MILITARY STANDARD

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

TO ALL HOLDERS OF MIL-STD-1599

1. ADD THE FOLLOWING PAGES TO MIL-STD-1599

NEW PAGES	DATE
210.1 thru 210.6	8 June 1988
604.1 thru 604.4	8 June 1988
701-1 thru 701.2	8 June 1988
702.1 thru 702.3	8 June 1988
901.1	8 June 1988
902.1	8 June 1988

2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-STD-1599 will verify that page additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the military standard is completely revised or canceled.

Custodians:
Army - AV
Navy-AS
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Review activities:
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Preparing activity:
Air Force - 11

Project 31GP-0020

AMSC N/A

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UNIVERSAL JOINTS AND COUPLINGS

1. Scope. This requirement establishes criteria and guidance information relative to the selection and use of universal joints and couplings for torsional control driveshafts in aerospace vehicle applications. Criteria includes type descriptions and typical applications, and performance.

2. Documents applicable to Requirement 210.

MIL-U-3963	Universal Joint, Anti-Friction Bearings
MIL-J-6193	Joints, Universal, Plain, Light and Heavy Duty
MS20270	Joint-Universal, Plain, Light Duty
MS20271	Joint-Universal, Plain, Heavy Duty
MS24312	Joint-Universal, Anti-Friction Bearing, Round Hub

3. Appication. Universal joints and couplings may be used in primary and secondary flight controls and other control systems.

3.1 Universal joint usage

3.1.1 Classifications of universal joints. Two general classifications of universal joints are:

a. Cardan (Hooke's) Joint)

b. Constant velocity joint

3.1.1.1 Cardan (Hooke's Joint. The Cardan (Hooke's Joint) is available in two types :

a. Plain bearing

b. Anti-Friction bearing

3.2 Coupling usage. Couplings are used for the transmitting of torque between shafts or associated equipment.

3.2.1 Rigid couplings. Rigid couplings are used when no angular axial misalignment occurs.

3.2.2 Flexible couplings. Flexible couplings are used for small angular misalignment of less than three degrees, although for intermittent low speed applications, the misalignment may be increased.

4. Design requirements

4.1 Design and construction. It is the intention of this' requirement to define universal joints and couplings of such a design that will operate a long period of years with a minimum of servicing. The design and construction shall be the lightest and most compact consistent with the following requirements in their order of importance.

a. Reliability

b. Maintainability

c. Efficiency

4.2 Materials. Materials shall be selected in accordance with Requirement 104.

4.3 Corrosion Protection. Corrosion protection shall be provided in accordance with Requirement 105.

5. Performance. Universal joints and coupling performance is dependent upon the subjected application or usage.

5.1 Universal joint performance

5.1.1 Plain bearing universal joints. Plain bearing universal joints are used where limiting speeds up to 2000 rpm are attained.

5.1.2 Anti-friction bearing universal joints. Anti-friction bearing universal joints are more expensive and weigh more than plain bearing types. These joints shall only be used where high torques or speeds must be transmitted.

5.1.3 Constant velocity joints. Constant velocity joints are larger, weigh more, and cost more than Cardan (Hooke's Joints) type joints; therefore their use shall be limited.

5.1.4 Vibration. The use of a single universal joint is not preferred where the operating speed is high or where a large amount of power is to be transmitted due to non-uniform angular velocity causing undesirable vibrations. A double universal joint assembly or two joints connected by a short shaft shall be used to eliminate the vibration.

5.1.5 Misalignment. The universal joint shall be used when the misalignment exceeds two degrees and does not exceed 30 degrees.

5.1.6 Angle and shaft speed. The suggested maximum universal joint angle for corresponding shaft speeds is listed in table 210-1.

Table 210-I. Angle and shaft speed.

SHAFT SPEED (RPM)	MAXIMUM OPERATING ANGLE (DEGREES)		
	PLAIN BEARING TYPE	PLAIN BEARING TYPE (OIL BATH)	ANTIFRICTION BEARING TYPE
Less than 175	30 (1)	-	-
175-1000	15 (1)	15	15
1000-2000	15 (1)	15	15
2000-3000			12.5
3000-4000			8.5
4000-5000			6.5
Over 5000			5.0

(1) For Intermittent Power Operation or Hand Drive

5.1.7 Torque limitation

5.1.7.1 Plain bearing universal joint. Typical torque limiation for plain bearing universal joints are listed in table 210-II.

