

AEROSPACE-CIVIL TYPE VARIABLE DELIVERY HYDRAULIC PUMP

Foreword

Prior to starting the update of AS595 to the "B" revision two other aerospace hydraulic pump specifications namely MIL-P-19692 and ISO 8278, were reviewed to determine their applicability for commercial aircraft hydraulic systems. From the review it was concluded that neither MIL-P-19692 nor ISO 8278 fully met the requirements of commercial aircraft hydraulic systems designers because:

1. MIL-P-19692 is a specification for pumps used on military aircraft. It contains some requirements that are not applicable to commercial aircraft.
2. Only metric dimensions and standards are used in ISO 8278. However, commercial aircraft extensively utilize dimensions and standards which are based on English or American units.
3. Neither of the specifications refers to the airworthiness regulations that are applicable to commercial aircraft hydraulic pumps.

AS595B is technically and editorially equivalent to the other two specifications.

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SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

SAE AS595 Revision B

TABLE OF CONTENTS

Foreword	1
1. SCOPE.....	6
1.1 Purpose.....	6
1.2 Field of Application.....	6
2. REFERENCES.....	6
2.1 Applicable Documents	6
2.1.1 SAE Publications.....	6
2.1.2 FAR Publications from the FAA	7
2.1.3 NAS Standards	7
2.1.4 Radio Technical Commission for Aeronautics Documents	7
2.1.5 International Standards Organization Documents	7
2.1.6 Joint Aviation Authorities Committee Documents	7
2.1.7 U.S. Government Documents	7
2.2 Definitions	8
3. REQUIREMENTS	9
3.1 General	8
3.1.1 System Specification.....	9
3.1.2 System Characteristics	9
3.1.3 Airworthiness Requirements	9
3.2 Qualification	10
3.3 Functional Requirements	10
3.3.1 Hydraulic Fluid	10
3.3.2 Rated Discharge Pressure	10
3.3.3 Maximum Full-Flow Pressure.....	12
3.3.4 Inlet Pressures	12
3.3.5 Case Drain Pressures	13
3.3.6 Case Drain Flow.....	13
3.3.7 Rated Temperature.....	13
3.3.8 Minimum Continuous Fluid Temperature	13
3.3.9 Maximum Displacement.....	13
3.3.10 Rated Flow	14
3.3.11 Rated Speed	14
3.3.12 Rated Endurance	14
3.3.13 Torque and Heat Rejection	17
3.3.14 Efficiency.....	17
3.3.15 Discharge Pressure Pulsations.....	17
3.3.16 Variable Delivery Control	17
3.3.17 Response Time	17
3.3.18 Stability.....	20

SAE AS595 Revision B

TABLE OF CONTENTS (Continued)

3.3.19	Maximum Transient Pressure	20
3.3.20	Depressurization	20
3.3.21	Balance	20
3.3.22	Adjustment	21
3.3.23	Safety Wire Sealing.....	21
3.3.24	Directionally Critical Components	21
3.4	Environmental Requirements.....	21
3.4.1	Altitude	21
3.4.2	Ambient and Pad temperatures	21
3.4.3	Vibration	21
3.4.4	Operational Shocks and Crash Safety	21
3.4.5	Other Environmental Conditions	22
3.4.6	Fire Resistance	22
3.4.7	Sonic Fatigue	22
3.4.8	Sonic Effect.....	22
3.5	Installation Requirements.....	22
3.5.1	Dimensions	22
3.5.2	Weight.....	22
3.5.3	Mounting	23
3.5.4	Drive Coupling.....	23
3.5.5	Ports.....	23
3.6	Detail Requirements.....	23
3.6.1	Materials.....	23
3.6.2	Corrosion Protection	24
3.6.3	Castings	24
3.6.4	Reclaimed Materials.....	25
3.6.5	Seals	25
3.6.6	Standard Parts	25
3.6.7	Marking	25
3.6.8	Electroconductive Bonding.....	26
3.7	Strength Requirements	26
3.7.1	Pressure Loads	26
3.7.2	Proof and Ultimate Pressure Requirements.....	27
3.7.3	Impulse (Fatigue) Requirements.....	27
3.8	Design and Construction.....	28
3.8.1	Lubrication.....	28
3.8.2	External Leakage	28
3.8.3	External Tube Connections.....	28
3.8.4	Interchangeability	28
3.9	Maintainability	28
3.9.1	Maintenance Concept	28
3.9.2	Useful Life and Storage Conditions.....	28
3.9.3	Maintainability Features	28
3.10	Reliability Requirements	29
3.10.1	Mean Time Before Unscheduled Removals.....	29
3.10.2	Data Requirements	29

SAE AS595 Revision B

TABLE OF CONTENTS (Continued)

4.	QUALITY ASSURANCE PROVISIONS	29
4.1	Responsibility for Inspection	29
4.2	Classification of Tests	29
4.3	Test Stand Requirements	30
5.	ACCEPTANCE TESTS	30
5.1	Examination of the Product	30
5.2	Test Program and Inspection Methods	30
5.2.1	Proof Pressure Tests	31
5.2.2	Break-In Run	31
5.2.3	Load Cycles	31
5.2.4	Teardown Inspection	31
5.2.5	Filter Patch Test	32
5.2.6	Calibration	32
5.2.7	Electroconductive Bonding	33
5.3	Preparation for Shipment	33
5.4	Storage and Packing	33
6.	QUALIFICATION TESTS	33
6.1	Qualification Procedure	33
6.1.1	Qualification By Similarity	33
6.1.2	Pump Qualification Test Report	34
6.2	Range of Qualification Tests	34
6.3	Acceptance Tests	34
6.4	Fluid Immersion Test	35
6.5	Dimensional Check	35
6.6	Calibration	35
6.6.1	Pump Inlet Pressurized	35
6.6.2	Minimum Operating Speed	35
6.6.3	Flow Rate and Driving Torque Values	35
6.7	Maximum Pressure, Response Time and Pressure Pulsation Tests	35
6.7.1	System Impedance	36
6.7.2	Maximum Pressure Test	36
6.7.3	Determination of Response Time	37
6.7.4	Pressure Pulsation Test	38
6.8	Heat Rejection Test	38
6.8.1	Principle	38
6.8.2	Determination of Heat Rejection	38
6.9	Vibration Tests	38
6.9.1	Mounting of the Test Pump	38
6.9.2	Resonant Frequency Vibration Test	39
6.9.3	Cyclic Frequency Vibration Test	39

SAE AS595 Revision B

TABLE OF CONTENTS (Continued)

6.9.4	Other Vibration Tests	39
6.10	Low Temperature and Thermal Shock Test.....	39
6.10.1	Thermal Shock	40
6.11	Endurance Testing	40
6.11.1	Fluid for Endurance Test.....	40
6.11.2	Filtration for Endurance Test.....	41
6.11.3	Filter Check	41
6.11.4	Calibration	41
6.11.5	Start-Stop Cycles	41
6.11.6	Air Injection	41
6.11.7	Failure of Parts.....	42
6.11.8	Teardown Inspection.....	42
6.12	Cavitation Test	42
6.13	Drive Coupling Shear Test.....	42
6.14	Fire Resistance Test - Engine Driven Pump Only.....	42
6.15	Structural Tests	43
6.15.1	Proof Pressure Test	43
6.15.2	Ultimate Pressure Test.....	43
6.15.3	Pressure Impulse Test	43
6.16	Environmental Tests	43
7.	NOTES	43
7.1	Key Words.....	43
FIGURE 1 - Pressure/Delivery Characteristics Curves of Pumps		11
FIGURE 2a - Nomograph of Maximum Recommended Values for Rated Speeds Against Pump Displacement (American Units)		15
FIGURE 2b - Nomograph of Maximum Recommended Values for Rated Speeds Against Pump Displacement (Metric Units)		16
FIGURE 3 - Typical Variation of Pressure Against Time - Transient from Maximum Full-Flow Pressure to Rated Discharge Pressure (Zero Flow)		18
FIGURE 4 - Typical Variation of Pressure Against Time - Transient from Rated Discharge Pressure to Maximum Full-Flow Pressure		19
FIGURE 5		26
FIGURE 6		26
TABLE 1 - Metallic Coatings		24
TABLE 2 - Endurance Test Conditions		40

SAE AS595 Revision B

1. SCOPE:

This SAE Aerospace Standard (AS) establishes the general requirements for pressure compensated, variable delivery hydraulic pumps, suitable for use in commercial aircraft hydraulic systems.

