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OAK RIDGE
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MARTIN MARIETTA

MTI 88TR9

FREE-PISTON STIRLING ENGINE DIAPHRAGM-COUPLED HEAT-ACTUATED HEAT PUMP COMPONENT TECHNOLOGY PROGRAM

Volume II
PHASE IIA AND IIB FINAL REPORT: LENNOX TEST PROGRAM

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PHASE IIA and IIB FINAL REPORT: LENNOX TEST PROGRAM

R. A. Ackermann

25 January 1988

Report Prepared by

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1.0 INTRODUCTION

This volume addresses the testing of the Mark I heat pump module conducted by Lennox Industries. The following information is contained herein:

- Appendix A, Lennox Test Plan
- Appendix B, Lennox Test Data Spread Sheet
- Appendix C, Lennox Parametric Test Data Plots
  - Refrigerant Flow versus Evaporator Temperature, Attachment C-1
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- Appendix D, Lennox Parametric Test Data Sheets.

APPENDIX A

LENNOX TEST PLAN

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- TEST PLAN -

LENNOX INDUSTRIES' EVALUATION

OF A FREE-PISTON STIRLING ENGINE HEAT PUMP

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February 9, 1987

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MTI wishes to acknowledge the support provided to this program by the technicians, engineers, and managers at both Lennox Industries and John Deere & Co. Their background and knowledge of heating, ventilating and air-conditioning equipment, and manufacturability were key elements in the success of this work.

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TEST PLAN FOR LENNOX INDUSTRIES' EVALUATION OF A FREE-PISTON STIRLING ENGINE HEAT PUMP

1.0 Introduction

Since 1981, Mechanical Technology Incorporated has been developing a Free-Piston Stirling Engine Heat Pump (FPSE/HP) module. The module consists of a Stirling engine driver, hydraulic transmission, and a refrigerant compressor. Recently, the unit's development has progressed sufficiently to warrant an independent evaluation of its performance and expanded mapping of its operation over a broad range of refrigerant conditions. This testing shall be performed by Lennox Industries Inc. in their facilities at Carrollton, Texas. The objective of the Lennox tests shall be to:

1. Verify the performance of the FPSE/HP module

2. Map the unit's performance over a broad range of condenser and evaporator conditions

This test report discusses the test procedures that will be followed and describes the specific tests that shall be performed to meet the stated objectives. In addition, the report describes the equipment that will be shipped to Lennox, the Lennox facilities in which the testing shall be performed, and the instrumentation furnished with the heat pump module and the instrumentation that is part of the Lennox facilities.

For completeness, several appendices are included which describe the MARK I heat pump system and provide operating instructions for the heat pump module and data acquisition system (DAS). The following are the appendices included:

APPENDIX A - Description of the MARK I System and DAS
APPENDIX B - MTI DAS Output Format and Definition of Terms
APPENDIX C - MARK I System Operating Instructions
APPENDIX D - MTI DAS Operating Instructions
APPENDIX E - Instrumentation Systems and Electrical Wiring Diagrams

2.0 Background

The FPSE/HP module consists of a natural gas-powered Stirling engine which delivers power through a diaphragm from the engine working fluid to a hydraulic transmission-driven refrigerant compressor. The compressor is designed for use in a heat pump utilizing refrigerant R-22. Figure 1 is a layout drawing of the FPSE/HP module. The power unit located above the engine diaphragm is the MARK I FPSE, developed by MTI under the GRI-sponsored "Residential FPSE Development Program." The lower end consisting of the hydraulic transmission and refrigerant compressor was developed by MTI under the DOE-sponsored "Free-Piston Stirling Engine Diaphragm-Coupled Heat-Actuated Heat Pump Technology Program."

In the MARK I FPSE/HP design shown in Figure 1, the engine and lower end subassemblies form a coupled resonant system that efficiently converts thermal energy from the natural gas into the heating and cooling capacity delivered by the refrigerant. In the engine, the displacer shuttles the engine working fluid (helium) between the hot and cold spaces, generating the driving pressure wave for the system. The pistons (refrigerant compressor) extract work from the gas to power the load (refrigerant circuit). Hence, in this system, power is extracted from the engine and delivered to the compressor through the hydraulic fluid, providing a force/displacement transfer path between the engine and compressor. This coupling also applies the proper dynamics to the engine, providing resonant characteristics and volumetric phase relationships.

Hermetic separation between the engine working fluid and refrigerant is achieved by employing a flexible metal diaphragm between the engine and hydraulic system. Engine power is transferred to the compressor through the volumetric displacements of the diaphragm and corresponding displacement of oil in the hydraulic transmission induced by the pressure wave in the engine.

The FPSE/HP module that will be tested at Lennox was developed to be self-supporting by including several subcomponents in the package that provide monitoring and control of the heat pump module. The total package, defined as the MARK I system package, includes:

- FPSE/HP Module

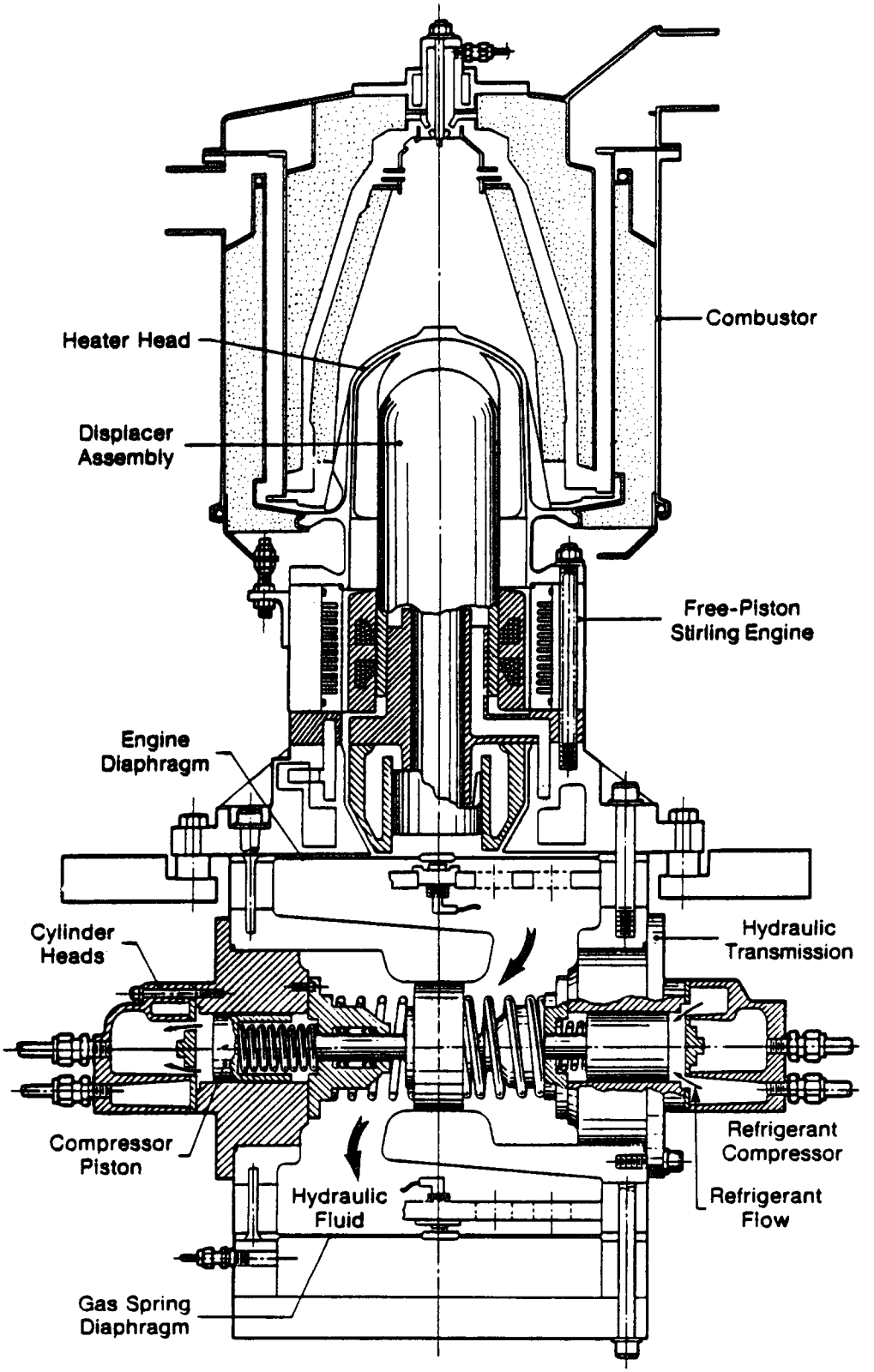


Figure 1 MARK I Free-Piston Stirling Engine-Driven Heat Pump Module

- System Auxiliaries
  - Combustion controller and air blower
  - Hydraulic transmission oil management system
  - Displacer drive electronics

- Data Acquisition System and Performance Measuring Instrumentation

To achieve self-sufficiency for the MARK I system package, a system was defined that would provide for maximum laboratory reliability. For maximum data collection purposes, the system is defined with a data acquisition system and a full complement of system instrumentation. For maximum flexibility, the system is configured with separate subsystem packages that offer easy exposure to critical circuitry and components.

A description of the MARK I system package is provided in Appendix A.

3.0 Facilities

The MARK I will be installed in the Lennox Industries Inc. R&D Laboratory in Carrollton, Texas. The R&D Laboratory contains state-of-the-art test equipment for testing conventional heating and cooling equipment. A combination of the technology employed in testing natural gas-fired furnaces and the technology used in testing electrically-driven heat pumps and compressors can be used effectively to test the MARK I power module.

The MARK I and its support hardware will be physically located in a cinderblock-walled room with a pull down steel door adjacent to the compressor calorimeters. This location was specified for both safety and security reasons. Due to the high operating temperatures and pressures, it is desirable to limit personnel access to the MARK I during testing. The door will be locked during non-working hours to further secure the equipment. The room is environmentally conditioned, allowing the ambient temperature around the MARK I to be controlled during testing.

The MARK I will be connected to a compressor calorimeter that has the ability to maintain specified compressor suction and discharge conditions and to measure the mass flow rate of refrigerant pumped at those conditions. Included in the calo-

rimeter is a Macsym computer based data acquisition system which automatically records operating data, performs necessary calculations, and outputs the results of a test to a line printer. Provisions may be made for writing to a floppy disk if required.

4.0 Test Set Up

The MARK I system compressor will be connected to the discharge and suction ports of the test calorimeter by a line set fabricated on-site. In conformance with industry test standards, a vacuum will be pulled on the compressor and line set for a time sufficient to ensure a leak-tight and contaminant-free system. The calorimeter service valves will be opened, and R-22 vapor will be admitted to the compressor. Pressure taps and Type-T thermocouples will be included in the line set and will be located as near as possible to the suction and discharge ports on the compressor.

The MARK I support equipment will include positive displacement flow meters to measure natural gas flow and combustion air flow. A pressure transducer will be installed in the natural gas line and the combustion air line, along with thermocouples to allow a calculation of volumetric flow to be performed. A Cutler Hammer natural gas calorimeter will periodically report higher heating value (HHV) of the natural gas to the data acquisition system. In addition, an exhaust sampling port is added before the secondary air valve. This port allows the taking of undiluted exhaust samples for the purpose of measuring burner characteristics and overall heater efficiency. Equipment available for exhaust analysis are a Thermoelectron NO/NOx analyzer and an Infared Industries CO/CO_2 analyzer.

The coolant system of the MARK I will be connected to a laboratory chilled water loop, and a flow rate of 7 gpm and entering water temperature, as defined in the test plan, will be maintained during the testing.

Barometric pressure readings will be available to the data acquisition system for calculation purposes.

In addition to the instrumentation contained in the compressor calorimeter, the MARK I system contains a complete instrumentation package to provide continual

monitoring and performance calculations of the heat pump module to be performed on the MARK I PC-based data acquisition system.

A schematic of the test hook-up is given in Figure 2, showing the locations of the necessary instruments to make the performance evaluation. Table 1 provides a description of the types of instruments employed in these locations. In the Table, overall accuracy is defined as the sum of the measuring device, readout, and data acquisition system accuracies for each parameter. The percentage value/value provided is the largest difference between the parameter and its calibration reference over the entire operating range (i.e., if a displacer stroke of 18mm is recorded, the actual value could lie between 17.64 and 18.36mm; ±2% of recorded value).

5.0 Test Procedure

Three sets of tests will be performed at Lennox. They are:

- Verification Testing - Verification tests shall be performed to verify data repeatability. This testing will involve setting the heat pump module at a pre-established operating point and checking the repeatability of the data with data recorded at MTI. Verification testing will be performed initially and then at the start and end of each day's testing. If the unit repeats the performance presented in Table 2, further testing will proceed. If the data can not be repeated, corrective action will be taken and the verification point re-run.

- Qualification Testing - Qualification tests shall be performed to measure the MARK I heat pump module's performance at a descrete set of ambient temperature conditions between 0 and 95°F. This testing shall provide a measure of the MARK I's capacity and performance over a broad range of ambient temperatures. This testing shall also verify the previous performance results obtained for the MARK I system.

- Parametric Testing - After successful completion of the qualification tests, parametric testing of the MARK I will begin. Parametric testing is intended to provide a map of the operating performance of the MARK I. Heater head temperature, coolant flow rate, and coolant inlet temperature

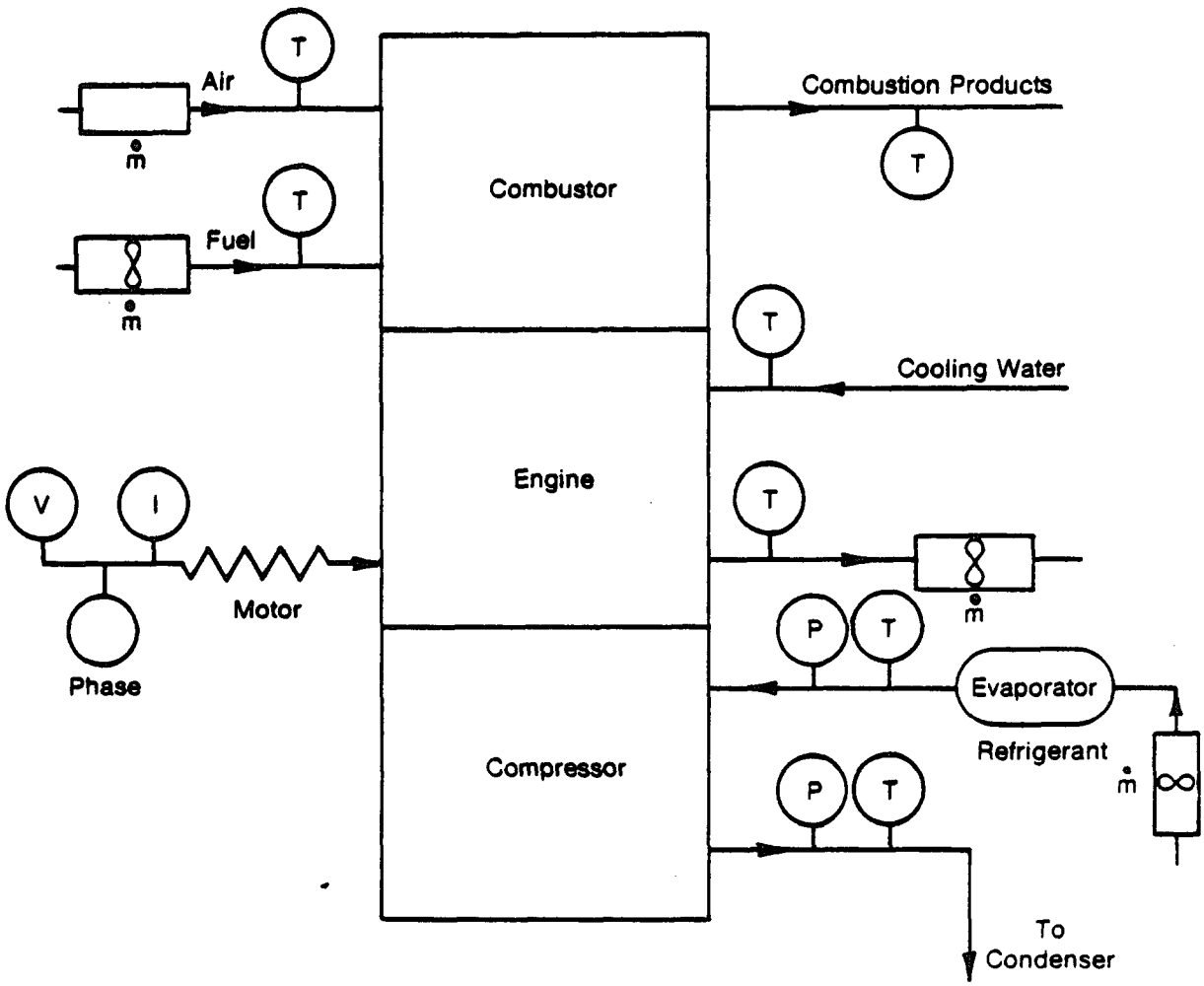


Figure 2 HAHP System Schematic Showing Performance Parameters

TABLE I - HAHP PERFORMANCE MEASUREMENT INSTRUMENTS

PARAMETER	PROBE OR INSTRUMENT TYPE	OVERALL ACCURACY	RANGE
Engine Displacer Stroke	Eddy Current/DAS	+/- 2%	0-22 mm
Engine Pressure Amplitude	Piezoresistive/DAS	+/- 1%	0-65 Bar
Engine Pressure Phase	DAS	+/- .1 Degree	0-360 Degrees
Engine Cooling Water Inlet Temperature	RTD	+/- 1/2% (.05 C max)	0-20 C
Engine Cooling Water Outlet Temperature	RTD	+/- 1/2% (.05 C max)	0-20 C
Engine Displacer Motor Current	V/R (precision resistor)	+/- 1/2%	0-13 Amps
Engine Displacer Motor Voltage	Voltage Divider	+/- 1%	0-100 Volts
Engine Displacer Motor Phase	DAS	+/- .1 Degree	0-360 Degrees
Compressor Piston Stroke	Eddy Current/DAS	+/- 2%	0-18 mm
Compressor Cylinder Pressure Amplitude (Left and Right Sides)	Piezoresistive/DAS	+/- 1-1/2%	0-300 psia
Compressor Cylinder Pressure Phase	DAS	+/- .1 Degree	0-360 Degrees
Compressor Suction Pressure	Piezoresistive	+/- 1%	0-120 psia
Compressor Discharge Pressure	Piezoresistive	+/- 1%	0-300 psia
Compressor Suction Temperature	Thermistor	+/- 1% (1 F max)	0-100 F
Compressor Discharge Temperature	Thermistor	+/- 1-1/2% (3 F max)	0-200 F
Compressor Freon Flowrate	Coriolis-Force Mass Flowmtr	+/- 2%	0-900 lb/hr
Combustor Air Flowrate	Laminar - Flow Element	+/- 2%	0-20 scfm
Combustor Fuel Flowrate	Positive Displacement Totalizer-Temp Compensated	+/- 1%	0-2 scfm
Combustor Fuel Inlet Pressure	U-Tube Manometer	+/- 1%	0-40" H20
Combustor Air Inlet Temperature	Type-K Thermocouple	+/- 2%(4 F max)	70-200 F
Combustor Gas Outlet Temperature	Type-K Thermocouple	+/- 2%(10 F max)	70-500 F
Refrigerant Condenser Outlet Temperature	Remote Indicating Dial Thermometer	+/- 2% (2.5 C max)	0-120 F

will be held constant. Displacer stroke will be set and held constant. For each condensing temperature specified, at least five evaporating temperatures will be selected to facilitate cross-plotting and minimize the number of tests required, and the MARK I will be operated at these five conditions. The condensing temperature will be changed and the five tests will be repeated. This will be continued until an operating map is generated for the entire allowable operating region. At least three different displacer strokes will be specified and mapping performed.

A detailed discussion for the operating parameters for these tests follows.

5.1 Verification Testing

For verification tests, the unit shall be brought to steady state at the operating point defined in Table 2. Past experience with the MARK I system has shown that this point is very repeatable for a well-running unit. A criteria of ±5% on the refrigerant mass flow shall be used as a measure of the performance repeatability.

5.2 Qualification Testing

Qualification testing will be performed by taking steady-state data at seven different ambient temperature conditions: 0°, 17°, 32°, 47°, 80°, 87°, and 95°F. The refrigerant (R-22) suction and discharge conditions for each of the ambient temperatures and two additional test points used for additional evaluation are given in Table 3.

For each of these ambient conditions, a series of points shall be run by varying X_D (displacer stroke) to obtain a given compressor stroke (X_P). A matrix for this data is provided in Table 4. Three data scans shall be taken for each point so that reliable steady-state data is assured. Steady-state is defined as that period of time of system operation in which none of the performance parameters differ from scan to scan by more than 3%. After attaining steady state, the time between each scan shall be at least five minutes. The optimum frequency is defined as that frequency which corresponds to the largest ratio of piston stroke to motor current. For all of these points, the following parameters shall be held constant:

TABLE 2

MARK I HEAT PUMP MODULE PERFORMANCE
(95°F Ambient Temperature)

		MARK I S/N 1 SCAN 7
DATE		10-9-86
REFRIGERANT		R-22
TRANSMISSION FLUID		10CS Mineral Oil
REGENERATOR MATRIX		1.0-mil Screen
SET POINT PARAMETERS		
T(Head)	(°C)	724.5
P(Mean)	(Bar)	60.3
Frequency	(Hz)	58.5
Air Fuel Ratio		13.9
Bearing Pressure	(Bar)	67.8
P(Suction)	(psia)	90.3
T(Suction)	(°F)	51.2
P(Discharge)	(psia)	275.7
T(Discharge)	(°F)	170.0
T(Liquid)	(°F)	106.0
Xp	(mm)	16.7
MEASURED PARAMETERS		
Xd	(mm)	15.2
$\theta d,p$	(°)	76.2
Combustor Exhaust Temperature	(°F)	170.0**
Combustor Fuel ΔP	("H2O)	7.5
Firing Rate(HHV)	(W)	9,785.3
Engine PV	(W)	2,333.3
P(Motor)	(W)	37.9
Rejected Heat	(W)	5,428.0
Motor Current	(Amp)	0.63
Refrigerant Flow	(LBM/hr)	394.9
Capacity	(BTU/hr)	-27,057
Engine Effic *	(%)	23.8
Lower End Effic	(%)	60.7
Compressor COP		3.40
Heat Pump COP		0.81

* Based on higher heating value of the fuel

** Condensate not collected.

TABLE 3

HEAT PUMP TEST CONDITIONS

R-22 REFRIGERANT

Conditions @ Compressor	COOLING 95°F	87°F	80°F	Test Pt*	HEATING 47°F	32°F	17°F	0°F	Test Pt*
Ts/TD °F Sat	45/ 121	47.5/ 105	50/ 95	45/ 130	35/ 100	20/ 97	5/ 95	-12/ 90	30/ 110
Discharge Pressure (psia)	277.4	225.5	196.5	311.5	210.6	202.1	196.5	183.1	241.0
Suction Pressure (psia)	90.7	94.7	98.7	90.7	76.2	57.7	42.9	29.8	69.6
Suction Gas Temperature** (°F)	55	57.5	60	65	45	30	15	-2	50
Pressure Ratio	3.06	2.38	1.99	3.43	2.76	3.50	4.58	6.14	3.46

*ARI Compressor Rating Test Points - with 20° Superheat and 15° Subcooling

**Includes at least 10°F superheat for the ambient temperature points and 20°F for the two test points

Note: To allow for assessment of test results, the following information is to be included:

1. At the conditions of 17°F ambient and 95°F ambient, perform the maximum piston stroke test at a second engine cooling water inlet temperature of 40°C, and provide measurement results of oil circulation (as % of refrigerant flow) and a schematic showing energy flow and accountability for each of the tests run at these ambient temperature conditions.

2. For each test point, provide sufficient engine information so that COP values can be calculated by the reader.

3. For each test point, provide the measured discharge gas temperature leaving the compressor.

TABLE 4

MATRIX OF TEST DATA FOR DIFFERENT AMBIENT TEMPERATURES AND COMPRESSOR PISTON STROKES

(STEEL DIAPHRAGMS)

°Day	Frequency	Compressor Piston Stroke (Xp) 10mm	14mm	18mm[3]
0°	Optimum at 18mm Xp	[1]		X
17° [2]	Optimum at 18mm Xp		X	X
32°	Optimum at 18mm Xp		X	X
47°	Optimum at 18mm Xp	X	X	X
Test Pt 1	Optimum at 18mm Xp			X
80°	Optimum at 18mm Xp	X	X	X
87°	Optimum at 18mm Xp		X	X
95° [2]	Optimum at 18mm Xp		X	X
Test Pt 2	Optimum at 18mm Xp			X

[1]After steady-state has been reached, 3 scans are taken at 5-minute intervals

[2]At the 17 and 95°F ambient conditions, an additional test with a cooling water inlet temperature of 40°C shall be performed at the maximum compressor piston stroke of 18mm

[3]The compressor piston stroke shall not exceed 18.5mm for the steel diaphragms

- Average Heater Head Temperature ~1328°F ±18°F (720°C)
- Engine Coolant Inlet Temperature ~70°F ±9°F (21°C)
- Engine Mean Pressure ~60 Bar ±1/2 Bar
- Displacer Motor Current <10 Amps
- Maximum Piston Stroke <18.5mm

It should be noted that some of the points in the matrix may not be attainable due to the constraints listed above.

In addition to running the 17°F and 95°F ambient temperature tests with a cooling water inlet temperature of 21°C, a second series of tests at the maximum compressor piston stroke shall be performed for a cooling water inlet temperature of 40°C. These two additional tests shall be run after the qualification test matrix has been completed. Verification tests shall be conducted prior to the start of each qualification test and at completion of the day's testing.

Results of the qualification tests will be presented in both tabular and graphical form. Tabular results will consist of a summary of all key performance parameters at each operating point. Graphical results will be presented for the heating and cooling capacity and heating and cooling heat pump module COP's (described in Section 6.1 and shown in Figure 4).

5.3 Parametric Testing

Parametric testing will be performed to map the performance of the heat pump module over a broad range of evaporator and condenser conditions. Parametric tests shall be run at three compressor piston strokes: 18mm, 14mm, and 10mm. At each compressor piston stroke, a series of condensing pressures shall be set. At each condenser setting, data will be recorded at a minimum of five evaporator conditions. The test matrix for this testing is given in Table 5. For these tests, the following parameters shall be held constant:

- Average Heater Head Temperature ~1328°F ±18°F (720°C)
- Engine Coolant Inlet Temperature ~70°F ±9°F (21°C)
- Engine Mean Pressure ~60 Bar ±1/2 Bar
- Displacer Motor Current <10 Amps
- Maximum Piston Stroke <18.5mm

TABLE 5

CONDITIONS FOR COMPRESSOR MAPPING

(CONDENSER TEMPERATURE) Saturated Discharge (°F)	(EVAPORATOR TEMPERATURE) Saturated Suction (°F) -20	0	20	35	50
80°	X	X	X		
90°	X	X	X		
100°		X		X	X
120°			X	X	X
130°			X	X	X

NOTES:

1) Superheat at compressor will be held between 15 and 25°F

2) Subcooling liquid leaving condenser will not be less than 10°F

3) Compressor piston stroke setting for the steel diaphragms shall be 10, 14, and 18mm. The stroke shall not exceed 18.5mm.

Performance shall be mapped over the range specified in Table 5, and performance maps will be plotted for the following parameters:

- Refrigerant Mass Flow Rate
- Cooling Capacity
- Condenser Rejected Heat
- Natural Gas Energy Input Based on HHV
- Engine Rejected Heat
- Engine PV Power

For each run, sufficient data will be recorded to determine:

- Stroke and/or displacement;
- Refrigeration capacity;
- Condenser rejected heat;
- Fuel consumption and total energy input;
- Power input to compressor;
- Engine rejected heat;
- Pressures (engine, compressor, refrigeration, fuel gas, etc.)
- Temperatures (engine, compressor, hydraulic fluid, refrigeration cycle, cooling water, combustion inlet and exhaust);
- Credibility of results; and the
- Various performance results required (heat pump COP, compressor COP, engine efficiency, etc.).

These parameters shall be plotted as a family of curves for the three independent variables: discharge and suction conditions, and compressor piston stroke. These tests shall be run with 15 to 25°F of superheat in the refrigerant suction gas and 10 to 15°F of subcooling in the liquid refrigerant. Before each series of tests and at the conclusion of each day's testing, the verification test point shall be run to check the quality of the data. Also, if the runs produce questionable data, the verification test point will be run as a check means. Upon the resolution of the problem, the questioned runs will be repeated. The plots of refrigeration capacity are to be presented at the standard conditions of subcooling (15°F) and superheat (10-20°F).

6.0 Data Reduction

Data reduction shall consist of both the computing of heat pump performance from the qualification and parametric testing and data validation through quality assurance checks.

6.1 Heat Pump Module Performance

A full compliment of engine, hydraulic transmission, compressor, and refrigerant measurements shall be recorded at each test point, and a large array of performance maps can be generated as required for evaluation. The MARK I heat pump module data to be acquired by the MTI data acquisition system are given in Table 6, and the heat pump system measurements to be acquired by the Lennox data acquisition system are given in Table 7. In addition to these primary measurements, secondary (or redundant) measurements will also be made to validate the data quality. The primary and secondary measurements for several key performance parameters are given in Table 8.

From the measurements described in Tables 6 and 7, performance maps for the compressor, engine, and system will be generated as follows.

6.1.1 Heat Pump Compressor Performance

A simplified flow schematic for the heat pump lower end is shown in Figure 3. The parameters that must be measured to determine heat pump module performance and allow the generation of the performance maps are:

- Refrigerant inlet static pressure
- Refrigerant outlet static pressure
- Refrigerant inlet temperature
- Refrigerant outlet temperature
- Refrigerant mass flow rate
- Power input (engine PV)
- Power output (compressor cylinder PV)

The following subsections define the detailed measurements and methods to be utilized in making the performance calculations.

TABLE 6

DATA TO BE ACQUIRED BY MTI DATA ACQUISITION SYSTEM

	Units
• DYNAMIC DATA	
Engine Displacer Stroke	mm
Compressor Piston Stroke	mm
Displacer Motor Voltage	Volts
Displacer Motor Current	Amps
Displacer Gas Spring Pressures	Bar
Compression Space Pressure	Bar
Compressor Cylinder Pressures	psia
• STEADY-STATE DATA	
Natural Gas Flow Rate	scfm
Combustion Air Flow Rate	scfm
Engine Coolant Flow Rate	gpm
Refrigerant Flow Rate	LBm/hr
Natural Gas Inlet Pressure	"H_2O
Gas Bearing Inlet Pressure	Bar
Hydraulic Transmission Oil Cavity Pressures	Bar
Refrigerant Manifold Suction and Discharge Pressures	psia
Operating Frequency	Hz
Housing Mounted Accelerometer	g's
Displacer Motor Input Power	Watts
• TEMPERATURE DATA	
Engine Coolant and Discharge Temperatures	°C
Combustor Air Inlet and Exhaust Temperatures	°C
Heater Head Temperatures	°C
Engine Compression Space Temperature	°C
Refrigerant Manifold Suction and Discharge Temperatures	°C
Hydraulic Transmission Oil Temperature	°C

TABLE 7

DATA TO BE ACQUIRED BY LENNOX DATA ACQUISITION SYSTEM

	Units
• NATURAL GAS	
Volumetric Flow Rate	Ft^3/min
Higher Heating Value	BTU/Ft^3
Pressure at Meter	psia
Temperature at Meter	°F
• COMBUSTOR AIR	
Volumetric Flow Rate	Ft^3/min
Pressure at Meter	psia
Temperature at Meter	°F
Barometric Pressure	"Hg
• EXHAUST	
Exhaust Temperature	°F
CO/CO_2 Content	%
NO/NOx Content	%
• COOLANT	
Volumetric Flow Rate	gpm
Inlet Temperature, Cooler	°F
Outlet Temperature, Cooler	°F
Outlet Temperature, Exhaust Cooler	°F
• REFRIGERANT LOOP	
Mass Flow Rate Circulated	LB/hr
Discharge Temperature	°F
Suction Temperature	°F
Liquid Temperature	°F
Discharge Pressure	psig
Suction Pressure	psig
• POWER SUPPLY	
Power Consumption	Watts
Voltage	Volts
Current	Amps

TABLE 8

HEAT PUMP MODULE REDUNDANT PERFORMANCE MEASUREMENTS

REFRIGERANT PARAMETERS

Performance Parameter	Primary Measurement*	Secondary Measurement*
Refrigerant Flow Flow	Coriolis Force Meter	Compressor PV Diagrams
Refrigerant Pressures	Piezoresistive Transducers	Precision Pressure Gages
Refrigerant Temperatures	Type-T Thermocouple	Type-K Thermocouple
Fuel Flow	Temp Compensated Positive Displacement Meter (Lennox)	Temp Compensated Positive Displacement Meter (MTI)

* For accuracy of instrumentation used, see Table 1.

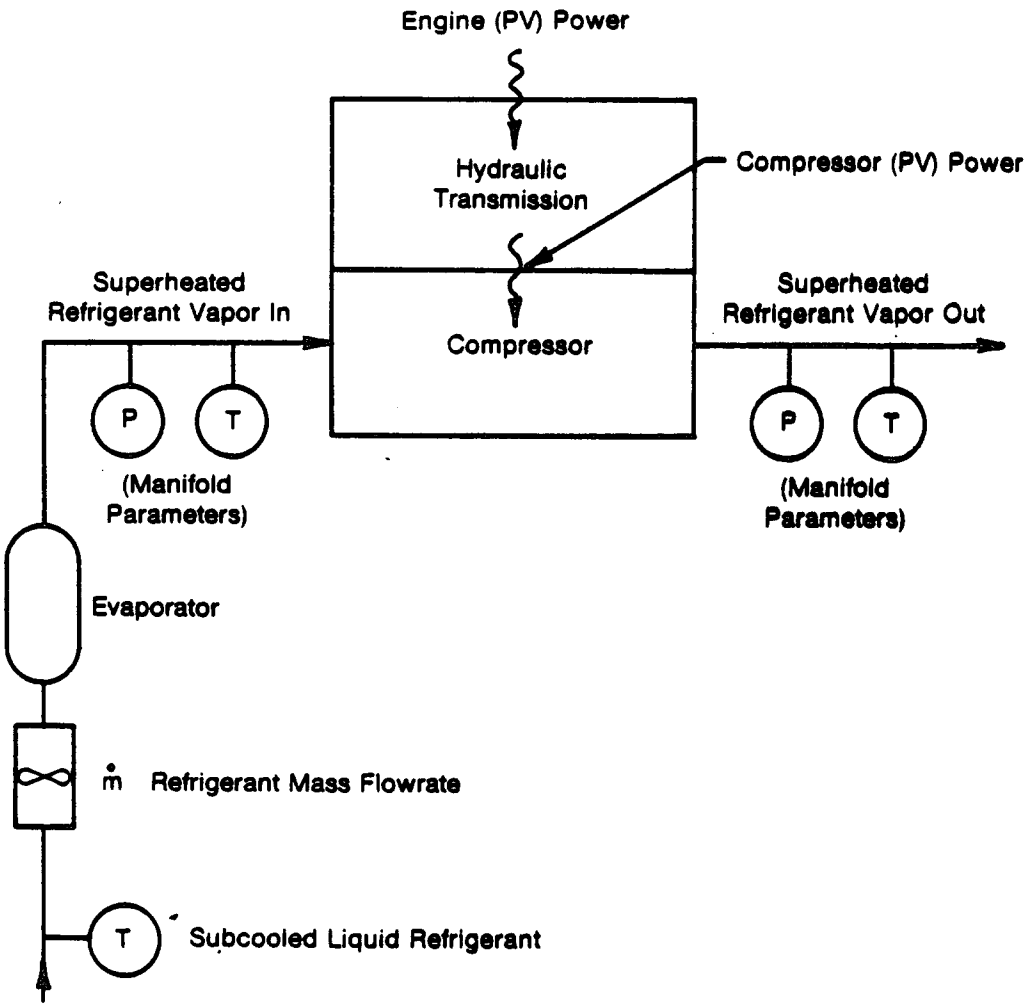


Figure 3 Flow Schematic for Heat Pump Module Lower End

Figure 4 provides the typical heating/cooling loads for the average home rated for 3 RT of cooling at a 95°F ambient temperature. Measured capacity of the heat pump shall be plotted on this graph as shown by the sample data points, and the performance of the unit shall be evaluated at the operating points described in Table 3. All data will be generated using refrigerant R-22.

Cooling Performance - The refrigeration cycle in simplified form is shown in Figure 5. Starting at station 1, the liquid refrigerant is evaporated at constant pressure between 1 and 2 and slightly superheated (at least 10°F). The superheated refrigerant vapor is compressed between stations 2 and 3 and then cooled and condensed and subcooled (at least 15°F) between stations 3 and 4. Finally, the liquid is passed through an expansion valve, decreased in pressure, and partially vaporized between stations 4 and 1.

The cooling capacity and the cooling COP (assuming perfect thermal isolation from the test cell) are calculated from the following expressions:

$$\text{Cooling Capacity}_{\text{System}} = \text{heat absorbed in the evaporator} \doteq \dot{m}\,(h_2 - h_1)$$

$$\text{COP (Cooling)}_{\text{System}} = \frac{\dot{m}\,(h_2 - h_1)}{FR}$$

Where: $\dot{m}$ = refrigerant mass flow rate

h_2 = enthalpy of the refrigerant vapor leaving the evaporator.

h_1 = enthalpy of the refrigerant entering the evaporator. $h_1 = h_4$ where h_4 is calculated from the actual subcooling at station 4; in plotting this data, H_4 will be corrected to a standard 15°F subcooling.

FR = firing rate of the combustor based on the higher heating value of the fuel = $\dot{m}_{gas}$ (HHV). The HHV of the natural gas is 1032 BTU/scf.

In addition, the absolute transmission loss and the efficiencies of the hydraulic transmission and the compressor are calculated as follows:

Transmission Loss = PV (Engine) - PV (Compressor)

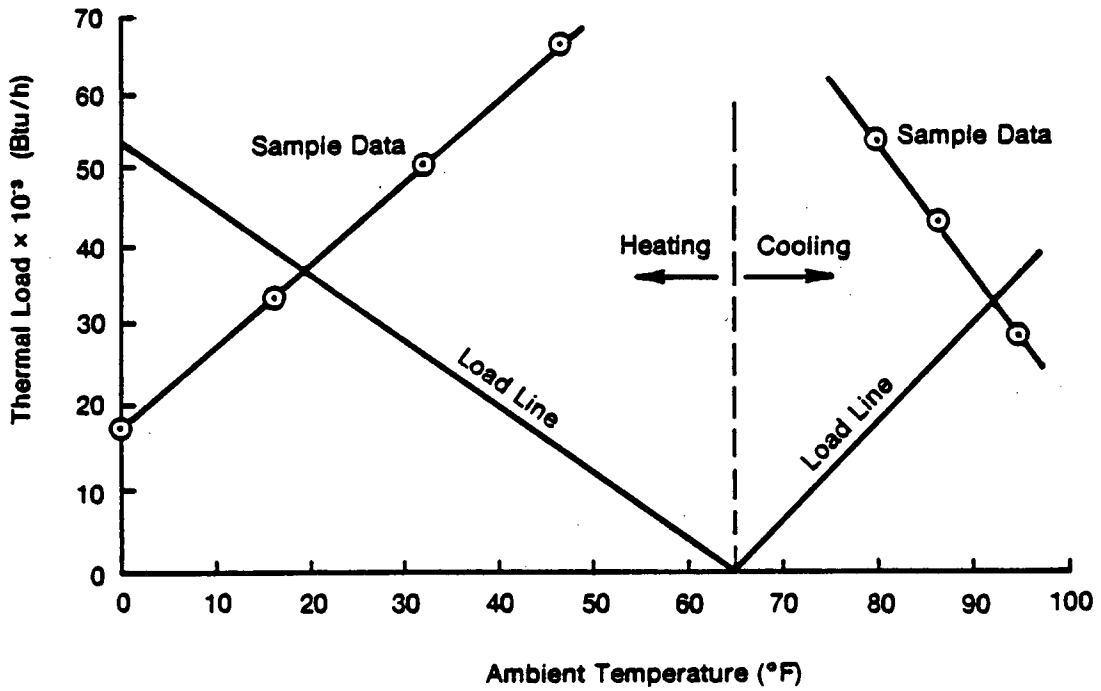


Figure 4 HAHP Module Heating and Cooling Capacity

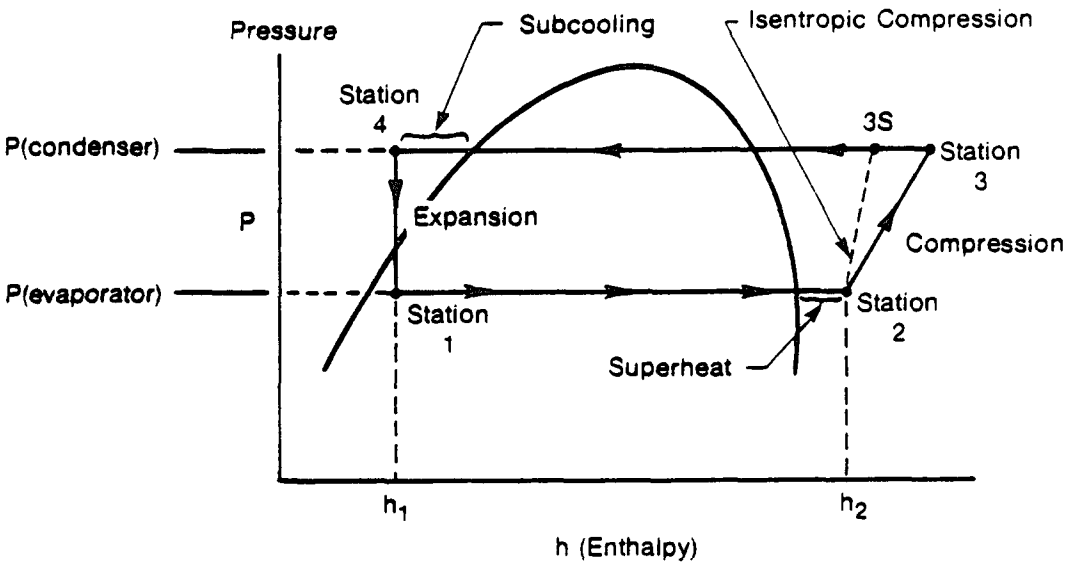


Figure 5 Schematic of Refrigeration Cycle

η (Hydraulic Transmission) = PV (Compressor)/PV (Engine)

η (Compressor) = Compressor Isentropic Power/PV (Compressor)
= $\dot{m}$ $(h_{3s}-h_2)$/PV (Compressor)

Where: PV (compressor) = PV work as measured by pressure transducers in the compressor cylinders and displacement probes monitoring compressor piston motion.

PV (engine) = PV work as measured by pressure transducers in the engine and displacement probes monitoring engine power piston motion. Average of PVKUL (He cavity) and PVU-OIL (upper oil cavity) work.

$\dot{m}$ = Refrigerant mass flow rate.

h_{3s} = Isentropic enthalpy of refrigerant vapor leaving the compressor manifold.

h_2 = Enthalpy of the refrigerant vapor entering the compressor (manifold).

<u>Heating Performance</u> - The ambient conditions (four points) below 65°F require slightly different calculations for performance evaluation. In the heating mode, performance is based on the energy exchange across the condenser rather than across the evaporator as in the cooling mode. Also included is the engine waste heat rejected to the cooling water.

The heating capacity and the gross thermal heating COP are defined as follows:

Heating Capacity$_{System}$ = condenser reject heat + engine reject heat
= $\dot{m}$ $(h_3 - h_4)$ + $Qrej_{water}$ (0.85)

Gross Thermal COP (Heating)$_{System}$ = [$\dot{m}$ (h_3-h_4) + $Qrej_{watr}$ (0.85)] / FR

Where: $\dot{m}$ = Refrigerant mass flow rate.

h_3 = Enthalpy of refrigerant vapor leaving the compressor (manifold).

h_4 = Enthalpy of refrigerant liquid leaving the condenser; h_4 is calculated from the actual subcooling at station 4. Mapping values will be corrected to 15°C of subcooling.

$Qrej_{water}$ = Rejected engine heat = $\dot{m}_{water}$ (Cp)(ΔT).

FR = Firing rate of the combustor based on the higher heating value of the fuel = $\dot{m}_{gas}$ (HHV). The HHV is assumed to be 1032 BTU/scf (based on local gas utility information).

0.85 = Standard accepted efficiency of conventional heat exchangers.

The calculations for the transmission loss and efficiency of the hydraulic transmission and the compressor are made in the same manner as those in the cooling mode.

Energy Balance - An energy balance check for the engine at each data point is calculated from the following expression (see Figure 6):

$$E_{in} = E_{out}$$

$$Q_{air} + FRL + P_{motor} = Qrej_{air} + Qrej_{water} + PV\ (engine)$$

Where: Q_{air} = Energy content of the combustor inlet air.

FRL = Firing rate of the combustor based on the lower heating value of the fuel = $\dot{m}_{gas}$ (LHV). The LHV for natural gas is 929 BTU/scf (as determined by local gas company).

$Qrej_{air}$ = Energy content of the combustor exhaust gases.

$Qrej_{water}$ = Rejected engine heat = $\dot{m}_{water}(Cp)_{water}(\Delta T)_{water}$.

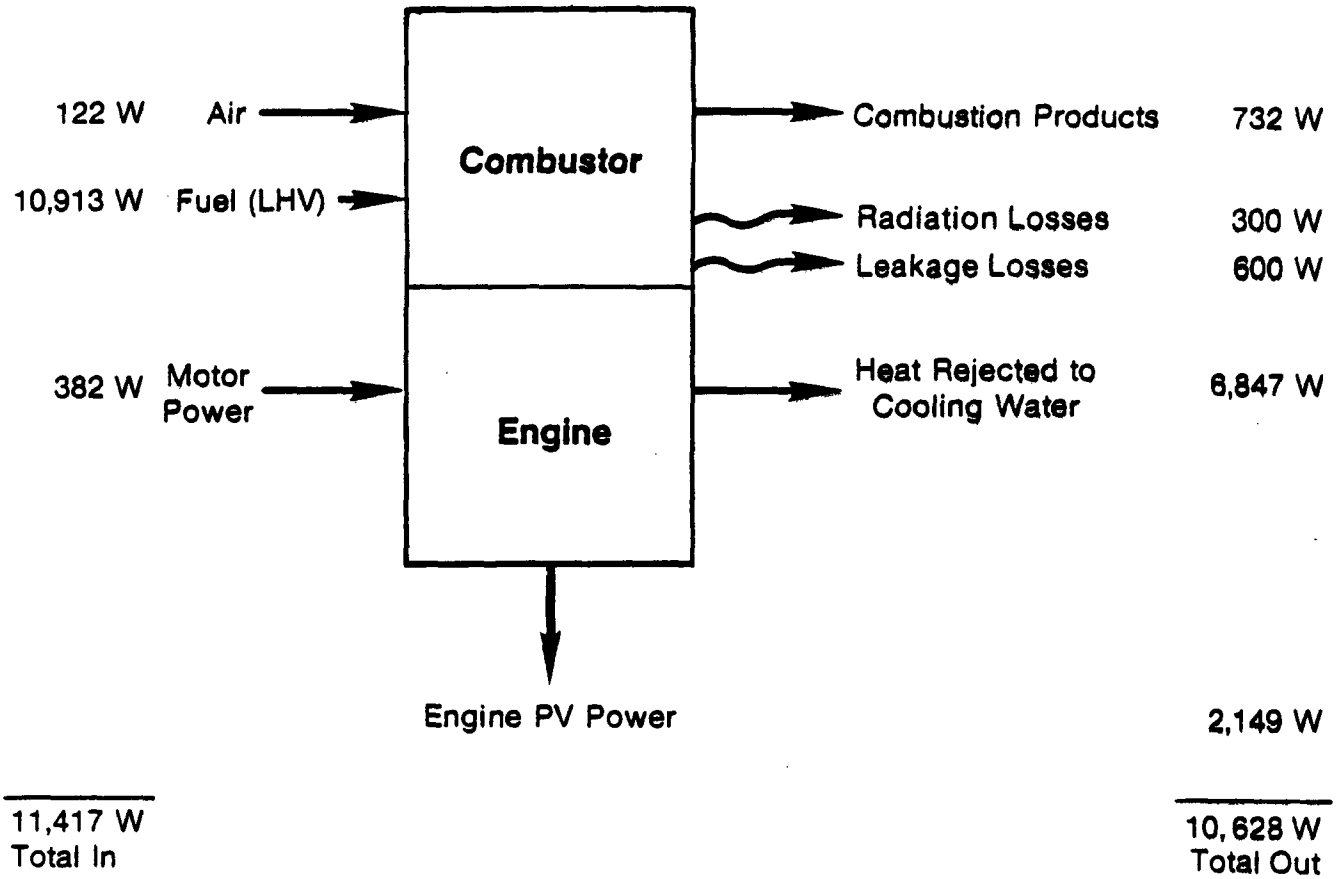
P_{motor} = Electric power input to the engine displacer motor.

PV (engine) = PV work as measured by pressure transducers in the engine and displacement probes monitoring engine power piston motion. Average of PVKUL (He cavity) and PVU-OIL (upper oil cavity) work.

Finally, an energy balance confidence value is calculated from:

$$\text{Confidence Value} - E_{out}/E_{in}$$

The closer this confidence value is to unity, the greater the accuracy and reliability of the data collected. This value will never be consistently 1.0, since some lesser order energy terms (such as thermal losses to the test cell) are omit-



With Losses $\frac{\text{Energy Out}}{\text{Energy In}} = 0.93$ (Δ = 789 W)

Figure 6 Upper End Energy Balance After Instrumentation Calibration

ted, actual heating value of the gas fuel is not determined, and because of the compound effect of instrument and data acquisition system inaccuracies. It is generally felt that values above 0.85 represent acceptable data, values above 0.90 are consistent with good data, and values above 0.95 represent exceptional data.

6.1.2 Engine Performance

Engine performance is measured by engine efficiency, combustor efficiency, and displacer motor power. The following definitions define these terms.

Engine Efficiency

The engine efficiency defines the amount of useful PV work that is developed in the engine from the natural gas input energy.

$$\eta_e = [PV\ (Engine)]/FR$$

Where: $PV\ (engine) = \pi f P_c X_p A_p \sin\Theta_{x,p}$

- f = Operating frequency
- P_c = Compressor space pressure amplitude
- X_p = Compressor piston displacement amplitude
- A_p = The piston area acted upon by the hydraulic oil
- $\Theta_{x,p}$ = Phase angle between the compressor piston motions and pressure amplitude
- FR = Firing rate of the fuel (for natural gas, the HHV is 1032 BTU/scf)

Combustor Efficiency

Combustor efficiency is defined as the ratio of the energy delivered to the working fluid of the Stirling engine to the input energy from the natural gas. For consistence in comparing combustor efficiency from run to run, the heater head temperature must also be specified. For this test program, the average heater head temperature is:

$$T\ (Average\ Heater\ Head) = 720°C \pm 10°C$$

Then, the combustor efficiency is defined as:

$$\eta_c = [Q\ (Head)/FR] = [Q\ (Rej) + PV\ (Engine) - P\ (Motor)]/FR$$

Where: Q (Head) = The heat added to the working fluid of the engine
Q (Rej) = Heat rejected from the engine
PV (Engine) = Engine PV power as defined above
FR = Firing rate (based on the HHV of the fuel)
P (Motor) = Displacer control input power

Referring to Figure 6, an alternative definition for combustor efficiency is:

$$\eta_c = [FR + Q\ (Air) - Q\ (Combustion) - Q\ (Losses)]/FR$$

Where: Q (Air) = Energy of the input air stream
Q (Combustion) = The energy leaving the combustor in the exhaust stream
Q (Losses) = Energy lost through heat leakages from the combustor

This alternative equation is used as a quality control check on the validity of the engine performance.

Displacer Motor Power

The MARK I Stirling engine employs a linear motor on the displacer drive. The function of this motor is to facilitate starting and to provide power to the displacer for stroke control. The displacer control allows external control of the displacer for stroke modulation, providing primary engine control to the system for load matching at different ambient operating conditions. Since this represents an energy input to the cycle, it must be accounted for in all energy balances made on the system.

6.2 Accuracy of the Performance Calculations

The accuracy of the heat pump performance calculations are determined from the instrumentation accuracies given in Table 1. The accuracies for several key

performance parameters are given in Table 9. The accuracies were calculated as follows.

1. Considering the cooling COP:

$$COP\ (Cooling) = \dot{m}_{ref}\Delta h\ /\ \dot{m}_{fuel}Q$$

Where: $\dot{m}_{ref}$ = The refrigerant flow rate
Δh = Refrigerant enthalpy change across the evaporator
$\dot{m}_{fuel}$ = The natural gas flowrate
Q = The higher heating value of the fuel

The accuracy is computed by differentiating this equation and taking the square root of the sum of the squares, i.e.:

$$d\ (COP,\ Cooling) = \left[\left(\frac{\Delta h}{\dot{m}_{fuel}Q} \cdot d\dot{m}_{ref}\right)^2 + \left(\frac{\dot{m}_{ref}}{\dot{m}_{fuel}Q} \cdot d(\Delta h)\right)^2 + \left(\frac{1}{\dot{m}_{fuel}} \cdot \frac{\dot{m}_{ref}\Delta h}{\dot{m}_{fuel}Q} \cdot d\dot{m}_{fuel}\right)^2\right]^{\frac{1}{2}}$$

This can further be shown to reduce to:

$$d\ (COP,\ Cooling) = COP\ \left[\left(\frac{d\dot{m}_{ref}}{\dot{m}_{ref}}\right)^2 + \left(\frac{d(\Delta h)}{\Delta h}\right) + \left(\frac{d\dot{m}_{fuel}}{\dot{m}_{fuel}}\right)^2\right]^{\frac{1}{2}}$$

2. The accuracies given in Table 1, as a percentage of the measured value, are:

- Compressor Refrigerant Flowrate - Coriolis force mass flowmeter = ±2%
- Refrigerant Enthalpy Change - Suction pressure = ±1%
- Natural Gas Flowrate - Positive displacement totalizer - ±1%

Substituting these values into the above equation given the accuracy of the COP at 3.0 RT and the 95°F rating point as:

$$d\ (COP,\ Cooling)\ /\ COP\ (Cooling) = \pm 2.4\%$$

TABLE 9

PERFORMANCE ACCURACY

PERFORMANCE PARAMETER	ACCURACY
$\frac{d\,(COP,\ Cooling)}{COP\ (Cooling)}$	± 2.4%
$\frac{d\,(COP,\ Heating)}{COP\ (Heating)}$	± 3.4%[1]
$\frac{d\,(Engine\ Efficiency)}{Engine\ Efficiency}$	± 2.6%

[1]Assumes a ±2% overall accuracy on the Lennox coolant flow meter

APPENDIX A

DESCRIPTION OF THE MARK I

AND DATA ACQUISITION SYSTEMS

DESCRIPTION OF THE MARK I AND DATA ACQUISITION SYSTEMS

A.1 Introduction

The MARK I system consists of the Free-Piston Stirling engine heat pump module, system auxiliaries, and the DAS. The system was configured to provide maximum flexibility for testing at Lennox, at a complete data package for diagnostic and performance testing. This appendix provides a description of both the heat pump system and the DAS. Additional appendices provide operating instructions for the equipment.

A.2 System Process and Instrumentation Diagram

Figure A-1 is the MARK I P&ID Diagram, which represents the major subsystem and all instrumentation. The major subsystems are:

- Helium System - The helium system maintains the engine working gas at 60 Bar mean pressure, which relies on a high-pressure helium source, typically a pressurized industrial gas cylinder. Regulation of engine pressure is controlled via solenoid charge/discharge valves.

- Oil Management System - The oil management system maintains a constant volume of oil in the compressor housing. This oil acts as a transmission, linking the engine to the refrigerant compressor. The oil is also charged to 60 Bar mean presure, and any leakage that occurs must be pumped back into the housing via the oil management system. The oil management system is triggered via diaphragm mean position sensors. Oil flow into and out of the compressor housing is also controlled via solenoid charge/discharge valves.

- Cooling Water System - The cooling water system is used to collect engine and combustor waste heat. This is accomplished by circulating 2 gpm of coolant. The system is designed to tie into the Lennox chilled water system, and all waste heat will be measured and rejected via this laboratory system.

- Inlet Air and Natural Gas Systems - The inlet air and natural gas systems provide properly proportioned gas flows for combustion. These flows will be

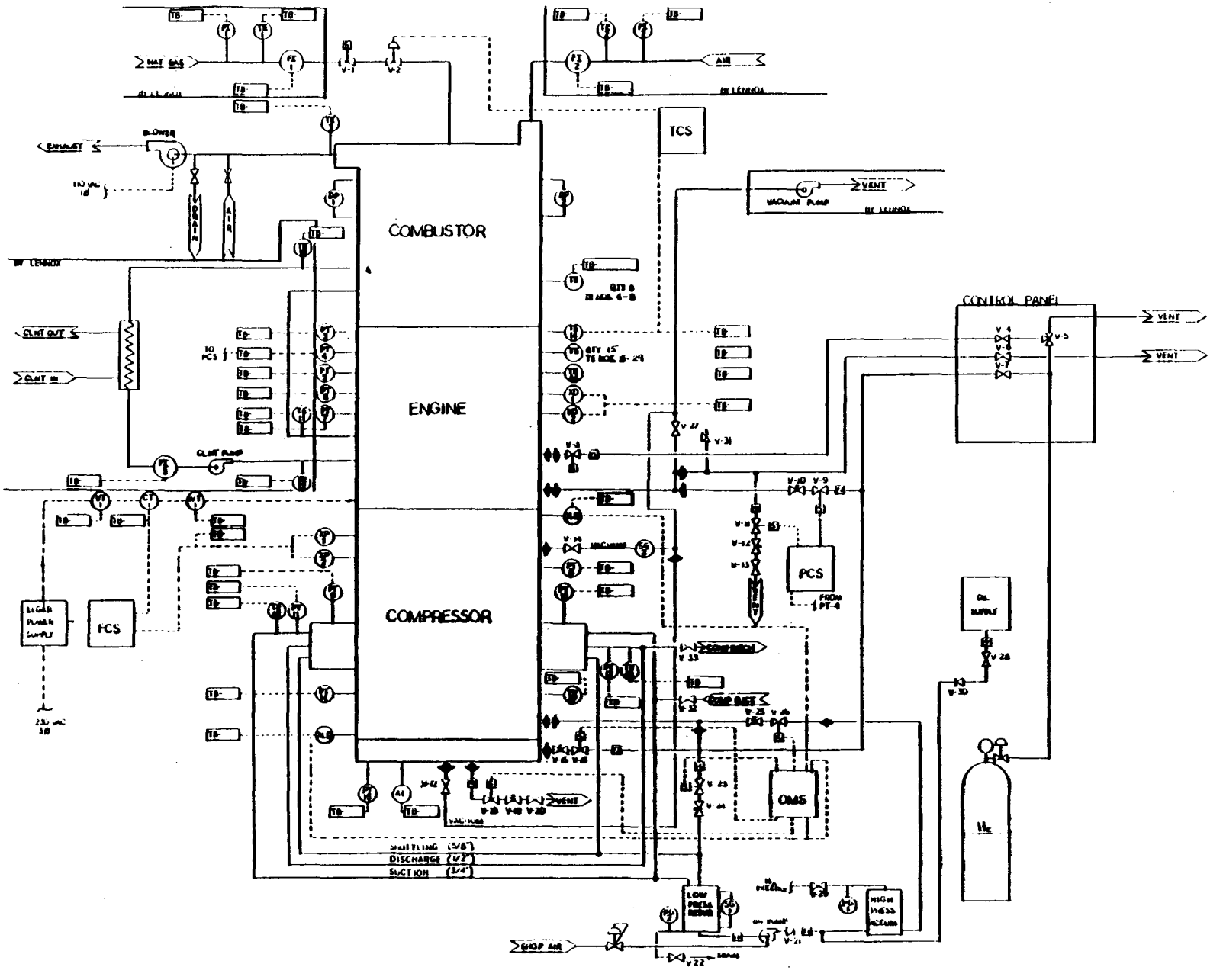


Figure A-1 MARK I Process and Instrumentation Diagram

regulated by pneumatically controlled valves for ease and reliability. The vacuum system is provided for oil filling purposes only.

A.3 MARK I Heat Pump Test Package

The MARK I system package is shown in Figure A-2 and consists of the following components:

- Test Stand - Supports the engine, combustor, and compressor. It ties into the other support packages by tubing and electrical connections.

- Mechanical Support Package - Houses the main oil supply reservoir and the oil management system.

- Electrical Support Package - Houses all signal conditioning circuitry as well as all control system circuitry.

- Operator Console - Houses the necessary components to start, run, and stop the test unit. The operator console and the data acquisition CRT will contain the necessary readouts for operator control and monitoring.

- Data Acquisition System - A stand-alone system capable of all signal sampling, processing, and storage. The system is configured about an IBM PC-XT.

A.4 MARK I Data Acquisition System

An IBM PC data acquisition system was developed to acquire data from the MARK I engine. The hardware components of this system are:

- An IBM PC-XT personal computer with 256 kilobytes of memory. This system includes one hard disk drive (10 megabyte capacity) and one floppy disk drive (360 kilobyte capacity), as well as a keyboard. An 8087 Math Graphics Display Adapter Card (for graphics capability) and a QUADRAM Quadboard card (for a parallel port, clock, additional serial port, and space for additional memory expansion) were added to the basic system. A green-screen monochrome monitor and an ESPON FX80+ printer were also added to the system.

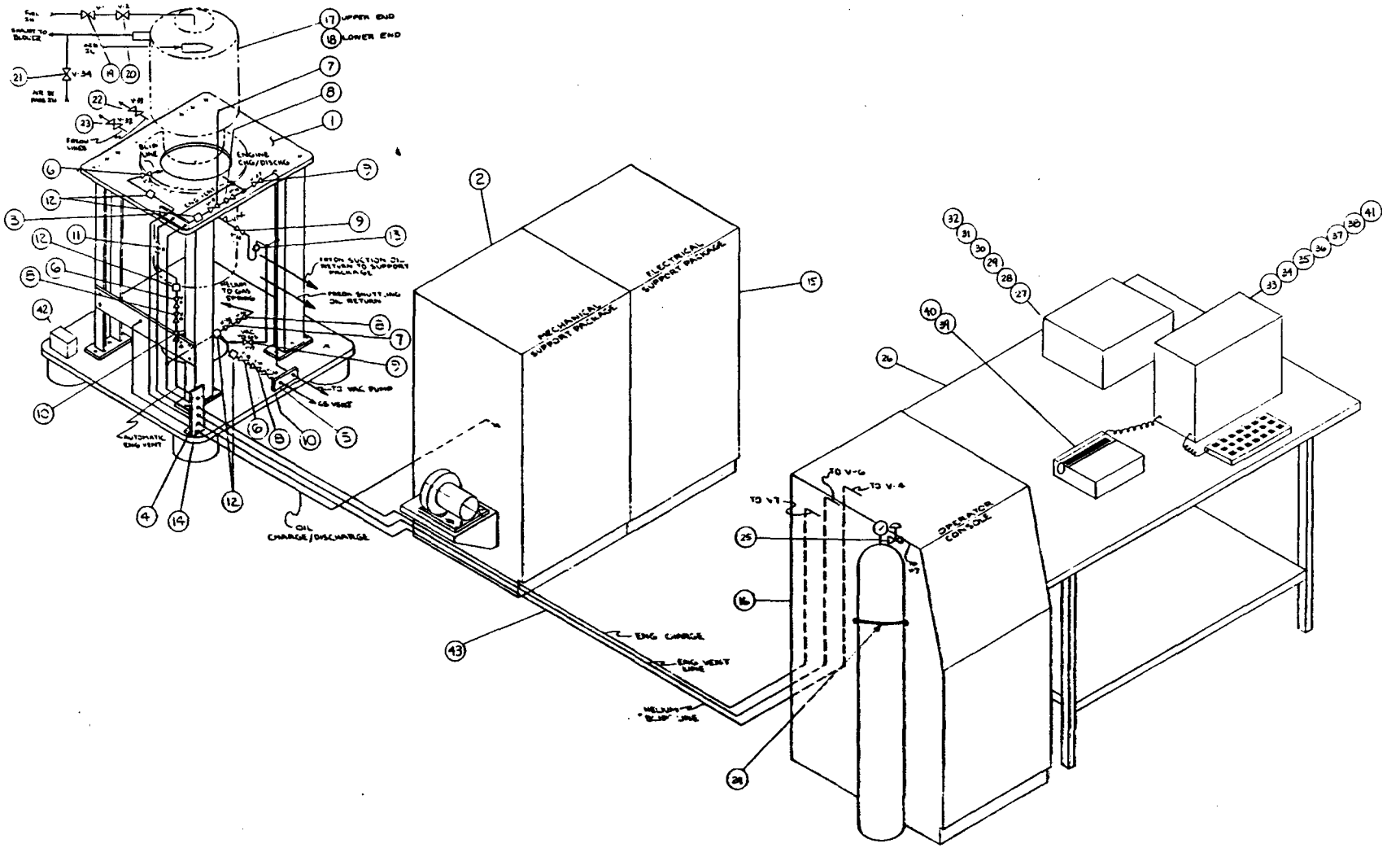


Figure A-2 MARK I System Package

- Four data acquisition system boards to actually perform the analog to digital (A/D) conversions, which are:

  - A Data Translation DT2818 Board, known as a simultaneous sample-and-hold board, can take up to four channels of data simultaneously. This board is used to acquire points from dynamic signals for later waveform analysis. This board also has digital output capability, which is used in a manner described below.

  - A Data Translation DT2808 Board used for A/D conversion on steady-state channels such as flows. Sixteen channels of data can be taken with this card.

  - Two Action Instruments TC15M Thermocouple Input Boards, each reading up to 15 thermocouple channels and performing on-board linearization for Type-K thermocouples.

  - An MTI-build multiplexer that allows users to take dynamic readings on more channels than the four allowed by the DT2818. The user can send a digital output from the DT2818 to the multiplexer, switch channels, and acquire data again.

- An expansion box to hold the data acquisition boards. This box has two communication boards; one to go to the PC and one to stay in the expansion box, as well as an interconnection cable.

- Four termination boards that connect via ribbon cable to a data acquisition board at one end and to the raw data signals at the other end.

The software for the MARK I data acquisition system will monitor a subset of the data channels and flag alarm conditions. A scan of all channels can be initiated manually at any time or automatically at preset time intervals.

When a complete scan is requested, the program will scan acquired data from the four data acquisition boards. The necessary amplitude and phase calculations will be performed on the dynamic data, along with the conversion of all the data to

engineering units. Calculations will then be performed and data written to disk. Reports and graphs can then be generated as required.

