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DESIGN, MANUFACTURE, AND TEST OF COOLANT PUMP-MOTOR ASSEMBLY FOR BRAYTON POWER CONVERSION SYSTEM

by Louis E. Gebacz

Prepared by
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for Lewis Research Center

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16. Abstract

This report covers the design, development, fabrication, and testing of seven coolant circulating pump-motor assemblies. The pump-motor assembly is driven by the nominal 44.4-volt, 400-Hz, 3-phase output of a nominal 56-volt dc input inverter. The pump-motor assembly will be used to circulate Dow Corning 200 liquid coolant for use in a Brayton cycle space power system. The pump-motor assembly develops a nominal head of 70 psi at 3.7 gpm with an over-all efficiency of 26 percent. The report includes the design description, drawings, photographs, reliability results, and developmental and acceptance test results.

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SUMMARY

Pesco Products has designed and developed a hermetically sealed pump-motor assembly (PMA) to circulate Dow Corning coolant in a Brayton Cycle Space Power Conversion System.

The PMA has a nominal rating of 3.7 gpm and 70 psi head rise at an operating speed of 11,200 rpm with a nominal inverter input of 56 v dc, and an over-all PMA efficiency of 26%. The specification requirement is 60 psi minimum head rise at rated flow. The PMA has an average weight of 15 pounds and the average weight of the inverter is 25 pounds six ounces.

This report includes a description of the pump and motor design, assembly and envelope drawings, reliability results, pump, motor, and bearing calculations, development test results, and acceptance test results.

Seven PMA's were fabricated and acceptance tested under the contract. Six assemblies were shipped to NASA-Lewis Research Center and the seventh unit was used for development testing. Test results show a pumping ability down to five feet NPSH at 79°F; a starting capability at -71°F with a head rise of 62 psi at 3.7 gpm and at +150°F with a head rise of 68.6 psi at 3.7 gpm flow. A 20,000 hour endurance test on the PMA and inverter was successfully completed.

No degradation in unit performance was observed during the 20,000 hour test. Disassembly inspection showed the unit to be in excellent condition with the parts meeting the original blueprint requirements. The unit was reassembled as is and seal-welded for use as a spare unit.

A minimum of design and testing problems were encountered during the performance of this program. The PMA meets or exceeds the requirements of the contract specification.

INTRODUCTION

NASA-Lewis Research Center issued contract number NAS 3-10935 for the design, development, fabrication, and testing of a pump-motor inverter assembly for the circulation of Dow Corning 200 coolant in a Brayton Cycle Space Power Conversion System.

The power conversion system has potential use with solar, radio-isotope and nuclear reactor heat sources. The power output is 2.0 KW to 15 KW at 1200 Hertz. The system is designed for an unattended space life of five years.

The PMA is a hermetically sealed unit that is powered by a static inverter designed and developed by Gulton Industries, Incorporated under a subcontract, for the Borg-Warner Corporation, Pesco Products Division. A portion of the 1200 Hertz Brayton Power System electrical output is converted to dc power. The static inverter inverts and conditions the dc power (50 to 60 v dc), to 400 Hertz quasi-square wave three phase power (approximately 39.5 v ac - 47.5 v ac) to drive the PMA. All inverters were acceptance tested for 100 hours at Gulton. The work conducted by Gulton Industries on the inverter - Gulton P/N EMIU-104D - is documented in NASA CR-72671 entitled "Final Report - Design and Manufacture of Static Inverter for Brayton Power Conversion System" (Reference 1).

The purpose of the program is to develop flight type hardware with maximum reliability during the design life as the primary objective. Other objectives are maximum combined efficiency of the pump, motor, and inverter, small size and light weight. The units are designed to meet NASA environmental specifications P-1224-1 and P-1224-2 but were not tested to these specifications.

The development PMA and inverter were assurance tested for 250 hours running time with 250 start-stop cycles. Also run were cold start tests at -65°F, hot tests at 150°F, NPSH tests down to 5 feet, reverse rotation tests, and dry start-up tests. This same unit has subsequently completed a 20,000 hour endurance test in the test loop at Pesco. The test loop is automated for unattended operation and has hot and cold ambient capability but no vacuum ambient capability. The other six PMA's were acceptance tested at Pesco for 100 hours prior to shipment to NASA-Lewis Research Center, five with inverters and one using sine wave power.

The PMA is similar to liquid hydrogen and liquid oxygen chilldown pumps that Pesco has developed for use on the Saturn vehicle. These pumps are also powered by a 400 cycle quasi-square wave inverter.

UNIT DESIGN

Pump Assembly

The pump assembly is of the centrifugal type mounted directly on the same shaft with the 400 Hz electric motor. The unit is designed to pump Dow Corning 200 (dimethyl silicone fluid) with a viscosity grade of 2.0 centistokes at 77°F and to meet the following performance requirements.

Pump Design Capacity	- 3.7 gpm
Pump Design Head Rise	- 60 psi (159 ft) min.
Available Net Positive Suction Head	- 20 psi (53 ft) min.
Steady-State Fluid Temperature	- 20° to 100°F
Minimum Temp - Initial Start-up	- -65°F

The PMA and integral filter are contained in a stainless steel cylindrical casing. The design includes provisions for seal welding for hermetically sealing the assembly. The seal weld joints provide a minimum capability of three (3) rewelds with only minor machining for disassembly and reassembly. Drawing 115146-100, Figure A and Figure B shows the unit assembly and envelope dimensions. Figure C is a photograph of the PMA, and Figure D is a photograph of the individual components in the PMA.

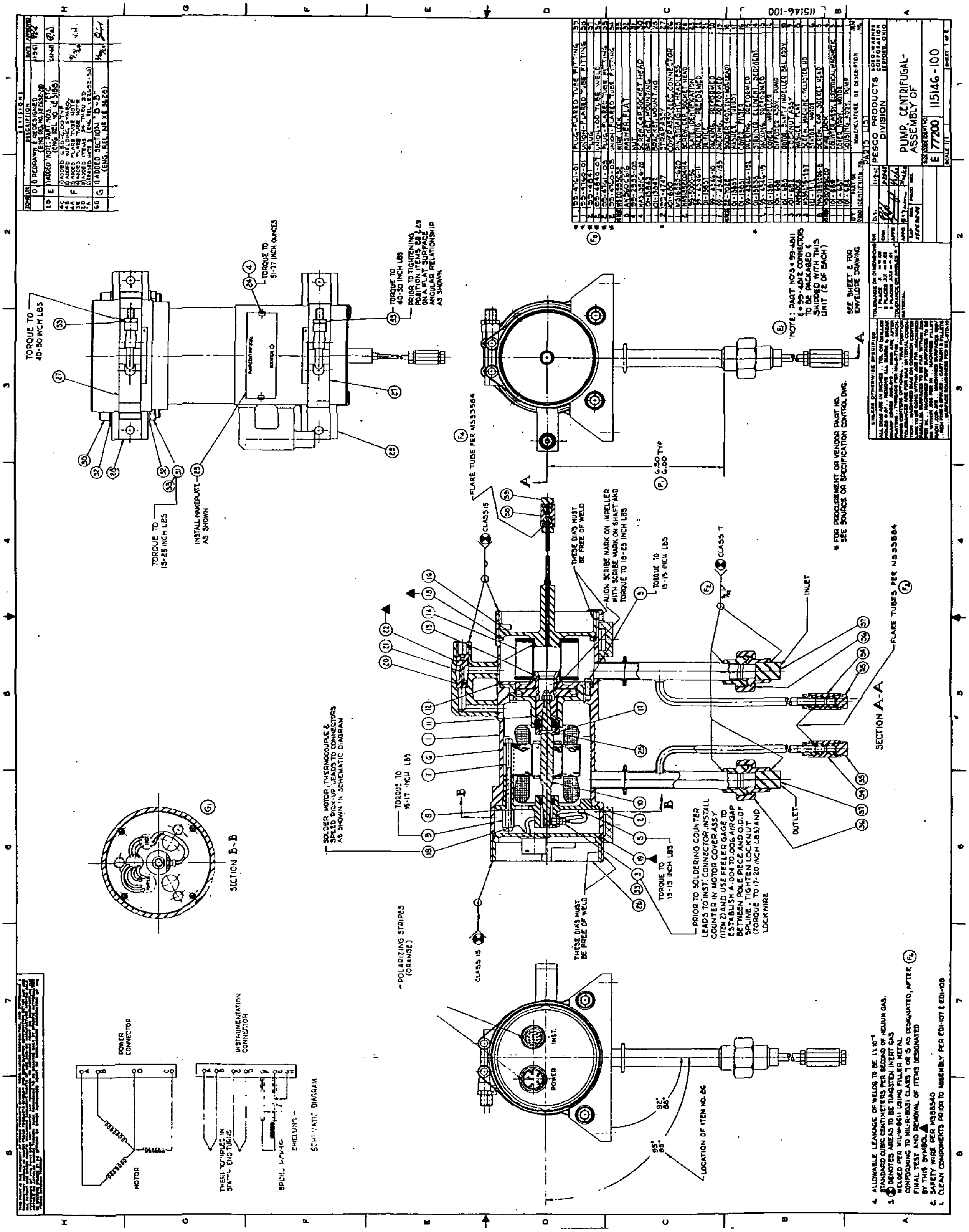

SECTION A-A
SECTION B-B
PUMP, CENTRIFUGAL-ASSEMBLY OF
115146-100
PESCO PRODUCTS DIVISION

FIGURE A

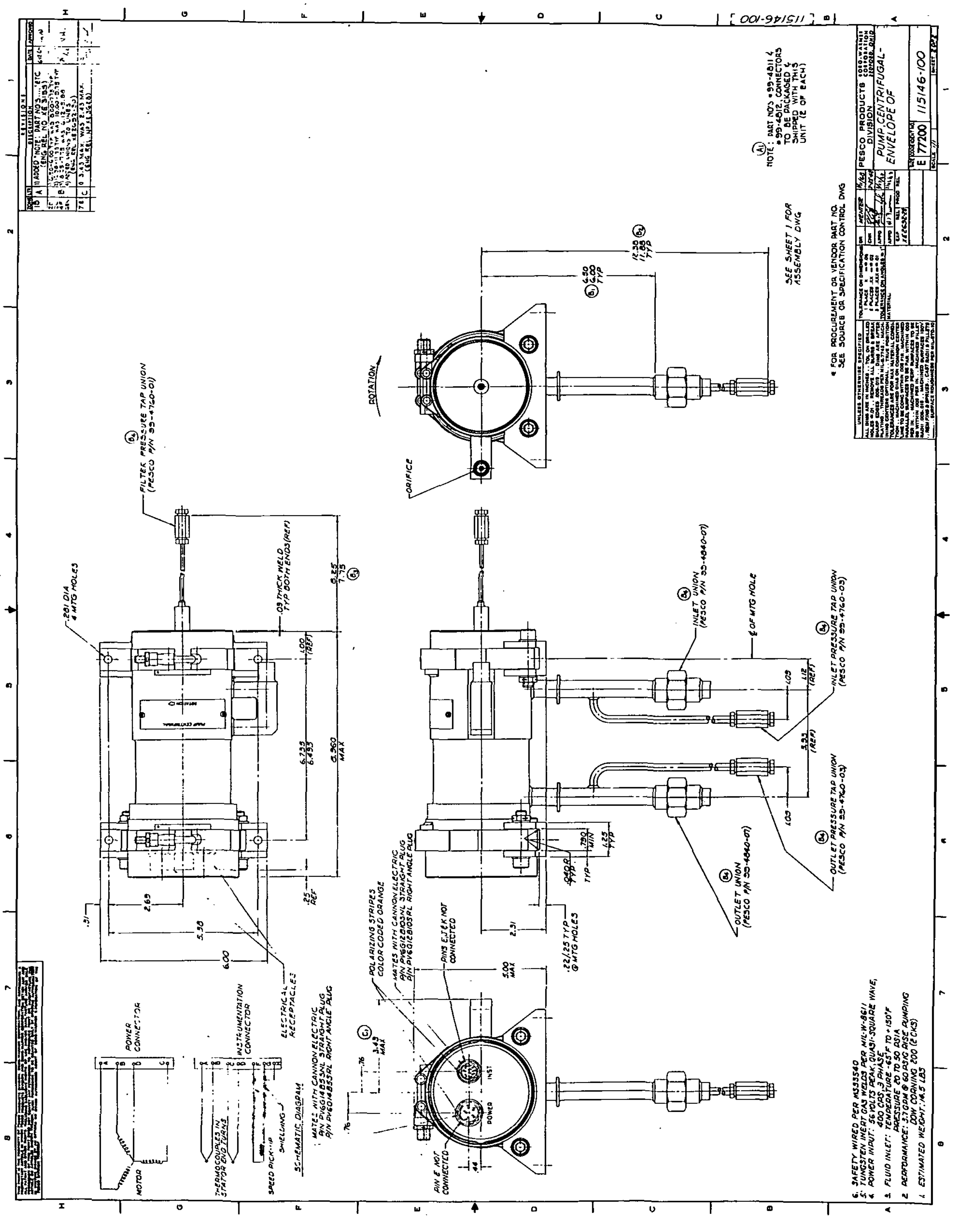
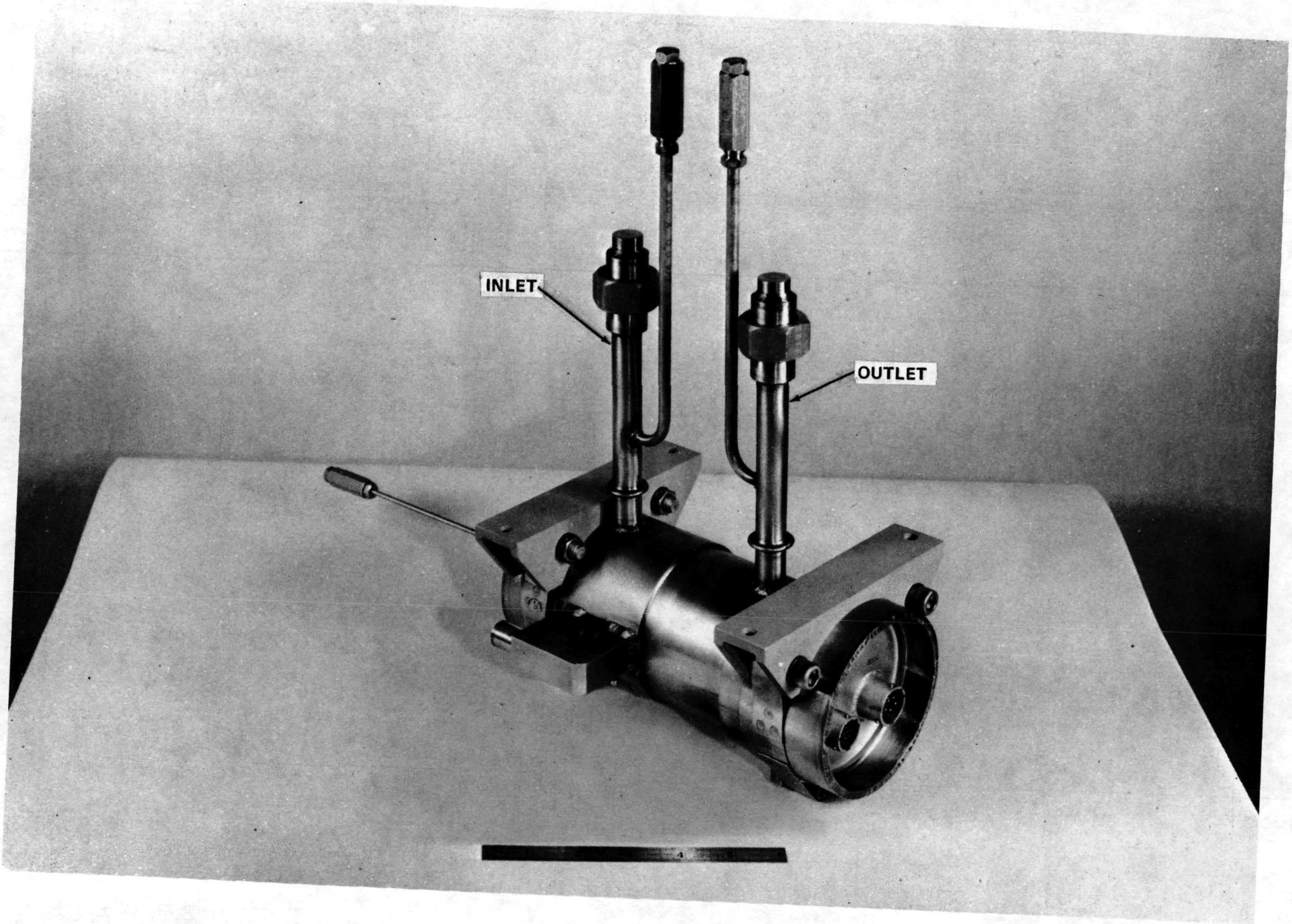

PESCO PRODUCTS DIVISION
PUMP, CENTRIFUGAL-ENVELOPE OF
115146-100
ROTATION
ORIFICE
FILTER PRESSURE TAP UNION (PESCO P/N 99-4760-01)
INLET UNION (PESCO P/N 99-4940-01)
INLET PRESSURE TAP UNION (PESCO P/N 99-4760-03)
OUTLET UNION (PESCO P/N 99-4940-01)
OUTLET PRESSURE TAP UNION (PESCO P/N 99-4760-03)
ELECTRICAL RECEPTACLES
POWER CONNECTOR
INSTRUMENTATION CONNECTOR
SCHEMATIC DIAGRAM
MOTOR
SEE SHEET 1 FOR ASSEMBLY DWG

FIGURE B

FIGURE C

6



PUMP MOTOR ASSEMBLY

PMA PARTS LAYOUT

FIGURE D

Pump design

Pumping is provided by a radial flow impeller discharging into a diffuser. The flow is then directed through the motor cavity. In this manner, the entire pump flow is used to cool the motor windings and helps to promote long unit life.

The pump design includes a replaceable orifice in an external bypass from the pump discharge to the pump inlet. The design provides for either o-ring sealing or seal welding. Present units have the bypass blocked off and the assembly seal welded.

The unit pressure and flow requirements dictate a specific speed of approximately 480, which is at the low end of the specific speed range normally covered by centrifugal pumps. A radial flow impeller design with eight drilled .123" diameter holes and a diffuser with nine .056" diameter holes was utilized to obtain the required performance. The efficiency of this type of pump design is inherently low and the pump efficiency obtained for this unit is approximately 45% to 50%.

The general head-flow characteristic of this low specific speed pump is relatively flat from shut-off to rated flow conditions. The head characteristic is flat or rises slightly to approximately 60% rated flow, then it decreases slowly as it approaches rated flow. Beyond rated flow, the head decreases more rapidly.

Hydraulic calculations

The hydraulic calculations for the pump impeller and the diffuser are included in Appendix B.

Bearings

The pump rotating assembly support is provided by two hydrodynamically lubricated sleeve-type bearings. These carbon graphite bearings are used in conjunction with chrome plated journals on the shaft. Hydrodynamic lubrication is provided by the Dow Corning 200 (2.0 centistokes) fluid being pumped.

Figure 1 in Appendix A is a plot of the specific gravity versus temperature for the Dow Corning silicone fluid 200 at 2 centistokes. Figure 2 is a plot of the ASTM Standard viscosity versus temperature for Dow Corning 200 fluid at 2 centistokes.

Bearing design calculations were based on the design criteria defined in the Cast Bronze Bearing Design Manual, Franklin Institute Research Laboratories (Reference 2).

A copy of the bearing computer study for the journal bearings is included in Appendix B.

All axial thrust is taken by the bearing installed in the diffuser housing assembly. This bearing includes two thrust faces and one radial bearing in one assembly. The bearing in the motor cover assembly carries only radial loads.

Bearing lengths determined by the foregoing procedure were:

.365 diameter journal - .2625 length
.300 diameter journal - .210 length

Diametral clearance between journal and bearing bore were:

.365 diameter journal - .0015 in.
.300 diameter journal - .0015 in.

Based on 110°F ambient oil temperature, fluid temperatures of the film in the bearings were:

.365 diameter journal - 120°F
.300 diameter journal - 120°F

The minimum film thickness (ho) was calculated to be .000181 inches for the .300 diameter bearing assuming a one pound load, and .000163 inches for the .365 diameter bearing assuming a three pound load.

Filter

The full flow filter is located integrally in the pump housing at the impeller inlet. The filter element is of all metal woven mesh construction, and has a nominal rating of 2 microns and an absolute rating of 5 microns. The maximum allowable design pressure drop is 5 psi at 3.7 gpm, but actual test experience has shown the filter drop to be less than one psi at rated flow. The filter element is assembled in the unit with two o-ring seals to prevent contaminant leaks past the filter element.

Barstock unit tests

An aluminum barstock pump was fabricated to the selected diffuser and impeller hydraulic design. The unit was mounted on a dynamometer and tests were conducted to evaluate pump performance with and without a diffuser, with two holes plugged in the diffuser, two holes plugged in the impeller, and with increased hole size in the diffuser. A plot of pump performance at 11,300 rpm with each of the above unit configurations is shown on Figures 3 through 5 in Appendix A.

Motor Assembly

The 4-pole, 3-phase motor in the Model 115146-100 PMA is used to drive a centrifugal pump which circulates coolant in the Brayton power conversion system. The motor is rated at .6 hp at 11,000 rpm. It is designed for continuous and unattended operation in a space environment for a minimum period of five years and is designed to achieve maximum efficiency with an objective of 0.7 power factor at the design point. It is also designed to run for a period of five minutes at maximum pump capacity without exceeding a winding temperature of 180°F.

In the preliminary design stage of the program, three alternative motor designs were offered. These were briefly:

Alternative 1 - A motor and inverter design to meet all of the listed requirements of the initial RFP.

Alternative 2 - A motor design to meet all of the listed requirements driven by a previously qualified inverter.

Alternative 3 - A motor design which exceeds the 5% slip requirements at 150% of rated torque driven by a previously qualified inverter.

Alternative 3 was chosen for reasons discussed in the motor design section, and was modified to obtain maximum efficiency during the final design stage. Development tests were then performed on a prototype motor and compared to predicted performance.

Motor design

A motor designed to meet the requirements of the initial request for proposal was large in size and had a rotor resistance such that the existing qualified static inverter could not be utilized. The large size of the motor also yielded a very high pull-out to running torque ratio resulting in a lower than peak value of efficiency at the operating point. The larger rotor size also increased the hydraulic fluid losses which further reduced the efficiency.

A motor design to meet all of the listed requirements driven by a previously qualified inverter would be feasible, but would have to be coordinated with the inverter supplier because the operating power factor would be low. This alternative would necessitate deviations from the inverter specification since the inverter would not have sufficient capacity to drive the motor.

An alternate motor design was proposed which exceeded the specified 5% slip requirement at 150% of rated torque and which produced slightly less than 150% starting torque at -100°F. The 5% slip requirement, while in the original request for proposal, was not included in the final contract specifications. This design, however, was capable of meeting all of the application requirements with the advantages of minimum weight, higher efficiency and power factor, and lower current drain. The final computer calculation is included in Appendix B, Tables B1 through B4, and the motor characteristic performance curve is shown in Figure 6, Appendix A.

Motor laminations

The motor laminations are of a new optimized design, specifically developed for this unit. They are silicon sheet steel per AISI M-19, 29 gage (.014 inch), heat treated after punching to restore permeability lost due to punching stresses and to reduce iron losses. The stator slot size was designed to provide maximum efficiency. The L/D ratio for the rotor was optimized for wet running in DC 200-2 fluid. The rotor cage was designed to provide the necessary starting torque over the specified temperature range of +100°F to -100°F.

Motor insulation

The motor insulation system is composed of polyimide coated glass, Teflon, and DuPont Pyre ML impregnating varnish. These materials have proven to be effective in motors running submerged in various fluids at temperatures comparable to the specified operating temperatures. Tests were conducted which showed compatibility with Dow Corning DC-200-2. The test results are included in the section titled "Dow Corning DC-200-2 Compatibility Tests."

Connectors

In the initial design Pesco proposed using three separate connectors, one for power input, one for thermocouple output, and one for the speed sensor. An investigation was conducted concerning the possibility of using a single connector for all leads. Cross-talk tests were performed at Pesco using a dummy motor. No cross-talk or interference could be detected during the performance of these tests. Details are included in the section "Connector Cross-Talk Test."

In the final design, two connectors were used, ITT Cannon Part No. PV3H14B5PN SPCL for the power lead connector and ITT Cannon Part No. PV3H12B10PN SPCL for the instrumentation connector.

Thermocouples

Two iron-constantan thermocouples are used to sense stator winding temperature in the PMA. The thermocouples are located in the center of the end turns approximately 180° apart on the lead end of stator.

Speed sensor

The speed sensor used is a standard catalog item purchased from Electro Products Lab, Incorporated - Chicago, Illinois. This transducer had previously been used satisfactorily on the Saturn chilldown pumps. A compatibility test with DC-200-2 was performed at Pesco and no ill effects could be detected.

Motor development tests

The original design called for the use of eighteen turns per coil of No. 20 AWG magnet wire. In order to minimize the possibility of wire and insulation damage, and to allow easier assembly, equivalent coils consisting of one No. 22 and one No. 24 AWG wound in parallel were used.

Upon their completion, the prototype stator and rotor assemblies were placed in a bar stock body having the same internal dimensions as the final pump body configuration. Also incorporated into this body were the final design carbon bearings.

The following tests were performed on the prototype motor using sinusoidal input from a standard 400 Hz generator:

1. No load saturation-dry motor.

2. No load saturation-wet motor (submerged in DC-200-2 fluid)

3. Locked rotor saturation-wet motor.

4. Wet motor performance at 38.8, 43.5, and 46.5 line-to-line volts.

5. Dry motor performance 38.8, 43.5, and 46.5 volts.

6. Two-phase performance-wet motor, 38.8 and 46.5.

A breadboard static inverter was then obtained from Gulton and the above tests were repeated with the exception of the two-phase tests (No. 6 above).

In order to improve starting at low temperature, a second rotor was fabricated with a 0.188 skew (skew of the first rotor was 0.094). This rotor was assembled in the prototype housing and stator and performance tests were run at 39.0 and 43.5 volts. Results showed that the .094 skew rotor was more efficient and therefore it was used in the final design.

Plotted results of above tests are found in Figures 7 through 26, Appendix A.

Test data on the prototype unit with .094 skew rotor revealed that the losses due to fluid friction and the iron losses were less than those calculated resulting in a slightly higher efficiency than was calculated. The lower power factor resulted from the test current value being higher than the calculated current. These results are shown in Tables C1 and C2 of Appendix C, and graphically on Figure 6, Appendix A.

In comparing a motor tested dry to one submerged in DC-200 (Figures 11 and 14), the speed is higher while the current and power input is lower for a dry motor. This results in a significantly higher efficiency because of the absence of the fluid drag on the rotor.

In comparing a motor tested with a sine wave voltage input to one with a quasi-square wave input (Figures 11 and 20) the speed is lower while the current and input power are slightly higher for the inverter powered motor. This results in a slightly lower efficiency which is attributed to the increase in iron losses due to the shape of the input wave form.

A motor test using a rotor with a larger skew (0.188 versus 0.094) resulted in a fairly large drop in efficiency (6%) Figure 26. Based on this, it was decided to retain the original rotor with the 0.094 skew.

Motor-pump development tests in cold box

Since the predicted starting torque was not realized during the motor prototype test, several tests were performed with the barstock motor-pump combination placed in a cold chamber at a temperature of -65°F. (A contract modification changed the minimum fluid temperature requirement for start-up from -100°F to -65°F.)

Acceleration and voltage variation tests showed that the motor was capable of starting and accelerating the unit to rated conditions, at voltages that were below the low specification limit. These test results are shown graphically in Figures 27 through 36, Appendix A.

Connector cross-talk test

An MS3102A connector and mating plug with pins for two iron-constantan thermocouples was used for the test.

The connector was mounted to an available Pesco motor of similar size. Two I/C thermocouples were taped to the end turns of the motor windings. A speed pickup was mounted in the motor cavity and leads including the power leads were brought out through the connector. The motor was operated no-load and the speed was monitored on a digital counter and also by a Strobotac. Temperature was recorded on a strip chart recorder. Phase resistances were taken before and after the test. Since the counter and strobe readings agreed and no noise could be detected on either the counter or temperature recorder signals, it was concluded that a single connector could be used for all leads and that accurate data could be obtained without cross-talk interference. Results are shown in Appendix C, Table C3.

Dow Corning DC-200-2 compatibility tests

In order to determine if the working fluid in any way affected the materials in the motor assembly, a stator assembly and all assembly parts were submerged in 1000 ml of the fluid for a period of four weeks; no evidence of deterioration, weight loss or gain, color change, softening, or crazing was detected.

A Model 115146-100 speed pickup was submerged in the fluid for a period of nine weeks. Coil resistance, insulation resistance and dielectric strength were measured and recorded during this period. No deterioration was detected during this test.

Final design motor performance

Table I is a tabulation of motor performance at rated horsepower (0.36) with nominal voltage input.

TABLE I

MOTOR PERFORMANCE

	Predicted Value	Actual Value
rpm	11,280	11,280
efficiency (%)	67.0	68.5
power factor (%)	67.0	64.5
locked rotor torque (lb. in.)	2.60	2.06
torque at operating point (lb. in.)	2.00	2.00
life	5 years	See note

NOTE: Endurance tested for 20,000 hours with no deterioration in performance.

Although the motor did not develop the predicted starting torque, the nature of the centrifugal pump is such that very little starting torque is required, and this was not considered to be critical. The motor met or exceeded all of the application requirements.

PUMP-MOTOR ASSEMBLY DEVELOPMENT TEST PROGRAM

The development test program was performed on the final packaged design of the coolant circulating pump, Pesco Model 115146-100, Unit S/N X-2149.

The development tests were run in accordance with Engineering Report 5289, Revision B, entitled "Development Test Program Plan for Pesco Model 115146-100 Coolant Circulating Pump for a Brayton Cycle Space Power System." A copy is included in Appendix F.

PMA S/N X-2149A was mounted in the test loop per test schematics, Figures 1 through 5 of Engineering Report 5289, Revision B. Figure E is a photograph of the test setup used for the hot and cold ambient testing. Figure F is a photograph of the PMA installed in the test loop, and Figure G is a photograph of the Gulton inverter installed on the cold plate.

Electrical checks (dielectric, resistance, and continuity) were conducted at various times during the development program. No performance degradation was noted.

Test Series 1 - PMA Calibration-Sine Wave Power

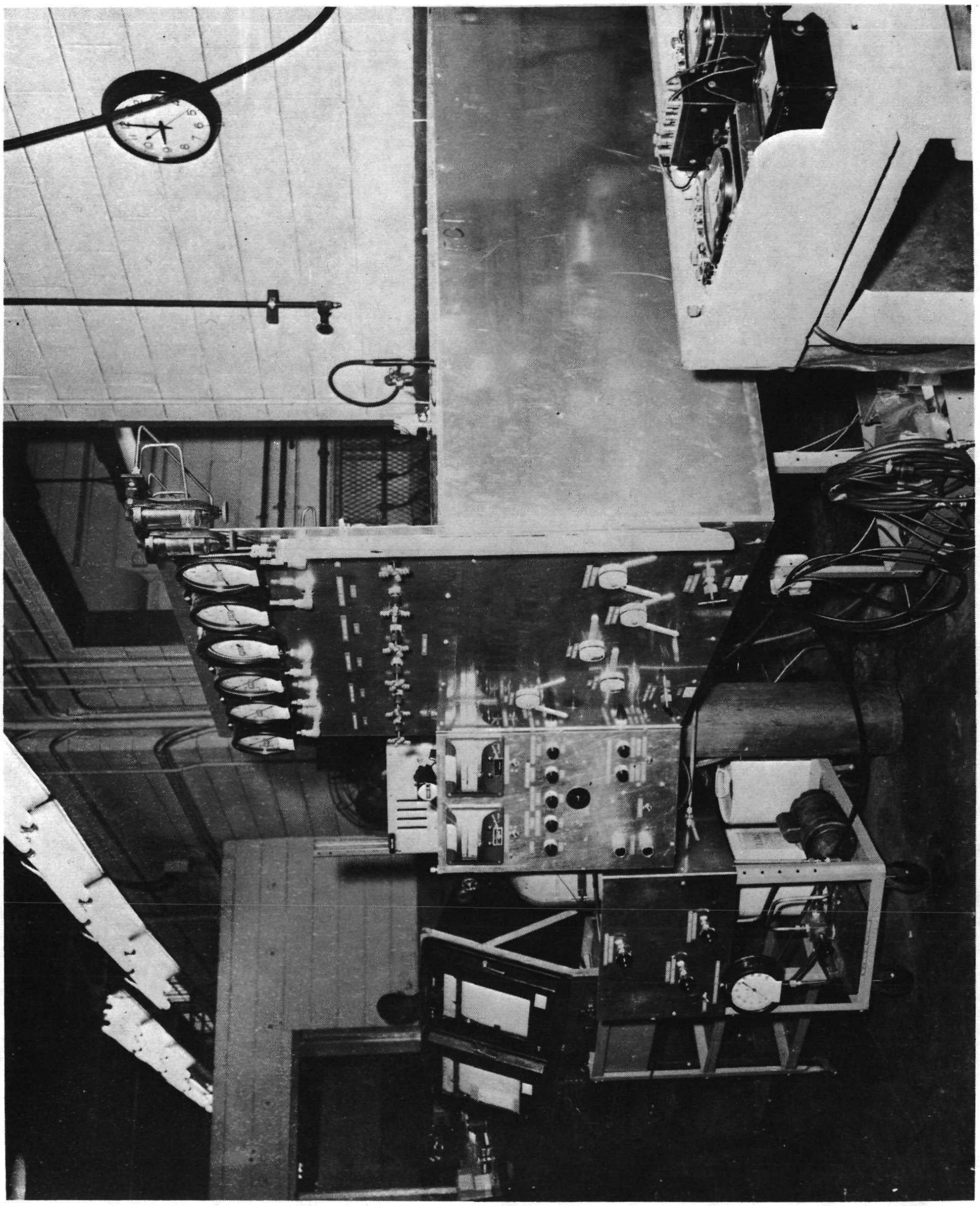
Tests were made to determine the head-flow performance to substantiate analytical pump characteristics and to determine motor performance using 400 Hz sine wave power. Testing was conducted at the conditions defined in paragraph 4.2.2 of Engineering Report 5289-B.

Figures 37 through 39 show unit performance with sine wave power.

Test Series 2 - PMA Calibration-Inverter Power

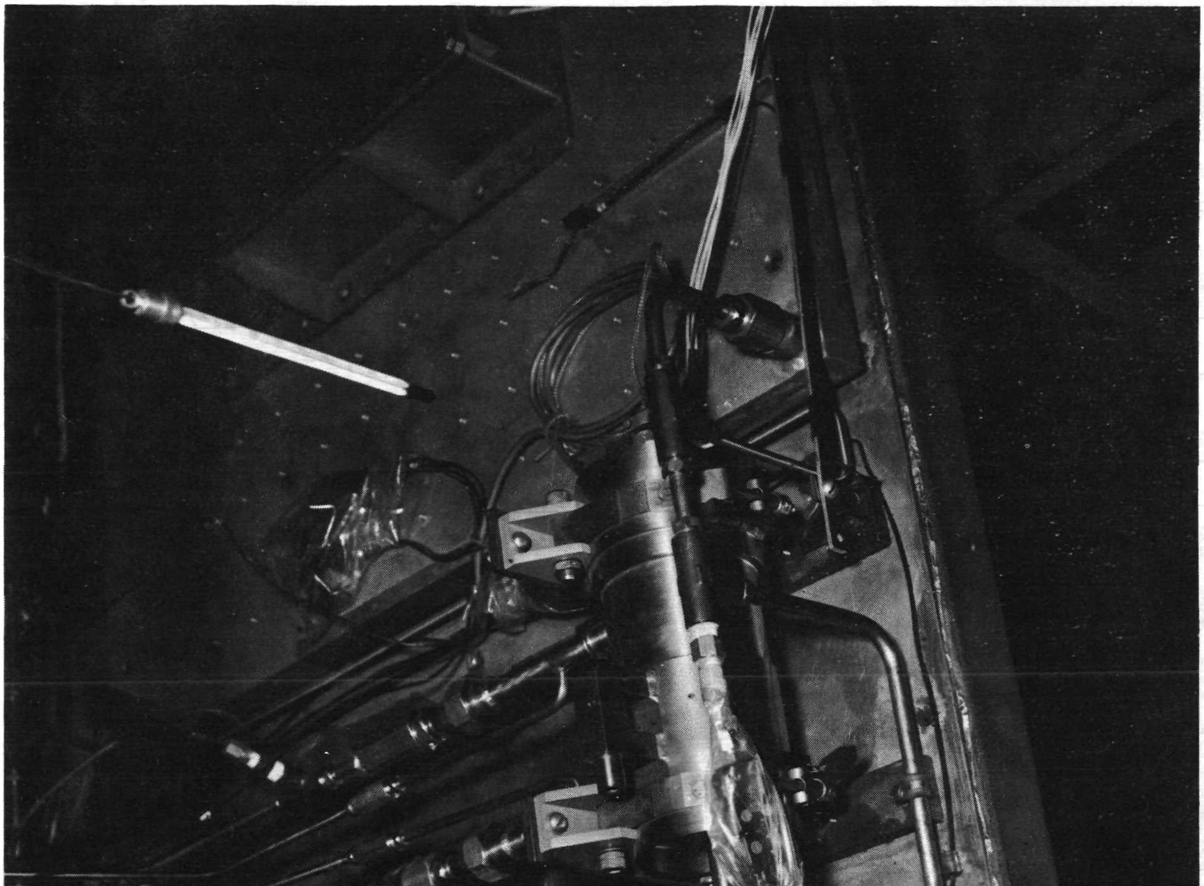
The calibrations outlined in Test Series 1 were repeated using quasi-square wave input power (Gulton Inverter S/N 25509). Motor input voltage was the same as in Test Series 1. Figures 40 through 42 are plots of the unit performance at the three input voltages.

Table II compares the pump performance at 78°F and 3.7 gpm flow for a sine wave input and a quasi-square wave input. The tabulation shows that the PMA head rise is slightly higher with sine wave power than the quasi-square wave power for an equivalent input voltage. The PMA efficiency, however, is approximately the same.



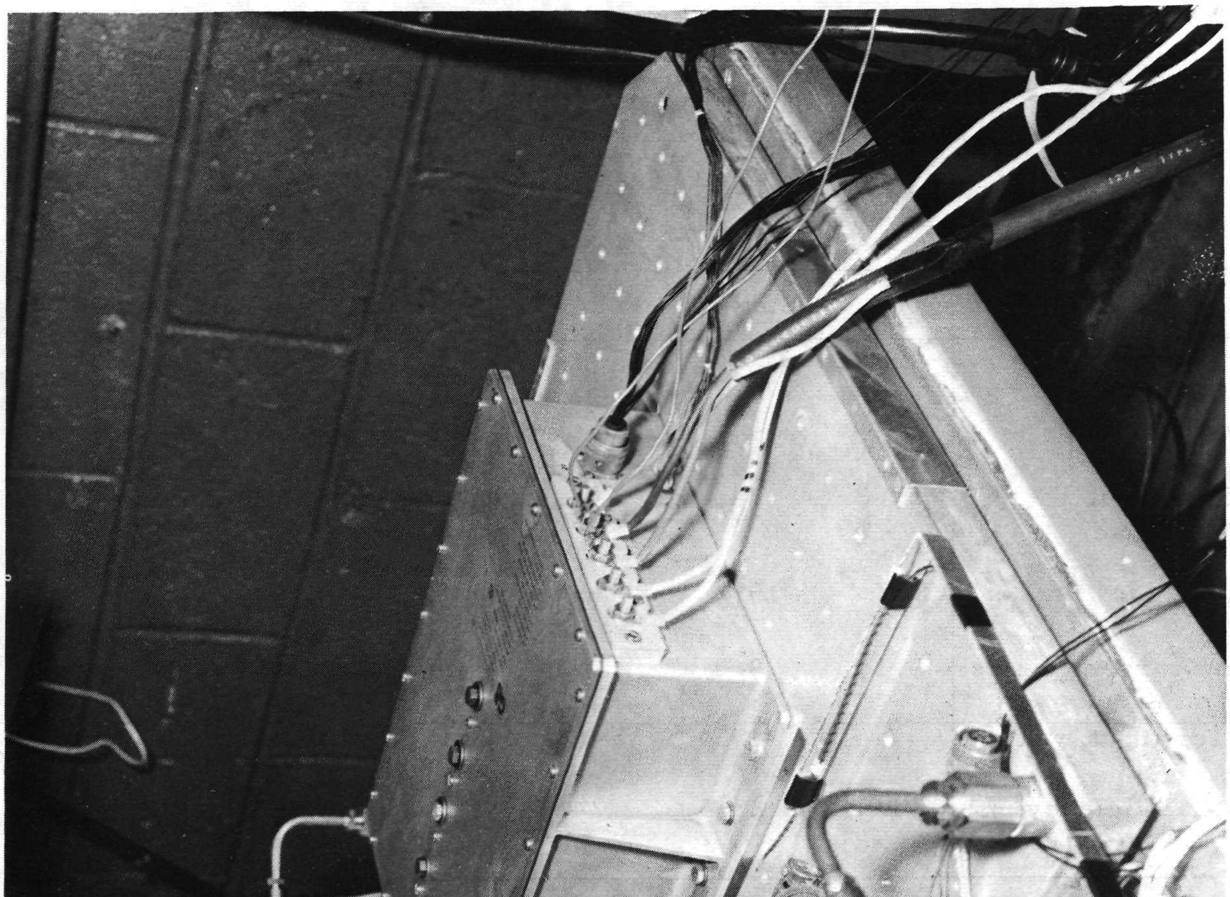
HOT AND COLD AMBIENT TEST SET-UP

FIGURE E



PMA INSTALLED IN TEST LOOP

FIGURE F



INVERTER AND COLD PLATE IN TEST LOOP

FIGURE G

TABLE II

PMA PERFORMANCE AT 78°F AND 3.7 GPM

	Sine Wave			Square Wave		
Inverter input voltage, dc				50	56	60
Motor input voltage, ac	39.8	44.4	47.5	39.6	44.4	47.5
Head, psi	69	71.9	73	68.0	71.1	72.6
Line current, amps	9.1	9.0	9.1	9.2	9.1	9.2
Motor input, watts	454	473	480	456	465	475
PMA Efficiency, %	24.5	24.5	24.5	24.0	24.6	24.6

Test Series 3 - Reduced Diameter Impeller Tests

Tests were performed to determine the maximum amount that the outside diameter of the impeller could be reduced before the head rise and the pump efficiency decreased approximately 20%. It was determined that the impeller O. D. could be reduced from 2.120" O. D. to 1.820" O. D. This amount of impeller trimming reduced the head rise from 66 psi to 49.5 psi and the pump efficiency from 40% to 33% at a nominal pump flow of 3.7 gpm and a pump speed of 11,300 rpm. Tests were run on a dynamometer using the barstock pump assembly. Figure 43 is a plot of the test results.

Test Series 4 - Net Positive Suction Head Tests (NPSH)

These tests were run to determine the effect of reduced inlet pressures on pump performance in accordance with paragraph 4.2.5 of Engineering Report 5289-B. Pump inlet pressures were varied from 0 psig to 25 inches Hg vacuum (37 feet to 5 feet NPSH, approximately) as measured ahead of the integral filter rather than at the pump inlet downstream of the filter. At 79°F fluid temperature, a NPSH of seven (7) feet was obtained before pump performance fell significantly with an audible cavitation noise. This means the pump will function normally at inlet pressures as low as 2.7 psia which far exceeds the 20 psia (53 feet) minimum required by the contract. Due to the low vapor pressure of DC-200, the NPSH and pump inlet pressure values are practically the same.

Figures 44 through 46 show NPSH performance at three input voltages and four pump flow rates.

Test Series 5 - Low Temperature and High Temperature Tests

The purpose of these tests was to determine the effect of fluid viscosity and temperature on motor-pump performance. Pump calibrations as described in Test Series 2 were conducted at an ambient and pump inlet temperature of -65°F and also with an inverter cold plate outlet temperature at 150°F maximum.

Table III shows the DC-200 viscosity effects on pump performance. The DC-200 viscosity varies from two centistokes at 78°F to approximately one centistoke at 150°F and to approximately twelve centistokes at -65°F.

TABLE III

PMA PERFORMANCE - SQUARE WAVE AT 3.7 GPM

	78°F			150°F			-65°F		
Input voltage, dc	50	56	60	50	56	60	50	56	60
Head, psi	68	71.1	72.6	64.5	68.6	70.1	57.2	62	62.5
Line current, amps	9.2	9.1	9.2	8.8	8.5	8.8	11.8	10.8	10.6
Motor input, watts	456	465	475	433	425	431	562	571	580
PMA efficiency, %	24	24.6	24.6	24	26	26.3	16.4	17.5	17.5

The test loop side and top covers were in place for the hot and cold ambient temperature testing.

Figures 47 through 49 are plots of performance at three input voltages and -65°F ambient, and Figures 50 through 52 are performance plots with 150°F fluid and three input voltages.

During the -65°F temperature run, the unit reached operating speed in 1.01 seconds with the maximum starting current at 21.0 amperes. This agrees with the cold test results obtained with the barstock unit - Figure 29. The room ambient temperature acceleration time is one-half second.

Test Series 6 - Shut-off Flow Tests

The PMA was operated at shut-off conditions for three minutes with a fluid inlet temperature of 80°F and an inverter input voltage of 60 v dc. Unit speed increased from 11,340 rpm at a flow of 3.7 gpm to 11,500 rpm at shutoff and the motor winding temperature increased from 87°F to 110°F. Pump head decreased from 72.7 psi to 69.5 psi.

Test Series 7 - Reverse Rotation and Dry Start-up

With the PMA filled with fluid, the unit was subjected to three reverse rotation starts with 50 v dc input to the inverter. Pump head dropped from 68.3 psi at 3.7 gpm to 22.6 psi at 1.94 gpm and the unit speed increased from 11,040 rpm to 11,350 rpm.

The PMA was drained and the unit was subjected to two dry starts of 10 seconds maximum each conducted thirty minutes apart. No adverse effects were noted in unit performance.

Dielectric and Continuity Check

A dielectric check was performed on the power connector only by applying 1500 volts (rms) and 60 Hz between the four motor pins connected together and the motor housing. The current leakage was less than 500 micro-amperes.

Table C4 in Appendix C shows the results of the dielectric, continuity, and insulation resistance checks. This is typical of the electrical checks made throughout the program.

250 Hour Design Assurance Test

The 250 hour design assurance test with 250 start-stop cycles was performed on unit S/N X2149A which had been used for series 1 through 7 development tests. A pump calibration was performed prior to the start of the assurance test and Figure 53 is a plot of the unit performance. At the conclusion of the test, a recalibration of the pump was performed and Figure 54 is a plot of the post test unit performance. Unit performance after the 250 hour test was better than at the start.

No unit performance degradation was noted after the environmental tests, NPSH tests, dry start-ups, reverse rotation tests, or 250 hour assurance test with 250 start-stop cycles. In fact, performance continued to improve throughout the developmental program, as shown in Table IV. This appears to be due to "wearing in" of the bearings.

TABLE IV

PMA PERFORMANCE AT 3.7 GPM, 56 V DC INPUT TO INVERTER, AND 78°F FLUID

Accum. hours run	Head psi	PMA Efficiency %	Speed rpm	Calibration Test
0.4	69.2	21.9	11,100	Initial
111	71.1	24.6	11,210	Test Series 2
129	71.4	25.7	11,240	Before 250 hour test
381	72.1	27.0	11,280	After 250 hour test

Unit Disassembly and Inspection

The PMA was disassembled and inspected after a total running time of 384.3 hours and 314 starts. Critical dimensions were inspected and recorded. Unit condition was excellent with dimensions repeating original inspection records. Testing and inspection results indicate that the unit design life of five (5) years is attainable. Copies of the inspection records are included in Appendix D.

Unit 20,000 Hour Endurance Test

The unit was reassembled with no change of parts and a 20,000 hour endurance test was conducted. The unit was tested in accordance with paragraph 6.0 of test procedure ER-5289-B which is included in Appendix F. After 5000 hours of running time the unit was removed from test, the seal welds were machined off and the unit disassembled for inspection.

Unit disassembly showed the unit to be in excellent condition with no measurable wear evident on the bearings, the shaft bearing journals, or pump-motor components. Disassembly inspection records are included in Appendix D.

The unit was reassembled, rewelded and retested in accordance with paragraph 7.0 of Engineering Report 5289-B. Testing was continued for a total of 20,000 hours. Figures 55, 56 and 57 are calibration curves at the start of the 20,000 hour test, at 5000 hours and at 20,000 hours, respectively. Unit performance at the conclusion of the 20,000 hour test was better by 1.0 psi head rise than at the start, as shown in Table V.

TABLE V

PMA PERFORMANCE AT 3.7 GPM, 56 V DC INPUT TO INVERTER, AND 78°F FLUID

Accum. hours run	Head psi	PMA Efficiency %	Speed rpm	Calibration Test
0.0	71.9	25.2	11,260	Initial
5063.	72.7	26.4	11,270	After 5000 hours
20008.	72.9	26.5	11,280	After 20,000 hours

No degradation in performance was encountered during the test as shown by the head and speed versus running time curves on Figures 58 through 63 for the 20,000 hours of endurance testing.

Unit disassembly showed the unit to be in excellent condition with the measurement of critical shaft and bearing dimensions meeting the original blueprint requirements. Disassembly inspection records are included in Appendix D. Photographs of the unit integral filter, the rotor and the thrust-radial bearing are shown on Figures H, I and J, respectively.

The unit was reassembled with all the original parts, rewelded and acceptance tested for use as a spare unit.

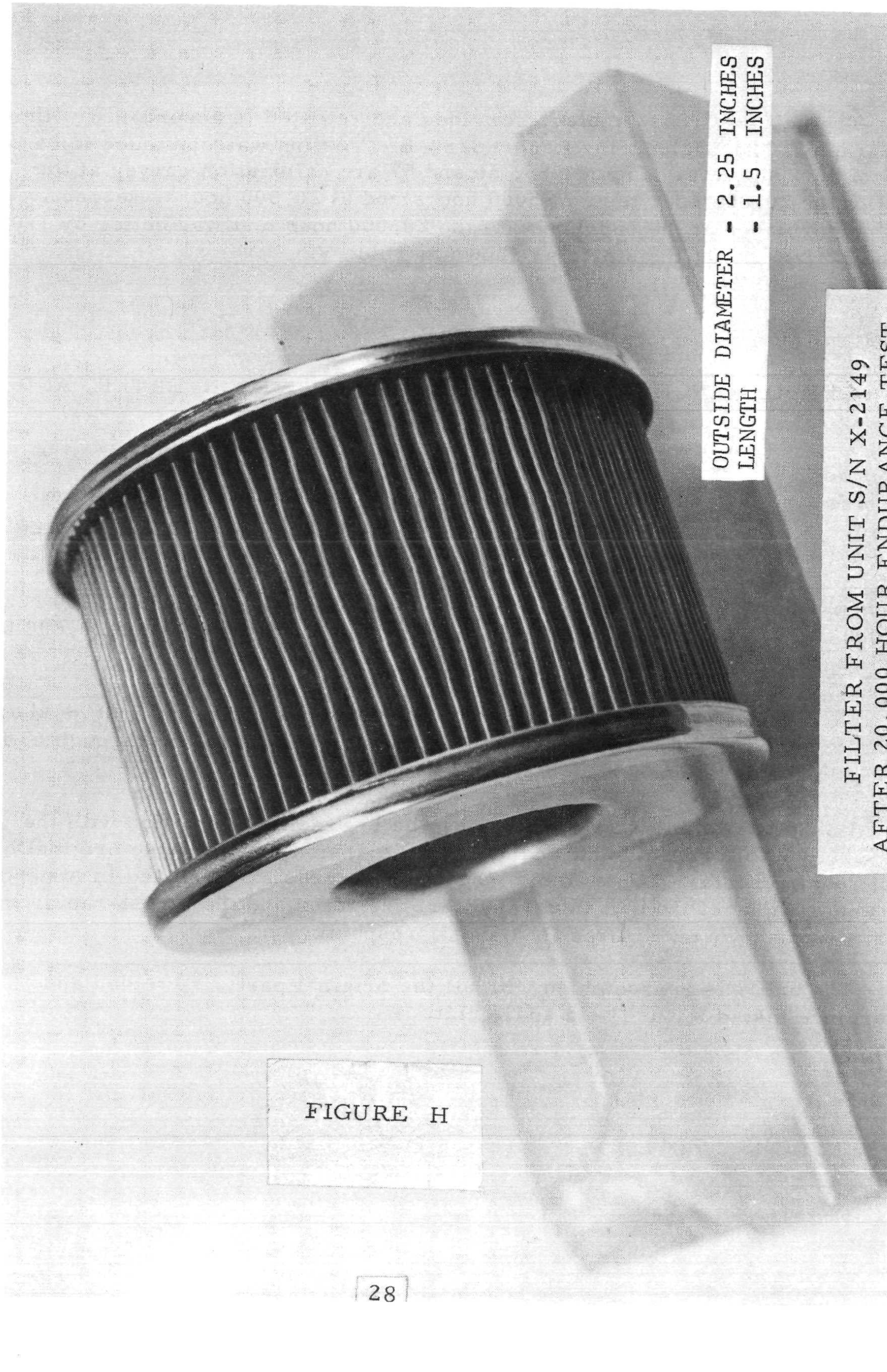
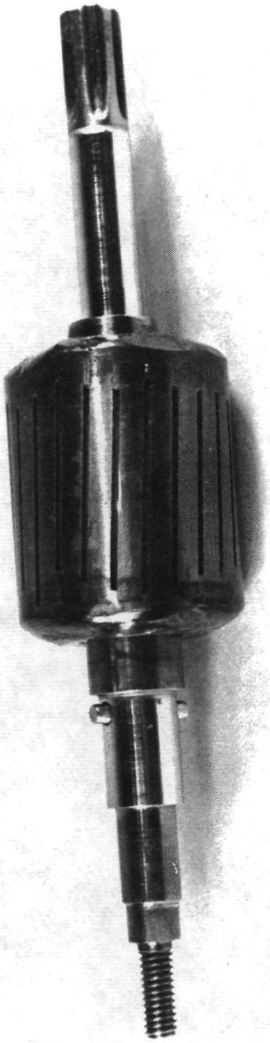

OUTSIDE DIAMETER - 2.25 INCHES
LENGTH - 1.5 INCHES
FILTER FROM UNIT S/N X-2149
AFTER 20,000 HOUR ENDURANCE TEST

FIGURE H



SHAFT LENGTH - 4.875 INCHES
ROTOR DIAMETER - 1.057 INCHES

SHAFT ASSEMBLY FROM UNIT S/N X-2149
AFTER 20,000 HOUR ENDURANCE TEST

FIGURE I

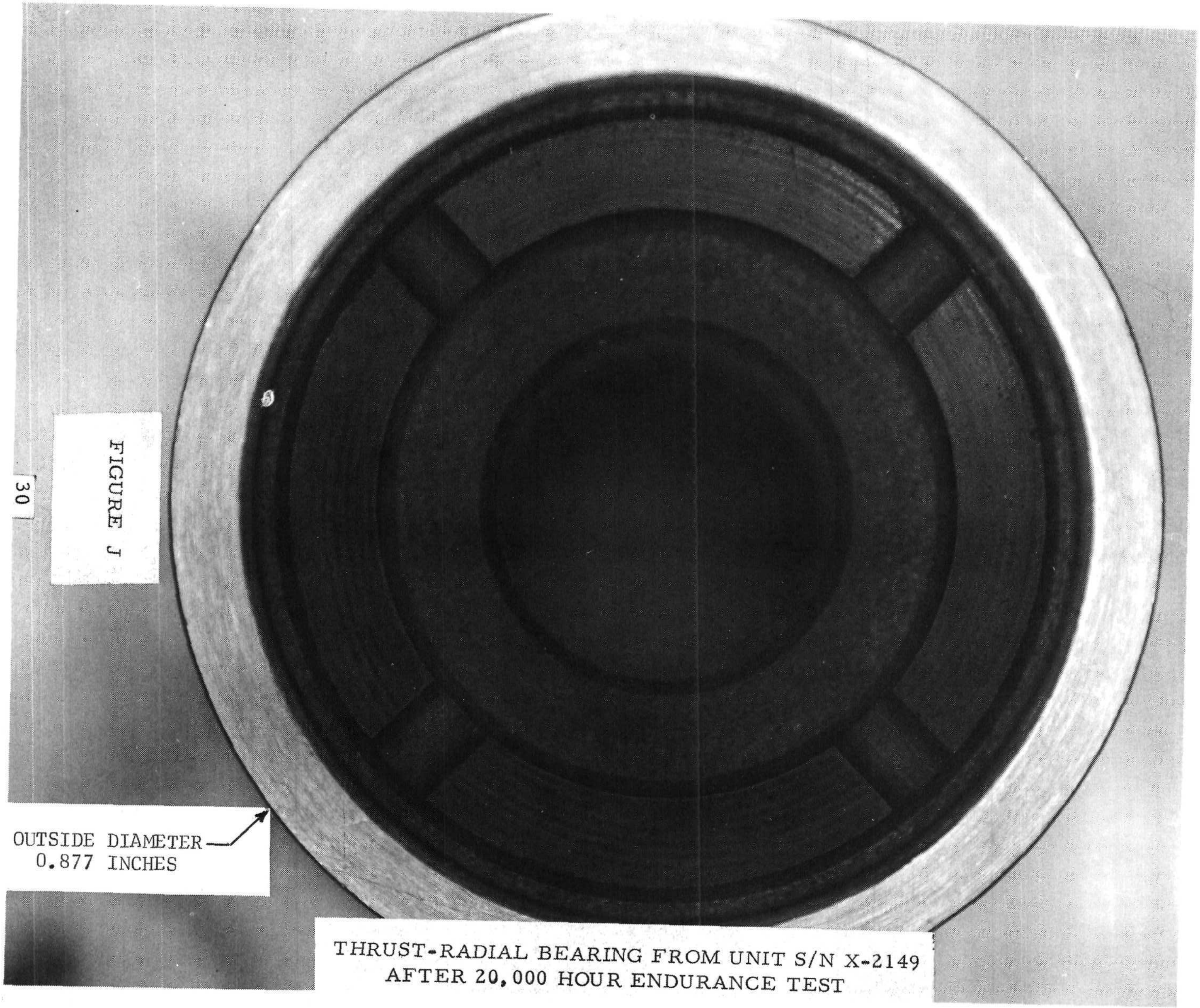


FIGURE J

THRUST-RADIAL BEARING FROM UNIT S/N X-2149
AFTER 20,000 HOUR ENDURANCE TEST

PUMP-MOTOR ASSEMBLY ACCEPTANCE TESTS

Motor Acceptance Tests

The PMA's were tested in accordance with Pesco Acceptance Test Procedure TR-700, Revision B. The motor for each assembly was assembled into a test housing and calibrated as a component. Component testing included a dielectric check of the power connector to 1500 v rms 60 Hz for one minute, an insulation check of each pin with a 50 v dc megger, and a continuity check of each pin of both connectors.

The motor calibration consisted of mounting the motor on a torque measuring stand and connecting it to a slave inverter. A typical electrical data sheet, Table C5, and the results of the motor calibrations for all seven units, Tables C6 through C12, are included in Appendix C. A composite torque-speed curve based on the test results of all units is shown on Figure 64.

PMA Unit Acceptance Tests

Unit acceptance tests were performed in the test loop with installation and instrumentation as shown in Figures 1 through 5 of Engineering Report 5289, Revision B, in Appendix F.

Six PMA's, S/N X2143 through S/N X2148, were acceptance tested and shipped to NASA-Lewis Research Center. The acceptance test included the following individual tests in sequence:

a) Dielectric and resistance checks
b) Pump calibration tests
c) 100 hour endurance test
d) Pump calibration test
e) Seal welding - helium leak test
f) Proof pressure test
g) Helium leak test
h) Dielectric and resistance test
i) Pump calibration test

All units were tested and shipped with an inverter with the exception of unit S/N X2148. This unit was tested on sine wave power since this unit was scheduled for sine wave power testing at NASA-Lewis Research Center.

