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SUPERSEDING
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MILITARY SPECIFICATION

PUMPS, HYDRAULIC, VARIABLE FLOW, GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification and a detail pump specification establish the requirements for variable flow hydraulic pumps, for use in aircraft hydraulic systems conforming to and as defined in MIL-H-5440 and MIL-H-8891, as applicable. The general requirements for type I and type II hydraulic systems pumps are specified in MIL-H-8775 and for type III system pumps in MIL-H-8890.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, Standards, and handbooks. The follow specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2d).

SPECIFICATIONS

FEDERAL

A-A-55057	- Panels, Hood/Hood Based; Construction and Decorative
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
PPP-B-566	- Boxes, Folding, Paperboard
PPP-B-585	- Boxes, Wood, Wirebound
PPP-B-591	- Boxes, Shipping, Fiberboard, Wood-Created
PPP-B-601	- Boxes, Wood, Created-Plywood
PPP-B-621	- Boxes, Wood, Nailed and Lock-Corner
PPP-B-676	- Boxes, Setup
PPP-T-60	- Tape, Packaging, Waterproof

MILITARY

MIL-P-116	- Preservation, Methods of
MIL-B-121	- Barrier Material, Greaseproofed, Waterproofed, Flexible
MIL-H-5440	- Hydraulic Systems, Aircraft, Design and Installation Requirements for
MIL-C-5501	- Caps and Plugs, Protective, Dust and Moisture Seal, General Specification for
MIL-C-5541	- Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-H-6083	- Hydraulic Fluid, Petroleum Base, for Preservation and Operation
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-F-8815	- Filter and Filter Elements, Fluid Pressure, Hydraulic Line, 15 Micron Absolute & 5 Micron Absolute, Type II Systems General Specification for
MIL-H-8890	- Hydraulic Components, Type III (-65°F to Plus 450°F), General Specification for (ASG)
MIL-H-8891	- Hydraulic Systems, Manned Flight Vehicles, Type III Design, Installation and Data Requirements for, General Specification for

MIL-L-10547 - Liner, Case, and Sheet, Overwrap, Water Vaporproof or Waterproof, Flexible
MIL-T-10727 - Tin Plating; Electrodeposited or Hot Dipped, for Ferrous and Nonferrous Metals
MIL-C-11796 - Corrosion Preventive Compound, Petrolatum, Hot Application
MIL-P-15024 - Plates, Tags, and Bands for Identification of Equipment
MIL-C-16173 - Corrosion Preventive Compound, Solvent Cutback, Cold-Application
HIL-C-26074 - Coatings, Electroless Nickel Requirements For
MIL-H-46170 - Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base
MIL-R-83248 - Rubber, Fluorocarbon Elastomer, High Temperature Fluid, and Compression Set Resistant
MIL-P-83461 - Packings, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275°F (135°C)

STANDARDS

MILITARY

MIL-STD-129 - Marking for Shipment and Storage
MIL-STD-130 - Identification Marking of U.S. Military Property
MIL-STD-276 - Impregnation of Porous Nonferrous Metal Castings and Powdered Metal Components
MIL-STD-781 - Reliability Testing for Engineering Development, Qualification, and Production
MIL-STD-810 Environmental Test Methods and Engineering Guidelines

(See supplement 1 for list of MS sheet form standards, and specification sheet.)

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the DODSSP, Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of the documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2d).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM-B633 - Zinc on Iron & Steel, Electrodeposited Coatings of (DoD Adopted)
ASTM-D1974 - Fiberboard Shipping Containers, Methods of Closing, Sealing, and Reinforcing, Standard Practice for
ASTM-D3951- Packaging, Commercial (DoD Adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

UNIFORM CLASSIFICATION COMMITTEE

Uniform Freight Classification Rules

(Application for copies should be addressed to the Consolidated Classification Committee, 202 Chicago Union Station, Chicago, IL 60606.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE-ARP819 - Fluid System Characteristics Affecting Hydraulic Pump Operation (DoD Adopted)
SAE-AS1300 - Ring-Locked Fluid Connection Type, Standard Dimensions For (DoD Adopted]
SAE-AS4201 - Port-Ring Lock Fluid Connection Type 8000 PSI Standard Dimension For (DoD Adopted)

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

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of Precedence. In the event of a conflict between the text of this document and the references cited herein (except for related associated detail specifications, and MS standards), the text of this document shall take precedence. Nothing in this document, however supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Precedence. The requirements of MIL-H-8775 and MIL-H-8890, as applicable, apply with the exceptions and additions specified herein. In case of conflict between the requirements of this specification and the requirements of MIL-H-8775 and MIL-H-8890, the requirements of this specification take precedence.

3.1.1 System specifications. These pumps shall be designed for installation in hydraulic systems as specified in MIL-H-5440 for type I and type II or MIL-H-8891 for type 111, as applicable.

3.1.2 System characteristics. The detail specification shall include the hydraulic system characteristics in which the pump is to be used, as referenced in SAE-ARP819.

3.2 Qualification. Pumps furnished under this specification shall be products which have been inspected and passed the first article or qualification inspection as specified herein and in the detailed pump specification.

3.3 Functional requirements.

3.3.1 Hydraulic fluid. The hydraulic fluid shall be specified in the detail specification.

3.3.2 Rated discharge pressure. This is the maximum pressure against which the pump is required to operate continuously at rated temperature and rated speed. The design of the pump shall be such as to maintain rated discharge pressure at the following combination and range of conditions:

From 100°F (38°C) to rated fluid temperature.

b. From 50 to 100 percent of rated speed and specified overspeed at rated inlet pressure and zero flow, using the hydraulic fluid specified in the detail pump specification.

The values of the rated discharged pressure and tolerance range shall be specified in the detail pump specification and the values shall be in accordance with table I. The permissible tolerance range on rated discharge Pressure shall be doubled in each direction for fluid temperatures below 100°F (38°C) or pump speeds from 25 to 50 percent of rated speed.

TABLE I Rated discharge pressure.

psi	kPa
1500	10500
3000	21000
4000	28000
5000	35000
8000	56000

3.3.2.1 Overpressure. All pumps with rated discharge pressure up to and including 3000 psi (21000 kPa) shall be qualified to 125 percent of rated discharge pressure. Pumps with rated discharge pressure above 3000 psi (21000 kPa) shall be qualified to a discharge pressure of 850 psi (6000 kPa) above their rated pressures. Overpressure values are listed below:

a. 1500 psi (10500 kPa) system = 1875 psi (13000 kPa) overpressure
b. 3000 psi (21000 kPa) system = 3750 psi (26000 kPa) overpressure

c. 4000 psi (28000 kPa) system = 4850 psi (34000 kPa) overpressure
d. 5000 psi (35000 kPa) system = 5850 psi (41000 kPa) overpressure
e. 8000 psi (56000 kPa) system = 8850 psi (62000 kPa) overpressure

3.3.3 Maximum full-flow pressure. This is the maximum discharge pressure at which rated flow can be developed at rated temperature, rated speed, and rated inlet pressure. Its value shall be no less than 95 percent of rated discharged pressure, unless indicated differently in the detail specification.

3.3.4 Rated inlet pressure. This is the indicated pressure at the inlet port of the pump when the pump is operating at rated speed, maximum full-flow pressure, and rated temperature. The rated inlet pressure shall be measured at the inlet port of the pump. Rated inlet pressure shall be measured at the inlet port of the pump in a manner which indicates the static head, and shall be expressed in psia or kPa absolute. The value shall be established in the detail pump specification.

3.3.4.1 Minimum inlet pressure. This is the lowest inlet pressure at which the pump shall be required to operate during a system failure or during system flow transients. The detail specification shall state a value and whether it applies during transients or during a steady state failure case. Note that since the aircraft system impedance may not be specified in 4.3.2.1.6.1.1 (impedance of pump test circuit), it is important to determine the pump response in the aircraft circuit and that the inlet portion of the system shall be designed to respond as rapidly as the pump. Dynamic cavitation in the inlet sections of the pump will otherwise occur.

3.3.4.2 Maximum inlet pressure. This is the maximum steady state inlet pressure at which the pump shall be required to operate in the hydraulic systems. The value of the maximum inlet pressure shall be established in the detail pump specification.

3.3.5 Case drain port pressure and flow. Unless otherwise specified in the detail specification, all pumps shall be designed to withstand a proof pressure of at least 500 psi (3450 kPa) at the case drain port or 150 percent of rated case drain pressure, whichever is greater, without permanent damage or impairment of pump function.

3.3.5.1 Rated case drain pressure. Rated case drain pressure is the nominal case drain port pressure at which the pump is required to operate continuously in the system. The value shall be stated in the detail pump specification.

3.3.5.2 Maximum transient case drain pressure. This is the maximum pressure spike that may be imposed on the pump case drain port. A value and a frequency of occurrence shall be specified in the detail pump specification.

3.3.5.3 Case drain flow. At rated discharge pressure, rated inlet temperature and at any speed from 50 to 100 percent of rated speed, the pump shall be capable of producing a minimum case drain flow at a given maximum

differential pressure between case drain pressure and inlet pressure as specified in the detail pump specification. Minimum and maximum case drain flow shall be specified in the detail pump specification under conditions as specified in the detail pump specification.

3.3.6 Rated temperature. The rated temperature of the pump shall be the maximum continuous fluid temperature at the inlet port of the pump.

3.3.6.1 Maximum system temperature. The rated temperature is related to the maximum temperature of the hydraulic system in which the pump is to be used according to table II and shall be one of the values listed herein. It shall be specified in the detail pump specification.

3.3.6.2 Minimum fluid temperature. The minimum continuous fluid temperature at the pump inlet port is not related to the rated temperature by this specification. A minimum continuous fluid temperature, if required, shall be specified in the detail specification.

TABLE II. Temperature relationship.

Hydr-aulic Systems	Maximum System Temp °F(°C)	Rated Temperature at Pump Inlet				
		psi 1500 kPa 10500	3000 21000	4000 28000	5000 35000	8000 56000
		°F(°C)	°F(°C)	°F(°C)	°F(°C)	°F(°C)
Type I	160(70)	110(45)	110(45)	105(40)	95(35)	75(25)
Type II	275(135)	225(110)	225(110)	220(105)	210(100)	190(90)
Type III	450(232)	390(200)	390(200)	385(195)	375(190)	355(180)

3.3.7 Displacement. The displacement of the pump shall be the theoretical volume of the hydraulic fluid delivered in one revolution of its drive shaft. It shall be expressed as cubic inches per revolution (CU in/rev) or milliliters per revolution (ml/rev). The displacement of any pump model shall be determined by calculation from the geometry and dimensions of the pump. The effects of allowable manufacturing tolerances, deflections of the pump structure, compressibility of the hydraulic fluid, internal leakage and temperature shall be excluded from the calculation because the displacement is intended to be an index of the size of the pump rather than of its performance.