APPENDIX B

MTI DAS OUTPUT FORMAT AND DEFINITION OF TERMS

MTI DAS OUTPUT FORMAT AND DEFINITION OF TERMS

B.1 Introduction

The MARK I DAS for Lennox tests was formatted to be similar to the MTI laboratory DAS. The output format consists of dynamic data used to calculate performance parameters, steady-state operating data such as the refrigerant flow rate, temperature data, and a block of computed performance data that quantitatively describes the performance of the engine, hydraulic transmission, and compressor. The following sections describe the data format and define the terms used.

B.2 Data Format

The data format is shown in Figure B-1. Under the heading "Dynamic Data", data is presented as the mean value, the amplitude, and phase angle, referenced from the displacer motion. Dynamic data is harmonic data which is sinusoidal in nature and constant during steady-state operation. Steady-state data is also presented to define the engine parameters such as mean engine pressure, frequency, and coolant flow rate. Temperature data represents steady-state temperatures taken throughout the engine, hydraulic transmission, and compressor. Finally, the last section, "Calculations", provides performance data based on calculations performed from the dynamic and steady-state data. The important computations of engine PV power, heat rejected, and firing rate are presented in this section.

B.3 Definition of Terms

Definitions for the output format are given in Table B-1.

FIGURE B-1

MARK I DATA ACQUISITION SYSTEM OUTPUT FORMAT

LENNOX DATA ACQUISITION TEST
SCAN # 12 DATE: 09-18-1985 TIME: 10:01:37 FILE: CHANEL2

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
XD	-0.43	4.15	0.00
XP	-100.00	0.00	30.76
VT1	0.00	0.00	30.76
CT1	-0.15	0.07	-47.89
PT-3	-100.00	0.00	38.90
PT-6	-100.00	0.00	-4.06
PT-7	-100.00	0.00	9.79
PT-9	-35.00	0.00	6.94
PT-10	-35.00	0.00	7.49
PT-15	-100.00	0.00	2.69
OPEN	0.00	0.00	-5.06

STEADY STATE DATA

FI-1	FI-2	FI-3	FI-4	PI-1	PI-2	PT-4	PT-5
4.9	0.0	0.1	0.2	0.4	0.5	6.1	7.1
PT-8	PT-11	PT-12	PT-14	FREQUENCY	A1	WT-1	DELTAT
8.2	1.8	2.0	10.7	3.0	3.0	30.6	3.1

TEMPERATURE DATA

TE-1	TE-2	TE-3	TE-4	TE-5	TE-6	TE-7	TE-8
22.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0
TE-9	TE-10	TE-11	TE-12	TE-13	TE-14	TE-15	TE-16
-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0
TE-17	TE-18	TE-19	TE-20	TE-21	TE-22	TE-23	TE-24
-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0
TE-25	TE-26	TE-27	TE-28	TE-29	TE-30		
-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0		

CALCULATIONS

FREQUENCY	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	PUMP PWR	ALPHA
0.5984E+02	0.2000E+04	0.3000E+04	0.4000E+04	0.5000E+04	0.6000E+04	0.7000E+04	0.8000E+04
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
0.9000E+04	0.1000E+05	0.1100E+05	0.1200E+05	0.1300E+05	0.1400E+05	0.1500E+05	0.1600E+05
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE			
0.1700E+05	0.1800E+05	0.1900E+05	0.2000E+05	0.2100E+05			

TABLE B-1

DAS PARAMETER LABELS

	LABEL	DESCRIPTION	UNITS
1	XD	DISPLACER POSITION	mm
2	XP	PISTON POSITION	mm
3	VT-1	DISPLACER MOTOR VOLTAGE	VAC
4	CT-1	DISPLACER MOTOR CURRENT	Amps
5	PT-3	COMPRESSION SPACE PRESSURE	Bar
6	PT-6	LOWER SIDE GAS SPRING PRESSURE	Bar
7	PT-7	HOT SIDE GAS SPRING PRESSURE	Bar
8	PT-9	LEFT HAND CYLINDER PRESSURE	Bar
9	PT-10	RIGHT HAND CYLINDER PRESSURE	Bar
10	PT-15	LOWER GAS SPRING PRESSURE	Bar
11	FI-1	GAS FUEL FLOW	scfm
12	FI-2	COMBUSTION AIR FLOW	scfm
13	FI-3	ENGINE COOLANT FLOW	gpm
14	FI-4	FREON FLOW	LBm/hr
15	PI-1	GAS FUEL PRESSURE	"H2O
16	PI-2	COMBUSTION AIR PRESSURE	"H2O
17	PT-4	COMPRESSION SPACE PRESSURE	Bar
18	PT-5	BEARING FEED PRESSURE	Bar
19	PT-8	UPPER OIL CAVITY PRESSURE	Bar
20	PT-11	FREON COMPRESSOR SUCTION PRESSURE	psia
21	PT-12	FREON COMPRESSOR DISCHARGE PRESSURE	psia
22	PT-14	LOWER OIL CAVITY PRESSURE	Bar
23	A-1		
24	WT-1	DISPLACER MOTOR POWER	Watts
25	DELTAT		
26	TE-1	GAS FUEL TEMPERATURE	^{o}C
27	TE-2	COMBUSTION AIR TEMPERATURE	^{o}C
28	TE-3	EXHAUST GAS TEMPERATURE	^{o}C
29	TE-4 TO TE-9	HEATER HEAD EXHAUST TEMPERATURES	^{o}C
30	TE-10	COMBUSTOR COOLANT EXIT TEMPERATURE	^{o}C
31	TE-11	ENGINE COOLANT EXIT TEMPERATURE	^{o}C
32	TE-12	ENGINE COOLANT INLET TEMPERATURE	^{o}C
33	TE-13		
34	TE-14	CONTROL TEMPERATURE	^{o}C
35	TE-15 TO TE-29	HEATER HEAD TEMPERATURES	^{o}C
36	TE-30		
37	TE-44	COMPRESSION SPACE TEMPERATURE	^{o}C
38	TE-45	COMPRESSOR SUCTION TEMPERATURE	^{o}C
39	TE-46	COMPRESSOR DISCHARGE TEMPERATURE	^{o}C
40	TE-47	OIL TEMPERATURE	^{o}C
41	FREQUENCY	DISPLACER MOTOR FREQUENCY	Hz
42	A/F RATIO	AIR TO FUEL RATIO	
43	LS GSPOW	LOAD SIDE GAS SPRING POWER	Watts
44	HS GSPOW	HEATER SIDE GAS SPRING POWER	Watts
45	PMOTI	MOTOR POWER INPUT	Watts
46	PWROD	PV POWER TO DISPLACER	Watts
47	PUMP PWR	DISPLACER PUMPING POWER	Watts
48	ALPHA	PHASE ANGLE MOTOR CURRENT TO DISPLACER VELOCITY	Deg
49	PV POWER	ENGINE PV POWER	Watts
50	QREJ	HEAT REJECTED BY ENGINE COOLANT	Watts
51	NENG	ENGINE EFFICIENCY	%
52	PLHVP	PV POWER-COMPRESSOR LEFT HAND CYLINDER	Watts
53	PRHVP	PV POWER-COMPRESSOR RIGHT HAND CYLINDER	Watts
54	GSPOW	TOTAL GAS SPRING POWER	Watts
55	NLE	LOWER END EFFICIENCY	%
56	QFUEL	GAS FUEL FLOW	
57	QEXHAUST	HEAT REJECTED FROM EXHAUST GAS	Watts
58	TAVGH	AVERAGE HEATER HEAD TEMPERATURE	C
59	HEAT BAL		
60	QAIR	COMBUSTION AIR FLOW	
61	FIRING RATE	HEAT INPUT FROM GAS FUEL	Watts

APPENDIX C

MARK I SYSTEM OPERATING INSTRUCTIONS

MARK I SYSTEM OPERATING INSTRUCTIONS

C.1 Introduction

The following operating instructions for the MARK I are presented:

C-2 Procedure for Charging System
C-3 Procedure for Starting/Running the System
C-4 Engine Shutdown Procedure
C-5 Procedure for Discharging System

These procedures should be read and fully understood before any attempt is made to operate the system.

C.2 Procedure for Charging System

This procedure covers filling the system with oil and helium to engine charge pressure. To accomplish this, the system is first vacuumed, filled with oil, and then pressurized with helium. It will be necessary to refer to MTI drawing 1018D08-0103 (MARK I system P&ID).

To begin, preset all system valves to the following positions:

V-1 CLOSED	V-11 CLOSED	V-20 CLOSED	V-29 CLOSED
V-2 CLOSED	V-12 1/2 TURN OPEN	V-21 N/A	V-30 N/A
V-3 CLOSED	V-13 CLOSED	V-22 CLOSED	V-31 N/A
V-4 CLOSED	V-14 OPENED	V-23 CLOSED	V-32 CLOSED
V-5 N/A	V-15 1/2 TURN OPEN	V-24 1/2 TURN OPEN	V-33 CLOSED
V-6 CLOSED	V-16 CLOSED	V-25 1/2 TURN OPEN	V-35 OPENED
V-7 CLOSED	V-17 OPENED	V-26 CLOSED	V-36 N/A
V-9 CLOSED	V-18 CLOSED	V-27 OPEN	
V-10 1/2 TURN OPEN	V-19 1/2 TURN OPEN	V-28 CLOSED	

With the valves now in their preset positions, the unit is ready to be evacuated, or vacuumed, in preparation for oil introduction.

Vacuuming the System

1. Connect a helium supply bottle to the system and set the pressure regulator to 50 psi.

2. Connect the vacuum pump as described by the system P&ID.

3. Turn on the vacuum pump and permit the system to be evacuated to -30" Hg as noted by the gage on the vacuum pump. Note that the pump should be applying vacuum to the compressor housing, lower gas spring, and the engine cavities simultaneously.

4. With the vacuum pump running, monitor the positions of the upper and lower diaphragms. If excessive diaphragm bulge occurs, take the following precautionary actions:

   a. If the lower diaphragm is bulging excessively upward, it may be necessary to cut down on the rate of evaluation from the compressor housing. This can be accomplished by slightly closing off V-14.

   b. If the lower diaphragm is bulging excessively downward, it may be necessary to cut down on the rate of evacuation from the lower gas spring cavity. This is accomplished by slightly closing off V-17.

   c. If the upper diaphragm is bulging excessively upward, it may be necessary to cut down on the rate of evacuation of the engine cavity. This can be accomplished by slightly closing V-27.

   d. If the upper diaphragm is bulging excessively downward, it may be necessary to cut down on the rate of evacuation of the compressor housing. This can be accomplished by slightly closing V-14.

When sufficient vacuum of the three cavities has been achieved:

5. Close V-14

6. Close V-17

7. Close V-27

8. Turn off the vacuum pump.

Oil Fill Procedure

This section of the procedure covers filling the compressor housing with transmission fluid. The fluid is drawn into the housing by the vacuum previously established. The following steps are to be taken:

1. Fill the oil supply reservoir located in the mechanical support package with approximately four gallons of 10 CS mineral oil.

2. Ensure that the low pressure reservoir has a static supply of oil to fill the sight glass approximately 1/4 full.

3. Set the pressure control system in manual.

4. Set the oil management system in manual.

5. Open V-28.

   Oil is now being introduced into the compressor cavity. As the compressor cavity fills, the upper diaphragm will bulge upward and the lower diaphragm will bulge downward. To counteract this, helium should be introduced to the lower gas spring and to the engine. This can be done with the pressure control system and the oil management system placed in AUTOMATIC; however, until the system operator has experience/confidence in this mode, it is recommended that these systems be left in the manual mode and the diaphragm bulge be handled manually.

6. Open V-7

7. Open V-13

8. Open V-20

9. Introduce helium to the lower gas spring as required to control diaphragm bulge by opening solenoid V-16.

10. Introduce helium to the engine as required to control diaphragm bulge by opening solenoid V-9.

    The compressor cavity is considered filled when oil is seen in the sight glass provided (SG-2).

11. When the compressor cavity is full, close V-28 and V-35.

12. Set the shop air pressure to V-36 to achieve a pressure of 1200 psi on PG-1.

The unit is now considered to be filled adequately with oil and pressurization with helium may begin.

Helium Pressurization

This section covers the pressurization of the engine, compressor cavity, and the lower gas spring to a mean average of 60 Bar (880 psi). The easiest way to raise the mean pressure of the unit is to employ the pressure control system and the oil management system in their AUTOMATIC modes.

IT IS IMPERATIVE THAT THE ENGINE MEAN PRESSURE RATE OF INCREASE NOT EXCEED 2 BAR PER MINUTE.

1. Set the pressure regulator on the helium supply bottle to 1000 psi.

2. Set the oil management system to the AUTOMATIC mode.

3. Set the engine mean pressure set point control to 1 Bar.

4. Place the pressure control system in the AUTOMATIC mode.

5. Open V-7

6. Slowly increase the engine mean pressure set point to 2 Bar. This is accomplished by turning the mean pressure set point control knob clockwise. Note the increase in mean pressure on the display panel. Note that the oil management system has begun to control the mean position of the diaphragms by introducing helium to the lower gas spring cavity. IF THE OIL MANAGEMENT SYSTEM IS NOT CONTROLLING THE DIAPHRAGM POSITION AT THIS POINT, NOTIFY THE TEST ENGINEER AND DO NOT PROCEED ANY FURTHER.

7. Continue to manually increase the engine mean pressure at a rate not to exceed 2 Bar per minute until 20 Bar mean pressure is reached.

8. At 20 Bar mean pressure, perform a leak check of all helium and oil lines. Correct all leaks before proceeding.

9. With all lines tight and secure at 20 Bar, proceed to increase the mean pressure to 60 Bar. Do not exceed 2 Bar per minute pressurization rate.

10. At 60 Bar, perform a leak check of all helium and oil lines. Correct all leaks before proceeding.

The system is now pressurized and is ready to be started.

C.3 Procedure for Starting/Running the System

This procedure covers the routine startup of the system. This procedure assumes that the system has been pressurized appropriately to a mean pressure of 60 Bar.

Several auxiliary systems need to be set to prepare for engine startup. These systems are:

- Data Acquisition System
- Water System
- Freon Flow Loop/Calorimeter
- Operator Console
- Natural Gas/Air System

Starting the Data Acquisition System

1. Turn on the power to the computer, computer terminal, and printer.

2. When the computer is ready to accept commands, the terminal screen will show " >c ". Type in the work "LENNOX" and hit a carriage return.

3. The DAS program will begin execution by asking the operator for the datafile name in which the data is to be stored. The Test Engineer should provide this name. Type in the datafile name and hit a carriage return.

4. The test engineer should review the alarm functions and limits at this time. Set the alarm limits to the desired values.

Starting the Water System

1. The cooling water to the engine is to be turned on and a flowrate to the engine of approximately 2 gpm is to be established.

2. Set the cooling water inlet temperature as specified by the Test Plan.

Starting the Calorimeter System

1. Connect the calorimeter loop to the compressor freon line terminations.

2. Establish freon suction and discharge conditions consistent with loop design.

3. Open V-32

4. Open V-31

Starting the Operator Console

1. Turn on the operator console cooling fan.

2. Disconnect the displacer motor energization circuit by pressing the red displacer motor stop button.

3. Turn on the Elgar power supply located at the bottom of the operator console.

4. Turn the amplitude of the function generator all the way down (counter-clockwise).

5. Turn on the Krohn Hite function generator located above the power supply in the operator console.

Starting the Natural Gas/Air System

1. Set the temperature control system to the manual mode.

2. Turn on the combustion air blower via the manual throw switch located on the Operator Console.

3. Turn the control temperature set point to the minimum setting. This is accomplished by turning the temperature control pot all the way counter-clockwise.

4. Set the fuel control valve to the minimum firing rate set point by turning the fuel control pot all the way counter-clockwise.

5. Turn on the combustor ignitor via the manual throw switch located on the operator console.

6. Permit natural gas flow to the combustor by opening V-1.

7. Adjust the air flow to achieve a combustible mixture of approximately 15:1.

8. Gas ignition will be noted by an increase in heater head control temperature which is continuously displayed on the operator console. As soon as ignition is achieved, turn off the ignitor.

9. Allow the combustor to fire at the minimum setting. Ramp the heater head temperature to above 100°C at a rate consistent with this setting.

Starting the Engine

1. Energize the displacer motor circuit by pressing the green displacer motor start button.

2. Rotate V-5 to either the blip-up or blip-down position.

3. Open solenoid V-3.

4. Simultaneously open V-4 and turn up the amplitude of the function generator to start the displacer motion.

5. With the displacer motion about its mid-stroke position, close V-4 and adjust the amplitude setting of the function generator to approximately 2 amps.

6. Close V-3

7. Set the temperature control system to the AUTOMATIC control mode.

8. Increase the heater head temperature to 500°C by increasing the fuel firing rate.

9. Increase the displacer motion to 10mm by increasing the displacer motor current as required.

10. Steady out at this operating point. Adjust he fuel flow appropriately to maintain the 500°C heater head temperature. Maintain an air/fuel ratio of 13:1. Take several data scans to establish that nominal operating conditions have been reached.

At this point, the engine is started and is operating at a reasonably low power level. Power level can be increased by increasing the displacer motion and by

raising the combustor firing rate. The system Test Plan should be followed at this point.

C.4 Engine Shutdown Procedure

This procedure covers engine shutdown in both a voluntary mode as well as an emergency shutdown mode.

Voluntary Shutdown

1. Cool the engine heater head by shutting off the fuel flow by closing V-1.

2. As the heater head temperature falls, the motor current will rise. Maintain the displacer stroke at the highest level which does not exceed the motor current level of 6 amps.

3. When the heater head control temperature drops below 200°C, shut off the displacer by pressing the red displacer motor stop button.

4. Shut off the Elgar power supply.

5. Shut off the function generator.

6. When the heater head temperature drops below 100°C, shut off the combustion air blower.

7. When the heater head temperature drops below 50°C, shut off the cooling water to the engine.

8. Isolate the freon compressor from the freon calorimeter loop by closing V-32 and V-33.

The engine system is now shutdown from operation but remains pressurized. Caution must continue to be exercised around the pressurized system.

The engine system can remain at pressure with the pressure control system and oil management system functioning in the AUTOMATIC mode. However, for long periods of

time between runs, it is recommended that the system be depressurized and drained of oil.

Emergency Shutdown

The purpose of this section of the procedure is to compile a list of operator instructions to be implemented in the event that the system must be shutdown in the hot state. These instructions should be clearly understood by the operator in the event that they are suddenly needed. It is the intent of these instructions to be IMPLEMENTED when needed as opposed to REFERRED TO when needed.

If the engine must be stopped suddenly while the engine is at temperature, perform the following:

1. Shut off power to the displacer motor by pressing the displacer motor stop button.

2. Simultaneously shut off the fuel flow by closing V-3.

The engine may show a tendency to keep running when operating at low degree conditions. These conditions represent large engine stroke conditions although the engine power levels are low. The necessary actions required to stop the displacer and power piston is to increase the damping on each of these free oscillators. This can be accomplished by:

1. Quickly lowering the compressor pressure ratio (to damp the piston; and

2. Opening V-3 (to damp the displacer).

With the engine stopped in the hot condition, it is anticipated that the system fault will be cleared and that an engine re-start can be accomplished to complete the Test Plan. If not, the system will cool as the engine cooling water remains circulating and the combustor air blower continues to circulate ambient air.

C.5 Procedure for Discharging System

This procedure covers depressurization of the system from the 60 Bar mean operating level. The procedure also covers the draining of oil from the compressor cavity. It will be necessary to refer to MTI drawing 1018008-0103 (MARK I system P&ID).

This procedure assumes that the system is being voluntarily shutdown in a normal mode. All systems are considered to be operational.

The following steps are to be taken.

1. With the pressure control system in the automatic mode, decrease the system pressure setting by rotating the control setting knob counter-clockwise.

   IT IS IMPERATIVE THAT THE DISCHARGE RATE NOT EXCEED 2 BAR PER MINUTE.

   Note that the oil management system which continues to operate in the automatic mode will automatically maintain the diaphragm positions by venting both helium from the lower gas spring and oil from the compressor cavity as required.

2. Monitor the level of the oil collected in the low pressure reservoir during this depressurization. If the level is 1/2 the sight glass length, open V-22 as required to maintain the oil level below the 1/2 full level.

3. When the mean pressure level has been reduced to 1 Bar, the compressor cavity can be drained of oil by removing the upper and lower drain caps labeled and located on the compressor housing. The oil is to be collected in a clean container and returned to the oil supply reservoir located in the mechanical support package.

4. Set the pressure control system and the oil management system to the manual modes.

The unit is now depressurized and drained of oil and can be handled/approached routinely.

APPENDIX D

MTI DATA ACQUISITION OPERATING INSTRUCTIONS

MTI DATA ACQUISITION OPERATING INSTRUCTIONS

D.1 System Overview and Hardware Description

The data acquisition system for LENNOX testing is based on an IBM PC/XT computer system. The base system contains:

- 256 KBytes of memory
- 10 Mbyte hard disk
- 360 Kbyte floppy disk drive
- Keyboard

The following hardware has been added:

- A Zenith monochrome (green) monitor
- Color/graphics display card
- 8087 math coprocessor chip
- Quadram Quadboard with serial port and printer port, and 0 Kbytes of added memory (with a potential of an additional 384 Kbytes)
- Epson FX80+ printer
- Tecmar Expansion Chassis
- Data Translation DT2818 simultaneous sample and hold A/D card
- Data Translation DT2808 A/D card
- 2 Data Translation DT707 Terminal Boards to connect to the DT2818 and DT2808
- 2 Action Instruments TC15 thermocouple input cards
- 2 Action Instruments TC15T Terminal Boards for TC input

The following software packages are used:

- IBM DOS 3.1 Operating System
- IBM BASIC Compiler 2.0
- LOTUS 1-2-3 (for graphics)
- KEDIT system editor

This system allows for data acquisition on 4 dynamic channels (using the DT2818), 16 steady-state channels (using the DT2808), and 30 thermocouple channels (15 on each TC15). In addition, an 8-channel multiplexer has been constructed and connected to one channel of the DT2818 to allow the acquisition of data from up to 11 dynamic channels.

Three dynamic channels are wired to channels 0, 4, and 6 of the DT707 terminal board, while the MTI-built MUX is connected to the second of the four channels; that is channel 2. In addition, the MUX is wired to digital output terminals of the DT707 for bits 0, 1, and 2 of digital output port 0. The software sends a 3-bit pattern to this port, and the MUX then switches to the appropriate channel.

A channel assignment file has been established to indicate to the software which channels are on which boards. Those channels labeled DY 01 to DY 33 are dynamic channels (11 channels in groups of 3 to indicate mean, amplitude, and phase). The first, third, and fourth channels are connected only to the DT707 board. The second, fifth, and succeeding channels are connected via the multiplexer on its channels 1 through 8.

The channels labeled SS 01 to SS 16 are steady-state channels, connected to the DT707 which is connected to the DT2808 board. On the DT707, these are connected as channels 0 to 15. The channels labelled TA 01 to TA 15 are thermocouple (Type-K) channels connected to the first of the TC boards. The channels labeled TB 01 to TB 15 are thermocouple (Type-K) channels connected to the second of the TC boards.

A program called TESTCHAN has been written to allow the checking of connections on all four boards. See the software documentation for more details on this program.

D.2 User Manual

D.2.1 Documentation for Test Program TESTCHAN

D.2.1.1 Overview

The program TESTCHAN has been written to allow the user to obtain the raw voltage and temperature readings directly, for purposes of verifying channel connections, etc. There are 3 subprograms, one for each data acquisition board: the DT2818 for

dynamic data, the DT2808 for steady-state data, and the TC15's for temperature data. This program uses the same data acquisition subroutines as the data acquisition program LENNOX.

The user, in response to the standard DOS prompt "C>", types in "TESTCHAN" and hits the enter key. A menu is presented, with four options: take dynamic data, take steady-state data, take temperature data, and quit. The user enters the first letter of his/her choice and the program proceeds to take data from the appropriate board, or to stop if "Q" is typed. When data has been taken, the user can return from the menu by hitting any key.

When requesting dynamic data, the user is asked which of the eight MUX channels should be connected, to which the user enters a number from 1 to 8. The data is then acquired from all four channels connected to the DT707 termination board, with the raw data being written to a file. The harmonic analysis is performed, and the mean, amplitude, and phase values are printed to the screen, with the units being volts and degrees. The user is then asked to press any key to return to the menu.

When the steady-state option is chosen, the program takes data from the 16 channels of the DT2808 board and writes the acquired values (in volts) to the screen. The program then loops, taking data continuously, until the user presses any key. At that point, the program returns to the menu.

When the thermocouple option is chosen, the program takes data from the 15 channels of each thermocouple board. This data is converted to degrees C on the TC15 boards, and the data is printed on the screen with one column for each board. The program then loops, taking data continuously, until the user presses any key. At that point, the program returns to the menu.

D.2.1.2 Outputs

The program, in addition to the display output, creates two files containing raw data from dynamic channels. DATA1.PRN contains the 200 points taken from channel 0, which are used in the frequency calculation. DATA2.PRN contains five columns of data, the first column being time and the remaining columns being the data acquired (99 points over 4 cycles) from all four currently connected dynamic chan-

nels. This data can be printed out (e.g. PRINT DATA2.PRN) or can be plotted using LOTUS 1-2-3. These files are overwritten each time dynamic data is taken, so if some particular scans are to be saved, the data files must be renamed.

D.2.1.3 Errors

If a board error occurs during data acquisition, a detailed error message is written to the screen. In the case of the Data Translation Boards, the error codes can be looked up in the respective manual.

D.2.2 Documentation for Data Acquisition Program LENNOX

D.2.2.1 Overview

LENNOX is the data acquisition and monitoring program for the GRI engine. The program is controlled via the use of special function keys. These allow the operator to choose the mode of operation, take a scan of data, and reset alarm conditions. The program has the ability to scan 11 dynamic channels, 16 steady-state channels, 30 thermocouple channels, and perform up to 46 calculations on the scanned data. The monitor loop of the program scans all steady-state data and displays chosen values on the terminal. A 'full scan' scans dynamic data in addition to all steady-state data, performs calculations on the data, and may or may not store the data to hard disk. The program has two modes of operation. Manual mode required the operator to hit a function key when a full scan is desired. Automatic mode takes a full scan every N minutes where N is the time interval chosen by the operator. Alarm conditions exist for certain steady-state variables with the ability to turn the limit checking on or off for any alarm condition during program execution.

The program is invoked by typing "LENNOX". After the program does some initializing, the operator is asked for the name of the data file in which to store the scanned data. If the file entered does not exist, a new data file is created and the message "CREATING NEW FILE" is displayed. If the file entered already exists, the message "DATA FILE CONTAINS N SCANS" is displayed, where N is the number of scans already in the file.

The program enters the monitor loop which scans the steady-state channels and updates the display with current values. The scanning takes about six seconds, and the display update takes about three seconds. During every loop, alarm condition checking is done for the variables specified in the alarm file "ALARM.FIL". If any of the variables exceed the limits specified in the alarm file, the terminal beeps as it is written to the screen and the variable will blink. The first time a variable exceeds its limits, an alarm condition violation report is sent to the printer, giving the operator a running hardcopy of problems encountered during engine testing. The program stays in the monitor loop until the operator hits one of the function keys.

A title is always displayed at the top of the screen. The first line of the title contains the mode of operation (manual or automatic) and the current function being performed. The next line displays the current time and, if the mode is automatic, the time the next full scan will take place. The third line is an error line. When an error occurs, a message in bold print will appear on this line and the terminal will beep.

D.2.2.2 Function Keys

Up to six different functions are displayed at the bottom of the screen. During the monitor loop, the operator may invoke any of these functions by hitting one of the function keys at the left of the keyboard (F1 through F10). When the operator hits a function key, the current function is completed before the new function is invoked. Therefore, there will be a slight delay of up to nine seconds before the new function is invoked. The operator is asked to be patient during this time and need only hit the function keys once.

When the operator hits the "MANUAL" function key, the program is put into a manual mode of operation. In this mode, the operator must hit a function key each time a full scan is desired. The program is then returned to the monitor loop, scanning steady-state data and displaying it.

When the operator hits the "AUTOMATIC" function key, the program is put into an automatic mode of operation. The operator is presented with a menu of 10 new function keys. Each key represents a time interval (in minutes) between full scans. When the operator chooses the desired time interval, a full scan is immediately

taken and the program is returned to the monitor loop. The next full scan will automatically be taken N minutes from the start of the full scan just taken, where N is the time interval chosen. The current time and time of next scan is displayed in the title on the screen so the operator can see when to expect the next full scan.

When the operator hits the "SCAN" function key, a full scan is taken, including dynamic and steady-state data, calculations are performed, the display is updated, and a report is sent to the printer. The scanned data is not stored to disk. After the full scan is taken, the program is returned to the monitor loop. This function key may be hit during either mode of operation (manual or automatic). Its main purpose is to get a printout of all channels and calculations at any point in time.

When the operator hits the "STORE" function key, a full scan is taken of both dynamic and steady-state data, calculations are performed, the display is updated, a report is sent to the printer, and the data is stored to disk. After the full scan is taken, the program is returned to the monitor loop. This function key may be hit during either mode of operation, manual or automatic. If the program is in automatic mode, hitting "STORE" will not change when the next full automatic scan will occur.

When the operator hits the "ALARM" key, all the alarm conditions are displayed on the screen with an asterisk next to the ones which are currently in effect. The operator may then set any condition by entering the letter in front of the variable for which he wishes limit checking. Hitting carriage return terminates 'set' mode and enters 'clear' mode. The operator can then turn off limit checking for any alarm condition. Hitting carriage return brings the program back to the monitor loop with the new alarm conditions in effect. Note that the letters entered must be capital letters.

When the operator hits the "STOP" key, the program is terminated.

D.2.2.3 Outputs

There are several outputs the program produces, both to the printer and to the terminal.

During the monitor loop, the terminal is updated with the current scanned values. The display contains two calculated values (A/F Ratio and Firing Rate) in addition to several scanned steady-state values. The DISPLAY file determines what variables will be displayed. If any of the steady-state values exceed their alarm condition limits, the value is beeped as it is displayed. The value also blinks until the value corrects itself or until the alarm condition check is turned off for that variable via the "ALARM" key. Figure D-1 is an example of the terminal in the monitor loop.

When the operator hits the "ALARM" key, an alarm condition display appears on the terminal. The display contains all the alarm conditions, their variable codes from the channel assignment file, and their minimum and maximum limits. All alarm conditions which are currently active have an asterisk next to them. The operator is instructed to set or clear any of the variables. Figure D-2 is an example of the display.

Whenever a full scan is taken, either by hitting the "SCAN" or "STORE" keys, or by entering AUTOMATIC mode, a scan report is printed on the line printer. If the scan was not stored, the second line of the report title will say "FULL SCAN". If the scan was stored, the second line of the report title will say "SCAN # NN", where NN is the number of the scan just stored to disk. The title of the report contains the title string from the Channel Assignment File, the scan number, the time of the scan, and the name of the Channel Assignment File. The report contains all the scanned dynamic data in terms of mean, amplitude, and phase. It also contains all the scanned steady-state date, thermocouple data, and calculations. The report is printed in compressed mode on the printer so it will all fit on 8-1/2 by 11 paper. Figure D-3 is an example of a scan report.

Whenever an alarm condition is violated for the first time, an alarm condition report is printed on the line printer. It contains the alarm(s) description, variable code, minimum and maximum limits, and actual value of the variable exceeding the alarm condition. Figure D-4 is an example of this report.

D.2.2.4 Files

There are several files that the program uses.

MANUAL MODE
TIME: 11:54:58

MONITORING STEADY STATE DATA

MEAN PRESSURE BARS	FREQUENCY HERTZ	FIRING RATE WATTS	SUCTION PRESSURE PSIA	DISCHARGE PRESSURE PSIA
6.2	2.4	3.	1.9	11.4
BEARING PRESSURE BARS		A/F RATIO	SUCTION TEMP DEG C	DISCHARGE TEMP DEG C
7.4		0.	-1000.0	-1000.0
COOLANT FLOWRATE GPM	HD EXHAUST TEMP DEG C			FREON FLOWRATE LB/HR
0.1	-1000.0			0.2
COOLANT INLET TEMP DEG C	HD CONTROL TEMP DEG C	MOTOR POWER KW		
-1000.0	-1000.0	24.4		

1 2AUTO 3SCAN 4STORE 5ALARMS 6STOP 7 8 9 10

Figure D-1 Monitor Loop Terminal Display

MANUAL MODE ALARM CONDITIONS
TIME: 11:53:40

ALARM	DESCRIPTION	VARIABLE	MINIMUM	MAXIMUM
* A =	Mean Pressure (Bars)	SS 7	57	63
* B =	Bearing Pressure (Bars)	SS 8	64	-
* C =	Coolant Flowrate (GPM)	SS 3	.5	-
* D =	Coolant Inlet Temp (Degc)	TA 12	-	50
* E =	Heater Head Control Temp (Degc)	TA 14	-	750
* F =	Heater Head Exhaust Temp (Degc)	TA 4	-	850
* G =	Motor Power (KW)	SS 15	-	8

(* denotes set alarm condition)

ENTER ALARM LETTER TO BE SET, <CR> when done setting

Figure D-2 Alarm Condition Terminal Display

LENNOX DATA ACQUISITION TEST
SCAN # 12 DATE: 09-18-1985 TIME: 10:01:37 FILE: CHANEL2

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
XD	-0.43	4.15	0.00
XP	-100.00	0.00	30.76
VT1	0.00	0.00	30.76
CT1	-0.15	0.07	-47.89
PT-3	-100.00	0.00	38.90
PT-6	-100.00	0.00	-4.06
PT-7	-100.00	0.00	9.79
PT-9	-35.00	0.00	6.94
PT-10	-35.00	0.00	7.49
PT-15	-100.00	0.00	2.69
OPEN	0.00	0.00	-5.06

STEADY STATE DATA

FI-1	FI-2	FI-3	FI-4	PI-1	PI-2	PT-4	PT-5
4.9	0.0	0.1	0.2	0.4	0.5	6.1	7.1
PT-8	PT-11	PT-12	PT-14	FREQUENCY	A1	WT-1	DELTAT
8.2	1.8	2.0	10.7	3.0	3.0	30.6	3.1

TEMPERATURE DATA

TE-1	TE-2	TE-3	TE-4	TE-5	TE-6	TE-7	TE-8
22.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0
TE-9	TE-10	TE-11	TE-12	TE-13	TE-14	TE-15	TE-16
-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0
TE-17	TE-18	TE-19	TE-20	TE-21	TE-22	TE-23	TE-24
-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0
TE-25	TE-26	TE-27	TE-28	TE-29	TE-30		
-1000.0	-1000.0	-1000.0	-1000.0	-1000.0	-1000.0		

CALCULATIONS

FREQUENCY	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	PUMP PWR	ALPHA
0.5984E+02	0.2000E+04	0.3000E+04	0.4000E+04	0.5000E+04	0.6000E+04	0.7000E+04	0.8000E+04
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
0.9000E+04	0.1000E+05	0.1100E+05	0.1200E+05	0.1300E+05	0.1400E+05	0.1500E+05	0.1600E+05
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE			
0.1700E+05	0.1800E+05	0.1900E+05	0.2000E+05	0.2100E+05			

Figure D-3 Output Scan Report

ALARM CONDITION VIOLATION REPORT

14:08:21

ALARM DESCRIPTION	VARIABLE	MINIMUM	MAXIMUM	CURRENT
Mean Pressure (Bars)	SS 7	57	63	7.128906
Bearing Pressure (Bars)	SS 8	64	-	8.496094
Coolant Flowrate (GPM)	SS 3	.5	-	.1904297

Figure D-4 Alarm Condition Violation Report

The DATA FILE, which is used to store the scanned data, is a random access file with a record length of 512 bytes. The first record is a header record containing the number of scans in the file, the channel assignment file used when the scans were taken, and a title string for internal use. Each subsequent record contains all the data for each individual scan, along with the scan time and calculations performed on the scanned data. The file may contain up to 100 scans (101 records including the header record). The file is named by the operator at the beginning of the program.

The Channel Assignment File is a file containing information about the data to be scanned. See Figure D-5 for an example listing. It includes a header line containing the actual number of dynamic, steady-state, thermocouple board A, thermocouple board B, and calculated variables that are being used. The header line also contains the title to be used on all the output reports. The title must be enclosed in double quotes (\"). The second line in the file is a description of the subsequent lines in the file. The remaining lines in the file describe all the variables being scanned or calculated. For each variable, there is a label, a code name and code number, a gain factor, resolution, and units. Each line is numbered sequentially for reference.

The label is a short description of the variable. It must be 12 characters long, including blanks, and must be enclosed in double quotes (\"). The labels are used when printing the scan report.

The code name is a two character code describing the type of data (DY-dynamic, SS-steady-state, TA-thermocouple board A, TB-thermocouple board B, and CA-calculation). The code number is the number of the channel to which the variable is connected. For example, DY05 is the dynamic variable on channel 5. For calculations, the code number is the number of the calculation. For example, CA15 is the fifteenth calculation. The code name must be enclosed in double quotes ("DY10").

The gain factor is a multiplier used to change the raw voltage being read to engineering units. If the gain is a -1, a curve fit for air flow rate is performed on the data. A gain of -2 performs a curve fit for fuel flow on the data. All thermocouple data is received from the board already converted to degrees C; therefore, their gain is 1.

30,16,15,15,21 "LENNOX DATA ACQUISITION TEST"

	LABEL	--CODE--		GAIN	RESOLUTION	UNITS
1	"XD MEAN "	"DY"	01	10	02	"MM "
2	"XD AMP "	"DY"	02	10	02	"MM "
3	"XD PHASE "	"DY"	03	10	02	"DEG "
4	"XP MEAN "	"DY"	04	10	02	"MM "
5	"XP AMP "	"DY"	05	10	02	"MM "
6	"XP PHASE "	"DY"	06	10	02	"DEG "
7	"VT1 MEAN "	"DY"	07	18.6	02	"VAC "
8	"VT1 AMP "	"DY"	08	18.6	02	"VAC "
9	"VT1 PHASE "	"DY"	09	18.6	02	"DEG "
10	"CT1 MEAN "	"DY"	10	100	02	"AMPS "
11	"CT1 AMP "	"DY"	11	100	02	"AMPS "
12	"CT1 PHASE "	"DY"	12	100	02	"DEG "
13	"PT-3 MEAN "	"DY"	13	10	02	"BARS "
14	"PT-3 AMP "	"DY"	14	10	02	"BARS "
15	"PT-3 PHASE "	"DY"	15	10	02	"DEG "
16	"PT-6 MEAN "	"DY"	16	10	02	"BARS "
17	"PT-6 AMP "	"DY"	17	10	02	"BARS "
18	"PT-6 PHASE "	"DY"	18	10	02	"DEG "
19	"PT-7 MEAN "	"DY"	19	10	02	"BARS "
20	"PT-7 AMP "	"DY"	20	10	02	"BARS "
21	"PT-7 PHASE "	"DY"	21	10	02	"DEG "
22	"PT-9 MEAN "	"DY"	22	3.5	02	"BARS "
23	"PT-9 AMP "	"DY"	23	3.5	02	"BARS "
24	"PT-9 PHASE "	"DY"	24	3.5	02	"DEG "
25	"PT-10 MEAN "	"DY"	25	3.5	02	"BARS "
26	"PT-10 AMP "	"DY"	26	3.5	02	"BARS "
27	"PT-10 PHASE "	"DY"	27	3.5	02	"DEG "
28	"PT-15 MEAN "	"DY"	28	10	02	"BARS "
29	"PT-15 AMP "	"DY"	29	10	02	"BARS "
30	"PT-15 PHASE "	"DY"	30	10	02	"DEG "
31	"OPEN "	"DY"	31	0	02	" "
32	"OPEN "	"DY"	32	0	02	" "
33	"OPEN "	"DY"	33	0	02	" "
34	"FI-1 "	"SS"	01	1	01	" "
35	"FI-2 "	"SS"	02	1	01	" "
36	"FI-3 "	"SS"	03	1	01	"GPM "
37	"FI-4 "	"SS"	04	1	01	"LB/HR"
38	"PI-1 "	"SS"	05	1	01	" "
39	"PI-2 "	"SS"	06	1	01	" "
40	"PT-4 "	"SS"	07	10	01	"BARS "
41	"PT-5 "	"SS"	08	10	01	"BARS "
42	"PT-8 "	"SS"	09	10	01	"BARS "
43	"PT-11 "	"SS"	10	2	01	"PSIA "
44	"PT-12 "	"SS"	11	2	01	"BARS "
45	"PT-14 "	"SS"	12	10	01	"PSIA "
46	"FREQUENCY "	"SS"	13	1	01	"HERTZ"
47	"A1 "	"SS"	14	1	01	" "
48	"WT-1 "	"SS"	15	10	01	"KW "
49	"DELTAT "	"SS"	16	1	01	"DEG C"
50	"TE-1 "	"TA"	01	1	01	"DEG C"

Figure D-5 Channel Assignment File

51	"TE-2	"	"TA"	02	1	01	"DEG C"
52	"TE-3	"	"TA"	03	1	01	"DEG C"
53	"TE-4	"	"TA"	04	1	01	"DEG C"
54	"TE-5	"	"TA"	05	1	01	"DEG C"
55	"TE-6	"	"TA"	06	1	01	"DEG C"
56	"TE-7	"	"TA"	07	1	01	"DEG C"
57	"TE-8	"	"TA"	08	1	01	"DEG C"
58	"TE-9	"	"TA"	09	1	01	"DEG C"
59	"TE-10	"	"TA"	10	1	01	"DEG C"
60	"TE-11	"	"TA"	11	1	01	"DEG C"
61	"TE-12	"	"TA"	12	1	01	"DEG C"
62	"TE-13	"	"TA"	13	1	01	"DEG C"
63	"TE-14	"	"TA"	14	1	01	"DEG C"
64	"TE-15	"	"TA"	15	1	01	"DEG C"
65	"TE-16	"	"TB"	01	1	01	"DEG C"
66	"TE-17	"	"TB"	02	1	01	"DEG C"
67	"TE-18	"	"TB"	03	1	01	"DEG C"
68	"TE-19	"	"TB"	04	1	01	"DEG C"
69	"TE-20	"	"TB"	05	1	01	"DEG C"
70	"TE-21	"	"TB"	06	1	01	"DEG C"
71	"TE-22	"	"TB"	07	1	01	"DEG C"
72	"TE-23	"	"TB"	08	1	01	"DEG C"
73	"TE-24	"	"TB"	09	1	01	"DEG C"
74	"TE-25	"	"TB"	10	1	01	"DEG C"
75	"TE-26	"	"TB"	11	1	01	"DEG C"
76	"TE-27	"	"TB"	12	1	01	"DEG C"
77	"TE-28	"	"TB"	13	1	01	"DEG C"
78	"TE-29	"	"TB"	14	1	01	"DEG C"
79	"TE-30	"	"TB"	15	1	01	"DEG C"
80	"FREQUENCY	"	"CA"	01	00	00	"HERTZ"
81	"A/F RATIO	"	"CA"	02	00	00	" "
82	"LS GSPOW	"	"CA"	03	00	00	"WATTS"
83	"HS GSPOW	"	"CA"	04	00	00	"WATTS"
84	"PMOTI	"	"CA"	05	00	00	"WATTS"
85	"PWROD	"	"CA"	06	00	00	"WATTS"
86	"PUMP PWR	"	"CA"	07	00	00	"WATTS"
87	"ALPHA	"	"CA"	08	00	00	"DEG "
88	"PV POWER	"	"CA"	09	00	00	"WATTS"
89	"QREJ	"	"CA"	10	00	00	"WATTS"
90	"NENG	"	"CA"	11	00	00	" "
91	"PLHVP	"	"CA"	12	00	00	"WATTS"
92	"PRHVP	"	"CA"	13	00	00	"WATTS"
93	"GSPOW	"	"CA"	14	00	00	"WATTS"
94	"NLE	"	"CA"	15	00	00	" "
95	"QFUEL	"	"CA"	16	00	00	"WATTS"
96	"QEXHAUST	"	"CA"	17	00	00	"WATTS"
97	"TAVGH	"	"CA"	18	00	00	"DEG C"
98	"HEAT BAL	"	"CA"	19	00	00	"WATTS"
99	"QAIR	"	"CA"	20	00	00	"WATTS"
100	"FIRING RATE	"	"CA"	21	00	00	"WATTS"

Figure D-5 cont'd

The resolution is a number representing the number of digits to the right of the decimal used when the data is being displayed on the screen. In general, all dynamic data uses two decimals, steady-state uses one decimal, and calculations use 0 decimal digits.

The units describe the engineering units used. It must be five characters long, including blanks, and must be enclosed in double quotes. These units are used for the terminal display.

If the Channel Assignment File is changed in any way, a new file must be created in the editor from a copy of the old file and given a new name.

The Channel Assignment Name File (CHANNEL.NAM) contains the name of the current Channel Assignment File. If the Channel Assignment File is changed in any way, it must be given a new name and the Channel Assignment Name File must be edited to reflect the new name. A data file can only be used with the Channel Assignment File with which it was created. If the operator desires to use an old Data File (perhaps for obtaining summary reports), the Channel Assignment File with which the data was created must exist on the hard disk.

The Display file (DISPLAY) is a file describing what is to be displayed on the terminal during the monitor loop of the program. See Figure D-6 for an example listing. It contains two types of lines - text and variable lines. Text lines are prefixed with a letter T and contain a line of text that is to be written to the terminal. Variable labels are units written to the terminal in this way. Variable lines are prefixed with the letter V and contain five variables separated by blanks. A dummy code of 0000 is used to write a blank field to the terminal.

The Alarm file (ALARM.FIL) is a file describing the alarm conditions for the variables which have alarm checking. See Figure D-7 for an example listing. Alarms can only be checked on steady-state data, and there is a limit of up to 10 alarms for the program. The first line in in the file is a line describing the subsequent lines. The remaining lines each contain an index number, a label, a code name and number, a minimum limit, and a maximum limit. The index number is just used for reference.

```
T        MEAN                                FIRING        SUCTION       DISCHARGE
T      PRESSURE        FREQUENCY              RATE        PRESSURE        PRESSURE
V SS7 SS13 CA21 SS10 SS12
S
T       BEARING                                A/F         SUCTION       DISCHARGE
T      PRESSURE                               RATIO          TEMP            TEMP
V SS06 Q000 CA2 TB15 TB14
S
T       COOLANT        HD EXHAUST                                          FREON
T      FLOWRATE           TEMP                                            FLOWRATE
V SS03 TA04 0000 0000 SS4
S
T       COOLANT        HD CONTROL          MOTOR
T      INLET TEMP         TEMP              POWER
V TA12 TA14 SS15 0000 0000
```

Figure D-6 Display File

	DESCRIPTION	--CODE--		MINIMUM	MAXIMUM
1	"Mean Pressure (Bars) "	"SS"	07	57.	63.
2	"Bearing Pressure (Bars) "	"SS"	08	64.	-999.
3	"Coolant Flowrate (GPM) "	"SS"	03	.5	-999.
4	"Coolant Inlet Temp (Degc) "	"TA"	12	-999.	50.
5	"Heater Head Control Temp (Degc)"	"TA"	14	-999.	750.
6	"Heater Head Exhaust Temp (Degc)"	"TA"	04	-999.	850.
7	"Motor Power (KW) "	"SS"	15	-999.	8.

Figure D-7 Alarm File

The label is a short description of the variable. It must be 31 characters long and must be enclosed in double quotes. The label is used in the alarm display on the terminal and in the alarm violation report on the printer.

The code name and number are the same as in the Channel Assignment File. Only code names SS, TA, and TB are valid in this file.

The minimum and maximum are real numbers which are used for limit checking for the variable described in the variable code. If there is no limit, a -999. is used as a flag to the program that no checking is to be done.

D.2.2.5 Errors

If an error occurs in the program, a message will print in bold print on the third line of the title block at the top of the terminal and the terminal will beep. The error message will give the BASIC error number of the error and the line number in the program where the error occurred (see page A-3 in the BASIC REFERENCE manual for a description of all errors). The program may terminate or resume depending upon the error. Specific errors may generator a more specific error message. Those messages are listed below.

CHANNEL ASSIGNMENT FILE MISMATCH - This error occurs when the data file the user specifies at the beginning of the program was not created with the current Channel Assignment File. This error causes the program to terminate. The operator must edit the CHANNEL.NAM file to reflect the correct Channel Assignment File name.

DISK FULL - NO ROOM-FOR DATA FILE - This error occurs when a new data file is being created and there is no room on the hard disk for the file. This error causes the program to terminate. The operator should copy some data files onto floppy disks to make room on the hard disk for program data file storage.

DATA FILE HAS REACHED MAX CAPACITY - POINT CANNOT BE STORED - This error occurs when an attempt is made to store more than 100 scans of data in the data file. The scan is not stored and the program resumes. The operator should "STOP" the program and start it again using a new data file name.

FATAL BOARD ERROR - STATUS = XXXXX HEX - This error may occur during the acquiring of dynamic or steady-state data if the board detects an error. The program proceeds to read the error register of the board and reports the values in the error bytes. (Refer to page 7-4 of of the DT2801 manual). This error causes the program to terminate.

FATAL ERROR - ILLEGAL STATUS REGISTER VALUE OF XXXX HEX - This error may occur during the acquiring of dynamic or steady-state data if the board is in an error condition before the acquisition is ready to start. (Refer to page 2-15 of the DT2801 manual). This error causes the program to terminate.

TURN PRINTER ON-LINE, THEN HIT <CR> - This error occurs at the beginning of the program if the printer is offline. The operator is prompted to turn the printer online and hit a <cr> to continue the program. The program can not check to see if the printer is turned off so the operator must always check the printer before invoking the program

D.2.3 Documentation for Post Processing Program POST

D.2.3.1 Overview

POST is the post processing program for GRI engine data. Given a data file of saved scans, the program will produce output reports identical to the scan reports produced during the LENNOX data acquisition program or summary reports summarizing the data for given scans and plot files to be used by the plotting software LOTUS. Plot files are automatically created when summary reports are generated. The program is invoked by typing POST. After the program does some initializing, the operator is asked for several inputs and the operator chosen report is generated. After the report has been generated, the operator may choose to generate another report from the same or different data file.

D.2.3.2 Inputs

Several inputs are required from the operator by this program. When this program is invoked, the first piece of information which must be input is the data file name. (At this point, the program may be terminated by hitting <CR>.) If the input file name exists, the file is read, and the number of scans the data file

contains is displayed on the terminal. The operator must next choose the input and type of report to be created. The operator may choose to create a Standard or a Summary report. A Standard report reproduces data points as taken and calculated during the test. A Summary report reproduces selected test data in tabular form (rows and columns) in a format convenient for plotting. Note that to produce a Summary report, the operator must first create a Summary Descriptor File before running the POST program (see section 2.3.4). After choosing the type of report, the operator is then prompted for type of scan, consecutive or random. If consecutive is chosen, the operator is asked to enter the starting and ending scan numbers for the report to be generated. If random is chosen, the operator is asked to enter the number of random scan numbers desired and then the scan numbers themselves. If a standard report was requested, as many reports as scan numbers requested will be generated. If a summary report was requested, a row of numbers will be generated in the report for each scan number requested. The next several inputs are only asked for if the operator chooses "summary" for the type of report. The operator is presented with a menu of options for describing the summary report. The menu includes all the predefined Summary Descriptor Files, an option for entering a new Summary Descriptor File name, and an option for creating a new Summary descriptor File from the program. If the operator chooses to enter a new Summary Descriptor File name, he is asked to enter the file name.

If the operator chooses to create a new file, he is asked to give it a name, enter the number of variables in the new report, and enter the variable codes (from the Channel Assignment File). Checking is done when the codes are input to ensure they are valid codes. Finally, the last thing the operator is asked for is the output device, printer or terminal. If terminal is chosen, the report will go to the terminal, and lines greater than 80 characters will wrap. At the end of each report, the operator will be prompted to "HIT ANY KEY" before the program continues on and asks for "MORE REPORTS?". If the printer is chosen, reports will be printed on the printer in compressed mode so that the report will fit on 8-1/2 by 11 paper.

D.2.3.3 Outputs

The POST program can generate 3 types of outputs.

The output report is a report identical to the scan report generated by the LENNOX data acquisition program. The title of the report contains the title string from the Channel Assignment File, the scan number, the time of the scan, and the name of the Channel Assignment File. The report contains all the scanned dynamic data in terms of mean, amplitude, and phase. It also contains all the scanned steady-state data, thermocouple data, and calculations. The report is printed in compressed mode on the printer so it will all fit on 8-1/2 by 11 paper. Several reports may be generated at once by choosing a sequence of scan numbers during the input phase of the program. Figure D-3 is an example of an output report.

The summary report summarizes given variables for a range or sequence of scans. The title of the report contains the title string from the Channel Assignment File, the name of the data file the data comes from, and the date and time the report was generated. The report contains columns of numbers of the specified variables for operator requested scans. In addition to the scan number and the date/time, which are automatically generated, the operator may choose up to 10 variables to be summarized. The variable labels and a numeric descriptor are printed at the top of the report. If any variable codes specified in the Summary Descriptor File are illegal, the columns of numbers for that variable will be -9999. and the label for that variable will be blank. The report is printed in compressed mode on the printer so that it will fit on 8-1/2 by 11 paper. Figure D-8 is an example of this report.

The plot files are generated whenever a summary report is generated and can be used in the plotting software LOTUS to produce plots of any of the summary report variables.

D.2.3.4 Files

There are several files that the program uses.

The DATA FILE in which the scanned data is stored is a random access file with a record length of 512 bytes. The first record is a header record containing the number of scans in the file, the channel assignment file used when the scans were taken, and a title string used for internal use. Each subsequent record contains all the data for each individual scan along with the scan time and calculations

LENNOX DATA ACQUISITION TEST
DATA SUMMARY REPORT DATA FILE: VINCE DATE: 09-24-1985 TIME: 14:04:05

NO	DATE	TIME	XP MEAN	XP AMP	XP PHASE	FI-1	PT-5	DELTAT	TE-1	TE-16	FREQUENCY	FIRING RATE
1	2		3	4	5	6	7	8	9	10	11	12
30	0918	1056	-.1000E+03	0.1261E-03	-.5493E+02	0.4878E+01	0.6787E+01	0.1338E+01	0.2300E+02	-.1000E+04	0.0000E+00	0.0000E+00
31	0918	1102	-.1000E+03	0.1261E-03	0.1172E+02	0.4888E+01	0.6934E+01	0.1289E+01	0.2300E+02	-.1000E+04	0.0000E+00	0.0000E+00
32	0918	1107	-.1000E+03	0.1261E-03	0.5427E+02	0.4858E+01	0.6934E+01	0.1289E+01	0.2300E+02	-.1000E+04	0.0000E+00	0.0000E+00
33	0918	1112	-.1000E+03	0.1261E-03	-.8178E+02	0.4897E+01	0.6592E+01	0.1318E+01	0.2300E+02	-.1000E+04	0.0000E+00	0.0000E+00

Figure D-8 Summary Report

performed on the scanned data. The file may contain up to 100 scans (101 records including the header record).

The Channel Assignment File is a file containing information about the data to be scanned. See Figure D-5 for an example listing. It includes a header line containing the actual number of dynamic, steady-state, thermocouple board A, thermocouple board B, and calculated variables that are being used. The header line also contains the title to be used on all the output reports. The title must be enclosed in double quotes (\"). The second line in the file is a description of the subsequent lines in the file. The remaining lines describe all the variables being scanned or calculated. For each variable, there is a label, a code name and code number, a gain factor, resolution, and units. Each line is numbered sequentially for reference.

The label is a short description of the variable. It must be 12 characters long, including blanks, and must be enclosed in double quotes (\"). The labels are used when printing the output report.

The code name is a two character code describing the type of data (DY-dynamic, SS-steady-state, TA-thermocouple board A, TB-thermocouple board B, and CA-calculation). The code number is the number of the channel to which the variable is connected. For example, DY05 is the dynamic variable on channel 5. For calculations, the code number is the number of calculations. For example, CA15 is the fifteenth calculation. The code name must be enclosed in double quotes ("DY10"). The code is used when describing the summary report to be generated.

The gain factor is a multiplier used to change the raw voltage being read to engineering units. It is not used by this program.

The resolution is a number representing the number of digits to the right of the decimal used when data is being printed. It is not used by this program.

The units describe the engineering units used. It must be 5 characters, including blanks, and must be enclosed in double quotes. These units are not used by this program.

The Summary Descriptor Files are files that describe the summary reports to be generated. There are several predefined files already set up that the operator may choose. These files are called "SUMMARY1.FIL" through "SUMMARYN.FIL" and contain up to 10 variable codes to use when generating the summary report. For example, if a summary descriptor file contains the codes DY01, SS01, and CA01, the summary report will generate columns of data for the first dynamic channel, the first steady-state channel, and the first calculation in addition to the scan numbers and data/times the scans were stored. The operator may create his own Summary Descriptor File from within the program or use a Summary Descriptor File previously created. See Figure D-9 for an example Summary Descriptor File.

The Summary Descriptor Control File (SUMMARY.CTL) is a file that contains all the predefined Summary Descriptor Files from which the operator can choose. The program is limited to 10 entries in this file. Each Summary Descriptor File has a description and name in this file, both of which must be enclosed with double quotes and right padded with blanks. The descriptions can be any length and the names must adhere to DOS file naming conventions. If the operator wishes to add a new predefined Summary Descriptor File to the system, he simply creates the new file via the program create function and then edits the Summary Descriptor Control File to add the new file's description and name. See Figure D-10 for an example of this file.

Plot files are output files automatically generated as a result of generating a summary report. They contain columns of numbers identical to the summary report's columns with the exception of the date/time column. Instead of scan date/time, the value is the elapsed time from the first operator chosen scan. The first line in the file contains the variable's labels which are used by LOTUS. The plot files are named automatically by the program. It takes the first 16 characters of the current data file name, appends a number to it, and gives it a file extension of ".PRN". For example, if three summary reports were being generated from the data file "ABCDEFGH", the following plot files would be generated: ABCDEF1.PRN, ABCDEF2.PRN, ABCDEF3.PRN. Note that if summaries from the same data file were generated later, these files would be overwritten with new plot files.

```
DY04
DY05
DY06
SS01
SS08
SS16
TA01
TB01
CA01
CA21
```

Figure D-9 Summary Descriptor File

```
SUMMARY DESCRIPTION                    SUMMARY FILENAME
"DESCRIPTION A  TEST 10 VARS "         "SUMMARY1.FIL"
"DESCRIPTION B  TEST BAD CODE"         "SUMMARY2.FIL"
"DESCRIPTION C  TEST 5 VARS  "         "SUMMARY3.FIL"
"DESCRIPTION D  TEST 1 VAR   "         "SUMMARY4.FIL"
```

Figure D-10 Summary Descriptor Control File

D.2.3.5 Errors

If an error occurs in the POST program, a message will print in bold print on the third line of the title block at the top of the terminal and the terminal will beep. The error message will give the BASIC error number of the error and the line number in the program where the error occurred (see page A-3 in the BASIC REFERENCE manual for a description of all errors). The program will terminate as a result of the error. Errors occurring during the input phase of the program are handled differently. If an operator inputs an incorrect response to the input prompt, the terminal beeps and the operator is reprompted. Specific errors may generate a more specific error message. Those messages are listed below.

DISK FULL - NO ROOM FOR NEW FILE - This error occurs when the operator is creating a new Summary Descriptor File from the program and the hard disk becomes full. This error causes the program to terminate. The operator should copy some data files onto floppy disks to make room on the hard disk for program file storage.

ERROR - FILE NOT FOUND - This error occurs when the operator specifies the name of a file that doesn't exist. Either the data file name does not exist, the Channel Assignment File used when the data file was created doesn't exist, or a Summary Descriptor File that the operator specified to use doesn't exist. The error causes the program to terminate.

TURN PRINTER ON-LINE, THEN HIT <CR> - This error occurs at the beginning of the program if the printer is offline. The operator is prompted to to turn the printer online and hit <CR> to continue the program. The program can not check to see if the printer is turned off so the operator must always check the printer before invoking the program.

D.2.4 Generating Plots Using LOTUS 1-2-3

Files which contain data for plotting are created by the POST program and the TESTCHAN program. LOTUS 1-2-3 was purchased to generate plots from this data. The user can run LOTUS under his control referring as needed to the LOTUS manual or can invoke a command file to aid in the plotting process. The procedures follow.

The two choices of interest on this menu are 1-2-3, which contains the graphics program, and Printgraph, which is used to print a hardcopy after a graph is created and saved. Type the "1" to select 1-2-3 then hit any key as requested. The spreadsheet program then begins.

Enter "/" to bring up the command menu. In 1-2-3, to select a menu option, either move the cursor to that option and hit the enter key or type in the first letter of that option. In this discussion, the first letter method will be used. The "esc" will serve to back up in case of a typing error.

To create a plot using the "automated" version, enter "F" to bring up the "Files" menu. Enter "R" to retrieve the file containing the plotting routine, then type in "PLOT" and hit return when asked for the file name. This automatically starts the plotting command file. The first order of business here is to bring in the data to be plotted. The program prompts you for the name of that plot file, so type in the name and hit the return key. The plot file is then "imported" into 1-2-3. The next series of questions ask the user which columns of data are to be plotted. Note the layout of the spreadsheet into cells. To use 20 points in column A for X-axis data, enter A1.A20 and hit return. To use 50 points in column F, enter F1.F50 and hit return. In this manner, the user specifies the X data and the first set of Y data. The user is then prompted for labels, and when this set of questions is answered, the graph is "viewed". Hit any key to leave this mode. Next, save the graph in order to get a hard copy, so enter a name and hit return. Now it is necessary to back out of 1-2-3, so hit Q and then Y. The procedure for running Printgraph follows.

To generate plots without the command file, the following command sequence should help. First, import the file using the sequence "/FIN" and now enter the plot file name. Then bring up the menu with "/", and enter "GTXX". This specifies the Graph Program, with type of plot being XY. Now specify the X range. When this is done, enter "A" to specify the first set of Y values, and enter its range. To view the graph, hit "V"; and to enter labels, change the scale, etc., enter "O" for Options. When the graph is completed, save it. Then enter "/QY" to exit the 1-2-3 program.

To run Printgraph at this time, enter "P". Set the fonts by entering "OF1" followed by hitting the enter key. Then type "QS" and select your graph file by hitting the enter key. "G" will then print the graph. To exit, enter "QYEY".

D.2.5 Managing the Files

Files on this system are named with a file name and an extension, as in POST.BAS, where POST is the file name, and BAS is the extension. However, a file need not be named with an extension (e.g. "FILE1" is a valid name).

To obtain a directory listing of all files in a disk area, type in "DIR *.*/P", followed by enter. The "/P" stops the listing at each full page. To find all names of files with the extension.PRN, type in "DIR *.PRN/P". See the DOS manual for more details.

To copy a file (for example, named POST.BAS) to a floppy disk, first put the floppy disk in the disk drive, and close the disk drive door. Then enter "COPY C:POST.BAS A:POST.BAS". This will copy the file from the hard disk (labelled C:) to the floppy disk (labelled A:). Since C: is the default, the shorter version of the form "COPY POST.BAS A:" will work as well. Again see the IBM DOS manual for more details.

To conserve disk space, it will occasionally be necessary to erase plot files (created by the POST program). These files all have the suffix PRN, so to erase them all, simply type "ERASE *.PRN". To erase only one, for example named TEST1.PRN, type "ERASE TEST1.PRN".

D.2.6 Program Maintenance

Batch files have been provided to compile and link the three main programs. To run these batch files, called BLLENNOX.BAT, BLPOST.BAT, and BLTEST.BAT, respectively, type in the file name. That is, to compile and link LENNOX, type in "BLLENNOX".

ATTACHMENT A - DYNAMIC DATA ACQUISITION DETAILS

The LENNOX program acquires dynamic data by interacting with the Data Translation DT2818 Simultaneous Sample and Hold A/D board. The DT2818 is connected via ribbon cable to a DT707 terminal board, to which analog signals are wired. The DT2818 board is used to acquire waveform data on up to four channels simultaneously. This data is transferred to page 3 of the RAM of the IBM PC via DMA (direct memory access). After the data is acquired, it is then read into arrays for frequency computations and harmonic analysis. Since the DT2818 board is limited to four channels, an eight channel multiplexer was designed and built, and is wired to the second channel of the four. At the proper time, the program instructs the DT2818 to send 3 bits of digital output to the MUX, commanding the appropriate relay to close, thus passing the signal to channel 2.

The sequence of dynamic data acquisition is as follows: 200 points of dynamic data are acquired from channel 0 at a sampling rate of 2000 Hertz and are placed into the array VFREQ#. The average is computed and then subtracted. The program counts the number of zero crossings in this data, computing the frequency by dividing this number by the total time interval over which data was taken. A sampling time interval is calculated, based on this frequency, to enable the acquisition of 99 points over four cycles. Next a 3-bit code is sent to digital output port 0 of the DT2818 board to set the MUX to channel 1. Four channels of data are taken, and the data is stored in the array VOLTS#. The appropriate harmonic analysis (Goertzel algorithm) is performed to obtain mean, amplitude, and phase values for these signals. The phase is computed with respect to the first signal. The program then enters a loop, looping over the MUX channel numbers from 2 to 7, in which the next channel is set on the MUX, two channels of data are acquired (the reference channel and the MUX channel), and the harmonic analysis is performed.

When the data acquisition is complete, the means, amplitudes, and phases are stored in the array DYN!(I,J), where I=1 indicates the mean, I=2 indicates the amplitude and I=3 indicates the phase. The J subscript indicates the channel number, with the MUX channel data corresponding to J=2, J=5,6, etc. The dynamic data acquisition code is based on code from two programs provided by Data Translation. These programs, called MANEP14 (for reading the A/D using DMA) and MANEP11 (for writing digital output) are documented in the DT2801 manual and the

DT2818 addendum by Data Translation. Board error codes are also documented in this manual.

ATTACHMENT B - STEADY-STATE DATA ACQUISITION DETAILS

Steady-state data is acquired from three different boards: a Data Translation DT2808 Board, and two Action Electronics TC15 thermocouple boards.

The DT2808 board is connected via ribbon cable to a DT707 terminal board, which in turn is wired to 16 analog signals on channels 0 to 15. The code for acquiring data using this board is modeled extensively after the program MANEP07 (to read A/D) provided and documented by Data Translation. The data is acquired and stored in the SS! array in locations 1 through 16. The acquired voltages are converted to engineering units by multiplying by the appropriate gain, or via a special calculation.

The TC15 boards are connected via ribbon cable to T/C termination boards, which in turn are wired to the Type K thermocouples in the engine. Code is provided by Action Instruments to acquire data from these boards, but the code is written for interpretive BASIC, and we wished to compile our program. Hence the data acquisition code for these two boards was written at MTI.