A plot of head, current, power, and efficiency versus flow of each unit shipped, based on the final calibration test, is included in Figures 65 through 70.

All units passed the 100 hour acceptance test without difficulty. One unit, S/N X2144, was rejected at the dielectric check after seal welding just prior to shipment. The unit dielectric leakage exceeded the maximum of 500 micro-amperes at 1000 v ac 60 Hz. Specification limit is 500 micro-amps at 1500 v ac 60 Hz. Disassembly of the unit revealed that a stator end turn was assembled too close to the motor cover assembly, thus providing a high resistance short circuit. The unit was rebuilt with a new stator, re-tested and shipped.

Another unit, S/N X2147, has a different head characteristic than the others which is probably due to a deviation in angle of one of the diffuser holes. It still meets the performance specifications, however.

All units showed an improvement in performance with running time similar to that experienced with the development PMA. Efficiencies at the end of the 100 hour acceptance test ranged from 0.4 to 2.2 percentage points better than at the start of the test.

RELIABILITY PROGRAM - PUMP MOTOR ASSEMBLY

Component Reliability Analysis for Pump-Motor Assembly Pesco Model No. 115146-100

This analysis consists of the generic failure rates of each of the components of the PMA. The following two documents have been used in acquiring the generic failure rates of the individual components:

1. Reliability Analysis Program Handbook prepared by General Electric, Large Jet Engine Division at Cincinnati for Mechanical Components.

2. MIL-DHBK-217 for electrical components.

Detailed failure analysis sheets appear in Appendix E.

The inherent reliability estimate for the pump-motor assembly is 51,576 hours Mean Time Between Failure (MTBF) as against the 57,412 hours MTBF which was the preliminary estimate. The present analysis includes the failure rate modifiers which have been calculated by taking into consideration the stress levels, material strengths, the environment conditions, et cetera. These modifiers are then used in estimating the updated failure rates. The summary of the total failure rates of the pump and motor are listed below:

Sub-Assembly	Failure Rate per 10^6 Hours
Pump and Housing	9.401
Electric Motor	9.988
Total	19.389

$$\text{MTBF} = \frac{1,000,000}{19.389}$$

$$= 51,576 \text{ hours}$$

Reliability Failure Mode, Effect and Criticality Analysis for Pump-Motor Assembly, Pesco Model No. 115146-100

This study was performed to determine the feasible modes of failure and their criticality in the PMA used in the Brayton Cycle Systems. The analysis has been made starting at the system level and expanding downward to the component system level and finally to the component level.

The analysis of failure modes for the PMA has been performed in two phases. The first phase takes each subassembly and part individually and determines its failure modes and the effect of each failure mode on the component output. The failure rate (in events per one million hours) for each failure mode is included. The results of this analysis are presented in the "Component Reliability Report" which is included in Appendix E.

The second phase takes each failure mode and classifies it in accordance with the criticality or consequence of the failure. The criticality categories are such as "Pump inoperative, no flow or pressure" and "Low discharge flow and/or pressure." The reasons why each failure mode should not occur or why its probability of occurrence has been minimized are given for each failure mode. The results of this analysis are presented in the "Failure Mode Cause Analysis" which is also included in Appendix E.

The new failure rate for the pump-motor (centrifugal) assembly was estimated to be 19.389 occurrences in one million hours or 51,576 hours Mean Time Between Failure.

Relative probability of occurrence of the different failure modes is as listed below:

Failure Type	% Failures (Relative Probability of Occurrence)
Pump Inoperative (no flow or pressure)	60.69
Low Discharge and/or Pressure	39.31

The critical components are the two sleeve bearings, the stator and rotor assemblies, the filter and the weld joints.

CONCLUSIONS

A pump-motor assembly, Pesco Model 115146-100, was designed, developed, and tested which meets or exceeds the specified design requirements. A pump head rise of 68 psi was obtained compared to the required minimum of 60 psi at the minimum 50 v dc input to the inverter, with 80°F fluid, and at the rated flow of 3.7 gpm.

The pump suction performance is much better than specified. The pump will function normally with an available NPSH as low as 7 feet compared to the required minimum of 53 feet.

The performance of all units improved with running time, apparently due to wearing in of the bearings. The efficiency of the development PMA increased from 21.9% to 27% at rated conditions during the first 381 hours of operation.

Test experience to date indicates that the design life of five years is attainable. A 20,000 hour endurance test was completed on Unit Serial Number X2149 with no degradation in performance. Unit disassembly at the conclusion of the test indicated no signs of wear with critical bearing and shaft journal dimensions within the original print dimensions. The unit was reassembled and rewelded as is for use as a spare unit.

REFERENCES

1) Lachenmeier, G., "Design and Manufacture of Static Inverter for Brayton Power Conversion System," NASA CR-72671, Gulton Industries Report No. 2403, dated December 3, 1969.

2) Rippel, H. C., "Cast Bronze Bearing Design Manual," The Franklin Institute Research Laboratories, Philadelphia, Pennsylvania. Third Printing dated September, 1967.

APPENDIX A

FIGURES

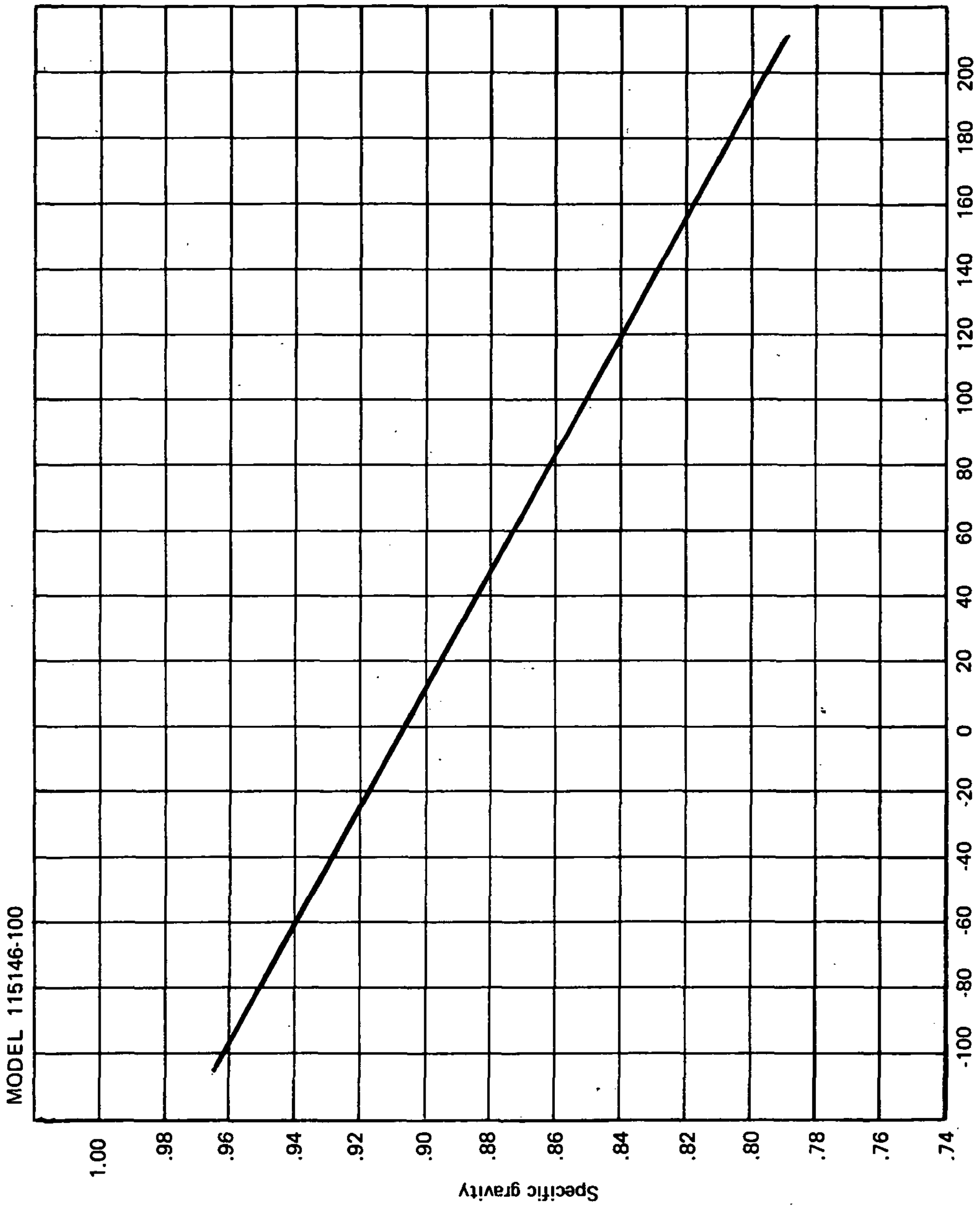


Figure 1. - Specific gravity vs temperature
Dow-Corning silicone fluid 200 - 2 centistoke

MODEL 115146-100

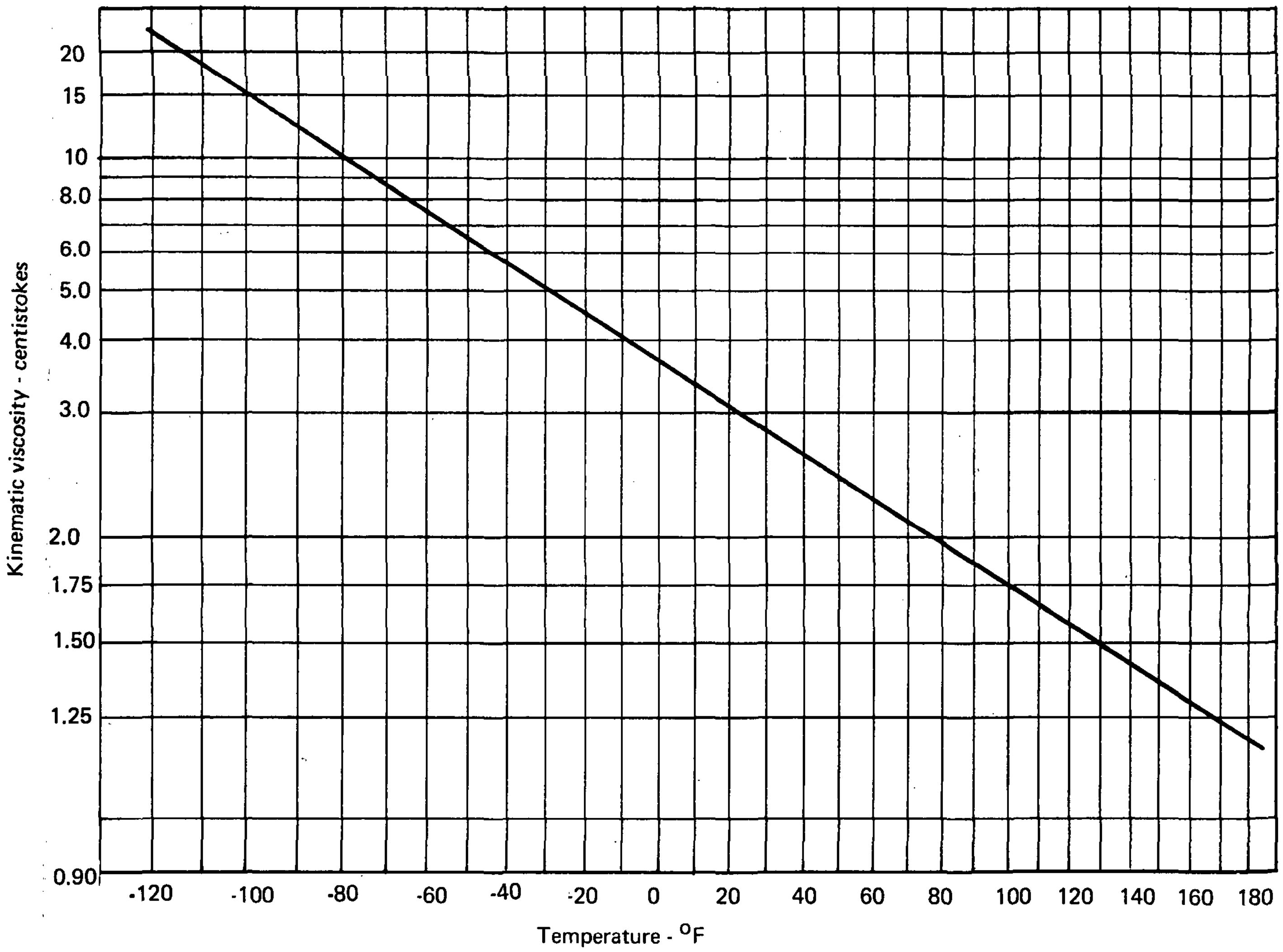


Figure 2. - A.S.T.M. Standard viscosity - temperature chart
Dow-Corning silicone fluid 200 - 2 centistokes

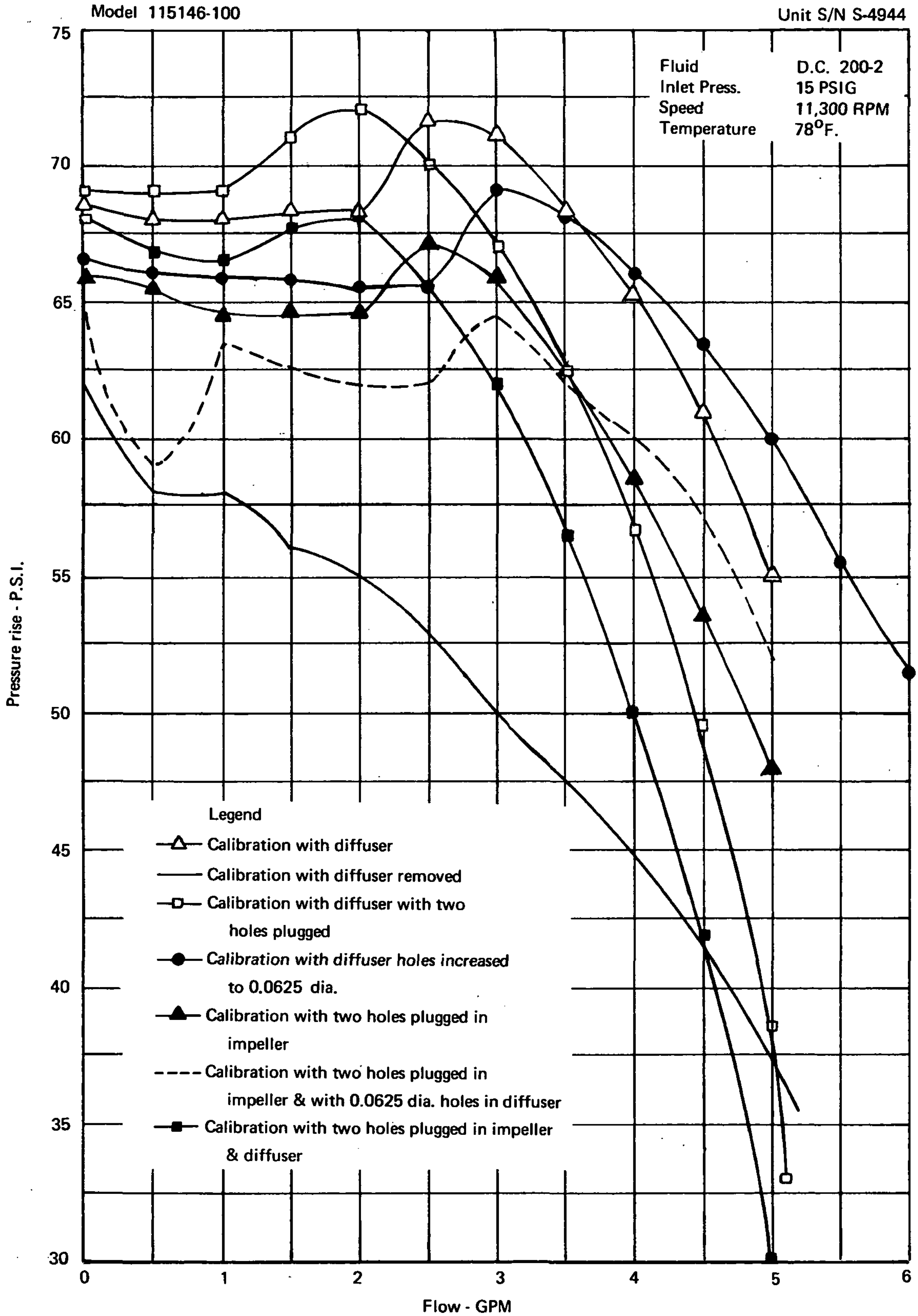


Figure 3. - Barstock pump test performance - Head vs Flow composite curve for various unit configurations

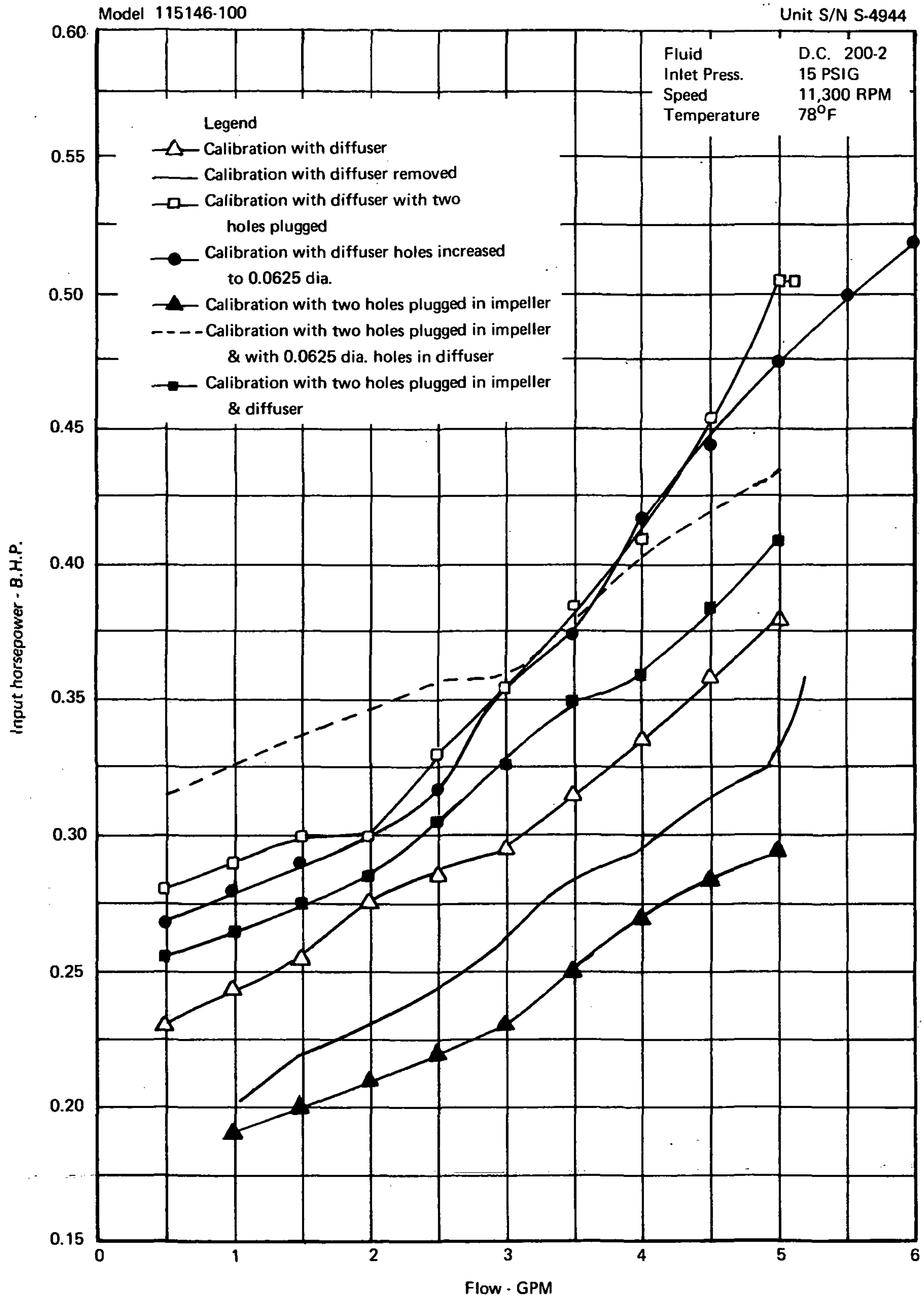


Figure 4. - Barstock pump test performance - Input H.P. vs Flow composite curve for various unit configuration

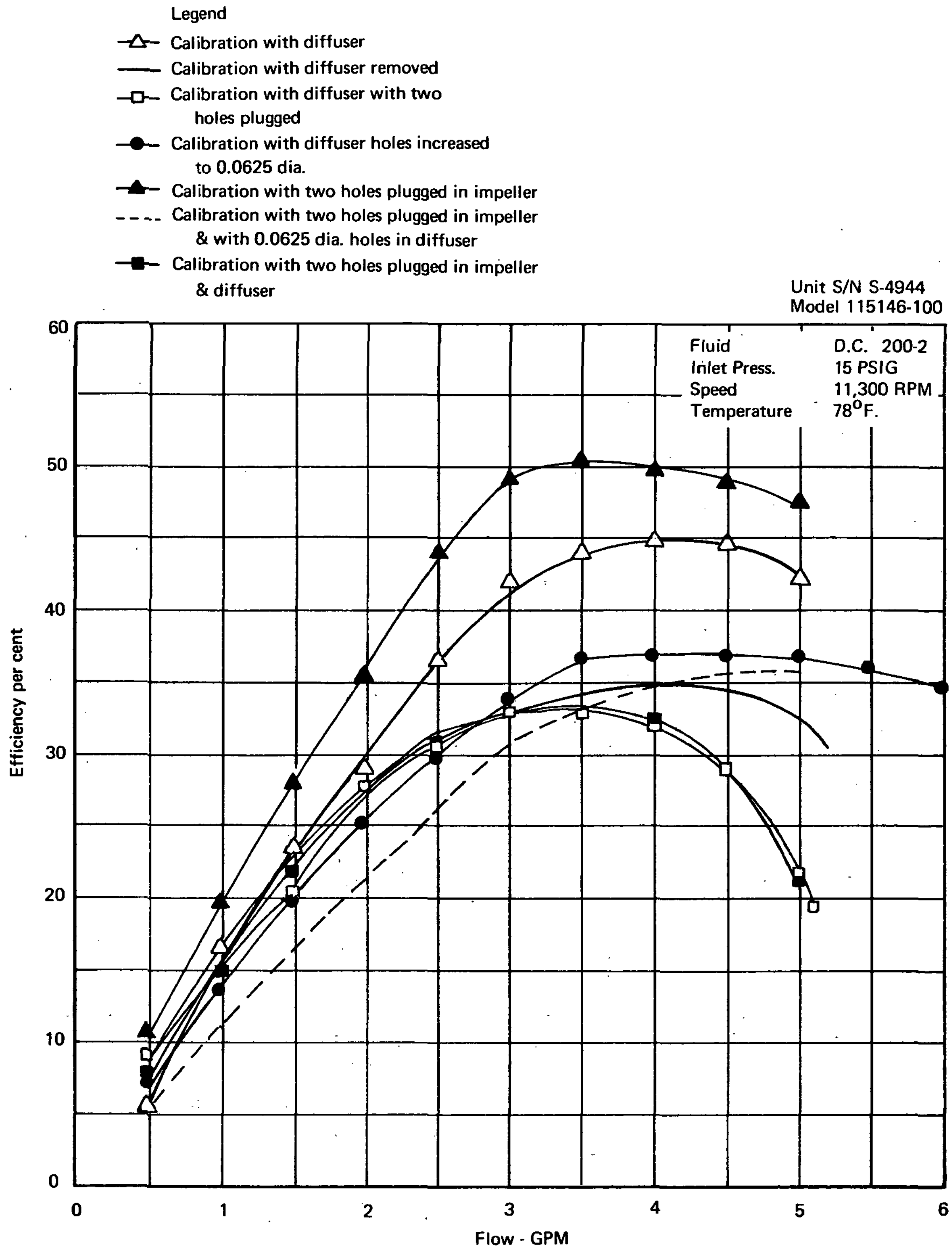


Figure 5. - Barstock pump test performance - Efficiency vs Flow
Composite curve for various unit configurations

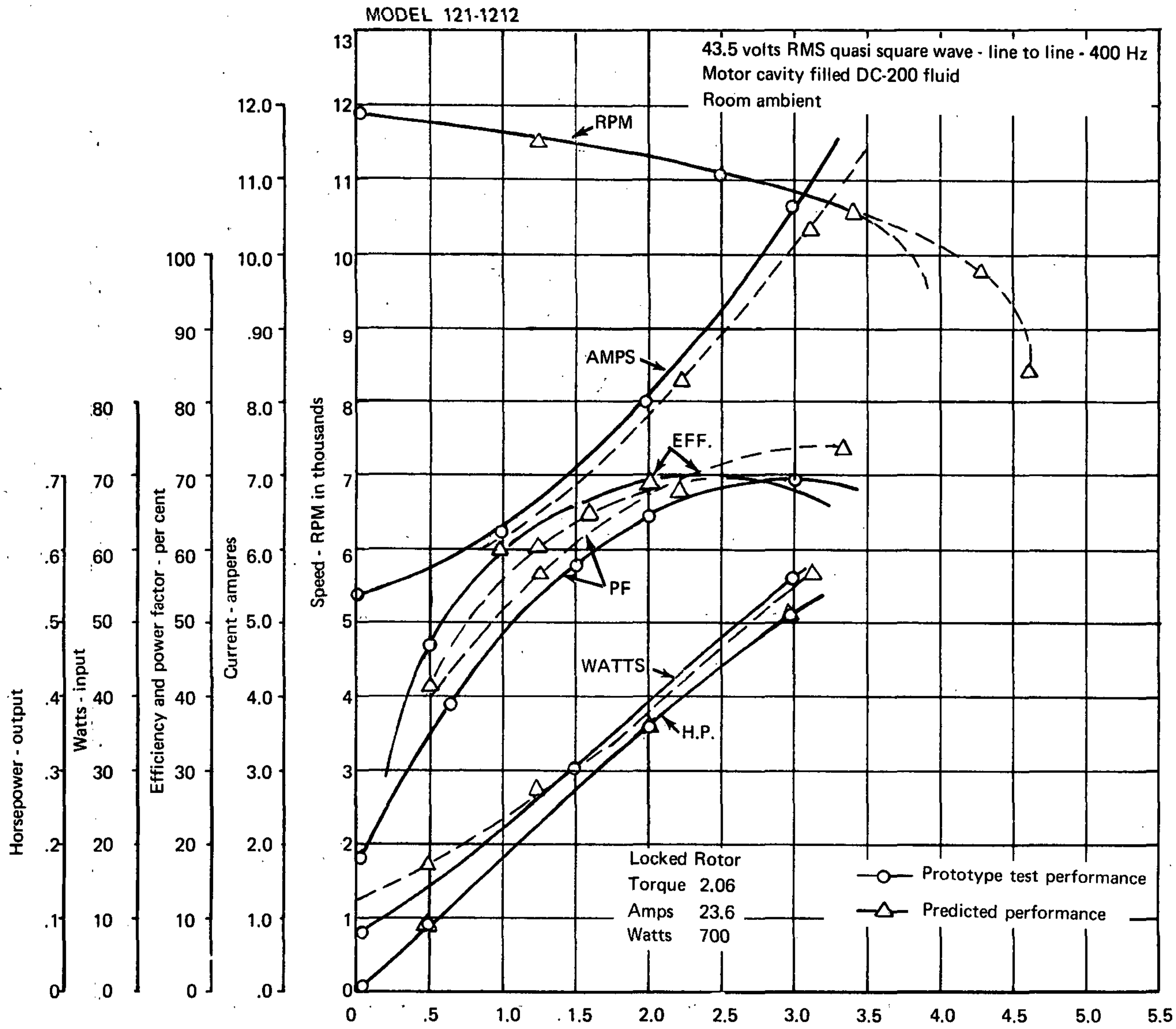


Figure 6. - Motor performance curve - Predicted vs Prototype results
Wet motor, 43.5 volts quasi - square wave, three phase, 400 Hz input

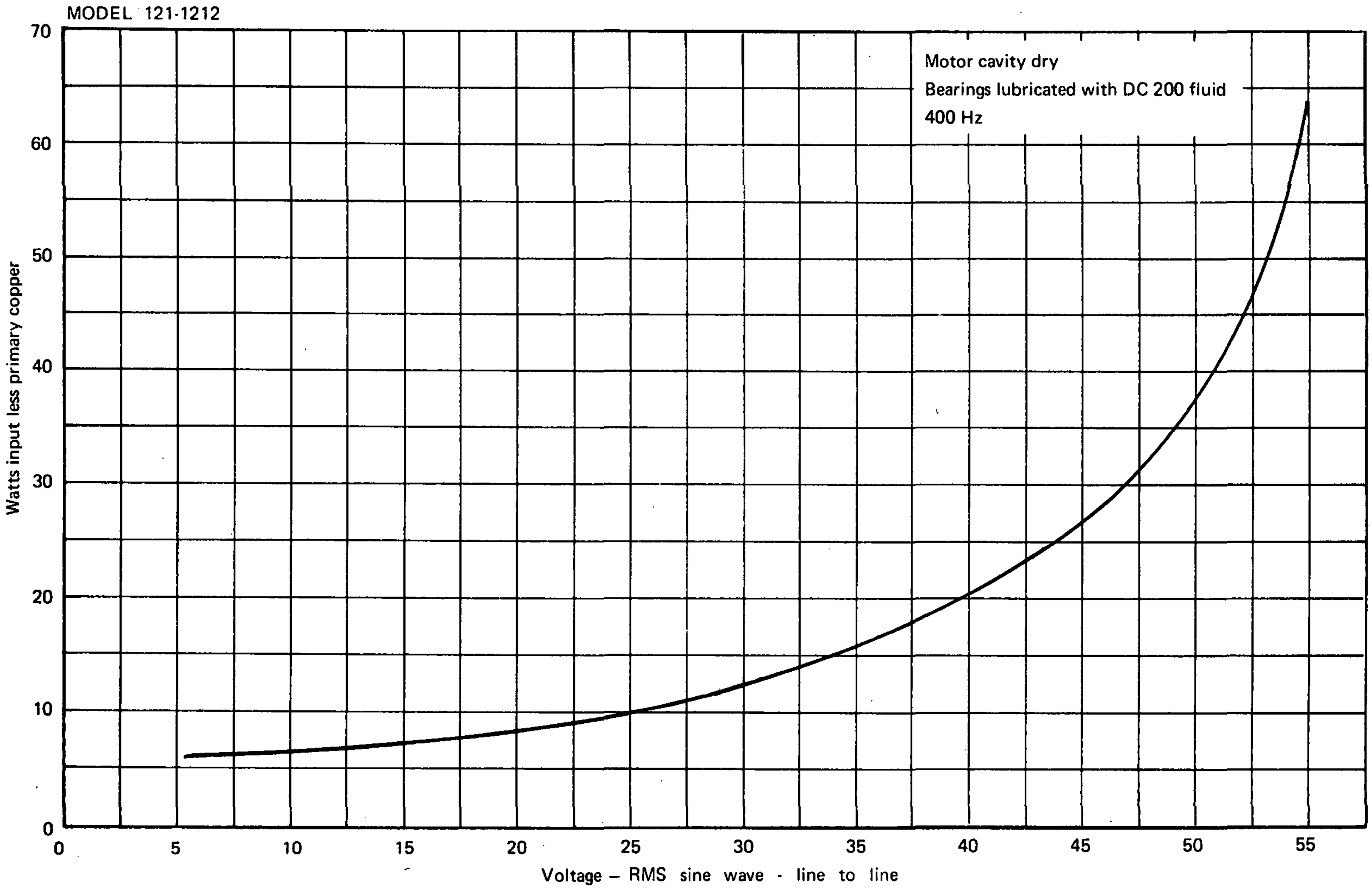


Figure 7. - Prototype motor no-load saturation test curve - Dry motor with sinusoidal voltage input

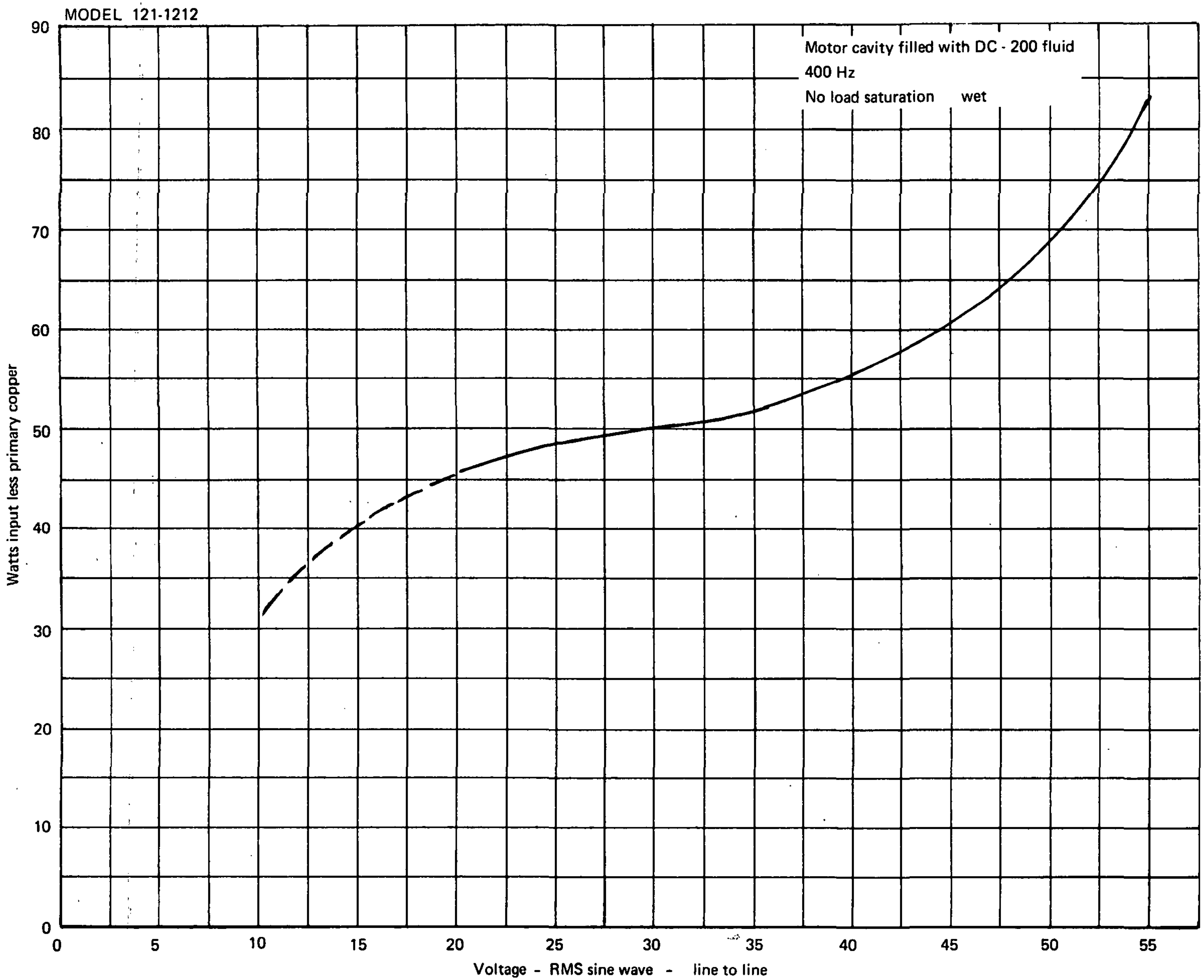


Figure 8. - Prototype motor no-load saturation test curve - wet motor with sinusoidal voltage input

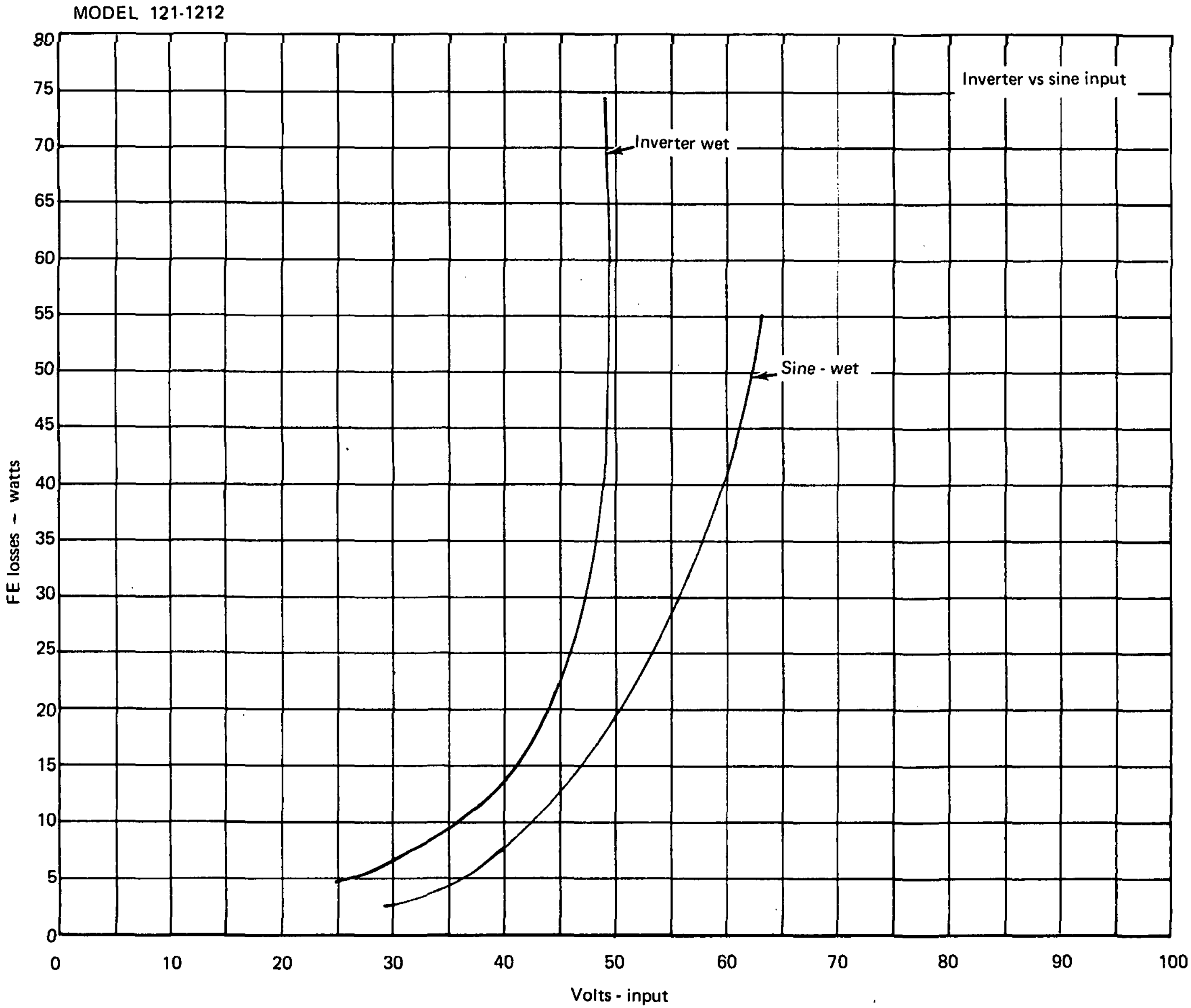


Figure 9. - Prototype motor iron loss test curve - wet motor, sinusoidal and quasi-square wave inverter input

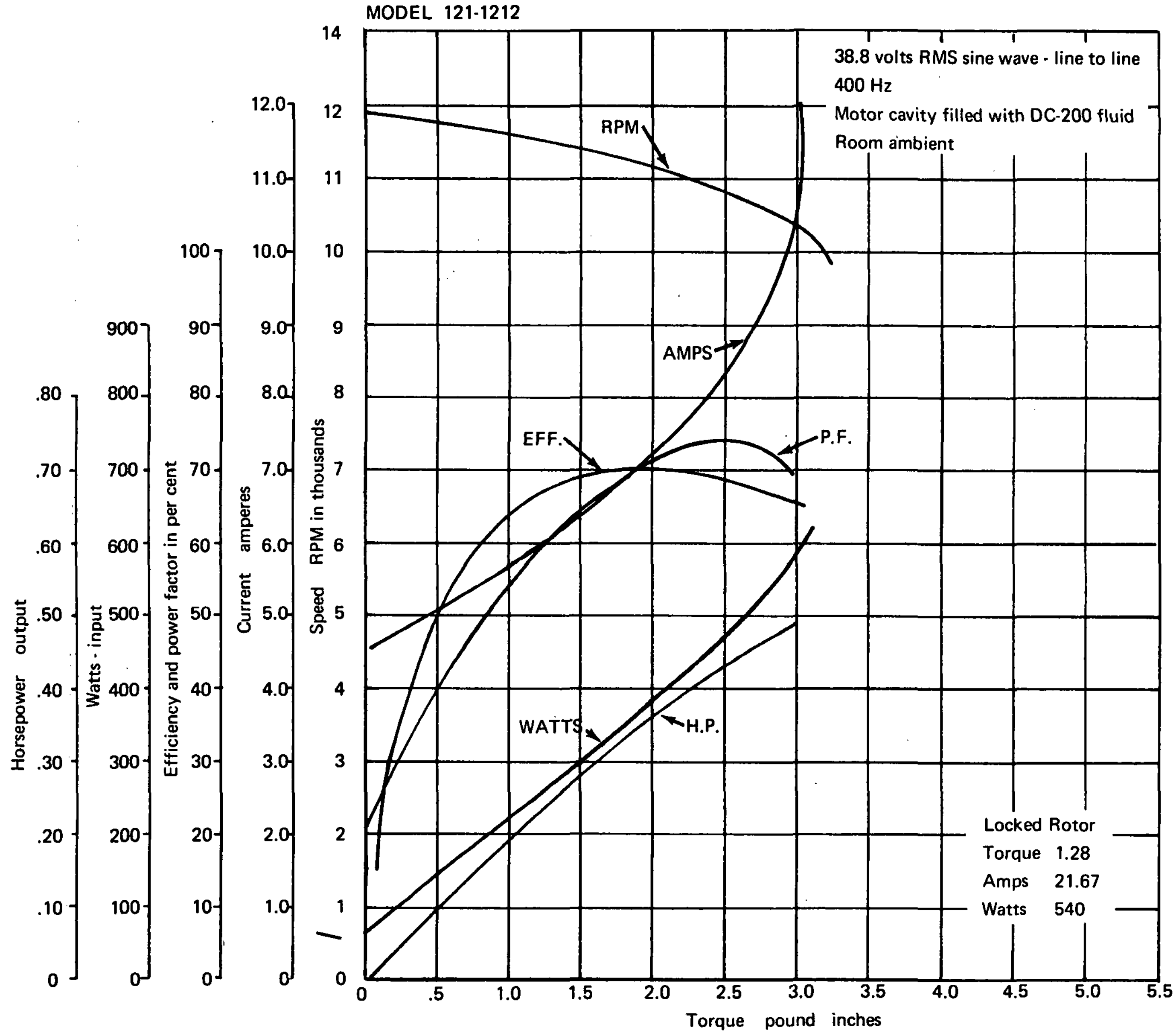


Figure 10. - Prototype motor test performance curve - wet motor, 38.8 volts, sine wave input 400 Hz - three phase

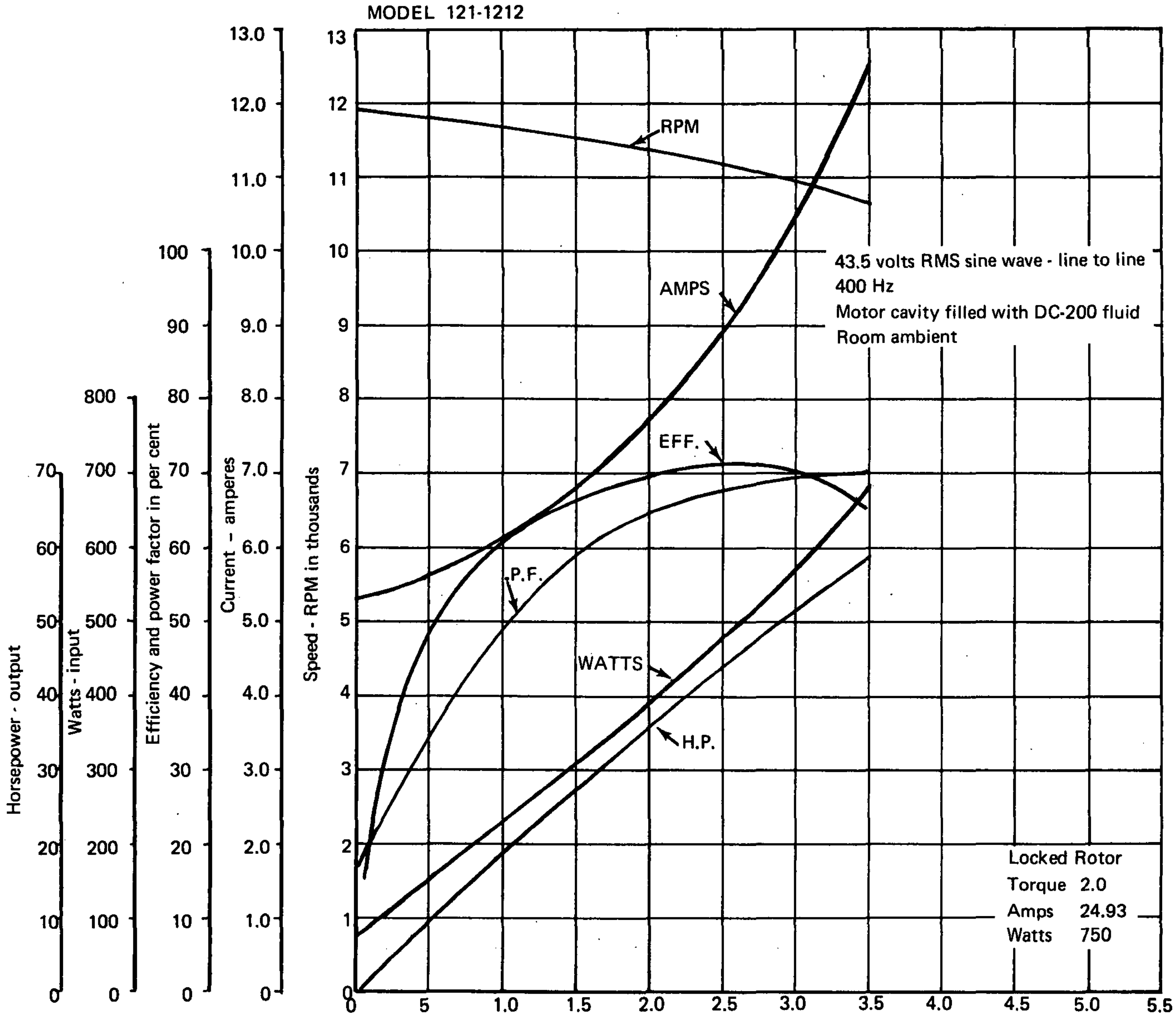


Figure 11. - Prototype motor test performance curve - wet motor, 43.5 volts sine wave input, 400 Hz - three phase

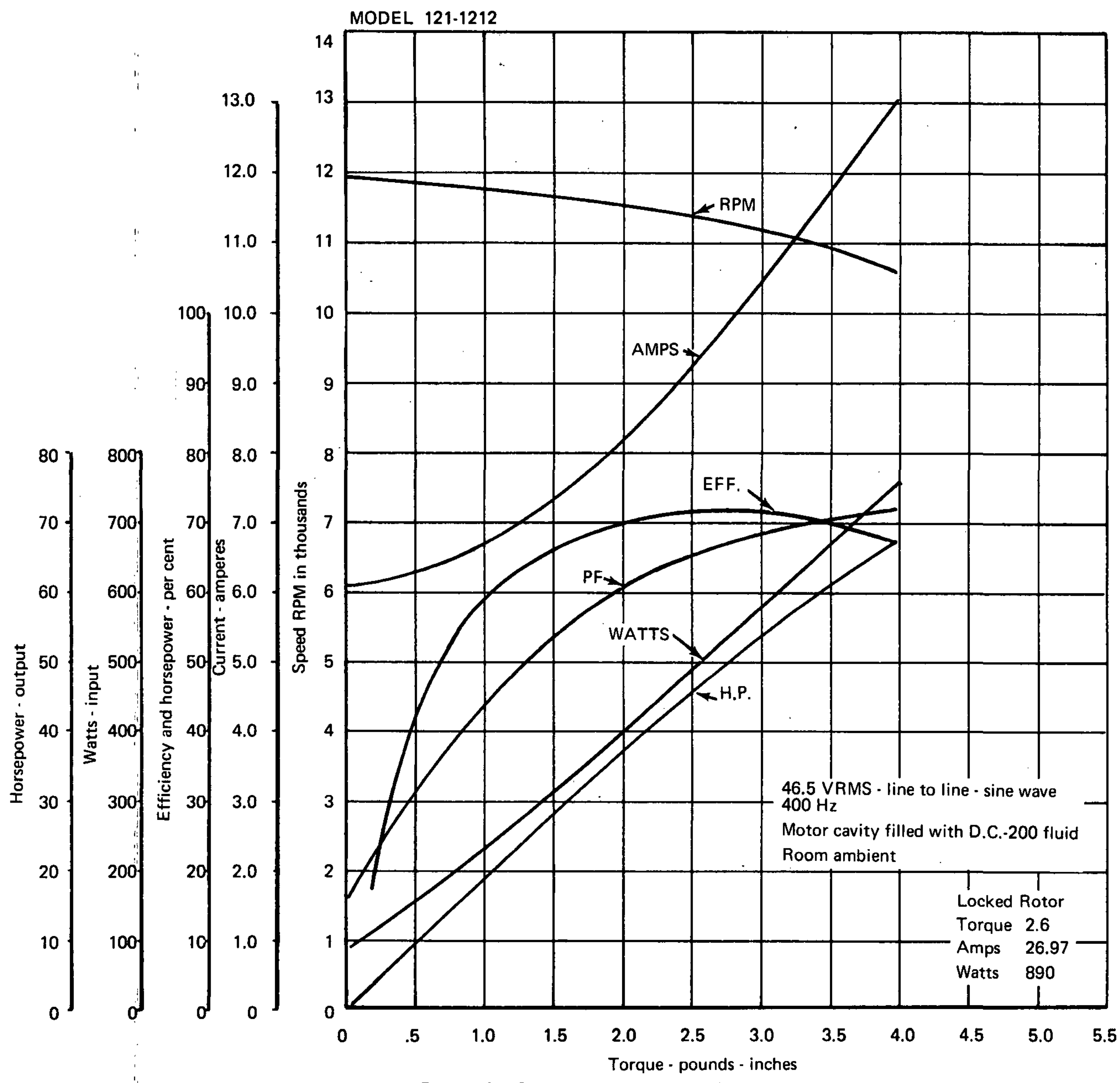


Figure 12. - Prototype motor test performance curve - wet motor, 46.5 volts sine wave input, 400 Hz - three phase

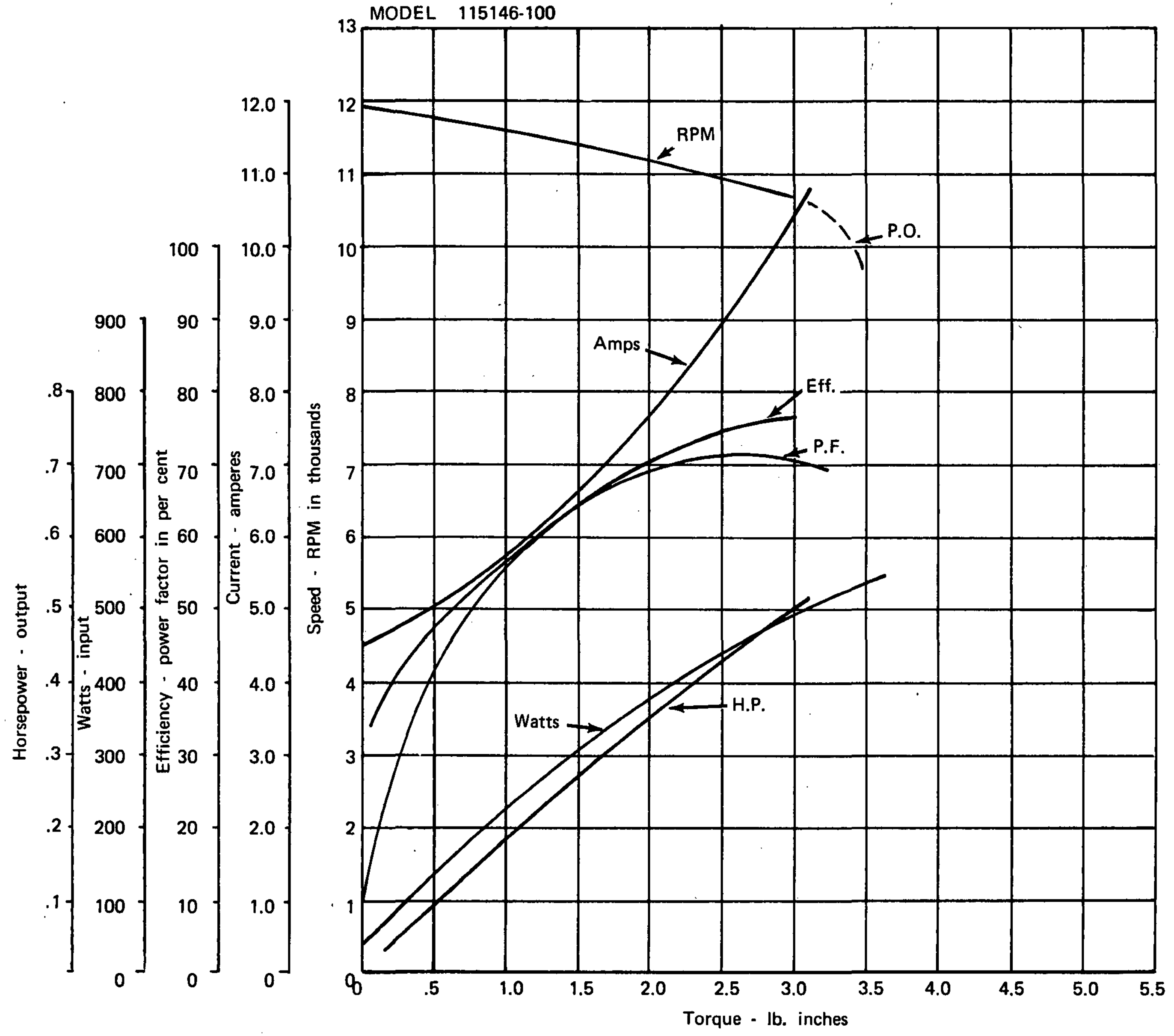


Figure 13. - Prototype motor test performance curve - dry motor, 38.8 volts, sine wave input, 400 Hz, three phase

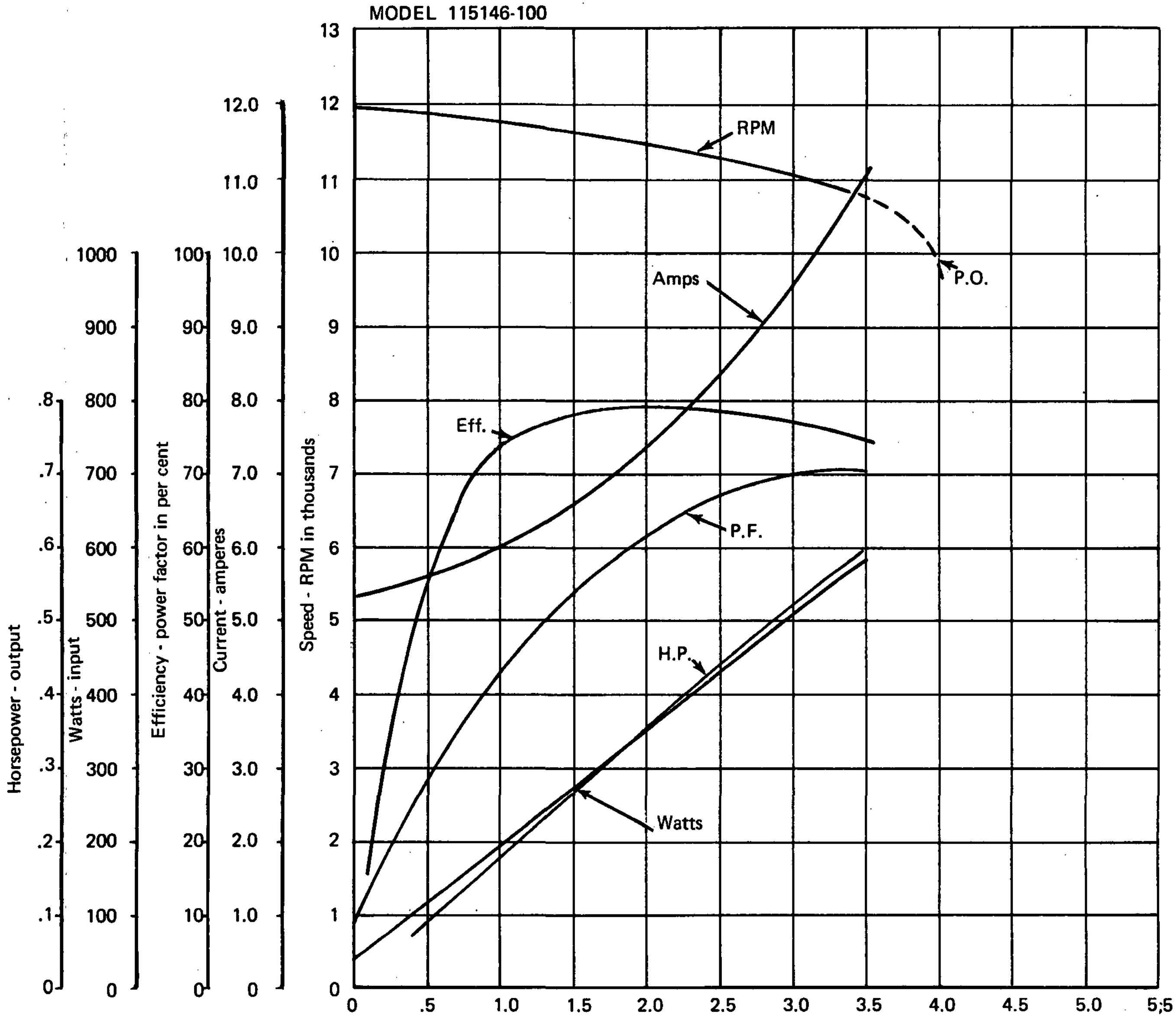


Figure 14. - Prototype motor test performance curve - dry motor, 43.5 volts, sine wave input 400 Hz, three phase

