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AEROSPACE RECOMMENDED PRACTICE

SAE ARP1281

REV.
B

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ACTUATORS: AIRCRAFT FLIGHT CONTROLS, POWER OPERATED, HYDRAULIC, GENERAL SPECIFICATION FOR

TABLE OF CONTENTS

1.	SCOPE	5
1.1	Purpose	5
1.2	Product Classification	5
1.3	Field of Application	5
2.	REFERENCES	6
2.1	Applicable Documents	6
2.1.1	SAE Publications	6
2.1.2	Military Publications	6
2.1.3	Information References	9
2.2	Definitions	10
3.	TECHNICAL REQUIREMENTS	12
3.1	Abbreviations	12
3.1.1	MTBF	12
3.1.2	EMI	12
3.1.3	Other Abbreviations	12
3.2	Design	12
3.2.1	Hydraulic Control Valves	12
3.2.2	Electrical Components	13
3.2.3	Physical Characteristics	14
3.2.4	Structural Characteristics	14
3.2.5	Design Characteristics	15
3.2.6	Materials	19
3.2.7	Parts	20
3.2.8	Identification and Marking	20
3.2.9	Safety	20
3.2.10	Human Performance/Engineering	21
3.2.11	Bearings	21

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SAE ARP1281 Revision B

TABLE OF CONTENTS (Continued)

3.3	Processes, Construction/Assembly Requirements	22
3.3.1	Processes	22
3.3.2	Construction/Assembly Requirements	22
3.3.3	Workmanship	24
3.4	Performance	24
3.4.1	Performance, Standard Conditions	24
3.4.2	Leakage	26
3.4.3	Reliability	26
3.4.4	Performance, Environmental Conditions	26
3.4.5	Input and Output Limit Loads	27
3.4.6	Load Capability of Dual-Load-Path-Elements	27
3.4.7	Fatigue	27
3.4.8	Operating Life	28
3.5	Installation/Maintenance Requirements	28
3.5.1	Maintainability	28
3.5.2	Contamination	29
3.5.3	Electromagnetic Interference	29
3.5.4	Interchangeability	29
3.6	Documentation	30
3.6.1	Analysis Requirements	30
3.6.2	Reliability Analysis	30
3.6.3	Design Analysis	30
3.6.4	Qualification Analysis	30
3.6.5	Drawings	30
3.6.6	Plastic Model	30
4.	QUALITY ASSURANCE PROVISIONS	30
4.1	General	30
4.2	Test Requirements	31
4.2.1	Optional Procedures	31
4.3	Classification of Tests	31
4.3.1	Acceptance Tests	31
4.3.2	Preproduction Tests	31
4.3.3	Qualification Tests	31
4.4	Test Procedures	31
4.4.1	Acceptance Test	31
4.4.2	Preproduction Test Procedure	32
4.4.3	Qualification Test Procedure	32
4.5	Test Conditions	32
4.5.1	Test Fluid	32
4.5.2	Fluid Temperature	32
4.5.3	Test Fluid Filtration	32
4.5.4	Hydraulic Power Supply	33
4.5.5	Environmental Conditions	33
4.5.6	Test Instruments	33
4.5.7	Test Fixtures	33
4.5.8	Steady-State Tests	33
4.5.9	Mission-Profile Tests	33

SAE ARP1281 Revision B

TABLE OF CONTENTS (Continued)

4.6	Acceptance Test Methods	33
4.6.1	General	33
4.6.2	Examination of Product	34
4.6.3	Operation and External Leakage	34
4.6.4	Chatter	34
4.6.5	Proof Pressure	34
4.6.6	Internal Leakage	34
4.6.7	Supplementary Acceptance Tests	34
4.6.8	Rejection and Retest	35
4.7	Preproduction Test Methods	35
4.7.1	Sampling and Tests	35
4.7.2	Pretest Inspection	35
4.7.3	Acceptance Tests	35
4.7.4	Proof Load	35
4.7.5	Pressure Drop	36
4.7.6	Cylinder Friction	36
4.7.7	Immersion	36
4.7.8	Performance Verification Tests	36
4.7.9	Extreme Temperature Performance	36
4.7.10	Altitude	37
4.7.11	Acceleration	37
4.7.12	Shock	37
4.7.13	Vibration	37
4.7.14	Endurance	37
4.7.15	Burst Pressure	39
4.8	Qualification Test Methods	39
4.8.1	Sampling and Tests	39
4.8.2	Pretest Inspection	39
4.8.3	Acceptance Tests	39
4.8.4	Proof Load	39
4.8.5	Pressure Drop	39
4.8.6	Cylinder Friction	39
4.8.7	Immersion	39
4.8.8	Performance Verification Tests	39
4.8.9	Extreme Temperature Performance	39
4.8.10	Altitude	40
4.8.11	Humidity	40
4.8.12	Fungus	40
4.8.13	Salt Fog	40
4.8.14	Dust	40
4.8.15	Acceleration	40
4.8.16	Shock	40
4.8.17	Vibration	40
4.8.18	Endurance	40
4.8.19	Burst Pressure	40
4.8.20	Reliability Tests	40
4.8.21	Contamination Tests	40
4.8.22	Structural Tests	41
4.8.23	EMI Tests	41

SAE ARP1281 Revision B

TABLE OF CONTENTS (Continued)

4.9	Test Reports, Design Changes, and Approval Data	41
4.9.1	Preproduction and Qualification Test Reports	41
4.9.2	Subsequent Design Changes	41
4.9.3	Qualification Approval of Similar Units	41
4.10	Preproduction and Qualification Test Failures	41
5.	PREPARATION FOR DELIVERY	42
5.1	Preservation and Packaging	42
5.1.1	Cavities	42
5.1.2	Servoactuator Attachment Bearings	42
5.1.3	Piston Rod and Input Linkage	42
5.1.4	Servoactuator	42
5.2	Packing	42
5.2.1	Immediate Use Shipment	42
5.2.2	Domestic Shipment	42
5.2.3	Overseas Shipment	42
5.3	Marking of Shipments	42
APPENDIX A	TECHNICAL NOTES AND COMMENTS	43
FIGURE 1	Dimensions for End Caps and Locknuts	16
TABLE 1	Dynamic Characteristics	25
TABLE 2	Environmental Criteria	27
TABLE 3	Acceptance Tests	35
TABLE 4	Load Cycle Schedule Number of Cycles	38

SAE ARP1281 Revision B

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) establishes the requirements for the design, performance, and tests for hydraulically powered servoactuators for use in aircraft flight control systems.

1.1 Purpose:

This document is to be used as a guide and supplemental specification in preparing a detail specification for a particular servoactuator application.

1.2 Product Classification:

Servoactuators covered by this specification shall be of the following types and classes:

- a. Type I: -65 °F to +160 °F fluid temperature range
- b. Type II: -65 °F to +275 °F fluid temperature range
- c. Type III: -65 °F to +390 °F fluid temperature range
- d. Class A - Power Actuators
- e. Class B - Signal Conversion Actuators
- f. Class C - Power and Signal Conversion Actuator Combination

1.3 Field of Application:

A servoactuator in the flight control system positions an aerodynamic control surface or other force effector to produce forces and moments on the aircraft for stability and control of the vehicle. These servoactuators may be controlled by mechanical, electrical, photonic or fluidic inputs, or combinations thereof, and may be powered by one or more hydraulic systems. The complete actuator assembly may incorporate basic components such as servovalve, input linkage and electrical, optical, and/or mechanical position feedback systems, and redundancy logic in addition to the actuating cylinder. These components are usually designed as an integral package, but in some cases are physically separated. Additional components may also be included and configured integrally or separately such as bypass valves, filters, pressure switches, motor or solenoid operated shutoff valves, thermostatic control valves, hydraulic logic, mechanical locking devices and electrical transducers.

By title this is a general specification and is not intended to be universal for all applications. The original version of this document was intended for military usage, consequently, the requirements still reflect such use. However, the basic requirements of this ARP may and should be applicable to commercial usage as well, providing the appropriate considerations are given, particularly for environmental conditions.

Revision A updated the document and combined it with requirements from a proposed military specification which had not been issued.

SAE ARP1281 Revision B

2. REFERENCES:

The following publications form a part of this specification to the extent specified herein. The latest issue of all SAE Technical Reports shall apply.