This document shall be used in conjunction with the procurement specification for each pump model.

1.1 Purpose:

The purpose of this document is to provide in one document, the requirements for the design, construction, acceptance and qualification testing of civil type variable delivery hydraulic pumps. In addition, the parameters which must be specified in the procurement specification for each pump model are also identified.

1.2 Field of Application:

This document applies to hydraulic pumps which are fitted to commercial transport aircraft hydraulic systems that are designed to comply with FAR and/or JAR 25 regulations.

Although the document is primarily for pumps that are driven by an engine via an accessory gearbox, the document can, in general terms, be also applied to pumps that are driven by other means such as electric motors, ram air turbines, and engine bleed air turbines.

2. REFERENCES:

2.1 Applicable Documents:

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

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS568	Aerospace Size Standard for O-rings
ARP819	Fluid System Characteristics Affecting Hydraulic Pump Operation
AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
ARP1288	Placarding of Aircraft Hydraulic Equipment to Identify Phosphate-Ester Fluid Compatibility
ARP1383	Impulse Testing of Hydraulic Actuators, Valves, Pressure Containers and Similar Fluid System Components
AIR1922	System Integration Factors that Affect Hydraulic Pump Life

SAE AS595 Revision B

2.1.1 (Continued):

- AS4059 Aerospace Cleanliness Classification for Hydraulic Fluids
- AS4716 Gland Design, O-ring and Other Elastomeric Seals
- ARP4752 Design and Installation of Commercial Transport Aircraft Hydraulic Systems

- AMS 2402 Plating - Zinc

2.1.2 FAR Publications from the FAA: Available from the Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAR Part 25 Code of Federal Regulations, 14 CFR1.1, Part 25 Airworthiness Standards, Transport Category Airplanes

2.1.3 NAS Standards: Available from Aerospace Industries Association, 1250 Eye Street NW, Washington, DC 20005.

- NAS 1613 Packing, Preformed, O-ring, Ethylene Propylene Rubber
- NAS 1638 Cleanliness of Parts Used in Hydraulic Systems

2.1.4 Radio Technical Commission for Aeronautics Documents: Available from RTCA Secretariat, Suite 500, 1425 K Street, N.W., Washington, DC 20005.

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

2.1.5 International Standards Organization Documents: Available from American National Standards Institute, 1430 Broadway, New York, NY 10018.

- ISO 2685 Environmental Test Conditions for Airborne Equipment - Resistance to Fire in Designated Fire Zones
- ISO 8278 Hydraulic, Pressure Compensated, Variable Delivery Pumps - General Requirements

2.1.6 Joint Aviation Authorities Committee Documents: Available from Civil Aviation Authority, Printing and Publications Services, Grenville House, Cheltenham, Glos. GL50 2BN, United Kingdom.

JAR 25 Joint airworthiness requirements, large aeroplanes

2.1.7 U.S. Government Documents: Available from DODSSP, Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

- AND 10260 Flange - Type X Accessory Mounting
- AND 10261 Flange - Type XI Accessory Mounting
- AND 10262 Flange - Type XII Accessory Mounting
- AND 10263 Flange - Type XIII Accessory Mounting
- AND 10264 Flange - Type XIV Accessory Mounting
- AND 10265 Flange - Type XV Accessory Mounting

SAE AS595 Revision B

2.1.7 (Continued):

AND 10266	Flange - Type XVI Accessory Mounting
AND 10267	Flange - Type XVII Accessory Mounting
AND 10268	Flange - Type XVIII Accessory Mounting
AND 10269	Flange - Type XIX Accessory Mounting
QQ-C-320	Chromium Plating (Electrodeposited)
QQ-N-290	Nickel Plating (Electrodeposited)
QQ-P-416	Plating Cadmium (Electrodeposited)
QQ-S-365	Silver Plating, Electrodeposited; General Requirements for
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-H-5606	Hydraulic Fluid, Petroleum Base; Aircraft, Missile and Ordnance
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-H-8775	Hydraulic System Components, Aircraft and Missiles, General Specification for
MIL-R-8791/1	Retainer, Packing, Hydraulic and Pneumatic, Tetrafluoroethylene Resin
MIL-T-10727	Tin Plating; Electrodeposited or Hot Dipped, for Ferrous and Non-Ferrous Metals
MIL-P-19692	Pumps, Hydraulic, Variable, General Specification for
MIL-C-26074	Coating, Electroless Nickel, Requirements for
MIL-R-83248	Fluorocarbon - 75 Durometer
MIL-H-83282	Hydraulic Fluid, Fire Resistance Synthetic Hydrocarbon Base, Aircraft
MIL-P-83461	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved, Performance at 275 °F
MIL-R-83485	Rubber Fluorocarbon Elastomer, Improved Performance at Elevated Temperatures
MIL-STD-276	Impregnation of Porous Non-Ferrous Metal Castings
MS3330	Flange Accessory, 2,653 B.C. Square, Design Standard for
MS3331	Flange Accessory, 5,000 B.C. Square, Design Standard for
MS3332	Flange Accessory, 5,000 B.C. Round, Design Standard for
MS3334	Flange Accessory, 10,000 B.C. Round, Design Standard for
MS21344	Fitting, Installation of Flared Tube, Straight Threaded Connectors, Design Standard for
MS27595	Retainer, Packing Backup, Continuous Ring, Tetrafluoroethylene
MS33514	Fitting End, Standard Dimensions for Flareless Tube Connection and Gasket Seal
MS33515	Fitting End, Standard Dimensions for Bulkhead Flareless Tube Connections
MS33566	Fitting, Installation of Flareless Tube, Straight Threaded Connectors
MS33649	Bosses, Fluid Connection - Internal Straight Thread

2.2 Definitions:

PURCHASER: The purchaser is the organization that has the engineering responsibility for the hydraulic system that includes the pump. Typically, the purchaser is an aircraft manufacturer or a modification center. The purchaser is responsible for the compilation of the procurement specification.

SAE AS595 Revision B

2.2 (Continued):

PROCUREMENT SPECIFICATION: The procurement specification 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.

SUPPLIER: The supplier is the manufacturer of the hydraulic pump who will be responsible for the design, production, and qualification of the pump. The supplier shall be approved by the purchaser for the design, development and manufacture of aerospace hydraulic 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 MIL-H-8775 apply with the exceptions and additions specified herein. In the case of a conflict between the requirements of this standard and the procurement specification, the requirements of the procurement specification shall take precedence.

3.1.1 System Specification: The pump shall be designed for installation in hydraulic systems as defined in ARP4752.

3.1.2 System Characteristics: Using the guidelines of ARP819, the procurement specification shall include the characteristics of the hydraulic system in which the pump is to be used.

3.1.3 Airworthiness Requirements: The hydraulic pump shall comply with Federal Airworthiness Regulations (FAR), Part 25 (for US certified aircraft) or to Joint Airworthiness Requirements (JAR), Part 25 (for non-US certified aircraft). The sections in these regulations that are applicable to hydraulic pumps are as follows.

- a. 25.581 Lightning protection
- b. 25.603 Materials
- c. 25.613 Material strength properties and design values
- d. 25.621 Casting factors
- e. 25.1163 Powerplant accessories
- f. 25.1183 Flammable fluid-carrying components
- g. 25.1435 Hydraulic systems

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

SAE AS595 Revision B

3.2 Qualification:

Pumps furnished under this document shall be products which have passed the qualification tests as specified in the procurement specification.

