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SUPERSEDING
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MILITARY SPECIFICATION

HYDRAULIC SYSTEMS, MANNED FLIGHT VEHICLES, TYPE III DESIGN, INSTALLATION & DATA REQUIREMENTS FOR, GENERAL SPECIFICATION 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 Type III manned flight vehicle hydraulic systems.

1.2 Classification - Type III flight vehicle hydraulic systems for temperature range from -65° + 39°F (see 3.3) shall be of the following classes, as specified:

Class 3,000 pound per square inch (psi) - Where the cutout pressure at the main pressure controlling device is 3,000 psi.

Class 4,000 psi - Where the cutout pressure at the main pressure controlling device is 4,000 psi.

2. APPLICABLE DOCUMENTS

* 2.1 Issues of Documents - 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

Military

MIL-B-5087	Bonding, Electrical, and Lighting Protection for Aerospace Systems
MIL-W-5088	Wiring, Aircraft, Installation of
MIL-H-5440	Hydraulic Systems, Aircraft, Types I and II, Design, Installation and Data Requirements for

* Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Engineering Specifications and Standards Department (Code 93) Naval Air Engineering Center, Lakehurst, N.J. 08733, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 1650

Military (Continued)

	MIL-T-5522	Test Requirements & Methods for Aircraft Hydraulic and Emergency Pneumatic Systems
	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-T-6845	Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic System, 1/8 Hard Condition
	MIL-F-7179	Finishes and Coatings: Protection of Aerospace Weapons Systems, Structures and parts; General Specification for
*	MIL-M-7997	Motors, Aircraft Hydraulic, Constant Displacement
	MIL-G-8348	Gage Assemblies, Air Pressure, Dial Indicating Chuck Type, Self-Contained (Asg)
	MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft
	MIL-T-8504	Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, seamless and Welded
	MIL-B-8584	Brake Systems, Wheel, Aircraft, Design Of
	MIL-D-8706	Data and Tests, Engineering: Contract Requirements for Aircraft Weapon Systems
	MIL-F-8785	Flying Qualities of Piloted Airplane's
	MIL-F-8815	Filter and Filter Elements, Fluid pressure, Hydraulic Line, 15 Micron Absolute and 5 Micron Absolute, Type II & III Systems
	MIL-H-8890	Hydraulic Components, Type III, (-65° to + 450°F), General Specification for (Asg)
	MIL-R-8931	Reservoirs: Aircraft and Missile, Hydraulic, Separated Type
	MIL-F-9490	Flight Control Systems - Design, Installation and Test Of, Piloted Aircraft, General Specification for
	MIL-F-18372	Flight Control Systems: Design, Installation and Test of, Aircraft (General Specification for)
	MIL-P-19692	Pump, Hydraulic, Variable Delivery, General Specification for
	MIL-V-25675	Valves, Check, Miniature, Hydraulic, Aircraft and Missile
*	MIL-V-81940	Valve, Sampling and Bleed, Hydraulic, Type II Systems
	MIL-F-83300	Flying Qualities of Piloted V/STOL Aircraft
*	MIL-C-85052	Clamp, Loop, Cushion, General Specification for

STANDARDS

Federal

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

Military

MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-1247	Markings, Functions, and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missile, and Space Systems
MS21344	Fittings - Installation of Flared Tube, Straight Threaded Connectors, Design Standard for
MS33583	Tubing End - Double Flare, Standard Dimensions for
MS33584	Tubing End - Standard Dimensions for Flared
MS33611	Tube Bend Radii (Asg)
MS33656	Fitting End, Standard Dimension for Flared Tube Connections and Gasket Seal
MS33657	Fitting End, Standard Dimension for Bulkhead Flared Tube Connections

Air Force-Navy Aeronautical

AN6240	Filter - Hydraulic Replaceable Element Vent Tube
AN929	Cap Assembly, Pressure Seal Flared Tube Fitting (Supersedes. AN920)

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

Air Force Systems Command Design Handbook

AFSC DH 2-2	Crew Stations and Passenger Accommodations

(When requesting applicable documents, refer to both title and number. Copies of unclassified documents may be obtained from the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120. Requests for copies of classified documents should be addressed to the Naval Publications and Forms Center, via the cognizant Government representative.)

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 Engineers, Inc., Aerospace Recommended Practices

ARP 243	Nomenclature, Aircraft Hydraulic and Pneumatic Systems
ARP 584	Coiled Tubing
* ARP 994	Recommended Practice for the Design of Tubing Installation for Aerospace Fluid Power System
AS 1290	Graphic Symbols for Aircraft Hydraulic and Pneumatic Systems
* AIR 1362	Physical Properties of Hydraulic Fluids

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

National Aerospace Standards Association, Inc., Standard

NAS 1638	Cleanliness Requirements of 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. DESIGN REQUIREMENTS

* 3.1 Configuration requirements - The hydraulic system and components thereof shall be designed to operate satisfactorily under all conditions that the vehicle may encounter within the structural limitations of the vehicle, including forces or conditions caused by accelerations deceleration, zero gravity (g) negative g, or any flight altitudes obtainable with the vehicle, 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).

3.1.1 Subsystem isolation - Two or more subsystems pressurized by a common pressure source, one of which is essential to flight operation and the other not essentials shall be so isolated that the system essential to flight operation will not be affected by any damage to the nonessential system.

3.1.2 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 vehicle. Other conferences shall take place during the appropriate development phases of the vehicle,

3.1.3 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 tubing and fittings, identical to those installed in the first flight vehicle. 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 vehicle 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 paragraph 3.1 shall be demonstrated, The functional mockup shall be used to determine the performance of the hydraulic system prior to the first flight of the vehicle and to evaluate any significant changes to be made to the system during production of the vehicle.

3.1.4 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.

3.2 Intrinsic requirements

3.2.1 Materials - Materials used in the manufacture of hydraulic systems 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.

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

3.2.3 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.

3.2.4 Nomenclature - The nomenclature used shall conform to SAE publication ARP 243.

3.2.5 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.

