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LUNAR BASE HEAT PUMP

D. Walker
D. Fischbach
R. Tetreault
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02154-1196
(617) 890-3200

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Approved Final Report
Contract No. NAS9-18819

Prepared for

NASA Lyndon B. Johnson Space Center
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1. INTRODUCTION

A heat pump is a device that elevates the temperature of a heat flow by means of an energy input. By doing this the heat pump can cause heat to transfer from a cool region to a warm one. This approach is used in many common devices such as refrigerators or air conditioners. For aerospace applications, heat pumps can be used in two cases. The first consists of raising the temperature of heat energy so that the amount of radiator surface required is reduced. The second involves situations where heat cannot be directly rejected by radiators, because the heat sink temperature is higher than that of the heat source.

During future missions to the moon and other planets, the crew and support equipment will be exposed to more severe thermal environments for longer periods of time. A heat pump must be used to enable rejection of moderate temperature waste heat to these more severe environments.

An example of such a situation is the rejection of heat from the lunar surface during lunar day. The lunar base thermal control system (TCS) will collect waste heat from the crew habitat at a temperature of about 275°K. Effective radiator temperatures during lunar day are very high, on the order of 350 to 375°K, due to extensive incident thermal radiation on the radiator surface. Direct rejection at this elevated temperature is not possible. This problem can be overcome by the use of a heat pump that will collect heat energy at a suitable temperature for life support, and raise the temperature of the heat energy to the effective radiator temperature for rejection to space.

The first step in the development of a heat pump for this application was to determine the radiator rejection temperature that optimizes the system mass of the TCS to its lowest possible value. To do this, curves of system mass versus radiator rejection temperature were generated for a system capable of rejecting 5 kW of thermal energy. The basic tradeoff examined the impact of radiator area and power generation masses on radiator temperature.

The analysis showed that the design point is controlled by the radiator area required for direct heat rejection during lunar night. Then, given this radiator area, the daytime design point depends only on the coefficient of performance (COP) of the heat pump. A more efficient heat pump requires less power and allows the fixed radiator to operate at a lower temperature. The lower radiator operating design temperature results from less compressor power needing to be rejected as heat. The lower system mass results from the reduced need for power.

For COPs in the range of 45 to 60 percent of Carnot efficiency, the optimum lunar noontime radiator design temperature varies from 381 to 374°K, respectively. Simultaneously, the total system mass (power supply plus radiators) varies from 1,000 to 810 kg. Figure 1 shows the relation between system mass and fraction of Carnot COP. The mass penalties applied to this study were 3.85 kg/m^2 and 25 kg/kW for radiator area and power, respectively.

Analyses of many potential refrigerants were then performed in refrigeration cycles in order to determine the most efficient heat pump design for the lunar base application. In general, the analyses showed that many fluids were not suitable because their critical temperatures were not high enough to allow use at the radiator temperatures considered. Several different

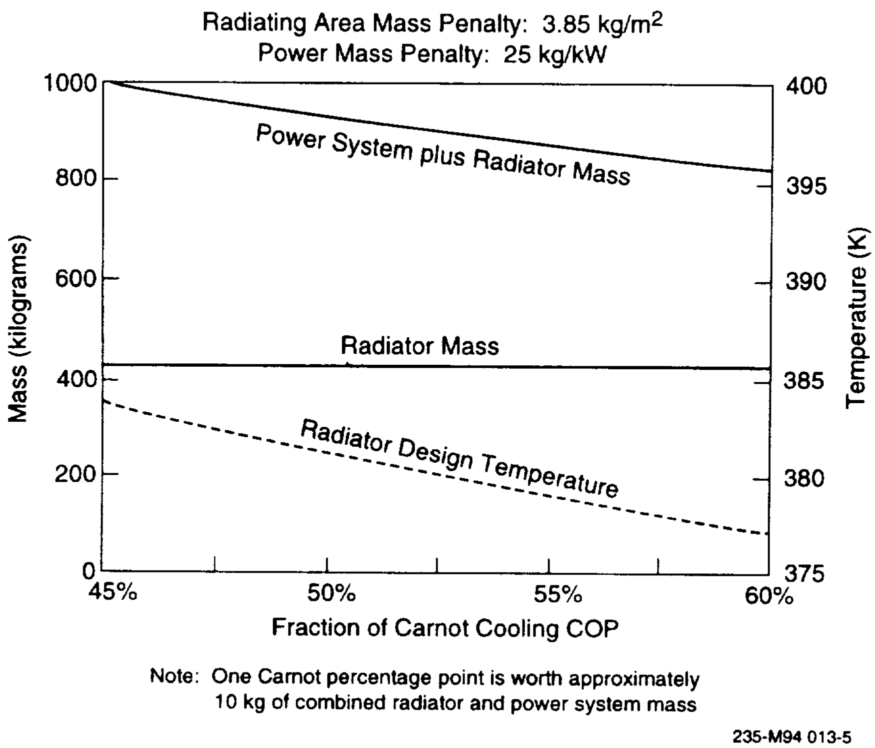


Figure 1. System mass versus fraction of Carnot cooling COP

fluids were identified, however, that could perform at COPs of 50 percent of Carnot. Tables 1 and 2 show the refrigerants and cycles producing the best results. The highest COP was obtained through the use of refrigerant CFC-11 in a three-stage compression cycle.

Figures 2 and 3 illustrate the elements of a three-stage cycle. Compression is performed over three levels with the discharge gas of the first-stage being the suction gas of the second and the discharge gas of the second being the suction gas of the third. Cooling of the gas is

Table 1. Single refrigerant cycles

Refrigerant	Configuration	COP	% Carnot
CFC-11	(three-stage)	1.41	56
n-Butane	(two-stage)	1.30	52
HCFC-123a	(two-stage)	1.28	51
Ammonia	(three-stage)	1.24	50

Table 2. Cascaded cycles

Upper Stage Refrigerant	Configuration	Lower Stage Refrigerant	COP	% Carnot
Water	Two-stage	HCF-123a	1.27	51
Water	Two-stage	Ammonia	1.25	50
HCFC-123a	Two-stage	Ammonia	1.20	48

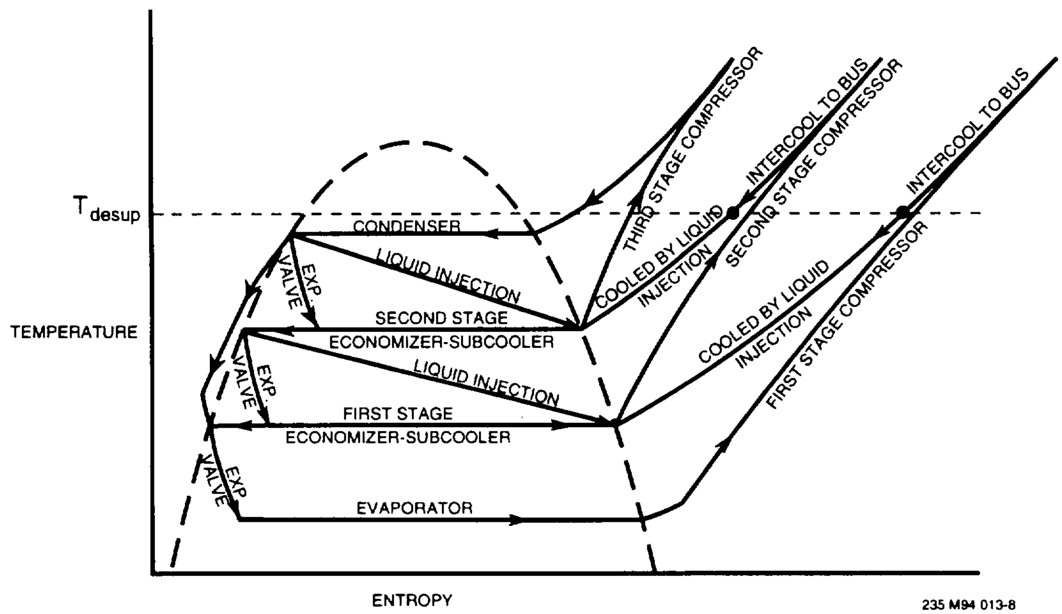


Figure 2. ***Three-stage refrigeration system with economizer-subcoolers, interstage liquid injection, and intercooling by bus fluid***

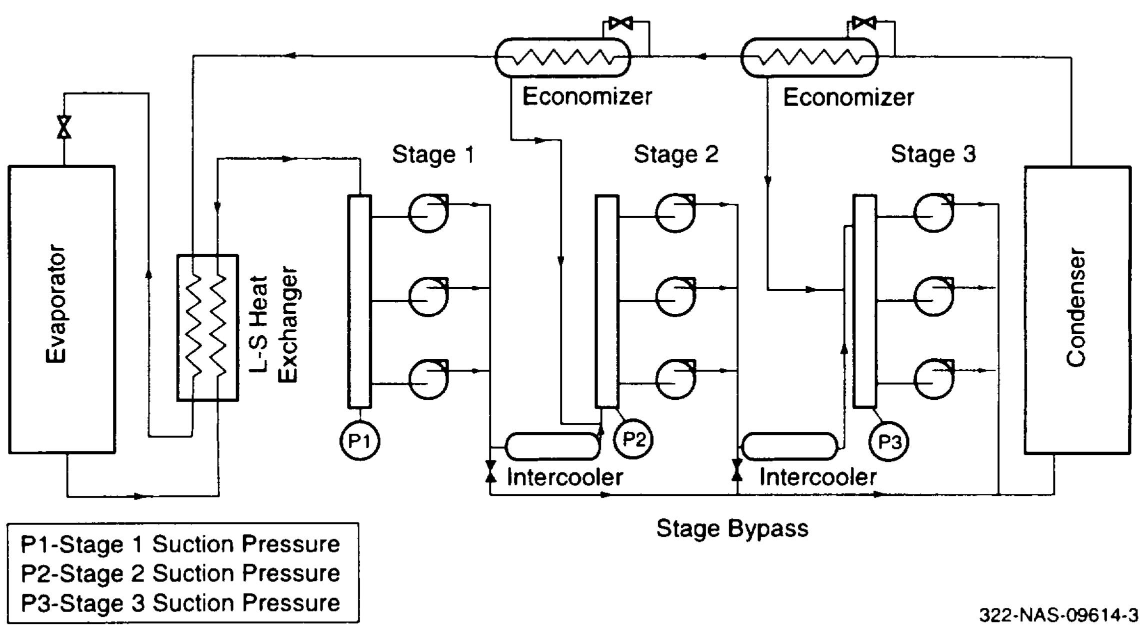


Figure 3. ***Flow diagram of the lunar heat pump with control points***

provided between stages to reduce the inlet temperature of the gas in the second and third stages to prevent damage to the compressors. Intercooling is provided by the use of economizer–subcoolers that produce interstage cooling gas by subcooling the refrigerant liquid passing to the evaporator. A liquid–suction heat exchanger is used at the evaporator to prevent wet–compression in the first–stage. For off–design operation, direct rejection of heat to the thermal bus is possible at the second-stage discharge.

