SAE Aerospace
An SAE International Group

# AEROSPACE STANDARD

SAE AS838

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## Aircraft Hydraulic Starter/Pumps

1. SCOPE

1.1 Scope - This specification established (1) the common requirements for hydraulic units capable of functioning as starters and as pumps suitable for use in aircraft and missiles and (2) the methods to be used for demonstrating compliance with these requirements.

1.2 Model Specification - A Model Specification, conforming to Appendix I of this specification, shall be prepared for each starter/pump model by either the purchaser or the starter/pump manufacturer. Where conflicts exist, the requirements of the Model Specification shall govern.

2. APPLICABLE DOCUMENTS

2.1 The following documents shall form a part of this standard 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 manufacturer's Model Specifications. Supplementary specifications, standards, or the like, 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 manufacturer's Model Specification or as may be otherwise mutually agreed upon between the vendor and the purchaser.

2.1.1 Aerospace Material Specifications (AMS)

| | |
|---|---|
| AMS 2400 | Plating - Cadmium |
| AMS 2402 | Plating - Zinc |
| AMS 2403 or 2424 | Plating - Nickel |
| AMS 2406 | Plating - Chromium Hard |
| AMS 2408 | Plating - Tin |
| AMS 2410 or 2412 | Plating - Silver |
| AMS 2470 | Anodic Treatment - Aluminum Base Alloys |
| AMS 2473 or 2474 | Chemical Treatment - Aluminum Base Alloys |
| AMS 2475 | Protective Treatments - Magnesium Base Alloys |

2.1.2 Industry Standards

| | |
|---|---|
| USA B46.1 | Surface Texture |
| AS 478 | Identification Marking Methods |
| AS 567 | General Practices for Use of Lockwire, Key Washers and Cotter Pins |

2.1.3 Military Specifications

| | |
|---|---|
| MIL-P-116 | Preservation, Methods of |
| MIL-C-5501 | Caps and Plugs, Protective, Dust and Moisture Seal |
| MIL-H-6083 | Hydraulic Fluid, Petroleum Base, Preservative |
| MIL-P-6906 | Plates, Information and Identification |
| MIL-S-7742 | Screw Threads, Standard, Aeronautical |
| MIL-H-8775 | Hydraulic Systems Components, Aircraft General Specification for |
| MIL-F-8815 | Filters and Filter Elements, Fluid Pressure, Hydraulic, Line; 15 Micron Absolute Type II Systems |
| MIL-C-11796 | Corrosion Preventative, Petrolatum, Hot Application |
| MIL-P-19692 | Pumps, Hydraulic, Variable Delivery, General Specifications for |
| MIL-H-5440 | Hydraulic Systems, Aircraft, Types I and II Design, Installation, and Data Requirement for |

2.1.4 Military Standards

MIL-STD-100 Engineering Drawing Practices

| | |
|---|---|
| MS33586 | Metals,Definition of Dissimilar |
| MIL-STD-129 | Marking of Shipments |
| MS33649 | Bosses, Fluid Connection, Internal Straight Thread |

2.1.5 Publications - (Air Force-Navy Aeronautical Bulletins)

| | |
|---|---|
| No. 445 | Changes, Engineering, to Aircraft Engines, Propellers, and Aeronautical Equipment in Production and Service |

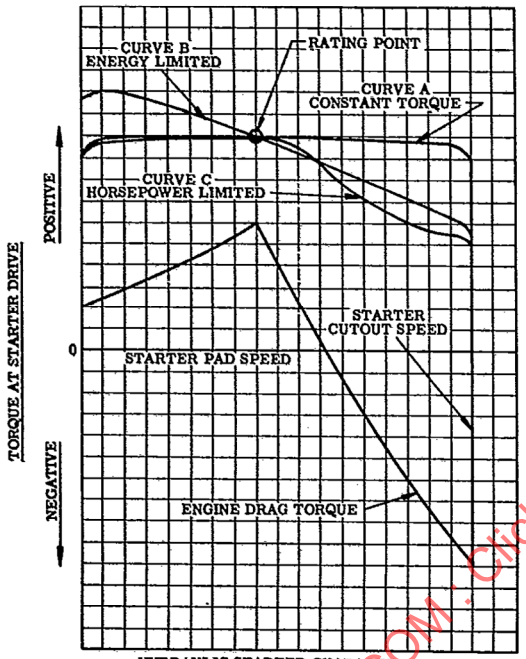
3. REQUIREMENTS

3.1 General Requirements - This section describes the general requirements for hydraulic starter/pumps, either fixed or variable displacement, suitable for operation in hydraulic systems conforming to the requirements of MIL-H-5440, or as otherwise specified by the Model Specification. The starter/pumps shall include any combination of the components listed below needed

to satisfactorily meet the requirements of the AS and the Model Specification.

