AEROSPACE RECOMMENDED PRACTICE

ARP4943™	REV. A
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Superseding ARP4943	

(R) Ground Support Equipment Hydraulic Systems, Design and Installation, Recommended Practices for

RATIONALE

ARP4943 has been updated to Revision A for the following reasons:

a. Minor technical changes have been made;

b. Applicable Document references have been updated;

c. Editorial changes have been made to improve the readability of the document.

TABLE OF CONTENTS

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) covers the design and installation requirements for hydraulic systems (up to 8000 psig [56 MPa]) for ground support equipment (GSE). This ARP is derived from AS5440, which provides hydraulic system requirements for aircraft. The recommendations herein are primarily intended for GSE that exchange hydraulic fluid with the aircraft, such as hydraulic service carts, rather than GSE with non-interfacing hydraulic systems. The GSE may be mobile, portable, or stationary.

1.1 Classification

The hydraulic systems defined by this document shall be capable of servicing aircraft systems and components of all types and classes defined in AS5440. The terminology, Class XXXX, where XXXX is the GSE system pressure, is utilized within this document.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific examption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS3384 Rubber, Fluorocarbon Elastomer (FKM), 70 to 80 Hardness, Low Temperature Sealing Tg -22 °F (-30 °C), for Elastomeric Shapes or Parts in Gas Turbine Engine Oil, Fuel, and Hydraulic Systems

AMS4081 Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn, Round, 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T4), Solution Heat Treated and Naturally Aged

AMS4083 Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn, Round, 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T6), Solution and Precipitation Heat Treated

AMS5561 Steel, Corrosion- and Heat-Resistant, Welded and Drawn or Seamless and Drawn Tubing, 9.0Mn - 20Cr - 6.5Ni - 0.28N, High-Pressure Hydraulic

AMS5566 Steel, Corrosion-Resistant, Seamless or Welded Hydraulic Tubing, 19Cr - 10Ni (304), High Pressure, Cold Drawn

AMS-P-83461 Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275 °F (135 °C)

AIR1657 Handbook of Hydraulic Metric Calculations

AIR1922 Aerospace - System Integration Factors That Affect Hydraulic Pump Life

ARP584 Coiled Tubing - Corrosion-Resistant Steel, Hydraulic Applications, Aerospace

ARP994 Design of Tubing Installations for Aerospace Hydraulic Systems

ARP4835 Aerospace Fluid Power - Hydraulic Thermal Expansion Relief Valves

AS1241 Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft

AS4059	Aerospace Fluid Power - Contamination Classification for Hydraulic Fluids
AS4157	Coupling Assemblies, Hydraulic, Self-Sealing, Quick Disconnect, 8000 Pounds per Square Inch, Gage
AS4330	Tubing, Flared, Standard, Dimensions for, Design Standard
AS4395	Fitting End, Flared, Tube Connection, Design Standard
AS4396	Fitting End, Bulkhead, Flared, Tube Connection, Design Standard
AS4716	Gland Design, O-Ring and Other Seals
AS5440	Hydraulic Systems, Military Aircraft, Design and Installation, Requirements for
AS5781	Retainers (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Single Turn, Scarf-Cut, for Use in AS4716 Glands
AS5782	Retainers (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Solid, Un-Cut, for Use in AS4716 Glands
AS5857	Gland Design, O-Ring and Other Elastomeric Seals, Static Applications
AS5860	Retainers (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Single Turn, Scarf-Cut, for Use in AS5857 Static Glands
AS5861	Retainers, (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Solid, Un-Cut, for Use in Static Glands to AS5857
AS6235	Face Seal Gland Design, Static, O-Ring and Other Seals, for Aerospace Hydraulic and Pneumatic Applications
AS8791	Hydraulic and Pneumatic Retainers (Backup Rings), Polytetrafluoroethylene (PTFE) Resin
AS33514	Fitting End, Standard Dimensions for Flareless Tube Connection and Gasket Seal
AS33515	Fitting End, Standard Dimension for Bulkhead Flared and Tube Connections
AS33583	Tubing End, Double Flare, Standard Dimensions for
AS33611	Tube Bend Radii
AS85421	Fittings, Tube, Fluid Systems, Separable, Beam Seal, 3000/4000 psi, General Specification for
AS85720	Fittings, Tube, Fluid Systems, Separable, High-Pressure Beam Seal, 5000/8000 psi, General Specification for
SAE J1926/1	Specification for Straight Thread O-Ring Boss Port

