MIL-STD-1599
31 January 1980

MILITARY STANDARD

BEARINGS, CONTROL SYSTEM COMPONENTS, AND ASSOCIATED HARDWARE USED IN THE DESIGN AND CONSTRUCTION OF AEROSPACE MECHANICAL SYSTEMS AND SUBSYSTEMS

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31 January 1980

DEPARTMENT OF DEFENSE
Washington, DC 20360

Bearings, Control System Components, and Associated Hardware Used in the Design and Construction of Aerospace Mechanical Systems and Subsystems

MIL-STD-1599

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to ASD/ENESS, Wright-Patterson AFB, OH 45433 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

The purpose of this standard is to establish requirements for the selection and use of bearings, control system components, and associated hardware. The existing documentation on these components covers a great variety of configurations, stress, internal structure, performance variations, materials, and finishes. Of these varieties, many duplicate the fulfillment of design and construction needs for a given application in an aerospace mechanical system, but none has application interchangeability or substitutability. This leads to proliferation of parts. Manufacturers, designers, engineers, and project officers often have problems in the selection of fasteners because of lack of knowledge of existing specifications or standards, or application, or where to locate them if they do exist. Additionally, the methods of installation and use of these components vary because of lack of standardized usage criteria and as a result, associated components must vary. The basic objectives of this standard can be summarized as:

> "To select from available standards and standardized methods of usage those bearings, control system components and associated hardware which will optimize performance and reliability of future aerospace mechanical systems while minimizing the logistic consideration of such things as cost, inventory, procurement, and maintenance."

It is also the purpose of this document to limit the selection of items and methodology to that specified herein; however, provisions are covered in Section 100. Requirement 101 is for release for use of components not listed in Section 100, Requirement 102 is for approval of methodology not specifically allowed herein, when required for new design and construction or when maintainability or life cycle cost benefits justify their use.

Selections and procedures. are limited to those listed herein.

CONTENTS

* Requirement not as yet published.

SECTION 200 GENERAL DESIGN REQUIREMENTS

SECTION 300 AIRFRAME BEARINGS

SECTION 400 - BEARING RETAINER RINGS, WASHERS, NUTS

* Requirement not as yet published

1/ Due to the length of this requirement, a table of contents is included for convenience.

SECTION 500 - GREASE/OIL SEALS, NON-INTEGRAL

SECTION 600 - CONTROL CABLE SYSTEMS

SECTION 700 - LATCH COMPONENTS

SECTION 800 - BALL SCREWS AND SHAFTS

SECTION 900 - MECHANICAL DRIVE COMPONENTS

* Requirement not as yet published

BEARINGS, CONTROL SYSTEM COMPONENTS, AND ASSOCIATED HARDWARE USED IN THE DESIGN AND CONSTRUCTION OF AEROSPACE MECHANICAL SYSTEMS AND SUBSYSTEMS

1. SCOPE

1.1 Requirements. This standard covers bearings, control system components, and associated hardware, required methods of using these components, and materials, finishes, and test methods of these components for use in design and construction of' aerospace mechanical systems, and covers the comprehensive presentation of approved engineering practices, procedures, and characteristics for the interface of these components.

1.2 Numbering system. This standard is divided into sections with numbered requirements applicable to each section.

1.3 Revision of requirements. This standard is issued in loose leaf form to permit the insertion or removal of new or revised requirements. Users should keep this document up to date by inserting revised or new sections as issued and removing superseded or cancelled pages. Revisions to individual paces shall be indicated by a revision date at the bottom right side of the page. Revision to a complete section shall be denoted by a letter following the requirement designation. For example: Requirement lOOA followed by the date.

1.4 Changes. Requests for changes to this document shall be submitted to Aeronautical Systems Division, ATTN: ENESS, Wright-Patterson AFB, OH 45433.

2. APPLICABLE DOCUMENTS

2.1 Issues of documents. See each individual requirement for reference to any applicable documents contained therein. The applicable issues shall be those in effect on the date of invitation for bids or request for proposal.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contractor officer.)

2.2 Acquisition of non-government documents referenced herein. Addresses for documents not obtainable from the government which are referenced herein are as follows:

ANSI	American National Standards Institute 1430 Broadway New York, NY 10018
NAS	National Standards Association 1321 Fourteenth St., NW Washington, DC 20005
AMS, AS, ARP, AIR, AMD	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096
ASTM	American Society of Testing and Materials 1916 Race Street Philadelphia, PA 19103

3. DEFINITIONS

3.1 Airframe bearing. A bearing especially designed for use in the control systems and surfaces of the aircraft.

3.2 Aligning thrust bearing, ball or roller. A thrust ball or roller bearing which by virtue of the shape of the seat washer is capable of considerable misalignment.

3.3 Annular bearing. An antifriction bearing primarily designed to support load perpendicular to shaft axis.

3.4 Ball bearing. An antifriction bearing using balls as rolling element.

3.5 Cam follower ball bearing. Special service ball bearing with extra heavy outer ring.

3.6 Clutch release ball bearing. A line of bearings designed for this special purpose.

3.7 Cylindrical roller bearing. Roller surface parallel to bearing axis.

3.8 Double row bearing, ball or roller. A bearing with two rows of rolling elements.

3.9 Duplex ball bearings. Two single row angular contact bearings selected dimensionally to be a matched pair or set.

3.10 Duplex ball bearings, back-to-back. A duplex pair of angular contact ball bearings with outer ring thrust faces adjacent and with ball load lines intersecting outside the pitch circle.

3.11 Duplex ball bearings face-to-face. A duplex pair of angular contact ball bearings with outer ring narrow faces adjacent and with ball load lines intersecting inside the pitch circle.

3.12 Duplex ball bearing, tandem. Assembly of two or more ball bearings so mounted as to divide the thrust load with ball load lines parallel.

3.13 Flanged bearing. Generally descriptive of antifriction bearings with outer ring or cup flanged on outside diameter.

3.14 Floating bearing. A floating bearing is one so designed or mounted as to permit axial displacement between shaft and housing.

3.15 Journal roller bearing. A cylindrical roller bearing (solid or wound rollers) with relatively high ratio roller length to diameter, separable rings and unit type roller assembly.

3.16 Maximum type roller bearing Cageless roller bearing with maximum number of rollers.

3.17 Metric bearing. A bearing designed to metric dimensions.

3.18 Miniature ball bearing. Ball bearings whose outside diameter dimensions are below and not including 3/8" or 9mm.

3.19 Multi-row bearing, ball or roller. A bearing with more than two rows of rolling elements.

3.20 Needle roller bearing. A radial needle roller bearing is a radial cylindrical roller bearing having a large ratio of pitch diameter to roller diameter and a large ratio of roller length to roller diameter.

3.21 Non-filling slot bearing. See roller bearing.

3.22 Outside cylindrical surface run-out with reference side. A bearing measurement defined in Anti-Friction Bearing Manufacturers Association (AFBMA) Standard Section No. 4.

3.23 Preload. Preload commonly refers to an internal loading characteristic in a bearing which is dependent of any external radial or axial load carried by the bearing.

3.24 Prelubricated bearing. A bearing originally lubricated by the manufacturer.

3.25 Pure radical load. Pure radial load is that load which results from a single source acting through the center of the bearing at right angles to the bearing axis.

3.26 Pure thrust load. Pure thrust load is that load which results from a single force applied in the direction coaxial with the bearing axis.

3.27 Races. The inner ring or outer ring of a cylindrical or needle roller bearing.

3.28 Raceway, inner ring. The path of the roller element on either ring of a ball or roller bearing.

3.29 Raceway depth. In a ball bearing, the vertical distance from bottom of raceway to inner ring outside diameter, or outer ring inside diameter.

3.30 Raceway, parallel with side. A bearing measurement defined in AFBMA Standard Section No. 4, as "Groove Runout with Reference Side."

3.31 Radial bearing. An antifriction bearing primarily designed to support load perpendicular to shaft axis.

3.32 Radial internal clearance. The radial internal clearance of a single row radial contact ball bearing is the average outer ring raceway diameter, minus the average inner ring raceway diameter, minus twice the ball diameter. The raceway diameters are taken at the bottom of the raceway.

3.33 Radial load. Radial load is that load which may result from a single force or the "resultant" of several forces acting in a direction at right angles to the bearing axis.

3.34 Radial play. See radial internal clearance.

3.35 Rating life. This term defined in AFBMA Standard section no. 9.

3.36 Roller bearing. A bearing using rollers as roller elements.

3.37 Seals: lip, felt type, labyrinth type. A seal in sliding contact with a rotating ring. Closure elements consisting of a circular part or parts affixed to one bearing ring and disposed radially toward the other bearing ring (or another member affixed to that ring), to run in close proximity thereto, and shaped to form a labyrinth of appreciable length.

3.38 Sealed bearing. A ball or roller bearing protected against loss of lubricant and from outside contamination.

3.39 Sealed and shielded bearing. Sealed on one side, shielded on other side.

3.40 Self-aligning radial bearing, ball or roller. A ball or roller bearing which by virtue of the raceway or outer ring construction, is capable of considerable misalignment.

3.41 Self-contained bearing. A unit bearing assembly (non-separable).

3.42 Separable bearing, or roller. A bearing assembly that may be separated completely or partially into its component parts.

3.43 Shielded and sealed bearing. Shielded on one side, sealed on other side.

3.44 Single row bearing, ball or roller. A bearing having only one row of rolling elements.

3.45 Single sealed bearing. Sealed on one side.

3.46 Single shielded bearing. Shielded on one side.

3.47 Special bearing. A bearing not meeting the requirements of Standard or Established Line Bearings.

3.48 Spherical roller bearing (radial). See Self-aligning radial bearing.

3.49 Spherical roller thrust bearing. See Self-aligning radial bearing.

3.50 Split bearing, single or double fracture. A bearing having either or both rings split across the raceway so as to facilitate assembly in certain applications.

3.51 Stand out, tapered roller bearing. The distance from the back face of the cone to the front face of the cup.

3.52 Straight roller bearing. A roller bearing of the radial type having cylindrical rollers.

4. GENERAL REQUIREMENTS

4.1 Application. The sections and requirements contained herein are intended to provide uniform requirements applicable to bearings, control system components, and associated hardware for use on aerospace mechanical systems and shall be incorporated by reference in general and detail weapon systems and equipment specifications. If a requirement contained herein conflicts with a requirement in the general or detail weapon system or equipment specification, the weapon system or equipment specification shall take precedence. If the requirement listed in the Table of Contents has not been published but is referenced herein, it is not applicable, and the requirements of the general or detail weapon system or equipment specification shall apply.

5. DETAIL REQUIREMENTS

5.1 Individual requirements. Individual requirements for each section follow.

6. NOTES

6.1 Marginal indicia. The margins of this standard will be marked to indicate where changes, deletions, or additions to the previous issue have been made. This is done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content as written, irrespective of the marginal notations and relationship to the previous issue.

Custodians:
Army - AV
Navy - AS
Air Force - 11

Review activities:
DLA - IS

Preparing activity:
Air Force - 11

Project 31GP-0008

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APPROVAL AND RELEASE FOR USE: PARTS

1. Scope. Parts identified and listed in the applicable requirements of this standard are approved parts and shall be given selection priority in new airframe and airborne mechanical and functional systems design. Parts not listed as approved for use herein require a release for use by the procuring activity prior to incorporation into design during engineering development and use in assembly during production. This requirement establishes uniformity in the preparation and submission procedures for justification and engineering documentation necessary for the evaluation and release for use of unapproved parts and references established procedures which may be contractual for a specific aircraft program. This requirement also establishes the point of contact for release requests.

2. Documents applicable to Requirement 101

MIL-STD-143	Standards arid Specifications, Order of Precedence for the Selection of
MIL-STD-965	Parts Control Program

3. Release for use procedures

3.1 Parts selection

3.1.1 Approved parts. Parts listed in the applicable requirements in this document are considered approved parts. These parts shall be given priority in design or modification programs.

3.1.2 Unapproved parts. Any part not listed in the applicable requirements herein shall be considered an unapproved part. When required, parts shall be selected in the order of precedence specified in MIL-STD-143.

3.2 Determination of approved and receiving approval for unapproved parts

3.2.1 Contract specifies MIL-STD-965. When the program contract specifies MIL-STD-965, the procedure for determination of approved parts and receiving approval for use in unapproved parts shall follow the procedures contractually selected from and listed in MIL-STD-965 and any specific contract deviations.

3.2.2 Contract details Procedures. When the program contract details specific procedures for determination of approved parts and approvals of non-approved parts, applicable procedures shall be followed.

3.2.3 Contract does not specify MIL-STD-965 or detail procedure. Approved parts listed herein shall be utilized insofar as practicable. Unapproved parts which are required shall be selected in accordance with the precedence specified in MIL-STD-143 arid shall be submitted to the procuring activity for release for use on the program. The procedure shall be as coordinated with the procuring activity.

4. Engieering data requirements. Data shall be submitted to the procuring activity as required by MIL-STD-965, or deviations thereto, or by contract agreement with the procuring activity.

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APPROVAL AND RELEASE FOR USE: METHODOLOGY

1. Scope. Procedures and methods specified in applicable requirements herein shall be considered required unless options are specifically allowed. When the contractor desires to use procedures or methods other than those specified or cannot use specified procedures or methods for specific applications, the procedure for approval shall be as detailed in this requirement.

2. Documents applicable to Requirement 102

U. S. Air Force Design Handbook 2-1	Airframe

3. Release for use procedure

3.1 Procedure or method selection

3.1.1 Approved methodology. All methodology listed in the applicable requirements herein are considered approved for use with noted restrictions or allowances. Methodology refers to bearing retention methods or load calculation procedures.

3.1.2 Optional methodology. When more than one procedure or method is specifically identified as optional herein, either procedure or method is considered approved.

3.1.3 Unapproved methodology. When procedures or methods are specifically disapproved herein, use is prohibited. Specific approval by the procuring activity is required for use of the procedure or method.

3.1.4 Non-specified methodology. When a procedure or method for accomplishing a required installation or design is neither approved nor disapproved or is not addressed, the contractor shall use the best known design practice from experience or testing.

4. Engineering data required. When procedures or methods not approved herein are required, the contractor shall furnish the data requested by the procuring activity.

5. Approval documentation. The contractor shall maintain a record of procuring activity approvals of methods or procedures used which require procuring activity approval.

6. Notes. MIL-STD-1599 takes precedence over applicable document specified in paragraph 2 of this requirement.

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EXCHANGEABILITY

1. Scope. This requirement shall govern the selection and use of exchangeable parts in the design and construction of aerospace mechanical systems and related subsystems.

2. Documents applicable to Requirement 103

MIL-STD-100	Engineering Drawing Practices
MIL-STD-280	Definitions of Item Levels, Item Exchangeability, Models , and Related Items

3. Definitions of elements. Refer to MIL-STD-100 and MIL-STD-280 for definitions of appropriate elements.

4. Design tolerances. During design selection and application, provisions shall be made for dimensional , physical , and functional properties' tolerances, so that parts having dimensional, physical and functional characteristics permitted by the part specification or drawing may be used without selection or Departure from the specified equipment performance.

5. Use of approved parts. Approved parts as defined in paragraph MIL-STD-1599 shall be used to the maximum extent practicable. If existing approved parts are not available, the procuring activity may grant authority to substitute a non-approved part. The equipment shall be designed so that the approved part can be used. When provision is made for the use of a substitute non-approved part, the approved part shall be identified on the applicable documentation .

6. Choice of parts. The part having the broadest characteristics and physical and functional tolerances that will fulfill the equipment performance requirements shall be used. However, if delays in development or production are caused by the procurement time required for such parts, approved or released substitute parts may be used if the originally selected, approved, or released part is identified on the applicable documentation.

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MATERIALS

1. Scope. This requirement delineates the materials approved for use in the construction of newly designed parts for approval to MIL-STD-1599, specifies restrictions of heat treats or applications, and notes materials which are not approved or are approved with specific conditions. This is the general materials requirement for new design and may contain statements which defer material selections and approvals to other specific requirements wherein the materials are more suitably covered in the requirement. This requirement does not address the materials approved on existing military standard (MS) drawings.

2. Documents applicable to Requirement 104

L-P-410	Plastic, Polyamide (Nylon), Rigid, Rods, Tubes, Flats, Molded and Cast Parts
L-P-523	Plastic Sheet and Film, FEP-Fluorocarbon, Extruded
QQ-C-390	Copper Alloy Castings (Including Cast Bar)
QQ-C-450	Copper-Aluminum Alloy (Aluminum Bronze) Plate, Sheet Strip and Bar (Copper Alloy Numbers 606, 612, 613, 614 and 628
QQ-C-530	Copper-Beryllium Alloy Bar, Rod and Wire
QQ-C-533	Copper-Beryllium Alloy Strip (Copper Alloy Numbers 170 and 172)
QQ-S-763	Steel Bars, Shapes and Forgings - Corrosion Resisting
ZZ-R-765	Rubber, Silicone
MIL-M-14	Molding Plastics and Molded Plastic Parts, Thermosetting
MIL-P-997	Plastic Material, Laminated, Thermosetting, Electric Insulation, Sheets, Glass Cloth, Silicone Resin
MIL-S-5000	Steel, Chrome-Nickel-Molybdenum (E4340) Bars and Reforging Stock
MIL-C-6021	Castings, Classification and Inspection of
MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-T-6736	Tubing Chrome-molybdenum, (4130) Steel, Seamless and Welded, Aircraft Quality
MIL-S-6758	Steel , Chrome-molybdenum, (4130) bars and Reforging Stock (Aircraft Quality)
MIL-R-6855	Rubber, Synthetic, sheets, Strips, Molded or Extruded Shapes
MIL-I-6868	Inspection Process, Magnetic Particle
MIL-H-6875	Heat Treatment of Steels, (Aircraft Practice), Process for
MIL-T-8504	Tubing Steel Corrosion-Resistant (304) Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded
MIL-S-8844	Steel Bar, Reforging Stock, and Mechanical Tubing, Low Alloy, Premium Quality
MIL-S-8949	Steel Bars, Plates, Sheets, Billets and Reforging Stock Type D6AC
MIL-T-9046	Titanium and Titantium Alloy, Sheet, Strip and Plate
MIL-T-9047	Titanium and Titantium Alloy - Bars, Forging and Forging Stock
MIL-P-15035	Plastic Sheet, Laminated, Thermosetting, Cotton-fabric-base, Phenolic Resin
MIL-S-25043	Steel Plate, Sheet, and Strip, 17-7 PH. Corrosion Resistant, Precipitation Hardening
MIL-R-25988	Rubber, Fluorosilicone Elastomer, Oil and Fuel Resistant, Sheets, Strips, Molded Parts and Extruded Shapes
MIL-H-81200	Heat Treatment of Titanium and Titanium Alloys
MIL-T-81556	Titanium and Titanium Alloys, Bars, Rod and Special Shaped Section, Extruded

MIL-T-81915	Titanium and Titanium Alloy Castings, Investment
MIL-R-83248	Rubber, Fluorocarbon Elastomer, High Temperature, Fluid and Compression Set Resistant
MIL-STD-l43	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-810	Environmental Test Methods
MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
AMS 2300	Premium Aircraft Quality Cleanliness - Magnetic Particle Inspection Procedure
AMS 2301	Aircraft Quality Steel Cleanliness - Magnetic Particle Inspection Procedure
AMS 3651	Polytetraflouroethylene, (Teflon)
AMS 4890	Copper-Beryllium Alloy Castings, Investment 2 Be - 0.4 Co - 0.3 Si
AMS 5343	Steel Castings, Investment, Corrosion Resistant 16 Cr - 4.0 Ni - 3.1 Cu Solution and Precipitation Heat Treated, 150,000 PSI (1034 MPA) Tensile Strength
AMS 5520	Sheet, Strip, and Plate - 15 Cr - 7.1 Ni - 2.5 Mo- 1.1 A1
AMS 5625	Bars High Expansion - 5.5 Mn - 9.5 Ni (0.55 - 0.65 C) Cold Drawn
AMS 5626	Bars and Forgings - Tool, High Speed, 18 W - 4 Cr - 1 V
AMS 5629	Steel Bars, Forging, Tubing and Rings, Corrosion Resistant - 13 Cr - 8 Ni - 2.3 Mo- 1.1 A1 Vacuum Induction + Consumable Electrode Melted
AMS 5639	bars, Forgings, Tubing and Rings - 19 Cr 10 Ni
AMS 5643	Steel Bars, Forgings, Tubing, and Rings Corrosion Resistant 16.5 Cr - 4.0 Ni - 4.0 Cu
AMS 5659	Bars, Forgings and Rings 15 Cr - 5 Ni - 0.30 (Cb + Ta) 4 Cu Consumable Electrode Melted
AMS 5673	Steel Wire. Corrosion Resistant 17CR-7. lN 1-1 . 1A1 Precipitation Hardenable, Spring Temper
AMS 6304	Bars, Forgings and Mech. Tubing - 0.95 Cr - 0.55 Mo - 0.30 V (0.40 - 0.50 c)
AMS 6440	Bars and Forgings - 1.45 C_r (.98-1.10C) Bearing Quality
AMS 6441	Tubing, Mechanical - 1.45 C_r (.98-1.10C) Bearing Quality
AMS 6442	Bars and Forgings - .50 C_r (.98-1.10C) Bearing Quality
AMS 6444	Bars, Forgings and Tubing - 1.45 C_r (.98-1.10C) Premium Quality Consumable Electrode Vacuum Melt
AMS 6487	Bars and Forgings - 5.0 Cr - 1.3 Mo - 0.50 V. Premium Quality , Consumable Electrode Vacuum Melted (0.38 - 0.43 C)

3. General requirements

3.1 General selection criteria. The selection of materials to be used in the design and construction of bearings and control system components for aerospace systems shal1 be made by the manufacturer and submitted to the prime contractor for approval. Particular attention shall be paid to the selection of standard materials to facilitate Interchangeability, stocking and replacement in service. The number of different types, sizes, strengths and consumable bulk materials shall be kept to a minimum. Operational requirements to be considered include , but are not limited to, load distribution and magnitudes , temperature range, environments, reliability requirements and life expectancy. Since rate of deterioration in service is highly significant to the life expectancy of parts, special consideration shall be given to those deterioration modes which largely contribute to service failure. The modes include pitting corrosion, galvanic corrosion, exfoliation corrosion, stress corrosion cracking, corrosion fatigue , thermal embrittlement, creep, fretting fatigue , oxidation, hydrogen embrittlement, weathering and fungus growth . Precautionary measures should be considered which include limitations of design operating stress levels, shot peening, heat treatments which reduce corrosion susceptibility and protective coatings and finishes. Special considerate ion shall also be given to cost , reliability, repairability, inspectability and maintainability. The requirements specified herein shall apply only for new design and shall not apply.to components covered by existing Military Standard (MS) drawings. The requirements which apply to exempted components shall be as specified in the prime contract or as subsequent y negotiated with the prime contractor.

3.2 Material specifications. All end item materials shall be procured to specifications. Procurement of materials to trade names and numbers is prohibited except where such materials are specifically called out in procurement specifications by trade name. The order of precedence for material specifications shall be in accordance with MIL-STD-143.

3.2.1 Seller specifications. For materials for which there are no preferred Federal, Military, AMS or prime Contractor material specification counterparts, seller specifications may be used subject to obtaining written approval of the prime contractor. Unique seller specifications may also require approval of the procuring activity. In those cases where the material is proprietary it may be exempted from this requirement if the procurement specification for the component part utilizing the proprietary product contains adequate technical requirements, quality assurance requirements and application limitations.

3.3 Design data and allowable materials properties. Design data and properties of materials shall be obtained from MIL-HDBK-5 or alternately from other sources subject to the approval of the prime contractor. Allowable properties based on static and fatigue test data may be used subject to the approval of the prime contractor. Properties other than those contained in MIL-HDBK-5 shall be substantiated and analyzed in accordance with procedures used for corresponding data in MIL-HDBK-5.

3.4 Metallic material requirements

3.4.1 Alloy steel

3.4.1.1 Alloy steel selection criteria

3.4.1.1.1 Quality. Alloy steels heat treated above 200 KSI FTU shall be procured as vacuum melt grade and shall meet the cleanliness requirements of AMS 2300. Alloy steels heat treated below 200 KSI FTU may be air melt grades. meeting the cleanliness requirements of AMS 3201. Exception: Rolling element braking steels which are primarily used in thin sections loaded in compression may be air melt material, but finished parts must meet the requirements of MIL-I-6868.

3.4. 1.1.2 A11oy limitation. Within their hardenability range, the following steels shall not be heat treated higher than the below listed ultimate tensile strength range or level.

41XX 1/, 43XX, 87XX Alloy Steels . . . . <200 KSI
HP9 Ni - 4 Co - .200 [2/]. . . . . .190 - 200 KSI
H-11, AMS 6304 . . . . <240 KSI
HP9 Ni - 4 Co - .30C [2/] D6AC . . . . .220 - 240 KSI
300 M. . . . . l . . . . .280 - 300 KSI

1/ 41XX, when used as rod end body in rolling element rod ends, may have outer raceway case hardened. The affective case depth shall be from a minimum of 25 percent to a maximum of 50 percent of the ring thickness.

2/ Critical components requiring fracture toughness capability.

3.4. 1.1.3 Procurement limitations. Alloy steel shall be selected such that the expected service temperature of the part does not violate the following considerations:

a. The ductile to brittle transition temperature of the steel shall be below any temperature likely to be experienced in service.

b. The maximum service temperature shall be at least 50°F below the tempering or aging temperature.

c* The operating temperature of the part shall not be within the temper brittle range for the alloy.

3.4. 1.1.4 Hardenability. The hardenability of quench and temper grades shall be sufficient to ensure transformation of quenching to not less than 90% martensite at the center of maximum cross section. Use of compositions that result in excessive harden ability shall be avoided.

3.4. 1.2 Recommended a lloy steels. Alloy steel hat-treat combinations considered as having demonstrated satisfactory performance in service are listed in table I. Heat treatment shall be in accordance with MIL-H-6875.

3.4.2 Corrosion resistant steel (CRES)

3.4.2.1 CRES selection criteria

3.4.2. 1.1 Quality. Heat treated CRES alloys for critical load carrying structures shall be procured as vacuum melted grades; e .g., PH 15-5 shall be procured to AMS 5659, 17-4PH to AMS 5643 (wrought products) or MAS 5343 (castings), and PH 13-8 Mo to AMS 5629. For magnetic particle inspection capability, PH 15-5 is preferred over 17-4PH for critical components.

TABLE 104-1. Recommended alloy steels.

Alloy	Specification	Usage
4130 1/	MIL-S-6758 or equiv 2/	General (<200 KSI)
4140 1/	MIL-S-5626 or equiv	
4340 1/	MIL-S-5000 or equiv	
4340	MIL-S-8844, CL1	
HP9 Ni-4 Co-.20	AMS 6525	High Toughness
H-11	AMS 6487	High Strength
	AMS 6304	
D6AC	MIL-S-8949	
HP9 Ni-4 Co-.30	AMS 6526	High Strength, High Toughness
300 M	MIL-S-8844, CL3	Ultra High Strength
50100	AMS 6442	
52100	AMS 6440, 6441	High Hardness
CEVM 52100	AMS 6444	

1/ Alternately equivalent 86XX, 87XX alloy steel grades may be substituted.

2/ MIL-T-6736 for tubing applications.

3.4.2.1.2 Prohibited CRES alloYs/conditions. The use of CRES alloys 431 and 19-9DL is specifically prohibited. The precipitation hardening or maraging CRES alloys (PH series, Almar series, Custom series, etc.) shall not be heat treated to their high range of strength conditions, i.e., aged below 1000°F. As examples, this heat treatment restriction prohibits aging the following CRES alloys to the listed conditions: 17-4PH to Condition H900/H925, 17-7PH to Condition H/RH 950, Custom 455 to Condition H900/H950, 15-5PH to H900 and PH13-8 Mo to Condition H950. Martensitic 400 series CRES grades shall not be used in the 150-180 ksi strength range. Precipitation hardening or maraging CRES alloys shall not be used in Condition A (solution treated or annealed).

3.4.2.1.3 Service temperature considerations. CRES alloys shall be selected such that the expected service temperature of the part will not violate the following considerations:

a. Maximum service temperature of precipitation hardening stainless steels shall be 750°F for extended periods of time.

b. Maximum service temperature of cold worked CRES shall be 400°F.

c. Maximum service temperature of restabilized austenitic stainless steel shall be 700°F.

d. Operating temperature during design life (time) shall not soften, as detectable by hardness test, CRES strengthened by cold work.

3.4.2.2 Recommended CRES Alloys. CRES alloy-heat treat. combinations considered as having demonstrated satisfactory performance in service are listed in table II. While CRES selection is not limited to this list, choice of other alloys and heat treatments shall require justification.

TABLE 104-11. Recommended CRES alloys.

Class	CRES Alloy	Specification	Recommended Condition
Austenitic (Unstabilized)	301 302 304 1/ 304L 310 316 316L	QQ-S-763	1/4 Hard and 1/2 Hard Cond. A and 1 /4 Hard Cond. A & Cond. B
	304 5/	MIL-T-8504	Cond. A
Austenitic (Stabilized)	321 347	QQ-S-763	Cond . Q
Semi-Austenitic	17-7PH 4/ PH 15-7 Mo	MIL-S-25043 AMS 5673 AMS 5520	CH900 CH900 TH1050
Precipitation Hardening	17-4PH 2/ 15-5PH 3/ PH13-8 Mo	AMS 5643 AMS 5659 AMS 5629	H1025 thru H1150 H1025 thru H1150 H1000
12 Cr Martensitic	410 420 440C	QQ-S-763	120 KS I Ftu Min & 180 KSI Ftu Min 120 KSI Ftu MIn & 200 KSI Ftu Min R_C 55 Min & Up

1/ 304 CRES per QQ-S-763 or AMS 5639 preferred when 302 not available .

2/ Except castings, Cond. H1000 is acceptable.

3/ Preferred material for critical applications over 17-4 PH.

4/ Spring Applications. MIL-S-25043 shall be used for leaf spring applications and AMS 5673 shall be used for coil spring applications .

5/ Tubing Applications.

3. 4.3 Aluminum alloys

3.4.3.1 Aluminum alloy selection criteria. Maximum corrosion resistance of aluminum alloy components is required. The limited general and stress corrosion resistance of high strength aluminum alloys (see paragraph 3.6, Definitions) require careful selection of composition, heat treatment, processing and mill product form. Stress corrosion resistant alloy/tempers shall be used for all parts fabricated from thick (0.5 and over) section mill products. While the use of special heat treatments and tempers (T611, T651, T652, polyalkalene glycol quench, etc.) may be desirable to reduce distortion or residual stresses, in no case shall it be considered to impart stress corrosion resistance to the base alloy.

3. 4.3.2 Recommended aluminum alloys. Aluminum alloy/temper combinations considered as having demonstrated satisfactory performance in service are listed in table III. While aluminum alloy selection is not limited to this list, choice of other alloys/tempers shall require justification. Heat treatment of aluminum alloys shall be in accordance with MIL-H-6088.

TABLE 104-III. Recommended aluminum alloys .

Mill Product	Alloy	Temper
Hand & Die Forgings	7075	T73, T735X (<3.0″)
	7175	T736, T736532 (<3.0″)
	7049	T73, T735X (≥ 3.0″)
	7050	T736.T7355X
	6061	T6,T652
	2219	T6,T852
Tube	2024	T62
	6061	T4, T6, T62
Extrusions & Bar Stock	7075	T76, T7651X (<0.5″)
	7075	T73, T7351X (>0. 5″)
	7049	T73, T7351X
	6061	T6, T651X
	2024	T62, T851x
	2219	
Plate	7075	T7351
	7475	T7351 1/
	2024	T851
	2124	T851 (>1.5)

1/ High Fracture Toughness

3.4.4 Titanium alloys

3.4.4.1 Titanium selection criteria. The use of titanium shall be limited to applications where cost and weight effectiveness can be demonstrated. Mill annealed Ti-6Al-4V shall be the primary alloy considered. For fracture critical applications, consider mill or beta annealed Ti-6A1-4V ELI; for higher strength applications, consider mill annealed Ti-6A1-6V-2Sn .

3.4.4.2 Recommended titanium alloys, Titanium alloy/mill product combinations considered as having demonstrated satisfactory performance in service are listed in table IV. While titanium alloy selection is not limited to this list, choice of other alloys shall require justification. The specifications listed shall be used for procurement of the materials listed. Heat treatment of titanium alloys shall be In accordance with MIL-H-81200.

TABLE 104-IV. Recommended titanium alloys.

Alloy	Mill Product	Condition	Specification
Ti-6A1-4V	Sheet, Plate 1/ Bar, Forging 1/	Annealed Annealed	MIL-T-9046 MIL-T-9047
Ti-6A1-4V	Extrusion Casting	Annealed Annealed	MIL-T-81556 MIL-T-81915
Ti-6A1-6V-2Sn	Sheet, Plate Bar , Forgings	Annealed Annealed	MIL-T-9046 MIL-T-9047
Commercially Pure	Sheet Tube	Annealed Annealed	MIL-T-9046 2/

1/ Beta Annealed Ti-6A1-4V ELI - No known MIL, Fed, AMS Fed, AMS Spec. use Company Specification.

2/ CP.40 Tubing per ASTM B-338 (GR2)

3.4.5 Copper base alloys

3.4.5.1 Beryllium copper. For high bearing load applications, critical wear applications, and wear applications where good structural load capability is required , the use of beryllium copper is recommended. The preferred alloy is CA172. Wrought beryllium copper shall be procured to QQ-C-530 or QQ-C-533. Beryllium copper castings shall be procured to AMS 4890, classified (class and grade) per MIL-C-6021. Beryllium copper alloys are corrosion resistant and generally do not require a corrosion protection surface treatment. Beryllium copper will form a dark natural oxide (tarnish) which is generally considered to be beneficial to wear performance.

