AEROSPACE STANDARD

AS5440™ **REV. B**

Issued 1998-04
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Superseding AS5440A

Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For

RATIONALE

AS5440 has been updated to Revision B for the following reasons:

a. Minor technical changes have been made.

b. The references called up in the document 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 specification covers the design and installation requirements for Type I and II military aircraft hydraulic systems.

1.1 Intended Use

The design and installation requirements covered by this specification are intended for military aircraft hydraulic systems, such as the utility system, the flight control system, and various subsystems, and with component installation procedures for temperatures from -65 to 275 °F (-54 to +135 °C).

NOTE: Type III systems with a temperature range of -65 to 450° F (-54 to +232 °C) are covered by MIL-H-8891.

1.2 Classification

Military aircraft hydraulic systems shall be of the following types and classes, as specified below.

1.2.1 Types

a. Type I: Maximum fluid operating temperature +160 °F (+71 °C)

b. Type II: Maximum fluid operating temperature +275 °F (+135 °C)

1.2.2 Classes

The class of operating pressure shall consist of the following:

a. Class 1500 - 1500 psi (10345 kPa) nominal operating pressure

b. Class 3000 - 3000 psi (20690 kPa) nominal operating pressure

c. Class 4000 - 4000 psi (27580 kPa) nominal operating pressure

d. Class 5000 - 5000 psi (34500 kPa) nominal operating pressure

e. Class 8000 - 8000 psi (55000 kPa) nominal operating pressure

NOTE: For variable pressure level systems, such as 5000 psi (34500 kPa) and 3000 psi (20690 kPa), the highest pressure shall determine the pressure class. The pressure class shall be annotated with a "V" to indicate variable pressures (for example, class 5000V).

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 the 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 exemption has been obtained.

NOTE: Documents listed as "Inactive" or "Cancelled" are provided for information purposes only. The procuring agency may use these documents as guidance or invoke them as necessary.

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.

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
AMS4944	Titanium Alloy Tubing, Seamless, Hydraulic, 3.0Al - 2.5V, Cold Worked, Stress Relieved
AMS4945	Titanium Alloy Tubing, Seamless, Hydraulic, 3Al - 2.5V, Controlled Contractile Strain Ratio Cold Worked, Stress Relieved
AMS4946	Titanium Alloy Tubing, Seamless, Hydraulic, 3Al - 2.5V, Texture Controlled Cold Worked, Stress Relieved
AMS5561	Steel, Corrosion and Heat-Resistant, Welded and Drawn or Seamless and Drawn Tubing, 9.0Mn - 20Cr - 6.5Ni - .028N High-Pressure Hydraulic
AMS7287	Fluorocarbon Elastomer (FKM), High Temperature/HTS Oil Resistant/Fuel Resistant, Low Compression Set/70 to 80 Hardness, Low Temperature Tg -22 °F (-30 °C), for Seals in Oil/Fuel/Specific Hydraulic Systems
AMS7379	Rubber: Fluorocarbon Elastomer (FKM), Low Temperature Sealing Tg -40 °F (-40 °C) 70 to 80 Type ‘A’ Hardness For Elastomeric Seals in Aircraft Engine Oil, Fuel and Hydraulics Systems
AMS7410	Rubber: Fluorocarbon Elastomer (FKM), Aircraft Engine Oil, Fuel and Hydraulic Fluid Resistant 70 to 80 Shore Type A Hardness, Low Temperature Sealing Tg -47 °F (-43.9 °C) for Elastomeric Seals in Aircraft Engine, Fuel and Hydraulic Systems
AMS-P-83461	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275 °F (135 °C)
AMS-T-6845	Tubing, Steel, Corrosion-Resistant (S30400), Aerospace Vehicle Hydraulic System, 1/8 Hard Condition
AIR1362	Aerospace Hydraulic Fluids Physical Properties
AIR1657	Handbook of Hydraulic Metric Calculations
AIR1899	Aerospace Military Aircraft Hydraulic System Characteristics
AIR4057	Secondary Filters for Fluid Systems Reliability
AIR4543	Aerospace Hydraulics and Actuation Lessons Learned
AIR5829	Air in Aircraft Hydraulic Systems
ARP584	Coiled Tubing - Corrosion Resistant Steel, Hydraulic Applications, Aerospace
ARP994	Design of Tubing Installations for Aerospace Hydraulic Systems
ARP1383	Aerospace - Impulse Testing of Hydraulic Components
ARP4146	Coil Tubing - Titanium Alloy, Hydraulic Applications, Aerospace
ARP4378	Accumulator, Hydraulic, Welded Bellows, Factory Pre-Charged

ARP4379	Aerospace - Accumulator, Hydraulic, Cylindrical, Piston Separated
ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies
ARP4553	Self-Displacing Hydraulic Accumulator
ARP4727	Gland Design, Computation of Seal Squeeze and Gland Volume
ARP4763	Aerospace - General Requirements for Hydraulic Relief Valves
ARP4835	Recommended Design and Test Requirements for Hydraulic Thermal Expansion Relief Valves
ARP4946	Recommended Design and Test Requirements for Hydraulic Check Valves
ARP5891	Achieving Cleanliness Standards for Aircraft Hydraulic Systems During Manufacture
ARP7212	Recommended Design and Test Requirements for Hydraulic Flow Regulators
AS568	Aerospace Size Standard for O-Rings
AS603	Impulse Testing of Hydraulic Hose, Tubing, and Fitting Assemblies
AS604	Hose Assembly, Polytetrafluoroethylene, Metallic Reinforced, 3000 psi, 400 °F, Heavyweight, Hydraulic
AS614	Hose Assembly, Polytetrafluoroethylene, Metallic Reinforced, 4000 psi, 400 °F, Heavy Duty, Hydraulic and Pneumatic
AS1290	Graphic Symbols for Aircraft Hydraulic and Pneumatic Systems
AS1300	Port - Ring Locked Fluid Connection Type, Standard Dimensions For
AS1339	Hose Assembly, Polytetrafluoroethylene, Metallic Reinforced, 3000 psi, 400 °F, Lightweight, Hydraulic and Pneumatic
AS1709	Coupling Assembly, Hydraulic Self Sealing, Quick Disconnect
AS1975	Hose Assembly, Polytetrafluoroethylene, Para-Aramid Reinforced, 3000/4000 psi, 275 °F, Standard Duty, Hydraulic, Aircraft Systems
AS4052	Gland Design: Scraper, Landing Gear, Installation
AS4059	Contamination Classification for Hydraulic Fluids
AS4088	Aerospace Rod Scraper Gland Design Standard
AS4201	Port - Ring Locked Fluid Connection Type, 8000 psi, Design Standard
AS4251	Coupling Assemblies, Non-Locking Probe Style, Self-Aligning, Self-Sealing, Disconnects
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
AS5202	Port or Fitting End, Internal Straight Thread, Design Standard

AS5466 Aerospace - General Requirements for Hydraulic Fuse - Quantity Measuring

AS5467 General Requirements for Hydraulic Fuse - Flow Rate

AS5586 General Requirements for Hydraulic System Reservoirs

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

AS5994 Pump Units, Hydraulic, Electric Motor Driven, Variable Delivery

AS6235 Face Seal Gland Design, Static, O-Ring and Other Seals for Aerospace Hydraulic and Pneumatic Applications

AS7997 Motors, Aircraft Hydraulic, Constant Displacement, General Specification For

AS8584 Brake Systems, Wheel, Military Aircraft

AS8775 Hydraulic System Components, Aircraft and Missiles, General Specification for

AS19692 Aerospace – Military Type Variable Delivery, Pressure Compensated Hydraulic Pump

AS33583 Tubing End, Double Flare, Standard Dimensions For

AS33611 Tube Bend Radii

AS50881 Wiring Aerospace Vehicle

AS85421 Fittings, Tube, Fluid Systems, Separable, Beam Seal, 3000/4000 psi, General Specification for

AS85720 Fittings, Tube, Fluid Systems, Separable, High Pressure Dynamic Beam Seal, 5000/8000 psi, General Specification for

AS94900 Vehicle Management Systems - Flight Control Function, Design, Installation and Test of Piloted Military Aircraft, General Specification For

MA2010 Packing, Preformed - O-Ring Seal Standard Sizes and Size Codes, Metric

2.1.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

or, if using the Switzerland address:

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 22089 Aerospace - Hydraulic power transfer units - General specifications for

ISO 22181 Aerospace fluid systems and components - Variable displacement hydraulic motors - General specifications

2.1.3 NAS Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NASM85449 Clamp Assembly, Saddle-Type, Cushion, General Specification For

NASM85449/1 Clamp Assembly, Saddle-Type, Cushioned, NBR Rubber, 321 CRES, 275 °F, Fuel Resistant, General Purpose

NASM85449/3 Clamp Assembly, Saddle-Type, Cushioned, Silicone Fabric, Reinforced, 321 CRES, 500 °F, General Purpose

2.1.4 NAVAIR Publications

Available from Naval Air Warfare Center - Aircraft Division (Code AB43300), 48298 Shaw Rd., Building 1461, Patuxent River, MD 20760-1900.