2.1 Applicable Documents:

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP219	Procedures and Method for Conducting Test of Hydraulic Components in Contamination Controlled System
ARP490	Electrohydraulic Flow Control Servovalves
ARP598	The Determination of Particulate Contamination in Hydraulic Fluids by the Particle Count Method
ARP926	Design Analysis Procedure for Failure Mode, Effects and Criticality Analysis (FMECA)
ARP1192	Procedure for Calibration and Verification of Liquid Born Particle Counter: Absolute Standard
ARP1383	Impulse Testing of Hydraulic Actuators, Valves, Pressure Containers and Similar Fluid System Components
AIR1916	Aerospace Fluid Power and Control System Glossary
AS4059	Aerospace Cleanliness Classification for Hydraulic Fluids
AMS 2419	Cadmium-Titanium Plating

2.1.2 Military Publications: Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

FF-B-185	Bearings, Roller, Cylindrical, and Bearings Roller, Self-Aligning
QQ-C-320	Chromium Plating (Electrodeposited)
NN-P-530	Plywood, Flat Panel
PPP-B-636	Boxes, Shipping, Fiberboard
PPP-C-843	Cushioning Material, Cellulosic
MIL-P-116	Preservation, Methods of
MIL-B-121	Barrier Material, Grease-Proofed, Water-proofed, Flexible
MIL-B-131	Barrier Material, Water Vaporproof, Flexible
DOD-D-1000	Drawings, Engineering and Associated List
MIL-B-3990	Bearings, Roller, Needle, Airframe, Antifriction, Inch
MIL-C-5015	Connectors, Electrical, Circular Threaded, An Type, General Specification for
MIL-B-5087	Bonding, Electrical, and Lightning Protection, for Aerospace Systems
MIL-C-5501	Caps and Plugs, Protective, Dust and Moisture Seal
MIL-G-5514	Gland Design, Packings, Hydraulic, General Specification for
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft Missile and Ordnance
MIL-B-5687	Bearings, Sleeve, Washers, Thrust Sintered, Metal Powder, Oil-Impregnated, General Specification For

SAE ARP1281 Revision B

2.1.2 (Continued):

MIL-B-6038	Bearings, Ball, Bellcrank, Antifriction, Airframe
MIL-B-6039	Bearing, Double Row, Ball, Sealed Rod End, Antifriction, Self-Aligning
MIL-C-6021	Castings, Classification and Inspection of
MIL-E-6051	Electromagnetic Compatibility Requirements, System
MIL-H-6083	Hydraulic Fluid, Petroleum Base for Preservation and Operation
MIL-I-6868	Inspection Process, Magnetic Particle
MIL-F-7190	Forgings, Steel, Aircraft/Aerospace Equipment and Special Ordnance Applications
MIL-B-7949	Bearing, Ball, Airframe, Antifriction
MIL-M-7969	Motor, Alternating Current, 400-Cycle, 115/200 Volt System, Aircraft, General Specification for
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aerospace Vehicles
MIL-M-8609	Motors, Direct-Current, 28-Volt System Aircraft, Class A and B, General Specification for
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-H-8775	Hydraulic System Components, Aircraft and Missiles, General Specification for
MIL-S-8805	Switches and Switch Assemblies, Sensitive Push (Snap Action), General Specification for
MIL-F-8815	Filter and Filter Elements, Fluid Pressure, Hydraulic, Line, 15 Micron Absolute & 5 Micron Absolute, Type II System, General Specification for
MIL-C-8837	Coating, Cadmium (Vacuum Deposited)
MIL-S-8879	Screw Threads, Controlled Radius Root with Increased Minor Diameter, General Specification for
MIL-B-8976	Bearings, Plain Self-Aligning, All-Metal
MIL-F-9490	Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification for
MIL-Q-9858	Quality Program Requirements
MIL-C-11796	Corrosion Preventive Compound, Petrolatum, Hot Application
MIL-S-13165	Shot Peening of Metal Parts
MIL-A-21180	Aluminum- Alloy Castings, High Strength
MIL-F-22191	Films, Transparent, Flexible, Heat Sealable, for Packing Application
MIL-A-22771	Aluminum Alloy Forgings, Heat Treated
MIL-N-25027	Nut, Self-Locking, 250°F, 450°F, and 800°F
MIL-C-26482	Connector, Electrical (Circular, Miniature, Quick Disconnect, Environment Resisting)/& Suppl 1 Recepticals and Plugs, General Specification for
MIL-V-27162	Valves - Servo Control, Electro-Hydraulic, General Specification for
MIL-H-46170	Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base
MIL-B-83050	Bolt, Self-Retaining, Impedance Type
MIL-F-83142	Forging, Titanium Alloys, For Aircraft and Aerospace Applications

SAE ARP1281 Revision B

2.1.2 (Continued):

MIL-H-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537
MIL-A-83444	Airplane Damage Tolerance Requirements
MIL-P-83461/1	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275°F (135°C) Sizes and Tolerances
MIL-STD-12	Abbreviations for use on Drawings, Specifications, Standards, and in Technical Documents
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-143	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-454	General Requirements for Electronic Standard Equipment
MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for The Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-470	Maintainability Program Requirements (For Systems and Equipments)
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
MIL-STD-794	Parts and Equipment, Procedures for Packaging and Packing of
MIL-STD-810	Environmental Test Methods & Engineering Guidelines
MIL-STD-831	Test Reports, Preparation of
MIL-STD-838	Lubrication of Military Equipment
MIL-STD-866	Grinding of Chrome Plated Steel and Steel Parts Heat Treated to 180,000 PSI or Over
MIL-STD-882	System Safety Program Requirements
MIL-STD-889	Dissimilar Metals
MIL-STD-1472	Human Engineering Design Criteria for Military System, Equipment and Facilities
MIL-STD-1949	Inspection, Magnetic Particle
MIL-STD-6866	Inspection, Penetrant Method of
MIL-STD-45662	Calibration System Requirements
MS 3369	Bolt, Self Retaining, Positive Locking, CRES 90 KSI Fsu, 63 KSI Ftu, Hexagon Slotted Head, 450 Deg F and 650 Deg F
MS 15002	Fittings, Lubrication (Hydraulic) Surface Check, Straight Threads, Steel, Type II
MS 15981	Fastener, Externally Threaded, Self-Locking, Design and Usage Limitations for
MS 20995	Wire, Safety or Lock
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 Assembled Washer, 450°F (for Self Retaining Bolts)
MS 21343	Boss Spacing - Hydraulic Design, Standard for
MS 24391	Plug - Bleeder Tube Precision Type
MS 24665	Pin, Cotter (Split)

SAE ARP1281 Revision B

2.1.2 (Continued):

MS 33540	Safety Wiring and Cotter Pinning, General Practices for
MS 33588	Nuts, Self-Locking, Aircraft
MS 33602	Bolt, Self Retaining, Aircraft Reliability and
	Maintainability Design and Usage Requirements for
MS 33649	Boss Fluid Connection - Internal Straight Thread
AN 814	Plug and Bleeder - Screw Thread
AN 6204	Valve, Hydraulic Bleeder
AN 8514	Wrench - 3/8 Inch Square Drive Adjustable Spanner (.75 to 2
	Inches Dia)
AN 8515	Wrench - 1/2 Inch Square Drive Adjustable Spanner (1.75 to 4
	Inches Dia)
AN 8516	Wrench - 1/2 Inch Square Drive Adjustable Spanner (3.5 to 6
	Inches Dia)
AND 10067	Valve Installation - Hydraulic Bleeder (Standard Dimensions
	for)

Military Handbook MIL-HDBK-5 Metallic Materials and Elements for Aerospace Vehicle Structures

Military Handbook MIL-HDBK-17 Plastics for Flight Vehicles

Air Force Systems Command Design Handbook AFSC DH 1-6 System Safety

Technical Report AFFDL TR-74-116 Background Information and User Guide for MIL-F-9490

2.1.3 Information References: The following publications are provided for information purposes only and are not a required part of this document.

2.1.3.1 SAE Documents:

AIR1916 Aerospace Fluid Power and Control/Actuation System Glossary
 ARP1181 Terminology for Redundant Flight Control Systems
 SAE Technical Report Style Manual

2.1.3.2 Military Publications:

MIL-H-5440 Hydraulic Systems, Aircraft, Types I and II, Design and Installation Requirements for
 MIL-H-8890 Hydraulic Components, Type III (-65°F to Plus 450°F) General Specification for (ASG)
 MIL-H-8891 Hydraulic Systems, Manned Flight Vehicles, Type III Design, Installation and Data Requirements for, General Specification for
 MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes
 MIL-STD-961 Military Specification and Associated Documents Preparation of

SAE ARP1281 Revision B

2.1.3.3 Aerospace Fluid Component Designers:

Handbook RPL-TDR-64-25

2.2 Definitions:

The detail specification shall determine what definition shall be used in case a disagreement arises between those set forth herein and any other source with similar terms or definitions.

SERVOACTUATOR FLIGHT CONTROL: A mechanism capable of producing a controlled output position/motion of an aerodynamic control surface or other force effector in response to a command input.

ACTUATOR, POWER FLIGHT CONTROL: A flight control actuator using fluid or electrical power to drive the controlled output member, usually a ram or rotary shaft.

ACTUATOR, SIGNAL CONVERSION: An actuator capable of converting one or more input signals to a single output which is used to command a power actuator.

SERVOACTUATOR: An actuator that controls the magnitude of position outputs in response to the magnitude of the input signal.

FREQUENCY RESPONSE (BODE PLOT): The complex ratio of the actuation system output to the command input while the input is cycled sinusoidally at a constant amplitude and the frequency is varied. Frequency response is usually presented as a combined plot of normalized amplitude ratio (output to input) magnitude in dB, and of phase angle (output to input) in degrees versus logarithm of frequency (called a Bode Plot).

GAIN CROSSOVER, PHASE MARGIN FREQUENCY: The point on the open loop Bode Plot of the transfer function at which the magnitude crosses over unity, expressed in equation form as $\text{Log}_{10} G(j\omega) = 0$ dB where ω is the oscillation frequency in radians per second, and j is square root of minus one $\sqrt{-1}$. The frequency at gain crossover is called the phase margin frequency.

GAIN MARGIN: A measure of system stability defined as the gain required to raise the open loop amplitude ratio to 0 dB (unity gain) at the frequency corresponding to 180° of phase lag.

