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VON KARMAN CENTER

SNAP-8 DIVISION

ENGINEERING SUPPORT DOCUMENTATION FOR THE SNAP-8 LUBRICANT-COOLANT PUMP-MOTOR ASSEMBLY

A REPORT TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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AEROJET GENERAL TIRE GENERAL

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REPORT NO. 3152 FEBRUARY 1966

AEROJET-GENERAL CORPORATION
A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

Report No. 3152

Abstract

The documentation for the Lubricant-Coolant Pump-Motor Assembly (L/C PMA) of the SNAP-8 Space Power System is contained in one volume. This volume contains engineering and development test data. Log Books are available for each serial numbered PMA which covers the fabrication and assembly of each of the six delivered units.

Aerojet-General Corporation subcontracted the development of this assembly to the Tapco Division of Thompson Ramo Wooldridge, Inc. The development of the pump-motor assembly to pump polyphenyl ether was based upon an adaptation of a Tapco aircraft fuel pump.

Approved by

E. Eber, Manager
SNAP-8 Components Department

Report No. 3152

CONTRACT FULFILLMENT STATEMENT

This report is submitted as partial fulfillment of National Aeronautics and Space Administration Contract Number 5-417.

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I. INTRODUCTION

The Design Data File for the SNAP-8 Lubricant-Coolant Pump-Motor Assembly (L/C PMA) is contained in one volume. This volume presents the engineering design data and development test data.

The SNAP-8 nuclear-powered electrical generating system for space application utilizes a radiation-resistant fluid to lubricate bearings and to cool system components. This fluid, bis ether (mix phenoxy-phenyl and referred to as mix-4P3E) is circulated through the system with a centrifugal pump driven by an electric motor. The entire pump-motor assembly is hermetically sealed. Lubrication and cooling of the pump-motor assembly, itself, is accomplished by a small flow of the pumped fluid through the motor and down the hallow shaft which returns the flow to the inlet of the main pump.

Development of this 10,000 hour pump was subcontracted to the Tapco Division of Thompson Ramo Wooldridge, Inc., and was based upon an adaptation of one of their aircraft fuel pumps which used carbon bushings for both journal and thrust bearings.

The Aerojet-General Corporation subcontract was No. OP359790. Thompson Ramo Wooldridge, Inc. designated the project as No. 501-104013-08 and No. 516-004236-08.

To date, one unit, S/N 481501, has accumulated 4652 hours of test time under various conditions. Disassembly and inspection have shown no adverse conditions. This pump has been reassembled for additional testing.

Three other units, S/N 481502, S/N 481503, and S/N 481504, have operated for 273 hours, 1023 hours, and 1154 hours, respectively, in various test loops.

Unit S/N 481505 was subjected to preliminary vibration testing. Failure of one of the mounting straps occurred. These were replaced with heavier straps, however large amplifications remained. This problem is receiving current consideration with a view to isolation monitoring of the PMA.

II. DESIGN REQUIREMENTS

A. AGC-10191A, Development Product Specification, Pump-Motor Assembly, Lubrication and Cooling, SNAP-8

B. AGC-10320, Development Material Specification, Polyphenyl Ether, Mix-4P3E

C. Drawing 094246, L/C PMA Interface Control

AEROJET-GENERAL CORPORATION

CODE IDENT. NO. 70143

AGC-10191A
22 January 1965

Superseding
AGC-10191
15 October 1963

DEVELOPMENT

PRODUCT SPECIFICATION

PUMP-MOTOR ASSEMBLY, LUBRICATION AND COOLING, SNAP-8

1. SCOPE

1.1 Scope.- This specification establishes the requirements for the performance, design, and reliability goal for an organic-oil pump-motor assembly (PMA). The PMA will be supplied with 400-cps electrical power from a turbine alternator in a Rankine-cycle power system.

1.2 Function.- The PMA will be used to furnish the lubrication and cooling (L/C) fluid to the various components of the SNAP-8.

2. APPLICABLE DOCUMENTS

2.1 Department of Defense (DOD) documents.- The following DOD documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issue in effect on the date of this specification shall apply.

SPECIFICATIONS

Military

MIL-E-5272C 20 January 1960	Environmental Testing, Aeronautical and Associated Equipment, General Specifications for
MIL-P-6906	Plates, Information and Identification
MIL-M-17060B 8 March 1963	Motors; Alternating Current, Integral HP (Shipboard Use)
MIL-D-70327	Drawings, Engineering, and Associated Lists

STANDARDS

Military

MIL-STD-130A 8 September 1958	Identification Marking of U.S. Military Property
MIL-STD-271B 22 November 1961	Nondestructive Requirements for Metals

2.2 Aerojet-General Corporation (AGC) documents.- The following AGC documents, of the issue in effect on the date of this specification, form a part of this specification to the extent specified herein.

SPECIFICATION

AGC-10320	Polyphenyl Ether (Mix-4P3E)

STANDARD

AGC QCS H 1-6	Quality Control Standard

DRAWING

094246	L/C PMA Interface Control

2.3 Other documents.- The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issue in effect on the date of this specification shall apply.

American Society of Mechanical Engineers (ASME)

ASME	Power Test Code for Centrifugal Pumps

(Copies of ASME Publications may be obtained from the American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N.Y.)

Jet Propulsion Laboratory (JPL)

30236A	Design Specification, Spacecraft, Flight and Ground Support Equipment, R.F. Interference Control and Test Requirements

3. REQUIREMENTS

3.1 Performance requirements.-

3.1.1 Service fluid.- The service fluid shall be bis (mix-phenoxy-phenyl) ether in accordance with Specification AGC-10320.

3.1.2 Power supply.- The steady-state power supply shall be as follows:

(a)	Number of Phases:	3
(b)	Terminal Voltage:	208 ± 10 volts
(c)	Frequency:	400 ± 4 cps

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3.1.3 Pump performance.-

3.1.3.1 Design conditions.- The pump shall be designed to meet the following performance requirements for 10,000-hour steady-state operation:

(a)	Flow rate:	17 gpm
(b)	Static suction pressure:	3 psia(minimum)
(c)	Head rise:	115.7 feet (minimum)
(d)	Inlet temperature:	240° to 250°F
(e)	Average head-flow slope at design point:*	-2.5 feet/gpm
(f)	Maximum motor input at 17 gpm:	1600 watts

3.1.3.2 Alternate conditions.- The pump designed to meet the conditions of 3.1.3.1 shall (by modification of the impeller envelope) meet the following performance requirements:

(a)	Flow rate:	13.5 gpm
(b)	Static suction pressure:	3 psia(minimum)
(c)	Head rise (minimum):	115.7 feet
(d)	Inlet temperature:	220° to 250°F
(e)	Maximum motor input:	(to be determined)

3.1.3.3 Reduced flow condition.- The pump shall be equipped with an internal orificed bypass (accessible externally) capable of reducing in half the design flow at the design head rise (3.1.3.1). The bypass orifice shall (as an alternate to welding) allow for O-ring sealing utilizing a "Viton" ring.

*Design objective

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3.1.3.4 Off-design conditions.- The pump shall be designed to meet the following off-design performance conditions:

(a) Minimum shutoff head:

Design conditions (3.1.3.1):	123 feet
Alternate conditions (3.1.3.2):	73 feet

(b) Maximum discharge head at any flow:

Design conditions (3.1.3.1):	140 feet
Alternate conditions (3.1.3.2):	83 feet

(c) The input motor power at any point from shutoff to 100-percent design capacity shall not exceed the design point value.

(d) The pump shall have stable head rise over the range of 70 to 130 percent of design flow where the headflow curve has increasing negative slope with increasing flow.

3.1.4 Motor performance.-

3.1.4.1 Rating.- The motor horsepower rating shall be in accordance with the steady-state pump-design-point requirements as specified in 3.1.3.1. The motor rating shall include all mechanical and hydraulic loading dictated by the PMA design.

3.1.4.2 Maximum torque requirement.- The motor shall be capable of delivering 130 percent of the rated torque as required in 3.1.4.1 at a slip not to exceed 5 percent.

3.1.4.3 Speed.- The synchronous speed shall be 8000 rpm at 400-cps input.

3.1.4.4 Slip.- The motor slip shall not exceed 3 percent at the steady-state design point defined in 3.1.3.1.

3.1.4.5 Power factor.- The power factor shall be not less than 0.50 for the conditions of 3.1.3.1 and 0.40 for the conditions of 3.1.3.2 when operating at the steady-state design conditions defined in the respective paragraphs.

3.1.4.6 Motor input.- The motor power input shall not exceed 1600 watts for the design conditions defined in 3.1.3.1. Input power for the nominal operating conditions defined in 3.1.3.2 shall be determined when required.

3.1.4.7 Start and acceleration torque.- The motor shall be capable of delivering 130 percent of the required shaft torque at the speeds from zero to steady state at a starting-and-operating voltage-to-frequency ratio of 0.52.

3.1.5 Operating range.- The PMA shall be capable of operating under the following ranges for the specified periods without impairing subsequent performance or life:

(a)	Flow rate:	5 to 130 percent of design	5 hours
		50 to 130 percent of design	500 hours
		Shutoff	5 minutes
(b)	Inlet temperature:	220° to 250°F	10,000 hours
(c)	Voltage:	± 10 percent of design	500 hours
(d)	Frequency:	± 5 percent of design	500 hours

3.1.6 Startup.- The pump shall be capable of 50 normal starts without impairing subsequent operation or life. The pump shall be capable of the normal and abnormal starting modes described in the following subparagraphs.

3.1.6.1 Normal start Mode 1.- The PMA shall be capable of startup by instantaneous application of 208-volts, 400-cps, 3-phase electrical power with hydraulic and electrical conditions as described in 3.1.5. Conditions prior to startup shall be as specified in 3.1.7.1.

3.1.6.2 Normal start Mode 2.- The PMA shall be capable of startup by increasing electrical power as described below with hydraulic and thermal conditions as described in 3.1.5. Conditions prior to startup shall be as specified in 3.1.7.1.

(a)	Number of Phases:	3
(b)	Terminal Voltage:	0 to 208 line-to-line in 15 to 30 seconds
(c)	Voltage to Frequency Ratio (Volts/cps):	0.52 constant

3.1.6.3 Deleted

3.1.6.4 Abnormal start conditions.- The PMA shall be capable of three reverse rotation starts not to exceed 60 seconds of total operation. The conditions of this start mode shall be as described in 3.1.6.1. The PMA shall also be capable of two dry (no service or lubricant fluid present) starts not to exceed 10 seconds of total operation. The conditions of this start mode shall be as described in 3.1.6.1. The abnormal starts shall be at least 30 minutes apart. The above conditions must be met without impairing the life characteristics.

3.1.6.5 Cooling.- The PMA shall be self cooled.

3.1.7 Conditions prior to startup.-

3.1.7.1 Condition 1.- The conditions prior to normal start Modes 1 and 2 (3.1.6.1 and 3.1.6.2) shall be as follows:

(a)	Flow rate:	0 gpm
(b)	Temperature:	125° to 250°F
(c)	Static suction pressure:	3 psia (minimum)

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3.1.7.2 Deleted

3.2 Design requirements.-

3.2.1 Size and weight.- The size of the PMA shall be determined in conjunction with the design review. The target weight shall be 30 pounds (maximum).

3.2.2 Mounting.- The PMA shall be foot mounted on the motor frame as shown on AGC Drawing 094246. The PMA will be rigidly attached to the system structure. Structural vibration characteristics are to be determined at a later date.

3.2.3 Connections.- All connections and/or terminals shall be provided with noninflammable protective covers.

3.2.3.1 Pump.- The locations of the pump inlet and discharge shall be as shown on AGC Drawing 094246. The pipe connections shall be socket-weld type direct to the pump housing which shall be the female member. The pipe sizes shall be as follows:

(a) Pump inlet: 1.0-inch OD with 0.035-inch wall, 316 SS tube.

(b) Pump outlet: 0.75-inch OD with 0.035-inch wall, 316 SS tube.

The supplier shall provide a 4-inch long 304 or 316 SS tube on suction and discharge, as shown on AGC Drawing 094246.

3.2.3.2 Electrical.- The motor leads shall be brought through the housing in hermetically-sealed feed-through insulators. The lead wires shall be joined to the connector pins or terminals by TIG welding. The type and location of the insulators and terminals shall be with the concurrence and approval of AGC. Terminals shall be marked T_0, T_1, T_2, T_3 and the phase sequence shall be marked T_1, T_2, T_3.

3.2.4 Materials.- The materials used in the manufacture of the PMA shall be compatible with the requirements of this specification. There shall be no degradation of materials that will affect the PMA performance in 10,000 hours of unattended operation

at rated conditions in all the specified environments. With the possible exception of the bearing components, all parts in contact with the service fluid shall be fabricated from the following list of alloys:

(a) Alloy steels

(b) Stainless steels

(c) Carbon steels

(d) Nickel-base alloys

(e) Aluminum (pure)

NOTE

No copper alloys nor halogenated hydrocarbon compounds are allowed except in the stator winding or as temporary test seals.

Bearing component materials shall be consistent with the corrosion resistance of the above-listed materials. The pump impeller and housing shall be made of 316 (or equivalent series) stainless steel.

3.2.5 Seals.- The pump and drive motor shall be enclosed in a hermetically-sealed housing. No rotating shaft shall penetrate the housing.

3.2.5.1 Static seals.- All static seals shall be of the seal-weld type, designed for zero leakage. The allowable helium leak-rate is defined in paragraph 3.2.15.

3.2.5.2 Motor.- The stator winding and insulation system shall be: (1) capable of continuous immersion in the service fluid, or (2) hermetically sealed from the service fluid and PMA environment.

3.2.6 Rotation.- The PMA shaft rotation shall be counter clockwise when viewed from the pump inlet.

3.2.6.1 Rotation marking.- An arrow indicating the direction of rotation shall be permanently and conspicuously affixed to the motor housing.

3.2.7 Cooling.- The PMA shall be cooled by use of the service fluid (see 3.1.1). No provisions shall be made to transfer heat from the PMA to the environment or mounting through radiation, convection or conduction.

3.2.7.1 Deleted

3.2.8 Pipe loads.- The pump shall be capable of meeting the design performance for the 10,000-hour life when subjected to the following pipe loads measured at the pump inlet and discharge flanges.

(a)	Axial or radial force on flange:	Inlet, ±50 lb Outlet, ± 25 lb
(b)	Moment in any plane:	Inlet, ±200 in.-lb Outlet, ± 100 in.-lb

3.2.9 Reliability.- The design of the PMA shall be directed toward a reliability goal of 0.9887 while operating in accordance with the requirements of this specification throughout its service life.

3.2.9.1 Reliability program requirements.- The supplier shall conduct a reliability program in accordance with the applicable requirements of the procurement document (see 6.3.1).

3.2.10 Safety factors.- Design safety factors will be specified prior to award of contract.

3.2.10.1 Critical speed.- The shaft system first natural frequency shall be not less than 150 percent of the synchronous speed at the maximum frequency.

3.2.11 Safety wiring, staking, and locking.- Accidental loosening of screws, screw parts, fasteners, and other connections shall be prevented by safety wiring or other approved positive mechanical means on both stationary and rotating members. Staking shall be used only when the parts are permanently assembled. No bolts facing rotating members shall be a design objective.

3.2.12 Components.- The components comprising the PMA shall be in accordance with the following subparagraphs.

3.2.12.1 Pump.- The pump shall be a single-stage axial-inlet centrifugal type. The impeller shall be

designed to achieve overall hydraulic thrust balance consistent with the bearing design provided over the full operating range of the PMA. Radial hydraulic balance shall be provided consistent with the bearing design provided over the full operating range of the PMA. The PMA shall be designed such that the location of the pump outlet can be changed in 90-degree increments (or less) by rotating the pump housing about the longitudinal axes at assembly.

3.2.12.2 Motor.- The motor shall be in accordance with the following requirements:

(a) Type: Squirrel cage induction

(b) Number of poles: Six

(c) Connection: Wye-connected with the neutral brought out to a separate terminal on the motor housing

(d) Winding temperature: The motor losses, temperature environment, and associated cooling paths shall limit the maximum hot spot winding temperature to 200°C.

(e) Insulation: The insulation materials and treatment of same shall be compatible with the selected operating temperature and the selection of condition in 3.2.5.2.

(f) Thermocouples: Five thermocouples shall be provided and brought out to hermetically sealed terminals located on the motor housing. The thermocouples shall be located as follows:

(1) Three thermocouples: One thermocouple adjacent to each phase in the stator slot no less than 0.5 inch from the end lamination.

(2) Two thermocouples: Imbedded in outer extremity of stator end turns, one thermocouple at each end of assembly.

3.2.12.3 Bearings.- The bearings shall be lubricated with the service fluid and shall require no maintenance for the specified 10,000-hour life. The bearings shall be capable of operating under a load range from zero to the maximum defined by the sum of the most severe, internal mechanical, hydraulic, and magnetic loads and the acceleration loads defined in 3.3.4.4. The bearings shall be capable of sustaining the specified loads applied in any direction normal to the bearings' working surface.

3.2.12.4 Speed sensor.- The PMA shall be equipped with a pickup to determine the shaft speed. The pickup shall have the following characteristics:

(a) 800 pulses/second or greater at 8000 rpm

(b) 15 mv or greater at 1600 rpm

(c) Self-exciting

(d) External impedance of 25,000 ohms.

3.2.13 Overspeed.- The PMA's critical speed and mechanical construction shall be designed to be capable of operating at 12,000 rpm for a short period of time without impairing subsequent performance.

3.2.14 Assembly and disassembly.- The design of the PMA shall be such that it can be disassembled and assembled by use of hand tools. Only cutting of seal welds shall be permitted at disassembly. Seal-weld joints shall provide a minimum capability of three re-welds with only minor (to noncritical or nonreference areas) machining between disassembly and assembly permitted.

3.2.15 Leakage.- The maximum allowable helium leak-rate for the PMA shall be not greater than 10^{-7} cc/second when tested in accordance with MIL-STD-271.

3.3 Environmental.- The PMA will be exposed to four basically different environments plus ground tests in its life cycle. These phases will include storage and transportation, handling and vehicle integration, launch, and orbital operation. The PMA will be operating only during the ground test and orbital operation phases.

3.3.1 Storage and transportation.- The PMA shall be capable of withstanding without deterioration or performance decay the environments described in the following subparagraphs.

3.3.1.1 Normal storage.- The PMA shall be capable of storage in a temperature and humidity controlled environment for a period of two years without deterioration.

3.3.1.2 Temperature.- During storage and transportation, the PMA will be protected from the thermal environment. However, the thermal conditions will vary within the container and the PMA shall be capable of withstanding temperatures from -40°F to +160°F.

3.3.1.3 Pressure.- During the storage and transportation phase, the PMA will be subjected to pressures from sea level to a maximum altitude of 50,000 feet. The maximum change in pressure to which the PMA will be subjected is a reduction or increase in pressure of 1.25 psi per minute. This will occur in either a climb to 50,000 feet or a descent from 50,000 feet.

3.3.1.4 Shock.- The PMA shall be capable of withstanding transportation shocks applied to the PMA mounting in each of three mutually perpendicular axes of 4-g magnitude for one of the following time periods:

(a) Triangular pulse: 10 milliseconds

(b) Half-sine pulse : 8 milliseconds

(c) Rectangular pulse: 5 milliseconds.

3.3.1.5 Vibration.- The PMA shall be capable of withstanding sinusoidal transportation vibrations applied to the PMA mounting in three mutually perpendicular axes according to the following schedules:

Frequency Range	Amplitude	Duration
2 to 10 cps	0.40-inch DA	30-minute logarithmic sweep
10 to 500 cps	2.0-g peak	30-minute logarithmic sweep

Five minutes of vibration shall be applied at the same amplitude at each major resonant frequency.

3.3.1.6 Fungus.- The PMA shall be adequately protected from deterioration caused by growth of fungus.

3.3.2 Handling and vehicle integration.- During handling and vehicle integration, it can be anticipated that the PMA will be exposed to atmospheric and weather environments for a maximum period of six weeks. The PMA shall be capable of withstanding, without deterioration or performance decay, the environments described in the following subparagraphs.

3.3.2.1 Humidity.- The PMA shall be capable of withstanding a simulated 24-hour cycle of water vapor in the atmosphere with a 5-mile-per-second steady-state wind as follows:

(a) Six hours of 106°F air temperature at 65 percent relative humidity (absolute humidity 15.3 gms/ft^3)

(b) Six hours of decreasing air temperature to 91°F and increasing relative humidity to 100 percent.

(c) Eight hours of decreasing air temperature to 81°F with a release of 4.4 gms/ft^3 of water

(d) Four hours of increasing air temperature to 106°F and decreasing relative humidity to 50 percent.

3.3.2.2 Sand and dust.- The PMA shall be capable of withstanding a sand and dust density of 0.1 to 0.25 gms/ft^3 at a temperature of 77°F in an air stream of 2500 ft/minute for 3 hours with the relative humidity at

less than 30 percent. "Sand and dust" is defined as 140-mesh silica flour with characteristics as specified in MIL-E-5272.

3.3.2.3 Fungus.- The PMA shall be adequately protected from deterioration caused by growth of fungus.

3.3.2.4 Salt spray.- The PMA shall be capable of withstanding a 50-hour 20-percent salt-solution spray test.

3.3.2.5 Temperature.- The PMA shall be capable of withstanding temperature variations within -55°F to +160°F for two weeks.

3.3.3 Launch, lift-off to final termination of thrust.- The non-operating PMA shall be capable of withstanding without performance degradation the launch environments specified in the following subparagraphs.

3.3.3.1 Shock.- The PMA shall be capable of withstanding shocks applied to the PMA mounting in each of three mutually perpendicular axes of 35-g magnitude for one of the following time periods:

(a) Triangular pulse: 10 milliseconds

(b) Half-sine pulse: 8 milliseconds

(c) Rectangular pulse: 5 milliseconds

3.3.3.2 Vibration.- The PMA shall be capable of withstanding launch vibrations applied to the PMA mounting in three mutually perpendicular axes according to the following schedule of sinusoidal inputs:

Frequency Range	Amplitude	Duration
16 to 42 cps	2-g peak	30-minute logarithmic sweep
42 to 95 cps	0.022-inch DA	30-minute logarithmic sweep
95 to 2000 cps	10-g peak	30-minute logarithmic sweep

In addition, the PMA shall be capable of withstanding sinusoidal resonance vibrations in three mutually perpendicular axes for 5 minutes according to the following schedule:

Frequency Range	Amplitude
16 to 42 cps	1-g peak
42 to 95 cps	0.011-inch DA
95 to 2000 cps	5-g peak

3.3.3.3 Acceleration.- The PMA shall withstand the launch and lift-off accelerations according to the following schedule:

(a) 7 g for 5 minutes in a direction perpendicular to the shaft axes

(b) 3 g for 5 minutes in a direction parallel to the shaft axes

(c) Deleted

The PMA shaft will be normal to the central of the launch vehicle.

3.3.3.4 Acoustic noise.- The component shall withstand exposure to acoustic noise at 140 db integrated sound pressure level.

3.3.4 Orbital operation.- The PMA shall be capable of startup and operation in any orientation relative to the direction of the sun, planets, or moon, either in or out of the shadow of any planet or moon. It shall be capable of startup and operation in zero gravity, temperature, and vacuum environments of space. The PMA shall be capable of withstanding the cosmic, solar and Van Allen radiation encountered in a space environment with no deterioration of performance in a period of 10,000 hours.

3.3.4.1 Shock.- The PMA shall be subjected to shocks during operation in a space environment of 7-g on each of three mutually perpendicular axes with one of the wave forms and time durations indicated below:

(a) Triangular pulse for 10 milliseconds

(b) Half-sine-wave pulse for 8 milliseconds

(c) Rectangular pulse for 5 milliseconds.

3.3.4.2 Vibration.- The PMA will be subjected to vibrations in space while in operation of 0.25-g peak over a frequency range of 5 to 2000 cps. The input of these vibrations will be at the mounting of the PMA.

3.3.4.3 Self-generated vibration.- The PMA shall not self-generate vibrations over 0.25-g peak while operating in space over a frequency range of 5 to 2000 cps.

3.3.4.4 Acceleration.- After startup, the PMA shall be capable of withstanding a 3.5-g acceleration in a direction perpendicular to the shaft axis and plus or minus 1 g on each of the two mutually perpendicular axes parallel to the plane of mounting. These accelerations shall be sustained for periods not to exceed 5 minutes. In addition, the PMA shall be capable of operation with a maximum of 1-g acceleration in a direction perpendicular to the PMA shaft in a space environment for periods of 10,000 hours.

3.3.4.5 Micrometeorite penetration.- The PMA shall be protected from micrometeorite penetration encountered in space.

3.3.4.6 Radio frequency interference.- The PMA shall pass the tests described in JPL Specification 30236 to assure there will be no radio frequency interference with other assemblies in the SNAP-8 system.

3.3.4.7 Radiation.- The PMA shall be capable of withstanding without performance degradation (for 10,000 hours) the following cumulative radiation doses:

(a) 5×10^{12} NVT fast neutrons

(b) 5×10^{7} rads gamma

3.4 Service life.- The PMA shall be capable of continuous operation for periods up to 10,000 hours of unattended operation at rated loads and temperatures in all specified environments. The PMA shall be capable of 50 start and stop cycles during its service life.

3.5 Interchangeability.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with respect to installation

and performance and adequately serialized to provide for the use of matched or fitted subassemblies. Changes in part numbers shall be governed by the requirements of Specification MIL-D-70327.

3.6 Workmanship.- All machine surfaces shall have a smooth finish, and all details of manufacture, including the preparation of parts and accessories, shall be in accordance with the best practice of high-quality electrical equipment. Particular attention shall be given to neatness and thoroughness of welding, wiring, impregnation of coils, marking of parts, plating, lacquering, riveting, clearance between electrical connections, removal of burrs and sharp edges, and ruggedness.

3.7 Identification of product.- Equipment, assemblies, and parts shall be marked as specified in Standard MIL-STD-130.

3.7.1 Nameplate.- A nameplate conforming to Specification MIL-P-6906 shall be securely attached to a fixed part of each unit. The following information shall appear on the PMA nameplate in addition to the information required by Standard MIL-STD-130.

SNAP-8 L/C Pump-Motor Assembly

Horsepower:	_____	Locked rotor kVA:	_____
Volts:	208	Flow:	_____ gpm
Rated current:	_____	Pressure rise:	_____ psi
Phases	3	Fluid temperature:	_____ °F
Speed:	_____ rpm	AGC Dwg No.:	_____
Frequency:	400 cps	Serial No.:	_____
Temperature rise:	___ °C		

4. QUALITY ASSURANCE PROVISIONS

4.1 Test program- The PMA test program shall be accomplished in a manner to be defined by the supplier subject to approval by AGC to verify the conformance of the PMA to the requirements of this specification. (see 4.6 and 4.7).

4.2 Classification of tests.- The testing shall include the following classification of tests:

(a) Development tests (4.3)

(b) Deleted

(c) Acceptance tests (4.5)

4.3 Development tests.-

4.3.1 Scope of development tests.- Development tests are those tests that are necessary to verify the short-term conformance of development hardware to all specified design and operating requirements defined in 3.1 and 3.2. In addition, during this series of tests, the following characteristics shall be determined:

(a) Deleted

(b) Deleted

(c) Deleted

(d) Deleted

(e) Steady-state winding temperature at design point

(f) Pump pressure-rise, efficiency, BHP, and speed as a function of flow at 400 cps

(g) Cavitation NPSH* tests at 70, 100 and 130 percent of design capacity at 400 cps

(h) Assembly internal-pressure and temperature profiles under conditions described in 3.1.3.1, 3.1.3.2, 3.1.3.3 and 3.1.3.4 at flows varying from shutoff to 130 percent of design flow.

(i) Deleted

4.3.2 Sampling.- One PMA shall be subjected to development testing.

*Net positive suction head

4.3.3 Instrumentation.- The development PMA shall be instrumented by the contractor to permit the measurement of all parameters necessary to verify compliance to the specified operating conditions and the additional performance characteristics required. The instrumentation shall not change the performance characteristics of the PMA.

4.4 Environmental tests.- Deleted

4.5 Acceptance tests.-

4.5.1 Scope of acceptance tests.- Acceptance tests are those tests that verify calibration and proof of performance of each unit of deliverable hardware. Acceptance tests shall include, but not be limited to the following:

(a) Discharge pressure and motor input as a function of flow

(b) Cavitation NPSH tests at design capacity

(c) Hydrostatic proof-pressure

(d) Helium leak-tests

(e) Insulation high-potential and surge tests

(f) Winding resistance

(g) Four-hour heat-stabilization run

4.5.2 Sampling.- Acceptance tests shall be conducted on each unit of deliverable hardware.

4.6 Test procedures and specifications.- Informal submittal of procedures and specifications shall be accomplished prior to the initiation of tests. Instrument accuracy should be stated in documents. Wherever possible, MIL-M-17060 and the ASME Power Test Code for Centrifugal Pumps shall be used as guidance in the preparation of test procedures.

4.7 Test report.- A complete report covering all testing shall be submitted within 30 days after the completion of each test series. Supplier format will be acceptable providing the data presented is complete and logically arranged. Reports shall include calibration data for all instrumentation used.

4.8 Test equipment.- All necessary equipment to perform the required tests shall be furnished by the supplier. A 25-micron filter (nominal) shall be used in all loop testing.

4.9 Inspection by AGC.- AGC personnel may observe all phases of PMA testing and all processes of construction which are not specifically defined as proprietary during contract negotiation. Advance notice of time and place of all tests shall be given to AGC.

5. PREPARATION FOR DELIVERY

5.1 Suppliers responsibility.- The packaging, handling, marking, and method of shipment are the responsibility of the supplier. Each PMA shall be properly cleaned and sealed so it is ready for testing when received by AGC.

5.2 Cleanliness requirements.- All assemblies for test and delivery shall be assembled in a clean area with a particle analysis per-cubic-foot not exceeding:

(a) 1 particle equal to or greater than 50 microns

(b) 5 particles equal to or greater than 25 microns

(c) 35 particles equal to or greater than 10 microns

(d) 150 particles equal to or greater than 5 microns

6. NOTES

6.1 Data submittal.-

6.1.1 Design calculations.- Prior to the commencement of fabrication, the items described in the following

subparagraphs shall be submitted in reproducible form for approval.

6.1.1.1 Detailed layout.- The detailed layout indicating all running clearances, critical fits, and materials shall be submitted.

6.1.1.2 Electrical.-

6.1.1.2.1 Electromagnetic performance.- Complete motor-design calculations and supporting data shall be submitted with the layout drawing. These calculations shall include all motor-design impedances and losses for steady-state and startup conditions, and compensation for performance evaluation over the established temperature range.

6.1.1.2.2 Motor windings.- Complete insulation-material specifications, winding processes, and details of all connections to the external terminals shall be submitted with the layout drawing.

6.1.1.3 Mechanical.- Complete mechanical-design calculations and supporting data shall be submitted with the layout drawing. Included in these calculations shall be analysis of pump design, bearing design, bearing loads, critical speed, cooling system design, housing, pump, bearing stresses, and others as required.

6.1.1.4 Thermal.- Complete thermal calculations including thermal maps for steady-state operation shall be submitted with the layout drawing.

6.1.2 Drawings.- Prior to the delivery of finished hardware, complete engineering drawings to supplier format shall be submitted for approval. These shall include assembly drawings, detail drawings, detail subassembly drawings, wiring drawings, and parts lists. Drawings shall be maintained current by the vendor to reflect the latest designs and shall conform to the definitions of MIL-D-70327 Class 2, contractor design activity drawings. One reproducible and four copies of each shall be supplied.

6.1.3 Quality assurance.-

6.1.3.1 Source of supply.- The supplier shall comply with the quality assurance provisions contained

in AGC Quality Control Standard H 1-6 except as modified by the purchase agreement.

6.1.3.2 Source surveillance.- When required by the purchase agreement, the supplier's products, systems, facilities, and procedures shall be subject to source surveillance by an AGC supplier quality-control representative.

6.1.4 Reports.- Informal monthly letter progress reports, to include all design calculations on a current basis, shall be submitted summarizing technical progress within ten working days after the close of the report period. Bimonthly to monthly technical progress reviews will be conducted. A final technical report at the conclusion of each phase of the program shall also be submitted.

6.1.5 Instruction manual.- Prior to delivery of the first PMA, an instruction manual shall be submitted explaining in detail the procedure to be followed in installation, assembly, and disassembly of the unit and any special precautions necessary in the care and handling of the PMA. The manual shall be typewritten and reproduced in ozalid form. Four copies and one reproducible copy shall be submitted with each PMA configuration. Manuals shall be revised and resubmitted as often as necessary to reflect the latest design changes.

6.2 Special tools.- Two sets of any special tools required to assemble, disassemble, or handle the PMA shall be furnished and delivered with the PMA.

6.3 Precedence.- When the requirements of the contract, this specification, or applicable subsidiary specifications are in conflict, the following precedence will apply.

6.3.1 Contract.- The contract will have precedence over any specification.

6.3.2 This Specification.- Whenever the requirements of this specification and subsidiary specifications or drawings conflict, the requirements of this specification will govern. Any deviation from this specification or from subsidiary specifications or drawings, where applicable, must be specifically approved in writing by AGC.

Authorized for Release:

W. J. Pinkerton

W. J. Pinkerton, Head
Specifications and Standards
SNAP-8 Division
Von Karman Center

AEROJET-GENERAL CORPORATION

CODE IDENT. NO. 70143

AGC-10320
31 January 1964

DEVELOPMENT MATERIAL SPECIFICATION

POLYPHENYL ETHER, MIX-4P3E

1. SCOPE

1.1 This specification establishes the requirements for bis (mix-phenoxyphenyl) ether, hereinafter referred to as mix-4P3E.

2. APPLICABLE DOCUMENTS

2.1 Department of Defense documents.- Unless otherwise specified, the following document, listed in the Department of Defense Index of Specifications and Standards in effect on the date of invitation for bids, shall form a part of this specification to the extent specified herein.

STANDARD

Military

MIL-STD-290	Packaging, Packing and Marking of Petroleum and Related Products

(Copies of documents required by contractors in connection with specific procurement functions, should be obtained as indicated in the Department of Defense Index of Specifications and Standards.)

2.2 Other documents.- Unless otherwise specified, the following documents of the issue in effect on the date of invitation for bids, shall form a part of this specification to the extent specified herein.

STANDARDS

American Society for Testing Materials

ASTM-D92	Method of Test for Flash and Fire Points
ASTM-D97	Method of Test for Cloud and Pour Points
ASTM-D149	Method of Test for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
ASTM-D150	Method of Test for A-C Capacitance, Dielectric Constant, and Loss Characteristics of Electrical Insulating Materials
ASTM-D257	Method of Test for Electrical Resistance of Insulating Materials
ASTM-D270-61	Method of Sampling Petroleum and Petroleum Products
ASTM-D286	Method of Test for Autogeneous Ignition Temperatures of Petroleum Products
ASTM-D445	Method of Test for Kinematic Viscosity
ASTM-D664	Method of Test for Neutralization Number by Potentiometric Titration
ASTM-D1160	Method of Test for Distillation at reduced Pressure of Petroleum Products
ASTM-D1217	Method of Test for Density and Specific Gravity of Liquids by Bingham Pycnometer
ASTM-D1218	Method for Measurement of Refractive Index and Refractive Dispersion of Hydrocarbon Liquids

(Copies of ASTM Standards may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.)

2.3 Conflicting requirements.- If any of the requirements of this specification conflict with the requirements of the documents listed in 2.1 and 2.2, the requirements of this specification shall apply.

3. REQUIREMENTS

3.1 Material.- The mix-4P3E shall be a mixture of the six isomers of phenoxyphenyl ether known as bis (mix-phenoxyphenyl) ether. The isomers shall be in a ratio which shall have the properties specified herein. The minimum purity shall be 99 percent mix-4P3E by weight.

3.2 Physical and chemical properties.- The physical and chemical properties of the mix-4P3E shall be in accordance with Table I.

TABLE I

PROPERTY	VALUE
Boiling range, at 0.5 mm Hg	99 percent by weight shall boil at no lower than 400°F
Density, at 68°F	1.178 ± 0.040 g/ml
Fire point	525°F
Flash point	465°F
Pour point	20°F, or less
Neutralization number, to a ph 11	No measurable weak or strong acids
Refractive index, at 77°F	1.6210 ± 0.006
Phenol (weight percent as phenoxyphenol)	0.05 maximum
Spontaneous ignition	1000°F minimum
Total halogens, as chlorine and bromine	0.03 percent, by weight, maximum
Viscosity at 100°F	65 ± 5 centistokes
Viscosity at 210°F	6.2 ± 0.3 centistokes

PROPERTY	VALUE
Dielectric strength	300 volts/mil, or greater
Dielectric constant, at 10^3 cycles	4.46
Dissipation factor, at 10^3 cycles	0.0002, or less
Volume resistivity, at 70°F	1×10^{14} ohms-cm, or greater

NOTE: The halogen content limit may be lowered if the halogen content is shown to contribute to catalytic decomposition.

3.3 Specific heat and thermal conductivity.- The specific heat and thermal conductivity shall be within ± 10 percent of the nominal values shown in Figures 1 and 2.

3.4 Workmanship.- The finished lubricant and coolant oil shall be transparent, uniform in appearance, and shall be free from sediment, cloudiness, and suspended matter, and shall have little or no odor.

4. QUALITY ASSURANCE PROVISIONS

4.1 Supplier responsibilities.- The supplier shall be responsible for all tests specified herein. Unless otherwise specified, the supplier may use his own or any other inspection facilities and services acceptable to the Aerojet-General Corporation for the inspections and tests specified herein. Records of all inspections and tests shall be kept complete and available to the Aerojet-General Corporation in accordance with the requirements of the purchase contract. The Aerojet-General Corporation reserves the right to perform additional tests when such tests are deemed necessary to verify compliance with this specification.

4.1.2 Test reports.- The supplier shall furnish three certified copies of the results of tests performed on each bulk lot and each shipment required by this specification. The supplier shall also specify the method of testing used to determine the results, and the date the tests were performed.

4.2 Lot size.- A lot size shall be any quantity of homogeneous mixture of mix-4P3E from a single bulk lot which has been transferred to 55-gallon (or less) containers and delivered as a single shipment at one time.

4.2.1 Bulk lot.- A bulk lot shall be any quantity of homogeneous mixture of polyphenyl ether manufactured as one batch at one time and place.

4.3 Sampling.- Samples shall be selected from packaged lots in accordance with Table III of Standard ASTM-D270, using tube-sampling methods in accordance with Section 24 of Standard ASTM-D270.

4.4 Acceptance tests.- The test samples shall be subjected to the acceptance tests listed in (a) through (k).

(a)	Boiling point	(see 4.5, Table II)
(b)	Density	(see 4.5, Table II)
(c)	Fire point	(see 4.5, Table II)
(d)	Flash point	(see 4.5, Table II)
(e)	Pour point	(see 4.5, Table II)
(f)	Neutralization number	(see 4.5, Table II)
(g)	Refractive index	(see 4.5, Table II)
(h)	Viscosity	(see 4.5, Table II)
(i)	Autogeneous (spontaneous) ignition	(see 4.5.1)
(j)	Total halogen	(see 4.5.2)
(k)	Phenols	(see 4.5.3)

4.5 Test methods.- The supplier may select the method of performing the tests specified in 4.4. The mix-4P3E shall be subject to test at the Aerojet-General Corporation using the test methods specified in Table II, 4.5.1, and 4.5.2. In case of conflict between the test results obtained by the supplier and the test results obtained by the Aerojet-General Corporation, the test methods specified in Table II, 4.5.1, and 4.5.2 shall be used to determine the governing test results. Failure of the supplier's test results to be in accordance with the test results obtained using the test methods specified in Table II, 4.5.1, and 4.5.2 shall be basis for rejection.

TABLE II

TEST REQUIREMENTS AND METHODS

TEST REQUIREMENT	ASTM-STD
Boiling range	D-1160
Density	D-1217
Fire point	D-92
Flash point	D-92
Pour point	D-97
Neutralization number	D-664
Refractive index	D-1218
Viscosity, kinematic	D-445
Autogeneous (spontaneous) ignition	D-286
Dielectric strength	D-149
Dielectric constant	D-150
Dissipation factor	D-150
Volume resistivity	D-257

4.5.1 Total halogen.- The total halogen content (as chlorine and bromine) shall be determined using infrared spectroscopy.

4.5.2 Phenols.- The phenol content shall be determined using infrared spectroscopy.

4.6 Rejection and retest.- Mix-4P3E, which has been rejected during acceptance testing, may be reworked to correct the defects and then retested for acceptance. Prior to retesting, complete information concerning the reasons for failure and the corrective methods taken shall be furnished to the Aerojet-General Corporation. Mix-4P3E, which has been rejected during retesting, shall not be re-submitted for testing without the approval of the Aerojet-General Corporation.

5. PREPARATION FOR DELIVERY

5.1 Packaging.- Packaging shall be in accordance with Standard MIL-STD-290.

5.1.1 Packaging material.- The mix-4P3E shall be packaged in containers which are lined with polyolefin plastic, or containers which are made of polyolefin plastic.

5.2 Marking of packages.- Marking of packages shall be in accordance with Standard MIL-STD-290 and shall contain the bulk lot number, purchase order number, date of shipment, and the title and number of this specification. Also, the following note shall appear in capital letters on each package:

"THIS LUBRICATING AND COOLANT OIL IS NOT INTERCHANGEABLE AND SHALL NOT BE MIXED WITH ANY OTHER TYPE OF OIL."

6. NOTES

6.1 Intended use.- The mix-4P3E covered by this specification is intended for use as a high-speed lubricant and coolant.

6.2 Ordering data.- The purchase order shall specify the following data:

(a) Title, name, specification number, and date of this specification

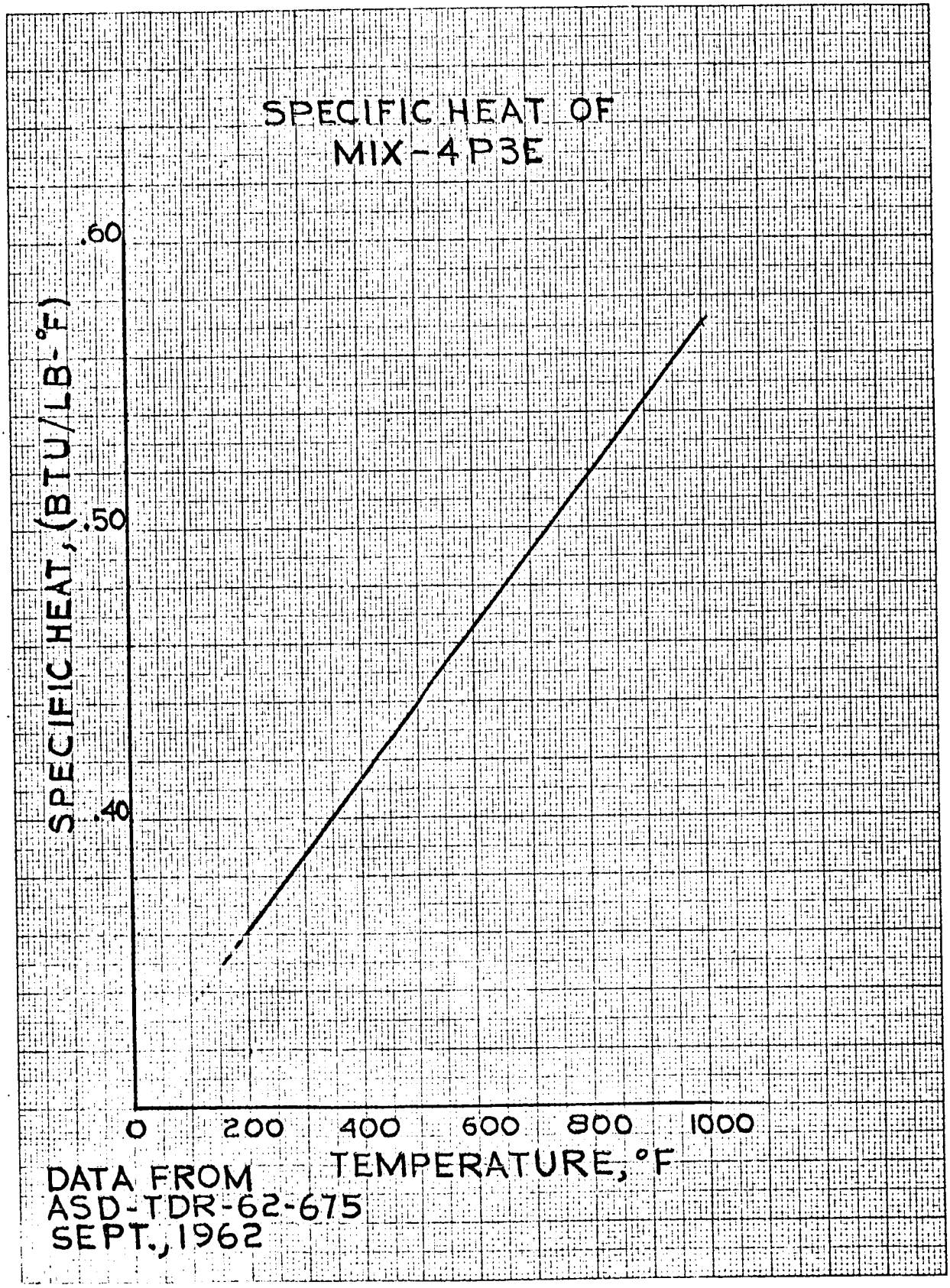
(b) Type and size of containers required

Authorized for Release:

E. J. Vilter

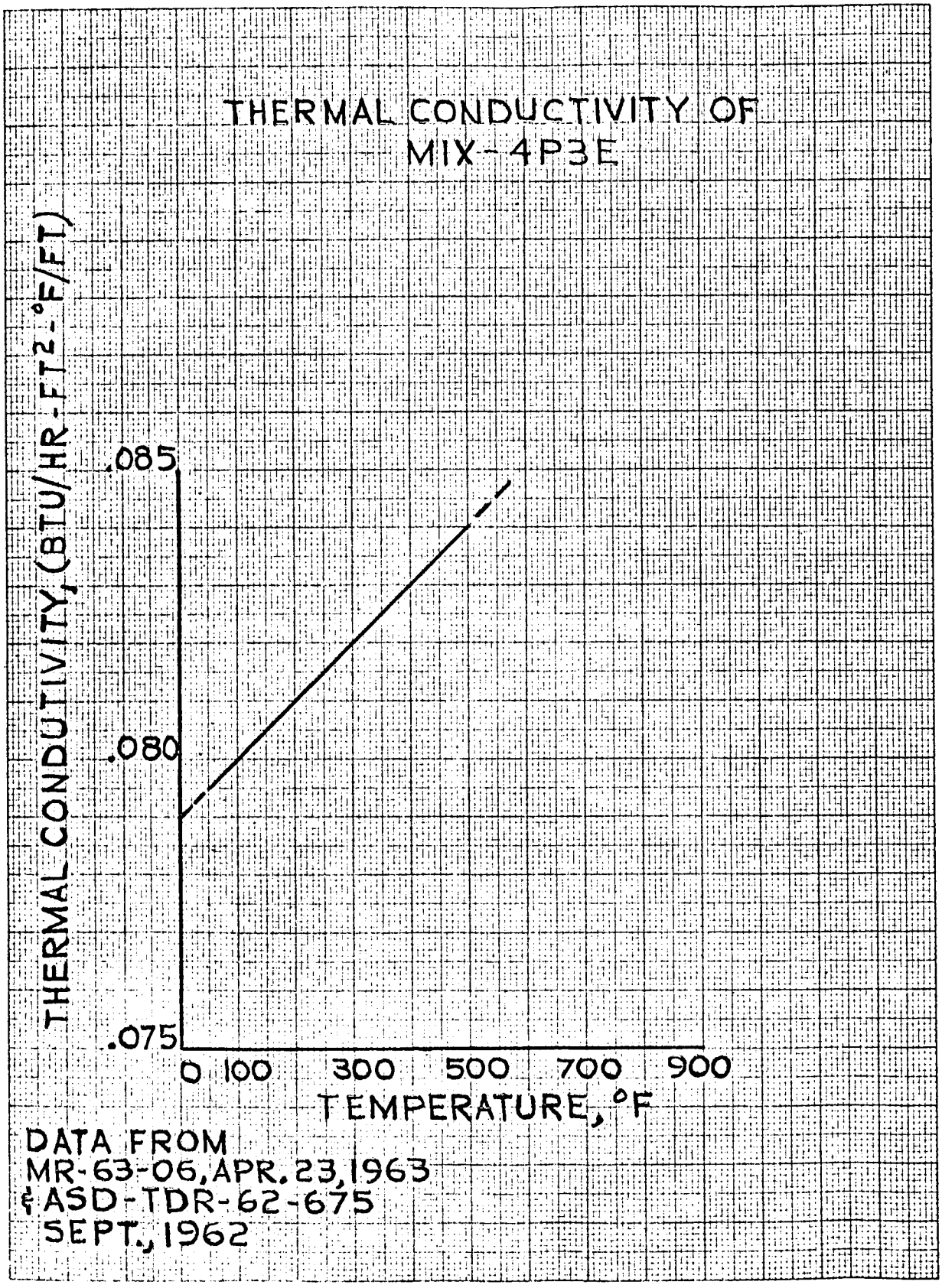
E. J. Vilter
Specifications and Standards
Engineering Services
SNAP-8 Division
Von Karman Center

FIG 1



Aerojet-General®
CORPORATION

FIG 2



Aerojet-General®
CORPORATION

DOCUMENT APPROVAL SIGNATURE SHEET

TYPE OF DOCUMENT	DOCUMENT NO.
DEVELOPMENT MATERIAL SPECIFICATION	AGC-10320

TITLE

POLYPHENYL ETHER, MIX-4P3E

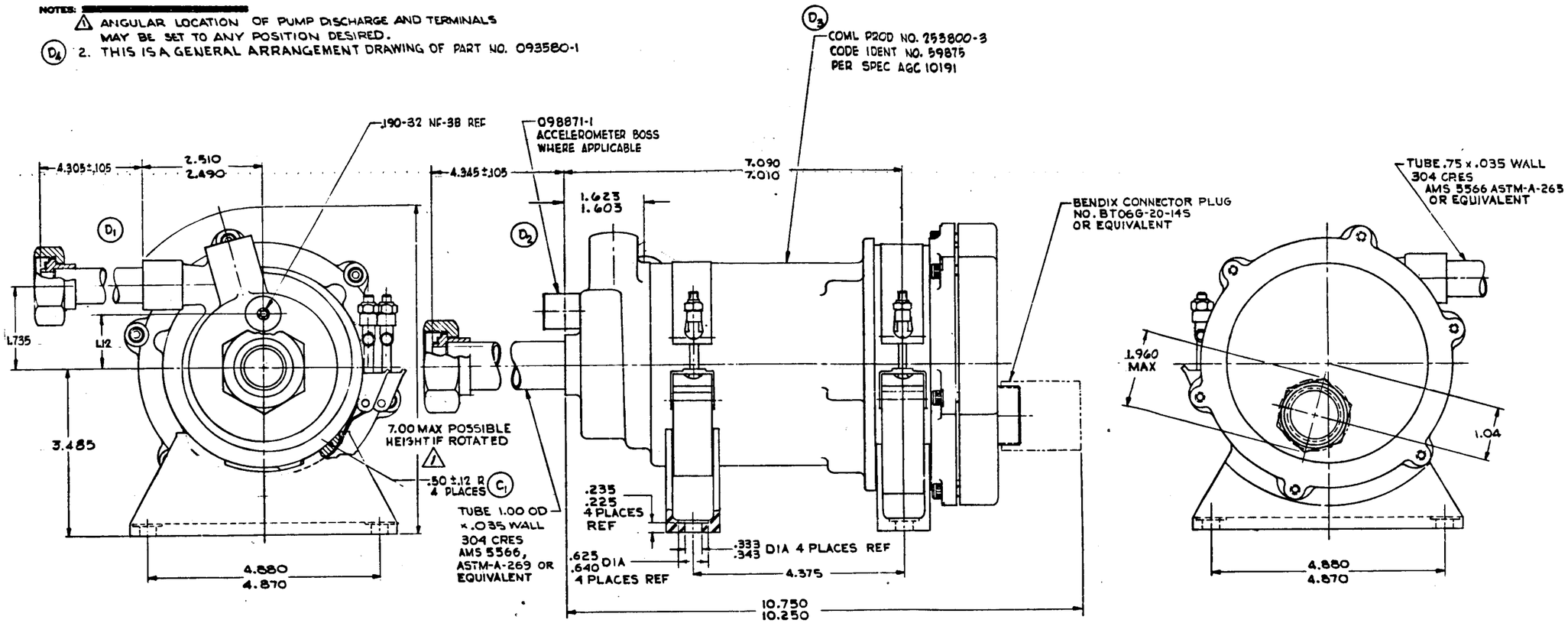
PREPARED BY	DEPT.	EXT.
W. J. Pinkerton	385	6042

APPROVAL SIGNATURE		DEPT.	DATE
F. H. Cassidy Cognizant Engineer - F. H. Cassidy	Bldg. 160	390	1-30-64
H. Deron for Senior Department Head - R. S. Carey	Bldg. 160	390	1-30-64
G. G. Takach for Quality Assurance - R. J. Simon	Bldg. 160	886	1-30-64
B. L. Amstadter for Reliability Engineering - M. A. Patterson	Bldg. 160	343	1-30-64
John N. Barger for System Engineering - L. P. Lopez	Bldg. 160	340	1-30-64
W. D. Daniels Producibility and Assembly - W. D. Daniels	Bldg. 160	383	1-30-64
C. M. Seabourn Technical Services Supervisor - C. M. Seabourn	Bldg. 160	372	C. M. Seabourn
C. N. Epstein Senior Engineer - C. N. Epstein	Bldg. 160	393	1-30-64

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED
A		SEE "A" CHANGE DCN	2-18-64	
B		SEE "B" CHANGE DCN	4-7-64	
C		(1) SEE INCORP ADCN	1-6-65	
D		(1-4) SEE DCN	1-3-66	

NOTES:

1. ANGULAR LOCATION OF PUMP DISCHARGE AND TERMINALS MAY BE SET TO ANY POSITION DESIRED.
2. (D4) THIS IS A GENERAL ARRANGEMENT DRAWING OF PART NO. 093580-1



QTY REQD	SYM	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	UNIT WT.	ZONE	ITEM NO.

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ANGULAR
.XX ± .03 ± 2°
.XXX ± .010
DO NOT SCALE DRAWING

TREATMENT
FINISH

		DATE
DRAWN		12-30-63
CHECK		1-17-64
DESIGN		1-2-64
STRUCTURE/STRESS		1-16-64
MATERIALS		1-16-64
		1-10-64
		1-15-64
DESIGN ACTIVITY APPR		1/16/64
CUSTOMER		1-15-64

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

TITLE
L/C PMA INTERFACE
CONTROL

CODE IDENT NO. 70143
SIZE D
DWG NO. 094246
SCALE
RELEASE DATE 1-23-64
SHEET

ON	THRU
EFFECTIVE SERIAL NO.	
USAGE DATA	

PART IDENT NO.	NEXT	FINAL	NEXT ASSY	USED ON
	QTY REQD PER ASSY		APPLICATION	

DRAWING LEVEL 1

SIMILAR TO
ACT WT
CALC WT 26 lb

III. CONFIGURATION AND IN-PROCESS SPECIFICATIONS

A. Drawing 253899-1 (TRW), Coolant & Lube Pump Layout

B. Final Design Review Meeting Agenda

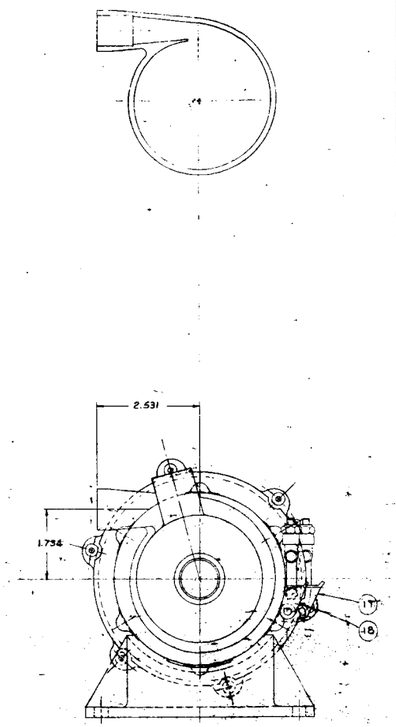
C. AEPS-5050, Process Specification - Soldering Electrical Connection for Models 212600 and 217700 (TRW)

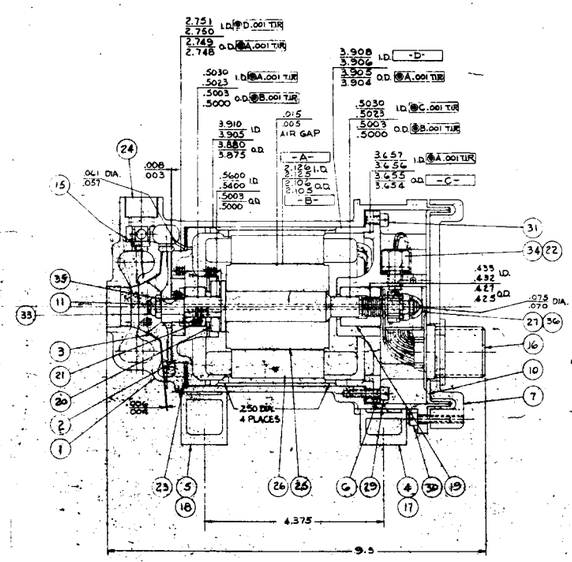
D. Spec. No. 02-1099 (TRW), Development Unit Assembly and Test Procedure, Model 253800-1 Lubrication and Coolant Pump

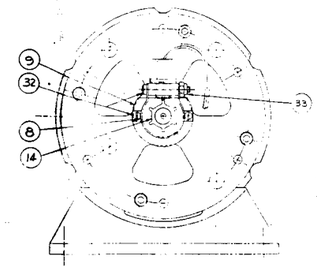
E. Drawing 253801 (TRW) - Pump Assembly

F. Drawing 253800 (TRW) - Pump Installation Centrifugal Pump

REVISIONS				
SYM	DESCRIPTION	DRN	DESIGN	CHK'D	DATE
A	REVISED AS OF THE ECO TAX REVIEW MEETING 5-16-62				5/16







50		LOCKWASHER	A286 OR 19-9	
35		KEY	316 S.S.	
34	208270	SPEED SENSOR	SEE SEPARATE MATL. PARTS LIST	
33		LOCKNUT	A286 OR 19-9	
32		FILL HD. SCREW	" "	
31		CAP SCREW	" "	
30		CAP SCREW	" "	
29		CAP SCREW	" "	
28	208266	WELL PLUG	316 S.S. SHEET	
27	208267	NUT-LOW CROWN	A286 OR 19-9	
26	208210	STATOR	SEE SEPARATE MATERIAL	
25	208207	ROTOR	PARTS LIST	
24	208266	BY-PASS BOLT	316 S.S.	
23	208265	SHIMS	301 OR 302	
22	208264	SHIMS	" "	
21	208261	FRONT BEARING	PURE CARBON	GRADE 4588RC
20	208262	THRUST BEARING	" "	" "
19	208263	REAR BEARING	" "	" "
18	208264	FRONT MTG BAND	316 S.S.	
17	208260	REAR MTG BAND	316 S.S.	
16	208259	CONNECTING	SEE SEPARATE MATL. PARTS LIST	

2538 1-9

15	208226	BY-PASS OR FILL	316 S.S. BAR	
14	208208	SPEED INDICATOR	416 S.S. BAR	ANNEALED
13	208225	SHIMS	301 OR 302	
12	208221	THRUST WASHER	410 S.S. BAR	CHROM PLATED
11	208209-2	SHAFT	410 S.S. BAR	CHROM PLATED
10	208220	DIAPHRAGM	316 S.S. SHEET	
9	208227	BEARING		
8	208223	SPEED INDICATOR		
7	208218	END COVER	316 S.S. CASTING	
6	208216	BEARING HOUSING	316 S.S. CASTING	
5	208224	FRONT MTG. BRKT.	"	
4	208222	REAR MTG BRKT.	"	
3	208212	IMPELLER	"	
2	208214	MOTOR HOUSING	"	
1	208219	OUTER HOUSING	316 S.S. CASTING	
NO	PART NO	NAME	MAT'L	FINISH

LIST OF PARTS

APPLICABLE SPECIFICATIONS UNLESS OTHERWISE SPECIFIED DIMENSIONS AND TOLERANCES IN ACCORDANCE WITH SPEC. MIL-STD-8	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES REMOVE ALL BURRS BREAK SHARP EDGES .005 DIA. MAX. CORNER RADII .005 FILLETS CART RADII	DFTM. CHKD. APPD.	F. W. 9-27-63 MATL'S SPEC. TREATMENT & FINISHES NEXT ASSY. OR REFERENCE NO. DWG. SIZE E
TOLERANCES ON: DECIMALS ± .X ± .01 .XX ± .005 .XXX ± .0005 FRACTIONS ± ANGLES ±			TITLE COOLANT AND FUEL PUMP ASSY. SCALE FULL SHEET 1 OF 1 MFR. CODE
			TAPCO GROUP THOMPSON RAMO WOOLDRIDGE INC. U.S.A. DRAWING NO. 253809-1

AEROJET-GENERAL CORPORATION

INTER-OFFICE MEMO
10-007-102

TO: Distribution

DATE: 21 April 1964
395/64-143:CPC:jg

FROM: C. P. Colker, Dept. 395

SUBJECT: Final Design Review Meeting - Lubricant/Coolant Pump-Motor Assembly

DISTRIBUTION: All Senior Dept. Heads, W. A. Andersen, C. G. Boone, E. Eber, A. L. Fangmeyer, C. A. Lang, P. H. Hudson, R. W. Powell, C. R. Withrow, G. G. Takach, M. A. Patterson, N. Van De Verg, 395 files

Reference: (a) L/C PMA Materials List, Memo

Enclosures:
(1) Agenda for L/C PMA Design Review Meeting
(2) L/C PMA Estimated Performance Curve No. 395/64-00031
(3) L/C PMA Pertinent Data and Performance
(4) L/C PMA Applicable Documentation
(5) L/C PMA Interface Control Drawing No. 094246 (AGC)
(6) L/C PMA Pump Coolant & Lube Pump Layout Drawing No. 253899 (TRW)*

(* To be distributed at Design Review Meeting)

The purpose of this memorandum is to announce the subject meeting to be held on Tuesday, 28 April 1964, at ~~1:30~~ 9:00 pm, in Conference Room ~~114-115~~, 15+E Building 160. It is requested that the addressees and/or additional interested members of their departments be present at the meeting.

The attached agenda covers the specific L/C PMA topics to be discussed. Also enclosed are the layout drawing, applicable documentation list, and estimated performance curve. Interested personnel may obtain copies of all listed TRW documentation from Mr. E. J. Vilter, Dept. 380.

The purpose of the meeting is to establish and insure proper and appropriate coordination, review and approval by all required cognizant personnel.

Eber for
C. P. Colker
Rotating Machinery Dept. 395

Approved:

Eber
E. Eber, Head
Rotating Machinery Dept.
SNAP-8 Division

Enclosure (1)

FINAL DESIGN REVIEW MEETING

LUBRICANT/COOLANT PUMP-MOTOR ASSEMBLY

28 APRIL 1964

AGENDA

I. INTRODUCTION

The purpose of this Final Design Review is to present the finalized L/C PMA design and information that is new or different from the preliminary design review held on 30 October 1963. The "ground rules" for the design will be discussed.

II. OVERALL PMA PERFORMANCE

The predicted performance for the L/C PMA is shown on Enclosure (2). Other pertinent steady state operating data is shown in Enclosure (3).

III. DESIGN PRESENTATION

The presentation will cover the following L/C PMA design areas. Design revisions since the Preliminary Design Review will be emphasized.

A. Motor Design

The motor design data, including computer calculations and in-air test results from the Westinghouse contract, will be discussed in conjunction with the following topics.

1. Materials
2. Terminals (Bendix Hermetic TRW 03-10137) (PMA R63-83)
3. Speed Sensor (PMA R63-20)
4. Motor Performance (PMA R63-8)

B. Mechanical Design

1. Self Contained Lubrication & Cooling System (PMA R63-80)
2. Bearing Requirements (PMA R63-19 & R63-24)
3. Materials (see attachment)
4. Thermal Analysis (PMA R63-34)
5. Critical Speed (PMA R63-4)
6. Pump Performance (PMA R63-56)
7. Hermetically Sealed
8. Assembly and Dissassembly Procedure, TRW 02-1099

C. System Requirements

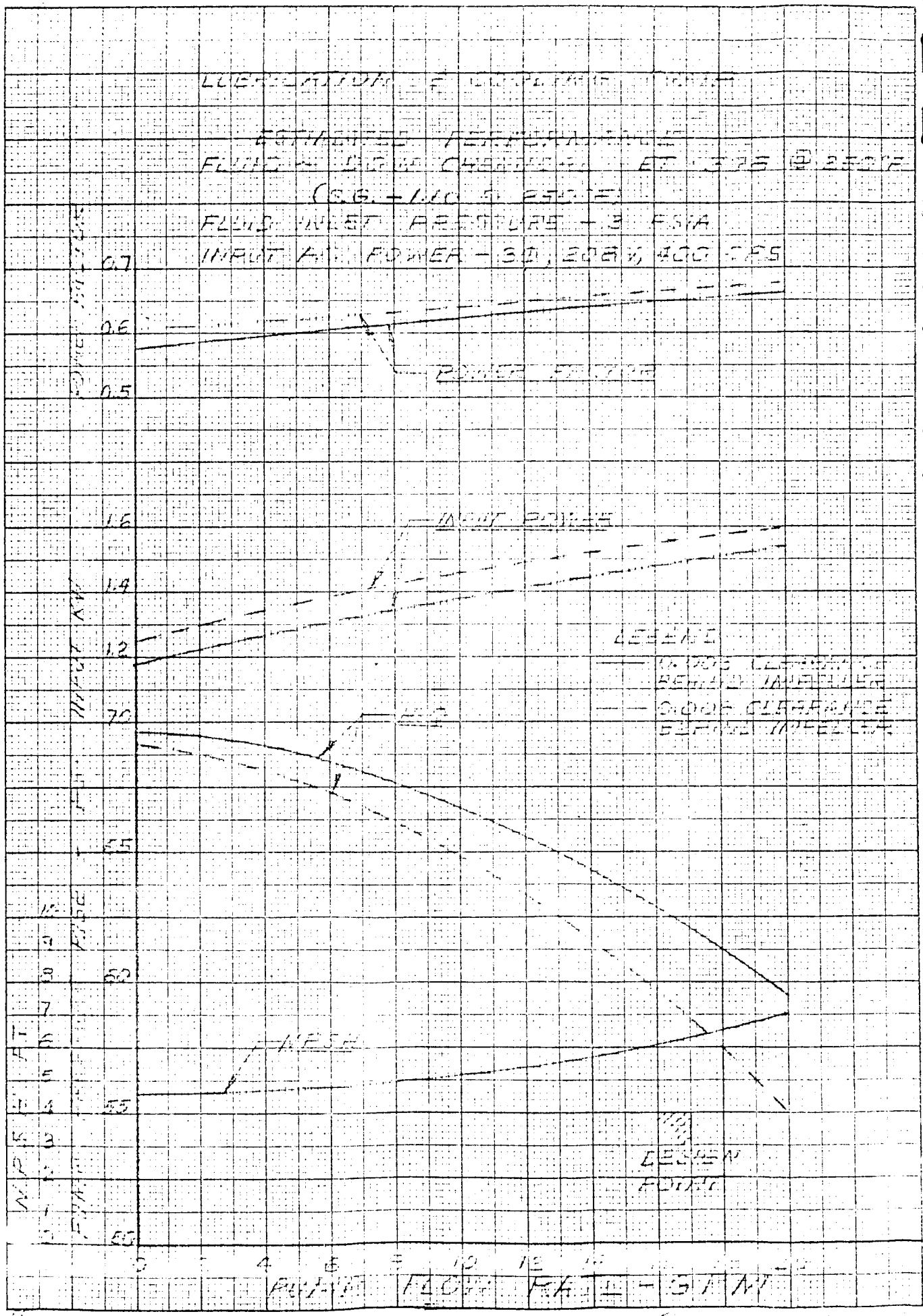
1. Start-up Operation
2. Steady-state Operation
3. Installation

IV. TEST PLAN

The Test Plans for the 1000 hour component development test and the PMA acceptance tests at TRW will be presented. The plan for operational testing the L/C PMA in conjunction with component testing in LML-3 and LML-3 will also be discussed.

V. SCHEDULE

The "L/C PMA - Unit Allocation and Test Schedule" (Reference 03P0-64-0040) will be discussed.



KEUFFEL & ESSER CO.
10 X 10 TO 1/2 INCH 46 1322
CORPORATION

L/C PUMP-MOTOR ASSEMBLY

PERTINENT DATA & PERFORMANCE

Number of Poles	6
Speed	7820 rpm
Rotor Size (d x l)	2.10 x 2.40 in.
Air Gap	.005/.015 in.
Flow	9400 lb/hr
	17 gpm
Inlet Pressure (min)	6.3 ft
	3 psia
Discharge Pressure	58 psia (min)
Delta H	115.5 ft (min)
Inlet Temperature	220-250°F
AVG Density	60.5 lb/ft³
	2.0 ft/psi
Output Hydraulic HP	.58 HP
Shaft HP	1.34 HP
Pump Efficiency	43.25%
Motor Input HP	2.127 HP
Motor Input KW	1.588 KW
Motor Efficiency	63%
Power Factor	.66
Overall Efficiency	27.2%

ENCLOSURE (4)

L/C PMA APPLICABLE DOCUMENTATION

	Report No. (TRW)
A. Design File	
1. Impeller Sizing Report - Justification of the impeller chosen for the L/C PMA	PMA-R63-2
2. Critical Speed - An analysis of the critical frequency determined with and without bearing stiffness	PMA-R63-4 PMA-R63-81
3. Design Detail Motor Calculation - Computer design calculation of motor performance at various loads	PMA-R63-8
4. Stress Analysis - Structural analysis of various PMA components	PMA-R63-18
5. Radial Bearing Analysis - Maximum operation radial bearing loads. Computer and hand calculations.	PMA-R63-19
6. Speed Sensor - Data and drawings which constitute design data information	PMA-R63-20
7. L/C PMA Internal Flow - Determination of pressure drops and internal flow	PMA-R63-21
8. Thrust Bearing Analysis - Determination of load carrying capacity of thrust bearing	PMA-R63-23
9. Thrust Analysis - Determination of hydraulic thrust	PMA-R63-24
10. Performance Analysis - Contains estimated H Q curves as a function of clearance, including bearing loads	PMA-R63-56
11. Volute NPSH Area Variation - Analysis of change in flow area as a function of pressure	PMA-R63-57
12. Power Balance - Tabulation of losses	PMA-R63-58
13. Electrical Connector Design - A description of design and construction of a Bendix connector	PMA-R63-63
14. Motor Hot Spot Temperature - Winding hot spot temperature calculation	PMA-R63-64

		Report No. (TRW)
15.	Comparison of Bearing Fits	
15.	Comparison of Bearing Fits - Tabulation Comparison of various TRW pumps	PMA-R63-67 PMA-R63-84
16.	Screw Pumps - Design justification	PMA-R63-80
17.	Estimated Suction Performance - Curve of NPSH	PMA-R63-83
18.	Failure Mode Analysis - Types of failures and required action	ER-5592
19.	TRW Connector, Electrical Hermetic Sealed - Specification for Connector	03-10137

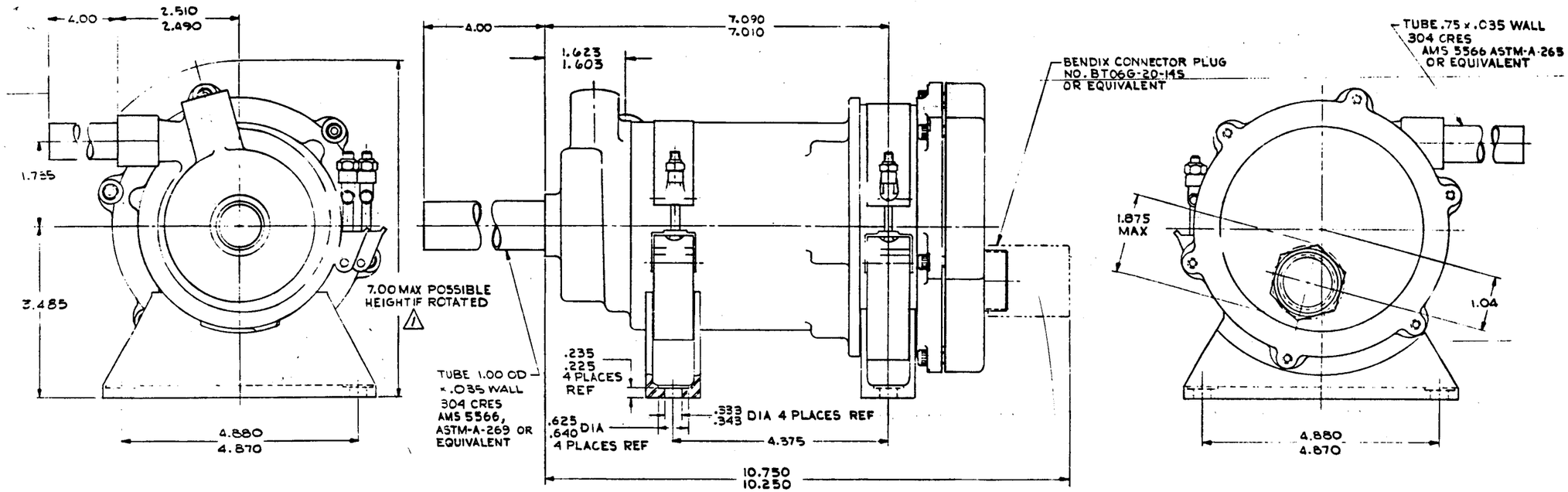
B. Reference Material

1.	TRW Motor, Electrical, Coolant & Lube Pump Specification	03-10129
2.	TRW Development Unit Assembly & Test Procedure	02-1099
3.	SNAP-8 Lubrication & Cooling PMA Specification	AGC-10191
4.	Work Statement, Revised 22 January 1964	
5.	Subcontract (NAS 5-417)	OP-359790
6.	Quality Engineering Instruction	851-321

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED
A		SEE "A" CHANGE DCN	[illegible]	[illegible]

NOTES: [redacted]

1. ANGULAR LOCATION OF PUMP DISCHARGE AND TERMINALS MAY BE SET TO ANY POSITION DESIRED.
2. THIS IS A GENERAL ARRANGEMENT DRAWING OF COML PROD NO. 253899-1 CODE IDENT NO. 59875 PER AGC SPEC 10191.



QTY REQD	SYM	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	UNIT WT.	ZONE	ITEM NO.

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ANGULAR
.XX ± .03 ± 1°
.XXX ± .010
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT WT | CALC WT 26#

DRAWN TOM SHARP 12-10-63
CHECK [illegible]
DESIGN [illegible] 1-2-64
STRUCTURE STRESS [illegible]
MATERIALS [illegible] 1-6-64
[illegible] 1-10-64
[illegible] 1-15-64
DESIGN ACTIVITY APPD [illegible] 1/16/64
[illegible]

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

TITLE
L/C PMA INTERFACE CONTROL

CODE IDENT NO. 70143 | SIZE D | DWG NO. 094246

SCALE | RELEASE DATE | SHEET

ON	THRU	PART DASH NO	NEXT	FINAL	NEXT ASSY	USED ON
EFFECTIVE SERIAL NO. USAGE DATA			QTY REQD PER ASSY		APPLICATION	

DRAWING LEVEL 1

M. Brandner 2/1/61	Thompson Ramo Wooldridge Inc. CLEVELAND 17, OHIO	SPECIFICATION NO. AEPS-5050
R. W. Quirk 2/2/61		PAGE NO. 1 OF 4
G. T. Fornadley 2/3/61	ENGINEERING SPECIFICATION	ISSUED February 13, 1961
		REVISED Rev. "A" JAB 6/13/62

Process Specification - Soldering Electrical Connection for Models 212600 and 217700

1.0 Purpose: The purpose of this specification is to provide a procedure for producing a satisfactory solder connection for Models 212600 and 217700 lead wires.

2.0 Scope: The specification applies only to the soldering of Models 212600 and 217700 lead wires.

3.0 Applicable Specification: The following specification form part of this specification. In case of conflicting statements this process specification takes precedence.

3.1 MIL-S-6872 - Soldering Process, General Specification For

3.2 QQ-S-571 - Solder: Lead Alloy, Tin Lead Alloy, and Tin Alloy: Flux Cored Ribbon and Wire, and Solid Form

4.0 Material and Equipment Required

4.1 Solder, Composition Ag 2.5 per QQ-S-571 (TX-94244-15)

4.2 Flux

4.2.1 Flux, T.S.C. Flux manufactured by Handy and Harman, 82 Fulton, New York, N. Y.

4.2.2 Flux, Kester 1544, manufactured by Kester Solder Company, Chicago, Illinois

4.3 Flux Remover, Printed Circuit Cleaner, manufactured by John B. Moore, 316 Marion Building, Cleveland 13, Ohio

4.4 Resistant Soldering Unit, Manufactured by Ideal Industires, Inc., Sycamore, Illinois, No. 12-124 or similar.

4.5 Bicarbonate of Soda

4.6 Brush, stiff bristled

4.7 Trichloroethylene or general solvent

4.8 Solder Pot, Capable of maintaining a temperature range of 680 - 750°F.

4.9 Rotary soft wire brush - Brush Rotary Steel Wire Type - 1 1/2 X .0025" X 3/16 X 3/8 or equivalent.

Process Specification - Soldering Electrical Connection for Models 212600 and 217700

5.0 Preliminary Procedure

5.1 Stripping of Wire Insulation: The conductors should be exposed by stripping the insulation from the lead wires to a length of 5/16 ± 1/32 inches. Care should be taken not to nick or scratch the conductors.

5.2 Cleaning of Parts: All foreign material shall be removed from the surfaces which are to be soldered by using solvent.

5.2.1 Contaminants on Conductors which are residuals from manufacturing of the wire can be removed most effectly by mechanical methods such as an abrasive eraser - then cleansed in solvent. Note: This applies only when solder does not wet the conductors during pretinning operation.

5.3 The solder pot containing 2.5 Ag solder shall be heated to the operating temperature of 680 - 750°F.

6.0 Soldering Procedure:

6.1 Pretinning of Lead Wires: The stripped ends of the lead wire shall be dipped in Kester flux 1544 and excess shaken off.

6.1.1 Skim off oxides on surface solder with wiper (Note: Wiper to be thin laminated glass fiber) then slowly immerse the fluxed lead wire into the solder until the flux breaks away from the immersed conductor. Slowly remove from solder and shake off excess.

6.1.2 The tinned conductor shall be thoroughly wetted with solder and shiny in appearance.

6.1.3 Clean flux residues with Printed Circuit Flux Remover.

6.2 Pretinning of connector solder cups.

6.2.1 Place connector on holding fixture and set resistant soldering unit on low range. (Note: Keep contacts of unit free of oxides.)

6.2.2 Dip the 2.5 Ag solder in T.E.C. Flux and shake off excess. Place fluxed solder wire into solder cup. Make electrical contact with tips of soldering unit. As soon as solder starts to melt, remove solder wire at a rate which will deposit a minimum amount of solder on surfaces of cups. (Continued)

6.0 Soldering Procedure (Continued)

6.2.2 (Continued)
Continue to apply heat for a few seconds. (Caution: Fumes of flux should not be inhaled - use good ventalation.) Repeat this procedure for all soldering cups.

6.2,3 Clean off oxides that were formed by soldering with a rotary wire brush. Also, remove all soldering beads, balls, and etc. that have formed on the outside of the barrel and on the insert.

6.2.4 Neutralizing Flux: Prepare a 10 per cent solution of Bicarbonate of Soda (i.e. one (1) part by weight of soda to nine (9) parts by weight of water) in a glass container. Dip pretinned connector into neutralizing solution for 5 - 10 seconds. Then rinse connectors in hot running water for five (5) minutes. Remove connector from hot water, and bake in oven at 220 - 300°F. for 30 - 60 minutes.

6.3 Soldering of Lead Wires onto Connector:

6.3.1 Place pretinned connector on holding fixture and set resistance soldering unit on low range. (Note: Keep contacts of unit free of oxides.)

6.3.2 Dip pretinned lead wire into Kester 1544 Flux and shake off excess. Make electrical contact with tips of soldering unit. As soon as solder starts to melt in soldering cup, insert lead wire and bottom in soldering cup. While holding lead wire firmly in bottom of cup, remove resistance heating tips and wipe excess solder from joint with Kimwipe using a downward motion. Do not disturb wire until solder solidifies. Repeat this procedure for all connections.

6.3.3 Clean solder joints of residue with a stiff bristled brush saturated with Printed Circuit Flux Remover.

7.0 Inspection of Solder Joint:

7.1 The solder joint shall have dull gray to a shiny appearance.

7.2 Solder joints shall be well wetted and still not have an excessive amount of solder.

WRITTEN BY: M. Brandner 2/1/61	Thompson Ramo Wooldridge Inc. CLEVELAND 17, OHIO	SPECIFICATION NO. AEPS-5050
APPROVED - PROJECT ENGR R. W. Quirk 2/2/61		PAGE NO. 4 OF 4
APPROVED - PRODUCT ENGR G. T. Fornadley 2/3/61	ENGINEERING SPECIFICATION Z-683 PRINTED IN U.S.A.	ISSUED February 13, 1961
		REVISED Rev. "A" JAB 6/13/62

SUBJECT

Process Specification - Soldering Electrical Connection for Models 212600 and 217700

7.0 Inspection of Solder Joint: (Continued)

7.3 There shall be no evidence of solder balls, beads, etc. on barrel and insert of connector.

7.4 All strands of the conductor shall be within the O.D. of the barrel. If any strands are frayed, they may be cut-off. (Note: Not more than two strands per conductor shall be removed.)

7.5 A dot of paint shall be placed on each solder joint showing evidence of inspection for the above requirements.

7.5.1 The color of this dot shall identify the Inspector performing the operation.

ljk

TAPCO A DIVISION OF
Thompson Ramo Wooldridge Inc.
23555 EUCLID AVENUE • CLEVELAND 17, OHIO

SPEC NO. 02-1099
Date 3/20/64
Contract No. _____
Customer No. _____
Copy No. _____
No. of Pages _____
STATUS _____
COMM. NO. _____
REL. DATE _____

TITLE: Development Unit Assembly & Test Procedure, Model 253800-1 Lubrication & Coolant Pump.

PREPARED BY:

E. P. Jira,
Development Engineer
Title

APPROVED BY:

L. C. Hays, Reliability Office
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Title

L. J. Weiss,
Senior Project Engineer
Title

REVISIONS

Date	Rev.	Paragraph	Remarks and E.O.	Authorization

REFERENCES

1. AGC-10191, Aerojet-General Corporation, "SNAP-8 Lubrication & Cooling Pump - Motor Assembly Specification for".

2. AGC Exhibit A of Purchase Order, Work Statement L/C PMA for TRW Electromechanical Division of Thompson Ramo Wooldridge Inc.

3. ER-5471, Thompson Ramo Wooldridge Inc., "Work Statement, SNAP-8 Lubrication & Cooling Centrifugal Pump Model 253800-1, Aerojet General Corporation".

I. FOREWORD

Model 253800-1 Lubrication & Coolant Pump has been designed to meet the requirements of Aerojet-General Specification AGC-10191 and Work Statement, Reference 1 and 2, and is to be used to furnish the lubrication and cooling fluid to various components of the SNAP-8 orbital power system. Development testing of this unit is intended to verify the analytical studies and demonstrate the capability of the pump motor assembly to meet the basic requirements of the Reference 1 document.

This document is intended to serve as the development unit assembly and test procedure for Model 253800-1 Lubrication & Coolant Pump.

The development testing of this unit is authorized by Aerojet-General Corporation, Purchase Order OP-359790, Prime Contract No. NAS 5-417.

II. OBJECT

The object of this document is to formally present the development unit assembly and test procedure to which the 253800-1 Lubrication & Coolant Pump will be subjected and has been prepared to fulfill the requirements of Aerojet General Corporation Specification AGC-10191, Reference 1, paragraph 4.6, and AGC Work Statement, Reference 2.

III. TEST SPECIMEN

The development tests shall be performed on one Model 253800-1 Lubrication & Coolant Pump. The parts for the test specimen shall be manufactured by Model Shop techniques to production drawings and will be inspected to assure compliance with the program Quality Assurance requirements. During assembly of the test specimen, the part, serial, and inspection report numbers of each component will be recorded on the Build Sheet (see Figure 1) to provide a complete history of parts that comprise the test specimen. All significant observations during assembly will be noted on appropriate log pages. Critical fits, clearances, dimensions, etc., shall be entered in the appropriate areas provided (see Figures 1 and 2). All information required on the build sheets must be completed prior to release of the pump assembly. The unit shall be assembled as shown on Assembly Drawing 253801 and in accordance with the following instructions:

After subassembly of bearing housing and motor housing with rotating group in place, place housing on V blocks. Measure radial movement of shaft by indicator by lifting shaft assembly from rest until clearance taken up within bearings. Repeat in different positions (90° apart) on each end of shaft.

Impeller End_____; _____. Speed Sensor End_____; _____.

Determine on go-no-go basis minimum air gap of .005, using .005 pin from bearing housing end. Check twice: _____; _____.

The above subassembly and shaft/bearing clearance, and Item 3 end play measurement shall be performed with all parts wiped dry.

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Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

Refer to Figure 2 for location of the following dimensions:

1. Dimension A - Obtain at a total of eight points in the following manner:

   A) Mark impeller near O.D. at two points 180° apart with corresponding marks on housing.

   B) Measure and record four times, impeller to housing clearances at impeller, without rotating impeller, at 90° increments:
   1)_____, 2)_____, 3)_____, 4)_____.

   C) Measure and record four times, impeller to housing clearances at one point of housing and rotate impeller in 90° increments:
   1)_____, 2)_____, 3)_____, 4)_____.

   D) A variation in excess of .0025 between any of the readings obtained in B and C above shall be cause for rejection.

2. Dimension B - Obtain at a total of four points in the following manner:

   A) Repeat Item 1.B above(with the end play taken up toward the pump inlet):
   1)_____, 2)_____, 3)_____, 4)_____.

3. End Play - Determine end play by indicator method with axial load applied to shaft:
   1)_____, 2)_____, 3)_____, 4)_____.

   A) End play less than .001 or greater than .003 shall be cause for rejection.

4. Dimension C - This dimension shall be taken at four points equally spaced:
   1)_____, 2)_____, 3)_____, 4)_____.

5. Dimension D - This dimension shall be taken at each impeller blade at a distance of approximately 1/32 inside impeller O.D. by rotating impeller:
   1)_____, 2)_____, 3)_____, 4)_____, 5)_____,
   6)_____, 7)_____.

6. Dimension G -

   A) For max. G, subtract minimum D from maximum C:

   Max. G = _____ - _____ = _____

   B) For min. G, subtract maximum D from minimum C:

   Min. G = _____ - _____ = _____

7. Dimension E - Measure and record E four places 90° apart:
   1)_____, 2)_____, 3)_____, 4)_____.

8. Dimension F - Measure F four places 90° apart:
   1)_____, 2)_____, 3)_____, 4)_____. (Depth micrometer bar to ride against motor assembly pilot bore during measurement.)

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CLEVELAND, OHIO, U. S. A.

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9. Dimension H -

A) For Max H, subtract min E from max F:

Max H = _____ - _____ = _____

B) For Min H, subtract max E from min F:

Min H = _____ - _____ = _____

10. Dimension J - (For Reference Only)

A) Optimum J = Max G + End Play + .005 - Min. H:

= _____ + _____ + _____ - _____ = _____

B) Actual J = Measured total shim thickness = _____
(After completion of Item 14)

11. Dimension I - (For Reference Only)

A) Minimum I = Min. H + J - Max. G - End Play:

= _____ + _____ - _____ - _____ = _____

B) Maximum I = Max. H + J - Min. G + End Play:

= _____ + _____ - _____ + _____ = _____

12. Dimension L - Identify four bearing housing connector stop posts. Install rotating assembly prior to addition of 208265 shims and measure L. Rotation of shaft should not be possible at this time due to impeller seating on housing throat:

1)_____, 2)_____, 3)_____, 4)_____.

Determine if end play has been taken up entirely. If not, contact Engineering for further instructions.

13. Dimension M - Install 208265 shims, rotating assembly, and install and torque 93007-10 bolts. Measure and record M (taken at same points as L):

1)_____, 2)_____, 3)_____, 4)_____.

14. Impeller/Throat Clearance Check:

Min. Imp/Throat Clearance = L - M - End Play

Min. Imp/Throat Clear = _____ - _____ - _____ = _____

Min. Imp/Throat clearance less than .004 or greater than .006 shall be cause for rejection. Add or remove shims as necessary to obtain .004/.006

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impeller/throat clearance. Record final shim thickness as Item 10.B.

Assembly of the test specimen will be performed by Development Engineering Test personnel. Any subsequent teardown or overhaul will be documented on the Overhaul Sheet (see Figure 3).

IV. TEST PROCEDURE

A. Installation

During all operational tests, the pump shall be mounted in the test stand provided for this application. The unit shall be mounted in a vertical position with the inlet tube down and the electrical connector up. All operational tests shall be performed with the neutral motor lead floating (not connected).

B. Test Fluid

The test fluid for all testing shall be Dow Chemical Company Bis (Polyphenyl) Ether ET-378. Said fluid to be 'degassed' prior start of tests.

Test fluid samples shall be taken for submittal to Aerojet General for information purposes. As a minimum, a sample shall be taken at completion of 500 hours and 1000 hours of the Abbreviated Life Test. Also, a sample shall be taken prior to the addition of any fluid to the system and a record kept as to quantity and frequency of refills.

C. Instrumentation

All instrumentation shall be calibrated against standards or masters prior to commencement of development testing and thereafter at intervals in keeping with Quality Assurance requirements.

Instrumentation employed during development testing shall consist of two categories; 1) test stand ("permanent" instrumentation used for development and acceptance testing) and, 2) prototype instrumentation (to assist in pump operation analysis). Instrumentation and accuracy for each of the classifications is as follows:

1. Test Stand

Fluid Flow - Gal/Min - ± 0.5%
Inlet Pressure - PSIA - ± 0.5%
Discharge Pressure - PSI - ± 0.5%
Inlet Fluid Temperature - °F - ± 3°F
Outlet Fluid Temperature - °F - ± 3°F
Motor Phase 1 Temperature - °F - ± 3°F (connector pins N&P)
Motor Phase 2 Temperature - °F - ± 3°F (connector pins T&U)
Motor Phase 3 Temperature - °F - ± 3°F (connector pins H&J)
Motor Lead End Extension Temperature - °F - ± 3°F (connector pins R&S)
Motor Anti Lead End Extension Temperature - °F - ± 3°F (connector pins B&C)

Speed - RPM - $\pm$ 10 RPM (connector pins F&M)
Phase Input Current - Amps - $\pm$ 0.75%
Phase Input Power - Watts - $\pm$ 0.75%
Input Voltage - Volts - $\pm$ 0.75%
Input Frequency - Cycles/Sec - $\pm$ 0.75%

2. Prototype

Pressure and temperature data shall be recorded for these additional locations shown in Figure 5.

Impeller Suction Side Pressure - PSI - $\pm$ 0.5%
Lower Motor Cavity Pressure - PSI - $\pm$ 0.5%
Upper Motor Cavity Pressure - PSI - $\pm$ 0.5%
Upper Brg. Hsg. Temp. - °F - $\pm$ 3°F (connector pins R&S - in lieu of Lead End Extension Temperature)
Return Flow Fluid Temp. - °F - $\pm$ 3°F (connector pins K&V)

D. Individual Tests

All significant observations during tests shall be entered as comments on the appropriate pages of the test sheet or log, as applicable.

Individual tests shall be performed in accordance with the procedures listed below. During all operational tests, sufficient time shall be allowed for stabilization prior to taking of any data.

1. Examination of Product - All component parts shall be examined visually at assembly to check for visual defects, deterioration, or any other imperfection that would result in rejection of the pump assembly or any component part. In addition, all moving parts shall be visually examined to assure that they operate freely without sticking or binding.

   During initial or subsequent assembly or disassembly, a complete build sheet shall be maintained utilizing forms shown as Figures 1, 2, and 3.

2. Dielectric Strength - A room temperature, sea level dielectric strength test (megger) shall be performed on the motor housing assembly per MIL-STD-202A, Method 301. Test voltage shall be 1416 Volts A.C. applied for one minute and the voltage shall be applied between the motor power leads joined together and the motor housing. Data taken shall include test voltage, time, current leakage, and test equipment identification.

3. Helium Leak Test - The pump shall be subjected to a helium leak test per MIL-STD-771B. Leakage shall not exceed 10^{-7} cc/sec. Test results shall be entered on the build sheet.

4. Calibration - The pump shall be calibrated from 0 to maximum obtainable flow in 3 GPM increments (data shall also be taken at a flow setting of 17 GPM). Data taken for each flow setting shall be in accordance with Figure 4. Test conditions shall be as follows:

   Suction Inlet Pressure - 5.0 and 3.0 PSIA $\pm$ 0.1 PSIA
   Inlet Fluid Temperature - 250°F $\pm$ 4°F
   Input Voltage - 208 Volts $\pm$ 2 Volts
   Input Frequency - 400 CPS $\pm$ 4 CPS

5. 1000 Hour Abbreviated Life Test - The pump shall be subjected to a 1000 hour abbreviated life test. Input power to the pump shall be 208 Volts $\pm$ 2 Volts, 400 CPS $\pm$ 4 CPS and fluid inlet temperature shall be 250°F $\pm$ 4°F for the life test. Procedures and sequence of the test shall be as follows:

   a) 0 to 2 Hours - With 5.0 PSIA $\pm$ 0.1 PSIA suction inlet pressure, operate pump at 17 GPM flow and record data every 5 minutes.

   b) With conditions given in (a) above, reduce suction inlet pressure to 4.0, 3.0 then in 0.2 PSIA increments, while maintaining 17 GPM flow. Record all data at each inlet pressure level until 20% drop in head (discharge) is reached.

   c) With 5.0 PSIA $\pm$ 0.1 PSIA suction inlet pressure, set flow at 12 GPM and perform "steady state" run, recording data every two minutes until internal temperatures and pressures have stabilized.

   d) Repeat Item (b) except that flow shall be 12 GPM.

   e) Repeat Item (a) except that flow shall be 22 GPM.

   f) Repeat Item (b) except that flow shall be 22 GPM.

   g) Repeat Item (a) with 17 GPM flow with inlet to be at 3.0 PSIA.

   h) Allow unit to run at condition (g), recording all data a minimum of 2 times each day. The pump shall be subjected only once to test conditions described by items (a) through (g) prior to a total accumulated time of 500 hours.

   i) Perform calibration per paragraph IV.F.4 (only 3.0 PSIA inlet).

   j) Disassemble, inspect and rebuild pump. Inspection to include visual inspection for wear or deterioration, physical measurement of bearing bores and journals, and photographs.

k) Perform calibration per paragraph IV.D.4 (only at 3.0 PSI inlet).

l) Repeat Items (a) through (j) for a total accumulated running time of 1000 hours.

NOTE: The abbreviated life test is to be run continuously, however the various sequences are to be performed on a normal 8 hour shift, 5 day week basis. During "non coverage" hours (nights or weekends), the unit shall be operated at 3.0 PSIA suction inlet, 17 GPM flow, and 250°F inlet temperatures.

5. Dielectric Strength - At the completion of the 1000 hour abbreviated life test, a Dielectric Strength test shall be performed per paragraph D.3.

E. Data

Data taken shall consist of assembly or disassembly information or actual operational data as applicable, and shall be entered on the appropriate data sheet. Total operational accumulated running time shall also be kept on the operation data sheet (Figure 4).

All data, including build sheets, overhaul sheets, and operational data, shall be kept in a unit log book.

FIGURE 1

253500-1 LUBE & COOLANT PUMP

Part No.	Chg. Ltr.	Qty.	I.R. No.	Name	S/N	Comments
208208		1		Indicator, Rotation Pickup		
208209-1		1		Rotor & Shaft Assy.		
208209-2		1		Shaft		
208209-3		1		Thrust Washer		
208207		1		Rotor		
208212		1		Impeller		
208214-1		1		Motor Housing Assy.		
208210		1		Stator		
208214-2		1		Motor Hsg.		
208261		1		Front Bearing		
208262		1		Thrust Bearing		
208216-1		1		Bearing Hsg. Assy.		
208216-2		1		Bearing Hsg.		
208263		1		Rear Bearing		
208218		1		End Cover		
208220		1		Electrical Connector		
208223		1		Speed Indicator Guard		
208224		1		Front Mtg. Bracket		
208225		1		Rear Mtg. Bracket		
208226		1		By Pass Orifice Plate		
208257		1		Bearing Retainer		
208258		1		Volute Hsg.		
208259		1		Front Mtg. Band Clamp		
208260		1		Rear Mtg. Band Clamp		
208264-1				Shim		
208264-2				Shim		
208264-3				Shim		
208264-4				Shim		
208264-5				Shim		
208264-6				Shim		
208264-7				Shim		
208265-1				Shim		
208265-2				Shim		
208265-3				Shim		
208288				Varnish		

Part No.	Chg. Ltr.	Qty.	I.R. No.	Name	S/N	Comments
208265-4				Shim		
208265-5				Shim		
208265-6				Shim		
208265-7				Shim		
208266		1		By Pass Bolt		
208267		1		Cap Nut		
208270		1		Speed Sensor		
208595		1		Tube, Inlet		
208596		1		Tube, Outlet		
208615		1		Washer, Elect. Conn.		
208765		1		Bolt, Bypass		
MS19070-003		1		Lockwasher		91976-1
MS20500-524		1		Nut, Self Locking		91110-2
MS20995C20		AR		Lockwire		90956
MS20995C32		AR		Lockwire		90956-1
MS35275-12		4		Screw, Fil. Hd.		90866-13
MS35275-14		2		Screw, Fil. Hd.		90866-24
MS35275-35		1		Screw, Fil. Hd.		90866-26
MS35275-60		4		Screw, Fil. Hd.		90866-25
MS35276-1		1		Key		90323
NAS1021C06		1		Nut, Self Locking		91982-1
QQS571		AR		Solder		94244-26
93007-10		12		Bolt, 12 Point		
94100-86		1		Nameplate		
94095-14		1		Electrical Conn. Dust Cap		
94502-3		1		Packing "O" Ring		
94255-4		AR		Fiber Glass Tape		
94255-5		AR		Fiber Glass Sleeve		
208771-1		2		Adapter		
208771-2		10		Adapter		
208771-3		4		Adapter		

Lower Bearing I.D.:
Upper Bearing I.D.:
Impeller/Throat Clear (W/End Play Toward Inlet):
End Play:

Lower Journal O.D.:
Upper Journal O.D.:
Impeller/Hsg. Clear (W/End Play Away From Inlet):

Proof Pressure Test: Test Date , Pressure , Time , Results

Helium Leakage Test: Test Date , Leakage

GOV'T. INSPECTOR | TRW QUAL. ASSURANCE | DATA PAGE NO. | ASSEMBLED BY: | DATE:

FIGURE 2

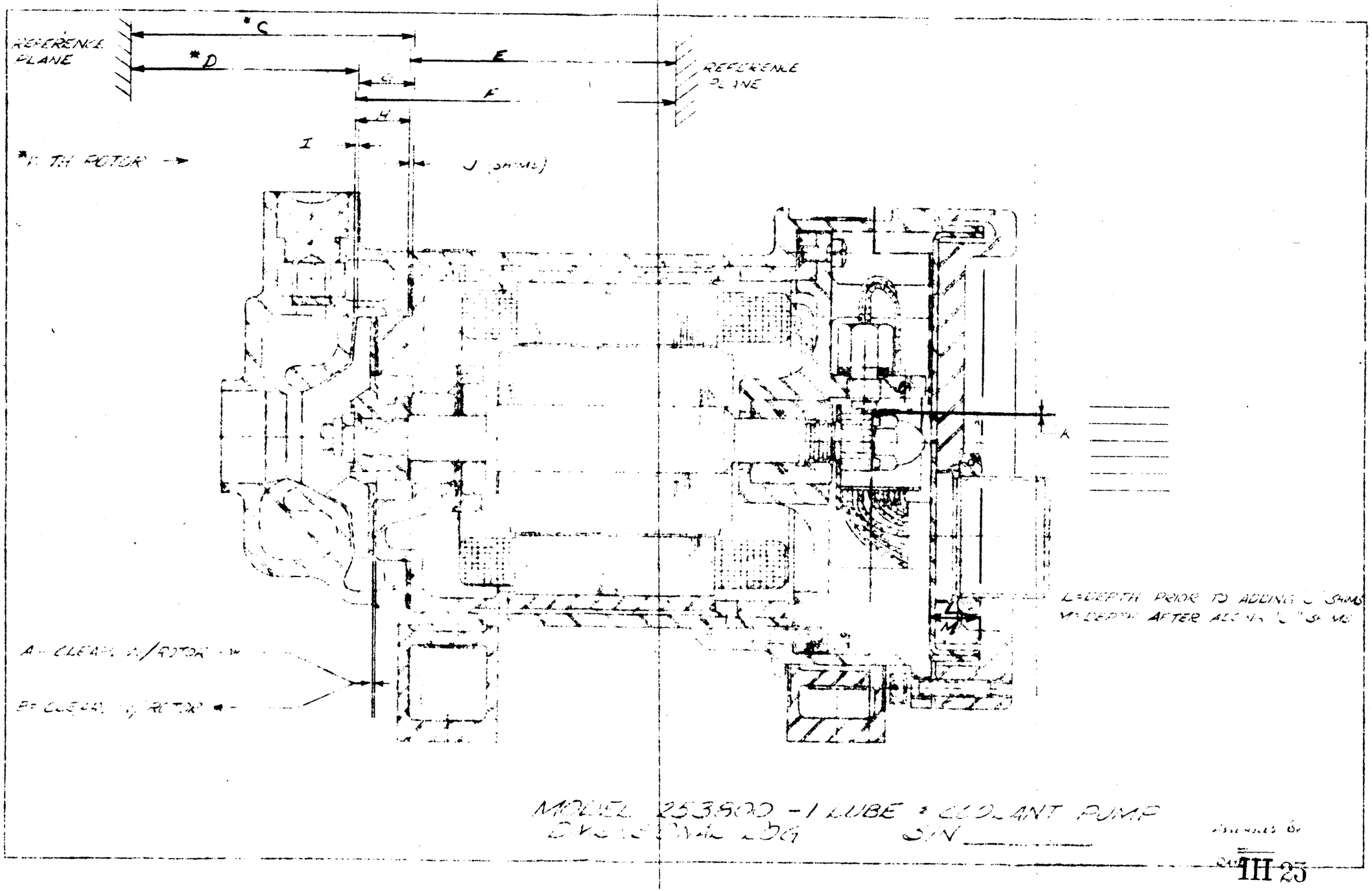

REFERENCE PLANE
*C
*D
E
F
G
H
I
J (SHIMS)
REFERENCE PLANE
*V. TH ROTOR →
A - CLEAR W/ROTOR
B = CLEAR W/ROTOR
K
L=DEPTH PRIOR TO ADDING "J" SHIMS
M=DEPTH AFTER ADDING "J" SHIMS
MODEL 253800 -1 LUBE & COOLANT PUMP
DIMENSIONAL LOG
S/N

FIGURE 3

Thompson Ramo Wooldridge Inc.
CLEVELAND, OHIO U.S.A.

OVERHAUL SHEET MODEL 253800-1 LUBE & COOLANT PUMP

SER. NO.

PARTS REMOVED						
Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments

REPLACEMENT						
Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments

Proof Pressure Test: Test Date _____, Pressure _____, Time _____, Results _____

Helium Leakage Test: Test Date _____, Results _____

LOWER BEARING I.D.: LOWER JOURNAL O.D.:
UPPER BEARING I.D.: UPPER JOURNAL O.D.:
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

REASON FOR OVERHAUL:

LOWER BEARING I.D.: LOWER JOURNAL O.D.:
UPPER BEARING I.D.: UPPER JOURNAL O.D.:
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

DATA PG. NO.

GOV'T. INSPECTOR	TRW QUAL. ASSURANCE	OVERHAULED BY:
		DATE:

FIGURE 4

Thompson Ramo Wooldridge Inc.

FLOW GPM	INLET PRESSURE / DISCH PRESS	PUMP PRESSURE	INLET	OUTLET TEMP °F	MTR. PHASE 1 TEMP °F / MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F / UPPER BRG. HSG. TEMP. °F	RETURN FLOW TEMP. °F / LOWER HSG. TEMP °F	UPPER HSG. TEMP. °F / ANTI LEAD END EXT TEMP. °F	IMP SUCTION PRESS. 1 PSIA	UPPER MTR. CAVITY PR. PSIA / LOWER MTR CAV PR. PSIA	CLOCK TIME	INDIVIDUAL TEST TIME HRS. MIN.	PUMP TOTAL ACCUM. RUN TIME HRS. MIN.

