Appendix H

AIRWORTHINESS QUALIFICATION REQUIREMENTS

HYDRAULIC SYSTEMS
FOREWORD

1. This document provides guidance for conducting ground and flight tests and is approved for use by the U.S. Army Combat Capabilities Command, Aviation & Missile Center, Aviation Engineering Directorate and is available for use by all Departments and Agencies of the Department of Defense.

2. This document is intended for application to manned or unmanned fixed- or rotary-wing military aircraft.

3. The testing protocols and procedures defined herein are to be followed by platform manufacturers in order for components to receive an airworthiness release (AWR).

4. Additional platform-level or system integration requirements for a hydraulic system and/or its components are not addressed herein.

5. Comments, suggestions, or questions on this document should be addressed to:

   U.S. Army Aviation & Missile Center
   Attn: Aviation Engineering Directorate (FCDD-AMA-P)
   Bldg 4488
   Redstone Arsenal, AL 35898-5000

   or e-mailed to:

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SUMMARY OF CHANGE MODIFICATIONS

1. The following changes have been made: Not applicable; initial issue.

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UNITED STATES ARMY
CCDC AVIATION & MISSILE CENTER
AVIATION ENGINEERING DIRECTORATE
REDSTONE ARSENAL, ALABAMA

FUNCTIONAL DIVISION: ________________________
Curtis J. Stevens
Chief, Propulsion Division

APPROVED BY: ______________________________
David G. Stephan
Associate Director for Technology
Aviation Engineering Directorate

DATE: ____________________
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1. SCOPE

This standard establishes the performance, design and airworthiness qualification requirements and guidelines for rotorcraft hydraulic systems. The requirements are identified in Section 4. Performance guidelines are addressed in Section 5. Should the contractor elect to utilize design/performance criteria other than those contained herein, the contractor is expected to explain his design selection. The agreed to design criteria/parameters will form the basis for the subsequent qualification test program. The qualification test guidelines in Section 6 represent the framework for the contractor’s test plans. The contractor is expected to address each of the qualification guidelines or explain why a particular guideline is not applicable or how it has been tailored to reflect the design configuration.

2. APPLICABLE DOCUMENTS

2.1 Commercial Specifications.

- AIA/NAS1638 Cleanliness Requirements of Parts Used in Hydraulic Systems
- SAE AS4059 Aerospace Fluid Power – Cleanliness Classification for Hydraulic Fluids
- SAE AS4716 Gland Design, O-Ring And Other Elastomeric Seals
- SAE AS5440 Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For
- SAE AS8879 Screw Threads – UNJ Profile, Inch
- SAE AS19692 Pumps, Hydraulic, Variable Flow, General Specification For
- SAE ARP4146 Coiled Tubing – Titanium Alloy, Hydraulic Applications, Aerospace
- SAE ARP4379 Aerospace – Accumulator, Hydraulic, Cylindrical, Piston Separated
- SAE ARP 584 Coiled Tubing, Corrosion Resistant Steel, Hydraulic Applications
- SAE ARP 603 Impulse Testing Of Hydraulic Hose, Tubing And Fitting Assemblies
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SAE ARP 1281  Actuators: Aircraft Flight Controls, Power Operated, Hydraulic, General Specification For

SAE ARP 1383  Impulse Testing Of Aerospace Hydraulic Actuators, Valves, Pressure Containers, And Similar Fluid System Components

2.2  Military Specifications.

ADS-1B-PRF  Rotorcraft Propulsion System Airworthiness Qualification Requirements

ADS-9C  Propulsion System Technical Data

MIL-F-8815  Filter and Filter Elements, Fluid Pressure, Hydraulic Line, 15 Micron Absolute and 5 Micron Absolute, Type II Systems General Specification For

MIL-G-5514  Gland Design; Packings, Hydraulic, General Requirements For

MIL-PRF-46170  Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base, NATO Code No. H-544

MIL-PRF-5606  Hydraulic Fluid, Petroleum Base; Aircraft, Missile And Ordnance

MIL-PRF-6083  Hydraulic Fluid, Petroleum Base, For Preservation And Operation

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-R-8931  Reservoirs, Aircraft and Missile, Hydraulic, Separated Type

MIL-STD-461  Control Of Electromagnetic Interference Emissions And Susceptibility, Requirement For The

MIL-STD-462  Electromagnetic Interference Characteristics, Measurement Of
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MIL-STD-463 Definitions And Systems Of Units, Electromagnetic Interference And Electromagnetic Compatibility Technology

MIL-STD-464 Electromagnetic Environmental Effects Requirements For Systems

MIL-STD-810 Environmental Engineering Considerations and Laboratory Test, Test Method Standard For

MIL-V-81940 Valve, Sampling and Bleed, Hydraulic, Type II System

2.3 International Standards.

ISO-12103-1 Road Vehicles – Test Dust For Filter Evaluation – Part 1: Arizona Dust Test

STANAG 3212 Diameters for Gravity Filling Orifices

3. DEFINITIONS

3.1 Accumulator – A container in which fluid is stored under pressure as a source of fluid power.

3.2 Actuator – A device for converting fluid energy into mechanical energy.

3.3 Cylinder – A device which converts fluid power into linear mechanical force and motion. It usually consists of a moveable element such as a piston or piston rod, plunger rod, plunger or ram, operating within a cylindrical bore.

3.4 Directional Control Valve – A device that can control the start, stop and change in direction of fluid flow. A directional control valve consists of at least two spool (switching) positions and two working ports.

3.5 Filter – A device whose primary function is the retention by a porous media of insoluble contaminants from a fluid.

3.6 Flow Divider – A device which separates the fluid flow into two or more paths.

3.7 Inert Gas – A gas which does not undergo chemical reactions under a set of given conditions. Inert gases are used to avoid unwanted chemical reactions degrading a sample.
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3.8 Micron – Same as micrometer. It is the average of the openings between pieces of the filter.

3.9 Motor – A device which converts hydraulic fluid power into mechanical force and motion. It usually provides rotary mechanical motion.

3.10 Power Pump – A device which converts mechanical force and motion into hydraulic fluid power.

3.11 Pressure Reducing Valve – A valve which limits the maximum pressure at its outlet regardless of the inlet pressure.

3.12 Pressure Regulator – A valve that automatically cuts off the flow of a liquid or gas at a certain pressure.

3.13 Relief Valve – A pressure operated valve which by-passes pump delivery to the reservoir, limiting system pressure to a predetermined maximum value.

3.14 Reservoir – A container for storage of liquid in a fluid power system.

3.15 Snubber – A device that uses a capillary orifice to smooth out hydraulic line pulsation and surges without the use of any moving parts.

3.16 Standard Part – NAS, AN or MS standard parts identified by their standard part numbers. Commercial Standard Parts developed specifically for use in aircraft propulsion systems are preferred and should be considered for use prior to consideration of other parts. Where general purpose standards, as defined by envelope dimensions or Qualified Products List (QPL’s), are used in critical or high strength applications, parts should be identified by the manufacturer’s part number. Parts derived from general purpose standards or Military Standards solely on an inspection or selection basis should be identified by contractor part numbers and all previous identification marks should be removed.

4. GENERAL REQUIREMENTS

4.1 Performance. The Hydraulic system shall meet its allocated performance and function in such a manner that the aircraft shall be able to be operated safely throughout the operating envelope and meet the performance requirements as defined in the applicable contractual specification.

4.2 Qualification. The following qualification requirements for the Hydraulic system are required to verify compliance with the performance requirements above as applicable to the aircraft design configuration.

4.2.1 Analysis. System design and performance analysis shall be documented, using ADS-9C and the criteria below as a guide. Consult the applicable Contract Data Requirements List (CDRL) for submittal requirements.
4.2.2 **Component Tests.** At a minimum, the following tests shall be conducted and a subsequent teardown inspection, to determine the post test condition, shall be performed. Consult the applicable CDRL for submittal requirements.

   a. Examination of Product
   b. Immersion
   c. Proof and Burst Pressure
   d. External and Internal Leakage
   e. Pressure Drop
   f. Extreme Temperature
   g. Endurance
   h. Impulse
   i. Vibration, Shock, and Acceleration
   j. Humidity
   k. Fungus
   l. Sand and Dust
   m. Salt Fog
   n. Icing
   o. Explosion Proof (where applicable)
   p. Dielectric Strength (where applicable)
   q. Electromagnetic Compliance / Interference (where applicable)

4.2.3 **Assembly/System Level Tests.** Aircraft system level tests shall be conducted in accordance with ADS-1B-PRF.

5. **PERFORMANCE GUIDELINES**

5.1 **Fluid.** Hydraulic systems and associated ground equipment should be designed to use fluid conforming to MIL-PRF-5606 or MIL-PRF-83282 as these are the standard fluids in the DOD inventory. Considerations should be made for eventual use with MIL-PRF-87257 hydraulic fluid. MIL-PRF-6083 or MIL-PRF-46170 should not be used due to known performance and reliability issues resulting from its high barium content. Components previously stored or tested using MIL-PRF-6083 or MIL-PRF-46170 fluid shall be thoroughly drained and flushed with MIL-PRF-5606 or MIL-PRF-83282 prior to use.

5.2 **Hydraulic Seals.** SAE AS4716 should be used for gland design and seal assembly installation. O-rings with cross-sectional diameters of 0.070 inch or less, or their equivalent proprietary seals, should not be used as external seals.

5.2.1 **Gland Design.** Seal gland dimensions shall conform to the general requirements specified in SAE AS4716. Nonstandard glands for specialized seal assemblies should be used only with the approval of the procuring activity. Care shall be taken to prevent binding and interference at the most adverse temperature extremes.
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5.2.2 O-ring and Seal Assemblies. O-rings and other seal assemblies should conform to the general requirements specified in SAE AS5440.

5.2.3 Backup Rings. Backup rings should conform to the general requirements specified in SAE AS5440. Scarf-cut backup rings may be used on dynamic applications where minimum seal friction is required for satisfactory operation or where access to the gland prevents installation of solid backup rings. If solid backup rings are used on dynamic piston applications, friction due to pressure entrapment between the backup rings must be considered in the design of the device. Extra care, training and drawing notes should be implemented to prevent backup rings designed for SAE AS4716 grooves from being inadvertently used in MIL-G-5514 grooves and vice versa.

5.3 General System Design. The hydraulic systems and components thereof should be designed to operate satisfactorily under all conditions that the aircraft may encounter within the structural limitations of the aircraft, including forces or conditions caused by acceleration, deceleration, zero gravity, negative g, or any flight attitudes obtainable with the aircraft, structural deflection, vibration, or other environmental conditions. The hydraulic system(s) should be configured such that any two fluid system failures due to combat or other damage which cause loss of fluid or pressure will not result in complete loss of flight control. For rotary-wing aircraft, the surviving system(s) should provide sufficient control for return to the intended landing area (including shipboard areas and land). Hydraulic systems should be as simple and foolproof as possible and in accordance with design, operation, inspection, and maintenance objectives specified in the aircraft design requirements.