The base registers on these boards have been set to 290 hex and 260 hex via switches on the boards. To program the boards, one must access the registers, and the register locations of interest (1 to 5) are obtained by adding the register number to the base address. To read channel data, the following sequence of operations must be performed:

1. Write the channel number to register 3

2. Write 0 to register 1

3. Write a 3 to register 1

4. Read the LO byte on register 4

5. Read the HI byte on register 5

The LO byte contains the low byte of channel data, while bits 0 - 4 in the HI byte are the high byte of channel data. The temperature reading (°C) is then computed

by multiplying the value in register 5 by 256 and adding it to the value in register 4. Bit 5 in the HI byte signals polarity (1 is positive), bit 6 is an overrange indicator (1 = yes), and bit 7 signals data ready (0 is ready), and the software checks these bits for these conditions. The software to perform all of these functions uses the BASIC statements OUT, to write to a register, and INP, to read from a register. The WAIT statement is also used to detect data ready, but it was found that a longer delay was required before the data could be read, and hence a dummy loop was inserted. The switches on the cards are set for Type-K thermocouples, °C, and Continuous Scan Mode. In this mode, the channels are updated every 200 microseconds, and each reading is averaged with the previous. However, the board was not ready with the data in milliseconds, as noted above, and the actual sample rate would seem to be much less. A test program was written and tested with working thermocouples, and the current rate of data acquisition is sufficient. The program was tested for Convert on Command Mode, but the board did not work as advertised.

ATTACHMENT C - LENNOX PROGRAM DOCUMENTATION AND FLOWCHARTS

The LENNOX program is made up of a main program, 11 subroutines, and 12 utility routines. The main program is event driven with the ability to interrupt the program at any point via the special function keys. The utility routines are a collection of short routines used by many or all of the other subroutines. They perform utilities to the other routines such as printing a title. Error trapping is used throughout the code and passes execution to one of two error handling routines (one resumes where the program left off at the time of the error and the other terminates program execution). The following line numbering conventions were used in the code:

NAME	TYPE	DESCRIPTION	LINE #
MAIN	Program	Main driver program	1- 999
MANUAL	Subroutine	Sets MANUAL mode	1000- 1999
AUTOMATIC	Subroutine	Sets AUTOMATIC mode	2000- 2999
ALARM	Subroutine	Sets/clears alarm conditions	3000- 3999
STORE	Subroutine	Takes full scan and stores data	4000- 4999
SCAN	Subroutine	Takes full scan	5000- 5999
SCANSS	Subroutine	Scans steady-state channels	6000- 6999
SCANDY	Subroutine	Scans dynamic channels + FFT	7000- 7999
DISPLAY	Subroutine	Displays scanned data to CRT	8000- 8999
REPORT	Subroutine	Prints scan report	10000-10999
VIOLATE	Subroutine	Checks alarms for violations	11000-11999
CALCS	Subroutine	Performs calculations	12000-16999
KEYPRG	Utility	Programs function keys	40000-40999
KEYSTOP	Utility	Stops all function keys	41000-41999
PTITLE	Utility	Prints title lines to CRT	42000-42999
KEYON	Utility	Turns on all function keys	43000-43999
KEYOFF	Utility	Turns off all function keys	44000-44999
INITAD	Utility	Initializes for A/D routines	45000-45999
WAIT	Utility	Pauses program	46000-46999
INITCALC	Utility	Initializes calculations	47000-47999

PCHECK	Utility	Checks printer for On-line	48000-48999
ERROR	Utility	Error handling with stop	50000-50999
ERROR	Utility	Error handling with resume	51000-51999
STOP	Utility	Stops program	55555-55999

Since the main program is difficult to follow because of its event driven nature, a flowchart of the main program is displayed in Figure D-11. The other routines are self documenting.

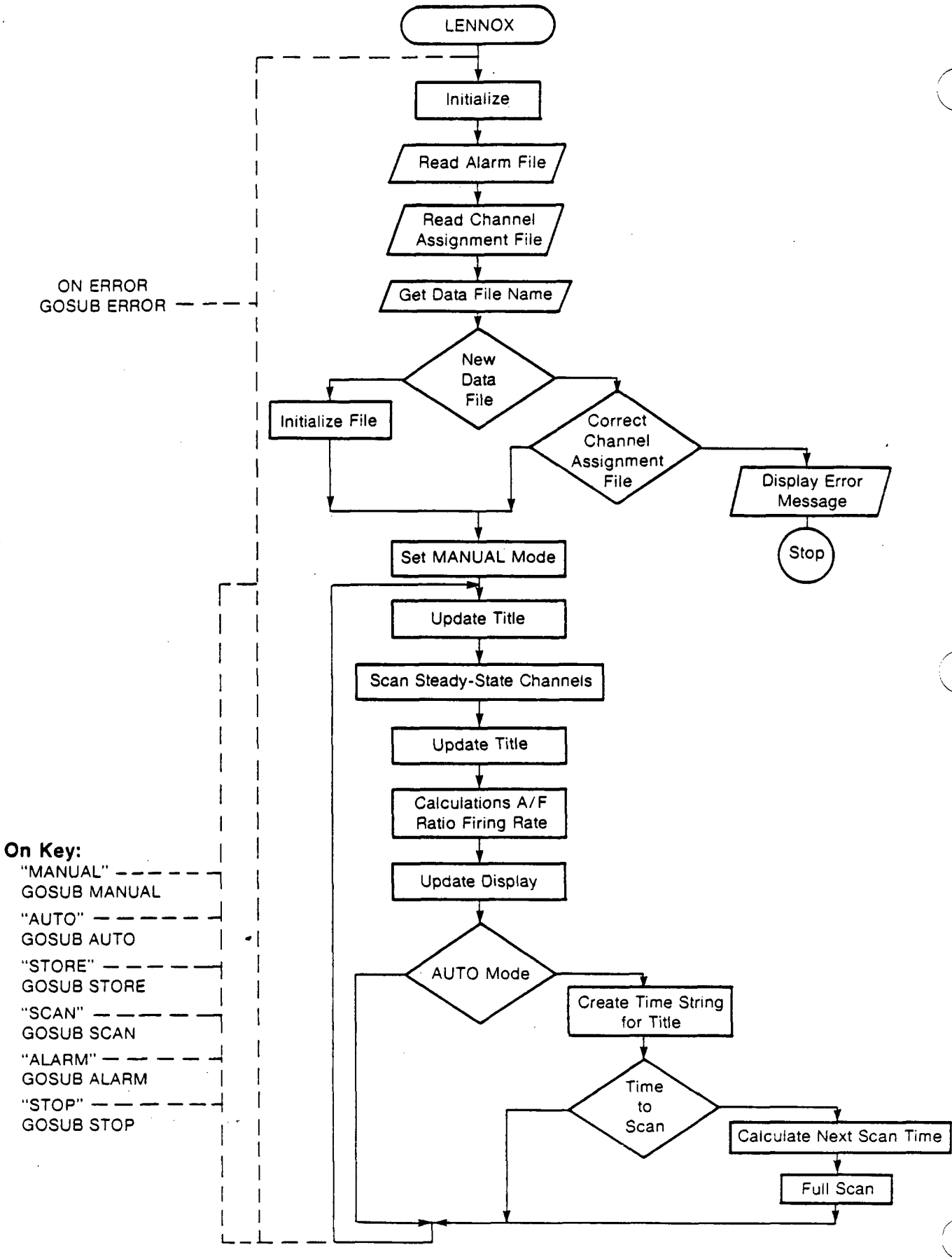


Figure D-11 LENNOX Main Program Flowchart

ATTACHMENT D - POST PROGRAM DOCUMENTATION AND FLOWCHARTS

The POST program is made up of a main program, seven subroutines, and six utility routines. The utility routines are a collection of short routines used by many or all of the other subroutines. They perform utilities to the other routines such as printing a title. Error trapping is used throughout the code and passes execution to an error handling routine that terminates program execution. The following line numbering conventions were used in the code:

NAME	TYPE	DESCRIPTION	LINE #
MAIN	Program	Main driver program	1 - 999
INPUT	Subroutine	Gets user input	1000- 1999
OUTPUT	Subroutine	Generates standard report	2000- 2999
READ	Subroutine	Reads record in data file	3000- 3999
REPORT	Subroutine	Prints standard report (CRT)	4000- 4999
REPORT	Subroutine	Prints standard report (LPT1:)	5000- 5999
SUMMARY	Subroutine	Prints summary report to LPT1:	6000- 6999
SUMMARY	Subroutine	Prints summary report to CRT	7000- 7999
WAIT	Utility	Pauses program	10000-10999
CENTER	Utility	Centers labels	12000-12999
PTITLE	Utility	Prints title lines to CRT	15000-15999
PCHECK	Utility	Checks printer for on-line	16000-16999
ERROR	Utility	Error handling with stop	50000-50999
STOP	Utility	Stops program	55555-55999

Flowcharts of the more difficult routines to follow (MAIN, INPUT, and SUMMARY) are displayed in Figures D-12, D-13, and D-14. The other routines are self documenting.

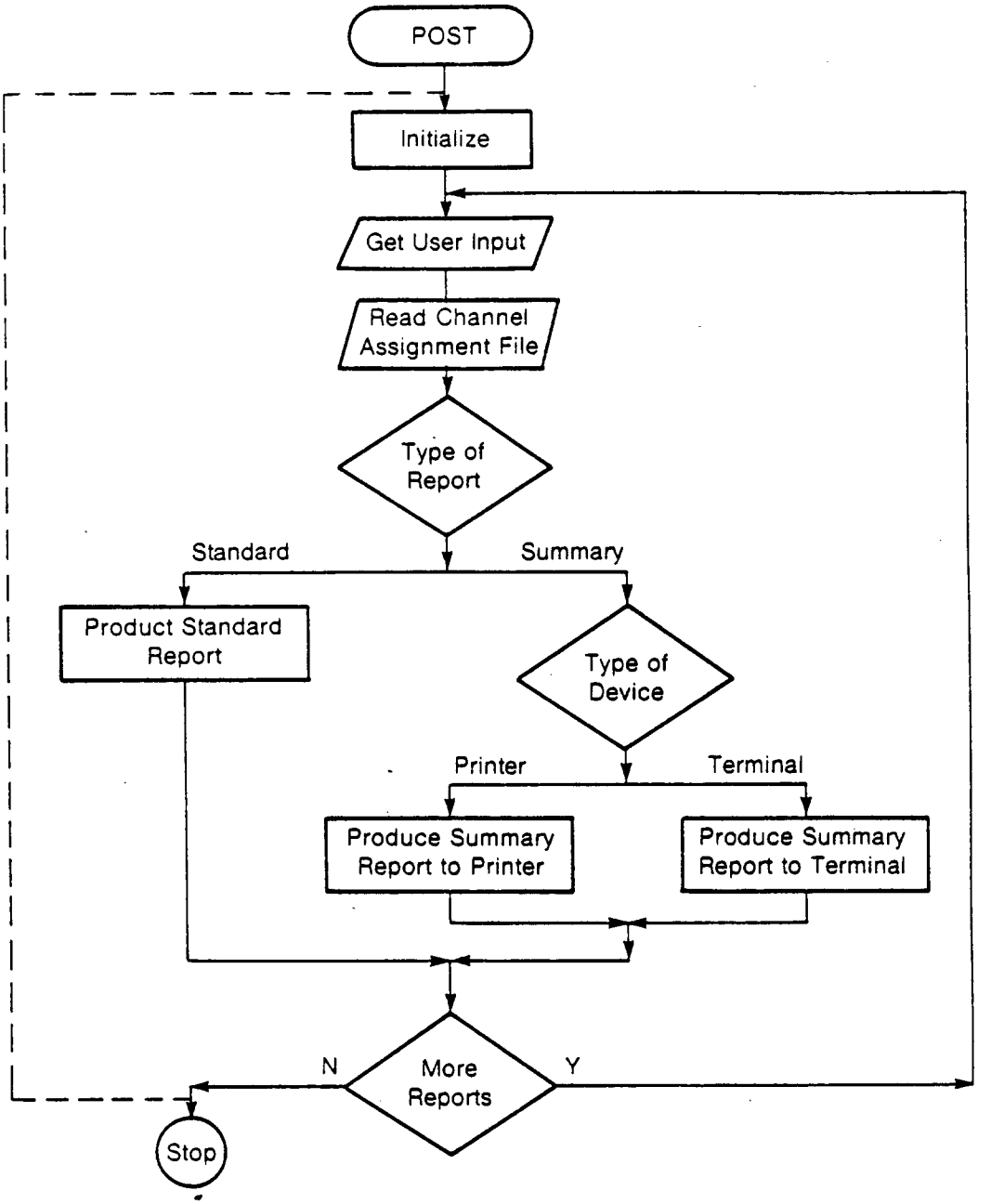


Figure D-12 POST Main Program Flowchart

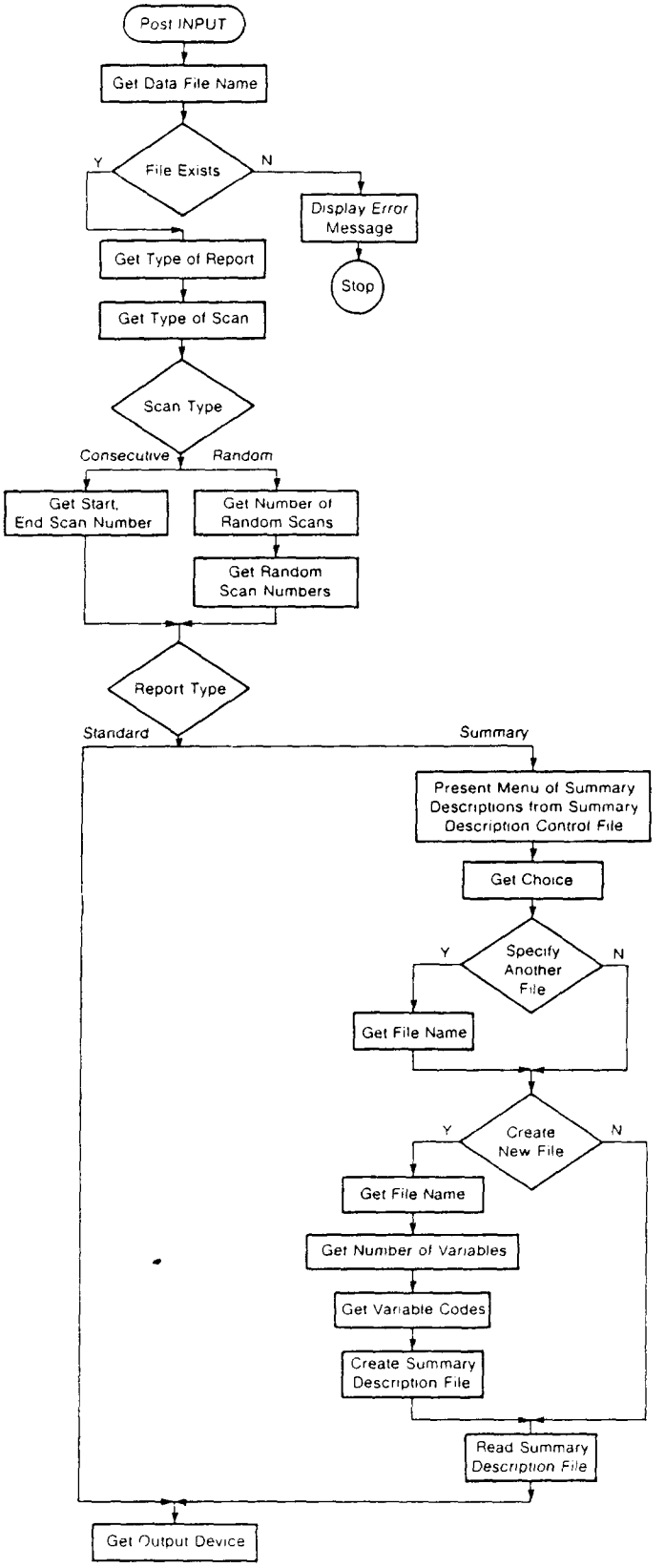


Figure D-13 POST INPUT Routine Flowchart

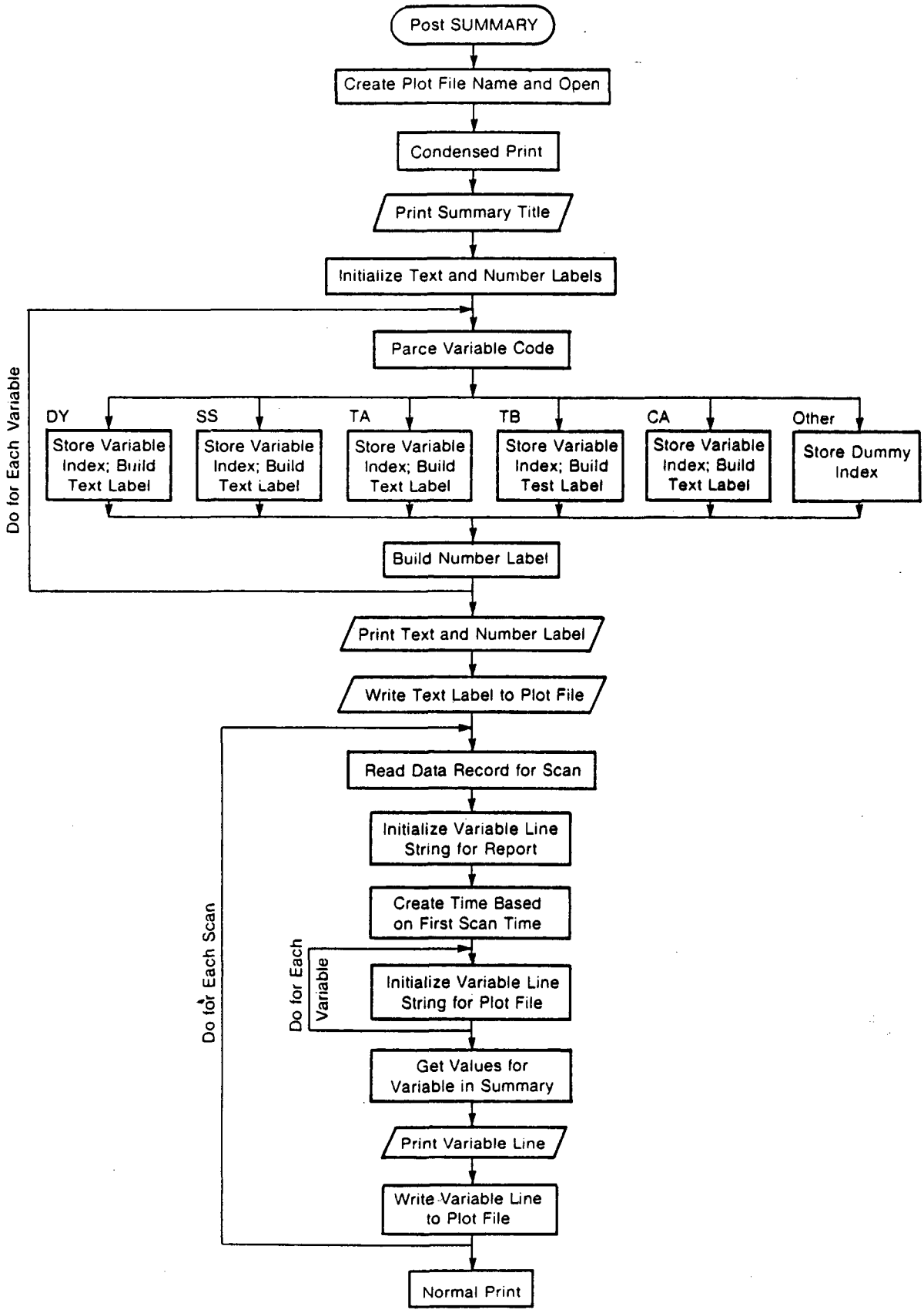


Figure D-14 POST SUMMARY Routine Flowchart

APPENDIX E

INSTRUMENTATION SYSTEMS AND ELECTRICAL WIRING DIAGRAMS

INSTRUMENTATION SYSTEMS AND ELECTRICAL WIRING DIAGRAMS

E.1 Purpose

The purpose of this Appendix is to provide guidelines for the operation and maintenance of those system components associated with instrumentation and electrical control. Primarily, there are three areas of discussion which contribute to this understanding of the System Package:

1. Subsystem Descriptions - This section addresses the various measurement systems which comprise the package instrumentation, controls circuitry which interface with some of this instrumentation to provide manual or automatic regulation of specific processes, and auxiliary circuits which are necessary for engine or combustor support.

2. Subsystem Location and Interconnection - This section calls attention to a number of support package layouts, interconnection cabling information, and wiring list details. This section is principally for use in gaining familiarity with the system and for assembling and disassembling the major cabinets, enclosures, and the power and signal cables which are routed between them. Operators and service technicians will find it an invaluable aid in troubleshooting electrical problems.

3. Subsystem Operation and Maintenance - This section furnishes guidelines for the calibration, checkout, and troubleshooting of specific circuits in these systems.

E.2 Subsystem Descriptions

From an instrumentation and control viewpoint, the Lennox/MARK I System can be divided into the following six subsystems:

1. Pressure Control System (PCS)
2. Temperature Control System (TCS)
3. Oil Management System (OMS)
4. Primary Engine Instrumentation Systems

5. Displacer Motor, Blower Motor, Ignition, Fuel Valve, and Blip Valve Power and Controls (Auxiliary Equipment Controls)
6. Data Acquisition System (DAS) (Discussion of the DAS can be found in Appendix D of this manual).

• Pressure Control System (PCS, MTI 1018D07-0099)

The PCS provides either automatic or manual control of engine mean pressure by admitting or depleting helium via 'charge' or 'discharge' solenoid valves (V-16 and V-18 on the System Process and Instrumentation Diagram, MTI 1018D08-0103). In the automatic mode, two comparator circuits, U2A and U2B, assess the difference in voltage levels representing engine mean pressure and an adjustable setpoint pressure to regulate engine pressure about the setpoint, ± a nominal 0.5 Bar. During system operation, the PCS will automatically compensate for pressure changes due to temperature, leakage losses, or other effects.

In the manual mode, the comparator circuits and relay driver circuits, Q1 and Q2, are overridden by the operator. Relays K1 and K2 are activated directly to charge or discharge engine pressure. This mode is usually used to initially charge the system and permits the operator to stop at selected points on the way up and check for leaks.

A small digital panel meter located on the Operator's Console provides a constant indication of engine mean pressure, P_m. By momentarily depressing toggle switch SW-3, the operator can observe the setpoint pressure as dialed in by turning R26, a 10-turn potentiometer.

• Temperature Control System (TCS, MTI 1018B07-0102)

The TCS adjusts the fuel flow rate to the engine combustor by regulating the position of a control valve in accordance with a heater head temperature setpoint. The output of a Type-K thermocouple designated as 'control' is supplied to an Operator's Console panel meter, where it is converted to mV/°C and fed to an isolation amplifier, U2. This buffered signal is then compared with a setpoint temperature, established by the operator, at differential amplifier U1A. The output is buffered by U1B to control a 4-20 mA current generator, Q1. An I/P

converter attached to the fuel control valve responds to the current to reposition the valve such that the ΔT error signal is minimized.

Auxiliary circuits in the form of air valve control and air-to-fuel (A/F) ratio circuits (refer to MTI 1018C07-0154) work together with the TCS to maintain a stable heater head operating temperature. Fuel flow and air flow rates are detected by Flow Technology flowmeters installed in the natural gas and air inlet supply lines. These pulse-type signals are enhanced by range extension amplifiers (REA's) and converted to digital displays (in CFM) and proportional to DC analog outputs in special Analogic digital panel meters. Outputs from these signal conditioners are scaled and fed to a divider, U2, which provides a 10X (Air Flow Rate/Fuel Flow Rate) signal. A differential amplifier, U1C, reacting to a comparison of this signal with an A/F ratio setpoint voltage established at the Operator's Console by a potentiometer, controls the base drive for a 4-20 mA current generator, Q1. This current performs a function similar to that for the fuel valve, only in this instance, it is the position of the air valve that is adjusted. An auto/manual toggle switch, S1, allows the operator to override the A/F circuitry and position the air valve directly. The A/F ratio value is acquired by the DAS.

Air and fuel flow rates are also monitored by dry-type totalizing flow meters, furnished by Lennox. These values are encoded by special circuits to provide DC levels proportional to actual flow in CFM. These DC figures, each updated once per revolution of the respective flowmeter, are sent to the DAS where they are used in such calculations as air/fuel ratio and firing rate.

- <u>Oil Management System (OMS, MTI 1018D07-0100)</u>

The primary function of the OMS is to maintain proper midstroke positioning of the compressor's upper and lower diaphragms. Channels 5 and 6 of the Kaman KD-4300 Displacement Measurement System, using 6u-type eddy current probes mounted in the upper and lower oil cavities, provide the necessary position information for each diaphragm. Each signal is bipolar, with diaphragm midstroke being represented by 0.0 volts DC. The X_{UD} (upper) and X_{LD} (lower) signals are low-pass filtered to remove high frequency components. In one section of the OMS circuit, this signal is routed to a summing amplifier to yield an "X_D" value for comparison with a threshold, or reference, DC level. For example, this X_D signal, if larger than

the threshold setting of R22, will trigger the U2 comparator and driver U3 to open a discharge solenoid valve V23 and restore both diaphragms to a midstroke condition. In another section of the OMS, the X_{LD} signal is simply compared to a threshold level to determine whether a nitrogen charge or discharge valve should be activated. Table E-1 indicates valve action for the five types of diaphragm conditions.

Here, too, the operator has the capability of manually charging or discharging the pressure in either the gas spring or oil cavities by selecting the 'manual' position for toggle switches S1 - S4 (switch positions are shown in the 'automatic' mode). Indicator lights at the Operator Console and on the relay driver card inform the operator of the individual valve operating states.

- Primary Engine Instrumentation Systems

The measurement circuits which comprise the primary engine instrumentation systems provide information on a variety of operational parameters. These include:

- Temperature
- Pressure (absolute, differential)
- Flow
- Displacement
- Acceleration

With the exception of coolant water differential temperature readings, all MARK I temperatures are taken using Type-K Chromel-Alumel thermocouples. Up to 30 thermocouples can be monitored with the present DAS Reference Junction cards, although a patch panel and installed cabling can accommodate as many as 36. Engine coolant inlet and outlet temperatures are monitored with semiconductor temperature detectors furnished by Lennox. A differential temperature circuit, also supplied by Lennox and installed in the combustion support package, provides a 10 mVDC/°F output to the DAS.

Engine and compressor absolute pressures greater than 50 Bar are measured with Kistler 4045A100 piezoresistive pressure transducers and 4611 signal conditioners (lower suction and discharge pressures are taken with Kistler 4045A20 transduc-

TABLE E-1

VALVE ACTION FOR DIFFERENT DIAPHRAGM CONDITIONS

PARAMETER	DIAPHRAGM RELATIONSHIP TO MIDSTROKE	OMS LOGIC	CORRECTIVE ACTION TAKEN
XUD XLD		XUD = 0 XLD = 0	None
XUD XLD		XUD > Threshold XLD < Threshold	Decrease nitrogen pressure in lower gas spring volume Open solenoid valve V18, N_2 Discharge
XUD XLD		XUD < Threshold XLD > Threshold	Increase nitrogen pressure in lower gas spring volume Open solenoid valve V16, N_2 Discharge
XUD XLD		XUD > Threshold XLD > Threshold XD = XUD + XLD > Threshold	Decrease oil pressure; open solenoid valve V23, Oil Discharge
XUD XLD		XUD < Threshold XLD < Threshold XD = XUD + XLD < Threshold	Increase oil pressure; open solenoid valve V26, Oil Charge

ers). Because of the size restriction, compressor left and right-hand valve plate pressures are measured using smaller Kulite XTM-190-500 SG bonded strain gage transducers with Analog Devices model 2B31J signal conditioning. Air and fuel line pressures are taken with Lennox-provided Validyne DP45-28 and DP45-30 differential pressure transducers, respectively, and a Validyne CD-280-DUAL carrier/demodulator conditioning system.

Flow rate measurements for both air and natural gas supplied to the combustor are taken with dry-type turbine meters furnished by Lennox. An American AL-800 is used to totalize air flow. An optical sensor installed inside the meter generates a pulse equivalent to one complete revolution of the main shaft of the counter; a special Lennox-designed logic circuit converts this pulse frequency to an analog signal proportional to flow rate. A similar circuit is used with a Lancaster model L-175 meter to provide fuel flow rate information (schematics for this circuitry are available from Lennox).

For air valve control purposes, air and fuel flow rates are also obtained with turbine flowmeters and associated signal conditioning equipment. This permits a continuous, approximately linear updating of flow rates, thereby allowing the air/fuel ratios and air valve control circuitry to respond smoothly to changes in flow demands.

At MTI, a Bearingless E100 flowmeter will be used to measure engine coolant water flow. A pulse output proportional to flow rate (nominally 750 pulses/liter) will be converted to a DC equivalent and scaled by an MTI-built circuit to yield values of flow in units of GPM. At the Lennox facility, an in-house calorimeter will perform this measurement function.

One of the most critical measurements to be taken will be that of the displacer, compressor piston, and diaphragm displacements. Indications of displacer and piston strokes are essential for proper operation of the Lennox MARK I power module. The operator must utilize these signals to establish an optimum operating point; a dual-trace X-Y_1, X-Y_2 oscilloscope has been installed in the Operator Console for this purpose. In addition, calculations of PV power are made using the X_D stroke information. As mentioned earlier, the Oil Management System relies heavily on accurate diaphragm position measurements in order to regulate oil and nitrogen pressures properly.

A Kaman KD-4300, 6-channel displacement measurement system was selected for all six of the above measurements. Eddy current proximity probes, having appropriate geometric shapes and range capabilities dictated by their physical location inside the system, were selected based on their reliability, insensitivity to oil or other nonconductive media, linearity, and past performance in a number of MTI engine designs and builds. Those sensors dedicated to displacer and piston stroke measurements are part of redundant systems; i.e., they are each made up of two sensors, each located 180° from one another to provide a simple method of correcting for axial misalignment while stroking. The targets, copper for the compressor piston and aluminum for the displacer, are machined with a fixed taper of 40 mils rise per one inch run. The probes, which are stationary, monitor the gap presented to them as the targets move up and down.

Following signal conditioning by their associated channel in the KD-4300 system, the two piston signals, X_{P1} and X_{P2}, and the two displacer signals, X_{D1} and X_{D2}, are each summed and averaged by MTI-built circuits (refer to drawing 1018808-0097) housed inside the KD-4300 chassis in the Electrical Support Package. The resulting X_P and X_D signals become dynamic sinusoidal waveforms during system operation, but maintain a DC component, or offset, indicative of any off-center condition. (When viewed on an oscilloscope, this can be a very helpful diagnostic tool for detecting improper porting conditions or other system imbalances). In order that the operator has a real-time indication of these two strokes, rms-to-DC converters (U2) and scaling amplifiers (U3) are used to generate DC levels proportional to peak-peak target motion. Digital panel meters on the Operator Console provide the information in mm's.

The X_D signal is also analyzed in a software program to produce frequency information and by an rms-to-DC converter to provide a static reading for the DAS monitor (see MTI drawing 1018807-156).

Provisions have been made for the installation of an accelerometer on the engine or its test stand. A Kistler Piezotron® signal coupler has been incorporated in the Electrical Support Package, and a dynamic channel has been allotted in the DAS for signal acquisition.

To provide a means of comparing calculated PV power with electrical input power, a power sense circuit has been installed in the Operator Console, electrically

in-line with the output of the Elgar (displacer motor) power supply. This circuit is shown schematically in MTI drawings 1018B07-0152 and 1018B07-0153. Output voltage is sensed by a potential transformer, PT. Current into the motor is sensed by a 5:1 current transformer, CT, and converted to an AC voltage through the use of a 50 watt burden transducer. Power is measured using an F.W. Bell Hall-effect watt transducer, sensing line voltage and current directly. The low-level DC output is scaled in software to give an approximate indication of motor input power in kilowatts.

- Auxiliary Equipment Controls

Those controls associated with the auxiliary equipment are located on the front panels of the Operator Console cabinet and include the following (refer to MTI drawings 1018C07-0101 and 1018C10-0095):

- A toggle switch for activating the fuel (natural gas) solenoid valve via a 24 VDC control relay, CR-2.
- A toggle switch for activating the combustion air blower via a 24 VDC control relay, CR-1, and motor starter, MP-1.
- A toggle switch for energizing a 24 VDC control relay, CR-3, and providing a spark via a 20 kW ignition transformer, T1.
- A toggle switch for energizing the 'blip' solenoid valve.
- Toggle switches for energizing the cabinet cooling fans at the Electrical Support Package and Operator's Console.
- Power on-off, range, and other miscellaneous controls for operating two oscilloscopes, a phase meter, a function generator, and the Elgar 1751 power supply.
- A displacer motor shutdown circuit (see dwg 1018B07-0153) that permits the operator to disengage the Elgar power source from the displacer motor while, at the same time, paralleling the motor output with a low resistance load for braking.

E.3 Subsystem Location and Interconnection

The purpose of this section is to familiarize the reader (i.e., the system operators or service technicians) with the location of the major electrical subsystems within the entire Lennox/MARK I package and the manner in which they are electrically interconnected.

Table E-2 is a listing of the Electrical and Combustion Support Packages and the Operator's Console that comprise part of the MARK I package and the major electrical systems or circuitry contained in each. It is intended to be a quick reference for locating circuitry and schematics for troubleshooting purposes. In order for this table to be a useful tool in operating and servicing the MARK I system, information is provided in the form of one-line electrical diagrams and wiring lists that cover all electrical interconnections. MTI drawing 1018D10-0150 and the associated Wiring List furnish detailed descriptions of each signal and power lead routing and termination. MTI drawing 1018C10-0190 goes further and illustrates the floor plan layout for each cable run.

Cabling designations are grouped in two categories as to their purpose: "K" precedes signal cabling abbreviations; "P" precedes names for both AC and DC power cabling. Table E-3 lists most of the cabling runs associated with the MARK I system package, these can be found alphabetically in the Wiring List.

Signal cabling routed to and from the Data Acquisition System junction box enclosure, and the internal circuit card layout for the DAS enclosure, are shown in MTI drawing 1018D08-0188. Appendix D contains a detailed description of the DAS hardware and interconnections.

Information concerning facility 110 VAC and 230 VAC, 3ϕ power feeds is available from MTI drawing 1018B08-0157. These cables have not been assigned a "P" designation but can be identified by their "J" connector assignments.

Cable termination points; i.e., bulkhead receptacles, thermocouple jack panels, or special feedthroughs, are specified on MTI drawing 1018B08-0185. This drawing, when used with the electrical one-line diagrams or with the associated wiring list, is invaluable when cable interconnections are made or troubleshooting via signal-tracing is performed. Though not to scale, each receptacle is shown in its relative position on the side of the applicable support package, cabinet, or enclosure.

E.4 Subsystem Operation and Maintenance

This section is intended to enhance the brief operational descriptions given in the 'Subsystem Description' for each of the circuits in the Lennox MARK I system.

TABLE E-2

INSTRUMENTATION ALLOCATION IN THE MARK I SYSTEM PACKAGE

- ELECTRICAL SUPPORT PACKAGE (ESP)
  1018D10-0094

ASSOCIATED ELECTRICAL SYSTEM	SYSTEM COMPONENTS	RELATED MANUAL AND DRAWINGS	PART LOCATION	SYSTEM FUNCTION
1. Displacement Measurement System	A. KD-4300 Chassis: 1. Chan 1-DC & RF cards for probe type 2UB (XD1) 2. Chan 2 cards for 2UB (XD2) 3. Chan 3 cards for 1U (XP1) 4. Chan 4 cards for 1U (XP2) 5. Chan 5 cards for 6U (XUD) 6. Chan 6 cards for 6U (XLD) 7. Xd, Xp signal conditioning cards (MTI)	Kaman Instruments KD-4300 Sys. Manual	Top section of ESP	To convert 6 displacement measurements into convenient signals for monitoring piston and displacer motion, and maintaining engine oil pressure via the Oil Management System; to convert XD stroke signal to a frequency equivalent to system operating frequency.
	B. XD to Frequency Card	1018B07-0156	ESP,Rack2,Slot1	
2. Oil Management System (OMS)	A. Relay Card B. Logic Card	1018D07-0100 1018D07-0100	ESP,Rack1,Slot2 ESP,Rack1,Slot1	To regulate engine oil pressure by monitoring upper & lower diaphragm position and manipulating charge and discharge valves.
3. Pressure Control System (PCS)	A. PCS Card	1018D07-0099	ESP,Rack1,Slot3	To maintain system pressure throughout the Pmean Auto Regulation Circuit and helium charge and discharge solenoid valves
4. Pressure Monitoring Circuits	A. Kistler 4611 signal conditioners panel 1. PT4-4045A100 2. PT5-4045A100 3. PT8-4045A100 4. PT11-4045A20 5. PT12-4045A20 6. PT14-4045A100 7. PT3-4045A100 8. PT6-4045A100 9. PT7-4045A100 10. PT15-4045A100	Kistler 4611 Operating Manual; Kistler 4045 Piezoresistive pressure transducer installation manuals	Mid-section of ESP: Top row;position 1 Top row;position 2 Top row;position 3 2nd row;position 1 2nd row;position 2 2nd row;position 3 3rd row;position 1 3rd row;position 2 4th row;position 1 4th row;position 2	To measure and process the following pressures: Mean Engine Bearing Supply Upper Oil Plenum Suction Discharge Lower Oil Plenum Compression Space Lowside Gas Spring Highside Gas Spring Lower Gas Spring

TABLE E-2 cont'd

- ELECTRICAL SUPPORT PACKAGE cont'd
  1018D10-0094

ASSOCIATED ELECTRICAL SYSTEM	SYSTEM COMPONENTS	RELATED MANUAL AND DRAWINGS	PART LOCATION	SYSTEM FUNCTION
4. Pressure Monitoring Circuits cont'd	B. Kulite Pressure Transducer signal conditioners 1. PT9-XT-190-500 2. PT10-XT-500	Analog Device 2B31J Instrument Bulletin 1018B08-0098	 ESP,Rack2,Slot2 ESP,Rack2,Slot3	 Left Hand Valve Plate Right Hand Valve Plate
5. Temperature Control System (TCS)	A. TCS Card B. Air Valve and Air/Fuel Rate Card	1018B07-0102 1018C07-0154	ESP,Rack1,Slot4 Esp,Rack1,Slot5	To adjust the fuel flow rate to the engine combustor by regulating the position of the fuel control valve in accordance with a heater head temp setpoint; to position an air control valve in response to an air/fuel ratio demand
6. Acceleration Monitor	A. AC1 Transducer	Kistler 8612 and Charge Coupler 5108 Bulletins	Inside, bottom of ESP	To process the accelerometer signal.

TABLE E-2 cont'd

- COMBUSTION SUPPORT PACKAGE (CSP)
  1018D10-0187

ASSOCIATED ELECTRICAL SYSTEM	SYSTEM COMPONENTS	RELATED MANUAL AND DRAWINGS	PART LOCATION	SYSTEM FUNCTION
1. ΔT CW	A. Temp Sensitive semi-conductors and differential amp	Lennox circuits	CSP,upper shelf, left side	Measure coolant water inlet and outlet temp and provide a differential temp reading to the DAS.
2. Combustion Gas Pressures	A. PA (Lennox) B. PF (Lennox)	Validyne DP-45 pressure transducers with CD-280 signal condit.	CSP,upper shelf, right side	Measure combustion air (PA) inlet and fuel (PF) pressure for DAS.
3. Combustion Gas Flow Measurements	A. FI-5 (Air) FTI-FT-24NENA-GAA-1	1018C07-0154	Air line,vertical section,left side of CSP; range ext. amps and frequency-to-DC conv. are in ESP	A/B-The fuel and air flow measurements are used by the TCS to regulate the combustion processes via positioning of the fuel and air valves
	B. FI-6 (Fuel) FTI-FT-10NEDI-GAA-1	1018C07-0154	Gas line,vertical section, left side of CSP	
	C. FI-1 (Air) American AL-800 dry meter w/encoder	1018B07-0102 (Lennox circuit)	Flow Meters-outside CSP, left side. Ckts.-2nd shelf,CSP	C/D-These flow measurements are acquired by the DAS for calculations
	D. FI-2 (Fuel) Lancaster L-175 dry meter w/encoder	1018B07-0102 (Lennox circuit)		
4. Combustion Blower Control	A. Motor starter; 3/4 HP blower;relay	1018D08-0103	Starter-on outside left wall of CSP Blower-mounted on bottom of CSP	To provide sufficient air flow to support fuel combustion.

TABLE E-2 cont'd

- OPERATOR'S CONSOLE (Op Con)
  1018D10-0095

ASSOCIATED ELECTRICAL SYSTEM	SYSTEM COMPONENTS	RELATED MANUAL AND DRAWINGS	PART LOCATION	SYSTEM FUNCTION
1. Oil Management System (OMS)	A. Panel switches, indicators	1018D07-0100	2nd panel from top, right side, Op Con	Houses Auto/Manual control with indicator lights for oil charge, oil discharge, nitrogen charge, and nitrogen discharge.
2. Pressure Control System (PCS)	A. Panel switches, indicator lights, dial potentiometer	1018D07-0099	2nd panel from top, left side, Op Con	Houses Auto/Manual control with indicators for engine pressure, charge and discharge valve operation.
3. Temperature Control System (TCS)	A. Panel switches, dial potentiometer	1018B07-0102	Digital panel meter panel, lower right side, Op Con	Provides operator with control of air valve, air/fuel ratio, and control temperature setpoint
4. Auxiliary Equipment	A. Panel switches (toggle & pushbutton)	1018C07-0101	Panel directly above Elgar power unit, Op Con	Allows operator to remotely control the displacer motor power, ESP and Op Con fans, combustion blower, blip solenoid valve, ignitor and fuel solenoid valve
5. Miscellaneous	A. Krohn-Hite Function Generator	1018D10-0095	2nd panel, vertical section, left side, Op Con	Provides the Elgar PS unit with a variable frequency and amplitude drive signal
	B. Krohn-Hite Phase Meter	1018D10-0095	2nd panel, vertical section, right side, Op Con	Provides the operator with a convenient means of measuring phase angles
	C. BNC Jack Panel	1018D10-0095	Top panel, vertical section, Op Con	Provides access to selected signals for oscilloscope viewing or troubleshooting
	D. Phillips Dual-Trace Oscilloscopes	1018D10-0095	Bottom, sloping section, Op Con	Provides a convenient means of observing pressure & displacement signals.
	E. Elgar Model 1751 Power Unit	1018D10-0095; Elgar Op. Manual	Bottom, vertical section, Op Con	Provides high voltage at variable frequency to the displacer drive motor.
	F. Power Sense Circuit	1018B07-0152	Inside Op Con above connector panel	Measures the output power supplied by the Elgar PS unit; provides voltage and current signals.

TABLE E-3

INTERCONNECTION CABLING

CABLE DESIGNATION	FROM	TO	SIGNALS CARRIED
K-AC-1	ETS	ESP	Accelerometer output
K-Dynamic	ESP	DAS	Dynamic pressure and displacement
K-Flow	CSP	ESP	Air and fuel flow measurements
K-Kaman	ETS	ESP	Displacement
K-Kistler	ETS	ESP	Pressure
K-Lennox #1	ESP	DAS	Combustion gas pressure and flow; TCS circuit information; coolant flow rate
K-Lennox #2	CSP	ESP	Combustion gas pressure and flow; refrigerant flow rate; coolant flow rate; ΔT_{CW}
K-Lennox #2 Jumpers	CSP	CSP	Internal jumpers for 'K-Lennox #2' signals
K-OMS & X	ESP	Op Con	Displacements and oil management system controls
K-Oscope	DAS	Op Con	Pressure signals
K-PT9	ETS	ESP	Kulite pressure transducer output
K-PT10	ETS	ESP	Kulite pressure transducer output
K-Static	ESP	DAS	DC equivalents of acceleration and frequency; static pressures

TABLE E-3 cont'd

CABLE DESIGNATION	FROM	TO	SIGNALS CARRIED
K-T & PCS	ESP	Op Con	Part of TCS and PSC
K-Temp 1	ETS	DAS	Engine thermocouples
K-Temp 2	ETS	DAS	Heater head/combustor thermocouples
K-Temp 3	DAS	Op Con	Control temperature to TCS
K-Temp 4	ETS	DAS	Open for Lennox thermocouple
K-VWI	Op Con	DAS	Voltage, current, and power measurements; acceleration and X_D, X_P displacements to oscilloscope jacks
P-Blip Valve	Op Con	ESP	Blip valve control power
P-Blip Switch	ESP	Op Con	Blip valve control- switch
P-Ignitor	Op Con	ETS	Ignition power
P-Comb	Op Con	CSP	Blower and fuel valve control
P-Disp Pwr	Op Con	ETS	Displacer motor power
P-OMS	ESP	MSP	Part of Oil Management System solenoid valve control
P-SOLV	ETS	ESP	Engine pressure control to solenoid valves

ETS - Engine Test Stand
MSP - Mechanical Support Package

Circuit operation can best be observed through system calibrations and checkouts. This section provides basic guidelines for various calibrations and instructions for performing simple checkout procedures to determine whether or not a system is functioning properly. In addition, circuit conditions that will aid in troubleshooting are also provided.

• Pressure Control System (PCS)

The PCS utilizes one pressure transducer to sense engine mean pressure. This piezoresistive transducer is calibrated using a standard dead-weight calibrator; the assigned Kistler 4611 conditioner is adjusted for 'zero' pressure (1 atmosphere = 0.1 VDC) and at a higher 'span' setpoint pressure (typically 800 psig = 56.17 Bar = 5.617 VDC). The PCS circuit logic, however, can not be easily adjusted using a real applied pressure, since the iterations necessary to properly tune the comparators would make such a calibration very cumbersome and difficult to achieve with the accuracies of a dead-weight calibrator. Instead, the following procedure is preferred (refer to MTI drawing 1018D07-0099): NOTE: The system should be depressurized for this calibration; all circuits and components directly associated with the PCS should be connected and energized at this time.

1. De-energize the Pmean signal conditioner by unplugging the ±15 VDC power supply card at the J-box inside the ESP.

2. Temporarily disconnect the conditioner's output at the ESP-TB-1 located to the left of the conditioner array (as viewed from the inside of the ESP).

3. Connect a precision DC power supply capable of outputting 0.00 - 10.00 volts to this ESP-TB; observe proper polarity.

4. To provide better access to the PCS (Pmean Auto-Regulation) Card, for the following step an extender board should be inserted between the edge connector and card.

5. Attach a high-input impedance DVM, 0-10.00 VDC, to pin 3 of U1A (+) and circuit common; connect a second DVM to pin 4 of U1B (+) and circuit common.

6. Turn the setpoint Pmean adjust pot fully counter-clockwise.

7. At the Operator Console, place the auto/man switch, SW1, in the "MANUAL" position, and the Charge/Discharge switch, SW2, in the "OFF" position. The helium charge light (red) and the discharge light (amber) should be illuminated; the auto light (amber) should be extinguished.

8. Slowly rotate the setpoint adjust pot clockwise until only the helium charge light (red) is illuminated.

9. Place the Manual Charge/Discharge switch in the "CHARGE" position; solenoid valve SV-9 should actuate.

10. Place the Manual Charge/Discharge switch in the "DISCHARGE" position; SV-11 should actuate.

11. Place the Auto/Man switch in the "AUTO" position; the yellow auto light should also illuminate.

12. Temporarily depress the Setpoint Adjust toggle switch, SW3, and adjust the setpoint pressure to 60 Bar as read on the Operator Console panel meter.

13. Turn on the DC power supply and set the output at 6.00 VDC.

14. Monitoring the output of U1A, adjust R6 (on the PCS card) to obtain 6.00 VDC.

15. Using the DC power supply, vary the output from 5.90 to 6.10 VDC. The helium charge light should illuminate and SV-9 should actuate at 59.5 ±.1 Bar as read on the Operator Console DPM and extinguish/close at 60.5 ±.1 Bar.

16. Return the output of the DC power supply to 6.00 VDC.

17. Monitoring the output of U1B, adjust R19 (on the PCS card) for 6.01 VDC.

18. Vary the output of the DC power supply from 6.00 to 6.10 and back to 5.90 VDC. The helium discharge light should illuminate and SV-11 actuate at 60.6 ±1 Bar and extinguish/close at 59.8 ±1 Bar as read on the Operator Console panel meter.

19. Remove DVM connections, extender card, and reinsert the PCS card into its assigned slot.

20. Check PCS operation by setting the DC power supply to 5.40 VDC and the setpoint adjust pot to read 55.0 Bar. The helium charge light (red) should be illuminated, indicating that the system is below setpoint pressure and calling for additional helium pressurization.

21. Slowly increase the output of the DC power supply in .01 VDC increments and note points at which the lights and associated solenoid valves are actuated. Similarly, decrease the output until all lights are extinguished and both valves are de-energized (closed). These values should compare favorably with the following:

Pmean Setpoint = 55.0 Bar

	DC Power Supply Output (Bar)	He Charge Light	SV-9	He Discharge Light	SV-11
Increasing Pressure:					
• Valve energized (light on)	54.0	X	X		
• Valve de-energized (light off)	54.0			X	X
Increasing Pressure:					
• Valve energized (light on)	55.6			X	X
• Valve de-energized (light off)	55.6	X	X		
Decreasing Pressure:					
• Valve energized (light on)	54.6				
• Valve de-energized (light off)	54.6	X	X	X	X

22. De-energize the DC power supply and disconnect from ESP TB-1 and -11.

23. Reconnect the signal conditioner signal lead (yellow) to the ESP terminal strip and restore the PCS system to its normal operating condition.

Should adjustments to the PCS card not produce the desired operation as described above, refer to Troubleshooting Table E-4 and attempt to correct the problem using its recommendations. If still unsuccessful, MTI Instrumentation should be contacted.

• Temperature Control System (TCS)

The TCS is actually comprised of two valve positioning circuits. A pneumatically-driven globe valve, used to regulate the flow of methane fuel, is controlled by a circuit responsive to the difference in temperature between a setpoint value (established by the operator by adjusting P1 on his Operator Console TCS control panel) and a control temperature thermocouple attached to the heater head. Consequently, instrumentation calibration involves a continuity or temperature response test of the Type-K thermocouple. (Generally, all thermocouples are given a linearity check prior to system installation by inserting them individually, or as a group, in a sand bath and noting the millivolt output response to various temperatures within the range found on the heater head or combustor). An Omega 199-K-C Temperature Indicator is used to convert the control thermocouple reading to an analog 1 mV/°C signal. This signal is isolated from the logic portion of the TCS circuit using an AD-290A Isolation Amplifier.

TCS card operation can be checked in the following manner:

1. De-energize the fuel valve I/P converter by temporarily pulling the TCS card from its slot (ESP, Rack 1, Slot 4). Ensure that natural gas flow to the valve is turned off.

2. Disconnect the white lead to the I/P converter at TB-CSP2-1 (see K-Lennox #2 Jumpers Wiring Sheet) and insert a DC milliameter between TB-CSP2 and the white lead to the converter.

TABLE E-4

PCS TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSES	RECOMMENDED CORRECTIVE ACTION
1) SV-9 and/or SV-11 do not actuate in either Auto or Manual mode	a) Loss of 24 VDC power	a) Check for proper voltage output from 24 VDC power supply; signal trace using the applicable drawings and wiring list.
	b) Cable P-SOLV disconnected	b) Reconnect and perform a voltage check.
2) SV-9 and SV-11 operate simultaneously; charge and discharge indicator both illuminated	a) Comparator U2A and U2B trip points overlap	a) Readjust R6 and R19 to provide deadband between solenoid valve activation. NOTE: Hysteresis effects may interfere with adjustments.
3) SV-9 and/or SV-11 'chatter' near actuation setpoints	a) U1A and U1B have introduced undesirable oscillations	a) Check filter capacitors C10 and C11.
	b) Boost pump pulsations are interfering with comparator setpoints	b) If DC voltage levels at U1C pin 12 are varying at the boost pump rate, an LP filter circuit may be needed to produce a more constant DC level; consult Engineering.
4) SV-9 and/or SV-11 do not operate in the Auto mode; Manual mode operation is possible; light indicators operate correctly	a) Relay K1 and/or K2 are faulty	a) Check relays for proper operation; replace or repair as necessary.

3. Disconnect the control thermocouple (T/C 14) at the ETS jack panel. Insert a Type-K millivolt/temperature indicator calibration device such as a Thermoelectric Micromite® or equivalent.

4. Replace the TCS card in its slot. At the Operator Console, turn the temperature setpoint potentiometer fully counter-clockwise.

5. Apply 20 ±3 psi air to the valve regulator. Note that with no air supplied, the valve is in its fully closed position.

6. Adjust the Micromite® simulator for the following temperatures and note the settings of the potentiometer which will cause the fuel valve to go from partially closed to fully open (5.9 ±.2 mA to 20.0 ±.2 mA). Note also that the fuel valve is closed during loss of electrical power.

Heater Head Control Temperature (°C)	Potentiometer Setting for Desired Temperature: Valve Partially Closed (5.9 mA)	Valve Fully Open (20.0 mA)
400	2.65	4.23
450	3.59	4.74
500	3.46	5.20
550	4.52	5.73
600	5.19	6.19
650	5.36	6.67
700	5.65	7.16
750	6.72	7.76
800	7.19	8.15

These settings are approximate and may differ slightly from one operation check to another. Settings are also close to desired operating temperatures; i.e., 5.36 represents 536°C. Valve should be responsive to potentiometer settings within the range given for each of the selected control temperatures.

7. Return the circuits to normal condition when the system checkout is complete.

Should adjustments to the TCS control potentiometer not produce the desired operation as described above, refer to Table E-5 and attempt to correct the problem. If still unsuccessful, MTI Instrumentation should be contacted.

The second valve positioning circuit in the TCS also controls the position of a pneumatically-driven globe valve. In this instance, it is the flow of combustion air which is regulated. The method by which a 4-20 mA control signal is generated is identical to that used in the fuel valve positioning circuit; however, air valve position is dependent upon the scaled ratio of air flow to fuel flow and, therefore, is slave to the fuel valve circuit.

Lennox has provided the flowmeters and signal conditioning circuitry as mentioned earlier in this Appendix. However, these flowmeters provide DAS information and are not used in the air valve control scheme, since their outputs are non-linear and discontinuous. Instead, turbine flowmeters and associated range extending amplifiers and frequency-to-DC converters have been selected for this purpose. The air/fuel ratio and air valve control circuits are MTI designs and are shown schematically in MTI drawing 1018C07-0154.

The following discussion is provided in the event the turbine flow meters for air and gas are <u>not</u> utilized in the control scheme and flow rates from the dry-type meters are used instead.

As noted in the calibration data for each dry-type flowmeter, as provided by Lennox, the DC outputs vary inversely and non-linearly with respect to their measured flow rate. For example,the air flow rate at 700 cfh produces a 3 VDC signal, whereas at 300 cfh the output increases to approximately 7 VDC. Similar points for the fuel flow rate are 50 cfh and 18 cfh, respectively (refer to Figure E-1). Consequently, the DC levels as received by the air/fuel ratio section behave opposite to that found in previous valve control circuits fashioned at MTI. To compensate for this 'reverse' logic, inputs to the AD533 divider would have to be reversed to provide a true air/fuel ratio output. This can be explained by the following math exercise:

$$\text{Output of AD533} = 10\ Z/X = 10\ \frac{(1\ /\ \text{Fuel Flow})}{(1\ /\ \text{Air Flow})} = 10\ \frac{\text{Air Flow}}{\text{Fuel Flow}}$$

TABLE E-5

FUEL CONTROL/TCS TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSES	RECOMMENDED CORRECTIVE ACTION
1) Fuel valve remains fully open with air supply applied; no operator control at desired temperature	a) Driver transistor Q1 has base-emitter short	a) Pull TCS card and replace Q1.
	b) Control T/C faulty - shorted junction near ambient temperature	b) Temporarily pull TCS card; replace T/C or substitute with known good T/C.
	c) Transistor Q1 biased to saturation	c) Check output of LM324-B; correct if faulty.
	d) AD290A-U2 faulty; low or zero output	d) replace AD290A.
2) Fuel valve remains fully closed with air supply applied; no oper-	a) Driven transistor Q1 is faulty; open base-emitter junction	a) Pull TCS card and replace Q1.

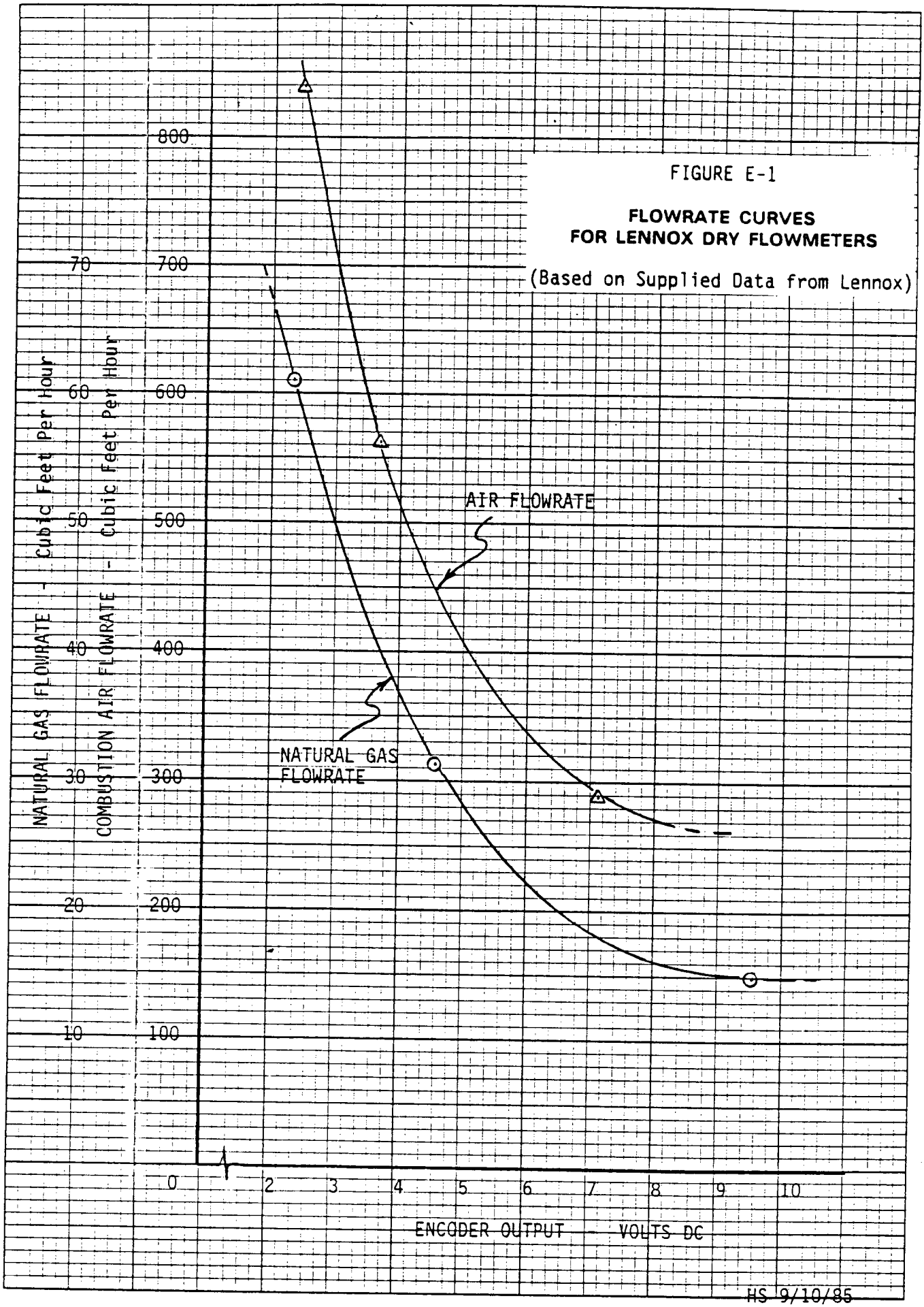


FIGURE E-1

FLOWRATE CURVES FOR LENNOX DRY FLOWMETERS

(Based on Supplied Data from Lennox)

The conversion factor for changing air flow in cfh to Lbm/hr is:

scfh = 13.1 Lbm/hr

The conversion factor for changing fuel flow, based on a specific gravity for methane of .56, is:

scfh = 23.4 Lbm/hr

A typical air/fuel ratio for the combustor used in the Lennox system package is 20. This infers an air mass flow rate 20 times the accompanying fuel mass flow rate. Thus, if the air valve is opened to flow 800 cfh (61.04 Lbm/hr), the fuel valve must provide 3.05 Lbm/hr (71.4 cfh). From the calibration curves, this corresponds to an air/fuel voltage ratio of 3.33 VDC to 2.98 VDC, or 1.12; the effective gain of 10 (.5) or 5 for the divider boosts this signal to 5.6 VDC, where it is compared with a DC signal established by the operator by turning the Air/Fuel Ratio Setpoint Potentiometer, P1, at the Operator Console. (Figure E-2 is a plot of the turbine flowmeter flow rates in ACFM versus the conditioner outputs in DC volts). The difference is then amplified in U1-C, inverted in U1-D, and applied to the base of Q1 where a current signal is generated to position the air valve.

At low flow rates, automatic control via the air/fuel ratio setpoint may not be possible, since outputs from the flowmeters are erratic and could cause valve positioning errors. To overcome this drawback, an Auto/Manual Mode Switch is provided at the Operator Console, complete with a potentiometer, P9, for inserting a false biasing signal to permit positioning the air valve for these flow conditions. Proper valve operation can be ascertained quite easily by placing the Auto/Manual Mode Switch in the "MANUAL" position. With 20 psi pressure applied to the I/P converter, the operator should be able to cycle the air valve from its fully open to its fully closed position by adjusting P9. Note that with no air pressure applied to the diaphragm, the valve 'fails' fully open.

An operational checkout of the air valve and air/fuel ratio control circuit is not as straightforward as the fuel valve portion. Two separate function generators are needed to simulate the outputs of the air and fuel flow rate transmitters. The

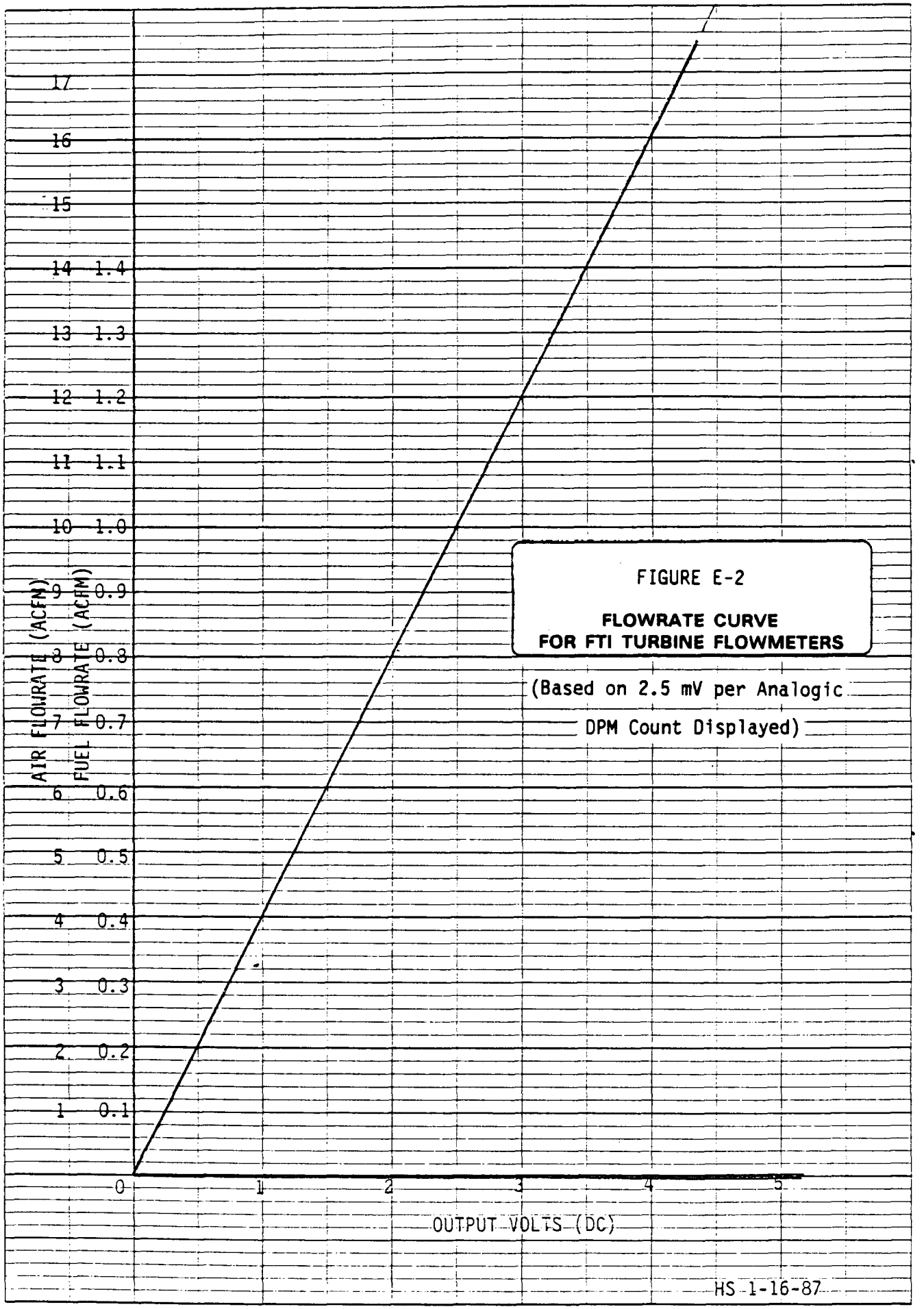


FIGURE E-2

FLOWRATE CURVE FOR FTI TURBINE FLOWMETERS

(Based on 2.5 mV per Analogic DPM Count Displayed)

following procedures should be followed if operation is questionable and minor adjustments are to be made:

1. Remove power from the air/fuel ratio and air valve control circuit by pulling the PCB card from ESP, Rack 1, Slot 5. Note that the air valve 'fails' open.

2. Locate the two FTI Range Extending Amplifiers in Slot 6, Rack 1 of the ESP. Temporarily remove the PCB and insert an extender card. Reinsert the PCB.

3. Using a DVM or DC voltmeter, check for +24 VDC ±4 VDC between edge connector pins 6,F (+) and 4,D (-). Using a line-isolated, portable oscilloscope, verify that the REA's are producing a carrier frequency of approximately 45 KHz by observing the output of each REA at edge connector pins 14,R and 16,T (for air) and 18,V and 20,X (for fuel). If present, observe the waveforms at the signal input terminals at the Analogic Measureometer DPM's. For no flow, the outputs should be a zero DC level (some small offset may be present).

4. Supply air and/or fuel flow temporarily and observe the oscilloscope waveforms. Square wave pulses should be evident, frequency dependent on flow rate.