2.1.2 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

AN 929	Cap Assembly, Pressure Seal Flared Tube Fitting
MIL-DTL-9395	Switches, Pressure
MIL-DTL-25427	Coupling Assembly, Hydraulic, Self-Sealing, Quick Disconnect
MIL-DTL-81940	Valve, Sampling and Bleed, Hydraulic
MIL-F-8815	Filter and Filter Elements, Fluid Pressure, Hydraulic Line, 5 and 15 Micron Absolute, Type II Systems
MIL-G-5514	Gland Design, Packings, Hydraulic, General Requirements for
MIL-HDBK-470	Maintainability Program for Systems and Equipment
MIL-HDBK-502	Logistics Support Analysis
MIL-HDBK-781	Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production
MIL-P-24691	Pipe and Tube, Carbon Alloy and Stainless, Seamless and Welded, General Specification
MIL-PRF-5606	Hydraulic Fluid, Petroleum Base; Aircraft, Missile and Ordnance
MIL-PRF-28800	Test Equipment for Use with Electrical and Electronic Equipment
MIL-PRF-81836	Filter, Fluid, Pressure, Hydraulic, 5000/8000 psi, 3 Micron, Style A, Mechanical Indicator
MIL-PRF-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft
MIL-PRF-87257	Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base Aircraft and Missile
MIL-STD-882	System Safety Program Requirements
MIL-STD-889	Dissimilar Metals
MIL-STD-1247	Marking, Functions and Hazard Designation of Hose, Pipe, and Tube Lines for Aircraft, Missile and Space Systems
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-T-8504	Tubing, Steel, Corrosion Resistant 304, Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded
MIL-V-8813	Valves, Aircraft, Hydraulic Pressure Relief, Type II System
MS21344	Fittings, Installation of Flared Tube, Straight Thread
WD ASTM PS93	Resin, Polyamide, Hot-Pressed or Pressed and Sintered

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM A312 Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes

ASTM A376 Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes, High Temperature

2.2 Acronyms and Abbreviations

The procurement activity will define any peculiar abbreviations and acronyms used for clarity and understanding.

2.3 Definitions

The procurement activity will provide any nonstandard definitions.

3. REQUIREMENTS

3.1 Materials

Materials used in the manufacture of GSE hydraulic systems shall be high quality, industrial components suitable for the purpose and shall conform to applicable standards identified herein. Where no standard is specified, and the procuring activity has not specified one, materials conforming to contractor's specifications may be used, provided that they are equivalent to the industrial standards.

3.1.1 Dissimilar Metals

Unless protected against electrolytic corrosion, dissimilar metals shall not be used in intimate contact with each other. Dissimilar metals are defined in MIL-STD-889.

3.2 Design

The hydraulic systems and components thereof shall be designed to operate satisfactorily under all conditions that the GSE may encounter within the structural limitations of the GSE, including forces or conditions caused by specified acceleration or deceleration rates.

3.3 Fluid

Fluid shall be as specified by the procurement activity. Fluid conforming to MIL-PRF-83282 or MIL-PRF-87257 is preferred for ground support equipment systems rated at 4000 psig (28 MPa) or greater. Other fluids may be utilized where applicable at operating pressures below 4000 psig (28 MPa). Fire retardant fluids such as those conforming to AS1241 require special care and handling and may pose safety hazards to the operator. Preservative fluids may be utilized, but only with the approval of the procurement activity.

3.4 Seals

Seal materials shall be compatible with the specified fluid. To maximize utilization, consider materials mutually compatible with several fluids, such as MIL-PRF-5606, MIL-PRF-83282, and MIL-PRF-87257. For static applications, O-ring packing squeeze shall be a minimum of 10% at the most adverse tolerance conditions. O-ring packings with cross section widths of 0.070 inch (1.8 mm) or less are not recommended for dynamic applications.

3.4.1 Gland Design

Seal gland dimensions shall conform to the requirements of AS4716, AS5857, or AS6235, except for specialized proprietary packings. Nonstandard glands shall be used only with the specific approval of the procurement activity. Care shall be taken to prevent binding and interference at the most adverse temperature extremes. Standard clearance may be used for system pressure levels greater than 3000 psig (21 MPa) and the seal life improved by using proprietary type packing shapes and high modulus backup ring materials.