MODEL 115146-100

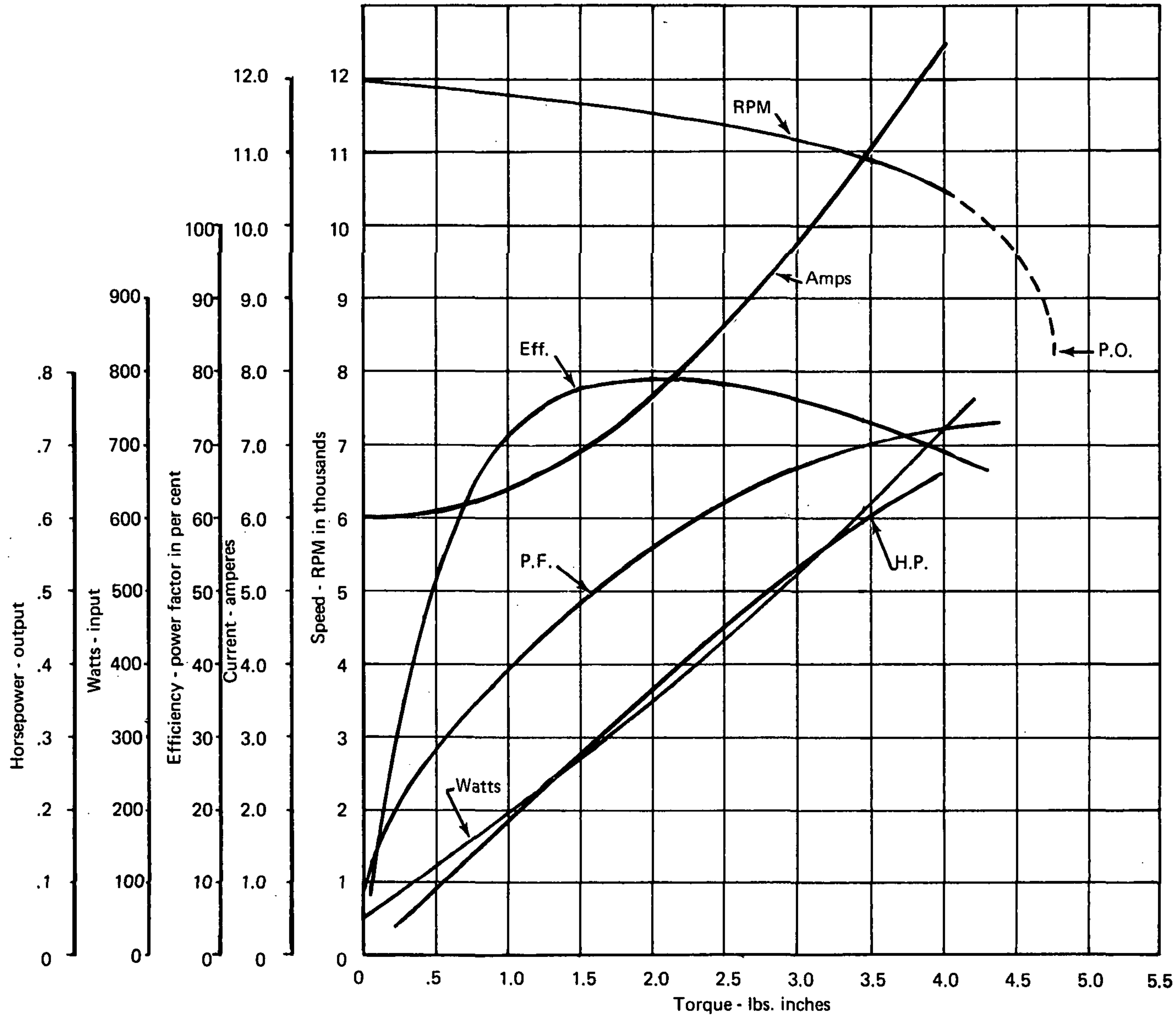


Figure 15. Prototype motor test performance curve - dry motor, 46.5 volts, sine wave input, 400 Hz, three phase

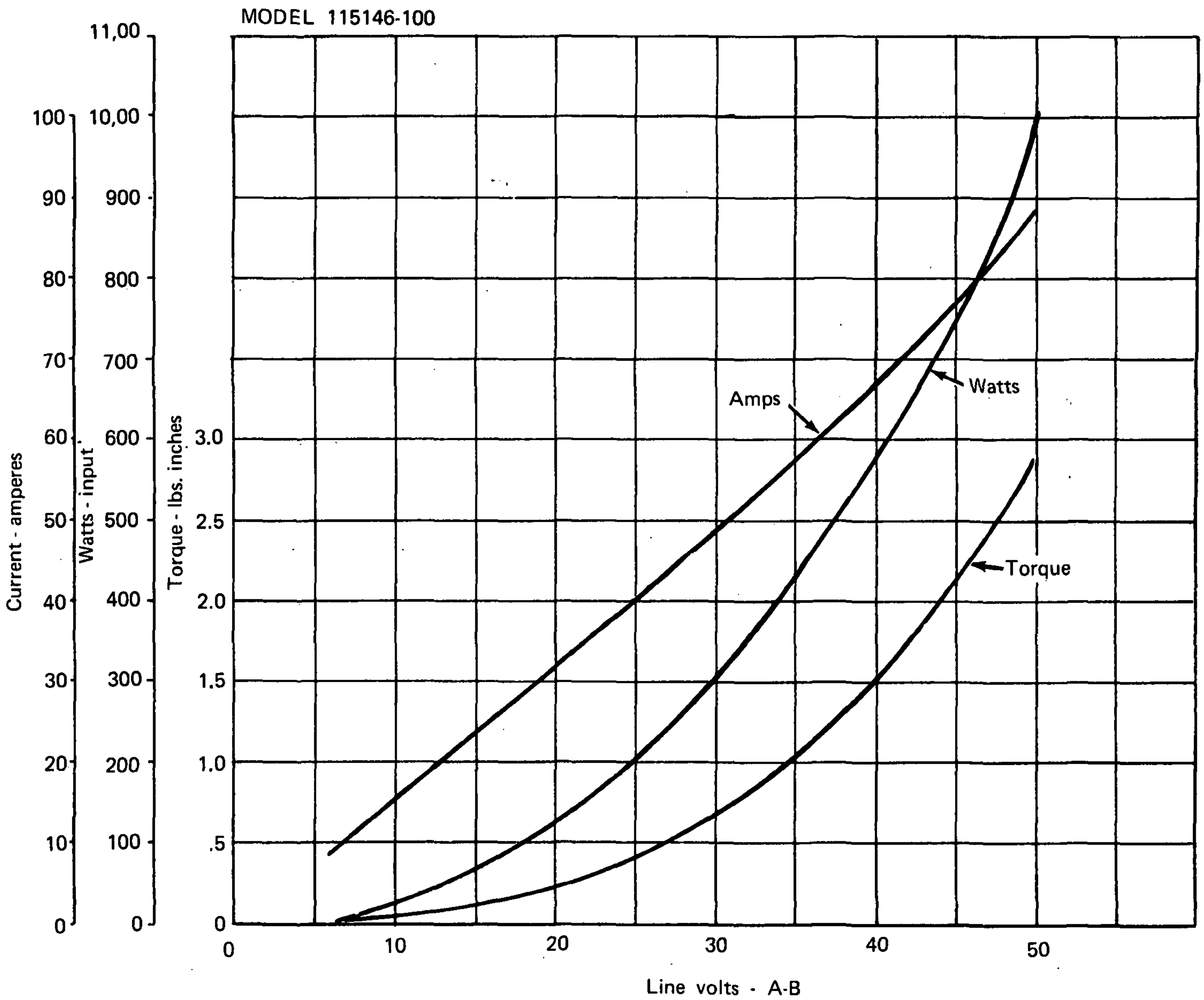


Figure 16. Prototype motor locked rotor saturation test curve - wet motor, sine wave input, 400 Hz

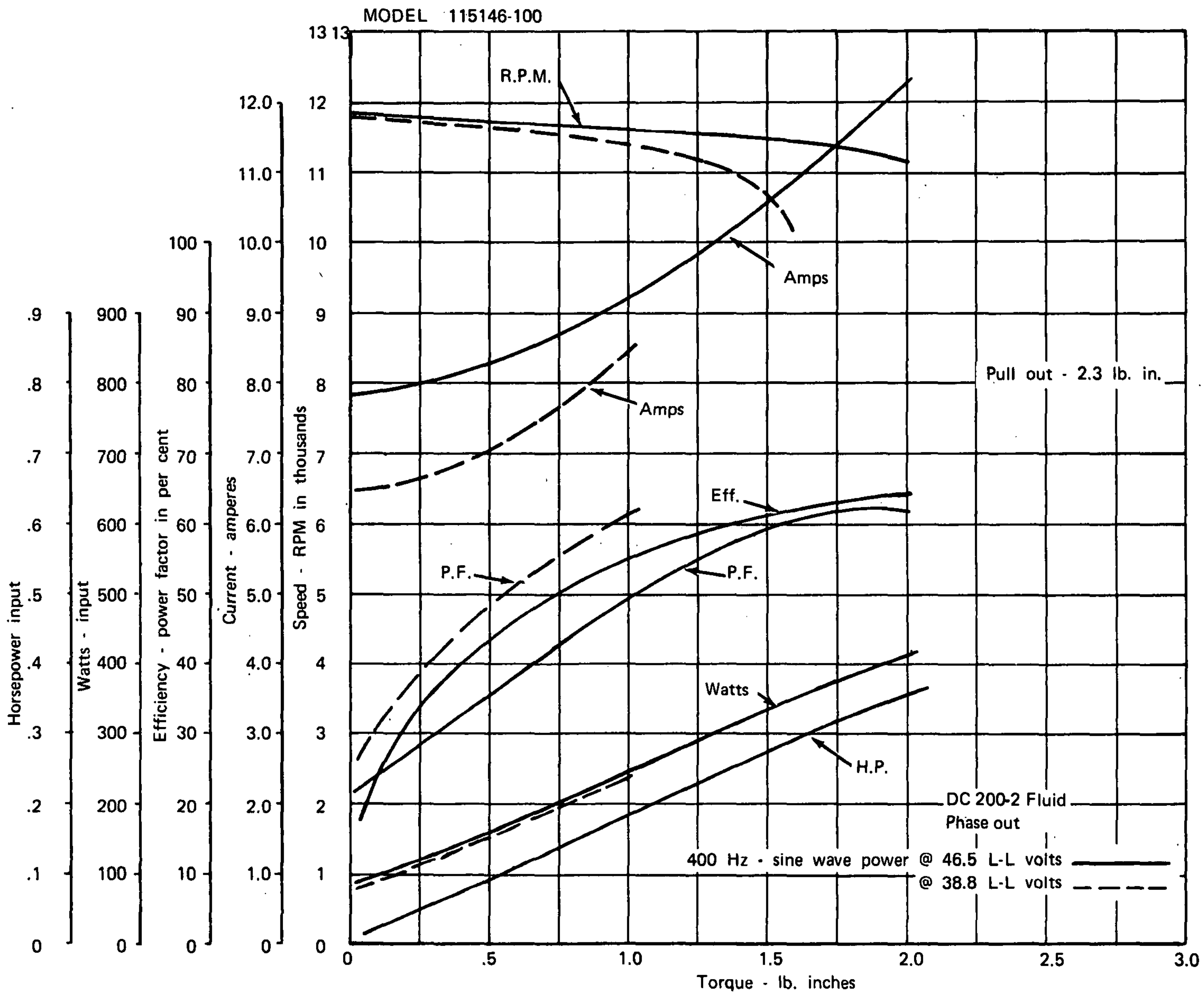


Figure 17. - *Prototype motor two-phase test performance curve* - wet motor, 46.5 and 38.8 volts, sine wave input, 400 Hz

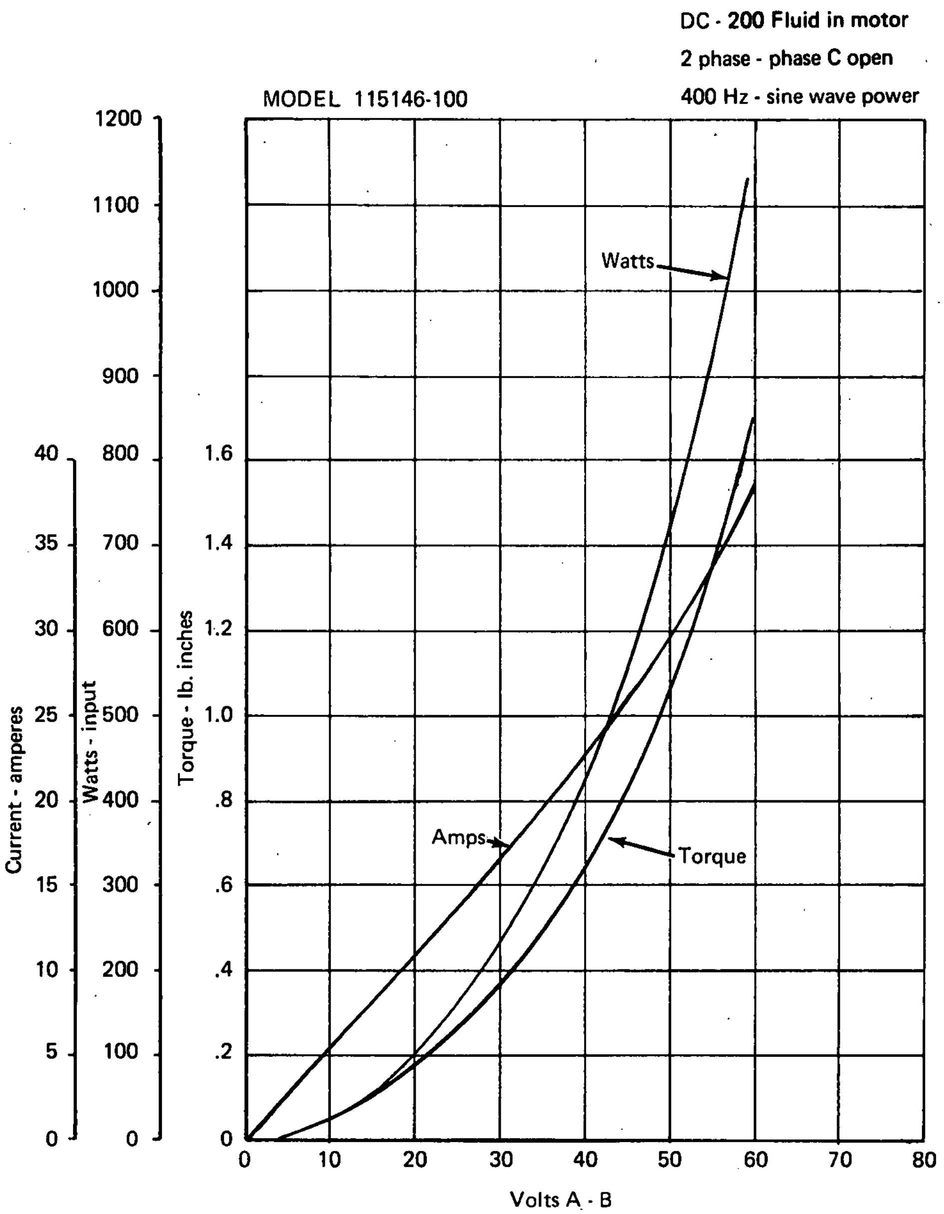


Figure 18. - Prototype motor two-phase locked rotor saturation test curve - wet motor, sine wave input, 400 Hz

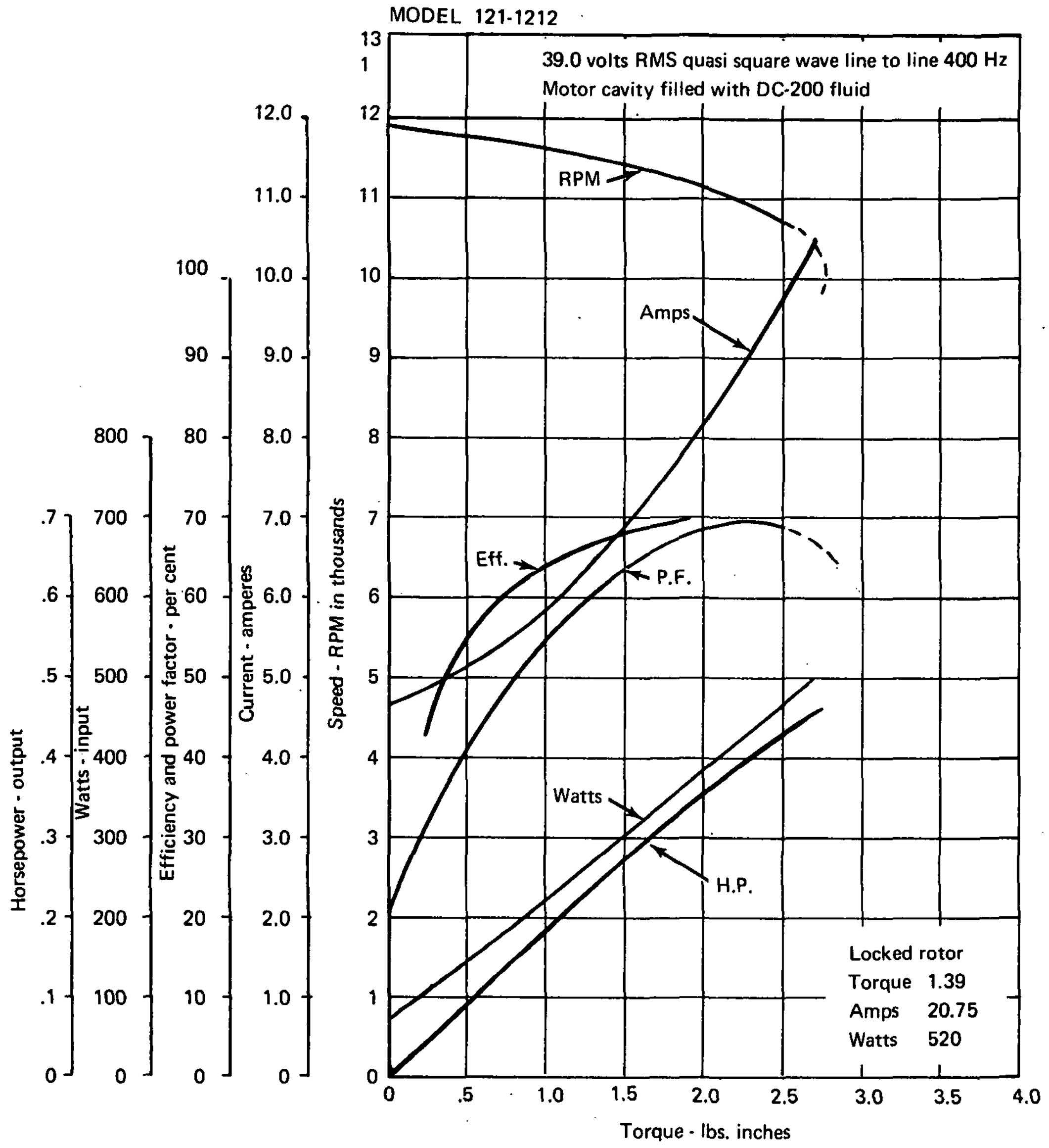


Figure 19. - Prototype motor test performance curve - wet motor, 39 volts, quasi-square wave input, 400 Hz, three phase

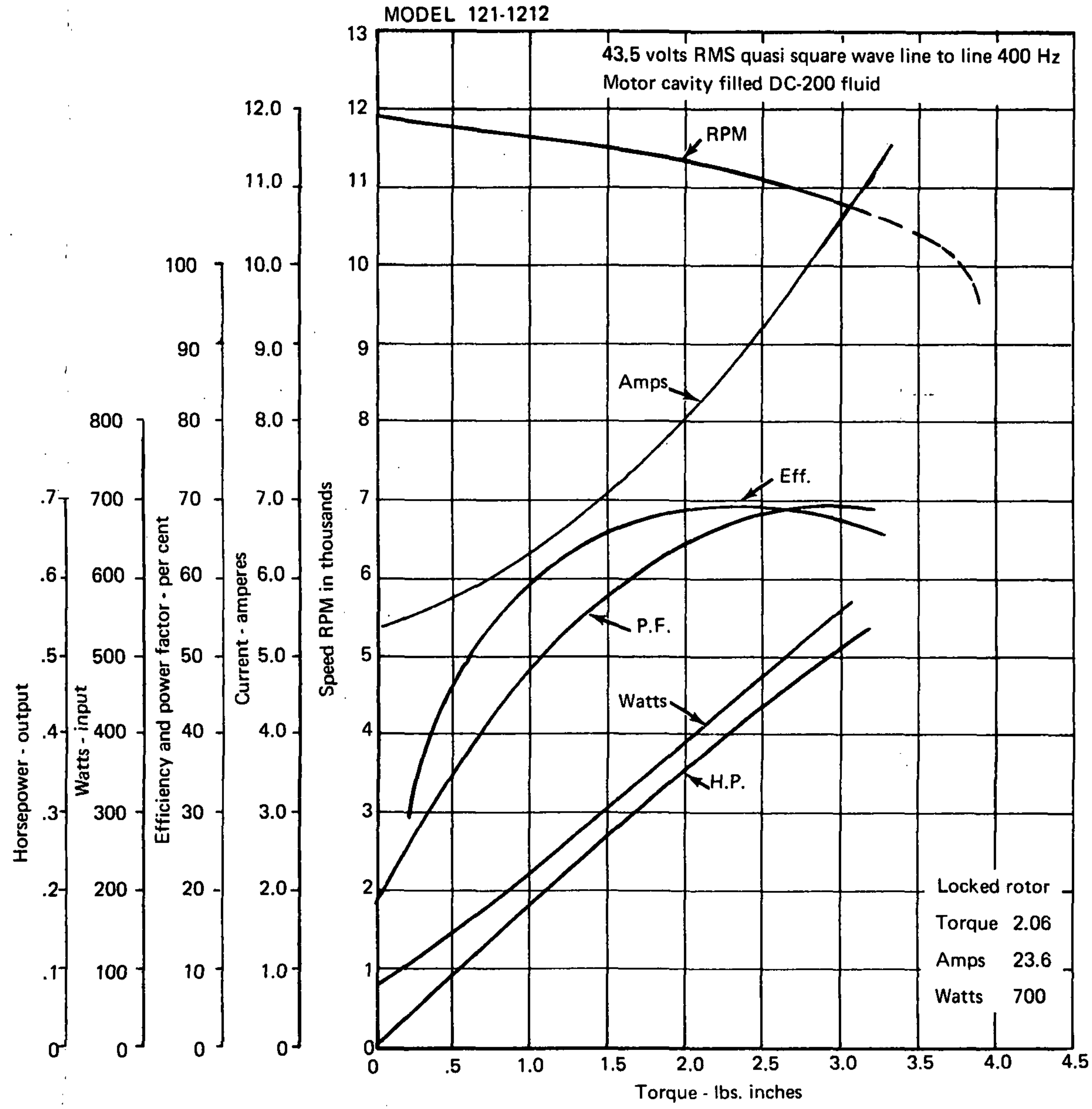


Figure 20. - Prototype motor test performance curve - wet motor, 43.5 volts, quasi-square wave input, 400 Hz, three phase

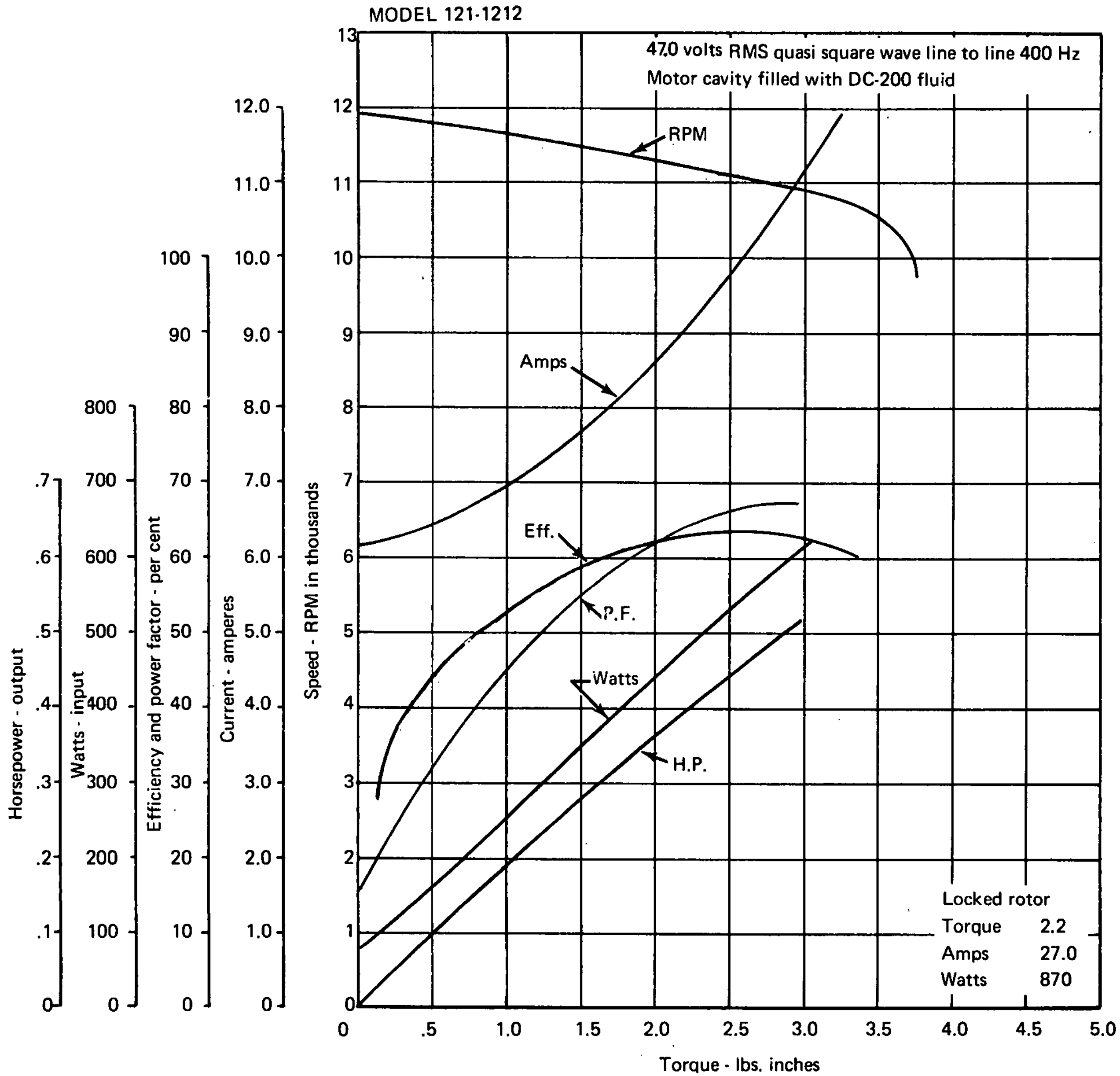


Figure 21. - Prototype motor test performance curve - wet motor, 47 volts, quasi-square wave input, 400 Hz, three phase

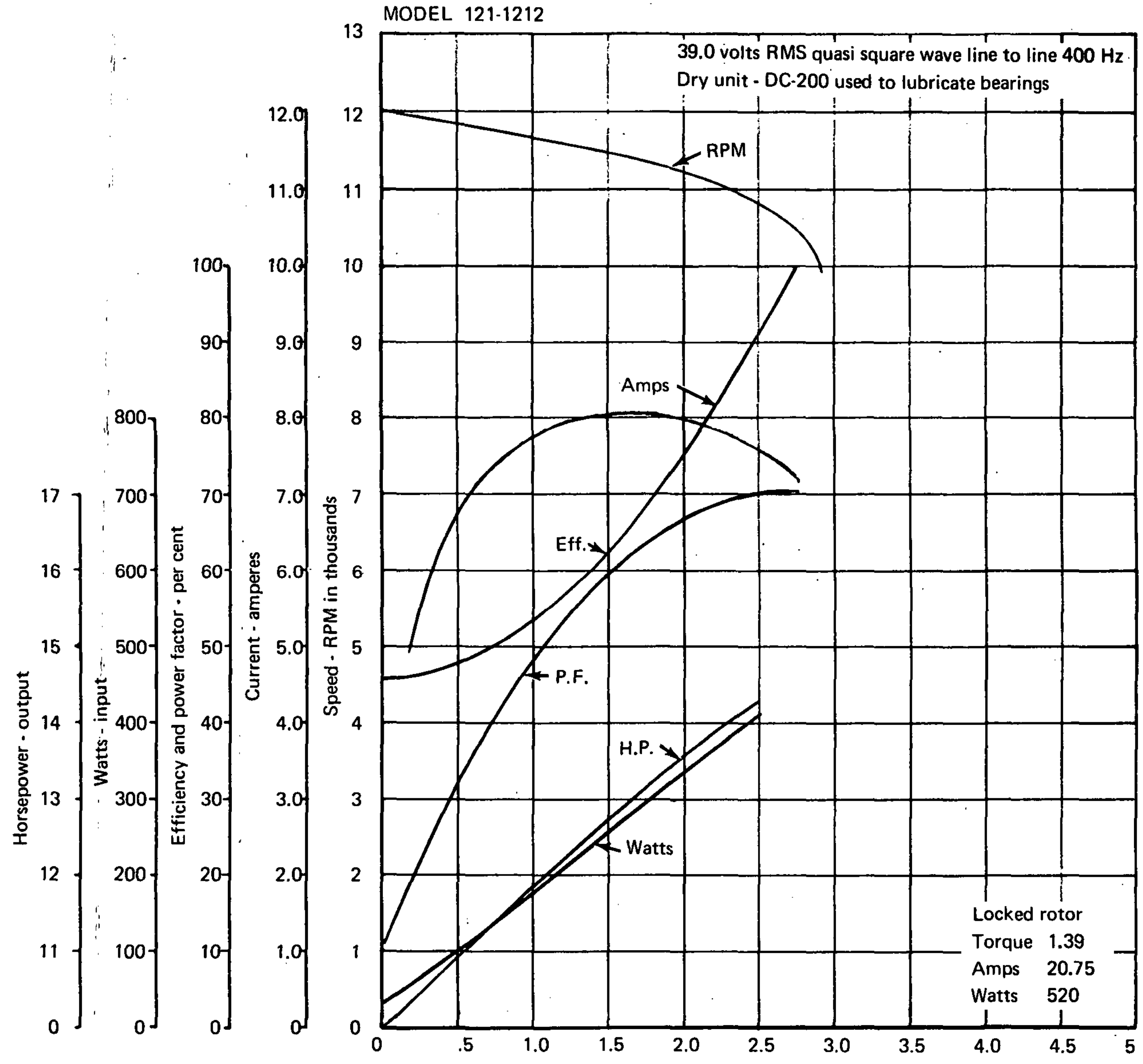


Figure 22. - Prototype motor test performance curve - dry motor, 39 volts quasi-square wave input, 400 Hz, three phase

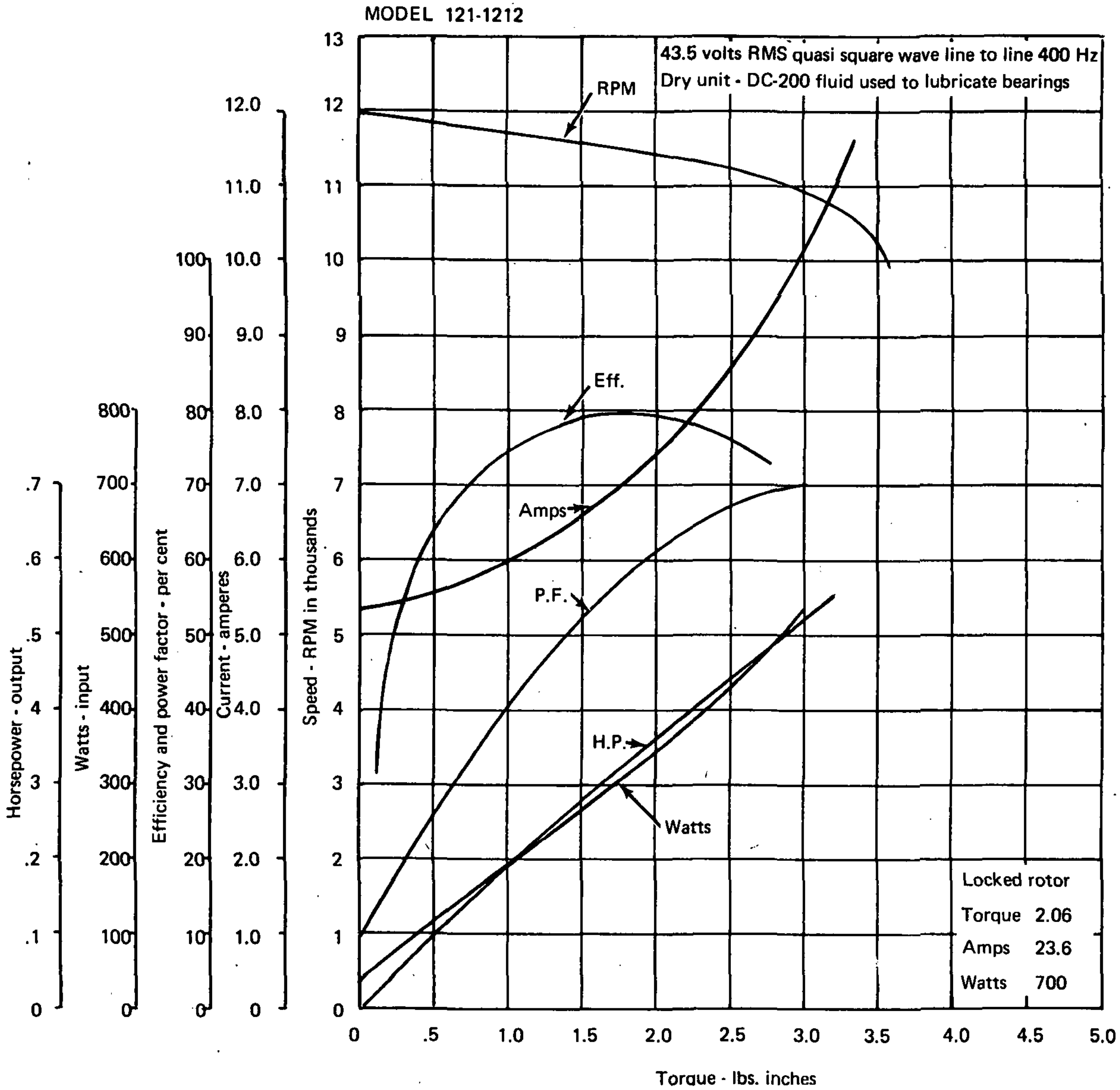


Figure 23. - Prototype motor test performance curve - dry motor, 43.5 volts quasi-square wave input, 400 Hz, three phase

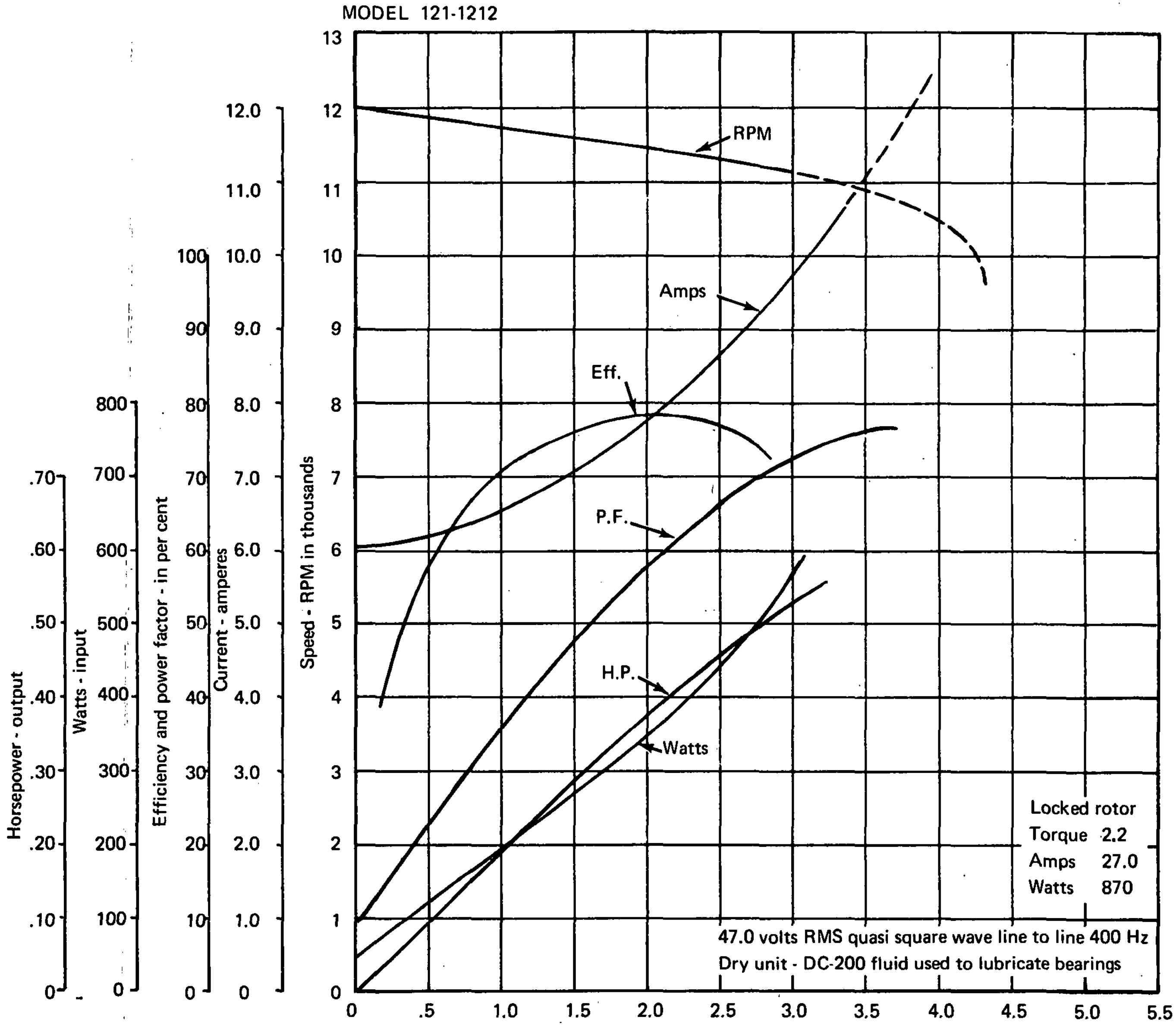


Figure 24. - Prototype motor test performance curve - dry motor, 47 volts, quasi-square wave input, 400 Hz, three phase

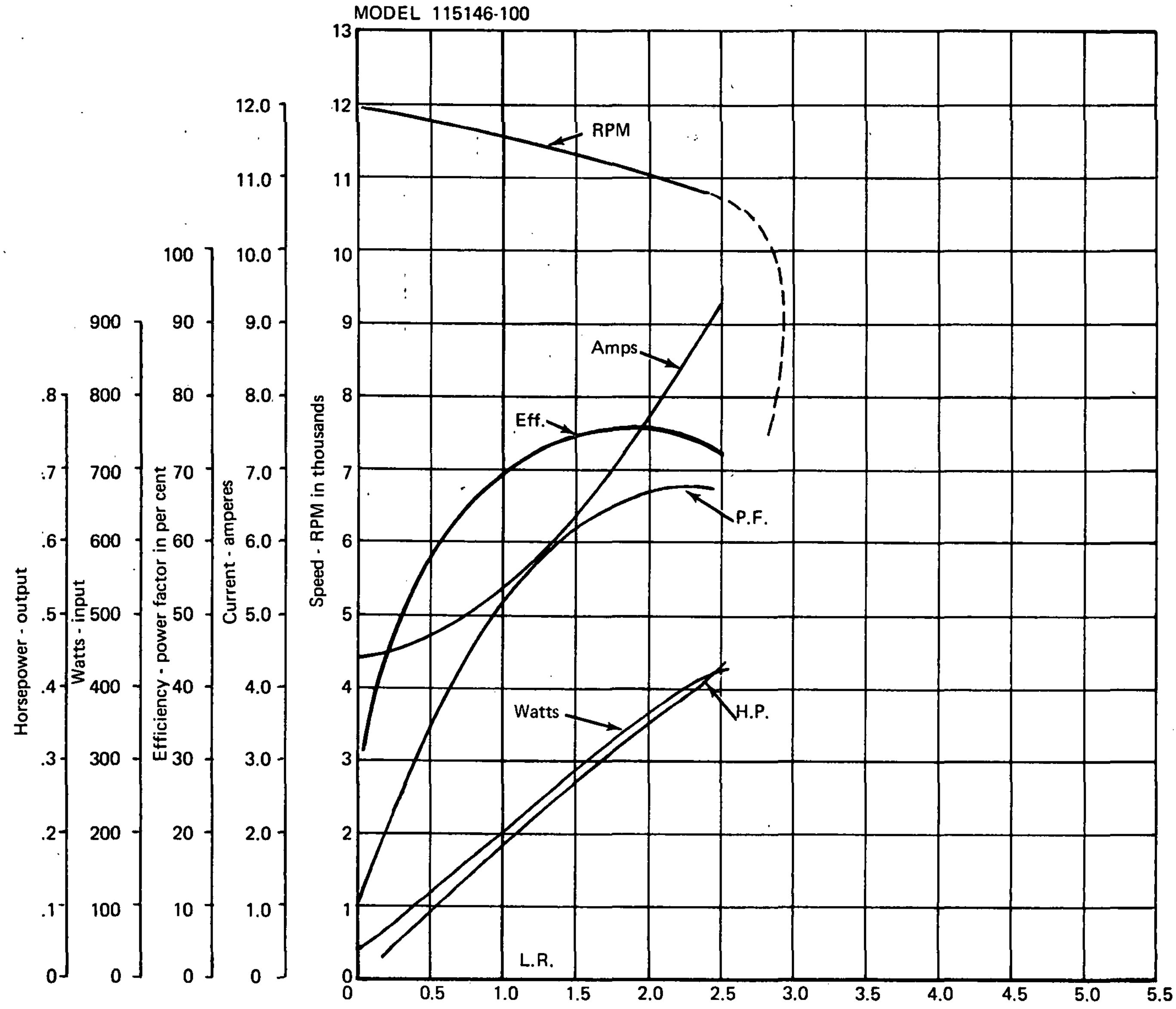


Figure 25. - Motor test performance curve - dry motor with 0.188 inches rotor skew, 39 volts, quasi-square wave input, 400 Hz, three phase

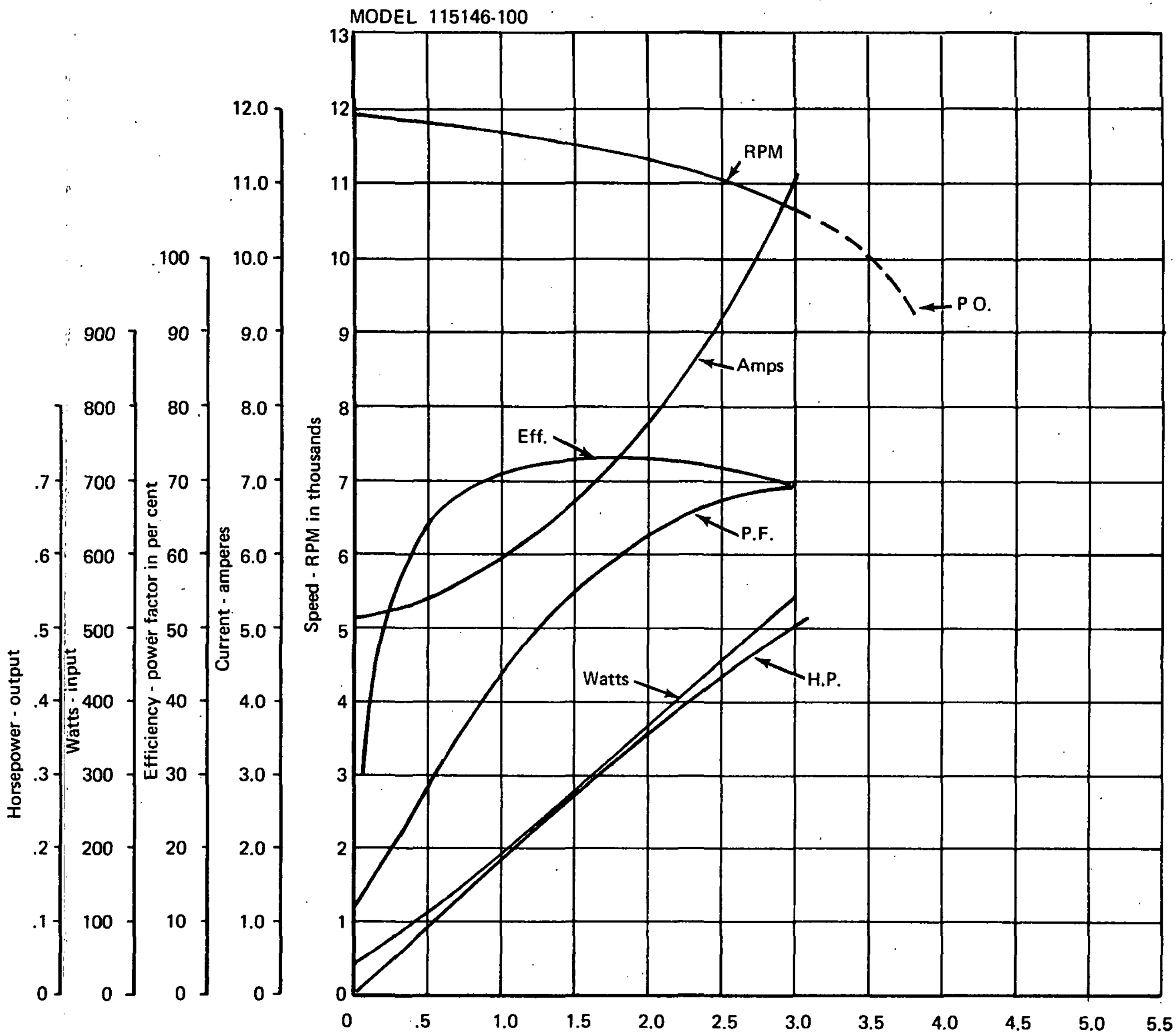


Figure 26. - Motor test performance curve - dry motor with 0.188 inches rotor skew, 43.5 volts, quasi-square wave input, 400 Hz, three phase

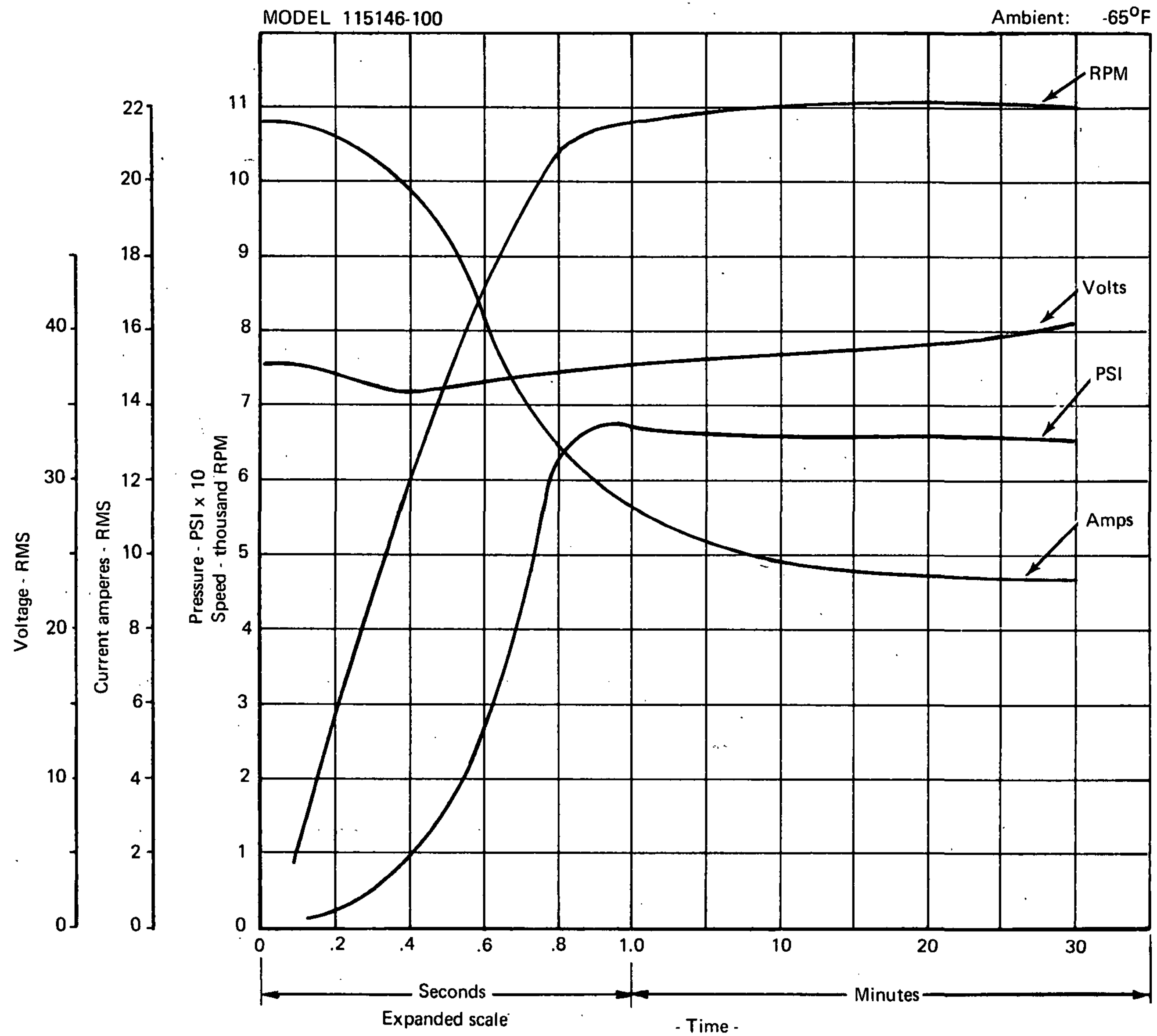


Figure 27. - Barstock PMA acceleration test curve at -65°F, sine wave input, 41 volts, 400 Hz, three phase, 30 minute test

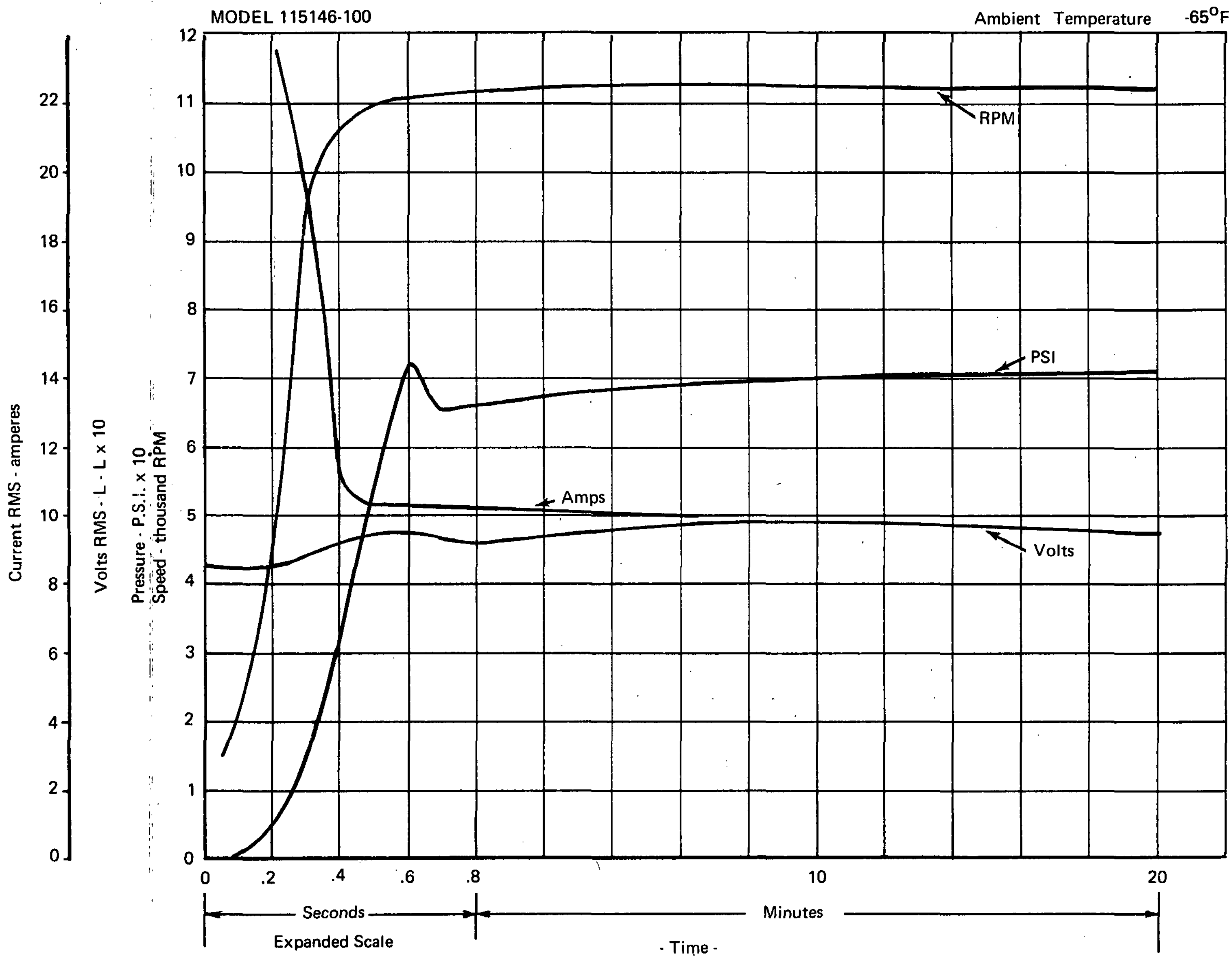


Figure 28. - Barstock PMA acceleration test curve at -65°F, sine wave input, 47 volts, 400 Hz, three phase, 20 minute test

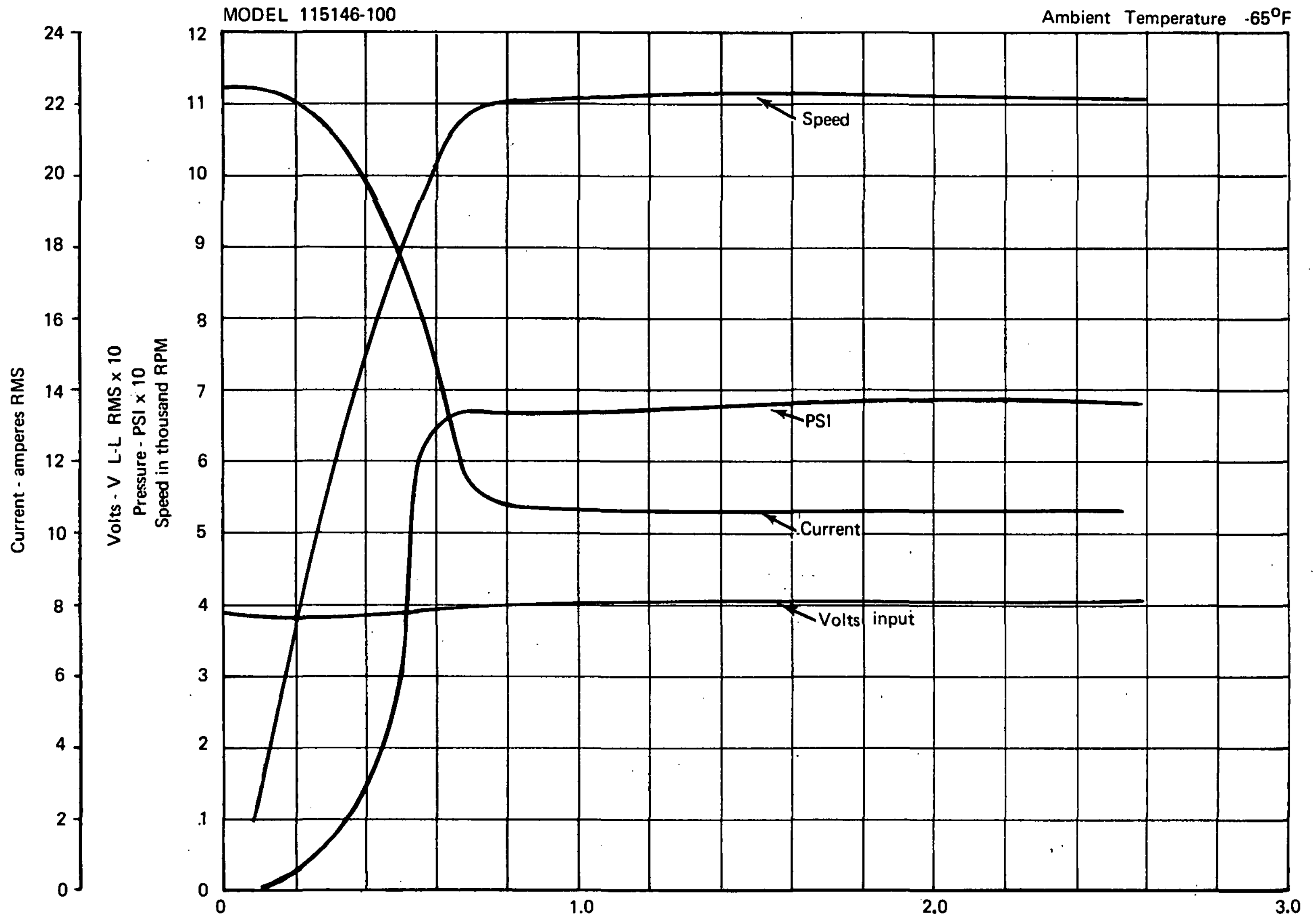


Figure 29. - Barstock PMA acceleration test curve at -65°F, sine wave input, 41 volts, 400 Hz, three phase, 3 second test

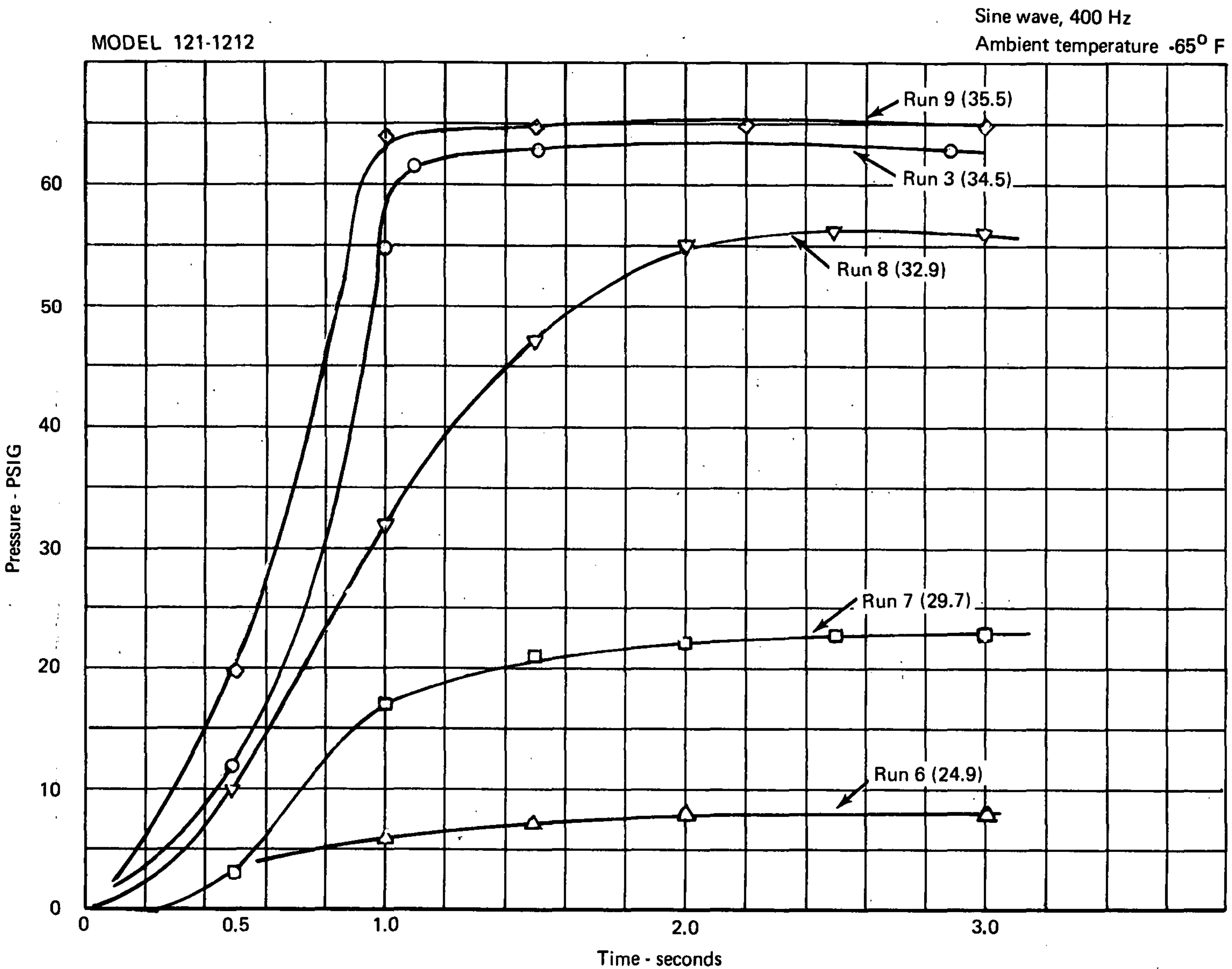


Figure 30. - Barstock PMA acceleration curves at -65°F and at various voltages - pump discharge pressure versus time - sine wave input, 400 Hz, three phase