5.1.7.2 Anti-friction universal joint. Typical torque limitation for anti-friction universal joints are listed in table 210-III.

5.2 Coupling performance

5.2.1 Rigid couplings. Typical rigid couplings used for torque transmission are listed in table 210-IV.

5.2.2 Flexible couplings. Typical flexible couplings recommended for use in aircraft applications are described in table 210-V.

Table 210-II. Typical torque limitations, plain bearing U-joint.

TYPE	JOINT SIZE	ULTIMATE STATIC TORQUE (IN.-LB.)	HAND DRIVEN LOW RPM (MAX. IN.-LB.)	TORQUE LOAD (MAX.)	HORSE POWER TRANSMITTED (MAX.)
Plain Bearing (Light Duty) MS 20270	3/8	175	-	26	0.07
	1/2	250	130	38	0.11
	5/8	500	250	75	0.21
	3/4	1000	500	150	0.42
	7/8	1750	875	262	0.73
	1	2500	1250	375	1.05
	1-1/4	5000	2500	750	2.08
	1-1/2	7500	3750	1125	3.15
Plain Bearing (Heavy Duty) MS 20271	3/8	200	-	30	0.08
	1/2	600	300	90	0.25
	5/8	1080	540	162	0.45
	3/4	1900	1100	285	0.80
	7/8	3000	1750	450	1.26
	1	4700	2500	705	1.99
	1-1/4	9500	5000	1425	4.00
	1-1/2	14500	7500	2175	6.04

Table 210-III. Typical torque limitations, anti-friction bearing U-joint.

TYPE	JOINT SIZE	ULTIMATE STATIC TORQUE (IN.-LB.)	500 RPM 100,000 REV. (IN.-LB.	1500 RPM 100,000 REV. (IN.-LB.)
Ball Bearing Joints MS 24312	3/4	1500	500	167
	1	3000	1000	333
	1-1/4	7500	1500	500
	1-1/2	11000	2000	667
	1-3/4	15000	2500	833
	2	20000	3000	1000

Table 210-IV. Rigid couplings.

METHODS FOR TORQUE TRANSMISSION	
TYPES	APPLICATIONS
A. Rigid couplings, bolted sleeves, flanges, or keyed bolts.	Transfer of rotational, low torque; no angular or linear displacement.
B. Splines	Transfer of rotational, low torque, small linear displacement, no angular displacement.
C. Serrations	Transfer of rotational, high torque; with no angular displacement with or without small linear displacement.

Table 210-V. Flexible couplings.

Type	Shaft Diameter (in)	Power Transmission Capabilities	Continuous RPM (Max.)	Deflection	Remarks
A. Flexible Member Element	1/2 and larger	Approximately equal to shaft capacity	30,000	± 1 degree per flexible element	Available in wide range of types and sizes for most applications
B. Miniature Flexible Element	up to 5/8	60 in-lbs	30,000	± 1 degree maximum	for use in servo-mechanism and other small devices
C. Bellows Type	3/4 and larger	140 HP	10,000	± 1 degree maximum	–
D. Gear Type	1/2 and larger	Approximately equal to shaft	20,000	± 2 degrees maximum	Not suitable for heavy shock loads

BOLTS, DUAL SAFETYING

1. Scope. This requirement establishes criteria and information relative to the application of self-retaining bolts for dual safetying when used with bearings, control system components, and latch mechanisms as specified in 201, 202, 204, 206, 207, and 211. This requirement parallels Requirement 203 of MIL-STD-1515.

1.1 Classifications. Self-retaining bolts shall be of the following types.

Type I - Positive-locking bolts. Type I bolts are designed to be installed and removed after the retaining element release button is actuated to allow the locking elements to retract into the bolt body (Figure 604-1).

Type II - Impedance-type bolts. Type II bolts are designed to be installed and removed by overcoming the frictional force of the retaining elements (figure 604-2).

