AEROSPACE STANDARD

AS595™	REV. E

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Revised 2022-11

Superseding AS595D

(R) General Requirements for the Design and Testing of Civil Type Pressure Compensated, Variable Delivery Hydraulic Pumps

RATIONALE

AS595 has been updated to Revision E for the following reasons:

a. The title and scope have been revised.

b. It incorporates technical and editorial changes, including removing all the references to JAR airworthiness regulations.

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1. SCOPE

This SAE Aerospace Standard (AS) provides general design and test requirements for a flat cut-off pressure compensated, variable delivery hydraulic pump for use in a civil aircraft hydraulic system with a rated system pressure up to 5000 psi (34500 kPa).

NOTE: Hydraulic pumps may incorporate features such as a clutch in the input drive, which will not be covered by this standard.

1.1 Purpose

The requirements contained in this document are compiled for inclusion in a procurement specification for a civil type flat cut-off pressure compensated, variable delivery hydraulic pump.

NOTE: The requirements in this AS should be reviewed by the purchaser and only those requirements that are applicable for a specific application should be incorporated in the procurement specification.

1.2 Field of Application

This AS is primarily for hydraulic pumps driven by an engine; however, it also can be applied to pumps driven by other power sources such as electric motors, ram air turbines, and engine bleed air turbines. These pumps may be soft cut-off pressure compensated, variable delivery type due to input power limitations.

Pumps conforming to this standard are intended mainly for use in civil aircraft hydraulic systems conforming to the general requirements of ARP4752, and the regulations of 14 CFR 25 and/or CS-25. However, pumps conforming to this AS can also be used in:

- Civil aircraft hydraulic systems that conform to the regulations of 14 CFR 23 and/or CS-23. For these applications, the equivalent 14 CFR 23 and/or CS-23 regulations should be used in place of the 14 CFR 25 and/or CS-25 regulations.
- Helicopter hydraulic systems that conform to the regulations of 14 CFR 27 and/or CS-27. For these applications, the equivalent 14 CFR 27 and/or CS-27regulations should be used in place of the 14 CFR 25 and/or CS-25 regulations.
- Helicopter hydraulic systems that conform to the general requirements of ARP4925, and the regulations of 14 CFR 29 and/or CS-29. For these applications, the equivalent 14 CFR 29 and/or CS-29 regulations should be used in place of the 14 CFR 25 and/or CS-25 regulations.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this standard to the extent specified herein. The latest issue of the SAE documents shall apply. The applicable issue of the other documents shall be the issue in effect at the date of the purchase order. In the event of a conflict between the text of this document and the 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 +1 724-776-4970 (outside USA), www.sae.org.

AIR1922 Aerospace - System Integration Factors That Affect Hydraulic Pump Life

ARP1288 Placarding of Aircraft Hydraulic Equipment to Identify Phosphate-Ester Fluid Compatibility

ARP4386 Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies

ARP4752 Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems

ARP4925 Aerospace - Design and Installation of Commercial Transport Helicopter Hydraulic Systems

AS1241 Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft

AS1300 Port - Ring Locked Fluid Connection Type, Standard Dimensions for

AS4273 Fire Testing of Fluid Handling Components for Aircraft Engines and Aircraft Engine Installations

AS4941 Aerospace - General Requirements for Commercial Aircraft Hydraulic Components

AS5202 Port or Fitting End, Internal Straight Thread, Design Standard

2.1.2 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany (for visitors and for mail over 1 kg) and Postfach 10 12 53, D-50452 Cologne, Germany (for mail 1 kg or less); Tel: +49 221 8999 000, www.easa.europa.eu.

CS-23 Certification Specifications for Normal, Utility, Aerobatic and Commuter Aeroplanes

CS-25 Certification Specifications for Large Aeroplanes

CS-27 Certification Specifications for Small Rotorcraft

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 23 Code of Federal Regulations, Part 23 Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes

14 CFR 25 Code of Federal Regulations, Part 25 Airworthiness Standards: Transport Category Airplanes

14 CFR 27 Code of Federal Regulations, Part 27 Airworthiness Standards: Normal Category Rotorcraft

14 CFR 29 Code of Federal Regulations, Part 29 Airworthiness Standards: Transport Category Rotorcraft

2.1.4 ISO Publications

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

ISO 2685 Aircraft - Environmental Test Procedure for Airborne Equipment - Resistance to Fire in Designated Fire Zones

2.1.5 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA/DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

2.1.6 U.S. Government Publications

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

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

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

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

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

2.2 Related Publications

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

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

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

2.3 Definitions

Refer to ARP4386 for general hydraulic system terms that are used in this SAE Aerospace Standard.

DESIGN OPERATING PRESSURE: This is the normal maximum steady pressure.

NOTES:

1. Excluded are reasonable tolerances, transient pressure effects such as may arise from pressure ripple, reactions to system functioning, or demands that may affect fatigue.

2. This term is used in the 14 CFR 25 and CS-25.1435(a)(1) airworthiness regulation that is concerned with the strength of each hydraulic system element, including hydraulic components.

3. This definition is too general to be used in pump design; instead, “rated discharge pressure” is considered to adequately encompass its implied meaning.

DISCHARGE PRESSURE PULSATIONS: These are the oscillations of the discharge pressure, occurring during nominally steady-state operating conditions, at a frequency equal to the number of pistons times the drive shaft speed, or a multiple thereof.

NOTES:

1. The peak-to-peak amplitude of the oscillations is the difference between the average minimum and the average maximum oscillations recorded during a 1-second trace.

2. This is a characteristic of the pump and the system operating together.

FLAT CUT-OFF PRESSURE COMPENSATED, VARIABLE DELIVERY HYDRAULIC PUMP: This is a pump that provides nearly constant pressure at the pump output at all flows lower than the maximum flow capacity of the pump.

See Figure 1 for the pressure-flow characteristics of this type of pump.

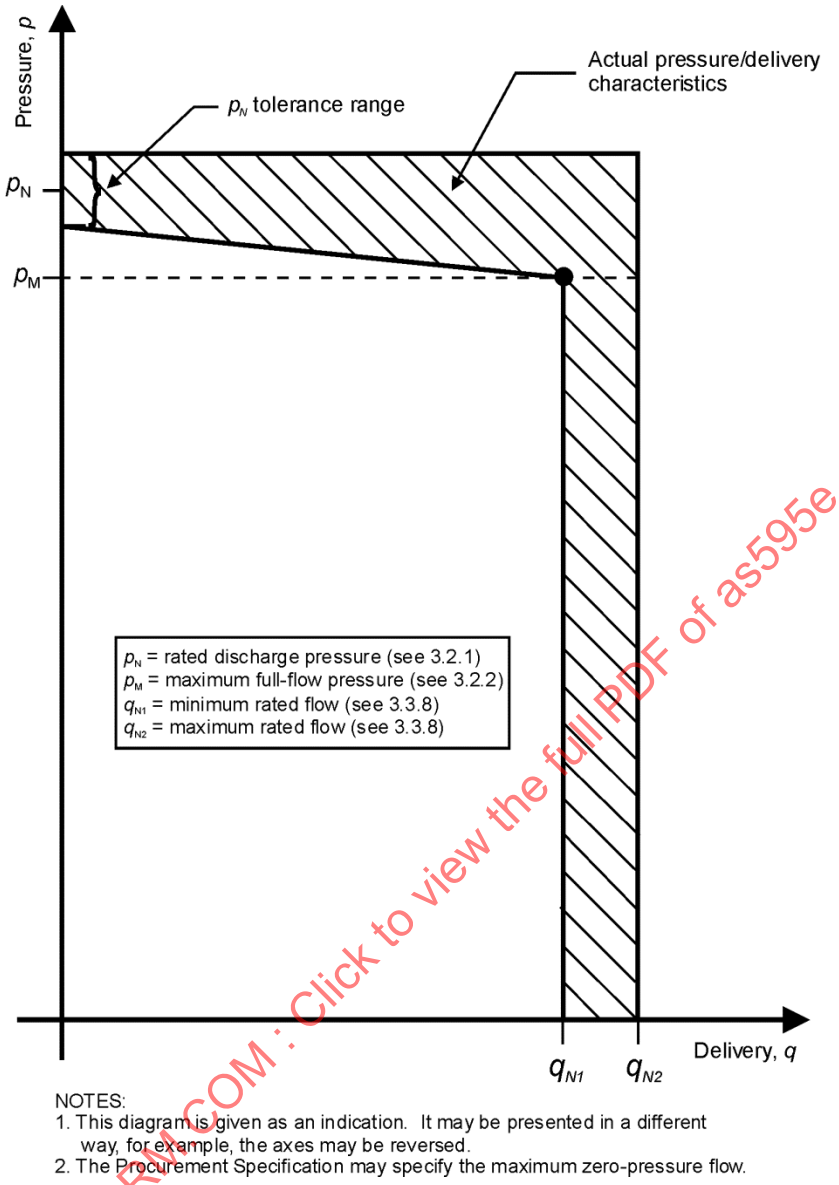

Figure 1 - Pressure/delivery characteristics of a flat cut-off pressure compensated, variable delivery hydraulic pump

MAXIMUM CASE DRAIN PRESSURE: This is the maximum pressure developed within the case of the pump.