3.3 Fluids requirements - The fluids for all hydraulic systems and in the test stands used for ground testing of the hydraulic system shall be in accordance with MIL-H-8446.

* 3.3.1 Fluid handling - The hydraulic fluid shall be stored in containers which insure exclusion of moisture and oxygen. Transfer of fluid from the containers to the vehicle hydraulic system shall be accomplished by the use of ground equipment which will minimize the length of time that air and moisture is in contact with the fluid. All fluid introduced into the vehicle shall be filtered through a filter capable of removing particles in excess of 5 microns.

* 3.3.2 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 3.3.2.1, without exceeding the following fluid temperature limits in any portion of the system(s). The maximum hotspot temperatures shall be specified in the model specification. In addition, provisions shall be incorporated in the air vehicle to maintain the fluid temperature at levels below detrimental thermal breakdown of the fluid and below detrimental effect to other system components. The system shall be capable of full performance with the fluid at any temperature through the range of -20°F to + 390°F; the system performance at any temperature between -65°F and -20°F shall be adequate and in accordance with the subsystem and component specifications. The hydraulic systems shall operate satisfactorily within the range of ambient temperature specified in the detail specifications for the equipment. Operation at these low temperatures shall not result in any permanent degradation of system(s) or component performance.

3.3.2.1 Climatic extremes - Ground operation, flight operation and storage climatic extremes shall be in accordance with the weapon system procurement specification,

3.4 Power pumps and reservoirs - The power pumps may be either engine, mechanical transmission or electrically driven, The reservoirs may be of the separated or non-separated type and employ either gas or bootstrap type pressurization.

3.4.1 <u>Power pumps</u> - The hydraulic system pump(s) shall be compatible with the installed vehicle system and shall not cause abnormal or undesirable effects on the installed system in the vehicle. 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 on production aircraft. 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.

3.4.1.1 <u>Multiple pumps, engine-driven</u> - Multiple engine vehicle 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.

3.4.1.2 <u>Pumps, variable-delivery</u> - Variable-delivery pumps shall be in accordance with MIL-P-19692. For 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.

* 3.4.1.3 <u>Electric-motor-driven pumps</u> - 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.

3.4.1.4 <u>Emergency power pumps</u> - 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.

* 3.4.1.5 <u>Pump pulsation</u> - 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 vehicle 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 start up to the maximum speed, pressures and flows that the pump will be subjected to when installed in the vehicle, 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 vehicle, and any additional major corrections required shall be made prior to the first flight.

3.4.1.6 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.

3.4.1.7 Pump supply line - The fluid supply line from the reservoir to the pump or system of pumps shall be designed to permit full output capability of the pump or system of pumps without cavitation from a fluid temperature of -20°F. Capability of pump or system or pumps to start at -65°F fluid temperature and to provide adequate flow while warming up shall be provided. Test data and analysis shall be furnished for the approval of the procuring activity, showing that satisfactory service life of the pump or pumps will be indicated under all operating conditions of the vehicle. This information may be included in the system design report (see 6.2.4). (Ref. 3.4.2.4 Reservoir Pressurization)

* 3.4.1.8 Pump supply shutoff valves - Pump Supply (suction) shut-off valves shall be provided if the fire protection requirements of the particular model vehicle specify the need for such equipment in the hydraulic system. These valves, when required, shall not be located on the engine side of firewalls or flame-tight diaphrams 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.

* 3.4.2 Reservoirs - Hydraulic reservoirs shall be in accordance with MIL-R-8931 as applicable. Installation of pressurized reservoirs shall include a suitable repressurization valve for maintenance purposes. Hydraulic reservoirs shall be of the type listed in paragraph 3.4.2.2.

* 3.4.2.1 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 altitudes of the vehicle.

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

(c) Protection from combat damage,

(d) If practicicable, 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.

(e) If routing of the pump case drain line cannot be accomplished so that breaking of the fluid column by gravity after engine shutdown is prevented, suitable provisions shall be installed to maintain the fluid column to the pump after engine shutdown.

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

(g) In aircraft with dual system, reservoir positions for the two reservoirs shall be sufficiently different so that malfunction caused by violent aircraft manuever, such as negative "g" conditions, shall prevent loss of both systems through pump cavitation or supply line loss.

3.4.2.2 Reservoir types

3.4.2.2.1 Nonseparated type - The reservoir shall incorporate an expansion space pressurized with an inert gas excluding any fluid in contact with air. All vent. or relief, and repressurizing lines shall employ check valves or other suitable means to permit flow from the reservoir and prevent introduction of atmospheric air into the reservoir.

3.4.2.2.2 Separated type - The reservoir pressurization shall be effected by any suitable method with the exception of a gas in contact with the fluid. Normal operation of the system shall not introduce gas into the hydraulic fluid, and provisions shall be made to entrap entrained gas which may have entered the system and prevent its circulation. Provisions shall be made for the removal of this trapped gas.

3.4.2.3 Emergency reservoir - When a hydraulic emergency system is used in any military vehicle 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.

* 3.4.2.4 Reservoir pressurization - Reservoir pressurization requirements are derived from either the Steady State or the Transient Response condition. Both methods shall be calculated and the larger of the two shall be utilized. The steady state calculation utilizes the pressure drop in the suction line and all components in the suction line plus the pump inlet requirements. The transient response is considered to be the amount of pressure required to accelerate the column of fluid in the suction line between the reservoir and the pump inlet as required by changes in system flow demands. These calculations shall be in accordance with the formula outlined below:

$$P = \frac{WLV.}{g\ t\ (144)}$$

Where: P = Reservoir pressure (psi)
W = Specific weight of the fluid (lb/ft^3)
L = Length of the suction line in (ft)
V = Fluid velocity in (feet per second) in suction line
g = Acceleration due to gravity (32.2 ft/sec-see)
t = Pump response in time (see)

3.4.2.5 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 vehicle. 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 a 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.