3.4.2 Packings

O-ring packings shall conform to AMS-P-83461 series, AMS3384, or made from other compounds compatible with the specified fluid in the AMS3300 and AMS7200 series. Packing configurations other than O-rings may be used in standard glands with the approval of the procurement activity.

3.4.3 Backup Rings

Backup rings shall conform to AMS, AS8791. Nonstandard backup rings may be used for systems with pressure level greater than class 3000, subject to the approval of the procurement activity.

3.5 General System Design

Hydraulic systems shall be as simple and fool-proof as possible and in accordance with design, operation, inspection, and maintenance objectives.

3.5.1 Fluid Temperature Limitations

3.5.1.1 Nonoperating/Storage

The hydraulic system shall be able to withstand temperatures of -65 to +275 °F (-54 to 135 °C) with relative humidity (condensing) ranging up to 100%.

3.5.1.2 Operating

The hydraulic system shall be capable of operating within temperatures of -40 to +240 °F (-40 to 116 °C) with relative humidity (noncondensing) ranging up to 95%. The system shall have an overtemperature shutdown capability to prevent damage to aircraft systems, where applicable.

3.5.2 Fluid System Temperature

Unless otherwise specified by the procurement activity, it is recommended that fluid system temperature be controllable between +80 °F (27 °C) (or ambient if higher) and +160 °F (71 °C) as measured at the outlet of the GSE. The temperature controller shall be capable of maintaining set temperature at ±5 °F (±3 °C) in the manual mode (operator selected set temperature) of operation or ±5 °F (±3 °C) in the automatic mode of operation. See 3.7.11.3 for fluid operating limitations.

3.5.3 Fire Hazards

The hydraulic system shall be so designed and installed with other systems that it will eliminate or isolate the system(s) from fire hazards caused by proximity of combustible gases, heat sources, or electrical ignition sources. Hydraulic lines and equipment located in the vicinity of heat and ignition sources that may cause spontaneous ignition or sustained fire of hydraulic leakage from these lines or equipment shall be protected by devices such as firewalls, shrouds, or equivalent means that will prevent fluid ignition. When electric motors, switches and other sources of sparks are installed in the same compartment as hydraulic equipment, the electrical equipment shall be above the hydraulic equipment.

3.5.4 Loads

The installation of hydraulic systems and components shall be designed to withstand 1.5 times the operational static and dynamic loads which are not of hydraulic nature. The installation shall be designed to withstand such loads when applied simultaneously with the appropriate hydraulic pressure requirements identified in 3.5.5.

3.5.5 Pressure Limitations

The following limitations shall apply to all classes of systems:

3.5.5.1 Variable Delivery Pump Systems

Pump unloading (cutoff) pressure shall be the system design pressure. The maximum limit of full-flow systems shall be system pressure less 150 psi (100 kPa). The system relief valve setting at maximum flow shall be system pressure plus 850 psi (590 kPa) (maximum) for Class 5000 systems and below, and 115% of system pressure for Class 8000 systems.

3.5.5.2 Thermal Relief Valves

Thermal relief valves shall be set at system relief valve setting plus 150 psi (100 kPa).

3.5.5.3 Proof and Burst Pressures

The following values, in percent of supply pressure, shall be utilized in the design of GSE:

a. Lines and fittings utilized in the pressure side shall be 200% for proof and 300% for burst, while those in the return shall be 100% for proof and 150% for burst. Values for hoses shall be in accordance with the applicable procurement specification but shall be 125% (minimum) for proof and 250% (minimum) for burst.

b. Components containing air and fluid under pressure shall be 200% for proof and 400% for burst per ARP4379.

c. Pump suction and case drain line components and reservoir shall be:

    1. 150% proof and 300% burst of reservoir operating pressure for non-pressurized reservoirs, and

    2. 200% proof and 400% burst of reservoir operating pressure for gas pressurized reservoirs.

d. Components subjected to system pressure shall be 150% proof and 250% burst.

e. Components under return pressure, except hoses, shall be 100% proof and 150% burst.

f. Heat exchangers shall be 150% proof and 250% burst/collapse of design heat exchanger pressure.

g. The system shall be 150% for proof. There shall be no burst test required.

h. Those components subjected to suction shall have a burst rating of 50 psi (35 kPa) (external) pressure.