3.1.1 Starter/Pump Assembly - The starter/pump design shall incorporate a hydraulic rotating assembly suitable for converting fluid energy into mechanical energy in the form of rotary motion and converting rotary motion into fluid energy.

3.1.2 Control Assembly - Variable displacement starter/pumps shall be equipped with suitable controls for providing an automatically controlled change in displacement during the starting cycle, the pumping cycle, or




HYDRAULIC STARTER CHARACTERISTICS
FIGURE 1

both. The starting cycle shall be in accordance with Curve "B" or "C" of Fig. 1. The pumping cycle shall be in accordance with the rated output flow and pressure as a PUMP.

3.1.3 Gear Assembly - For applications requiring a speed ratio between the hydraulic assembly and the output shaft, the necessary gear assembly shall be incorporated within the construction of the starter/pump.

3.1.4 Shaft Seal - The starter/Pump design shall incorporate an output shaft seal assembly to prevent the leakage of hydraulic fluid or gear case lubricant from the starter /pump or the entry of engine lubricant into the starter. The shaft seal shall be replaceable without additional disassembly of the starter/pump.

3.1.5 Parts Containment - In the event of an internal failure of the starter/pump, all parts shall be contained within the starter/pump housing and there shall be no loss of flu'd from the starter/pump due to the failure, and the starter/pump shall remain attached to the mounting pad of the engine accessory drive.

3.2 Performance Characteristics

3.2.1 Starter Performance - The following paragraphs, together with Fig. 1, describe the typical starter performance characteristics of hydraulic starter/pumps when they are operated from different types of hydraulic power sources.

3.2.1.1 Fixed Displacement - Fixed displacement starters, except for variations in efficiency, produce an output torque essentially proportional to input hydraulic pressure. Typical performance is shown in Fig. 1. Curves "A" and "B" represent performance during operation in conjunction with constant pressure (constant torque) and energy limited (decreasing pressure) hydraulic power systems respectively.

3.2.1.2 Variable Displacement - Variable displacement starters, when operated from a constant pressure horsepower limited source, produce essentially constant torque during the initial portion of the starting cycle until reaching rated flow. For the balance of the starting cycle, output torque decreases along an approximately constant horsepower line. Typical performance is shown as Curve "C" of Fig. 1.

3.2.2 Pump Performance - Variable delivery pumps deliver flow at essentially constant pressure from rated flow to cut-off.

3.3Design Requirements

3.3.1 Starter/Pump Functional Requirements - The starter/pumps shall be designed and constructed to satisfy the performance requirements specified below when operating under the rated hydraulic conditions as defined.

3.3.1.1 Hydraulic Fluid - The starter/pumps shall meet the functional requirements using the hydraulic fluid defined in the Model Specification.

3.3.1.2 Rated Temperature - The rated temperature is defined as the maximum fluid temperature at the starter/pump inlet port. The rated temperature shall be stated in the Model Specification and shall be one of the values listed in Table I.

TABLE I

| Hydraulic System | Rated Temperature |
|---|---|
| Type I | 160 F |
| Type II | 275 F |
| Type III | 450 F |

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 may be specified in the Model Specification.

3.3.1.3 Rated Case Pressure - The rated case pressure is defined as the maximum pressure to be allowed in the case and shall be specified in the Model Specification.

3.3.1.4 Rated Speed - The starter/pump will have two rated speeds, one as a starter and one as a pump.

The starter rated speed is defined as the maximum output shaft speed at which rated torque is produced and is usually related to engine light-off speed. The pump rated speed is defined as the maximum speed at which the pump will operate continuously at rated temperature, pressure, and flow. Both rated speeds shall be stated in the Model Specification. The maximum allowable speed without damage to the starter shall be specified in the Model Specification.

3.3.1.5 Operating Mode Transition - The starter/pump shall automatically revert to the pumping mode upon removal of the starting cycle input signal.

3.3.1.6 Balance - The moving parts of the starter/pump shall not cause destructive vibrations under any conditions of operation, at all speeds up to and including 120% of maximum speed.

3.3.1.7 Leakage - External leakage from the starter/pump housing or from any static seal thereof, of sufficient magnitude to form a drop, shall not be permitted. Leakage from the drive shaft seal, under specified operating conditions, shall not exceed the values specified in Section 4.5.