TRW QUALITY ASSURANCE

CONSULTANT INSPECTOR

MODEL 253800-1 LUBE & COOLANT PUMP

ENGR

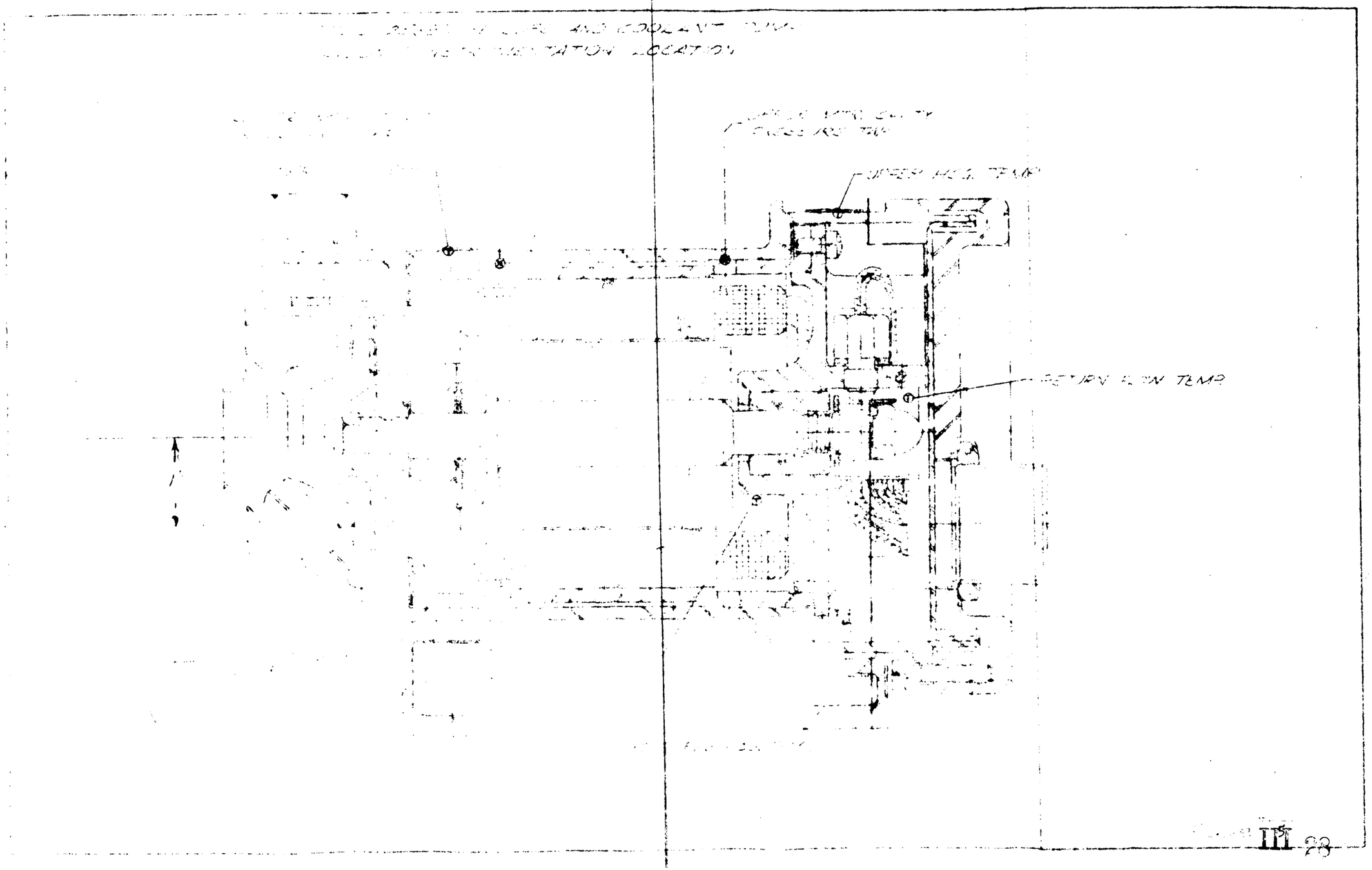
DATE

SER. NO.

DATA PG. NO

PROJ.

FIGURE 5

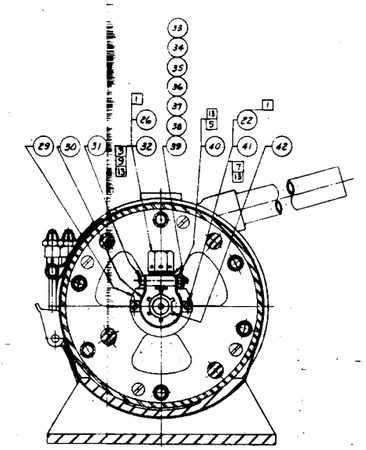


NOTES: UNLESS OTHERWISE SPECIFIED

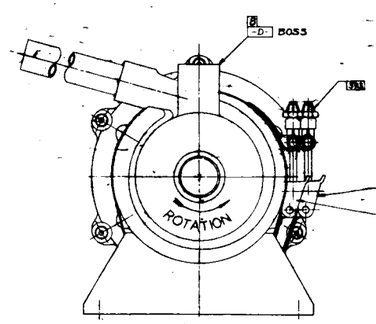
1. LOCKWIRE PER SPEC. MS35540 USING ITEM 22
2. VENDOR ITEM - SEE SPECIFICATION CONTROL OR SOURCE CONTROL DRAWING.
3. TORQUE TO 30 - 35 IN. LBS.
4. TORQUE TO 15 - 20 IN. LBS.
5. TORQUE TO 4 - 7 IN. LBS.
6. TORQUE TO 10 - 15 IN. LBS.
7. TORQUE TO 3 - 5 IN. LBS.
8. DATUM -A- IS DEFINED AS A LINE PASSING THRU THE CENTERS OF DATUM HOLES -B- & -C- IN ITEM #1. DATUM HOLE -B- IS DEFINED AS THE HOLE IN LINE WITH BOSS -D-.
9. ITEM 32 & MOTOR LEADS ARE TO BE POSITIONED IN LINE WITH EACH OTHER AND BOSS -D- AS SHOWN.
10. WELD PER MIL-W-6611 USING ASTM-A371 CLASS ER316L FILLER MATERIAL AS REQUIRED
11. PENETRANT INSPECT PER MIL-I-6866 TYPE II (A)
12. HELIUM LEAK TEST PER MIL-STD-271. MAX. ALLOWANCE HELIUM LEAKAGE 10^{-7} CC/SEC.
13. THE TORQUE VALUE GIVEN IS THE TORQUE REQ'D. IN ADDITION TO NORMAL RUN ON TORQUE.
14. ATTACH WIRES TO CONNECTOR BY SOLDERING PER SPEC MIL-S-6872, USING ITEM 43.
15. PRIOR TO REMOVAL OF ELECTRICAL CONNECTOR, TAG WIRES FOR IDENTIFICATION.
16. CLEANING OR DEGREASING OF COMPONENT PARTS AT ASSEMBLY SHALL BE ACCOMPLISHED BY FLUSHING WITH DOWTHERM 'A'. NO OTHER CLEANING AGENT OR METHOD SHALL BE USED.
17. AFTER ASSEMBLY, FILL UNIT WITH FRESH DOW ET378 AND ALLOW UNIT TO DRIP DRAIN.
18. ANGULAR LOCATION OF PUMP DISCHARGE AND TERMINALS MAY BE ROTATED BY PURCHASER TO TO POSITION DESIRED.

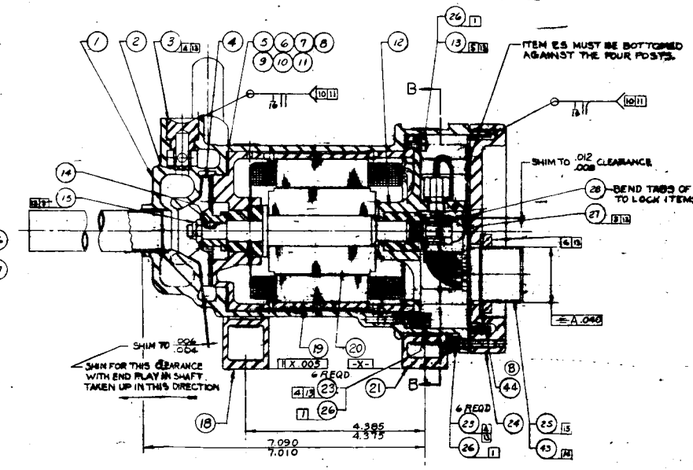
LEADS	CONNECTOR PIN MARKINGS	WIRE MATL	IDENTIFICATION
T_1	E		PHASE I
	B	CHROMEL	PHASE I THERMOCOUPLE
	H	ALUMEL	
	C	CHROMEL	LEAD END EXTENSION THERMOCOUPLE
	J	ALUMEL	
T_2	G		PHASE II
T_0	A		'Y' NEUTRAL
	D	CHROMEL	PHASE II THERMOCOUPLE
	K	ALUMEL	
	N	CHROMEL	END EXTENSION THERMOCOUPLE
	S	ALUMEL	
T_3	L		PHASE III
	P	CHROMEL	PHASE III THERMOCOUPLE
	T	ALUMEL	
	R		OPEN
	U		OPEN
	V		OPEN
	F		SPEED SENSOR
	M		

WIRE CONNECTION DIAGRAM

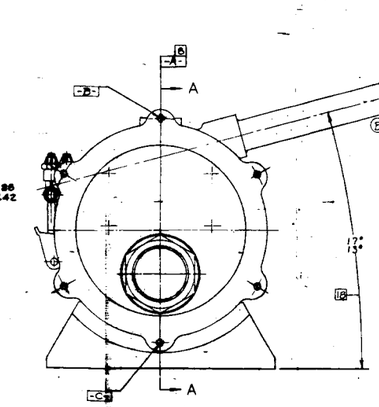


REVISIONS					
SYM.	DESCRIPTION	DRAWN	CHECK	APPR.
A	(IN NOTE #11) WAS "TYPE I"	[illegible]	MDM	2-6-68
B	ADDED ITEM #44	[illegible]	J.J.T.	2-27-68





SECTION A-A
(NOT A TRUE SECTION)



1	44	208615	WASHER, ELECT. CONN.	
AR	43	002-871	WIR-E-42-7S SOLDER	MIL-S-6872
1	42	208208	INDICATOR, ROT. PUMP	
6	41	MS-35270-[illegible]	SCREW, M.HCH, FIL. HD	[illegible]
1	40	[illegible]-1001-C06	NUT, SELF LOCK, HIGH	[illegible]
AR	39	208264-7	SHIM	
AR	38	208264-6	SHIM	
AR	37	208264-5	SHIM	
AR	36	208264-4	SHIM	
AR	35	208264-3	SHIM	
AR	34	208264-2	SHIM	
AR	33	208264-1	SHIM	
1	32	208270	SPEED SENSOR	
1	31	MS-35270-[illegible]	SCREW, M.HCH, FIL. HD	[illegible]
1	30	208263	SUPPORT, SPEED INDICATOR	
1	29	208257	RETAINER, BEARING	
1	28	[illegible]-[illegible]-[illegible]	LOCKWASHER	[illegible]
1	27	208267	NUT	
AR	26	[illegible]	WIRE, LOCK	[illegible]
1	25	208120-1	CONNECTOR ASSEMBLY	(2)
1	24	208218	COVER, END	
16	23	93007-10	BOLT 12 POINT (REAR)	(2)
AR	22	MS-[illegible]	WIRE, LOCK	[illegible]
1	21	208216	BRACKET, CONN. MOUNTING	
1	20	208[illegible]-1	ROTOR & SHAFT ASSY	[illegible]
1	19	208204-1	HOUSING, MOTOR, ASSY OF	[illegible]
1	18	208[illegible]	[illegible]	
1	17	208[illegible]	[illegible]	(2)

253801 TAB B

1	16	208268	CLAMP, [illegible] REAR MTG.	(2)
1	15	MS-[illegible]	NUT, SELF LOCK, [illegible]	[illegible]
1	14	MS-[illegible]	KEY	[illegible]
4	13	MS-35270-[illegible]	SCREW, M.HCH, FIL. HD	[illegible]
1	12	208274	HOUSING, [illegible], ASSY OF	[illegible]
AR	11	208264-7	SHIM	
AR	10	208264-6	SHIM	
AR	9	208264-5	SHIM	
AR	8	208264-4	SHIM	
AR	7	208264-3	SHIM	
AR	6	208264-2	SHIM	
AR	5	208264-1	SHIM	
1	4	[illegible]	[illegible]	
1	3	[illegible]	BOLT, [illegible]	
1	2	[illegible]	[illegible]	
1	1	[illegible]	[illegible]	

ITEM NO.	QUAN. REQ'D	PART NO.	DESCRIPTION
			LIST OF MATERIAL

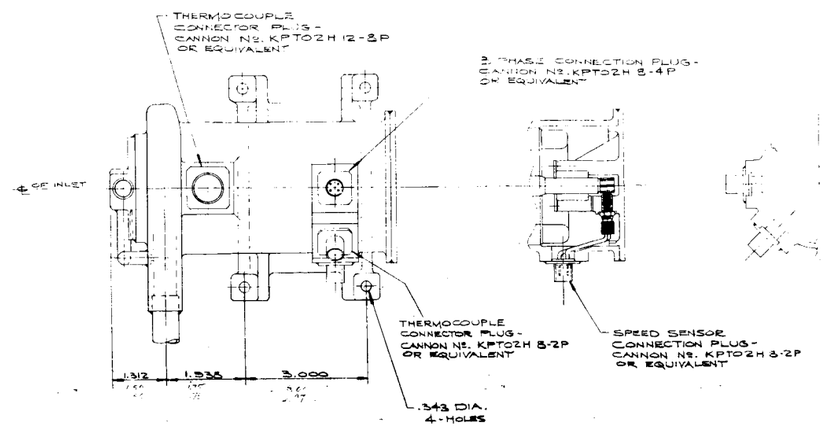
NEXT ASSY. 253800-1
TAPCO GROUP
U.S.A.
253801

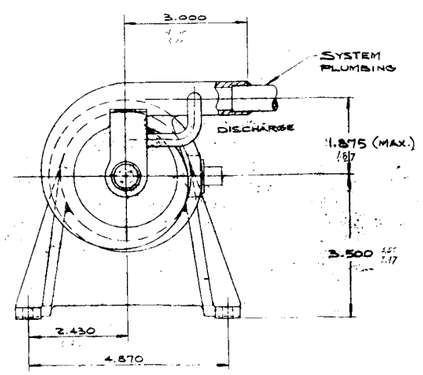
NOTES : UNLESS OTHERWISE SPECIFIED

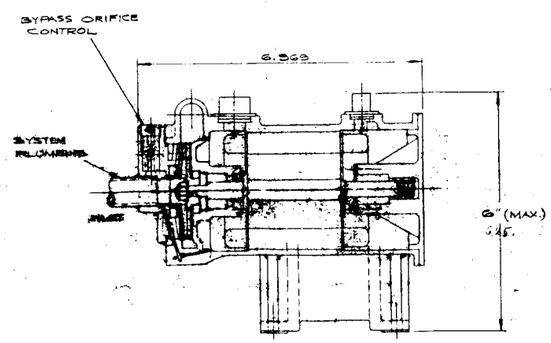
1. EST. WET. WEIGHT [illegible] TOTAL

2. MOTOR DATA :
   CONTINUOUS DUTY, 200 VOLT, 400 CPS, 3 PHASE
   4 WIRE, Y CONNECTION, 6 POLE

3. PUMP RATING 4700 REL. ATTITUDE [illegible] PUMP PRESSURIZING GAS WHEN PUMPING DOWN ET 375 OR EQUIVALENT FLUID AT +250 °F. TEMP. WITH 10 PSIA INLET & DISCHARGE PRESSURE







WIRING DIAGRAM

PRELIMINARY

MODEL PART NO 253800-1

APPLICABLE SPECIFICATIONS UNLESS OTHERWISE SPECIFIED DIMENSION AND TOLERANCING IN ACCORDANCE WITH SPEC. MIL-STD-8	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES REMOVE ALL BURRS BREAK SHARP EDGES .005 (.13) MAX. CORNERS .005 (.13) FILLET CAST RADII ~ 1/8 TOLERANCES ON DECIMALS ± FRACTIONS ± ANGLES ±	DRWN	LIST OF PARTS		REV. NO.
		CHKD.			E
		APPD.		TAPCO GROUP THOMPSON RAMO WOOLDRIDGE INC. U.S.A.	
		ENG.	PUMP INSTALLATION CENTRIFUGAL PUMP		
		ENG.			
		MFG.			
		MFG.		253800 TAB	
		MFG.		59875 SHEET 1 OF 1	

IV. PERFORMANCE DATA

A. Head-Capacity Curves

1. S/N 481502 (395/64-00104)
2. S/N 481503 (395/64-00105)
3. S/N 481504 (395/64-00106)
4. S/N 481505 (395/64-00107)
5. S/N 481506 (395/64-00108)
6. S/N 481507 (395/64-00109)

B. Development Unit Performance Curves

1. S/N DU-1, Head-Capacity (395/64-00117)
2. S/N DU-1, NPSH (395/64-00118)

C. Development Test Results at TRW, 8/5/64

D. TM-4004 (TRW), Development Test - Model 253800-1 & 2 Lubrication and Coolant Pump

E. Start Tests at 95 Cycles - AGC Memo No. 395/64-304, L/C PMA Electrical Startup Requirements

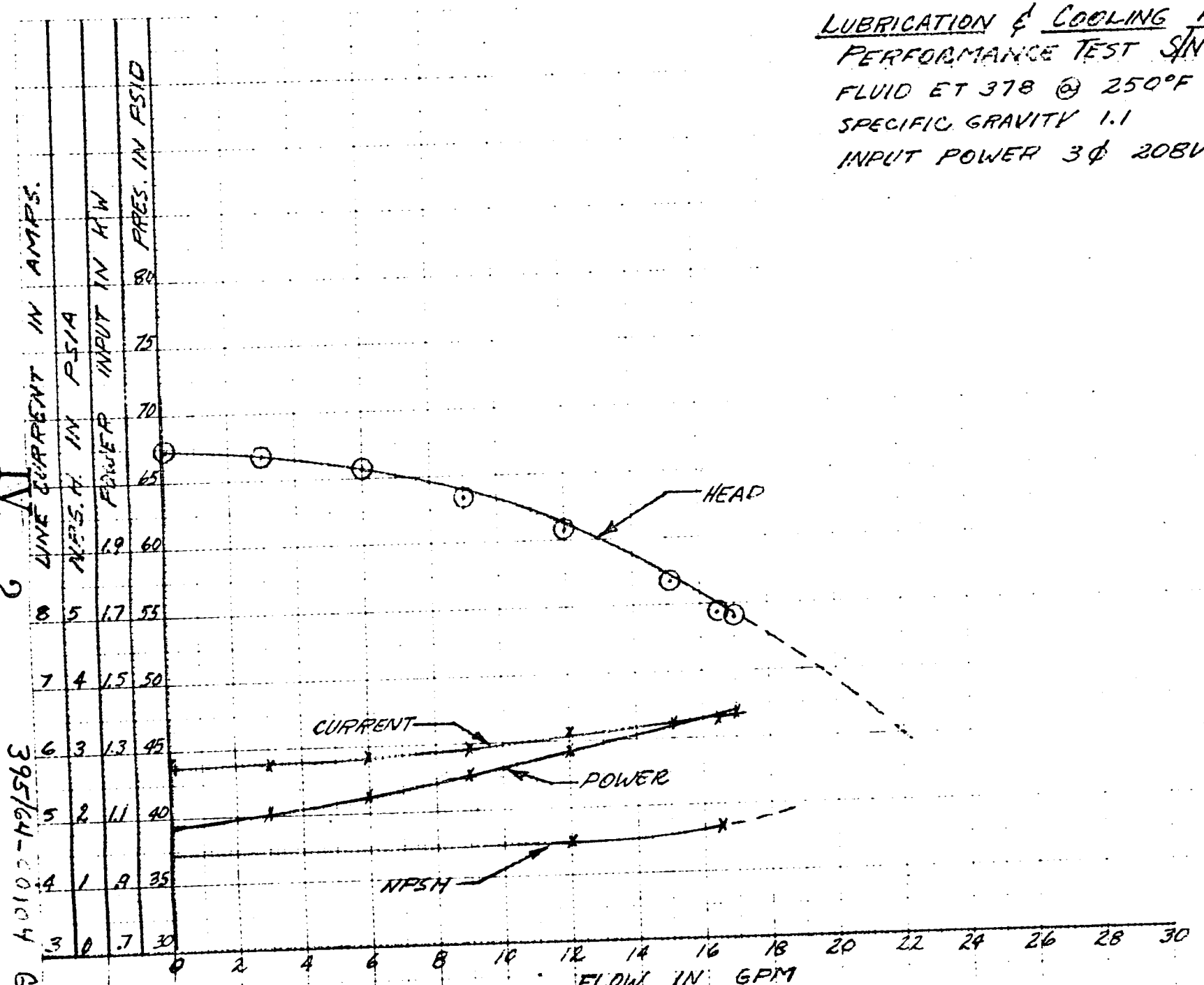
F. Typical Head-Capacity Operating Range for Design Loads on Bearings

G. -1 L/C PMA Environmental Test Procedure #371.0209 and Supplement No. 1 #371:64:0209A

H. L/C PMA Environmental Testing - Vibration Tests, Initial Results, Memo No. 4832:65-13, dtd 18 January 1965, Failure Report No. 1211

Aerojet-General®
CORPORATION

LUBRICATION & COOLING PUMP
PERFORMANCE TEST S/N 481502
FLUID ET 378 @ 250°F
SPECIFIC GRAVITY 1.1
INPUT POWER 3φ 208V 400CPS

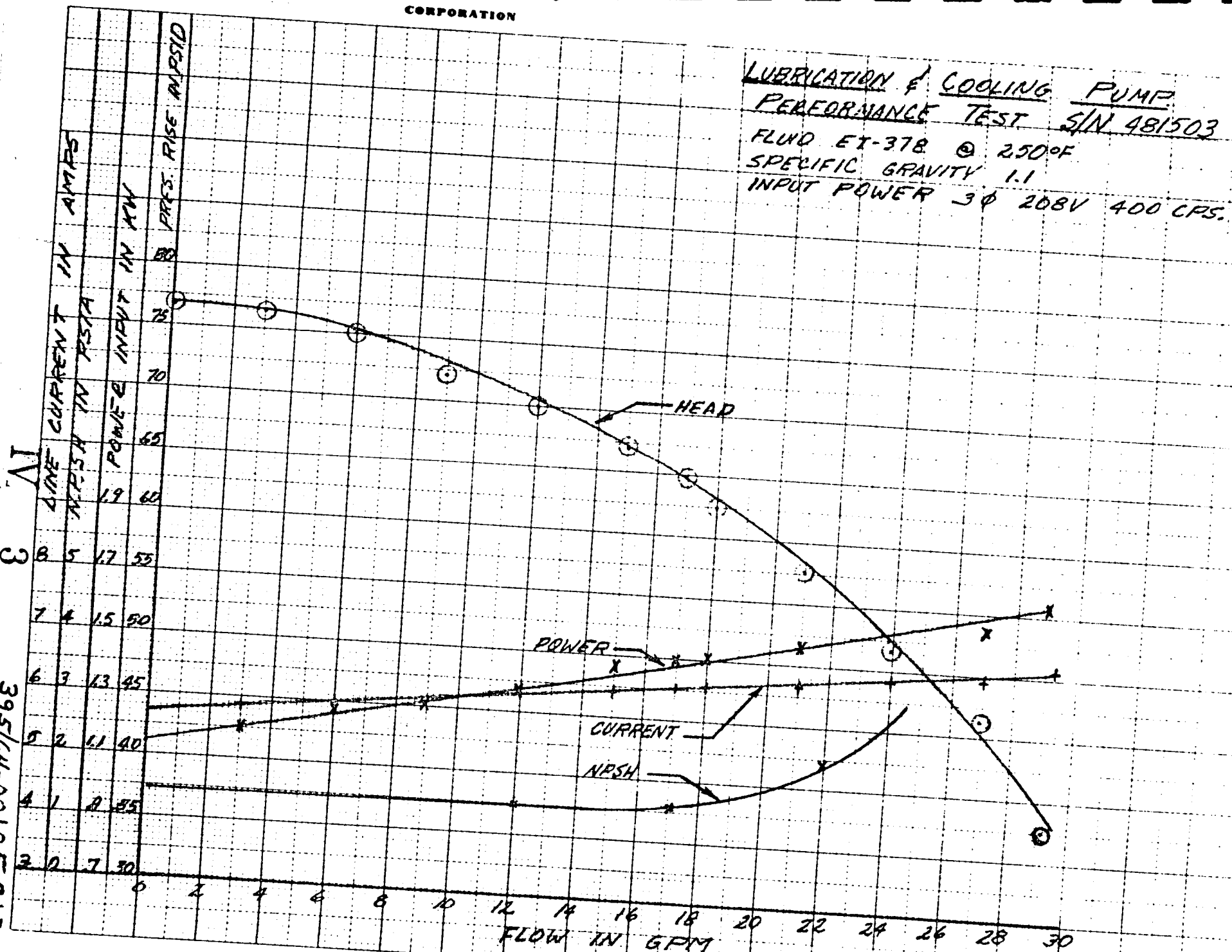


IV 2

395/64-C0104 G

10-15-64

Aerojet General®
CORPORATION

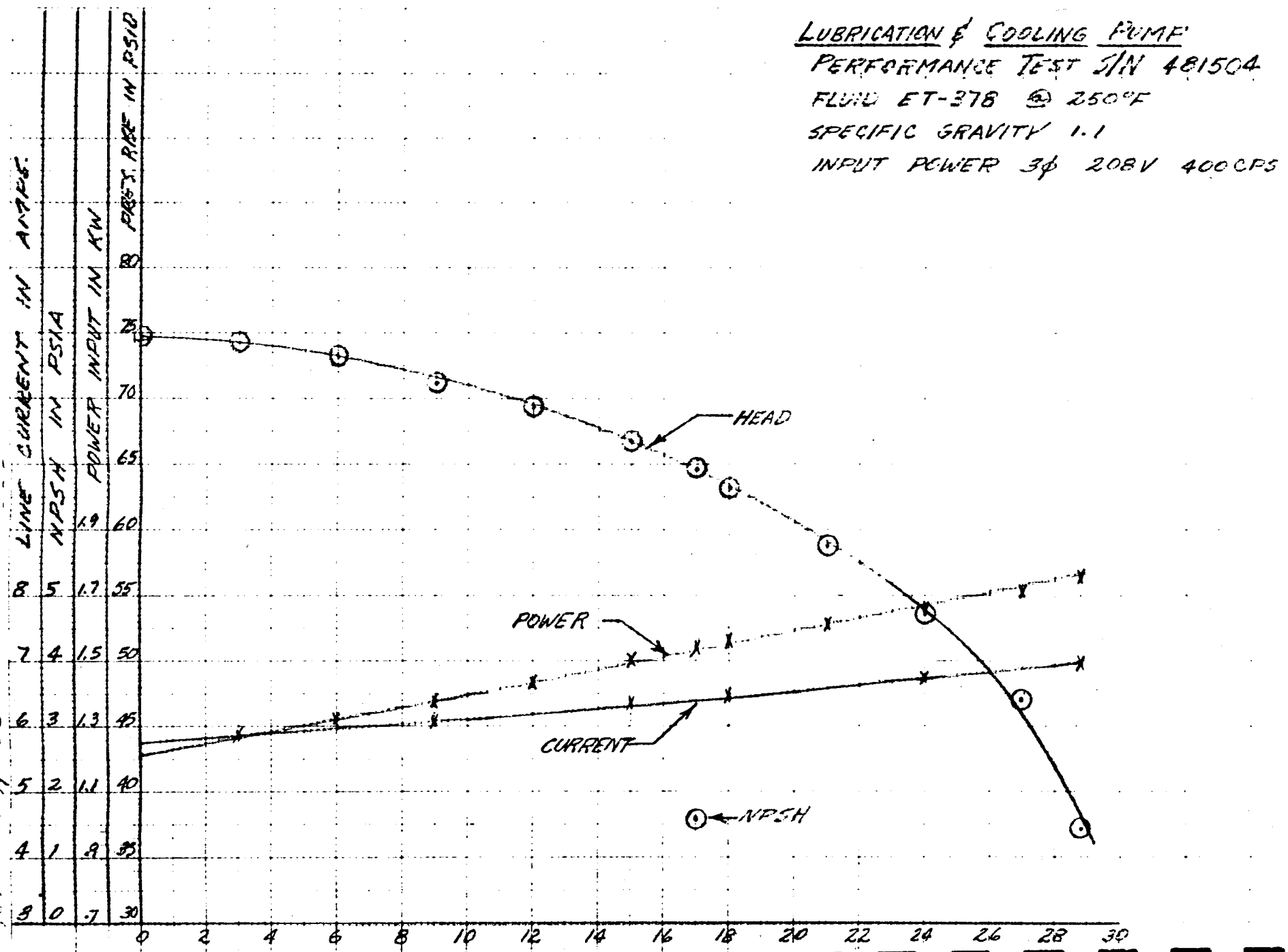


IV 3

395/64-00105 6JB

10-15-64

Aerojet-General®
CORPORATION

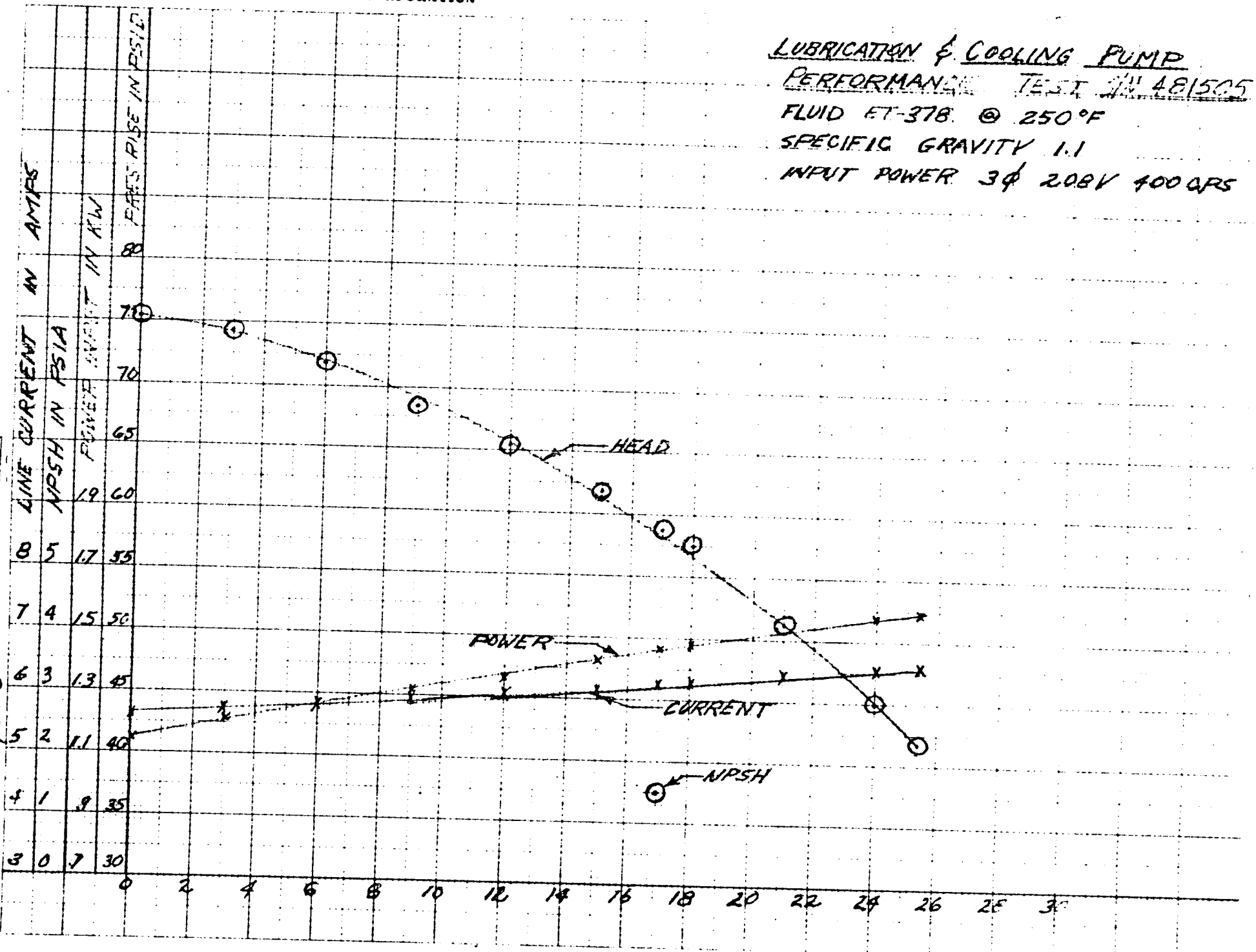


IV 4

395/64-00106

10-15-64

Aerojet-General®
CORPORATION

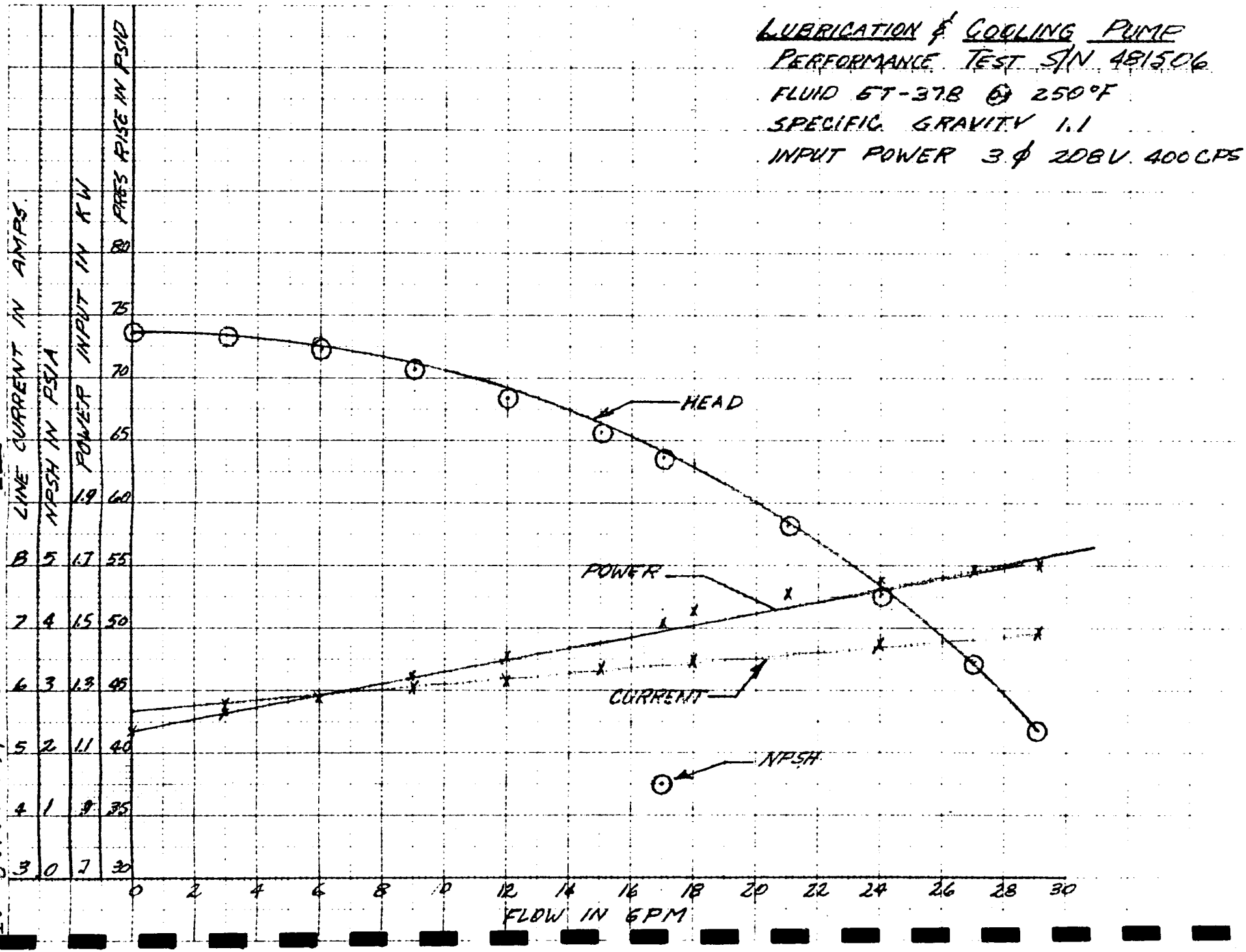


395/64-00107 GTE

10-15-64

M 5

Aerojet-General®
CORPORATION

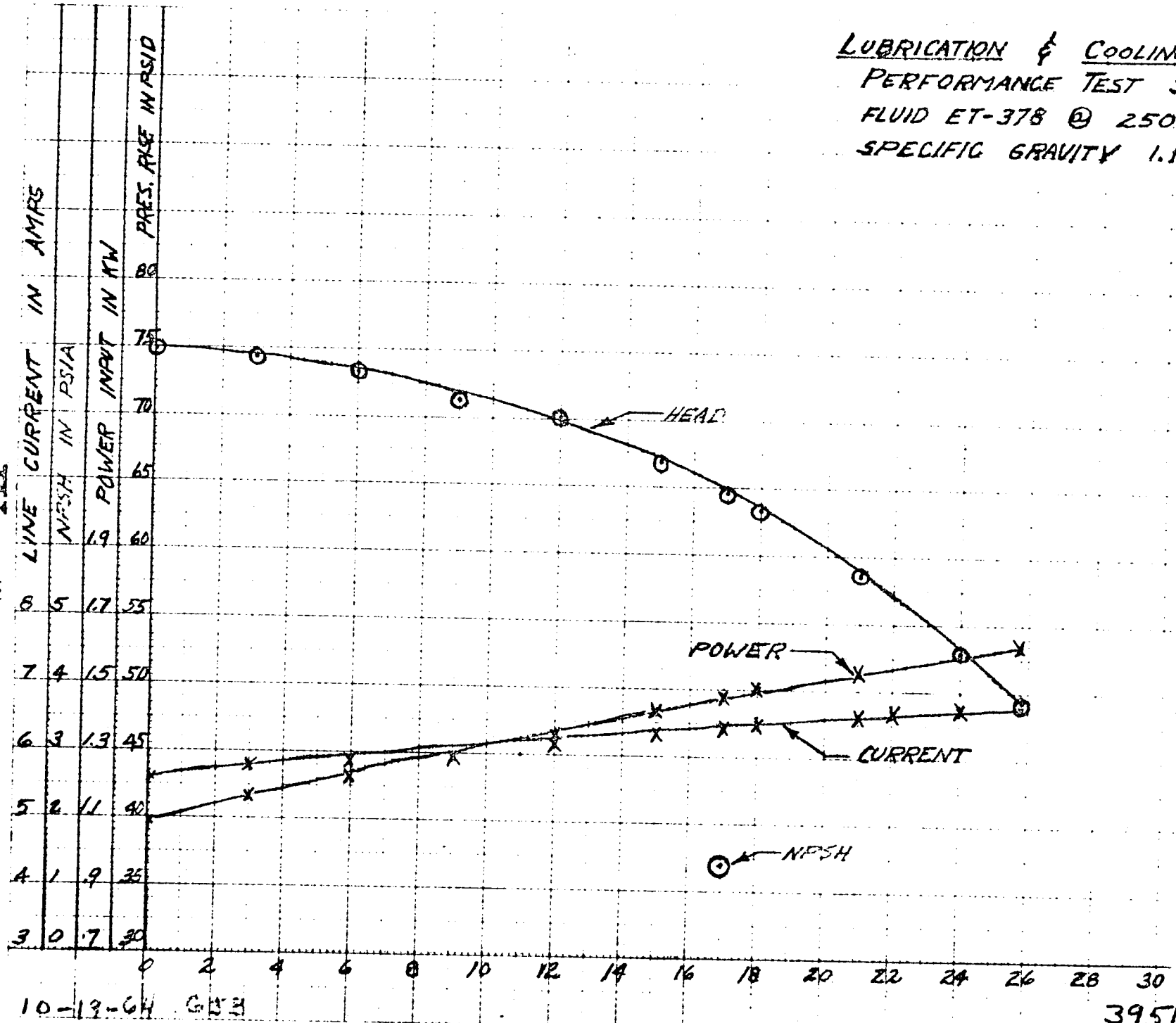


395/64-00108

IV. 6

10-15-64

Aerojet-General®
CORPORATION



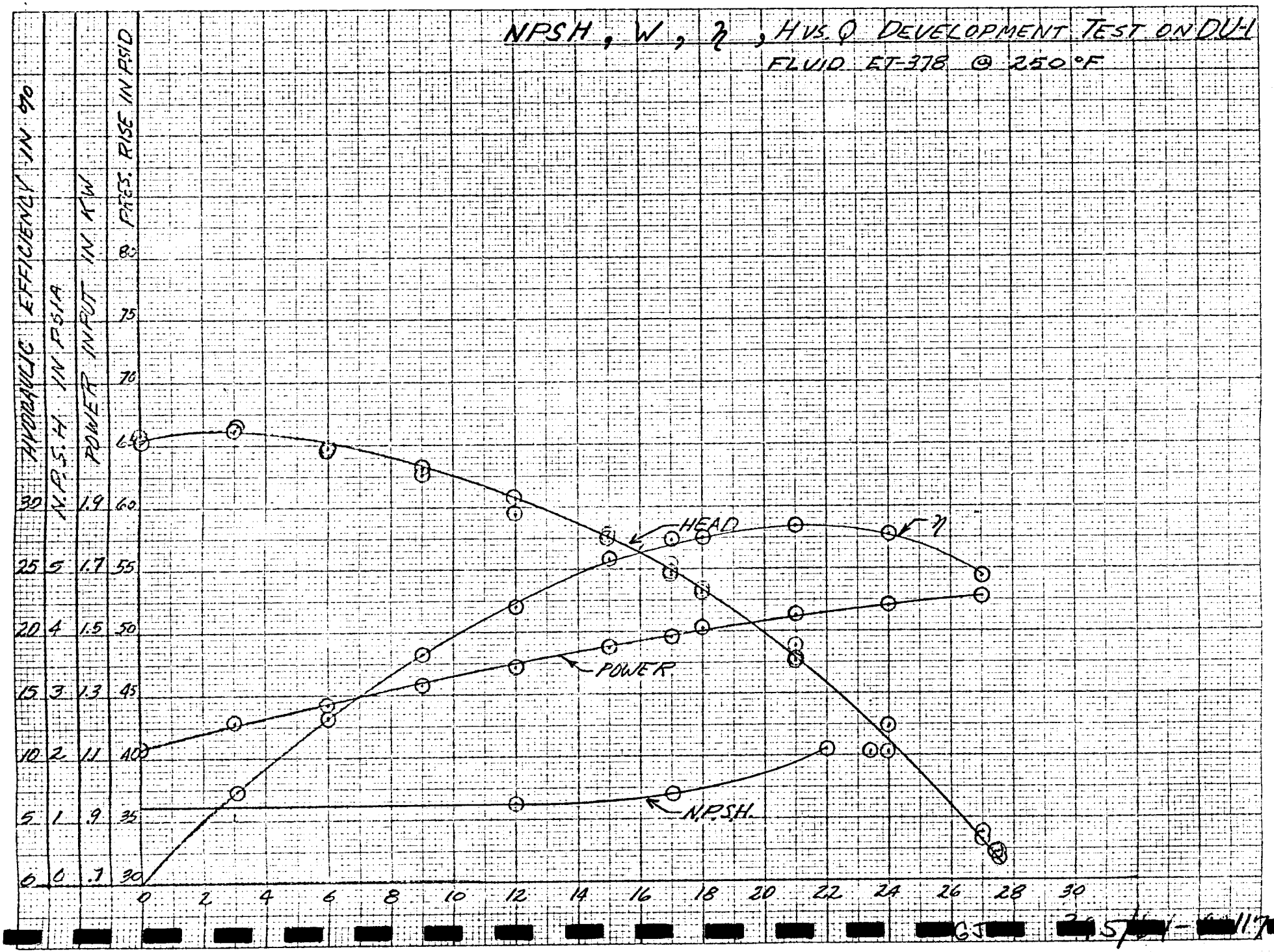
LUBRICATION & COOLING PUMP
PERFORMANCE TEST S/N 481507
FLUID ET-378 @ 250 °F
SPECIFIC GRAVITY 1.1

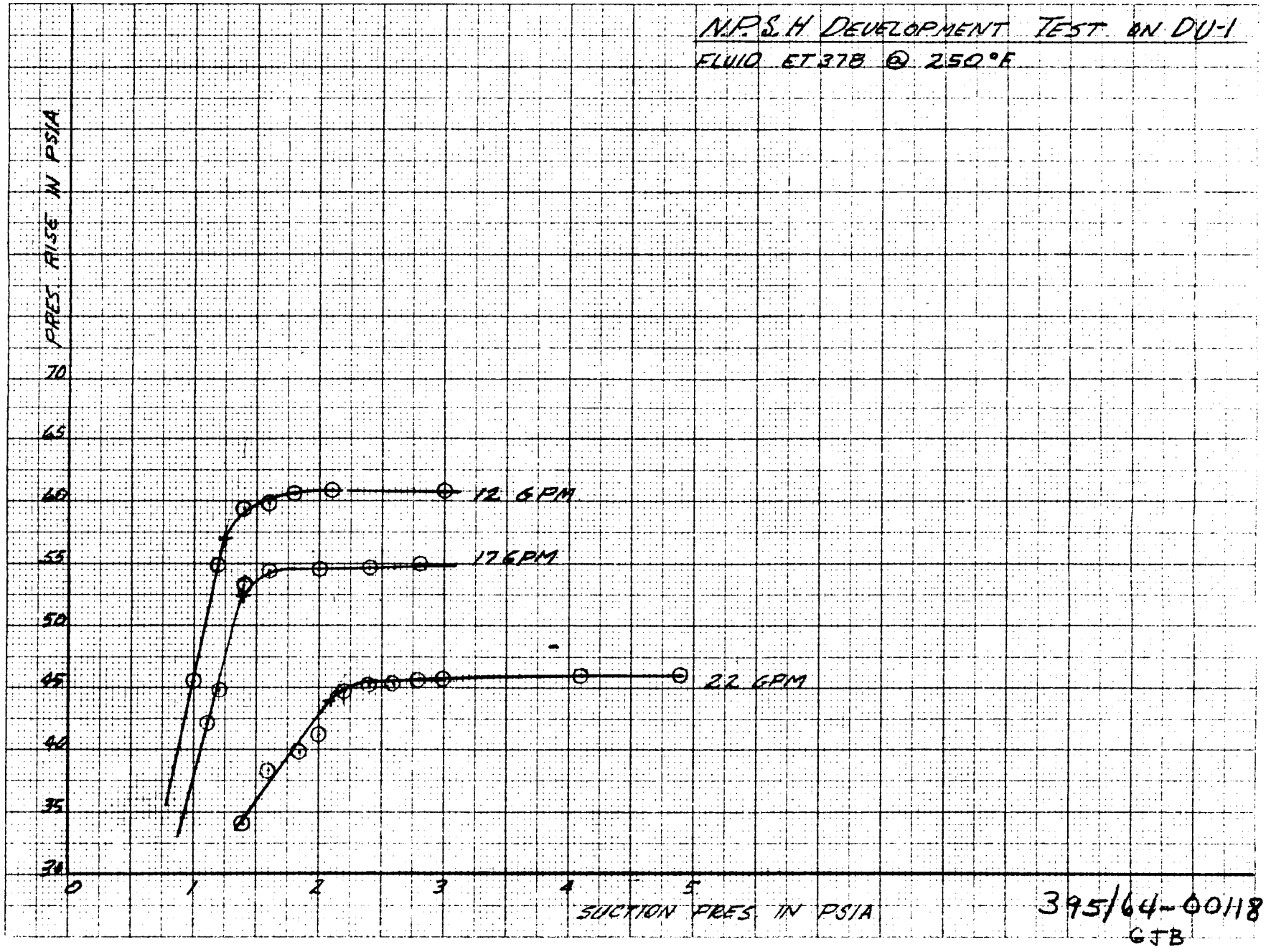
10-19-64 GJB

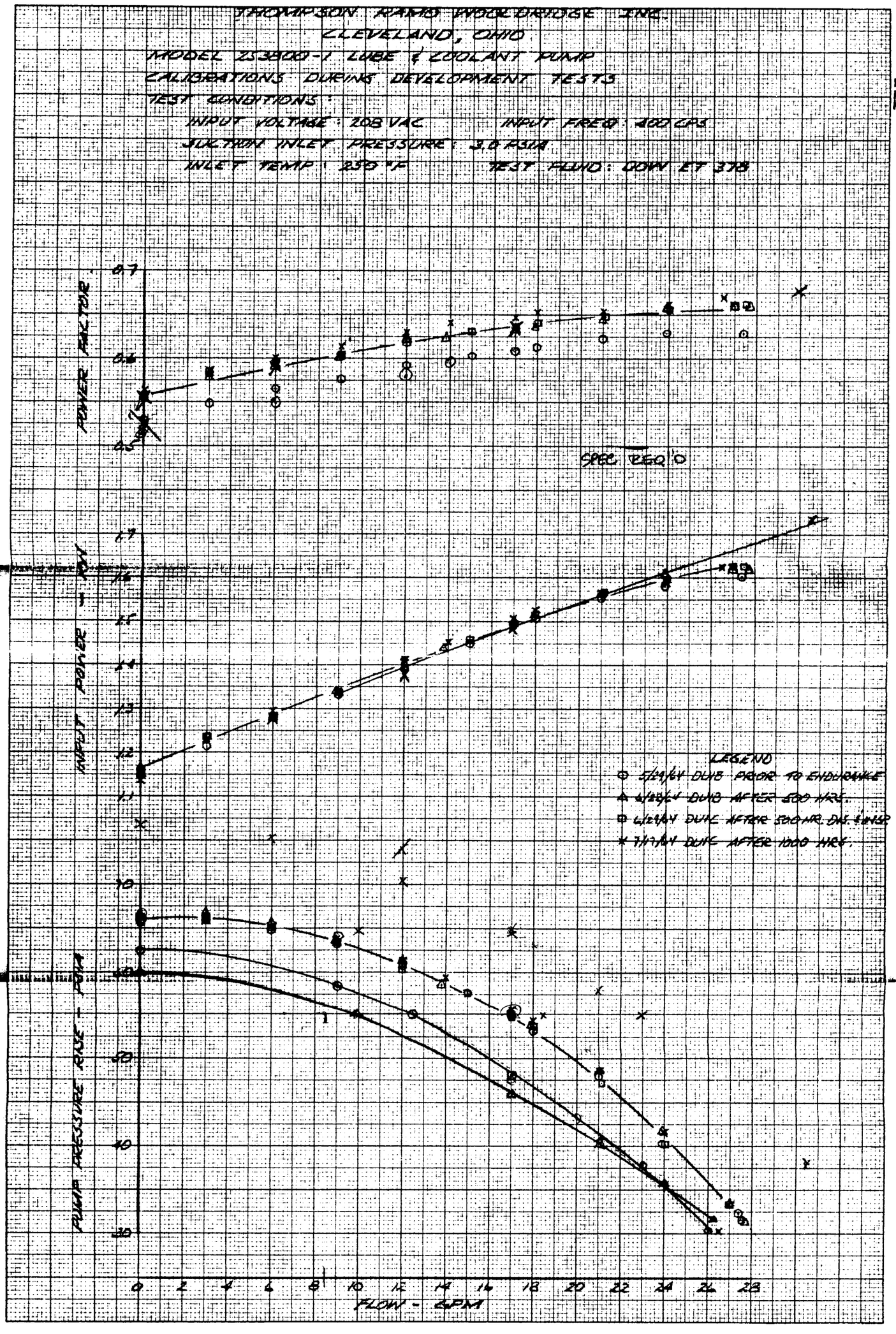
395/64-00109

CLEARPRINT PAPER CO. C38 20 X 20 DIVISIONS PER INCH, 100 X 200 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1010
CLEARPRINT CHARTS

Aerojet-General®
CORPORATION




N.P.S.H DEVELOPMENT TEST ON DU-1
FLUID ET 378 @ 250°F
PRES RISE IN PSIA
70
65
60
55
50
45
40
35
30
0
1
2
3
4
5
SUCTION PRES IN PSIA
12 GPM
17 GPM
22 GPM
395/64-00118
GJB


THOMPSON RAMO WOOLDRIDGE INC.
CLEVELAND, OHIO
MODEL 2S3900-1 LUBE & COOLANT PUMP
CALIBRATIONS DURING DEVELOPMENT TESTS
TEST CONDITIONS:
INPUT VOLTAGE: 208 VAC
INPUT FREQ: 400 CPS
SUCTION INLET PRESSURE: 3.0 PSIA
INLET TEMP: 250 °F
TEST FLUID: DOW ET 378
POWER FACTOR
SPEC REQ'D
INPUT POWER - KW
LEGEND
5/29/64 DUB PRIOR TO ENDURANCE
6/28/64 DUB AFTER 500 HRS.
6/29/64 DUB AFTER 500 HR. DIS & INSP
7/17/64 DUB AFTER 1000 HRS.
PUMP PRESSURE RISE - PSIA
FLOW - GPM

TECHNICAL MEMORANDUM (TM-4004)

Development Test - Model 253800-1 & 2 Lubrication & Coolant Pump

TRW ELECTROMECHANICAL DIVISION
THOMPSON RAMO WOOLDRIDGE INC.
23555 euclid avenue • cleveland, ohio 44117

IV 11

TRW Accessories Division
23555 Euclid Avenue
Cleveland 17, Ohio

TECHNICAL MEMORANDUM (TM-4004)
PROJECT NO. 512-004236-08
DATE September 15, 1964

PREPARED BY: E. P. Jira, Development Engineer, Accessories Division Engineering

CHECKED BY: W. V. Edwards, Project Engineer, Accessories Division Engineering

APPROVED BY: L. J. Weiss, Sr. Project Engineer, Accessories Division Engineering

TITLE: Development Test - Model 253800-1 & -2 Lubrication & Coolant Pump

SUMMARY

Model 253800-1 & -2 Lubrication and Coolant Pump was designed and developed to meet the requirements of Aerojet-General Corporation Specification AGC 10191, and is intended for use on the Snap 8 orbital power system. Development Testing was authorized by AGC Purchase Order OP 359790, Prime Contract No. NAS 5-417, and was accomplished under TRW Project No. 516-004236-08.

FOREWARD

Development Testing of Model 253800-1 Lube and Coolant Pump was performed in accordance with TRW Specification 02-1099. Tests were limited to Acceptance Tests (to establish basic performance ability and correlation with Deliverable Units) and a 1000 hour Abbreviated Life Test. The test specimen was a Model 253800-1 pump, serialized DU1, assembled specifically for development testing. Models -1 and -2 are basically identical except that the -1 incorporates a seal welded bypass bolt whereas the -2 model employs an "o" ring sealed bolt. Data obtained with the -1 model therefore is considered applicable to the -2 model.

Weight of Model 253800-1 Lube and Coolant Pump, S/N DU1, was 25.4 pounds (as measured in the dry assembled condition). Reference is here made to drawings 253800 Installation and 253801 Assembly for a pictorial description of the pump.

RESULTS

A list of the tests performed, and the page numbers of the respective data sheets, are as follows:

TEST	DATA PAGE NO.	COMMENT
Examination of product	5 - 31	See Discussion C
Dielectric strength	32	See Discussion D
Helium leak test	33	
Calibration	37	
1000 hour abbreviated life test	38 - 50	
500 hour disassembly and inspection	43 - 45	See Discussion E
Motor phase resistance	51	
Dielectric stength test after 1000 hours	52	
1000 hour disassembly and inspection	53 - 54	See Discussion F

DISCUSSION

A. Power Factor

During the development 1000 hour abbreviated life test, an increase in power factor was noted. This increase was noted over the entire pump flow range, and exhibited itself as a decrease in line amps. Specifically, at rated flow (17 gpm), power factor at start of test was .609 (6.80 amps, 1490 watts), .632 after 500 hours (6.57 amps, 1500 watts), .637 (6.52 amps, 1498 watts) after 500 hour disassembly and inspection, and .648 (6.45 amps, 1508 watts). This increase in power factor as analyzed by TRW and Westinghouse, the motor supplier, is attributed to an increase in the permeability in the motor magnetic circuit. It is concluded that this change resulted from thermal aging and stress relief within the stator core during the life test. This permeability change is not considered to be detrimental since it does not adversely effect the structural qualities of the motor and actually results in a performance improvement.

Changes in the power factor of an electric motor could occur due to such conditions as a change in rotor/stator, radial or axial alignment, or a change in the "air" gap due to rotor growth or stator bore shrinkage. These items have been ruled out as contributing factors in this instance due to readings taken before and after the 1000 hour test as well as at the 500 hour point.

B. Pressure Gage Correction

During development testing, gage readings were not corrected for change in gage line ullage. This correction should be applied since, with the pump inoperative, the gages were "zeroed" by disconnecting the lines at the gages and allowing the fluid in the lines to stabilize. When the lines were reconnected and the pump operated, the ullage was reduced due to the application of pressure, and the corresponding increased fluid level in the gage line detracted from the true pressure by a factor of the change in height times the density of the fluid. A list of corrections for the various gage readings is included as pages 55 and 56.

C. Examination of Product

The development test unit was initially assembled and serialized as DU1. Concurrent with this assembly, AGC directed that assembly be accomplished in a "clean" assembly area. The unit was then disassembled, cleaned in commercial grade Acetone, and reassembled in the clean box as S/N DU1A. Reference is here made to the photographs contained herein as pages 57 thru 59 showing the assembly clean box and the disassembled development unit.

D. Dielectric Strength

During initial Dielectric Strength testing, a failure was noted by excessive leakage in the motor. An analysis was performed on the stator and breakdown attributed to an accumulation of machining particles forming a current path between a void in the winding insulation and the stator housing. Reference is here made to Failure Report No. 5101, contained herein as pages 25 and 26.

E. 500 Hour Disassembly and Inspection

As scheduled, the unit was disassembled and inspected after completion of 500 hours of Abbreviated Life Testing. There was no evidence of excessive wear or deterioration. Reference is here made to pages 60 thru 64 for a pictorial view of the pump after 500 hours.

F. 1000 Hour Disassembly and Inspection

The unit was disassembled and inspected after completion of the 1000hour Abbreviated Life test and again there was no evidence of excessive wear or deterioration. Reference is here made to pages 65 thru 67 for a pictorial view after completion of testing.

CONCLUSION

Disassembly and Inspection of the development unit after 500 and 1000 hours of abbreviated life testing revealed no evidence of undue wear or deterioration. On this basis, a high confidence level is supported that the Model 253800-1 & -2 Lube and Coolant pump should meet the operational life requirements of AGC specification 10191.

A DIVISION OF

[illegible] Inc.

[illegible] AVENUE • CLEVELAND 17, OHIO

[illegible] NO. _____

Date _____

Contract No. _____

Customer No. _____

Copy No. _____

No. of Pages _____

STATUS _____

COMM. NO. _____

REL. DATE _____

TITLE: _____

UNIT S/N DU1

PREPARED BY

ASSEMBLY of 3/19 & 3/20/[illegible]

_____ _____

Title Title

APPROVED BY

_____ _____ _____

Q.C. RELIABILITY _____

Title Title

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

1. [illegible] Lubrication & [illegible] specification for".

2. [illegible], Work Statement [illegible] for [illegible] Division of Thompson Ramo [illegible].

3. [illegible], [illegible] Inc., "Work Statement, [illegible] Centrifugal Pump Model [illegible]-1, Aerojet [illegible] Corporation".

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S/N DU1

I. FORWARD

[illegible] has been designed to meet the [illegible] Work Statement, [illegible] fluid to [illegible] power system. Development [illegible] demonstrate the capability [illegible] to meet the basic requirements of the [illegible].

This [illegible] development unit assembly and test procedure [illegible] Lubrication & Coolant Pump.

The development [illegible] of this unit is authorized by Aerojet-General Corporation, [illegible] Contract No. [illegible].

II. OBJECT

The [illegible] the development unit assembly and [illegible] Lubrication & Coolant Pump will be [illegible] to fulfill the requirements of Aerojet General [illegible], Ref. 1, paragraph [illegible], and AGC Work Statement, Ref. [illegible].

III. TEST SPECIMEN

The development [illegible] Lubrication & Coolant [illegible] manufactured by [illegible] will be [illegible] requirements. During assembly of the test [illegible] numbers of each [illegible] to provide a complete [illegible]. All significant [illegible] be noted on appropriate log pages. [illegible] will be entered in the appropriate [illegible]. All information required on the build [illegible] of the pump [illegible] unit shall be [illegible] Assembly Drawing [illegible] and in accordance with the [illegible].

After [illegible] with [illegible] shaft by [illegible] within [illegible]: .0017, .0016.

[illegible] pin from [illegible]

ACCEPTS .005 THICKNESS FEELER GAUGE (GAUGE 1/8" WIDE AT TIP & TAPERED)

1. [illegible] following [illegible]:

A) [illegible] 180° apart with corresponding marks on [illegible].

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S/N DU1

B) Measure and record four times, impeller to housing clearances at impeller, without rotating impeller, at 90° increments:
1) .003, 2) .004, 3) .005, 4) .005.

C) Measure and record four times, impeller to housing clearances at one point of housing and rotate impeller in 90° increments:
1) .003, 2) .003, 3) .003, 4) .003.

D) A variation in excess of .0005 between any of the readings obtained in B and C shall be cause for rejection.

2. Dimension B - Obtain at a total of four points in the following manner:

A) Repeat Item 1.B above with the end play taken up toward the pump connector end:
1) .003, 2) .004, 3) .006, 4) .006.

3. End Play - Determine end play by [illegible] method whereby rotor first against thrust face and then [illegible] back to stop:
1) .0013, 2) .0013, 3) .0012, 4) .0011. .001 BY SUBTRACTION OF 1.B.4) FROM 2.A.4)

A) End play less than .001 or greater than .001 shall be cause for rejection. (END PLAY TAKEN WITH 40# AXIAL.

4. Dimension C - This dimension shall be taken at four points equally spaced:
1) 14.0215, 2) 14.0216, 3) 14.0215, 4) 14.0214.

5. Dimension D - This dimension shall be taken at each impeller blade at a distance of approximately 1/[illegible] [illegible] impeller [illegible].
1) 14.6551, 2) 14.6545, 3) 14.6562, 4) 14.6573, 5) 14.6573.
6) 14.6568, 7) 14.6558. BY ROTATION OF IMPELLER 14.6546 TO 14.6585

6. Dimension G -

A) For max. G, subtract [illegible] D from [illegible] C:

Max G = 14.6585 - 14.0214 = .6371

B) For min. G, subtract [illegible] D from [illegible] G:

Min G = 14.6546 - 14.0216 = .6330

14.6585
14.0214
.6371

14.6546
14.0216
.6330

7. Dimension E - Measure and record four places 90° apart:

1) 6.543, 2) 6.543, 3) 6.543, 4) 6.544.

8. Dimension F - Measure [illegible] 90° apart:

1) 7.165, 2) 7.1685, 3) 7.166, 4) 7.165.
(Depth micrometer [illegible] against motor assembly pilot bore during measurement.)

NEGLECT THIS READING — RUNOUT IN CONTOUR AT THIS AREA (INSUFFICIENT MACHINING STOCK ON CASTING)

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S/N DU 1

7.165
6.544
.621

7.166
6.543
.623

9. Dimension H -

A) For Max H, subtract Min F from Max F:

Max H = 7.166 - 6.543 = .623

B) For Min H, subtract Max F from Min F:

Min H = 7.165 - 6.544 = .621

.6371
.0013
.005
.6434
.621
.023

10. Dimension J -

A) Optimum J = Max G + End Play + .005 - Min. H:

= .6371 + .0013 + .005 - .621 = .0224

B) Allowable J = Optimum J ± .001.

C) Actual J = Measured total shim thickness = .023

.6371
.0013
.6384

11. Dimension I -

A) Minimum I = Min. H + J - Max. G - End Play:

= .621 + _____ - .6371 - .0013 = _____

B) Maximum I = Max. H + J - Min. G + End Play:

= .623 + _____ - .6330 + .0013 = _____

.6330
.0013
.6343

C) Minimum I less than .004 or max. I greater than .009 shall be cause for rejection.

12. Dimension L - Mark four points on bearing housing 90° apart. Install rotating assembly prior to addition of 20[illegible] shims and measure L. Rotation of shaft should not be possible at this time due to impeller seating on housing throat.

1) ~~1.788~~ 1.755, 2) ~~1.788~~ 1.757, 3) 1.765, 4) 1.7535. MEASURED TO CAST SURFACE

Determine if end play has been taken up entirely. If not, contact engineering for further instructions. ROTATING ASS'Y WOULD NOT TURN

13. Dimension M - Install 20[illegible] shims, rotating assembly, and install and torque [illegible]-10 bolts. Measure and record M (taken at same points as L):

1) 1.7505, 2) 1.755, 3) 1.7655, 4) 1.7505.
ROTOR TURNED FREELY - NO INDICATION OF RUB

14. Impeller/Throat Clearance Check:

Min. Imp/Throat Clearance = L - M - End Play

Min. Imp/Throat Clear = _____ - _____ - _____ = _____

Min. Imp/Throat clearance less than .004 or greater than .006 shall be cause for rejection.

Assembly of the test specimen will be performed by Development Engineering Test personnel. Any subsequent teardown or overhaul will be documented on the Overhaul Sheet (see Figure 1).

IV. TEST PROCEDURE

A. Installation

During all operational tests, the pump shall be mounted in the test stand provided for this application. The unit shall be mounted in a vertical position with the inlet tube down and the electrical connector up. All operational tests shall be performed with the neutral motor lead floating (not connected).

B. Test Fluid

The test fluid for all testing shall be Dow Chemical Company Bis (Polyphenyl) Ether ET-37[illegible]. Said fluid to be 'degassed' prior start of tests.

Test fluid samples shall be taken for submittal to Aerojet General for information purposes. As a minimum, a sample shall be taken at completion of 500 hours and 1000 hours of the Abbreviated Life Test. Also, a sample shall be taken prior to the addition of any fluid to the system and a record kept as to quantity and frequency of refills.

C. Instrumentation

All instrumentations shall be calibrated against standards or masters prior to commencement of development testing and thereafter at intervals in keeping with Quality Assurance requirements.

Instrumentation employed during development testing shall consist of two categories; 1) test stand ("permanent" instrumentation used for development and acceptance testing) and, 2) prototype instrumentation (to assist in pump operation analysis). Instrumentation and accuracy for each of the classifications is as follows:

1. Test Stand

Fluid Flow - Gal/Min - ± 0.5%
Inlet Pressure - PSIA - ± 0.5%
Discharge Pressure - PSI - ± 0.5%
Inlet Fluid Temperature - °F - ± 3°F
Outlet Fluid Temperature - °F - ± 3°F
Motor Phase 1 Temperature - °F - ± 3°F (connector pins [illegible])
Motor Phase 2 Temperature - °F - ± 3°F (connector pins [illegible])
Motor Phase 3 Temperature - °F - ± 3°F (connector pins P&T)
Motor Lead End Extension Temperature - °F - ± 3°F (connector pins C&J)
Motor Anti Lead End Extension Temperature - °F - ± 3°F (connector pins N&S)

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S/N DU 1

Speed - RPM - ± 10 RPM (connector pins F&M)
Phase Input Current - Amps - ± 0.75%
Phase Input Power - Watts - ± 0.75%
Input Voltage - Volts - ± 0.75%
Input Frequency - Cycles/Sec - ± 0.75%

2. Prototype

Pressure and temperature data shall be recorded for those additional locations shown in Figure [illegible].

Impeller Suction Side Pressure #1 - PSI - ± 0.[illegible]%
Impeller Suction Side Pressure #2 - PSI - ± 0.[illegible]%
Lower Motor Cavity Pressure - PSI - ± 0.[illegible]%
Upper Motor Cavity Pressure - PSI - ± 0.[illegible]%
Upper Brg. Hsg. Temp. - °F - ± 3°F (connector pins C&J - in lieu of Lead and Extension Temperature)
Return Flow Fluid Temp. - °F - ± 3°F (connector pins R&U)

D. Individual Tests

All significant observations during tests shall be entered as comments on the appropriate pages of the test sheet or log, as applicable.

Individual tests shall be performed in accordance with the procedures listed below. During all operational tests, sufficient time shall be allowed for stabilization prior to taking of any data.

1. Dielectric Strength - A room temperature, sea level dielectric strength test (megohm) shall be performed on the motor housing assembly per MIL-STD-202A, Method 301. Test voltage shall be 1416 Volts A.C. applied for one minute and the voltage shall be applied between the motor power leads joined together and the motor housing. Data taken shall include test voltage, time, current leakage, and test equipment identification.

2. Examination of Product - All component parts shall be examined visually at assembly to check for visual defects, deterioration, or any other imperfection that would result in rejection of the pump assembly or [illegible]. [illegible]

During initial or subsequent assembly or disassembly, a complete build sheet shall be maintained utilizing forms shown as Figures 1, 2, and 3.

3. Calibration - The pump shall be calibrated from 0 to maximum obtainable flow in 3 GPM increments (data shall also be taken at a flow setting of 17 GPM). Data taken for each flow setting shall be in accordance with Figure 4. Test conditions shall be as follows:

Suction Inlet Pressure - 5.0 & 3.0 PSIA ± 0.1 PSIA
Inlet Fluid Temperature - [illegible] ± 4°F
Input Voltage - 20[illegible] Volts ± 2 Volts
Input Frequency - 4[illegible] CPS ± 4 CPS

During initial settings take note of pressure from tap at connector end. If pressure is below atmospheric call Engineering for further instructions.

4. 1000 Hour Abbreviated Life Test - The pump shall be subjected to a 1000 hour Abbreviated Life test. The unit shall be seal welded prior to start of these tests. Input power to the pump shall be 20[illegible] Volts ± 2 Volts, 4[illegible] CPS ± 4 CPS, and fluid inlet temperature shall be 2[illegible]0°F ± 4 [illegible] for the life test. Procedures and sequence of the test shall be as follows:

a) 0 to 2 Hours - With 5.0 PSIA ± 0.1 PSIA suction inlet pressure, operate pump at 17 GPM flow and record data every [illegible] minutes.

b) With conditions given in (a) above, reduce suction inlet pressure to 4.0, 3.0 then in 0.2 PSIA increments, while maintaining 17 GPM flow. Record all data at each inlet pressure level until 20% drop in head (discharge) is reached.

c) With 5.0 PSIA ± 0.1 PSIA suction inlet pressure, set flow at 12 GPM and perform "steady state" run, recording data every two minutes until internal temperatures and pressures have stabilized.

d) Repeat Item (b) except that flow shall be 12 GPM.

e) Repeat Item (a) except that flow shall be 22 GPM.

f) Repeat Item (b) except that flow shall be 22 GPM.

g) Repeat Item (a) with 17 GPM flow with inlet to be at 3.0 PSI.

h) Allow unit to run at condition (g), recording all data a minimum of 2 times each day. The pump shall be subjected only once to test conditions described by items (a) through (g) prior to a total accumulated time of [illegible] hours.

i) Perform calibration per paragraph IV.D.2 only 3.0 PSI inlet.

j) Disassemble, inspect and rebuild pump. Inspection to include visual inspection for wear or deterioration, physical measurement of bearing bores and journals, and photographs.

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k) Perform calibration per paragraph IV.[illegible] only at 3.0 PSI inlet.

l) Repeat items (a) through (j) for a total accumulated running time of 1000 hours.

NOTE: The abbreviated life test is to be run continuously, however the various sequences are to be performed on a normal 8 hour shift, 5 day week basis. During "non coverage" hours (nights or weekends), the unit shall be operated at 3.0 PSIA suction inlet, 17 GPM flow, and 250°F inlet temperatures.

5. Dielectric Strength - At the completion of the 1000 hour abbreviated life test, a Dielectric Strength test shall be performed per paragraph V.1.

E. Data

Data taken shall consist of assembly or disassembly information or actual operational data as applicable, and shall be entered on the appropriate data sheet. Total operational accumulated running time shall also be kept on the operation data sheet (Figure 4).

All data, including build sheets, overhaul sheets, and operational data, shall be kept in a unit log book.

516.0-4236.05 ✓
E. Jira
DU-1

Aerojet General
Snap 8
Electrical Connections in pump.
Contract OP-359790

tested
4.30.64
208 220
DU-1
MIL-STD-271C

See exceptions
atmospheric
2 minutes.
$2.4 = 5.5 \times 10^{-5}$ cc/sec of Helium
4.5×10^{-10} cc/sec of Helium
1×10^{-7} cc/sec of Helium

1) Exceptions to MIL STD 271C -
1) Calibrated leak in side part of leak detector MS9AB
2) Helium sprayed on external portion of part
3) was not placed in a bag).

Procedure. 1) SC4 in side part of machine
2) Pumped down to less 10^{-3} mm Hg.
3) Checked MS9AB by opening & closing SC4 immediate reaction. Less 1 minute to stabilize.
4) Sprayed Helium on electrical connections & continued to spray for 2 minutes.
5) No reaction on leak indicator
6) Opened & Closed SC4 - immediate reaction
7) Part ok -
J Sudick
8851-50

Thompson Ramo Wooldridge Inc.

253500-1 LUBE & COOLANT PUMP

Part No.	Chg. Ltr.	Qty.	I.R. No.	Name	S/N	Comments
208208	N/C	1	54484-1	Indicator, Rotation Pickup	7	
208209-1	D	1		Rotor & Shaft Assy.	7	
208209-2		1		Shaft		
208209-3		1		Thrust Washer		
208207		1		Rotor		
208212	A	1	54770-01	Impeller	11	
208214-1	A	1		Motor Housing Assy.	1	
208210		1		Stator	2	
208214-2		1		Motor Hsg.	1	
208261		1		Front Bearing	7	
208262		1		Thrust Bearing	8	
208216-1	B	1	54760-A-01	Bearing Hsg. Assy.	8	
208216-2		1		Bearing Hsg.	2	
208263		1		Rear Bearing	8	
208218	C	1	54758-01	End Cover	1	
208220-1	B	1		Electrical Connector	6	
208223	N/C	1	54772-1	Speed Indicator Guard	1	[illegible]
208224	N/C	1	54764-1	Front Mtg. Bracket	1	SK 19788 (R 16227)
208225	N/C	1	54759-1	Rear Mtg. Bracket	1	
208226	N/C	1	54486-1	By Pass Orifice Plate	8	
208257	A	1	54487-1	Bearing Retainer	1	
208258	B	1	41905	Volute Hsg.	5	SK 19733 (R16223)
208259	A	1	54788-2	Front Mtg. Band Clamp	2A	
208260	A	1	54788-1	Rear Mtg. Band Clamp	2A	
208264-1	N/C		54757-1	Shim		
208264-2	N/C	2	54757-1	Shim		
208264-3	N/C		54757-1	Shim		.069 SHIM TOTAL
208264-4	N/C		54757-1	Shim		
208264-5	N/C		54757-1	Shim		
208264-6	N/C		54757-1	Shim		
208264-7	N/C	3	54757-1	Shim		
208265-1	N/C		54757-1	Shim		
208265-2	N/C		54757-01	Shim		
208265-3	N/C		54757-01	Shim		
201220-6	D	1	55352-01	Nut Hex		
208615	N/C	1		SPACER	6	

Part No.	Chg. Ltr.	Qty.	I.R. No.	Name	S/N	Comments
208265-4	N/C		54757-01	Shim		
208265-5	N/C	2	54757-01	Shim		
208265-6	N/C		[illegible]	Shim		
208265-7	N/C		54757-01	Shim		
208266	C	1	55374-1	By Pass Bolt	10	
208267	N/C	1	R-13245	Cap Nut		
208270	B	1	8[illegible]25	Speed Sensor	1	
208595	N/C	1	R-[illegible]596	Tube, Inlet	1	
208596	N/C	1	R-[illegible]596	Tube, Outlet	1	
SK 19786	N/C	1		SPACER, LOCKWASHER		LOCKWASHER GROOVE ON SHAFT TOO SHORT. SPACER ALLOWS TO POSITION LOCKWASHER
SK 19776				WIRE, CONNECTOR		
MS19070-003	N/C	1	54689-2	Lockwasher		91976-1
MS20500-524	N/C	1	54684-1	Nut, Self Locking		91110-2
MS20995C20	N/C	AR	54672-01	Lockwire	1	90956
MS20995C32	N/C	AR	54672-01	Lockwire	1	90956-1
MS35275-12	N/C	4	[illegible]683-1	Screw, Fil. Hd.		90866-13
MS35275-14	N/C	2	54689-1	Screw, Fil. Hd.		90866-24
MS35275-35	N/C	1	54689-1	Screw, Fil. Hd.		90866-26
MS35275-60	N/C	4	54689-1	Screw, Fil. Hd.		90866-25
MS35276-1	N/C	1	55025-1	Key		90323
NAS1021C06	N/C	1	54683-1	Nut, Self Locking		91982-1
QQS571	N/C	AR	54676-1	Solder		94244-26
93007-10	N/C	12	54[illegible]-1	Bolt, 12 Point		
94100-86	A	1	54[illegible]75-1	Nameplate	3	
94095-14	N/C	1	54[illegible]67-1	Electrical Conn. Dust Cap		

THERMOCOUPLE INSTALLED IN BRG HSG 208216-1 .067/.073 DIA. 3/16 DEEP, PELLED OVER EDGE
THERMOCOUPLE INSTALLED AT WIRE GUIDE

DURING SOAK RINSE OF 208214-1 MTR. HSG, OBSERVED BLACK-GRAY PARTICLES BEING FLUSHED FROM HSG. - MAJORITY WERE MINUTE PARTICLES (APPEARED AS MIST IN FLUID)

IMP NUT TORQUE 60 IN-lbs. - BRG HSG/MTR HSG BOLT TORQUE 5 IN-lbs.
TORQUED MTR HSG/VOL HSG SCREWS TO 20 IN-lbs.

Lower Bearing I.D.: .5017
Upper Bearing I.D.: .502
Impeller/Throat Clear (W/End Play Toward Inlet):
End Play:

Lower Journal O.D.: .5001
Upper Journal O.D.: .5001
Impeller/Hsg. Clear (W/End Play Away From Inlet):

Proof Pressure Test: Test Date , Pressure , Time , Results

Helium Leakage Test: Test Date , Leakage

GOV'T. INSPECTOR | TRW QUAL. ASSURANCE | DATA PAGE NO. 1 | ASSEMBLED BY: F. REALENCE | DATE: 3/20/64

OVERHAUL SHEET MODEL 253807-1 LUBE & COOLANT PUMP

TEARDOWN DUI

Part No.	Chg.	Qty.	I.R. No.	PARTS REMOVED Name	S/N	Comments

UNIT COMPLETELY DISASSEMBLED, CLEANED, AND PARTS PLACED IN BAGS.

TECHNICAL GRADE ACETONE USED FOR CLEANING

ADDED FIBERGLAS TAPE WRAP TO LEADWIRES AND VARNISHED SAME.
FIBERGLAS TAPE OBTAINED FROM WESTINGHOUSE - SEE LETTER FROM WESTINGHOUSE PROVIDING INFORMATION CONCERNING TAPE.

VARNISH (DUPONT ML TYPE RK 692) OBTAINED FROM TRW PRODUCT ENGINEERING (SPEED SENIOR SUPPLIER). VARNISH LOT NO. P551729

VARNISH CURED FOR 1 HR. @ 212°F (100°C), 1 HR. @ 300°F (150°C) AND 1 HR @ 428°F (220°C) — PER AGC LETTER 932:IV:0257 4/9/64

208212 A	1	54770-01	IMPELLER		11	TO BE REWORKED

LOWER BEARING I.D.: LOWER JOURNAL O.D.:
UPPER BEARING I.D.: UPPER JOURNAL O.D.:
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

REASON FOR OVERHAUL: TO CLEAN AND REASSEMBLE UNIT — AGC DIRECTION

REPLACEMENT

Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments
ALLEG. LEAD WIRE WRAP & VARNISH — SEE TEARDOWN REMARKS						
4 BRG. HSG/MTR HSG. RETAINER BOLTS TORQUED TO 6 IN-LB.						
TORQUED IMPELLER NUT TO 57 IN-LB. (30-27 RUN OR TORQUE)						
DURING REBUILD — COULD NOT OBTAIN PROPER END PLAY LOCKING — CHECKED 208214 MTR HSG NUT AND FOUND .062 FOR LOCK-ON. APPROX .001 OVERSIZE						
208214 MTR HSG NUT WAS TO BE REPAIR						
SK19890		1		IMPELLER	11	208212 REWORKED

Proof Pressure Test: Test Date , Pressure , Time , Results

Helium Leakage Test: Test Date , Results

LOWER BEARING I.D.: LOWER JOURNAL O.D.:
UPPER BEARING I.D.: UPPER JOURNAL O.D.:
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

GOVT. INSPECTOR	TRW QUALITY ASSURANCE	DATA PG. NO. / OVERHAULED BY:
		TEARDOWN 4/8/64 REDENCE/JIRA REBUILD 4/21/64 DENCE DATE:

Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

BUILD OF DUIA
AFTER CLEANING"

I. FOREWORD

Model 253800-1 Lubrication & Coolant Pump has been designed to meet the requirements of Aerojet-General Specification AGC-10191 and Work Statement, Reference 1 and 2, and is to be used to furnish the lubrication and cooling fluid to various components of the SNAP-8 orbital power system. Development testing of this unit is intended to verify the analytical studies and demonstrate the capability of the pump motor assembly to meet the basic requirements of the Reference 1 document.

This document is intended to serve as the development unit assembly and test procedure for Model 253800-1 Lubrication & Coolant Pump.

The development testing of this unit is authorized by Aerojet-General Corporation, Purchase Order OP-359790, Prime Contract No. NAS 5-417.

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The object of this document is to formally present the development unit assembly and test procedure to which the 253800-1 Lubrication & Coolant Pump will be subjected and has been prepared to fulfill the requirements of Aerojet General Corporation Specification AGC-10191, Reference 1, paragraph 4.6, and AGC Work Statement, Reference 2.

III. TEST SPECIMEN

The development tests shall be performed on one Model 253800-1 Lubrication & Coolant Pump. The parts for the test specimen shall be manufactured by Model Shop techniques to production drawings and will be inspected to assure compliance with the program Quality Assurance requirements. During assembly of the test specimen, the part, serial, and inspection report numbers of each component will be recorded on the Build Sheet (see Figure 1) to provide a complete history of parts that comprise the test specimen. All significant observations during assembly should be noted on appropriate log pages. Critical fits, clearances, dimensions, etc., shall be entered in the appropriate areas provided (see Figures 1 and 2). All information required on the build sheets must be completed prior to release of the pump assembly. The unit shall be assembled as shown on Assembly Drawing 253801 and in accordance with the following instructions:

After subassembly of bearing housing and motor housing with rotating group in place, place housing on V blocks. Measure radial movement of shaft by indicator by lifting shaft assembly from rest until clearance taken up within bearings. Repeat in different positions (90° apart) on each end of shaft.

Impeller End .0016 ; .0017 . Speed Sensor End 0.0015 . 0.00155.

Determine on go-no-go basis minimum air gap of .005, using .005 pin from bearing housing end. Check twice: _____; _____.

The above subassembly and shaft/bearing clearance, and Item 3 end play measurement shall be performed with all parts wiped dry. After measurements have been taken, the subassembly shall be disassembled, parts cleaned with ET-378, and subassembly reperformed.

Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A. [illegible] S/N [illegible]

Refer to Figure 2 for location of the following dimensions:

1. Dimension A - Obtain at a total of eight points in the following manner:

   A) Mark impeller near O.D. at two points 180° apart with corresponding marks on housing.

   B) Measure and record four times, impeller to housing clearances at impeller, without rotating impeller, at 90° increments:
   1) .005, 2) .0045, 3) .0035, 4) .0045.

   C) Measure and record four times, impeller to housing clearances at one point of housing and rotate impeller in 90° increments:
   1) .005, 2) .0035, 3) [illegible], 4) [illegible].

   D) A variation in excess of .0025 between any of the readings obtained in B and C above shall be cause for rejection.

2. Dimension B - Obtain at a total of four points in the following manner:

   A) Repeat Item 1.B above with the end play taken up toward the pump connector end:
   1) .006, 2) .005, 3) .0035, 4) .0045.

3. End Play - Determine end play by indicator method with 30# axial load applied to shaft:
   1)_____, 2)_____, 3)_____, 4)_____.

   A) End play less than .001 or greater than .003 shall be cause for rejection.

END PLAY CHECKED AT APPROX .0001 - COULD FEEL DRAG IN ROTOR. TORE DOWN UNIT AND FOUND 208214 .863/.862 DIMENSION WAS .864+. MSG. TO BE REWORKED

4. Dimension C - This dimension shall be taken at four points equally spaced:
   1)_____, 2)_____, 3)_____, 4)_____.

5. Dimension D - This dimension shall be taken at each impeller blade at a distance of approximately 1/32 inside impeller O.D. by rotating impeller:
   1)_____, 2)_____, 3)_____, 4)_____, 5)_____,
   6)_____, 7)_____.

6. Dimension G -

   A) For max. G, subtract minimum D from maximum C:

   Max. G = _____ - _____ = _____

   B) For min. G, subtract maximum D from minimum C:

   Min. G = _____ - _____ = _____

7. Dimension E - Measure and record E four places 90° apart:
   1)_____, 2)_____, 3)_____, 4)_____.

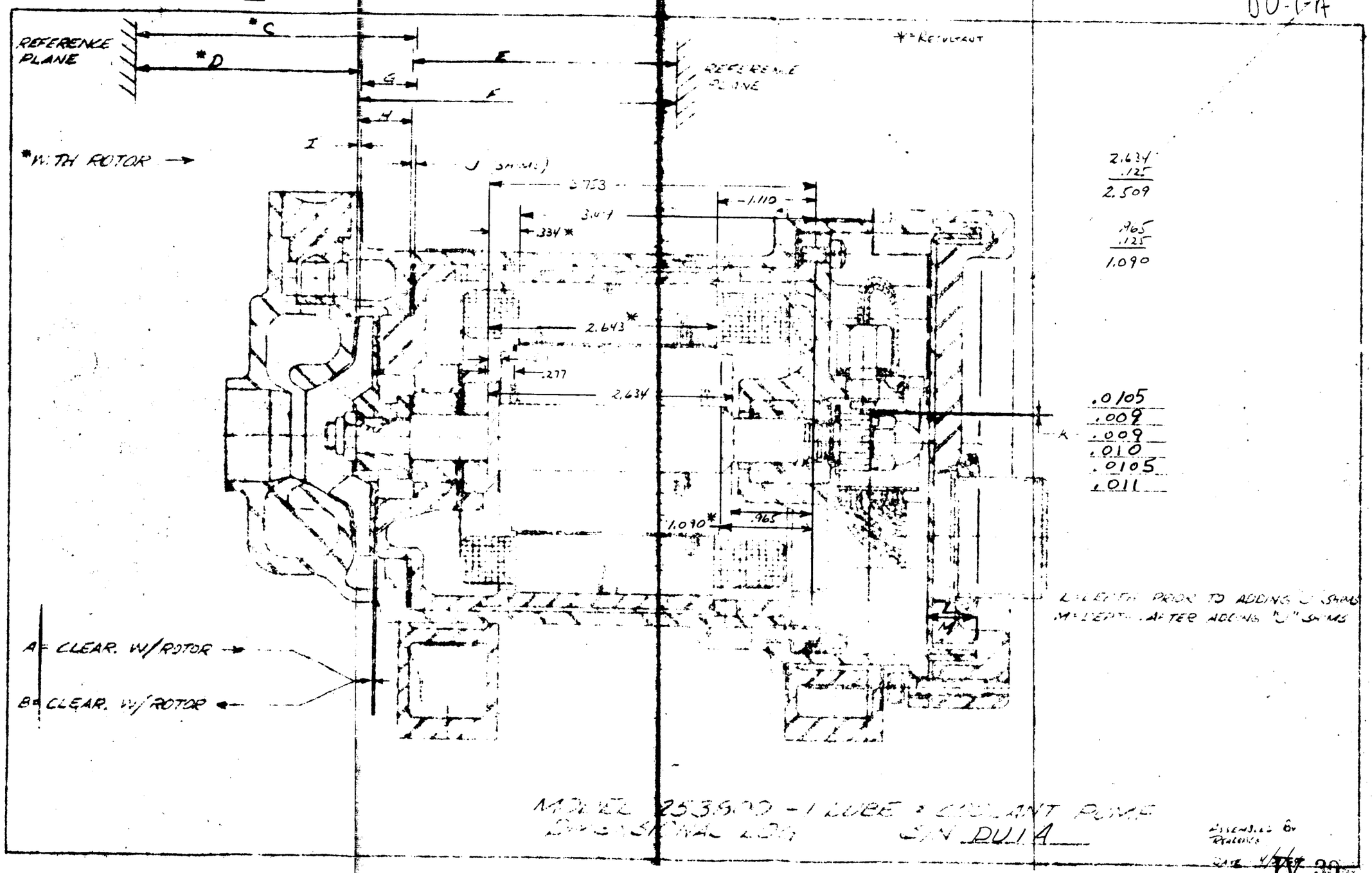
8. Dimension F - Measure F four places 90° apart:
   1)_____, 2)_____, 3)_____, 4)_____. (Depth micrometer bar to ride against motor assembly pilot here during measurement.)

TPFC-84 REV.

Thompson Ramo Wooldridge Inc.

FIGURE 2

DU-1-A



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The development tests shall be performed on one Model 253800-1 Lubrication & Coolant Pump. The parts for the test specimen shall be manufactured by Model Shop techniques to production drawings and will be inspected to assure compliance with the program Quality Assurance requirements. During assembly of the test specimen, the part, serial, and inspection report numbers of each component will be recorded on the Build Sheet (see Figure 1) to provide a complete history of parts that comprise the test specimen. All significant observations during assembly should be noted on appropriate log pages. Critical fits, clearances, dimensions, etc., shall be entered in the appropriate areas provided (see Figures 1 and 2). All information required on the build sheets must be completed prior to release of the pump assembly. The unit shall be assembled as shown on Assembly Drawing 253801 and in accordance with the following instructions:

After subassembly of bearing housing and motor housing with rotating group in place, place housing on V blocks. Measure radial movement of shaft by indicator by lifting shaft assembly from rest until clearance taken up within bearings. Repeat in different positions (90° apart) on each end of shaft.

Impeller End .002 ; .0021 . Speed Sensor End .0019 ; .002 .

Determine on go-no-go basis minimum air gap of .005, using .005 pin from bearing housing end. Check twice: .005 OK 2 places .015 will NOT GO 2 places

The above subassembly and shaft/bearing clearance, and Item 3 end play measurement shall be performed with all parts wiped dry. After measurements have been taken, the subassembly shall be disassembled, parts cleaned with ET-378, and subassembly reperformed.

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REPORT NO. 02-1099

Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

DUIA [illegible]

Refer to Figure 2 for location of the following dimensions:

1. Dimension A - Obtain at a total of eight points in the following manner:

   A) Mark impeller near O.D. at two points 180° apart with corresponding marks on housing.

   B) Measure and record four times, impeller to housing clearances at impeller, without rotating impeller, at 90° increments:
   1) .004, 2) .0035, 3) .004, 4) .0045.

   C) Measure and record four times, impeller to housing clearances at one point of housing and rotate impeller in 90° increments:
   1) .004, 2) .0045, 3) .0045, 4) .0035.

   D) A variation in excess of .0025 between any of the readings obtained in B and C above shall be cause for rejection.

2. Dimension B - Obtain at a total of four points in the following manner:

   A) Repeat Item 1.B above with the end play taken up toward the pump connector end:
   1) .007, 2) .006, 3) .006, 4) .007.

3. End Play - Determine end play by indicator method with 30# axial load applied to shaft:
   1) .0021, 2) .0021, 3) .0022, 4) .0022.

   A) End play less than .001 or greater than .003 shall be cause for rejection.

4. Dimension C - This dimension shall be taken at four points equally spaced:
   1) 6.0155, 2) 6.0157, 3) 6.0154, 4) 6.0157.

5. Dimension D - This dimension shall be taken at each impeller blade at a distance of approximately 1/32 inside impeller O.D. by rotating impeller:
   1) 6.6503, 2) 6.6501, 3) 6.6503, 4) 6.6506, 5) 6.6507, 6) 6.6508, 7) 6.6508.

6. Dimension G -

   A) For max. G, subtract minimum D from maximum C:

   Max. G = 6.6508 - 6.0154 = .6354

   B) For min. G, subtract maximum D from minimum C:

   Min. G = 6.6501 - 6.0157 = .6344

7. Dimension E - Measure and record E four places 90° apart:
   1) 7.545, 2) 7.545, 3) 7.545, 4) 7.545.

8. Dimension F - Measure F four places 90° apart:
   1) 8.165, 2) 8.166, 3) 8.165, 4) 8.166. (Depth micrometer bar to ride against motor assembly flat face during measurement.)

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Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A

[illegible] OVERHAUL

9. Dimension H -

A) For Max H, subtract min E from max F:

Max H = 8.166 - 7.545 = .621

B) For Min H, subtract max E from min F:

Min H = 8.165 - 7.545 = .620

10. Dimension J -

A) Optimum J = Max G + End Play + .005 - Min. H:

= .6354 + .0022 + .005 - .620 = .0226

B) Allowable J = Optimum J ± .001.

C) Actual J = Measured total shim thickness = _____

11. Dimension I -

A) Minimum I = Min. H + J - Max. G - End Play:

= _____ + _____ - _____ - _____ = _____

B) Maximum I = Max. H + J - Min. G + End Play:

= _____ + _____ - _____ + _____ = _____

C) Minimum I less than .004 or max. I greater than .015 shall be cause for rejection.

12. Dimension L - Identify four bearing housing connector stop posts. Install rotating assembly prior to addition of [illegible] shims and measure L. Rotation of shaft should not be possible at this time due to impeller seating on housing throat:

1) 1.505, 2) 1.507, 3) 1.507, 4) 1.506.

Determine if end play has been taken up entirely. If not, contact Engineering for further instructions.

13. Dimension M - Install 208265 shims, rotating assembly, and install and torque 93007-10 bolts. Measure and record M (taken at same points as L):

1) 1.500, 2) 1.502, 3) 1.501, 4) 1.500. 1.505-1.500 [illegible] Add .002 [illegible] 5/16

1.498 1.499 1.499 1.500

14. Impeller/Throat Clearance Check:

Min. Imp/Throat Clearance = L - M - End Play

Min. Imp/Throat Clear = 1.505 - 1.498 - .0022 = .004 [illegible]

Min. Imp/Throat clearance less than .004 or greater than .006 shall be cause for rejection.

DU-1-A

TRW JET & ORDNANCE DIVISION
THOMPSON RAMO WOOLDRIDGE INC.

HELIUM LEAK TEST REPORT

Customer: Aerojet General Corp. Program: Snap 8 Date Tested: 5-11-64

Part Name: L & C / FMA Serial No.: DU 1A Drawing No.: 253800-1

Specification and/or Procedure to which test is Performed: Mil-Std-271C

Sensitivity Check on Calibrated Leak: $4.2 = 5.5 \times 10^{-8}$ cc/sec of helium

Smallest Leak Detectable: 2.7×10^{-10} cc/sec of helium

Leak rate permitted: 1×10^{-7} cc/sec of helium

Pressure: at or slightly above atmospheric Time: 3 minutes

Description of Procedure:

1) Pumped down part with external pump - approximately 2 hours.
2) MS9AB (leak Detector) connected to larger diameter tube & SC4 Calibrated Leak (5.5×10^{-8} cc/sec of helium) connected to smaller diameter tube.
3) P/D with MS9AB - approximately 4 hours.
4) Tightened nuts on part after spraying with helium.
5) Hood over part - Hood enclosed all of the part except approximately 2" required to connect the hose to tubes.
6) Pumped down to less than 10^{-3} mm Hg. & sprayed joints.
7) SC4 open 1.2+ - SC4 closed 1.0+
8) Leak indicator set at 0 - with SC4 valve closed.
9) Checked time to stabilize @ 1.2 - 45 seconds.
10) Closed SC4 & set Leak Indicator at "0" & applied helium to hood at/or slightly above atmospheric pressure.
11) .05 reading on leak indicator after 3 minutes. Opened SC4 - 1.2 after 3 minutes.
12) Calculations: (See paragraph 6.3.1 of Mil-Std-271C)

$$LR = \frac{5.5 \times 10^{-8} \text{ cc/sec} \times .05 \text{ (1st reading)}}{1.2 \text{ (SC4 open - 2nd reading)} - .05 \text{ (1st reading)}}$$

$$LR = \frac{27.5 \times 10^{-10} \text{ cc/sec of helium}}{1.15}$$

$$LR = 23 \times 10^{-10}$$

$$LR = 2.3 \times 10^{-9} \text{ cc/sec of helium}$$

13) Leak rate less than 1×10^{-7} cc/sec of helium.
14) Part OK.

John Sudick
John Sudick
Materials Engineering Department

Witnessed by C. J. Magee, USAF Inspector

TPFC-557

Thompson Ramo Wooldridge Inc.

DU-1-A

TEST EQUIPMENT - SLAUGHTER DIELECTRIC TESTER MODEL 122
SLAUGHTER CO.
PIQUA, OHIO

TEST VOLTAGE of 1416 VAC Applied for 15 MINUTE SEC.

LEAKAGE Approx 440 Microamps. After 15 sec. of Power Application LEAKAGE Indicator Pegged Indicating Breakdown.

TEST PERFORMED PER MIL-STD-202A, METHOD 301

AFTER TEST:

PHASE T1	& GROUND	.4 ohms	RESIST
PHASE T2	& GROUND	.4 ohms	RESIST
PHASE T3	& GROUND	.4 ohms	RESIST.
PHASE T1	& T2	.9 ohms	RESIST.
PHASE T2	& T3	.9 ohms	RESIST.
PHASE T1	& T3	.9 ohms	RESIST.

TITLE DIELECTRIC STRENGTH TEST

MODEL 253800-1 L&C PUMP S/N DU-1A

FLUID

ENGR. E. [illegible]
E. [illegible]
DATE [illegible]
TEST NO.
PROJECT [illegible]
DATA PG. 1

TAPCO GROUP RELIABILITY OFFICE—FAILURE AND CONSUMPTION REPORT

SYSTEM	1. TYPE, MODEL, SERIES: E53800-1 LC/PMA	2. S/N: DUIA	3. REPORTING FACILITY: DEV. ENG.	4. TEST PHASE: ELECTRIC TEST		5. REPORT NO. NO. 5101
UNIT	6. NAME (NOUN): PUMP	7. NUMBER	8. S/N ORIG. / REPLACEMENT	9. MODEL DESIGNATION		10. INITIAL REPORT NO.
ASSEMBLY	11. NAME (NOUN): PUMP	12. NUMBER MODEL	13. S/N ORIG. / REPLACEMENT	14. MANUFACTURER: TRW		15. REF. DESIGNATION NO.
PART	16. NAME (NOUN): STATOR	17. NUMBER MODEL: 203210	18. S/N ORIG.: 2 / REPLACEMENT	19. MANUFACTURER: WESTINGHOUSE		20. REF. DESIGNATION NO.

21. DATE AND TIME OF FAILURE — MONTH: [illegible] DAY: [illegible] YEAR: [illegible] TIME: (0-2400 HRS.) [illegible]

22. HIGHEST LEVEL DISABLED: .0 [ ] MODULE .1 [ ] PART .2 [ ] SUB ASSY .3 [ ] ASSY .4 [ ] UNIT .5 [ ] SUB SYST .6 [ ] SYSTEM .7 [ ] WEAPON

23. HIGHEST LEVEL REMOVED: .0 [ ] .1 [ ] .2 [ ] .3 [ ] .4 [ ] .5 [ ] .6 [ ]

OPERATING PERIOD — 24. UNIT: [illegible] .1 [ ] SEC .2 [ ] MIN .3 [ ] HRS .4 [ ] MOS .5 [ ] CYCLES ____ 25. ASSY.: NONE .1 [X] .2 [ ] .3 [ ] .4 [ ] .5 [ ] CYCLES ____

AT TIME OF FAILURE

26. LOCATION
- .1 [X] BENCH/CELL
- .2 [ ] FINAL INSPECTION
- .3 [ ] NORMAL USAGE ★
- .4 [ ] IN TRANSIT.
- .5 [ ] STORAGE

27. ACTION PERFORMED
- .1 [X] TESTING
- .2 [ ] P.M./INSPECTION
- .3 [ ] OVERHAUL
- .4 [ ] NOTHING

28. OPERATING STATUS
- .1 [X] NORMAL
- .2 [ ] ABNORMAL ★
- .3 [ ] OFF

29. REASON FOR REPORT
- 1 [X] FAILED ITEM
- .2 [ ] PREV. MAINTENANCE
- .3 [ ] EQUIP. MODIFICATION
- .4 [ ] FACILITY FAILURE
- .5 [ ] DESIGN IMPROVEMENT
- 6 [ ] PROCED. IMPROVEMENT

30. REPLACEMENT SOURCE
- .1 [X] STOCK ROOM
- .2 [ ] BENCH STOCK
- .3 [ ] OTHER FACILITY ★
- .4 [ ] CANNABILIZED
- .5 [ ] NONE AVAILABLE
- .6 [ ] NONE REQUIRED

31. ACTION ON ASSEMBL
- .1 [ ] REPAIRED IN PLACE
- .2 [ ] REPAIRED-REINSTA
- .3 [ ] ADJUSTED
- .4 [ ] REPLACED
- .5 [X] NONE OF ABOVE ★

FS | FAT | FC

32. DESCRIPTION AND APPARENT CAUSE OF TROUBLE ★ EXPLAIN

RETURNED TO MANUFACTURER FOR ANALYSIS

ENGINE LEAKAGE ENCOUNTERED AFTER APPROX. 15 SEC. OF APPLICATION of 1Hz VAC DIELECTRIC TEST VOLTAGE. LEAKAGE PRIOR TO FAILURE WAS APPROX 440 MICROAMPS. [illegible]

33. REPAIR TIME — HRS. MIN.
- .1 DIAGNOSIS
- .2 OBTAIN REPL.
- .3 REP. ACTION
- .4 CHECKOUT

34. TEST EQUIPMENT USED: SLAUGHTER DIELECTRIC TESTER

35. REPORTED BY/DATE: EP/[illegible] 5/14/64

Thompson Ramo Wooldridge Inc.
RELIABILITY OFFICE

FAILURE ANALYSIS REPORT

TPFC-2201 PRINTED IN U.S.A.

REPORT No. REL 1

1. GENERAL

PAGE 1 OF

PHOTOGRAPHS ATTACHED

FAILURE & CONSUMPTION REPORT No. 5101

DATE OF ANALYSIS May 19, 1964

FACILITY TRW, Cleveland, Ohio LOCATION 23555 Euclid Avenue

2. IDENTIFICATION

NAME Elect. Motor Stator NUMBER 1 TYPE OR MODEL 253800-1

MFR. Westinghouse, Lima, Ohio SERIAL No. 2

3. HISTORY This stator failed the dielectric strength requirements of TRW Specification No. 03-10129 after it was assembled into the motor housing.

4. ANALYSIS The analysis was conducted at Westinghouse in the presence of the writer. The following is the sequence of steps taken to reach a conclusion:

1. Westinghouse conducted a 500-volt dielectric test on the motor housing assembly which confirmed the TRW rejection.

2. Westinghouse slotted one side of the motor housing to release the grip on the stator. The stator was then removed from the motor housing.

3. The stator was subjected to the 500-volt dielectric test and again failed. (see below)

5. CONCLUSIONS Since it appears obvious that the failure was caused by foreign conductive material, the conclusion is: clean all future pump motor assemblies in acetone in an ultrasonic degreaser after all machining operations have been completed and prior to any additional assembly. Wrap or bag to keep out all foreign particles between all noncontinuous assembly operations.

6. RECOMMENDATIONS Provide an extra clean operation. Clean all future motor assemblies with acetone in a sonic cleaner after machining operations have been completed and prior to further assembly of the motor.

4. ANALYSIS (cont.): 4. The area in chich the failure occurred was washed in a solvent, scrubbed with a brissel brush and dried in an air blast and again subjected to the 500-volt dielectric test which it passed; it was then subjected to a 1000-volt and a 1500-volt test which it also passed. The breakdown appeared to take place from the motor winding (on antilead end approx. 1/16" from end lamination) to the lamination.

SUBMITTED BY: M. V. Ross

7. APPROVAL

FIGURE 3

Thompson Ramo Wooldridge Inc

CLEVELAND, OHIO U.S.A.

DUIA

OVERHAUL SHEET MODEL 253800-1 LUBE & COOLANT PUMP

DUIB

PARTS REMOVED

Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments
HSG/CONNECTOR SEAL WELD REMOVED PER DWG SK 19913						
UNIT COMPLETELY DISASSEMBLED IN EFFORT TO DETERMINE AREA OF BREAKDOWN						
MEGGER CHECK - POWER LEAD TO CONNECTOR ~ 100,000 MEGOHMS. POWER LEAD TO MOTOR HOWING ~ 1 MEGOHM APPLIED 50 VOLTS D.C.						
STATOR TO BE REMOVED FROM HSG.						
208210		1		STATOR	2	
208214-2		1		MOTOR HSG. ASSY.	1	
208270	B	1	89395	SPEED SENSOR	1	
208220				ELECT. CONNECTOR	6	
MOTOR RETURNED TO WESTINGHOUSE FOR FAILURE ANALYSIS						
[illegible]		1				
[illegible]		1		[illegible]		
[illegible]		1				

LOWER BEARING I.D.: LOWER JOURNAL O.D.:
UPPER BEARING I.D.: UPPER JOURNAL O.D.:
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET)

REASON FOR OVERHAUL: DIELECTRIC BREAKDOWN

E. JIRA, W.V. EDWARDS, L. HAYS, F. READENCE 5/12/64

REPLACEMENT

Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments
208270	B	1	89395	SPEED SENSOR	2	
208214-2		1		MOTOR HSG ASSY	4	
208210		1		STATOR	4	
SK 19934				ELECT. CONN.	3	(WAS 208220 S/N 3 - REWORKED TO "MATCH" VOLUTE HSG. HEIGHT)

AFTER ATTACHMENT OF ELECTRICAL CONNECTOR, IT WAS NOTED THAT 4 STRANDS OF SPEED SENSOR WIRE TO PIN F WERE BROKEN. THE WIRE WAS CUT OFF AND MOVED TO PIN D (THE NORMALLY OPEN PIN LOCATION). TEST STAND CONNECTOR REWORKED ACCORDINGLY.