Multiple compressors are used in each stage to provide a means of capacity control and for operating redundancy. This approach is referred to as multiplexing. In a multiplexed system, the number of compressors operating at any given time is chosen to match the capacity of the compressors with the thermal rejection load. Compressors are controlled by on/off cycling, or in the more advanced version suggested here, variable speed operation of several of the compressors can also be employed for finer control.

System control must also be applied to compensate for the large variation in condensing temperature seen over the lunar day. The impact of this change is shown in Figure 4. Three stages of compression are needed for heat rejection during the time period of approximately 0 to 40 deg of lunar noon. From 40 to 70 deg, the condensing temperature drops to the point where only two stages are needed, while from 70 deg to the beginning of lunar night, one stage of compression is adequate. At the points of 40 and 70 deg, the control consists simply of turning off all compressors associated with either the third or second-stages, respectively. Heat pump start up is the reverse of this process. Initial operation is in the single stage mode until the condensing temperature reaches the point where two–stage compression is required. Full three–stage operation is reached as the condensing temperature rises further to its maximum value.

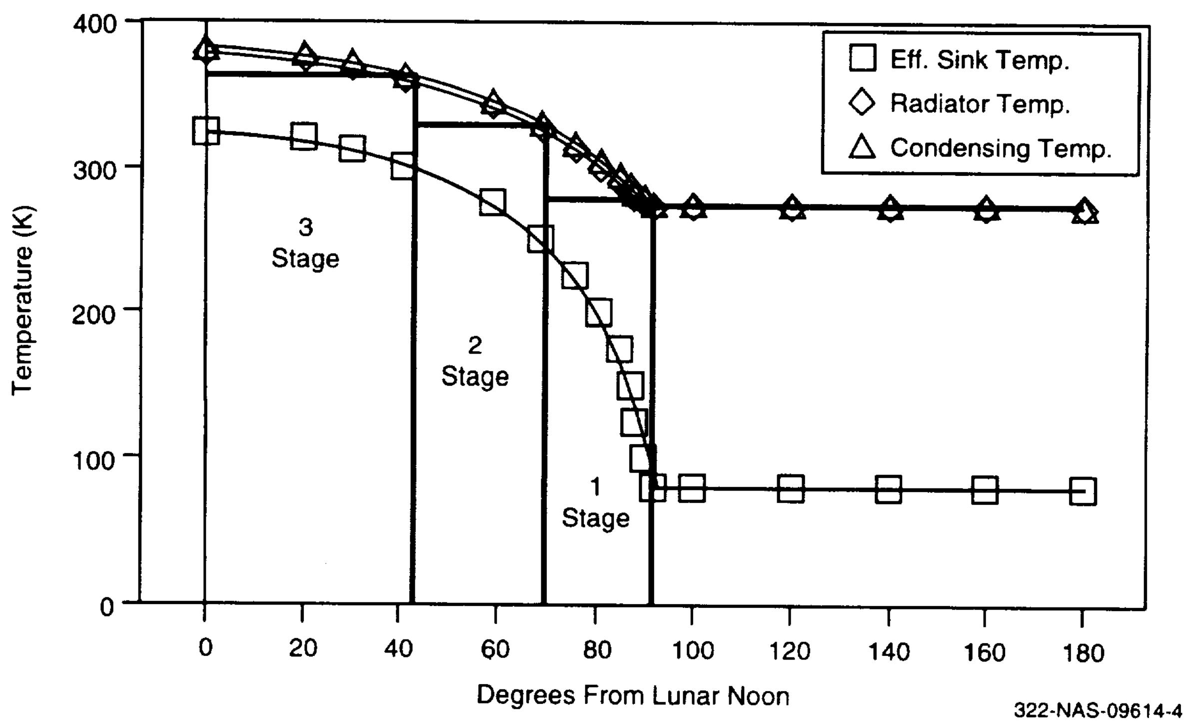


Figure 4. Estimated heat pump condenser temperature during lunar operation

Efforts for the development of the High-Lift heat pump were then turned to design and fabricate a prototype unit for use in the NASA Johnson Life Support Systems Integration Facility (LSSIF). The LSSIF is operated by NASA Johnson to provide system-level integration, operational test experience, and performance data that will enable NASA to develop flight-certified hardware for future planetary missions.

The design criteria for the LSSIF heat pump consisted of the following:

- Maximum and minimum heat rejection loads from the internal thermal control system (ITCS) of 1 and 5 kW, respectively. Heat rejection is accomplished by removing heat from a glycol-water loop operating at a flow rate of 0.22 kg/s.

- The outlet temperature from the heat pump of the ITCS glycol-water loop must be maintained at 4°C ±1.7°C.

- Heat is rejected from the heat pump using an external thermal control system (ETCS) that consists of a glycol-water loop operating at an inlet temperature ranging from -8 to 88°C and a flow rate of 0.57 kg/s.

- The heat pump must be capable of operating in a direct rejection mode when the ETCS temperature is less than the 4°C outlet temperature of the ITCS.

The heat pump designed and fabricated for this application has all of the functional characteristics of the unit designed for the lunar base. The heat pump employs two stages of compression with an economizer for intercooling and liquid subcooling. Both stages of compression are multiplexed with three and five compressors in the first and second-stage, respectively. The heat pump is designed to operate in either one or two stages, depending upon the ETCS rejection temperature. All control modes called for in the lunar base unit can be tested and demonstrated with the LSSIF prototype.

Several major differences exist between the lunar base and LSSIF heat pumps. The LSSIF unit employs refrigerant HCFC-123, while CFC-11 was chosen for the lunar base system. CFC-11 is an ozone depleting chemical (ODC) that is no longer in production. Only two stages of compression were needed for the LSSIF unit because the maximum rejection temperature was lower than for the lunar base application (90°C versus 108°C). Also, a liquid-suction heat exchanger was not employed on the LSSIF unit because of low-side pressure drop limitations which were set by compressor cooling requirements. The immediate substitute refrigerant is HCFC-123. All components of the prototype are commercially available, rather than flight-qualified hardware. The use of commercial grade hardware allows the heat pump to be tested and reconfigured inexpensively. Changes to the prototype can be made without the engineering and certification efforts associated with flight-qualified equipment.

The development of the high-lift heat pump took place over a three-phase program. In Phase I, the design criteria of the lunar base unit were defined and a conceptual design of the heat pump was formulated. The prototype unit for the LSSIF was designed in detail in Phase II. In Phase III, the subject of this report, fabrication and testing of the prototype were undertaken.

2. SYSTEM DESCRIPTION

2.1 Heat Pump Cycle and State Points

The prototype high-lift heat pump employs a vapor compression refrigeration cycle as shown in Figure 5. The refrigerant used in the heat pump is HCFC-123, which has a high enough critical temperature to allow heat rejection by two-phase condensing to a 88°C (190°F) heat sink. The heat pump employs two stages of compression with intercooling when the ETCS is above a temperature of 38°C (100°F). At cooling loop temperatures below 38°C (100°F), the second-stage of compression is turned off and only the first-stage compressors are employed. For two-stage operation, an economizer heat exchanger is used for a combination of intercooling and subcooling of refrigerant liquid prior to entry in the evaporator. The state point pressures and temperatures in the diagram refer to operation of the heat pump at the design condition of ETCS cooling loop temperature of 88°C (190°F).

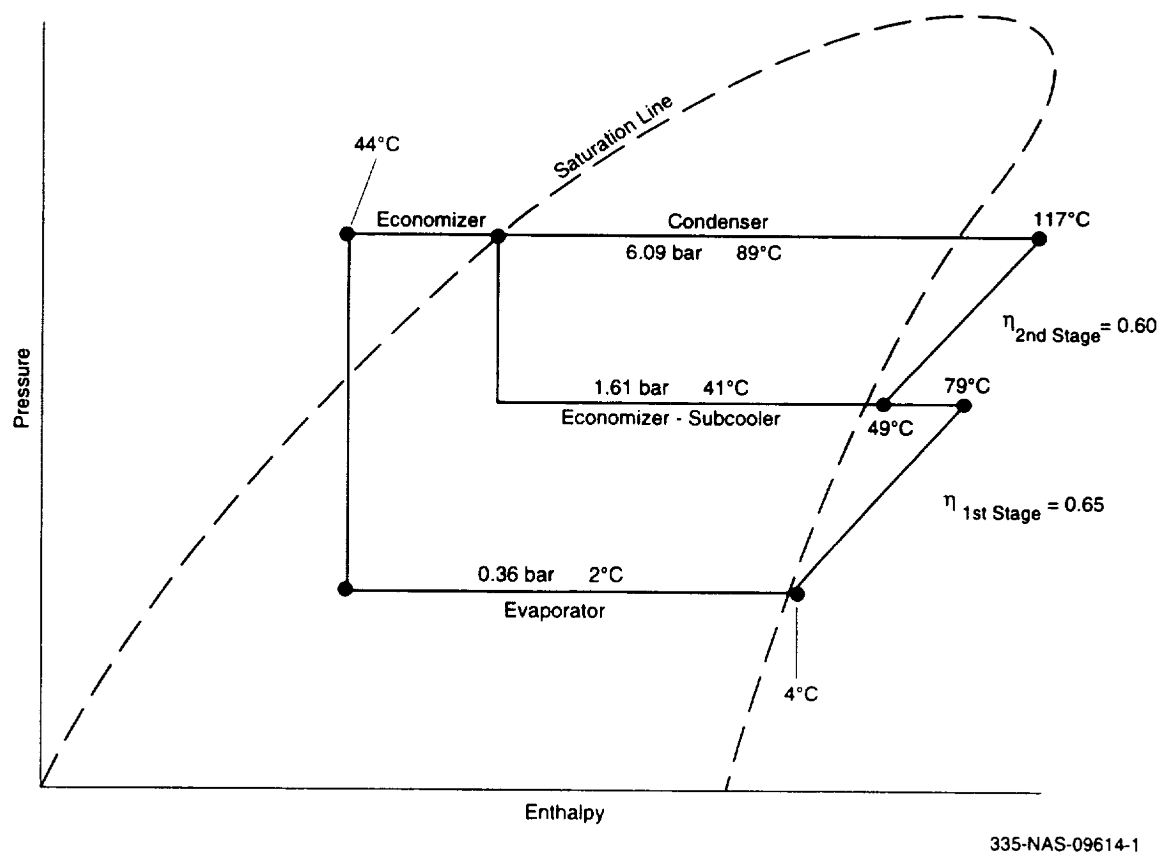


Figure 5. High-lift heat pump pressure-enthalpy diagram

2.2 Heat Pump Flow Diagram

Figure 6 shows the flow diagram for the high–lift heat pump. The evaporator consists of two direct expansion heat exchangers with the evaporating refrigerant on one side of the exchanger and the ITCS water–glycol mixture on the other. Operation of the heat exchangers consists of first direct expansion of the refrigerant in a control valve prior to entry into the heat exchangers. The flow of refrigerant is split between the two heat exchangers and manual valves are available at the entrance of each heat exchanger to balance flow if necessary. The water–glycol mixture flows through the exchangers in series to cool the liquid to the final temperature.