3.3.1.8 Contamination - The starter/pump shall be capable of withstanding fluid system contamination as specified in the Model Specification.

3.3.1.9 Service Life - The starter/pump shall be designed to perform satisfactorily for 1200 start cycles of engine starting operation and 750 hr of pumping operation, or as stated in the Model Specification. The actual number of start cycles to be specified may be expected to vary between 1200 and 2400 cycles, depending on the application.

3.3.2 Starter Functional Requirements

3.3.2.1 Rated Inlet Pressure - The rated inlet pressure is defined as the maximum pressure required at the starter inlet port when operating at rated torque, rated outlet pressure, rated speed, and rated temperature. The rated inlet pressure shall be stated in the Model Specification. Typical values are listed in Table II.

TABLE II

| System Pressure | Rated Inlet Pressure |
|---|---|
| 3000 psig | 2800 psig |
| 4000 psig | 3750 psig |
| 5000 psig | 4700 psig |

3.3.2.2 Rated Outlet Pressure - The rated outlet pressure shall be specified in the Model Specification. It is defined as the outlet pressure against which the starter must produce rated torque at rated speed under rated inlet pressure and temperature. A typical value of outlet pressure is 150 psig.

3.3.2.3 Rated Torque - The rated torque is defined as the minimum torque at the starter output shaft when operating at rated pressures, rated temperature, and rated speed. The rated torque shall be stated in the Model Specification together with the maximum continuous torque, the maximum peak transient torque, and the minimum torque at minimum cutoff speed.

3.3.2.4 Rated Consumption - The rated consumption is defined as the maximum fluid flow allowable to meet the torque retuirements at any starter output shaft speed from zero rpm to rated speed. The rated flow shall be stated in the Model Specification together with the maximum flow during no-load operation.

3.3.2.5 Displacement Control - Variable displacement starters shall automatically control change in displacement during the starting cycle.

3.3.2.6 Cut-Out Speed - The cut-out speed is defined as the starter output shaft speed at which starter operation is terminated automatically. The starter/pump shall be capable of two (2) minutes continuous operation at maximum cut-out speed. The minimum and maximum cut-out speeds shall be stated in the Model Specification.

3.3.2.7 Continuous Motoring - The starters shall be capable of motoring operation for a minimum of 10 hours at the rating point (Fig. 1). Motoring cycles shall be of 10 minutes duration.

3.3.3 Pump Functional Requirements

3.3.3.1 Rated Discharge Pressure - The rated discharge pressure shall be specified in the Model Specification and shall be the discharge pressure corresponding to the pump full cut-off flow operating conditions.

3.3.3.2 Maximum Full Flow Pressure - Full flow pressure is the maximum pressure obtainable with the pump in full displacement and shall be specified in the Model Specification.

3.3.3.3 Rated Inlet Pressure - The rated inlet pressure shall be specified in the Model Specification. It shall be the minimum inlet pressure to produce rated outlet conditions and rated life.

3.3.3.4 Rated Delivery - The pump rated delivery shall be specified in the Model Specification. It shall be the maximum flow, at rated speed, inlet pressure, fluid temperature, and maximum full flow pressure.

3.3.3.5 Overall Efficiency - Overall efficiency shall be specified in the Model Specification.

3.3.3.6 Pressure Pulsations - Pressure pulsations which shall occur exclusive of transient surge shall not exceed the, value specified in the Model Specification.

3.3.3.7 Variable Delivery Control

3.3.3.7.1 Speed of Response - The control shall regulate the flow from zero to maximum flow or vice versa in 0.05 seconds or less at any speed above 50% rated speed or as specified in the Model Specification.

3.3.3.7.2 Stability - The pump pressure shall stabilize to a steady state value within one second when the pump is subjected to the test specified in 4.5.8.2.

3.3.3.7.3 Maximum Transient Pressure - The maximum transient pressure during cut-out shall not exceed more than 135% of nominal rated pressure when the pump is subjected to the transient pressure test specified in 4.5.8.2.

3.3.3.7.4 Adjustment - Means shall be provided to adjust the delivery control mechanism to cause zero flow to occur at rated discharge pressure. This adjustment shall be preferably continuous, or acceptably in steps of less than 1% of rated discharge pressure, over a minimum range of 95% to 130% 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 application of standard hand tools. Where practicable, the arrangement of the adjustment means shall permit adjustment to be made while operating under full system pressure with negligible loss of fluid.