3.3.8 Rated flow. The rated flow of the 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 detail pump specification. It shall be expressed as compressed flow in U.S gallons per minute (gpm) or liters per minute (l/rein), and its value shall be specified in the detail pump specification.

3.3.9 Rated speed. The rated speed of the pump shall be the maximum speed at which the detail specification requires the pump to operate continuously at rated temperature and rated discharge pressure. The rated speed of the pump shall be established in the detail pump specification. The nomography on figure 1 and figure 2 show approximate practical rated speeds for current pumps for three system pressure levels. Several system factors such as fluid, temperature, duty cycle, contamination, expected life, etc., will influence the values.

3.3.9.1 Overspeed. Unless othewise specified in the detail pump specification, all pumps shall be capable of operation at 115 percent of rated speed for the durations and at the conditions in table V.

3.3.10 Rated endurance. Unless modified by the detail pump specification, the rated endurance shall be 2000 hours for models in type I and type II systems (MIL-H-5440), and 500 hours for models in type III systems (MIL-H-8891).

3.3.11 Performance.

3.3.11.1 Torque and heat rejection. The performance requirements of torque and heat rejection shall be specified in the detail specification. The minimum performance requirements shall be stated as maximum input torque at rated flow and maximum heat rejection at rated discharge pressure.

3.3.11.2 Efficiency. Where the detail specification states a required minimum efficiency, it shall be the ratio of the output power to the input power when the pump is operated at rated speed and maximum full-flow pressure using the hydraulic fluid specified in the detail pump specification and expressed as percentage. This ratio is commonly referred to as “over-all-efficiency” and includes volumetric efficiency. For the purpose of this specification, volumetric efficiency shall not be segregated. When calculating output power from flow and pressure change, only the net difference between inlet and outlet pressure of the pump shall be used; the flow may be measured in the low pressure side of the discharge line provided that efficiency calculations compensate for fluid compressibility. Note that as discharged pressure is increased, the compressibility of the fluid reduces apparent pump efficiency even if pump performance itself does not change. Variation in bulk modulus of the fluid will therefore appear as a variation in pump efficiency.

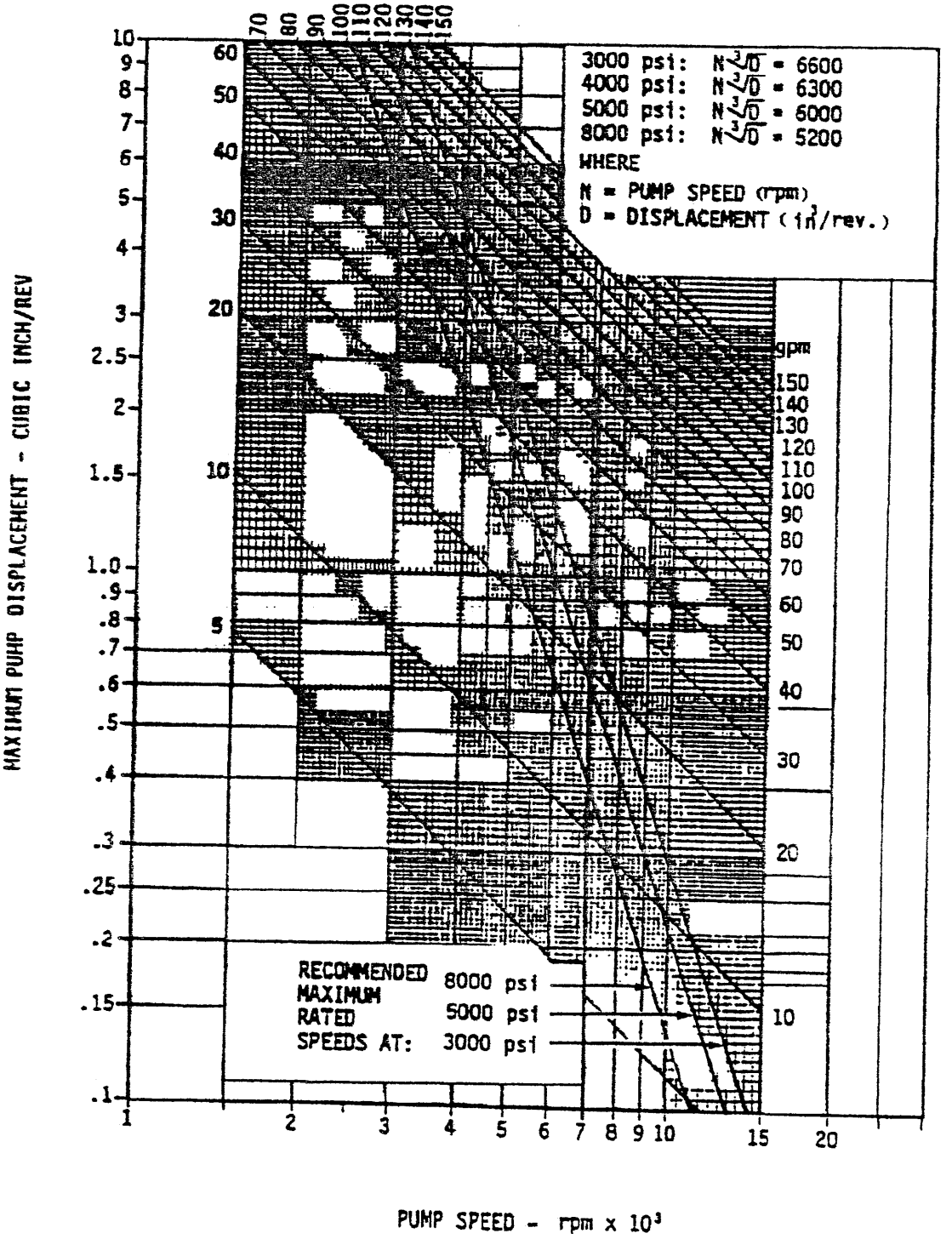

FIGURE 1. Maximum pump displacement vs pump speed.
(in-pounbd unit)

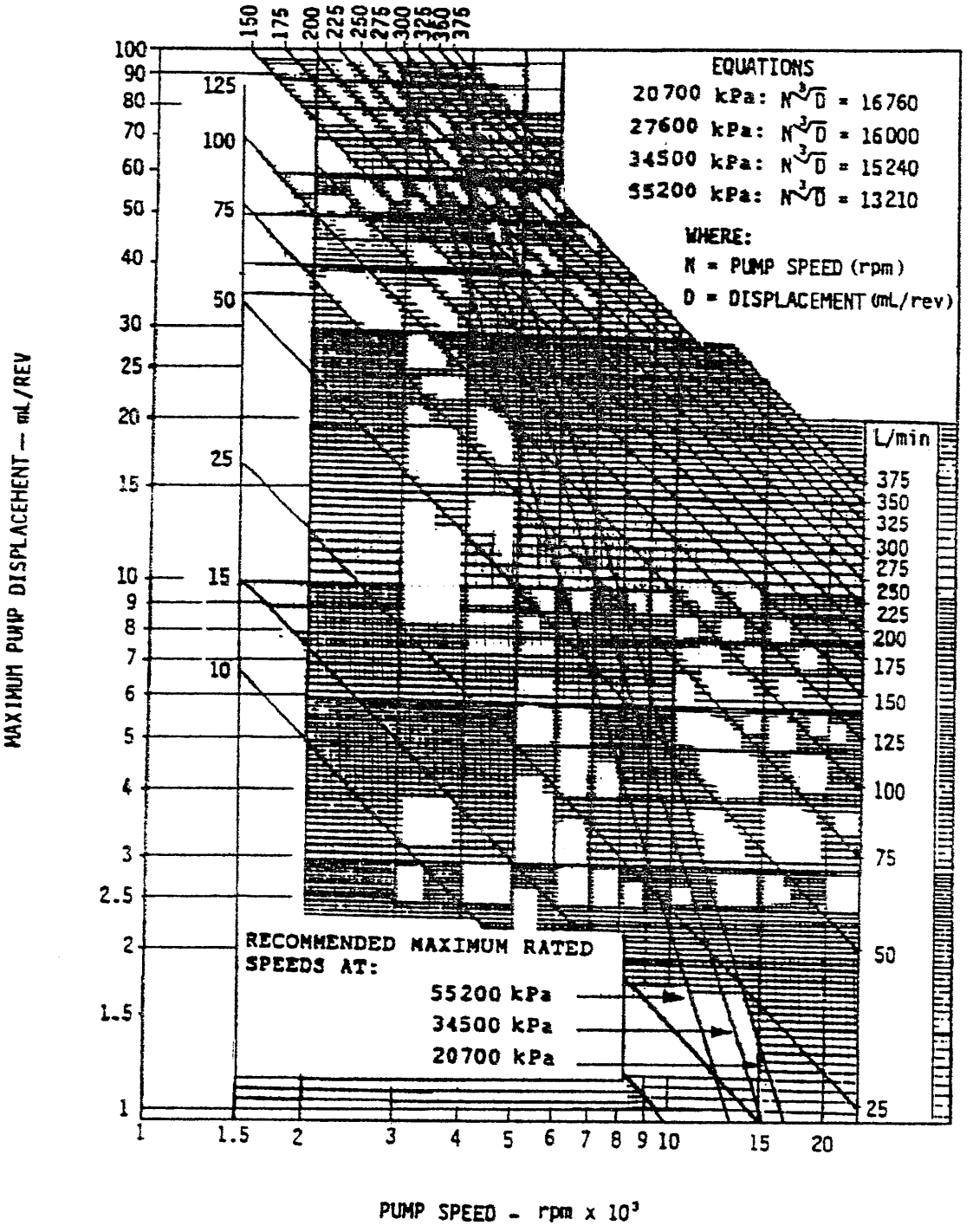

FIGURE 2. Maximum pump displacement vs pump speed.
(metric unit)

3.3.12 Pressure pulsations. Pressure pulsations are the oscillations of the discharge pressure, occuring during nominally steady operating conditions, at a frequency equal to or higher than the pump drive shaft speed. The amplitude of pressure pulsations shall be determined by the test procedure of 4.3.2.1.6.4. These pulsations shall not exceed ± 300 psi (± 2100 kPa) under any condition, or a pressure band specified by the detail pump specification. The pump shall be tested in the circuit which simulates the actual system in which the pump is to be installed, as defined in the detail pump specification. The system volume shall be simulated using tubing of the discharge line diameter. A tubing line length whose natural frequency is resonant with pulsation frequency shall be avoided.

3.3.13 Variable flow control. The pump shall incorporate flow control means which shall act to increase the flow of the pump from zero to its maximum full-flow value for any given operating speed as the discharge pressure is reduced from rated discharge pressure to maximum full-flow pressure and vice versa.

