



AEROSPACE RECOMMENDED PRACTICE

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(R) Aerospace Design and Installation of Commercial Transport Helicopter Hydraulic Systems

RATIONALE

The changes to ARP4925 at Revision B include:

- a. Technical changes to reflect the latest hydraulic system technologies.
- b. Editorial changes including updating the references and improving the readability of the document.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) establishes the factors which should be considered in the design and installation of a commercial transport rotorcraft hydraulic system, including the applicable airworthiness regulations that affect the hydraulic system.

This ARP also provides information and guidelines on the many factors that arise in the design process to provide cost effectiveness, reliability, maintainability and accepted design and installation practices.

2. REFERENCES

The majority of the documents referenced in this section are aerospace hydraulic system and component standards. Also included are advisory, guidance, and certification documents that can be used to design and evaluate all rotorcraft hydraulic systems. However, these documents may be supplemented, or overridden by, specific rotorcraft contractual or airworthiness requirements. Military specifications are included as they provide important and relevant requirements and guidance for commercial applications.

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

AIR310	Fittings, Catalog of Flared, Flareless, Pipe Threaded, Port, Hose, and Other Type Tube Standard Connectors
ARP490	Electrohydraulic Servovalves
ARP584	Coiled Tubing, Corrosion Resistant Steel, Hydraulic Applications, Aerospace
AS595	Aerospace - Civil Type Variable Delivery, Pressure Compensated, Hydraulic Pump
AS620	Hose Assemblies, Convolute Polytetrafluoroethylene Metallic Reinforced, High Temperature, Medium Pressure, Aircraft
AIR737	Aerospace Hydraulic and Pneumatic Specifications, Standards, Recommended Practices, and Information Reports
AIR797	Hose Characteristics and Selection Chart
ARP819	Fluid System Characteristics Affecting Hydraulic Pump Operation
AIR887	Liquid Filter Ratings, Parameters and Tests
ARP994	Recommended Practice for the Design of Tubing Installations for Aerospace Fluid Power Systems
AS1055	Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings, and Similar System Components
AS1227	Hose Assembly, Convolute Polytetrafluoroethylene, Metallic Reinforced, Low Pressure, Up to 400 °F, Aircraft

AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
ARP1280	Aerospace - Application Guide for Hydraulic Power Transfer Units
ARP1281	Actuators: Aircraft Flight Controls, Power Operated, Hydraulic, General Specification for
AS1290	Graphic Symbols for Aircraft Hydraulic and Pneumatic Systems
AS1300	Port - Ring Locked Fluid Connection Type, Standard Dimensions for
AS1339	Hose Assembly, Polytetrafluoroethylene, Metallic Reinforced, 3000 psi, 400 °F, Lightweight, Hydraulic and Pneumatic
AIR1379	Pre-stressing (Autofretting) of Hydraulic Tubing Lines
AIR1388	Service Damage Limits for Aircraft Hydraulic Tubing
AIR1569	Handling and Installation Practice for Aerospace Hose Assemblies
AS1709	Coupling Assembly, Hydraulic Self Sealing, Quick Disconnect
AS1896	Coupling Assembly, Self-Sealing, One Side Only, Hydraulic
ARP1897	Clamp Selection and Installation Guide
AIR1922	System Integration Factors That Affect Hydraulic Pump Life
AS3121	Plug, Expansion - Aluminum, 2024-T4 and 2024-T351, Long; Std and .010 Oversize Diameters (UNS A92024)
AS3131	Plug, Expansion - CRES, 303, Short; Std and e
AIR4057	Secondary Filters for Fluid System Reliability
AS4059	Aerospace Fluid Power - Cleanliness Classification for Hydraulic Fluids
AIR4092	Investigation of PTFE "Melt" Phenomenon for High Pressure Hoses
ARP4146	Coiled Tubing - Titanium Alloy, Hydraulic Applications, Aerospace
AIR4150	Inspection of In-service Airborne Accumulators for Corrosion and Damage
ARP4378	Aerospace-Accumulator, Hydraulic, Welded Bellows, Factory Precharged
ARP4379	Aerospace - Accumulator, Hydraulic, Cylindrical, Piston Separated
AS4395	Fitting End, Flared, Tube Connection, Design Standard
AS4396	Fitting End - Bulkhead Flared Tube Connection, Design Standard
ARP4553	Accumulator, Hydraulic, Cylindrical Aircraft, Self-Displacing
ARP4835	Aerospace Fluid Power-Hydraulic Thermal Expansion Relief Valves
AS4941	General Requirements for Commercial Aircraft Hydraulic Components
AS5169	Fitting, Port Plug and Bleeder