3.3 Functional Requirements:

3.3.1 Hydraulic Fluid: The applicable hydraulic fluid shall be specified in the procurement specification.

It is assumed that civil type hydraulic pumps will generally use phosphate-ester based fluids per AS1241. However, for some applications (predominately small commercial aircraft), the pumps may use mineral based fluid as per MIL-H-5606 and/or synthetic based fluid per MIL-H-83282.

It must be noted that AS1241 fluids are not mixable or interchangeable with MIL-H-5606 or MIL-H-83282 fluids. In addition, the seals, bearing finishes and the pump timing used for AS1241 fluids are generally not compatible with the military specification fluids and vice versa.

Therefore, pumps that are designed and qualified for use with AS1241 fluids cannot use MIL-H-5606 or MIL-H-83282 fluids and vice versa.

3.3.2 Rated Discharge Pressure: This is the pressure which the pump is required to maintain at rated temperature, rated speed, rated inlet pressure and at zero flow (see Figure 1).

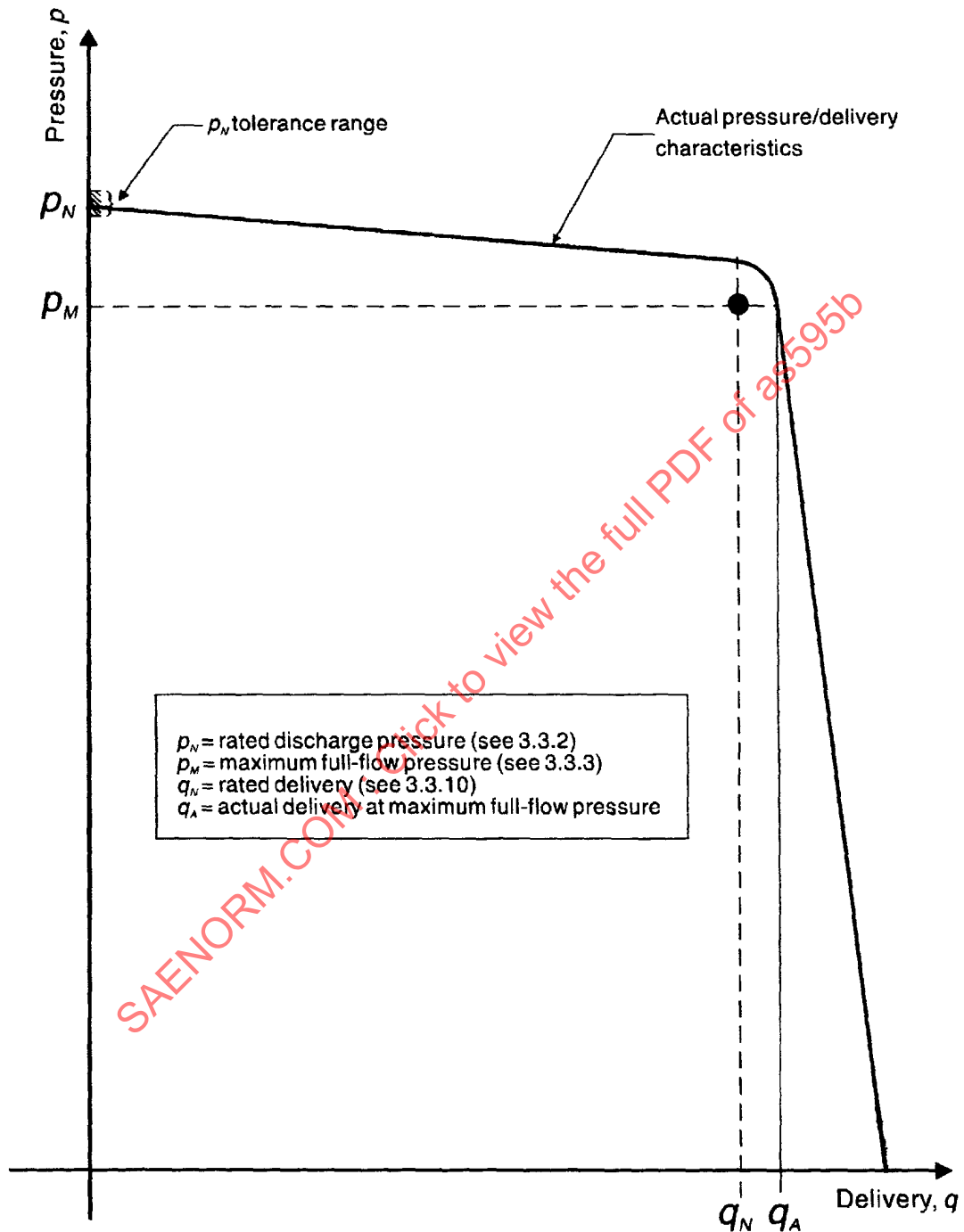
The design of the pump shall be such as to maintain rated discharge pressure, using the hydraulic fluid specified in the procurement specification, at the following range of conditions:

- a. From 100 °F (38 °C) to rated temperature
- b. From 50 to 100% of rated speed
- c. At rated inlet pressure

The value of the rated discharge pressure shall be stated in the procurement specification. The following nominal values of rated discharge pressure are commonly used:

- a. 1500 psi (10 345 kPa)
- b. 3000 psi (20 690 kPa);
- c. 4000 psi (27 586 kPa);
- d. 5000 psi (34 483 kPa).

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



NOTE: This diagram is given as an indication. It may be presented in a different way, for example, the axes may be reversed

FIGURE 1 - Pressure/Delivery Characteristics Curves of Pumps

SAE AS595 Revision B

3.3.3 Maximum Full-Flow Pressure: This is the maximum discharge pressure at which the pump control will not be acting to reduce pump delivery at rated temperature, speed and inlet pressure.

Its value shall be no less than 95% of the rated discharge pressure, unless otherwise specified in the procurement specification (see Figure 1).

3.3.4 Inlet Pressures:

3.3.4.1 Rated Inlet Pressure: This is the pressure at the inlet port of the pump when it is operating at rated speed, maximum full-flow pressure and rated temperature.

The value of the rated inlet pressure shall be stated in psia or kPa absolute and contained in the procurement specification.

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

3.3.4.2 Cavitation Pressure: This is the inlet pressure when the discharge flow is reduced by 2%, with the pump running at the following conditions and progressively reducing the inlet pressure:

- a. It is running at rated speed
- b. The inlet temperature is the rated temperature
- c. The pump is delivering 90% of maximum full-flow pressure

3.3.4.3 Minimum Inlet Pressure: This is the lowest inlet pressure at which the pump may be required to operate during a system failure or during a system high flow transient condition.

The procurement specification shall state a value of the minimum inlet pressure and whether it applies during a transient condition or during a steady state failure case. Although the aircraft system impedance may not be that specified in 6.7.1.1 (impedance of pump test circuit), it should be noted that:

- a. It is important to determine the pump response in the aircraft circuit;
- b. The hydraulic system should be designed such that the supply of fluid to the pump is able to respond as rapidly as the pump. Dynamic cavitation in the inlet sections of the pump will otherwise occur. AIR1922 should be used as a guide for the sizing of the inlet lines so that they match the response requirements for the pump in the circuit.

3.3.4.4 Maximum Inlet Pressure: This is the maximum steady state inlet pressure at which the pump may be required to operate. The value of the maximum inlet pressure shall be stated in the procurement specification.

SAE AS595 Revision B

3.3.5 Case Drain Pressures:

3.3.5.1 Rated Case Drain Pressure: This is the nominal pressure at the pump case port at which the pump is required to operate continuously in the system.

The value of the rated case drain pressure shall be stated in the procurement specification.