3.4.5.2 Alluminium bronze, bearing alloys. For moderate bearing loads, wrought CA630 aluminum-nickel bronze per QQ-C-450 is the preferred alloy. For lighter duty, the other wrought aluminum bronze alloys per QQ-C-450 will be acceptable. Aluminum bronze (alloys 952-958) and manganese bronze (alloys 861-868) castings are acceptable and, where used, shall be classified (class and grade) per MIL-C-6021, and procured per QQ-C-390. The use of bronze alloys other than those discussed above shall require justification.

3.4.6 Other alloys,

3.4.6.1 Nickel & cobalt base (superalloy) alloys. The use of nickel and cobalt base superalloys is acceptable. Castings shall be classified (class and grade) per MIL-C-6021. Nickel and cobalt base alloys do not require corrosion protection surface treatments.

3.5 Non-metallic materials.

3.5.1 General selection criteria.

3.5.1.1 Selection considerations. Organic materials shall have maximum practicable resistance to degradation and aging. This resistance shall include resistance to ozone, polymer reversion, hydrolysis, aircraft and GSE fluids and lubricants, fuel, heat aging, low and high temperature and weapons systems propellants. Organic materials shall also be selected so as to minimize the dangers resulting from smoke or fire hazards. The organic materials used shall be compatible with other materials they contact and, in particular, shall not induce or accelerate corrosion of metal structure they contact. Decomposition and other products, including volatile and leachable constituents, released by organic materials under normal operating conditions or curing shall not be injurious or otherwise objectionable with respect to materials, components, or personnel with which they come in contact. The aircraft parts and equipment shall be designed so that the materials are not nutrients for fungi except when used in permanent, hermetically sealed assemblies and other accepted and qualified parts such as paper capacitors and treated transformers. Other necessary fungi nutrient material applications require treatment by a method which will render the resulting exposed surface fungi resistant. Moisture resistance shall be considered as no permanent degradation of properties. The criteria for the determination of fungi and moisture resistance shall be that contained in MIL-STD-810.

3,5.1.2 Selection limitations. The use of polyester polyurethane elastomers for molded components, potting or sealing is prohibited. All organic materials having ester linkages shall be tested for hydrolytic stability. The use of natural leather and wood is prohibited.

3.5.2 Seals and molded elastomers.

3.5.2.1 Silicone. Molded silicone rubber products shall be procured to ZZ-R-765 class IIIB. Silicone rubber may be used to 500°F and shall not be used where contact with fuel or lubrication oil is likely. The long term weatherability of silicone rubber is excellent and its use is preferred over Neoprene.

3.5.2.2 Neoprene. Where used, Neoprene shall be procured to MIL-R-6855, class II, type A. Neoprene shall not be used above 220°F or for applications involving exposure to fuel or oil . Silicone rubber is preferred over Neoprene.

3. 5.2.3 Fluorocarbon. Fluorocarbon (Viton) products shall be procured to MIL-R-83248. Fluorocarbon may be used within the temperate range -40°F to +450°F. Fluorocarbons are fuel and oil resistant .

3.5.2.4 Fluorosilicone. Fluorosilicone products shall be procured to MIL-R-25988. Fluorosilicone may be used in the temperature range -70°F to 400°F. Fluorosilicone is resistant to aircraft fuels and oils.

3.5.2.5 Buna-N. Buns-N rubber products shall be procured to MIL-R-6855, class I. Buns-N rubber is resistant to aircraft oils and fuels. The maximum continuous service temperature for Buns-N shall be 220°F. Buna-N elastomers may be subjected to intermittent exposures in the 220° to 275°F range when specific military specifications or standards define service temperatures above 220°F. For example, the MS (Buna-N) "0" rings may be used for exposures up to 275°F and are acceptable for use in hydraulic systems. Buna-N elastomers per MIL-R-6855, class I or MIL-P-25732 are acceptable for low temperature service to -65°F.

3.5.3 Plastics

3.5.3.1 Fluorocarbon. Fluorocarbon, tetrafluoroethylene (TFE) and fluorinated ethylene propylene (FEP) plastics are recommended for low friction and chemical inertness requirements. TFE shall be procured to AMS 3651 and FEP shall be procured to L-P-523. Bonding of TFE and FEP products shall require etching of the TFE and FEP surface to be bonded.

3.5.3.2 Polyamide. Polyamide plastic is recommended for seals, bushings, guides and similar parts. The preferred material is Nylon 6/6 per L-P-410 in weather or wear grade for use up to 200°F. For applications up to 300°F use the heat resistant grade of Nylon 6/6. For electrical applications the low strength, low water absorption Nylon 6/10 grade per L-P-410 is recommended .

3.5.3*3 Reinforced plastic laminates. Reinforced plastic laminates may be used for guides, wear blocks, and similar parts. For exposures up to 200°F phenolic cotton laminates per MIL-P-15035 shall be used. For higher temperatures, up to 450°F, silicone fiberglass laminates per MIL-P-997 shall be used .

3.5.4 Lubricants. See requirement 203.

COATINGS, PLATINGS, AND FINISHES

1. Scope. This requirement establishes engineering criteria and requirements for the selection and application of optimum corrosion resistant procedures or processes for bearings and control system components for aerospace systems.

2. Documents applicable to Requirement 105

QQ-N-290	Nickel Plating (Electrodesposited)
QQ-P-416	Plating, Cadmium (Electrodeposited)
TT-P-1757	Primer Coating, Zinc Chromate, Low Moisture Sensitivity
MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-T-5544	Thread Compound, Antisieze, Graphite-Petrolatum
MIL-F-7179	Finishes and Coatings: Protection of Aerospace Weapons Systems, Structures and Parts; General Specification for
MIL-B-7949	Bearing, Ball, Airframe, Antifriction
MIL-A-8625	Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-C-8837	Coating, Cadmium (Vacuum Deposited)
MIL-T-10727	Tin Plating; Electrodeposited or Hot Dipped, for Ferrous and Nonferrous Metals
MIL-C-11796	Corrosion Preventative Compound, Petrolatum, Hot Application
MIL-C-16173	Corrosion Preventative Compound, Solvent Cutback, Cold Application?
MIL-P-16232	Phosphate Coatings, Heavy, Manganese or Zinc Base (for Ferrous Metals)
MIL-C-23217	Coating, Aluminum, Vaccuum Deposited
MIL-P-23377	Primer Coatings, Epoxy Polyamide, Chemical and Solvent Resistant
MIL-C-26074	Coating, Nickel-Phosphorous, Electroless Nickel, Requirements for
MIL-S-81733	Sealing and Coating Compound, Corrosion Inhibitive
MIL-C-81751	Coating, Metallic-Ceramic
MIL-C-83488	Coating, Aluminum, Ion Vapor Deposited
MIL-STD-870	Cadmium Plating, Lou Embrittlement, Electrodeposition
MIL-STD-1568	Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems
AMS 2419	Cadmium-Titanium Alloy Plating

3. Requirements

3.1 General. All new weapon system contracts require the submittal of a finishing corrosion control document of the complete system for approval by the procuring activity. In general, the corrosion control document as required by MIL-STD-1568 must conform to the requirements of MIL-S-5002 and MIL-F-7179 but with some exceptions as modified by each individual contract. With some functional components such as bearings, the requirements of MIL-S-5002 and MIL-F-7179 cannot be met or are not practical and specific deviations must be obtained. The following specific requirements are intended to clarify or modify the corrosion control procedures for bearings and other control system components.

3.2 Finished bearings or other components. In those cases where the bearings (or other components) are covered by a military specification, the specified finish shall be acceptable even though it does not meet all of the requirements of MIL-S-5002 and MIL-F-7179. For bearings (or other components) not covered by a military specification, the following deviations shall be considered on a case-by-case basis.

3.2.l Rolling element bearings

3.2.1.1 Cadmium plate per QQ-P-416, type I, class 2 is acceptable for use in place of type II, class 2 plating in those cases where subsequent machining and handling will result in damage to the dicromate conversion coating and lead to rejections due to appearance characteristics. Examples of such components are ball. roller, and needle bearing races and ball and roller bearing rod end bodies.

3.2.1.2 Grease or oil lubricated bearings fabricated of AISI 440C steel require no supplemental corrosion protection and no supplemental corrosion protection is required on the raceways, balls, rollers, or needles of low alloy steel bearings when grease or oil lubricated.

3.2.2 Plain and plain spherical bearings

3.2.2.1 Grease lubricated bearings shall require no supplemental corrosion protection on the functional wear surface. The nonfunctional surfaces shall be cadmium plated per QQ-P-416, type II, class 2, except when in contact with titanium in which case the nonfunctional surfaces shall be tin-plated per MIL-T-10727. For plain spherical bearings where the inner race (ball) is either beryllium copper or aluminum bronze , no supplemental corrosion protection shall be required on any surface of the inner race .

3.2.2.2 For TFE lined plain spherical bearings where the inner race (ball) is AISI 440C steel, no supplemental corrosion protection shall be required on any surface of the inner race.

3.2. 2. 3 Dry film coated bearings shall require no supplemental corrosion protection on the functional wear surfaces where these surfaces are AISI 440C steel , beryllium copper , or aluminum bronze.

3.3 Installation of bearings/bushings in housing. The interface between the bearing/bushing OD and housing ID involves a number of different metal and coating/ plating combinations and all must be adequately treated for corrosion resistance in order to prevent corrosion of the housing . The bearing/bushing OD will be either a corrosion resistant material or will be plated/coated with an appropriate material at the time of fabrication. The housing material can be any of the structural metals presently used for aerospace applications and if not properly protected will result in unacceptable dissimilar metal combinations. Table I is a listing of dissimilar metals and table II is a corrosion rating sheet for materials used in aerospace system. The required corrosion protection for the various combinations of metals are described in the following paragraphs. In all cases except where adhesive bonding is used, or where the bearing OD has lubrication grooves and holes , both the bearing OD and housing ID shall be coated with zinc chromate primer per TT-P-1757, epoxy primer per MIL-P-23377, or sealant per MIL-S-81733 and the bearing installed wet. The remaining surfaces of the parts shall be finished in accordance with the applicable finish documents and enginering requirements. For bearings with lubrication grooves, the housing II) and bearing OD shall be coated with the grease specified for the bearing . The requirements for adhesively bonded bearings are controlled by other specifications.

3.3.1 Titanium versus titanium. No additional corrosion protection required .

NOTE: Coating, plating, or other surface treatment to produce adequate anti fretting characteristics shall be considered for each application and provided when deemed necessary.

3.3.2 Titanium versus Corrosion resistant alloys. No additional corrosion protection required other than passivation of the CR ES.

3.3.3 Titanium versus aluminum alloys. The aluminum alloy shall be anodized per MIL-A-8625, type I or type II, or coated per MIL-C-5541, class IA, depending upon the surface treatment required by the finish document for the alloy in question. The edges shall be touched up after installation with the MIL-P-23377 epoxy primer or other equivalent primer or sealant so that all nonfunctional surfaces of the aluminum are primed or sealed.

3.3.4 Titanium versus low alloy steels . Where practical, the low alley steel shall be electroless nickel plated per MIL-C-26074 , grade C, class I or electroplated nickel per QQ-N-290, class II. Where plating is not practical, the low alloy steel shall be phosphate coated per MIL-P-16232.

3. 3.5 Magnesium. Magnesium and magnesium alloys are prohibited from general use in these applications. Approval by the procuring activity is required for each application for which use of these materials is proposed . Approval of the appropriate corrosion protection for the application is also required.

3. 3.6 Aluminum versus aluminum. Both the bearing OD and the housing ID shall be anodized per MIL-A-8625, type I or type II; or coated per MIL-C-5541, class IA, depending upon the surface treatment required by the finish document for the alloy in question. The edges shall be touched Up after installation with the MIL-P-23377 epoxy primer or other approved primer or sealant so that all nonfunctional surfaces of the aluminum are primed or sealed.

3.3.7 Aluminum versus corrosion resistant alloys. The aluminum alloy shall be anodized per MIL-A-8625, type I or type II; or coated per MIL-C-5541 , class IA, depending upon the surface treatment, required by the finish document for the alloy in question. The edges shall be touched up after installation with the MIL-P-23377 epoxy primer or other approved primer or sealant so that all nonfunctional surfaces of the aluminum are primed or sealed.

TABLE I. Dissimilar metals.

Group 1	Group 2	Group 3	Group 4	Group 5
3000, 5000 and 6000 series aluminum alloys	Aluminum alloys (all)			
Tin	Tin	Tin		
	Zinc			
	Cadmium			
	Tin-lead (solder)			
	Beryllium			
		Low alloy steel		
		CRES	CRES	
		Lead		
		Nickel alloys	Nickel alloys	
		Titanium	Titanium	
			Chromium Copper Brass Bronze Beryllium Copper Alluminum Bronze	Copper Silver Graphite Gold Palladium

NOTES:
1. Of the metals listed, those appearing in any one group are considered similar; those appearing in different groups only are dissimilar.
2. In the case of plated metal, the identity of the plate determines similarity; for example, cadmium plated steel is "similar" to aluminum, nickel plated steel is not.

TABLE II. Corrosion rating sheet.

Poor	Fair	Good	Excellent
Aluminum	Aluminum	PH Steels	300 Series CRES
Bare 2000 Series	Bare 1100	17-4PH	
Bare 7000 Series	Bare 3003	17-7PH	A286
	Bare 5000	15-7PH	
	Bare 6000	13-8PH	
	Clad 2000		
Low Alloy Steel	Clad 7000	Nickel	Inconel
PH 9-4-20			
PH 9-4-30	400 Series CRES		Rene 41
AM-355			
AISI 4340			Titanium
AISI 4130			
AISI 52100			

3.3.8 Aluminum versus low alloy steels. The aluminum alloy shall be anodized per MIL-A-8625, type I or type II; or coated per MIL-C-5541, class IA, depending upon the surface treatment required on the finish document for the alloy in question. The low alloy steel shall be plated (coated) with one of the following:

a. cadmium plate per QQ-P-416, type II, class 2 where tensile strength is less than 180,000 psi

b. Vacuum deposition cadmium plate per MIL-C-8837, type II, class 2 where tensile strength is over 180,000 psi

c. Ti-cad plate per AMS 2419-3

d. Metallic ceramic coat per MIL-C-81751, type 1, class 4

e. Ion vapor deposited aluminum per MIL-C-83488

f. Low embrittlement cadmium plate per MIL-STD-870.

The edges shall be touched up after installation with the MIL-P-23377 epoxy primer or other equivalent primer or sealant so that all nonfunctional surfaces of the aluminum are primed or sealed.

3.3.9 Corrosion resistant alloy versus corrosion resistant alloy. No additional corrosion protection required other than passivation.

3.3.10 Corrosion resistant alloy versus low alloy steel. The low alloy steel shall be plated (coated) with one of the following:

a. Electroplated nickel per QQ-N-290, class 2, grade A

b. Metalalic-ceramic coat per MIL-C-81751, type I, class 4

c. Electroless nickelplate per MIL-C-26074, grade C, class I.

The edges shall be touched up after installation with the MIL-P-23377 epoxy primer.

3.3.11 Low alloy steel versus low alloy steel. Both bearing OD and housing ID shall be plated (coated) with one of the following:

a. Cadmium plate per QQ-P-416, type II, class 2 where tensile strength is less than 180,000 psi .

b. Vacuum deposition cadmium plate per MIL-C-8837, type II, class 2 where tensile strength is over 180,000 psi,

c. Ti-Cad plate per AMS 2419-3

d. Metallic ceramic coat per MIL-C-81751, type I, class 4,

e. Electroless nickel plate per MIL-C-26074, grade C, class 1,

f. Electroplated nickel per QQ-N-290, class 2, grade A

g. Ion vapor deposted aluminum per MIL-C-83488

h. Low embrittlement cadmium plate per MIL-STD-870

The edges shall be touched up after installation with the MIL-P-23377 epoxy primer.

NOTE: The combination of cadmium plate versus nickel plate shall be avoided.

3.4 Installation of shafts (pins) into bearing bores. The shafts (pins) that are installed through the bearing bores will be either standard military or Industry type fasteners; or special company designs because of specific design requirements. In all cases where corrosion protection is required because of the specific shaft (pin) material, the appropriate plating (coating) will be specified by the military or industry standard; or the individual company print. No additional corrosion protection is required on the bearing bores regardless of the metal involved. For example, airframe control ball bearing fabricated in accordance with specification MIL-B-7949 are supplied with bare (unplated) low alloy steel (AISI 52100) inner race bores but no added corrosion protection is required. In some cases, certain requirements may necessitate the use of added corrosion protection at the time of shaft installation. This will be called out as a specific requirement on the assembly drawing.

3.5 Adjustable parts. Threads of adjustable parts such as tie rods, cable terminals, rod end clevis', turn buckles, and cam followers shall be protected both before and after assembly with antisieze compound conforming to MIL-T-5544; or protected with corrosion-preventative compound conforming to MIL-C-16173, grade 2 or grade 4, or MIL-C-11796, class 3 unless otherwise called out on the applicable drawing.

CONTENTS

CONTENTS - Continued

BEARING USAGE

1. Scope. This requirement establishes criteria and information relative to selection of bearings in aerospace vehicle applications. Only those bearings used in the aerospace vehicle proper are covered. Bearings used in specific equipment such as engines, generators, gear boxes, and landing gear wheels are excluded from coverage in this requirement.

1.1 Approved bearings of various types shall be as listed in the appropriate section 300 requirement of this document. Until publication of the specific requirements, there are no approved or disapproved bearings. Bearings of all types covered herein shall be selected in accordance with the criteria and guidelines of this requirement. Submittal of such selections per requirement 101 is not required until such time as appropriate section 300 requirements are published.

2. Documents applicable to requirement 201

QQ-C-465	Copper-Aluminum Alloys (Aluminum Bronze)(Copper Alloy Numbers 606, 614, 630, and 642) Rod, Flat Products with Finished Edges (Flatwise, Strip, and Bar), Shapes, and Forgings
QQ-C-530C	Copper-Berryllium Alloy Bar, Rod, and Wire (copper alloy numbers 172 and 173)
MIL-B-3990	Bearings, Roller, Needle, Airframe, Anti-Friction
MIL-B-6039	Bearing, Double Row, Ball, Sealed Rod End, Anti-Friction, Self-Aligning
MIL-B-7949	Bearings, Ball, Airframe, Anti-Friction
MIL-B-8914	Bearing, Roller, Self-Aligning, Airframe, Anti-Friction
MIL-B-8952	Bearing, Roller, Rod End, Anti-Friction, Self-Aligning
MIL-B-8976	Bearings, Plain, Self-Aligning, All-Metal
MIL-G-23827	Grease, Aircraft and Instruments, Gear and Actuator Screw
MIL-G-81322	Grease, Aircraft, General Purpose, Wide Temperature Range
MIL-B-81819	Bearings, Plain, Self-Lubricating, Self-Aligning, High Speed Oscillation
MIL-B-81820	Bearings, Plain, Self-Aligning, Self-Lubricating, Low Speed Oscillation
MIL-B-81934	Bearings, Sleeve, Plain and Flanged, Self-Lubricating
MIL-B-81934/1	Bearing, Sleeve, Plain, Self-Lubricating, 325°F
MIL-B-81934/2	Bearing, Sleeve, Flanged, Self-Lubricating, 325°F
MIL-B-81935	Bearing, Plain, Rod End, Self-Aligning, Self-Lubricating
MIL-B-81935/1	Bearing, Plain, Rod End, Self-Aligning, Self-Lubricating, Externally Threaded, -65°F to +325°F
MIL-B-81935/2	Bearing, Plain, Rod End, Self-Aligning, Self-Lubricating, Internally Threaded, -65°F to +325°F
MIL-B-81936	Bearing, Plain, Self-Aligning (BeCu CRES Race), General Specification for
MIL-B-81936/1	Bearings, Plain, Self-Aligning, BeCu Ball, CRES Race, (With Staking Groove), -65°F to +350°F
MIL-B-81936/2	Bearings, Plain, Self-Aligning, BeCu Ball, CRES Race, -65°F to +350°F
MS14101	Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, -65°F to 325°F, Narrow, Grooved Outer Ring
MS10102	Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, Wide, Chamfered Outer Ring, -650 to 325°F -65°F to 325°F, Wide, Grooved Outer Ring

MS10103	Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, Wide, Grooved Outer Ring, -65°F to 325°F
MS10104	Bearing, Plain, Self-Lubricating, Self-Aligning, Low Speed, Narrow, Chamfered Outer Ring, -65°F to 325°F
MS21150	Bearing, Double Row, ball, Rod End, Precision, Solid Shank, Self-Aligning, Anti-Friction, Airframe, Type I, -65°F to 350°F
MS21151	Bearing, Double Row, Ball, Rod End, Precision, External Thread, Self-Aligning, Anti-Friction, Airframe, Type II, -65°F to 350°F
MS21152	Bearing, Double Row, Ball, Rod End, Precision, Hollow Shank, Self-Aligning, Anti-Friction, Airframe, Type III, -65°F to 350°F
MS21153	Bearing, Ball, Rod End, Precision, Internal Thread, Self-Aligning, Anti-Friction, Airframe, Type IV, -65°F to 350°F
MS21154	Bearing, Plain, Self-Aligning, Grooved Outer Ring
MS21155	Bearing, Plain, Self-Aligning
MS21220	Bearing, Roller, Rod End, Internal Thread, Self-Aligning, Anti-Friction, Airframe, Heavy Duty, Type II, -67°F to 350°F, Sealed
MS21221	Bearing, Roller, Rod End, External Thread, Self-Aligning, Anti-Friction, Airframe, Heavy Duty, Type I, -67°F to 350°F, Sealed
MS21223	Bearing, Roller, Rod End, External Thread, Self-Aligning, Anti-Friction, Airframe, Heavy Duty, Type II, -67°F to 350°F, Sealed
MS21428	Bearing, Ball, Airframe, Anti-Friction, Extra Light Duty, -65°F to 350°F, Precision
MS21432	Bearing, Roller, Needle, Track Roller, Integral Stud, Type VII, Anti-Friction, Inch
MS24461	Bearing, Roller, Needle, Single Row, Heavy Duty, Type I, Anti-Friction, Inch
MS24462	bearing, Roller, Needle, Single Row, Thin Shell, Type II, Anti-Friction
MS24463	bearing, Roller, Needle, Single Row, Heavy Duty, Self-Aligning Type 111, Anti-Friction, Inch
MS24464	Bearing, Roller, Needle, Double Row, Heavy Duty, Self-Aligning, Type IV, Anti-Friction, Inch
MS24465	bearing, Roller, Needle, Single Row, Heavy Duty, Track Roller, Type V, Anti-Friction, Inch
MS24466	Bearing, Roller, Needle, Double Row, Heavy Duty, Track Roller, Type VI, Anti-Friction, Inch
MS27640	Bearing, Ball, Airframe, Anti-Friction, Heavy Duty, -65°F to 350°F
MS27641	Bearing, Ball, Airframe, Anti-Friction, Intermediate Duty, -65°F to 350°F
MS27642	Bearing, Ball, Airframe, Extra Light Duty, -65°F to 350°
MS27643	Bearing, Ball, Airframe, Anti-Friction, Self-Aligning, Double Row, Heavy Duty, -65°F to 350°F
MS27644	Bearing, Ball, Airframe, Anti-Friction, Double Row, Heavy Duty, -65°F to 350°F
MS27645	Bearing, Ball, Airframe, Anti-Friction, Self-Aligning, Light and Heavy Duty, -65°F to 350°F
MS27646	Bearing, Ball, Airframe, Anti-Friction, Extra Light Duty, -65°F to 350 °F
MS27647	Bearing, Ball, Airframe, Anti-Friction, Extra Wide, Double Row, Intermediate Duty, -65°F to 350°F

MS27648	Bearing, Ball, Airframe, Anti-Friction, Externally Self-Aligning, Extra Light Duty, -65°F to 350°F
MS27649	Bearing, Ball, Airframe, Anti-Friction, Intermediate Duty, -65°F to 350°F
MS28913	Bearing, Roller, Self-Aligning, Double Row, Airframe, Anti-Friction, Sealed, Type II, -67°F to 350°F
MS28914	Bearing, Roller, Self-Aligning, Double Row, Wide Inner Ring, Airframe, Anti-Friction, Sealed, Type III, -67°F to 350°F
MS28915	Bearing, Roller, Self-Aligning, Double Row, Torque Tube, Airframe, Anti-Friction, Sealed, Type IV, -67°F to 350°F
MS81934/1	Bearing, Sleeve, Plain, Self-Lubricating, 325°F
MS81934/2	Bearing, Sleeve, Flanged, Self-Lubricating, 325°F
MS81935/1	Bearing, Plain, Rod End, Self-Aligning, Self-Lubricating, Externally Threaded, -65°F to +325°F
MS81935/2	Bearing, Plain, Rod End, Self-Aligning, Self-Lubricating, Internally Threaded, -65°F to +325°F
MS81936/1	Bearings, Plain, Self-Aligning, BeCu Ball, CRES Race, (With Staking Groove), -65°F to +350°F
MS81936/2	Bearings, Plain, Self-Aligning, BeCu Ball, CRES Race, -65°F to +350°F
AMS 4640	Rods , Bars, and Forgings, Aluminum Bronze, 81.5 Cu, 10.3 Al, 5 Ni, 2.8 Fe
AMS 4880	Castings, Centrifugal Aluminum Bronze, 81.5 Cu, 10.3 Al, 5 Ni, 2.8 Fe
AMS 5630	Bars and Forgings 17 Cr, 0.5 Mo (0.95-1.20 C)
AMS 5643	Bars, Forging, Tubing and Rings, 16 Cr, 4.0 Ni, 0.30 (Cb + Ta) 4. Cu
NAS 72	Bushing, Clamp-up, Steel, Chrome-Plated
NAS 73	Bushing, Clamp-up, Steel, Cadmium Plated
NAS 74	Bushing, Clamp-up, Bronze
NAS 75	Bushing, Plain, Press-Fit, Steel
NAS 76	Bushing, Plain, Press-Fit, Bronze
NAS 77	Bushing, Flanged, Press-Fit, Steel and Bronze
NAS 537	Bushing, Sleeve, Press-Fit, Undersize Inside Diameter
NAS 538	Bushing, Flanged, Press-Fit, Undersize Inside Diameter

AFBMA standards, section no. 1, "Terminology and Definitions for Anti-Friction Ball and Roller Bearings and Parts".

3. Bearing definitions, terminology and descriptions. Aerospace vehicle bearings as used herein, is a term which applies to all types of bearings used in the design of the actual aerospace vehicle excluding those bearings used in equipment and machinery of a specialized nature such as engines, generators gear boxes and landing gear wheels.

3.1 Definitions and terminology. Definitions and terminology, as used herein, shall be based on AFBMA section no. 1, "Terminology and definitions for Anti-Friction Ball and Roller Bearings and Parts". This base will be modified and augmented by those definitions and that terminology generally accepted currently by the Bearing Manufacturing and Airframe Manufacturing Industries and the using U.S. Government Services.

3.2 Bearing type descriptions. Bearings are generally classified into several "Types" based on details of geometry and construction and on the nature of usage. The following types are common in aerospace vehicle design.

3.2.1 Anti-friction bearings. These bearings are commonly termed "rolling element bearings" and the terms are used interchangeably. They utilize a complement of balls, rollers, or needles separating an outer ring and an inner ring. The outer ring is usually mounted in the housing and the inner ring on a shaft. Other elements of these bearings may be rolling element separators, shields or seals, and seal retainers.

3.2.1.1 Ball bearings. The ball bearings used in aerospace vehicles are primarily annular ball bearings. Linear motion ball bearings are used in a few special applications. Annular ball bearings are intended for use in rotational or oscillatory applications, under radial, axial, or combination loading. Linear motion ball bearings (or bushings) are intended for linear or axial motion between the shaft and housing and have no axial or thrust load capability. Annular ball bearings are available, within a given configuration, with varying numbers of balls in the rolling element complement. The three common configurations are illustrated in figure 201-2. Several configurations of ball bearings have been standardized and developed specifically for airframe use. They generally have rugged construction, full ball complements, seals, and corrosion resistant plating. They are intended for heavy, oscillatory loads and have no relubrication capacity.

3.2.1 .1.1 Ball complement. Most types of ball bearings are available in three configurations, each containing a different complement of balls (see figure 201.2) as follows:

a. Full complement (filling slot type). This bearing configuration contains the maximum quantity of balls, with no cage or retainer separating the balls. It is best suited to most airframe applications as it will withstand the highest loads and is most satisfactory for oscillating or low speed loads not exceeding 500 rpm.

b. Maximum complement (filling slot type. This bearing configuration contains the maximum quantity of balls, with a cage or retainer separating the balls, and is for heavy radial loads at speeds not exceeding 5000 rpm. The thrust load capability is somewhat less than half the static load limit.

c. Conrad. This bearing configuration contains a cage or retainer to separate the balls, has no filling slot and is for relatively light radial loads but high speed applications not to exceed 15,000 rpm. Thrust and radial capacity are approximately equal and about one-third the static limit capacity of the full complement type. The Conrad bearing has the lowest load capacity of the three types of ball bearings because it contains fewer balls. The number of balls is limited by the method of assembly.

3.2.1.1.2 Typical airframe ball bearings. Bearings of various configurations and capacities are available for airframe use where radial loads are large, thrust loads relatively small, and misalignment is less than 15 minutes of arc. They are given a letter type designation and an MS number and include: MS27640(KP), MS27641(KP-A), MS27642(KP-B), and MS27644(DPP). Where the alignment exceeds 15 minutes of arc, bearings of similar geometry to the above are available with aligning capability but with some sacrifice in load capacity. They include MS27645(KSP & KSP-A) and MS27643(DSP). These typical airframe bearings are listed in table 201-1. Other characteristics and applications of ball bearings include:

a. Low torque

b. For oscillating motion or slow intermittent rotation (below 500 revolutions per minute (rpm) for general airframe use)

c. Designed to carry radial and thrust loads

d. Low static load capacity

e. Good radial and axial position accuracy

f. Prelubricated for rated life of bearing but no provisions for relubrication. (See requirements 301 and 304 for specific approved bearings.)

3.2.1 .1.3 Airframe torque tube bearings. Extra light duty ball bearings *of* the MS27642(KP-B) and MS27646(B500DD) series are used in relatively large diameter torque tube applications where radial loads are large, thrust loads are small, and misalignment is less than 15 minutes of arc. For torque tube applications where initial installation misalignment occurs, and thrust loads are small and unidirectional, MS27648(KP-BS) self-aligning bearings may be used. They are not dimensionally interchangeable with the MS27642(KP-B) bearings. Bearings with self-aligning outer rings shall not be used for operational misalignment as they are designed to accommodate only initial installation misalignment.

3.2.1.2 Needle bearings

3.2.1.2.1 Typical airframe needle bearings. Needle bearings carry higher radial loads, within a particular envelope, than other types of antifriction bearings. For optimum performance, installation alignment must be good, shaft deflection limited, and thrust loads avoided. Type MS24462(NCC) bearings must be supported in rigid housings because of their thin outer race. Type MS24463(NBE) and MS24464(NBK) may be used where limited initial installation alignment occurs. (Typical needle bearings are listed in table 201-11. Specification approved bearings are listed in requirement 303.) Characteristics arid applications of needle bearings include:

a. Low torque

b. For oscillating motion and slow intermittent rotation (below *100* rpm)

c. Designed to carry radial loads

d. Can be relubricated

e. Alignment of needle bearings other than self-aligning types is critical; misalignment will result in limited life

f. Adequate lubrication and occasional rotation through an angle greater than 150 is necessary to minimize fretting.

NOTE: For the purposes of this discussion, an airframe needle bearing contains a full complement of needle rollers; there are no separators or retainers in airframe needle bearings.

3.2.1.2.2 Track rollers, yoke type and stud type. Special needle bearings are available for use in rolling applications on tracks such as in wing flap applications. Single row MS24465(NBF) and double row MS24466(NBL) track track rollers are available for clevis mounting in a yoke. MS21432(HRS) cam followers have an integral stud for cantilever mounting. These bearings are illustrated in table 201-11. The crowned rollers are not intended for deliberate misalignment in applications, but will compensate for small amounts of adverse dimensional tolerance and deflection induced misalignment .

3.2.1.3 Roller bearings. Typical roller bearings are listed in table 201-111. See requirement 302 for specifically approved bearings.

3.2.1.3.1 Typical airframe roller bearings. Roller bearings are useful for applications where loading is beyond the capability of comparable size ball bearings and where a combination of the following characteristics is desirable in the design application:

a. All types are self-aligning.

b. Accept slow rotation (below 100 rpm) in addition to oscillation.

c. All types are pre-lubricated and have provision for relubrication, except MS28912 bearings.

d. Low torque.

e. Carry radial, thrust, and combined loads.

f. Equipped with seals.

g. Corrosion-resistant plating.

3.2.1 .3.2 Airframe torque tube bearings. Light duty roller bearings of the MS28915 series are used in relatively large diameter torque tube applications where radial loads are large and thrust loads minimal.

3.2.2 Plain bearings. This class of bearings is frequently referred to as "sliding surface bearings" and Includes all types of bearings in which surfaces slide relative to one another, whether separated by a lubricant or in intimate contact. Included are cylindrical sleeves or bushings as used in so-called "static joint" applications. Plain bearings are divided into spherical, cylindrical, rod ends, and special bearings based on the design geometry and application.

3.2.2.1 Spherical bearings. The term spherical bearing as used herein refers to a bearing composed of a spherical shaped piece with a hole for a shaft and employed as an inner race and spherically concave single piece outer member conforming to the shape of the inner race. A grease lubricant, dry film lubricant, or TFE type liner may be employed between the races for lubrication. The outer member may be permanently swaged around the outer portion of the inner or slotted to accept the inner member. The two types of spherical bearings are therefore identified as the metal-to-metal type and the lined type. Both typed are included in table 201-IV.

3.2.2.1.1 Metal-to-metal type. These bearings can be used in basically all airframe applications with lubricant provisions per requirement 203. Dry film lubrication may be used in certain applications where there is limited bearing motion under load or where elevated temperatures are beyond the grease capability. When these bearings are used in the pilot-feel portion of primary control systems, it is essential to determine that friction levels and radial play are acceptable. Table 201-IV shows typical bearings of this type and approved bearings are specified in requirement 306.

