533
		AMS 4880	AMS 4534	AMS 4880	AMS 4535
		AMS 4590*	AMS 4535	AMS 4590*	
		AMS 4881*		AMS 4881*	
Static Joint	Non-rotating movement under deflection e.g. trunnion pivot joints under 1g static load	50 - 80 ksi (414 - 552 MPa) (1)	60 - 90 ksi (414 - 620 MPa) (1)	47 ksi (324 MPa)	90 ksi (620 MPa)
	Slight rotation movement under load e.g. torsion links	45 - 60 ksi (310 - 414 MPa)	45 - 65 ksi (310 - 448 MPa)	47 ksi (324 MPa)	90 ksi (620 MPa)
Dynamic Joint	Rotating movement. Major portion of movement under normal operating pressure e.g. actuator pins	13 ksi (90 MPa)	13 - 15 ksi (90 - 103 MPa)	15 ksi (103 MPa)	20 ksi (138 MPa)
	Rotating movement. All movement under normal operating pressure e.g. truck pivot joints	10 ksi (69 MPa)	10 ksi (69 MPa)	10 ksi (69 MPa)	10 ksi (69 MPa)
Shock Strut Bearings	Upper and lower bearings under linear motion	Reference AIR5883	Reference AIR5883		

(1) Reference Table 2 Remarks for rationale. Lower range is typically used for new design and higher range for derivatives/re-design.
Reference is for solid ball. Split and slotted entry designs use lower pressure.
* AMS4590 and AMS4881 have better material properties than AMS4640 and AMS4880. They are used when a higher allowable is warranted, but cost more.

TABLE 2 - LANDING GEAR BEARINGS

Bearing Material	Remarks
Aluminum-Nickel-Bronze AMS 4640 Bar and Rod AMS 4880 Centrifugal Casting AMS 4590 Bar and Rod AMS 4881 Centrifugal Casting	A very good bearing material of moderate strength and wear resisting properties when properly lubricated. Suitable for slow intermittent rotation and oscillatory motions. (Note: there is no design limit data in MMPDS for Aluminum-Nickel-Bronze.) Requires lubrication. Material will gall but not readily due to its moderate lubricity. More expensive than aluminum bronze. Centrifugal castings are used in large bearing diameters to minimize costs, but due to equivalent properties are used in smaller diameters as well. Typically the housing interface surfaces of this material are cadmium plated or IVD aluminum coated and primed and further protected with a corrosion preventative compound to minimize galvanic attack. Oscillatory bearing wear testing indicates that these alloys offer equivalent wear characteristics to beryllium copper for loads up to 45 ksi bearing pressure, without the environmental concerns and global material restrictions of beryllium copper. AMS 4590 and AMS 4881 alloys offer improved strength properties over AMS 4640 and AMS 4880 and are used when envelope restrictions cause increased joint loading and for oversize repair bearings.
Copper Beryllium AMS 4535 (TF00) Tubing AMS 4533 (TF00) Bar and Rod AMS 4534 (TH04) Bar and Rod	A good bearing material of exceptionally high strength and wear resisting properties when properly lubricated. Suitable for slow, intermittent rotation and oscillatory motions. It has good heat transfer properties. It tends to resist galling; however, in the absence of a lubrication film at high stress conditions galling is probable. The full high strength tempers (TF00 and TH04) offer the greatest load capability with limited ductility. Higher ductility tempers are available for journal bearings, which are mechanically formed into place during installation. Material costs are generally significantly higher than aluminum-nickel-bronze or aluminum-bronze. It is used when dictated by size and envelope limitations such as exist in some redesign efforts. A-Basis design limits are available in MMPDS. Typically the housing interface surfaces of this material are cadmium plated or IVD aluminum coated and further protected with a good corrosion preventative compound to minimize galvanic attack. The material has significant environmental impact issues, is banned for use in many locations and, therefore, is not often used for new design.
Copper Nickel Tin AMS 4596 AMS 4597	This bearing material may offer an environmentally compliant replacement to beryllium copper of exceptionally high strength and properties. Preliminary testing indicates it provides the best bearing material properties with a 3 - 10% minimum elongation (depending on temper), but there is insufficient service data to indicate if the material is acceptable in the field. The material should be suitable for slow, intermittent rotation and oscillatory motions, and tends to resist galling. Material costs are significantly higher than aluminum nickel bronze but may required in some redesign efforts due to size, envelope and environmental limitations.
17-4 PH CRES AMS 5643 Bars, and Tubing	An undesirable bearing material of exceptionally high strength. Suitable primarily for static joints and intermittent rotation and oscillatory motions where high load carrying capability is required while allowing relative motion against another high load bearing material such as beryllium copper. The material galls readily and in the absence of a lubrication film at high stress conditions galling will be excessive. Material costs are significantly higher than aluminum nickel bronze and may require some redesign efforts due to size, envelope and environmental considerations. A-Basis design limits are available in MMPDS. Typically the housing interface surfaces of this material do not require cadmium plating or IVD aluminum coating and are passivated and coated with a good corrosion preventative compound unless the material is to be installed in an aluminum housing.