2. Documents applicable to Requirements 604.

MIL-B-23964	Bolts, Self-Retaining, Positive-Locking
MIL-B-83050	Bolts, Self-Retaining, Impedance-Type
MIL-STD-1515	Fastener Systems For Aerospace Applications
MS 3369	Bolts, Self-Retaining, Positive-Locking, CRES 90 ksi F_{su}, 63 ksi F Hexagon Slotted Head, 450%
MS 14146	Nut, Self-Locking, Castellated, Hexagon, Counterbored, Captive Washer, 450%
MS 21125	Bolts, Self-Retaining, Positive-Locking, CRES 90 ksi F_{su}, 63 KSI F Pan Heed, 450%
MS 21126	Spacer, Grooved, Self-Retaining Bolt, Aluminum Alloy
MS 21128	Spacer, Grooved, Self-Retaining Bolt, CRES
MS 21130	Bolts, Self-Retaining, Positive-Locking, CRES 90 ksi F_{su}, 63 ksi, F_{su}, 100° Flub Head, 450°F
MS 21224	Nut, Self-Locking, catenated, Hexagon, Counterbored, Captive Washer, 250°F, Non-Metallic Insert
MS 21244	Nut, Castellatd, Hexagon, Counterbored, Captive Washer, 450°F
MS 27576	Bolts, Self-Retaining, Impedance-Type, 95 ksi F_{su}' Hex Head, 450°F
MS 27577	Bolts, Self-Retaining, Impedance-Type, 95 ksi F_{su}, Flush Head, 450°F
MS 33540	Safety Wiring and Cotter Pinning, General Practices For
MS 33602	Bolts, Self-Retaining, Aircraft Reliability and Maintainability, Design and Usage Requirement For

3. Design and-usage limitations. Fasteners in the category established by this requirement shall be subject to the following design and usage limitations.

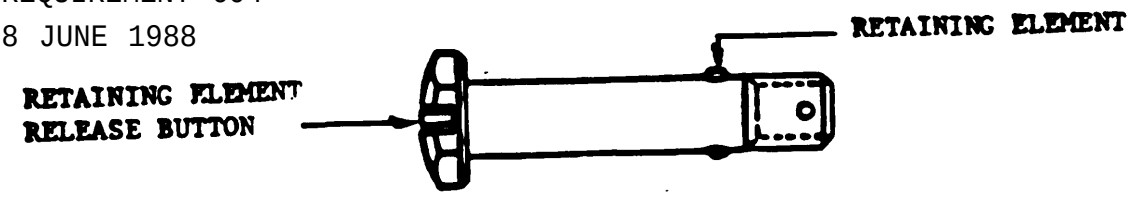


FIGURE 604-1. Positive-locking bolts.

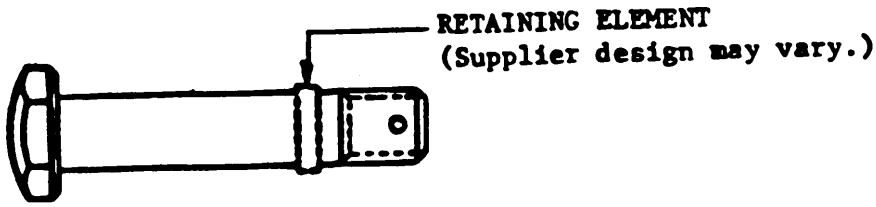
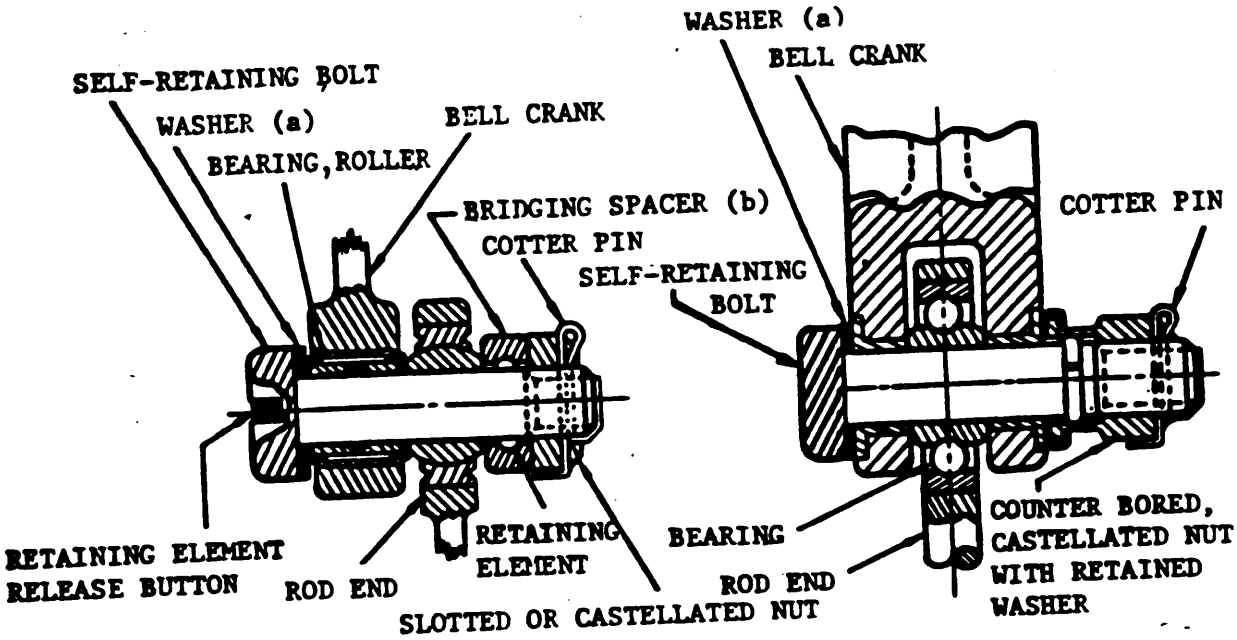