NAVAIR 01-1A-17 Aviation Hydraulics Manual

NAVAIR 01-1A-20 Aviation Hose and Tube Manual

2.1.5 U.S. Government Publications

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

AN929 Cap Assembly, Pressure Seal Flared Tube Fitting

MIL-DTL-5508 Fuses, Aircraft Automatic Quantity-Measuring, Hydraulic (Inactive)

MIL-DTL-5513 Joints, Hydraulic, Swivel

MIL-DTL-8348 Gage Assemblies, Air Pressure, Dial Indicating Chuck Type, Self-Contained (Inactive)

MIL-DTL-9395 Switches Pressure (Absolute, Gage and Differential), General Specification For

MIL-DTL-19068 Valve, Shuttle, Hydraulic, Aircraft, Type II Systems (Inactive)

MIL-DTL-25579 Hose Assembly, Tetrafluoroethylene, High Temperature, Medium Pressure, General Specification For

MIL-DTL-27267 Hose, CRES Wire Reinforced, Polytetrafluoroethylene, 450 Degrees F, Medium Pressure

MIL-DTL-27272 Fittings, Polytetrafluoroethylene Hose, High Temperature, Medium Pressure, General Requirements For

MIL-DTL-83296 Fittings, Corrosion Resistant Steel, High Temperature, High Pressure (3000 PSI), Hydraulic and Pneumatic, General Specification for

MIL-DTL-83298 Hose, Conductive, Polytetrafluoroethylene Tube, High Temperature, High Pressure (3000 PSI), Hydraulic and Pneumatic

MIL-DTL-85052 Clamp, Loop, Cushion, General Specification For

MIL-DTL-85052/1 Clamp, Loop, Tube, 17-7 PH CRES, 275 °F, Fuel and Petroleum Based Hydraulic Fluid Resistant

MIL-DTL-85052/3 Clamp, Loop, Tube, 17-7 PH CRES, 500 °F

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-F-8815/4 Filter, Fluid, Pressure, Hydraulic Line, 3000 PSI, Absolute 5 Micron, Style A, Bypass, -65 Degrees F to +275 Degrees Fahrenheit

MIL-F-8815/5 Filter, Fluid, Pressure, Hydraulic Line 3000 PSI, Absolute 5 Micron, Style B, Non Bypass, -65 Degrees F to +275 Degrees Fahrenheit

MIL-F-8815/6 Filter Elements, Noncleanable, Fluid Pressure, Hydraulic Line, 3000 PSI, 5 Micron Absolute -65 Degrees F to +275 Degrees Fahrenheit

MIL-F-83300 Flying Qualities of Piloted V/STOL Aircraft

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

MIL-H-8891 Hydraulic Systems, Manned Flight Vehicles, Type III Design, Installation and Data Requirements For, General Specification For (Inactive)

MIL-H-85800 Hose Assemblies, Polytetrafluoroethylene Aramid Fiber Reinforced, 5000 and 8000 psi, General Specification For

MIL-HDBK-2069 Aircraft Survivability

MIL-HDBK-2089 Aircraft Survivability Terms

MIL-P-5954 Pump Unit, Hydraulic, Electric Motor Driven Fixed Displacement (Not for New Design)

MIL-PRF-5503 Actuators: Aeronautical Linear Utility, Hydraulic, General Specification For

MIL-PRF-5606 Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance (Inactive)

MIL-PRF-6083 Hydraulic Fluid, Petroleum Base, for Preservation and Operation

MIL-PRF-25675 Valves, Check, Miniature, Hydraulic, Aircraft and Missile (Inactive)

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

MIL-PRF-81836 Filter and Disposable Element, Fluid Pressure, Hydraulic, 3 Micron Absolute, General Specification For

MIL-PRF-83282 Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537

MIL-PRF-87257 Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile

MIL-STD-464 Electromagnetic Environmental Effects Requirements for Systems

MIL-STD-1247 Markings, Functions and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missile, and Space Systems (Inactive)

MIL-STD-1472 Human Engineering

MIL-STD-1797 Flying Qualities of Piloted Aircraft

MIL-STD-5522 Test Requirements and Methods for Aircraft Hydraulic and Emergency Pneumatic Systems

MIL-STD-7179 Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems

MIL-T-8504 Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded (Inactive)

MIL-V-5519 Valves, Regulating Fluid Pressure (Inactive)

MIL-V-5525 Valves, Aircraft Power Brake (Inactive)

MIL-V-5530 Valves, Aircraft Hydraulic Shuttle (Cancelled)

MIL-V-8566 Valves; Aircraft Hydraulic Flow Regulator (Inactive)

MIL-V-8813 Valves, Aircraft, Hydraulic Pressure Relief, Type II Systems (Inactive)

MIL-V-19067 Valves, Check, Controllable, Hydraulic, Aircraft, Type II Systems (Inactive)

MIL-V-29592 Valve, Air Vent, Automatic, Hydraulic, Low Pressure Type II Systems, General Specification For

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

MIL-V-85245 Valve, Relief, Hydraulic, High Response, Type II Systems, General Specification For

MS14169 Circular Spline and Adapter Details Engine Driven Accessories

MS14184 Nonmetallic Shaft-Coupling Details, Engine Driven Accessories

MS21344 Fitting, Installation of Flared Tube, Straight Threaded Connectors, Design Standard For

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 U.S. Government Publications

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

FED-STD-791 Testing Method of Lubricants, Liquid Fuels and Related Products

2.3 Definitions

General definitions for terminology used within this document may be found in ARP4386. The following definitions are unique to this document.

UTILITY SYSTEM: This is the hydraulic system that supplies power for the normal operation of any services on the aircraft, excluding the operation of the aircraft's primary flight control system surfaces.

FLIGHT CONTROL SYSTEM: This is the hydraulic system that supplies power for primary flight control systems used to actuate such surfaces as ailerons, rudders, elevators, stabilizers, spoilers, rotor blades, vectoring, or combined function surfaces.

COMBINED FLIGHT CONTROL UTILITY SYSTEM: This is the hydraulic system that supplies a portion of the power required for primary flight control and also supplies power to the utility services.

3. REQUIREMENTS

3.1 Materials

Materials used in the manufacture of hydraulic systems in military aircraft shall conform to applicable government and industry specifications. The use of contractor specifications instead of the applicable government and industry specifications requires the approval of the procuring agency.

The use of aluminum materials in flight control components in 5000 psi (34500 kPa) systems and above requires special precautions to ensure conformance to the fatigue requirements for production configuration parts. The use of aluminum alloy parts for 5000 psi (34500 kPa) and greater is not encouraged and shall not be used unless approved by the contracting activity.

3.2 Design

The hydraulic systems and components shall be designed to operate under all conditions that the aircraft may encounter within the structural limitations of the aircraft, including forces or conditions caused by:

a. Acceleration or deceleration

b. Zero gravity (g), negative g, or any flight attitudes obtainable with the aircraft

c. Structural deflection

d. Vibration

e. Other environmental conditions

The hydraulic systems shall be configured such that failure of any two fluid systems resulting from combat or other damage which causes the loss of fluid or pressure will not result in a complete loss of flight control.

Fixed-wing aircraft shall maintain level one flying qualities of MIL-STD-1797 with one fluid system failure (including the power source) and level three flying qualities including carrier landing, with two fluid system failures.

Rotary wing aircraft and piloted V/STOL aircraft shall meet MIL-F-83300 flying qualities with two fluid system failures for return to the intended landing area (including shipboard areas and land).

General aircraft combat survivability guidelines are provided in MIL-HDBK-2069 and MIL-HDBK-2089.

3.3 Hydraulic Fluid

Fluid conforming to MIL-PRF-83282 and/or MIL-PRF-87257 shall be used for hydraulic systems and associated ground equipment.

NOTES:

1. The use of MIL-PRF-5606 is discouraged; however, it is considered an acceptable substitute for MIL-PRF-87257 if required by the contracting activity.

2. MIL-PRF-83282 has the best flammability resistance followed by MIL-PRF-87257 and then MIL-PRF-5606.

The operational fluid shall be used as the preservative fluid when storing components. Hydraulic fluids containing barium (i.e., MIL-PRF-46170 or MIL-PRF-6083) shall not be used as a test or preservative fluid.

3.4 Hydraulic Seals

O-rings with cross-sectional diameters of 0.070 inch (1.78 mm) or less, or their equivalent proprietary seals, shall not be used as external seals. The best practice is to avoid the usage of 0.070 inch (1.78 mm) or less in internal sealing applications.

3.4.1 Gland Design

The configuration and dimensions of seal glands for radial sealing shall conform to the requirements of AS4716 for dynamic and static applications.

Non-standard glands for specialized seal assemblies shall only be used with the approval of the contracting activity.

For static face sealing (internal and external pressure applications), seal glands shall conform to the requirements of AS6235.

For system pressure levels above class 3000, the diametral clearance gaps of AS4716 may be reduced from the minimum of 0.003 inch (0.08 mm) to improve seal life and aid in preventing seal assembly extrusion. Care shall also be taken to prevent binding and interference at the most adverse temperature extremes. AS4716 provides a minimum of 0.005 inch (0.13 mm) or 5%, whichever is larger, at ambient temperature and extremes of tolerance and eccentricity. Standard clearance may be used for system pressure levels greater than 3000 psi (20690 kPa) if proprietary-type seal assemblies and high-modulus backup ring materials are used.

The use of the procedures detailed in ARP4727 is recommended for the calculation of seal squeeze and gland occupancy volume for radial seals when reviewing seal and gland design details.

3.4.2 O-Ring and Seal Assemblies

O-ring elastomer materials shall conform to AMS-P-83461, AMS7287, AMS7379, or AMS7410. Seal assembly configurations other than O-rings may be used in standard glands if the design permits. Any elastomer components within those assemblies shall use materials per AMS-P-83461, AMS7287, AMS7379, or AMS7410.

Other elastomer materials and designs can be qualified for specialty applications based on system requirements. The use of these materials is subject to the approval of the Purchaser.

O-rings not covered by a specification should conform to AS568 or MA2010 for dimensions and tolerances. When nonstandard seals are necessary to demonstrate compliance with the requirements of the Procurement Specification, they may be used subject to the approval of the Purchaser and indicated on the component's assembly drawing.