3.2.2. 1.2 Lined type bearings. These bearings are used in similar applications to the metal-to-metal type where relubrication is impossible or undesirable . The liners are sacrificial and normal wear rates can be accelerated by liquid contaminants, temperature extremes, and impact loading. The designer must size these bearings so that adequate life is attained under the service loading and environment. Table 201-IV shows typical bearings of this type and approved bearings are specified in requirement 307. As with metal-to-metal bearings, it is essential to determine that friction levels and radial play due to wear are acceptable when these bearings are used in the pilot-feel portion of primary control systems.

3.2.2.2 Journal bearings. Journal bearings are used in aerospace vehicle applications similar to those in which plane spherical bearings are used. However, they have no misaligning capability. They are of simple construction with a flanged or unflanged "sleeve" or "bushing" acting as the outer member and rotation occurring between the sleeve and a structure-connecting shaft or pin. These bearings are available with the same lubrication options as is afforded on the inside diameter (ID) of spherical bearing outer races. Material choices are also similar, as are load capability and application limitations. Journal bearings may be used without lubrication provisions in static joints to protect structure and provide an economical, easily replaced design element. Table 201-V shows typical standard journal bearings and bushings. Approved journal bearing standards are specified in requirements 309 and 310. All others require specific approval in accordance with requirement 101.

3.2.3 Rod end bearings. These bearings are intended for use on push-pull rods as end fittings to permit functional attachment to mechanisms and structure. They consist of a self-aligning bearing in housing with an integral shank for attachment to the rod. They are available with antifriction ball or roller bearings and with metal-to-metal or lined plain spherical bearings. Shanks may be solid or hollow and may be either internally or externally threaded as appropriate for the designed attachment. Limitations on applications are governed by the insert or "cartridge" bearings and on fatigue considerations of the housing. Typical rod end bearings are illustrated and described in table 201-VI. Requirement 308 specifies approved rod end bearings.

3.2.4 Miscellaneous bearings. Several other types of bearings are occasionally used in aerospace vehicle design. These consist of linear motion ball bearings (ball bushings), pillow block bearings, instrument bearings, loader slot spherical bearings, and snap assembly spherical bearings.

3.2.4.1 Linear notion ball bearings. These bearings are used in applications where slow axial travel, with or without limited rotation, Is a design requirement. (Typical linear motion ball bearings are illustrated in figure 201-1.) Their use should be limited to those standards specified in requirement 311 and within the following:

a. Rotary motion less than 360° and not to exceed 10 rpm

b. Shaft hardness of at least Rc 50

c. Shaft surface 125 RHR or better

3.2.4.2 Pillow block bearing. Pillow block bearings are sometimes used for mounting equipment and mechanisms. They consist of a bolt-down housing with a variety of types of cartridge bearings. They are not included in the scope of MIL-STD-1599 and must be individually selected or designed and approved Per requirement 101.

3.2.4.3 Instrument bearings. These bearings are included in the design of many types of equipment used on aerospace vehicles. As such they are not presently within the scope of MIL-STD-1599. If used in aerospace vehicle-proper design they require approval in accordance with requirement 101.

3.2.4.4 Loader slot spherical bearings. There are numerous designs that fall into the general category of loader slot (Messerschmidt) bearings. Each has its own advantages and disadvantages. The following discussion applies to loader slot bearings as a group.

a. A major advantage of loader slot bearings is the close tolerance that can be achieved by grinding the inside spherical diameter of the outer ring. Excellent conformity between ball and outer race can be accomplished. This also means that a close tolerance on radial and axial play can be accomplished. This advantage is not so pronounced on small diameter bearings since conformity is fairly easy to achieve on small parts by swaging.

b. Very high strength steels or specialty materials can be Used in the outer race for better wear characteristics, high static load capacity, high temperature capability, corrosion resistance, or other special requirements. In a swaged bearing the race is usually relatively soft and ductile to prevent race cracking during swaging and to get good conformity. It should be noted here that it is possible to make a swaged bearing with a relatively hard outer race by using maraging steel components which can be heat treated after the swaging process. In some applications it is also possible to gain the advantages of a hard outer race without the disadvantages of a loader slot bearing by using the fractured outer race technique.

c. It is possible to replace the ball in the field without replacing the entire bearing.

d. The requirement to properly orient the slot with respect to the load is a major disadvantage of loader slot bearings. In some applications where load varies in direction over 60° to 90°, it is impossible. If reverse loader slot bearings are used (ball has the reduced section instead of the race) proper orientation is impossible.

e. A loader slot can significantly reduce the bearing area. Selection should be limited to bearings with fairly narrow balls to prevent this loss from being excessive.

f. It is difficult to retain grease and keep dirt and contaminates out unless the loading slot is sealed. It is possible to seal the loading slot, but this can reduce the effective bearing area and makes the bearing more expensive.

3.2.4.5 Snap assembly spherical bearing. These bearings are not covered by MS standards. They are of a torque tube bearing configuration with large diameter-to-width ratios. The races are sufficiently thin as to permit assembly of the ball within the race by elastic deformation. As non-standard bearings, they require approval in accordance with requirement 101 for use in aerospace vehicle design.

4. Bearing selection. In selecting a bearing for a specific aerospace vehicle application, the functional characteristics of the bearing must be optimally matched against the application requirements. The bearing type must be determined through an evaluated of envelope dimensions, unique geometry, and load and life characteristics.

4.1 Selection within types. The two types of bearings considered are anti-friction or “rolling element” bearings and plain or “sliding surface” bearings.

4.1.1 Anti-friction bearings. This type of bearing includes ball, roller, and needle bearings. Each of these sub-types emphasizes certain envelope and operational characteristics. Table 201-VII highlights a number of parameters to be used in selecting between anti-friction and plain bearings and in selecting the optimum anti-friction bearing. Figure 201-3 is a guide which aids in selection of a specific standard anti-friction bearing. See also tables 201-1, 201-11, and 201-111.

4.1.2 Plain bearings. Figure 201-4 is matrix of the available standard plain journal bearings and plain spherical bearings. It is intended for use in making a selection of a plain bearing for a specific application in conjunction with tables 201-IV and 201-V.

4.2 Selection for systems application. Optimum selection of a bearing for a system application is often dictated by the unique set of requirements imposed on the bearing by the specific system function.

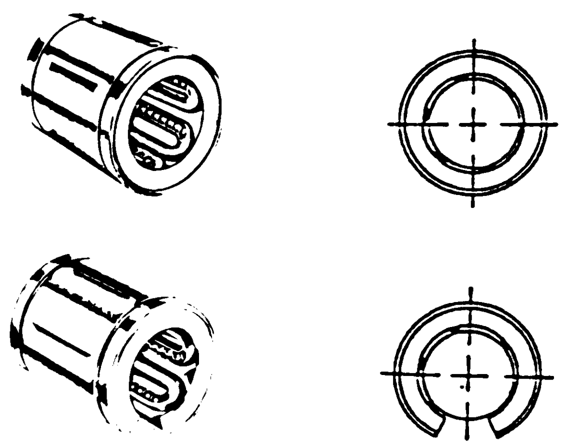


FIGURE 201-1. Linear motion ball bearings.

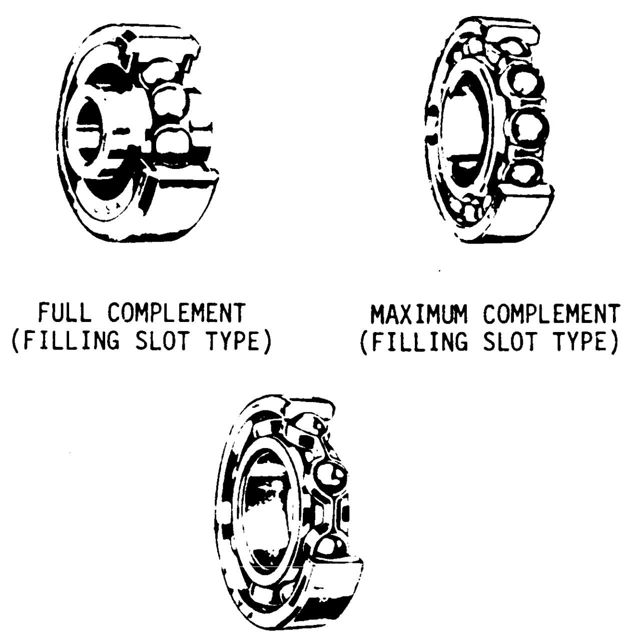


FIGURE 201-2. Annular ball bearings.

TABLE 201-I. Typical ball bearings.

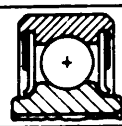
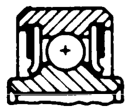
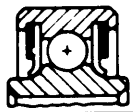
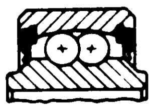
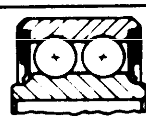
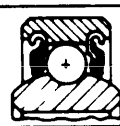
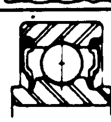
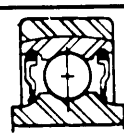
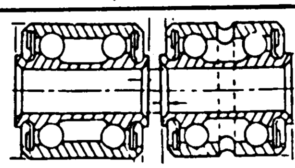
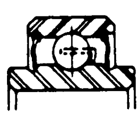
ILLUSTRATION	TYPICAL SERVICE	BORE SIZE RANGE	SERIES	MILITARY STANDARD
	Heavy Duty	0.1900–0.6250	KP	MS27640
	Light Duty	0.1900–1.2500	KP-A	MS27641
	Light Duty	1.313-3.063	KP-B	MS27642
	Heavy Duty Self-Aligning	3/16 thru 5/8	DSP	MS27643
	Extra-Heavy Duty	0.1900–0.6250	DPP	MS27644
	Light and Heavy Duty Self-Aligning	0.1900–0.6250	KSP KSP-A	MS27645
	EXTRA-LIGHT DUTY	0.6250-2.3125	B500DD MB500DD	MS27646 MS21428
	EXTRA-LIGHT DUTY SELF-ALIGNING	1.0000-3.0630	KP-BS	MS27648
	INTERMEDIATE DUTY EXTRA WIDE	0.2500-0.5000	DW GDW	MS27647
	INTERMEDIATE DUTY	0.1900-1.2500	AWAK	MS27649

TABLE 201-11. Typical needle bearings.

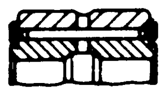
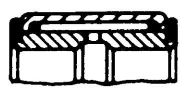
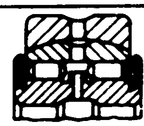
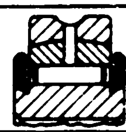
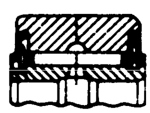
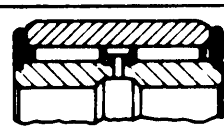
ILLUSTRATION	TYPICAL SERVICE	BORE SIZE RANGE	SERIES	MILITARY STANDARD
	Heavy Duty	0.1900 thru 5.0000	NBC	MS24461
	Extra-light Duty Oscillation	0.1900 thru 1.2500	NCC	MS24462
	Heavy Duty Self-Aligning Single Row	0.1900 thru 0.3125	NBE	MS24463
	Heavy Duty Self-Aligning Double Row	0.3750 thru 3.5000	NBK	MS24464
	Track Roller Single Row	0.1900 thru 2.7500	NBF	MS24465
	Track Roller Double Row	0.3750 thru 2.000	NBL	MS24466
	Track Roller Single Row	Stud Diameter 0.1900 thru 0.500	HRS	MS21432

TABLE 201-III. Typical roller bearings.

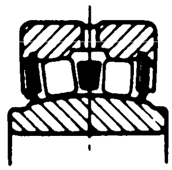
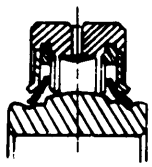
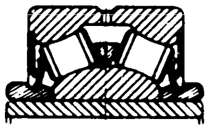
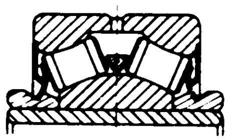
ILLUSTRATION	TYPICAL SERVICE	BORE SIZE RANGE	SERIES	MILITARY STANDARD
	Extra light duty, self-aligning torque tube	1.0000 - 3.0630	DAT	MS28915
	Self-aligning, intermediate duty	0.1900 - 0.5000	SA	MS21431
	Self-aligning, heavy duty, high thrust	0.2500 - 0.7500	DAS	MS28913
	Self-aligning, extra heavy duty, high thrust	0.2500 - 0.8750	DAS	MS28914

TABLE 201-IV. Typical spherical type bearings.

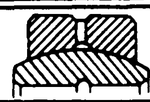
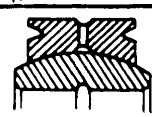
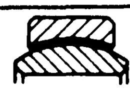
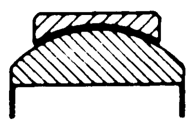
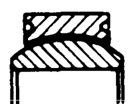
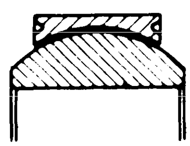
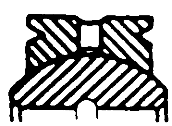
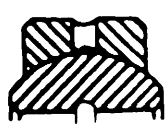
ILLUSTRATION	TYPICAL SERVICE	BORE SIZE RANGE	SERIES & MATERIALS	MILITARY STANDARD
	Infrequent oscillation or misalignment, heavy loads	0.1900 to 1.0000	Narrow series steel ball & race, grease lubricated.	MS21155
	Intermittent oscillation or misalignment, light to medium loads.		Narrow series, steel ball, bronze race, grease lubricated.	MS21154 (Grooved outer race for staking)
	Intermittent to steady oscillation or misaligning, medium to heavy loads.	0.1900 to 1.0000	Narrow series CRES ball & race. Teflon lined.	MS14104
			Wide series CRES ball & race. Teflon lined.	MS14102
			Narrow series grooved ring. CRES ball & race TFE Lined	MS14101
			Wide series grooved ring. CRES ball & race TFE Lined	MS14103
		0.2500 to 1.5000	Narrow series grooved ring. BeCu ball CRES race	MB1936/1
			Narrow series BeCù ball CRES race	MB1936/2

TABLE 201-V. Journal bearing and bushings.

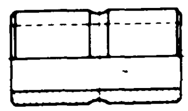
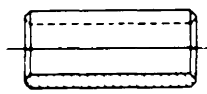
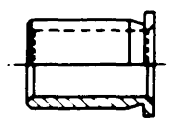
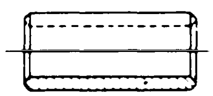
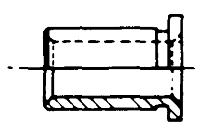
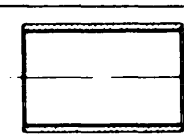
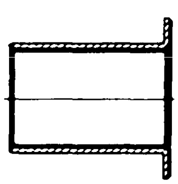
ILLUSTRATION	TYPICAL SERVICE	BORE SIZE RANGE	SERIES & MATERIALS	MILITARY STANDARD
	Clamp up on shaft heavy static loads, little movement.	0.190 to 1.000	Steel 4130 chrome plated on O.D.	NAS 72
	Clamp up on shaft heavy static loads, little movement.	0.190 to 1.000	Steel, 4130 cadmium plated all over	NAS 73
	Clamp up on shaft medium static load, movement on O.D.	0.196 to 1.000	Bronze, Al	NAS 74
	Press fit, heavy static loads, little movement.	0.190 to 1.250	Steel, cadmium plated	NAS 75
	Press fit, medium static loads, movement on I.D. of bushing	0.190 to 1.250	Bronze, Al (Cd plated)	NAS 76
	Press fit, heavy static loads, (steel) medium static loads & medium oscillating loads (bronze)	0.190 to 1.250	Steel (Cd plated) or Bronze (Cd plated)	NAS 77
	Press fit, inside undersize for reaming. Heavy static loads (steel) Medium static and medium oscillating (bronze)	0.1790 to 1.2190	Steel (4130) Cd plated Bronze, Al (Cd plated)	NAS 538
	Press fit, inside undersize for reaming. Heavy static loads (steel) Medium static and medium oscillating (bronze)	0.1790 to 1.2190	Steel (4130) Cd plated Bronze, Al (Cd plated)	NAS 538
	Movement between bearing bore and shaft. Can handle fretting conditions. Radial load only.	0.2515 to 2.0015	Aluminum or CRES shell Teflon lining	MS 81934/1
	Movement between bearing bore and shaft. Can handle fretting conditions. Radial load and thrust load in one direction.	0.2515 to 2.0015	Aluminum or CRES shell Teflon lining	MS 81934/2

TABLE 201-VI. Rod end bearings.

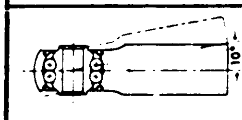
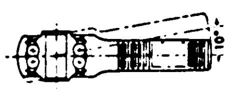
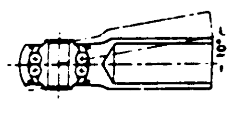
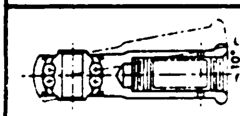
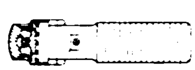
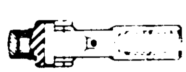
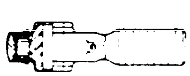
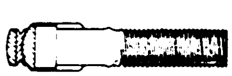
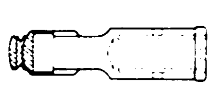
ILLUSTRATION	TYPICAL SERVICE	BORE SIZE RANGE	TYPE	MILITARY STANDARD
Ball Bearing Rod Ends				
	Low to medium static loads, medium dynamic radial and thrust load	0.1900 to 0.2500	Self aligning ball bearing, solid shank	MS 21150
	Low to medium static loads, medium dynamic radial and thrust load	0.1900 to 0.6250	Self aligning ball bearings, externally threaded shank	MS 21151
	Low to medium static loads, medium dynamic radial and thrust load	0.1900 to 0.2500	Self aligning ball bearing, hollow shank	MS 21152
	Low to medium static loads, medium dynamic radial and thrust loads	0.1900 to 0.3125	Self aligning ball bearing, internal thread	MS 21153
Roller Bearing Rod Ends				
	Medium static loads, light thrust and radial dynamic loads	0.2500 to 0.3750	Roller bearing, self aligning, externally threaded shank	MS 21223 (MIL-B-8952)
	Medium static loads, medium dynamic radial and thrust loads	0.2500 to 0.3750	Roller bearing, self aligning, internally threaded shank	MS 21220 (MIL-B-8952)
	Medium static loads, medium dynamic radial and thrust loads	0.2500 to 0.6250	Roller bearing, self aligning, externally threaded shank	MS 21221 (MIL-B-8952)
Plain Spherical Bearing Rod Ends				
	High static loads, medium dynamic and thrust loads	0.1900 to 1.0000	Plain bearing TFE lined, externally threaded shank	M/81935/2 (MIL-B-81935)
	High static loads, medium dynamic and thrust loads	0.1900 to 1.0000	Plain bearing TFE lined, internally threaded shank	M/81935/1 (MIL-B-81935)

TABLE 201-VII. Bearing selection parameters.

OPERATING PARAMETER	ROLLING ELEMENT BEARINGS			SLIDING ELEMENT BEARINGS	
	BALL BEARINGS	NEEDLE BEARINGS	ROLLER BEARINGS	TFE LINED BEARINGS	METAL ON METAL BEARINGS
Load Capacity (For a Given Envelope Size)					
Radial (Static)	Low	Medium	Medium	Medium	High
Axial (Static)	Low	Cannot Tolerate	Medium	Medium	High
Moment	Low	Extremely Limited	Low	Medium	High
Shock	Low	Medium	Medium (Preloading Helps)	Medium	High
Vibration	Rapid Fretting	Mod. Fretting	Rapid Fretting (Preloading Helps)	Medium	High
Type of Operation					
Small Oscillation	Possible Fretting	Best of Rolling Element	Possible	Handle Well	Reversed Loading Req'd
Oscillation	Good	Good	Good	Good	Reversed Loading Req'd
Slow Rotation	Good	Good	Good	Limited by Surface Speed	Excellent
Speed					
High Speed Oscillation (Continuous)	Excellent With Cages	Excellent With Cages	Excellent With Cages	Excellent at Small Angles	Poor
High Speed Oscillation (Intermittent)	Excellent	Excellent	Excellent		Requires Reverse Loading
High Speed Rotation (Continuous)	Excellent With Cages	Not Intended	Excellent With Cages	Do Not Use	(TBD)
High Speed Rotation (Intermittent)	Excellent With Cages	Not Intended	Excellent With Cages	Consult Standards	(TBD)
High Acceleration	Requires Preload	Not Intended	Requires Preload	Good	Good
Duty Cycle	No Effect	No Effect	No Effect	May Cause Heat	May Cause Heat
Temperature					
Continuous	Dependent on Grease Seals and Mat'l -65°F to 350°F for Standards	Dependent on Grease Seals and Mat'l. to 250°F Standards	Dependent on Grease Seals and Mat'l. to 350°F Standards	-65°F to 325°F	Dependent on Mat'l and Lube
Maximum				375°F	Dependent on Mat'l Expansion
Minimum				High Increase in Friction	Good
Misalignment	Decrease in Capacity	Cannot Tolerate	Good	Good	Good
Coefficient	.0015	.0025	.002	Dependment on Load and Temp .03 – .10	.2
Position Accuracy	Dependment on Internal Clearance	Dependent on Internal Clearance	Dependent on Internal Clearance	Changes with Wear	Approx. .001 Initially, Changes with Wear
Environmental Conditions Dirt, Water, Contaminates Phosphate Ester Fluids Vacuum	Permanently Sealed No Problems With MS Outgas of Lube	(TBD) (TBD) Outgas of Lube	Sealed and Purged With Lube Outgas of Lube	Increased Wear Rate Increased Wear Rate No Effect	Purged with Lube No Effect Outgas of Lube
Required Life Shelf Service	Dependent on Lube Limited by Wear, Galling, Seizing and Fretting	Dependent on Lube Limited by Wear, Galling, Seizing and Fretting	Dependent on Lube Limited by Wear, Gallling, Seizing and Fretting	Excellent Limited by Wear	Dependent on Lube and Load
Retention Methods	Stake Housing	Stake Housing	Stake Housing	Stake Housing or BRG	Stake Housing or BRG
Maintenance	Permanently Packed	Relubrication Req'd	Relube for High Loads	Self Lubricating	Relubricate Often
Pressure Differential	May Purge	May Purge	May Purge	No Problem	No Problem
Stiffness	Low	Medium	Medium	(TBD)	High

NOTE: Many of the above parameters are highly dependent on the application. Therefore the information should be used only as a guide toward the initial bearing selection.

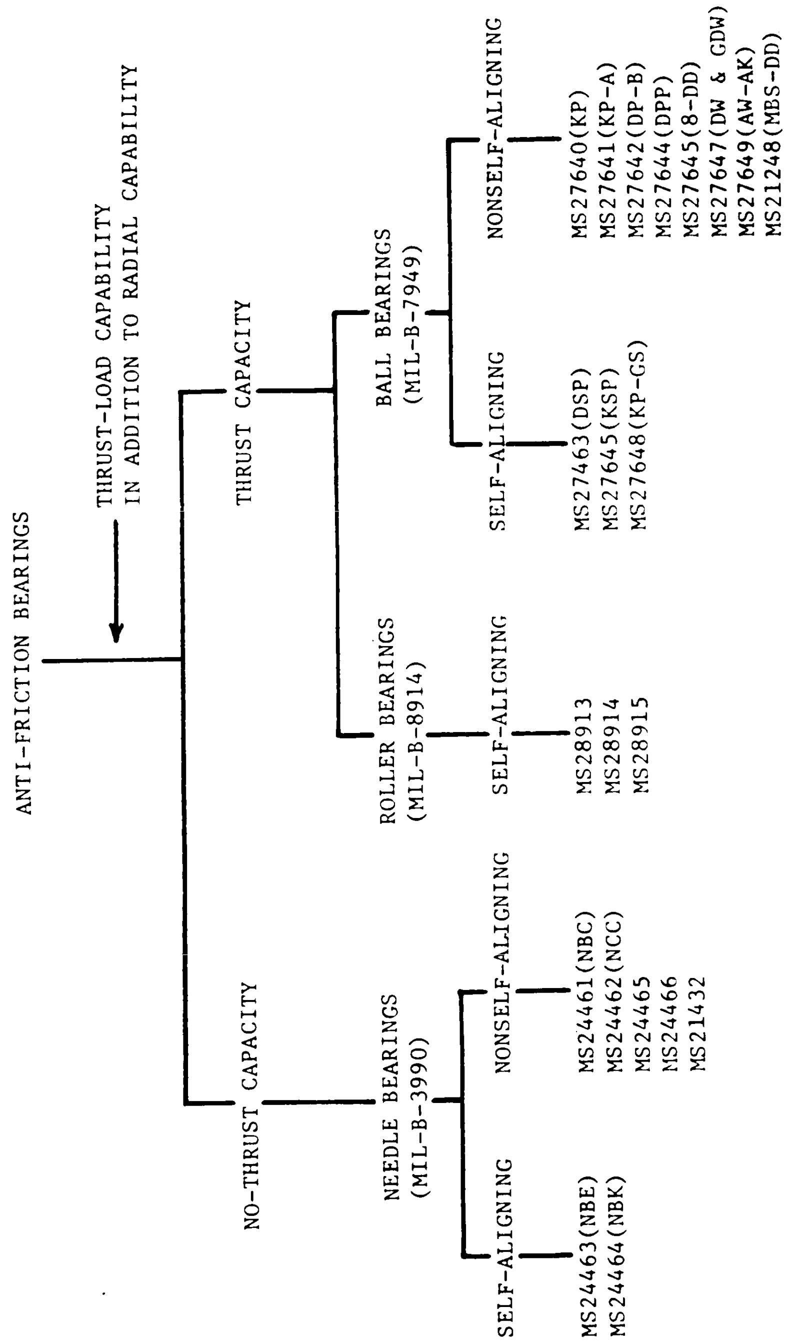


FIGURE 201-3. Standard anti-friction bearing selection matrix.

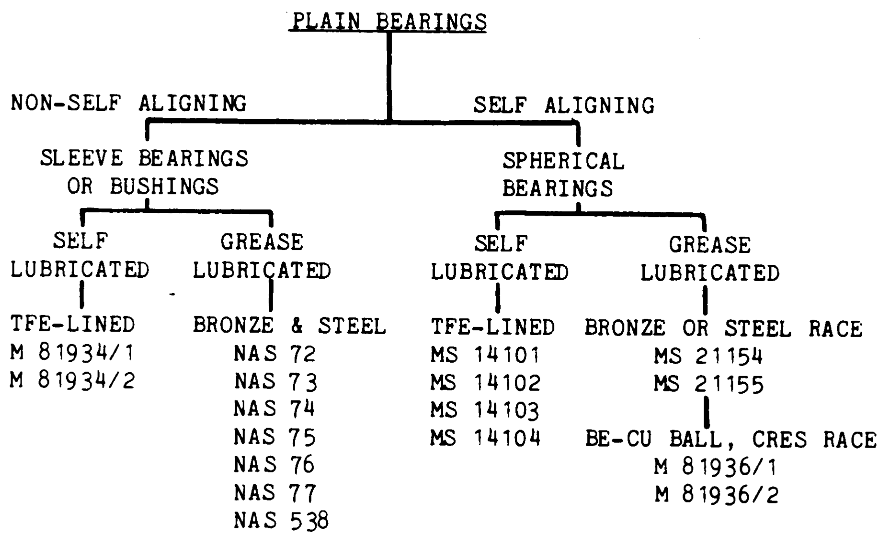


FIGURE 201-4. Plain bearing standard selection matrix (see requirements 306, 307, 309 and 310).

4.2.1 Primary control systems. These systems utilize numerous bearings in the control surface positioning mechanisms. Due to the possibility of friction build-up, emphasis should be placed on anti-friction bearings per requirement 206. Primary control surface hinge and support bearings do not have such critical friction requirements. Accordingly, plain bearings should be considered to minimize weight and envelope penalties. The unit dynamic loading on these bearings must be kept sufficiently low to obtain design life. Rod end bearings used in control rods shall be meet this requirement and requirement 207.

4.2.2 Secondary and auxiliary control systems. Bearings used in these systems shall be subject to the limitations of this requirement and requirement 207.

4.2.3 Landing gear. Bearings used in aerospace vehicle landing gear can be functionally categorized into:

a. Structural bearings to transfer major loads between the gear and the vehicle structure, such as trunnion bearings.

b. Bearings, other than major load-carrying bearings, which maintain the gear in the appropriate deployed position. These include end attach bearings on side struts and drag struts.

c. Landing gear actuation mechanism bearings.

4.2.3.1 The above first two categories of bearings normally carry very high loads while in an essentially "static" situation. Bearing rotation is that due to structural deflection but loads are high, of an impact nature, and often reversing. The same bearings must permit sufficient rotation to permit gear extension and retraction. Loads during actuation are due primarily to only the gear weight plus air loads and are commonly about ten percent of the "static" loads. Plain bearings function well in these applications and, where sufficient space is available, anti-friction roller bearings may also be used.

4.2.3.2 Landing gear actuation mechanism bearings should be isolated from the primary load paths in the gear. This permits bearing selection and sizing based only on the actuation loads. Bearing selection is based on the same considerations as in other actuation systems. Plain bearings and anti-friction roller bearings are both suitable.

4.2.4 Flaps and spoilers. Bearing loading in these applications differs from landing gear bearing loading in that maximum loading occurs while these surfaces are deployed into the slip stream. Accordingly, the static and dynamic loading of the bearings is quite close and bearing selection is based on bearing life under dynamic loading. Hinge, support, and actuation mechanisms use bearings of the plain or, on occasion, anti-friction roller bearings for these applications. Most flap systems use structural tracks to deploy the flaps with the flaps attached to the tracks with a flap carriage. Flap carriage bearings require high load capacity, minimum envelope, and low friction. Track roller bearings should be used for such applications.

4.3 Selection based on bearing characteristics. Selection of the proper bearing for an aerospace vehicle application requires consideration of a number of specific bearing functional characteristics. These include friction, torque, temperature capabilities, static and dynamic load capabilities, and rotational and alignment capabilities.

4.3.1 Friction. Airframe anti-friction full type bearings may be considered to have a running coefficient of friction of 0.0025. A conservative value for caged ball bearings is 0.0015. Use a value of 0.0025 for needle complement track rollers and 0.002 for roller bearings. Table 201-VII includes representative friction coefficient values. Properly lubricated metal-to-metal plain bearings, both spherical and journal, operate with a friction coefficient varying between 0.10 and 0.30. The low figure relates to reverse loading and considerable motion, while the higher value occurs with heavy, unidirectional loading and relatively slow motion. A coefficient of 0.20 is a reasonably conservative value for most design work. TFE fabric lined plain bearings may be considered to have a friction coefficient of .03-.10. The coefficient decreases for TFE with increases in temperature and load. The increase at low temperatures is considerable and adequate allowances must be made in design. If a design requires lower friction than is indicated above for proper functioning, it may be necessary to use special bearings with variations in materials, lubricants, internal geometry, or sealing techniques. Such special bearings require approval per requirement 101.

4.3.2 Torque. The coefficient of friction of a bearing is an indirect measure of the bearing's resistance to rotation. As such, the designer needs certain information on bearing internal geometry to make the necessary calculations. A more direct approach is to work with torsional resistance or torque.

4.3.2.1 Anti-friction bearings. At normal temperatures, these bearings introduce relatively little frictional torque into control system mechanisms. The running torque of a grease lubricated anti-friction bearing under load at moderate temperature can be estimated from the formula.

$T = \mu_f R F_r$ where

T = torque, inch pounds

μ_f = friction coefficient (see 4.3.1 and table 201-VII)

R = 1/2 bearing bore, inches

F_r = radial load, pounds

At low temperature and light load, a large portion of the torque generated by the bearing is due to the resistance of the grease. Another large portion of the torque is due to seal drag. Figure 201-6 and 201-7 show the no-load starting and running torque of a number of standard bearings. Values are shown for a temperature range of -65°F to 70°F.

$T_T = T + T_{NL}$, where

T_T = torque at desired temperature, inch pounds

T = torque at 70°F, inch pounds

T_{NL} = no load torque at desired temperature, inch pounds, (from figure 201-6)

The torque values shown in figures 201-5 and 201-6 are average values from limited test data. Values for individual bearings in specific applications will show significant scatter based on the grease used, the amount and distribution of the grease, effect of seals, bearing source, and the installation fit and retention method. A comparison of the low temperature properties and characteristics of several greases can be found in requirement 203. The values from the figures will give realistic frictional torque values for a complete system. For those instances where only one or two bearings are involved, the torque values in the figures should be multiplied by the factors listed with the figures. These factors represent the maximum scatter experienced in testing. For operating speeds significantly higher than the bearing peripheral speed of one inch per second, the frictional torque values computed should be multiplied by a speed factor obtained from figure 201-7.

4.3.2.2 Plain bearings

4 .3.2.2.1 The torque of plain bearings varies more than that of rolling element bearings. Friction coefficients of the sliding surface in these bearings vary with speed and load, and in the case of TFE-lined and grease-lubricated bearings vary markedly with temperature. It is possible to estimate average torque for these bearings at various loads at room temperature by the following formula,

$$T + \mu_f R F_r$$

where

T = torque, in.-lb.

μf = friction coefficient from paragraph 4.3.1

F_r = radial load, lbs.

R = one-half of diameter in inches (use ball diameter for spherical bearings turning on ball; use bore diameter for plain bearings and spherical bearings turning on bore).

4.3.2.2.2 Friction coefficients for TFE-lined plain bearings at various temperatures and stress levels are shown in figure 201-8, which is based on average values obtained in tests of journal bearings.