The evaporated refrigerant flows from the evaporator to the suction of the first-stage compressors. Three compressors are employed, one is equipped with variable–speed capability. The compressors are operated on the basis of suction pressure. The two fixed–speed compressors are cycled on and off, while the variable speed unit is operated in the speed range of 50 to 125 percent, in order to maintain the suction pressure at the set point value.

In single stage operation, the discharge of the first-stage compressors is piped directly to the condenser where the ETCS cooling loop is used to condense the refrigerant. The liquid refrigerant then returns to the evaporator.

In two–stage operation, the discharge of the first-stage compressors is piped to the suction of the second-stage compressors. At the suction manifold, the gas from the economizer is combined with the first-stage discharge gas and is used to cool the gas to a temperature acceptable to the second-stage compressors. The five second-stage compressors are operated continuously. The discharge gas from these compressors is sent to the condenser.

The liquid refrigerant flows from the condenser and passes through the economizer prior to entry in the evaporator. At the economizer, a portion of the liquid flow is split from the main flow and is expanded through a control valve. The liquid and vapor from this expansion is passed through one side of the economizer and is fully evaporated in order to subcool the remainder of the refrigerant liquid going to the evaporator. The gas generated at the economizer is added to the second-stage suction.

Temperature control of the ITCS liquid loop is achieved by the use of a flow control valve that bypasses a portion of the liquid flow around the evaporator. The final temperature of the liquid is controlled by monitoring the outlet temperature and comparing that to the set point of a proportional–integral–differential (PID) controller that positions the bypass valve.

A direct heat exchange mode is also available when the temperature of the ETCS loop is below 0°C (32°F). The heat pump is shut down and the ITCS flow is sent to the direct heat exchanger where heat is removed from the ITCS loop directly to the ETCS loop. Outlet control temperature is achieved using the same bypass flow control valve described previously. Further control of the ETCS liquid flow is available when the ITCS bypass is too low to maintain final outlet temperature above 2.2°C (36°F). At this point the ETCS flow is bypassed around the direct heat exchanger until the ITCS liquid temperature is above 3.3°C (38°F). This condition can occur when the ETCS temperature is below 0°C (32°F) and the ETCS load is small. At this point, the amount of water by-passed by the ITCS control valve is not large enough to maintain the outlet temperature at the desired minimum value.

2.3 Heat Pump Components

Table 3 contains a list of all major components found in the high–lift heat pump. Table 4 lists the instrumentation employed on the heat pump.

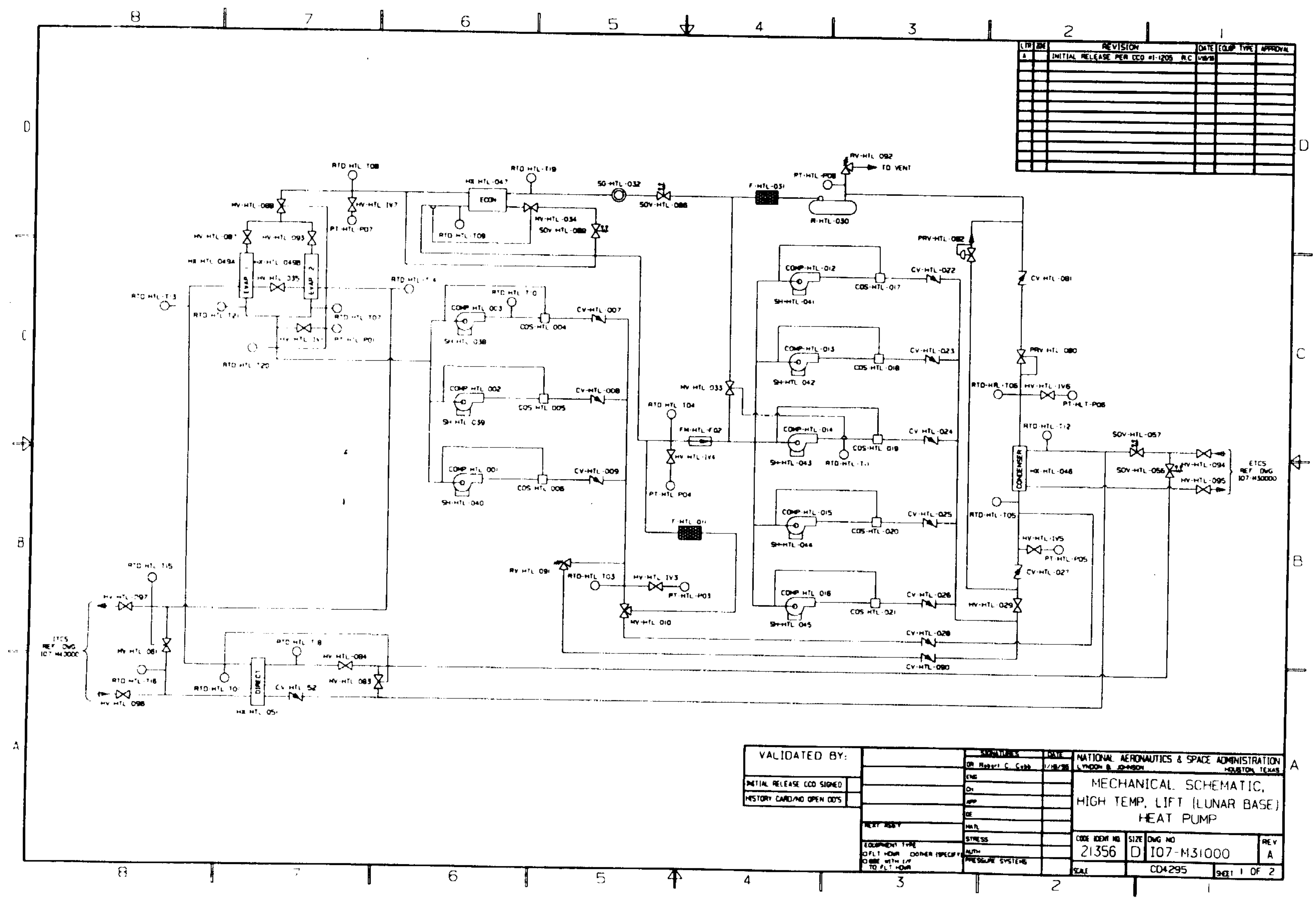


Figure 6. Mechanical schematic for the high-lift heat pump

Table 3. High-lift heat pump parts list

SOV-HTL-057	COOLING WATER SOLENOID VALVE	ATKOMATIC (15458-G)	1500 PSIG, 500°F
SOV-HTL-056	COOLING WATER SOLENOID VALVE	ATKOMATIC (15441)	1500 PSIG, 500°F
CV-HTL-052	COOLING WATER CHECK VALVE	SUPERIOR (805C-14S)	500 PSIG
HX-HTL-051	DIRECT HEAT EXCHANGER	FLATPLATE (PS400-14)	450 PSIG
HX-HTL-49B	EVAPORATOR 2	FLATPLATE (PS600-60)	450 PSIG
HX-HTL-049A	EVAPORATOR 1	FLATPLATE (PS600-60)	450 PSIG
HX-HTL-047	ECONOMIZER	FLATPLATE (PS400-10)	450 PSIG
HX-HTL-046	CONDENSOR	FLATPLATE (PS600-60)	450 PSIG
SH-HTL-045	COMPRESSOR 8 SUMP HEATER	KLIXON (14614H16-400)	37 WATTS
SH-HTL-044	COMPRESSOR 7 SUMP HEATER	KLIXON (14614H16-400)	37 WATTS
SH-HTL-043	COMPRESSOR 6 SUMP HEATER	KLIXON (14614H16-400)	37 WATTS
SH-HTL-042	COMPRESSOR 5 SUMP HEATER	KLIXON (14614H16-400)	37 WATTS
SH-HTL-041	COMPRESSOR 4 SUMP HEATER	KLIXON (14614H16-400)	37 WATTS
SH-HTL-040	COMPRESSOR 3 SUMP HEATER	MARS (3240)	86 WATTS
SH-HTL-039	COMPRESSOR 2 SUMP HEATER	MARS (3240)	86 WATTS
SH-HTL-038	COMPRESSOR 1 SUMP HEATER	MARS (3240)	86 WATTS
HV-HTL-035	BALL VALVE	BUTTERBALL (BB2)	175 PSI
MV-HTL-034	ECONOMIZER EXPANSION VALVE	ALCO (XB-1019-1/2-1B	
MV-HTL-33	LIQUID INJECTION VALVE AND CONTROLLER	SPORLAN (Y1037-FV-1/3)	500 PSIG
SG-HTL-032	REFRIGERANT SIGHT GLASS	PARKER (35493)	500 PSIG
F-HTL-031	LIQUID FILTER	SPORLAN (C-305-S)	500 PSIG
R-HTL-030	RECEIVER	STANDARD (UR-20)	
HV-HTL-029	BALL VALVE	SUPERIOR (590-14ST)	500 PSIG
CV-HTL-028	STAGE 2 BYPASS CHECK VALVE	SUPERIOR (805C-14S)	500 PSIG
CV-HTL-027	CHECK VALVE	SUPERIOR (805C-14S)	500 PSIG
CV-HTL-026	STAGE 2 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
CV-HTL-025	STAGE 2 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
CV-HTL-024	STAGE 2 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
CV-HTL-023	STAGE 2 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
CV-HTL-022	STAGE 2 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
COS-HTL-021	COMPRESSOR 8 OIL SEPARATOR	AC&R (S5181)	450 PSIG
COS-HTL-020	COMPRESSOR 7 OIL SEPARATOR	AC&R (S5181)	450 PSIG
COS-HTL-019	COMPRESSOR 6 OIL SEPARATOR	AC&R (S5181)	450 PSIG
COS-HTL-018	COMPRESSOR 5 OIL SEPARATOR	AC&R (S5181)	450 PSIG
COS-HTL-017	COMPRESSOR 4 OIL SEPARATOR	AC&R (S5181)	450 PSIG
COMP-HTL-016	SECOND STAGE ROTARY COMPRESSOR 8	MARS (22545)	405 PSIG, 250°F
COMP-HTL-015	SECOND STAGE ROTARY COMPRESSOR 7	MARS (22545)	405 PSIG, 250°F
COMP-HTL-014	SECOND STAGE ROTARY COMPRESSOR 6	MARS (22545)	405 PSIG, 250°F
COMP-HTL-013	SECOND STAGE ROTARY COMPRESSOR 5	MARS (22545)	405 PSIG, 250°F
COMP-HTL-012	SECOND STAGE ROTARY COMPRESSOR 4	MARS (22545)	405 PSIG, 250°F
F-HTL-011	STAGE 2 SUCTION FILTER	SPORLAN (SF-289-T	400 PSIG
MV-HTL-010	STAGE 2 BYPASS VALVE	SPORLAN (8D7B)	300 PSIG
CV-HTL-009	STAGE 1 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
CV-HTL-008	STAGE 1 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
CV-HTL-007	STAGE 1 CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
COS-HTL-006	COMPRESSOR 3 OIL SEPARATOR	AC&R (S5185)	450 PSIG
COS-HTL-005	COMPRESSOR 2 OIL SEPARATOR	AC&R (S5185)	450 PSIG
COS-HTL-004	COMPRESSOR 1 OIL SEPARATOR	AC&R (S5185)	450 PSIG
COMP-HTL-003	FIRST STAGE SCROLL COMPRESSOR 3	TRANE (CSHS-093)	350 PSIG
COMP-HTL-002	FIRST STAGE SCROLL COMPRESSOR 2	TRANE (CSHS-093)	350 PSIG
COMP-HTL-001	FIRST STAGE SCROLL COMPRESSOR 1	TRANE (CSHS-093)	350 PSIG
REF. DES.	DESCRIPTION	MFG./P.N	SPECIFICATION

