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MILITARY SPECIFICATION

HYDRAULIC SYSTEMS, AIRCRAFT, TYPES I AND II, DESIGN AND INSTALLATION REQUIREMENTS FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the design and installation requirements for types I and II aircraft hydraulic systems.

1.2 Classification. Aircraft hydraulic systems shall be of the following types and classes, as specified:

Types

Type I - -54° to +71°C (-65° to +160°F) temperature range
Type II - -54° to +135°C (-65° to +275°F) temperature range

Classes

1,500 pounds per square inch (psi); where the cutout pressure at the main pressure controlling device is 1,500 psi
3,000 psi; where the cutout pressure at the main pressure controlling device is 3,000 psi.

2. APPLICABLE DOCUMENTS

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

SPECIFICATIONS

Federal

MMM-A-1617 Adhesive, Rubber Base, General Purpose

Military

MIL-B-5087	Bonding, Electrical, and Lightning Protection, for Aerospace Systems
MIL-W-5088	Wiring, Aircraft, Selection and Installation of
MIL-A-5498	Accumulators, Aircraft Hydropneumatic Pressure
MIL-C-5503	Cylinders; Aeronautical, Hydraulic Actuating, General Requirements for
MIL-F-5508	Fuses, Aircraft Automatic Quantity Measuring, Hydraulic
MIL-F-5509	Fittings, Flared Tube, Fluid Connection
MIL-P-5510	Packing, Preformed, Straight Thread Tube Fitting Boss
MIL-J-5513	Joints, Hydraulic Swivel
MIL-G-5514	Gland Design; Packings, Hydraulic, General Requirements for
MIL-P-5516	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, 160°F
MIL-V-5519	Valves, Regulating Fluid Pressure
MIL-R-5520	Reservoirs, Aircraft, Hydraulic, Non-Separated Type
MIL-T-5522	Test Procedure for Aircraft Hydraulic and Pneumatic Systems, General
MIL-V-5525	Valves, Aircraft Power Brake
MIL-V-5527	Valves; Aircraft, Hydraulic Thermal Expansion Relief
MIL-V-5528	Valves, Hydraulic Controllable Check
MIL-V-5530	Valves, Aircraft Hydraulic Shuttle
MIL-H-5606	Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance
MIL-P-5954	Pump Unit, Hydraulic, Electric Motor Driven, Fixed Displacement
MIL-P-5994	Pump, Hydraulic, Electric-Motor-Driven, Variable Delivery, General Specification for
MIL-H-6083	Hydraulic Fluid, Petroleum Base, for Preservation and Testing
MIL-T-6845	Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic System, 1/8 Hard Condition
MIL-T-7081	Tube, Aluminum Alloy, Seamless, Round, Drawn, 6061, Aircraft Hydraulic Quality
MIL-F-7179	Finishes and Coatings: Protection of Aerospace Weapons Systems, Structures and Parts, General Specification for
MIL-P-7858	Pump, Hydraulic, Power Driven, Fixed Displacement
MIL-M-7997	Motors, Aircraft Hydraulic, Constant Displacement, General Specification for
MIL-G-8348	Gage Assemblies, Air Pressure, Dial Indicating Chuck Type, Self-Contained
MIL-T-8504	Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded
MIL-V-8566	Valves; Aircraft Hydraulic Flow Regulator
MIL-B-8584	Brake Systems, Wheel, Aircraft, Design of
MIL-D-8706	Data and Tests, Engineering: Contract Requirements for Aircraft Weapon Systems
MIL-H-8775	Hydraulic System Components, Aircraft and Missiles, General Specification for

MIL-F-8785	Flying Qualities of Piloted Airplanes
MIL-R-8791	Retainer, Packing, Hydraulic, and Pneumatic Tetrafluoroethylene Resin
MIL-V-8813	Valves: Aircraft, Hydraulic Pressure Relief, Type II Systems
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-H-8891	Hydraulic Systems, Manual Flight Vehicles, Type III, Design Installation and Data Requirements for
MIL-A-8897	Accumulators, Hydraulic, Cylindrical, 3,000 PSI, Aircraft Type II Systems
MIL-R-8931	Reservoirs: Aircraft and Missile, Hydraulic, Separated Type
MIL-C-8956	Clamps, Loop, Tube Support
MIL-S-9395	Switch Pressure (Absolute Gauge and Differential) General Specification for
MIL-F-9490	Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification for
MIL-F-18280	Fittings, Flareless Tube, Fluid Connection
MIL-F-18372	Flight Control Systems; Design, Installation and Test of, Aircraft (General Specification for)
MIL-V-19067	Valves, Check, Controllable, Hydraulic, Aircraft, Type II Systems
MIL-V-19068	Valves, Shuttle, Hydraulic, Aircraft, Type II Systems
MIL-P-19692	Pumps, Hydraulic, Variable Delivery, General Specification for
MIL-C-25427	Coupling Assembly, Hydraulic, Self-Sealing, Quick Disconnect
MIL-H-25579	Hose Assembly, Tetrafluoroethylene, High Temperature Medium Pressure, General Requirements for
MIL-V-25675	Valves, Check, Miniature, Hydraulic, Aircraft and Missile
MIL-P-25732	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, 275°F
MIL-V-27162	Valves, Servo Control, Electro-Hydraulic, General Specification for
MIL-H-27267	Hose Tetrafluoroethylene, High Temperature, Medium Pressure
MIL-F-27272	Fitting, Tetrafluoroethylene, Hose, High Temperature, Medium Pressure, General Requirements for
MIL-H-38360	Hose Assembly, Tetrafluoroethylene, High Temperature, High Pressure, Hydraulic and Pneumatic
MIL-V-81940	Valve, Sampling and Bleed, Hydraulic, Type II Systems
MIL-H-83282	Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft
MIL-F-83296	Fittings, Tetrafluoroethylene Hose, High Temperature, High Pressure (3000 psi), Hydraulic and Pneumatic
MIL-H-83298	Hose, Tetrafluoroethylene, High Temperature, High Pressure (3000 psi), Hydraulic and Pneumatic
MIL-F-83300	Flying Qualities of Piloted V/STOL Aircraft

STANDARDS

Federal

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

Military

MIL-STD-1247	Markings, Functions and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missile, and Space Systems
MS21105	Clamp, Loop, Cushioned, Wedge, Fluid Resistant, 500°F, Cres Type III, Class B
MS21344	Fittings - Installation of Flared Tube, Straight Threaded Connectors, Design Standard for
MS33515	Fitting End, Standard Dimensions for Bulkhead Flareless Tube Connections
MS33566	Fittings, Installation of Flareless Tube, Straight-Threaded Connectors
MS33583	Tubing End - Double Flare, Standard Dimensions for
MS33584	Tubing End - Standard Dimensions for Flared
MS33611	Tube Bend Radii
MS33620	Chart, Hose Selection
MS33656	Fitting End, Standard Dimensions for Flared Tube Connection and Gasket Seal
MS33657	Fitting End, Standard Dimensions for Bulkhead Flared Tube Connection

Air Force-Navy Aeronautical

AN929	Cap Assembly, Pressure Seal Flared Tube Fitting
AN6240	Filter - Hydraulic Replaceable Element Vent Type

PUBLICATIONS

Navy Department Specification

SD-24	General Specification for Design and Construction of Aircraft Weapon Systems
Vol. I	Fixed Wing Aircraft
Vol. II	Rotary Wing Aircraft

Navy Department Technical Manual

NAVAIR 01-1A-17	Aviation Hydraulics Manual

Air Force Systems Command Design Handbook

AFSC DH 2-2	Crew Stations and Passenger Accommodations

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

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

Society of Automotive Engineering, Inc. Aerospace Recommended Practices and Aeronautical Standards

ARP 584	Coiled Tubing
AS 1290	Graphic Symbols for Aircraft Hydraulic and Penumatic Systems

(Application for copies should be addressed to the Society of Automotive Engineering, Inc., 400 Commonwealth Drive, Warrendale, Pa 15096.)

National Aerospace Standards Association, Inc. Standard

NAS 1638	Cleanliness Requirements for Parts Used in Hydraulic Systems

(Application for copies should be addressed to the National Aerospace Standards Association, Inc., 1321 Fourteenth St., N.W., Washington, D. C. 20005.)