4.3.2.2.3 The frictional torque in standard beryllium copper ball/stainless steel race bearings varies significantly with the type and amount of grease in the bearing. With no lubrication the friction coefficient can be as high as 0.54 and varies linearly with applied load. Clean, well-lubricated bearings show friction coefficients between 0.01 and 0.10. For these bearings lubricated with MIL-G-81322 or MIL-13-23827 grease, between -65°F and 300°F, and operating within the established load ratings, a Conservative friction coefficient value of 0.20 should be used.

4.3.3 Temperature capability All bearings used in an aerospace vehicle design shall be capable of functioning within the appropriate ambient temperature range specified in the design contract. Where variations exist from the specified ambient temperature range in specific applications, other factors must be considered. These include the maximum temperature exposure, duration of exposure, percent of bearing load rating while exposed, and amount of bearing motion during the extreme temperature exposure. If it is apparent that the standard bearing cannot function properly in an extreme situation, a special bearing is required. The following ground rules shall be applied in establishing the design of the special bearing:

a. It is desirable to continue with MS envelope and basic design if practicable.

b. Special bearings must be approved to requirement 101.

c. Materials recommended for bearings intended for extreme temperature use are shown in requirement 104.

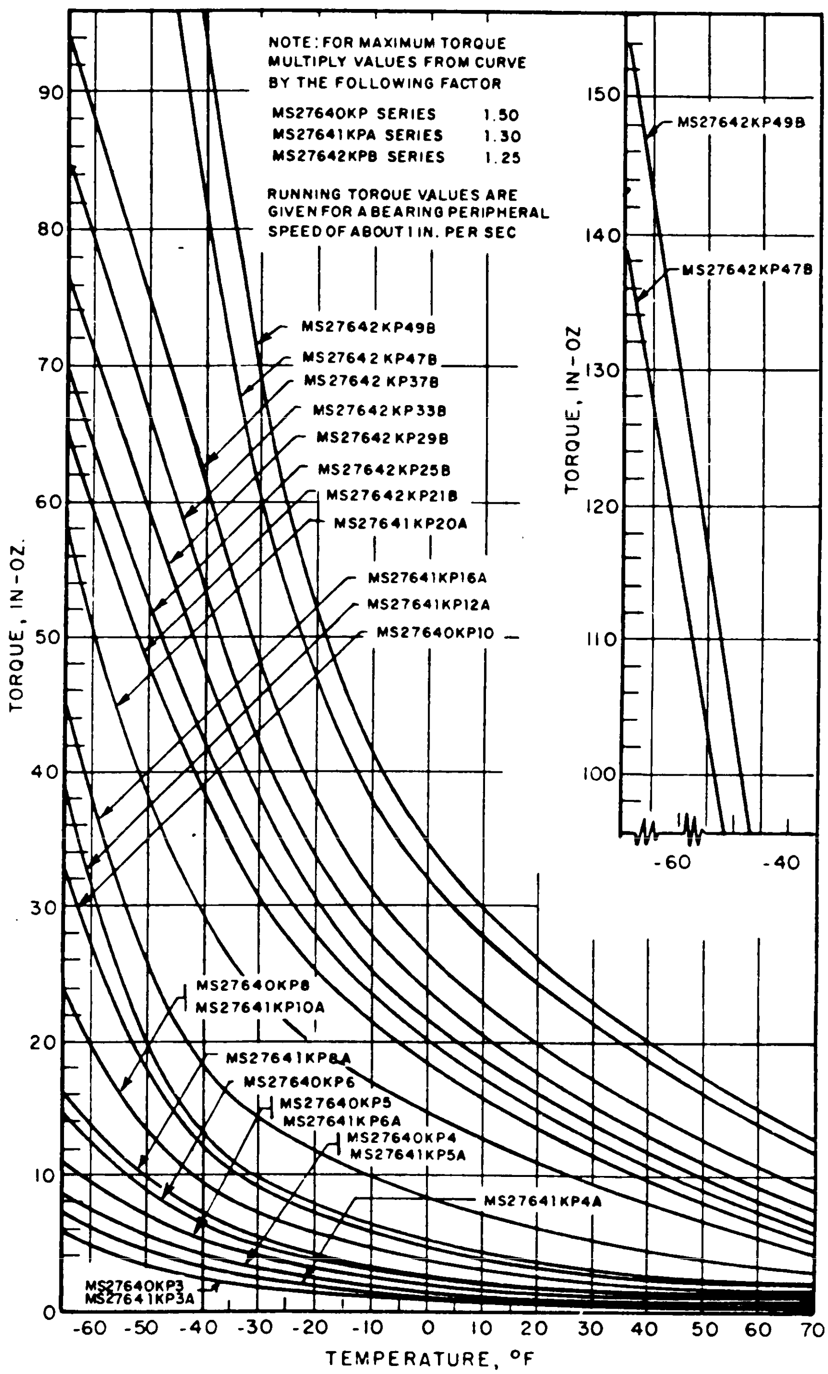


FIGURE 201-5. Average no load starting torque.

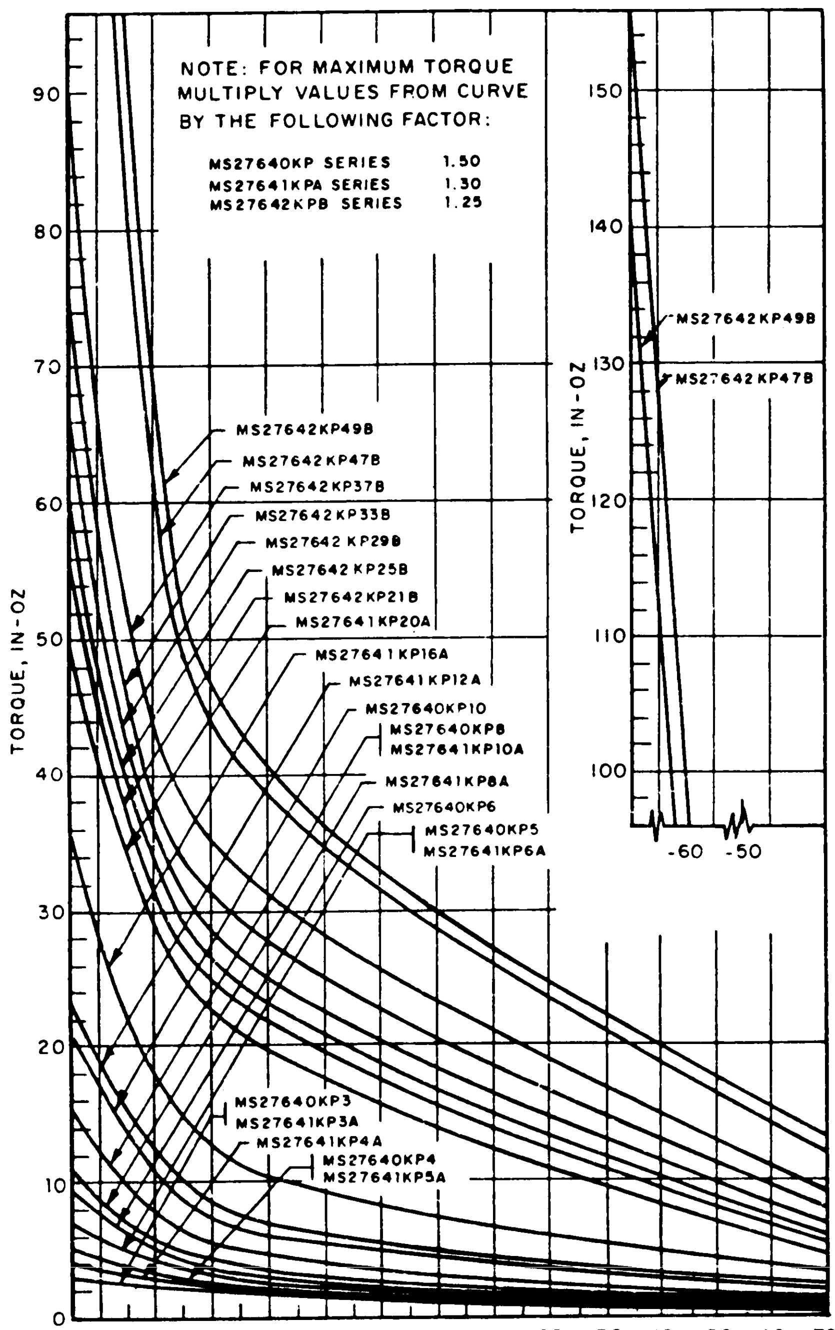


FIGURE 201-6. Average no load running torque.

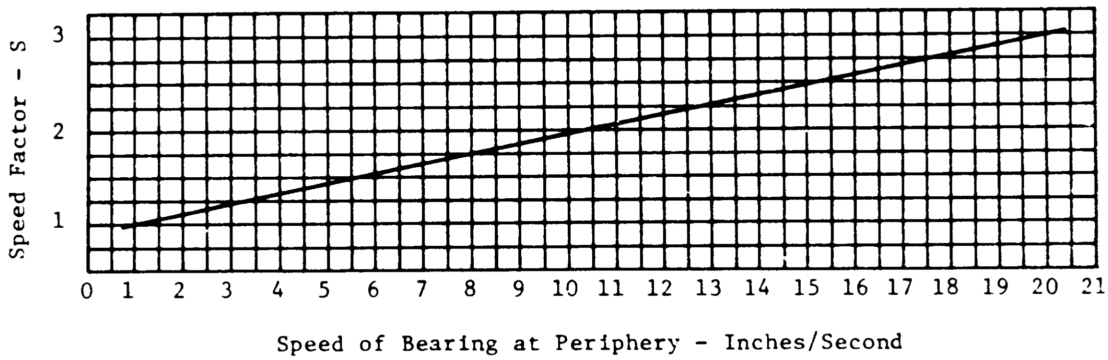


FIGURE 201-7. Bearing friction speed factor.

4.3.4 Load capacity Two primary load conditions must be considered to properly select a bearing for an aerospace vehicle application. "Static" loading is concerned with the strength of the bearing and its ability to resist significant deformation and fracture. "Dynamic" loading is concerned with the oscillation or rotation of the bearing while under fixed or changing load and is limited by fatigue and wear.

4.3.4.1 Anti-friction bearings

4.3.4.1.1 Ball bearings

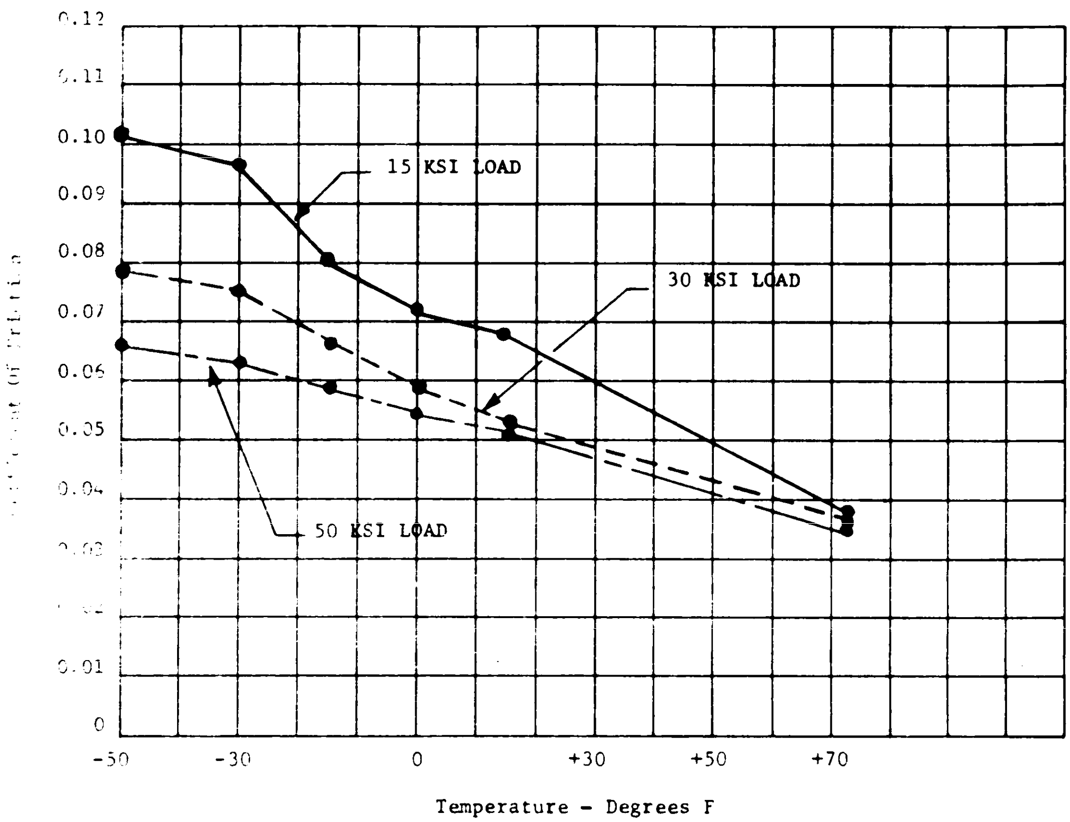
4.3.4.1 .1.1 Static capacity. Static limit load capacities are shown on the approved standards included in requirement 301. The radial static limit load (SLR) ratings for ball bearings are based On the formula

$$SLR = K N D^2$$

where

K = design factor

N = number of balls
D = ball diameter, in.



Mating Surface: Polished pH 13-8 Steel, Cond. H-1000, 4-5 RHR Surface Finish
Speed = 0.82 Lineal Feet Per Minute

FIGURE 201-8. Effect of temperature and unit load on friction coefficient of TFE liner.

Figures 201-9 and 201-9 can be used in comparing standard ball bearings capacities on the basis of bore and outside diameter dimensions to aid in bearing selection. Allowable K factors are 10,000 for deep groove bearings, 4800 for single-row self-aligning bearings, 3800 for double-row self-aligning bearings, and 3200 for rod-end bearings, 3800 for double-row self-aligning bearings, and 3200 for rod-end bearings. The static limit load can be applied to the bearing for a short period of time without affecting the smooth operation or endurance under the normal loads and oscillatory motion encountered in airframe applications. The minimum static fracture load (where an actual breakage of the bearing occurs) is not less than 1.5 times the static limit load. Axial static capacity varies from approximately 50% to 60% of radial capacity for nonself-aligning ball bearings and 13% to 20% for self-aligning types. These bearings cannot take full rated radial and thrust limit loads simultaneously. The combined loading situation is covered later in this requirement.

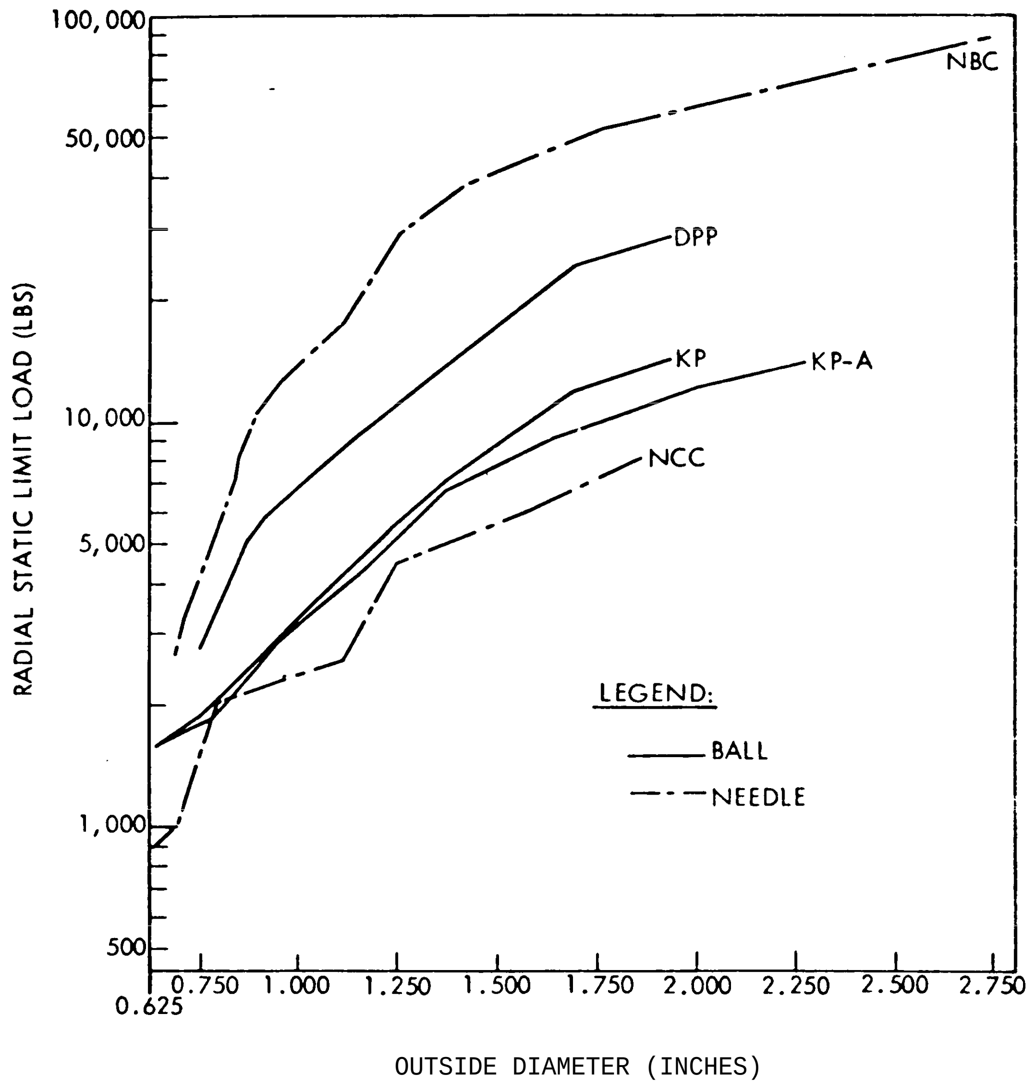


FIGURE 201-9. Static limit load ratings for anti-friction control-type bearings.

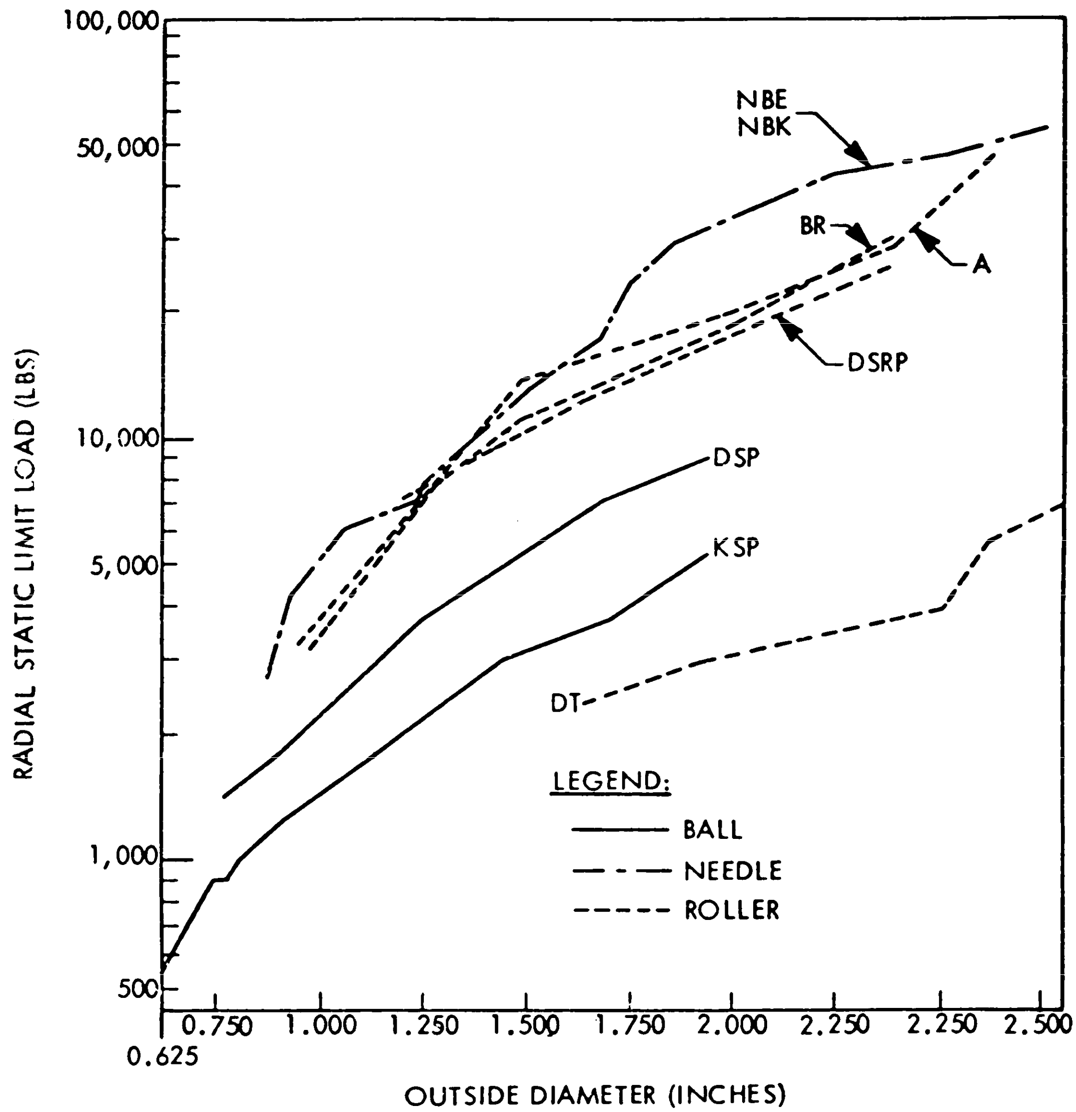


FIGURE 201-10. Static limit load ratings for anti-friction control-type bearings, self-aligning .

4 .3.4.1.1.2 Dynamic capacity. The basic dynamic capacity of an airframe ball bearing is the constant radial load at which 90% of a group of identical bearings running at the same speed, temperature and angle of oscillation will meet or exceed a fatigue life of 2000 revolutions. An oscillatory cycle, through an angle of at least the ball spacing, is considered equivalent to a revolution. If a bearing life of more than 2000 cycles or revolutions is required, the applied constant radial load must be reduced to a value below the basic dynamic capacity of the bearing. The dynamic capacity of an airframe ball bearing is related to the cyclic life by the following formula.

$$C = \frac{C_o}{L},$$

where

C = dynamic capacity desired

C_o = basic dynamic capacity at L_{10} = 2000 revs. (equals average life of 10,000 cycles)

L = life factor from figure 201-11, which is based on the formula

$$L = \left(\frac{n}{2000}\right)^{\frac{1}{3.6}},$$

where

n = desired bearing life

The basic dynamic capacity is based on the inner race moving and the outer race stationary. If the reverse is true, reduce the basic dynamic capacity by dividing by a factor of 1.20.

4.3.4.1 .1.3 Equivalent loading. If the magnitude of the load applied to the bearings varies greatly, a constant mean load which has the same influence on bearing life must be computed to permit proper sizing of the bearing. In this instance, the following rules apply:

a. If load magnitude varies less than 30%, use the high load value.

b. If greater variation in load magnitude occurs, use an estimated load somewhat higher than the arithmetic average, taking into account the relative percentage of total life at each significant load level.

c. If a more exact load figure is desired, the variable dynamic load magnitudes may be stepped off to a number of incremental load values associated with a finite proportion of total bearing life and used in the equation:

$$P = \left[\frac{N_1(P_1)^{3.6} + N_2(P_2)^{3.6} + \ldots N_n(P_n)^{3.6}}{N}\right]^{\frac{1}{3.6}}, \text{ where}$$

P = equivalent dynamic load to result in the same life as the variable loads

N = $N_1+N_2+\ldots N_N$ = total cycles or revolutions

P_1 = load acting during N_1 revolutions

P_2 = load acting during N_2 revolutions

P_N = load acting during N_N revolutions

4.3.4.1.1.4 Moment loading. In some cases a moment or overturning load is presented in an airframe bearing application. This moment loading should not exceed the limit moment rating given for each non-aligning bearing in the MS Self-aligning bearings are not designed to carry any moment loading. See table 201-VIII for limit moment ratings.

4.3.4.1.1.4 Combined loading. An airframe control bearing frequently is applied such that it must carry loads composed of axial as well as radial components. It is then necessary to convert these loads into a so-called equivalent load. An approximation for combining radial and thrust loads for either static or dynamic conditions can be obtained from the formula

$P = F_r + YF_t$, where

P = the equivalent load

F_r = the applied radial load

F_t = the applied thrust load

Y = a thrust factor = $\dfrac{\text{radial load rating}}{\text{thrust load rating}}$

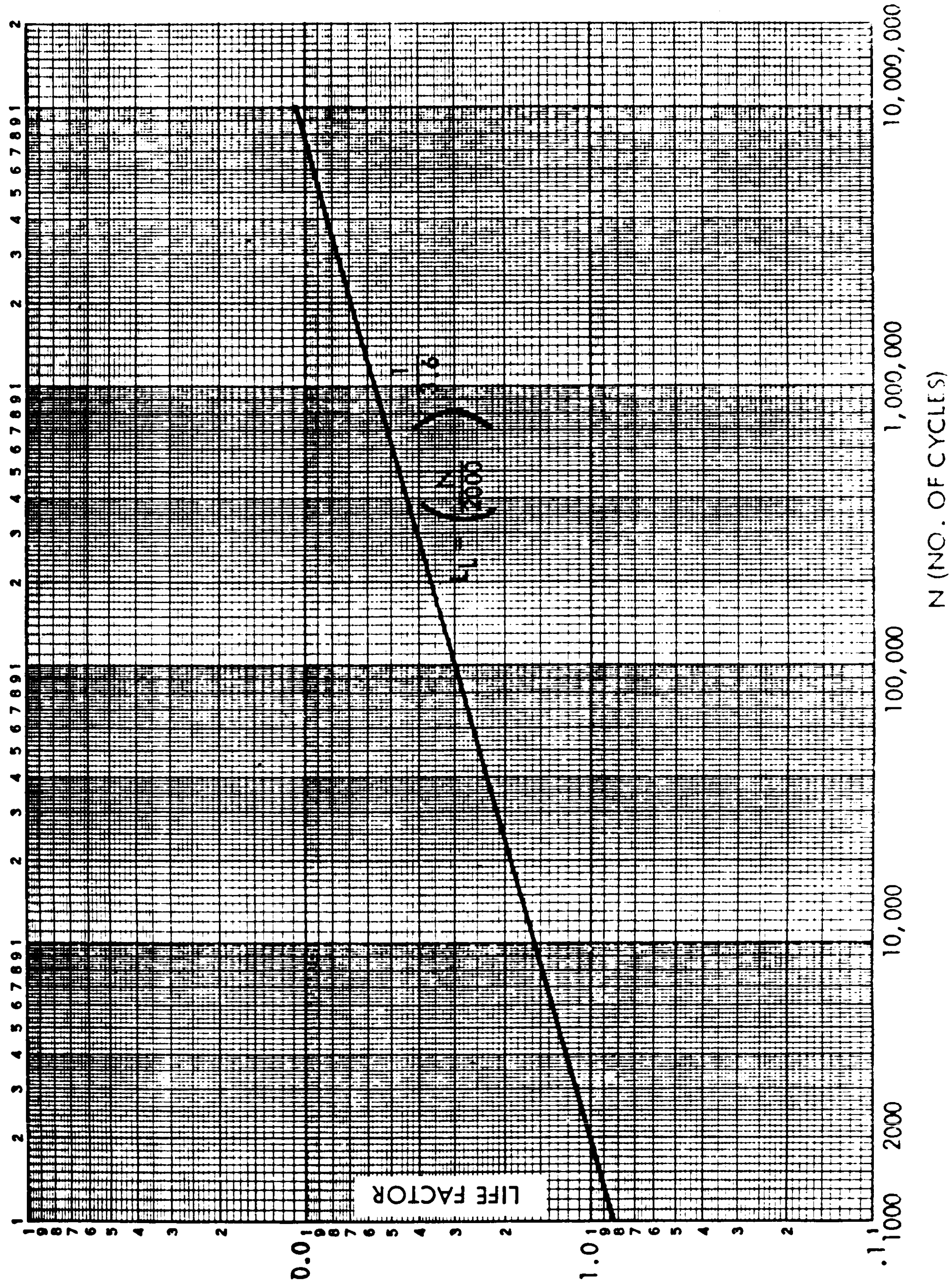


FIGURE 201-11. Life factors for ball bearings.

TABLE 201-VIII. MS ball bearings limit moment ratings.

Bearing	Limit Load Moment Rating Inch-Lbs	Moment Constant Kη (1/Inch)
MS27640-3A	58.0	12.10
MS27640-3	88.7	10.10
MS27640-4	136.0	8.85
MS27640-5	370.0	6.76
MS27640-6	644.0	5.44
MS27640-8	1170.0	4.46
MS27640-10	1520.0	4.09
MS27641-3	49.6	12.10
MS27641-4	88.6	10.20
MS27641-5	114.0	8.75
MS27641-6	143.0	7.68
MS27641-8	227.0	6.15
MS27641-10	598.0	5.02
MS27641-12	945.0	4.13
MS27641-16	1600.0	3.25
MS27641-20	2170.0	2.81
MS27642-16	444	3.60
MS27642-21	1480	2.96
MS27642-23	1700	2.76
MS27642-25	1930	2.60
MS27642-29	2420	2.31
MS27642-33	3150	2.03
MS27642-37	3780	1.85
MS27642-47	6880	1.45
MS27642-49	8520	1.42
MS27642-52	TBD	TBD
MS27642-56	TBD	TBD
MS27642-60	TBD	TBD
MS27642-64	TBD	TBD
MS27642-68	TBD	TBD
MS27642-72	TBD	TBD
MS27642-76	TBD	TBD
MS27642-80	TBD	TBD
MS27642-84	TBD	TBD
MS27642-88	TBD	TBD
MS27642-92	TBD	TBD
MS27642-96	TBD	TBD

TABLE 201-VIII. MS ball bearings limit moment ratings. - Continued

Bearing	Limit Load Moment Rating Inch-Lbs	Moment Constant K_η (1/Inch)
MS27644-3	38.3	44.4
MS27644-4	90.9	19.8
MS27644-5	56.3	71.0
MS27644-6	278.0	19.0
MS27644-8	590.0	13.2
MS27644-10	1600.0	5.88
MS27646-38	255	5.89
MS27646-39	329	5.16
MS27646-40	414	4.59
MS27646-41	567	3.88
MS27646-42	825	3.27
MS27646-43	1130	2.83
MS27646-44	1470	2.44
MS27646-45	1890	2.12
MS27646-46	2290	1.92
MS27647-4A	129	3.88
MS27647-4	392	2.30
MS27647-5	882	1.81
MS27647-6	2010	1.29
MS27647-8	4860	.967
MS27649-3	28.3	10.6
MS27649-4	41.2	9.72
MS27649-5	72.3	8.29
MS27649-6	80.5	7.45
MS27649-8	170.0	5.85
MS27649-10	286.0	4.89
MS27649-12	456.0	3.94
MS27649-16	706.0	3.12
MS27649-20	995.0	2.71

The equivalent load should be equal to the applied radial load if the applied thrust load does not exceed 10% of F_r. The equivalent load calculated shall never be greater than the bearing rating in either the static or dynamic condition. A more general and accurate formula for computing the equivalent load is

$$P = XVF_f + YF_t, \text{ where}$$

the notation is as above, and

X = a radial factor

V = a rotation factor, 1.0 for inner ring rotation and 1.2 for outer ring rotation

For standard MS airframe control bearings, X and Y factors are as follows:

MS standard	X	Y
MS27640	1.00	3.00
MS27641	1.00	3.00
MS27642	1.00	3.00
MS27643	0.65	3.70
MS27644	0.50	1.69
MS27645	0.40	4.57

NOTE : In no instance shall the calculated equivalent load be greater than the bearing rating.

4.3.4.1.2 Roller bearings. This section is concerned with aircraft control roller bearings using either concave or convex rollers. Such bearings are covered by requirement 302. Commerical and tapered roller bearings are not within the scope of this requirement. The several load ratings shown on the military standards, and covered herein, include limit load, dynamic load, and ultimate load ratings. They are applicable to loading in either the radial or axial directions. The load ratings essentially represent demonstrated bearing capacities, factored to provide appropriate safety margins.

4.3.4.1 .2.1 Static capacity. The basic static load capacity of a roller bearing is termed the limit load rating. This is the maximum load which the bearing can carry without subsequently affecting performance to the rated life at the dynamic load rating. If the limit load rating is exceeded, the life of the bearing is no longer predictable. The static limit load rating of both single-row and double-row concave and convex roller bearings is given by the formula:

$SLR = 12000NDL \cos a$ where,

SLR = static limit load rating, lb.

N = the number of rollers

D = the mean roller diameter, in.

L = the roller contact length, in.

a = the roller inclination angle to the bearing bore axis, degrees

The above formula provides the radial rating for the bearing. The axial capacity ranges from 10% of the radial capacity for single row bearings to 72% for certain of the wide series double row bearings. The ultimate load rating, also a function of the limit load rating, is defined as the load which can be applied and held for three minutes without structural failure of the bearing. Actual fracture usually occurs at a load level substantially higher than the ultimate load rating. The ultimate load rating is calculated as the limit load rating multiplied by a factor of 1.5. In application, brinelling will occur on the race surface if subjected to a load equal to the ultimate load rating. The bearing will still be operative even though the races may be brinelled, but the bearing should be replaced.