7. HOUSING FITS FOR JOURNAL BEARINGS

Journal bearings, plain or flanged, are installed with interference fits for retention in the housing. The standard interference fit for 2.00 in (50.8 mm) and greater diameter is 0.001 in/in (0.0254 mm/mm) diameter plus an additional 0.002 inch (0.051 mm) disregarding bore or bushing plating thickness up to 0.0003 in (0.008 mm) per plated surface. For diameters less than 2.00 in (50.8 mm), the interference should be 0.001 in/in (0.0254 mm/mm) diameter and the additional 0.002 in (0.051 mm) should be proportionally reduced until it is eliminated for a 1.00 in (25.4 mm) diameter. In addition when selecting an interference fit, consideration should be given to:

- Hoop stresses generated by the interference fit (including temperature effects)
- Temperature limitation during the installation process
- Material temperature limitation (especially on aluminum)
- Effect on shot peened surfaces (higher temperature may reduce the benefits of shot peening)

One method of assembly is the temperature differential method where the bearing is cooled with dry ice (-98 °F/-72 °C) or liquid nitrogen (-340 °F/-207 °C) for extreme conditions to -340 °F (-207 °C) . The housing may be heated up to 200 °F (93.3 °C) as required. If materials go through a transformation/phase change after freezing with liquid nitrogen, verify no degradation in material properties will occur. Reference Figure 2 for proper temperature for bushing and substrate material at different bearing sizes. Provisions for holding the bushings in position during temperature stabilization are required. Usually bearing inside diameters require sizing after temperature stabilization for good alignment and clearance conditions, and to obtain the proper surface finish.

Proper tooling is required to perform assembly by temperature differential. Special consideration should be given to the warm-up time between removing the bushing from the cooling source and the installation to avoid jamming of the bushing before it is completely seated.

8. BEARING TO PIN CLEARANCES

The clearance between the pin or shaft and the bearing is commonly in the range defined by ANSI B4.1 RC5 or RC6 for landing gear applications. For self-lubricating bearings, the typical clearance between the shaft and bearing (bushing) is 0.001 inch (0.025 mm) of diametrical clearance per 1 inch (25.4 mm) of diameter with a minimum of 0.001 inch (0.025 mm) of clearance.

9. CORROSION PREVENTION

On modern aircraft landing gear installations, the most frequent damage found in service and at landing gear overhaul is corrosion in lugs and fittings in which bearings are assembled.