PHASE CROSSOVER, GAIN MARGIN FREQUENCY: The point on the open loop Bode Plot of the transfer function at which the phase angle is -180° . The frequency at which phase crossover occurs is called the gain margin frequency.

PHASE MARGIN: A measure of system stability defined as the phase lag to be added to achieve 180° of phase lag at the open loop frequency response corresponding to 0 dB amplitude ratio.

SAE ARP1281 Revision B

2.2 (Continued):

TRANSIENT RESPONSE: The response of a system to an input that is nonsinusoidal, may change in magnitude abruptly, and be of a long or short duration, e.g., a step function, impulse, square wave, ramp, etc.

LINEARITY: A measure of the linear relationship between input and output over the entire operating range.

RATED VELOCITY: Rated velocity is the nominal velocity the servoactuator is capable of under specified external load conditions and rated pressures.

THRESHOLD: The threshold of a servoactuator is the lowest level of input which will produce a perceptible and measurable output.

HYSTERESIS: Hysteresis is the difference in the servoactuator increasing input command value and the decreasing input command value required to produce the same output value during a complete cycle of input command when cycled throughout the full range of travel. The cycling rate must be significantly below the control bandpass so that velocity error signals are not included in this parameter.

NULL SHIFT: A shift for whatever reason of the normal input to output static relationship.

EXTERNAL LOADS: External loads are loads imposed on the actuator output. The loads will vary with aerodynamic, flight and environmental conditions; e.g., "g" forces during flight maneuvers, airspeed, altitude and control surface displacement.

OPEN LOOP GAIN: The equivalent output rate per unit of position error, or the product of the forward and feedback gains in units/sec/unit input (sec^{-1}).

STIFFNESS: Servoactuator stiffness is the ability of the output to resist motion when subjected to external forces.

CHATTER: Servoactuator chatter is a low amplitude (usually) high frequency oscillation of the output.

DUAL LOAD PATH: A type of passive paralleling wherein two separate load carrying paths exist. Each load path is capable of carrying sufficient load such that failure of either path will not jeopardize system performance nor integrity.

ELECTROMAGNETIC INTERFERENCE: Any electrical or electronic disturbance phenomenon, signal or emission (man made or natural) which causes undesirable responses, unacceptable responses, malfunctions, degradation of performance, or premature and undesired location, detection or discovery by enemy forces, except deliberately generated interference.

SAE ARP1281 Revision B

2.2 (Continued):

ACCEPTANCE TESTS: Those tests performed on production components to determine the acceptability of, and assure the continuance of, the quality of that component.

PREPRODUCTION TESTS: See 4.3.2.

QUALIFICATION TESTS: See 4.3.3.

3. TECHNICAL REQUIREMENTS:

Servoactuators covered by this specification shall be designed in accordance with a detail specification to be prepared by the airframe contractor. The detail specification shall use the requirements of this specification. The methods set forth in MIL-F-9490 for the preparation of a specification shall be used as a guide. This specification shall take precedence in case of conflict with the requirements of other applicable documents. In case of disagreement between this specification and the detail specification, the detail specification shall govern provided the detail specification has been previously approved by the procuring activity.

3.1 Abbreviations:

3.1.1 MTBF - Mean Time Between Failure

3.1.2 EMI - Electromagnetic Interference

3.1.3 Other Abbreviations: For other abbreviations, use of MIL-STD-12 is recommended.

3.2 Design:

3.2.1 Hydraulic Control Valves:

3.2.1.1 Mechanical Input Servovalves: Mechanical input servovalves shall be designed to give smooth operation. Internal leakage shall be held to a practicable minimum consistent with permissible operating forces, temperature effects, control sensitivity, fluid contamination levels, and other governing factors. Critical parts of the control valve (e.g., spool and sleeve on a slide valve design) shall be made of materials which are compatible in mechanical properties, especially with respect to coefficient of expansion and galling tendencies.

3.2.1.2 Electrohydraulic Servovalves: Electrohydraulic servovalves shall be designed in accordance with MIL-V-27162 and ARP490. Life and environmental requirements shall be consistent with those for the servoactuator. The detail specification shall define the electrical parameters of the servovalve.

SAE ARP1281 Revision B

- 3.2.1.3 Bypass Valves: If bypass valves are utilized to interconnect the cylinder ports during certain modes of operation, the detail specification shall define the type of valve normally "open" or normally "closed", control parameters (electrical and/or hydraulic), allowable pressure drop between cylinder ports at rated flow, and allowable leakage.
- 3.2.1.4 Motor-Operated Valves: DC motors for operating valves shall conform to MIL-M-8609 and AC motors shall conform to MIL-M-7969.
- 3.2.1.4.1 Limit Switches: When limit switches are used, they shall conform to MIL-S-8805 and shall be actuated by positively secured means. A failure of the switches shall not affect manual override.
- 3.2.1.4.2 Voltage for Motor-Operated Valves: Electrically actuated valves designed for 28 V DC systems shall operate at a minimum of 18 V with operating pressure applied to the valve, and shall operate at 1 1/2 times operating pressure at 28 V. Electrically actuated valves designed for 115 V AC systems shall operate at a minimum of 85 V with operating pressure applied to the valve and shall operate at 1 1/2 times operating pressure at a maximum of 115 V. The above operating voltages shall be met at maximum fluid and ambient temperatures.
- 3.2.1.5 Solenoid Operated Valves: Solenoids for operating valves shall be in accordance with MIL-H-8775.
- 3.2.1.5.1 Creepage and Clearance Distances: The minimum creepage distance of .250 in and clearance distance of .125 in shall apply between uninsulated current carrying parts and ground when voltages of 3.2.1.4.2 are used. The minimum spacing between uninsulated current carrying parts and any other portion of the solenoid (other than insulating material) shall be .125 in.
- 3.2.1.6 Load Limiting Relief Valves: The detail specification shall specify relevant parameters of load limiting relief valves, when used, including supply and differential pressure extremes, flow relief criteria, and reset pressure.
- 3.2.1.7 Fluidic or Optic Type Input Servovalves: Emerging technology on servovalves, including photonic and fluidic servovalves, may be specified in future systems. These servovalves shall be designed consistent with the requirements for the servoactuator application. The detail specification shall define the optic or fluidic parameters required of the servovalve as appropriate to its application.
- 3.2.2 Electrical Components:
- 3.2.2.1 Position Transducer: Electrical characteristics such as linearity, sensitivity, excitation voltage, null voltage, stroke from null, etc., and requirements relating to type, location, and electrical interface, shall be in accordance with the detail specification.