3.3.3.7.5 Windmill - When specified in the Model Specification, the pump shall be designed to require essentially zero input torque at speeds from zero to 20% pump rated speed. It shall not be damaged by continuous operation at this condition.

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

3.3.4.1 Altitude - Provided that inlet pressure is maintained in accordance with 3.3.3.3, starter/pump performance shall not be affected by change of altitude.

3.3.4.2 Temperature - Starter/pumps shall be designed to operate in an ambient air temperature, ranging from -65 F to the maximum value specified in the Model Specification.

3.3.4.3 Vibration - Starter/pumps shall be capable of withstanding all normal vibrations excited by the driving means in accordance with the vibration envelope specified in the Model Specification.

3.3.4.4 Impact - Starter/pumps shall be designed to withstand impact shocks of 30 g, applied in any direction, for a maximum time duration of 10 milliseconds.

3.3.4.5 Acceleration - Starter/pumps shall be designed to withstand sustained accelerations (greater than 1 second) of 10 g applied in any direction.

3.3.4.6 Atmospheric Conditions - Starter/pumps shall be designed to withstand continuous exposure, either operating or non-operating, to salt spray, sand and dust, humidity, and fungus.

3.3.5 Installation Requirements - The starter/pumps shall be designed for mounting on the engine accessory drive specified in the Model Specification. Installation or removal of the starter/pumps shall not require special tools.

3.3.5.1 Rotation - Drive rotation for the starter/pumps shall be identified as viewed from the anti-drive end of the starter and shall be stated in the Model Specification. It shall be clearly marked on the starter/pump housing.

3.3.5.2 Moment of Inertia - The effective polar moment of inertia of the engine assembly, related to the starter output shaft, shall be determined and shall be stated in the Model Specification.

3.3.5.3 Dimensions - The starter/pump, envelope shall be within the dimensions shown on the manufacturer's installation drawing and the location of fluid ports and electrical connectors shall be as shown. The location of the center of gravity of the starter/pump shall be indicated on the drawing.

3.3.5.4 Weight - The dry weight of the starter/pump shall not exceed the value stated in the Model Specification.

3.3.5.5 Drive Couplings - The starter/pump shall incorporate a drive coupling with a shear section or torque limiting device. The maximum static torque transmitted shall not exceed the value stated in the Model Specification if the torque limiting device is a shear section. The drive coupling shall be held in place by a positive retainer replaceable without disassembly of the starter/pump. The type of coupling shall be specified in the Model Specification.

3.3.5.6 Ports - Inlet and outlet ports shall conform to Drawing MS33649. Seal drain ports shall conform to Drawing MS33649. All ports shall be sized and located as shown on the manufacturer's installation drawing.

3.3.6 Detail Requirements - The starter/pumps shall be designed and constructed so as to perform the intended purpose defined in the Model Specification during normal service usage and to withstand the environmental conditions as defined in Section 3.3.4.

3.3.6.1 Materials - Materials used in the manufacture of these starter/pumps shall be of high quality, suitable for the purpose, and shall conform to properly selected specifications. Materials conforming to contractor's specifications may be used provided the specifications are released by the Government and contain provisions for adequate tests. The use of contractor's specifications will not constitute waiver of Government inspection.

3.3.6.1.1 Selection of Material - Specifications and standards for all materials and parts, and Government certification and approval of processes and equipment, which are not specifically designated herein and which are necessary for the execution of this specification,

shall be selected in accordance with Standard MIL-STD-143, except as provided in paragraphs 3.3.6.1.2 and 3.3.6.1.3.

3.3.6.1.2 Standard Parts - Standard parts (MS, AN, or JAN) shall be used wherever they are suitable for the purpose, and shall be identified on the drawings by their part numbers. In the event there is no suitable corresponding standard part in effect on the date of invitation for bids, commercial parts may be used provided they conform to all requirements of this specification.

3.3.6.1.3 Standard Materials and Processes - Where performance or reliability of the starter/pumps will be jeopardized by the use of materials and processes as defined in paragraph 3.3.6.1.1, alternate materials and processes may be used subject to the approval of the procuring activity. Such materials and processes shall be selected so as to provide the maximum degree of corrosion resistance consistent with the performance requirements.

3.3.6.1.4 Metals - All metals used in the construction of the starter/pumps except metals which are in constant contact with hydraulic fluids, shall be of a corrosion-resisting type or shall be suitably protected in accordance with paragraph 3.3.6.2. The use of dissimilar metals, as defined by Standard MS33586 shall be avoided wherever practicable.

