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485 LEXINGTON AVENUE
NEW YORK 17, N.Y.

AEROSPACE STANDARD

AS 595A

CIVIL TYPE AIRCRAFT VARIABLE DELIVERY HYDRAULIC PUMP

Issued 2-1-59
Revised 7-10-64

1. SCOPE

1.1 This specification establishes the common requirements and provides a guide for special requirements for variable delivery hydraulic pumps, suitable for use in civil aircraft. It also specifies the methods to be used for demonstrating compliance with these requirements.

1.2 Model Specification - A pump Model Specification, conforming to Appendix I of this specification, shall be prepared for each distinct pump model by either the purchaser who intends to purchase and install that model or the pump manufacturer, and shall be submitted to the purchaser for approval.

2. APPLICABLE SPECIFICATIONS, OTHER PUBLICATIONS, AND DRAWINGS

2.1 The following documents shall form a part of this specification to the extent specified herein. The applicable issue of each shall be that in effect on the date of this Aerospace Standard unless otherwise specified in the Model Specification. Supplementary specifications, standards, etc., which by reference in any of the following publications are indicated to be part thereof, shall not be considered as effective except as specifically stated in the Model Specification, or as may be otherwise mutually agreed upon between the vendor and purchaser.

Federal Specifications

QQ-C-320	Chromium Plating (Electrodeposited)
QQ-N-290	Nickel Plating
QQ-P-416-1	Plating, Cadmium (Electrodeposited)
VV-P-236	Petrolatum, Technical
QQ-Z-325	Zinc Plating (Electrodeposited)

3. REQUIREMENTS

3.1 Functional Requirements

3.1.1 Hydraulic Fluid - The basic design of any pump normally presumes the use of a specific fluid, and the ability of the pump to meet the functional requirements stated below is predicated on the use of that fluid. Therefore the identity of the hydraulic fluid that the particular pump model is designed to handle shall be fully defined in the Model Specification.

3.1.2 Rated Discharge Pressure - The rated discharge pressure of a pump is defined as the maximum pressure against which that pump is designed to operate continuously at rated temperature and rated speed. It shall be expressed as pounds per square inch gage (psig).

3.1.2.1 The design of the pump shall be such as to maintain its rated discharge pressure at the following combination of conditions: rated temperature, rated speed, rated inlet pressure, and zero flow, using the hydraulic fluid specified in the Model Specification.

3.1.2.2 The value of the rated discharge pressure shall be stated in the Model Specification.

3.1.3 Maximum Full Flow Pressure - The maximum full flow pressure of a pump is defined as the maximum discharge pressure at which the pump control will not be acting to reduce pump delivery. It shall be expressed as pounds per square inch gage (psig), and its minimum value shall be established in the Model Specification.

3.1.3.1 For purposes of acceptance and pre-production testing the value of maximum full flow pressure shall be set to the cutout and full flow pressures defined by the Model Specification.

3.1.4 Inlet Pressure - The rated inlet pressure of a pump is defined as the indicated pressure at the inlet port of the pump when it is operating at rated speed, maximum full flow pressure, and a specified fluid inlet temperature. 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 pounds per square inch absolute (psia).

3.1.4.1 The required maximum and minimum values of inlet pressure at stated values of fluid inlet temperature shall be specified in the Model Specification.

3.1.5 Case Drain Port Pressure - Unless a different value is specified in the Model Specification, all pumps shall be designed to withstand a pressure of 150 psi maximum and surges to 500 psi for at least 20,000 cycles at the case drain port without permanent damage or impairment of function.

3.1.6 Rated Temperature - The rated temperature of a pump is defined as the maximum continuous fluid temperature at the inlet port of the pump. It is expressed in degrees Fahrenheit (F).

3.1.6.1 The rated temperature is related to the maximum temperature of the hydraulic system in which the pump is to be used according to the value shown and shall be one of the values as follows:

Hydraulic System	Maximum System Temperature	Rated Temperature of Pump Inlet
Type I	160 F	140 F
Type II	275 F	240 F
Type III	450 F	400 F

It shall be specified in the Model Specification.

3.1.7 Minimum Continuous Fluid Temperature - This temperature at the pump inlet port is not related to the rated temperature by this specification. A minimum continuous fluid temperature may be specified in the Model Specification.

3.1.8 Maximum Displacement - The maximum displacement of a pump is defined as the maximum theoretical column of hydraulic fluid delivered in revolution of its drive shaft. It shall be expressed as cubic inches per revolution (cu. in. rev.).

3.1.8.1 The maximum displacement of any pump model shall be determined by calculation from 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 effects of allowable manufacturing tolerances, of deflections of the pump structure, of compressibility of the hydraulic fluid, of internal leakage, and of temperature shall be excluded from the calculation, because the maximum displacement is intended to be an index of the size of the pump rather than of its performance.

3.1.8.2 The maximum displacement of a pump shall be specified in the Model Specification and shall be equal to or not more than 20% greater than the specified value.

3.1.9 Rated Delivery - The rated delivery of a pump is defined as the measured output of the pump under conditions of rated temperature, rated speed, and maximum full flow pressure, using the hydraulic fluid specified in the Model Specification. It shall be expressed in U. S. gallons per minute (gpm), and its value specified in the Model Specification.

3.1.10 Rated Speed - The rated speed of a pump shall be the maximum speed at which the pump is designed to operate continuously at rated temperature, and rated discharge pressure. The rated speed shall be measured and stated as rpm of the pump drive shaft.

3.1.10.1 The rated speed of any individual model pump shall be established in the Model Specification.

3.1.11 Rated Endurance - The rated endurance of a pump is defined as the total number of hours of operation to be included in the endurance phase of its pre-production test (see paragraph 4.3.3.9).

3.1.11.1 A pump used on commercial aircraft, using a realistic test sequence shall have a life test of no less than 4000 hours unless otherwise specified in the Model Specification.

3.1.12 Efficiency - The efficiency of a pump is defined as the ratio of output power to input power when the pump is operated at rated temperature, rated speed, and maximum full flow pressure, using the hydraulic fluid specified in the Model Specification. It is customarily stated as a percentage. The above ratio is commonly referred to as "over-all efficiency" and includes volumetric efficiency. In the determination of output power by calculation from flow rate and pressure change, only the net pressure difference between inlet and outlet ports of the pump shall be used.