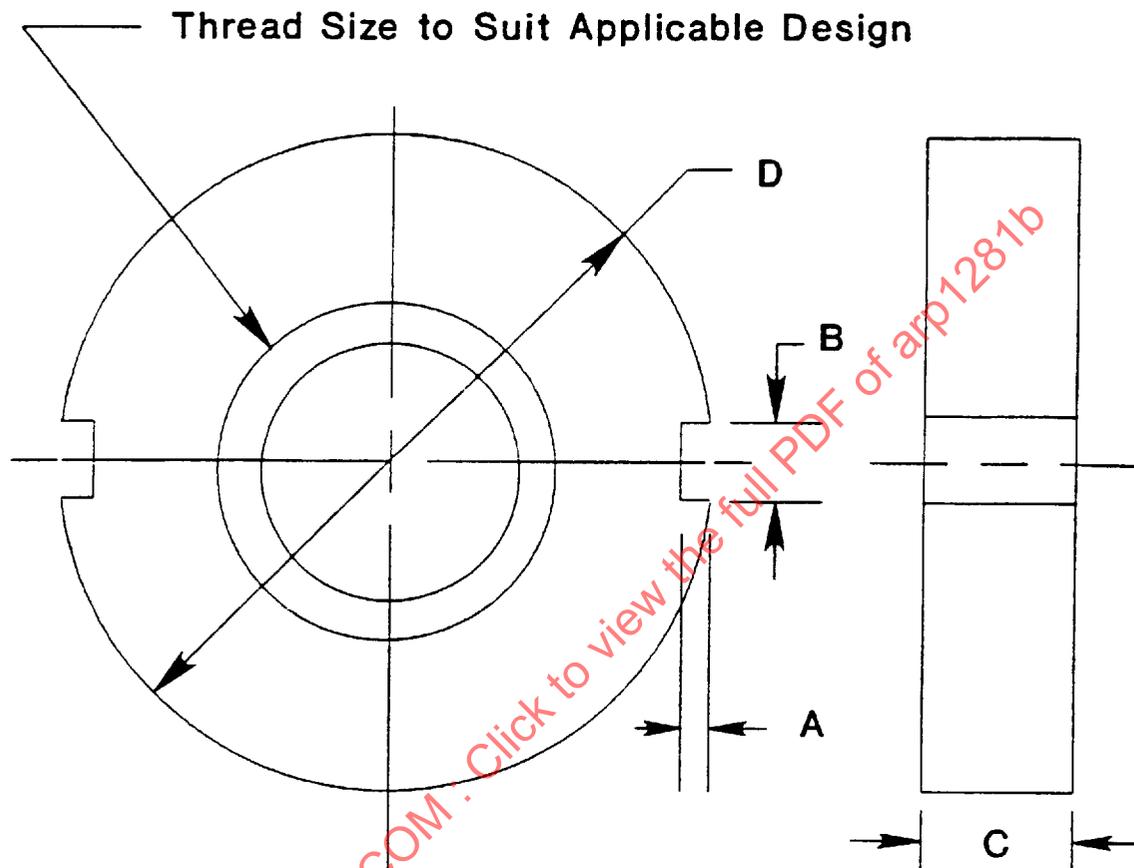
SAE ARP1281 Revision B

- 3.2.2.2 Dielectric and Insulation Properties: The 28 V components shall be capable of withstanding a test voltage of not less than 600 V rms from 60 s. These test voltages should not be applied more than three times during the useful life of the component.
- 3.2.2.3 Electrical Power: Electrical components, including solenoid valves, shall be capable of proper operation with electrical power in accordance with MIL-STD-704.
- 3.2.2.4 Electrical Connectors: Unless otherwise specified in the detail specification, electrical connectors conforming to MIL-C-5015 or MIL-C-26482 shall be installed as an integral part of the electrical component of the servoactuator to facilitate maintenance and replacement. Connectors shall be mounted to preclude nuisance warning indications and intermittent operation when subjected to applicable temperature differentials, vibration, and shock. They shall be "polarized" so that it is impossible to mismatch them on a particular piece of equipment.
- 3.2.3 Physical Characteristics:
- 3.2.3.1 Weight: The detail specification shall specify the maximum dry weight of the servoactuator. It shall be designed for the lightest weight compatible with specification requirements. Maximum consideration shall be given to achieving a minimum weight in accordance with good design practices, safety, and vulnerability.
- 3.2.3.2 Dimensions: The detail specification shall specify the maximum permissible envelope dimensions of the servoactuator for the following:
- Static condition, e.g., shipping
 - Operating condition, i.e. maximum space required for servoactuator, linkages, connectors, and related parts when installed and operated.
- 3.2.3.3 Mounting: Mounting provisions for the servoactuator shall be in accordance with the detail specification. Sufficient clearance shall be provided between servoactuator, structure and other components to preclude binding or jamming due to possible combination of temperature effects, loads and deflections, including structural deflections.
- 3.2.3.4 Moisture Pockets: Servoactuator housing designs which could result in pockets, wells, traps and the like into which water, condensed moisture or other liquids can drain into or collect, shall be avoided. If such designs are unavoidable, provisions for draining moisture from these pockets shall be incorporated, or areas adequately treated to preclude corrosion or damage due to extended periods of entrapment.
- 3.2.4 Structural Characteristics:
- 3.2.4.1 Strength: Unless otherwise specified, servoactuators shall be designed in accordance with the material strengths of MIL-HDBK-5 and MIL-HDBK-17.

SAE ARP1281 Revision B

- 3.2.4.2 **Damage Tolerance:** The elements of a servoactuator that are essential to aircraft safety shall meet the requirements of MIL-A-83444. Servoactuators shall incorporate materials, stress levels, and structural configurations which allow incipient failure detection, routine in-service inspection, minimize crack initiation, and minimize failure due to the propagation of undetected flaws, cracks, or other damage. The detail specification shall specify magnitude, direction and type of all externally applied loads. All possible combinations of loading shall be specified, together with the diagram of the operational geometry. The return port passages shall be structurally acceptable at normal system operating pressure.
- 3.2.5 **Design Characteristics:**
- 3.2.5.1 **Cylinder Assembly:** The cylinder assembly shall be designed in accordance with the detail specification. The design shall also consider the following requirements.
- 3.2.5.1.1 **Piston Head and Rod Assembly:** Piston shall have adequate bearing area on the cylinder wall to carry compression, bending and vibration loads without discernible deformation or excessive wear. Rod bearing shall be of sufficient length to ensure satisfactory operation and adequate life.
- 3.2.5.1.2 **Eccentricity:** Total eccentricity of the piston head and rod including that of the bores for the same, shall not cause binding or galling over the specified operating condition.
- 3.2.5.1.3 **Scraper Rings:** The detail specification shall specify the type of scraper ring(s) to be used. Consideration shall be given to the latest design techniques and technology.
- 3.2.5.1.4 **Wiper Rings:** The use of wiper rings is subject to approval of the procuring activity.
- 3.2.5.1.5 **Dashpots:** Where the kinetic energy of the cylinder and mechanism is too great to be adequately absorbed by an external stop, dashpots or snubbers may be used to reduce piston velocity gradually at the end of the stroke. A simple device, preferably self-cleaning, shall be used. An analysis shall be made to ensure sufficient structural strength and seal extrusion resistance to withstand the hydraulic pressures anticipated during operation. The rate of change of piston velocity and load inertia shall be as specified in the detail specification.
- 3.2.5.1.6 **End Caps, Locknuts and Adjustment Nuts (See Figure 1):** End caps, locknuts, and adjustment nuts may have wrench flats or hexes, be knurled, or contain milled slots for spanner wrenches, as applicable to the design; when spanner wrench slots are used, they shall be dimensioned in accordance with Figure 1. Drilled hole-type nuts requiring the use of pin-type spanner wrenches shall not be used in servoactuator designs. Positive locking methods are to be used to prevent rotation of the end caps, locknuts, and adjustment nuts.

SAE ARP1281 Revision B



D DIAMETER	A MIN	B MIN	C MIN	SPANNER WRENCH
3/4 to 2 incl	0.120	0.120	1/4	AN-8514
1 3/4 to 4 incl	0.120	0.190	5/16	AN-8515
3 1/2 to 6 incl	0.190	0.250	3/8	AN-8516

FIGURE 1 - Dimensions for End Caps and Locknuts

SAE ARP1281 Revision B

- 3.2.5.1.7 Rod Ends: These components shall be designed to minimize stress risers. Integral antirotation devices are preferred and shall be arranged to prevent excessive airframe attach fitting wear. Controlled radius root threads conforming to MIL-S-8879 or special threads with root radii greater than specified in MIL-S-8879 are required. The assembly of the rod end to the piston rod shall result in a minimum thread preload equivalent to the maximum rod end load. A positive locking arrangement, positively safetied, shall be used to maintain the thread preload. Safety wiring and cotter pinning shall be in accordance with MS 33540.
- 3.2.5.1.8 Seals: Unless otherwise specified in the detail specification, seal design characteristics shall comply with the gland design requirements of MIL-G-5514, and packing requirements of MIL-P-83461/1. The seal designs whether vented or unvented (single or two stage) shall have the written approval of the procuring activity. Seal operating life shall be given either in terms of total hours of operation or in number of cycles of operation of specified amplitudes and rates which represent actual usage.
- 3.2.5.1.9 Vulnerability: The detail specification shall establish the vulnerability requirements. These detail requirements shall stress rip stop designs, construction materials and proper positioning of the more critical components both electrical and hydraulic, so as to provide greater protection from a hostile environment such as enemy ground fire.
- 3.2.5.1.10 Proof Pressures: The inlet port (ports) of the servoactuator shall be capable of withstanding a pressure 1.5 nominal operating pressure for 3 min. The outlet port(s) of the servoactuator shall be capable of withstanding normal supply pressure for 3 min.
- 3.2.5.1.11 Burst Pressures: The detail specification shall specify the inlet and return burst pressures. Test and test conditions in 4.7.15 are set forth as a guide.
- 3.2.5.2 Ports and Plugs:
- 3.2.5.2.1 Ports: The location and size of all ports shall be in accordance with the detail specification. The return ports shall be physically different than the pressure ports to avoid improper connections when the unit is installed in the system. The return ports shall be oriented at the highest point in the installation to facilitate bleeding of entrapped air. All ports for the tube connections shall be clearly and permanently marked. Where applicable, the directions of flow shall be indicated. Use of a single letter for marking, such as "P" for pressure and "R" for return is not acceptable. Where space is limited abbreviations of MIL-STD-12 are recommended and must be approved by the procuring activity. Decalcomanias shall not be considered a permanent marking. Raised letters, engraving, and/or stamping are preferred.

SAE ARP1281 Revision B

3.2.5.2.2 Fluid Porting through Interfaces: Fluid porting through interfacing surfaces which deflect under structural loading or pressure conditions shall utilize balanced quill tubes with seals on both ends. Face seals may be used for certain applications where the design is sufficiently rigid to prevent adverse deflections caused by pressure loads or structural loads.

3.2.5.2.3 Fillets: Unless otherwise specified in the detail specification, the intersection of highly stressed thin wall cylinder barrels with heavy bulkhead areas shall incorporate generous radii. The fatigue notch sensitivity factor (q) of any portion of the servoactuator shall be limited to .70 as shown in Equation 1:

$$K_f = 1 + (K_t - 1)q \quad (\text{Eq.1})$$

where (from MIL-HDBK-5):

K_f = fatigue strength reduction factor (dimensionless)
 K_t = theoretical stress concentration factor (dimensionless)
 q = fatigue notch sensitivity (dimensionless)

hence for above q value:

$$K_f = .70K_t + .30 \quad (\text{Eq.2})$$

Additional data in Appendix A under A.6.

3.2.5.2.4 Fluid Passages: Unless otherwise specified in the detail specification, all intersecting holes in manifold section which are drilled shall be inclined at an angle not less than 60°. Material thickness between a cylinder bore and a parallel passage shall be equivalent to the basic cylinder wall thickness plus the wall thickness surrounding the passage.

3.2.5.2.5 Bosses: Unless otherwise specified in the detailed specification, threaded bosses for connecting fittings shall conform to MS 33649. Spacing of parts for connecting fittings shall conform to MS 21343.