5. Note the counts displayed on each rate meter and measure the DC output voltage at the + SIG and SIG RET terminals of each DPM. The equivalent scale conversion factors are as follows:

Flow	Frequency	Factor (CFM/Hz)	Display (CFM)	DC Output	Sensitivity
Air	120 Hz	.111	13.34	3.335	2.5 mV/CFM
Fuel	160 Hz	.0073	1.170	2.925	2.5 mV/CFM

6. If the readouts and analog outputs are correct and air valve operation is still questionable, the circuit can be checked out as follows:

   a. Remove the Range Extending Amplifiers from the slot in the ESP. Return the Air Valve Control Card to its proper position in the ESP.

b. Disconnect the red (+) lead from TB-CSP2-4. Insert a DC milliameter between the terminal post and the red lead to the air valve I/P.

c. Using an extender card, reinsert the Air Valve Control Card in its proper slot. Place the Auto/Manual Switch in the "AUTO" position and rotate P1 fully counter-clockwise.

d. Using two square wave function generators, apply a 5 volt-pk signal to the input terminals of each Analogic DPM. Adjust the frequency of the 'air flow' simulator to approximately 120 Hz; the DC output voltage as measured between the Air Valve Control Card edge connector pins L (+) and 10 (-) should be approximately 3.3 VDC. Similarly, adjust the frequency of the 'fuel flow' simulator to 160 Hz; the DC voltage at pins M (+) and 11 (-) should be about 2.9 VDC. (Refer to Figure E-3 for these DC Volts - Frequency Input relationships).

e. With a small air/fuel ratio setpoint, the air valve should be closed in spite of the simulated air flow signal. Rotate P1 clockwise until motion of the air valve stem is observed and note setting. Further clockwise rotation of P1 should result in a fully opened air valve.

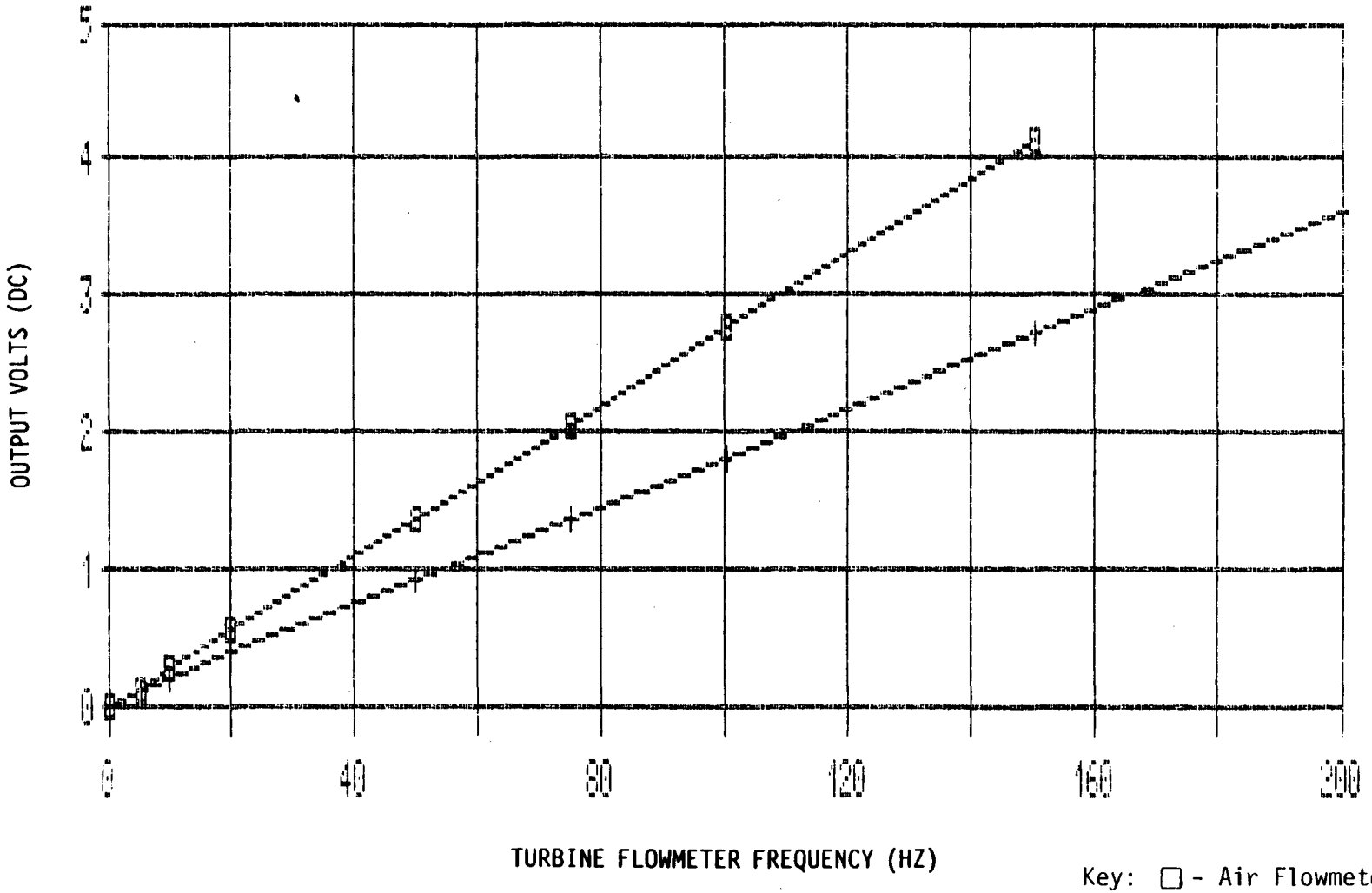
f. Adjust P1 for an approximate midstroke setting of the air valve. Adjustments of the function generator in accordance with the air/fuel ratio should bring a corresponding repositioning of the valve stem. For example, with 'air' at 3 VDC and 'fuel' changed to 2 VDC representing an air/fuel ratio larger than setpoint, the air valve should open to match setpoint. The DC current level should also be indicative of the valve movement (4 mA - fully open; 20 mA - fully closed). NOTE: There are a number of possible air/fuel ratio combinations that could be used to check valve operation. However, any adjustments to gain or offset potentiometers should be made with both air and fuel control systems intact and functioning. Reference E-1 is the set-up procedure for the AD533 divider as suggested by the manufacturer.

g. When checks are complete, remove the test equipment and restore the Air Valve Control and Air/Fuel Ratio Circuits to normal.

FIGURE E-3

ANALOGIC DPM OUTPUT VOLTAGE VS TURBINE FLOWMETER FREQUENCY

(Air and Fuel Flowmeters)



Key: □ - Air Flowmeter
+ - Fuel Flowmeter

Should adjustments to the Air/Fuel Ratio or Manual Valve Control potentiometers not produce the desired operation as described above, refer to Troubleshooting Table E-6 and attempt to correct the problem using its recommendations. If still unsuccessful, MTI Instrumentation should be consulted.

• Oil Management System (OMS)

The OMS consists of two diaphragm position measurement systems and a logic/relay card to analyze diaphragm conditions and adjust oil and gas spring pressures accordingly. Calibrations are, therefore, limited to the Kaman KD-4300 Displacement Measurement System - channel 5 for the upper (X_{UD}) diaphragm and channel 6 for the lower (X_{LD}).

Diaphragm calibrations can be performed in two ways: simultaneously as part of the system; or individually, when the compressor is disassembled. The preferred way is to do both at the same time, under conditions more representative of engine operation and true diaphragm deflection. This method provides a way to observe the actual static position of each diaphragm and the corresponding output from the Kaman system. (Refer to P&ID drawing 1018D08-0103).

A combination vacuum and pressurization rig is connected to the valve V-45 at the compressor. Valves V-46 and V-34 are opened so that pressures in various compressor cavities can equalize. By alternately pressurizing and applying a vacuum to the compressor space, the upper and lower diaphragms can be forced away from, or drawn into, the compressor to simulate diaphragm deflections about midstroke. Dial indicators are used to detect diaphragm movement accurately.

The second method calibrates the 6U-type displacement probes in one direction only, away from the probe surface, for a positive-going DC voltage output. It does not provide an accurate representation of diaphragm behavior since it assumes non-curvature of the diaphragm target as the gap between it and the probe widens, and also assumes bi-directional symmetry about midstroke. In this method, the diaphragms are readily accessible; no pressurization system is needed. A dial indicator with a range of 0-150 mils is positioned directly above the diaphragm's center button. Using three adjustment screws spaced on the outer perimeter of the space ring 120° apart, the diaphragm is raised from its midstroke position (approximately 165 mils away from the probe) a total of 120 mils in 10 mil incre-

TABLE E-6

AIR CONTROL/TCS TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSES	RECOMMENDED CORRECTIVE ACTION
1) Air Valve is fully open; no response from P1 or P9 settings in the Auto or Manual modes	a) Transistor Q1 is open	a) Replace Q1.
	b) No base drive voltage present at Q1-base	b) Check LM324, U1-D and replace if necessary.
2) Air Valve is fully closed; no response from P1 or P9 settings in the Auto or Manual modes	a) Transistor Q1 is shorted base to emitter	a) Replace Q1.
	b) Q1 is heavily forward-biased	b) Check operation of U1-D; replace LM324 if faulty.
3) Air Valve is erratic; fuel flow and air flow indications are less than .01 CFM and 90 CFM, respectively	a) Air Valve control is not possible at low flow rates	a) Place system in manual mode until flows are high enough for the automatic mode to function properly.

ments. Adjustments are made in accordance with the instructions of Reference E-2. The 'zero' pot is adjusted at true diaphragm midstroke; the 'gain' is adjusted at 50 mils, and the 'coarse' and 'fine' linearity pots are set at the 100 mil mark.

Should the OMS require adjustments or an operational check, the OMS logic board and relay section can be checked as follows.

NOTE: Before proceeding, ensure that either the oil or nitrogen volumes have been depressurized and manual valves closed, or that the Auto-Off-Manual switches for the four solenoid valves (located at the Operator Console) have been placed in the "OFF" position. Otherwise, simulated diaphragm positioning as described in the following checkout procedure could accidentally distort or stress-fatigue one or both of the diaphragms.

1. Remove the X_{LD} and X_{UD} signals from the OMS logic card by temporarily disconnecting the following leads from Kaman KD-4300 connector J12:

Signal	Lead Color	ESP Terminal Board
X_{LD}	Green (+)	1
X_{LD}	Red (-)	3
X_{UD}	Blue (+)	2
X_{UD}	Red (-)	4

2. Connect a 0-1 VDC power supply to the X_{LD} leads and another similar supply to the X_{UD} leads lifted from the ESP terminal board. Apply the DC voltages and observe circuit indications as listed in Table E-7 (refer to Table E-1).

3. With the system depressurized and isolated by proper valving, the four solenoid valves may be checked out by placing their switches in the "AUTO" position and repeating the tests in Step #2.

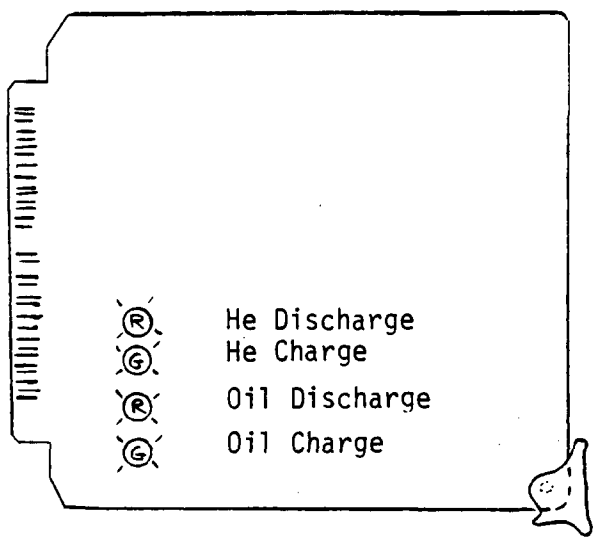
4. Should indications not be correct according to Table E-7, further troubleshooting is needed and adjustments may be necessary. Follow the procedure given in Table E-8. Should troubleshooting in accordance with Table E-8 prove

TABLE E-7

CIRCUIT INDICATIONS

POSITION OF DIAPHRAGMS	DC SIGNAL LEVELS XUD	XLD	INDICATOR LIGHT STATUS (on = X) He Chg	He Dschg	Oil Chg	Oil Dschg
Upper Lower	-0.5	-0.5		X	X	
Upper Lower	-0.5	+0.5	X			
Upper Lower	+0.5	+0.5	X			X
Upper Lower	+0.5	-0.5		X		

PCB STATUS LIGHT LOCATION:



unsuccessful in finding and repairing the faulty circuit conditions, MTI Instrumentation should be contacted.

5. When tests on the OMS are complete, return all circuits and connections to their normal positions.

• Primary Engine Instrumentation Systems

As mentioned earlier, pressure transducers sensing pressures in the 1-100 Bar range are calibrated using a portable dead weight tester. Kistler Model 4045A100 piezoresistive transducers utilize Kiag 4611 signal conditioners mounted in the Electrical Support Package. Due to the inherent linear response of the transducers to applied pressure, only two calibration setpoints are required: a zero adjustment sets the DC output of the transducer conditioner to 0.100 VDC at atmospheric pressure (1 Bar), and a thumbwheel switch behaves as a 'span' adjustment and is usually set for 5.617 VDC output at 800 psig (56.17 Bar). It may require several iterations before both measurements are within the desired tolerance. The resulting sensitivity is 10 Bar/1 VDC. The 20-30 Bar range model 4045A20 transducers are adjusted at 1 atmosphere and 200 psig (0.10 and 7.397 VDC, respectively) for a sensitivity of 2 Bar/1 VDC.

Troubleshooting of the Kistler pressure transducer systems is generally a straightforward matter of signal tracing in accordance with the applicable wiring list. The faulty unit is not repairable in-house and must be sent out for repairs; a stock replacement is substituted.

Six restrictions in the compressor valve plate cylinder housings prohibit the use of the Kistler transducer. Instead, Kulite XTM-190-500 transducers are used, with special Analog Devices AD2B31J strain gage amplifiers providing both excitation and signal conversion capabilities. Calibrations are carried out using the dead weight tester for a 10 Bar/1 VDC sensitivity. Adjustments on the AD2B31J board include 'Excitation', 'Output Offset', and 'Fine Span'; the 'Filter Offset' and 'Input Offset' adjustments are generally unnecessary.

The following References pertain to the above pressure-monitoring instrumentation and should be used for further information on system performance and setup:

TABLE E-8

OMS TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSES	RECOMMENDED CORRECTIVE ACTION
1) Solenoid valve(s) do not respond* to OMS card inputs simulating associated diaphragm condition in either Auto or Manual modes	a) Loss of 24 VDC power to valve(s)	a) Check pin 19 on the Relay Card for +24 VDC. Signal trace as necessary.
	b) Loss of 12 VDC power to relays	b) Check output of regulator U4; repair or replace as necessary.
	c) Relay(s) defective	c) Relay action can be initiated by shorting the appropriate relay card pin (Z, Y, X, or W) to common, or by placing the appropriate switch in Manual.
	d) Driver U3 is defective	d) Repair or replace as necessary.
2) Fuel valve remains fully closed	e) Comparator U2 is defective	e) Verify that signal levels to the comparator section input terminals are present as follows*. Make adjustments or repair or replace as necessary.
	f) Operational amplifier U1 is faulty (low pass filter/ buffer)	f) For the input voltage levels given in Table E-7, check that the output of each section of U1 is approximately 1.25 X this value. Check and repair or replace U1 as necessary.
	g) +/-15 VDC power to circuitry not available	g) Check power supply and rail voltages. Repair or replace as necessary.

* Signal levels, section e):

U2 (LM339) Pin #	Approximate DC Voltage	Pot Adjustment
8	+0.2	R31
11	-0.2	R35
4	+0.2	R22
7	-0.2	R26

Reference E-3 Kistler 4045A Series Pressure Transducers
Reference E-4 Kistler/Kiag 4611 Signal Conditioners
Reference E-5 Kulite Bulletin on the XTM Series Transducers
Reference E-6 Analog Devices 2B31J Product Bulletin

The Validyne DP-45 Differential Pressure Transducers, supplied by Lennox and used to measure the low air supply and natural gas line pressures, are calibrated using a portable hand pump unit such as the Druck DPI-600 or the Ametek Mod-Cal System. Diaphragms inside these capacitive-type sensors have been sized for the anticipated pressure range to which each will be exposed: the fuel transducer, PI-1, uses a -30 diaphragm capable of 0-40 inches of water column; the air transducer, PI-2, uses a -28 diaphragm to sense an expected 0-20 inch range.

A Validyne CD-280-DUAL carrier demodulator, also provided by Lennox, consists of two channels, each with a 'zero' and 'span' adjustment. The sensitivity of each matched system is as follows:

Channel 2: PI-1 (Fuel) 4" H_2O/1 VDC
Channel 1: PI-2 (Air) 2" H_2O/1 VDC

Bulletins on the Validyne DP-45 transducer and the CD-280 carrier demodulator are included as References E-7 and E-8, respectively.

There are four different flow measurements associated with the Lennox MARK I System Package:

Flow	Instrumentation Used	Principle	Output(s)
1) Refrigerant (R-22)	Micromotion D25S	Coriolis effect to measure mass flow	4-20 mA 0-10 VDC
2) Coolant Water	MTI Bearingless E100	Bearingless Turbine Optical	~800 pulses/liter
3) Fuel (Natural Gas)	Lennox-Lancaster L-175	Totalizer/Encoder	(Fig. E-1)
	MTI-Flow Technology FT-10NEDI	Turbine Flowmeter	(Fig. E-2)

4) Air Supply	Lennox-American AL-800	Totalizer/Encoder	(Fig. E-1)
	MTI-Flow Technology FT-24NENA	Turbine Flowmeter	(Fig. E-2)

Calibration of the gas flow measurements (items #1, 3, and 4) must be accomplished by outside sources having the necessary equipment; MTI has chosen this method, and all conditioning circuit designs and all data acquired are based on furnished calibration sheet information. The coolant water flowmeter (item #2) was calibrated in-house using a 50-gallon barrel-and-elapsed timer method (volumetric). The following References are included:

Reference E-9 Micromotion Model D Mass Flowmeters Instruction Manual
Reference E-10 Bearingless E-100 Operating Brochure
Reference E-11 Installation and Operation Manual, Standard Line FTI Turbine Flowmeters FT-32 and Smaller

As discussed earlier in Section E.2, displacement measurements are perhaps the most critical of all measurements being taken. Accurate, reliable information in piston, displacer, and diaphragm positions is essential for proper engine control and operation. The stroke data that is sent to the DAS is used in a variety of calculations for determining system performance. Consequently, the techniques used in calibrating each displacement measurement circuit must be representative of true target-probe interaction. For this reason, it is advantageous to perform each of the six calibrations during engine or compressor assembly.

Reference E-2 provides general instructions for adjusting the four potentiometers on the RF card section of the KD-4300 system. In addition, the following guidelines are given:

1. The RG-178/U coaxial cable lengths are very critical in the tuning of each RF card. If microdot connectors or cable splices must be installed, it is important that very little change in overall cable length result.

2. With the exception of the -6U diaphragm transducers X_{UD} and X_{LD}, each probe has a back-up. Therefore, during engine operation when troubleshooting access is limited, it is possible to reconfigure the X_P or X_D systems to eliminate a

questionable probe input. This is done by removing the suspect probe's DC and RF printed circuit boards and connecting an RG-58 coaxial cable jumper between the associated BNC jacks at the ESP (X_{P1} to X_{P2}, or X_{D1} to X_{D2}). This ensures that the summation, averaging, and stroke circuits continue to function as intended.

3. Measurement of the resistance of each probe, taken at the engine or compressor feedthrough, is a quick way to determine whether the probe and internal connections are at fault. Ohm meter readings are typically:

-1U	7.8 to 8.6 Ohms
-2UB	4.7 to 5.1 Ohms
-6U	3.4 to 4.1 Ohms

4. If 'zero' or midstroke adjustments are made, use caution to ensure that the proper potentiometer is adjusted. There are at least 24 front-panel trim adjustments possible; make sure the correct pot is touched.

5. Special calibration fixtures have been designed for ease in attachment to the piston or to the displacer should re-calibration be necessary following engine teardown. A precision dial indicator with spring-loaded contact stem is used in conjunction with the calibration fixtures to provide position indication during X_P and X_D calibrations. Mention has previously been made of the manner in which the X_{UD} and X_{LD} probes may be calibrated.

6. There are two each of the KD-4300-1U, -2UB, and -6U measurement systems. For this reason, it is possible to interchange elements of one system to another of the same model. This facilitates troubleshooting, especially when the problem is difficult to signal trace any other way. When this direct substitution method is used, care must be taken not to readjust the potentiometer settings; this would invalidate a previously satisfactory calibration.

Should problems arise with the Kaman KD-4300 system or with any of the associated circuits that can not be located or corrected with the information included in this Appendix, notify MTI Instrumentation for assistance.

The method by which temperature measurements are taken on the Lennox System Package have been discussed earlier. Whether Type-K thermocouples or semiconductor devices, calibration usually involves submitting the transducer to a water or sand bath-controlled temperature range and observing its output response. If a thermocouple is in good condition and a problem remains, a millivolt generator may be substituted for the transducer and the signal traced to the DAS. (MTI has no provisions for checking the coolant water differential temperature circuitry provided by Lennox aside from a water bath calibration).

The accelerometer, a Kistler 816A7 (see Reference E-12), together with a Kistler 5108 Piezotron® coupler, is an optional installation, capable of providing assembly vibration data from 0 to 50 g's. A dynamic DAS channel has been alloted to this signal.

Auxiliary equipment controls, such as 'Blip' valve and 'Ignitor', are mentioned in other Appendices of this instruction manual under those sections relating to system start-up and operation.

APPENDIX B

LENNOX TEST DATA SPREAD SHEET

LENNOX TEST DATA

COMPUTER SPREAD SHEET

TEST PT NO	COND TEMP (F)	EVAP TEMP (F)	LIQUID TEMP (F)	SUCTION TEMP (F)	COND PRESSURE (PSIA)	EVAP PRESSURE (PSIA)	PRESSURE RATIO
1 (VRY)	121	45	106	65	277.4	90.7	3.06
2 (ARI-C)	130	45	115	65	311.5	90.7	3.43
3 (95F)	121	45	106	65	277.4	90.7	3.06
4 (87F)	105	47	90	67.5	225.5	94.7	2.38
5 (80F)	95	50	80	70	196.5	98.7	1.99
6 (ARI-H)	110	30	95	50	241.0	69.6	3.46
7 (47F)	100	35	85	45	210.6	76.2	2.76
8 (32F)	97	20	82	30	202.1	57.7	3.50
9 (17F)	95	5	80	15	196.5	42.9	4.58
10 (0F)	90	-12	75	-2	183.1	29.8	6.14
11	80	-20	0	0	158.3	24.8	6.38
12	80	0	65	20	158.3	38.7	4.09
13	80	20	65	40	158.3	57.7	2.74
14	90	-20	0	0	183.1	24.8	7.38
15	90	0	75	20	183.1	38.7	4.73
16	90	20	75	40	183.1	57.7	3.17
16A	90	35	75	55	183.1	76.2	2.40
17	100	0	85	20	210.6	38.7	5.44
17A	100	20	85	40	210.6	57.7	3.65
18	100	35	85	55	210.6	76.2	2.76
19	100	50	85	70	210.6	98.7	2.13
20	120	20	105	40	274.6	57.7	4.76
21	120	35	105	55	274.6	76.2	3.60
22	120	50	105	70	274.6	98.7	2.78
23	130	20	0	40	311.5	57.7	5.40
23A	130	25	115	45	311.5	63.5	4.91
24	130	35	115	55	311.5	76.2	4.09
25	130	50	115	70	311.5	98.7	3.16
25R	130	50	115	70	311.5	98.7	3.16
26	110	50	95	70	241.0	98.7	2.44
27	110	35	95	55	241.0	76.0	3.17
28	110	20	95	40	241.0	57.7	4.18

Note: Conditions as shown and plotted in the results are as established and measured at the compressor.

TEST PT NO	PISTON STROKE (MM) HIGH	MEDIUM	LOW	REFRIGERANT FLOW RATE (LBM/HR) HIGH	MEDIUM	LOW	LIQUID ENTHALPY (BTU/LBM)
1 (VRY)	0	16.2	0	0	431.4	0	41.17
2 (ARI-C)	17.3	14	0	471.9	190	0	44.07
3 (95F)	18	17.3	14.2	591.7	517.5	248.4	41.17
4 (87F)	17.1	14	0	613.7	387.6	0	36.16
5 (80F)	17.2	14	10	710.4	487.4	215.7	33.11
6 (ARI-H)	17	14	0	353.6	132	0	37.7
7 (47F)	17.1	14	12.6	458.1	251.6	156.1	34.63
8 (32F)	17	15	0	318.7	170.3	0	33.71
9 (17F)	18	17	0	191.2	155.6	0	33.11
10 (0F)	17.5	0	0	69.8	0	0	31.61
11	0	0	0	0	0	0	0
12	17.1	15	14	147.4	37.8	0	28.64
13	17.1	14	13	345.6	183.4	114.3	28.64
14	0	0	0	0	0	0	0
15	17.3	14	0	128.2	0	0	31.61
16	17	15.1	14	310.3	185.6	123.6	31.61
16A	17	14	12.1	490.9	310	189.4	31.61
17	17	14	0	102.1	0	0	34.6[illegible]
17A	17	15.2	14	271.1	160.5	86	34.63
18	17	14	12.6	443.1	227.2	152.7	34.63
19	17.1	14.2	10	682.1	472.1	150.8	34.63
20	17.4	14	0	200.3	0	0	40.85
21	17.1	14.7	14	372.2	173.7	115	40.85
22	17	14.1	12.2	564.3	307.1	145.5	40.85
23	0	0	0	0	0	0	0
23A	17	14	0	205.1	0	0	44.07
24	16.9	15.1	14	302.6	147.8	55	44.07
25	16.2	14.1	13.1	457.7	259.8	138.5	44.07
25R	17	0	0	530	0	0	44.07
26	17.3	14.1	12.1	643.2	400.3	239	37.68
27	17	14	0	412.2	193.9	0	37.68
28	17	14	0	212.1	0	0	37.68

TEST PT NO	CONDENSER INLET ENTHALPY (BTU/LBM) HIGH	MEDIUM	LOW	FIRING RATE (WATTS) HIGH	MEDIUM	LOW	SUCTION ENTHALPY (BTU/LBM)
1 (VRY)	0	125.4	0	0	10592.1	0	112.13
2 (ARI-C)	126.27	125	0	11888.7	7000	0	112.13
3 (95F)	123.98	125.18	121.52	14224.7	11776	7138.3	112.13
4 (87F)	122.86	121.32	0	11428.7	7785.9	0	112.36
5 (80F)	121.39	120.46	117.72	11413.2	7840.2	4476.1	112.58
6 (ARI-H)	126.36	125	0	11265.8	6100	0	110.68
7 (47F)	126.2	126.5	121.18	10661.1	6886.8	5807.3	109.47
8 (32F)	125.54	124.16	0	10212.6	7103.8	0	108.03
9 (17F)	129.2	127.96	0	9780.2	8359.3	0	106.55
10 (0F)	118.54	0	0	7439	0	0	105.01
11	0	0	0	0	0	0	104.68
12	127	123.01	121	8053.08	5439.8	4356.1	107.62
13	122.8	121.75	120.1	9546	6340.5	5282.5	109.71
14	0	0	0	0	0	0	0
15	128	126	0	8301.17	2203.4	0	107.62
16	124.4	123.77	121.4	10124.6	7219.21	5645.2	109.71
16A	122.9	123	120	11083	7238.39	5372.58	111.19
17	123.4	122	0	7387.5	220	0	118.06
17A	125	125	123	9873.17	6795.3	5011.3	109.71
18	123.7	126.5	126.27	11372.7	7074.9	5583.28	116.37
19	122.64	121.5	119.28	12201.8	8407.2	4349.7	112.58
20	128.5	126	0	9648.2	3350	0	109.71
21	126.2	124.2	123	11131.4	6963.3	5907.8	111.19
22	125.1	124.8	122.27	12350.7	7709.4	5251.5	112.58
23	0	0	0	0	0	0	0
23A	128.3	126	0	9885.5	3860.9	0	110.21
24	127.76	125.41	124	10326.7	7216.1	5551.6	111.2
25	126.19	125.03	122.78	10929.6	7476.1	5725.7	112.58
25R	126.19	0	0	12600	0	0	112.58
26	123.7	123.6	121.4	13023.6	8183.8	5909.7	112.58
27	125.6	123.7	0	11178.7	6694.7	0	111.19
28	127.7	126	0	8818.6	4181	0	109.71

TEST PT NO	ENGINE POWER (WATTS) HIGH	MEDIUM	LOW	DISPLACER STROKE (MM) HIGH	MEDIUM	LOW
1 (VRY)	0	2309	0	0	16.29	0
2 (ARI-C)	2793.4	0	0	18.6	0	0
3 (95F)	3251.4	2768.1	1494.6	21.87	17.66	11.09
4 (87F)	2556.6	1599.5	0	16.75	12.14	0
5 (80F)	2482.2	1604.7	712.5	16.74	12.53	7.52
6 (ARI-H)	2119.4	970	0	14.78	0	0
7 (47F)	2267.8	1246.2	829.6	15.14	10.27	8.02
8 (32F)	1926.9	1135.3	0	13.1	9.28	0
9 (17F)	1597	1271.6	0	11.92	10.1	0
10 (0F)	898	0	0	8.3	0	0
11	0	0	0	0	0	0
12	1159.4	592	363.2	10.15	6.57	0
13	1688.8	940.2	782	12.85	8.79	7.37
14	0	0	0	0	0	0
15	1189.1	100	0	9.94	0	0
16	1827.7	1175.9	923.9	12.88	9.79	8.04
16A	2126.3	1365	841.4	14.82	10.87	8.18
17	1295.4	0	0	9.68	0	0
17A	1792.8	1145.1	775	12.65	9.45	0
18	2235.2	1227.9	823.7	14.85	10.11	8.06
19	2547.9	1691	596.6	16.99	12.78	6.85
20	1821.6	0	0	12.63	0	0
21	2481	1208.1	893.8	15.96	10.98	0
22	2795.9	1565.5	833	18.28	12.37	9.71
23	0	0	0	0	0	0
23A	1843	0	0	13.63	0	0
24	2166.8	1223.6	730.7	16	10.97	0
25	2509.2	1522.6	930.9	18.08	13.38	12.13
25R	3011.4	0	0	0	0	0
26	2780.5	1718.4	1016.7	18.2	12.72	9.46
27	2259.8	1173.1	0	15.57	9.91	0
28	1686.1	571	0	12.02	0	0

TEST PT NO	EVAPORATO HEAT INPUT (BTU/HR) HIGH	MEDIUM	LOW	CONDENSER REJECT HEAT (BTU/HR) HIGH	MEDIUM	LOW
1 (VRY)	0	30612.14	0	0	36336.82	0
2 (ARI-C)	32117.51	12931.4	0	38790.18	15376.7	0
3 (95F)	41987.03	36721.8	17626.46	48998.67	43475.17	19958.94
4 (87F)	46763.94	29535.12	0	53207.79	33008.01	0
5 (80F)	56455.48	38733.67	17141.67	62714.11	42574.39	18250.37
6 (ARI-H)	25805.72	9633.36	0	31350.17	11523.6	0
7 (47F)	34284.20	18829.74	11682.52	41948.21	23114.49	13510.45
8 (32F)	23685.78	12656.69	0	29266.22	15403.63	0
9 (17F)	14041.72	11427.26	0	18372.40	14758.66	0
10 (0F)	5123.32	0	0	6067.714	0	0
11	0	0	0	0	0	0
12	11641.65	2985.444	0	14498.26	3567.186	0
13	28017.79	14868.23	9266.301	32541.69	17076.37	10453.87
14	0	0	0	0	0	0
15	9744.482	0	0	12357.19	0	0
16	24234.43	14495.36	9653.16	28792.73	17104.89	11098.04
16A	39065.82	24669.8	15072.45	44814.26	28330.9	16741.06
17	8518.203	0	0	9063.417	0	0
17A	20354.18	12050.34	6456.88	24499.30	14504.38	7599.82
18	36218.99	18571.32	12481.69	39466.91	20872.86	13993.42
19	53169.69	36800.19	11754.86	60031.62	41011.32	12765.22
20	13792.65	0	0	17556.29	0	0
21	26180.54	12218.05	8089.1	31767.27	14477.89	9447.25
22	40477.23	22028.28	10436.71	47542.27	25781.04	11846.61
23	0	0	0	0	0	0
23A	13565.31	0	0	17275.57	0	0
24	20313.53	9921.814	3692.15	25324.59	12022.05	4396.15
25	31357.02	17798.89	9488.635	37586.32	21033.40	10901.33
25R	36310.3	0	0	43523.6	0	0
26	48175.68	29982.47	17901.1	55328.06	34393.77	20009.08
27	30300.82	14253.58	0	36240.62	16679.27	0
28	15277.56	0	0	19093.24	0	0

TEST PT NO	ENGINE HIGH	REJECT (WATTS) MEDIUM	HEAT LOW	HEATING CAPACITY (BTU/HR) HIGH	MEDIUM	LOW
1 (VRY)	0	5909.1	0	0	53464.34	0
2 (ARI-C)	6566	3900	0	57821.73	26680.85	0
3 (95F)	7669	6217	3965	71227.27	61495.14	31451.49
4 (87F)	6174.2	4204.4	0	71103.70	45194.46	0
5 (80F)	6314.5	4276.3	2514.2	81016.69	54969.24	25537.78
6 (ARI-H)	6211.7	3529.4	0	49354.78	21753.56	0
7 (47F)	5855.9	3799.4	3136.4	58921.54	34127.05	22601.31
8 (32F)	5574.8	4112.2	0	45424.77	27322.84	0
9 (17F)	5677.4	4734.9	0	34828.35	28482.76	0
10 (0F)	4443.7	0	0	18947.77	0	0
11	0	0	0	0	0	0
12	4942.2	3209	2493.5	28823.23	12868.47	7227.409
13	5579.8	3815.2	2869.9	48714.74	28134.73	18772.28
14	0	0	0	0	0	0
15	4940.8	1528.6	0	26678.10	4430.647	0
16	5590.18	4261.4	3151.4	44995.87	29456.56	20232.37
16A	6107.3	3900	3105.8	62516.27	39635.05	25743.22
17	3924.2	220	0	20437.71	637.67	0
17A	5503.8	4104.3	3278.4	40452.07	26400.69	17102.26
18	6026.1	3945.3	3113.64	56933.56	32308.31	23018.31
19	6596.9	4606.5	2405.3	79152.73	54363.26	19736.98
20	5327	2105.1	0	32996.60	6101.632	0
21	5986.8	3863.6	3321.9	49120.00	25676.53	19075.77
22	6615	4288.56	3022.7	66715.85	38211.43	20607.90
23	0	0	0	0	0	0
23A	5118.4	2450	0	32111.25	7101.325	0
24	5750	4136.4	3267.5	41990.96	24011.40	13866.99
25	6179	4318.2	3312.9	55496.15	33549.71	20503.77
25R	6823	0	0	63300.06	0	0
26	7148	4568.2	3300.7	76046.54	47634.70	29576.15
27	6201.9	3801.6	0	54216.83	27698.21	0
28	5105.3	3000	0	33890.95	8695.5	0

TEST PT NO	COOLING CAPACITY (BTU/HR) HIGH	MEDIUM	LOW	THERMAL HIGH	HEATING MEDIUM	COP LOW
1 (VRY)	0	30612.14	0	0	1.480225	0
2 (ARI-C)	32117.51	12931.4	0	1.426271	1.117756	0
3 (95F)	41987.03	36721.8	17626.46	1.468415	1.531400	1.292087
4 (87F)	46763.94	29535.12	0	1.824488	1.702245	0
5 (80F)	56455.48	38733.67	17141.67	2.081673	2.056071	1.673127
6 (ARI-H)	25805.72	9633.36	0	1.284732	1.045794	0
7 (47F)	34284.20	18829.74	11682.52	1.620756	1.453205	1.141313
8 (32F)	23685.78	12656.69	0	1.304373	1.127926	0
9 (17F)	14041.72	11427.26	0	1.044313	0.999212	0
10 (0F)	5123.32	0	0	0.746946	0	0
11	0	0	0	0	0	0
12	11641.65	2985.444	0	1.049605	0.693728	0.486553
13	28017.79	14868.23	9266.301	1.496527	1.301262	1.042133
14	0	0	0	0	0	0
15	9744.482	0	0	0.942456	0.589684	0
16	24234.43	14495.36	9653.16	1.303288	1.196569	1.051025
16A	39065.82	24669.8	15072.45	1.654174	1.605768	1.405159
17	8518.203	0	0	0.811297	0.85	0
17A	20354.18	12050.34	6456.88	1.201516	1.139337	1.000803
18	36218.99	18571.32	12481.69	1.468082	1.339182	1.209009
19	53169.69	36800.19	11754.86	1.902337	1.896268	1.330659
20	13792.65	0	0	1.002925	0.534129	0
21	26180.54	12218.05	8089.1	1.294059	1.081351	0.946895
22	40477.23	22028.28	10436.71	1.584101	1.453511	1.150790
23	0	0	0	0	0	0
23A	13565.31	0	0	0.952586	0.539382	0
24	20313.53	9921.814	3692.15	1.192449	0.975799	0.732503
25	31357.02	17798.89	9488.635	1.489032	1.316010	1.050148
25R	36310.3	0	0	1.473259	0	0
26	48175.68	29982.47	17901.1	1.712355	1.706923	1.467648
27	30300.82	14253.58	0	1.422290	1.213294	0
28	15277.56	0	0	1.127015	0.609901	0

TEST PT NO	THERMAL COOLING COP HIGH	MEDIUM	LOW	MOTOR POWER (WATTS) HIGH	MEDIUM	LOW
1 (VRY)	0	0.847534	0	0	312.01	0
2 (ARI-C)	0.792233	0.541742	0	619.29	0	0
3 (95F)	0.865600	0.914474	0.724129	867.16	493.78	-21.97
4 (87F)	1.199940	1.112437	0	364.29	6.63	0
5 (80F)	1.450588	1.448795	1.123050	390.29	33.77	-26.01
6 (ARI-H)	0.671737	0.463120	0	151.46	0	0
7 (47F)	0.943056	0.801812	0.589940	199.32	-60.13	-65.04
8 (32F)	0.680138	0.522486	0	21.73	-80.05	0
9 (17F)	0.421035	0.400883	0	-55.84	-84.13	0
10 (0F)	0.201967	0	0	-108.09	0	0
11	0	0	0	0	0	0
12	0.423933	0.160942	0	-86.57	-4.5	0
13	0.860712	0.687672	0.514413	15.39	-63.02	27.42
14	0	0	0	0	0	0
15	0.344242	0	0	-103.12	0	0
16	0.701940	0.588823	0.501459	3.46	-78.93	-59.8
16A	1.033677	0.999468	0.822709	146.86	-30.6	-52.8
17	0.338139	0	0	-92.04	0	0
17A	0.604564	0.520039	0.377848	-17.03	-87.84	0
18	0.933938	0.769782	0.655586	156.56	-53.56	-65.37
19	1.277867	1.283643	0.792508	372.2	60.2	-27.11
20	0.419225	0	0	-13.31	0	0
21	0.689722	0.514556	0.401531	219.06	15.01	0
22	0.961091	0.837926	0.582808	480.65	42.84	57.46
23	0	0	0	0	0	0
23A	0.402417	0	0	89.19	0	0
24	0.576858	0.403212	0.195032	279.94	28.88	0
25	0.841349	0.698173	0.485982	599.44	155.01	232.86
25R	0.845093	0	0	0	0	0
26	1.084781	1.074380	0.888300	528.1	96.51	-10.16
27	0.794893	0.624365	0	196.2	-41.63	0
28	0.508042	0	0	-56.57	0	0

TEST PT NO	COMP HIGH	HEATING MEDIUM	COP LOW	COMP HIGH	COOLING MEDIUM	COP LOW
1 (VRY)	0	4.614967	0	0	3.887903	0
2 (ARI-C)	4.072248	0	0	3.371742	0	0
3 (95F)	4.419361	4.605801	3.916139	3.786957	3.890342	3.458484
4 (87F)	6.103206	6.051747	0	5.364063	5.415020	0
5 (80F)	7.409247	7.780369	7.511602	6.669833	7.078488	7.055277
6 (ARI-H)	4.337831	3.483870	0	3.570662	2.912404	0
7 (47F)	5.424433	5.439290	4.775807	4.433379	4.431005	4.129652
8 (32F)	4.454029	3.978855	0	3.604742	3.269304	0
9 (17F)	3.373702	3.403627	0	2.578465	2.635344	0
10 (0F)	1.981501	0	0	1.673095	0	0
11	0	0	0	0	0	0
12	3.667147	1.767053	0	2.944604	1.478879	0
13	5.650769	5.326243	3.920272	4.865206	4.637510	3.474923
14	0	0	0	0	0	0
15	3.047524	0	0	2.403178	0	0
16	4.619805	4.265752	3.522630	3.888423	3.614966	3.064009
16A	6.180695	6.086580	5.834803	5.387881	5.300033	5.253237
17	2.051793	0	0	1.928367	0	0
17A	4.007445	3.714509	2.875724	3.329412	3.086039	2.443242
18	5.178004	4.984994	4.981965	4.751881	4.435326	4.443756
19	6.909447	7.112230	6.274666	6.119661	6.381931	5.778030
20	2.826346	ERR	0	2.220447	ERR	0
21	3.754903	3.514375	0	3.094550	2.965820	0
22	4.986593	4.829398	4.170563	4.245558	4.126417	3.674213
23	0	0	0	0	0	0
23A	2.748860	0	0	2.158490	0	0
24	3.427435	2.881275	1.764326	2.749238	2.377919	1.481787
25	4.392787	4.051067	3.434173	3.664757	3.428095	2.989140
25R	4.238400	0	0	3.535957	0	0
26	5.835367	5.869501	5.771383	5.081016	5.116685	5.163361
27	4.702959	4.169537	0	3.932149	3.563155	0
28	3.320794	0	0	2.657151	0	0

TEST PT NO		ENGINE EFF HIGH	MEDIUM	LOW
1	(DRY)	0	0.217992	0
2	(ARI-D)	0.234962	0	0
3	(95F)	0.228574	0.235062	0.209377
4	(87F)	0.223699	0.205435	0
5	(80F)	0.217485	0.204675	0.159178
6	(ARI-H)	0.188126	0.159016	0
7	(47F)	0.212717	0.180954	0.142854
8	(32F)	0.188678	0.159815	0
9	(17F)	0.163289	0.152118	0
10	(0F)	0.120715	0	0
11		0	0	0
12		0.143969	0.108827	0.083377
13		0.176911	0.148284	0.148035
14		0	0	0
15		0.143244	0.045384	0
16		0.180520	0.162884	0.163661
16A		0.191852	0.188577	0.156610
17		0.175350	0	0
17A		0.181583	0.168513	0.154650
18		0.196540	0.173557	0.147527
19		0.208813	0.201137	0.137158
20		0.188602	0	0
21		0.222883	0.173495	0.151291
22		0.226375	0.203063	0.158621
23		0	0	0
23A		0.186434	0	0
24		0.209825	0.169565	0.131619
25		0.229578	0.203662	0.162582
25R		0.239	0	0
26		0.213497	0.209975	0.172039
27		0.202152	0.175228	0
28		0.191198	0.136570	0

APPENDIX C

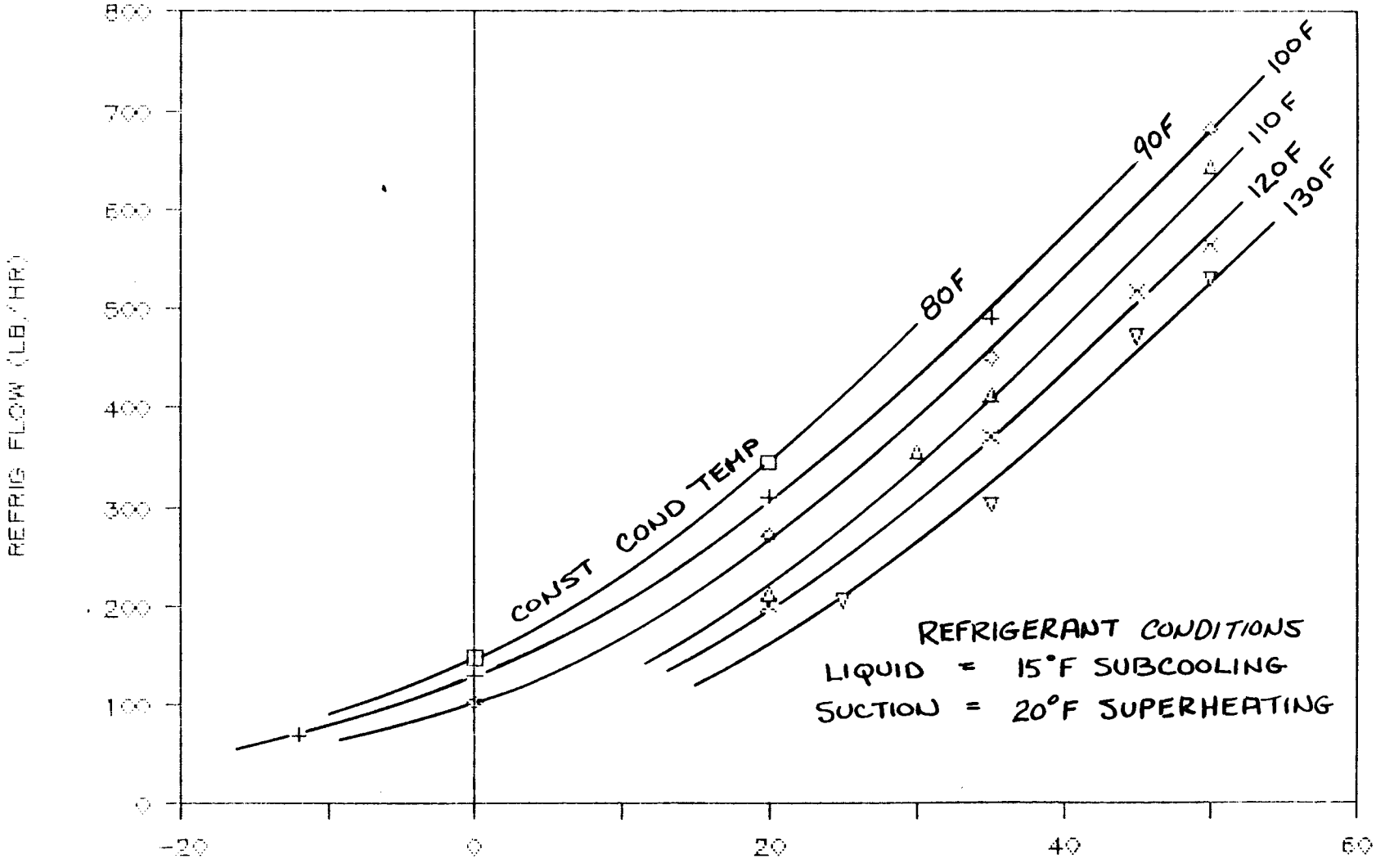
LENNOX PARAMETRIC TEST DATA PLOTS

Attachment C-1

Refrigerant Flow versus Evaporator Temperature
(14- and 17-mm Piston Strokes)

REFRIG FLOW VS EVAPORATOR TEMP

17MM PISTON STROKE

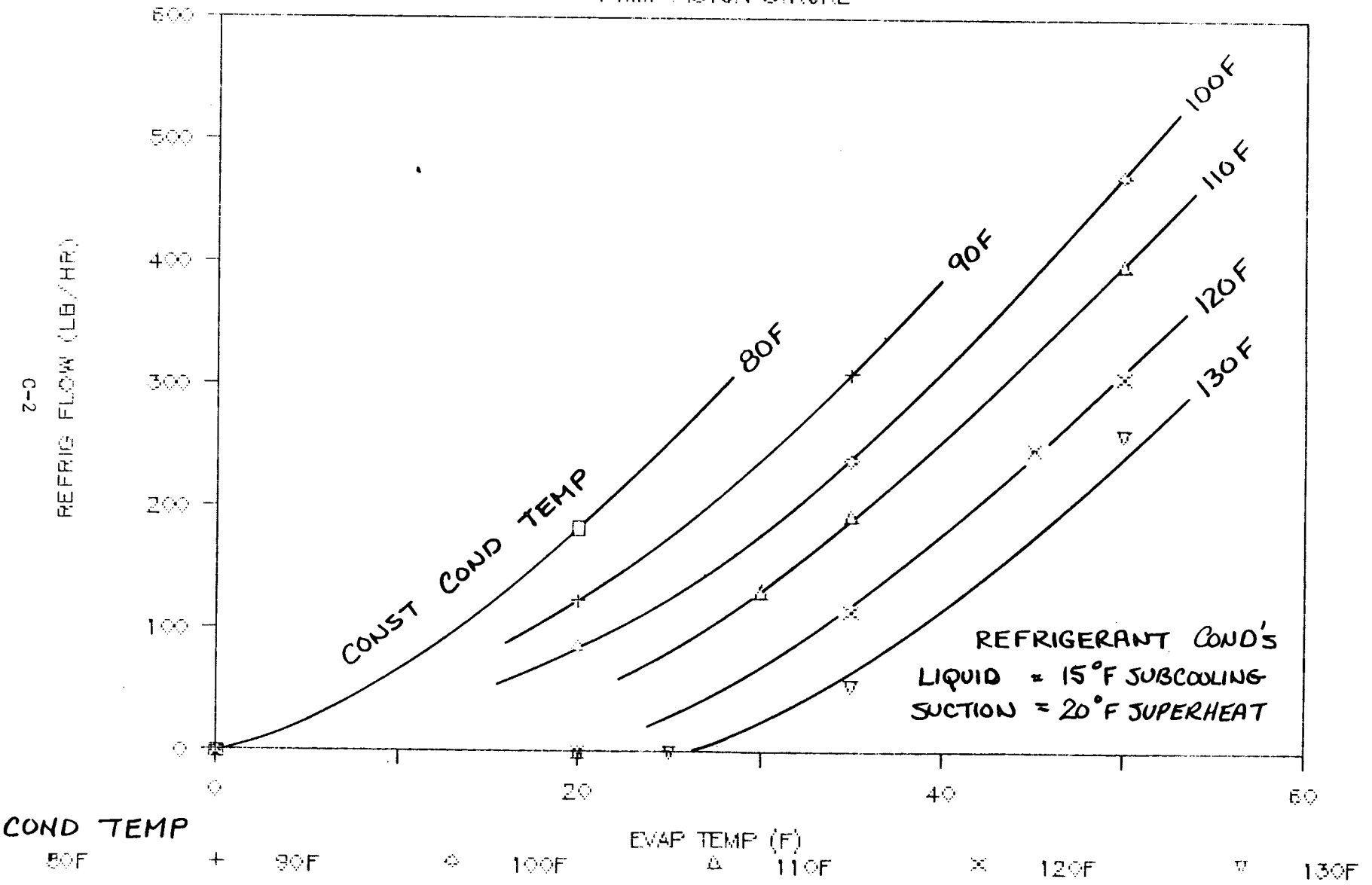


COND TEMP

80F + 90F ◇ 100F △ 110F × 120F ▽ 130F

REFRIG FLOW VS EVAPORATOR TEMP

14MM PISTON STROKE



Attachment C-2

Condenser Reject Heat versus Evaporator Temperature

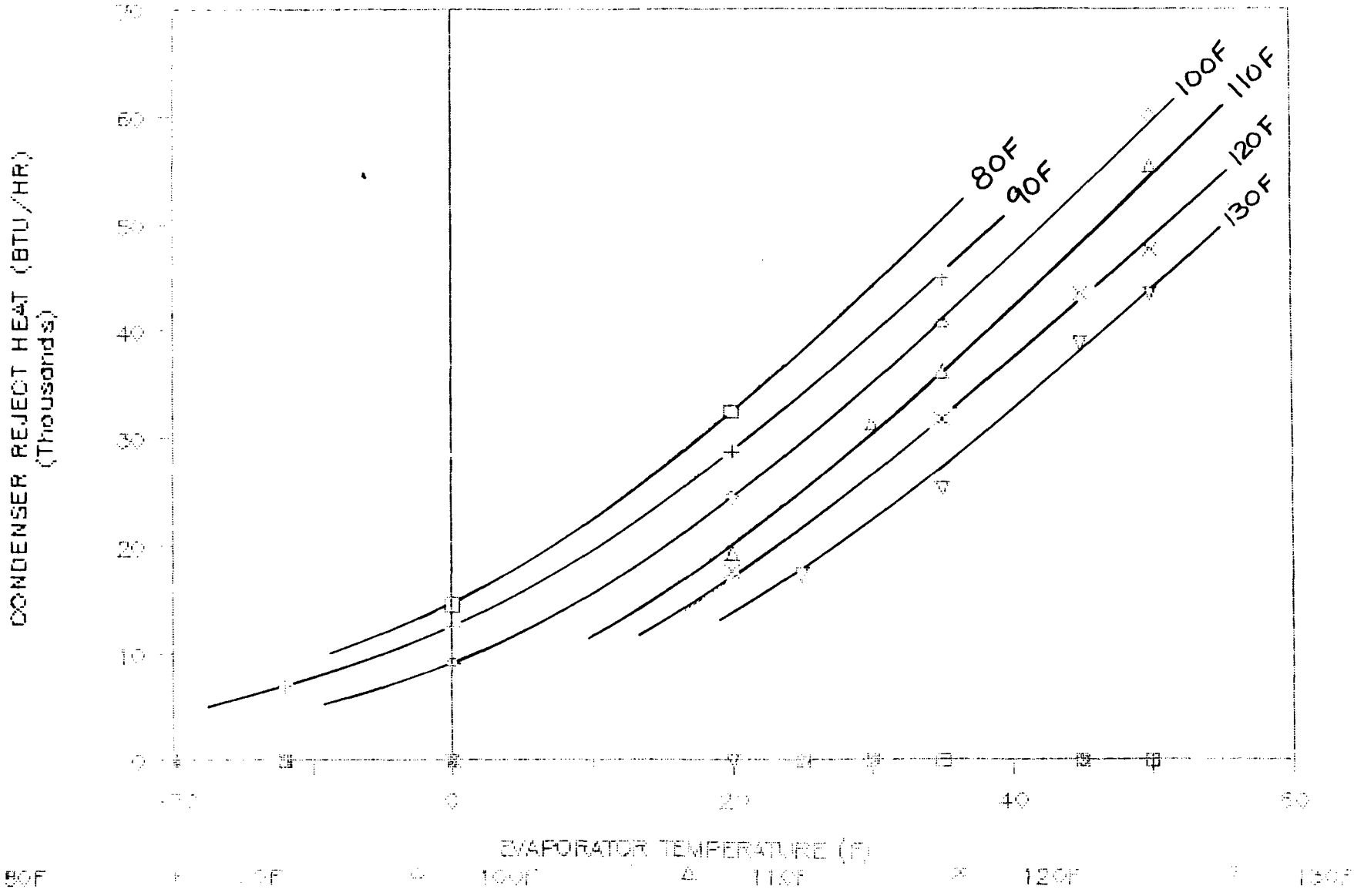
and

Evaporator Heat Input versus Evaporator Temperature

(14- and 17-mm Piston Strokes)

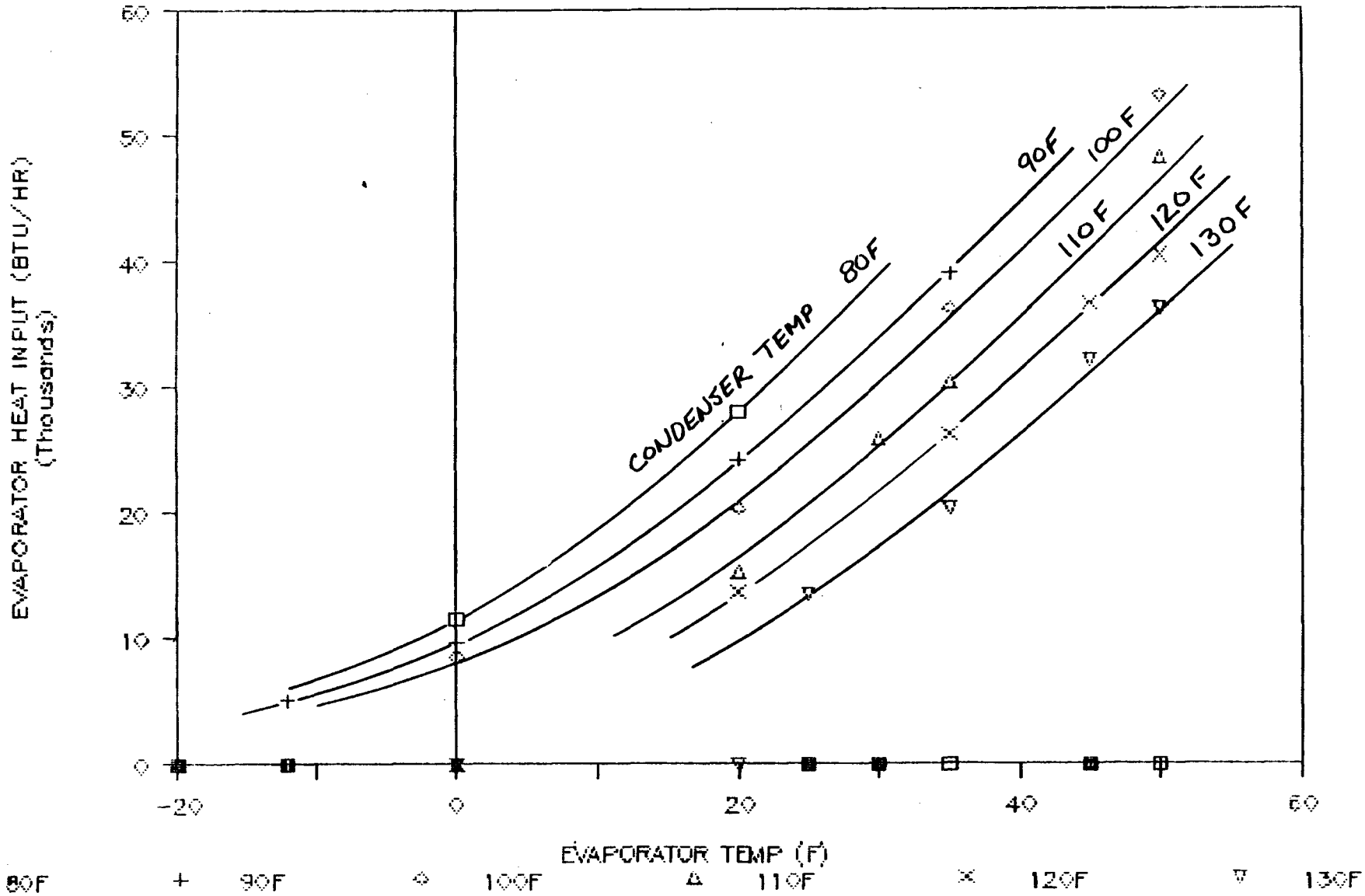
FPSE/HP MODULE MAPS (COND REJECT HEAT)

PISTON STROKE = 17MM



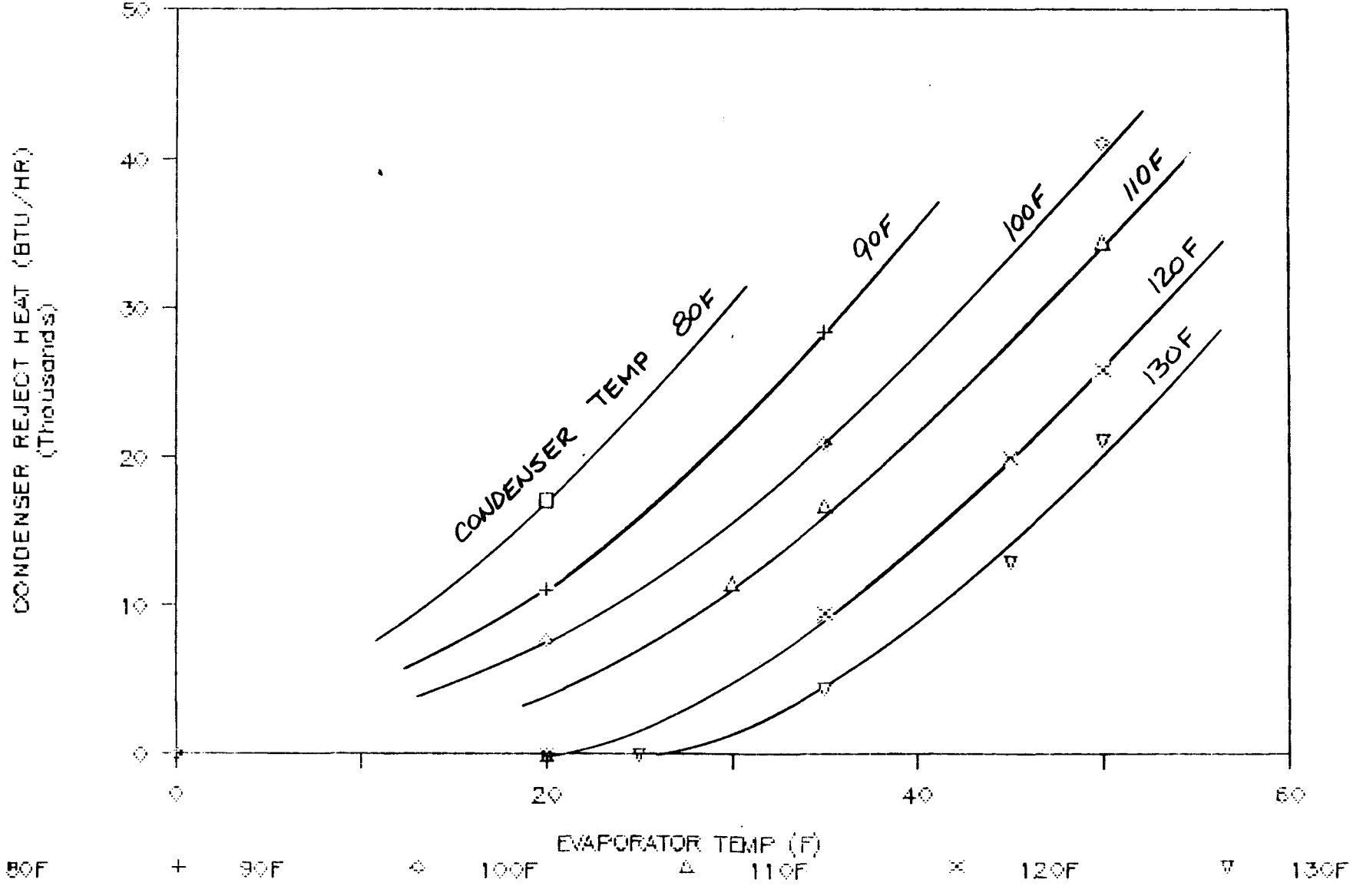
FPSE/HP MODULE MAPS (EVAP HEAT INPUT)

PISTON STROKE = 17MM



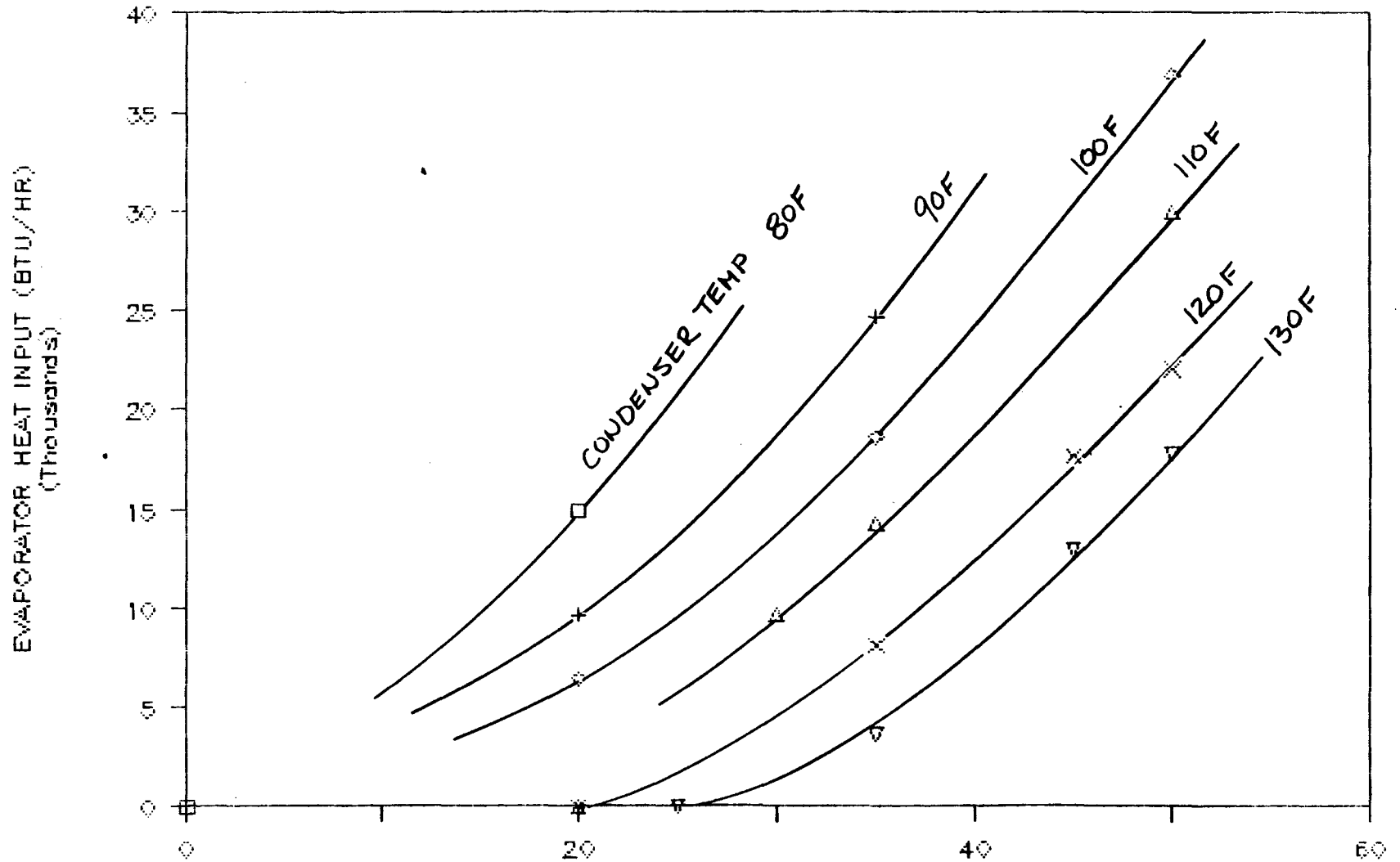
FPSE/HP MODULE MAPS (COND REJECT HEAT)