5.3.1 Fluid Temperature Limitations. The hydraulic system(s) should be capable of operating under any condition encountered within the operating envelope, including climatic extremes, without exceeding a bulk fluid temperature limit in any portion of the system(s) of 135°C (275°F). The hydraulic system should be capable of starting and operating at fluid temperatures down to -32°C (-25°F) for MIL-PRF-83282 and -54°C (-65°F) for MIL-PRF-5606 and MIL-PRF-87257. Operation at these temperatures should not result in any degradation of system(s) or component performance.

5.3.1.1 Climatic Extremes. Ground operation, flight operation and storage climatic extremes should be in accordance with the contractual specification.

5.3.2 Fire Hazards. The hydraulic system should be integrated with other systems that will eliminate or isolate the system(s) from fire hazards caused by proximity of combustible gases, heat sources, bleed-air ducts or electrical equipment, etc. Hydraulic lines and equipment located in the vicinity of heat and ignition sources that will cause spontaneous ignition or sustained fire of hydraulic leakage from these lines or equipment should be protected by devices such as firewalls, shrouds, or equivalent means that will prevent fluid ignition.

5.3.3 Strength.
5.3.3.1 **Additional Loads.** All hydraulic systems and components which are subjected, during operation of the aircraft, to structural or other loads which are not of hydraulic origin should withstand such loads when applied simultaneously with appropriate proof pressure without exceeding the yield point at the maximum operating temperature.

**Rationale.** Components should be capable of simultaneously withstanding the hydraulic pressure loads, and the loads the aircraft will put on the component. For example, the rotor actuators will see not only hydraulic pressure loads, but loads introduced from the rotor forces.

5.3.3.2 **Accelerated Loads.** Actuating cylinders and other components and their attaching lines and fittings, subject to accelerated loads, should be designed and tested on the basis of a pressure equal to the maximum pressure that will be developed, without exceeding the yield point at the maximum, operating temperature.

5.3.4 **Pressure Limitations.**

5.3.4.1 **System Pressures.** System proof and burst pressures should be in accordance with Tables I and II. Peak pressure resulting from any phase of the system operation should not exceed 135 percent of the main system, subsystem, or return system pressure for normal operation. Lines, fittings, and equipment in return circuits should be designed for one-half the nominal system pressure.

5.3.4.2 **Back Pressure.** The system should be so designed that proper functioning of any unit will not be affected by the back pressure or changes in the back pressure in the system. The system or systems should also be so designed that malfunctioning of any unit in the system will not render any other subsystem, emergency system, or alternate system inoperative because of back pressure.

5.3.4.3 **Brakes.** Back pressure resulting from the operation of any unit while the aircraft is on the ground should create no greater back pressure at the brake valve return port than 90 percent of that pressure which will cause contact of braking surfaces. In addition, supply pressure to the brake system should not drop below the maximum brake-operating pressure during the operation of any other subsystem in the aircraft during taxiing, landing, or takeoff.

5.3.4.4 **Pressure Regulation.** Systems employing power-operated pumps should utilize a pressure-regulating device and an independent means of limiting excessive pressure. When the pump-driving mechanism is in continuous operation, such as engine or transmission drives, a variable-displacement pump should be used. When the pump is driven by an electric motor, a pressure switch may be used to deactivate the electric motor as the primary method of pressure regulation. In any case, an independent safety relief valve should be provided.

**Table I**
## Appendix H

### Typical Proof Pressure (minimum)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Proof Pressure</th>
<th>Percent System Pressure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Lines, fittings and hoses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Pressure Circuits</td>
<td>6,000</td>
<td>200</td>
<td>Proof pressure values for hose to be in accordance with the applicable detail specification</td>
</tr>
<tr>
<td>(2) Return and case drain circuits</td>
<td>3,000</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>b. Accumulators</td>
<td>6,000</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>c. Pump suction and reservoir</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Non-pressurized reservoirs</td>
<td>50</td>
<td>---</td>
<td>150% of reservoir operating pressure</td>
</tr>
<tr>
<td>(2) Bootstrap reservoirs</td>
<td>---</td>
<td>---</td>
<td>200% of reservoir operating pressure</td>
</tr>
<tr>
<td>(3) Gas pressurized reservoirs</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>d. Components under system pressure</td>
<td>4,500</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>e. Components under return pressure only</td>
<td>2,250</td>
<td>75</td>
<td>Exception hose, which should be 125% of nominal system pressure</td>
</tr>
</tbody>
</table>

### Table II

#### Typical Burst Pressure (minimum)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Burst Pressure</th>
<th>Percent System Pressure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Lines, fittings and hoses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Pressure circuits</td>
<td>12,000</td>
<td>400</td>
<td>Proof pressure values for hose to be in accordance with the applicable detail specification</td>
</tr>
<tr>
<td>(2) Return and case drain circuits</td>
<td>6,000</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>b. Accumulators</td>
<td>12,000</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>c. Pump suction and reservoir</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Non-pressurized reservoirs</td>
<td>100</td>
<td>---</td>
<td>300% of reservoir operating pressure</td>
</tr>
<tr>
<td>(2) Bootstrap reservoirs</td>
<td>---</td>
<td>---</td>
<td>400% of reservoir operating pressure</td>
</tr>
<tr>
<td>(3) Gas pressurized reservoirs</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>d. Components under system pressure</td>
<td>7,500</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>e. Components under return pressure only</td>
<td>4,500</td>
<td>150</td>
<td>Exception hose, which should be 250% of nominal system pressure</td>
</tr>
</tbody>
</table>
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5.3.5 **Reservoir Pressurization.** Systems should be designed so that air does not contact the fluid during the normal function of the system(s). The reservoir pressure should be adequate to prevent cavitation at the inlet to the pump under all operating conditions.

**Rationale:** Because of the problems caused by gas entrapped in the circulating loop of aircraft hydraulic systems, separated reservoirs are preferred.

5.3.5.1 **Reservoir Bootstrap Pressurization.** Reservoir pressurization should be maintained in the event normal system pressure (reservoir bootstrap pressure) is lost.

5.3.6 **Fluid Flow Effects.** The systems should be so designed that malfunctioning of any unit or subsystem will not occur because of reduced flow, such as created by single-pump operation of a multi-pump system, or reduced engine speed. The systems should be designed so that increased flow will not adversely affect the proper functioning of any unit/subsystems, e.g. increased flow rate caused by accumulator operation or units affected by airloads.

5.3.7 **Subsystem Isolation.** Two or more subsystems pressurized by a common pressure source, one of which is essential to flight operation and the other not essential, should be so isolated that the system essential to flight operation will not be affected by any damage to the nonessential system.

5.3.8 **Ground Servicing Provisions.** Each hydraulic system should include a set of self-sealing couplings for attachment of ground servicing equipment. System ground servicing provisions should be so designed that pressurization of any hydraulic system in the aircraft is not necessary in order to service another hydraulic system. In particular, use of only one hydraulic power source should be necessary to service the system, without use of Y connections between the power source and the aircraft or use of a second ground test stand connected to another hydraulic system in the aircraft. A central ground servicing station should be provided for each system that includes connections for attachment of ground servicing equipment for system checkout and flushing, reservoir bleeding/filling, and accumulator air-nitrogen charging.

5.3.8.1 **Ground Servicing Connections.** A set of self-sealing couplings consisting of bulkhead halves and protective caps with safety chains should be provided at a convenient location in the aircraft, easily accessible from the ground, for attachment of ground support equipment. The ground connections should be compatible with those connections supplied on the ground servicing units in use by the procuring activity. Electric-motor-driven pumps used in emergency or auxiliary systems should not be used for ground servicing purposes unless the motor is designed for continuous operation.

5.3.8.1.1 **Reservoir Supercharging Connection.** When reservoirs are normally pressurized by either compressed air or nitrogen, a ground supercharging connection should be provided and should consist of a fitting end for attachment to a ground
supercharging unit. A protective cap with a safety chain should be provided to protect the end connection when not in use.

5.3.8.1.2 Reservoir Filling Connection. Reservoirs should be filled by low-pressure replenishment methods.

5.3.8.2 Ground Servicing Data. The following data should be attached in a permanent manner on the aircraft near the ground servicing connections:

Set ground servicing unit reservoir pressurizing valve to_____ psi. 1/
Set ground servicing unit relief valve to____ psi. 1/
Set ground servicing unit volume output to____gpm. 1/
Set ground servicing unit pressure compensator to____psi. 1/
Use hydraulic fluid conforming to_____. 1/
Ground servicing unit output filter should be______microns absolute. 1/
(Any other precautions or information considered necessary.)

1/ The contractor should fill in these values.

5.3.9 Removal of Entrapped Air. Suitable means, such as bleeder valves, should be provided for removal of entrapped air where it interferes with the proper functioning of the hydraulic system. Disconnection of lines or loosening of tubing nuts does not constitute suitable means. Equipment and system configuration should, insofar as practicable, be designed to automatically scavenge free air to a reservoir or other collection points where operation will not be affected and where release can be conveniently accomplished.

5.3.9.1 System Air Tolerance. The system should be designed and configured such that the effects of entrapped air on system performance are minimized during all conditions of intended aircraft operation.

5.3.10 Power Pumps. The hydraulic system pump(s) should be compatible with the installed aircraft system and should not cause abnormal or undesirable effects on the installed system in the aircraft. All pumps qualified for a given application should be physically and functionally interchangeable and should be compatible with the system and with each other in multiple pump systems.

5.3.10.1 Emergency Power Pumps. Hydraulic pumps required to provide emergency power for direct application to flight controls or other essential hydraulic flight requirements should not be used for any other function.

5.3.10.2 Multiple Pumps. Multiple engine aircraft hydraulic systems using engine-driven pumps should have pumps driven by at least two engines. A sufficient number of engine-driven pumps, augmented where necessary by pumps driven from other sources of power (e.g., electric motors or auxiliary power units), should be provided to assure operation of control surface boost or power systems with any minimum combination of
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engines which will maintain flight and to assure operation of power brake systems and any other services needed during taxiing with any minimum combination of engines which may be used for taxiing.

5.3.10.3 Pump Pulsation. For all power-generating components (engine pumps, power packages, transfer units, etc.), pump pulsation’s should be controlled to a level which does not adversely affect the aircraft system tubing, components, and supports installation. The contractor should determine by test the effect of pump pulsation’s (pump ripple) on the hydraulic system.

5.3.10.4 Pump Rotation Reversal. For equipment not designed to withstand reverse rotation, the system and components should be designed so that no single failure will permit reverse rotation.

