U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: HYDRAULIC SYSTEM CERTIFICATION TESTS AND ANALYSIS

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Initiated by: ANM-110

AC No: 25.1435-1

1. PURPOSE. This advisory circular (AC) provides guidance material for use as an acceptable means, but not the only means, of demonstrating compliance with the airworthiness standards for transport category airplanes that contain hydraulic system requirements. It is not mandatory and does not constitute a regulation.

2. RELATED DOCUMENTS. Section 25.1435 of 14 Code of Federal Regulations (CFR) part 25, as amended through Amendment 25-104, and other sections relating to hydraulic installations.

a. Related Federal Aviation Regulations (FAR). Sections which contain requirements for the design, substantiation and certification of hydraulic systems include:

§ 25.301	Loads.
§ 25.303	Factor of safety.
§ 25.863	Flammable fluid fire protection.
§ 25.1183	Flammable fluid-carrying components.
§ 25.1185	Flammable fluids.
§ 25.1189	Shutoff means.
§ 25.1301	Function and installation.
§ 25.1309	Equipment, systems and installations.
§ 25.1322	Warning, caution and advisory lights.
§ 25.1541	Markings and Placards: General.

Additional part 25 sections (and their associated advisory circulars where applicable) that can have a significant impact on the overall design and configuration of hydraulic systems are, but are not limited to:

§ 25.671	Control systems: General.
§ 25.729	Retracting mechanism.
§ 25.903	Engines.
§ 25.943	Negative acceleration. (JAR 25.1315)

b. Advisory Circulars (AC).

AC 25.1309-1A	System Design and Analysis
AC 120-42A	Extended Range Operation with Two Engine Airplanes
AC 20-128A	Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure

c. Technical Standard Orders (TSO).

TSO-C47	Pressure Instruments-Fuel, Oil, and Hydraulic
TSO-C75	Hydraulic Hose Assemblies (JTSO-2C75)

Advisory Circulars and Technical Standard Orders can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785.

d. Society of Automotive Engineers (SAE) Documents.

ARP 4752	Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems
ISO 7137	Environmental Conditions and Test Procedures for Airborne Equipment (not an SAE document but is available from the SAE)

These documents can be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

e. Military Documents.

MIL-STD-810	Environmental Test Methods and Engineering Guidelines

These documents can be obtained from Department of Defense, Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

3. <u>BACKGROUND</u>.

a. Effective February 1, 1965, 14 CFR part 25 replaced Part 4b of the Civil Air Regulations (CAR). For hydraulic systems, CAR 4b.653, 4b.654 and 4b.655 respectively became §§ 25.1435(a), 1435(b) and 1435(c) of part 25. Since then § 25.1435 has been revised under Amendment 25-13 (1967), Amendment 25-23 (1970), Amendment 25-41 (1977), Amendment 25-72 (1990), and Amendment 25-104 (2001), to make the regulations more comprehensive and to delete redundancies.

b. In Europe, the Joint Aviation Requirements (JAR) -25 were developed by the Joint Aviation Authorities (JAA) to provide a common set of airworthiness standards for use within the European aviation community. The airworthiness standards for European type certification of transport category airplanes, JAR-25, are based on part 25.

c. Although part 25 and JAR-25 are very similar, they are not identical. Differences between the part 25 and JAR-25 can result in substantial additional costs when airplanes are type certificated to both standards. These additional costs, however, frequently do not bring about an increase in safety. For example, part 25 and JAR-25 may use different means to accomplish the same safety intent. In this case, the manufacturer is usually burdened with meeting both requirements, although the level of safety is not increased correspondingly. Recognizing that a common set of standards would not only economically benefit the aviation industry, but would also maintain the necessary high level of safety, the FAA and JAA consider harmonization to be a high priority.

d. In 1992, the harmonization effort was undertaken by the Aviation Rulemaking Advisory Committee (ARAC). A working group of industry and government hydraulic systems specialists of Europe, Canada, and the United States was chartered by notice in the <u>Federal Register</u> (57 FR 58843, December 12, 1992). The working group was tasked to develop harmonized standards and any collateral documents, such as advisory circulars, concerning new or revised requirements for hydraulic systems, and the associated test conditions for hydraulic systems, installed in transport category airplanes (§ 25.1435).

e. The advisory material contained in this AC was developed by the Hydraulic Systems Harmonization Working Group to ensure consistent application of the revised standards.