3. REQUIREMENTS

3.1 Materials. Materials used in the manufacture of hydraulic systems in military aircraft shall be of high quality, suitable for the purpose, and shall conform to applicable Government specifications. Materials conforming to contractor's specifications may be used, provided it can be clearly demonstrated that they are at least equivalent to Government specifications with respect to operating characteristics and that a savings in weight or cost can be accomplished. Contractor's specifications must be satisfactory to the Government and contain provisions for adequate tests. The use of contractor's specifications will not constitute waiver of Government inspection.

3.2 Design. The hydraulic systems and components thereof shall be designed to operate satisfactorily under all conditions that the aircraft may encounter within the structural limitations of the aircraft, including forces or conditions caused by acceleration, deceleration, zero gravity (g), negative g, or any flight attitudes obtainable with the aircraft, structural deflection, vibration, or other environmental conditions. (For Navy use only, see Navy Department publications SD-24, Volumes I and II.) The hydraulic system(s) shall be configured such that any two fluid system failures due to combat or other damage which cause loss of fluid or pressure will not result in complete loss of flight control. For fixed-wing aircraft, the surviving system(s) shall provide sufficient control to meet the level 3 flying qualities of MIL-F-8785 for conventional takeoff and landing and MIL-F-83300 for vertical takeoff and landing. For rotary-wing aircraft, the surviving system(s) shall provide sufficient control for return to the intended landing area (including shipboard areas and land).

* 3.3 Fluid. Fluid conforming to MIL-H-5606 shall be used for hydraulic systems and associated ground equipment. MIL-H-83282 hydraulic fluid shall be used instead of MIL-H-5606 when specified by the procuring activity.

3.4 Packings. MIL-G-5514 shall be used as a guide for packing installations.

3.4.1 Type I systems. Packings shall conform to MIL-P-5516 or MIL-P-25732 (excluding boss applications). Packings used in bosses shall conform to MIL-P-5510.

3.4.2 Type II systems. Packings conforming to MIL-P-25732 shall be used within the performance constraints reflected by qualification requirements and tests of MIL-P-25732. Nonstandard packing may be used subject to approval of the procuring activity. The major performance constraints of MIL-P-25732 are summarized in 3.4.2.1 and 3.4.2.2.

3.4.2.1 For maximum fluid temperature of 107°C (225°F). If the maximum fluid temperature does not exceed 107°C (225°F), the standard seal is suitable for the normal life reflected by endurance test B of MIL-P-25732.

3.4.2.2 For maximum fluid temperature between 107° and 135°C (225° and 275°F). If maximum fluid temperature is between 107° and 135°C (225° and 275°F), the life expectancy of the standard seal shall be reduced proportionally from the normal life reflected by endurance test B of MIL-P-25732 to the reduced life reflected by endurance test A of MIL-P-25732. (The total accumulated time of exposure to 135°C (275°F) during qualification tests is approximately 80 hours.) The reduced life expectancy shall be clearly defined in all appropriate publications. Packings used in bosses shall be subjected to the approval of the procuring activity.

3.4.3 Backup rings. Backup rings shall conform to MIL-R-8791.

3.5 Hydraulic system data submittal and approval. Hydraulic system data submittal and approval requirements for a specific model aircraft will be covered by a contract with the appropriate procuring activity. Typical information and data required are listed in 6.2. The data shall be furnished in accordance with MIL-D-8706 or in accordance with appropriate line items of the Contractor Data Requirements List (DD Form 1423), as applicable.

3.5.1 Service-contractor conferences. The contractors shall confer with the hydraulic engineers of the applicable service on the proposed hydraulic systems during the early stages of design in order to take advantage of exchange of information and to coordinate development programs. The first conference shall take place at the time when the preliminary schematic diagram is established for the aircraft. Other conferences shall take place during the appropriate development phases of the aircraft.

* 3.5.2 Functional mockup and simulator. A functional mockup and simulator of the hydraulic system or systems shall be constructed to determine system performance. Arrangement shall be made for the application of simulated flight loads and forces. Prototype components or suitable laboratory models may be used for systems development testing. However, prior to the first flight, testing shall be accomplished on the simulator with all components incorporated, including flight instrumentation, tubing and fittings, identical to those installed in the first flight aircraft. Pending the availability of production components, prototype components or suitable laboratory models may be used. One test on the simulator shall simulate a mission profile so as to duplicate an actual aircraft condition. Items shall operate in sequence for a check on unusual back pressure, surges, temperature, pump pulsation, etc. The system shall simulate startup, flight-control checkout, door closing, braking, steering, flap retraction, gear retraction, and power flight control under takeoff, cruise, approach, landing, and taxi conditions. All emergency modes and system failure conditions as required by 3.2 shall be demonstrated. The functional mockup shall be used to determine the performance of the hydraulic system prior to the first flight of the aircraft and to evaluate any significant changes to be made to the system during production of the aircraft.

* 3.6 General system design. Hydraulic systems shall be as simple and foolproof as possible and in accordance with design, operation, inspection, and maintenance objectives specified in the aircraft design requirements. For Navy aircraft NAVAIR 01-1A-17 shall be used as a guide for the maintenance aspects of the design of the aircraft.

* 3.6.1 Fluid temperature limitations. The hydraulic system(s) shall be capable of operating under any condition encountered within the operating envelope, including the conditions specified in 3.6.1.1 and without exceeding the following bulk fluid temperature limits in any portion of the system(s):

a. Type I - 71°C (160°F)

b. Type II - 135°C (275°F)

Operation at these temperatures shall not result in any degradation of system(s) or component performance except as noted in 3.4.2.2.

* 3.6.1.1 Climatic extremes. Ground operation, flight operation and storage climatic extremes shall be in accordance with the weapon system procurement specification.

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

3.6.3 Strength

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

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

3.6.4 Pressure limitations

* 3.6.4.1 System pressures. System pressures shall be in accordance with table I. Peak pressure resulting from any phase of the system operation shall not exceed 135 percent of the main system, subsystem, or return system pressure when measured with electronic equipment, or equivalent. Lines, fittings, and equipment in return circuits shall be designed for one-half the nominal system pressure.

3.6.4.2 Back pressure. The system shall be so designed that proper functioning of any unit will not be affected by the back pressure or changes in the back pressure in the system. The system or systems 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.

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

TABLE I. System Pressures

Characteristics	Nominal System Pressure		Percent System Pressure	Remarks
	Class 1500	Class 3000		
Automatic pressure regulator - Accumulator system (closed center)				
a. Regulator cutout pressure	1,500	3,000	---	System design pressure
b. Upper limit of operating for all units (regular cut-in pressure)	1,250	2,600	---	---
c. Maximum system relief valve setting, at maximum system flow	1,900	3,850	---	MIL-V-8813 units
Open-center-type system (constant-delivery pump)				
a. System design pressure	1,500	3,000	---	Relief valve full-flow setting
b. Upper limit for full-flow system pressure	1,350	2,700	---	
c. System Relief valve setting, at maximum system flow	1,500	3,000	---	MIL-V-8813 units
Closed- or open-center system (variable-volume pump)				
a. Pump unloading pressure	1,500	3,000	---	System design pressure
b. Maximum limit of full-flow system pressure	1,450	2,950	---	---
c. Maximum system relief valve setting, at maximum system flow	1,900	3,850	---	MIL-V-8813 units
Thermal relief valve setting (maximum)				
a. Equal to system relief valve setting plus values noted	150	150	---	---
Proof pressure (minimum)				
a. Lines, fittings and hoses	3,000	6,000	200	Proof pressure values for hose to be in accordance with the applicable detail specification.
b. Components containing air and fluid under pressure	3,000	6,000	200	MIL-A-5498 or MIL-A-8897, as applicable.
c. Pump suction and case drain line components and reservoir				
(1) Non-pressurized reservoirs	50	50	---	- - - - - - - - - -
(2) Bootstrap reservoirs	---	---		150% of reservoir operating pressure.
(3) Gas pressurized reservoirs	---	---		200% of reservoir operating pressure.