3.4.2.6 Gas-pressurized reservoirs - The gas pressure shall be controlled by an externally nonadjustable pressure-regulating device to control the gas pressure in the reservoir. A relief valve shall also be connected to the gas space to protect the reservoir and pump from excessive pressure. If the pressure regulator and relief valve are combined into one housing, a single failure in that unit shall not permit overpressurization of the reservoir. Devices that introduce air into the hydraulic fluid shall not be used. When the gas is separate from the fluid by a piston or other device, operation of the system shall not introduce gas into the hydraulic fluid . Provision shall be made to remove entrained gas which may have entered the system during servicing or operation.

3.4.2.7 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.

3.4.2.8 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.

* 3.4.2.9 Reservoir bootstrap pressurization - Reservoir pressurization shall be maintained in the event normal system pressure (reservoir bootstrap pressure) is lost due to an air-lock. Maintaining reservoir pressurization will minimize pump pressure recovery time.

3.5 General system design requirements - Hydraulic systems shall be as simple and foolproof as possible and in accordance with design, operation, inspection, and maintenance objectives specified in the vehicle design requirements,

3.5.1 Strength -

3.5.1.1 Additional loads - All hydraulic systems and components which are subjected, during operation of the vehicle, 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.

3.5.1.2 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.

3.5.2 Pressure limitations -

3.5.2.1 System pressures - System pressure 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 operating pressure when measured with electronic equipment, or equivalent. Lines, fittings, and equipment in return circuits shall be designed for one-half the nominal system operating pressure.

3.5.2.2 Proof and burst - The systems individual components shall be designed to withstand the proof and burst pressure requirements of Table I throughout the ambient and fluid temperature range after loss of strength of materials caused by aging at elevated temperatures for the life of the systems or component.

3.5.2.3 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.

* 3.5.2.3.1 Brakes - Back pressure resulting from the operation of any unit while the vehicle 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 vehicle during taxiing, landing, or takeoff.

* TABLE I. SYSTEM PRESSURES, PSI

CHARACTERISTICS	NOMINAL OPERATING PRESSURE 3,000	NOMINAL OPERATING PRESSURE 4,000	PERCENT OPERATING PRESSURE	REMARKS
Closed-Center Type System (Variable Volume Pump)				
(a) Pump unloading pressure	3,000	4,000		
(b) Max. limit full flow sys. press.	2,950	3,950		
(c) Max. system relief valve setting at maximum system flow	3,850	4,850		
Thermal Relief Valve Setting (Maximum)				
(a) Equal to system relief valve max. setting plus values noted	150	150		
Proof Pressure				
(a) Lines & fittings press. circuits	6,000	8,000	200	
(b) Hoses				Proof press. values for hose to be in accord. with applicable detail spec.
(c) Components containing air and fluid under pressure	6,000	8,000	200	
(d) Pump suction, case drain line components and reservoir				
1) Non-pressurized reservoirs	50	50		
2) Bootstrap reservoirs				150% of res. oper. press.
3) Gas pressurized reservoirs				200% of res. oper. press.
(e) Components normally under system fluid pressure only	4,500	6,000	150	
(f) Collapse pressure of parts subject to suction pressure	50 External	50 External		Except reservoir and pump seal chambers
(g) Return circuits (lines, fittings, and components)	3,000	4,000	200	Except hose, which shall be 125% of actual max.press.
Burst Pressure (Minimum)				
(a) Lines and fittings	12,000	16,000	400	
(b) Hoses				Hose burst press. to be in accordance with applicable detail spec.
(c) Components containing air and fluid under pressure	12,000	16,000	400	
(d) Pump suction, case drain line components and reservoir				
1) Non-pressurized reservoir	100	100		
2) Bootstrap reservoir				300% of res. oper. press.
3) Gas pressurized				400% of res. oper. press.
(e) Components normally under fluid pressure only	7,500	10,000	250	
(f) Components in return circuits (lines, fittings, & components)	6,000	8,000	200	Except hoses which shall be 250% of nominal sys. press.
Collapse pressure of parts subject to suction pressures	50 External	50 External		

*

* 3.5.4 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 vehicle 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 vehicle or use of a second ground test stand connected to another hydraulic system in the vehicle. (For filtration requirements, see 3.10.8) 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 inert gas charging.

Note: Single system operation, in multi-system aircraft, and vigorous cycling of the control surfaces, can cause air to form in the other non-pressurized, or non-operating, system(s). Ground support equipment shall be configured to prevent air formation in the non-pressurized system(s) that can cause erratic or damaging system operation.

k 3.5.4.1 Ground test connections - A separate set of self-sealing coupling consisting of bulkhead halves and protective caps shall be provided at a convenient location in the vehicle, 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. 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.

Note: No existing connections specified at this time. The procuring activity shall specify the type of coupling to be used.

* 3.5.4.1.1 Reservoir pressurization connection - Reservoirs which are normally pressurized by inert gas, a ground charging connection shall be provided and shall consist of a fitting end in accordance with MS33656-4 or MS33657-4 for attachment to a ground charging unit. A protective cap with safe automatic venting mechanism add a safety chain shall be provided to protect the end connection when not in use. The automatic-venting mechanism must prevent injury to servicing personnel.

* 3,5.4.1.2 Reservoir filling provisions - Servicing connection and necessary valving to accomplish pressure filling of reservoirs from a ground source shall be provided. To preclude air introduction, filling provisions shall be so designed that open fluid containers cannot be used. Fluid shall be filtered at the fluid source. Fluid level indication shall be provided. Reference MIL-R-8931 and MIL-H-8890. Filling instructions shall be provided immediately adjacent to the filling connections, The ground test connection may be used for this purpose. Where emergency filling provisions are incorporated the design filling procedure is subject to prior approval by the procuring activity.

3.5.4.2 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
Set ground test stand relief valve to _____ psi
Set ground test stand output to _____ gpm
Set ground test stand pressure compensator to _____ psi
Use hydraulic fluid conforming to MIL-H-8446
Ground test stand output filter shall be _____ microns absolute
(Any other precautions or information considered necessary.)

NOTE: The contractor shall fill in the above values.