3.2.5.2.6 Plugs: Permanently installed plugs that will not be removed during the life of the servoactuator shall be of any form suitable for the purpose, except that pipe threaded plugs shall not be used. Removable plugs for Type I and Type II servoactuators shall conform to MS 24391 or AN 814 and shall be compatible with seals specified in the detail specification. Plugs used for retention, shall be approved by procuring agency. In systems not otherwise capable of preventing air entrapment, suitable bleeder plugs shall be provided at the highest practicable point in the servoactuator. Suggested types are plugs conforming to MS 24391, or valves conforming to AN 6204, installed in bosses conforming to MS 33649 or AND 10067. Other types may be used, subject to approval of the procuring organization.

SAE ARP1281 Revision B

- 3.2.5.3 Linkages: Servoactuator linkages shall consider designs and means for precluding sand, dust, water, or ice from impairing normal operation.
- 3.2.6 Materials: The materials used in servoactuators shall be suitable for the service and purpose intended and shall conform to the applicable material specification when such specifications exist for the type material being used. Nonspecification materials may be used provided it can be demonstrated that their use will result in a superior product. The use of each material in its application shall be substantiated. MIL-HDBK-5 shall be used as the authority for strength of all actuator metals. Use of materials for critical structural applications shall be approved by the procuring agency.
- 3.2.6.1 Metals: All metals shall be compatible with the hydraulic fluid used and with the intended temperature, function or service, and storage conditions to which the components will be exposed. The metals used shall possess adequate corrosion resistant characteristics or shall be suitably protected to resist corrosion which may result from such conditions as: dissimilar metal combinations, moisture, salt spray, and high temperature deterioration, as applicable. Requirements of MIL-STD-889 shall be followed regarding the use of dissimilar metals. Consideration shall be given to providing materials resistant to fluid erosion.
- 3.2.6.2 Castings and Forgings: Castings and forgings shall be designed to the criteria, as applicable, in specifications MIL-C-6021, MIL-F-7190, MIL-A-21180, MIL-A-22771, and MIL-F-83142.
- 3.2.6.3 Type I and Type II Components: Unless otherwise specified, ferrous, titanium, or aluminum alloys shall be used for structural components which resist or transfer the primary load of the servoactuator. Wrought, forged, or cast aluminum alloys may be used to house the valving, internal linkage, and carry hydraulic fluid to the cylinders. Inclusion of a parting line through hydraulic ports is prohibited. Aluminum pressure vessels subjected to 3000 psi or greater shall be forged without flash formation at die parting lines.
- 3.2.6.4 Type III Components: Ferrous or titanium alloys shall be used for all structural components of the servoactuator. Aluminum alloys shall be limited to nonstructural application.
- 3.2.6.5 Fluids: For Type I and Type II systems, the servoactuator and its components shall be designed to operate and be compatible with hydraulic fluid MIL-H-83282 or MIL-H-5606. Use of MIL-H-5606, particularly for test purposes, shall have the approval of the procuring agency. The detail specification shall specify the fluid to be used when components of the servoactuator are operating in a Type III system environment.

SAE ARP1281 Revision B

3.2.7 Parts:

- 3.2.7.1 Use of Standard Parts:** Standard type parts not specified herein shall be selected from established standards and specifications, where such exist, providing that they are technically suitable. When two or more products will satisfy design requirements, the election shall be made in such manner as to be most economical to the purchaser. Except as modified by the economic consideration noted, standard parts shall be selected in the order of precedence specified in MIL-STD-143.
- 3.2.7.2 Hydraulic Closures:** Multiscrew retained flanges or covers for hydraulic components shall not be used where other methods are practical. When employed, structural and sealing adequacy shall be demonstrated by considering the most severe case of load and pressure, and all screws shall be positively safetied with lockwire in accordance with MS 33540, or self-locking fasteners if approved by the procuring activity.
- 3.2.7.3 Filters and Screens:** The requirements for an inlet filter as an integral component for the servoactuator shall be controlled by the detail specification. Screens shall be installed in all cylinder passages between the control servovalve and the cylinder when they are to be considered as individual maintenance items. They shall be located as specified in the detail specification. Screens shall be installed in the inlet to prevent hydraulic line contaminants from entering the servovalve or servoactuator provided that an integral filter is not a requirement.
- 3.2.7.4 Lock Wiring:** All hardware and components which are not positively secured by other means, shall be secured by MS 20995 lockwire or MS 24665 cotter pins in accordance with MS 33540.
- 3.2.8 Identification and Marking:**
- 3.2.8.1 Identification:** The identification requirements for servoactuator shall be as specified in MIL-STD-130.
- 3.2.8.2 Marking and Serialization:** Each servoactuator shall be marked and serialized. Placards shall be the engraved or chemically etched type and mechanically secured to the component parts. Adhesive foil placards used shall be approved by procuring activity. Placards and data plates shall be located such that they can be read when the component to which they are attached is installed in the air vehicle.
- 3.2.9 Safety:** The servoactuator and its components shall be designed to provide a maximum of safety to personnel during the course of installation and maintenance. Adequate precautionary warnings are information that shall be affixed to components when considered necessary for safety or to prevent needless damage. An example is a component with a compressed spring. Special attachment or lift points shall be designated when the weight of the servoactuator requires special handling provisions. Servoactuators shall meet the safety requirements of AFSC DH 1-6 and MIL-STD-454. Applicable paragraphs of MIL-STD-882 shall be referred to for guidance.

SAE ARP1281 Revision B

3.2.10 Human Performance/Engineering: When applicable, the design shall consider and apply the principles, analysis, criteria and philosophies of human engineering as defined in MIL-STD-1472. This shall include the application, during all phases of the actuator design, of knowledge as to man's unique capabilities and limitations regarding the installation, operation and maintenance of the actuator package. The following general requirements are established to reduce the possibility of human errors during assembly and maintenance of the actuator package:

- a. When reversed or rotated mounting of an interfacing component cannot be tolerated, nonsymmetrical mounting arrangements (including keyways or pins) shall be used.
- b. "Stacked" assemblies shall use flanged arrangements which prevent assembly if a part is omitted, or indicator markings which are exposed when the part is missing.

3.2.11 Bearings:

3.2.11.1 Antifriction Bearings: Approved type, ball bearings in accordance with MIL-B-6038, MIL-B-6039, and MIL-B-7949 shall be used except as indicated in the following paragraphs. Sealed bearings are preferable over shielded bearings in an atmospheric environment. Shielded or unprotected bearings are acceptable within the hydraulic fluid system environment. In the event design limitations do not permit the use of ball bearings, prelubricated, shielded roller or needle bearings may be used in accordance with MIL-B-3990 and FF-B-185. Where needle or roller bearings are used, consideration shall be given to relubrication provisions. The inner race of the bearing shall be clamped to prevent rotation of the inner race with respect to the pivot bolt. Bearing installation shall be arranged in such a manner that failure of the rollers or balls will not result in a complete separation of the attachment. Direct axial application of control forces to a bearing shall be avoided if possible.

3.2.11.2 Spherical Bearings: Where design limitations preclude the use of antifriction bearings, spherical type, plain bearings approved by the procuring organization may be used.

3.2.11.3 Journal Bearings: The use of plain type journal bearings shall be avoided. However, where substantiated, and where play and friction are not major considerations, journal or plain bearings in accordance with MIL-B-8976 with adequate and accessible provisions for lubrication may be used.

3.2.11.4 Attachment Bearings: Self-aligning bearings or universal joints shall be used wherever necessary in end connections to remove excessive bending loads. Bending loads resulting from rotational friction in the bearing shall be taken into consideration. The detail specification shall specify the maximum amount of looseness of fit (backlash) of the attachment bearings (defined as bearings).

SAE ARP1281 Revision B

3.2.11.5 Sintered Bearings: Sintered type, or oil impregnated bearings shall not be used in those parts of the servoactuator which have slow moving or oscillating motions. Fast moving rotating applications such as in qualified motors are permissible. Bearings shall conform to MIL-B-5687.

3.3 Processes, Construction/Assembly Requirements:

3.3.1 Processes: Unless otherwise specified herein, processes or special tooling used in the design of this unit shall conform to the following:

3.3.1.1 Metal Coatings: Ferrous alloys heat-treated to 200 000 psi ultimate tensile strength and above shall utilize protective coatings which minimize or eliminate hydrogen embrittlement. These include vacuum deposited cadmium (MIL-C-8837), titanium cadmium (AMS 2419), or chromium applied in accordance with QQ-C-320. External surfaces of ferrous alloy parts, including external seal grooves need not be coated if the chromium content of the alloy is greater than 12%. Anodized coatings shall be in accordance with MIL-A-8625.

3.3.1.2 Grinding: Grinding of high strength steel shall be in accordance with MIL-STD-866.

3.3.1.3 Stabilization: The detail specification shall specify the materials and processing required for dimensional stability. Martensitic steels heat treated to hardness of 50 RC or higher should be subzero treated during the hardening process in order to complete transformation for approximate dimensional stability.

3.3.1.4 Residual Magnetism: All parts made of materials that are capable of retaining residual magnetism, but are not intended to function as magnets, shall be demagnetized sufficiently to prevent system or component malfunction, including malfunction due to accumulation of magnetic contaminants.