3.3.6.1.5 Packings - All packings shall be in accordance with the requirements of MIL-H-5440.

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

3.3.6.2.1 Ferrous and Copper Alloys - Ferrous alloy requiring corrosion preventative treatment, and all copper alloys except for parts having bearing surfaces, shall have a suitable electrodeposited metallic coating selected from the following list, except that tin, cadmium, and zinc plating shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors, nor where subject to abrasion. Where not indicated, class or type are at the option of the manufacturer.

| | |
|---|---|
| Cadmium Plating | AMS 2400 |
| Zinc Plating | AMS 2402 |
| Chromium | AMS 2406 |
| Nickel | AMS 2403 or AMS 2404 |
| Silver | AMS 2410 or AMS 2412 |
| Tin | AMS 2408 |

3.3.6.2.2 Aluminum Alloys - Unless otherwise authorized, all aluminum alloys shall be anodized in accordance with Specification AMS 2470 except that in the absence of abrasive conditions they may be coated with chemical film in accordance with Specification AMS 2473 or AMS 2474. The exceptions noted will be subject to the approval of the procuring activity.

3.3.6.2.3 Magnesium Alloys - All magnesium parts shall be treated for protection against corrosion in accordance with Specification AMS 2475, or by other treatments specifically approved for the purpose by the procuring activity.

3.3.6.3 Screw Threads - Except where necessary for functional or manufacturing purposes, only straight threads conforming to MIL-S-7742 shall be used.

3.3.6.3.1 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 the practices outlined in Standard AS 567. Star washers and lockwashers shall not be used. Jam nuts shall also be properly safetied. Parts with tapered threads need not be safety wired or positively locked.

3.3.6.4 Identification of Product - The equipment shall be marked for identification in accordance with Standard AS 478.

3.3.6.4.1 Nameplate - Each starter/pump shall be clearly and permanently marked with a durable nameplate conforming to MIL-P-6906, securely attached to a part of the starter/pump which will not ordinarily be renewed during normal service life, and specify the following information:

STARTER/PUMPS: HYDRAULIC, (FIXED)
(VARIABLE) DISPLACEMENT
Model Specification
Type (If Applicable)
Stock No. (If Applicable)
Direction of Rotation (Arrows)

Manufacturer's Part No.
Contract No.
Manufacturer's Name or Trade-Mark
U.S. Property (If Applicable)
Hydraulic Fluid
Manufacturer's Serial Number
Rated Pump Outlet Pressure, psig
Rated Pump Flow, gpm
Rated Pump Speed, rpm
Rated Starter Inlet Pressure, psig
Rated Starter Speed, rpm

3.3.6.4.2 AN or MIL Designations - AN or MIL designations shall not be applied to a product, except for qualification test samples, nor referred to in correspondence, until notice of approval has been received from the activity responsible for qualification, or from the Aeronautical Standards Group.

3.3.6.5 Lubrication - Starter/pumps shall be self-lubricated

with no provisions for lubrication other than the hydraulic fluid. Provision for coupling shaft lubrication may be specified in the Model Specification.

3.3.6.6 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 number shall be governed by the drawing number requirements of Specification MIL-STD-100. Sub-assemblies of selected mating parts must be interchangeable as assembled units, and shall be indicated on the manufacturer's drawings. The individual parts of such sub-assemblies need not be interchangeable.

3.3.6.7 Surface Finish - Surface finishes where required shall be established and shall be specified in the manufacturer's drawings as defined in Standard USA B46.1.

3.3.6.8 Workmanship - All details of workmanship shall be in accordance with high grade manufacturing practices for aircraft hydraulic pumps and motors.

3.3.6.9 Design Changes - No changes shall be made in the design or materials of a starter/pump model which has successfully completed the qualification tests, except when such changes are processed in accordance with the provisions of ANA Bulletin No. 445.

3.3.6.9.1 Service Bulletins - When requested by the the purchaser at the time of approval of a change, the contractor shall submit a service bulletin, prepared in accordance with Specification MIL-B-18364, in order to permit the purchaser to incorporate the change in starters previously delivered.

3.3.6.9.2 Parts List - The parts list of a starter/pump model which successfully completes the qualification test shall constitute a requirement for production starters. Departure from the approved starter/pump parts list in features of design and construction shall be governed by the provision herein for changes in design.

3.3.6.9.3 Responsibility for Changes - Approval by purchaser of changes from the qualification test starter/pump does not relieve the contractor of full responsibility for the results of such changes on any starter/pump characteristic.