3.3.13.1 Response time. The response time of the pump shall be the time interval between the instant when an increase (or decrease) in discharge pressure change initiates; and the subsequent instant 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 versus time shall be employed as the criterion of movement of the flow control mechanism. All pump models when operating at rated inlet temperature at rated speed and in a circuit whose system impedance as specified in 4.3.2.1.6.1.1 for response tests, shall have a response time of .050 seconds maximum unless otherwise specified in the detail pump specification.

3.3.13.2 Stability. The stability of the pump shall be the freedom from persistent or quasi/persistent oscillation or “hunting" of the flow control mechanism at any frequency that can be traced to the pump flow control means. The oscillographic trace of discharge pressure versus time shall be employed as the criterion of the stability. All pump models, under any operating condition within the limits established in the detail pump specification and at any speed greater than 50 percent of rated speed, after being disturbed from steady-state operation by a change in flow demand or a change in pump speed, shall recover steady-state operation (other than permissible pressure pulsations as specified in 3.3.12), within one second after initial response to that change in flow demand. When required by the contracting activity, the pump manufacturer shall provide pump data to permit the system designer to integrate pump dynamic performance into his complete pump and system analysis.

3.3.13.3 Maximum transient pressure. The maximum transient pressure shall be the peak value of the oscillographic trace of discharge pressure, made during operation of a pump, as specified in 4.3.2.1.6.2 and measured as shown on figure 3. The maximum transient pressure, as determined in the transient pressure test specified in 4.3.2.1.6.2, shall not exceed 135 percent

of rated discharge pressure for systems up to 5000 psi (34,500 kPa) and 120 percent for systems above 5000 psi or as defined in the detail pump specification.

3.3.13.4 Depressurization. When it is a requirement of the detail specification that the pump be depressurized, either automatically or remotely as by an electrical signal, the repressurization control shall not, when deenergized, interfere with the normal operation of the variable flow control. The detail pump specification shall specify the requirements of qualification tests and quality conformance tests of the repressurization control. When full-flow repressurization is required, the detail pump specification shall identify the minimum and maximum operating pressure.

3.3.14 Balance. The moving parts of the hydraulic pump shall be 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 and required overspeed.

3.3.15 Adjustment. Means shall be provided to adjust the flow control mechanism to cause zero flow to occur at rated discharge pressure. This adjustment shall be preferably continuous, or acceptable in steps of less than one percent of rated discharge pressure over a minimum range of from 95 percent of rated pressure to 105 percent of overpressure. The adjustment means shall be capable of being positively locked, and it shall be possible to accomplish adjustment and locking by the application of standard hand tools. Where practicable, the design shall permit adjustment to be made while operating under full system pressure with negligible loss of fluid.

3.3.16 Safety wire sealing. Lead type safety wire sealing shall not be used.

3.3.17 Directionally critical components. Wherever practical, internal parts which are subject to malfunction and failure to operate due to reverse installation or rotated assembly shall have mechanical provisions to prevent improper installation or assembly.

3.4 Environmental requirements. In general, pumps shall be designed to operate, without limitations as to time, impairment of function or change in adjustment, under environmental conditions as specified in 3.4.1 through 3.4.5. Except as specifically directed herein, testing to demonstrate compliance with these requirements is not mandatory.

3.4.1 Altitude. Provided that inlet pressure is maintained to at least the rated value as specified in 3.3.4, pump performance shall not be affected by change of altitude.

3.4.2 Temperature. For purposes of design, it shall be asumed that the ambient temperature surrounding the pump shall be such that no heat is transferred to and from the pump except by normal circulation of the working fluid.

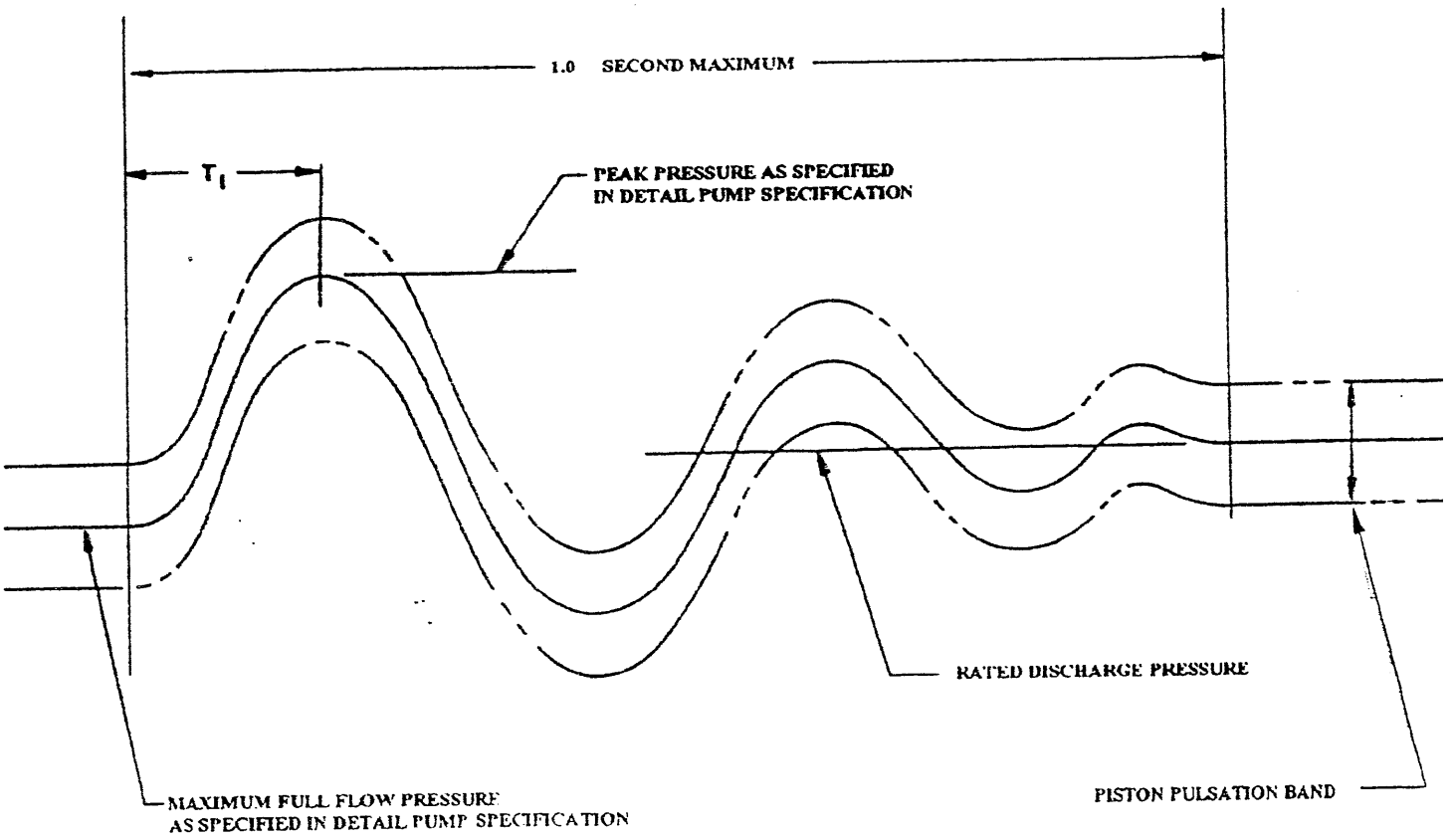

FIGURE 3. Typical pressure transient full flow to zero flow.

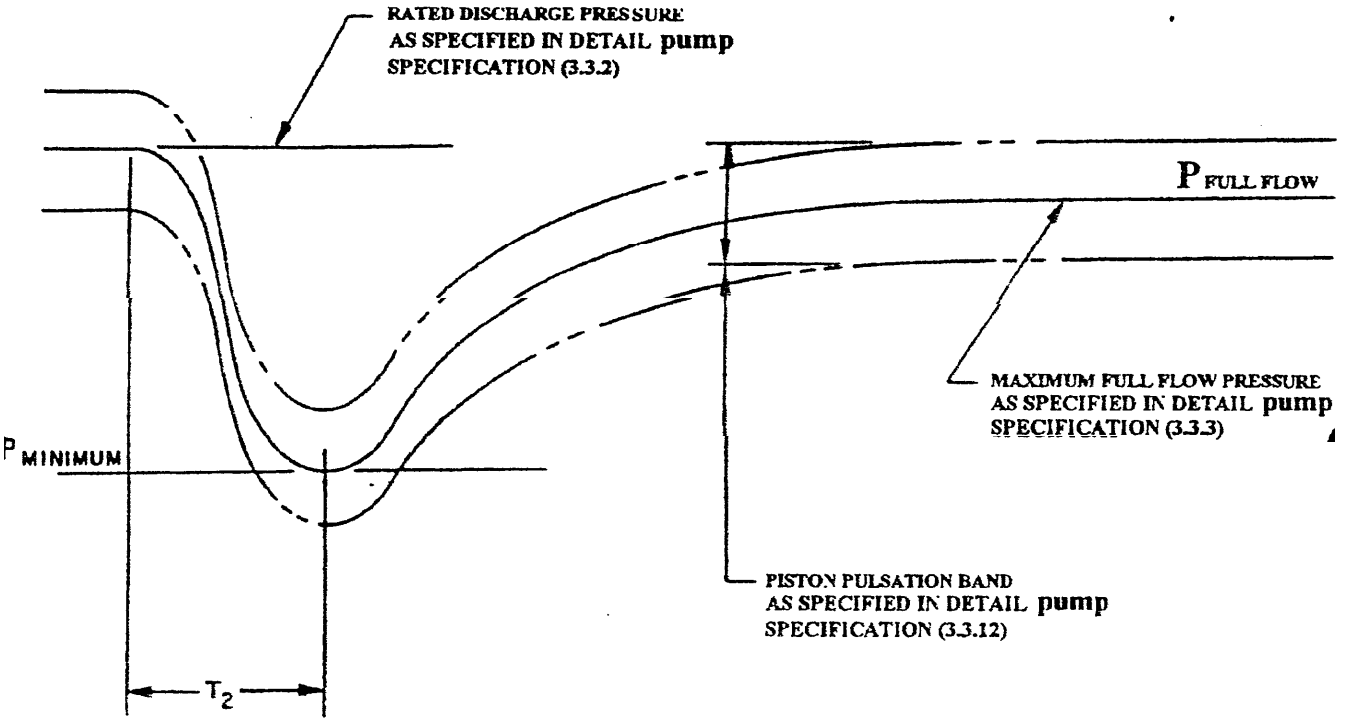

FIGURE 4 Typical pressure transient zero flow to full flow.

3.4.3 Vibration. Pumps shall be capable of withstanding vibrations excited by the driving means. For design and test purposes, torsional vibration excited by the driving means shall be considered negligible. As part of the qualification test, all pump models shall be subjected to the vibration tests specified in 4.3.2.1.8.