3.3.5.2 Case Drain Port Pressure: Unless a different value is specified in the procurement specification, all pumps shall be designed to withstand at least 300 000 pressure cycles of 0 to 150 to 0 psi (0 to 1034 to 0 kPa) at the case drain port without permanent damage or impairment of function.

3.3.5.3 Maximum Transient Case Pressure: This is the maximum pressure spike that may be imposed on the pump case drain port. The value, duration and frequency of occurrence of the maximum transient case pressure shall be stated in the procurement specification.

3.3.6 Case Drain Flow: The procurement specification shall specify that the pump shall be capable of producing at least a minimum case drain flow to sufficiently cool the pump under the following conditions:

- a. Rated discharge pressure (zero delivery flow)
- b. Rated inlet 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.

3.3.7 Rated Temperature: The rated temperature of a pump shall be the maximum continuous fluid temperature at the inlet port of the pump.

3.3.8 Minimum Continuous Fluid Temperature: A minimum continuous fluid temperature at the pump inlet port may be specified in the procurement specification.

3.3.9 Maximum Displacement: The maximum displacement of a pump is the maximum theoretical volume of hydraulic fluid delivered in one revolution of its drive shaft. It shall be expressed as cubic inches per revolution (in^3/rev) or milliliters per revolution (ml/rev).

The maximum displacement of any pump model shall be determined by calculations using the geometry and dimensions of the pump. The dimensions of the cylinder bore and maximum stroke shall be taken at their nominal values as stated on the pertinent drawings. The following effects shall be excluded from the calculation of the maximum displacement as it is intended to be an index of the pump size rather than of its performance:

SAE AS595 Revision B

3.3.9 (Continued):

- a. Allowable manufacturing tolerances
- b. Deflections of the pump structure
- c. Compressibility of the hydraulic fluid
- d. Internal leakage
- e. Temperature

3.3.10 Rated Flow: The rated flow of a pump shall be the measured output of the pump under conditions of rated temperature, rated speed, rated inlet pressure and maximum full-flow pressure, using the hydraulic fluid specified in the procurement specification. The rated flow shall be expressed in gallons per minute (gpm) or liters per minute (l/min) and its value specified in the procurement specification.

3.3.11 Rated Speed: The rated speed of a pump shall be established by the supplier. It shall be the maximum speed at which the pump is designed to operate continuously at rated temperature and at rated discharge pressure. The rated speed shall be stated as revolutions per minute (rpm) of the pump drive shaft.

The rated speed of any individual model pump shall be established in the procurement specification. As an indication, the maximum recommended values are given in the nomograph in Figure 2.

If speeds are kept well below those indicated by the curves, operating life expectancies will be substantially higher than otherwise can be expected. 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.

It should be noted that a pump should never be used at a sufficiently low running speed such that the bearing lubrication is in the boundary layer rather than being hydrodynamically balanced.

3.3.11.1 Overspeed: Unless stated otherwise in the procurement specification, the pump shall be capable of operation at 115% of rated speed for the durations and at the conditions of Table 2.

3.3.12 Rated Endurance: The rated endurance of a pump is the total number of hours and cycles of operation to be included in the endurance phase of its qualification testing (see 6.11). The pump shall complete the endurance test without the replacement of functional components including the shaft seal.

A pump used on commercial aircraft, using a realistic test sequence, shall have a life test of not less than 2000 h, unless otherwise specified in the procurement specification.

SAE AS595 Revision B

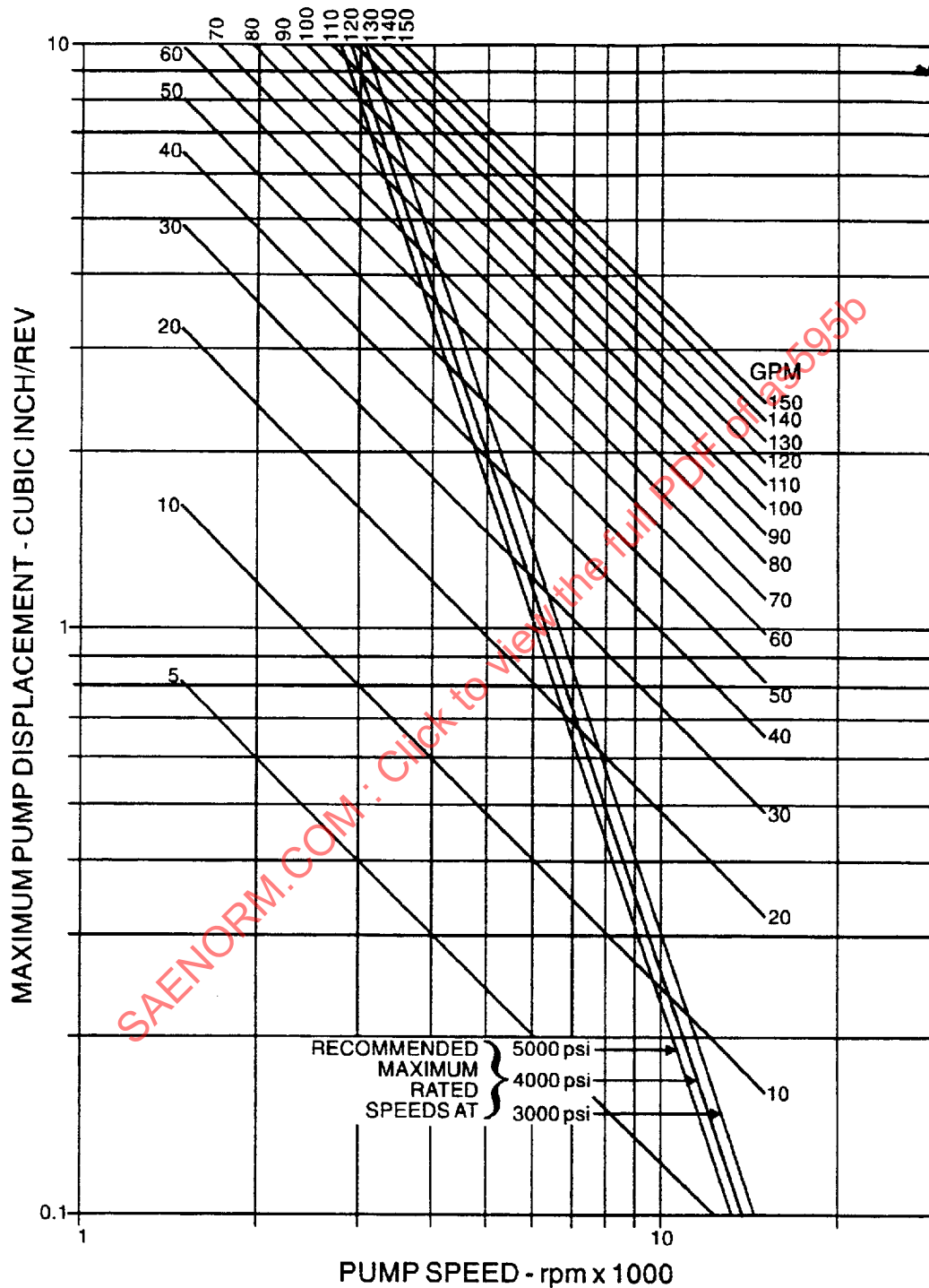


FIGURE 2A - Nomograph of Maximum Recommended Values for Rated Speeds Against Pump Displacement (American Units)