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of Tests - The inspection and testing of the starter/pumps shall be classified as follows:

(a) Qualification Tests - Qualification tests are those tests accomplished on samples submitted for qualification as a satisfactory product.

(b) Inspection Tests - Inspection tests are those tests accomplished on all starter/pumps manufactured and submitted for acceptance under contract.

4.2 Qualification Tests

4.2.1 Sampling Instructions - The qualification test samples shall consist of two starter/pumps. The qualification test program shall be conducted by the starter/pump manufacturer at his own facility or at a testing laboratory acceptable to the purchaser. The division of tests between samples and the order of testing shall be specified in the Model Specification.

4.2.2 Tests - The qualification tests of starter/pumps shall consist of all the tests of the Model Specification or of this specification as described under Section 4.5, Test Methods. The qualification tests may be supplemented with tests under actual service conditions, if specified in the Model specification.

4.3 Inspection Tests - Each starter/pump shall be subjected to the following tests, in the order listed, as described under Section 4.5, Test Methods:

(a) Examination of Product
(b) Break-In Run
(c) Proof Pressure Test
(d) Tear-Down Inspection
(e) Functional Test

4.4 Test Conditions - Unless otherwise specified herein or in the Model Specification, all tests shall be conducted at an ambient temperature within the range of 50 F to 100 F. Inspection tests shall be conducted in the order specified in paragraph 4.3. The order in which all other tests are conducted shall be as specified in the Model Specification.

4.4.1 Hydraulic Fluid - All tests shall be conducted using the hydraulic fluid specified in the Model Specification.

4.4.2 Filtration - Except for low temperature tests, all test systems shall incorporate 15 micron absolute filters, conforming to Specification MIL-F-8815, located in the inlet lines to the starters.

4.4.3 Measurements - Unless otherwise specified, the required test operating conditions shall be within the following limits:

| | |
|---|---|
| Inlet Pressure | ± 2% |
| Outlet Pressure | ± 2% |
| Inlet Temperature | ± 10% |
| Shaft Speed | ± 2% |
| Torque | ± 2% |
| Fluid Flow | ± 2% |

Accuracy of the instrumentation for all tests shall be consistent with MIL-Q-9858.

4.5 Test Methods

4.5.1 Examination of Product - Each starter/pump shall be carefully examined to determine conformance with the applicable drawings and with all other requirements of this specification or the Model Specification which are not covered by specific tests.

4.5.2 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 hr minimum at 30% to 75% of rated rpm and 1/2 hr minimum at 80% to 100% of rated rpm.

4.5.3 Proof Pressure Test - During this run, there shall be no external leakage sufficient to form a drop, except that the shaft seal may leak at a rate not to exceed 5 ml per hour.

4.5.3.1 Pump Proof Pressure Test - Each starter/pump shall be operated as a pump for one minute with the case and inlet pressure maintained at 450 to 500 psig, 125% rated speed, no demand, and with fluid temperature optional. The pressure control shall be adjusted for 125% rated discharge pressure at no flow.

4.5.3.2 Motor Proof Pressure Test - While operated as a motor, each starter/pump shall be operated for 5 minutes at 125% of rated inlet pressure, 500 psig case and outlet pressure, and rated temperature. The load on the starter output shaft shall be regulated so as to maintain rated speed.

4.5.4 Tear-Down Inspection - After the above break-in run, and proof pressure test, each starter/pump shall be disassembled and inspected by the starter/pump manufacturer. If all parts are in acceptable condition, the starter/pumps shall be reassembled and placed on functional test. If working parts require replacement, the starter/pump shall be reassembled using the replacement parts, and the entire inspection test procedure repeated.

4.5.5 Functional Test - Each starter/pump shall be subjected to the following runs to determine conformance with the functional requirements.

4.5.5.1 Starter Operation

4.5.5.1.1 Static Torque - The starter/pump output shaft shall be locked and rated pressure applied to the inlet port with the outlet port open. Leakage from the outlet port and output shaft torque shall be measured and recorded. Torque shall not be less than 90% of rated torque.

4.5.5.1.2 Running Torque - The starter/pump shall be operated at rated starter speed with rated hydraulic conditions applied to the fluid ports and load inertia as specified in the Model Specification. Speed, torque, and fluid flow shall be measured and recorded.

Torque shall not be less than rated torque, and flow shall not exceed rated flow. This test shall be repeated at minimum cut-out speed at which point torque shall not be, less than the value specified in the Model Specification and flow shall not exceed rated flow.