NOTE: This could include failure conditions (for example, the bypass pressure of the case drain system filter at its terminal dirt capacity).

MAXIMUM FULL-FLOW PRESSURE: This is the point of pump saturation where the pump displacement is at its maximum and any additional flow demand will result in the reduction of the pump discharge pressure.

MAXIMUM INLET PRESSURE: This is the maximum steady-state inlet pressure at which the pump may be required to operate.

MAXIMUM TRANSIENT DISCHARGE PRESSURE: This is the peak value of the discharge pressure recorded during a discrete transient event (normally found when cycling from the maximum full flow pressure to rated pressure (zero flow).

MINIMUM INLET PRESSURE: This is the lowest inlet pressure at which the pump may be required to operate during a system failure or a system high flow transient condition.

PUMP OVERALL EFFICIENCY: This is defined as a ratio of the pump output power (hydraulic) to the pump input power (mechanical).

NOTE: The efficiency includes volumetric efficiency.

PUMP CASE DRAIN PORT (also called the PUMP COOLING PORT): This is the location where the pump case leakage flow is directed out of the pump and returned to the hydraulic system reservoir.

PUMP INLET PORT (also called the PUMP SUCTION PORT): This is the location where the fluid is supplied to the pump by the hydraulic system reservoir.

PUMP OUTLET PORT (also called the PRESSURE PORT or the DELIVERY PORT or the DISCHARGE PORT): This is the location where the pump discharges pressurized flow to the hydraulic system.

PUMP SHAFT DRAIN PORT (also called the DRAIN PORT or the SHAFT SEAL PORT): This is the location where any shaft seal leakage flow is collected for external drainage.

PURCHASER: This is the organization that has the engineering responsibility for the hydraulic system including the pump.

NOTE: Typically, the purchaser is an aircraft manufacturer, a system supplier, or a modification center. The purchaser is responsible for the compilation of the procurement specification.

PROCUREMENT SPECIFICATION: This is the document that includes the following:

a. Technical requirements

b. Acceptance and qualification test requirements

c. Reliability requirements

d. Quality requirements

e. Packaging requirements

RATED CASE DRAIN PRESSURE: This is the nominal pressure at the pump case drain port at which the pump is required to operate continuously in the system.

RATED DISCHARGE PRESSURE: (p_n in Figure 1) This is the nominal discharge pressure that the pump is required to maintain at rated temperature, rated speed, rated inlet pressure, rated case drain pressure, and zero flow.

RATED ENDURANCE: This is the total number of hours and cycles of operation to be included in the endurance phase of its qualification testing.

RATED FLOW: (q_n in Figure 1) This is the measured flow rate of the pump under conditions of:

- Rated temperature
- Rated speed
- Rated inlet pressure
- Rated case drain pressure
- Maximum full-flow pressure
- Using the hydraulic fluid specified in the procurement specification

RATED INLET PRESSURE: This is the minimum pressure at the inlet port of the pump when it is operating at rated speed, maximum full-flow pressure, and rated temperature.

RATED SPEED: This is the maximum speed at which the pump is designed to operate continuously at the rated temperature.

RATED TEMPERATURE: This is the maximum continuous temperature of the fluid to be supplied at the inlet port of the pump.

RESPONSE TIME: This is an indicator of the time to recover a steady-state displacement after the application of a flow demand disturbance.

NOTES:

1. On most pump models it is not possible to measure the pump displacement (i.e., the theoretical volume delivered by the pump in one revolution). Instead, a test can be carefully designed wherein it is possible to deduce the change in displacement of the pump by the inspection of the pump discharge pressure. This measurement is called “response time,” as it is a dynamic characteristic of a pump operating in a specified discharge circuit. It is not strictly an attribute of the pump. For this reason, the term “response time” is used throughout this document instead of “pump response time.” In such a test, the response time is the time interval between the instant when an increase (or decrease) in discharge pressure changes initiates; and the subsequent instant when the discharge pressure reaches its first maximum (or minimum) value.

2. In Figures 2 and 3, the time intervals t_1 and t_2 are the response times as a function of the system impedance. The real-time plot of discharge pressure versus time is used as the criterion of movement of the flow control mechanism.

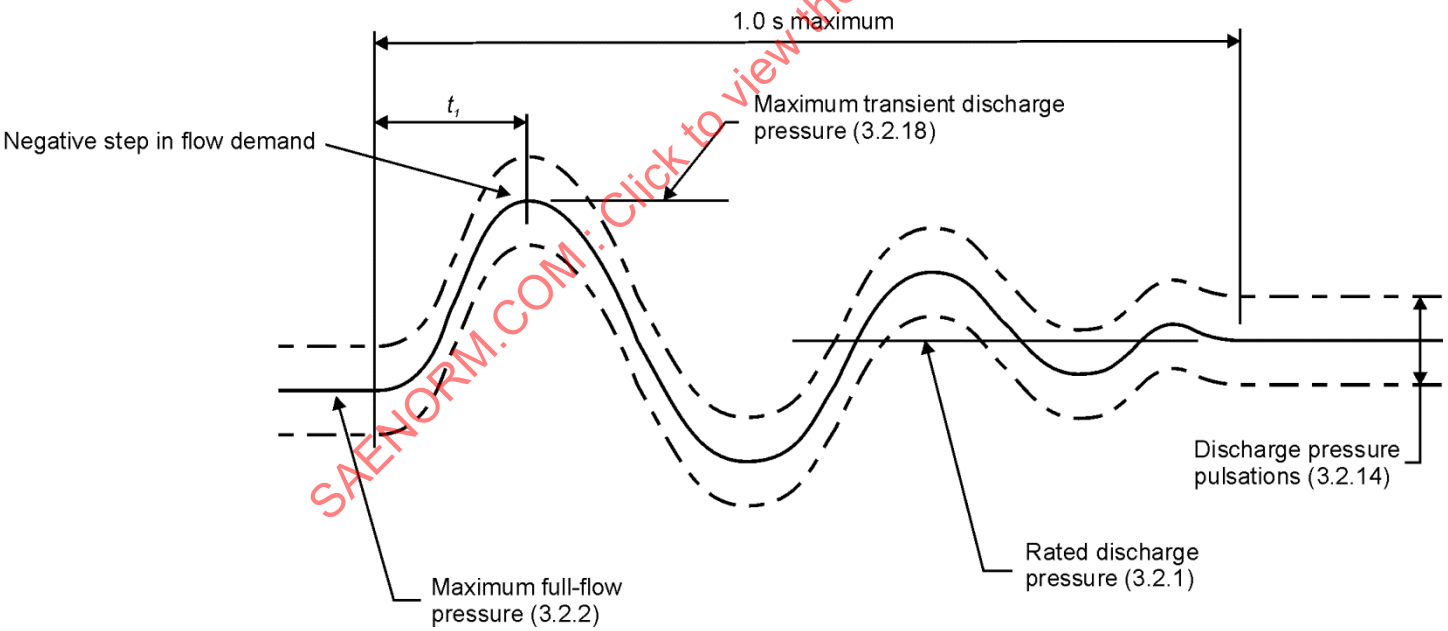

Figure 2 - Typical variation of discharge pressure against time - transient from maximum full-flow pressure to rated discharge pressure (zero-flow)