14MM PISTON STROKE



FPSE/HP MODULE MAPS (EVAP HEAT INPUT)

14MM PISTON STROKE



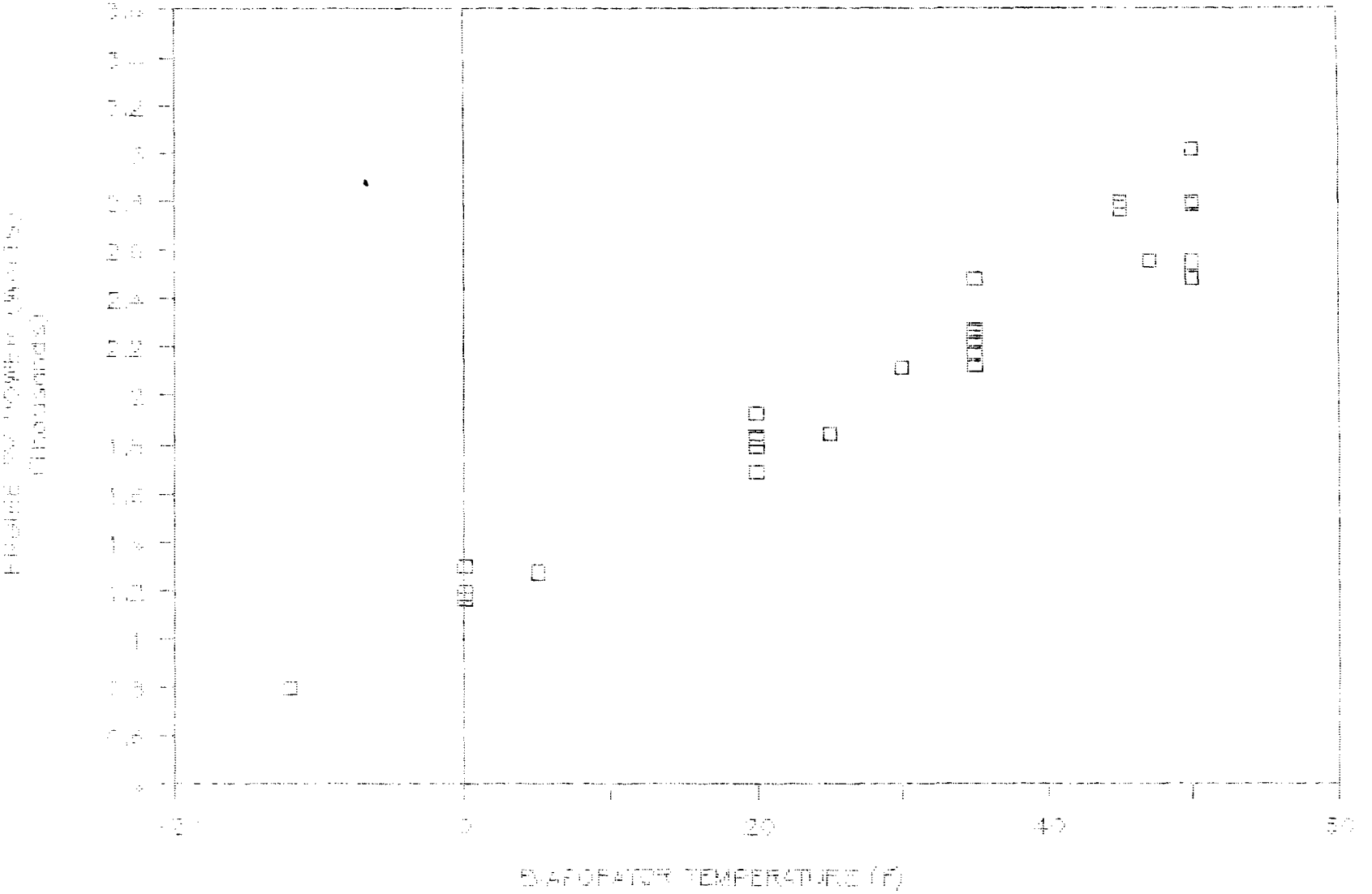
80F + 90F ◇ 100F △ 110F × 120F ▽ 130F

Attachment C-3

Engine PV Power versus Evaporator Temperature
(14- and 17-mm Piston Strokes)

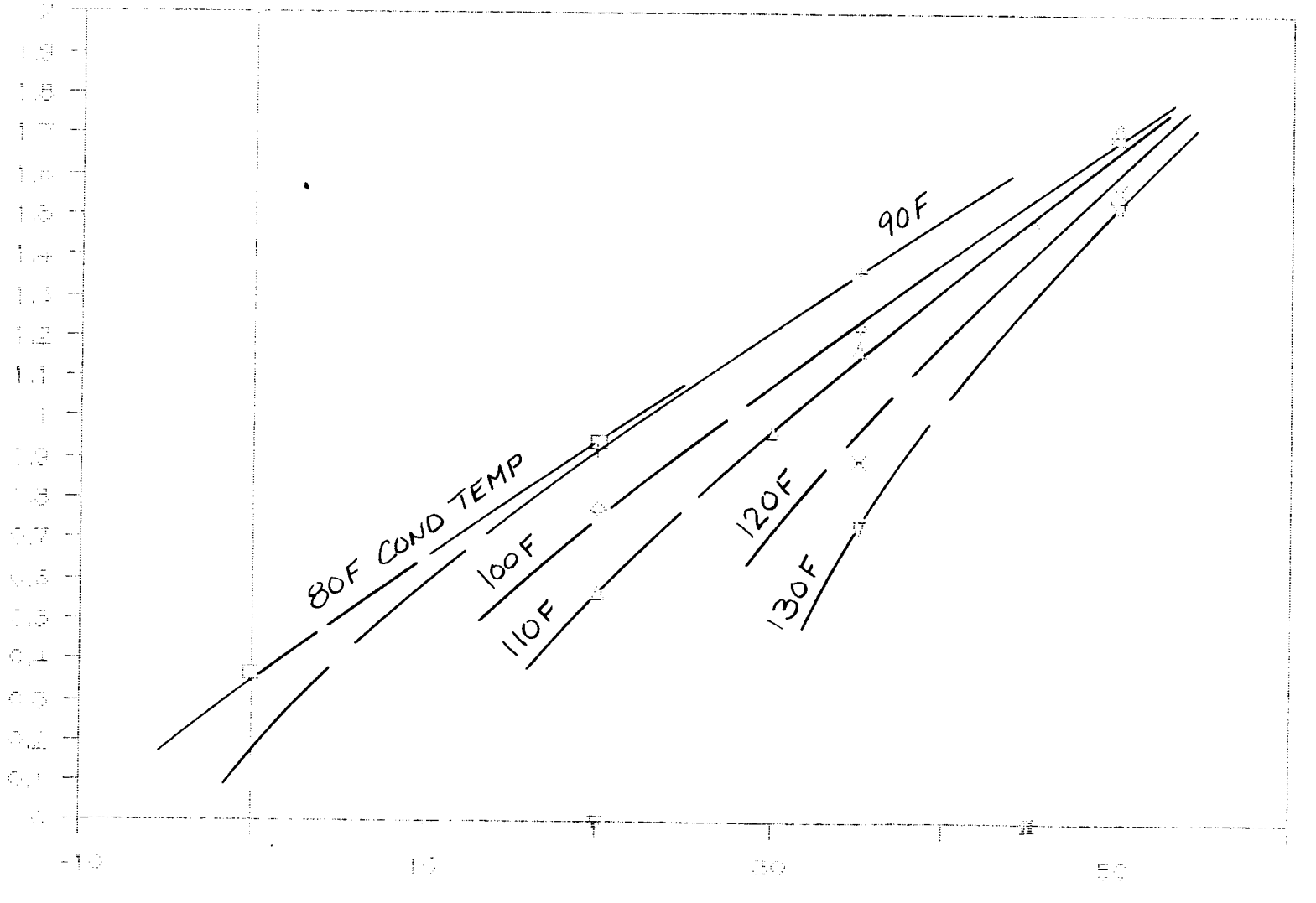
HIGH STROKE ENGINE PV POWER

ALL CONDENSER TEMPERATURES



ENGINE Pv POWER VS EVAPORATOR TEMP

14MM PISTON STROKE



Attachment C-4

Firing Rate versus Evaporator Temperature

and

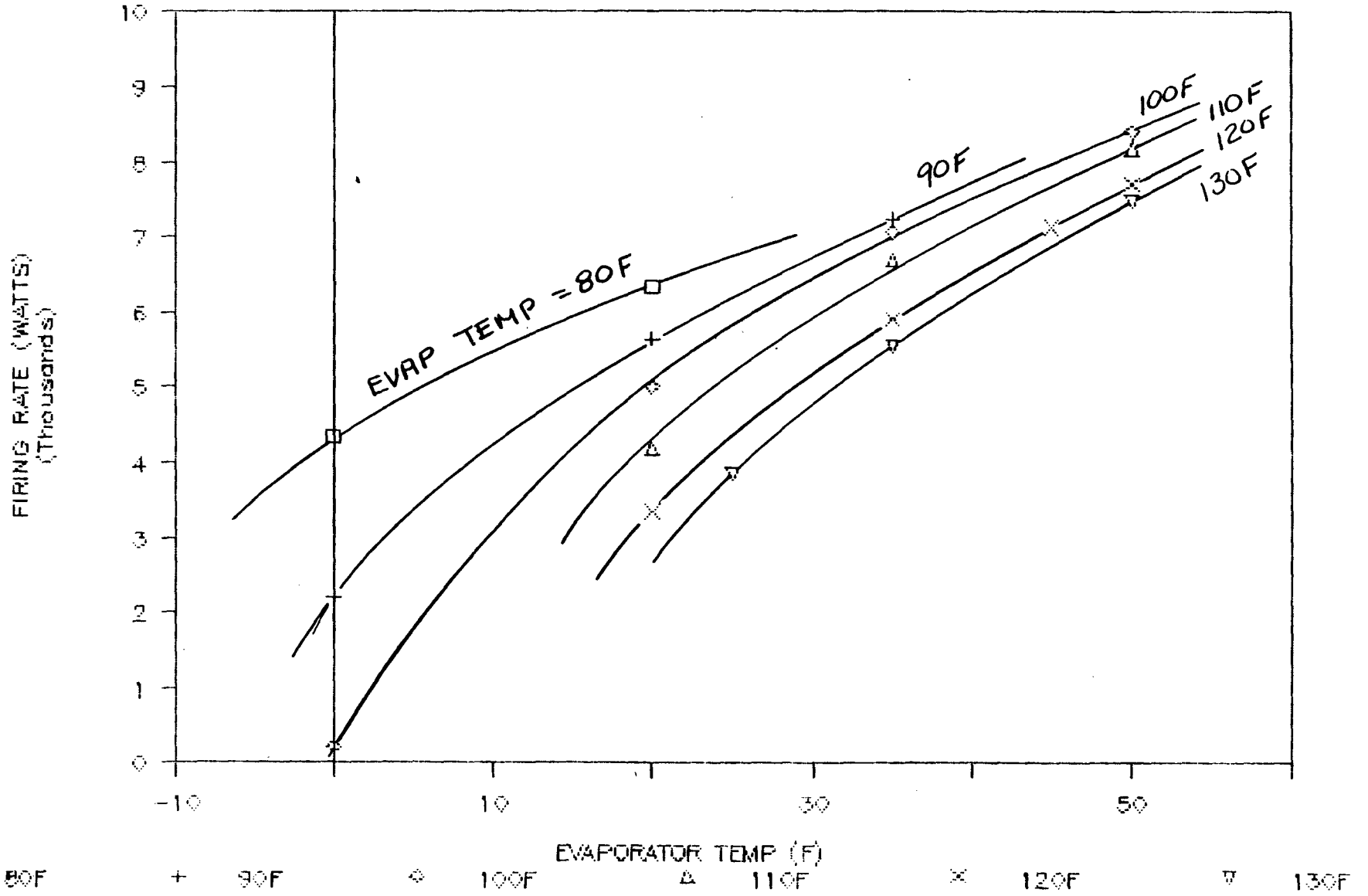
Engine Reject Heat versus Evaporator Temperature

(14- and 17-mm Piston Strokes)

17MM PISTON STROKE

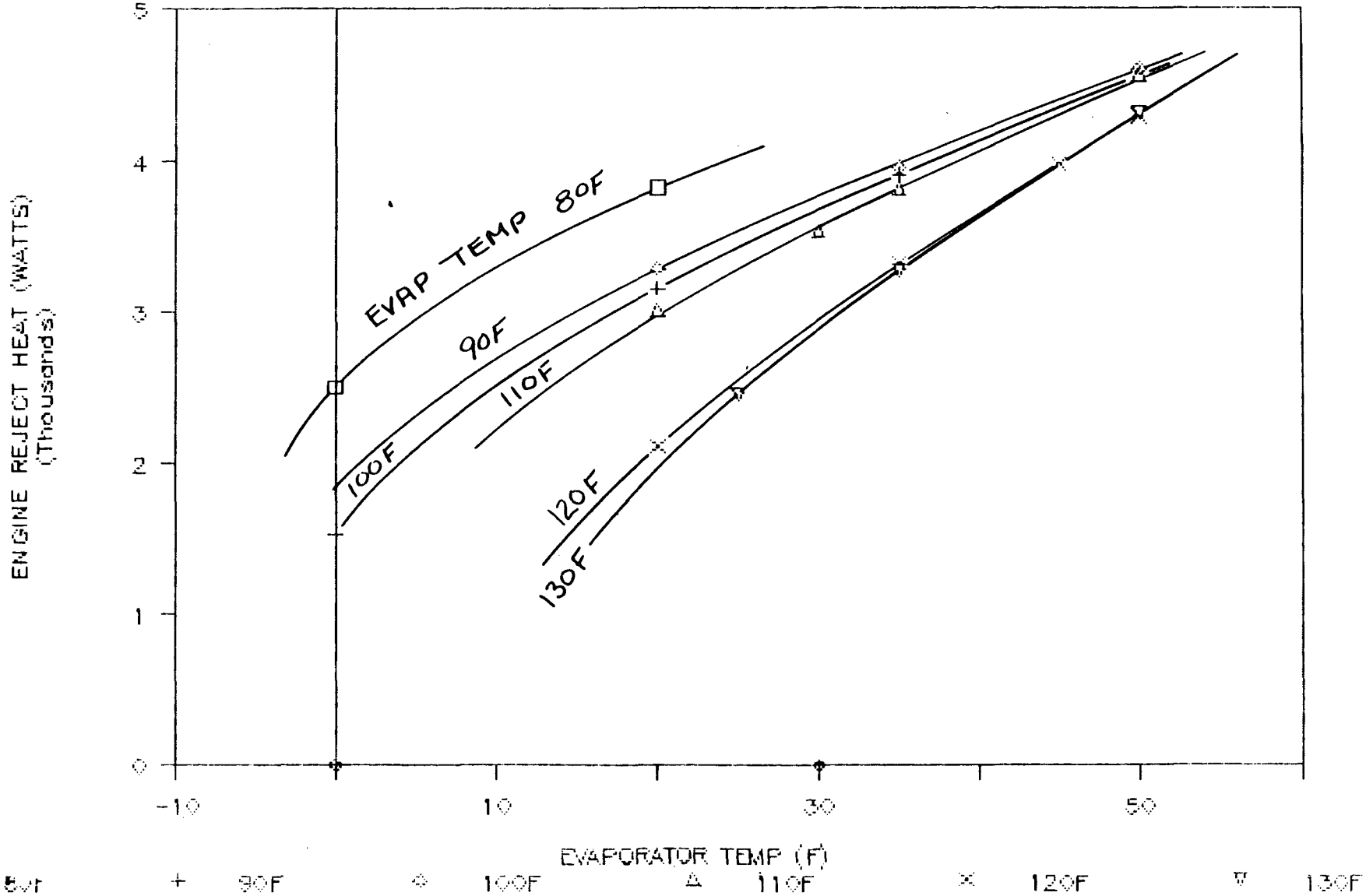
FIRING RATE VS EVAPORATOR TEMP

14MM PISTON STROKE



ENGINE REJECT HEAT VS EVAPORATOR TEMP

14MM PISTON STROKE

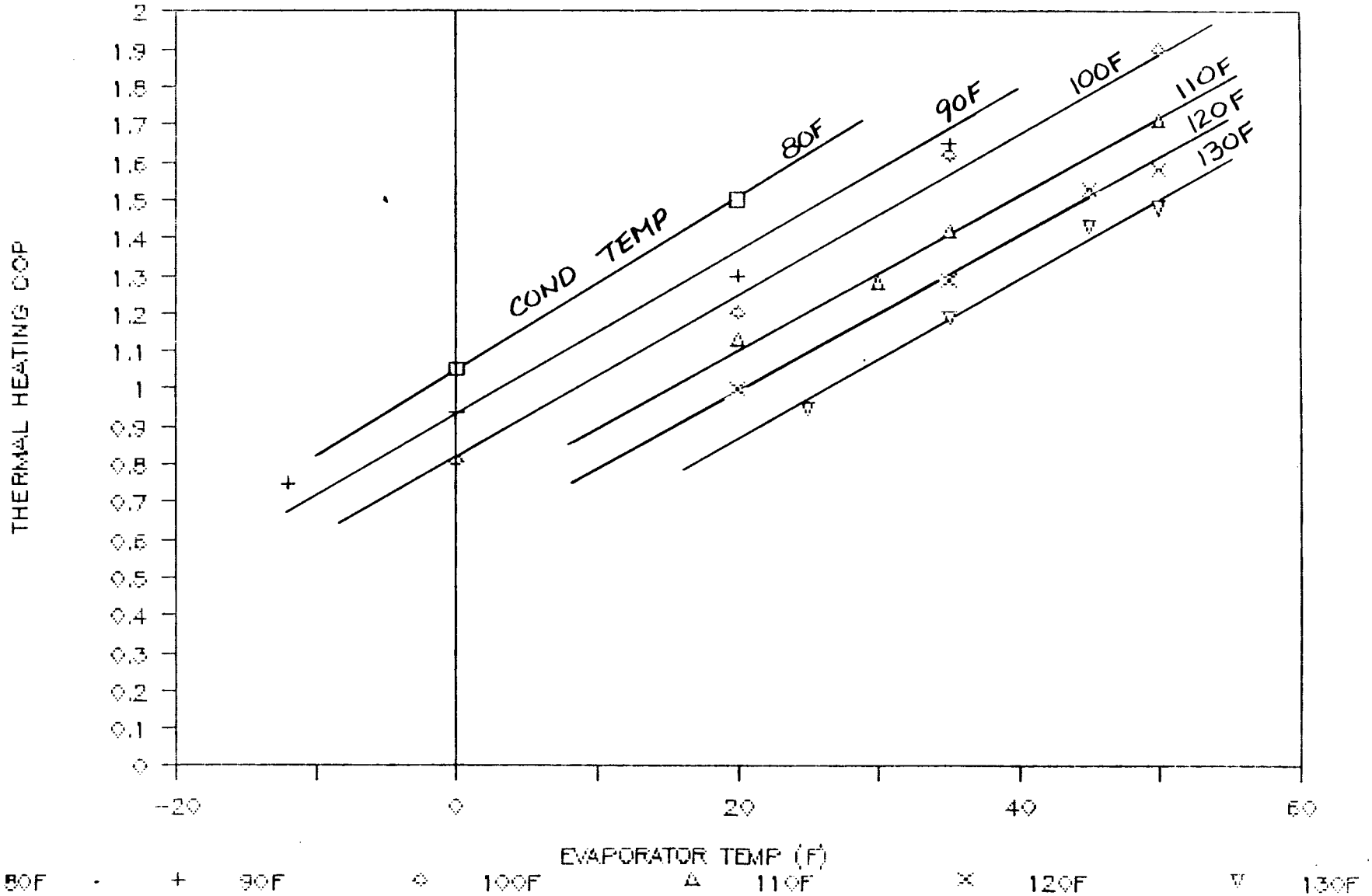


Attachment C-5

Thermal Heating COP versus Evaporator Temperature
and
Thermal Cooling COP versus Evaporator Temperature
(14- and 17-mm Piston Strokes)

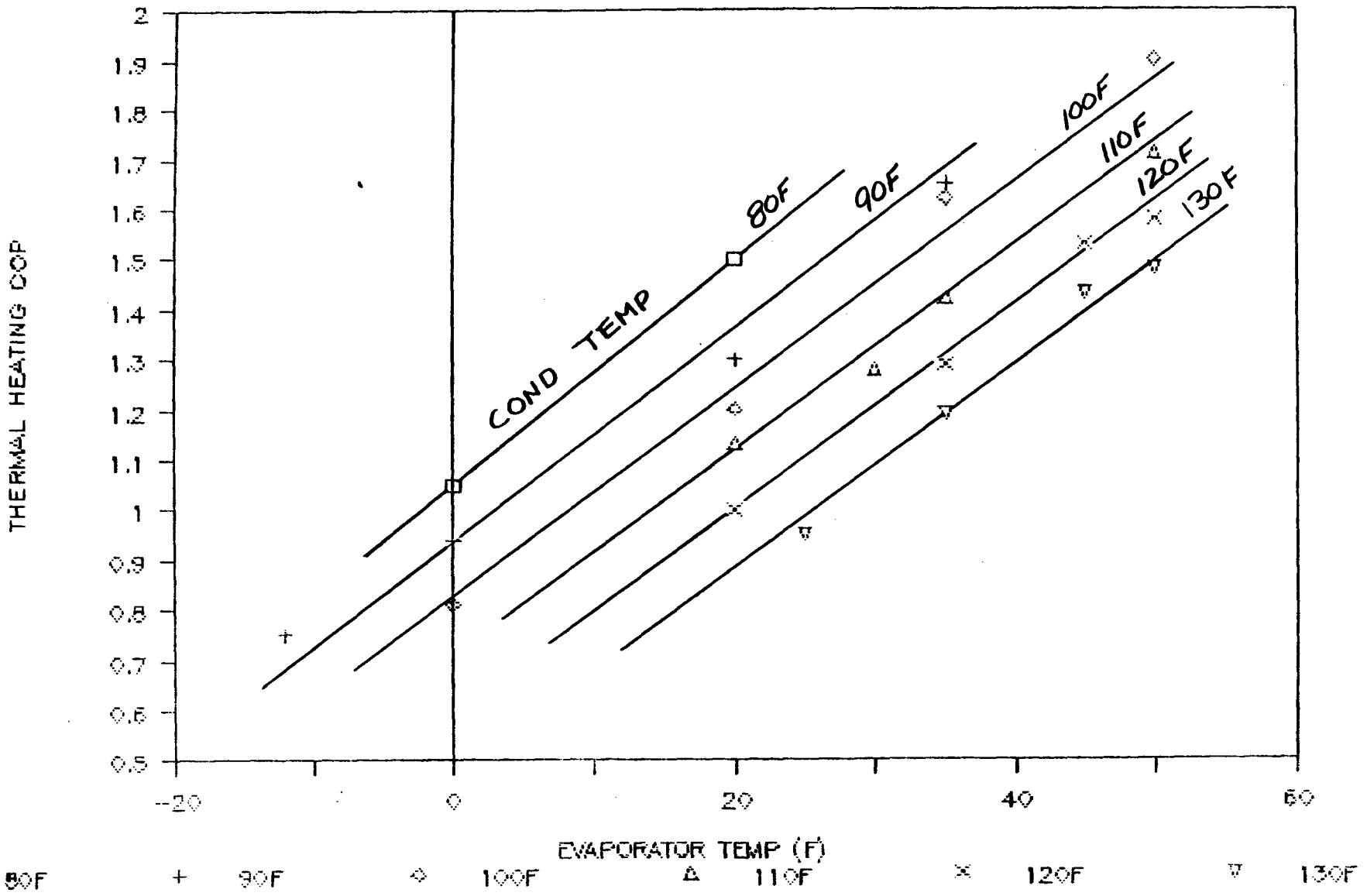
FPSE/HP MODULE MAPS (THERMAL HEAT COP

17MM PISTON STROKE



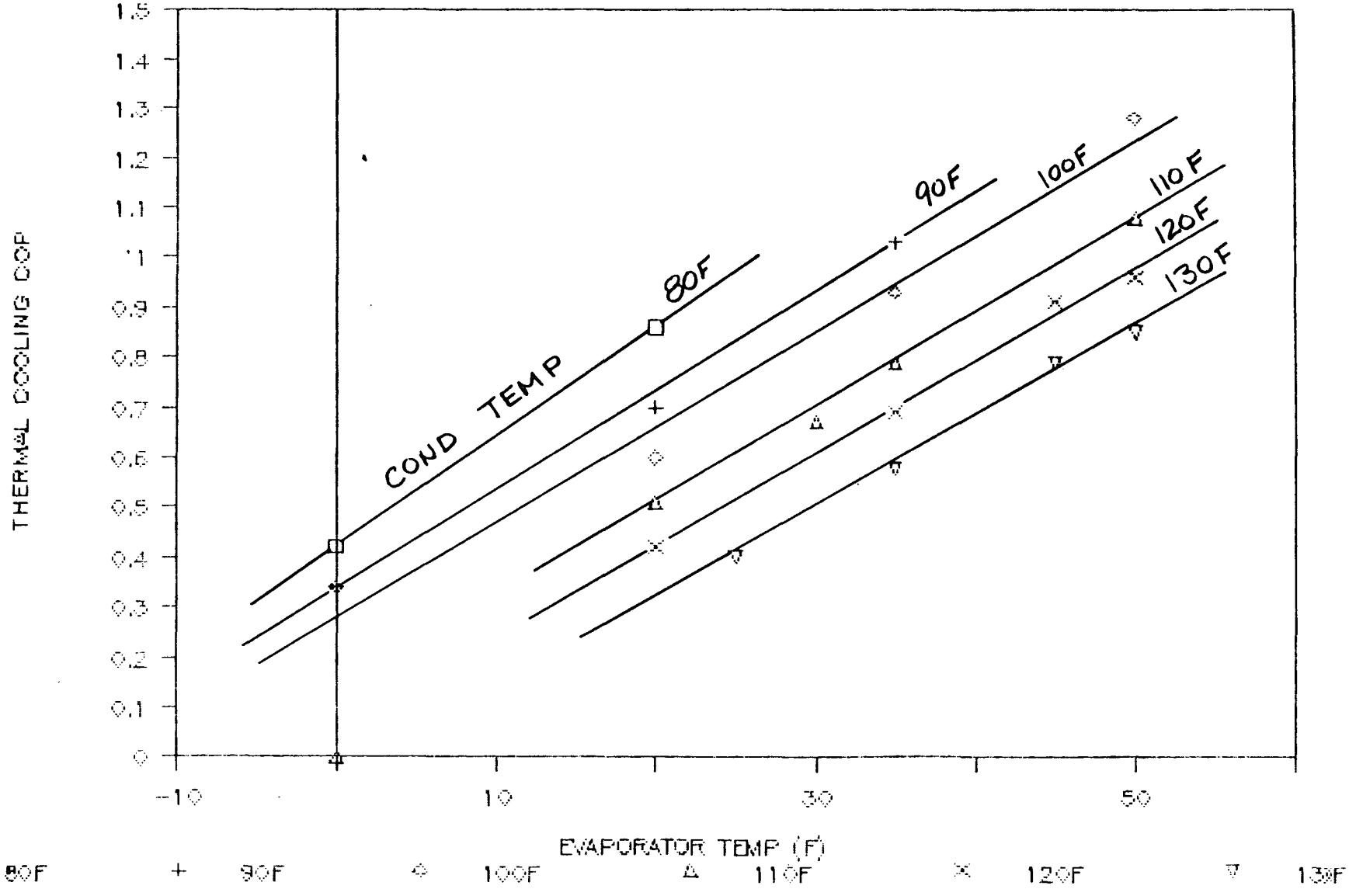
FPSE/HP MODULE MAPS (THERMAL HEAT COP)

14MM PISTON STROKE



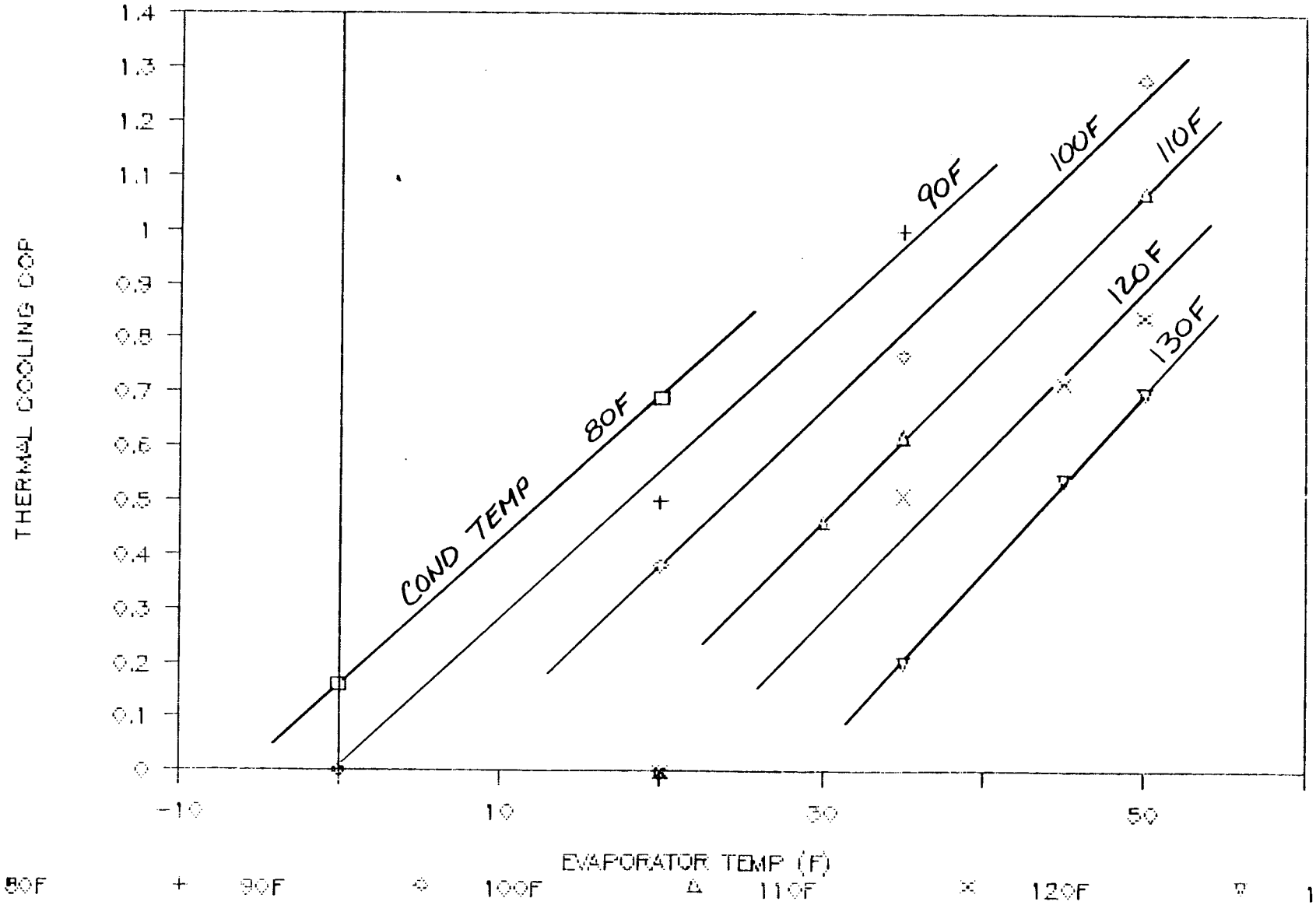
FPSE/HP MODULE MAPS (THERMAL COOL COP)

17MM PISTON STROKE



FPSE/HP MODULE MAPS (THERMAL COOL COP)

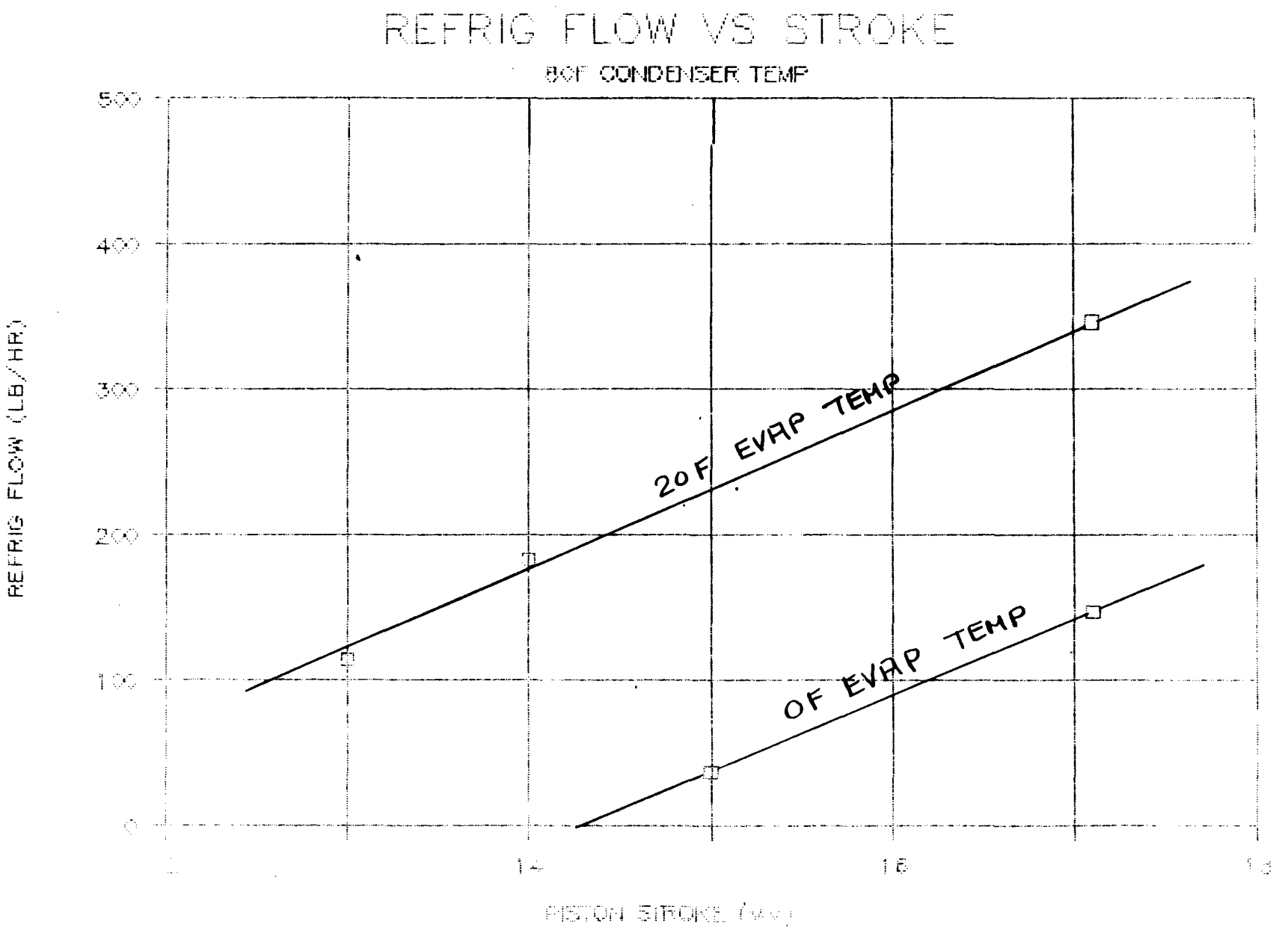
14MM PISTON STROKE

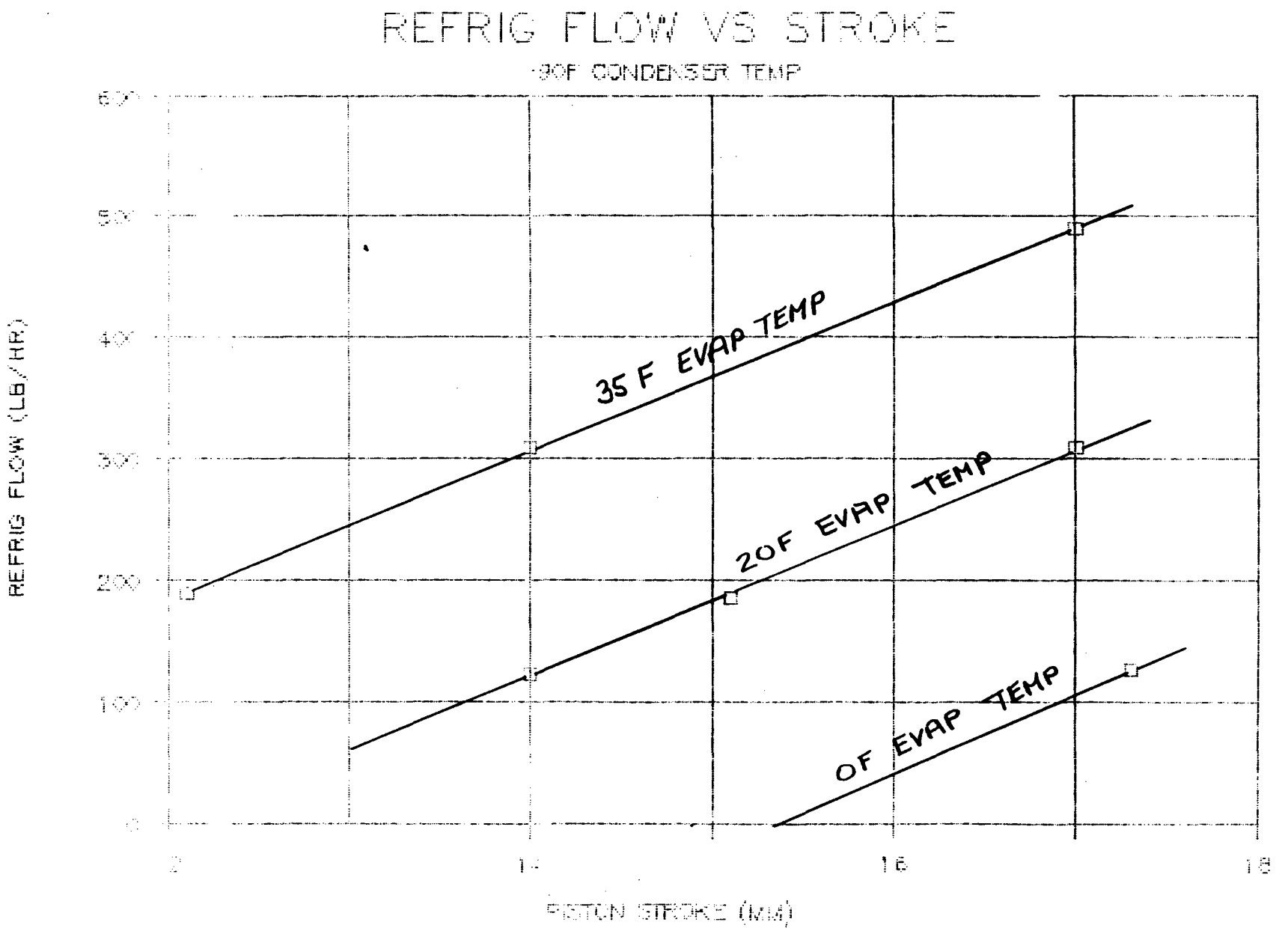


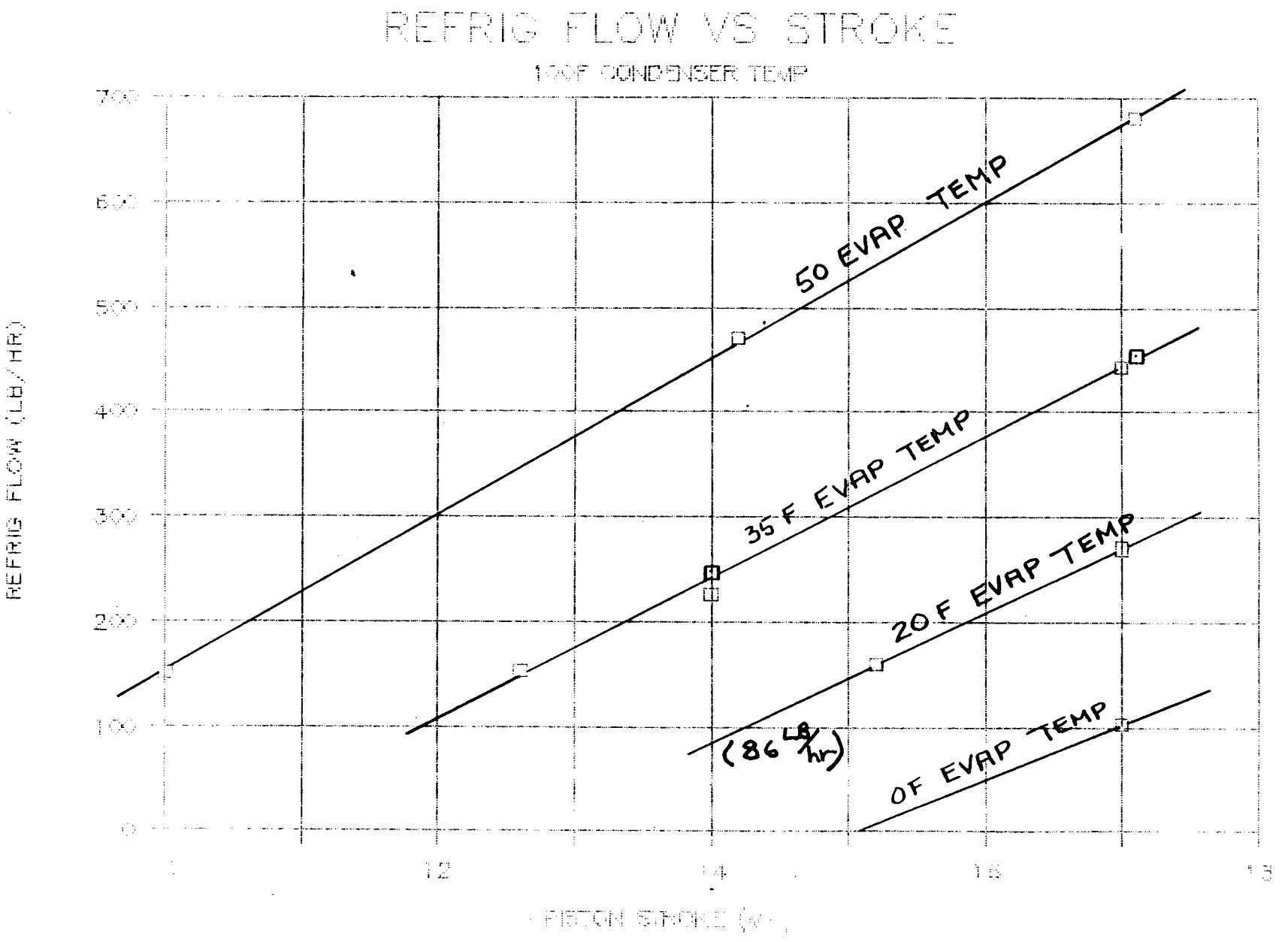
80F + 90F ◇ 100F △ 110F × 120F ▽ 130F

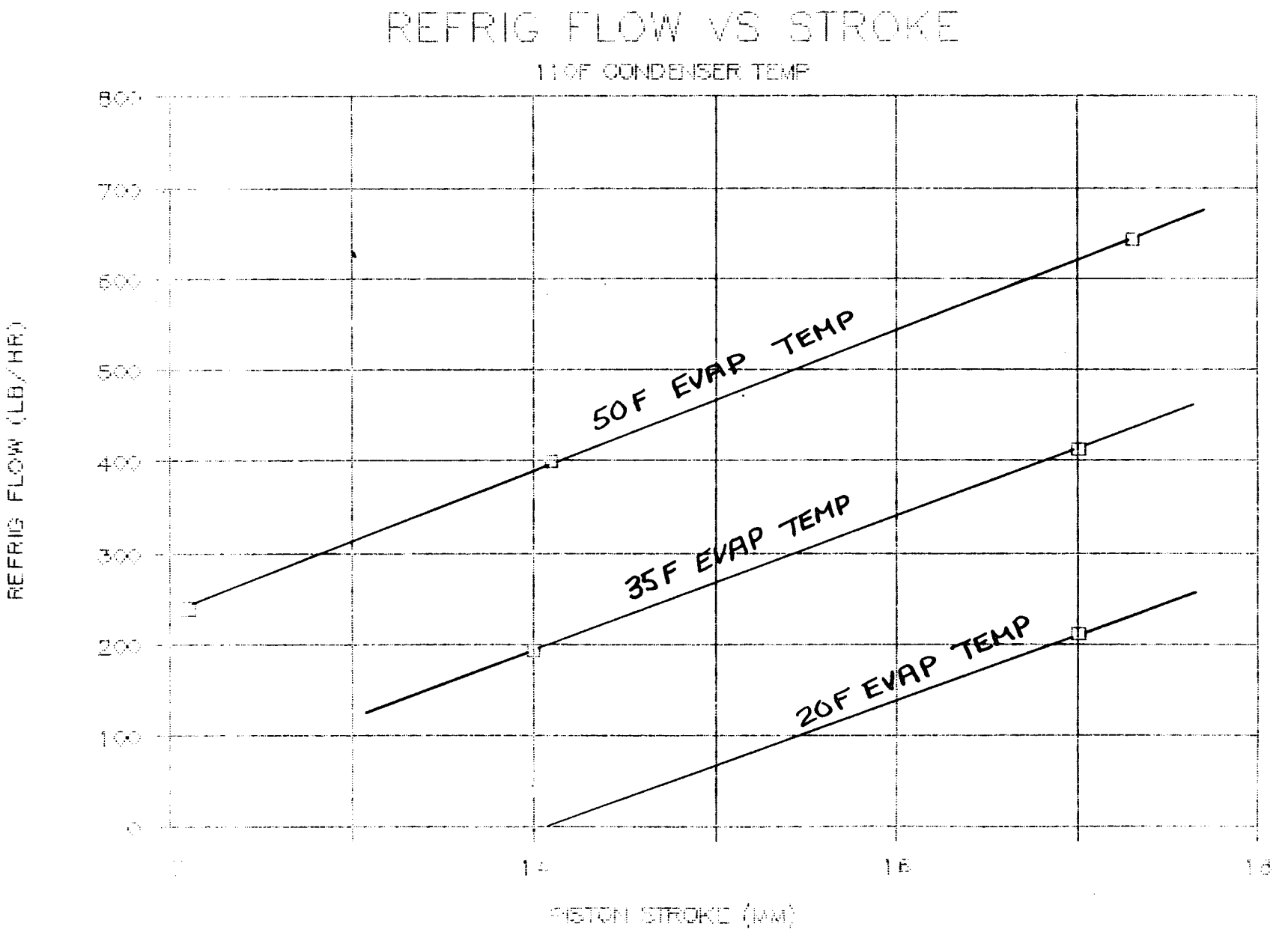
Attachment C-6

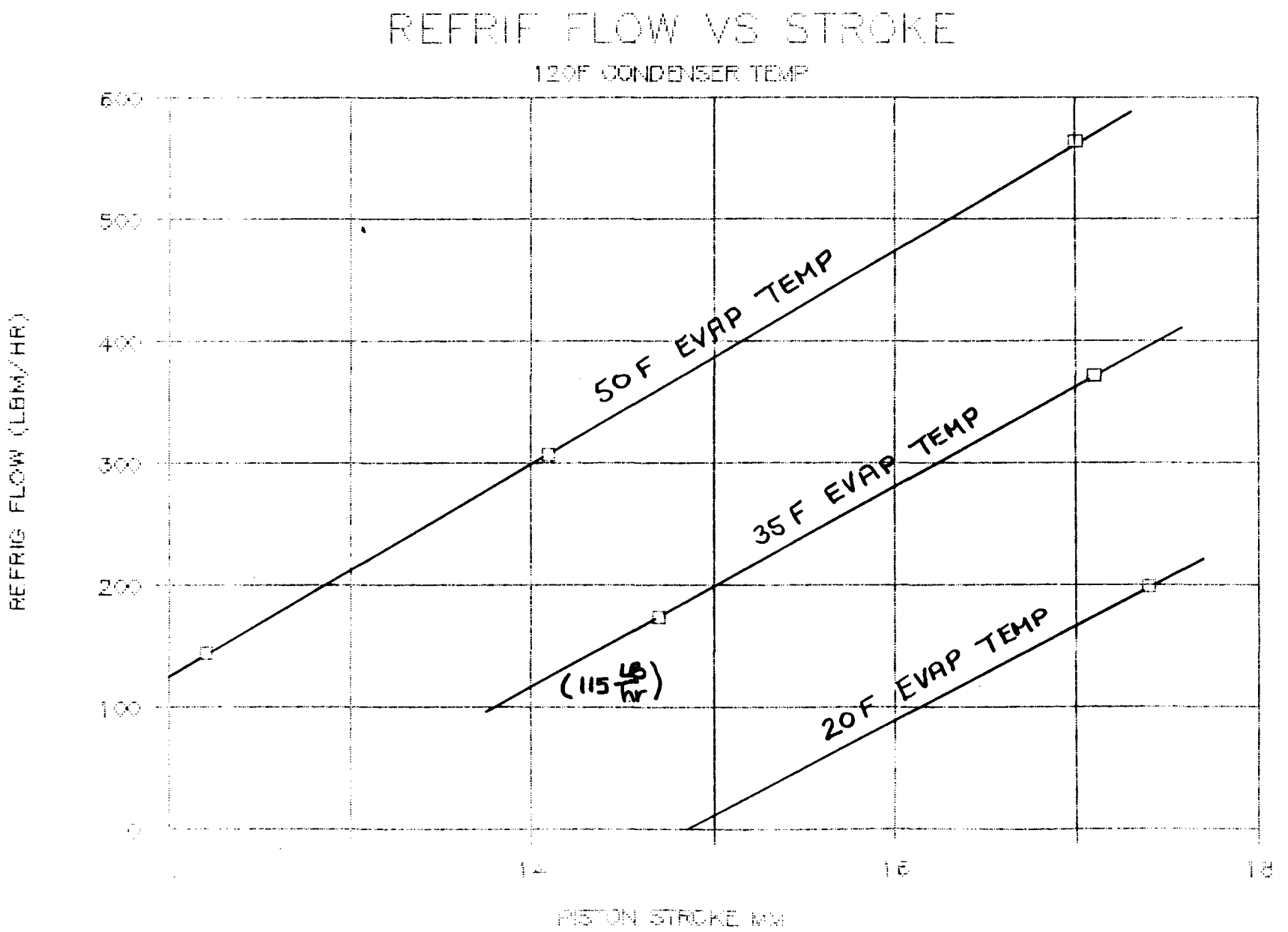
Refrigerant Flow versus Piston Stroke

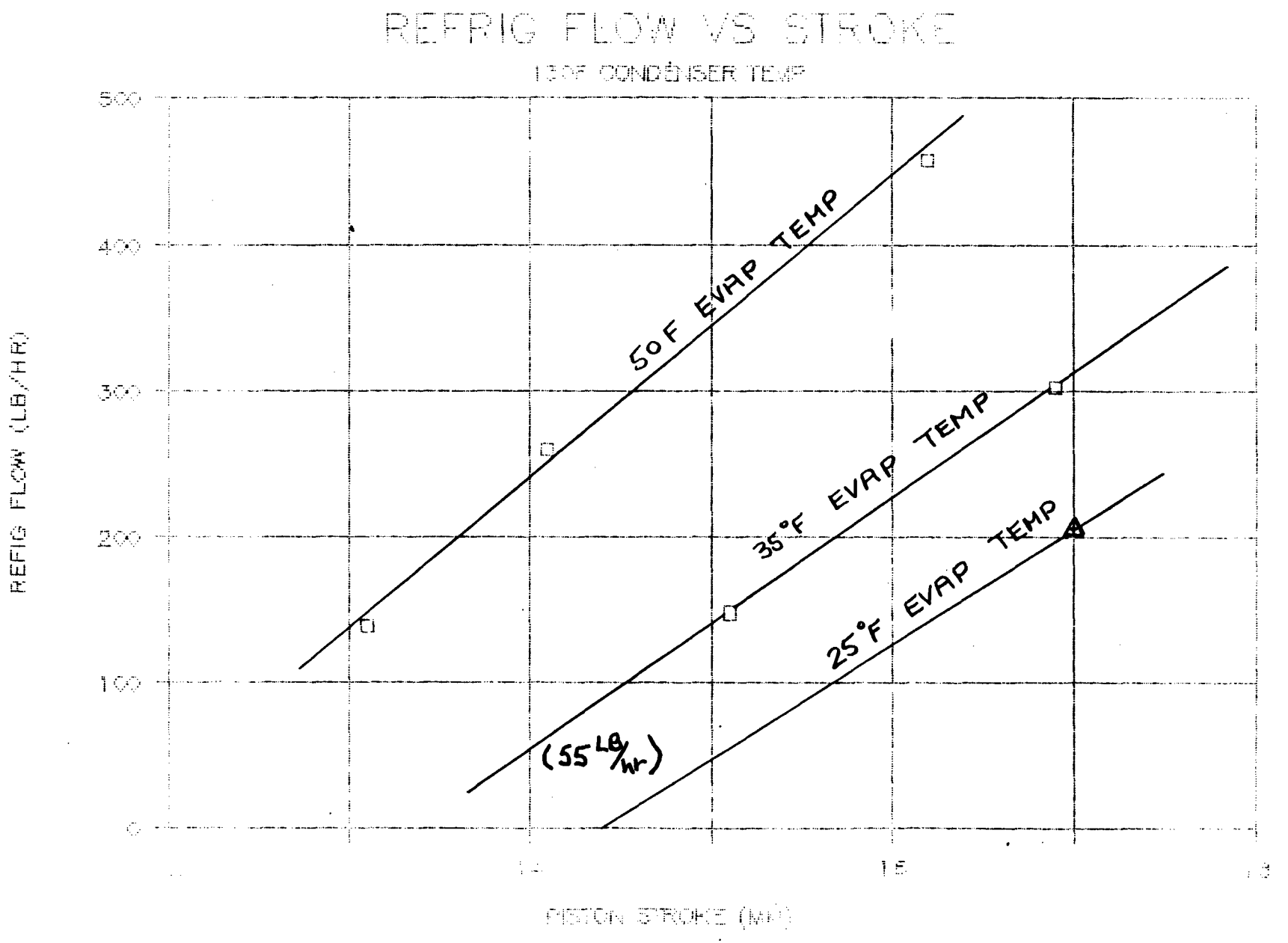

REFRIG FLOW VS STROKE
80F CONDENSER TEMP
REFRIG FLOW (LB/HR)
500
400
300
200
100
0
14
16
20F EVAP TEMP
0F EVAP TEMP


REFRIG FLOW VS STROKE
90F CONDENSER TEMP
REFRIG FLOW (LB/HR)
PISTON STROKE (MM)
35 F EVAP TEMP
20F EVAP TEMP
0F EVAP TEMP


REFRIG FLOW VS STROKE
100F CONDENSER TEMP
REFRIG FLOW (LB/HR)
700
600
500
400
300
200
100
0
12
14
16
18
50 EVAP TEMP
35 F EVAP TEMP
20 F EVAP TEMP
0F EVAP TEMP
(86 LB/hr)


REFRIG FLOW VS STROKE
110F CONDENSER TEMP
REFRIG FLOW (LB/HR)
800
700
600
500
400
300
200
100
0
14
16
18
PISTON STROKE (MM)
50F EVAP TEMP
35F EVAP TEMP
20F EVAP TEMP


REFRIF FLOW VS STROKE
120F CONDENSER TEMP
REFRIG FLOW (LBM/HR)
600
500
400
300
200
100
0
14
16
18
PISTON STROKE MM
50F EVAP TEMP
35F EVAP TEMP
20F EVAP TEMP
(115 LB/HR)

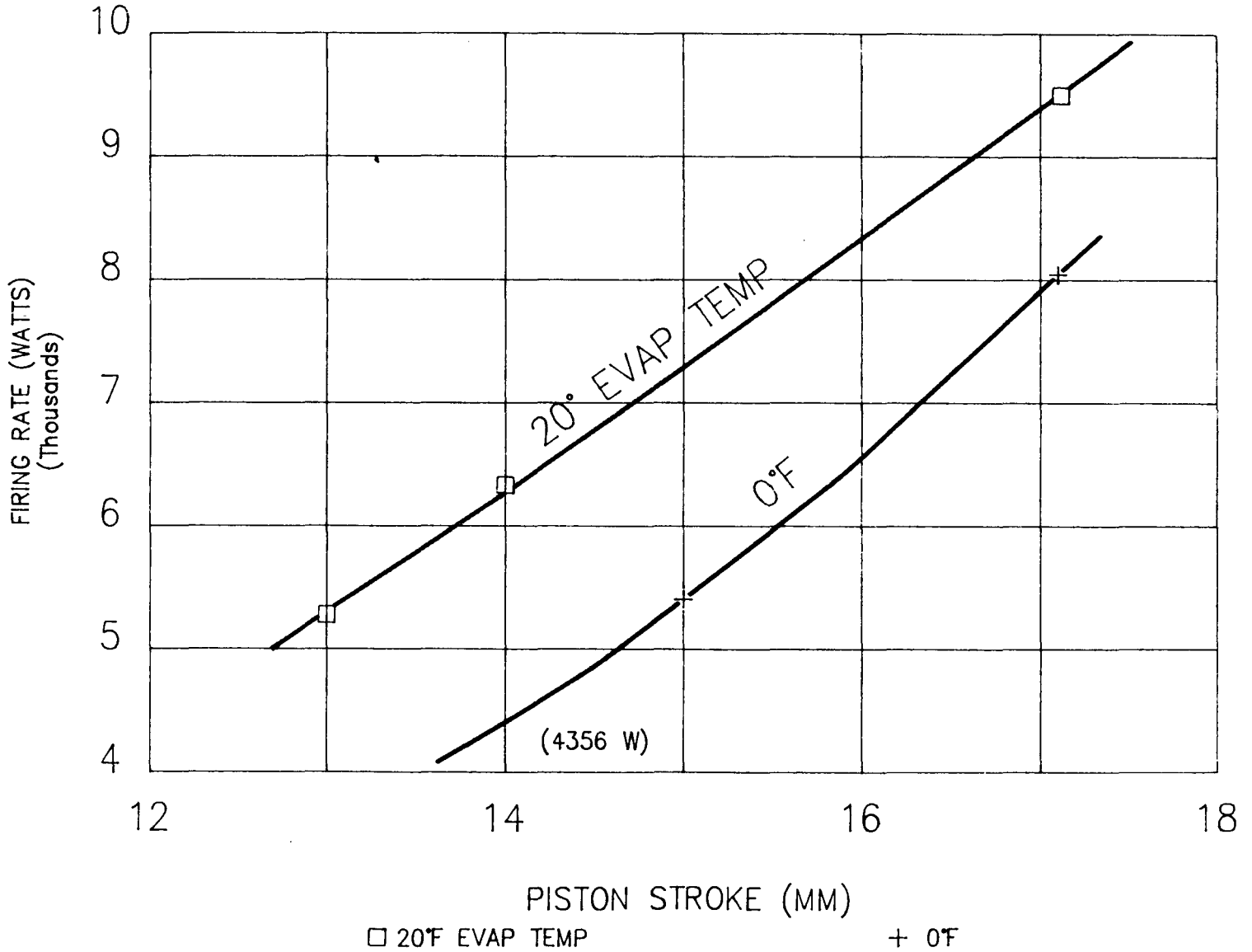

REFRIG FLOW VS STROKE
130°F CONDENSER TEMP
500
400
300
200
100
0
REFRIG FLOW (LB/HR)
50°F EVAP TEMP
35°F EVAP TEMP
25°F EVAP TEMP
(55 LB/hr)
PISTON STROKE (MM)

Attachment C-7

Firing Rate versus Piston Stroke
and
Firing Rate versus Evaporator Temperature
(14- and 17-mm Piston Strokes)

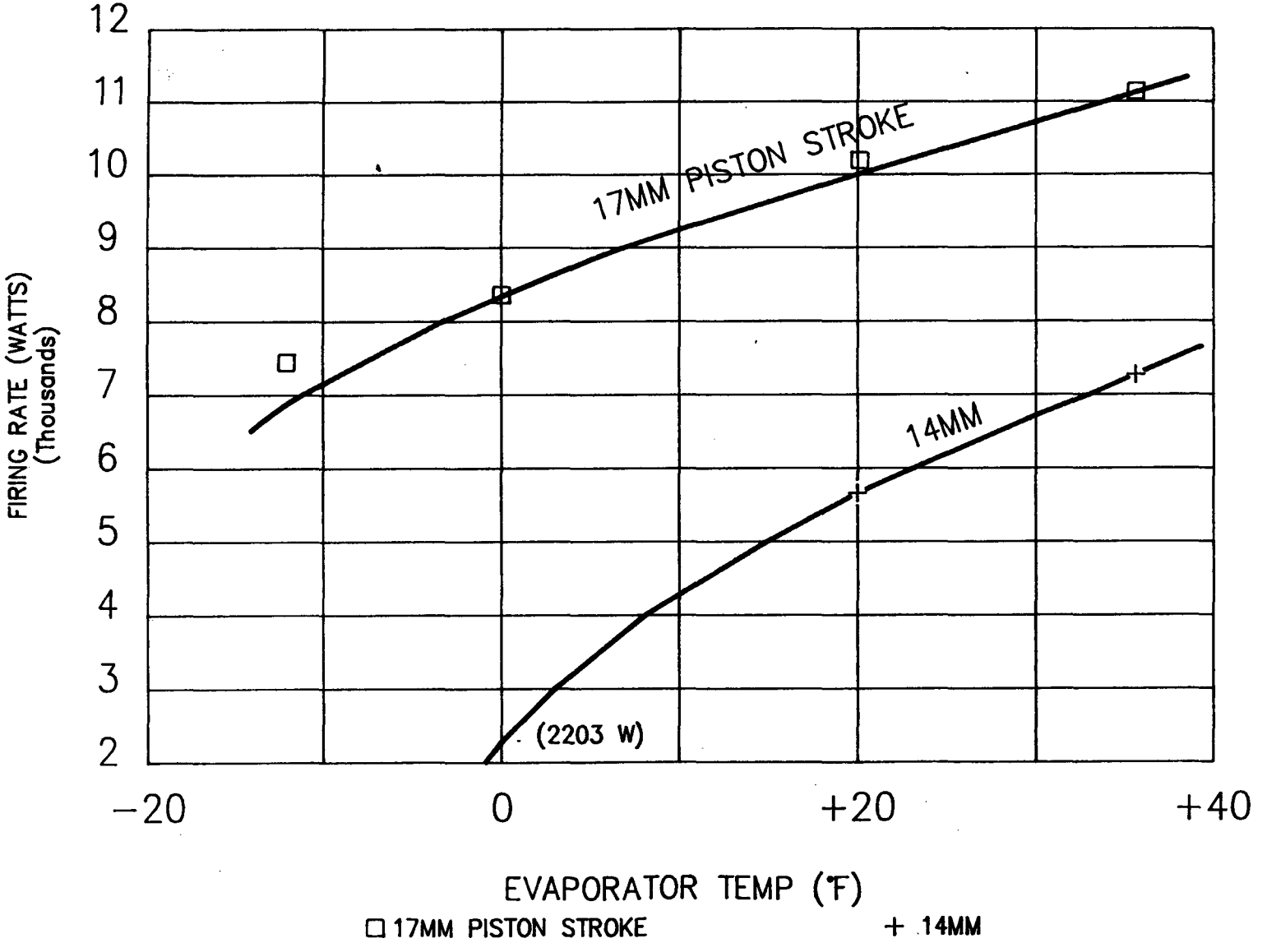
FIRING RATE VS PISTON STROKE

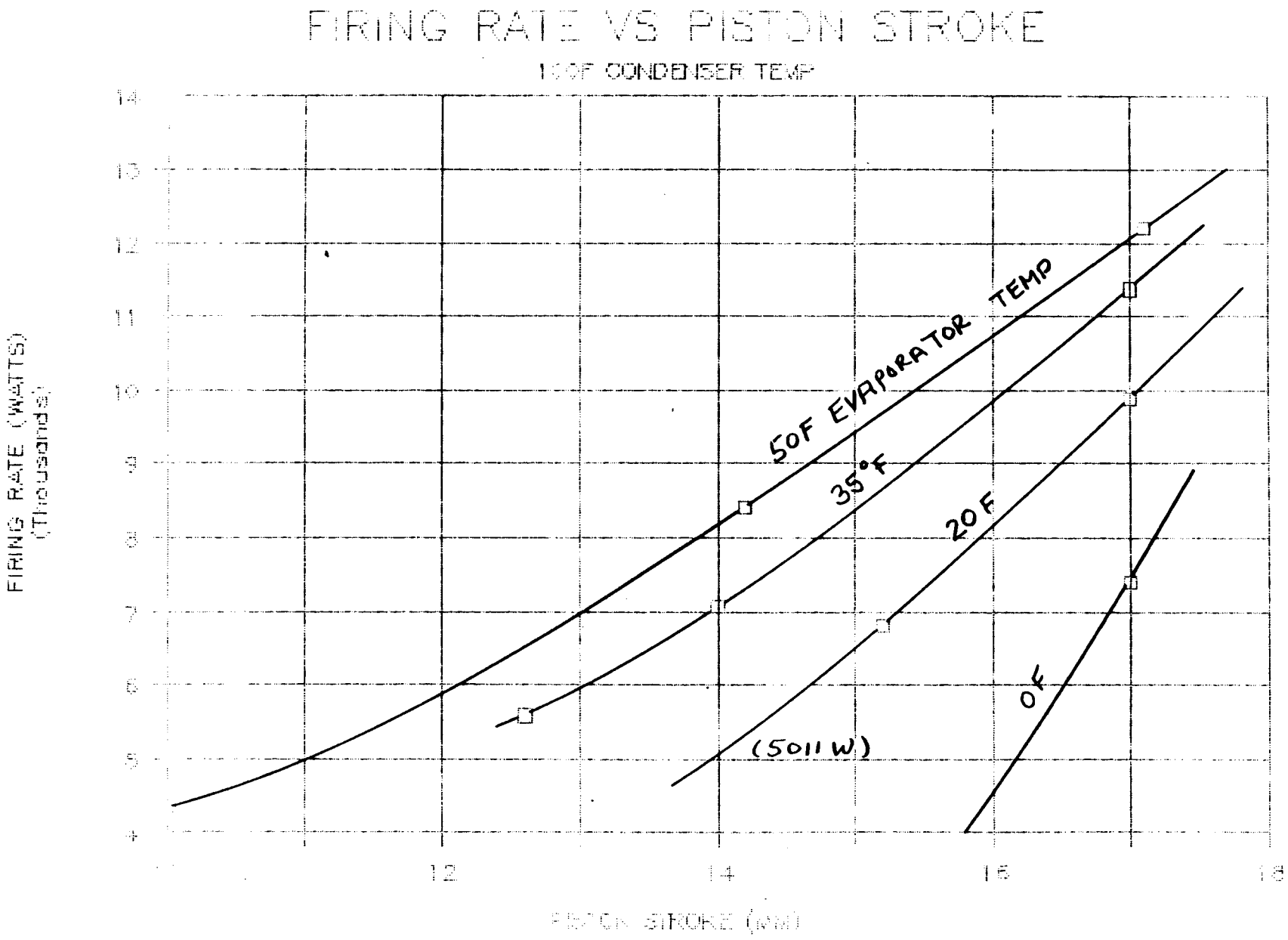
80°F CONDENSER TEMPERATURE



FIRING RATE VS EVAPORATOR TEMP

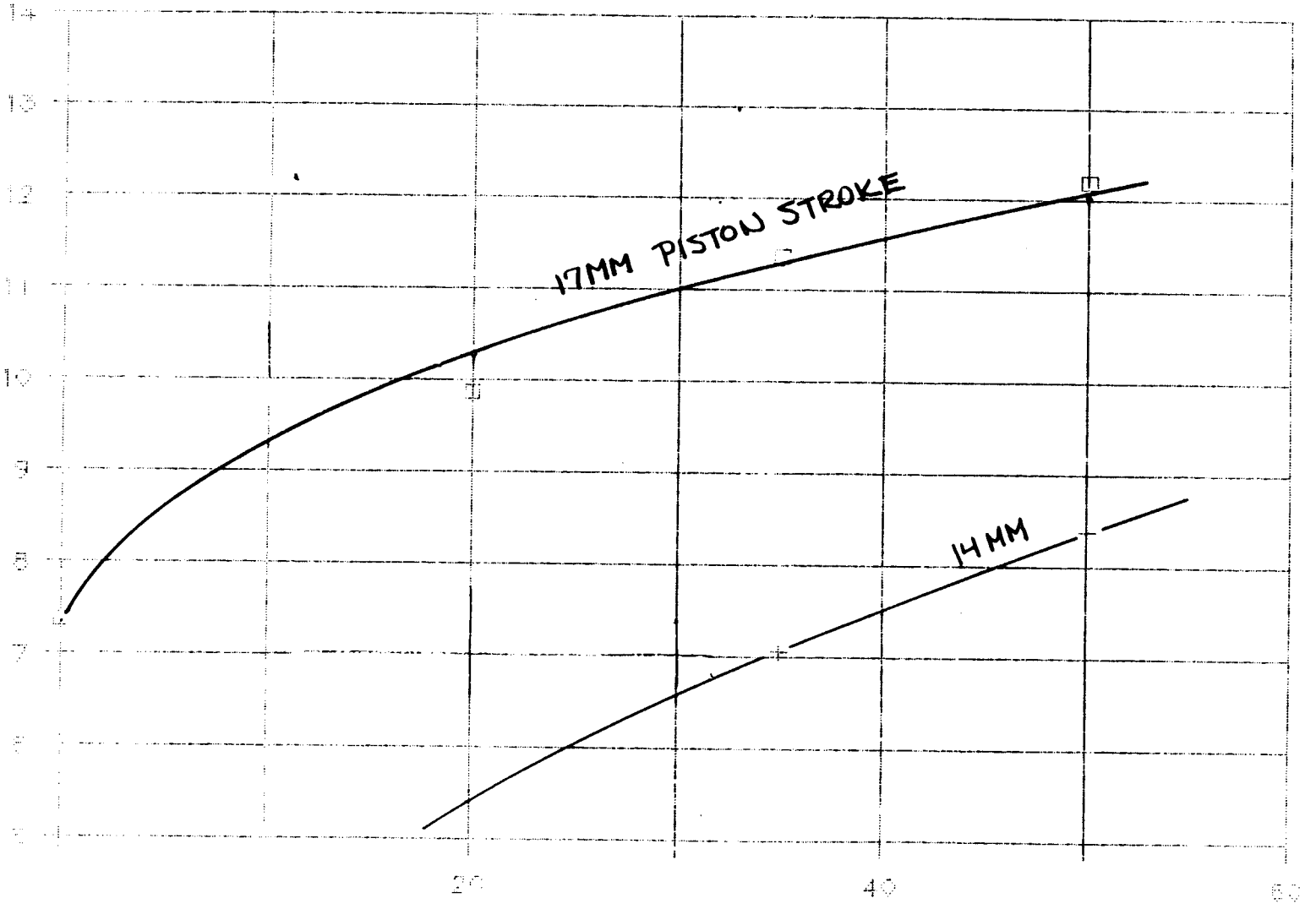
90°F CONDENSER TEMPERATURE




FIRING RATE VS PISTON STROKE
100F CONDENSER TEMP
FIRING RATE (WATTS)
(Thousands)
PISTON STROKE (MM)
50F EVAPORATOR TEMP
35°F
20F
0F
(5011 W)
14
13
12
11
10
9
8
7
6
5
4
12
14
16
18

