AEROSPACE RECOMMENDED PRACTICE

Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

ARP 1281

Issued January 1974
Revised

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

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PREPARED BY
SUBCOMMITTEE A-6D, SERVOVALVE AND FLUID ACTUATION PANEL, of
SAE COMMITTEE A-6, AEROSPACE FLUID POWER & CONTROL TECHNOLOGIES

1. SCOPE

1.1 Scope: This specification establishes the requirements for power operated hydraulic servoactuators when used in flight control systems. These servoactuators may be controlled by mechanical, hydraulic or electrical inputs or combinations thereof, and may be powered by one or more hydraulic systems. The complete servoactuator package may incorporate primary components such as control servovalve, input linkage and position feedback lever in addition to the actuating cylinder. Secondary components may also be included such as stability and control augmentation actuators, bypass valves, residual pressure compensators, electrohydraulic servovalves, filters, pressure switches, motor or solenoid operated shut-off valves, thermostatic control valves, hydraulic logic, mechanical locking devices and electrical transducers.

1.2 Classification: Servoactuators covered by this specification are classified as follows:

Type I -65° F to +160° F (-54° C to +71° C) fluid temperature range.

Type II -65° F to +275° F (-54° C to +135° C) fluid temperature range.

Type III -65° F to +450° F (-54° C to +232° C) fluid temperature range.

2. APPLICABLE DOCUMENTS

2.1 Documents: The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

Specifications:

Federal

FF-B-185 - Bearings, Roller, Cylindrical, and Bearings Roller, Self-Aligning

QQ-C-320 - Chromium Plating (Electrodeposited)

QQ-N-290 - Nickel Plating (Electrodeposited)

QQ-P-416 - Plating, Cadmium (Electrodeposited)

QQ-S-365 - Silver Plating, Electrodeposited, General Requirements for

QQ-Z-325 - Zinc Coating, Electrodeposited, Requirements for

Military

MIL-A-8625 - Anodic Coatings, for Aluminum and Aluminum Alloys

MIL-B-3990 - Bearings, Roller, Needle, Airframe, Antifriction

MIL-B-5087 - Bonding, Electrical, and Lightning Protection, for Aerospace Systems

MIL-B-5628 - Bearings, Plain, Airframe

MIL-B-6038 - Bearings, Ball, Bellcrank, Antifriction, Airframe

MIL-B-6039 - Bearings, Ball Rod End, Antifriction, Self-Aligning

MIL-B-7949 - Bearing, Ball, Airframe, Antifriction

MIL-C-5015 - Connectors, Electrical, "AN" Type

2.1 Documents (Continued)

Military (Continued)

MIL-C-5501 - Caps and Plugs, Protective, Dust and Moisture Seal

MIL-C-5541 - Chemical Films and Chemical Film Materials for Aluminum and Aluminum Alloys

MIL-C-8837 - Coating, Cadmium (Vacuum Deposited)

MIL-C-11796 - Corrosion Preventing Compound, Petrolatum, Hot Application

MIL-C-18244 - Control and Stabilization Systems, Automatic Piloted Aircraft, General Specification for

MIL-C-26074 - Coating, Nickel - Phosphorous, Electroless Nickel, Requirements for

MIL-C-26482 - Connectors, Electric, Circular, Miniature, Quick Disconnect

MIL-C-45662 - Calibration System Requirements

MIL-D-1000 - Drawing, Engineering and Associated List

MIL-F-3541 - Fittings, Lubrication

MIL-F-7190 - Forgings - Steel for Aircraft and Special Ordnance Applications

MIL-F-8815 - Filter and Filter Elements, Fluid Pressure, Hydraulic, Line, 15 Micron Absolute, Type II Systems

MIL-F-9490 - Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification for

MIL-F-18372 - Flight Control Systems - Design, Installation and Test of, Aircraft (General Specification for)

MIL-F-22191 - Films, Transparent, Flexible, Heat Sealable, for Packaging Applications

MIL-F-25682 - Filter and Filter Element, Fluid Pressure, Hydraulic, Absolute, 25 Micron, -65° F to 450° F and 600° F

MIL-G-5514 - Packings, Installation and Gland Design, Hydraulic, General Specification for

MIL-H-5440 - Hydraulic Systems, Aircraft, Types I and II, Design, Installation, and Data Requirements for

MIL-H-5606 - Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance

MIL-H-6083 - Hydraulic Fluid, Petroleum Base, for Preservation and Testing

MIL-H-8775 - Hydraulic System Components, Aircraft and Missiles, General Specification for

MIL-H-8890 - Hydraulic Components, Type III, (-65° to +450° F), General Specification for

MIL-H-8891 - Hydraulic Systems, Manned Flight Vehicles, Type III, Design, Installation, and Data Requirements for

2.1 Documents (Continued)

Military (Continued)

MIL-I-6866 - Inspection, Penetrant Method of

MIL-I-6868 - Inspection Process, Magnetic Particle

MIL-L-6880 - Lubrication of Aircraft, General Specification for

MIL-M-8609 - Motors, Direct-Current, 28-Volt System Aircraft, Class A and B, General Specification for

MIL-N-25027 - Nut, Self-Locking, 250°F, 450°F, and 800°F, 125 KSI FTU, 60 KSI FTU, and 30 KSI FTU