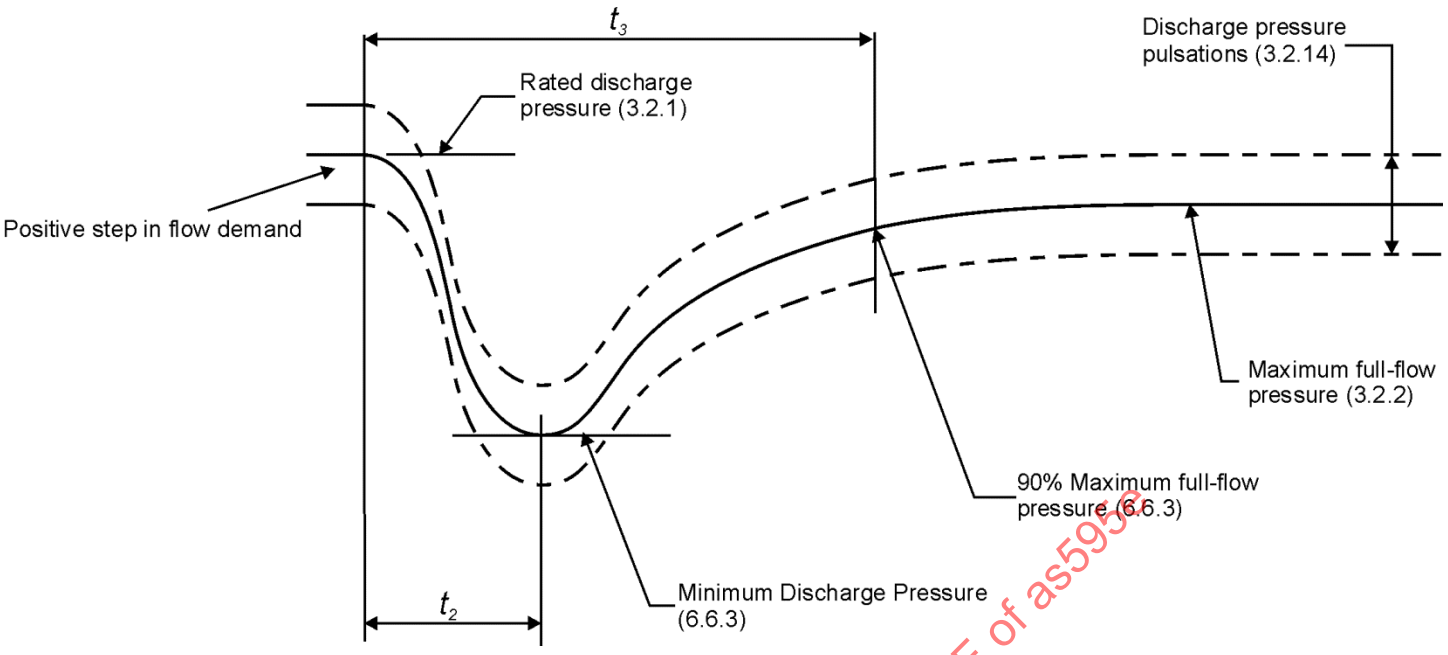

Figure 3 - Typical variation of discharge pressure against time - transient from rated discharge pressure (zero-flow) to maximum full-flow pressure

SCATTER FACTOR: This is the multiplication factor to be applied for hydraulic impulse fatigue testing when pressure impulse testing is conducted on one or more test specimens.

STABILITY: This is the freedom from persistent or quasi-persistent oscillation or “hunting” of the delivery control mechanism at any frequency that can be traced to the pump delivery control means, within stated limits in the procurement specification.

SOFT CUT-OFF PRESSURE COMPENSATED, VARIABLE DELIVERY HYDRAULIC PUMP: This is a pump that incorporates a control means to reduce the slope of the steady-state pressure/flow curve to achieve two objectives:

- Keep the maximum flow at the lower pressure
- Develop full pressure at reduced flow

SUPPLIER: This is the organization that has the responsibility for the design, production, and qualification of the pump. Normally, the purchaser would approve the supplier for the design, development, and manufacture of these pumps.

3. REQUIREMENTS

The purchaser shall prepare a procurement specification for each pump for which design approval is desired.

3.1 General

The requirements of AS4941 apply with the exceptions and additions specified herein. The procurement specification shall take precedence in the case of a conflict between the requirements of this standard and the procurement specification.

3.1.1 System Specification

The pump shall be designed for installation in hydraulic systems as defined in ARP4752, and as defined in the procurement specification.

3.1.2 System Characteristics

The procurement specification shall include the characteristics of the hydraulic system in which the pump is to be used.

3.1.3 Hydraulic Fluid

The procurement specification shall state the applicable hydraulic fluid.

3.1.3.1 Hydraulic Fluid Contamination

The procurement specification shall state the hydraulic fluid contamination limits per AS4059 for:

a. Aircraft at new build

b. In-service (typical and maximum)

3.1.4 Airworthiness Regulations

The hydraulic pump shall comply with Title 14 of the Code of Federal Regulations (14 CFR), Part 25 (for U.S. certified aircraft) or to EASA Certification Specifications (CS) (for European certified aircraft).

The sections in these regulations that apply to hydraulic pumps are as follows:

a. 25.581 - Lightning protection

b. 25.899 - Electrical bonding and protection against static electricity

c. 25.901(c) - Installation (regarding Sustained Engine Imbalance)

d. 25.1163 - Powerplant accessories

e. 25.1183 - Flammable fluid-carrying components

f. 25.1301(a), (b) - Function and installation

g. 25.1309(a) - Equipment, systems, and installations

h. 25.1435 - Hydraulic systems

i. CS25.1541 - Markings and placards, General

The impact of these requirements on the design, manufacture, and qualification of civil-type hydraulic pumps will be referred to in this document.

AS4941 covers the following airworthiness regulations, which also affect the design of civil hydraulic pumps:

a. 25.603 - Materials

b. 25.613 - Material strength properties and design values

c. 25.621 - Casting factors

3.1.5 Fluid Immersion Requirements

3.1.5.1 Electrical Components

If the pump contains electrical components which are in contact with the system hydraulic fluid (partially or completely), they shall conform to all the functional and performance requirements specified hereinafter being immersed in the applicable hydraulic fluid (see 3.1.3) for 72 hours at the rated hydraulic fluid temperature specified in 3.2.6.

3.1.5.2 Nonmetallic Parts

If the pump contains non-metallic parts other than standard seals in standard glands, it shall conform to all the functional and performance requirements specified hereinafter being immersed in the applicable hydraulic fluid (see 3.1.3) for 7 days at the rated hydraulic fluid temperature specified in 3.2.6.

3.2 Performance Requirements

3.2.1 Rated Discharge Pressure

The procurement specification shall state the value of the rated discharge pressure.

NOTE: The following nominal values of rated discharge pressure are commonly used:

a. 1500 psi (10345 kPa)

b. 3000 psi (20690 kPa)

c. 4000 psi (27586 kPa)

d. 5000 psi (34482 kPa)

The permissible tolerance range for the rated discharge pressure shall be ±50 psi (±345 kPa) unless otherwise specified in the procurement specification. This tolerance range shall be doubled for fluid temperatures below 100 °F (38 °C) or pump speeds from 25 to 50% of the rated speed.

The pump shall be able to maintain the rated discharge pressure, using the hydraulic fluid specified in the procurement specification, at the following range of conditions:

- From 20 °F (-7 °C) to the rated temperature
- From 50 to 100% of the rated speed
- At rated inlet pressure

3.2.2 Maximum Full-Flow Pressure

NOTE: This is p_M in Figure 1.

The maximum full-flow pressure shall be between 0 to 200 psi (0 to 1380 kPa) less than the rated discharge pressure (see Figure 1) unless otherwise specified in the procurement specification.

3.2.3 Inlet Pressures

3.2.3.1 General

The inlet pressure shall be measured at the inlet port of the pump in a manner that indicates the static head.

3.2.3.2 Rated Inlet Pressure

The procurement specification shall state the value of the rated inlet pressure, which shall be in psia or kPa absolute.

3.2.3.3 Minimum Inlet Pressure

The procurement specification shall state the value of the minimum inlet pressure, which shall be in psia or kPa absolute. In addition, the procurement specification shall state:

- If it applies during a short-term high flow condition or a steady-state failure condition
- The minimum hydraulic fluid temperature that is expected when the pump encounters the minimum inlet pressure

When specifying the minimum inlet pressure, the system designer should consider the inertial effects of the fluid in combination with the fastest permissible pump response rate (refer to AIR1922). Any allowable performance degradation when the pump operates at the minimum inlet pressure shall be stated in the procurement specification.

The procurement specification shall include the circuit impedance for the pump inlet and outlet piping system and/or a complete physical description of the circuit. This is to enable the purchaser to conduct a dynamic flow analysis to determine the pump operation at the minimum inlet pressure.

3.2.3.4 Maximum Inlet Pressure

The procurement specification shall state the value of the maximum steady-state inlet pressure, which shall be in psia or kPa absolute.

3.2.4 Case Drain Pressures

3.2.4.1 Rated Case Drain Pressure

The procurement specification shall state the value of the rated case drain pressure.

3.2.4.2 Maximum Transient Case Pressure

The procurement specification shall state the value, duration, and frequency of occurrence of the maximum transient case pressure.