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

3.5.5 Removal of entrapped air - Suitable means, such as bleeder valves, shall be provided for removal of entrapped air. 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 3.10.4).

3.5.5.1 System air tolerance - The system shall be designed and configured such that the presence of entrapped air that is not removed or scavenged per paragraph 3.5.5 shall not cause sustained loss of system pressure or degradation of system performance during all conditions of intended vehicle operation.

3.5.6 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 multipump systems, pressure-indicating equipment shall be provided for each pump to enable the flight crew to check for proper operation of each pump with shutdown of any engine. The pressure indicators shall be so located as to be readily visible by the flight crew.

3.5.6.1 System low-pressure warning light - In addition, but not as a substitute for the requirement of 3.5.8, 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 vehicles, 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 vehicle operation and maintenance manuals and provided such condition does not occur during flight unless a system malfunction exists.

3.5.6.2 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.

* 3.5.7 Temperature indicators - Temperature indicators shall be provided to alert the flight crew of impending system failure due to excessive fluid temperatures. These temperature indicators shall be so located as to be readable by the flight crew personnel. The sensor (pickup) in the system shall be approved by the procuring activity.

3.5.8 Fluid quantity indicators - Fluid quantity indicators shall be provided to indicate the fluid level in the hydraulic systems reservoirs. These indicators shall be so located as to be readable by the operating personnel.

3.5.9 Fluid sampling valves

* 3.5.9.1 Navy - A fluid sampling valve 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 tbe 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. Sampling valves shall be in general accordance with the requirements of MIL-V-81940, except that they shall be suitable for the temperature and pressure specified in the detail specification.

3.5.9.2 Army - Sampling valves shall be provided in hydraulic systems. These valves shall be located in each hydraulic system at points where the fluid contaminants can be most detrimental to the performance of the flight vehicle. The number of valves required for each system and their location shall be as agreed upon by the contractor and the procuring activity. Reference paragraph 3.1.2.

* 3.6 Utility system design requirements - All hydraulically operated services (excluding flight controls covered by 3,1) that are essential to the accomplishment of the basic vehicle mission (bomb-bay doors, in-flight refueling, gun drives, etc.} or essential to land and stop the vehicle (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 vehicle.

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

3.6.2 Application - The general requirements of 3.5 and subparagraphs thereto apply to the utility system.

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

3.7 Flight-control system design requirements - 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 objective, automatic bypass of the fluid in the dead system from one side of the actuator to the other side shall be provided.

3.7.1 Definitions - Primary flight controls include those control systems used to operate primary vehicle control surfaces such as ailerons, rudders, elevators, stabilizers, or combined function surfaces.

3.7.1.1 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.

3.7.1.2 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. A system of this type may have electrical or electronic pilot input modes.

3,7.1,3 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.

3,7.1.3.1 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 vehicle, 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 by means of a suitable valve. 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.

3.7.2 **Application** - The general requirements of 3.5 and subparagraphs thereto apply to the flight control system. For flight control operational state classifications refer to MIL-F-9490 and MIL-F-18372.

3.7.3 Hydraulic power failure - In vehicles where direct mechanical control sufficient to obtain vehicle 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,

3.7.3.1 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 vehicle. 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 vehicle has a single engine, the emergency power source shall be independent of the operation of this engine. on multiple-engine vehicles, 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 vehicles 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.

3.7.3.2 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.

3.7.4 System separation, survivability & clearance - 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, For additional flight control system details refer to MIL-F-9490 and MIL-F-18372.

3.7.5 Subsystem pressure - Subsystems 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.

3.7.6 Power sources - Vehicle 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 auto rotation.

3.7.7 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 pumps, failed valves and other heat generating failures. The effects of differential fluid temperature in tandem units shall also be demonstrated.

3.8 Emergency system design for utility system requirements

3.8.1 Types - Where emergency devices are required in hydraulic systems, the emergency systems shall be completely independent of the main system up to, but no 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, ges-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.

3.8.2 High-lift devices - Where safe operational landings cannot be accomplished without the use of hydraulically operated high-lift devices, they shall be powered by two independent hydraulic systems or be provided with a suitable emergency system.

3.8.3 Emergency-line venting - The emergency line from the shuttle valves shall be vented to the reservoir or to a low-pressure non-surging 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.

3.9 Component design requirements - All components used in the system shall conform to MIL-H-8890 and applicable detail specifications.

3.9.1 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. Where non-standard components are used envelope drawings and specifications shall be provided that are suitable for competitive procurement.

3.9.2 Orifices - Orifices larger than 0.012 inch but smaller than 0.070 inch in diameter shall be Protected by adjacent filter 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 filter elements shall be strong enough to withstand system design flow and pressure up to and including blocked flow without rupture or permanent deformation.

3*9.3 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 structural or fluid containment material for the actuation or control devices in Navy vehicles.

3.10 Component installation requirements

3.10.1 Installation design practice - 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. All components shall be installed in a manner to prevent their use as handies, steps, etc.

3.10.1.1 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.

* 3.10.1.2 Pilot's cockpit and compartment - No component containing hydraulic fluid shall be mounted in the pilot's cockpit or crew compartment without approval of the procuring activity.

3.10.2 Accumulators - If practicable, accumulators shall be installed in areas of controlled temperature environment. Consideration shall be given to installations which will provide protection for crew members, passengers and adjacent vehicle subsystems against accumulator rupture. Accumulators shall be charged with an inert gas only. Installation with the gas side down should be considered in order to permit easier checking for oil leakage past the piston and removal of oil or water from the gas side.

NOTE : Critical performance parameter is the temperature envelope of -65° to 390°F.

3.10.2.1 Measurement of accumulator gas Pressure - A permanent pressure gage shall be attached to the gas side of the accumulator. A gage indicating accumulator gas pressure shall never be used to indicate equivalent hydraulic pressure.

3.10,2.2 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.

3.10.2.3 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 for which the accumulator will be serviced.

3.10.2.4 Accumulator location - The accumulator in the vehicle shall not be located near a hot air duct or other similar component that may fail and result in the accumulator overheating.