3.5.5.4 Surge Pressure

When operating at various pressures, peak pressure resulting from any phase of the system operation shall not exceed the 135% of the operating pressure for Class 5000 (and below) systems and 120% for Class 8000. This shall apply to the main system, subsystem or return system pressures when measured with electronic or other test equipment.

3.5.5.5 Back Pressure

System design must consider the effects of back pressure on various circuit components and functional devices that require drain lines. The circuit system design shall include safety provisions to prevent malfunctions caused by back pressure surges.

3.5.5.6 Pressure Regulation

Methods for limiting pressure in self-contained and facility supplied GSE are identified. When utilizing pressure control servovalves, independent filtration on the pilot port inlet shall be provided:

a. Self-contained GSE shall have system pumps which shall utilize a pressure regulator device and an independent means of limiting excessive pressure. When the pump driving mechanism is in continuous operation, such as engine drives, a variable displacement pump must be used. In any case, an independent safety relief valve shall be provided.

b. Facility supplied GSE shall utilize a pressure regulating valve and an independent means of limiting excessive pressure. When multiple pressures are required simultaneously, an equal number of pressure regulating valves shall be utilized. The pressure regulating device, if electrically actuated, shall fail to the low pressure setting.

3.5.5.7 Variable Pressure Systems

Pumps with variable pressure control for systems requiring power demand control shall be equipped with a maximum pressure override control set at 115% of system maximum operating pressure.

3.5.5.8 Return System

Lines, fittings, and equipment in the GSE return circuit shall be designed for operation at one-half the normal GSE system operating pressure. For external or unit-under-test (UUT) return circuit components, the recommended pressure for design is full GSE system operating pressure. It is common practice for the component level test articles to be proof tested with the return port blocked while applying full operating pressure to the supply port or to pressurize the return port directly up to full operating pressure.

3.5.6 Reservoir Pressurization

Reservoirs utilized in Class 4000 and higher systems shall be designed so that the contained hydraulic fluid is isolated from ambient atmosphere during normal operations. Pressurization of the reservoir shall be with inert gases and be protected with a relief valve and thermal protective device.

3.5.6.1 Reservoir Supercharging Connection

When reservoirs are normally pressurized by nitrogen or other inert gases, a supercharging connection shall be provided and shall consist of fitting end in accordance with AS4395-4 or AS4396-4 for attachment to ground supercharging unit. A protective cap in accordance with AN929 with a safety chain shall be provided to protect the end connection when not in use.

3.5.7 Fluid Velocity Limitations

Tubing size and maximum fluid velocity for each system shall be determined considering, but not limited to, the following:

a. Allowable pressure drop at minimum required operating temperatures.

b. Pressure surges caused by high fluid velocity, fast response valves, and pistons bottoming out.

c. Back pressure in return lines, as it may affect brakes and pump case drain lines.

d. Pump inlet pressure, as affected by long suction lines, and a high response rate variable-delivery pump. Consideration shall be given to both pressure surges and cavitation.

e. Recommended maximum velocities are 20 ft/s (6 m/s) for pressure lines, 10 ft/s (3 m/s) for return lines, and 4 ft/s (1 m/s) for suction lines.

3.5.7.1 Fluid Flow Effects

The systems shall 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 shall also be designed that increased flow will not adversely affect the proper functioning of any unit or subsystems, such as increased flow rate caused by accumulator operation or units affected by the operation with aiding loads.

3.5.8 Quick Disconnect Couplings (QDC)

QDC shall be utilized when fluid leakage and/or contamination is to be prevented. The following QDC configurations can be utilized dependent upon the procuring activity's requirements:

a. The hydraulic test unit shall have three pressure and one return QDC. One pressure QDC will be for 3000 psig (21 MPa), one for 5000 psig (34 MPa), and one for 8000 psig (55 MPa). Each QDC shall have an attached dust cap or plug. If the aircraft interface is typically a male QDC, then the female QDC shall be installed on GSE and hose end that interfaces to aircraft. The hose end that interfaces to the GSE is then a male QDC. QDC polarity shall be as shown in Table 1 to prevent inadvertent cross connection. The QDC shall meet the performance requirements of MIL-C-25427, except the 5000 psig (34 MPa) and 8000 psig (55 MPa) QDCs shall always comply with AS4157.