4.3.4.1 .2.2 Dynamic capacity. The basic dynamic capacity of a roller bearing is termed the dynamic load rating. The dynamic load rating is defined on the basis of a unidirectional load that will result in an average bearing life (L_{50}) of 10,000 cycles at 90° oscillation before evidence of contact fatigue (spalling) occurs. The angle of oscillation is defined at 180° of angular travel within an included arc of 90°. The load/life relationship for roller bearings is shown in figure 201-11. The dynamic load rating for roller bearings is that load which results in an average life (L_{50}) of 10,000 cycles at 90° oscillation. In most aerospace operations, the dynamic (applied) operating load is much less that the rated load for the bearing. It is then necessary to determine bearing life based on the applied load. The load/life equation listed below can be used to calculate bearing life at any load (P_e). Average bearing life (L_{50}) signifies that 50$ of a given group of bearings will survive 10,000 cycles, at the rated dynamic load. In cases where higher performance reliability is required, L_{10} is often used. The L_{10} life means that of a given group of bearings, 90% are expected to survive. The relationship between L_{50} and L_{10} life is approximately 5 to 1. Therefore, if the L_{50} life is 10,000 cylces, the L_{10} life would be 2,000 cycles, at the rated dynamic load. The load/life relationship can be expressed:

$$L_{50} = (D.L./Pe)^{3.67} \text{ for 10000 cycle life}$$

$$L_{10} = (D.L./Pe)^{3.67} \text{ for 2000 cycle life}$$

where

D.L. = the dynamic load rating

Pe = the dynamic operating load

The bearing life, based on race surface contact fatigue which is the assumed mode of failure, is a function of the number and magnitude of contact stresses at any given point on the race surface. Since the internal design of the bearing and the angle of oscillation determine the number of contact stresses, it becomes necessary to evaluate the effects of the degree of oscillatory motion upon the rated bearing life. Basically, the evaluation of the effect of the oscillation angle can be separated Into two categories:

a. Angle oscillation above 25° included angle. The failure mode is usually contact fatigue, in which case the life of the bearing is predictable. Generally speaking, the bearing life expectancy will increase as the angle of oscillation approaches 250, from the rated oscillation of 90° included angle.

b. Angles of oscillation below 25° included angle. ordinarily the failure mode is fretting, in which event the bearing life is not predictable. At these lower angles of oscillation the adjacent roller paths do not overlap. Therefore, there is no opportunity for adequate redistribution of the grease and eventually the oil film will break down, resulting in metal-to-metal contact between the roller and the raceways.

It is advantageous to relubricate the bearing frequently to avoid possible fretting. Also, the circulation of grease in the bearing can be greatly assisted if the oscillation angles under 25° are interspersed with angles of motion above 25°. If the angle of oscillation is other than an Included angle of 900, the bearing life can be estimated by dividing the life at 90° by a factor from figure 201-12.

4.3.4.1 .2.3 Equivalent and combined loads. Aerospace vehicle bearing applications rarely involve a constant, unidirectional load which is either purely radial or axial. If load magnitude is varying, an equivalent mean load can be computed to aid in bearing selection and sizing. Similarly, If both radial and axial components are present, they can be combined into radial load which has equal effect on the bearing life. The following procedure should be used in determining equivalent loads when applied loads are of varying magnitude and direction.

a. Symbols:

P_c = equivalent radial dynamic load-lbs. (combining axial and radial dynamic loads)

P = equivalent radial dynamic load at 90° osc. - lbs.

P_1 = individual equivalent radial dynamic load representing one condition in the spectrum-lbs.

P_e = equivalent radial dynamic load representing the various loads in the spectrum-lbs.

F_r = applied maximum radial dynamic load-lbs.

F_a = applied maximum axial dynamic loads-lbs.

f_1 = number of cycles, at one condition, divided by the total spectrum cycles.

Ke = oscillation factor-see figure 201-12

Cy = total cycles required

$D.L._r$ = radial dynamic load rating-lbs

$L.L._a$ = axial limit load rating-lbs.

$L.L._r$ = radial limit load rating-lbs.

b. Procedure:

STEP 1. Determine the equivalent radial dynamic load.

$$P_c = F_r + 2.5 F_a$$

This equation combines the thrust and radial loads. The single row bearings carry momentary or intermittent thrust loads, but are not for continuous thrust . Therefore, for single row bearings, P_c is equal to F_r. NOTE: If multiple operating conditions exist, they should be considered separately under steps (1) and (2), and then summarized in step (3). F_a must not exceed 30% of F_r.

STEP 2. Determine equivalent radial dynamic load at 90° oscillation.

$$P = K_O P_O$$

When oscillation is restricted to less than 250 included angle, lubrication may become a limiting factor, in which case, fretting damage terminates the useful bearing life. The K_O values, on the low oscillation range of figure 201-12 are, intended for initial selection. (Actual performance in this range of small motions may vary considerably with each application.)

STEP 3. Determine equivalent radial dynamic load representing spectrum loading (if applicable).

$$P_e = f_1(P_1)\ 3.67 + f_2(P_2)\ \ 3.67 + \ldots f_n(P_n)\ 3.67 \Big]^{.273}$$

This equation is used only when various load levels exist. If only one dynamic load level occurs, then P becomes P_e and step (4) can be completed.

STEP 4. Determine the required radial dynamic load rating.

$$D.L._r \geq \left[P_e \frac{Cy}{10,000}\right]^{.273}$$

Average life (L_{50}) is assumed in this equation. If a 90% (L_{10}) survival is desired, then substitute 2,000 for 10,000 in the equation.

STEP 5. Select a bearing meeting the dynamic load rating requirement from requirement 302.

STEP 6. Check static load ratings or bearing selected.

The limit load rating on the selected bearing must be equal to or larger than the maximum applied static loads. Both radial and axial limit load ratings ($L.L_r$ and $L.L._a$) must be considered.

The ultimate load ratings is calculated as 1.5 times the limit load rating ($L.L._r$ or $L.L._a$).

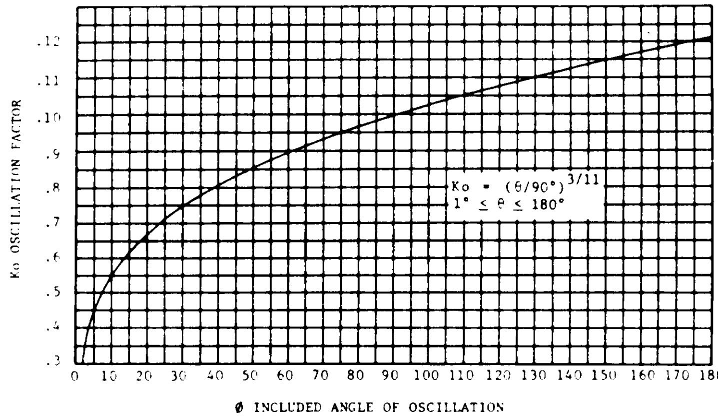


FIGURE 201-12. Oscillation angle factors for roller bearings.

4.3.4 .1.3 Needle bearings

4.3.4.1.3.1 Static capacity. The "limit load" is the maximum static radial load which can be applied to a bearing without impairing its subsequent function in aerospace vehicle applications. The "ultimate load" or static fracture load is not less than 1.5 times the limit load rating. By definition the aircraft static capacity load rating is a load which does permanent damage to raceway and roller such that it should not be expected to perform in aerospace vehicle applications. In short, a load equal to the aircraft static capacity is a load that damages the bearing. Needle bearings can be separated into two general groups. The first group, which includes MS24461, MS24462, MS24463 and MS24464, are designed to be installed in the users' housing and would receive massive support from this housing. This differentiates this group from the second group (MS24465, MS24466 and MS21432) which are track rollers. This second group has heavy cross-sectioned outer rings and the bearings roll on these outer rings. The "limit load rating" for the first group with the exception of MS24462 series is equal to 2/3 of the aircraft static capacity and the "ultimate load rating" for the MS24462 series is equal to 1/2 the aircraft static capacity while the "ultimate load rating" is 3/4 ASC. The "limit load rating" for the MS24465 and MS24466 series of track rollers is 4/9 of ASC and the "ultimate load rating" is 2/3 of ASC. Extensive testing has shown that the "limit load rating" of the MS21432 is 2/3 of ASC and the "ultimate load rating" is equal to the ASC. To fully realize this rating, compensation must be provided for stud deflection to insure full track contact under load. Table 201-IXA, B and C list the limit load ratings and ultimate load ratings for the referenced MS series of needle bearings. The aircraft static capacity for needle bearings expressed in pounds with the exception of the MS24462 (drawn cup) series is based on the formula:

$ASC = 12000\ i\ (Z-3)\ \ell_{eff}\ D$ where

i = the number of rows of rollers

z = the number of rollers per row

ℓ_{eff} = the minimum roller contact length in inches

D = the minimum roller diameter in inches

TABLE 201-IXA. Capacity ratings of MS series needle bearings (housed typed).

	Limit loads (lbs)	Ultimate Loads (lbs)	Basic dynamic load Rating C_r (lbs)
MS24461- 3	1800	2700	805
- 4	2870	4300	1120
- 5	4070	6100	1430
- 6	6330	9500	1980
- 7	8000	12000	2310
- 8	11600	17400	3690
- 9	15000	22500	4450
-10	18900	28300	5220
-12	23900	35800	6060
-14	30500	45800	8540
-16	33900	50900	9030
-20	37900	56800	9420
-24	44200	66300	10200
-28	50500	75700	10900
-32	56800	85200	11600
-36	63100	94600	12400
-40	69400	104100	12900
-44	75800	113500	13500
-48	82000	123000	14100
-52	88300	132500	14600
-56	96700	145100	15300
-60	103000	154500	15800
-64	109000	169000	16300
-80	134000	201000	18100

TABLE 201-IXB. Capacity ratings of MS series needle bearings (housed type).

	Limit loads (lbs)	Ultimate load (lbs)	Basic dynamic load Rating C_r (lbs)
MS24462- 3	1150	1725	1280
- 4	1365	2050	1300
- 5	1535	2300	1400
- 6	2945	4420	2270
- 7	3235	4850	2900
- 8	3785	5680	3180
-10	4350	6525	3460
-12	7050	10600	4920
-14	7900	11850	5250
-16	8700	13050	5540
-20	13100	19650	8980
MS24463- 3	1800	2700	805
- 4	2870	4300	1120
- 5	4070	6100	1430
MS24464- 6	4530	6800	1760
- 7	5870	8800	2110
- 8	8670	13000	3420
- 9	11800	17700	4300
-10	15500	23200	5190
-12	20000	30000	6160
-14	25800	38700	8730
-16	28700	43000	9230
-20	31400	47100	9490
-24	36600	54900	10200
-32	47100	70600	11700
-40	57500	86200	13000
-48	67900	10190	14200
-56	80100	12020	15300

TABLE 201-IXC. Capacity ratings for track roller bearings.

	Limit loads (lbs)	Ultimate loads (lbs)	Basic dynamic load Rating C_r (lbs)
MS24465- 3	1150	1725	1280
- 4	1910	2860	1430
- 6	3600	5400	2700
- 8	5780	8600	4300
-10	8530	12800	6400
-12	14200	21400	10700
-14	19300	28800	14400
-20	25300	37800	18900
MS24466- 6	7130	10740	5370
- 8	12500	18740	9370
-10	19900	30000	15000
-12	28500	42800	21400
-14	38500	57800	28900
-16	44900	67200	33600
-20	59500	89200	44600
-27	71300	107000	53600
-28	92000	138000	69000
-32	102000	153000	76600

The ASC for the MS24462 series is based on the formula:

ASC in pounds = 15800 dm ℓeff where

dm = pitch diameter of the roller complement in inches

ℓeff = minimum roller contact length in inches

4.3.4 .1.3.2 Dynamic rating, housed needle bearings. When adequate lubrication for needle bearings exists, the mode of failure is considered to be surface fatigue. Basic dynamic rating, C_r, for a housed needled bearing (i.e., MS24461, MS24462, MS24463, and MS24464) is that calculated, constant, radial load which a group of apparently identical bearings with a stationary outer ring can theoretically endure for a rating life of one million revolutions rating of the inner ring. The basic dynamic load rating is a reference value only, the base value of one million revolutions rating life having been chosen for ease of calculation. Since applied loading as great as the basic dynamic load rating tends to cause local plastic deformation of the rolling surfaces, it is not anticipated that such heavy loading would normally be applied. Values for C_r can be found in tables 201-9A and 201-9B. The life of a housed needle bearing is expressed as the oscillations or cycles that a bearing will complete before failure. Life will vary from one bearing to another, but stabilizes into a predictable pattern when considering a large group of the same size and type of bearings. The "L-10" or "rating life" of a group of such bearings is defined as the number of revolutions (or hours at a given constant speed) that 90% of the tested bearings will complete or exceed before the first evidence of fatigue develops. Thus it can be predicted with 90% reliability that a bearing will meet or exceed the calculated "L-10" life providing normal fatigue is the failure mode. Some critical applications, however, require definition of life at reliabilities greater than 90%. To determine bearing life with reliabilities greater than 90%, the "L-10" life as calculated must be adjusted by a factor a1 so that $L_1 = a_1 L_{10}$. The life adjustment factors shown below are recommended.

Reliability %	L_n rating life	a_1 life adjustment reliability factor
90	L_{10}	1
95	L_5	0.62
96	L_4	0.53
97	L_3	0.44
98	L_2	0.33
99	L_1	0.21

Empirical calculations and experimental data point to a predictable relationship between bearing load and life. This relationship may be expressed by a formula. In this empirical formula, the bearing life is found to vary inversely as the applied load to an exponential power. The life of a housed bearing when failure is due to surface fatigue can be determined from the basic dynamic load rating and the equivalent load, This can be expressed by the relationship.

$L_L = \frac{C_r}{P_e}$ where

C_r = basic dynamic load rating

P_e = equivalent load

L_L = factor from figure 201-13

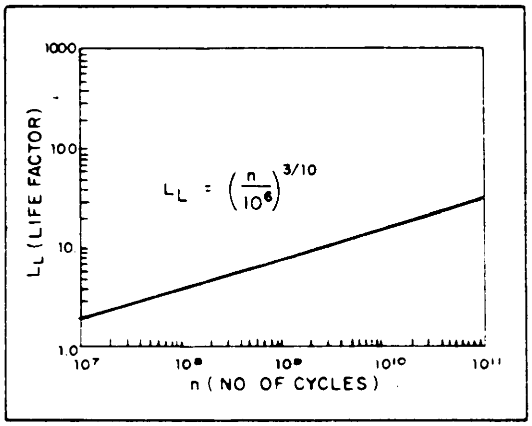


FIGURE 201-13. Life factors for housed needle bearings.

The above relationship holds for the usual aerospace vehicle application and the MS series of housed needle bearings. If the race hardness is less than Rc58 the above relationship must be modified to

$$L_L = \frac{C_r}{P_e \times H_F}$$

where H_F is a hardness factor taken from the following data:

raceway hardness HRC	hardness factor HF
58	1.00
57	1.02
56	1.04
55	1.07
54	1,12
53	1.19
52	1.28
51	1.41
50	1.59
49	1.78
48	2.00
47	2.24
45	2.50
45	2.76
44	3.06
43	3.39
42	3.77
41	4.16
40	4.55

For convenience basic load life curves for the MS series of housed needle bearings are shown in figures 201-30 through 201-33.

4.3.4.1.3.3 Equivalent loading, housed needle bearings. It is sometimes necessary to determine an equivalent load if the bearing is subject to various load levels during a duty cycle. This can be done by using the following relationship:

$$P_e = [\Sigma f (F)^{10/3}]^{3/10}, \text{ where}$$

P_e = equivalent load, lb.

f = proportion of total life at a particular load

F = radial load level, lb.

The equivalent radial load should then be used in the load-life calculations. In no case may the equivalent load exceed the indicated limit load for the bearing.

4.3.4.1 .3.4 Dynamic rating, track rollers. The dynamic rating of the second group of needle bearings. The track rollers, is shown on figures 201-34, 201-35, and 201-36. Use the curves on these figures or charts to determine the load/life relationship. A limiting value is shown on the figures. Bearing "capacity as a track roller" data for these three series are shown on table 201-9C. This is defined as the load which will result in 20,000 revolutions L-10 of the track roller bearing. For loads less than the CTR, life is based upon a 10/3rds relationship. Thus:

$$L_L = \left(\frac{CTR}{P_e}\right)^{10/3} \times 20,000 \quad (CTR > P_e)$$

For loads in excess of the capacity of a track roller life values as a 6th power function. Thus:

$$L_L = \left(\frac{CTR}{P_e}\right)^{6} \times 20,000 \quad (CTR < Pe)$$

Figures 207-14 thru -16 are a graphic representation of this data.

4.3.4.1.3.5 Equivalent loading, track rollers. To calculate the L-10 life in revolutions of a track roller bearing, use the information contained in paragraph 4.3.4.1 .3.3 above. This formula is correct as long as the individual loads are less than the capacity as a track roller. If a significant portion of the bearing life occurs at loads in excess of the CTR, the following formula must be used:

$$L_L = \frac{20,000}{\Sigma\, Ti \left(\frac{P_{ea}}{CTR}\right)^{6} + \Sigma\, ti \left(\frac{P_{eb}}{CTR}\right)^{10/3}}$$

where:

L_L = life in revolutions L-10

Pe_a = loads greater than CTR

Peb = loads less than CTR

Ti = fraction of the total revolutions at load Pea

ti = fraction of the total revolutions at load P_{eb}

CTR = bearing capacity as track roller

4.3.4.1.3.6 Track strength. Another factor in the use of track rollers is the strength of the supporting track to resist permanent deformation by the track roller bearing. The strength of the track is often considerably less than the load that the bearing can support. When using a 180,000 psi or lower strength track, the strength of the track is the determining factor rather than any characteristic of the bearing. The strength of the track can be Increased by selecting a track material which can be hardened to higher strength levels. The relationship between track hardness and track strength is shown in figure 201-14. Note that this relationship applies to steel tracks only and does not apply to track surfaces of other materials, such as titanium.

4.3.4.2 Plain bearings

4.3.4.2.1 Spherical, TFE lined. Radial and axial static limit loads are tabulated on the military standards for bearings approved in requirement 307. The loads defined in MIL-B-81820 are as follows:

a. The radial static limit load is that load (when applied for two minutes to the bearing) which will not cause a permanent set of more than 0.003 in.

b. The axial static limit load is that load (when applied for two q inutes to the bearing) which will not cause a permanent set of more than 0.005 in.

c. The ultimate load is 1.5 times the radial or axial limit load. When this load is applied to the bearing, ball or race fracture or ball push-out will not occur.

4.3.4.2.1.2 Dynamic capacity. The military standards list a qualification dynamic load rating for these bearings. The qualification test per MIL-B-81820 is conducted under various sets of stated conditions which fall within the range of aerospace vehicle applications. For example, under loading at the dynamic load rating, ± 25° oscillation, a testing rate of 10 CPM, and room temperature, the bearing must perform for 25000 cycles with no more than 0.0045 inch wear. A number of other factors, when combined with those stated above, affect the wear rate of the bearing. These include: (1) type of loading (unidirectional or reversing), (2) angle of oscillation, (3) oscillation rate, (4) temperature, and (5) contamination. Bearing manufacturers, as well as aerospace vehicle designers, have produced considerable test data resulting in modifying factors or curves which may be used to aid in bearing selection. It should also be noted that the controlling MIL-B-81820 for these bearings permits adjustments downward in load and upward in allowable wear for certain conditions of temperature and contamination. Since the effects of the variables on the life of a TFE-lined bearing are relatively intangible, both previous experience and performance-demonstrating functional testing play an important part in the selection process. An example of a method for TFE-lined bearing selection for an application follows.

Procedure to select a bearing for L_N cycles of oscillatory life at an oscillation angle, θ, and load, P:

(1) Determine an equivalent life, L_E, from the expression,

$$L_E = \frac{L_N F_A F_C}{K_\theta}$$, where

F_A = application factor (factors additive, if more than one condition applies)

F_c = contamination factor

K_θ = angle factor from figure 201-15

(2) Using L_E, from figure 201-16

(3) The required rated dynamic capacity, P_R, of the bearing is determined from the relationship,

$$P_R = \frac{P}{F_L}$$

(4) Select a bearing with a dynamic load rating equal to or great.er than P_R.

(5) Check bearing static rating against the design static loads.

Condition	F_A
Steady load	i
Reversing load	2
Vibration	3
Impact load	4
-65°F to 0 and 175°F to 350°F	2
Continuous misalignment	2

Degree of contamination	F_c
none	1
occasional	2
continuous	6

NOTE: A bearing size factor is included in the MS ratings. Oscillation rate factors are not significant in aerospace vehicle applications where the rate is low and intermittent.

$T = T_{40} \times F_T$

where

- T = track capacity for a specific bearing, lb
- T_{40} = capacity of R_c = 40 track (standard MS sheets), lb
- F_T = track strength factor from graph

If T_{40} is not known:

$T = D \times L \times K$

where

- T = track capacity for a specific bearing, lb
- D = OD of track roller, in.
- L = contact length of track roller, in
- K = constant, psi, from graph

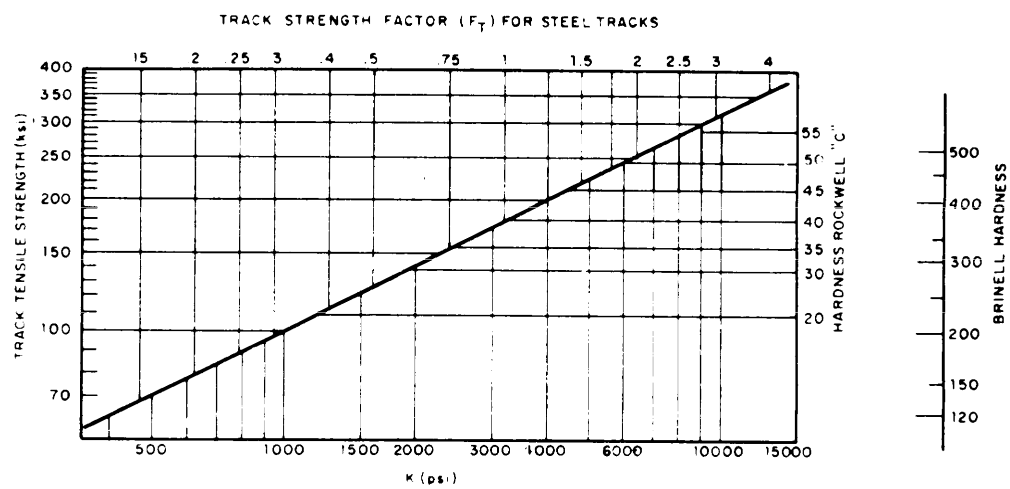


FIGURE 201-14. Strength factors for tracks of different hardness.

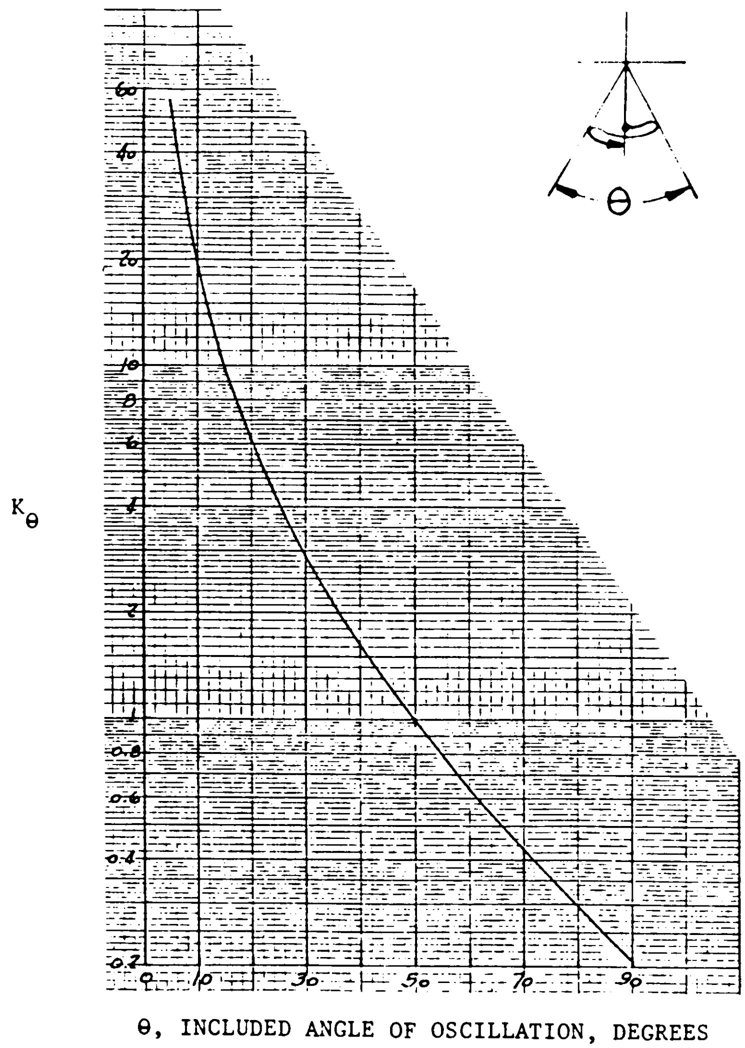


FIGURE 201-15. Oscillation angle factor. K_Θ for TFE-lined plain spherical bearings

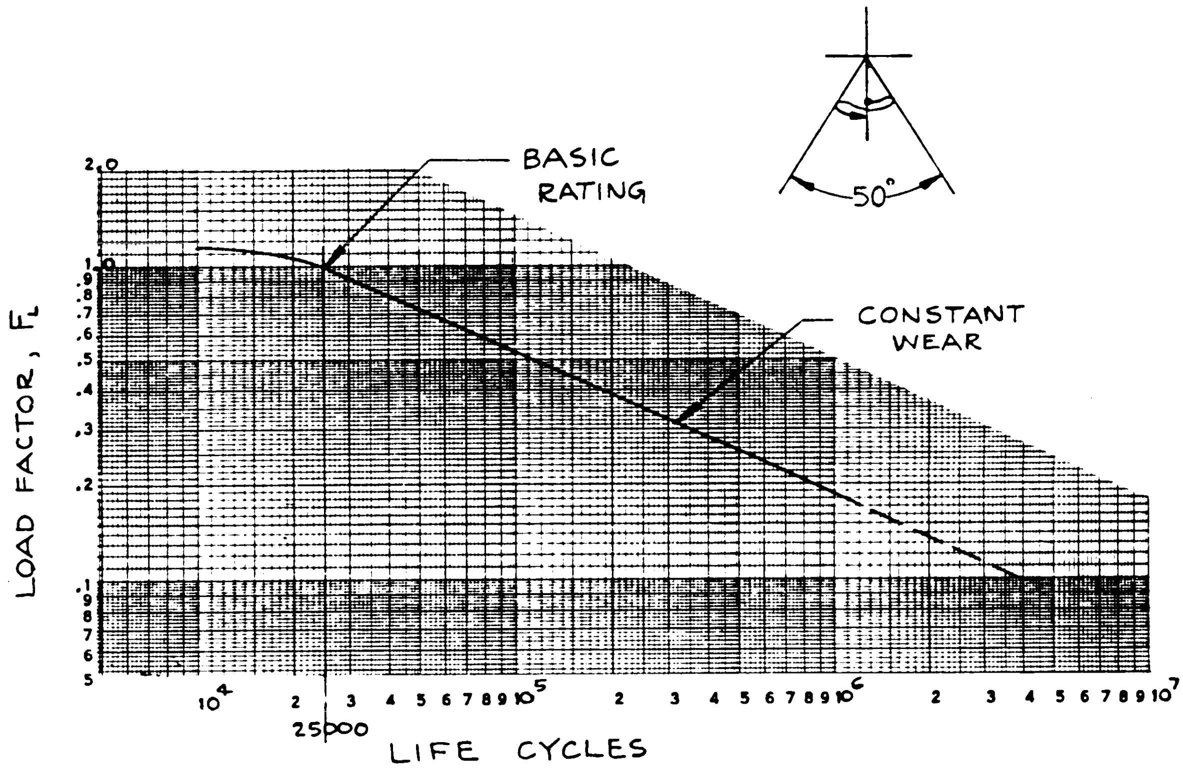


FIGURE 201-16. Load/life characteristics of TFE-lined plain spherical bearings.

4.3.4.2.1.3 Equivalent load. Where the design loading varies during the bearing duty cycle, compute an equivalent load, P_E, from the following relationship and use it in the life calculations.

$$P_E = [\Sigma K(P)^{3.6}]^{\frac{1}{3.6}}, \text{ where}$$

P = applied load levels; P_1, P_2, P_3, ... P_N.

K = proportion of the duty cycle at which the various load levels are applied.

4.3.4.2.2 Spherical bearings, grease or dry film lubricated

4.3.4.2.2.1 Static capacity. The controlling specifications define the static limit load capacity as a load at which a specified amount of permanent set is not exceeded. The values selected are such that subsequent operation of the bearing is not adversely affected. Ultimate load capacity is not less than 1 1/2 times the limit load capacity. At ultimate capacity no fracture of the ball or race or ball pushout will occur.

4.3.4.2.2.2 Dynamic capacity. Dry-film lubricated bearings have high dynamic capacity up to 50,000 psi unit loading, but life is difficult to predict due to wear through the thin coating. Accordingly, they are best used in joints which are relatively static under load with only incidental rotation or misalignment motion. Bronze race bearings will provide essentially unlimited service life when loaded up to 13000 psi, properly lubricated and operated at 10CPM maximum. For shorter, finite life at higher loads, stress values from figure 201-14 can be used with the bearing race projected area. Bearings using beryllium copper balls are rated at 30,000 psi to 40,000 psi, depending on whether rotation is at the spherical surface or in the bore, and whether ball is clamped or free to rotate on the pin.

4.3.4.2.3 TFE-lined journal bearings

4.3.4.2.3.1 Static capacitv. The static limit load capacity of these bearings is defined by MIL-B-81934 as

SL = 50,000 B (L-.1) for aluminum bearings, and

SL = 78,500 B (L-.1) for CRES bearings,

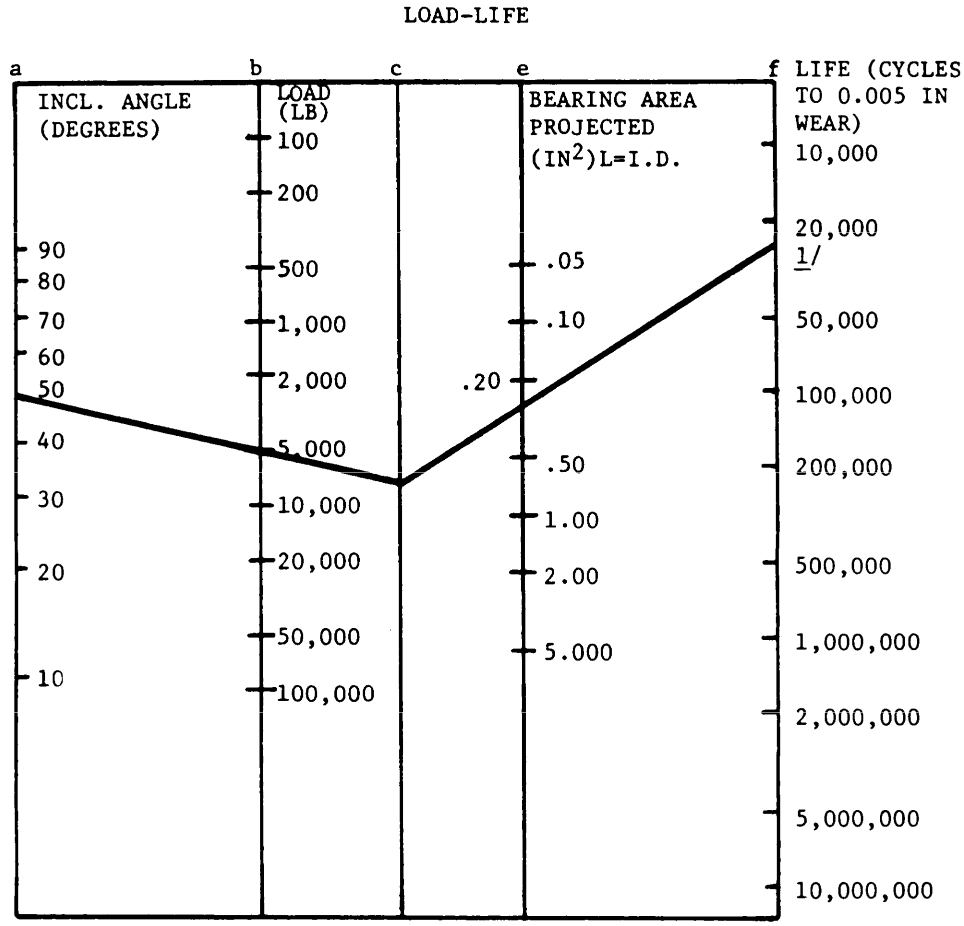
where

SL = static limit load capacity, lbs.

E = bearing bore, in.

L = bearing length, in.

Due to pin bending and edge loading, static capacity is not significantly improved by increasing bearing length beyond a dimension equal to the bore diameter.



1/ EXAMPLE: A PLAIN BEARING WITH 0.3 IN^2 PROJECTED AREA, OPERATING AT ±25° OSCILLATION AND 5,000 LBS LOAD WILL GIVE 26,000 CYCLES OF LIFE BEFORE 0.005 IN. WEAR OCCURS.

FIGURE 201-17. Load/life characteristics for TFR-lined journal bearings.

4.3.4.2.3.2 Dynamic capacity. The dynamic load capacity, under the specification qualification conditions, is defined as

DL = 37,500 B (L-l), where

DL = dynamic load capacity, lb.

B = bearing bore, in.

L = bearing length, in.

Figure 201-17 is a nomograph which relates bearing life, applied load, angle of oscillation, and the projected area of the bushing. It is intended as an aid in sizing a bearing for a specific application. In addition, the procedures outlined for considering variables in selecting a TFE-lined spherical apply to journal bearings. The performance indicated in figure 201-17 will be obtained only with a properly designed pin, shaft, or bolt as a mating member. Such a design includes a blended lead-in to avoid installation damage, a minimum hardness of R_c 40, and a surface finish of at least RHR 8. This finish should be obtained by a final operation other than grinding, such as honing, polishing, or lapping.