3.4.3 Backup Rings

AS5781 and AS5782 backup rings shall be used in AS4716 seal glands. Solid backup rings shall conform to AS5782. Scarf-cut backup rings conforming to AS5781 may be used on dynamic applications where minimum seal friction is required for satisfactory operation or where access to the gland prevents installation of AS5782. If AS5782 solid backup rings are used on dynamic piston applications, friction due to pressure entrapment between the backup rings shall be considered in the design of the device.

Extra care, training, and drawing notes should be implemented to prevent backup rings designed for AS4716 grooves from being inadvertently used in MIL-G-5514 grooves and vice versa. Note that backup rings per AS5781 and AS5782 are color-coded to help prevent incorrect installation into MIL-G-5514 glands.

Nonstandard backup rings may be used for system pressure levels greater than class 3000, subject to the approval of the contracting activity. AS5781 and AS5782 provide alternate backup ring material recommendations for pressure applications higher than 3000 psi (20690 kPa).

3.4.4 Scrapers

Components with rod seals that may be exposed to water, dirt, or ice shall have a scraper using a gland per AS4088 or AS4052, as applicable. The scraper lip shall maintain contact with the rod throughout the expected temperature range. The outer diameter of the scraper shall also maintain contact with its gland throughout the expected temperature range and under all expected rod eccentricity within the rod gland.

3.5 General System Design

Hydraulic systems shall be as simple and foolproof as possible and per design, operation, inspection, and maintenance objectives specified in the aircraft design requirements. For Navy aircraft, the hydraulic system shall be designed to accommodate the maintenance procedures described in NAVAIR 01-1A-17 and NAVAIR 01-1A-20 manuals.

Each hydraulic system shall be separated from all other systems, and fluid shall not be transferred between systems such that one reservoir level would increase and another reservoir level would decrease.

3.5.1 Fluid Temperature Limitations

The MIL-PRF-83232 fluid hydraulic system shall be capable of starting and operating at fluid temperatures between -40 °F (-40 °C) and the upper limit of the operating envelope.

The MIL-PRF-87257 fluid hydraulic system shall be capable of starting and operating at fluid temperatures between -65 °F (-54 °C) and the upper limit of the operating envelope.

Fluid temperatures shall not exceed +160 °F (+71 °C) for Type I systems and +275 °F (+135 °C) for Type II systems at any point in the system. Operation at these temperatures shall not result in any degradation of the system.

With contracting agency approval, any reduced actuator rates at low temperatures may be acceptable.

3.5.1.1 Climate Extremes

Ground operation, flight operation, and storage climatic extremes shall be per the weapon system procurement specification.

3.5.2 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 the proximity of combustible gases, heat sources, bleed-air ducts, 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 fire walls, shrouds, or equivalent means that will prevent fluid ignition.

Rotating components that fail and continue to rotate shall be disconnected from their driving source, incorporate a shear shaft to allow disconnect in the event of seizure, or be stopped to prevent heat generation and the possibility of fire.

3.5.3 Surge Pressure

Peak pressure resulting from any phase of the system operation shall not exceed the percent value shown in Table 1 for the main system, subsystem, or return system pressures when measured with electronic or other test equipment. Any failure (such as a blown line) which causes a pressure surge in excess of acceptable peak pressure limits shall be substantiated with the fatigue life of the system and approved by the contracting activity. This resulting surge pressure shall not exceed the proof pressure. The use of a relief valve to limit peak pressure is discouraged and is only acceptable if approved by the contracting agency. The relief valve response time and wide-open failure modes shall be assessed.

Table 1 - System peak pressure

Pressure Class, psi (kPa)	Peak Pressure
1500, 3000, 4000, and 5000 (10350, 20690, 27600, and 34500)	135% of the system's nominal operating pressure on the pressure side, 50% of nominal operating pressure on the return side
8000 (55000)	120% of the system's nominal operating pressure on the pressure side, 50% of nominal operating pressure on the return side

3.5.3.1 Pressure Limitations

The pressure limitations shall be as follows:

- Pump pressure: Pump output pressures shall be in accordance with Table 2A and the fluid temperature, speed, and flow conditions defined in AS19692, 3.2.2 and 3.2.3.

- Relief valve pressure setting: See Table 2B.

- Minimum proof pressure: See Table 2C.

- Minimum burst pressure: See Table 2D.

Table 2A - Pump pressures

Component or Characteristic	Pressure (see Note 1)		Remarks
	Class 5000 (34500 kPa) and below	Class 8000 (55000 kPa)	
1. Pump pressure at zero flow	100% + 150 psig (1035 kPa) max	100% + 150 psig (1035 kPa) max	100% = Class Pressure (Maximum pump output pressure shall not exceed Class Pressure + 150 psi [1035 kPa].)
2. Pump minimum pressure at full flow	Pump pressure at zero flow -150 psig (-1035 kPa)	Pump pressure at zero flow -150 psig (-1035 kPa)	

Table 2B - Relief valve pressure settings

Component or Characteristic	Pressure (see Note 1)		Remarks
	Class 5000 (34500 kPa) and below	Class 8000 (55000 kPa)	
1. System relief valve a. Maximum pressure at rated flow	100% + 850 psid (100% + 5900 kPa)	100% + 850 psid (100% + 5900 kPa)	100% = Class Pressure See 3.10.22.
b. Minimum pressure at reseat	Maximum pump output + 100 psid (700 kPa)	Maximum pump output + 100 psid (700 kPa)	
2. Thermal relief valve cracking pressure	100% + 1000 psid (100% + 7000 kPa)	100% + 1000 psid (100% + 7000 kPa)	

Table 2C - Proof pressures (minimum)

Component or Characteristic	Pressure (see Note 1) Class 5000 (34500 kPa) and below	Pressure (see Note 1) Class 8000 (55000 kPa)	Remarks
1. Lines, fittings, hoses, and couplings a. Pressure circuits b. Return and case drain circuits	 200% 100%	 200% 100%	100% = Class Pressure Proof pressure values for hoses are to be per the applicable specification but not less than this table.
2. Accumulators	200%	200%	
3. Low-pressure side of reservoir and pump suction line for the following reservoir types: a. Hydraulically pressurized (Bootstrap) reservoir b. Gas-pressurized reservoirs	 150% of maximum reservoir pressure 200% of maximum reservoir pressure	 150% of maximum reservoir pressure 200% of maximum reservoir pressure	See Note 3.
4. Components under system pressure	150%	150%	See Note 4.
5. Components under return pressure only	100%	100%	Except for hoses which shall be 125% of the system pressure.
6. Heat exchangers	150% of maximum heat exchanger pressure	150% of maximum heat exchanger pressure	
7. Pump/Motor Case Drain	150% of the maximum case pressure or 500 psig (3500 kPa), whichever is greater	150% of the maximum case pressure or 500 psig (3500 kPa), whichever is greater	Consider case pressure with the maximum back pressure and dirty filter elements.
8. Complete System a. Pressure side b. Return side	 150% 75%	 150% 75%	 Aircraft-installed systems only

Table 2D - Burst pressures (minimum)

Component or Characteristic	Pressure (see Note 1) Class 5000 (34500 kPa) and below	Class 8000 (55000 kPa)	Remarks
1. Lines, fittings, hoses, and couplings a. Pressure circuits b. Return and case drain circuits	 400% 200%	 300% 150%	100% = Class Pressure Burst pressure values for hoses are to be per the applicable specification but not less than this table.
2. Accumulators	400%	400%	
3. Low-pressure side of reservoir and pump suction line for the following reservoir types: a. Hydraulically pressurized (Bootstrap) reservoir b. Gas-pressurized reservoirs	300% of maximum reservoir pressure 400% of maximum reservoir pressure	300% of maximum reservoir pressure 400% of maximum reservoir pressure	See Note 3.
4. Components under system pressure	250%	200%	See Note 4.
5. Components under return pressure only	150%	150%	Except for hoses which shall be 250% of the system pressure.
6. Heat exchangers	250% of maximum heat exchanger pressure	250% of maximum heat exchanger pressure	
7. Pump/Motor Case Drain	250% of the maximum case pressure or 850 psig (5900 kPa), whichever is greater	250% of the maximum case pressure or 850 psig (5900 kPa), whichever is greater	
8. Collapse pressure of parts subject to suction	50 psid (350 Kpa) external	50 psid (350 Kpa) external	

Notes:
1. The percentage of supply pressure, pressure in psig, or as otherwise noted.
2. Components shall be capable of full performance following the application of proof pressures.
3. The reservoir relief valve full flow pressure and back pressure in any over board drainage system shall be considered in determining the maximum reservoir pressure.
4. Any components subject to pressure in the reverse direction shall be pressurized in both directions to verify the integrity of the mounting interfaces, internal components, and the valve body during proof and burst tests.

3.5.3.2 Back Pressure

The system and components shall be designed to function properly and prevent a change of state under the influence of maximum back pressure. The effect of back pressure shall be considered for brakes, clutches, solenoids, internal actuator mechanical locks, and internal hydraulic lock valves included in the hydraulic system. The system or systems shall 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.

Return back pressure and associated component pressure drop effects including dirty filter bypass valve full flow setting and reservoir low-pressure relief valve setting should be considered as back pressure. Specific attention shall be applied to brake systems, pressure-operated locks, and pressure-operated valve elements.

3.5.3.3 Brakes

Back pressure resulting from the operation of any other subsystem on the aircraft shall create no greater back pressure at the brake valve return port than 90% of that pressure which will cause contact with braking surfaces. In addition, supply pressure to the brake system shall not drop below the minimum full capability brake-operating pressure during the operation of any other subsystem in the aircraft during taxiing, landing, or takeoff.