Table 1 - Aircraft/hydraulic test unit interconnection polarity allows lower system pressures to be connected to higher pressure aircraft

Aircraft Interconnect Hose psig (MPa)	Aircraft System Pressure psig (MPa) 3000 (21)	Aircraft System Pressure psig (MPa) 5000 (34)	Aircraft System Pressure psig (MPa) 8000 (55)
3000 (21)	YES	YES	YES
5000 (34)	NO	YES	YES
8000 (55)	NO	NO	YES

b. The hydraulic test unit shall include one pressure and one return QDC. Each QDC is to be provided with an attached dust cap. QDC installed adjacent to each other shall be of different size or have polarity to prevent inadvertent cross connection. The QDC shall be capable of being connected to 3000 psig, 4000 psig, 5000 psig, and 8000 psig (21 MPa, 28 MPa, 34 MPa, and 55 MPa) aircraft. The use of jumpers (pig tails) shall be required to adapt to different line sizes. The QDC shall meet the performance requirements of MIL-C-25427, except 8000 psig (55 MPa) or applicable specification sheets.

c. The hydraulic test unit QDC shall be in accordance with MIL-C-25427, except 8000 psig (55 MPa) or applicable specification sheets. QDC installed adjacent to each other shall be of different size or have polarity to prevent inadvertent cross connection.

3.5.9 Removal of Entrapped Air

Suitable means shall be provided for the removal of entrapped air from ground support hydraulic systems. De-aeration capability must be provided in all nonpressurized reservoirs. Class 4000 systems and above shall be provided with a fluid degasser.

3.5.10 Power Pumps

3.5.10.1 Main Hydraulic Supply High Pressure Pumps

The main hydraulic supply high pressure pumps shall be variable volume, axial piston type rated for continuous duty at the maximum system operating pressures. Each pump shall be equipped with a pressure compensator control that will supply oil upon systems demand at a given, adjustable set pressure. Pump volume controls shall also include an adjustable, maximum volume set point control variable from 1/8 to full volume capacity. Pumps shall be rated for continuous duty at the systems operating temperature and input drive speeds. Pump drive input mountings shall be in accordance with SAE/ANSI hydraulic power pump standards and have spline drive shafts which include polyamide bushings (per MIL-R-46198) to minimize wear. Oil lubricated splines are allowed. Consideration shall be given for interchangeability of pumps as to form, fit, and function between similar units and applications. Pumps shall be rated for the systems fluid requirements. Consideration must be given to the volumetric efficiency and heat rise from inlet to outlet of the pump.

3.5.10.2 Main Hydraulic Supply Boost and Auxiliary Pumps

Low pressure boost and auxiliary pumps shall be compatible with the rated speeds, volumes, pressures, temperatures, fluids, and system functions. These pumps must be of a positive displacement type and may be direct driven or belt driven.

3.5.10.3 Other Pumps

Other pumps may be required and shall be of good commercial quality suitable for the systems and service intended.

3.5.10.4 Pump Pulsations (Ripple)

The main axial piston high pressure pump output lines shall be equipped with a device to prevent fluid born pulsations and noise. Pump output pulsations shall not exceed 1% of the operating pressure as measured at the supply disconnect. Pumps that can demonstrate that they do not exceed 1% may be exempted.

3.5.10.5 Pump Rotation Reversal

For equipment not designed to withstand reverse rotation, the system and components shall be designed so that no single failure will permit reverse rotation.

3.5.10.6 Electric Motor-Driven Pumps

Electric motor-driven pumps shall be close coupled, end bell-mounted type, direct drive.

3.5.11 Special Tools

Hydraulic systems shall be so designed that standard hand tools shall be required for installation or removal of components.

3.5.12 System Pressure Indication

Pressure-indicating equipment activity shall be provided to indicate the system pressure in hydraulic systems or subsystems. On engine-drive multi-pump systems, pressure indicating equipment shall be provided for each pump to check for proper operation of each pump. The pressure indicators shall be so located as to be readily visible.

3.5.12.1 Pressure Gauges

Pressure gauges shall be of the direct drive, multi-wound, helical, bourdon-tube type. Stability, where required, can be accomplished with isolators or snubbers.