4.3.4.2.4 Metallic journal bearings

4.3.4.2.4.1.1 Static capacity. Metal journal bearings are used primarily to handle static loads and can be loaded to values that are approximately one-half of the compressive yield strength of the material. Using the projected area of the bearing (length x diameter) with the stress values in figure 201-18, the load capacity can be determined.

4.3.4.2.4.2 Dynamic capacity. Although steel bushings (if lubricated) can be used for a few cycles of low speed oscillation without galling or excessive wear taking place, bronze bushings should be employed if an appreciable amount of motion is expected between the shaft and the bushing. Under dynamic conditions, excessive wear of the bronze bushing is the mode of failure. Figure 201-19 is a plot of life versus unit load under well-lubricated (MIL-G-81322 grease) conditions.

5. Installation and retention. Design requirements and recommendations for bearing installation and retention are covered in requirement 202. Satisfactory bearing performance is obtained by proper installation practice and appropriate retention techniques as much as by optimum bearing selection.

6. Miscellaneous design consideration

6.1 Lubrication provisions. Requirement 203 specifies methods required for provision of lubrication facilities where applicable including location of fittings relative to access for relubrication.

6.2 Bearing safetying. Requirement 204 specifies requirements for and methods of safetying bearings.

MATERIAL	YIELD STRESS, KSI	MAXIMUM TEMPERATURE* (°F)
4130 Steel (180 KSI UTS)	115	350
17-4 Steel (AMS 5643)	90	500
Beryllium Copper (Fed Spec QQ-C-530)	90	350
A1-Ni-Bronze (AMS 4640 and 488)	60	350
A1-Bronze (Fed Spec QQ-C-465)	40	350

* Maximum temperature at which bushing can be used without loss of static capacity.

FIGURE 201-18. Stress Capability of metal journal bearings.

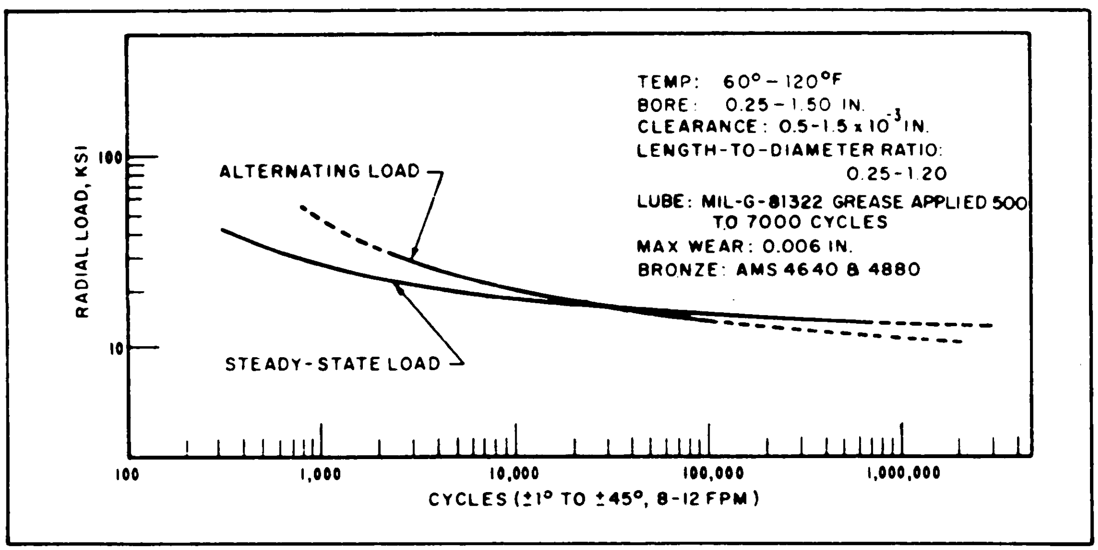


FIGURE 201-19. Load/life characteristics for grease lubricated journal bearings.

7. Quality assurance Provisions in desire

7.1 Proof loading for retention. Where retention methods are used which require proof loading, engineering drawings specifying the bearings shall also specify the requirement for proofloading and proof load value and direction.

7.2 Safetying. Where safetying is required, the engineering drawing specifying the bearing shall also specify the requirement for and method of safetying. The engineering drawing may reference a DOD or contractor document which delineates safetying of methods and procedures.

7.3 Starting torque. Where starting torque is critical to functioning of an assembly, the installation drawing specifying the bearing shall include a notation that starting torque shall be within a specified range or a maximum range after bearing is installed.

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SAFETYING PRACTICES

1. Scope. This requirement states general methodology for safetying practices to be used In flight control systems. This requirement specifically delineates approved safetying methods and devices and specifies the application of these methods and devices. This requirement covers only those devices whose primary function is safetying, and excludes those devices which have integral locking features incorporated into the item being locked. Since safetying and retention occasionally become coincident functions, a fine distinction must be made between the two. Refer to requirements 202, 206, 207, 208, 401, 402, 601 and 604 for additional methods and devices which may provide a safetying function coincident with a retention function. Special applications involving conditions not covered by the basic principles described herein shall be shown on the assembly drawing, and where contradiction occurs between a drawing and these instructions, the drawing shall take precedence.

2. Documents applicable to requirement 204

MIL-T-8878	Turnbuckle, Positive Safetying
MS 20995	Wire, Safety or Lock
MS 21251	Turnbuckle Body, Clip Locking
MS 21252	Clevis, Rod End; Turnbuckle, Clip Locking
MS 21253	Clevis End, Turnbuckle, Clip Locking (For bearing)
MS 21254	Eye End, Turnbuckle, Clip Locking (For pin)
MS 21255	Eye End, Turnbuckle, Clip Locking (For wire rope)
MS 21256	Clip, Locking, Turnbuckle
MS 24665	Pin, Cotter, (split)
MS 33540	Safety Wiring and Cotter Pinning, General Practices for
MS 33736	Turnbuckle Assemblies, Clip Locking of

3. Usage and design

3.1 Preferred usage. The preferred methods of preventing rotation and loss of nuts, bolts, or screws are:

Use of self-locking bolts, screws, nuts, and inserts. (See requirement 402)
b. Use of cotter pins with castellated nuts.
c. Use of safety wire and drilled head bolts or screws.

In assemblies that may require periodic removal, where possible use either self-locking nuts or castellated nuts to be locked with cotter pins. Turnbuckle clips shall be used for positive safetying or turnbuckle components. Rod end bearings used in control rods shall be safetied as noted in requirement 207. Safetying of push-pull controls shall be as specified in requirement 208 and safetying of control cable components such as quick disconnects, cable take-up links and terminals shall be as specified in requirements 206 or 601.

3.2 Cotter pins

3.2.1 Cotter pin usage Cotter pins are generally used to restrain relative motion between two parts by inserting the cotter pin through a hole in one part and slots in the other part and spreading the exposed ends. Their use is favorable because they can be installed and removed quickly. Cotter pins shall be used:

a. With castellated nuts and drilled bolts and *screws* to insure nut retention.

b. With self-locking castellated nuts and drilled bolts and screws to provide a dual locking feature .

c. As a retaining device on pins or shafts.

3.2.2 Applicable cotter pin design standard. Design standard MS33540 shall be used for design practices, functional limitations and installation procedures . The selection of materials shall be made from MS24665 and shall be in accordance with temperature, atmosphere and service 1 imitations given in MS33540.

3.3 Safety wiring

3.3.1 Safety wiring usage. Safety (lock) wiring is the securing together of two or more parts with safety wire which shall be installed in such a manner that any tendency for a part to loosen will be counteracted by additional tightening of the wire. Safety wire (lock wire) shall be used:

a. To prevent the loosening of threaded parts in applications where other locking means such as cotter pins, key (bent tab) washers, self-locking fasteners, etc. would not be feasible.

b. In the case of single attachment bolts used head-down where loss of the bolt would affect safety of flight the bolt shall be safety wired through the head of the bolt to retain it in place following loss of the nut; unless otherwise restrained in position by means that are independent of the attaching nut.

c. To prevent the loss of disconnected items such as caps, plugs, etc.

d. To secure valve handles and external snap rings.

CAUTION

Safety wire should not be used to retain parts or limit the amount of motion between parts in applications where relative motion is normal since this will cause cold working and failure of the safety wire.

3.3.2 Applicable safetying wire design standards. Design standard MS 33540 shall be used for design practices, functional limitations, preferred material usage, installation procedures and all other requirements. MS 20995 lockwire referenced therein is the approved part callout.

3.4 Turnbuckle clips

3.4.1 Turnbuckle clip usage. Turnbuckle clips are used to prevent rotational movement between the turnbuckle body and the turnbuckle end. They can be installed manually without the use of tools and are self-retained in the assembly.

3.4.2 Applicable turnbuckle clip desire standards. Design standards MS21251, MS21252, MS21253, MS21254, MS21255, MS21256 and procurement specification MIL-T-8878 shall be used for design practices, functional limitations, and material usage. Design standard MS33736 shall be used for Installation procedures of the turnbuckle assembly. MS21256 locking clip referenced therein is the approved part callout.

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CONTROL CABLE SYSTEM DESIGN REQUIREMENTS

1. Scope

1.1 This ‘requirement establishes engineering criteria and requirements for the selection and application of mechanical controls system cable and components. This requirement is limited to components selection and does not establish selection criteria for control cable systems relative to sizing, tensioning, actuating and similar system oriented design requirements. This document Is not intended to address cables used as static structural members nor as means of transferring operating loads in structural/functional systems such as winches. Push-pull control cable requirements are included as requirement 208. Approved components for cable assemblies and systems are listed in appropriate requirements in section 600.

2. Documents applicable to requirement 206

MIL-T-781	Terminal, Wire Rope, Swaging
MIL-C-5688	Cable Assemblies, Aircraft, Proof Testing and Prestretching of
MIL-T-6117	Terminal, Cable Assemblies, Swaged Type
MIL-P-7034	Pulleys, Groove, Antifriction Bearing, Grease Lubricated, Aircraft
MIL-T-8878	Turnbuckle, Positive Safetying
MIL-F-9490	Flight Control Systems-Design, Installation and Test of Piloted Aircraft, General Specification for
MIL-C-16173	Corrosion-Preventive Compound, Solvent Cutback, Cold-Application
MIL-F-18372	Flight Control Systems: Design, Installation and Test of, Aircraft (General Specification for)
MIL-W-83420	Wire Rope, Flexible, For Aircraft Control
MS20392	Pin, Straight, Headed-Drilled Shank
MS20663	Ball End, Wire Rope, Swaging, Double Shank
MS20664	Ball End, Wire Rope, Swaging, Single Shank
MS21256	Clip, Locking, Turnbuckle
MS33602	Bolts, Self-Retaining, Aircraft Reliability and Maintainability, Design and Usage, Requirement for
MS33736	Turnbuckle Assemblies, Clip Locking of
MIL-STD-1515	Fastener Systems for Aerospace Applications
NAS 302 - NAS 310	Cable Assembly, Swaged Type, Type. I Terminals
NAS 312 - NAS 320	Cable Assembly, Swaged Type, Type I & Type II Terminals
NAS 322 - NAS 330	Cable Assembly, Swaged Type, Type II Terminals
NAS 427	Pin-Pulley Guard
NAS 1435	Terminal, Strap, Cable (Eye End and Fork End)

3. Design requirements

3.1 Control cable assesmbly requirements. The requirements set forth in this paragraph apply to mechanical wire-rope-type cable systems used in primary, secondary and auxiliary control cable systems.

3.1.1 Control cable material

3.1.1.2 Bare cable. All control cable used in primary, secondary and auxiliary control systems shall conform to MIL-W-83420, type I, composition A or B.

3.1.1.2 Lockclad cable. Cable onto which aluminum or steel tubing is swaged for basically the entire length or a high percentage of the length may be used in primary, secondary or auxiliary controls systems. Cable which forms the Core of the lockclad cable shall conform to MIL-W-83420, type I, composition A or B. The contractor shall be prepared to show the customer from vendee data or design handbook tabulations based on test or experience that the lockclad material and diameter will provide the appropriate EA values and thermal coefficient of expansion used for the application.

3.1.1.3 Non-metallic material jacketed cable. Cable which is jacketed with non-metallic tubing may be used in primary, secondary, and auxiliay controls systems. Jacketed cable shall conform to MIL-W-83420, type II, composition A or B.

3.1.1.4 Cable type selection. Bare, lockclad and non-metallic material jacketed cable as noted above may be used in all applications except as restricted herein or as required by specific contracts. Primarily because of weight, lockclad should be used only where stretch of bare cable qust be reduced.

3.1.1.5 Cable material selection. Unless otherwise required in the specific contract, MIL-W-83420, type I on II, composition B, or lockclad using type I cable as the core should be considered for all applications in a potentially corrosive environment and in all landing gear wheel wells or other applications subject to runway debris.

3.1.2 Control cable terminals

3.1.2.1 Attachment to cable. All terminals on cable used in primary or secondary controls systems which attach directly to the cable at the ends or any other point shall be attached to the cable by swaging per the requirements T-6117. Terminals swaged to lockclad cable shall be swaged to bare cable except the special condition whereby the lockclad extends the entire length of the cable assembly. Type III terminals as described in requirement 601 may be swaged over the cladding. Jacket material shall be removed in the area of the terminal prior to swaging. Terminals attached to cables used in auxiliary controls systems shall be swaged per MIL-T-781 except that crimped type terminals with or without loops may be used in cable assemblies such as lanyards. Caution: cladding shall never be removed from lockclad cable. Stripping of cladding is disallowed. Lockclad cable assemblies shall be manufactured with gaps in the cladding for all areas which will go around pulleys, receive terminals, or where a bend of more than 2 degrees is inherent in the application.

3.1.2.2 Approved terminals. Only the terminals specified in requirement 601 may be considered approved for use in design.

3.1.2.3 Approved cable assemblies. NAS 302 - NAS 330 cable assemblies are approved for use within the restrictions set forth herein. Cable assemblies manufactured in accordance with this requirement using terminals approved in requirement 601 may be detailed and identified by airframe or cable assembly manufacturer's pant numbers without further approvals by authority of MIL-STD-1599.

3.1.2.4 Terminal usage. Usage of terminals shall comply with the following:

a. Swaged/non-threaded terminals. Types I and III terminals as noted in requirement 601 may be used in primary, secondary and auxiliary controls systems. Type II terminals are approved only in secondary and auxiliary controls systems except as noted in paragraph b. Type IV terminals are approved only for items such as lanyards.

b. Ball end terminals. MS 20663 and MS 20664 ball end terminals may be used in primary controls systems to attach cable assemblies to bell cranks and quadrants. Ball end terminals with NAS 1435 straps may be used only in secondary or auxiliary controls systems. Balls without shanks may be used in auxiliary controls systems only when used as a terminal. Balls without shanks may be used in secondary or auxiliary controls systems at points other than the ends of the assemblies for purposes of operating limit switches or other non-structural functions. Swaged plugs may be used as terminals only in auxiliary controls or cable systems, such as static lines for paradropping.

c. Swaged/threaded terminals. Terminals which are swaged to the cable and threaded on the non-swaged end shall be limited to those types used with turnbuckles or through components with a connection free to align with the cable direction. Control cables assemblies shall not be attached to equipment, bellcranks, etc., by threading into open or closed-end tapped holes. Chain to cable swaged fittings shall be attached by stud (clevis pin) and cotter pin.

d. Cable end. All cable assemblies shall terminate at both ends with swaged terminals. Cable assemblies shall not terminate in cut cable ends beyond the extent of normal protrusion beyond terminals noted in terminal swaging specifications or terminal drawings.

e. Design for installation. Cable assemblies shall not be applied such that swaging of tenminals is required after cable assembly is mounted in aincraft.

f. Crimped terminals and loops. Crimped type terminals (type IV) with or without loops shall be used only for non-critical auxiliary applications such as lanyards.

3.1.3 Control cable assembly strength criteria.

3.1.3.1 Control cable associated components. All terminals, pins, bolts, nuts, or other items attached directly to the loaded cable shall be structurally capable of' withstanding the minimum b-caking strength of the cable. This applies both in attachment to or connection with the cable and physical construction of pants. The exception to this requirement is a component specifically designated to fail prior to loads which may damage equipment in auxiliary systems only. Ball terminals without shanks and plug terminals shall not be considered to withstand more than 80 percent of cable strength and shall be used only in auxiliary cable systems.

3.1.3.2 Lockclad and jacketed cable. Strength criteria shall be based on the wire rope strength only, even when type III terminals are used with lockclad cable.

3.1.4 Control cable-to-cable connections

3.1.4.1 Clevis/eve connections. Control cable assemblies may be connected by clevis and eye terminals with bolt/nut attachment, safetied as specified in requirement 601. Secondary and auxiliary control cable systems may be connected by MS20663 and NAS 1435 terminals with bolt/nut attachment) safetied as specified in requirement 601.

3.1.4.2 Turnbuckles and terminls. Cables may be connected by threaded fittings and turnbuckles. Assembly shall be accomplied per MS33736. In addition, when using aluminum turnbuckles, all male threads shall have MIL-C-16173, grade 2 or 4, corrosion preventive compound applied before assembly. Regardless of material, there shall be no more than three threads on either terminal exposed after assembly and adjustment of turnbuckle assemblies. After complete assembly of the turnbuckle assembly and installation of the clip, MIL-C-16173 corrosion-preventive compound shall be applied to the whole assembly. All turnbuckle terminal assemblies shall be safetied per MS33736 using MS21256 clips. The military wrap system is not approved for use on aerospace systems whereby MIL-STD-1599 is a requirement.

3.1.4.3 Cable take-up) links. Cable take-up links may be used in primary or secondary controls or auxiliary cable systems where course adjustment is required. The link shall mate with two threaded or swaged eye end terminals. The link is assembled by placing the side plates on both sides of the eye end terminals of the cable assemblies to be joined and placing the bolts through the plate, eyes, and plate, and installing the nuts on the bolt. The link therefore provides the capability of lengthening or shortening cable runs in amounts greater than turnbuckle adjustment spans. The link shall be safetied by either the use of self-retaining bolts or the use of self-locking castellated nuts with cotter pins. No other safetying is required, but may be added at the option of the airframe manufacturer.

3.1.4.4 Clad-to-clad connections. Type III internal and external terminals may be used in primary, secondary, or auxiliary control cable sytems for connection of two lockclad cable assemblies whereby the cladding extends to the end of the cable assembly. Safetying shall be accomplished as noted in requirement 601.

3.1.4.5 Quick disconnects. Quick disconnects utilizing MS20663 and MS20664 ball ends are not approved for primary control systems. They may be used in secondary controls or auxiliary cable systems. Quick disconnects which are swaged onto cable or thread to approved terminals may be utilized on all systems, but must meet all requirements of swaged or threaded terminals as specified herein. Swaging shall be in accordance with MIL-T-6117 or MIL-T-8878, as applicable. Quick disconnects using the ball type terminals do not required safetying. All quick disconnects used in primary control systems require safetying as shown in requirement 601.

3.2 Design usage requirements of control cable assembles

3.2.1 Loading

3.2.1.2 Sizing and material. Control cable material and sizing shall be in accordance with the following in addition to requirements of MIL-F-9490 or MIL-F-18372 as applicable:

a. Cable material shall be either MIL-C-83420, type I or II, composition A or B as specified in the model specification for the aircraft. If the model specification does not specify the material, type I or II, composition B should be considered for all cable located in a corrosive environment or subject to runway debris.

b. Lockclad cable is intended for the purpose of reduction of tensile stretch and matching the thermal coefficient of expansion of the cable more nearly to that of the aluminum airframe structure. While the cladding adds to the strength of the cable assembly, no structural credit shall be given to the added strength of the clad material in design considerations.

c. Loop type termination of cables shall be considered no greater than 80 percent of the cable ultimate strength for loading determinations.

3.2.2 Control cable routing and support

3.2.2.1 Support. Control cable shall be supported by pulleys at all points whereby the direction is changed 2 degrees or more when the rig load is less than 50 pounds and 1 percent when the rig load is 50 pounds or greater. Control cable shall be supported by fairleads at least every 100 inches of length unsupported by pulleys and in any location where "slap" may contact structure. Cable shall be supported by pulleys or fairleads on at least one side of any bulkhead through which the cable passes. Design shall be such that lockclad is not required to bend over fairleads or pulleys and such that maximum bend due to weight of lockclad or tolerances of mounting is not greater than 2 percent.

3.2.2.2 Location relative to Structure. Cable shall be routed and connection points located such that sufficient clearance is provided to prevent fouling of fittings or damage to structure, equipment, or cable due to structural deflection, thermal expansion, tolerance accumulation, functioning equipment, or other factors. Where cable passes through holes in bulkheads or the possibility of contact with structure or fixed equipment exists, fairleads shall be provided.

3.2.2.3 Fairleads. Anti-friction fairleads shall be used for support of cables for purposes of sag reduction and general support. Fairlead strips may be used in auxiliary cable systems only for protection of structure and cables where peculiar designs may allow contact of the cable with structure or equipment. When anti-friction fairleads are used in opposition, the space between opposing flanges shall be less than 1/4 and more than 1/8 diameter of the cable. Fairlead roller installation should be such that cable does not vibrate within the space between opposing fairleads, such as by staggering fairleads. Approved fairleads are listed in requirement 603.

3.2.2.4 Pulleys and brackets. Pulleys shall conform to requirement 603. Sizes shall conform to MIL-P-7034 and associated MS documents. Pulleys shall be aligned with the cable run such that axial pull-off angle is not greater than 2 degrees in either direction off center line of pulley groove. Pulley guard pins shall be NAS 427 or MS20392 types. NAS 427T cantilever type pins shall not be used in lengths greater than 2 1/2 inches when unsupported at one end. Where angle of wrap is 20 degrees or less, one guard pin is required; 20 degrees to 120 degrees, 2 are required; and over 120 degrees, 3 are required. Pulley brackets shall be attached to primary structure only. Ratio of cable diameter to pulley diameter of 20:1 or greater should be considered for enhancing fatigue life of cables.

3.2.2.5 Cable connection locations. Cane shall be exercised in locating cable connections to assure that cable assemblies and connecting components, (turnbuckles, cotter pins, safety wire, quick disconnects, links, etc.), cannot snag on each other or surrounding structure or equipment. Turnbuckles shall be staggered to prevent crossrigging.

3.2.2.6 Bellcrank or structure termination. Terminations into bellcranks or structure shall be aligned such that the cable does not misalign relative to the swaged terminal more than 2 degrees. Swivel arrangements may be used to circumvent misalignment.

3.2.3 Fasteners used in control cable systems

3.2.3.1 Bolt and nut selection

3.2.3.1.1 Structural requirement. Selection of bolts and nuts shall be in accordance with the structural requirements of the specific application and the requirements of this standard.

3.2.3.1.2 Approved bolts and nuts. Pants listed in MIL-STD-1515 are considered approved parts herein.

3.2.3.1.3 Retention requirement. Lath removable bolt, screw, nut, pin, or other removable fastener, the loss of which would preclude or impair continued safe flight, shall incorporate two separate locking or retention devices either of which must be capable of preventing loss of the fastener by itself and retain it in its proper installation with the other locking or retention device missing, failed, or malfunctioning. Clevis pins shall not be used. Clevis bolts with shear castle nuts and cotter pins are considered satisfactory in shear applications as one of the two methods of retention. Bolts of less than 1/4 inch diameter shall not be used for critical applications as the single attachment. Where self-retaining bolts are used and which constitute one of the two retention methods, their selection and installation shall be within the limitations of MS33602, and only one type shall be used in any given system. Provisions for prevention of over-torquing bolts and thereby causing binding of other control system components shall be considered and appropriate precautions taken. Bolts mounted head down shall be self-retaining type bolts or have heads safety wired to structure or other components to prevent loss of bolt if nut is loose.

3.2.3.2 Cotter pins and studs. Pants approved in MIL-STD-1515 may be used herein. Special pins for type III terminals shall be per requirement 601.

3.2.4 Pressure seals. Pressure seals shall be used with the following conditions:

a. Pressure differential. Pressure seals approved in requirement 605 shall be used if system pressure differential requirement can be met. If not, a seal shall be designed or selected by the contractor. If a vendor-identified seal is selected, it must be submitted for approval per requirement 101. If the seal is designed by the contractor, it is outside the scope of this document.

b. Alignment. Alignment of the cable through the seal shall be within 2 degrees of the center line of the seal during all operating positions of the cable travel.

3.3 Test requirements

3.3.1 Control cable assemblies. Control cable assemblies shall be tested as follows:

a. All cable assemblies manufactured with swaged terminals shall be proof loaded to 60 percent of ultimate cable strength per MIL-C-5688.

b. Cable assemblies shall be loaded to ultimate strength as required by MIL-T-6117. Cable assemblies loaded to ultimate strength per this requirement shall not be used on aircraft.

c. There shall be no broken wires in cable assemblies as required by MIL-W-83420.

4. Quality assurance provisions

4.1 Control cable assemblies

4.1.1 Lubricant removal. Cleaning processes used by airframe manufactures shall not remove internal lubrication of cable applied by the cable manufacturer.

4.1.2 Turnbuckle clips. MS21256 clips shall not be used more than once. When 'adjusting turnbuckles, removed clips shall be discarded and new clips used for safetying.

5. Design, selection, and approved callout. (see requirements section 600 for approved pants).

6. Tooling, There are no special tooling requirements.

7. Intended use and guidance criteria

7.1 The purpose of this requirement is to establish required criteria. Where there are no requirements in a specific area and guidance information may be included, the lack of requirements is so noted.

8. Notes

8.1 Equipment. Actuators, tension regulators, servos, bellcranks, and other control system equipment are not in the scope of MIL-STD-1599. Interfaces of this equipment with cable or push-pull controls; however, must comply with the requirements herein as applicable.

8.2 Swaged fittings other than termination. Fittings such as plugs or no-shank balls which are swaged onto cable as an additional fitting to the two terminals may be used for triggering limit switches, or other applications of this nature, but shall not be used to transmit loads to or from the cable system.

8.3 Specially designed fittings. Swaged fittings designed specifically for use as cutter or for other funtions must be approved per the procedure in requirement 101.

CONTROL ROD SYSTEM

1. Scope. This requirement establishes engineering criteria and requirements and application of rigid rods or tubes used for transferring linear motion in the controls and other functional systems and requirements for associated hardware. This requirement is not scoped to determine load requirements for systems, sizing and material selection for rods, or rigid rods used as structural components. Approved rod components are listed in requirement 602 and the various bearing requirements specified herein.

2. Documents applicable to requirement 207.

FED-STD-245	Tolerances for Aluminum Alloy and Magnesium Alloy Wrought Products
MMM-A-1754	Adhesive and Sealing Compound, Epoxy, Metal Filled
WW-T-700/3	Tube, Aluminum Alloy, Drawn, Seamless, 2024
MIL-S-8879	Screw Threads, Controlled Radius Root With Increased Minor Diameter; General Specification for
MIL-T-6845	Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic System, 1/8 Hard Condition
MIL-H-6088	Heat Treatment of Aluminum Alloy
MIL-H-6875	Heat Treatment of Steels (Aircraft Practice), Process for
MIL-F-7179	Finishes and Coatings: Protection of Aerospace Weapons Systems, Structures, and Parts
NAS 513	Washer, Rod End Locking
NAS 1193	Locking Device, Positive Index

3. Design requirements

3.1 Rod material and construction

3.1.1 Material selection. The material shall be selected based on the loading requirements of the system. Magnesium is hereby prohibited because of its corrosion characteristics. Otherwise there are no restrictions on material selections. (See paragraph 7.1).

3.1.2 Finish. Exterior of rods shall be plated, passivated, painted or coated in accordance with the modes specification of the airframe under contract for the rod material and area of the airframe as applicable. Interior finish of rods shall comply with MIL-F-7179 or contractually approved company specifications.

3.1.3 Configuration. Tubes shall be symmetrical in cross section with material, wall thickness, and outside dimensions commensurate with the static, environmental and dynamic requirements of the system. This requirement is not to preclude formed clevis ends or local deformation as clearance requirements dictate. The tolerances for the dimensions specified on rod drawings shall be as defined in the applicable tubing specification. Local repair of minor defects is acceptable provided the repaired area is not less than the minimum wall defined in the specification, and provided there shall be no material removal from the swaged sections after swaging. Dimensional increase in wall thickness as required for integral formed clevis ended tubes may have more than one tube diameter and wall required in one part. These may be specified by outer diameter (O.D.) and wall, and will require the appropriate tube specification tolerance to apply, unless specific application dictates other tolerances. Transition from one wall thickness to another will be as detailed by drawing.

3.1.4 Loads, tube and rod assembly strength. Assemblies shall be capable of withstanding limit loads without permanent deformation. Limit loads are maximum or jam loads, the extreme loading the rod assembly can receive prior to failure of components of the functional system other than the rod assembly. Ultimate loads are 1.5 times limit loads. Rod end or tube deformation at ultimate load is acceptable including loss of balls or rollers in antifriction bearings provided the assembly supports the ultimate load. This requirement does not apply to controlled shearout or force limiter assemblies. Mounting adjustable rod assemblies for tension and/or compression fatigue allowable or static testing shall require th adjustable rod end to be engaged only sufficiently to cover the inspection hole. Control rod assemblies designed as torque tubes are not within the scope of this Requirement. Control rod assemblies functioning in push-pull mode shall not be subjected to torsional loads.

3.1.4.1 Assembly static strength and fatigue determination. Tubing corss section size and material, end fitting configuration and material and method of configuring or attaching end fittings shall be such that ultimate tension and compression loads and fatigue life can be achieved without destruction of any component of the assembly. The contractor shall be able to demonstrate that all rods used in critical systems are capable of static loads and fatigue requirements of the system if required by the procuring agency. Determination of criticality of a control system relative to this requirement is the responsibility of the contractor with procuring agency concurrence.

3.1.5 End construction. Aluminum and steel tubes may be swaged directly over an end fitting. Because of the dificulty in effecting a swage engagement between nipple inner diameter (I.D.) and convoluted or knurled end fitting, the swaged material must have adequate ductility and a differential in hardness between qating surfaces, Integrity is further affected by nipple wall thickness. Substantiating data for minimum engagement as well as conformance with static and fatigue strength requirements shall be available for all swage installed attachments as required by the procuring agency. Flashwelding as a means of attaching end fittings to rods shall be used only with steel rods and steel end fittings.

3.2 Design usage of control rods

3.2.1 End configurations

3.2.1.1 Fixed ends. All rod assemblies used in primary and secondary controls systems shall have at least one fixed end except vernier coupling as defined in paragraph 3.2.1.2. The term “fixed end” as used herein is defined as attachment of the end fitting in such a manner that rotation or dimensional change will cause failure. The strength of the fixed end relative to preventing rotation shall be considered that of the weakest member of the end assembly relative to forces tending to rotate the rod. In auxiliary controls or in vernier coupler systems where both ends are adjustable, threads on both ends of the rod shall be either right or left hand, not one of each. Rods shall not be used as "turnbuckles" for adjustment of length. Examples of fixed ends are shown in figure 207-1.

3.2.1.2 Vernier coupling effect. Vernier coupling may be required in some systems to prcisely position a hydraulic servo relative to cockpit control for example. An NAS 1193 indexable, positive locking device alone will not effect this close adjustment because the fixed end requires the opposite end to be oriented as defined by drawing, making possible adjustment only to the closest 180 degree position. Procuring agency approval is required if both ends of a rod are vernier couplings in primary and secondary controls systems. Examples of vernier coupler rod assemblies are shown in figure 207-2. Vernier coupling is accomplished with nominal gage length covering the inspection hole or holes and shall be shown to maintain 1.2 thread diameters minimum engagement of both threaded attachments after maximum vernier rotation in either direction.

3.2.1.3 Adjustable ends. Adjustable ends may be threaded directly into tube nipples or may be threaded into an insert which may be affixed by swaging or otherwise, provided the insert can be shown to be attached to the tube as defined for fixed ends per paragraph 3.2.1.1. All adjustable ends shall be threaded per MIL-S-8879 unless otherwise permitted in the contract with the procuring agency. Inspection holes or other qeans shall be provided for assurance of sufficient thread engagement. Hole location is illustrated in figure 207-3.

3.2.1.4 Bearings. Bearings used with control rods which are integral rod end bearings or mounted in an eye end arrangement shall be capable of misalignment. The exception of these requirements are rods which terminate in an eye or clevis which is attached to a misaligning type bearing. In these cases, the bearing in the rod may be a journal bearing or bushing per requirement 309 or 310, or may be eliminated altogether. Figure 207-4 illustrates these applications.

3.2.2 Rod attachment to equipment

3.2.2.1 Fixed end. Fixed ends shall be terminated in a hollow or solid shank rod end bearing per requirement 308 or an eye or clevis arrangement with bearings installed in the eye or one or both sides of the clevis per requirement 202. Figure 207-4 illustrates methods of attachment to equipment.

3.2.2.2 Adjustable end. Externally threaded rod end bearings shall be slotted and ends of rods notched for safetying with NAS513 or NAS1193. Internally threaded rod end bearings may be notched and external threads of ends of rods slotted for safetying with NAS513 or NAS1193. These conditions are required in primary and secondary control applications. Alternately, control applications may be non-slotted and non-notched and installed with a check nut in auxiliary controls applications.