FIGURE 2 - Maximum Recommended Values

SAE AS595 Revision B

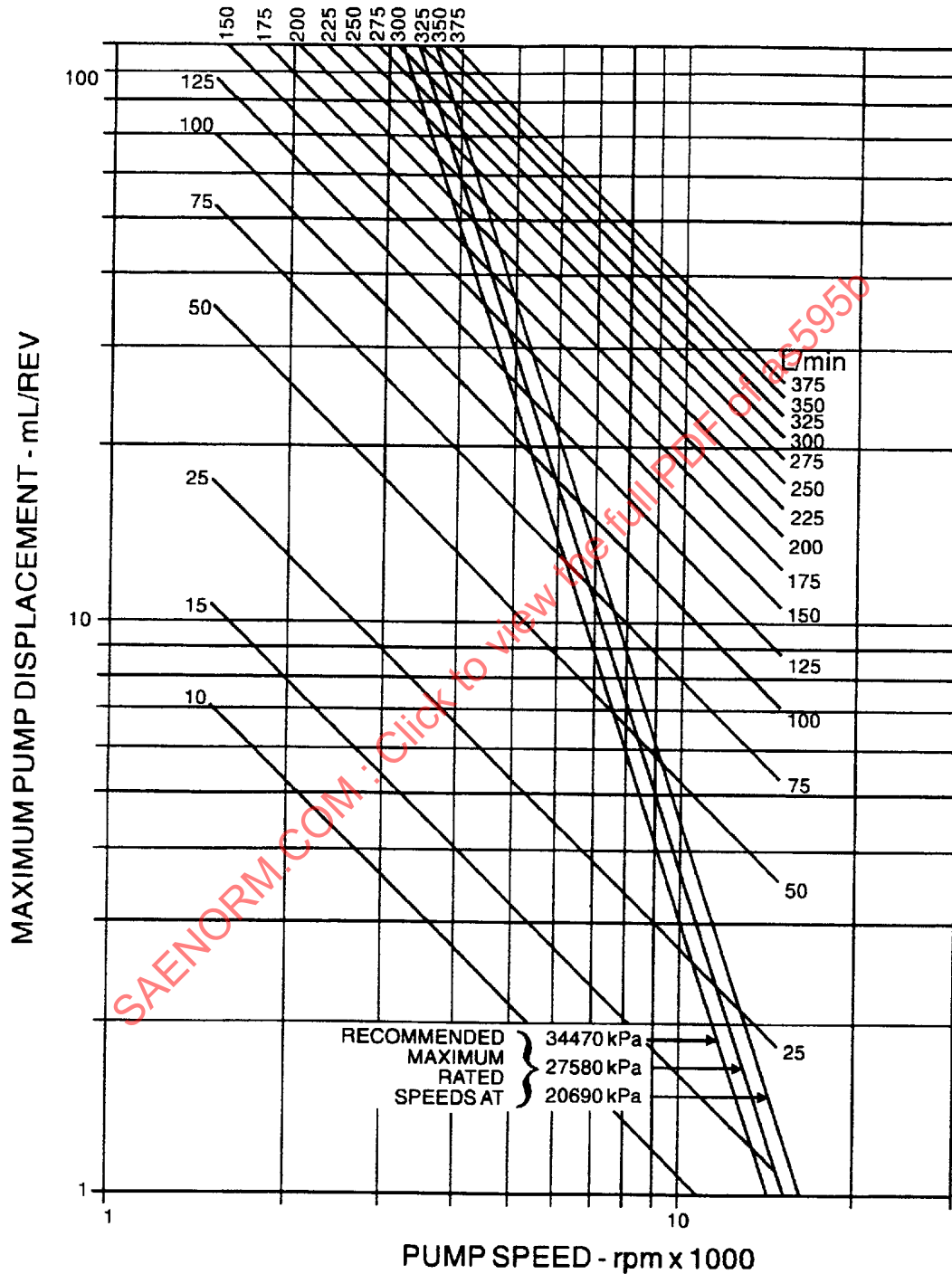


FIGURE 2B - Nomograph of Maximum Recommended Values for Rated Speeds Against Pump Displacement (Metric Units)

FIGURE 2 - (Continued)

SAE AS595 Revision B

3.3.13 Torque and Heat Rejection: The procurement specification shall specify:

- a. The maximum value of input torque 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 pressure, temperature and rotation speed

3.3.14 Efficiency: The efficiency of a pump is defined as the ratio of output power to input power when the pump is operated under rated conditions and at maximum full-flow pressure. It shall be stated as a percentage.

NOTE: The above ratio is commonly referred to as "overall efficiency" and includes volumetric efficiency.

When determining the output power by calculations of the flow rate and pressure change, only the net pressure difference between inlet and outlet ports of the pump shall be used. The flow rate may be as measured in the low pressure side of the discharge line, provided that the efficiency calculations compensate for fluid compressibility.

A target degradation limit in efficiency may be considered as an objective after the qualification endurance test.

3.3.15 Discharge Pressure Pulsations: Pressure pulsations are the oscillations of the discharge pressure, occurring during nominally steady operating conditions, at a frequency equal to or higher than the pump drive shaft speed.

JAR 25.1435(a)(4) requirements state that pulsations shall not exceed 10 percent of the rated discharge pressure. However, as a design objective, the pressure pulsation band should be held to approximately 5% in order to significantly improve the reliability of the hydraulic system.

The amplitude of pressure pulsations shall be determined by the test procedure of 6.7.4.

3.16 Variable Delivery Control: The delivery control means shall act to increase the delivery of the pump from zero to its maximum full-flow pressure value. 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.

3.3.17 Response Time: The response time of the pump shall be defined as the time interval between the moment when an increase (or decrease) in discharge pressure begins and the subsequent moment when the discharge pressure reaches its first maximum (or minimum) value. In Figures 3 and 4, the time intervals t_1 and t_2 are the response times of the pump as a function of the system impedance.

The oscillographic trace of discharge pressure against time shall be used as the criterion of movement of the delivery control mechanism. All pump models shall have a response time of 0.050 s maximum, unless otherwise specified in the procurement specification when:

SAE AS595 Revision B

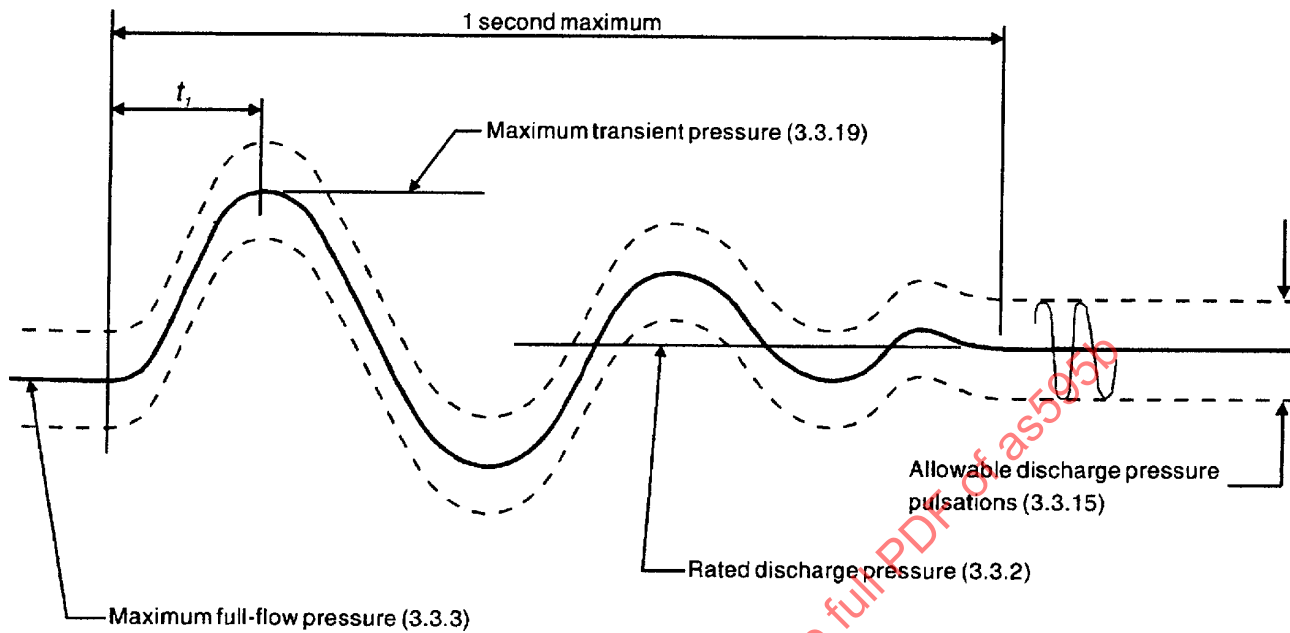


FIGURE 3 - Typical Variation of Pressure Against Time - Transient from Maximum Full-Flow Pressure to Rated Discharge Pressure (Zero Flow)