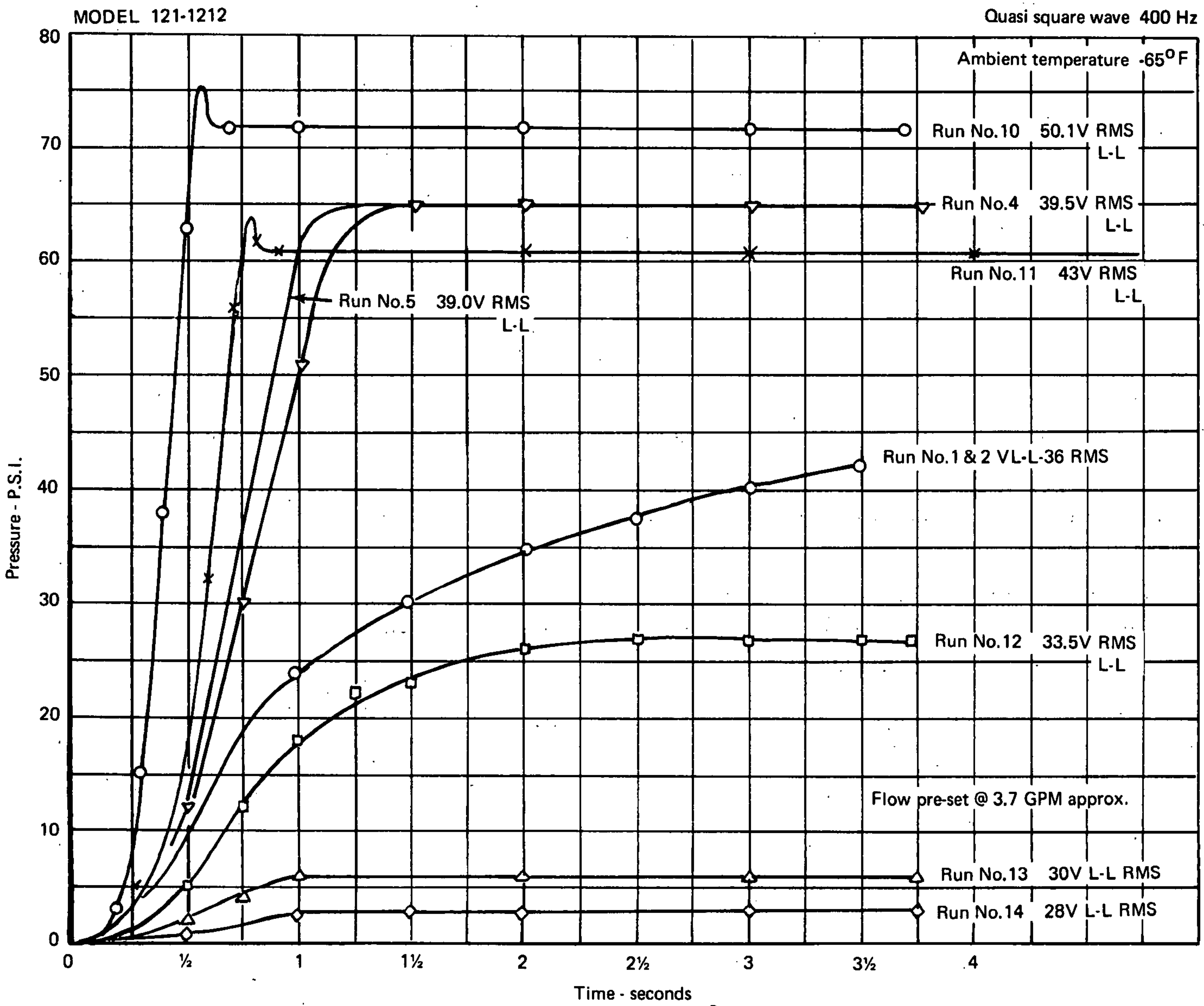


Figure 31. - Barstock PMA acceleration test curves at -65° and at various voltages - pump discharge pressure versus time - quasi-square wave input, 400 Hz, three phase

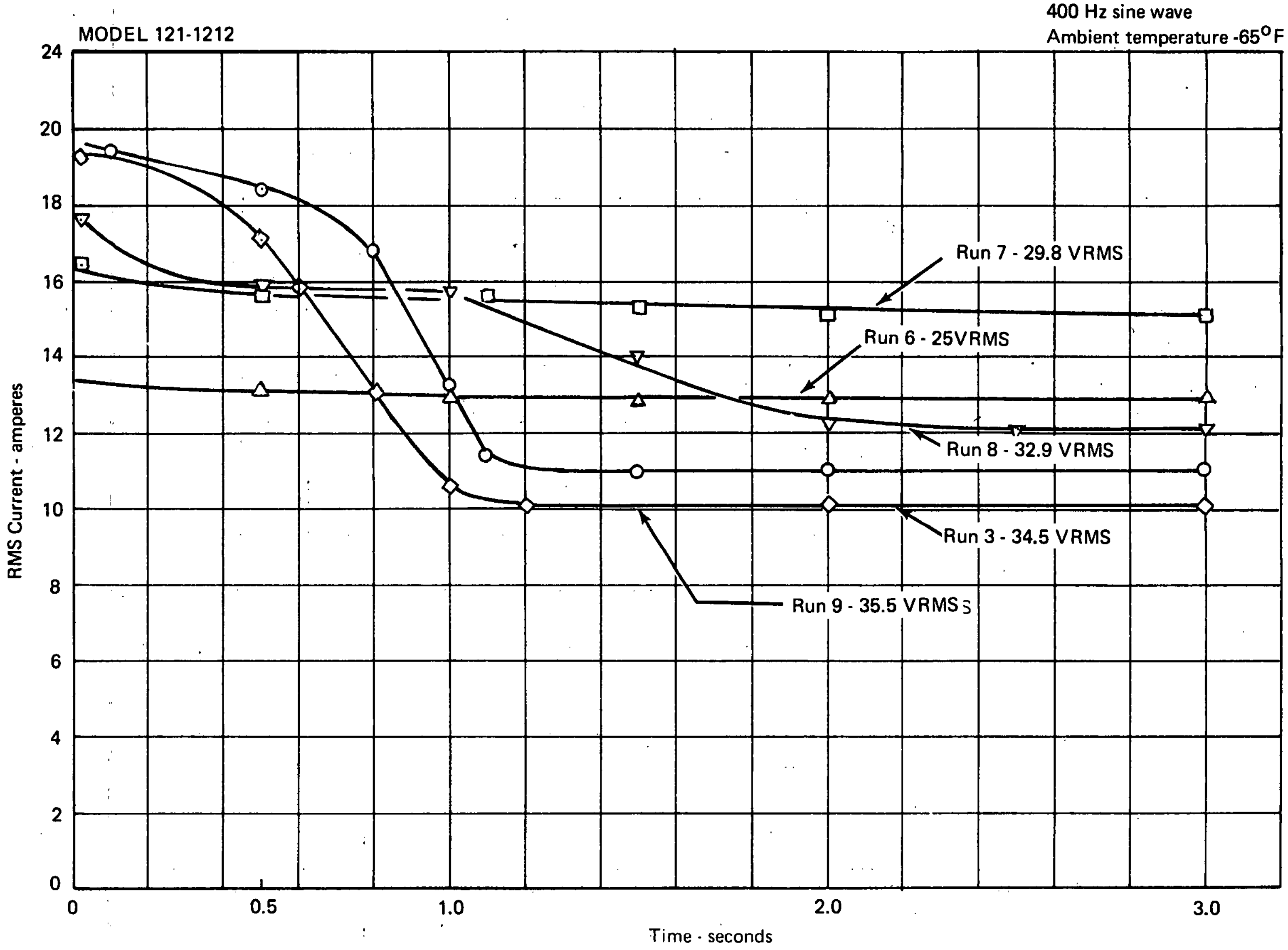


Figure 32. - Barstock PMA acceleration test curves at -65°F and at various voltages-motor current versus time-sine wave input, 400 Hz, three phase

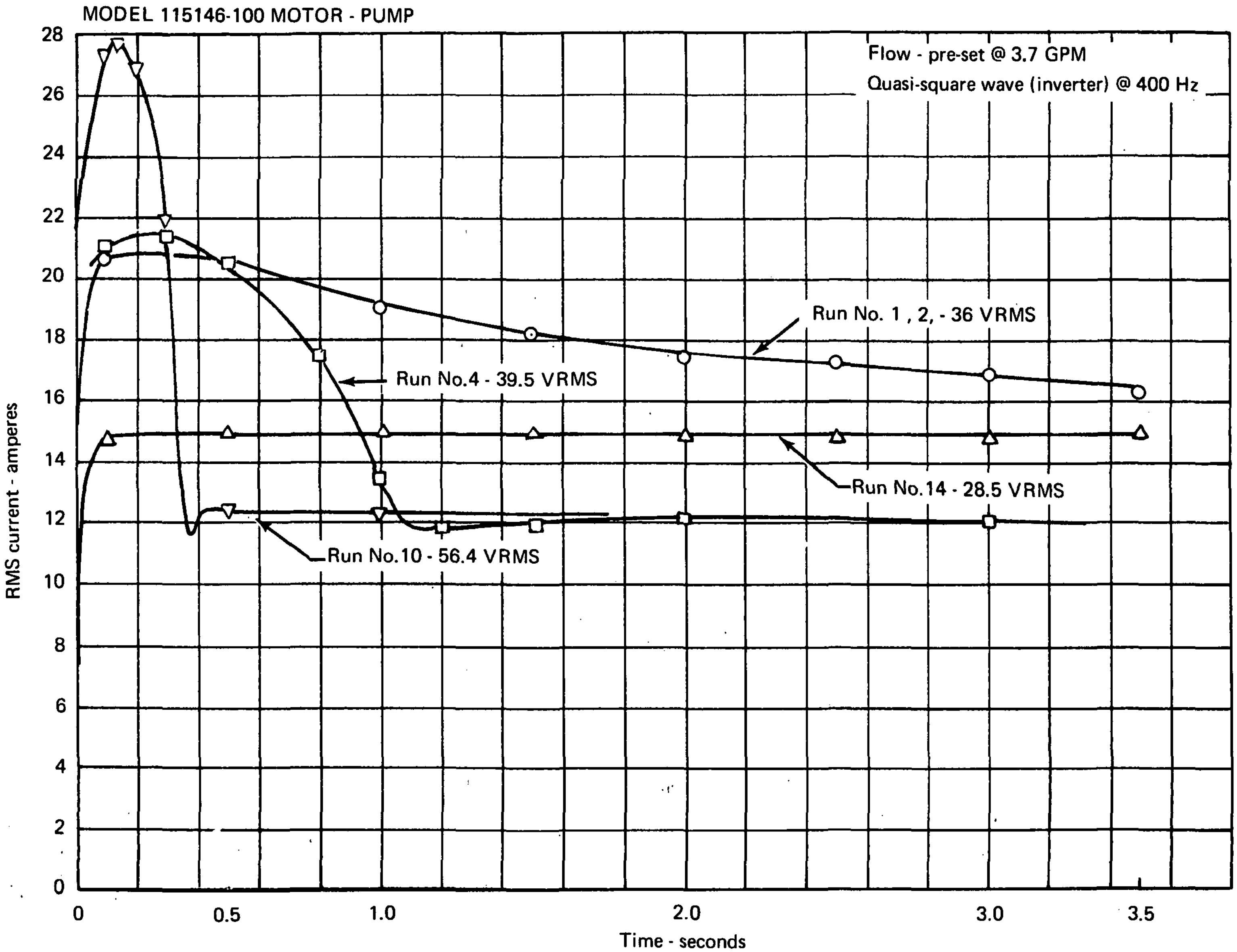


Figure 33. - Barstock PMA acceleration test curves at -65°F and at various voltages-motor current versus time-quasi-square wave input, 400 Hz, three phase

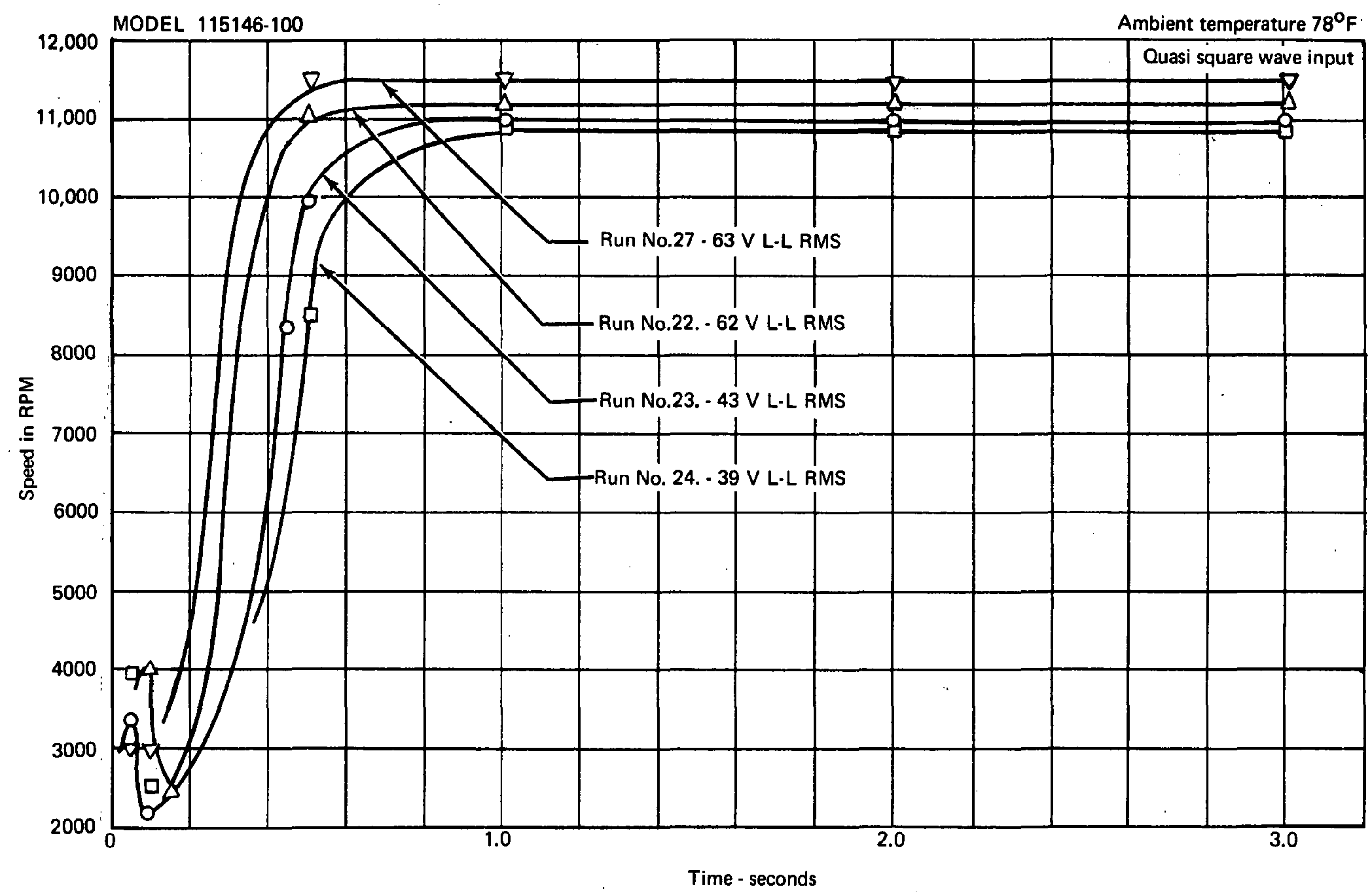


Figure 34. - Barstock PMA acceleration test curves at -65°F and at various voltages - speed versus time - quasi-square wave input, 400 Hz, three phase

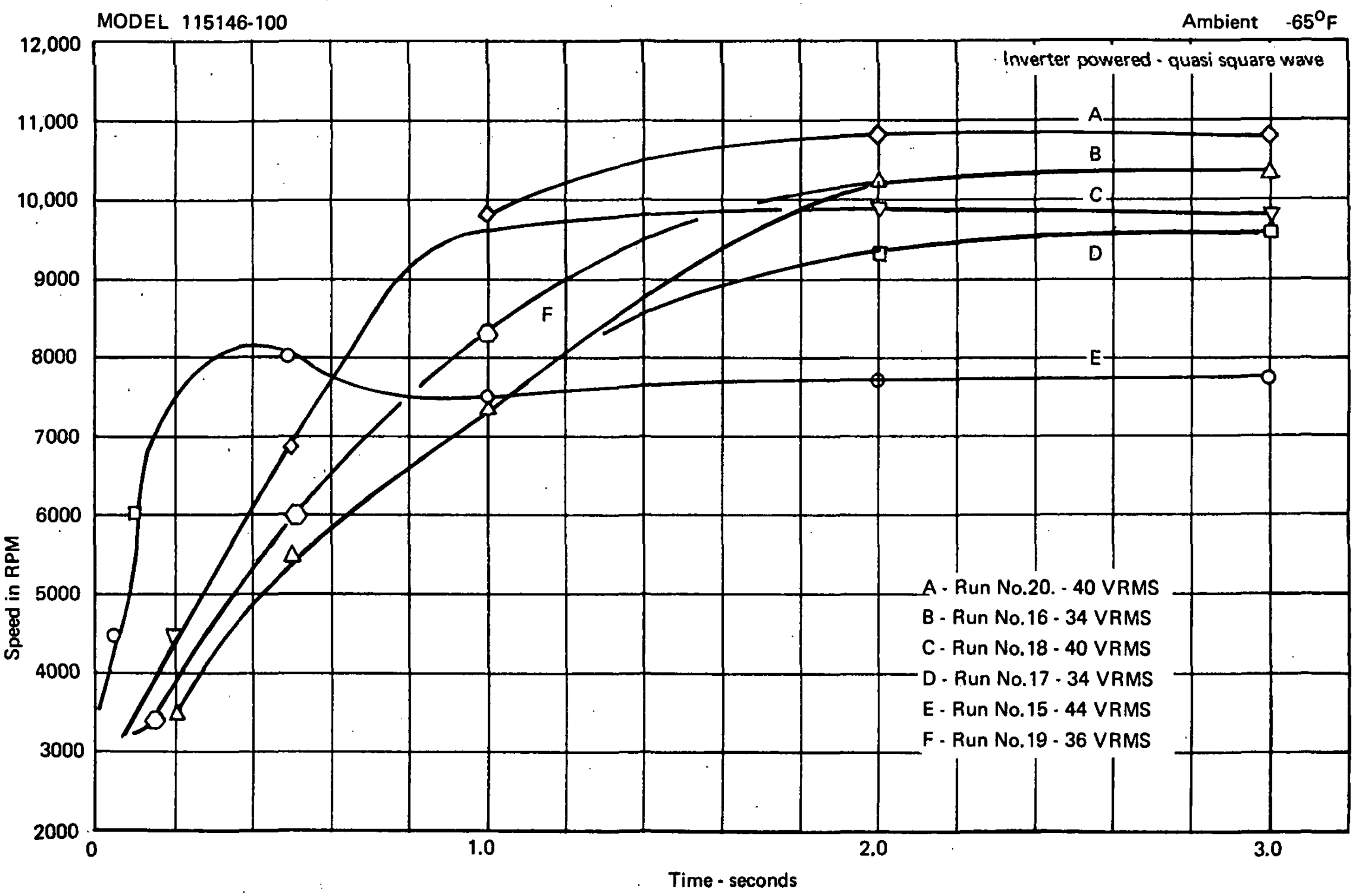


Figure 35. - Barstock PMA acceleration test curves at -65°F and at various voltages - Speed versus Time - quasi-square wave input, 400 Hz, three phase

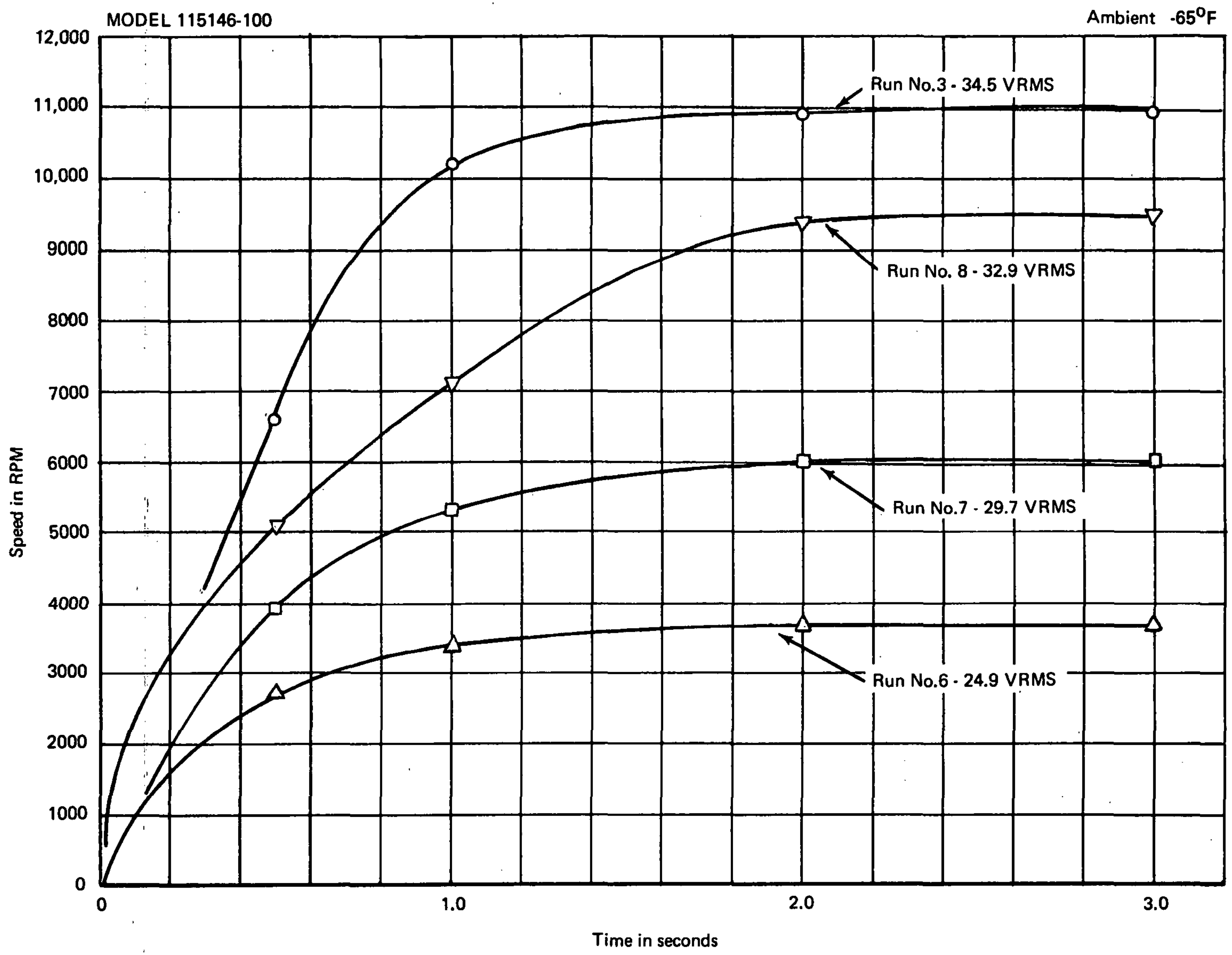


Figure 36. - Barstock PMA acceleration test curves at -65°F and at various voltages - Speed versus Time-sine wave input, 400 Hz, three phase .

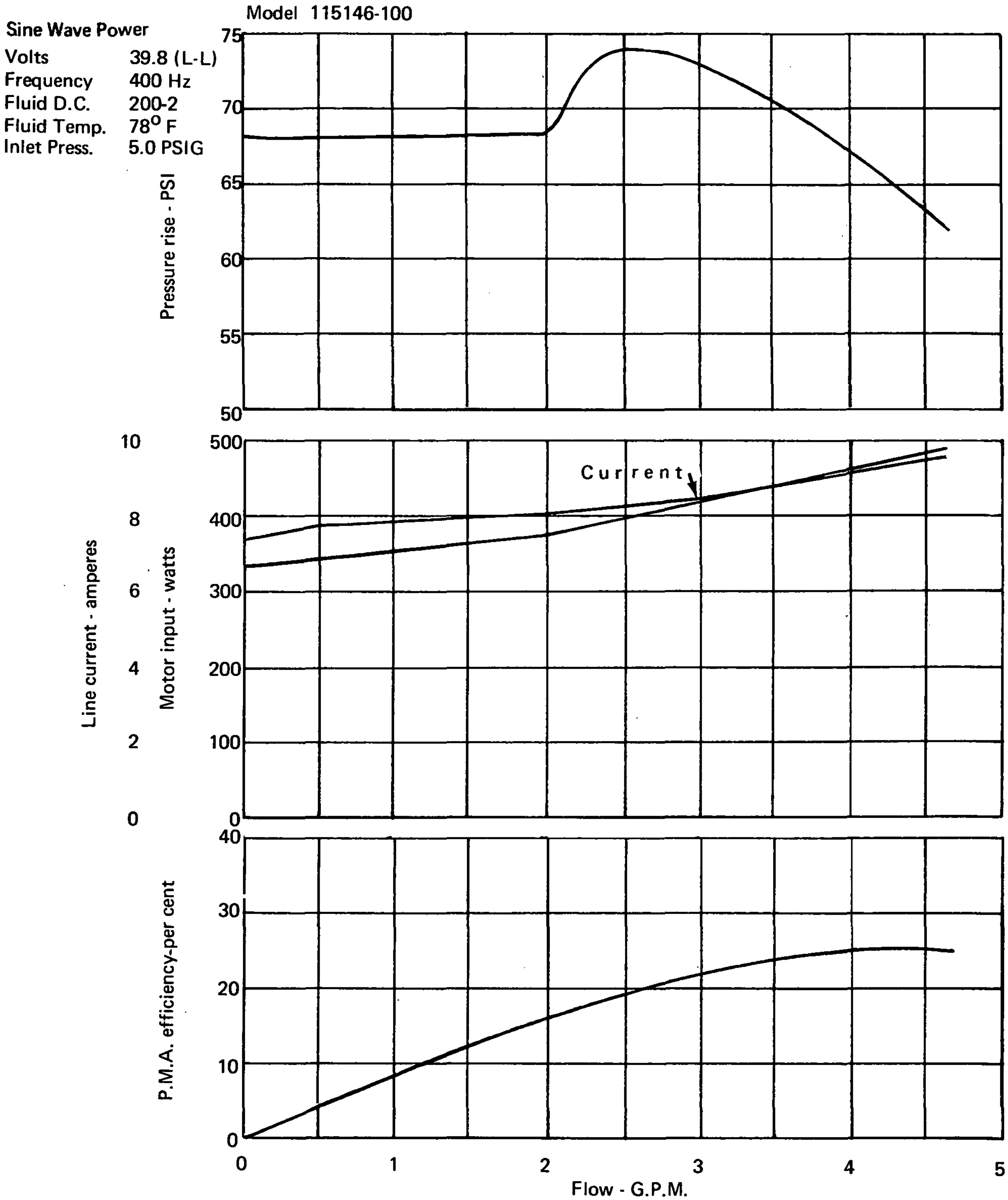


Figure 37. - PMA S/N X-2149 test performance per ER 5289B Para. 4.2.2 - sine wave power, 39.8 V.A.C.

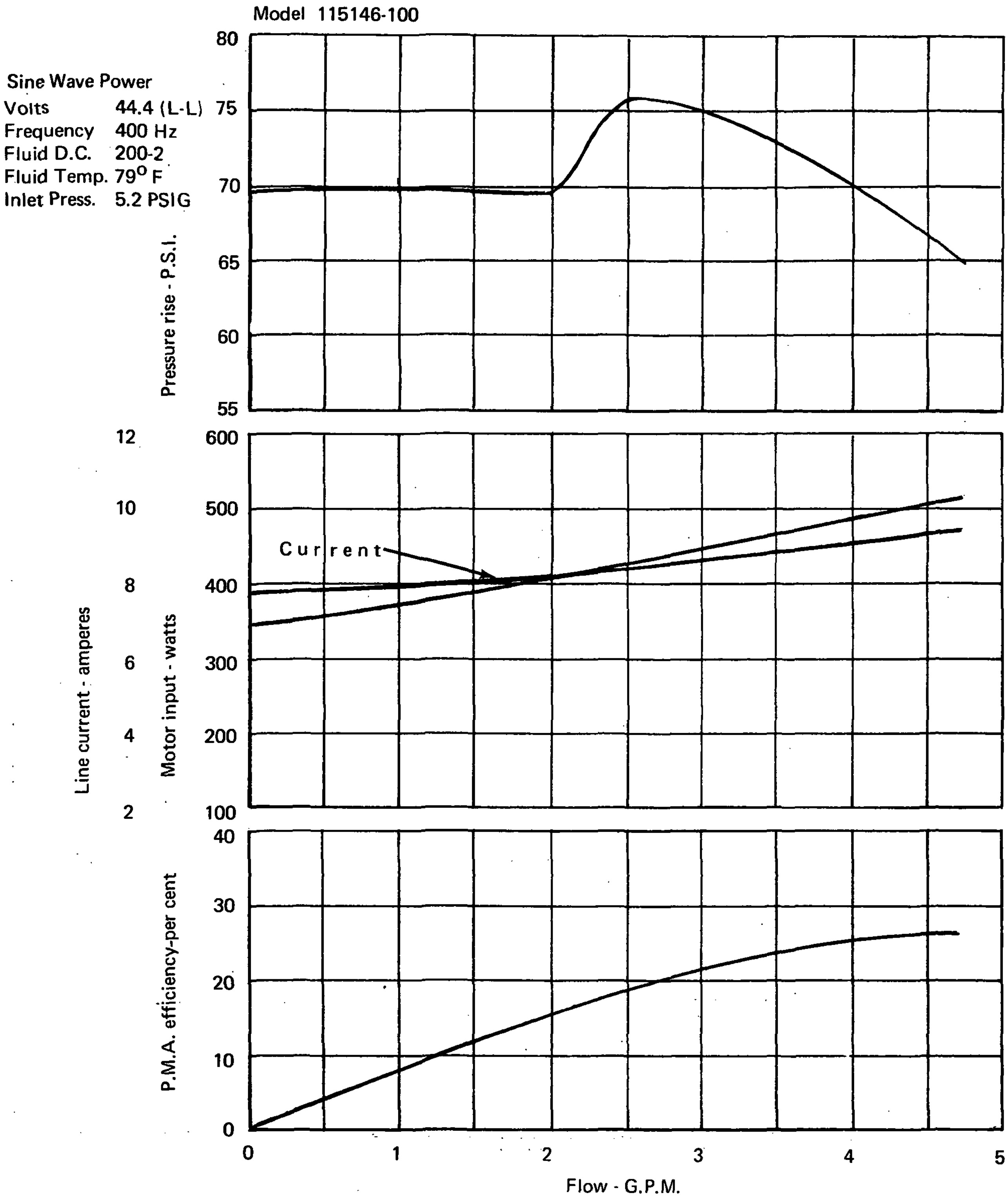


Figure 38. - PMA S/N 2149 test performance - calibration per ER 5289B Para. 4.2.2. sine wave power, 44.4 V.A.C.

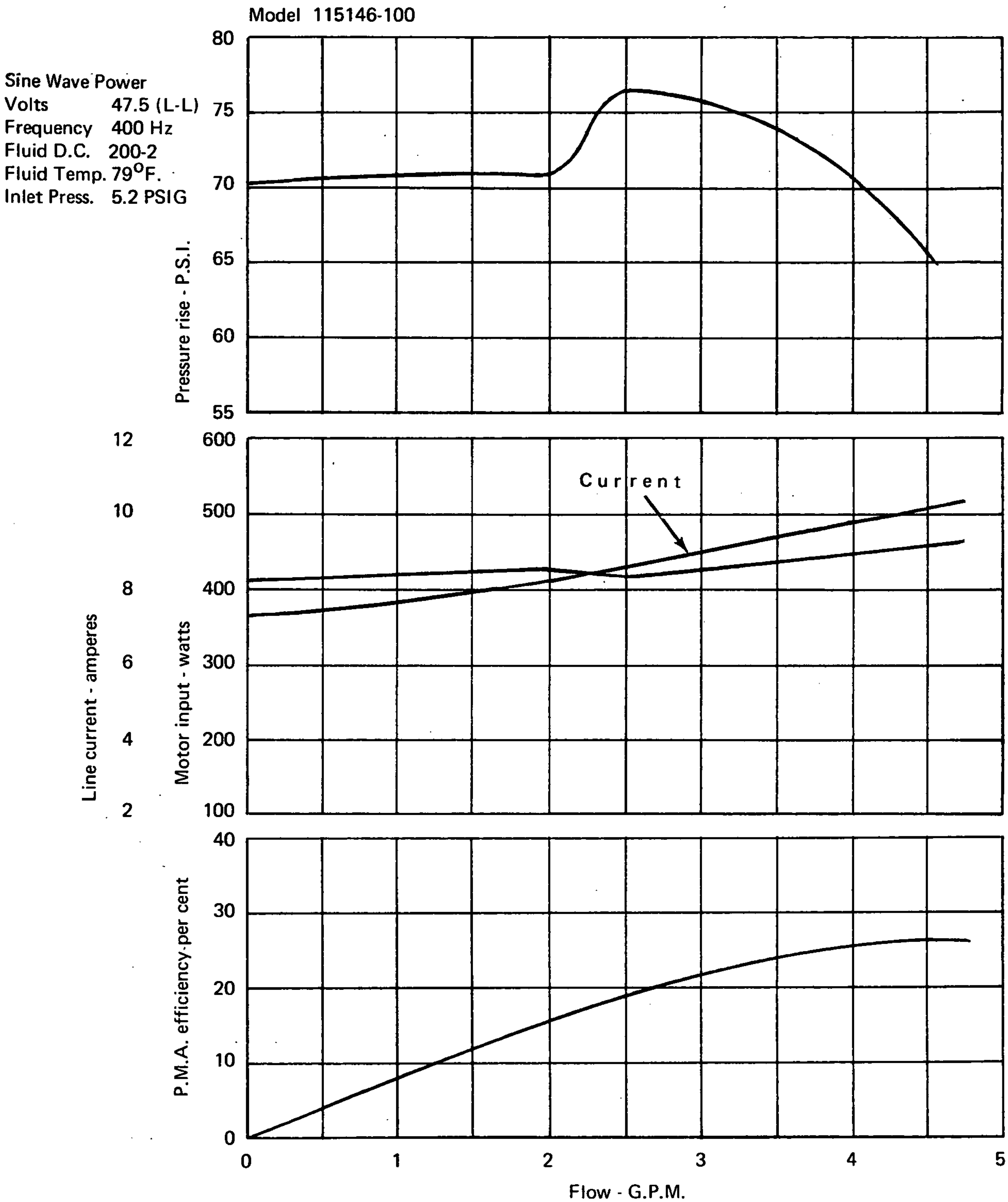


Figure 39. - PMA S/N X-2149 test performance - calibration per ER-5289B Para. 4.2.2, sine wave power, 47.5 V.A.C.

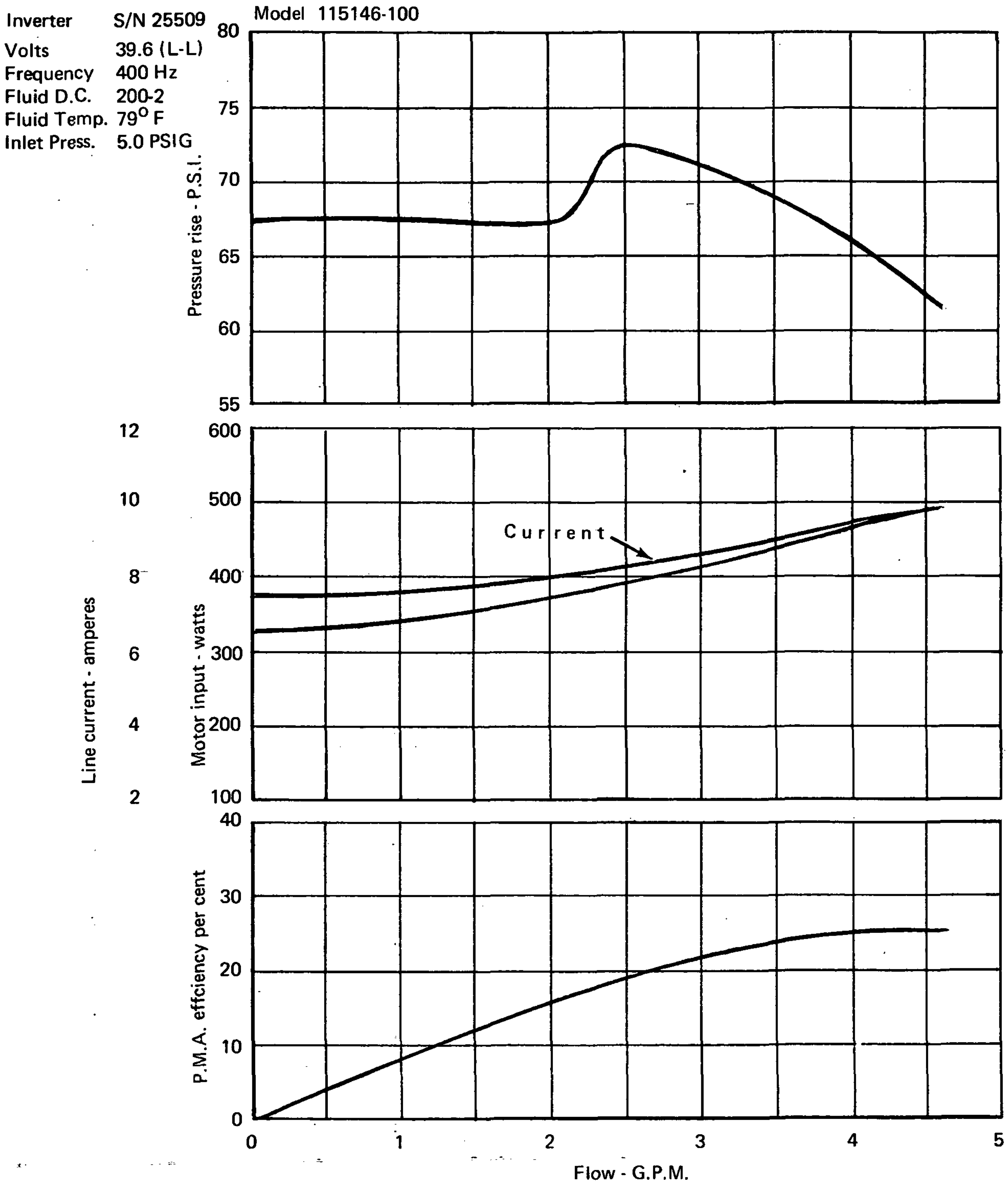


Figure 40. - PMA S/N X-2149 test performance - calibration per ER 5289B para. 4.2.3, inverter power, 39.6 V.A.C.

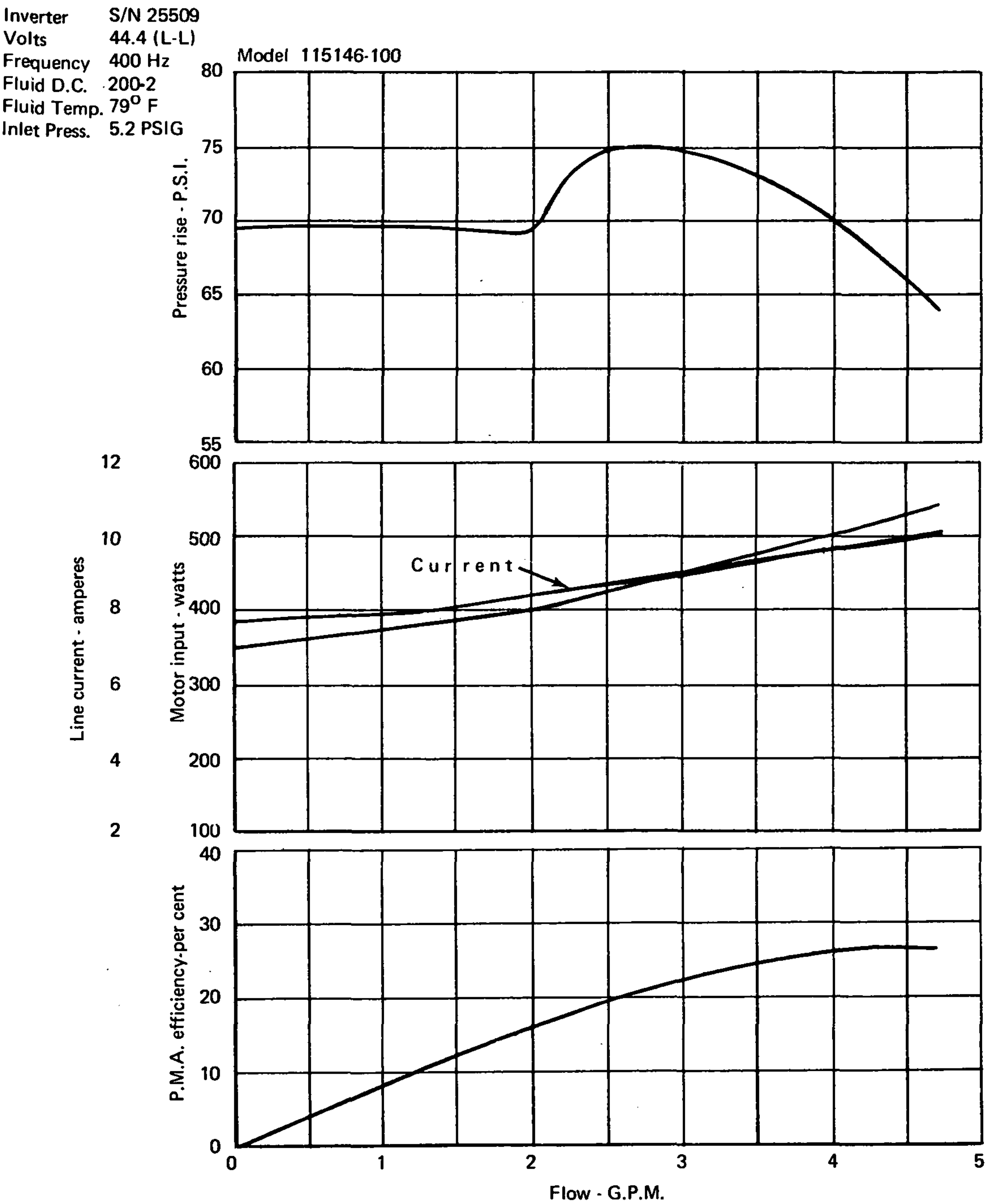


Figure 41. - PMA S/N X-2149 test performance-calibration per ER-5289B para. 4.2.3, inverter power, 44.4 V.A.C.

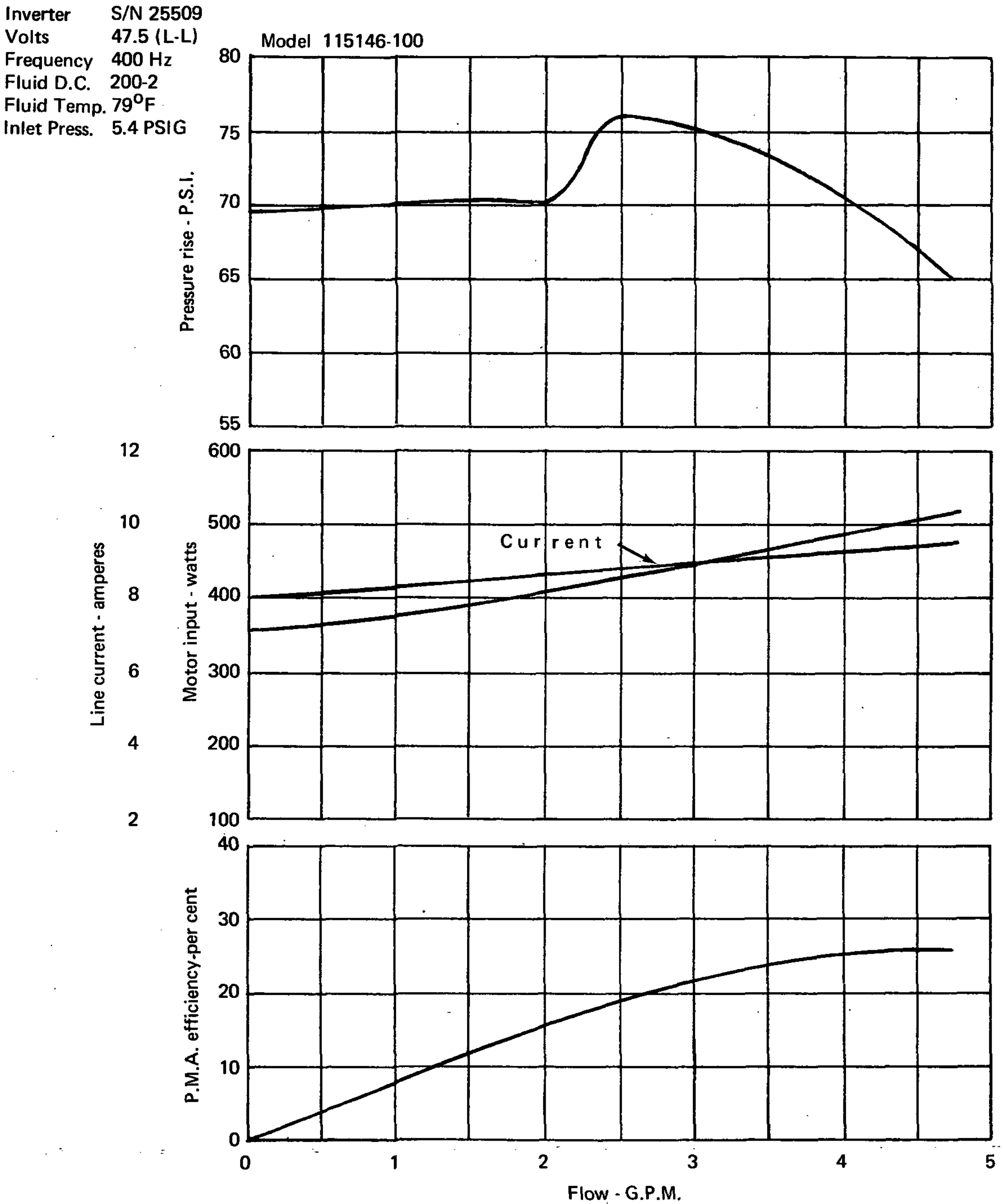


Figure 42. - PMA S/N X-2149 test performance - calibration per ER-5249B para. 4.2.3, inverter power, 47.5 V.A.C.

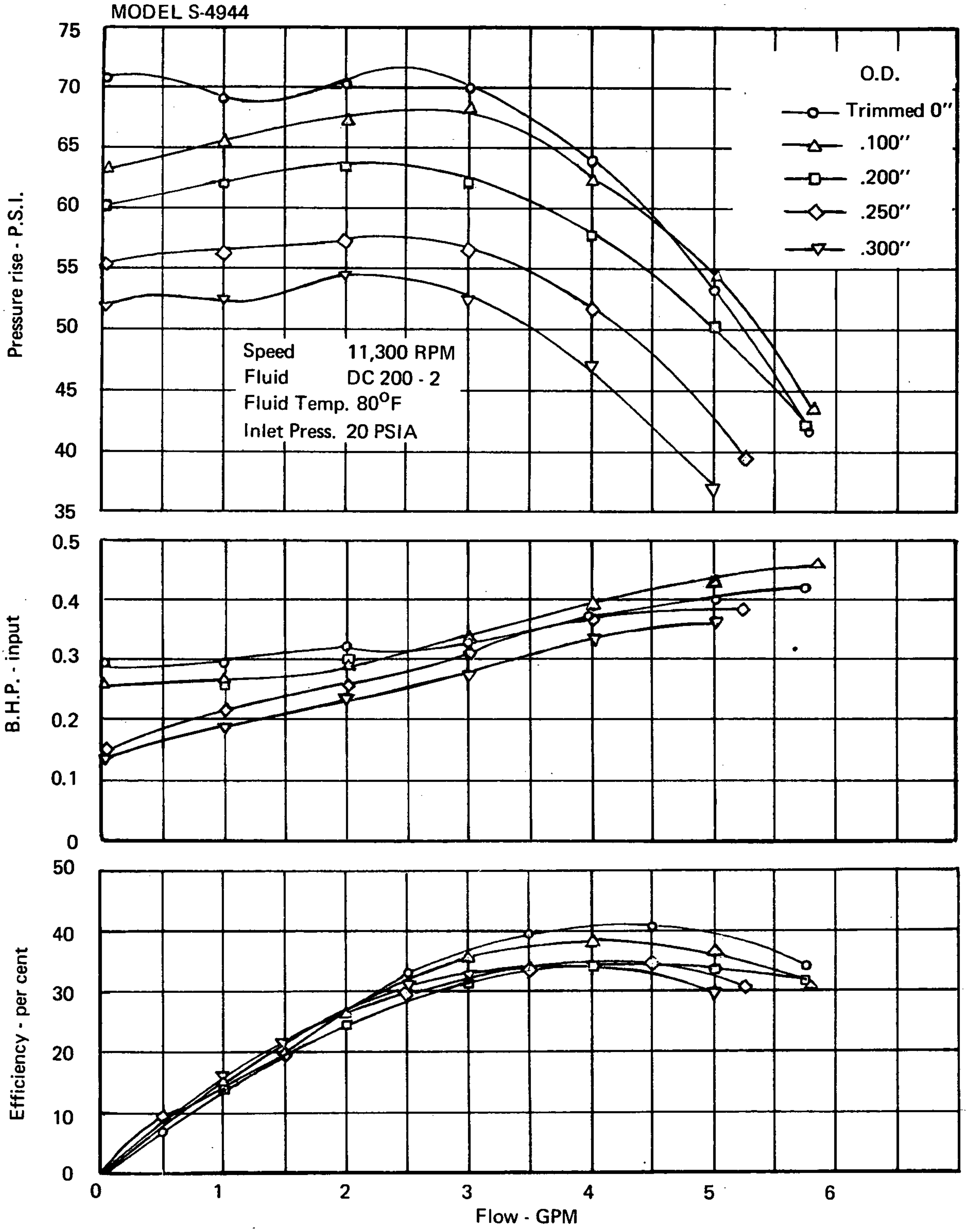


Figure 43. - Barstock pump performance - calibration on dynamometer at various impeller diameters per ER-5289B, para. 4.2.4.

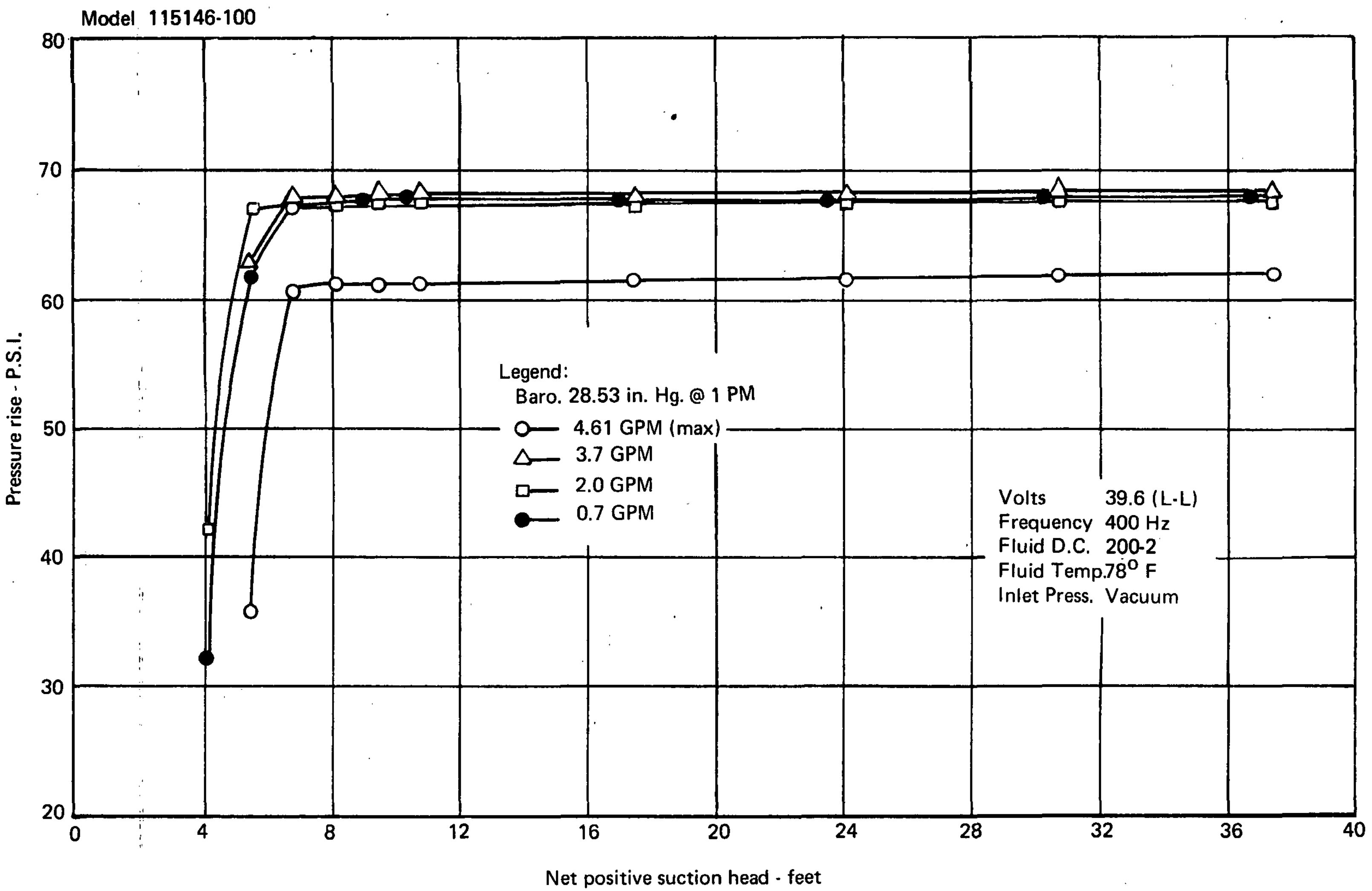


Figure 44. - PMA S/N X-2149 test performance - NPSH calibration per ER 5289B, para. 4.2.5. at 39.6 V.A.C.

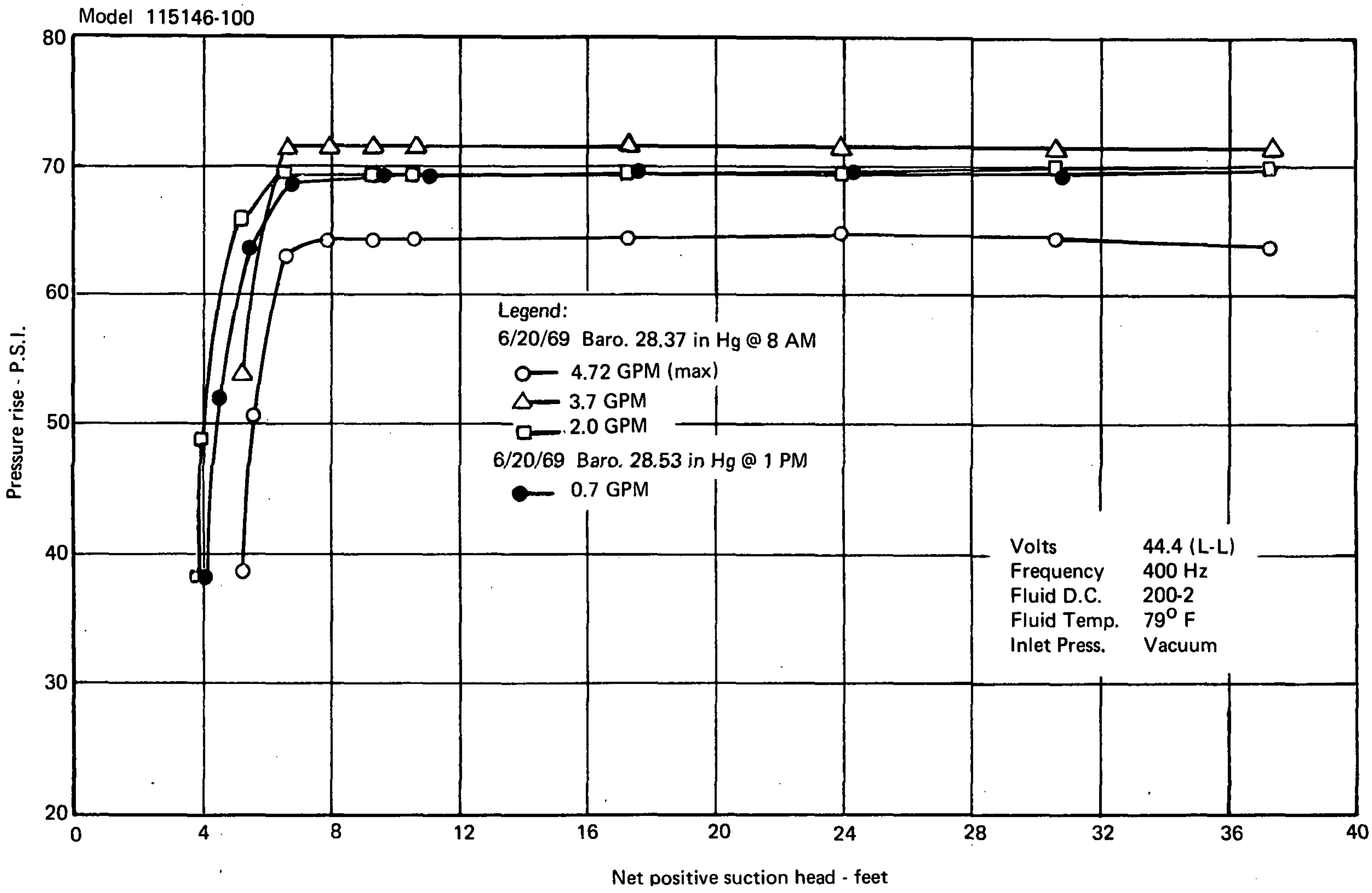


Figure 45. - PMA S/N X-2149 test performance - NPSH calibration per ER 5289B, para. 4.2.5. at 44.4 V.A.C.