3.2.2.3 Safetying

3.2.2.3.1 Fixed end. Safetying of the rod is not applicable.

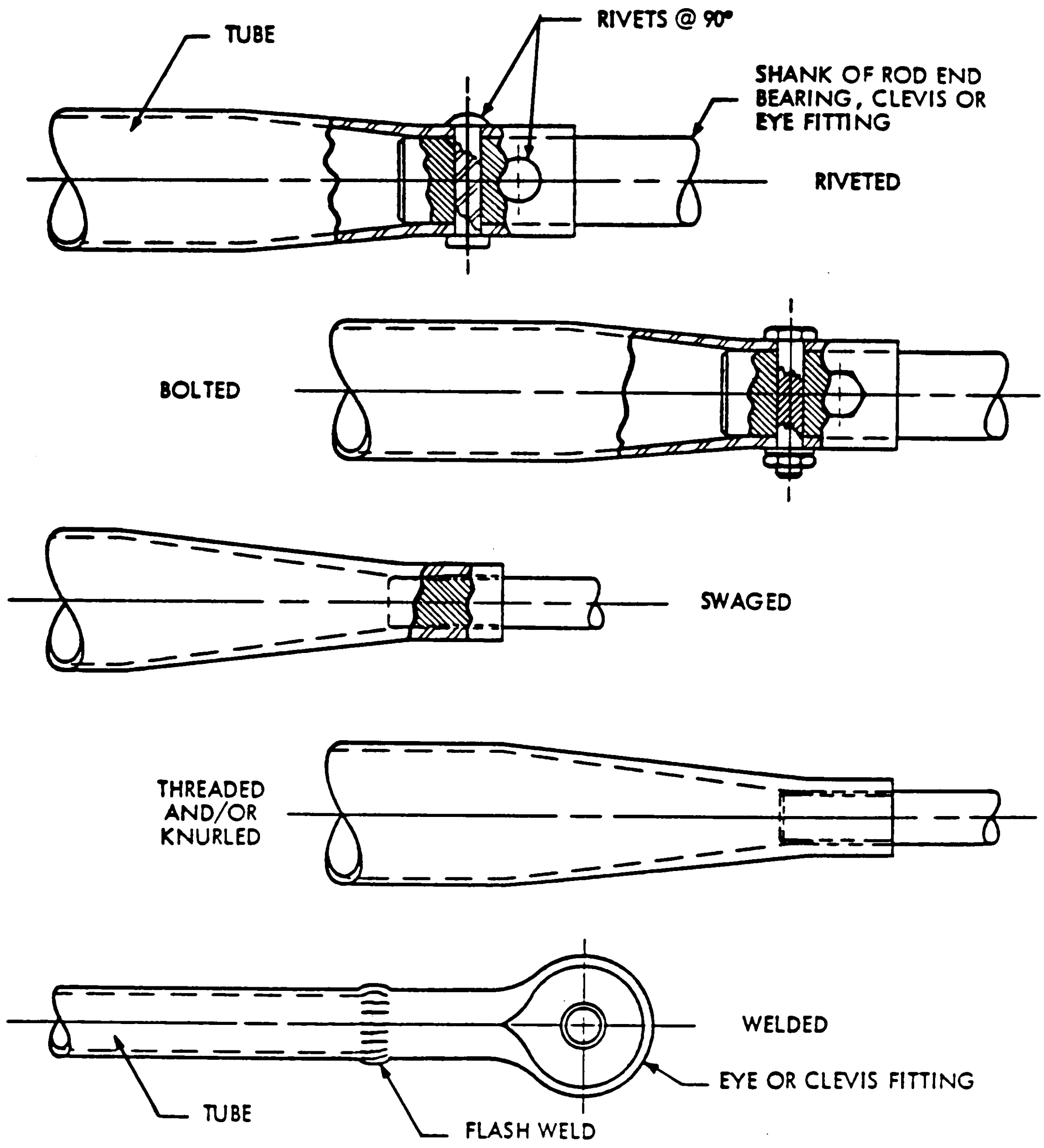


FIGURE 207-1. Fixed ends.

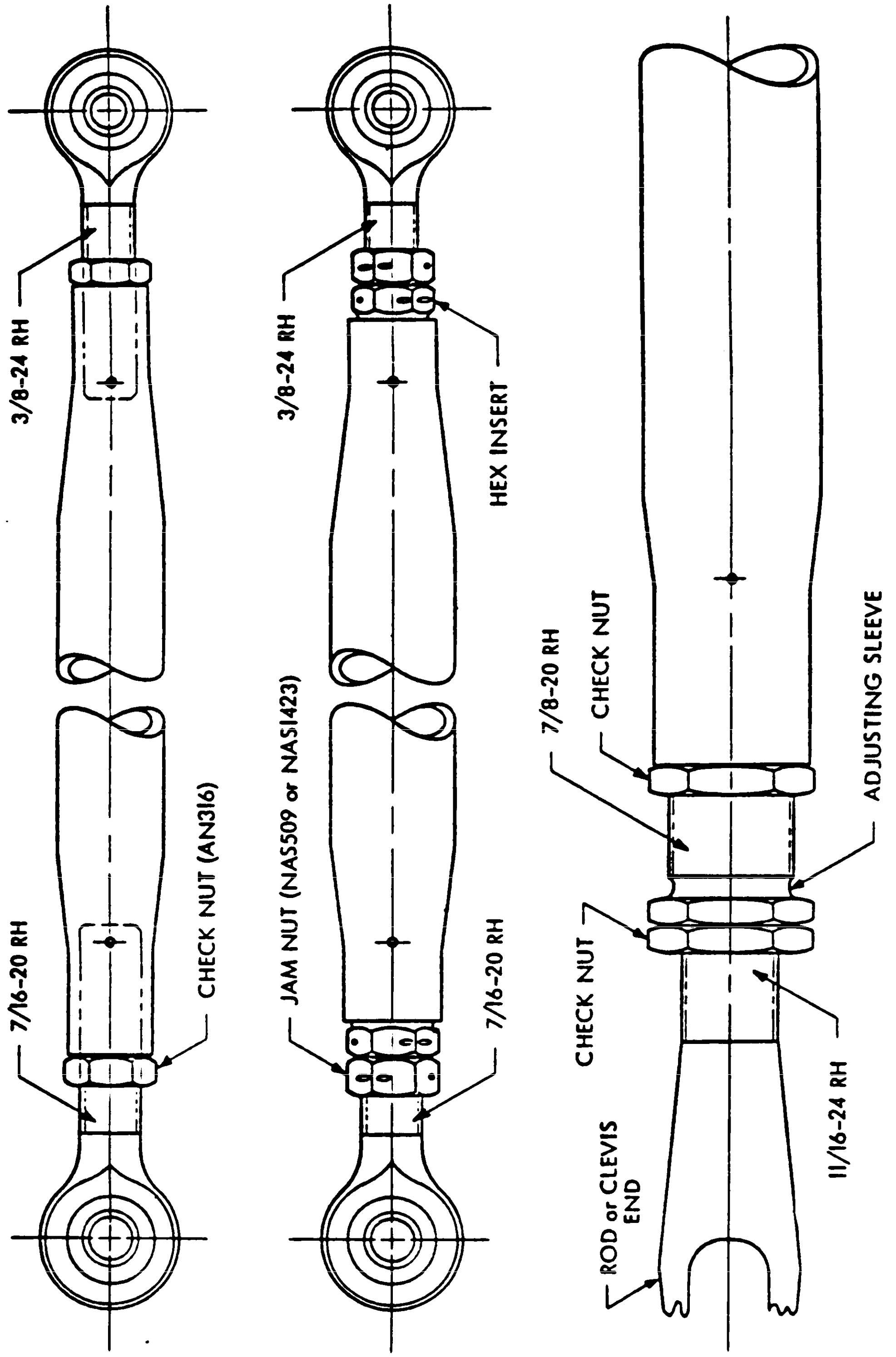


FIGURE 207-2. Vernier couplers, examples.

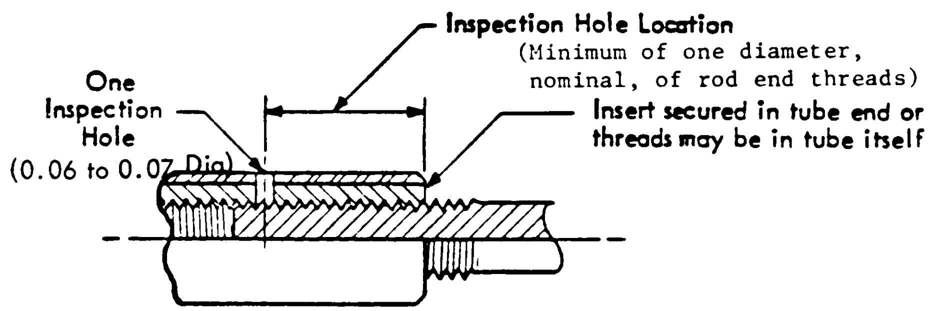


FIGURE 207-3. Inspection hole.

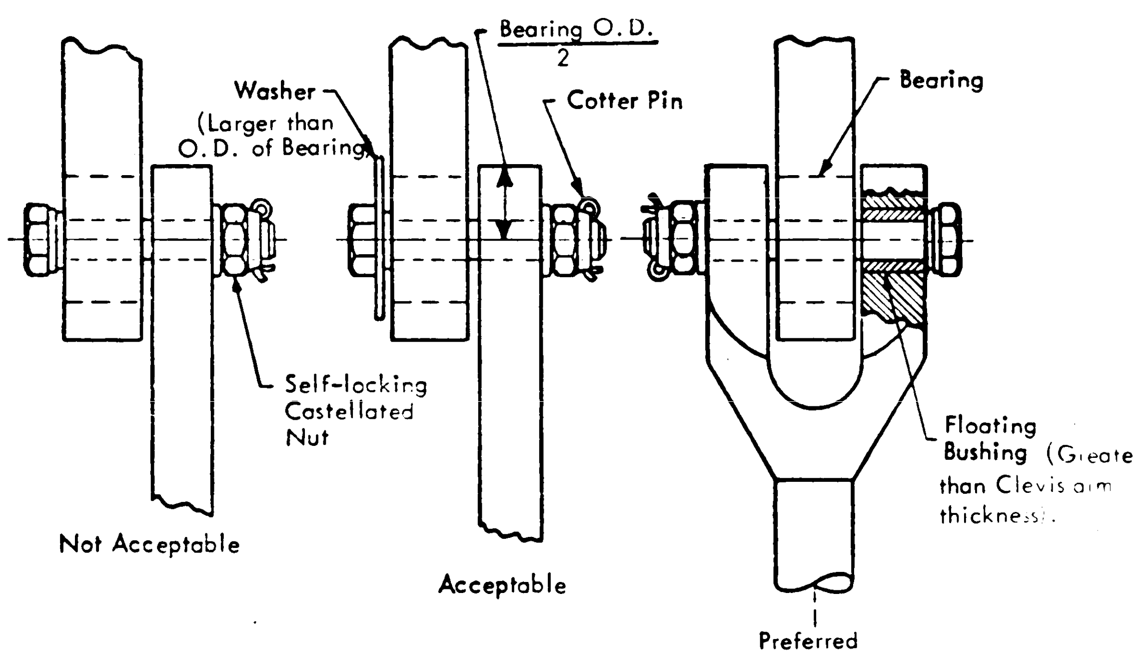


FIGURE 207-4. Methods of attachment.

3.2.2.3.2 Adjustable end. Rod end bearing installation into the rods in primary and secondary controls systems may be safetied by the use of an NAS513 or NAS1193 locking device. For cost reasons, NAS1193 should only be uses where adjustment requirements exceed the capabilities of NAS513. The nut shall be safety wired to the locking device as shown in figure 207-5.

3.2.2.4 Washer use in cantilever mounting. As illustrated in figure 207-4, when rods are attached to structure, a washer of outside diameter larger than the bearing outside diameters shall be used to prevent loss of the rod by loss of bearing retention.

3.2.2.5 Straightness and angularity requirements. All control rods shall be straight as opposed to angular or "dog-leg" designs. Straightness and angularity requirements of the control rods shall be specified on engineering drawings of the rods.

3.2.2.6 Drain. ventilation requirement. Moisture accumulation may occur tending to partially fill the tubes of rod assemblies not intentionally drained or alternately sealed. Aluminum tubes may be hermetically sealed with a thorough application of a metal filled epoxy sealing/adhesive compound per MMM-A-1754 to the mating threads or surfaces. Drain holes are effective in protecting tubes from bursting from freezing water, but may reduce fatique capability by 90 percent. Blind inserts installed with an epoxy sealing compound per MMM-A-1754 may be used to seal the tube end mounting an adjustable rod end as illustrated in figure 207-6. An effective seal requires application of epoxy to the full engagement of both female and male mating parts. Members to be bonded shall be cleaned and free of any trace of oil or grease. Curing of hermetically sealed tubes using an MMM-A-1754 sealing compound shall be at room temperature. Inserts or rod ends so installed may, at prime manufacturer's option, and/or where acceptance testing requires, each be torque tested to verify the bond. Steel tubes other than CRES are difficult to protect from corrosion on I.D. and are difficult to seal. CRES tubes are difficult to seal, but require no corrosion protection. All steel tubes shall have drain holes to protect against collecting water, except that steel tubes that can be demonstrated to be hermetically sealed may be used at discretion of prime contractor.

3.3 Rod and component inspection. Rod assemblies used in primary control systems or other applications considered critical to safety cf flight shall be inspected for material and process integrity on a 100 percent basis.

4. Quality assurance provisions

4.1 Initial testing. Testing shall be accomplished at the contractor's discretion or as required in specific contracts. The contractor is responsible for the integrity of rods for defined system requirements.

5. Design. selection, and approved callout. See requirements sections 300 and 600 for approved parts.

6. Tooling. There are no special tooling requirements.

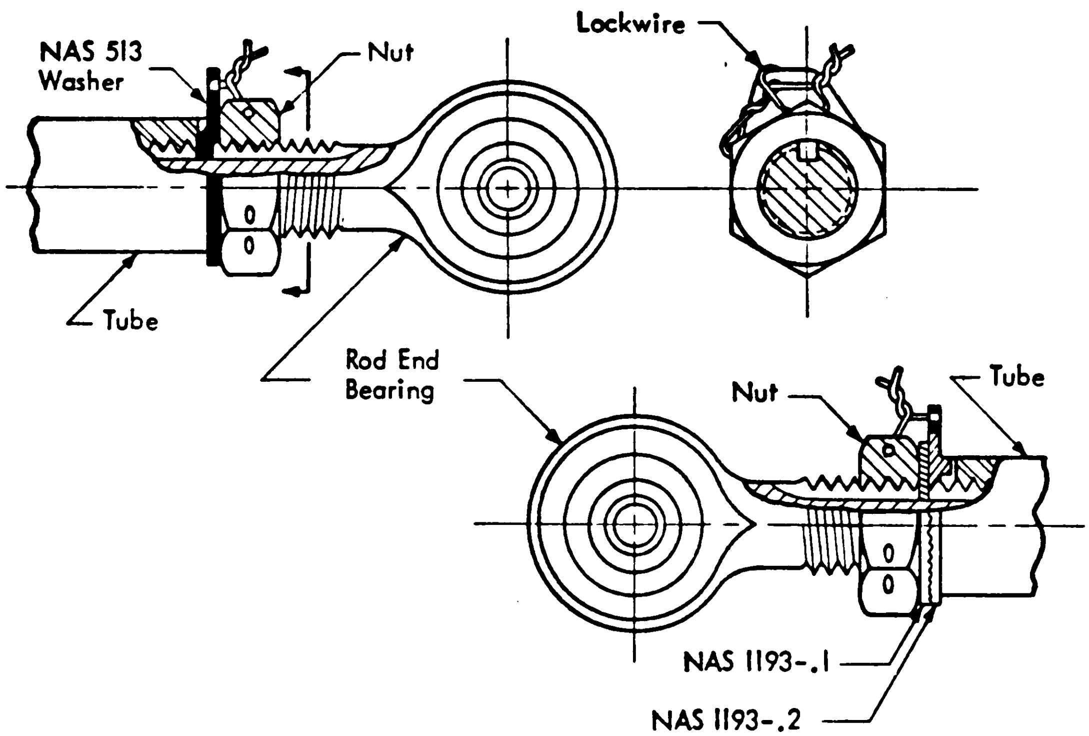


FIGURE 207-5. Adjustable end safetying.

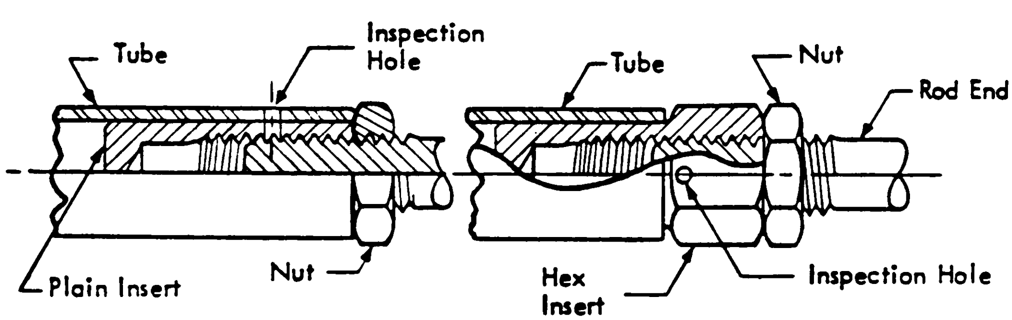


FIGURE 207-6. Blind inserts.

7. Intended use or guidance criteria

7.1 Materials

7.1.1 Alluminum, steel or titatnium tubing may be swaged to an appropriate nipple diameter and tapped to receive a threaded rod end. Titanium tubing work hardens badly with rotary swaging and is more responsive to vail swaging. This process loses greater area in reduction and is therefore a poor candidate for control rod manufacture. The wall increase occurring in the taper is least for titanium, somewhat greater for steel and greatest for aluminum. However, all swagings elongate during swaging, universally having less cross sectional area at the nipple than the body. The further setion loss from tapping the nipple requires accuracy in forecasting the appropriate nipple diameter and in the case of aluminum tubes, adds to the desirability of forming threads on the nipple I.D. as compared with cutting threads. Forming threads in steel or titanium tubing is not practical in that these swaged nipples lack ductility for the required thread imprinting. To obtain appropriate section for threading steel or titanium tubes, the unswaged blank may be precontoured or the center section after swaging may be turned off providing the appropriate wall tolerance is maintained.

7.1.2 Steel or titanium tubes for control rod assemblies may be required to support loads in excess of aluminum tubing capability. Abrupt sectional change as well as cut threads are sensitive to fatigue loading. Fatigue capability of these assemblies shall be established and shall be in excess of system requirements.

7.1.3 2024 aluminum tubing is most commonly utilized in manufacturing of control rod assemblies. Some swage reduction is possible in T3 temper, most swaging will require “O” (or annealed) material for swaging with subsequent heat treat to -T42 or -T62 in accordance with MIL-H-6088. The practical limit for reduction in 13 or O temper depends on equipment and technique. Reduction in T3 requires subsequent heat treat to T81. Drawing requirement should define acceptable micro-structure or fold depth in the critical area rather than prescribe manufacturing steps.

7.1.4 Many high strength alloys having desirable characteristics in a finished part are undesirable for swage fabrication. The physical characteristic most necessary to the swaging process is ductility. Materials having less than 10 percent elongation may be a poor candidate for swaging. CRES tube manufactured to MIL-T-6845 has excellent ductility, may be specially drawn to 100 KSI tensile strength and is inexpensive. Where loads or environmental considerations preclude aluminum tube, this CRES tube should be evaluated first.

7.1.5 Heat treatment of rods or rod components of alloy steel or heat treatable CRES shall be heat treated in accordance with MIL-H-6875.

7.2 Loading

7.2.1 An airframe requirement for a control rod assembly presumes assembly column loading in compression as well as tension. Where practicable the load in tension shall be the greatest. Tubes selected to support compression loads

In a system are lightest if selected with large diameter and light wall. The limiting factors may be accommodation in the airframe or the largest diameter economically reducable to effect an attachment to the desired rod end, an aluminum tube 1.375″ O.D. x .035″ wall to be threaded to receive a 3/8-24 rod end will require swaging to a nipple diameter approximately .525 inch. This reduction of slightly more than 60 percent (1 - .525/1.375) approaches the practical limit. Reduction in excess of 50 percent will increase costs disproportionately.

7.3 Drawings/Terminology/Practice

7.3.1 Common terminology applicable to swaged tubs is recommended per figure 207-7.

7.3.2 Swage angle should be limited to close tolerance only if structure or installation dictates.

7.3.3 Effective definition of a swaged tube should define nipple diameter, length, minimum wall allowable swage angle, and concentricity relative to tube body.

7.3.4 Tube cross section area reduction is inherent in the swaging process. The wall increase occurring in the taper coincides with an increase in length. the approximate wall thickness (W_2) remaining in the nipple and available for attachment may be calculated as follows:

$$W_2 = (D_1/D_2)(W_1)(.9)$$

Where D_1 = original tube diameter, D_2 = nipple diameter and W_1 = original wall thickness.

7.3.5 Where an integral clevis or threaded nipple is required to have greater material thickness or cross section than the tube body, manufacture should be allowed from larger diameter and heavier wall tube at supplier option. As illustrated in figure 207-8, the integral formed clevis tube is traced turned to the dimensions shown from 1.375 O.D. x .188 wall stock size. The clevis end is then formed from the original material size to meet the .178/.183 clevis ear thickness requirement, The threaded nipple can be either mandrel swaged, turned and swaged, or swaged and turned to obtain the material thickness at the threaded end(s). When the detail drawing indicates "Tube Body" as shown, tolerances per FED-STD-245 will be maintained.

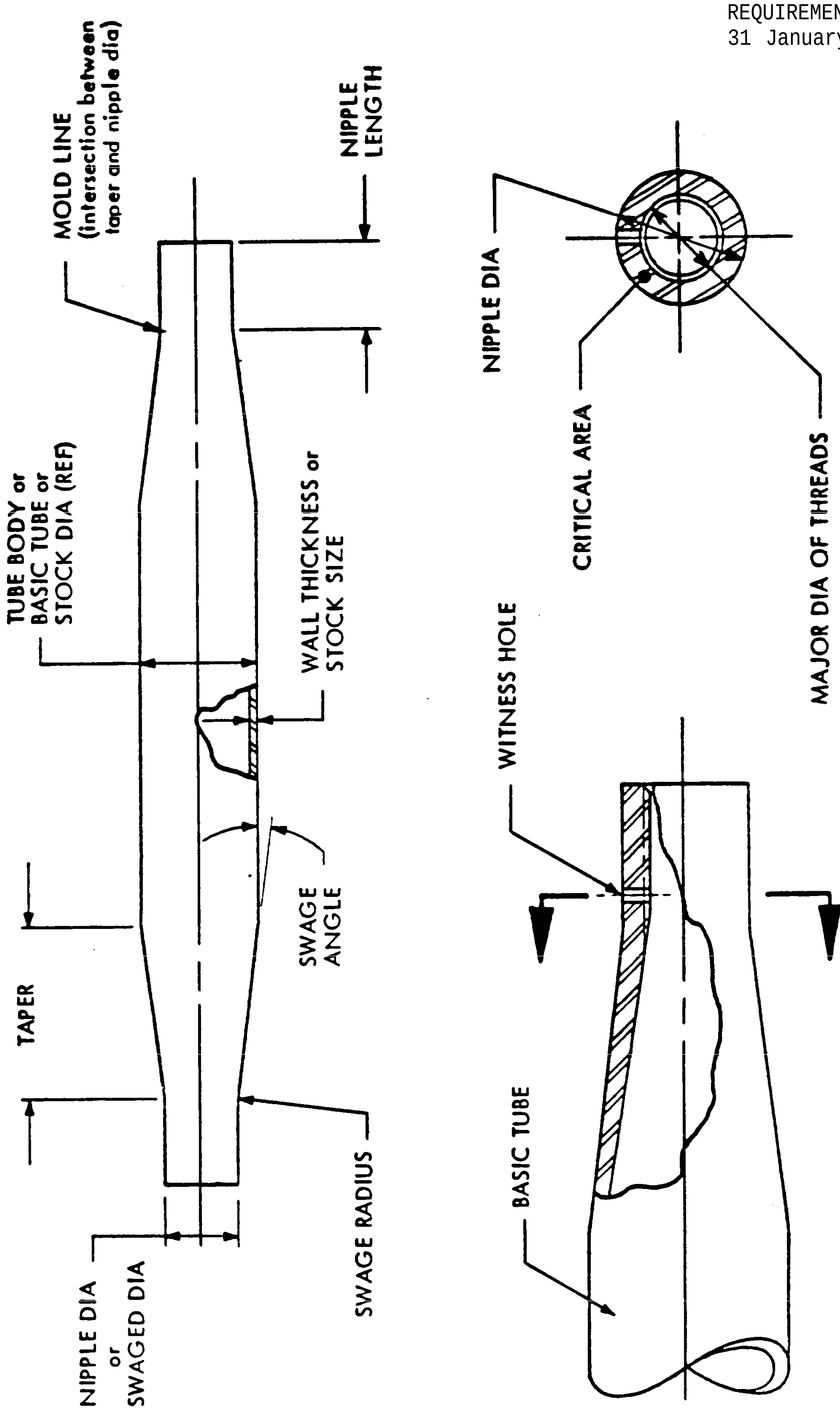
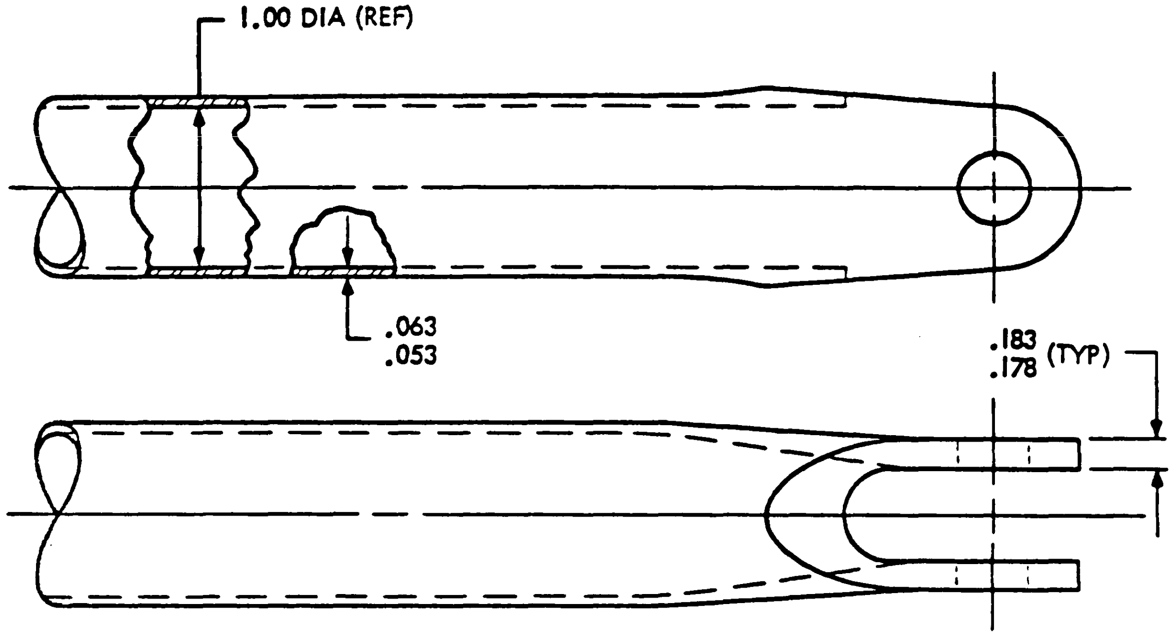
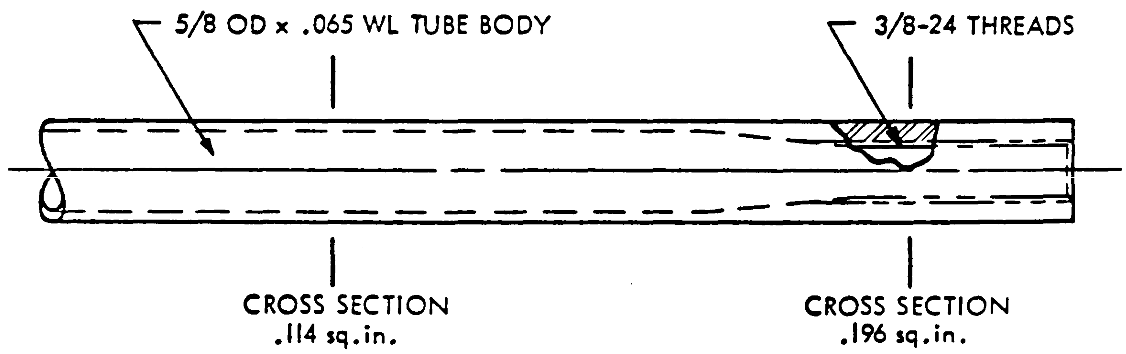


FIGURE 207-7. Common terminology.



INTEGRAL FORMED CLEVIS
Manufactured from 1-3/8 OD x .188 WL Aluminum Tube



THREADED NIPPLE
Example of Manufacture from 3/4 OD x .125 WL Aluminum Tube

FIGURE 207-8. Integral formed clevis and threaded nipple.

ANTI-FRICTION BEARINGS, NEEDLES, INCLUDING TRACK ROLLERS

1. Scope. This requirement establishes engineering criteria and requirements for the selection and application of needle bearings and track rollers for aerospace systems.

2. Documents applicable to requirement 303

MS17131	Bearing, Roller, Needle, Thin Outer Race, Without Inner Race, Open End and Closed End
MS17136	Race, Beaning, Inner, Carbon Steel, Needle Roller Bearings
MS21432	Bearing, Roller, Needle, Track Roller, Integral Stud, Type 7, Anti-Friction, Inch
MS24461	Bearing, Roller, Needle, Single Row, Heavy Duty, Type 1, Anti-Friction, inch
MS24462	Bearing, Roller, Needle, Single Row, Thin Shell, Type 2, Anti-Friction
MS24463	Bearing, Roller, Needle, Single Row, Heavy Duty, Self Aligning, Type 3, Anti-Friction, Inch
MS24464	Bearing, Roller, Needle, Double Row, Heavy Duty, Self Aligning, Type 4, Anti-Friction, Inch
MS24465	Bearing, Roller, Needle, Single Row, Heavy Duty, Track Roller, Type 5, Anti-Friction, Inch
MS24466	Bearing, Roller, Needle, Double Row, Heavy Duty, Track Roller, Type 6, Anti-Friction, Inch
MS51961	Beaning, Roller, Needle: Thick Outer Ring with Rollers and Cage
MS51962	Ring, Bearing Inner: For Needle Roller Bearings with Thick Outer Ring

3. Requirements

3.1 General. Needle bearings and track rollers are used throughout airframe applications in a variety of different modes of operation. Their application and mounting is somewhat more critical than other anti-friction bearings. For detailed instructions on the application and mounting of needle bearings and track rollers, refer to requirement 201, MIL-STD-1599, covering bearing usage.

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AIRFRAME BEARINGS, SPHERICAL, ALL-METAL

1. Scope

1.1 This requirement defines the characteristics and application of metal-to-metal plain spherical bearings and lists the approved bearings in this category.

1.2 Application. All-metal plain spherical bearings are used in applications where the ratio of static load to dynamic load is high. That is, bearing loads are relatively low during movement between the ball and the outer ring and relatively high when there is no motion between the ball and the outer ring. They are also used in areas where the service imposes impact loading and in areas where the bearings is lightly loaded. All-metal plain spherical bearings are used in applications where environmental conditions and/or application requirements exceed the capabilities of lined spherical bearings. (see requirement 307). Where all-metal plain spherical bearings are used, provisions for relubrication are normally required to prevent, or minimize, fretting and galling.

1.3 Classification. All-metal plain spherical bearings are classed according to the materials used, the lubrication features, and the retention features.

1.3.1 Materials. The available all-metal plain spherical bearing material combinations are defined in the referenced military standards and include bearings with a steel ball and steel outer ring, with a steel ball and aluminum bronze outer ring, and with a beryllium copper ball and stainless steel outer ring.

1.3.2 Lubricating features. All-metal plain spherical bearings are available with two types of lubrication features. The standard type (no type code included in part number) incorporates a lubrication groove in the ball bore with three lubrication channels from the ball bore to the ball OD, This type also includes lubrication grooves in the outer ring OD and ID, with three lubrication channels from the outer ring ID to the outer ring OD. The standard lubrication feature is available for all material combinations. The beryllium copper ball and stainless steel outer ring combination has an optional lubrications feature. When the letter "R" is included in the part number, the lubrication groove and channels are eliminated from the ball component and are present in the outer ring only. ("R" means "outer ring only.")

1.3.3 Retention features, Two styles of all-metal plain spherical bearings are available as defined on the referenced military standards. These standards include a style which incorporates a retention groove machined into the outer ring faces for staking of the bearings into a chamfered housing and a style with a chamfered outer ring OD to be used where the retention device is included in, or is a part of the housing, Requirement 202 of this military standard describes specific bearing retention techniques in detail.

2. Documents applicable to requirement 306

MIL-B-8976	Bearings, Plain, Self-Aligning, All-Metal
MIL-G-81322	Grease, Aircraft, General Purpose, Wide Temperature Range (paragraph 4.6.2)
MIL-B-81936/l	Bearings, Plain, Self-Aligning, -65°F to +350°F
MIL-B-81936/2	Bearings, Plain, Self-Aligning, BeCu Ball, Cres Race, -65°F to +350°F
MS21154	Bearings, Plain, Self-Aligning, Grooved Outer Ring, -65°F to +350°F
MS21155	Bearings, Plain, Self-Aligning, -65°F to +350°F
ANSI B46.1	Surface Texture, Surface Roughness, Waviness and Lay

3. General. An all-metal plain spherical bearing is a machine element allowing a load to be transmitted from one structural member into another. At the same time, the bearing permits relative movement between the two structural members while preventing separation and minimizing mechanical damage or wear. A plain spherical bearing permits rotational movement about its bore axis and misalignment rotation about the two remaining axes. Where the ball ID and OD are lubricated, and the ball is not positively locked to the pin, rotational motion (oscillation) will occur between the pin OD and the ball ID and misaligning motion will occur between the ball OD and outer ring ID.

4. Design requirements

4.1 Qualification. Pearings specified in paragraph 2.2 shall be used in design and shall be procured from qualified manufacturers as required by procurement specifications.

4.2 Materials. The materials are listed on the applicable standard.

4.3 Design. Bearing design conforms to that specified on the applicable military standard or drawing.

4.4 Dimensions and tolerances. Dimensions and tolerances are specified on the applicable military standard or drawing. Dimensions not shown shall be at the option of the manufacturer.