3.2.4.3 Maximum Case Drain Pressure

The procurement specification shall state the value of the maximum case drain pressure.

3.2.5 Case Drain Flow

The procurement specification shall state that the pump shall be capable of producing sufficient case drain flow to limit the differential temperature between the inlet port and the case drain port to a stated maximum value.

This shall be under the following conditions:

a. Rated discharge pressure (zero delivery flow)

b. Rated temperature

c. Any speed between 50 to 100% of rated speed

d. A given maximum differential pressure between case pressure and inlet pressure

The minimum and maximum case drain flow shall be stated at conditions specified in the procurement specification.

The procurement specification shall state the minimum case flow if the case drain flow is routed to a system heat exchanger.

3.2.6 Rated Fluid Temperature

The procurement specification shall state the value of the rated fluid temperature.

3.2.7 Minimum Continuous Fluid Temperature

The procurement specification may state the value of the minimum continuous fluid temperature at the pump inlet port.

3.2.8 Thermal Shock

The hydraulic pump shall not malfunction if it is supplied with hydraulic fluid at the rated temperature when it is at a temperature of -65 °F (-54 °C) or a different low ambient temperature specified in the procurement specification.

3.2.9 Rated Output Flow

The procurement specification shall state the rated output flow of the pump, at the rated case drain pressure. The rated flow shall be expressed in gallons per minute (gpm) or liters per minute (l/min). The minimum and maximum rated flow (q_{n1} and q_{n2} in Figure 1) shall be specified.

NOTE: The maximum flow delivered by the pump at the maximum full-flow pressure will often exceed the rated flow of the pump, thereby providing a design margin against the rated requirements.

3.2.10 Rated Speed

The procurement specification shall state the rated speed of the pump. The rated speed shall be stated as revolutions per minute (rpm) of the pump drive shaft.

NOTES:

1. As an indication, the maximum recommended values are given in the nomographs in Figures 4A and 4B. If speeds are kept well below those indicated by the curves, the operating life may be improved; exceeding the recommended speeds may impact the reliability and life of the pump. However, several system factors such as fluid, temperature, duty cycle, contamination, expected life, etc., will also influence the values. AIR1922 lists some of these influencing factors and their effects.

2. Care shall be taken in the determination of the rated speed to ensure that it is not exceeded over the aircraft operating conditions. For example, for an engine-driven pump, there may be situations when a combination of factors results in the pump running at speeds greater than 100% of its normal running speed.

3.2.10.1 Overspeed

The pump shall be capable of operation at 115% of the rated speed for 100 hours unless otherwise specified in the procurement specification.

3.2.11 Rated Endurance

The pump shall complete the endurance test specified in 6.9 without the replacement of functional components including the shaft seal.

NOTE: The endurance test includes a test to determine if the pump is affected by the ingestion of air in the inlet line.

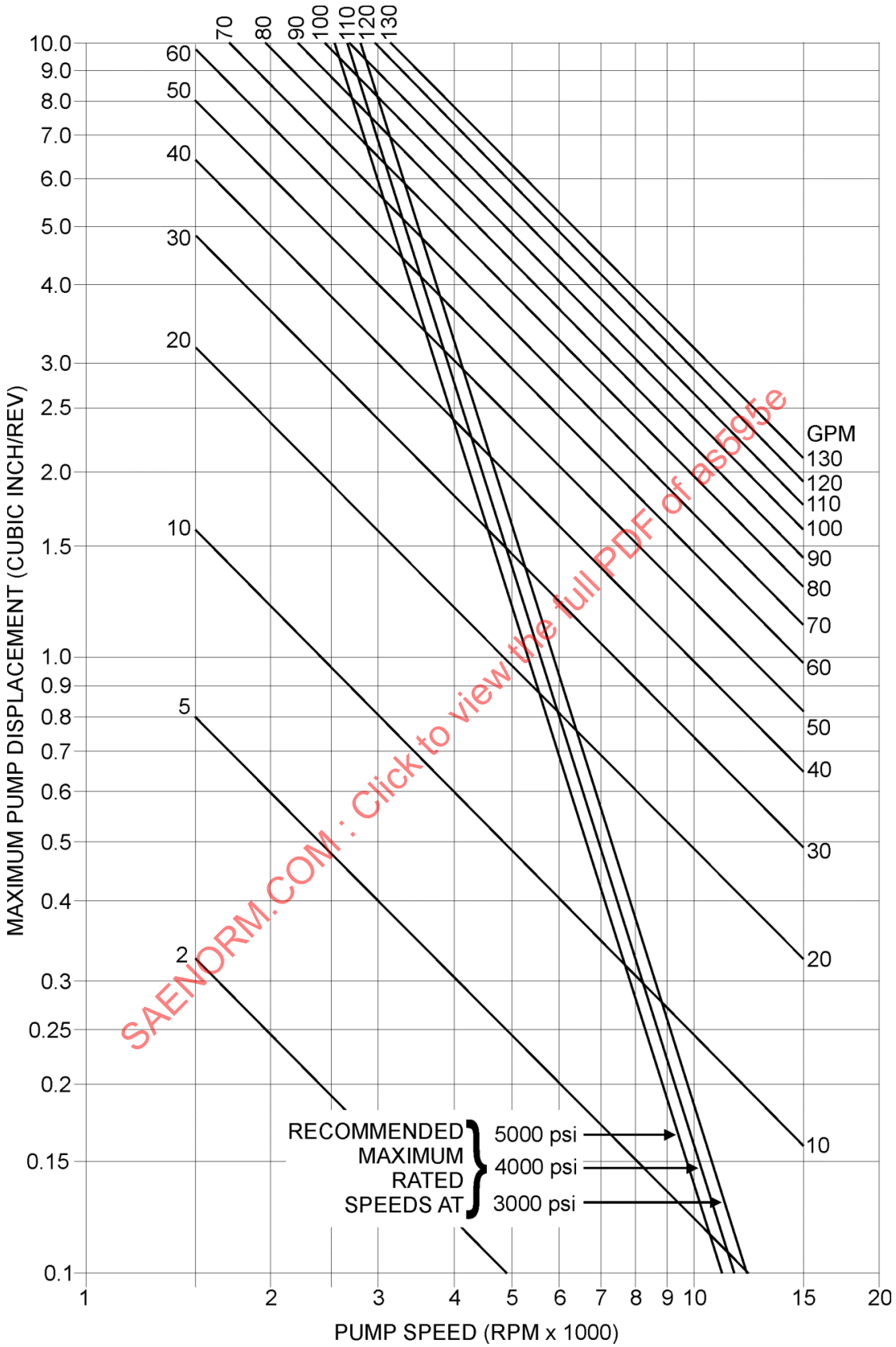

Figure 4A - Nomograph of maximum recommended values for rated speeds against pump displacement (U.S. English units)