AS5202	Port or Fitting End, Internal Straight Thread, Design Standard
AS5440	Hydraulic Systems, Aircraft, Design and Installation, Requirements for
AS5586	General Requirements for Hydraulic System Reservoirs
AS5994	Pump Units, Hydraulic, Electric Motor Driven, Variable Delivery
AS7997	Motors, Aircraft Hydraulic, Constant Displacement, General Specification for
AS18280	Fittings, 24° Cone Flareless, Fluid Connection, 3000 psi
AS19692	Pumps, Hydraulic, Variable Flow, General Specification for
AS33566	Fittings, Installation of Flareless Tube – Straight Threaded Connectors
AS33611	Tube Bend Radii
AMS4081	Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn, Round 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T4) Solution Heat Treated and Naturally Aged - Composition similar to UNS A96061
AMS4083	Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn, Round 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T6) Solution and Precipitation Heat Treated - Ref. UNS 96061
AMS4944	Titanium Alloy Tubing, Seamless, Hydraulic, 3.0Al-2.5V, Cold Worked, Stress Relieved
AMS5561	Steel, Corrosion and Heat-Resistant, Welded and Drawn or Seamless and Drawn Tubing 9.0Mn - 20Cr - 6.5Ni - 0.28N High-Pressure Hydraulic
AMS-T-7081	Tube, Aluminum Alloy, Seamless, Round, Drawn, 6061, Aircraft Hydraulic Quality

2.1.2 European Aviation Regulations

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452 Cologne, Germany, Tel: +49-221-8999-000, www.easa.eu.int.

CS-25	Certification Specifications for Large Aeroplanes
CS-29	Certification Specifications for Large Rotorcraft

2.1.3 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

14 CFR Part 25	Airworthiness Standards: Transport Category Airplanes
14 CFR Part 29	Airworthiness Standards: Transport Category Rotorcraft
TSO-C75	Hydraulic Hose Assemblies
TSO-C140	Aerospace Fuel, Engine Oil, and Hydraulic Fluid Hose Assemblies

2.1.4 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org or from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 12	Pipelines, Identification Schemes
ISO 2685	Aircraft – Environmental Test Procedure for Airborne Equipment – Resistance to Fire in Designated Fire Zones
ISO 11217	Aerospace – Hydraulic System Fluid Contamination – Location of Sampling Points and Criteria for Sampling
ISO 22089	Aerospace – Hydraulic Power Transfer Units – General Specifications

2.1.5 U.S. Government Publications

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6396, <http://quicksearch.dla.mil/>.

MIL-DTL-5498	Accumulators, Hydraulic, Cylindrical, 3000 psi, Aircraft
MIL-PRF-5503	Actuators: Aeronautical Linear Utility, Hydraulic, General Specifications for
MIL-J-5513	Joints, Hydraulic Swivel
MIL-PRF-5606	Hydraulic Fluid, Petroleum Base; Aircraft, Missile and Ordnance
MIL-P-7858	Pump, Hydraulic, Power Driven, Fixed Displacement (Cancelled)
MIL-F-8815	Filter and Filter Elements, Fluid Pressure, Hydraulic Line, 15 Micron Absolute and 5 Micron Absolute, Type II Systems, General Specification for
MIL- DTL-9395	Switch Pressure (Absolute Gauge and Differential), Specification for
MIL- DTL-19068	Valves, Shuttle, Hydraulic, Aircraft, Type II Systems
MIL-DTL-25427	Coupling Assembly, Hydraulic, Self-Sealing, Quick Disconnect, General Specification For
MIL-H-25579	Hose Assembly, Tetrafluoroethylene, High Temperature, Medium Pressure, General Requirements for
MIL-H-27267	Hose Tetrafluoroethylene, High Temperature, Medium Pressure
MIL-DTL-27272	Fittings, Polytrafluoroethylene Hose, High-Temperature, Medium-Pressure, General Specification
MIL-PRF-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft
MIL-DTL-83296	Fittings, Corrosion Resistant Steel, High Temperature, High Pressure (3000 psi), Hydraulic and Pneumatic
MIL-DTL-83298	Hose, Polytetrafluoroethylene, High Temperature, High Pressure (3000 psi), Hydraulic and Pneumatic
MIL-PRF-87257	Hydraulic Fluid, Fire Resistant; Low Temperature Synthetic Hydrocarbon Base, Aircraft and Missile

3. OVERALL HYDRAULIC SYSTEM REQUIREMENTS

3.1 General Requirements

3.1.1 Design

The system must be designed such that the rotor controls remain functional following many types of system and/or component failures. Rotor controls in this case means the main rotor controls for the fore and aft rotor on tandem rotor designs, or the main and anti-torque device controls on single main rotor designs.