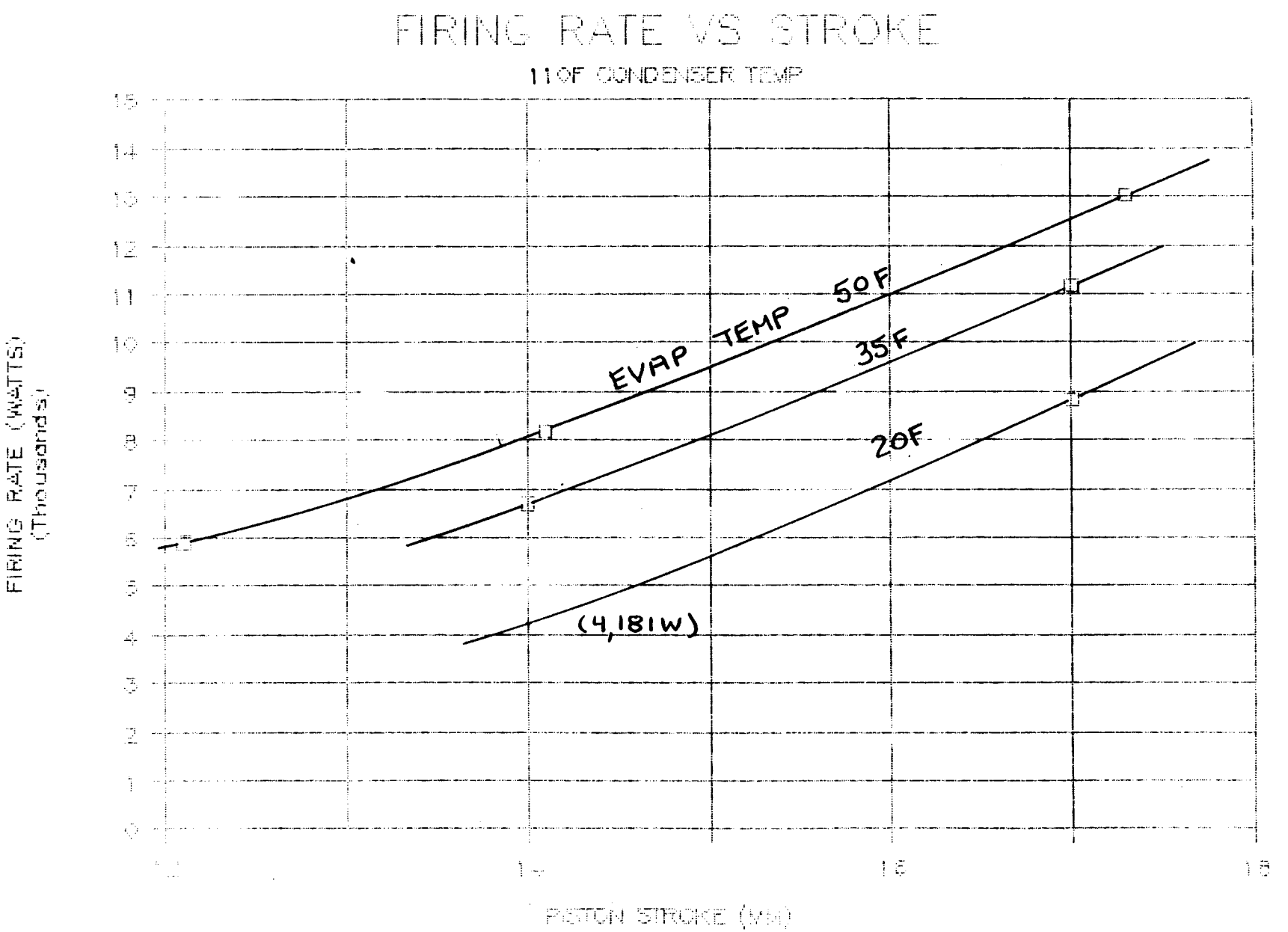
FIRING RATE VS EVAPORATOR TEMP

100°F CONDENSER TEMP



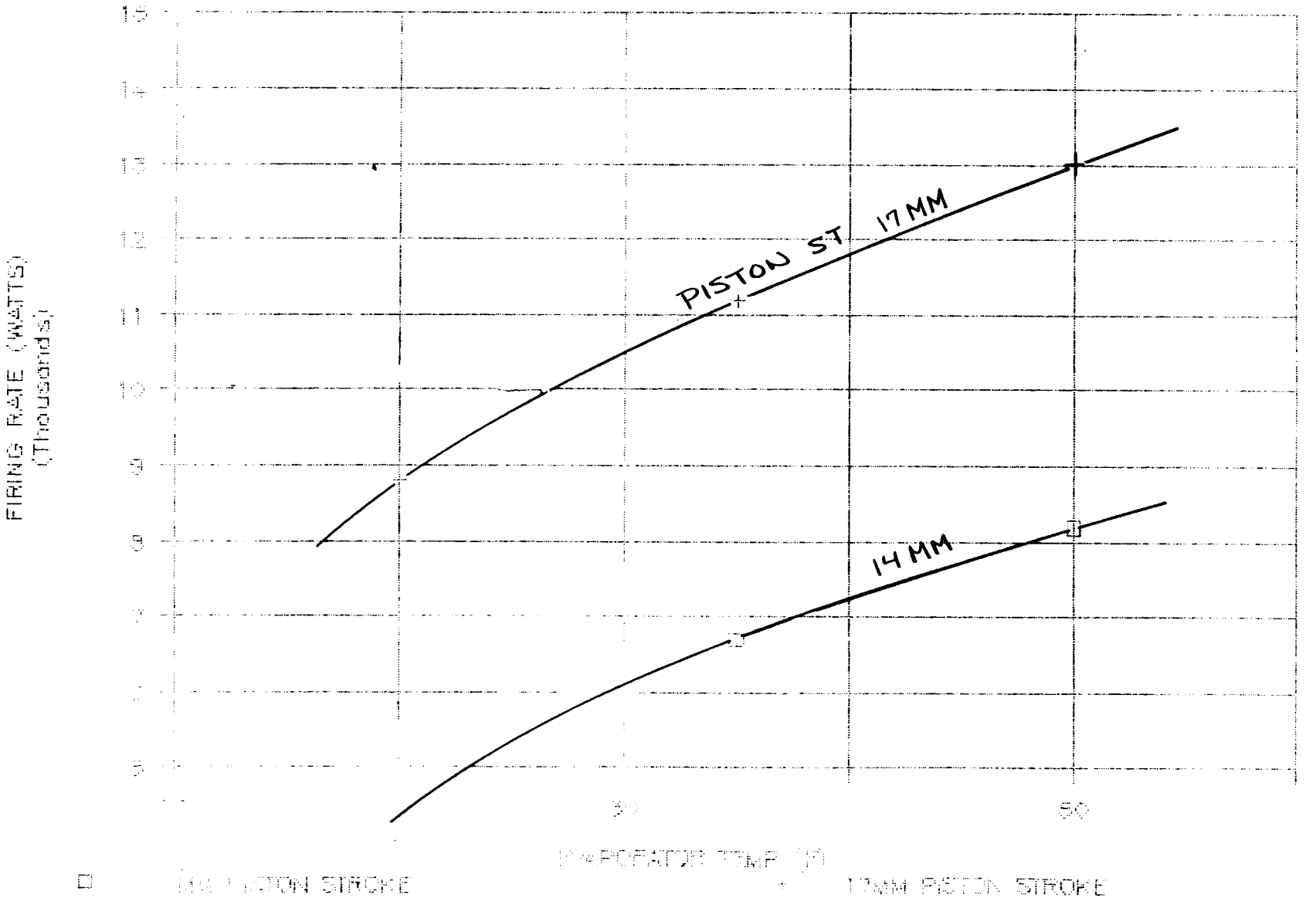
EVAPORATOR TEMP (°F)

□ 17MM PISTON STROKE + 14MM


FIRING RATE VS STROKE
110F CONDENSER TEMP
FIRING RATE (WATTS)
(Thousands)
PISTON STROKE (MM)
EVAP TEMP
50F
35F
20F
(4,181W)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

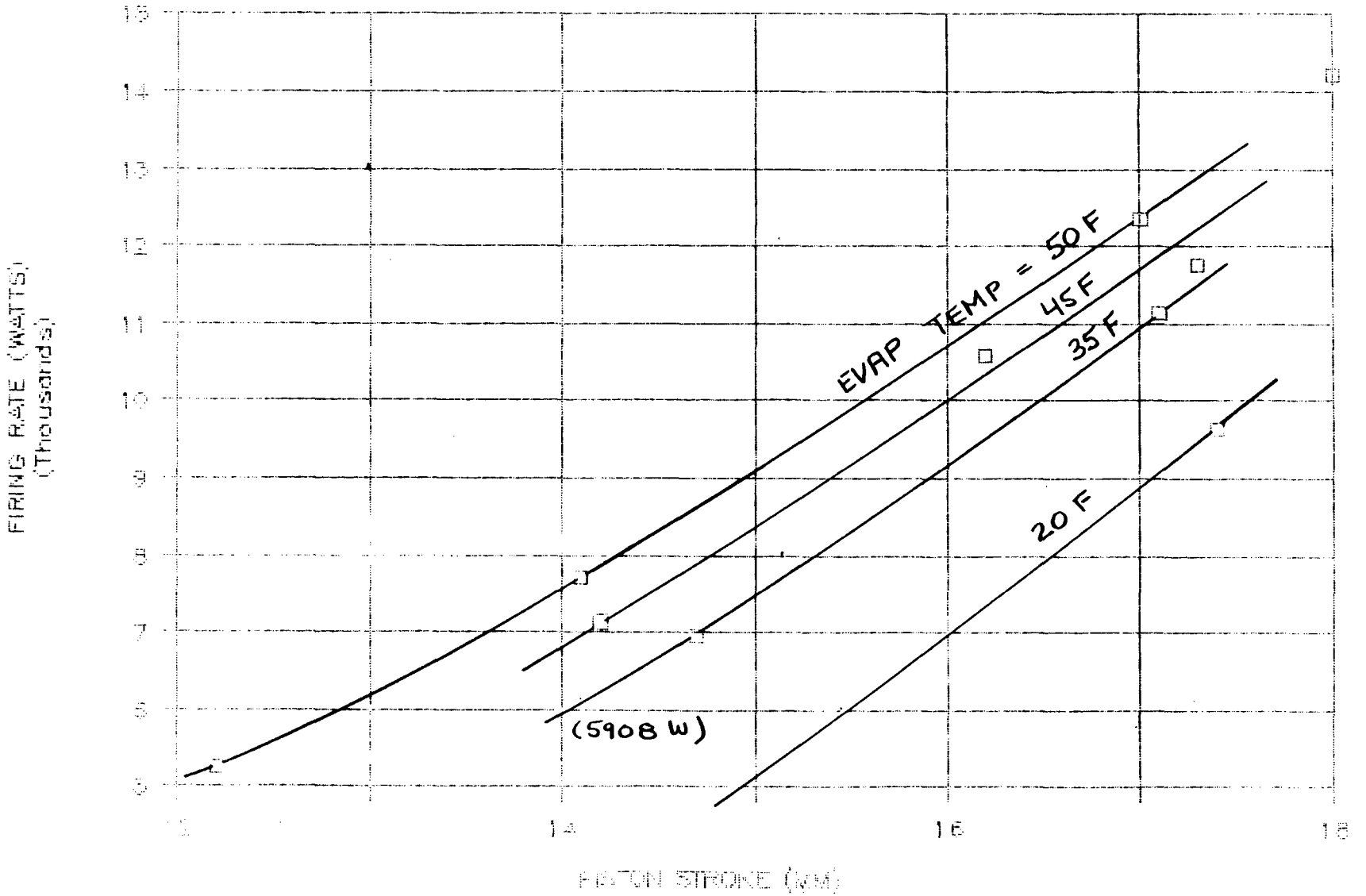
FIRING RATE VS EVAPORATOR TEMP

110°F CONDENSER TEMP

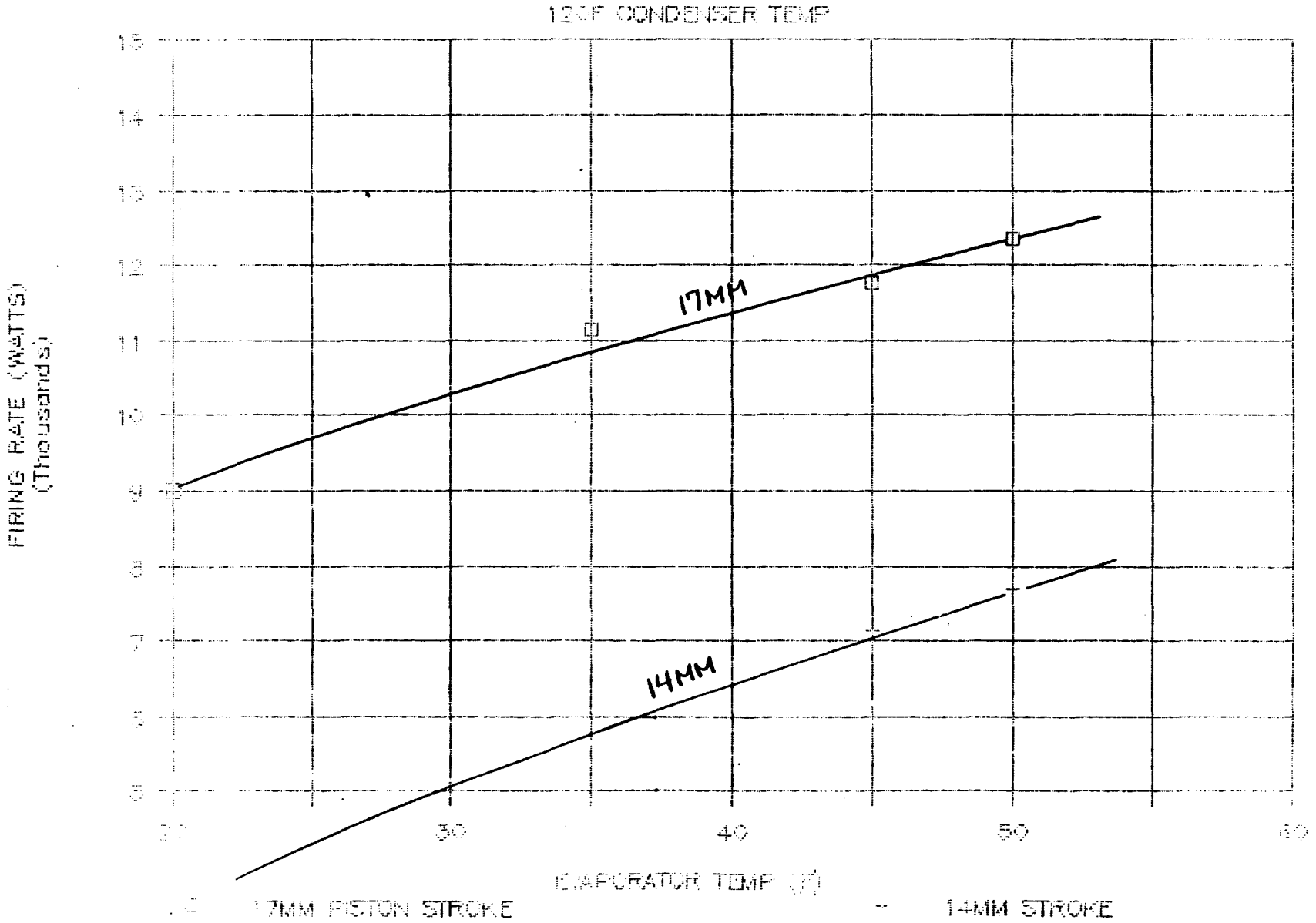


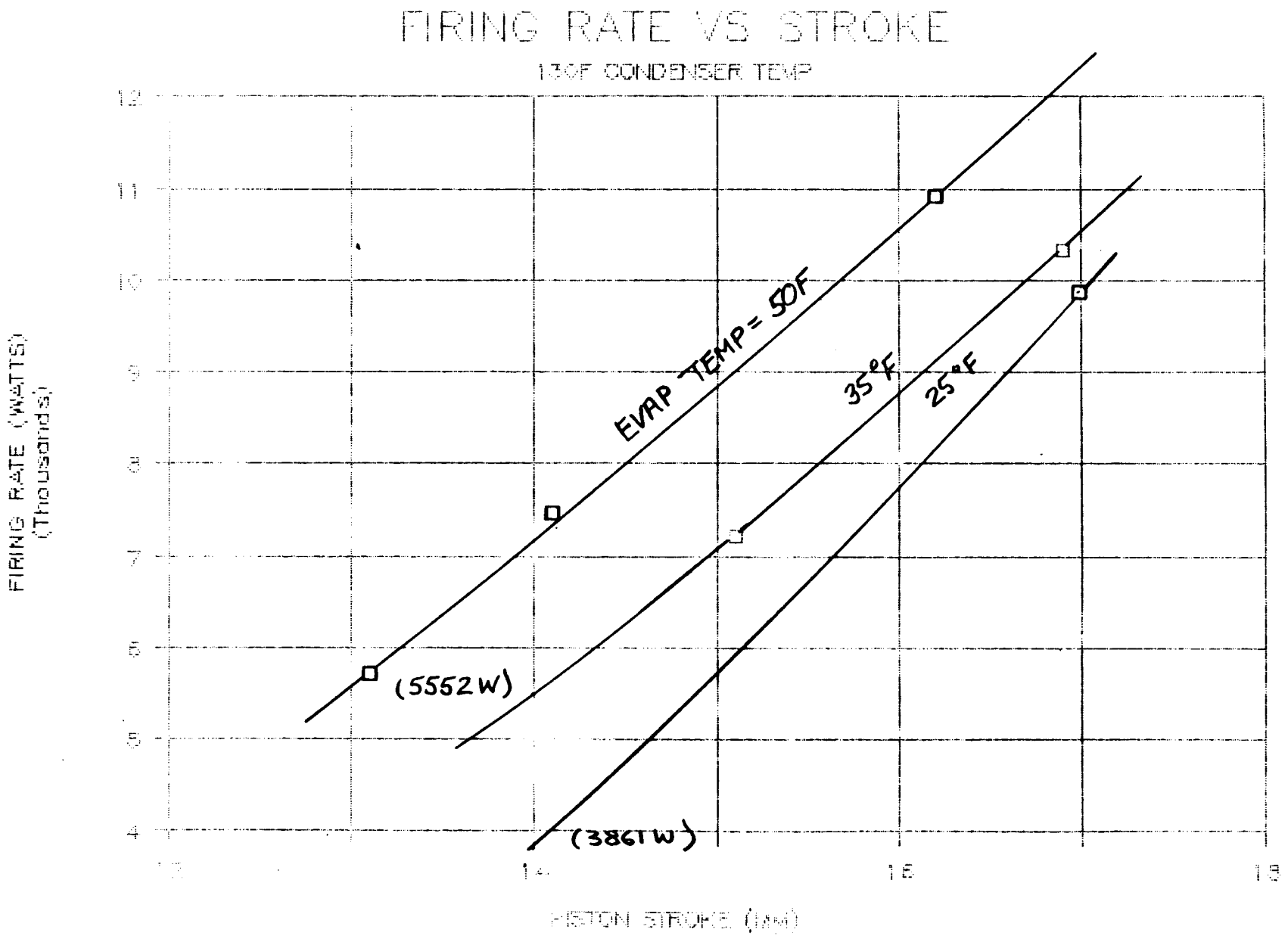
FIRING RATE VS PISTON STROKE

130F CONDENSER TEMP



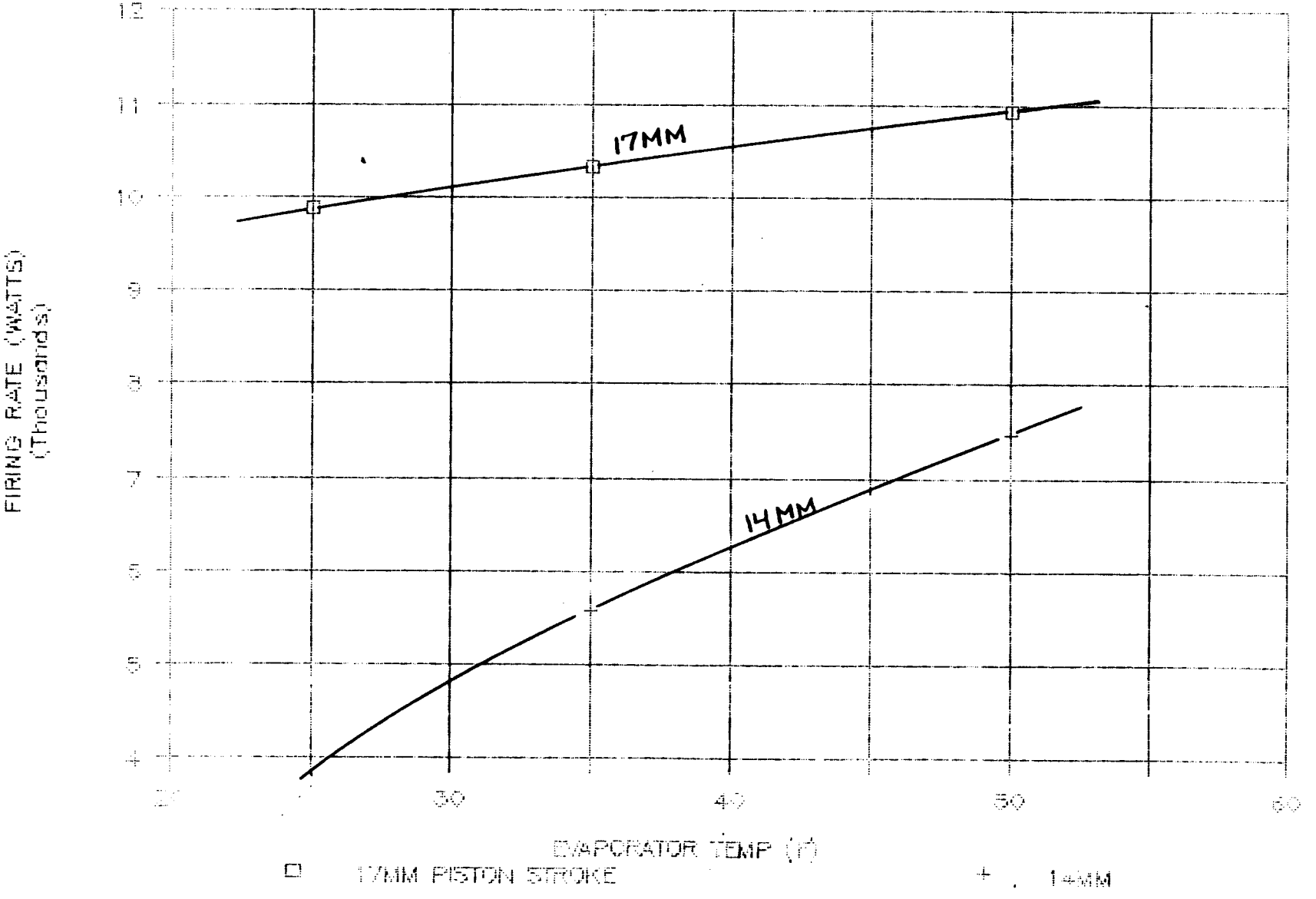
FIRING RATE VS EVAPORATOR TEMP




FIRING RATE VS STROKE
130F CONDENSER TEMP
FIRING RATE (WATTS)
(Thousands)
PISTON STROKE (IN)
EVAP TEMP = 50F
35°F
25°F
(5552W)
(3861W)
12
11
10
9
8
7
6
5
4
14
16
18

FIRING RATE VS EVAPORATOR TEMP

130F CONDENSER TEMP

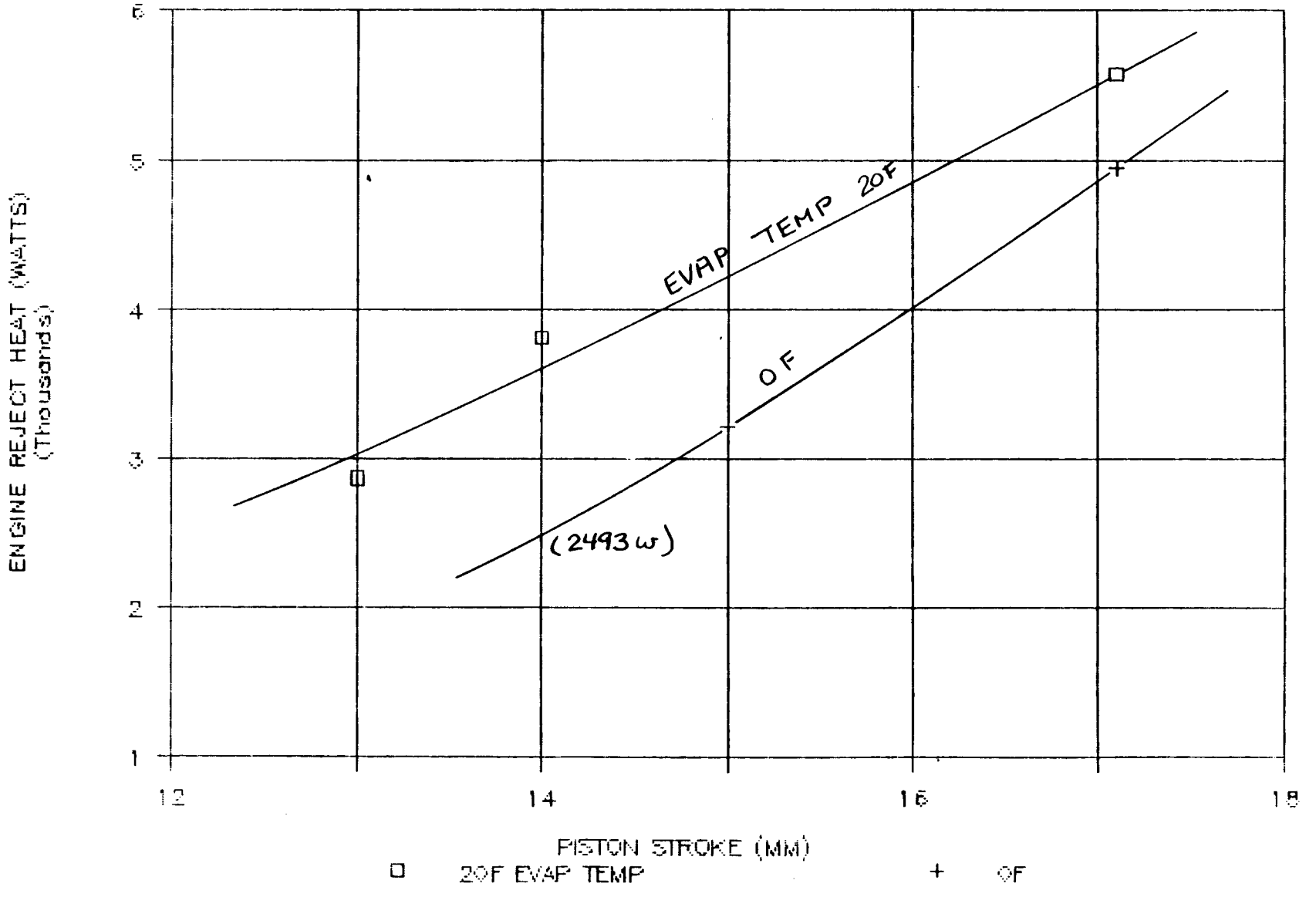


Attachment C-8

Engine Reject Heat versus Piston Stroke
and
Engine Reject Heat versus Evaporator Temperature
(14- and 17-mm Piston Strokes)