MIL-P-5517 - Plastic Parts in Aircraft Hydraulic Equipment, General Tests for

MIL-P-25732 - Packing, Preformed, Petroleum Hydraulic Fluid Resistant, 275°F

MIL-Q-9858 - Quality Program Requirements, Military Specification

MIL-S-4040 - Solenoid, Electrical, General Specification for

MIL-S-5002 - Surface Treatments and Metallic Coatings for Metal Surfaces or Weapon Systems

MIL-S-6743 - Switches, Push Button and Limit

MIL-S-8802 - Sealing Compounds, Temperature Resistant, Integral Fuel Tanks and Fuel Cell Cavities High Adhesion

MIL-S-8805 - Switches and Switch Assemblies, Sensitive and Push (Snap Action), General Specification for

MIL-S-8879 - Screw Threads, Controlled Radius Root with Increased Minor Diameter, General Specification for

MIL-T-10727 - Tin Plating - Electrodeposited or Hot-Dipped, For Ferrous and Non Ferrous Metals

MIL-V-7915 - Valves - Hydraulic, Directional Control, Slide Selector

MIL-V-27162 - Valves - Servo Control, Electro-Hydraulic, General Specification for

Standards:

Military

MIL-STD-130 - Identification Marking of U.S. Military Property

MIL-STD-210 - Climate Extremes for Military Aircraft

MIL-STD-785 - Requirements for Reliability Program (for Systems and Equipment)

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

MIL-STD-810 - Environmental Test Methods

2.1 Documents (Continued)

Standards:

Military (Continued)

MIL-STD-831 - Test Reports, Preparation of

MIL-STD-889 - Military Standard Dissimilar Materials

MS 15002 - Fittings, Lubrication (Hydraulic) Surface Check, Straight Threads, Steel, Type II

MS 24391 - Plug - Bleeder Screw Thread, Precision Type

MS 28776 - Scraper, Piston Rod

MS 28778 - Packing, Preformed, Straight Thread Tube Fitting Boss

MS 33540 - Safety Wiring and Cotter Pinning, General Practices for

MS 33547 - Pins, Spring Functional Limitations of

MS 33586 - Metals, Definition of Dissimilar

MS 33588 - Nuts, Self-Locking, Aircraft, Design and Usage Limitations of

MS 33649 - Bosses, Fluid Connection - Internal Straight Thread

MS 33675 - Scraper, Installation, Packing Gland Ring

Air Force - Navy Aeronautical

AN 814 - Plug and Bleeder - Screw Thread

AN 6204 - Valve, Hydraulic Bleeder

ANA Bulletin 438 - Age Control of Air Sensitive Elastomers

AND 10067 - Valve Installation - Hydraulic Bleeder (Standard Dimensions for)

AND 10074 - Boss Spacing - Hydraulic

NAS 1638 - Cleanliness Requirements for Parts Used in Hydraulic System

Publications:

Defense Supply Agency

Cataloging Handbook H6-1 - Part 1 - Federal Item Identification Guides for Supply Cataloging

Department of Defense

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

2.1 Documents (Continued)

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

2.2 Other Publications: The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

Society of Automotive Engineers, Inc.

Aerospace Recommended Practices

ARP 243 - Nomenclature, Aircraft Hydraulic and Pneumatic Systems

ARP 490 - Electrohydraulic Flow-Control Servovalves

ARP 926 - Design Analysis Procedure for Failure Mode, Effects and Criticality Analysis (FMECA)

Aerospace Material Specification

AMS 2419 - Cadmium-Titanium Alloy Plating

(Application for copies should be addressed to the Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York 10001.)

3. REQUIREMENTS

3.1 Specifications: The complete specification for servoactuators consists of this specification, a detailed specification to be prepared by the airframe contractor in compliance with applicable portions of MIL-F-9490 (Air Force) or MIL-F-18372 (Navy) and the following specification as limited herein.

	Types I and II	Types III
Hydraulic Systems	MIL-H-5440	MIL-H-8891
Hydraulic Components	MIL-H-8775	MIL-H-8890

3.2 Precedence of Specifications: This specification shall take precedence in case of conflict with the requirements of other military specifications.

3.3 Materials: The materials used in servoactuators shall be suitable for the service and purpose intended and shall conform to the applicable government specification when such specifications exist for the type of 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 in the Design Analysis per 3.6.1. 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.

3.3.1 Metals: All metals shall be compatible with the hydraulic fluid used and with the intended temperature, functional 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. Dissimilar metals are defined in MIL-STD-889 shall not be used in direct contact during fabrication, installation or assembly. Consideration shall be given to providing materials resistant to fluid erosion.

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%.

3.3.1.2 Type I and Type II Components: Unless otherwise specified, ferrous, titanium, or aluminum alloys may 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 pressure vessels and hydraulic ports is prohibited. Aluminum pressure vessels subjected to 3,000 psi or greater hydraulic pressure shall be forged without flash formation at die parting lines.

3.3.1.3 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.

3.3.1.4 Stabilization: For heat treat hardened martensitic steels hardness ranges in excess of Rc 50, a cold stabilization treatment is considered a necessary operation to transform retained austenite for improved dimensional stability. Where such materials are used, the detail specification shall specify the materials and the processing required.

3.3.1.5 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.

3.3.2 Mechanical Rubber Components: Mechanical rubber components and seals shall be designed primarily from elastomeric material possessing the maximum resistance to ozone, weathering, and temperature, and shall be compatible with the hydraulic fluids with which they are in contact.