Rationale: On the CH-47, a check valve which isolates the flight control pump from PTU (Power Transfer Unit) pressure failed, causing the outlet port of the pump to be exposed to PTU pressure. Depending on the rate of leakage, this could run the pump like a motor, generating enough torque to cause it to rotate in the opposite direction.

5.3.11 Pump Supply Shutoff Valves. Pump supply (suction) shutoff valves should be provided if the fire protection requirements of the particular model aircraft specify the need for such equipment in other systems, such as fuel or lubricating oil systems, or both. These valves, when required, should not be located on the engine side of firewalls or flame-tight diaphragms but should be located as close as practicable to these members. However, the valves should be so removed from the engine that the loss of the engine from the attaching structure will not impair the operation of the valve. These valves should be operable from the cockpit, to both the closed and open positions.

5.3.12 Special Tools. Hydraulic systems should be so designed that special tools will not be required for installation or removal of components unless it can be shown that use of special tools is unavoidable.

Rationale: Weapon systems have much better maintainability in the field when special tools are not required.

5.3.13 System Pressure Indication. Pressure indicating equipment acceptable to the procuring activity should be provided to indicate the system pressure in hydraulic systems or subsystems. On engine-driven multi-pump systems, pressure indicating equipment should be provided for each pump to enable the flight crew to check for proper operation of each pump without shutdown of any engine. The pressure indicators should be so located as to be readily visible by the flight crew.

5.3.13.1 System Low-Pressure Warning Light. In addition, but not as a substitute for the requirement of 5.3.13, a suitable warning light should be installed in the cockpit in a conspicuous location to warn the pilot of low hydraulic system pressure. The light should be actuated by a pressure switch in the system. There should be a separate
warning light for each hydraulic system. The warning light, or lights, should not be actuated by any combination of flight-control operations under normal operations. A momentary flicker of the warning light during ground checkout only is permissible, provided such condition is adequately described in the appropriate aircraft operation and maintenance manuals and provided such condition does not occur during flight unless a system malfunction exists.

Rationale: Flight crews need a quick visual indication of low hydraulic system pressure so precautionary measures can be taken in a timely manner.

5.3.13.2 Maintenance Check Gages and Indicators. Pressure gages/indicators that require a preflight, postflight, or daily check should not require work-stands or platforms in order to read the gages or indicators.

5.4 Utility System Design. All hydraulically operated services (excluding flight controls covered by 5.5) that are essential to the accomplishment of the basic aircraft mission (weapon system actuators, cargo handling components, etc.) or essential to land and stop the aircraft (landing gear, brakes) should have provisions for emergency actuation. No single failure of the utility system should result in loss of the aircraft. Wheel brake systems should perform to the requirements of the system specification.

5.5 Flight-Control System Design. In dual flight-control systems, both systems should be so designed that ground support equipment may be connected to either one of the flight-control systems and that system may be operated without adverse effect on the dead system, such as overflow of the system or failure of any part thereof. In order to accomplish this objective, automatic bypass of the fluid in the dead system from one side of the actuator to the other side should be provided.

5.5.1 System Isolation. Whenever hydraulic power is required for primary flight controls, a completely separate, integral, and adequate hydraulic system should be provided to supply only the primary flight controls. This hydraulic system should not be used to supply any other system or component in the aircraft. This hydraulic system should be as simple as practicable and should contain a minimum number of components. Dual actuator systems may employ the combined flight-control/utility system for one-half of the power, in which case the flight-control system should be given pressure priority.

5.5.2 Hydraulic Power Failure. In aircraft where direct mechanical control sufficient to maintain emergency aircraft control cannot be accomplished following hydraulic power failure, an emergency power source should be provided, supplying sufficient hydraulic power to satisfy controllability requirements.

5.5.2.1 Emergency System Application. The means of engaging the emergency power system should be either manual or automatic; however, they should be of the simplest and most reliable nature possible consistent with the requirements of the aircraft. Manual engagement of the emergency power system should not be used unless specifically approved by the procuring activity. If the aircraft has a single engine, the
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emergency power source should be independent of the operation of this engine. On multiple-engine aircraft, the emergency source of power should be on a different engine than the primary source of power. In some cases, it is permissible to utilize the utility hydraulic system as the emergency source of power, if it is accomplished in such a way that there is no interconnection with the flight-control power system and no single failure can cause loss of both systems. Consideration should be given to the possibility of out-of-fuel landings wherein none of the engines are operating. In aircraft which are capable of being landed without engine power, this condition should not be considered an emergency, and provisions should be made for landings with one of the power systems failed while out of fuel. When designing for this condition, extreme care must be exercised not to reduce the reliability of the power systems. It should always be possible to reengage the flight controls or return them to normal following operation of the emergency hydraulic system.

5.5.2.2 Disengagement and Bypassing. Where direct mechanical control is utilized following primary hydraulic system failure, or as made necessary by other system design conditions, provisions should be made for automatic, direct bypassing of the fluid from one side of the primary flight-control actuator to the other. Where the actuator can be disengaged from the system, bypassing will not be required. For dual actuator systems, where necessary, both systems should provide automatic bypass.

Rationale: Fluid must be able to be bypassed from one side of the actuator to the other without hydraulic pressure to prevent actuator “lockup”.

5.5.3 System Separation. Where duplicate hydraulic systems are provided, these systems should be separated as far as possible to obtain the maximum advantage of the dual system with regard to vulnerability from gunfire or engine fires. Where practicable, dual systems should be on opposite sides of the fuselage or similarly separated. In any case, the systems necessary for safety of flight should be separated. Where it is deemed necessary, in a particular aircraft model, for these systems to come together, as in a dual tandem surface actuator, that actuator should be protected from the threat to a degree specified by the procuring activity. Adequate consideration should be given to the clearance between moving flight-control-system components and structure or other components to insure that no possible combination of temperature effects, airloads, or structural deflections can cause binding, rubbing, or jamming of any portion of the primary flight-control system.

5.5.4 Subsystem Pressure. Subsystems and branch circuits which use a pressure lower than the full system pressure should be designed to withstand and operate under the full pressure or should have an adequate relief valve installed downstream of the pressure reducing valve if the full pressure would be detrimental or dangerous. This relief valve may be incorporated into the same housing as the pressure reducer, provided that the relief valve mechanism is independent of the pressure reducer mechanism.
5.5.5 **Power Sources.** Rotorcraft primary flight-control systems should have transmission-driven pumps as a source of power so that power will be available during auto rotation.

5.5.6 **System Temperature.** The hydraulic flight control actuators should provide the required actuation rates under minimum and maximum in-flight fluid and ambient temperatures. The flight critical components should not bind or jam under any combination of in-flight fluid and ambient conditions including single failures, such as relief valves, worn pump, failed valves and other heat generating failures. The effects of differential fluid temperature in tandem units should also be demonstrated.

5.6 **Emergency System Design for Utility System.**

5.6.1 **Types.** Where emergency devices are required in hydraulic systems, the emergency systems should be completely independent of the main system. The system should be so designed that failure of an actuator in one subsystem should not prevent the operation of or cause the failure of both normal and emergency actuation of another subsystem. These emergency systems should utilize hydraulic fluid, compressed gas, gas-generating devices, direct mechanical connection, or gravity. Mechanical connections may include electromechanical units.

5.7 **Component Design.**

5.7.1 **Standard Components.** Standard components should be used in preference to nonstandard components wherever they will perform the function required by the system operating needs. Where no applicable standard component exists, a minimum size envelope compatible with the performance, installation, inspection, and maintenance requirements should be used.

Rational: Existing U.S. Army or commercially available hydraulic filters with the same performance criteria such as pressure, micron rating and flow rates should be used whenever possible instead of creating a new design.

5.7.2 **Orifices.** Orifices larger than 0.005 inch but smaller than 0.070 inch in diameter should be protected by adjacent strainer elements having screen openings one-third to two-thirds of the diameter of the orifice being protected. Orifices smaller than the .005 inch diameter are prohibited unless otherwise directed by the procuring activity. Orifices and strainer elements should be strong enough to absorb system design flow and pressure without rupture or permanent deformation.

5.7.3 **Actuators Essential to Safe Operation of the Aircraft.** Where two or more independent hydraulic systems are utilized to power services essential for safe flight (e.g., primary flight controls), the actuation and control devices should be designed and constructed (either parallel or series configuration) so that no single structural or hydraulic failure will cause loss of more than one hydraulic system or allow transfer of
5.7.4 **Structural Strength.** The components should have sufficient strength to withstand all loads or combinations of loads resulting from hydraulic pressure, vibration, temperature variations, actuation or operations, and torque loads for connection of tube fittings.

5.7.5 **Reverse Installation.** All components should be designed such that reverse or incorrect installation in the aircraft or sub-assembly cannot be made. Internal parts which are subject to malfunction or failure due to reversed or rotated assembly should be designed to render improper assembly impossible.

5.7.6 **Metals.** All metals should be compatible with the fluid and intended temperature, functional, service, fatigue loading and storage conditions to which the components will be exposed. The metals should possess adequate corrosion-resistant characteristics or be suitably protected to resist corrosion which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high temperature deterioration.

5.7.7 **Threaded Parts.** All threaded parts should be securely locked or safetied. The use of threads per SAE AS8879 is preferred for all load-bearing applications.

5.7.8 **Pumps.**

5.7.8.1 **Power Pumps, Variable-Delivery and Fixed-Displacement.** For variable-delivery pumps, the pressure differential between the pump-case cooling port and the reservoir should be such as to permit the pump to maintain adequate cooling flow in any pump flow condition.

5.7.8.2 **Functional Guidelines.**

5.7.8.2.1 **Rated Case Drain Pressure.** Rated case drain pressure is that maximum pressure at which the pump is required to operate in the system. Rated case drain pressure should be stated in the detail specification.

5.7.8.2.2 **Case Drain Flow.** At rated discharge pressure, rated inlet temperature, and at any speed from 50 to 100 percent of rated speed, the pump should be capable of producing a minimum case drain flow at a given maximum differential pressure between case pressure and inlet pressure as specified in the detail specification. Minimum and maximum case drain flow should be stated in the detail specification under conditions as specified in the detail specification.

5.7.8.2.3 **Rated Temperature.** The rated temperature of the pump should be the maximum continuous fluid temperature at the inlet port of the pump. It should be expressed in degrees Fahrenheit (°F).
5.7.8.2.4 Maximum System Temperature. The rated temperature of the pump should be 225°F or the value listed in the detail specification.

5.7.8.2.5 Minimum Fluid Temperature. The minimum continuous fluid temperature at the pump inlet port is not related to the rated temperature by this standard. A minimum continuous fluid temperature may be specified in the detail specification.