3.1.12.1 A minimum value for all efficiencies shall be specified in the Model Specification.

3.1.13 Pressure Pulsations - For the purposes of this specification, pressure pulsations are defined as oscillations of the discharge, the inlet and the drain pressures, occurring during nominally steady operating conditions, at a frequency equal to or higher than the pump shaft speed. The amplitude of pressure pulsations, as determined by the test procedure of paragraph 4.3.3.5.3, shall be recorded and shall not exceed such limits as may be prescribed in the Model Specification.

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

3.1.14.1 Speed of Response - The speed of response of the delivery control means is defined as the time required for the control to regulate from rated discharge pressure to maximum full flow pressure or vice versa.

3.1.14.1.1 The oscillographic trace of discharge pressure vs. time shall be employed as the criterion of movement of the delivery control mechanism.

3.1.14.1.2 All pump models, when operating at rated temperature and at any speed greater than 50% of rated speed, shall regulate from rated discharge pressure to maximum full flow pressure or any intermediate pressure, and vice versa in not more than 0.05 second.

3.1.14.2 Stability - Stability is defined as freedom from persistent or quasi-persistent oscillation or "hunting" of the delivery control mechanism.

3.1.14.2.1 The oscillographic trace of discharge pressure vs. time shall be employed as the criterion of stability.

3.1.14.2.2 All pump models, when operating at rated temperature and at any speed greater than 50% of rated speed, after being disturbed from steady state operation by a change in flow demand, shall recover steady state operation--other than permissible pressure pulsations, as defined in Paragraph 3.1.13--in not more than one second after the initial response to that change in flow demand.

3.1.14.3 Maximum Transient Pressure - The maximum transient pressure is defined as the peak value of the oscilloscopic trace of discharge pressure, made during operation of a pump, as prescribed in paragraph 4.3.3.5.1.

3.1.14.3.1 The value of the maximum transient pressure, as determined in the transient pressure tests specified in paragraph 4.3.3.5.1 of this specification, shall not exceed 150% of rated discharge pressure.

3.1.15 Rated Horsepower - The rated horsepower of the pump is defined at the maximum horsepower output at rated delivery and maximum full flow pressure.

3.2 Environmental Requirements - In general, pumps shall be designed to operate, without limitation as to time, and without impairment of function or change in adjustment, under the environmental conditions specified below. Except as specifically directed herein, testing to demonstrate compliance with these requirements shall not be mandatory.

3.2.1 Altitude - Provided inlet pressure is maintained in accordance with paragraph 3.1.4, pump performance shall not be affected by change of altitude from sea level to 80,000 feet or vice versa.

3.2.2 Ambient and Pad Temperatures - The estimated ambient and pump pad temperatures shall be as specified in the Model Specification.

3.2.3 Vibration - It shall be a design objective that pumps shall be capable of withstanding all normal vibrations excited by the driving means.

3.2.3.1 For design purposes, linear vibrations excited by typical turbine propulsion engines of current design shall be assumed to be defined by Figure 1.

3.2.3.2 For design and test purposes, torsional vibrations excited by the driving means shall be considered negligible.

3.2.3.3 As part of the pre-production test, all pump models shall be subjected to the vibration test specified in paragraph 4.3.3.7 of this specification.

3.2.4 Accelerations - All pumps shall be designed to withstand sustained accelerations of 20 g applied in any direction during operation.

3.2.5 Atmospheric Conditions - All pumps shall be designed to withstand continuous exposure, in the configuration as installed in aircraft, 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.

3.2.6 Sonic Fatigue - The pump shall not be adversely affected or prematurely failed due to external noises as defined in the Model Specification.

3.2.7 Sonic Affect - The pump shall not generate noise greater than that indicated in the Model Specification.

3.3 Installation Requirements

3.3.1 Dimensions - Dimensions pertinent to the installation of pumps in aircraft shall be shown on the manufacturer's Installation Drawing.

3.3.2 Weight - The dry weight of the completely assembled pump shall not exceed the value specified in the Model Specification.

3.3.3 Mounting - All pumps shall incorporate a standard mounting flange, which shall be in accordance with either AND10261 or AND10262, as specified in the Model Specification.

3.3.3.1 The oil holes and oil flow, specified on drawings AND10261 and AND10262, shall not be applicable.

3.3.3.2 The mounting flange drain bosses specified on drawings AND10261 and AND10262, as applicable, shall be required, and all of them may be tapped at the option of the pump manufacturer. By agreement between the pump manufacturer and the purchaser, only certain of the bosses shall be tapped for external connection; in such case, the boss or bosses to be so tapped shall be specifically designated on the installation drawing of the pump which accompanies the Model Specification.

3.3.3.3 Pump operation shall be unaffected by the position in which the pump is mounted on the engine drive pad, or by the orientation in space of the plane of the pump mounting flange.

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

3.3.4 Drive Coupling - A replaceable part of the pump assembly, incorporating a shear section, shall be interposed between the pump drive shaft and the engine accessory drive shaft by which the pump is to be driven. This shear coupling part shall be held in place by a positive retainer.

3.3.5 Ports - Port sizes shall be in accordance with MS 33524; port configuration shall be specified in the Model Specification.

3.3.5.1 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 as specified in MIL-F-5509.

3.3.5.2 Inlet, outlet, mounting flange seepage drain and case drain ports shall be identified on each pump by clear and permanent markings.

3.4 Detail Requirements

3.4.1 Material - Materials and processes used in the manufacturer of these products shall be of high quality, suitable for the purpose and shall conform to applicable specifications. Materials conforming to the pump manufacturer's material specifications may be used, provided the specifications are acceptable to the purchaser and contain provisions for adequate tests. The use of the pump manufacturer's specifications will not constitute waiver of other applicable specifications.

3.4.1.1 Selection of Materials - Specifications and standards for all materials and parts, which are necessary for the execution of this specification, shall be selected as provided in the following paragraphs.

3.4.1.2 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 paragraph 3.4.1.3.

3.4.1.2.1 Type I System Pumps - Except for internal surfaces in constant contact with hydraulic fluid, ferrous alloys shall have a chromium content of not less than 12% or shall be suitably protected against corrosion as specified under Paragraph 3.4.1.3. O-ring grooves for external seals shall not be considered as internal surfaces in constant contact with hydraulic fluid.

3.4.1.2.2 Type II and Type III System Pumps - Ferrous alloys shall have a chromium content of not less than 12% chrome or shall be suitably protected against corrosion, as specified under paragraph 3.4.1.3. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to or on internal surfaces in contact with hydraulic fluid or exposed to its vapors. Magnesium shall not be used. Where performance or reliability of the pump will be jeopardized by the use of materials and processes, as defined in paragraphs 3.4.1.2 and 3.4.1.3 alternate materials and/or processes may be used subject to the approval of the purchaser. Such materials and/or processes shall be selected so as to provide the maximum degree of corrosion resistance consistent with the performance requirements.