TABLE I. System Pressures (cont'd)

Characteristics	Nominal System Pressure Class 1500	Nominal System Pressure Class 3000	Percent System Pressure	Remarks
Proof pressure (minimum) (cont'd)				
d. Components under system pressure only and pressure circuits (including lines, fittings and hoses)	2,250	4,500	150	- - - - - - - - - -
e. Components under return pressure only and return circuits (including lines, fittings and hoses)	1,125	2,250	75	Except hose, which shall be 125% of nominal system pressure.
Burst pressure (minimum)				
a. Lines, fittings and hoses	6,000	12,000	400	Burst pressure valves for hoses to be in accordance with the applicable detail specification.
b. Components containing air and fluid under pressure	6,000	12,000	400	MIL-A-5498 or MIL-A-8897 as applicable
c. Pump suction and case drain line components and reservoir				
(1) Non-pressurized reservoir	100	100	---	
(2) Bootstrap reservoir	---	---		300% of reservoir operating pressure.
(3) Gas pressurized reservoir	---	---		400% of reservoir operating pressure.
d. Components under system pressure only	3,750	7,500	250	
e. Components in return circuits (including lines, fittings and hoses)	2,250	4,500	150	Except hose, which shall be 250% of nominal system pressure.
Collapse pressure of parts subject to suction	50 external	50 external	---	---

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

* 3.6.5 Reservoir pressurization. Type I systems requiring pump inlet pressurization may utilize reservoirs of the nonseparated pressurized type (gas and hydraulic fluid in contact) or the separated (airless) type. Type II systems shall be designed so that air does not contact the fluid during the normal function of the system(s). The reservoir pressure shall be adequate to prevent cavitation at the inlet to the pump under all operating conditions.

* 3.6.5.1 Reservoir bootstrap pressurization. Reservoir pressurization shall be maintained in the event normal system pressure (reservoir bootstrap pressure) is lost.

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

a. Allowable pressure drop at minimum required operating temperatures

b. Pressure surges caused by high fluid velocity and fast response valves

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

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

3.6.6.1 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 multi-pump system, or reduced engine speed. The systems shall also be so designed that increased flow will not adversely affect the proper functioning of any unit or subsystems, such as increased flow rate caused by accumulator operation or units affected by airload operation.

3.6.6.2 Acceleration effects. System and component operation shall not be adversely affected by the maximum (positive and negative) g loadings obtainable with the aircraft. Consideration shall be given to determine the effect of g on the actuated service, the fluid columns, other large fluid masses, the mass of the operating controls, and any other unit or subsystems that could be affected by the g capabilities of the aircraft.

3.6.7 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.

3.6.8 Ground test provisions. Each hydraulic system shall include a set of self-sealing couplings for attachment of ground test equipment. System ground test provisions shall be so designed that pressurization of any hydraulic system in the aircraft is not necessary in order to test another hydraulic system. In particular, use of only one hydraulic test stand shall be necessary to test the system, without use of Y connections between the test stand and the aircraft or use of a second ground test stand connected to another hydraulic system in the aircraft. (For filtration requirements, see 3.11.9.) A central ground servicing station shall be provided for each system that includes connections for attachment of ground test equipment for system checkout and flushing, reservoir bleeding, reservoir fill, and accumulator air-nitrogen charging.

* 3.6.8.1 Ground test 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 test equipment. The ground connections shall be compatible with those connections supplied on ground test units in use by the procuring activity. Connections on ground test units are as follows:

Pressure connections on ground test units

Aeroquip T150S1-8D coupling half
Aeroquip E155-25-8D nut
Aeroquip 155S9-8D dust plug
Aeroquip T150S1-12D coupling half
Aeroquip E155-25-12D nut
Aeroquip 155S9-12D dust plug
Aeroquip E155-25-16D nut (Air Force only)
Aeroquip T150S1-16D coupling half (Air Force only)
Aeroquip 155S9-16D dust plug (Air Force only)

Suction connections on ground test units

Aeroquip T150S1-16D coupling half
Aeroquip E155-25-16D nut
Aeroquip 155S9-16D dust plug
Aeroquip B140S1-20D coupling half
Aeroquip E145-25-20D nut
Aeroquip 145S9-20D dust plug
Aeroquip B140S1-24D coupling half (Air Force only)
Aeroquip E145-25-24D nut (Air Force only)
Aeroquip 145S9-24D dust plug (Air Force only)
Aeroquip T150S1-12D coupling half
Aeroquip E155-25-12D nut
Aeroquip 155S9-12D dust plug

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.

3.6.8.1.1 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 in accordance with MS33656-4 or MS33657-4 for attachment to a ground supercharging unit. A protective cap in accordance with AN929 with a safety chain shall be provided to protect the end connection when not in use.

3.6.8.1.2 Reservoir filling connection. Reservoirs shall be filled by low-pressure replenishment methods. The reservoir filling connection for Navy aircraft shall be a suitable check valve with an MS33656-6 or MS33657-6 fitting end for attachment to ground filling equipment. A protective cap in accordance with AN929, with a safety chain, shall be provided to protect the end connection when not in use. Unless otherwise specified by the procuring activity, direct pouring of fluid into the reservoir (including in-flight fluid replenishment provisions) shall not be provided.

3.6.8.2 Ground test data. The following data shall be attached in a permanent manner on the aircraft near the ground test connections:

Set ground test reservoir pressurizing valve to __________ psi. 1/
Set ground test stand relief valve to ________ psi. 1/
Set ground test stand volume output to _______ gpm. 1/
Set ground test stand pressure compensator to _________ psi. 1/
Use hydraulic fluid conforming to _________. 1/
Ground test stand output filter shall be __________ microns absolute. 1/
(Any other precautions or information considered necessary.)

1/ The contractor shall fill in these values.

Caution note: The aircraft manufacturer shall provide a caution note stipulating the maximum safe flow for landing-gear retraction checks during the time the aircraft is on jacks.

3.6.9 Removal of entrapped air. Suitable means, such as bleeder valves, shall be provided for removal of entrapped air where it interferes with the proper functioning of the hydraulic system. Disconnection of lines or loosening of tubing nuts does not constitute suitable means. Equipment and system configuration shall, insofar as practicable, be designed to automatically scavenge free air to a reservoir or other collection points where operation will not be affected and where release can be conveniently accomplished. (See 3.11.4.)

3.6.9.1 System air tolerance. The system shall be designed and configured such that the presence of entrapped air shall not cause sustained loss of system pressure or degradation of system performance during all conditions of intended aircraft operation.

3.6.10 Power pumps. The hydraulic system pump(s) shall be compatible with the installed aircraft system and shall not cause abnormal or undesirable effects on the installed system in the aircraft. In each system, the primary pump applications which normally require continuous operation shall be provided with at least two qualified pump designs from separate manufacturing sources. All pumps qualified for a given application shall be physically and functionally interchangeable and shall be compatible with the system and with each other to allow mixed use in multiple pump systems.

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

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

3.6.10.3 Pump pulsation. For all power-generating components (engine pumps, power packages, transfer units, etc), pump pulsations shall be controlled to a level which does not adversely affect the aircraft system tubing, components, and supports installation. The contractor shall determine by test the effect of pump pulsations (pump ripple) on the hydraulic system. Initial tests shall be conducted on the functional mockup and simulator, with suitable recording equipment, and shall cover the complete speed range from zero revolution per minute (rpm) to the maximum speed, pressures, and flows that the pump will be subjected to when installed in the aircraft. Adverse effects including induced resonant vibrations shall be eliminated. Results of the functional mockup/simulator tests for pump ripple effects shall be documented, forwarded to the procuring activity, and shall be verified on the first aircraft, and any additional corrections required shall be made prior to the first flight.

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

3.6.11 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 flametight diaphragms but shall be located as close as practicable 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. These valves shall be operable from the cockpit, to both the closed and open positions.

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

3.6.13 System pressure indication. Pressure-indicating equipment acceptable to the procuring activity shall be provided to indicate the system pressure in hydraulic systems or subsystems. On engine-driven multi-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 shutdown of any engine. The pressure indicators shall be so located as to be readily visible by the flight crew.