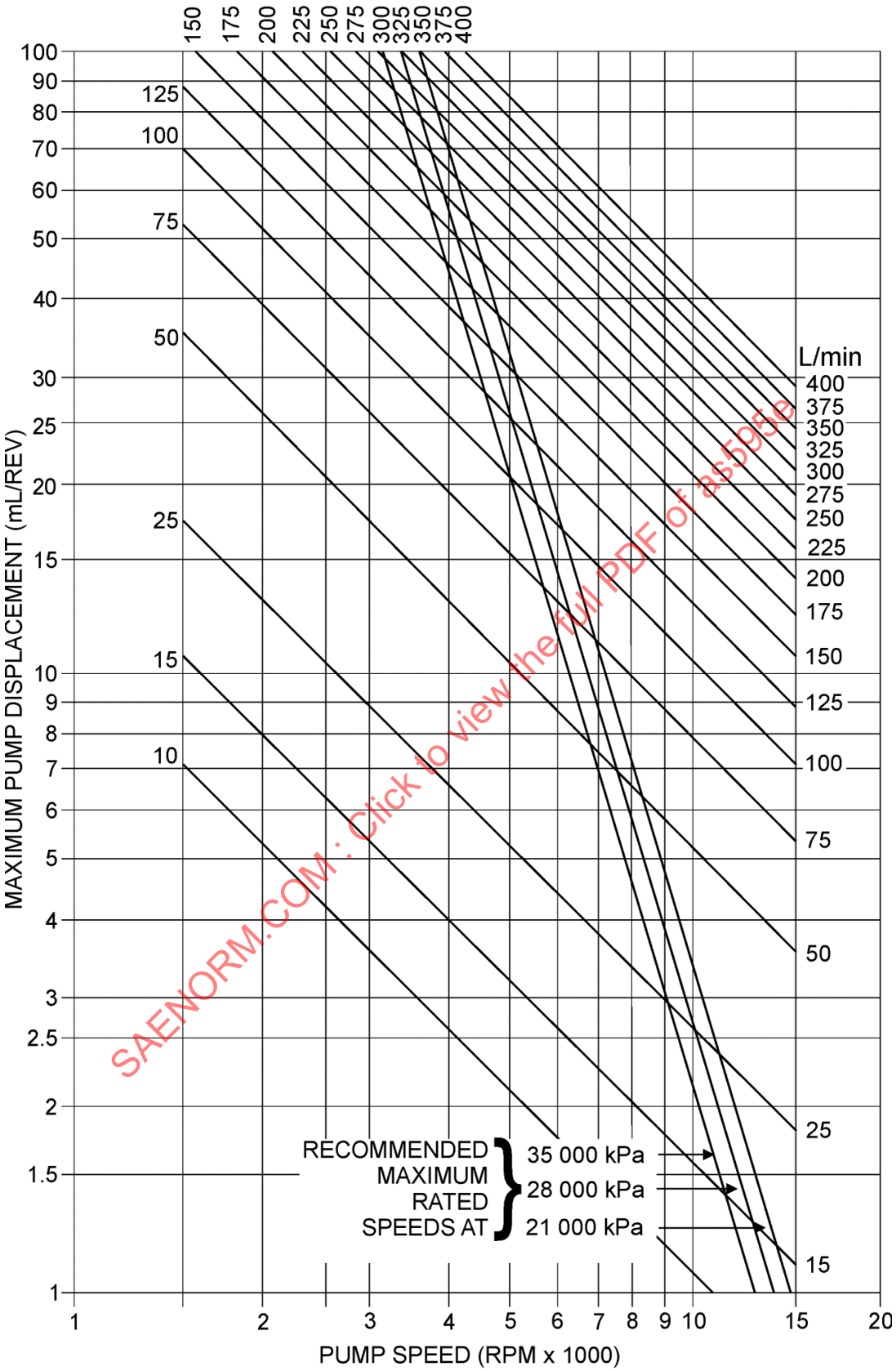

Figure 4B - Nomograph of maximum recommended values for rated speeds against pump displacement (metric units)

3.2.12 Torque and Heat Rejection

The procurement specification shall state:

a. The maximum value of input torque or power for rated flow and temperature conditions for the pump

b. The maximum value of heat rejection, or input torque, when the pump is operated at zero flow, at rated temperature, and rated speed

3.2.13 Pump Overall Efficiency

The procurement specification may require a target pump overall efficiency for a new pump about to be delivered to the purchaser and a degradation limit in the efficiency as an objective at the end of the qualification endurance test.

NOTES:

1. The pump overall efficiency is obtained from Equation 1:

$$\text{Pump overall efficiency (\%)} = (\text{Output fluid power}/\text{Input shaft power}) \times 100 \quad \text{(Eq. 1)}$$

where:

Input shaft power = shaft torque x shaft speed

Output fluid power = ΔP x Rated flow

where:

ΔP = The pump pressure rise (i.e., Full-flow pressure - Inlet pressure)

a. The dimensional constants for English and metric units are not invoked.

b. If this equation is to be used, the flow rate measurement shall be made on the compressed flow stream.

2. If the flow rate measurement is to be measured when the flow stream is uncompressed, the following equation shall be used:

$$\text{Output fluid power} = \Delta P \times \text{Expanded flow rate} \times (1 - [\Delta P/B]) \quad \text{(Eq. 2)}$$

where:

B = The effective adiabatic bulk modulus, determined with the pressure equal to the average of the pump inlet and outlet pressures

3.2.14 Discharge Pressure Pulsations

The procurement specification shall state the maximum permitted amplitude of the discharge pressure pulsations.

The amplitude of pressure pulsations shall be determined by the test procedure of 6.6.4.

3.2.15 Variable Delivery Control

The delivery control means shall act to vary the delivery of the pump from zero to its maximum full-flow pressure value and vice versa. This shall be for any given operating speed as the discharge pressure is reduced from rated discharge pressure to maximum full-flow pressure and vice versa.

3.2.16 Response Time

The procurement specification should specify the appropriate response time (t_1 and t_2 in Figures 2 and 3 which are the response times of the pump as a function of the system impedance) that best meets the overall hydraulic system needs.

In the absence of a response time that is defined in the procurement specification, the response time, t_1, in a circuit producing a maximum pressure rise rate of at least 50000 psi/s (345000 kPa/s) when the pump flow is suddenly stopped from the rated flow condition may be used to quantify the pump response characteristics that are independent of the actual system. In a circuit whose system impedance produces the above rise rate, the maximum pump response time (t_1) shall be 0.050 second when operating at rated inlet temperature and rated speed.

NOTES:

1. An arbitrary selection of response time, without performing the appropriate system analysis, can result in less than optimum performance and life of both the hydraulic pump and the hydraulic system.

2. The procurement specification may state the minimum and maximum response time for the pump to decrease the flow from full flow to zero (t_1), and a separate minimum and maximum response time for the pump to increase the flow from zero to full flow (t_2).

3. Refer to AIR1922 for recommended inlet pressure and response time.

The real-time plot of discharge pressure against time shall be used as the criterion of movement of the delivery control mechanism. All pump models shall have a maximum response time when:

a. Operating at rated inlet temperature

b. At rated speed

c. In a circuit with the system impedance defined in 6.6.1

3.2.17 Stability

The real-time plot of discharge pressure against time shall be used as the criterion of stability.

All pump models shall recover steady-state operation (other than permissible pressure pulsations as specified in 3.2.14) within not more than 1.0 second after the initial response to a change in flow demand. This shall occur for:

a. Any operating condition within the limits stated in the procurement specification

b. Any speed greater than 50% of the rated speed, or the speed corresponding to ground idle on a cold day if the pump is an engine-driven pump

When required by the procurement specification, the pump manufacturer shall provide an adequate description of the pump dynamic performance to permit the system designer to integrate pump dynamic performance into his complete pump/system analysis.

3.2.18 Maximum Transient Discharge Pressure

The value of the maximum transient discharge pressure shall not exceed:

a. 1000 psi (6897 kPa) psi above the rated discharge pressure, as determined in the maximum pressure test specified in 6.6.2, or

b. 125% of the rated discharge pressure, or

c. The maximum pressure specified in the procurement specification

3.3 Functional Requirements

3.3.1 External Leakage

There shall be no external leakage allowed under any combination of environments specified herein except that the shaft seal may leak at a rate not to exceed 12 drops per hour, or as stipulated in the procurement specification.

NOTE: Any evidence of wetness sufficient to form a drop should be considered leakage.

3.3.2 Depressurization

If it is required by the procurement specification that the pump be depressurized either automatically or remotely (for example, using an electrical signal), the depressurization control shall not, when de-energized, interfere with the normal operation of the variable delivery control.

The procurement specification shall state:

a. If a blocking valve is also to be fitted in the pump discharge port to isolate the pump from the system when the pump is depressurized

b. The performance requirements for the pump when it is depressurized, for example:

    - The low output pressure, or
    - The low input torque, or
    - The low output pressure and the low torque

c. The acceptance and qualification tests for the depressurization control

d. The maximum and minimum operating pressure when full-flow depressurization is required

e. The duty cycle of the depressurizing device including:

    - The number of applications
    - The percentage of the flight time when the pump is depressurized

If the depressurization is controlled by a solenoid valve, then the procurement specification shall define the following requirements:

a. The response time of the valve

b. The electrical requirements including:

    - The resistance
    - The rated current
    - The dielectric strength
    - The bonding requirement
    - The voltage range for activation, for example, 18 to 28 VDC

- The minimum drop-out voltage
- The maximum allowed voltage peak at deactivation

c. The electrical connector definition

3.3.3 Balance

The moving parts of the hydraulic pump shall be inherently balanced, and the pump shall not vibrate in such a manner as to cause the failure of any part in the pump or drive mechanism at speeds up to the overspeed value specified in 3.2.10.1.

3.3.4 Adjustment

Means shall be provided to adjust the delivery control mechanism to cause zero flow to occur at rated discharge pressure. This adjustment shall, preferably, be continuous or it is acceptable for it to be in steps of less than 1% of the rated discharge pressure over a minimum range from 95 to 105% of the rated pressure.

The adjustment device shall be capable of being securely locked and it shall be possible to carry out adjustment and locking using only standard hand tools. Where practicable, the adjustment device shall be fitted in such a way that adjustments can be made while operating under full system pressure with negligible loss of fluid.

3.4 Strength Requirements

The procurement specification for the pump shall state the design operating pressure for the inlet, delivery, and case pressure parts of the pump.