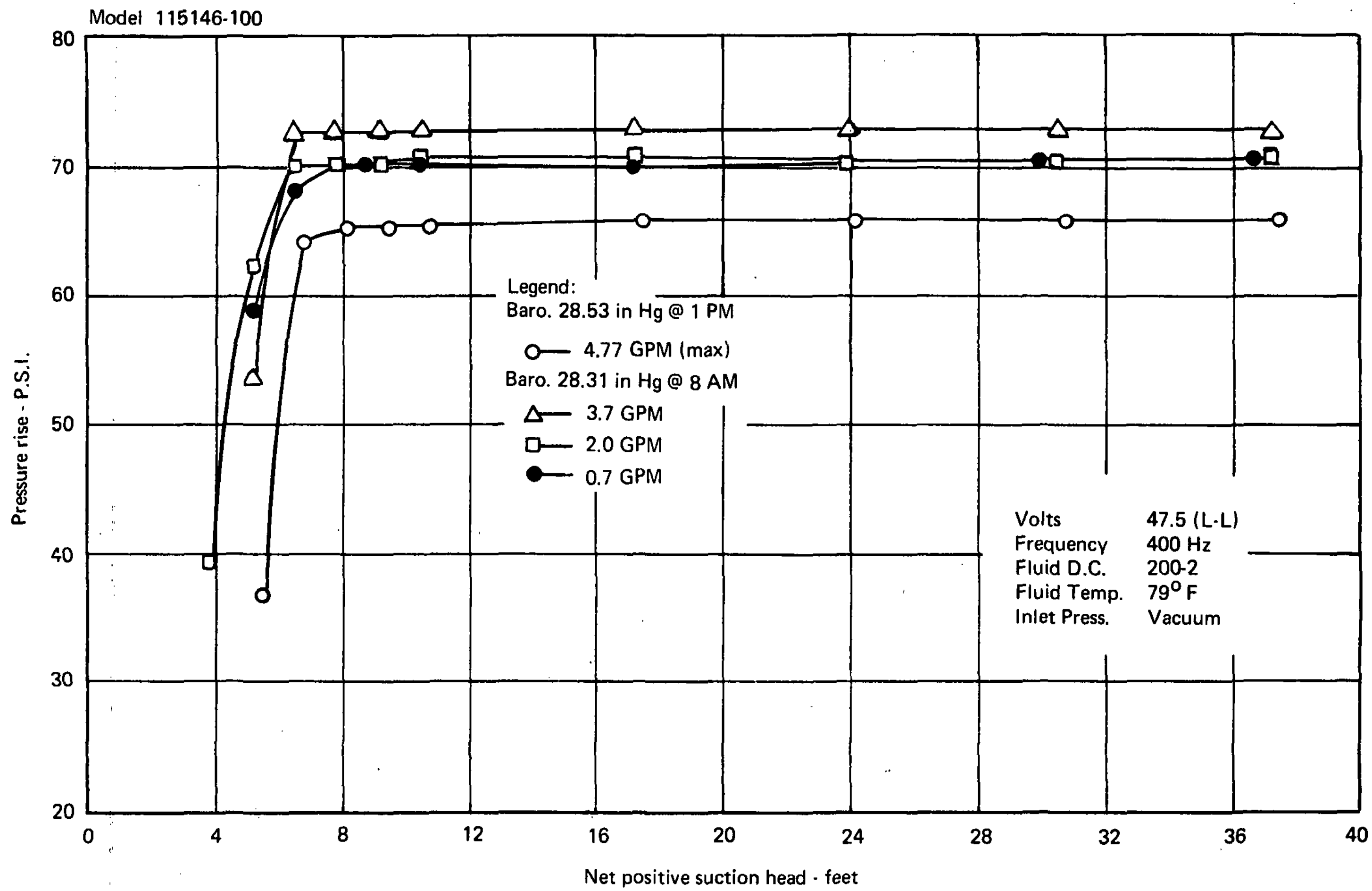


Figure 46. - PMA S/N X-2149 test performance - NPSH calibration per ER-5289B, para. 4.2.5. at 47.5 V.A.C.

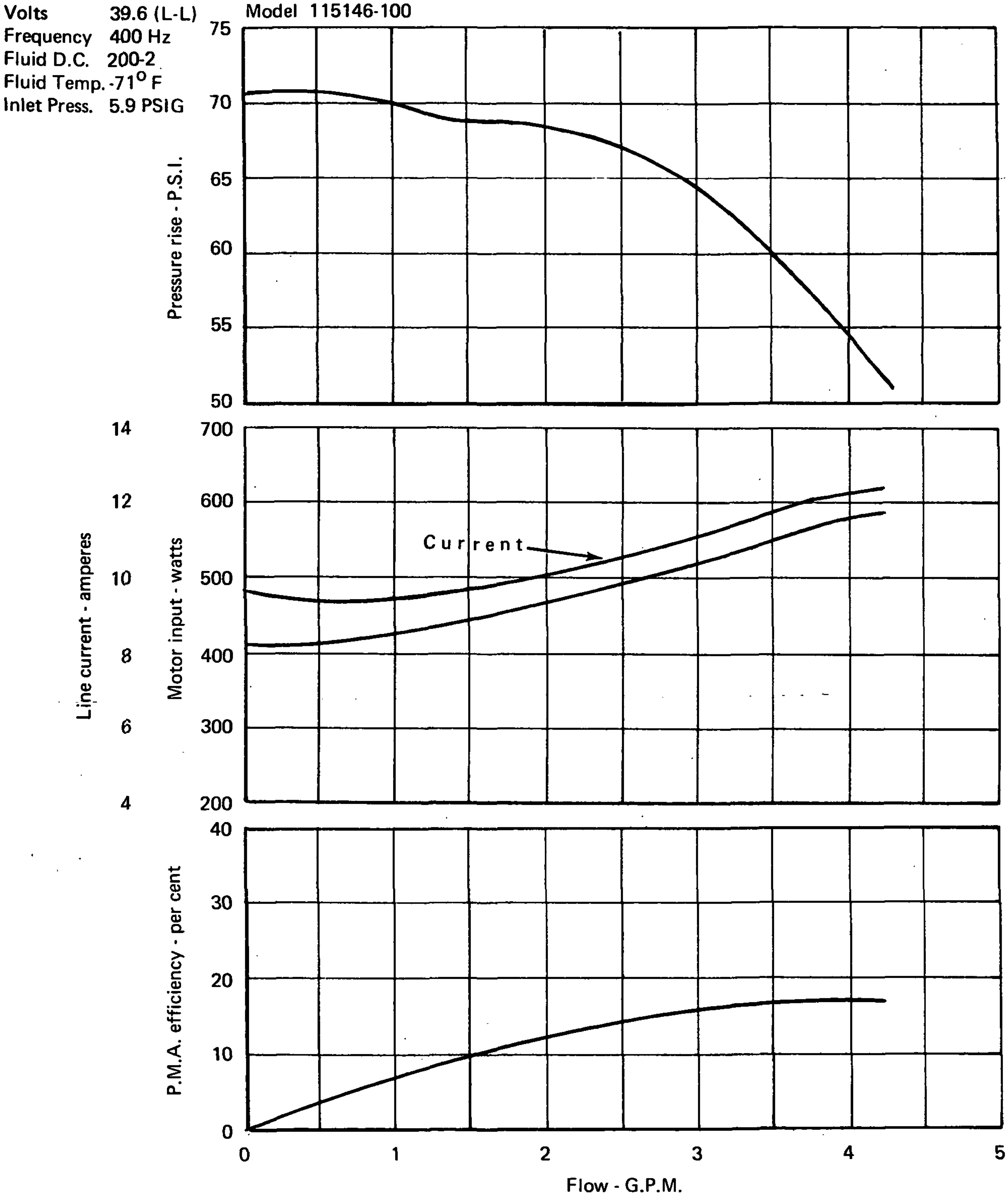


Figure 47.- PMA S/N X-2149 test performance - calibration at $-71^{\circ}F$ and 39.6 V.A.C. inverter power per ER-5289B para. 4.2.6

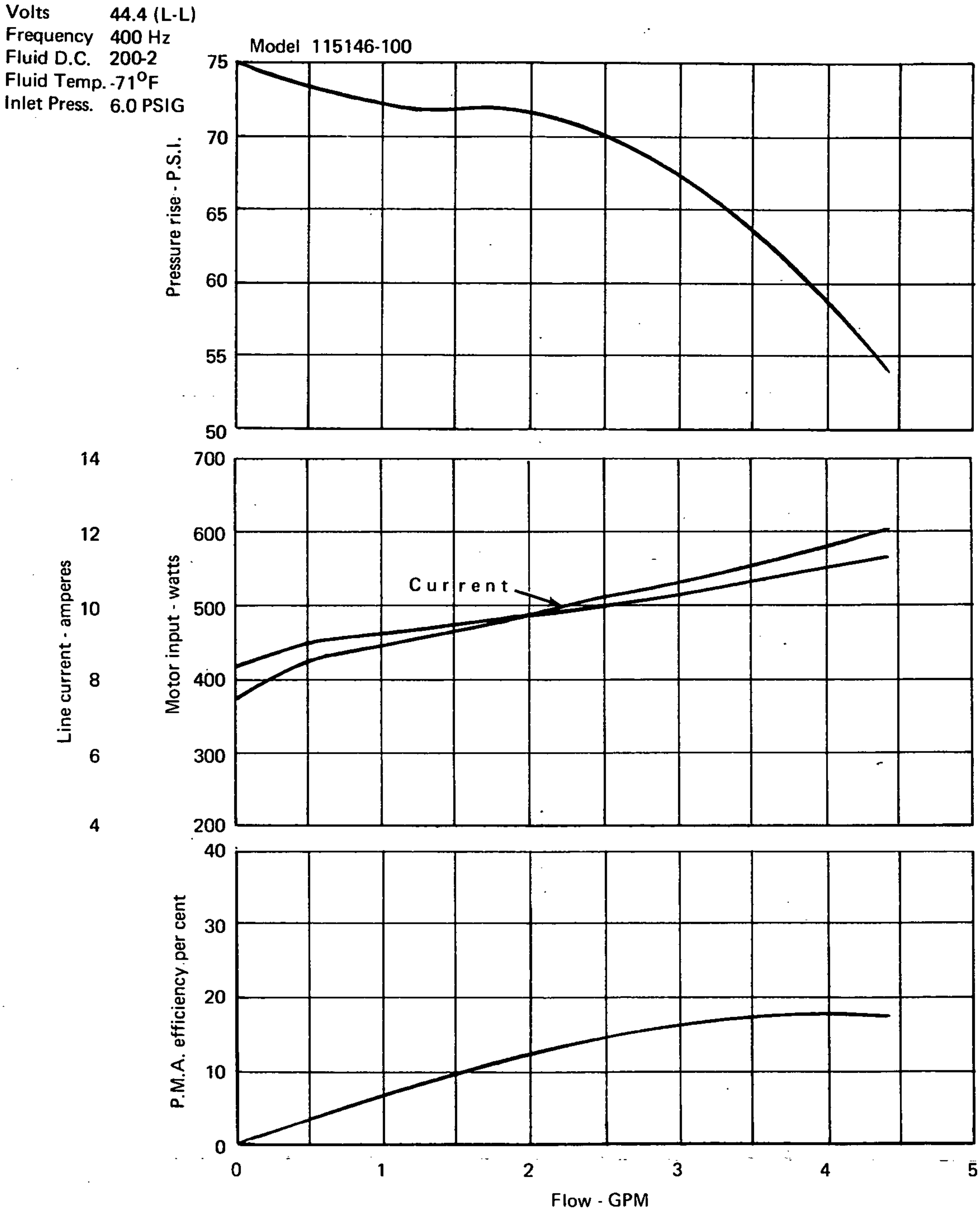


Figure 48. - Pump S/N X-2149 test performance - calibration at -71°F and 44.4 V.A.C. inverter power per ER-5289B, para. 4.2.6

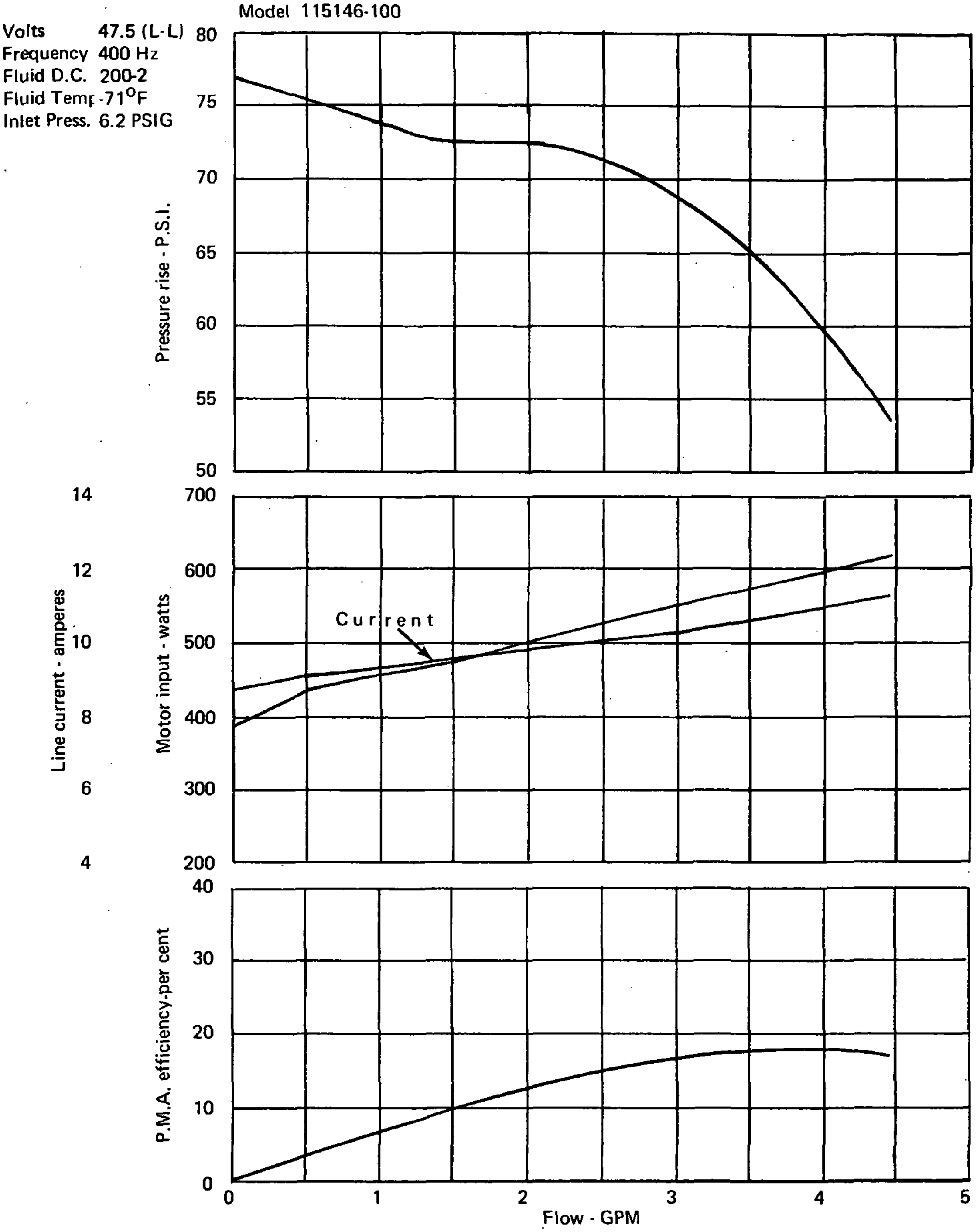


Figure 49. - PMA S/N X-2149 test performance calibration at -71°F and 47.5 V.A.C. inverter power per ER-5289B para. 4.2.6

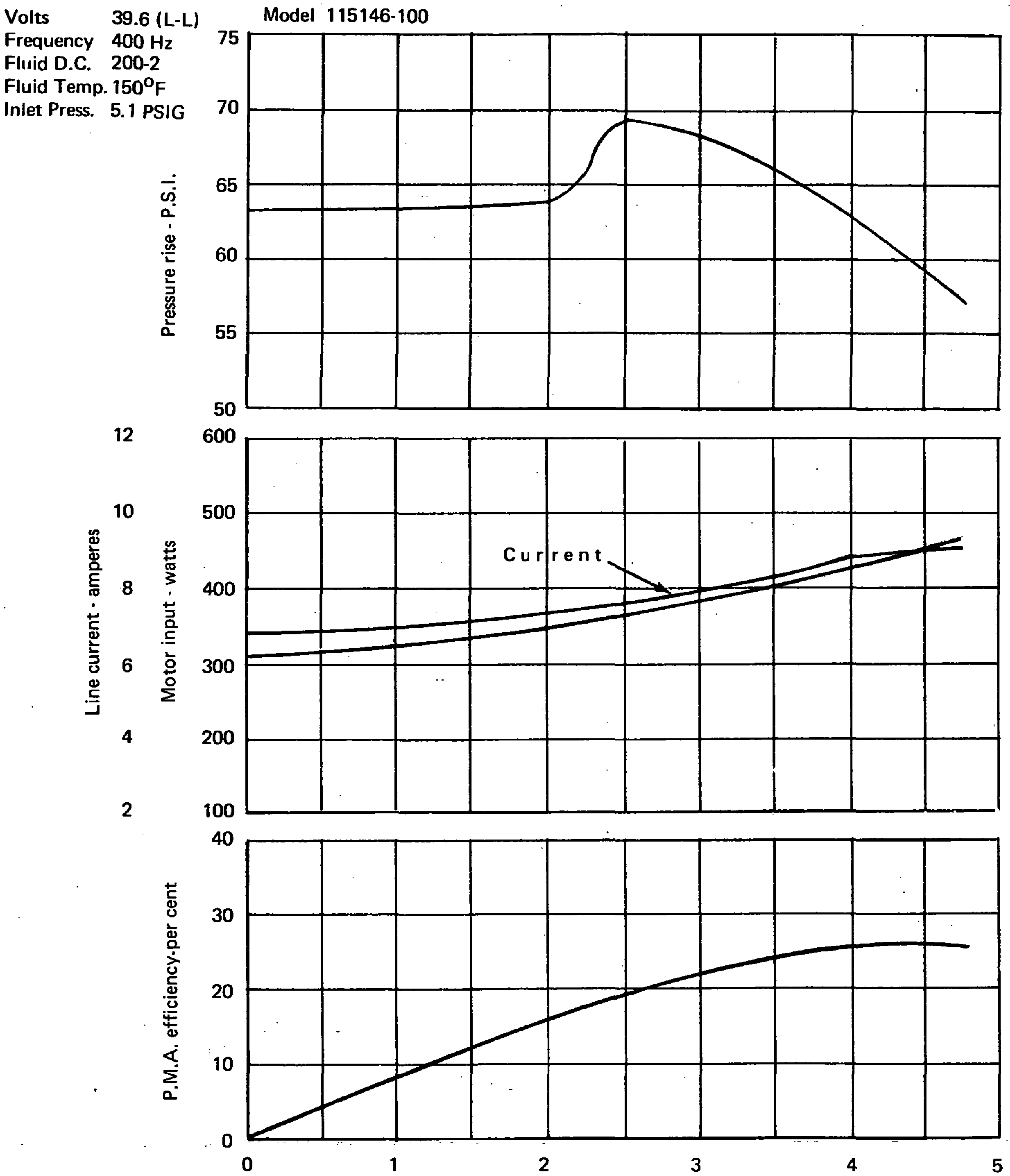


Figure 50. - PMA S/N X-2149 test performance calibration at +150°F and 39.6 V.A.C. inverter power per ER-5289B para. 4.2.6

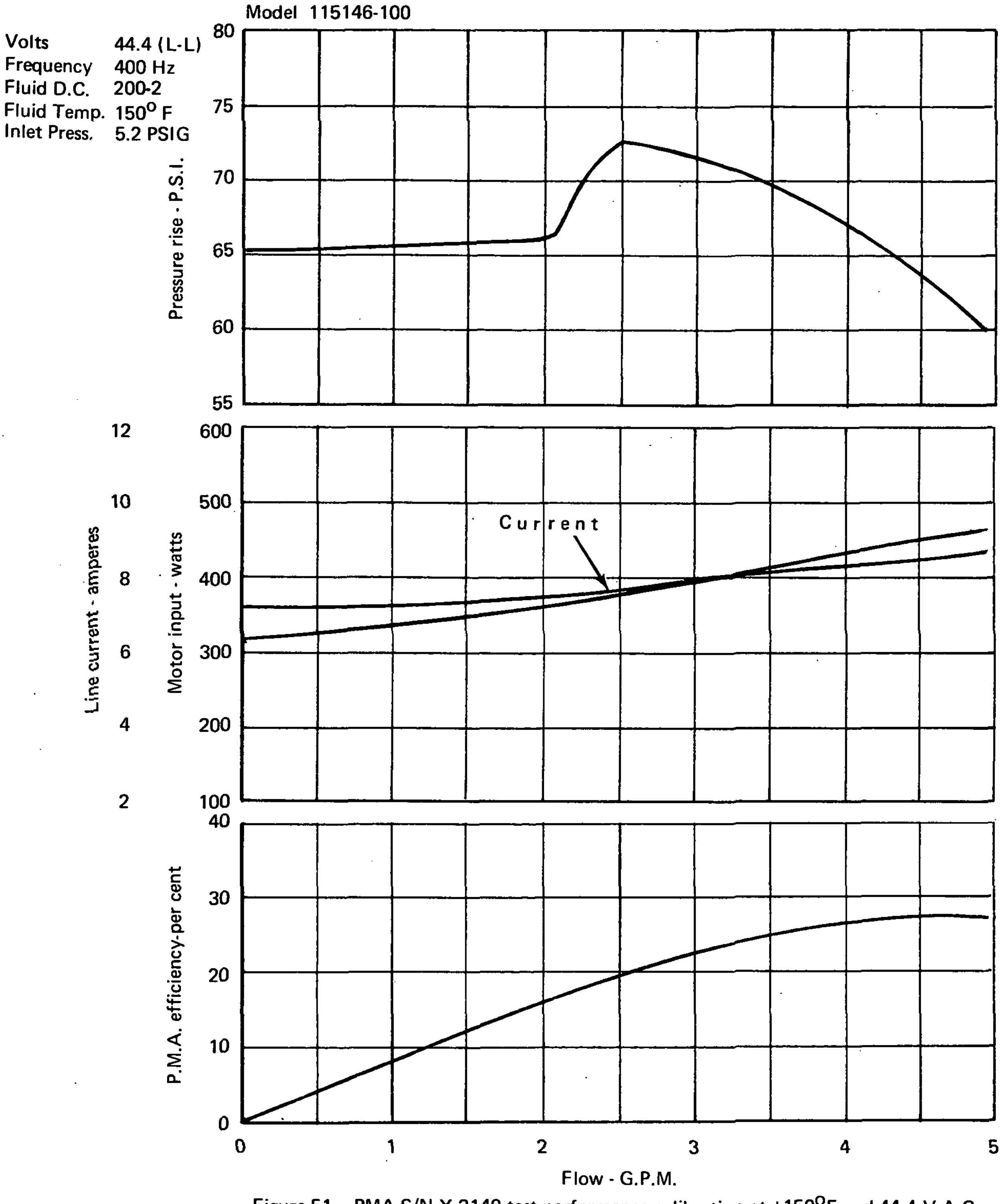


Figure 51. - PMA S/N X-2149 test performance calibration at +150°F and 44.4 V.A.C. inverter power per ER 5289B para. 4.2.6

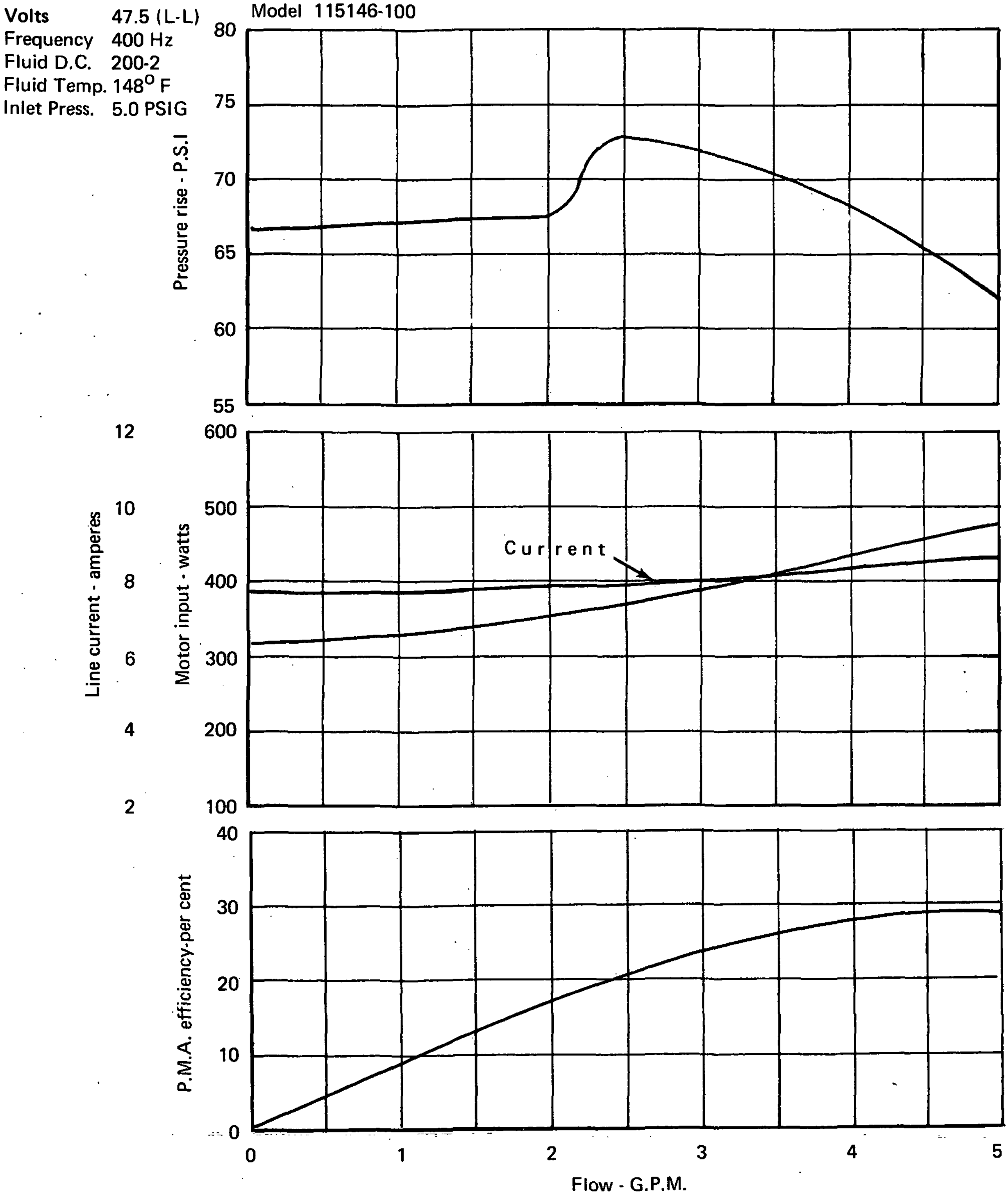


Figure 52. - PMA S/N X-2149 test performance calibration at +148°F and 47.5 V.A.C. inverter power per ER 5289B para. 4.2.6

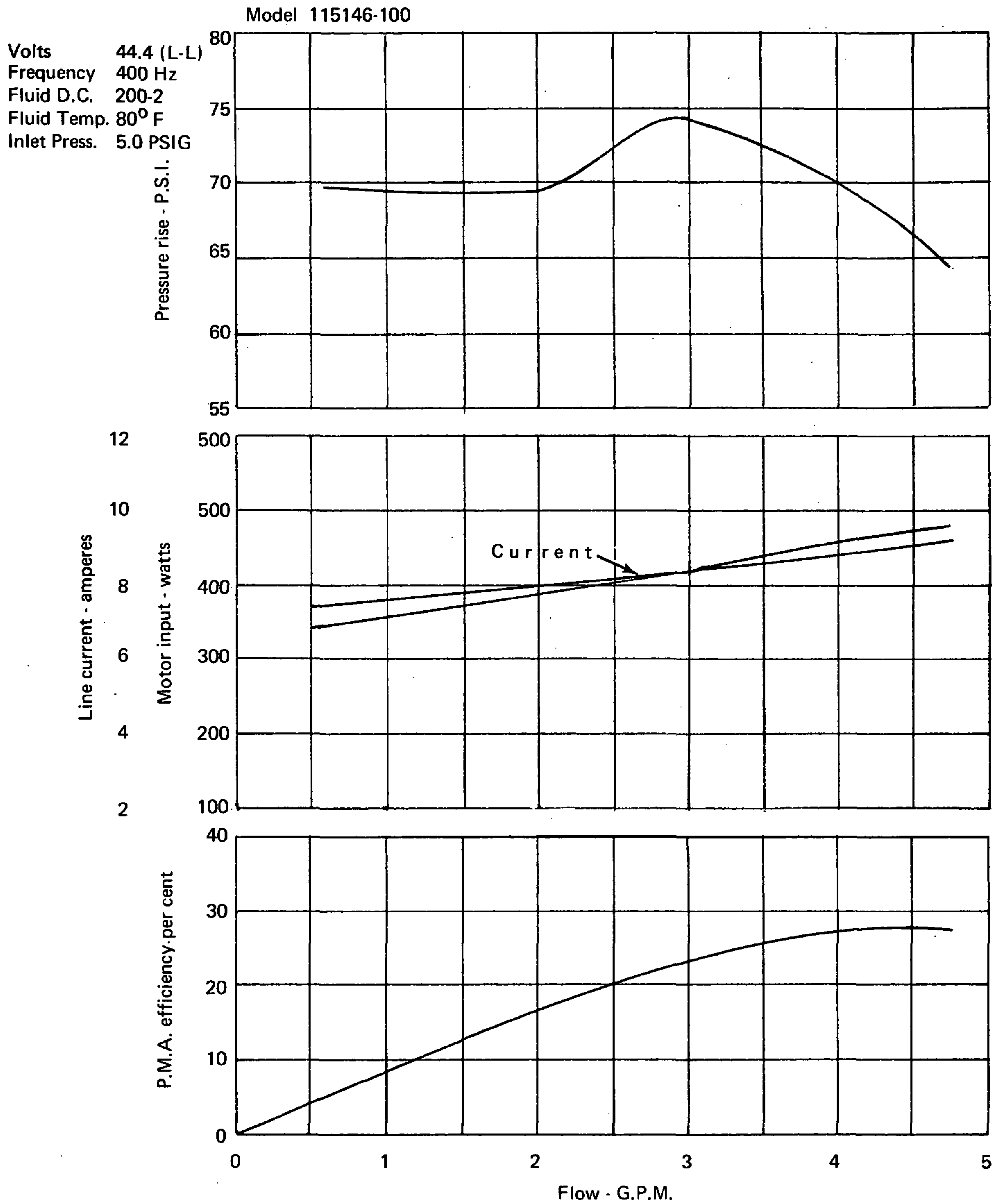


Figure 53. - PMA S/N X-2149 test performance calibration at 44.4 V.A.C. inverter power (prior to starting 250 hour assurance test) per ER-5289B para. 5.2

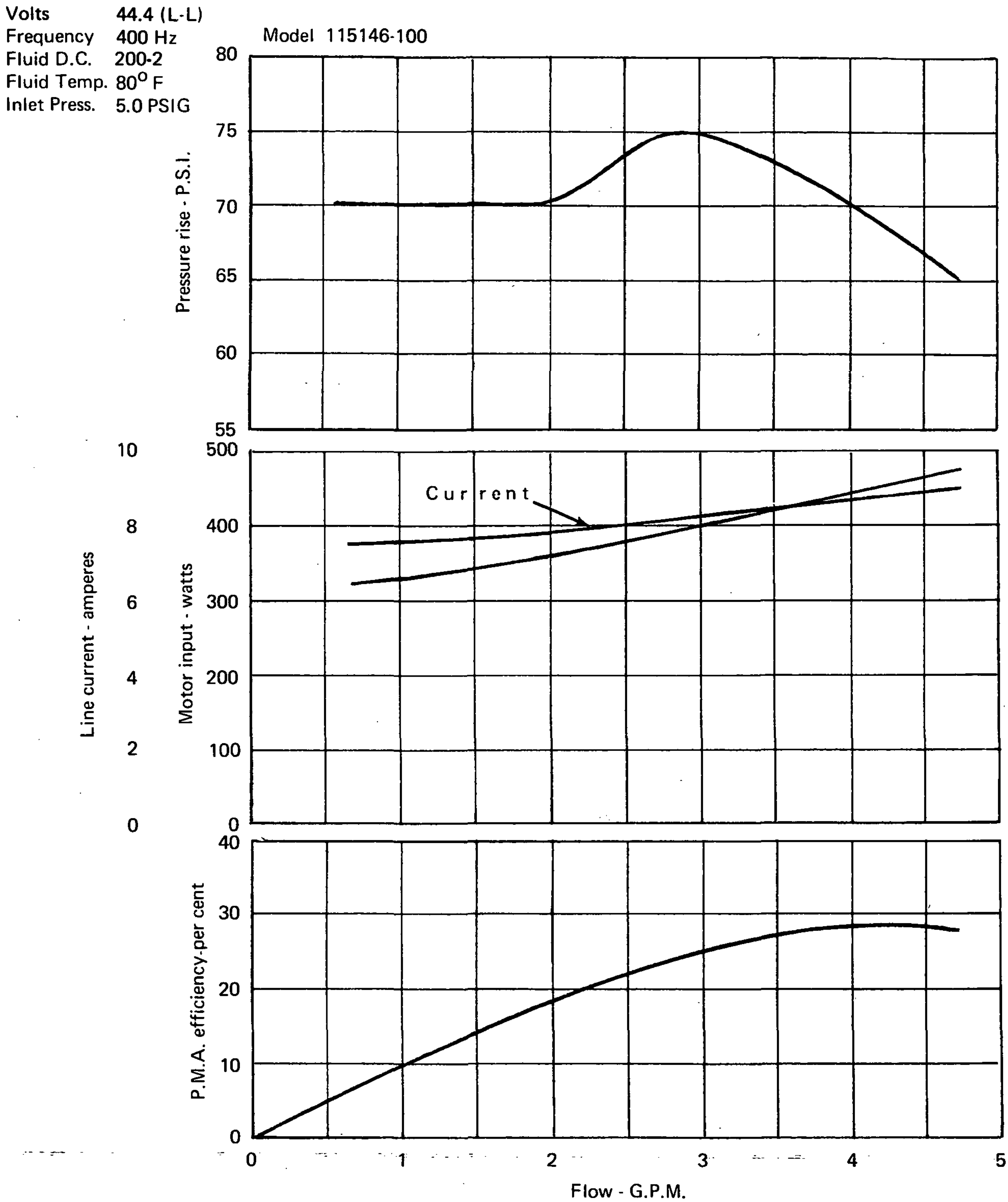


Figure 54. - PMA S/N X-2149 test performance calibration at 44.4 V.A.C. inverter power (after 250 hour assurance test) per ER-5289B

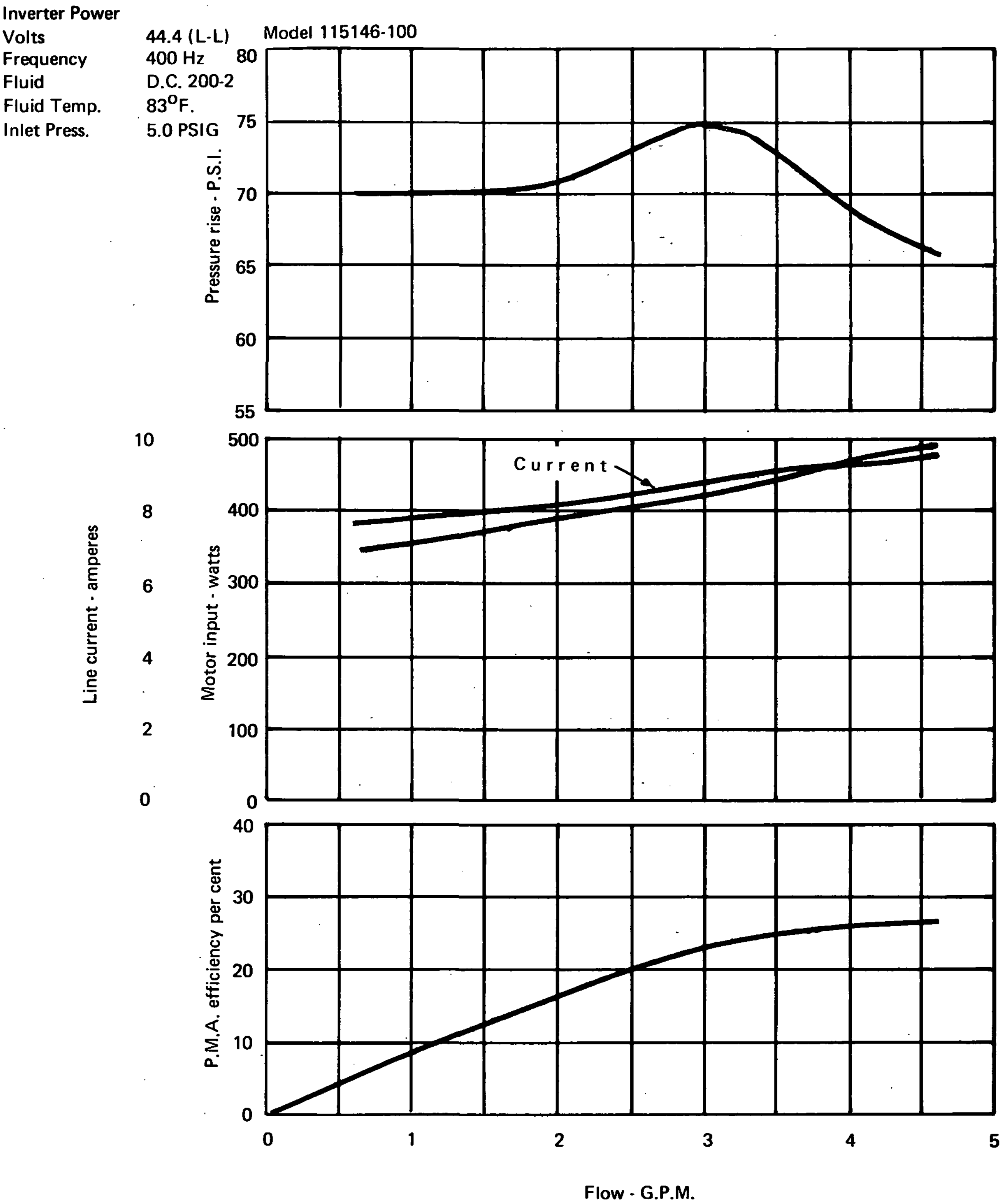


Figure 55. PMA S/N X-2149 test performance - test calibration at 44.4 V.A.C. power before 20,000 hour endurance test

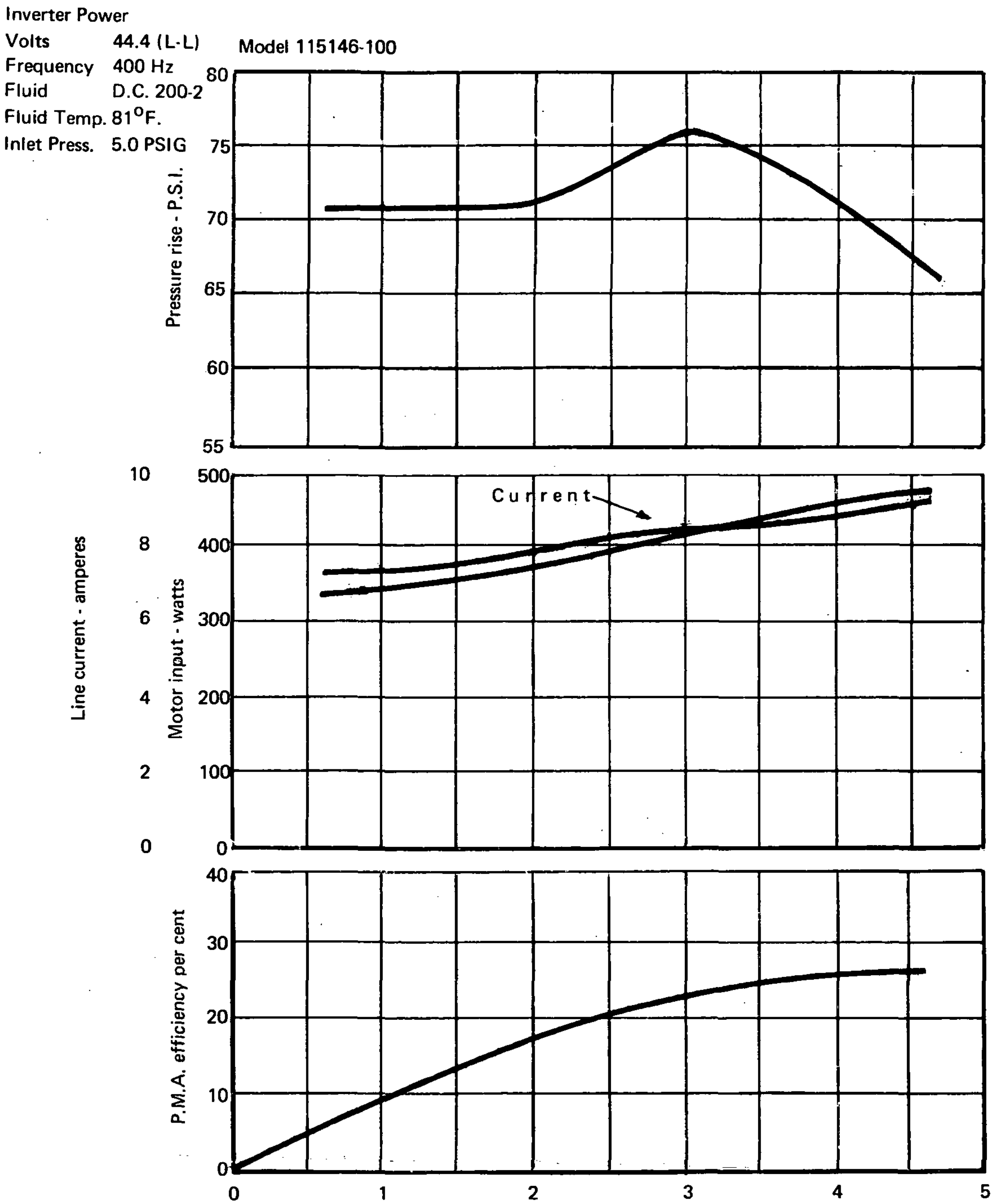


Figure 56. - PMA S/N X-2149 test performance - test calibration at 44.4 V.A.C. power after 5000 hours of endurance test

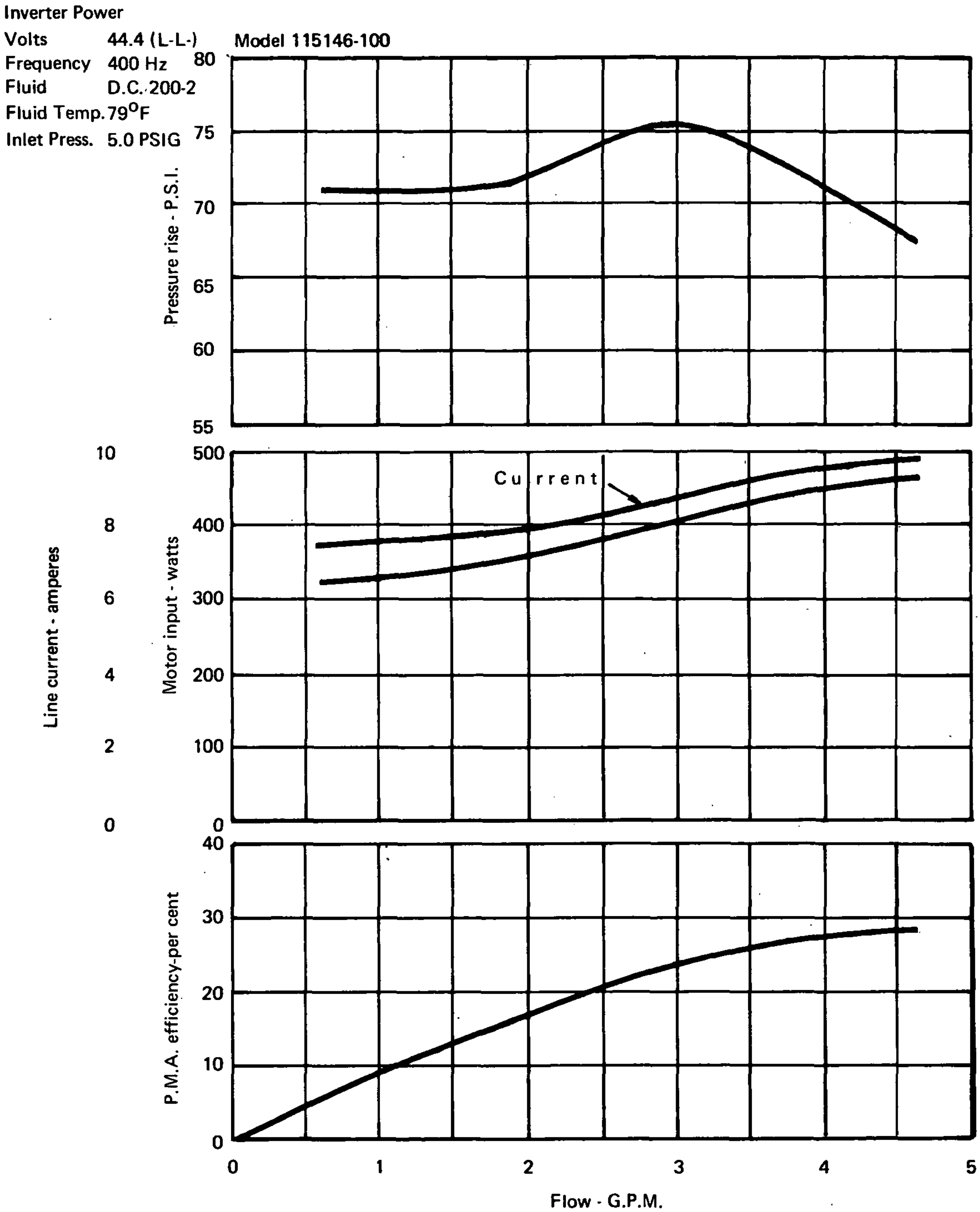


Figure 57. - PMA S/N X-2149 test performance - test calibration at 44.4 V.A.C. power after 20,000 hour endurance test

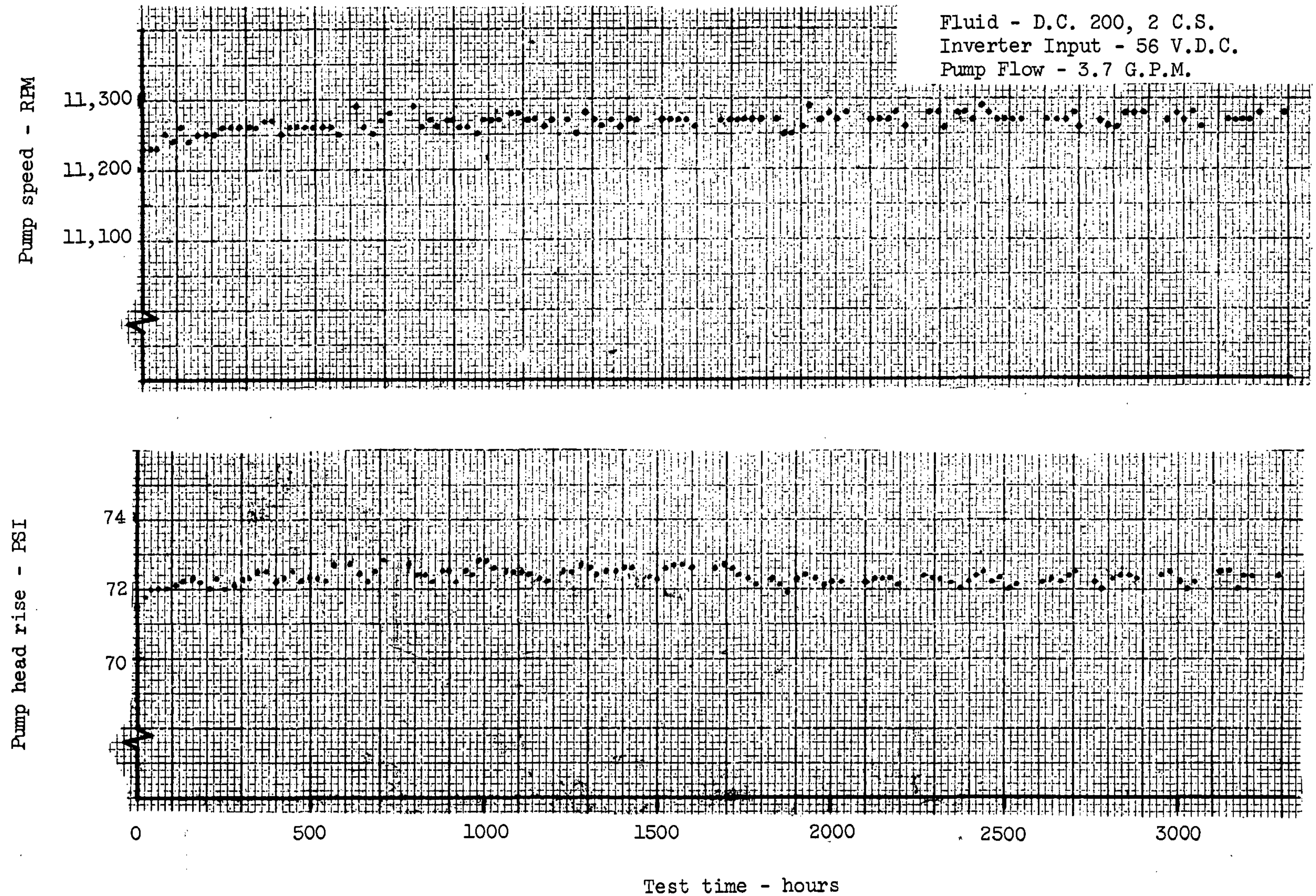


Figure 58. - PMA S/N X-2149 - 20,000 hour endurance test.

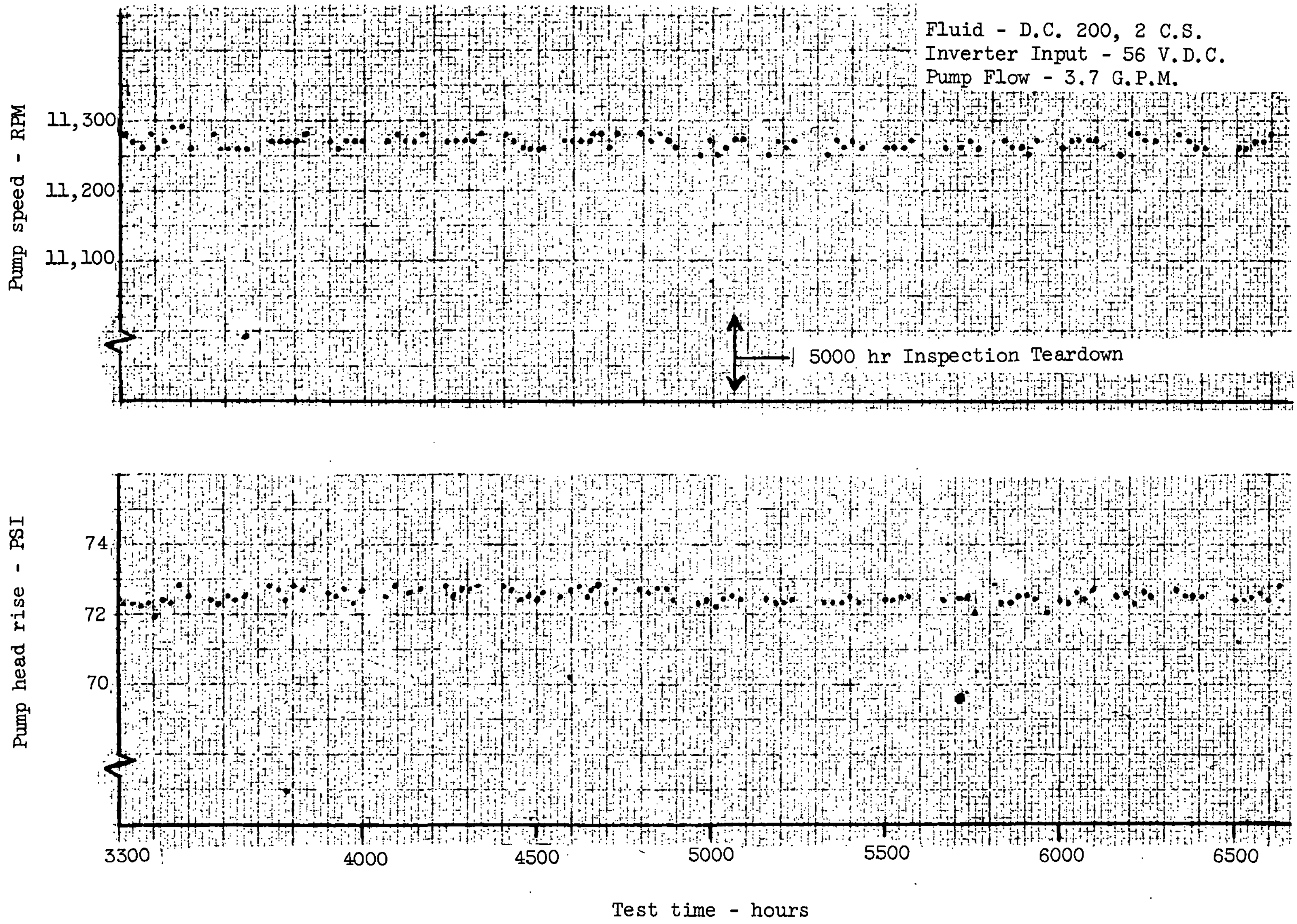


Figure 59. - PMA S/N X-2149 - 20,000 hour endurance test.

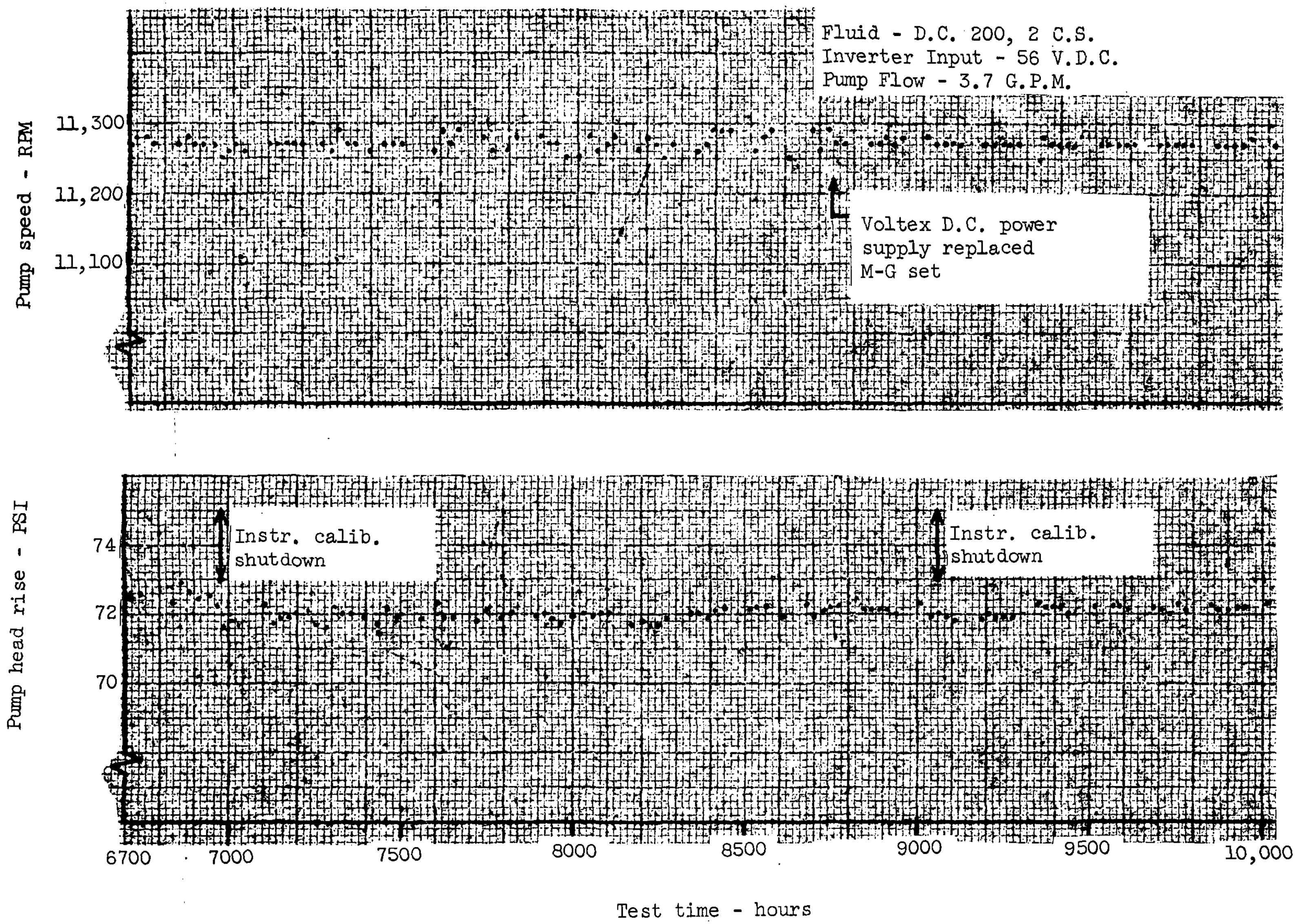


Figure 60. - PMA S/N X-2149 - 20,000 hour endurance test.

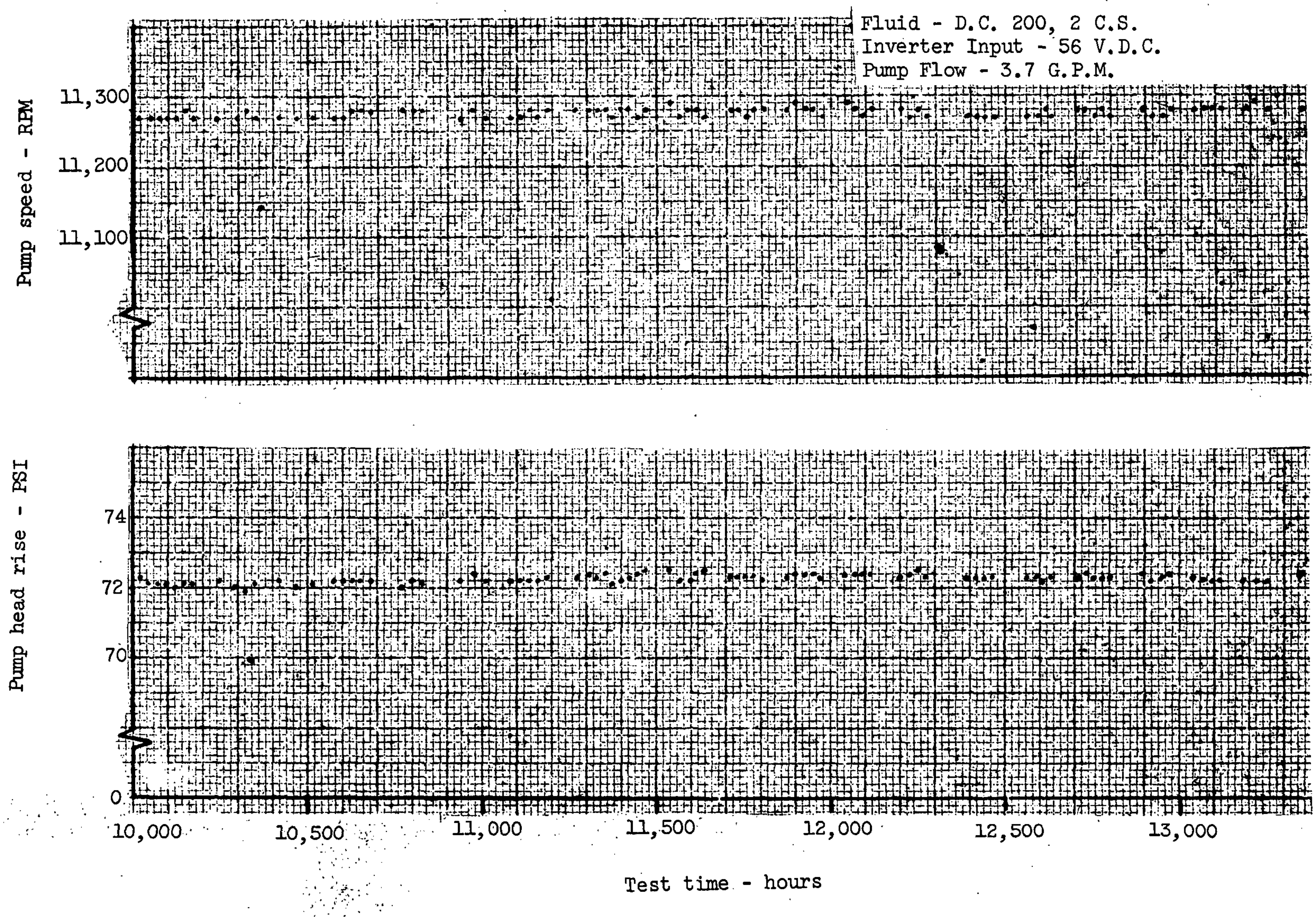


Figure 61. - PMA S/N X-2149 - 20,000 hour endurance test.