3.6.13.1 System low-pressure warning light. In addition, but not as a substitute for the requirement of 3.6.13, a suitable 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 in the system. For Navy aircraft, there shall be a separate warning light for each hydraulic system. The warning light, or lights, shall not be actuated by any combination of flight-control operations under normal operations. A momentary flicker of the warning light during ground checkout only is permissible, provided such condition is adequately described in the appropriate aircraft operation and maintenance manuals and provided such condition does not occur during flight unless a system malfunction exists.

3.6.13.2 Maintenance check gages and indicators. Pressure gages/indicators that require a preflight, postflight, or daily check shall not require workstands or platforms in order to read the gages or indicators.

3.6.14 Fluid sampling valves (Navy). 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 be sufficient to adversely affect the fluid sample. The valve nozzle shall be designed so that penetration of a thin plastic membrane cover on the sampling container neck, when so provided, can be readily accomplished. 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.

3.7 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 (bomb-bay doors, in-flight refueling, etc) or essential to land and stop the aircraft (landing gear, brakes (excluding types I and IV brakes, etc)) shall have provisions for emergency actuation. No single failure of the utility system shall result in loss of the aircraft.

3.7.1 Definition. The utility system shall include all systems used for the normal operation of any service on the aircraft, excluding the systems used for the operation of the aircraft primary control surfaces.

3.7.2 Application. The general requirements of 3.6 and subparagraphs thereto apply to the utility system.

3.7.3 Wheel brake systems. Wheel brake systems shall be in accordance with MIL-B-8584.

3.8 Flight-control system design. Flight-control systems which require hydraulic power for operation shall conform to MIL-F-9490 for Air Force or MIL-F-18372 for Navy, as applicable. In dual flight-control systems, both systems shall be so designed that a ground test stand may be connected to either one of the flight-control systems and that system may be operated without adverse effect on the dead system, such as overflow of the system or failure of any part thereof. In order to accomplish this objection, automatic bypass of the fluid in the dead system from one side of the actuator to the other side shall be provided.

3.8.1 Definitions. Primary flight controls include those control systems used to actuate such surfaces as ailerons, rudders, elevators, stabilizers, or combined function surfaces.

3.8.1.1 Power-boosted flight-control system. A power-boosted flight-control system is a reversible control system wherein the pilot effort, which is exerted through a set of mechanical linkages, is at some point in these linkages boosted by a hydraulic power source.

* 3.8.1.2 Power-operated flight-control system. A power-operated flight-control system is an irreversible control system wherein the pilot either electrically or mechanically, actuates a power control servomechanism. This mechanism actuates the primary control surface or corresponding device.

3.8.1.3 Combined flight-control/utility system. A combined flight-control/utility system (combined system) is a system that supplies a portion of the power required to operate the flight-control system and also supplies power to the utility system.

* 3.8.2 System isolation. Whenever hydraulic power is required for primary flight controls, a completely separate, integral, and adequate 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 procuring activity. This hydraulic system shall be as simple as practicable and shall contain a minimum number of components. Dual actuator systems may employ the combined flight-control/utility system for one-half of the power, in which case the flight-control system shall be given pressure priority. In addition, the combined flight-control/utility system shall be so designed that the portions of the system required for operation only during the takeoff and landing phases of flight (e.g., landing gear or wing flaps) may be isolated from the rest of the system by means of a suitable shutoff valve in the pressure line, controllable from the cockpit, and check valves in the return lines so located that a rupture in any portion of the utility system will not cause loss of fluid from the reservoir when the system isolation valve is closed. When isolation valves are used in a combined flight-control/utility system to isolate nonessential flight functions, the system shall be designed to preclude inadvertent isolation, during taxi or ground operation, that would result in loss of wheel braking, nose-gear steering, or other critical functions.

3.8.3 Hydraulic power failure. In aircraft where direct mechanical control sufficient to obtain aircraft controllability to pass the emergency requirements of MIL-F-8785 cannot be accomplished following hydraulic power failure, an emergency power source shall be provided, supplying controllability requirements.

3.8.3.1 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 is preferred, when suitable. Automatic engagement of the emergency power system shall not be used unless specifically approved by the procuring 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 and no single failure can cause loss of both systems. Consideration shall be given to the possibility of out-of-fuel landings wherein none of the engines are operating. Inasmuch as some turbojet engines will not windmill enough to provide adequate flight-control power supply during landing, it may be necessary to provide emergency power sources not dependent upon engine operation. In aircraft which are capable of being landed without engine power, this condition shall not be considered an emergency, and provisions shall be made for landings with one of the power systems failed while out of fuel. When designing for this condition, extreme care must be exercised not to reduce the reliability of the power systems. It shall always be possible to reengage the flight controls or return them to normal following operation of the emergency hydraulic system, and where a ram-air turbine is used as the source of emergency power, it shall be capable of extension, operation, and retraction under any flight conditions.

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

* 3.8.4 System separation. Where duplicate hydraulic systems are provided, these systems shall be separated as far as possible to obtain the maximum advantage of the dual system with regard to vulnerability from gunfire or engine fires. Where practicable, dual systems should be on opposite sides of the fuselage, the wing spar, or similarly separated. In any case the systems necessary for safety of flight shall be separated a minimum of 18 inches, preferably in a plane perpendicular to ground fire. Where it is deemed necessary, in a particular aircraft model, for these systems to come together, as in a dual tandem surface actuator, that actuator shall be protected from the threat to a degree specified by the procuring activity. Adequate consideration should be given to the clearance between moving flight-control-system components and structure or other components to insure that no possible combination of temperature effects, airloads, or structural deflections can cause binding, rubbing, or jamming or any portion of the primary flight-control system.

3.8.5 System pressure. Systems which use a pressure lower than the full system pressure shall be designed to withstand and operate under the full pressure or shall have an adequate relief valve installed downstream of the pressure reducing valve if the full pressure would be detrimental or dangerous. This relief valve may be incorporated into the same housing as the pressure reducer, provided that the relief valve mechanism is independent of the mechanism of the pressure reducer.

* 3.8.6 Power sources. Aircraft primary flight-control hydraulic systems shall have engine-driven pumps as their source of power, unless sufficient justification exists for using other power sources and is specifically approved by the procuring activity. Helicopter primary flight-control systems shall have transmission-driven pumps as a source of power so that power will be available during the auto rotation.

* 3.8.7 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 conditions including single failures, such as relief valves, worn pump, failed valves and other heat generating failures. The effects of differential fluid temperature in tandem units shall also be demonstrated.

3.9 Emergency system design for utility system

3.9.1 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 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. Use of other types of emergency systems shall require specific approval of the procuring activity.

3.9.1.1 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 be provided with a suitable emergency system.

3.9.2 Emergency-line venting. The emergency line from the shuttle valves shall be vented to the reservoir or to a low-pressure (15 psi gage maximum, above reservoir pressurization) nonsurging return line when the emergency system is not in use, except as authorized by the procuring activity. When shuttle valve leakage is not critical, the line may be vented to the atmosphere. After use of a compressed-gas emergency system, the system shall be bled directly to the atmosphere rather than to the reservoir.

3.10 Component design. All components used in the system shall conform to MIL-H-8775 and applicable detail specifications.

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

* 3.10.2 Orifices. Orifices larger than 0.012 inch but smaller than 0.070 inch in diameter shall be protected by adjacent strainer elements having screen openings 0.008 to 0.012 inch in diameter. Orifices smaller than the above range shall be protected by adjacent elements having openings smaller than the orifices and shall be subject to approval of the procuring activity. Orifices and strainer elements shall be strong enough to absorb system design flow and pressure without rupture or permanent deformation.

* 3.10.3 Actuators essential to safe operation of the aircraft. Where two or more independent hydraulic systems are utilized to power services essential for safe flight (e.g., primary flight controls), the actuation and control devices shall be designed and constructed (either parallel or series configuration) so that no single structural or hydraulic failure will cause loss of more than one hydraulic system or allow transfer of 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) in Navy aircraft.

* 3.11 Component installation. If a fluid such as MIL-H-6083, which is different from the specified fluid, is used for component testing and shipping, it shall be drained prior to the installation of the component in the aircraft.

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

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

3.11.2 Accumulators. Accumulators shall be installed with the utmost consideration given to the protection of crewmembers in the case of rupture due to gunfire. For type I systems, hydraulic accumulators shall be in accordance with either MIL-A-5498 or MIL-A-8897 and the standard drawings listed therein. For type II systems, accumulators shall be in accordance with MIL-A-8897.