MEGGER CHECK - POWER LEAD TO MOTOR HSG
APPLIED 500 VOLTS D.C.
30 SEC. 3750 MEGOHMS
1 MIN 3700 MEGOHMS
2 MIN 3100 MEGOHMS

[illegible]

Proof Pressure Test: Test Date , Pressure , Time , Results

Helium Leakage Test: Test Date , Results

LOWER BEARING I.D. LOWER JOURNAL O.D.:
UPPER BEARING I.D. UPPER JOURNAL O.D.:
SHAFT END PLAY
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

DATA PG. NO.

GOVT. INSPECTOR	TRW QUAL. ASSURANCE	OVERHAULED BY:
		DATE:

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After subassembly of bearing housing and motor housing with rotating group in place, place housing on V blocks. Measure radial movement of shaft by indicator by lifting shaft assembly from rest until clearance taken up within bearings. Repeat in different positions (90° apart) on each end of shaft.

Impeller End .0017 ; .0017 . Speed Sensor End .0017 ; .0015 .

Determine on go-no-go basis minimum air gap of .005, using .005 pin from bearing housing end. Check twice: .006 OK 2 places .015 will NOT Go 2 places

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Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

REPORT NO. 02-1099

Build of DU1B

Refer to Figure 2 for location of the following dimensions:

1. Dimension A - Obtain at a total of eight points in the following manner:

   A) Mark impeller near O.D. at two points 180° apart with corresponding marks on housing.

   B) Measure and record four times, impeller to housing clearances at impeller, without rotating impeller, at 90° increments:
   1) .004, 2) .0035, 3) .004, 4) .004.

   C) Measure and record four times, impeller to housing clearances at one point of housing and rotate impeller in 90° increments:
   1) .004, 2) .0035, 3) .004, 4) .005.

   D) A variation in excess of .0025 between any of the readings obtained in B and C above shall be cause for rejection.

2. Dimension B - Obtain at a total of four points in the following manner:

   A) Repeat Item 1.B above with the end play taken up toward the pump connector end:
   1) .007, 2) .0075, 3) .007, 4) .0065.

3. End Play - Determine end play by indicator method with 30# axial load applied to shaft:
   1) .0025, 2) .0024, 3) .0025, 4) .0025.

   A) End play less than .001 or greater than .003 shall be cause for rejection.

4. Dimension C - This dimension shall be taken at four points equally spaced:
   1) 6.0151, 2) 6.0155, 3) 6.0156, 4) 6.0152.

5. Dimension D - This dimension shall be taken at each impeller blade at a distance of approximately 1/32 inside impeller O.D. by rotating impeller:
   1) 6.6502, 2) 6.6500, 3) 6.6500, 4) 6.6504, 5) 6.6505, 6) 6.6504, 7) 6.6505.

6. Dimension G -

   A) For max. G, subtract minimum D from maximum C:

   Max. G = 6.6505 - 6.0151 = .6354

   B) For min. G, subtract maximum D from minimum C:

   Min. G = 6.6500 - 6.0156 = .6344

7. Dimension E - Measure and record E four places 90° apart:
   1) 7.545, 2) 7.545, 3) 7.545, 4) 7.545. ← RDG INCORRECT
   7.483 7.484 7.481 7.4835

8. Dimension F - Measure F four places 90° apart:
   1) 8.165, 2) 8.166, 3) 8.165, 4) 8.166. ← RDG INCORRECT (Depth micrometer bar to ride against motor assembly pilot bore during measurement.)

TPFC-34 REV. 8.167 8.1075 8.1865 [illegible]

Thompson Ramo Wooldridge Inc. REPORT NO. [illegible]

CLEVELAND, OHIO, U. S. A. Build S/N [illegible]

9. Dimension H -

A) For Max H, subtract min E from max F:

Max H = 8.166 - 7.545 = .621 ← RDG INCORRECT
8.108 - 7.484 = .624

B) For Min H, subtract max E from min F:

Min H = 8.165 - 7.545 = .620 ← RDG INCORRECT
8.1065 - 7.483 = .6235

10. Dimension J -

A) Optimum J = Max G + End Play + .005 - Min. H:

= .6354 + .0025 + .005 - .620 = .0229

B) Allowable J = Optimum J ± .001.

C) Actual J = Measured total shim thickness = _____

11. Dimension I -

A) Minimum I = Min. H + J - Max. G - End Play:

= _____ + _____ - _____ - _____ = _____

B) Maximum I = Max. H + J - Min. G + End Play:

= _____ + _____ - _____ + _____ = _____

C) Minimum I less than .004 or max. I greater than .015 shall be cause for rejection.

12. Dimension L - Identify four bearing housing connector stop posts. Install rotating assembly prior to addition of 208265 shims and measure L. Rotation of shaft should not be possible at this time due to impeller seating on housing throat:

1) 1.447, 2) 1.448, 3) 1.448, 4) 1.447.

Determine if end play has been taken up entirely. If not, contact Engineering for further instructions.

13. Dimension M - Install 208265 shims, rotating assembly, and install and torque 93007-10 bolts. Measure and record M (taken at same points as L):

1) [illegible], 2) [illegible]39, 3) [illegible], 4) [illegible]05.

14. Impeller/Throat Clearance Check:

Min. Imp/Throat Clearance = L - M - End Play

Min. Imp/Throat Clear = 1.447 - 1.439 - [illegible] = .0055 [illegible] 6/24/[illegible]

Min. Imp/Throat clearance less than .004 or greater than .006 shall be cause for rejection.

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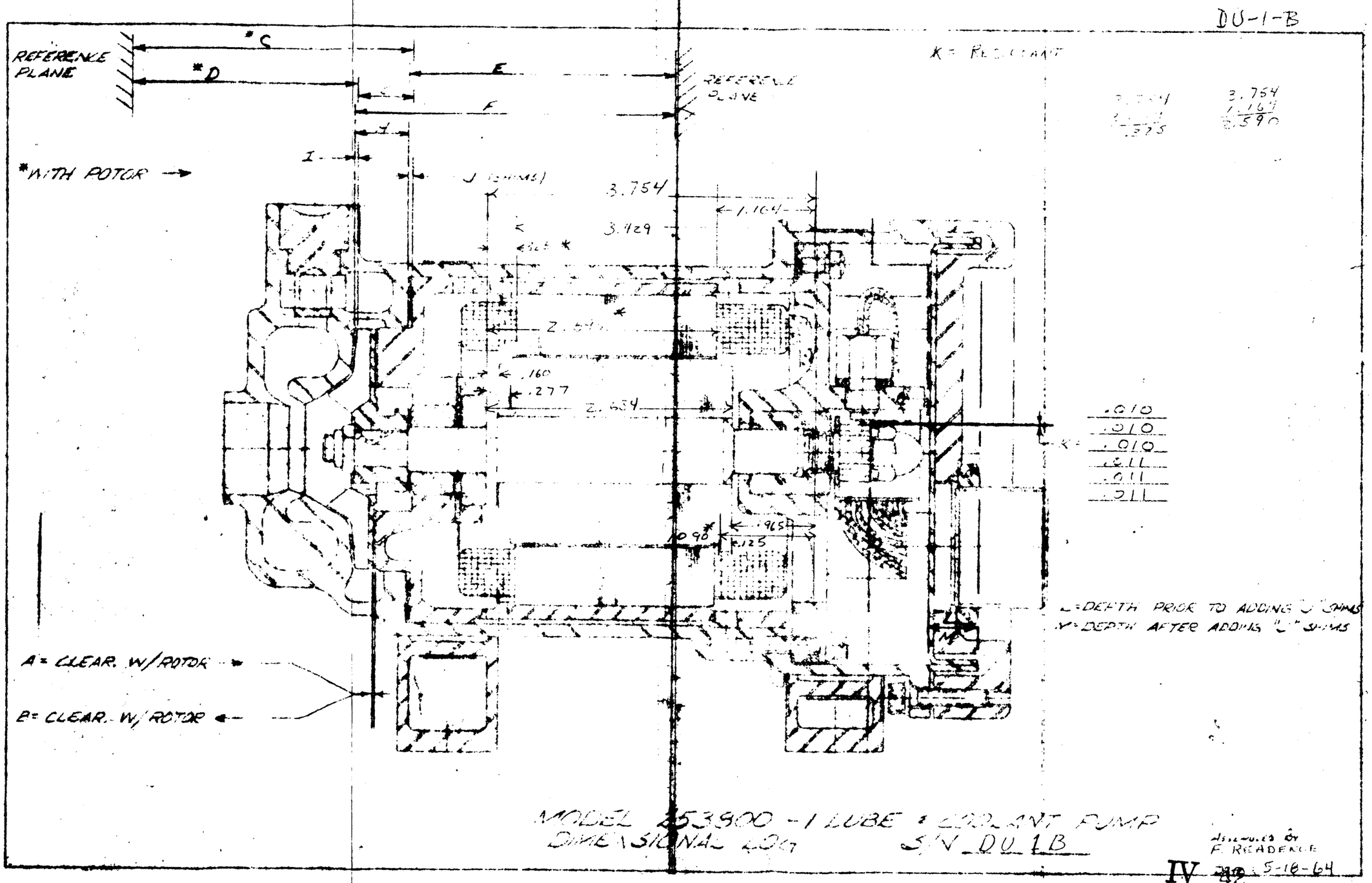
TPFC-34 REV.

Thompson Ramo Wooldridge Inc.
CLEVELAND, OHIO, U.S.A.

FIGURE 2



TPFC-557

Thompson Ramo Wooldridge Inc.

DU-1-B

TEST EQUIPMENT - SLAUGHTER DIELECTRIC TESTER MODEL 122
SLAUGHTER CO.
PIQUA, OHIO

TEST VOLTAGE of 1416 VAC APPLIED FOR 1 MIN:

RESULTS:

20°220 CONNECTOR ONLY - 57 MICROAMPS LEAKAGE

20°214-1 MTR. HSG ASSY - 130 MICROAMPS LEAKAGE

TEST PERFORMED PER MIL-STD-202A METHOD 201:
NO EVIDENCE of BREAKDOWN OR EXCESSIVE LEAKAGE

TITLE DIELECTRIC STRENGTH TEST
MODEL 2[illegible] LC/PMA S/N DU1B

ENGR. E. [illegible]
F. [illegible]
DATE 5/22/64
TEST NO.
PROJECT [illegible]
DATA PG. NO. 1

FLUID

E. Jiro

TRW JET & ORDNANCE DIVISION
THOMPSON RAMO WOOLDRIDGE INC.
23555 EUCLID AVENUE • CLEVELAND, OHIO 44117

MAY 28 1964

HELIUM LEAK TEST REPORT

Customer: Aerojet General Corp. Program: Snap 8 Date Tested: 5-26-64

Part Name: L & C / PMA Serial No.: DU 1B Drawing No.: 253800-1

Specification and/or Procedure to which test is Performed: Mil-Std-271C

Sensitivity Check on Calibrated Leak: Direct - 2.5 - 5.5 X 10^{-8} cc/sec of helium

Smallest Leak Detectable: 4.5 X 10^{-10} cc/sec of helium

Leak rate permitted: 1 X 10^{-7} cc/sec of helium

Pressure: at or slightly above atmospheric Time: 2 minutes

Description of Procedure:

1) Pumped down part with external pump - approximately 2 hours.
2) MS9AB (leak detector) connected to larger diameter tube & SC4 Calibrated Leak (5.5 X 10^{-8} cc/sec of helium) connected to smaller diameter tube.
3) P/D with MS9AB - approximately 4 hours to obtain less 10^{-3} mm Hg.
4) Sprayed helium on the pump, connections, joints. No indication.
5) Hood over part - Hood enclosed all of the part except approximately 2" required to connect the hose to tubes.
6) Closed SC4 - 0.2 on leak indicator.
7) Opened SC4 - 0.38 on leak indicator. 1 minute to stabilize.
8) Helium forced into hood - at or slightly above atmospheric pressure.
9) SC4 Closed - 0.2. No reaction above 0.2.
10) SC4 Opened - 0.38. Held for 2 minutes.
11) Calculations: (see paragraph 6.3.1 of Mil-Std-271C)
12) LR = $\frac{5.5 \times 10^{-8} \text{ cc/sec of helium} \times 0}{.18 \text{ (2nd reading)} \quad 0 \text{ (1st reading)}}$ Using 0.2 as zero point.
13) LR = 0
14) Leak rate less than 1 X 10^{-7} cc/sec of helium.
15) Part OK.

John Sudick
John Sudick
Materials Engineering Department

Witnessed by A. A. Trykowski, USAF Inspector

IV. 44

FIGURE 4

Thompson Ramo Wooldridge Inc

TANK	FLOW GPM	INLET PRESSURE	DISCH. PRESS.	PUMP PRESSURE HSG PSI	PHASE 1		PHASE 2		PHASE 3				INLET	OUTLET TEMP °F	MTR. PHASE 1 TEMP °F	MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F	UPPER BRG. HSG. TEMP. °F	RETURN FLOW TEMP °F	LOWER HSG. TEMP °F	UPPER HSG TEMP °F	OUTLET LEAD END EXT TEMP °F	IMP SUCTION PRESS. 1 PSIG [redacted]	UPPER MTR CAVITY PR. PSIG	LOWER MTR CAV PSIG	CLOCK TIME	INDIVIDUAL TEST TIME HRS.	MIN.	PUMP ACCUM TIME HRS	MIN
14.1	27.0	8.8	26.8	30.3	3.51	288	3.51	281	3.6	290			7760	100	145	145	151	149	126	227	190	145	14.0	16.5	15.5	17.24	0	5	0	5
3.95	17.0	3.1	42.3	53.5	3.20	242	3.20	240	3.28	248			7750	NOT	250	250	249	245	245	308	315	248	9.8	19.0	18.8		0	25		
	12.0	3.1	49.0	60.2	3.10	228	3.10	222	3.17	230			7765	REACING PROPERLY	256	256	254	250	250	309	315	255	12.5	21.8	21.3		0	30		
6.55	22.0	3.2	34.9	46.0	3.30	255	3.30	250	3.38	260			7730		261	263	264	258	257	308	315	260	9.8	17.8	17.2		0	38		
				STOP																							0	41	0	41

CHECKED THERMOCOUPLES — ALL READING 12° HIGH DUE TO SETTING UP IN ERROR FOR IRON-CONSTANTAN — WILL INDICATE (ELECTRICALLY) EXTERIOR THERMOCOUPLES TO AVOID POSSIBILITY OF GROUND LOOP.

PUMP RELAXION FOR 400 LBS 208

TRANSFORMER RATIO 2:1 AMMETER WESTON 6518 WATTMETER WESTON 14087 VOLTMETER WESTON 110759

LINE AMPS = AVERAGE PHASE AMP READING × TRANSFORMER RATIO

TOTAL WATTS = PUMP PHASE WATTS × TRANSFORMER RATIO

COMMENTS: 5/26/64 BAR. PRES. = 14.3 PSIA

TRW QUALITY ASSURANCE

GOVERNMENT INSPECTOR

TITLE MODEL 253000-1 LUBE & COOLANT PUMP

PERFORMANCE CHECK

FLUID ET 378

DRAFTER WVE
F.R.
DATE 5/26/64
SER. NO DU1B
DATA PG NO 2
PROJ. 516-004236-08

FIGURE 4

Thompson Ramo Wooldridge Inc

Tank Pr.	Flow GPM	Inlet Pressure	Disch. Press.	Pump Pressure								Net
		START										
14.3	16.5	10.5	33.0		4.75	410	4.70	400	4.75	412	7685	94
14.3	17.0	9.6	32.0	42.7	4.42	378	4.40	378	4.45	380	7720	96
	16.8	10.0	52.5	56.8	3.70	292	3.68	290	3.71	295	7793	117
	17.0	8.45	47.0	52.8	3.46	262	3.44	260	3.50	265	7832	143
	16.8	5.1	44.0	53.2	3.41	241	3.35	241	3.41	246	7766	

INLET TEMP THERMOCOUPLE NOT FUNCTIONAL. RESTART & STOP

INTERIM REPLACEMENT THERMOCOUPLE & RESTART

ATTEMPTED TO FIND REASON FOR VARIATION BETWEEN INLET TEMP. & RESERVOIR TEMP. & ALSO PUMP INTERNAL TEMP. APPROX 50° LOWER THAN EXTERNAL TEMPS.

STOP

RESTART PUMP OPERATED AT 17 GPM

STOP COULD NOT FIND CAUSE

RESTART PUMP OPERATED AT 17 GPM

STOP

7/8/64 START PUMP OPERATED AT 17 GPM. PUT THERMOMETER IN RESERVOIR IT AGREED WITH INLET TEMPS.

PUT THERMOCOUPLE ON CONNECTOR FOUND PUMP INTERNAL TEMP. READING SAME AS CONNECTOR TEMPS.

STOP SIGNAL PUMP & CHANGED TO LOW TEMP. LOOP FOUND PUMP INTERNAL TEMPS. AGAIN FOLLOWED CONNECTOR TEMP.

PUMP RATING IN FOR 400 PSI 208

TRANSFORMER RATIO 2:1 WESTON 0518 WESTON 14087 WESTON 110779

LINE AMPS AVERAGE PHASE

TOTAL WATTS

COMMENTS: 5/20/64 BAR. PRESS. 14.3 PSIA

Outlet Temp °F	Mtr Phase 1 Temp °F	Mtr Phase 2 Temp °F	Return Flow Temp °F	Upper Hyd. Temp °F	Tap Suction Press. P.S.I.G.	Upper Hyd. Cont. Pr. P.S.I.G.	Clock Time	Thermo Cal Test Time Hrs.	Thermo Cal Test Time Min.	Pump Accum. Time Hrs.	Pump Accum. Time Min.
							0935			0	41
	94 94	93 86	86 100	94 100				0	03		
	100 100	95 85	97 104	130 107				0	06		
	120 120	125 116	116 154	55 125				0	11		
	148 148	150 145	136 210	295 150				0	16		
	240 241	236 235	232 300	305 290				0	45		
								1	34	1	45
							1115	0	00	1	45
								0	46	2	31
							1330				
								0	58	2	57
							1600	0	00		
								0	20	3	19
							1710	0	00	3	19
								0	30	3	49
							0848	0	00	3	49
								0	54	4	43

TRW SOAT ASSEMBLY

AMERICAN MASTER

MODEL ASSEMBLY & LIQUID COOLANT PUMP

STARTUP & LEVELOPMENT TEST CALIBRATION
(PAR. IV.D.3 OF 02-1099)

SER. NO.

DATA PG. NO. 3

SHEET 3 OF

PROJ. 573-

FIGURE 4

Thompson Ramo Wooldridge Inc.

FLOW GPM	INLET PRESSURE / DISCH. PRESSURE	PHASE							OUTLET TEMP °F	MTR. PHASE 1 TEMP °F / MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F / UPPER BRG. HSG. TEMP °F	RETURN FLOW TEMP °F / LOWER BRG. HSG. TEMP °F	UPPER HSG. TEMP °F / ANTI LEAKAGE EXT. TEMP °F		IND. SUCTION PRESS. IN. HG. / [redacted]	UPPER MTR. CAVITY PR. PSIG / LOWER MTR. CAV. PR. PSIG	CLOCK TIME	INDIVIDUAL TEST TIME HRS.	MIN.	PUMP TOTAL RUN TIME HRS.	MIN
																			4	43
	START	INSTALLED THERMOCOUPLE IN UPPER MTR. HSG. CAVITY														1500	0	0		
	STOP	STILL HAD TEMP. "LAG"															0	10	4	53
	START	AFTER BLEEDING PUMP TO CREATE AIR POCKET NEAR CONNECTOR														1516	0	0	4	53
		NO EFFECT																		
17.0	12.3 53.3	3.40 248	3.38 247	3.42 250	6.80	1490	7810	249		206 207	205 208	202	200			1527	0	11	5	04
17.0	12.3 53.3	3.40 248	3.38 247	3.42 250			7805	255		215 215	214 215	210	208			1538	0	22	5	15
17.0	12.3 53.3	3.40 248	3.38 247	3.42 250			7805	255		220 220	219 220	214	215			1549	0	33	5	26
17.0	12.3 53.3	3.40 248	3.38 247	3.42 250			7805	255		222 222	220 220	217	215			1600	0	44	5	37
17.0	12.3 53.3	3.40 248	3.38 247	3.42 250			7805	256		223 224	220 222	218	215			1611	0	55	5	48
17.0	12.3 53.3	3.40 248	3.38 247	3.42 250			7805	256		225 225	222 224	219	216			1622	1	06	5	59
17.0	12.3 53.3	3.40 248	3.38 247	3.42 250	6.80	1490	7805	256		225 225	222 224	220	216			1630	1	14	6	07
5/29/60	START															1005	0	00	6	07
	STOP																0	24	6	31

PUMP BREAK IN FOR: 400 HRS. 208 VOLT

TRANSFORMER RATIO: 2:1 AMMETER: WELTON 6518 VOLTMETER: WELTON 14087 WATTMETER: WELTON 110759

LINE AMPS: AVERAGE PHASE AMPS READING × TRANSFORMER RATIO

TOTAL WATTS: TOTAL WATTS READING × TRANSFORMER RATIO

COMMENTS:

TRW QUALITY ASSURANCE

COMPANY INSPECTOR

TITLE: MODEL 253800-1 LIGE & CRYOGENIC PUMP

ENGR: EL
FK
DATE: 5/28/61
SERIAL NO: DU18
DATA PG NO: 4
PROJ:

FIGURE 4

Thompson Ramo Wooldridge Inc

FLOW GPM	INLET PRESSURE	DISCH. PRESSURE										
			START									
0	5.1	55.9	65.2	3.00	188	3.00	188	3.05	191	6.04	1150	7845	250
3.1	5.1	57.2	66.2	3.05	200	3.05	200	3.10	205	6.14	1210	7845	245
6.0	5.1	55.5	64.8	3.12	210	3.10	210	3.18	203	6.27	1266	7825	255
9.0	15.0	53.2	62.0	3.19	220	3.19	220	3.23	223	6.41	1320	7825	255
12.0	5.0	50.0	59.4	3.26	230	3.25	230	3.30	235	6.54	1380	7810	255
15.0	5.0	48.5	57.9	3.35	240	3.32	240	3.38	245	6.70	1450	7800	251
17.0	4.9	45.8	55.3	3.28	245	3.35	245	3.40	250	6.76	1470	7775	251
18.0	5.0	44.2	53.6	3.40	250	3.39	250	3.44	255	6.82	1510	7785	251
21.0	4.9	39.3	48.8	3.45	259	3.42	258	3.50	260	6.92	1550	7775	251
24.0	5.0	32.8	42.2	3.50	262	3.46	260	3.52	268	7.00	1580	7775	252
27.0	5.1	24.5	33.8	3.52	268	3.50	268	3.57	272	7.08	1610	7770	251
27.5	5.1	23.0	32.3	3.52	268	3.50	268	3.57	272	7.08	1616	7770	251
27.4	3.0	21.0	32.0	3.52	270	3.50	268	3.57	263	7.06	1602	7770	251
23.9	3.0	28.6	40.2	3.50	262	3.46	260	3.52	261	6.92	1580	7770	251
21.0	3.0	36.5	47.9	[illegible]	256	3.43	257	3.50	261	6.92	1552	[illegible]	251
18.0	3.0	41.7	53.1	3.40	250	3.38	249	3.45	255	6.82	1506	7785	252
17.0	3.0	43.4	54.8	3.40	242	3.37	247	3.4[illegible]	250	6.80	1490	7795	252
15.0	3.0	46.3	57.7	3.33	240	3.31	240	3.38	245	6.66	1450	7795	252
12.0	3.1	49.3	60.6	3.25	230	3.23	230	3.30	235	6.52	[illegible]	7805	253
9.0	3.1	57.8	63.1	3.20	220	3.18	220	3.25	225	6.42	1330	7820	253
6.0	3.0	53.5	64.9	3.15	211	3.12	212	3.20	218	6.31	1282	7835	252
3.0	3.0	54.8	66.2	3.08	200	3.05	200	3.10	206	6.15	1212	7845	250
0	3.0	54.5	65.9	3.00	190	3.00	190	3.05	195	6.04	1150	7845	250

POWER FACTOR	OVERALL EFF. %	MTR. PHASE 1 TEMP °F	MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F	RETURN FLOW TEMP °F	UPPER MTR. TEMP °F	IMP. SUCTION PRESS. PSIG	UPPER MTR. CAVITY PR. PSIG	CLOCK TIME	INDIVIDUAL TEST TIME HRS.	INDIVIDUAL TEST TIME MIN.	TOTAL ELAPSED TIME HRS	TOTAL ELAPSED TIME MIN
												6	31
									1347	0	00	6	31
.522	0	226 / 230	225 / 227	220 / 300	247	225	18.4	27.5 / 27.0	1412	0	25		
.546	7.4	225 / 225	223 / 224	225 / 249	266	216	19.0	25.0 / 24.8	1415	0	28		
.561	13.4	226 / 226	225 / 225	220 / 250	257	220	19.4	23.5 / 23.0	1420	0	32		
.575	18.5	225 / 225	220 / 222	216 / 250	250	216	16.0	22.2 / 22.0	1425	0	37		
.591	22.3	221 / 221	219 / 221	215 / 249	255	215	14.5	20.8 / 20.2	1430	0	43		
.601	26.0	220 / 220	217 / 220	214 / 246	255	212	15.0	20.0 / 19.8	1443	0	56		
.609	27.6	220 / 220	216 / 220	213 / 246	255	213	14.2	19.2 / 19.0	1450	1	03		
.615	27.8	220 / 219	216 / 219	214 / 246	255	212	14.0	19.0 / 17.8	1457	1	10		
.623	28.7	220 / 220	217 / 220	214 / 249	255	212	13.0	18.0 / 17.5	1505	1	18		
.628	27.9	221 / 221	217 / 220	217 / 249	260	215	12.0	17.0 / 16.8	1511	1	24		
.635	24.6	222 / 223	220 / 221	217 / 250	260	215	10.0	15.6 / 15.0	1517	1	30		
.635	24.0	223 / 223	220 / 220	216 / 249	260	215	9.8	15.0 / 14.8	1520	1	33		
.629	24.1	224 / 223	220 / 221	216 / 249	260	215	7.5	16.0 / 16.2	1544	1	57		
.629	26.5	225 / 224	220 / 223	217 / 249	261	216	7.8	14.0 / 15.6	1548	2	01		
.623	28.2	223 / 223	220 / 223	217 / 249	260	216	10.0	16.0 / 15.6	1553	2	06		
.614	27.6	222 / 223	219 / 222	215 / 249	258	215	11.0	17.3 / 17.0	1558	2	11		
.609	27.2	222 / 221	221 / 221	215 / 249	256	215	11.8	16.0 / 16.5	1603		16		
.603	26.0	221 / 221	219 / 220	215 / 249	256	215	12.6	19.0 / 17.6	1607	2	20		
.592	22.8	220 / 220	219 / 220	214 / 246	255	214	13.8	20.1 / 19.8	1613	2	26		
.576	18.6	220 / 220	219 / 220	215 / 249	255	215	14.4	21.0 / 20.8	1620	2	33		
.565	13.2	220 / 220	219 / 215	215 / 249	255	214	15.1	22.0 / 21.5	1625	2	36		
.541	7.1	220 / 221	220 / 220	215 / 250	255	215	16.4	23.0 / 22.8	1628	2	41		
.529	0	225 / 221	220 / 226	225 / 275	261	216	17.0	25.3 / 25.0	1631	2	44	9	15

400 [illegible] 208 [illegible]

WESTON 65 B — WESTON 4087 — WESTON 1057

COMMENTS: [illegible]

5/24/[illegible] BAR. PRESS. 14.4 PSIA

MODEL [illegible]

ELEC. [illegible] TEST CHART

TRW [illegible] 02-1099

DATE 5/29/[illegible]

SER. NO [illegible]

DATA PG. NO 3

PROJ. [illegible]

FIGURE 4

Thompson Ramo Wooldridge Inc.

FLOW GPM	INLET PRESSURE	DISCH. PRESS.	PUMP PRESSURE RISE PSI											
	START LIFE TEST													
17.0	3.0	44.0	55.4	3.38	245	3.35	245	3.41	250	6.76	1480	7795	253
17.0	3.0	44.0	55.4	3.40	247	3.35	245	3.41	250	6.77	1484	7795	251
17.0	3.0	44.0	55.4	3.40	246	3.35	245	3.41	250	6.77	1482	7795	251
17.0	3.0	43.8	55.2	3.40	246	3.36	245	3.41	250	6.78	1482	7795	252
17.0	3.0	43.8	55.2	3.40	246	3.36	245	3.41	250	6.78	1462	7795	252
17.0	3.0	43.8	55.2	3.40	246	3.36	245	3.41	250	6.78	1482	7795	252
16.8	1.3	38.5	51.5	3.38	242	3.35	3.35	3.41	249	6.76		7780	262
17.1	2.9	43.5	54.9	3.36	242	3.35	242	3.40	250	6.74	1468	7775	263
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.43	250	6.77	1480	7775	251
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.43	250	6.77	1480	7775	250
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7775	250
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	251
17.1	5.1	45.8	55.0	3.38	245	3.35	245	3.42	250	6.77	1480	7780	253
17.1	5.1	45.8	55.0	3.39	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	252
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	249
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	5.0	45.8	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254
17.1	4.1	44.5	54.7	3.38	245	3.35	245	3.42	250	6.77	1480	7780	250
17.0	3.1	43.7	54.9	3.38	245	3.35	245	3.42	250	6.77	1480	7780	253

OUTLET TEMP °F	MTR. PHASE 1 TEMP °F / MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F / UPPER BRG. HSG. TEMP °F	RETURN FLOW TEMP °F / LOWER WHEEL TEMP °F	UPPER HSG. TEMP °F / REF. LEAK EXT. TEMP	DATE	IMP. SUCTION PRESS. IN PSIG	UPPER MTR. CAVITY PR. PSIG / LOWER MTR. CAV. PR. PSIG	CLOCK TIME	CHRONOLOGICAL TEST TIME HRS. MIN.	PUMP TOTAL ACCUM. RUN TIME HRS. MIN
	225 224	221 223	217 250	256 217	5/29/64	12.1	18.1 17.8	1631	0 00	9 15
	224 223	220 223	216 250	256 215		12.1	18.0 18.0		0 10	9 25
	224 223	220 223	216 250	256 215		12.1	18.0 17.8		0 20	9 35
	221 221	220 221	215 250	257 215		12.0	18.0 17.8		0 30	9 45
	221 221	220 221	215 250	257 215		12.0	18.0 17.8		0 40	9 55
	221 221	220 220	215 249	256 215	5/29/64	12.0	18.0 17.8	1731	0 50	10 05
	229 230	229 228	225 251	264 221	6/2/64	5.5	16.0 15.5	0758	87 20	97 35
	229 229	228 227	223 251	263 220		12.0	19.5 19	0847	88 16	98 31
	224 225	223 251	220 247	229 215		14.4	20.7 20.2	11.05	90 34	100 49
	222 223	220 222	217 245	255 215		14.5	20.2 20.0	11.10		
	221 222	220 221	217 245	255 215		14.5	20.2 20.0	11.15		
	222 223	221 221	217 246	256 215		14.5	20.2 20.0	11.20		
	222 224	222 222	217 248	258 215		14.5	20.2 20.0	11.25		
	229 224	224 218	219 250	260 217		14.5	20.2 20.0	11.30		
	224 225	224 218	220 250	260 217		14.5	20.3 20.0	11.35		
	224 225	224 219	220 250	260 217		14.5	20.2 20.0	11.40		
	225 225	224 224	220 250	260 219		14.5	20.3 20.0	11.45		
	220 221	220 220	219 245	253 213		14.5	20.2 20.0	11.50		
	215 216	215 215	210 243	251 208		14.5	20.2 20.0	11.55		
	223 225	223 229	219 248	258 217		14.4	20.3 20.0	12.55		
	223 225	223 229	219 247	258 217		14.4	20.3 20.0	13.00		
	225 225	224 224	220 248	258 217		14.4	20.3 20.0	13.05	92 34	102 49
	225 226	225 225	220 249	258 217		14.4	20.3 20.0	13.10		
	219 220	219 218	215 249	252 210		13.2	19.0 19.0	13.51		
	220 221	220 220	216 246	256 215		12.0	19.7 19.2	13.53	93 22	103 37

PUMP PLEASURE FOR

400 208

TRANSFORMER RATIO 2:1 WESTON 6518 WESTON 4087 WESTON 1107

TOTAL WATTS

COMMENTS: 6/2/64 BAR. PRES. = 14.3 PSIA

PROJECT ENGINEER

MODEL 25300-1 SUMP

DEVELOPMENT ABBREVIATED LIFE TEST
(TRW V.L.4 of 02-1099)

ET 378

DER. NO DU 6
DATA PG. NO 6

FIGURE 4

Thompson Ramo Wooldridge Inc.

FLOW GPM	INLET PRESSURE / DISCH. PRESS.	PUMP PRESSURE RISE PSI	PHASE																					
17.0	2.8 / 43.5	55.0	3.38	245	3.35	245	3.42	250	6.77	1480	7785	254	221	223	221	221	217	246	256	215	11.9	19.0	185	14:09	93	33	103	48
17.0	2.6 / 43.0	54.7	3.38	245	3.35	245	3.42	250	6.77	1460	7775	254	223	224	213	222	219	247	259	217	11.5	18.5	18.2	14:16				
17.0	2.4 / 42.8	54.7	3.38	245	3.35	245	3.42	250	6.77	1460	7775	251	220	221	220	220	217	249	255	215	11.3	18.0	17.7	14:38				
17.0	2.2 / 42.5	54.6	3.38	245	3.35	245	3.42	250	6.77	1480	7775	251	221	221	220	220	217	246	256	215	10.7	18.2	18.3	14:47				
17.0	2.0 / 42.2	54.5	3.38	245	3.35	245	3.42	250	6.77	1480	7775	252	220	221	221	221	216	248	258	215	10.5	17.8	17.5	14:55	94:24		104	39
17.0	2.0 / 42.0	54.3	3.38	245	3.35	245	3.42	250	6.77	1480	7775	259	223	224	221	221	217	249	260	216	10.3	17.8	17.5	15:07				
17.0	1.6 / 41.7	54.4	3.38	245	3.35	245	3.42	250	6.77	1480	7780	254	225	225	225	224	220	250	263	218	10.0	17.7	17.3	15:25				
17.0	1.4 / 40.3	53.2	3.38	245	3.35	245	3.42	252	6.77	1484	7780	248	220	221	220	220	217	238	299	213	8.5	16.5	16.0	15:36				
16.8	1.2 / 31.8	44.9	3.38	245	3.35	245	3.42	252	6.77	1484	7780	247	216	218	219	217	210	240	247	210	4 (IN. HG.)	11.5	7.0	15:42				
16.6	1.1 / 28.8	42.0	3.38	245	3.35	245	3.42	252	6.77	1484	7780	246	216	218	217	217	210	238	259	209	14.5 (IN. HG.)	9.8	9.5	15:50	95:19		105	34
17.0	2.9 / 43.8	55.2	3.38	245	3.35	245	3.42	250	6.77	1482	7780	246	215	216	215	215	211	237	250	208	12.0	18.4	18.0	16:20				
17.0	2.9 / 43.8	55.2	3.38	245	3.35	245	3.42	250	6.77	1480	7780	246	215	216	215	215	211	237	259	208	12.0	18.4	18.0	16:25	95	54	106	09
16.8	1.5 / 42.3	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7780	250	222	222	221	221	217	243	255	215	10.0	17.8	17.5	07:50	111	19	121	34
17.1	2.9 / 43.8	55.2	3.38	245	3.35	245	3.42	250	6.77	1480	7780	250	222	222	221	221	217	245	255	215	12.1	19.1	18.7	8:[illegible]	112	24	122	39
12.0	4.9 / 51.7	61.1	3.26	230	3.23	230	3.30	234	6.53	1388	7790	250	220	220	220	220	215	244	252	213	15.9	22.0	21.6	09:17				
12.0	4.9 / 51.7	61.1	3.26	230	3.23	230	3.30	234	6.53	1388	7790	250	220	220	220	220	215	244	252	213	15.9	22.0	21.6	09:27				
12.0	5.1 / 51.8	61.0	3.27	230	3.23	230	3.30	235	6.53	1390	7790	250	220	220	219	220	215	244	252	213	16.0	22.1	21.8	09:47	113	16	123	31
12.0	4.1 / 50.7	60.9	3.27	230	3.23	230	3.30	235	6.53	1390	7790	250	220	220	219	220	215	241	250	211	14.8	21.5	21.0	10:00				
12.0	3.0 / 49.3	60.7	3.27	230	3.23	230	3.30	235	6.53	1390	7785	250	219	220	219	219	215	240	250	211	12.7	20.7	20.3	10:40				
12.0	2.1 / 48.7	60.9	3.27	230	3.23	230	3.30	235	6.53	1390	7795	250	218	219	219	218	215	240	250	210	12.6	20.0	19.7	11:07	114	36	124	51
12.0	1.8 / 48.0	60.5	3.27	230	3.23	230	3.30	235	6.53	1390	7795	249	219	219	219	219	219	240	250	210	12.0	20.0	19.5	11:30				
12.0	1.6 / 47.2	59.9	3.27	230	3.24	230	3.30	235	6.54	1390	7785	248	219	219	219	219	215	240	250	210	11.0	19.2	19.0	11:40				
12.0	1.9 / 46.5	59.9	3.27	230	3.24	230	3.30	235	6.54	1390	7785	247	220	220	219	219	215	240	250	210	10.5	19.0	18.7	11:45	115	14	125	29
12.0	1.2 / 41.8	54.9	3.27	230	3.24	230	3.30	235	6.54	1390	7800	250	220	220	220	220	215	243	253	213	4.9	16.3	16.0	14:35	118	04	128	19
11.9	1.0 / 32.2	45.5	3.27	230	3.24	230	3.30	235	6.54	1390	7800	249	220	221	221	220	215	241	252	215	8" HG	11.0	10.5	14:45	118	14	128	29

NPSH

NPSH

INTERNAL TEMPS FOR REFERENCE ONLY

OUTLET TEMP °F	MTR. PHASE 1 TEMP °F / MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F / UPPER BRG. MTR. TEMP. °F	RETURN FLOW TEMP °F / LOWER MTR. TEMP °F	UPPER MTR. TEMP °F / LOWER LEAKOFF EXT. TEMP °F	DATE	IMP. SUCTION PRESS. IN PSIG / UPPER MTR. CAVITY PR. PSIG	UPPER MTR. CAVITY PR. PSIG / LOWER MTR. CAV. PR. PSIG	CLOCK TIME	INDIVIDUAL TEST TIME HRS. MIN.	TOTAL ACCUM. RUN TIME HRS. MIN.
	STARTED CHANGEOVER TO "NAVY" CONDITION									

PUMP BREAKER

400 208

TRANSFORMER RATIO 2:1 AMMETER WESTON 6518 WESTON 19087 VOLTMETER WESTON 110759

LINE AMPS AVERAGE PHASE AMPS (MULTIPLIED BY TRANSFORMER RATIO)

TOTAL WATTS (SUM OF PHASE WATTS X THE TRANSFORMER RATIO)

COMMENTS: 6/2/64 BAR PRESS. 14.3 PSIA
6/3/64 BAR PRESS 14.3 PSIA

NEW OUTLET ASSEMBLY

SUBMERSIBLE PROBE

MODEL 253800-1 LIQUID & CONTAMINANT PUMP

DETAIL RECEIVING INSPECTION (PAR IV.D.7 of 02-1099)

SHEET 3 OF

SER. NO 001B
DATA PG NO 7

FIGURE 4

Thompson Ramo Wooldridge Inc.

FLOW GPM	INLET PRESSURE DISCH PRESS.			PHASE							
17.0	3.0	44.0	55.3	3.38	245	3.35	245	3.42	250	6.77	1480	7785	250
16.9	2.5	43.2	55.1	3.38	245	3.35	245	3.42	250	6.77	1480	7785	252
17.0	3.0	43.8	55.2	3.38	245	3.35	245	3.42	250	6.77	1480	7785	252
22.0	5.0	36.5	45.9	3.45	259	3.42	258	3.50	262	6.91	1558	7765	254
22.1	4.9	36.5	46.0	3.45	259	3.42	258	3.50	262	6.91	1558	7765	254
22.0	4.1	35.7	46.0	3.45	259	3.42	258	3.50	262	6.91	1558	7765	256
22.0	3.0	34.2	45.6	3.45	259	3.42	258	3.50	262	6.91	1558	7765	254
22.0	2.8	34.0	45.6	3.45	259	3.42	258	3.50	262	6.91	1558	7765	250
22.0	2.6	33.5	[illegible]	3.46	260	3.45	260	3.52	265	6.95	1570	7760	244
22.0	2.4	33.2	45.8	3.47	260	3.45	260	3.52	266	6.96	1572	7765	246
22.0	2.2	32.5	44.7	3.47	260	3.45	260	3.52	265	6.96	1570	7765	246
21.8	2.0	28.8	41.2	3.47	260	3.45	260	3.52	265	6.96	1570	7765	241
22.0	1.8	27.2	39.8	3.47	260	3.45	260	3.52	265	6.96	1570	7765	248
22.0	1.6	25.5	38.3	3.47	260	3.45	260	3.52	265	6.96	1570	7765	246
22.0	1.4	21.0	34.0	3.47	260	3.45	260	3.52	265	6.96	1570	7765	246
17.0	3.0	43.8	55.2	3.38	245	3.35	245	3.42	250	6.77	1480	7785	246
										POWER		FAILURE	

NPSH

LOOKED THERMOCOUPLE AT UPPER MTR. HSG. PRES. TAP AND RECALIBRATED TEMP. READOUT

															START
17.0	3.1	43.5	54.8	3.38	245	3.35	242	3.42	250	6.77	1474	7785	254	275
17.0	3.0	43.2	54.6	3.38	245	3.35	242	3.42	250	6.77	1474	7785	254	275
17.1	4.0	44.3	54.7	3.38	245	3.35	242	3.42	250	6.77	1474	7775	254	275
17.0	3.0	43.5	54.9	3.38	245	3.35	242	3.42	250	6.77	1474	7775	256	279
17.0	3.0	43.5	54.9	3.38	245	3.35	242	3.42	250	6.77	1474	7775	255	278

PUMP SHUTDOWN DUE TO POWER FAILURE LAST KNOWN OPERATING TIME WAS 6-6-64

INTERNAL TEMPS. FOR REFERENCE ONLY

UPPER MOTOR CAVITY °F	MTR PHASE 1 TEMP °F	MTR PHASE 2 TEMP °F	MTR PHASE 3 TEMP °F	BRG. HSG. TEMP. °F	RETURN FLOW TEMP °F	LOWER MOTOR TEMP °F	UPPER HSG TEMP. °F	ANTI LEAKAGE EXT. TEMP. °F		INP SUCTION PRESS. 1 PSIG	UPPER MTR. CAVITY PR. PSIG	LOWER MTR CAV PR. PSIG	CLOCK TIME	INDIVIDUAL TEST TIME HRS.	MIN.	PUMP ACCUM RUN TIME HRS.	MIN
	220	220	220	220	215	241	251	213	6-3-64	12.5	19.0	18.7	1530	118	39	129	14
	221	222	221	221	217	244	255	215	6-4-64	11.2	18.7	18.3	0800	135	29	145	44
	221	222	221	221	217	245	255	215		12.2	19.0	18.7	0815	135	44	145	59
	224	225	224	224	219	248	256	218		12.0	18.5	18.0	0910	136	39	146	54
	224	225	224	224	220	248	259	217		12.0	18.6	18.2	9:40	137	09	147	24
	227	229	226	227	224	250	261	220		11.0	18.0	17.5	10:30	137	59	148	14
	225	226	225	225	221	246	255	219		9.7	16.5	16.0	10:52	138	21	148	36
	223	224	223	224	219	240	250	216		9.5	15.0	15.6	10:56	138	25	148	40
	219	220	219	220	215	239	246	212		9.3	15.5	15.0	11:00	138	29	148	44
	216	217	216	217	213	236	246	210		8.5	15.1	14.8	11:08	138	37	148	52
	215	217	217	217	211	236	246	210		7.8	14.7	14.0	11:10	138	39	148	54
	215	217	216	217	210	234	243	208		3.2	12.0	11.7	11:12	138	41	148	56
	216	218	216	216	210	234	244	209		2.0	11.0	11.0	11:15	138	44	148	59
	217	218	216	217	210	236	246	210		0	9.8	9.6	11:19	138	48	149	03
	216	219	218	217	210	236	247	210		13 (in Hg)	7.8	7.5	11:21	138	50	149	05
	215	215	215	215	210	240	250	209		12.2	18.6	18.2	11:40	139	09	149	24
													1300	140	29	150	44
													1545	140	29	150	44
	214	215	214	215	210	249	257	207		10.5	18.7	18.2	16:10	140	54	151	09
	220	220	220	220	215	249	256	214	6-4-64	10.5	18.7	18.2	16:25	141	09	151	24
	221	221	220	220	216	245	253	215	6-5-64	12.9	20.0	19.7	0755	157	39	167	54
	223	224	223	223	217	249	255	215		11.5	19.2	19.0	1005	159	49	170	04
	222	223	221	221	216	249	253	215	6-5-64	11.4	19.2	19.0	1615	165	59	176	14
													0430	178	14	188	29

400 ~ 208

2:1 WELTON 6578 WELTON 14687 WELTON 110759

6-4-64 BAR. PRESS. 14.4 PSIA
6-5-64 BAR. PRESS. 14.4 PSIA

MODEL 253A001 SERIAL 5 CONTROL PUMP

DEVELOPMENT ACCELERATED LIFE TEST
PAR. IV.D.4 of 02-1099

ET 378

EW
F.R. G.S.
6-3-64
SER. NO DU18
DATA PG NO 8

PROJ. 516-00/236-08

FIGURE 4

Thompson Ramo Wooldridge Inc.

UPPER MTR CAVITY — INTERNAL TEMP. REFERENCE ONLY

	Flow GPM	Inlet Pressure	Disch Press	Press	Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G	Upper Mtr Cavity Temp °F	Mtr Phase 1 Temp °F / Mtr Phase 2 Temp °F	Mtr Phase 3 Temp °F / Upper Brg Hsg Temp °F	Return Flow Temp °F / Lower Hsg Temp °F	Upper Hsg Temp °F / Anti... Ext Temp °F	Date	Suction Press	Upper Mtr Cavity Pr / Lower ... Pr. PSIG	Clock Time	Individual Test Time Hrs. Min.	Pump Accum Time Hrs. Min.
B.P. 14.3 PSIA	RESTARTED																6-8-64			11 45	178 14	188 29
	17.0	3.0	43.5	54.8	3.36 / 250	3.34 / 250	3.30 / 250	6.67	1500	7775	250	271	216 / 217	217 / 216	211 / 241	250 / 210	6-8-64	12.2	19.8 / 19.5	1200	178 29	188 44
	17.0	3.0	43.5	54.8	3.36 / 250	3.34 / 250	3.30 / 250			7725	254	277	224 / 225	225 / 224	220 / 247	258 / 219		12.0	19.8 / 19.4	2100	187 29	197 44
B.P. 14.2 PSIA	17.0	3.0	43.5	54.7	3.36 / 250	3.34 / 250	3.30 / 250			7775	257	279	224 / 225	224 / 222	218 / 249	257 / 221	6-9-64	12.1	19.8 / 19.4	0800	198 29	208 44
	17.0	3.0	43.5	54.7	3.36 / 250	3.34 / 250	3.30 / 250			7775	250	275	220 / 221	221 / 220	217 / 248	256 / 220		12.1	19.7 / 19.3	1600	206 29	216 44
B.P. 14.2 PSIA	17.2	6.8	47.0	54.4	3.30 / 250	3.28 / 250	3.29 / 249			7800	262	284	227 / 228	226 / 225	220 / 252	260 / 220	6-10-64	15.9	22.6 / 22.0	0800	222 29	237 44
	17.0	3.1	43.5	54.6	3.30 / 250	3.27 / 246	3.28 / 245			7760	250	273	220 / 220	220 / 219	215 / 245	252 / 211		11.8	18.8 / 18.2	0900	223 29	233 14
	17.0	3.0	43.5	54.7	3.30 / 250	3.27 / 246	3.28 / 245			7770	246	265	213 / 213	212 / 211	205 / 240	245 / 207		12.0	19.7 / 19.4	1600	230 29	240 44
B.P. 14.4 PSIA	16.8	2.0	42.0	54.4	3.29 / 250	3.27 / 247	3.28 / 246			7725	258	280	224 / 224	224 / 222	217 / 251	260 / 217	6-11-64	10.0	17.8 / 17.5	0800	246 29	256 44
	17.0	3.0	43.5	54.9	3.29 / 250	3.27 / 247	3.28 / 246			7775	246	264	213 / 213	212 / 211	205 / 240	245 / 207		12.0	18.8 / 18.4	1000	248 29	258 44
B.P. 14.4 PSIA	17.0	2.7	43.7	55.4	3.30 / 251	3.29 / 250	3.29 / 250			7810	245	267	214 / 214	214 / 215	210 / 240	248 / 207	6-12-64	12.0	18.5 / 18.0	0800	270 29	280 44
	17.0	3.0	43.6	55.0	3.30 / 251	3.29 / 250	3.29 / 250			7780	246	270	214 / 214	214 / 215	211 / 240	249 / 208		12.0	18.6 / 18.0	1600	278 29	288 44
B.P. 14.2 PSIA	17.1	5.0	45.3	54.5	3.30 / 250	3.29 / 250	3.29 / 250	6.59	1500	7800	247	270	216 / 217	216 / 215	211 / 241	250 / 210	6-15-64	13.6	20.0 / 19.6	0800	342 29	352 44
	POWER SHUTDOWN @																			1030	344 59	355 14
	RESTARTED																			1100	344 59	355 14
	16.9	3.1	43.0	54.1	3.29 / 249	3.28 / 249	3.28 / 248	6.57	1492	7770	249	270	215 / 215	215 / 215	210 / 243	251 / 210		11.0	19.0 / 18.0	1147	345 46	356 01
	16.9	3.0	43.0	54.4	3.29 / 249	3.29 / 250	3.29 / 250			7775	250	275	220 / 221	221 / 220	215 / 246	254 / 215		11.2	18.3 / 18.0	1300	346 59	357 14
B.P. 14.4 PSIA	17.0	3.0	43.3	54.7	3.29 / 250	3.28 / 249	3.29 / 250			7785	255	279	228 / 221	220 / 220	215 / 250	256 / 215	6-16-64	11.1	18.7 / 18.4	0800	365 59	376 14
	17.0	2.9	43.2	54.7	3.29 / 250	3.28 / 249	3.29 / 249			7795	258	279	220 / 220	220 / 220	215 / 251	258 / 215		11.3	18.8 / 18.4	1425	372 24	382 39
	POWER FAILURE @																			1455	372 54	383 09
	RESTARTED																			1625	372 54	383 09
	17.0	3.0	43.2	54.6	3.29 / 250	3.28 / 249	3.29 / 249	6.57	1496	7785	253	277	220 / 220	220 / 220	215 / 249	257 / 215		11.2	18.8 / 18.4	1700	373 29	383 44
B. 14.4 PSIA	16.9	2.0	42.7	55.1	3.29 / 249	3.27 / 249	3.29 / 249			7775	260	285	225 / 225	225 / 225	220 / 250	260 / 218	6-17-64	10.7	18.2 / 17.9	0800	388 29	398 44
	17.0	3.0	43.3	54.7	3.29 / 249	3.27 / 249	3.29 / 249			7780	254	278	220 / 220	220 / 220	215 / 248	259 / 218		11.1	18.5 / 18.2	1700	397 29	407 44
B. 14.4 PSIA	17.1	5.5	45.2	54.1	3.28 / 248	3.26 / 248	3.27 / 247			7765	260	281	225 / 225	225 / 225	220 / 250	259 / 220	6-18-64	14.0	20.6 / 20.3	0800	412 29	422 44
	17.0	3.1	43.7	55.0	3.28 / 248	3.27 / 248	3.27 / 247	6.55	1486	7770	256	280	225 / 226	225 / 225	220 / 250	258 / 220		11.8	19.8 / 19.4	1600	420 29	430 44

400 208

2:1 — WESTON 651B — WESTON 14087 — WESTON 110759

Remarks: B.P. = BAROMETRIC PRESSURE

Model ... Pump

DEVELOPMENT ABBREVIATED LIFE TEST
PAR. IV. D 4 OF 02-1099

ET 378

Data sheet 9

FIGURE 4

	FLOW GPM	INLET PRESSURE / DISCH PRESS	PUMP PRESSURE RISE PSI												
C ?. 14.3 PSIA	17.0	3.0	43.3	54.6	3.29	250	3.28	249	3.28	249	6.57	1496	7770	247
	17.0	3.0	43.4	54.7	3.29	250	3.28	249	3.28	249	6.57	1496	7775	247
P. 14.4 PSIA	17.0	3.1	43.4	54.7	3.29	250	3.28	249	3.28	249	6.57	1496	7775	249
B.P. 14.3 PSIA	17.1	3.2	44.2	54.8	3.29	250	3.28	249	3.28	249	6.57	1496	7770	248
	17.1	3.1	43.3	54.5	3.29	250	3.28	249	3.28	249	6.57	1496	7770	249
	CALIBRATION													
	27.7	3.0	20.0	31.3	3.42	270	3.40	270	3.40	270	6.81	1620	7760	246
	27.0	2.8	22.0	33.5	3.42	270	3.40	270	3.40	270	6.81	1620	7760	245
	23.9	2.9	30.3	41.7	3.40	269	3.40	268	3.40	268	6.80	1610	7780	244
	21.0	2.9	37.2	48.6	3.38	262	3.35	260	3.35	260	6.72	1564	7780	246
	17.9	3.0	42.5	53.8	3.30	254	3.30	252	3.30	251	6.60	1514	7790	246
	17.0	3.0	43.8	55.1	3.29	250	3.28	250	3.28	250	6.57	1500	7790	248
	13.8	2.9	47.2	58.6	3.22	240	3.20	240	3.20	240	6.41	1440	7810	248
	12.0	3.0	50.0	61.3	3.18	235	3.15	237	3.15	235	6.32	1414	7820	249
	8.9	3.0	52.2	63.5	3.10	225	3.08	223	3.08	222	6.17	1340	7830	249
	6.0	3.0	54.4	65.7	3.02	215	3.00	213	3.00	213	6.01	1282	7845	248
	3.0	3.1	55.6	66.8	2.98	208	2.96	205	2.96	205	5.93	1236	7860	248
	0	3.1	55.3	66.5	2.91	196	2.90	194	2.90	194	5.81	1168	7860	
												STOP		

UPPER MTR. CAVITY — INTERNAL TEMP REFERENCE ONLY

Thompson Ramo Wooldridge Inc.

TEMP °F	MTR. PHASE 1 TEMP °F	MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F	UPPER BRG. HSG. TEMP °F	RETURN FLOW TEMP °F	LOWER BRG. HSG. TEMP °F	UPPER HSG. TEMP °F	ANTI LEAK CAP EXT. TEMP °F	DATE	IMP SUCTION PRESS. PSIG	UPPER MTR. CAVITY PR. O.G. PSIG	LOWER MTR. CAVITY PR. O.G. PSIG	CLOCK TIME	CHRONOLOGICAL TEST TIME HRS	MIN	PUMP ALL ON TIME HRS	TOTAL RUN MIN
265	213	213	214	211	207	235	245	205	6-19-64	11.8	18.3	18.0	0800	42	1	446	44
262	210	210	211	210	202	235	245	200		12.0	18.3	18.2	2000	448	29	458	44
270	217	217	216	216	219	240	250	210	6-20-64	11.8	18.5	18.2	1000	462	29	472	44
270	217	217	217	216	214	240	250	211	6-22-64	12.3	19.1	18.6	0800	508	21	518	44
271	219	220	220	219	215	242	251	213		11.2	18.4	18.0	0815	508	4	518	59
274	221	220	220	220	216	240	250	215		6.8	12.5	12.5	0950	510	19	520	34
275	220	220	220	220	216	240	251	215		7.0		13.0	0957				
270	220	220	220	219	215	239	250	213		8.9	15.0	14.8	1008				
270	220	220	220	219	215	240	250	213		10.[illegible]	16.4	16.0	1016				
270	219	220	219	217	215	242	250	211		11.4	17.0	17.2	1023				
270	219	220	219	217	215	242	250	210	.632	12.0	18.2	18.2	1045				
270	216	216	215	215	210	243	250	210		12.0	20.9	19.5	1105				
270	217	217	217	216	213	243	251	211		14.0	20.8	20.5	1114				
270	218	218	218	217	215	244	251	210		14.2	22.0	21.5	1120				
270	218	218	218	217	213	243	250	210		15.8	22.0	22.6	1125				
270	220	219	218	217	215	244	251	210		17.0	24.0	23.7	1132				
295	228	233	230	225	217	284	269	230		17.0		26.0	1135				
													1137	512	06	522	21

PUMP BREAK IN FOR [illegible]

400 CP 208 [illegible]

TRANSFORMER RATIO 2:1 AMMETER WESTON 6518 ATTENUATOR WESTON 14087 [illegible] WESTON 110759

LINE AMPS [illegible]

TOTAL RATIO [illegible]

COMMENTS: CALIBRATION AFTER 500 HRS

TRW QUALITY ASSURANCE

QUALITY ASSURANCE INSPECTOR

MODEL 253000-1 CASE & COOLANT PUMP

DEVELOPMENT ABBREVIATED LIFE TEST
PAR. IV D.4. OF 02-1099

SER. NO DU1B
DATA PG. NO 10.

FLUID: ET 378

PROJ. 516-00423688

FIGURE 4

Thompson Ramo Wooldridge Inc.
CLEVELAND, OHIO U.S.A.

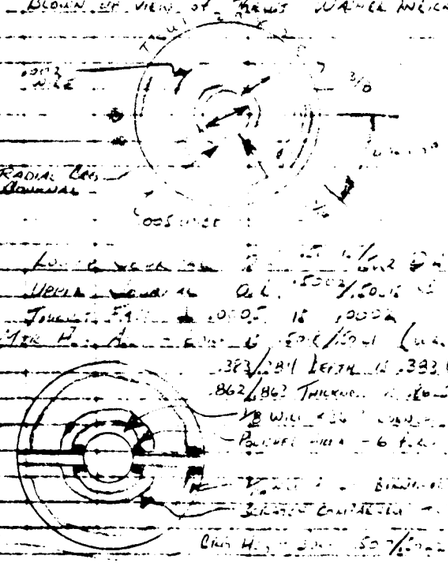
DISASSEMBLY & INSPECTION OF 2½ HOUR SCHEDULE OF SERIES LIFE

OVERHAUL SHEET MODEL 153800-1 LUBE & COOLANT PUMP S/N DUIC

PARTS REMOVED							REPLACEMENT						
Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments	Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments

DISASSEMBLED & INSPECTED UNIT.

1. FOUND 2 HARDWARE PARTICLES ON 3.11/3.00 DIA. VOLUTE HOUSING. ONE PARTICLE WAS APPROX. ¼" LONG AND UNDER [illegible] EXAMINATION IT APPEARED TO BE A THREAD OF TRW INTERLOCK THERMOCOUPLE INSULATION. SECOND PARTICLE WAS APPROX. 3/16" LONG AND APPEARED TO BE SAME MATERIAL BUT IN ROUGHENED CONDITION.
2. FOUND PIECE OF TRW VARNISHED THERMOCOUPLE INSULATION IN BOTTOM OF MOTOR CAVITY. PIECE WAS APPROX. 3/16" WIDE & ¼" LONG.
3. ROTOR ASSEMBLY - THRUST WASHER HAS SLIGHT CIRCUMFERENTIAL SCRATCH 360° AT APPROX. 3.11" DIA. NO EVIDENCE OF EXCESSIVE WEAR ON THRUST PADS. NO EVIDENCE OF WEAR ON RADIAL BEARING. BLOWN UP VIEW OF THRUST WASHER INDICATING "SCRATCH".



LOWER BEARING I.D.: LOWER JOURNAL O.D.:
UPPER BEARING I.D.: UPPER JOURNAL O.D.:
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

REASON FOR OVERHAUL: SCHEDULED DISASSEMBLY & INSPECTION AFTER COMPLETION OF 500 HR. OF ABBREVIATED LIFE TEST.
NO [illegible] WERE [illegible] IN [illegible] WITHIN [illegible] BEARING ACCURACY.

W.V. EDWARDS, C. COLKER, A. SMITH
G. PASINA, J. DUNN

REPLACEMENT: ALL PARTS REVARNISHED WHEN NECESSARY — SONIC "DEGREASED" MOTOR HOUSING

Proof Pressure Test: Test Date, Pressure, Time, Results

Helium Leakage Test: Test Date, Results

LOWER BEARING I.D.: LOWER JOURNAL O.D.
UPPER BEARING I.D.: UPPER JOURNAL O.D.
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

GOV'T. INSPECTOR	TRW QUAL. ASSURANCE	DATA PK. NO. OVERHAULED BY: F. READENCE
		DATE: 26 Jul 64

FIGURE 3

Cont of DU1C 6/26/64

After subassembly of bearing housing and motor housing with rotating group in place, place housing on V blocks. Measure radial movement of shaft by indicator by lifting shaft assembly from rest until clearance taken up within bearings. Repeat in different positions (90° apart), on each end of shaft:
Impeller End .0016, .0017; Speed Sensor End .0016, .0017.

Determine on go-no-go basis minimum air gap of .005, using .005 pin from bearing housing end. Check twice: .005 .015 2 PLACES; .015 WIRE NOT GO 2 PLACES.

The above subassembly and shaft/bearing radial clearance, and Item 3 end play measurement shall be performed with all parts wiped dry.

Refer to Figure 2 for location of following dimensions:

1. Dimension A - Obtain at a total of eight points in the following manner:

   A. Mark impeller near O.D. at two points 180° apart with corresponding marks on housing.

   B. Measure and record four times, impeller to housing clearances at impeller, without rotating impeller, at 90° increments: 1) .004, 2) .0035, 3) .004, 4) .0045.

   C. Measure and record four times, impeller to housing clearances at one point of housing and rotate impeller in 90° increments: 1) .004, 2) .004, 3) .004, 4) .0035.

   D. A variation in excess of .0025 between any of the readings obtained in B and C shall be cause for rejection.

2. Dimension B - Obtain at a total of four points in the following manner:

   A. Repeat Item 1.B above (with the end play taken up toward the pump inlet) 1) .007, 2) .007, 3) .0065, 4) .007.

3. End Play - Determine end play by indicator method with axial load applied to shaft rotor first against thrust face and then moved back to stop: 1) .0028, 2) .003, 3) .0029, 4) .003.

   A. End play less than .001 or greater than .003 shall be cause for rejection.

4. Dimension C - This dimension shall be taken at four points equally spaced: 1)____, 2)____, 3)____, 4)____.

5. Dimension D - This dimension shall be taken at each impeller blade at a distance of approximately 1/32 inside impeller O.D. by rotating the impeller: 1)____, 2)____, 3)____, 4)____, 5)____, 6)____, 7)____.

6. Dimension G -

   A. For maximum G, subtract minimum D from maximum C:

      Max. G = ____ - ____ = ____.

   B. For minimum G, subtract maximum D from minimum C:

      Min. G = ____ - ____ = ____.

7. Dimension E - Measure and record E four places 90° apart: 1)____, 2)____, 3)____, 4)____.

8. Dimension F - Measure F four places 90° apart: 1)____, 2)____, 3)____, 4)____.
   (Depth micrometer bar to ride against motor assembly pilot bore during measurement.)

9. Dimension H -

   A. For Maximum H, subtract minimum E from maximum F:
      Max. H = ____ - ____ = ____.

   B. For Minimum H, subtract maximum E from minimum F:
      Min. H = ____ - ____ = ____.

10. Dimension J - (For Reference Only)

    A. Optimum J = Max. G + End Play + .005 - Min. H:
       = ____ + ____ + ____ - ____ = ____.

    B. Actual J = Measured total shim thickness = ____. (After completion of Item 14)

11. Dimension I - (For Reference Only)

    A. Minimum I = Min. H + J - Max. G - End Play:
       = ____ + ____ - ____ - ____ = ____.

    B. Maximum I = Max. H + J - Min. G + End Play:
       = ____ + ____ - ____ + ____ = ____.

12. Dimension L - Identify four bearing housing connector stop posts. Install rotating assembly prior to addition of 208265 shims and measure L. Rotation of shaft should not be possible at this time due to impeller seating on housing throat: 1) 1.399, 2) 1.400, 3) 1.396, 4) 1.398.
    Determine if end play has been taken up entirely. If not, contact Engineering for further instructions.

13. Dimension M - Install 208265 shims, rotating assembly, and install and torque 93007-10 bolts. Measure and record M (taken at same points as L): 1) 1.392, 2) 1.393, 3) 1.389, 4) 1.391.

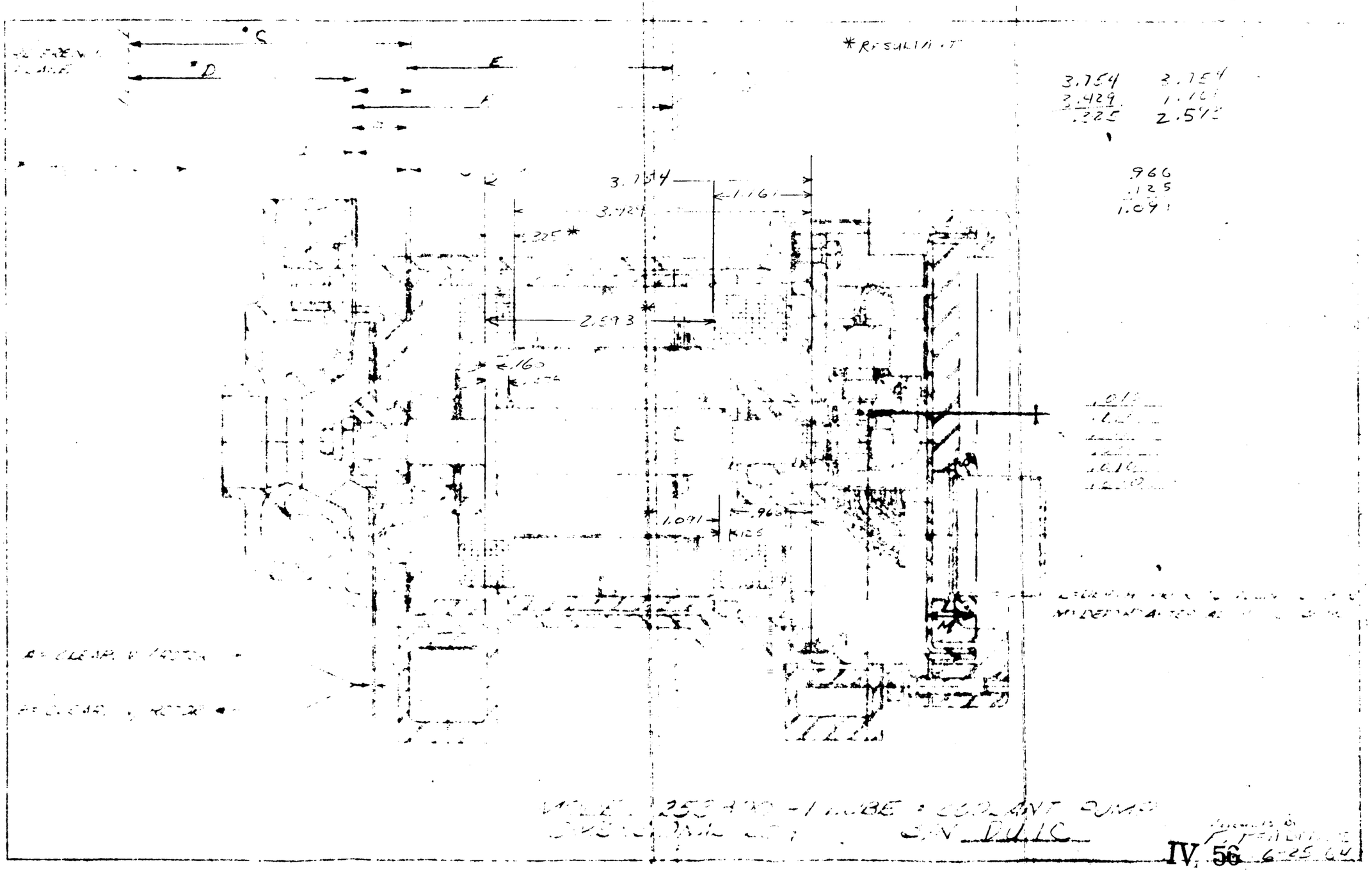
14. Impeller/Throat Clearance Check:

    Minimum Imp/Throat Clearance = L - M - End Play

    Minimum Imp/Throat Clearance = 1.399 - 1.392 - .0029 = .0041.

    Minimum Imp/Throat Clearance less than .004 or greater than .006 shall be cause for rejection. Add or remove shims as necessary to obtain .004/.006 impeller/throat clearance. Record final shim thickness as Item 10.B.

FIGURE 2



P.F.

Thompson Ramo Wooldridge Inc

FIGURE 4

	Flow GPM	Inlet Pressure	Disch Press	Pump Pressure Rise PSI	Phase MV	°F	Phase MV	°F	Phase MV	°F	[illegible]	[illegible]	[illegible]	[illegible]
B.P. 14.4 PSIA 90° Amb.	17.0	3.0	43.2	54.6	3.28	250	3.25	250	3.25	250	6.52	1500	7800	249
	12.0	3.1	44.2	55.5	3.28	250	3.25	250	3.24	250			7745	255
	17.0	3.1	44.2	555	3.29	250	3.25	250	3.24	250			7790	250
P. 14.4 BA 86° Amb	17.0	3.1	43.2	54.5	3.29	251	3.25	250	3.27	250	6.54	1502	7110	240
				** ↗										
				* ↘										
HUSQ	27.5	3.0	20.2	31.6	3.42	273	3.40	270	3.40	270	6.81	1626	7750	246
	27.0	3.0	21.8	33.2	3.41	271	3.40	270	3.40	270	6.81	1622	7750	248
	24.0	3.0	29.7	40.1	3.37	267	3.36	265	3.36	265	6.74	1594	7750	251
	21.1	3.0	35.8	47.2	3.37	262	3.34	260	3.34	260	6.70	1564	7750	246
	18.0	2.9	42.2	53.6	3.30	254	3.29	252	3.28	252	6.57	1516	7755	249
	17.0	3.1	43.3	54.6	3.28	250	3.25	249	3.25	250	6.52	1498	7760	251
	15.0	2.9	46.1	57.6	3.22	245	3.20	243	3.20	242	6.41	1460	7770	254
	12.0	3.0	49.0	60.4	3.15	234	3.12	232	3.12	232	6.26	1396	7770	250
	9.0	3.0	52.0	63.4	3.06	225	3.05	222	3.05	222	6.12	1338	7715	249
	6.0	3.0	53.6	65.0	3.00	215	2.98	213	2.97	213	5.98	1282	7790	250
	3.0	3.0	54.6	66.0	2.95	206	2.93	205	2.93	205	5.87	1236	7812	250
	0	2.9	54.2	65.7	2.90	195	2.88	193	2.89	192	5.78	1160	7820	–
	17.0	5.1	45.7	55.0	3.28	250	3.25	250	3.25	250	6.52	1500	7750	250
	17.0	5.1	45.7	55.0	3.28	250	3.25	250	3.26	250	6.52	1500	7750	249
	17.0	5.1	45.7	55.0	3.28	250	3.25	250	3.25	250	6.52	1500	7750	246
	17.0	4.0	44.4	54.8	3.25	251	3.25	250	3.25	250	6.52	1502	7740	249
	17.0	3.1	43.4	54.7	3.25	251	3.25	250	3.25	250	6.52	1502	7745	251
C. 14.4 PSIA 70° Amb.	17.0	3.9	44.4	54.9	3.28	251	3.25	250	3.25	250	6.52	1502	7745	243
	16.9	2.0	41.8	54.2	3.28	251	3.25	250	3.25	250	6.52	1502	7780	250

Flow GPM	Upper Cav Temp °F / Outlet Temp °F	Mtr Phase 1 Temp MV / Mtr Phase 2 Temp MV	Mtr Phase 3 Temp MV / Upper Brg Hsg Temp MV	Return Flow Temp MV / Lower Hsg Temp °F	Upper Temp °F / Coil Temp	Date	Imp Suction Press PSIG	Upper Mtr Cavity Pr PSIG / Lower Mtr Cav Pr PSIG	Clock Time	Individual Test Time Hrs:Min	Pump Total Run Time Hrs:Min
									1640	51[illegible]	522:21
17.0	265			/ 23	26[illegible] / 175	6-26-64	11.9	/ 19.7	1650	512:16	522:31
12.0	271 / 1.33	1.50 / 1.45	1.48 / 1.48	1.40 / 260	275 / 197		12.5	20.[illegible] / 20.[illegible]	1715	512:41	522:56
17.0	270 / 1.37	1.50 / 1.45	1.48 / 1.49	1.40 / 260	274 / 205		12.5	20.8 / 20.6	1900	514:26	524:41
17.0	250 / 1.20	1.41 / 1.35	1.42 / 1.38	1.23 / 245	252 / 160	6-29-64	12.9	18.6 / 18.3	0800	575:26	585:41
	°F	°F / °F	°F / °F	°F							
27.5	266 / 264	273 / 271	272 / 271	26[illegible] / 250	270 / 198		8.0	13.0 / 12.8	1120	578:46	58[illegible]:01
27.0	270 / 267	276 / 274	275 / 274	27[illegible] / 252	272 / 200		8.1	13.4 / 13.0	1130	578:56	589:11
24.0	270 / 267	277 / 274	275 / 274	272 / 255	274 / 200		9.8	15.0 / 14.8	1150	579:16	589:31
21.1	268 / 266	275 / 272	274 / 273	270 / 250	266 / 195		10.3	16.4 / 16.3	1310	580:36	590:51
18.0	268 / 266	275 / 272	274 / 273	270 / 250	26[illegible] / 198		12.2	18.5 / 18.3	1320	580:46	591:01
17.0	268 / 266	275 / 272	274 / 273	270 / 255	271 / 200	.637	12.1	19.5 / 19.2	1330	580:56	591:11
15.0	270 / 268	277 / 274	[illegible] / 275	272 / 258	27[illegible] / 200		13.0	20.4 / 20.2	1340	581:[illegible]	59[illegible]:21
12.0	265 / 262	271 / 269	272 / 270	266 / 250	264 / 195		14.0	21.7 / 21.3	1400	581:26	591:41
9.0	26[illegible] / 260	269 / 266	269 / 266	264 / 2[illegible]	[illegible] / 19[illegible]		15.2	22.6 / 22.[illegible]	1405	581:31	591:46
6.0	265 / 263	271 / 269	271 / 270	266 / 255	268 / 200		16.0	24.2 / 23.8	1420	581:46	592:01
3.0	26[illegible] / 263	273 / 270	272 / 271	267 / [illegible]	270 / 200		16.9	25.[illegible] / 25.0	1430	581:56	592:11
0	270 / 273	293 / 293	293 / 286	282 / 297	269 / 201		17.0	27.3 / 27.0	14[illegible]	58[illegible]:[illegible]6	592:21
17.0	268 / 270	273 / 270	273 / 273	269 / 255	270 / 203		15.0	21.5 / 21.0	1515	582:41	5[illegible]:56
17.0	268 / 270	272 / 271	273 / 273	269 / 255	270 / 202		15.0	21.4 / 21.0	1520	582:46	593:01
17.0	263 / 265	268 / 265	267 / 267	264 / 250	261 / 200		15.0	21.3 / 21.0	1530	582:56	5[illegible]:11
17.0	265 / 267	269 / 268	269 / 269	266 / 252	269 / 200		13.4	[illegible] / 19.8	1550	583:16	593:31
17.0	270 / 272	274 / 272	274 / 274	271 / 258	273 / 203		12.3	[illegible] / 19.7	1605	583:31	5[illegible]:46
17.0	256 / 259	262 / 260	262 / 261	258 / 245	257 / 194	6-30-64	13.4	19.7 / 19.3	0800	599:26	609:41
16.9	265 / 267	271 / 270	271 / 269	267 / 251	265 / 200		10.0	18.2 / 17.9	0850	600:16	610:31

400 · 208

Transformer Ratio 2:1 · Ammeter Welton 6518 · Wattmeter Welton 14087 · Voltmeter Welton 110759

Line Amps = Average Phase Amp Reading × Transformer Ratio

Total Watts = Sum of Phase Watts × Transformer Ratio

Comments: * Internal Temperatures Compensated For Upper Cavity Temperature: Ex - 270°F Upper Cav. Temp. = 5.42 MV Mtr. Phase 1 Thermocouple = 0.14. 5.42 + 0.14 = 5.56 MV = 276°F

** Internal Thermocouple MV Readings in Error for First Four Readings Due To Including MV for Room Temperature.

Test Stand Plug Thermocouple Leads Changed To Copper Wire

TRW Quality Assurance

Engineering Approved

Title: Model 253800-1 [illegible] Pump

[illegible]

Fig. IV. [illegible] 4 [illegible]

Eng. [illegible]

Date

Ser. No. [illegible]

Data Pg. No. 11

FIGURE 4

Thompson Ramo Wooldridge Inc

NPSH

FLOW GPM	INLET PRESSURE	DISCH PRESS									UPPER CAV. / CONN. PIN	MTR. PHASE 1 TEMP / MTR. PHASE 2 TEMP °F *	MTR. PHASE 3 TEMP °F / UPPER BRG. HSG. TEMP. °F *	RETURN FLOW TEMP / LOWER HSG. TEMP °F	UPPER TEMP °F / ANTI LEAD END EXT. TEMP °F	DATE	IMP. SUCTION PRESS. PSIG	UPPER MTR. CAVITY PR. PSIG / LOWER CAV. PR. PSIG	CLOCK TIME	INDIVIDUAL TEST TIME HRS. MIN.	TOTAL RUN TIME HRS. MIN.
17.0	1.8	41.2	53.8	3.28 251	3.25 250	3.25 250	6.52	1502	7780	249	264/200	270/269	270/269	266/250	264/266	6-30-64	9.3	18.9/17.5	0855	600:21	610:36
17.0	1.6	40.0	52.8	3.28 251	3.25 250	3.25 250			7780	249	264/200	270/269	270/269	266/250	264/266		8.0	17.4/17.0	0905	600:31	610:46
17.0	1.4	37.0	50.0	3.28 251	3.25 250	3.25 250			7790	249	265/200	271/270	271/270	268/250	265/267		5.0	15.3/15.0	0915	600:41	610:56
17.0	1.2	32.8	46.0	3.28 251	3.25 250	3.25 250			7790	246	264/200	270/269	270/269	266/250	265/266		0"Hg	12.7/12.5	0920	600:46	611:01
17.0	1.1	25.8	39.1	3.28 251	3.25 250	3.25 250	6.52	1502	7795	247	264/200	271/270	271/270	267/250	265/267		5"Hg	11.0/6.8	0925	600:51	611:06
12.0	4.9	51.7	61.2	3.17 239	3.14 238	3.14 238	6.30	1430	7780	246	257/195	265/263	265/262	264/245	255/257		16.4	22.9/22.5	0955	601:21	611:36
12.0	5.0	51.3	60.7	3.17 239	3.14 238	3.14 238			7805	249	261/195	268/266	267/266	262/251	260/262		16.3	23.1/22.8	1000	601:26	611:41
12.1	5.0	51.7	61.1	3.17 239	3.14 238	3.14 238			7805	246	261/195	267/265	267/266	263/250	261/263		16.4	23.3/23.0	1010	601:36	611:51
12.0	4.0	50.5	60.9	3.17 239	3.14 238	3.14 238			7810	249	261/198	267/266	267/266	263/250	264/264		15.1	23.0/22.3	1040	602:06	612:21
12.0	3.0	49.5	60.9	3.17 239	3.14 238	3.14 238			7800	247	260/195	265/265	266/265	265/248	259/261		14.3	22.8/22.5	1100	602:26	612:41
12.0	2.0	48.4	60.8	3.17 239	3.14 238	3.14 238			7810	249	262/200	267/266	267/266	263/250	264/264		12.5	22.4/22.0	1110	602:36	612:51
12.0	1.8	47.9	60.5	3.17 239	3.14 238	3.14 238			7810	247	260/198	266/266	266/266	263/250	262/261		12.0	20.6/20.3	1115	602:41	612:56
12.0	1.6	46.4	59.2	3.17 237	3.14 238	3.14 238			7815	249	261/195	268/266	267/266	262/251	260/262		11.3	19.5/19.2	1120	602:46	613:01
12.0	1.4	45.3	58.3	3.17 239	3.14 238	3.14 238			7815	249	261/196	268/266	267/266	263/250	260/261		10.4	19.0/18.8	1125	602:51	613:06
12.0	1.2	42.0	54.2	3.17 239	3.14 238	3.14 238			7810	247	260/198	266/266	267/266	261/249	261/261		5.0	16.5/16.2	1130	602:56	613:11
12.0	1.0	33.0	46.4	3.17 239	3.14 238	3.14 238	6.30	1430	7805	246	261/196	267/266	267/266	262/251	260/262		7.0"Hg	11.3/11.0	1135	603:01	613:16
22.0	5.0	37.0	46.4	3.36 263	3.33 262	3.33 262	6.68	1574	7765	249	264/197	270/269	270/269	266/252	264/266		12.3	18.6/18.3	1200	603:26	613:41
22.0	5.0	36.8	46.2	3.36 263	3.33 262	3.33 262			7765	248	263/197	269/268	269/268	265/251	263/265		12.3	18.5/18.2	1300	604:26	614:41
22.0	4.0	35.9	46.3	3.36 263	3.33 262	3.33 262			7765	247	260/196	266/266	267/266	262/251	269/262		11.2	18.0/17.8	1330	604:56	615:11
22.0	3.0	34.0	45.4	3.36 263	3.33 262	3.33 262			7755	249	265/199	271/269	270/270	266/251	265/267		10.2	16.5/16.0	1425	605:51	616:06
22.0	2.0	33.0	45.4	3.36 263	3.33 262	3.33 262			7755	249	265/200	271/270	270/270	266/251	266/267		9.0	15.6/15.3	1450	606:16	616:31
22.0	1.8	32.8	45.4	3.38 266	3.35 265	3.35 265			7765	249	267/200	272/271	272/271	268/253	268/269		8.7	15.4/15.0	1500	606:26	616:41
22.0	1.6	32.4	45.2	3.38 266	3.35 265	3.35 265			7770	249	267/200	272/271	272/271	268/253	268/269		8.2	15.1/14.8	1505	606:31	616:46
22.0	1.4	31.2	44.2	3.38 266	3.35 265	3.35 265	6.72	1592	7770	249	267/200	273/271	272/271	268/251	267/268		7.4	14.3/14.0	1510	606:36	616:51
21.8	1.25	20.9	34.0	3.34 262	3.32 260	3.32 260			7770	249	270/200	275/275	276/274	273/255	270/271		12"HG	12.4/7.6	1530	606:56	617:11
17.0	3.0	43.5	54.9	3.28 251	3.25 251	3.25 250	6.52	1504	7755	249	265/200	271/270	270/270	267/251	265/267		12.0	20.0/19.8	1550	607:16	617:31

400 208

2:1 WESTON 6518 WESTON 11037 WESTON 11059

* SEE DATA PAGE 11 FOR METHOD OF DETERMINING PUMP INTERNAL TEMPS.

DEVELOPMENT - ABBREVIATED LIFE TEST
PAR IV. D. 4 OF 02-1099
ET 378

DATE 6-30-64
SER. NO DU 1C
DATA SH. NO 12

FIGURE 4

Thompson Ramo Wooldridge Inc.

	FLOW GPM	INLET PRESSURE PSIG											
B. 14.3 PSIA 90° AMB.	17.0	3.1	43.7	54.9	3.28	251	3.25	250	3.25	250	6.52	1502	7750	249
	17.0	3.6	43.9	54.6	3.28	251	3.25	250	3.25	250			7750	249
	17.0	3.1	43.7	54.9	[illegible]	[illegible]	[illegible]	250	3.25	250	6.52	1502	7755	249
	SHUTDOWN FOR CALIBRATION TEST OF 481503													
	RESTARTED													
	17.0	3.0	43.6	54.9	3.28	251	3.25	250	3.25	250	6.52	1502	7760	249
	17.0	3.1	43.7	54.9	3.28	251	3.25	250	3.25	250			7755	249
B.P. 14.3 P.S.I.A	17.1	2.8	43.5	55.0	3.29	256	3.26	254	3.27	253			7826	248
	17.0	3.5	44.1	54.9	3.29	254	3.26	252	3.27	252	6.55	1516	7800	246
	STOP FOR CAVITATION TEST OF 481503													
	RESTART													
	17.0	3.0	42.5	53.8	3.28	251	3.24	250	3.24	250	6.51	1502	7753	249
	17.0	2.75	44.0	55.5	[illegible]	258	3.28	254	3.28	253			7768	250
B.P. 14.2 PSIA 64° AMB	17.0	3.9	42.0	52.3	3.28	250	3.25	250	3.25	250	6.52	1500	7745	250
	NOTE - ALTERNATOR START													
	17.0	3.1	43.5	54.1	3.22	[illegible]	3.22	[illegible]	3.23	[illegible]			7785	249
	17.0	2.9	43.6	54.5	3.20	250	[illegible]	[illegible]	[illegible]	256	6.43	1508	7795	249
B.P. 14.3 PSIA 90° AMB	17.2	3.8	43.5	54.0	[illegible]	[illegible]	[illegible]	[illegible]	3.22	[illegible]	7-6-64		7780	255
	17.0	3.0	43.8	55.1	3.20	250	3.21	248	3.29	257			7780	250
	17.0	2.9	43.9	54.3	3.21	250	3.21	247	3.29	255			7780	250
	17.0	3.1	44.0	56.2	3.20	250	3.22	246	3.29	254			7775	255
	17.0	3.1	44.0	56.2	3.21	250	3.21	246	3.29	254			7775	254
(565)	17.0	3.1	44.0	56.2	3.20	250	3.19	245	3.25	254			7780	252
B.P. 14.3 88°F AMB.	17.0	4.1	43.0	53.2	3.22	249	3.18	245	3.23	252	7-7-64		7775	254
	17.2	3.0	44.0	55.3	3.21	250	3.20	248	3.28	255	6.46	1506	7780	250

UPPER CAVITY °F	LOWER DIN °F	OUTLET TEMP °F	MTR PHASE 1 TEMP °F	MTR PHASE 2 TEMP °F	MTR PHASE 3 TEMP °F	RETURN FLOW TEMP °F	UPPER MTR TEMP °F	LOWER MTR TEMP °F	ANTI LEAK CAV TEMP °F	DATE	TAP SUCTION PRESS IN PSIG	UPPER MTR CAVITY PR. PSIG	LOWER MTR CAV PR. PSIG	CLOCK TIME	ACCUMULATED TEST TIME HRS	MIN	ACCUMULATED TEST TIME HRS	MIN
267	200	272	271	272	271	268	263	269	269		11.8	20.1	19.8	1900	610	26	620	11
264	197	271	269	270	269	266	250	[illegible]	266	7-1-64	13.0	19.8	19.2	0800	623	26	639	11
264	[illegible]	271	269	270	269	266	[illegible]	[illegible]	266		12.0	19.7	19.2	1330	628	56	639	11
										7-1-64								
										7-1-64				1800	628	56	639	11
266	200	271	269	271	270	266	250	263	266		12.3	20.0	19.5	1820	629	16	639	31
264	200	271	270	271	269	266	250	264	266		13.0	19.7	19.3	1900	629	56	640	11
265	195	271	270	272	270	267	250	265	264	7-2-64	11.5	19.6	19.0	0840	643	36	653	51
264	198	270	269	269	269	266	27	265	263		13.1	20.1	19.8	1343	648	39	658	54
481503														1351	648	47	659	02
										7-2-64				1615	648	47	659	02
270	181	276	274	277	274	270	251	263	268		11.0	-	18.4	1630	648	47	659	02
265	196	[illegible]	269	270	270	264	250	264	263		12.5	19.8	19.5	1725	649	47	659	57
265	192	[illegible]	269	271	270	269	255	265	263	7-3-64	11.0	-	220	0800	666	17	677	32
WOULD NOT STAY AT										400 CPS	-	STOPPED		1457	671	09	681	24
														1510	671	09	681	24
264	200	269	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	264	262		12.0	19.0	19.0	1540	671	39	681	54
265	200	271	270	272	270	267	250	265	264		13.0	19.5	19.0	1615	672	14	682	29
265	195	271	270	271	270	275	255	265	262		16.0	26	23.5	0800	735	59	746	14
267	192	272	271	[illegible]	270	268	255	270	263		13.0	19.9	19.8	0915	737	14	747	29
265	195	271	269	271	270	265	255	36	269		13.0	19.9	19.2	1115	739	14	749	29
265	170	271	269	270	269	264	255	260	263		13.0	20.0	19.7	1315	741	14	751	29
265	192	269	266	270	266	264	255	262	264		13.0	19.9	19.7	1415	742	14	752	29
269	195	274	272	275	273	269	255	36	260		13.0	20.0	19.8	1615	744	14	754	29
271	191	271	272	272	274	271	251	271	263		12.0	21.0	19.0	0800	759	57	770	14
266	200	271	270	269	269	267	[illegible]	266	265		13.0	20.0	19.8	1615	768	14	778	29

WESTON 6518 WESTON 14027 WESTON 110759

* See Data Pg. 11 for Method of Determining Pump Internal Temps.

Devel. Accelerated Life Test
Par. N.6.4 of 02-1099

ET 378

SER. NO DU1C
DATA PG NO 13
PROJ. 516-00436-02

FIGURE 4

Thompson Ramo Wooldridge Inc.

	FLOW GPM	INLET PRESSURE	DISCH. PRESS.								
B.P. 14.3 PSIA 80° AMB.	17.1	5.1	46.0	55.2	3.20 / 250	3.20 / 248	3.28 / 257	6.45	1510	7780	250
	17.0	2.9	43.8	55.2	3.20 / 250	3.20 / 245	3.27 / 255			7780	251
B.P. 14.3 PSIA 80° AMB.	17.2	7.2	47.8	51.9	3.20 / 250	3.20 / 245	3.27 / 255			7780	254
	17.0	2.9	44.0	55.4	3.20 / 250	3.20 / 245	3.27 / 255			7775	250
B.P. 14.2 PSIA [illegible] AMB.	17.0	2.4	43.3	55.2	3.20 / 250	3.20 / 245	3.27 / 255			7780	250
	17.0	3.0	44.0	55.3	3.20 / 250	3.20 / 245	3.28 / 255			7785	250
B.P. 14.2 PSIA 85° AMB	17.0	2.9	44.0	55.3	3.20 / 250	3.20 / 247	3.28 / 255			7785	254
	17.0	2.9	44.0	55.3	3.20 / 250	3.20 / 247	3.28 / 255			7780	247
B.P. 14.3 PSIA 76° AMB	17.1	4.8	45.8	55.3	3.20 / 250	3.20 / 246	3.28 / 255			7790	245
	17.1	3.1	44.2	55.4	3.20 / 250	3.20 / 247	3.28 / 255			7785	247
B.P. 14.4 PSIA [illegible]° AMB.	17.1	4.0	44.1	54.5	3.20 / 250	3.20 / 247	3.28 / 255			7785	246
	17.1	3.1	44.2	55.3	3.20 / 250	3.20 / 247	3.28 / 255	6.45	1504	7785	249
SHUTDOWN TO MEASURE OHM RESISTANCE B[illegible]											
RESTARTED											
B.P. 14.4 PSIA [illegible]5° AMB	17.1	3.1	44.1	55.4	3.20 / 250	3.20 / 247	[illegible]	6.45	1504	7785	249
	[illegible]	3.1	43.8	55.1	[illegible] / 250	3.20 / 247	3.28 / 255			[illegible]	[illegible]
	17.0	3.0	43.9	55.3	3.20 / 250	3.20 / 247	3.28 / 255			7785	241
B.P. 14.4 PSIA 82° AMB	17.1	4.2	44.0	54.2	3.20 / 250	3.20 / 247	3.28 / 256			7780	248
	17.1	3.0	43.7	55.1	3.20 / 250	3.20 / 247	3.28 / 257	6.45	1504	7800	243

UPPER AU. & F PIN CONN °F / OUTLET TEMP °F	MTR. PHASE 1 TEMP °F / MTR. PHASE 2 TEMP °F	MTR. PHASE 3 TEMP °F / UPPER HS TEMP °F	RETURN FLOW TEMP °F / LOW HS TEMP °F	UPPER HS TEMP °F / ANTI LEAD END CNT TEMP °F	DATE	IMP SUCTION PRESS. PSIG	UPPER MTR CAVITY PR PSIG / LOWER PR PSIG	CLOCK TIME	TECHNICAL TEST TIME HRS. MIN.	RUN TIME HRS. MIN.
268 / 193	276 / 273	276 / 273	269 / 255	268 / 268	7-8-64	15.0	21.5 / 21.0	0800	783:59	794:14
265 / 198	271 / 270	[illegible] / 270	267 / 259	269 / [illegible]		12.4	19.8 / 19.5	1600	791:59	802:14
267 / 193	[illegible] / 272	[illegible]	[illegible] / 258	266 / [illegible]	7-9-64	17.0	23.0 / 22.6	0800	807:59	818:14
265 / 195	[illegible] / 26[illegible]	271 / 270	[illegible] / 251	265 / [illegible]		12.5	19.7 / 19.0	1600	815:59	826:14
265 / 188	271 / 270	272 / 270	[illegible] / 253	265 / [illegible]	7-10-64	12.0	19.[illegible] / 18.8	0800	831:59	842:14
265 / 194	271 / 269	271 / 270	266 / 255	265 / 263		12.8	19.6 / 19.2	1600	839:59	850:14
266 / 190	273 / 271	273 / 271	267 / 257	267 / 266	7-13-64	12.8	19.6 / 19.0	0800	903:59	914:14
260 / 190	266 / 265	267 / 265	262 / 250	260 / 259		12.8	19.6 / 19.0	1600	911:59	922:14
257 / 187	265 / 262	263 / 262	259 / 246	257 / 257	7-14-64	15.0	20.8 / 20.2	0800	927:59	938:14
260 / 190	266 / 265	267 / 265	263 / 25[illegible]	260 / 258		12.8	19.8 / 19.2	1600	935:59	946:14
269 / 190	[illegible] / 265	[illegible] / 26[illegible]	[illegible]	260 / 260	7-15-64	12.5	19.5 / 19.0	0800	951:59	[illegible]2:14
264 / 190	271 / 269	270 / 269	265 / 251	263 / 263		12.[illegible]	20.[illegible] / 19.5	1010	954:09	964:24
[illegible] OFF 2 PHASES TO HELP DETERMINE TEMP.										
					7-15-64			1030	954:[illegible]	964:24
26[illegible] / 193	27[illegible] / [illegible]	270 / 269	264 / 251	263 / 262		12.5	20.0 / 19.5	1500	958:39	968:[illegible]
[illegible] / 191	267 / 266	267 / 266	263 / [illegible]	261 / 26[illegible]	7-16-64	12.5	20.2 / 19.7	0300	975:39	[illegible]
263 / 196	270 / 264	269 / 269	264 / 251	263 / 262		12.6	20.0 / 19.5	1600	983:39	993:54
260 / 194	266 / 265	266 / 265	259 / 250	260 / 259		12.5	20.0 / 19.5	0800	999:39	1009:54
258 / 194	264 / 261	265 / 263	260 / 247	258 / 257		12.0	19.5 / 19.0	1105	1002:44	1012:59

CONT'D NEXT PAGE

400 208 Z1 [illegible] 6518 [illegible] 14.87 [illegible] 110759

Z

Z

[illegible] E.J.

DEVELOPMENT ABBREVIATED LIFE TEST
P.R. IV D.4. OF 02-1099

7-8-64

SER. NO. 001C

DATA PG NO. 14

PROJ.

ET 375

FIGURE 4

B.P. = 14.4 PSIA

26.5	3.1	14.0	30.3	3.35	270	3.35	267	3.40	275	6.73	1624	7790	245
24.0	3.1	30.3	41.6	3.30	265	3.30	260	3.39	270	6.66	1590	7790	255
21.0	3.1	37.4	48.7	3.28	260	3.29	256	3.35	265	6.61	1562	7795	250
12.0	3.1	43.0	54.3	3.21	252	3.21	250	3.30	260	6.48	1524	7800	250
17.0	2.9	44.1	55.6	3.20	250	3.20	247	3.28	257	6.45	1508	7800	250
14.0	3.0	48.0	59.4	3.11	240	3.11	239	3.20	247	6.28	1452	7812	248
12.0	3.1	50.0	61.3	[illegible]	[illegible]	3.06	[illegible]	[illegible]	[illegible]	6.21	1410	7816	[illegible]
9.0	3.1	52.5	63.8	3.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.13	1336	[illegible]	250
6.0	3.1	53.8	65.1	[illegible]	[illegible]	2.94	[illegible]	[illegible]	[illegible]	5.98	1294	7812	247
3.0	3.0	55.0	66.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.81	1230	7812	[illegible]
0	3.0	55.0	66.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.67	1156	7825	—
17.0	3.0	43.8	55.2	3.20	248	3.20	242	3.25	250	6.43	1410	7775	250
17.0	3.1	44.0	55.3	3.20	248	3.20	243	3.25	250	6.43	1482	7780	249

SHUTDOWN

400 208

2:1 WELTON 6:18 WELTON 14:27

WELTON 110:59

Thompson Ramo Wooldridge Inc

Upper Cav. Conn. Fin	Upper Cavity Temp	Anti Lead Cap Ext Temp	P.F.	Imp Sulfuric Press. PSIG	Upper Cavity Pr. PSIG / Upper Cap Pr. PSIG	Clock Time	Chronological Test Time Hrs. Min.	Time Hrs. Min.
						11:05	1002:44	1012:59
199 276 274 276 274 270	251 270 268			3.0	10.0	11:30	1003:09	1013:24
200 260 278 260 277 274	260 271 272			9.5	15.8	11:40		
200 276 274 275 274 271	255 269 268			11.0	17.5	11:47		
200 272 271 272 271 268	254 267 266			12.2	19.2	11:55		
197 271 261 271 269 266	251 264 264	.648		12.6	19.6	13:04		
197 268 267 268 267 261	251 263 262			14.0	21.0	13:17		
196 [illegible]	[illegible] 261 [illegible]			14.8	22.0	13:25		
195 [illegible]	[illegible] 260 259			15.4	23.4	13:37		
197 [illegible]	[illegible] 260 257			[illegible]	24.0	13:50		
190 [illegible]	250 260 257			[illegible]	25.0	13:57		
197 [illegible]	[illegible] 276 277			[illegible]	27.2	14:01	1005:40	[illegible]
205 282 280 282 280 277	265 277 275			12.5	20.0	14:10	1005:49	1016:04
195 266 264 266 264 262	252 260 259			12.6	20.2 19.6	16:00	1007:39	1017:54

DEVELOPMENT ACCELERATED LIFE TEST
PAGE IV. D. 4 OF 02-1099

ENGR. E.W. F.C.
DATE 7/17/64
SER. NO DU1C
DATA PG. NO 15

ET 276

PROJ. 576-00 V-36-00

TIME AFTER STOP MIN	SEC		RESISTANCE OHMS							
0	30		1.461							
1	00		1.460							
1	30		1.456							
2	00		1.452							
	30		1.449							
3	00		1.446							
	30		1.443							
4	00		1.440							
	30		1.437							
5	00		1.434							
	30		1.432							

EQUIPMENT: INDUSTRIAL INSTRUMENT [illegible] RN-1 S/N A 7797

RESISTANCE PHASE 1 TO PHASE 2 (PINS E TO 8)

TITLE MOTOR PHASE RESISTANCE

MODEL [illegible]-1 L/C PMA S/N DUIC

FLUID

ENGR. E J

FR

DATE 7/15/64

TEST NO.

PROJECT [illegible]

[illegible] Voltage of [illegible] VAC [illegible] 1 [illegible]
[illegible] Leak [illegible]

Results: 2.0 Microamps Leakage + Condensation G

Test [illegible] Per [illegible] A [illegible]
No Evidence of Breakdown or Excessive Leakage

Equipment: [illegible] Dielectric Tester Model [illegible]
[illegible] Co
[illegible], Ohio

TITLE Dielectric Strength Test Motor [illegible]
(After Flushing with [illegible])
[illegible] L/C [illegible] [illegible]

ENGR. [illegible]
DATE [illegible]
TEST NO.
PROJECT [illegible]

FLUID

IV

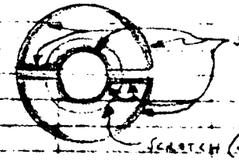
DISASSEMBLY & INSPECTION OF DUIC AFTER 1000 HRS
OVERHAUL SHEET MODEL 253800-1 LUBE & COOLANT PUMP — SER NO. DV-1-C

PARTS REMOVED

Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments

DISASSEMBLED & INSPECTED OUT.

1. GENERAL OBSERVATION: ALL PARTS APPEARED TO BE IN EXCELLENT CONDITION WITH NO SIGNS OF EXCESSIVE WEAR OR DETERIORATION.
2. ROTOR ASSEMBLY:
   FOUND NO CHANGE IN SURFACE MARKS ON ROTOR THRUST WASHER.
   NO EVIDENCE OF WEAR ON RADIAL BEARINGS. (MARKS ON THRUST WASHER SAME AS REPORTED ON PREVIOUS TEARDOWN).
   LOWER JOURNAL O.D. .5001 @ .00005 } WAS .5001/.5002 @ .00005 AT
   UPPER JOURNAL O.D. .5001 @ .00005 } 500 HR. TEARDOWN
   THRUST FACE ⊥ .00045
3. MOTOR HSG. ASS'Y
   RADIAL BRG. BORE .5015 (WAS .5018/.5021 AT 500 HRS)
   .383/.384 DEPTH IN .383 (SAME AT 500 HRS)
   .862/.863 THICKNESS IN .8615 (.8625 @ 500 HRS, .8610 PRIOR TO TEST)
   THRUST FACE "WEAR" PATTERN:



SHADED AREAS INDICATE BURNISHED SPOTS - BURNISHED AREA: NOW ALMOST CONTINUOUS AS OPPOSED TO DISCRETE SPOTS OF PREVIOUS TEARDOWN.

SCRATCH (SEE DUIC TEARDOWN).

4. BRG. HSG. ASS'Y — BORE .5016 (WAS .5017/.5022 @ 500 HRS)
5. ROTOR O.D. PRIOR TO END. 2.1058 AFTER 1000 HRS
   O.D. IS 2.1055 - 2.1055
6. STATOR I.D. PRIOR TO END. 2.1246 - 2.1256 AFTER 1000 HRS.
   I.D. IS 2.1249 - 2.1253

LOWER BEARING I.D.: LOWER JOURNAL O.D.:
UPPER BEARING I.D.: UPPER JOURNAL O.D.:
SHAFT END PLAY:
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

REASON FOR OVERHAUL: SCHEDULED DISASSEMBLY & INSPECTION AFTER COMPLETION OF 1000 HRS. OF ABBREVIATED LIFE TEST

E.P. JIRA
T.P. LEDUKA
W.V. EDWARDS
8/4/64

Part No.	Chg.	Qty.	I.R. No.	Name	S/N	Comments

TEARDOWN CONT'D.

7. ROTOR / STATOR POSITION

As Assembled	After 1000 Hrs.	
3.754	3.7545	.3754
3.439	3.432	3.432
.325	.322	.3225
1.161	1.161	3.7545
2.593	2.5935	1.161
.160	.160	2.5935
.278	.280	
.125	.125	.966
.966	.966	.125
1.091	1.091	1.091

Proof Pressure Test: Test Date , Pressure , Time , Results

Helium Leakage Test: Test Date , Results

LOWER BEARING I.D. LOWER JOURNAL O.D.
UPPER BEARING I.D. UPPER JOURNAL O.D.
SHAFT END PLAY
IMPELLER TO THROAT CLEARANCE (WITH END PLAY TOWARD INLET):
IMPELLER TO HSG. CLEARANCE (WITH END PLAY AWAY FROM INLET):

DATA PG. NO.

GOV'T. INSPECTOR	TRW QUAL. ASSURANCE	OVERHAULED BY:
		DATE: IV 64

TPFC-557

Thompson Ramo Wooldridge Inc.