5.7.8.2.6 Maximum Displacement. The maximum displacement of the pump should be the maximum theoretical volume of hydraulic fluid delivered in one revolution of its drive shaft. It should be expressed as cubic inches per revolution (cu. in./rev). The maximum displacement of any pump should be determined by calculation from the geometry and dimensions of the pump. The effects of allowable manufacturing tolerances, of deflections of the pump structure, of compressibility of the hydraulic fluid, of internal leakage, and of temperature should be excluded from the calculation, because the maximum displacement is intended to be an index of the size of the pump rather than of its performance.

5.7.8.2.7 Rated Delivery. The rated delivery of the pump should be the measured output of the pump under conditions of rated temperature, rated speed, and maximum full-flow pressure, using the hydraulic fluid specified in the detail specification at rated inlet pressure. It should be expressed as compressed flow in U.S. gallons per minute (gpm), and its value specified in the detail specification.

5.7.8.2.8 Rated Speed. The rated speed of the pump should be the maximum speed at which the detail specification requires the pump to operate continuously at rated temperature and rated discharge pressure.

5.7.8.2.9 Rated Endurance. The value of the rated endurance should be specified in the detail specification and should be not less than 2000 hours.

5.7.8.3 Performance.

5.7.8.3.1 Torque and Heat Rejection. The performance requirements should be stated in the detail specification. The minimum performance requirements may be stated as maximum input torque at rated delivery and maximum heat rejection at rated discharge pressure.

5.7.8.3.2 Efficiency. Where the detail specification states a required minimum efficiency, it should be the ratio of output power to input power when the pump is operated at rated speed, and maximum full-flow pressure, using the hydraulic fluid specified in the detail specification. It should be stated as percentage. The above ratio is commonly referred to as “over-all efficiency” and includes volumetric efficiency. For the purposes of this standard, volumetric efficiency should not be segregated. In the determination of output power by calculation from flow rate and pressure change, only the net pressure difference between inlet and outlet ports of the pump should be used, and
the flow rate may be as measured in the low pressure side of the discharge line at the option of the detail specification, provided adequate compensation is made for compressibility in calculating efficiency.

5.7.8.3.3 Pressure Pulsations. Pressure pulsations should be the oscillations of the discharge pressure, occurring during nominally steady operating conditions, at a frequency equal to or higher than the pump drive shaft speed. These pulsations should not exceed ±10 percent of rated discharge pressure or a pressure band specified in the detail specification under any condition, when the pump is tested in the circuit which simulates the actual system in which the pump is to be installed. The system volume may be simulated using tubing of the discharge line diameter being careful to avoid a line length whose natural frequency is resonant with pulsation frequency.

5.7.8.4 Variable Delivery Control. All pump models should incorporate delivery control means which should act to increase the delivery of the pump from zero to its maximum full-flow value for any given operating speed as the discharge pressure is reduced from rated discharge pressure to maximum full-flow pressure and vice versa.

5.7.8.4.1 Response Time. The response time of the pump should be the time interval between the instant when an increase (or decrease) in discharge pressure change initiates; and the subsequent instant when the discharge pressure reaches its first maximum (or minimum) value. The oscillographic trace of discharge pressure versus time should be employed as the criterion of movement of the delivery control mechanism. Pumps should have a response time specified in the detail specification.

5.7.8.4.2 Stability. The stability of the pump should be the freedom from persistent or quasi-persistent oscillation or “hunting” of the delivery control mechanism at any frequency that can be traced to the pump delivery control means. The oscillographic trace of discharge pressure versus time should be employed as the criterion of stability. The time required to recover steady-state operation after being disturbed should be specified in the detail specification.

5.7.8.4.3 Maximum Transient Pressure. The maximum transient pressure should be the peak value of the oscillographic trace of discharge pressure, made during operation of a pump. The value of the maximum transient pressure should not exceed 135 percent of rated discharge pressure or the maximum pressure defined in the detail specification.

5.7.8.4.4 Depressurization. When it is a requirement of the detail specification that the pump be depressurized either automatically or remotely as by an electrical signal, the depressurization control should not when de-energized interfere with the normal operation of the variable delivery control.

5.7.8.5 Balance. The moving parts of the hydraulic pump should be inherently balanced and the pump should not vibrate in such a manner as to cause failure of any part in the pump or drive mechanism at speeds up to and including 125 percent of rated speed.
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(maximum speed at which the detail specification requires the pump to operate continuously at rated temperature and discharge pressure).

5.7.8.6 Adjustment. Means should be provided to adjust the delivery control mechanism to cause zero flow to occur at rated discharge pressure. This adjustment should be preferably continuous, or acceptably in steps of less than 1 percent of rated discharge pressure, over a minimum range from 95 percent to 130 percent of rated discharge pressure. The adjustment means should be capable of being positively locked; and it should be possible to accomplish adjustment and locking by the application of standard hand tools. Where practicable, the arrangement of the adjustment means should permit adjustment to be made while operating under full system pressure with negligible loss of fluid.

5.7.8.7 Lubrication. The hydraulic pump should be self-lubricated with no provisions for lubrication other than the circulating fluid.

5.7.8.8 Drive Coupling. A replaceable part of the pump assembly, incorporating a shear section, should be interposed between the pump drive shaft and the engine accessory drive shaft by which the pump is to be driven. This shear coupling part should be held in place by a positive retainer. Both ends of the coupling should be designed to include a plastic spline bushing to minimize spline wear. A plastic spline bushing at only the gear box drive interface may be used if the plastic bushing is not adaptable to the pump interface.

5.7.8.9 Maintainability. All wear surfaces should be replaceable or repairable. Disconnects, mounting and wiring provisions should be designed to prevent erroneous connections.

5.7.8.10 Environmental. Pumps should not be affected by change of altitude, and should be capable of withstanding vibrations excited by the driving means. All pumps should be designed to withstand sustained accelerations applied in any direction and able to withstand continuous exposure, in the configuration as installed in aircraft, and either operating or non-operating, to salt spray as encountered in marine or coastal areas and to sand and dust as encountered in desert areas.

5.7.8.11 Structural Strength. The structural design of the ports and of the affected sections of the pump housing should be such as to withstand the application of a torque 2.5 times the maximum installation torque.

5.7.8.12 Markings. Inlet, outlet, and case drain ports should be identified on each pump in clear and permanent markings. In addition, the direction of rotation of the pump should be clearly and permanently marked on an exposed surface of the pump housing.

5.8 Component Installation.
5.8.1 Design Practice and Installation. The hydraulic system component installation requirements specified in the following subparagraphs are considered to be representative of good design practice; however, it is recognized that variations from these practices will, in many cases, be necessary due to specific installation exigencies. All installation of standard parts or components should be designed to accommodate the worst dimensional and operational conditions permitted in the applicable part or component specification. All components should be installed and mounted to satisfactorily withstand all expected acceleration loads, wrench loads, vibration effects, etc.

5.8.2 Accumulators. Accumulators should be installed with the utmost consideration given to the protection of crewmembers in the case of rupture due to gunfire. Accumulators should be provided with a fluid port and a gas port. The accumulator should be provided with a suitable piston type separator to separate the fluid and gas within the accumulator. Accumulators should contain a safety provision to assure dissipation of the accumulator gas pressure and fluid pressure before any component parts can be disassembled. Each accumulator should be provided with a permanent, legible, attached warning in red letters stating:

MAXIMUM OPERATING PRESSURE ____ PSI.
RELEASE GAS AND FLUID PRESSURE BEFORE DISASSEMBLING, STORING, OR SHIPPING ACCUMULATOR.

5.8.2.1 Measurement of Accumulator Gas Pressure. When accumulator gas charge is critical to the functioning of the hydraulic system or subsystem, a permanent pressure gage should be attached to the gas side of the accumulator. In non-critical installations, the use of the pressure gage should be at the discretion of the procuring activity. A gage indicating accumulator gas pressure should never be used to indicate equivalent hydraulic pressure to the crewmembers. Standard hydraulic gages should be used and should be attached with the shortest practicable length of line and minimum number of fittings.

5.8.2.2 Accumulator Accessibility. In all accumulator installations space should be provided around the gas charging valve for use of a high-pressure, gas-testing gage assembly and for standard fitting connections to charge accumulators.

5.8.2.3 Accumulator Instructions. Instructions for servicing the accumulator with gas pressure with the accumulator oil chamber discharged should be provided immediately adjacent to the accumulator. Adequate information should be included to indicate the proper gas preload pressure throughout the temperature range for which the accumulator will be serviced.

5.8.2.4 Gas Guidelines. All rotary-wing aircraft hydraulic system accumulators should be charged with either air or inert gas (i.e. nitrogen).

5.8.3 Actuating Cylinders. Hydraulic actuating cylinders should be so installed that they do not interfere with the adjacent structure and are readily accessible for
maintenance and inspection. If possible, the cylinder should be installed in a protected area, or if exposed, be protected from flying debris during landing and takeoff. Bearings or bushings used in the actuators should be depot level replaceable.

5.8.4 Fluid Sampling Valves. If required by the detail specification, a fluid sampling valve, conforming to MIL-V-81940, should be provided in the system return line that is common to all actuating circuits and should be located upstream of the main return line filter. The sampling valve(s) should be located in a readily accessible area and should allow convenient use of sampling containers. Fluid sampling valves should also be provided in other portions of the system if considered necessary by the procuring activity. The sampling valve(s) should allow representative fluid samples to be taken while the system is fully pressurized. Contamination generated by the operation of the valve should not adversely affect the fluid sample. The valve nozzle should include a protective cap, and the cap should also prevent external leakage in the event of valve malfunction. The cap should be provided with a security chain, or equivalent, to prevent loss of the cap.

5.8.4.1 There exist the potential for sensors to be installed in the hydraulic fluid that will be capable of detecting particulates, temperatures, moisture, and entrained solvents or other physical properties.

5.8.5 Directional Control Valves. The installation of directional control valves should be compatible with the control valve performance such that the system operation will not be affected by back pressure, interflow, or pressure surges which might tend to cause the valves to open or move from their setting or cause them to bypass fluid in other than the intended manner. No hydraulic control valves should be installed in the cockpit.

5.8.5.1 Directional Control Valve Handle Installation. When the effective length of the directional control valve handle exceeds 0.8 inch, limiting stops, external to the valve, should be provided. These stops should be capable of withstanding 75r pound-inches limit load (where, r, equals the effective handle length) and should be so positioned that no load will be applied to the internal valve stops, unless the valve has been specifically designed to handle subject loads.

5.8.5.2 Multiple Control Valve Systems. In systems which incorporate two or more directional control valves, provision should be made to prevent fluid from being transferred inadvertently, at any possible valve setting, from the cylinder ports of one valve into the cylinder ports of another valve.