3.11.2.1 Measurement of accumulator gas pressure. When accumulator gas charge is critical to the functioning of the hydraulic system or subsystem, a permanent pressure gage shall be attached to the gas side of the accumulator. In noncritical installations, the use of the pressure gage shall be at the discretion of the procuring activity. A gage indicating accumulator gas pressure shall never be used to indicate equivalent hydraulic pressure to the crewmembers. AN or MS standard hydraulic gages shall be used and shall be attached with the shortest practicable length of line and minimum number of fittings.

3.11.2.2 Accumulator accessibility. In all accumulator installations space shall be provided around the gas charging valve for use of a MIL-G-8348 high-pressure, gas-testing gage assembly and for standard fitting connections to charge accumulators.

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

3.11.2.4 Gas requirements. For type I systems, accumulators may be charged with air or inert gas (nitrogen). For type II systems, accumulators shall be charged with inert gas only. For Army use only, all rotary-wing aircraft hydraulic system accumulators shall be charged with either air or inert gas (nitrogen).

3.11.3 Actuating cylinders. Hydraulic actuating cylinders shall be so installed that they do not interfere with the adjacent structure and are readily accessible for maintenance and inspection. If possible, the cylinder should be installed in a protected area, or if exposed, be protected from flying debris during landing and takeoff. Actuating cylinders other than those used for primary flight control shall conform to MIL-C-5503.

* 3.11.4 Bleeder valves. Where required, bleeder valves shall conform to MIL-V-81940 and shall be so located that they can be operated without necessitating removal of other aircraft components. Such installations shall permit attachment of a flexible hose so that fluid bled off may be directed into a container.

3.11.5 Brake valves. Brake valves shall be installed in accordance with MIL-B-8584.

3.11.6 Check valves. Check valves shall conform to MIL-V-25675.

3.11.7 Directional control valves. The installation of directional control valves shall be compatible with the control valve performance such that the system operation will not be affected by back pressure, interflow, or pressure surges which might tend to cause the valves to open or move from their setting or cause them to bypass fluid in other than the intended manner. No hydraulic control valves shall be installed in the pilot's cockpit or compartment without the approval of the procuring activity.

3.11.7.1 Directional control valve handle installation. All installations of directional control valve handles shall conform to AFSC DH 2-2 for the Air Force and the Army, and for the Navy as approved by the Cockpit Board of the Naval Air Systems Command. When the effective handle length exceeds 0.8 inch, limiting stops, external to the valve, shall be provided. These stops shall be capable of withstanding 75r pound-inches limit load (where, r, equals the effective handle length) and shall be so positioned that no load will be applied to the internal valve stops, unless the valve has been specifically designed to handle subject loads.

3.11.7.2 Multiple control valve systems. In systems which incorporate two or more directional control valves, 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.

3.11.7.3 Control valve actuation. Control valve operation may be direct, such as push-pull rods or cable control, or indirect, such as electrically operated controls. Push-pull rods shall require a minimum or no adjustment. Sheathed flexible controls shall not be used without specific approval of the procuring activity. 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 wherever practicable and at the option of the procuring activity.

3.11.7.4 Control valve wiring. Electrically operated control valves shall be wired in accordance with MIL-W-5088.

3.11.8 Other valves. Other valves shall conform to MIL-V-5525, MIL-V-5527, MIL-V-5528, MIL-V-8566, MIL-V-19067, or MIL-V-27162, as applicable.

3.11.9 Filter requirements. All vent openings or fluid exposed to breathing action through vents shall be protected by filters. Line filters, when installed in the aircraft system in close proximity to an accumulator, shall be installed upstream of the accumulator. Where pressure-drop indicators are provided on the filter assembly, the indicator shall be easily visible to servicing personnel. When a screen or filter is provided either internally or in close proximity to a component, suitable provisions shall be made for removal of the screen or filter for cleaning or replacement. Sintered-type elements shall not be used.

* 3.11.9.1 Navy aircraft filters. All filters installed in the hydraulic system(s) shall be in general accordance with the requirements of MIL-F-8815/4, MIL-F-8815/5 and MIL-F-8815/6 as applicable. These filters shall be used to filter all of the circulating fluid in the system. Filtration design shall be capable of maintaining the particulate contamination level of the normally operating system at a level not to exceed Class 8 of NAS 1638 or Navy Standard Class V as determined in accordance with Method 3009 of FED-STD-791 or by use of automatic particle counting equipment approved by the procuring activity. Fluid samples for contamination tests shall be obtained from sample valve specified in 3.6.14 and an acceptable level assured at aircraft delivery.

* 3.11.9.2 Air Force and Army aircraft filters. Filters in accordance with MIL-F-8815/1, MIL-F-8815/2 and MIL-F-8815/3 shall be provided in all hydraulic systems. Filters incorporating elements having absolute ratings lower (finer) than 15 microns may be used, subject to approval of the procuring activity. These filters shall be used to filter all circulating fluid in the system. The acceptable contamination level for aircraft delivery shall be specified by the procuring activity.

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

3.11.9.3.1 Pressure line installation. A no-bypass-type line filter(s) shall be installed in the system pressure line and shall be so located that all fluid from the aircraft pump(s) and the ground test equipment pressure connection will be filtered prior to entering any major equipment or components of the system. In multi-pump systems, each pump shall have a separate filter installation.

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

3.11.9.3.3 Reservoir fill line installation. A no-bypass-type line filter shall be installed to filter all fluid entering the system through the reservoir fill connection.

3.11.9.3.4 Pump-case drain line installation. Each pump-case drain (bypass) line shall have a bypass-type filter installed.

3.11.9.3.5 Pump suction line. Filters shall not be installed between the system reservoir and the pump suction port unless specifically authorized by the procuring activity.

* 3.11.9.4 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 suitable screen-type filter element. This element may be included as a part of the sequence valve assembly.

* 3.11.10 Fittings. All tube fittings (other than connections at production break points, to removable components, and where needed to facilitate maintenance) shall be permanently joined employing no screw threads or similar mechanical means and shall require approval by the procuring activity prior to installation in the applicable aircraft. In addition, suitable 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. Removable components shall accept fittings conforming to MIL-F-5509 or MIL-F-18280. Their selection shall be subject to the approval of the procuring activity. They shall be connected and assembled in accordance with MS21344 or MS33566. The use of fittings in removable components other than those conforming to MIL-F-5509 or MIL-F-18280 shall require approval of the procuring activity. No thread lubricant other than hydraulic fluid specified in 3.3 shall be used on hydraulic fittings unless specifically authorized by the procuring activity.

* 3.11.10.1 Universal fittings. Universal fittings conforming with MS33515 and MS33657 shall not be used in boss applications in hydraulic systems unless written approval is obtained from the procuring activity.

3.11.11 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.

3.11.12 Flow regulators. Flow regulators may be installed in the hydraulic system to limit the rate of fluid flow. The direction and rate of fluid flow 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.

3.11.13 Protective devices. Hydraulic fuses, circuit breakers, reservoir level sensors, or other similar devices may be used to meet survivability requirements established by the procuring activity. The specific application of such devices shall be subject to the approval of the procuring activity. 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 mockup and simulator. Fuses used in type I systems shall conform to MIL-F-5508.

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

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

3.11.15.1 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 suitable diameter and length to insure priming a dry pump and obtaining full-rated flow at -54°C (-65°F) temperature with 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.

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

3.11.15.3 Hand pump handle length. The effective operating handle length of hand pumps shall be such that the handle load shall not exceed 67 pounds. The length of this handle travel at the handgrip shall not exceed 18 inches.

* 3.11.16 Flexible connections. Whenever relative motion exists between two points, metal coiled tubing in accordance with ARP 584 is preferred.

* 3.11.16.1 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. Medium pressure tetrafluoroethylene hose assemblies shall conform to MIL-H-25579. These hose assemblies (using permanently attached fittings) may be used, with adequate space provided to permit replacement with spares made of MIL-H-27267 hose and MIL-F-27272 fittings. High pressure tetrafluoroethylene hose assemblies shall conform to MIL-H-38360. Adequate space shall also be provided to permit replacement with spares made of MIL-H-83298 hose and MIL-F-83296 fittings. Hose selections shall be made from MS33620.