~~Ass'y.~~ Unit No.		Application of Voltage		Time Min. Sec.		Results 1000 Megohms			
4		Neutral/Case		0		6			
	(After 1000 Hr.			30		50			
	Life Test and Fuse After Dissy)			1 00		70			
				1 30		90			
		Phase I/Case		0		2			
				30		30			
				40		40			
		Phase II/Case		0		3			
				30		50			
6		Neutral/Case		0		110			
	(Prior To Use)			30		300			
				1 00		500			
				1 30		800			
		Phase I/Case		0		50			
				30		400			
		Phase II/Case		0		50			
				30		500			
		Phase III/Case		0		50			
				30		500			
9		Neutral/Case		0		50			
	(Prior To Use)			30		250			
				1 00		400			
				1 30		400			
		Phase I/Case		0		50			
				30		90			
				1 00		90			
				1 30		90			
500	V DC	[illegible]							

TITLE Insulation Resistance Check	ENGR. E.
	P. D.
208214-1 Motor Assemblies	DATE 8/13/64
	TEST NO.
General Radio Co Megohmmeter Type 1862-B	PROJECT 512-004236-[illegible]
S/N 1851	
FLUID	

IV 65

Gage Readings Taken During Development Test Were Not Corrected For Change in Gage Line Fluid Level Due To Pressurization of Ullage When Pump was Operative. Assuming Constant Atmospheric Pressure of 14.3 PSIA and 200°F Line Fluid Temperature with 250°F Inlet Temperature, Corrections Can Be Computed as Follows:

1. Discharge Pressure

Ullage at 0 PSIG = 24 inches

@ 20 PSIG $P_1V_1 = P_2V_2$ $V_2 = \frac{14.3}{34.3} \times 24 = 10$ inches

Correction @ 20 PSIG = 24 − 10 = 14 × .0405 #/in³ = + 0.57 PSIG

@ 40 PSIG $V_2 = \frac{14.3}{34.3} \times 24 = 6.3$ inches

Correction @ 40 PSIG = 24 − 6.3 = 17.7 × .0405 = + 0.72 PSIG

@ 60 PSIG $V_2 = \frac{14.3}{34.3} \times 24 = 4.6$ inches

Correction @ 60 PSIG = 24 − 4.6 = 19.4 × .0405 = + 0.79 PSIG

2. Impeller Suction Pressure Ullage at 0 PSIG = 0 inches

@ 5 PSIG $V_2 = \frac{14.3}{19.3} \times 10 = 7.4$ inches

Correction @ 5 PSIG = 10 − 7.4 = 2.6 × .0405 = + 0.11 PSIG

@ 10 PSIG $V_2 = \frac{14.3}{24.3} \times 10 = 5.9$ inches

Correction @ 10 PSIG = 10 − 5.9 = 4.1 × .0405 = + 0.17 PSIG

@ 20 PSIG $V_2 = \frac{14.3}{24.3} \times 10 = 9.2$

10 − 4.2 = 5.8 × .0405 = + 0.24 PSIG

TITLE Development Test Gage Factors

Model 2533-1 L/C PMA

ENGR. [illegible]

DATE 2/13/64

TEST NO.

PROJECT 516-00[illegible]

FLUID

TPFC-557

Thompson Ramo Wooldridge Inc.

3. Upper Cavity Pressure

Ullage @ 0 PSIG = 10 inches

@ 10 PSIG	$\frac{14.3}{24.3} \times 10 = 5.9$	10 - 5.9 =	4.1 × .0405 =	+ 0.17 PSIG
@ 15 PSIG	$\frac{14.3}{24.3} \times 10 = 4.9$	10 - 4.9 =	5.1 × .0405 =	+ 0.21 PSIG
@ 20 PSIG	$\frac{14.3}{24.3} \times 10 = 4.2$	10 - 4.2 =	5.8 × .0405 =	+ 0.24 PSIG

4. Lower Cavity Pressure

Ullage @ 0 PSIG = 24 inches

@ 10 PSIG	$\frac{14.3}{24.3} \times 24 = 14.1$	24 - 14.1 =	9.9 × .0405 =	+ 0.40 PSIG
@ 15 PSIG	$\frac{14.3}{24.3} \times 24 = 11.7$	24 - 11.7 =	12.3 × .0405 =	+ 0.50 PSIG
@ 20 PSIG	$\frac{14.3}{24.3} \times 24 = 10$	24 - 10 =	14 × .0405 =	+ 0.57 PSIG

TITLE Development Gage Testing Cont'd

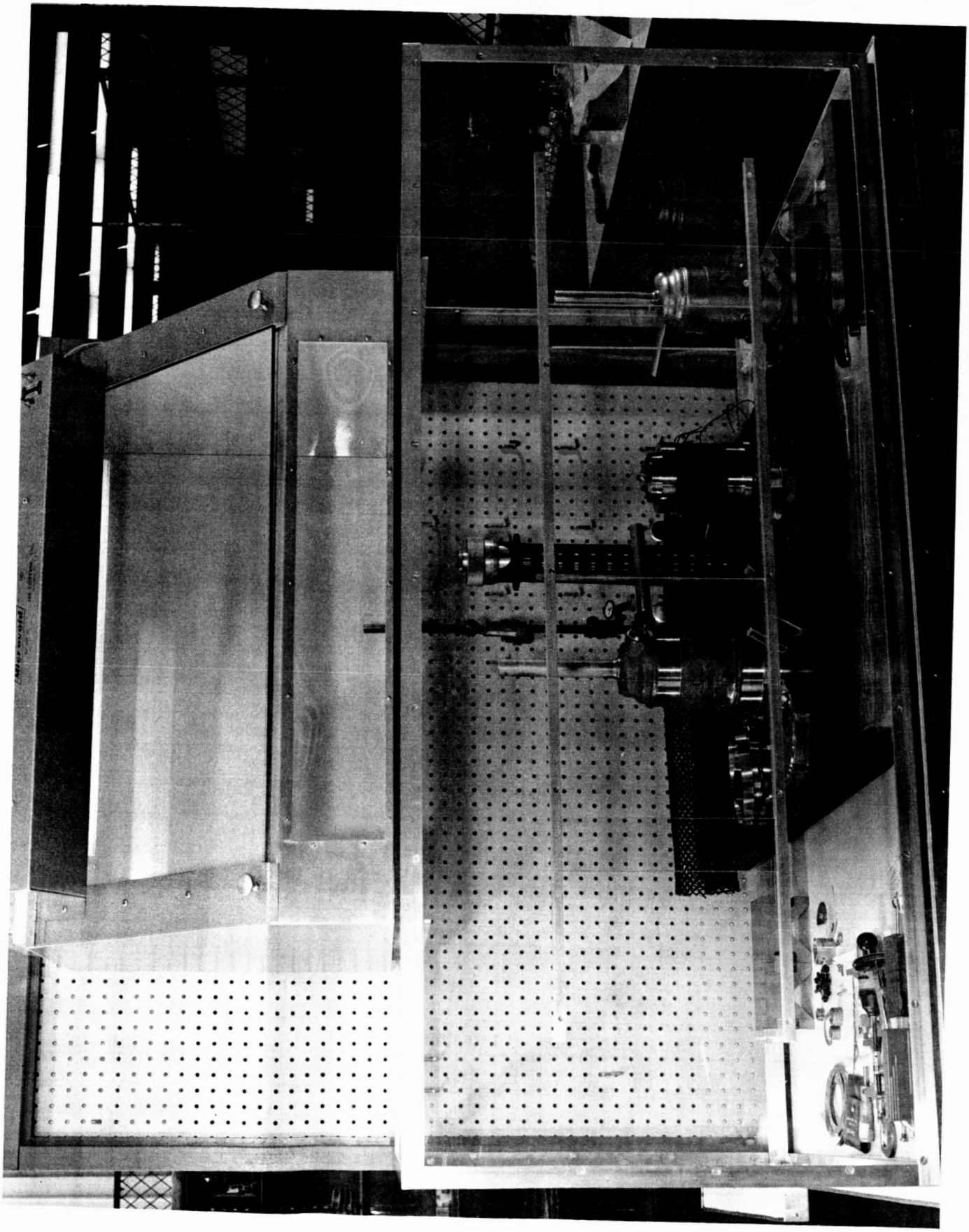
ENGR.

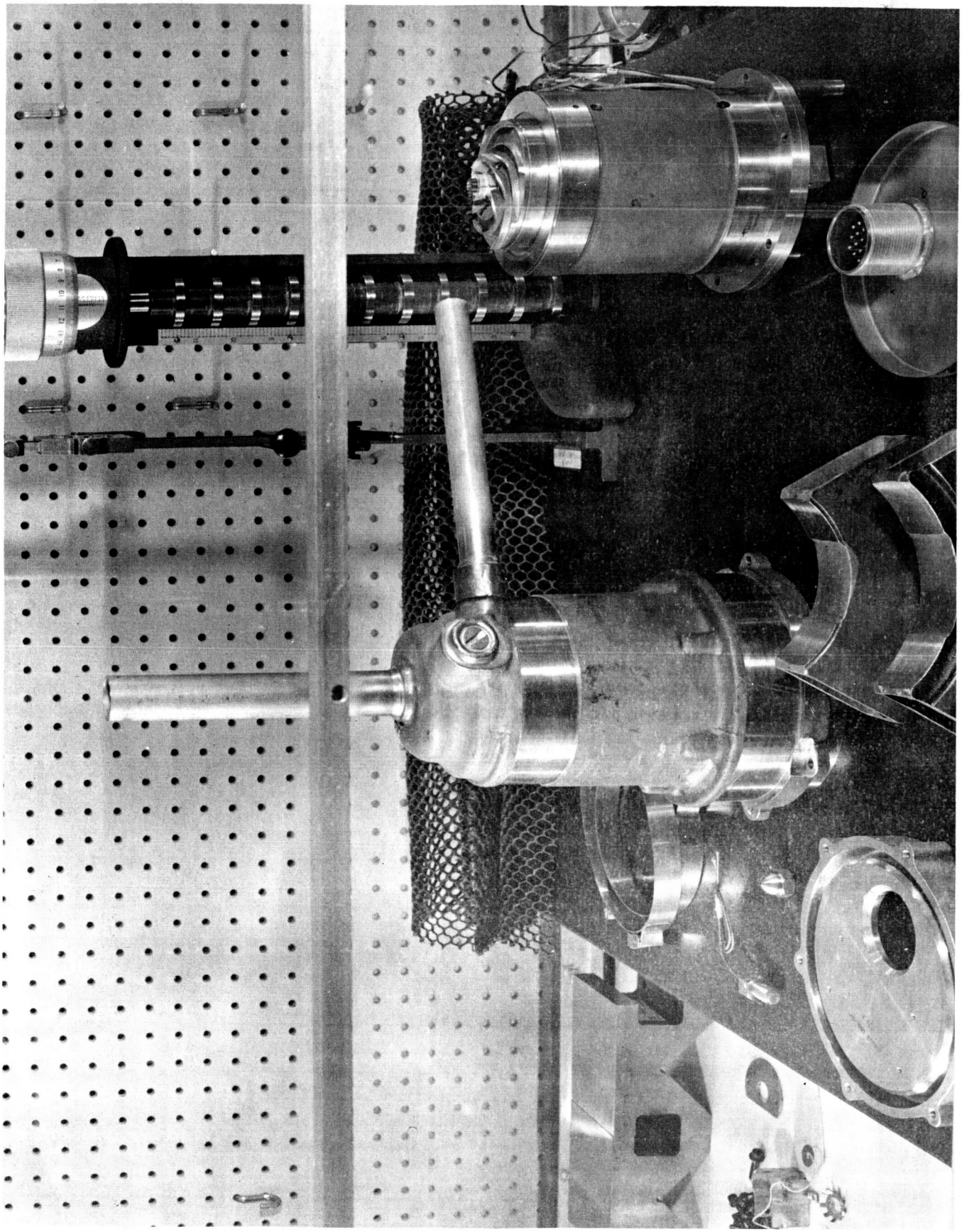
DATE

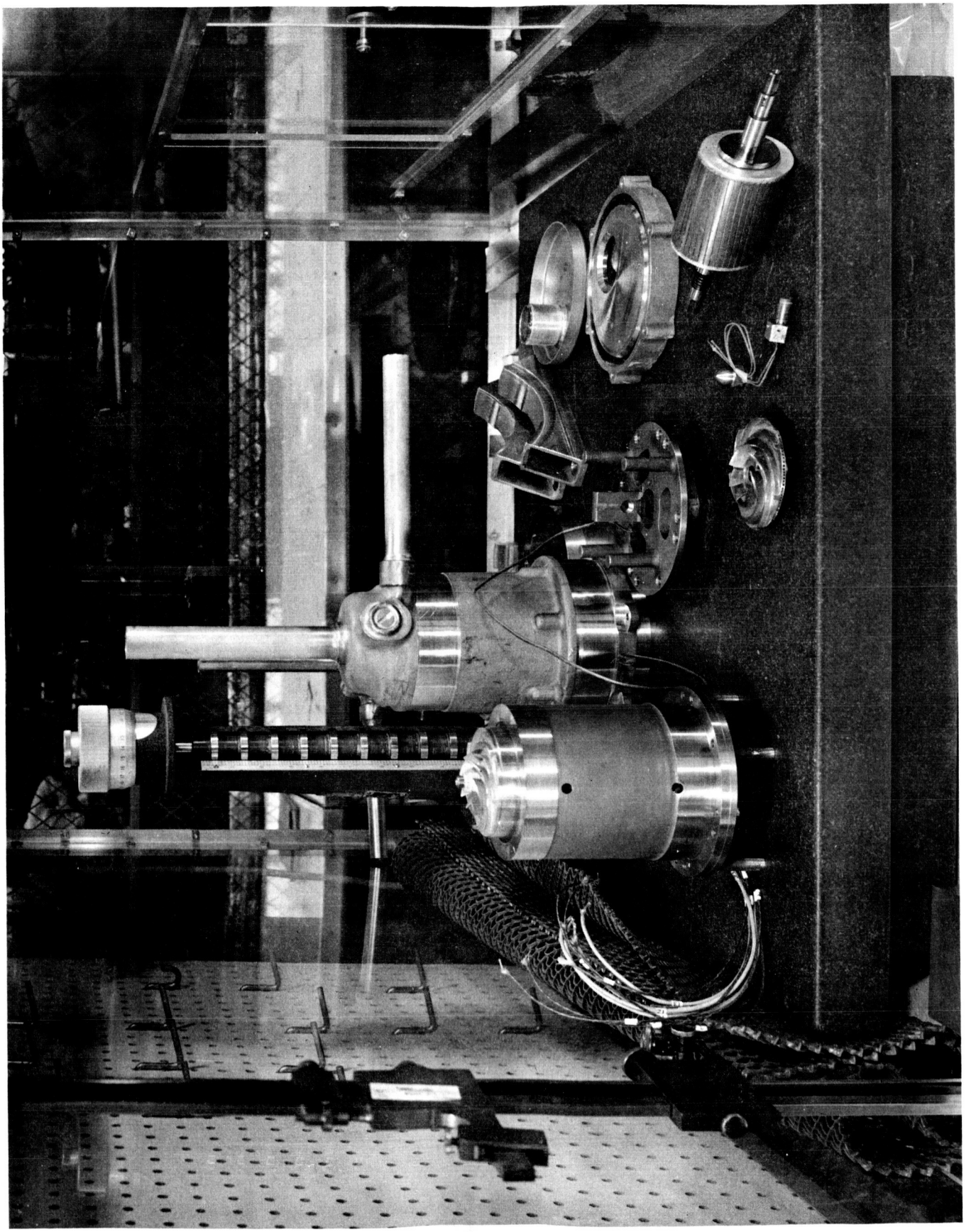
TEST NO.

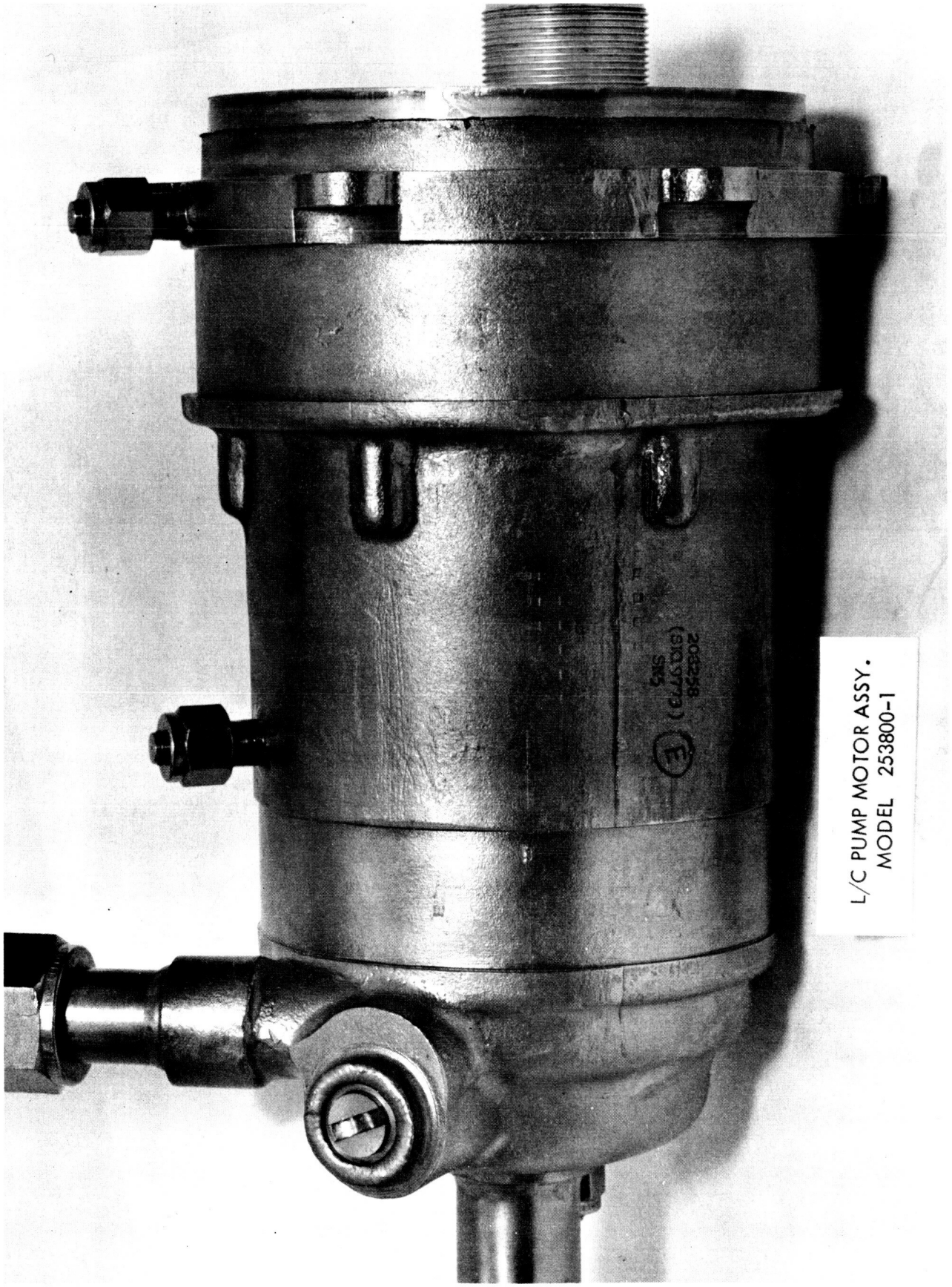
PROJECT

FLUID



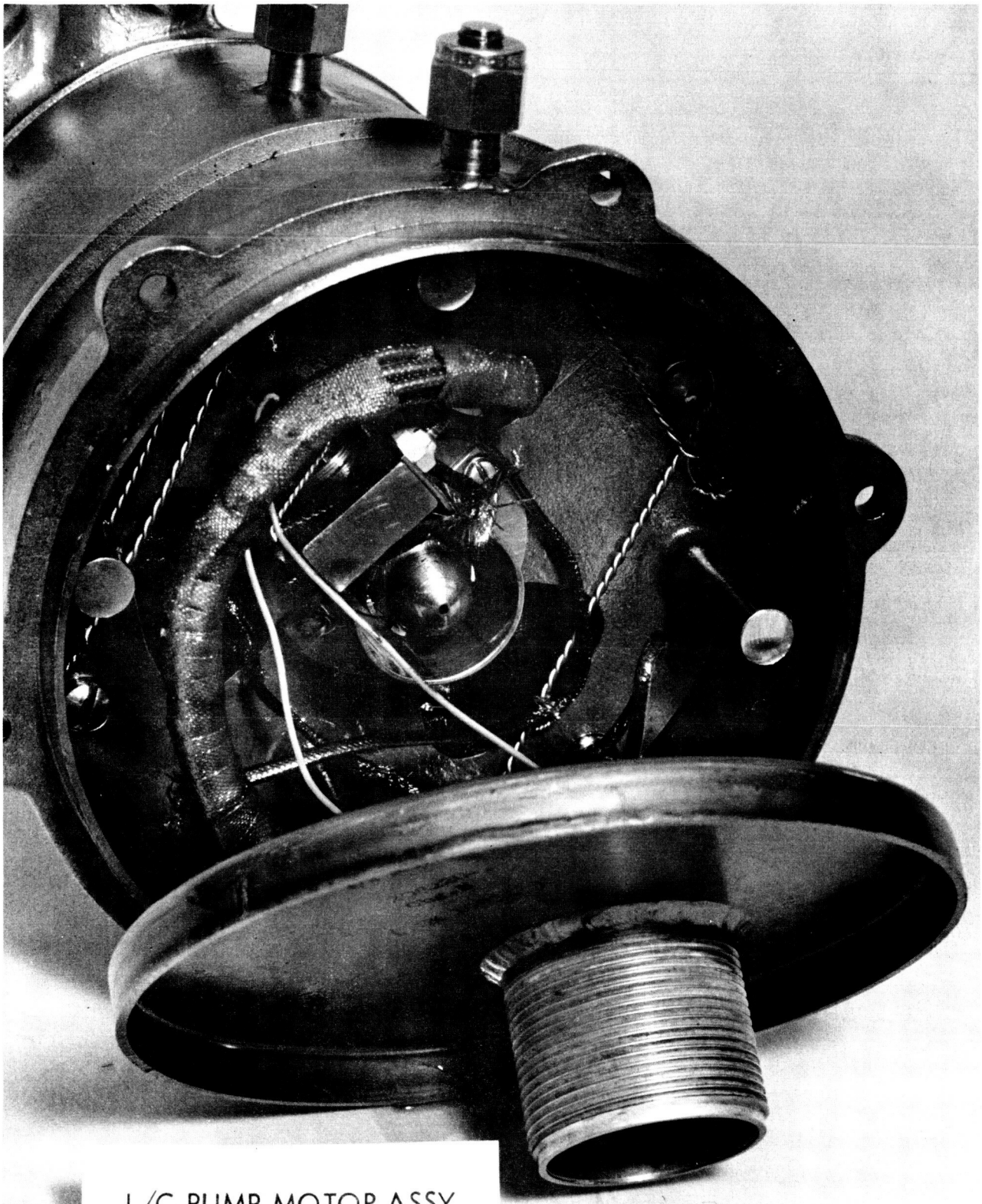






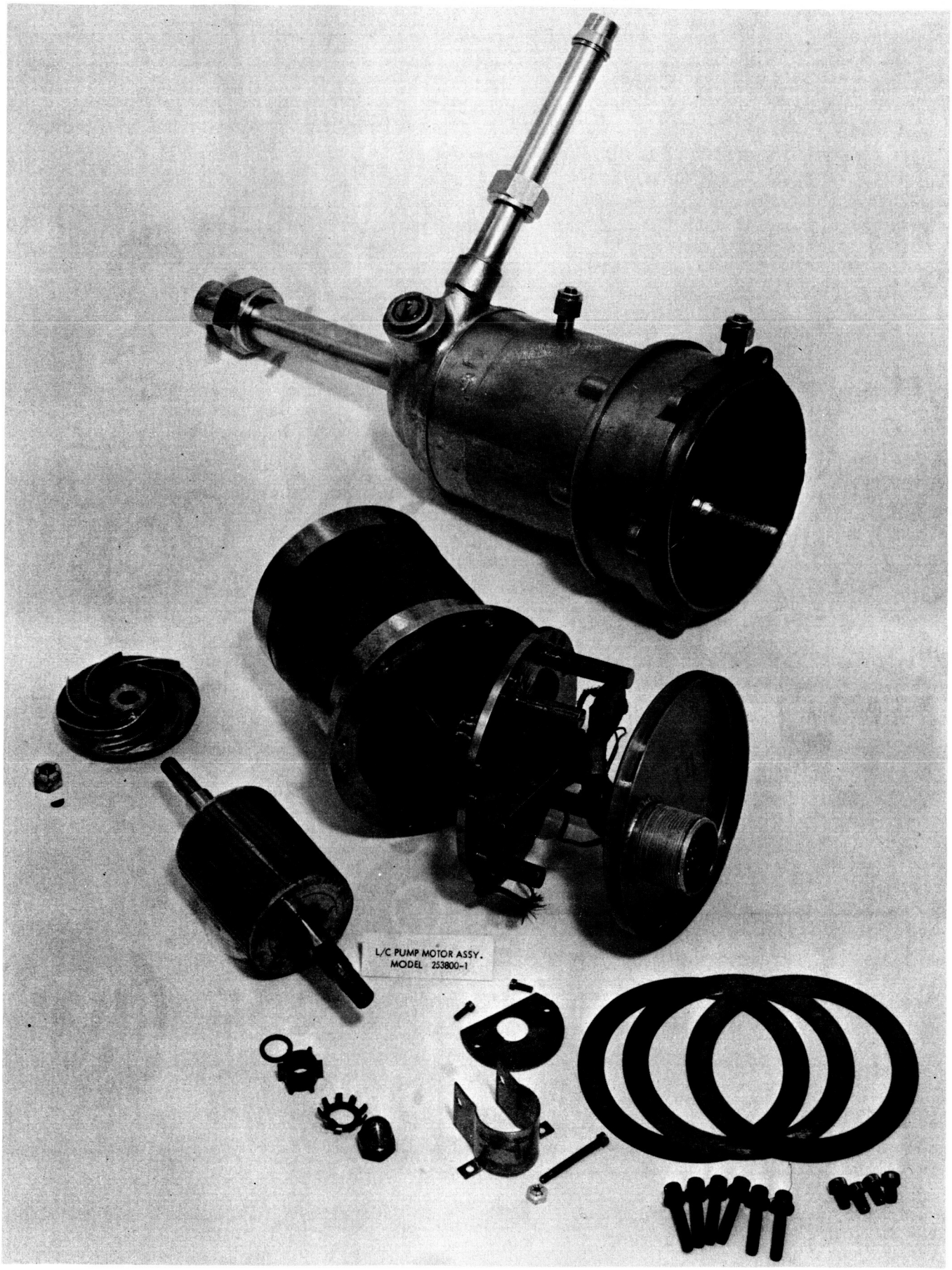
L/C PUMP MOTOR ASSY.
MODEL 253800-1

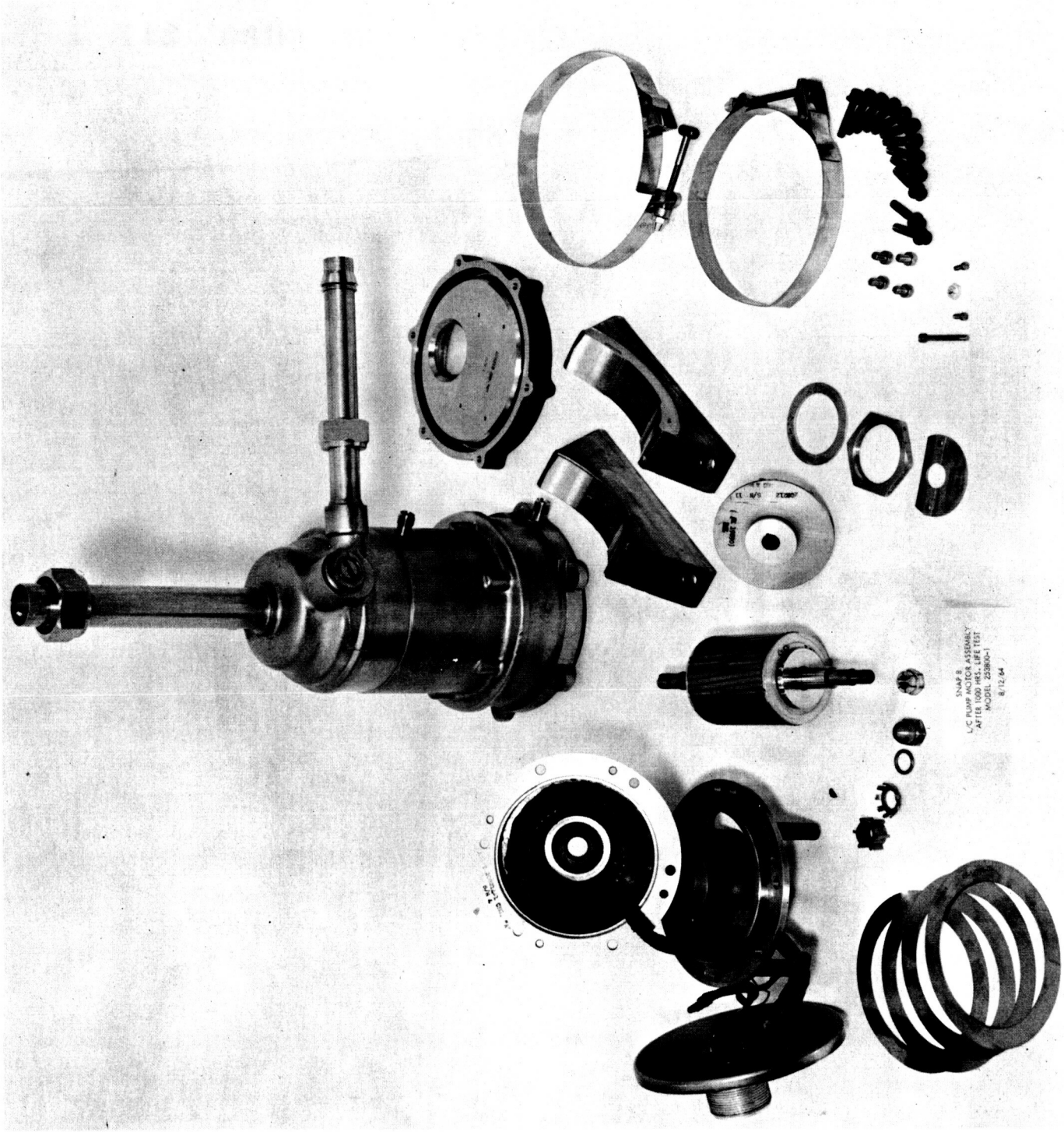
L/C PUMP MOTOR ASSY.
MODEL 253800-1

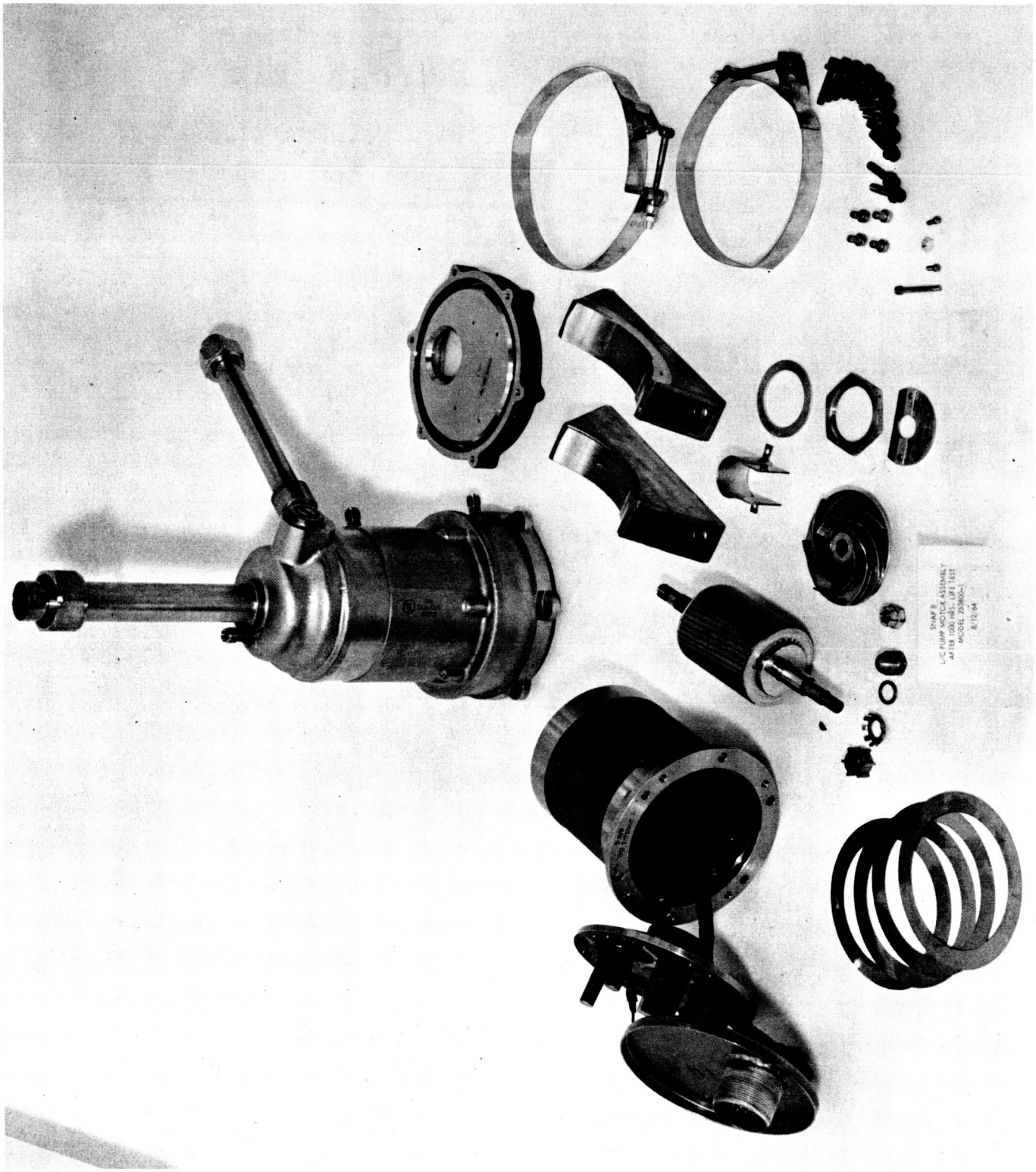


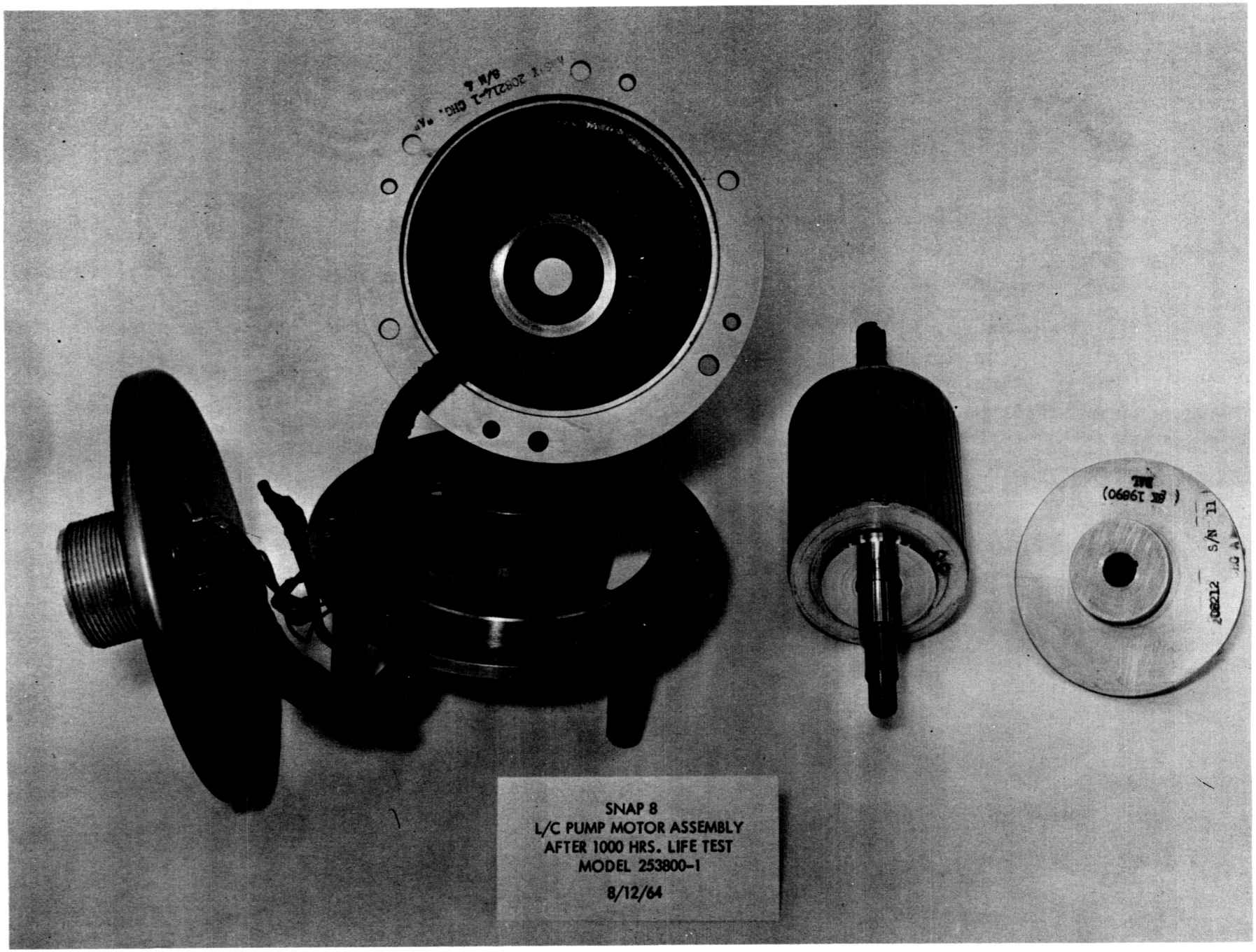
L/C PUMP MOTOR ASSY.
MODEL 253800-1

L/C PUMP MOTOR ASSY.
MODEL 253800-1


L/C PUMP MOTOR ASSY.
MODEL 253800-1


SNAP 8
L/C PUMP MOTOR ASSEMBLY
AFTER 1000 HRS. LIFE TEST
MODEL 253800-1
8/12/64


SNAP 8
L/C PUMP MOTOR ASSEMBLY
AFTER 1000 HRS. LIFE TEST
MODEL 203800-1
8/12/64



SNAP 8
L/C PUMP MOTOR ASSEMBLY
AFTER 1000 HRS. LIFE TEST
MODEL 253800-1
8/12/64

AEROJET-GENERAL CORPORATION

INTER-OFFICE MEMO
10-007-102

TO: F. N. Collamore

DATE: 17 September 1964
GJB:vsh:395-64:304

FROM: G. J. Baenteli

SUBJECT: L/C PMA Electrical Startup Requirements

DISTRIBUTION: CGBoone, CTColker, EEber, RGGeimer, RWMarshall, EFPerez, JRPope, DSpitz, 395 File

ENCLOSURE: (1) Test Results

As a result of your inquiry of L/C pump startup behavior at 95 cps, reduced voltages of 19 V and 36 V, and a PMA bulk temperature of 125°F, a test setup was made in the electrical lab of Bldg. 194. The test description results are shown in Enclosure (1).

G. Baenteli
Rotating Machinery
SNAP-8 Division

APPROVED:

E. Eber, Head
Rotating Machinery
SNAP-8 Division

TEST RESULTS

TEST SETUP

A L/C PMA, Serial No. 481503 was partially filled with FT-378, capped at suction and discharge, and installed in a temp controlled oven. The unit was supplied with 3 ϕ 95 cps electrical power capable of variable voltage.

Prior to initiation of electrical testing the unit was exposed to a 4-hour temperature environment of 125°F.

TEST RESULTS

The test results are as follows:

Motor Temp	°F	125	125
Voltage Applied L to L	Volts	18.8	36.2
Inrush Current 1 ϕ	Amps	7.05	9.60
Steady State Current 1 ϕ	Amps	3.10	3.20
Frequency	Cps	95	96
Steady State Speed	RPM	1750±25	1750±25
Acceleration Time	SEC	.7	.3

A test was run at breakaway voltage:

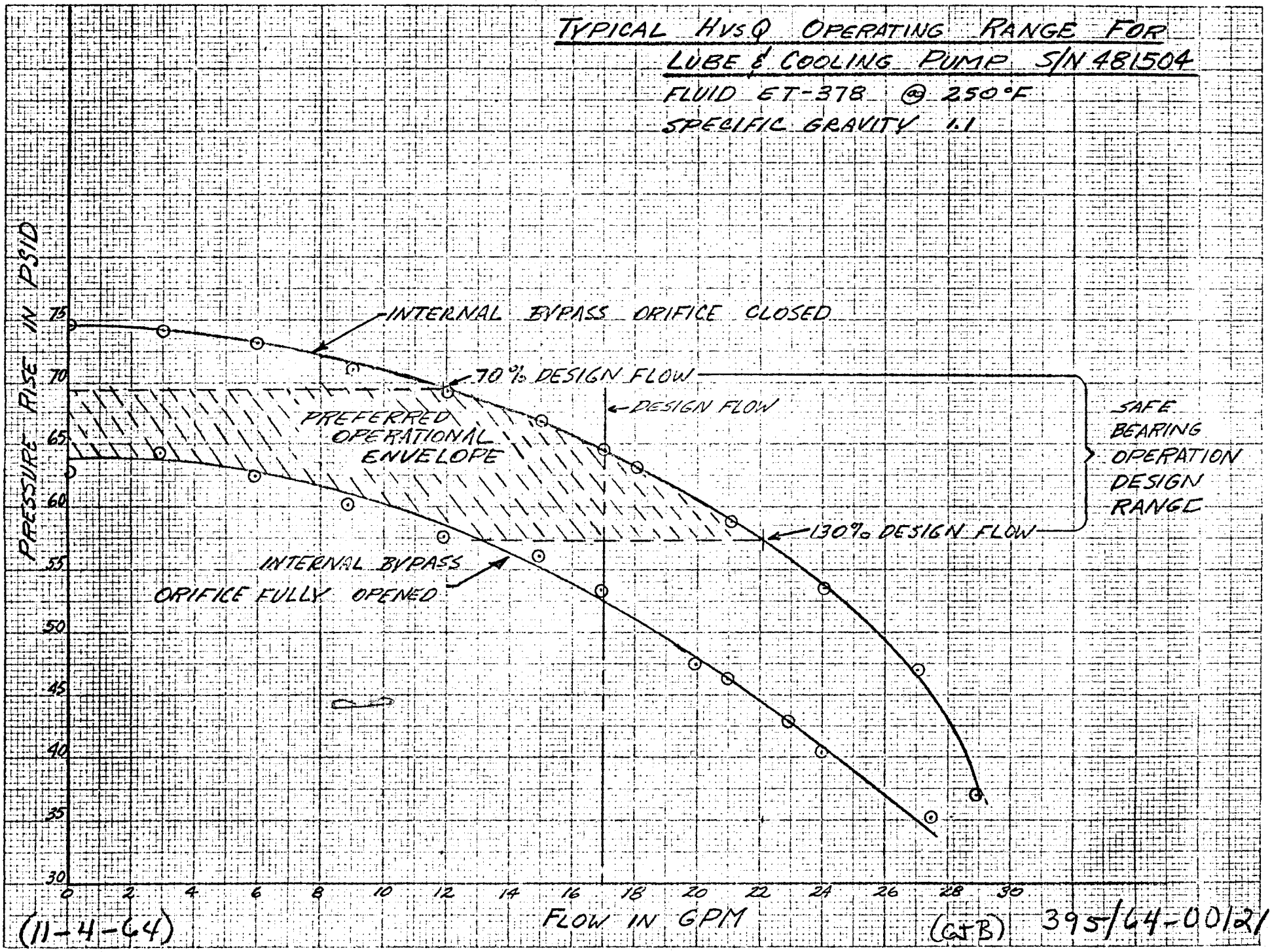
Motor Temp	°F	125
Voltage applied L to L	Volts	5.5
Inrush Current 1 ϕ	Amps	Not apparent
Steady State Current 1 ϕ	Amps	2.15
Frequency	Cps	95
Steady State Speed	RPM	180±5
Acceleration Time	SEC	2.7

In the breakaway voltage test above acceleration past 180 RPM was not experienced even though the PMA power remained on for several seconds.

EQUIPMENT LIST

Item	Identification	Accuracy
Statham Thermostatically Controlled Oven	ACO 15898	± 2%
Statham Thermometer	Shop No. 395	± 3%
Ocilloscope	Shop No. 420	± ½%
Volt Meter	Shop No. 482	± ½%
Amp Meter	Shop No. 418C	± ½%
Counter	Shop No. 430	± ½%

Aerojet-General®
CORPORATION



ENVIRONMENTAL TEST PLAN

FOR

SNAP-8 COMPONENTS

371.0209

Prepared by:	Paul Angelus Test Engineer	5-26-64 Date
Approved by:	S. Seplow Supervisor - Environmental Test Section	5/26/64 Date
Approved by:	R. W. T. Dunn Operations Manager	6/3/64 Date
Approved by:	Neil Patterson Reliability	3 JUNE 64 Date
Approved by:	R. G. Boone Chief Engineer	6/4/64 Date

Distribution: Department Heads, A. B. Beckman, Jr., G. A. Bowles, E. G. Brittain, L. H. Choin, L. C. Glenn, Y. Goren, R. A. Hazen, R. M. Hill, D. W. Howell, L. B. Kelly, A. H. Kreeger, R. W. Marshall, R. S. Miller, B. S. Pilling, J. R. Pope, B. Sugerman, G. G. Takach, W. D. Waldron, Test File

AEROJET-GENERAL CORPORATION

SNAP-8 DIVISION

TEST OPERATIONS DEPARTMENT

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	Table
SNAP-8 Component Environmental Tests	I
Test Sequence - Sample No. 1 and No. 2	II
Test Facilities A	III
Test Facilities B	IV

APPENDIX A - GENERAL TEST PLAN DISCUSSION

APPENDIX B - PROOF TESTS

APPENDIX C - TEST FACILITY REQUIREMENTS

APPENDIX D - SUBCONTRACTOR TEST FACILITIES

APPENDIX E - SNAP-8 COMPONENT ENVIRONMENTAL TEST PROGRAM SCHEDULE

ENVIRONMENTAL TEST PLAN FOR SNAP-3 COMPONENTS

1.0 INTRODUCTION

1.1 SCOPE

This plan covers the -1 model hardware and material sample testing. The plan includes the following:

a - Test objectives

b - General test methods

c - Test items

d - Environmental exposures

e - Environmental stress levels and durations

f - Proof tests

g - Failure criteria

h - Measurement requirements

i - Documentation

j - Test schedules

k - Test facilities

1.2 TEST OBJECTIVES

The objectives of the Environmental Test Program are to disclose any critical design weaknesses and to provide reasonable assurance that the SNAP-8 system and its components will withstand the environmental hazards encountered during transportation, storage, vehicle integration, launch, separation, and termination of thrust.

2.0 REFERENCE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS

NASA 417	Appendix 1, Statement of Work, Task III dated 6/29/63
NASA 417-2	SNAP-8 Environmental Specification dated 2/25/64
MIL-I-26600 (USAF)	Interference Control Requirements, Aeronautical Equipment, Notice I, dated 1 June 1962
MIL-E-5272 (ASG)	Environmental Testing, Aeronautical and Associated Equipment, General Specification for, Amendment I dated 20 January 1960
MIL-C-9436A (ASG)	Chamber, Sand and Dust Testing dated 5 May 1955
MIL-C-9452 (USAF)	Chamber, Fungus Resistance Testing dated 8 June 1954
MIL-STD-810 (USAF)	Military Standard, Environmental Test Methods for Aerospace and General Equipment dated 14 June 1962

2.2 AGC DOCUMENTS

Specifications: AGC-10152	SNAP-8 Power Conversion System Model Specification dated 17 January 1964 (Draft for Approval)

2.2 AGC DOCUMENTS (cont.)

343:R0300n	General Test Plan Reliability Testing of SNAP-8 Components (First Draft) dated 6 April 1964
393-64-0001	Preliminary Draft Integrated Test Plan SNAP-8 Electrical Generating System
	SNAP-8 Division Procedures

3.0 GENERAL DISCUSSION

The fundamental concepts of the environmental test program are summarized below and detailed discussions of the items listed are contained in Appendix A.

3.1 The environmental tests of this test plan will be conducted at the component level on development hardware (-1).

3.2 Two samples of each component and one PCS Structure will be subjected to the environmental tests listed in Table I. The NPS (-3) Type Approval Test listed in Table I is not within the scope of this test plan.

3.3 The applicable environments, the stress levels and duration, and the test methods will follow the requirements of NASA Specification 417-2.*

3.4 Wherever tests on material samples can provide adequate design assurance, sample testing will be utilized.

---

*Humidity and Salt Spray Tests shall be performed in accordance with the applicable paragraphs of MIL-E-5272 except that the duration of the Humidity Test shall be 48 hours and the duration of the Salt Spray Test shall be 25 hours.

3.5 The components will be tested at the most severe stress level only.

3.6 In lieu of testing, removal of environmental hazards through protective measures will be investigated and appropriate recommendations offered as alternatives.

3.7 The susceptibility of each component to the various environmental stresses will be analyzed and the test program will be concentrated on those environments which are potentially detrimental.

3.8 The PCS Structure will be subjected only to the shock and vibration tests in order to ascertain the shock and vibration input levels to the individual components.

3.9 The test program is predicated on the concept that, generally, test verification of the design on the component level will demonstrate system capabilities.

4.0 TEST PLAN

4.1 DESCRIPTION OF TESTS

4.1.1 Environmental Tests

The following environmental tests will be performed in accordance with the requirements of NASA 417-2. Table I lists each component and the tests to which they will be subjected.

4.1.1.1 Climatic Tests

Title	NASA 417-2 Paragraph No.
a. Humidity MIL-E-5272	4.4.1
b. Sand & Dust	3.3.1.3
c. Fungus	3.3.1.4
d. Salt Spray MIL-E-5272	4.6.1
4.1.1.2 Dynamic Tests	
a. Shock	3.4.2.1
b. Vibration	3.4.2.2
c. Acoustic Noise	3.4.2.3
d. Acceleration	3.4.2.4
4.1.1.3 Other Environments	
a. Pressure Tests (Vacuum)	3.4.3.2
b. RF Generation & Interference	3.6

4.1.2 Proof Tests

Prior to and following each set of environmental exposures, proof tests will be performed to detect failure or degradation. The proof tests will be selected to expedite the detection of the individual component failure modes.

4.1.2.1 Visual Examination

All components will be visually inspected and all faults recorded. Magnifying glass, microscopic examination, cross sections, radiographic examinations, die penetrants and chemical analysis will be utilized as required to supplement the visual inspection.

4.1.2.2 Helium Leak Detection

Helium leak detection techniques will be employed as applicable to detect deterioration of component structural integrity.

4.1.2.3 Operational Tests

When required, the functional capabilities of the components will be checked by the performance of operational tests at simulated design conditions. The design parameters and the required operational characteristics of the individual components will be specified in the detailed test specifications.

4.1.2.4 Electrical Tests

Electrical tests consisting of continuity tests, resistance tests, insulation resistance tests, and dielectric strength tests will be performed on appropriate components to detect degradation of their electrical properties.

4.1.2.5 Disassembly and Final Inspection

Following the completion of all environmental testing, components shall be disassembled for internal examination and inspection as required.

4.2 TEST ITEMS

The components to be subjected to the environmental tests are listed in Table I. All components shall have successfully completed the acceptance test as required by their respective specifications. The components will be delivered to test with their respective simulated prototype bracketry.

4.3 TEST PREPARATION

4.3.1 Test Fixtures

Test fixtures will be designed and fabricated for each component type subjected to environmental tests. To insure a realistic simulation of dynamic conditions, provisions will be made, if required, to include associated piping from the component to the first tie point to the structure. Protective devices will be incorporated in the fixture to reduce hazards to test personnel or equipment (e.g., NaK or Hg spillage containment).

4.3.2 Test Sample Preparation

4.3.2.1 Gas filled components. Helium shall be substituted as the charging medium for all component test samples containing gasses to facilitate quantitative evaluation of leak rates.

4.3.2.2 Liquid filled components. Components will be dynamically tested with their respective working fluid in accordance with design specifications except that a substitute fluid may be used during the environmental testing of all NaK filled components. Viscosity and density similarities will determine the selection of the substitute fluids so that the test information, with respect to dynamic conditions, will be valid. Candidate fluids at present, are water, with a sodium dichromate additive, and JP-5. Some operational tests may be conducted with substitute fluid if valid information can be obtained.

4.3.3 Identification

All components submitted for environmental testing shall be suitably marked for identification in accordance with Table II.

4.4 TEST SEQUENCE

The sequence of testing shall be in accordance with Table II. The test sequence may be changed to expedite the test program if the validity of the tests is not affected.

4.5 FAILURE CRITERIA

Failure is defined as the inability of components to meet minimum specified requirements.

4.5.1 Catastrophic Failure

A failure is considered catastrophic when the component can no longer perform its function.

4.5.2 Degradation Failure

A failure is considered degrading when the component functions but not within the specified limits.

4.5.3 Component Failure

Failure criteria for each component will be defined in the detailed test specification based on the individual component design specifications.

4.6 PROCEDURE FOLLOWING FAILURE

If failure occurs, the ensuing procedure shall be followed.

4.6.1 The test shall cease and cognizant personnel immediately notified.

4.6.2 The cause of failure shall be determined.

4.6.3 In the case of degradation failure, testing shall be resumed. Documentation of the degradation failure shall be in accordance with Paragraph 4.8 of this test plan.

4.6.4 In the case of catastrophic failure, the tests shall be terminated.

4.6.4.1 If the fault is minor,* the component shall be repaired and the portion of the test (during which the failure occurred) shall be repeated in its entirety with the approval of the NASA Project Manager.

4.6.4.2 If the fault is major,* suitable corrective action (possibly design modification) will be undertaken under the auspices of the cognizant design engineer. The corrected component shall be subjected to tests to verify the modified unit.

4.6.4.3 Documentation of the catastrophic failure shall be in accordance with Paragraph 4.8 of this test plan.

4.6.5 In the event of failure or malfunction due to test facility, instrumentation, or test fixture, the failure or malfunction shall be corrected and the test resumed repeating only that portion of the test during which the failure or malfunction occurred. Documentation of the equipment failure or malfunction shall be in accordance with Paragraph 4.8 of this test plan.

4.7 MEASUREMENTS AND TEST DATA

4.7.1 Measurements

In order to evaluate component capabilities, measurements of test conditions, stress inputs and outputs, operational parameters, and indications of structural conditions, shall be recorded. Operational parameters will be selected to show failure or degradation and to indicate malfunction location and failure mode. The methods of measurements (analogue, digital, or meter indications) will be determined by the specific parameters specified by the component specification.

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*Major and minor faults will be defined in the individual detailed component test specifications.

4.7.2 Test Data

Test data recorded during the environmental test program will be reduced as required for evaluation. Transient conditions and step functions will be plotted and analogue data reduced for quick comparison with design limits. Data sheets and worksheets, depicting the calculations necessary to derive test parameters, will be attached to the detailed component specifications. Test data will also include instrumentation information identifying the instruments used as well as their accuracies and calibration histories and all pertinent information necessary to duplicate the test setup.

Representative requirements for test data are presented as follows:

4.7.2.1 Visual Examination

4.7.2.1.1 Detailed descriptions of any faults, degradations, changes, or discrepancies.

4.7.2.1.2 Photographs and sketches.

4.7.2.2 Non-Destructive Testing

4.7.2.2.1 X-rays, ultra-sonics.

4.7.2.3 Destructive Testing

4.7.2.3.1 Cross-sections (welds).

4.7.2.4 Laboratory Analysis

4.7.2.4.1 Chemical

4.7.2.4.2 Metallurgical

4.7.2.5 Helium Leak Detection

4.7.2.5.1 Leak rate and instrument setting.

4.7.2.5.2 Methods of application; pressure, spray, etc.

4.7.2.5.3 Locations of leaks

4.7.2.6 Operational Tests

4.7.2.6.1 Inputs

4.7.2.6.2 Outputs

4.7.2.6.3 Instrument ranges, settings, sensitivities, special calibration, etc.

4.7.2.6.4 Warmup time

4.7.2.6.5 Time, elapsed time, response time.

4.7.2.6.6 Events

4.7.2.7 Environmental Tests

4.7.2.7.1 Temperature

4.7.2.7.2 Humidity

4.7.2.7.3 Salt Concentration

4.7.2.7.4 Velocity

4.7.2.7.5 Pressure, vacuum

4.7.2.7.6 Radio Frequency Interference

4.7.2.7.7 Acceleration stresses (g's), input and output levels.

(1) Vibratory

(2) Shock

(3) Sustained acceleration

4.7.2.7.8 Acoustic noise levels and calibration

4.7.2.7.9 Frequency

4.7.2.7.10 Displacement

4.7.2.7.11 Time duration

4.7.2.7.12 Instrumentation and calibration

4.8 DOCUMENTATION

4.8.1 Equipment Logs

Equipment logs will be maintained in accordance with SNAP-8 Division Procedures V-D2 and V-D3.

4.8.2 Failure Reporting

Failure reporting and analysis will be in accordance with SNAP-8 Division Procedures VI-A4 and VI-A8.

4.8.3 Test Reports

A test report will be prepared for each component and will include test specifications, test procedures, test setups, instrumentation, test results, conclusions, and recommendations. Photographs of test setups and mechanical failures will be attached. Charts, graphs, etc. will be included for visual representation of test results.

4.9 DISPOSITION OF TEST ITEMS

Following disassembly and inspection, the components shall be cleaned, prepared for storage, identified, and stored. Components which have been subjected to the tests of the environmental test program may be used for any additional testing; however, they shall not be used for flight hardware unless requested by the NASA Program Manager.

TABLE I

SNAP-8 COMPONENT ENVIRONMENTAL TESTS

COMPONENTS	NUMBER OF UNITS	CLIMATICS: HUMIDITY 3.3.1.2 Note 2	CLIMATICS: SALT SPRAY 3.3.1.5 Note 3	CLIMATICS: FUNGUS 3.3.1.4 Note 1	CLIMATICS: WIND 3.3.3 Note 4	CLIMATICS: SAND & DUST 3.3.1.3 Note 5	OTHER ENVIRONMENTS: PRESSURE (VAC) 3.4.3.2 Note 6	OTHER ENVIRONMENTS: RFI 3.6	DYNAMICS: VIBRATION 3.4.2.2	DYNAMICS: SHOCK 3.4.2.1	DYNAMICS: ACCELERATION 3.4.2.4	DYNAMICS: ACOUSTIC NOISE 3.4.2.3	DYNAMICS: TRANSPORTATION VIBRATION & SHOCK 3.2.5 - 3.2.6 Note 7
NaK PMA Primary	2	X	X	X	NA	X	X	X	X	X	X	X	NA
NaK PMA HRL	2	X	X	X		X	X	X	X	X	X	X	
Hg PMA	2	X	X	X		X	NA	X	X	X	X	X	
L/C PMA	2	X	X	X		X	X	X	X	X	X	X	
Turbine Alternator Assembly	2	X	X	X		X	X	X	X	X	X	X	
Boiler	2	NA	NA	NA		NA	X	NA	X	X	X	X	
Condenser	2	NA	NA	NA		NA	X	NA	X	X	X	X	
Auxiliary Start Loop Heat Exchanger	2	NA	NA	NA		NA	X	NA	X	X	X	X	
Speed Control Module	2	X	X	X		X	X	X	X	X	X	X	
Voltage Regulator Module	2	X	X	X		X	X	X	X	X	X	X	
Transformer Reactor Assembly	2	X	X	X		X	X	X	X	X	X	X	
Protective System Module +	2	X	X	X		X	X	NA	X	X	X	X	
Power Conditioner +	2	X	X	X		X	X	X	X	X	X	X	
Parasitic Load Resistor	2	X	X	X		X	X	X	X	X	X	X	
Vehicle Load Breaker +	2	X	X	X		X	NA	NA	X	X	X	X	
Inverter Assembly*	2	X	X	X		X	X	X	X	X	X	X	
Start Programmer*	2	X	X	X		X	X	X	X	X	X	X	
Harness Assembly Low Current High Current	2	X	X	X		X	NA	NA	X	X	X	X	
Battery Assembly +	2	X	X	X		X	X	NA	X	X	X	X	
Expansion Reservoir NaK Primary	2	X	X	X		NA	X	NA	X	X	X	X	
Expansion Reservoir NaK HRL	2	X	X	X		NA	X	NA	X	X	X	X	
Expansion Reservoir L/C	2	X	X	X		NA	X	NA	X	X	X	X	
Hg Filter Separator	2	NA	NA	NA		NA	NA	NA	X	X	X	X	
NaK Hot Trap Primary	2	NA	NA	NA	↓	NA	NA	NA	X	X	X	X	↓
Hg Injection System*	2	X	X	X	NA	X	X	NA	X	X	X	X	NA

TABLE I (cont.)

COMPONENTS	NUMBER OF UNITS	CLIMATICS					OTHER ENVIRONMENTS		DYNAMICS				
		HUMIDITY 3.3.1.2 Note 2	SALT SPRAY 3.3.1.5 Note 3	FUNGUS 3.3.1.4 Note 1	WIND 3.3.3 Note 4	SAND & DUST 3.3.1.3 Note 5	PRESSURE (VAC) 3.4.3.2 Note 6	RFI 3.6	VIBRATION 3.4.2.2	SHOCK 3.4.2.1	ACCELERATION 3.4.2.4	ACOUSTIC NOISE 3.4.2.3	TRANSPORTATION VIBRATION & SHOCK 3.2.5 - 3.2.6 Note 7
Hg Flow Control Valve*	2	X	X	X	NA	X	NA	X	X	X	X	X	NA
Temperature Control Valve*	2	X	X	X	↓	X	X	NA	X	X	X	X	↓
Auxiliary Start Loop Shutoff Valve*	2	X	X	X	↓	X	NA	X	X	X	X	X	↓
PCS Structure +	1	NA	NA	NA	NA	NA	NA	NA	X	X	NA	NA	NA
NPS (TAT)	1	NA	NA	NA	X	NA	NA	NA	X	X	X	X	X

X - Indicates test to be performed in accordance with referenced paragraph of NASA Specification 417-2.
* - Startup Component.
\+ - Deferred to FY 1966.
NA - Not Applicable.

NOTES:
1. Fungus tests will be performed on material samples only.
2. Humidity tests will be performed to verify the capability of electrical feed thrus to withstand humidity conditions.
3. Salt Spray tests will be performed to verify the capability of electrical feed thrus to withstand corrosive effects of salt atmosphere.
4. Wind tests will be performed on the system level only.
5. Sand & Dust tests will be performed to verify the capability of electrical feed thrus to withstand erosion.
6. Liquid and gas filled units only will be tested. (Launch-ready conditions).
7. Transportation vibration & shock tests will be performed on the system level only.

TABLE II

TEST SEQUENCE

Sample No. 1

	Test	Paragraph
a.	Proof Tests	4.1.2
b.	Shock Tests	4.1.1.2.a
c.	Proof Tests	4.1.2
d.	Vibration Tests	4.1.1.2.b
e.	Proof Tests	4.1.2
f.	Acceleration Tests	4.1.1.2.d
g.	Proof Tests	4.1.2
h.	Acoustic Noise Tests	4.1.1.2.c
i.	Proof Tests	4.1.2
j.	Sand & Dust Test	4.1.1.1.b
k.	Humidity Test	4.1.1.1.a
l.	Salt Spray Tests	4.1.1.1.d
m.	Proof Tests	4.1.2
n.	Vacuum Tests	4.1.1.3.a
o.	Proof Tests	4.1.2
p.	Fungus*	4.1.1.1.c
q.	RFI	4.1.1.3.b
r.	Disassembly & Final Inspection	4.1.2.5
s.	Disposition of Sample	4.9

*Material Samples only.

TABLE II (cont.)

Sample No. 2

	Test	Paragraph
a.	Proof Tests +	4.1.2
b.	Shock Tests +	4.1.1.2.a
c.	Proof Tests +	4.1.2
d.	Vibration Tests +	4.1.1.2.b
e.	Proof Tests +	4.1.2
f.	Acoustic Noise Tests +	4.1.1.2.c
g.	Proof Tests +	4.1.2
h.	Acceleration Tests	4.1.1.2.d
i.	Proof Tests	4.1.2
j.	Disassembly & Final Inspection	4.1.2.5
k.	Disposition of Samples	4.9

+All startup components identified as Sample No. 2 will be subjected to tests "a" through "g" in accordance with the appropriate Startup Components Reliability Test Procedure. All other components identified as Sample No. 2 will be subjected to tests "a" through "k" in accordance with the provisions of this test plan.

TABLE II (cont.)

Sample No. 2

	Test	Paragraph
a.	Proof Tests +	4.1.2
b.	Shock Tests +	4.1.1.2.a
c.	Proof Tests +	4.1.2
d.	Vibration Tests +	4.1.1.2.b
e.	Proof Tests +	4.1.2
f.	Acoustic Noise Tests +	4.1.1.2.c
g.	Proof Tests +	4.1.2
h.	Acceleration Tests	4.1.1.2.d
i.	Proof Tests	4.1.2
j.	Disassembly & Final Inspection	4.1.2.5
k.	Disposition of Samples	4.9

+All startup components identified as Sample No. 2 will be subjected to tests "a" through "g" in accordance with the appropriate Startup Components Reliability Test Procedure. All other components identified as Sample No. 2 will be subjected to tests "a" through "k" in accordance with the provisions of this test plan.

TABLE III

TEST FACILITIES (A)

COMPONENTS DIMENSIONS & WEIGHTS	DYNAMIC TEST FACILITIES				CLIMATIC TEST FACILITIES			OTHER ENVIRONMENTS TEST FACILITIE	
	VIBRATION	SHOCK	ACCELER-ATION	ACOUSTIC NOISE	HUMIDITY	SALT SPRAY	SAND & DUST	PRESSURE (VACUUM)	RFI
Hg PMA 28" x 16" x 15" - 150 lbs	B	E	H	J	L	N	O	S	T
L/C PMA 8" x 12" x 16" - 28 lbs	B	E	I	J	K	M	O	S	T
Inverter 22" x 16" D - 150 lbs	B	E	H	J	L	N	O	S	T
Start Programmer 12" x 6" D - 15 lbs	B	D	I	J	K	M	O	S	T
Transformer Reactor Assembly 40" x 20" x 20" - 325 lbs	B	F	H	J	L	N	P	S	T
Battery Assembly 12" x 12" x 14" 140 lbs	B	E	I	J	K	M	O	S	NA
Electrical Harness 14" x 40" x 4" 15 lbs (Hi current)	B	E	H	J	L	N	P	NA	NA
Voltage Regulator Module (LT) 16" x 16" x 16" - 64 lbs	B	E	I	J	K	M	O	S	T
Speed Control Module 12" x 12" x 12" 30 lbs	B	D	I	J	K	M	O	S	T
Protective System Module (Size and Weight Not Available)									
Boiler 58" x 32" x 24" - 978 lbs	C	E	G	J	NA	NA	NA	S	NA
Condenser 64 x 20" x 12" - 130 lbs	B	E	G	J	NA	NA	NA	S	NA
Auxiliary Start System Heat Exchanger 34" x 8" D - 29 lbs	B	E	H	J	NA	NA	NA	S	NA
Expansion Reservoir NaK Pri. 37" x 14" D - 41 lbs	B	E	H	J	L	N	P	S	NA

Table III
Sheet 1

TABLE III (cont.)

COMPONENTS DIMENSIONS & WEIGHTS	DYNAMIC TEST FACILITIES				CLIMATIC TEST FACILITIES			OTHER ENVIRONMENTS TEST FACILITIES	
	VIBRATION	SHOCK	ACCELER-ATION	ACOUSTIC NOISE	HUMIDITY	SALT SPRAY	SAND & DUST	PRESSURE (VACUUM)	RFI
Expansion Reservoir NaK HRL 28" x 12" D - 22 lbs	B	F	H	J	L	N	O	S	NA
Expansion Reservoir L/C 25" x 14" D - 24 lbs	B	F	H	J	L	N	O	S	NA
Parasitic Load Resistor 44" x 9" D - 68 lbs	B	E	H	J	L	N	P	S	T
Turbine Alternator Assembly 44" x 28" x 16" - 658 lbs	C	E	G	J	L	N	P	S	T
NaK PMA Pri 32" x 30" x 28" 375 lbs	B	F	H	J	L	N	O	S	T
NaK PMA HRL 32" x 30" x 28" 375 lbs	B	F	H	J	L	N	O	S	T
Vehicle Load Breaker 6"x 6" x 6" - 10 lbs	A	D	I	J	K	M	O	S	T
Power Conditioner 4" x 4" x 5" 8 lbs	A	D	I	J	K	M	O	S	T
Hg Injection System 16" x 20" x 24" - 226 lbs	B	E	I	J	L	N	O	S	T
Hg Flow Control Valve 16" x 16" x 5" - 10 lbs	B	E	I	J	K	M	O	S	T
Temperature Control Valve HRL 9" x 2" D - 13 lbs	A	D	I	J	K	M	O	S	T

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Table III
Sheet 2

TABLE III (cont.)

COMPONENTS DIMENSIONS & WEIGHTS	DYNAMIC TEST FACILITIES				CLIMATIC TEST FACILITIES			OTHER ENVIRONMENTS TEST FACILITIES	
	VIBRATION	SHOCK	ACCELER-ATION	ACOUSTIC NOISE	HUMIDITY	SALT SPRAY	SAND & DUST	PRESSURE (VACUUM)	RFI
ASL Shutoff Valve 5" x 5" x 10" 6 lbs	A	D	I	J	K	M	O	S	T
NaK Hot Trap Pri (size & weight not available)									
Hg Filter Separator (size & weight not available)									
PCS Structure 96" D base x 144" ht x 63" D Top wt. with simulated launch weighted components = 5471 lb	GFE	GFE	NA	NA	NA	NA	NA	NA	NA

TABLE IV

TEST FACILITIES (B)

FACILITY TYPE	IDENTIFICATION	HOUSED AT	DESCRIPTION	
Vibration	A	AGC VKC	Ling Electronics Model 219	Vibration System
			Maximum Force Rating	500 lb force (g-vector) Sine 350 lb force (g-rms) Random
			Maximum displacement	1 inch Double Amplitude
			Frequency Range, Sinusoidal & Random	5-5000 cps
			Cycling	Logarithmic
			Cycling Rate	Variable
Vibration	B	AGC VKC	MB Electronics Model C-200	Vibration System
			Maximum Force Rating	21,500 lb force (g-vector) Sine 15,000 lb force (g-rms) Random
			Maximum Displacement	1.0 inch Double Amplitude
			Frequency Range, Sinusoidal & Random	5-2000 cps
			Cycling	Logarithmic
			Cycling Rate	Variable
Vibration	C	Sub-contractor facility	Ling Electronics Model L-249	Vibration System
			Maximum Force Rating	30,000 lb force (g-vector) Sine 24,000 lb force (g-rms) Random
			Maximum Displacement	1 inch Double Amplitude
			Frequency Range, Sinusoidal & Random	5-2000 cps
			Cycling	Logarithmic
			Cycling Rate	Variable
Shock	D	AGC VKC	Barry Varipulse Shock Test Machine Model 15750	
			Acceleration Range	10-400 "g"
			Maximum Weight	100 lbs (Specimen and Fixture)
			Maximum Specimen Size	14" x 14" x 14" (Specimen and Fixture)
			Pulse Shape	1/2 Sine
			Pulse Duration	8 ± 1 Milliseconds
Shock	E	Sub-contractor facility	Machine Dynamics Shock Test Machine Model DS-10-16-10	
			Acceleration Range	20-175 "g"
			Maximum Weight	2500 lbs (Specimen and Fixture)
			Platform Size	20" x 40"
			Pulse Shape	Variable
			Pulse Duration	Variable

TABLE IV (cont.)

TEST FACILITIES (B)

FACILITY TYPE	IDENTIFICATION	HOUSED AT	DESCRIPTION	
Shock	F	Sub-contractor facility	High Impact Shock Test Machine	
			Acceleration Range	20-500 "g"
			Maximum Weight	1000 lbs
			Platform Size	36" x 33" x 36"
			Pulse Shape	Variable
			Pulse Duration	Variable
Acceleration	G	AGC VKC	Ring Channel Centrifuge	
			Maximum Capacity	220,000 "g" lbs
			Boom Diameter	80 feet
			Maximum Weight	10,000 lbs (Specimen and Fixture)
			Maximum Speed	1000 knots (40.32 rpm)
Acceleration	H	Sub-contractor facility	Centrifuge	
			Maximum Capacity	6000 "g" lbs
			Maximum Weight	600 lbs
			Specimen Size	48" x 20" x 20"
Acceleration	I	Sub-contractor facility	Centrifuge	
			Maximum Capacity	2000 "g" lbs
			Maximum Weight	100 lbs
			Specimen Size	24" x 24" x 18"
Acoustic Noise	J	Sub-contractor facility	Acoustic Noise Generator	
			Wide band random spectrum	5 to 2000 cps
			Acoustic power output	162 db re: 0.0002 dynes/cm^2 (microbar
Humidity	K	AGC VKC	Humidity Chamber	
			Range: Humidity	5 to 100% RH
			Temperature	-100°F to 250°F
			Size	28" x 24" D
			Programmed for MIL-E-5272	
Humidity	L	Sub-contractor	Humidity Chamber	
			Range: Humidity	5 to 100% RH Cycling
			Temperature	0°F to 200°F Cycling
			Size	3' x 3' x 5'
			Programmed for MIL-E-5272	

Table IV
Sheet 2

TABLE IV (cont.)

TEST FACILITIES (B)

FACILITY TYPE	IDENTIFICATION	HOUSED AT	DESCRIPTION	
Salt Spray	L	AGC VKC	Salt Spray Chamber Range: Temperature Salt Concentration Size	 95 ± 2°F As required per MIL-E-5272 28" x 23" x 23"
Salt Spray	N	Sub-contractor facility	Salt Spray Chamber Range: Temperature Salt Concentration Size	 Controlled as needed As required per MIL-E-5272 5' x 3' x 3'
Sand & Dust	O	Sub-contractor facility	Sand and Dust Chamber Velocity Temperature Humidity Controlled. Dust density monitoring. Meet requirements per MIL-E-5272 Size	 to 200 fpm Room to 200°F 4' x 4' x 4'
Sand & Dust	P	Sub-contractor facility	Sand and Dust Chamber Velocity Temperature Humidity Controlled. Dust density monitoring. Meet requirements per MIL-E-5272 Size	 to 2300 fpm Room to 190°F 8' x 8' x 16'
Fungus	R	Sub-contractor facility	Fungus Chamber Meet requirements per MIL-E-5272 Size All testing under cognizance of mycologist	 3' x 3' x 16'
Vacuum	S	AGC VKC	Bemco Space Simulation Chamber Model A-450 Work Space Pressure Pump Speed	 8-1/2' dia x 8' long 1×10^{-7} torr 40,000 cfm at 1×10^{-6} torr

TABLE IV (cont.)

TEST FACILITIES (B)

FACILITY TYPE	IDENTIFICATION	HOUSED AT	DESCRIPTION
Radio Frequency Interference	T	AGC VKC	Screen Room - Double wall constructed so that attenuation measurements are in accordance with MIL-STD-285, dated 25 June 1956, Military Standard Attenuation Measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of Radio Interference and Field Intensity Meter - Stoddart Aircraft Radio Co. Model NM-10A Range 14 kc to 250 kc Noise and Field Intensity Meter - Empire Devices Products Corp. Model NF-105 Plug in unit T-A/NF-105 Range - 0.15 Mc to 30 Mc Plug in unit T-1/NF-105 Range - 20 Mc to 200 Mc Plug in unit T-2/NF-105 Range - 190 Mc to 400 Mc Plug in unit T-3/NF-105 Range - 400 Mc to 1000 Mc

APPENDIX A

GENERAL TEST PLAN DISCUSSION

Paragraph 3.0 - General Discussion

Paragraph 3.1 - Testing at Component Level

The tests will be conducted at component level because early detection of critical design weaknesses will allow prompt corrective action, design modification, prior to integration of the component into the system. Identification of failure and its cause within a component may be more readily isolated. The dependent failures usually developed at system level tend to obscure the primary cause. A component failure occurring in the system may cause other components to fail (dependent failure). Consequently, the true sequence of failures cannot readily be determined and effective corrective action cannot be accomplished.

Paragraph 3.2 - Sample Size

The assurance derived from environmental tests is in direct ratio with the sample size. Testing two sets of each component will better confirm a design capability of withstanding environmental stresses encountered during the period extending from manufacture to orbit. Assigning two sets of samples allows the integration of the environmental test with the startup reliability test program. The climatics as well as the dynamics will be performed only on one set of samples. The second set will be subjected to dynamic tests only. Evaluation of the cumulative effects of both climatic and dynamic exposures as compared to the effects of only dynamic exposures, may be accomplished.

A primary purpose of the test program is to reveal critical design weaknesses. However, based on a single test sample, it cannot be conclusively determined whether a failure is random or is inherent in the component design. (A random failure is one which cannot normally be attributed to the design of the component).

Paragraph 3.4 - Material Samples

Where tests on material samples provide adequate assurance, the test will be conducted on such samples. For example, fungus testing can very reliably be conducted on material samples. In some cases, humidity, salt spray and sand and dust tests can also be performed on material samples.

Paragraph 3.6 - Alternates

When analysis showed that the environmental hazard could be prevented by more economical means than design and associated testing, protective devices such as packaging, thermal control, covers, etc. are recommended.

Paragraph 3.7 - Selection of Environments

In order to derive the maximum benefits from the test program, the test effort will be concentrated on the most detrimental environments. The relative susceptibility of each item to each environment was evaluated and only potentially hazardous environments were included.

As an economy measure, if the component encounters the same environment at different levels during the four phases of development and application (transportation shock and vibration, launch shock and vibration), the component will be tested only at the highest stress levels. By withstanding the most severe stresses, the design capability for the less severe stresses is automatically verified. The general approach is to include only those environments which present a hazard to component

or system survival. Environments considered not detrimental are listed below: (Paragraph numbers refer to NASA Specification 417-2).

Temperature

Paragraph 3.2.3 - Storage & Transportation

Paragraph 3.3.2 - Handling & Vehicle Integration

Low temperature extreme of -40°F sky radiation temperature under non-operating conditions is not detrimental to any of the components and the high extreme is far below the design temperatures. Temperature control may be provided as needed.

Rain, Humidity, Sand & Dust, Salt Spray

Paragraph 3.2.1 - Transportation & Storage

It is relatively easy to provide adequate protection for the above exposures during the period of transportation and storage.

Paragraph 3.3.1 - Handling & Vehicle Integration

During integration and ground checkout the components may be exposed from time to time to some, or all, of the above climatic exposures and adequate protection might be cumbersome. Those components equipped with space seals and those with ceramic electrical terminals can be affected, and they will be tested with their respective protective devices installed. Others might suffer slight surface deterioration that would not affect their operational capabilities and material sample testing, if required, can determine the need for protective measures or design modification. Rain does not present any hazard since most components and systems are sealed. Units open to space will be protected.

Pressure

Paragraph 3.2.4 - Transportation

All components will be designed for space operation and the susceptible items will be tested at 10^{-6} torr. No useful information can be gained by tests at lower stress level.

Other Environment Pressure

Paragraph 3.4.3.2

Components which are not gas or liquid filled under launch-ready conditions will not be tested at 10^{-6} torr.

Wind

Paragraph 3.3.3

Components will not be subjected to the wind test. This test will be performed on the NPS during the Type Approval Test.

Shock

Paragraph 3.2.5 - Transportation

Paragraph 3.3.4 - Integration

Components will not be subjected to the transportation shock tests. These tests will be performed on the system level during the Type Approval Tests.

Vibration

Paragraph 3.2.6 - Transportation

Paragraph 3.3.5 - Integration

Components will not be subjected to the transportation vibration tests. These tests will be performed on the system level during the Type Approval Tests.

Combined Loading

Paragraph 3.4.2.5 - Launch

No facilities are available to simulate the conditions of shock, vibration, acceleration, and acoustic noise simultaneously. Design verification will be accomplished by exposure to the individual stresses as the most economical and practical approach. No combined exposure tests are planned.

Paragraph 3.4.3.1 - Explosive Atmosphere

All electrical components are hermetically sealed and unenergized at launch with the exception of the battery. The low voltage (28 V) precludes the possibility of arc over or corona at launch conditions. The test conditions defined in MIL-E-5272C are not representative of the EGS prelaunch condition.

Space Operation

Paragraph 3.5 and SNAP-8 Statement of Work, Task III (2)(c)

No facilities exist to simulate true space conditions including zero 'g'. Operational testing under space conditions will not be performed.

Radio Frequency Interference

Paragraph 3.6

The electrically operated components will be tested for RFI generation. The test methods described in MIL-I-26600 will be followed on smaller items which can be operated in the screen room.

However, the procedure will be modified for larger components and systems which can be operated only in the test loops. Comparative surveys of background and operating interference levels will be conducted. The test instrumentation, antennae and frequencies scanned shall follow, where practical, the dictates of specification, MIL-I-26600 (USAF). The detected RFI shall be recorded, plotted and the resulting graph shall become a part of the test report. Prior to energizing the component to be tested, the identical frequencies shall be scanned and the background radio frequency interference detected shall be recorded and plotted. The graph shall become part of the test report.

APPENDIX B

PROOF TESTS

A. NaK PMA, PRIMARY, HRL

1. Visual
2. Two hours steady-state operation with substitute fluid (water at 150°F) at design pressure and flow with rated electrical inputs.

Measurements

1. Flow
2. Inlet Pressure
3. Discharge Pressure
4. Stator Cavity Pressure
5. RPM
6. Input Power or Current
7. Insulation Resistance
8. Dielectric Tests
9. Hot Spot Temperatures

B. Hg PMA, L/C PMA

1. Visual
2. Helium Leak Detection Tests
3. Two hours steady-state operation at design conditions (temperature, fluid, pressure, flow, electrical inputs, lube and cooling)

Measurements

1. Flow
2. Inlet Pressure
3. Discharge Pressure
4. Fluid Temperature
5. RPM
6. Input Power or Current
7. Hot Spot Temperatures
8. Insulation Resistance
9. Dielectric Tests

C. TURBINE ALTERNATOR ASSEMBLY

1. Visual
2. Helium Leak Detector Test
3. Two hours steady-state operation (cold gas) at rated output and load

Measurements

1. Output (volts, current, power) versus frequency versus gas flow
2. Hot Spot Temperatures
3. Cooling Fluid Temperatures
4. Insulation Resistance
5. Dielectric Tests

D. BOILER, CONDENSER, AUXILIARY LOOP HEAT EXCHANGER, EXPANSION RESERVOIR, PRIMARY, NaK HRL, L/C

1. Visual
2. Helium Leak Test
3. Proof pressure at ambient
4. Operation, expansion reservoirs only: 5 full excursions at design pressures (substitute fluid for the NaK reservoirs)

E. VOLTAGE REGULATOR MODULE, SPEED CONTROL MODULE AND TRANSFORMER REACTOR ASSEMBLY

1. Visual

2. Helium Leak Test

3. Two hours steady-state operation at simulated design conditions

Measurements

1. Two sets of a family of calibration curves at the beginning and at the conclusion of the two-hour period

2. Insulation Resistance

3. Dielectric Tests

F. POWER CONDITIONER

No information is available.

G. PROTECTIVE SYSTEM MODULE

1. Visual

2. Operation: 5 cycles at simulated design conditions

Measurements

Actuating volts/frequency versus time

H. PARASITIC LOAD RESISTOR

1. Visual
2. Helium Leak Test
3. Two hours operation at design conditions (flow, temperature, pressure and fluid)

Measurements

1. Power (each phase)
2. Resistance
3. Temperature fluid (inlet and outlet)
4. Flow
5. Pressure (ΔP)
6. Hot Spot Temperatures (heaters)
7. Insulation Resistance at design temperatures
8. Dielectric Breakdown

I. VEHICLE LOAD BREAKER, TRANSFER CONTACTOR

1. Visual
2. Helium Leak Test
3. *Operation, actuation: make and break at rated load

Measurements

1. Volts, actuating
2. Response Time
3. Contact Resistance
4. Insulation Resistance
5. Dielectric Tests

*Sample No. 2 will be subjected to operational test in accordance with the Startup Components Reliability Test Procedure.

J. INVERTER & CONTACTOR

1. Visual

2. Helium Leak Test

3. *Operation: two hour cycle at rated input and load including low volt/frequency, high volt/frequency and transient conditions.

Measurements

1. Input volts

2. Input current or power

3. Outputs: volts, current or power versus frequency versus time

4. Hot Spot Temperatures

5. Insulation Resistance

6. Dielectric Tests

*Sample No. 2 will be subjected to operational test in accordance with the Startup Components Reliability Test Procedure.

K. START PROGRAMMER

1. Visual

2. Helium Leak Test

3. *Operational, 5 abbreviated cycles (approximately 30 minutes) at simulated design conditions (rated inputs, outputs in rated loads)

Measurements

1. Events (outputs) versus time

2. Insulation Resistance

*Sample No. 2 will be subjected to operational test in accordance with the Startup Components Reliability Test Procedure.

L. HARNESS ASSEMBLIES (SECTIONS)

1. Visual

2. Insulation Resistance

3. Dielectric Tests

4. Resistance

M. BATTERY ASSEMBLY

1. Visual

2. Operation: 5 hours with rated total load, cycled

Measurements

1. Volts output versus time

2. Current

3. Insulation Resistance

N. Hg FILTER SEPARATOR, NaK HOT TRAP

1. Visual

2. Helium Leak Test

3. Proof Pressure

0. Hg INJECTION SYSTEM & FLOW CONTROL VALVE

1. Visual

2. Helium Leak Test

3. *Operation: 5 injection cycles at simulated design conditions (sequence, timing, pressures, input volts)

Measurements

1. Flow versus time

2. Sequence and timing of events

*Sample No. 2 will be subjected to operational test in accordance with the Startup Components Reliability Test Procedure.

P. TEMPERATURE CONTROL VALVE

1. Visual

2. Helium Leak Test

3. *Operation: 5 cycles of actuation at simulated design conditions

Measurements

1. Actuating temperature versus time

2. Pressure

3. Flow

*Sample No. 2 will be subjected to operational test in accordance with the Startup Components Reliability Test Procedure.

Q. AUXILIARY START LOOP SHUTOFF VALVE

1. Visual

2. Helium Leak Test

3. *Operation: 5 cycles of actuation at simulated design conditions

Measurements

1. Actuating volts

2. Response time

3. Insulation resistance

*Sample No. 2 will be subjected to operational test in accordance with the Startup Components Reliability Test Procedure.

APPENDIX C

TEST FACILITY REQUIREMENTS

The Environmental Test Facilities required for the conduction of the Environmental Test Program in accordance with this plan will be selected in the following manner. The test environments to be simulated will be in accordance with Paragraph 4.1.1 of this test plan and the facilities required to simulate or produce these environments will be dependent on the size and/or launch ready weights of the subsystems to be tested.

In order to make the most efficient and economical use of facilities available at AGC VKC Azusa and facilities housed in the various commercial laboratories in the Los Angeles area the tests to which the components will be subjected are divided into three categories as listed in Table III.

A list of facilities housed either at the AGC VKC or at subcontractor facilities will be found in Table IV. Table III depicts by identification letter the environmental test facility to be used for each type of test for each component to be tested. The test facility is selected on the basis that the environment simulated will either meet or exceed the requirements necessary for the conduction of the test.

A survey has been conducted of various subcontractor test facilities in the Los Angeles area and these facilities will be used, where necessary, to supplement the facilities housed at AGC VKC Azusa. The results of the test facility survey will be found in Appendix D.

Operational tests will be performed utilizing existing SNAP-8 test loops as required which are housed at AGC-VKC - Azusa.

APPENDIX D

SUBCONTRACTOR TEST FACILITIES

Test Facilities required to perform the environmental tests delineated in this program plan are listed in Table IV. A survey was conducted in the Los Angeles area to locate potential vendors with the capabilities to supplement AGC equipment available at VKC. Technical evaluation of the potential subcontractor facilities and their supporting equipment was accomplished and the AGC Suppliers Quality Engineering Representative team will undertake their own evaluation to decide whether they meet AGC standards and qualify as potential subcontractors.

The facilities and subcontractors who meet SNAP-8 technical requirements are listed below.

Vibration Equipment (Ref. Table IV,C)

Equipment & Ratings	Subcontractor
Ling Electronics Model L249 30,000 lb force (g-vector) Sine	Wyle Laboratories, El Segundo
24,000 lb force (g-rms) Random	Wyle Laboratories, Norco
	United Testings Lab., Monterey Park
	Component Evaluation Lab., El Monte

Shock (Ref. Table IV,E)

Equipment & Ratings	Subcontractor
a. Shock Test Machine Acceleration Range: 20-175 "g" Max. Weight: 2500 lbs Platform Size: 20" x 40" Pulse Shape & Duration: Variable	Wyle Laboratories (a & b), El Segundo Wyle Laboratories (a & b), Norco United Testing Lab (a & b), Monterey Park
b. Wave Synthesizer, Exacto in conjunction with Ling L 249 Vibration System	

Shock (Ref. Table IV,F)

a. Shock Test Machine Acceleration Range: 20-500 "g" Maximum Weight: 1000 lbs Platform Size: 36" x 33" x 36" Pulse Shape & Duration: Variable	Wyle Laboratories (a & b), El Segundo Wyle Laboratories (a & b), Norco United Testing Lab (a & b), Monterey Park
b. Wave Synthesizer, Exacto in conjunction with various Vibration Systems	

Acceleration (Ref. Table IV,H & I)

a. Centrifuge Max Capacity: 6000 "g" lbs Max Weight: 600 lbs Specimen Size: 48" x 20" x 20"	Wyle Laboratories (a & b), El Segundo Wyle Laboratories (a & b), Norco United Testing Lab., (a & b) Monterey Park Rototest Labs. Lynwood (b)

b. Centrifuge

Max Capacity: 4000 "g" lbs	Component Evaluation Lab., El Monte (a, b)
Max Weight: 200 lbs	
Specimen Size: 24" x 24" x 18"	

Acoustic Noise (Ref. Table IV,J)

Equipment & Ratings	Subcontractor
Acoustic Noise Generator	Norair, Hawthorne
Wide band random spectrum 5-2000 cps	Rototest Labs., Lynwood
Output Power: 162 db re: 0.0002 dynes/cm^2 (microbar)	

Humidity (Ref. Table IV,L)

Equipment & Ratings	Subcontractor
Humidity Chamber	Wyle Laboratories, Norco
Range: 5-100 RH	Space-General, El Monte
Temperature: $0^{o}F$ to $200^{o}F$ Cycling	Wyle Laboratories, El Segundo
Programmed for MIL-E-5272 tests	United Testing Lab., Monterey Park
Size 3' x 3' x 5'	

Salt Spray (Ref. Table IV,N)

Equipment & Ratings	Subcontractor
Salt Spray Chamber	Wyle Laboratories, Norco
Temperature: controlled	
Salt Concentration as per MIL-E-5272	
Size: 5' x 3' x 3'	

Sand & Dust (Ref. Table IV,O & P)

Equipment & Ratings	Subcontractor
a. Sand & Dust Chamber Velocity: to 200 fpm Temperature: Room to 200°F Humidity: Controlled Dust Density: Monitored Meet the requirements of MIL-E-5272 Size: 4' x 4' x 4'	Wyle Laboratories, Norco (b) United Testing Lab. (b), Monterey Park Wyle Laboratories, El Segundo (a) Component Evaluation Lab., El Monte (a) Rototest Labs., Lynwood (a)
b. Sand & Dust Chamber Same as above Size: 8' x 8' x 16'	

Fungus (Ref. Table IV,R)

Equipment & Ratings	Subcontractor
Fungus Chamber Meet the requirements of MIL-E-5272 Size: 12" x 12" x 18"	Wyle Laboratories El Segundo United Testing Lab., Monterey Park Rototest Lab., Lynwood

Additional facilities will be investigated and new ones will be added to this list. In this manner, competitive bids will allow the most competent and economic subcontractor selection and facilitate meeting schedule requirements.

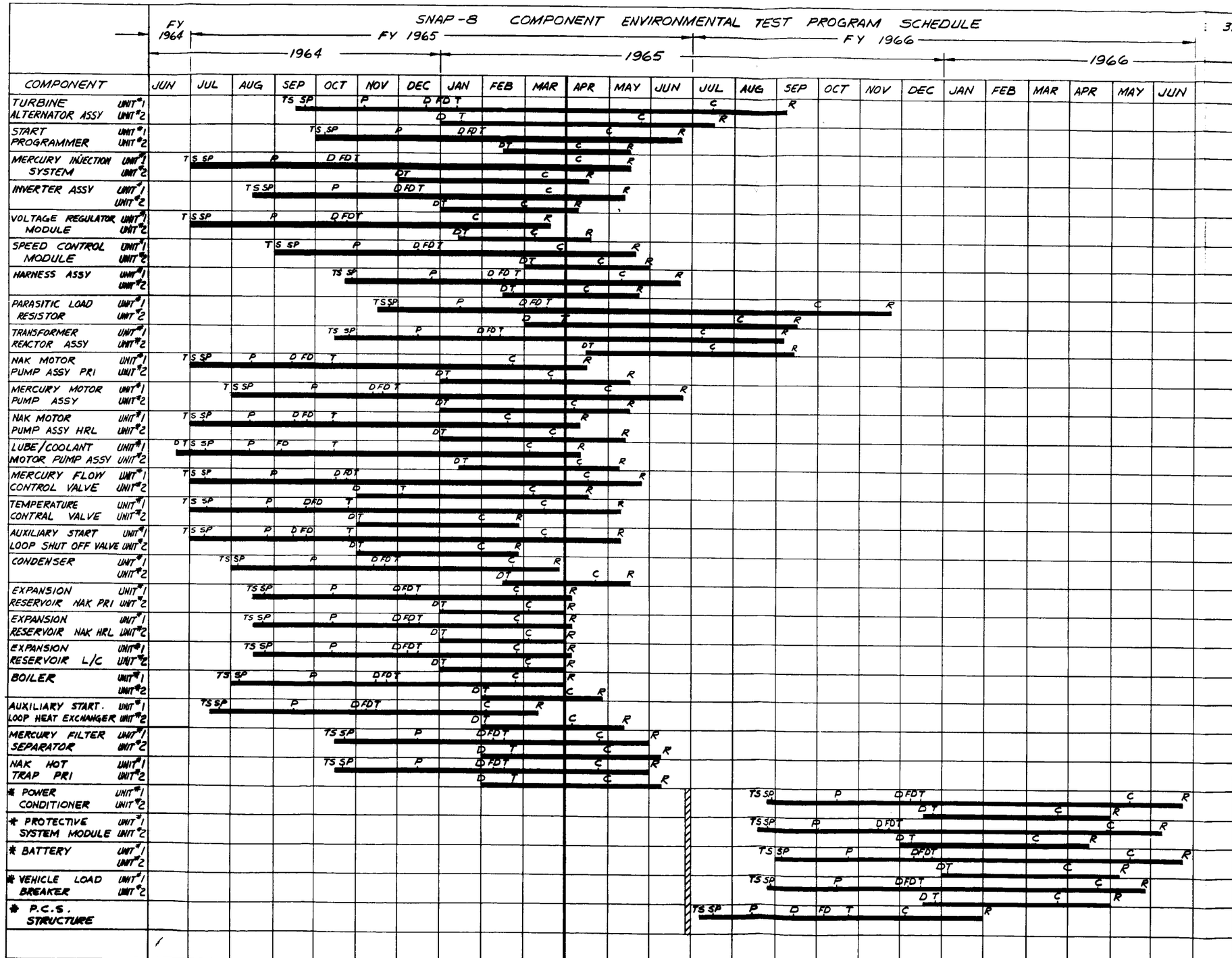
APPENDIX E

SNAP-8 COMPONENT ENVIRONMENTAL TEST PROGRAM SCHEDULE

May 28, 1964

SNAP-8 COMPONENT ENVIRONMENTAL TEST PROGRAM SCHEDULE

371.0209



LEGEND:

- TS - TEST REQUEST & SPECIFICATION
- SP - START TEST PROCEDURE
- P - PROCEDURE DELIVERY TO LERC
- D - COMPONENT DELIVERY
- FD - FIXTURE DELIVERY
- T - TEST START
- C - TEST COMPLETE
- R - TEST REPORT COMPLETE

*NOTE: SINCE THESE UNITS HAVE BEEN DEFERRED, THE DELIVERY DATES SHOWN HAVE BEEN ASSUMED IN ORDER TO COMPLETE THIS PRELIMINARY TEST SCHEDULE. THE TIMES INDICATED REPRESENT ELAPSED TIME ONLY.

371:64:C209-A
10 November 1964

SUPPLEMENT NO. 1

TO

ENVIRONMENTAL TEST PLAN FOR SNAP-8

COMPONENTS

EP-001

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AEROJET-GENERAL CORPORATION

SNAP-8 DIVISION

TEST OPERATIONS DEPARTMENT

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APPENDIX C - PROOF TESTS
APPENDIX D - -1 SNAP-8 COMPONENT ENVIRONMENTAL TEST PROGRAM SCHEDULE

SUPPLEMENT NO. 1
TO
ENVIRONMENTAL TEST PLAN FOR SNAP-8 COMPONENTS
(371.0209-5/26/64)

1.0 INTRODUCTION

1.1 SCOPE

This plan covers the environmental testing of ten -1 model SNAP-8 components. The plan includes the following:

a. Test Objectives
b. Test Items
c. Environmental Exposures
d. Stress Levels and Durations
e. Proof Tests
f. Failure Criteria
g. Measurement Requirements
h. Documentation
i. Test Facilities
j. Test Schedules

1.2 TEST OBJECTIVES

The objective of the limited environmental program is to disclose any critical structural weaknesses of ten SNAP-8 -1 components.

2.0 REFERENCE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS

NASA 417	Appendix 1, Statement of Work, Task III dated 6/29/63.
NASA 417-2	SNAP-8 Environmental Specification dated 2/25/64

2.2 AGC DOCUMENTS

Specifications:

AGC-10152	SNAP-8 Power Conversion System Model Specification dated 17 January 1964 (Draft for Approval).
371.0209	Environmental Test Plan for SNAP-8 Components dated 26 May 1964.
--	SNAP-8 Division Procedures: V-D2, V-D3, VI-A4, and VI-A8.

3.0 TEST PLAN

3.1 DESCRIPTION OF TESTS

The components will be subjected to environmental exposures and proof tests as delineated in the following paragraphs.

3.1.1 Environmental Tests

The components will be subjected to shock and vibration in accordance with the requirements of NASA 417-2. Table I lists the components, the tests and applicable paragraphs of NASA 417-2 for detailed test requirements. Test facility requirements are listed in Tables III and IV and described in Appendix A. Subcontractor test facilities are listed in Appendix B.

3.1.2 Proof Tests

Proof tests will be conducted prior to and after the conclusion of the environmental tests in accordance with Table II. Test results from the first set of tests will be used as reference to evaluate

the post-exposure results. A comparison of the two sets of test results will disclose any degradation. The following proof tests will be performed as applicable:

a. Visual Examination
b. Helium Leak Detection
c. Proof Pressure Test
d. Operational Tests

Appendix C delineates the proof tests for the individual components.

3.2 TEST ITEMS

The components to be subjected to environmental testing are listed in Table I. All components shall have successfully completed the acceptance tests as required by their respective specifications. The components will be delivered for test with their respective (actual or simulated) prototype bracketry.

3.3 TEST PREPARATION

3.3.1 Test Fixtures

Test fixtures will be designed and fabricated for each component. To insure realistic simulation of dynamic conditions, provisions will be made, if required, to include associated piping from the component to the first tie-point to the structure.

3.3.2 Test Sample Preparation

Components will be dynamically tested in launch ready condition with their respective working fluids. Substitute fluids will be used during the dynamic testing of all NaK filled components. Operational tests may also be conducted with substitute fluids.

3.4 TEST SEQUENCE

The sequence of testing shall be in accordance with Table II.

3.5 FAILURE CRITERIA

Failure is defined as the inability of components to meet minimum specified requirements. Failures are classified according to their nature and severity as follows:

3.5.1 Critical Failure

A critical failure is defined as a failure, defect, or performance degradation which causes a mission abort or safety hazard.

3.5.2 Major Failure

A major failure is defined as a defect or degradation of performance in excess of tolerance limits which would not necessarily cause a mission abort but affects the ability of the system to meet mission requirements.

3.5.3 Minor Failure

A minor failure is defined as a failure other than critical or major which has no significant effect on the ability of the system to perform satisfactorily. Secondary failures shall be included in this category.

3.5.4 Incidental Failure

An incidental failure is defined as a failure whose cause is due to conditions external from the equipment such as accidental damage, installation or operation error, test equipment failure, or scheduled replacement or adjustment.

3.6 PROCEDURE FOLLOWING FAILURE

If failure occurs, the ensuing procedure shall be followed:

3.6.1 The test shall cease and cognizant personnel shall be immediately notified.

3.6.2 The cause of failure shall be determined.

3.6.3 In case of critical failure, the test will be terminated. Suitable corrective action, possibly design modifications, will be undertaken under the auspices of the cognizant design engineer. The corrected component will be subjected to tests to verify the modified unit.

3.6.4 In the case of major failure, testing may be resumed with the approval of the NASA Project Manager until test completion or critical failure occurs. In the event of critical failure, the requirements of Paragraph 3.6.3 apply.

3.6.5 In case of minor failure, the test will be interrupted, the fault will be corrected, and that portion of the test in which the failure occurred will be repeated with the approval of NASA Project Manager.

3.6.6 In case of incidental failure the provisions of Paragraph 3.6.5 will apply

3.6.7 Documentation of all failures shall be in accordance with Section 3.8 of this plan.

NOTES: 1) Failure definition for each component will be given in the individual detailed component specification.

2) Repetition of tests required to verify corrective actions does not fall within the scope of this program.

3.7 MEASUREMENTS AND TEST DATA

3.7.1 Measurements

In order to evaluate component capabilities, measurements of test conditions, stress inputs and outputs, operational parameters, and indications of structural conditions shall be recorded. Operational parameters will be selected to show failure or degradation and to indicate malfunction location and failure mode. The methods of measurement (analogue, digital, or meter indications) will be determined by the specific parameters specified by the component specification.

3.7.2 Test Data

Test data recorded during the environmental test program will be reduced as required for evaluation. Transient conditions and step functions will be plotted and analogue data reduced for quick comparison with design limits. Data sheets and worksheets depicting the calculations necessary to derive test parameters, will be attached to the detailed component specifications. Test data will also include instrumentation information identifying the instruments used as well as their accuracies and calibration histories and all pertinent information necessary to duplicate the test setup.

Representative requirements for test data are presented as follows:

3.7.2.1 Visual Examination

3.7.2.1.1 Detailed descriptions of any faults, degradations, changes, or discrepancies.

3.7.2.1.2 Photographs and sketches.

3.7.2.2 Non-Destructive Testing

3.7.2.2.1 X-rays, ultrasonics.

3.7.2.3 Laboratory Analysis

3.7.2.3.1 Chemical

3.7.2.3.2 Metallurgical

3.7.2.4 Helium Leak Detection

3.7.2.4.1 Leak rate and instrument setting.

3.7.2.4.2 Methods of application: pressure, spray, etc.

3.7.2.4.3 Locations of leaks

3.7.2.5 Operational Tests

3.7.2.5.1 Inputs

3.7.2.5.2 Outputs

3.7.2.5.3 Instrument ranges, settings, sensitivities, special calibration, etc.

3.7.2.5.4 Warmup time

3.7.2.5.5 Time, elapsed time, response time.

3.7.2.5.6 Events

3.7.2.6 Environmental Tests

3.7.2.6.1 Temperature (ambient)

3.7.2.6.2 Humidity (ambient)

3.7.2.6.3 Acceleration stresses (g's), input and output levels.

1. Vibratory
2. Shock

3.7.2.6.4 Frequency

3.7.2.6.5 Displacement

3.7.2.6.6 Time Duration

3.7.2.6.7 Instrumentation and Calibration

3.8 DOCUMENTATION

3.8.1 Equipment Logs

Equipment logs will be maintained in accordance with SNAP-8 Division Procedures V-D2 and V-D3.

3.8.2 Failure Reporting

Failure reporting and analysis will be in accordance with SNAP-8 Division Procedures VI-A4 and VI-A8.

3.8.3 Quality Assurance

Quality assurance provisions will be in accordance with Section XVI of the SNAP-8 Quality Program Plan, Report No. 24.05.

3.8.4 Test Reports

A test report will be prepared for each component and will include test specifications, test procedures, test setups, instrumentation, test results, conclusions, and recommendations. Photographs of test setups and mechanical failures, if any, will be attached. Charts, graphs, etc., will be included for visual representation of test results.

3.9 DISPOSITION OF TEST ITEMS

After completion of the tests, the components shall be cleaned, prepared for storage, identified, and stored.

TABLE I

LIMITED ENVIRONMENTAL TESTS FOR -1 SNAP-8 COMPONENTS

Components	Shock 417-2 Para 3.4.2.1	Vibration 417-2 Para 3.4.2.2
Turbine Alternator Assembly	X	X
NaK PMA, Primary	X	X
NaK PMA, HRL	X	X
L/C PMA	X	X
Hg PMA	X	X
Boiler	X	X
Condenser	X	X
Expansion Reservoir, NaK Primary	-	X
Expansion Reservoir NaK HRL	-	X
Expansion Reservoir L/C	-	X

"X" indicates test to be performed.