3.10.3 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.

3.10.4 Bleeder valves - Bleeder valves shall be so located that they can be operated without necessitating removal of other vehicle components. Such installations shall permit attachment of a flexible hose so that fluid bled off may be directed into a container.

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

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

3.10.7 Directional control valves - The installation of directional control valves shall be compatible with the control valve performance such that the system operation 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.

3,10.7.1 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 75 pound-inches limit load 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.

3.10.7.2 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.

* 3.10.7.3 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. 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,

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

* 3.10.8 Filters - Line filters, when installed in the vehicle system in close proximity to an accumulator, shall be installed upstream of the accumulator. Pressure-drop indicators shall be 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 replacment. Sintered-type elements shall not be used. Filters shall not be installed between the system reservoir and the pump suction port unless specifically authorized by the procuring activity.

3.10.8.1 Navy vehicle filters - All filters installed in the hydraulic system(s) shall be in general accordance with the requirements of MIL-F-8815 (5 micron absolute type) except that each filter element and the filter assembly shall be suitable for the temperature and pressure specified in the detail specification, Filter elements shall be the disposable (throwaway), depthtype unit. These filters shall be used to filter all the the circulating fluid in the system. In all aircraft delivered, the system contamination level shall not exceed the particle size and range listed as class 8 of Table I of NAS 1638 as determined in accordance with method 3009 of FED-STD-791.

* 3.10,8.2 Air Force and Army vehicle filters - All filters installed in the hydraulic system(s) shall be in general accordance with the requirements of MIL-F-8815 (15 micron absolute type) except that each filter

element and the filter assembly shall be suitable for the pressure and temperature specified in the detail specification. 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.

3.10.8.3 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.

3.10.8.3.1 Pressure line installation - Anon-bypass-type filter(s) shall be installed in" the system pressure line and shall be so located that all fluid from the vehicle 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.

3.10.8.3.2 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 reservoir and/or pump suction line.

3.10.8.3.3 Reservoir fill line installation - A non-bypass-type line filter shall be installed to filter all fluid entering the system through the reservoir fill connection. The-absolute filtration rating shall be in agreement with paragraph 3.10.8.1 and 3.10.8.2 respectively.

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

3.10.8.4 Sequencing valves - Where hydraulic sequencing is critical, 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.

3.10.9 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 vehicle. In addition, suitable repair and replacement methods involving failed tubing and fittings shall be established for each vehicle model and shall be included in the applicable vehicle publications. Separable fittings (e.g., a screw thread design) shall be used on removable components where needed to facilitate maintenance and production. The tube fitting designs shall be selected primarily on the basis of high-reliability and light weight, and shall be qualified by a comprehensive test program. Consideration shall be given to selection of fittings and installation equipment of types which are already in the inventory of the using service. Suitable repair and replacement methods involving failed tubing and fittings shall be established. No thread lubricant other than hydraulic fluid specified in 3.3 shall be used on tube fittings, unless specifically authorized by the procuring activity.

3.10.9.1 Universal fittings - Universal fittings shall not be used in hydraulic systems unless written approval is obtained from the procuring activity.

3.10.10 F1ow dividers - Flow dividers shall not be used if the effect of a malfunction of the flow divider would result in an unsafe flight condition.

3.10.11 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.

* 3.10.12 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 during any flow or pressure variations or any conditions of system operation is a design requirement. The function and reliability of such devices shall be demonstrated in the functional mockup and simulator. (Ref. par. 3.1.3)

3.10.13 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.

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

3.10.14.1 Manually operated pump installation - The handle of the hand pump shall be so arranged that it will not be necessary for the pilot to lower or turn his head from the line of necessary flight vision to actuate the pump.

3.10.14.2 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 -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.

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

3.10.14.4 Hand pump handle length - The effective operating handle length of hand pumps shall be such that the handle load shall not exceed 75 pounds, The sweep envelope of this handle travel at the handgrip shall not exceed 18. radial inches.

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

* 3.10.15.1 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. If possible, additional installation space shall be provided to permit replacement with spares of slightly larger space envelope requirements.

* 3.10.15.2 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.

* 3.10.15.3 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 specifications

* 3.10.15.4 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 adequately protected.

* 3.10.15.5 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.

3.10,16 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.

3.10.17 Motors - All motors shall be accessible for maintenance and inspection, Proper case flow connections to the reservoir shall be provided. Installation of hydraulic motors shall be such that the motor housing shall not be subjected to overpressurization. Shaft seal drain shall be vented to prevent return of this fluid to the hydraulic systems.

3.10.18 Relief valves, system and thermal expansion -With specific approval of the procuring activity, relief valves may be incorporated as-part of another unit, Provided they comply with applicable relief 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.

3.10.18.1 System relief valves - Provisions shall be made to insure that pressures 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.

3.10.18.2 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.)

* 3.10.19 Restrictor valves - Adjustable orifice restrictor valves may be used in experimental vehicles but only fixed orifice restrictor valves shall be used in service test and production vehicles. For one-way restrictors, the direction of restricted and unrestricted flow shall be indicated on the restrictor valves. (For orifice filtration requirements, see 3.9.2)

3.10.20 Self-sealing couplings - Hydraulic systems shall be provided with self-sealing couplings for each engine or mechanical transmission driven pump and so located that the powerplant or mechanical transmission 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.

3.10.20.1 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. Means shall be provided to prevent damage to the system due to thermal expansion of the fluid if a pressure trap is created when self-sealing couplings are disconnected.

3,10.21 Shuttle valves - 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. Where the above installation cannot be made, a 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. When emergency line venting is required, see paragraph 3.8.3.

3.10.22 Pressure switches - Pressure switches may be installed in hydraulic systems where the regulation of hydraulic pressure is requited 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 be approved by the procuring activity.

3.10.23 Swivel joints - Swivel joints may be used where relative motion exists between two points (see 3.10.15). 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.