3.3.3 Control and Inspection: Forgings used in the assembly shall be controlled and inspected in accordance with the requirements of MIL-F-7190 and MIL-I-6868.

3.4 Design and Construction:

3.4.1 Servoactuator Assembly:

3.4.1.1 Reliability: 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 specified in terms of 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 in the detail specification as any malfunction causing performance degradation outside the limits of the specification.

3.4.1.2 Maintainability: The maintainability characteristics for the servoactuator shall be specified in the detail specification 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 on the servoactuator while installed in the air vehicle.

d. The mean maintenance man-hours required to perform a maintenance task, including overhaul, in the field and depot maintenance shops.

3.4.1.2 (Continued)

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).

3.4.1.2.1 Maintenance and Repair Cycles: The time interval between preventative maintenance tasks shall be specified in air vehicle flight hours in the detail specification. The time interval between filter element replacements, providing the hydraulic system cleanliness is maintained at all times to class 6 per NAS 1638 or better, shall be specified in air vehicle flight hours.

3.4.1.3 Useful Life: Useful life, defined as the time from the delivery of the servoactuator from the supplier's facility until its identity is destroyed, shall be as specified in the detail specification and shall be compatible with 3.4.1.1.

3.4.1.4 Vulnerability: The detail specification shall establish the vulnerability design requirements. Consideration shall be taken to the proper positioning of the more critical components so as to provide protection from ground fire.

3.4.1.5 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.

3.4.1.6 Strength: 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.

3.4.1.6.1 Output and Input Operating Loads: The detail specification shall specify the maximum external operating loads resulting from the minimum pressure differential across the actuator for all stroke positions of the actuator.

3.4.1.6.2 Output and Input Limit Loads: The detail specification shall specify the output limit loads and prohibit permanent deformation or brinneling of parts. These loads shall be combined with the limit load factors.

3.4.1.6.3 Output and Input Ultimate Load: The detail specification shall specify that the servoactuator shall withstand with the output restrained a load 1.5 times the limit load specified in 3.4.1.6.2 without failure for a specified period of time.

3.4.1.7 Stiffness: The detail specification shall indicate the required servoactuator and mounting structure spring rate, load inertia, structural mounting arrangement of mechanical input members, and stability requirements. Consideration shall be given to the effect on the fluid spring rate (bulk modulus) under the most adverse conditions of temperature and air entrapment. Where multiple hydraulic systems are involved single system criteria shall be defined.

3.4.1.8 Orientation: Normal installation position or range of positions shall be as specified in the detail specification. Partial or complete inversion of the servoactuator, as encountered during flight, with the servoactuator either nonoperative, in standby operation, or in full operation shall have no adverse effect on its performance.

3.4.1.9 Assembly Criteria: All servoactuator component parts shall be designed to preclude incorrect assembly and the assembly shall be incapable of being installed incorrectly.

3.4.1.10 Damage Prevention: All elements of the servoactuator shall be suitably guided, protected, or covered where it is possible for them to be damaged by dropping of articles, tools, dirt, ice, etc.

3.4.1.11 Drainage: Adequate provisions shall be made to drain components subject to the accumulation of moisture or fluid leakage. Pockets, wells, traps and the like into which water, condensed moisture or other liquids can drain or collect shall be eliminated, or properly drained.

3.4.1.12 Accessibility and Serviceability: The servoactuator shall be designed for servicing when installed in the specified aircraft area and the detail specification shall identify preferred location for such servicing. Servoactuator components shall be designed, installed and located when possible so that inspection, rigging, removal, 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. 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.

3.4.1.12.1 It is desirable that installation be implemented without requiring adjustments of the servoactuator. All components requiring lubrication other than those being lubricated with the hydraulic fluid shall be capable of being lubricated in accordance with MIL-L-6880. Lubrication fittings shall be in accordance with MIL-F-3541 and MS 15002. Whenever possible, permanently lubricated components shall be provided.

3.4.1.13 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 and information 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.

3.4.1.14 Multiple Channel Servoactuators: Units powered by two or more hydraulic systems shall be designed to preclude the possibility of a single structural failure causing the loss of two or more hydraulic systems. In addition, lack of hydraulic pressure in one system shall exert a minimum effect on the performance of the remaining system(s). The conditions relating to performance effect shall be specified in the detail specification.

Tandem cylinders shall be designed with a vent between adjacent hydraulic systems to prevent interflow. Output members, rod and rod ends, shall be capable of carrying the full loads with all hydraulic systems operating in unison.

3.4.1.15 Lower Pressure Systems: Systems which operate at pressure lower than full hydraulic system pressure shall be designed to withstand and operate under the full system pressure or shall have a relief valve installed downstream of the pressure reducer if full systems pressure would be detrimental or dangerous.

3.4.1.16 Fluids: The servoactuators shall be designed for hydraulic fluid specified in the detail specification.

3.4.1.17 Storage: The servoactuator shall be designed for a maximum practical storage life without reconditioning before operational use or return to storage. The servoactuator shall be capable of withstanding controlled field storage for a period of five years without degradation of service life, performance, and reliability. The servoactuator shall be capable of immediate service use without operational conditioning or maintenance during storage periods up to 24 months. However, units which contain elastomeric items shall, when properly prepared for storage, have a minimum shelf life according to ANA Bulletin 438.