TABLE II

TEST SEQUENCE

Tests	Paragraph
a. Proof Tests	3.1.2
b. Shock	3.1.1
c. Vibration	3.1.1
d. Proof tests	3.1.2

TABLE III

TEST FACILITIES (A)

Components Dimensions & Weights	Dynamic Test Facilities Vibration	Shock
Hg PMA	B	E
28 x 16 x 16" - 150 lbs		
L/C PMA	B	E
8 x 12 x 16" - 28 lbs		
Expansion Reservoir NaK Primary	B	E
27 x 14" Dia - 41 lbs		
Expansion Reservoir NaK HRL	B	F
28 x 12" Dia = 22 lbs		
Expansion Reservoir L/C	B	F
28 x 14" Dia - 24 lbs		
Turbine Alternator Assembly	C	E
44 x 28 x 16" - 658 lbs		
NaK PMA Primary	B	F
32 x 30 x 28" - 375 lbs		
NaK PMA HRL	B	F
32 x 30 x 28" - 375 lbs		
Boiler	C	E
58 x 32 x 24" - 978 lbs		
Condenser	B	E
64 x 20 x 12" - 130 lbs		

TABLE IV

TEST FACILITIES (B)

Facility Type	Identification	Housed At	Description	
Vibration	A	AGC VKC	Ling Electronics Model 219	Vibration System
			Maximum Force Rating	500 lbs force (g-vector) Sine 350 lbs force (g-rms) Random
			Maximum Displacement	1 inch Double Amplitude
			Frequency Range, Sinusoidal & Random	5-5000 cps
			Cycling	Logarithmic
			Cycling Rate	Variable
Vibration	B	AGC VKC	MB Electronics Model C-200	Vibration System
			Maximum Force Rating	21,500 lb force (g-vector) Sine 15,000 lb force (g-rms) Random
			Maximum Displacement	1.0 inch Double Amplitude
			Frequency Range, Sinusoidal & Random	5-2000 cps
			Cycling	Logarithmic
			Cycling Rate	Variable
Vibration	C	Sub-contractor Facility	Ling Electronics Model L-249	Vibration System
			Maximum Force Rating	30,000 lb force (g-vector) Sine 24,000 lb force (g-rms) Random
			Maximum Displacement	1 inch Double Amplitude
			Frequency Range, Sinusoidal & Random	5-2000 cps
			Cycling	Logarithmic
			Cycling Rate	Variable
Shock	D	AGC VKC	Barry Varipulse Shock Test Machine Model 15750	
			Acceleration Range	10-400 g
			Maximum Weight	100 lbs (Specimen and Fixture)
			Maximum Specimen Size	14 x 14 x 14 (Specimen and Fixtu
			Pulse Shape	1/2 Sine
			Pulse Duration	8 ±1 Millisecond

Table IV - Test Facilities (B) - (Continued)

Facility Type	Identification	House At	Description	
Shock	E	Sub-Contractor Facility	Machine Dynamics Shock Test Machine Model DS-10-16-10	
			Acceleration Range	20-175 g
			Maximum Weight	2500 lbs (Specimen and Fixture)
			Platform Size	20 x 40"
			Pulse Shape	Variable
			Pulse Duration	Variable
Shock	F	Sub-Contractor Facility	High Impact Shock Test Machine	
			Acceleration Range	20-500 g
			Maximum Weight	1000 lbs
			Platform Size	36 x 33 x 36"
			Pulse Shape	Variable
			Pulse Duration	Variable

NOTE: All shock testing may be performed using a vibration system of adequate capacity in conjunction with a wave synthesizer.

APPENDIX A

TEST FACILITY REQUIREMENTS

The Environmental Test Facilities required for the conduction of the Environmental Test Program in accordance with this plan will be selected in the following manner

The test environments to be simulated will be in accordance with Section 3.1.1 of this test plan and the facilities required to simulate or produce these environments will be dependent on the size and/or launch-ready weights of the subsystems to be tested.

In order to make the most efficient and economical use of facilities available at AGC VKC Azusa and facilities housed in the various commercial laboratories in the Los Angeles area, the tests to which the components will be subjected are listed in Table III.

A list of facilities housed either at the VKC VKC or at subcontractor facilities will be found in Table IV. Table III depicts by identification letter the environmental test facility to be used in each type of test for each component to be tested. The test facility is selected on the basis that the environment simulated will either meet or exceed the requirements necessary for the conduction of the test.

A survey has been conducted of various subcontractor test facilities in the Los Angeles area and these facilities will be used, where necessary, to supplement the facilities housed at AGC VKC Azusa. The results of the test facility survey will be found in Appendix B.

Operational tests will be performed utilizing existing SNAP-8 test loops as required which are housed at AGC VKC Azusa.

APPENDIX B

SUBCONTRACTOR TEST FACILITIES

Test facilities required to perform the environmental tests delineated in this program plan are listed in Table IV. A survey was conducted in the Los Angeles area to locate potential vendors with the capabilities to supplement AGC equipment available at VKC. Technical evaluation of the potential subcontractor facilities and their supporting equipment was accomplished and the AGC Suppliers Quality Engineering Representative team have undertaken their own evaluation and decided that they meet AGC standards and qualify as potential subcontractors.

The facilities and subcontractors who meet SNAP-8 technical requirements are listed below.

Vibration Equipment (Reference: Table IV,C)

Equipment & Ratings	Subcontractor
Ling Electronics Model L249 30,000 lb force (g-vector) Sine 24,000 lb force (g-rms) Random	Wyle Laboratories El Segundo
	Wyle Laboratories Norco
	United Testing Laboratory Monterey Park
	Component Evaluation Laboratory El Monte

Shock (Reference: Table IV, E)

a. Shock Test Machine Acceleration Range - 20-175 g Maximum Weight - 2500 lbs Platform Size - 20 x 40" Pulse Shape & Duration - Variable	Wyle Laboratories (a & b) El Segundo
	Wyle Laboratories (a & b) Norco
	United Testing Laboratory (a & b) Monterey Park
b. Wave Synthesizer, Exact Electronics, Inc. in conjunction with Ling L249 Vibration System	

Appendix B - Subcontractor Test Facilities (Continued)

Shock (Reference: Table IV, F)

Equipment & Ratings	Subcontractor
a. Shock Test Machine Acceleration Range - 20-500 g Maximum Weight - 1000 lbs Platform Size - 36 x 33 x 36" Pulse Shape & Duration - Variable	Wyle Laboratories (a & b) El Segundo Wyle Laboratories (a & b) Norco United Testing Laboratory (a & b) Monterey Park
b. Wave Synthesizer, Exact Electronics, Inc. in conjunction with various Vibration Systems	

APPENDIX C

PROOF TESTS

A. NaK PMA, PRIMARY, HRL

1. Visual
2. Two hours steady-state operation with substitute fluid at design pressure and flow with rated electrical inputs.

MEASUREMENTS

1. Flow
2. Inlet Pressure
3. Discharge Pressure
4. Stator Cavity Pressure
5. RPM
6. Input Power or Current
7. Insulation Resistance
8. Dielectric Tests
9. Hot Spot Temperatures

B. Hg PMA, L/C PMA

1. Visual
2. Two hours steady-state operation at design conditions (temperature, fluid, pressure, flow, electrical inputs, lube, and cooling).

MEASUREMENTS

1. Flow
2. Inlet Pressure
3. Discharge Pressure
4. Fluid Temperature
5. RPM
6. Input Power or Current
7. Hot Spot Temperatures
8. Insulation Resistance
9. Dielectric Tests

Appendix C - Proof Tests - (Continued)

C. TURBINE ALTERNATOR ASSEMBLY

1. Visual
2. Helium Leak Detector Test
3. 20 minutes steady-state operation (cold gas) at rated output and load

MEASUREMENTS

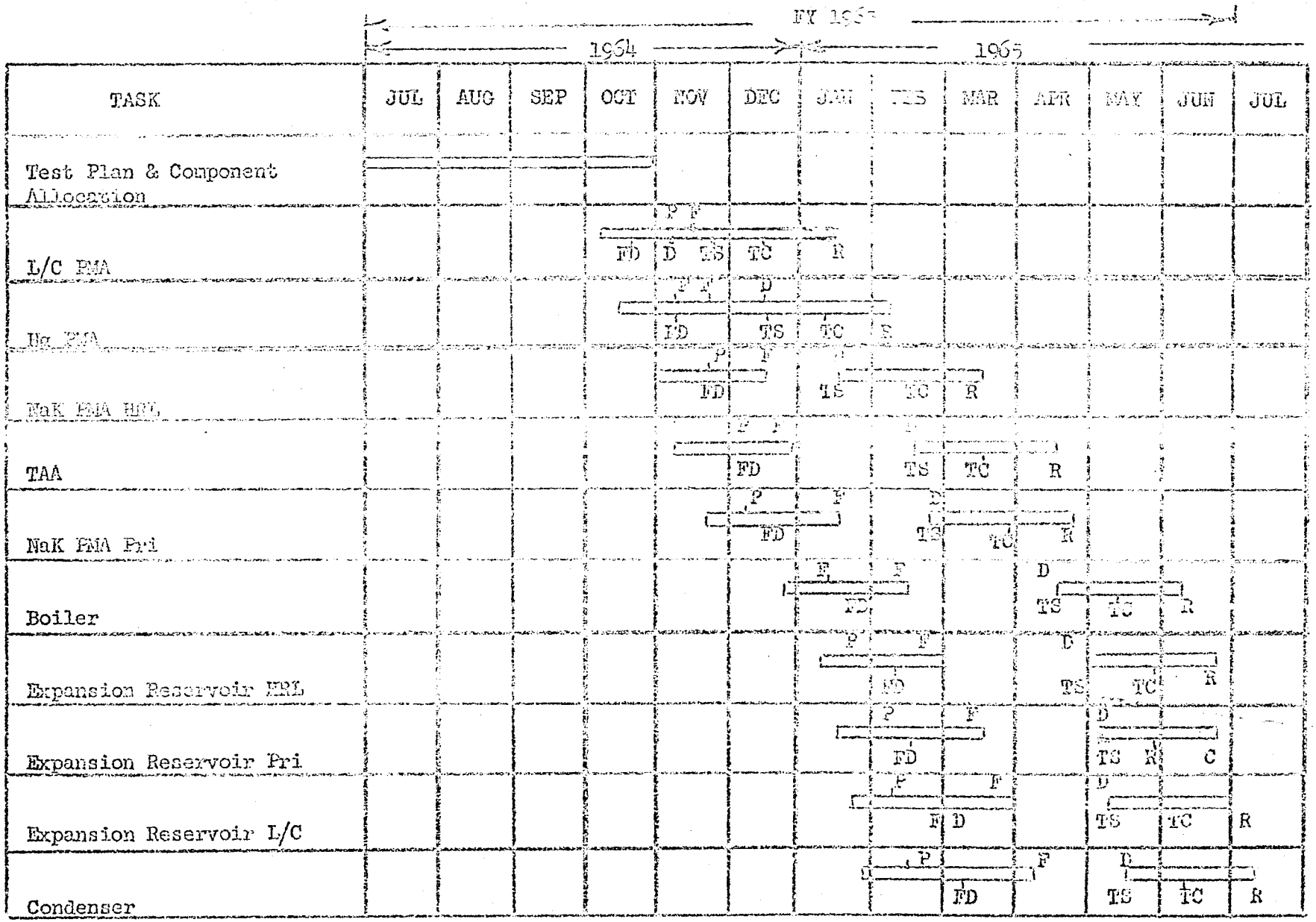
1. Output (volts, current, power) versus frequency versus gas flow
2. Hot Spot Temperatures
3. Cooling Fluid Temperatures
4. Insulation Resistance
5. Dielectric Tests

D. BOILER, CONDENSER, EXPANSION RESERVOIR, PRIMARY, NaK HRL, L/C

1. Visual
2. Helium Leak Test
3. Proof pressure at ambient
4. Operation, expansion reservoirs only: 5 full excursions at design pressures (substitute fluid for the NaK reservoirs)

APPENDIX D

-1 SNAP-8 COMPONENT ENVIRONMENTAL TEST PROGRAM SCHEDULE



P = Procedure Completed
FD = Fixture Design Completed
F = Fixture Fabricated & Checkout
D = Component Delivery

TS = Test Start
TC = Test Completed
R = Report

NOTE: Delivery dates from PERT Chart 0380-64-0125 (10/9/64)

IV 157

18 January 1965
CME:ns
4832-65-13

MEMORANDUM TO: E. S. Chalpin

FROM: C. N. Epstein

SUBJECT: L/C PMA Environmental Testing
- Vibration Tests, Initial Results

DISTRIBUTION: J. R. Pope, G. J. Baenteli, G. Oiye, C. P. Colker, S.L. Bradley, W. M. Waters, M. G. Cherry, J. J. Marick, E. Eber, C.G. Boone, S. Seplow, 4832 File, B. S. Pilling

1. SUMMARY OF RESULTS

During the week of 4 Jan. 65 vibration tests were begun on the L/C PMA environmental test unit. Significant results were as follows:

a. The rear clamp band (P/N 208260) failed during an early testing phase. The part was replaced and modification of a physical feature on the rear mounting bracket (P/N 208225) which had contributed to the failure was effected. A similar modification was effected on the forward mounting bracket (P/N 208224) and testing was resumed.

b. Design changes were initiated to cover the bracket modifications noted in (a.) and to provide stronger clamp bands for future use.

c. Transmission of vibrations to the PMA at the g-levels called for in the environmental testing specification was limited by physical characteristics of the adapter plate (P/N 096921) on all three axes of forced vibration. Vibrations on the vertical (Y) axis were discontinued above 300 cps when the rear clamp band failure occurred. Because of excessive absorption of shaker input energy by the adapter plate above this frequency, vibrations on the Y axis were not resumed. On the axial (X) and transverse (Z) axes vibrations were possible through the entire frequency range called for (16 - 2000 cps) but inputs to the pump were limited to 2-g level. 6g to 19g peak input levels are called for in the sweep test phase of the environmental vibration test schedule, and 3g to 9.5g peak input levels are called for in the 5-minute resonance tests. Resonances were noted during both the X and Z axes sweeps, with amplification factors of from 6 to 12.

d. Because of the limiting performance of the adapter plate (P/N 096921) on all three axes it has been decided to build a new test base for continuation of the L/C PMA vibration and shock tests,[1] rather than to attempt modifications of the present base. A frame type base is considered which should also be adaptable for vibration and shock testing of the other SNAP-8 pump components.

2. CLAMP BAND FAILURE AND CORRECTIVE ACTION

Initiation of failure of the rear clamp band (P/N 208260) appears to have occurred where the band made a sharp bend around a lower corner of the rear mounting bracket (P/N 208225). (See Fig. 1) The bracket corners in this position on both sides of each bracket were found to

Note 1: Applies if the PMA test configuration in this phase continues to include accessory piping and harness.

be in the as-cast condition, presenting a rough and irregular edge to the band at the cornering position. In the remedial action which was taken it was found possible to file a full ½-inch radius relief over the bracket corners, and the engineering change to improve this feature on other brackets will provide for a ½-inch relief radius at these corners. A relatively small bearing pattern between the bracket pads and housing support surfaces observed at this time, with some signs of fretting corrosion in progress at the contact points, occasioned examination of the machined surfaces of the bracket pads, and it was found that the forward mounting bracket pads were axially concave by about .010 inch, resulting in the sharp edge bearing pattern which was observed between these pads and the pump housing. A better control of this feature in fitting the brackets to the pump housings is recommended.

Although the bands which were used to continue the vibration testing on the environmental test L/C FMA unit were previously used,* the folds impressed by the bracket corners were relocated on reassembly so that they would be pressed out on relatively large radius sections of the pump housing or bracket undersides. These bands have come through subsequent vibrations in satisfactory condition. However, the heavier bands which are now on order will be a desirable improvement. In addition, it is suggested that a design specification be made instructing assembly of the band so that the weld area on the band be located at least one inch above the bracket corner.

* The forward band was the original environmental test unit item. The rear band was borrowed from another L/C FMA.

3. PROBLEMS OF ADAPTER PLATE P/N 096921

The FMA adapter plate used in the initial L/C FMA vibration tests was of a conventional design to satisfy the requirements for mounting alternately to the shaker head and the shaker horizontal movement adapter plate, and to accommodate the mounting thereon of the L/C FMA and accessory piping required in the vibration testing in two alternate positions. Inability of the adapter plate to transmit vibrations from the shaker to the FMA without excessive energy absorption is attributed to several conditions:

a. The plate (41" x 43" x 3") has 25 3/4" dia. holes in a 28-inch dia. central area, counterbored 1¼" dia. to 1½-inch depth to permit bolting to the shaker head or the shaker horizontal movement adapter plate. The distribution of these holes and the shallow lower thickness of the FMA adapter plate which remains firmly bolted to the shaker or shaker horizontal movement adapter plate contribute to the flexibility of the FMA adapter plate in any direction of vibration.

b. The configuration of the L/C FMA and accessory piping called for in this test results in the mass of the pump being concentrated on one corner of the adapter plate, providing a considerable inertia at this point (including the mass of the solid adapter plate in this peripheral zone) to be overcome by the inadequate stiffness of the connecting structure in the central plate mooring area during high frequency high g-level vibrations.

c. The material in the PMA adapter plate (Al-6061-O) is subject to quality consistency variations which could result in considerable absorption of energy from the shaker.

The PMA adapter plate is of a configuration and material often used successfully to provide an adequate foundation for shaker test hardware in vibration and shock tests. However, in this case, a stiffer supporting structure is required in order to minimize intermediate absorption of shaker energy. The use of a steel double I-beam base is recommended.[1] At this stage it is planned to review the requirements of the Hg PMA and the NaK PMA environmental test configurations in order to select a twin I-beam section and length combination which should provide universal adaptability for all pump units. It is planned to reinforce the I-beam flanges with gussets to prevent 'flange-flap' and to weld the two beams together along the flange edges. The vertical section of the I-beams will be most effective in resisting unscheduled movement of any masses overhanging the shaker platform in the Y-axis of excitation. The adjacent/integrated section of two I-beams in parallel will provide excellent support against unscheduled movement of top-mounted masses during X- and Z-axis excitations. (The I-beam orientation will be horizontal/diagonal during the latter movements.)

4. VALIDATION OF SHEEP TEST RESULTS

Verification of instrument observations during test against recorded data, vibration amplitude vs. frequency, (the latter available for X- and Z-axis vibrations only) establishes the following information: (See Fig. 2)

Input g's Accelerometers 2,3	Vibration Axis	Accelerometer Axis	Accelerometer No.	Resonant Freq. (cps)	Output g's	Amplification Factor
2	X	X	5	310	24	12
		Y	6	315	4	-
		Z	4	320	7	-
2	Z	X	5	386	14	-
		Y	6	387	3.7	-
		Z	4	384	12	6

Although none of the above data present an alarming situation so far as general rotating machinery test amplification factors are concerned, it is recommended that the L/C PMA bearing and support design features be reviewed in the light of this information.

5. OPERATIONS TO FOLLOW

a. A new PMA adapter base will be fabricated and tested independently on the shaker.[2]

Note 1, 2: Applies if the PMA test configuration in this phase continues to include accessory piping and harness.

b. As soon as the new PMA adapter base is fabricated and the vibration laboratory is available for the resumption of testing, the following measures will be carried out:

(1) Completion of the resonance search on the Y-axis, and per-spec. verification of 2-g input results on the X- and Z-axes, with a 10-minute sweep test on each axis according to the following schedule:

Freq. (cps)	Input
16 - 100	6g peak
100 - 180	.0118 in. (DA displ.)
180 - 2000	19g peak

(2) Five minute resonance tests to be conducted on each axis, at the most critical resonant frequencies determined in operation (1). Schedule:

Freq. (cps)	Input
16 - 100	3g peak
100 - 180	.0059 in. (DA displ.)
180 - 2000	9.5g peak

(3) Shock tests, to include three shocks in each direction on each axis (total = 18 shocks), input pulse, each shock = 35g's.

The above measures are the minimum operations called for in NASA Spec. 417-2, modified by subsequent NASA-AGC negotiations. Additional Acoustic Noise, Random Vibration, Sustained Acceleration, and Combined Loading tests may be called for by subsequent developments.

c. Upon completion of the vibration and shock tests, the L/C PMA will be returned to LML-3 for performance of post-environmental operational proof tests.

C. N. Epstein

C. N. Epstein

Approved:

E. S. Chalpin

E. S. Chalpin, Head
Rotating Machinery Section
SNAP-8 Division

Initial Conditions	First Event	Second Event	Ultimate Failure
A — Sharp corner at bracket bend			
B — High tensile stress in band	D — Vibration initiates crack in band at forward end of corner (Sketch item 1)	E — Crack in band at D increases stress in adjacent weld line area at opposite edge of band (Sketch item 2)	F — Crack initiated at E establishes weakest section in band and crack crosses weld area from this point to complete break (Sketch item 3)
C — Spot welds in band end assembly adjacent to A			

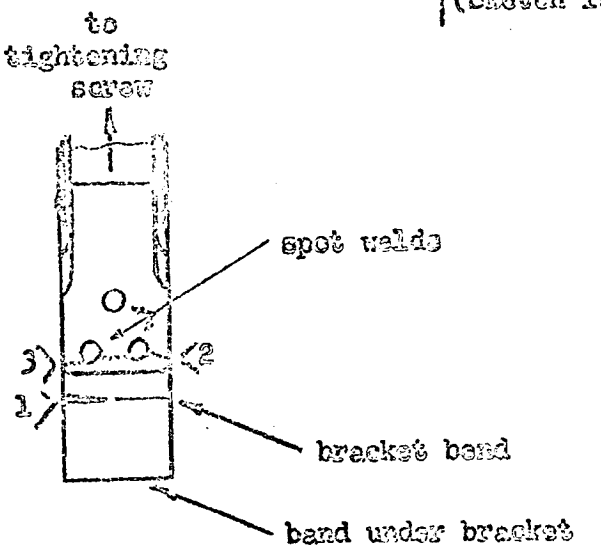
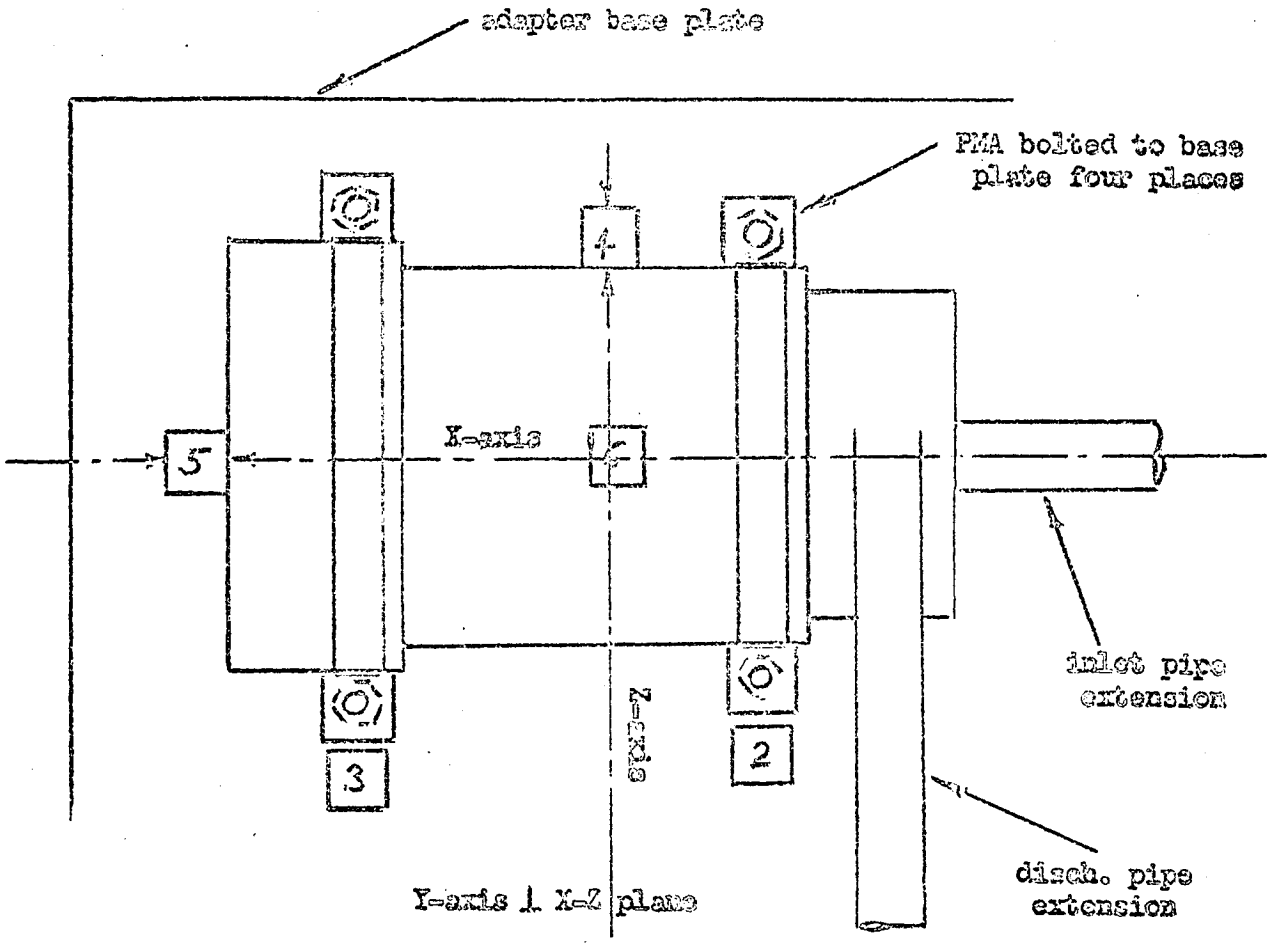


Fig. 1

ESTIMATED SEQUENCE OF FAILURE IN CLAMP BAND P/N 208260



Accelerometer [4] attached to side of PMA picks up output accelerations on Z-axis

Accelerometer [5] attached to end of PMA picks up output accelerations on X-axis

Accelerometer [6] attached to top of PMA picks up output accelerations on Y-axis

Input g's to PMA are signalled from accelerometers [2] and [3] which are attached to the base plate and oriented in the direction of input vibration for each test.

Fig. 2

PMA ACCELEROMETER LOCATION PLAN

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIA

10-052-129 (REV. 8/63)

RELIABILITY FAILURE REPORT

1 REPORT NO. 1211 A

MODEL -1 S/N A

DATE 1-6-65

2 IDENTIFICATION OF HARDWARE

NEXT ASSEMBLY NAME Lube Coolant Pump Motor Assy.

PART NO. 253800-3 S/N 48505 MFGR: TRW

FAILED PART NAME: Mounting Clamp (MOTOR END)

PART NO. MBC60522C S/N 5A MFGR:

Aeroquip 520M, 208260-A

3 X-REF. REPORTS

I.R. NO.

F.I.R. NO.

OTHER

4 DETAILED DESCRIPTION OF FAILURES – SYMPTOMS – ETC.

Motor end mounting clamp broke at spot weld during resonance frequency scan.
300 ~ 15 g measured at input accelerometer at rear mounting bracket

5 REPORTED BY: S. Saplow PHONE 6163

SUPERVISOR: S L Bradley Q.C.

6 TEST DESCRIPTION

TEST SITE: Vibration Lab

TEST SERIES: D-7-F

PRE-DECLARED TEST ___ YES (✓) NO ( )

TEST SPEC. NO. EC-[illegible] PARA. [illegible]

TYPE OF TEST Vibration Environmental Test

7 EQUIPMENT REWORK DATA

REWORK INSTRUCTIONS:
Radius Foot of PMA to about 1/8" R by hand grinding. This will eliminate creasing effect on band which lead to premature failure
Fit new bands.

REPLACEMENT PART S/N

8 EQUIPMENT RETEST DATA

RETESTED BY: Q.C. VERIFICATION

10 FAILED PART DATA

PRELIMINARY EXAMINATION:
Strap torn in two, at spot weld also torn where strap bends over end of mounting bracket. One spot weld started to tear loose. See Photos.

11 PRELIM. DISPOSITION OF PART:

HOLD FOR RELY. ANALYSIS ( )

ROUTE TO MRB ( )

REWORK PER INSTRUCTIONS (X)

12 OPERATING TIME AND/OR CYCLES:

TOTAL 8 minutes

9 PROJECT ENGINEERING: John R Pope. RELIABILITY APPROVAL: H E Rice

FOR RELIABILITY USE ONLY

13 FAILURE REPORT DISPOSITION

INITIATE FAILURE ANALYSIS ( )

HOLD FOR CRITICAL SURVEILLANCE ( )

NO ACTION REQUIRED Noted (X)

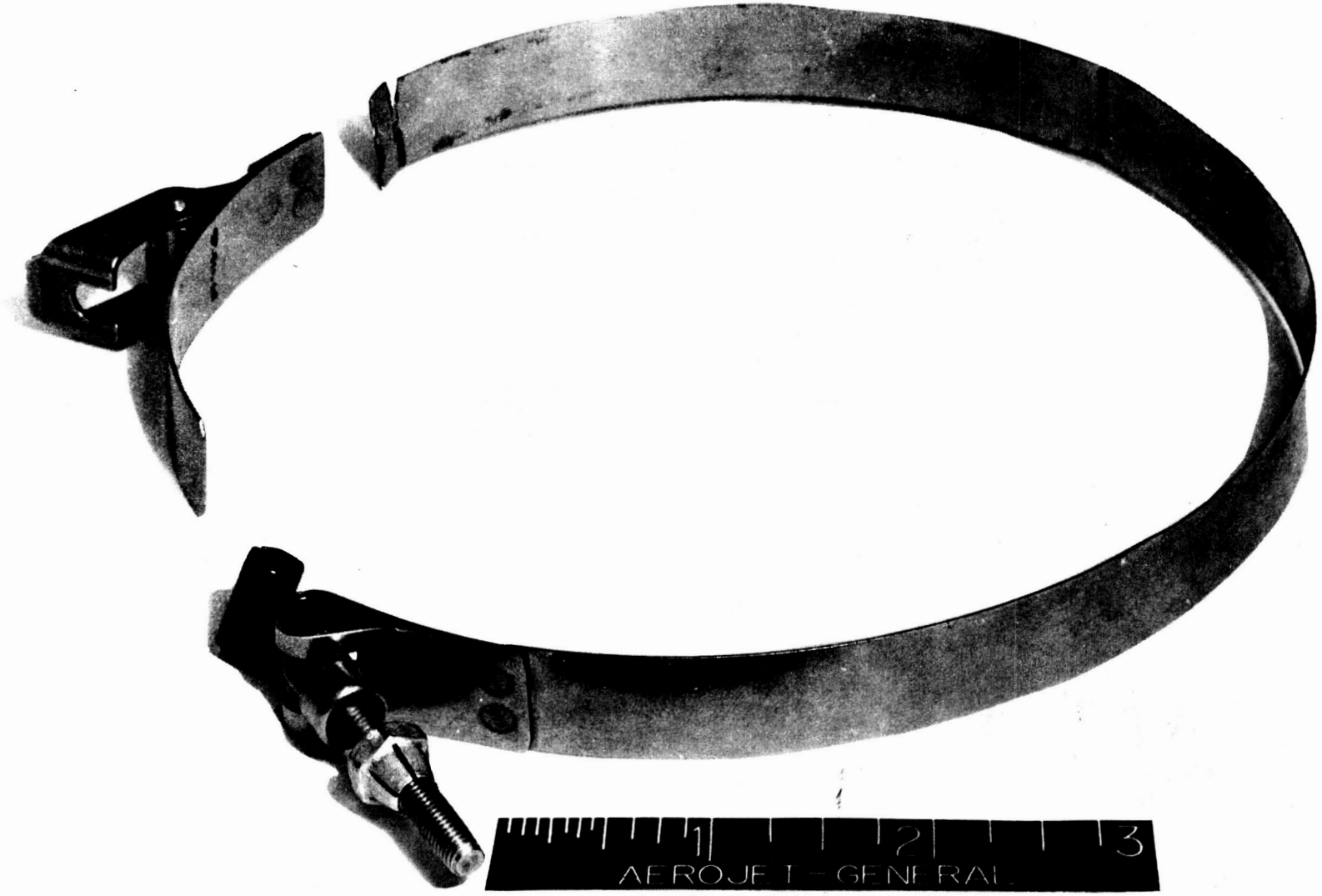
14 EFFECT OF FAILURE

ON MISSION COMPLETION —

ON ABORT CAPABILITY —

15 DISCUSSION AND DIRECTION: Minor Failure:
Recommend modifying PMA mounting support brkts as noted in Rwk instr. also increase width of mounting clamps. Evaluate clamp design and installation.

RELIABILITY APPROVAL: H E Rice DATE 1-6-65



L/C PMA MOUNTING CLAMP
MBC 60522C S/N 5A RFR # 1211

IV. 165

Photo # 165-297

L/C PMA MOUNTING CLAMP
MBC 60522C S/N 5A RFR # 1211

IV 166

Photo # 165-296

V. ENGINEERING ANALYSES

A. Pump

B. Motor

C. Bearings and Critical Speeds

D. Stress

IMPELLER SIZING

REPORT #PMA-R63-2

V

DATA FOR PUMP 209,100 [FROM TAPCO ER-4274 - REV. A: "QUALIFICATION REPORT WATER INJECTION PUMP MODEL 209100 TO REPUBLIC AVIATION CORP. PRODUCT SPECIFICATION RE-P-75", pp. 59, 60, 103, 104]

TWO-STAGE, HYDRAULIC MOTOR DRIVEN PUMP

WATER TEMPERATURE: 155 °F
WATER INLET PRESSURE: 13 TO 20 PSIA.
OIL (MOTOR DRIVE MEDIUM): 225 °F
OIL INLET PRESSURE: 2650 PSIG } (2500 PSI. OIL Δp.)
OIL OUTLET PRESSURE: 150 PSIG }

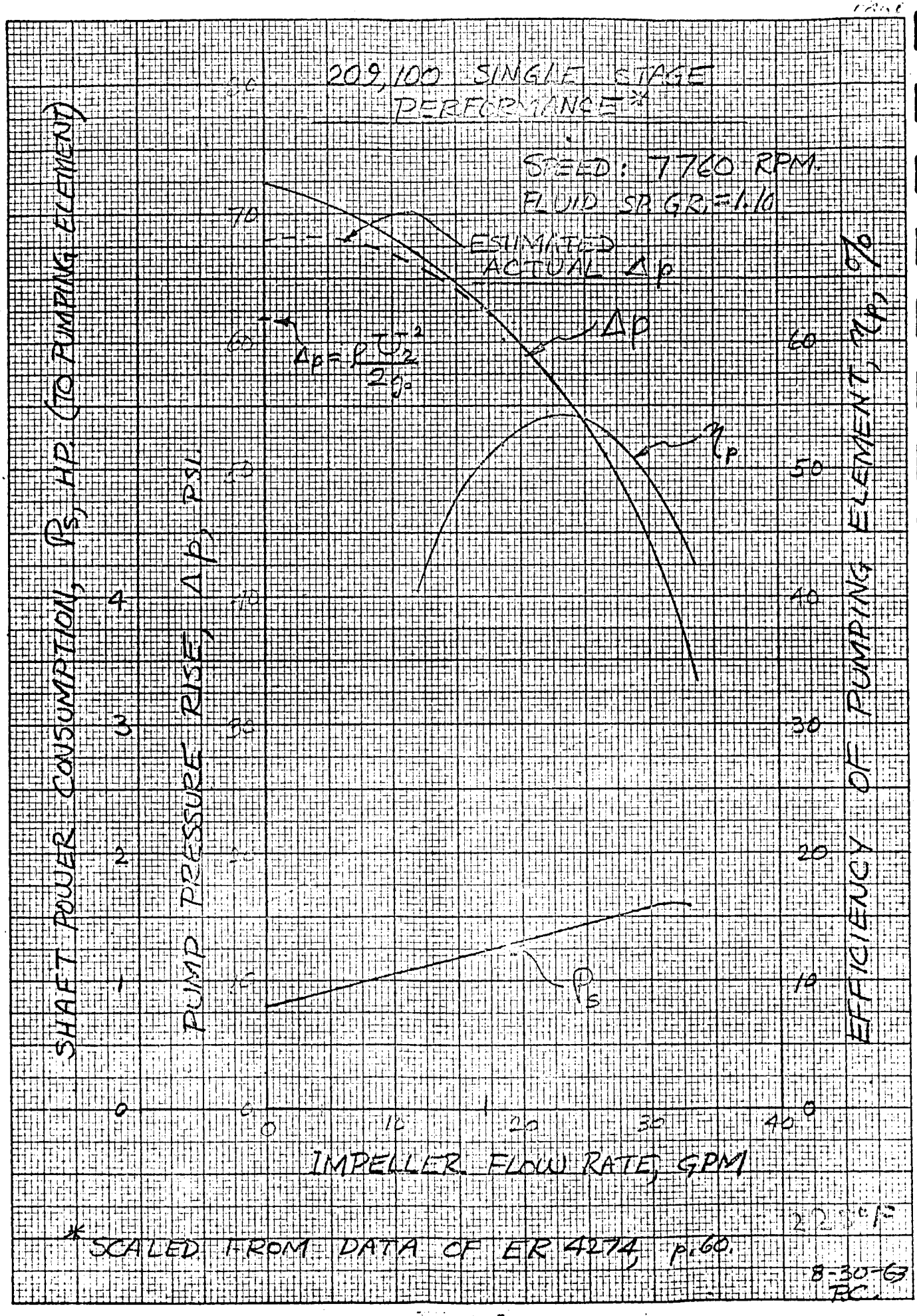
DATA PT.	WATER FLOW, GPM.	WATER PRESS. RISE, PSI	OIL FLOW, GPM	SHAFT POWER, HP.	SPEED, RPM.	PUMP ELEMENT EFF'Y	SCALED TO 7760 RPM: ETHER FLOW, GPM	SCALED TO 7760 RPM: ETHER PRESS. RISE PSI. (SINGLE STG.)
1	0	341	7.58	NOT AVAILABLE (FLOW-LIMITER TAKES PART OF OIL Δp)*	12,500	0	0	72.4
2	5.0	331	7.55					
3	10.0	229	7.65					
4	15.0	331	7.75					
5	20.0	341	8.04	9.83	12,980	0.405	11.97	67.0
6	25.0	320	7.95	9.75	12,850	0.479	15.10	64.1
7	30.0	284	7.76	9.57	12,500	0.519	18.61	60.2
8	34.8	251	7.50	9.40	12,050	0.542	22.40	57.2
9	40.0	209	7.28	9.20	11,630	0.530	26.6	51.1
10	45.0	166	7.14	9.03	11,380	0.482	30.7	42.5
11	48.2	140	7.10	9.00	11,320	0.438	33.0	36.1

DATA PT.	SHAFT POWER HP. AT 7760 RPM: WATER	ETHER 1. STG.
5	2.10	
6	2.15	
7	2.28	
8	2.51	
9	2.68	
10	2.88	
11	2.90	

STRAIGHT LINE VAR. TO 1.57 HP. AT 30 GPM

SHUT-OFF: 1.46 → 0.803 (EXTRAPOLATED)

*SHUT-OFF EXTRAPOLATION OF SHAFT POWER: STRAIGHT-LINE SHAFT POWER VARIATION WITH WATER FLOW AT CONSTANT SPEED (cf SHAFT-POWER VARIATION AT LEFT) GIVES 6.12 HP. AT SHUT-OFF AT 12500 RPM. AND p. 103 OF REF. ABOVE GIVES 7.58 GPM OIL FLOW, WHICH CHECKS THIS SHUT-OFF SPEED FROM ABOVE DATA (OF 7.58 GPM.)

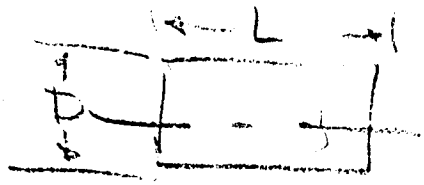


*SCALED FROM DATA OF ER 4274, p.60.

8-30-63
RC

K+E 10 X 10 TO THE ½ INCH KEUFFEL & ESSER CO. 359-11G MADE IN U.S.A.

FOR ROTOR $D = 2.105$ in.
$L = 2.250$ in.



$$\left(1 + 5\frac{L}{D}\right) = 1 + 5.34 = 6.34$$

$$0.260 \times \frac{6.34}{5.10} \times 0.84 = 0.272 \text{ hp}$$

$$Re = 0.84 \times 10^5$$

$$C_m = 0.0098 \quad 0.333 \text{ hp.}$$

Check:

$$HP_{DF} = \left(2.55 \times 0.0098 \times \overset{41.3 \times 10^{1}}{(2.105)^5} \times \overset{0.468 \times 10^{12}}{(7760)^3} \times 1.1 \times \cancel{10^{-12}}\right)(6.34) \text{ hp.}$$

$= 0.336$ hp ROTOR FRICTION

190w elect. loss

PRELIMINARY ESTIMATE OF MAX. PUMP POWER

ASSUME 2gpm. IMPELLER LEAKAGE

∴ 19 GPM IMPELLER FLOW & (FROM CURVE)

$P_s = 1.27$ hp.
ROTOR FRICTION $= 0.34$ hp.
TOTAL → 1.61 hp.
EXISTING IMP. (NO CHGS.)

SHAVE IMP. BL. HT. *

$\eta_{p(19\ GPM)} = 0.54$

$\Delta p = 57.5$ psi

$Q = 19$ gpm

$P_s = 1.18$ hp. TO P. ELEMENT

FRICTION OF ROTOR $= 0.34$

TOTAL ROTOR HP. → $\boxed{1.52 \text{ hp.}}$

* CAUSES NO CHG. IN SHUT-OFF PRESSURE RISE

* NEW IMP. BL. HT. ABOVE WEB = PRESENT VALUE $\times \frac{19}{22} \times 0.8$

Total BHP (pump & rotor) = .15 HP @ 90w and 125°F.

Check & Bmp @ 220w @ 200°F

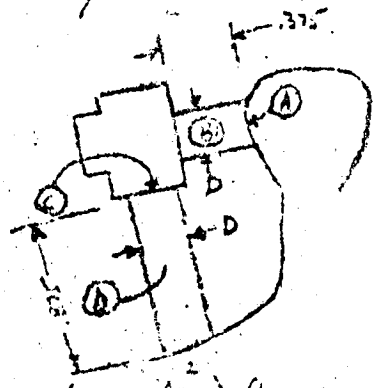
8-30-63
PC.

Thompson Ramo Wooldridge Inc.

SUBJECT: [illegible] L & C Pump - Internal Flow REPORT NO. PMA-[illegible]-21

By Pass Sizing

Req'd: Pump Must Include By Pass Arrangement Which Will Permit Customer To Set Pump Outlet Flow Between ½ and Rated Flow. This Will Be Done By Insertion of Orifice in By Pass Line. The By Pass Passage Without an Orifice Must Therefore Be Capable of Returning ½ Rated Flow (8.5 GPM) at a Pressure Drop Less Than Pump Output Pressure at Rated Flow (55 PSI) Type



By Pass Configuration

$$\Delta p_T = \Delta p_{(A)} \text{ (Entrance Loss)} + \Delta p_{(B)} \text{ (Line Loss)} + \Delta p_{(C)} \text{ (Entrance Loss)} + \Delta p_{(D)} \text{ (Line Loss)}$$

$$\Delta p_{(A)} = \left(1.5 - \frac{A_{(B)}^2}{A_{vc}^2}\right) \frac{\rho}{2g_c} V_{(B)}^2$$

where Entrance Loss is Considered to Be 1½ Vel. Hd. for Sharp Edged Entrance. Actually Loss Will Approach 1 Vel. Hd. with a Break of Sharp Edge.

$$\Delta p_{(B)} = \frac{.013 V f_c L_c S G^2}{d_c^5}$$

where f = Friction Factor, L = Length, Ft, S = Sp. Gr., G = Flow, GPM, d = Dia. Line — Small.

$\Delta p_{(C)} = \Delta p_{(B)}$ when $L_{(C)} = L_{(B)}$ ✓

$$\Delta p_{(D)} = \frac{.013 V f_c L_D S G^2}{d_D^5}$$ Small

Let: $\frac{A_{(B)}^2}{A_{vc}^2} = 0$ (Low Loss Δp); $G = 8.5$ GPM; $d = .250''$; $\rho = .0315$ #/ft³

$V_{(B)} = V_{(D)} = \frac{Q}{A} = \frac{8.5 \text{ GPM}}{.250^2} \cdot \frac{\text{Gal}}{231} \cdot \frac{\text{ft}^3}{\text{Gal}} \cdot \frac{\text{min}}{60 \text{ sec}} \cdot \frac{144 \text{ in}^2}{\text{ft}^2} = 23.0$ ft/sec ✓

$R_e = \frac{VD}{\nu} = 23.0 \cdot .250 \cdot \frac{\text{ft}^2}{\text{sec}} \cdot \frac{\text{sec}}{.0315 \text{ ft}^2} = 1.75 \cdot 10^4$. $f_c = \frac{\tau_c}{\rho} = .026$

V 6

Thompson Ramo Wooldridge Inc.

SUBJECT: [illegible] REPORT NO. [illegible]

$$\Delta p_T = 1.5 \times \frac{.0395 \times 12 \times 55.6 \times 55.6}{64.4} + .0134 \times .026 \times \frac{.375}{12} \times 1.1 \times \frac{8.5^2}{(.25)^5} + 1.5 \times \frac{.0395 \times 12 \times 55.6 \times 55.6}{64.4} + .0134 \times .026 \times \frac{.375}{12} \times 1.1 \times \frac{8.5^2}{(.25)^5}$$

Close

$$\Delta p_T = 34.2 + .88 + 34.2 + \frac{.375}{.375} \times .88 \cong 68 \text{ psi}$$ — Too High

From above, it can be seen that line losses are negligible ✓

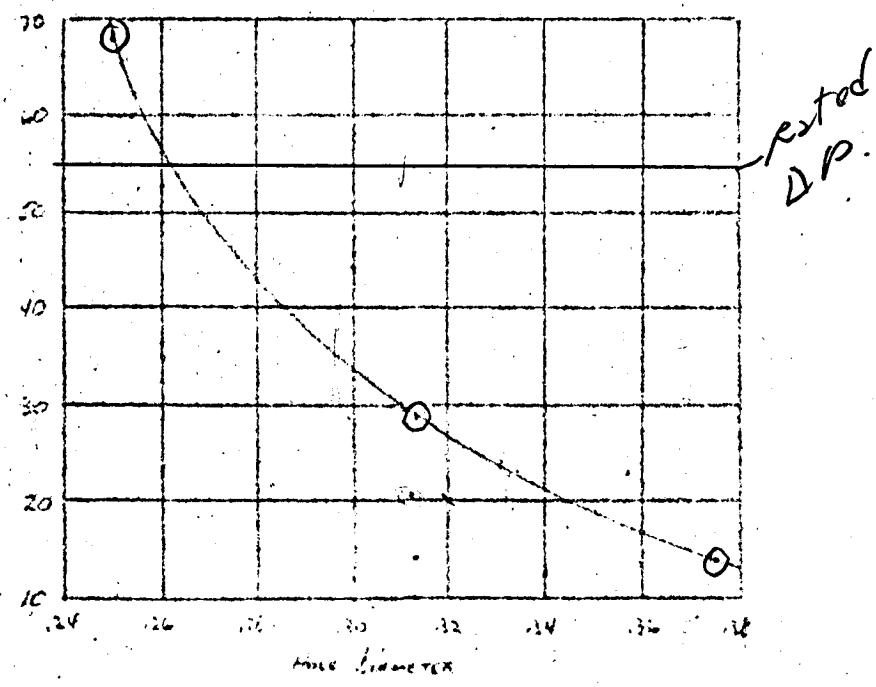
Therefore with .375 Δ $V_B = V_D = \frac{Q}{A} = \frac{8.5 \times .321 \times 4}{3.14 \times .14} = 24.8$ Ft/sec

$$\Delta p_T = \frac{1.5 \times .0395 \times 12 \times 24.8 \times 24.8}{64.4} (\times 2) = 13.6 \text{ psi}$$

With .3125 Δ $V_B = V_D = \frac{Q}{A} = \frac{8.5 \times .321 \times 4}{3.14 \times .0955} = 36.4$ Ft/sec

$$\Delta p_T = \frac{1.5 \times .0395 \times 12 \times 36.4 \times 36.4 \times 2}{64.4} = 29.3 \text{ psi}$$

Let Hole Dia. = .320/.295 inch



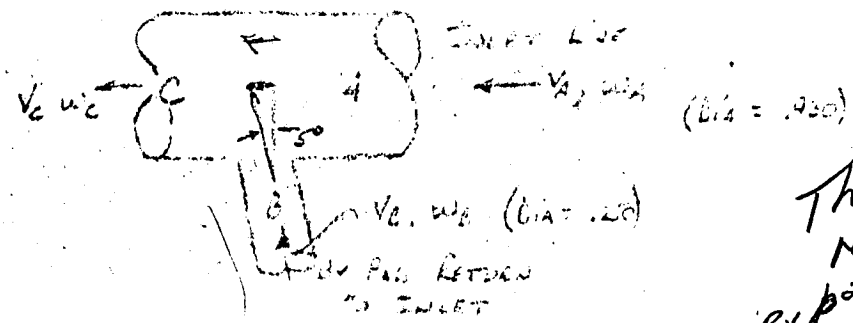
Check! Re on high side Took $1\frac{1}{2}\frac{V^2}{2g}$ × 2 Times more like a total of $2\frac{V^2}{2g}$

V 7

Thompson Ramo Wooldridge Inc.

SUBJECT: [illegible] REPORT NO. [illegible]

FLOW SCHEMATIC UNDER HALF FLOW BYPASS CONDITIONS



They're NOTS! Bypass should increase to small radial component not disturb the suction velocity profile

$$\Sigma F = \frac{V_C w_C}{g} - \frac{V_A w_A}{g} - \frac{\sin 5^\circ V_B w_B}{g}$$

$$V_A = \frac{Q_A}{A_A} = \frac{8.5\ \text{GAL}}{\text{MIN}} \times \frac{231\ \text{IN}^3}{\text{GAL}} \times \frac{1}{.785 \times (.930)^2\ \text{IN}^2} \times \frac{\text{MIN}}{60\ \text{SEC}} = \frac{8.5 \times 231}{.785 \times .865 \times 60} = 48.2\ \text{IN/SEC} = 4.02\ \text{FT/SEC}$$

$$V_B = \frac{Q_B}{A_B} = \frac{8.5 \times 231}{.785 \times .250^2 \times 60} = \frac{8.5 \times 231}{.785 \times .0625 \times 60} = 668\ \text{IN/SEC}$$

$$\sin 5^\circ \times V_B = .087 \times 668 = 58\ \text{IN/SEC} = 4.83\ \text{FT/SEC}$$

~40/sec

4.0/sec

$$V_C = 2 V_A\ (\text{FOR } 17\ \text{GPM}) = 96.4\ \text{IN/SEC} = 8.04\ \text{FT/SEC}$$

$$w_A = \frac{8.5\ \text{GAL}}{\text{MIN}} \times \frac{231\ \text{IN}^3}{\text{GAL}} \times \frac{\text{MIN}}{60\ \text{SEC}} \times \frac{.03125^\#}{\text{IN}^3} = 1.295\ \#/\text{SEC} = w_B$$

$$w_C = 2 \times w_A = 2.59\ \#/\text{SEC}$$

$$\Sigma F = \frac{8.04\ \text{FT}}{\text{SEC}} \times \frac{2.59\ \#}{\text{SEC}} \times \frac{\text{SEC}^2}{32.2\ \text{FT}} - \frac{4.02 \times 1.295}{32.2} - \frac{4.83 \times 1.295}{32.2} = .647 - .162 - .194 = .291^\#$$

$$\Delta p = \frac{.291^\#}{.785 \times (.930)^2\ \text{IN}^2} = .428\ \text{psi}\ (\text{TOO HIGH})$$

IF RETURN ANGLE IS MADE 12° MINIMUM, $\sin 12^\circ \times V_B = .208 \times \frac{668}{12} = 11.6$ FT/SEC

$$\Sigma F = .647 - .162 - \frac{11.6 \times 1.295}{32.2} = .647 - .162 - .467 = .018^\#$$

$$\Delta p = \frac{.018}{.785 \times .865} = .0265\ \text{psi}$$ ∴ 2 PSI INLET WOULD REDUCE TO 2.97 O.K.

What's this

Thompson Ramo Wooldridge Inc.

SUBJECT: MODEL 253600-1 INTERNAL FLUID FLOW REPORT NO. PMA-R63-2.1

HEAT REJECTED BY MOTOR = INPUT − OUTPUT

OUTPUT = HYD. HP_{OUTPUT} ÷ PUMP EFF.

AT RATED FLOW: $HP_{OUT} = \frac{19 \text{ GPM} \times 60 \text{ PSI}}{1715 \times 52.5\%} = 1.27$ HP

INPUT = [TOTAL IMP. OUTPUT + FLUID FRICTION LOSSES] ÷ MOTOR EFF.

($BrHP_{INPUT}$ HP PREVIOUSLY CALCULATED IN PMA-R63-2 = 1.61 HP (1.27 + .34 FLUID FRICTION))

∴ INPUT = $\frac{1.61}{82\% \text{ MOT. EFF.}}$ = 1.965 HP

∴ HEAT REJECTED = 1.965 − 1.27 = .695 HP ✓

.695 HP × 42.42 = 29.5 BTU/MIN. ✓

FLOW REQUIRED TO MAINTAIN 40°F TEMP. RISE OF MOTOR (WITH 260°F FLUID):

$Q = wC_p\Delta T$ $\quad w = \frac{29.5 \text{ BTU}}{\text{MIN}} \times \frac{1}{40°F} \times \frac{1 \text{ °F}}{.394 \text{ BTU}} = 1.875$ #/MIN

$\frac{1.875 \#}{\text{MIN}} \times \frac{\text{GAL}}{8.34 \times 1.1 \#} = .20$ GAL/MIN. ✓

SINCE HEAT REJECTED BY MOTOR IS NOT GENERATED IN ONE AREA ONLY, ALLOW TOTAL COOLANT FLOW TO EQUAL .2 GPM THROUGH ROTOR/STATOR GAP + .2 GPM THROUGH "GAP" BETWEEN OUTSIDE HSG. AND INTERMEDIATE HSG.

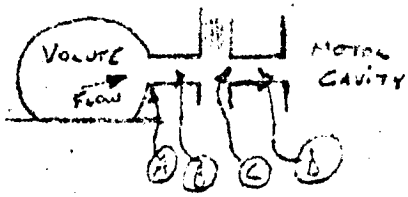
∴ TOTAL COOLANT FLOW = .4 GPM

Then $\Delta T \approx 20°F$

Thompson Ramo Wooldridge Inc.

SUBJECT: 25800 L&C Pump ~ Internal Flow REPORT NO. [illegible]

Volute To Motor Case Level



Flow = .45 GPM (.4 GPM Thru Coolant + .05 GPM Max. Anticipated Gas Coolant)

Let Δp_T = 30 psi (To yield 25 psi inlet to Gas with 55 psi Pump Disch. Press)

Pk - Loss Thru Brgs ?

$$\Delta p_{TOTAL} = \Delta p\,(A \to B) + \Delta p \text{ Thru } (B) + \Delta p\,(C \to D) + \Delta p \text{ Thru } (D)$$

$$\Delta p_A = \left(1 - \frac{A_B^2}{A_A^2}\right)\frac{\rho}{2g_0} V_B^2 \quad \text{where } \frac{A_B^2}{A_A^2} \doteq 0 \quad V_B^2 = \left(\frac{Q_B}{A_B}\right)^2$$

$$\Delta p_B = \frac{.0134 f_B L_B \rho G^2}{D_B^5} \quad \text{where: } f_B = \text{friction factor}, \; L_B = \text{length, ft}, \; \rho = \text{density}, \; G = \text{flow, GPM}, \; D = D_B, \text{ inches}$$

$$\Delta p_C = .2\left(1 - \frac{A_C^2}{A_D^2}\right)\frac{\rho}{2g_0} V_C^2$$ ~ Assuming .2 of Loss since Area C is not true reducer.

where $\frac{A_C^2}{A_D^2} \doteq 0$ $\quad V_C^2 = V_D^2$ $\quad (A_C = A_D)$

$$\Delta p_D = \frac{.0134 f_D L_D \rho G^2}{L_D^5} \quad \text{where } f_D = f_C, \; L_D = L_C$$

$$\Delta p_T = \frac{\rho}{2g_0}\left(\frac{Q_B}{A_B}\right)^2 + \frac{.0134 f_B L_B \rho G^2}{D_B^5} + 0.2\frac{\rho}{2g_0}\left(\frac{Q_C}{A_C}\right)^2 + \frac{.0134 f_D L_D \rho G^2}{D_D^5} \qquad A_B = \frac{\pi D_B^2}{4}$$

$$\Delta p_T = \frac{\rho}{2g_0} \times \frac{16 Q_B^2}{\pi^2 D_B^4} + \frac{.0134 f_B L_B \rho G^2}{D_B^5} + 0.2\frac{\rho}{2g_0} \times \frac{16 Q_C^2}{\pi^2 D_C^4} + \frac{.0134 f_D L_D \rho G^2}{D_D^5}$$

Assuming $D = .060''$ $\quad V = \frac{4Q}{\pi D^2} = \frac{.45 \text{ Gal}}{\text{min}} \times \frac{231 \text{ in}^3}{\text{Gal}} \times \frac{\text{min}}{60 \text{ sec}} \times \frac{4}{3.14 \times .060^2 \text{ in}^2} = 43.9$ ft/sec

$R = \frac{VD}{\mu}$ where μ [illegible] $= \frac{43.9 \times .060 \times [illegible]}{[illegible]} \times 10^5 = 3.37 \times 10^5$ Low Flow: $f_B \doteq .042$

$$\Delta p_T = \frac{.0732}{144} \times \frac{16 \times 43.9^2}{[illegible]} + \frac{.0134 \times .042 \times [illegible] \times 43.9 \times 43.9 \times [illegible]}{[illegible]} + \frac{.2 \times .0732 \times 43.9 \times 43.9}{[illegible]} + \frac{.0134 \times .042 \times [illegible] \times 43.9 \times 43.9 \times [illegible]}{[illegible]}$$

$$\Delta p_T = .00732 \times 43.9 \times 43.9 + \frac{.261}{.116} + .00134 \times 43.9 \times 43.9 \cdot \frac{.130}{.116} = 14.2 + 2.25 + 2.84 + 1.25 = 20.5 \text{ psi}$$

Flow is Too Low ~ Let $D = .060''$.

Thompson Ramo Wooldridge Inc.

SUBJECT: 253800 LEC Pump ~ Internal Flow REPORT NO. PMR-R63-21

$V_B = \frac{.45 \times 231 \times 4}{60 \times 3.14 \times .0036 \times 12} = 51.2$ ft/sec $\quad R = \frac{51.2 \times .060 \times 10^5}{12 \times 6.3 \times 1.075} = 3.78 \times 10^3 \quad f_t = .04$

$\Delta p_T = .00736 \times 51.2^2 + .0134 \times .04 \times \frac{.25}{12} \times 1.1 \times \frac{.2025}{.078 \times 10^5} + .001472 \times 51.2^2 + .0134 \times .04 \times \frac{.125}{12} \times \frac{.2025}{.078 \times 10^5}$

$= 19.3 + 3.19 + 3.86 + 1.59 = 28$ psi

$1\frac{1}{2} \frac{V^2}{2g} \frac{1}{21} \sim 29$ psi

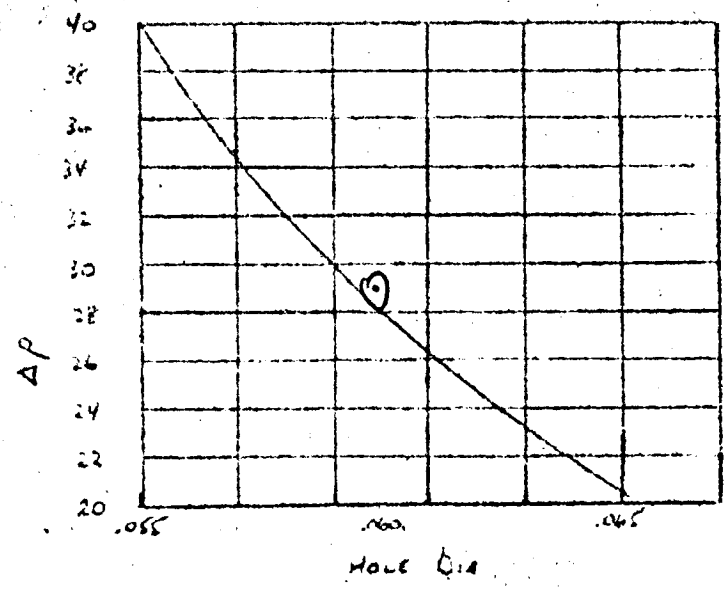
At $b = .055$

$V_B = \frac{.45 \times 231 \times 4}{60 \times 3.14 \times .003025 \times 12} = 60.8$ ft/sec $\quad R = \frac{60.8 \times .055 \times 10^5}{12 \times 6.3 \times 1.075} = 4.22 \times 10^3 \quad f_t = .039$

$\Delta p_T = .00736 \times 60.8^2 + .0134 \times .039 \times \frac{.25}{12} \times 1.1 \times \frac{.2025}{.05 \times 10^5} + .001472 \times 60.8^2 + .0134 \times .039 \times \frac{.125}{12} \times \frac{.125}{.05 \times 10}$

$\Delta p_T = 27.2 + 4.8 + 5.4 + 2.8 = 40.2$ psi

LET HOLE DIA. = .057/.061 — IF no Brg Flow



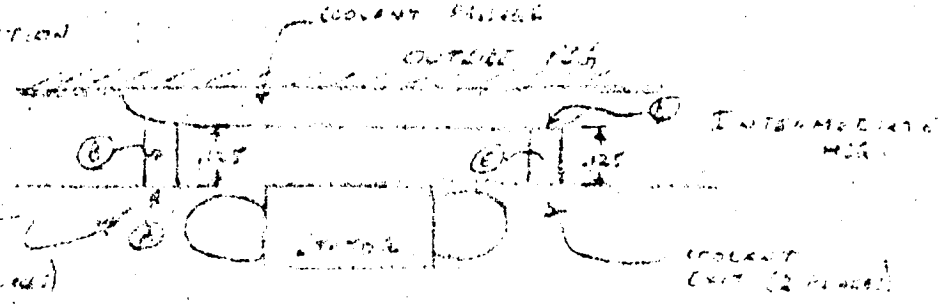
ΔP vs HOLE DIA @ .45 GPM FLOW

"OUTSIDE" MOTOR COOLANT FLOW RETURN

COOLANT FLOW RETURN INTERMEDIATE HOUSING AND OUTSIDE HOUSING PREVIOUSLY SET AT .2 GPM TO PROVIDE FULL MOTOR COOLANT FLOW.

$\Delta T = 20°F$

CONFIGURATION



PRESSURE DROP FOR OUTSIDE COOLANT FLOW FROM ΔP AT INTERNAL ROTOR "AIR GAP" (PREVIOUSLY CALCULATED AT 2.5 PSI) ASSUMING FULL FLOW INTO EACH ENTRANCE AND EXIT.

$$\Delta P_{T_{ENTRANCE}} = \underbrace{\left(1.5 - \frac{A_B^2}{A_{H.C.}^2}\right)}_{\text{MAX. ENTRANCE LOSS FOR SHARP EDGED HOLE}} \frac{\rho}{2g_c} V_B^2 + \underbrace{\frac{\rho}{2g_c} V_B^2}_{\text{LINE LOSS}}$$

small

THE LINE LOSS WILL BE NEGLIGIBLE, AND THEREFORE ΔP_{EXIT} = ENTRANCE LOSS

$V_B = \frac{Q_B}{A_B}$ WITH .250 DIA, $\frac{Q_B}{A_B} = \frac{.1 \text{ GPM}}{\text{PER}} \times .321 \frac{\text{FT}^3}{\text{GAL}} \times \frac{4}{3.14 \times .0625} = .655$ FT/SEC

AS $\frac{A_B^2}{A_{H.C.}^2}$ APPROACHES 0 $\quad \Delta P_{T_{ENTRANCE}} = \frac{1.5 \times .0395 \times 12 \times .655 \times .655}{64.4} = \frac{1.5 \times 3.95 \times 12 \times 6.55 \times 6.55 \times 10^{-4}}{64.4} = .0047$ PSI

WITH .188 HOLE $V_B = \frac{.1 \times .321 \times 4}{3.14 \times .188^2} = 1.16$ FT/SEC

$\Delta P_T = \frac{1.5 \times .0395 \times 12 \times 1.16 \times 1.16}{64.4} = .015$ PSI $\quad \Delta P =$

LET HOLES = .250 DIA.

For Flow Return Holes, Line Loss is Again Negligible, and:

$$\Delta p_{T_{EXIT}} = 1.5 \times \frac{\rho}{2g_0} V_E^2 \quad \text{where } \Delta p_{T_{EXIT}} = 2.8 \text{ psi}$$

$$V_E = \frac{Q_E}{A_E} = \frac{.1\ \text{Gal}}{\text{min}} \times \frac{231\ \text{in}^3}{\text{Gal}} \times \frac{\text{Ft}^3}{1728\ \text{in}^3} \times \frac{4}{3.14 \times D_E^2\ \text{in}^2} \times \frac{\text{Ft}^2}{\text{in}^2} \times \frac{\text{min}}{60\ \text{sec}} =$$

$$V = \frac{.1\,(231)}{(.050)^2 \frac{\pi}{4}}$$

$$V = 16.4'/\text{sec}$$

$$H_c = 4.1'$$

$$\therefore \Delta p_{T_{EXIT}} = 1.5 \times \frac{\rho}{2g_0}\left(\frac{.1 \times 231 \times 4}{3.14 \times D_E^2} \frac{\text{Ft}}{\text{sec}}\right)^2$$

$$\left(\frac{.1 \times 231 \times 4}{3.14\, D_E^2}\right)^2 = \frac{.00165}{D_E^4}$$

$$D_{E_{EXIT}}^4 = \frac{1.5 \times .0375 \times 12}{64.4} \times \frac{.00165}{2.8} = \frac{1.5 \times 3.95 \times 12 \times .165 \times 10^{-4}}{64.4 \times 2.8} = .065 \times 10^{-4}$$

≈ 2 psi

close enough

$$D_{E_{EXIT}} = .505 \times 10^{-1} = .050''$$

With $D_{E_{EXIT}} = .055''$ $\quad V_E = \frac{.1 \times 231 \times 4 \times 10^2}{3.14 \times .302} = 13.55$ Ft/sec

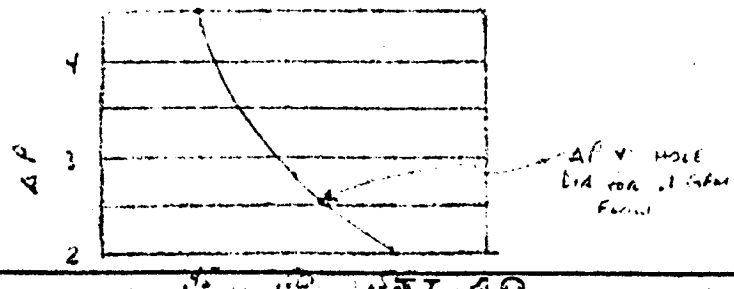
$$\Delta p_{T_{EXIT}} = \frac{1.5 \times .0375 \times 12}{64.4} \times 13.55 \times 13.55 = 2.03 \text{ psi}$$

With $D_{E_{EXIT}} = .045''$ $\quad V_E = \frac{.1 \times 231 \times 4 \times 10^2}{3.14 \times .2025} = 20.2$ Ft/sec

$$\Delta p_{T_{EXIT}} = \frac{1.5 \times .0375 \times 12}{64.4} \times 20.2 \times 20.2 = 4.5 \text{ psi}$$

If inlet edge were broken on .045" hole, $\Delta p_T = 4.5 \times \frac{1.0}{1.5} = 3$ psi

∴ Make return hole .045/.050 and break sharp corner on inlet.



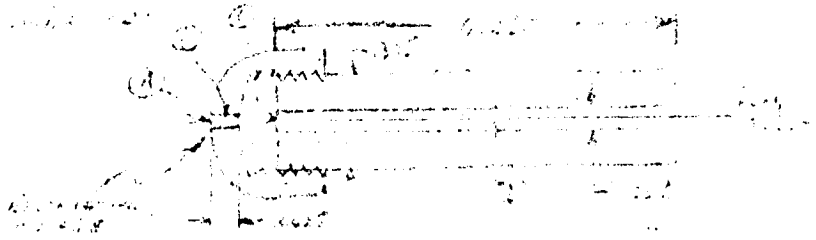
Thompson Ramo Wooldridge Inc.

SUBJECT: [illegible] REPORT NO. [illegible]

[illegible]

[illegible]

[illegible]



$\Delta p_T = \Delta p_{(1)} + \Delta p_{(2)} + [illegible] + [illegible]$

ORIFICE LOSS LINE LOSS [illegible] [illegible]

$\Delta p_{(1)} = K \frac{\rho}{2g} V_b^2$ where $K = \frac{1}{C_A^2} = \frac{1}{.61^2} = 2.7$ where $C_A = 0.61$ (Marks Pg. 23.1)

$\Delta p_{(2)} = \frac{[illegible]}{[illegible]}$ ([illegible]) [illegible]

$\Delta p_{(3)} = \left(1.5 - \frac{[illegible]}{[illegible]}\right) \frac{[illegible]}{[illegible]} V_b^2$

$\Delta p_{(4)} = \frac{[illegible]}{[illegible]}$

$V_b = \frac{[illegible]}{[illegible]} = [illegible]$ [illegible] $= 1.612 \times 10^3$ $f_b = .04$

$\Delta p_{(2)} = [illegible] = 1.6$ psi

$\Delta p_{(3)} = \left(1.5 - \frac{[illegible]}{[illegible]}\right) \frac{[illegible]}{[illegible]} \times [illegible] = 1.3[illegible] \times \frac{[illegible]}{[illegible]} \times [illegible] = 1.1$ psi

$\Delta p_{(4)} = 22.2 + 1.6 + 1.1 = 19.5$ psi

21 1/2 max

NO

we are not measuring Flow

Thompson Ramo Wooldridge Inc.

SUBJECT: [illegible] REPORT NO. [illegible]

$\therefore \Delta_{P_{(B)}} = 2.7 \frac{\rho}{2g} V_B^2$ $\quad V_B = \frac{\Delta_B}{\Delta_B} = \frac{[illegible]}{[illegible]}$

$\Delta_{P_{(B)}} = \frac{2.7 \times [illegible]}{64.4} \left(\frac{[illegible]}{[illegible]} \right)^2 = .01990 \times \frac{[illegible]}{[illegible]} = 19.5$

$\Delta_B^4 = \frac{.0199 \times [illegible]}{19.5} = .2735 \times 10^{-4}$ $\quad \Delta_B = .723 \times 10^{-1} = .0723$ in

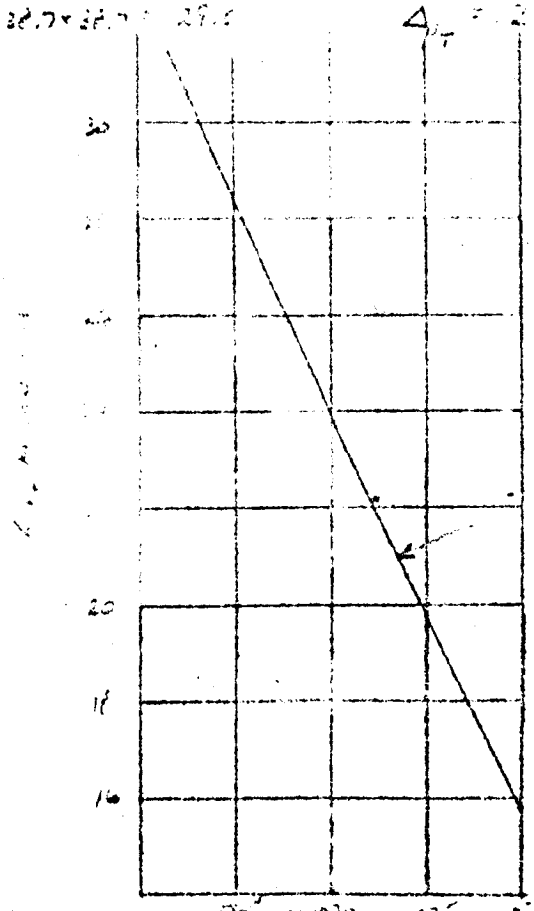
Let $\Delta_B = .080$ in $\quad V_B = \frac{[illegible]}{2.445 \times .0064} = 25.6$ ft/sec

$\Delta_{P_{(B)}} = .0199 \times 25.6 \times 25.6 = 13.05$ psi

$\Delta_{P_T} = 13.1 + 2.7 = 15.8$ psi

Let $\Delta_B = .065$ $\quad V_B = \frac{[illegible]}{2.445 \times .004255} = 38.7$ ft/sec

$\Delta_{P_{(B)}} = .0199 \times 38.7 \times 38.7 = 29.8$ $\quad \Delta_{P_T} = 29.8 + 2.7 = 32.5$ psi



size should be

$222(2.1) = 1.5 \frac{V^2}{2g}$

$V^2 = 2000$

$V = 44.6$ 1/sec

$A = \frac{.321(.40)}{0.44.6}$

$A = 0.0288$

$D = .0605''$ max

[illegible] 9/30/63

Z-710 REV. PRINTED IN U.S.A.

RESTRICTING ORIFICE DIA. V 15

(CLASSIFICATION)

PREPARED [illegible] 9/27/63

CHECKED [illegible]

INITIALS - DATE

PAGE 7 — AS A RESULT OF DESIGN REVIEW MEETING WITH AGC, ELIMINATE ORIFICE ON COOLANT FLOW AROUND STATOR O.D. THIS WILL PERMIT MORE FLOW AROUND O.D. AS OPPOSED TO THRU AIR GAP AND WILL ELIMINATE ΔP ACROSS ROTOR — THUS INCREASING NET THRUST, AND REQUIRING RESIZING OF "CAP NUT" ORIFICE.

REVISION TO PAGE 9,

PASSAGE DOWN CENTER OF SHAFT MUST RETURN COOLANT FLOW OF 0.4 GPM TO INLET.

ΔP of RETURN PASSAGE MUST = 55 psi (PUMP PRESS. RISE) − 30 psi (VOL. TO MTR. CAVITY ΔP) = 25 PSI

ASSUMING 0 Δp ACROSS MOTOR.

FROM PAGE 9, $\Delta p_T = \Delta p_{(A)} + \Delta p_{(B)} + \Delta p_{(C)} + \Delta p_{(D)}$

$$\Delta p_{(A)} = K \frac{\rho}{2g} V_B^2 \quad \text{WHERE } K = \frac{1}{C_A^2} = \frac{1}{.61^2} = 2.7$$

$$\Delta p_{(B)} \cong 0$$

$$\Delta p_{(C)} = \left(1.5 - \frac{A_L^2}{A_C^2}\right) \frac{\rho}{2g} V_D^2$$

$$\Delta p_{(D)} = \frac{.013 V f_D L_D S G}{D_D^5}$$

$$\Delta p_{(D)} = 1.6 \text{ psi}$$

$$\Delta p_{(C)} = 1.1 \text{ psi}$$

$\Delta p_{(A)}$ MUST EQUAL $25 - 1.6 - 1.1 = 22.3$ psi

FROM PAGE 10 GIVEN, LET ORIFICE DIA. = .070/.075 IN.

Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: 253800 Revised Performance Analysis REPORT NO. PMA-R63-56

Impeller Total Flow = Outlet Flow + Coolant Flow + Leakage Flow

Outlet Flow = Req'd Discharge Flow
Coolant Flow = .45 GPM — assume constant over entire flow range

Leakage Flow — From Pg. 11 of PMA-R63-24 (Imp. Thrust Anal.)

With .008 Clearance Behind Imp. (Max) and 0.06 Eff. Hole Area (& 70 PSI @ 0 Flow, 55 PSI @ Rated) & 5# Thrust Toward Inlet Due to ΔP over shaft exposed to inlet pressure.

@ Zero Flow; Thrust = 33# + 5 = 38#
Leakage = 4.65 GPM
(Imp Total Flow = .45 + 4.65 = 5.10) Hole ΔP = 660 #/ft² = 4.58 #/in²

@ Rated Flow; Thrust = 23# + 5 = 28#
Leakage = 3.6 GPM
Hole ΔP = 400 #/ft² = 2.78 #/in²
(Imp. Total Flow = 17 + .45 + 3.6 = 21.05 GPM)

With .003 Clearance (Min.) Behind Imp & 0.06 Eff. Hole Area

@ Zero Flow; Thrust = 13 + 5 = 18#
Leakage = 0.5 GPM
(I.T.F. = .45 + 0.5 = .95 GPM) Hole ΔP ≈ 0

@ Rated Flow; Thrust ≈ 13 + 5 = 18#
Leakage = 0.3 GPM
(I.T.F. = .45 + 0.3 = 17.8 GPM) Hole ΔP ≈ 0

From Pg. 2 of PMA-R63-2
with Max Clear (.008) Behind Imp.

@ 17 GPM Outlet Flow; I.T.F. = 21.05 GPM; ΔP = 58.6; SHP = 1.34 (@ 7760 RPM)
Total HP Req'd = 1.34 + .34 Fluid Friction + .02 (Low Brg.) + .03 (Thrust) + .01 (Upper Brg.) + .03 (Ensor Gear) = 1.77

Rad. Brg. HP taken as max from Truline calcs.
Thrust Brg. from Barish calc.

V 17

(CLASSIFICATION)

PREPARED [illegible] 10/11/63
CHECKED
INITIALS - DATE

Thompson Ramo Wooldridge Inc.

SUBJECT: [illegible] REPORT NO. PMA-R63-56

@ 2+ Shutoff; I.T.F. = 5.10 GPM; ΔP = 68 PSI; SHP = 0.93 (@ 7760 RPM)
Total HP = 0.93 + .34 + .02 + .02 + .01 + .02 = 1.36 HP

@ 6.5 GPM Outlet; I.T.F. ≅ 13.5 GPM; ΔP ≅ 65.5 PSI; SHP ≅ 1.13
Total HP ≅ 1.13 + .34 + .02 + .03 + .01 + .03 ≅ 1.56 HP

From Above Data, Pump Constant Speed Curve Can Be Drawn and Perf. Estimated By Matching Est. Motor Perf. — See Page 3

With 1.5 (.003) Clearance Behind Imp.

@ 0 Flow; I.T.F. = 0.95 GPM; ΔP = 68 PSI; SHP = 0.81
Total HP = 0.81 + .34 + .09 = 1.24

@ 8.5 GPM; I.T.F. ≅ 9.3 GPM; ΔP ≅ 67 PSI; SHP ≅ 1.03
Total HP ≅ 1.03 + .34 + .09 ≅ 1.46

@ 17 GPM; I.T.F. = 17.6 GPM; ΔP = 62 PSI; SHP = 1.25
Total HP = 1.25 + .34 + .09 = 1.68

Again Constant Speed Curves Can Be Drawn & Est Perf. Obtained. See Page [illegible]

Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: 253800 Revised Performance Analysis REPORT NO. PMA-R63-56

Impeller "Bleed Back" Hole Resizing

Effective Hole Area = 0.06 in²

With Discharge Coefficient = .82, Actual Area = $\frac{.060}{.82}$ = .0733 in²

With 7 Holes, Area per Hole = $\frac{.0733}{7}$ = .0105 in²

$A = \frac{\pi D^2}{4}$ $D^2 = \frac{.0105 \times 4}{3.14}$ = .0134 in² D = .116 in

If Discharge Coefficient were 0.61 instead of 0.82 (clear discharge instead of "Broomy")

Actual Area = $\frac{.06}{.61}$ = .0984 in²

For 7 Holes, Area per Hole = $\frac{.0984}{7}$ = .0140 in²

$D^2 = \frac{.0140 \times 4}{3.14}$ = .0178 in² D = .133 in.

Let Hole Dia = .133/.123

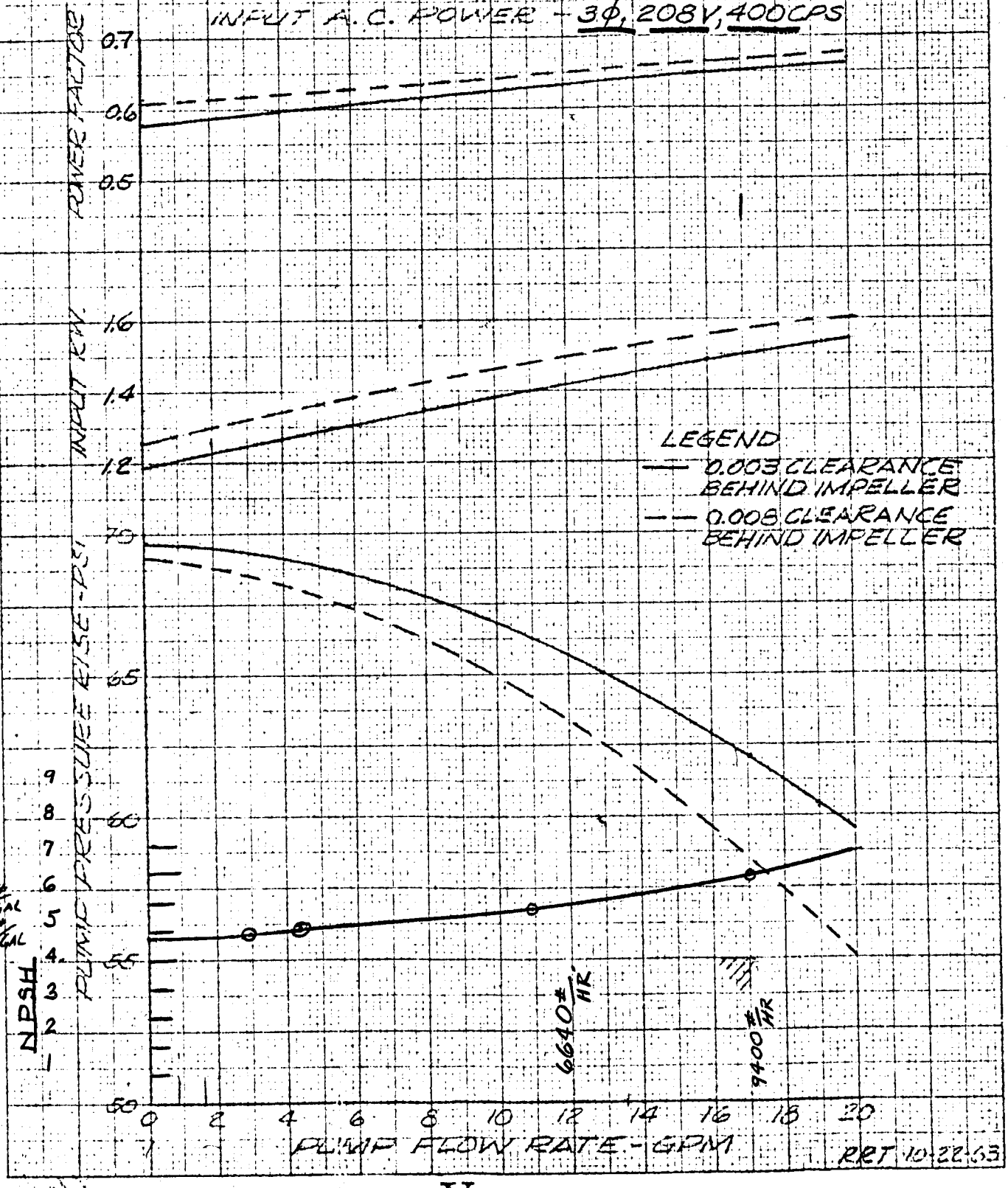
Under these conditions, if return flow is "broomy", effective area becomes .0984 × .82 = 0.08 in². This would result a decrease in thrust of approx. 5# and an increase in leakage flow of approx. 0.2 GPM under the most adverse conditions.

FIG. 4

TAPCO DIVISION CLEVELAND OHIO
THOMPSON RAMO WOOLDRIDGE INC
LUBRICATION & COOLING PUMP
MODEL 253800-1
ESTIMATED PERFORMANCE

PROOF PRESSURE
113 ± 2 PSIG

FLUID - DOW CHEMICAL ETA - 378 @ 250°F
(154 - 110 @ 250°F)
FLUID INLET PRESSURE - 5 PSIA
INPUT A.C. POWER - 3φ, 208V, 400CPS



@ 100°: 9.76 #/GAL
@ 250°: 9.18 #/GAL
2.1 FT/PSI

RRT 10-22-63

Fig. 5

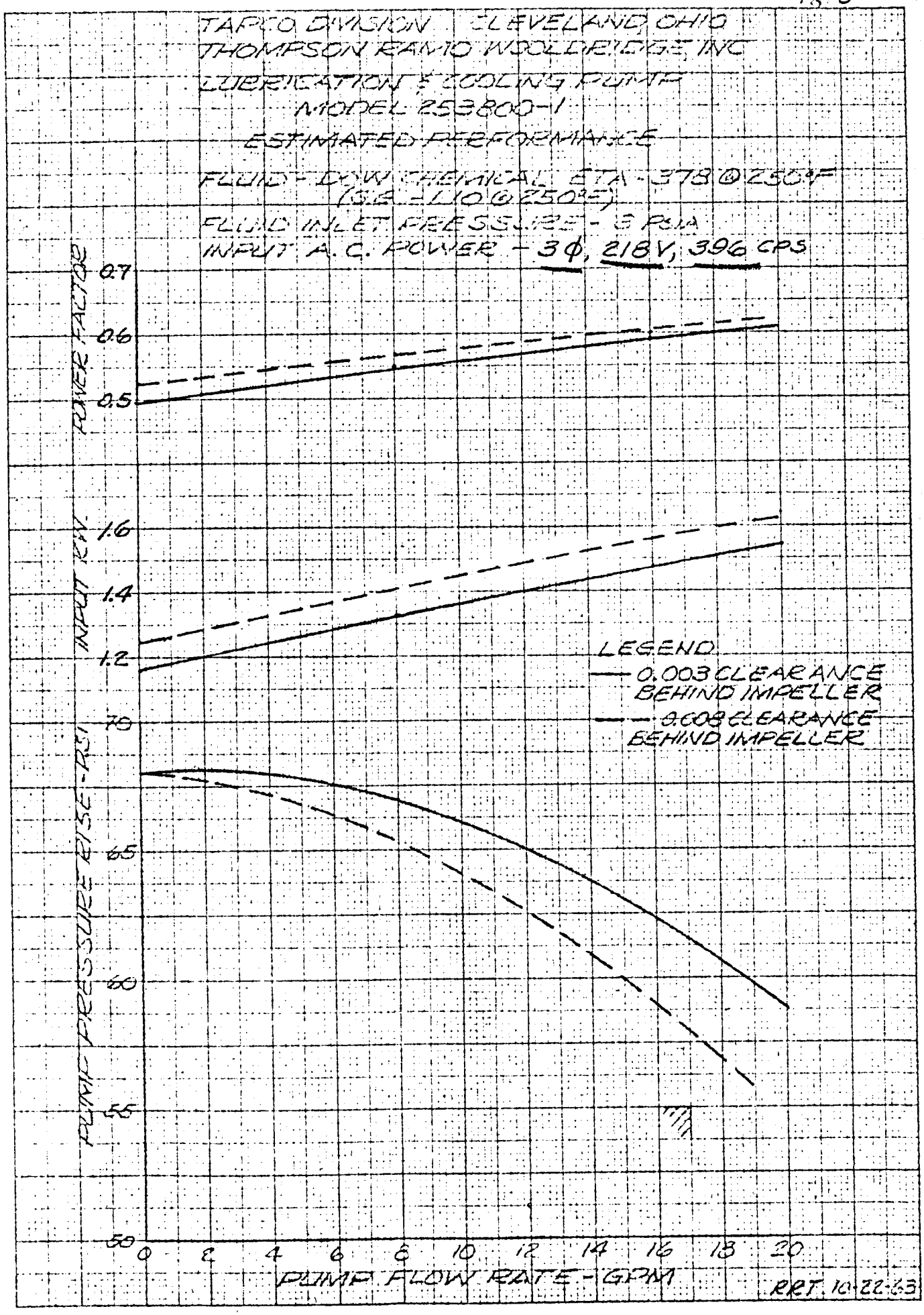
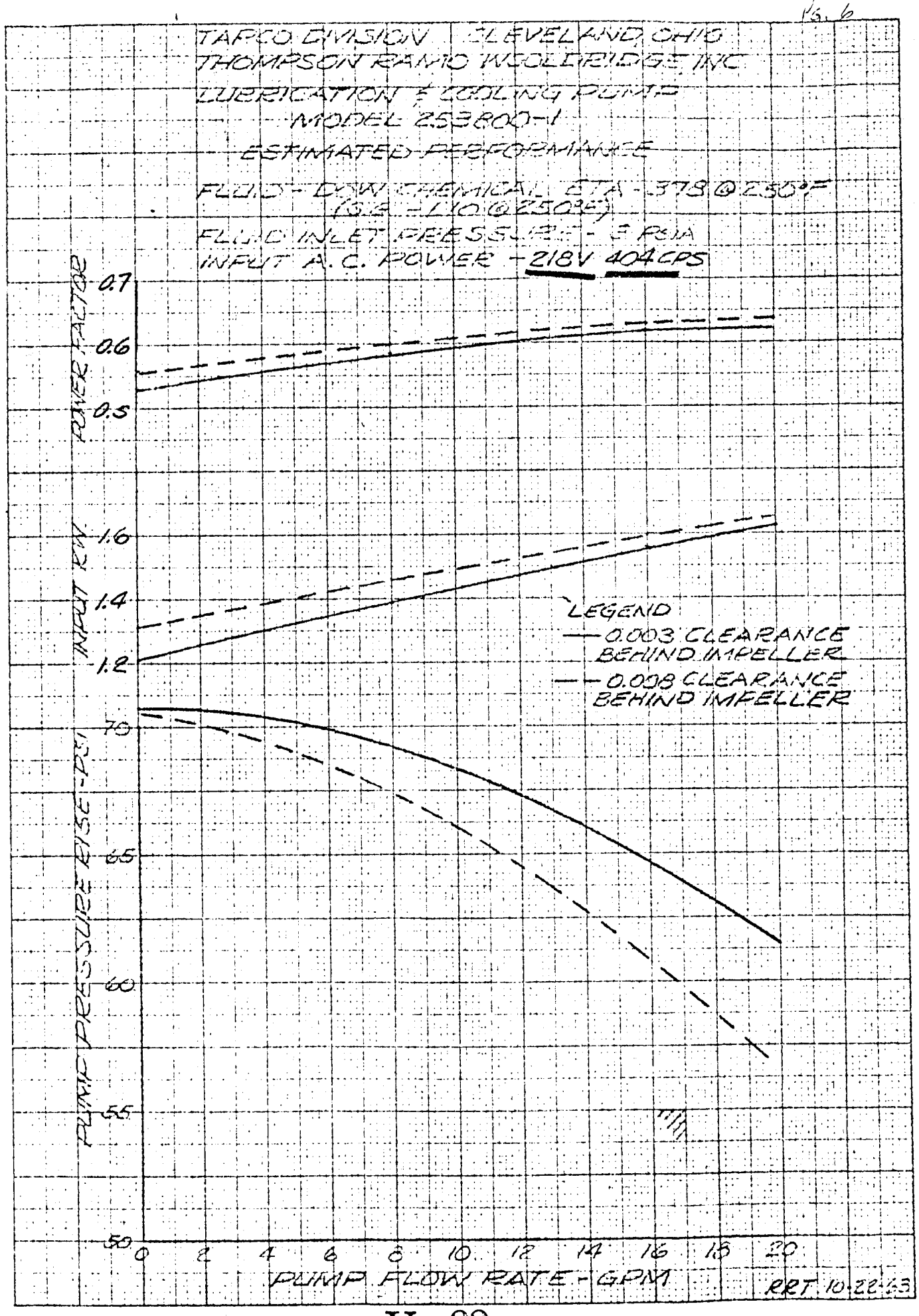
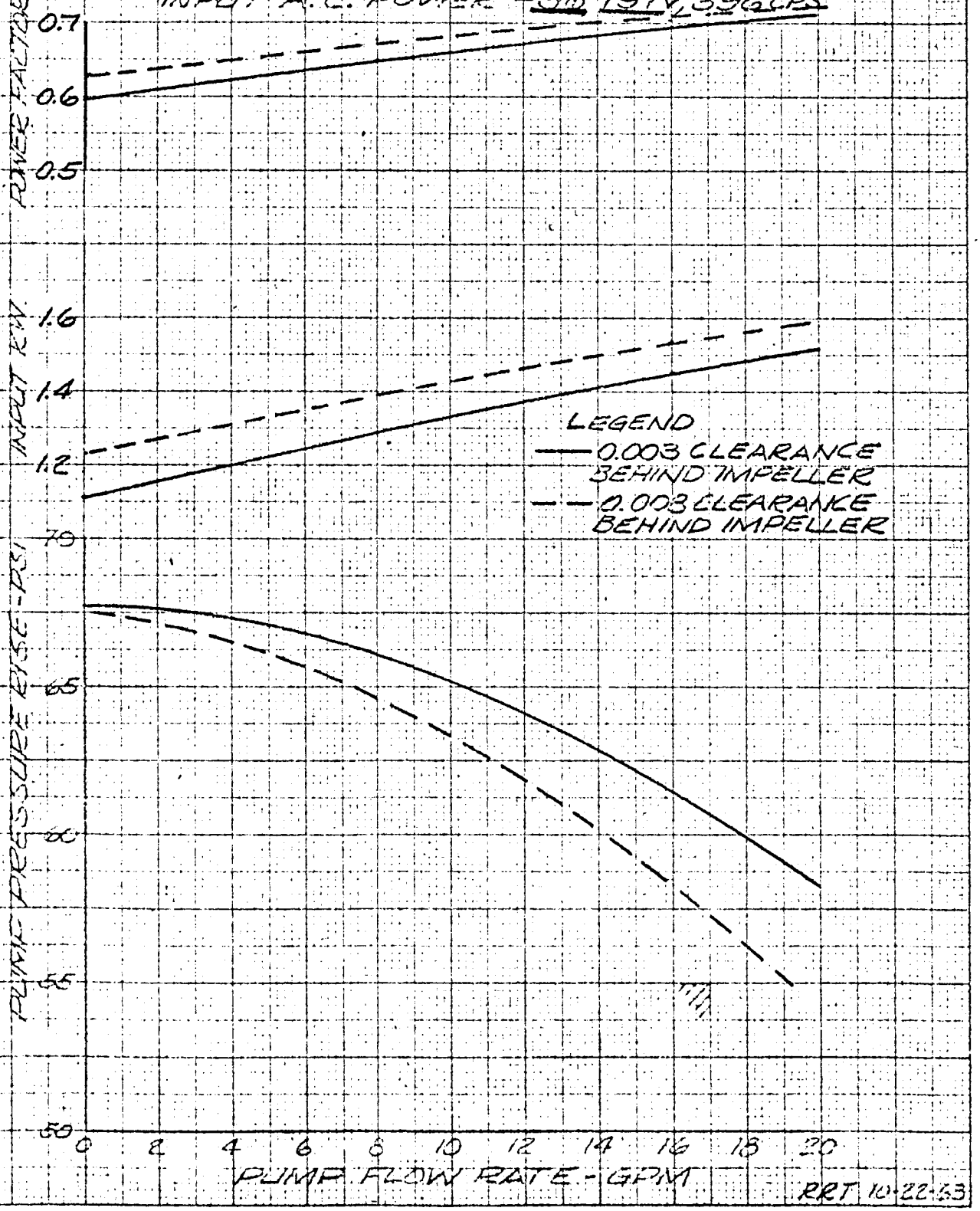

TAPCO DIVISION CLEVELAND, OHIO
THOMPSON RAMO WOOLDRIDGE INC
LUBRICATION & COOLING PUMP
MODEL 253800-1
ESTIMATED PERFORMANCE
FLUID - DOW THERMAL ETA - .378 @ 250°F
(S.G. = 1.10 @ 250°F)
FLUID INLET PRESSURE - 3 PSIA
INPUT A.C. POWER - 3 φ, 218 V, 396 CPS
POWER FACTOR
0.7
0.6
0.5
INPUT KW
1.6
1.4
1.2
PUMP PRESSURE RISE - PSI
70
65
60
55
50
0
2
4
6
8
10
12
14
16
18
20
PUMP FLOW RATE - GPM
LEGEND
0.003 CLEARANCE BEHIND IMPELLER
0.008 CLEARANCE BEHIND IMPELLER
RRT 10-22-63

Fig. 6


TAPCO DIVISION CLEVELAND OHIO
THOMPSON RAMO WOOLDRIDGE INC
LUBRICATION & COOLING PUMP
MODEL 253800-1
ESTIMATED PERFORMANCE
FLUID - DOW CHEMICAL ETA - .378 @ 250°F
(S.G. = .710 @ 250°F)
FLUID INLET PRESSURE - 5 PSIA
INPUT A.C. POWER - 218V 404CPS
POWER FACTOR
0.7
0.6
0.5
INPUT KW
1.6
1.4
1.2
PUMP PRESSURE RISE - PSI
70
65
60
55
50
0
2
4
6
8
10
12
14
16
18
20
PUMP FLOW RATE - GPM
LEGEND
0.003 CLEARANCE BEHIND IMPELLER
0.008 CLEARANCE BEHIND IMPELLER
RRT 10-22-63

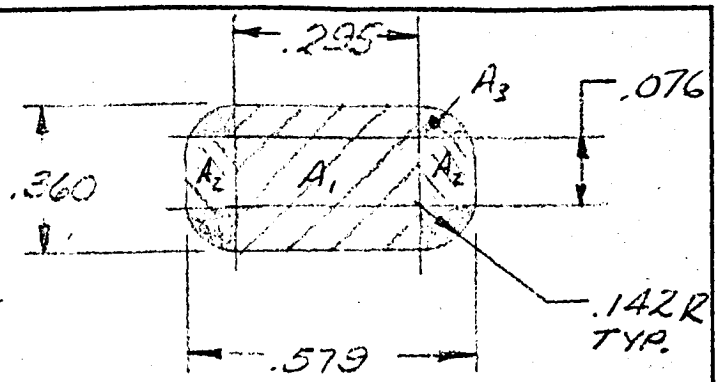
TAPCO DIVISION CLEVELAND OHIO
THOMPSON RAMO WOOLDRIDGE INC
LUBRICATION & COOLING PUMP
MODEL 2538001-1
ESTIMATED PERFORMANCE

FLUID - DOW CHEMICAL STA-378 @ 250°F
(S.G. = 1.10 @ 250°F)
FLUID INLET PRESSURE - 3 PSIA
INPUT A.C. POWER - 3φ 197V, 396 CPS



RRT 10-22-63

.360	.579
.284	.284
.076	.295

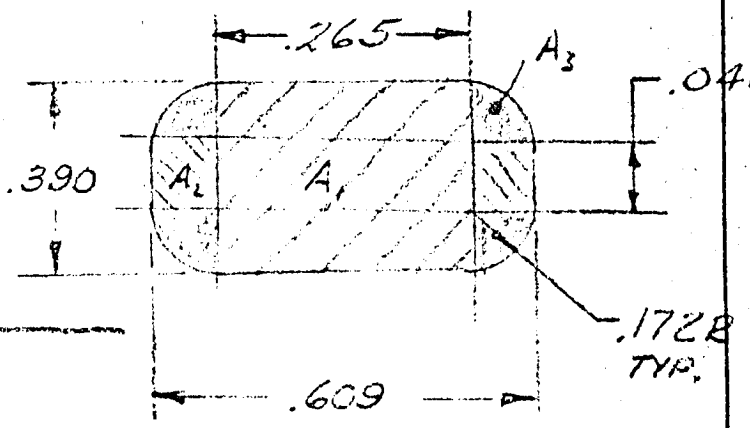


$A_1 = (.295)(.360) = .106 \text{ in}^2$

$A_2 = (2)(.076)(.142) = .022$

$A_3 = \pi(.142)^2 = .063$

$A_{T_{MIN}} = .191 \text{ in}^2$



.390	.609
.344	.344
.046	.265

SECTION D-D AT SHEAR WATER (253899 LAYOUT)

$A_1 = (.265)(.390) = .103 \text{ in}^2$

$A_2 = (2)(.046)(.172) = .016 \text{ in}^2$

$A_3 = \pi(.172)^2 = .073 \text{ in}^2$

$A_{T_{MAX}} = .212 \text{ in}^2$

% AREA VARIATION AT SHEAR WATER $= \frac{.212 - .191}{.191}$

$= \frac{.021}{.191} = 11.0\%$

THE VOLUTE SIZING REQUIRED A MINIMUM AREA OF 0.186 in^2 BASED ON A VOLUTE DESIGN FLOW OF 22 GPM VS THE IMPELLER DESIGN FLOW OF 17 GPM. THIS MARGIN HAS BEEN ADDED TO ACCOUNT FOR MANUFACTURING DEVIATIONS AND TO ASSURE THE PUMP DESIGNER THAT THE IMPELLER FLOW WILL NOT BE RESTRICTED IN THE VOLUTE.

NOW THAT THE VOLUTE DESIGN HAS BEEN JUSTIFIED, WE WILL EXAMINE THE EFFECT OF TOLERANCE ON THE RADIAL LOAD ON THE BEARINGS DUE TO REACTION IN THE VOLUTE.

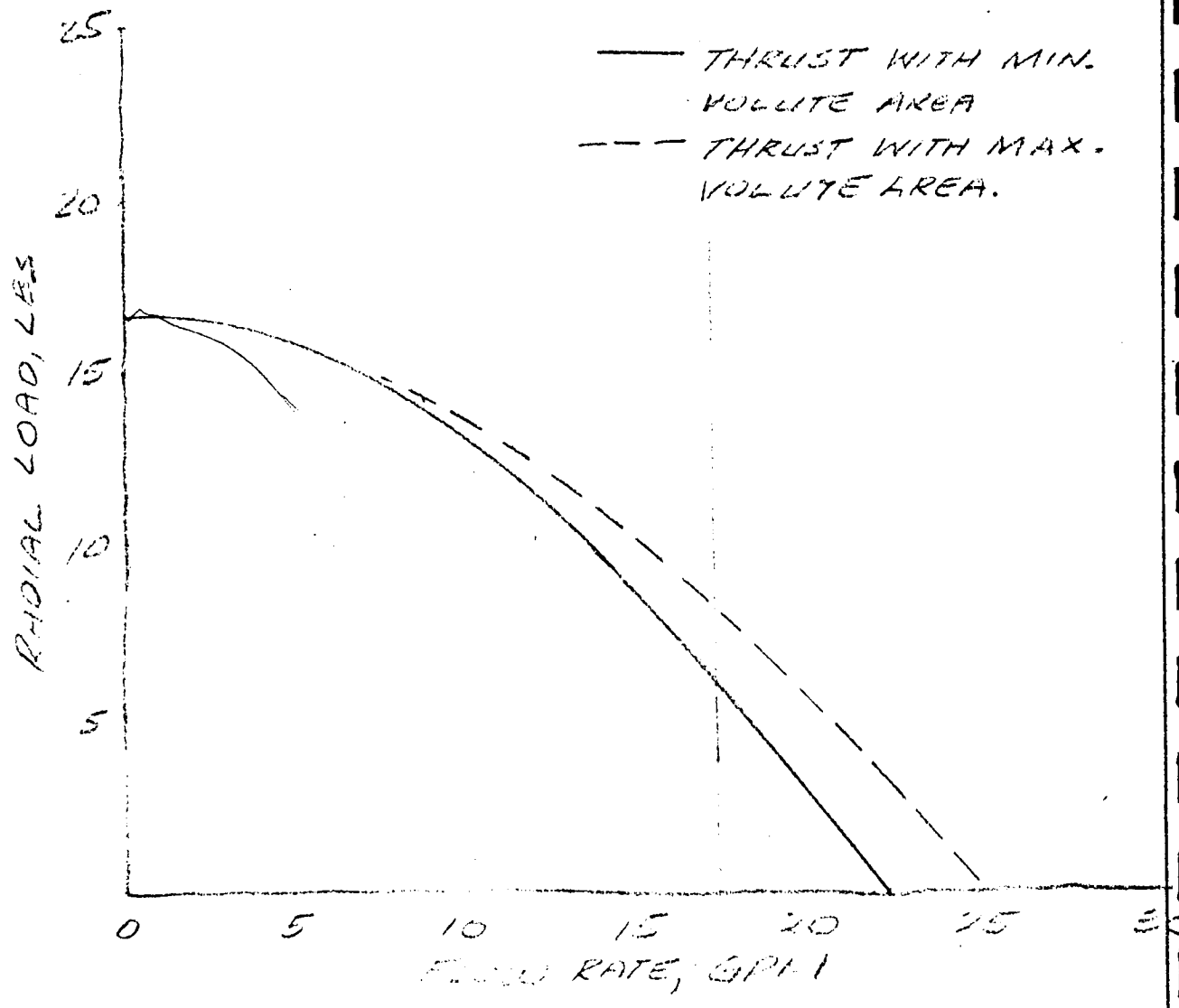
REFERRING TO PMA-R63-19, PG ii WE HAVE:

$$F = K_p d W$$

WHERE $K = 0.36\left[1 - \left(\frac{Q}{Q_N}\right)^2\right]$

THE 10% VARIATION IN AREA OVER THE MINIMUM REQUIRED VOLUTE AREA OF 0.191 in^2 WILL INCREASE THE VOLUTE DESIGN FLOW PROPORTIONALLY, SINCE $Q = VA$.