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

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

3.11.16.4 Hose protection. Hose shall be suitably protected against chafing where necessary to preclude damage to the hose and to the adjoining structure, tubing, wiring, and other equipment. Hose assemblies (including end fittings) of amphibious aircraft which are subject to salt water immersion shall be covered with three coats of type II rubber conforming to MMM-A-1617. If type II is not available, type III may be used.

3.11.16.5 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, will not be detrimental to the installation either by causing strains on the end fittings or excessive binding or chafing of the hose.

3.11.17 Lock valves. Use of lock valves to hydraulically lock actuating cylinders shall require approval of the procuring activity. 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.

3.11.18 Motors. All constant-displacement motors shall be in accordance with MIL-M-7997. All motors shall be accessible for maintenance and inspection and shall be located in an appropriately cool or warm space depending upon their service. Proper case overflow connections to the reservoir shall be provided. Shaft seal drains shall be vented overboard.

3.11.19 Power pumps, variable-delivery and fixed-displacement. Variable-delivery pumps shall be in accordance with MIL-P-19692. For variable-delivery pumps, the pressure differential between the pump-case cooling port and the reservoir shall be such as to permit the pump to maintain adequate cooling flow in any pump flow condition. Fixed-displacement pumps shall be in accordance with MIL-P-7858.

3.11.19.1 Electric-motor-driven pumps. Electric-motor-driven hydraulic pumps in accordance with MIL-P-5954 or MIL-P-5994 may be used, as necessary, for either normal, emergency, or auxiliary operation of hydraulic systems.

3.11.20 Pressure regulators (unloading valves). Pressure regulators, or unloading valves in accordance with MIL-V-5519 (type I systems only), are normally used in conjunction with an engine-driven, fixed-displacement-type pump and an accumulator. Since this type of power circuit is considered inferior to the variable-displacement-type pump, specific written approval of the procuring activity must be obtained prior to use thereof. When an unloading valve is used, the return line to the reservoir shall be as short as possible and shall not be subjected to back pressure or pressure surges in excess of allowable values stated herein without specific approval of the procuring activity. The unloading valve shall have the drain port piped directly to the reservoir or routed to some return line in which the maximum pressure does not exceed the reservoir pressurization and is not subjected to pressure surges. The tubing connecting the unloading valve shall be so designed and installed that the pressure surges in the system will not affect the operation of the unloading valve at any flow rate of the system. In addition, provisions shall be made in the system to eliminate any harmful shocks caused by pressure surges due to the operation of the unloading valve.

3.11.21 Relief valves, system and thermal expansion. Relief valves shall conform to MIL-V-8813. With specific approval of the procuring activity, relief valves may be incorporated as part of another unit, provided they comply with applicable relief valve requirements. Relief valves are designed to be used as a safety device to prevent bursting of, or damage to, the system in the event the normal pressure regulation device in the system malfunctions; or, in a blocked line condition, to relieve excessive pressure due to either thermal expansion of the fluid or overload forces on actuating units. Therefore, relief valves shall not be used as the sole means of limiting pressure in a power circuit but shall function only as a safety valve.

* 3.11.21.1 System relief valves. Provisions shall be made to insure that pressure in any part of the power system will not exceed a safe limit above the cutout pressure of the hydraulic system. Pressure relief valves, as specified herein, shall be located in the hydraulic system wherever necessary to accomplish this pressure relief (see table I). The system relief valve shall have a capacity equal to or greater than the combined rate of flow of pumps where fixed-displacement pumps with common cutout regulators are used, or equal to or greater than the rated flow of the largest pump when variable-volume pumps with a common pressure line are used. The systems shall be designed so that excessive temperature (over 71°C (160°F) for type I; over 135°C (275°F) for type II) does not occur due to fluid flowing through a relief valve. As an alternative, a temperature warning and indication system may be used if approved by the procuring activity.

3.11.21.2 Thermal expansion relief valves. Relief valves shall be installed as necessary to prevent excessive pressure rise and system damage resulting from thermal expansion of hydraulic fluid. Internal valve leakage shall not be considered an acceptable method of providing thermal relief. (For relief valve setting, see table I.)

3.11.22 Reservoirs. Hydraulic reservoirs shall be in accordance with MIL-R-5520 or MIL-R-8931, as applicable. When a hydraulic emergency system is used in any military aircraft except trainer types, a separate emergency reservoir shall be provided. The emergency reservoir shall be located as remote as practicable from the main reservoir to minimize gunfire damage. It shall be possible to fill the main and emergency reservoirs through a common filler port, unless the two reservoirs are so far distant as to make this requirement impracticable. The feed and vent lines in the two reservoirs shall be so located that rupture of either of the reservoirs or the feedlines will not cause loss of sufficient fluid from the other reservoir to impair the system operation. Reservoirs shall be suitably protected (i.e., return line relief valve) to prevent failure or damage when rapid discharge of the main or emergency system into the reservoirs is encountered. Installations of pressurized reservoirs shall include a suitable depressurization valve for maintenance purposes.

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

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

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

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

d. Protection from combat damage

e. If practicable, suction lines 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, or where the reservoir cannot be located above the pump, suitable provisions shall be installed to maintain the fluid column to the pump after engine shutdown. A swing type check valve in the suction port of the reservoir should normally maintain the fluid column to the pump.

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

3.11.22.2 Reservoir venting. If a vent is provided in the reservoir, it shall be so arranged that loss of fluid will not occur through the vent during flight maneuvers or ground operations of the aircraft. A filter in accordance with AN6240 shall be incorporated into the vent line if the temperature requirement is suitable. If a filler cap is used, the act of removing the filler cap shall automatically vent the reservoir in such manner that the energy contained in the pressurizing air is not dissipated by imparting kinetic energy to either the filler cap or the fluid contained in the reservoir or elsewhere in the system.

3.11.22.3 Gas-pressurized reservoirs. The air (or inert 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 air pressure regulator and relief valve are combined into one housing, a single failure in that unit shall not permit overpressurization of the reservoir. Devices, such as aspirators, that introduce air into the hydraulic fluid shall not be used. When the air is separated from the fluid by a piston or other device, operation of the system shall not introduce air into the hydraulic fluid. Provision shall be made to remove entrained air which may have entered the system during servicing or operation.

3.11.22.4 Reservoir air pressurization moisture removal equipment. When engine bleed air is used for reservoir pressurization, a suitable moisture removal unit shall be so located as to protect the pressure regulation lines and equipment. An adequate filter shall be provided.

3.11.22.5 Reservoir fluid level indication. Reservoir fluid level indication shall be provided in the cockpit. Indicator fluid level markings shall correspond with the direct-reading fluid level indicator markings provided on the reservoir and shall be lighted in accordance with applicable cockpit lighting requirements. A suitable warning light shall also be provided to advise 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.

3.11.23 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. For one-way restrictors, the direction of restricted and unrestricted flow shall be indicated on the restrictor valves and adjacent structure. (For orifice filtration requirements, see 3.10.2.)

3.11.24 Self-sealing couplings. Hydraulic systems shall be provided with self-sealing couplings for each engine-driven pump and so located that the powerplant section can be readily removed for servicing. A suitable coupling shall be used in each line going to each pump. Self-sealing couplings shall also be provided on all hydraulically operated brake installations where it is necessary to disconnect the brake line in order to remove the wheel. The self-sealing coupling 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. Sufficient clearance shall be provided around the coupling to permit connection and disconnection. Self-sealing couplings installed adjacent to each other shall be of different size or be otherwise designed that inadvertent cross connection of the lines cannot occur. Couplings shall conform to MIL-C-25427.

3.11.24.1 Airframe break points. When self-sealing couplings are provided at airframe break points, especially in flight-control systems, and where disconnection of such a coupling or couplings will adversely affect the operation of any of the systems, adequate means shall be provided to prevent the inadvertent disconnection of the couplings. Such means shall also provide adequate 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.