3.4.4 Acceleration. All pumps shall be designed to withstand sustained acceleration of 10g applied in any direction.

3.4.5 Atmospheric conditions. All pumps shall be designed to withstand continuous exposure, as installed in the application and either operating or non-operating, to salt spray as encountered in marine or coastal areas and to sand and dust as encountered in desert areas. If resistance to other matter is needed, these shall be identified in the detail pump specification.

3.5 Installation requirements.

3.5.1 Dimensions. Dimensions pertinent to the installation of pumps aircraft shall be specified on the manufacturer's installation drawing.

3.5.2 Weight. Both wet and dry weights shall be specified on the installation drawing.

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

MS3330 through MS3334 design standards for flanges having bolt circle (BC) diameters 2.653", 5", 8", and 10"

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. Reorientation of the pump due to vehicle 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 and bushing A replaceable part of the pump assembly, incorporating a shear section, shall be interposed between the pump drive shaft and the driver such as an engine accessory drive shaft. The coupling shall be positively retained to the pump drive shaft. The interface between the coupling and the driver shall be as outlined in the detail pump specification. For interface splines that are not force-lubricated, the detail pump specification shall specify all material and dimensional aspects of a non-metallic spline bushing to protect the driver. The shear characteristics of the bushing shall be such that it does not fail before the coupling shear section, and shall be capable of transmitting, as a minimum, a

torque in excess of 3 times the maximum torque requirements of the pump.

3.5.5 Ports. Ports shall incorporate ring locked type boss fittings conforming to SAE-AS1300 for systems up to 5000 psi, and SAE-AS4201 for systems above 5000 psi, unless otherwise specified in the detail pump 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, resulting from the attachment or removal of fittings and hoses when installing or removing pumps during field maintenance, without permanent distortion or impairment of function.

3.5.5.2 Port markings. Inlet, outlet, and case drain ports shall be identified in accordance with MIL-STD-130 on each pump with clear and permanent markings.

3.6 Detail requirements,

3.6.1 Material. Materials used shall conform to the applicable pump specifications and be compatible with the hydraulic fluid. The pump manufacturer's material specifications are acceptable provided they are approved by the contracting activity and contain provisions for adequate tests. The use of the pump manufacturer's specifications shall not constitute waiver of other applicable specifications.

3.6.1.1 Metals. All metals shall be compatible with the hydraulic fluid and applicable temperature, function, service, and storage conditions. Magnesium shall not be used. To minimize the corrosion of internal parts in fluids with chlorine levels over 100 ppm and water levels over 250 ppm, ferrous alloys shall have a chromium content of not less than 12 percent such as 440C and BG-42 or shall be protected against corrosion as specified in 3.6.1.2. O-ring grooves for external seals shall not be considered as internal surfaces in constant contact with hydraulic fluid. The use of alternative materials and processes requires approval of the contracting activity. Such materials or processes shall be selected so as to provide the maximum degree of corrosion resistance consistent with the performance requirements.

3.6.1.2 Corrosion protection. Metals which do not inherently possess corrosion-resisting characteristics shall be protected to resist corrosion which may result from such conditions as dissimilar metal combinations, moisture, salt spray, or high temperature deterioration. Ferrous alloys requiring corrosion preventive treatment, and all copper alloys, except for parts having bearing surfaces, shall have an electrodeposited metallic coating selected from table III. Tin plating, cadmium plating, and zinc plating shall not be used for internal parts or parts where internal surfaces in contact with hydraulic fluid or exposed to its vapors and not where subject to abrasion. Where not indicated in the contract, selection of class and type of

coating are at the option of the manufacturer. Other coatings shall be used with the approval of the contracting activity. Unless otherwise specified in the contract, all aluminum alloys shall be anodized in accordance with MIL-A-8625, except that in the absence of abrasive conditions they shall be coated with chemical film in accordance with MIL-C-5541. The exceptions noted will be subject to the approval of the contracting activity.

3.6.1.3 Castings. Castings shall be of high quality, clean, sound, and free from cracks, blow holes, porosity, and other defects. Defects not materially affecting the quality of the castings shall be repaired at the foundry or during machining by peening, impregnation, welding, or other methods acceptable to the contracting activity. Inspection and repair of castings shall be governed by quality control techniques and shall be satisfactory to the contracting activity. When impregnated castings are used, they shall be in accordance with impregnation procedures and inspection requirements of MIL-STD-276.

TABLE III. Metallic coatings.

Type of Coating	Specification to Be Used
Cadmium plating	QQ-P-416, Type II, Class 2
Zinc plating	ASTM-B633
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

3.6.2 Seals. For type I system pumps, static and dynamic seals shall be in accordance with MIL-P-83461. For type II system pumps, static and dynamic seals shall be in accordance with MIL-R-83248. Back-up rings shall be in accordance with MIL-R-8791/1 or MS27595. Other seals and back-up rings necessary to demonstrate compliance with the requirements of this specification may be used with the approval of the contracting activity. All seal installation designs shall conform to MIL-H-5440. For type III system pumps, seals and back-up rings used shall be subject to approval of the contracting activity.

3.6.3 Identification of product. A nameplate conforming to MIL-P-15024 and the applicable MIL-P-15024 specification sheet as required by the detail specification shall be securely attached to the pump. It shall contain the following information, marked in accordance with MIL-STD-130 in the spaces provided.

Detail pump specification no. _____
Manufacturers part no (or identification) _____
Manufacturers name or trademark _____
Serial number _____
Fluid _____

Rating:

Flow _____ gpm or 1/m
Pressure _____ psi or kPa
Speed _____ rpm

Any nameplate data required in addition to the above shall be specified in the detail pump specification.

3.6.4 Design and construction.

3.6.4.1 Lubrication. Except for the coupling shaft spline, the hydraulic pump shall be self-lubricated with no provisions for lubrication other than the circulating fluid.

3.6.4.2 Leakage. External leakage from the pump housing or from any static seal 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 4.4.2.

3.6.5 Reliability. The pump shall have an upper test mean-time-between-failure, θ as defined in MIL-STD-781, of 2000 hours, at a discrimination ratio of 3.0.1 (see 6.4.1.3), and a decision risk of 10 percent (see 6.4.1), when operating duty cycle as specified in the detail pump specification.

3.6.6 Maintainability. The hydraulic pump shall be designed to meet the maintainability requirements as specified in the detail pump specification. Where possible, the pump shall include the following maintainability features.

a. All wear surfaces shall be replaceable or repairable.
b. Disconnects, mounting, and wiring provisions shall be designed to prevent erroneous connections.
c. Components which are not functionally interchangeable shall not be physically interchangeable.
d. The design shall permit line replacement of the unit or module using standard tools only.
e. The design shall be such-that special or unique equipment is minimized for shop repair, overhaul, and checkout.

3.7 Workmanship. Pumps shall meet all design requirements and dimensional requirements of this specification and detail pump specification. Improper fabrication, loose materials, defective internal parts, damaged or

improperly assembled parts, peeling or chipping of plating or finish, galling of mating parts, nicks and burrs of metal parts shall be considered for rejection of the pump assembly.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material (see 6.3).

4.2 Classification of inspections. For the purpose of demonstrating pump compliance with this specification, MIL-H-8775, or MIL-H-8890, as applicable, and the detail pump specification, the following test program shall be performed:

a. Qualification (see 4.3).
b. Quality conformance (see 4.4).
c. Reliability tests (see 4.5).

4.3 Qualification. The qualification tests are conducted to demonstrate conformance of the pump design to the requirements of this specification MIL-H-8775 or MIL-H-8890, as applicable, and with the detail pump specification to ensure their suitability for use in specific installations, and to verify the manufacturer's ability to produce the items.

4.3.1 Qualification approval procedure.

4.3.1.1 Similarity. A pump or portion thereof may be qualified because it is similar to a qualified product approved by a contracting activity. For similarity to apply, the new parts shall be functionally similar to those of the qualified product and the operating requirements for new product shall be no greater than those for the qualified me. A report substantiated by

drawings showing similarity to the qualified article shall be submitted in lieu of one containing actual test results (see 6.3).

4.3.1.2 Qualification test report. A report of the tests performed and the result shall be submitted to the contracting activity, The report shall include full evaluation of the extent of compliance of the tested pumps to the specified requirements. The report shall include a full description of the manner in which the tests were performed including instrumentation description, schematic diagrams, photographs as appropriate, arid copies of the test data sheets. Hydraulic test circuits shall be described in complete detail for each test. A parts list of the pump shall accompany the report (see 6.3).

4.3.2 Qualification tests. These tests shall consist of the following, performed in the order listed on one sample pump, or the same test performed on two sample pumps (A and B) on a selected basis as shown in table IV. The detail pump specification shall include any supplemental requirements, test methods, and number of test samples to ensure satisfactory operation and service life in the particular installation.

4.3.2.1 Qualification test methods. The hydraulic fluid used in all qualification tests shall be that specified in the detail specification. Unless otherwise specified in the detail pump specification, the required steady state test operating conditions shall be maintained within the following limits:

a. Inlet temperature:
   -70°F to +110°F, ± 5°F (-56°C to +45°C, ±3°C)
   +111°F to +225°F, ±10°F (+46°C to +110°C, ±6°C)
   +226°F to +390°F, ±15°F (+111°C to +200°C, ±8°C)
b. Inlet pressure within + 2 percent
c. Pump shaft speed within ±2 percent
d. Discharge pressure within ±2 percent
e. Flow within ±2 percent

Accuracy of the instrumentation for all tests shall be consistent with the measurement tolerances required.

4.3.2.1.1 Method of selection. The pump or pumps chosen for the qualification test shall be representative of those pumps to be produced in future production.

4.3.2.1.2 Quality conformance. The pumps selected for the test shall be subjected to a quality conformance inspection. Selected parts shall be checked for compliance with drawing requirements, and actual dimensions of critical features shall be recorded. After assembly of the pumps, quality conformance shall be conducted in accordance with section 4.4.

TABLE IV. Qualification tests.

Item	Description of Tests	Requirements Paragraphs	Test Paragraphs	Pump samples	
				A	B
a.	Quality conformance	----	4.3.2.1.2	X	X
b.	Fluid immersion	----	4.3.2.1.3	X	---
c.	Proof pressure	----	4.4.2.1	X	X
d.	Calibration	----	4.3.2.1.5	X	X
e.	Maximum pressure	3.3.13.3	4.3.2.1.6.2	---	X
f.	Response time	3.3.13.1	4.3.2.1.6.3	---	X
g.	Pressure pulsation	3.3.12	4.3.2.1.6.4	---	X
h.	Heat rejection	3.3.11.1	4.3.2.1.7	---	X
i.	Vibration	3.4.3	4.3.2.1.8	---	X
j.	Low temperature and thermal cycle	----	4.3.2.1.9	---	X
k.	Endurance	3.3.10	4.3.2.1.10	X	-
*l.	Cavitation	----	4.3.2.1.10.9	X	X
*m.	Drive coupling and spline bushing shear	3.5.4	4.3.2.1.10.10	X	X
n.	Additional tests if any, sample A or B, as required by the detail pump specification				

* Performanced on either pump (A) or pump (B)

4.3.2.1.3 Fluid immersion test. Where electrical components are a part of the pump assembly, they, as part of their qualification test, shall be separately subjected to a fluid immersion test prior to the start of the qualification test. This will consist of continuous immersion for 72 hours in the hydraulic fluid at rated temperature. After the 72-hour soak period, the component shall remain in the fluid at normal temperature until ready for further tests.

