

AEROSPACE RECOMMENDED PRACTICE

ARP1281™

REV. C

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Superseding ARP1281B

(R) Actuators: Aircraft Flight Controls, Power Operated, Hydraulic,
General Specification For

RATIONALE

ARP1281C has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE:

This aerospace recommended practice provides a framework and suggested procedures or values for requirements for the design, performance, and test of hydraulically powered servoactuators for use in aircraft flight control systems.

The original version of this document was intended for military usage: consequently, the requirements still often reflect such use. However, the basic requirements of this ARP may and should be applicable to commercial usage as well, provided that appropriate considerations are given for the applicable FAR/JAR 25 regulations, hydraulic fluids, and environmental conditions.

1.1 Purpose:

This recommended practice is a guide and surrogate specification for preparing a detail specification for a particular servoactuator application.

1.2 Product Classification:

Servoactuators covered by this recommended practice are of the following classes:

Class A - Power Actuators

Class B - Signal Conversion Actuators

Class C - Power and Signal Conversion Actuator Combination

For military aircraft, the servoactuators covered by this recommended practice include those in the following types of hydraulic systems:

- a. Type I - 65 to +160 °F (-54 to +71 °C) fluid temperature range
- b. Type II - 65 to +275 °F (-54 to +135 °C) fluid temperature range
- c. Type III - 65 to +390 °F (-54 to +199 °C) fluid temperature range

For commercial aircraft, the servoactuators covered by this recommended practice include those suitable for use with type IV and type V phosphate ester fluids.

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.

2. REFERENCES:

Following are listings of documents and pertinent definitions associated with hydraulically powered aircraft flight control actuators. These publications form a part of this document to the extent referenced herein. The latest issue of all documents shall apply.

2.1 Applicable Documents:

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

AMS 2403	Plating, Nickel, General Purpose
AMS 2406	Plating, Chromium, Hard Deposit
AMS 2419	Cadmium-Titanium Plating
AMS 2426	Coating, Cadmium Vacuum Deposition
AMS-A-21180	Aluminum - Alloy Castings, High Strength
AMS-A-22771	Aluminum Alloy Forgings, Heat Treated
AMS-C-8837	Coating, Cadmium (Vacuum Deposited)
AMS-F-7190	Forgings, Steel, Aircraft/Aerospace Equipment and Special Ordnance Applications
AMS QQ-C-320	Chromium Plating (Electrodeposited)
AMS-S13165	Shot Peening of Metal Parts
AMS-STD-2175	Castings, Classification and Inspection of
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)
ARP1383	Impulse Testing of Hydraulic Actuators, Valves, Pressure Containers and Similar Fluid System Components
AIR4066	Hydraulic Servoactuator Materials
ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation, and Control Technologies
ARP4493	Direct Drive Valves
ARP4763	Aerospace Fluid Power Relief Valves
AIR4922	Primary Flight Control Hydraulic Actuation System Interface Definition
ARP4945	Aerospace - Solenoid Valve, Hydraulic, Three-Way, Two-Position, Direct Acting
AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
AS1290	Graphic Symbols for Aircraft Hydraulic and Pneumatic Systems
AS4059	Aerospace Cleanliness Classification for Hydraulic Fluids
AS4088	Rod Scraper Gland Design Standard
AS4716	Gland Design, O-ring and Other Elastomeric Seals
AS4941	Hydraulic System Components, Commercial Aircraft, General Specification For
AS5169	Fitting, Port Plug and Bleeder FSC 4730
AS5440	Hydraulic Systems, Aircraft, Design and Installation Requirements for
AS6038	Bearings, Ball, Bellcrank, Antifriction, Airframe

2.1.1 (Continued):

AS6039	Bearings, Ball, Rod End, Double Row, Self-Aligning
AS7949	Bearings, Ball, Airframe, Antifriction
AS8775	Hydraulic System Components, Military Aircraft, General Specification for
AS8976	Bearings, Plain Self-Aligning, All-Metal
AS8879	Screw Threads - UNJ Profile, Inch
AS33649	Boss Fluid Connection - Internal Straight Thread
AS39901	Bearings, Roller, Needle, Airframe, Antifriction, Inch
J2470	Hydraulic Fluid Power – Valves – Method for Assessing the Lock Sensitivity to Contaminants

2.1.2 ASTM Publications: Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM B 381	Specification for Titanium and Titanium Alloy Forgings
ASTM D 1974	Fiberboard Shipping Containers, Methods of Closing, Sealing, and Reinforcing, Standard Practice for
ASTM E 1417	Standard Practice For Liquid Penetrant Examination
ASTM E 1444	Standard Practice For Magnetic Particle Examination