THE VOLUTE RADIAL FORCE WILL VARY AS SHOWN BY THE FOLLOWING PLOT AND IS NOT CONSIDERED TO BE SIGNIFICANT.



REFERRING TO A.J. STEPANOFF, CENTRIFUGAL & AXIAL FLOW PUMPS, 2ND EDITION, JOHN WILEY & SONS INC, NEW YORK, PG. 117, FIG. 7.7(a)

BY EXAMINATION OF FIG. 7.7(a) IT CAN BE SEEN THAT BY OVERDESIGNING THE VOLUTE WE NEVER REACH THE POINT WHERE THE RADIAL FORCE WILL REVERSE DIRECTION. ALSO, IT CAN BE SEEN THAT THE DIRECTION

Thompson Ramo Wooldridge Inc.

SUBJECT: VOLUTE AREA VARIATION

REPORT NO. PMA-R61-57

OF THE FORCE VECTOR, K WILL NOT BE SHIFTED SIGNIFICANTLY BY A CHANGE OF 1.22 IN THE FACTOR K.

POWER BALANCE AT RATED CONDITIONS -

FLUID - POLYPHENYL ETHER @ 250°F
DOW CHEMICAL ET-378
INLET PRESSURE - 3 PSIA
INPUT POWER - 3φ AC, 200V, 400 CPS

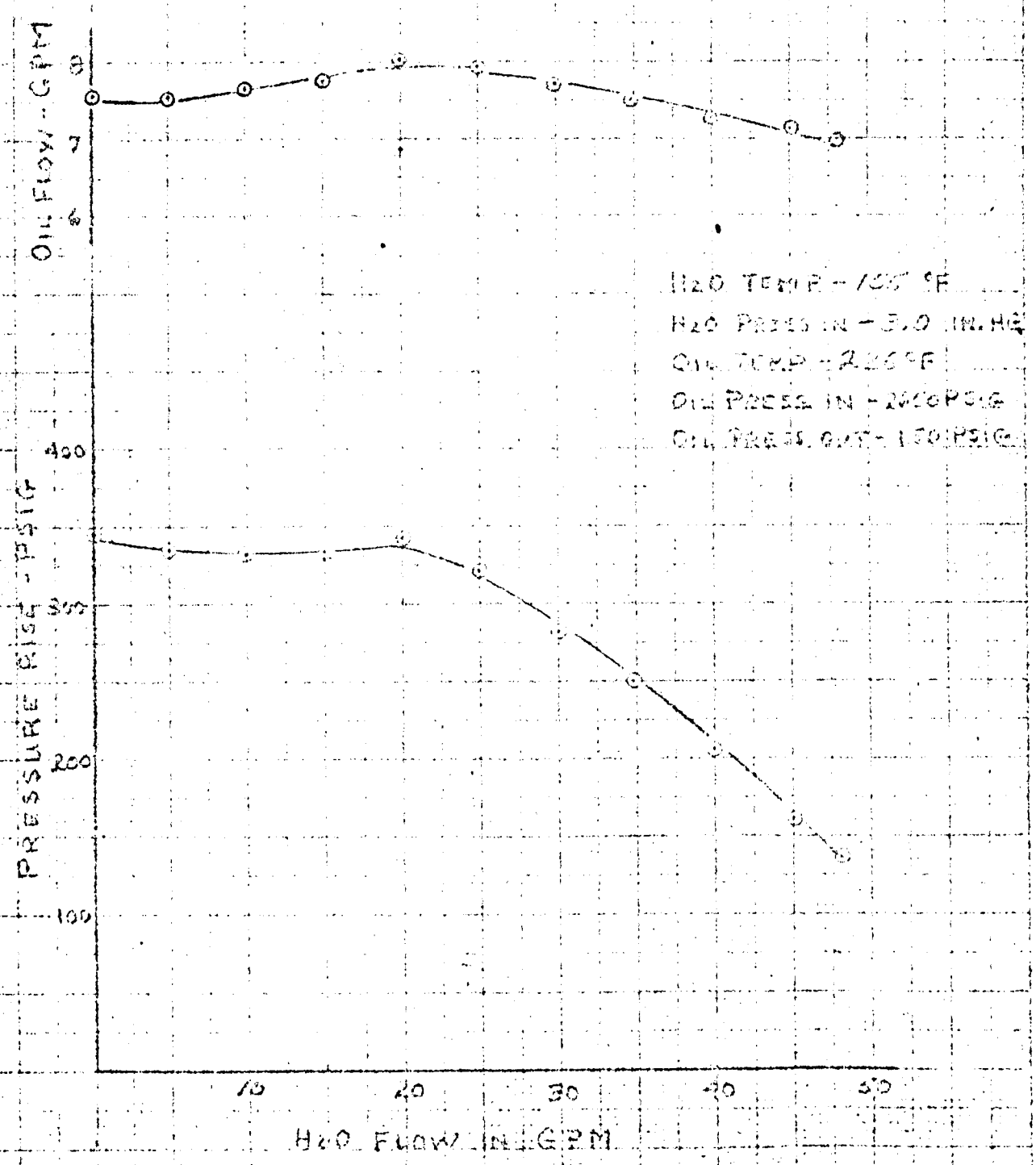
	SUB-TOTAL	TOTAL	CUM TOTAL
1. HYDRAULIC HP.	0.58	0.58	0.58
LEAKAGE LOSSES	0.14	0.14	
2. IMPELLER HYD. HP.			0.72
IMPELLER INEFFICIENCY LOSSES		0.62	
2. PUMPING ELEMENT HP.			1.34
FLUID FRICTION -	0.34		
SLEEVE BRG. LOSS -	0.03		
THRUST BRG. LOSS -	0.05		
SENSOR GEAR FRICTION -	0.02		
	0.43	0.43	
3. SHAFT HP.			1.77
STATOR I²R LOSS -	0.11		
STATOR IRON LOSS -	0.07		
STATOR STRAY LOAD LOSS	0.03		
		0.21	
			1.98
ROTOR I²R LOSS -	0.11		
ROTOR CORE LOSS -	0.007		
ROTOR STRAY LOAD LOSS -	0.030		
		.147	
4. MOTOR HP.		2.127	2.127

MODEL 209100 WATER INJECTION PUMP - PUMPING ELEMENT

Predecessor of Model 253800 Lube & Coolant Pump

Pages 2 and 3 represent qualification test calibration data from the Model 209100 Water Injection Pump. Since qualification testing did not require variations in inlet pressure, a production model pump was tested to determine affect of inlet pressure on performance, however test stand limitations did not permit inlet pressures below -14" Hg. This performance is shown on page 4 and indicates no change in performance with inlet pressure variations from -3 to -14" Hg.

THOMPSON RAMO WOOLDRIDGE
CLEVELAND OHIO
CTA LIMITS CALIBRATION
MODEL 209100 HYD. DRIVEN H_2O PUMP
QUAL PUMP #1 HYD. MTR. #2
CALIBRATION PRIOR TO OVERSPEED
REPUBLIC SPEC REP-75 AMMENDMENT VII
PARA 5.4.8



Thompson Ramo Wooldridge Inc.

WATER FLOW G.P.	WATER [illegible]	WATER [illegible]	[illegible]	[illegible]	[illegible]	WATER [illegible]	[illegible]		
34.1	-3.0 [illegible]	250	7.50	[illegible]	150	155	225		
40.0	-5.0 [illegible]	2[illegible]	7.[illegible]	[illegible]	150	155	[illegible]		
45.0	-7.1 [illegible]	1[illegible]	7.14	[illegible]	150	155	225		
48.2	-[illegible]	136	7.[illegible]	2650	150	155	229		
30.0	-7.[illegible]	[illegible]	7.7[illegible]	2650	150	155	229		
25.0	[illegible]	3[illegible]1	7.[illegible]	[illegible]	150	155	229		
[illegible]	[illegible]	343	[illegible]	2650	155	155	[illegible]		
15.0	2.5 [illegible]	3[illegible]4	7.[illegible]	2650	150	15[illegible]	[illegible]		
10.0	3.[illegible]	333	7.[illegible]	[illegible]	150	15[illegible]	224		
5.0	4.[illegible]	335	7.[illegible]	[illegible]	150	155	225		
[illegible]	[illegible]	34[illegible]	7.[illegible]		[illegible]	[illegible]			

TITLE [illegible] PRIOR TO OVERSPEED

[illegible]

ENGR

FR. D.S.

DATE [illegible]

TEST NO.

PROJECT [illegible]

FLUID 1170

RESULTS OF TESTS ON MODEL 209100 IN PRODUCTION ACCEPTANCE TEST STAND:

1. INLET SUCTION - 3" HG. BELOW ATMOSPHERIC

FLOW PPH	RPM @ 160°F	MOTOR ΔP, PSI	DISCHG. PRESS. PSI	OIL FLOW	H_2O TEMP, °F
0	0	2450	250	7.50	154
15,000	30.7	2450	243	6.80	154
17,000	34.8	2450	246	7.06	154

2. INLET SUCTION - 6" HG

0	-	260	7.58	
30.7	2375	240	6.80	
34.8	2500	248	7.12	154.

3. INLET SUCTION - 12" HG

0	-	270	7.65	154
30.7	2400	236	6.80	154
34.8	2500	250	7.20	154

4. INLET SUCTION - 14" HG

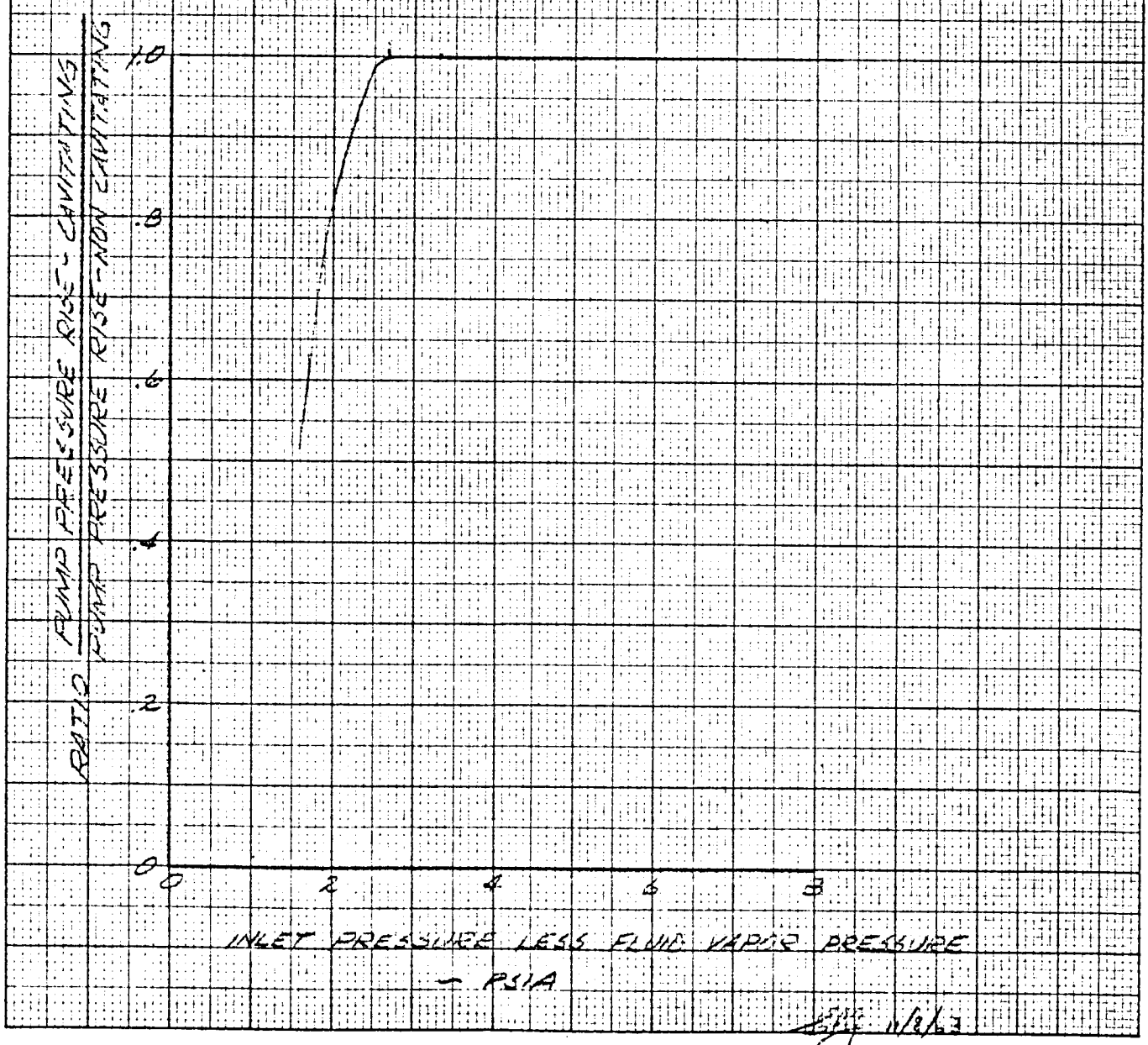
0				
30.7				
34.8	2650	240	7.3	160°F

5. INLET SUCTION - 16" HG

UNABLE TO OBTAIN READINGS - INLET CAVITATING

TRW ELECTROMECHANICAL DIVISION
CLEVELAND, OHIO

MODEL 253800-1 LUBE & COOLANT PUMP
ESTIMATED SUCTION PERFORMANCE
PUMP OUTLET FLOW – 17 GPM ET 378 @ 250°F
PUMP PRESSURE RISE (NON CAVITATING) – 57 PSI



11/8/63

TRW ELECTROMECHANICAL DIVISION

Thompson Ramo Wooldridge Inc.

23555 EUCLID AVENUE · CLEVELAND 17, OHIO

TAPCO NO. 03-10137

Date 11/27/63

Contract No.

Customer No.

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No. of Pages

STATUS

DATE REL. 11/29/63

COMM. No.

CONNECTOR, ELECTRIC, HERMETICALLY SEALED

PREPARED BY

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Development Engineer	Senior Development Engineer
Title	**Title**

APPROVED BY

W. V. Edwards,	T. F. LeQuyea,	L. J. Weiss,
Project Engineer	Quality Assurance	Senior Project Engineer
Title	Title	**Title**

REVISIONS

Date	Rev.	Paragraph	Remarks and E.O.	Authorization

CONNECTOR, ELECTRIC, HERMETICALLY SEALED

1.0 SCOPE

This specification establishes the requirements for a hermetically sealed, jam nut type, electric receptacle connection suitable for use in a space and nuclear radiation environment when the connector is a part of the TRW Model 253800 Lubrication and Cooling Pump.

2.0 APPLICABLE DOCUMENTS

The following documents are applicable to the extent specified herein:

Military Specifications

MIL-E-5272C	Environmental Testing, Aeronautical & Associated Equipment, General Specification for
MIL-D-70327	Drawings, Engineering & Associated Lists
MIL-C-5015	Connectors, Electric "AN" Type
MIL-Q-9858	Quality Control System Requirements

Military Standards

MIL-STD-202A	Test Methods for Electronic & Electrical Component Parts
MIL-STD-271B	Nondestructive Testing Requirements for Metals

Jet Propulsion Laboratory (JPL)

30236A	Design Specification, Spacecraft, Flight & Ground Support Equipment, R. F. Interference Control & Test Requirements.

Drawing

TRW Source Control Drawing 208220 entitled, "Connector Assembly"

Other

Service Fluid Dow Chemical Company BIS (polyphenyl) Ether ET-378.

3.0 REQUIREMENTS

3.1 Performance - The electric connector shall be capable of meeting all of the performance requirements of this specification when installed as part of a lubrication and cooling pump-motor assembly for a "space" application. The operating fluid of the pump will be Dow Chemical Company BIS (polyphenyl) ET-378.

3.1.1 Reliability - The reliability design objective for the lubricating and cooling pump-motor assembly including the connector is 98.9% for 10,000 hours of continuous rated operation in the orbital environment.

3.1.2 Power Supply - The steady-state power supply is:

Number of phases	3
Terminal voltage	208 ± 5%
Frequency (cps)	400 ± 1%

3.1.3 Current Rating - The maximum continuous current rating for the #16 size contacts of the connector shall be eight (8) amps continuous and 20 amperes in-rush current. The current rating of the remaining contacts shall be consistent with good design practice.

3.1.4 Proof Pressure Test - The connector shall be capable of withstanding, without impairment of function, an hydrostatic proof pressure test of 118 psig for a minimum of five minutes. The test shall be conducted with a compatible fluid. The presence of moisture on any surface opposite the pressure side of the connector shall constitute a leak and will be cause for rejection. It shall be permissible to support the mounting diaphragm during this test up to within 1/8" of the diaphragm-to-shell weld.

3.1.5 Helium Leakage - The maximum allowable helium (He) leak rate for the electric connector shall not be greater than 10^{-9} cc/sec as tested per MIL-STD-271B (Class e).

3.2 Design & Construction

3.2.1 Materials - There shall be no degradation of materials in the electric connector that will affect the lubrication and cooling pump performance in 10,000 hours of unattended operation at rated conditions in all specified environments. All parts in contact with the operating fluid shall be fabricated from the following list of alloys:

Alloy steels	Aluminum
Stainless steels	Silver
Carbon steels	No copper alloys or halogenated hydrocarbon compounds are allowed.
Nickel base alloys	Pure copper will be allowed as a brazing material.

3.2.2 Finishes - All materials used in the connector which are not inherently resistant to the operating and environmental conditions specified herein shall be treated to resist such effects. The finishes used shall assure proper functioning of the connector.

3.2.3 Joining Methods - "Rolling", "spinning", "staking", or "crimping" shall not be used as the primary means of joining unless sufficient proof of reliability is given and buyer approval obtained.

3.2.4 Snap Rings - Snap rings or similar retainers shall not be used without approval of the buyer.

3.2.5 Stress Concentration - Abrupt changes in cross-sections shall not be used in the design. Generous radii, good surface finishes, and other techniques to avoid stress concentration shall be employed.

3.3 Environmental - The electric connector, when a part of the lubrication and cooling pump-motor assembly, will be exposed to four basically different environments plus ground tests in its life cycle. These phases are storage and transportation; handling and vehicle integration; launch; and orbital operation. The pump will be operating only during the ground test and orbital operation phases.

3.3.1 Storage & Transportation - The connector, when assembled to the pump-motor assembly, shall be capable of withstanding without deterioration or performance decay, the environments described in this section.

3.3.1.1 Normal Storage - The connector, when assembled to the pump-motor assembly, shall be capable of storage in a temperature and humidity controlled environment for a period of two (2) years without deterioration.

3.3.1.2 Temperature - During storage and transportation, the connector as part of the pump-motor assembly will be protected from the thermal environment. However, the thermal conditions will vary within the container and the pump-motor assembly with the connector shall withstand temperatures from -40°F minimum to +160°F.

3.3.1.3 Pressure - During the storage and transportation phase, the connector assembled to the pump-motor assembly will be subjected to pressures from sea level to a maximum altitude of 50,000 feet. The maximum change in pressure to which the connector assembled to the pump-motor assembly will be subjected is a reduction or increase in pressure of 1.25 psi per minute. This will occur in either a climb to 50,000 feet or a descent from 50,000 feet.

3.3.1.4 Shock - The connector while assembled to the pump-motor assembly shall be capable of withstanding transportation shocks applied to the pump-motor assembly mounting in each of three mutually perpendicular axes of 4 g's magnitude for one of the following time periods:

a)	Triangular pulse	10 milliseconds
b)	Half-sine pulse	8 milliseconds
c)	Rectangular pulse	5 milliseconds

3.3.1.5 Vibration - The connector assembled to the pump-motor assembly shall be capable of withstanding sinusoidal transportation vibrations applied to the pump-motor assembly mounting in three mutually perpendicular axes according to the following schedules:

Frequency Range	Amplitude	Duration
2 - 10 cps	.40 inches DA(double amplitude)	30-min. logarithmic sweep
10 - 500 cps	2.0 g peak	30-min. logarithmic sweep

NOTE: For the purpose of connector design and analysis, it should be assumed that the connector is subject to an amplification factor of 10.

Five minutes of vibration shall be applied at the same amplitude at each major resonant frequency.

3.3.1.6 Fungus - Materials which are nutrients to fungi shall not be used unless adequately protected to prevent impairment of function of the connector.

3.3.2 Handling & Vehicle Integration - During handling and vehicle integration, it can be anticipated that the connector, as assembled to the pump-motor assembly, will be exposed to atmospheric and weather environments for a maximum period of six (6) weeks. The connector as part of the pump-motor assembly shall be capable of withstanding without deterioration or performance decay, the environments described in this section.

3.3.2.1 Humidity - The connector as part of the pump-motor assembly shall be capable of withstanding a simulated twenty-four (24) hour cycle of water vapor in the atmosphere with a 5 m/sec steady-state wind as follows:

a) Six (6) hours of 106°F air temperature at 65% relative humidity (absolute humidity 15.3 gms/ft^3).

b) Six (6) hours of decreasing air temperature to 91°F and increasing relative humidity to 100%.

c) Eight (8) hours of decreasing air temperature to 81°F with a release of 4.4 gms of water minimum per ft^3 of air.

d) Four (4) hours of increasing air temperature to 106°F and decreasing relative humidity to 50%.

3.3.2.2 Sand & Dust - The connector as assembled to the pump-motor assembly shall be capable of withstanding a sand and dust density of 0.1 to 0.25 gms/ft^3 at a temperature of 77°F in an air stream of 2500 ft/min for three (3) hours with the relative humidity at less than 30%. "Sand and Dust" is defined as 140 mesh silica flour with characteristics as specified in MIL-E-5272C.

3.3.2.3 Fungus - Materials which are nutrients to fungi shall not be used unless adequately protected to prevent impairment of function of the connector.

3.3.2.4 Salt Spray - The pump-motor assembly shall be capable of withstanding a 50 hour 20% salt solution spray test per MIL-E-5272C.

3.3.2.5 Temperature - The connector when assembled to the pump-motor assembly shall be capable of withstanding temperature variations within -55°F to +160°F for two weeks.

3.3.3 Launch, Lift-Off to Final Termination of Thrust - The nonoperating pump-motor assembly (with the connector assembled shall be capable of withstanding without performance degradation to launch environments specified in this section.

3.3.3.1 Shock - The pump-motor assembly (with the connector assembled) shall be capable of withstanding transportation shocks applied to the pump-motor assembly mounting in each of three mutually perpendicular axes of 35 g's magnitude for one of the following time periods:

a)	Triangular pulse	10 milliseconds
b)	Half-sine pulse	8 milliseconds
c)	Rectangular pulse	5 milliseconds

3.3.3.2 Vibration - The pump-motor assembly (with the connector assembled) shall be capable of withstanding launch vibrations applied to the pump-motor assembly mounting in three mutually perpendicular axes according to the following schedule of sinusoidal inputs:

Frequency Range	Amplitude	Duration
16 - 42 cps	2 g peak	30-minute logarithmic sweep
42 - 95 cps	.022 inch DA (double amplitude)	30-minute logarithmic sweep
95 - 2000 cps	10 g peak	30-minute logarithmic sweep

In addition, the pump-motor assembly (connector assembled) shall be capable of withstanding sinusoidal resonance vibration in three mutually perpendicular axes for five (5) minutes according to the following schedules:

Frequency Range	Amplitude
16 - 42 cps	1 g peak
42 - 95 cps	.011 inch DA (double amplitude)
95 - 2000 cps	5 g peak

NOTE: For the purpose of connector design and analysis, it should be assumed that the connector is subject to an amplification factor of 10.

3.3.3.3 Acceleration - The pump-motor assembly (connector assembled) shall withstand the launch and lift-off accelerations according to the following schedules:

7 g's for five (5) minutes in a direction perpendicular to the shaft axes.
3 g's for five (5) minutes in a direction parallel to the shaft axes.
4.5 g's for five (5) minutes in both directions along mutually perpendicular axes.

The pump-motor assembly will be normal to the axes of the launch vehicle.

3.3.3.4 Acoustic Noise - The component shall withstand exposure to acoustic noise at 140 decibels integrated sound pressure level.

3.3.4 Orbital Operation - The pump-motor assembly (connector assembled) shall be capable of start-up and operation in any orientation relative to the direction of the sun, planets, or moon, either in or out of the shadow of any planet or moon. It shall be capable of start-up and operation in temperature, vacuum, and zero gravity environments of space. The connector as assembled to the pump-motor assembly shall be capable of withstanding the cosmic, solar and Van Allen radiation encountered in a space environment with no deterioration of performance in a period of 10,000 hours.

3.3.4.1 Shock - The connector while assembled to the pump-motor assembly shall be subjected to shocks during operation in a space environment of 7 g's on each of three mutually perpendicular axes with one of the wave forms and time duration as indicated below:

a) Triangular pulse for 10 milliseconds
b) Half-sine wave pulse for 8 milliseconds
c) Rectangular pulse for 5 milliseconds

3.3.4.2 Vibration - The connector assembled to the pump-motor assembly will be subjected to vibrations in space while in operation of 1/4 g peak over a frequency range of 5 - 2000 cps. The input of these vibrations will be at the mounting of the pump-motor assembly.

NOTE: For the purpose of connector design and analysis, it should be assumed that the connector is subject to an amplification factor of 10.

3.3.4.3 Self-Generated Vibration - The connector as part of the pump-motor assembly shall not self-generate vibrations over 1/4 g peak while operating in space over a frequency range of 5 - 2000 cps.

3.3.4.4 Acceleration - After start-up, the connector as part of the pump-motor assembly shall be capable of withstanding a 3-1/2 g acceleration in a direction perpendicular to the shaft axis and plus or minus (±) 1 g on each of the two mutually perpendicular axes. These accelerations will be sustained for periods not to exceed five (5) minutes. In addition, the connector as assembled to the pump-motor assembly shall be capable of operation with a maximum of one (1) g acceleration in a direction perpendicular to the pump-motor shaft in a space environment for periods of 10,000 hours.

3.3.4.5 Micrometeorite Penetration - The connector as assembled to the pump-motor assembly shall be protected from micrometeorite penetration encountered in space.

3.3.4.6 Radio Frequency Interference - The connector as assembled to the pump-motor assembly shall pass the tests described in JPL Specification 30236A to assure that there will be no radio frequency interference with other assemblies in the SNAP-8 system.

3.3.4.7 Radiation - The connector as assembled to the pump-motor assembly shall be capable of withstanding without performance degradation, for 10,000 hours, the following cumulative radiation doses:

2×10^{13} NVT (neutron velocity time integrated) fast neutrons

5×10^{7} rads gamma

3.4 Service Life - The electric connector, when a part of the lubricating and coolant pump-motor assembly, shall be capable of continuous operation up to 10,000 hours of unattended operation at the specified loads and temperature in all specified environments. The connector shall be capable of a minimum of 50 start-and-stop cycles during its service life.

3.5 Interchangeability - All parts having the same manufacturer's part number shall be directly and completely interchangeable with respect to installation and performance, and adequately serialized to provide for the use of matched or fitted subassemblies. Changes in part numbers shall be governed by the requirements of specification MIL-D-70327.

3.6 Workmanship - All machined surfaces shall have a smooth finish, and all details of manufacture, including the preparation of parts shall be in accordance with the best practices of high-quality electrical equipment. Particular attention shall be given to neatness and thoroughness of welding, marking of parts, plating, clearance between electrical connections, removal of burrs and sharp edges, and ruggedness.

3.7 Identification of Product - Equipment, assemblies, and parts shall be marked as specified in TRW Specification 02-5000.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 The requirements of MIL-Q-9858 shall apply as well as all Purchase Order requirements.

4.2 Tests To Be Performed By The Connector Vendor

4.2.1 Examination of Product - Each electric connector shall be inspected to determine compliance of the material, workmanship, marking, finishes, and dimensional requirements of this document.

4.2.2 Dielectric Withstanding Voltage - The electric connector shall show no evidence of breakdown when 1500 volts (rms) (60 cps) is applied between the two closest contacts and between the shell and the contacts closest to the shell in accordance with MIL-STD-202, Method 301.

4.2.3 Helium Leakage Test - The maximum allowable helium (He) leak rate for the electric connector shall not be greater than 10^{-9} cc/sec as tested per MIL-STD-271B (class e).

5.0 PREPARATION FOR DELIVERY

The packing, handling, marking, and method of shipment are the responsibility of the electric connector contractor. This shall be accomplished in such a manner that the connector will arrive at the contractor's facility in an undamaged, clean and operable condition.

6.0 DRAWINGS

The configuration of this connector shall comply with TRW Source Control Drawing 208220.

The supplier shall provide TRW an installation and assembly drawing depicting envelope, weight, cross-sectional views and materials and processes prior to the start of final assembly.

TAPCO A DIVISION OF
Thompson Ramo Wooldridge Inc.
23555 EUCLID AVENUE • CLEVELAND 17, OHIO

TAPCO NO. 03-10129

Date 8/22/63

Contract No. _____

Customer No. _____

Copy No. _____

No. of Pages _____

Corrections: (W.A.A.) 3.1.7 — 3.2.3
Fig. 1: ??
Source Control Dwg.
for what.

MOTOR, ELECTRIC, COOLANT & LUBE PUMP
MODEL 253800-1

SECOND PRELIMINARY

PREPARED BY

E. F. Jira
Development Engineer
Title

W. V. Edwards
Project Engineer
Title

APPROVED BY

L. J. Weiss
Senior Project Engineer
Title

Title

REVISIONS

Date	Rev.	Paragraph	Remarks and E.O.	Authorization

V 42

MOTOR, ELECTRIC, COOLANT & LUBE PUMP
MODEL 253800-1

1. SCOPE

1.1 This specification defines the characteristics and performance requirements for an electric motor used to drive Model 253800-1 Centrifugal Pump.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue specified form a part of this specification to the extent specified herein.

Specifications - Military

MIL-P-52388 Pump, Centrifugal, Fuel Booster, Aircraft, general specification for

MIL-E-52720 Environmental Testing, Aeronautical and Associated Equipment, General Specification for

MIL-W-7139A Wire, Electrical, Insulated, Copper, 600 volt 400°F

MIL-W-0061600 Wiring Guided Missile Installation of General Specification

MIL-M-17060B Motors; Alternating Current, Integral H.P.

MIL-D-70327 Drawings, Engineering & Associated Lists.

Military Standards

MIL-STD-202A Test Methods for Electronic & Electrical Component Parts

TAPCO, A Division of Thompson Ramo Wooldridge, Inc.

ER-1820A Electric Motors for Aircraft Fuel Booster Pumps, General Specification for

American Institute of Electrical Engineers (AIEE)

AIEE STD 43 Recommended Guide for Testing Insulation Resistance of Rotating Machinery.

AIEE STD 51 Guiding Principles for Dielectric Tests.

American Standards Association (ASA)

ASA C50.20-1954 American Standard Test Code for Polyphase Induction Motors & Generators.

Jet Propulsion Laboratory (JPL)

30236A Design Specification, Spacecraft, Flight & Ground Support Equipment, R. F. Interference Control & Test Requirements.

DRAWINGS

TAFCO, A Division of Thompson Ramo Wooldridge, Inc.

208207, Rotor

208210, Stator

3. REQUIREMENTS

3.1 Performance - The motor shall be capable of meeting all of the performance requirements of this specification while operating submerged in Dow Chemical Company Bis (Polyphenyl) Ether DE-378.

3.1.1 Operation - The motor shall be capable of 30,000 hours of unattended operation in an orbital environment.

3.1.1.1 Rated Torque - The rated torque under conditions defined in paragraphs 3.1.3, 3.1.4, 3.1.5 and 3.1.6 shall be 12.0 in/lbs. See Fig. 1 for performance requirements.

3.1.2 Power Supply - The steady-state power supply is:

Number of Phases: 3

Terminal Voltage: 200 ± 5%

Frequency (cps): 400 ± 3%

3.1.3 Speed - The synchronous speed shall be 6000 rpm at 400 cps input.

3.1.4 Slip - The motor slip shall not exceed 3% at the steady-state design point.

3.1.5 Power Factor - The power factor shall not be less than 0.50 when operating at the steady-state design conditions.

3.1.6 Motor Input - The motor power input shall not exceed 1600 watts for the design conditions.

3.1.7 Start & Acceleration Torque - The motor shall be capable of delivering 130% of the required shaft torque at the speeds from zero to steady state at a starting and operating voltage to frequency ratio of 0.52.

what??

X

reword to clarify.

Torque at zero freq. = 0

3.1.8 Operating Range - The motor shall be capable of operating under the following ranges for the specified periods without impairing subsequent performance or life:

Voltage:	± 10% design	500 hours
Frequency:	± 5% design	500 hours

3.1.9 Startup - The motor shall be capable of 50 normal starts without impairing subsequent operation or life. The motor shall be capable of the normal and abnormal starting modes described in this section.

3.1.9.1 Normal Start Mode 1 - The PMA (Pump Motor Assembly) shall be capable of startup by instantaneous application of 208 volts - 400 cps 3 phase electrical power with conditions as described in paragraph 3.1.9. Conditions prior to startup shall be:

Temperature 150°F to 250°F.

Flow through PMA from auxiliary source.

3.1.9.2 Normal Start Mode 2 - The PMA (Pump Motor Assembly) shall be capable of startup by increasing electrical power as described below with conditions as described in paragraph 3.1.8. Conditions prior to startup shall be as in paragraph 3.1.9.1 or as 3.1.9.1 with no circulation flow:

Number of Phases: 3

Terminal Voltage: 0 to 208 line-to-line in 15 to 30 sec.

Voltage to Frequency Ratio (volts/cps): 0.52 constant

3.1.9.3 Abnormal Start Conditions - The PMA shall be capable of three reverse rotation starts not to exceed 60 seconds of total operation. The conditions of this start mode shall be as described in paragraph 3.1.9.1. The PMA shall also be capable of two dry (no service or lubricant fluid present) starts not to exceed 10 seconds of total operation. The conditions of this start mode shall be as described in paragraphs 3.1.9.1. The abnormal starts shall be no closer than 30 minutes apart. The above conditions must be met without impairing the life characteristics.

3.1.10 Minimum Torque Requirement - The motor shall be capable of delivering 130% of the rated torque at a slip not to exceed 5%.

3.2 Motor Design

a) Type - squirrel cage induction

b) Number of poles - six

c) Connection - Wye-connected with the neutral to be brought out to a separate terminal on the motor housing

d) Winding temperature - The motor losses, temperature environment, and associated cooling paths shall limit the maximum hot spot winding temperature to 200°C.

e) Thermocouples - Five (5) thermocouples shall be provided, to be brought out to hermetically sealed terminals located on the motor housing. The thermocouples shall be located as follows:

Three (3) - One thermocouple adjacent to each phase in the stator slot no less than 1/2 inch from the end lamination.

Two (2) - Imbedded in outer extremity of stator end turns, one thermocouple at each end of assembly.

3.2.1 Envelope - The motor shall meet the requirements defined by [illegible] Drawings

and

3.2.2 Materials - The materials used in the manufacture of the motor shall be comparable with the requirements of this specification. There shall be no degradation of materials that will affect the motor performance in 10,000 hours of unattended operation at rated conditions in all the specified environments. All parts in contact with the service fluid shall be fabricated from the following list of alloys:

Alloy Steels

Stainless Steels

Carbon Steels

Nickel Base Alloys

Aluminum

NOTE:

No uninsulated copper, copper alloys, or Halogenated Hydrocarbon compounds are allowed.

3.2.3 Insulation - The insulation materials and treatment of same shall be compatible with the selected operating environments when submerged in [redacted] BIS (Polyphenyl) Ether ET-378.

An ML insulation system is considered acceptable. Any other insulation system shall require prior approval of the Buyer. [redacted] Pyre ML Varnish (RK-692) is considered acceptable and compatible with the fluid.

3.3 Environmental - The motor as part of the pump-motor assembly will be exposed to four basically different environments plus ground tests in its life cycle. These phases will include storage and transportation, handling and vehicle integration, launch, and orbital operation. The PMA will be operating only during the ground test and orbital operation phases.

3.3.1 Storage & Transportation - The pump-motor assembly shall be capable of withstanding without deterioration or performance decay the environments described in this section.

3.3.1.1 Normal Storage - The pump-motor assembly shall be capable of storage in a temperature and humidity controlled environment for a period of two years without deterioration.

3.3.1.2 Temperature - During storage and transportation, the PMA will be protected from the thermal environment. However, the thermal conditions will vary within the container and the PMA shall withstand temperatures from -40°F minimum to +160°F.

3.3.1.3 Pressure - During the storage and transportation phase, the PMA will be subjected to pressures from sea level to a maximum altitude of 50,000 feet. The maximum change in pressure to which the PMA will be subjected is a reduction or increase in pressure of 1.25 psi per minute. This will occur in either a climb to 50,000 feet or a descent from 50,000 feet.

3.3.1.4 Shock - The PMA shall be capable of withstanding transportation shocks applied to the PMA mounting in each of three mutually perpendicular axes of 4 g's magnitude for one of the following wave periods:

a) Triangular pulse 10 milliseconds

b) Half-sine pulse 8 milliseconds

c) Rectangular pulse 5 milliseconds

3.3.1.5 Vibration - The PMA shall be capable of withstanding sinusoidal transportation vibrations applied to the PMA mounting in three mutually perpendicular axes according to the following schedules:

Frequency Range	Amplitude	Duration
2-10 cps	.40 inches DA	30 min. logarithmic sweep
10-500 cps	2.0 g peak	30 min. logarithmic sweep

Five minutes of vibration shall be applied at the same amplitude at each major resonant frequency.

3.3.1.6 Fungus - The PMA shall be adequately protected from deterioration caused by growth of fungus.

3.3.2 Handling & Vehicle Integration - During handling and vehicle integration, it can be anticipated that the PMA will be exposed to atmospheric and weather environments for a maximum period of six weeks. The PMA shall be capable of withstanding without deterioration or performance decay, the environments described in this section.

3.3.2.1 Humidity - The PMA shall be capable of withstanding a simulated twenty-four (24) hour cycle of water vapor in the atmosphere with a 5 m/sec steady-state wind as follows:

a) Six (6) hours of 106°F air temperature at 95% relative humidity (absolute humidity 15.3 gms/ft^3).

b) Six (6) hours of decreasing air temperature to 91°F and increasing relative humidity to 100%.

c) Eight (8) hours of decreasing air temperature to 81°F with a release of 4.4 gms/ft^3 of water.

d) Four (4) hours of increasing air temperature to 106°F and decreasing relative humidity to 50%.

3.3.2.2 Sand & Dust - The PMA shall be capable of withstanding a sand and dust density of 0.1 to 0.25 gms/ft^3 at a temperature of 77°F in an air stream of 2500 ft/min for 3 hours with the relative humidity at less than 30%. "Sand and dust" is defined as 140-mesh silica flour with characteristics as specified in MIL-E-52720.

3.3.2.3 Fungus - The PMA shall be adequately protected from deterioration caused by growth of fungus.

3.3.2.4 Salt Spray - The PMA shall be capable of withstanding a 50-hour 20% salt solution spray test.

3.3.2.5 Temperature - The PMA shall be capable of withstanding temperature variations within -55°F to +160°F for two weeks.

3.3.3 Launch, Lift-off to Final Termination of Thrust - The non-operating PMA shall be capable of withstanding without performance degradation the launch environments specified in this section.

3.3.3.1 Shock - The PMA shall be capable of withstanding transportation shocks applied to the PMA mounting in each of three mutually perpendicular axes of 35 g's magnitude for one of the following time periods:

a) Triangular pulse 10 milliseconds

b) Half-sine pulse 8 milliseconds

c) Rectangular pulse 5 milliseconds

3.3.3.2 Vibration - The PMA shall be capable of withstanding launch vibrations applied to the PMA mounting in three mutually perpendicular axes according to the following schedule of sinusoidal inputs:

Frequency Range	Amplitude	Duration
16-42 cps	2 g peak	30 min. logarithmic sweep
42-95 cps	.011 inch DA	30 min. logarithmic sweep
95-2000 cps	10 g peak	30 min. logarithmic sweep

In addition, the PMA shall be capable of withstanding sinusoidal resonance vibrations in three mutually perpendicular axes for 5 minutes according to the following schedule:

Frequency Range	Amplitude
16-42 cps	1 g peak
42-95 cps	.011 inch DA
95-2000 cps	5 g peak

3.3.3.3 Acceleration - The PMA shall withstand the launch and lift-off accelerations according to the following schedule:

7 g's for 5 minutes in a direction perpendicular to the shaft axes.

3 g's for 5 minutes in a direction parallel to the shaft axes.

4.5 g's for 5 minutes in both directions along mutually perpendicular axes.

The PMA shaft will be normal to the axes of the launch vehicle.

3.3.3.4 Acoustic Noise - The component shall withstand exposure to acoustic noise at 140 db integrated sound pressure level.

3.3.4 Orbital Operation - The PMA shall be capable of startup and operation in any orientation relative to the direction of the sun, planets, or moon, either in or out of the shadow of any planet or moon. It shall be capable of startup and operation in zero gravity, temperature, and vacuum environments of space. The PMA shall be capable of withstanding the cosmic, solar and Van Allen radiation encountered in a space environment with no deterioration of performance in a period of 10,000 hours.

3.3.4.1 Shock - The PMA shall be subjected to shocks during operation in a space environment of 7 g's on each of three mutually perpendicular axes with one of the wave forms and time durations as indicated below:

a) Triangular pulse for 10 milliseconds

b) Half-sine wave pulse for 8 milliseconds

c) Rectangular pulse for 5 milliseconds

3.3.4.2 Vibration - The PMA will be subjected to vibrations in space while in operation of 1/4 g peak over a frequency range of 5-2000 cps. The input of these vibrations will be at the mounting of the PMA.

3.3.4.3 Self-Generated Vibration - The PMA shall not self-generate vibrations over 1/4 g peak while operating in space over a frequency range of 5-2000 cps.

3.3.4.4 Acceleration - After startup the PMA shall be capable of withstanding a 3-1/2 g acceleration in a direction perpendicular to the shaft axis and plus or minus 1 g on each of the two mutually perpendicular axes. These accelerations will be sustained for periods not to exceed 5 minutes. In addition, the PMA shall be capable of operation with a maximum of 1 g acceleration in a direction perpendicular to the PMA shaft in a space environment for periods of 10,000 hours.

3.3.4.5 Radio Frequency Interference - The PMA shall pass the tests described in JPL Specification 30236A to assure there will be no radio frequency interference with other assemblies in the SNAP-8 system.

3.3.4.6 Insulation Resistance - The motor shall be subjected to an insulation resistance test per MIL-STD-202A, Method 302, Test Condition B.

3.3.4.7 Dielectric Strength, Sea Level - The motor shall be subjected to a room temperature, sea level dielectric strength test per MIL-STD-202A, Method 301. A voltage of 1500 volts (RMS) of commercial frequency shall be applied between the external connections of each mutually insulated circuit and between each external connection and the motor case.

3.3.4.8 Radiation - The PMA shall be capable of withstanding without performance degradation, for 10,000 hours, the following cumulative radiation doses:

2×10^{13} NVT fast neutron

5×10^{7} rads gamma

3.4 Service Life - The PMA shall be capable of continuous operation for periods up to 10,000 hours of unattended operation at rated loads and temperatures in all specified environments. The PMA shall be capable of 50 start and stop cycles during its service life.

3.5 Interchangeability - All parts having the same manufacturer's part number shall be directly and completely interchangeable with respect to installation and performance and adequately serialized to provide for the use of matched or fitted subassemblies. Changes in part numbers shall be governed by the requirements of Specification MIL-D-70327.

3.6 Workmanship - All machine surfaces shall have a smooth finish, and all details of manufacture, including the preparation of parts and accessories, shall be in accordance with the best practice of high-quality electrical equipment. Particular attention shall be given to neatness and thoroughness of welding, wiring, impregnation of coils, marking of parts, plating, lacquering, riveting, clearance between electrical connections, removal of burrs and sharp edges, and ruggedness. Applicable specifications: MIL-T-5021A, MIL-W-5088B, MIL-W-0081600, ACC-STD-2795.

4. QUALITY ASSURANCE PROVISIONS

4.1 Tests To Be Performed By The Motor Vendor

4.1.1 Examination of Product - Each motor shall be inspected to determine compliance with the material, workmanship, marking, finish, and dimensional requirements of this document.

4.1.2 Calibration - Motors delivered shall be calibrated to insure compliance with the requirements of Figure 1. Copies of the results of these tests shall be delivered with the motors and shall include speed, torque, horsepower, amps, power factor, and efficiency.

4.1.3 Dielectric Strength - A dielectric strength test shall be conducted on all delivered motors per MIL-STD-202A, Method 301, and winding resistance per MIL-STD-202A, Method 302, Condition 3.

5. PREPARATION FOR DELIVERY

The packing, handling, marking, and method of shipment are the responsibility of the motor contractor. This shall be accomplished in such a manner that motor will arrive at the contractor's facility in an undamaged, operable condition.

6. NOTES

6.1 Data Submittal

6.1.1 Design Calculations - Prior to commencement of fabrication, the items described in this paragraph shall be submitted to TRNCO in reproducible form. Said items will be forwarded to the prime contractor.

6.1.1.1 Electromagnetic Performance - Complete motor design calculations and supporting data shall be submitted. These calculations shall include all motor design impedances and losses for steady-state and startup conditions, and compensation for performance evaluation over the established temperature range.

6.1.1.2 Motor Windings - Complete insulation material specifications, winding processes, and details of all connections to the external terminals shall be submitted.

6.1.2 Drawings - Prior to the delivery of finished hardware, complete engineering drawings shall be submitted. These shall include assembly drawings, detail drawings, detail subassembly drawings, wiring drawings, and parts lists. Drawings shall be maintained current by the vendor to reflect the latest designs and shall conform to the definitions of MIL-D-70327 Class 2, contractor design activity drawings. One reproducible and four copies of each shall be supplied.

TAPCO DIVISION CLEVELAND, OHIO
THOMPSON RAMO WOOLDRIDGE INC.

MOTOR PERFORMANCE REQUIREMENTS
MODEL 253300-1 COOLANT & LUBE PUMP
INPUT POWER: 3 PHASE AC
208 VOLTS ± 5%
400 CPS ± 1%

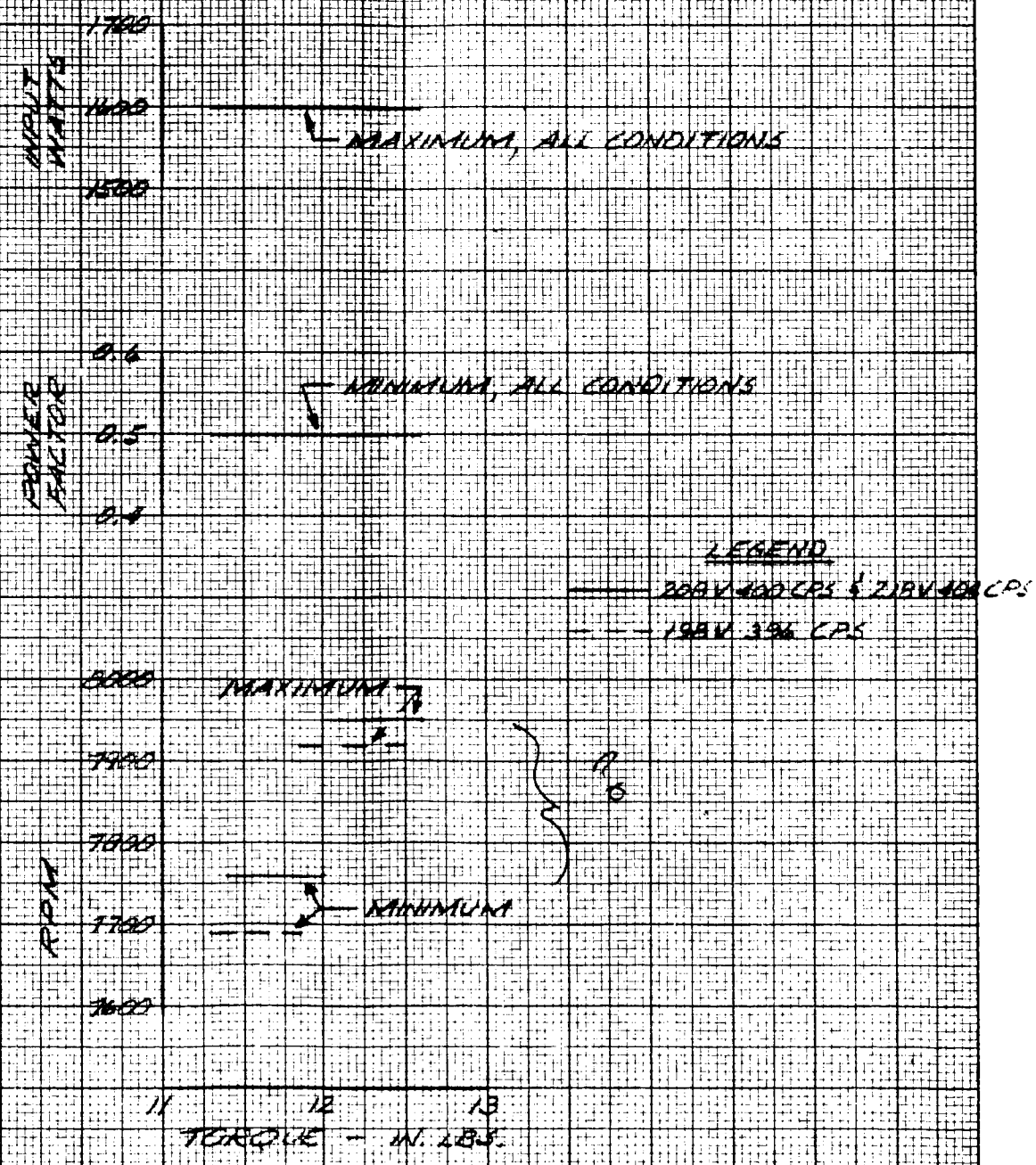


FIGURE 1

V

NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM LISTED ON THIS DRAWING AND IDENTIFIED BY VENDORS NAME, ADDRESS, AND PART NUMBER HAVE BEEN TESTED AND APPROVED BY TAPCO GROUP, THOMPSON RAMO WOOLDRIDGE INC. FOR USE IN BOOSTER PUMPS. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY TAPCO GROUP, THOMPSON RAMO WOOLDRIDGE INC.

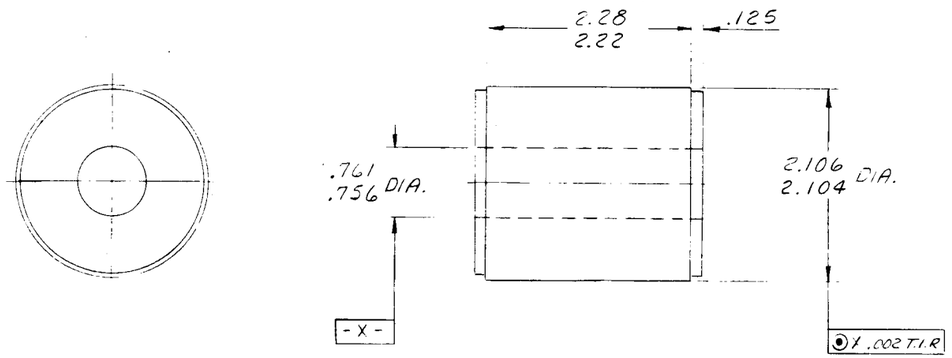
2. APPROVED SOURCE:
   WESTINGHOUSE ELECTRICAL CORP.
   LIMA, OHIO
   PART NO. EDSK 299241
   H4-1 CODE NO. 88109

3. THIS ROTOR (207207) AND STATOR (208210) TOGETHER. (TO BE USED INTERCHANGEABLY) COMPLETE MOTOR PERFORMANCE REQUIREMENTS PER TRW SPEC. 03-10129.

4. VENDOR PART NO. MUST APPEAR ON PART. PART MARKING IN ACCORDANCE WITH TRW SPEC. 02-5000 PARA. 5.3.

REVISIONS

SYM.	DESCRIPTION	D.C.N.	DRAWN	CHK'D	DATE



208207

SOURCE CONTROL DRAWING

ITEM No.	REQD.	PART NO.	DESCRIPTION	REF. NO.

LIST OF PARTS

APPLICABLE SPECIFICATIONS UNLESS OTHERWISE SPECIFIED	UNLESS OTHERWISE SPECIFIED			
DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH SPEC. MIL-STD-8.	DIMENSIONS ARE IN INCHES REMOVE ALL BURRS BREAK SHARP EDGES .005/.015 MACH. CORNERS .005/.020 FILLET R. CAST RADII ±			
	TOLERANCES ON –			
	DECIMALS	FRACTIONS ±		
	.X = ±.1	ANGLES ±		
	.XX = ±.03			
	.XXX = ±.010	CORE SHIFT ±		

DFTM.	[illegible]	4-17-63
CHKD.		
APPD.		
ENG. APPD.		
ENG. APPD.		
MATL. APPD.		
MFG.		

MATL. & SPEC.: 2
TREATMENT & HARDNESS:
TITLE: ROTOR
SCALE: 1/1
WEIGHT:
MFG. CODE: 5300
DO NOT SCALE DWG.
DEVL
DRAWING STATUS
NEXT ASSY. OR REFERENCE NO.: 208209
DWG. SIZE: C

TAPCO GROUP
THOMPSON RAMO WOOLDRIDGE INC.
U. S. A.

DRAWING NO. 208207
H4-1 CODE 59875
SHEET 1 OF

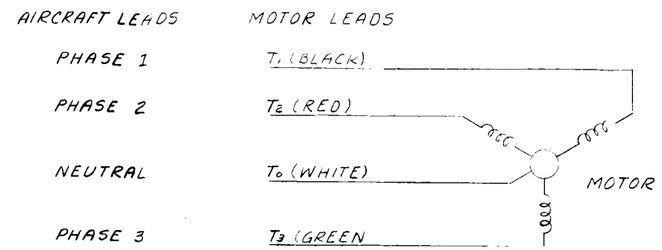
NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM LISTED ON THIS DRAWING AND IDENTIFIED BY VENDORS NAME, ADDRESS, AND PART NUMBER HAVE BEEN TESTED AND APPROVED BY TAPCO GROUP, THOMPSON RAMO WOOLDRIDGE INC. FOR USE IN BOOSTER PUMPS. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY TAPCO GROUP, THOMPSON RAMO WOOLDRIDGE INC.

2. APPROVED SOURCE:
   WESTINGHOUSE ELECTRICAL CORP.
   LIMA, OHIO
   PART NO. EDSK 299241
   H4-1 CODE NO. 88109

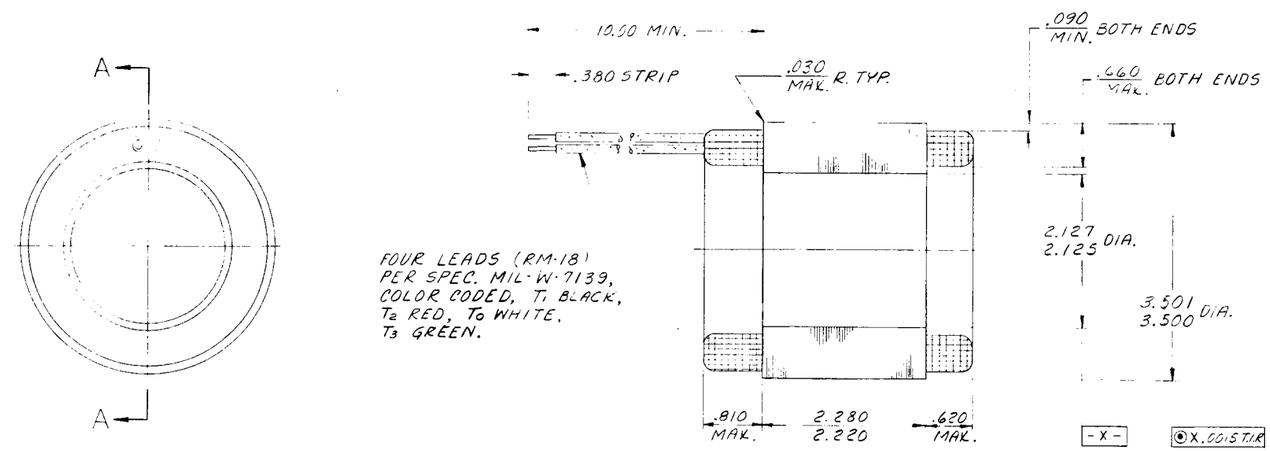
3. THIS STATOR (207210) AND ROTOR (208207) TOGETHER. (TO BE USED INTERCHANGEABLY) COMPLETE MOTOR PERFORMANCE REQUIREMENTS PER TRW SPEC. 03-10129

4. VENDOR PART NO. MUST APPEAR ON PART. PART MARKING IN ACCORDANCE WITH TRW SPEC. 02-5000 PARA. 5.3.



WIRING DIAGRAM

ELECTRICAL CONNECTIONS OF LEADS TO MOTOR TO PRODUCE C.W. ROTATION VIEWING MOTOR FROM LEAD END. C.W. ROTATION NECESSARY FOR PUMPING ACTION.



FOUR LEADS (RM-18) PER SPEC. MIL-W-7139, COLOR CODED, T_1 BLACK, T_2 RED, T_0 WHITE, T_3 GREEN.

SECTION AA

REVISIONS

SYM.	DESCRIPTION	D.C.N.	DRAWN	CHK'D	DATE

208210

SOURCE CONTROL DRAWING

ITEM No.	REQD.	PART NO.	DESCRIPTION	REF. NO.

LIST OF PARTS

APPLICABLE SPECIFICATIONS UNLESS OTHERWISE SPECIFIED
DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH SPEC. MIL-STD-8.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
REMOVE ALL BURRS
BREAK SHARP EDGES .005/.015
MACH. CORNERS .005/.020 FILLET R.
CAST RADII ± ~
TOLERANCES ON –
DECIMALS .X = ±.1 .XX = ±.03 .XXX = ±.010
FRACTIONS ± 1/64
ANGLES ±
CORE SHIFT ±

DFTM. [illegible] 4-17-63
CHKD.
APPD.
ENG. APPD.
ENG. APPD.
MATL. APPD.
MFG.

MATL. & SPEC. 2
TREATMENT & HARDNESS
TITLE STATOR
SCALE 1/1
WEIGHT
MFG. CODE 5300
DEVL
DO NOT SCALE DWG.
DRAWING STATUS

NEXT ASSY. OR REFERENCE NO.
DWG. SIZE D
TAPCO GROUP
THOMPSON RAMO WOOLDRIDGE INC.
U. S. A.
DRAWING NO. 208210
H4-1 CODE 59875
SHEET 1 OF 1

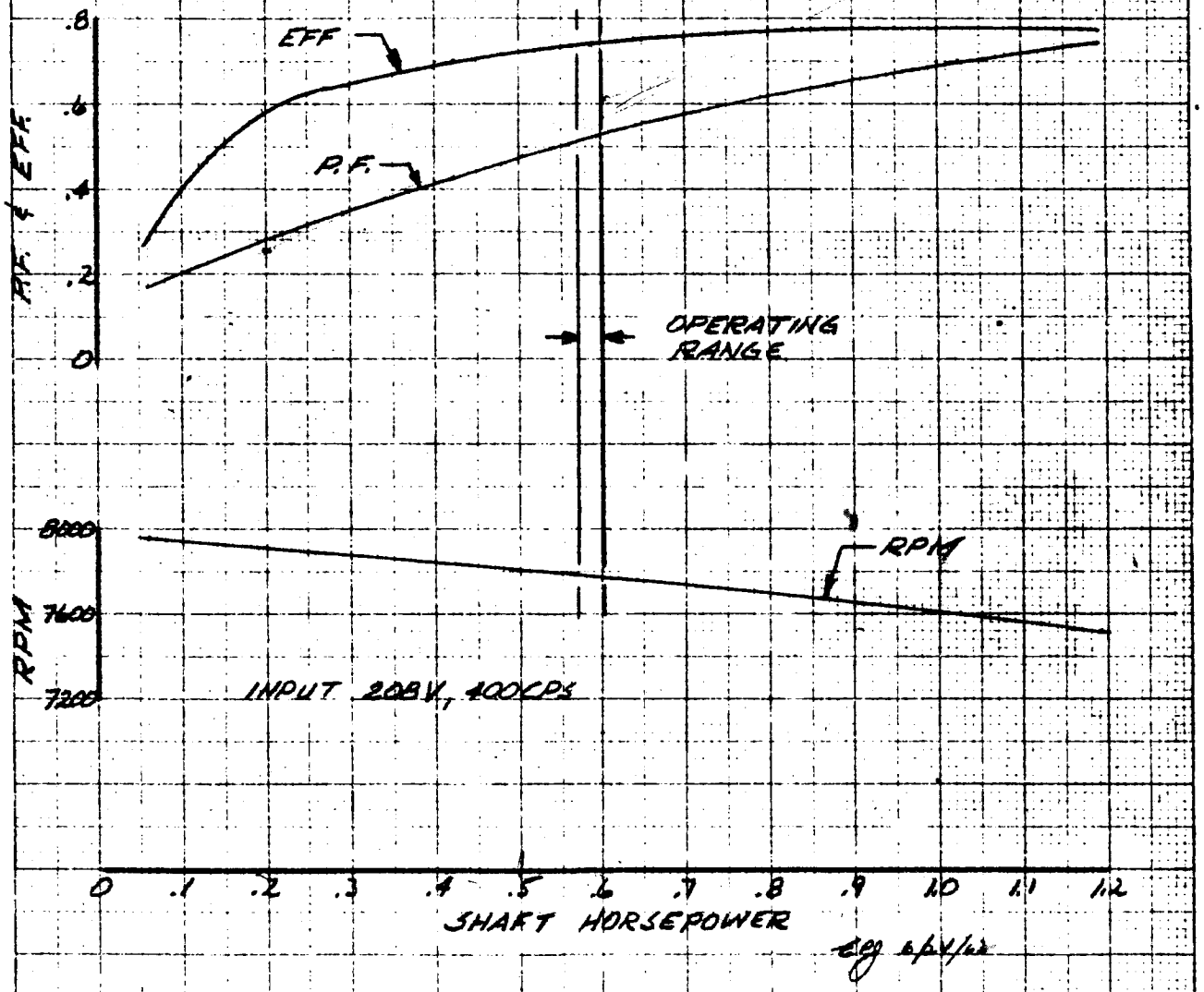
HP x 746
EFF

TAPCO DIVISION

THOMPSON RAMO WOOLDRIDGE INC., CLEVELAND, OHIO

MODEL 253800-1 LUBRICATION & COOLING PUMP

ESTIMATED MOTOR PERFORMANCE & PUMP OPERATING RANGE



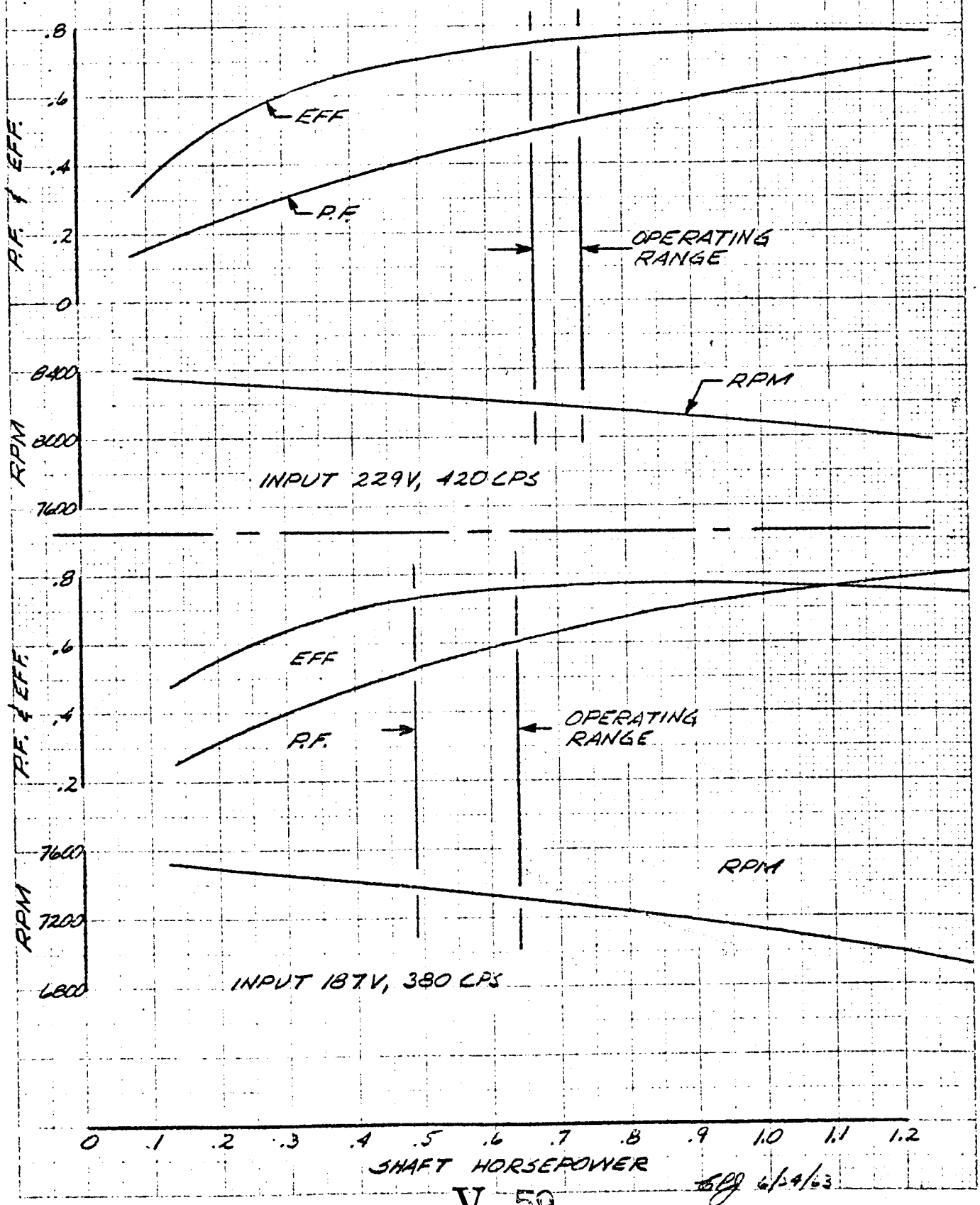
SK 18031

TAPCO DIVISION

THOMPSON RAMO WOOLDRIDGE INC., CLEVELAND, OHIO

MODEL 253500-1 LUBRICATION & COOLING PUMP

ESTIMATED MOTOR PERFORMANCE & PUMP OPERATING RANGE

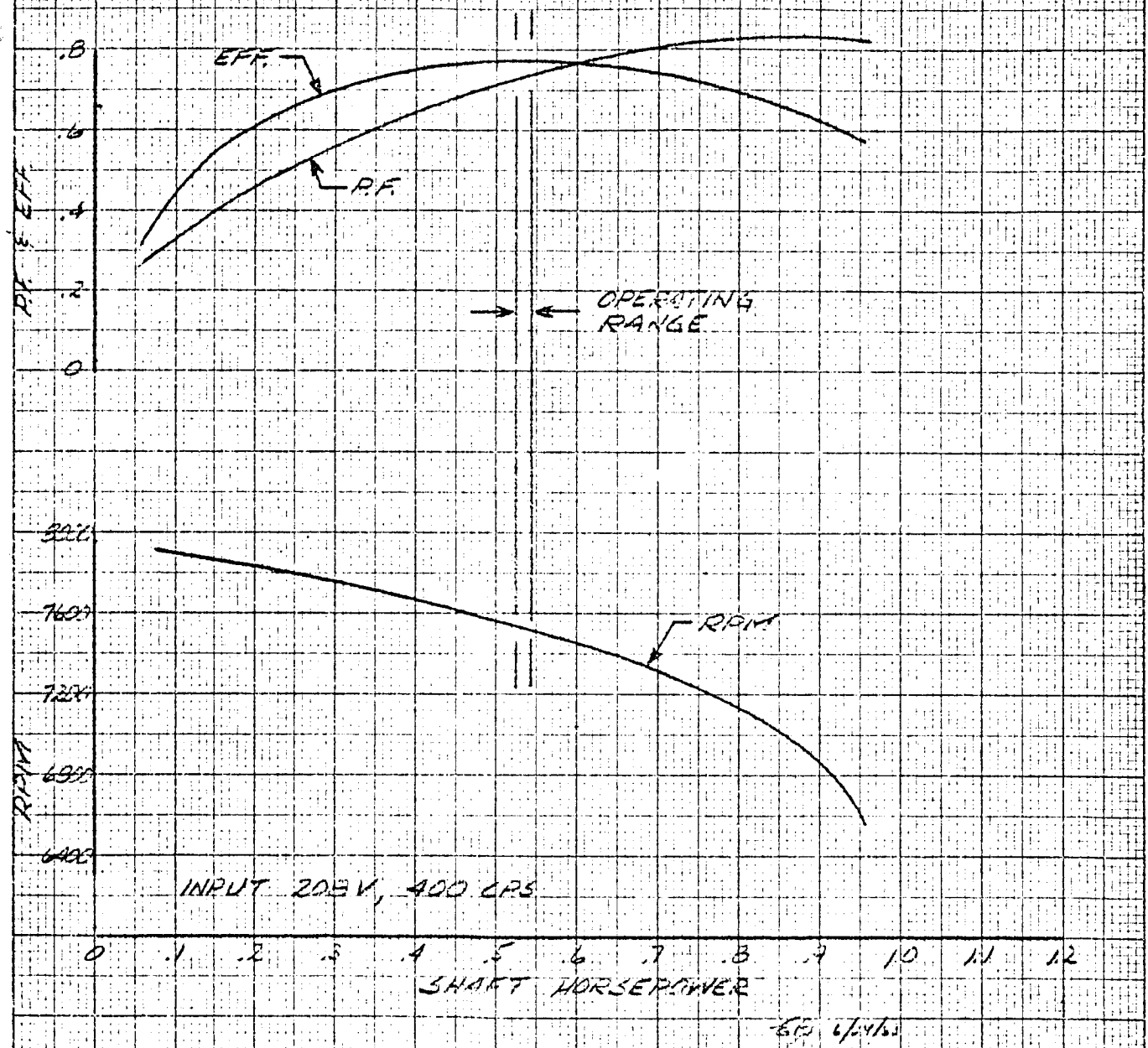


6/24/63

SK 18032

THOMPSON RAMO WOOLDRIDGE INC., CLEVELAND, OHIO

MODEL 253900-1 LUBRICATION & COOLING PUMP
ESTIMATED MOTOR PERFORMANCE & PUMP OPERATING RANGE
ALTERNATE MOTOR (INCREASED SLIP)



60 6/24/63

SK 18033

10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO.

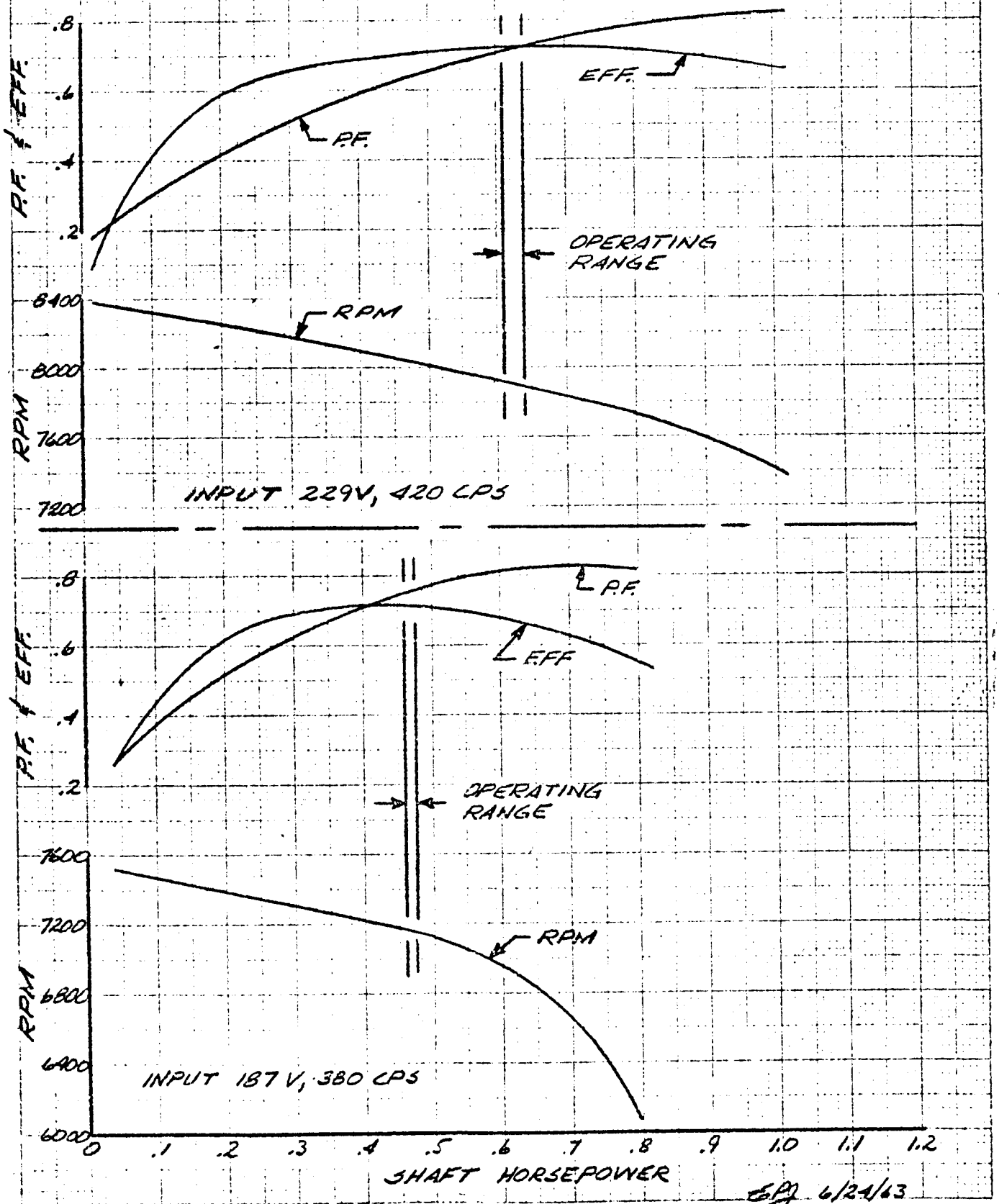
TAPCO DIVISION

THOMPSON RAMO WOOLDRIDGE INC., CLEVELAND, OHIO

MODEL 253900-1 LUBRICATION & COOLING PUMP

ESTIMATED MOTOR PERFORMANCE & PUMP OPERATING RANGE

ALTERNATE MOTOR (INCREASED SLIP)



EPJ 6/24/63

SK 18034

DESIGN DETAILS FOR CALCULATING PERFORMANCE
1.48 HP, 6 POLE, AC MOTOR PARTS

REVISED - SEPTEMBER 27, 1963

THOMPSON RAMO WOOLDRIDGE P.O. 08-52-901

WESTINGHOUSE GENERAL ORDER OLD 23210

Punching Dimensions

Stator		Rotor	
Code	Dimension	Code	Dimension
OD	3.500	ROD	2.185
ID	2.125	IDDPR	.750
SSUBP	36 slots	SSUBR	47 slots
A2PR	.1944	A1DPR	.084
BPR	.487	EDPR	.025
EPR	.060	BDPR	.172
A1PR	.110	DDPR	.010
CPR	.010	CDPR	.010
DPR	.015	A2DPR	.061

The above code letters refer to dimensions as shown on Attachment No. 1 to these calculations.

Winding Information

Stack length - 2.25 inches
20 turns per coil
2 paths in parallel
Throw of 4 (coil will lie in slots 1 and 5, etc.)
Wire diameter - .0285 inches, 21 gage
Coil perimeter - 7.71 inches
Resistance of wound primary (line-to-neutral) .5279 ohms at 25°C
Reference Attachment No. 2 for wiring diagram.

36 slots, 6 pole
q = 2 slots/p/φ
full pitch 6 slots
2/3 pitch

Resistance Ring Information, Rotor

OD of resistance ring - 2.105 inches
ID of resistance ring - .75 inches
Resistance ring thickness - .125 inches
Resistance ring material - silver, 100% conductivity
Resistance of resistance ring - referred to primary .0615 ohms at 25°C

Conductor Bar, Rotor

Conductor bar material - silver, 100% conductivity
Length - 2.25 inches
Area of conductor bar - .0102 square inches
Resistance of conductor bars - referred to primary .4041 ohms at 25°C
The cross section of the conductor bar will be trapezoidal in shape with dimension on the four sides as follows: .055, .135, .078, .185 inches.
The temperature coefficient for resistance is .0039 ohms per ohms per °C.

Losses

39 watts for windage
10 watts for friction
Stator core loss per phase - 20 watts

Impedances

Rotor is skewed one stator slot
Magnetizing reactance is 22.3 ohms
Total stator leakage reactance is 2.128 ohms
Total rotor leakage reactance is 1.173 ohms

Electrical Steel

29 Gage, ASTM-4345-55 AISI Type M15
Stator core will be welded together.

Stator Winding Insulation

Magnet Wire 100% IACS Copper Heavy ML Polyimide Film
Slot Liner and Slot Phase Separator - Per DuPont Quality Code Numbers 6500, 6507, and 6508.
Sleeving, ML treated fiber glass
Varnish, DuPont Pyre - ML DuPont Type RK 692
Flexible lead wire, Rockestos Micatemp (RCSS-300) Type
Spacers and wedges, Silicone Glass Laminate, NEMA Grade G-7
Mica tape, 3M Isomica - Silicone Mica Paper Tape Type V 2084-100 Series

Thermocouples

Thermocouples will be of Chromel - Alumel Type

The calculations previously submitted in a July 10, 1963 letter will run with a 125°C winding temperature, 150°C on the rotor. Additional calculations will be supplied in the next few days with a winding temperature of 150°F.

The 10,000 hours life is a design objective but cannot be guaranteed at this time as Westinghouse has not previously run motors in ST 378 solution.

[illegible]

DESIGN DETAILS FOR CALCULATING PERFORMANCE
1.48 HP, 6 POLE, AC MOTOR PARTS

THOMPSON RAMO WOOLDRIDGE P.O. 08-52-001

WESTINGHOUSE GENERAL ORDER CLD 23210

RECEIVED
SEP 5 1963
TAPCO R D & E
Purch. & Serv. Admin.

Punching Dimensions

STATOR

Code	Dimension
OD	3.500
ID	2.125
SSUBP	36 slots
A2PR	.1944
BPR	.487
EPR	.060
A1PR	.110
CPR	.010
DPR	.015

ROTOR

Code	Dimension
ROD	2.105
IDDPR	.750
SSUBS	47 slots
A1DPR	.084
EDPR	.025
BDPR	.172
DDPR	.010
CDPR	.010
A2DPR	.061

The above code letters refer to dimensions as shown on Attachment No. 1 to these calculations.

Winding Information

Stack length - 2.25 inches
20 turns per coil
2 paths in parallel
Throw of 4 (coil will lie in slots 1 and 5, etc.)
Wire diameter - .0285 inches, 21 gage
Coil perimeter - 7.71 inches
Resistance of wound primary (line-to-neutral) .5279 ohms at 25°C
Reference Attachment No. 2 for wiring diagram.

THIS DOCUMENT CONTAINS
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THAN THE EXPRESS PURPOSE FOR WHICH
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Resistance Ring Information, Rotor

OD of resistance ring - 2.105 inches
ID of resistance ring - .75 inches
Resistance ring thickness - .125 inches
Resistance ring material - copper, 100% conductivity
Resistance of resistance ring - referred to primary .0615 ohms at 25°C

Conductor Bar, Rotor

Conductor bar material - copper, 100% conductivity
Length - 2.25 inches
Area of conductor bar - .0102 square inches
Resistance of conductor bars - referred to primary .4041 ohms at 25°C
The cross section of the conductor bar will be trapezoidal in shape with dimension on the four sides as follows: .055, .185, .078, .185 inches.
The temperature coefficient for resistance is .0039 ohms per ohms per °C.

Losses

30 watts for windage
10 watts for friction
Stator core loss per phase - 20 watts

.0615
.4041
.4656

Impedances

Rotor is skewed one stator slot
Magnetizing reactance is 22.3 ohms
Total stator leakage reactance is 2.128 ohms
Total rotor leakage reactance is 1.173 ohms

Electrical Steel

29 Gage, ASTM-A345-55 AISI Type M15
Stator core will be welded together.

Stator Winding Insulation

Magnet Wire 100% IACS Copper Heavy ML Polymide Film
Slot Liner and Slot Phase Separator - Per DuPont Quality Code Numbers 6500, 6507, and 6508.

Stator Winding Insulation (cont'd.)

Sleeving, Varflex Type H untreated fiber glass
Varnish, Westinghouse Doryl Varnish, Cat. No. B-109-4
Flexible lead wire, Rockestos Micatemp (RSS5-300) Type
Spacers and wedges, Doryl Laminate
Fiber glass tape, fiber glass woven, heat cleaned

Thermocouples

Thermocouples will be of Chromel - Alumel Type

The calculations previously submitted in a July 10, 1963 letter will run with a 125°C winding temperature, 150°C on the rotor. Additional calculations will be supplied in the next few days with a winding temperature of 150°F.

The 10,000 hours life is a design objective but cannot be guaranteed at this time as Westinghouse has not previously run motors in EF 378 solution.

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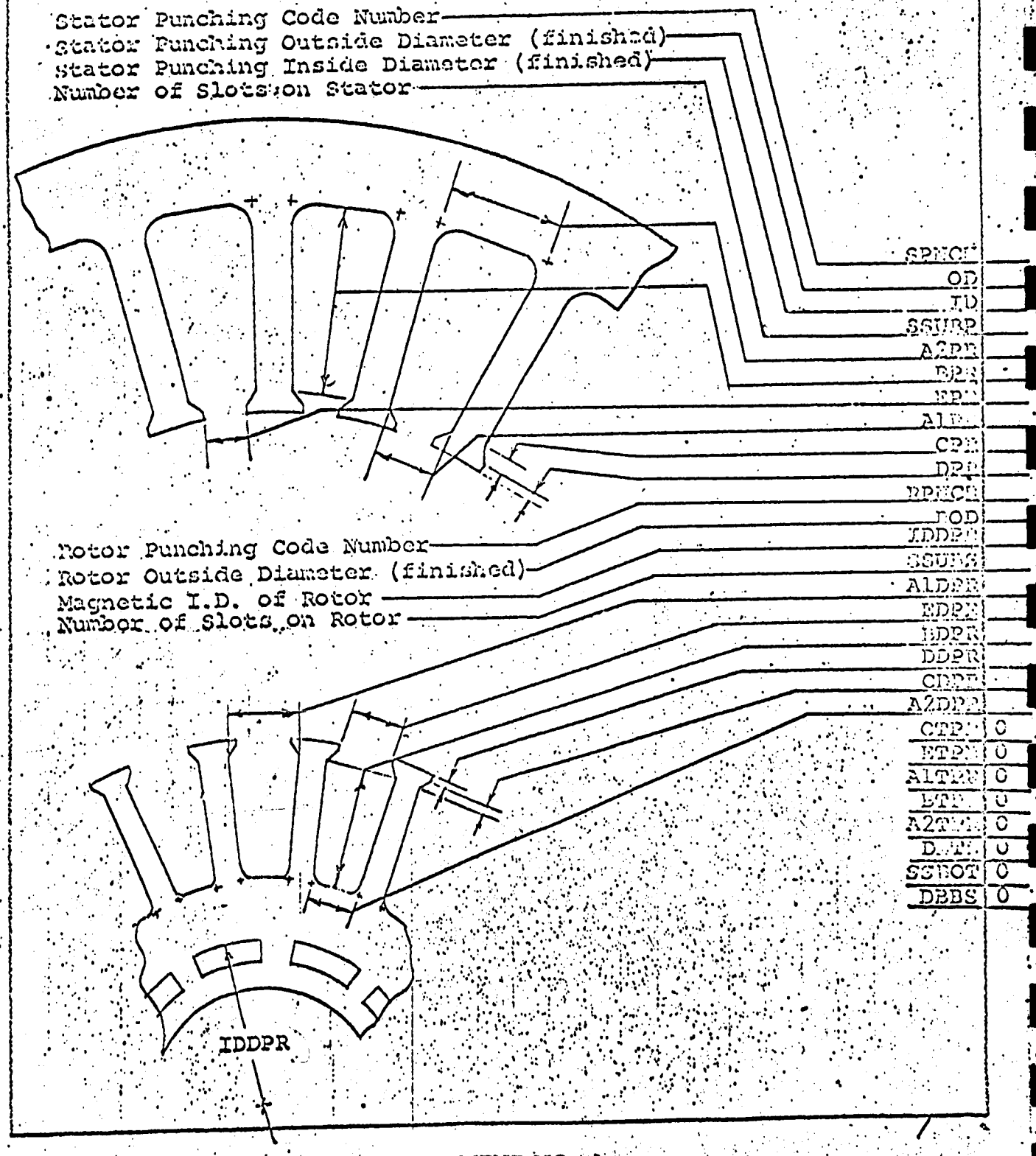
PICTORIAL DEFINITION OF SYMBOLS FOR PUNCHING DIMENSIONS

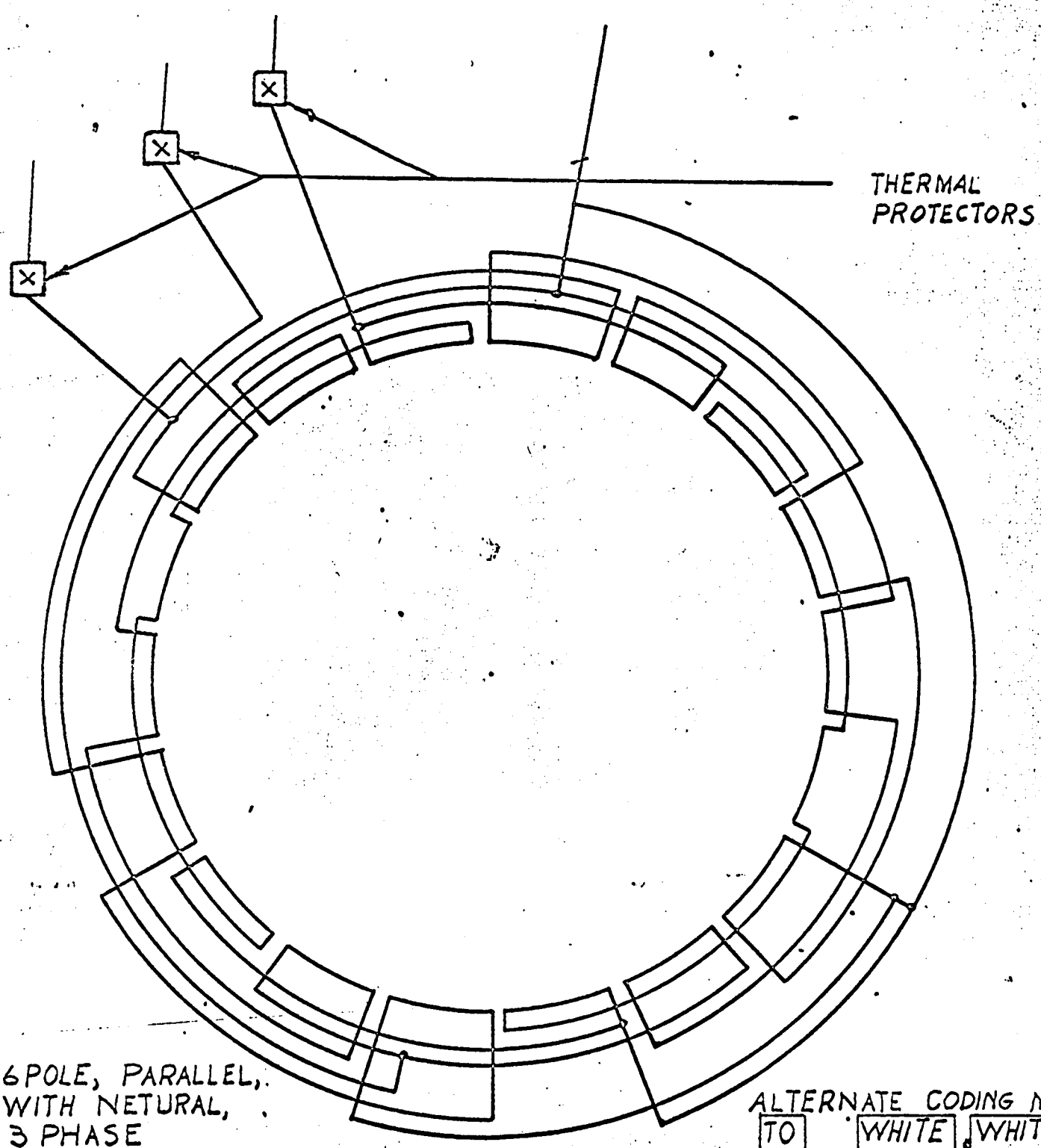
SINGLE-DECK ROTOR WIRE-WOUND STATOR



ATTACHMENT NO. 1

Fig. 5

WIRING DIAGRAM



6 POLE, PARALLEL, WITH NETURAL, 3 PHASE

ALTERNATE CODING METHOD

T0	WHITE	WHITE
T1	BLACK	RED
T2	RED	YELLOW
T3	GREEN	BLUE

X CONNECT THERMAL PROTECTORS WHEN CALLED OUT ON WOUND PRIMARY.

EDSK 284188

ATTACHMENT NO. 2

8.37	7920.	0.789	5.18	0.770	0.410	784.
12.72	7880.	1.193	5.64	0.818	0.535	1087.
16.89	7840.	1.575	6.22	0.838	0.626	1402.
20.85	7800.	1.934	6.88	0.845	0.690	1708.
24.60	7760.	2.270	7.58	0.845	0.734	2003.
31.46	7680.	2.874	9.05	0.837	0.785	2560.
37.47	7600.	3.388	10.53	0.824	0.809	3069.
42.68	7520.	3.817	11.97	0.807	0.819	3528.
47.12	7440.	4.170	13.35	0.790	0.820	3939.
50.85	7360.	4.452	14.65	0.772	0.816	4302.
53.95	7280.	4.672	15.87	0.754	0.809	4620.
56.49	7200.	4.838	17.02	0.737	0.799	4896.
60.15	7040.	5.037	19.08	0.704	0.777	5339.
62.30	6880.	5.098	20.88	0.672	0.753	5659.
62.94	6800.	5.091	21.69	0.657	0.740	5781.
63.33	6720.	5.062	22.44	0.642	0.728	5881.
63.54	6560.	4.958	23.79	0.614	0.704	6026.
63.17	6400.	4.809	24.96	0.587	0.680	6114.
60.74	6000.	4.335	27.31	0.524	0.627	6166.
57.34	5600.	3.819	29.03	0.468	0.582	6086.
53.73	5200.	3.323	30.34	0.417	0.545	5949.
50.22	4800.	2.867	31.34	0.369	0.513	5789.
46.97	4400.	2.458	32.14	0.326	0.486	5628.
44.00	4000.	2.093	32.78	0.285	0.464	5472.
38.89	3200.	1.480	33.75	0.213	0.427	5193.
34.72	2400.	0.991	34.44	0.149	0.400	4956.
31.27	1600.	0.595	34.96	0.093	0.378	4757.
28.31	800.	0.269	35.36	0.044	0.361	4590.
26.34	0.	-0.002	35.69	-0.000	0.346	4450.

ML NO. P I F SL RL. CURVE NO. SET

208 VOLTS (L-L)
400 CPS
65°C ON WIND
40 WATTS FRICT & WIND

PMA-R63-8
PG. 7

2.83	7960.	.266	4.81	.542	.213	369.
6.38	7920.	.601	5.00	.715	.348	626.
9.82	7880.	.920	5.29	.780	.462	880.
13.15	7840.	1.226	5.67	.809	.553	1130.
16.35	7800.	1.517	6.12	.823	.623	1374.
19.43	7760.	1.793	6.61	.829	.677	1612.
25.17	7680.	2.299	7.69	.828	.747	2070.
30.37	7600.	2.745	8.82	.819	.786	2499.
35.05	7520.	3.135	9.95	.806	.808	2899.
39.21	7440.	3.470	11.07	.791	.820	3268.
42.88	7360.	3.754	12.15	.775	.824	3609.
46.10	7280.	3.991	13.19	.759	.825	3920.
48.89	7200.	4.187	14.19	.743	.822	4202.
53.37	7040.	4.469	16.04	.711	.811	4688.
56.59	6880.	4.630	17.71	.680	.796	5079.
57.79	6800.	4.674	18.47	.665	.788	5243.
58.77	6720.	4.697	19.20	.650	.779	5388.
60.13	6560.	4.692	20.53	.622	.761	5627.
60.86	6400.	4.633	21.71	.594	.743	5809.
60.76	6000.	4.336	24.16	.532	.698	6080.
59.09	5600.	3.936	26.05	.475	.658	6178.
56.69	5200.	3.506	27.53	.423	.623	6176.
54.01	4800.	3.084	28.71	.375	.592	6119.
51.31	4400.	2.685	29.66	.331	.565	6035.
48.68	4000.	2.316	30.44	.291	.541	5936.
43.88	3200.	1.670	31.65	.217	.502	5729.
39.73	2400.	1.134	32.52	.152	.472	5531.
36.16	1600.	.688	33.18	.095	.448	5352.
33.01	800.	.314	33.69	.045	.428	5193.
30.84	0.	-.002	34.10	0.000	.411	5053.
				EFF	PF	SET

ML NO. P I F SL RL CURVE NO.

208 VOLTS (L-L) 20 TPC

400 CPS

3.5" OD PUNCHING

2 1/4" STACK

40 WATTS FRICT & WIND

125°C ON WINDING

PMA-R63-8
PG. 10

5.79	7840.	.540	4.60	.714	.358	564.
8.94	7801.	.830	4.89	.779	.474	794.
11.99	7761.	1.107	5.27	.809	.566	1020.
14.92	7722.	1.370	5.70	.823	.636	1242.
17.73	7682.	1.620	6.18	.829	.688	1457.
22.97	7603.	2.077	7.22	.828	.756	1871.
27.71	7524.	2.480	8.31	.819	.793	2258.
31.97	7444.	2.831	9.41	.806	.813	2620.
35.76	7365.	3.133	10.48	.791	.823	2954.
39.12	7286.	3.390	11.52	.775	.827	3261.
42.06	7207.	3.605	12.52	.759	.826	3541.
44.61	7128.	3.782	13.47	.743	.823	3796.
48.71	6969.	4.038	15.24	.711	.812	4235.
51.64	6811.	4.183	16.82	.680	.797	4588.
52.75	6732.	4.223	17.55	.665	.788	4736.
53.64	6652.	4.244	18.24	.650	.780	4867.
54.89	6494.	4.240	19.50	.622	.762	5083.
55.56	6336.	4.187	20.63	.595	.743	5249.
55.49	5940.	3.921	22.97	.532	.699	5494.
53.96	5544.	3.558	24.76	.475	.658	5581.
51.74	5148.	3.168	26.16	.423	.623	5576.
49.27	4752.	2.784	27.27	.376	.592	5522.
46.76	4356.	2.422	28.16	.332	.564	5440.
44.33	3960.	2.088	28.89	.291	.541	5346.
39.88	3168.	1.503	30.00	.217	.501	5150.
36.05	2376.	1.019	30.80	.153	.471	4964.
32.77	1584.	.617	31.40	.096	.446	4796.
29.88	792.	.281	31.87	.045	.426	4648.
27.90	0.	-.002	32.23	0.000	.409	4518.

ML NO. P I F SL RL CURVE NO. SET

197 VOLTS (L-L) 20 TPC

396 CPS

3.5" OD PUNCHING

2 1/4" STACK

40 WATTS FRICTION & WIND

-125°C ON WINDING

Rec'd 7/15/62

TMA-R63-8
Pg. 8

5.69	7999.	.542	4.44	.720		[illegible]
8.79	7958.	.832	4.75	.783	.487	792.
11.77	7918.	1.108	5.14	.812	.579	1018.
14.63	7878.	1.371	5.59	.825	.648	1239.
17.38	7837.	1.620	6.08	.830	.698	1455.
22.49	7756.	2.075	7.14	.829	.763	1867.
27.10	7676.	2.474	8.24	.819	.798	2252.
31.23	7595.	2.821	9.34	.806	.816	2610.
34.90	7514.	3.119	10.41	.791	.825	2941.
38.12	7433.	3.371	11.45	.775	.827	3244.
40.95	7352.	3.581	12.44	.758	.826	3520.
43.39	7272.	3.753	13.39	.742	.822	3770.
47.28	7110.	3.999	15.14	.710	.810	4198.
50.04	6948.	4.136	16.71	.679	.794	4540.
51.07	6868.	4.171	17.43	.664	.785	4682.
51.89	6787.	4.189	18.10	.649	.776	4808.
53.01	6625.	4.178	19.35	.621	.757	5013.
53.58	6464.	4.120	20.46	.594	.738	5168.
53.33	6060.	3.844	22.74	.531	.693	5391.
51.70	5656.	3.478	24.48	.475	.652	5459.
49.46	5252.	3.090	25.83	.423	.615	5441.
47.00	4848.	2.710	26.90	.376	.584	5377.
44.54	4444.	2.354	27.75	.332	.557	5288.
42.16	4040.	2.026	28.46	.291	.533	5189.
37.85	3232.	1.455	29.52	.217	.493	4987.
34.15	2424.	.934	30.28	.153	.463	4797.
30.99	1616.	.595	30.84	.096	.438	4627.
28.21	808.	.271	31.27	.045	.418	4473.
26.32	0.	-.002	31.61	0.000	.402	4347.

ML NO. P I F SL RL CURVE NO. SET

197 VOLTS (L-L) 20 TPC

404 CPS

7.5" OD PUNCHING

125°C ON WINDING

PMA-R63-8
Pg. 9

7.08	7840.	.650	5.70	.708	.523	697.
10.88	7801.	1.010	5.98	.772	.431	974.
14.57	7761.	1.345	6.33	.804	.521	1248.
18.13	7722.	1.665	6.76	.819	.593	1516.
21.56	7682.	1.970	7.23	.826	.649	1778.
27.98	7603.	2.530	8.30	.827	.726	2282.
33.82	7524.	3.027	9.45	.818	.772	2758.
39.09	7444.	3.461	10.62	.806	.797	3202.
43.80	7365.	3.837	11.78	.791	.811	3616.
47.98	7286.	4.159	12.91	.776	.818	3997.
51.67	7207.	4.429	14.00	.760	.821	4347.
54.88	7128.	4.653	15.05	.743	.820	4666.
60.07	6969.	4.980	17.01	.711	.811	5219.
63.85	6811.	5.172	18.78	.680	.798	5668.
65.29	6732.	5.228	19.60	.665	.790	5858.
66.47	6652.	5.260	20.37	.651	.782	6027.
68.17	6494.	5.266	21.80	.622	.765	6310.
69.14	6336.	5.210	23.07	.595	.748	6529.
69.34	5940.	4.899	25.73	.532	.705	6865.
67.71	5544.	4.465	27.79	.475	.666	7007.
65.22	5148.	3.993	29.42	.423	.632	7035.
62.37	4752.	3.525	30.73	.375	.602	6998.
59.44	4356.	3.080	31.81	.331	.575	6925.
56.59	3960.	2.665	32.70	.290	.552	6835.
51.31	3168.	1.933	34.10	.217	.514	6638.
46.67	2376.	1.319	35.13	.152	.484	6441.
42.64	1584.	.803	35.92	.095	.460	6257.
39.04	792.	.367	36.52	.045	.441	6091.
36.53	0.	-.002	37.01	0.000	.424	5942.

ML NO. P I F SL RL CURVE NO. SET

218 VOLTS (L-L) 20 TPC

396 CPS

3.5" OD PUNCHING

2 ¼" STACK

40 WATTS FRIC & WIND

125°C ON WINDING

PMA-R63-8
PG. 11

6.97	7999.	.663	5.44	.714	[illegible]	[illegible]
10.71	7958.	1.014	5.72	.779	.448	971.
14.33	7918.	1.350	6.10	.809	.539	1245.
17.82	7878.	1.670	6.56	.823	.610	1513.
21.17	7837.	1.973	7.06	.829	.665	1775.
27.43	7756.	2.531	8.16	.828	.738	2278.
33.11	7676.	3.023	9.33	.819	.780	2751.
38.21	7595.	3.452	10.51	.806	.803	3192.
42.76	7514.	3.822	11.68	.791	.815	3601.
46.78	7433.	4.136	12.81	.775	.821	3977.
50.31	7352.	4.400	13.90	.759	.822	4320.
53.37	7272.	4.616	14.94	.743	.820	4633.
58.28	7110.	4.929	16.88	.711	.810	5170.
61.80	6948.	5.107	18.63	.680	.795	5602.
63.12	6868.	5.156	19.43	.665	.787	5783.
64.18	6787.	5.181	20.18	.650	.778	5944.
65.67	6625.	5.175	21.58	.621	.761	6208.
66.45	6464.	5.109	22.82	.594	.742	6409.
66.35	6060.	4.782	25.39	.531	.698	6709.
64.58	5656.	4.344	27.39	.475	.658	6823.
62.01	5252.	3.873	28.96	.423	.623	6827.
59.13	4848.	3.410	30.21	.375	.592	6771.
56.22	4444.	2.971	31.23	.331	.566	6684
53.40	4040.	2.566	32.07	.290	.542	6582.
48.28	3232.	1.856	33.40	.217	.504	6373.
43.83	2424.	1.263	34.37	.152	.474	6170.
39.99	1616.	.768	35.11	.095	.450	5985.
36.58	808.	.351	35.69	.045	.431	5820.
34.22	0.	-.002	36.15	0.000	.415	5674.

ML NO.	P I F	SL	RL	CURVE NO.	SET

218 VOLTS (L-L) 20 TPC

404 CPS

3.5" OD PUNCHING

2¼" STACK

40 WATTS FRIC & WIND

125 °C ON WINDING

PMA-R63-8
Pg. 12

UNBALANCED MAGNETIC PULL

METHOD USED TO DETERMINE THE AVERAGE UNBALANCED PULL WAS OBTAINED FROM AN ARTICLE BY A. COVO TITLED "UNBALANCED MAGNETIC PULL IN INDUCTION MOTORS WITH ECCENTRIC ROTORS" FOUND IN "AIEE TRANSACTIONS PART III-B. POWER APPARATUS & SYSTEMS, 1954".

POLES = P = 6

DIA OF AVERAGE AIR GAP, INCHES = D = 2.115

STACK WIDTH = W = 2.125

AIR GAP = Δ = .010 INCHES

GAP FACTOR = K_1 = 1.325

B_m = 37,800 LINES/IN^2 AT NO LOAD
36,500 LINES/IN^2 AT FULL LOAD

AIR GAP FLUX DENSITY.

$$\cot \gamma = \frac{\text{AMP TURNS OF STEEL NO LOAD} - \text{AMP TURNS OF STEEL FULL LOAD}}{B_m \text{ NO LOAD} - B_m \text{ FULL LOAD}}$$

$$= \frac{36.1 - 27.4}{(37.8 - 36.5)\,10^{+3}} = \frac{8.7}{1,300} = .0067$$

$$A_{FE} = 3.19 \times .0067 = .0214$$

$$K_s = 1 + \frac{.0214}{1.325 \times .01} = 2.62$$

$$P_{AV} = \text{MAGNETIC PULL} = \frac{\pi D W}{72.13 \times 10^6} B_m^2 \, C_{AV}$$

$$= \frac{(\pi)(2.115)(2.125)}{72.13 \times 10^6} (36.5)^2 \, 10^6 = 260 \, C_{AV}$$

FOR AN ECCENTRICITY OF .002 OR $\delta = .002$

$$\frac{\delta}{\Delta} = \frac{.002}{.010} = .2$$

$$e = \frac{\delta}{K_s \Delta} = \frac{.2}{2.62} = .0762$$

C_{AV} = FIG 3 = .04

$P_{AV} = 260\ C_{AV} = (260)(.04) = 10.4$ LBS

FOR AN ECCENTRICITY OF .005 OR $\delta = .005$

$$\frac{\delta}{\Delta} = \frac{.005}{.010} = .5$$

$$e = \frac{.5}{2.62} = .182$$

$C_{AV} = .09$

$P_{AV} = (260)(.09) = 23.4$ LBS

FOR AN ECCENTRICITY OF .01 OR $\delta = .01$

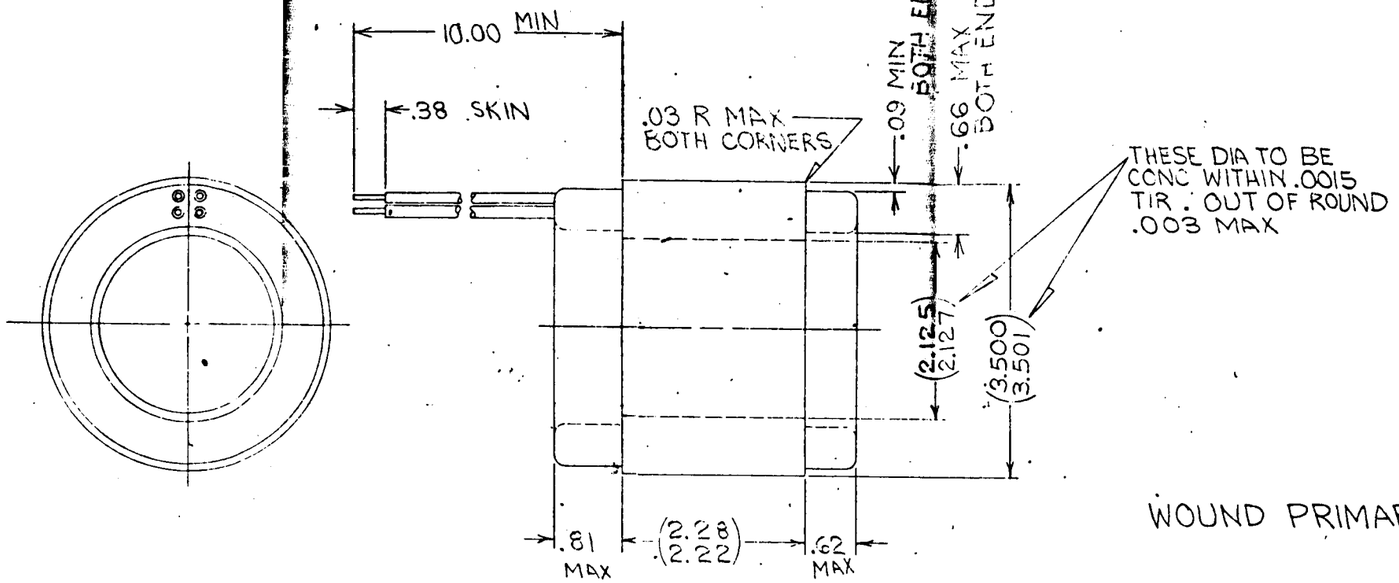
$$\frac{\delta}{\Delta} = \frac{.01}{.01} = 1$$

$$e = \frac{1}{2.62} = .383$$

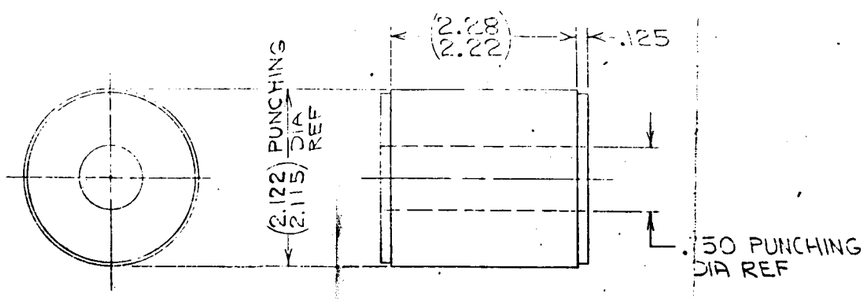
$C_{AV} = .21$

P.R. Moser

$P_{AV} = 260 \times .21 = 54.5$ LBS V 7-9-63



WOUND PRIMARY



RECOMMENDED GRIND OD - (2.106/2.104)

RECOMMENDED SHAFT DIM'S.
(.747/.748) DIA BEFORE FLUTE
(.756/.761) DIA AFTER FLUTE - NO REVERSE TAPER.