3.5.3.4 Pressure Regulation

System pumps shall use an internal pressure regulating device to limit excessive pressure and to maintain constant pressure at varying flow demands. An independent safety relief valve shall be incorporated into each system. The safety relief valve shall be designed to handle the maximum flow of the pump and have a response rate that limits surge pressure per 3.5.3.

The maximum pressure at rated flow and minimum pressure at reseat shall be per Table 2B.

3.5.3.5 Variable Pressure Systems

Systems that vary the pump operating pressure as power demand varies shall provide hydraulic power with pump(s) failed at the high or low pressure setting to maintain the flying qualities outlined in 3.2. All design factors and pressure ratings cited in this document shall be applied at the maximum pump discharge pressure.

3.5.3.6 Return System

As a minimum, lines, fittings, and equipment in return circuits shall be designed for 0.5X system pressure, except for some components as noted in Table 2C.

3.5.3.7 Minimum Differential Pressure

Components shall meet the required performance at the minimum differential pressure.

The design should consider supply pressure effects due to pressure drop, pressure droop, system shutdown, or operating pressures lower than the main pump along with the back-pressure effects.

Return pressure and associated pressure drop effects should be considered as back pressure.

3.5.4 Strength

3.5.4.1 Additional Loads

All hydraulic systems and components which are subjected, during the operation of the aircraft, to structural or other loads which are not of hydraulic origin shall withstand such loads when applied simultaneously with appropriate proof pressure as specified in Table 2C without exceeding the material yield point at the maximum operating temperature.

3.5.4.2 Loads Due to Aircraft Acceleration

All components and their attached lines and fittings, subjected to loads resulting from airframe accelerations, shall be designed and tested based on a pressure equal to the maximum pressure that will be developed, at the maximum operating temperature. This operation shall not exceed the material yield point.

3.5.5 Reservoir Pressurization

The reservoir shall be designed so that the hydraulic fluid is completely separated from the atmosphere during the normal functioning of the system.

3.5.6 Fluid Velocity Limitations

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

a. The allowable pressure drop at the minimum required operating temperatures.

b. Any pressure surges caused by high fluid velocity, rapid closure of valves, and rapid actuator piston deceleration.

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

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

3.5.6.1 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 multiple-pump system, or reduced engine speed. The systems shall also be designed such that increased flow will not adversely affect the proper functioning of any unit or subsystems; examples include increased flow rate caused by accumulator operation or units affected by the operation with aiding loads.

3.5.7 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, shall be so isolated that the system essential to flight operation will not be affected by any damage to the nonessential system.

3.5.8 Ground Service Provisions

Each hydraulic system shall include a set of self-sealing couplings for attachment of ground power sources. System ground service provisions shall be so designed that pressurization of any hydraulic system in the aircraft is not necessary to test another hydraulic system. An accessible location or locations shall be provided for each system that includes connections for attachment of ground service equipment for system checkout and flushing, reservoir bleeding, reservoir fill, and accumulator nitrogen charging.

3.5.8.1 Ground Service Connections

A set of self-sealing couplings consisting of bulkhead halves and protective caps shall be provided at a convenient location in the aircraft, easily accessible from the ground, for attachment of ground service equipment. The aircraft bulkhead halves shall mate with the ground cart hose halves without the use of adapters. The self-sealing couplings shall be per 3.10.25.

Electric motor-driven pumps used in emergency or auxiliary systems shall not be used for ground test purposes unless the motor is designed for continuous operation.

3.5.8.1.1 Reservoir Supercharging Connection

When reservoirs are normally pressurized by either compressed air or nitrogen, a ground supercharging connection shall be provided and shall consist of a fitting end per AS4395-04 or AS4396 for attachment to a ground supercharging unit. A protective cap per AN929 with a safety chain shall be provided to protect the end connection when not in use.

3.5.8.1.2 Reservoir Filling Connection

Reservoirs shall be filled by low-pressure replenishment methods. The reservoir filling connection shall be a check valve and a self-sealing coupling for attachment to ground-filling equipment. A filter shall be provided between the filling connection and the reservoir. Direct pouring of fluid into the reservoir (including in-flight fluid replenishment provisions) shall not be provided. When the reservoir level is not readily visible from the fill connection, a remote indicator shall be provided at that point.

3.5.8.2 Ground Service Information

The following information shall be attached permanently on the aircraft near the ground service connections:

Set ground service reservoir pressurizing valve to __________ psig (kPa).
Set ground service stand relief valve to __________ psig (kPa).
Set ground service stand volume output to __________ gpm (lpm).
Set ground service stand pressure compensator to __________ psig (kPa).
Use hydraulic fluid conforming to __________.
Ground service stand output filter shall be __________ microns absolute.

NOTE: Any other precautions or information considered necessary shall also be added.

The contractor shall fill in the values of the blank underlined.

3.5.9 Removal of Entrapped Air

Each hydraulic system shall be equipped with an air removal device to vent undissolved air from the system.

Each system shall be equipped with a manual bleed valve. Bleed valves shall be accessible without exposing personnel to undue hazards.

Refer to AIR5829 for a discussion of sources of air and design for air reduction and elimination in hydraulic systems.

3.5.9.1 Onboard Deaeration Equipment

When the need is recognized, consideration shall be given to the use of onboard deaeration equipment that will remove both dissolved and undissolved air from the hydraulic oil and systems.

3.5.10 Power Pumps

The hydraulic pump(s) shall be compatible with the installed aircraft system and shall not cause abnormal or undesirable effects on the installed aircraft system. All pumps qualified for a given application shall be physically and functionally interchangeable and shall be compatible with the system and each other to allow mixed-use in multiple pump systems.

The pump drive couplings shall be designed to include nonmetallic spline bushings to minimize wear. The spline bushings shall be designed per MS14169 or MS14184 and shall be supplied with the gearbox.

3.5.10.1 Emergency Power Pumps

Hydraulic power pumps designed to provide emergency power to flight critical systems or brakes shall not be used for any other functions.

3.5.10.2 Multiple Pumps

Multiple-engine aircraft shall have pumps directly driven by at least two engines. The hydraulic systems shall have a sufficient number of engine pumps, augmented, if necessary, by pumps powered by other separate sources, to provide power to all systems critical for the safe operation of the air vehicle. This requirement shall be met with any combination of engines operating to maintain flight or to be used while taxiing.

3.5.10.3 Pump Pulsation

For all power-generating components (engine pumps, power packages, transfer units, etc.), pump pulsations shall be controlled to a level that does not adversely affect the aircraft system tubing and components, and supports the installation. The contractor shall determine by testing the effect of pump pulsations (pump ripple) on the hydraulic system.

The initial tests shall be conducted on the functional simulator (see Section 4), with recording equipment, and shall cover the complete speed range from zero revolutions per minute (rpm) to the maximum speed, pressures, and flows that the pump will be subjected to when installed in the aircraft.

Any adverse effects including induced resonant vibrations shall be eliminated.

The results of the functional simulator tests for pump ripple effects shall be documented, forwarded to the contracting activity, and verified on the first aircraft, and any additional corrections required shall be made before the first flight.

3.5.10.4 Pump Rotation Reversal

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

3.5.10.5 Attenuators

The harmful effects of pump cavitation resulting from system failure or air ingestion from improper maintenance shall be considered in the design of each hydraulic system. Where appropriate, as determined upon review by the contracting activity, attenuators shall be installed to minimize these harmful effects.

3.5.11 Pump Supply Shutoff Valves

Pump supply (suction) shutoff valves shall 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, shall not be located on the engine side of firewalls or flame-tight diaphragms but shall be located as close as the design permits to these members. However, the valves shall be so removed from the engine that the loss of the engine from the attaching structure will not impair the operation of the valve.

The pump supply shutoff valves shall be operable from the cockpit to both the closed and open positions.

Means to relieve excessive pressure accumulation shall be provided if no other pressure relief features in the isolated volume are provided.

3.5.12 Special Tools

Hydraulic systems shall be so designed that special tools will not be required for the installation or removal of components. Where special tools are necessary, they shall require approval by the contracting activity.

3.5.13 System Pressure Indication

Pressure-indicating equipment shall be provided to indicate the system pressure in hydraulic systems or subsystems. This pressure indication may be displayed to the flight crew in conjunction with other information on a multifunction, multiplexed display. For emergency conditions of decreasing or fluctuating pressure, the pressure indication shall be displayed immediately to the flight crew.

On engine-driven multiple-pump systems, pressure-indicating equipment shall be provided for each pump to enable the flight crew to check for proper operation of each pump without the shutdown of any engine.

3.5.13.1 System Low-Pressure Warning Light

In addition, but not as a substitute for the requirement of 3.5.13, a warning light shall be installed in the cockpit in a conspicuous location to warn the pilot of low hydraulic system pressure. The light shall be actuated by a pressure switch or other sensors in the system. There shall be a separate warning light for each hydraulic system.

The warning light, or lights, shall not be actuated by any combination of normal flight-control operations.

A momentary flicker of the warning light during ground checkout only is permissible, provided such condition is described in the appropriate aircraft operation and maintenance manuals and provided such condition does not occur during flight unless a system malfunction exists.

3.5.13.2 Maintenance Check Gages and Indicators

Any pressure gages and indicators that require a preflight, postflight, or daily check shall not require work stands or platforms to read them.

3.5.14 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 fully pressurized. Contamination generated by the operation of the valve shall not adversely affect the fluid sample. The valve nozzle shall include a protective cap, and the cap shall also prevent external leakage in the event of valve malfunction. The cap shall be provided with a security chain, or equivalent, to prevent loss of the cap.

3.5.15 Automatic Diagnostic Monitor System

Integral with each hydraulic system, a diagnostic system shall be provided to continuously monitor the system and components and detect out-of-tolerance conditions. These out-of-tolerance conditions shall be detected during flight operations and give an indication of a failed or failing component and indicate maintenance actions needed such as filter replacement, accumulator recharging, and over-temperature indication.