The complex aerodynamic forces to which the rotor blades are subjected during flight coupled with any unbalances inherent in the rotating system produce significant vibrations within the airframe and oscillatory forces within the control system. These vibrations and forces, which are substantially different than those encountered in fixed-wing aircraft, must be taken into account when designing the hydraulic system(s), components and installations.

3.1.2 System Pressure

Working pressures common in commercial transport rotorcraft in operation today are 1000 psi (6895 kPa) or less for smaller rotorcraft, 1500 psi (10 340 kPa) to 2000 psi (13 790 kPa) for medium size rotorcraft, and 3000 psi (20 680 kPa) to 4000 psi (27 580 kPa) for larger rotorcraft. Higher pressures may be used in the next generation of transport rotorcraft. This will impact the availability of suitable ground support equipment, but the use of higher pressure levels will result in reduced installation envelopes and can lead to a reduction in system weight, but to a lesser extent than which can be realized in fixed wing systems due to the relatively compact system arrangement. Plumbing in a rotorcraft is usually a smaller percentage of the overall hydraulic system weight than for a fixed wing aircraft. A cost/benefit trade is advisable early during development.

3.1.3 Hydraulic Fluid

MIL-PRF-5606, MIL-PRF-83282, and MIL-PRF-87257 are referred to as hydrocarbon based fluids in this document. Mineral-hydrocarbon based fluid conforming to MIL-PRF-5606 has been the most commonly used hydraulic fluid in rotorcraft to date. However, synthetic-hydrocarbon based fluids conforming to MIL-PRF-83282 or MIL-PRF-87257 are now in service in the commercial rotorcraft fleet. These fluids should be considered over MIL-PRF-5606 as they offer superior fire resistance. MIL-PRF-83282 fluid has the disadvantage of higher viscosity at low operating temperatures. MIL-PRF-5606 or MIL-PRF-87257 can be substituted where the use of MIL-PRF-83282 causes rotorcraft operating restrictions at low temperatures. For new rotorcraft, the flammability aspects of the selected fluid(s) should be understood and coordinated with the regulatory agency early in the design cycle.

Where rotorcraft are certified for use with more than one type of fluid, the manufacture's maintenance publications should provide procedures for fluid changeover. Hydraulic fluid types are typically changed gradually, either by "topping up" or by partially draining and servicing of a system, as testing has shown that changing system fluid in its entirety results in seal shrinkage and subsequent leakage.

Phosphate-ester fluids, while used in commercial fixed-wing aircraft, are generally not used in commercial rotorcraft. The majority of commercial transport rotorcraft were derived from military rotorcraft. Many commercial rotorcraft operations started using military surplus rotorcraft, and later on derivatives of military models. Maintenance facilities evolved to service such rotorcraft. Also, due to the smaller rotorcraft size and compact systems, the total volume of fluid contained in a rotorcraft system is but a fraction of the volume contained in the systems of large transport aircraft. System volumes of less than 1 gallon (3.8 L) are common. Larger rotorcraft may have somewhat larger fluid capacities, with reservoir sizes between 1 and 2 gallons (4 to 8 L). The limited size of the rotorcraft market has never warranted the changeover to phosphate-ester fluids.

It must be noted that phosphate-ester based and hydrocarbon based hydraulic fluids are not compatible. Furthermore, components may be designed with materials (elastomeric or polymeric seals et cetera) that are not compatible with all fluid types.

If the design specification requires the use of phosphate-ester fluids, fluids conforming to AS1241 should be used.

3.1.4 System Temperatures

Each hydraulic system should be designed for operating in ambient temperatures as dictated by individual rotorcraft model operating requirements. System operation should not be degraded at:

- a. The minimum temperature that the rotorcraft will likely be subjected to during an overnight cold soak.
- b. The maximum temperature which could occur during prolonged ground operation or temperature soak-back, for example on engine or main gear box mounted components. Engine temperatures of 320 °F (160 °C) and transmission housing temperatures of 220 °F (105 °C) are common with higher temperatures possible on future rotorcraft. Therefore, provisions should be made to protect the hydraulic system from these temperature extremes.