3.4.1.2.3 Magnesium Alloys - The use of magnesium and its alloys shall be subject to the prior approval of the purchaser.

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

3.4.1.4 Castings - Castings shall be of high quality, clean, sound, and free from cracks, blow holes, 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.

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

3.4.3 Screw Threads - Except where necessary for functional or manufacturing purposes, only straight threads conforming to National Fine Thread Series, Class 3 (NF3) or Unified Fine Thread Series, Classes UNF-3A or UNF-3B shall be used.

3.4.3.1 Safetying - Threaded parts shall be positively locked or safetied by safety wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with standard aircraft practices. Star washers and lockwashers shall not be used. Jam nuts shall also be properly safetied.

3.4.4 Marking

3.4.4.1 Identification of Product - The equipment shall be marked for identification in accordance with standard practices and the purchaser's requirements.

3.4.4.2 Nameplate - A nameplate containing the following information legibly filled in shall be securely attached to the pump. The information shall be marked in the spaces provided:

AIRCRAFT VARIABLE DELIVERY HYDRAULIC PUMP

Model Specification No. _____
(or identification)

Mfs. Part No. _____
Mfs. Name or Trade Mark _____
Serial Number _____
Fluid _____

3.4.4.2.1 Any nameplate data required in addition to the above shall be specified in the Model Specification.

3.4.5 Design and Construction

3.4.5.1 Lubrication - The hydraulic pump shall be self-lubricated with no provisions for lubrication other than the circulating fluid.

3.4.5.2 Lubricants - Lubricants where used on threads or drive splines shall be suitable for use with the hydraulic fluid used. These must be approved by the purchaser. Lubrication shall be so accomplished that no disassembly for relubrication is necessary during endurance testing.

3.4.5.3 Retainer Rings - Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in any location where failure or dislocation of the ring will allow blow-apart of the equipment or failure of the unit. Neither shall they be used in locations where the buildup of clearances and manufacturing tolerances will allow destructive end play in the assembly contributing toward failure of packings or gaskets, brinelling, or fatigue failure of parts.

3.4.5.4 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 Section 4 of this specification.

3.4.5.5 Bosses - Internally threaded bosses shall be used where possible for connecting fittings and shall conform to drawing AND10050, unless otherwise specified in the Model Specifications. Spacing of ports for connecting fittings shall conform to drawing AND10074.

3.4.5.6 External Tube Connections - External male threaded tube connections, when used, shall conform to drawing AND10056 and AND10057 or MS33514, MS33515. Male threaded tube fitting ends of 3000 psi components shall be steel except that in sizes above 1/2 inch, tube size, these may be aluminum alloy or steel. Caution should be used in the use of aluminum alloy where repeated assembly could damage the fitting which is an integral part of the component thus rendering the entire component unserviceable.

3.4.5.7 Boss Clearance - Bosses shall be made deep enough or shall incorporate fitting stops to prevent damage to internal mechanism or restriction of fluid flow when universal fittings are screwed into the bosses to excessive depths.

3.4.5.8 Function Adjustment - Means shall be provided to adjust the delivery control mechanism to cause zero flow to occur at rated discharge pressure. This adjustment shall be preferably infinite, or acceptably in steps of less than 1% of rated discharge pressure, over a minimum range from 95% to 105% of rated discharge pressure. 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. Function adjustment shall be factory sealed unless otherwise specified by the purchaser. Where practicable, the arrangement of the adjustment means shall permit adjustment to be made while operating under full system pressure and with negligible loss of fluid.

3.4.6 Workmanship - All details of workmanship shall be in accordance with high grade aircraft, hydraulic pump manufacturing practices.

3.4.6.1 Cleanliness - All parts shall be clean and free from dirt, sand, and other foreign particles. Extreme care shall be taken to prevent dirt entering the assembled pump.

3.4.6.2 Surface Roughness - Surface roughness finishes where required shall be established and shall be specified in the manufacturer's drawings or as outlined in AS 291. The determination of surface finish shall be made by the use of surface roughness measuring equipment with an accuracy of plus or minus 15% at the level being measured.

3.4.7 Interchangeability - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the purchaser's requirements. Sub-assemblies composed of selected mating parts must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual parts of such assembled units need not be interchangeable.

3.4.8 Special Tools - The design shall be such that special or unusual tools shall not be used, unless absolutely necessary, for normal service maintenance and inspection of the equipment.

3.4.9 Maintenance

3.4.9.1 Repair and Replacement - Repair and replacement of parts shall be possible without discarding serviceable parts.

3.4.9.2 Overhaul - The pump shall operate on the aircraft without requiring maintenance or repair for the flight hours as specified in the Model Specification.

3.4.10 Reliability - Reliability shall be a prime consideration in the design, development and manufacture of this pump. Reliability will be achieved into the unit by such means as parts de-rating, high quality parts, close manufacturing controls, and inspection surveillance.

3.4.10.1 Justified unscheduled removal rate for pumps operating on aircraft shall be a maximum 0.25 per 1000 pump flight hours or as specified in the Model Specification.

4. QUALITY ASSURANCE PROVISIONS

4.1 General - For the purpose of demonstrating compliance of pumps with this specification and the applicable Model Specification, two distinct test programs shall be conducted, hereinafter referred to as Acceptance Tests and Design Approval Tests.

4.1.1 Acceptance Tests - This is essentially a routine inspection test program intended to contribute to overall quality control by demonstrating that all pumps of a given model perform within certain limits established in this specification and the pertinent Model Specification.

4.1.2 Design Approval Tests - This is a comprehensive and basic test program intended to demonstrate the suitability of a given model pump for use in the application for which it is specified. This program shall be conducted on selected samples of each pump model.

4.1.2.1 In cases where the pump model, for which design approval is desired, incorporates the same working parts as a pump model which has previously received design approval, all or some portion of the design approval tests may be waived by agreement between the purchaser and the pump manufacturer.

4.1.3 Filter Patch Standard - Provision shall be made in the Model Specification for the establishment of a Preliminary Patch Standard before the start of the Design Approval Test or before the first pump to be delivered under the contract, whichever occurs first. 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, thereafter the standard in effect for that test, will become the standard for the remainder of the contract.