3.4.2 Cylinder Assembly: The cylinder assembly shall conform to the envelope shown on the specification control drawing and to the requirements of MIL-C-5503 as applicable.

3.4.2.1 Piston Head and Rod Bearing Length:

3.4.2.1.1 Bearing Area: The piston head(s) shall have adequate bearing area on the cylinder wall to carry any of the compression, bending and vibration loads without discernible deformation. The length of the piston rod bearing shall be sufficient to insure satisfactory operation and adequate service life.

3.4.2.1.2 Bearing Overlap: The servoactuator bearing overlap is considered to be the distance between the extreme faces of the rod bearing and the piston bearing when the piston is fully extended. As a general rule, this overlap should be at least 1-1/2 times the piston diameter, particularly where long strokes or unbalanced piston configurations are involved.

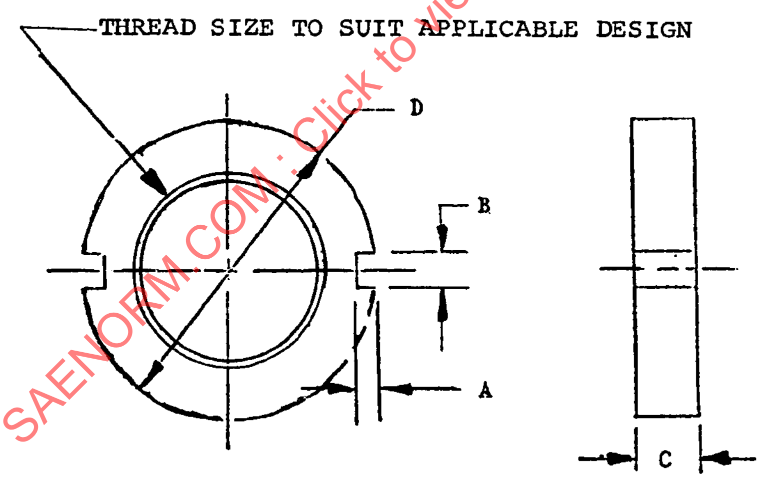
3.4.2.1.3 Eccentricity: The allowable eccentricity, total indicator reading (T.I.R.) between the outside diameter of all piston heads and rods plus the eccentricity between the bores for the piston head and the bores for the rods after assembly shall not cause detrimental binding or galling within the required temperature and pressure operating ranges.

3.4.2.2 Scraper Rings and Wipers:

3.4.2.2.1 Scraper Rings: Scraper rings suitable for the application or conforming to MS28776 installed in a groove per MS33675, shall be provided for servoactuator piston rods which are exposed to dirt, ice, and foreign matter detrimental to the normal functioning and service life of the cylinder assembly.

3.4.2.2.2 Wipers: The use of wipers for seal lubrication is not current practice in military or commercial applications and is to be discouraged.

3.4.2.3 Dashpots: Where the kinetic energy of cylinder and mechanism are 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 design, preferably selfcleaning, shall be used. An analysis shall be made to ensure sufficient structural strength to withstand high hydraulic pressures encountered during operation. The rate of change of piston velocity and load inertia shall be as specified in the detail specification.



D DIAMETER	A MIN	B MIN	C MIN
3/4 to 2 incl	0.120	0.120	1/4
1 3/4 to 4 incl	0.120	0.190	5/16
3 1/2 to 6 incl	0.190	0.250	3/8

FIGURE 1
DIMENSIONS FOR END CAPS AND LOCKNUTS, FOR USE WITH SPANNER WRENCHES AN-8514, AN-8515, AND AN-8516 KEY ARM TYPE ONLY

3.4.2.4 End Caps, Locknuts, and Adjustment Nuts: 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.

3.4.2.5 Rod Ends: These components shall be designed to minimize stress risers. Integral anti-rotation devices means are preferred. 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.

3.4.3 Mechanical Input Control Servovalves: The control valve(s) shall be designed to give smooth operation. Internal leakage shall be a practicable minimum, consistent with permissible operating forces, temperature effects, control sensitivity, fluid contamination levels, and other governing factors. The spool and sleeve shall be made of materials which are similar in mechanical properties, especially in regards to coefficient of expansion.

3.4.3.1 Synchronization: Servovalves in multiple channel servoactuators shall produce cylinder pressure 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.

3.4.3.2 Flow Forces: Mechanical input servovalves may be designed to reduce flow forces consistent with the requirements of 3.4.3.6. Flow force compensation shall not cause negative flow force gradients (i.e., forces which tend to move the spool away from null), and the design shall be consistent with the requirements of the detail specification.

3.4.3.3 Friction: Breakout and dynamic friction shall be controlled in accordance with the detail specification.

3.4.3.4 Stops: The servovalves shall have integral stops to limit spool travel in both directions. These stops, when required, shall withstand the limit load specified in the detail specification without deformation or jamming.

3.4.3.5 Direction of Force: The valve shall have not more than 5 percent change in operating force due to the input being applied to the spool at any angle within 5 degrees (.08 rad) from the axial direction.

3.4.3.6 Input Operating Force: The detail specification shall specify the force requirements for shearing any particle that may enter the valve and the maximum load that will be applied to the spool and linkage. The allowable operating force required to move or hold the spool in any position shall also be specified. It is desirable to specify operating force and temperature as a function of dwell time under pressure prior to applying the input force. Inlet and return pressure and degree of filtration shall be specified.