4.3.2.1.4 Proof pressure tests. The proof pressure test of 4.4.2.1 shall be repeated after completing pump reassembly.

4.3.2.1.5 Calibration test. The pump flow rate and driving torque shall be determined at each of the following speeds; minimum operating speed, 25, 50, 75, 100 and 110 percent of rated speed. At each speed, flow and torque shall be recorded at the following pressures: 25, 50, 75, and 100 percent of maximum full-flow pressure and at 5 equally spaced increments of flow between maximum full-flow pressure and rated discharge pressure. Unless otherwise specified in the detail pump specifications, calibrations shall be recorded at the inlet condition specified in 3.3.4 and flow measurements shall be taken in the line downstream of the load valve and corrected for fluid compressibility.

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

4.3.2.1.5.2 Minimum operating speed. The speed shall be reduced below 25 percent of the rated speed to determine the speed below which the discharge flow or pressure becomes erratic. This point shall be recorded and designated the minimum operating speed for that condition.

4.3.2.1.5 Maximum pressure, response time, and pressure pulsations. Pressure transducer and recording equipment shall be used to provide an oscillographic record or its equivalent of the pressure to time function of the pump and its hydraulic circuit through the transient and steady state periods described in the following three tests. The pressure transducer and recording equipment shall be capable of static calibration with repetitive accuracy of 5 percent of rated pressure and readability of 3 percent of rated pressure. It shall be considered essential that the dynamic calibration of the equipment is valid for the dynamic conditions. The pressure transducer shall be located in the pump discharge line as close as possible to the outlet fitting. Tests shall be conducted at rated conditions unless noted otherwise below, or in the detail pump specification.

4.3.2.1.6.1 System impedance.

4.3.2.1.6.1.1 Response time. The system impedance of the test circuit when determining pump response shall be such that when the pump is operating at rated speed, maximum full-flow pressure, and rated inlet temperature, the rate of pump discharge pressure rise, when the flow in the system is suddenly stopped (the minimum rise rate of the maximum slope of pressure rise) shall be 50,000 psi/sec (345,000 kPa/see). This will be as calculated from system volume, pump rated flow, and fluid bulk modulus at rated temperature and rated discharge pressure.

4.3.2.1.6.1.2 All other tests. The system impedance of the test circuit when determining maximum pressure, pressure pulsations, stability, and the remaining qualification tests, shall be specified in the detail pump specification. Both inlet circuit and high pressure circuit shall simulate the application.

4.3.2.1.6.2 Maximum pressure test. The test circuit specified in 4.3.2.1.6.1.2 shall be used. Flow changes shall be initiated by a solenoid operated valve with an actuation response time 0.020 second or less, or as specified in the detail pump specification. As the test pump is cycled between steady state maximum full-flow pressure and steady state rated discharge pressure, an oscillographic record of the pressure-to-time function through the transient period shall be made in each direction. The test shall be run at 50 percent and 100 percent of rated pump speed. Air entrainment in the hydraulic fluid shall be at a minimum. Unless otherwise specified in the detail pump specification, the peak pressure transient as measured on the above record shall not exceed the limits of the maximum transient pressure (see 3.3.13.3).

4.3.2.1.6.3 Response time. With the test circuit specified in 4.3,2.1.6.1.1, and load valves set at a flow condition equivalent to maximum full-flow pressure at each of the test speeds, the solenoid valve, which changes discharge line from full open to full closed, or vice versa, shall then be used to execute the test. The pump shall be run at 50, 75, and 100 percent of rated speed or as specified in the detail pump specification. With the solenoid valve open and the test pump operating at steady state maximum full-flow pressure, an oscillographic record shall be made of the pressure-time function through the transient period associated with the closing of the solenoid valve and establishment of steady state rated discharge pressure. Typically, this record shall be similar to figure 3, and the response time, T1, as indicated thereon, shall not exceed 0.050 seconds at 100 percent of rated speed. At 50 and 75 percent of rated speed, T1 shall not exceed the value specified in the detail pump specification. The response time T2 for the change from rated discharge pressure to maximum full-flow pressure shall be recorded and, as indicated on figure 4, shall not exceed 0.050 seconds at 100 percent rated speed or as specified in the detail pump specification. At 50 and 75 percent of rated speed, the response time T2 shall not exceed the value specified in the detail pump specification. Check the response time for small incremental changes of flow as follows: Introduce a parallel flow path which includes an orifice and a downstream solenoid valve with 0.020 second response or as specified in the detail pump specification. This orifice shall be adjusted to pass 5 percent of maximum full-flow and the main load throttling valve shall be adjusted to pass 90 percent of maximum full-flow for each of the three pump speed settings. Check response time at each speed setting when the small flow path solenoid is opened and closed with the main flow path solenoid valve both opened and closed. The response time at rated speed shall not exceed 0.050 seconds.

4.3.2.1.6.4 Pressure pulsations. The test circuit specified in 4.3.2.1.6.1.2 shall be equipped with a dynamic pressure transducer of zero volume and a frequency response of 20 Hz to 100 kHz. With pump at rated discharge pressure, vary the speed from 50 to 100 percent of rated speed at a rate of change not exceeding 100 RPM per second. During this period an oscillographic record of the pulsation pattern shall be made. This speed scan shall be repeated at 25, 50, 75 and 100 percent of rated flow. Values of pressure pulsation shall not exceed the limits specified in 3.3.12.

4.3.2.1.6.5 Pressure control and stability. The calibration tests of 4.4.2.6 shall be extended to check pump stability and discharge pressure for the fluid temperature range as outlined in the detail pump specification.

4.3.2.1.7 Heat rejection. The rate of heat rejection at specified conditions shall be considered equal to the difference between the input and output horsepower of the pump at those conditions. Output power of the pump may be calculated based on flow measurements in the low pressure side of the discharge line provided compensation is made for fluid compressibility in calculating output power. To determine the rate of heat rejection, the pump shall be run at rated speed and rated inlet temperature, and the input and output power determined at rated discharge pressure, maximum full-flow pressure, and at least 2 additional flow points between those values. The maximum acceptable value of heat rejection rate at specified operating conditions shall be specified in the detail pump specification.

4.3.2.1.8 Vibration tests.

4.3.2.1.8.1 Test pump mounting orientation. The test pump shall be mounted on a vibration generating mechanism successively in each of at least 3 positions. All of the testing specified shall be performed in each of the mounting positions. One of these mounting positions shall be such that the direction of vibratory motion shall be parallel to the shaft axis of the pump. Another mounting position if and when practicable, shall be such that the direction of vibratory motion shall be parallel to the axis of the compensating mechanism. When the pump is equipped with an electrical repressurization device, an additional mounting position shall be such that the direction of vibratory motion is parallel to the electric repressurizing valve (EDV) mechanism.

4.3.2.1.8.2 Resonant frequency vibration. Resonant frequencies shall be searched according to the double amplitude and frequency charts of MIL-STD-810, Method 514.3. Applicable procedures and test values shall be specified in the detail pump specification.

4.3.2.1.8.3 Cyclic frequency vibration. Upon completion of the resonant frequency vibration, a cycling vibration shall be imposed in accordance with MIL-STD-810, Method 514.3. Applicable procedures and test values shall be specified in the detail specification.

4.3.2.1.8.4 Other vibration tests. The detail specification will require other vibration tests to be performed when a particular installation imposes severe environmental conditions peculiar to its system requirements.

4.3.2.1.8.5 Pump operation. Throughout the above vibration tests the pump shall be operated in the test circuit of 4.3.2.1.6.1.2. Fluid inlet temperature shall be 140°F ±40°F (60°C ±22°C) regardless of the rated temperature of the pump being tested, and ambient temperatures shall be maintained at room ambient conditions. The pump discharge shall be continuously cycled between zero flow and approximately 50 percent of rated

flow at approximately 5 cycles per minute (cpm) with a valve response time of 0.5 second maximum. Where the pump is equipped with a repressurizing means, cycle between pressurized and repressurized modes as required by the detail pump specification.

4.3.2.1.9 Low temperature and thermal cycle test. All low temperature requirements apply equally to the pump body and hydraulic fluid. The ambient environment temperature may vary ±20°F (±11°C). After at least 18 hours at the minimum inlet temperature specified in the detail pump specification [or -65°F ±5°F (-54°C ±3°C) in the absence of a value in the detail pump specification] the pump shall be started and uniformly accelerated to 50 percent of rated speed in not more than 10 seconds, unless otherwise specified in the detail pump specification. Five runs shall be made with the outlet pressure as low as practicable and the inlet pressure as specified in the detail pump specification. The rated speed shall be reached within 20 seconds after start-up. When rated speed has been reached, it shall be maintained for at least 10 seconds; observations shall indicate whether the pump displaces fluid through the hydraulic system. Then 5 starts and runs shall be made, with the pump discharge line terminating in a load valve which is set to pass fluid at 90 percent of maximum full-flow pressure at room temperature. The pump shall be allowed to run until rated fluid temperature is reached after each of these five starts. In addition, five starts shall be made with the pump discharge line completely closed so that the pump shall operate at rated discharge pressure. Throughout these tests, after each run, the pump and fluid shall be allowed to stand idle long enough for them to be restored to the above soaking temperature before starting the next run. When the pump includes a repressurization device that is used as an engine starting aid, the device shall be activated during starts and deactivated as specified in the detail pump specification.

4.3.2.1.9.1 Thermal shock. To conduct the thermal shock cycle, the hydraulic pump and fluid shall be cooled to -65°F (-54°C) or a temperature specified in the detail pump specification. The hydraulic reservoir temperature shall be maintained at rated temperature and contain a volume of fluid equal to that in the aircraft system or as specified in the detail pump specification. The pump shall be started and brought up to rated speed in a time interval specified in the detail pump specification. Discharge pressure shall be set to cause the pump to deliver rated flow or as specified in the detail pump specification. The pump shall not malfunction.

4.3.2.1.10 Endurance test. A sample pump shall complete a 2000 hour endurance test as outlined in table V for type I and type II systems. For type III systems, the test shall be outlined in the detail pump specification. Unless otherwise specified in the detail pump specification, the following test conditions apply to table V:

a. Rated inlet pressure (see 3.3.4).
b. Rated case drain pressure (see 3.3.5.1).
c. Inlet fluid temperature shall be 180°F ±10°F (80°C ±5°C) except:
    (1) Phase 2 and 5 shall each include at least 200 hours at rated

temperature.