4.2 Acceptance Test Procedures - Each hydraulic pump submitted for delivery under a procurement contract shall be subjected to the acceptance tests specified herein. Acceptance or approval of material during course of manufacture shall in no case be construed as a guarantee of the acceptance of the finished product.

4.2.1 Acceptance Test Methods

4.2.1.1 Examination of Product - The pump shall be examined to determine conformance with the applicable drawings and all requirements of this specification and of the pertinent Model Specification for which there are no specific tests.

4.2.1.1.1 Proof Test - The method, procedure, criteria, and sequence with respect to other phases of the acceptance test program, of a proof pressure test of the pump, if such be required, shall be defined in full detail in the Model Specification. Unless otherwise specified in the Model Specification, no proof pressure test shall be included in the acceptance test program.

4.2.1.2 Break-In Run - The break-in run shall be made with any desired pressure in the inlet and outlet lines and shall consist of 1/2 hour minimum at 80 per cent to 100 per cent of rated rpm.

4.2.1.2.1 After the above break-in run, the pump shall be disassembled and inspected by the pump manufacturer. If all parts are in acceptable condition, the pump shall be reassembled and placed on functional test. If working parts require replacement, the pump shall be reassembled, using the replacement parts, and the break-in run and subsequent disassembly, inspection, and reassembly repeated.

4.2.1.3 Functional Test - The Functional Test shall comprise the following runs:

(a) One-half hour at rated speed and maximum full flow pressure.

(b) One-half hour at rated speed with the discharge pressure varied between maximum full flow pressure and rated discharge pressure at a frequency of 6 cycles per minute.

(c) One hour at rated speed and rated discharge pressure; except that at 10-minute intervals the discharge pressure shall be reduced to maximum full flow pressure for one minute.

4.2.1.3.1 During all of the Functional Tests the hydraulic fluid used shall be that specified in the Model Specification. It shall be supplied to the pump at rated temperature ± 10 F and at the inlet pressure specified in the Model Specification.

4.2.1.3.2 During the Functional Test, shaft seal leakage shall be checked and shall not exceed an average rate of 5ml per hour. No other leakage of sufficient magnitude to form a drop shall be permitted.

4.2.1.3.3 Calibration - At the completion of run (c) the torque required to drive the pump at rated speed and rated discharge pressure shall be measured and recorded. The delivery of the pump at rated speed and maximum full flow pressure shall be measured and shall not be less than the minimum value of rated delivery specified in the Model Specification.

4.2.1.4 Filter Patch Test - Filters as recommended shall be installed in the inlet, outlet, and case-drain or cooling port lines of the test setup. The fluid in the filter bowls downstream of the pump shall be checked by the procedure in paragraph 4.2.1.4.1 below for contamination accumulated.

4.2.1.4.1 Oil from the filter bowl shall be processed as follows:

(a) Carefully remove the bowl to avoid oil spillage.

(b) Pour the oil into a precleaned beaker having approximately twice the volume of the filter bowl.

(c) Rinse the filter element with (approx) 20 cc of trichlorethylene or other suitable solvent from a solvent dispenser thru a 2 micron or finer membrane filter.

(d) Rinse the residue from the bowl with the same apparatus, but invert the bowl and direct the clean solvent stream upward to the bottom and sides of the bowl. Use 20 cc of solvent (approx).

(e) Stir the beaker to assure a uniform dispension of particles in the oil. Caution- The heavier metal particles will fall rapidly to the bottom; therefore good agitation is required to keep them suspended.

(f) Remove an adequate sample of the oil for processing by the particle count method per ARP 598. The volume of oil for analysis must be sized to give a quantity of particles within the realm of good statistical counting.

4.3 Design Approval Tests

4.3.1 First Sample Tests - These tests shall be conducted on the first sample pump:

Acceptance Test (Ref. para. 4.2.1)
Fluid Immersion Test (Ref. para. 4.3.3.2)
Proof Pressure Test (Ref. para. 4.3.3.3)
Calibration Test (Ref. para. 4.3.3.4)
Maximum Transient Pressure Test (Ref. para. 4.3.3.5.1)
Response Time Test (Ref. para. 4.3.3.5.2)
Pressure Pulsation Test (Ref. para. 4.3.3.5.3)
Heat Rejection Test (Ref. para. 4.3.3.6)
Vibration Test (Ref. para. 4.3.3.7)

4.3.2 Second Sample Tests - These tests shall be conducted on the second sample pump:

Acceptance Test (Ref. para. 4.2.1)
Proof Pressure Test (Ref. para. 4.3.3.3)

Additional Tests, if any, required by the Model Specification

Low Temperature Test (Ref. para. 4.3.3.8)
Endurance Test (Ref. para. 4.3.3.9)
Cavitation Test (Ref. para. 4.3.3.10)
Drive Coupling Shear Test (Ref. para. 4.3.3.11)

4.3.2.1 In cases where the entire program is to be conducted on one sample pump, the tests shall be run in the same order except that the Acceptance Test of paragraph 4.3.2 shall be omitted.

4.3.3 Design Approval Test Methods - The hydraulic fluid used in all design approval tests shall be that specified in the Model Specification. Unless otherwise noted, required test operating conditions shall be maintained within the following limits:

Inlet Pressure within 5%

Inlet Temperature - TYPE I - 70 F to 160 F within ± 5 F.
TYPE II - 160 F to 275 F within ± 10 F.
TYPE III - 275 F to 400 F within ± 15 F.

Pump Shaft Speed within 5%

Discharge Pressure within 5%

Flow within 2%

4.3.3.1 Acceptance Tests - The acceptance tests which are included in the design approval test program shall be run exactly as specified in Paragraph 4.2.1 of this specification. The pumps shall meet or exceed these acceptance test requirements both before and after the Design Approval Tests, except for shaft seal leakage and any other changes as permitted by the Model Specification.

4.3.3.2 Fluid Immersion Test - The pumps shall be immersed continuously for a period of 72 hours in hydraulic fluid maintained at Type I maximum rated temperature. All internal parts of the pumps shall be in contact with the fluid during this immersion. After the 72 hour soak period, the pump shall remain in the fluid at normal room temperature until ready for test. The pumps shall not be exposed to any air internally for any appreciable length of time during this period.

4.3.3.3 Proof Pressure Test - The pump delivery control mechanism shall be temporarily adjusted, or modified, to enable the pump to develop 150% of rated discharge pressure. The pump shall be operated for 3 minutes at rated speed, rated temperature, any convenient inlet pressure, and 150% of normal rated discharge pressure. There shall be no external leakage at or above a rate which will form drops except at the shaft seal. There shall be no evidence of structural failure or permanent distortion.