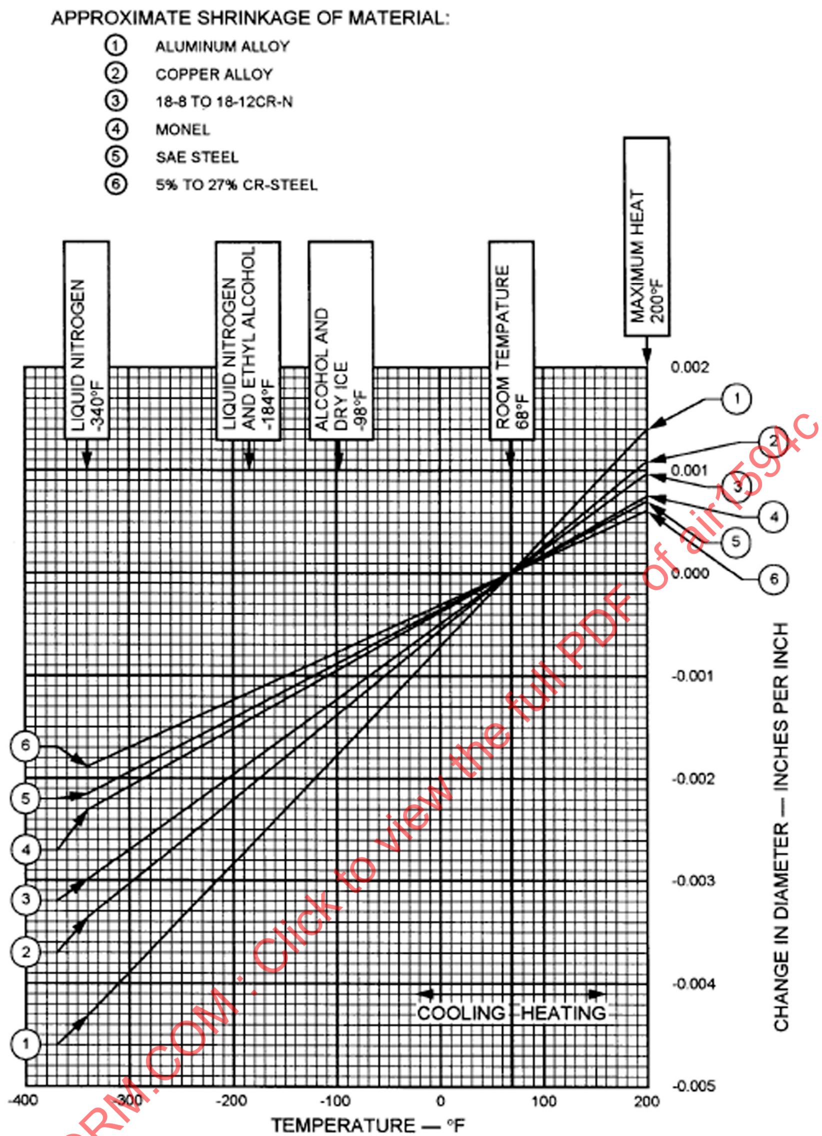

FIGURE 2 - SUB-ZERO INSTALLATION OF BEARINGS

9.1 Potential Corrosion Causes

a. Entrapment of moisture between the mating surfaces of the lug and bearing. Fillet sealing bearings using fuel tank sealing compounds such as MIL-PRF-81733 promote moisture entrapment if the sealing becomes brittle over time.

b. Lug deflection or stretch ovalization during application of loads allowing moisture ingress.

c. Depletion of corrosion protection plating due to chemical action or wearing due to lug and bearing flange deflections or vibration fretting. This is especially true for split bearings that are not secured with an interference fit.

d. Unit loading beyond the stress corrosion threshold of lug or fitting. Commonly accepted design criteria for 1g sustained stresses is less than one-half of Fty for the lug material at the bearing lug interface.

e. Lug or housing sectional stress discontinuity.

f. Bushing rotation or migration.

g. Inadequate, and breakdown or lack of lubricant.

9.2 Potential Corrosion Prevention Methods

a. Titanium-cadmium or non-embrittlement cadmium plating 0.0002/0.0003 in (0.0051/0.0076 mm) thick on the lug or fitting face, bore and chamfer. Cadmium plating 0.0002/0.0003 in (0.0051/0.0076 mm) thick on the bearing outside diameter and end faces. These platings can be as much as 0.0005 in (0.0127 mm) thick if the plating is considered in the interference fit sizing. Cadmium plating thickness, however, is not recommended to be taken into consideration as it is difficult to control in a production environment. Cadmium plated joint temperature is limited to 450 °F (232 °C) to avoid cadmium diffusion/embrittlement. IVD aluminum is considered an equivalent corrosion protection to non-embrittlement cadmium when applied per approved specification.

b. Zinc-Nickel plating 0.0003/0.0007 in (0.0076/0.0018 mm) thick on the bearing outside diameter and end faces.

c. Corrosion preventive compound MIL-PRF-16173 or equivalent covering housing bore before bearing insertion. Corrosion preventive compounds such as Cor-Ban 27L are widely used for this purpose and have proven to reduce corrosion vs. sealing bearings with a sealing compound. Ensure adequate corrosion preventive compound to fill cavity common to the bushing radius and lug chamfer.

d. Sealing compound equivalent to fuel tank sealant such as MIL-PRF-81733 is applied to housing face between housing and bearing flange for bearings that must not rotate, cannot have an interference fit, and are adhesively sealed in place. Care should be taken to prevent moisture from being trapped in the sealed joint. Also, with some joint designs it is feasible to coat the housing bore with sealant prior to inserting the bushing. Sealed joints must not be allowed to rotate. In the event the bearing rotates or the sealing compound becomes brittle and cracks, the joint is prone to more severe corrosion than if no sealant were used as it will entrap moisture in the joint.

NOTE: Some corrosion preventive compounds and the sealants are not compatible materials. Surfaces that have had a corrosion prevention compound applied must be thoroughly cleaned with an environmentally compliant cleaning solvent before sealant adhesion can be effective.

e. Hard chrome plating or nickel plating of bores and faces of the housing results in good corrosion protection. Bores and faces of housings can be plated with plate to size chrome or nickel and polished to finished dimensions followed by wiping with epoxy primer and allowed to cure fully. The chrome or nickel plating replaces the cadmium plating on the bores and faces of the housings. The chrome or nickel plate thickness is 0.0015 to 0.0025 in (0.0381 to 0.0635 mm). However, the structural fatigue lives of the high heat treated steel lugs and housings are reduced when compared with cadmium plated parts. The reduction in fatigue life can be as much as 60% unless the material process control includes such preventive measures as shot peen, bake, etc.