3.4.1 Proof and Ultimate Pressure Requirements

3.4.1.1 Proof Pressure Requirements

The pump shall withstand the proof pressure (the design operating pressure multiplied by 1.5) for a minimum of 2 minutes without permanent deformation that would prevent it from performing its intended functions. This is to comply with 14 CFR 25/CS-25.1435(a)(1) regulations.

3.4.1.2 Ultimate Pressure Requirements

The pump shall withstand the ultimate pressure (the design operating pressure multiplied by 2.0) for a minimum of 1 minute without rupture. This is to comply with 14 CFR 25/CS-25.1435(a)(1) regulations.

3.4.2 Fatigue Requirements

The pump shall withstand the fatigue effects of all cyclic pressures, including transients and externally induced loads, taking into consequence the effect of pump failure. This is to comply with 14 CFR 25/CS-25.1435(a)(4) regulations.

The procurement specification shall state:

- The overall predicted duty cycle for the outlet, inlet, and case parts of the pump, throughout the lifetime of its application
- The overall predicted duty cycle for the external drive shaft load throughout the lifetime of its application

NOTE The supplier shall ensure that the fatigue loads for those parts of the pump that are directly connected to the drive shaft, as well as the drive shaft, will not cause a life limitation.

- The scatter factor that is to be applied for analysis or fatigue (pressure impulse) testing

An example of the scatter factor that could be applied is provided in Table 1.

Table 1 – Scatter factor example

No of Test Specimens	Factor to be Applied for One Component Life
1	6
2	5.2
3	4.5
4	4.1
5	3.75
6	3.45

In addition, when defining the duty cycle for impulse testing, the following should be considered:

a. The pressure variations due to the pump pulsation levels

b. The peak transient pressure generated by the pump as it reacts to changes in flow demands

NOTE: The test pressure cycles to be used are:

a. Basic pressure cycles:

- Case port - 0 to rated case drain pressure - 0 psi (kPa)
- Outlet port - 0 to rated discharge pressure - 0 psi (kPa)
- Inlet port - 0 to maximum inlet pressure - 0 psi (kPa)

b. Transient pressure cycles*: Nominal pressure** - peak transient pressure spike - nominal pressure

* To be applied at the inlet and outlet ports.

** Nominal pressure for the outlet port is the rated discharge pressure; nominal pressure for the inlet port is the hydraulic reservoir pressure (i.e., no flow being supplied by the pump).

3.4.3 Vibration

Pumps shall be capable of withstanding vibrations excited by the driving means. All pumps shall be designed to withstand the applicable vibration levels as stated in RTCA/DO-160 unless otherwise specified in the procurement specification. In addition, the vibrational effects of engine windmilling with an engine fan blade out and a tire burst shall be considered.

For design and test purposes, torsional vibration excited by the driving means shall be considered negligible. As part of the qualification tests, all pump models shall be subjected to the vibration tests specified in 6.14.

3.4.4 Operational Shocks and Crash Safety

Per AS4941 requirements.

In addition, an engine-driven pump shall be designed to withstand the effects of a fan blade out. The procurement specification shall state the acceleration levels and the time durations.

3.4.5 Acceleration Forces

The pump shall be designed to withstand the steady-state acceleration forces levels per MIL-STD-810.

3.4.6 Handling Loads

Per AS4941 requirements.

3.5 Environmental Requirements

All pumps shall be designed to operate under the environmental conditions specified below for the design life of the pump without any impairment of function or change in adjustment.

Except as specifically directed herein, testing to demonstrate compliance with these requirements shall not be mandatory.

3.5.1 Altitude

Provided that the inlet and case drain pressures are maintained per 3.2.3 and 3.2.4, respectively, pump performance shall not be affected by a change of altitude from sea level to the maximum specified altitude or vice versa.

3.5.2 Ambient and Pad Temperatures

It shall be assumed that the ambient temperature surrounding the pump shall be such that no heat is transferred to or from the pump, except by normal circulation of the working fluid, unless otherwise specified in the procurement specification.

3.5.3 Other Environmental Conditions

The pump shall be designed to comply with the following sections of RTCA/DO-160 unless otherwise specified in the procurement specification:

a. Fluids susceptibility: The procurement specification shall state the relevant fluids that have to be considered

b. Salt spray: This requirement only applies if the pump is mounted in an unpressurized part of the aircraft and is defined as Category S

c. Water resistance: The procurement specification shall state the applicable Category for the pump

d. Sand and dust

e. Humidity: The procurement specification shall specify the applicable category

f. Fungus resistance: The procurement specification shall specify the applicable category

g. Icing: If a solenoid depressurization valve is used to control the pump, the procurement specification shall specify the applicable Category and the number of icing cycles

Tests shall be carried out to show compliance with the salt spray, sand and dust, and icing (if applicable) requirements. Compliance with the other requirements can be demonstrated by design analysis.

If a solenoid depressurization valve is used to control the pump, then compliance with electromagnetic interference (EMI) requirements, as specified in the procurement specification, shall also apply.

3.5.4 Fire Resistance

The hydraulic pump shall be fire-resistant if it is installed in an area that is subjected to engine fire conditions (that is, an engine-driven pump). This is to obtain compliance with the 14 CFR 25/CS-25.1183 regulation.

The procurement specification shall state the running speed of the pump, and the flow through the pump that will occur during engine fire conditions. This is to enable the necessary precautions to be incorporated into the pump design for the pump to be shown to fully comply with this requirement.

3.5.5 Sonic Fatigue

The pump shall not be adversely affected or shall not prematurely fail due to external noises, as stated in the procurement specification.

3.5.6 Acoustic Noise

The pump shall not generate acoustic noise greater than that stated in the procurement specification.

The procurement specification shall define the measurement conditions.

3.6 Installation Requirements

3.6.1 Dimensions

Dimensions pertinent to the installation of pumps in aircraft shall be specified on the supplier's installation drawing and in the procurement specification.

3.6.2 Weight

The dry weight of the completely assembled pump shall be stated on the supplier's installation drawing.

The supplier should also provide an estimate of the weight of fluid in a filled pump so that the weight of the pump as installed in the aircraft can be determined.

3.6.3 Mounting

The procurement specification shall state the flange design.

3.6.3.1 Orientation

The case drain port of the pump should be located at or near the top of the pump as it is installed on its drive pad. The shaft drain port should be located at or near the base of the pump as it is installed on its drive pad. The reorientation of the pump due to aircraft attitude shall not affect pump operation.

3.6.3.2 Direction of Rotation

The direction of rotation of the pump shall be clearly and permanently marked on an exposed surface of the pump housing.

3.6.4 Drive Coupling

The drive coupling shall be a replaceable part of the pump assembly and shall incorporate a shear section as a means to comply with 14 CFR 25/CS-25.1163(c) regulation. The drive coupling shall only fail at its shear section. The drive coupling shall be held in place in the pump by a positive retainer.

The procurement specification shall state the interface between the coupling and the driver, including the coupling spline lubrication at the engine accessory gearbox end or the non-metallic insert in the gearbox.

3.6.4.1 Drive Coupling Materials

The material that is chosen for the drive coupling, and the parts of the pump that interface with the drive coupling, shall have excellent wear resistance properties.

Consideration shall be given to the use of non-metallic spline inserts in the pump and at the pump/gearbox interface (if the gearbox does not already incorporate a non-metallic insert) to achieve the required wear resistance requirements. However, care must be taken in the design and installation of the non-metallic inserts to prevent their premature failure.

3.6.5 Ports

NOTE: Care shall be taken in the selection of the port sizes to prevent any possibility of incorrectly installing hoses and/or pipes onto the pump.

3.6.5.1 Pump Outlet Port

Unless otherwise specified in the procurement specification, the pump outlet port shall be as follows:

- For pumps with rated discharge pressure up to 3000 psi (20690 kPa), they shall be per AS1300 or AS5202
- For pumps with rated discharge pressure greater than 3000 psi (20690 kPa), they shall be per AS1300

3.6.5.2 Pump Inlet and Case Drain Ports

Unless otherwise specified in the procurement specification, the pump inlet and case port shall be per AS1300 or AS5202.

3.6.5.3 Pump Shaft Seal Port

Unless otherwise specified in the procurement specification, the pump shaft seal port shall be per AS5202.

The size of the pump shaft seal port shall cater for a total loss of the pump shaft seal. This is because if the port is too small, the build-up pressure in the pump/accessory drive interface when the shaft seal has failed can lead to pressure build and the subsequent entering of hydraulic fluid into the auxiliary gearbox.