3.10.24 Vents - All vent openings or fluid exposed to breathing action through vents shall be protected by filters. For reservoir, reference paragraph 3.10.20.6.

3.11 Tubing -

3.11.1 Tubing materials - Tubing shall be either corrosion-resistant steel conforming to MIL-T-6845 or MIL-T-8504. 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. The minimum wall thickness in any alloy or tube size shall be not less than .020 inch.

3.11.2 Tube sizing - Tubing size is a function of several parameters. One of the more important parameters is pressure drop. Generally they should be sized to permit approximately 107. of system operating pressure drop in the total pressure transmission system, i.e., pump to actuator, and a 107. drop for the return system at the minimum rated fluid temperature, Unless otherwise specified the rated temperature is -20°F. This pressure drop analysis shall utilize the data listed in AIR 1362 "Physical Properties of Hydraulic Fluids". Another important parameter is fluid velocity which results in pressure surges and spikes and is discussed in paragraph 3.5.3 "Fluid velocity limitations". Additional parameters are located with respect to the: (1) pump pressure line, this high energy line is sensitive to resonance conditions developed from pump ripple, structural vibrations and engine vibrations, and (2) structural defections between connecting end points, and (3) specific local applications.

3.11.3 Tubing fabrication -

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

3.11.3.2 Tubing and fitting identification - All hydraulic oil lines shall be permanently marked in accordance with MIL-STD-1247. (For l pplications in systems where environmental temperatures do not pemit the use of markings in accordance with MIL-STD-1247, the contractor shall prepare an identification specification and submit it for approval to the procuring activity.) A sufficient number of hydraulic lines shall be marked in conspicuous locations throughout the vehicle 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", "Flaps down", etc. These markings shall be repeated as often as necessary, particularly on lines entering and emerging from closed compartments, to facilitate maintenance work. (The direction of flow shall be clearly indicated on the lines leading to and from each component requiring unidirectional flow, such as check valves. If the lines are not visible, a permanent marking on the structure immediately adjacent to the component shall be provided which indicates direction of flow through the component for proper installation.) Where fittings are located in members such as bulkheads and webs, each fitting location shall be identified (placard) as to system function, wing the same terminology as on its connecting line. (Especially conspicuous identification shall distinguish dual parallel systems piping where they are in close proximity to each other.)

* 3.11.3.3 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 or MS21344. Aluminum-alloy fittings shall not be used.

3.11.3.4 Tubing pre-stress (Autofrettage) . Each cold drawn, stress relieved titanium tube assembly shall be pre-stressed by the l pplication of pressure to within approximately 5% of the minimum yield strength. This process may be performed on the bench or in the aircraft. This process can also be applied to other tubing materials such as stainless steel and aluminum. The benefits to be derived from this process is improved fatigue life and ovality reduction.

* 3.11.4 Tubing installation - Tubing shall be installed in accordance with ARP 994.

3.11.4.1 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 fhammable 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 vehicle, 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.

3.11.4.2 Tubing connections - Where two or more lines are attached to a hydraulic component and incorrect connection of lines to the component is possible, the two lines shall be sufficiently different to prevent such an occurrence.

3.11,4.3 Tubing supports - All hydraulic tubing shall be supported from rigid structure by tube clamps in accordance with MIL-C-85052 clamps or by suitable multiple block-type clamps. Where temperatures make the MIL-C-85052 clamp unsatisfactory clamps suitable for the . temperature Involved shall be used as approved by the procuring activity. Supports shall be placed as near as practicable to bends to minimize overhand of the tube. Recommended spacings between supports are shown 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, installation shall be in accordance with 3.11.4.4 and 3.11.10. 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)	MAX. LENGTH BETWEEN SUPPORT CENTERS (MEASURED ALONG TUBE)(INCHES)
1/8	11-1/2
3/16	14
1/4	16
5/16	18
3/8	20
1/2	23
5/8	25-1/2
3/4	27-1/2
1	30
1- 1/4	31-1/2
1- 1/2	32-1/2

* 3.11.4.4 Installation clearances - Where tubing is supported to structure or other rigid members, the clearances shall be in accordance with ARP 994.

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

3.11.4.6 Designed motion in tubing - Looped or straight tubing shall not be used between two connections where there is designed relative linear motion. Coiled tube and torsion-tube installations of corrosion-resistant steel tubing shall be designed and installed in accordance with the data given in ARP 584.

3.11.4.7 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 system in which such tubing is used will be possible at -65°F temperature.

3.11.5 Tubing in fire hazard areas - Within powerplant compartments and at other locations where fires are likely to occur, all hydraulic tubing shall be corrosion-resistant steel, unless the tubing is separated from the engine or potential fire area by a flametight barrier. Where separable tube fittings are required, they shall be corrosion-resistant or carbon steel.

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

3.11.7 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 in 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.

3.11.8 System protection from combat damage - Redundant systems shall be separated a minimum of 18 inches, preferably in a plane perpendicular to ground fire, or be protected to a degree specified by the procuring activity.

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

3.1l.10 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 vehicle.

3.11.11 Corrosion protection - All tubing in exposed areas, such as wheel wells, weapon 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.

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 vehicles 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 vehicle. 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 vehicle shall be test-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, modified as necessary, except that this specification shall be used where any reference to MIL-H-5440 is made therein.

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 vehicle 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.

5. PACKAGING

This section is not applicable to this specification.

6. NOTES

6.1 Intended use - The design and installation requirements covered by this specification are applicable to manned flight vehicle hydraulic systems such as the utility system, the flight control system, various subsystms, and component installation procedures for type III (-65° to +390°F) temperature range. The requirements of this specification are general as applicable to hydraulic systems and are based on Service experience to date. Requirements of this specification may be waived for specific applications upon presentation of substantiating data to the procuring activity, l s l pplicable, and approval by such l ctivity.

6.2 Submittal of data - To obtain approval of the hydraulic system, data submittal and approval requirements for a specific model vehicle will be covered by a contract with the appropriate procuring activity. 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). Applicable data in the following subparagraphs should be included in compliance with 3.1.4.