The information shall be stored during the flight. After the flight, the information shall be displayed upon demand at a central location on the aircraft readily accessible to ground maintenance personnel without the use of work stands, platforms, or any other ground support equipment.

The sensors installed in the hydraulic system to accomplish this monitoring shall not degrade the safety of the hydraulic system. The design of the system shall enable the integrity of the sensors and sensor circuits to be checked.

The system should monitor the following components and conditions and record the conditions indicating maintenance required and conditions indicating component deterioration leading to failure:

- Main system hydraulic pumps
- Accumulators
- Filters
- Reservoir fluid levels
- Reservoir fluid temperature
- System free air

3.6 Utility System Design

All hydraulically operated services (excluding flight controls covered by 3.2) that are essential to the accomplishment of the basic aircraft mission (weapon-bay doors, in-flight refueling, etc.) or essential to land and stop the aircraft (landing gear, brakes, excluding Types I and IV brakes of AS8584) shall have provisions for emergency actuation. No failure of the utility system shall result in the loss of the aircraft or damage that would prevent safe flight and safe landing of the aircraft.

3.6.1 Wheel Brake Systems

Wheel brake systems shall be per AS8584.

3.7 Flight Control System Design

Flight control systems, as defined in 2.3, which require hydraulic power for operation shall conform to AS94900.

When multiple hydraulic systems are used for flight control, the hydraulic systems shall be so designed that ground service equipment may be connected to either one of the flight control systems and that system may be operated without adverse effects on the unpressurized system, such as overflow of the system or failure of any part thereof. To accomplish this objective, automatic bypass of the fluid in the unpressurized system from one side of the actuator piston to the other side may be provided.

3.7.1 System Isolation

Whenever hydraulic power is required for primary flight controls, a completely separate, integral hydraulic system shall be provided to supply only the primary flight controls. This hydraulic system shall not be used to supply any other system or component in the aircraft unless approval is obtained from the contracting activity. This hydraulic system shall contain a minimum number of components.

Dual hydraulic actuator systems may employ the combined flight control and utility system function for one-half of the power, in which case the flight control function shall be given pressure priority.

3.7.1.1 Hydromechanical Component's Built-in-Test (BIT) Function

All primary flight control hydromechanical components shall be monitored for failure conditions and fully integrated into the BIT routines of the flight control system.

3.7.2 Hydraulic Power Failures

An emergency power source shall be designed to provide controllability for those aircraft where direct mechanical control is unable to obtain aircraft controllability and the emergency requirements of MIL-STD-1797 cannot be accomplished following hydraulic power failures.

3.7.2.1 Emergency System Application

The means of engaging the emergency power system shall be either manual or automatic; however, they shall be of the simplest and most reliable nature possible, consistent with the requirements of the aircraft. Manual engagement of the emergency power system shall not be used unless specifically approved by the contracting activity.

If the aircraft has a single engine, the emergency power source shall be independent of the operation of this engine. On multiple-engine aircraft, the emergency source of power shall 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. No single failure can cause loss of both flight control and utility systems.

Consideration shall be given to the possibility of landings wherein none of the engines are operating. Because some engines will not windmill sufficiently to provide flight control power during landing, it may be necessary to provide emergency power sources not dependent upon engine operation. In aircraft which are capable of landing without engine power, this condition shall not be considered an emergency, and provisions shall be made for landings with one of the power systems failing while out of fuel. When designing for this condition, extreme care shall be exercised not to reduce the reliability of the power systems.

The flight control power system shall return to normal operation upon the correction of the emergency condition.

Where a ram air turbine is used as the source of emergency power, it shall be capable of extension and operation under any flight conditions. The ram air turbine shall be capable of retraction if the flight control system returns to normal operation.

3.7.2.2 Disengagement and Bypass

Where direct mechanical control is utilized following a primary hydraulic system failure, provisions shall be made for automatic, direct bypass of the fluid from one side of the primary flight control actuator piston to the other side. Where the actuator can be disengaged from the system, a bypass will not be required. For dual actuator systems, the failed system shall provide an automatic bypass. Bypass damping may be required on stiffness-critical actuator designs.

3.7.3 System Separation

Hydraulic systems shall be separated as far as the design will allow them to be less vulnerable and more survivable to gunfire or engine fires. Where design permits, multiple hydraulic systems should be on opposite sides of the fuselage, the wing spar, or similarly separated. The systems necessary for a safe flight shall be separated by a minimum of 18.0 inches (460 mm) unless survivability and vulnerability analyses show that less separation is satisfactory. Where it is deemed necessary for these systems to come together, as in a dual tandem surface actuator, the actuator shall be protected from the threat to a degree specified by the contracting activity.

3.7.4 Subsystems Pressure

Subsystems and branch circuits that use a pressure lower than the full system pressure shall be designed to withstand and operate under full system pressure or shall have a relief valve installed downstream of the pressure-reducing valve. This relief valve may be incorporated into the same housing as the pressure reducer, provided the relief valve mechanism is independent of the pressure reducer mechanism. The relief valve shall be capable of handling the maximum flow of the pressure reducer when failed full open. The bypass of the relief valve shall cause an external indicator to signal a failed pressure reducer.

3.7.5 Flight Control Power Sources

Aircraft primary flight control hydraulic systems shall have engine-driven pumps as their source of power. Helicopter primary flight control systems shall have transmission-driven pumps as a source of power so that power will be available during autorotation.

3.7.6 System Temperature

The hydraulic flight control actuators shall provide the required actuation rates under minimum and maximum in-flight fluid and ambient temperatures. The flight critical components shall not bind or jam under any combination of in-flight fluid and ambient temperature conditions including single undetected failures, such as relief valves, worn pumps, failed valves, and other heat-generating failures. The effects of differential fluid temperature in tandem units shall also be demonstrated during actuator qualification testing.

3.8 Emergency System Design for Utility Systems

3.8.1 Emergency System Types

Where emergency devices are required in hydraulic systems, the emergency systems shall be completely independent of the main system up to, but not necessarily including, the shuttle valve, the actuating cylinder, or the motor. The system shall be so designed that failure of an actuator in one subsystem shall not prevent the operation of or cause the failure of both normal and emergency actuation of another subsystem. These emergency systems shall utilize hydraulic fluid, compressed gas, gas-generating devices, direct mechanical connection, or gravity. Mechanical connections may include electromechanical units.

3.8.1.1 High Lift Devices

Where safe operational landings cannot be accomplished without the use of hydraulically operated high lift devices, they shall be powered by dual actuator hydraulic systems or shall be provided with an emergency system.

3.8.2 Emergency Line Venting

The emergency line from the shuttle valves shall be vented to the reservoir or a low-pressure (15 psi [100 kPa]) gage maximum, above reservoir pressurization) non-surging return line when the emergency system is not in use. When shuttle valve leakage is not critical, the line may be vented to the atmosphere. Provisions shall be made to bleed the compressed gas into the atmosphere rather than back to the reservoir after the actuation of the emergency system.

3.9 Components

All components used in the system(s) shall conform to AS8775, and the appropriately detailed specifications, except the requirements shall be upgraded to agree with Tables 2A through 2D for the operating and test pressures. All components used shall meet the impulse testing requirements as specified in AS603 or recommended in ARP1383. All protective finishes shall be per MIL-STD-7179.

3.9.1 Standard Components

Standard components shall be used in preference to nonstandard components. Where no applicable AN, MS, or industry standard exists, a uniquely designed component compatible with the performance, installation, inspection, and maintenance requirements shall be used.

3.9.2 Fixed Orifices

Orifices larger than 0.005 inch (0.13 mm) in diameter but smaller than 0.070 inch (1.78 mm) in diameter shall be protected by adjacent integral strainer elements (last chance screens) having screen openings one-third to two-thirds of the diameter of the orifice being protected. Orifices smaller than 0.005 inch (0.13 mm) in 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. The filter element should be strong enough to withstand a blocked flow condition with a pressure differential specified in the detail specification without rupture. Sintered metal powder type elements shall not be used.

3.9.3 Actuators Essential to the 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 shall be designed and constructed (either parallel or series configuration) so that no single structural or hydraulic failure may cause loss of more than one hydraulic system or allow transfer of fluid from one system to another. Aluminum shall not be used as a barrel material for actuators essential to safe operation (flight control and landing gear).

3.10 Component Design and Installation

If a fluid which is different from the specified fluid is used for component testing and shipping, it shall be drained and flushed with the specified fluid before the installation of the component in the aircraft.

3.10.1 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 of AN or MS standards. All components shall be installed and mounted to withstand all expected acceleration loads, wrench loads, and vibration effects.

3.10.1.1 Reverse Installation

All system components shall be designed so that reverse installation cannot occur. Nonstandard components shall be used, if necessary, to conform to these requirements.

3.10.2 Accumulators

Accumulators shall be installed with the utmost consideration given to the protection of crew members and flight essential systems in case of rupture resulting from gunfire. Hydraulic accumulators shall be per ARP4553 (self-displacing hydraulic accumulators), ARP4378 (factory pre-charged welded bellows hydraulic accumulators), or ARP4379 (piston-separated accumulators).

3.10.2.1 Measurement of Accumulator Gas Pressure

When the accumulator gas charge is critical to the functioning of the hydraulic system or subsystem, a permanent pressure-indicating device shall be attached to the gas side of the accumulator. The pressure-indicating device shall not be used to indicate equivalent hydraulic pressure to the crew members. Factory pre-charged welded bellows hydraulic accumulators per ARP4378 do not require a gas pressure indicating device.