3.6.5.4 Maximum Wrenching Torque

If hoses and/or tubes are directly installed onto the pump without using quick-disconnect couplings, then the pump shall withstand 250% of the maximum wrench torque required for making the tubing connection, as specified in the procurement specification, without any permanent deformation of the pump (in particular the area around the connection ports) or impairment of function.

3.6.5.5 Port Markings

The inlet, outlet, case drain, and shaft drain ports shall be identified on each pump by clear and permanent markings.

3.7 Construction

3.7.1 Safety Wire Sealing

Lead-type safety wire sealing shall not be used.

3.7.2 Directionally Critical Components

Wherever practical, internal parts that are subject to malfunction or failure due to reverse installation or out of true position shall have mechanical provisions to ensure that they cannot be installed or assembled incorrectly.

3.7.3 Pump Dry Running

No elements of the pump shall exit the envelope of the pump if the supply of hydraulic fluid to the pump is zero, or less than the volume the pump displaces, for any duration up to the maximum flight time. The procurement specification shall state the time and the running speed when the pump will be running under these conditions.

3.7.4 Materials

Per AS4941 requirements.

3.7.4.1 Metals

Per AS4941 requirements.

3.7.5 Corrosion Protection

Per AS4941 requirements.

3.7.6 Castings

Per AS4941 requirements.

3.7.7 Reclaimed Materials

Per AS4941 requirements.

3.7.8 Seals

Per AS4941 requirements, except that the external seals shall have a minimum cross-section of 0.103 inches (nominal) or larger.

3.7.9 Standard Parts

Per AS4941 requirements.

3.8 Detail Requirements

3.8.1 Marking

3.8.1.1 Identification of the Product

The pump must be marked for identification per standard practices (refer to ARP1288) and the purchaser's requirements, as a means of compliance with the 14 CFR 25/CS-25.1301 regulation.

3.8.1.2 Nameplate

Unless otherwise specified in procurement specification, a nameplate containing the following information (see Figure 5) legibly filled in shall be securely attached to the pump. The information shall be marked in the spaces provided.

PUMP, HYDRAULIC, VARIABLE DELIVERY, AIRCRAFT
Procurement Specification No._____ Mfrs. part No.*_____ Mfrs. name or trademark_____ Serial number_____ Fluid_____

* (or identification)

Figure 5 - Nameplate data

The following in Figure 6 shall be provided if required by the procurement specification:

Rating:	
Delivery _____	gpm*
Pressure_____	psi+
Speed _____	rpm

*(or l/min; +(or kPa)

Figure 6 - Additional nameplate data

The procurement specification shall state any other additional required nameplate data and if an amendment label is required.

The color of the nameplate shall be purple and aluminum for pumps designed for AS1241 hydraulic fluids. The color of the nameplate shall be black and aluminum for pumps designed for MIL-PRF-5606, MIL-PRF-83282, or MIL-PRF-87257 fluids.

3.8.1.3 Amendment Label

The procurement specification shall state if an amendment label is required.

3.8.2 Electro-Conductive Bonding

The 14 CFR 25/CS-25.581 regulations require that the aircraft must be protected against the catastrophic effects of lightning. The 14 CFR 25/CS-25.899 regulations require protection against the buildup of static electricity. To comply with these regulations, the hydraulic pump must have a facility to enable it to be effectively bonded to the airframe. The procurement specification shall state the bonding requirements.

3.9 Design and Construction

Per AS4941 requirements.

3.10 Maintainability

Per AS4941 requirements.

3.11 Reliability Requirements

Per AS4941 requirements.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

Per AS4941 requirements.

4.2 Classification of Tests

Per AS4941 requirements.

4.3 Test Stand Requirements

The following tolerance limits are set for the required steady-state operating conditions for the test stands that are employed for the acceptance tests and the qualification tests unless otherwise agreed to between the supplier and the purchaser:

a. Inlet pressure: ±2% of rated inlet pressure, but not less than ±5 psi (±34 kPa)

b. Case pressure: ±2% of rated case pressure, but not less than ±15 psi (±103 kPa)

c. Delivery pressure: ±2% of rated delivery pressure, but not less than ±30 psi (±207 kPa)

d. Inlet temperature: -70 to 110 °F, within ±5 °F (-57 to 43 °C, within ±3 °C); 110 to 225 °F, within ±10 °F (43 to 107 °C, within ±6 °C)

e. Pump shaft speed: within ±100 rpm

f. Flow: within ±2% of rated flow

g. Torque: ±2% of pump maximum input torque

The accuracy of the instrumentation shall be consistent with the measurement tolerances required.

NOTE: Care shall be taken to ensure that the peak values of the pressure pulses at delivery are accurately recorded. For example, if the pump is running at 4000 rpm and has nine pistons, then the fundamental frequency (f_0) = 600 Hz. If the detection of the magnitude with a sine pulse with 5% accuracy is required, then this requires 10 times more sampling, i.e., 6000 Hz.

Filtration requirements: Per AS4941 requirements, except for the qualification endurance testing (see 6.9).

5. ACCEPTANCE TESTS

Each hydraulic pump submitted for delivery under a procurement contract shall be subjected to the acceptance test requirements specified below. These shall consist of:

a. Visual and dimensional examinations

b. A test program to determine product conformance to the dimensional, workmanship, functional, and performance requirements of this standard and the procurement specification; the test program is specified in 5.2

5.1 Examination of the Product

The pump shall be examined to determine conformance with the applicable standards and all requirements of this standard and of the procurement specification, for which there are no specific tests.

5.2 Test Program and Inspection Methods

Throughout the test program, there shall be no external leakage sufficient to form a drop except that the shaft seal may leak at a rate not to exceed 12 drops per hour, or as stipulated in the procurement specification.

Starting with 5.2.2, the hydraulic fluid in the test circuit shall be as specified in the procurement specification. Filter elements as specified in the procurement specification shall be installed in the pump inlet, outlet, and case drain port lines of the test set-up. The rating of the filter elements shall be agreed upon between the purchaser and the supplier.

The supplier shall repeat the applicable parts of the conformance test procedure if, at any phase of testing, working parts require replacement. The break-in run portion may be omitted if the rotating group assembly was not affected.

5.2.1 Proof Pressure Tests

These tests may be conducted at normal operating temperature, either statically or with the pump in operation. There shall be no evidence of permanent deformation following the tests.

The outlet port shall be pressurized for at least 1 minute to the proof pressure stipulated in the procurement specification. With the outlet port at rated pressure, the case drain and inlet ports shall be pressurized for at least 1 minute to the proof pressures stipulated in the procurement specification.

NOTE: During this test, the shaft seal leakage may exceed the maximum allowable leakage for normal operation. If this does occur, it shall not be considered a test failure.

5.2.2 Break-in Run

The break-in run may be conducted at any desired operating conditions as deemed optimal by the supplier but must include at least 15 minutes of operation at rated speed and temperature while at maximum full-flow pressure.

5.2.3 Load Cycles

A step-function load shall be imposed causing the pump to cycle from rated discharge pressure (no flow) to maximum full-flow pressure at 6 cycles per minute for at least 15 minutes, or as specified in the procurement specification, with equal dwells at each load condition.

5.2.4 Teardown Inspection

A teardown inspection shall be conducted after completion of the proof, break-in, and cycling tests on a minimum of three pumps of a given model of an initial production run or as specified in the procurement specification. The pumps shall be disassembled and inspected; if all parts are in acceptable condition, the pump shall be reassembled, and the test program continued. The requirements of this paragraph may be omitted after the last pump has successfully passed the inspection.

The teardown inspection shall be reinstated whenever the following changes in a production program occur:

a. Continuity of manufacturing is interrupted; permissible periods of production interruption shall be designated in the procurement specification

b. Alternate tooling and production facilities are designated

The teardown inspection shall also be reinstated if a failure occurs during conformance testing, which:

- Upon inspection reveals visible damage to the pump, and
- May not, in all cases, be detected by measurable test parameters

5.2.5 Fluid Contamination Test

5.2.5.1 General

This test shall be conducted to prevent shipment of a functionally acceptable but materially deteriorating pump. The fluid from the pump case drain shall be checked for contamination as agreed to between the supplier and the purchaser.

5.2.5.2 Use of Inline Particle Counters

Ideally, inline particle counters should be used to check for an incipient pump failure by continuously monitoring the particle sizes and quantities. If there is a noticeable increase in the number of particles in the case drain line after the break-in run has been completed, then the pump should be stopped and removed for a teardown inspection.

5.2.5.3 Filter Patch Test

If inline particle counters are not available, then the use of filter patches to check for an incipient pump failure is an acceptable alternative means.