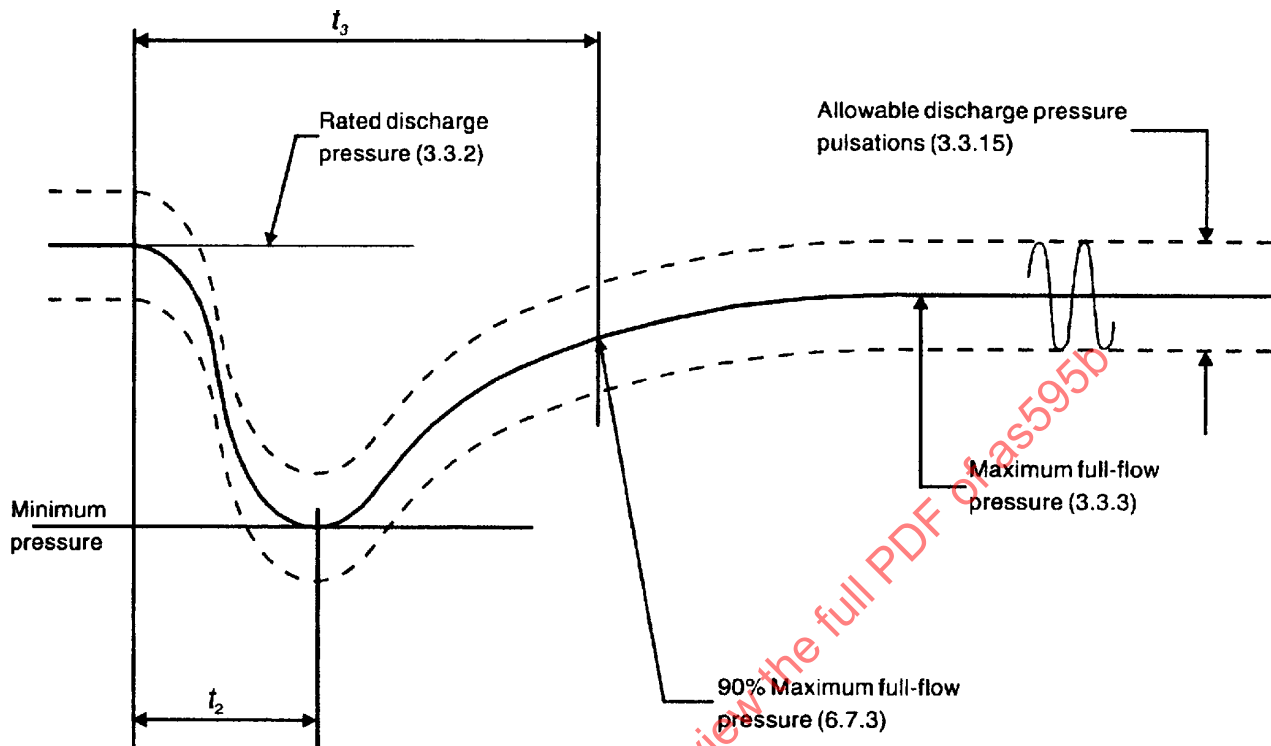


FIGURE 4 - Typical Variation of Pressure Against Time - Transient from Rated Discharge Pressure to Maximum Full-Flow Pressure

SAE AS595 Revision B

3.3.17 (Continued):

- a. Operating at rated inlet temperature
- b. At rated speed
- c. In a circuit, the system impedance of which is that defined in 6.7.1.1 for response tests

Refer to AIR1922 for inlet pressure requirements and response time.

3.3.18 Stability: The stability of the pump shall be 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. The oscillographic trace 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 3.3.15) within not more than 1.000 s 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

When required by the purchaser, the pump manufacturer shall provide adequate pump parameters to permit the system designer to integrate pump dynamic performance into his complete pump/system analysis.

3.3.19 Maximum Transient Pressure: The maximum transient pressure shall be defined as the peak value of the oscillographic trace of discharge pressure made during operation of the pump, as specified in 6.7.2 and measured as shown in Figure 3.

JAR 25.1435(a)(4) requirements state that the value of the maximum transient pressure, as determined in the transient pressure test specified in 6.7.2, shall not exceed 125% of the rated discharge pressure or the maximum pressure specified in the procurement specification.

3.3.20 Depressurization: If it is required by the procurement specification that the pump be depressurized either automatically or remotely, (for example, by means of 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 specify the qualification and inspection tests for the depressurization control. When full-flow depressurization is required, the procurement specification shall identify the maximum and minimum operating pressure.

3.3.21 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 failure of any part in the pump or drive mechanism at speeds up to 115% of rated speed.

SAE AS595 Revision B

- 3.3.22 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.

- 3.3.23 Safety Wire Sealing: Lead type safety wire sealing shall not be used.

- 3.3.24 Directionally Critical Components: Wherever practical, internal parts which 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.

3.4 Environmental Requirements:

All pumps shall be designed to operate under the environmental conditions specified below without:

- a. Any limitation as to time
- b. Any impairment of function or change in adjustment

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

- 3.4.1 Altitude: Provided that the inlet and case drain pressures are maintained in accordance with 3.3.4 and 3.3.5 respectively, pump performance shall not be affected by change of altitude from sea level to 60 000 ft (18 288 m) or vice versa.

- 3.4.2 Ambient and Pad Temperatures: Unless specified in the procurement specification, 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.

- 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 specified in the procurement specification.

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 6.9.

- 3.4.4 Operational Shocks and Crash Safety: All pumps shall be designed to withstand sustained accelerations in accordance with RTCA/DO-160 requirements unless specified in the procurement specification.

SAE AS595 Revision B

3.4.5 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 identify 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 determine the applicable Category for the pump
- d. Sand and dust

Tests shall be carried out to show compliance with the salt spray and sand and dust 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 stated in the procurement specification, shall also apply.

3.4.6 Fire Resistance: FAR/JAR 25.1183 and FAR/JAR 25.1435(c) requirements state that if the hydraulic pump is installed in an area which is subjected to engine fire conditions (that is, an engine driven pump), it must be fire resistant.

The procurement specification for the pump must 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 in order for the pump to be shown to fully comply with this requirement.

3.4.7 Sonic Fatigue: The pump shall not be adversely affected or prematurely failed due to external noises as defined in the procurement specification.

3.4.8 Sonic Effect: The pump shall not generate acoustic noise greater than that indicated in the procurement specification.

3.5 Installation Requirements:

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

3.5.2 Weight: The wet and dry weight of the completely assembled pump shall be stated on the installation drawing.

SAE AS595 Revision B

3.5.3 Mounting: Unless otherwise specified in the procurement specification, all pumps shall incorporate a standard mounting flange. This shall be in accordance with one of the following standards:

- a. MS3330 through MS3334; or
- b. AND10260 through AND10269.

3.5.3.1 Orientation: The case drain port of the pump shall be located at or near the top of the pump as it is installed on its drive pad. The shaft seal drain port shall 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.

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

3.5.4 Drive Coupling: The drive coupling shall be a replaceable part of the pump assembly and shall incorporate a shear section to comply with FAR/JAR 25.1163(c) and JAR 25.1435(a)(8) regulations. 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 interface between the coupling and the driver shall be as outlined in the procurement specification including the coupling spline lubrication at the engine accessory gearbox end or the nonmetallic insert in the gearbox.

3.5.5 Ports: The ports' configurations shall be in accordance with MS33649 unless otherwise specified in the procurement specification.