3.11.25 Shuttle valves. Shuttle valves shall conform to MIL-V-5530 for type I and MIL-V-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 component parts of applicable AN- or MS-approved shuttle valves in a suitable cartridge, unless specifically approved otherwise by the procuring activity. Where the above installation cannot be made, a standard shuttle valve may be located at the actuator port. In the event neither of the above installations is possible, a length of rigid line is permissible between the cylinder port and the shuttle valve, provided that the rigid line and shuttle valve are firmly attached to the actuating cylinder. Flexible hose shall not be used between the actuating cylinder port and the shuttle valve.

* 3.11.26 Pressure switches. Pressure switches may be installed in hydraulic systems where the regulation of hydraulic pressure is required by controlling an electric-motor-driven pump or other applications approved by the procuring activity. Adequate precautions shall be taken to prevent chatter or cutoff. Pressure switches shall conform to the applicable requirements of MIL-S-9395.

3.11.27 Swivel joints. Swivel joints shall be designed in accordance with MIL-J-5513. Life test data shall be submitted to the procuring activity for approval. Where lines or fittings are used to drive swivel joints, they shall be adequately supported and shall be of sufficient strength to insure a satisfactory operating installation.

3.11.28 Tubing

* 3.11.28.1 Tubing materials. Tubing shall be either corrosion-resistant steel conforming to MIL-T-6845 or MIL-T-8504 or class T6 aluminum alloy conforming to MIL-T-7081. Higher strength-to-weight ratio steel or titanium tubing may be used with the approval of the procuring activity. Tubing mounted on shock struts shall be corrosion-resistant steel. For Navy aircraft, aluminum alloy tubing shall not be used in any pressure or actuating circuit lines. The minimum wall thickness in any alloy or tube size shall be not less than .020 inch.

3.11.28.2 Tubing bends. Bends shall be uniform and shall be in accordance with MS33611.

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

3.11.28.4 Designed motion in tubing. Looped or straight aluminum-alloy tubing shall not be used between two connections where there is designed relative motion. Coiled tube and torsion tube installations shall be designed and installed in accordance with the data given in ARP 584.

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

* 3.11.28.6 Tubing in fire hazard areas. Aluminum tubing shall not be used within powerplant compartments and at other locations where fires are likely to occur. Where separable tube fittings are required, they shall be corrosion-resistant or carbon steel.

3.11.28.7 Tubing and fitting identification. All hydraulic fluid lines shall be permanently marked in accordance with MIL-STD-1247. A sufficient number of hydraulic lines shall be marked in conspicuous locations throughout the aircraft in order that each run of 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) as to system function, using the same terminology as on its connecting line.

3.11.28.8 Tubing supports. All hydraulic tubing shall be supported from rigid structure by MS21105 (MIL-C-8956, type III, class B) cushioned steel clamps or by suitable multiple-tube block-type clamps. Supports shall be placed as near as practicable to bends to minimize overhang of the tube. Recommended spacings between supports are specified in table II, except that where tubes support fittings such as unions and tees, spacings should be reduced approximately 20 percent. Where tubes of different diameters are connected together, an average spacing distance may be used. In any event, the installation shall be in compliance with 3.11.29.6 and 3.11.29.7. Provisions shall be made in support locations to accommodate change in tubing length caused by expansion and contraction. In order to facilitate inspection and repair, tubing shall not be bundled together.

TABLE II. Hydraulic Line Support Spacings

Nominal Tube OD (inches)	Maximum Length Between Support Centers (measured along tube)	
	Aluminum alloy (inches)	Steel (inches)
1/8	9-1/2	11-1/2
3/16	12	14
1/4	13-1/2	16
5/16	15	18
3/8	16-1/2	20
1/2	19	23
5/8	22	25-1/2
3/4	24	27-1/2
1	26-1/2	30
1-1/4	28-1/2	31-1/2
1-1/2	29-1/2	32-1/2

3.11.28.9 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 below the aforementioned to prevent fire from line leakage. Hydraulic lines shall not be grouped with lines carrying other flammable fluids in order to prevent inadvertent cross connection of different systems. Hydraulic drain and vent lines shall exhaust in areas where the fluid will not be blown into the aircraft, collect in pools in the structure, or be blown onto or near exhaust stacks, manifolds, or other sources of heat. Tubing shall be located so that damage will not occur due to being stepped on, used as handholds, or by manipulation of tools during maintenance. Components and lines shall be so located that easy accessibility for inspection, adjustment, and repair is possible. Hydraulic tubing shall not be used to provide support of other aircraft installations, such as wiring, other aircraft tubing, or similar installations. Attachment of so-called marriage clamps for spacing of such installations is likewise prohibited.

3.11.28.10 Tubing flares and assembly. Tubing flares shall conform to MS33583 or MS33584. When installing tube connections, care should be exercised to keep the wrench torque used to assemble each joint within the limits specified on MS21344. Male threaded aluminum-alloy flared fittings shall not be used with stainless-steel lines below size -8.

* 3.11.28.11 Tubing pre-stress. Each titanium tube assembly shall be pre-stressed by the application of pressure to approximately 5 percent of the minimum yield strength. This test may be performed on the bench or in the aircraft.

3.11.29 Design of system installations

3.11.29.1 Component lines. Two or more lines attached to a hydraulic component shall be sufficiently different to prevent incorrect connection to the component.

3.11.29.2 Drain lines. Drain or 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 manner as to permit mixture of the fluids at any of the components being drained or vented.

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

3.11.29.4 Bonding. The aircraft hydraulic system components and lines shall be bonded to the aircraft in accordance with MIL-B-5087.

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

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

3.11.29.7 Corrosion protection. All tubing in exposed areas, such as wheel wells, weapons bays, and cove areas, shall be adequately protected against corrosion, particularly under the sleeve at the fittings, in accordance with MIL-F-7179 or procedures approved by the procuring activity.

3.11.29.8 Suction line to power-driven pumps

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

3.12 Workmanship. Workmanship shall be high grade throughout to insure proper operation and service life.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Inspection. The hydraulic system installation of one of the first complete experimental and production aircraft shall be subject to inspection for conformance to the requirements of this specification by engineering representatives of the procuring activity. It is expected that this inspection will be performed at the contractor's plant concurrently with similar engineering inspections of other systems of the aircraft. Detailed arrangements for the inspection will be the subject of correspondence between the procuring activity and the contractor.

4.2.1 Vibration. The hydraulic system of the first flight aircraft shall be tested prior to first flight to determine if any destructive vibration occurs as the result of any and all combinations of engine and hydraulic pump speed, and hydraulic pump flows and pressures. Hydraulic lines, hoses and their supports, fittings, and all components shall be checked. Corrective action shall be taken on any discrepancies.

4.2.2 Ground and flight tests. Ground and flight tests shall be conducted in accordance with MIL-T-5522.

4.3 Cleaning of parts and systems. To assure that the hydraulic system is free of contamination, all parts of the hydraulic system shall be thoroughly cleaned prior to installation, and each new hydraulic system shall be operated at least 10 times in order to insure filtration of all circulating fluid. Ground equipment which is used for this cleaning process shall be provided with filters with the same, or finer degree, of filtration used in the aircraft system. Dead-end lines in the system shall be properly connected with jumpers to completely clean such lines. If the filter element in the hydraulic system is used during this operation, it shall be replaced.

* 4.3.1 System contamination level for production aircraft. For Navy aircraft only, a minimum of two contamination tests (see requirements 3.11.9.1) shall be performed on each major system, separated by a minimum of 2 flight hours and a determination made that a stable or decreasing particulate level has been achieved.

5. PREPARATION FOR DELIVERY

This section is not applicable to this specification.

6. NOTES

6.1 Intended use. The design and installation requirements covered by this specification are intended for use in aircraft hydraulic systems, such as the utility system, the flight-control system, various subsystems, and component installation procedures for types I and II aircraft hydraulic systems.

6.1.1 Type III -54° to +232°C (-65° to +450°F) systems are covered by MIL-H-8891.

6.2 Typical submittal data. To obtain approval of the hydraulic system, applicable data in the following subparagraphs should be included in compliance with 3.5.