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 vehicle during the preliminary design and definition phases of a research, experimental or prototype vehicle. 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 vehicle. 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 fluid temperature versus time curves for fluid temperature (including hotspots) for typical missions.

(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 vehicle, The trade study should consider reliability and all logistic aspects over the expected life of the vehicle 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/or 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) If it is determined by the preliminary service-contractor conference (see 3.1.2) that MIL-H-8890 is not adequate for a specific vehicle, the contractor shall prepare and submit for approval a general specification for components similar to MIL-H-8890. This document shall specify the performance, design, and testing requirements for all components in the hydraulic system and also shall be the controlling document for components not otherwise covered by an applicable component specification.

(b) Hydraulic system schematic diagram in accordance with 6.2.3.2 should be submitted for approval.

(c) Hydraulic system design report in accordance with 6.2.4 should be submitted for approval.

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

(e) 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) Flexible connectors including hoses (if nonstandard)

(4) Packings and packing installations (if nonstandard)

(5) Fluids (if nonstandard)

(6) 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. Tne list of surveillance items will be established during the service-contractor conference (see 3.1.2).

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

(g) A failure mode and effects analysis of failures and malfunctions affecting performance and safety shall be submitted.

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

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

(b) The test reports, as well as the specifications and other applicable engineering data covering the hydraulic system componeuts, other than those specified in 6.2.2(e), 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 vehicle 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 vehicle 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 requited 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.

(1) 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 systems should be indicated.

(q) Tubing and hose lines should be identified in accordance with AS1290.

(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 AS1290.

(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 at maximum system temperature.

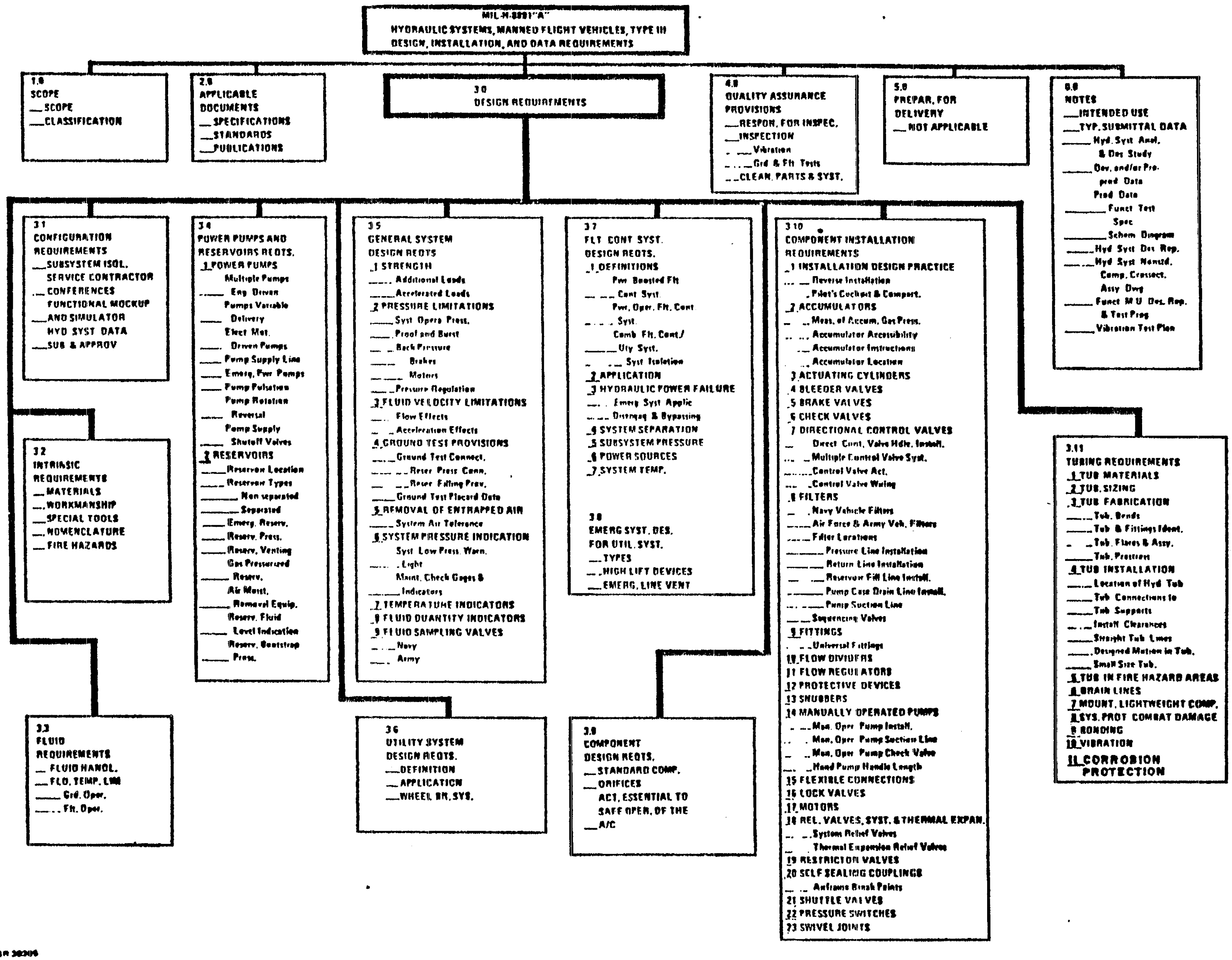
(t) Pressure and temperature pickup locations to be installed for instrumentation purposes in accordance with MIL-T-5522 should be indicated on the copies of the schematic diagrams submitted to the procuring activity.

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

6.2.4 Hydraulic system design report - 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 vehicle. 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 nonstandard 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.