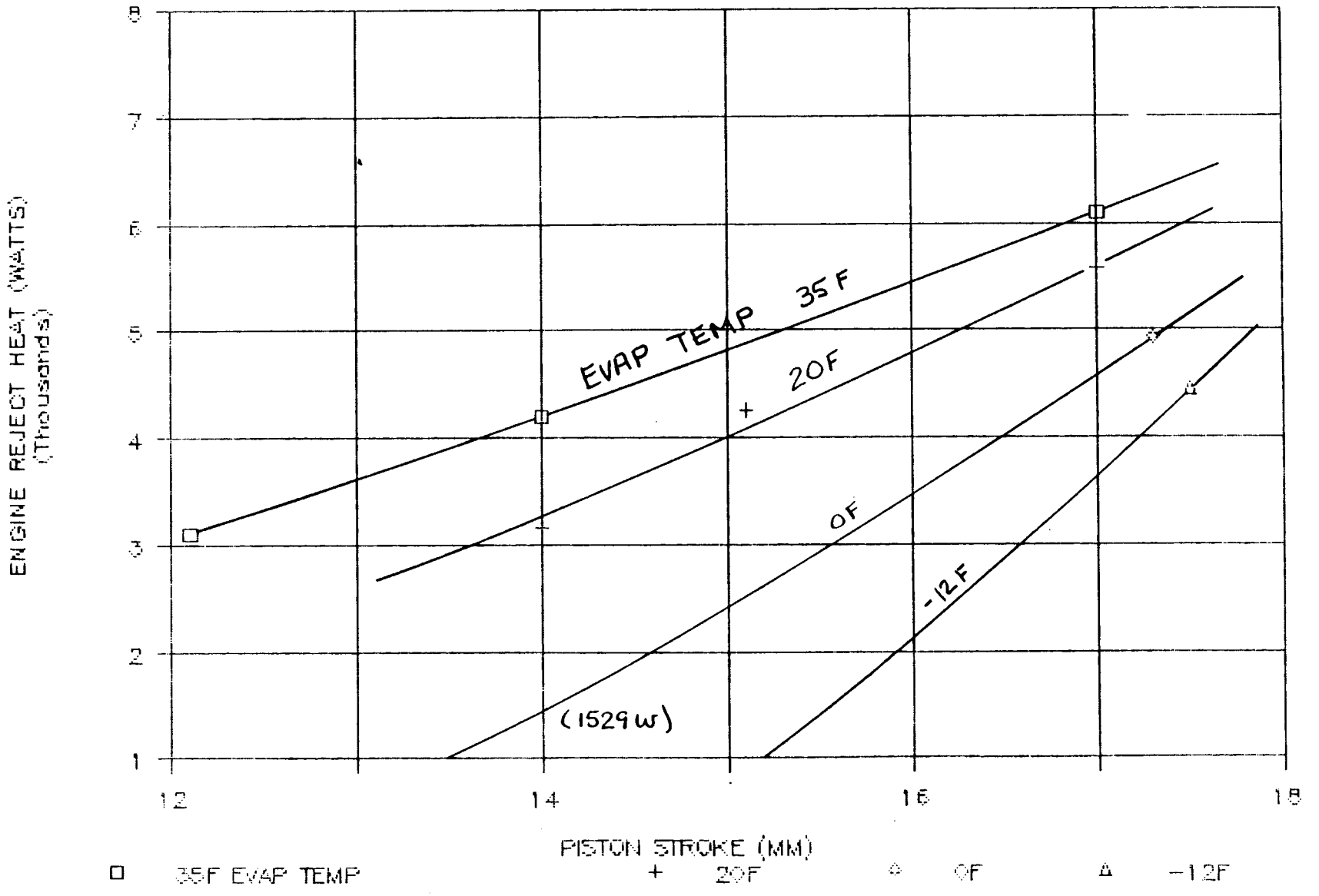
ENGINE REJECT HEAT VS PISTON STROKE

80F CONDENSER TEMP



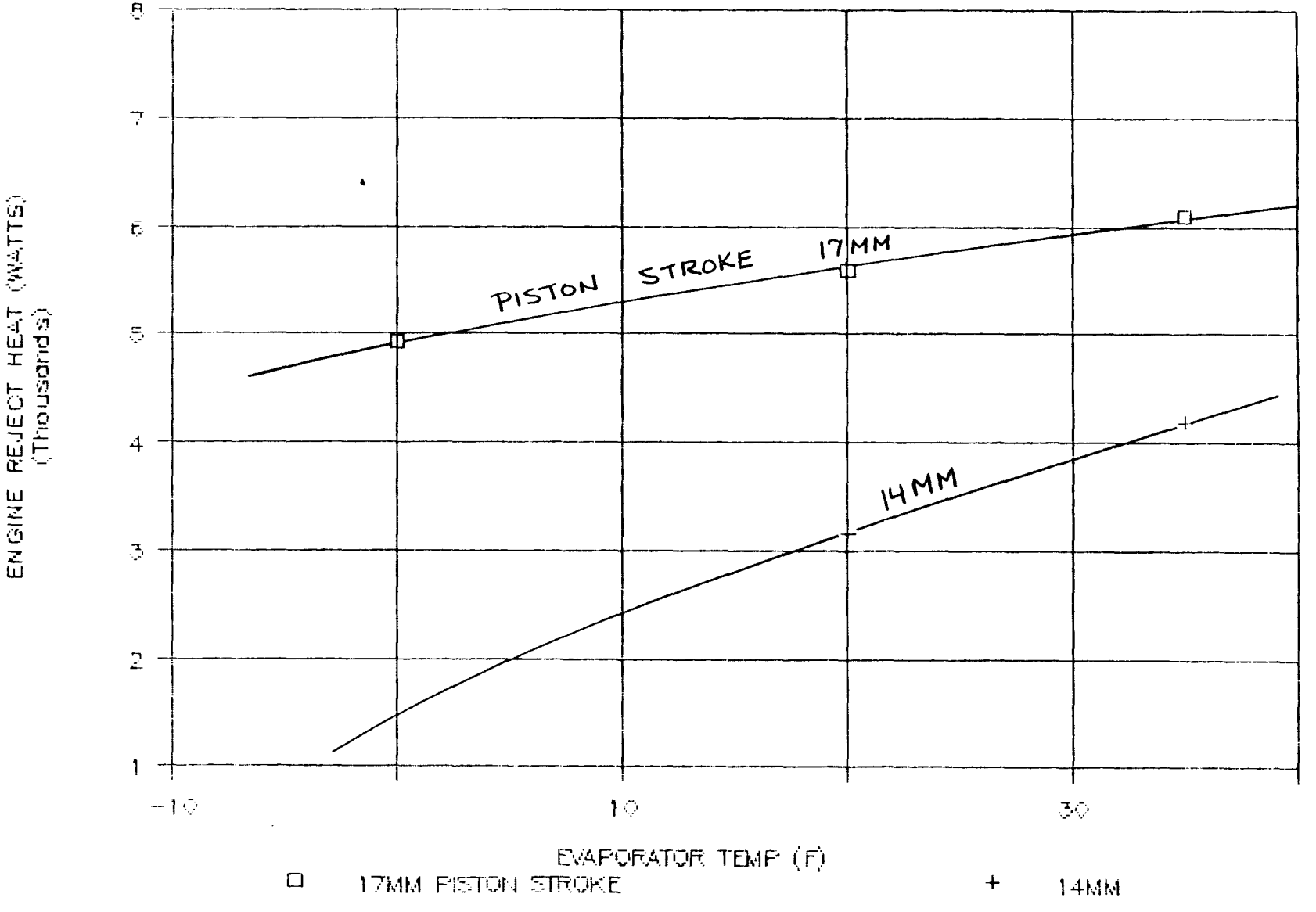
ENGINE REJECT HEAT VS PISTON STROKE

90F CONDENSER TEMP



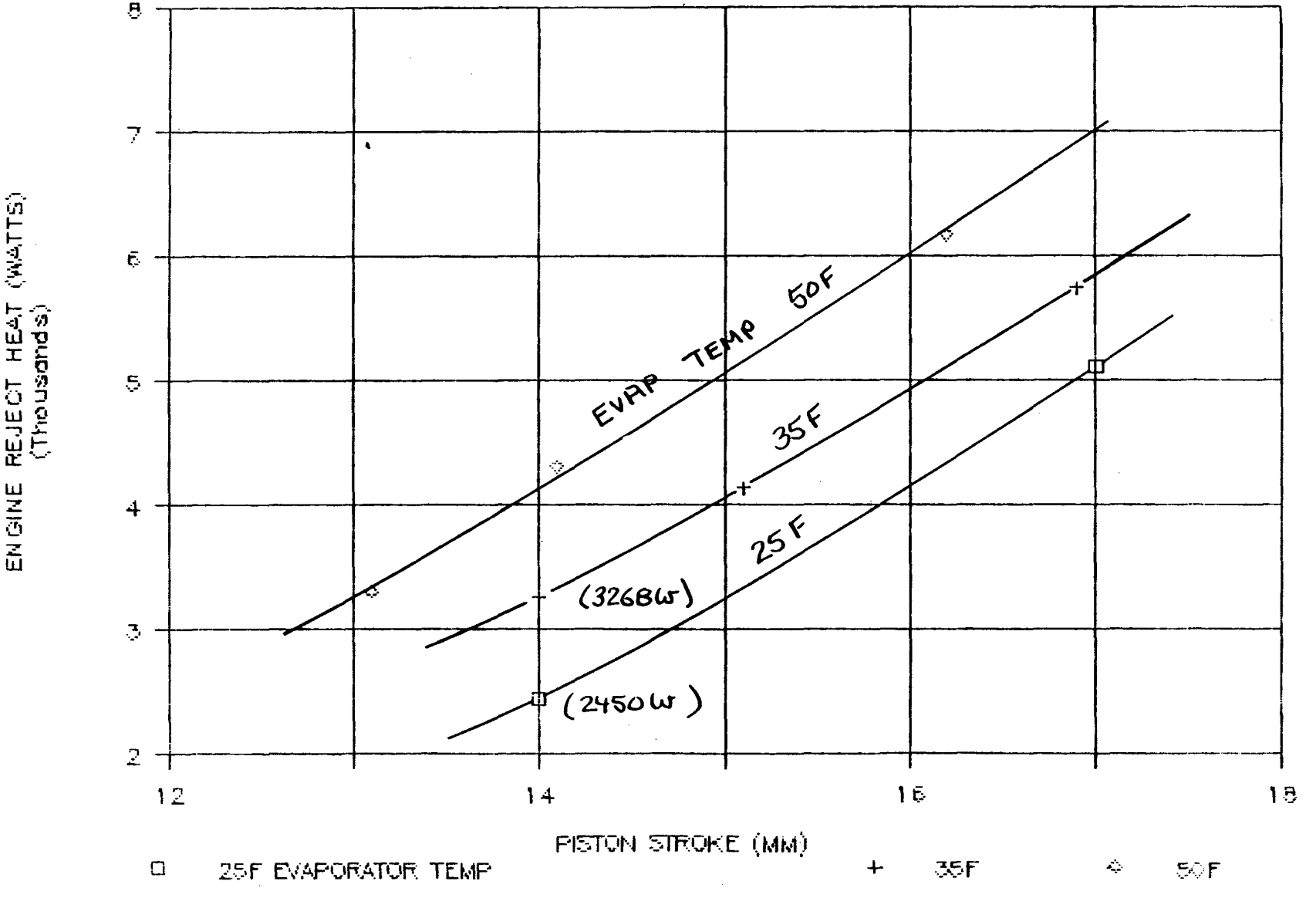
ENGINE REJECT HEAT VS EVAPORATOR TEMP

90F CONDENSER TEMP



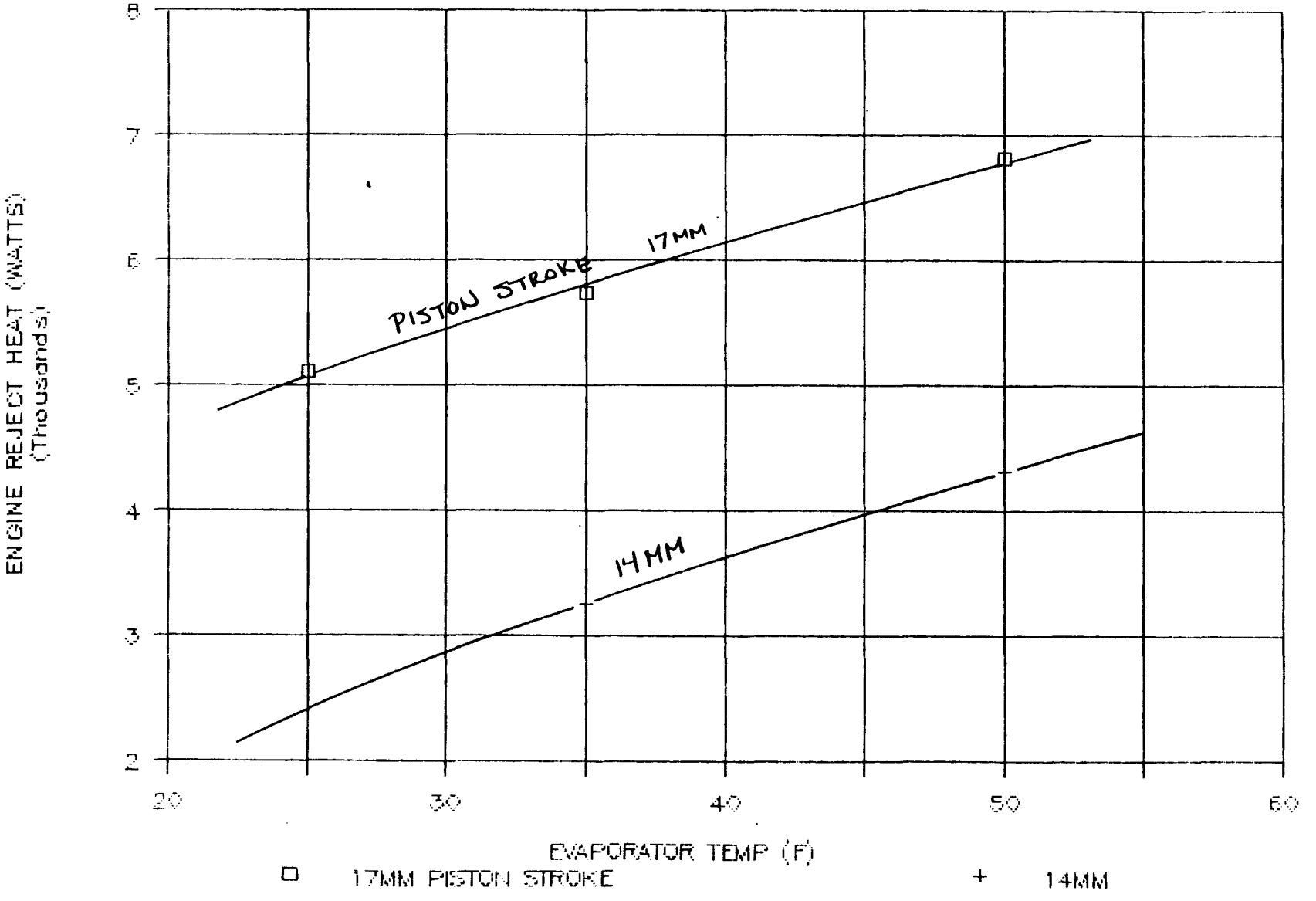
ENGINE REJECT HEAT VS PISTON STROKE

130F CONDENSER TEMP



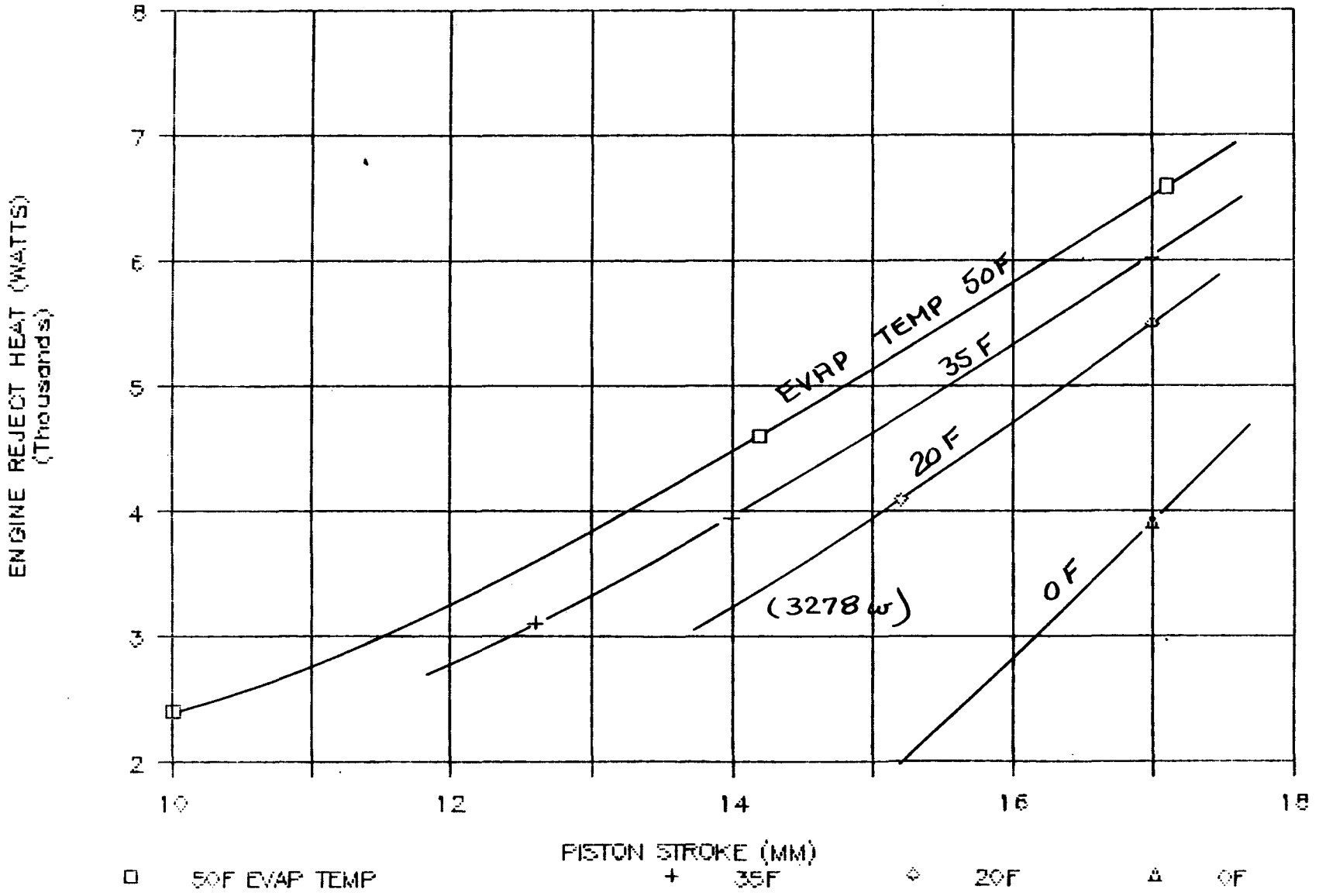
ENGINE REJECT HEAT VS EVAPORATOR TEMP

130F CONDENSER TEMP



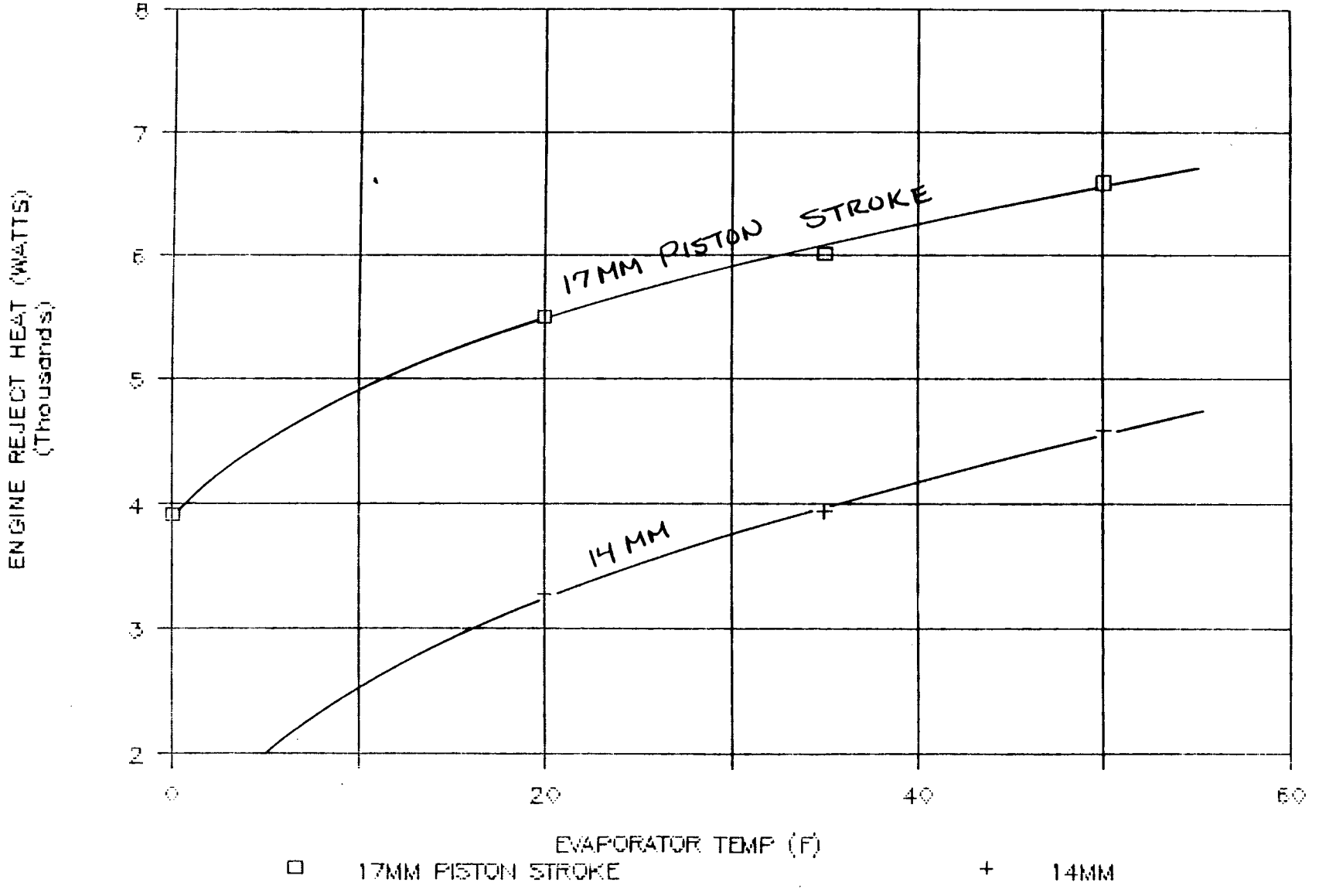
ENGINE REJECT HEAT VS PISTON STROKE

100F CONDENSER TEMP



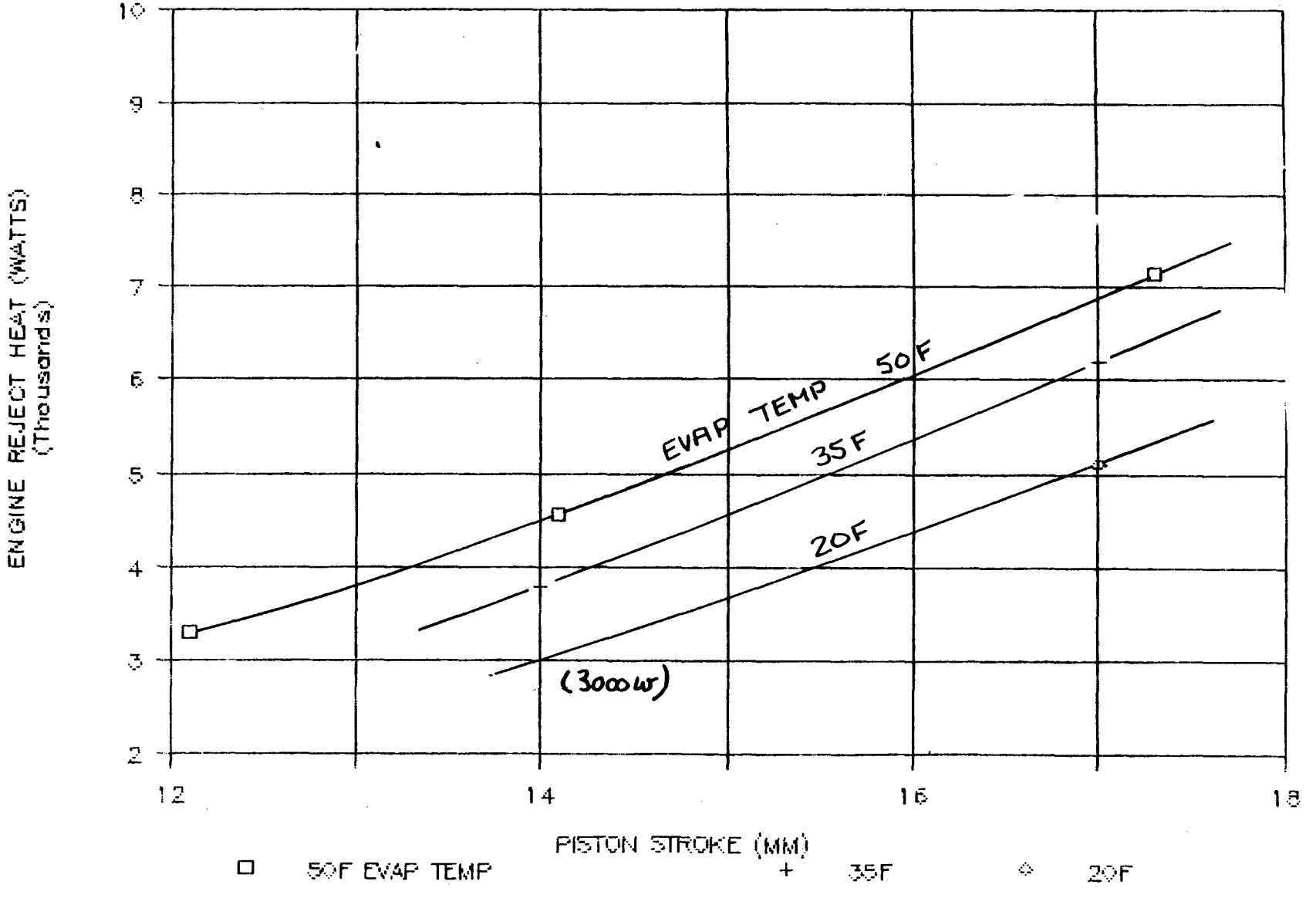
ENGINE REJECT HEAT VS EVAPORATOR TEMP

100F CONDENSER TEMP



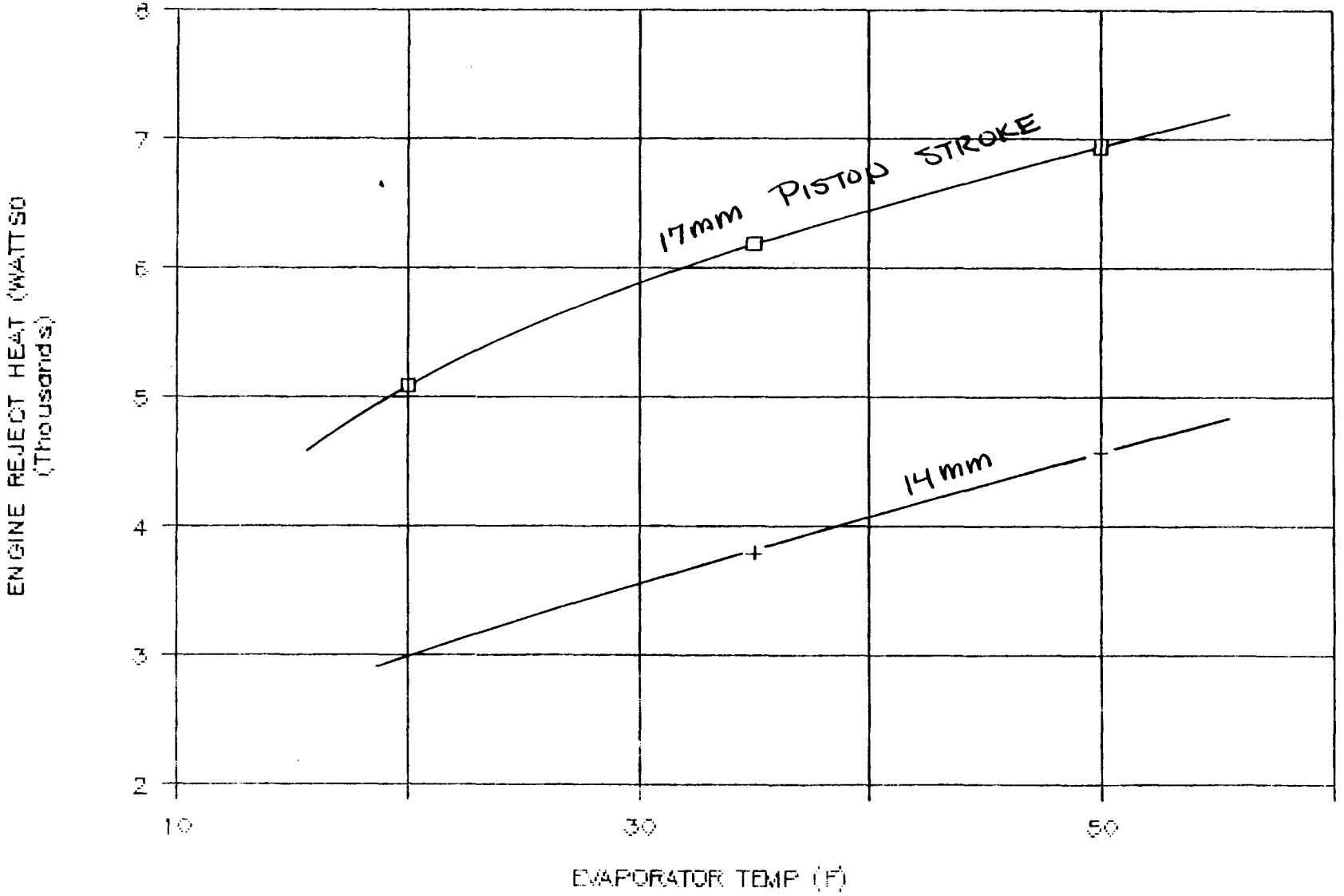
ENGINE REJECT HEAT VS PISTON STROKE

110F CONDENSER TEMP



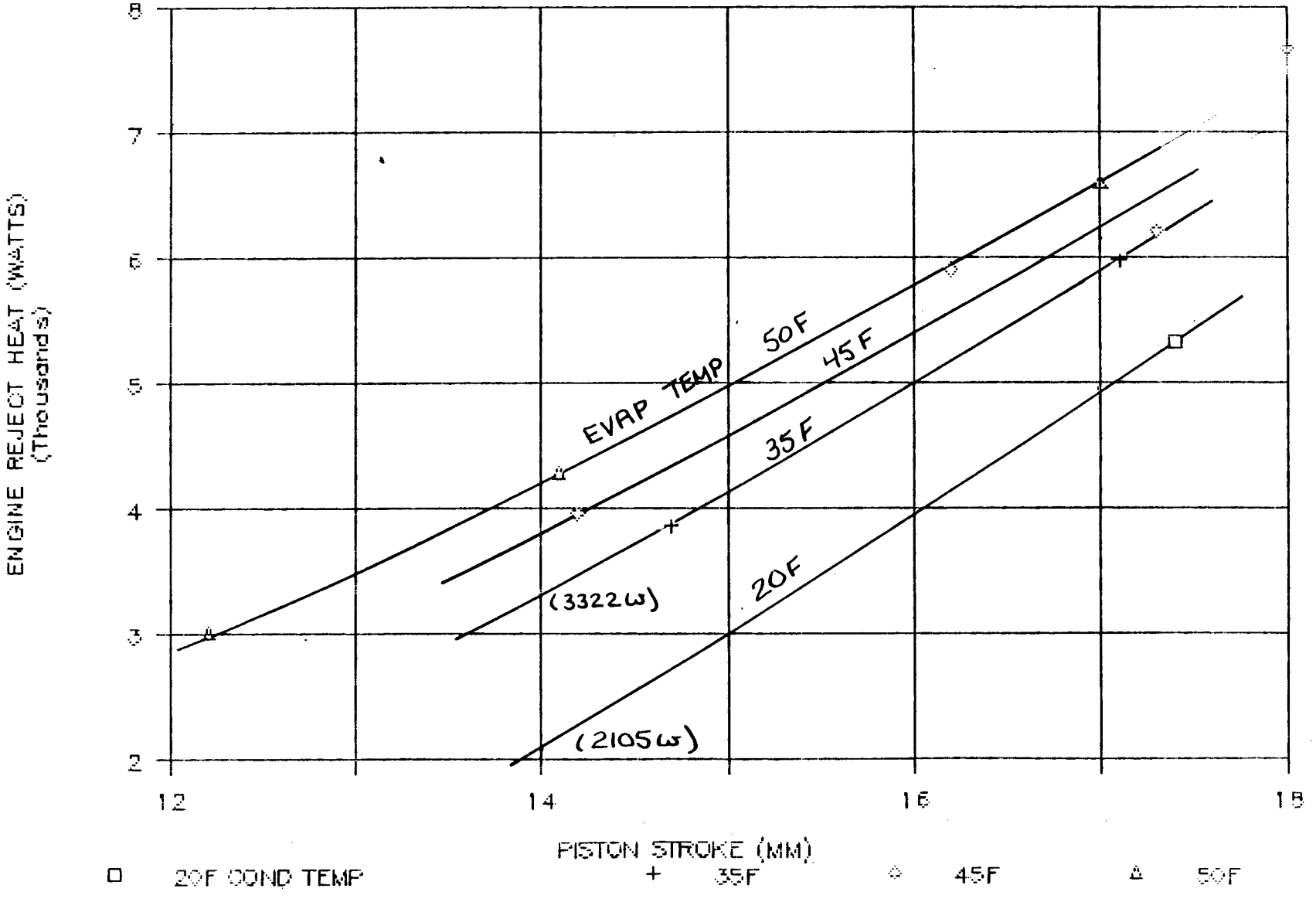
ENGINE REJECT HEAT VS EVAPORATOR TEMP

110°F CONDENSER TEMP



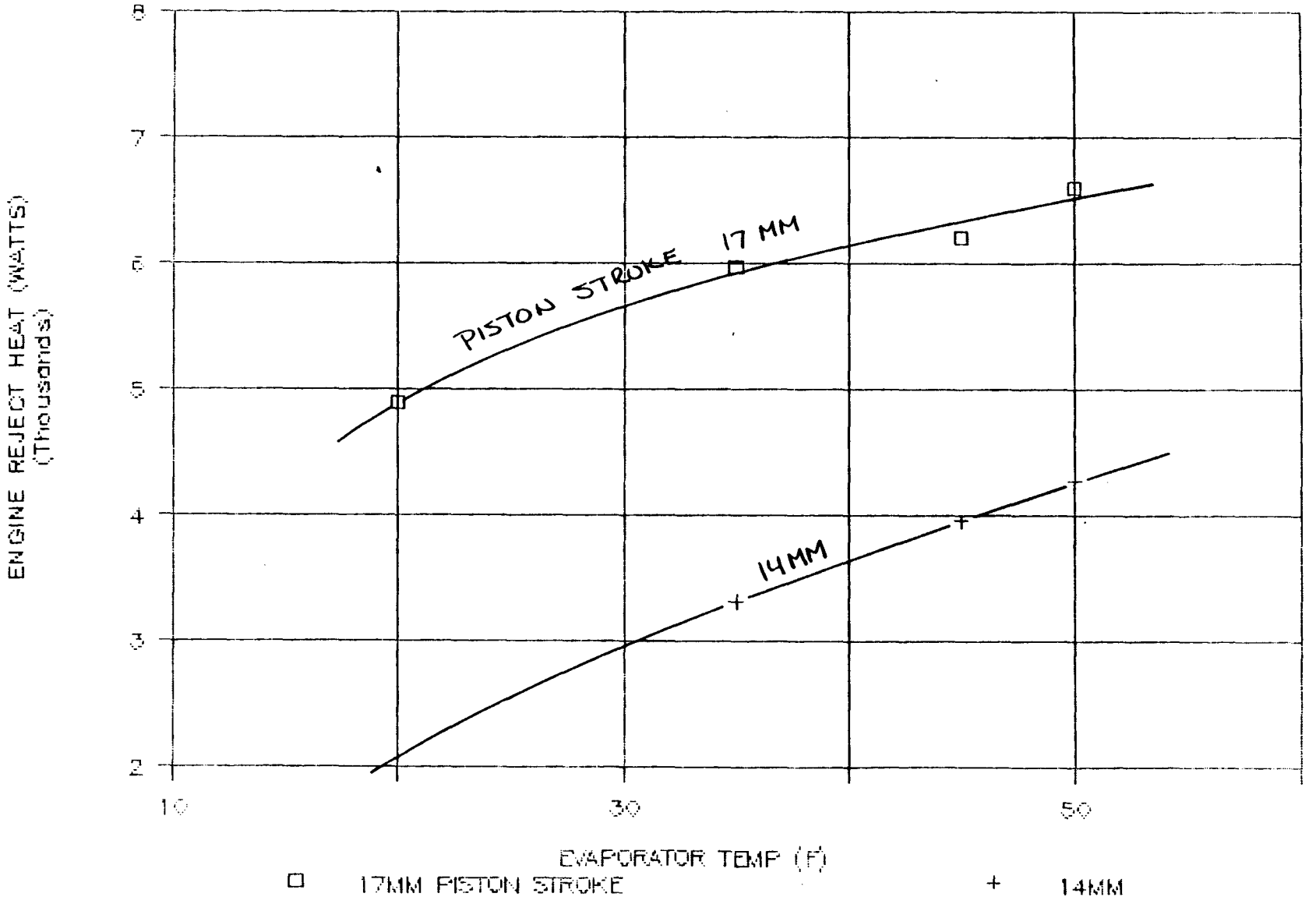
ENGINE REJECT HEAT VS PISTON STROKE

120F CONDENSER TEMP



ENGINE REJECT HEAT VS EVAPORATOR TEMP

120F CONDENSER TEMP



Attachment C-9

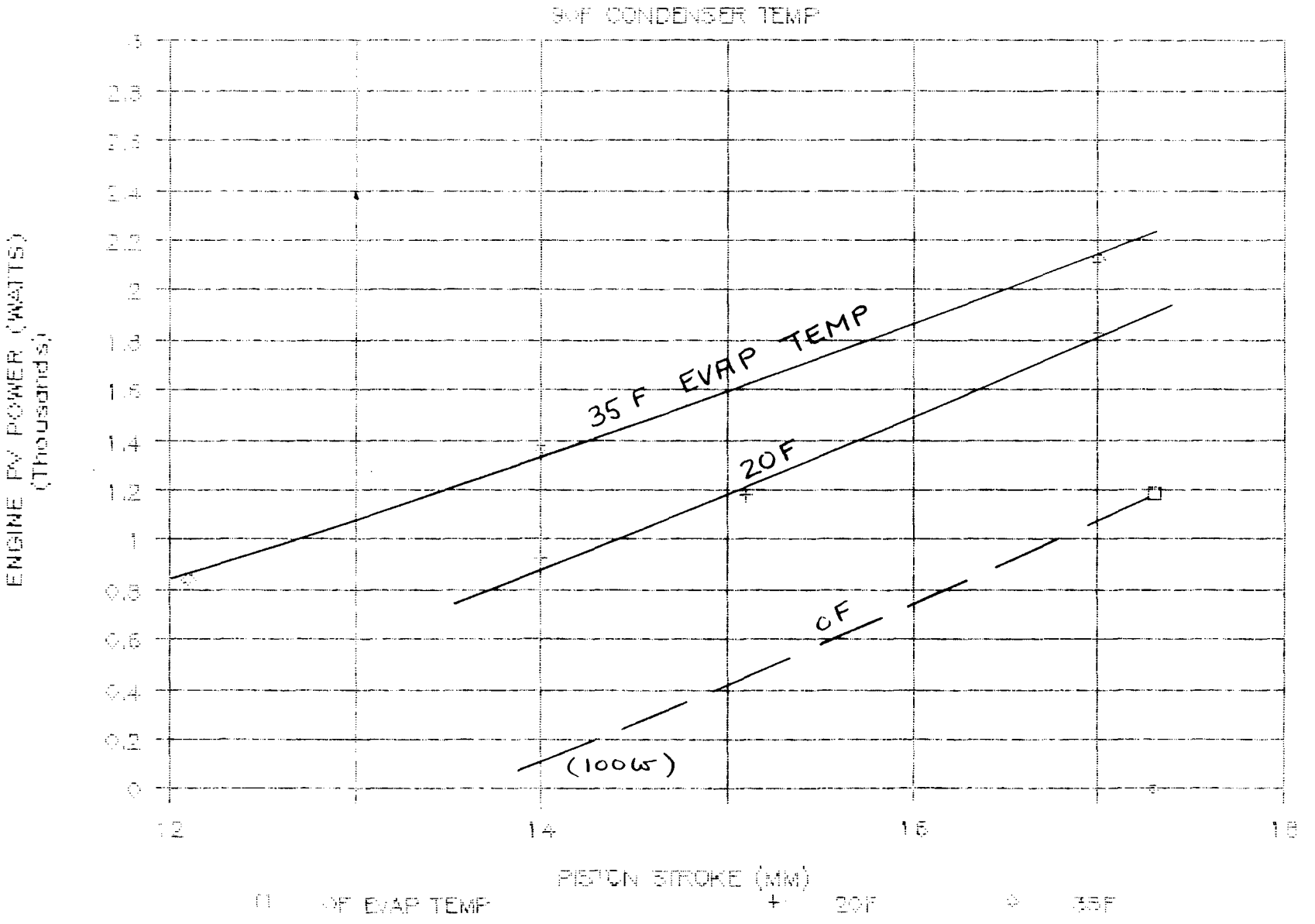
Engine PV Power versus Piston Stroke

and

Engine Reject Heat versus Evaporator Temperature

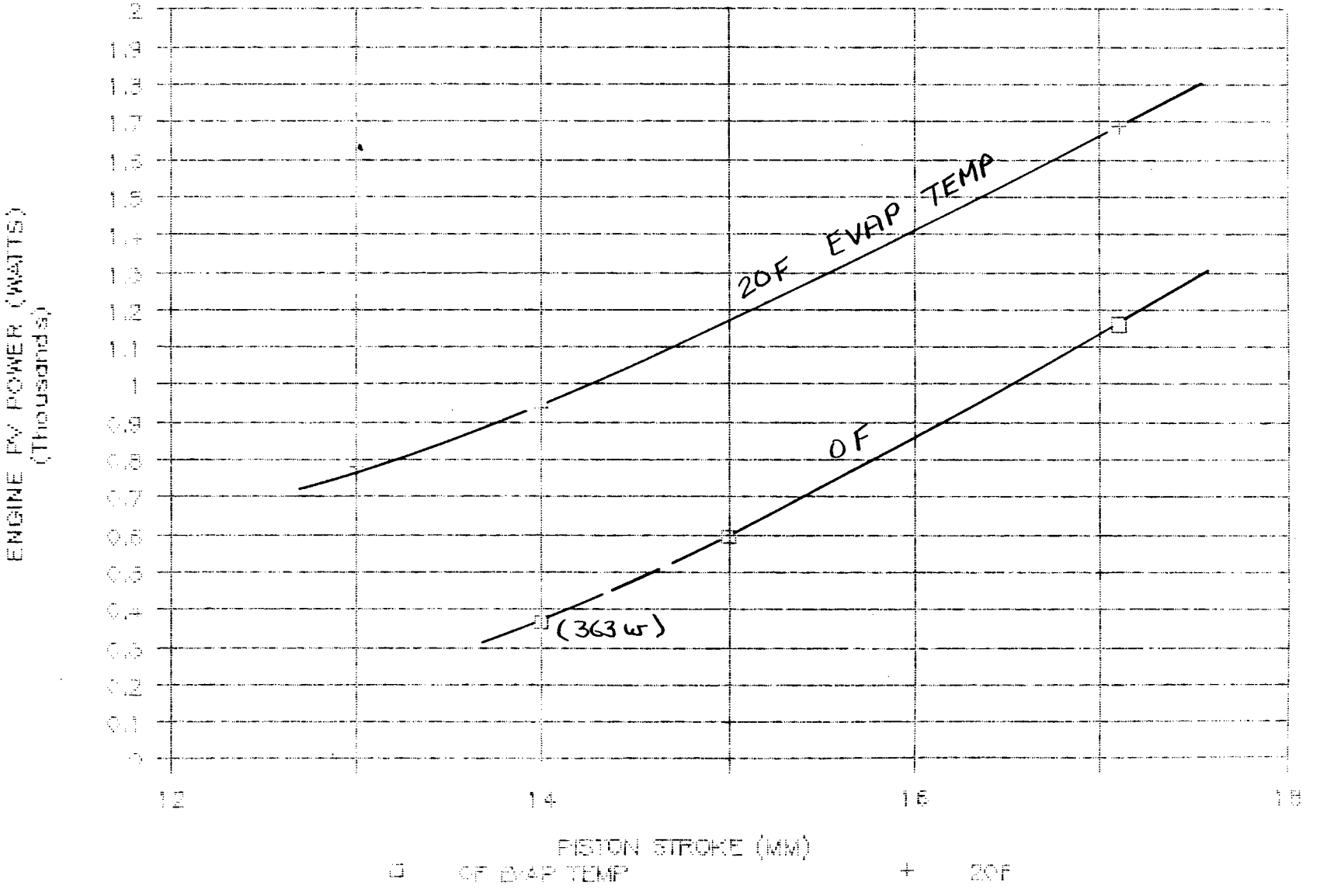
(14- and 17-mm Piston Strokes)

ENGINE PV POWER VS PISTON STROKE



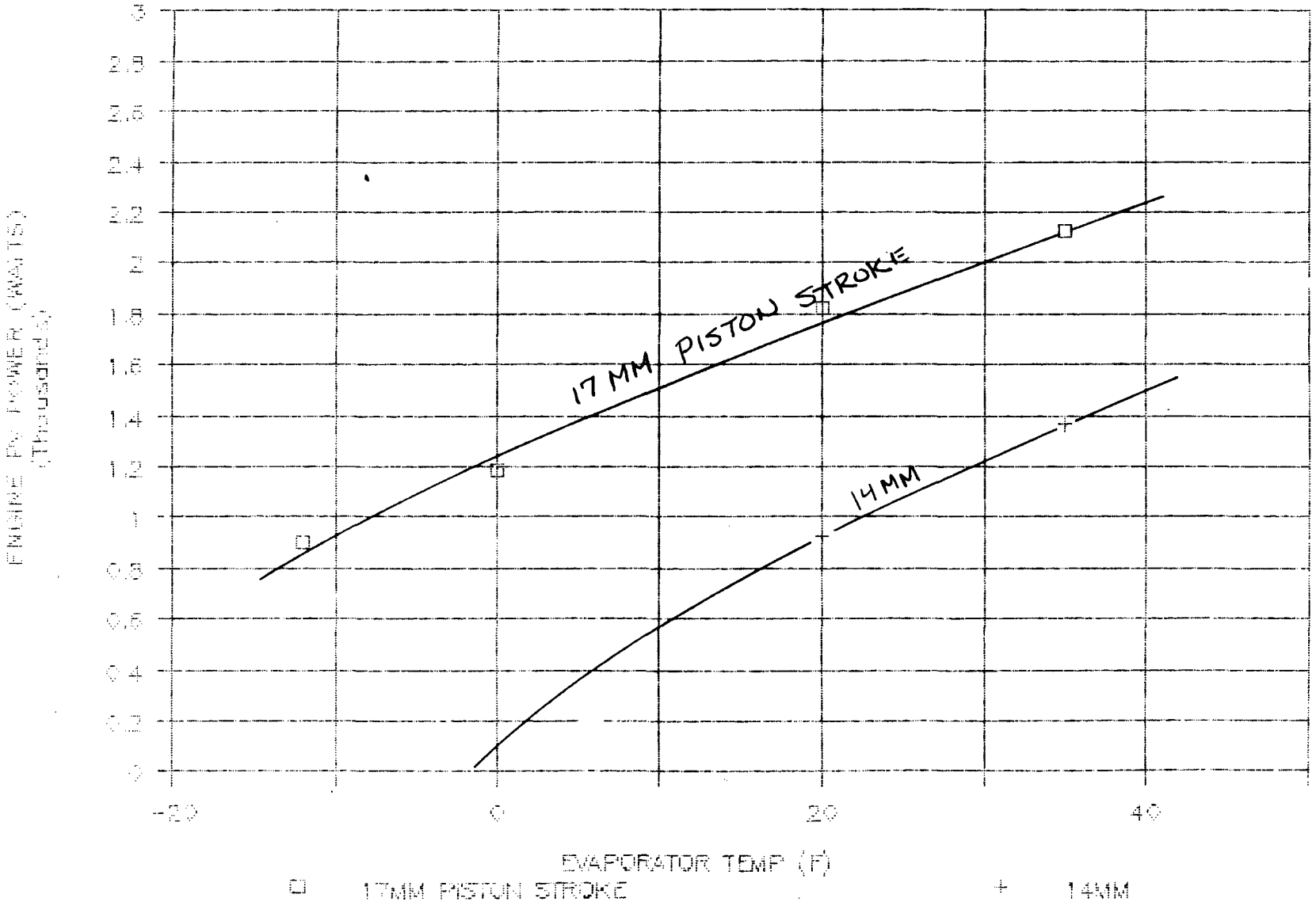
ENGINE PV POWER VS PISTON STROKE

80F CONDENSER TEMP



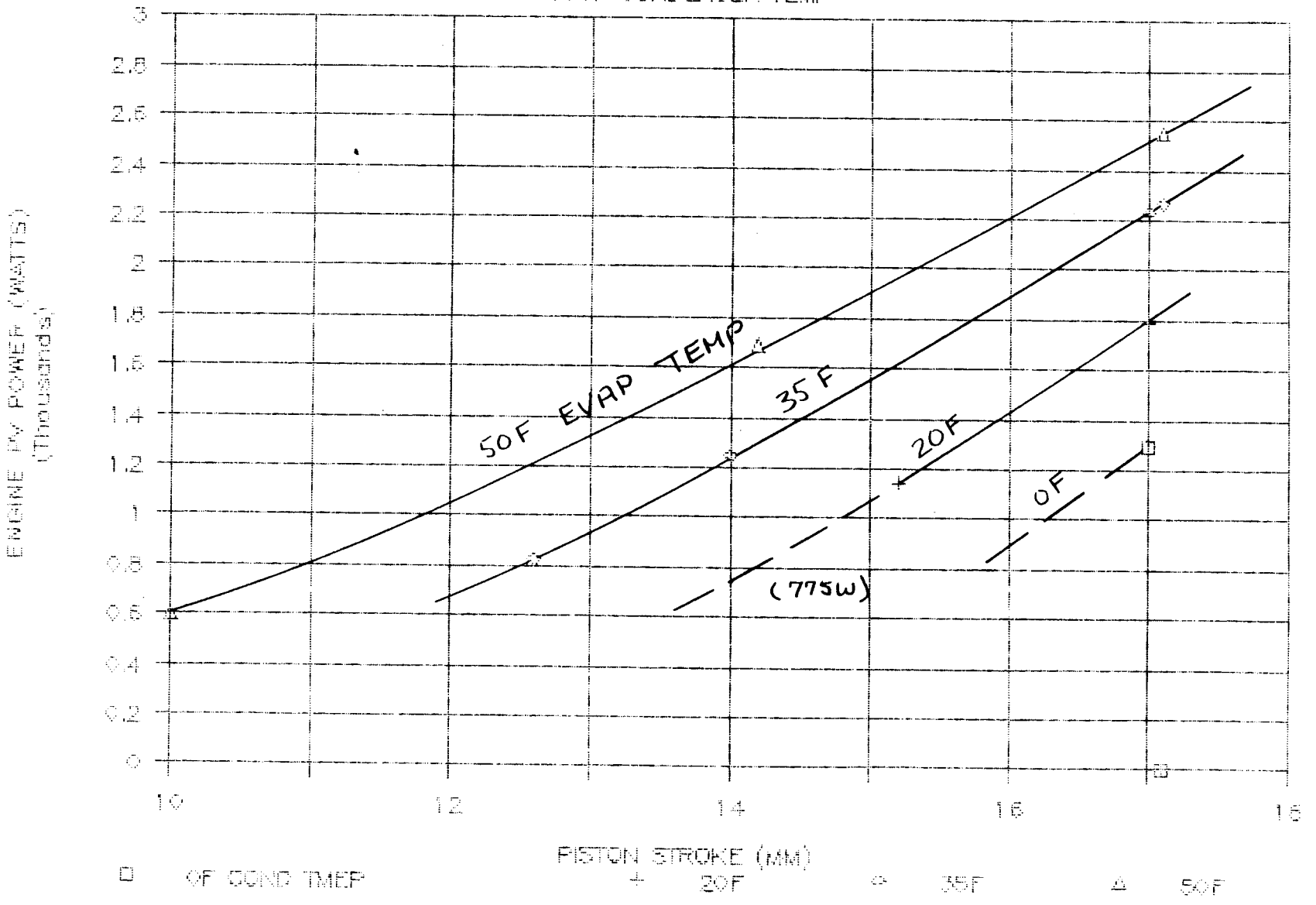
ENGINE PV POWER VS PISTON STROKE

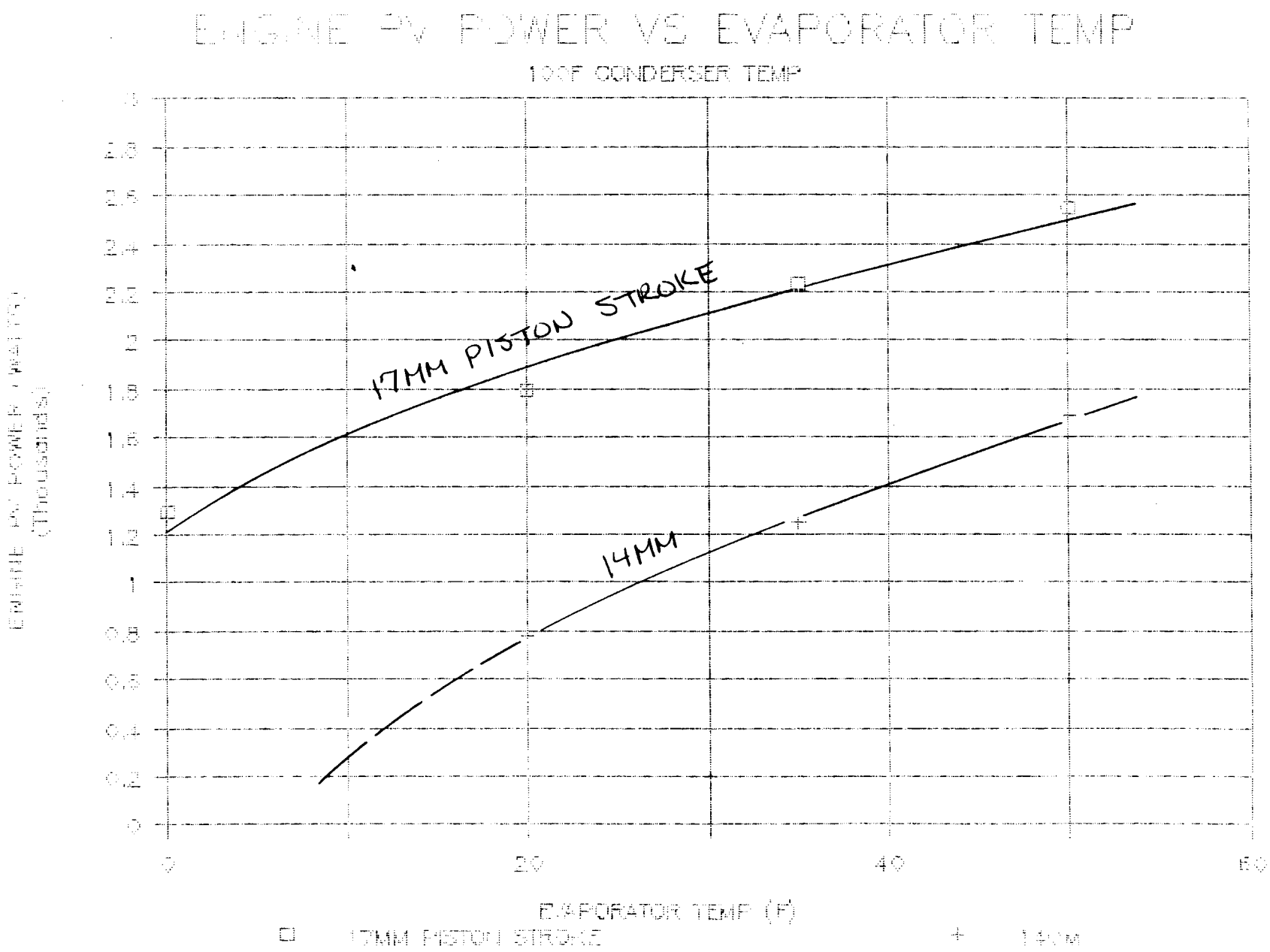
90F CONDENSER TEMP



ENGINE PV POWER VS PISTON STROKE

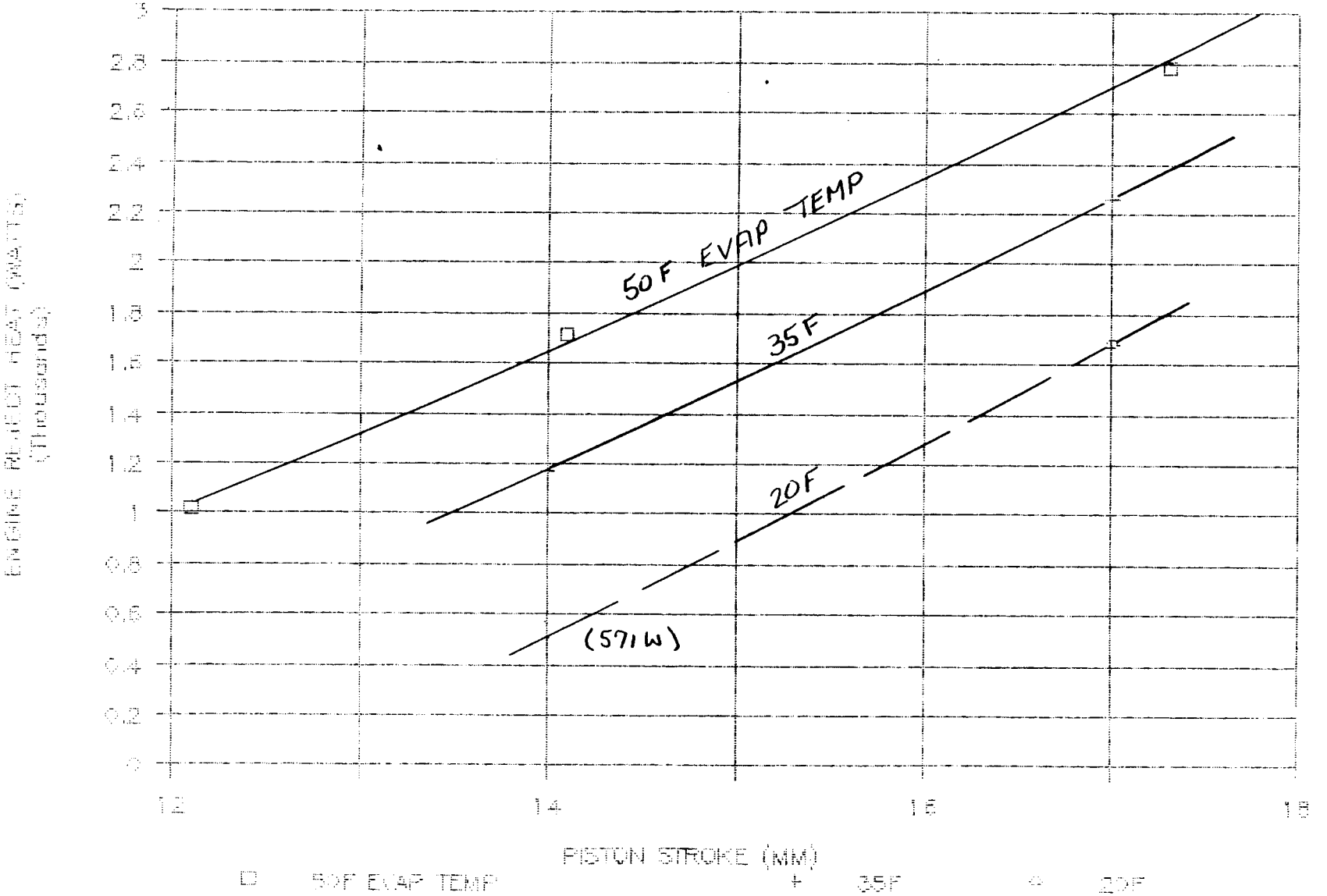
100F CONDENSER TEMP




ENGINE PV POWER VS EVAPORATOR TEMP
100F CONDENSER TEMP
17MM PISTON STROKE
14MM
ENGINE PV POWER (Thousands)
EVAPORATOR TEMP (F)
0
20
40
60
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
17MM PISTON STROKE
14MM

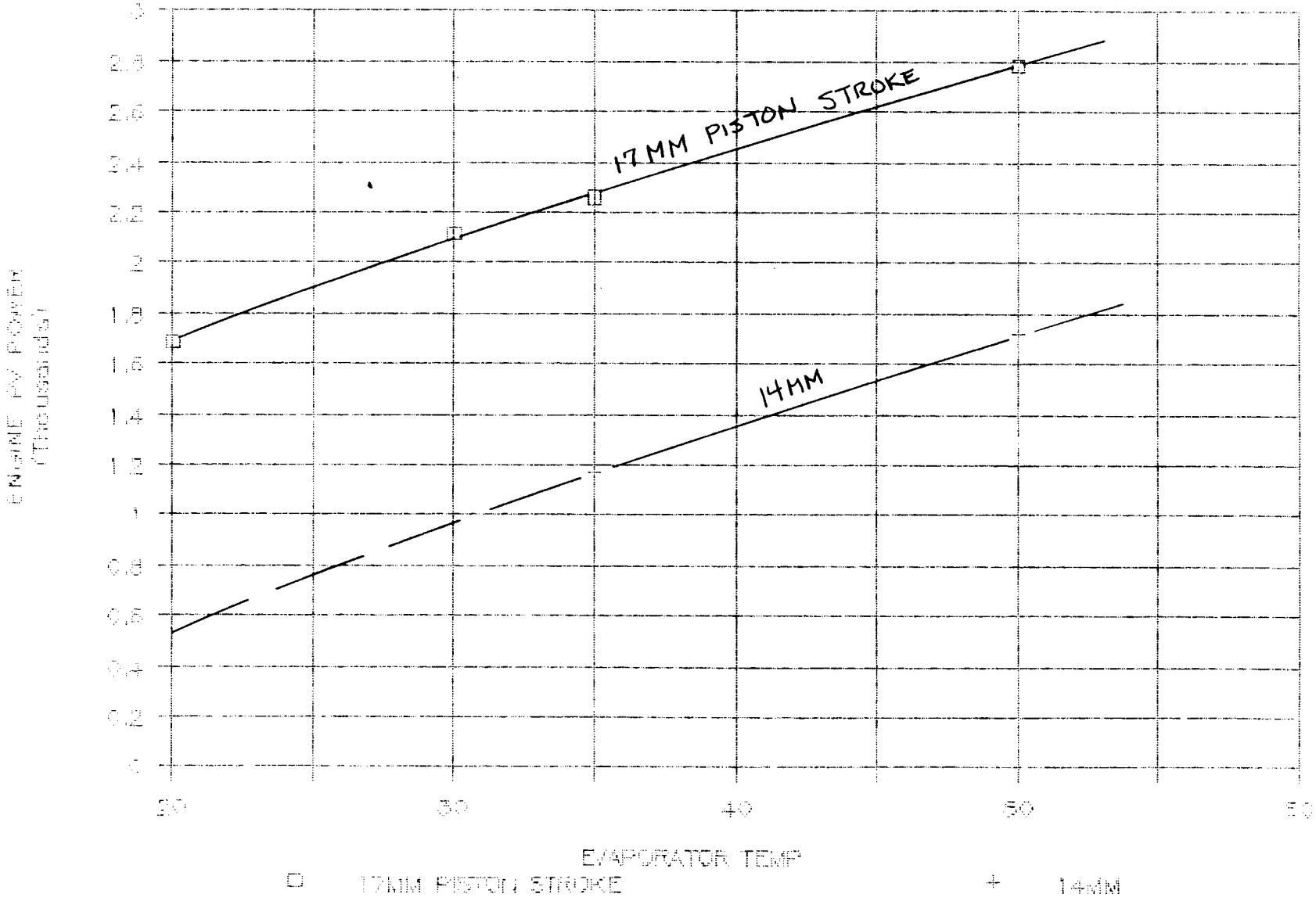
ENGINE REJECT HEAT VS PISTON STROKE

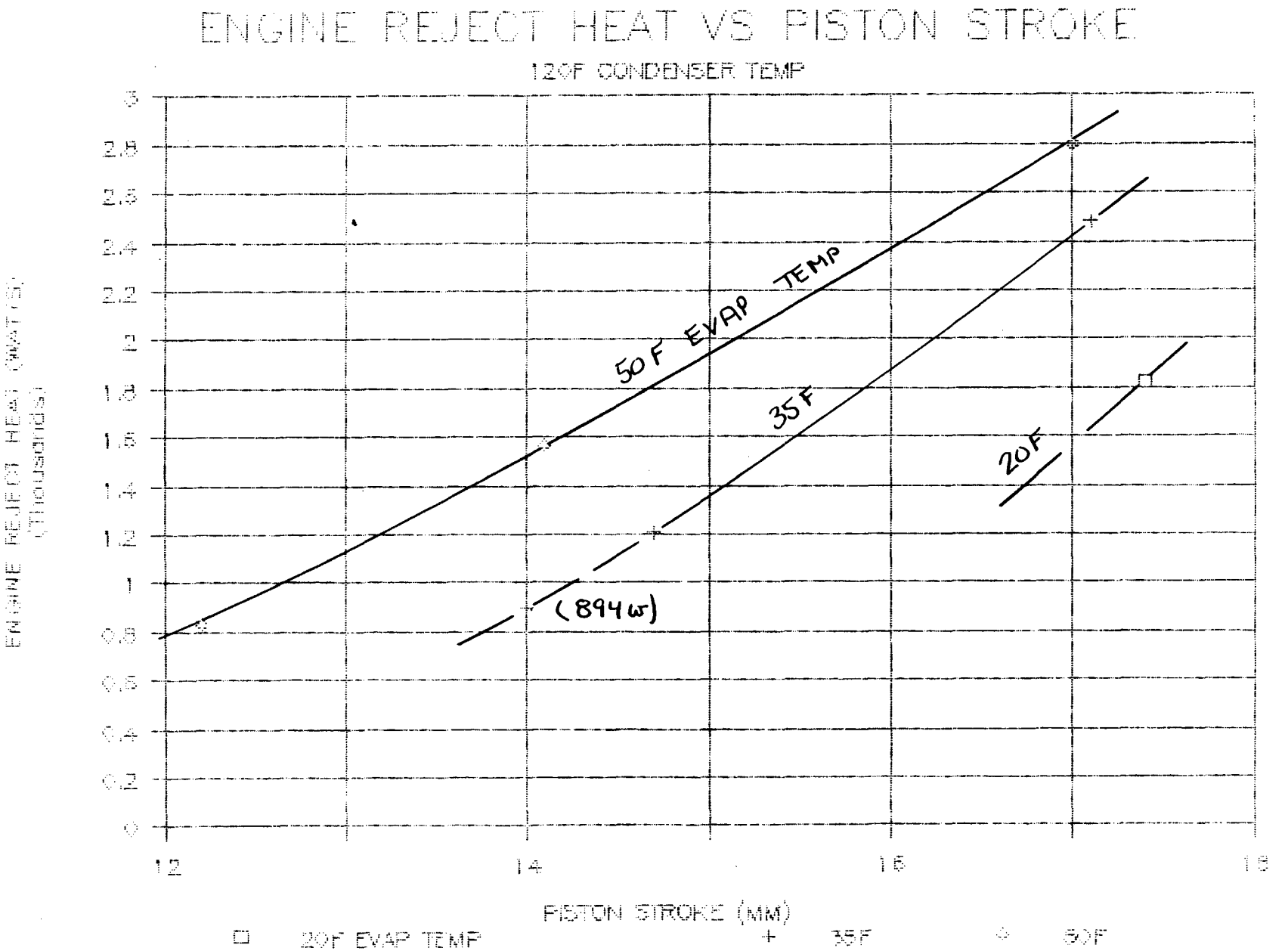
110°F CONDENSER TEMP

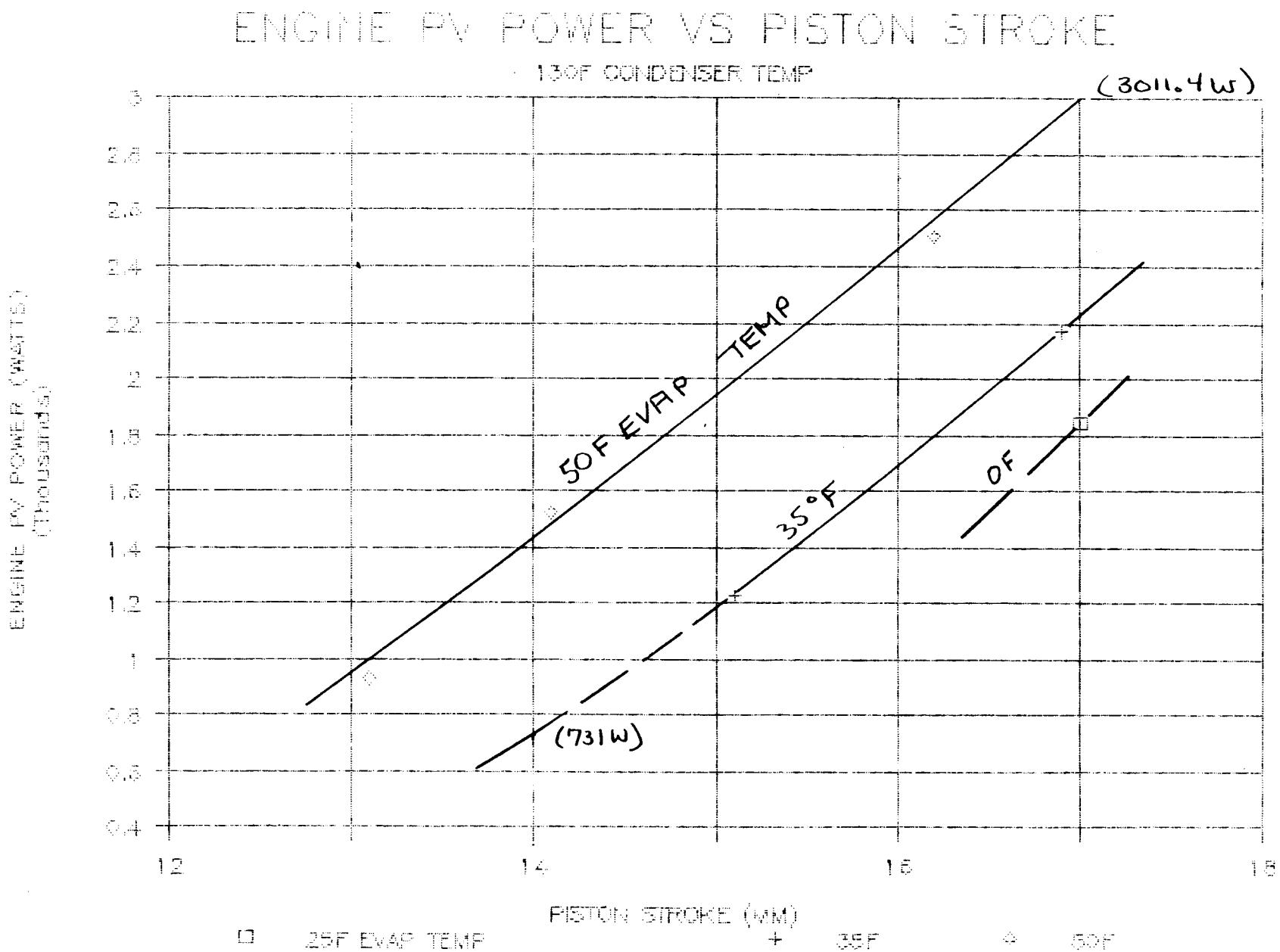


ENGINE PV POWER VS EVAPORATOR TEMP

110F CONDENSER TEMP

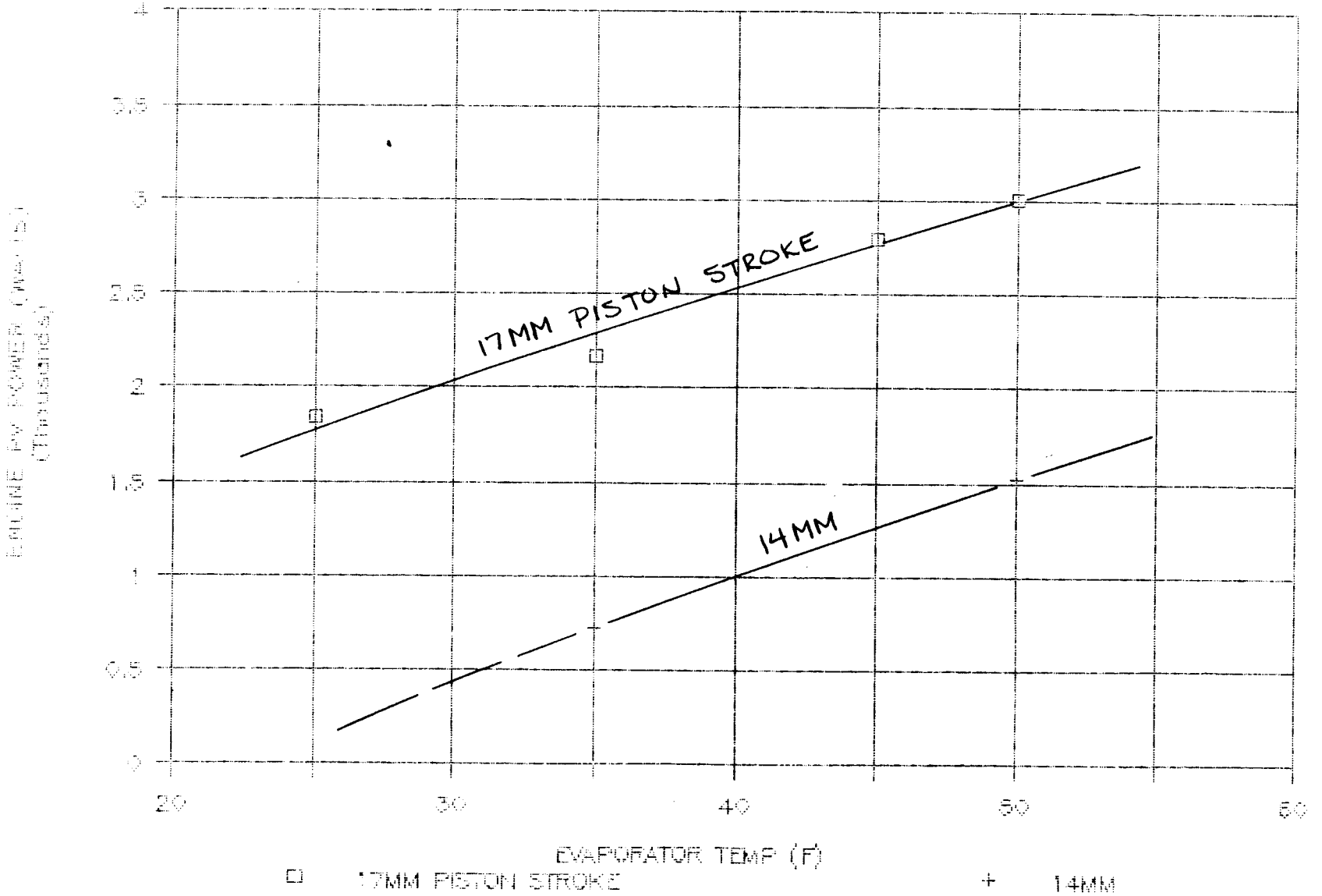



ENGINE REJECT HEAT VS PISTON STROKE
120F CONDENSER TEMP
ENGINE REJECT HEAT (WATTS)
(Thousands)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12
14
16
18
PISTON STROKE (MM)
50F EVAP TEMP
35F
20F
(894w)
20F EVAP TEMP
35F
50F


ENGINE PV POWER VS PISTON STROKE
130F CONDENSER TEMP
(3011.4W)
50F EVAP TEMP
35°F
0F
(731W)
ENGINE PV POWER (WATTS)
(Thousands)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
12
14
16
18
PISTON STROKE (MM)
25F EVAP TEMP
35F
50F

ENGINE PV POWER VS EVAPORATOR STROKE

130°F CONDENSER TEMP



APPENDIX D

LENNOX PARAMETRIC TEST DATA SHEETS

Lennox Test Matrix

Test Cond No.	Discharge Pressure, psig	Suction Pressure, psig	Liq. Temp. @ Flowrator, °F	Suction Temp., °F	No. of Compressor Strokes	Comments
Verification Testing						
1	261.0	75.6	106.0	51.2	1	See notes 1 through 6
Qualification Testing - Cooling						
2	296.8	76.0	115.0	65.0	2	ARI rating point
3	262.7	76.0	106.0	55.0	2	95° OD point
4	210.8	80.0	90.0	60.0	3	87° OD point
5	181.8	84.0	80.0	65.0	4	80° OD point
Qualification Testing - Heating						
6	226.3	54.9	95.0	50.0	4	ARI rating point
7	195.9	61.5	85.0	45.0	4	47° OD point
8	187.4	43.0	82.0	30.0	3	32° OD point
9	181.8	28.2	80.0	15.0	2	17° OD point
10	168.4	15.1	75.0	-2.0	1	0° OD point
Parametric Testing						
11	143.6	10.1	70.0	0.0	3	80° cond/-20° suct
12	143.6	24.0	70.0	20.0	3	80° cond/0° suct
13	143.6	43.0	70.0	40.0	3	80° cond/20° suct
14	168.4	10.1	80.0	0.0	3	90° cond/-20° suct
15	168.4	24.0	80.0	20.0	3	90° cond/0° suct
16	168.4	43.0	80.0	40.0	3	90° cond/20° suct
17	195.9	24.0	90.0	20.0	3	100° cond/0° suct
18	195.9	61.5	90.0	55.0	3	100° cond/35° suct
19	195.9	84.0	90.0	70.0	3	100° cond/50° suct
20	259.9	43.0	105.0	40.0	3	120° cond/20° suct
21	259.9	61.5	105.0	55.0	3	120° cond/35° suct
22	259.9	84.0	105.0	70.0	3	120° cond/50° suct
23	296.8	43.0	115.0	40.0	3	130° cond/20° suct
24	296.8	61.5	115.0	55.0	3	130° cond/35° suct
25	296.8	84.0	115.0	70.0	3	130° cond/50° suct

Notes

1. Each test condition should be at steady state in which none of the performance parameters differ from scan to scan by more than 3%. There should be atleast 3 scans per test condition at 10-min intervals.
2. The engine coolant loop (water chiller rig) should be maintained at 2.5 gpm for all test conditions.
3. The engine coolant inlet temperature should be 34°F for verification testing and all other test conditions. All qualification and parametric testing should be repeated for 70°F inlet temperature. Qualification test conditions 3 and 9 should be performed at an additional cooling water inlet temperature of 104°F.
4. No oil should be returned to the suction line and provisions to capture and measure oil circulation (as % of refrigerant flow) will be performed at qualification test conditions 3 and 9.
5. The compressor stroke (capacity) and the engine operating parameters should be controlled by personnel at the MTI operator's console. The compressor stroke will vary from 50% to full stroke.
6. There is a total of 144 test points, excluding verification testing, which will be repeated from day to day depending on the repeatability of these data with the data recorded at MTI.

LENNOX DATA ACQUISITION TEST AVERAGE OF 12 SCANS
DATE: 05-06-1987 TIME: 06:52:55 THRU 07:29:22 FILE: CHANNEL
RANDOM SCANS: 1 2 3 4 5 6 7 8 9 11 12 13

Test Point Number 12
Piston Stroke = 17.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.03	10.15	0.00
PIST STROKE	-0.59	17.16	-104.19
MOTOR VOLTS	0.77	53.76	74.68
MOTOR AMPS	0.20	3.36	-115.88
COMP SP PRES	60.06	7.11	-112.01
LSGS PRESS	60.35	3.28	2.46
HSGS PRESS	59.85	3.86	-174.75
L/H CYL PRES	4.52	3.91	93.71
R/H CLY PRES	4.19	4.23	-85.44
LGS PRESS	59.92	2.29	76.93
AC-1	-0.53	1.17	78.29

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.45	10.61	3.13	150.22	6.21	6.83	59.90	66.51
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
60.04	37.86	160.02	58.78	56.56	27.30	0.01	22.31

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	66.1	678.6	121.6	725.3	178.2	160.8	32.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
28.0	79.4	9.0	41.0	22.0	753.9	747.3	734.5
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
722.8	716.0	699.0	696.1	726.3	718.3	741.4	740.8
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
731.5	737.4	736.3	753.1	690.3	758.5		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.973	20.855	36.176	111.530	-86.573	383.168	28.640	110.532
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1159.441	4128.752	0.146	438.701	496.385	59.321	0.918	0.433
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
865.352	726.822	1068.926	9.038	7909.533	4.991	758.500	68.417
Kp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.099	39.828	12301.548	0.456	3.170	26756.547	0.992	3.808

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-06-1987 TIME: 09:14:30 THRU 09:53:50 FILE: CHANNEL
CONSECUTIVE SCANS: 27 THRU 40

Test Point Number 13
Piston Stroke = 17.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.13	12.85	0.00
FIST STROKE	-0.44	17.07	-101.20
MOTOR VOLTS	0.74	84.61	92.37
MOTOR AMPS	0.17	0.56	119.95
COMP SF PRES	59.89	7.14	-112.68
LSGS PRESS	60.36	4.15	2.16
HSGS PRESS	59.80	4.76	-174.97
L/H CYL PRES	5.68	3.97	108.77
R/H CLY PRES	5.62	4.10	-72.28
LGS PRESS	59.68	2.28	79.92
AC-1	-0.55	1.47	80.33

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.54	13.86	3.08	343.71	8.85	10.37	59.82	65.99
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
60.07	57.68	160.14	59.09	56.08	28.46	0.00	21.60

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	62.4	717.9	116.9	758.1	183.4	163.4	34.4
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
29.4	64.5	8.2	39.0	22.0	751.8	747.1	726.6
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
719.9	715.3	692.2	685.6	739.2	714.4	730.1	731.3
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
720.9	727.6	753.5	757.4	713.1	747.6		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.564	22.971	50.779	165.978	15.386	481.344	28.640	110.392
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1689.830	5587.355	0.176	719.221	717.776	53.088	0.855	0.525
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1200.275	724.900	426.745	12.068	9598.050	6.860	757.429	71.857
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.089	34.340	28098.738	0.858	4.892	48577.438	1.483	5.634

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 05-06-1987 TIME: 08:08:01 THRU 08:44:12 FILE: CHANNEL
CONSECUTIVE SCANS: 14 THRU 26

Test Point Number 13
Piston Stroke = 14.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.07	8.79	0.00
PIST STROKE	-0.35	13.96	-98.80
MOTOR VOLTS	0.76	53.30	72.39
MOTOR AMPS	0.20	2.82	-95.48
COMP SP PRES	60.02	5.75	-108.37
LSGS PRESS	60.26	2.83	2.48
HSGS PRESS	59.90	3.29	-173.52
L/H CYL PRES	5.86	3.76	100.15
R/H CLY PRES	5.89	3.94	-79.57
LGS PRESS	60.01	1.88	82.19
AC-1	-0.54	0.96	84.09

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.36	8.91	3.06	186.79	4.33	5.14	59.92	66.79
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
57.02	58.01	160.97	59.44	56.45	26.03	0.00	21.28

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	68.0	656.1	124.0	690.9	174.8	158.8	30.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.0	62.0	8.5	38.9	22.0	755.1	753.2	745.7
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
726.4	722.1	705.4	701.8	723.0	724.6	740.2	739.8
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
739.6	745.5	729.8	744.9	675.2	757.3		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.067	22.027	27.336	101.736	-73.017	275.226	28.640	110.450
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
940.213	3846.754	0.151	366.467	389.435	32.165	0.808	0.342
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
726.892	728.231	198.860	7.530	6238.570	4.752	757.538	82.308
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.016	34.139	15281.374	0.717	4.777	28555.121	1.341	5.436

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-06-1987 TIME: 13:58:43 THRU 14:37:55 FILE: CHANNEL
CONSECUTIVE SCANS: 68 THRU 81

Test Point Number 15
Piston Stroke = 17.3 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.00	9.94	0.00
PIST STROKE	-0.61	17.60	-96.08
MOTOR VOLTS	0.72	63.38	70.03
MOTOR AMPS	0.20	3.55	-87.02
COMP SP PRES	60.20	6.98	-104.10
LSGS PRESS	60.51	3.19	2.25
HSGS PRESS	59.96	3.75	-173.75
L/H CYL PRES	4.93	4.47	99.20
R/H CLY PRES	4.19	4.82	-81.27
LGS PRESS	59.92	2.32	84.61
AC-1	-0.52	0.93	85.48

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.46	11.45	3.04	120.95	6.61	7.67	59.99	65.88
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
60.73	37.70	185.21	59.18	56.78	27.92	0.01	21.71

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	66.0	685.6	120.6	727.0	181.1	162.0	33.0
Tcool exit	**Tfreon discn**	**Tfreon inlet**	**Tcomp oil**	**Taambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
29.0	87.9	11.0	42.8	22.9	747.1	753.0	734.9
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
719.1	712.5	696.9	693.9	729.9	720.2	735.1	735.6
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
736.5	741.4	739.6	754.1	694.3	756.9		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.278	22.079	31.753	127.209	-103.118	387.158	31.606	110.884
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1189.113	4983.036	0.147	439.061	459.415	38.023	0.758	0.443
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
965.344	726.724	314.614	9.786	8088.885	6.215	756.929	63.071
Xb CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.347	42.445	9588.866	0.346	2.365	26119.406	0.946	2.876

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 05-06-1987 TIME: 11:16:37 THRU 11:52:41 FILE: CHANNEL
CONSECUTIVE SCANS: 41 THRU 53

Test Point Number 16
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.07	12.88	0.00
PIST STROKE	-0.56	17.19	-93.32
MOTOR VOLTS	0.77	86.98	90.38
MOTOR AMPS	0.17	0.66	23.24
COMP SP PRES	59.84	6.86	-106.21
LSGS PRESS	60.37	4.16	1.99
HSGS PRESS	59.75	4.72	-174.18
L/H CYL PRES	6.10	4.67	111.80
R/H CLY PRES	6.03	4.93	-68.80
LGS PRESS	59.64	2.26	87.09
AC-1	-0.53	1.11	88.12

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.55	14.19	3.15	312.08	9.32	10.76	59.82	66.58
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.43	57.09	186.13	58.80	56.57	28.11	0.00	21.25

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
23.0	61.0	723.8	119.2	763.8	188.0	167.0	35.3
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
29.0	72.8	7.8	41.0	22.0	753.2	754.5	729.9
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
723.1	717.8	691.3	685.2	741.6	716.8	733.1	735.6
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
727.6	733.8	758.1	766.0	717.5	753.7		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.082	23.204	47.205	192.339	3.457	487.038	31.606	110.327
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1827.652	5714.232	0.187	721.749	745.208	30.980	0.805	0.535
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1264.594	728.738	341.426	12.413	9767.705	6.867	766.000	80.769
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.001	39.828	24567.305	0.737	3.945	45541.477	1.366	4.650

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-06-1987 TIME: 12:20:16 THRU 12:59:36 FILE: CHANNEL
CONSECUTIVE SCANS: 54 THRU 67

Test Point Number 16
Piston Stroke = 15.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.02	9.79	0.00
PIST STROKE	-0.46	15.12	-94.12
MOTOR VOLTS	0.74	59.43	75.24
MOTOR AMPS	0.19	2.73	-97.56
COMP SP PRES	60.05	6.09	-104.53
LSGS PRESS	60.33	3.15	2.29
HSGS PRESS	59.88	3.64	-173.51
L/H CYL PRES	6.23	4.47	103.98
R/H CLY PRES	6.05	4.69	-76.12
LGS PRESS	59.91	2.02	86.74
AC-1	-0.52	0.70	87.32

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.41	9.93	3.08	195.44	5.22	6.21	59.86	65.51

UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
57.90	57.31	185.45	59.74	57.02	26.60	0.00	21.33

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	66.4	668.1	124.8	702.6	181.6	164.4	32.0

Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.0	71.1	8.9	40.6	22.0	754.0	747.9	737.4

Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
726.6	719.9	702.4	699.5	720.6	716.2	738.6	738.4

Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b
730.9	736.1	739.4	749.4	685.4	753.9

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.516	21.624	31.532	126.518	-78.932	333.441	31.606	110.506

PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1175.950	4294.621	0.165	452.457	472.823	33.510	0.790	0.391

QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
647.964	726.295	268.417	8.452	7144.636	5.273	754.000	68.643

Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
15.109	38.839	15420.108	0.632	3.844	30475.096	1.249	4.490

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-07-1987 TIME: 09:25:41 THRU 10:04:57 FILE: CHANNEL
CONSECUTIVE SCANS: 82 THRU 95

Test Point Number 16A
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.11	14.82	0.00
FIST STROKE	-0.62	17.19	-95.93
MOTOR VOLTS	0.74	102.17	100.89
MOTOR AMPS	0.19	2.93	102.24
COMP SP PRES	59.66	7.05	-110.63
LSGS PRESS	60.34	4.80	2.01
HSGS PRESS	59.63	5.38	-174.77
L/H CYL PRES	7.13	4.53	116.80
R/H CLY PRES	7.10	4.69	-63.83
LGS PRESS	59.39	2.26	84.76
AC-1	-0.53	1.32	85.92

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.62	16.09	3.07	490.55	11.17	13.13	59.74	66.72
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.50	75.55	186.73	58.83	56.26	28.89	0.00	21.20

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	59.0	744.1	115.8	779.8	191.3	168.1	37.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
30.0	67.0	14.3	41.3	23.0	751.3	749.5	720.4
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
718.3	715.3	688.9	682.1	746.4	715.4	729.1	728.2
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
718.6	726.6	762.9	763.3	729.3	742.6		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.794	23.821	63.283	225.794	146.864	558.527	31.606	111.451
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2126.255	6231.692	0.195	886.603	903.122	32.381	0.843	0.597
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1458.643	725.819	463.542	14.219	10886.890	7.694	763.429	81.286
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.006	37.850	39167.680	1.054	5.402	62868.105	1.692	6.177

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-07-1987 TIME: 11:06:06 THRU 11:45:16 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 14

Test Point Number 16A
Piston Stroke = 14.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.01	10.87	0.00
PIST STROKE	-0.49	14.14	-93.43
MOTOR VOLTS	0.74	68.56	86.50
MOTOR AMPS	0.18	0.99	-111.85
COMP SP PRES	59.99	5.74	-107.32
LSGS PRESS	60.32	3.50	2.15
HSGS PRESS	59.91	3.99	-173.83
L/H CYL PRES	7.30	4.28	110.80
R/H CLY PRES	7.43	4.50	-69.48
LGS PRESS	59.94	1.87	86.97
AC-1	-0.53	0.70	87.95

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.42	10.24	3.04	313.56	5.53	6.45	59.87	65.81

UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.23	76.16	186.38	58.87	56.78	26.44	0.00	21.30

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
29.0	67.0	672.0	123.4	712.6	181.4	162.4	32.0

Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.3	64.8	14.0	39.8	23.0	753.1	747.9	735.3

Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
726.7	721.2	702.7	698.8	724.8	716.4	737.4	737.0

Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b
731.2	737.1	742.9	751.4	689.4	752.0

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.456	21.740	36.538	146.380	-30.600	344.280	31.606	111.403

PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1365.047	4120.052	0.186	529.975	550.789	19.109	0.794	0.400

QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
960.851	726.952	491.586	8.702	7325.708	5.139	753.071	63.714

Xo CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.005	33.768	25020.639	1.001	5.381	40613.062	1.625	6.163

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 06-03-1987 TIME: 09:11:05 THRU 09:50:38 FILE: CHANNEL
CONSECUTIVE SCANS: 28 THRU 41

Test Point Number 16A
Piston Stroke = 12.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.21	8.18	0.00
PIST STROKE	-0.63	12.32	-92.05
MOTOR VOLTS	0.74	48.93	76.43
MOTOR AMPS	0.36	2.18	-103.68
COMP SP PRES	60.11	4.83	-103.77
LSGS PRESS	60.25	2.64	2.56
HSGS PRESS	59.90	3.00	-172.34
L/H CYL PRES	7.66	4.04	105.82
R/H CLY PRES	7.56	4.23	-74.34
LGS PRESS	60.10	1.62	88.57
AC-1	-0.49	0.50	91.15

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.31	9.19	3.06	190.83	3.68	4.99	59.79	65.16
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.79	76.18	185.33	59.70	57.23	25.23	0.00	21.14

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
30.0	68.1	648.0	104.9	688.2	151.3	136.8	29.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
25.0	61.8	15.5	35.7	23.9	749.8	741.8	737.5
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
727.2	724.1	709.4	705.6	723.9	720.8	735.1	734.2
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
733.1	737.9	730.1	740.1	674.6	747.8		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.692	26.202	24.841	102.983	-52.764	222.277	31.606	111.658
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
841.375	3304.625	0.159	324.195	336.127	20.288	0.793	0.296
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
631.280	725.419	122.924	7.756	5305.872	4.089	749.786	75.214
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
12.081	21.103	15276.239	0.843	5.356	26457.822	1.461	5.914

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-07-1987 TIME: 12:40:01 THRU 13:19:17 FILE: CHANNEL
CONSECUTIVE SCANS: 15 THRU 28

Test Point Number 17A
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.04	12.65	0.00
PIST STROKE	-0.65	17.29	-87.99
MOTOR VOLTS	0.72	84.37	88.48
MOTOR AMPS	0.15	0.54	-87.93
COMP SP PRES	59.91	6.67	-100.88
LSGS PRESS	60.42	4.09	1.89
HSGS PRESS	59.80	4.64	-173.76
L/H CYL PRES	6.49	5.30	113.42
R/H CLY PRES	6.31	5.68	-66.49
LGS PRESS	59.61	2.26	92.97
AC-1	-0.53	0.69	96.97

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.55	14.06	3.02	270.99	8.99	10.63	59.96	66.20

UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
57.55	57.11	213.17	59.84	56.99	28.25	0.00	21.36

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
29.0	62.0	722.5	119.7	763.3	189.9	166.9	36.0

Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
29.0	79.9	7.9	41.9	23.0	749.0	752.1	728.5

Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
722.4	717.1	692.4	687.4	743.9	719.0	734.8	736.0

Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b
727.9	734.2	756.9	766.6	718.5	751.3

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.632	23.107	43.704	200.841	-17.027	480.326	34.627	110.329

PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1792.790	5502.682	0.185	710.694	763.452	47.436	0.825	0.530

QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1247.052	729.138	481.790	12.245	9699.896	6.887	766.571	79.143

Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
16.986	39.630	20514.600	0.619	3.358	40458.684	1.222	4.009

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 06-03-1987 TIME: 11:59:04 THRU 12:38:23 FILE: CHANNEL
CONSECUTIVE SCANS: 56 THRU 69

Test Point Number 17A
Piston Stroke = 15.2 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.13	9.45	0.00
PIST STROKE	-0.90	15.70	-87.67
MOTOR VOLTS	0.76	57.50	72.04
MOTOR AMPS	0.38	3.16	-97.73
COMP SP PRES	59.90	5.89	-97.98
LSGS PRESS	60.25	3.05	2.10
HSGS PRESS	59.77	3.51	-172.67
L/H CYL PRES	6.87	5.09	106.76
R/H CLY PRES	6.41	5.44	-73.37
LGS PRESS	59.71	2.03	92.90
AC-1	-0.49	0.29	105.09

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.40	9.60	3.02	159.97	4.83	5.60	59.79	66.17
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.73	57.38	212.02	59.19	57.51	26.66	0.00	21.39

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
30.0	67.6	659.4	124.0	694.1	180.5	161.5	32.4
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.0	79.6	11.7	44.6	23.0	757.6	753.0	741.6
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
729.0	723.7	702.8	697.9	724.9	715.7	734.9	735.1
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
733.7	739.6	736.8	746.6	677.5	752.1		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.021	21.450	27.273	134.306	-87.841	321.842	34.627	111.008
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1145.082	4204.146	0.168	419.680	444.912	26.661	0.764	0.379
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
800.401	726.129	147.428	8.135	6810.042	5.273	757.571	80.071
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
15.214	47.390	12218.884	0.526	3.153	26657.068	1.147	3.731

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-30-1987 TIME: 13:47:11 THRU 14:26:27 FILE: CHANNEL
CONSECUTIVE SCANS: 58 THRU 71

Test Point Number 18
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.10	14.85	0.00
FIST STROKE	-0.45	17.01	-88.73
MOTOR VOLTS	0.69	103.67	101.40
MOTOR AMPS	0.09	3.09	102.62
COMP SP PRES	59.74	6.79	-104.65
LSGS PRESS	60.53	4.85	1.87
HSGS PRESS	59.78	5.36	-174.18
L/H CYL PRES	7.50	5.26	119.97
R/H CLY PRES	7.47	5.49	-60.97
LGS PRESS	59.53	2.26	92.03
AC-1	-0.56	0.90	94.27

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.63	16.38	3.11	447.63	11.56	13.77	59.91	65.97
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
57.79	76.28	213.60	58.85	56.85	29.30	0.00	21.57

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
26.0	56.0	748.8	115.9	790.7	189.2	170.8	38.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
30.0	73.9	13.0	43.0	21.0	747.1	753.3	718.9
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
708.8	709.2	691.4	680.7	759.2	715.4	727.8	729.9
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
724.9	732.7	763.3	764.6	727.3	749.5		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.346	23.737	59.951	252.975	157.696	562.559	34.627	111.231
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2235.249	6352.410	0.201	924.093	934.998	36.027	0.832	0.615
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1524.600	726.914	402.373	14.609	11102.327	7.721	764.714	84.000
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.007	48.424	34290.586	0.905	4.496	58306.250	1.539	5.228

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-30-1987 TIME: 09:07:25 THRU 09:46:53 FILE: CHANNEL
CONSECUTIVE SCANS: 30 THRU 43

Test Point Number 18
Piston Stroke = 14.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.00	10.11	0.00
PIST STROKE	-0.29	13.99	-86.37
MOTOR VOLTS	0.71	63.69	81.35
MOTOR AMPS	0.09	1.73	-98.54
COMP SP PRES	59.86	5.48	-99.28
LSGS PRESS	60.28	3.26	2.10
HSGS PRESS	59.89	3.68	-172.83
L/H CYL PRES	7.62	4.85	112.07
R/H CLY PRES	7.52	5.15	-67.83
LGS PRESS	59.88	1.88	94.42
AC-1	-0.54	0.22	110.13

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.40	9.28	3.09	231.27	4.99	5.61	59.67	65.34
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
61.35	75.24	212.75	58.57	57.48	26.34	0.00	21.36

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
26.6	64.2	661.9	107.4	701.9	162.1	146.4	30.9
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
26.9	82.0	28.0	38.9	22.0	756.8	757.8	748.7
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
734.1	725.1	699.9	693.4	733.4	715.5	728.9	731.5
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
734.1	743.6	732.6	742.4	676.2	755.8		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.099	20.497	31.295	147.480	-53.555	319.246	84.252	188.538
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1227.940	4059.560	0.177	468.959	500.752	26.607	0.792	0.386
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
699.474	726.343	458.395	7.920	6946.253	4.977	757.786	81.571
Xo CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.044	34.149	18278.408	0.771	4.371	33027.559	1.393	5.081

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-29-1987 TIME: 15:57:37 THRU 16:37:04 FILE: CHANNEL
CONSECUTIVE SCANS: 16 THRU 29

Test Point Number 18
Piston Stroke = 12.6 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.02	6.06	0.00
PIST STROKE	-0.41	12.56	-67.63
MOTOR VOLTS	0.71	43.04	71.24
MOTOR AMPS	0.10	3.07	-115.44
COMP SP PRES	60.02	4.92	-98.27
LSGS PRESS	60.25	2.59	2.47
HSGS PRESS	59.96	2.96	-171.88
L/H CYL PRES	7.70	4.68	106.09
R/H CLY PRES	7.78	5.02	-73.26
LGS PRESS	60.06	1.69	93.16
AC-1	-0.53	0.34	-98.09

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.32	8.08	3.12	146.85	3.54	4.41	59.79	65.26
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.60	75.61	212.36	60.03	58.11	25.56	0.00	21.39

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	67.0	637.0	117.7	669.0	168.6	154.1	30.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
26.0	77.9	28.2	38.9	23.0	748.0	747.6	743.0
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
727.0	720.9	699.9	693.7	718.3	713.9	728.0	728.9
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
730.1	738.9	725.4	732.0	657.0	750.8		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.611	22.377	23.529	108.070	-65.374	230.948	25.713	205.443
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
827.031	3433.117	0.152	308.456	345.761	21.293	0.798	0.305
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
636.961	720.524	107.946	6.827	5456.309	4.170	750.766	93.786
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
12.634	31.301	11608.763	0.623	4.137	23273.213	1.249	4.744