3.5.13 Fluid Sampling Valves

A fluid sampling valve, conforming to MIL-V-81940, shall be provided in the system return line that is common to all actuating circuits and shall be located upstream of the main return line filter. The sampling valve(s) shall be located in a readily accessible area and shall allow convenient use of sampling containers. Fluid sampling valves shall also be provided in other portions of the system if considered necessary by the procuring activity. The sampling valve shall allow representative fluid samples to be taken while the system is pressurized. Contamination generated by the operation of the valve shall not be sufficient to adversely affect the fluid sample.

3.5.14 Flow Control Systems

Flow control shall be provided if specified by procuring activity.

3.6 Components

All components used in the system(s) shall be high grade industrial components, preferably of the class used in the machine tool industry. All components shall be rated by the component manufacturer for the maximum pressures and flows they will be subjected to in the operation of the test stand. Components may be used at pressures and flows greater than their rating only if sufficient testing has been accomplished and the test data shows the components meets all other requirements of this specification and their intended usage.

3.6.1 Standard Components

Standard components shall be used in preference to nonstandard components wherever they may 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 shall be used.

3.6.2 Fixed Orifices

Orifices larger than 0.005 inch (0.13 mm) but smaller than 0.070 inch (1.8 mm) in diameter shall be protected by adjacent strainer elements (last chance screens) having screen openings 1/3 to 2/3 of the diameter of the orifice being protected. Orifices smaller than the 0.005 inch (0.13 mm) diameter are prohibited. Multiple-orifice, fixed restrictors are recommended as a means of increasing the orifice diameter and allowing the use of coarser strainer elements, minimizing the risk of clogging. Orifice and strainer elements, in combination, shall be strong enough to absorb system design flow and pressure drop without rupture or permanent deformation.

3.6.3 Accumulators

Accumulators, if used, shall be per ARP4379.

3.7 Component Installation

3.7.1 Design Practice and Installation

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

3.7.1.1 Reverse Installation

All system components shall be designed so that reverse installation cannot occur. Special purpose components may be used, if necessary, to conform to these requirements. Flow direction arrows shall be marked on the part in two locations.

3.7.2 Bleeder Valves

Where required, bleeder valves shall be so located that they can be operated without removal of other components. Such installation shall permit attachment of a flexible hose so that fluid bleed off may be directed into a container.

3.7.3 Check Valves

Check valves shall be utilized whenever reverse flow cannot be tolerated. Specific applications for check valves are:

3.7.3.1 Pump Outlet

The outlet of each high pressure supply pump (see 3.5.10.1) shall be provided with a check valve to prevent system backflow. It is recommended that cracking pressure be set at 50 to 60 psig (345 to 415 kPa) to aid in pulsation dampening of the system.

3.7.3.2 Anti-cavitation

When positive displacement boost pumps are used, a check valve circuit shall be provided around the boost pump to allow the main pump to pull a suction in case of boost pump failure. The cracking pressure shall be 2 psig (7 kPa) maximum.

3.7.4 Directional Control Valves

The installation of directional control valves shall be compatible with the control valve performance such that the system operation may not be affected by back pressure, inter-flow, 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.

3.7.4.1 Directional Control Valve Handle Installation

All installations of directional control valve handles shall conform to MIL-STD-1472 and shall incorporate internal or external stops capable of withstanding limit loads of 75 times R in-lb (330 times R mN-m), where R is the effective handle length in inches (millimeters), without detrimental effects.

3.7.4.2 Control Valve Actuation

Control valve operation may be direct, such as push-pull rods, cable control, or indirect, such as electrically or pneumatically operated controls. Push-pull rods shall require minimum or no adjustment. Cable control shall be designed to provide minimum adjustment and positive control. All controls shall be designed to prevent overtravel or under-travel of the valve control handle by use of external or internal stops. Electrically operated valves shall be provided with mechanical override control mechanisms wherever practicable and at the option of the procurement activity.

3.7.4.3 Control Valve Wiring

Electrically operated control valves shall be wired in accordance with best commercial practices unless specified in procurement specification. Individual wire labeling is not necessary; however, cable bundled wires shall be labeled corresponding to their identification on the interconnection drawing.

3.7.5 Filters

Filters shall contain elements with an element collapse pressure 1000 psig (7 MPa) higher than the differential relief valve setting. All filters installed in the hydraulic system(s) shall be qualified to MIL-PRF-81836. All filter elements shall be noncleanable type. A differential pressure monitoring device shall be specified by the procuring activity. The filters shall be capable of maintaining the specified fluid cleanliness under all conditions of flow, flow variations, differential pressure, vibrations, temperature, and other factors.