3.10.2.2 Accumulator Accessibility

In accumulator installations that require gas charging in the field, adequate access shall be provided around the gas charging valve for the use of a MIL-DTL-8348 high-pressure, gas-testing gage assembly and for standard fitting connections to charge accumulators.

3.10.2.3 Accumulator Instructions

If the accumulator is rechargeable in the field, instructions for servicing the accumulator with gas pressure with the accumulator oil chamber discharged shall be provided adjacent to the accumulator. Information shall be included to indicate the proper gas preload pressure throughout the temperature range for which the accumulator will be serviced.

3.10.2.4 Gas Requirements

Accumulators shall be charged with inert gas only, such as dry nitrogen or helium.

3.10.3 Actuating Cylinders

Hydraulic actuating cylinders shall be so installed that they shall not interfere with the adjacent structure and are readily accessible for maintenance and inspection. If design permits, the cylinder shall be installed in a protected area, or if exposed, it shall be protected from flying debris during landing and takeoff.

Actuating cylinders other than those used for primary flight control shall conform to MIL-PRF-5503. For higher pressure systems, MIL-PRF-5503 shall be used except the performance pressures shall be per Tables 2C and 2D.

3.10.4 Bleed Valves

Manual bleed valves shall conform to MIL-V-81940 and shall be so located that they can be operated without the removal of other aircraft components. Such installations shall permit the attachment of a flexible hose so that fluid bleed-off may be directed into a container (see 3.5.9).

When used, automatic bleed valves shall be per MIL-V-29592 and be so designed that failure in the open position results in minimal leakage of fluid. In the most adverse case of flight duration, pressure, and temperature, the automatic bleed valve leakage shall not exceed the emergency reserve capacity of the reservoir.

3.10.5 Brake Valves

Brake valves shall be installed per AS8584 and shall conform to MIL-V-5525.

3.10.6 Check Valves

Check valves shall conform to MIL-PRF-25675, MIL-V-19067, or ARP4946.

3.10.7 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, internal flow, or pressure surges which might tend to cause the valves to open or move from their setting or cause them to transfer fluid from one system to the other. Hydraulic control valves shall not be installed in the pilot's cockpit or compartment.

3.10.7.1 Directional Control Valve Handle Installation

All installations of directional control valve handles shall conform to MIL-STD-1472. Valve installation shall incorporate internal or external stops capable of withstanding limit loads generated by the application of 75 pounds (335 N) on the handle grip without detrimental effects.

3.10.7.2 Multiple Control Valve Systems

In systems that incorporate two or more directional control valves, a provision shall 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.

3.10.7.3 Control Valve Actuation

Control valve operation may be direct, such as push-pull rods, cable control, or indirect, such as electrically operated controls. Push-pull rods shall require a minimum or no adjustment. Sheathed flexible controls shall not be used. Cable control shall be designed to provide minimum adjustment and positive control. All controls shall be designed to prevent overtravel or undertravel of the valve control handle by use of external or internal stops. Electrically operated valves shall be provided with mechanical override control mechanisms.

3.10.7.4 Control Valve Wiring

Electrically operated control valves shall be wired per AS50881.

3.10.8 Pressure Regulating Valves

Valves that reduce pressure for utility circuits shall conform to MIL-V-5519.

3.10.9 Filters

Filters per MIL-F-8815 with an element collapse pressure of 150% of operating pressure shall be provided in all hydraulic systems. These filters shall be used to filter all circulating fluid in the system. The pump pressure line filter shall be located downstream from the ground servicing connection point; otherwise, an additional filter shall be required to filter fluid entering the aircraft from the ground servicing unit.

All vent openings or fluid exposed to breathing action through vents shall be protected by filters.

Line filters installed in the aircraft system close to an accumulator shall be, if the design permits, installed upstream from the accumulator.

When a secondary or last chance type filter screen is used internal to or close to a component, provisions shall be made for the removal and replacement of the screen.

Sintered metal powder-type elements shall not be used in hydraulic systems. These types of filters may be used only as air vent filters.

The system filter condition shall be monitored electronically.

3.10.9.1 Aircraft Filters

All filters installed in the hydraulic system(s) shall be per the requirements of MIL-F-8815/4, MIL-F-8815/5, or MIL-F-8815/6 as applicable. All filter elements shall be capable of maintaining the particulate contamination level equal to or better than Class 8 per AS4059.

Fluid samples for contamination tests shall be obtained from sampling valves specified in 3.5.14.

3.10.9.2 Filter Locations

Filters shall be provided in the following locations as a minimum requirement.

3.10.9.2.1 Pressure Filter Installation

A non-bypass-type filter shall be installed in the system pressure circuit and shall be so located that all fluid from the aircraft pump will be filtered before entering any major equipment or components of the system. In multiple pump systems, each pump shall have a separate filter installation.

3.10.9.2.2 Return Filter Installation

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

3.10.9.2.3 Reservoir Fill Filter Installation

A non-bypass-type filter shall be installed to filter all fluid entering the system through the reservoir fill connection. The main system return filter or the pump case drain filter may also be used for this function provided check valves are installed in the system to prevent backflow to components. Also, the fill fluid flow rate shall be limited to prevent the opening of the filter housing bypass valve.

3.10.9.2.4 Pump Case-Drain Filter Installation

Each pump case-drain line shall have a filter installed. A bypass-type filter prevents blocking the case line in the event of a clogged filter element with the resulting risk of contamination to the downstream components, such as heat exchangers and reservoirs. A non-bypass filter prevents downstream contamination but may result in a blocked case line and resulting pump overheat.

3.10.9.2.5 Pump Suction Filter Installation

Filters shall not be installed between the system reservoir and the pump suction port.

3.10.9.3 Hydraulic Sequencing

Where hydraulic sequencing is critical, and where contamination can prevent proper sequencing, each sequence valve shall be protected from contamination in each direction of flow by a screen-type filter element. This element may be included as a part of the sequence valve assembly.

3.10.9.4 Ground Support Equipment Filtration

All ground support equipment hydraulic filters shall be qualified to MIL-PRF-81836.

3.10.10 Fittings

As much as the design permits, tube fittings shall be of the permanent type employing no screw threads. Threaded, reconnectable type fittings shall be used for component installation, production breakpoints, and at other points consistent with the maintenance plan of the aircraft.

Repair and replacement methods involving failed tubing and fittings shall be established for each aircraft model and shall be included in the applicable aircraft publications.

Fittings with threaded connections shall conform to AS85421 for Class 4000 pressure (27600 kPa) or less and AS85720 for greater than Class 4000. For installation in the aircraft, no lubrication or bonding material shall be applied to the threads of reconnectable fittings except for the fluid specified in 3.3. Any other lubricating material necessary for the correct installation of the fitting is specified in the fitting specification and is permanently applied to the fittings.

3.10.10.1 Boss Fittings

Ring-locked type boss fittings shall be used in all components. Ports for these fittings shall conform to the requirement of AS1300 for Class 5000 systems (34500 kPa) and below and AS4201 for Class 8000 systems (55000 kPa). These ring-locked fittings shall mate to either AS85421 or AS85720 fittings. For Class 4000 systems (27600 kPa) and below, an AS5202 port may be used if the design permits.

3.10.11 Flow Dividers

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

3.10.12 Flow Regulators

Flow regulators may be installed in the hydraulic system to limit the rate of fluid flow. They shall conform to MIL-V-8566 for Type I systems or ARP7212. The direction and rate of fluid flow shall be clearly indicated on the flow regulator and the adjacent structure. Regulators used under continuous dynamic conditions shall not adversely affect the operation of the hydraulic system.

3.10.13 Protective Devices

Hydraulic fuses, circuit breakers, reservoir level sensors, or other similar devices may be used to meet survivability requirements. Premature or inadvertent shutoff or any other malfunction of such devices shall not occur during any flow or pressure variations or any conditions of system operation. The function and reliability of such devices shall be demonstrated in the functional simulator (see Section 4).

Hydraulic fuses shall conform to MIL-DTL-5508 for Type I systems, or AS5466 or AS5467 (as applicable).

3.10.13.1 Second Tier Screens

It is recommended that second-tier screens, as defined by AIR4057, should, when fully clogged, withstand a proof pressure test without collapse, rupture, or permanent deformation.

3.10.14 Snubbers

Pressure snubbers shall be used with all hydraulic pressure transmitters, hydraulic pressure switches, and hydraulic pressure gages unless the application calls for a fast response of the device. When snubbing is not used, the design shall demonstrate the capability of surviving the environment. Snubbers may be an integral part of the pressure transmitter switch or gauge. Pneumatic pressure gages are excluded from this requirement.

3.10.15 Manually Operated Pumps

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

3.10.15.1 Manually Operated Pump Suction Line

No screen or filter shall be used in the suction line of the pump. The suction line shall be of a diameter and length to ensure priming a dry pump and obtaining full rated flow at -40 °F (-40 °C) temperature within 12 complete cycles at a rate of 20 cycles per minute. The pump circuit shall be capable of full priming and rated flow in flight at the highest altitude at which pump operation is essential and intended.

3.10.15.2 Manually Operated Pump Check Valve

A standard check valve shall be provided in the pump pressure line.

3.10.15.3 Hand Pump Handle Length

The effective operating handle length of hand pumps shall be such that the handle load shall not exceed 67 pounds (300 N). The length of this handle travel at the handgrip shall not exceed 18 inches (45.7 cm).

3.10.16 Flexible Connections

Whenever relative motion exists between two points, metal coiled tubing per ARP584 or ARP4146 shall be used unless hoses, extension units, or swivels are demonstrated to be superior in the application and the environment. Hoses are preferred over extension units and swivels and shall be selected according to the following paragraphs.