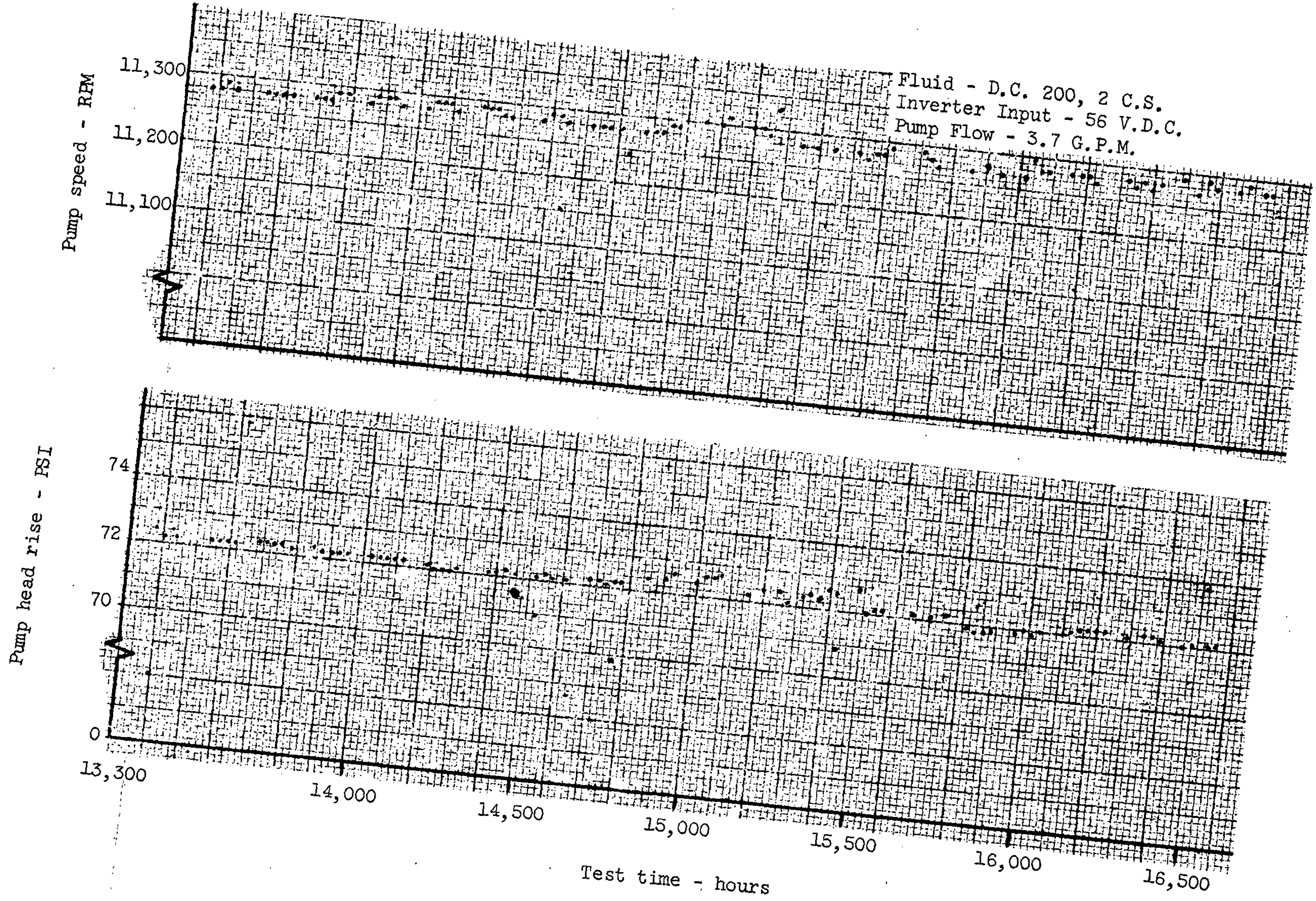


Figure 62. - PMA S/N X-2149 - 20,000 hour endurance test.

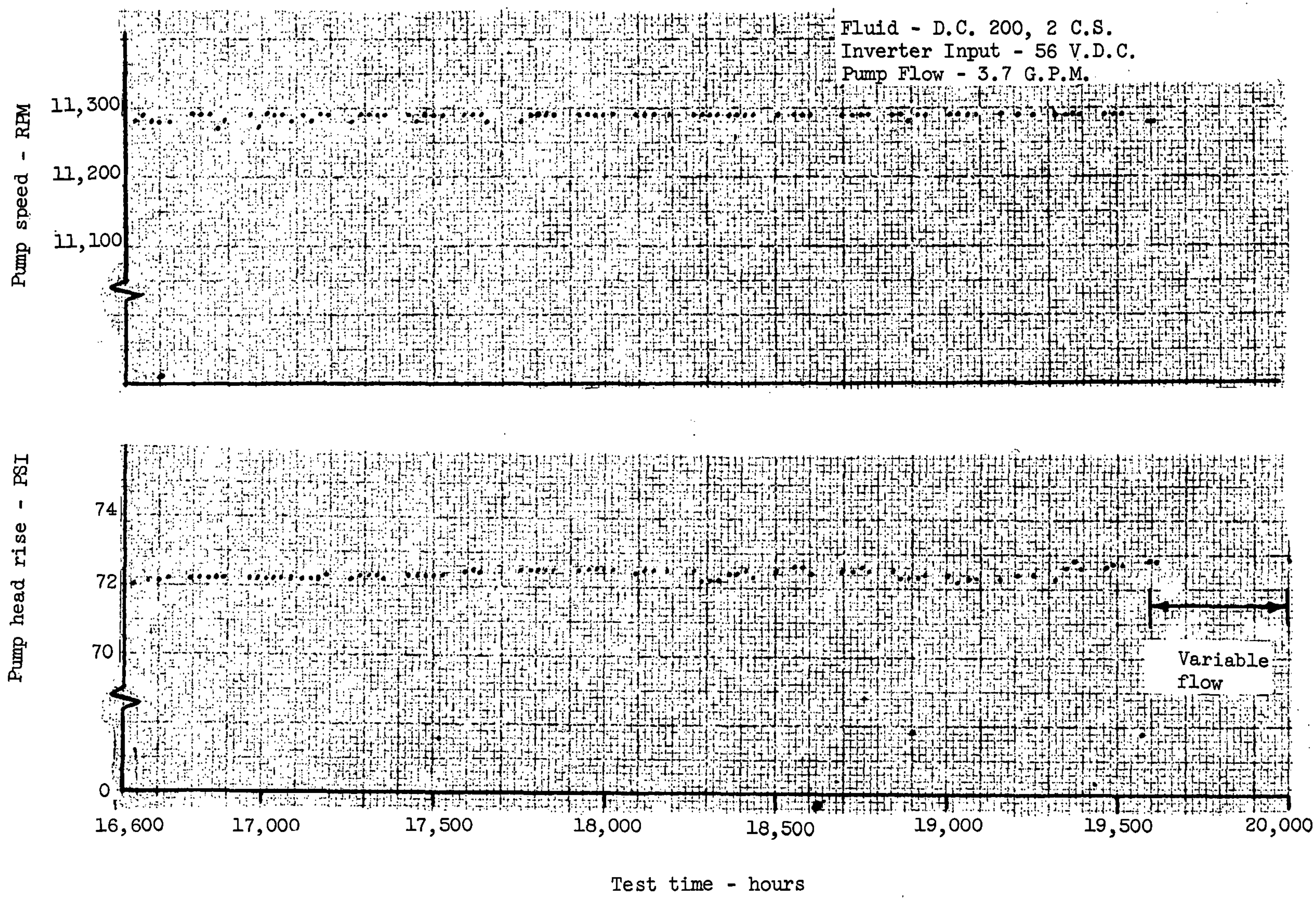


Figure 63. - PMA S/N X-2149 - 20,000 hour endurance test.

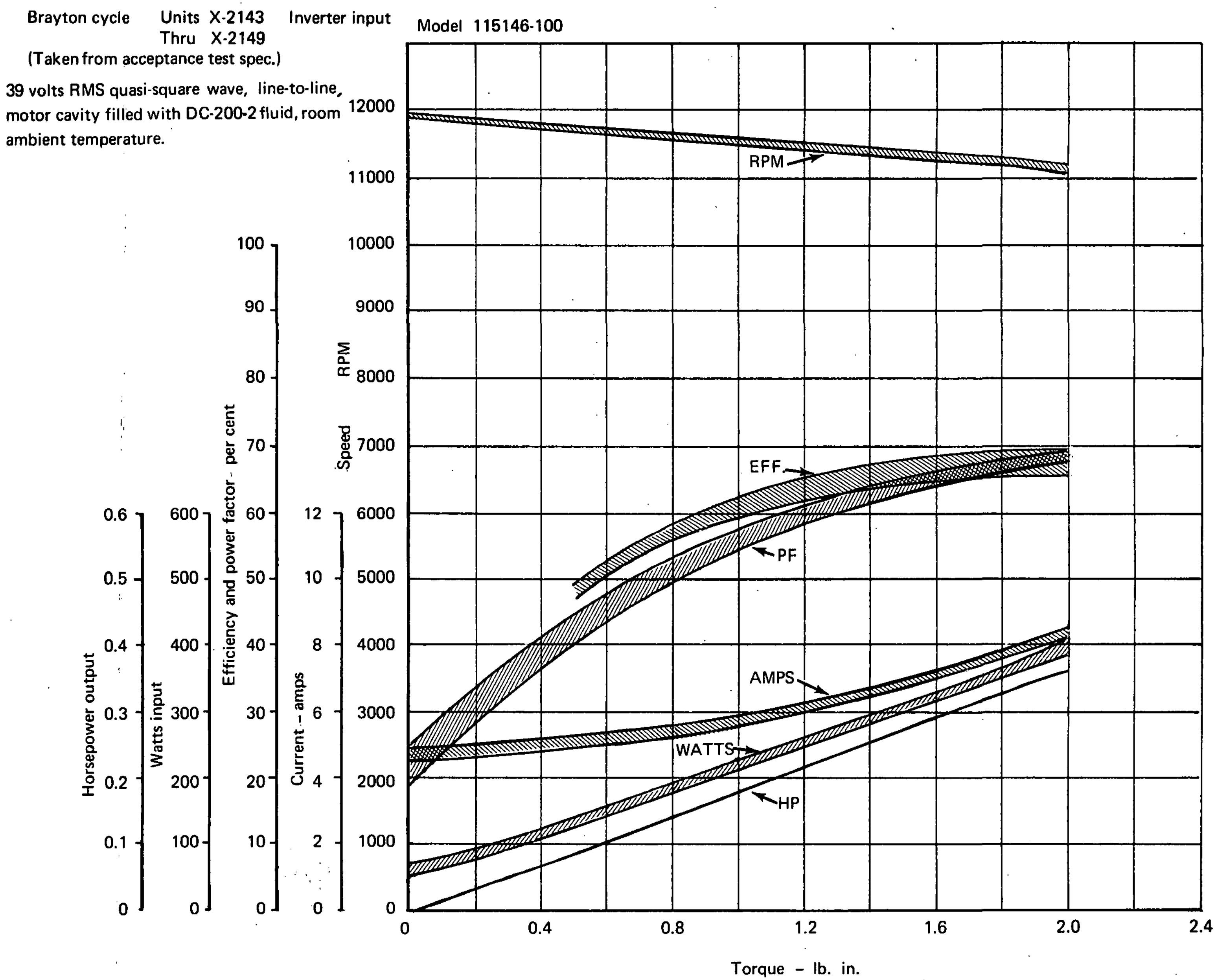


Figure 64. - Motor test performance variation of all motors (X-2143 through X-2149) - wet motor 39 volts, 400 Hz, three phase quasi-square wave input taken from acceptance test specifications calibration data

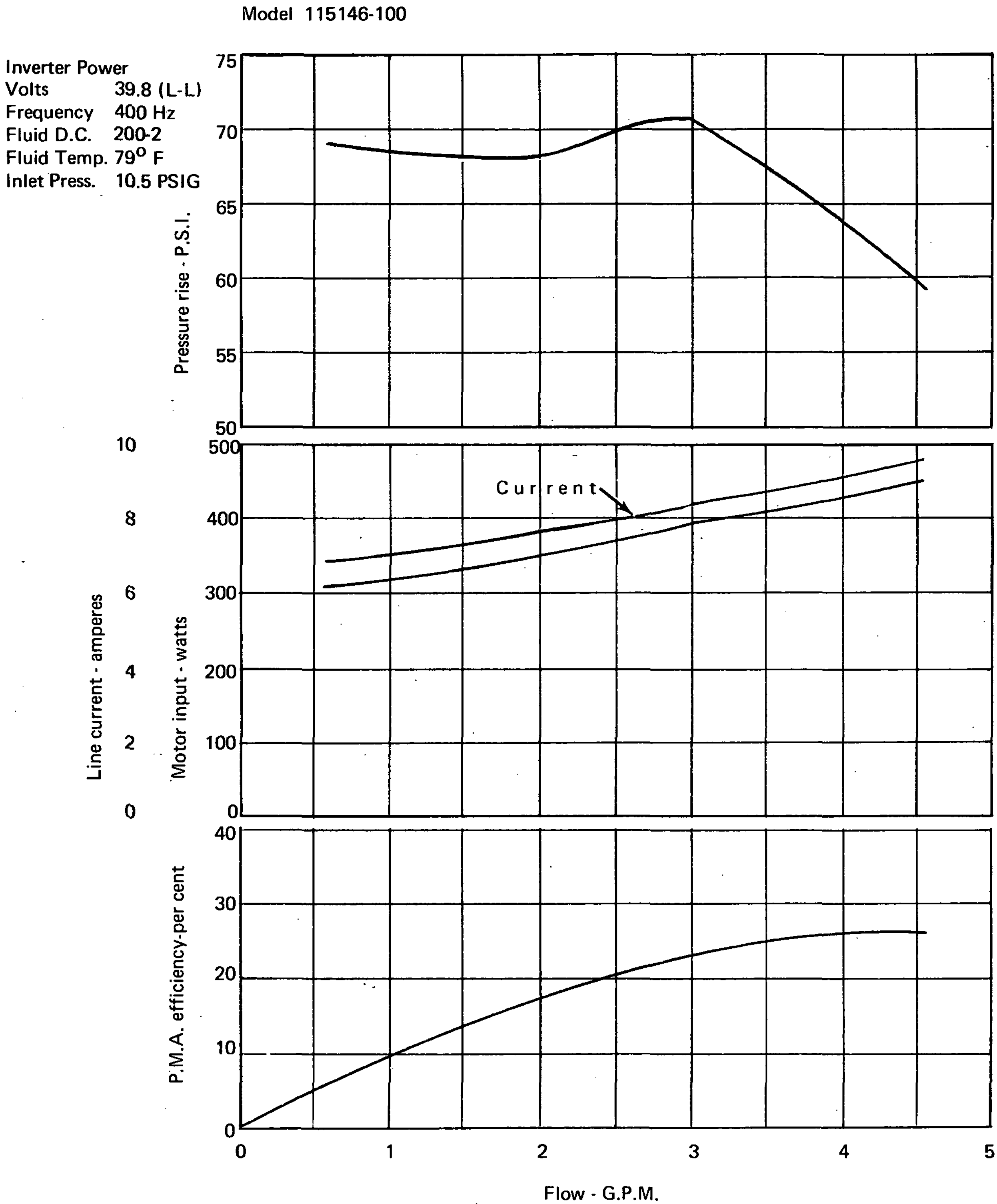


Figure 65. - PMA S/N X-2143 test performance - final acceptance test calibration at 39.8 V.A.C. inverter power

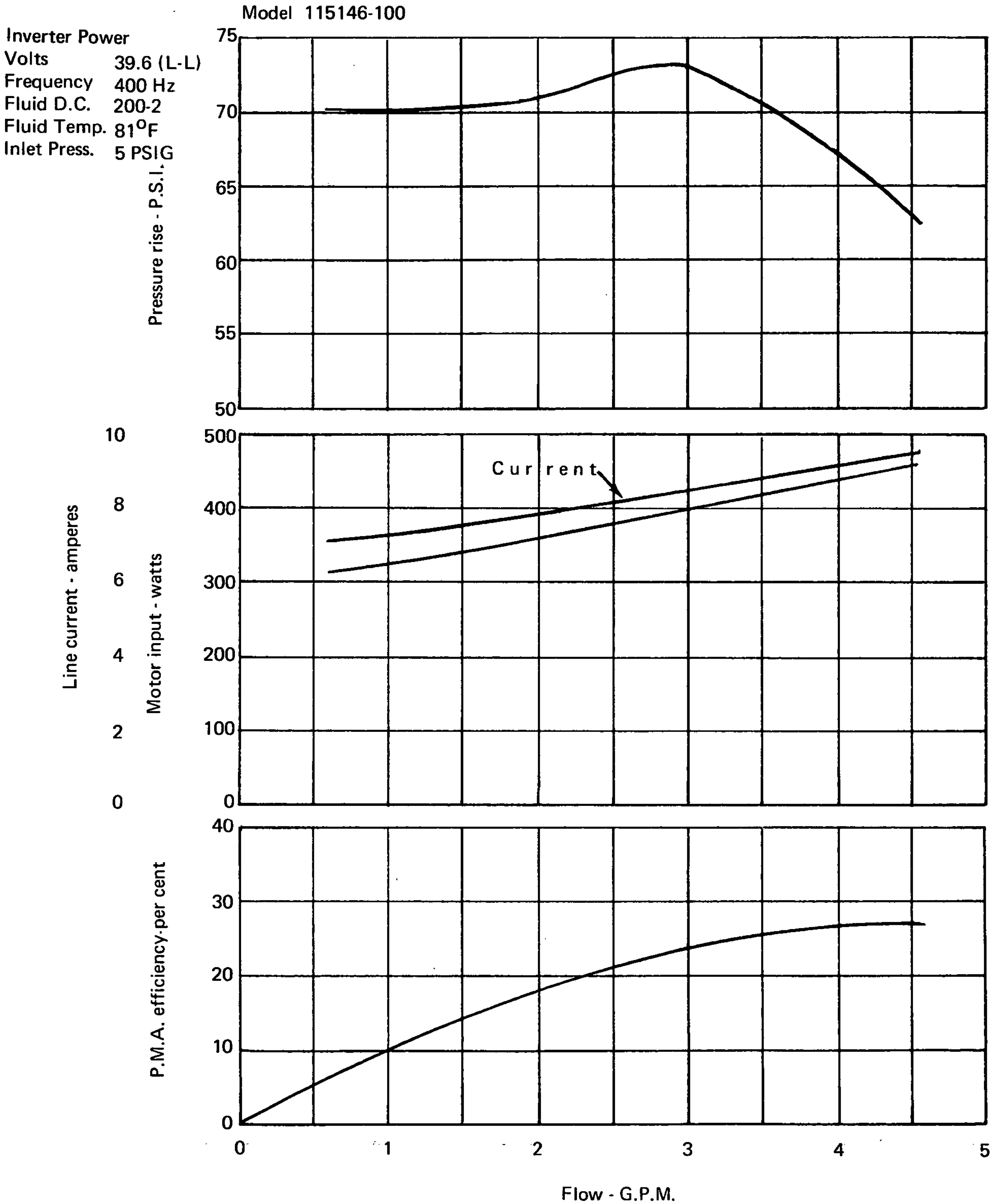


Figure 66. - PMA S/N X-2144 test performance - final acceptance test calibration at 39.6 V.A.C. inverter power

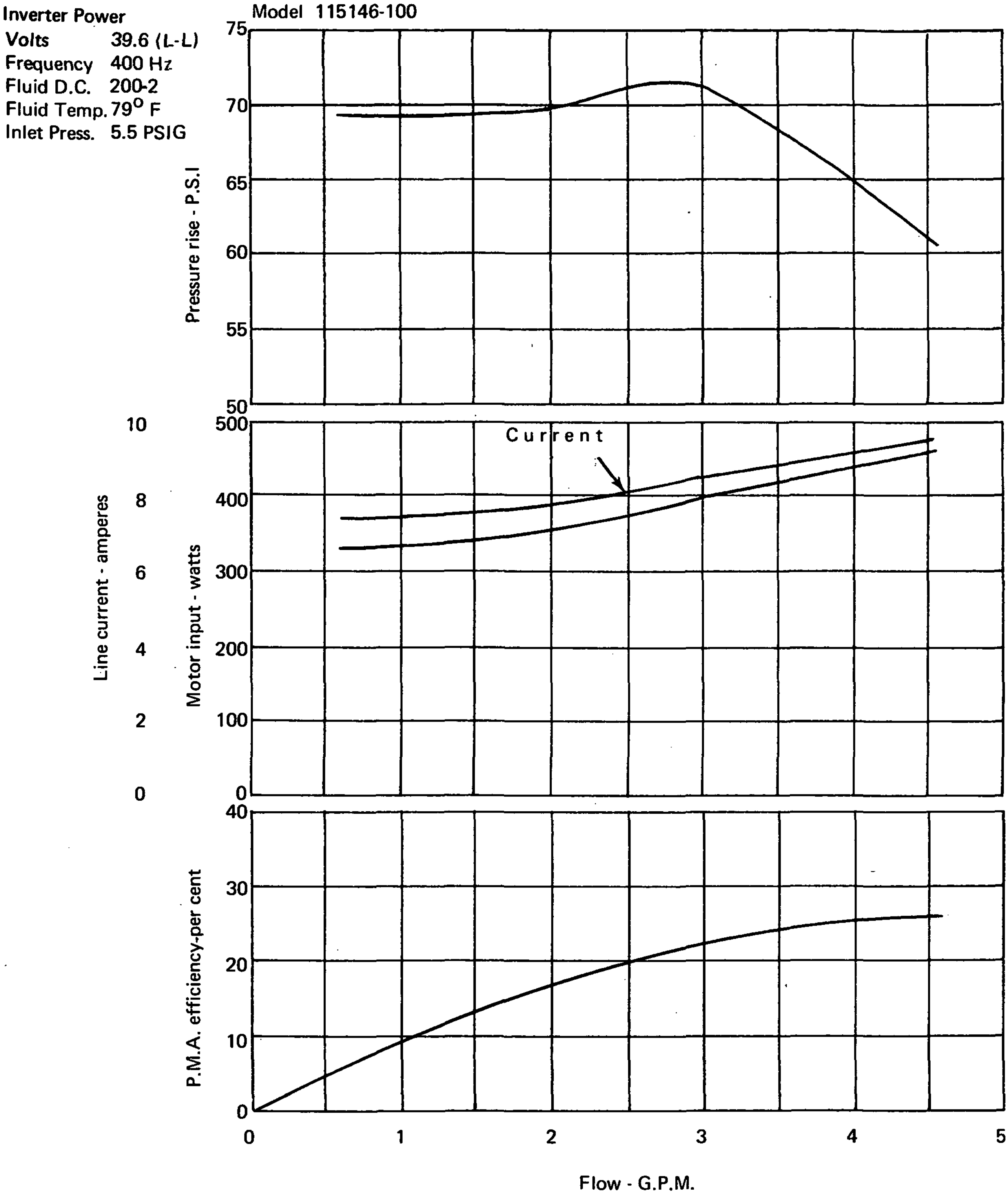


Figure 67. - PMA S/N X-2145 test performance - final acceptance test calibration at 39.6 V.A.C. inverter power

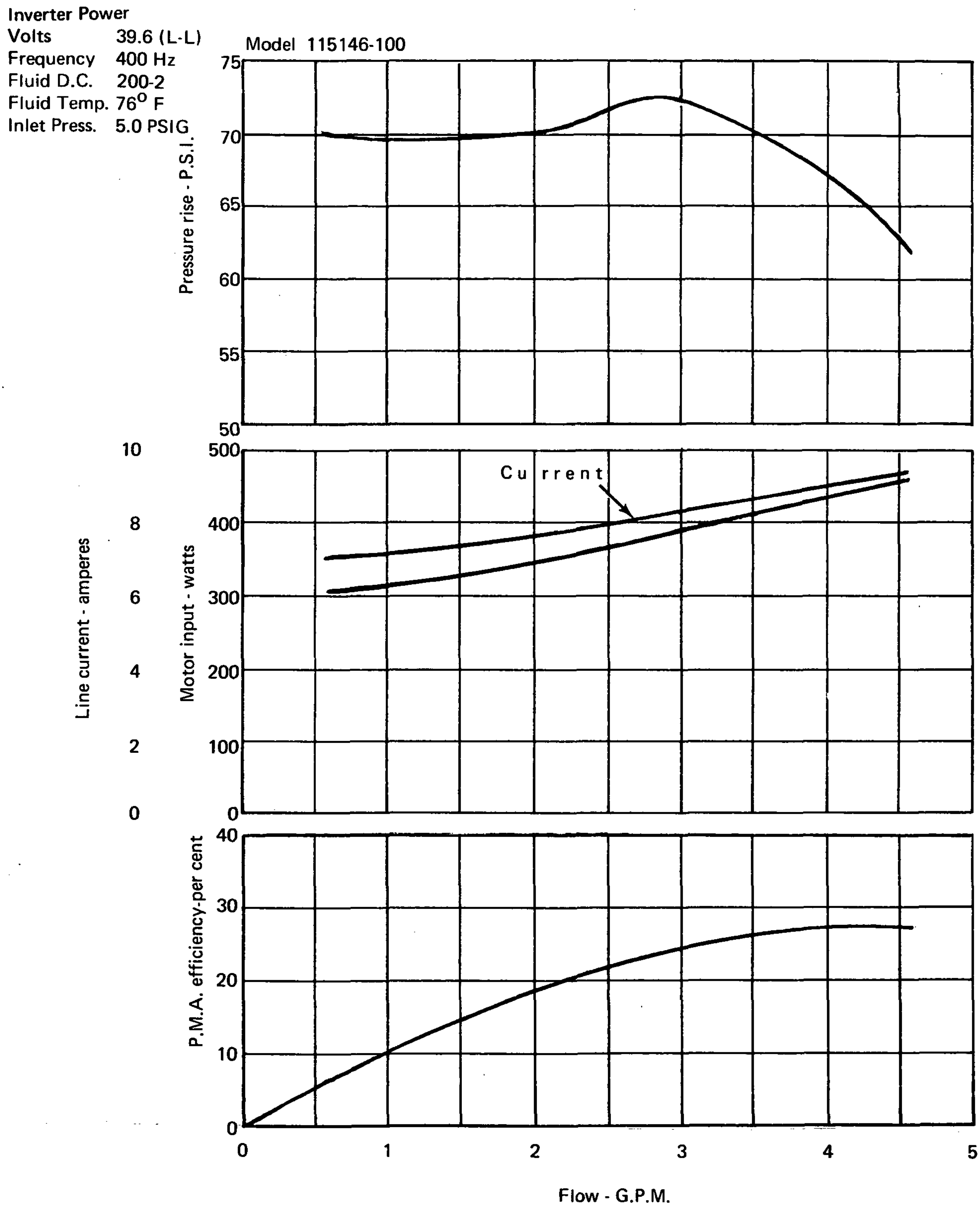


Figure 68. - PMA S/N X-2146 test performance - final acceptance test calibration at 39.6 V.A.C. inverter power

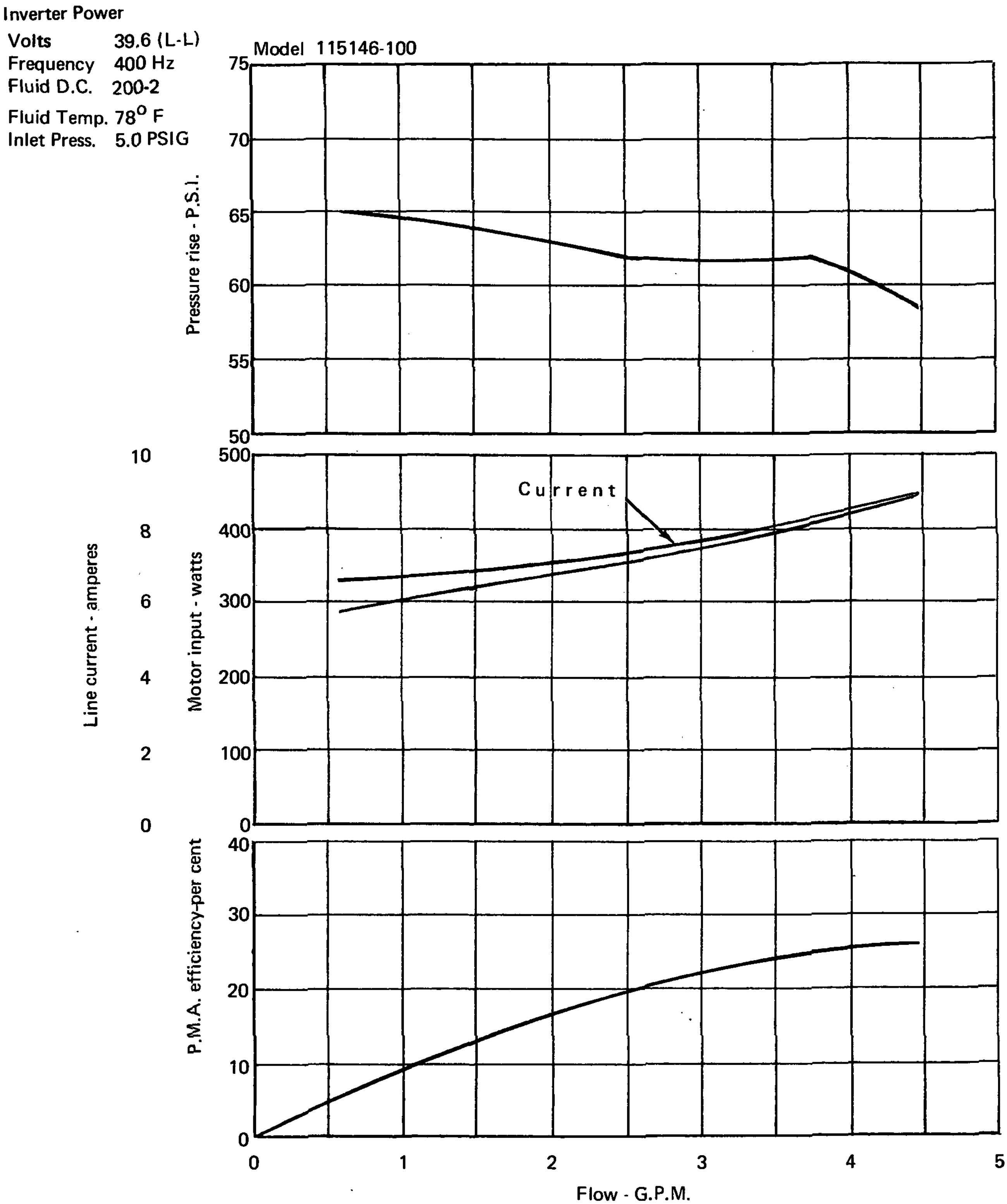


Figure 69. - PMA S/N X-2147 test performance - final acceptance test calibration at 39.6 V.A.C. inverter power

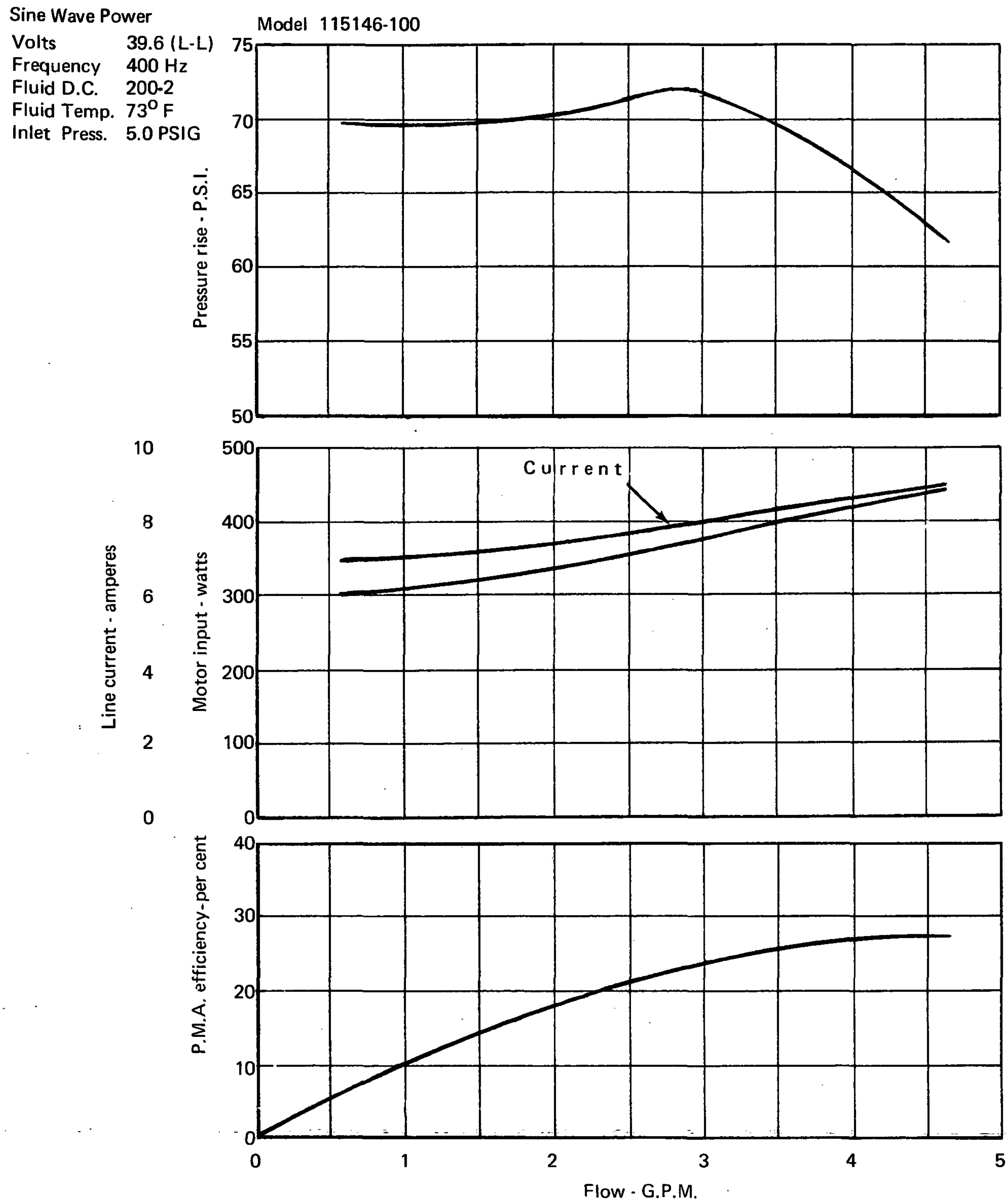


Figure 70. - PMA S/N X-2148 test performance - final acceptance test calibration at 39.6 V.A.C. sine wave power

APPENDIX B
DESIGN DATA

PUMP HYDRAULIC CALCULATIONS

PROJECT NO. 104081-A

MODEL BRAYTON CYCLE COOLANT PUMP FOR NASA-LEWIS

FLUID: SILICONE DC-200
VISCOSITY: 2.0 CS @ 77°F
15 CS @ -100°F
SPECIFIC GRAVITY: .873 @ 60°/60°

PUMP DISCHARGE DIA. DESIRABLE
1ST ATTEMPT 0.375 OD TUBE (INITIALLY PROPOSED)
$-\underline{0.275}$ ID TUBE, ASSUMED
FOR .100 ÷ 2 = 0.050 WALL ASSUMED

DISCH. VEL. $= \frac{.409\ Q}{D^2} = \frac{409 \times 3.7}{0.275^2} = \frac{20\ FT/SEC^2}{2g} =$
6.22 FT. = V.H. TOO HIGH FOR GOOD EFF.

2ND ATTEMPT { 0.50 IN. OD DISCH. TUBE
PUMP DISCH. { & 0.40 IN. ID DISCH. TUBE

DISCH. VEL. $= \frac{.409 \times 3.7}{.4^2} = \frac{.409 \times 3.7}{.16} = \frac{[9.44\ FT/SEC]^2}{2g} =$ (9.46)
1.38 FT. = V.H.

BEARING LIFE:
5 YEARS @ 11,000 RPM = 5 X 8760 HR/YEAR X 60 MIN/HR
= 43800 HRS. X 60 MIN/HR
= 2.63×10^6 MIN
2.63×10^6 MIN. X 1.1×10^4 RPM = 28,900,000,000 REV.

2^{ND} ATTEMPT (CONT'D.)

VEL. HEAD = 2 FT. MAX.
STATIC HEAD = 159 FT. MIN.
$\boxed{\text{TOTAL HEAD} = 161 \text{ FT. MIN.} = H}$

1^{ST} APPROXIMATE $BHP = \frac{161 \text{ FT.} [3.7 \times (.873 \times 8.34) \text{gal}]}{33,000 \times (.35 \text{ ESTIM } \eta)}$

$\boxed{Q = 3.7 \text{ GPM}}$

$= \frac{1.61 \times 2.7}{33.0} = \frac{(\text{H.H.P. OUT} = 0.1318)}{\text{ESTIM.MIN.} \eta = .35} =$

$= \underline{0.377 \text{ BHP ESTIM. (MAX.)}}$

$\frac{.1318}{\text{ESIM. MAX. } \eta = .40} = 0.33$ BHP ESTIM. (MIN.)

IMPELLER:

N_s @ 10,500 RPM 1^{ST} ESTIM $= \frac{10,500 \times 3.7^{1/2}}{161^{3/4} = 45} = 450$

$u_2 = 5.68 \left(\frac{161}{.55} = 293\right)^{1/2} = \underline{97.5 = u_2}$

1^{ST} ESTIM. of $V_{2R} = \phi u_2 = .14 \times 97.5 = \underline{13.7 \text{ FT/SEC} = V_{2R}}$

1^{ST} ESTIM. of $A_2 = \frac{.321 Q}{V_{2R}} = \frac{.321 \times 3.7}{13.7} = \underline{.087 \text{ IN}^2 = A_2}$

8 HOLES @ .087 IN^2 AREA TOTAL

$\frac{.087}{8} = .0109 \text{ IN}^2/\text{HOLE}$

(FOR $\phi = 0.14$)

$\left[(.0109) \frac{\pi}{4} = 0.0139\right]^{1/2} = 0.118$ IN. DIA. HOLE CALC.

$\left(\frac{.123 \text{ NOMINAL HOLES USED}}{.118 \text{ CALC}} = 1.045\right)^2 = 1.09 \times \text{CALC. } Q$

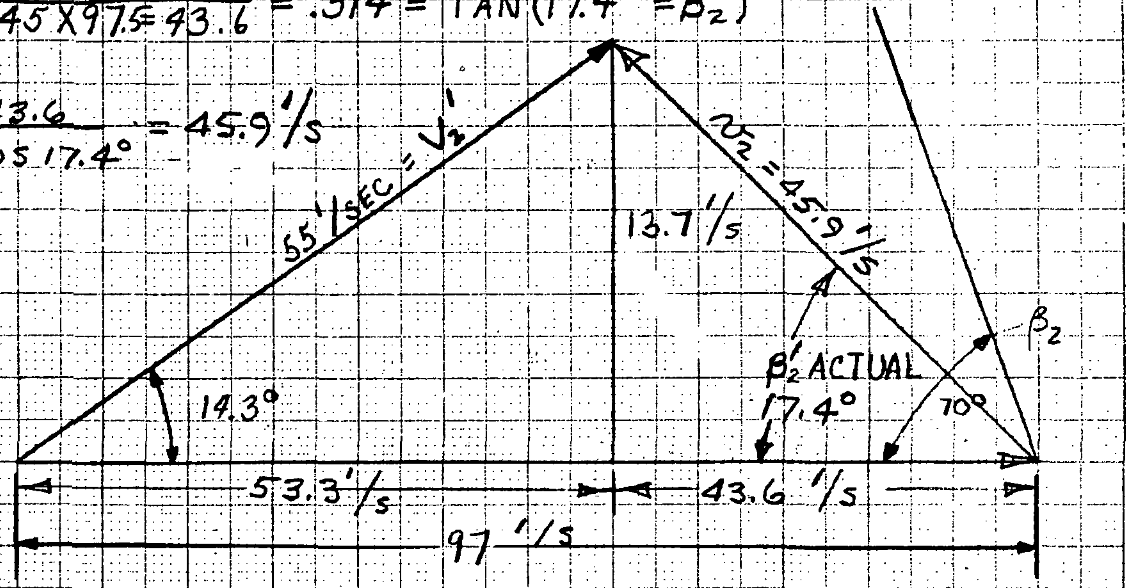
$1.09 \times 3.7 = 4.04$ GPM

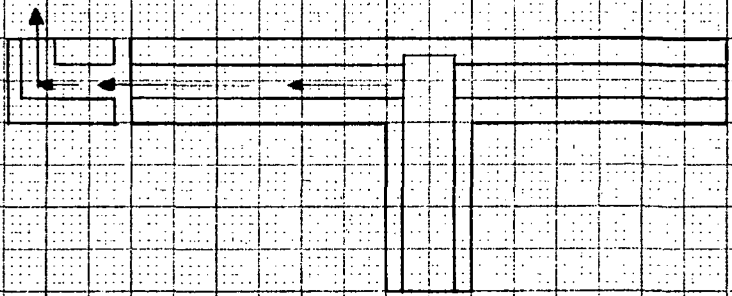
$\tan \alpha'_2 = \phi/\psi = \frac{.14}{.55} = .255\,, \quad \alpha'_2 = 14.3^\circ$

$\frac{.55 \times 97.5 = 53.3\ '/s}{\cos 14.3^\circ} = 55\ '/s = V'_2$

$\frac{13.7}{.45 \times 97.5 = 43.6} = .314 = \tan(17.4^\circ = \beta'_2)$

$\frac{43.6}{\cos 17.4^\circ} = 45.9\ '/s$





$A = \left(\frac{.321 \times 3.7}{45.9} = \frac{.0259\ \text{IN}^2)}{8\ \text{HOLES}}\right] = .00323\ \text{IN}^2/\text{HOLE}$

$\left(\frac{.00323}{\pi/4}\right)^{1/2} = .00412]^{1/2} = .0642$ IN. DIA IMP HOLES

ASSUMING NO REL. ROTAT. OF FLUID IN IMP. PASSAGE HOLES, NO FRICTION, PERFECT GUIDANCE, OBVIOUSLY IMPOSSIBLE

BASED ON ESTIM. 55'/SEC. V_1' ABS., REQ'D CROSS SECTION OF CHANNEL BEFORE DIFFUSER RING =

$$\frac{.321 \times 3.7}{53.3} = \frac{.0223 \text{ IN}^2}{8} = \frac{.00223 \text{ IN}^2 ?}{.123} = .0181''$$

9 HOLES IN DIFFUSER @ $\frac{360°}{9}$ = 40° INTERVALS

ENTRANCE AREA $= \frac{.321 \times 3.7}{55\ '/s = V_2'} = .0216$ IN² TOTAL

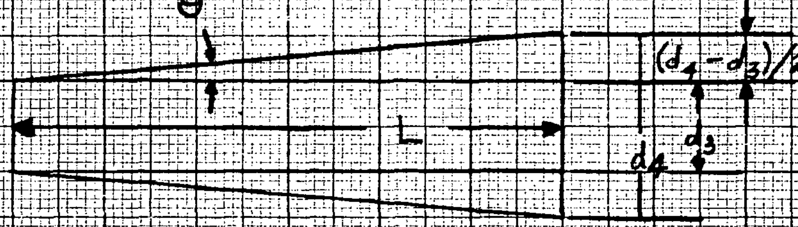
$$\frac{.0216}{9} = (.00240 \text{ IN}^2/\text{HOLE}) \times \frac{1}{\pi/4} = .00305]^{1/2} = .0553 \text{ IN. INLET}$$

$d_3 = \frac{.055}{.057}$

MIN. DIA. RATIO CONICAL DIFFUSER SECTION = 1.5 TO 1

" AREA " " " " $= 1.5^2 = 2.25$ TO 1

" V.H. " " " " $= 2.25^2 = 5.08$ TO 1



$\frac{d_4}{d_3} = 1.5$

$d_4 = \frac{.055}{.057} \times 1.5 = \frac{.0825}{.0855} = d_4$

$$\frac{\frac{d_4 - d_3}{2}}{L} = \frac{d_4 - d_3}{2L} = \text{TAN } \theta$$

$L = \frac{(d_4 - d_3)}{2 \text{ TAN } \theta}$ MAX θ = 4° TAN = .0699 X 4 = .280

$$L = \frac{(1.5 d_3 - d_3)}{2 \text{ TAN } \theta} = \frac{.5 d_3}{} = \frac{d_3}{4 \text{ TAN } \theta} = \frac{\overset{\text{MIN.}}{.055}}{\underset{\text{MAX.}}{.280}} = .196 \text{ MIN LENGTH OF DIFFUSER}$$

MIN θ = 3.5° TAN = .0612 X 4 = .244

$$L = \frac{(1.5\,d_3 - d_3)}{2\ \text{TAN}\,\Theta} = \frac{.5\,d_3}{2\ \text{TAN}\,\Theta} = \frac{d_3}{4\ \text{TAN}\,\Theta} = \frac{.057\ \text{MAX.}}{.244\ \text{MIN.}} = .234 \text{ MAX. LENGTH OF DIFFUSER}$$

TRY .25 LENGTH OF DIFFUSER:

@ 3.5°

$$\begin{array}{r} .0306 \\ \underline{.055} \\ .0856 \end{array}$$

(TAN 3.5° = .061) X .25 = .0153 EXP./SIDE X2 = .0306 MIN.

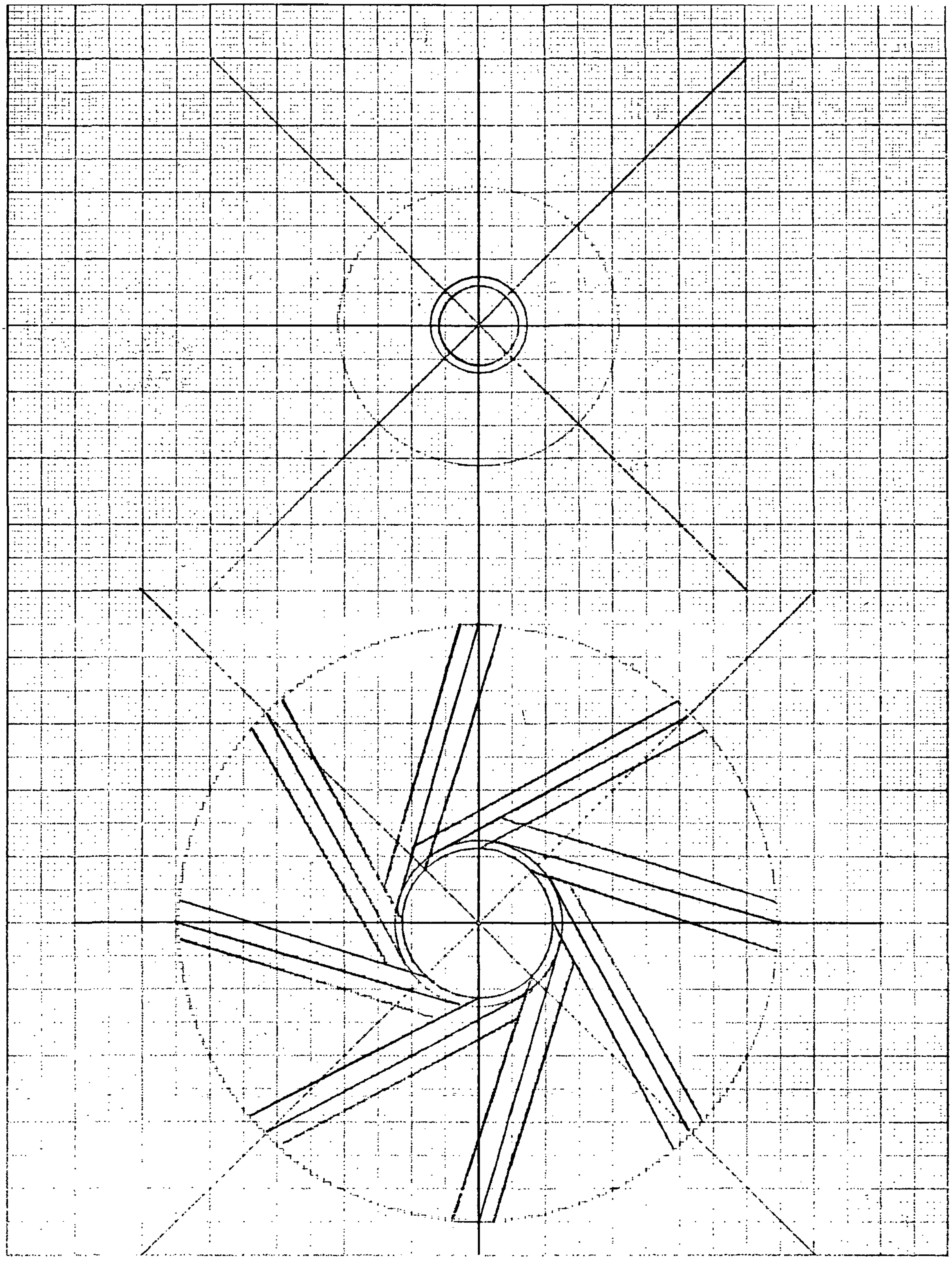
$$\left[\left(\frac{.0856}{.055} = 1.56\right)^2 = 2.43 \text{ EXP RATIO}\right]^2 = 5.92 = \text{VH RATIO}$$

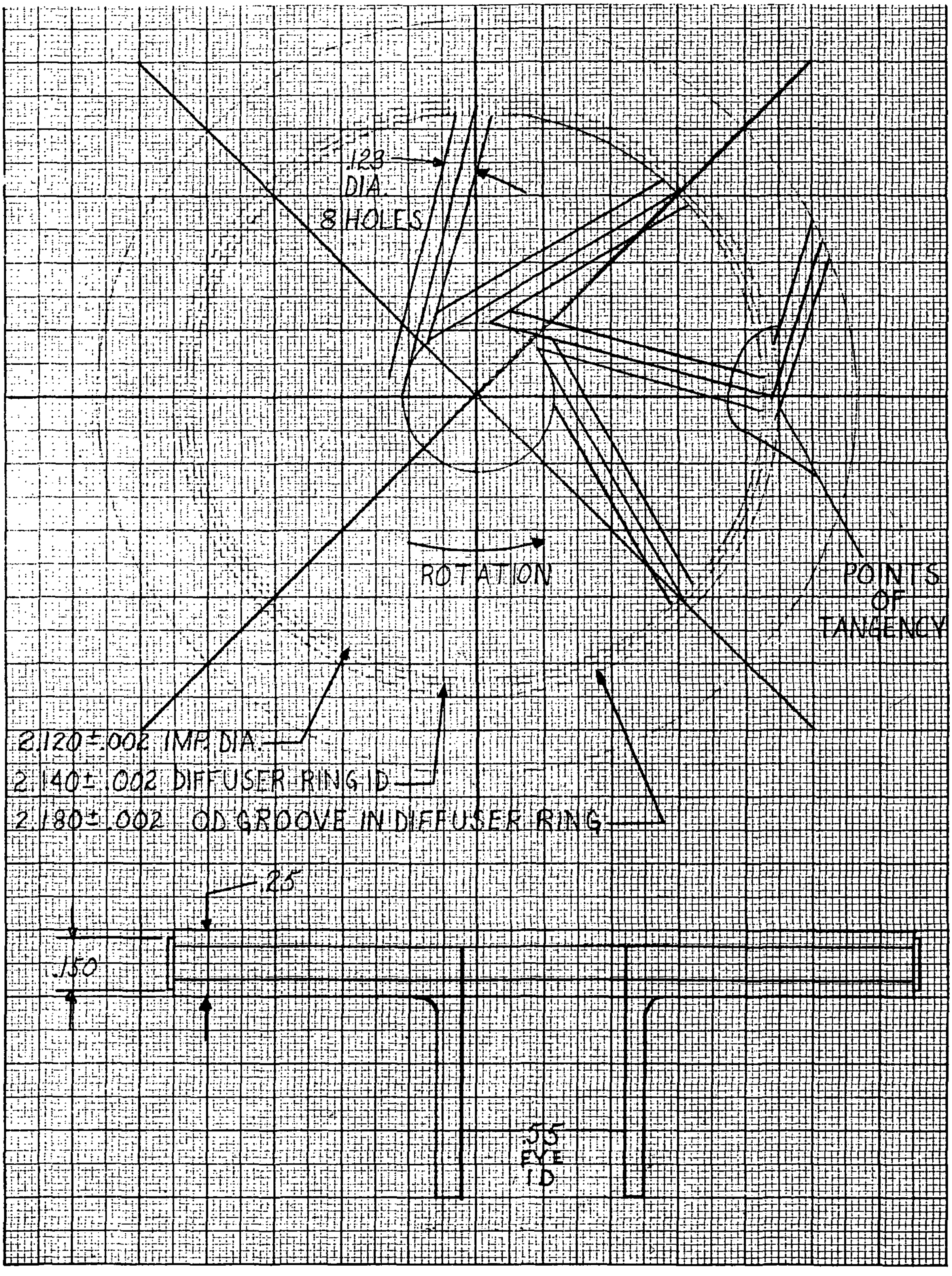
@ 4.0°

$$\begin{array}{r} .0350 \\ \underline{.0570} \\ .0920 \end{array}$$

(TAN 4.0° = .0699) X .25 = .0175 / SIDE X 2 SIDES = .0350

$$\left[\left(\frac{.0920}{.055} = 1.67\right)^2 = 2.8 \text{ EXP. RATIO}\right]^2 = 7.8 = \text{VH RATIO}$$




.123
DIA
8 HOLES
ROTATION
POINTS
OF
TANGENCY
2.120±.002 IMP. DIA.
2.140±.002 DIFFUSER RING ID
2.180±.002 OD GROOVE IN DIFFUSER RING
.25
.150
.55
EYE
I.D.

JOURNAL BEARING DESIGN CALCULATIONS*

bearing diameter inches	bearing length inches	diametral clearance inches	shaft speed rpm	bearing load pounds
0.3000	0.210	0.0005	11000.	1.
centistoke viscosity at -100 f	centistoke viscosity at 100 f	a p i gravity degrees	inlet oil temperature degrees f	maximum allowable oil temp
15.0	1.7	30.5	-100.	170.
not used	oil flow pressure p s i	bore groove depth inches	micro finish rms	bare metal friction coefficient
-0.	0.	0.	8.	0.10
ambient fluid temp f	surface area ratio	surface heat loss rate	bearing heat flow rate	housing heat flow rate
-100.	10.5	50.0	1740.	1730.
thermal expansion rate shaft	thermal expansion rate bearing	not used	heat flow bearing metal	rotating weight pounds
5.10	3.70	-0.	435.	0.15
shock load pounds	shock load seconds	temperature rise interval	heat input btu/min	static pressure p s i
0.	0.	10.	0.	75.