5.8.5.3 Control Valve Actuation. Control valve operation may be direct, such as push-pull rods or cable control, or indirect, such as electrically operated controls. Push-pull rods should require a minimum or no adjustment. Sheathed flexible controls should not be used. Cable control should be designed to provide minimum adjustment and positive control. All controls should be designed to prevent overtravel or undertravel of the valve control handle by use of external or internal stops. Electrically operated valves should be provided with mechanical override control mechanisms wherever practicable.
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5.8.6 Filters. Filters in accordance with MIL-F-8815 (or applicable detail specification sheet) should be provided in all hydraulic systems. These filters should be used to filter all circulating fluid in the system. The pump pressure line filter should be located downstream from the ground servicing connection port, otherwise, an additional filter should be required to filter fluid entering the aircraft from the ground servicing unit. All vent openings or fluid exposed to breathing action through vents should be protected by filters. Line filters, when installed in the aircraft system in close proximity to an accumulator, should be installed upstream of the accumulator. Where pressure-drop indicators are provided on the filter assembly, the indicator should be easily visible to servicing personnel. In addition, replacement of the filter should be required before the indicator can be reset. When a screen or filter is provided either internally or in close proximity to a component, suitable provisions should be made for removal of the screen or filter for cleaning or replacement. Sintered-type elements should not be used.

5.8.6.1 Aircraft Filters. Filters should be provided in all hydraulic systems. Primary filter elements should have an absolute rating of no more than 5 microns and be capable of maintaining the particulate contamination level at a level no higher than Class 8 per SAE AS4059 (maximum service limit). Filters incorporating elements having absolute ratings lower (finer) than 15 microns may be used, but for secondary filtration purposes only (i.e. adding additional protection for a specific component). The acceptable contamination level for aircraft delivery should be specified in the contractual specification.

5.8.6.2 Filter Locations. Filters should be provided in the following locations as a minimum guideline.

5.8.6.2.1 Pressure Line Installation. Non-bypass-ing type line filter(s) should be installed in the system pressure line and should be so located that all fluid from the aircraft pump(s) and the ground support equipment pressure connection will be filtered prior to entering any major equipment or components of the system. In multi-pump systems, each pump should have a separate filter installation.

5.8.6.2.2 Return Line Installation. A bypass-ing type line filter should be installed in the return line. All fluid entering the return circuit should be circulated through the filter prior to entering the return line to the pump(s) and reservoir.

5.8.6.2.3 Reservoir Fill Line Installation. A non-bypass-ing type line filter should be installed to filter all fluid entering the system through the reservoir fill connection.

5.8.6.2.4 Pump-Case Drain Line Installation. Each pump-case drain (bypass) line should have a bypass-ing type filter installed.

5.8.6.2.5 Pump Suction Line. Filters should not be installed between the system reservoir and the pump suction port unless specifically authorized by the procuring activity.
5.8.6.3 **Hydraulic Sequencing.** Where hydraulic sequencing is critical, and where contamination can prevent proper sequencing, each sequence valve should be protected from contamination in each direction of flow by a suitable screen-type filter element. This element may be included as a part of the sequence valve assembly.

5.8.7 **Fittings.** All tube fittings (other than connections at production break points, to removable components, and where needed to facilitate maintenance) should be permanently joined employing no screw threads or similar mechanical means. In addition, suitable repair and replacement methods involving failed tubing and fittings should be established for each aircraft model and should be included in the applicable aircraft publications. Removable components should accept standard fittings. No thread lubricant other than hydraulic fluid specified in 5.1 should be used on hydraulic fittings.

5.8.8 **Flow Dividers.** Flow dividers should not be used if the effect of a malfunction of the flow divider would result in an unsafe flight condition.

5.8.9 **Flow Regulators.** Flow regulators may be installed in the hydraulic system to limit the rate of fluid flow. The direction and rate of fluid flow should be clearly indicated on the flow regulator and the adjacent structure. Regulators used under continuous dynamic conditions should not adversely affect the operation of the hydraulic system.

5.8.10 **Protective Devices.** Hydraulic fuses, circuit breakers, reservoir level sensors, or other similar devices may be used to meet survivability requirements established by the procuring activity. Pre-mature or inadvertent shutoff or any other malfunction of such devices should not occur during any flow or pressure variations or any conditions of system operation. The function and reliability of such devices should be demonstrated in the functional mockup and simulator.

5.8.11 **Snubbers.** Pressure snubbers should be used with all hydraulic pressure transmitters, hydraulic pressure switches, and hydraulic pressure gages. Pneumatic pressure gages are excluded from this requirement.

**Rationale:** Snubbers provide dampening for more accurate pressure readings.

5.8.12 **Manually Operated Pumps.** Where a manually operated pump is required, either a hand-actuated or foot-actuated pump should be selected, based on trade-off studies. In installations where the pump can be operated by personnel in a standing position, strong consideration should be given to a foot pump to minimize physical exertion.

5.8.12.1 **Manually Operated Pump Suction Line.** No screen or filter should be used in the suction line of the pump. The suction line should be of suitable diameter and length to insure priming a dry pump and obtaining full-rated flow at -54°C (-65°F) temperature for MIL-PRF-5606 (-32°C (-25°F) for MIL-PRF-83282) with 12 complete
cycles at a rate of 20 cycles per minute. The pump circuit should be capable of full priming and rated flow in flight at the highest altitude at which pump operation is essential and intended.

5.8.12.2 Manually Operated Pump Check Valve. A standard check valve should be provided in the pump pressure line.

5.8.12.3 Hand Pump Handle Length. The effective operating handle length of hand pumps should be such that the handle load should not exceed 67 pounds. The handle travel at the handgrip should not exceed 18 inches.

5.8.13 Flexible Connections. Whenever relative motion exists between two points, metal coiled tubing in accordance with SAE ARP 584 or SAE ARP4146 is preferred, unless hoses, extension units, or swivels are demonstrated to be superior in the application and the environment. In the case of the latter, hoses are preferred over extension units and swivels and should be selected per the requirements of SAE AS5440.

5.8.14 Hose Assemblies. Hose assemblies should not be subjected to torsional deflection (twisting) when installed or during system actuation. No hose clamp type installation should be used in hydraulic systems.

5.8.14.1 Hose Support. The support of a flexible line should be such that it will never tend to cause deflection of the rigid lines under any possible relative motion that may occur. Flexible hose between two rigid connections may have excessive motion restrained where necessary but should never be rigidly supported as by a tight rigid clamp around the outside diameter of the flexible hose. Extreme care should be used in the selection and placement of the supports to assure the flexible line is not restricted and does not rub on structure or adjacent members during any portion of its excursion.

5.8.14.2 Hose Bend Radii. The minimum radius of bend of hose assemblies should be a function of hose size and flexing range to which the hose installation will be subjected. The minimum bend radii for hoses should be as listed in the applicable hose specification.

5.8.14.3 Hose Protection. Hose should be suitably protected against chafing where necessary to preclude damage to the hose and to the adjoining structure, tubing, wiring, and other equipment. Hose assemblies including end fittings of amphibious aircraft which are subject to salt water immersion should be suitably protected.

5.8.14.4 Provisions For Hose Elongation and Contraction. Hose assemblies should be so selected and installed that elongation and contraction under pressure, within the hose specification limits, will not be detrimental to the installation either by causing strains on the end fittings or excessive binding or chafing of the hose.

5.8.15 Lock Valves. Where lock valves are used, provisions should be made for fluid expansion and contraction through-out the temperature range. Where several
actuating cylinders are mechanically tied together, only one lock valve should be used to hydraulically lock all actuators so tied together.

5.8.16 **Motors.** All motors should be accessible for maintenance and inspection and should be located in an appropriately cool or warm space depending upon their service. Proper case overflow connections to the reservoir should be provided. Shaft seal drains should be vented overboard.

5.8.17 **Electric-Motor-Driven Pumps.** Electric-motor-driven hydraulic pumps may be used, as necessary, for either normal, emergency, or auxiliary operation of hydraulic systems.

5.8.18 **Pressure Regulators (Unloading Valves).** When an unloading valve is used, the return line to the reservoir should be as short as possible and should not be subjected to back pressure or pressure surges in excess of allowable values stated herein. The unloading valve should have the drain port piped directly to the reservoir or routed to some return line in which the maximum pressure does not exceed the reservoir pressurization and is not subjected to pressure surges. The tubing connecting the unloading valve should be so designed and installed that the pressure surges in the system will not affect the operation of the unloading valve at any flow rate of the system. In addition, provisions should be made in the system to eliminate any harmful shocks caused by pressure surges due to the operation of the unloading valve.

5.8.19 **Relief Valves, System and Thermal Expansion.** Relief valves may be incorporated as part of another unit. Relief valves are designed to be used as a safety device to prevent bursting of, or damage to, the system in the event the normal pressure regulation device in the system malfunctions; or, in blocked line condition, to relieve excessive pressure due to either thermal expansion of the fluid or overload forces on actuating units. Therefore, relief valves should not be used as the sole means of limiting pressure in a power circuit but should function only as a safety valve.

5.8.19.1 **System Relief Valves.** Provisions should be made to insure that pressure in any part of the power system will not exceed a safe limit above the cutout pressure of the hydraulic system. Pressure relief valves, as specified herein, should be located in the hydraulic system wherever necessary to accomplish this pressure relief. The system relief valve should have a capacity equal to or greater than the combined rate of flow of pumps where fixed-displacement pumps with common cut-out regulators are used, or equal to or greater than the rated flow of the largest pump when variable-volume pumps with a common pressure line are used. The systems should be designed so that excessive temperature over 135°C (275°F) does not occur due to fluid flowing through a relief valve. As an alternative, a temperature warning and indication system may be used.

5.8.19.2 **Thermal Expansion Relief Valves.** Relief valves should be installed as necessary to prevent excessive pressure rise and system damage resulting from thermal expansion of hydraulic fluid. Internal valve leakage should not be considered an acceptable method of providing thermal relief.
5.8.20 Reservoirs. When a hydraulic emergency system is used in any military aircraft except trainer types, a separate emergency reservoir should be provided. The emergency reservoir should be located as remote as practicable from the main reservoir to minimize gunfire damage. It should be possible to fill the main and emergency reservoirs through a common filler port, unless the two reservoirs are so far distant as to make this guideline impracticable. The feed and vent lines in the two reservoirs should be so located that rupture of either of the reservoirs or the feedlines will not cause loss of sufficient fluid from the other reservoir to impair the system operation. Reservoirs should be suitably protected (i.e., return line relief valve) to prevent failure or damage when rapid discharge of the main or emergency system into the reservoirs is encountered. Installations of pressurized reservoirs should include a suitable depressurization valve for maintenance purposes.