3.7.5.1 High Pressure Filters

High pressure filters shall be in accordance with MIL-PRF-81836, or another filter test specification specified by the procurement activity. The filter element shall have a demonstrated ability to maintain its specified filtration efficiency to a maximum differential pressure specified by the procurement activity, under the conditions of flow, flow variations, and vibrations present in operation of the system. Fluid delivered to the aircraft shall be at least two classes cleaner than the class specified in accordance with AS4059 for the aircraft. The filter shall demonstrate the ability to deliver fluid to this cleanliness level under all operating conditions. The pressure filters shall be equipped with a dif serential pressure monitoring device capable of providing an electrical signal when the predetermined differential pressure across the filter is reached. The pressure filters shall not be equipped with bypass valves.

3.7.5.2 Low Pressure Filters

Low pressure filters including the return line, case drain and the various service filters shall meet the filtration efficiency requirements of MIL-PRF-81836. They shall be able to maintain their specified filtration efficiency to a differential pressure equal to the maximum pressure at the particular location in the system.

The low pressure filters shall demonstrate an ability to maintain a fluid cleanliness class equal to the class maintained by the pressure filters, under all operating conditions. Low pressure filters shall be equipped with impending bypass signaling devices and bypass valves. Bypass valves shall be so designed as to have zero leakage below the specified bypass pressure.

The pressure drop at a maximum flow through the filters or in the bypass mode shall not exceed the value required to ensure that the maximum return pressure specified by the procurement activity or the equipment can be met.

3.7.5.3 Filter Locations

Filters shall be provided in the following locations as a minimum requirement. Other filter locations shall be provided at the option of the procurement activity.

3.7.5.3.1 Pressure Line Installation

A no-bypass-type line filter shall be installed in the system pressure line and shall be so located that all fluid may be filtered prior to entering any major equipment or components of the system. In multi-pump systems, each pump shall have a separate filter installation.

3.7.5.3.2 Return Line Installation

A bypass-type line filter shall be installed in the return line. All fluid entering the hydraulic system and return circuit shall be circulated through the filter prior to entering the return line to the pump(s) and reservoir.

3.7.5.3.3 Pump-Case Drain Line

For pumps requiring case drain lines, an outlet port check valve and micronic type filter with indicating by-pass shall be installed. The case drain tube/piping line shall be equal to the drain port size. The filter shall be rated for 250% of the case drain flow with a clean element. Case drain flow to be determined at maximum pressure at a fully compensated zero flow condition.

3.7.5.3.4 Pump Suction Line Installation

Boost pumps, auxiliary pumps, and unboosted main pumps shall be protected by means of a 100 mesh per inch (4 mesh per mm) cleanable strainer with magnets and a vacuum switch alarm set at -5 in Hg (-17 kPa) or pump manufacturer's recommendation. Boosted main hydraulic power supply pumps shall be protected by a micronic type bypassing filter with replaceable element, a differential pressure switch alarm set to initiate at least 5 psi (34 kPa) below the bypass valve opening pressure. Caution shall be used in the sizing of suction lines and suction components as not all components have full area passages.

3.7.6 Fittings

All tube fittings (other than connections at removable components, and where needed to facilitate maintenance) shall be permanently joined employing no screw threads and shall require approval of the procurement activity prior to installation. Fittings with threaded connections shall conform to AS85720.

3.7.6.1 Universal Fittings

Universal fittings conforming with MS33515 and AS4396 shall not be used in boss applications in hydraulic systems unless written approval is obtained from the procurement activity.

3.7.6.2 Boss Fittings

Where practical, ring-lock type boss fittings shall be used in components that are frequently removed and subject to damage. Ports for these fittings shall conform to the requirements of SAE J1926/1. These ring-lock fittings shall mate to either AS85421 or AS85720 fittings. For Class 8000 systems, certified fittings may be limited. The procuring activity shall be aware of these limitations prior to specifying these ring-lock fittings.

3.7.7 Snubbers

Pressure snubbers shall be used with all hydraulic pressure transmitters, hydraulic pressure switches, and hydraulic pressure gages as required. Pneumatic pressure gages are excluded from this requirement.