* **Truline Bearing Company, 29000 Lakeland Boulevard, Wickliffe, Ohio**
See Pages 123 and 124 for description of calculated operating characteristics.

calculated operating conditions 5146

index	special conditions		new value	1
05	bearing load	pounds	1.0	
09	oil inlet temperature	deg f	-100.0	
16	ambient oil temperature	deg f	-100.0	

room temp clear	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
0.0005	1.	-60.	-63.	257.8	257.8	0.00016	81.	0.0006
0.0010	1.	-70.	-73.	428.9	428.9	0.00085	74.	0.0011
0.0015	1.	-80.	-82.	546.2	546.2	0.00198	67.	0.0016

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
0.1291	0.0034	-60.	-65.	0.072	0.	0.00016	15.	-60.
0.0841	0.0022	-85.	-74.	0.109	0.	0.00085	15.	-70.
0.0717	0.0013	-90.	-83.	0.301	0.	0.00198	15.	-80.

oper oil visc	sommer -feld number	cbbi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
7.20	3.5260	0.000	14.	-0.0	0.0002	0.0032	1.0487	2.8
8.41	1.1303	0.001	14.	-0.0	0.0009	0.0024	3.5293	7.1
9.94	0.6131	0.003	14.	-0.0	0.0014	0.0016	5.2100	5.8

ioct

calculated operating conditions 5146

index	special conditions		new value
05	bearing load	pounds	1.0
09	oil inlet temperature	deg f	110.0
16	ambient oil temperature	deg f	110.0

room temp clear	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
0.0005	1.	120.	119.	183.2	183.2	0.00047	71.	0.0005
0.0010	1.	120.	119.	215.3	215.3	0.00231	51.	0.0010
0.0015	1.	120.	119.	189.8	189.8	0.00463	37.	0.0015

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
0.0298	0.0008	115.	119.	0.235	0.	0.00047	16.	120.
0.0177	0.0005	115.	119.	0.560	0.	0.00231	16.	120.
0.0142	0.0004	115.	119.	0.743	0.	0.00463	16.	120.

oper oil visc	sommer -feld number	cbbi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
1.31	0.8619	0.002	14.	-0.0	0.0002	0.0008	1.5967	10.6
1.31	0.2063	0.008	14.	-0.1	0.0000	0.0008	3.2637	7.4
1.31	0.0904	0.019	14.	-0.1	0.0018	0.0008	4.9300	6.0

oct

calculated operating conditions 5146

index	special conditions		new value
05	bearing load	pounds	0.155
09	oil inlet temperature	deg f	-100.0
16	ambient oil temperature	deg f	-100.0

3

room temp clear	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
0.0005	1.	-50.	-54.	271.5	271.5	0.00003	84.	0.0006
0.0010	1.	-70.	-73.	510.6	510.6	0.00016	83.	0.0011
0.0015	1.	-80.	-82.	732.1	732.1	0.00042	81.	0.0016

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
0.7224	0.0029	-75.	-56.	0.013	0.	0.00003	2.	-50.
0.5072	0.0021	-85.	-74.	0.035	0.	0.00016	2.	-70.
0.4069	0.0017	-90.	-83	0.053	0.	0.00042	2.	-80.

oper oil visc	sommer -feld number	cbhi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
6.22	19.9435	0.000	2.	-0.0	0.0001	0.0039	1.8347	3.9
8.40	7.2793	0.000	2.	-0.0	0.0002	0.0024	3.5293	2.8
9.92	3.9485	0.000	2.	-0.0	0.0003	0.0016	5.2190	2.3

ect

index	special conditions		new value
05	bearing load	pounds	0.155
09	oil inlet temperature	deg f	110.0
16	ambient oil temperature	deg f	110.0

room temp clear	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
0.0005	1.	120.	119.	228.5	228.5	0.00009	82.	0.0005
0.0010	1.	120.	119.	408.1	408.1	0.00069	76.	0.0010
0.0015	1.	120.	119.	508.8	508.8	0.00194	67.	0.0015

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
.1751	0.0007	115.	119.	0.043	0.	0.00009	2.	120.
0.0902	0.0004	115.	119.	0.166	0.	0.00069	2.	120.
0.0649	0.0003	115.	119.	0.312	0.	0.00194	2.	120.

oper oil visc	sommer -feld number	cbbi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
1.31	5.5545	0.000	2.	-0.0	0.0000	0.0008	1.5957	4.2
1.31	1.3297	0.001	2.	-0.0	0.0003	0.0008	3.2633	2.9
1.31	0.5826	0.003	2.	-0.1	0.0008	0.0008	4.9300	2.4

ect

calculated operating conditions 5145

index	special conditions		new value 5
01	bearing diameter	inches	0.375
02	bearing length	inches	0.2625
17	housing surface ratio	ratio	9.35
20	housing heat flow	factor	1440.0
25	dead weight rotating parts	pounds	0.795
05	bearing load	pounds	3.0
09	oil inlet temperature	deg f	-100.0
15	ambient oil temperature	deg f	-100.0

room temp clear	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
0.0005	1.	-40.	-44.	248.1	248.1	0.00040	79.	0.0005
0.0010	1.	-50.	-53.	398.2	398.2	0.00179	70.	0.0011
0.0015	1.	-80.	-81.	513.1	513.1	0.00364	54.	0.0016

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
0.0542	0.0063	-70.	-47.	0.110	0.	0.00040	30.	-40.
0.0483	0.0047	-80.	-65.	0.254	0.	0.00179	30.	-60.
0.0475	0.0047	-90.	-82.	0.350	0.	0.00364	30.	-80.

oper oil visc	sommer-feld number	cbbi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
5.45	2.1450	0.001	33.	-0.0	0.0009	0.0065	1.4873	7.5
7.21	0.7740	0.002	33.	-0.1	0.0025	0.0044	2.8487	5.4
9.95	0.4900	0.003	33.	-0.0	0.0026	0.0022	4.2100	4.4

pct

calculated operating conditions 5146

index	special conditions		new value
05	bearing load	pounds	3.0
09	oil inlet temperature	deg f	110.0
15	ambient oil temperature	deg f	110.0

room temp clear	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
0.0005	1.	130.	129.	169.4	169.4	0.00085	59.	0.0005
0.0010	1.	120.	119.	191.3	191.3	0.00389	43.	0.0010
0.0015	1.	120.	119.	162.8	162.8	0.00755	34.	0.0015

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
0.0131	0.0013	126.	123.	0.277	0.	0.00085	30.	130.
0.0121	0.0012	115.	119.	0.607	0.	0.00389	30.	120.
0.0098	0.0010	115.	119.	0.779	0.	0.00756	30.	120.

oper oil visc	sommer-feld number	cbbi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
1.24	0.6909	0.002	33.	-0.0	0.0007	0.0022	1.2493	8.2
1.31	0.1699	0.010	33.	-0.1	0.0015	0.0011	2.5967	5.7
1.31	0.0742	0.023	33.	-0.1	0.0030	0.0011	3.9300	4.6

act

index	special conditions		new value
05	bearing load	pounds	0.795
09	oil inlet temperature	deg f	-100.0
16	ambient oil temperature	deg f	-100.0

room temp clear	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
0.0005	1.	-40.	-44.	269.9	269.9	0.00012	83.	0.0006
0.0010	1.	-60.	-63.	480.4	480.4	0.00059	80.	0.0011
0.0015	1.	-70.	-72.	673.0	673.0	0.00150	77.	0.0016

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
0.2372	0.0032	-70.	-47.	0.032	0.	0.00012	8.	-40.
0.1652	0.0043	-30.	-65.	0.084	0.	0.00059	8.	-59.
0.1351	0.0035	-85.	-74.	0.145	0.	0.00150	8.	-70.

oper oil visc	sommer-fold number	cbbi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
5.43	3.0763	0.000	9.	-0.0	0.0003	0.0066	1.4873	3.8
7.10	2.9157	0.001	9.	-0.0	0.0008	0.0044	2.8497	2.8
8.40	1.5700	0.001	9.	-0.1	0.0016	0.0033	4.1950	2.3

ject

index	special conditions		new value
05	bearing load	pounds	0.795
09	oil inlet temperature	deg f	110.0
16	ambient oil temperature	deg f	110.0

room temp clea	final oper cond	oil film temp	brg back temp	min film thick	min shock film	oil flow gpm	shaft angle degrees	final oper clear
.0005	1.	130.	129.	212.5	212.5	0.00029	80.	0.0005
.0010	1.	120.	119.	344.6	344.6	0.00187	68.	0.0010
.0015	1.	120.	119.	379.4	379.4	0.00471	56.	0.0015

coef of frict	horse power heat	oil out temp	brg hsg temp	shaft ecc ratio	pres flow gpm	induced flow gpm	mean load psi	estimate hot spot temp
.0649	0.0017	120.	128.	0.093	0.	0.00029	8.	130.
.0371	0.0010	115.	119.	0.292	0.	0.00187	8.	120.
.0274	0.0007	115.	119.	0.485	0.	0.00471	8.	120.

oper oil visc	sommer -feld number	cbbi brg number	p-v less 000	unbal heat btu/min	hp to oil	hp to ambient	oper clear ratio	critical speed ratio
1.23	2.5029	0.001	0.	-0.0	0.0002	0.0022	1.2493	4.2
1.31	0.6401	0.003	0.	-0.0	0.0007	0.0011	2.5957	2.9
1.31	0.2794	0.006	0.	-0.1	0.0018	0.0011	3.9300	2.4

act

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.)

$\overline{P}$ - 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 - °F.
T-HSG	-	Temperature of housing surface - °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. $(D/C)^2 un/P$ - (P is W/DL, u is viscosity in Reyns, and n is speed in rps.)
A	-	Bearing characteristic number, dimensionless. M^2W/DZN.
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.

TABLE B 1

PESCO AC MOTOR COMPUTER CALCULATIONS
38.8 VOLTS L-L MOTOR INPUT
400 HZ, 3 PHASE, 50 VOLTS PEAK
HOT +100°F

PESCO AC MOTOR COMPUTER CALCULATIONS

TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS
0.038	1.00	11880.	0.007	4.4784	6.138	29.56	88.96	300.	9.	0.45	34.12	39.2
0.350	2.00	11760.	0.065	4.7532	36.408	41.98	134.10	319.	10.	1.78	34.12	38.4
0.652	3.00	11640.	0.120	5.1293	50.385	51.72	178.29	344.	12.	3.94	34.12	37.6
0.941	4.00	11520.	0.171	5.5788	57.983	59.01	221.25	374.	15.	6.88	34.12	36.8
1.215	5.00	11400.	0.219	6.0775	62.442	64.32	262.72	408.	17.	10.53	34.12	36.1
1.475	6.00	11280.	0.264	6.6067	65.130	68.12	302.46	443.	21.	14.83	34.12	35.3
1.719	7.00	11160.	0.304	7.1520	66.729	70.80	340.32	480.	24.	19.69	34.12	34.5
1.946	8.00	11040.	0.340	7.7030	67.614	72.66	376.15	517.	28.	25.06	34.12	33.8
2.156	9.00	10920.	0.373	8.2520	68.009	73.91	409.86	554.	33.	30.84	34.12	33.1
2.350	10.00	10800.	0.402	8.7934	68.055	74.69	441.41	590.	37.	36.97	34.12	32.4
2.440	10.50	10740.	0.415	9.0600	67.978	74.95	456.35	608.	39.	40.15	34.12	32.0
2.527	11.00	10680.	0.428	9.3233	67.847	75.13	470.75	626.	42.	43.39	34.12	31.6
2.609	11.50	10620.	0.439	9.5830	67.669	75.25	484.61	643.	44.	46.68	34.12	31.3
2.687	12.00	10560.	0.450	9.8388	67.450	75.30	497.92	661.	46.	50.02	34.12	30.9
2.761	12.50	10500.	0.460	10.0905	67.195	75.31	510.69	678.	49.	53.39	34.12	30.6
2.832	13.00	10440.	0.469	10.3380	66.909	75.27	522.93	694.	51.	56.80	34.12	30.2
2.898	13.50	10380.	0.477	10.5810	66.596	75.19	534.65	711.	54.	60.24	34.12	29.9
2.961	14.00	10320.	0.484	10.8195	66.258	75.07	545.85	727.	56.	63.69	34.12	29.5
3.020	14.50	10260.	0.491	11.0533	65.900	74.92	556.55	742.	59.	67.16	34.12	29.2
3.076	15.00	10200.	0.497	11.2825	65.523	74.75	566.75	758.	61.	70.63	34.12	28.9
3.128	15.50	10140.	0.503	11.5070	65.130	74.54	576.47	773.	64.	74.10	34.12	28.5
3.177	16.00	10080.	0.508	11.7267	64.722	74.32	585.71	788.	66.	77.58	34.12	28.2
3.223	16.50	10020.	0.512	11.9417	64.301	74.08	594.49	802.	69.	81.04	34.12	27.8
3.266	17.00	9960.	0.516	12.1520	63.869	73.82	602.83	816.	71.	84.50	34.12	27.5
3.306	17.50	9900.	0.519	12.3576	63.427	73.54	610.73	830.	74.	87.94	34.12	27.2
3.343	18.00	9840.	0.521	12.5585	62.976	73.25	618.20	843.	76.	91.36	34.12	26.8
3.377	18.50	9780.	0.524	12.7548	62.518	72.94	625.27	857.	78.	94.76	34.12	26.5
3.409	19.00	9720.	0.525	12.9465	62.053	72.63	631.94	870.	81.	98.13	34.12	26.2
3.438	19.50	9660.	0.526	13.1337	61.582	72.31	638.22	882.	83.	101.48	34.12	25.9
3.464	20.00	9600.	0.527	13.3165	61.105	71.98	644.14	894.	86.	104.80	34.12	25.6
3.488	20.50	9540.	0.527	13.4949	60.625	71.64	649.70	906.	88.	108.08	34.12	25.2
3.510	21.00	9480.	0.527	13.6690	60.140	71.29	654.91	918.	90.	111.33	34.12	24.9
3.530	21.50	9420.	0.527	13.8388	59.653	70.94	659.80	929.	92.	114.55	34.12	24.6
3.548	22.00	9360.	0.526	14.0045	59.162	70.59	664.36	941.	95.	117.72	34.12	24.3
3.564	22.50	9300.	0.525	14.1662	58.669	70.23	668.62	951.	97.	120.86	34.12	24.0
3.578	23.00	9240.	0.524	14.3238	58.174	69.87	672.59	962.	99.	123.96	34.12	23.7
3.590	23.50	9180.	0.522	14.4776	57.678	69.51	676.27	972.	101.	127.01	34.12	23.4
3.601	24.00	9120.	0.520	14.6276	57.181	69.14	679.68	982.	103.	130.02	34.12	23.1
3.609	24.50	9060.	0.518	14.7738	56.682	68.77	682.84	992.	105.	132.99	34.12	22.8
3.617	25.00	9000.	0.516	14.9164	56.184	68.41	685.74	1002.	107.	135.92	34.12	22.5
3.623	30.00	8400.	0.482	16.1614	51.209	64.76	703.34	1086.	126.	162.76	34.12	19.6
3.422	40.00	7200.	0.390	17.8949	41.691	58.16	699.46	1202.	155.	204.01	34.12	14.4
3.132	50.00	6000.	0.298	18.9886	33.007	52.80	673.84	1276.	174.	232.42	34.12	10.0
2.848	60.00	4800.	0.216	19.7122	25.158	48.54	643.03	1324.	188.	252.26	34.12	6.4
2.596	70.00	3600.	0.148	20.2131	18.045	45.13	613.03	1358.	198.	266.52	34.12	3.6
2.382	80.00	2400.	0.090	20.5738	11.551	42.36	585.74	1382.	205.	277.05	34.12	1.6
2.202	90.00	1200.	0.041	20.8423	5.569	40.09	561.55	1400.	210.	285.06	34.12	0.4
2.123	95.00	600.	0.020	20.9517	2.738	39.10	550.56	1407.	212.	288.35	34.12	0.1
2.079	98.00	240.	0.007	21.0109	1.084	38.55	544.31	1411.	214.	290.15	34.12	0.0
2.065	99.00	120.	0.003	21.0297	0.540	38.37	542.28	1413.	214.	290.72	34.12	0.0
TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS

MODEL NO. 121-1198	E	22.400	R1	0.161	XO	5.115	F AND W-SYNC	40.000
CALC. NO. 20	PHI	3.000	R2	0.269	KP	0.914		
SEPT 28, 1967	RPM-SYNC	12000.000	X	0.989	FE LOSS	34.123		

TABLE B 2

PESCO AC MOTOR COMPUTER CALCULATIONS
38.8 VOLTS L-L MOTOR INPUT
400 HZ, 3 PHASE, 50 VOLTS PEAK
COLD - 100°F

PESCO AC MOTOR COMPUTER CALCULATIONS

TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS
0.144	1.00	11880.	0.027	4.6769	17.455	37.03	116.39	314.	6.	0.75	34.12	54.8
0.661	2.00	11760.	0.123	5.3291	48.165	53.37	191.13	358.	8.	2.97	34.12	53.7
1.146	3.00	11640.	0.211	6.1696	60.232	63.26	262.28	414.	10.	6.51	34.12	52.6
1.593	4.00	11520.	0.291	7.1007	66.082	68.87	328.65	477.	14.	11.19	34.12	51.6
1.994	5.00	11400.	0.360	8.0599	69.123	71.88	389.36	541.	18.	16.82	34.12	50.5
2.349	6.00	11280.	0.420	9.0094	70.668	73.31	443.87	605.	23.	23.18	34.12	49.4
2.657	7.00	11160.	0.470	9.9268	71.331	73.74	491.95	667.	28.	30.05	34.12	48.4
2.917	8.00	11040.	0.511	10.7990	71.436	73.53	533.63	725.	33.	37.27	34.12	47.3
3.134	9.00	10920.	0.543	11.6191	71.171	72.89	569.16	780.	38.	44.64	34.12	46.3
3.310	10.00	10800.	0.567	12.3840	70.652	71.96	598.90	832.	44.	52.05	34.12	45.3
3.384	10.50	10740.	0.576	12.7455	70.321	71.42	611.76	856.	46.	55.73	34.12	44.8
3.450	11.00	10680.	0.584	13.0933	69.953	70.84	623.35	879.	49.	59.37	34.12	44.3
3.507	11.50	10620.	0.590	13.4274	69.553	70.23	633.74	902.	51.	62.97	34.12	43.8
3.556	12.00	10560.	0.595	13.7482	69.125	69.59	643.01	923.	54.	66.52	34.12	43.3
3.599	12.50	10500.	0.599	14.0561	68.675	68.94	651.22	944.	56.	70.01	34.12	42.8
3.634	13.00	10440.	0.601	14.3512	68.205	68.27	658.43	964.	59.	73.43	34.12	42.3
3.664	13.50	10380.	0.603	14.6341	67.718	67.59	664.71	983.	61.	76.79	34.12	41.9
3.688	14.00	10320.	0.603	14.9052	67.217	66.90	670.12	1001.	64.	80.07	34.12	41.4
3.706	14.50	10260.	0.603	15.1648	66.704	66.21	674.73	1019.	66.	83.27	34.12	40.9
3.720	15.00	10200.	0.602	15.4134	66.181	65.51	678.59	1035.	68.	86.39	34.12	40.4
3.729	15.50	10140.	0.599	15.6515	65.649	64.81	681.75	1051.	70.	89.43	34.12	39.9
3.734	16.00	10080.	0.597	15.8794	65.110	64.12	684.28	1067.	72.	92.39	34.12	39.5
3.736	16.50	10020.	0.593	16.0975	64.564	63.43	686.22	1081.	74.	95.26	34.12	39.0
3.734	17.00	9960.	0.590	16.3064	64.014	62.75	687.62	1095.	76.	98.05	34.12	38.5
3.729	17.50	9900.	0.585	16.5064	63.460	62.07	688.52	1109.	78.	100.76	34.12	38.1
3.721	18.00	9840.	0.580	16.6979	62.903	61.39	688.96	1122.	80.	103.39	34.12	37.6
3.711	18.50	9780.	0.575	16.8813	62.343	60.73	688.99	1134.	82.	105.94	34.12	37.1
3.698	19.00	9720.	0.570	17.0570	61.781	60.07	688.63	1146.	83.	108.41	34.12	36.7
3.683	19.50	9660.	0.564	17.2252	61.219	59.43	687.93	1157.	85.	110.80	34.12	36.2
3.667	20.00	9600.	0.558	17.3865	60.655	58.79	686.92	1168.	87.	113.12	34.12	35.8
3.649	20.50	9540.	0.552	17.5410	60.092	58.16	685.62	1178.	88.	115.36	34.12	35.3
3.629	21.00	9480.	0.545	17.6891	59.528	57.54	684.06	1188.	90.	117.53	34.12	34.9
3.608	21.50	9420.	0.539	17.8311	58.965	56.93	682.26	1198.	91.	119.63	34.12	34.5
3.586	22.00	9360.	0.532	17.9674	58.403	56.34	680.25	1207.	93.	121.66	34.12	34.0
3.563	22.50	9300.	0.525	18.0981	57.843	55.75	678.06	1216.	94.	123.63	34.12	33.6
3.539	23.00	9240.	0.518	18.2235	57.283	55.17	675.69	1224.	95.	125.53	34.12	33.2
3.515	23.50	9180.	0.511	18.3439	56.725	54.60	673.17	1232.	97.	127.37	34.12	32.7
3.489	24.00	9120.	0.504	18.4596	56.170	54.05	670.52	1240.	98.	129.15	34.12	32.3
3.463	24.50	9060.	0.497	18.5707	55.616	53.50	667.75	1247.	99.	130.87	34.12	31.9
3.437	25.00	9000.	0.490	18.6774	55.064	52.97	664.87	1255.	100.	132.53	34.12	31.5
3.162	30.00	8400.	0.421	19.5464	49.694	48.16	632.61	1313.	110.	146.49	34.12	27.4
2.654	40.00	7200.	0.303	20.5868	39.894	40.97	566.84	1383.	122.	164.20	34.12	20.1
2.259	50.00	6000.	0.214	21.1547	31.326	36.01	511.92	1421.	129.	174.36	34.12	14.0
1.962	60.00	4800.	0.149	21.4969	23.797	32.43	468.54	1444.	133.	180.69	34.12	8.9
1.741	70.00	3600.	0.099	21.7192	17.084	29.75	434.28	1459.	136.	184.88	34.12	5.0
1.574	80.00	2400.	0.059	21.8722	10.990	27.68	406.86	1469.	137.	187.82	34.12	2.2
1.446	90.00	1200.	0.027	21.9822	5.343	26.03	384.55	1477.	139.	189.96	34.12	0.5
1.394	95.00	600.	0.013	22.0267	2.641	25.32	374.90	1480.	139.	190.82	34.12	0.1
1.366	98.00	240.	0.005	22.0497	1.050	24.93	369.53	1481.	140.	191.29	34.12	0.0
1.357	99.00	120.	0.002	22.0572	0.524	24.81	367.80	1482.	140.	191.44	34.12	0.0
TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS

MODEL NO. 121-1198	F	22.400	R1	0.096	XO	5.115	F AND W-SYNC	56.000
CALC. NO. 20	PHI	3.000	R2	0.160	KP	0.914		
SEPT 28, 1967	RPM-SYNC	12000.000	X	0.989	FE LOSS	34.123		

TABLE B 3

PESCO AC MOTOR COMPUTER CALCULATIONS
43.3 VOLTS L-L MOTOR INPUT
400 HZ, 3 PHASE, 56 VOLTS PEAK
HOT + 100°F

PESCO AC MOTOR COMPUTER CALCULATIONS

TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS
0.11	1.00	11880.	0.022	5.368	14.53	28.02	113.	404.	13.9	0.5	43.0	39.2
0.50	2.00	11760.	0.094	5.654	41.48	39.82	169.	425.	15.5	2.2	43.0	38.4
0.88	3.00	11640.	0.162	6.049	53.98	49.32	224.	455.	17.7	4.9	43.0	37.6
1.24	4.00	11520.	0.226	6.526	60.76	56.62	278.	491.	20.6	8.5	43.0	36.8
1.58	5.00	11400.	0.286	7.060	64.70	62.08	330.	531.	24.1	13.1	43.0	36.1
1.90	6.00	11280.	0.341	7.630	67.03	66.08	379.	574.	28.2	18.5	43.0	35.3
2.21	7.00	11160.	0.391	8.221	68.37	68.97	427.	619.	32.7	24.5	43.0	34.5
2.49	8.00	11040.	0.436	8.821	69.06	71.03	471.	664.	37.7	31.2	43.0	33.8
2.75	9.00	10920.	0.477	9.422	69.30	72.45	514.	709.	43.0	38.5	43.0	33.1
2.99	10.00	10800.	0.513	10.016	69.23	73.39	553.	754.	48.6	46.1	43.0	32.4
3.11	10.50	10740.	0.530	10.309	69.10	73.72	572.	776.	51.5	50.1	43.0	32.0
3.21	11.00	10680.	0.545	10.599	68.92	73.96	590.	798.	54.4	54.2	43.0	31.6
3.32	11.50	10620.	0.559	10.885	68.70	74.14	607.	819.	57.4	58.3	43.0	31.3
3.41	12.00	10560.	0.572	11.167	68.44	74.25	624.	840.	60.4	62.5	43.0	30.9
3.51	12.50	10500.	0.585	11.445	68.15	74.31	640.	861.	63.5	66.7	43.0	30.6
3.60	13.00	10440.	0.596	11.719	67.83	74.31	655.	882.	66.6	70.9	43.0	30.2
3.68	13.50	10380.	0.606	11.988	67.48	74.28	670.	902.	69.7	75.2	43.0	29.9
3.76	14.00	10320.	0.615	12.257	67.12	74.20	684.	922.	72.8	79.6	43.0	29.5
3.83	14.50	10260.	0.624	12.511	66.73	74.09	698.	942.	75.9	83.9	43.0	29.2
3.90	15.00	10200.	0.632	12.765	66.33	73.95	710.	961.	79.0	88.3	43.0	28.9
3.97	15.50	10140.	0.638	13.014	65.91	73.78	723.	979.	82.1	92.6	43.0	28.5
4.03	16.00	10080.	0.645	13.258	65.48	73.59	734.	998.	85.2	97.0	43.0	28.2
4.09	16.50	10020.	0.650	13.497	65.04	73.38	745.	1016.	88.3	101.3	43.0	27.8
4.14	17.00	9960.	0.654	13.730	64.59	73.15	756.	1033.	91.4	105.7	43.0	27.5
4.19	17.50	9900.	0.658	13.959	64.13	72.90	766.	1051.	94.5	110.0	43.0	27.2
4.24	18.00	9840.	0.662	14.182	63.66	72.63	775.	1067.	97.5	114.3	43.0	26.8
4.28	18.50	9780.	0.664	14.401	63.19	72.35	784.	1084.	100.5	118.5	43.0	26.5
4.32	19.00	9720.	0.666	14.614	62.71	72.06	793.	1100.	103.5	122.8	43.0	26.2
4.35	19.50	9660.	0.668	14.822	62.22	71.76	800.	1116.	106.5	127.0	43.0	25.9
4.39	20.00	9600.	0.669	15.026	61.73	71.45	808.	1131.	109.5	131.1	43.0	25.6
4.42	20.50	9540.	0.669	15.225	61.24	71.13	815.	1146.	112.4	135.2	43.0	25.2
4.45	21.00	9480.	0.669	15.419	60.74	70.80	822.	1161.	115.3	139.3	43.0	24.9
4.47	21.50	9420.	0.668	15.608	60.24	70.47	828.	1175.	118.1	143.4	43.0	24.6
4.49	22.00	9360.	0.667	15.793	59.74	70.13	834.	1189.	120.9	147.4	43.0	24.3
4.51	22.50	9300.	0.666	15.973	59.23	69.79	839.	1202.	123.7	151.3	43.0	24.0
4.53	23.00	9240.	0.664	16.149	58.73	69.44	844.	1216.	126.4	155.2	43.0	23.7
4.55	23.50	9180.	0.662	16.321	58.22	69.09	849.	1229.	129.2	159.0	43.0	23.4
4.56	24.00	9120.	0.660	16.488	57.71	68.74	853.	1241.	131.8	162.8	43.0	23.1
4.57	24.50	9060.	0.657	16.652	57.20	68.38	857.	1253.	134.4	166.5	43.0	22.8
4.58	25.00	9000.	0.654	16.811	56.69	68.03	861.	1265.	137.0	170.2	43.0	22.5
4.59	30.00	8400.	0.611	18.203	51.64	64.48	883.	1370.	160.7	204.0	43.0	19.6
4.33	40.00	7200.	0.495	20.145	42.00	57.99	879.	1516.	196.8	255.9	43.0	14.4
3.96	50.00	6000.	0.377	21.372	33.22	52.69	848.	1609.	221.5	291.7	43.0	10.0
3.60	60.00	4800.	0.274	22.184	25.28	48.47	809.	1670.	238.6	316.7	43.0	6.4
3.28	70.00	3600.	0.187	22.746	18.11	45.08	772.	1712.	250.9	334.7	43.0	3.6
3.00	80.00	2400.	0.114	23.151	11.57	42.33	738.	1743.	259.9	347.9	43.0	1.6
2.77	90.00	1200.	0.052	23.452	5.56	40.07	707.	1766.	266.7	358.0	43.0	0.4
2.67	95.00	600.	0.025	23.575	2.73	39.09	693.	1775.	269.5	362.2	43.0	0.1
2.61	98.00	240.	0.009	23.642	1.08	38.53	686.	1780.	271.1	364.4	43.0	0.0
2.59	99.00	120.	0.004	23.663	0.53	38.36	683.	1781.	271.5	365.2	43.0	0.0
TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS

MODEL NO. 121-1198	E	25.100	R1	0.161	XO	4.761	F AND W-SYNC	40.000
CALC. NO. 21	PHI	3.000	R2	0.269	KP	0.909		
SEPT 28, 1967	RPM-SYNC	12000.000	X	0.985	FE LOSS	43.073		

TABLE B 4

PESCO AC MOTOR COMPUTER CALCULATIONS
43.5 VOLTS L-L MOTOR INPUT
400 HZ, 3 PHASE, 56 VOLTS PEAK
COLD - 100°F

PESCO AC MOTOR COMPUTER CALCULATIONS

TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS
0.27	1.00	11880.	0.052	5.578	26.48	34.93	146.	420.	8.9	0.9	43.0	54.8
0.92	2.00	11760.	0.171	6.265	53.36	50.85	239.	471.	11.3	3.7	43.0	53.7
1.52	3.00	11640.	0.281	7.164	63.89	60.93	328.	539.	14.8	8.1	43.0	52.6
2.08	4.00	11520.	0.380	8.171	68.92	66.90	411.	615.	19.2	13.9	43.0	51.6
2.58	5.00	11400.	0.467	9.216	71.46	70.24	487.	694.	24.4	20.9	43.0	50.5
3.02	6.00	11280.	0.541	10.258	72.67	71.94	555.	772.	30.3	28.9	43.0	49.4
3.40	7.00	11160.	0.603	11.269	73.10	72.59	615.	848.	36.6	37.5	43.0	48.4
3.73	8.00	11040.	0.654	12.232	73.03	72.55	668.	921.	43.1	46.5	43.0	47.3
4.00	9.00	10920.	0.694	13.141	72.63	72.04	712.	989.	49.8	55.8	43.0	46.5
4.22	10.00	10800.	0.724	13.990	72.01	71.22	750.	1053.	56.4	65.0	43.0	45.3
4.32	10.50	10740.	0.736	14.392	71.64	70.72	766.	1083.	59.7	69.6	43.0	44.8
4.40	11.00	10680.	0.745	14.779	71.23	70.19	781.	1112.	62.9	74.2	43.0	44.3
4.47	11.50	10620.	0.753	15.151	70.80	69.61	794.	1140.	66.2	78.7	43.0	43.8
4.53	12.00	10560.	0.760	15.508	70.34	69.01	806.	1167.	69.3	83.2	43.0	43.3
4.59	12.50	10500.	0.764	15.851	69.86	68.39	816.	1193.	72.4	87.6	43.0	42.8
4.63	13.00	10440.	0.767	16.181	69.36	67.75	825.	1218.	75.5	91.9	43.0	42.3
4.67	13.50	10380.	0.769	16.496	68.85	67.09	833.	1242.	78.4	96.1	43.0	41.9
4.70	14.00	10320.	0.769	16.799	68.33	66.43	840.	1264.	81.3	100.2	43.0	41.4
4.72	14.50	10260.	0.769	17.089	67.80	65.76	846.	1286.	84.2	104.2	43.0	40.9
4.74	15.00	10200.	0.767	17.366	67.25	65.09	851.	1307.	86.9	108.1	43.0	40.4
4.75	15.50	10140.	0.764	17.632	66.71	64.41	855.	1327.	89.6	111.9	43.0	39.9
4.76	16.00	10080.	0.761	17.887	66.15	63.74	858.	1346.	92.2	115.7	43.0	39.5
4.76	16.50	10020.	0.757	18.131	65.59	63.06	861.	1365.	94.8	119.3	43.0	39.0
4.76	17.00	9960.	0.752	18.365	65.03	62.39	862.	1382.	97.2	122.8	43.0	38.5
4.75	17.50	9900.	0.746	18.588	64.46	61.73	864.	1399.	99.6	126.2	43.0	38.1
4.74	18.00	9840.	0.740	18.803	63.89	61.07	864.	1415.	101.9	129.5	43.0	37.6
4.73	18.50	9780.	0.734	19.008	63.32	60.42	864.	1431.	104.2	132.7	43.0	37.1
4.71	19.00	9720.	0.727	19.205	62.74	59.78	864.	1446.	106.3	135.8	43.0	36.7
4.69	19.50	9660.	0.719	19.393	62.17	59.14	863.	1460.	108.4	138.8	43.0	36.2
4.67	20.00	9600.	0.712	19.574	61.60	58.51	862.	1473.	110.4	141.7	43.0	35.8
4.65	20.50	9540.	0.704	19.747	61.02	57.90	860.	1486.	112.4	144.6	43.0	35.3
4.62	21.00	9480.	0.696	19.913	60.45	57.29	859.	1499.	114.3	147.3	43.0	34.9
4.60	21.50	9420.	0.687	20.072	59.88	56.69	856.	1511.	116.1	149.9	43.0	34.5
4.57	22.00	9360.	0.679	20.225	59.31	56.10	854.	1522.	117.9	152.5	43.0	34.0
4.54	22.50	9300.	0.670	20.371	58.74	55.52	851.	1533.	119.6	155.0	43.0	33.6
4.51	23.00	9240.	0.661	20.512	58.17	54.95	848.	1544.	121.3	157.4	43.0	33.2
4.48	23.50	9180.	0.653	20.647	57.60	54.39	845.	1554.	122.9	159.7	43.0	32.7
4.45	24.00	9120.	0.644	20.776	57.04	53.84	842.	1564.	124.4	161.9	43.0	32.3
4.41	24.50	9060.	0.635	20.901	56.48	53.30	839.	1573.	125.9	164.1	43.0	31.9
4.38	25.00	9000.	0.626	21.021	55.92	52.78	835.	1582.	127.4	166.2	43.0	31.5
4.03	30.00	8400.	0.538	21.996	50.47	48.02	795.	1656.	139.5	183.8	43.0	27.4
3.39	40.00	7200.	0.387	23.165	40.53	40.88	713.	1744.	154.7	206.1	43.0	20.1
2.88	50.00	6000.	0.274	23.803	31.80	35.95	644.	1792.	163.3	218.9	43.0	14.0
2.50	60.00	4800.	0.190	24.187	24.12	32.39	590.	1821.	168.7	226.9	43.0	8.9
2.21	70.00	3600.	0.126	24.437	17.27	29.73	547.	1840.	172.2	232.2	43.0	5.0
1.99	80.00	2400.	0.076	24.609	11.06	27.66	512.	1853.	174.6	235.9	43.0	2.2
1.82	90.00	1200.	0.034	24.732	5.35	26.02	484.	1862.	176.4	238.6	43.0	0.5
1.75	95.00	600.	0.016	24.781	2.64	25.32	472.	1866.	177.1	239.7	43.0	0.1
1.71	98.00	240.	0.006	24.808	1.04	24.93	465.	1868.	177.4	240.3	43.0	0.0
1.70	99.00	120.	0.003	24.816	0.52	24.81	463.	1868.	177.6	240.5	43.0	0.0
TORQUE IN.LB	SLIP	RPM	HP	I AMPS	EFF	PF	WATTS	VA	PRI LOSS	SEC LOSS	IRON LOSS	F W LOSS

MODEL NO. 121-1198	E	25.100	R1	0.096	XO	4.761	F AND W-SYNC	56.000
CALC. NO. 21	PHI	3.000	R2	0.160	KP	0.909		
SEPT 28, 1967	RPM-SYNC	12000.000	X	0.985	FE LOSS	43.073		

APPENDIX C

MOTOR TEST DATA

TABLE C1

PERFORMANCE TEST DATA - MODEL 115146-100
AT 39.VOLTS, 400.CYCLES, 3 PHASE

PROTOTYPE MOTOR

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C
0.	11980.	0.	32.00	0.	4.583	10.3	0.002	309.6	32.0	42.
0.500	11820.	0.094	102.00	68.6	4.803	31.4	0.015	324.5	32.0	43.
1.000	11640.	0.185	176.00	78.3	5.347	48.7	0.030	361.2	38.2	46.
1.500	11450.	0.273	256.00	79.4	6.300	60.2	0.046	425.6	52.6	47.
2.000	11220.	0.356	336.00	79.1	7.380	67.4	0.065	498.5	70.3	49.
2.500	10890.	0.432	424.00	76.0	8.947	70.2	0.092	604.3	101.6	50.

PULL-OUT-TORQUE IS 3.50 LB.IN.

REGULAR SKEW (.094)

TABLE C2

PROTOTYPE MOTOR

AC MOTOR SEPARATION OF LOSSES

MODEL NUMBER 115146-100

PROJECT NUMBER 852202-1

DATE 5-9-68 TEST NO 2 TESTER KADES

NO LOAD SATURATION WET MOTOR
SINE WAVE INPUT 400 CPS (.094 SKEW)

STATOR RES, COLD 0.166 STACK 1.125 SYNC RPM 12000.

RATED VOLTAGE 46.50 BT RATED 90.0 F+W 47.00

VOLTS LINE	AMPS AVG	VOLT AMPS	POWER FACTOR	*	WATTS LOSS TOTAL	COPPER	F+W	IRON	*	TOOTH DENS	WTS/IN IRON
55.0	8.67	825.6	13.8	*	114.0	39.9	47.0	27.1	*	106.5	24.1
50.0	6.91	598.1	15.4	*	92.0	25.4	47.0	19.6	*	96.8	17.4
45.0	5.68	442.7	18.1	*	80.0	17.2	47.0	15.8	*	87.1	14.0
40.0	4.75	328.8	20.1	*	66.0	12.1	47.0	6.9	*	77.4	6.2
35.0	4.07	246.5	24.3	*	60.0	8.9	47.0	4.1	*	67.7	3.7
30.0	3.44	178.7	31.3	*	56.0	6.3	47.0	2.7	*	58.1	2.4

TABLE C3

RECORD SHEET

Pg 1 of 1
104081A
MK-JP
9/18/67

Purpose: CHECK DISCONNECT Model: 21000/ Type: NASA LEWIS Serial No: 1687 Date: 9/18/67

PLUG FOR CROSSTALK BETWEEN THERMOCOUPLE PINS, POWER PINS AND RPM PICKUP PINS. SPECIAL PLUG MS3102A & MATING PLUG WITH PINS FOR THERMOCOUPLE OF IRON CONS. MTL.

THIS UNIT HAS DEFECTIVE ROTOR BUT WAS USED TO DETERMINE IF CROSSTALK WAS PRESENT. MOTOR RUN NO LOAD.

				x5			x5		PICKUP COUNTER	STROBE
TIME	HZ	E	IA	IB	IC	WA	WB	WC	RPM	RPM
START	400	200	4.22	442	4.22	19	60	42	7970	7960
5 MIN	"	"	4.16	4.36	4.16	16	57	36	7970	7970
10 MIN			4.16	4.33	4.15	16	56	36	7970	7970

SHUT OFF: NO SIGNS OF CROSS TALK; SPEED PICKUP TRACKING STROBE RPM; AND THERMOCOUPLE READINGS SHOWED NO CHANGE DUE TO POWER LEAD & PICKUP LEAD PROXIMITY.

PHASE RESISTANCE @ 72 °F = .071 Ω M TO L (A)
" " " = .073 Ω N TO L (B)
" " " " = .075 Ω K TO L (C)

PHASE RESISTANCE DIRECTLY AFTER SHUT OFF M TO L (A)
@ 30 SEC = .091 Ω
@ 1 MIN 0 SEC = .081 Ω
@ 1 MIN 20 SEC = .080 Ω
@ 1 MIN 40 SEC = .080 Ω

THERMOCOUPLE LEGEND
#1 & #5 = STATOR END TURN
#2, 3, 4 = STATOR END TURN
#6 = ROOM AMBIENT.

SPEEDOMAX CHART FINAL TEMPERATURES @ SHUT OFF
END TURN #1 & 5 = 167 °F
END TURN #2, 3, 4 = 162 °F
ROOM AMB. #6 = 72 °F

TABLE C4

RECORD SHEET
(TYPICAL)

104081·A
J.V.

Purpose: DIELECTRIC, INSULATION RESISTANCE TEST AND CONTINUITY PER T.R. 700 REV. B AND PARA. 5.1 OF E.R. 5289, REV A   Model: 115146-100   Type: BRAYTON CYCLE   Serial No: X·2149·A   Date: 7·2·69

STATOR S/N 7   ROTOR S/N 3

PARA. 2.5.2   INSULATION RESISTANCE @ 50 V.D.C.

INSTRUMENT PLUG PIN A TO CASE = 200,000 MEGOHMS
" " " B " " = "
" " " C " " = "
" " " D " " = "
" " " E " " = "
" " " F " " = "
" " " G " " = "
" " " H " " = "
" " " J " " = "
INSTRUMENT PLUG PIN K TO CASE = 200,000 MEGOHMS

POWER PLUG PIN A TO CASE = 100,000 MEGOHMS
" " " B " " = 100,000 "
" " " C " " = 100,000 "
" " " D " " = 100,000 "
POWER PLUG PIN E TO CASE = 200,000 MEGOHMS

PINS F·G = PICK UP COIL RESISTANCE = 110 OHMS @ 81 °F

THERMOCOUPLE CONTINUITY = A·B = OK
C·D = OK

WINDING RESISTANCE A·D = .205 OHMS @ 81 °F
B·D = .206 OHMS @ 81 °F
C·D = .206 OHMS @ 81 °F

PARA. 2.5.1 DIELECTRIC CHECK (POWER CONNECTOR ONLY)
POWER PLUG PINS TO CASE @ 1500 V.R.M.S. - 60 Hz
FOR 1 MINUTE = .41 M.A. NO BREAKDOWN.

TABLE C5

RECORD SHEET

P9 1 of 1
104081A
MK

Purpose: TEST PER BRAYTON CYCLE MOTOR TEST SPEC. TR-700 REV. B Model: 115146-100 Type: BRAYTON CYCLE Serial No: X 2149 Date: 3-3-69

STATOR S/N 7 — 1.0" TORQUE ARM
ROTOR S/N 3

M NASA 43

PAR. 2.5.2 INSULATION RESISTANCE & CONTINUITY CHECK

INSTRUMENT PLUG PIN A TO CASE = 150,000 MEG Ω
" " " B " " = " "
" " " C " " = " "
" " " D " " = " "
" " " E " " = " "
" " " F " " = " "
" " " G " " = " "
" " " H " " = " "
" " " J " " = " "
" " " K " " = 150,000 MEG Ω ; PICKUP COIL RES. = 120 Ω

WINDING RESISTANCE A-D = .205 Ω B-D = .206 Ω C-D = .206 Ω ; THERMOCOUPLE CONTINUITY A-B = O.K., C-D = O.K.

POWER PLUG PIN A TO CASE = 150,000 MEG Ω
" " " B TO CASE = 150,000 MEG Ω
" " " C TO CASE = 150,000 MEG Ω
" " " D TO CASE = 150,000 MEG Ω
" " " E TO CASE = 150,000 MEG Ω

PAR. 2.5.1 DIELECTRIC CHECK (POWER CONNECTOR ONLY)
POWER PLUG PINS TO CASE; 1500 V. R.M.S. 60 HZ FOR 1 MINUTE = 0.28 MA ; NO BREAKDOWN

PAR. 2.5.3.1 CALIBRATION (SUBMERGED IN DC 200)

	WT. LBS.	E_{A-B} MOTOR	$E_{D.C.}$ INVERTER	I_A x2	I_B x2	I_C x2	W_A x2	W_B x2	W_C x2	RPM	A-B °F	C-D °F
	0	38.8	52.2	2.48	2.45	2.37	12	13	12	11880	77	77
	1	"	54.5	3.09	3.03	2.97	37	37	36	11550	78	78
	2	"	56.2	4.30	4.27	4.15	64	64	64	11150	92	92
L.R.	1.45	"	54.6	4.27 x5	4.27 x5	4.22 x5	35 x5	40 x5	35 x5	0	100	100

PAR 2.5.3.2 NO LOAD DRY - FLUID ON BRGS ONLY.

0	38.8	51.7	2.42 x2	2.40 x2	2.38 x2	8 x2	9 x2	8 x2	11940	102	102

PAR 2.5.4 ROTATION: CW DRIVE END

TABLE C6

PERFORMANCE TEST DATA - MODEL 115146-100
AT 39. VOLTS 400. CYCLES 3. PHASE

PROJECT 104081 A

DATE OF TEST 10/1/68 TEST NUMBER 1. TESTER KADES

X-2143
EXC 711

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C	
0.	11930.	0.	46.00	0.	4.300	15.9	0.006	289.0	46.0	38.	DRY
0.	11930.	0.	68.00	0.	4.567	22.2	0.006	306.9	68.0	39.	DRY
0.	11880.	0.	82.00	0.	4.580	26.6	0.010	307.8	82.0	33.	WET
1.000	11560.	0.183	223.00	61.4	5.813	57.1	0.037	390.7	86.1	36.	
2.000	11140.	0.354	394.00	67.0	8.400	69.8	0.072	564.5	130.2	39.	
1.440	0.	0.	570.00	0.	21.533	39.4	1.000	1447.1	570.0	44.	

TABLE C7

PERFORMANCE TEST DATA - MODEL 115146-100
AT 39. VOLTS 400. CYCLES 3. PHASE

PROJECT 104081 A

DATE OF TEST 10/10/68 TEST NUMBER 2. TESTER KADES

X-2144
EXC713

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C	
0.	11990.	0.	36.00	0.	4.573	11.7	0.001	307.3	36.0	46.	DRY
0.	11900.	0.	78.00	0.	4.640	25.0	0.008	311.8	78.0	33.	WET
1.000	11590.	0.184	230.00	59.7	5.973	57.3	0.034	401.4	92.8	34.	
2.000	11150.	0.354	404.00	65.4	8.480	70.9	0.071	569.9	139.9	37.	
1.580	0.	0.	605.00	0.	21.733	41.4	1.000	1460.5	605.0	48.	

PULL-OUT-TORQUE IS 1.95 LB.IN. AT 8000. RPM @ 33.8 VOLTS

TABLE C8

PERFORMANCE TEST DATA - MODEL 115146-100
AT 39. VOLTS 400. CYCLES 3. PHASE

PROJECT 104081-A

DATE OF TEST 11-19-68 TEST NUMBER 4 TESTER KADES

BRAYTON CYCLE
STATOR S-4 ROTOR R-14 S/N 2145

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C	
0.	11990.	0.	38.00	0.	4.573	12.4	0.001	307.3	38.0	34.	UNIT DRY Fluid on Brg. only
0.	11900.	0.	76.00	0.	4.693	24.1	0.008	315.4	76.0	34.	WET
1.000	11570.	0.184	227.00	60.4	5.987	56.4	0.036	402.3	90.0	28.	
2.000	11150.	0.354	390.00	67.7	8.487	68.4	0.071	570.3	125.9	29.	
1.470	0.	0.	540.00	0.	21.400	37.5	1.000	1438.1	540.0	33.	
1.720	0.	0.	540.00	0.	21.533	37.3	1.000	1447.1	540.0	37.	

TABLE C9

PERFORMANCE TEST DATA - MODEL 115146
AT 39. VOLTS 400. CYCLES 3. PHASE

PROJECT 104081

DATE OF TEST 1/10/69 TEST NUMBER 1 TESTER KADES

BRAYTON CYCLE
X 2146

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C	
0.	11950.	0.	36.00	0.	4.800	11.2	0.004	322.6	36.0	45.	FLUID ON BRG. ONLY
0.	11890.	0.	66.00	0.	4.873	20.2	0.009	327.5	66.0	34.	
1.000	11560.	0.183	222.00	61.7	6.087	54.3	0.037	409.0	85.1	39.	
2.000	11220.	0.356	382.00	69.6	8.433	67.4	0.065	566.7	116.3	38.	
1.520	0.	0.	545.00	0.	21.667	37.4	1.000	1456.0	545.0	42.	

TABLE C10

PERFORMANCE TEST DATA - MODEL 115146
AT 39. VOLTS 400. CYCLES 3. PHASE

PROJECT 104081

DATE OF TEST 1/17/69 TEST NUMBER 1 TESTER KADES

BRAYTON CYCLE
X 2147

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C	
0.	11960.	0.	34.00	0.	4.400	11.5	0.003	295.7	34.0	38.	FLUID ON BRG. ONLY
0.	11880.	0.	70.00	0.	4.487	23.2	0.010	301.5	70.0	29.	
1.000	11560.	0.183	220.00	62.2	5.753	56.9	0.037	386.6	83.1	32.	
2.000	11110.	0.353	392.00	67.1	8.340	69.9	0.074	560.5	128.9	36.	
1.600	0.	0.	540.00	0.	21.167	38.0	1.000	1422.4	540.0	43.	

TABLE C11

PERFORMANCE TEST DATA - MODEL 115146
AT 39. VOLTS 400. CYCLES 3. PHASE

PROJECT 104081

DATE OF TEST 2/11/69 TEST NUMBER 1 TESTER KADES

BRAYTON CYCLE
X 2148

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C	
0.	11930.	0.	48.00	0.	4.920	14.5	0.006	330.6	48.0	37.	FLUID ON BRG. ONLY
0.	11860.	0.	80.00	0.	4.967	24.0	0.012	333.8	80.0	28.	
1.000	11560.	0.183	225.00	60.8	6.060	55.2	0.037	407.2	88.1	31.	
2.000	11160.	0.354	386.00	68.5	8.327	69.0	0.070	559.6	121.7	33.	
1.620	0.	0.	615.00	0.	22.167	41.3	1.000	1489.6	615.0	41.	

TABLE C12

PERFORMANCE TEST DATA - MODEL 115146

AT 39. VOLTS 400. CYCLES 3. PHASE

PROJECT 104081

DATE OF TEST 3/3/69 1 TEST NUMBER TESTER KADES

BRAYTON CYCLE
X 2149

TORQUE LB-IN	RPM	HP	WATTS INPUT	EFF	AMPS	POWER FACTOR	SLIP	VOLT AMPS	WATTS LOSS	TEMP DEG C
0.	11940.	0.	50.00	0.	4.813	15.5	0.005	323.5	50.0	39. FLUID ON BRG. ONLY
0.	11880.	0.	74.00	0.	4.867	22.6	0.010	327.0	74.0	25.
1.000	11550.	0.183	220.00	62.2	6.060	54.0	0.037	407.2	83.2	26.
2.000	11150.	0.354	386.00	68.4	8.480	67.7	0.071	569.9	121.9	33.
1.450	0.	0.	550.00	0.	21.267	38.5	1.000	1429.2	550.0	38.

APPENDIX D DISASSEMBLY INSPECTION DIMENSIONAL RECORD	IDR No. ____ Issued ____ Revision ____ Page ____ of ____ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100	Eng. Appv. [illegible]
Pesco Part No. 101-688 Rev. A	Q. C. Appv. [illegible]
Part Name DIFFUSER ASSY, PUMP	Inspected by F 7
Serial No. [illegible]	Date [illegible]

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
BEARING I.D. "Y" DIAMETER	D-6	.3663 - .3661	.3662
~~BEARING BORE I.D.~~	~~D-6~~	~~.8755 - .8750~~	
"Z" PILOT DIAMETER	E-6	2.6250 - 2.6245	2.6248
PILOT DIA. FOR IMPELLER COVER	D-4	2.1420 - 2.1415	2.1417
SQUARENESS OF DIFFUSER BACK FACE TO "Z" & "Y" DIA'S	B-4	.0005 F.I.R.	.0002
IMPELLER WEAR RING I.D.	D-4	.760 - .759	.7594 - .7599
CONCENTRICITY BETWEEN "Y" AND "Z" DIAMETERS	C-7	.0005 F.I.R.	.0005
BEARING FACES SQUARE TO "Y" DIAMETER	E-6	.0005 TOTAL	.0001
CONCENTRICITY BETWEEN WEAR RING I.D. AND "Z" DIA.	C-4	.0005 F.I.R.	.0005
CONCENTRICITY BETWEEN PILOT DIAMETER AND "Z" DIA.	C-4	.0005 F.I.R	.0005

Remarks:

UNIT SERIAL NO. X 2149-A
FOLLOWING 250 HR. ENDURANCE TEST
THRUST BRG. FACE LOCATION (E-5) .812 - .809 = .812
THRUST BRG. FACE LOCATION (E-5) 1.158 - 1.155 = 1.157

PPD-933

INSPECTION DIMENSIONAL RECORD	IDR No. Issued Revision Page ___ of ___ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100	Eng. Appv.
Pesco Part No. 121-1211 Rev. A	Q. C. Appv.
Part Name ROTOR, MOTOR, COMPLETE	Inspected by
Serial No. 9	Date

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
SHAFT PILOT "Y" DIAMETER	B-4	.2807 - .2804	.2805
BEARING JOURNAL "Z" DIA.	B-4	.3650 - .3648	.365
BEARING JOURNAL "X" DIA.	B-7	.3000 - .2998	.2999 - 3000
FINISH ON "Z" DIAMETER	B-4	2√	3√ TO 6√
FINISH ON "X" DIAMETER	B-7	2√	2√
CONCENTRICITY BETWEEN	B-8	.0005 T.I.R.	.0005
"Y" AND "Z" DIAMETERS			
CONCENTRICITY BETWEEN	B-8	.0005 T.I.R.	.0005
"X" AND "Z" DIAMETERS			
SQUARENESS OF SHAFT	C-3	.0005 TOTAL	.0001
SHOULDER TO "Y" DIAMETER			
SQUARNESS OF SHAFT	C-4	.0005 TOTAL	.00005
SHOULDER TO "Z" DIAMETER			

Remarks: UNIT SERIAL NO. X 2149-A FOLLOWING 250 HR. ENDURANCE TEST.

INSPECTION DIMENSIONAL RECORD	IDR No. Issued Revision Page ___ of ___ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1
Pesco End Item Part No. 115146-100 Pesco Part No. 01-13832 Rev. Part Name WASHER, THRUST Serial No. 9	Eng. Appv. Q. C. Appv. Inspected by P 7 Date

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish	
		Drawing	Actual
WASHER WIDTH	C-3	.126-.125	.1257
FINISH ON WASHER FACES	D-4	4√	2√
FLATNESS OF WASHER FACES	D-3	.0000464 TOTAL	.000023
PARALLELISM OF WASHER FACES	D-3	.0005 TOTAL	.0004

Remarks: UNIT SERIAL NO. X 2149-A FOLLOWING 250 HR. ENDURANCE TEST.

INSPECTION DIMENSIONAL RECORD	IDR No. ____ Issued ____ Revision ____ Page ____ of ____ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100	Eng. Appv.
Pesco Part No. 01-13833 Rev.	Q. C. Appv.
Part Name WASHER THRUST	Inspected by (7)
Serial No. 15	Date

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
WASHER WIDTH	C-3	.181 - .180	.1807
FINISH ON WASHER FACES	B-4	4	3
FLATNESS OF WASHER FACES	B-3	.0000464 TOTAL	.000023
PARALLELISM OF WASHER FACES	B-3	.0005 TOTAL	.00025

Remarks: UNIT SERIAL NO. X 2149-A FOLLOWING 250 HR. ENDURANCE TEST.

INSPECTION DIMENSIONAL RECORD Unit S/N X 2149-A	IDR No. ______ Issued ______ Revision ______ Page ______ of ______ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1
Pesco End Item Part No. 115146-100	Eng. Appv. [signature] 4/24/70
Pesco Part No. 101-688 Rev. A	Q. C. Appv. P 85
Part Name Diffuser Assy, Pump	Inspected by P 7
Serial No. S/N # 9	Date [illegible]

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish	
		Drawing	Actual
Bearing I.D. "Y" Diameter	D-6	.3663 - .3661	.3662 - .3663
~~Bearing Bore I.D.~~	~~D-6~~	~~.8755 - .8750~~	This dim. to be omitted
"Z" Pilot Diameter	E-6	2.6250 - 2.6245	2.6248 - 2.625
Pilot Dia. for Impeller Cover	D-4	2.1420 - 2.1415	2.142
Squareness of Diffuser Back Face to "Z" & "Y" Dia's	B-4	.0005 F.I.R.	.0001
Impeller Wear Ring I.D.	D-4	.760 - .759	.7592
Concentricity Between "Y" and "Z" Diameters	C-7	.0005 F.I.R.	.0002
Bearing Faces Square to "Y" Diameter	E-6	.0005 Total	.0003
Concentricity Between Wear Ring I.D. and "Z" Dia.	C-4	.0005 F.I.R.	.0004
Concentricity Between Pilot Diameter and "Z" Dia.	C-4	.0005 F.I.R	.0003

Remarks:

Following 5000 Hr Endurance Test

Thrust Brg. Face Location (E-5) .812 - .809 = .81[illegible]

Thrust Brg. Face Location (E-5) 1.158 - 1.155 = 1.15[illegible]

PPD-933

INSPECTION DIMENSIONAL RECORD UNIT S/N X-2149-A	IDR No. ______ Issued ______ Revision ______ Page ______ of ______ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1
Pesco End Item Part No. 115146-100	Eng. Appv. [signature] 4/24/70
Pesco Part No. 121-1211 Rev. A	Q. C. Appv. P 85
Part Name ROTOR, MOTOR, COMPLETE	Inspected by P 7
Serial No. S/N 9	Date 4/24/70

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual	
SHAFT PILOT "Y" DIAMETER	B-4	.2807 - .2804	.2805 - .28055	P 7
BEARING JOURNAL "Z" DIA.	B-4	.3650 - .3648	.36495	P 7
BEARING JOURNAL "X" DIA.	B-7	.3000 - .2998	.2999 - .29995	P 7
FINISH ON "Z" DIAMETER	B-4	2 √	3 √	
FINISH ON "X" DIAMETER	B-7	2 √	6 √	
CONCENTRICITY BETWEEN "Y" AND "Z" DIAMETERS	B-8	.0005 T.I.R.	.00015	
CONCENTRICITY BETWEEN "X" AND "Z" DIAMETERS	B-8	.0005 T.I.R.	.00035	P 7
SQUARENESS OF SHAFT SHOULDER TO "Y" DIAMETER	C-3	.0005 TOTAL	.00015	P 7
SQUARNESS OF SHAFT SHOULDER TO "Z" DIAMETER	C-4	.0005 TOTAL	.0002	

Remarks: UNIT S/N 2149-A FOLLOWING 5000 HR. ENDURANCE TEST

INSPECTION DIMENSIONAL RECORD	IDR No. ___ Issued ___ Revision ___ Page ___ of ___
Unit S/N X-2147-A	NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100	Eng. Appv. 4/24/70
Pesco Part No. 01-13832 Rev.	Q. C. Appv. P 85
Part Name WASHER, THRUST	Inspected by P 7
Serial No. 9	Date

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
WASHER WIDTH	C-3	.126-.125	.1257
FINISH ON WASHER FACES	D-4	4✓	9✓
FLATNESS OF WASHER FACES	D-3	.0000464 TOTAL	.000036
PARALLELISM OF WASHER FACES	D-3	.0005 TOTAL	.00045

Remarks:

Following 5000 Hr Endurance Test

INSPECTION
DIMENSIONAL
RECORD

Unit S/N X 2149-A

IDR No.
Issued
Revision
Page ____ of ____

NASA BRAYTON CYCLE PROGRAM
MODEL NO: 115146-100
REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100
Pesco Part No. 01-13835 Rev.
Part Name WASHER, THRUST
Serial No. 15

Eng. Appv. [signature] 4/24/72
Q. C. Appv. P 85
Inspected by P 7
Date

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
WASHER WIDTH	C-3	.181 - .180	.1804
FINISH ON WASHER FACES	B-4	4√	6√
FLATNESS OF WASHER FACES	B-3	.0000464 TOTAL	.000026
PARALLELISM OF WASHER FACES	B-3	.0005 TOTAL	.000020

Remarks:
Following 5000 Hr. Endurance Test

INSPECTION DIMENSIONAL RECORD	IDR No. ____ Issued ____ Revision ____ Page ____ of ____ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100	Eng. Appv.
Pesco Part No. 101-688 Rev. A	Q. C. Appv.
Part Name Diffuser Assy, Pump	Inspected by
Serial No. X-2149-B	Date

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish	
		Drawing	Actual
Bearing I.D. "Y" Diameter	D-6	.3663 - .3661	.3662
~~Bearing Bore I.D.~~	~~D-6~~	~~.8755 - .8750~~	
"Z" Pilot Diameter	E-6	2.6250 - 2.6245	2.6248
Pilot Dia. For Impeller	D-4	2.1420 - 2.1415	2.1416
Cover			
Squareness of Diffuser	B-4	.0005 F.I.R.	.0005
Back Face to "Z" & "Y" Dia's			
Impeller Wear Ring I.D.	D-4	.760 - .759	.7595
Concentricity Between	C-7	.0005 F.I.R.	.0005
"Y" and "Z" Diameters			
Bearing Faces Square	E-6	.0005 Total	.0003
to "Y" Diameter			
Concentricity Between Wear	C-4	.0005 F.I.R.	.0005
Ring I.D. and "Z" Dia.			
Concentricity Between Pilot	C-4	.0005 F.I.R.	.0005

Diameter and "Z" Dia.