5.8.20.1 Reservoir Location. It is desired that the reservoir should be so located that the following conditions will be obtained.

a. A static head of fluid will be supplied to the hand pump and the power-driven pump or pumps in all normal flight attitudes of the aircraft.

b. The length of suction line to the pump is a minimum.

c. The best available temperature and pressure is utilized, but must not be installed in engine compartments.

d. Protection from combat damage.

e. If practicable, suction lines should be so routed as to prevent breaking of the fluid column caused by gravity after engine shutdown and during the parking period. Where such routing is not possible or where the reservoir cannot be located above the pump, suitable provisions should be installed to maintain the fluid column to the pump after engine shutdown. A swing-gate type check valve in the suction port of the reservoir should normally maintain the fluid column to the pump.

f. If routing of the pump bypass cannot be accomplished so that breaking of the fluid column by gravity after engine shutdown is prevented, check valves should be incorporated in the lines.

5.8.20.2 Reservoir Venting. If a vent is provided in the reservoir, it should be so arranged that loss of fluid will not occur through the vent during flight maneuvers or ground operations of the aircraft. A filter should be incorporated into the vent line if the temperature requirement is suitable. If a filler cap is used, the act of removing the filler cap should automatically vent the reservoir in such manner that the energy contained in the pressurizing air is not dissipated by imparting kinetic energy to either the filler cap or the fluid contained in the reservoir or elsewhere in the system.
5.8.20.3 Gas-Pressurized Reservoirs. The air (or inert gas) pressure should be controlled by an externally nonadjustable pressure-regulating device to control the gas pressure in the reservoir. A relief valve should also be connected to the airspace to protect the reservoir and pump from excessive pressure. If the air pressure regulator and relief valve are combined into one housing, a single failure in that unit should not permit over-pressurization of the reservoir. Devices, such as aspirators, that introduce air into the hydraulic fluid should not be used. When the air is separated from the fluid by a piston or other device, operation of the system should not introduce air into the hydraulic fluid. Provision should be made to remove entrained air which may have entered the system during servicing or operation.

5.8.20.4 Reservoir Air Pressurization Moisture Removal Equipment. When engine bleed air is used for reservoir pressurization, a suitable moisture removal unit should be so located as to protect the pressure regulation lines and equipment. An adequate filter should be provided.

5.8.20.5 Reservoir Fluid Level Indication. Indicators should be incorporated in the reservoir design to automatically provide a continuous visual indication of reservoir fluid level. Temperature compensation for accurate fluid indication should be included in the design. The use of a dip stick, or the necessity for the manipulation or movement of any of the component parts in order to obtain the reading should not be acceptable. Reservoir fluid level indication should be provided in the cockpit. Indicator fluid level markings should correspond with the direct-reading fluid level indicator markings provided on the reservoir and should be lighted in accordance with applicable cockpit lighting requirements. A suitable warning light should also be provided to advise the pilot of a low fluid level condition. The cockpit fluid level indicator should not eliminate the requirement for the direct-reading fluid level indicator on the reservoir itself, as this is required for reservoir servicing with power OFF.

5.8.20.6 Reservoir Capacity. Hydraulic reservoirs should be designed to provide a minimum total available capacity sufficient to provide fluid for all combinations of system use, including but not limited to accumulator charging, thermal considerations, fluid compression, and maximum system usage.

5.8.20.6.1 Emergency Reserve Capacity. In those cases where an emergency reserve capacity of fluid is required, the minimum volume should be equal to 125 percent of the fluid required for the emergency purposes. The volumetric capacity of those subsystems which can be powered with means other than hydraulic fluid should not be considered, provided that no fluid is drawn from the reservoir during such operation. No allowances for return of fluid to the reservoir should be made in determining emergency reserve capacity. The emergency reserve capacity should be provided in a separate reservoir.

5.8.20.7 Filling and Refill. The reservoir design should be such that initial filling of the reservoir installed in the vehicle, and any subsequent refilling or replenishment of the fluid, should be accomplished only through the use of an external force device such as a hand pump or power pump. No provision should be incorporated which permits the
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transfer of hydraulic fluid into the reservoir by gravity flow from an external container. The reservoir filling ports should be so designed and installed at locations where it should prevent the above procedure. If a “fill module” is used for transfer of fluid into the reservoir, the gravity fill orifice should have a minimum internal diameter of 1.5 inches.

Rationale: NATO standardized agreement (STANAG) 3212 established a minimum internal diameter for hydraulic fluid gravity fill orifices.

5.8.20.8 Draining. The reservoir should contain provision for draining hydraulic fluid completely from the reservoir when the vehicle is at rest, without the necessity of disconnecting any tubing connections.

5.8.20.9 Bleeding. Reservoir design and installation should be such that if entrained air bubbles in the hydraulic fluid are allowed to accumulate in any space in the reservoir, means should be provided for removing entrapped air in a bleeding operation without any tubing disconnection. Also, provisions should be provided in any re-circulating system reservoir for either automatic or periodic manual removal of any hydraulic fluid from any cavities in the reservoir in which fluid is not present by design, such as the gas side of a gas-pressurized piston type reservoir.

5.8.21 Restrictor Valves. Adjustable orifice restrictor valves may be used in experimental aircraft, but only fixed orifice restrictor valves should be used in service test and production aircraft. For one-way restrictors, the direction of restricted and unrestricted flow should be indicated on the restrictor valves and adjacent structure. (For orifice filtration requirements, see 5.7.2.)

5.8.22 Self-Sealing Couplings. Hydraulic systems should be provided with self-sealing couplings for each engine-driven pump and so located that the powerplant section can be readily removed for servicing. A suitable coupling should be used in each line going to each pump. Self-sealing couplings should also be provided on all hydraulically operated brake installations where it is necessary to disconnect the brake line in order to remove the wheel. The self-sealing coupling should be attached to the brake, and it should be possible to remove the wheel without damaging the coupling. Self-sealing couplings should also be provided at all other points in the hydraulic system which require frequent disassembly or, where convenient, to isolate parts of the system as in jacking and servicing one landing gear only. Sufficient clearance should be provided around the coupling to permit connection and disconnection. Self-sealing couplings installed adjacent to each other should be of different size or be otherwise designed that inadvertent cross connection of the lines cannot occur.

5.8.22.1 Airframe Break Points. When self-sealing couplings are provided at airframe break points, especially in flight-control systems, and where disconnection of such a coupling or couplings will adversely affect the operation of any of the systems, adequate means should be provided to prevent the inadvertent disconnection of the couplings. Such means should also provide adequate indication when a coupling connection is incomplete. If the means of preventing inadvertent disconnection are not
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absolutely positive, the system should be so designed that a hydraulic lock resulting from an inadvertent coupling disconnection will not be the cause of an aircraft accident.

5.8.23 Shuttle Valves. Shuttle valves should not be used in installations in which a force balance can be obtained on both inlet ports simultaneously which may cause the shuttle valve to restrict flow from the outlet port. Where shuttle valves are necessary to connect an actuating cylinder with the normal and emergency systems, the shuttle valve unit should be built into the appropriate cylinder head. Where the above installation cannot be made, a standard shuttle valve may be located at the actuator port. In the event neither of the above installations is possible, a length of rigid line is permissible between the cylinder port and the shuttle valve, provided that the rigid line and shuttle valve are firmly attached to the actuating cylinder. Flexible hose should not be used between the actuating cylinder port and the shuttle valve.

5.8.24 Pressure Switches. Pressure switches may be installed in hydraulic systems where the regulation of hydraulic pressure is required by controlling an electric-motor-driven pump or other applications. Adequate precautions should be taken to prevent chatter or cutoff.

5.8.25 Swivel Joints. Where lines or fittings are used to drive swivel joints, they should be adequately supported and should be of sufficient strength to insure a satisfactory operating installation.

5.8.26 Tubing.

5.8.26.1 Tubing Bends. Forcing, bending, or stretching of tubing to accomplish installation should not be permitted.

5.8.26.2 Installation of Small Size Tubing. If tubing in sizes smaller than 1/4-inch outside diameter (-4 size) is used in hydraulic systems, particular care should be taken to properly install, support, and protect it, and it must be shown that proper operation of the service in which such tubing is used will be possible at -54°C (-65°F) temperature.

5.8.26.3 Designed Motion in Tubing. Looped or straight aluminum-alloy tubing should not be used between two connections where there is designed relative motion. Coiled tube and torsion tube installations should be designed and installed in accordance with the data given in SAE ARP-584. Rigid tubing end connections should not be used.

5.8.26.4 Tubing in Fire Hazard Areas. Aluminum tubing should not be used within powerplant compartments and at other locations where fires are likely to occur. Where separable tube fittings are required, they should be corrosion-resistant or carbon steel.

5.8.26.5 Tubing and Fitting Identification. All hydraulic fluid lines should be permanently marked. A sufficient number of hydraulic lines should be marked in conspicuous locations throughout the aircraft in order that each run of line may be traced. This marking should indicate the unit operated and the direction of flow, such as “PUMP
SUCTION →” or “SERVOCYLINDER RETURN →”. These markings should be repeated as often as necessary, particularly on lines entering and emerging from closed compartments, to facilitate maintenance work. Where fittings are located in members, such as bulkheads and webs, each fitting location should be identified (placarded) as to system function, using the same terminology as on its connecting line.

5.8.26.6 Tubing Supports. All hydraulic tubing should be supported from rigid structure by cushioned steel clamps or by suitable multiple-tube block-type clamps. Supports should be placed as near as practicable to bends to minimize overhang of the tube. Where tubes of different diameter are connected together, an average spacing distance may be used. Provisions should be made in support locations to accommodate change in tubing length caused by expansion and contraction.

5.8.26.7 Location of Hydraulic Tubing. Hydraulic lines should not be installed in the cockpit or cabin and should be remote from personnel stations. In addition, hydraulic lines should be located remotely from exhaust stacks and manifolds; electrical, radio, oxygen, and equipment lines; and insulating materials. In all cases, the hydraulic lines should be below the aforementioned to prevent fire from line leakage. Hydraulic lines should not be grouped with links carrying other flammable fluids in order to prevent inadvertent cross connection of different systems. Hydraulic drain and vent lines should exhaust in areas where the fluid will not be blown into the aircraft, collect in pools in the structure, or be blown onto or near exhaust stacks, manifolds, or other sources of heat. Tubing should be located so that damage will not occur due to being stepped on, used as handholds, or by manipulation of tools during maintenance. Components and lines should be so located that easy accessibility for inspection, adjustment, and repair is possible. Hydraulic tubing should not be used to provide support of other aircraft installations, such as wiring, other aircraft tubing, or similar installations. Attachment of so-called marriage clamps for spacing of such installations is likewise prohibited.

5.8.26.8 Tubing Flares and Assembly. When installing tube connections, care should be exercised to keep the wrench torque used to assemble each joint within the specified limits. Male threaded aluminum-alloy flared fittings should not be used with stainless-steel lines below size -8.

5.8.26.9 Tubing Pre-Stress. Each titanium tube assembly should be pre-stressed by the application of pressure to approximately 95 percent of the minimum yield strength. This test may be performed on the bench or in the aircraft.