4.5 Surface texture. Surface texture is in accordance with the applicable military standard or drawing. Surface texture shall be measured in accordance with ANSI B46.1.

4.6 Lubrication and temperature

4.6.1 All plain spherical bearings require some form of lubrication to reduce friction within the bearing and to minimize metallurgical bonding (welding) between the bearing components. The bearings described by the referenced military standards are designed to facilitate grease lubrication and, as such, will be suitable for operation within the temperature range from -65°F (-54°C) to +350°F (+177°C).

4.6.2 For preservation purposes, the bearings are shipped lubricated in accordance with the applicable military standard or drawing. Where no lubrication is specified, the bearing will be shipped packed in MIL-G-81322. The date (month, year) of lubrication shall be marked on each bearing package.

4.7 Hardness. The component hardness is as specified on the applicable military standard or drawing.

5. Performance

5.1 Static load ratings. Static loads are loads which are imposed on plain spherical bearing while there is no relative motion between the bearing components.

5.1.1 Static radial limit load. The static radial limit load is the maximum load which can be applied to the bearing and housing in direction A, (see figure 1) with a limited amount of permanent set as defined in the applicable specification .

5.1.2 Static radial ultimate load. The static radial ultimate load is 1.5 times the static radial limit load. After application of the static radial ultimate load, there may be significant permanent deformation of the bearing components . There shall not, however, be any cracked or broken components.

5.1.3 Static axial limit load. The static axial limit load is the maximum load that can be applied to the bearing and housing in direction B or C (see figure 1) with a limited amount of permanent set as defined in the applicable specification .

5.1.4 Static axial ultimate load. The static axial ultimate load is 1.5 times the static axial limit load. After application of the static axial ultimate load, there may be significant permanent deformation of the bearing components. There shall not, however, be any cracked or broken components.

5.2 Dynamic (oscillating) load ratings. Dynamic loads are loads which are imposed on a plain, spherical bearing while there is relative motion between the the bearing components. Dynamic load ratings as specified on the military standards are qualification loads used to develop comparative data for bearing performance, These bearings can be operated dynamically at loads up to the specified limit loads; however, the amount of wear developed will be affected by the magnitude of the load and the oscillation angle. When operated dynamically, all-metal bearings should periodically experience reverse loading so that the lubricant is redistributed to the load zone to minimize wear.

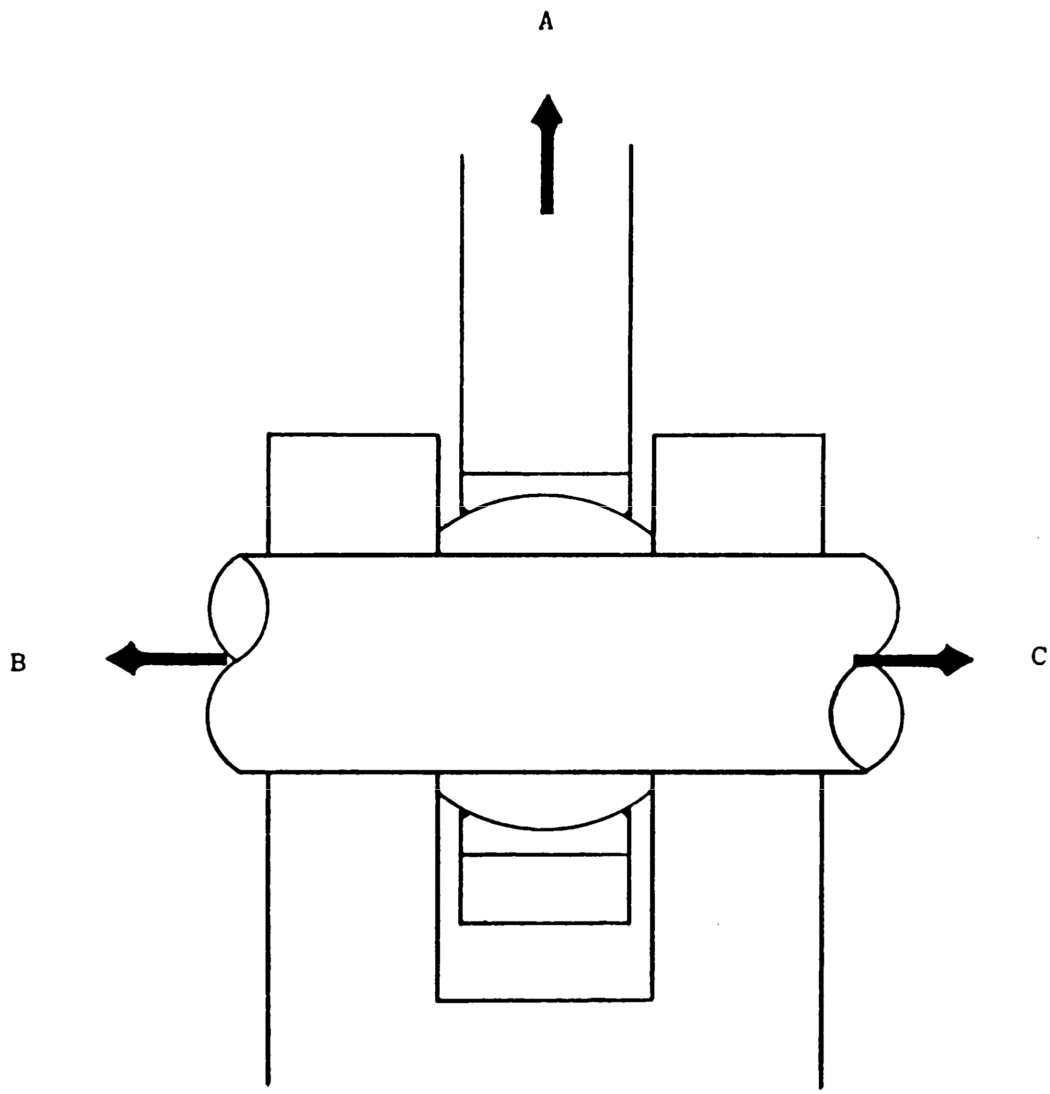

FIGURE 1. Static load ratings.

AIRFRAME BEARINGS, SPHERICAL, LINED

1. Scope

1.1 This requirement defines the characteristics and application of lined, plain, spherical bearings and lists the approved bearings in this category.

1.2 Application. Lined, plain, spherical bearings are used in applications where it is necessary for the bearing to function without requiring relubrication. The liner in the bearing provides a permanent source of low friction lubricant and the bearings do not require relubrication throughout their service life. The application of lined, plain, spherical bearings shall be limited to areas where the ambient temperature does not exceed the range from -65°F to +325°F. In addition, lined, plain, spherical bearings are not recommended in applications where the service imposes severe impact loading or continuous long-term high speed full rotation.

1.3 Classification. Lined, plain, spherical bearings are classed according to the race width. MS14101 and MS14104 define narrow series lined, plain, spherical bearings, MS14102 and MS14103 define wide series lined, plain, spherical bearings,

1.3.1 Materials. Lined, plain, spherical bearings as defined by the applicable MS Standards are supplied with an outer ring fabricated from 17-4 PH stainless steel per AMS 5643. The standard (no identifier in part number) lined, plain, spherical bearings as defined by the MS Standards include a ball fabricated from 440C stainless steel. Where improved corrosion resistance is required, the MS bearings can be supplied with a PH 13-8Mo stainless steel ball. This option is obtained by including the code letter "C" in the Part number. These bearings include self-lubricating liners to reduce friction within the bearing and do not require relubrication through their service life. As this self-lubricating liner is expended, an increase in radial play will be noticed.

1.3.2 Type. Two types of lined, plain, spherical bearings are available, Type I lined, plain, spherical bearings include a fabric or filament-wound liner of uniform thickness which is bonded to the ID of the outer ring. Type II lined, plain, spherical bearings incorporate a molded composition liner.

1.3.3 Retention features. Two styles of lined, plain, spherical bearings are available as defined on the applicable military standards. These standards include a style which incorporates a retention groove machined into the outer ring faces for staking of the bearing into a chamfered housing, and a style with a chamfered outer ring OD to be used where the retention device is included in, or is part of the housing. Requirement 202 of this military standard describes specific bearing retention techniques in detail.

2. Documents applicable to requirement 307

MIL-B-81819	Bearings, Plain, Self-Lubricating, Self-Lubricating, High-Speed Oscillation
MIL-B-81820	Bearings, Plain, Self-Aliqning, Self-Aligning, Low-Speed Oscillation
MS14101	Bearing, Plain, Self-Lubricating, Self-Aligning, Low-Speed, Narrow, Grooved Outer Ring, -65°F to +325°F

MS14102	Bearing, Plain, Self-Lubricating, Self-Aligning, Low-Speed, Wide, Chamfered Outer Ring, -67°F to +325°F
MS14103	Bearing, Plain, Self-Lubricating, Self-Aligning, Low-Speed, Wide, Grooved Outer Ring, -65°F to +325°F
MS14104	Bearing, Plain, Self-Lubricating, Self-Aligning, Low-Speed, Narrow, Chamfered Outer Ring, -65°F to +325°F
AMS 5643	Steel Bearings, Forgings, Tubing and Rings, Corrosion Resistant 16Cr-4.0Ni-0.30 (Cb-Ta)-4.0Cu (paragraph 1.3.1)
ANSI B46.1	Surface Texture, Surface Roughness, Waviness and Lay

3. General. A plain, spherical bearing is a machine element allowing a load to be transmitted from one structural member into another. At the same time, the bearing permits relative movement between the two structural members while preventing separation and minimizing mechanical damage or wear. A plain, spherical bearing permits rotational movement about its bore axis and misalignment rotation about the two remaining axes.

4. Design requirements

4.1 Qualification. MS14101 through MS14104 bearings shall be used in design and shall be procured from qualified manufacturers as required by procurement specifications.

4.2 Materials. The material is as listed on the applicable standard,

4.3 Design. Bearing design conforms to that specified on the applicable military standard or drawing.

4.4 Dimensions and tolerances. Dimensions and tolerances are as specified on the applicable military standard or drawing. Dimensions not shown shall be at the option of the manufacturer.

4.5 Surface texture. Surface texture is in accordance with the applicable military standards or drawing. Surface texture shall be measured in accordance with ANSI B46-1.

4.6 Lubrication and temperature. Lined, plain, spherical bearings are permanently lubricated by a low-friction liner included between the outer race and ball. These bearings do not require relubrication. They are suitable for operation in the temperature range from -65°F to +325°F.

4.7 Hardness. The component hardness is as specified on the applicable military standard or drawing.

5. Performance

5.1 Static load ratings. Static loads are loads which are imposed on a plain, spherical bearing while there is no relative motion between the bearing components,

5.1.1 Static radial limit load. The static radial limit load is the maximum load which can be applied to the bearing and housing in direction A (see requirement 306, figure 306-1) with a limited amount of permanent set as defined in the applicable specification.

5.1.2 Static radial ultimate load. The static radial ultimate load is 1.5 times the static radial limit load. After application of the static radial ultimate load, there may be significant, permanent deformation of the bearing components. There shall not, however, be any cracked or broken components.

5.1.3 Static axial limit load The static axial limit load is the maximum load that can be applied to the bearing and housing in direction B or C (see requirement 306, figure 306-1), with a limited amount of permanent set as defined in the applicable specification.

5.1.4 Static axial ultimate load The static axial ultimate load is 1.5 times the static axial limit load. After application of this load, there may be significant permanent deformation of the bearing components. There shall not, however, be any cracked or broken components.

5.2 Dynamic (oscillating) load ratings. The dynamic load is a load applied to the bearing (generally a radial load) while the bearing is functioning. During dynamic loading, the self-lubricating liner in the bearing will sustain wear as it provides lubrication.

5.2.1 MIL-B-81820 and MS14101, MS 14102, MS14103, and MS14104 define oscillating loads (or dynamic loads) for those airframe bearings shown on the MS sheets. These dynamic loads are defined for test purposes only. Standard dynamic wear tests are included in MIL-B-81820 which define the test conditions for these qualification tests. The bearings can, however, be operated at other loads than those defined as “oscillating load” and up to the “radial limit load” . Under the standard test conditions in MIl-P-81820, with no contamination, the bearing must not develop more than .0045 liner wear after 25,000 cycles. Higher loads will result in more wear as will the presence of contamination .

5.2.2 MIL-B-81819 includes four (4) sets of wear test conditions for typical helicopter rotor head applications. These test requirements are not for qualification purposes, but are to be used to compare the performance of potential liner systems.

5.2.2.1 Because of the wide variety of operating conditions, it has not been possible to standardize helicopter rotor head bearings. The four (4) sets of test conditions in MIL-B-81819 have been selected to blanket the total range of expected applications and one (1) of those conditions should closely approximate the actual requirements for any helicopter. Ideally, when a designer begins defining his rotor head applications, he can select that test condition which most closely approximates his bearing size and operational requirements . Data for that test condition from several bearing manufacturers will be available at the Naval Air Development Center. Upon request, he will receive and can select the best candidate liners for his requirements. Additional qualification testing may be required to his specific conditions.

5.2.2.2 As with the airframe bearings, increased loads and the presence of contaminating environments will reduce the wear life of helicopter rotor head bearings.

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CONTROL CABLE ASSEMBLY COMPONENTS

1. Scope. This requirement establishes the approved terminals (fittings), turnbuckles, turnbuckle fittings and other components used directly with mechanical control cables or attached to control cables.

2. Documents applicable to requirement 601

MIL-T-781	Terminal, Wire Rope, Swaging
MIL-C-5688	Cable Assemblies: Aircraft, Proof Testing and Restretching of
MIL-T-6117	Terminal-Cable Assemblies, Swaged Type
MIL-T-8878	Turnbuckles, Positive Locking
MIL-C-16173	Corrosion-Preventive Compound Solvent Cutback, Cola Application
MIL-C-83420	Wire Rope, Flexible, For Aircraft Control
AN 100	Thimble, Wire Cable
MIL-STD-143	Standards and Specifications, Order of Preference For the Selection Of
MS20658	Terminal, Wire Rope, Swaging, Fork End
MS20663	Ball End, Wire Rope, Swaging, Double Shank
MS20664	Ball End, Wire Rope, Swaging, Single Shank
MS20667	Terminal, Wire Rope, Swaging, Fork End
MS20668	Terminal, Wire Rope, Swaging, Eye End
MS21251	Turnbuckle Body, Clip Locking
MS21252	Clevis End, Turnbuckle, Clip Locking
MS21253	Clevis End, Turnbuckle, Clip Locking (For Bearing)
MS21254	Eye End, Turnbuckle, Clip Locking (For Pin)
MS21255	Eye End, Turnbuckle, Clip Locing (For Wire Rope)
MS21256	Clip, Locking, Turnbuckle
MS21259	Terminal, Wire Rope, Stud
MS21260	Terminal, Wire Rope, Stud
MS51844	Sleeve, Swaging Wire Rope
NAS 287	Terminal, Chain-to-Cable (For Swaging)
NAS 1435	Terminal; Strap, Cable (Eye End and Fork End)

3. Control cable attachments and terminal connections

3.1 Control cable. Control cable shall meet the requirements of MIL-W-83420 as noted in requirement 206.

3.2 General requirements

3.2.1 Primary, secondary control systems, auxiliary cable system. These items are defined in paragraph 3 Definitions, of the basic MIL-STD-1599.

3.2.2 Terminal types. Terminal types, as used herein, are used to differentiate between swaged or crimped type terminals which may be used in primary, secondary controls and auxiliary cable systems. Types I and III are approved for all systems, type II is approved secondary controls systems and auxiliary cable systems, type IV is approved only auxiliary cable systems for items removed from aircraft before flight.

3.2.3 Terminal attachment to cable. All terminals (fittings) attached directly to cable shall be by the swaging method for all systems except the attachment of lanyards or similar systems removed from aircraft before flight. The latter may be crimped type.

3.2.4 Approved parts. All parts listed in paragraph 2 are approved within the usage criteria specified herein. Use of these parts does not require submittal of approval requests per requirement 101.

3.3 Terminal (fittings), swaged, not threaded

3.3.1 Eve and fork tvpe (type I)

3.3.1.1 Material and configuration. The material, configuration, and quality shall conform to MIL-T-781 and MS20658, MS20667, or MS20668.

3.3.1.2 Usage and attachment. Attachment to the cable shall be by swaging in accordance with MIL-T-6117. These fittings shall not be swaged over the cladding of Lockclad.

3.3.1.3 Strength. When gripped by a pin through the eye or fork bores, cable assemblies qust withstand the ultimate tensile strength of the cable. All. requirements of MIL-T-781, MIL-C-5688, and MIL-T-6117 must be q et.

3.3.1.4 Safetying. With respect to the swaged terminal attachment to the cable, no further safetying is necessary or permitted.

3.3.2 Single and double shank ball ends (type I for ball. type II with NAS 1435 strap)

3.3.2.1 Material and configuration The material, configuration, and quality shall conform to MIL-T-781 and MS20663 or MS20664.

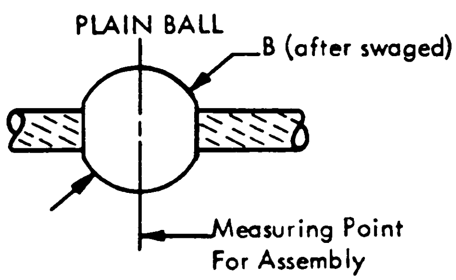
3.3.2.2 Usage and attachment. Attachment to the cable shall be by swaging in accordance with MIL-T-6117. These fittings shall not be swaged over the cladding of Lockclad. These fittings may be used with NAS 1435 straps terminal on secondary control or auxiliary cable assemblies. These ball ends may be installed into a slot of a component and retained by the configuration of the slot or by a clevis pin and cotter pin or bolt and nut. The slot shall provide that sufficient contact between ball and housing is made to carry ultimate design load. The retaining pin shall carry no operating load. It is for the purpose of retention in the slot only.

3.3.2.3 Strength. Cable assemblies with MS20663 or MS20664, with or without the NAS 1435 strap, shall withstand the minimum breaking strength of the cable. All requirements of MIL-T-781, MIL-C-5688, and MIL-T-6117 shall be met.

3.3.2.4 Safetying. With respect to the swaged ball end or NAS 1435 strap, no further safetying is necessary or permitted.

3.3.3 Swaged ball, no shank (type I except as noted in 3.3.3.2)

3.3.3.1 Dimensions and configuration. The dimensions and configuration shall conform to figure 601-1 and table 601-1. halls meeting the dimensional and other requirements herein may be identified by airframe manufacturer or vendor part numbers and considered approved.



Material: Same as MIL-T-781 for swaged terminals

FIGURE 601-1. Configuration of swaged ball no shank.

TABLE 601-1. Dimensions of swaged ball. no shank.

Cable Diameter, inch	B*
1/16	.19
3/32	.25
1/8	.31
5/32	.38
3/16	.44
7/32	.50
1/4	.57
9/32	.63
5/16	.69
3/8	.81

*See figure 601-1.

3.3.3.2 Usage and attachment. The swaged ball shall not be used as a terminal end on a cable used in the primary or secondary control system. It may be used on primary or secondary control cables if swaged at some point between the terminals for purposes of actuating a limit switch, signal device, or similar application. It shall not be permitted to carry structural loads. The ball is attached to the cable by the swaging method.

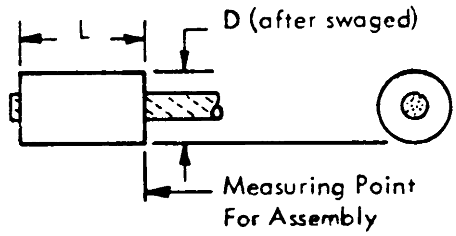
3.3.3.3 Strength. The ball shall hold no more than 60 percent (with the exception of the 3/64-inch size, or smaller, which is 46 percent) of the minimum breaking strength of the cable but shall not be used in a design requiring its retention to be more than 40 percent (30 percent for 3/64-inch size or smaller) of the cable strength under any condition of functioning. The ball shall be proof loaded to 40 percent (30 percent for 3/64-inch size or smaller) of the cable strength for 100 percent of assemblies. The ball shall not slip or deform at this load.

3.3.3.4 Safetying. With respect to the swaged ball attached to the cable, no further safetying is necessary or permitted.

3.3.4 Swaged plug (type II).

3.3.4.1 Dimensions and configuration. The dimensions and configuration shall conform to figure 601-2 and table 601-II. Plugs meeting the dimensional and other requirements herein may be identified by airframe manufacturer or vendor part numbers and considered approved.

SHORT PLUG



Material: Same as MIL-T-781 for swaged terminals

FIGURE 601-2. Configuration of swaged plug

Table 601-II. Dimensions of swaged plug.

Cable Diameter, inch	L*	D*
1/16	.38	.25
3/32	.50	.31
1/8	.63	.38
5/32	.69	.44
3/16	.75	.50
7/32	.88	.56
1/4	1.00	.63
9/32	1.13	.69
5/16	1.25	.75
3/8	1.56	.81

*See figure 601-2.

3.3.4.2 Usage and attachment. The swaged cylinder may be used for the same applications as the swaged ball, no shank, and if thus used, must meet all the requirements of paragraph 3.3.3.2. It may also be used as an end terminal on cables in auxiliary systems only, such as paratroop static lines. It shall not be used as an end terminal on primary or secondary control cables. The plug is attached to the cable by swaging.

3.3.4.3 Strength. The swaged plug shall be capable of withstanding the minimum breaking strength of the cable and must meet the requirements of MIL-C-5688 and MIL-T-6117.

3.3.4.4 Safetying. With respect to the swaged plug attached to the cable, no further safetying is necessary or permitted.

5.3.5 Swaged terminal, cable to roller chain (typeI)

3.3.5.1 Material and configuration. The material and configuration shall conform to NAS 287.

3.3.5.2 Attachment to cable. Attachment to the cable shall be by swaging in accordance with MIL-T-6117.

3.3.5.3 Strength. Cable assemblies with NAS 287 terminals must withstand the ultimate breaking strength of the cable. All requirements of MIL-T-781, MIL- C-5688, and MIL-T-6117 shall be met.

3.3.5.4 Safetying. With respect to the swaged terminal, no further safetying is necessary or permitted.

3.3.6 Swaged terminals for lockclad cable assemblies (type III)

3.3.6.1 Material and configuration. The terminal material shall be of corrosion-resistant ferrous base capable of being swaged per MIL-T-6117. The configuration may be to the requirements of the contractor identified by contractor or terminal manufacturer's part number. Detailed terminals shall be submitted for approval per requirement 101.

3.3.6.2 Attachment. These terminals shall be swaged over the cladding of the lockclad cable. Terminals swaged directly to the cable, even though the assembly includes lockclad, are not covered by this paragraph and shall meet the requirements in the section of this requirement applicable to the specific type terminal used. The end of the terminals covered by this paragraph which are not swaged shall meet the requirements of the applicable section of this requirement regarding connection and safetying. If the connection does not resemble standard connections, the contractor may use his method provided it meets the requirements of paragraph 3.3.6.

3.3.6.3 Strength. Swaged terminals swaged over the cladding shall meet the minimum breaking strength of the base cable over which the cladding is applied both in swaging and structural configuration of the terminal. Lockclad assemblies shall meet the requirements of MIL-C-5688 and MIL-T-6117.

3.3.6.4 Safetying. If the terminal mates with a turnbuckle, it shall be capable of the clip lock safetying method and therefore safetied per the herein approved turnbuckle assembly safetying practice. If the terminal ends in an eye, fork, or stud, safetying shall comply with the requirements for other eyes, forks, or studs covered herein. If other configuration connections are used, the contractor shall furnish a company standard for the safetying procedure *or* define explicit requirements on the appropriate drawings for safetying requirements.

3.4 Terminals (fittings), swaged and threaded

3.4.1 Swaged, thread for use with turnbuckles (type I)

3.4.1.1 Material and configuration. The material, configuration, and quality shall conform to MIL-T-6117 and MS21260.

3.4.1.2 Attachment. Attachment to the cable shall be by swaging in accordance with MIL-T-781. These fittings shall not be swaged over the cladding of clad cable.

3.4.1.3 Strength. When held by the terminal threads, cable assemblies shall withstand the minimum breaking strength of the cable. All requirements of MIL-T-781, MIL-C-5688, and MIL-T-6117 shall be met.

3.4.1.4 Safetying. With respect to the swaged terminal attached to the cable, no further safetying is necessary or permitted. See paragraph 3.8.1, "Turnbuckle assembly", for assembly and safetying of turnbuckle assemblies.

3.4.2 Swaged, threaded shank (type I)

3.4.2.1 Material and configuration. The material, configuration, and quality shall conform to MIL-T-6117 and MS21259.

3.4.2.2 Usage and attachment. Attachment to the cable shall be by swaging in accordance with MIL-T-781. These fitting shall not be swaged over the cladding of clad cable. MS21259 shall not be used with turnbuckles. It may be used for attachment to bell cranks or other components by running through a hole with an approved self-locking nut on the opposite end. MS21259 shall not be threaded into a closed-end tapped hole.

3.4.2.3 Strength. When held by the terminal threads, cable assemblies shall withstand the minimum breaking strength of the cable. All requirements of MIL-T-781, MIL-C-5688, and MIL-T-6117 shall be met.

3.4.2.4 Safetying. With respect to the swaged terminal attached to the cable, no further safetying is necessary or permitted. The self-locking nut shall be safety wired to the component through which the terminal passes in primary or secondary control systems. A cotter pin or any method requiring a hole through the terminal is not permitted. The self-locking nut may be safety wired in auxiliary cable systems at the option of the design activity.

3.5 Turnbuckle assembly components

3.5.1 Turnbuckle barrel (type I)

3.5.1.1 Material and configuration. The material, configuration, and quality shall conform to MIL-T-8878 and MS21251. Steel turnbuckles are not approved for aircraft use.

3.5.1.2 Usage. The MS21251 aluminum and brass turnbuckles are approved for primary controls, secondary controls, and auxiliary cable assemblies. The appropriate size turnbuckle shall be used for the applicable size cable as noted on MS21251.

3.5.1.3 Strength. The MS21251 aluminum and brass turnbuckles shall withstand the minimum breaking strength of the appropriate size cable. Size selection shall be on this basis.

3.5.1.4 Safetying. MS21256 shall be used. See requirement 206.

3.5.2 Eye and fork fittings, threaded (type I)

3.5.2.1 Material and configuration. The material, configuration, and quality shall conform to MS21253, MS21254, MS21255, or MIL-T-8878 and MS21252.

3.5.2.2 Usage. The appropriate size eye or fork shall be used for the applicable size cable as noted on the MS drawings.

3.5.2.3 Strength. These fittings shall withstand the ultimate tensile strength of the appropriate size cable. Size selection will be on this basis.

3.5.2.4 Safetying. See requirement 206.

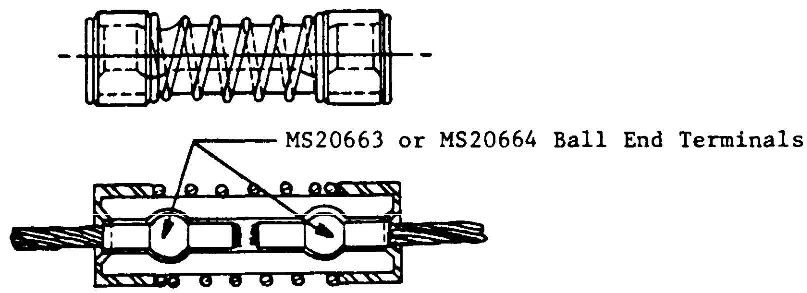


FIGURE 601-3. Ball-end terminal quick disconnect.

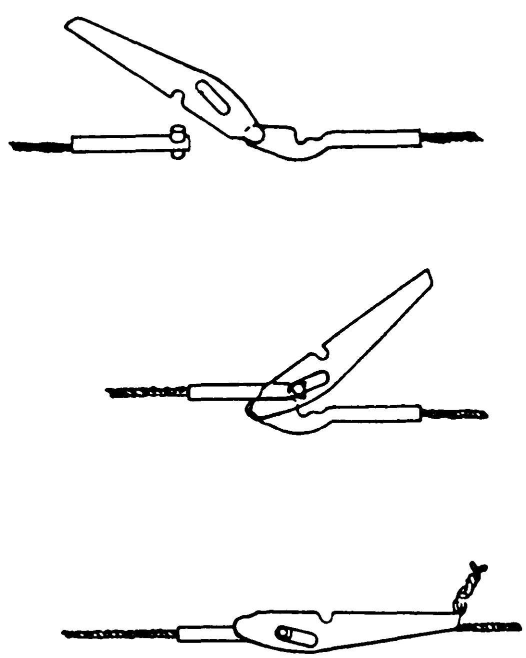


FIGURE 601-4. Turnbuckle type and swage type quick disconnects.

3.6 Quick disconnects

3.6.1 Configuration. The configuration shall conform to figures 601-3 (type II) and 601-4 (type I) and shall conform to vendor products qualifed by aerospace contractors to the requirements and to other applicable considerations.

3.6.2 Usage. See requirement 206, paragraph 3.1.4.5.

3.6.3 Strength. The quick disconnect must be capable of withstanding the minimum breaking strength of the cable.

3.6.4 Safetying. Safetying is not required for ball-end terminal quick disconnect. Use safety wire as shown for the turnbuckle-swaged terminal type in figure 601-4.

3.7 Cable take-up links (type I)

3.7.1 Material and configuration. Cable take-up links shall consist of two side plates of material and thickness in accordance with requirements of this standard with holes drilled in the side plates and shear bolts arid self-locking nuts installed in two of the holes. Company standard or vendor part numbers q ay be used for the link assembly. Shear bolts and nuts shall comply with the requirements of this standard.

3.7.2 Usage and attachment. See requirement 206.

3.7.3 Strength. The thickness of material of side plates and shear strength of bolts shall be sufficient to withstand the minimum breaking strength of the size and material cable assemblies which shall be connected by the link assembly.

3.7.4 Safetying. Safetying, in addition to self-locking fasteners, is at the option of the contractor.

3.8 Connection and safetying of control cable assemblies

3.8.1 Turnbuckle assembly

3.8.1.1 Assembly procedure. See requirement 206.

3.8.1.2 Safetying. See requirement 206.

3.8.2 Eye-to-fork, eye- or fork-to-structure assembly

3.8.2.1 Assembly procedure. Place eye in fork or clevis in structure or place fork over lug in structure and insert self-retaining bolt and install a castellated nut and cotter pin.

3.8.2.2 Safetying. No additional safetying is required for eye-to-eye-fork, eye- or fork-to-structure assembly.

3.8.3 Assembly of two Complete lockclad assemblies

3.8.3.1 Assembly procedure. See paragraph 3.3.6.2.

3.8.3.2 Safetying See paragraph 3.3.6.4.

3.8.4 Quick disconnect. See paragraph 3.6.

3.8.5 Cable take-up links. See paragraph 3.7.

3.9 Auxiliary cable attachments and terminations

3.9.1 Cable. See paragraphs 3.1 through 3.8.

3.9.2 General requirements

3.9.2.1 Usage. All components, methods, and procedures in paragraphs 3.1 through 3.8 may be used for auxiliary cable systems.

3.10 Loop-type components and assembly (type IV)

3.10.1 General requirement. Loop-type connections shall not be used in primary controls, secondary controls, or auxiliary cable systems. They may be used for ball-lock, quick-release pins, streamers, and similar applications.

3.10.2 Crimped sleeve (type IV)

3.10.2.1 Material and configuration. Looping the cable around on AN100 thimble is recommended but not mandatory. The cable shall be looped as required and MS51844 sleeves installed by crimping with a crimping tool.

3.10.2.2 Usage and attachment. Crimped sleeves shall be used only in auxiliary applications, such as streamers for air intake scoops, where failure will not create a safety hazard and parts are removed before flight. Sleeve shall be crimped over double section of cable after looping, utilizing vendor-supplied tools.

3.10.2.3 Strength. The loop sleeve shall be capable of withstanding 80 percent of the minimum breaking of the cable. Note that the AN100 will distort at this load. The requirement of MIL-C-5688 and MIL-T-6117 may be imposed at the option of the design activity. Note that ultimate tensile failure as specified in MIL-T-6117 would be 80 percent of cable strength.

3.10.2.4 Safetying. Safetying of the cable loop, sleeve, or thimble is not required. Safetying of the bolt is at the option of the design activity.

4. Design, selection and approved callout. Only the parts listed in paragraph 2 are approved, except those parts defined within this document which are designed per the details herein and are considered approved regardless of designation by contractor. All other parts required shall be selected in accordance with MIL-STD-143 prior to request for customer approval.

5. Tooling. There are not specific tooling controls required in addition to those necessary to meet the requirements of specifications and standards or delineated herein.

6. Intended use and guidance criteria. All suggestions are covered in applicable areas herein or in requirement 206.

CONTROL RODS

1. Scope. This requirement was established for the purpose of listing approved rod assemblies and components for use in primary, secondary and auxiliary controls systems. However, as of this issue of MIL-STD-1599, there are no standard rods or rod assemblies and a limited number of standards for components available for listing. Rod components listed are limited to safetying devices and rod end bearings. Other items shall be designed in accordance with the requirements specified in requirement 207.

2. Documents applicable to requirement 602

NAS 513	Washer, Rod End Locking
NAS 1193	Locking Device, Positive Index

3. Control rod construction and components

3.1 Approved control rods. assemblies and components

3.1.2 Control rod assemblies. Control rod assemblies shall comply with requirement 207.

3.1.3 Control rod components

3.1.3.1 Rod end bearings. Approved rod end bearings are those listed in requirement 308.

3.1.3.2 Rod safetying devices. Rod end bearings shall be safetied by the use of NAS 513 or NAS 1193 locking devices.

3.1.3.3 All other rod components. All other rod components shall comply with requirement 207.

3.1.4 Rod construction. Rods shall be constructed in accordance with the requirements of requirement 207, insofar as those criteria apply.

3.1.5 Rod assemblies. Rod assemblies shall be configured in accordance with the requirements of requirement 207, insofar as those criteria apply.

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