PMA-R63-8
Pg. 6

DFTM: JACK WREN 9-3-63	OUTLINE
ENG	ROTOR & PRIMARY
ENG	
	EDSK 299241

Thompson Ramo Wooldridge Inc.

SUBJECT: 253000 Radial Bkg Load Re-evaluation

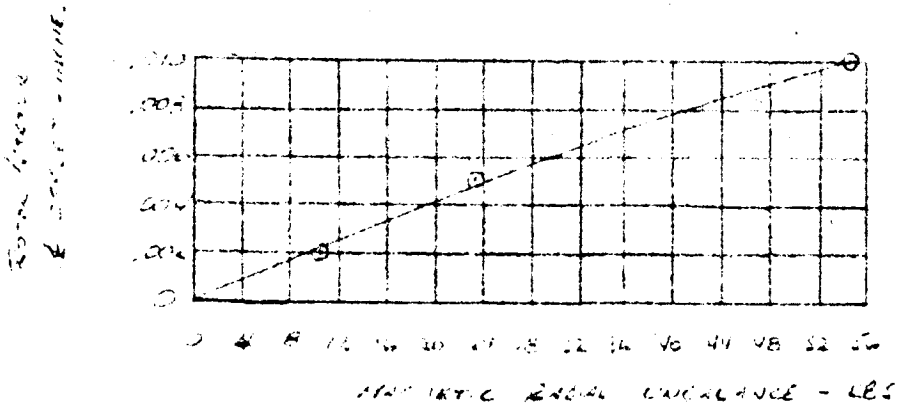
REPORT NO. PMA-R63-19 Supplement 1

Rotor/Stator Eccentricity

⊙ Stator I.D./Hsg. = .001
Brg Hsg O.D. To Pilot (Clear) = .003
⊙ Brgs To Pilot = .001
⊙ Rotor O.D. To Journals = .001
Clearance Shaft Journal To Brg. = .003
2 | .009
.0045 (Max ℄ Shift)

Stator I.D. 2.1255 ± .0005
Rotor O.D. 2.1055 ± .0005
2 | .0200 ± .001

Air Gap a
a result of size .010 ± .0005
± .0045
.010 ± .005 Max Possible "Air Gap" Variation



Thompson Ramo Wooldridge Inc.

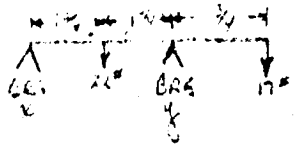
TRW

SUBJECT: Radial [illegible] Re-Evol Cont'd

REPORT NO. PMR-R[illegible]-17 SUPPLEMENT 1

For Max Loads:

Assume Max Rotor/Stator Eccentricity, Therefore Max Side Load = 22#
Impeller Radial Load = 17# (@ 0 Flow)



(For Max Magnetic & Radial Loads)

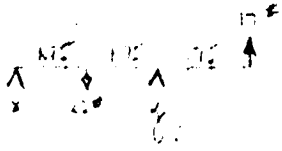
$\overset{\curvearrowright +}{\Sigma M_{x}}$ $22 \times 1.75 + 17 \times 4.25 - 3.5y = 0$

$35.5 + 72.3 = 3.5y$ $y = 31.7\#$ (↑)

$\overset{\curvearrowright +}{\Sigma M_{y}}$ $17 \times .75 - 22 \times 1.75 + 3.5x = 0$

$25.7 = 3.5x$ $x = 7.3\#$ (↑)

Check $22 + 17 = 39 = [illegible] = 39$



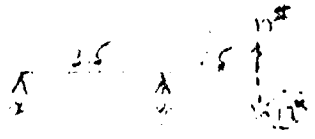
$\overset{\curvearrowright +}{\Sigma M_{x}}$ $22 \times 1.75 - 17 \times 4.25 - 3.5y = 0$

$-33.8 = 3.5y$ $y = -9.7\#$ (↓)

$\overset{\curvearrowright +}{\Sigma M_{y}}$ $-22 \times 1.75 - 17 \times .75 + 3.5x = 0$

$-35.5 - 12.7 + 3.5x = 0$ $x = 14.7\#$ (↑)

Check [illegible]



$\overset{\curvearrowright +}{\Sigma M_{x}}$ $\pm 17 \times 4.25 \mp 3.5y = 0$

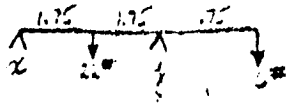
$y = +20.6\# - 20.6\#$ (↑ or ↓)

Check $17 = 20.6 - 3.6 = 17$

$\overset{\curvearrowright +}{\Sigma M_{y}}$ $\pm 17 \times .75 \mp 3.5x = 0$

$x = -3.6\#, +3.6\#$ (↓ or ↑)

Rated Conditions



$\overset{\curvearrowright +}{\Sigma M_{x}}$ $22 \times 1.75 + 6 \times 4.25 - 3.5y = 0$

$64 = 3.5y$ $y = 18.3\#$ (↑)

$\overset{\curvearrowright +}{\Sigma M_{y}}$ $-22 \times 1.75 + 6 \times .75 + 3.5x = 0$

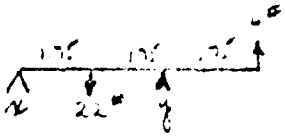
$34 = 3.5x$ $x = 9.7\#$ (↑)

Check [illegible] = 28 = 18.3 + 9.7 = 28

Thompson Ramo Wooldridge Inc.

SUBJECT: Radial Brg. Removal Cont'd. REPORT NO. PMA-[illegible]

Supplement 1



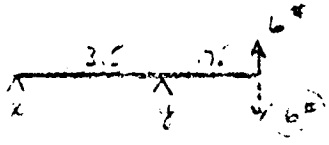
$\overset{\curvearrowright}{\Sigma M_x}$ $22 \times 1.75 - 6 \times 4.25 - 3.5y = 0$

$43 = 3.5y$ $y = 3.7^{\#}$ (↑)

$\overset{\curvearrowright}{\Sigma M_y}$ $-22 \times 1.75 - 6 \times .75 + 3.5x = 0$

$43 = 3.5x$ $x = 12.3^{\#}$ (↑)

CHECK $22 - 6 = 16 = 3.7 + 12.3 = 16$



$\overset{\curvearrowright}{\Sigma M_x}$ $\pm 6 \times 4.25 \mp 3.5y = 0$

$y = \pm 7.3^{\#}$ ↑ or ↓

$\overset{\curvearrowright}{\Sigma M_y}$ $\pm 6 \times .75 \mp 3.5 = 0$

$x = \mp 1.3^{\#}$ ↑ or ↓

CHECK $6 = 7.3 - 1.3 = 6$

SUMMARY

y BEARING (Imp. End) MAX LOAD = 31.7# (MAX MAG. + MAX RAD → 0 FLOW)
MIN LOAD = 3.7# (MAX MAG + MIN RAD → RATED)

x BEARING (Sensor End) MAX LOAD = 14.7# (MAX MAG + MAX RAD → 0 FLOW)
MIN LOAD = 1.3# (0 MAG + MIN RAD → RATED)

Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: Speed Sensor - PMA Sheet 8 REPORT NO. PMA R63-20

Attached Info, Data & Dwgs. Constitute Design Information Regarding Speed Sensor To Be Used For PMA.

Dwgs. Are Shown As SK Which Constitute "For Engineering Only". Final Drgs. Are Req'd Prior Fabrication.

Z-710 REV. PRINTED IN U.S.A.

V 82

(CLASSIFICATION)

PREPARED

CHECKED

INITIALS - DATE

Thompson Ramo Wooldridge Inc.
CLEVELAND, OHIO, U. S. A.
REPORT NO. ETM-666

DESIGN ANALYSIS

MAGNETIC PICKUP

TAPCO Operations has successfully designed and built several styles of magnetic pickups. Currently we are building pickups in large quantities for the Terrier Missile. The electrical design of these pickups has strictly been on a comparative basis, since the operation of a magnetic pickup with a rotating wheel does not lend itself to accurate computation. Certain theory and design criteria, however, have been developed in the state of the art which act as a guide in pickup and its associated wheel design. These shall be advanced here and I shall show how our present design is based on these criteria.

Basically, the magnetic pickup is as shown in Figure #1, a permanent magnet connected to a pole piece which is wound with a pickup coil around it.

The magnetic pickup will produce a voltage output when any magnetic material moves near the pole piece at the end of the pickup. The exciting material can be anything which is attracted by a magnet such as iron or steel. This includes all castings, bars, forgings, and sheet steel, with the exception of a few of the stainless steel alloys which are not magnetic.

Any device which produces a dynamic discontinuity of magnetic material in the field of the pickup will produce an electrical voltage based on the basic generated voltage equation $e = N \frac{d\phi}{dt}$

where: N = number of turns on pickup

and: $\frac{d\phi}{dt}$ = flux linkage change through coil with respect to time.

In our particular case this dynamic discontinuity is produced by a wheel with teeth similar to a gear.

With any given speed and clearance conditions, a maximum power output will result when the field is filled with a relatively infinite mass of magnetic material at one instant and a complete absence of such material at the next. A reasonable approach to these conditions exists when the cross section of the tooth is equal or greater than the pole piece and the space between the teeth is equal or greater than three times the pole piece. Also the height of the teeth should be equal to or greater than the diameter of the pole piece. Such large tooth gears are necessary only when maximum output is desired. A small toothed gear is usually satisfactory.

Thompson Ramo Wooldridge Inc.
CLEVELAND, OHIO, U. S. A.

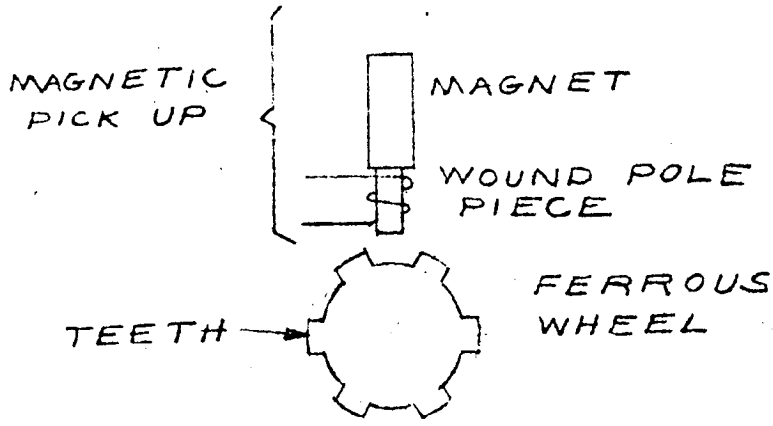


Figure # 1

In our particular pickup design the space limitations limited the size to 3/8" diameter and 1" in length. So our standard 5/8" x $1\frac{1}{32}$" high temperature pickup was merely scaled down. Materials will also be modified to meet radiation requirements. The output for our standard pickup with a 2 1/4" soft iron wheel with 16 teeth is as follows:

Cycles per Sec.	Voltage A-C
0	0
160	2.80
200	4.05
300	5.7
400	7.3
500	9.7
600	10.20
700	12.60
800	14.10
900	15.79
1000	17.47
1600	25.39

From this data it was predicted that the requirements of 15 M.V. at 160 cps would easily be met even with wheel size and pickup limitations.

A prototype wheel of 3/4" diameter with six teeth was machined out of 416 stainless steel and a 3/8" prototype pickup was made, and the following results were obtained:

CPS	RPM	Volts A-C
0	0	0
50	500	.075
100	1000	.163
160	1600	.244
200	2000	.305
300	3000	.455
400	4000	.558
500	5000	.713
600	6000	.850
700	7000	.964
800	8000	1.09
900	9000	1.23
1000	10,000	1.35
1100	11,000	1.47
1200	12,000	1.61
1400	14,000	1.80
1600	16,000	2.05

CONCLUSIONS

As can be seen from the results, the electrical output design objective has been met since the voltage output at 1600 RPM is 244 millivolts as compared to a minimum requirement of 15 millivolts.

TPFC-34 REV.

PAGE _____ OF _____

REPORT NO. _____

Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

ENGINEERING PROCESS

SPECIFICATION

TPE-PS- SK 1009

MAGNETIC PICKUP

Rev. Letter	Revision	Date

V 87

350°F MAGNETIC PICKUP

1.0 Vapor degrease or wash pole piece SK1002 and magnet SK1003 with methyl-ethyl ketone.

1.1 Mix 10 gm of Shell Epon Adhesive 901 per drawing 206729-1 and 1.09 gm of Shell Epon Curing Agent B-3 per drawing and blend uniformly.

1.2 Apply a thin coating of adhesive (approximately .005") to adjoining sides of pole piece and magnet.

1.3 Assemble into holding fixture making sure magnet and pole piece are concentric.

1.3.1 Apply 5 - 10 pounds force to pole piece and magnet while curing adhesive.

1.3.2 Cure: 0.5 hr. at 240°F
1.5 hr. at 350°F

2.0 Pole, Magnet and Coil

2.1 Insert back washer SK1001 per sketch 2.4.1.

2.2 Insert front washer SK1000 per sketch 2.4.1.

2.3 Assemble pole piece and magnet with washers in place into winding fixture.

2.4 Level wind one layer of glass roving 206358 on magnet and pole piece and fill the gap between the back washer and the magnet with roving per sketch 2.4.1. Leave 3/16" on back of magnet (free of) roving for chucking magnet into fixture. Cure for 1 hour at 350°F.

3.0 Wind coil per assembly drawing SK1006

3.1 Make solder connection of magnet wire to lead wire using solder QQ-S-571 SN10-W-AR-P2 FR. 94244-26 per sketch 3.1.1.

3.2 Secure magnet wire and lead wire with one wrap of Hold Down Tape per sketch 3.1.1.

3.3 Assemble unit back into winding fixture and wind 4 turns of glass roving 206358 on to magnet assembly at the solder connection. This is to hold lead wires while level winding assembly to 5/8" dimension.

TPFC 34 REV.

3.4 Remove tape holding magnet wire and lead wire.

3.5 Level wind glass roving 206358 evenly on to assemble and over the washer holding fixture per sketch 3.1.1.

3.6 Place assembly in an oven at 350°F for a period of one (1) hour.

4.0 After assembly has cured per para. 3.6, machine to print SK 1006

5.0 Assembly of magnet assembly into housing and end cap (insert SK 1004.

5.1 Mix 10 gm of Shell Epon Adhesive 901 per drawing 206729-1 and 1.09 gm of Shell Epon Curing Agent 15-3 per drawing 206729-2 and blend uniformly.

5.2 Apply approximately .005" of adhesive to body of magnet assembly and insert 206264. SK 1009

5.3 Press insert SK 1004 into magnet assembly.

5.4 Place insert end of magnet assemble into the coil end of housing SK 1007 and press until insert is flush with housing and oriented per sketch 5.4.1.

5.5 Place assembly into oven at a temperature of 250°F for 1 hour.

5.6 Raise temperature of oven to 350°F and let assembly cure for an additional 1 hour.

5.7 Remove assembly from oven and let cool to room temperature.

5.8 Dip coil end of assembly into Dupont type RK-692 varnish and draw a vacuum of 20 inches of mercury for 10 minutes.

5.9 Release vacuum.

6.0 Final cure.

6.1 Cure assembly at 250°F for 1 hour and 350°F for 1.5 hours.

7.0 Magnetize pickups.

7.1 Place shorting bars ED 976-5 on magnetizing fixture in the position as shown in sketch 7.1.1.

7.2 Place pickup between shorting bars.

7.3 Turn the variac in a clockwise direction until 8 amps is read on the meter of ED 975, then turn variac slowly counter clockwise until meter reads zero.

7.4 Repeat 7.3 two times.

7.5 Pickups are to be stored with some separation between individual units.

Prepared by: M. C. STELMACH Date _____

Engineering Approved by _____ Date _____

Quality Approved by _____ Date _____

Process Engineering Approved _____ Date _____

11/26/62

mf

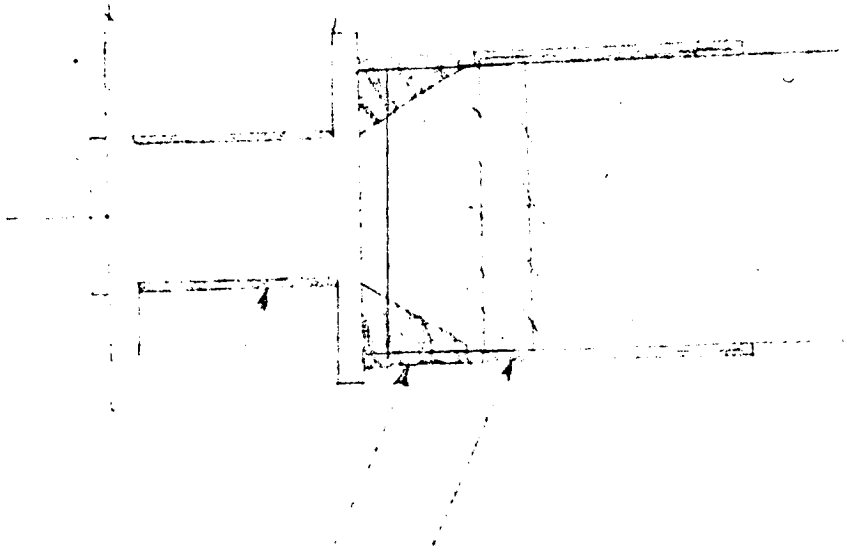
REPORT NO.

Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U S A

SKETCH 241

SK 1000 SK 1001

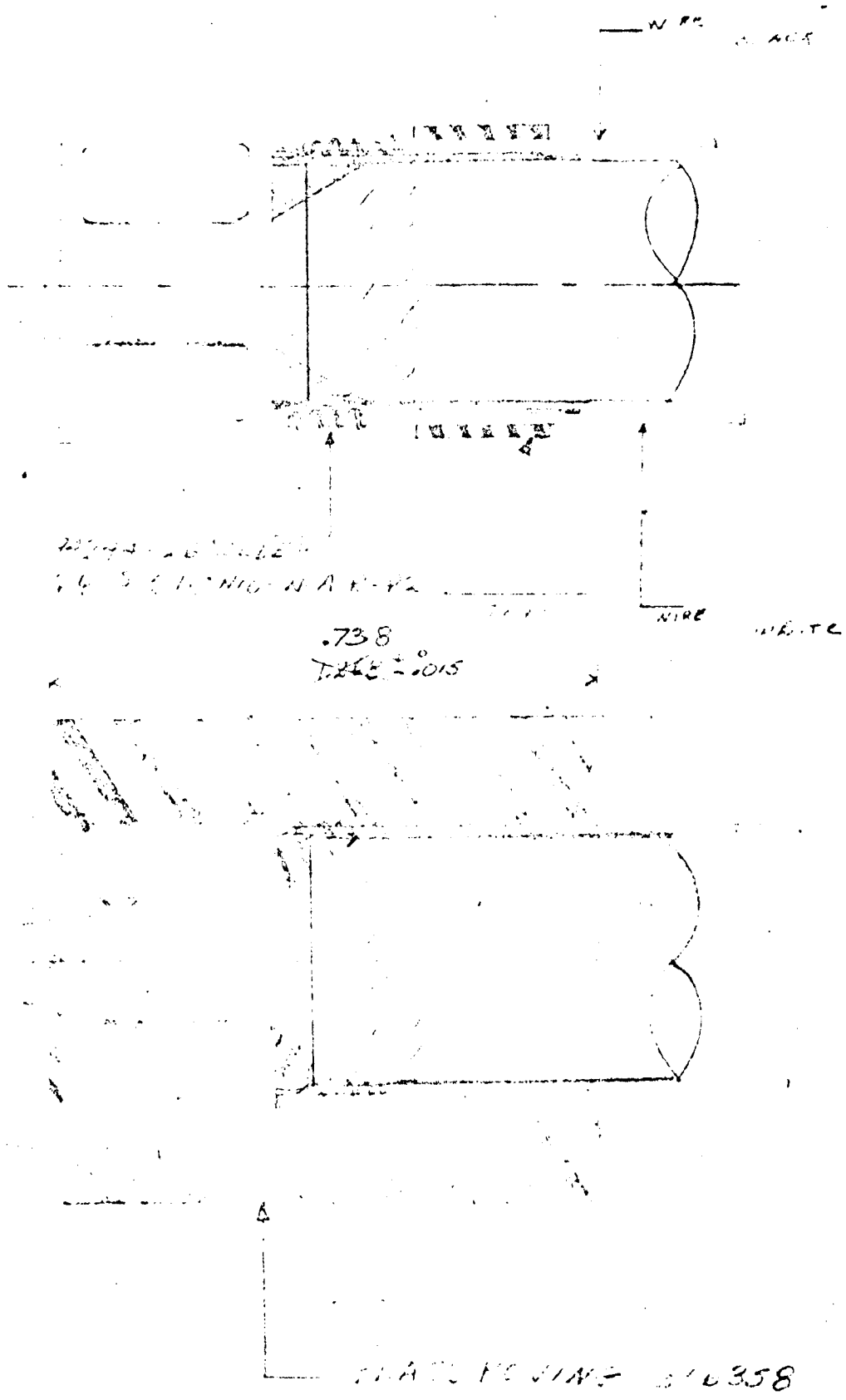


SINGLE LAYER
206358

SINGLE LAYER
206358

FILL WITH
206358

3.1.1

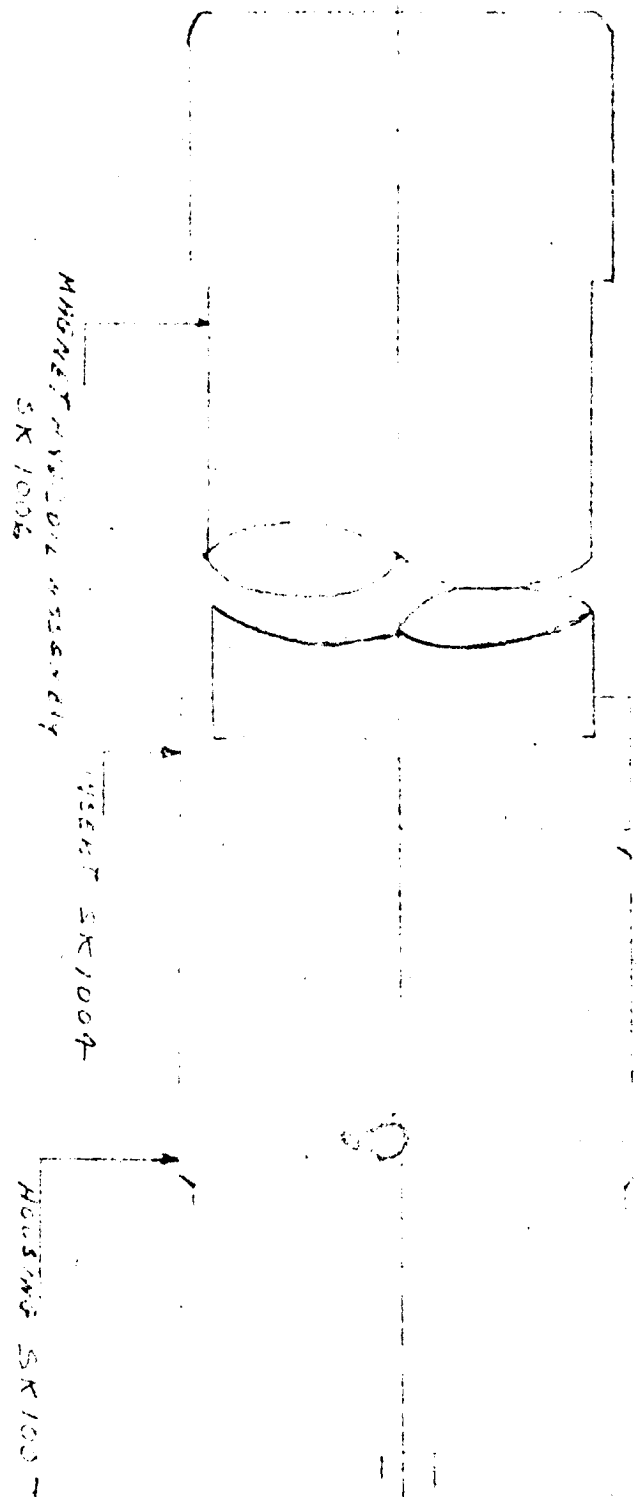


Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

REPORT NO. PR-463-10

5.4.1



OR EXCITATION FOR ASSEMBLY OF MAGNET AND COIL ASSEMBLY TO HOUSING

Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

REPORT NO. PMA-RCS-20

ENGINEERING PROCESS

SPECIFICATION

TPE-PS- SK 1009

MAGNETIC PICKUP

Rev. Letter	Revision	Date

V 94

TPE-34 REV

350°F MAGNETIC PICKUP

1.0 Vapor degrease or wash pole piece SK1002 and magnet SK1003 with methyl-ethyl ketone.

1.1 Mix 10 gm of Shell Epon Adhesive 901 per drawing 206729-1 and 1.09 gm of Shell Epon Curing Agent B-3 per drawing and blend uniformly.

1.2 Apply a thin coating of adhesive (approximately .005") to adjoining sides of pole piece and magnet.

1.3 Assemble into holding fixture making sure magnet and pole piece are concentric.

1.3.1 Apply 5 - 10 pounds force to pole piece and magnet while curing adhesive.

1.3.2 Cure: 0.5 hr. at 240°F
1.5 hr. at 350°F

2.0 Pole, Magnet and Coil

2.1 Insert back washer SK1001 per sketch 2.4.1.

2.2 Insert front washer SK1000 per sketch 2.4.1.

2.3 Assemble pole piece and magnet with washers in place into winding fixture.

2.4 Level wind one layer of gloss roving 206358 on magnet and pole piece and fill the gap between the back washer and the magnet with roving per sketch 2.4.1. Leave 3/16" on back of magnet (free of) roving for chucking magnet into fixture. Cure for 1 hour at 350°F.

3.0 Wind coil per assembly drawing SK1006

3.1 Make solder connection of magnet wire to lead wire using solder QQ-S-571 SN10-W-AR-P2 FR. 94244-26 per sketch 3.1.1.

3.2 Secure magnet wire and lead wire with one wrap of Hold Down Tape per sketch 3.1.1.

3.3 Assemble unit back into winding fixture and wind 4 turns of glass roving 206358 on to magnet assembly at the solder connection. This is to hold lead wires while level winding assembly to 5/8" dimension.

3.4 Remove tape holding magnet wire and lead wire.

3.5 Level wind glass roving 206358 evenly on to assemble and over the washer holding fixture per sketch 3.1.1.

3.6 Place assembly in an oven at 350°F for a period of one (1) hour.

4.0 After assembly has cured per para. 3.6, machine to print SK 1006

5.0 Assembly of magnet assembly into housing and end cap (insert SK 1004.

5.1 Mix 10 gm of Shell Epon Adhesive 901 per drawing 206729-1 and 1.09 gm of Shell Epon Curing Agent 15-3 per drawing 206729-2 and blend uniformly.

5.2 Apply approximately .005" of adhesive to body of magnet assembly and insert 206264. SK 1009

5.3 Press insert SK 1004 into magnet assembly.

5.4 Place insert end of magnet assemble into the coil end of housing SK 1007 and press until insert is flush with housing and oriented per sketch 5.4.1.

5.5 Place assembly into oven at a temperature of 250°F for 1 hour.

5.6 Raise temperature of oven to 350°F and let assembly cure for an additional 1 hour.

5.7 Remove assembly from oven and let cool to room temperature.

5.8 Dip coil end of assembly into Dupont type RK-692 varnish and draw a vacuum of 20 inches of mercury for 10 minutes.

5.9 Release vacuum.

6.0 Final cure.

6.1 Cure assembly at 250°F for 1 hour and 350°F for 1.5 hours.

7.0 Magnetize pickups.

7.1 Place shorting bars ED 976-5 on magnetizing fixture in the position as shown in sketch 7.1.1.

Thompson Ramo Wooldridge Inc.

CLEVELAND, OHIO, U. S. A.

REPORT NO.

7.2 Place pickup between shorting bars.

7.3 Turn the variac in a clockwise direction until 8 amps is read on the meter of ED 975, then turn variac slowly counter clockwise until meter reads zero.

7.4 Repeat 7.3 two times.

7.5 Pickups are to be stored with some separation between individual units.

Prepared by: M. C. STELMACH Date

Engineering Approved by Date

Quality Approved by Date

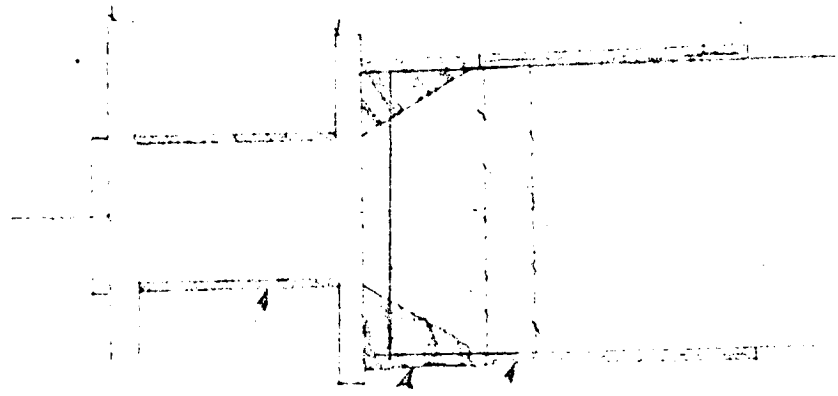
Process Engineering Approved Date

11/26/62

mf

SKETCH 241

SK 1000 SK 1001



SINGLE LAYER
206358

SINGLE LAYER
206358

FILL WITH
206358

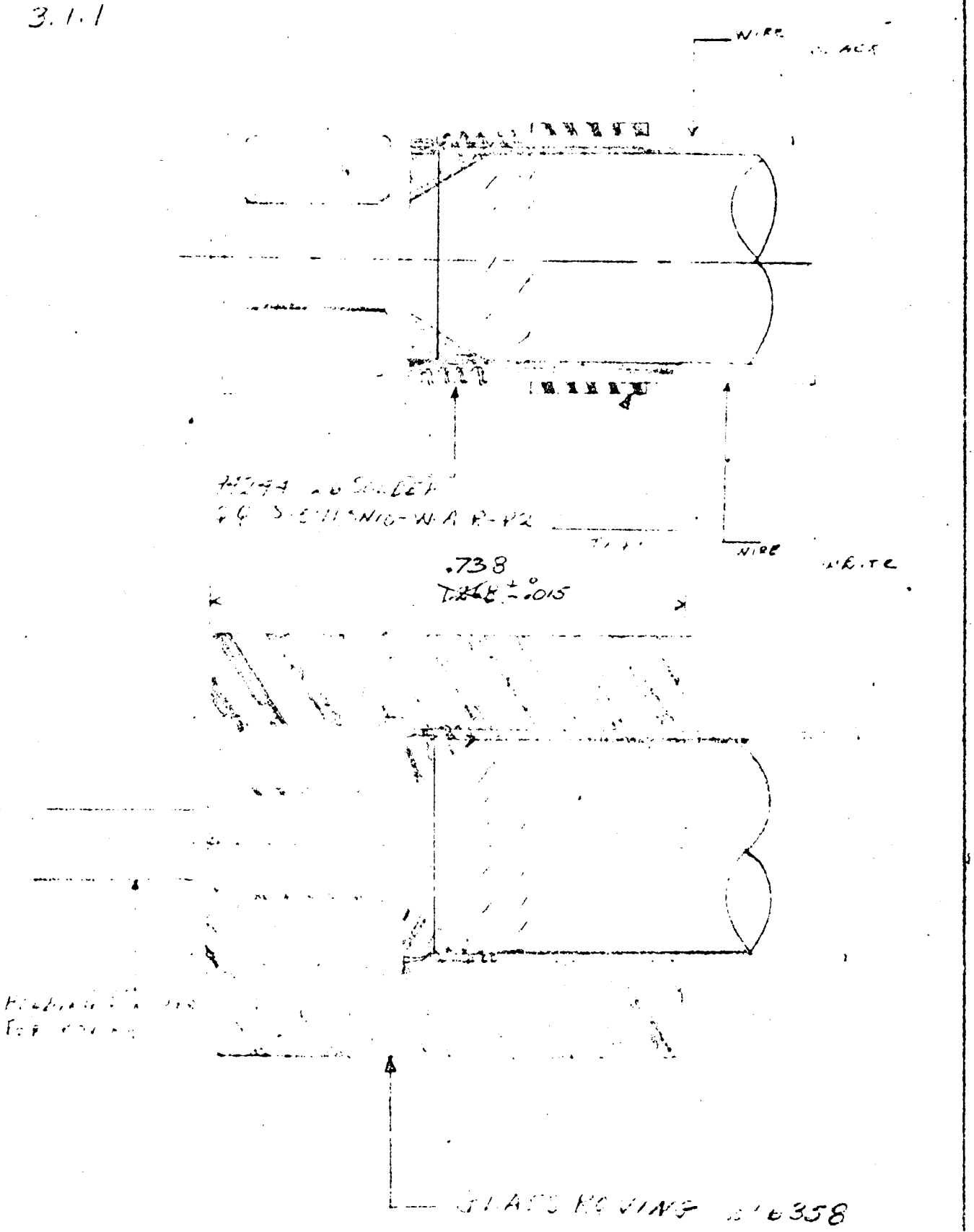
V 98

Thompson Ramo Wooldridge Inc.

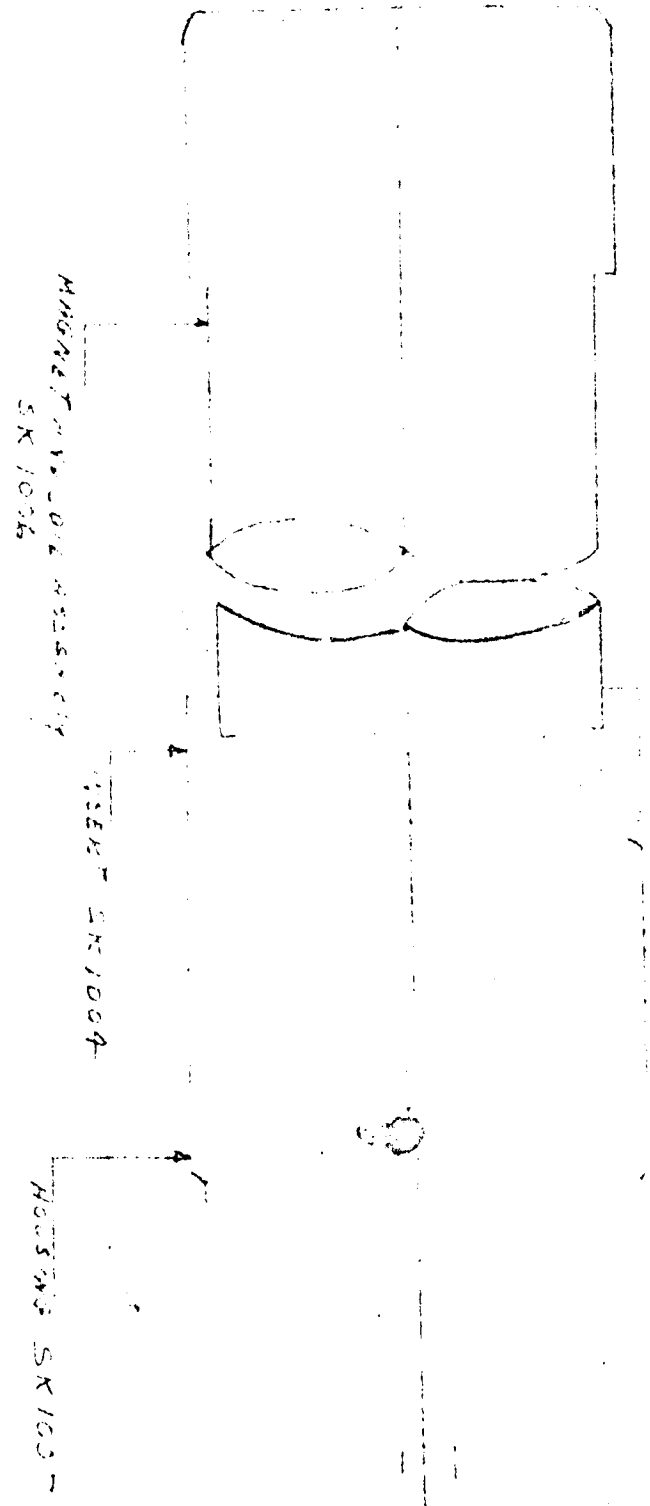
CLEVELAND, OHIO, U. S. A.

REPORT NO. PMA-163-20

3.1.1



5.4.1



DIMENSION FOR ASSEMBLY OF MAGNET AND COIL ASSEMBLY TO HOUSING

SNAP-8 ELECTRICAL CONNECTOR DESIGN SUMMARY

The tenative selection of the SNAP-8 Lubrication and Coolant Pump electrical connector is a ceramic hermetically sealed jam nut type receptacle manufactured by the Scintilla Division of Bendix Corporation, Sidney, N.Y.

The ceramic insert of the hermetic seal is made of an unglazed high density alumina ceramic (95% nominal aluminum oxide, Al_2O_3). The ceramic is not glazed because Bendix has found a deterioration of electrical characteristics at 1000°F. Their work with unglazed ceramic inserts over the past 6 to 8 years indicates no problem with unglazed ceramic. They also note that their ceramic material is not hydroscopic.

The contacts are made from an "A" nickel alloy and gold plated to a minimum thickness of 100 micro-inches. The motor lead contacts are #16 in size and are capable of carrying the necessary 8 amperes continuous and 20 amps starting currents required by the pump-motor assembly. This rating has been established by tests conducted at Bendix on a connector with #16 contacts in an ambient of 350°F. The contacts are welded to a diaphragm sleeve of Kovar (a Ni-Fe-Co alloy) which is in turn, copper brazed to the ceramic insert. The purpose of the diaphragm is to equalize the difference in thermal expansion between the "A" nickel contacts and the ceramic insert. The thermocouple lead contacts (#16 or #20) and the speed sensor lead contacts (#26) will be fitted with adaptors. This item is under discussion with the vendor at the present time.

The connector shell will be made of 316 stainless steel and will be welded or brazed to a 0.060 baffle by the vendor to preclude damage to the hermetic seal. The baffle will then be seal welded to the pump-motor assembly. The shell O.D. will be threaded and fitted with a jam nut. The ceramic insert will be heliarc welded to the shell. Metallizing on the connector will be moly-manganese.

The connector will be leakage checked at 10^{-9} cc/sec. on a go-no-go arrangement per MIL-C-26482 using a VEECO or similar arrangement.

Material compatibility, particularly with respect to the Kovar alloy, which contains cobalt is under study at the present time.

It should be noted that both ceramic and boron-free glass hermetic inserts have been considered in TRW's evaluation of the problem. It is our opinion that the ceramic hermetic insert connector is justified on the basis of materials, constructional details and the vendor's experience with the design.

MOTOR HOT SPOT TEMPERATURE & LOCATION

Westinghouse, the motor supplier, has advised that their analysis indicates the motor hot spot temperature will be located within the motor end turns. They are of the opinion that there will be less circulation of "coolant" fluid in this area as compared to the stator slots due to the proximity of the wires to each other thereby creating a virtual solid end turn. The Westinghouse calculations for the expected hot spot temperature are attached.

RECEIVED
OCT 15 1963
TSPC I & E
Purch. & Serv. Admin.

HEAT TRANSFER CALCULATIONS

1.48 HP, 6-Pole, A-C Motor
Thompson Ramo Wooldridge P.O. 08-52-901
Westinghouse General Order CLD-23210

Calculations have been made which demonstrate that the winding hot spot temperature will not exceed 200°C.

The motor is cooled by passing polyphenyl ether Dow Corning ET-378 through the motor and through a hollow frame at a total rate of .4 gallons per minute flowing in an axial direction. Of this total flow, .2 gpm flows through the air gap and the other .2 gpm flows through the hollow frame. The fluid enters at 260°F and leaves at 280°F.

A thorough and accurate analysis of heat transfer within this motor would require data on heat transfer coefficients which are not readily available. It would also require dimensions of the cooling ducts in the frame. In this case, it is considered entirely adequate to demonstrate by calculation that heat transfer in the air gap will remove the major portion of the losses without an excessive temperature rise. The required calculations are as follows:

Fluid Temperature Rise

.4 gpm is equivalent to 211 $\frac{\text{lb.}}{\text{hr.}}$

Total electrical loss is 195 watts, or 666 $\frac{\text{Btu}}{\text{hr.}}$

C_p for ET-378 is .4 $\frac{\text{Btu}}{\text{lb.-°F}}$

°F rise in oil from electrical losses

$$= \frac{666 \ \text{Btu/hr.}}{.4 \ \frac{\text{Btu}}{\text{lb.-°F}} \ 211 \ \frac{\text{lb.}}{\text{hr.}}} = 7.9°\text{F}$$

The 20°F differential (280°F out - 260°F in) specified by TRW appears to include an adequate allowance for friction and turbulence in the fluid.

Stator Heat Transfer

Electrical losses in the stator consist of 80 watts I^2R loss in the windings, 55 watts iron loss, plus an unknown portion of 25 watts total stray load loss. In order to demonstrate adequate cooling, the pessimistic assumption is made that 130 watts of this total must be removed from the stator bore.

The rotor speed, plus the roughness factor of the stator slots, will certainly result in turbulence and improved heat transfer in the air gap, but another pessimistic assumption will be made and the flow will be considered laminar. In laminar flow, the heat transfer is entirely by conduction, and an average conduction path length of .004 inch seems reasonable in a .012 inch air gap.

The total heat transfer area in the stator bore is 14.85 inches, of which about 50% is insulating material (slot wedges), leaving 7.42 inches active heat transfer area.

The conductivity of ET-378 is $.0068 \frac{\text{Btu}}{\text{in.-°F-hr.}}$

The calculated temperature rise from the fluid to the stator I.D. is:

$$°\text{F Rise} = \frac{130 \text{ watts } (3.41 \frac{\text{Btu}}{\text{watt-hr.}})(.004 \text{ in.})}{7.42 \text{ in.}^2 \ (.0068 \frac{\text{Btu}}{\text{in.-°F-hr.}})} = 35°\text{F}$$

Rotor Heat Transfer

Electrical losses in the rotor consist of 80 watts I^2R loss in the copper, 5 watts core loss, and an unknown portion of the 25 watts total stray load loss. The temperature rise in the rotor will be less than the rise in the stator because there is less heat with twice as much effective heat transfer surface at the air gap (no insulating wedges).

Stator Winding Hot Spot Temperature

The hot spot temperature will be less than 20°F hotter than the stator bore sufface temperature, based on comparison to other motors of similar size and rating.

Hot Spot Total Temperature

The calculated hot spot temperature, based on pessimistic calculations, is 335°F. This is well below the 200°C (392°F) maximum allowable temperature.

280°F	oil out
35°F	surface to fluid
20°F	hot spot temperature
335°F	hot spot temperature

L. C. Carter

AED Equipment Systems Engrg. - L. C. Carter

LCC:fs

Thor Vindersen
Quality Assurance
Reliability

March 31, 1964

F-64-204

Aerojet-General Corporation
Post Office Box 296
Azusa, California

Attention: Mr. L. Z. Miner,
Subcontract Administrator

Subject: Contract OP-359790,
Transmittal of Data

Dear Mr. Miner:

In accordance with the requirements of the subject contract we are submitting herewith ten (10) copies of the motor test data for the 208210 (SN-1) Stator (208210 Stator and 208210 Rotor Assembly form Motor for 253800-1 L/C PMA). This data was submitted by the motor supplier, Westinghouse Electric Corporation.

It should be noted that this data was obtained with an "undersized" Stator I.D. and Test Rotor O.D. since the Stator was shipped to TRW with stock on the I.D. for subsequent machining. Westinghouse has stated the difference in performance with the final size should be insignificant.

If you require additional information, please feel free to contact the undersigned at your convenience.

Very truly yours,

TRW ELECTROMECHANICAL DIVISION

ORIGINAL SIGNED BY

M. K. Boggins
Contract Administrator

MKB/pr

Enclosures (10)

TEST RECORD
WESTINGHOUSE FORM 2500E 5-57

THE SPACE ABOVE THIS LINE IS FOR FILING AND MUST NOT BE WRITTEN ON

K 1662427

SUBJECT 1.48 HP. 208V. 7830 RPM. 3Ø 400~ A.C. MOTOR PARTS

CUSTOMER THOMPSON-RAMO-WOOLDRIDGE P/N 959C547-1 SERIAL NO. #1

S. O. OR TEST NO. F3-349 D. OR L. SPEC. NO. E6E-55 SHAFT NO. CY 18369 FRAME NO. 3.5" O.D.

TO DETERMINE VERIFICATION OF DESIGN (DYNA #8 SCALES #111

PARA. 5

VOLTS	1-2	208	208	208	208		208
A-1	CIRS X 2	2.45	2.72	3.34	4.39	X4	3.47
A-2	X 2	2.48	2.79	3.42	4.47	X4	3.49
A-3	X 2	2.48	2.78	3.38	4.47	X4	3.60
W-1	S/100 X 4	8	67	123	192	X8	164
W-2	X4	12	72	128	201	X8	166
W-3	X4	14	75	132	203	X8	168
W-N	LOSS -8	128	848	1524	2376		3976
RPM	C.W.	8000	7913	7833	7722		7436
TORK	OZ.FT.	0	9.8	19.2	30		49.0
FREQ		400	400	400	400		400
Top MDG.	°C	38	39.5	42	42		46

VOLTS	1-2	218	218	218	218		218
A-1	CIRS X 2	2.77	2.89	3.19	3.63	X4	3.22
A-2	X 2	2.8	2.96	3.26	3.72	X4	3.26
A-3	X 2	2.81	2.96	3.26	3.72	X4	3.25
W-1	S/100 X4	10	51	95	137	X8	157
W-2	X4	14	56	100	143	X8	160
W-3	X4	17	60	105	148	X8	159
W-N	S/1 LOSS 8.96	156	659	1191	1703		3799
RPM	C.W.	7900	7862	7828	7754		7446
TORK	OZ.FT	0	7.0	14.5	21.4		48
FREQ		396	396	396	396		396
Top MDG.	°C	38	38	38	40		42

RPM. HEWLETT-PACKARD S/N 2642
FREQ " " " S/N 120-04583

SEE PAGE K 168 2420 FOR METERS USED

V 102

PREVIOUS TEST PAGE 3-4-64 DATE N. WISE - B. SPRINGER SIGNED P.R. MOSER ENGINEER IN CHARGE

THE SPACE ABOVE THIS LINE IS FOR FILING AND MUST NOT BE WRITTEN ON K 1662428

SUBJECT 1.48HP 208V 7800RPM. 3Ø400~AC MOTOR PARTS

CUSTOMER THOMPSON-RAMO-WOOLDRIDGE P/N 959C547-1 SERIAL NO. #1

S. O. OR TEST NO. F3-349 D. OR L. SPEC. NO. E6F-5J SHAFT NO. CY18359 FRAME NO. 3.5" O.D.

TO DETERMINE VERIFICATION OF DESIGN DYNA #8 SCALE #111

PARAS.							
VOLTS	1-2 CIRS	197	197	197	197		197
A-1	X2	2.16	2.44	2.83	3.62	X4	2.87
A-2	X2	2.2	2.51	2.92	3.68	X4	2.87
A-3	X2	2.18	2.49	2.89	3.68	X4	2.87
W-1	6/100 X4	7	61	96	147	X8	128
W-2	X4	11	65	100	153	X8	129
W-3	X4	12	67	103	154	X8	131
W-N	LOKS 7.26	112	764	1188	1808		3096
RPM		8050	7997	7940	7860		7605
TORK		0	8.8	14.6	22.5		38.1
FREQ		404	404	404	404		404
TOP WDG.	°C	38	40	40	42		45

K 1662427 — PREVIOUS TEST PAGE

3-4-64 — DATE

N. WISE - B. SPRINGER — SIGNED

P.R. MOSER — ENGINEER IN CHARGE

TEST RECORD
WESTINGHOUSE FORM 2809E BODY

I.R. 68-52901-B-01
1662415

THE SPACE ABOVE THIS LINE IS FOR FILING AND MUST NOT BE WRITTEN ON

SUBJECT 1.48 HP 208 V. 7800 RPM 3Ø 400~ A-C MOTOR PARTS

CUSTOMER THOMPSON-RAMO-WOOLDRIDGE P/N 959C547-1 CERTIF. NO. 182

S. O. OR TEST NO. E3-349 SK. OR L. SPEC. NO. ML675498 SHAFT NO. ELF-55-CY18359 FRAME NO. 3.5" O.D.

TO DETERMINE VERIFICATION OF DESIGN DYNA #8 SCALE # 111

STATOR WEIGHT								STATOR WEIGHT					
	#2	3 LB.	7½ OZ					#1	3 LB.	7½ OZ			
			RES. @		24°C (KELVIN BRIDGE S/N #31394)								
T1 -	T2	-	1.0558	Ω			T1 -	T2	-	1.0501	Ω		
T1 -	T3	-	1.0553	Ω			T1 -	T3	-	1.0500	Ω		
T2 -	T3	-	1.0505	Ω			T2 -	T3	-	1.0502	Ω		
T1 -	T0	-	.5529	Ω			T1 -	T0	-	.5525	Ω		
T2 -	T0	-	.5533	Ω			T2 -	T0	-	.5529	Ω		
T3 -	T0	-	.5528	Ω			T3 -	T0	-	.553	Ω		
		N.L.	F.L.		N.L.			N.L.	F.L.				
VOLTS	CIR 300 1-2	208	208		208			208	208				
A-1	CIR 5 X2	2.29	3.45	X2	2.28		X2	2.53	3.41				
A-2	X2	2.28	3.38	X2	2.3		X2	2.58	3.47				
A-3	X2	2.43	3.56	X2	2.44		X2	2.62	3.5				
W-1	51/100 X2	78	274	X2	28		X2	18	253				
W-2	X2	67	260	X2	14		X2	23	259				
W-3	X2	88	284	X2	36		X2	32	272				
WN	LOSS -9	157	1627		147		LOSS -9	137	1559				
RPM	CW	7925	7816		7980		CW	7990	7841				
TORK	OZ-FT	0	19.2		0			0	19.2				
FREQ.		400	400		400			400	400				
S/N		2	2		2			1	1		VOLT	18026	
TOP WDG.T.		49°C	52°C		40°C			35°C	40°C		A-1	10285	
											A-2	10293	
FORCED COOLING AIR USED											A-3	11351	
											W-1	14754	
											W-2	14756	
GROUND CHECKED @ 1800 60~ FOR 1 SEC. O.K.											W-3	13854	

REPUN

Complete test on other sheet

HEWLETT-PACKARD COUNTER FOR FREQ. S/N 120-01603 MODEL 521A
HEWLETT-PACKARD COUNTER FOR RPM S/N 120-05118 MODEL 521A

PREVIOUS TEST PAGE — DATE 2-20-63 — SIGNED BARRY-LAMMERS — ENGINEER IN CHARGE P.R. MOSER

Westinghouse Electric Corporation
Aerospace Electrical Division

I.R. 08-52901B-01

INSPECTION CHECK LIST

Drawing Number 940D523 Rev. None Change Document No. _____

Part Name Primary, Wound Ser. No. 2 Shop Order CY 18359

MERTZ

Characteristic	Insp. Method	Remarks	Insp. Stamp & Date
Check winding and insertion of			
thermocouples per 940D523	Visual		W 18 2/15/64
1.000/1.250	Scale		W 18 "
Test for shorts between phases			
per Its. 472418-1	Hi-voltage supply	OK NG	2/15/64
Check welding of leads per			
928A234	Visual		W 18 2/15/64
Test per Its. 472418-1	Surge & Hi Voltage Supply	OK NG	W 18 2/15/64
13 in. Min.	Scale	Ins. (960C509-1) P.O. 381361	W 18 "
30°	Protractor	Lot No. 2	W 18 "
60°	Protractor	Ins. (960C509-2) P.O 381361	W 18 "
10° Typ	Protractor	Lot No. 2	"
Check dip and bake per 928A210	Visual	Lot No. Ins. (960C509-3) P.O. 381361 2	W 18 "
3.500/3.501	Gage Bl. Comp.	Wedge (945B822-1) P.O. 381276	W 18 2/20/64
2.105/2.111	Intramics	Lot No. 1	W 18 "
62 Max. WC	Scale	Lead (945B942-1) P.O. 39D 381359	W 18 2/18/64
81 Max	Scale	Lot No 1	W 18 "

*Out of Tolerance
**Dim. to be Recorded

W AED Inspector W 18 Date 2/20/64

Customer Inspector _____ Date _____

Government Inspector _____ Date _____

AED-1452-PA

I.R. 08-52901B-01

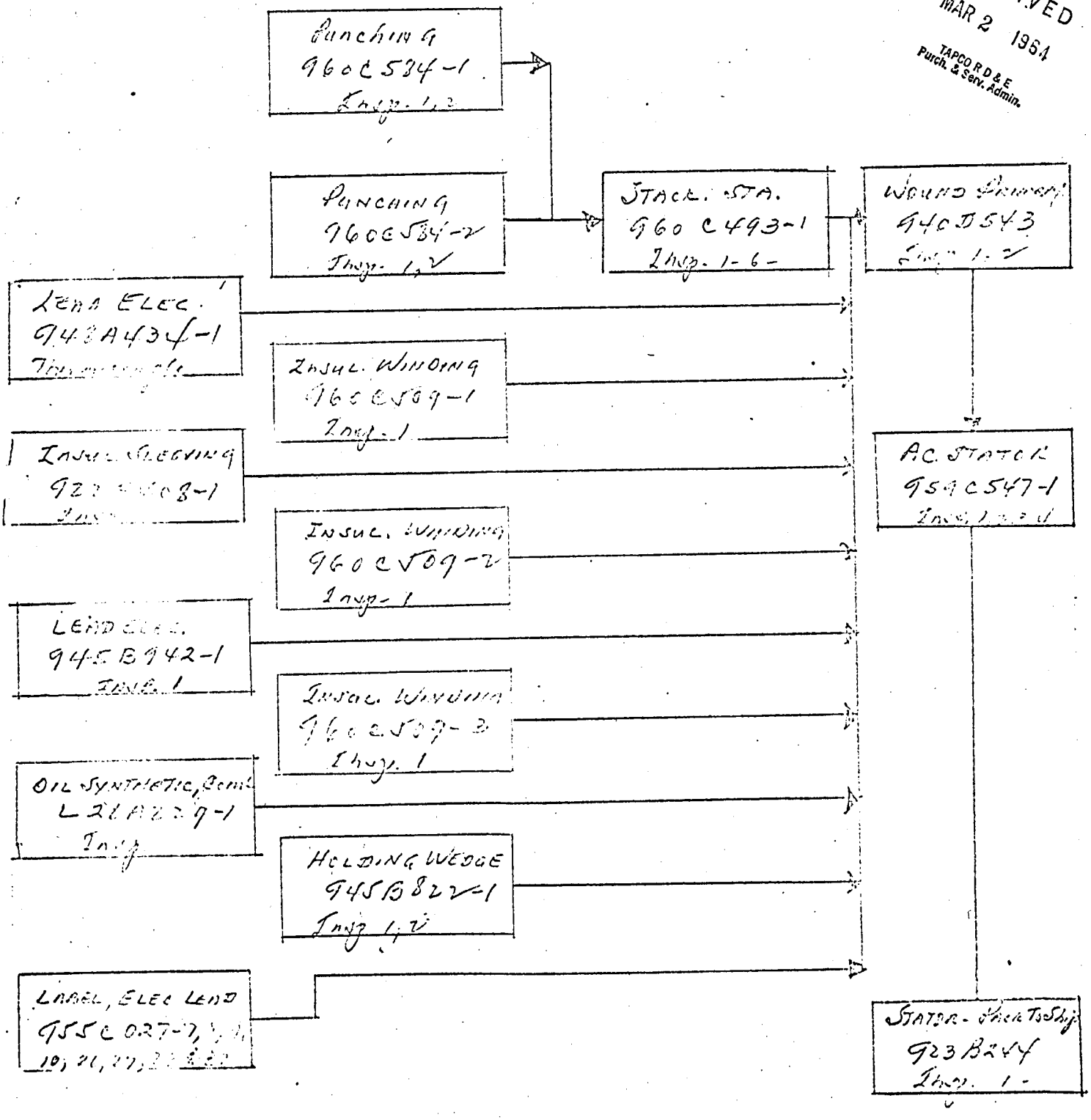
INSPECTION CHECK LIST

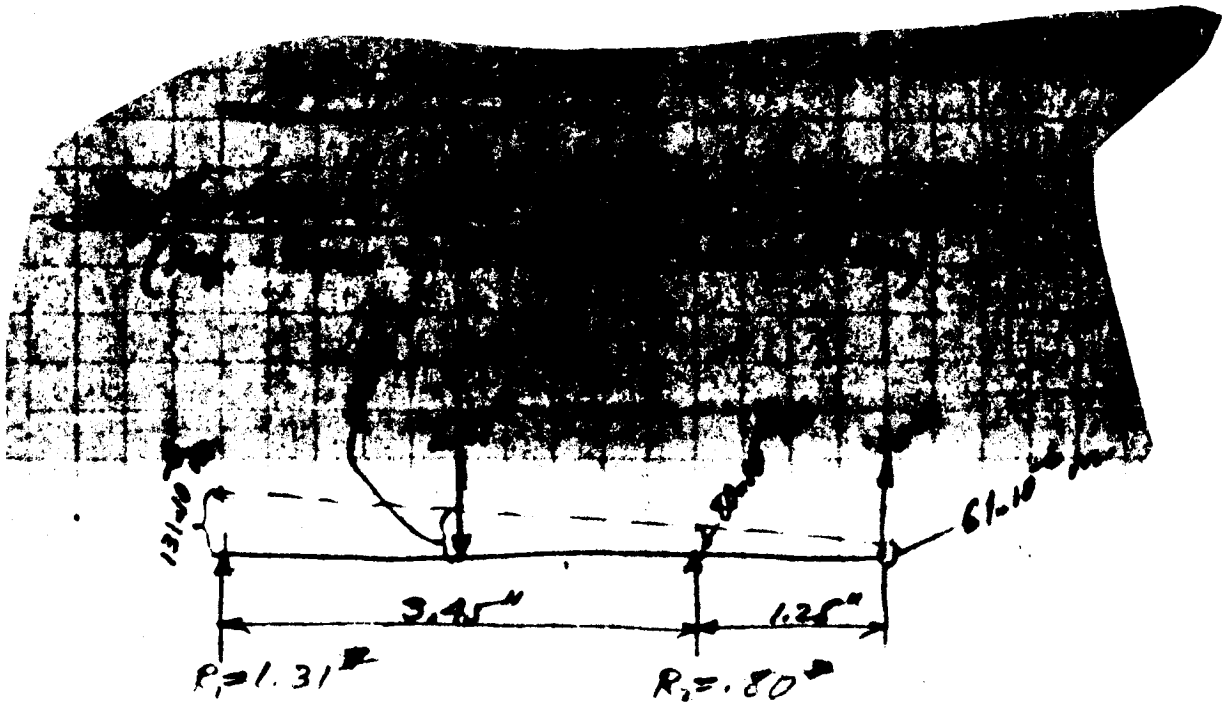
Drawing Number 940D523 Rev. None Ser. No. 2

Characteristic	Insp. Method	Remarks	Insp. Stamp & Date
.66 Max	Scale	Wire (L28A215-1) P.O. 39D 38/260	(W 18) 2/8/[illegible]
.09 Min.	Scale	Lot No. 1	
		Sleeve (L28A240-1) P.O. 38/277	
		Lot No. 1	
		Tape (L28A213-1) P.O. 38/278	
		Lot No. 1	
		Tape (L28A218-1) P.O. 38/279	
		Lot No. 1	
		Ins. (928A408-1) P.O. 38/281	
		Lot no. 1	
		Lead (928A434-1) P.O. 38/282	
		Lot No. 1	
		Rod (L28A237-1) P.O. 39D 38/268	
		Lot No. 1	

959C547-1
A.C. STATOR
I.R.-08-52901B-01

RECEIVED
MAR 2 1964
TAPCO R D & E
Purch. & Serv. Admin.





$$R_1\, 3.45 = 2.41 \times \frac{3.45}{2} + .30 \times 1.25$$

$$R_1 = 1.205 + .108 = 1.313^{\#} \text{ say } 1.31^{\#}$$

$$R_2\, 3.45 = 2.41\, \frac{3.45}{2} - .30 \times 4.70$$

$$R_2 = 1.205 - .408 = .797^{\#} \text{ say } .80^{\#}$$

Let's assume a bearing stiffness $K = 10^4$ lbs/in.

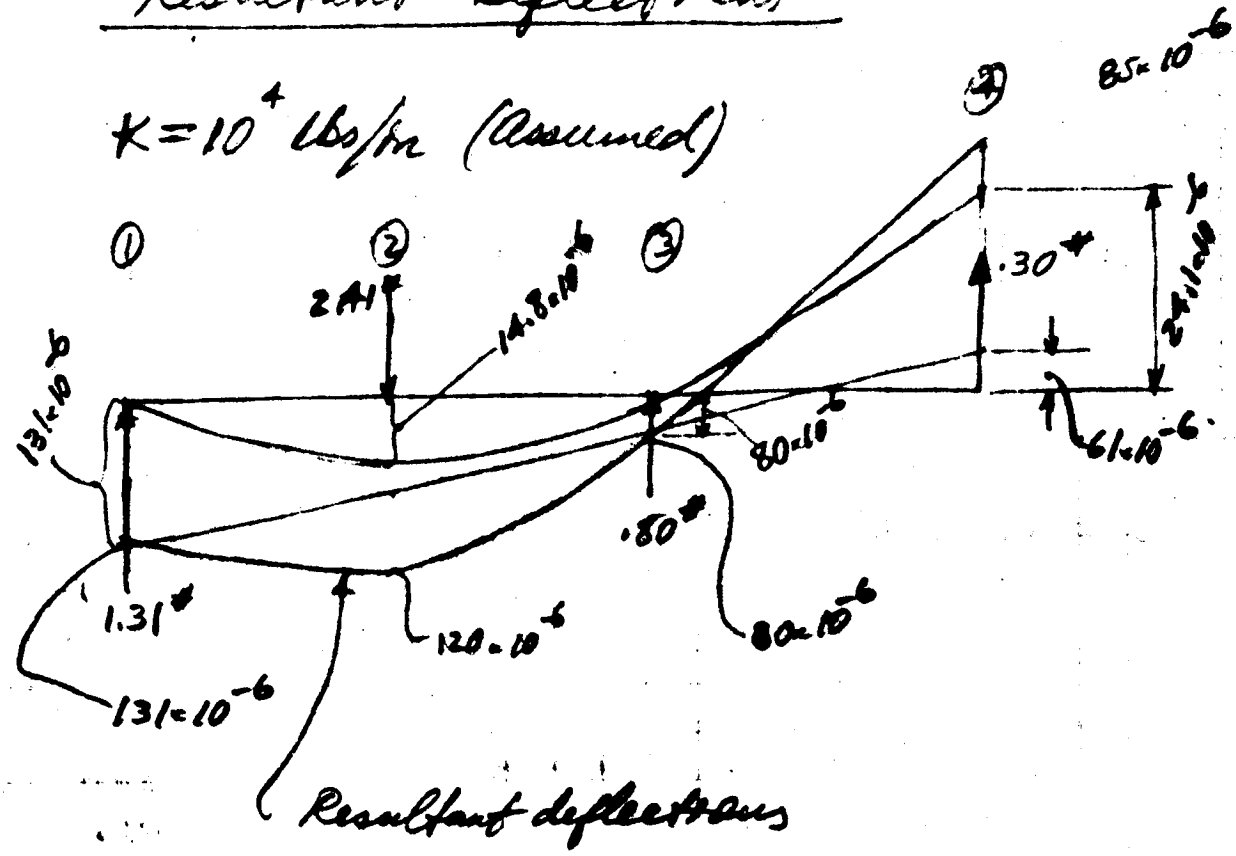
The deflection (additional) due bring deflection is as follows:

$$y_{R_1} = \frac{1.31}{10^4} = 131 \times 10^{-6} \text{ in}$$

$$y_{R_2} = \frac{.80}{10^4} = 80 \times 10^{-6} \text{ in}$$

Resultant Deflections

$K = 10^4$ lbs/in (Assumed)



Critical Speed Calculations

Station	W lbs	Y in	Y^2	WY	WY^2
1	1.31	131×10^{-6}	$17{,}200\times10^{-12}$	172×10^{-6}	$22{,}500\times10^{-12}$
2	2.41	120	[illegible]	[illegible]	[illegible]
3	.80	80	6,400	64	5,120
4	.30	85	7,225	26	2,167
				552×10^{-6}	$64{,}487\times10^{-12}$

$$N_{CR} = 188\sqrt{\frac{\Sigma WY}{\Sigma WY^2}}$$

$$N_{CR} = 188\sqrt{\frac{552\times10^{-6}}{64{,}487\times10^{-12}}} = 188000\sqrt{85.6\times10^{-6}} = 1880\times9.28 = \underline{\underline{17{,}400 \text{ rpm}}}$$

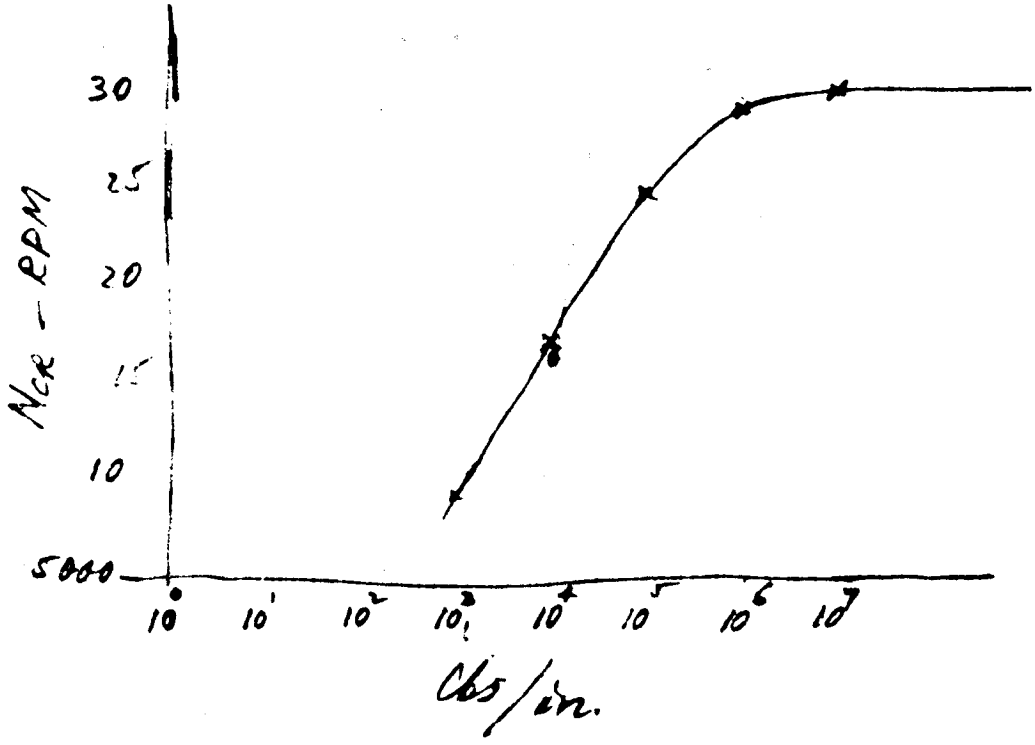
Assume, $K = 10^6$ lbs/in.

Then,

$$y_{K_1} = 1.31 \times 10^{-6} \text{ in.}$$

$$y_{K_2} = .8 \times 10^{-6} \text{ in.}$$

Since the above have a negligible effect, the N_{CR} will be essentially the same as originally calculated, that is $N_{CR} = 30{,}100$ rpm



The asymptotic line is based on conservative calculations of weight distribution. The bearing spring constant has a negligible influence on the crit. speed, when it reaches a value greater than 10^6 lbs/in.

Effect of Motor Mag. Force and Pump Radial Force on Bearing Displacement

6.00# – Radial Pump Load
55.00# – Motor Mag. Load

$R_1\, 3.45 = 57.4\,\frac{3.45}{2} + 6.30 \times 1.25$

$R_1 = 28.7 + 2.3 = 31^{\#}$

$R_2\, 3.45 = 57.41\,\frac{3.45}{2} - 6.30 \times 4.70$

$R_2 = 28.7 - 8.6 = 20.1$ say $20^{\#}$

Displacement of Bearing

Left Bearing

$y_{k_1} = \frac{31}{10^4} = .0031$ in.

$k = 10^4$ lbs/in.

Right Bearing

$y_{k_2} = \frac{20}{10^4} = .002$ in.

$k = 10^6$

$y_{k_1} = .000031$ in.
$y_{k_2} = .000020$ in.

Displacement Range of Bearings

$31 \times 10^{-6} < y_{k_1} < 31 \times 10^{-4}$ max. possible
$20 \times 10^{-6} < y_{k_2} < 20 \times 10^{-4}$ " "

An actual evaluation of k, for bearings under consideration, is about 2×10^5 lbs/in.
then, max. $y = .00015$ in.

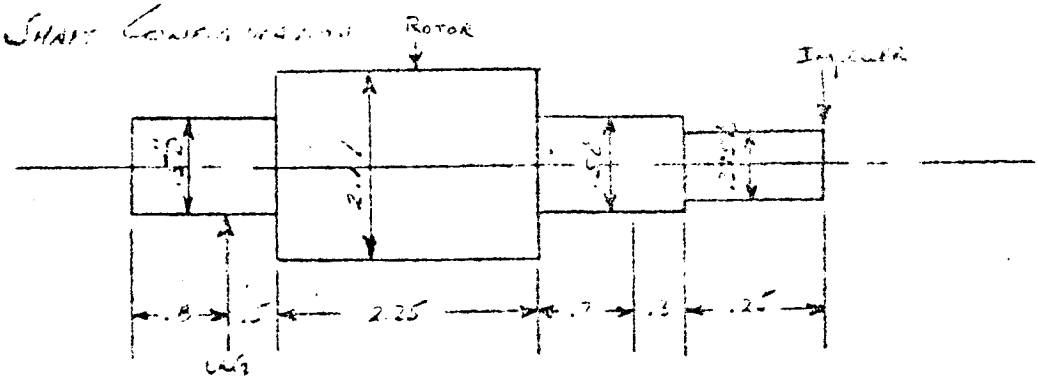
(CLASSIFICATION)

Thompson Ramo Wooldridge Inc.

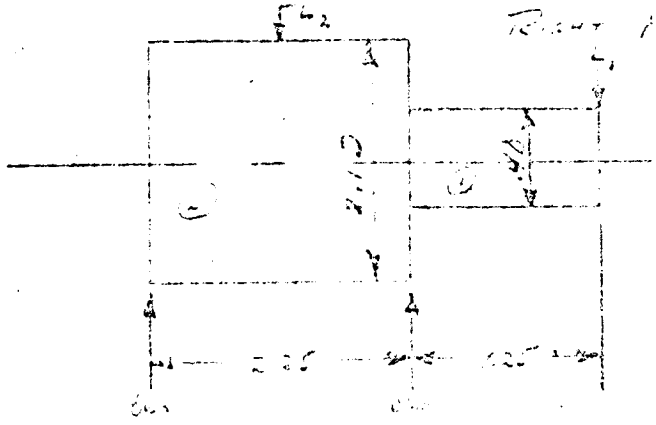
PAGE 1

SUBJECT: [illegible] REPORT NO. PMA-R62-4

1) Shaft Configuration



Simplifying the Shaft and Neglecting Left Side Protrusion and Allowing Right Protrusion to Be Constant Dia.



$I_1 = \frac{\pi d^4}{64} = \frac{3.14(.4)^4}{64} = \frac{3.14 \times .0256}{64} = .00256 \text{ in}^4$

$I_2 = \frac{\pi d^4}{64} = \frac{3.14(2.1)^4}{64} = \frac{3.14 \times 19.5}{64} = .4[illegible] \text{ in}^4$

L_1 = Imp. Wt. + Shaft Extension Wt. ([illegible] Total Wt. Concentrated at End)

$L_1 = .25^{\#} + \frac{3.14 \times 4 \times .4}{4} \times .125 \times .3 = .25 + .05 = .30^{\#}$

L_2 = Rotor Wt. + Shaft Wt. (Assume Solid Steel Rotor)

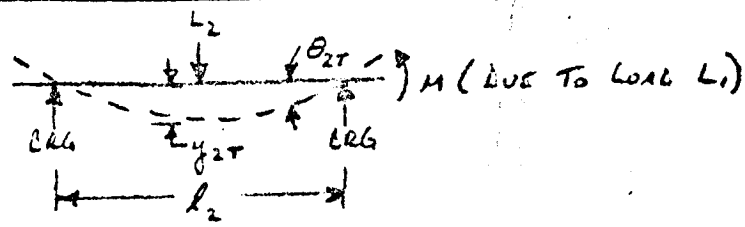
$L_2 = \frac{3.14 \times [illegible]}{4} \times [illegible] \times .25 \times .3 = [illegible]^{\#}$

V 117

Thompson Ramo Wooldridge Inc.

SUBJECT: Model 253800-1 Critical Speed Cont'd. REPORT NO. PMA-R63-4

For Rotor Portion



$y_{2T} = y_2 + y_M$ $\qquad \theta_{2T} = \theta_2 + \theta_M$

y_2 = Defl. Due To Load L_2 $\qquad y_M$ = Defl Due To M

θ_2 = End Slope Due To L_2 $\qquad \theta_M$ = End Slope Due To M

From Roark "Formulas for Stress & Strain" Case 11

$$y_2 = \frac{1}{48}\frac{L_2 \ell_2^3}{E I_2} = \frac{1}{48} \times \frac{2.34 \times (2.25)^3}{30 \times 10^6 \times .906} = \frac{2.34 \times 11.4 \times 10^{-6}}{48 \times 30 \times .906} = .0204 \times 10^{-6} \text{ in.}$$

$$\theta_2 = \frac{1}{16}\frac{L_2 \ell_2^2}{E I_2} = \frac{1}{16} \times \frac{2.34 \times (2.25)^2}{30 \times 10^6 \times .906} = \frac{2.34 \times 5.06 \times 10^{-6}}{16 \times 30 \times .906} = .0257 \times 10^{-6} \text{ Rad.}$$

From Roark Case 19

$$y_M = \frac{1}{6}\frac{M}{E I_2}\left[3\left(\frac{\ell_2}{2}\right)^2 - \frac{\ell_2^2}{4} - \ell_2^2\right] = \frac{.30 \times 1.25}{6 \times 30 \times 10^6 \times .906}\left[3 \times 1.266 - .633 - 5.06\right]$$

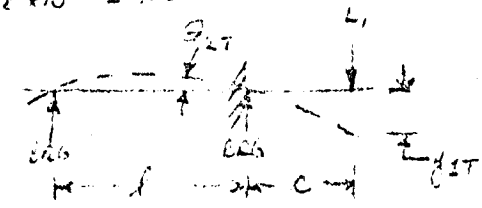
$$y_M = \frac{.30 \times 1.25 \times 1.893 \times 10^{-6}}{6 \times 30 \times .906} = .00435 \times 10^{-6} \text{ in.}$$

$$\theta_M = \frac{1}{3}\frac{M \ell_2}{E I_2} = \frac{0.30 \times 1.25 \times 1.25}{3 \times 30 \times 10^6} = .00438 \times 10^{-6} \text{ Rad.}$$

$$y_{2T} = .0204 \times 10^{-6} + .00435 \times 10^{-6} = .02475 \times 10^{-6} \text{ in.}$$

$$\theta_{2T} = .0257 \times 10^{-6} + .00438 \times 10^{-6} = .03508 \times 10^{-6} \text{ Rad.}$$

For Impeller End Extension



$y_{1T} = y_1 + y_{\theta 2}$ $\qquad y_1$ = defl @ L_1 due To L_1 $\qquad y_{\theta 2}$ = defl @ L_1 due To θ_{2T}

From Roark Case 2 (with Fixed Brg)

$$y_1 = \frac{1}{3}\frac{L_1 c^3}{E I} = \frac{.30 \times (1.25)^3}{3 \times 30 \times 10^6 \times .001256} = \frac{.30 \times 1.95 \times 10^{-6}}{3 \times 30 \times .001256} = 5.18 \times 10^{-6} \text{ in.}$$

$y_{\theta 2} = \theta_{2T} \times c = .03508 \times 10^{-6} \times 1.25 = .0439 \times 10^{-6}$ in.

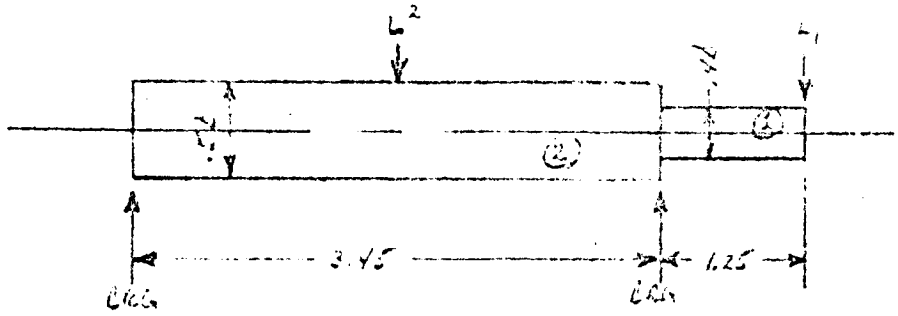
$y_{1T} = 5.18 \times 10^{-6} + .0439 \times 10^{-6} = 5.2239 \times 10^{-6}$ in.

Total Deflection $= y_T = y_{1T} + y_{2T} = 5.2239 \times 10^{-6} + .02475 \times 10^{-6}$

$= 5.2487 \times 10^{-6}$ in.

$N_c = \frac{188}{\sqrt{y_T}} = \frac{188}{\sqrt{5.2487 \times 10^{-6}}} = \frac{188 \times 10^3}{2.29} = 82000$ RPM

2) For Extreme Condition (Neglecting Shaft Ext To Left of Left Brg.)



$L_1 =$ Imp. Wt + Area (1) Shaft Wt $= .25 + .05 = 0.30$ #

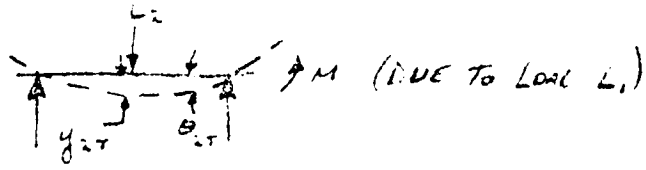
$L_2 =$ Rotor Wt + Area (2) Shaft Wt.

$L_2 = \frac{3.14 \times 2.1 \times 2.1}{4} \times 2.25 \times .3 + \frac{3.14 \times .5 \times .5}{4} \times 1.2 \times .3 = 2.34 + .07 = 2.41$ #

$I_1 = \frac{\pi d_1^4}{64} = \frac{3.14(.4)^4}{64} = .001256$ in^4

$I_2 = \frac{\pi d_2^4}{64} = \frac{3.14(.5)^4}{64} = \frac{3.14 \times .0625}{64} = .00491$ in^4

FOR AREA 2



$y_{2T} = y_2 + y_M$ $\qquad \theta_{2T} = \theta_2 + \theta_M$

ROARK CASE 11

$$y_2 = \frac{1}{48}\frac{L_2 l_2^3}{EI_2} = \frac{1}{48} \times \frac{2.41 \times (3.45)^3 \times 10^{-6}}{30 \times .00491} = \frac{2.41 \times 41 \times 10^{-6}}{48 \times 30 \times .00491} = 14.0 \times 10^{-6} \text{ IN.}$$

$$\theta_2 = \frac{1}{16} \times \frac{L_2 l_2^2}{EI_2} = \frac{2.41 \times (3.45)^2 \times 10^{-6}}{16 \times 30 \times .00491} = \frac{2.41 \times 11.9 \times 10^{-6}}{16 \times 30 \times .00491} = 12.2 \times 10^{-6} \text{ RAD.}$$

ROARK CASE 19

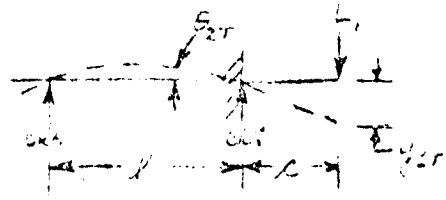
$$y_M = \frac{1}{6}\frac{M}{EI_2}\left[3\left(\frac{l_2}{2}\right)^2 - \frac{l_2^2}{8} - l_2^2\right] = \frac{.30 \times 1.25 \times 10^{-6}}{6 \times 30 \times .00491}(1.893) = .804 \times 10^{-6} \text{ IN.}$$

$$\theta_M = \frac{1}{3}\frac{M l_2}{EI_2} = \frac{.30 \times 1.25 \times 3.45 \times 10^{-6}}{3 \times 30 \times .00491} = 2.93 \times 10^{-6} \text{ RAD}$$

$$y_{2T} = 14.0 \times 10^{-6} + .804 \times 10^{-6} = 14.804 \times 10^{-6} \text{ IN.}$$

$$\theta_{2T} = 12.2 \times 10^{-6} + 2.93 \times 10^{-6} = 15.13 \times 10^{-6} \text{ RAD}$$

FOR AREA 1



$y_{1T} = y_1 + y_{RAD}$

ROARK CASE 1

$$y_1 = \frac{1}{3}\frac{L_1 c^3}{EI_1} = \frac{30 \times (1.25)^3}{3 \times 30 \times 10^{-6} \times .001256} = 5.18 \times 10^{-6} \text{ IN.}$$

$y_{\theta 2} = \theta_{2T} \times c = 15.13 \times 10^{-6} \times 1.25 = 18.9 \times 10^{-6}$ in.

$y_{1T} = 5.18 \times 10^{-6} + 18.9 \times 10^{-6} = 24.08 \times 10^{-6}$ in.

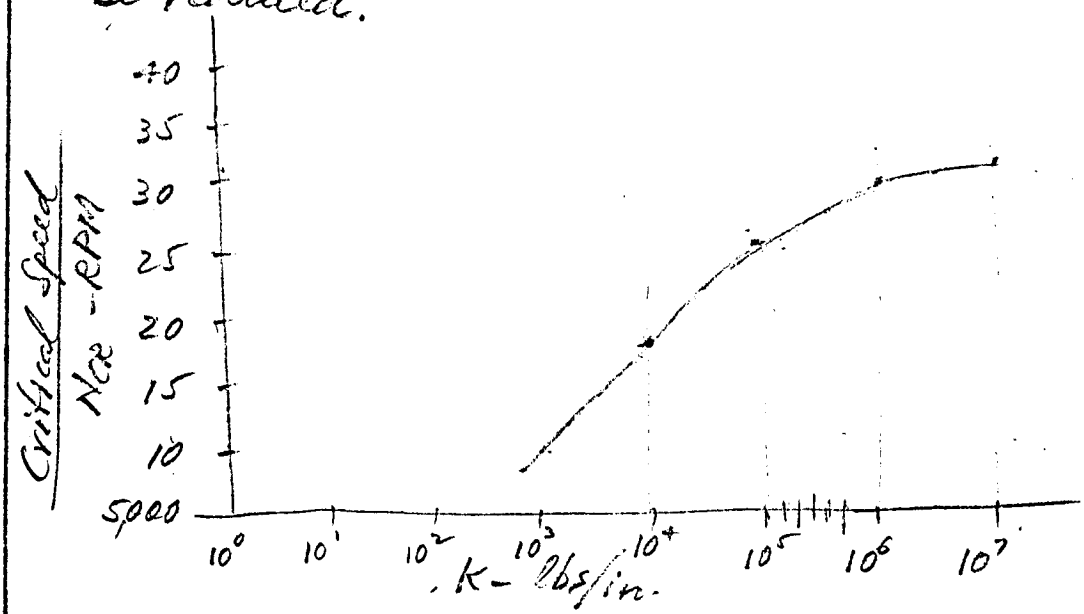
TOTAL DEFLECTION = $y_T = y_{1T} + y_{2T}$?

$y_T = 24.08 \times 10^{-6} + 14.80 \times 10^{-6} = 38.88 \times 10^{-6}$ in. ?

$$N_c = \frac{188}{\sqrt{y_T}} = \frac{188}{\sqrt{38.88 \times 10^{-6}}} = \frac{188 \times 10^3}{6.24} = 30100 \text{ RPM}$$

Comments:

Above answers do not reflect the bearing stiffness. The critical speed will then be reduced.



Bearing Stiffness, K

1. Clearance [illegible] .001/.0012 — LET — Based on Prel Anal. of Resultant Flow, Friction Drag, etc.

2. [illegible]

3. [illegible]

4. [illegible]

5. [illegible]

Oil Flow $= \dfrac{\pi D (p_1 - p_2) c^3}{12 \mu l}$

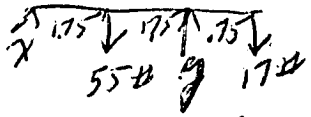
[illegible] .940/.941 O.D. .5013/[illegible] I.D. [illegible]

[illegible] 100°F MIN 260°F MAX.

MAX ALLOW. Temp of OIL IN BRGS = 350

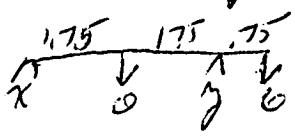
19g(pk) @ 180 cps 19 x .7 ≅ 13.5 @ 1/180 sec = 13.5 g for .00555 sec.
13.5 x 3.6 = 48# wt. of rot parts

MAX LOAD



y = 49#
x = 23.9#

MIN LOAD



y = 7.3#
x = −1.3#

From ASME Paper No. 59-[illegible]

$F = K p d W$

Where: K = Parameter Dependent on Flow $= 0.36\left[1-\left(\frac{Q}{Q_m}\right)^2\right]$

Q = Flow

Q_m = Flow Corresponding to Peak Pump Eff. (22 GPM)

p = Discharge Pressure, psi

d = Impeller Dia. in. (2.70 in.)

W = Impeller Width Inclusive Shrink in. (.250 in.)

F = Force in Radial Direction

1.) At 17 GPM, $K = 0.36\left[1-\left(\frac{Q}{Q_m}\right)^2\right] = 0.36\left[1-.[illegible]\right] = .[illegible]$

$p = 57$ PSI

$F = .145 \times 57 \times 2.70 \times .250 = 5.[illegible]^{\#}$

2.) When ½ of Flow [illegible] to Inlet, Impeller Actually Sees Rated Flow. We Therefore Load Under These Conditions Would Equal Load at Rated Flow.

3.) At Half Flow, $K = 0.36\left[1-\left(\frac{Q}{Q_m}\right)^2\right] = .306$ [illegible]

$F = .306 \times 69 \times 2.70 \times .250 = 14.2^{\#}$

4.) At Zero Flow, $K = 0.36$ and $p = 70$ psi

$F = 0.36 \times 70 \times 2.70 \times .250 = 17^{\#}$

Items 3 & 4 represent conditions which will exist only intermittently during Pump Calibrations or Checkout. Items 1 & 2 represent loads which could exist for 10000 hr. life requirement

Thompson Ramo Wooldridge Inc.

SUBJECT: RADIAL BEARING ANALYSIS REPORT NO. PMA-RG3-19

REF COMPUTER DATA

PGS 2,3,4 & 5 INDICATE THE FRONT RADIAL BEARING IS BASICALLY VERY GOOD. IT IS HYDRODYNAMICALLY FILM SUPPORTED AT ALL TIMES, IS STABLE IN TEMPERATURE, NOT SUBJECT TO HALF FREQUENCY WHIRL, AND HAS AN ADEQUATE FILM THICKNESS.

THE DATA ALSO CONTAINS INDICATIONS THAT FILM THICKNESS DISAPPEARS UNDER ABNORMAL CONDITIONS CONSIDERED, NAMELY - MAX. SHOCK LOAD, MAX. IMPELLER RADIAL LOAD AT SHUT OFF PLUS MAX. RADIAL MAGNETIC LOAD (BASED ON LINE TO LINE ROTOR/STATOR CONDITION). ACTUALLY SPECIFICATION NOTES NON OPERATING CONDITION. THE DATA WAS USED AS ONLY AN OVERALL CHECK. SINCE SHOCK LOAD IS EXPERIENCED FOR SUCH A SHORT DURATION, THE EFFECTS SHOULD NOT BE DETREMENTAL TO THE BEARING.

W.W. - how reliable is analysis - what are problems of lift-off

PGS. 6 & 7 INDICATE THE REAR RADIAL BEARING IS ALSO STABLE & SUPPORTED ON A ADEQUATE OIL FILM.

1. What is film condition at max pump + magnetic + imbalanced load + max (3.5g) G-load?
2. How is ~~[illegible]~~ angular disalignment of bearing handled
3. What [illegible] computer printout exists.
4. What is [illegible] time 0 to TIME? Full load is not applied, full speed?
5. Why [illegible] [illegible]?
6. Are conditions realistic 100°, 18 psi, 8100 rpm?
7. [illegible] how reliable?

TROLINE BEARING COMPANY BEARING SPECULATIONS

TAPCO BEARINGS-POLYPHENYL ETHER 2556

DESCRIPTION OF BEARING

	D	L	C	N	W
1	.5015	.500	.0020	8100	49
	(1ST) CENTISTOKES (2ND)		API	T-OIL	T-MAX
6	56.00	6.15	-12.5	260	360
	Q-MAX	P-OIL	LENGTH RATIO	MICRO	FS
11	.250	13		8	.10
	T-AIR	A/DL	SH	SS	S
16	260	9.4	12.0	133.0	400.0
	CEXPS	CEXPM	SP GR	SP HT	WM
21	5.4	2.7	5.5	.12	3.60
	WS	TS	DT	H ADD	STATIC P
26	45	.00555	10	.00	.00
	(1ST) GROOVE DEPTHS (2ND)		REFERENCE (1ST) TEMPERATURES (2ND)		
31	.000000	.000000	.000000	560.000000	670.000000

OPERATING CONDITIONS

LOAD	SPEED
49	8100

INLET TEMP		AX TO P		OIL FLOW		OIL PRES		A BIEST
9	260.000	10	360.000	11	.250	12	13.000	16	260.000

C	N	T-MIN	T-MAX	THICK	TH-S	Q-ACT	P	[illegible]
.0020	-1	260.	275.	111.	19.	.00241	13.0	3.[illegible]16
.0030	1	270.	267.	79.	.	.01002	13.0	3.542

F	MP	T-OUT	T-MOD	LOC	L-S	Q-MIN	W/DL	L/D
.0042	.0086	300.	275.	.86	.97	.00016	195.4	.997
.0040	.0074	260.	267.	.94	1.00	.00029	195.4	.997

Z	S	A	KV(000)	DM	HR	TIME	HC	NC
3.158	.0283	.0842	.07.	-.1	.0	.60	.012	11.1
3.461	.0121	.1965	.07.	-.4	.0	.00	.012	8.8

SPECIFIC CONDITIONS

LOAD	SPEED
49	8100

INLET TEMP		MAX TEMP		OIL FLOW		OIL PRES		AMBIENT	
9	260.000	10	360.000	11	.250	12	16.000	16	260.000

C	K	T-FILM	T-BACK	THICK	TH-S	Q-ACT	P	M
.0020	1	280.	275.	111.	19.	.00334	18.0	3.316
.0030	1	270.	267.	79.	.	.01387	18.0	5.342

F	HP	T-OUT	T-HSG	ECC	L-S	Q-MIN	W/DL	L/D
.0042	.0066	300.	275.	.86	.97	.00018	195.4	.997
.0043	.0074	280.	267.	.94	1.00	.00029	195.4	.997

Z	S	A	PV(000)	DH	HK	TIME	HC	NC
3.138	.0285	.0842	207.	-.2	.0	.70	.012	11.1
3.461	.0121	.1982	207.	-.7	.0	.00	.012	8.8

[illegible]

LOAD	SPEED
49	8100

[illegible]	INLET TEMP		MAX TEMP		OIL FLOW		OIL PRESS		AMBIENT
[illegible]	100.000	10	250.000	11	.250	12	15.000	16	100.000

[illegible]	[illegible]	T-FILM	T-BACK	THICK	TH-S	Q-ACT	P	[illegible]
.0020	1	150.	163.	[illegible]	150.	.00071	13.0	3.830
.0030	1	150.	134.	[illegible]	125.	.00177	13.0	3.726

[illegible]	[illegible]	T-OUT	T-MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.0[illegible]	.0142	200.	160.	.07	.[illegible]	.[illegible]	195.4	.997
.1111	.0175	200.	137.	.75	.[illegible]	.[illegible]	195.4	.997

[illegible]	[illegible]	[illegible]	PV(100)	DH	[illegible]	TIME	[illegible]	[illegible]
11.0[illegible]4	.0034	.0[illegible]	207.	-.0	.0	1.00	.012	10.8
19.1[illegible]4	.0084	.0411	207.	-.0	.0	.50	.012	8.5

SPECIAL CONDITIONS

LOAD	SPEED
49	8100

INLET TEMP		MAX TEMP		OIL [illegible]		OIL PRES		AMBIENT	
9	100.000	10	250.000	11	.250	12	18.000	16	100.000

C	K	T-FILM	T-BACK	THICK	TH-S	Q-ACT	P	[illegible]
.0020	1	160.	165.	214.	130.	.00099	18.0	5.636
.0030	1	190.	137.	255.	129.	.00245	18.0	5.726

F	HF	T-[illegible]	T-[illegible]	[illegible]	[illegible]	[illegible]	W/DL	L/D
.0090	.0142	200.	160.	.67	.65	.00019	195.4	.997
.0111	.0170	200.	157.	.75	.91	.00031	195.4	.997

Z	S	A	PV(000)	DH	HR	TIME	HC	NC
11.026	.0835	.0288	207.	-.1	.0	1.35	.012	10.6
19.156	.0585	.0411	207.	-.2	.0	.65	.012	8.5

[illegible]

LOAD	SPEED
1.	7760

INLET TEMP		MAX TEMP		[illegible]		[illegible]		[illegible]	
				.00051					
9	290.000	10	340.000	11	.000	12	15.000	16	290.000

[illegible]	[illegible]	T-[illegible]	T-[illegible]	T[illegible]	T[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.7	3.220
[illegible]	1	310.	[illegible]	[illegible]	.	[illegible]	1.0	3.214

[illegible]	[illegible]	T-[illegible]	T-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	.0021	330.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	.0014	330.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.334	1.0713	[illegible]	4.	-.0	.0	1.76	.012	1.6
2.364	.4007	[illegible]	4.	-.0	.0	3.34	.012	1.3

OPERATING CONDITIONS

LOAD	SPEED
1	7760

INLET TEMP		MAX TEMP		OIL FLOW		OIL PRES		AMBIENT	
				.00051					
9	100.000	10	250.000	11	.000	12	16.000	16	100.000

C	K	T-FILM	T-BACK	T-PICK	TH-S	Q-ACT	P	[illegible]
.0020	1	170.	155.	8[illegible]1.	425.	.00051	17.9	5.666
.0030	1	160.	147.	13[illegible]9.	406.	.00051	5.7	5.694

F	HP	T-OUT	T-HSS	[illegible]	E-S	Q-MIN	W/DL	L/D
.3265	.0100	240.	153.	.0[illegible]	.53	.00010	3.9	.997
.2550	.0078	220.	145.	.0[illegible]	.71	.00016	3.9	.997

Z	S	A	PV(000)	DH	HR	TIME	HC	NC
12.[illegible]04	4.5080	.0[illegible]05	4.	-.[illegible]	.0	1.2[illegible]	.012	1.5
15.[illegible]00	2.2469	.0010	4.	-.[illegible]	.0	1.62	.012	1.2

TRULINE BEARING COMPANY
29000 Lakeland Blvd.
Wickliffe, Ohio

DESCRIPTION OF CALCULATED OPERATING CHARACTERISTICS

C - Clearance of bearing at 70°F in inches. Difference between bore of bearing and shaft diameter.

K - Final condition of operation of bearing.

1. Full film operation - load is completely supported on oil film, reaching a stable operating condition.

2. Bearing is partially film supported, but partial contact is expected. Oil film is too thin relative to roughness of bearing and shaft.

3. Oil supply is inadequate to maintain oil film.

4. No oil supply. Bare metal friction only.

11. Bearing is out of control. Bearing was full film supported at highest permissible temperature, but temperature was still rising.

12. Bearing is out of control. Highest allowable temperature was condition #2.

13. Bearing is out of control. Last calculation was condition #3 with temperature still rising.

14. Bearing is out of control, with no lubricant.

15. Bearing is seized with zero clearance.

T-FILM - Temperature of average oil film - °F.

T-BACK - Temperature of Bearing back - °F.

THICK - Minimum Oil film thickness under average load - Micro inches.

TH-S - Minimum Oil film thickness under shock load - Micro inches.

Q-ACT - Oil Flow through bearing - gallons per minute. (In some programs also reported in DROPS/MIN.)

P - Back - Pressure of oil supply to bearing - psi.

M - Clearance ratio under operating condition, 1000 C/D.

F	-	Coefficient of friction in bearing under final operating condition.
HP	-	Horsepower absorbed by bearing.
T-OUT	-	Temperature of out flowing oil - ^{o}F.
T-HSG	-	Temperature of housing surface - ^{o}F.
ECC	-	Eccentricity ratio of bearing under average load. (Zero indicates shaft is running in center of bearing, 1.000 indicates shaft is resting on bearing).
E-S	-	Eccentricity ratio of bearing at end of shock load.
Q-MIN	-	Oil flow minimum required to supply full oil film.
W/DL	-	Average unit load over projected area, W/DL psi.
L/D	-	Length to diameter ratio.
Z	-	Operating viscosity of oil, absolute viscosity centipoises.
S	-	Sommerfeld number, dimensionless. $(D/C)^2un/P$ - (P is W/DL, u is viscosity in Reyns, and n is speed in rps.)
A	-	Bearing characteristic number, dimensionless. M^2W/D^2ZN.
ZN/P	-	Reynolds number.
DH	-	Unbalanced heat of bearing, Btu/minute. If positive, bearing is absorbing more heat from friction than it is giving off to the air and the oil, and is still rising in temperature. If negative, bearing temperature will stop rising before it reaches this value.
HR	-	Heating rate of bearing. Degrees F per minute which bearing temperature is rising.
TIME	-	Time in minutes, from start of bearing operation, to reach stable temperature.
HC	-	Heat capacity of bearing - Btu bearing will absorb per degree F rise in temperature.
NC	-	Ratio of critical speed to actual speed. A ratio of 1.0 or less indicates bearing will be subject to half frequency whirl.

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4. No oil supply. Bare metal friction only.

11. Bearing is out of control. Bearing was full film supported at highest permissible temperature, but temperature was still rising.

12. Bearing is out of control. Highest allowable temperature was condition #2.

13. Bearing is out of control. Last calculation was condition #3 with temperature still rising.

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M - Clearance ratio under operating condition, 1000 C/D.

F	-	Coefficient of friction in bearing under final operating condition.
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T-OUT	-	Temperature of out flowing oil - ^{o}F.
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S	-	Sommerfeld number, dimensionless. $(D/C)^2un/P$ - (P is W/DL, u is viscosity in Reyns, and n is speed in rps.)
A	-	Bearing characteristic number, dimensionless. M^2W/D^2ZN.
ZN/P	-	Reynolds number.
DH	-	Unbalanced heat of bearing, Btu/minute. If positive, bearing is absorbing more heat from friction than it is giving off to the air and the oil, and is still rising in temperature. If negative, bearing temperature will stop rising before it reaches this value.
HR	-	Heating rate of bearing. Degrees F per minute which bearing temperature is rising.
TIME	-	Time in minutes, from start of bearing operation, to reach stable temperature.
HC	-	Heat capacity of bearing - Btu bearing will absorb per degree F rise in temperature.
NC	-	Ratio of critical speed to actual speed. A ratio of 1.0 or less indicates bearing will be subject to half frequency whirl.

Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: 253700 Radial Bkg Load Re-evaluation

REPORT NO. PMA-R63-19 Supplement 1

Rotor/Stator Eccentricity

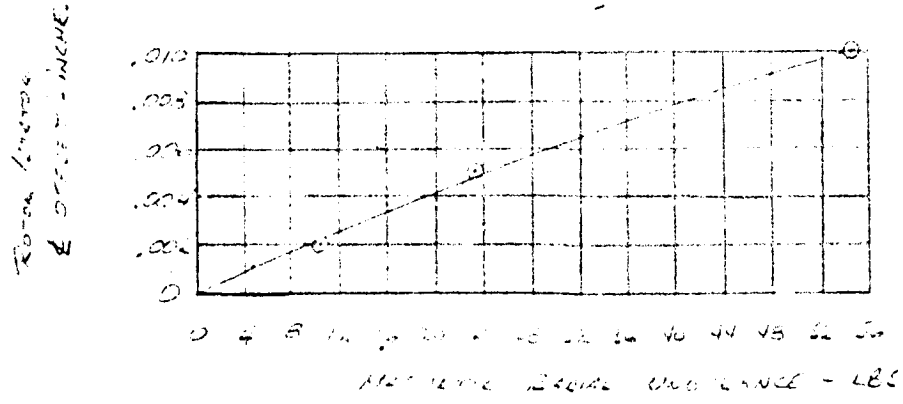
⊙ Stator I.D./Hsg. =	.001
Brg Hsg. O.D. To Pilot (Clear.) =	.003
⊙ Brgs To Pilot =	.001
⊙ Rotor O.D. To Journals =	.001
Clearance Shaft Journ. To Brg. =	.003
2	.009
	.0045 (Max ℄ Shift)

Stator I.D.	2.1255	± .0005
Rotor O.D.	2.1055	± .0005
2	.0200	± .001

Air Gap as a Result of Size .010 ± .0005

± .0045

.010 ± .005 Max Possible "Air Gap" Variation



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Thompson Ramo Wooldridge Inc.