3.5.5.1 Structural Strength: The structural design of the ports and of the affected sections of the pump housing shall be such as to withstand the application of a torque 2.5 times the maximum value specified in MS21344 or MS33566, as applicable, without permanent distortion or impairment of function.

3.5.5.2 Port Markings: The inlet, outlet, case drain and seal drain ports shall be identified on each pump by clear and permanent markings.

3.6 Detail Requirements:

3.6.1 Materials: FAR/JAR 25.603 requirements state that the materials and processes used in the manufacture of these products shall be of high quality, suitable for the purpose and shall conform to applicable specifications. Materials conforming to the supplier's material specifications may be used, provided the specifications are acceptable to the purchaser and contain provisions for adequate tests.

The use of the supplier's specifications will not constitute the waiver of other applicable specifications. The choice of materials, and the assumed strength of the materials shall comply with FAR/JAR 25.613 regulations.

SAE AS595 Revision B

3.6.1.1 Metals: All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall possess adequate corrosion-resisting characteristics, or shall be suitably protected in accordance with 3.6.2. Magnesium shall not be used.

3.6.2 Corrosion Protection: Metals which do not inherently possess adequate corrosion-resisting characteristics shall be suitably protected, in accordance with the following subparagraphs, to resist corrosion which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high temperature deterioration as applicable.

3.6.2.1 Ferrous and Copper Alloys: Ferrous alloys requiring corrosion preventive treatment, and all copper alloys, except for parts having bearing surfaces, shall have a suitable electrodeposited metallic coating selected from Table 1.

Tin, cadmium, and zinc plating shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors and not where subject to abrasion. Where not indicated, class and type are at the option of the manufacturer.

TABLE 1 - Metallic Coatings

Material	Specification
Cadmium plating	QQ-P-416, Type II, Class 2
Zinc plating	AMS 2402
Chromium plating	QQ-C-320
Nickel plating	QQ-N-290
Silver plating	QQ-S-365
Tin plating	MIL-T-10727, Type I
Electroless nickel	MIL-C-26074

Other metallic or nonmetallic coatings or treatments, the use of which has been demonstrated to be satisfactory to the purchaser (such as electrodeposited 85% tin, 15% cadmium alloy) may be used.

3.6.2.2 Aluminum Alloys: Unless otherwise authorized, all aluminum alloys shall be anodized in accordance with MIL-A-8625, except that in the absence of abrasive conditions they may be coated with chemical film in accordance with MIL-C-5541. The exceptions noted will be subject to the approval of the purchaser.

3.6.3 Castings: Castings shall be of high quality, clean, sound, and free from cracks, blow holes, and excessive porosity and other defects. Defects not materially affecting the suitability of the castings may be repaired at the foundry or during machining by peening, impregnation, welding, or other methods acceptable to the purchaser. Inspection and repair of castings shall be governed by quality control techniques and standards satisfactory to the purchaser.

SAE AS595 Revision B

3.6.3 (Continued):

When impregnation castings are used, they shall be in accordance with impregnation procedures and inspection requirements of MIL-STD-276.

The casting factors assumed in the design of the hydraulic pump shall comply with FAR/JAR 25.621 regulations.

3.6.4 Reclaimed Materials: Reclaimed materials shall be utilized to the maximum extent possible within the quality limits required by this specification.

3.6.5 Seals:

3.6.5.1 Packings: Wherever possible, O-rings shall conform to aerospace dimensional standards such as AS568, and glands to AS4716.

Sealing elastomer material shall conform to NAS1613 in all pumps designed for use with fluids per AS1241.

Pumps designed for operation in fluids per MIL-H-5606 or MIL-H-83282 shall use nitrile sealing elastomers conforming to MIL-P-83461 or fluorocarbon elastomers conforming to MIL-R-83248 or MIL-R-83485. Fluorocarbon material is often preferred if system fluid temperatures are expected to exceed 160 °F (71 °C). Of the two materials in this category, MIL-R-83485 is rated for a wider temperature range.

3.6.5.2 Backup Rings: Backup rings should conform to MIL-R-8791/1 or MS27595. Nonstandard seals necessary to demonstrate compliance with the requirements of this specification may be used, subject to the approval of the purchaser.

3.6.6 Standard Parts: Aerospace standard parts (Military or Commercial) shall be used whenever they are suitable for the purpose, and shall be identified on the drawings by their standard part identifying numbers.

3.6.7 Marking:

3.6.7.1 Identification of the Product: FAR/JAR 25.1301 requirements state that the pump must be marked for identification in accordance with standard practices (refer to ARP 1288) and the purchaser's requirements.

3.6.7.2 Nameplate: 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.

SAE AS595 Revision B

PUMP, HYDRAULIC, VARIABLE DELIVERY, AIRCRAFT
Procurement Specification No. _____
Mfrs. part No.* _____
Mfrs. name or trademark _____
Serial number _____
Fluid _____

*(or identification)

FIGURE 5

The following in figure 6 is to be provided if required by the procurement specification:

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

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

FIGURE 6

Any additional nameplate data required shall be specified in the procurement specification.

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

3.6.8 Electroconductive Bonding: FAR/JAR 25.581 requirement states that the aircraft must be protected against catastrophic requirements from lightning. In order to comply with this regulation, the hydraulic pump must have a facility to enable it to be effectively bonded to the airframe. The resistance measured shall not exceed 300 milliohms unless otherwise specified in the procurement specification.

3.7 Strength Requirements:

3.7.1 Pressure Loads: FAR 25.1435(a)(1) requires the pump to be designed to withstand the design operating pressure loads in combination with limit structural loads which may be imposed. No permanent or temporary deformation of the pump is permitted under these conditions that would prevent it from performing its intended function.

SAE AS595 Revision B

3.7.1 (Continued):

The design operating pressure is defined in FAR 25.1435(a)(1) regulations as the maximum normal operating pressure, excluding any transient pressures. The equivalent JAR 25.1435(a)(1) requirement is identical to the FAR 25 regulation except that "working pressure" is used instead of "design operating pressure". The working pressure is equivalent to the maximum steady state pressure of the of the system.

The procurement specification for the pump shall define the design operating pressure or working pressure (as applicable) for the suction, delivery and case pressure parts of the pump. In addition, the procurement specification for the pump shall define the limit structural load if applicable.

3.7.2 Proof and Ultimate Pressure Requirements:

3.7.2.1 Proof Pressure Requirements: The FAR 25.1435(a)(1), JAR 25.1435(a)(2) requirements state that the pump withstand without rupture the design operating pressure or working pressure loads multiplied by 1.5 in combination with ultimate structural loads that can reasonably occur simultaneously. In addition, the JAR 25.1435(a)(10) requirement (no equivalent FAR 25 regulation) states that the pump must withstand the loads due to the working pressure multiplied by 1.5, without leakage or permanent distortion.

3.7.2.2 Ultimate Pressure Requirements: The JAR 25.1435(a)(10) requirements state that the pump must withstand the loads due to the working pressure multiplied by 2.0, without rupture.

For applications that are required to comply with FAR 25 regulations, there is not a formal ultimate pressure requirement. However, the procurement specification may stipulate a value that matches system requirements.

3.7.3 Impulse (Fatigue) Requirements: The JAR 25.1435(a)(11) requirement states that an adequate allowance must be made for fatigue for any part of the hydraulic system which is subject to fluctuating or repeated external or internal loads. Although there is no equivalent FAR 25 regulation, the procurement specification for the pump shall state:

- a. An overall predicted duty cycle for the delivery (high pressure), suction and case ports of the pump, throughout the lifetime of its application;
- b. The scatter factor that is to be applied for analysis or fatigue (pressure impulse) testing.

In addition, when defining the duty cycle for the 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.