The operating time and duty shall be chosen such as to yield the most significant patch information for the particular pump model and shall be a permanent part of the acceptance test procedure along with the filter membrane specifics.

The procurement specification shall make provisions for the establishment of a preliminary patch standard before the start of the quality conformance tests of the first pump to be delivered under the contract. This preliminary patch standard may be modified by agreement of the contracting parties until the completion of the functional test of the 25th pump to be delivered under the contract, or as agreed between the purchaser and the supplier. Thereafter, the standard in effect for that test will become the standard for the remainder of the contract.

5.2.5.3.1 Filter Sampling Method

Check the fluid in the pump case drain filter bowl for contamination accumulated during the functional test performed per 5.2.2 and 5.2.3.

5.2.5.3.2 Patch Preparation

Collect the fluid in the filter bowl in a clean container. Rinse both the filter bowl and element with the appropriate volume of a suitable fluid solvent and add to the applicable container.

The total resulting fluid shall be passed through a membrane having a diameter of approximately 1.85 inches (47 mm), which will trap contaminants in each filter bowl. The procurement specification shall state the membrane material. Wash the membrane free of fluid with the appropriate volume of fluid solvent. After drying, the resultant filter patch shall be coated with a clear lacquer and permanently attached to the log sheet of the test.

All fluid solvents shall be filtered through a 0.45 µm pore size membrane before use in all stages of the patch preparation procedure.

5.2.5.3.3 Patch Comparison

Each filter patch specified in the acceptance test procedure shall be compared with the standard patch then in effect and any discrepancy noted in the test log.

If the contamination level exceeds that of the standard, the filter patch test may be repeated. The second patch shall show equal or less contaminant than the standard patch to be acceptable. If it does not, up to two additional patch tests may be run to establish the trend. If the patches remain unacceptable, the pump should be disassembled to determine the source of the contamination and corrective action taken.

5.2.6 Calibration

During the calibration tests, the test conditions shall be as specified in the procurement specification. Typically, these are:

- Rated inlet and case pressures
- Rated inlet fluid temperature or typical system fluid temperature
- Normal room ambient conditions

The pump shall be tested for at least the following characteristics and the results shall conform to the limits of the procurement specification:

a. Rated discharge pressure variation as the pump speed is varied from 50 to 100% of the rated speed

b. There shall be no indication of pressure control instability as the pump speed is varied from 50 to 100% of the rated speed through the flow range; the procurement specification shall define specific system conditions if any are required

c. The flow of the pump at the maximum full-flow pressure and the rated speed shall be measured and recorded; the flow may be measured on the low-pressure side of the discharge line provided adequate compensation is made for fluid compressibility when stating the value

d. The case drain flow at rated discharge pressure and rated speed shall be measured and recorded

e. The input torque at maximum full-flow pressure and/or at rated discharge pressure shall be measured if required by the procurement specification; this test need not be conducted if pump torque is not especially critical or there is no requirement for the pump overall efficiency in the application

f. The response time of the pump to provide the rated flow from zero flow and vice-versa with the pump running at the rated speed

5.2.7 Depressurization Valve Tests

If the pump has a depressurization means, then the following shall be checked:

a. When the depressurization means has activated, the output pressure and/or the input torque

b. The response time for the activation of the depressurization means

5.2.8 Electro-Conductive Bonding

Measure the electrical resistance between any point on the mounting flange face and specified points on the pump (for example, the pump inlet, case, delivery, and shaft seal connections). It shall not be greater than the value specified in the procurement specification.

5.3 Preparation for Shipment

Per AS4941 requirements.

5.4 Storage and Packing

Per AS4941 requirements.

6. QUALIFICATION TESTS

Qualification tests, to verify whether the pump design conforms to the requirements of this standard and the procurement specification, shall consist of the tests specified herein.

6.1 Qualification Procedure

6.1.1 Qualification by Similarity

Per AS4941 requirements.

6.1.2 Pump Qualification Test Report

Per AS4941 requirements.

6.2 Range of Qualification Tests

The qualification tests shall be conducted on pumps that are fully representative of the pumps to be manufactured.

The number of pumps to be used during the qualification testing shall be agreed upon between the supplier and the purchaser.

The qualification tests to be carried out are as follows:

a. Expanded envelope acceptance tests (see 6.3)

b. Fluid immersion test (see 6.4)

c. Flow rate and driving torque values (see 6.5.1)

d. Heat rejection test (see 6.5.2)

e. Maximum pressure test (see 6.6.2)

f. Determination of response time test (see 6.6.3)

g. Pressure pulsation test (see 6.6.4)

h. Minimum inlet pressure test (see 6.7)

i. Solenoid tests (see 6.8)

j. Endurance test (see 6.9)

k. Low temperature and thermal shock tests (see 6.10)

l. Other environmental tests (see 6.11)

m. Fire resistance test (see 6.12)

n. Proof pressure test (see 6.13.1)

o. Ultimate pressure test (see 6.13.2)

p. Fatigue test (see 6.13.3)

q. Vibration test (see 6.14)

r. Operational shocks test (see 6.15)

s. Steady-state acceleration test (see 6.16)

t. Handling loads test (see 6.17)

u. Wrench loads test (see 6.18)

x. Drive coupling shear test (see 6.19)

y. Any additional tests required by the procurement specification

6.3 Expanded Envelope Acceptance Tests

Those acceptance tests that are also part of the qualification test program shall be performed exactly as specified in 5.2, except that:

a. The pressure control test of 5.2.6 shall be extended to check the discharge pressure at cut-off, as well as the pump stability, throughout the complete fluid temperature and speed range, as specified in 3.2.1

NOTE: The low-temperature test is defined in 6.10.1.

b. The shaft seal leakage is allowed to degrade to a maximum of 2 mL/h, or as stipulated in the procurement specification. This shall be throughout the qualification program

6.4 Fluid Immersion Test

Per AS4941 requirements.

NOTE: The mating electrical connectors shall be installed before starting the test.

6.5 Calibration

6.5.1 Flow Rate and Input Torque Values

Install a load valve in the test circuit to set the flow for each test case.

Regulate the pressure at the pump inlet port to the rated inlet pressure at full-flow and rated speed conditions.

Determine the values of flow and input torque at 50%, 75%, 100%, and 110% of rated speed. At each of these speeds, make four sets of flow and torque recordings at 25%, 50%, 75%, and 100% of maximum full-flow pressure and rated discharge pressure and five equally spaced increments of flow between zero flow and the flow rate associated maximum full-flow pressure.

Perform calibrations at the rated inlet condition specified in 3.2.3 and 3.2.6, unless otherwise specified in the procurement specification. Flow measurements may be made in the line downstream of the load valve but shall be corrected for fluid compressibility.

6.5.2 Heat Rejection Test

6.5.2.1 Principle

The principle of this test is to enable the rate of heat rejection of the pump over the expected normal range of operating conditions to be calculated. The rate of heat rejection at specified conditions shall be equal to the difference between the input and output power of the pump at those conditions.

The output power may be calculated based on flow measurements in the low-pressure side of the discharge line, provided that adequate compensation is made for fluid compressibility when calculating the output power.

6.5.2.2 Determination of Heat Rejection

To determine the rate of heat rejection, run the pump at the rated speed, the rated inlet pressure, and the rated temperature, and measure the input and output power at:

a. The rated discharge pressure

b. The maximum full-flow pressure

c. At least two additional flow points between these values

The procurement specification shall state any additional requirements, should it be desired to determine the rate of heat rejection at operating conditions other than these. The procurement specification shall state the maximum acceptable value of heat rejection rate, in British thermal units per minute (Btu/min) or kilowatts (kW), at specified operating conditions.

6.6 Maximum Pressure, Response Time, and Pressure Pulsation Tests

Pressure transducers and recording equipment shall be used to provide a permanent record of the dynamic pressure/time history of the pressure/time function of the pump and its hydraulic circuit throughout the transient and steady-state periods described in the following three tests.

The pressure transducers and recording equipment shall be capable of static calibration with repeatable accuracy of 5% of rated pressure and readability of 3% of rated pressure over a frequency range of zero to five times the pump piston fundamental frequency. An essential consideration is that the dynamic calibration of the pick-up and recording equipment is valid for the dynamic conditions. The pressure transducers shall be located in the pump discharge line as close to the pump outlet fitting as is physically possible. The pressure pulsations shall be measured with a pressure transducer with a volume of approximately zero relative to the test circuit volume and shall have a response rate and frequency range capability to allow pressure pulsations to be accurately measured over the pump operating speed. The tests shall be conducted at the rated conditions unless otherwise noted below or in the procurement specification.