5.8.27 Design of System Installations.

5.8.27.1 Component Lines. Two or more lines attached to a hydraulic component should be sufficiently different to prevent incorrect connection to the component.

5.8.27.2 Drain Lines. Drain or vent lines coming from the pump, reservoir, or other hydraulic components should not be connected to any other line or any other fluid system.
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in the aircraft in such manner as to permit mixture of the fluids at any of the components being drained or vented.

5.8.27.3 Mounting Lightweight Components. Lightweight components that do not have mounting provisions may be supported by the tubing installation, provided that the component is rigidly installed and does not result in destructive vibration or cause other adverse conditions of the tubing installation. Clamps or similar devices may be used to support such units to structure, provided that nameplates, flow-direction arrows or markings, or other data is not obscured and that the supporting member(s) do not affect the operation of the unit.

5.8.27.4 Bonding. The aircraft hydraulic system components and lines should be bonded to the aircraft in accordance with MIL-STD-464.

5.8.27.5 Vibration. The complete hydraulic system, including lines and components, should be designed to withstand the effect of vibration, pump pulsation, and shock loads encountered during service operation of the aircraft.

5.8.27.6 Tubing Clearance. Where tubing is supported to structure or other rigid members, a minimum clearance of 1/16 inch should be maintained with such member. A minimum clearance of 1/4 inch should be maintained with adjacent structure, tubing, or other installations. In areas where relative motion of adjoining components exists, a minimum clearance of 1/4 inch should be maintained under the most adverse conditions that will be encountered.

5.8.27.7 Corrosion Protection. All tubing in exposed areas, such as wheel wells, weapons bays, and cove areas, should be adequately protected against corrosion, particularly under the sleeve at the fittings.

5.8.27.8 Suction Line to Power-Driven Pumps. The supply line to the power-driven pump(s) should be designed to provide adequate flow and pressure at the pump inlet port. This guideline should include operating the pump at the maximum output flow required of the pump and should include all ground and flight conditions the aircraft will encounter. Zero g and negative g conditions and low-temperature start and operation should also be included in the above guideline.

6. QUALIFICATION GUIDELINES

6.1 Qualification Test Conditions. The following test conditions apply to qualification testing, unless otherwise modified by, or added to, in the applicable detail specification.

6.1.1 Adverse Tolerance Conditions. The component should be capable of functioning when assembled with adverse tolerance parts without any degradation in component performance or life. The manufacturer should verify compliance with this guideline by mathematical analysis or by actual test.
6.1.2 **Test Fluid.** The test fluid used for qualification purposes shall be in accordance with 5.1.

6.1.3 **Temperature Conditions.** Unless otherwise specified, the ambient and outlet fluid temperatures should be within the range indicated in each individual test. For the components with appreciable heat generating characteristics such as relief valve, solenoid-operated units, etc., the outlet fluid temperature should be as specified, and the inlet fluid and ambient temperature may be decreased to compensate for this heat generation. However, in no case should the inlet fluid temperature or ambient temperature be decreased by more than 25°F. For zero-flow condition tests, the ambient temperature should be as specified. The ambient inlet and outlet fluid temperature should be stated in the test report. Fluid temperature should be measured as near as practicable to the component ports. During all soaking periods, the system should be bled of air and should be maintained full of fluid. Unless otherwise specified, the following tolerances should be applied respectively to the following basic temperatures referred to throughout the tests specified:

- 275° ± 5°F
- 100° ± 5°F
- 225° ± 5°F
- -65° +0°/-5°F
- 160° +5°/-0°F

6.1.4 **Filtration.** For qualification testing, the test fluid should be continuously filtered through a filter element with a micron rating equivalent to the micron rating of the filter element used in the aircraft.

6.1.5 **Qualification of Similar Units.** In the case of a series of devices which are intended to serve the same general function in a hydraulic system, qualification of one device of the series may, at the discretion of the procuring activity, be applied to any other devices of the series if all the internal working parts are identical in every detail with the corresponding internal working parts of the qualified device, and provided it meets the proof, burst pressure, and such operational requirements as may be designated by the procuring activity.

6.2 **Component Qualification Tests.**

6.2.1 **Quality Conformance Tests.** Unless otherwise specified in the detail specification, the qualification tests for a component should consist of all the tests listed in paragraph 4.2.2 and should be conducted using the guidelines below.

6.2.1.1 **Quality Conformance Test Conditions.** Unless otherwise specified in the detail specification, fluid and ambient temperatures should be between 70° and 120°F.

6.2.1.2 **Examination of Product.** Each component should be carefully examined to determine conformance to the requirements of applicable design specifications for
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design, weight, workmanship, marking, conformance to applicable government and manufacturer’s drawings, specifications and standards for any visible defects.

6.2.2 Immersion.

6.2.2.1 Nonmetallic Parts. Components containing nonmetallic parts other than plastic parts or standard seals in glands known to be compatible with hydraulic fluid should be immersed in hydraulic fluid for a period of 72 hours at a temperature of 275°F ± 2°F prior to conducting the qualification tests specified herein or in the detail specification. All internal parts should be in contact with the fluid during this period.

6.2.3 Pressure Tests.

6.2.3.1 Proof Pressure. A proof pressure, as specified in Table I or the detail specification, should be applied at the temperature specified in the detail specification for at least two successive times and held 2 minutes for each pressure application. The rate of pressure rise should not exceed 25,000 psi per minute. The equipment should be operated in its normal function between applications of the test pressure. There should be no evidence of external leakage, other than a slight wetting at seals insufficient to form a drop, excessive distortion, or permanent set. Components which require varying test pressures in different elements may have these pressures applied either separately or simultaneously as specified in the detail specification. Components that are subject to pressure in the reverse direction such as check valves, shut off valves or accumulators should be pressurized in both directions, either separately or simultaneously as specified in the detail specification.

6.2.3.2 Burst Pressure. A burst pressure, as specified in Table II or the detail specification, should be applied at the temperature specified in the detail specification to the component at a maximum pressure rise rate of 25,000 psi per minute. The component should not rupture under this pressure nor should leakage exceed that permitted in external leakage test specified herein. The pressure may be increased above that specified in order to secure data on actual rupture pressure. This should be the last test performed because of its destructive nature. Components that require different test pressures in different elements should have these pressures applied either separately or simultaneously, whichever is the most critical. Components that are subject to pressure in the reverse direction such as check valves, shut off valves or accumulators should be pressurized in both directions, either separately or simultaneously as specified in the detail specification.

6.2.4 Leakage Tests.

6.2.4.1 External Leakage. During the course of all the tests listed in this standard, external leakage, other than a slight wetting insufficient to form a drop through static seals, should be cause for rejection. Where external, dynamic seals are utilized, permissible leakage past such seals should be no greater than that specified in the detail specification.
6.2.4.2 Internal Leakage. These tests should be performed with the component held in the position most conducive to leakage. Pressures of 5 psi and of normal operating pressure should be held for a period of 5 minutes each, unless otherwise specified in the detail specification. In each case, the leakage measurement should consist of the last 3 minutes of the 5 minute period. The rate of leakage should not exceed that specified in the detail specification for the qualification test.

6.2.5 Pressure Drop. Pressure drop characteristics for a range of 0 to 150 percent of rated flow or as specified in the detail specification should be determined for the component. The pressure drop observed at rated flow should not exceed the value permitted by the applicable detail specification.

6.2.6 Extreme Temperature Functioning Tests.

6.2.6.1 Low Temperature. The component should be connected to a static head of 1 to 3 feet of the test fluid or rated working pressure, whichever is the more critical condition. This arrangement should be maintained at a temperature not warmer than -65°F for 3 hours after the temperature has stabilized at -65°F. After this period the component should be actuated at least two times. Variation of actuating forces or regulation, as applicable should not exceed that permitted by the detail specification. The quality conformance tests for leakage should be performed after each actuation and the requirements of the detail specification satisfied.

6.2.6.2 Intermediate Temperature. Immediately following the low temperature test (6.2.6.1), the test arrangement should be warmed rapidly to a temperature of 160°F. While the temperature is being raised, the component should be actuated at maximum increments of 36°F to determine satisfactory operation throughout the temperature range. These check tests should be made without waiting for temperature of the entire component to stabilize. For complex components, the 36°F increment may be increased in the detail specification to allow for time to perform functional tests.

6.2.6.3 High Temperature. In the case of standard components, the temperature should be maintained at 275°F, or in the case of nonstandard components, the temperature should be maintained at the highest value which the component is expected to encounter for a length of time sufficient to allow all parts of the component to attain the temperature. In no case should the temperature at which this test is conducted be less than 275°F. The component should then be actuated at least two times. In the case of pressure actuation or regulation, the variation from room temperature actuation or regulation should not exceed that permitted by the detail specification. The qualification test for leakage should be performed after each actuation and the requirements of the detail specification satisfied.

6.2.6.4 Differential Temperature. For components utilizing fluid from two systems, the component should be operated with the fluid temperature maintained at a differential temperature of the maximum differential possible for the system. The component should
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be actuated at least two times. Variation of actuating forces or regulation, as applicable should not exceed that permitted by the detail specification for the differential temperature condition.

6.2.6.5 Temperature Limits. Solenoids (where applicable) should be subjected to the high temperature and low temperature test procedures of MIL-STD-810.

6.2.7 Temperature Rise. Solenoids (where applicable) should be tested at the dc or ac voltage and at the frequency as specified in the detail specification. The dc test source should be used to measure coil resistance prior to and immediately after operation. The dc resistance measurements should be used to determine temperature rise.

6.2.8 Endurance.

6.2.8.1 General. The component should be subjected to cyclic operation and to other fatigue tests, such as hydraulic impulse, in accordance with the requirements of the detail specification which should indicate number of cycles, schedule of cycling, cycle rate, stroke, rate of flow, loads, temperature, impulse peaks, etc. When applicable, leakage should be checked at 25, 50, 75 and 100 percent of the number of cycles required. At the conclusion of the endurance test, the component should operate satisfactorily and should be disassembled and carefully inspected. There should be no evidence of excessive wear in any part of the component.

6.2.8.1.1 Contaminated Fluid. The ability of the component to perform in a contaminated fluid environment should be demonstrated by actual test. The test fluid used for endurance cycling of all hydraulic components shall be at a cleanliness level of SAE AS4059 (NAS1638) Class 5 minimum. At least 20 percent of endurance cycling should be performed with hydraulic fluid at a cleanliness level of SAE AS4059 (NAS1638) Class 8 minimum (maximum service limit). Until standard mixture of contaminants is available that best represents those found in a typical rotorcraft hydraulic system, ISO Medium Test Dust (ISO 12103-A3) per ISO 12103-1 should be used as the principal contaminant. Alternate contaminants (or actual used hydraulic fluid) may be substituted with prior approval.