6.2.1 Hydraulic system analysis and design study. The data listed in this paragraph should be submitted for evaluation of design studies of a proposed new aircraft during the preliminary design and definition phases of a research, experimental, or prototype aircraft. The contractor should submit a report covering such design studies and analysis as are required to establish the design parameters of the hydraulic system of the proposed aircraft. The design analysis should show that the hydraulic system fulfills the needs imposed by the weapon system requirements. This report should include the following information and data:

a. Hydraulic system schematic or block diagram

b. Pressure and flow rates versus time for each mission profile along with the load analysis

* c. A thermal analysis with temperature versus time curves for fluid temperature for typical missions and for ground operations. This analysis shall include the highest and lowest temperatures expected to flight including the maximum temperatures due to single failures such as worn pumps, relief valve bypass etc.

d. Nonflammable (or less flammable) hydraulic fluids should be considered in the interest of reducing the potential fire hazard in a combat environment. The fluid selection should be based on a trade study to insure that specific improvements in safety and survivability are realized without excessive penalty in hydraulic system performance, operational capability, or cost of the aircraft. The trade study should consider reliability and all logistic aspects over the expected life of the aircraft including supply and maintenance as well as impact on support and service equipment on the flight line, in repair shops, and overhaul facilities.

e. Analyses or trade studies should include the following:

(1) Optimum approach to permanent tube joining

(2) Optimum separable tube fitting design

(3) Whether tubing materials having a strength-to-weight ratio higher than that of MIL-T-6845 can be used successfully, consistent with (1) and (2) alone, and be available within the time constraints of the program schedule.

6.2.2 Developmental and preproduction data. The following data should be submitted during the development phase of the hydraulic system and should be suitable for use as production procurement data:

a. Hydraulic systems schematic diagram in accordance with 6.2.3.2 should be submitted for approval.

b. Hydraulic system design report in accordance with 6.2.4 should be submitted for approval.

c. Hydraulic system ground and flight test report in accordance with MIL-T-5522 should be submitted for approval.

d. Detail specifications and test reports for the following components should be submitted for technical review and approval:

(1) Pumps and motors

(2) Flight-control actuators and servos

(3) Valves and switches (Army)

(4) Flexible connectors including hoses (if nonstandard)

(5) Packings and packing installations (if nonstandard)

(6) Fluids (if nonstandard)

(7) Fittings (if nonstandard)

NOTE: Other components that may require surveillance, in view of the criticalness of the particular item to the proper functioning of the weapon system, may be specified after the hydraulic system schematic diagrams have been reviewed. The list of surveillance items will be established during the service-contractor conference (see 3.5.1).

e. Cross-sectional assembly drawings, in accordance with 6.2.5, of all nonstandard hydraulic components should be submitted for information.

f. Analysis of failures and malfunctions affecting performance and safety should be submitted.

6.2.2.1 The following procedure should be adapted by the contractor for components not listed under 6.2.2(d):

a. The contractor should certify, upon completion of validating tests, that the hydraulic component conforms to the applicable military or contractor-prepared specifications approved by the procuring activity and is satisfactory for use in the particular aircraft weapon system hydraulic system.

b. The test reports, as well as the specifications and other applicable engineering data covering the hydraulic system components, other than those specified in 6.2.2(d), should be retained by the contractor and should be available to the procuring activity upon request, with the exception that all the cross-sectional assembly drawings should be submitted for information.

c. The contractor should list in a status of equipment list those components that are contractor certified for data availability and compliance with the applicable Government-approved specifications.

6.2.3 Production data. Where changes have been made in the hydraulic system over the developmental hydraulic system, the developmental data required in 6.2.2 should be submitted.

6.2.3.1 Functional test specification. A specification incorporating the necessary functional tests of the hydraulic system of production aircraft should be submitted to the procuring activity for approval.

6.2.3.2 Schematic diagram. The schematic diagram should consist of one copy of the conventional size and one copy approximately 11 inches in height. The arrangement of the schematic diagram should be such as to present the system in a clear and easily readable form, with complete subsystems grouped and labeled accordingly. Emphasis should be placed on simplicity and clarity of presentation, with location in the aircraft being of secondary importance. Nomenclature of each unit should be made adjacent to or in the vicinity of each unit. In addition, the schematic diagram should contain the following information:

a. Operating pressure of all systems and subsystems

b. All relief valve reseat and full flow pressures

c. Initial gas pressure of accumulators and their normal capacities

d. Pressure range of pressure regulators

e. Diameter, wall thickness, and material of tubing

f. Total and reserve fluid capacities of reservoir, or reservoirs, and the system; reservoir pressure; and method of pressurization

g. Displacement of fluid in cubic inches of each actuating cylinder for both extension and retraction

h. Actuating cylinder pistonhead diameter, rod diameter, effective piston area, and total and working stroke of each cylinder.

i. Displacement per revolution and number of required revolutions of hydraulic motors for each half-cycle of operation and the torque load required for each unit

j. Type of power-driven pump and displacement, including flow rate curve showing engine and pump rpm, for all phases of flight such as takeoff, climb, cruise, and landing

k. Indicated fluid flow direction through all hydraulic lines

l. Reservoir pressurizing system source, operating pressure, and schematic diagram of plumbing

m. Simple schematic diagram of linkage showing mechanical disconnects, downlocks, and uplocks, and other data to tie the mechanical system to the hydraulic system for analysis

n. A simple schematic wiring diagram of the electrical portion of the hydraulic system giving current loads and describing functions. (This diagram and data may be on a separate drawing.)

o. Name and part number of all units. Standard part numbers should be indicated where applicable. Nonstandard units should also include name of manufacturer and the manufacturer's part number.

p. Connections for testing with auxiliary or ground test power system should be indicated.

*q. Tubing and hose lines should be identified in accordance with AS 1290.

*r. Hydraulic components should be shown in simple schematic form. Multiple position units, such as selector valves, should clearly indicate internal fluid porting. Flow path of selector valves should be shown for each position of the valves. Hydraulic components should be shown in accordance with AS 1290.

s. Maximum and normal system temperature (estimated). In estimating maximum and normal system temperatures, the following conditions should be specified:

(1) Location of temperature

(2) Altitude

(3) Ambient temperature

(4) Compartment temperature

(5) Engine power setting

(6) Time duration of flight and time duration limitations for ground operation at maximum system temperature

t. Pressure and temperature pickup locations to be installed for instrumentation purposes in accordance with MIL-T-5522 should be indicated on the copies of the schematic diagrams submitted to the procuring activity.

u. Hydraulic system block diagram. (This may be a separate sheet of the schematic diagram.)

6.2.4 <u>Hydraulic system design report.</u> The hydraulic system design report should be submitted prior to or with the final schematic diagram. The report should incorporate sufficient design calculations and data to verify that the hydraulic system design complies with all design requirements. A hydraulic system temperature survey (minimum through maximum) should be included considering the location of the hydraulic system in the aircraft. The time of flight at maximum system temperature and conditions under which this temperature occurs should be included. Compartment temperatures should be estimated. For primary flight-control systems, peak and average flow rates and the power spectrum should be indicated. Duration of peak flow rates should also be indicated. The minimum temperature at which full performance occurs should be determined by the contractor and submitted for approval.

6.2.5 Hydraulic system nonstandard component cross-sectional assembly drawings. The cross-sectional assembly drawings for each nonstandard hydraulic component should contain sufficient information in order that an evaluation of the unit can be made. Such information should include the applicable specification, the material protective finish of each part, and bearing data. This information may appear as a written addition to the drawing. Reason for the use of a non-standard component, where a standard exists, should be submitted with the component drawing.

6.2.6 Functional mockup design report and test program. A report describing the general design of the functional mockup and the anticipated test program should be submitted to the procuring activity for approval not later than 30 days prior to beginning construction of the mockup, in order that any modification of the mockup or revision of the test program recommended by the procuring activity may be included.

6.2.7 Vibration test plan. A test plan for the vibration test in 4.2.1 should be submitted to the procuring activity for approval not later than 30 days prior to start of the test.

6.3 Marginal indicia. The outside margins of this specification are marked with an asterisk to indicate where changes (additions, modifications, corrections, deletions) from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the last previous issue.

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Navy - AS
Air Force - 11

Review activity:
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User activity:
Army - MI

Preparing activity:
Air Force - 11

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ALPHABETICAL INDEX

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c. Reason/Rationale for Recommendation:

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