MIL-H-8891"A"
HYDRAULIC SYSTEMS, MANNED FLIGHT VEHICLES, TYPE III
DESIGN, INSTALLATION, AND DATA REQUIREMENTS
1.0 SCOPE
SCOPE
CLASSIFICATION
2.0 APPLICABLE DOCUMENTS
SPECIFICATIONS
STANDARDS
PUBLICATIONS
3.0 DESIGN REQUIREMENTS
4.0 QUALITY ASSURANCE PROVISIONS
RESPON. FOR INSPEC.
INSPECTION
Vibration
Grd & Flt Tests
CLEAN. PARTS & SYST.
5.0 PREPAR. FOR DELIVERY
NOT APPLICABLE
6.0 NOTES
INTENDED USE
TYP. SUBMITTAL DATA
Hyd. Syst Anal. & Des Study
Dev. and/or Pre-prod Data
Prod Data
Funct Test Spec
Schem Diagram
Hyd Syst Des Rep.
Hyd Syst Nomcld. Comp. Crossect. Assy Dwg
Funct M U Des. Rep. & Test Prog
Vibration Test Plan
3.1 CONFIGURATION REQUIREMENTS
SUBSYSTEM ISOL.
SERVICE CONTRACTOR
CONFERENCES
FUNCTIONAL MOCKUP
AND SIMULATOR
HYD SYST DATA
SUB & APPROV
3.2 INTRINSIC REQUIREMENTS
MATERIALS
WORKMANSHIP
SPECIAL TOOLS
NOMENCLATURE
FIRE HAZARDS
3.3 FLUID REQUIREMENTS
FLUID HANDL.
FLD. TEMP. LIM
Grd. Oper.
Flt. Oper.
3.4 POWER PUMPS AND RESERVOIRS REQTS.
1 POWER PUMPS
Multiple Pumps
Eng Driven
Pumps Variable
Delivery
Elect Mot.
Driven Pumps
Pump Supply Line
Emerg. Pwr Pumps
Pump Pulsation
Pump Rotation
Reversal
Pump Supply
Shutoff Valves
2 RESERVOIRS
Reservoir Location
Reservoir Types
Non separated
Separated
Emerg. Reserv.
Reserv. Press.
Reserv. Venting
Gas Pressurized
Reserv.
Air Moist.
Removal Equip.
Reserv. Fluid
Level Indication
Reserv. Bootstrap
Press.
3.5 GENERAL SYSTEM DESIGN REQTS
1 STRENGTH
Additional Loads
Accelerated Loads
2 PRESSURE LIMITATIONS
Syst Opera Press.
Proof and Burst
Back Pressure
Brakes
Motors
Pressure Regulation
3 FLUID VELOCITY LIMITATIONS
Flow Effects
Acceleration Effects
4 GROUND TEST PROVISIONS
Ground Test Connect.
Reser Press Conn.
Reser Filling Prov.
Ground Test Placard Data
5 REMOVAL OF ENTRAPPED AIR
System Air Tolerance
6 SYSTEM PRESSURE INDICATION
Syst Low Press Warn.
Light
Maint. Check Gages & Indicators
7 TEMPERATURE INDICATORS
8 FLUID QUANTITY INDICATORS
9 FLUID SAMPLING VALVES
Navy
Army
3.6 UTILITY SYSTEM DESIGN REQTS.
DEFINITION
APPLICATION
WHEEL BR. SYS.
3.7 FLT CONT SYST. DESIGN REQTS.
1 DEFINITIONS
Pwr Boosted Flt Cont Syst
Pwr. Oper. Flt. Cont Syst
Comb Flt. Cont/ Uty Syst.
Syst Isolation
2 APPLICATION
3 HYDRAULIC POWER FAILURE
Emerg Syst Applic
Diverting & Bypassing
4 SYSTEM SEPARATION
5 SUBSYSTEM PRESSURE
6 POWER SOURCES
7 SYSTEM TEMP.
3.8 EMERG SYST. DES. FOR UTIL. SYST.
TYPES
HIGH LIFT DEVICES
EMERG. LINE VENT
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STANDARD COMP.
ORIFICES
ACT. ESSENTIAL TO SAFE OPER. OF THE A/C
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Pilot's Cockpit & Compart.
2 ACCUMULATORS
Meas. of Accum. Gas Press.
Accumulator Accessibility
Accumulator Instructions
Accumulator Location
3 ACTUATING CYLINDERS
4 BLEEDER VALVES
5 BRAKE VALVES
6 CHECK VALVES
7 DIRECTIONAL CONTROL VALVES
Direct Cont. Valve Hdlr. Install.
Multiple Control Valve Syst.
Control Valve Act.
Control Valve Wiring
8 FILTERS
Navy Vehicle Filters
Air Force & Army Veh. Filters
Filter Locations
Pressure Line Installation
Return Line Installation
Reservoir Fill Line Install.
Pump Case Drain Line Install.
Pump Suction Line
Sequencing Valves
9 FITTINGS
Universal Fittings
10 FLOW DIVIDERS
11 FLOW REGULATORS
12 PROTECTIVE DEVICES
13 SNUBBERS
14 MANUALLY OPERATED PUMPS
Man. Oper Pump Install.
Man. Oper Pump Suction Line
Man. Oper Pump Check Valve
Hand Pump Handle Length
15 FLEXIBLE CONNECTIONS
16 LOCK VALVES
17 MOTORS
18 REL. VALVES, SYST. & THERMAL EXPAN.
System Relief Valves
Thermal Expansion Relief Valves
19 RESTRICTOR VALVES
20 SELF SEALING COUPLINGS
Airframe Break Points
21 SHUTTLE VALVES
22 PRESSURE SWITCHES
23 SWIVEL JOINTS
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1 TUB MATERIALS
2 TUB. SIZING
3 TUB FABRICATION
Tub. Bends
Tub & Fittings Ident.
Tub. Flares & Assy.
Tub. Pressure
4 TUB INSTALLATION
Location of Hyd Tub
Tub Connections to
Tub Supports
Install Clearances
Straight Tub Lines
Designed Motion in Tub.
Small Size Tub.
5 TUB IN FIRE HAZARD AREAS
6 DRAIN LINES
7 MOUNT. LIGHTWEIGHT COMP.
8 SYS. PROT COMBAT DAMAGE
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