3.4.4 Linkage and Pivots: Linkages and associated pivot points must be designed to minimize the possibility of a single failure permitting a catastrophic condition in the flight control circuit. The input linkage shall permit direct input lever force, modified by the linkage ratio, to the control servovalve prior to reaching full input travel in the event the servovalve becomes jammed or frozen. All control input pivot points must provide low friction with minimal play. Pivot points shall contain permanent type fasteners or positive locking means. Friction locks are not considered to be positive locking means. Dual load path linkage structure is encouraged where the installation prevents periodic inspection.

3.4.5 Electrohydraulic Servovalves: Electrohydraulic servo-valves shall be designed in accordance with MIL-V-27162 and SAE ARP 490. Life and environmental requirements shall be consistent with those for the servoactuator. The detail specification shall define the electrical parameters of the servovalve.

3.4.6 By-Pass 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.

3.4.7 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 close as possible to the servovalve and shall remove 250 micron or larger contamination particles.

Screens shall be installed in the inlet to prevent hydraulic line contaminants to the control servovalve or servoactuator entering the unit providing an integral filter is not a requirement.

3.4.8 Electrically Controlled On/Off Valves:

3.4.8.1 Voltage: Electrically actuated valves designed for 28-volt direct-current systems shall operate at a minimum of 18 volts with operating pressure applied to the valve, and shall operate at 1-1/2 times operating pressure at 28 volts. Electrically actuated valves designated for 115-volt alternating-current systems shall operate at a minimum of 85 VAC with operating pressure applied to the valve, and shall operate at 1-1/2 times operating pressure 115-VAC.

3.4.8.2 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.

3.4.8.3 Motor-Operated Valves: Motors for operating valves shall conform to MIL-M-8609.

3.4.8.4 Solenoid-Operated Valves: Solenoid for operating valves shall be in accordance with MIL-S-4040 and the following requirements.

3.4.8.4.1 Temperature Rise: Solenoids designed for continuous operation on a 115 volt alternating current and 28-volt direct-current systems shall not have a temperature rise greater than the maximum fluid operating temperature. These requirements shall pertain with the valve installed on the servo actuator.

3.4.8.4.2 Coils: The 28-volt solenoids shall be capable of withstanding a test voltage of not less than 600 volts rms for 60 seconds. The 115-volt solenoids shall be capable of withstanding a test voltage of not less than 1,250 volts rms for 60 seconds. These test voltages should not be applied more than three times during the useful life of the coil. The coils shall be wound and insulated to meet the performance requirements specified herein. The coils shall be completely insulated from the frame and other ground parts and shall be suitably taped and impregnated as required to prevent damage under prolonged exposure to humidity and salt-fog environmental conditions.

3.4.8.4.3 Terminals: The solenoid coil shall be terminated with a connector as specified in the procurement document and of appropriate size suitably plated and insulated from the solenoid housing and designed to withstand tension and bending loads.

3.4.8.4.4 Creepage and Clearance Distances: The minimum creepage distance between uninsulated current-carrying parts and ground shall be 0.125 in. (3.18 mm) and the minimum spacing between uninsulated current-carrying parts and any other portion of the solenoid, other than the insulating material. The minimum clearance between current-carrying parts of opposite polarity, shall be 0.062 in. (1.57 mm).

3.4.9 Position Transducer: Requirements relating to type, location, and the electrical interface shall be in accordance with the detail specification. The electrical characteristics shall meet the requirements of 3.4.8.

3.4.10 Miscellaneous Design Details:

3.4.10.1 Electrical Connectors: 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 component replacement. Connectors shall be ridigly mounted and shall be of such construction that they will not warp or cause intermittent operation when subjected to the levels of temperature differential, vibration, and shock specified for the equipment.

3.4.10.2 Joints: All adjoining parts shall be secured in a manner that would preclude loosening when subjected to internal or external loading or vibration. Welding, brazing, swaging or other approved methods may be used provided the primary loads can be carried by the base metal. Sweat-soldering shall not be used to join any parts.

3.4.10.2.1 All threaded joints shall be locked securely and in a way that would prevent load reversal at the threads. All threaded joints which carry primary structural loads shall be positively locked in the assembled position to prevent loosening or changing adjustment during operation. The use of jam locknuts is not considered a positive locking means unless lockwired and otherwise restrained.

3.4.10.3 Hydraulic Closures: Multi-screw 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 with complete loss of at least one screw which is located in a critical area.

3.4.10.4 Internal Piston Locks: If internal locks are required, the detail specification shall specify the pressure conditions at which unlocking will occur and the pressure under which the actuator must remain locked. It shall also specify the externally induced loading and pressure conditions.

3.4.10.4.1 The lock design shall be as simple as possible, and upon command, the lock shall operate without subjecting the structure to unnecessary loads. It must be designed to accommodate any internally induced loads. The detail specification shall specify maximum piston motion under specified pressure and load requirements.

3.4.10.5 Ports: The location and size of all ports shall be in accordance with the detail specification. The return ports shall be a larger size than the pressure ports to avoid improper connections when the unit is installed in the system and normally shall be oriented at the highest point in installation to facilitate bleeding of entrapped air.