4.3.3.3.1 At the conclusion of the proof pressure test, the pump delivery mechanism shall be restored to its normal adjustment or configuration.

4.3.3.4 Calibration Test - Values of flow rate and driving horsepower shall be determined at minimum operating speed, 25, 50, 75, 100, and 110% of rated speed. At each of these speeds ten sets of flow and horsepower recordings shall be made at approximately the following pressures: 25, 50, 75, and 100% of maximum full flow pressure; at five equally spaced increments of either pressure or flow between maximum full flow pressure and rated discharge pressure. Unless otherwise specified in the Model Specification, calibrations will be made at each of the following three inlet conditions.

4.3.3.4.1 Pump Inlet at Sea Level Pressure - Regulate the pressure at the pump inlet port to be 15 psia for each of the flow and horsepower recorded readings.

4.3.3.4.2 Pump Inlet Pressurized - Regulate pump inlet pressure at the inlet port such that it is 80 psia for each of the flow and horsepower recorded readings.

4.3.3.4.3 Pump Inlet at Altitude Equivalent Pressure - Regulate pump inlet pressure at the inlet port such that it is 7 psia for each of the flow and horsepower recorded readings.

4.3.3.4.4 Minimum Operating Speed - At each of the ten test conditions, the speed shall be reduced below 25% of rated speed to determine the speed at which the discharge flow or pressure becomes erratic. This point shall be recorded and designated the minimum operating speed for that condition.

4.3.3.5 Maximum Pressure, Response Time, and Pressure Pulsations - Pressure pick-up and recording equipment shall be used to provide an oscillographic record, or its equivalent, of the pressure-time function of the pump and its hydraulic circuit through the transient and steady state periods described in the following three tests. The pressure pick-up and recording equipment shall be capable of static calibration with repetitive accuracy of 5% of rated pressure and readability of 3% of rated pressure. It should be considered essential that the dynamic calibration of the pick-up and recording equipment is valid for the dynamic operating conditions. The system impedance of the test circuit used in all tests shall be such that when the pump is operating at rated speed, maximum full flow, and rated inlet temperature; the rate of pump discharge pressure rise, when the flow in the system is suddenly stopped shall have minimum pressure rise slope of 25,000 to 35,000 psi per second.

4.3.3.5.1 Maximum Pressure Test - As the test pump is caused to operate from steady state maximum full flow pressure to steady state rated discharge pressure, an oscilloscopic record of the pressure-time function through the transient period shall be made. The test shall be run at 50 and 100% of rated pump speed. An hydraulic actuating cylinder may be bottomed to produce the pressure change in the hydraulic circuit. If used, any relief valve between the pump and the actuating cylinder shall be set to crack at a pressure more than 150% of rated pump pressure. Air entrainment in the hydraulic fluid shall be at a minimum. Unless otherwise specified in the Model Specification, the peak pressure as measured on the above record shall not exceed 150% of rated discharge pressure.

4.3.3.5.2 Response Time - The discharge portion of the system shall consist of the following items arranged in the order listed: The test pump, a pressure gage as close to the discharge port as possible with a valve to isolate the gage, a pressure pick-up device as close to the discharge port as possible (not more than three feet of hose or tubing of the discharge port size) a quick-opening solenoid valve (.02 seconds or less), a hand throttle valve as close to the solenoid valve as possible, a pressure gage, and a second hand throttle valve with as little hydraulic line as possible between the two hand throttle valves. The two hand throttle valves shall be adjusted for each test with the solenoid valve open and the pump operating at the test conditions as follows: Adjust the first valve to maintain maximum full flow pressure at the discharge port of the pump; adjust the second valve to maintain 50% of this pressure on the gage located between the two hand throttle valves. The solenoid valve, which changes discharge line from full open to full closed, or vice versa, shall then be used to execute the test. Runs shall be made at 50, 75, and 100% of rated speed. 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 the establishment of steady state rated discharge pressure. Typically this record should be similar to

Figure 2, and the response time, as indicated thereon, shall not exceed 0.05 second. In a similar procedure, the response time for the change from rated discharge pressure to maximum full flow pressure shall be recorded and, as indicated in Figure 3, shall not exceed 0.05 second.

4.3.3.5.3 Pressure Pulsations - The test setup specified in Paragraph 4.3.3.5.2 shall be modified for use in this test by adding means whereby any hydraulic pressure specified for this test can be applied, as by a gage tester, simultaneously to the discharge pressure pick-up and the discharge pressure indicating gage when the pump is not running in order to provide on the oscillographic record a calibrating trace of the nominal discharge pressure with respect to which the pressure pulsations are to be measured. As the test pump is caused to operate at the following speeds and system pressures, an oscillographic record shall be made of the steady state pressure pulsation pattern using the discharge system described in Paragraph 4.3.3.5.2. The solenoid may be omitted or maintained open for this test. Runs shall be made at 50, 75, and 100% of rated speed, and at each speed at maximum full flow pressure, rated discharge pressure, and three equally spaced increments of either flow or pressure between maximum full flow pressure and rated discharge pressure. The hand-throttle valve nearest the pump shall be used to regulate the pressure at the pump discharge port. The second hand-throttle valve shall be used to maintain 50% of the discharge pressure between the two hand-throttle valves. During the test recording period, the gage shall be isolated from the hydraulic system by appropriate valves.

4.3.3.6 Heat Rejection Tests - The object of these tests is to measure the rate of heat rejection of the pump over the expected normal range of operating conditions. The rate of heat rejection at the specified conditions shall be considered equal to the difference between the input and output horsepower of the pump at those conditions. To determine the rate of heat rejection, the pump, shall be run at rated speed, rated inlet temperature, and the input and output horsepower measured at rated discharge pressure, maximum full flow pressure, plus at least two additional flow points between those valves. Should it be desired to determine the rate of heat rejection at operating conditions other than those specified above, the additional requirements shall be defined in the Model Specification.

The maximum acceptable value in British thermal units per minute-(btu/min.) of heat rejection rate at specific operating conditions shall be specified in the Model Specification.

4.3.3.6.1 Preparation of Test Sample - The pump and hydraulic line fittings except for the mounting bracket shall be enclosed by a coating of not less than two inches of "85 per cent magnesia" or its equivalent thermal insulation. Temperature sensing devices shall be placed in the oil stream at the pump inlet and case drain lines. Caution should be taken to assure constant ambient conditions. Means should be provided for maintaining the face of the mounting bracket in contact with the pump at rated inlet temperature.