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

A-A-1898	Cushioning Material, Cellulosic, Packaging
A-A-66057	Panels, Wood/Wood Based; construction and Decorative
JSSG-2006	Aircraft Structures, General Specification For
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-DTL-5015	Connectors, Electrical, Circular Threaded, An Type, General Specification for
MIL-C-11796	Corrosion Preventive Compound, Petrolatum, Hot Application
MIL-C-26482	Connector, Electrical (Circular, Miniature, Quick Disconnect, Environment Resisting)/& Suppl 1 Recepticals and Plugs, General Specification for (Inactive for New Design)
MIL-F-9490	Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification for
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance (Inactive for New Design)
MIL-HDBK-454	General Requirements for Electronic Standard Equipment
MIL-HDBK-470	Designing and Developing Maintainable Products and Systems
MIL-HDBK-831	Test Reports, Preparation of
MIL-HDBK-838	Lubrication of Military Equipment
MIL-PRF-131	Barrier Material, Water Vaporproof, Flexible
MIL-PRF-6083	Hydraulic Fluid, Petroleum Base for Preservation and Operation
MIL-PRF-8805	Switches and Switch Assemblies, Sensitive Push (Snap Action), General Specification for
MIL-PRF-8815	Filter and Filter Elements, Fluid Pressure, Hydraulic, Line, 15 Micron Absolute & 5 Micron Absolute, Type II System, General Specification for

2.1.3 (Continued):

MIL-PRF-22191	Barrier Materials, Transparent, Flexible, Heat Sealable
MIL-PRF-46170	Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base
MIL-PRF-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537
MIL-PRF-87257	Hydraulic Fluid, Fire Resistant, Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile
MIL-STD-100	Engineering Drawings
MIL-STD-129	Standard Practice for Military Marking
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-461	Requirements for The Control of Electromagnetic Interference Characteristics of Systems and Equipment
MIL-STD-464	Electromagnetic Environmental Effects, requirements for Systems
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-810	Environmental Test Methods & Engineering Guidelines
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-1839	Standard Practice for Calibration and Active Measurement Requirements
MIL-STD-2073-1	DOD Standard Practice for Military Packaging
MS 21343	Boss Spacing - Hydraulic Design, Standard for (Inactive for New Design)
AN 6204	Valve, Hydraulic Bleeder
MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
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
(Available from Defense Technical Information Center, Ft. Belvoir, VA 22060-6218)

2.1.4 NAS Publications: Available from Aerospace Industries Association, 1250 Eye Street NW, Washington, DC 20005.

NAS 847	Caps and Plugs, Protective, Dust and Moisture Seal
NASM 3369	Bolt, Self Retaining, Positive Locking, CRES 90KSI Fsu, 63KSI FtU, Hexagon Slotted Head, 450 Deg F. and 650 Deg F
NASM 15981	Fastener, Externally Threaded, Self-Locking, Design and Usage Limitations for
NASM 20995	Wire, Safety or Lock
NASM 21224	Nut, Self-locking, Castellated, Hexagon Counterbored, Assembled Washer, 250°F, Non-metallic Insert (for Self Retaining Bolts)
NASM 21244	Nut, Castellated, Hexagon Counterbored Assembled Washer, 450°F (for Self Retaining Bolts)
NASM 24665	Pin, Cotter (Split)
NASM 25027	Nut, Self-Locking, 250°F, 450°F, and 800°F

2.1.4 (Continued):

NASM 33540	Safety Wiring and Cotter Pinning
NASM 33588	Nuts, Self-Locking, Aircraft
NASM 33602	Bolt, Self Retaining, Aircraft Reliability and Maintainability Design and Usage Requirements for
NASM 83050	Bolt, Self-Retaining, Impedance Type

2.1.5 FAR Publications from the FAA: Available from the Federal Aviation Administration, 800 Independence Avenue, SW, Washington DC 20591.

FAR Part 25	Code of Federal Regulations, CFR1.1, Part 25 Airworthiness Standards, Transport Category Airplanes
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2.1.6 Joint Aviation Authorities Committee Documents: Available from Civil Aviation Authority Printing and Publications Services, Grenville House, Cheltenham, Glos. GL50 2BN, United Kingdom.

JAR 25	Joint Airworthiness Requirements, Large Airplanes
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2.1.7 Radio Technical Commission for Aeronautics Documents: Available from RTCA Secretariat, 44 Suite 500, 1425 K Street, Washington DC 20005.