LENNOX DATA ACQUISITION TEST AVERAGE OF 15 SCANS
DATE: 04-29-1987 TIME: 11:39:12 THRU 12:21:40 FILE: CHANNEL
CONSECUTIVE SCANS: 71 THRU 85

Test Point Number 19
Piston Stroke = 17.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.25	16.99	0.00
PIST STROKE	-0.64	17.13	-92.60
MOTOR VOLTS	0.66	116.52	111.20
MOTOR AMPS	0.10	6.40	112.70
COMP SP PRES	59.35	7.00	-110.33
LSGS PRESS	60.20	5.49	1.91
HSGS PRESS	59.41	6.05	-174.69
L/H CYL PRES	8.72	4.94	124.16
R/H CLY PRES	8.86	5.13	-56.63
LGS PRESS	59.06	2.25	88.28
AC-1	-0.53	1.15	89.49

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.68	17.04	3.07	693.23	12.71	14.68	59.51	65.66
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.64	98.15	213.18	58.99	56.48	29.57	0.00	21.20

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	57.0	753.9	118.0	805.6	193.0	174.0	40.3
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
30.0	69.0	22.0	47.0	23.0	749.2	749.2	713.0
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
707.3	709.8	689.9	677.0	752.3	706.4	720.2	723.1
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
717.9	728.0	766.1	764.5	729.1	745.1		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.937	22.748	79.032	295.800	372.199	638.552	600.085	-22.698
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2547.850	6784.484	0.213	1076.294	1097.507	41.455	0.853	0.669
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1622.376	723.311	518.432	15.217	11934.873	8.362	766.133	89.133
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.057	54.379	54143.137	1.329	6.226	80701.258	1.981	7.016

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-29-1987 TIME: 12:59:07 THRU 13:38:31 FILE: CHANNEL
CONSECUTIVE SCANS: 86 THRU 99

Test Point Number 19
Piston Stroke = 14.2 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.12	12.78	0.00
FIST STROKE	-0.42	14.10	-89.32
MOTOR VOLTS	0.69	86.36	96.84
MOTOR AMPS	0.09	1.46	111.01
COMP SP PRES	59.50	5.71	-106.53
LSGS PRESS	60.09	4.13	2.02
HSGS PRESS	59.60	4.60	-173.99
L/H CYL PRES	8.94	4.67	120.38
R/H CLY PRES	9.12	4.87	-59.56
LGS PRESS	59.46	1.88	91.66
AC-1	-0.53	0.69	93.48

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.48	11.31	3.02	479.56	6.76	7.76	59.63	64.57
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
56.02	98.44	212.30	59.14	56.92	27.49	0.00	21.57

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	63.6	683.4	123.4	728.9	184.3	166.9	33.6
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.5	67.0	22.0	42.5	23.0	761.1	772.4	754.8
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
743.4	734.5	698.1	687.1	727.8	702.9	720.2	724.8
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
729.6	742.3	753.1	747.4	687.2	748.4		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.400	21.156	47.644	192.950	60.203	403.632	221.359	-21.014
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1690.951	4727.900	0.206	706.553	738.002	32.183	0.854	0.460
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
992.931	726.757	277.843	9.732	8218.660	5.919	772.429	85.643
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.180	41.237	37454.723	1.335	6.491	55380.562	1.974	7.220

LENNOX DATA ACQUISITION TEST AVERAGE OF 15 SCANS
DATE: 04-29-1987 TIME: 14:43:03 THRU 15:25:30 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 15

Test Point Number 19
Piston Stroke = 10.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.07	6.85	0.00
PIST STROKE	-0.27	9.80	-80.77
MOTOR VOLTS	0.69	39.89	81.46
MOTOR AMPS	0.10	1.48	-118.88
COMP SP PRES	59.92	3.77	-93.47
LSGS PRESS	60.11	2.20	2.68
HSGS PRESS	59.83	2.45	-169.87
L/H CYL PRES	9.15	4.14	112.92
R/H CLY PRES	9.47	4.36	-65.80
LGS PRESS	60.01	1.34	100.07
AC-1	-0.52	0.27	-93.82

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.25	8.00	3.16	153.61	2.87	4.27	59.68	63.89
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
60.96	99.57	212.12	59.19	58.11	24.64	0.00	21.48

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.3	67.0	639.4	117.5	668.3	164.9	151.1	31.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
25.0	61.0	21.9	38.9	23.0	749.1	748.8	747.5
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
734.0	729.9	714.0	709.5	724.0	724.0	734.2	735.8
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
737.2	744.1	732.0	735.5	665.3	752.2		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.637	28.311	18.478	94.498	-27.107	131.888	9.849	208.877
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
596.625	2647.481	0.140	215.378	247.258	15.802	0.776	0.238
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
613.059	727.947	64.593	6.749	4257.939	3.164	752.200	86.933
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
9.983	31.500	11993.973	0.825	5.893	20686.277	1.423	6.389

LENNOX DATA ACQUISITION TEST AVERAGE OF 16 SCANS
DATE: 04-29-1987 TIME: 09:38:34 THRU 10:21:46 FILE: CHANNEL
CONSECUTIVE SCANS: 55 THRU 70

Test Point Number 20
Piston Stroke = 17.4 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.05	12.63	0.00
PIST STROKE	-0.47	17.46	-76.19
MOTOR VOLTS	0.70	83.93	89.39
MOTOR AMPS	0.08	0.45	-111.56
COMP SP PRES	59.50	6.36	-89.40
LSGS PRESS	60.09	4.09	1.54
HSGS PRESS	59.42	4.54	-172.89
L/H CYL PRES	7.35	6.72	119.21
R/H CLY PRES	6.79	7.17	-61.93
LGS PRESS	59.17	2.30	104.28
AC-1	-0.51	0.62	-91.78

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.55	13.24	3.08	202.98	8.65	9.95	59.58	66.17
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
57.82	57.00	276.34	59.06	58.14	28.08	0.00	21.35

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.5	62.3	712.3	114.1	760.9	181.6	161.9	36.8
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
29.0	95.3	11.9	44.3	23.1	759.4	767.4	742.8
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
737.1	729.9	692.9	681.7	745.5	706.6	719.1	723.1
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
723.6	735.7	756.1	753.0	705.4	744.2		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.579	21.704	36.142	227.244	-13.313	473.426	196.512	201.558
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1821.596	5469.726	0.192	681.828	674.271	30.653	0.747	0.530
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1134.884	726.433	538.367	11.509	9474.019	6.733	767.375	85.688
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.391	45.893	14248.913	0.441	2.296	33664.148	1.041	2.867

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-26-1987 TIME: 16:33:02 THRU 17:09:38 FILE: CHANNEL
CONSECUTIVE SCANS: 42 THRU 54

Test Point Number 21
Piston Stroke = 17.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.07	15.96	0.00
FIST STROKE	-0.62	17.14	-73.83
MOTOR VOLTS	0.73	107.93	105.11
MOTOR AMPS	0.13	4.13	114.99
COMP SP PRES	59.34	6.14	-92.27
LSGS PRESS	60.15	5.19	1.64
HSGS PRESS	59.34	5.62	-173.52
L/H CYL PRES	8.41	6.81	128.25
R/H CLY PRES	8.38	7.34	-51.81
LGS PRESS	59.04	2.25	107.00
AC-1	-0.53	0.11	0.75

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.64	15.74	3.13	376.26	11.29	12.92	59.59	65.78
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.60	75.61	277.45	58.20	57.62	29.07	0.00	21.54

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	59.3	741.8	117.9	789.5	191.7	171.1	40.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
29.0	89.0	14.0	46.0	23.8	750.5	751.5	714.1
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
712.0	714.5	693.6	679.8	746.5	704.6	719.6	723.7
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
723.7	732.1	767.5	765.1	722.8	744.8		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.150	22.402	61.532	321.792	219.060	572.087	392.906	-24.994
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2370.189	6220.706	0.214	951.943	1023.832	39.494	0.835	0.622
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1458.003	724.292	500.003	13.925	11052.880	7.533	767.538	87.769
Xo CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.065	49.106	26546.854	0.704	3.285	50166.348	1.330	3.975

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-28-1987 TIME: 15:24:22 THRU 16:03:26 FILE: CHANNEL
CONSECUTIVE SCANS: 28 THRU 41

Test Point Number 21
Piston Stroke = 14.7 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.00	10.98	0.00
PIST STROKE	-0.43	14.59	-61.93
MOTOR VOLTS	0.70	92.65	87.10
MOTOR AMPS	0.10	2.66	4.07
COMP SP PRES	59.63	4.91	-75.38
LSGS PRESS	60.07	3.57	1.53
HSGS PRESS	59.52	3.86	-171.16
L/H CYL PRES	8.75	6.53	130.09
R/H CLY PRES	8.73	7.05	-49.19
LGS PRESS	59.48	1.95	118.50
AC-1	-0.53	0.60	-72.89

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.40	9.19	3.02	174.51	4.84	5.53	59.54	65.69
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.05	76.03	277.18	60.10	58.04	26.36	0.00	21.33

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	67.4	660.6	121.6	694.0	176.4	160.9	33.3
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.0	83.1	13.8	43.0	23.0	758.0	762.6	748.4
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
738.7	732.4	699.8	688.9	722.7	704.3	718.4	722.6
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
732.0	742.1	747.2	740.5	674.4	745.6		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.668	20.245	27.317	208.424	15.013	307.599	80.619	85.934
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1208.101	4011.464	0.177	438.208	501.446	35.093	0.781	0.385
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
765.458	723.871	431.996	7.798	6837.059	5.031	762.571	88.143
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.659	42.646	12306.128	0.527	2.994	26186.998	1.122	3.539

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-28-1987 TIME: 11:35:35 THRU 12:11:35 FILE: CHANNEL
CONSECUTIVE SCANS: 76 THRU 88

Test Point Number 22
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.06	18.28	0.00
PIST STROKE	-0.62	17.14	-75.67
MOTOR VOLTS	0.70	127.89	113.16
MOTOR AMPS	0.10	7.53	111.29
COMP SP PRES	59.39	6.22	-97.48
LSGS PRESS	60.25	5.94	1.60
HSGS PRESS	59.36	6.40	-174.06
L/H CYL PRES	9.74	6.69	132.38
R/H CLY PRES	9.81	7.12	-48.26
LGS PRESS	58.93	2.24	104.88
AC-1	-0.52	0.48	115.10

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.69	15.69	3.02	574.89	12.45	13.13	59.64	65.78

UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
57.73	97.89	277.34	58.86	57.17	29.85	0.00	21.48

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
26.0	59.1	745.9	122.9	806.9	197.6	174.1	42.4

Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
30.4	84.0	21.0	45.6	23.0	755.5	753.3	714.4

Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
715.0	717.3	692.1	677.3	743.9	699.7	722.1	726.3

Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b
724.4	732.7	771.6	770.1	723.9	748.7

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.755	20.417	78.198	382.511	480.652	654.235	624.551	-21.289

PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2795.676	6686.732	0.230	1161.046	1209.697	30.643	0.848	0.682

QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1489.768	725.297	846.811	13.926	12136.771	8.373	771.692	94.385

Ap CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.034	50.256	41231.711	0.995	4.322	67840.156	1.637	5.077

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-28-1987 TIME: 13:04:01 THRU 13:43:12 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 14

Test Point Number 22
Piston Stroke = 14.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.03	12.37	0.00
PIST STROKE	-0.43	14.00	-71.56
MOTOR VOLTS	0.68	84.63	95.54
MOTOR AMPS	0.10	1.12	117.00
COMP SP PRES	59.51	5.03	-89.35
LSGS PRESS	60.03	4.01	1.76
HSGS PRESS	59.52	4.38	-172.65
L/H CYL PRES	10.00	6.34	127.15
R/H CLY PRES	10.08	6.72	-52.55
LGS PRESS	59.35	1.87	109.15
AC-I	-0.51	0.73	-77.46

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.44	9.45	3.05	316.04	5.55	5.96	59.53	64.75
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
58.25	98.83	277.93	58.87	58.31	26.50	0.00	20.90

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	66.0	669.4	128.9	710.7	186.3	168.2	34.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
27.0	81.0	22.0	44.2	23.0	763.9	766.9	750.1
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
740.1	733.9	699.0	689.0	730.7	708.8	723.0	728.0
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
734.9	744.0	748.9	747.7	679.6	754.1		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.815	18.856	40.071	222.828	42.842	367.631	146.462	-26.997
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1565.515	4513.834	0.205	631.849	680.377	24.772	0.839	0.428
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
834.386	727.452	218.074	8.079	7618.168	5.596	766.929	87.357
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
14.078	46.136	22717.566	0.873	4.255	39631.004	1.524	4.969

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-28-1987 TIME: 14:14:18 THRU 14:50:30 FILE: CHANNEL
CONSECUTIVE SCANS: 15 THRU 27

Test Point Number 22
Piston Stroke = 12.2 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.02	9.71	0.00
FIST STROKE	-0.51	12.22	-54.04
MOTOR VOLTS	0.70	88.33	91.49
MOTOR AMPS	0.10	3.21	25.39
COMP SP PRES	59.73	3.86	-68.13
LSGS PRESS	59.97	3.14	1.73
HSGS PRESS	59.56	3.36	-170.09
L/H CYL PRES	10.07	6.01	136.16
R/H CLY PRES	10.43	6.46	-42.73
LGS PRESS	59.67	1.63	126.35
AC-1	-0.53	0.60	-61.00

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.30	7.64	2.99	149.74	3.26	4.17	59.68	65.08
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.52	98.61	276.79	58.35	58.37	24.81	0.00	20.81

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	68.0	645.7	129.2	681.3	178.5	164.4	34.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
25.0	75.8	21.8	43.0	23.7	750.6	752.0	744.0
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
734.0	729.4	703.2	696.0	721.1	711.2	726.7	728.6
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
731.2	738.7	737.0	737.5	669.0	745.5		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.771	22.435	24.105	180.089	57.464	205.749	49.920	64.607
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
833.037	3159.310	0.163	287.103	341.905	18.492	0.763	0.288
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
647.072	723.538	195.553	6.457	5107.892	3.998	752.000	83.000
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
12.249	40.695	10758.182	0.617	3.806	21360.113	1.225	4.313

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-07-1987 TIME: 14:04:44 THRU 14:44:00 FILE: CHANNEL
CONSECUTIVE SCANS: 29 THRU 42

Test Point Number 23A
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.13	13.63	0.00
PIST STROKE	-0.76	17.43	-66.66
MOTOR VOLTS	0.76	95.94	97.99
MOTOR AMPS	0.18	1.95	105.95
COMP SP PRES	59.79	5.90	-81.27
LSGS PRESS	60.47	4.45	1.49
HSGS PRESS	59.71	4.83	-172.29
L/H CYL PRES	8.27	7.47	127.27
R/H CLY PRES	7.68	8.22	-52.93
LGS PRESS	59.47	2.26	114.39
AC-1	-0.51	1.56	-75.05

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.55	14.21	3.08	206.79	9.18	10.83	59.93	65.11
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
60.23	62.77	290.47	58.65	58.52	28.08	0.00	20.98

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.3	62.0	727.6	121.2	766.9	191.1	169.2	37.8
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
29.0	99.0	13.8	46.7	23.0	748.8	756.7	728.8
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
724.2	720.1	690.7	684.1	744.0	714.4	732.4	733.7
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
727.4	734.5	766.4	767.4	723.6	747.4		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSFOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
59.103	23.111	41.579	285.337	89.187	472.370	44.064	111.366
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1843.030	5785.703	0.188	679.431	736.922	72.979	0.779	0.535
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1278.296	729.267	397.045	12.366	9787.798	7.103	767.571	83.500
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.048	53.522	13917.278	0.417	2.231	34208.676	1.024	2.793

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-27-1987 TIME: 11:24:07 THRU 12:00:53 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 13

Test Point Number 24
Piston Stroke = 16.9 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.07	16.00	0.00
PIST STROKE	-0.49	16.92	-62.76
MOTOR VOLTS	0.68	121.86	104.46
MOTOR AMPS	0.09	4.74	90.42
COMP SP PRES	59.78	5.58	-81.34
LSGS PRESS	60.54	5.25	1.49
HSGS PRESS	59.71	5.63	-173.06
L/H CYL PRES	9.06	7.53	134.62
R/H CLY PRES	8.83	8.19	-44.64
LGS PRESS	59.35	2.24	118.07
AC-1	-0.53	0.58	-79.58

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.58	12.96	3.11	307.12	9.42	10.05	59.90	65.84
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
61.31	76.68	290.47	57.74	58.03	28.14	0.00	20.90

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.1	63.0	733.7	120.7	760.8	184.0	165.3	39.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
39.0	95.8	14.0	46.0	23.0	732.2	752.8	722.0
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
705.8	698.0	687.5	682.2	753.5	708.3	730.5	732.7
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
733.6	737.9	741.5	766.8	725.5	756.4		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.547	19.856	57.039	347.817	279.935	519.352	374.752	-0.422
PV POWER	**QREJ**	**WENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2166.804	5946.173	0.211	835.404	946.580	39.706	0.824	0.569
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1142.157	725.492	626.908	11.291	10260.433	7.243	766.846	84.692
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
16.923	51.396	20920.723	0.597	2.831	43210.152	1.234	3.513

LENNOX DATA ACQUISITION TEST AVERAGE OF 6 SCANS
DATE: 04-27-1987 TIME: 12:54:17 THRU 13:09:26 FILE: CHANNEL
CONSECUTIVE SCANS: 14 THRU 19

Test Point Number 24
Piston Stroke = 15.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.03	16.97	0.00
PIST STROKE	-0.56	15.12	-64.05
MOTOR VOLTS	0.69	75.16	86.20
MOTOR AMPS	0.08	0.81	-84.03
COMP SP PRES	59.64	5.13	-76.47
LSGS PRESS	60.01	3.55	1.56
HSGS PRESS	59.51	3.86	-171.40
L/H CYL PRES	9.23	7.28	126.58
R/H CLY PRES	9.15	7.99	-52.86
LGS PRESS	59.42	2.00	117.04
AC-1	-0.51	2.92	-72.48

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.41	9.52	3.14	156.42	5.24	6.08	59.57	65.48
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
60.34	76.95	290.47	58.64	59.24	26.20	0.00	20.74

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	67.0	673.0	127.7	706.0	178.7	163.0	34.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
26.0	90.5	14.8	47.0	23.0	744.8	749.3	735.7
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
724.0	716.7	694.0	689.0	727.3	704.0	728.0	731.0
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
736.2	741.5	732.0	746.0	687.0	751.7		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
59.637	20.343	28.266	206.346	-28.882	328.077	63.989	174.033
PV POWER	**QREJ**	**WENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1223.551	4534.357	0.171	453.339	523.639	42.027	0.806	0.399
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
807.871	722.933	52.366	8.116	7145.500	5.461	751.667	64.667
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
15.107	54.379	10606.450	0.435	2.559	25933.494	1.063	3.082

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-27-1987 TIME: 14:00:16 THRU 14:39:24 FILE: CHANNEL
CONSECUTIVE SCANS: 20 THRU 33

Test Point Number 25
Piston Stroke = 16.2 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.01	18.08	0.00
PIST STROKE	-0.62	16.21	-64.15
MOTOR VOLTS	0.74	136.47	115.74
MOTOR AMPS	0.09	8.93	105.62
COMP SP PRES	59.56	5.35	-88.03
LSGS PRESS	60.24	5.91	1.53
HSGS PRESS	59.42	6.30	-173.56
L/H CYL PRES	10.47	7.47	138.44
R/H CLY PRES	10.56	8.08	-41.38
LGS PRESS	59.18	2.14	116.63
AC-1	-0.50	0.24	-94.76

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.62	12.11	3.12	465.01	9.59	9.12	59.60	65.21
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
61.08	98.97	290.47	57.60	57.72	28.68	0.00	20.71

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	63.0	726.7	129.9	765.1	193.3	174.5	42.4
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
29.0	90.1	21.0	48.0	23.0	740.9	753.1	719.6
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
709.9	702.9	686.1	681.4	750.6	705.6	728.1	730.4
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
734.2	740.2	743.1	763.4	719.6	755.8		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.292	17.499	74.448	407.016	599.440	566.346	614.530	-15.621
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2509.181	6555.531	0.235	1013.992	1104.911	33.844	0.845	0.601
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1133.304	724.729	399.656	10.517	10699.568	7.963	763.429	82.071
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
16.163	57.420	31855.299	0.872	3.720	57212.973	1.566	4.460

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-27-1987 TIME: 15:07:13 THRU 15:46:13 FILE: CHANNEL
CONSECUTIVE SCANS: 34 THRU 47

Test Point Number 25
Piston Stroke = 14.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.04	13.38	0.00
FIST STROKE	-0.50	14.07	-57.77
MOTOR VOLTS	0.71	102.08	101.34
MOTOR AMPS	0.09	3.14	87.93
COMP SP PRES	59.52	4.48	-77.09
LSGS PRESS	60.10	4.35	1.54
HSGS PRESS	59.51	4.64	-172.26
L/H CYL PRES	10.70	7.23	136.59
R/H CLY PRES	10.86	7.78	-42.06
LGS PRESS	59.32	1.87	122.96
HC-1	-0.54	1.32	-65.23

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.43	7.76	3.08	265.67	4.90	4.66	59.61	66.16
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.63	99.56	290.47	59.17	58.45	26.20	0.00	20.79

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	67.2	664.6	144.8	689.7	195.6	180.1	35.7
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
26.2	87.0	22.0	47.1	23.0	757.9	753.0	743.2
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
728.7	722.4	701.1	697.3	731.6	712.6	732.9	736.9
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
742.7	748.4	732.7	750.0	684.1	762.5		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
59.126	16.145	41.342	269.854	155.013	347.141	182.293	2.070
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1522.649	4398.167	0.210	560.762	659.165	26.076	0.802	0.407
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
735.926	728.472	291.191	6.579	7245.086	5.408	762.500	78.357
Xo CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.121	54.596	18242.336	0.738	3.514	34273.262	1.386	4.144

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-27-1987 TIME: 16:33:52 THRU 17:13:28 FILE: CHANNEL
CONSECUTIVE SCANS: 48 THRU 61

Test Point Number 25
Piston Stroke = 13.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.05	12.13	0.00
FIST STROKE	-0.54	13.04	-43.42
MOTOR VOLTS	0.70	119.13	99.87
MOTOR AMPS	0.10	6.04	50.26
COMP SP PRES	59.65	3.65	-59.07
LSGS PRESS	60.02	3.94	1.42
HSGS PRESS	59.48	4.11	-170.82
L/H CYL PRES	10.62	6.90	145.49
R/H CLY PRES	11.01	7.50	-33.16
LGS PRESS	59.43	1.73	137.13
AC-1	-0.54	0.60	-50.70

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.32	6.39	3.03	141.88	3.18	3.35	59.56	64.98
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
60.75	99.60	290.47	58.48	58.28	25.29	0.00	21.09

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	68.8	646.9	146.4	669.0	190.9	177.1	38.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
26.0	82.7	21.7	46.0	23.0	744.0	738.0	732.2
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
719.1	716.0	700.9	698.7	725.9	715.4	728.7	729.1
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
734.1	740.3	723.0	733.3	675.3	750.5		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.731	17.732	30.943	254.900	232.885	224.283	139.382	39.743
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
930.879	3358.904	0.172	307.102	383.993	36.427	0.763	0.303
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
588.153	721.495	422.203	5.374	5400.887	4.197	750.500	75.214
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
13.059	51.380	9735.353	0.528	3.125	20914.962	1.134	3.585

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 06-03-1987 TIME: 16:31:16 THRU 17:10:32 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 14

Test Point Number 26
Piston Stroke = 17.3 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.05	18.20	0.00
PIST STROKE	-1.12	18.13	-83.37
MOTOR VOLTS	0.72	136.82	111.81
MOTOR AMPS	0.37	7.94	99.03
COMP SP PRES	59.45	6.70	-103.39
LSGS PRESS	60.37	5.95	1.79
HSGS PRESS	59.44	6.47	-174.33
L/H CYL PRES	9.39	5.85	130.55
R/H CLY PRES	9.26	6.15	-50.33
LGS PRESS	59.01	2.28	97.87
AC-1	-0.50	1.09	98.98

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.75	19.91	3.07	657.26	15.11	18.13	59.80	61.84
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.73	97.80	244.73	56.95	56.57	30.24	0.00	21.14

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
29.0	55.3	771.6	117.5	807.9	202.9	181.9	42.9
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
31.0	76.9	21.9	46.4	24.0	748.4	757.9	716.1
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
713.0	711.6	687.9	678.1	757.4	704.2	715.4	717.1
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
715.0	726.8	778.5	762.9	752.3	734.3		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.051	24.743	86.217	362.221	528.070	680.098	37.705	112.706
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2780.487	7365.521	0.215	1206.717	1239.679	60.210	0.882	0.729
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
2013.500	724.705	343.225	18.032	12940.886	9.093	778.500	100.429
Xb CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.273	49.479	49295.848	1.116	5.203	77895.414	1.763	5.966

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 06-03-1987 TIME: 17:44:43 THRU 18:23:47 FILE: CHANNEL
CONSECUTIVE SCANS: 15 THRU 28

Test Point Number 26
Piston Stroke = 14.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.17	12.72	0.00
PIST STROKE	-0.83	14.46	-79.46
MOTOR VOLTS	0.76	90.53	99.28
MOTOR AMPS	0.37	2.18	98.56
COMP SP PRES	59.73	5.36	-98.04
LSGS PRESS	60.28	4.16	1.90
HSGS PRESS	59.71	4.53	-172.86
L/H CYL PRES	9.64	5.49	124.40
R/H CLY PRES	9.61	5.83	-55.72
LGS PRESS	59.56	1.88	100.93
AC-1	-0.49	0.29	107.22

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.48	12.22	3.02	404.71	6.86	8.33	59.88	64.43
UUC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.75	98.06	242.62	59.23	57.51	26.82	0.00	20.93

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
29.0	64.4	692.3	122.8	725.2	186.6	167.0	33.9
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.0	74.4	22.0	43.5	24.0	751.2	755.8	734.9
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
727.1	723.1	701.4	694.0	740.1	714.4	724.8	725.0
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
728.1	734.4	757.1	747.9	703.7	745.1		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.954	22.861	45.415	226.989	96.507	393.435	37.705	112.730
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1718.350	4700.594	0.210	680.694	719.465	28.630	0.818	0.460
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1071.318	726.748	269.115	10.511	8176.210	5.892	757.143	63.143
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.110	41.237	30363.604	1.088	5.195	48403.707	1.734	5.948

LENNOX DATA ACQUISITION TEST AVERAGE OF 9 SCANS
DATE: 06-03-1987 TIME: 19:02:59 THRU 19:44:34 FILE: CHANNEL
CONSECUTIVE SCANS: 29 THRU 37

Test Point Number 26
Piston Stroke = 12.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.21	9.46	0.00
PIST STROKE	-0.76	12.40	-76.50
MOTOR VOLTS	0.74	63.28	89.04
MOTOR AMPS	0.32	0.66	44.66
COMP SP PRES	59.82	4.45	-91.67
LSGS PRESS	60.09	3.02	2.08
HSGS PRESS	59.68	3.31	-171.10
L/H CYL PRES	9.86	5.23	120.70
R/H CLY PRES	9.74	5.54	-58.12
LGS PRESS	59.79	1.61	104.84
AC-1	-0.49	0.33	-83.19

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.34	9.96	3.11	239.46	4.35	5.90	59.67	62.92
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
59.65	98.78	243.81	59.53	58.11	25.24	0.00	21.05

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
30.0	67.0	665.2	118.1	692.0	173.2	156.4	31.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
25.0	71.6	22.0	40.0	23.1	755.1	751.4	741.7
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
734.6	732.4	713.9	708.6	727.3	718.2	733.1	733.1
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
733.1	738.8	751.9	743.2	688.6	746.0		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.637	26.032	27.048	154.977	-10.160	248.204	37.705	112.730
FV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1016.684	3441.754	0.176	411.062	464.451	39.165	0.876	0.325
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
798.970	729.630	58.078	8.450	5776.900	4.185	755.111	66.556
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
12.090	34.043	17965.650	0.911	5.222	30029.539	1.522	5.825

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 06-03-1987 TIME: 15:20:57 THRU 16:00:13 FILE: CHANNEL
CONSECUTIVE SCANS: 84 THRU 97

Test Point Number 27
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.06	15.57	0.00
PIST STROKE	-1.08	17.78	-80.56
MOTOR VOLTS	0.75	110.00	102.57
MOTOR AMPS	0.35	3.58	100.96
COMP SP PRES	59.61	6.38	-97.73
LSGS PRESS	60.34	5.04	1.76
HSGS PRESS	59.52	5.54	-173.67
L/H CYL PRES	8.14	5.98	125.20
R/H CLY PRES	7.90	6.39	-54.96
LGS PRESS	59.24	2.24	100.52
AC-1	-0.49	0.72	103.65

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.64	15.84	3.08	419.61	11.12	12.59	59.79	62.74
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.54	75.99	243.43	59.36	57.06	29.48	0.00	21.55

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
30.0	60.0	734.2	120.3	774.0	196.6	173.1	40.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
30.0	82.0	15.7	46.0	24.0	750.7	755.4	722.5
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
719.4	715.8	687.5	679.5	751.1	708.4	724.1	725.6
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
718.9	728.4	766.5	762.3	729.0	741.3		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.537	22.458	61.775	298.590	196.196	569.005	37.705	111.694
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2259.832	6453.821	0.205	951.367	1010.000	58.141	0.871	0.621
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1480.426	725.343	234.021	13.956	11049.921	7.937	766.500	87.000
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
16.955	48.424	31046.818	0.823	4.036	55610.230	1.474	4.794

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 06-03-1987 TIME: 20:05:52 THRU 20:45:08 FILE: CHANNEL
CONSECUTIVE SCANS: 38 THRU 51

Test Point Number 27
Piston Stroke = 14.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.17	9.91	0.00
FIST STROKE	-0.81	14.39	-77.85
MOTOR VOLTS	0.73	64.71	83.44
MOTOR AMPS	0.34	1.34	-96.91
COMP SP PRES	59.81	5.19	-90.76
LSGS PRESS	60.17	3.20	2.01
HSGS PRESS	59.70	3.54	-171.45
L/H CYL PRES	8.54	5.68	117.09
R/H CLY PRES	8.27	6.07	-62.58
LGS PRESS	59.75	1.87	103.00
AC-1	-0.49	0.35	-91.09

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.39	10.22	3.07	200.41	4.96	6.21	59.70	63.24
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
59.54	76.12	242.72	59.30	58.14	26.31	0.00	21.28

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
30.0	68.0	665.1	118.4	694.1	176.5	158.9	31.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
26.0	78.0	15.3	40.0	24.0	754.0	750.9	737.0
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
729.6	726.9	704.1	698.6	724.1	711.1	723.0	728.0
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
728.0	734.6	749.3	741.8	684.6	743.1		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.571	23.200	29.163	166.723	-41.630	302.875	37.705	111.621
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1173.090	4075.395	0.177	450.981	492.429	51.873	0.823	0.373
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
835.789	724.586	69.565	8.664	6639.191	5.031	754.000	69.357
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
14.027	31.674	14813.451	0.654	3.754	29060.381	1.282	4.367

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 06-03-1987 TIME: 14:02:38 THRU 14:41:45 FILE: CHANNEL
CONSECUTIVE SCANS: 70 THRU 83

Test Point Number 28
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.06	12.02	0.00
FIST STROKE	-1.06	17.85	-82.29
MOTOR VOLTS	0.76	78.28	83.87
MOTOR AMPS	0.35	1.60	-92.82
COMP SP PRES	59.78	6.46	-94.70
LSGS PRESS	60.27	3.84	1.87
HSGS PRESS	59.65	4.31	-172.79
L/H CYL PRES	7.03	5.86	114.43
R/H CLY PRES	6.45	6.36	-65.60
LGS PRESS	59.48	2.26	98.32
AC-1	-0.49	0.19	96.12

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.53	12.60	3.08	213.18	7.85	8.87	59.74	63.10

UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.20	56.97	243.23	59.13	57.58	28.06	0.00	21.39

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
30.0	65.0	698.4	122.0	740.4	188.1	167.0	35.0

Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
29.0	90.0	14.0	44.0	24.0	748.1	759.7	736.1

Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
724.0	717.1	692.8	687.6	747.4	718.4	731.8	731.9

Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b
732.9	738.9	748.4	758.1	705.1	751.9

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.055	21.491	38.973	206.148	-56.565	451.477	37.705	111.403

PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1686.108	5435.406	0.188	624.956	676.707	56.899	0.785	0.505

QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1106.938	728.162	175.853	10.844	8987.811	6.672	759.714	72.143

Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.022	42.646	15710.579	0.512	2.758	34957.793	1.139	3.367

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-16-1987 TIME: 12:01:05 THRU 12:40:46 FILE: CHANNEL
CONSECUTIVE SCANS: 43 THRU 56

Test Point Number 10 (0°F)
Piston Stroke = 17.5 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.02	8.30	0.00
PIST STROKE	0.62	15.74	-98.12
MOTOR VOLTS	0.72	53.98	56.58
MOTOR AMPS	0.12	4.90	-88.67
COMP SP PRES	60.48	7.05	-104.07
LSGS PRESS	60.79	2.68	2.45
HSGS PRESS	60.38	3.25	-173.51
L/H CYL PRES	4.79	4.18	92.37
R/H CLY PRES	3.81	4.65	-88.96
LGS PRESS	60.54	2.37	82.91
AC-1	-0.53	1.33	83.04

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.41	8.57	3.21	57.11	4.61	5.19	60.18	67.37
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
60.90	28.58	184.48	60.96	56.29	27.17	0.01	21.28

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.0	67.9	659.9	124.5	699.9	170.4	158.3	31.4
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
28.0	87.4	15.3	42.4	22.0	739.6	728.4	723.1
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
707.1	701.6	695.7	696.1	736.4	721.5	741.6	741.5
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
736.0	738.8	708.0	740.1	671.3	763.0		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.849	18.320	24.004	94.912	-108.094	324.501	76.363	178.673
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
897.963	4993.757	0.129	283.930	277.041	64.409	0.643	0.393
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
696.548	721.448	-100.677	7.204	6976.724	5.892	763.000	91.714
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.513	43.676	4215.279	0.176	1.412	19916.012	0.836	1.817

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 05-07-1987 TIME: 16:42:42 THRU 17:21:55 FILE: CHANNEL
CONSECUTIVE SCANS: 56 THRU 69

Test Point Number 9 (17°F)
Piston Stroke = 18.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.04	11.92	0.00
PIST STROKE	-0.69	18.22	-91.27
MOTOR VOLTS	0.72	78.31	83.07
MOTOR AMPS	0.18	1.54	-81.59
COMP SP PRES	59.91	7.13	-101.45
LSGS PRESS	60.48	3.83	2.04
HSGS PRESS	59.83	4.38	-173.57
L/H CYL PRES	5.24	4.87	106.29
R/H CLY PRES	4.76	5.29	-71.85
LGS PRESS	59.67	2.40	89.76
AC-1	-0.51	0.98	88.67

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.55	13.84	3.07	201.12	8.89	10.35	59.91	64.68
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
61.10	42.10	198.31	58.92	56.78	28.00	0.00	21.04

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	61.0	716.7	120.9	755.4	189.6	168.1	35.3
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
29.0	88.7	9.0	45.0	23.0	747.0	748.9	726.9
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
721.7	716.5	691.1	685.2	740.7	716.6	731.4	732.1
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
724.6	731.1	757.6	760.8	710.9	749.1		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.275	22.864	41.431	183.138	-55.866	479.498	33.110	110.532
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1596.973	5654.052	0.166	630.203	680.054	54.450	0.824	0.527
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1236.466	726.414	362.595	12.048	9595.099	6.968	760.786	75.571
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
18.006	48.424	15570.855	0.476	2.872	35732.801	1.091	3.565

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-23-1987 TIME: 10:10:46 THRU 10:50:03 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 14

Test Point Number 9 (17°F)
Piston Stroke = 17.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.08	10.10	0.00
PIST STROKE	-0.24	16.95	-93.17
MOTOR VOLTS	0.70	64.02	74.93
MOTOR AMPS	0.11	2.74	-88.61
COMP SP PRES	60.08	6.82	-102.02
LSGS PRESS	60.40	3.25	2.05
HSGS PRESS	59.94	3.78	-173.59
L/H CYL PRES	5.49	4.89	103.40
R/H CLY PRES	4.94	5.13	-78.92
LGS PRESS	59.94	2.29	87.65
AC-1	-0.53	0.75	92.56

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.47	9.72	3.11	148.27	5.92	6.44	59.72	65.62
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
62.02	42.06	198.96	58.99	57.02	27.60	0.00	21.57

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
26.0	64.4	678.4	118.5	717.8	174.4	158.7	31.4
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
28.0	86.0	7.0	37.9	22.0	742.8	747.4	733.4
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
714.7	705.6	690.8	688.9	737.6	714.6	737.3	738.4
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
739.2	744.8	722.6	747.5	684.4	762.7		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.587	18.458	30.100	134.091	-84.133	389.695	134.785	178.609
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1271.598	4952.901	0.157	515.923	467.097	39.980	0.775	0.450
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
806.774	724.176	438.676	8.316	8077.473	6.026	762.714	78.357
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.124	31.321	11426.208	0.414	2.638	28426.951	1.031	3.245

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-23-1987 TIME: 13:14:51 THRU 13:54:05 FILE: CHANNEL
CONSECUTIVE SCANS: 29 THRU 42

Test Point Number 8 (32°F)
Piston Stroke = 17.3 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.16	13.10	0.00
PIST STROKE	-0.28	17.01	-90.22
MOTOR VOLTS	0.72	88.81	92.66
MOTOR AMPS	0.06	0.52	100.09
COMP SP PRES	60.23	6.90	-103.43
LSGS PRESS	60.72	4.27	1.83
HSGS PRESS	60.07	4.82	-174.23
L/H CYL PRES	6.37	5.18	113.74
R/H CLY PRES	6.46	5.47	-66.84
LGS PRESS	59.97	2.31	90.35
AC-1	-0.55	0.77	95.36

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.57	12.56	3.07	313.91	8.68	9.58	60.01	66.36
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
60.91	57.66	205.77	60.33	56.95	28.41	0.00	21.30

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
26.8	63.1	723.6	125.7	763.2	186.9	169.2	34.9
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
28.7	78.0	7.9	38.9	23.1	740.7	757.1	729.8
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
713.0	704.6	690.4	685.5	751.7	711.4	736.6	737.7
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
738.9	744.2	738.4	762.2	715.2	761.6		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.545	19.652	45.990	199.563	21.725	508.749	284.679	-10.089
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1926.897	5763.136	0.194	783.007	808.144	29.279	0.826	0.553
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1127.450	728.076	468.968	10.860	9918.827	7.103	762.357	76.857
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.258	31.118	24063.676	0.711	3.859	45617.668	1.347	4.394

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-23-1987 TIME: 14:56:58 THRU 15:33:30 FILE: CHANNEL
CONSECUTIVE SCANS: 44 THRU 56

Test Point Number 8 (32°F)
Piston Stroke = 15.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.09	9.26	0.00
FIST STROKE	-0.21	14.74	-88.30
MOTOR VOLTS	0.70	56.64	73.07
MOTOR AMPS	0.09	2.84	-91.38
COMP SP PRES	59.93	5.88	-98.70
LSGS PRESS	60.17	2.99	2.14
HSGS PRESS	59.76	3.44	-172.63
L/H CYL PRES	6.62	4.95	107.35
R/H CLY PRES	6.50	5.13	-74.14
LGS PRESS	59.76	2.00	92.43
AC-1	-0.54	0.36	101.06

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.40	9.24	3.05	165.78	4.84	5.80	59.63	65.50
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
59.41	58.01	203.39	58.94	57.39	25.68	0.00	20.52

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	68.0	670.2	128.5	703.0	178.9	164.8	30.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
26.0	74.8	10.0	40.0	24.0	740.4	743.9	735.1
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
717.9	708.9	697.2	696.3	736.0	718.1	740.5	742.0
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
739.2	742.7	721.5	748.0	682.0	761.2		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.947	20.252	26.737	129.490	-80.050	314.020	70.676	181.384
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1135.289	4147.758	0.164	435.378	408.976	29.046	0.745	0.385
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
785.284	725.769	353.415	7.795	6910.487	5.157	761.231	79.231
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
15.003	31.674	12764.167	0.541	3.297	27030.586	1.146	3.873

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-15-1987 TIME: 12:50:06 THRU 13:29:17 FILE: CHANNEL
CONSECUTIVE SCANS: 15 THRU 28

Test Point Number 7 (47°F)
Piston Stroke = 17.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.10	15.14	0.00
PIST STROKE	0.74	15.20	-90.67
MOTOR VOLTS	0.71	109.70	102.55
MOTOR AMPS	0.13	3.68	93.75
COMP SP PRES	59.84	6.91	-106.55
LSGS PRESS	60.71	4.94	1.86
HSGS PRESS	59.96	5.49	-174.55
L/H CYL PRES	7.56	5.22	119.25
R/H CLY PRES	7.67	5.50	-62.21
LGS PRESS	59.79	2.28	90.15
AC-1	-0.51	1.16	91.35

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.61	11.65	3.18	452.95	8.85	8.65	59.91	66.05
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
58.33	74.92	212.77	59.84	56.50	28.60	0.00	21.22

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
25.0	64.0	715.4	129.8	755.2	192.1	174.9	38.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
29.0	74.0	14.4	42.1	22.0	755.6	751.2	722.5
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
720.9	716.2	694.6	687.4	750.1	705.9	728.5	731.2
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
732.1	741.7	746.6	758.6	708.7	754.7		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.027	16.898	61.925	246.134	199.317	575.218	454.556	-3.747
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2267.757	6194.147	0.215	952.712	958.094	39.008	0.843	0.592
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1081.819	726.652	499.582	10.005	10549.817	7.372	758.571	71.143
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.098	43.059	34803.586	0.966	4.497	77280.383	34.627	7.258

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-15-1987 TIME: 14:18:11 THRU 14:57:16 FILE: CHANNEL
CONSECUTIVE SCANS: 29 THRU 42

Test Point Number 7 (47°F)
Piston Stroke = 14 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.01	10.27	0.00
PIST STROKE	0.84	12.47	-86.54
MOTOR VOLTS	0.69	66.25	80.14
MOTOR AMPS	0.13	1.85	-88.75
COMP SF PRES	59.84	5.56	-101.45
LSGS PRESS	60.26	3.31	2.03
HSGS PRESS	59.89	3.76	-173.37
L/H CYL PRES	7.71	4.91	110.71
R/H CLY PRES	7.98	5.22	-69.04
LGS PRESS	59.91	1.89	92.49
AC-1	-0.53	0.50	95.14

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.40	7.87	3.17	243.68	4.38	4.58	59.64	65.46
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.00	75.34	212.63	60.11	57.16	26.47	0.00	21.60

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
26.0	67.0	657.4	139.2	688.1	187.8	173.8	31.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
27.0	72.0	14.0	40.4	22.0	757.7	745.8	739.0
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
728.6	723.0	704.7	701.2	734.2	719.9	737.9	739.8
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
738.9	744.0	726.9	743.8	674.1	762.1		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.752	17.306	31.037	140.567	-60.129	325.136	90.400	178.752
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSFOW	NLE	QFUEL
1246.172	4083.397	0.183	494.565	532.735	34.302	0.827	0.383
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
710.425	727.867	229.561	6.620	6806.786	4.870	762.143	88.071
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.116	38.047	18708.752	0.805	4.408	44127.500	34.627	7.119

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-24-1987 TIME: 09:49:42 THRU 10:28:50 FILE: CHANNEL
CONSECUTIVE SCANS: 57 THRU 70

Test Point Number 7 (47°F)
Piston Stroke = 12.6 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.03	8.02	0.00
PIST STROKE	-0.22	12.32	-83.04
MOTOR VOLTS	0.72	50.31	71.46
MOTOR AMPS	0.11	2.67	-94.15
COMP SP PRES	60.16	4.82	-93.97
LSGS PRESS	60.36	2.60	2.28
HSGS PRESS	60.00	2.91	-171.33
L/H CYL PRES	7.83	4.79	110.33
R/H CLY PRES	8.20	5.04	-69.00
LGS PRESS	60.21	1.69	97.83
AC-1	-0.54	0.21	-108.85

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.31	7.69	3.08	153.23	3.38	4.30	59.79	65.76
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
60.25	75.93	212.69	59.91	57.93	25.50	0.00	21.47

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	67.6	646.0	116.8	666.0	165.1	152.5	30.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
26.0	67.7	15.2	37.6	23.0	755.4	732.2	735.9
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
730.9	725.9	711.0	707.0	724.0	717.0	729.1	726.0
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
723.7	729.0	729.0	720.1	668.0	744.7		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.523	21.951	21.650	112.622	-65.039	226.951	21.373	184.154
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
829.584	3286.973	0.154	306.485	338.517	23.280	0.779	0.296
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
600.298	721.433	254.890	6.505	5402.347	4.036	755.357	87.357
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
12.605	27.968	11795.987	0.640	4.170	22832.131	1.238	4.700

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 05-07-1987 TIME: 15:34:54 THRU 16:11:18 FILE: CHANNEL
CONSECUTIVE SCANS: 43 THRU 55

Test Point Number 6 (Heating)
Piston Stroke = 17.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.00	14.78	0.00
PIST STROKE	-0.76	17.35	-81.05
MOTOR VOLTS	0.74	102.43	101.44
MOTOR AMPS	0.17	3.04	108.25
COMP SP PRES	59.78	6.43	-96.83
LSGG PRESS	60.44	4.79	1.72
HSGG PRESS	59.66	5.28	-173.68
L/H CYL PRES	7.60	5.99	122.50
R/H CLY PRES	7.48	6.44	-57.70
LGS PRESS	59.42	2.26	99.85
AC-1	-0.53	0.39	111.78

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.62	16.29	3.01	357.54	11.31	13.31	59.86	66.47
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
60.19	69.04	242.81	58.94	57.32	29.04	0.00	21.30

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	59.0	745.3	118.0	781.3	194.1	172.1	39.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
30.0	84.1	14.0	47.0	23.0	746.6	750.5	719.2
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
716.2	712.8	685.3	678.3	744.4	709.9	726.0	726.1
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
717.8	726.7	766.2	762.7	730.4	739.8		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.866	23.873	54.791	272.071	151.455	548.813	37.705	111.403
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2119.379	6156.432	0.193	884.372	943.749	44.304	0.864	0.603
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1513.648	724.128	524.833	14.387	10988.035	7.736	766.231	87.923
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.034	54.379	26349.856	0.702	3.647	49613.125	1.323	4.394

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-14-1987 TIME: 13:30:59 THRU 14:07:17 FILE: CHANNEL
CONSECUTIVE SCANS: 88 THRU 100

Test Point Number 5 (80°F)
Piston Stroke = 17.2 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.27	16.74	0.00
PIST STROKE	0.64	15.37	-96.22
MOTOR VOLTS	0.71	126.06	108.49
MOTOR AMPS	0.11	6.40	93.97
COMP SP PRES	59.54	7.21	-113.02
LSGS PRESS	60.43	5.45	1.93
HSGS PRESS	59.55	6.02	-175.11
L/H CYL PRES	8.54	4.57	123.42
R/H CLY PRES	8.73	4.73	-57.97
LGS PRESS	59.30	2.27	84.63
AC-1	-0.52	1.52	84.02

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.65	12.27	3.16	708.97	9.56	9.31	59.59	66.72
DOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.71	96.80	199.74	59.27	55.78	29.33	0.00	21.62

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	64.0	714.7	135.0	754.0	199.0	180.4	40.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
30.0	66.0	22.0	44.4	24.0	753.1	752.8	718.1
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
718.1	714.0	691.2	683.1	744.9	696.9	717.4	721.7
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
726.5	738.2	748.9	755.4	709.8	746.3		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.318	16.864	77.076	263.920	390.292	629.180	642.579	-3.969
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2482.182	7000.654	0.222	1056.860	1061.102	40.180	0.853	0.625
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1176.508	722.036	169.797	10.535	11203.259	8.377	755.385	72.308
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.177	43.748	56447.883	1.476	6.663	112.730	33.110	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-14-1987 TIME: 15:33:05 THRU 16:12:26 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 14

Test Point Number 5 (80°F)
Piston Stroke = 14.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.16	12.53	0.00
PIST STROKE	0.81	12.47	-95.55
MOTOR VOLTS	0.71	85.13	94.05
MOTOR AMPS	0.10	0.84	100.36
COMP SP PRES	59.66	5.88	-111.64
LSGS PRESS	60.18	4.06	2.09
HSGS PRESS	59.65	4.53	-174.54
L/H CYL PRES	8.73	4.27	116.15
R/H CLY PRES	8.97	4.46	-64.43
LGS PRESS	59.61	1.87	85.27
AC-1	-0.53	0.98	85.19

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.45	8.22	3.22	480.27	5.00	4.95	59.58	66.20
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.19	97.35	198.43	59.51	56.43	26.04	0.00	20.82

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	68.0	658.0	143.7	690.8	194.1	179.6	32.0
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
26.2	63.2	21.0	40.9	24.0	759.0	746.9	734.5
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
725.1	722.0	698.7	693.1	728.0	708.8	727.8	731.7
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
735.0	741.8	730.4	744.1	672.1	758.0		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.958	15.952	47.063	167.999	33.772	392.388	210.461	-10.359
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1604.734	4443.052	0.207	673.706	691.178	26.185	0.851	0.433
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
763.602	723.405	414.045	6.900	7739.398	5.219	759.000	86.857
Xo CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.052	33.966	38161.426	1.444	6.969	112.568	33.110	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-22-1987 TIME: 12:00:10 THRU 12:39:30 FILE: CHANNEL
CONSECUTIVE SCANS: 71 THRU 84

Test Point Number 5 (80°F)
Piston Stroke = 10.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.10	7.52	0.00
PIST STROKE	-0.17	9.85	-84.64
MOTOR VOLTS	0.71	48.75	82.76
MOTOR AMPS	0.13	1.08	-95.52
COMP SP PRES	60.46	3.94	-99.08
LSGS PRESS	60.45	2.44	2.57
HSGS PRESS	60.19	2.72	-171.23
L/H CYL PRES	9.03	3.86	114.29
R/H CLY PRES	9.37	4.05	-65.19
LGS PRESS	60.41	1.37	95.95
AC-1	-0.53	0.14	113.32

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.26	6.41	3.19	210.34	2.51	3.34	60.00	66.12
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
61.04	98.36	198.29	59.56	57.69	23.70	0.00	20.55

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.4	68.2	639.1	140.0	658.1	181.2	169.4	28.4
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
24.1	59.0	22.0	34.2	24.0	748.0	733.4	738.0
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
724.6	722.1	718.6	718.6	733.4	733.4	742.0	740.9
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
743.0	747.0	720.2	731.8	668.9	759.2		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.176	21.794	21.378	99.057	-26.009	170.989	23.521	185.520
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
712.543	2658.005	0.161	276.550	297.559	15.061	0.808	0.248
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
559.846	729.448	172.900	5.403	4437.181	3.148	759.214	90.286
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
10.129	17.425	15719.165	1.037	6.473	24468.985	1.615	6.900

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-22-1987 TIME: 12:00:10 THRU 12:39:30 FILE: CHANNEL
CONSECUTIVE SCANS: 71 THRU 84

Test Point Number 5 (80°F)
Piston Stroke = 10.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.10	7.52	0.00
FIST STROKE	-0.17	9.85	-84.64
MOTOR VOLTS	0.71	48.75	82.76
MOTOR AMPS	0.13	1.08	-95.52
COMP SP PRES	60.46	3.94	-99.08
LSGS PRESS	60.45	2.44	2.57
HSGS PRESS	60.19	2.72	-171.23
L/H CYL PRES	9.03	3.86	114.29
R/H CLY PRES	9.37	4.05	-65.19
LGS PRESS	60.41	1.37	95.95
AC-1	-0.53	0.14	113.32

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.26	6.41	3.19	210.34	2.51	3.34	60.00	66.12
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
61.04	98.36	198.29	59.56	57.69	23.70	0.00	20.55

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.4	68.2	639.1	140.0	658.1	181.2	169.4	28.4
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
24.1	59.0	22.0	34.2	24.0	748.0	733.4	738.0
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
724.6	722.1	718.6	718.6	733.4	733.4	742.0	740.9
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
743.0	747.0	720.2	731.8	668.9	759.2		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.176	21.794	21.378	99.057	-26.009	170.989	23.521	185.520
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
712.543	2658.005	0.161	276.550	297.559	15.061	0.808	0.248
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
559.646	729.448	172.900	5.403	4437.181	3.148	759.214	90.286
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
10.129	17.425	15719.165	1.037	6.473	24468.885	1.615	6.900

LENNOX DATA ACQUISITION TEST AVERAGE OF 15 SCANS
DATE: 04-14-1987 TIME: 11:36:23 THRU 12:18:22 FILE: CHANNEL
CONSECUTIVE SCANS: 71 THRU 85

Test Point Number 4 (87°F)
Piston Stroke = 17.1 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.20	16.75	0.00
FIST STROKE	0.68	15.20	-88.78
MOTOR VOLTS	0.71	125.36	107.65
MOTOR AMPS	0.15	5.97	94.56
COMP SP PRES	59.74	6.84	-106.99
LSGS PRESS	60.65	5.48	1.78
HSGS PRESS	59.79	6.04	-174.75
L/H CYL PRES	8.82	5.42	125.25
R/H CLY PRES	8.96	5.69	-56.07
LGS PRESS	59.50	2.27	91.99
AC-1	-0.52	1.22	92.47

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.65	12.25	3.22	616.75	9.58	9.32	59.82	65.44
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.25	93.17	228.80	57.77	56.38	29.47	0.00	21.56

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	64.0	719.1	134.1	757.7	198.9	180.5	40.4
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
30.0	74.0	21.0	44.0	24.0	753.0	753.7	718.2
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
718.0	714.0	692.5	684.4	748.7	699.3	719.2	722.9
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
727.5	739.2	749.1	757.3	713.7	747.7		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
56.858	16.849	72.192	287.545	364.287	626.375	599.737	-4.555
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
2556.455	7189.010	0.229	1105.411	1120.266	36.304	0.871	0.624
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1177.467	723.445	-169.786	10.515	11181.505	8.444	757.333	72.933
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
17.100	42.646	47126.465	1.235	5.400	112.568	36.158	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-14-1987 TIME: 09:23:02 THRU 10:02:25 FILE: CHANNEL
CONSECUTIVE SCANS: 57 THRU 70

Test Point Number 4 (87°F)
Piston Stroke = 14.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.08	12.14	0.00
PIST STROKE	0.75	12.45	-87.38
MOTOR VOLTS	0.70	82.57	91.26
MOTOR AMPS	0.08	0.22	67.04
COMP SP PRES	60.28	5.63	-103.95
LSGS PRESS	60.77	3.96	1.94
HSGS PRESS	60.26	4.41	-173.87
L/H CYL PRES	9.04	5.13	117.63
R/H CLY PRES	9.25	5.40	-63.18
LGS PRESS	60.30	1.88	93.34
AC-1	-0.53	0.38	95.95

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.46	9.52	3.22	381.66	5.60	6.21	60.12	66.18
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
60.10	93.15	227.53	59.61	57.44	30.91	0.00	21.17

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
28.0	67.0	677.7	124.3	717.9	178.5	164.4	32.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
27.0	71.0	20.0	38.4	24.0	750.9	743.6	729.4
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
721.3	717.0	703.0	697.9	738.9	714.3	734.5	736.7
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
736.1	743.1	728.8	751.3	689.4	755.9		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.910	18.477	42.104	181.215	6.627	386.007	169.261	22.961
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
1599.475	4960.544	0.208	659.320	672.838	23.305	0.833	0.434
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
807.987	726.505	-164.340	8.017	7701.557	5.830	755.857	66.429
Xo CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
13.993	27.421	29100.684	1.107	5.332	112.406	36.158	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 12 SCANS
DATE: 04-01-1987 TIME: 15:59:50 THRU 16:37:08 FILE: CHANNEL
RANDOM SCANS: 49 50 51 52 53 54 55 56 57 59 60 61

Test Point Number 3 (95°F)
Piston Stroke = 14.2 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.78	12.10	0.00
FIST STROKE	-0.44	14.12	-73.37
MOTOR VOLTS	0.76	75.86	90.60
MOTOR AMPS	0.13	0.68	-69.70
COMP SF PRES	59.56	5.10	-89.94
LSGS PRESS	59.99	3.78	1.59
HSGS PRESS	59.45	4.13	-173.11
L/H CYL PRES	9.94	6.46	122.34
R/H CLY PRES	10.11	6.99	-56.71
LGS PRESS	59.06	1.87	107.33
AC-1	-0.53	0.70	-78.51

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.45	6.84	3.01	262.77	6.67	3.95	59.55	64.14

UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
58.36	89.84	278.59	58.89	58.39	25.95	0.00	21.24

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
29.0	69.9	672.7	108.6	686.9	212.7	198.9	34.0

Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
26.0	80.0	14.2	46.3	25.0	761.4	754.3	725.2

Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
718.2	717.7	713.9	706.2	710.1	714.0	724.1	728.7

Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b
734.2	738.2	726.3	737.0	676.3	765.0

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.835	13.368	33.343	192.554	-8.042	365.192	130.832	159.700

PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
1494.647	3744.553	0.200	546.994	627.461	33.479	0.788	0.425

QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
713.655	722.322	1060.400	5.687	7469.331	4.708	765.000	88.667

Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
14.188	46.259	0.000	0.000	0.000	0.000	0.000	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-01-1987 TIME: 14:20:33 THRU 14:57:56 FILE: CHANNEL
CONSECUTIVE SCANS: 36 THRU 48

Test Point Number 3 (95°F)
Piston Stroke = 18.0 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-1.05	21.87	0.00
PIST STROKE	0.30	17.11	-79.75
MOTOR VOLTS	0.71	162.76	116.07
MOTOR AMPS	0.09	11.27	97.18
COMP SP PRES	60.37	6.74	-101.97
LSGS PRESS	60.85	6.98	1.57
HSGS PRESS	59.93	7.49	-174.72
L/H CYL PRES	9.43	6.89	128.70
R/H CLY PRES	9.76	7.48	-50.50
LGS PRESS	59.33	2.39	101.09
AC-1	-0.56	0.79	107.70

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.79	12.27	3.05	598.57	17.68	9.99	60.13	68.19
UOC PRESS.	FR/SU PRESS.	FR/DI PRESS.	LOC PRESS.	FREQUENCY	RTD-OUT	MOTOR POWER	RTD-IN
59.74	89.57	281.05	58.64	57.17	30.20	0.00	20.70

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.2	64.6	743.2	95.4	752.8	203.5	187.5	48.7
Tcool exit	Tfreon disch	Tfreon inlet	Tcomp oil	Tambient	Teng cnt 14a	Th/h 15	Th/h 16
31.0	83.0	18.0	48.5	24.3	710.9	772.6	676.3
Th/h 17	Th/h 18	Th/h 19	Th/h 20	Th/h 21	Th/h 22	Th/h 23	Th/h 24
660.4	663.7	657.0	649.2	712.9	657.2	670.9	670.8
Th/h 25	Th/h 26	Th/h 27	Th/h 28	Th/h 29	Th/h 14b		
676.9	689.9	716.0	711.5	703.7	699.9		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.497	13.552	107.288	473.472	867.157	833.582	1008.888	-7.184
PV POWER	QREJ	NENG	PLHVP	PRHVP	GSPOW	NLE	QFUEL
3251.358	7669.004	0.229	1276.248	1421.995	44.590	0.830	0.809
QEXHAUST	TAVGH	HEAT BAL	QAIR	FIRING RATE	COOL DELTA T	MAX HEAD TEM	HEAD DELTA T
1290.547	681.092	2004.270	10.968	14224.689	9.503	772.615	123.462
Xp CALC.	QCONVECT	COMPCOOL CAP	COOLING COP	COMPCOOL COP	COMPHEAT CAP	HEATING COP	COMPHEAT COP
18.039	54.856	0.000	0.000	0.000	0.000	0.000	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-10-1987 TIME: 12:17:36 THRU 12:57:18 FILE: CHANNEL
CONSECUTIVE SCANS: 1 THRU 14

Test Point Number 3 (95°F)
Piston Stroke = 17.3 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.01	17.66	0.00
PIST STROKE	0.18	16.02	-75.04
MOTOR VOLTS	0.70	136.36	-70.09
MOTOR AMPS	0.13	7.51	-88.38
COMP SP PRES	60.27	6.37	-95.77
LSGS PRESS	61.06	5.81	1.58
HSGS PRESS	60.06	6.24	-174.20
L/H CYL PRES	9.40	6.84	132.11
R/H CLY PRES	9.38	7.31	-49.56
LGS PRESS	59.89	2.32	105.74
AC-1	-0.51	0.66	107.91

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.63	11.92	3.19	511.48	9.36	8.89	60.05	66.95
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
59.42	89.38	281.44	59.45	57.13	28.86	0.00	21.25

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
26.0	64.0	711.1	136.1	768.9	206.2	181.9	42.6
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
30.0	87.0	19.0	42.0	23.5	752.1	762.1	721.9
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
717.7	712.8	690.4	682.7	750.4	702.2	723.9	729.8
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
741.5	753.1	748.5	773.6	705.3	757.2		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
57.625	16.874	72.470	350.687	493.784	648.079	669.000	178.378
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2768.056	6422.599	0.242	1168.812	1176.899	38.623	0.848	0.605
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1151.627	727.395	872.236	10.203	11442.899	7.614	773.643	90.929
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.330	38.465	36354.238	0.931	3.851	112.242	41.166	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 13 SCANS
DATE: 04-10-1987 TIME: 13:44:20 THRU 14:20:35 FILE: CHANNEL
CONSECUTIVE SCANS: 15 THRU 27

Test Point Number 2 (Cooling)
Piston Stroke = 17.3 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	-0.14	18.60	0.00
PIST STROKE	0.13	15.95	-68.92
MOTOR VOLTS	0.73	138.85	-64.41
MOTOR AMPS	0.09	9.07	-74.74
COMP SP PRES	60.08	6.00	-91.08
LSGS PRESS	60.81	6.08	1.50
HSGS PRESS	59.83	6.49	-173.95
L/H CYL PRES	9.88	7.58	135.47
R/H CLY PRES	9.74	8.21	-45.91
LGS PRESS	59.63	2.30	112.02
AC-1	-0.53	0.21	83.19

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.64	12.31	3.18	470.22	9.65	9.29	59.94	66.01
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
57.85	89.33	290.47	59.82	57.58	29.19	0.00	21.28

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
27.8	64.2	715.7	139.0	770.1	210.4	185.6	44.2
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
30.0	94.0	21.0	47.9	25.6	751.3	763.7	721.4
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
718.1	713.5	691.1	682.8	750.7	700.6	723.1	729.4
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
741.1	752.5	753.1	774.5	709.8	755.8		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.137	17.101	76.763	403.978	619.268	652.136	718.529	164.736
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2793.419	6637.154	0.240	1177.486	1207.916	46.483	0.855	0.617
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1216.427	727.821	835.269	10.545	11628.280	7.910	774.462	91.615
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
17.256	49.333	32212.301	0.811	3.381	112.568	44.064	0.000

LENNOX DATA ACQUISITION TEST AVERAGE OF 14 SCANS
DATE: 04-30-1987 TIME: 15:19:04 THRU 15:58:28 FILE: CHANNEL
CONSECUTIVE SCANS: 72 THRU 85

Test Point Number 1 (Verificatio:
Piston Stroke = 16.2 mm

DYNAMIC DATA

	MEAN	AMPLITUDE	PHASE
DISP STROKE	0.02	16.29	0.00
FIST STROKE	-0.53	16.20	-71.67
MOTOR VOLTS	0.69	122.02	106.17
MOTOR AMPS	0.08	5.20	95.56
COMP SP PRES	59.69	5.76	-91.93
LSGS PRESS	60.59	5.32	1.63
HSGS PRESS	59.80	5.75	-173.42
L/H CYL PRES	9.37	6.68	132.01
R/H CLY PRES	9.44	7.17	-47.95
LGS PRESS	59.50	2.15	109.16
AC-1	-0.52	0.19	132.32

STEADY STATE DATA

FUEL FLOW	AIR FLOW	COOLANT FLOW	FREON FLOW	FUEL PRESS.	AIR PRESS.	MEAN PRESS.	BRG. PRESS.
0.61	12.20	3.11	440.89	9.32	8.94	59.95	65.33
UOC PRESS.	**FR/SU PRESS.**	**FR/DI PRESS.**	**LOC PRESS.**	**FREQUENCY**	**RTD-OUT**	**MOTOR POWER**	**RTD-IN**
59.33	90.47	278.22	59.14	57.48	29.13	0.00	21.60

TEMPERATURE DATA

Tgas fuel	Tair b/o	Tcomb air in	Tair p/h in	Tcomb p/h in	Tcomb p/h ou	Teng exhaust	Tcomp space
25.4	59.8	709.4	124.5	755.8	192.4	174.9	40.0
Tcool exit	**Tfreon disch**	**Tfreon inlet**	**Tcomp oil**	**Tambient**	**Teng cnt 14a**	**Th/h 15**	**Th/h 16**
30.0	85.6	18.0	44.6	21.0	759.4	766.9	738.1
Th/h 17	**Th/h 18**	**Th/h 19**	**Th/h 20**	**Th/h 21**	**Th/h 22**	**Th/h 23**	**Th/h 24**
727.1	723.5	687.5	674.5	737.8	699.6	719.1	724.9
Th/h 25	**Th/h 26**	**Th/h 27**	**Th/h 28**	**Th/h 29**	**Th/h 14b**		
731.4	742.9	762.4	757.4	699.9	754.6		

CALCULATIONS

FREQ CALC	A/F RATIO	LS GSPOW	HS GSPOW	PMOTI	PWROD	LIQ ENTHALPY	SUC ENTHALPY
58.069	17.756	63.725	340.197	312.071	547.672	41.166	112.077
PV POWER	**QREJ**	**NENG**	**PLHVP**	**PRHVP**	**GSPOW**	**NLE**	**QFUEL**
2309.057	6193.453	0.215	946.255	1017.132	35.724	0.851	0.598
QEXHAUST	**TAVGH**	**HEAT BAL**	**QAIR**	**FIRING RATE**	**COOL DELTA T**	**MAX HEAD TEM**	**HEAD DELTA T**
1145.947	725.371	639.172	10.628	10719.297	7.533	769.214	94.714
Xp CALC.	**QCONVECT**	**COMPCOOL CAP**	**COOLING COP**	**COMPCOOL COP**	**COMPHEAT CAP**	**HEATING COP**	**COMPHEAT COP**
16.194	53.308	31264.391	0.855	3.968	55067.160	1.506	4.708

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