Table 3. High-lift heat pump parts list (continued)

REF. DES.	DESCRIPTION	MFG./P.N.	SPECIFICATION
FM-HTL-F02	FLOW METER	GH FLOW AUTOMATION	
RTD-HTL-T20	FIRST STAGE SUCTION (RTD)	MINCO	0-100°F
RTD-HTL-T19	ECONOMIZER LIQUID IN (RTD)	MINCO	0-200°F
RTD-HTL-T18	ETCS-DIRECT HX INLET (RTD)	MINCO	0-250°F
RTD-HTL-T16	ITCS-DIRECT HX INLET (RTD)	MINCO	0-100°F
RTD-HTL-T15	ITCS-HEAT PUMP OUTLET (RTD)	MINCO	0-100°F
RTD-HTL-T14	ITCS-EVAPORATOR OUTLET (RTD)	MINCO	0-100°F
RTD-HTL-T13	ITCS-EVAPORATOR INLET (RTD)	MINCO	0-100°F
RTD-HTL-T12	ETCS-CONDENSER INLET (RTD)	MINCO	0-250°F
RTD-HTL-T11	COMPRESSOR 6 DISCHARGE (RTD)	MINCO	50-300°F
RTD-HTL-T10	COMPRESSOR 1 DISCHARGE (RTD)	MINCO	50-300°F
RTD-HTL-T09	ECONOMIZER VAPOR OUT (RTD)	MINCO	0-200°F
RTD-HTL-T08	ECONOMIZER LIQUID OUT (RTD)	MINCO	0-200°F
RTD-HTL-T07	EVAP 2 SUCTION (RTD)	MINCO	0-200°F
RTD-HTL-T06	CONDENSER OUTLET (RTD)	MINCO	0-200°F
RTD-HTL-T05	CONDENSER INLET (RTD)	MINCO	0-200°F
RTD-HTL-T04	SECOND STAGE DISCHARGE (RTD)	MINCO	50-300°F
RTD-HTL-T03	FIRST STAGE DISCHARGE (RTD)	MINCO	50-300°F
RTD-HTL-T21	EVAP 1 SUCTION (RTD)	MINCO	0-100°F
RTD-HTL-T01	ITCS-DIRECT HX OUTLET (RTD)	MINCO	0-100°F
HV-HTL-097	ITCS-OUTLET VALVE	JONES (02-G-GA)	350 PSIG
HV-HTL-096	ITCS INLET VALVE	JONES (02-G-GA)	350 PSIG
HV-HTL-095	ETCS OUTLET VALVE	JONES (02-G-GA)	350 PSIG
HV-HTL-094	ETCS INLET VALVE	JONES (02-G-GA)	350 PSIG
HV-HTL-093	BALANCE VALVE-EVAPORATOR 2	NUPRO (SS8BW)	100 PSI @ 100°F
RV-HTL-092	RELIEF VALVE	PARKER (H2)	200 PSIG
RV-HTL-091	RELIEF VALVE	REFRIG. MANU. CO. (A01691)	150 PSIG
CV-HTL-090	RELIEF VALVE CHECK VALVE	SUPERIOR (805C-14S)	500 PSIG
SOV-HTL-089	ECONOMIZER SOLENIOD VALVE	SPORLAN (E3S120)	500 PSI
MV-HTL-088	EVAPORATOR EXPANSION VALVE	NUPRO (SS8BW)	100 PSI @ 100°F
HV-HTL-087	BALANCE VALVE-EVAPORATOR 1	NUPRO (SS8BW)	100 PSI @ 100°F
SOV-HTL-086	REFRIGERANT SOLENOID VALVE	SPORLAN (ME145250)	500 PSI
HV-HTL-084	BALL VALVE	BUTTERBALL (BB2)	175 PSI
MV-HTL-083	COOLING WATER BYPASS VALVE	DRAGON (P10F7511T)	600 PSI
PRV-HTL-082	REFRIGERANT FORWARD-PRESSURE REGULATOR	PARKER (A9)	400 PSIG
CV-HTL-081	REFRIGERANT CHECK VALVE	SUPERIOR (803B-10S)	500 PSIG
PRV-HTL-080	REFRIGERANT BACK-PRESSURE REGULATOR	PARKER (A8A)	450 PSIG
PT-HTL-P07	EXPANSION VALVE INLET (ANALOG)	SETRA (280E)	0-100 PSIG
PT-HTL-P06	CONDENSER OUTLET (ANALOG)	SETRA (280E)	0-100 PSIG
PT-HTL-P05	CONDENSER INLET (ANALOG)	SETRA (280E)	0-100 PSIG
PT-HTL-P04	SECOND STAGE INLET (ANALOG)	SETRA (280E)	0-100 PSIG
PT-HTL-P03	FIRST STAGE DISCHARGE (ANALOG)	SETRA (280E)	0-100 PSIG
PT-HTL-P08	RECEIVER (ANALOG)	SETRA (280E)	0-100 PSIG
PT-HTL-P01	FIRST STAGE SUCTION	SETRA (280E)	0-100 PSIG
HV-HTL-IV7	ISOLATION VALVE	HENRY (6471A)	450 PSIG
HV-HTL-IV6	ISOLATION VALVE	HENRY (6471A)	450 PSIG
HV-HTL-IV5	ISOLATION VALVE	HENRY (6471A)	450 PSIG
HV-HTL-IV4	ISOLATION VALVE	HENRY (6471A)	450 PSIG
HV-HTL-IV3	ISOLATION VALVE	HENRY (6471A)	450 PSIG
HV-HTL-IV1	ISOLATION VALVE	HENRY (6471A)	450 PSIG
MV-HTL-061	CHILLED WATER BYPASS VALVE	DRAGON (P10F7511T)	600 PSI

Table 4. High-lift heat pump instrument list

INSTRUMENT NUMBER	MEASUREMENT	TYPE
TEMPERATURE		
T1	ITCS – DIRECT HX OUTLET	RTD
T2	EVAP 1 SUCTION	RTD
T3	FIRST-STAGE DISCHARGE	RTD
T4	SECOND-STAGE DISCHARGE	RTD
T5	CONDENSER INLET	RTD
T6	CONDENSER OUTLET	RTD
T7	EVAP2 SUCTION	RTD
T8	ECONOMIZER LIQUID OUT	RTD
T9	ECONOMIZER VAPOR OUT	RTD
T10	COMPRESSOR 1 DISCHARGE	RTD
T11	COMPRESSOR 6 DISCHARGE	RTD
T12	ETCS – CONDENSER OUTLET	RTD
T13	ITCS – EVAPORATOR INLET	RTD
T14	ITCS – EVAPORATOR OUTLET	RTD
T15	ITCS – HEAT PUMP OUTLET	RTD
T16	ITCS – DIRECT HX INLET	RTD
T17	ETCS – CONDENSER INLET	RTD
T18	ETCS – DIRECT HX INLET	RTD
T19	ECONOMIZER LIQUID IN	RTD
T20	FIRST-STAGE SUCTION	RTD
PRESSURE		
P1	FIRST-STAGE SUCTION	ANALOG
P2	RECEIVER	ANALOG
P3	FIRST-STAGE DISCHARGE	ANALOG
P4	SECOND-STAGE DISCHARGE	ANALOG
P5	CONDENSER INLET	ANALOG
P6	CONDENSER OUTLET	ANALOG
P7	EXPANSION VALVE INLET	ANALOG
	POWER	
W1	TOTAL HEAT PUMP	ANALOG

2.3.1 Compressors

The first-stage consists of three Trane CSH5-093 scroll-type compressors. The second-stage consists of five Mars 22545 rotary piston compressors. The minimum number of compressors required in each stage is determined by the design mass flow rate based on comparisons of capacity charts and expected operating conditions. These are best estimates as actual capacity charts for R-123 do not yet exist for most commercially available compressors. Both scroll and rotary piston machines are used because they are less susceptible to damage from liquid slugging or wet compression compared with other compressor types. At least three compressors per stage are required to provide reasonable redundancy and control for a ground test system, and to conform to standard commercial practice. Redundancy requirements for a space or planetary based system will not be met by this system, as it is expected all seven compressors will be required for operation at the maximum design load. However, off-design conditions should permit selective compressor isolation if maintenance or repair is required.

Three first-stage compressors are actually used to meet the minimum flow requirements, the redundancy requirements for commercial level reliability, and the flow variability to allow reasonable load following over the entire operating range. One of the first-stage compressors is capable of variable speed control. The other two require on/off operation only. None of the first-stage compressors requires unloading capability, neither partial nor full. The compressor control scheme is described in a separate section of this report.

Five second-stage compressors are used to meet the minimum flow requirements, the redundancy requirements for commercial level reliability, and the flow variability to allow reasonable load following over the entire operating range. Each compressor is either on or off. No unloading or speed variation is required with these compressors. Five compressors operating in on/off mode will yield 20 percent load increments for the second-stage.

Each first stage compressor, operates on 208 Vac, three-phase power, and each second-stage compressor operates on 208 Vac single phase power.

2.3.2 Oil Separation and Separators

Each compressor discharge has its own oil separator. These are commercial grade, cyclone type similar to the Simons 5000 Series of separator. Each separator has its own return lines to its corresponding compressor sump. The first and second-stage separators are not interchangeable due to the different flow and pressure ratings.

2.3.3 Compressor Sump Heaters

Each compressor has a sump heater in order to prevent refrigerant condensation when it is shut down. Condensation can cause liquid slugging and excess power surges upon compressor start-up. Each heater is commercial grade, wraparound type of at least 50W rating, similar to the Mars model 3240 sump heater.

2.3.4 Heat Exchangers

Five heat exchangers are used in the LSSIF high-lift heat pump system as shown in Table 5. They are all of similar construction, using brazed parallel plates to maximize heat transfer while minimizing size, weight and cost.