3.4.10.5.1 Port Marking: All ports for the tube connections shall be clearly and permanently marked to indicate the connections to be made. Where applicable, the directions of flow shall be indicated. Use of abbreviations or a single letter for marking, such as "P" for pressure and "R" for return, is not acceptable. Decalcomanias shall not be considered a permanent marking. Raised letters, engraving, and/or stamping are preferred.

3.4.10.6 Fluid Porting Through Interfaces: Fluid porting through interfacing surfaces which deflect under structural loading or pressure conditions shall utilize balanced quills 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.

3.4.10.7 Fillets: The intersection of highly stressed, thin wall cylinder barrels with heavy bulkhead areas shall incorporate generous radii. The notch sensitivity factor (q) of any portion of the servoactuator shall be limited to .70 for determination of the design stress concentration factor (K_f) in the following equations.

$$q = \frac{K_f - 1}{K_t - 1} \qquad \text{Therefore } K_f = 0.70\, K_t + 0.30$$

where K_t = Theoretical Stress Concentration Factor based on geometric considerations only.

3.4.10.8 Fluid Passages: All intersecting holes in manifold sections which are drilled shall be inclined at an angle not less than 60° (1.05 rad).

3.4.10.8.1 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.

3.4.10.9 Seals: The use of standard seals is desirable but not mandatory. However, any non-standard seal used shall provide adequate sealing for not less than 500,000 cycles under a load distribution equivalent to the seal life cycle percentage of the total life cycle expectancy. All non-standard seals shall be justified by previous practice and/or demonstration tests and approved by the procuring activity and/or airframe contractor prior to usage. In the interest of maintenance and logistics, all servoactuators for a given hydraulic system shall use the same seal design. Sufficient clearance shall exist to permit assembly of the servoactuator without damage to seals where they pass threaded parts or sharp corners. Seal designs shall preclude admittance of air in installations where the unit is subjected to suction pressures.

3.4.10.10 Lubricator Fittings and Bushings: 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.

3.4.10.11 Plugs: Permanently installed plugs that will not be removed during the life of the servoactuator shall be 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 sealed with gaskets conforming to MS 28778. Removable plugs for Type III servoactuators shall be compatible with seals specified in the detail specification.

3.4.10.11.1 Bleeder Plugs: 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 AND10067. Other types may be used, subject to approval of the procuring organization.

3.4.10.12 Bosses: Threaded bosses for connecting fittings shall conform to the requirements of the detail specification. Spacing of ports for connecting fittings shall conform to AND10074. Tube fittings and tubing, if incorporated in the assembly, shall conform to MIL-H-5440 or MIL-H-8891. Nonstandard connections shall conform to the requirements of the detail specification.

3.4.10.13 Bearings (General):

3.4.10.13.1 Antifriction: Approved type, ball bearings in accordance with MIL-B-6038, MIL-B-6039, and MIL-B-5949 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 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.

3.4.10.13.2 Spherical Bearings: Where design limitations preclude the use of anti-friction bearings, spherical type, plain bearings approved by the procuring organization may be used.

3.4.10.13.3 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-5628 with adequate and accessible provisions for lubrication may be used.

3.4.10.13.4 Sintered Bearings: Sintered type, or oil impregnated bearings shall not be used.

3.4.10.14 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 subjected to the primary structural loads). The allowable increase during endurance testing shall also be specified. If the spring rate of the bearing is critical, the detail specification shall define the allowable limits.

3.4.10.15 Fasteners: In general, fastenings and other miscellaneous hardware used in servoactuators such as nuts, bolts, etc., shall be those for which AN or MS standard exist. In cases where it is not obvious why non-standard parts are used, justification shall be required prior to procuring organization approval. In applications for which no suitable AN standard part is available, commercial parts may be used provided they conform to all of the requirements of this and the detail specification. The selection of fasteners shall insure ease and reliability of maintenance and shall eliminate the possibility of their loss from critical connections. Ability to inspect installed fasteners to insure integrity and security must be assured.

3.4.10.15.1 Bolts: Bolts smaller than 1/4 in. (6.35 mm) shall not be used to make single bolt connections, or connections which are essential to the structural performance of the servoactuator.

3.4.10.15.2 Bolt Retention: Self-locking nuts, drilled bolts, Huck bolts, castellated nuts, cotter pins, plate nuts, safety wire, or some equivalent positive means of bolt retention, shall be used. Self-locking nuts shall not be used for critical applications such as attachment of rod ends to bellcranks and attachment of servoactuators to structure, where a single attaching bolt is used to retain the component or connection servoactuator. When self-locking nuts are used, they shall be in accordance with MIL-N-25027 and MS 33588.

3.4.10.15.3 Retaining Rings: Standard retaining rings may be used in locations where they are not subjected to loads and where their loss would in no way compromise control of the aircraft. Load bearing rings may be used when they are completely enclosed so that no conceivable load, either internal or external can separate or dislodge them. Each installation utilizing retaining rings must be approved by the procuring organization.

3.4.10.16 Lock Wiring: All hardware and components which are not positively secured by other means, shall be secured by lockwire or cotter pins in accordance with MS 33540.

3.5 Performance:

3.5.1 Open Loop Gain: The detail specification shall specify values for open loop gain of the servoactuator as defined as the product of valve flow gain times the feedback ratio, divided by the cylinder net piston area times valve to actuator motion (feedback ratio). Gain around the valve hydraulic null may be defined by specifying allowable phase shift and amplitude ratio for small amplitude frequency response.