FIGURE 604-2. Impedance-type bolts.



TYPE I (Positive-Locking Type)

TYPE II (Impedance-Type)

(a) Washer selected to take up excess bolt grip length and build up in clearance due to tolerances.

(b) A bridging spacer or a castellated nut with a counterbore or recess for the retaining element may be used (3.2.5).

FIGURE 604-3. Example joints.

3.1 Joint design. The joint shall be designed so that with a self-retaining bolt installed, the joint integrity is not dependent on washers or any other normally removable parts, other than bolts. Maximum of two washers may be used to adjust for tolerance variation and, when required, they shall be used under the head of the bolt, but not under the nut. Bridging spacers may be used on positive-locking bolts only. (Figure 604-3).

3.2 Usage. Self-retaining bolts shall be of any approved type and shall be used in accordance with the following design and usage requirements.

3.2.1 Self-retaining bolts shall be used in control systems where the bolt serves as an axis of rotation and where separation of the linkage will affect safety of flight. These include controls for flight, fuel, engine air induction, and propeller systems.

3.2.2 The bolts shall be additionally locked in position by nonself-locking or self-locking castellated nuts properly secured by cotter pins in accordance with MS33540.

3.2.3 When self-retained bolts that are not identified by an MS part number are used, the retaining element and its locking device shall be a design used on bolts that have qualification approval to MIL-B-23964 for positive locking bolts or MIL-B-83050 for impedance-type bolts.

3.2.4 Self-retaining bolts that have had the retaining element or locking device reworked or reprocessed shall not be used.

3.2.5 Bridging *spacers* shall not be used with impedance-type bolts (Type II). Bridging spacers used with Type I positive-locking bolts shall be selected from MS 21126 or MS21128.

3.2.6 Counterbored castellatd nuts with captive washers shall be selected from MS14146, MS21224, or MS21244.

3.2.7 Impedance-type bolts (Type II) shall not be used in control systems of Navy aircraft.

3.3 Preferred parts. Corrosion-resistant steel parts are preferred over alloy steel parts.

4. Design selection and approved callout. Fasteners in the category established by this requirement shall be selected from and specified by standard part numbers in documents listed in section 2 of this requirement.

5. Intended use and guidance criteria. Table 604-1 is presented as an aid in the selection of self-retaining bolts.

Table 604-I. Selection of self-retaining bolts.

Head Style	Drawing Number	Procurement Specifications	Material	Temperature Limit	Finish	Bolt Types
Hex	MS3369	MIL-B-23964	CRES	450°F	Passivated	Positive Locking
Pan	MS21125	MIL-B-23964	CRES	450°F	Passivated	Positive Locking
Flush	MS21130	MIL-B-23964	CRES	450°F	Passivated	Positive Locking
Hex	MS27576	MIL-B-83050	CRES, STEEL	450°F	Passivated Cadmium Plated	Impedance Type
Flush	MS27577	MIL-B-83050	CRES, STEEL	450°F	Passivated Cadmium Plated	Impedance Type

BEARING SHAFT BOLTS

1. SCOPE. This requirement establishes the criteria for the selection of bolts used as bearing shafts, other than dual safetying bolts (Requirement 604). It also establishes design guidance for special design bearing shaft bolts.