3.10.16.1 Hose Assemblies

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

Class 1500 (10345 kPa) polytetrafluoroethylene hose assemblies shall conform to MIL-DTL-25579. These hose assemblies shall have permanent-type end fittings, and their installation shall allow space to permit replacement with spares conforming to MIL-DTL-27267 and MIL-DTL-27272.

Class 3000 (20690 kPa) polytetrafluoroethylene hose shall conform to AS604 and AS1339.

Class 4000 (27600 kPa) polytetrafluoroethylene hose shall conform to AS614 and AS1975. Installations shall permit replacement with MIL-DTL-83298 hoses and MIL-DTL-83296 hose fittings.

Class 5000 (34500 kPa) and Class 8000 (55000 kPa) aramid fiber hoses shall conform to MIL-H-85800.

3.10.16.2 Hose Support

The support of a flexible line shall be such that it will not tend to cause deflection of the rigid lines under any possible relative motion that may occur. A flexible hose between two rigid connections may have excessive motion restrained where necessary but shall not be rigidly supported 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 ensure that the flexible line is not restricted and does not rub on the structure or adjacent members during any portion of its excursion. Clamping of aramid fiber hoses is not permitted unless absolutely necessary to prevent chafing. Extreme caution shall be used in clamping these hoses to prevent any damage to the chafe guard or underlying fibers.

3.10.16.3 Hose Bend Radii

The minimum radius of bend for hose assemblies shall be a function of hose size and flexing range to which the hose installation will be subjected. The minimum bend radius as installed for hoses shall be per the applicable hose specification.

3.10.16.4 Hose Protection

The hose shall be protected against chafing where necessary to preclude damage to the hose and the adjoining structure, tubing, wiring, and other equipment.

3.10.16.5 Provisions for Hose Elongation and Contraction

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

3.10.17 Lock Valves

Where lock valves are used, provisions shall be made for fluid expansion and contraction throughout the temperature range. Where several actuating cylinders are mechanically tied together, only one lock valve shall be used to hydraulically lock all actuators so tied together.

3.10.18 Motors

All constant-displacement motors shall be per AS7997, and variable displacement motors should be per ISO 22181.

They shall be accessible for maintenance and inspection.

Case flow connections shall be provided using a check valve in the case drain line. All case drain lines should be connected to the system return line upstream of the reservoir provided the return steady state pressure is lower than the motor case pressure. The connection of case drain lines to actuator return lines is prohibited. The shaft seal drain shall be vented overboard.

3.10.19 Variable Delivery Power Pumps

Variable delivery pumps shall be per AS19692. The pressure differential between the pump-case cooling port and the reservoir shall be such as to permit the pump to maintain cooling flow in any pump flow condition including zero flow.

3.10.19.1 Electric Motor-Driven Pumps

Electric motor-driven hydraulic pumps per AS5994 may be used, as necessary, for either normal, emergency, or auxiliary operation of hydraulic systems.

3.10.20 Fixed Displacement Power Pumps

Fixed displacement pumps shall be per the procuring agency specifications. MIL-P-5954 can be used as a reference for the development of a fixed displacement pump specification. Fixed displacement power pumps shall not be used as the main source of fluid power in any system.

3.10.21 Power Transfer Units

Power transfer units per ISO 22089 should be used, as necessary, for either normal, emergency, or auxiliary operation of hydraulic systems.

3.10.22 Relief Valves, System, and Thermal Expansion

The system relief valves shall be designed per Table 2B as safety devices to prevent bursting or other damage to the system if the normal pressure regulation device malfunctions, a blocked line condition occurs, or overload forces are generated on actuating units.

Excessive system pressure caused by the thermal expansion of the fluid shall be relieved through the thermal expansion relief valves.

Relief valves are to be used as safety devices and not as pressure-regulating devices.

3.10.22.1 System Relief Valves

Relief valves shall conform to MIL-V-8813, MIL-V-85245, or ARP4763.

System pressure relief valves shall relieve excessive pressure by the bypass of fluid from the pressure to the return side (see Table 2B). The valves shall have a capacity equal to or greater than the rated flow of the largest pump when two or more pumps have a common pressure line. The systems shall be designed so that the fluid flowing through the system relief valves does not exceed the temperature of 160 °F (+71 °C) for Type I systems or 275 °F (+135 °C) for Type II systems.

3.10.22.2 Thermal Expansion Relief Valves

Thermal expansion relief valves shall conform to ARP4835. For subsystems isolated from the system relief valve, local relief valves shall be installed to prevent excessive pressure rise and system damage resulting from the thermal expansion of the hydraulic fluid. The valve shall relieve fluid to the return side of the system. Internal valve leakage shall not be considered an acceptable method of providing thermal relief (see Table 2B for the relief valve setting).

3.10.23 Reservoirs

Hydraulic reservoirs shall be designed per AS5586.

When a hydraulic emergency system is used in any military aircraft, except for trainer types, a separate emergency reservoir shall be provided. The emergency reservoir shall be located as remote as design permits from the main reservoir to minimize the effect of gunfire damage. Both the main and emergency reservoirs shall be serviceable through a common filler port unless the system or the reservoir design does not permit it.

The fill and vent lines for all hydraulic reservoirs shall be designed so that rupture of any reservoir, fill, or vent lines will not cause fluid exchange between reservoirs or loss of sufficient fluid from any other reservoir to impair system operation.

Reservoirs shall be protected from failure when a rapid discharge of the main or emergency system into the reservoirs is encountered.

Protection from overpressurization resulting from overfilling shall be incorporated into the reservoir subsystem.

Pressurized reservoir installations shall include a depressurization valve for maintenance purposes.

3.10.23.1 Reservoir Location

It is desired that the reservoir be located such that the following conditions will be obtained:

a. At a maximum practical height such that a positive static head of fluid shall be supplied to all pumps in all normal flight attitudes of the aircraft.

b. The length of the suction line to the pump shall be minimized to prevent cavitation.

c. The best available temperature and pressure is utilized; however, it shall not be installed in engine compartments.

d. Suction lines shall 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, provisions shall 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.

e. 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 shall be incorporated in the lines.

3.10.23.2 Gas-Pressurized Reservoirs

NOTE: Reservoir pressurization via gas includes air or inert gas-type reservoirs.

The gas pressure shall be controlled by an externally nonadjustable pressure-regulating device to control the gas pressure in the reservoir. A relief valve shall also be connected to the airspace to protect the reservoir and pump from excessive pressure. If the gas pressure regulator and relief valve are combined into one housing, a single failure in that unit shall not permit overpressurization of the reservoir.

3.10.23.3 Reservoir Air Pressurization Moisture Removal Equipment

When engine bleed air is used for reservoir pressurization, a moisture removal unit shall be installed at a location to protect the pressure regulation lines and equipment. Bleed line components shall be installed to minimize the effects of trapped moisture. A filter shall be provided.

3.10.23.4 Reservoir Fluid Level Indication

Reservoir fluid level indication shall be provided both on the reservoir itself as required in AS5586 and also in the cockpit. Both fluid level indications shall be temperature compensated for the correct volume for any temperature as specified in 3.5.1.1 of this document. Cockpit indicator fluid level markings shall correspond to the direct-reading fluid level indicator markings provided on the reservoir and shall be lighted per the applicable cockpit lighting requirements. A warning light shall also be provided to signal the pilot of a low fluid level condition. The cockpit fluid level indicator shall 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. The reservoir level monitoring and branch circuit isolation shall be accomplished electronically.

3.10.23.5 Hydraulic (Bootstrap) Reservoir Pressurization

If normal system pressure is lost for any reason, the hydraulic reservoir pressurization shall be maintained. Regulated hydraulic pressure during an inactive pump state helps to prevent pump cavitation and maintain return circuit pressurization to prevent air intrusion. This may be accomplished by placing an accumulator, check valve, and relief valve in the hydraulic pressurization circuit, or a mechanical provision in the reservoir. The provision for depleting this trapped pressure and depressurizing the reservoir for ground maintenance shall be incorporated into the circuit.

3.10.24 Restrictor Valves

Adjustable orifice restrictor valves may be used in experimental aircraft, but only fixed orifice restrictor valves shall be used in service test and production aircraft. One-way restrictors shall be designed with different port sizes on each end to prevent installation in the wrong flow direction. The direction of restricted and unrestricted flow shall be indicated on the restrictor.

NOTE: For fixed orifice filtration requirements, see 3.9.2.

3.10.25 Self-Sealing Couplings

Self-sealing couplings shall conform to AS1709.

Hydraulic systems should be provided with self-sealing couplings for each engine-driven pump and be located so that the pump can be readily removed for servicing. A coupling should be used in each line going to each pump.

Self-sealing couplings may also be provided on all hydraulically operated brake installations where it is necessary to disconnect the brake line to remove the wheel. The self-sealing coupling shall be attached to the brake, and it shall be possible to remove the wheel without damaging the coupling.

Self-sealing couplings shall 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. If required, provisions for connecting couplings with trapped pressure in the hydraulic system shall be incorporated into the coupling design.

The coupling design shall prevent inadvertent disconnection and provide an indication when a coupling connection is incomplete. If the means of preventing inadvertent disconnection are not absolutely positive, the system shall be so designed that a hydraulic lock resulting from an inadvertent coupling disconnection will not be the cause of an aircraft accident.

Clearance shall be provided around the coupling to permit connection and disconnection. Self-sealing couplings installed adjacent to each other shall be of different sizes or be otherwise so designed that inadvertent cross-connection of the lines cannot occur.