Capacity numbers shown in Table 5 represent the maximum design heat transfer rates expected. To ensure the design point of 5 kW of cooling could be met, each heat exchanger was oversized by approximately 30 percent to account for system development uncertainty. The direct heat exchanger was sized to provide 6.5 kW of cooling when the water inlet temperature is at or below 35°F.

The evaporator consists of two Flat Plate Inc., Model FP5X20-20, plate-fin heat exchangers. The evaporator is single phase water on one side and two-phase HCFC-123 on the other side. It absorbs heat from the chilled water loop, that simulates the habitat cooling loop, and transfers it to the refrigeration cycle, boiling the refrigerant in the process.

Table 5. Heat exchanger descriptions

Heat Exchanger	Heat Transfer Capacity (Btu/hr)	Type	Fluids Hot Side	Fluids Cold Side
1. Evaporator (2 HXs)	22,185 Btu/hr 6.5 kW (combined)	Parallel Plate	H_2O (15% Glycol)	R-123
2. Economizer	6,995 Btu/hr 2.05 kW	Parallel Plate	R-123	R-123
3. Direct	22,185 Btu/hr 6.5 kW	Parallel Plate	H_2O (15% Glycol)	H_2O (50% Glycol)
4. Condenser	38,942 Btu/hr 11.41 kW	Parallel Plate	R-123	H_2O (50% Glycol)

The economizer heat exchanger is a Flat Plate Inc., Model FP5X20-8, plate-fin heat exchanger. It is a single phase liquid to two-phase refrigerant "flash" evaporator. Refrigerant condensate is routed from its loop, undergoes a pressure drop through the economizer control valve, flashing to vapor, and is injected into the second-stage suction stream. This cools the second-stage suction vapor to prevent overheating of the second-stage compressor motor windings.

The condenser is a Flat Plate Inc., Model FP5X12-80, plate-fin heat exchanger. The evaporator is single phase water (50 percent Glycol) on one side and two-phase HCFC-123 on the other side. It transfers heat from the HCFC-123 vapor, condensing it in the process, to the rejection loop.

The direct heat exchanger is a Flat Plate Inc., Model FP5X12-30, plate-fin heat exchanger. It is a liquid to liquid heat exchanger that transfers heat directly from the chilled water loop to the rejection loop when vapor compression heat pumping is not required.

2.3.5 Check Valves

Each compressor has a check valve at its discharge to prevent high pressure back flow when shutdown. The second-stage branch of compressors also has a separate check valve to prevent back flow into the stage when it, only, is shutdown. This check valve is redundant with the four compressor discharge check valves. The second-stage bypass line has a check valve to prevent back flow to the first-stage. All check valves are commercial grade.

2.3.6 Filters

There is a vapor filter at the suction to the second-stage compressors and a liquid filter/drier at the receiver discharge. These filters are standard refrigeration components.

2.3.7 Receiver

A liquid refrigerant receiver is located downstream of the condenser. Its purpose is to store high pressure condensed refrigerant, and is used specifically to accommodate different operating charges in the evaporator and condenser during varying load conditions. The receiver comes with its own outlet isolation valve. This valve used in conjunction with the condenser isolation ball valve is used to isolate the refrigerant in the high pressure side of the heat pump, and away from most major components, to allow maintenance on the major components without removing the refrigerant charge.

2.3.8 Bypass Valves

Three way, two position solenoid operated valves are placed in the chilled water supply and return lines to divert chilled water from the evaporator to the direct heat exchanger. These valves are commercial grade and allow full system flow to either the evaporator or direct heat exchanger. They also isolate chilled water flow to the bypassed heat exchanger. These valves and their function work in unison with the condenser rejection loop working fluid bypass valves so that chilled water and rejection loop working fluid flows will be either fully to the direct heat exchanger or fully to the evaporator or condenser.

Three way, two position solenoid operated valves are placed in the rejection loop supply and return lines to divert the rejection loop working fluid from the condenser to the direct heat exchanger. These valves are commercial grade and allow full system flow to either the condenser or direct heat exchanger. They also isolate rejection working fluid flow to the bypassed heat exchanger. These valves and their function shall work in unison with the evaporator chilled water bypass valves so that chilled water and rejection loop working fluid flows will be either fully to the direct heat exchanger or fully to the evaporator or condenser.

A three way, two position solenoid operated valve is used to divert first stage discharge gas around the second-stage compressors when they are not required.

2.3.9 Control Valves

All control valves are proportional type. Each valve will perform its control function independently based on a monitored temperature and local controller.

The controllers modulating refrigerant flow into the evaporator will adjust flow rate depending on outlet temperature; approximately 2.8°C of superheat will be maintained. The actual temperature will depend on heat exchanger pressure. The superheat is determined from evaporator pressure and outlet temperature readings which are evaluated by the central controller. The controller then sends a superheat value to the local controller that actuates the evaporator control valve.

The economizer control valve regulates the "flashing" of refrigerant condensate to the second-stage compressor suction in order to control second-stage compressor temperatures to within safe operating limits, protecting motor windings and avoiding lubricate breakdown. This process is supplemented by the liquid injection system.

The liquid injection control valve controls a relatively small liquid flow from the relatively cool liquid return line to be injected into the first-stage discharge/second-stage suction line. This liquid flow mixes with the first-stage vapor, evaporating, to cool the second-stage suction. Cooling the second-stage suction helps control second-stage compressor temperatures to within safe operating limits, protecting motor windings and avoiding lubrication breakdown. The liquid injection has an adverse effect on heat pump COP and is only used intermittently when economizer flow is inadequate to control second-stage suction temperature.

The chilled water loop control valve bypasses water around the evaporator to maintain a post-mixed stream temperature of 4°C ±1.7°C. If the control valve cannot maintain the desired temperature range, it will:

1. Divert all water through the evaporator if the outlet temperature is greater than 5.7°C.
2. Completely bypass the evaporator if the outlet temperature is less than 2.3°C.

The direct heat exchanger control valve operates 4°C to 1.7°C, to control the temperature of the chilled water, but will bypass rejection water around the direct heat exchanger in order to do so. This is because rejection water can be as low as -8°C, and, if chilled water is bypassed, the lower chilled water flow rates, coupled with very low temperatures in the rejection water loop, could present a freezing condition. In the event that the valve cannot maintain the desired temperature, it will:

1. Divert all rejection water to the direct exchanger if the chilled water outlet temperature is greater than 5.7°C.

2. Completely bypass the direct heat exchanger if the outlet temperature is less than 2.3°C.

2.3.10 Isolation Valves

Isolation valves at the exit of the receiver and inlet of the condenser are supplied in order to isolate the refrigerant charge from the rest of the system to allow maintenance.

2.3.11 Skid

The skid will be capable of supporting 1500 lb by fork lift lifting points. Its construction is mild steel and fastening is by welding. Its foot print is 120 cm x 182 cm. Figure 7 shows the skid details.

2.4 System Temperatures and Pressures

The high-lift heat pump is designed to remove a thermal load from the ITCS loop of between 1.0 and 5.0 kW. The heat pump can maintain the outlet temperature of the ITCS at 4°C ±1.7°C (39°F ±3°F) over this load range for either direct cooling or heat pump modes. Direct cooling is operated when the ETCS entering fluid temperature falls between –8.3 and 0°C (17 and 32°F). The heat pump is operated when the ETCS liquid temperature rises above 0°C (32°F). The heat pump operates in first-stage until the condenser pressure is greater than 150 kPa (22 psia). The second-stage is operated up to an ETCS inlet temperature of 88°C (190°F). The heat pump can be stopped and restarted at any point in its operation, however, it is not recommended to start the heat pump when the ETCS inlet temperature is greater than 54°C (130°F). If the ETCS temperature is above this value, heat pump restart should be delayed until the ETCS loop cools. The heat pump controller will start the heat pump in either direct cooling, single stage, or two–stage mode depending upon the values of the ETCS inlet temperature and the condenser pressure. The controller will delay restart of the heat pump 15 min after it is stopped.

Table 6 gives the estimated values of significant temperatures and pressures that will be seen during operation.

2.5 Electrical Diagram

Appendix A contains the complete electrical diagram for the high–lift heat pump.