3.3.1.5 Shot Peening: "Shot peening" for relief of metal stress shall be in accordance with MIL-S-13165.

3.3.2 Construction/Assembly Requirements:

3.3.2.1 Electrical Bonding and Grounding: Electrical bonding and grounding shall conform with the requirements of MIL-B-5087.

3.3.2.2 Staking, Peening, and Swaging: Each application of staking, peening, and swaging, or any other means of permanent deformation for locking purposes, shall be subject to procuring activity approval.

3.3.2.3 Safetying: Where practicable, threaded parts shall be safety wired in accordance with MS 33540. Other means of safetying shall be subject to procuring agency approval.

SAE ARP1281 Revision B

- 3.3.2.4 **Mechanical Joining:** Individual parts may be mechanically joined with removable fasteners, or threaded connections, or by qualified methods for permanent joining.
- 3.3.2.5 **Joining with Removable Fasteners:** Unless otherwise specified, in the detail specification, all removable fasteners shall be selected and used as follows:
- a. Bolts smaller than 1/4 in shall not be used to make single bolt connections, or connections essential to the structural performance of the servoactuator.
 - b. Pin joints on linkage that form a part of the actuator assembly and which do not require removal during installation shall be of the semipermanent (huck bolt) type. In areas considered critical to safety of flight, and where practicable, MS 33502 or MS 3369 self-retaining bolts with MS 21244 or MS 21224 nuts in accordance with MIL-B-83050 shall be used. Other methods shall be subject to approval of the procuring activity.
 - c. Bolt joints shall use a positive method of retention such as self-locking nuts, plate nuts or safety wire. Self-locking nuts shall be in accordance with MIL-N-25027 or MS 33588. However, if failure of a single fastener joint could result in reduction or loss of control then a dual locking device should be used.
- 3.3.2.6 **Retention of Removable Fasteners:** Removable fasteners, unless restrained from moving by the attachment of adjoining parts, shall incorporate a positive locking means or be safetied with cotter pins in accordance with MS 24665 or be safety wired with MS 20995 lockwire. Cotter pins and safety wiring shall be installed in accordance with MS 33540. Self-locking externally threaded fasteners or self-locking nuts shall not be used except within the limitations specified in MS 15981 and MS 24665.
- 3.3.2.7 **Threaded Joints:** All threaded joints shall be provided with adequate wrenching and holding provisions for assembly and disassembly of the joint before and after service use. Internal screw threads and external rolled threads shall be in accordance with the thread form requirements of MIL-S-8879. Pipe threads shall not be used.
- 3.3.2.8 **Joint Retention:** All adjoining parts shall be secured in a manner that will preclude loosening when subjected to internal or external loads or vibration.
- 3.3.2.9 **Use of Retainer Rings:** Retainer rings or pins shall not be used to retain loaded parts unless the rings are positively confined by a means other than depending on internal pressure or external loads. They shall not allow freeplay which could result in structurally destructive action or fatigue failure of the retained parts or failure of gaskets or packings. Where used, retainer rings shall be commercially available types which can be installed and removed with standard tools.

SAE ARP1281 Revision B

3.3.3 Workmanship:

- 3.3.3.1 Quality:** The servoactuator manufacturer shall exercise extreme care in fabricating, assembling, handling, and packing units to assure that all parts are free from pits, rust, scrapes, splits, cracks, burrs, sharp edges, and discontinuities. An internal-external microscopic examination shall be made to determine parts are free of contaminants, e.g., metal chips. Any part or component appearing to have a crack shall be subject to microscopic examination and/or tests of 3.3.3.2.
- 3.3.3.2 Physical Defect Inspection:** All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with MIL-STD-1949. All nonmagnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with MIL-STD-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.
- 3.3.3.3 Control and Inspection of Forgings:** Forgings and materials used in the assembly shall be controlled and inspected in accordance with the requirements of MIL-F-7190 and MIL-I-6868.

3.4 Performance:

- 3.4.1 Performance, Standard Conditions:** The detail specification shall specify the operating conditions such as supply and return pressures, temperature, actuator load, magnitude of input, degree of filtration, etc., whenever a test is conducted to verify a stated requirement. All values of performance and the tolerances related thereto shall be stated in the detail specification.
- 3.4.1.1 Dynamic Characteristics:** Unless otherwise stated, the servoactuator shall meet the requirements and performance parameters set forth in Table 1.
- 3.4.1.2 Control Valves:**
- 3.4.1.2.1 Synchronization:** Servovalves in multiple channel servoactuators shall produce cylinder pressures in each hydraulic system which are synchronized to the degree specified in the detail specification. It is desirable to minimize the differential pressure between systems in order to minimize structural fatigue and degradation of performance.
- 3.4.1.2.2 Flow Forces:** When control valve flow force compensation is used to meet the valve input operating force requirements, it shall not produce a net negative force which tends to move the valve away from null. Therefore, the use of negative flow force on individual valve porting elements is not prohibited but limited to the extent that the next valve flow force will tend to return the valve to null.

SAE ARP1281 Revision B

TABLE 1 - Dynamic Characteristics

Parameter	Requirements
Frequency Response	An input of 2 to 5% total amplitude and an input of 10 to 25% total amplitude shall be used. The output at these inputs to be within specified maximum and minimum limits.
Transient Response	Step input of 5%, 10%, and 25% of total amplitude, for both loaded and unloaded conditions.
Linearity	As defined in detail spec
Rated Velocity	As defined in detail spec
Threshold	As defined in detail spec
Hysteresis	As defined in detail spec
Null Shift	As defined in detail spec for changes in temperature, hydraulic supply pressure, acceleration, life, and use.
External Loads	As defined in detail spec
Open Loop Gain	As defined in detail spec
Chatter	As defined in detail spec
Gain Margin and Phase Margin	As defined in detail spec and in accordance and compatible with the MIL-F-9490 nonaerodynamic loops.
Stiffness	As specified in the detail spec including test methods and procedures set forth in AFFDL-TR-74-116.
Position Sensitivity	As defined in the detail spec

- 3.4.1.2.3 Friction: Breakout and dynamic friction shall be in accordance with the detail specification.
- 3.4.1.2.4 Servovalve Stops: The servovalve travel shall be limited in both directions by (internal or external) stops that are integral to the actuator. These stops shall withstand a limit load specified in the detail specification without deformation or jamming.
- 3.4.1.2.5 Direction of Force: The detail specification shall specify the permissible change in input operating force due to misalignment of the input to the valve.

SAE ARP1281 Revision B

3.4.1.2.6 Input Operating Force: The detail specification shall specify the force requirements that will be applied to the valve and linkage:

- a. For shearing any particle of contamination that may enter the valve
- b. When actuator is bottomed-out during maximum rate or displacement
- c. To move or to hold valve in any position

3.4.2 Leakage:

3.4.2.1 External Leakage: The detail specification shall establish allowable external leakage rates past hydraulic seals which contact components moving relative to the seals such as rod end glands. Methods of checking the leakage and conditions shall be specified based on the assembly configuration.

3.4.2.2 Internal Leakage: Allowable leakage from inlet to return and the associated conditions shall be specified in the detail specification. The leakage value shall represent the total for all individual components including seals and the control valve.

3.4.2.3 Intersystem Leakage: Allowable leakage between systems for multihydraulic supplied actuators shall be specified. The leakage value shall be specified under conditions of temperature and extreme differences between systems supply and return pressures.

3.4.3 Reliability:

3.4.3.1 Reliability Mean Time Between Failure: The mean time between failure (MTBF) of the servoactuator shall be specified in the detail specification and shall conform to the value established for the airframe contractor based on environment, utilization, complexity, and alternate modes of operation of the system. The MTBF shall be defined in terms of duty cycles or hours together with the confidence level. In addition, a MTBF shall be specified for actual flight test and service operation. Failure shall be defined as any malfunction causing performance degradation outside the limits as defined in the detail specification.

3.4.4 Performance, Environmental Conditions: The servoactuator shall not suffer any damage, deterioration, or degradation of performance when subjected to any environment or any natural combination of environments within the aircraft operational envelope as encountered during worldwide ground and airborne operations, as specified in MIL-STD-810 and in the detail specification. The servoactuator shall meet all the requirements listed in Table 2. The detail specification shall specify when applicable, the allowable damage and degraded performance after an extended life period for the servoactuator.

SAE ARP1281 Revision B

TABLE 2 - Environmental Criteria

Environment	Applicable Document(s)
Temperature, Ambient	Per Detail Specification
Fluid Temperature	Per Detail Specification
Altitude	Per MIL-STD-810, Method 500
Thermal Shock	Per Detail Specification
Salt Spray	Per MIL-STD-810, Method 509
Sand and Dust	Per MIL-STD-810, Method 510
Mechanical Shock	Per MIL-STD-810, Method 516
Acoustic Noise	Per MIL-STD-810, Method 515
Acceleration	Per Detail Specification
Humidity	Per Detail Specification
Fungus	Per Detail Specification
Vibration	Per MIL-STD-810, Method 514

3.4.5 Input and Output Limit Loads:

- 3.4.5.1 Input Limit Loads: Where mechanical pilot inputs are required, the detail specification shall specify the limit load which may be reached through the input and feedback linkage system in either direction in any position, including stops, with hydraulic systems energized or deenergized without permanent deformation set or brinelling of parts.
- 3.4.5.2 Output Limit Loads: The detail specification shall specify the maximum output limit load resulting from the maximum pressure differential which can be generated by any sustained pressure transient in the hydraulic system, above the normal operating pressures, across the actuator for all stroke positions of the actuator, without permanent deformation or brinelling of parts. These loads shall be combined with the acceleration limit load factors as defined in 3.4.4.
- 3.4.5.3 Input and Output Ultimate Load: The detail specification shall specify that the servoactuator shall withstand, with the output restrained, an output and input load 1.5 times the limit load specified in 3.4.5 without failure for a specified period of time.
- 3.4.6 Load Capability of Dual-Load-Path-Elements: The load path remaining after a single failure in dual-load-path elements shall meet the following requirements:
- Where the failure is not evident by visual inspection, the remaining path shall be capable of sustaining a fatigue spectrum equivalent to one overhaul period or as specified in the detail specification.
 - Where the single failure is obvious, the remaining load path shall be capable of withstanding, as ultimate load, loading equal to 1.15 times limit loads.
- 3.4.7 Fatigue: The servoactuator shall be designed to withstand all loading requirements for its specified application without the occurrence of fatigue failures during its specified useful life.