RTCA/DO-160	Environmental Conditions and Test Procedures for Airborne Equipment
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2.1.8 American Society of Mechanical Engineers Documents: Available from ASME International, Three Park Avenue, M/S 10E, New York, NY 10016-5990.

ASME Y14.100	Engineering Drawing Practices
ASME Y14.24	Types and Applications of Engineering Drawings
ASME Y14.34M	Associated Lists
ASME Y14.35M	Revision of Engineering Drawings and Associated Documents
ASME Y14.38	Abbreviations and Acronyms

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

2.1.9.1 Military Documents:

MIL-STD-961	Military Specification and Associated Documents Preparation of
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2.2 Definitions and Abbreviations:

2.2.1 Definitions: The detail specification shall determine the definitions that shall apply. ARP4386 contains the terminology, nomenclature, and definitions appropriate for use in servoactuators.

2.2.2 Abbreviations: The detail specification shall determine the abbreviations that shall apply. ARP4386 contains abbreviations for the terminology defined therein.

3. TECHNICAL REQUIREMENTS:

3.1 General:

Servoactuators covered by this practice should be designed in accordance with a detail specification to be prepared by the airframe contractor. The detail specification shall specify the requirements necessary to satisfy the particular application. The format, elements, and detailed procedures or values contained in this ARP are strongly recommended for use in the detail specification. The methods set forth herein for the preparation of a specification should be used as a guide.

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 and Direct Drive Valves: Electrohydraulic servovalves shall be designed in accordance with ARP490 and the Direct Drive Valves shall be designed in accordance with ARP4493. Life and environmental requirements shall be consistent with those for the servoactuator. The detail specification shall include the electrical parameters of the valve.

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: Electric motors for operating valves shall conform to requirements of AS8775.

3.2.1.4.1 Limit Switches: When limit switches are used, they shall conform to MIL-PRF-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-volt DC systems shall operate at a minimum of 18 volts with operating pressure applied to the valve, and shall operate at up to 1 1/2 times operating pressure at 28 volts. Electrically actuated valves designed for 115-volt AC systems shall operate at a minimum of 85 volts with operating pressure applied to the valve and shall operate up to 1 1/2 times operating pressure at a maximum of 115 volts. 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 AS8775. Direct acting three way, two position solenoid operated valves, often used in hydraulic flight control servoactuators, shall conform to requirements of ARP4945. The operating time needs to be specified in the detailed specification.
- 3.2.1.5.1 Creepage and Clearance Distances: The minimum creepage distance of 0.250 inch and clearance distance of 0.125 inch 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 0.125 inch.
- 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 reseal pressure. Relief valves shall conform to requirements of ARP4763.
- 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.
- 3.2.2.2 Dielectric and Insulation Properties: Minimum insulation resistance of valve coils and leadout wires should be specified under the full environment. For test purposes, it is recommended that this value be 100 megohms under room temperature and humidity conditions during a 60-second application of a dc differential equal to 500 V. Dielectric strength between mutually insulated circuits and between insulated circuits and ground should be specified. It is recommended that this value be 1050 VAC 60 Hz for one minute at sea level. Repeated applications of high voltage may eventually break down the coil insulation, so subsequent testing is usually done at 50% of the initial level.
- 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-DTL-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 or the maximum wet 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 (a) static condition, e.g. shipping and (b) 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 actuator movement, 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.
- 3.2.4.2 Damage Tolerance: The elements of a servoactuator that are essential to aircraft safety shall meet the requirements of JSSG-2006. 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 the rated system 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. Scraper ring glands shall conform to design standards of AS4088.
- 3.2.5.1.4 Rod Bushings: Rod Bushings shall be made from material (such as Aluminum - Bronze or Aluminum - Nickel - Bronze as defined in AMS 4640) that will not score the actuator rod. Deviations shall be specified in the detail specification.
- 3.2.5.1.5 Wiper Rings: The use of wiper rings is subject to approval of the procuring activity.
- 3.2.5.1.6 Dashpots and Snubbers: 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. Alternately, the maximum load allowed to be put into the adjoining structure by the actuator, in normal and failure conditions, will be specified in the detail specification.
- 3.2.5.1.7 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.
- 3.2.5.1.8 Rod Ends: These components shall be designed to minimize stress risers. Integral anti-rotation devices are preferred and shall be arranged to prevent excessive airframe attach fitting wear. Controlled radius root threads conforming to AS8879 or special threads with root radii greater than specified in AS8879 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 NASM 33540.