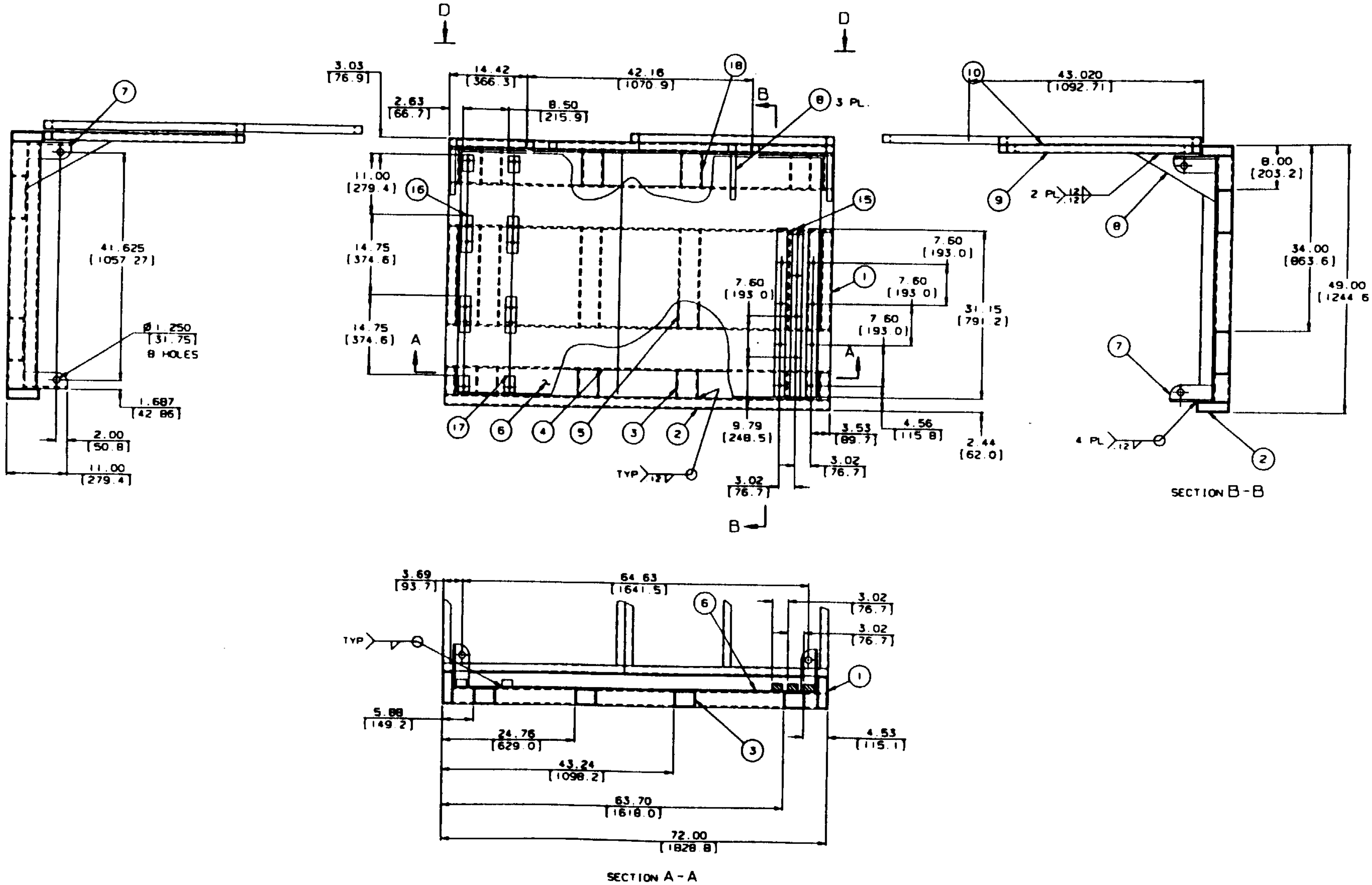


Figure 7. LSSIF heat pump skid

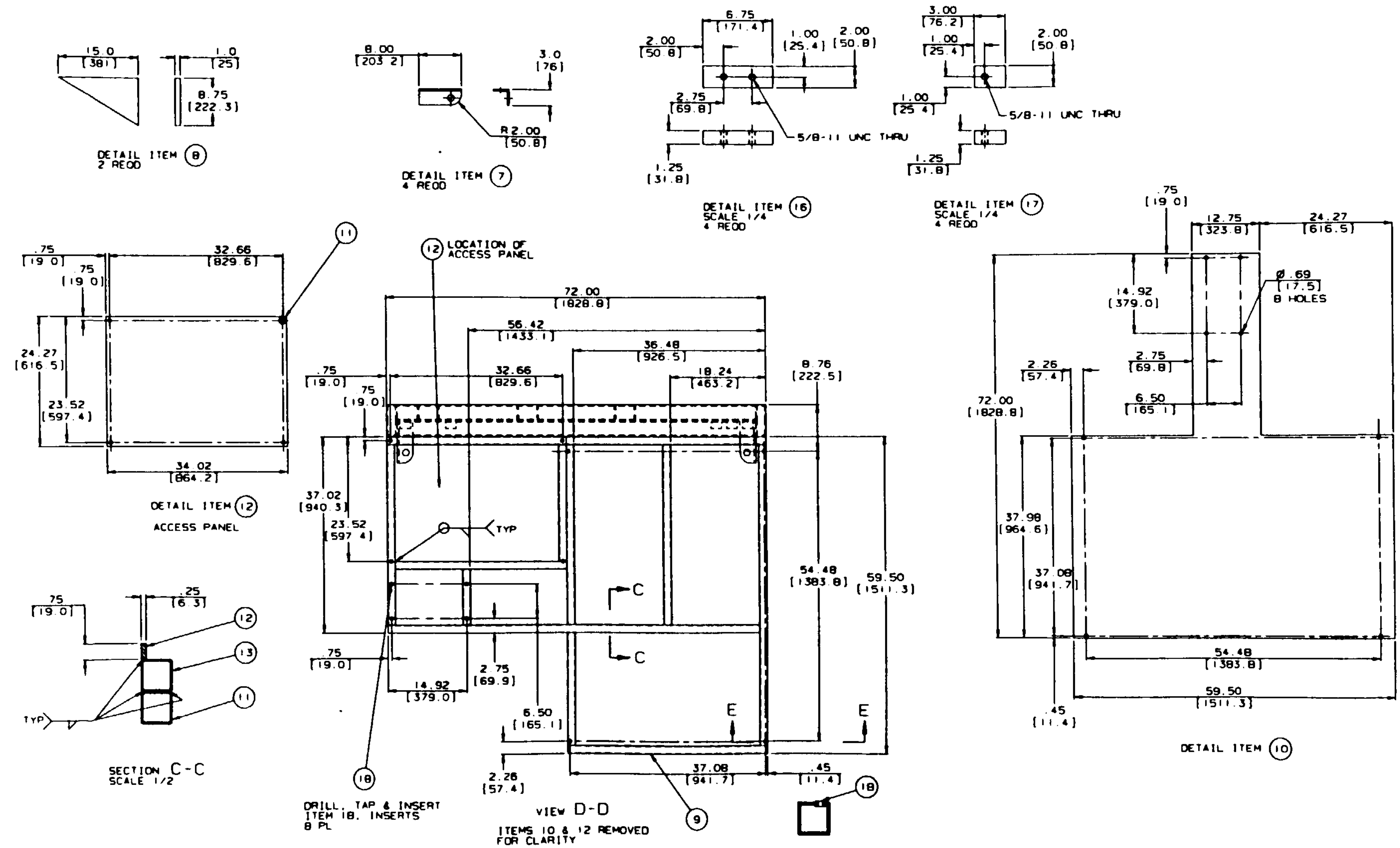


Figure 7. ***LSSIF heat pump skid (continued)***

Table 6. High-lift heat pump operating temperatures and pressures

Temperature °C (°F) Location	Nominal	Maximum	Minimum
ITCS			
Heat Pump Inlet	13 to 5 (55 to 41)	27 (80)	2 (36)
Heat Pump Outlet	6 to 2 (43 to 36)	18 (65)	1 (33)
ETCS			
Heat Pump Inlet			
Direct Mode	–8 to 1.7 (17 to 35)	1.7 (35)	–8 (17)
Heat Pump	1.7 to 88 (35 to 190)	90 (195)	1.7 (35)
Heat Pump Restart			
First-Stage		38 (100)	
Second-Stage		54 (130)	
Refrigerant			
First-Stage Superheat	0.6 to 5.6 (1 to 10)	11 (20)	0
First-Stage Discharge	49 to 116 (120 to 240)	135 (275)	38 (100)
Second-Stage Suction	16 to 79 (60 to 175)	104 (220)	2 (35)
Second-Stage Discharge	49 to 104 (120 to 220)	116 (240)	38 (100)
Refrigerant Pressure kPa (psia)			
First-Stage Suction	25.8 to 28.6 (3.8 to 4.3)	68.0 (10.0)	10.2 (1.5)
Single Stage Operation	54.4 to 149.6 (8.0 to 22.0)	183.6 (27.0)	27.2 (4.0)
Second-Stage Suction	40.8 to 149.6 (6.0 to 22.0)	183.6 (27.0)	20.4 (3.0)
Second-Stage Discharge	136.0 to 714 (20.0 to 105.0)	748 (110.0)	54.4 (8.0)

3. AUTOMATED CONTROLS

Automatic controls were developed for the high lift heat pump so that it could be run with minimal human monitoring and intervention.

The heat pump is not controlled by a single piece of equipment. A GE Fanuc Series 9030 PLC controller performs the majority of the data acquisition and control actions; however, several closed-looped, self-learning PID controllers supervise the function of select system valves. These individual controllers were used because of their expected suitability for this application, as well as to reduce PLC software complexity, minimizing development and troubleshooting costs of that system. Their operation is explained in subsection 2.3.9.

Tables 7 and 8 contain lists of the system control actions used to operate the high lift heat pump in the automatic mode. As seen in the tables, some are performed by the GE Fanuc software, whereas others are not. In these cases, the table further identifies the equipment

Table 7. Water systems control

Control Action	Fanuc Controlled?	Comments
ITCS Inlet Temperature (T16)	No	Control external to heat pump.
ITCS Final Outlet Temperature, Heat Pump Mode (T15)	No	PID closed–loop controller operating inlet/outlet mixing valve, setpoint adjustable on electrical panel. Fanuc drops compressors if outlet temperature falls below lower limit.
ITCS Final Outlet Temperature, Direct HX Mode (T15)	No	Same PID controller as in heat pump mode, however, Fanuc cuts out ETCS flow if temperatures drop below lower limit.
ITCS Evaporator Outlet Temperature (T14)	Yes	Regulated by controlling evaporator pressure in acceptable range; allows pressure to float high if outlet water temperature is too cold.
ITCS Direct HX Outlet Temperature (T1)	No	PID closed–loop controller bypasses ETCS water if ITCS water temperature drops too low.
ITCS Flow Rate	No	Control external to heat pump.
ETCS Inlet Temperature (T17 or T18)	No	Control external to heat pump.
ETCS Outlet Temperature (T12)	No	Not controlled; temperature rise dictated by heat pump rejection requirements.
ETCS Flow to DHX or Condenser	Yes	Controls solenoids; decision based on ETCS inlet water temperature.
ETCS Flow Rate	No	Control external to heat pump.

Table 8. Refrigeration system control

Control Action	Fanuc Controlled?	Comments
Evaporator Pressure (P1)	Yes	By means of compressor control.
Second-Stage Suction Pressure (P4)	No	Not controlled; floats depending on lift requirement (but could be controlled).
Condenser Pressure (P5)	No	Not controlled; floats depending on ETCS water inlet temperature.
Evaporator Refrigerant Flow Rate	No	PID Closed–Loop Controller (superheat calculated, and signal provided, by Fanuc).
Liquid Refrigerant to Evaporator	Yes	Fanuc controls solenoid on discharge of liquid receiver.
Economizer Refrigerant Flow Rate	No	Mechanical thermal expansion valve (TXV) controls using economizer outlet superheat (T20).
Liquid Refrigerant to Economizer	Yes	Fanuc controls solenoid on economizer inlet.
Second-Stage Discharge Gas Control	Yes	Fanuc controls bypass solenoid.
Heat Pump First and Second-Stage Control	Yes	Fanuc controls starting/stopping of first and second-stage as required based on pressures.
First-Stage Compressor Control	Yes	Fanuc cycles compressors on/off, and speed of Comp 3, to maintain evaporator suction pressure and ITCS evaporator outlet temperature.
Second-Stage Compressor Control	Yes	On/off only.
Heat Pump Start/Stop Cycle	No	Manually controlled at electrical panel.
Heat Pump Emergency Stop	No	Manually initiated at electrical panel.

performing the action as appropriate. Controls identified as being regulated by the Fanuc automatic control can also be manually overridden by use of on/off switches inside the electrical panel (one of the Fanuc modules). However, this mode is recommended only for troubleshooting and initial system checkout.

3.1 GE Fanuc Control Program Functions

The previous subsection summarized the actions required for control of the water systems and refrigeration system for automatic operation of the high lift heat pump. The contribution of the Fanuc in providing these functions was also identified. It executes these functions by performing all of the following:

- Determines the state in which the heat pump should operate.
- Adjusts system capacity to ensure loads varying between 1 to 5 kW are met, with a final outlet temperature ranging between 2.3 to 5.7°C.

- Performs transition actions between required states in an orderly, safe manner.

- Records, stores, and acts on system temperatures and pressures, as appropriate.

- Works in conjunction with other system controls, and in some cases, overrides these control to ensure setpoints are met.

- Provides communications with the ALSSIF system supervisory controller.

- Provides a manually controlled option for troubleshooting and system checkout.