SAE ARP1281 Revision B

3.4.8 Operating Life:

3.4.8.1 Total Cycles: The detail specification shall define an operating spectrum of percent stroke versus number of cycles for the servoactuator which shall be commensurate with its operational use as defined in MIL-F-9490.

3.4.8.2 Impulse Cycles: The detail specification shall specify the total number of impulse cycles the servoactuator shall be subjected to at the most critical output positions (e.g., retract and extend, if most critical).

3.4.8.3 Useful Life: The detail specification shall specify the useful life of the servoactuator which shall be considered as the time of its delivery from the supplier's facility until its identity is destroyed.

3.5 Installation/Maintenance Requirements:

3.5.1 Maintainability:

3.5.1.1 Maintainability Characteristics: Unless otherwise specified in the detail specification, the maintainability requirements shall be in accordance with MIL-STD-470. The servoactuator shall be designed such that the planned mission can be accomplished with a minimum expenditure of maintenance man hours, elapsed time, personnel skills, aerospace ground equipment (AGE), and technical data. The specific quantitative maintainability requirements shall be specified in terms of:

- a. The mean elapsed time required to perform corrective maintenance (M_{ct}) on the servoactuator while installed in the air vehicle.
- b. The 90 percentile maximum elapsed time required to perform corrective maintenance (M_{max}) on the servoactuator while installed in the air vehicle.
- c. The mean elapsed time required to perform preventive maintenance (M_{pt}) on the servoactuator while installed in the air vehicle.
- d. The mean maintenance manhours required to perform a maintenance task, including overhaul, in the field and depot maintenance shops.
- e. The mean, elapsed time required to perform servicing maintenance (M_{st}) on the unit while installed in the air vehicle.
- f. The mean time between unscheduled removals (MTUR).
- g. The mean time between unscheduled maintenance actions (MTBUM).

SAE ARP1281 Revision B

- 3.5.1.2 **Maintenance and Repair Cycles:** The detail specification shall specify the time interval between preventative maintenance tasks for actuator operating hours. The time interval between filter element replacement shall be specified in actuator operating hours and shall be based upon maintaining the hydraulic fluid cleanliness within the actuator at all times to Class 7 (military) or Class 8 (commercial) per AS4059 or better.
- 3.5.1.3 **Installation and Accessibility:** The servoactuator shall be designed, installed and located such that inspection, rigging, repair, lubrication and connection of such test equipment as may be required for field maintenance, can be readily accomplished without removal of the servoactuator from the aircraft. Installation should be implemented without requiring adjustments of the servoactuator. The design shall permit use of standard tools and test equipment. Suitable provisions for rigging pins, or the equivalent, shall be made in the mechanical input linkage. The detail specification shall define, as required, the method and accuracy of rigging the input.
- 3.5.1.4 **Lubrication:** All components requiring lubrication other than those being lubricated with the hydraulic fluid shall be capable of being lubricated in accordance with MIL-STD-838. Lubricator fittings conforming to MS 15002 and bushings or equivalent shall be provided in all end connections where relative motion between the mating parts exists, other than that caused by deflections between mating parts, unless ball or permanently lubricated bearings are used. Design of the end connection shall permit installation of oversize bushings when required. Whenever possible, permanently lubricated components shall be provided.
- 3.5.2 **Contamination:** The servoactuator including all control valves (servo, electrohydraulic, hydraulic logic, solenoid, etc.) shall be capable of meeting detail specification performance requirements for a period of 12.5 h while operating in a hydraulic fluid with a contamination level of Class 8 or less as defined in AS4059. Counting procedures for the contamination level in sampled fluid shall be as specified in ARP598. Automatic particle counters calibrated per ARP1192 may be used if approved by the procuring activity.
- 3.5.3 **Electromagnetic Interference:** Servoactuators operated and controlled by an electrical input shall be designed to meet the requirements of MIL-STD-461 and MIL-E-6051. The degree of compliance per MIL-STD-461 for actuator performance, test procedures, and test equipment shall be as set forth in MIL-STD-462 and the detail specification.
- 3.5.4 **Interchangeability:** Parts, components, sub-assemblies, and assemblies having the same part number shall meet the requirements of MIL-I-8500 and be interchangeable both physically and performance-wise with other parts bearing the same part number.

SAE ARP1281 Revision B

3.6 Documentation:

- 3.6.1 Analysis Requirements:** The detail specification shall indicate the general analysis approach and analysis procedures that could be applicable to all servoactuator designs for the specific vehicle.
- 3.6.2 Reliability Analysis:** A reliability analysis of the servoactuator using a reliability mathematical model shall be performed. The minimum reliability limits and prediction of MTBF shall be determined in accordance with MIL-STD-785. The failure mode and effects portion of this analysis shall be prepared in accordance with ARP926.
- 3.6.3 Design Analysis:** As a minimum, the following areas shall be considered:
- 3.6.3.1 Performance:** Substantiation of servoactuator performance and limits thereof.
- 3.6.3.2 Moving Parts Clearance:** Demonstration of adequate clearance of all moving parts under all combinations of environments and loads.
- 3.6.3.3 Selection of Materials and Minimum Size of Structural Members:** Justification shall be provided for materials and processes employed and for all operational stress levels anticipated.
- 3.6.4 Qualification Analysis:** When items, components, or complete servoactuators are qualified on similarity basis, sufficient data, i.e., test and/or analytical data shall be furnished to the procuring activity to demonstrate that those part, or parts, can be fully qualified.
- 3.6.5 Drawings:** Unless otherwise specified in the detail specification, drawings applicable to parts, components, subassemblies and the complete servoactuator assembly shall be in accordance with DOD-D-1000. Schematic drawings of the servoactuator's hydraulic, electrical and mechanical linkage systems shall form a part of the drawings to be submitted.
- 3.6.6 Model:** A full size model (plastic, rapid prototype or even solid CAD) may be submitted in lieu of written documentation to demonstrate noninterference of moving parts, spacing of fluid passages, etc., on complex servoactuator sections or of the complete assembly.

4. QUALITY ASSURANCE PROVISIONS:**4.1 General:**

The quality assurance provisions shall be in accordance with the detail specification and as specified herein. The supplier shall have a quality system which conforms to the requirements of MIL-Q-9858. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the procuring activity or airframe contractor as specified in the contract.

SAE ARP1281 Revision B

4.2 Test Requirements:

Appropriate testing, as outlined herein, shall be conducted during the development and production of servoactuators to insure proper design and performance, continuing quality throughout production, and the degree of unit reliability expected in service.

4.2.1 Optional Procedures: At the option of the procuring organization any of the test requirements specified herein may be waived, or modified, owing to design experience or operating considerations. Request for waiver or modification of test requirements shall be accompanied by complete detailed information and justification.

4.3 Classification of Tests:

The following test programs, for the purpose of demonstrating compliance of servoactuators with the requirements of this specification, shall be classified as follows:

4.3.1 Acceptance Tests: These tests are performed on each servoactuator to demonstrate baseline performance.

4.3.2 Preproduction Tests: These tests are performed on the initial unit(s) to provide a basis for preliminary design approval to proceed with the production program and initial aircraft flight tests. The preproduction test specimens shall approximate as nearly as practicable the intended units in design configuration, material, processing and production techniques. Safety of flight assurance tests, in addition to the acceptance tests, shall be as specified in the detail specification and should include tests as outlined in 4.7.

4.3.3 Qualification Tests: These tests are performed on production configuration servoactuators to confirm full compliance with the requirements of the detail specification. Each test specimen shall initially and periodically throughout the qualification tests, be subjected to the Acceptance Tests per 4.3.1.

4.4 Test Procedures:

4.4.1 Acceptance Test: The acceptance test procedure shall specify those tests which each servoactuator shall satisfactorily complete as a condition for acceptance. The procedure shall insure that each servoactuator which is accepted meets the basic dimensional and performance requirements. It shall describe tests in detail indicating the environmental conditions, specifying the test fixtures, equipment and instrumentation, the format of the individual unit test data sheet or test log, and the measurements and observations which shall be recorded. The procedure shall be updated when subsequent testing or usage indicates additional or modified tests should be incorporated.