SAE AS595 Revision B

3.8 Design and Construction:

- 3.8.1 Lubrication: Except for the coupling shaft spline, the hydraulic pump shall be self-lubricated with no provisions for lubrication other than the circulating fluid.
- 3.8.2 External Leakage: External leakage from the pump housing or from any static seal thereof of sufficient magnitude to form a drop shall not be permitted except at the drive shaft seal, where the rates of leakage under specified operating conditions shall not exceed the values specified in 5.2.
- 3.8.3 External Tube Connections: External threaded tube connections, when used, shall conform to drawing MS33514 or MS33515. External threaded tube fitting ends of 3000 psi (20 690 kPa), or higher pressure, components shall be steel.
- 3.8.4 Interchangeability: All parts having the same supplier's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in supplier's part numbers shall be governed by the purchaser's requirements. Subassemblies composed of selected mating parts must be interchangeable as assembled units, and shall be so indicated on the supplier's drawings. The individual parts of such assembled units need not be interchangeable.

3.9 Maintainability:

- 3.9.1 Maintenance Concept: The required maintenance concept shall be stated in the procurement specification, for example, "On Condition".
- 3.9.2 Useful Life and Storage Conditions: The requirements together with the appropriate definitions shall be stated in the procurement specification and shall consist of:
 - a. Life before it has to be overhauled (if applicable)
 - b. Storage life
 - c. Life before it has to be scrapped
- 3.9.3 Maintainability Features: The pump shall incorporate the following features in order to minimize its cost of ownership and the possibility of incorrect assembly:

- a. All wear surfaces shall be replaceable or repairable.

NOTE: The swaged ball seat in the piston/shoe assembly should not be disturbed. A new assembly shall be used if ball seat endplay becomes excessive.

- b. Electrical sockets and connections, mounting and wiring provisions shall be designed to prevent erroneous connections.

SAE AS595 Revision B

3.9.3 (Continued):

- c. Components which are not functionally interchangeable shall not be physically interchangeable.
- d. The design shall permit line replacement of the unit or any module of the unit, using standard tools only.
- e. The design shall be such that special or unique equipment is kept to a strict minimum for shop repair, overhaul and maintenance checks.

3.10 Reliability Requirements:

3.10.1 Mean Time Before Unscheduled Removals: The justified unscheduled removal rate for pumps operating on aircraft shall be a maximum 0.05 per 1000 flight hours unless otherwise stated in the procurement specification. This shall include the removal of the pump due to shaft seal leakage.

3.10.2 Data Requirements: The supplier shall provide the following data:

- a. The defect rate
- b. The failure rate
- c. The safety rate (if applicable)
- d. The failure modes and effects analysis (FMEA)

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

Unless otherwise specified in the contract or order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the supplier may use his own facilities or the services of any industrial laboratory that has the necessary approvals.

The purchaser reserves the right to perform any of the inspections contained in this document where such inspections are deemed necessary to ensure that supplies and services conform to the stipulated requirements.

4.2 Classification of Tests:

For the purpose of demonstrating compliance of pumps with this document and the applicable procurement specification, two distinct test programs shall be conducted, hereinafter referred to as Acceptance Tests and Qualification Tests.

SAE AS595 Revision B

4.3 Test Stand Requirements:

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

- a. Inlet pressure: 2% but not less than 5 psi (34 kPa)
- b. Case pressure: 2% but not less than 15 psi (103 kPa)
- c. Delivery pressure: 2% 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%
- g. The accuracy of the instrumentation shall be consistent with the measurement tolerances required.
- h. The test stands shall use sufficient filtration so as to maintain the cleanliness of the fluid to NAS1638 or AS4059 Class 6, or better, except for the qualification endurance testing (See 6.11).

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 document 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 document 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.

SAE AS595 Revision B

5.2 (Continued):

Starting with 5.2.3, the hydraulic fluid in the test circuit shall be as specified in the procurement specification. Filter elements qualified to MIL-F-8815, or as specified in the procurement specification, shall be installed in the pump inlet, outlet and case drain or cooling port lines of the test setup.

If, at any phase of testing, working parts require replacement, the entire conformance test procedure shall be repeated. 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 discharge port shall be pressurized for at least 1 min to the proof pressure stipulated in the procurement specification. With the discharge port at rated pressure, the case drain and inlet ports shall be pressurized for at least 1 min to the proof pressures stipulated in the procurement specification.

- 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 min 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 cpm for at least 15 min 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 3 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.

After the last pump has successfully passed the inspection, the requirements of this paragraph may be omitted. 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.

SAE AS595 Revision B

5.2.5 Filter Patch Test: This test shall be conducted to prevent shipment of a functionally acceptable but materially deteriorating pump (incipient failure). The fluid from the case drain and/or discharge of the pump shall be checked for contamination as agreed to between the supplier and the purchaser. 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.

Provisions shall be made in the procurement specification 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.

5.2.5.1 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:

- a. Rated inlet and case pressures
- b. Rated inlet fluid temperature or typical system fluid temperature
- c. 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 rated speed
- b. There shall be no indication of pressure control instability as the pump speed is varied from 50 to 100% of rated speed through the flow range. Specific system conditions, if any, must be defined in the procurement specification.
- c. The flow of the pump at maximum full-flow pressure and at rated speed shall be measured and recorded. The flow may be measured in the low pressure side of the discharge line provided adequate compensation is made for fluid compressibility when stating the value.

SAE AS595 Revision B

5.2.6 (Continued):

- d. The case drain flow at rated discharge pressure and at 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 in the application.

5.2.7 Electroconductive Bonding: Measure the electrical resistance between any point on the mounting flange face and specified points on the pump (for example, the pump suction, case, delivery and shaft seal connections). It shall not be greater than 300 milliohms, unless a higher value is stated in the procurement specification.

5.3 Preparation for Shipment:

After testing, the pump shall be drained and 90% filled with fresh, clean hydraulic fluid. The fluid used shall be either the specified hydraulic system fluid or preservative fluid which is compatible with the hydraulic system fluid.

5.4 Storage and Packing:

The method of storage and packing shall be defined in the procurement specification.

6. QUALIFICATION TESTS:

Qualification tests, for the purposes of checking whether the pump design conforms to the requirements of this document and the procurement specification, shall consist of the tests specified herein.

6.1 Qualification Procedure:

6.1.1 Qualification By Similarity: All or some of the qualification tests may be waived if the following conditions are met:

- a. The pump incorporates the same or operationally similar working parts and materials as a pump which was previously qualified
- b. The service requirements for the previous application for which the pump was qualified was equivalent to or greater than the service requirements for this application.

A report, substantiated by drawings showing the similarity with the qualified pump, shall be submitted instead of carrying out actual tests.

SAE AS595 Revision B

6.1.2 Pump Qualification Test Report: A report of the tests performed and the test results shall be compiled. This report shall include a full assessment of the extent to which the tested pumps comply with the specified requirements. The report shall include full descriptions of the manner in which the tests were performed, including instrumentation description, schematic diagrams, photographs, as appropriate, and copies of the test data sheets. Hydraulic test circuits shall be described in complete detail for each test. A set of parts' lists of the pump shall accompany the report.

6.2 Range of Qualification Tests:

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

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

The qualification tests to be carried out are as follows:

- a. Acceptance tests (see 6.3)
- b. Fluid immersion test (see 6.4)
- c. Dimensional check of working parts before endurance tests (see 6.5)
- d. Calibration (see 6.6)
- e. Maximum pressure test (see 6.7)
- f. Determination of response time test (see 6.7)
- g. Pressure pulsation test (see 6.7)
- h. Heat rejection test (see 6.8)
- i. Vibration test (see 6.9)
- j. Low temperature test (see 6.10)
- k. Endurance testing (see 6.11)
- l. Cavitation test (see 6.12)
- m. Drive coupling shear test (see 6.13)
- n. Fire resistance test (see 6.14)
- o. Structural tests (6.15)
- p. Environmental tests (6.16)
- q. Any additional tests required by the procurement specification

6.3 Acceptance Tests:

Those acceptance tests which 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 3.3.2
- 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 duration of the qualification program.