4.5.5.1.3 Leakage - During the starter functional test no external leakage, other than at the shaft seal, of sufficient magnitude to form a drop shall be permitted, shaft seal leakage shall not exceed 1 ml per hour when measured during the running torque test for a period of at least 15 minutes of operation.

4.5.5.2 Pump Operation

4.5.5.2.1 Contaminant Run - During the calibration runs specified in the Model Specification, the fluid in each filter bowl shall be collected in clean containers. Both the filter bowl and element shall be rinsed with 15 to 30 cubic centimeters (cc) of a suitable fluid solvent and added to the applicable container. The total resulting fluid shall be passed through a 47 millimeter (mm) disc, 0. 45 micron pore size, surface-retention type membrane (Millipore HAWP04700, or equal). The membrane shall be washed free of fluid with 15 to 30 cc 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.

Each filter patch resulting from the preceding test shall be compared with the standard patch then in effect and any discrepancy noted in the test log.

The second patch shall show less contaminant than the first patch, and shall also show equal or less contaminant than the standard patch. Duration of each test shall be specified in the Model Specification.

4.5.5.2.2 Delivery - At the completion of the other quality conformance tests, the torque required to drive the pump and the case drain flow shall be measured and recorded for the following conditions:

Rated speed, rated discharge pressure, rated inlet pressure, case pressure 20 psi above inlet pressure, and rated inlet temperature. The delivery of the pump at rated speed, rated maximum full-flow pressure, and at rated inlet temperature and pressure shall be measured and recorded. The measured values for torque, case drain flow, and delivery shall be within the limits specified in the Model Specification.

4.5.5.2.3 Leakage - During the pump functional test, no external leakage, other than at the shaft seal, of sufficient magnitude to form a drop shall be permitted. Shaft seal leakage shall not exceed 1 ml per hour when measured during the running torque test for a period of at least 15 minutes of operation.

4.5.5.3 Cycling Operation - The starter/pump shall be functionally tested by accelerating a flywheel to starter cut-out, then driven by the flywheel, operated as a pump to bring the flywheel to rest. The flywheel, cut-out speed, and time for acceleration shall be specified in the Model Specification.

4.5.6 Stall Torque Test - The stalled output torque of the starter shall be measured, with rated inlet pressure applied and the outlet port open, at four (4) equally spaced positions of the output shaft within one revolution. The minimum torque measured shall not be less than 90% of rated torque.

4.5.7 Transient Torque Test - The starter shall be

operated in accordance with the endurance duty cycle of paragraph 4.5.12.1. Continuous torque recording instrumentation, with a flat sinusoidal response to 1000 cps, shall be used to demonstrate that the maximum peak transient torque does not exceed the valve specified in the Model Specification.

4.5.8 Control Test - Pressure transducer 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 transducer 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 response of the pressure transducer and recording equipment be valid for the dynamic conditions.

4.5.8.1 Response Time - The discharge portion of the system shall consist of the following items arranged in the order listed:

(1) The test pump, (2) a pressure gage as close to the discharge port as possible with a cock or valve to isolate the gage, (3) a pressure transducer device as close to the discharge port as possible, (4) not more than 3 ft of hose or tubing of the discharge port size, (5) a quick-opening solenoid valve (0.02 second or less), (6) a hand throttle valve as close to the solenoid valve as possible, (7) a pressure gage, and (8) 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: The first valve shall be adjusted to maintain maximum full-flow pressure at the discharge port of the pump; the second valve shall be adjusted 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, oscillographic records 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 should be similar to Fig. 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 Fig. 3, shall not exceed 0.05 second. The response time shall be checked for small incremental change of flow as follows: A parallel flow path which includes an orifice and a downstream quick-operating solenoid valve shall be introduced. This orifice shall be adjusted to pass 5% of maximum full-flow pressure and

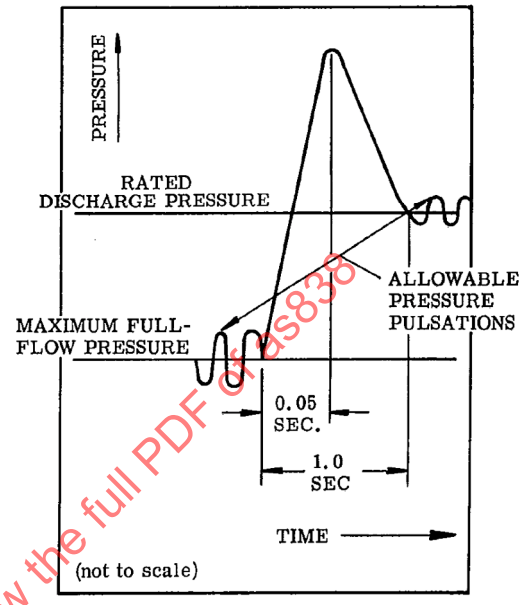



FIGURE 2. Typical pressure vs. time chart. For change from maximum full-flow pressure to rated discharge pressure (cutout).