4.3.3.6.2 Temperature Readings - Temperature differential readings for the determination of heat losses shall be taken at stabilized thermal conditions only. To assure this, a plot of temperature differential versus time and oil inlet temperature versus time shall be made. Measurements shall be made each five minutes for at least 30 minutes or until both temperature differential and controlled inlet temperature have remained constant for ten minutes. Evidence of remaining constant shall be less than 1/2 F variation in temperature differential and less than 1 F variation in inlet oil temperature. The temperature differential to be measured is that between the inlet oil and the case drain oil. This temperature differential shall be measured by means accurate to ± 5% of the measured differential.

4.3.3.6.3 Calculation of Heat Rejection Rate - Heat rejection rate shall be calculated as the product of the temperature differential in Fahrenheit, the mass flow rate of hydraulic fluid through the case drain port in pounds per minute, and the specific heat of the hydraulic fluid used. It shall be expressed in British thermal units per minute (btu min.). The hydraulic fluid used in this test shall be that specified in the Model Specification.

4.3.3.6.4 Alternate Method - Under the operating conditions specified in Paragraph 4.3.3.6, all the power absorbed by the pump is converted into heat and, when all temperatures have stabilized, is being rejected to the fluid passing through the case drain line. The heat rejection rate in btu min. can therefore also be calculated from the measured input horsepower.

4.3.3.7 Vibration Tests - The test pump shall be mounted on a vibration generation mechanism successively in each of three positions. All of the testing described shall be conducted in each of the three 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. Also, if and when practicable, the three mounting positions shall be mutually perpendicular.

4.3.3.7.1 Resonant Frequency Vibration - Resonant frequencies between 5 and 500 cycles per second shall be searched according to the double amplitude and frequency chart of Figure 1, Procedure 1, of MIL-E-5272A. If resonant frequencies are encountered the test specimen shall be vibrated for 4 hours at each such frequency in each of the three positions. When no such frequency is identified, then the test specimen shall be vibrated for 12 hours along each of its mutually perpendicular axis at an applied double amplitude of 0.009 and a frequency of 150 cycles per second.

4.3.3.7.2 Cyclic Frequency Vibration - Upon completion of the resonant frequency vibration, a cycling vibration shall be imposed, from 5 to 500 cycles and back to 5 cycles in a two-minute span and enduring for a four-hour period, in each of the three positions of mounting. During this cycling the conditions of Procedure 1 of Figure 1 of MIL-E-5272A shall be approximately maintained.

4.3.3.7.3 Pump Operation - Throughout the above vibration tests the pump shall be operated on a normal hydraulic system, such as will be used for the endurance test. Oil inlet temperature shall be maintained at 140 F regardless of the rated temperature of the pump being tested, and ambient temperatures shall be maintained at room ambient conditions. The pump discharge pressure shall be continuously cycled from rated discharge pressure (zero flow) to a discharge pressure of approximately 95% of rated discharge pressure, corresponding to approximately 50% of rated delivery. These pressure cycles shall be abruptly accomplished by electrically controlled hydraulic valves at a rate of 5 cycles per minute. Transition from one condition of flow to the other condition of flow must be accomplished in a valve time of less than 1/2 second.

4.3.3.8 Low Temperature Test - All temperature requirements apply equally to the pump body, hydraulic fluid, and ambient environment. After at least 18 hours at the minimum inlet temperature specified in the Model Specification--or at -65 F ± 5 F in the absence of such stipulation in the Model Specification--the pump shall be started and uniformly accelerated to rated speed in not more than 2 seconds. Twenty runs shall be made with the outlet pressure as low as practicable and the reservoir unpressurized. When rated speed has been reached it shall be maintained for at least ten seconds; observations shall indicate whether the pump displaces fluid through the hydraulic system. Then 5 starts and runs shall be made during which the pump discharge line ends in a relief valve set to pass fluid at maximum full flow pressure. In addition, 5 starts shall be made with the pump discharge line completely closed so that the pump will operate at rated discharge pressure. For each of the last ten starts a thirty-second starting interval shall be used to bring the pump to rated speed and then the pump shall operate for two full minutes at the required condition. 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.

4.3.3.9 Endurance Tests - As a minimum requirement, one sample pump shall complete the endurance test schedule consisting of eight (8) phases specified in Table IV in the order listed, plus two calibrations; the stop start cycles, filter checks, and air ingestion cycles are described in the following subparagraphs. Modification of any of the test conditions of Table IV, and/or additional endurance testing, either in the form of additional cycles in any of the eight phases may be required by specifying such modifications or additions in the Model Specification.

4.3.3.9.1 Calibration - Before starting the above endurance test, and again upon its completion, the pump shall be calibrated, using the procedure specified in paragraph 4.3.3.4; the results of these two calibrations shall be plotted on one chart to show the effect of the endurance test on the performance of the pump. During the calibration after the endurance test the performance of the pump shall meet the requirements (calibration after endurance) specified in the Model Specification.

4.3.3.9.2 Fluid - The hydraulic fluid used in the endurance test shall be that specified in the Model Specification. The endurance test system shall be charged with the amount of fluid specified below at the start of the endurance test and no fluid shall be added before the endurance test is completed except as follows:

(a) The amount of fluid unavoidably removed from the system in the course of specified filter checks may 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 may be replaced.

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

FLUID QUANTITY

Rated Delivery of Pump on Test	Amount of Fluid Initially in Endurance Test System
0 to 6 gpm	6 gallons
6 to 10 gpm	10 gallons
More than 10 gpm	20 gallons

4.3.3.9.3 Filtration - The hydraulic fluid to be charged into the endurance test system shall be passed through a 5 micron filter before entering the test system. Ten-micron filters shall be installed in the pump inlet, outlet, and case drain or cooling port lines throughout the endurance test.

4.3.3.9.4 Filter Check - At intervals of 50 hours during the eight phases of the endurance test, clean filter elements shall be installed in all three filters of paragraph 4.3.3.9.3; and the endurance test schedule resumed for two hours, at the end of which time these filter elements shall be removed and replaced with others. The filter elements removed after two hours running shall be checked in accordance with the procedure of paragraph 4.2.1.4.1.

4.3.3.9.5 Calibration - Before starting Phase 1 of the above endurance test, the pump shall be calibrated, using the procedure specified in paragraph 4.3.3.4; the results of these two calibrations shall be plotted on one chart to show the effect of the endurance test on the performance of the pump.