Remarks:

Thrust Brg. Face Location (E-5) .812 - .809 = .8102

Thrust Brg. Face Location (E-5) 1.158 - 1.155 = 1.157

PPD-933

INSPECTION DIMENSIONAL RECORD	IDR No. ___ Issued ___ Revision ___ Page ___ of ___ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End-Item Part No. 115146-100	Eng. Appv.
Pesco Part No. 121-1211 Rev. A	Q. C. Appv.
Part Name ROTOR, MOTOR, COMPLETE	Inspected by
Serial No. X-2149-B	Date 4/24/72

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
SHAFT PILOT "Y" DIAMETER	B-4	.2807 - .2804	.2804
BEARING JOURNAL "Z" DIA.	B-4	.3650 - .3648	.3650
BEARING JOURNAL "X" DIA.	B-7	.3000 - .2998	.2999
FINISH ON "Z" DIAMETER	B-4	2√	2√
FINISH ON "X" DIAMETER	B-7	2√	2√
CONCENTRICITY BETWEEN	B-8	.0005 T.I.R.	.0002
"Y" AND "Z" DIAMETERS			
CONCENTRICITY BETWEEN	B-8	.0005 T.I.R.	.0002
"X" AND "Z" DIAMETERS			
SQUARENESS OF SHAFT	C-3	.0005 TOTAL	.0005
SHOULDER TO "Y" DIAMETER			
SQUARENESS OF SHAFT	C-4	.0005 TOTAL	
SHOULDER TO "Z" DIAMETER			.0005

Remarks:

INSPECTION DIMENSIONAL RECORD	IDR No. ___ Issued ___ Revision ___ Page ___ of ___ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100	Eng. Appv.
Pesco Part No. 01-13832 Rev.	Q. C. Appv.
Part Name WASHER, THRUST	Inspected by
Serial No. X-2149-B	Date

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
WASHER WIDTH	C-3	.126-.125	.1256
FINISH ON WASHER FACES	D-4	4√	4√
FLATNESS OF WASHER FACES	D-3	.0000464 TOTAL	.0000464
PARALLELISM OF WASHER FACES	D-3	.0005 TOTAL	.000005

Remarks:

AFTER 20,000 HR. ENDURANCE TEST

INSPECTION DIMENSIONAL RECORD	IDR No. Issued Revision Page ____ of ____ NASA BRAYTON CYCLE PROGRAM MODEL NO: 115146-100 REFERENCE: 12QC-112-1

Pesco End Item Part No. 115146-100	Eng. Appv.
Pesco Part No. 01-13833 Rev.	Q. C. Appv.
Part Name WASHER, THRUST	Inspected by (P 7)
Serial No. S/N X-2149-B	Date 4/25/72

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Dimensional Tolerance - Concentricity - Finish: Actual
WASHER WIDTH	C-3	.181 - .180	.1805 (P 7)
FINISH ON WASHER FACES	B-4	4√	2√ (P 7)
FLATNESS OF WASHER FACES	B-3	.0000464 TOTAL	.0000464 (P 7)
PARALLELISM OF WASHER FACES	B-3	.0005 TOTAL	.000005 (P 7)

Remarks:

AFTER 20,000 HR. ENDURANCE TEST

INSPECTION DIMENSIONAL RECORD	IDR No. ___ Issued ___ Revision ___ Page ___ of ___

Pesco End Item Part No. 115146-100	Eng. Appv.
Pesco Part No. 101-687 Rev. B	Q. C. Appv.
Part Name COVER ASSY, MOTOR.	Inspected by P 7
Serial No. X-2149-B	Date 5/10/72

Dimensional Description	Zone	Dimensional Tolerance - Concentricity - Finish: Drawing	Actual
BEARING I.D.	B-5	.3013 - .3011	3012 P 7
BEARING BORE I.D	B-5	.5630 - .5625	N.A.
"Z" PILOT DIAMETER	C-5	3.1250 - 3.1245	N.A.
CONCENTRICITY OF BEARING	B-5	.0005 T.I.R.	N.A.
I.D. WITH "Z" DIAMETER			
SQUARENESS OF COVER FRONT	B-6	.0005 TOTAL	N.A.
FACE WITH "Z" DIAMETER			

Remarks:
AFTER 20,000 HR. ENDURANCE TEST

PPD-933

APPENDIX E
RELIABILITY ANALYSIS DATA

1. FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal
Sub-Assembly Number Sub-Assembly Name Pump
S/A Mission Time

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. $X10^{-6}$	Mod.	Total F.R. $X10^{-6}$	Reference
1) Housing-Assy	101-684	1	Housing					
Pump			1) Fatigue		0.3	1.2	0.36	Mat: Steel, CRES per
			2) Plas. Def.		0.2	1.2	0.24	QQ-S-763, Class 304L
								Cond. A.
2) Cover-Assy	101-680	1	Cover					
Connector			1) Fatigue		0.03	1.2	0.036	Mat: Steel, CRES per
			2) Plas. Def.		0.03	1.2	0.036	QQ-S-763, Class 304L
			3) Change of Pos.		0.03	1.2	0.036	Cond. A.
3) Cover-Filter	01-13831	1	Cover					
			1) Fatigue		0.03	1.2	0.036	
			2) Plas. Def.		0.03	1.2	0.036	
			3) Change of Pos.		0.03	1.2	0.036	
4) Orifice	01-13837	1	Flapper/Orifice					
			1) Erosion		0.2	1.0	0.2	Results only in increased
								bypass flow. Not serious.

FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal
Sub-Assembly Number ______ Sub-Assembly Name Pump
S/A Mission Time ______

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. X10-6	Mod.	Total F.R. $X10^{-6}$	Reference
5) Ports-Inlet,		2	Tube					
Outlet			1) All (Fatigue or		0.20	1.0	0.2	
			rupture, Plas. Def.)					
6) Weld-Joints		9	Weld Joint					
			1) Fatigue		0.10	1.0	0.90	Helium leak detector tests
			2) Imperfect Seal		0.40	0.3	1.08	to be performed before
								accepting.
7) Strainer-Element	01-13838	1	Filter Element					
Sediment			1) Foul		2.0	1.0	2.0	Denver Martin Hndbk-
			2) Fatigue		0.2	1.0	0.2	Failure Rates- .045 with
								Ka = 10.
8) Packing-Preformed	99-4346-19	2	O-Rings-Static					
			1) Change of Prop.		0.5	0.5	0.50	
			2) Extrude		0.1	0.3	0.06	
			3) Damage at Assy		0.2	1.0	0.40	

FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal
Sub-Assembly Number Sub-Assembly Name Pump
S/A Mission Time

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. $X10^{-6}$	Mod.	Total F.R. $X10^{-6}$	Reference
9) End-Cover	01-13811	1	Cover					
Impeller			1) Fatigue		0.03	1.2	0.036	Very low coefficient of
			2) Plas. Def.		0.03	1.2	0.036	thermal expansion.
			3) Change of Pos.		0.03	1.2	0.036	
10) Screw-Cap	NA51352	4	Screws					
Socket-Head	C06-8		1) All		0.10	0.5	0.15	Parallel redundancy two or
								more screws damaged.
11) Impeller	01-13830	1	Impeller					
			1) Erosion		0.02	4.66	0.093	
			2) Overstress		0.1	1.0	0.10	
12) Diffuser-Assy	101-688	1	Impingement Plate					
			1) Abrasion		0.02	9.6	0.192	
			2) Overstress		0.02	6.7	0.134	
13) Spacer		1	Spacer					
			1) Fatigue		0.03	1.0	0.03	
			2) Plas. Def.		0.03	1.0	0.03	
14) Shaft	21-1210	1	Shaft					Failure rates for shaft journal
			1) Fatigue		0.2	0.1	0.02	elements incorporated
			2) Shear		0.2	0.1	0.02	

FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal
Sub-Assembly Number ______ Sub-Assembly Name Pump
S/A Mission Time ______

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. $X10^{-6}$	Mod.	Total F.R. $X10^{-6}$	Reference
15) Thread	21-1210	1	Thread					
			Plas. Def., Change		0.4	0.5	0.2	Rate with journal bearing
			of Pos.					failure rates.
16) Washer, Flat	AN960C8	1	Washer, All		0.03	1.0	0.03	
17) Nut, Self-Locking	MS21046	1	Locknut					
	C08		All		0.1	1.0	0.1	
18) Washer-Thrust	01-13833	1	Washer, Thrust					
			1) Abrasion		0.03	1.0	0.03	
19) Pin-Straight	MS16555	1	Pin					
Headless	620		1) Fatigue		0.1	0.1	0.01	
			2) Shear		0.1	0.1	0.01	
20) Cover-Assy Motor	101-687	1	Cover					
			1) Fatigue		0.03	1.2	0.036	
			2) Plas. Def.		0.03	1.2	0.036	
			3) Change of Pos.		0.03	1.2	0.036	

FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal
Sub-Assembly Number ______ Sub-Assembly Name Pump
S/A Mission Time ______

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. $X10^{-6}$	Mod.	Total F.R. $X10^{-6}$	Reference
21) Locknut-Assy	101-692	3	Locknut					
			1) All		0.1	0.1	0.02	Parallel Redundancy.
22) Washer-Flat	AN960C8	3	Washer					
			1) Fatigue		0.03	0.5	0.03	Parallel Redundancy.
			2) Plas. Def.		0.03	0.5	0.03	
23) Screw-Machine	MS35275	3	Screws	3				
Fillister Head	-257		1) All		0.1	0.1	0.02	Parrallel Redundancy.
								Two or more broken.
24) Screw, Cap,	NAS1352	4	Screws					
Socket Head	C06-8		1) All		0.10	0.5	0.15	Parallel Redundancy.
25) Screws-Cap	NAS1351	4	Screws					
Socket Head	C6-28		1) All		0.1	0.5	0.15	Parallel Redundancy.
26) Nut	99-2933-03	4	Nut					
			1) All	2	0.1	0.1	0.02	Parallel Redundancy.
27) Washer-Flat	AN960C616	8	Washer					
			1) Fatigue	2	0.03	0.5	0.03	Parallel Redundancy.
			2) Plastic Def.	2	0.03	0.5	0.03	

FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal

Sub-Assembly Number Sub-Assembly Name Pump

S/A Mission Time

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. $X10^{-6}$	Mod.	Total F.R. $X10^{-6}$	Reference
28) Bracket-	01-13842	1	Bracket					
Mounting	01-13843	1	1) Fatigue		0.3	1.2	0.72	
			2) Plas. Def.		0.2	1.2	0.48	

FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal
Sub-Assembly Number ______ Sub-Assembly Name Motor
S/A Mission Time ______

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. X10^{-6}	Mod.	Total F.R. X10^{-6}	Reference
MOTOR								
1) Stator-Motor	121-1212	1	Stator Assy					
			All		1.125	1	1.125	MIL-HDBK-217
2) Rotor-Motor	121-1211	1	Rotor Assy					
			All	43	0.1	1	4.5	(24 bars He-arc welded.
								Damage up to 10% of the bars
								does not affect performance.
								Pesco test data on AC motor
								Model Z1.95.)
3) Connector		1	Connector		0.3	1	0.3	
4) Journal Bearing								
Hydrodynamic								
4.1 Bearing A	01-13834		Journal Bearing					
			Abrasion		2.5	0.471	1.18	Reliability figures with loads
			Foul		0.8	1.0	0.8	of 0.155 lb. and 0.795 lb. on
								bearings A and B. Mech-
								anical failure at -100°F.
4.2 Bearing B	01-13836		Abrasion		2.5	0.505	1.263	
			Foul		0.8	1.0	0.8	

FAILURE RATE ANALYSIS

Assembly Number 115146-100 Assembly Name Pump-Motor Centrifugal
Sub-Assembly Number ______ Sub-Assembly Name Motor
S/A Mission Time ______

Part Name	Part No.	No. Req'd	Elements	No. Elem.	Elem. F.R. $X10^{-6}$	Mod.	Total F.R. $X10^{-6}$	Reference
5) Sensor-Speed					0	1.0	0	Does not affect pump
								performance.
6) Solder Joint	22-7022	1	Connector	1	.02	1	.02	40% Sn 60% Pb
Connector								Melting point 360°F.
								Flow point 460°F.

PESCO PRODUCTS DIVISION
BORG-WARNER CORPORATION
2. FAILURE MODE CAUSE ANALYSIS

PUMP-MOTOR ASSEMBLY — COMPONENT
115146-100 — PESCO PART NUMBER

FAILURE TYPE	POTENTIAL CAUSE(S) OF FAILURE TYPE			REL. PROB. OF OCCUR.	REASONS WHY FAILURE TYPE SHOULD NOT OCCUR
	PART NAME	REF. NUMBER	CAUSE		
Pump inoperative, no flow or pressure	Shaft	4.3	Fracture of shaft in fatigue or shear.	53.27%	Low stress
	Thread	4.3a	*Change of position*, impeller misalignment leading to its jamming		*MIL specifications are followed*
	Nut	4.4	Nut loosens. Impeller misalignment ending in impeller jamming.		Nut self locking
	Filter	3.1	Contamination (extreme condition) conditional.		Full flow filter 5 micron absolute. All metal. Silicon fluid is pre-filtered before it is pumped.
	Impeller	4.1	Fracture under fatigue and plastic deformation		Stainless steel.
	End Cover-Bearing	2.2	Fracture under fatigue and plastic deformation		Stainless steel.
Pump inoperative. No flow or pressure	BearingsA and B	11.a and 11.b	Bearing seizure due to half frequency whirl conditions.		*Magnetic loads on the bearings are sufficient to avoid this condition*
	Bearings A and B	11.a and 11.b	Bearing seizure due to excessive heat and lack of lubrication		Motor assembly is completely immersed in the fluid
	Bearings A and B	11.a and 11.b	Bearing seizure due to contamination (silt/size)		Fluid is filtered at least twice. Pre-filteration before pumping and the full flow filter in the assembly.
	Ports: Inlet and Outlet	7.0	Fracture of inlet and outlet pipes (conditional-complete breakage) either in pipe or at the weld joint.		Stainless steel may be used. System tested for the pressure conditions.
	Pin	6.0	Fracture under fatigue and shear (impeller rubbing)		Past experience shows the failure of such a pin is remote
Pump inoperative, no flow or pressure.	Stator-Motor	10.0	Ground- Coil to stator core. Excessive current drawn leading to inverter burn off.		Coils are separated from the core by a polymide insulation.

PESCO PRODUCTS DIVISION
BORG-WARNER CORPORATION
FAILURE MODE CAUSE ANALYSIS

PUMP-MOTOR ASSEMBLY
COMPONENT

115146-100
PESCO PART NUMBER

FAILURE TYPE	POTENTIAL CAUSE(S) OF FAILURE TYPE			REL. PROB. OF OCCUR.	REASONS WHY FAILURE TYPE SHOULD NOT OCCUR
	PART NAME	PART NUMBER	CAUSE		
	Rotor	12.0	Joint fracture (conditional- one side joint of the rotor bars disintegrating.		Helium leak test.
Leakage (External)	External Housing	1.0	Fracture under fatigue and plastic deformation or cracks.	16.9%	Stainless Steel
	End Cover Housing	2.1	Fracture under fatigue and plastic deformation or cracks.		Stainless Steel
	Weld Joints	9.0	Disintegration of welds.		He-arc weld joints. Helium leak test.
	Connector	13.0	Loss of connector-hermetic seal		Helium leak test.
	Connector	13.0	Crack in connector-cover weld.		Inert gas welded and Helium leak test.
Leakage (Internal)	End Cover-Impeller	2.3	Erosion and overstress	8.02%	Stainless Steel
	O-rings	3.2	Fracture of O-ring in extrusion, change of position etc.		L-s Florocarbon or teflon would be used and lubricated.
Low discharge and/or pressure	Filter	3.1	Filter contamination	20.9%	Pre-filtered fluid is used. Full flow filter 5 micron absolute. All metal.
	Stator	10.0	Electrical failure. Open winding		Phase continuity tests are performed during acceptance testing.
	Rotor	12.0	Crack or break al-weld joint of one or more rotor bars.		Low stress joint. Helium leak test.
	Connector	13.0	Winding fracture due to vibrations etc.		Strain relieved with silicon joint and rubber tubes.
	External Housing	1.0	Fracture under fatigue and plastic deformation, cracks, or disintegration of weld joint.		Stainless steel. Joints are He-arc welded. Helium leak test.

PESCO PRODUCTS DIVISION
BORG-WARNER CORPORATION
FAILURE MODE CAUSE ANALYSIS

PUMP-MOTOR ASSEMBLY — COMPONENT

115146-100 — PESCO PART NUMBER

FAILURE TYPE	POTENTIAL CAUSE(S) OF FAILURE TYPE			REL. PROB. OF OCCUR.	REASONS WHY FAILURE TYPE SHOULD NOT OCCUR
	PART NAME	REF. PART NUMBER	CAUSE		
Low discharge and/or pressure.	End Covers (Housing)	2.1	Leakage due to cracks		Stainless steel.
	Connector	13.0	Loss of connector hermetic seal (leakage)		Helium leak test
	Connector	13.0	Crack in connector- cover weld		Inert gas welded and helium leak test
	Impeller	4.1	Fluid erosion		Low vapor pressure fluid. Inlet pressure is greater than the vapor pressure.
	Diffuser	4.2	Blocking of diffuser holes by O-ring debris.		Extrusion of O-ring is prevented by reducing the clearance between the filter and the seat.
	Orifice Bypass	8.0	Fluid erosion		
	Diffuser	4.2	Fluid erosion of holes and enlargement.	1.91%	Low vapor pressure fluid
No effect on pump performance	Sensor	14.0	Electrical failure.		Only a speed sensor and is not a control component in the pump motor assembly.

COMPONENT RELIABILITY REPORT

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Pesco Part No. 115146-100 Customer Part No. ______

Page 1 of 8
Date Prepared ______
Date Revised ______

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. $X10^{-6}$ Hrs.	Component Output Effect (Consequence)
1.0	External Housing	Fracture	Material - Stainless steel CRES per	0.6	External leakage
		Fatigue	QQ-S-763, Class 304L Condition A		Eventual loss of
		Plas. Def.			system. Pump
					inoperative.
2.0	End Covers				
2.1	Cover-Filter	Fracture	Same as 1.0	0.108	External leakage;
		Fatigue			Greater contamination
		Plas. Def.			of filter.
2.2	Cover-Connector	Fracture	Same as 1.0	0.108	External leakage.
		Fatigue			Eventual drop in
		Plas. Def.			discharge.
2.3	Cover-Impeller	Fracture	Same as 1.0	0.108	Internal leakage.
		Fatigue			Loss in flow.
		Plas. Def.			
2.4	Cover-Motor	Fracture	Material: Stainless steel, CRES per	0.108	Bearing seizure.
		Fatigue	QQ-S-763, Class 304L Cond. A.		Eventual breakdown.
		Plas. Def.			

COMPONENT RELIABILITY REPORT

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Pesco Part No. 115146-100 Customer Part No. ______

Date Prepared ______
Date Revised ______

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. $X10^{-6}$ Hrs.	Component Output Effect (Consequence)
3.0	Filter Element:				
3.1	Filter:	Contamination:	Material: Stainless Steel Mesh-	2.2	Contamination: Low
		& Fracture	5 micron absolute and 2 micron nominal.		fluid supply.
		Foul			Fracture: Unfiltered
		Fatigue			fluid supply.
3.2	O-Rings:	Leakage:	Material: Fluorinated silicone rubber	0.96	Leakage: No effect on
		Change of Pro-	per Pesco Spec PM 5022 Class I.		pump performance.
		perty.			Fracture: Possibility
		Extrude damage			of small fractured O-
		at assembly.			ring pieces entering
					impeller.
4.0	Pump Assembly				
4.1	Impeller	Erode	Material: Aluminum or Stainless Steel	0.12	Initially: No effect.
		Overstress			Eventually: No dis-
					charge flow and pres-
					sure.
4.2	Diffuser:	Abrasion	Material: Same as Impeller	.326	Fluid flow unpredic-
		Erode			table due to enlarge-
					ment of holes or plug-
					ging with the O-ring
					material.

Date Prepared
Date Revised

COMPONENT RELIABILITY REPORT

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Pesco Part No. 115146-100 Customer Part No.

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. X10^{-6} Hrs.	Component Output Effect (Consequence)
4.3	Shaft:	Fracture:	Chrome-moly steel- heat treated.	0.04	Pump inoperative.
		Fatigue	Low stress level.		Half frequency whirl:
		Shear			Pump inoperative.
4.4	Thread:	Plastic deformation.	Torquing controlled by torque wrenches.	0.2	Impeller misalignment and excessive wear.
		Change of position.			
4.5	Locknut	All	MIL - all metal self-locking.	0.1	Impeller wear.
4.6	Washer	Fatigue	Low stress level.	0.03	Impeller wear.
		Plastic deformation			

COMPONENT RELIABILITY REPORT

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Pesco Part No. 115146-100 Customer Part No.

Date Prepared
Date Revised

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. $X10^{-6}$ Hrs.	Component Output Effect (Consequence)
5.0	Screws, Nuts & Washers:				
5.1	Screws Cap Socket head-Impeller Cover	All (Fatigue shear, plastic deformation)	MIL-STD Screws	0.15	Excessive impeller wear. Unit noisy and loss in flow.
5.2	Screws Cap, Socket head- Motor Cover	All (Fatigue Shear, plastic deformation)	MIL-STD Screws	0.15	Bearing seizure and pump inoperative.
5.3	Screw-Machine fillister-head	All (Fatigue shear, plastic deformation)	MIL-STD Screws	0.02	Motor shorted. Pump inoperative.
5.4	Lock Nuts	All (Fatigue shear, plastic deformation.	MIL-STD	0.02	Same as 5.3
5.5	Washer-Flat (Screw-machine fillister head)	Fracture: Fatigue Plas. def.	Low stress level.	0.06	No serious effect. Eventually air gap reduces and motor performance varies.

COMPONENT RELIABILITY REPORT

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Pesco Part No. 115146-100 Customer Part No. ______

Date Prepared ______

Date Revised ______

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. $X10^{-6}$ Hrs.	Component Output Effect (Consequence)
5.6	Screws-Name Plate	Fracture		0	No effect on pump performance. Name plate would come loose.
5.7	Screws-Cap Socket Head (Bracket Mounting)	Fracture Shear	Low load.	0.15	Pump will fall off the mounting. Pump inoperative.
5.8	Nut - Bracket Mounting Screws	All	Low load.	0.02	Same as 5.7.
5.9	Washer	All	Low load.	0.06	Same as 5.7.
5.10	Spacer-Impeller	Abrasion	Same as 1.0.	0.06	Impeller Wear.

COMPONENT RELIABILITY REPORT

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Pesco Part No. 115146-100 Customer Part No. ____

Date Prepared ____
Date Revised ____

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. X10^{-6} Hrs.	Component Output Effect (Consequence)
6.0	Thrust Bearing	Abrasion	Carbon bearing material. Lightly loaded.	0.03	Lateral shaft movement-Impeller wear.
7.0	Pin	Fatigue Shear	Steel-Low stress level	0.02	Misalignment of thrust Bearing, impeller wear.
8.0	Ports:Inlet and Outlet	All (Fatigue or plastic deformation)	Material: Stainless steel. Low stress level.	0.2	Loss of flow. Eventually no flow.
9.0	Orifice-Bypass	Erosion	Material: Stainless steel	0.2	Increase in flow (not a serious effect)
10.0	Weld-Joints	Fracture Fatigue Imperfect seal	Helium leak detection tested.	1.98	Excessive external leakage and ultimate breakdown.
11.0	Bracket (Mounting)	Fracture Fatigue Plas. def.		1.20	

COMPONENT RELIABILITY REPORT

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Date Prepared

Pesco Part No. 115146-100 Customer Part No.

Date Revised

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. $X10^{-6}$ Hrs.	Component Output Effect (Consequence)
	Motor Assembly				
12.0	Stator	Electrical Failure	Material: 4 Pole, 3 Phase Wye-connected Copper with Polymide Insulation - 100% dielectric testing with 1500 volts RMS for 1 minute or 1750 volts for 1 sec. & ohmic resistance testing.	1.125	Speed drops, hence discharge and pressure drops.
		Open			
		Short			Excessive current would load the inverter and burn it.
13.0	Journal Bearing				
13a	Bearing A	Abrasion	Material: Carbon - Light positive load.	1.98	Pump inoperative with no load. Only magnetic loading effective in outer space. Half frequency whirl with ultimate seizure.
		Foul	Filtered fluid to cool and lubricate bearing.		
13b	Bearing B	Abrasion	Material: Carbon	2.063	Same as Bearing A.
		Foul	Same as Bearing A		

COMPONENT RELIABILITY REPORT

Date Prepared
Date Revised

Component Nomenclature Pump-Motor (Centrifugal) Assembly

Pesco Part No. 115146-100 Customer Part No.

Ref. No.	Subassy Part	Failure Mode Process	Design Factors and Considerations	Prob. $X10^{-6}$ Hrs.	Component Output Effect (Consequence)
14.0	Rotor	Joint Fracture	Heli-arc weld.	4.5	Pressure and discharge drop due to the reduction in speed
15.0	Connector		Helium leak detector tests.	0.3	Speed drops considerably.
16.0	Sensor		Material: Plastic	0.0	Does not affect pump performance.
17.0	Solder Joint Connector	Open	40% Tin 60% Lead Solder, per Spec QQ-S-571. Form wire .09. Melting point 360°F, and flow point 460°F.	0.02	Pump inoperative.

APPENDIX F

ENGINEERING REPORT NO. 5289-B

DEVELOPMENT TEST PROGRAM PLAN
FOR
PESCO MODEL 115146-100
COOLANT CIRCULATING PUMP

FOR A

BRAYTON CYCLE SPACE POWER SYSTEM

1.0 Introduction

The test program plan described herein is prepared in compliance with Task IV of NASA Contract NAS 3-10935 for the Lewis Research Center.

2.0 Object

The object of this report is to present a developmental test program plan for Pesco Model 115146-100 coolant circulating pump for a Brayton cycle space power system.

3.0 Discussion

3.1 Components

3.1.1 Motor Description

The motor is a .60 hp, 4-pole, 3-phase, 400 cycle ac machine. The inverter input is 56 volts dc nominal with a quasi-square wave output. The motor can be operated with a sine wave input. Motor speed is approximately 11,000 rpm at rated load. The motor is equipped with thermocouples and a speed sensing device.

3.1.2 Pump Description

Pumping is provided by a radial flow impeller discharging into a radial diffuser and through the motor cavity. In this manner, the entire pump flow is used to cool the motor windings. The pump is designed to deliver 3.7 gpm flow at 60 psi minimum head. The available inlet pressure, supplied by an accumulator in the system, is 20 psia minimum. An integral two micron nominal filter in the pump inlet is designed to have a ΔP of 2.5 psi maximum (clean) at the rated 3.7 gpm flow. See Assembly Drawing 115146-100 in Appendix for pump design details.

3.2 Test Equipment

The test loop for all tests will consist of the following equipment: fluid reservoir, heat exchanger, discharge throttle valve, inlet and discharge thermocouples, inlet and discharge pressure gages, inlet pressurizing system, inlet vacuum system, filter bypass system for filling, ammeters and voltmeters, turbine flow meter, electronic counter, system clean-up filter, removable sample patch system. The piping will include provisions for the cold plate. In addition, a cold test loop will be added for low temperature tests. A test set-up schematic and equipment list is shown in the Appendix.

Equipment and instrumentation of the following accuracy shall be used in conducting tests. The frequency of instrument calibration is every three months.

Index	Equipment Identification	Accuracy Tolerance
1.	Throttle Valve	Not applicable - micro-needle
2.	Cold Plate Throttle Valve	Not applicable - micro-needle
3.	Fill Filter	5 micron nominal
4.	System Clean-up Filter	5 micron nominal
5.	Removable Sample Patch	8 micron nominal
6.	Temperature Indicator	±1% of scale
7.	Digital Counter	1 count + time base
8.	Voltmeter	±1% of F. S.
9.	Ammeter	± 1% of F. S.
10.	Wattmeter	± 1% of F. S.
11.	Dielectric Tester	
12.	Recording Oscillograph	±2% of F. S.
13.	Flow Meter (Pump Flow)	± 1/2% of Indic.
14.	Flow Meter (Cold Plate Flow)	± 1/2% of Indic.

The test schematic and the electrical schematic for the test loop are shown in Figures 1, 2, 4, and 5. Figure 3 identifies the instrument and equipment callouts on the test schematics. (Contract provided equipment is indicated with an asterisk.)

A contractor provided dc static power supply and temperature recorder was utilized at the 10,000 hour point to facilitate unattended unit operation.

3.3 Cleanliness Requirements

The following specifications cover cleanliness of the components:

Components	Specification
Pump	EDI-107
Motor	EDI-108
Pump-Motor Assy.	EDI-108
Cold Plate	Marshall Space Flight Center Spec. 164, Type III, Class I with exceptions
Filter	MSFC Spec. 164, Type II, Class I with exceptions
Test Equipment	Applicable Specifications

The test fluid, DC200-2CS Grade, cannot be purchased conforming to any cleanliness requirements. The fluid used to fill the test reservoir will be filtered.

Contamination level of fluid in test equipment shall not be greater than SAE, Class 2 (see Table below).

SAE, ASTM, AIA Tentative Contamination Level Standards

Size Range (Microns)	Class Level 0	1	2	3	4	5	6
5-10	2,700	4,600	9,700	24,000	32,000	87,000	128,000
10-25	670	1,340	2,680	5,360	10,700	21,400	42,500
25-50	93	210	380	780	1,510	3,130	6,500
50-100	16	28	56	110	225	430	1,000
100 + (including Fibers)	1	3	5	11	21	41	92

Particles per 100 milliliter sample, as determined by SAE Aircraft Recommended Practice 598 (ARP 598).

3.4 Test Conditions

Unless otherwise specified, the following conditions will apply to all tests of motor and/or motor-pump assembly:

a)	Ambient Temperature	60° - 100°F
b)	Fluid	Per Interim Federal Spec. VV-D-00107 (D. C. 200 Grade 2 C. S.)
c)	Fluid Temperature	80° ± 10°F
d)	Motor Power Input	39/47 volts at 400 Hz ± 4 Hz Quasi-square wave 3-phase
e)	Equivalent Inverter Input	50 - 60 volts D.C.
f)	Pump Inlet Pressure	15 psia to 30 psia
g)	Room Ambient Humidity & Atmospheric Pressure	

Instrumentation voltage drop shall be compensated for by increasing the dc input to the inverter.

When testing of a motor or motor-pump assembly is required using sine wave power, the motor voltage shall be the same as that obtained if an inverter were used at the specified dc input voltage.

4.0 Development Tests

4.1 Motor Tests

The purpose of these tests will be to determine motor performance, circuit constants, and separation losses with sine wave and quasi-square wave power. The specific tests to be performed are:

4.1.1 Sine Wave Power

a) No load saturation - motor wet and dry
b) Locked rotor saturation - wet motor
c) Speed torque performance curves - motor wet and dry at 38.8 volts, 43.5 volts, and 46.5 volts rms L/L
d) Two-phase sine power tests

1. Speed-torque performance at 38.8 volts L-L rms
2. Speed-torque performance at 46.5 volts L-L rms
3. Locked rotor saturation.

4.1.2 Quasi-Square Wave (Inverter)

a) No load saturation - motor wet and dry
b) Locked rotor saturation - wet motor
c) Speed torque performance curves - motor wet and dry at 50 volts, 56 volts, and 60 volts dc.

4.1.3 Dielectric Check (Power Connector Only)

Apply 1500 volts (rms) 60 Hz for one minute between the four motor pins connected together and ground (motor housing). There shall be no arcing or other evidence of insulation breakdown. The current leakage shall not exceed 500 micro amperes.

4.1.4 Resistance and Continuity Check

Measure insulation resistance of each pin in the instrument and power connectors to case with a 50 v dc megger. Resistance of each pin to case shall exceed 20 megohms. Measure the resistance of each phase winding and the speed pick-up coil. Check thermocouple continuity A-B and C-D.

4.2 Motor-Pump Tests

4.2.1 Following assembly of the motor into the pump housing, repeat the dielectric and continuity tests of para. 4.1.3 and para. 4.1.4.

4.2.1.1 Test Mounting

The motor-pump shall be mounted on test fixture 97-1212. External plumbing shall be per test schematic as in Figure 1, or equivalent.

4.2.1.2 Wiring

Unit wiring is to be in accordance with Figure 4.

4.2.2 Test Series 1

The purpose of these tests will be to substantiate analytical pump characteristics necessary to provide the required head-flow curve and to determine motor performance using a sine wave power supply. Testing will consist of calibrations conducted at the following conditions:

1.	Pump Inlet Pressure	-	20 psia
2.	Pump Inlet Temperature	-	80°F ± 2°F
3.	Fluid	-	DC 200, 2 C.S. Grade
4.	Motor Voltage	-	Equivalent of inverter output voltage when inverter input voltage is 50, 56, and 60 volts dc.
5.	Cold Plate Flow Rate	-	0.58 gpm at pump flow rate of 3.7 gpm

The data listed below will be recorded at the following flow conditions: 0, 0.6, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 3.7, 4.0 and maximum flow in gpm

Inverter Input DC Volts
Inverter Input DC Amperes
Inverter Output AC Volts
Motor Input AC Volts
Motor Input AC Amperes
Motor Input AC Watts
Pump Inlet Pressure
Pump Flow
Pump Speed
Filter ΔP
Pump Inlet Temperature
Pump Discharge Temperature
Stator Winding Temperatures
Cold Plate Inlet Temperature
Cold Plate Discharge Temperature
Cold Plate Flow
Clock Time
Total Unit Running Time
Ambient Temperature
Barometric Pressure

All temperatures shall be recorded on a recording potentiometer.

4.2.3 Test Series 2

Calibrations as described in Test Series I will be repeated using quasi-square wave input power (inverter) instead of sine wave power.

Motor voltages will be the same as in Test Series I. Pertinent data will be recorded.

4.2.4 Test Series 3

Calibrations will be run on a dynamometer using the barstock pump assembly at successively smaller impeller diameters until the pump head drops below 50 psi at 3.7 gpm and 11,300 rpm with a fluid temperature of 80°F ± 2°F.

4.2.5 Test Series 4

The purpose of this test will be to determine the effect of various inlet pressures on pump performance. Inverter power will be used. NPSH calibrations at the same voltages and fluid conditions, as described in Test Series I, will be conducted with pump inlet pressures ranging from 0 psig to 25 in. Hg vacuum. Net positive suction head requirements will be determined at 0.7, 2.0, 3.7 and maximum gallons per minute flow.

4.2.6 Test Series 5

The purpose of this test will be to determine the effect of fluid viscosity and temperature on motor-pump performance. Calibrations, as described in Test Series 2, will be conducted at two temperature conditions. One condition will be at a PMA inlet and ambient temperature of -65°F. The other will be at an inverter cold plate outlet temperature near 150°F. The 150°F temperature is not to be exceeded and testing at this temperature shall be limited to 2-hour periods. Cold plate flow rate shall be 0.58 gpm at a pump flow rate of 3.7 gpm.

The test loop side and top covers shall be in place for the hot and cold ambient testing.

During the cold testing a starting current trace will be taken with 50 v dc input to the inverter. Motor acceleration and torque will be determined at cold start-up.

4.2.7 Test Series 6

The motor-pump will be operated on quasi-square wave power at a shut-off condition for three minutes. Winding temperatures will be determined and pertinent data recorded. Test conditions will be:

1)	Initial pump fluid temperature	-	80° ± 2°F
2)	Inverter voltage input	-	60 v dc

4.2.8 Test Series 7

With the motor-pump filled with fluid the unit will be subjected to three reverse rotation starts on quasi-square wave power, not exceeding 60 seconds of total operation. The motor-pump will be drained and the unit subjected to two dry starts not exceeding 10 seconds total running time. The two starts will be conducted 30 minutes apart. As much data will be recorded as possible. These test conditions will be:

1)	Initial pump fluid temperature	-	Ambient
2)	Inverter voltage input	-	50 v dc

5.0 Design Assurance Test

5.1 Dielectric and Continuity Check

Repeat the dielectric and continuity check of paragraphs 4.1.3 and 4.1.4.

5.2 Pump-Motor Calibration

Perform a pump-motor calibration at the following conditions:

Inlet Pressure	-	20 psia
Inlet Temperature	-	80°F ± 2°F
Input Power	-	56 v dc to inverter
Pump Flow	-	0.6, 1.0, 2,0, 3.0, 3.7, and maximum flow in gpm

Record data listed in paragraph 4.2.2.

Repeat above tests at 50 v dc input to the inverter.

5.3 Performance Test - 250 Hours

A 250-hour performance test will be conducted using the development pump-motor assembly, inverter, and cold plate.

The test will be conducted at the following conditions:

Pump Inlet Pressure	-	20 psia
Pump Temperature	-	80°F ± 2°F
Fluid	-	DC 200 - 2 C.S. Grade
Inverter Voltage Input	-	56 v dc
		(Ref: 44.4 v dc motor input

The pump shall be tested as follows:

Phase	Time (Hours)	Flow gpm
I	25	0.6
II	200	3.7
III	25	Maximum capacity

During each phase the pump-motor assembly will be stopped twice every two hours for one minute each stop with one minute operation between the stops for a total of 250 stops. The test parameters listed in paragraph 4.2.2 will be recorded prior to the first of the two stops every two hours.

At least one oscillograph trace of the start-up and coast down transient shall be obtained during each phase.

5.4 Pump Calibration

Repeat the pump calibration of paragraph 5.2 at the 56 v dc inverter input.

5.5 Resistance and Continuity Check

Repeat the resistance and continuity check of paragraph 4.1.4.

5.6 Disassembly and Inspection

The pump-motor assembly shall be disassembled and inspected. Critical dimensions shall be inspected and recorded, including the pump shaft and bearings.

5.7 Dielectric and Continuity Check

Clean and reassemble unit. Perform the dielectric check of paragraph 4.1.3 but at 1000 v ac and for 10 seconds maximum. Perform the resistance and continuity check of paragraph 4.1.4, but at the 100 volt dc megger voltage.

6.0 Endurance Test

A 20,000 hour accumulative endurance test will be conducted on the development pump-motor assembly, inverter, and cold plate. The test will be conducted at the following conditions:

Pump Inlet Pressure	-	20 psia
Pump Inlet Temperature	-	80°F ± 5°F
Fluid	-	DC200 - 2 C.S. Grade
Inverter Input Voltage	-	56 v dc
		(Ref: 44.4 v dc motor input)

6.1 Pump Calibration

Repeat the pump calibration of paragraph 5.2 at the 56 v dc inverter input.

Clean unit and remove o-rings from end covers.

6.2 Resistance and Continuity Check

Perform resistance and continuity check of paragraph 4.1.4, but at the 100 volt dc megger voltage.

6.3 Seal Weld

After cleaning, the end covers of the unit shall be seal welded in accordance with Note 3 of Pesco Drawing No. 115146-100, Sheet I - Government furnished fittings shall be welded to the inlet and discharge tubing in accordance with Pesco Drawing No. 115146-100, Sheet 1.

6.3.1 Proof Pressure Test

Prior to the helium leak test the unit shall be pressurized to 150 psig for five minutes minimum with an inert gas through the pump inlet line.

6.3.2 Helium Leak Test

The pump-motor assembly shall be helium leak tested in accordance with paragraph 4.3 of Pesco Test Specification TR-700.

6.4 Resistance and Continuity Check

Perform the resistance and continuity test in accordance with paragraph 4.1.4, but at the 100 v dc megger voltage.

6.5 Pump Calibration

Perform the pump calibration of paragraph 5.2 at the 56 v dc inverter input. Obtain an oscillograph trace of the start-up and coast down transient.

6.6 Endurance Test - First 5000 Hours

A 5000-hour accumulative endurance test will be conducted on the development pump-motor assembly, inverter, and cold plate. The unit will be run continuous, where possible, 24 hours a day on a normal work week basis. Unit will be operated at 3.7 gpm pump flow, 0.58 gpm cold plate flow, and nominal 56 v dc inverter input (Ref: 44.4 v ac at the motor input).

Data listed in paragraph 4.2.2 will be recorded at least once per shift.

6.7 Pump Calibration at 5000 Hours

Perform pump calibration per paragraph 5.2 at the 56 v dc inverter input after 5000 hours total running time. Obtain the oscillograph of the start-up and coast down transient.

6.8 Resistance and Continuity Check

Perform resistance and continuity check per paragraph 4.1.4 but at the 100 v dc megger voltage.

6.9 Disassemble and Inspect

Cut off seal welds on the PMA end covers, disassemble and inspect unit. Critical dimensions shall be recorded including pump shaft and bearing dimensions.

7.0 Reassembly and Reweld

7.1 Resistance and Continuity Check

Clean and reassemble unit. Perform resistance and continuity check of paragraph 4.1.4, but at the 100 v dc megger voltage.

7.2 Pump Calibration

Repeat the pump calibration of paragraph 5.2 at the 56 v dc inverter input.

Clean unit and remove o-rings from end covers.

7.3 Resistance and Continuity Check

Perform the resistance and continuity check of paragraph 4.1.4 but at the 100 v dc megger voltage.

7.4 Seal Weld

After cleaning, the end covers of the unit shall be seal welded in accordance with Note 3 of Pesco Drawing No. 115146-100, Sheet I.

7.4.1 Proof Pressure Test

Prior to the helium leak test the unit shall be pressurized to 150 psig for five minutes minimum with an inert gas through the pump inlet line.

7.4.2 Helium Leak Test

The pump-motor assembly shall be helium leak tested in accordance with paragraph 4.3 of Pesco Test Specification TR-700.

7.5 Resistance and Continuity Check

Perform the resistance test in accordance with paragraph 4.1.4, but at the 100 v dc megger voltage.

7.6 Pump Calibration

Perform the pump calibration of paragraph 5.2 at the 56 v dc inverter input voltage. Obtain an oscillograph trace of the start-up and coast down transient.

7.7 Endurance Test - Last 15,000 hours

Conduct an additional 15,000 hour accumulative endurance test on the development pump-motor assembly, inverter and cold plate. The unit will be run continuous, where possible, 24 hours a day on a normal work week basis. The unit will be operated at 3.7 gpm pump flow, 0.58 gpm cold plate flow, and nominal 56 v dc. (Ref: 44.4 v ac at the motor input).

Data listed in paragraph 4.2.2 will be recorded at least once per shift.

7.7.1 Endurance Test at 2.0 gpm

At an accumulated running time of 19,600 hours, the pump discharge flow shall be changed to 2.0 gpm and the unit run for 100 hours.

7.7.2 Endurance Test at 0.6 gpm

At an accumulated running time of 19,700 hours, the pump discharge flow shall be changed to 0.6 gpm and the unit run for 100 hours.

7.7.3 Endurance Test at Maximum Flow

At an accumulated running time of 19,800 hours, the pump discharge flow shall be changed to maximum flow and the unit run for 100 hours.

7.7.4 Endurance Test at 3.7 gpm

At an accumulated running time of 19,900 hours, the pump discharge flow shall be changed to 3.7 gpm. Obtain an oscillograph trace of the startup and coast down transient. The pump-motor and inverter shall be run for 100 hours and a sufficient number of start-stop cycles performed to accumulate a total of 100 start-stop cycles for the 20,000 hour endurance test.

7.8 Pump Calibration

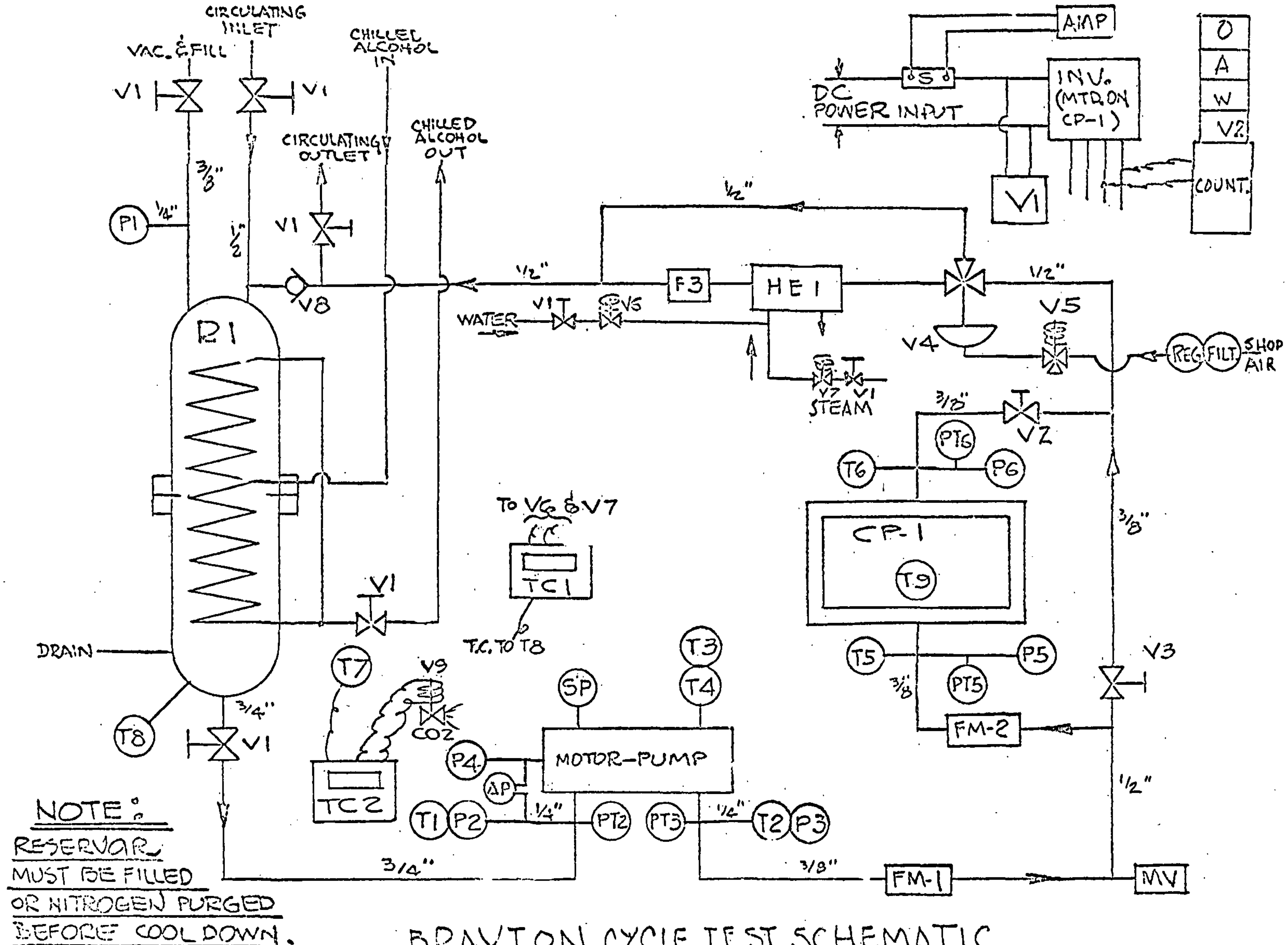
Perform the pump calibration of paragraph 5.2 at the 56 v ac inverter input voltage.

7.9 Resistance and Continuity Test

Perform the resistance and continuity check of paragraph 4.1.4 but at the 100 v dc megger voltage.

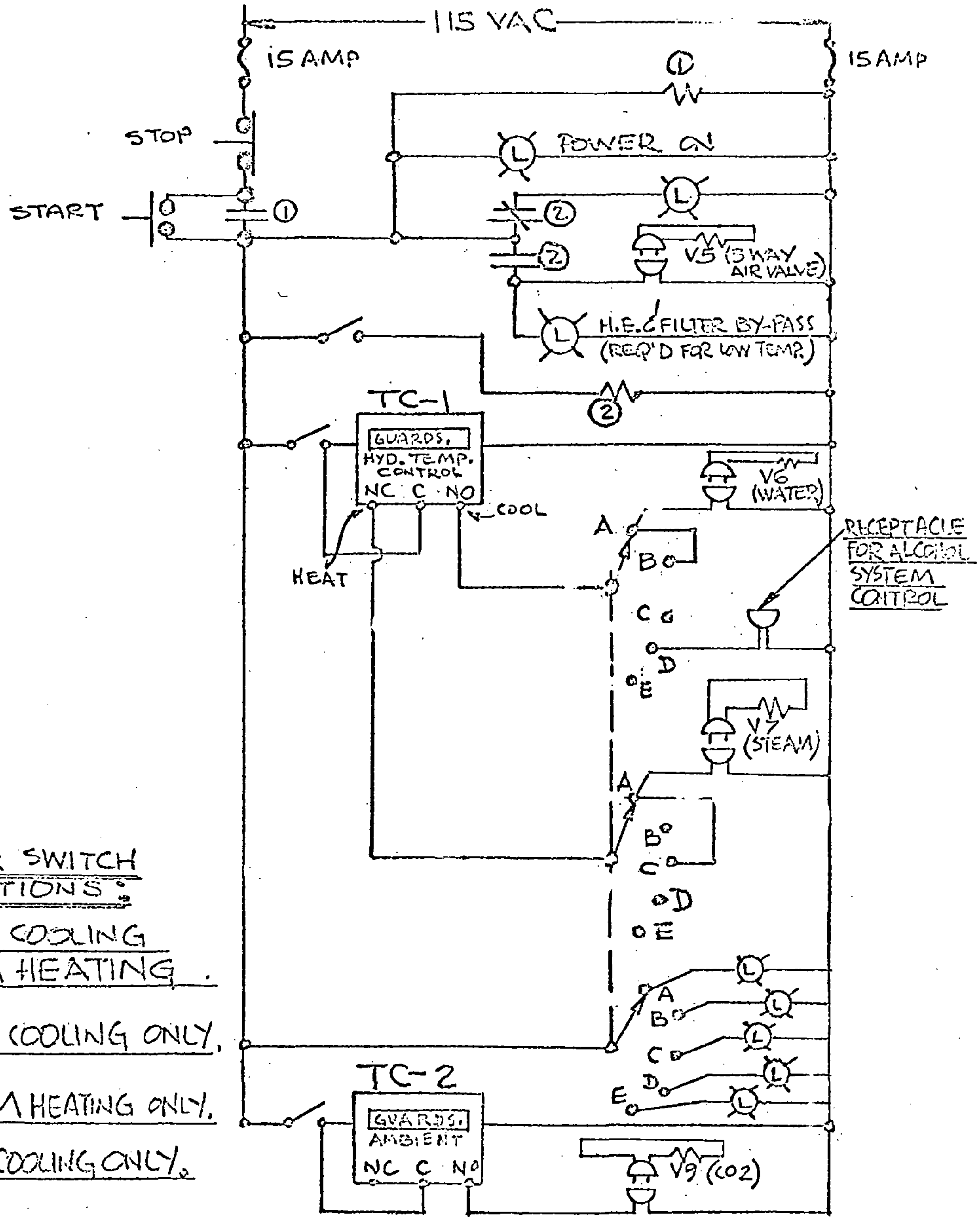
8.0 Disassemble and Inspect

Cut off seal welds on the PMA end covers, disassemble and inspect unit. Critical dimensions shall be recorded.



BRAYTON CYCLE TEST SCHEMATIC

FIGURE 1



SELECTOR SWITCH POSITIONS:

A. WATER COOLING STEAM HEATING.

B. WATER COOLING ONLY.

C. STEAM HEATING ONLY.

D. ALCOHOL COOLING ONLY.

E. OFF

BRAYTON CYCLE ELECTRICAL SCHEMATIC

FIGURE 2

EQUIPMENT LIST

CODE	TYPE	ITEM OR FUNCTION
*T1	I/C	Pump Fluid Inlet Temperature
*T2	I/C	Pump Fluid Discharge Temperature
T3	I/C	Motor Winding Temperature
T4	I/C	Motor Winding Temperature
*T5	I/C	Coldplate Inlet Temperature
*T6	I/C	Coldplate Outlet Temperature
*T7	I/C	Pump Ambient Temperature
*T8	I/C	Reservoir Fluid Temperature
P1	Bourdon Tube	Reservoir Pressure
P2	Bourdon Tube	Pump Inlet Pressure
P3	Bourdon Tube	Pump Discharge Pressure
P4	Bourdon Tube	Pump Filter Downstream Pressure
P5	Bourdon Tube	Coldplate Inlet Pressure
P6	Bourdon Tube	Coldplate Outlet Pressure
*V1	Globe	Manual Shutoff Valves
*V2	Throttle	Coldplate Throttle
*V3	Throttle	Pump Discharge Throttle
*V4	Flow Control	Diaphragm Operated 3-Way Diverting Valve
*V5	Solenoid	3-Way - Air Service
*V6	Solenoid	2-Way - Water Service
*V7	Solenoid	2-Way - Steam Service
*V8	Check	Flow Directional Control
*V9	Solenoid	2-Way - Liquid CO2 Service
*HE1	Shell & Tube	Stainless Steel Heat Exchanger (Water and Hydraulic Oil)
*HE2	Shell & Tube	Brass Heat Exchanger (Steam & Water)
*F3	Surface	4 Micron Absolute System Filter
*R1	-	Stainless Steel Reservoir
SG	-	Liquid Level Sight Glass
TC1	Thermocouple	Hydraulic System Temperature Controller

*Indicates contract provided equipment

FIGURE 3

EQUIPMENT LIST

CODE	TYPE	ITEM OR FUNCTION
TC 2	Thermocouple	Ambient Temperature Controller
FM-1	Turbine	Pump Output Flow Measurement
FM-2	Turbine	Coldplate Hydraulic Flow Measurement
* MV	-	Quick Release Valve for Contamination Bomb Sample
* CP-1	Avco	Coldplate
V1	-	Voltmeter (DC)
S	-	Shunt (As required by amperes)
AMP	-	Ammeter
Count.	-	Frequency Counter
* INV.	-	Inverter
A	-	Ammeter (per line)
W	-	Wattmeter (per line)
V2	-	Voltmeter (AC)
O	-	Oscilloscope (Wave Form)
* DC Power	-	Voltex Static DC Power Supply Mod. 82-253-1
* Temp Recorder	-	Minneapolis-Honeywell Mod. RY15306836

* Indicates contract provided equipment.

FIGURE 3 (continued)

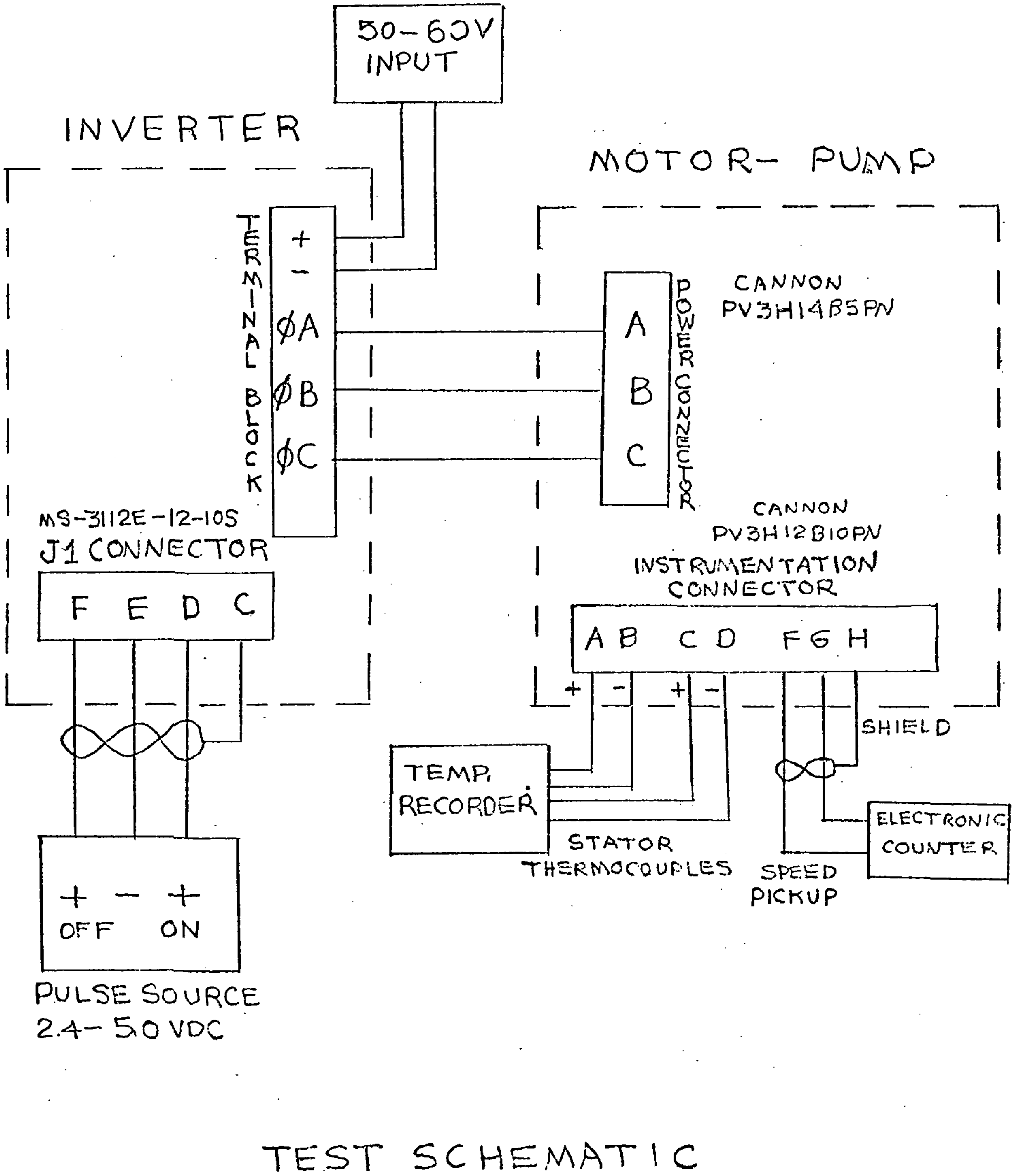
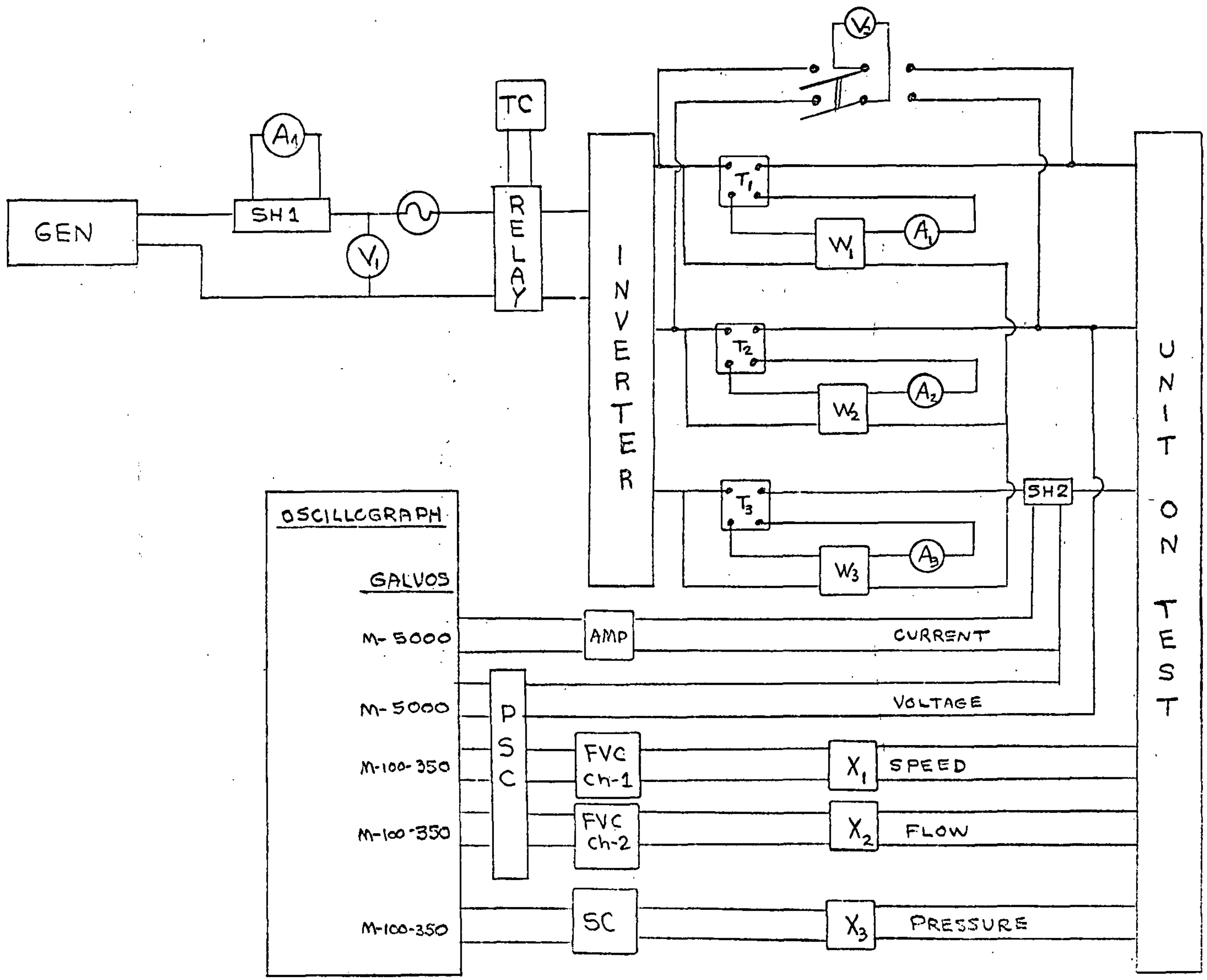

50-60V
INPUT
INVERTER
MOTOR- PUMP
TERMINAL BLOCK
+
-
ØA
ØB
ØC
POWER CONNECTOR
A
B
C
CANNON
PV3H14B5PN
MS-3112E-12-10S
J1 CONNECTOR
F E D C
CANNON
PV3H12B10PN
INSTRUMENTATION
CONNECTOR
A B C D F G H
+ - + -
SHIELD
TEMP.
RECORDER
STATOR
THERMOCOUPLES
ELECTRONIC
COUNTER
SPEED
PICKUP
+ - +
OFF ON
PULSE SOURCE
2.4- 5.0 VDC
TEST SCHEMATIC

FIGURE 4



TEST LOOP INSTRUMENTATION

FIGURE 5

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