3.7.8 Hose Assemblies

Selection of hose assemblies to meet other classes shall be in accordance with specified requirements. Hose assemblies shall mate with AS4395, AS33514, or ring-lock (dynamic beam-seal) fittings as required by procurement activity.

Hose construction to be polytetrafluorethylene (PTFE) lined with Aramid fiber reinforcement or stainless steel wire reinforcement for Class 8000 systems.

All hoses shall be clearly marked or tagged permanently with manufacturing date and pressure rating per MIL-STD-1247 or ARP6002.

3.7.9 Relief Valves

Relief valves shall be designed to be used as safety devices to prevent bursting of, or damage to, the system in the event the normal pressure regulation device in the system malfunctions or in a blocked line condition, to relieve excessive pressure from either thermal expansion of the fluid or overload forces on actuating units. Relief valves shall not be used as a sole means of limiting pressure in a power circuit but shall function only as a safety valve.

3.7.9.1 System Relief Valves

Provisions shall be made to ensure 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, shall be located in the hydraulic system wherever necessary to accomplish this pressure relief (see 3.5.5.1 and 3.5.5.2.) The system relief valve shall have a capacity 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 shall be designed so that excessive temperature does not occur from fluid flowing through a relief valve. As an alternative, a temperature warning and indication system may be used if approved by the procurement activity. All hydraulic pressure circuits shall require an adjustable pilot-operated two-stage type pressure safety relief valve set per 3.5.5.1. In circuit functions where the relief valve is also the pressure control, such as auxiliary control circuits, the maximum pressure is also the set control pressure. The relief valves shall be rated for the maximum pressure, flow, temperature, and operating characteristics of the system requirements.

3.7.9.2 Thermal Expansion

Thermal expansion relief valves shall conform to ARP4835.

3.7.10 Reservoirs

A stainless steel hydraulic fluid reservoir shall be provided and mounted within the GSE enclosure. Unless otherwise specified by the procurement activity, the reservoir shall be of the separated, non-pressurized type. The reservoir shall have sufficient structural strength; means to minimize surging, foaming, and vortexing return fluid; a sump; a drain valve; a vent with a vent filter; fluid connections; and fluid level indication. Moisture ingestion shall be minimized through use of a desiccant in the venting device.

3.7.10.1 Capacity

Reservoir fluid capacity shall be optimized for:

a. Prevention of damage to the aircraft or GSE due to insufficient fluid. A low liquid switch shall be provided to shut down the GSE.

b. Thermal expansion and contraction.

3.7.10.2 Reservoir Location

Insofar as practical, the reservoir shall be located for:

a. Ease of filling.

b. Ease of draining.

c. Maintenance of static head on pumps.

d. Ease of reading fluid level indication (use of remote indicator is permissible). Back light may be used.

3.7.10.3 Reservoir Temperature

A temperature gauge or transducer shall be incorporated to measure reservoir temperature within ±5 °F (±3 °C). The indicator shall be located on the service panel.

3.7.10.4 Reservoir Filling Connection

Reservoirs shall be filled by low pressure replenishment methods. The reservoir filling connection shall be a suitable check valve with an AS4395-6 or AS4396-6 fitting end for attachment to ground filling equipment. A protective cap in accordance with AN929, with a safety chain, shall be provided to protect the end connection when not in use.

3.7.10.5 Reservoir Drain Connection

Provide for draining and disposing of excess fluid with minimum spillage.

3.7.11 Heat Exchangers

3.7.11.1 Cooling

A standard commercially available heat exchanger(s) shall provide adequate degree of heat dissipation for operation at maximum steady state pressure flow attainable by the test stand, while operating at the hottest ambient temperature expected. Stationary stands shall be liquid cooled while portable stands shall be air cooled.

3.7.11.2 Location

Heat exchangers shall be installed in the return and/or relief valve line of test stands which return oil to the reservoir before the oil returns to the UUT when pressure drop through the heat exchanger(s) does not adversely affect tests to be performed. Where pressure drop does adversely affect the tests, a separate cooling loop shall be installed to provide necessary cooling. In closed loop systems (where oil returns to UUT without passing through reservoir) heat exchangers shall be installed in the flow loop provided the pressure is not higher than the heat exchanger's rating. In this case, a bleeder or the replenishment circuit shall be provided for the heat exchanger.