The system should be designed so that for normal operation the hydraulic fluid temperatures in the power generation systems range from -20 to 220 °F (-29 to 105 °C) for hydrocarbon based fluids and from -20 to 175 °F (-29 to +79 °C) for phosphate ester fluids. Operation of the system at the upper limits of the hydraulic fluids, +275 °F (135 °C) for hydrocarbon based fluids, and 225 °F (+107 °C) for phosphate ester fluids, should be limited to short periods or a reduction in system reliability may result.

Operation of all hydraulic services should still be possible at -65 °F (-54 °C), but performance degradation is expected. A warm-up time is typically allowed before the system is operational for flight.

It should be noted that the lower limit for cold soak ambient and operating temperatures for rotorcraft using MIL-PRF-83282 hydraulic fluid should be limited to -40 °F (-40 °C), or as established by test. This is due to the high kinematic viscosity of this fluid at low temperatures.

3.1.5 Hydraulic System Schematic Diagram

The symbols and presentation principles used in hydraulic system schematic diagrams should conform to AS1290. This provides a consistent set of symbols and drawings layouts which can be readily understood by a variety of disciplines and organizations including the rotorcraft hydraulic system engineers, rotorcraft customer, support engineers, component suppliers, and rotorcraft operator engineering and maintenance groups.

3.2 Applicable Airworthiness Requirements

Modern Commercial Transport Rotorcraft are designed to meet the airworthiness requirements defined in 14 Code of Federal Regulations, Part 29 (for rotorcraft certified by the US FAA) or EASA CS-29 Certification Specifications for Large Rotorcraft (for rotorcraft certified by EASA).

Some of the sections in these regulations which are applicable to the design of commercial transport rotorcraft hydraulic systems are:

29.141	General
29.143	Controllability and Maneuverability
29.307	Proof of Structure
29.601	Design
29.602	Critical Parts
29.603	Materials
29.610	Lightning and Static Electricity Protection
29.611	Inspection Provisions

29.671	Control Systems, General
29.672	Stability Augmentation, Automatic and Power Operated Systems
29.673	Primary Flight Controls
29.695	Power Boost and Power-Operated Control System
29.729	Retracting Mechanism
29.863	Flammable Fluid Fire Protection
29.901	Installation
29.921	Rotor Brake
29.1181	Designated Fire Zones: Regions Included
29.1183	Lines, Fittings, and Components
29.1185	Flammable Fluids
29.1189	Shutoff Means
29.1301	Function and Installation
29.1309	Equipment Systems and Installations
29.1322	Warning, Caution and Advisory Lights
29.1435	Hydraulic Systems
29.1461	Equipment Containing High Energy Rotors
29.1529	Instruction for Continued Airworthiness

The impact of these regulations on the design of commercial transport rotorcraft hydraulic systems will be referred to throughout this document.

3.3 Design Concepts and Overall Layout Requirements

The general concept and layout of the hydraulic system design and the type of components used within the system have to comply with the 14 CFR/CS requirements of 29.307, 29.671, 29.672, 29.695, 29.729, and 29.1309. These requirements are concerned with the effects of single and multiple failures of systems, power sources, subsystems or components within the system and their subsequent effect upon the operation of the rotorcraft. Consideration has to be given to the ability of the flight crew to maintain control of the rotorcraft at any point in the flight following a single failure. The regulations state that if power boosted or power operated control systems are used, an alternate system must be available that allows the continued safe flight and landing in the event of a single failure in the power portion of the system or failure of all engines. In this respect Part 29 regulations differ from those defined in Part 25 which require safe operation following a "two system" failure. The requirements for rotorcraft are less stringent in this area due to the shorter mission duration, which lowers the probability of a dual system failure occurring during the flight.

Section 29.1 of the regulations define designations and requirements for Category A and Category B rotorcraft. Rotorcraft category is a function of rotorcraft maximum weight and number of passenger seats. Some regulations change, or do not apply, depending on the rotorcraft category. Examples of regulations that change based on rotorcraft category include 29.1189 and 29.1309.

For rotorcraft designed for greater range, it is prudent to provide a two-fail-operate system configuration as required in 14 CFR/CS Part 25. In addition, the effect of the failures and subsequent degree of difficulty in safely operating the rotorcraft has to be related to the probability of these failure(s) occurring. Furthermore, the rotorcraft is designed to operate on unprepared landing sites. As such they may be required to operate under severe dust and sand conditions.

Off-shore operation exposes the systems and components to a salt atmosphere possibly leading to corrosion unless addressed properly during the design stage.