(2) Phase 4 shall include at least 100 hours at rated temperature (see 3.3.6.1).

(3) Phases 7 and 8 shall be conducted with the compensator as adjusted for overpressure in phase 6 (see 3.3.2.1).

TABLE V. Endurance test conditions.

CYCLE PARAMETERS								
Test Phase No.	% of Rated Speed	% of Rated Flow	Outlet Pressure	Dwell Time (Sec)	% of Rated Flow	Outlet Pressure	Dwell Time (Sec)	No of Test Hours 3/
1	67	0	Rated	5	Full	1/	25	130
2	100	5	2/	15	95	2/	15	690
3	115	5	2/	15	109	2/	15	60
4	100	0	Rated	5	100	1/	25	360
5	100	5	2/	15	15	2/	15	660
6	67	0	Over-Pressure	5	Full	1/	25	10
7	100	5	2/	15	95	2/	15	50
8	115	5	2/	15	109	2/	15	40

The following notes apply to table V:

1/ 95 percent of maximum full-flow pressure.

2/ Outlet pressure shall be adjusted to provide stipulated flow.

3/ A time tolerance of ±1 percent of the test hours in each phase is permissible for ease of test implementation. The total test hours of all phases combined shall be 2000 hours.

4.3.2.1.10.1 Filtration for endurance test. The hydraulic fluid to be used in the endurance test system shall be passed through a 5-micron absolute filter before entering the test system. Filter elements in accordance with MIL-F-8815, either 5-micron absolute or 15-micron absolute as specified in the detail pump specification, shall be installed in the pump inlet, outlet, and case drain or cooling port lines throughout the endurance test.

4.3.2.1 .10.2 Filter check. At intervals not to exceed 100 ±16 hours during the endurance test, pump condition shall be monitored by means of

filter patches conducted in accordance with 4.4.2.5.1, for significant changes from prior patches that may indicate impending failure.

4.3.2.1.10.3 Calibration. Before starting phase 1 of the endurance test and again upon completion of phases 2, 4, 5, and 8, the pump shall be calibrated using the procedure specified in 4.3.2.1.5, except that speeds other than rated shall be omitted. The results of these three calibrations shall be plotted on one chart if clarity permits, to show the effect of the endurance test on the performance of the pump.

4.3.2.1.10.4 Start-stop cycles. Start-stop cycles shall be performed as part of the endurance test. Fluid temperatures may range from ambient to rated but actual values shall be recorded.

4.3.2.1.10.4.1 Full-flow cycles. The pump shall be accelerated to rated speed within 15 seconds, or as specified in the detail pump specification, with the load orifice adjusted to 95 percent of maximum full-flow pressure for 200 cycles. The pump shall be stopped immediately after reaching rated speed. Deceleration time shall be recorded.

4.3.2.1.10.4.2 No flow cycles. Follow the same procedure as specified in 4.3.2.1.10.4.1, except the discharge line shall be blocked during starts and stops, and the number of cycles shall be 20. Between cycles, the discharge pressure shall reduce to 100 psi (700 kPa) or less. When the pump includes a repressurization device that is used as an engine starting aid, the device shall be deactivated when the pump reaches 50 percent of rated speed.

4.3.2.1.10.5 Pump case pressure cycles. With the shaft locked, pressurize the pump outlet port with an external source to rated pressure. Apply at least 20000 pressure cycles to the pump case, each to at least 500 psi (3450 kPa) or 150 percent of rated case drain pressure, whichever is greater. Unless otherwise specified in the detail pump specification, the time from the start of the pressure impulse to the initial return to normal case pressure shall be between 0.1 second and 0.5 second. An oscillographic, or equivalent, record of the pressure impulse shall be made. As an option, the test may be conducted with the pump operating at rated pressure instead of being externally pressurized.

4.3.2.1.10.6 Air ingestion. The ingestion of air by the hydraulic system for example, as a result of the replacement of components during line maintenance, shall be simulated during the endurance test by the following procedure:

The line supplying hydraulic fluid to the pump shall be arranged so that a 4-foot (1 m) section immediately adjacent to the pump can be disconnected, vented, drained, and reconnected without draining the rest of the test system. Each of the first 12 times that the test is shut down to install the filter elements for the 2-hour patch run (or alternatively, to remove these elements at the end of the 2-hour patch run), it shall be shut down while the pump is operating at full-flow; the reservoir shall be

repressurized, the 4-foot (1 m) length of inlet line shall be disconnected, vented, drained, and reconnected. During these operations, the filter elements shall be replaced. The pump shall then be started with the test system set to develop maximum full-flow. Thirty seconds after starting, the discharge pressure shall be recorded, then the reservoir shall be pressurized, and the endurance test schedule resumed. For this test, the aircraft reservoir, or some agreed upon facsimile, the aircraft suction line sizes, lengths, and configuration together with rated inlet pressure shall be used for this test.

4.3.2.1.10.7 Fluid. The hydraulic fluid used in the endurance test shall be as specified in the detail pump specification. The endurance test system shall be charged at the start of the endurance test and no fluid shall be added before the endurance test is completed except:

a. The amount of fluid unavoidably removed from the system during the specified filter checks and air ingestion tests shall be replaced.
b. In the event of failure of the test system external to the pump, resulting in loss of fluid or contamination not pertinent to pump endurance, the entire fluid supply shall be replaced.
c. To maintain fluid within the physical and chemical property limits established by the contracting activity.

A record shall be made of the test time and quantity of fluid added in each case and entered in the test log.

4.3.2.1.10.8 Failure of parts. If, during the qualification test program, the test is terminated because of a part failure, the pump shall be replaced or repaired using a redesigned part(s) or in the case of faulty material or workmanship, the contracting activity shall authorize the installation of a part of the original design. The program shall be considered complete when all parts within the pump have completed, without failure, the requirements of the program as specified in the applicable detail pump specification. Should pump tests be continued from point of failure with repaired or replaced part(s), subsequent failure of parts that have successfully completed total endurance requirements shall not be cause of rejection.

4.3.2.1.10.9 Cavitation test. The pump shall be operated at rated speed and rated inlet temperature and maximum full-flow pressure. The fluid pressure at the pump inlet port shall be adjusted to 120 percent of rated inlet pressure. The flow and delivery pressure shall be measured as inlet pressure is reduced in steps small enough to clearly establish the on-set of cavitation and its effect on output.

4.3.2.1.10.10 Drive coupling and spline bushing shear test. A drive coupling and spline bushing (when applicable) shall be set up for a shear test simulating the installation. Load shall be applied torsionally until failure takes place and the load producing the failure shall be recorded. The failure shall take place at the shear section of the coupling.

4.3.2.1.10.11 Tear down inspection. After completion of the endurance tests, the pump shall be disassembled and all parts visually inspected, or as specified in the detail pump specification. The general condition of the parts shall be reported.

4.4 Quality conformance. Each hydraulic pump submitted for delivery under a procurement contract shall be subjected to the quality conformance requirements specified herein. These shall consist of a routine visual and dimensional examination and a test program to determine product conformance to the workmanship, dimensional, functional, and performance requirements of this specification, MIL-H-8775 for type I and type II pumps or MIL-H-8890 for type III pumps, as applicable, and the pertinent detail specification.

4.4.1 Examinations.

4.4.1.1 Examination of product. The pump shall be examined to determine conformance with the applicable standards and all requirements of this specification, MIL-H-8775 or MIL-H-8890, as applicable, and of the pertinent detail pump specification for which there are no specific tests.

4.4.1.2 Packaging, packing, and marking. Preparation for delivery shall be in accordance with section 5 of this specification.

4.4.2 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 2 ml per hour, or as specified in the detail pump specification. Starting with load cycles (see 4.4.2.3), the hydraulic fluid in the test circuit shall be as specified in the detail pump specification. Filter elements conforming to MIL-F-8815 or as specified in the detail pump specification shall be installed in the pump inlet, outlet and case drain or cooling port lines of the test set-up. The pump inlet fluid shall be continuously filtered to 5 micron absolute. At any phase of testing, if working parts require replacement, the entire quality conformance test procedure shall be repeated. The break-in run portion shall be omitted if the rotating group assembly is not affected.

4.4.2.1 Proof pressure tests. These tests shall be conducted at any temperature, either statically or with the pump in operation. There shall be no evidence of permanent deformation following the test.

a. The discharge port shall be pressurized for at least one minute to the proof pressure specified in the detail pump specification.
b. With discharge port at rated pressure, the case drain and inlet port shall be pressurized for at least one minute to the proof pressures specified in the detail pump specification.

4.4.2.2 Break-in run. The break-in run shall be conducted at any desired operating conditions but shall include at least 15 minutes of operation at rated speed and temperature while the pump is running at maximum full-flow pressure.

4.4.2.3 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 detail specification with equal dwells at each load condition.

4.4.2.4 Tear down inspection. A tear down 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 detail pump specification. The pump shall be disassembled and inspected and if all parts are in acceptable condition, the pump shall be reassembled and the test program continued. After the last pump, the tear down 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 detail pump specification.
b. Alternate tooling and production facilities are designated.

4.4.2.5 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. The operating time and duty shall be chosen such as to yield the most significant patch information for a particular pump model, and shall be a permanent part of the acceptance test procedure along with the filter membrane specifics. Provision shall be made in the detail pump specification for establishment of a preliminary patch standard before the start of the quality conformance test of the first pump to be delivered tinder the contract. This preliminary patch standard shall be modified with the agreement of the contracting parties until the completion of the functional test of the 25th pump to be delivered under the contract, thereafter, the standard in effect for that test shall become the standard for the remainder of the contract.

4.4.2.5.1 Patch preparation. The fluid in the applicable filter bowl(s) shall be collected in individual clean containers. Rinse both the filter bowl and element with a minimum of 15 ml of a fluid solvent and add to the applicable container. The total resulting fluid shall be passed through a disc of #40 Whatman paper. Wash the disc free of fluid with a minimum of 15 ml of fluid solvent. After drying, the resultant filter patch shall be coated with clear lacquer and permanently attached to the log sheet of the test. All fluid solvent shall be filtered through a 0.45 micron pore size membrane prior to use during the foregoing procedure. Alternative procedures may be employed if those are more effective or definitive for a particular pump.

4.4.2.5.2 Patch comparison. Each filter patch specified in the quality conformance 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 first patch and

shall also show equal or less contaminant than the standard patch. If it does not, one or two additional patch tests may be run to establish a trend. If unsuccessful with these tests, the pump shall be disassembled to determine the source of the contamination and corrective action shall be taken.