3.10.25.1 Airframe Breakpoints

When self-sealing couplings are provided at airframe breakpoints, especially in flight control systems, and where disconnection of such a coupling or couplings will adversely affect the operation of any of these systems, the coupling design shall prevent inadvertent disconnection. The design shall also provide an indication when a coupling connection is incomplete. If the means of preventing inadvertent disconnection are not absolutely positive, the system shall be so designed that a hydraulic lock resulting from an inadvertent coupling disconnection will not be the cause of an aircraft accident.

3.10.25.2 Component, Modular Quick Disconnects

When self-sealing couplings are used to mount components, they shall conform to AS4251 except at specified pressure. The design shall provide for deflection and separation forces. Locating pins may be used to aid installation as specified in the procurement document.

3.10.26 Shuttle Valves

Shuttle valves shall conform to MIL-V-5530 for Type I systems and MIL-DTL-19068 for Type II systems. Shuttle valves shall 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 shall be built into the appropriate cylinder head, using parts of the applicable shuttle valve specification above. Where the above installation cannot be made, a standard shuttle valve may be located at the actuator port and shall be tested to the same requirements as the actuator. In the event neither of the above installations is possible, a length of a rigid line is permissible between the cylinder port and the shuttle valve, provided the rigid line and shuttle valve are firmly attached to the actuating cylinder.

Hoses shall not be used between the actuating cylinder port and the shuttle valve.

3.10.27 Pressure Switches

Pressure switches shall conform to the requirements of MIL-DTL-9395. Pressure switches may be installed in hydraulic systems where the regulation of hydraulic pressure is required by controlling an electric motor-driven pump. Precautions shall be taken to prevent chatter or cutoff.

3.10.28 Swivel Joints

Swivel joints shall be designed per MIL-DTL-5513 except all pressure-to-atmosphere dynamic seals shall be dual unvented. Hoses and coiled tubes have superior in-service life and should be used in place of swivel joints where design permits. Where lines or fittings are used to drive swivel joints, they shall be supported and strong enough to ensure proper operating installation.

3.10.29 Tubing

3.10.29.1 Tubing Materials

Tubing shall be either corrosion-resistant steel conforming to AMS-T-6845, MIL-T-8504, or AMS5561, or titanium alloy conforming to AMS4944, AMS4945, or AMS4946. Aluminum alloy tubing per AMS4081 or AMS4083 may be used in pump suction lines and drain lines only. The minimum wall thickness in any alloy or tube size shall be 0.020 inch (0.51 mm).

3.10.29.2 Tube Ovality and Bends

Bends shall be uniform and shall be per AS33611. Tubing ovality shall not exceed 3% for titanium alloys, 5% for corrosion-resistant steels, and 10% for aluminum alloys. These ovality limits apply to the tubing as installed in the air vehicle.

3.10.29.2.1 Tubing Pre-Stress (Autofrettage)

For tube flatness greater than the limits of AS33611, tubing pre-stress (autofrettage) may be used to reduce the flatness to meet the requirements of AS33611 for tube assemblies.

3.10.29.3 Installation of Small-Size Tubing

If tubing in sizes smaller than 3/8 inch (9.53 mm) outside diameter (-6 size) is used in hydraulic systems, particular care shall be taken to properly install, support, and protect it, and it shall be shown that proper operation of the service in which such tubing is used will be possible at -40 °F (-40 °C) temperature.

3.10.29.4 Straight Tubing

Straight tubing between two rigid tubing end connections shall not be used.

3.10.29.5 Tubing and Fitting Identification

All hydraulic fluid lines shall be permanently marked using identification markings that are per MIL-STD-1247. Hoses do not have to be marked if the adjacent tubing or component identifies the function.

Hydraulic lines shall be marked in conspicuous locations throughout the aircraft so that each run or line may be traced. This marking shall indicate the unit operated and the direction of flow, such as LANDING GEAR UP ----------> or FLAPS DOWN ---------->. These markings shall 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 shall be identified (placarded) with its system function, using the same terminology as on its connecting line.

3.10.29.6 Tubing Support

All hydraulic tubing shall be supported from a rigid structure by MIL-DTL-85052 (MIL-DTL-85052/1 or MIL-DTL-85052/3) loop-type cushion clamps, NASM85449 (NASM85449/1 or NASM85449/3) saddle type cushion clamps, or line block clamps. Supports shall be placed as close as the design permits to the start of the bend to minimize tube overhang. Maximum spacings between supports are specified in Tables 3 and 4, except that where tubes support fittings, such as unions and tees, spacings should be reduced by approximately 20%.

When the required spacing cannot be met, an analysis shall be provided to substantiate that the line's natural frequency falls outside of any excitation frequency band within the region of interest. Where tubes of different diameters are connected together, spacing of the smallest tube diameter shall be used. Provisions shall be made in support locations to accommodate a change in tubing length caused by expansion and contraction. To facilitate inspection and repair, tubing shall not be bundled together.

Table 3 - Hydraulic line support spacing, U.S. customary

Dash Size	Nominal Tube OD (inches)	Maximum Length Between Support Centers (measured along the tube) (inches)				
		Titanium		Steel		Aluminum Alloy
		(1)	(2)	(1)	(2)	
-3	0.188	13.0	7.0	14.0	8.0	12.0
-4	0.250	15.0	8.0	16.0	10.0	13.5
-5	0.313	16.0	9.0	18.0	11.0	15.0
-6	0.375	17.0	10.0	20.0	12.0	16.5
-7	0.438	18.5	11.0	21.5	13.0	18.0
-8	0.500	20.0	12.0	23.0	14.0	19.0
-9	0.563	21.0	12.5	24.25	15.0	20.5
-10	0.625	22.0	13.0	25.5	15.0	22.0
-11	0.688	23.0	14.0	25.5	15.0	22.0
-12	0.750	24.0	15.0	27.5	16.0	23.0
-13	0.813	25.0	15.5	28.0	17.0	24.0
-14	0.875	26.0	16.0	28.5	17.0	25.25
-15	0.938	27.0	16.5	29.0	17.5	25.25
-16	1.000	28.0	17.0	30.0	18.0	26.5
-20	1.250	31.0	19.0	31.5	19.0	28.5
-24	1.500	34.0	21.0	32.5	19.5	29.5

(1) Normal vibration environment.
(2) Severe dynamic environment – nacelle, landing gear, pump pressure line to the filter.

Table 4 - Hydraulic line support spacing, metric

Dash Size	Nominal Tube OD (millimeters)	Maximum Length Between Support Centers (measured along the tube) (centimeters)				
		Titanium		Steel		Aluminum Alloy
		(1)	(2)	(1)	(2)	
-3	4.78	33.0	17.8	35.6	20.3	30.5
-4	6.35	38.1	20.3	40.6	25.4	34.3
-5	7.95	40.6	22.9	45.7	27.9	38.1
-6	9.53	43.2	25.4	50.8	30.5	41.9
-7	11.13	47.0	27.9	54.6	33.0	45.7
-8	12.70	50.8	30.5	58.4	35.6	48.3
-9	14.30	53.3	31.8	61.6	38.1	52.1
-10	15.88	55.9	33.0	64.8	38.1	55.9
-11	17.48	58.4	35.6	64.8	38.1	55.9
-12	19.05	61.0	38.1	69.9	40.6	58.4
-13	20.65	63.5	39.4	71.1	43.2	61.0
-14	22.23	66.0	40.6	72.4	43.2	64.1
-15	23.83	68.6	41.9	73.7	44.5	64.1
-16	25.40	71.1	43.2	76.2	45.7	67.3
-20	31.75	78.7	48.3	80.0	48.3	72.4
-24	38.10	86.4	53.3	82.6	49.5	74.9

(1) Normal vibration environment.
(2) Severe dynamic environment – nacelle, landing gear, pump pressure line to the filter.

3.10.29.7 Location of Hydraulic Tubing

Hydraulic lines shall not be installed in the cockpit or cabin and shall be remote from personnel stations. In addition, hydraulic lines shall be located remotely from exhaust stacks and manifolds, electrical, radio, oxygen, and equipment lines, and insulating materials. In all cases, the hydraulic lines shall be routed below these items to prevent fire from line leakage. Hydraulic lines shall not be grouped with lines carrying other flammable fluids to prevent inadvertent cross-connection of different systems. Hydraulic drain and vent lines shall exhaust in areas where the fluid cannot 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 shall be located so that damage cannot occur from being stepped on, used as handholds, or by manipulation of tools during maintenance. Components and lines shall be so located that easy accessibility for inspection, adjustment, and repair is possible. Hydraulic tubing shall not be used to provide support for 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. Marriage or butterfly clamps may be used where required to maintain clearances between hydraulic tubing runs, but not for the support of such tubes.

3.10.29.8 Tubing Flares and Assembly

Tubing flares shall conform to AS33583 or AS4330 and shall be used only in drain or vent lines. When installing tube connections, care shall be exercised to keep the wrenching torque used to assemble each joint within the limits specified on MS21344.

3.10.30 Design of System Installations

The installation practices of ARP994 should be used as a guide for installing hydraulic systems.

3.10.30.1 Component Lines

Two or more lines attached to a hydraulic component shall be designed to prevent incorrect connection to the component.

3.10.30.2 Drain Lines

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

3.10.30.3 Mounting Lightweight Components

Lightweight components that do not have mounting provisions may be supported by the tubing installation, provided the component is rigidly installed and does not result in destructive vibration or cause other adverse conditions to 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 are not obscured and that the supporting members do not affect the operation of the unit. If the unit cannot be supported by a clamp, the tubes on each side of the components shall be clamped to the structure within 2.0 inches (50.8 mm) of the component.

3.10.30.4 Electrical Bonding, Grounding, and Lightning Protectors

The aircraft hydraulic system components, tubing, and distribution elements shall be bonded to the aircraft per MIL-STD-464. All electrically conductive components shall have a mounting point to structure resistance not exceeding 2.5 mΩ.