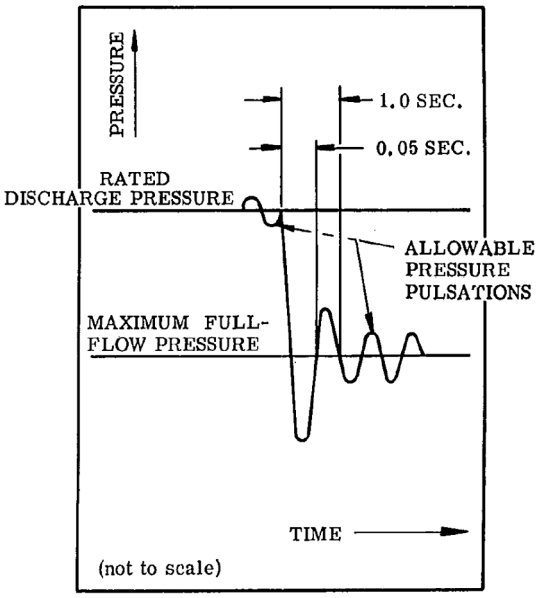



FIGURE 3. Typical pressure vs. time chart. For change from rated discharge pressure to maximum full-flow pressure (cutin).

the main load throttling valve shall be adjusted to pass 90% of maximum full-flow pressure for each of the three speed settings. Cheek speed of response 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.

4.5.8.2 Transient Pressure - As the test pump is caused to operate from steady state maximum full-flow pressure to steady state rated discharge pressure, an oscillographic 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. A 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 135% of rated discharge pressure.

4.5.9 Pressure Pulsation Test - The test set-up specified in paragraph 4.5.8.1 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 calibrated trace of the nominal discharge pressure with respect to which the pressure pulsations are to be measured. As the pump is operated at the following speeds and system pressures, an oscillographic record shall be made of the steady state pressure pulsation pattern using the discharge system specified in paragraph 4.5.8.1. 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 to cut off, 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 gages shall be isolated from the hydraulic system by appropriate cocks or valves. Valves shall not exceed limits specified in the Model Specification.

4.5.10 Low Temperature Test - The starter/pump and hydraulic test system shall be maintained at a temperature of -65 ±5 F for a minimum period of 8 hr and then operated for 10 consecutive endurance duty cycles in accordance with paragraph 4.5.12.1 except that the torque load shall be 90% of rated torque. Rated inlet and outlet pressures shall be maintained during the operating periods. The length of time between starts shall be such that the starter and fluid shall be at a temperature of -65 ñ 5 F for each start. The time required for each phase of each duty cycle and the temperature rise of the inlet fluid during each start shall be recorded.

4.5.11 Calibration Test

4.5.11.1 The starter/pump shall be tested to determine conformance to the minimum requirements of the Model Specification. Values of fluid flow rate and starter output torque shall be determined from zero drive speed to cut-off speed. Rated hydraulic conditions shall be maintained and all measurements shall be made under steady state operating conditions.

4.5.11.2 Pump Operation - 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, 10 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 5 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 the inlet condition specified in paragraph 4.5.11.2.1.

4.5.11.2.1 Pump Inlet Pressurized - Regulate the pressure at the pump inlet port to the rated inlet pressure for each of the flow and horsepower recorded readings.

4.5.12 Endurance Test

4.5.12.1 Starter Operation - The starter/pump shall complete a 1200 cycle (or number of cycles stated in the Model Specification) starting test without replacement of, or damage to, any of the component parts. All portions of the endurance test shall be run with rated hydraulic conditions applied to the starter. Each cycle shall consist of three consecutive phases as shown in Table III. Phase A shall consist of the acceleration of the specified inertia load to the specified speed. After the speed specified in Phase A is reached, the hydraulic

TABLE III

DUTY CYCLE PHASES

| | A | B | C |
|---|---|---|---|
| Flywheel Polar Moment of Inertia | RPM to which flywheel shall be accelerated | 10 seconds of pumping at following conditions | Maximum flow at full full flow pressure |
| Lb-Ft2 | | | |
| Per Model Specification | Cut-out | Rated Pressure No Flow | |