4.4.2.6 Calibration. During calibration, the test conditions shall be as specified in the detail pump 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 detail pump specification.

a. Rated discharge pressure variation as the pump speed is varied from 50 to 100 percent of rated speed or speeds specified in the detail pump specification.
b. There shall be no indication of pressure control instability as the pump speed is varied from 50 to 100 percent of rated speed throughout the flow range. Specific system conditions, if any, shall be defined in the detail pump specification.
c. The flow of the pump at the maximum full-flow pressure and rated speed shall be measured and recorded. Flow shall be measured in the low pressure side of the discharge line and compensation made for fluid compressibility when stating the value.
d. The case drain flow at rated discharge pressure and speed shall be measured and recorded.
e. Input torque at maximum full-flow pressure or at rated discharge pressure shall be measured if required by the detail pump specification. Such a test shall not be required if pump torque is not critical in the application.

4.5 Reliability test. The purpose of this test is to demonstrate that the equipment meets the specified performance and reliability requirements. This test shall be performed when specified by the contracting activity.

4.5.1 Test plan. The reliability test shall be conducted in accordance with MIL-STD-781, test plan VC, or an alternate plan if approved by the contracting activity. The load cycles shown are derived from fighter aircraft mission profiles shown in MIL-STD-781 plus a 50 percent factor. Load cycles for cargo/transport aircraft would be less severe but operating hours per mission would be higher.

4.5.2 Accept-reject criteria. The accept-reject criteria shall be as shown graphically for test plan VC of MIL-STD-781. The decision risk for this plan is 10 percent and the discrimination ratio is 3.0:1. Testing shall be continued until the total unit hours together with total count of relevant failures permit either an accept or reject decision. The test shall be completed when the total unit test hours in multiples of lower test mean-time

between-failure (MTBF), θ_1 plotted against total failures, falls in an accept or reject area of the graph. (θ_1 is 667 hours unless otherwise specified by the contracting activity).

4.5.3 Test samples. Unless otherwise specified by the contracting activity, the minimum number of test samples selected at random from the first 25 production pumps shall be 5.

4.5.3.1 Overhaul period of samples. In case of failure of samples during tests, no unit shall be overhauled with less than 180 hours of on-line testing. In the event that infant failures reduce the number of samples in the test program to less than 5, new units shall be selected at random from production beyond the initial 25.

4.5.4 General outline of tests. Unless otherwise specified by the contracting activity, the tests shall be performed simultaneously or in series on each of the 5 samples. Each pump shall be subjected to a sufficient number of 20 hour test spectra to demonstrate compliance (see 4.5.2). The 20 hour test spectrum is shown in table VI.

4.5.5 Failures during tests. A test pump shall be considered failed when the unit no longer conforms to the requirements of this specification, In the event that a failure of the test pump is attributed to a remedial design or quality control deficiency, testing on all five pumps shall be discontinued until the units have been reinspected or modified to correct the deficiency. Complete analysis and corrective action taken on all failures shall be recorded.

4.5.5.1 Replacement of failed units. Failed units shall be replaced with new or overhauled units and the tests continued until acceptance under the accept-reject criteria (see 4.5.2). When a unit fails in under 180 hours of on-line testing no overhaul is permitted and the unit shall be replaced by a new unit randomly selected from production units.

4.5.6 Test conditions and schedules.

4.5.6.1 General. The conditions, as specified for the normal endurance tests (see 4.3.2.1.10), shall apply for the reliability tests with respect to type and quantity of hydraulic fluid, filtration, system impedance, tolerance limits on fluid temperature, inlet pressure, case pressure, discharge pressure, pump speed, and flow. The test spectrum-shown in table Vi shall be followed.

4.5.6.2 Pump speed. Unless otherwise specified, the pump shall be maintained at rated speed for all tests.

4.5.6.3 Fluid temperature. Each 20 hour test period shall include 14 hours of operation with the pump inlet fluid temperature at rated temperature (4th through 17th hour) and 6 hours of testing at a lower fluid temperature as specified in the detail pump specification (first 3 and last 3 hours).

4.5.6.4 Case drain pressure and flow. Before the start of cycle tests, the case drain flow shall be measured and recorded while the pump is operating at rated speed, rated discharge pressure and rated inlet fluid temperature and while the case drain pressure is maintained at 20 psi (140 kPa) above inlet pressure or as specified in the detail pump specification. Case drain pressure shall be regulated to a value of 40 to 50 psi (275 to 345 kPa) or as specified in the detail pump specification, above inlet pressure, during pump operation at the start of the tests at no load flow and rated inlet temperature. This pressure shall be set with an orifice type restriction. The restriction shall not be removed nor changed throughout the tests but shall be modified by a bypass adjustment during case drain flow monitoring at the start of each 20-hour segment.

4.5.6.5 Inlet pressure. Inlet pressure shall be maintained as specified in the detail pump specification.

4.5.6.6 Test pressures. Test pressures shall be as specified in the detail pump specification and measured and recorded at the start of each 20-hour segment.

4.5.6.7 System bleeding. The system shall be thoroughly bled of air for all tests. After each component or filter change, the system shall be bled and fluid losses replenished.

4.5.6.8 Filter patch tests. Patch test samples shall be collected continuously throughout the 20-hour test segment or as specified by the contracting activity.

4.5.6.9 High flow load cycles. Each of the six-hour high flow load cycle periods (first three and last three hours) shall include 360 full test cycles consisting of 5 seconds at rated discharge pressure and 5 seconds at full-flow pressure. Load changes shall be effected using solenoid valves with operating times of 0.05 seconds or less.

4.5.6.10 Low flow load cycles. During 12 hours (4th through 16th) of the 20 hour segment, the pump shall be cycled continuously from 10 to 20 percent rated full-flow, operating for 5 seconds at each condition.

4.5.6.11 Start-stop cycles. At the start of each hour test, the pump shall be accelerated to rated speed within a 15 second period against a blocked line. The system pressure shall be reduced to approximately 100 psi (700 kPa) prior to each start. Pumps shall be allowed to coast to a stop against a blocked system immediately after reaching rated speed. The deceleration time shall be recorded. Fluid temperature shall range from ambient to normal test levels, but shall be recorded during the fast starts. At the option of the contracting activity, the start-stop cycle variables shall be changed as desired.

TABLE VI. Test spectrum.

LOG OF TEST HOURS	TEST CONDITIONS
0 ---------- 20	
0-0 0-0	Load cycles, at first three and last three hours.
0----------0	10% to 20% flow demand at fourth through fifteenth hour.
00	0% flow demand at sixteenth and seventeenth hour.
0----------0	Rated pump speed, all tests.
0-0 0-0	Lower than rated fluid temperature at first three and last three hours.
0----------0	Rated fluid temperature at fourth through seventeenth hour.
0----------0	Start stop cycle, one each hour.
0----------0	Patch test; collection continuous through 20 hour period optional
0----------0	Monitor external leakage, pump speed, pressure & flow at least once each hour throughout the test. Record case drain flow.

4.5.6.12 External leakage. Both static and dynamic shaft seal leakage shall be monitored throughout the entire test. External leakage, other than shaft seal leakage, sufficient to form a drop shall be considered a failure.

4.5.6.13 Performance verification. At the beginning of each 20 hour segment the units shall be operated at rated speed, rated temperature, and rated inlet pressure. Measurements of output and case flow shall be performed at rated full flow pressure.

4.5.6.14 Cold starts and rapid warm up. At the beginning of the endurance tests, three cold start cycles are to be performed on each pump sample. The fluid in the pump suction line and reservoir shall be stabilized at -65°F (-54°C) or to a temperature specified in the detail pump specification. After the cold soak the pump shall be brought up to rated speed and rated discharge pressure in not more than 15 seconds or as specified in the detail pump specification. Immediately after reaching rated speed, the

pump shall be load cycled in accordance with 4.5.6.9 for 10 minutes. Static and dynamic shaft seal leakage shall be recorded and the pump checked for external leakage.

5. PACKAGING

(Selection of applicable levels of preservation and packing shall be as specified by the contracting activity)

5.1 Preservation.

5.1.1 Level A. Unless otherwise specified by the contract or purchase order (see 6.2e), or by the detail pump specification, each pump shall be filled with a rust inhibiting fluid conforming to MIL-H-6083 or MIL-H-46170. All ports shall be sealed by closures conforming to MIL-C-5501. All exterior surfaces of the component shall be protected from corrosion. The preferred method is MIL-P-116 Method 1C, using a corrosion preventive compound conforming to MIL-C-11796 or MIL-C-16173. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to MIL-B-121 and sealed with tape conforming to PPP-T-60. Each wrapped component shall be cushioned and securely packaged within the most economical interior carton or box conforming to either PPP-B-566, PPP-B-676, or ASTM-D1924. The choice of the container shall be consistent with the weight and cube of the hydraulic component.

5.1.2 Minimum protection. The components shall be packaged using standard commercial prctice in accordance with ASTM-D3951.

5.2 Packing.

5.2.1 Level A. Components, preserved and packaged as specified in 5.1.1, shall be packed in exterior shipping containers conforming to PPP-B-601 (overseas type) or ASTM-D1924. Plywood, if used, shall be in accordance with A-A-55057. Case liners conforming to MIL-L-10547 and appendix thereto shall be furnished. A case liner is not required for containers conforming to ASTM-D1924 when all seams and closures are sealed with waterproof tape conforming to PPP-T-60, Type III, Class 1. Box closures shall be as specified in the appendix of the applicable box specification.

5.2.2 Level B. Components, preserved and packaged as specified in 5.1.1, shall be packed in exterior shipping containers conforming to PPP-B-591, PPP-B-621, PPP-B-585 (Class 1), ASTM-D1924, or PPP-B-601 (domestic type). Closures shall be as specified in the applicable box specification or appendix thereto. Fiberboard boxes shall conform to the special requirements of the applicable box specification and shall be limited to not more than 90 pounds gross weight.

5.2.3 Minimum protection. Components, packaged as specified in 5.1.2, shall be packed in containers of the type, size and kind commonly used for the purpose, in a manner that will ensure acceptance by common carrier and safe

delivery at destination. Shipping containers shall comply with the Uniform Freight Classification Rules, or regulations of other carriers as applicable to the mode of transportation.

5.3 Marking. III addition to any special marking required by the contract or order, or the detail pump specification, interior packages and exterior shipping containers shall be marked in accordance with MIL-STD-129.

5.3.1 Reinspection of marking. Reinspection of marking shall be as specified by the contracting activity (see 6.2h).

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The hydraulic pumps are intended for use on turbine engine driven aircraft for hydraulic operation of such mechanisms as powered flight control systems, landing gears, brakes, flaps, gun turrets, servo units, bomb-bay doors, and automatic pilots. The pumps are primarily intended to be driven by the airplane turbine engine and to supply fluid to systems in accordance with MIL-H-5440 or MIL-H-8891, as applicable. When driven by other means or used in uninhabited aircraft, additional tests and separate approval may be required by the contracting activity.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number and date of this specification, including amendments.
b. Type of system in which the pump is to be used (see 1.1). Manufacturer's part number.
d. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2).
e. Whether qualification inspection is waived (see 4.3.1.1).
f. Name and address of the laboratory which conduct the qualification inspection (see 4.3.1.2) and the name of the Government activity responsible for conducting the qualification inspection program.
g. Applicable levels of preservation, packaging, packing, and marking (see 5, and 5.3).
h. Reinspection of-marking (see 5.3.1).
i. Items of data requirements (see 6.3).