Therefore, the design of the overall hydraulic system has to relate to the type of potential failures within the system and their effect on the rotorcraft. This in turn is related to the type and number of services supplied by the hydraulic system.

Regardless of the number of hydraulic systems installed, if the rotorcraft contains power boosted or power operated controls, means must be provided to allow full control movement of all primary flight control prior to flight, or a means must be provided that will allow the pilot to determine that full control authority is available prior to rotor engagement.

3.3.1 Rotorcraft Utilizing a Single Main Hydraulic System

A single hydraulic system is typically adequate if the rotorcraft can be safety controlled following loss of the hydraulic system. If, however, the rotorcraft is equipped with a retractable landing gear, then 14 CFR/CS 29.729(c) requires that alternate methods for deploying the gear must be available if the gear cannot be deployed via free fall. Examples of the alternate means include a simple auxiliary hydraulic system or a stored gas system. Power boosted braking systems on rotorcraft usually are not required to be provided with a backup system due to the low landing speeds.

3.3.2 Rotorcraft Utilizing Two Independent Hydraulic Systems

Two independent hydraulic systems are required if the rotorcraft cannot be controlled without hydraulic power. Thus, if one of the two system fails, there shall be no, or negligible, effect on the rotorcraft handling and the rotorcraft can continue to fly safely then land. If the rotorcraft is equipped with a retractable landing gear, and the gear is powered by one of the two systems which supply the primary flight controls, the following must be provided:

- a. An alternate means to deploy the landing gear
- b. A priority valve which assures priority of the primary control system over any utility functions

3.3.3 Rotorcraft Utilizing More Than Two Hydraulic Systems

If the rotorcraft's hydraulic system supplies all the primary and secondary flight controls and the rotorcraft cannot be controlled without hydraulic power, and where certain mission requirements increase the probability of a dual power failure, three hydraulic systems should be considered. Even though this is not mandated by the regulations, it nevertheless represents prudent design practice. The requirement to provide a redundant power source for the landing gear on rotorcraft so equipped could be satisfied by the additional hydraulic system.

3.3.4 Loss of Electrical Power

Hydraulic components and subsystems are increasingly dependent upon electrical power to function properly. The electrical power generation and distribution system should have redundancy sufficient to support the required probability of continued safe flight and the ability to land. The overall system comprising the electrical power supply, distribution and the flight control system and its components (control valves, pump mode selectors and directional valves, etc.) should be configured such that following a complete failure of the main electrical system, the rotorcraft can continue safe flight and land safely under these conditions.

In addition, the relationship between the electrical supplies to the hydraulic components and the function of the hydraulic components must be carefully reviewed. This is especially true of electronic control systems which, due to their high impedance inputs, can be subject to spurious inputs.

This must be reviewed in the context that a potentially catastrophic event might possibly occur due to a combination of single failures of:

- a. The electrical and hydraulic systems
- b. Components within the two systems
- c. A failure of one of the systems and a component in the other system

3.3.5 Hydraulic System Backup Sources

Consideration has to be given to the level of redundancy of the power sources within the system. Usually each independent system contains a main hydraulic power source, for example a gearbox driven hydraulic pump, a switching valve or PTU (Power Transfer Unit) and a backup power source. Thus, if the main power source fails, the backup source will provide for continued safe operation.

If the rotorcraft has primary or secondary flight controls powered by the hydraulic system, then it has to comply with 14 CFR/CS 29.695(a). This states that the rotorcraft has to be controllable when all engines fail, allowing an autorotative descent to the ground. In order to comply with this requirement, at least one of the main system pumps and the backup pump, or all pumps, must be driven in such way as to ensure continued rotation as long as the main rotor is turning. Such pumps are typically driven by the main transmission.

Each pump should be driven off a separate drive train to prevent loss of all hydraulic pumps due to a single transmission shaft or gear failure. Backup sources may be electric motor driven.

Ram air turbine (RAT) systems are not used on rotorcraft. Rotorcraft airspeeds are low compared with fixed wing aircraft which would require a rather large turbine diameter and would be too heavy. Also finding a location on the rotorcraft to mount the RAT, where the airstream is relatively undisturbed, may be difficult or impossible. Finally, the main rotor functions effectively as a RAT during autorotation, as continued rotation is required during descent. Variation of main rotor RPM and hydraulic system flow demands during autorotation should be considered in system sizing.

Another means to provide backup power has been the use of an accumulator. This approach has extremely limited capability, as it provides power only for a very short time and thus is useful only as a means to control the rotorcraft for an emergency landing.