4. <u>DISCUSSION</u>.

a. <u>Element Design</u>.

(1) Reference § 25.1435(a)(1).

(a) The design operating pressure (DOP) is the normal maximum steady pressure. Excluded are reasonable tolerances, and transient pressure effects such as may arise from acceptable pump ripple or reactions to system functioning or demands that may affect fatigue. Fatigue is addressed in paragraph 4a(4) of this AC.

(b) The DOP for low pressure elements (e.g., return, case-drain, suction, reservoirs, etc.) is the maximum pressure expected to occur during normal user system operating modes. Included are transient pressures that may occur during separate or simultaneous operation of user systems such as slats, flaps, landing gears, thrust reversers, flight controls, power transfer units, etc. Short term transient pressures, commonly referred to as pressure spikes, that may occur during the selection and operation of user systems (e.g., those pressure transients due to the opening and closing of selector/control valves, etc.) may be excluded, provided the fatigue effect of such transients is addressed in accordance with paragraph 4a(4) of this AC.

(c) In local areas of systems and elements, the DOP may be different from the above due to the range of normally anticipated airplane operational, dynamic, and environmental conditions. Such differences should be taken into account.

(d) At proof pressure, seal leakage not exceeding the allowed maximum in-service leak rate is permitted. Each element should be able to perform its intended functions when the DOP is restored.

(e) For § 25.1435(a)(1), (a)(2), and (a)(3), the pressure and structural loads, as applicable, should be sustained for sufficient time to enable adequate determination that compliance is demonstrated. Typically a time of 2 minutes for proof conditions and 1 minute for ultimate condition will be considered acceptable.

(f) The term "pressure vessels" is not intended to include small volume elements such as lines, fittings, gauges, etc. It may be necessary to use special factors for elements fabricated from non-metallic/composite materials.

(2) Reference § 25.1435(a)(2). Limit structural loads are defined in § 25.301(a). The loading conditions of part 25, subpart C to be considered include, but are not limited to flight and ground maneuvers, and gust and turbulence conditions. The loads arising in these conditions should be combined with the maximum hydraulic pressures, including transients, that could occur simultaneously. Where appropriate, thermal effects should also be accounted for in the strength justification. For hydraulic actuators equipped with hydraulic or mechanical locking features, such as flight control actuators and power steering actuators, the actuators and other loaded elements must be designed for the most severe combination of internal and external loads that may occur in use. For hydraulic actuators that are free to move with external loads, i.e., do not have locking features, the structural loads are the same as the loads produced by the hydraulic actuators. At limit load, seal leakage not exceeding the allowed maximum in-service rate is permitted.

(3) Reference § 25.1435(a)(3). For compliance, the combined effects of the ultimate structural load(s) as defined in §§ 25.301 and 25.303 and the DOP, which can

reasonably occur simultaneously, should be taken into account with a factor of 1.5 applied to the DOP. In this case the overall structural integrity of the element should be maintained. However, it may be permissible for this element to suffer leakage, permanent deformation, operational/functional failure or any combination of these conditions. Where appropriate, thermal effects should also be accounted for in the strength justification.

(4) Reference § 25.1435(a)(4). Fatigue, the repeated load cycles of an element, is a significant contributor to element failure. Hydraulic elements are mainly subjected to pressure loads, but may also see externally induced load cycles (e.g. structural, thermal, etc.). The applicant should define the load cycles for each element. The number of load cycles should be evaluated to produce equivalent fatigue damage encountered during the life of the aircraft or to support the assumptions used in demonstrating compliance with § 25.1309. For example, if the failure analysis of the system allows that an element failure may occur at 25 percent of aircraft life, the element fatigue life should at least support this assumption.

(5) Reference § 25.1435(a)(5). Airplane environmental conditions that an element should be designed for are those under which proper function is required. They may include, but are not limited to: temperature, humidity, vibration, acceleration forces, icing, ambient pressure, electromagnetic effects, salt spray, cleaning agents, galvanic, sand, dust, and fungus. They may be location specific (e.g., in pressurized cabin vs. in unpressurized area) or general (attitude). For further guidance on environmental testing, suitable references include, but are not limited to: Military Standard, MIL-STD-810 "Environmental Test Methods and Engineering Guidelines", RTCA Document No. DO-160 (Environmental Conditions and Test Procedures for Airborne Equipment) as referenced in advisory circular No. AC 21-16, and International Organization for Standardization Document No. ISO 7137-Environmental Conditions and Test Procedures for Airborne Equipment.

b. System Design. (Reference § 25.1435(b)) Design features that should be considered for the elimination of undesirable conditions and effects are: (a) Design and install hydraulic pumps such that loss of fluid to or from the pump cannot lead to events that create a hazard that might prevent continued safe operation. For example, engine driven pump shaft seal failure or leakage, in combination with a blocked fluid drain, resulting in engine gear box contamination with hydraulic fluid and subsequent engine failure. (b) Design the system to avoid hazards arising from the effects of abnormally high temperatures which may occur in the system under fault conditions.