4.3.3.9.6 Stop-Start Cycles - The endurance test shall include a simulation of starting the pump against system load. At intervals of not more than four hours of test running, when the pump is operating at full flow, the test shall be shut down and the pump brought to a complete stop. The test shall be restarted immediately and the prescribed schedule restarted immediately and the prescribed schedule resumed. At least 200 stop-start cycles shall be included in the eight phases of the endurance test. Stops and restarts made in connection with filter checks and air-ingestion checks shall be included in the above total.

4.3.3.9.7 Pump Case Pressure Cycles - Throughout all eight phases of the endurance test, the pump case shall be subjected, at approximately equal intervals of running time, to internal pressure impulses originating in the case drain (or by-pass) line, to at least 500 psi peak pressure. The time from the start of the pressure impulse to the initial return to normal case pressure shall be not less than 0.1 and not more than 0.5 second.

4.3.3.9.7.1 At least 20,000 pressure cycles shall be applied to the pump case, distributed with reasonable uniformity over the eight phases of the endurance test.

4.3.3.9.7.2 An oscillographic or equivalent record of the pressure impulse shall be taken within the first hour of the endurance test and within each even hundredth hour thereafter to provide verification that the pressure-time history of the impulse complied with the requirements of paragraph 4.3.3.9.7.

4.3.3.9.8 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 eight phases of the endurance test, by the following procedure:

The line supplying oil to the pump shall be arranged so that a four-foot length of it immediately adjacent to the pump can be disconnected, vented, drained, and reconnected without draining the rest of the test system. Each time the test is stopped to install the filter elements for the two-hour patch run--or alternatively, to remove these elements at the end of the two-hour patch-run--it shall be shut down while the pump is operating at full flow; the reservoir shall be depressurized; the four foot length of inlet line shall be disconnected, vented, drained, and reconnected. During these operations, the filter elements will have been replaced. The pump shall then be started against full flow pressure; 30 seconds after starting, the discharge pressure shall be recorded, the reservoir re-pressurized, and the endurance test schedule resumed.

4.3.3.9.9 Cavitation Test - The pump shall be operated at rated speed, rated inlet temperature, and maximum full flow pressure. The fluid pressure at the pump inlet port shall be adjusted to 80 psia. The rate of flow and the driving horsepower shall be measured at this condition. These measurements shall be repeated as the inlet fluid pressure is reduced in steps of 10 psi to 15 psia and thence in steps of 1 psia until it is no longer possible to record pressure or torque. The above tests shall be discontinued when the pump flow drops to 50% of rated value. At the completion of all other tests the pump should be run at 4 psia inlet pressure for 25 hours. It shall continue to supply at least 25% rated flow and shall not fail due to catastrophic damage.

4.3.3.9.10 Drive Coupling Shear Test - The drive coupling shall be removed from the pump and set up for torsion test. It shall be loaded torsionally until failure takes place, and the load producing the failure recorded. The failure shall take place at the shear section of the coupling.

5. NOTES

5.1 Intended Use - The hydraulic pumps covered by this specification are intended for use in civil aircraft for hydraulic operation of such mechanisms as powered flight control systems, landing gear, brakes, flaps, servo units, and automatic pilots. These pumps are primarily intended to be driven by the aircraft engine. When driven by other means additional tests or separate approval may be required.

PREPARED BY SAE COMMITTEE A-6, AEROSPACE FLUID POWER TECHNOLOGIES

TABLE I

Phase	Percent of Rated Endurance	CYCLE						Inlet Pressure in psia Type	Percent of Rated Speed	Case Drain Port Pressure in psi Type
		Flow in Percent of Rated Delivery	Percent of Rated Discharge Pressure	Duration Time in Seconds	Flow in Percent of Rated Delivery	Percent of Rated Discharge Pressure	Duration Time in Seconds			
1	6.67	0	100	540	100	85	60	15	66.7	75
2	20.0	0	100	540	100	85	60	28	106.7	100
3	6.67	0	100	6	100	85	6	15	120	30
4	6.67	0	100	6	70	*	6	80	120	100
5	13.33	100	85	60	50	*	60	15	100	30
6	13.33	70	*	5	5	*	5	80	100	100
7	13.33	100	85	5	0	100	5	15	100	30
8	20.0	90	*	5	100	85	5	80	106.7	100

Notes:

1. One or more phases, totalling not less than 20% of Rated Endurance, shall be run at Rated Inlet Temperature. Unless otherwise specified in the Model Specification, the remainder of the Endurance Test shall be run at 140 F inlet temperature. The apportionment of Endurance Test time between Rated Inlet Temperature and the lower temperature(s) shall, where feasible, be based on a realistic appraisal of the mission profile of the aircraft in which the pump is to be installed.
2. Case Drain Port Pressure shall be set by means of a fixed restriction at maximum drain flow condition.
3. Pressure indicated by asterisk shall be adjusted to provide stipulated flow.