3.3.6 Hydraulic System Protection Devices

Consideration should be given to the use of protection devices to provide some capability of operating key hydraulic subsystems following loss of the primary system, or to protect against loss of the primary supply system due to a failure, such as a leak, in a subsystem or component.

Examples of these devices which can be used are:

3.3.6.1 Check Valve

This is the simplest of all protection devices and can be used to isolate subsystems from the main hydraulic system. This then allows the subsystem to be supplied by a secondary source:

- a. An accumulator which can supply power for a finite time or number of cycles
- b. A backup pump having its own fluid supply separate from the main system

Check valves can also be installed in the return ports/lines of the various components and services to prevent loss of fluid from the reservoir due to return system failure. If it is possible for the check valve to be latently failed open, a functional test to determine the correct operation of the valve should be conducted at an interval determined by a safety analysis.

3.3.6.2 Pressure Maintaining Valve (PMV)

This type of valve can be used to isolate a subsystem from the main system whenever the pressure upstream of the valve falls below a specified value. If the subsystem has an accumulator, the use of a PMV enables the accumulator to supplement the flow from the main system pump. However, following the loss of the main system, the valve would close and conserve the accumulator stored energy for the subsystem.

3.3.6.3 Priority Valve

This type of device is used to isolate nonessential functions from essential services in systems where the capacity limitation of the hydraulic power supply is inadequate to supply all functions simultaneously. This type of device does not protect against fluid loss but responds to pressure drops which occur in a system when the pump capacity is exceeded. This will assure that flight essential services have priority over nonessential ones by limiting, or momentarily interrupting, power flow to the nonessential functions.

3.3.6.4 Hydraulic Fuses

This type of device measures fluid flow (velocity or rate fuse) or fluid quantity (fluid quantity fuse) and interrupts the flow of fluid when a preset value of flow rate or fluid quantity is exceeded. Rate fuses are usually installed in the rotorcraft to isolate a failed subsystem where the failure results in excessive flow as occurs following a line failure. A quantity fuse is installed in subsystems which always use a predictable amount of fluid during a normal operational cycle, such as lowering or raising the landing gear. The fuse closes whenever the fluid volume displaced exceeds the amount predicted for normal operation. Both types of fuses have threshold limits which must be considered.

3.3.6.5 Electrically Operated Shutoff Valve (Isolation Valve)

This type of valve can be used to shut off all, or part, of a system in accordance with the overall system design logic arrangement. It can be used to isolate certain portions, or branches, of a system by electrically linking the valve to a reservoir quantity measurement arrangement or by using signals generated by the computer of a failure detection system. The latter uses pressure and/or fluid flow or quantity information to generate logical decision based upon various system algorithms.

3.3.6.6 Hydraulic Circuit Breaker (Flow Comparison Device)

This type of device compares the flow rate to and from a set of services. If the difference between the two rates exceeds the normal rate by a predetermined value, a shutoff valve will be actuated to isolate the faulty branch from the remainder of the hydraulic system. The rate comparator and shutoff valve are usually combined into one component.

3.4 Segregation Requirements

The location of components and the routing of lines has to consider the effects of a uncontained engine burst (as required by 14 CFR/CS 29.901(c)), and that of an engine, tail rotor or connecting drive shaft, or shaft coupling, failure. This is usually accomplished by routing the lines of each independent system with sufficient physical separation between each other such that neither a non-contained engine nor a shaft failure can damage the lines or components of all systems.

It is mandatory for safe operation of the rotorcraft that hydraulic power is maintained at those services required to maintain safe flight, which for a rotorcraft is the rotor control system. To meet this requirement, it may be necessary to locate systems on different sides of the transmission, which includes having the pump drive pads on opposite sides of the main gear box housing. It is also prudent to arrange the internal pump gearing to have each drive pad be driven by a different transmission section (load path) well upstream of the final combining stage. Supply and return lines for redundant systems should be routed on opposite sides of the fuselage.

On some occasions it may be necessary to route the plumbing from all hydraulic systems into a single area. In a rotorcraft with a tail rotor drive, this usually is the tail pylon area. Under these conditions it may be possible to damage all hydraulic systems which would prevent the rotorcraft from being controlled. For these reasons, consideration must be given to provide means to isolate this section of the system such that the primary control hydraulic system remains operational. The use of localized hydraulic systems should be considered on rotorcraft where isolation or protection means are inadequate to assure continued operation of the primary control system following a failure in the critical area, such as a tail drive shaft or shaft coupling failure.