3.2 Control Program Operation

3.2.1 Automatic Cycle Control

The heat pump automatic control system must first be started from the electrical panel by depressing the "Start Cycle" button. This enables the software to begin the control actions for which it is responsible. Once activated, it will continue to act in an automatic mode, transitioning between necessary states, until interrupted by one of the following actions:

- The "Stop Cycle" button is pushed, upon which all setpoints are ignored, and system is shutdown in an orderly fashion.

- The "Emergency Stop" button (E-STOP) is pushed, in which all system equipment is shut down and returned to its original startup condition. (Note: the control program is still operating when the E-STOP button is pushed.)

- The Auto/Manual Switch is moved to the manual position, in which case automatic setpoints are overridden for on/off switch control inside the electrical panel.

3.2.2 Heat Pump Operating States

When the system is in automatic operation, it can be in one of three states:

- Direct heat exchange only.
- Heat pump in operation, first-stage only.
- Heat pump in operation, both stages.

The method the control program uses to determine which state is required is based primarily on ETCS water inlet temperature. If the incoming water stream is 0°C or below, it is judged to have sufficient cooling capability to provide up to 5 kW of cooling for the ITCS stream. Therefore, the system will start or operate in direct heat exchange only. The only time ETCS water is routed to the direct heat exchanger is in this mode.

At temperatures greater than 0°C, the system will transition to the second mode, with only the first-stage of the heat pump being required at ETCS inlet temperatures below approximately 38°C. (The actual control action is based on condensing pressure, but it is directly related to this temperature.) As temperatures rise above this number, condensing pressures become too high for a single stage. When pressures rise above 22 psia, the second-stage is activated. The second-stage is turned off when condensing pressures fall back below 20 psia.

The control system is capable of handling transitions from any one state to any other state in automatic operation. In cases of manual intervention, the control program also assesses if it must perform a "hot stop" or "hot start." Hot stop is performed whenever the "Stop Cycle" is initiated when in two-stage operation. Hot start is performed whenever the system was shut down from either a normal or emergency shutdown, and the ETCS inlet temperature has not dropped below 38°C. (Note: the control program does not prevent the user from initiating a hot start at any ETCS water inlet temperature. However, it is not recommended that the heat pump be restarted at ETCS temperatures above 54°C. The reason is that second-stage compressors may not be able to overcome the large head differentials that will be experienced with higher condensing temperatures.) Both the hot start and hot stop cycles are similar to the normal starting and stopping procedures, except these procedures activate and secure equipment in a different order.

3.2.2 Automatic Compressor Control

When the heat pump is operating, both evaporator pressure and evaporator ITCS water outlet temperature are monitored to control the operation of the first-stage compressors. For "gross" adjustments, they are cycled to maintain an evaporator pressure of between 3.8 psia and 4.3 psia. (These pressures were selected through experimentation to provide sufficient ITCS water cooling during normal operation.) This pressure range is maintained by turning on or shutting off compressors to either increase or decrease the amount of refrigerant removed from the evaporator.

Six major operating tiers were established, ranging from one compressor at half speed (minimum capacity) to three compressors at full speed (maximum capacity). In-between maximum and minimum capacity, the system increments or decrements in half speed steps. To provide these major steps, compressors No. 1 and No. 2 are operated only in the on/off mode. However, the variable speed compressor (No. 3), whose speed is proportion to the output frequency from the variable frequency drive, is operated in either low speed mode (base frequency of 30 Hz) or high speed mode (base frequency of 60 Hz).

For minor adjustments at the high evaporator load end, the low speed and high speed modes of compressor 3 contain three additional speed increments. Rather than controlling by use of evaporator pressure, however, ITCS evaporator outlet temperature (T14) is used. In low speed mode, if this temperature rises above its setpoint of 39°F, the output speed signal will be increased to between 37 and 52 Hz as shown in the schedule in Table 9. Similarly, in high speed mode, output frequency to the compressor varies in three additional speed increments between 65 and 75 Hz. To prevent frequent compressor speed changes, a one-half degree (F) deadband was established before the compressor returns to the next lower speed as shown under the "decreasing temperature" portion of the table.

Suction pressure control of the compressors is also overridden if ITCS final outlet temperatures (T15) drop below its minimum setpoint of 36°F. (This is likely to occur when the required ITCS load is low, and ITCS inlet temperature drops below approximately 42°F.) In this case, the control system permits the evaporator to warm up by allowing suction pressure to float above its normal setpoint of 4.3 psia. The system will continue to shed capacity (reducing the number of compressors in operation) until the final outlet temperature returns to within its desired operating range. Once recovered (above 38°F), suction pressure control again takes precedence.

The five second-stage compressors are all single speed, hence, are only operated in the on/off mode. Due to the fact that this type of compressor may have difficulty starting against a high pressure differential, they are not cycled individually to control second-stage suction pressure. Instead, this pressure is permitted to seek its own level between first-stage suction pressure and condenser pressure. No degradation of performance was noticed as a result of this scheme. Rather, running the second-stage at it greatest capacity minimizes the pressure

Table 9. ***Variable frequency drive output to the variable speed compressor***

ITCS Evaporator Outlet Temperature (°F)	Low Speed Mode Output Frequency (Hz)	High Speed Mode Output Frequency (Hz)
Increasing Temperature		
Below 39.0°F	30	60
Above 39.0°F	37	65
Above 40.0°F	45	70
Above 41.0°F	52	75
Decreasing Temperature		
Above 40.5°F	52	75
Below 40.5°F	45	70
Below 39.5°F	37	65
Below 38.5°F	30	60

ratio required of the first-stage, maximizing the flow rate through each compressor in operation. It also permits reducing first-stage capacity to a minimum. (Most compressors are cooled by the refrigerant gas they compress. The low density of the gas at typical first-stage suction pressures inhibits effective heat removal from these compressors. Therefore, it is desirable to increase flow rate through any operating first-stage compressor to the greatest extent possible to assist in this cooling.)

3.2.3 System Major Component Conditions

Table 10 shows the desired condition of each major system component for the three automatic operating modes, the manual mode, and the system secured condition. The GE Fanuc software provides the necessary actions to bring the component status in line with that required for the desired state. This table can be used to verify proper equipment alignment during the three automatic modes (visual indications for most components are on the electrical panel door). It can also be used to decide on equipment alignment in the manual mode; however, caution should be used in the sequencing of component or equipment activation, as an undesirable condition may result. (Consistency with automatic routines is recommended if the manual mode is used.)

3.3 Control System Interfaces

The GE Fanuc is used for data acquisition of system temperatures, pressures, and the power consumption reading. It does so by use of multiple instrument input modules, both digital and analog, located in the expansion slots adjacent to the Fanuc controller (located inside the electrical panel). The wiring details are contained in the electrical diagram in Appendix C. All system temperatures, pressures, and compressor status are recorded and stored in data registers for monitoring by the supervisory controller. However, only a small portion of these are actually used for control actions. The remainder were placed in the system for performance analysis.

Table 10. Heat pump major component condition for different operating modes

	Heat Pump System Mode				
	Direct Heat Exchange	First-Stage Heat Pump	Second-Stage Heat Pump	Manual Mode	System Secured
GE Fanuc	On	On	On	On	On or Off
1st Stage Compressors	Off	On	On	As desired	Off
2nd Stage Compressors	Off	Off	On	As desired	Off
Condenser Solenoid	Closed	Open	Open	As desired	Closed
Direct HX Solenoid	Open	Closed	Closed	As desired	Closed
Liquid Refrigerant Solenoid	Closed	Open	Open	As desired	Closed
Economizer Solenoid	Closed	Closed	Open	As desired	Closed
2nd Stage Bypass Solenoid	Closed	Closed	Open	As desired	Closed
EVAP 1 PID Controller	Off (but powered)	On	On	As desired	Off
EVAP 2 PID Controller	Not Used	Not Used	Not Used	Not Used	Off
Economizer TXV	No flow	No flow	No flow	Operating	No flow
Superheat Signal to PID Control	False signal	On	On	On	False signal

The control system also uses a number of digital outputs, as well as two analog outputs, to send control signals to the high lift heat pump. These are shown in the next section, as well as in the electrical diagram in Appendix C.

3.3.1 Control System Inputs

For initiation of control actions using the GE Fanuc software, a total of five temperatures and four pressures are used. These are shown in Tables 11 and 12. This table identifies not only the register location of the raw analog signal, but also the location of the processed data to which the calibration has been applied. The table also shows the name of the measurement, as well as the purpose for which the data is used in the control program. Nicknames and reference descriptions used in the software are given in the variable table in Volume II of the operations manual.

The digital inputs required for heat pump operation are similarly shown in Table 13. As can be seen, these are either for control of the system in the manual mode, or for manual intervention of the system when it is operating in automatic mode. Nicknames and reference descriptions are given in the variable table of the control program.

Table 11. Control system analog input measurements

Instrument No.	Raw Input/ Processed Reading	Measurement	Used To
Temperatures			
T14	AI0014/R0047	ITCS–Evaporator Outlet	Control of low evaporator outlet temperature.
T15	AI0015/R0046	ITCS– Heat Pump Outlet	Control of both high and low heat pump final outlet temperature.
T17	AI0017/R0044	ETCS–Condenser Inlet	Determine direct HX or heat pump mode; to determine if hot start is required.
T18	AI0018/R0043	ETCS–Direct HX Inlet	Determine direct HX or heat pump mode.
T20	AI0020/R0051	First-Stage Suction	Calculate degrees superheat.

Table 12. Control system analog input measurements

Instrument No.	Raw Input/ Processed Reading	Measurement	Used To
Pressures			
P1	AI0033/R0080	First-Stage Suction	Adjust compressor capacity to maintain near–constant evaporator temperature.
P4	AI0036/R0077	Second-Stage Suction	Calculate pressure differential for economizer.
P5	AI0037/R0076	Condenser Inlet	Determine if one or two stage operations are required.
P7	AI0024/R0074	Expansion Valve Inlet	Calculate pressure differential for economizer.

3.3.2 Control System Outputs

The GE Fanuc uses a combination of both digital and analog outputs to perform its control functions. As shown in Table 14, the majority of these are digital outputs (data register begins with "Q"). The interface of these outputs with the GE Fanuc output modules are shown in the electrical diagram in Appendix A.

3.4 Control Program

The control program for the GE Fanuc Series 9030 PLC controller was written using ladder logic, a software package provided with the system.