10. LUBRICATION

Bearing lubrication has three basic functions: To provide a means of resisting adhesion between mating surface protrusions, to provide a low shear film to minimize the coefficient of friction, and to provide a corrosion resisting medium.

Provisions must be made so that lubrication of the landing gear can be accomplished with the weight of the aircraft resting on the landing gear.

Lubrication grooves should be arranged so pins or shafts are wiped with grease from the grooves. Lubrication paths in the housing should be arranged such that, if the bearing rotates, lubrication is not shut off from the sliding surfaces.

All landing gear joints, both static and dynamic, should be considered for lubricating provisions. A lubricator fitting should be provided for each surface to be lubricated. Service experience indicates that bearing/pin joins lubricated through grease passages in the substrate lug provide better lubrication than grease passages in the joint pin. If the lubricated surface is in close proximity to a non-metallic seal, the lubricant and seal material compound must be checked for compatibility.

For critical applications it is common to dedicate one lubrication passage per joint. Having multiple passage greasing routes cannot always guarantee lubrication to all the joints. Multiple fittings per joint are usually avoided as the spare unused fitting may promote inservice corrosion.

The lubricants most widely used are aircraft greases according to MIL-PRF-23827 and MIL-PRF-81322 or equivalents. These are general purpose greases for landing gears and other systems and mechanisms of the aircraft requiring periodic lubrication. In addition, new generation greases are being/have been developed that provide superior properties for this type of application such as better corrosion protection and low temperature performance. Aeroshell Grease 33 and MIL-PRF-32014 are examples of synthetic greases that do not absorb moisture.

Landing gear joints that are extremely highly loaded benefit from a high molybdenum content grease such as Royco 11MS. Care should be exercised in selecting a molybdenum grease. Molybdenum -disulfide grease such as MIL-G-21164 has excellent load carrying capability, but will absorb moisture in service and promotes joint corrosion.

11. SELF-LUBRICATING BEARINGS

11.1 Applications

Self-lubricating bearings are used in application where:

a. No scheduled maintenance is a requirement.

b. The bearing joint is inaccessible for lubricating purposes.

c. Loads and motions are within the allowable range.

d. Lubricated bearings are not practical.

e. Applications with high levels of vibration and/or dithering motion.

f. Limited rotational movement (no ability to wipe grease around).

Self-Lubricating bearings may not have the load carrying capability of lubricated bearings. The load carrying capability of various self-lubricating material vary widely. It is recommended to work with the self-lubricating bearing manufacturer to determine the appropriate load for a given material.

Performance of self-lubricated bearings can be aggravated by foreign particle contamination between the sliding surfaces, and excessive surface speeds which result in heat. Seals may be used to prevent contamination, however, the seals can trap the contaminants in the bearing resulting in additional bearing surface damage.

Experience indicates that bearing wear life is increased with better finishes on the surface that mates with the self-lubricating material. For example, small to medium size bearings should have a finish of 8 micro-inch (0.2 micro-meter) Ra and for larger bearings should be 16 micro-inch (0.4 micro-meter) Ra for practical manufacturing reasons in order to insure best bearing life. Likewise mating surface hardness can improve wear performance. It is recommended that the self-lube mating surface be Rc 40 or harder. The self-lube bearing manufacturer should be consulted for specific recommendations regarding mating surface condition at the design stage It should be kept in mind that the mating shaft for a self-lubricating bushing comprises one half of the bearing system, the bushing comprises the other.

Service experience indicates that self-lubricating bearings may tend to last longer than grease lubricated bearings. Grease lubricated bearings have corrosion issues, tend to damage mating shafts and migrate in housings. Self-lubricating bearings are made from corrosion resistant materials, and as long as care is taken on selection of materials to prevent galvanic corrosion, self-lubricating bearings tend to last longer. In addition, self-lubricating bearings typically have a lower and more consistent coefficient of friction as compared to lubricated bearings (typically .03 to .08 for self-lubricating as compared to .15 to .30 for lubricated bearings). This lower coefficient of friction is less likely to damage the mating shaft and also has a much reduced chance of having bearing migration in the housing. In applications where there is vibration or dithering motion, lubricated bearings normally have a greatly reduced life compared to self-lubricating bearings.