LINEAR VIBRATION SPECTRUM

FOR TYPICAL

TURBOJET ENGINE

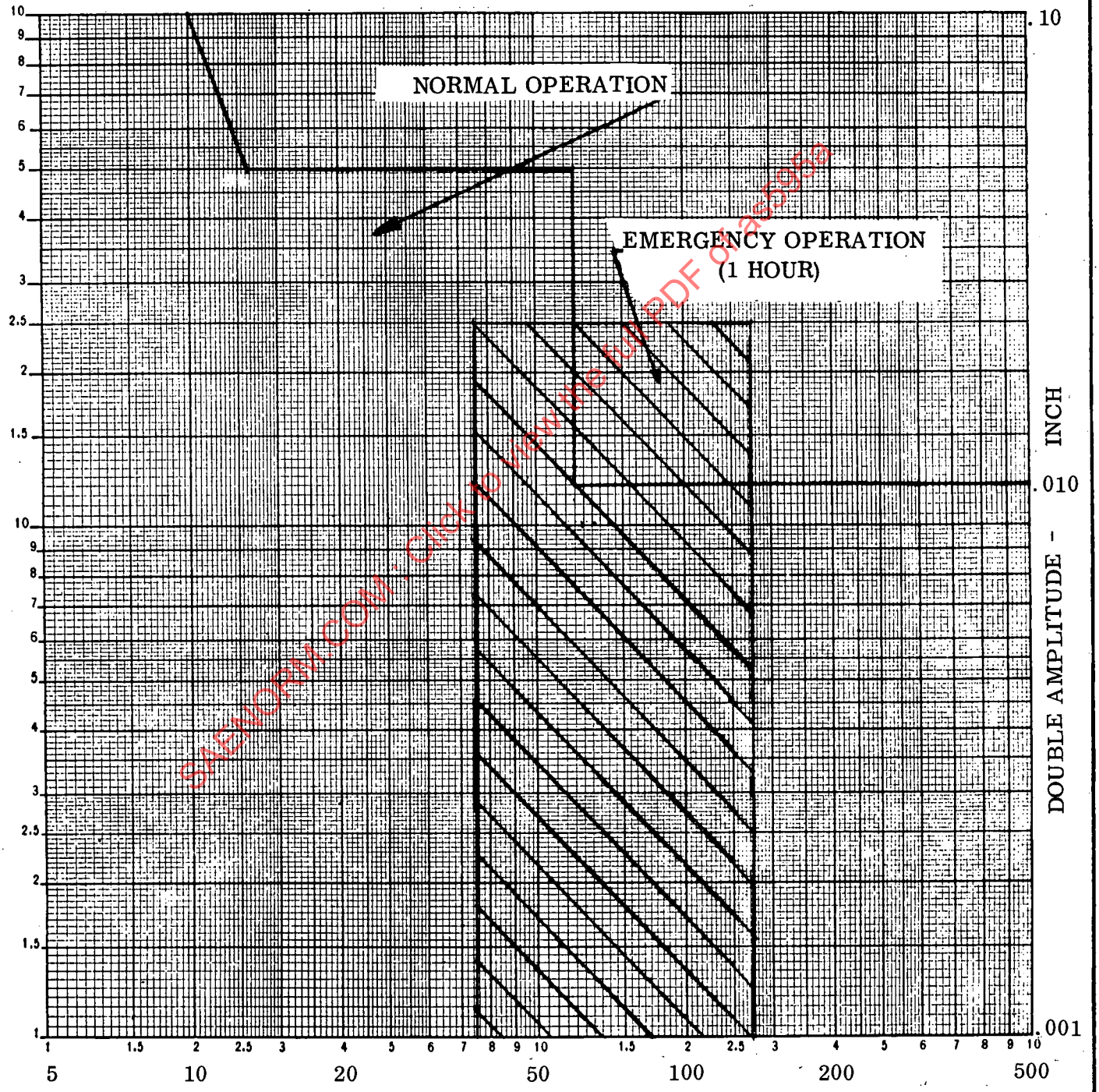
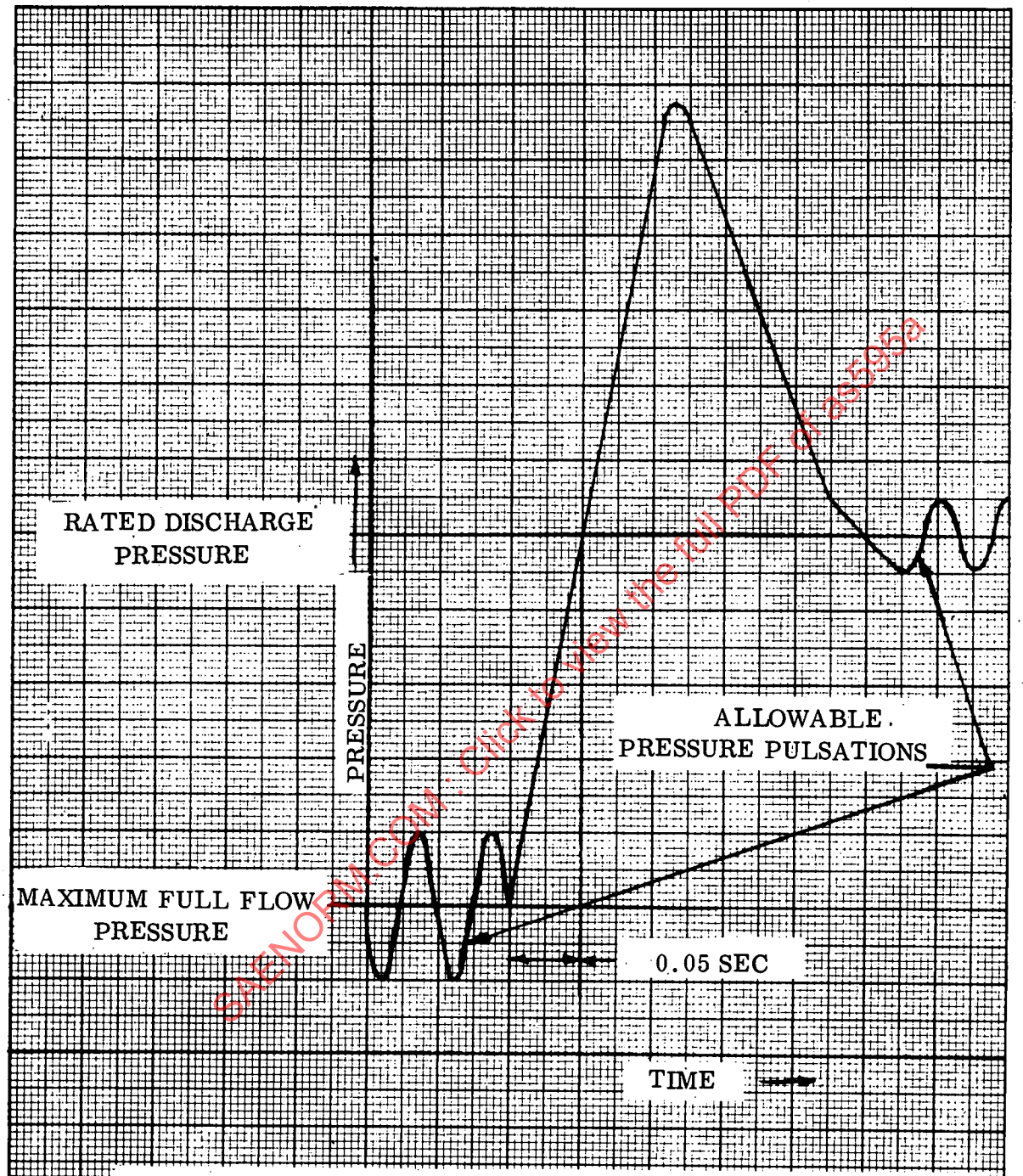


FIGURE 1



TYPICAL PRESSURE VS TIME CHART

FOR CHANGE

FROM MAXIMUM FULL FLOW PRESSURE

TO RATED DISCHARGE PRESSURE (CUT-OUT)

FIGURE 2