2. Documents applicable to Requirement 701.

MIL-STD-1515 Fastener Systems for Aerospace Applications

3. General

3.1 Standard bolts. Standard bolts shall be selected in accordance with " MIL-STD-1515.

3.2 Dual safetying bolts. Dual safetying bolts shall be selected in accordance with Requirement 604.

4. Design considerations. When bolts are used in conjunction with bearings, the following design criteria shall be considered.

4.1 Thread selections shall be in accordance with Requirement 108.

4.2 Bolts, studs, or screws shall extend through the self-locking nut for a length equivalent of 2 thread pitches. This length includes the chamfer.

4.3 Cadmium Plated bolts shall not be used in contact with titanium or in applications Acre the operating temperatures exceed 450%.

4.4 Silver plated bolts shall not be used in contact with titanium in applications where the operating temperatures exceed 600°F.

4.5 Silver plated bolts shall not be used with silver plated self-locking nuts.

4.6 Where possible and practicable, mating parts (except where flush head bolts are used) shall have similar external wrenching configurations.

4.7 Cadmium plated bolts shall not be used in space vehicle applications.

4.8 Wear life of TFE liners is highly dependent on the hardness and surface finish of the mating part. In applications *where* a bolt is used as the shaft in journal bearings or *bore* line spherical, optimum performance is obtained if the shank is honed, polished, or similarly finished after grinding. Recommended surface finish is RHR 16 maximum.

4.9 Wear life of TFE lined bearings is also dependent on the hardness and galling characteristics of the mating material. PH13-8Mo and chrome plated steel are suitable materials for use against TFE. Cadmium plated steel and bare titanium are not suitable materials for use against TFE. Contact the bearing suppliers concerning other materials and finishes.

4.10 Sharp edges or burrs on a part mating with TFE lined journal bearings may shave or cut the liner during installation, reducing its wear life. Special care shall be exercised to insure selected bolts have threads that are adequately truncated and lead in has smoothly blended or radiused **corners.**

4.11 Where nuts and bearing shaft bolts are used with anti-friction track rollers and needle bearings having retention end washers, the mounting faces of these components shall be held to a maximum of 0.001 inch flatness and 0.001 inch squareness with bolt shank or nut thread. Excessive concavity or out of squareness of these surfaces can cause bearing lock up at assembly.

NUTS

1. Scope. This requirement establishes the approved nuts used with bearing shaft bolts other than safetying and jam nuts specified in Requirement 402. It also establishes design requirements for special design nuts used with bearing shaft bolts including materials, finishes, tolerances, threads, and radii.

2. Documents applicable to Requirement 702

AN 310	Nut , Plain, Castellated, Airframe
AN 315	Nut , Plain, Airframe
AN 316	Nut , Jam, Hexagon
AN 320	Nut , Plain, Castellated, Shear
MS 14144	Nut , Self-Locking, Lightweight, Castellated, 450°F
MS 14145	Nut , Self-Locking, Lightweight, Thin Castellated, 450°F
MS 14146	Nut , Self-Locking, Castellated, Hexagon, Counterbored, Captive Washer, 450°F
MS 17825	Nut, Self-Locking, Castellated, Hexagon, 250°F Non-Metallic Insert
MS 17826	Nut, Self-Locking, Castellated, Hexagon, 250°F, Thin Non-Metallic Insert
MS 21224	Nut, Self-Locking, Castellated, Hexagon, Counterbored, Assembled Washer, 250°F, Non-Metallic Insert (For Self-Retaining Bolts)
MS 21244	Nut, Castellated, Hexagon, Counterbored

3. Design and Usage limitations. Fasteners in the category established by this requirement shall be subject to the following design and usage limitations.

3.1 Thread selection shall be in accordance with Requirement 108.

3.2 Where nuts and bearing shaft bolts are used with anti-friction track rollers and needle bearings having retention end washers, the mounting faces of these components shall be held to a maximum 0.001 inch flatness and 0.001 inch squareness with bolt shank or nut thread. Excessive concavity or out-of-squareness of these surfaces can cause bearing lock-up at assembly.