3.5.2 Position Sensitivity: The detail specification shall specify the actuator position sensitivity in terms of output position per unit input, together with allowable sensitivity tolerance.

3.5.3 Rated Velocity: The detail specification shall define a rated actuator velocity for specified conditions of supply and return pressures, temperature, static actuator loading, and magnitude of valve input.

3.5.4 Threshold: The threshold of a servo actuator is defined as the lowest level of input which produces a perceptible response of the cylinder output. The type and magnitude of the input command and the required cylinder output motion shall be as specified in the detail specification.

The operation conditions, such as pressures, temperatures, cylinder load, and degree of filtration prior to applying an input, shall be specified.

3.5.5 Hysteresis: The allowable hysteresis of a servoactuator, defined as the maximum difference between the increasing input and the decreasing input which cause the same cylinder output shall be specified in relation to the input signal. Operating conditions such as pressure, temperatures, cylinder load, magnitude of input, and degree of filtration shall be defined.

3.5.6 Frequency Response: Frequency response characteristics of a servoactuator are defined as the steady state relationship of the output amplitude to the input amplitude, and the output to input phase difference, when the input is subjected to constant amplitude sinusoidal signals of various frequencies. The detail specification may specify the allowable frequency response at more than one input amplitude. Unless otherwise specified, frequency response shall be considered to be a no-load condition. Maximum and minimum curves may be used to define the limits.

3.5.7 Null Shift: The detail specification shall specify permissible change in input command required to maintain a constant output position as a result of changes in temperature, pressures, acceleration, life and use.

3.5.8 Chatter: The design of the servoactuator shall be such as to preclude instability or chatter of the servoactuator under conditions of loading and input commands as specified in the detail specification. In no case shall high frequency pressure fluctuations not corresponding to input commands be present in the pressure and return lines of the servoactuator.

3.5.9 Operating Pressure: The nominal operating pressure, both supply and return, and the limits of pressure variations, shall be as specified in the detail specification. The magnitude and rate of change of internal pressure surges due to control valve operation shall be accounted for in the structural design.

3.5.10 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.

3.5.11 Leakage:

3.5.11.1 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 the piston seals and the control servovalve.

3.5.11.2 Intersystem Leakage: Allowable leakage between systems for multi-hydraulic supplied actuators shall be specified. The leakage value shall be specified under conditions of extreme difference between systems supply and return pressures.

3.5.12 Environmental: The servoactuator shall operate without degradation of performance as specified herein, during and after exposure to the following environmental conditions and possible combinations thereof as encountered during worldwide ground and airborne operations.

3.5.12.1 Temperature Range: The servoactuators shall be designed to operate satisfactorily throughout the temperature range specified in the pertinent specifications.

3.5.12.2 Atmospheric Pressure: The detail specification shall specify the altitude range through which the servoactuator will be expected to function.

3.5.12.3 Humidity: The detail specification shall specify the humidity environment in which the servoactuator will be expected to operate.

3.5.12.4 Salt Fog: The detail specification shall specify whether the servoactuator will be exposed to salt-sea atmospheres.

3.5.12.5 Sand and Dust: The detail specification shall specify whether the servoactuator will be exposed to fine-blowing sand and dust particles.

3.5.12.6 Fungus: The detail specification shall specify whether the servoactuator will be exposed to tropical climate.

3.5.12.7 Explosive Atmosphere: The detail specification shall specify whether the servoactuator will need to operate in an ambient explosive atmosphere.

3.5.12.8 Vibration: The detail specification shall specify the frequencies and amplitudes of sinusoidal vibration levels to which the servoactuator will be exposed.

3.5.12.9 Acceleration: The detail specification shall include the acceleration to which the servoactuator will be subjected. The servoactuator shall be capable of operating after application of the limit load factors listed in 3.4.1.6 acting independently through the cg of the assembly and each attached part. There shall be no permanent deformation during the application of these loads. In addition, neither the assembly nor any attached part shall become detached during the application of the ultimate load factors listed in 3.4.1.6.3 acting independently through the cg of the assembly and each attached part.

3.5.12.10 Shock: The detail specification shall specify the expected shock conditions to which the servoactuator will be subjected in terms of "g's" and duration of time.

3.5.12.11 Temperature Shock: The detail specification shall specify the conditions of temperature shock which the servoactuator will experience.

3.5.13 Surges: The detail specification shall specify the maximum allowable surge pressures developed by the servoactuator.

3.5.14 External Load Gradient: The detail specification shall include a figure showing the expected operational actuator hinge moment variations required versus output position.

3.5.15 Wear Life: The detail specification shall include wear life requirements as follows:

3.5.15.1 Manually Controlled System: Manually controlled servoactuators shall be cycled at least 2,100,000 cycles at expected loads, amplitudes, and frequencies. Unless otherwise noted, the test spectrum shall conform to applicable paragraphs of MIL-F-9490.

3.5.15.2 Automatically Controlled System: Servoactuators which received inputs from automatic flight control system shall be cycled at least 5,000,000 cycles at expected loads, amplitudes, and frequencies. Unless otherwise noted, the test spectrum shall conform to applicable paragraphs of MIL-F-9490.

3.5.15.3 Stability Augmentation System: Servoactuators, or portions thereof, which are utilized for stability augmentation shall be cycled at least 5,000,000 cycles at expected loads, amplitudes, and frequencies.