6.3 Consideration of data requirements. The following data requirements should be considered when this specification is applied on-a contract. The applicable Data Item Descriptions (DIDs) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the Dills are tailored to reflect the requirements

of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DOD FAR Supplement 227.405-70 exempts the requirement for a DD Form 1423. For the department of the Navy, the Contract Data Requirements are shown in SD8706.

Reference Paragraphs	DID Number	DID Title	Suggested Tailoring
4.3.1	DI-NDTI-80809A	Test/Inspection report	10.2.7
4.3.1.1	DI-NDTI-80809A	Test/Inspection report	Use contractor format
4.3.1.2	DI-NDTI-80809A	Test/Inspection report	Use contractor format

The above DIDs were those cleared as of the date of this specification. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DIDs are cited on the DD Form 1423.

6.4 Definitions.

6.4.1 Decision risk.

6.4.1.1 Consumer's risk (β). Consumer's risk (β)is the probability of accepting equipment(s) with a true mean-time-between-failure (MTBF) equal to the lower test MTBF (θ_1). The probability of accepting equipment(s) with the true MTBF less than the lower test MTBF (θ_1)will be less than θ_1.

6.4.1.2 Producer's risk (α). Producer's risk (α)is the probability of rejecting equipment(s) with a true MTBF equal to the upper test MTBF (θ_0). The probability of rejecting equipment(s) with true MTBF greater than the upper test MTBF will be less than α.

6.4.1.3 Discrimination ratio (d). The discrimination ratio is one of the standard test plan parameters which establishes the test plan envelop. The ratio discriminates between $\theta_0$and θ_1; i.e., d = θ_0/θ_1.

6.5 Subject term (key word) listing.

Aircraft
Discharge pressure
Flight control
Flow
Fluid power
Type I, II, III fluid systems

6.6 Chanages from Previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the

ALPHABETICAL INDEX

Paragraph		Page
3.4.4	Acceleration	15
4.5.2	Accept-reject criteria	31
6.2	Acquisition requirements	36
3.3.15	Adjustment	12
4.3.2.1.10.6	Air ingestion	27
4.3.2.1.6.1.2	All other tests	22
3.4.1	Altitude	12
2	APPLICABLE DOCUMENTS	1
3.4.5	Atmospheric conditions	15
3.3.14	Balance	12
4.4.2.2	Break-in run	29
4.3.2.1.10.3	Calibration	27
4.4.2.6	Calibration	31
4.3.2.1.5	Calibration test	22
3.3.5.3	Case drain flow	6
3.3.5	Case drain port pressure and flow	6
4.5.6.4	Case drain pressure and flow	33
3.6.1.3	Castings	17
4.3.2.1.10.9	Cavitation test	28
6.6	Changes from previous issue	37
4.2	Classification of inspections	19
4.5.6.14	Cold starts and rapid warmup	34
6.3	Consideration of Data requirements	36
6.4.1.1	Consumer's risk	37
3.6.1.2	Corrosion protection	16
4.3.2.1.8.3	Cyclic frequency vibration	24
6.4.1	Decision risk	37
6.4	Definitions	37
3.3.13.4	Repressurization	12
3.6.4	Design and construction	18
3.6	Detail requirements	16
3.5.1	Dimensions	15
3.5.3.2	Direction of rotation	15
3.3.17	Directionally critical components	12
6.4.1.3	Discrimination ratio (d)	37
3.3.7	Displacement	7
3.5.4	Drive coupling and bushing	15
4.3.2.1.10.10	Drive coupling and spline bushing shear test	28
3.3.11.2	Efficiency	8
4.3.2.1.10	Endurance test	25
3.4	Environmental requirements	12
4.4.1	Examinations	29
4.4.1.1	Examination of product	29
4.5.6.12	External leakage	34
4.5.5	Failures during tests	32
4.3.2.1.10.8	Failure of parts	28

INDEX

Paragraph		Page
4.3.2.1.10.2	Filter check	26
4.4.2.5	Filter patch test	30
4.5.6.8	Filter patch tests	33
4.3.2.1.10.1	Filtration for endurance test	26
4.3.2.1 .10.7	Fluid	28
4.3.2.1.3	Fluid immersion test	21
4.5.6.3	Fluid temperature	32
4.3.2.1.10.4.1	Full-flow cycles	27
3.3	Functional requirements	5
4.5.6.1	General	32
4.5.4	General outline of tests	32
2.1	Government documents	1
4.3.2.1.7	Heat rejection	24
4.5.6.9	High flow load cycles	33
3.3.1	Hydraulic fluid	5
3.6.3	Identification of product	17
4.5.6.5	Inlet pressure	33
3.5	Installation requirements	15
6.1	Intended use	36
3.6.4.2	Leakage	18
5.1.1	Level A	35
5.2.1	Level A	35
5.2.2	Level B	35
4.4.2.3	Load cycles	30
4.5.6.10	Low flow load cycles	33
4.3.2.1.9	Low temperature thermal cycle test	25
3.6.4.1	Lubrication	18
3.6.6	Maintainability	18
5.3	Marking	36
3.6.1	Material	16
3.3.3	Maximum full flow pressure	6
3.3.4.2	Maximum inlet pressure	6
4.3.2.1.6	Maximum pressure, response time, and pressure pulsations	22
4.3.2.1.6.2	Maximum pressure test	23
3.3.5.2	Maximum transient case drain pressure	6
3.3.13.3	Maximum transient pressure	11
3.3.6.1	Maximum system temperature	7
3.6.1.1	Metals	16
4.3.2.1.1	Method of selection	20
3.3.6.2	Minimum fluid temperature	7
3.3.4.1	Minimum inlet pressure	6
4.3.2.1.5.2	Minimum operating speed	22
5.1.2	Minimum protection	35
5.2.3	Minimum protection	35
3.5.3	Mounting	15

INDEX

Paragraph		Page
4.3.2.1.10.4.2	No-flow cycles	27
2.2	Non-Government publications	3
6	NOTES	36
2.3	Order of precedence	4
3.5.3.1	Orientation	15
4.3.2.1.8.4	Other vibration tests	24
4.5.3.1	Overhaul period of samples	32
3.3.2.1	Overpressure	5
3.3.9.1	Overspeed	8
5.2	Packing	35
5	PACKAGING	35
4.4.1.2	Packaging, packing, and marking	29
4.4.2.5.2	Patch comparison	30
4.4.2.5.1	Patch preparation	30
3.3.11	Performance	8
4.5.6.13	Performance verification	34
3.5.5	Ports	16
3.5.5.2	Postmarkings	16
3.1	Precedence	4
5.1	Preservation	35
4.3.2.1.6.5	Pressure control and stability	24
3.3.12	Pressure pulsations	11
4.3.2.1.6.4	Pressure pulsations	23
6.4.1.2	Producer's risk	37
4.3.2.1.4	Proof pressure tests	21
4.4.2.1	Proof pressure tests	29
4.3.2.1.10.5	Pump case pressure cycles	27
4.3.2.1.5.1	Pump inlet pressure	22
4.3.2.1.8.5	Pump operation	24
4.5.6.2	Pump speed	32
3.2	Qualification	5
4.3	Qualification	19
4.3.1	Qualification approval procedure.	19
4.3.1.2	Qualification test report	20
4.3.2	Qualification tests	20
4.3.2.1	Qualification test methods	20
4	QUALITY ASSURANCE PROVISIONS	19
4.3.2.1.2	Quality conformance	20
4.4	Quality conformance	29
3.3.5.1	Rated case drain pressure	6
3.3.8	Rated flow	7
3.3.2	Rated discharge pressure	5
3.3.10	Rated endurance	8
3.3.4	Rated inlet pressure	6
3.3.9	Rated speed	7
3.3.6	Rated temperature	7

INDEX

Paragraph		Page
5.3.1	Reinspection of marking	36
3.6.5	Reliability	18
4.5	Reliability test	31
4.5.5.1	Replacement of failed units	32
3	REQUIREMENTS	4
4.3.2.1.8.2	Resonant frequency vibration	24
3.3.13.1	Response time	11
4.3.2.1.6.1.1	Response time	22
4.3.2.1.6.3	Response time	23
4.1.1	Responsibility for compliance	19
4.1	Responsibility for inspection	19
3.3.16	Safety wire sealing	12
1	SCOPE	1
1.1	Scope	1
3.5.2	Seals	17
4.3.1.1	Similarity	19
2.1.1	Specifications, standards, and handbooks	1
3.3.13.2	Stability	11
4.3.2.1.10.4	Start-stop cycles	27
4.5.6.11	Start-stop cycles	33
3.5.5.1	Structural strength	16
6.5	Subject term (key word) listing	37
4.5.6.7	System bleeding	33
3.1.2	System characteristics	4
4.3.2.1.6.1	System impedance	22
3.1.1	System specifications	4
4.3.2.1.10.11	Teardown inspection	29
4.4.2.4	Teardown inspection	30
3.4.2	Temperature	12
4.5.6	Test conditions and schedules	32
4.5.1	Test plan	31
4.5.6.6	Test pressures	33
4.4.2	Test program and inspection methods	29
4.3.2.1.8.1	Test pump mounting orientation	24
4.5.3	Test samples	32
4.3.2.1.9.1	Thermal shock	25
3.3.11.1	Torque and heat rejection	8
3.3.13	Variable flow control	11
3.4.3	Vibration	15
4.3.2.1.8	Vibration tests	24
3.5.2	Weight	15
3.7	Workmanship	18

FIGURES

Page

FIGURE 1 MAXIMUM PUMP DISPLACEMENT vs PUMP SPEED (in-pound unit) 9

FIGURE 2 MAXIMUM PUMP DISPLACEMENT VS PUMP SPEED (metric unit) 10

FIGURE 3 TYPICAL PRESSURE TRANSIENT FULL FLOW TO ZERO FLOW 13

FIGURE 4 TYPICAL PRESSURE TRANSIENT ZERO FLOW TO FULL FLOW 14

TABLES

Page

TABLE I RATED DISCHARGE PRESSURE 5

TABLE II TEMPERATURE RELATIONSHIP 7

TABLE III METALLIC COATINGS 17

TABLE IV QUALIFICATION TESTS 21

TABLE V ENDURANCE TEST CONDITIONS 26

TABLE VI TEST SPECTRUM 34

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3. DOCUMENT TITLE
PUMPS, HYDRAULIC, VARIABLE FLOW, GENERAL SPECIFICATION FOR

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