3.3 Bolts, studs, or screws shall extend through the self-locking nut for a length equivalent of 2 threaded pitches. This length includes the chamfer.

3.4 Self-locking nuts that have been reworked or reprocessed shall not be used.

3.5 Cadmium plated self-locking nuts shall not be used in contact with titanium and titanium alloy bolts, screw or studs or in applications where the operating temperatures exceed 450°F.

3.6 Silver plated self-locking nuts shall not be used in contact with titanium and titanium alloy bolts, screws or studs or in applications where the operating temperatures exceed 600°F.

3.7 Silver plated self-locking nuts shall not be used with silver plated bolts.

4. Design selection and approved callout. Fasteners in the category established by this requirement shall be selected from and specified by applicable documents listed in this requirement.

5. Intended use and guidance criteria. Table 702-1 is presented as an aid in the selection of nuts.

6. General criteria notes

6.1 Ultimate stress classification. The ultimate stress classification (ksi) of nuts listed in Table 702-1 corresponds with the ultimate strength level of the mating externally threaded fastener. The ultimate stress classification of nuts listed is a guide, and generally obtained when tested with bolts having a minimum tensile strength greater than the rated tensile values and details.

6.2 Mating parts. Where possible and practicable, mating parts (except where flush head bolts are used) shall have similar external wrenching configurations.

6.3 Space applications. Cadmium-plated nuts shall not be used in space vehicle components or systems. Nuts that are lubricated with dry film lubricants may be used in space applications provided the lubricant has been approved as meeting the outgassing requirements.

TABLE 702-I. Aid in the selection of nuts.

Nut	Ultimate tensile stress KSI	Drawing Number	Procurement spec	Material	Temperature limitation, °F	Coating or plating
Plain (nonself-locking)	55	AN315	FF-N-836	Aluminum	250	Anodized
	55	AN316	FF-N-836	Steel	450	Cadmium
	110	AN315	FF-N-836	Steel	450	Cadmium
	110	AN315	FF-N-386	CRES	450	Passivated
Plain castellated (Nonself-locking)	29	AN320	FF-N-836	Aluminum	250	Anodized
	55	AN320	FF-N-836	Steel	450	Cadmium
	55	AN320	FF-N-836	CRES	450	Passivated
	55	AN310	FF-N-836	Aluminum	250	Anodized
	110	AN310	FF-N-836	Steel	450	Cadmium
	110	AN310	FF-N-836	CRES	450	Passivated
Plain castellated and counterbored (nonself-locking)	60	MS21244	FF-N-836	Steel	450	Cadmium
	60	MS21244	FF-N-836	A286 CRES	450	Passivated
Castellated (self-locking)	35	MS17826	MIL-N-25027	Steel	250	Cadmium
	60	MS14145	MIL-N-25027	Steel	450	Cadmium
	95	MS17825	MIL-N-25027	Steel	250	Cadmium
	125	MS14144	MIL-N-25027	Steel	450	Cadmium
Castellated and counterbored	60	MS14146	MIL-N-25027	Steel	450	Cadmium
	60	MS21224	MIL-N-25027	Steel	250	Cadmium

UNIVERSAL JOINTS

1. Scope. This requirement establishes the approved universal joints for use in aerospace vehicle applications.

2. Docments applicable to Requirement 901

ML-U-3963	Universal Joint, Anti-Friction Bearings
MIL-J-6193	Joints, Universal, Plain, Light and Heavy Duty
MS 20270	Joint-Universal , Plain, Light Duty
MS 20271	Joint-Universal , Plain, Heavy Duty
MS 24312	Universal Joint, Anti-Friction Bearing, Round Hub

3. Design requirements. Universal joints shall conform to the requirement of MIL-U-3963, MIL-J-6193, MS 20270, MS 20271, and MS 24312.

COUPLINGS

1. Scope. This requirement establishes the approved couplings for use in aerospace vehicle applications.

2. Documents applicable to Requirement 902.

Since there are no approved military listings for couplings, contractor designed couplings shall be identified by the contractor's part number.

3. Design requirements. Couplings shall conform to the design criteria specified in Requirement 210.