3.5.15.4 Impulse Cycles: Servoactuators shall be subjected to 50,000 pressure impulse cycles in both extended and retracted positions to 150% of rated operating pressure with full input command per 4.7.19.4.

3.6 Analysis Requirements: The detail specification shall indicate the general analysis approach and analysis procedures that would be applicable to all servoactuator designs for the specific vehicle.

3.6.1 Design Analysis: As a minimum the following areas shall be considered:

3.6.1.1 Performance: Substantiation of servoactuator performance and limits thereof.

3.6.1.2 Moving Parts Clearance: Demonstration of adequate clearance of all moving parts under all combinations of environments and loads.

3.6.1.3 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.

3.6.2 Reliability Analysis: As a minimum the following areas shall be considered:

3.6.2.1 MTBF Prediction: Demonstrate minimum reliability limits and include the reliability mathematical model.

3.6.2.2 Failure Mode and Effects: Prepare an analysis of the servoactuator and its components per ARP 926.

3.7 Identification and Marking:

3.7.1 Identification: The identification requirements for the servoactuator shall be as specified in MIL-STD-130.

3.7.2 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 shall not be used. 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.

3.8 Workmanship:

3.8.1 Quality: The supplier shall exercise extreme care in fabricating, assembling, handling, and packing actuator units to assure that the components are clean and free of internal and external contaminant. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, sharp edges, and discontinuities.

3.8.2 Physical Defect Inspection: All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All nonmagnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

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

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

3.8.3.2 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.

3.8.3.3 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.

4. QUALITY ASSURANCE PROVISIONS

4.1 Quality Program: 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 Government. Inspection records of the examination and tests shall be kept complete and available to the Government or airframe contractor as specified in the contract or order.

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 test, be subjected to the Acceptance Tests per 4.3.1.

4.3.4 Reliability Tests: These tests are performed, when required, on random production configuration servoactuators to demonstrate the probability that the units will continue to provide satisfactory performance when used under specified conditions. The reliability test program shall be defined in the detail specification.

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.

4.4.2 Preproduction Test Procedure: The preproduction or safety of flight test procedure shall specify those tests which are necessary to demonstrate that the servoactuator is satisfactory for limited life usage for initial flight tests prior to formal qualification test completion. Cycle testing may be shortened to demonstrate actual life anticipated and environmental 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 include the following:

4.4.3.1 Test Log: The test procedure shall prescribe the format for the test log, shall contain detail instructions for maintaining the test log, and shall make provisions for the certification by the government witness at stated periods.

4.4.3.2 Contingency Procedures: 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: The test fluid shall be the same as or compatible with the fluid specified in the detail specification.

4.5.2 Fluid Temperature: Unless otherwise specified the fluid temperature shall be maintained as specified for each individual test with a tolerance of ±5° F (±2.8° C). If the fluid temperature is not specified, the temperature shall be 80° F ± 5 (26.7° C ± 2.8). The fluid temperature shall be measured as near as practicable to the servoactuator ports. During all soaking periods, the servoactuators shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Filtration: Unless otherwise specified in the detail specification, the test fluid shall be continuously filtered through a filter element which conforms to a standard 25 micron absolute rating. The filter and element used shall be satisfactory for the temperature range encountered. The degree of contamination shall be specified in the detail specification.

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 ±5° F (±2.8° C) for test values specified herein. If environmental conditions are not specified or if "room conditions" are specified, the ambient temperature shall be 73° F ± 18, (22.8° C ±10), the barometric pressure shall be 27.3 ± 3.3 inches of mercury, and the relative humidity shall not exceed 80 percent.

4.5.6 Test Instruments: The instruments used to measure and record required test parameters shall be calibrated in accordance with MIL-C-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. A fixture which will simulate the aircraft installation including structural compliance and aerodynamic 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 sequence, magnitude, and duration of the conditions which the servoactuator is expected to encounter during the course of an actual air vehicle mission. Mission-profile tests may combine high and low temperature, rapid warmup, thermal shock, altitude, vibration, acceleration, shock, performance, and endurance tests as one integrated test, 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.

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, and any visible defects.

4.6.3 Operation and External Leakage: The servoactuator shall be cycled with the piston rod unrestrained through at least 25 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 minutes 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 minutes. There shall be no evidence of external leakage (other than slight wetting at seals insufficient to form a drop), excessive distortion or permanent set.

4.6.6 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 minutes 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. The leakage measurement shall be taken in the last 3 minutes of the 5 minute 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:

Paragraph No.	Test	Reference Paragraph
4.6.8.1	Loop Gain	3.5.1
4.6.8.2	Position Sensitivity	3.5.2
4.6.8.3	Rated Velocity	3.5.3
4.6.8.4	Threshold	3.5.4
4.6.8.5	Hysteresis	3.5.5
4.6.8.6	Frequency Response	3.5.6
4.6.8.7	Null Shift	3.5.7
4.6.8.8	Snubbing Rates	3.4.2.3
4.6.8.9	Input Operating Force	3.4.3.6
4.6.8.10	Synchronization	3.4.3.1
4.6.8.11	Electrohydraulic Servovalve Operation	3.4.5
4.6.8.12	Dielectric Strength	3.4.8.4.2
4.6.8.13	Internal Locks	3.4.10.4