Rationale: Testing with fluid at higher contamination levels is more representative of actual aircraft conditions and will provide a better indication of component reliability and expected life.

6.2.8.2 Aircraft Applications. The number of cycles selected should be based on the duty cycle over the anticipated life of the aircraft or the component, whichever is greater, multiplied by an appropriate safety factor. In either case, the cycles should be not less than the values specified in Table III.

<table>
<thead>
<tr>
<th>Type and Usage of Component</th>
<th>Cycles</th>
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Table III
Endurance Test

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<th>Standard</th>
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<td>Nonstandard</td>
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<td>-Frequent (more than 10 cycles per flight)</td>
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<td>-Flight control, steering, anti-skid, etc.</td>
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6.2.8.3 Endurance. The endurance tests should be governed by the following general test cycle, as well as the test methods specified in 6.2.8. The following tests should be performed in the sequence indicated:

General Test Cycle

a. Fill the component with hydraulic fluid to 90 percent of the total fluid volume of the unit. Cap the ports and place the component in heating chamber in which the ambient temperature is maintained at 275°F. Hold the component at the ambient temperature of 275°F for a period of 72 hours.

b. Conduct the proof pressure test specified in 6.2.3.1 at 275°F.

c. Conduct the low temperature test specified in 6.2.6.1 at -65°F for a minimum of 10 cycles. Test specimen to remain at -65°F for at least 4 hours, prior to conducting test. Increase in temperature during the test due to operation is permitted.

d. Immediately following the low temperature test, conduct the intermediate temperature test specified in 6.2.6.2 at 160°F, warm test arrangement rapidly to 275°F and actuate component at increments of approximately 36°F to determine satisfactory operation.

e. Conduct the high temperature test specified in 6.2.6.3 at 275°F for a minimum of 10 cycles.

f. Conduct 25 percent of the cycles of the endurance test specified in 6.2.8 at 275°F, with the consequent length of exposure at 275°F, unless either condition is modified as a result of 6.2.8.3.1.

g. Soak component at 275°F for 2 hours. Pressure is to be maintained during the first hour and reduced to approximately zero psi for the second hour.

h. Repeat the low temperature test specified in 5.2.6.1 at -65°F and the high temperature test specified in 6.2.6.3 at 275°F.

i. Conduct 75 percent of the cycles of the test specified in the endurance test in 6.2.8 at 225°F unless modified as the result of 6.2.8.3.1.

6.2.8.3.1 Elevated Temperature Cycling. The contractor should determine the percentage of the cycles a component is to operate at elevated temperatures and the
cumulative elevated temperature exposure of the component during its life or the life of
the aircraft, whichever is greater. The extent of elevated temperature endurance cycling
of a component should be based on the above determination.

6.2.8.4 Impulse.

6.2.8.4.1 Actuators, Valves, Pressure Containers and Similar Components. These
components should be subjected to an impulse test in accordance with SAE ARP1383
and as specified in the detail specification. Where SAE ARP1383 and the detail
specification conflict, the detail specification should take precedence.

6.2.8.4.2 Hose Assemblies, Tubing, Fittings, Quick Disconnect Couplings, Filters
and Other Transmission Line Components. These components should be subjected to an
impulse test in accordance with SAE ARP 603 and as specified in the detail specification.
Where SAE ARP 603 and the detail specification conflict, the detail specification should
take precedence.

6.2.9 Vibration, Shock and Acceleration. Components should be subjected to the
vibration, shock and acceleration test procedures of MIL-STD-810 (methods 514, 516 &
513 respectively) when specified in the detail specification.

6.2.10 Humidity. Moisture resistance should be established by the humidity test
procedure of MIL-STD-810. At the conclusion of this test, electrical components should
operate normally through 25 cycles at rated voltage. Solenoids (where applicable) should
be subjected to a dielectric strength test following humidity testing.

6.2.11 Fungus. Components which include materials that are not classified as fungus
inert by MIL-STD-464, Requirement 4, should be subjected to the fungus test of MIL-
STD-810, Method 508.

6.2.12 Sand and Dust. The components should be subjected to the sand and dust test
procedure of MIL-STD-810. This test may be omitted if all moving parts of the
component are exposed only to internal fluid.

6.2.13 Salt Fog. The components should be subjected to salt fog test procedures of
MIL-STD-810 unless it is established by the procuring activity that this test is not
required.

6.2.14 Icing. The component should be subjected to an icing test if its design is such
that accumulation of ice on external surfaces or inside of vent holes may cause
malfunction. When required, this test should be performed as specified in the detail
specification.

6.2.15 Explosion Proof. Components with a potential source of ignition should be
subjected to an explosion proof test in accordance with the explosive atmosphere test
procedure of MIL-STD-810.
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6.2.16 Electromagnetic Interference. Components that cause electromagnetic interference should be subjected to an electromagnetic interference test in accordance with MIL-STD-461, MIL-STD-462 and MIL-STD-463.

6.2.17 Actuation Above System Pressure. Components should be tested for actuation, under a pressure equal to thermal relief valve maximum setting of the circuit in which they are installed. This test should be conducted as specified in the detail specification.

6.2.18 Reliability. Tests should be conducted to demonstrate compliance with reliability requirements, including Mean Time Between Failure (MTBF), or equivalent, as specified in the detail specification.

6.2.19 Dielectric Strength. If a dielectric test is required following the humidity test (or the salt fog test), the solenoids should be baked for 6 hours at a maximum ambient temperature as specified in the detail specification prior to being subjected to the dielectric test. All solenoids should be subjected to a ___ Hertz alternating test voltage between terminals and case for one minute at the following root mean square amplitudes:

a. ____ volts at room temperature and pressure
b. ____ volts at maximum operating temperature and altitude.

Leakage current should not exceed one milliampere during these tests.

6.2.19.1 Subsequent Dielectric Tests. Subsequent dielectric tests on assembled hydraulic components or dielectric testing after environmental testing on the solenoid should be performed at 75 percent of the above voltages for 1 minute. Flashover or leakage current greater than one milliampere should constitute a failure. There should be no distinction between test voltage on prototype and production units.

6.2.20 Drop Out Voltage Test. Solenoid operated components should be tested for drop out voltage by applying nominal activation voltage and slowly reducing the applied voltage to 10% of the nominal activation voltage. The solenoid should drop out between 10% of the nominal activation voltage and the minimum activation voltage specified in the detail specification.

6.3 Hydraulic Pumps. Hydraulic pumps should be qualified in accordance with the requirements of SAE AS19692. The qualification tests outlined in this standard are in addition to the guidelines of the component qualifications presented in section 6.2. In cases of the same test parameters, the tests in SAE AS19692 should replace the guidelines of section 6.2 for testing of hydraulic pumps. Exception: Fluid contamination levels for 20 percent of endurance testing should be in accordance with the requirements of 6.2.8.1.1.
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6.4 Accumulators. Accumulators should be qualified in accordance with the requirements of SAE ARP4379. The qualification tests outlined in this standard are in addition to the guidelines of the component qualifications presented in section 6.2. In cases of the same test parameters, the tests in SAE ARP4379 should replace the guidelines of section 6.2 for testing of hydraulic accumulators. Exception: Fluid contamination levels for 20 percent of endurance testing should be in accordance with the requirements of 6.2.8.1.1.

6.5 Reservoirs. Hydraulic reservoirs should be qualified in accordance with the requirements of MIL-R-8931. The qualification tests outlined in this specification are in addition to the guidelines of the component qualifications presented in section 6.2. In cases of the same test parameters, the tests in MIL-R-8931 should replace the guidelines of section 5.8.20 for testing of hydraulic reservoirs. Exception: Fluid contamination levels for 20 percent of endurance testing should be in accordance with the requirements of 6.2.8.1.1.

6.6 Actuators, Flight Control. Servoactuators and all other actuators for use in aircraft flight control systems should be qualified in accordance with the requirements of SAE ARP 1281. The qualification tests outlined in this standard are in addition to the guidelines of the component qualifications presented in section 6.2. In cases of the same test parameters, the tests in SAE ARP1281 should replace the guidelines of section 6.2 for testing of hydraulic flight control actuators. Exception: Fluid contamination levels for 20 percent of endurance testing should be in accordance with the requirements of 6.2.8.1.1.

6.7. Ground/Flight Testing. Ground and flight tests shall be in accordance with paragraphs TBD.

6.7.1 Prior to first flight of any new hydraulic system all analysis contained in paragraph 6.1.1 (Adverse Tolerance Condition) and the following development and qualification requirements shall have been accomplished.

a. Quality Conformance Tests 6.2.1) with exception of environmental testing.
b. Immersion (6.2.2)
c. Proof Pressure Test (6.2.3.1)
d. Burst Pressure Test (6.2.3.2)
e. External Leakage Test (6.2.4.1)
f. Internal Leakage Test (6.2.4.2)
g. Pressure Drop (6.2.5)
h. Low Temperature Functioning Test (6.2.6.1)
i. Intermediate Temperature Functioning Test (6.2.6.2)
j. High Temperature Functioning Test (6.2.6.3)
k. Differential Temperature Functioning Test (6.2.6.4)
l. Solenoid Temperature Limits (6.2.6.5) where applicable
m. Solenoid Temperature Rise (6.2.7) where applicable
n. Endurance Test (6.2.8.3)
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- Elevated Temperature Endurance Cycling Test (6.2.8.3.1)
- Impulse Test (6.2.8.4.1) for actuators, pressure containers and similar components
  - Impulse Test (6.2.8.4.2) for hose assemblies, tubing, fittings, quick disconnect couplings, filters and other hydraulic line components
- Vibration, Shock and Acceleration Test (6.2.9)
- Electromagnetic Interference Test (6.2.16) where applicable

6.8 Environmental Testing: Typical environmental testing requirements for hydraulic components are identified in Appendix A.
## Appendix A – Environmental Testing Requirements (Typical)

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Appendix B - Acronyms.

ADS – Aeronautical Design
AIA – Aerospace Industries Association
AMCOM – Aviation and Missile Command
AN – Army Navy Standard
AS – Aerospace Standard
ARP – Aerospace Recommended Practice
CDRL – Contract Data Requirements List
°C – Degrees Celsius
cu. in./rev – cubic inches per revolution
DOD – Department of Defense
°F – Degrees Fahrenheit
g – Gravitational Force
gpm – gallons per minute
ISO – International Standards Organization
MIL-PRF – Military Performance Specification
MIL-STD – Military Standard
MTBF – Mean Time Between Failure
NATO – North Atlantic Treaty Organization
NAS – National Aerospace Standard
PTU – Power Transfer Unit
PSI – Pounds Per Square Inch
SAE – Society of Automotive Engineers
STANAG – NATO abbreviation for Standardization Agreement
PEO Program Executive Office
UNJ Threads– Unified National J Thread (controlled root radius)