(1) Reference § 25.1435(b)(1). Appropriate system parameters may include, but are not limited to, pump or system temperatures and pressures, system fluid quantities, and any other parameters which give the pilot indication of the functional level of the hydraulic systems.

(2) Reference § 25.1435(b)(2). Compliance may be shown by designing the systems and elements to sustain the transients without damage or failure, or by providing dampers, pressure relief devices, etc.

(3) Reference § 25.1435(b)(3). Harmful or hazardous fluid or vapor concentrations are those that can cause short term incapacitation of the flight crew or long term health effects to the passengers or crew. Compliance may be shown by taking design precautions, to minimize the likelihood of releases and, in the event of a release to minimize the concentrations. Suitable precautions, based on good engineering judgment, include separation of air conditioning and hydraulic systems, shut off capability to hydraulic lines, reducing the number of joints and elements, shrouding etc. In case of leakage, sufficient drainage should be provided.

(4) Reference § 25.1435(b)(4). Unless it has been demonstrated that there are no circumstances which can exist (on the airplane) under which the hydraulic fluid can be ignited in any of its physical forms (liquid, atomized, etc.), the hydraulic fluid should be considered to be flammable.

(5) Reference § 25.1435(b)(5). If more than one approved fluid is specified, the term suitable hydraulic fluid is intended to include acceptable mixtures. Typical nameplate marking locations for hydraulic fluid used are all hydraulic components having elastomer seals such as cylinders, valves, reservoirs, etc.

c. <u>Tests</u>. (Reference § 25.1435(c)) Test conditions should be representative of the environment that the element, subsystem or system may be exposed to in the design flight envelope. This may include loads, temperatures, altitude effects, humidity, and other influences (electrical, pneumatic, etc.). Testing may be conducted in simulators, stand alone rigs, integrated laboratory rigs, or on the airplane. The test plan should describe the objectives and test methods. All interfaces between the airplane elements and the test facilities should be adequately represented.

(1) Reference § 25.1435(c)(1). Testing for performance should demonstrate rates and responses required for proper system operation. Testing for fatigue (the repeated load cycling of an element) and endurance (the ability of parts moving relative to each other to continue to perform their intended function) should be sufficient to show the assumptions used in § 25.1309 analysis are correct, but are not necessary to demonstrate airplane design life. As part of demonstrating that the element(s), sub-system(s), or system(s) perform their intended functions, the manufacturer may select procedures and factors of safety identified in accepted manufacturing, national, military, or industry standards provided that it can be established that they are suitable for the intended application. Minimum design factors specified in those standards or the regulations may be used unless more conservative factors have been agreed to with the Administrator. An acceptable test approach for fatigue or endurance is to:

(a) Define the intended element life.

(b) Determine the anticipated element duty cycle.

(c) Conduct testing using the anticipated or an equivalent duty cycle.

(2) Reference § 25.1435(c)(2). The tests should include simulation of hydraulic system failure conditions in order to investigate the effect of those failures and to correlate with the failure conditions considered for compliance with § 25.1309. Relevant failure conditions to be tested are those which cannot be shown to be extremely improbable and have effects assessed to be major, hazardous, or have significant system interaction or operational implications.

(3) Reference § 25.1435(c)(3). Compliance with § 25.1435(c)(3) can be accomplished by applying a test pressure to the system using airplane pumps or an alternate pressure source (e.g., a ground cart). The test pressure to be used should be just below the pressure required to initiate system pressure relief (cracking pressure). Return and suction pressures are allowed to be those which result from application of the test pressure to the pressure side of the system.

Some parts of the system(s) may need to be separately pressurized to ensure the system is completely tested. Similarly, it may be permissible that certain parts of the system need not be tested if it can be shown that they do not constitute a significant part of the system with respect to the evaluation of adequate clearances or detrimental effects.

/s/

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