SAE ARP1281 Revision B

- 4.4.2 Preproduction Test Procedure: The preproduction or safety of flight test procedure shall specify those tests which are necessary to demonstrate the servoactuator is satisfactory for limited life usage for initial flight tests prior to formal qualification test completion. Cycle testing tests may be abbreviated to meet expected environmental conditions during flight tests. As a minimum, the preproduction or safety of flight tests shall include the tests of 4.7.
- 4.4.3 Qualification Test Procedure: The qualification test procedure shall specify those tests which are necessary to demonstrate that the servoactuator is satisfactory for the use for which it is intended. As a minimum, the qualification tests shall include all the applicable tests specified in 4.8 and its subparagraphs. These tests shall demonstrate that adequate margins exist with respect to all the critical parameters associated with the intended use of the servoactuator. Additional tests shall be added to the plan whenever it appears that the specified tests do not measure all of the parameters which may be critical in a particular application, such as certain dynamic characteristics of the servoactuator. The qualification test procedure shall prescribe the format for the test log and detail instructions for maintaining the test log. Also, provisions shall be included in the test procedure for certification by a representative of the procuring activity at stated periods during testing. The test procedure shall establish the procedure to be followed when the test specimens do not meet the individual test requirements.
- 4.5 Test Conditions:
- 4.5.1 Test Fluid: Unless otherwise specified in the detail specification, the test fluid for Type I and Type II system components shall conform to Specification MIL-H-5606, MIL-H-83282, MIL-H-6083 or MIL-H-46190. The test fluid for Type III components shall be the same as or equivalent to the fluid specified in the detail specification. For preproduction and qualification tests, the test fluid shall be the same fluid as that to be used in the system in which the actuator will be installed.
- 4.5.2 Fluid Temperature: Unless otherwise specified the fluid temperature shall be maintained as specified for each individual test with a tolerance of ± 10 °F. If the fluid temperature is not specified, the temperature shall be 100 °F ± 10 °F. The fluid temperature shall be measured as near as practicable to the servoactuators and shall be bled of air and inert gas and maintained full of fluid per 4.5.1.
- 4.5.3 Test Fluid Filtration: Unless otherwise specified in the detail specification, the test fluid shall be continuously filtered through a filter element which conforms to specification MIL-F-8815 (15 μ m or equivalent efficiency). The filter and element used shall be satisfactory for the temperature range encountered. Unless otherwise specified in the detail specification, the degree of contamination in the test setup, except for those tests required per 4.8.21, shall not exceed Class 7 (military) or Class 8 (commercial) per AS4059.

SAE ARP1281 Revision B

- 4.5.4 Hydraulic Power Supply: Tests shall be conducted with a power driven pump or fluid power source capable of supplying pressures and flow at the servoactuator ports as required by the detail specification. The test setup shall be such as to prevent air or moisture from coming in contact with the hydraulic fluid. Pressure spikes, pump ripple, contamination level, etc. shall be specified by the detail specification.
- 4.5.5 Environmental Conditions: Unless otherwise specified in the detail specification, the ambient temperature tolerance shall be ± 1 °F for test values specified herein. If environmental conditions are not specified or if "room conditions" are specified, the ambient temperature shall be $73 \text{ °F} \pm 18 \text{ °F}$, the barometric pressure shall be 27.3 ± 3.3 in Hg, and the relative humidity shall not exceed 80%.
- 4.5.6 Test Instruments: The instruments used to measure and record required test parameters shall be calibrated in accordance with MIL-STD-45662 and shall meet the accuracy requirements of MIL-STD-810. These instruments shall be recalibrated as necessary to insure accuracy of test results.
- 4.5.7 Test Fixtures: The servoactuators shall be mounted in appropriate test fixtures during testing outlined herein. The detail specification shall specify the degree to which the fixture will simulate the aircraft installation including structural compliance. The aerodynamic and inertia loading shall be utilized during the performance and endurance portion of the qualification tests.
- 4.5.8 Steady-State Tests: Steady-state tests are defined as tests conducted under selected steady-state conditions. Each test is usually conducted as an individual test, but in some cases may be combined, subject to the selected constant conditions. These tests do not include all the conditions to which the servoactuator will be subjected, but will be representative of those conditions and are intended to provide proof that the unit will operate satisfactorily in service under these conditions.
- 4.5.9 Mission-Profile Tests: Because of the advance in aircraft performance with the accompanying complexity in requirements, purely steady-state condition tests may be insufficient to provide proof that the component will operate satisfactorily in service. In such cases, it will be necessary to conduct tests simulating the frequency, magnitude, and duration of the conditions which the servoactuator is expected to encounter during the course of an actual air vehicle mission. Mission-shock, altitude, vibration, acceleration, shock, performance, and endurance tests as one integrated test, or as specified in the detail specification.
- 4.6 Acceptance Test Methods:
- 4.6.1 General: Each servoactuator shall be subjected to the following examination and acceptance tests specified in the detail specification. These tests may be supplemented by individual component tests when required.

SAE ARP1281 Revision B

- 4.6.2 Examination of Product: The servoactuator shall be carefully examined to determine conformance with the requirements of this specification and the detail specification for workmanship, marking, conformance to applicable engineering drawings, conformance to applicable AN or MS standards, and for any visible defects.
- 4.6.3 Operation and External Leakage: The servoactuator shall be cycled with the piston rod unrestrained through at least 500 full stroke cycles to demonstrate satisfactory operation, stroke, adjustment, freedom of motion, and other characteristics when specified in the detail specification. Pressure shall build up to system pressure at the end of each stroke. There shall be no leakage allowed at any joint or boss. Leakage, at each point where motion through external packings exist, shall meet the requirements of the detail specification.
- 4.6.4 Chatter: During the course of testing, the output motion of the servoactuator shall be monitored for evidence of adverse noise, chatter or instability. If a special test is required, testing procedure shall be as specified in the detail specification.
- 4.6.5 Proof Pressure:
- 4.6.5.1 Inlet Proof Pressure: The inlet port of the servoactuator shall be subjected to a pressure of 5 psig and also to 1.5 times the nominal operating pressure or the applicable proof pressure as specified, whichever is greater, for a period of 3 min for each pressure application. These pressures shall be applied with a maximum input signal or command position and the piston in both the fully extended and retracted directions. There shall be no evidence of external leakage (other than slight wetting at seals insufficient to form a drop), excessive distortion or permanent set.
- 4.6.5.2 Return Proof Pressure: The return port of the servoactuator shall be subjected to the operating system pressure or the specified return proof pressure whichever is greater, for a period of 3 min. There shall be no evidence of external leakage (other than a slight wetting at seals insufficient to form a drop), excessive distortion or permanent set.
- 4.6.6 Internal Leakage: The servoactuator shall be subjected to nominal operating pressure at the inlet port with the return port vented to atmosphere for a period of 5 min for each pressure application. The pressure shall be applied with a neutral or zero input signal or position and the servoactuator in its neutral position, and at each end of the stroke with extend and retract signal applied. The leakage measurement shall be taken in the last 3 min of the 5 min period. Rate of leakage shall not exceed that specified in the detail specification.
- 4.6.7 Supplementary Acceptance Tests: The detail specification shall specify which, if any, and the test procedures for the following acceptance tests in Table 3:

SAE ARP1281 Revision B

TABLE 3 - Acceptance Test

Paragraph No.	Test	Reference Paragraph
4.6.7.1	Loop Gain	Table 1
4.6.7.2	Position Sensitivity	Table 1
4.6.7.3	Rated Velocity	Table 1
4.6.7.4	Threshold	Table 1
4.6.7.5	Hysteresis	Table 1
4.6.7.6	Frequency Response	Table 1
4.6.7.7	Transient Response	Table 1
4.6.7.8	Chatter	Table 1
4.6.7.9	Stiffness	Table 1
4.6.7.10	External Load	Table 1
4.6.7.11	Null Shift	Table 1
4.6.7.12	Gain Margin and Phase Margin	Table 1
4.6.7.13	Synchronization	3.3.1.2.1
4.6.7.14	Electrohydraulic Servo Valve	3.1.1.2
4.6.7.15	Dielectric Strength	3.1.2.2
4.6.7.16	Snubbing Rates	3.1.5.1.5
4.6.7.17	Linearity	Table 1

4.6.8 Rejection and Retest: Failure of any servoactuator to conform to any of the acceptance tests shall be cause for rejection of that assembly. Servoactuator assemblies which have been rejected may be reworked or have parts replaced to correct the defects found in the original and resubmitted for acceptance. Replaced parts shall be in accordance with outstanding detail design drawings.

4.7 Preproduction Test Methods:

4.7.1 Sampling and Tests: The number of specimens to be used in testing, the applicable tests, and the order of combination in which the tests will be performed for each specimen shall be in accordance with the detail specification.

4.7.2 Pretest Inspection: The diameters, out of roundness, and finish smoothness on sliding surfaces such as cylinder bore, piston rods, and control linkage bearing surfaces, shall be accurately determined for each test specimen and recorded prior to initiation of the test program in order to determine degradation of the equipment due to the specified test.

4.7.3 Acceptance Tests: Each test specimen shall be subjected to the acceptance tests as defined in 4.6, to determine baseline capability and performance.

4.7.4 Proof Load: The inlet proof pressure test per 4.6.5 shall be repeated except the servoactuator shall be installed in a fixture with the piston rod restrained in an extended piston at one or more of its critical positions as a column (piston not bottomed). The test shall be conducted with both ambient and hydraulic fluid temperatures corresponding to the maximum rated value for the servoactuator type classification.