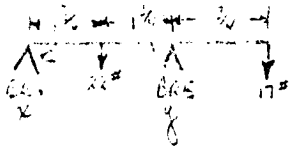
TRW

SUBJECT: [illegible] Re-Eval Cont'd

REPORT NO. PMA-R63-19 SUPPLEMENT 1

FOR MAX LOADS:

ASSUME MAX ROTOR/STATOR ECCENTRICITY, THEREFORE MAG. SIDE LOAD = 22#
IMPELLER RADIAL LOAD = 17# (@ 0 FLOW)



(FOR MAX MAGNITUDE & RADIAL LOADS)

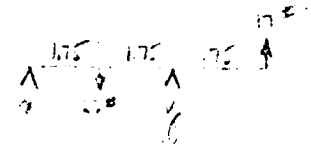
$\overset{+\curvearrowright}{\Sigma M_x}$ $22\times1.75 + 17\times4.25 - 3.5y = 0$

$38.5 + 72.3 = 3.5y$ $y = 31.7^{\#}$ (↑)

$\overset{+\curvearrowright}{\Sigma M_y}$ $17\times.75 - 22\times1.75 + 3.5x = 0$

$25.7 = 3.5x$ $x = 7.3^{\#}$ (↑)

CHECK $22+17 = 34 = 31.7 + 7.3 = 39$



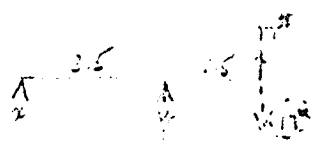
$\overset{+\curvearrowright}{\Sigma M_x}$ $22\times1.75 - 17\times4.25 - 3.5y = 0$

$-33.8 = 3.5y$ $y = -9.7^{\#}$ (↓)

$\overset{+\curvearrowright}{\Sigma M_y}$ $-22\times1.75 - 17\times.75 + 3.5x = 0$

$-38.5 - 12.7 + 3.5x = 0$ $x = 14.7^{\#}$ (↑)

CHECK $22-17 = 5 = 14.7 - 9.7 = 5$



$\overset{+\curvearrowright}{\Sigma M_x}$ $\pm17\times4.25 \mp 3.5y = 0$

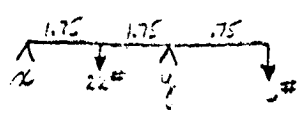
$y = +20.6^{\#}, -20.6^{\#}$ (↑ or ↓)

CHECK $17 = 20.6 - 3.6 = 17$

$\overset{+\curvearrowright}{\Sigma M_y}$ $\pm17\times.75 \mp 3.5x = 0$

$x = -3.6^{\#}, +3.6^{\#}$ (↓ or ↑)

RATED CONDITIONS



$\overset{+\curvearrowright}{\Sigma M_x}$ $22\times1.75 + 6\times4.25 - 3.5y = 0$

$64 = 3.5y$ $y = 18.3^{\#}$ (↑)

$\overset{+\curvearrowright}{\Sigma M_y}$ $-22\times1.75 + 6\times.75 + 3.5x = 0$

$34 = 3.5x$ $x = 9.7^{\#}$ (↑)

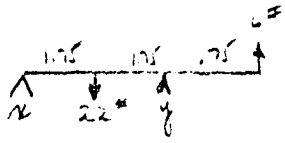
CHECK $22+6 = 28 = 18.3 + 9.7 = 28$

Thompson Ramo Wooldridge Inc.

SUPPLEMENT 1

SUBJECT: RADIAL LOAD REMOVAL CONT'D

REPORT NO. [illegible]



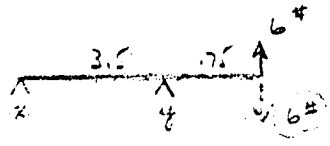
ΣM_x: $22 \times 1.75 - 6 \times 4.25 - 3.5y = 0$

$13 = 3.5y$ $\quad y = 3.7^{\#}$ (↑)

ΣM_y: $-22 \times 1.75 - 6 \times .75 + 3.5x = 0$

$43 = 3.5x$ $\quad x = 12.3^{\#}$ (↑)

CHECK $22 - 6 = 16 = 3.7 + 12.3 = 16$



ΣM_x: $\pm 6 \times 4.25 \mp 3.5y = 0$

$y = \pm 7.3^{\#}$ ↑ or ↓

ΣM_y: $\mp 6 \times .75 \mp 3.5x = 0$

$x = \mp 1.3^{\#}$ ↑ or ↓

CHECK $6 = 7.3 - 1.3 = 6$

SUMMARY

y BEARING (IMP. END)

MAX LOAD = 31.7# (MAX MAG. + MAX LOAD → 0 FLOW)

MIN LOAD = 3.7# (MAX MAG + MIN LOAD → RATED)

x BEARING (SENSOR END)

MAX LOAD = 14.7# (MAX MAG + MAX RAD → 0 FLOW)

MIN. LOAD = 1.3# (0 MAX + MIN RAD → RATED)

Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: Bearing Analysis - Thrust, Coolant & Lube Pump, Proj. 512-00428 REPORT NO. PMA R63-23

Ref. 1) Data By Thomas Barish, Dated Sept. 26, 1963
2) Model 127300 Thrust Load Calculations.

Based On Loads & Fluids Of Model 127300, (Operating In Much Less Viscous Fluid With Less Lubricity) It Is Concluded That The Thrust Brg. Of The PMA Will Adequately Carry The Load For The Life Intended With The Fluid & Loads As Computed.

In Addition, For Added Margin For Wetting Of The Brg Surface, Radial Grooves Have Been Provided In The PMA Thrust Brg.

PMA-R63-2

For Lance Group., T-R-W, Inc., Cleveland 17, Ohio. Elmer Jira.

Snap-8 Lubricant Pump: Thrust Bearing, Collar Type.

Data: 8000 rpm.: 10,000 Hrs. life at max. reliability. ET-378 Oil
8100 rpm. max.: 75 lb. Thrust 250° F max. Temp.

For comparison: on Pump 1[illegible]-300 successful with 30 psi:JP-4:110° F

Brg Size (as enlarged): 1-3/16 x 9/16 (after allowing for chamfers

Area: 1.10[illegible] -.249 = .859 sq.in. gives 41 psi.

Speed in feet/min. = 8000(π)7/8 /12 = 1830

Analysis per Wilcock & Hooser, "Dry Design" page 319.

Max. Unit pressure allowable 75 psi.

using 41 plus + 20% for oil grooves = 49 psi.

H.P. loss per sq/in. = .05

H.P. Loss = .05 x (.86-.17) = .0295 H.P. = 1.25 BTU/min.

Estimate of inlet flow oil pressure generated by rotation:

Assume oil at speed: = 8000(π)(7/8)/12(60) = 30.5 ft./sec.

Hydraulic head = h = $V^2/2g$ = 14.4 Ft. head

= .040 lb./cu.in. x 14.4 x 12 = 6.9 psi.

Can use 8 grooves 3/32" wide, leaving 8 pads, 5/16 x 5/16"

Outlet oil viscosity at about 300° = .62 x 10^{-6} Reyns

= .62 x 10^{-6} / 1.45 x 10^{-7} = 4.27 centipoises

Assuming .002" film,

Flow thru film = 1.2 x 10^{-3} i p_1 /Z_2

= .0019 x 8 x 6.9 / 4.27 = .0151 gpm.

for .001" film, .0019 gpm

Flow thru groove reliefs at grooves 45° x 1/16" long x .006" deep:

Z_2 = 4.27: l = 1/16: Q_c^o = 47200 x $(.006)^4$(6.9)/.255=.00165

Q_c = 8 x .9 x .00165 = .0119 gpm.

Total Flow: .0119 + .0019 = .0138 gpm.

Temp. Rise in Brg = 1.25 / .014 x.04 x 231 x .393 = 24.6°F

Coef. of Friction = (.0295 x 630000/8000 x .4375) / 35 = .015

Analysis by Shaw & Macks, "Analysis of Lubrication of Brgs" page 306

Coef. of Friction , $f = (1.65/(1-rho')(h/B)$

rho' equals density change taken at 250 and 300° ⟶ why?

$= .0389 / .04019 = .968$

(for mineral oils, this is 1 - .0004(50) = .98) ET-378 better by 1.6

using h = .0005" (film thickness) .0005"

B = brg length = 2.2" (?) ?

$F = (1.65/.032)(.0005/2.2) = \underline{.013}$ coef. of friction

Capacity, $P = (6\ mu\ U\ B / h^2)(.09)(1- rho')$

mu = .62 x 10^{-6} Reyns, U = Vel. in in/sec = 1830x12/60 = 366

B = 2.2" brg length,
h = .0005"

Capacity, $P = 6\ (.62 \times 10^{-6})(366)(2.2)(.09)(.032)/25 \times 10^{-8}$

= 35 Lb.

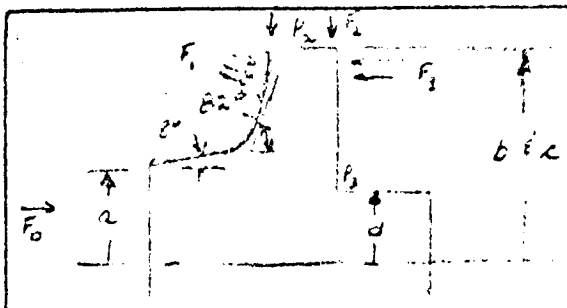
However this depends very much on film thickness which is not calculable. Also theory inadequate and low for high speeds.(quoting book).

THOMAS BARISH | 3210 WARRENSVILLE CENTER ROAD CLEVELAND 22, OHIO | Thomas Barish | Sept.27, 1963

Thompson Ramo Wooldridge Inc.

TAPCO GROUP

SUBJECT: 127300 THRUST LOAD CALCULATION PROJECT NO. PMA R63-23



$a = 0.900$

$b = c = 1.160$

$d = 0.700$

ASSUME $p_3 = 5$ psi (ACTUALLY WILL BE HIGHER SINCE CLOSE CLEARANCES ARE NOT MAINTAINED ON BACK SIDE OF IMPELLER.)

FROM THRUST STUDY BY KILL SCOTT

F_T = NET THRUST REACTION

$F_0 = 0$ (WORST CONDITION)

$F_1 \sin\alpha = \frac{\pi}{40} p_2 (4b^2 - 3ab - d^2)$ Pg 6 FORM. (3) (assuming all press. rise takes place on radial portion of blade)

AXIAL COMPONENT OF $F_2 = 0$

$F_3 = \int_{r_d}^{r_b} p_{d-b}\, 2\pi\, dr$ (FROM COOPER FORMULA FOR 253800-1)

$F_1 \sin\alpha = \frac{3.14 \times 14}{40}(4 \times 1.34 - 3 \times .9 \times 1.160 - .81) = \frac{3.14 \times 14 \times (.41)}{40} = 1.55$ PSI (TOWARD MOTOR)

$F_3 = \left[2\pi\left[p_3 - d\left(\frac{p_2 - p_3}{b - d}\right)\right]\right]\left[\frac{1}{2}(b^2 - d^2)\right] + \left[2\pi\left(\frac{p_2 - p_3}{b - d}\right)\frac{1}{3}(b^3 - d^3)\right]$

$F_3 = [illegible]$

$= [illegible] + 49.8$

$= -[illegible] + 49.8 = 26.6^{\#}$

$F_{TOTAL} = -F_1 + F_3 = -1.5 + 26.6 = 25^{\#}$ TOWARD INLET

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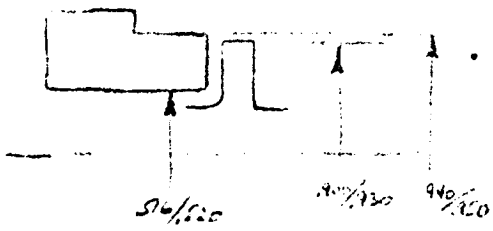
Thompson Ramo Wooldridge Inc.

TAPCO GROUP

SUBJECT: 127300 Thrust Calculation Cont'd PROJECT NO. PMA-R63-23

UNIT LOADING ON CALCS THRUST FACE



NEGLECTING .025/.026 SLOT ON BEARING

$$\text{CONTACT AREA} = \frac{\pi}{4}\left(.915^2 - .518^2\right) = \frac{3.14}{4}\left(.837 - .268\right) = \frac{3.14}{4} \times .569 = \underline{.446\ in^2}$$

$$S = \frac{P}{A} = \frac{25^{\#}}{.446\ in^2} = \underline{56\ psi}$$

THIS IS CONSIDERED TO BE MINIMUM LOADING BY VIRTUE OF LARGE Δp ASSUMED ACROSS BACK OF IMPELLER

Z-710 PRINTED IN U.S.A.

PREPARED

CHECKED

INITIALS - DATE

Thompson Ramo Wooldridge Inc.

SUBJECT: 253800 Thrust Analysis REPORT NO. 9[illegible]-R63-24

Axial Thrust Encountered in 253800 consists of Thrust Developed by Impeller plus Thrust Due to Differential Pressure Existing across Motor Rotor. Analysis indicates Impeller Thrust will be toward Inlet while Differential Pressure across Rotor results in thrust away from Inlet. ✓

Pages 1 & 2 indicate Force Due to Differential Pressure across Rotor results in Thrust of 9.3# away from Inlet. (Force toward inlet due to Unbalanced Pressure considered to be Negligible and therefore Neglected). meaning ???

Pages 3 thru 9 contain derivation of Force resulting from Impeller. These formulae were put into a computer program to study effects of Clearance behind the Impeller, Operating Condition (Shutoff or Rated Flow), "Balancing" Dia., and Bleedback to Inlet Hole Size. The results of this study are plotted on Page 11.

Example of results obtainable from Fig 11.

Chosen Conditions: .003" Clearance behind Impeller
1.4" Dia (0.7"R) "Balance"
.043 in² effective Return Hole Area

@ Shutoff, Thrust = 43# (43 - 9.3 = 34.7# Net Thrust)
Leakage Flow = 4.4 GPM — WOW! — 1289e
ΔP across Return Hole = 1150 #/ft² 8.0 psi

@ Rated Flow, Thrust = 28# (28 - 9.3 = 18.7# Net Thrust)
Leakage Flow = 3.4 GPM — WOW! 1289e
ΔP across Return Hole = 730 #/ft² 5.05 psi

V 144

Thompson Ramo Wooldridge Inc.

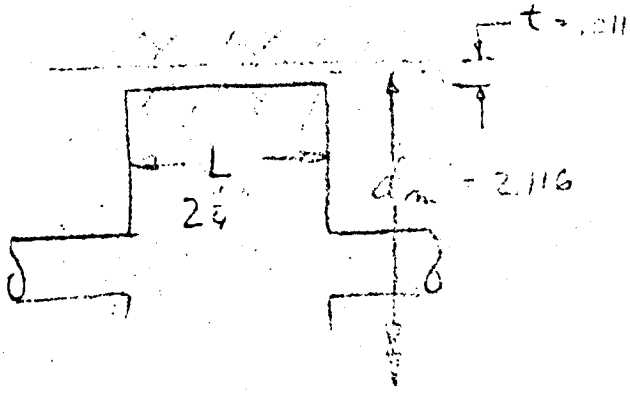
TAPCO GROUP

SUBJECT: SNAP-8 IMPELLER THRUST BALANCE PROJECT NO. PMA-R63-24

ASSUME $\frac{1}{4}$ GPM COOLING FLOW AXIALLY THROUGH MOTOR IN AWAY-FROM-INLET DIRECTION.

$$\Delta p = \frac{12 \mu V_{AVG}}{t^2} L$$

ASSUMING PARABOLIC FLOW DISTRIBUTION ACROSS RADIAL SPACE, t, $t \ll d_m$, MEAN DIA OF SPACE



$$V = \frac{Q}{A} \qquad A = t \pi d_m$$

$$Q = \frac{1}{4} \text{ GPM} \times \frac{1}{449} = 5.57 \times 10^{-4} \text{ ft}^3/\text{sec}$$

$$V = \frac{5.57 \times 10^{-4}}{(.011)(2.116)\pi} \times 144 = 1.098 \text{ ft/sec}$$

$$\mu = \nu \rho = (6.45 \times 10^{-5} \text{ ft}^2/\text{sec})(2.13 \frac{\text{lbf sec}^2}{\text{ft}^4})$$

$$\mu = 13.8 \times 10^{-5} \frac{\text{lbf sec}}{\text{ft}^2}$$

$$\Delta p = \frac{(12)\, 13.8 \times 10^{-5} \frac{\text{lbf sec}}{\text{ft}^2}\, 1.098 \text{ ft/sec}\, (2\frac{1}{4}/12) \text{ ft}}{(.011/12)^2 \text{ ft}^2}$$

$$\Delta p = 406 \text{ psf} = 2.82 \text{ psi}$$

I got 3.2 psi by TRO & Pomata

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Thompson Ramo Wooldridge Inc.

TAPCO GROUP

SUBJECT:

PROJECT NO. YMA-R63-24

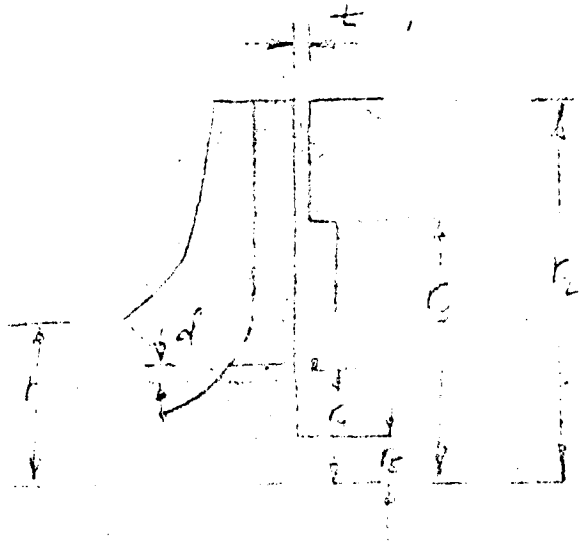
RESULTING AXIAL THRUST = PA

$= 2.82 \times \frac{\pi}{4}(2.105^2 - 0.5^2) = 9.26$ LB

THEN ALLOWABLE IMPELLER THRUST

UNBALANCE IS $9.26 + 40 = 49.26$ LB

Where did this come from



$r_1 = 0.5625$"

$r_2 = 1.350$"

$r_5 = 0.25$"

r_4 & t = ARBITRARY

r_3 & d = TO BE DETERMINED

V 146

FORCES AWAY FROM INLET –

$$F_A = p_{in}\,\pi r_1^2 + \frac{\pi \Delta p}{2}(r_2^2 - r_1^2) + \pi p_{in}(r_2^2 - r_1^2) + \Delta F$$

(REF APPX CASE III, $n = 2$)

ΔF IMPELLER THRUST UNBALANCE

$$F_A = \frac{\pi \Delta p}{2}(r_2^2 - r_1^2) + \pi r_2^2 p_{in} + \Delta F$$

↳ ?

FORCES TOWARD INLET –

$$F_T = \pi r_2^2 \Delta p + \pi\rho\left\{\left(\frac{6\nu r_3 V_{r_3}}{t} + \frac{\rho(r_3)}{\rho}\right)(r_2^2 - r_3^2) - V_{r_3}^2 r_3^2 \ln\frac{r_2}{r_3} - \frac{\omega^2}{16}(r_2^4 - r_3^4)\right\}$$

$$+ \frac{\pi\rho\omega^2}{16}(r_3^2 - r_5^2)^2 + \pi p_5(r_3^2 - r_5^2) + \pi r_5^2(p_{in} + \delta p)$$

(REF APPX CASES III & (II))

$$p_5 = p_3 - \frac{\rho\omega^2}{8}(r_3^2 - r_5^2)$$

$$p_3 = p_4 - \frac{\rho\omega^2}{8}(r_3^2 - r_4^2), \quad p_4 = p_{in} + \delta p$$

$$F_T = \pi r_2^2 \Delta p + \pi\rho\left\{\left(\frac{6\nu r_3 V_{r_3}}{t}\right)(r_2^2 - r_3^2) - V_{r_3}^2 r_3^2 \ln\frac{r_2}{r_3} - \frac{\omega^2}{16}(r_2^4 - r_3^4)\right\} + \frac{\pi\rho\omega^2}{8}(r_3^2 - r_4^2)(r_2^2 - r_3^2)$$

$$+ \pi(p_{in} + \delta p)(r_2^2 - r_3^2) + \frac{\pi\rho\omega^2}{16}(r_3^2 - r_5^2)^2 - \frac{\pi\rho\omega^2}{8}(r_3^2 - r_5^2)^2$$

$$+ \pi(p_{in} + \delta p)(r_3^2 - r_5^2) - \pi r_5^2(p_{in} + \delta p)$$

$$+ \frac{\pi\rho\omega^2}{8}(r_3^2 - r_4^2)(r_3^2 - r_5^2)$$

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$$F_T = \pi r_2^2 \Delta p + \pi \rho \left\{ \left(\frac{6\omega^2 r_3 V_{r_3}}{c^2} \right)(r_2^2 - r_3^2) - V_{r_3}^2 r_3^2 \ln \frac{r_2}{r_3} + \frac{\omega^2}{16} \left\{ r_2^2 (2r_4^2 - 2r_4^2 - r_2^2) + r_5^2 (2r_4^2 - r_5^2) \right\} \right\}$$

$$+ \pi \rho \omega r_2^2 + \pi \delta \rho (r_2^2 - r_5^2) + \pi \delta \rho r_5^2$$

EQUATING F_A & F_T

$$\pi r_2^2 \Delta p + \pi \rho \left\{ \frac{6\omega^2 r_3 V_{r_3}}{c^2} (r_2^2 - r_3^2) - V_{r_3}^2 r_3^2 \ln \frac{r_2}{r_3} + \frac{\omega^2}{16} \left\{ r_2^2 (2r_4^2 - 2r_4^2 - r_2^2) + r_5^2 (2r_4^2 - r_5^2) \right\} \right\}$$

$$+ \pi \rho \omega r_2^2 + \pi \delta \rho (r_2^2 - r_5^2) + \pi \delta \rho r_5^2$$

$$= \frac{\pi \Delta p}{2} (r_2^2 - r_1^2) + \pi r_2^2 \rho \omega + \Delta F$$

OR

$$\frac{\Delta F}{\pi} = \frac{6\omega^2 r_3 V_{r_3}}{c^2} (r_2^2 - r_3^2) - \rho V_{r_3}^2 r_3^2 \ln \frac{r_2}{r_3} + r_2^2 \Delta p + \frac{\rho \omega^2}{16} \left\{ r_2^2 (2r_4^2 - 2r_4^2 - r_2^2) + r_5^2 (2r_4^2 - r_5^2) \right\}$$

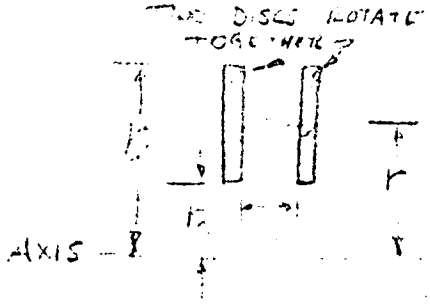
$$+ \delta \rho (r_2^2 - r_5^2) + \delta \rho r_5^2 - \frac{\Delta p}{2} (r_2^2 - r_1^2)$$

FINALLY WE ARE READY TO TRY SOME VALUES OF r_3, r_4, c, $\delta \rho$

PRESSURE DISTRIBUTIONS AND THRUST FORCES FOR ROTATING PLATES AND IMPELLERS

(5)

(I) SOLID BODY ROTATION



$$dp = \frac{1}{A}\, dF$$

$$dp = \left(\frac{1}{2\pi r\, dr}\right)\left(2\pi r\, dr\, \rho r \omega^2\right)$$

$$\Delta p = \int_{r_a}^{r_b} \rho \omega^2 r\, dr = \frac{\rho \omega^2}{2}\left(r_b^2 - r_a^2\right)$$

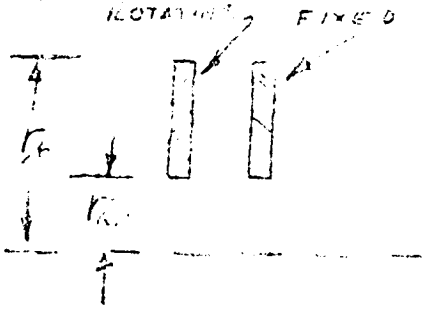
PRESSURE DISTRIBUTION $\quad p = \frac{\rho \omega^2}{2}\left(r^2 - r_a^2\right) + p_a$

THRUST FORCE $= \int p\, dA \qquad dA = 2\pi r\, dr$

$$F = \int_{r_a}^{r_b} \left(\frac{\rho \omega^2}{2}\left(r^2 - r_a^2\right) + p_a\right) 2\pi r\, dr$$

$$F = \frac{\pi \rho \omega^2}{4}\left(r_b^2 - r_a^2\right)^2 + \pi p_a \left(r_b^2 - r_a^2\right)$$

(II) HALF-SPEED ROTATION



ASSUME FLUID BETWEEN FIXED AND ROTATING MEMBERS ROTATES WITH HALF THE SPEED OF THE MOVING MEMBER.

THEN THE EQUATIONS ARE THE SAME AS CASE I EXCEPT THAT $\frac{\omega}{2}$ IS USED IN PLACE OF ω.

$$\Delta p = \frac{\rho \omega^2}{8}\left(r_b^2 - r_a^2\right)$$

$$p = \frac{\rho \omega^2}{8}\left(r^2 - r_a^2\right) + p_a$$

$$F = \frac{\pi \rho \omega^2}{16}\left(r_b^2 - r_a^2\right)^2 + \pi p_a \left(r_b^2 - r_a^2\right)$$

(III.) CENTRIFUGAL IMPELLER

FOR A GIVEN Δp, ASSUME PRESSURE DISTRIBUTION OF THE FORM

$$p = k\left(r^n - r_a^n\right) + p_a$$

WHERE $k = \dfrac{\Delta p}{r_b^n - r_a^n}$

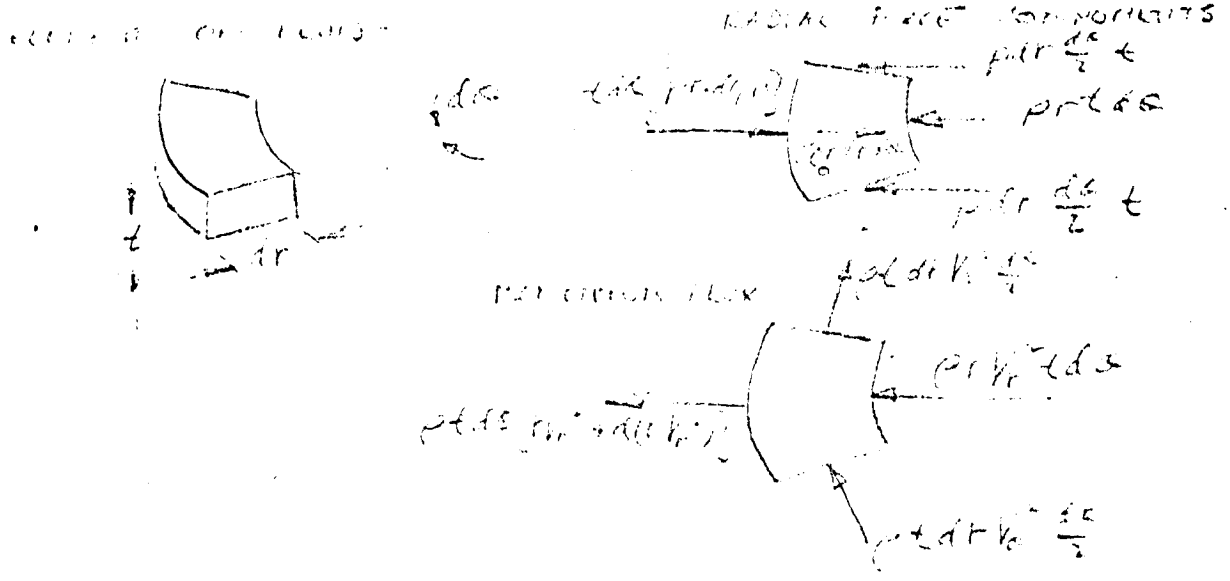
n DEPENDS ON GEOMETRY OF IMPELLER BLADES – USUALLY $2 \le n \le 3$

$$F = \int_{r_a}^{r_b} \left\{ \frac{\Delta p}{r_b^n - r_a^n}\left(r^n - r_a^n\right) - p_a \right\} 2\pi r\, dr$$

THIS REDUCES TO

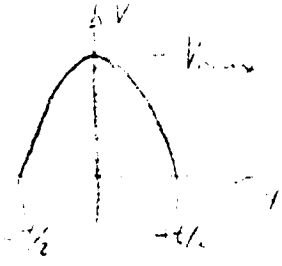
$$F = \frac{\pi \Delta p}{n+2}\left\{ 2 r_b^2 - \frac{n r_a^n \left(r_b^2 - r_a^2\right)}{r_b^n - r_a^n} \right\} + p_a \pi \left(r_b^2 - r_a^2\right)$$

(IV.) ROTOR & STATOR WITH SMALL AXIAL GAP AND IMPOSED Δp –



TO GET WALL FRICTION, FIND τ_0 $\quad \tau_0 = \mu \left(\dfrac{dV}{dx}\right)_{x=0}$

ASSUME PARABOLIC PROFILE OF RADIAL VELOCITY



$$V = V_{max} - \left(\frac{x}{t/2}\right)^2 V_{max}$$

$$= V_{max}\left\{1 - \left(\frac{2x}{t}\right)^2\right\}$$

$$\frac{dV}{dx} = \frac{8x}{t^2} V_{max}$$

$$\left.\frac{dV}{dx}\right|_{x=\pm t/2} = \mp \frac{4 V_{max}}{t} \quad \text{OR} \quad \tau_0 = \frac{4\mu V_{max}}{t} \qquad (1)$$

TO GET IN TERMS OF V_r, MASS-AVERAGE RADIAL VELOCITY —

$$V_r = \frac{1}{t/2}\int_0^{t/2} V\,dx = \frac{2}{t}\int_0^{t/2} V_{max}\left\{1-\frac{4x^2}{t^2}\right\}dx$$

$$V_r = \frac{2}{t}\left(\frac{t}{2} - \frac{4t^3}{24t^2}\right)V_{max} = \frac{2}{3}V_{max}$$

THEN $\tau_0 = \dfrac{6\mu V_r}{t}$ (1)

CONTINUITY —

$$\rho t\,d\theta\left\{rV_r + d(rV_r)\right\} + \rho t\,dr\,V_\theta - \rho t\,dr\,V_\theta - \rho t\,r\,d\theta\,V_r = 0$$

OR $d(rV_r) = 0$ (2)

$$\Sigma F = \text{MOM}_{out} - \text{MOM}_{in} =$$

$$\rho r t\,d\theta + 2\rho\,dr\frac{dr}{2}t - 2\tau_0 r\,dr\,d\theta - t\,d\theta\left\{pr + d(pr)\right\}$$
$$= \rho t\,d\theta\left\{rV_r^2 + d(rV_r^2)\right\} - \rho t\,dr\,V_\theta^2\frac{d\theta}{2} - \rho t\,dr\,V_\theta^2\frac{d\theta}{2}$$
$$- \rho t\,d\theta\,r\,V_r^2$$

OR $\rho t\,dr\,d\theta - 2\tau_0 r\,dr\,d\theta - t\,d\theta\,d(pr)$
$$= \rho t\,d\theta\,d(rV_r^2) - \rho t\,dr\,V_\theta^2\,d\theta$$

OR $\rho\,dr - \dfrac{2\tau_0 r\,dr}{t} - r\,dp - p\,dr = \rho\,d(rV_r^2) - \rho V_\theta^2\,dr$ (3)

$$V_r = \frac{V_{r_1} r_1}{r} \qquad dV_r = \frac{-V_{r_1} r_1}{r^2}\,dr \qquad (4)$$

ASSUME $V_\theta = \dfrac{\omega r}{2}$ (5)

REWRITING (3) —

$$-\frac{2\tau_0 r\,dr}{t} - r\,dp = \rho\left\{V_r\,d(rV_r) + rV_r\,dV_r\right\} - \rho V_\theta^2\,dr$$

SUBSTITUTING IN EQN'S (1), (4), (5) —

$$-\frac{12\mu r V_r\,dr}{t^2} - r\,dp = \rho r V_r\left(\frac{-V_{r_1} r_1}{r^2}\,dr\right) - \frac{\rho\omega^2 r^2}{4}\,dr$$

OR $\frac{12\mu r_1 V_{r_1}}{t^2} dr + r\,dp = \rho \frac{r_1^2 V_{r_1}^2}{r^2} dr + \frac{\rho\omega^2}{4} r\,dr$ (5)

$$dp = \rho r_1^2 V_{r_1}^2 \frac{dr}{r^3} + \frac{\rho\omega^2}{4} r\,dr - \frac{12\mu r_1 V_{r_1}}{t^2} \frac{dr}{r}$$

INTEGRATING, $\Delta p = \int_{r_1}^{r_2} dp$,

$$\Delta p = \frac{\rho r_1^2 V_{r_1}^2}{2}\left(\frac{1}{r_1^2} - \frac{1}{r_2^2}\right) + \frac{\rho\omega^2}{4}\frac{r_2^2 - r_1^2}{2} - \frac{12\mu r_1 V_{r_1}}{t^2} \ln\frac{r_2}{r_1}$$

$$\Delta p = \rho\left\{\frac{V_{r_1}^2}{2}\left[1 - \left(\frac{r_1}{r_2}\right)^2\right] + \frac{(r_2^2 - r_1^2)\omega^2}{8} - \frac{12\mu r_1 V_{r_1}}{t^2} \ln\frac{r_2}{r_1}\right\} \quad (6)$$

PRESSURE DISTRIBUTION,

$$p = p(r_1) + \int_{r_1}^{r} dp \qquad (\mu = \nu\rho)$$

$$p = \rho\left\{\frac{V_{r_1}^2}{2}\left[1 - \left(\frac{r_1}{r}\right)^2\right] + \frac{(r^2 - r_1^2)\omega^2}{8} - \frac{12\nu r_1 V_{r_1}}{t^2} \ln\frac{r}{r_1}\right\} + p(r_1)$$

AXIAL FORCE $= F \int_{r_1}^{r_2} p\,dA$, $dA = 2\pi r\,dr$

$$F = 2\pi\rho \int_{r_1}^{r_2}\left\{\frac{V_{r_1}^2}{2}\left[r - \frac{r_1^2}{r}\right] + \omega^2\frac{r^3 - r r_1^2}{8} - \frac{12\nu r_1 V_{r_1}}{t^2} r \ln\frac{r}{r_1} + \frac{r\,p(r_1)}{\rho}\right\} dr$$

THIS REDUCES TO

$$F = \pi\rho\left\{\frac{V_{r_1}^2}{2}\left[r_2^2 - r_1^2\left(1 + 2\ln\frac{r_2}{r_1}\right)\right] + \frac{6\nu r_1 V_{r_1}}{t^2}\left[r_2^2\left(1 - 2\ln\frac{r_2}{r_1}\right) - r_1^2\right] + \frac{\omega^2}{16}(r_2^2 - r_1^2)^2 + \frac{p(r_1)}{\rho}(r_2^2 - r_1^2)\right\} \quad (7)$$

TO FIND V_{r_1}, REWRITE EQ. (6)

$$V_{r_1}^2 \frac{1 - \left(\frac{r_1}{r_2}\right)^2}{2} - V_{r_1}\frac{12\nu r_1}{t^2}\ln\frac{r_2}{r_1} + \frac{r_2^2 - r_1^2}{8}\omega^2 - \frac{\Delta p}{\rho} = 0$$

$$V_{r_1} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$V_{r_1} = \frac{\frac{12\nu r_1}{t^2}\ln\frac{r_2}{r_1} \pm \left\{\frac{144\nu^2 r_1^2}{t^4}\left(\ln\frac{r_2}{r_1}\right)^2 - 2\left[1 - \left(\frac{r_1}{r_2}\right)^2\right]\left[\frac{\omega^2(r_2^2 - r_1^2)}{8} - \frac{\Delta p}{\rho}\right]\right\}^{1/2}}{\left[1 - \left(\frac{r_1}{r_2}\right)^2\right]}$$

(9)

$$F = \pi r_2^2 \Delta p + \pi \sigma \left\{ \frac{6 \nu r_1 V_{r_1}}{t^2} \left(r_2^2 - r_1^2 \right) - V_{r_1}^2 r_1^2 \ln \frac{r_2}{r_1} - \frac{\omega^2}{16} \left(r_2^4 - r_1^4 \right) + \frac{P(r)}{\rho} \left(r_2^2 - r_1^2 \right) \right\}$$

Thompson Ramo Wooldridge Inc.

TAPCO GROUP

SUBJECT: SUMMARY OF IBM THRUST CALC'S. → See graph sheet a-60

PROJECT NO.

$\Delta p = 70$ psi $\delta p = 3$ psi max

$r_3 = 0.5$ in.

$0.004 < t < 0.008$

$0.5 < Q < 3$ gpm

$+60 < \Delta F < +69$ lbf

(ΔF too large)

$\Delta p = 70$ psi $\delta p = 8$ psi max

$r_3 = 0.7$ in.

$0.004 < t < 0.008$

$0.8 < Q < 4.4$ gpm

$+20 < \Delta F < +43$ lbf

↓

For $r_3 = 0.7$, $.004 < t < .008$ Holes could be drilled overlap & no excess flow would result

$\Delta p = 55$ psi $r_3 = 0.7$

$0.004 < t < .008$ in.

$+15 < \Delta F < +39$ lbf

$0.6 < Q < 3.8$ gpm

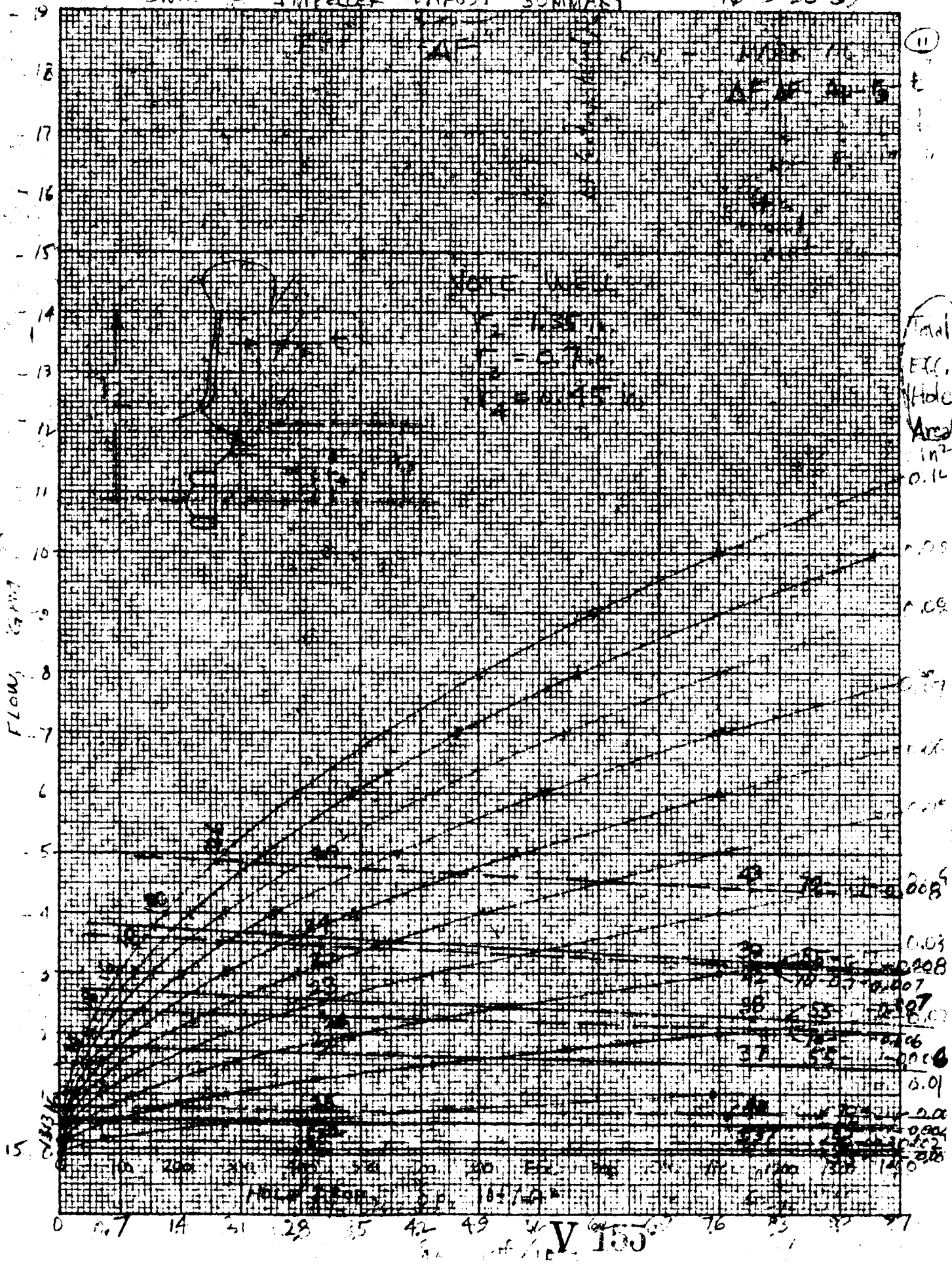
($r_3 > 0.7$ in.)

For large r_3, ΔF, Q variations too large over clearance range; (ΔF actually increases over clearance range) Balance could be achieved but over a very narrow clearance range (less than 0.004) and for high δp, which means oversized holes would result in excess flow.

For small r_3 ($r_3 < 0.7$) Excessive thrusts result over entire clearance range.

So use $r_3 = 0.7$ in., $t \leq 0.007$

SNAP 8 IMPELLER THRUST SUMMARY 9-28-63



Thompson Ramo Wooldridge Inc.

TAPCO GROUP

SUBJECT: [illegible] PROJECT NO. PMA-R63-24

Q [illegible]	0.25	0.5	1.0	1.5	2.0	3.0	5.0	10.0
δp A² [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A [illegible] in²	[illegible]	[illegible]	δp, psi					
0.1	0.005 / .67	0.019 / 2.74	0.076 / 10.9	0.172 / 24.8	[illegible] / 43.9	[illegible] / 99	1.91 / 275	7.64 / 1100
0.09	[illegible]	[illegible]	0.094 / 13.5	0.211 / 30.4	[illegible] / 54.1	0.849 / 122	[illegible]	[illegible]
0.08	[illegible] / 1.08	[illegible]	[illegible] / 17.1	[illegible] / 38.6	0.477 / 63.7	1.0[illegible] / 155	[illegible] / 429	[illegible] / 172[illegible]
0.07	0.010 / 1.44	[illegible]	0.155 / [illegible]	0.351 / [illegible]	0.622 / [illegible]	1.402 / [illegible]	[illegible] / 561	15[illegible] / 2240
0.06	0.014 / 2.0	[illegible] / 7.63	0.211 / 30.4	0.478 / 68.8	0.848 / 122	1.91 / 275	[illegible] / 763	[illegible] / 30[illegible]
0.05	[illegible]	0.016 / [illegible]	[illegible] / [illegible]	0.688 / [illegible]	1.22 / 176	2.75 / [illegible]	7.64 / 1100	[illegible] / 44[illegible]
0.04	[illegible] / 4.46	[illegible] / 17.1	0.475 / 68.4	1.075 / 155	[illegible] / 274	4.30 / 618	11.94 / 1720	47[illegible] / [illegible]
0.03	[illegible] / 7.92	0.211 / 30.4	0.845 / 122	1.91 / 275	[illegible] / 4[illegible]	7.64 / 1100	21.2 / 3050	[illegible]
0.02	0.125 / 18.0	0.475 / 68.4	1.9 / 274	4.30 / 619	7.63 / 1100	17.2 / 2480	47.8 / [illegible]	19[illegible] / 12[illegible]
0.01	0.5 / 72.0	1.9 / 274	7.6 / 1090	17.2 / 2480	[illegible] / 4400	[illegible] / 9920	[illegible] / 27,500	764 / 110,[illegible]

Q vs δp

Z-710 PRINTED IN U.S.A.

V 156

(CLASSIFICATION)

PREPARED [illegible]

CHECKED

INITIALS - DATE

Thompson Ramo Wooldridge Inc.

TAPCO GROUP

SUBJECT: HOLE DROP [illegible]

PROJECT NO. PMA-R63-24

$Q = AV \qquad V = \sqrt{2g\,\delta p}$

$Q = A\sqrt{2g\,\delta p}$

$\frac{\rho}{\gamma} = 2.13 \quad \frac{lbf\ sec^2}{in^4}$

$Q_{gpm} = \frac{A_{(in^2)} \times \sqrt{\frac{2g}{\gamma}\,\delta p_{(psi)}}}{0.321} = 36.2\, A_{(in^2)} \sqrt{\delta p_{(psi)}}$

$\left(\sqrt{\delta p_{(psi)}}\right)^2 = \left(\frac{Q_{(gpm)}}{36.2 \times A_{(in^2)}}\right)^2$

eg) For 7 hole @ $\frac{1}{8}$ in dia. $A = 7\left(\frac{1}{8}\right)^2 \times \frac{\pi}{4}$

$\delta p = \left(\frac{Q_{(gpm)}}{36.2 \times A_{(in^2)}}\right)^2$

$= 0.0653\ in^2$

$\delta p = Q = 3\ gpm$

$\delta p = \left(\frac{3}{36.2 \times 0.0653}\right)^2$ psi

0.933 psi

$Q_{(gpm)}$	$\delta p_{(psi)} (A_{(in^2)})^2$ (lbf-in²)
0.25	0.0487×10^{-3}
0.5	0.191×10^{-3}
1.0	0.764×10^{-3}
1.5	1.72×10^{-3}
2.0	3.05×10^{-3}
3.0	6.87×10^{-3}
5.0	19.1×10^{-3}
10.0	76.4×10^{-3}

$\frac{\delta p_{psi}}{A^2_{in^2}} = \frac{Q_{gpm}^2}{1310}$

MODEL 217700 VS 253800-1 FUEL PUMP

	217700	253800-1
A. OPERATING CONDITIONS		
1) TEMPERATURE		
a) FLUID	250°F	250°-260°F
b) AMBIENT (DRY)	500°F	—
2) FLOW	0 - 50 gpm	0 - 17 GPM
3) PRESS. RISE		
a) RATED	14.5 psi	58 psi
b) SHUT-OFF	37	75
4) FLUID	PWA-523A	DOW ET-378
a) VISCOSITY	4.07 @ 32°F	2500 @ 40°
	2.71 @ 66°	
	1.56 @ 130°	
	0.7 @ 250	6.3 @ 250°F
b) SPECIFIC GRAVITY	.775 @ 100°F	
	.736 @ 200°F	1.1 @ 250°F
	.698 @ 300°F	
B. MATERIALS		
1) SHAFT	S.S. 410 CHROME PLTD	410 CHR. PLTD
2) HSG'S	ALUM. AMS 4224 (ML)	410
3) BRGS	PURE CARBON P-658RC	PURE CARBON P-658RC

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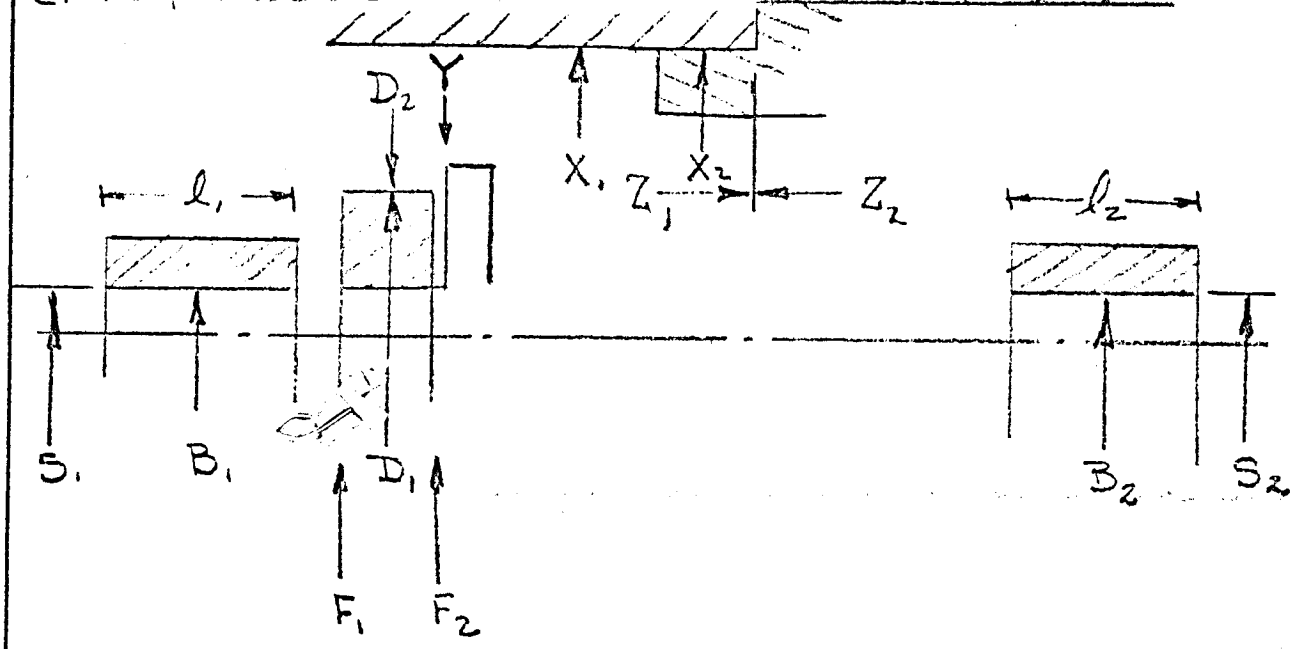
Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: Comparison ~ Bldg Fits [illegible]

REPORT NO. PMA-263-67

C. Fits & Tolerences



	217700	253800-1
D_1	1.0663 / 1.0658	
D_2	1.0608 / 1.0601	
Intf. Fit	.005 - .0062	.002 - .004
$F_2 \perp B_1$ TIR	—	.001
$F_1 \parallel F_2$	.002	—
$X_1 \perp Z_1$ & $B_1 \perp Z_1$	.002	
$X_2 \perp Z_2$ & $B_2 \perp Z_2$	.002	
$B_1 \odot X_1$	.002	.001
$B_2 \odot X_2$	.002	.001
$S_1 \odot S_2$	.0005	.0005
X_1 To X_2 Clearance	.002 To .004	.001 To .003
l_1 & l_2 (Less Chamfers)	.656 ± 1/32	.438 ± 1/32
B_1 & B_2	.6274 / .6279	.5000 / .5003
S_1 & S_2	.6253 / .6250	
Clearance (Dwg)	.0021 To .0029	.002 To .003
(@ Temp)	.0031 To .0039	.002 To .003
$Y \perp S_1$ & S_2 &	.001	.0005
Fcc. of B_1 In l_1 (Remnant)	.0007	.00037

PREPARED

CHECKED

INITIALS - DATE

	217700		258800-1	
Radial Load Max Fr. Brg, lbs			32.0	
Min Fr. Brg, lbs			3.7	
@ Rated Perf.	38.5	94	18.0	82
Radial Load Max Tail Brg, lbs			15	
Min " " , lbs			1.3	
@ Rated Perf.	60.5	146	12.3	56
Max Thrust Load; lbs (.433 In²)	47		(.831 In²) 38	
Th. Unit Load lbs/sq In.	107		45.8	
Shaft Surface Speed @ Radial Brgs	900 fps		1000 fps.	
" " " @ Thrust "	1250		1830	
(Based On Nom. Dia)				
Y ∥ F_2	.0042+		.0017	

D. Vibration Reqts MIL-E-5272

a) 150 Min. Each Axis - Cyclic
0 - ±10 G's

b) 30 Min Each Axis - Res.
4 G's Y Axis
7.5 Z "
10 X Axis

Added pages 7 & 8 Nov. 8, 1963.

for T-R-W Inc., Tapco Group, Cleveland 17, Ohio.

Snap-8 Lube Pump. Mechanical Critical Frequencies.

(1) The frequencies due to shaft deflections have already been checked: and as could be readilyseen from the proportions, are very high, well over 100,000 rpm. Hence the rotor and brg and shaft combination can be considered extremely rigid.

(2) This section covers the flexibility of the brg hydrodynamic film and possible resulting criticals. These are aside from the possible half-speed whirl and self-induced whip.

(3) Because of the semi-circular path of deflection in hydrodynamic brgs, there is no standard accepted method for checking spring rates. In fact, in a perfectly balanced unit, with no brg loads, the first deflections at right angles to the load, are high, and theoretically can produce very low criticals, approaching zero. However the smallest resulting loads shift to a higher spring rate and deflections nearer the load direction.

(4) Hence the method used here was to determine eccentricity, i.e., deflections at low loads, 2 "G", 3 "G" and 5 "G", and from these obtain the spring rate in this area.

(5) Also included, at the end, were the effects of the electrical force at the air gap, taken at the most unfavorable condition of .010" eccentricity (min. air gap of .010" reduced to .005"). Any yield at the brg would increase the pull at the air gap. This does not increase the equivalent spring rate because it is a pull: it decreases spring rate.

(6) Combining all this gives (at 260° oil)

Bearing total looseness	.0013"	.0021"	.0030"
Minimum Critical Frequency	27,300 rpm	19,600 rpm	16,200 rpm.

(plotted, curves page 6)

(7) Within the expected loosenesses, the mechanical critical frequency is not a problem

(8) The choice of internal looseness is not controlled by this factor. Past extensive practise has been, .0013"-.0021", but increased to .002-.003 for taking care of cold starts with aluminum housings. We should lean towards the lower figure here for its much greater capacity and margin for shocks. The reduced thru-flow will give greater temperature rise, but this is high only at cold start (100°F) and can be helped by grooves.

(9) Rechecked Nov. 8th for lower loads. Spring rates taken at 1 G loads (curve on page 8). This indicates clearance should be cut to .0013 to .0021 to keep critical above 12,000.

Thomas Barish

V 181

THOMAS BARISH	3210 WARRENSVILLE CENTER ROAD CLEVELAND 22, OHIO	Thomas Barish	Nov. 7, 1963

PMA-263-A1

FOR 1BC2

CRITICALS - IN OIL FILM BRGS.

REF. RAYMONDI & BOYD "FINITE L/D BRG." ASLE-I-151

BRGS LOWER ½"×½" UPPER ½"φ × ⅜"

OIL AT 260° = 4.2 centipoises AT .03-.04 lb/in²
= .60 × 10⁻⁶ reyns

N = 7760 = 129.3 RPS (used 120° Brg Curves)

	LOWER BRG L/D = 1.						UPPER BRG. L/D =					
Clearance	.0013 Loose			.0021			.0012			.0021		
Load	2G 3G 5G 4.8	7.2	12.0	4.8	7.2	12.0	4.0	6.0	10.	4	6	10.
P lb/in²	19.2	28.8	48	19.2	28.8	48	21.3	31.9	53.3	21.3	31.9	53.3
$(R/c)^2$	148,000			56,200			148,000			56,200		
S = $\frac{A}{C} = \frac{\mu N}{P}$	.60	.40	.239	.227	.151	.091	.54	.36	.216	.201	.134	.081
h_m/C	.70	.61	.48	.47	.385	.28	.59	.49	.382	.375	.305	.215
DEFL. MILS	.195	.254	.348	.555	.645	.765	.272	.352	.402	.666	.730	.82
MIN FILM MILS	.455	.396	.302	.445	.405	.295	.328	.318	.248	.384	.320	.226
cos ∠	.30	.39	.52	.55	.65	.72	.425	.51	.618	.625	.675	.785
DEFL IN LOAD DIRN MILS	.121	.099	.161	.274	.397	.549	.118	.161	.248	.416	.550	.645
Δ def MILS	2-5, 3-5G .122	.082		2-3, 3-5G .247	.146		.130	.079		.229	.157	
STRING WTE W/ 1000/in	56.1	56.5		28.7-35			46.0	50.8		31.4	29.3	

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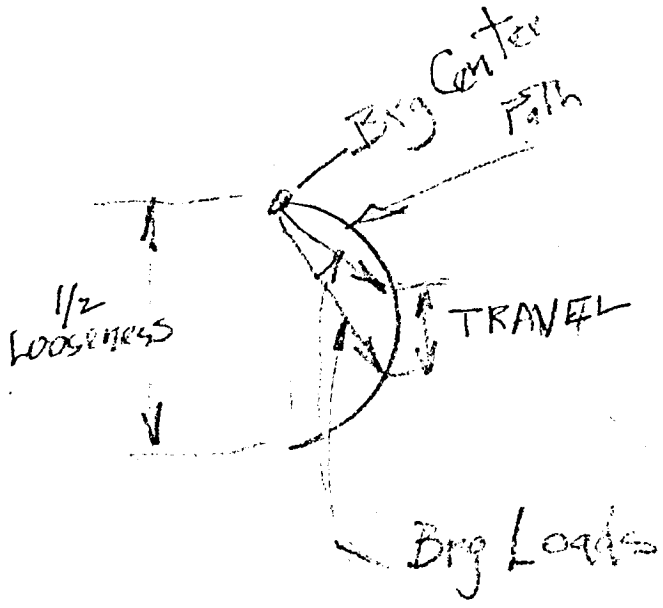
THOMAS BARISH	3210 WARRENSVILLE CENTER ROAD CLEVELAND 22, OHIO	T. Barish	11/4/62

PMA-R63-81

TAPCO SNAP-8 LUB PUMP – BRG CRITICALS

	Lower Brg				Upper Brg.			
Wt Load	2.4				2.0			
Looseness	.0013		.0021		.0013		.0021	
DEFL Load MINCHES	41.0	41.0	83.0	72.1	43.5	39.4	63.5	68.3

	.0013 Loose		.0021 Loose	
	2+.5G	3-5G	2-5G	3-5G
DEFL at CG MINCHES	42.2	40.3	73.2	70.5
CRITICAL RPM	28,900	29,600	22,000	24,400



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THOMAS BARISH
3210 WARRENSVILLE CENTER ROAD
CLEVELAND 22, OHIO

T. Barish 11/4/[illegible]

Repeat for .003 CLEARANCE
and 2 to 5 G

	LOWER BRG		UPPER BRG	
	2G	5G	2G	5G
Load	4.8	12	4.0	10.
P lbs/□"	19.2	48	21.3	53.3
$(R/c)^2$	16,670			
S =	.0674	.0275	.0638	.0243
h_n/c	.226	.095	.178	.075
MIN FILM M"	339.	143.	262.	113.
DEFL. M"	1141	1357	1238	1387
COS L	.774	.905	.822	.925
DEFL IN LOAD DIRECTN	886	1220	1020	1280
Δd	354 m"		260 m"	
Spring Rate	20,400		23,100	
DEFL/WT	118 m"		86.5	

average = 102.2 m"

CRITICAL 18,600 RPM

V 101

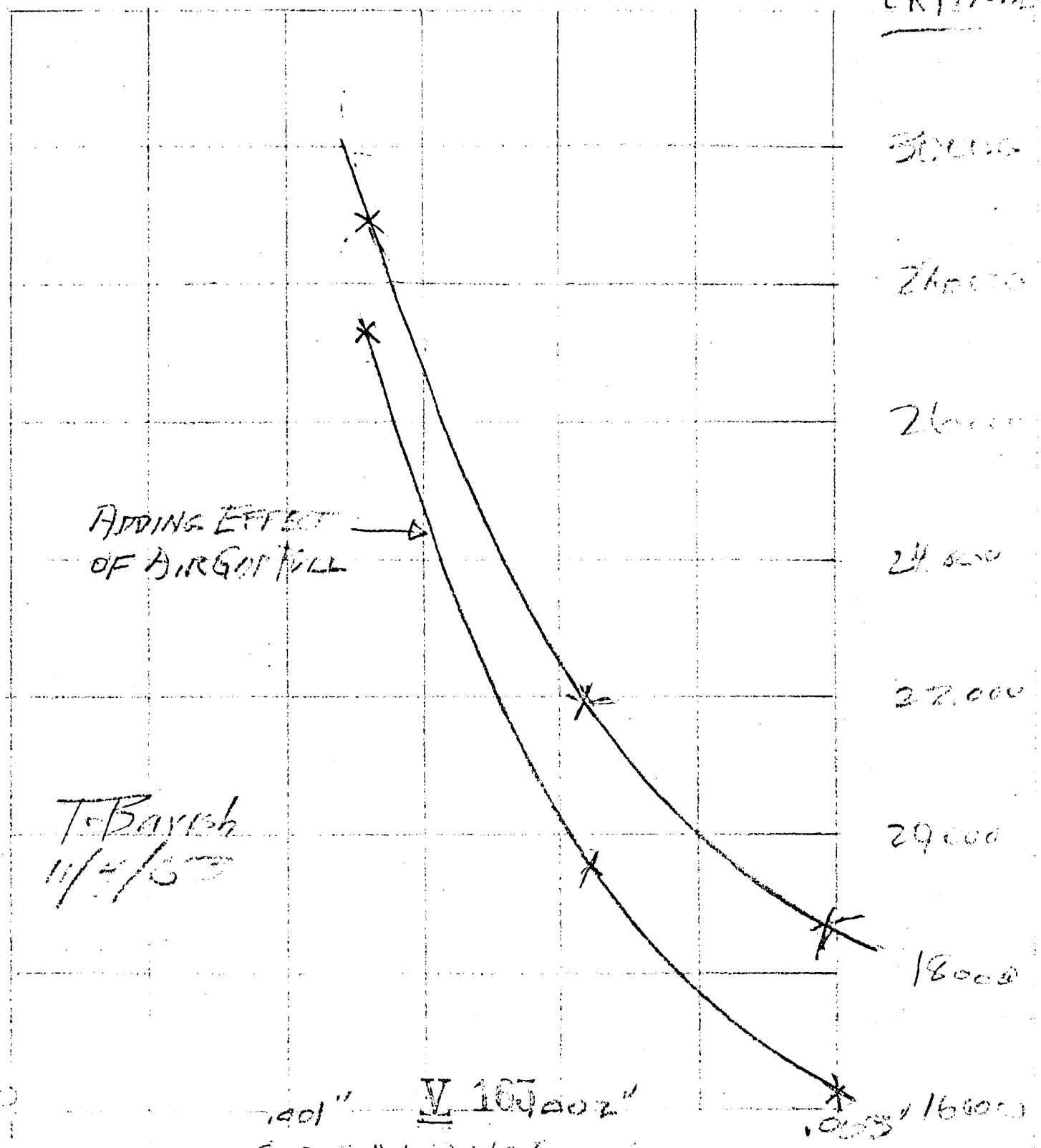
THOMAS BARISH	3210 WARRENSVILLE CENTER ROAD CLEVELAND 22, OHIO	T. Barish	9/[illegible]/63

PMA-R63-81

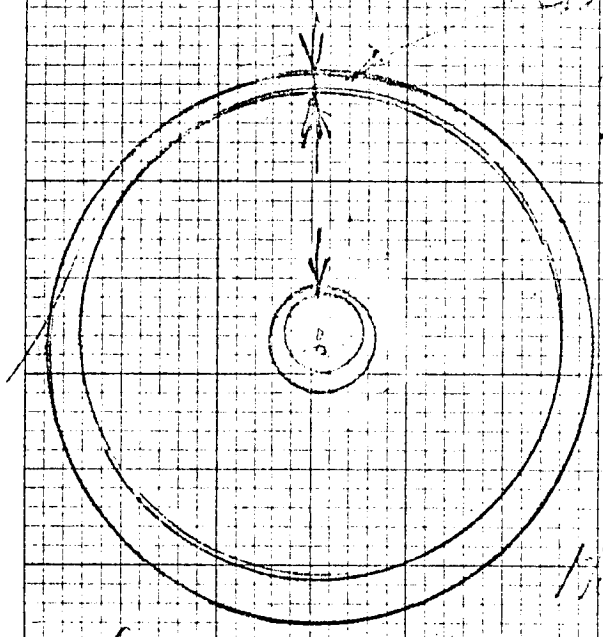
TAPCO SNAP, LUB [illegible] 5

CRITICAL SPEED (FROM FIRST YIELD)

VERSUS CLEARANCE



EFFECT OF AIR GAP FORCES



Assume [illegible] .010, = .005" air gap [illegible]

[illegible]

Varies [illegible] at [illegible] 18.3 lb

Rate [illegible] 3700 lb/in

However [illegible]

6/[illegible] [illegible] Spring [illegible] subtract [illegible] for .001" motion. Drag [illegible] increased and electrical pull (subtract [illegible]) is [illegible]

	Lower Brg [illegible]					Upper Brg [illegible]				
Loss	.0013		.0021		.003	.0013		.0021		.003
Load [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Film [illegible] Rate [illegible]	52.7	52.7	28.3	33	20.4	46.0	50.8	31.4	27.2	23.1
Loss [illegible]	55.0	55.0	25.2	[illegible]	16.7	42.5	47.1	27.7	25.6	[illegible]
DEFL [illegible] in in	45.6	[illegible]	96	81.8	14[illegible]	56.6	50.2	86.5	93.6	12[illegible]
Defl [illegible] (Whole [illegible])	49.1	47.2	91.5	87.6	134					
[illegible]	27,300		19,600		16,200					

PLOTTED P5

EUGENE DIETZGEN CO. MADE IN U.S.A.
NO. 340R-10 DIETZGEN GRAPH PAPER 10 X 10 PER INCH

TAPCO

T. Barish 11/8/63 (1)

SNAP-8 LUBE PUMP - CRITICALS

Recalc. of Report 11-7-63 For Lower "G" i.e 1G

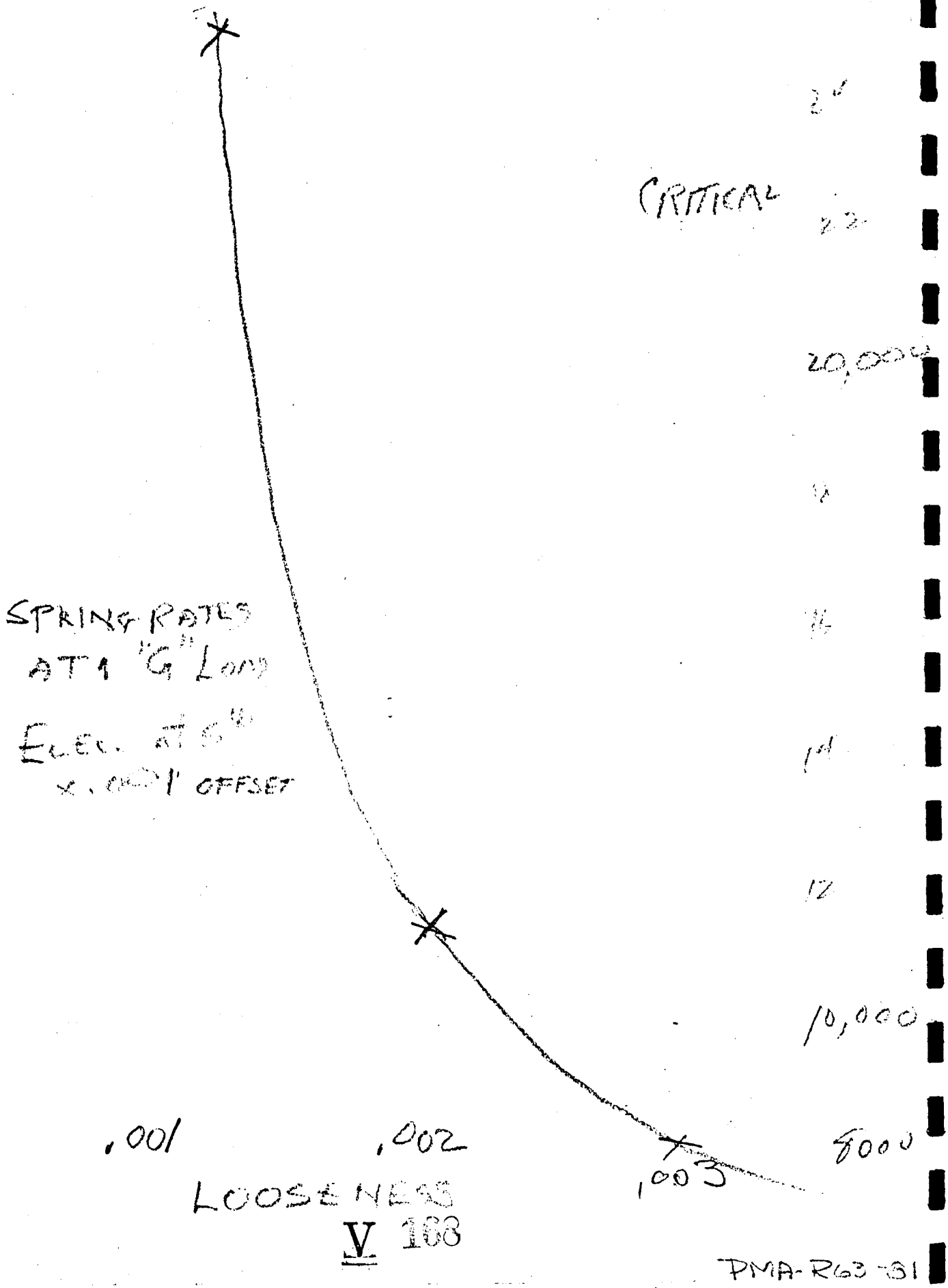
		Lower Brg 2.4 lb			Upper Brg 2.0 lb		
Looseness		.0013	.0021	.0030	.0013	.0021	.003
J (Somm. No.)							
	3/4G	1.60	.605	.179	1.44	.514	.170
	1 1/4G	.96	.363	.107	.86	.326	.102
Hn/C	3/4G	.867	.700	.420	.778	.578	.336
	1 1/4G	.791	.583	.310	.686	.469	.200
DEFL m"	3/4G	86.4	315	870	146	443	995
	1 1/4G	136.	437	1035	204	557	1200
COOL	3/4G	.133	.300	.580	.222	.422	.664
	1 1/4G	.201	.417	.690	.314	.531	.800
DEFL with Load m"	3/4G	11.5	64.5	505	32.4	187	660
	1 1/4G	28.4	182	715	69.7	296	960
ΔD m"		16.9	117.5	210	37.3	109	300
Spring Rate 1000 lb/in		71.0	10.22	5.72	29.8	9.17	3.33

ELECTRICAL .001" OFFCENTER (.009 gap) = 5 lb, .002", 5.625 lb

Rate = .625 lb / .001 = 625 lb/in Subtract

NET SPRING Rate	70.4	9.60	5.10	29.2	8.55	2.71
DEFL W	34.1	250	470	82.8	280	885
AVGE	55.8	265	677			

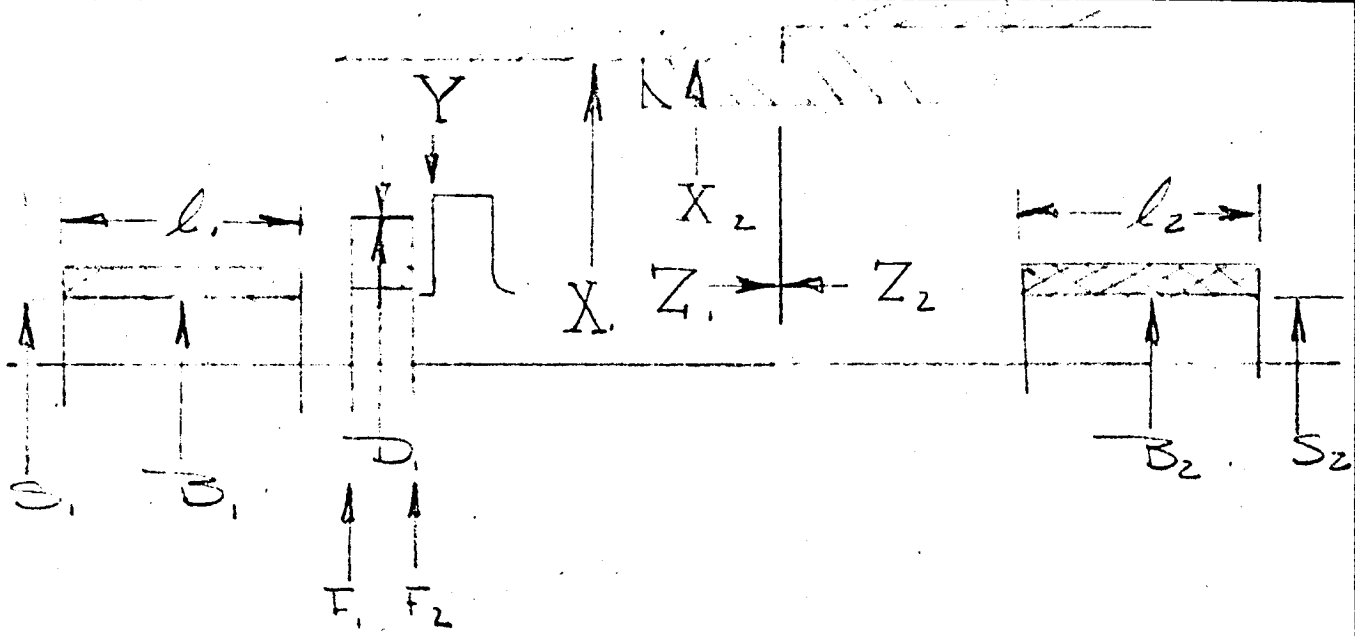
V 167


26
24
CRITICAL
22
20,000
18
16
14
12
10,000
8000
SPRING RATES
AT 1 "G" LOAD
ELEC. AT 6"
.001" OFFSET
.001
.002
.003
LOOSENESS

PMA-R63-31

Thompson Ramo Wooldridge Inc.

SUBJECT: Comparative Bkg. Fits & Misc. 1's 253800-1 REPORT NO. PMA-P63-84



Model Number	101100	100300	253800-1
$F_2 \perp B_1$	—	—	.001
$F_1 \parallel F_2$	.002 TIR	.0005	—
$B_1 \odot X_1$	.002 TIR	.002	.001
$B_2 \odot X_2$	.002 TIR	.002	.001
$S_1 \odot S_2$	.0005	.0005	.0005
X_1 To X_2 Clear.	.002 [illegible]	[illegible]	.001 - .003
ℓ_1 & ℓ_2	.718 Nom.	.53[illegible] Nom.	.433 Nom
S_1 To B_1 & S_2 To B_2 @ Pump.	.0036/.00[illegible]	.0021/.0013	.0013/.0021 ≈ .0013/.0021
Ecc. Of S_1 In ℓ_1			.00037
$Y \perp S_1$ & S_2 ℄	.0005 (S_1), .001 S_2	.001	.0005
$Y \parallel F_2$ (R)			.0017
Shaft Mat'l	S.S. 5610 (416)	S.S. 5610 (416)	410
Hsg Mat'l	355 T6/356 T6 Alum	355 T6/356 T6 Alum.	410
Bkg Mat'l	Gen[illegible] #39	[illegible] #39	[illegible] Carbon Pyrol
Fluid Temp. in Viscosity @ [illegible]	14[illegible]°F JP4	110°F [illegible]	250°F 6.3

PREPARED [illegible] 11/7

CHECKED

INITIALS - DATE

Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: Comparative Brg. [illegible] REPORT NO. [illegible]

Model Number	101100	100300	253800-1
Brg. O.D. (R.T.)	1.0663/1.0658	.941/.940	1.066/1.065
Brg. I.D.	.6214/.6269	.5016/.5021	.5030/.5023
Hsg. I.D.	1.063/1.0625	.9375/.9382	1.062/1.063
Hsg. Bore O.D.	1 3/8	1 1/4	1 5/8
Shaft O.D.	.6513/.6510	.5000/.5008	.5000/.5003
Brg. To Hsg. Intf. R.T. @ Temp.	.0038/.0026	.0035/.0018	.002/.004 .0027/.0007
Brg. Stress R.T. Max	8,720 psi	9,550 psi	12,400 psi
@ Temp. Max	6,900 "	8,510 "	8,380 "
R.T. Min	5,970 "	4,910 "	6,200 "
@ Temp. Min	4,140 "	3,820 "	2,168 "
Hsg. Stress R.T. Max	19,500 psi	18,100 psi	19,100 psi
@ Temp. Max	15,400 "	16,020 "	13,4[illegible] "
R.T. Min	13,300 "	9,300 "	[illegible] "
@ Temp. Min	9,260 "	7,230 "	3,480 "
Thrust Brg. O.D.	1.0663/1.0658	.941/.940	1.251/1.250
Brg. I.D.	.670/.661	.526/.516	.540/.560
Hsg. I.D.	1.0634/.0625	.9375/.9382	1.248/1.247
Hsg. Bore O.D.	1 3/8	1 1/4	1 5/8
Brg. To Hsg. Intf. R.T. @ Temp.	.0038/.0026	.0035/.0018	.002/.004 .0004/.0004

(Compressive Outer Surface)

(Tensile Inner Surface)

Thompson Ramo Wooldridge Inc.

TRW

SUBJECT: Comparative Bag Fes [illegible] 253800-1 REPORT NO. DMA-R63-84

			253800-1
Tangential Beg. Stress R.T. Max.	9630 psi	9,550 psi	9200 psi
@ Temp Max	7600 "	8,510 "	5530
R.T. Min	6600 "	4,910 "	4600
@ Temp. Min	4560 "	3,820 "	[illegible]20
Compressive (Outer surface)			
Beg. Stress R.T. Max.	14,700 psi	18,100 psi	24,[illegible]
@ Temp. Max.	11,600 "	16,020 "	14,480
R.T. Min	10,080 "	9,300 "	12,0[illegible]0
@ Temp. Min.	6,970 "	7,230 "	24[illegible]8
Tensile (Inner surface)			

Notes: Fuel Model 53600 Similar To 100300 In All Respects Except [illegible] NF_2 .002 & Monel Shaft Mat'l.
∴ Other Units With Operating Temp. In 250°F Range, Have Stresses Considerably Greater Than 253800-1 Values Shown.

FOR INNER BEARINGS:

$$a = \frac{.5027}{2} = .2513$$

$$b = \frac{1.066}{2} = .533$$

$$c = \frac{1.625}{2} = .8125$$

$$\delta \ (@\ 70°F) = .004 \text{ max.} \qquad .002 \text{ min.}$$

$$\delta \ (@\ 250°F) = \delta_{70} - \Delta T \times 2b \times \Delta\alpha$$

$$= \delta_{70} - (250-70) \times 1.066\,(9.6-2.7)\,10^{-6}$$

$$= \delta_{70} - 180 \times 1.066 \times 6.9 \times 10^{-6}$$

$$= \delta_{70} - .00132$$

$$= .0027 \text{ max.} \qquad .0007 \text{ min.}$$

$$P = \frac{\delta}{b\left[\dfrac{\dfrac{c^2-b^2}{c^2-b^2} + \mu_s}{E_s} + \dfrac{\dfrac{b^2+a^2}{b^2-a^2} - \mu_c}{E_c}\right]}$$

$$= \frac{.004}{.533\left[\dfrac{\dfrac{.8125^2+.533^2}{.8125^2-.533^2} + .26}{29\times10^6} + \dfrac{\dfrac{.533^2+.2513^2}{.533^2-.2513^2} - .075}{1.75\times10^6}\right]}$$

$$= \frac{.004}{.533 \times .9508 \times 10^{-6}} = \frac{4\times10^3}{.533\times.9508} = 7900 \text{ psi}$$

∴ Max. rad. stress @ 70° = 7900 psi
Min " " " " = 3950 "
Max. " " @ 250° = 5340 "
Min. " " " " = 1380 "

$$S_{ie} = -p\frac{b^2+a^2}{b^2-a^2} \quad \text{(bearing, compressive)}$$

Max. @ 70° = $7900 \frac{.533^2+.2513^2}{.533^2-.2513^2} = 7900 \times 1.57 = 12400$ psi

Min. @ 70° = $3950 \times 1.57 = 6200$ psi

Max. @ 250° = $5340 \times 1.57 = 8380$ psi

Min. @ 250° = $1380 \times 1.57 = 2168$ psi

$$S_{oe} = p\frac{c^2+b^2}{c^2-b^2} \quad \text{(housing, compressive)}$$

Max @ 70° = $7900 \frac{.8125^2+.533^2}{.8125^2-.533^2} = 7900 \times 2.52 = 19900$ psi

Min. @ 70° = $3950 \times 2.52 = 9950$ psi

Max. @ 250° = $5340 \times 2.52 = 13430$ psi

Min @ 250° = $1380 \times 2.52 = 3480$ psi

FOR THRUST BEARING:

$$a = \frac{.550}{2} = .275$$

$$b = \frac{1.200}{2} = .625$$

$$c = \frac{1.625}{2} = .8125$$

δ (@ 70°) = .004 max. .002 min

$$\delta\ (@\ 250°) = \delta_{70} - (250-70) \times 1.250\,(9.6-2.7)\,10^{-6}$$

$$= \delta_{70} - 180 \times 1.25 \times 6.9 \times 10^{-6}$$

$$= \delta_{70} - .00155$$

= .0024 max. .0004 min.

$$p = \frac{.004}{.625\left[\dfrac{\dfrac{.8125^2+.625^2}{.8125^2-.625^2}+.20}{29\times10^6} + \dfrac{\dfrac{.625^2+.275^2}{.625^2-.275^2}-.015}{1.75\times10^6}\right]}$$

$$= \frac{.004}{.625 \times 1.034 \times 10^{-6}} = \frac{4\times10^3}{.625\times1.034} = 6190 \text{ psi}$$

∴ Max. rad. stress @ 70°F = 6190 psi
Min. " " " " = 3095 psi
Max. " @ 250° = 3720 psi
Min. " " " " = 619

Thompson Ramo Wooldridge Inc.

SUBJECT: REPORT NO.

$$S_{it} = -p \frac{b^2+a^2}{b^2-a^2} \quad \text{(bearing, compressive)}$$

Max. @ 70° = 6190 × $\frac{.625^2+.275^2}{.625^2-.275^2}$ = 6190 × 1.485 = 9200 psi

Min @ 70° = 3095 × 1.485 = 4600 psi

Max. @ 250° = 3720 × 1.485 = 5530 psi

Min @ 250° = 619 × 1.485 = 920 psi

$$S_{ot} = p \frac{c^2+b^2}{c^2-b^2} \quad \text{(housing, tensile)}$$

Max. @ 70° = 6190 × $\frac{.8125^2+.625^2}{.8125^2-.625^2}$ = 6190 × 3.89 = 24 100 psi

Min @ 70° = 3095 × 3.89 = 12040 psi t.

Max. @ 250° = 3720 × 3.89 = 14480 psi t.

Min. @ 250° = 619 × 3.89 = 2408 psi. t.

FOR 100 300

$\mu_{alum.} = .36$

$E_{alum} = 9 \times 10^6$

$\alpha_{alum} = 13 \times 10^{-6}$

Radial bearings

$a = \frac{.502}{2} = .251$

$b = \frac{.940}{2} = .470$

$c = \frac{1.25}{2} = .625$

$\delta_{70°} = .0035$ max. $.0018$ min

$\delta_{110°} = \delta_{70°} - \Delta T \times 2b\,\Delta\alpha$

$= \delta_{70°} - (110-70) \times .94\,(13 \times 10^{-6} - 2.7 \times 10^{-6})$

$= \delta_{70°} - 40 \times .94 \times 10.3 \times 10^{-6}$

$= \delta_{70°} - 3.88 \times 10^{-4} = \delta_{70°} - .0004$

$= .0031$ max. $.0014$ min.

$$p = \frac{\delta}{b\left[\frac{\frac{c^2+b^2}{c^2-b^2} + \mu_a}{E_a} + \frac{\frac{b^2+a^2}{b^2-a^2} - \mu_c}{E_c}\right]}$$

$$= \frac{.0035}{.470\left[\frac{\frac{.625^2+.47^2}{.625^2-.47^2} + .36}{9 \times 10^6} + \frac{\frac{.47^2+.251^2}{.47^2-.251^2} - .075}{1.75 \times 10^6}\right]}$$

$$= \frac{.0035}{.470 \times 1.404 \times 10^{-6}} = \frac{3.5 \times 10^3}{.47 \times 1.404} = 5310 \text{ psi}$$

∴ Max radial stress @ 70°F = 5310 psi

Min " " " " = $\frac{.0018}{.0035} \times 5310 = 2730$ psi

Max " " @ 110°F = $\frac{.0031}{.0035} \times 5310 = 4700$ psi

Min " " " " = $\frac{.0014}{.0035} \times 5310 = 2120$ psi

$$S_{it} = -p \frac{b^2 + a^2}{b^2 - a^2}$$ (bearing, compressive)

@ 70°F. max. $S_{it} = 5310 \frac{.470^2 + .251^2}{.470^2 - .251^2} = 5310 \frac{.284}{.158}$

$= 5310 \times 1.8 = 9550$ psi c.

@ 70°F. min. $S_{it} = 2730 \times 1.8 = 4910$ psi c.

@ 110°F. max. $S_{it} = 4730 \times 1.8 = 8510$ psi c.

@ 110°F. min $S_{it} = 2120 \times 1.8 = 3820$ psi c.

$$S_{ot} = p \frac{c^2 + b^2}{c^2 - b^2}$$ (housing, tensile)

@ 70°F. max $S_{ot} = 5310 \frac{.625^2 + .470^2}{.625^2 - .470^2} = 5310 \frac{.611}{.179}$

$= 5310 \times 3.41 = 18,100$ psi t.

@ 70°F. min $S_{ot} = 2730 \times 3.41 = 9,300$ psi t

@ 110°F. max. $S_{ot} = 4700 \times 3.41 = 16,020$ psi t.

@ 110°F. min $S_{ot} = 2120 \times 3.41 = 7,230$ psi t.

For thrust bearing

$a = \frac{.521}{2} = .261$

$b = \frac{.940}{2} = .470$

$c = \frac{1.25}{2} = .625$

δ (@ 70°F.) = .0035 max. .0018 min

δ (@ 110°F) = .0031 max. .0014 min
(as for radial bearings)

Since the above thrust bearing constants are essentially the same as those for the radial bearings, the stresses are comparable.

For thrust bearing:

$$a = \frac{.670}{2} = .335$$

$$b = \frac{1.066}{2} = .533$$

$$c = \frac{1.375}{2} = .6875$$

δ (@ 70°F) = .0038 max. .0026 min.

δ (@ 140°F) = .0030 max. .0018 min.

$$p = \frac{\delta}{b\left[\dfrac{\dfrac{c^2+b^2}{c^2-b^2} + \mu_a}{E_a} + \dfrac{\dfrac{b^2+a^2}{b^2-a^2} - \mu_c}{E_c}\right]}$$

$$= \frac{.0038}{.533\left[\dfrac{\dfrac{.6875^2+.533^2}{.6875^2-.533^2} + .36}{9\times10^6} + \dfrac{\dfrac{.533^2+.335^2}{.533^2-.335^2} - .075}{1.75\times10^6}\right]}$$

$$= \frac{.0038}{.533\times 1.700\times10^{-6}} = \frac{3.8\times10^3}{.533\times1.7} = 4190 \text{ psi}$$

∴ Max. radial stress @ 70°F = 4190

Min " " " " = $\frac{.0026}{.0038}\times4190 = 2870$ psi

Max. " " @ 140°F = $\frac{.0030}{.0038}\times4190 = 3310$ "

Min " " " " = $\frac{.0018}{.0038}\times4190 = 1985$ "

$$S_{it} = -p\,\frac{b^2+a^2}{b^2-a^2} \qquad \text{(bearing, compressive)}$$

@ 70°F. max $S_{it} = 4190\,\dfrac{.533^2+.335^2}{.533^2-.335^2} = 4190\,\dfrac{.397}{.173}$

$= 4190 \times 2.298 = 9630$ psi c.

@ 70°F. min $S_{it} = 2870 \times 2.298 = 6600$ psi c.

@ 140°F. max. $S_{it} = 3310 \times 2.298 = 7600$ psi c.

@ 140°F. min. $S_{it} = 1985 \times 2.298 = 4560$ psi c.

$$S_{ot} = p\,\frac{c^2+b^2}{c^2-b^2} \qquad \text{(housing, tensile)}$$

@ 70°F. max. $S_{ot} = 4190 \times 3.51 = 14,700$ psi t.

@ 70°F. min. $S_{ot} = 2870 \times 3.51 = 10,080$ psi t.

@ 140°F max. $S_{ot} = 3310 \times 3.51 = 11,600$ psi t.

@ 140°F min. $S_{ot} = 1985 \times 3.51 = 6,970$ psi t.

325 IN MN

[illegible] 325 × .625 [illegible] 325 × .625 = 8.94 IN³/MIN

8.94 IN³ × [illegible] .039 [illegible]

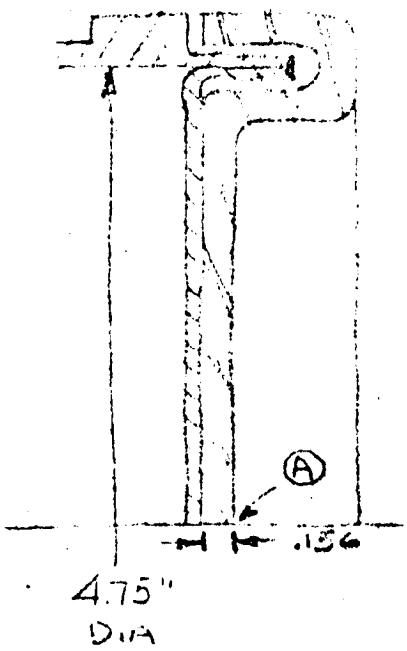
[illegible] × [illegible]

[illegible] = 3 [illegible] 5 [illegible] @ 0 FLOW

ASSUME ΔP @ .04 GPM = .2 ΔP @ FLOW

∴ OUTPUT = .04 GPM @ 0.4 PSI

END COVER:



Maximum internal pressure within housing while operating is 75 PSI

Use 1.5 factor for proof pressure

Check cover design @ 113 PSI ΔP

17000^2

TOTAL LOAD $= \frac{4.75^2 \pi}{4} \times 113 = 2000^{\#}$

LOAD PER BOLT (6 bolts) $= \frac{2000}{6} = 333^{\#}$

(A) Determine maximum stress in plate and deflection with uniformly distributed load, simply supported 4.75" dia edge. See Roark "Form. for Stress & Strain", 3rd Ed. page 194, Form. # 1.

$$\text{Max } S \text{ (at center)} = S_r = S_t = -\frac{3W}{8\pi m t^2}(3m+1)$$

$$= -\frac{3 \times 2000}{8\pi \frac{1}{.26} .156^2}\left(3\frac{1}{.26}+1\right) = -\frac{6000}{8\pi \times 3.34 \times .156^2} \times 12.52$$

$= -32{,}000$ psi on ℄, (compression on left face tension on right face)

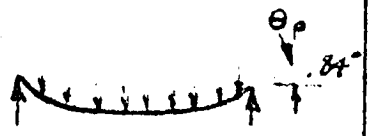
(NEGLECTING THE EFFECT OF THE HOLE FOR THE CONNECTOR)

$$\max.\ y\ (\text{at center}) = -\frac{3w(m-1)(5m+1)a^2}{16\pi E m^2 t^3}$$

$$= -\frac{3\times 2000\,(3.84-1)(19.25+1)\,2.375^2}{16\pi\times 3\times 10^7\times 14.8\times .156^3} = -\frac{6\times 2.84\times 20.25\times 2.375^2\times 10^3}{1.6\pi\times 3\times 1.48\times 1.56^3\times 10^6}$$

$$y_p = .0229''$$

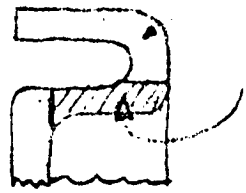
At outer edge, $\theta_p = \dfrac{3w(m-1)a}{2\pi E m t^3}$



$$\theta_p = \frac{3\times 2000\,(3.84-1)\,2.375}{2\pi\times 3\times 10^7\times 3.84\times .156^3} = \frac{2.84\times 2.375\times 10^3}{\pi\times 3.84\times 1.56^3\times 10^4}$$

$$= .0147 \text{ radians} \quad (.84^\circ)$$

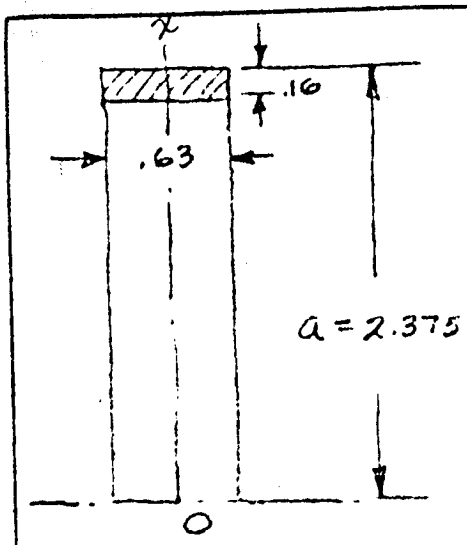
There will be some clamping of the edge due to the stiffening ring



Assume that the angular deflection of the stiffened edge is equal to that of a simply supported edge. ($\theta_f = \theta$) Determine the torsion resistance of the stiffening ring to such a twist:

From Timoshenko, "Strength of Mat'ls" Part II 2nd Ed. pg. 178 - 180, formula number shown in ( ).

$$\theta_f = \frac{M_t a^2}{E I_x}, \quad M_t = \frac{E I_x \theta_f}{a^2} \qquad (161)$$

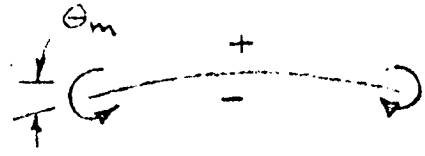


$$I_x = \frac{.16 \times .63^3}{12} = \frac{1.6 \times 6.3^3 \times 10^{-4}}{12}$$

$$= 33.3 \times 10^{-4} = 3.33 \times 10^{-3} \text{ in.}^4$$

From Roark, Form. 12 pg. 197 the edge moment (which has the dimensions # in/in) and the symbol M, produces an angular deflection at the edge of an unsupported plate as follows:

$$\theta_m = \frac{12(m-1)Ma}{Emt^3}$$



Now if $\theta_m \equiv$ deflection of an unloaded plate with an edge moment

$\theta_p \equiv$ deflection of a loaded plate with a plain simply supported edge. (.0981 rad.)

$\theta \equiv$ deflection of a loaded plate with a stiffened edge, simply supported

Then $\theta = \theta_p - \theta_m$

But if the edge & the stiffening flange roll in unison, $\theta_f = \theta$

Thus $\theta_f = \theta_p - \theta_m$

$$\frac{M_t a^2}{E I_x} = .0147 - \frac{12(m-1)M_t a}{Emt^3}$$

$$\frac{M_t a^2}{E I_x} + \frac{12(m-1)M_t a}{Emt^3} = .0147$$

$$M_t\left(\frac{a^2}{EI_x}+\frac{12(m-1)a}{Emt^3}\right)=.0147$$

$$M_t=\frac{.0147}{\frac{a}{E}\left(\frac{a}{I_x}+\frac{12(m-1)}{mt^3}\right)}=\frac{.0147E}{a\left(\frac{amt^3+12(m-1)I_x}{I_x mt^3}\right)}$$

$$=\frac{.0147\,E\,I_x\,mt^3}{a\left(amt^3+12(m-1)I_x\right)}$$

$$=\frac{.0147\times 3\times10^7\times 3.33\times10^{-3}\times 3.84\times .156^3}{2.375\left[2.375\times 3.84\times .156^3+12(3.84-1)\,3.33\times10^{-3}\right]}$$

$$=\frac{.147\times 3\times 3.33\times 3.84\times 1.56^3\times10^{-3}}{2.375\left(2.375\times 3.84\times 1.563\times10^{-3}+12\times 2.84\times 3.33\times10^{-3}\right]}$$

$$=\frac{147\times 3\times 3.33\times 3.84\times 1.56^3}{2.375\times 148.1}$$

$$=61.0\ \#\text{in.}/\text{in.}$$

Now determine plate stress for θ_m and add this algebraically to stress for θ_p.

For θ_m $\quad S_r=S_t=\dfrac{6M}{t^2}=\dfrac{6\times 61}{.156^2}=15{,}300$ psi

This is the stress everywhere on the unloaded plate with edge moment.

The stress at the plate center is $\pm(32000-15300)$ or $\pm$ 16,700 psi

The stress at the edge of the loaded, simply supported (and unstiffened) plate is given by Case 1 Roark, pg. 194

$$S_t=\frac{-3w}{8\pi mt^2}\left[(3m+1)-(m+3)\frac{r^2}{a^2}\right]$$

where $r=a$, $[3m+1-m-3]=2[m-1]$

$$S_t = -\frac{3 \times 2000}{8\pi \times 3.84 \times .156^2}\, 2\,(3.84-1) = -\frac{6 \times 2.84 \times 10^3}{4\pi \times 3.84 \times 1.56^2 \times 10^{-2}}$$

$$= -\frac{3 \times 2.84 \times 10^5}{2\pi \times 3.84 \times 1.56^2} = -14{,}500 \text{ psi} \quad \left(\text{compression on loaded side}\right)$$

Thus the tangential stress at the edge of stiffened and simply supported plate is $\pm\,(15{,}300 - 14{,}500) = \pm\,800$ psi

The radial stress at the edge of this plate is the stress due to the moment:

$$S_r = 15{,}300 \text{ psi}$$

THUS THE MAX. STRESS ANYWHERE ON PLATE IS $S_r = S_t =$ 16,700 psi at center

WHEN THE CONNECTOR HOLE IS NEGLECTED

Now determine the maximum deflection:

Let $y_p \equiv$ defl. at center on plain plate

$y_m \equiv$ " " " " unloaded plate with edge moment.

$y \equiv$ resultant defl. at center

$y = y_p - y_m \qquad y_p = .023$ see sheet #1

From Roark Case 12, pg. 197:

$$y_m = \frac{6(m-1)Ma^2}{Emt^3} = \frac{6 \times 2.84 \times 61 \times 2.375^2}{3 \times 10^7 \times 3.84 \times .156^3}$$

$$= \frac{\cancel{6}^{\,2} \times 2.84 \times 6.1 \times 2.375}{\cancel{3} \times \underset{1.92}{\cancel{3.84}} \times 1.56^3 \times 10^3} = 5.64 \times 10^{-3}$$

$$= .006''$$

$y = .023 - .006 = \underline{.017}$ " deflection at center

Now investigate the same plate with concentric circular opening for connector. (1.40" dia)
See Roark, Case 13, page 198:

$$\text{Max. } S = S_t = \frac{-3W}{4mt^2(a^2-b^2)}\left[a^4(3m+1)+b^4(m-1)-4ma^2b^2-4(m+1)a^2b^2\log\frac{a}{b}\right]$$

$$S_t = \frac{-3\times 2000}{4\times 3.84\times .156^2\,(2.375^2-.7^2)}\left[2.375^4\times 4.84+.70^4\times 2.84-4\times 3.84\times 2.375^2\times .70^2 - 4\times 4.84\times 2.375^2\times .70^2\log\frac{2.375}{.7}\right]$$

$$= -\frac{6\times 10^3}{4\times 3.84\times 1.56^2\times 10^{-2}\times 5.16}\left[155+139-42.4-53.6\log 3.39\right]$$

65.5 1.22 186.1

155
139
294.0
42.4
65.5
1.079
.561

$$= -\frac{6\times 186.1\times 10^5}{4\times 3.84\times 1.56^2\times 5.16}$$

$= -5.79\times 10^5 = 579{,}000$ psi (high but the assumptions are not realistic)

Try plate with fixed outer edge & concentric circular hole: See Roark, Case 17, Page 199

Max. $S = S_r$ at outer edge

$$= \frac{3W}{4t^2}\left[a^2-2b^2+\frac{b^4(m-1)-4b^4(m+1)\log\frac{a}{b}+a^2b^2(m+1)}{a^2(m-1)+b^2(m+1)}\right]$$

$$= \frac{3\times 2000}{\cancel{4}_{2}\times .156^2}\left[2.375^2-2\times .70^2+\frac{.70^4\times 2.84-4\times .70^4\times 4.84\log\frac{2.375}{.7}+2.375^2\times .7^2\times 4.84}{2.375^2\times 2.84+.70^2\times 4.84}\right]$$

$$= \frac{3\times 10^5}{1.56^2}\left[5.65-.98+\frac{.683-.95\times 1.22+13.4}{16+2.37}\right]$$

$$= 1.232\times 10^5\left[5.65-.98+\frac{12.92}{18.37}\right] = 1.232\times 10^5\times 5.38 = 663{,}000 \text{ psi}$$

Now try 5/16" uniformly thick plate and analyze with outer edge fixed as before

$$S_r \text{ at outer edge} = 663{,}000 \times \left(\frac{.156}{.313}\right)^2 = 166{,}000 \text{ psi}$$

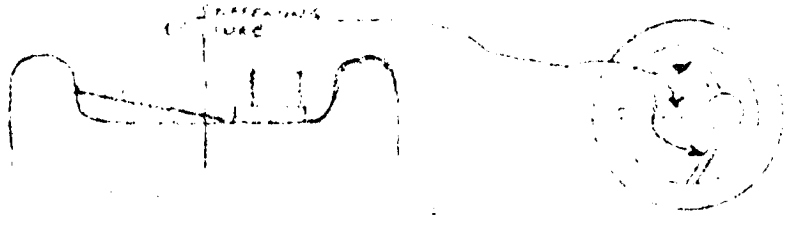
166,000 psi yield is obtainable in alloy structural steel, however this maximum stress can be reduced by dropping the proof pressure. The stress is proportional to the proof pressure and is equal to 166,000 psi at 113 psi proof.

Thus at 75 psi proof, $S = \frac{75}{113} \times 166{,}000$

$= 110{,}000$ psi

It would also seem sufficient to provide a boss around the connector hole about 2" dia so that the plate has .313" thickness at this location

FOREGOING CALCULATIONS HAVE NEGLECTED EFFECT OF CONNECTOR LOCKING NUT. WHEN TIGHTENED, THIS NUT WILL ADD A RECOMMENDED COL. AND WILL ALSO TEND TO CREATE A SOLID PLATE. TO INCREASE RIGIDITY FURTHER, 3 STIFFENING RINGS WILL ALSO BE ADDED.



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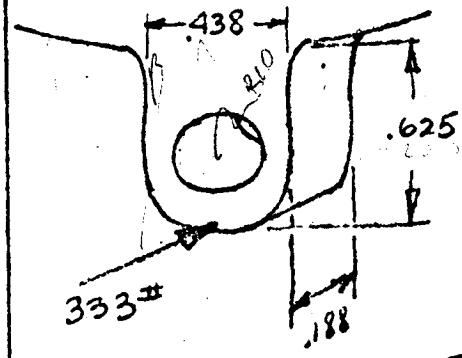
SUBJECT: [illegible] REPORT NO. [illegible]

COVER RETENTION EARS ON HOUSING: not correct ? not correct



$M_B = .333 \times .188 = 62.6$ # in.

$S_B = \frac{M_B y}{I}$, $y = .625$

$I = \frac{bd^3}{12}$

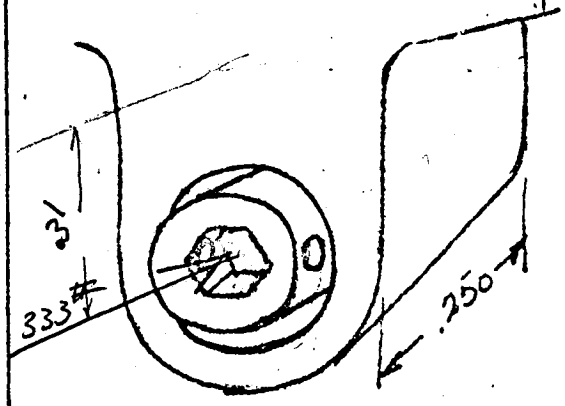
$= \frac{.438 \times .188^3}{12}$

$= 2.42 \times 10^{-4}$ in.^{4}

? not correct

$S_B = \frac{62.6 \times .625 \times 10^4}{2.42} = 162{,}000$ psi marginal

Increase ear thickness from .188 to .250 and counterbore a pocket for the screw head.



$S_B = 162{,}000 \times \left(\frac{.188}{.250}\right)^3$

$= 68{,}500$ psi

$M_B = 333\# \times .31 = 103$ in#

$S_B = \frac{mc}{I}$

$= \frac{103 \times .125}{6.5 \times 10^{-4}}$

$= 19{,}800$ PSI @ 113 PSI

$I = \frac{bh^3}{12}$

$= \frac{.5 \times .25^3}{12}$

$I = 6.5 \times 10^{-4}$

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SUBJECT: [illegible] REPORT NO. [illegible]

HOUSING (PRESSURE CONTAINMENT):

Check 4 3/4" dia. cylinder adjoining cover

$$S_t = \frac{p \times d}{2t} = \frac{113 \times 4.75}{2 \times .125} = 2150 \text{ psi O.K.}$$

HOUSING (CRUSHING BY STRAPS)

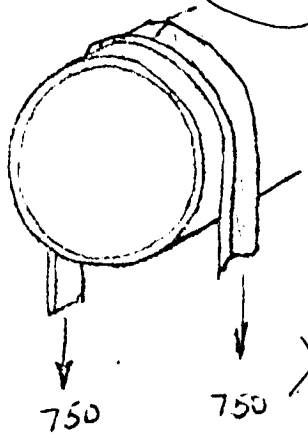
Assume 35 G. Shock load on one strap bearing entire weight of pump (22#)

$F = 35 \times 22 = 770^{\#}$

Assume initial tightening load of 1000#

$770 + 1000 = 1770^{\#}$ tension on "1/2" wide strap.

why



$$S_t = \frac{1770}{1/2} = 3540 \#/in$$

$$S_t = \frac{p \times d}{2t} = 3540 \#/in$$

INCORRECT

$$p = \frac{3540 \times 2t}{d} = \frac{3540 \times 2 \times .125}{4.75} = 186 \text{ psi equiv. external pressure}$$

NOT APPLICABLE should

The critical pressure from Roark, Case 9 pg. 318 Page 270 #6

$$p' = \frac{1}{4} \frac{E}{1-\nu^2} \frac{t^3}{r^3} = \frac{1}{4} \frac{3 \times 10^7}{1-.26^2} \frac{.125^3}{2.375^3}$$

$$= \frac{1}{4} \times \frac{3 \times 10^7}{.973} \times \frac{.125^3}{2.375^3} = \frac{3 \times 1.25^3 \times 10^4}{4 \times .973 \times 2.375^3} = .113 \times 10^4 = 1130 \text{ psi O.K.}$$