The control program executes whenever the GE Fanuc is powered up, unless the Fanuc is paused or stopped by an external command. While executing, however, it will not perform

Table 13. Digital control system inputs

Data Register	Description	Function
I0001	E–Stop	Stop system using Emergency Stop pushbutton (Auto or Manual Mode)
I0002	Start Cycle	Manually start the cycle using the pushbutton (Auto Mode only)
I0003	Stop Cycle	Manually stop the cycle using the pushbutton (Auto Mode only)
I0018	Compressor 1 Switch	Start/Stop Compressor 1 in Manual Mode
I0019	Compressor 2 Switch	Start/Stop Compressor 2 in Manual Mode
I0020	Compressor 3 Switch	Start/Stop Compressor 3 in Manual Mode
I0021	Compressor 4 Switch	Start/Stop Compressor 4 in Manual Mode
I0022	Compressor 5 Switch	Start/Stop Compressor 5 in Manual Mode
I0023	Compressor 6 Switch	Start/Stop Compressor 6 in Manual Mode
I0024	Compressor 7 Switch	Start/Stop Compressor 7 in Manual Mode
I0025	Compressor 8 Switch	Start/Stop Compressor 8 in Manual Mode
I0026	Stage 2 Bypass	Activate bypass in Manual Mode
I0027	Direct HX/Condenser	Activate Direct HX or Condenser in Manual Mode
I0028	Liquid Refrigerant	Activate Liquid Refrigerant in Manual Mode
I0029	Economizer	Activate Economizer in Manual Mode
I0032	Manual Mode Switch	Select Manual or Automatic Mode

automatic control actions unless the "Start Cycle" is activated from the electrical panel. The program will permit manual operations by switching to Manual Mode (described previously) without activating the "Start Cycle" pushbutton.

3.4.1 Program Organization

The program contains a main program and 29 subroutines for control of the high lift heat pump operation. The subroutines were created to break program into logical tasks or decision-making processes. Subroutine execution is controlled by the main program, and to some degree, several other major subroutines. During each program sweep, only those subroutines that are relevant to the heat pump state are executed. The software does permits branching from one subroutine to another, but once a subroutine is completed, program execution returns to the previous branch point.

3.4.2 Main Program and Program Subroutines

The logic flow diagram used for main program and subroutine development is found in Appendix B.

Basic descriptions of each program subroutine are included in Tables 15 and 16. Also included in the tables are the routines from which each subroutine can be called.

Table 14. Control system outputs

Data Register	Description	Function
Q0002	Compressor 2 Motor/Starter	Activates motor/starter control relay
Q0003	Compressor 3 Motor/Starter	Activates motor/starter control relay
Q0004	Compressor 4 Motor/Starter	Activates motor/starter control relay
Q0005	Compressor 5 Motor/Starter	Activates motor/starter control relay
Q0006	Compressor 6 Motor/Starter	Activates motor/starter control relay
Q0007	Compressor 7 Motor/Starter	Activates motor/starter control relay
Q0008	Compressor 8 Motor/Starter	Activates motor/starter control relay
Q0009	Variable frequency drive run	Gives auto or manual control of VFD
Q0017	Stage 2 Bypass	Activates solenoid control relay
Q0018	Condenser Bypass	Activates solenoid control relay
Q0019	Direct Heat Exchanger Bypass	Activates solenoid control relay
Q0020	Liquid Refrigerant Bypass	Activates solenoid control relay
Q0021	Economizer	Activates solenoid control relay
Q0022	Compressor 1 High Speed	Activates high speed motor/starter control relay
Q0023	Compressor 1 Low Speed	Not used, tied "low" in software, left in for future development.
Q0024	Compressor 1 speed select	Not used, tied "high" in software, left in for future development.
AQ0001	Variable Frequency Drive	Gives VFD a 4 to 20 mA signal proportional to 0 to 75 Hz.
AQ0002	Superheat	Gives evaporator PID flow controller a 4 to 20 mA signal proportional to superheat.

Table 15. Control program subroutines

Subroutine	Called From:	Purpose
MANUAL	MAIN	Controls digital outputs to compressors and solenoids; controls compressor startup timers.
DIRHX	MAIN	Controls automatic signal to direct HX solenoids.
HPREQ	MAIN	Determines if heat pump or direct HX should be operated.
ST1CTL	MAIN	Controls the starting, stopping, and adjustment of the first-stage compressors.
ST2REQ	MAIN	Determines if the second-stage is required during heat pump operation.
ST2CTL	MAIN	Controls the starting and stopping of the second-stage compressors.
ST1ST	ST1CTL	Sequences first-stage start (second-stage not required).
ST1STP	ST1CTL	Sequences first-stage stop (second-stage off).
ST1ADJ	ST1CTL	Determines if first-stage compressor capacity should be increased or decreased.
ST2ST	ST2CTL	Sequence for starting second-stage (first-stage on).
ST2STP	ST2CTL	Sequence for stopping second-stage (first-stage to stay on).
ST2ADJ	ST2CTL	Not used in final version; left in for future development.
ST1INCR	ST1ADJ	Decides how to increase capacity by 1/2 step.
ST1DECR	ST1ADJ	Decides how to decrease capacity by 1/2 step.
ST2INCR	ST2ADJ	Not used in final version; left in for future development.
ST2DECR	ST2ADJ	Not used in final version; left in for future development.
RESET	MAIN	Resets all retentive variables to starting condition in the event that E–STOP is used.
INIT	MAIN	Initializes certain registers to store data information.
READING	MAIN	Reads analog inputs, converts them using calibration data, and stores them in assigned data registers.
SUPHT	SUPHC	Calculates superheat based on suction pressure and suction gas temperature.
SUPHC	MAIN	Controls how often superheat is calculated, routes program to calculation subroutine and output subroutine. Also, generates a false, neutral signal (3 deg) if heat pump is not in operation to prevent controller hunting.
ST_STP	MAIN	Determines if Start Cycle or Stop Cycle buttons pushed.
ECONM	ST2CTL	Calculates if required pressure differential is available to run the economizer.

Table 16. Control program subroutines

Subroutine	Called From	Purpose
HOT_STP	ST1CTL	Sequence for stopping both stages simultaneously.
HOT_ST	ST1CTL	Sequence for starting both stages simultaneously.
ST_TEMP	ST1CTL	Determines whether, upon activation of Start Cycle, if water temperatures require starting one or two stages.
SUPHOUT	SUPHC	Calculates output signal required for variable frequency drive, places it in appropriate analog output register.
TURBO	MANUAL	Determines compressor three speed (frequency) in high speed mode based on ITCS evaporator outlet temperatures, provides output signal if speed change desired.
LOWTURB	MANUAL	Determines compressor three speed (frequency) in low speed mode based on ITCS evaporator outlet temperatures, provides output signal if speed change desired.

4. HEAT PUMP TEST LOOP

Figure 8 gives a diagram of the flow loop constructed to test the prototype heat pump. Two water loops are employed, referred to as the ITCS and the ETCS. The ITCS represents the cooling load to be met by the heat pump. Heat is provided to the loop by an electric heater that is actuated by a temperature controller. The heater is used to maintain the temperature of the water entering the heat pump. Heat is rejected from the heat pump through the ETCS loop. Heat is removed from the ETCS loop by a condensing unit. Temperature of the loop is controlled by a combination of on/off cycling of the condensing unit and a bypass valve in the ETCS loop that diverts a portion of the flow around the condensing unit. Instrumentation is provided in both flow loops to measure the inlet and outlet temperatures and the flow rates.

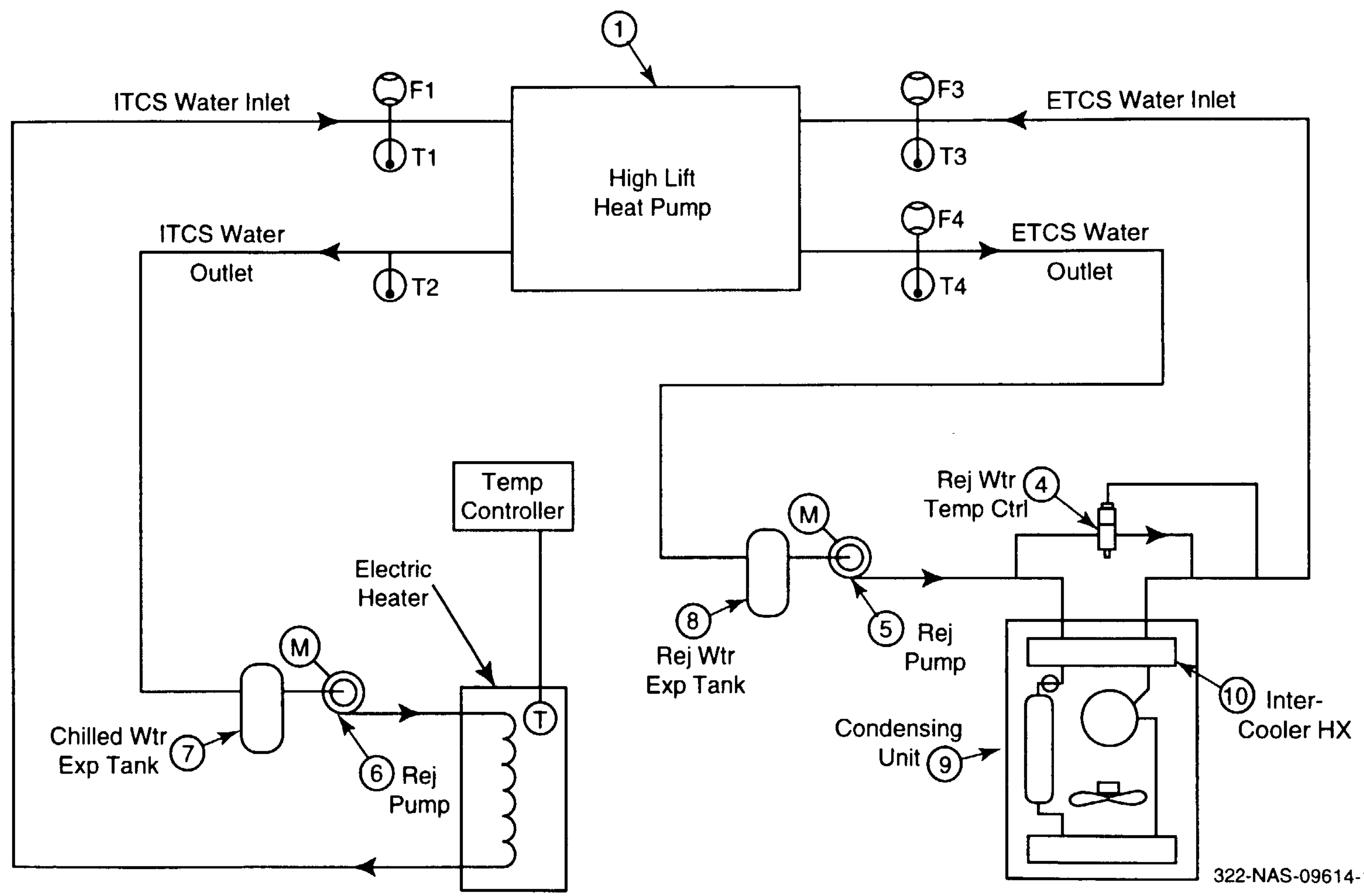


Figure 8. ***Heat pump test loop***

5. PERFORMANCE TEST RESULTS

Two performance tests were conducted for NASA personnel prior to the shipment of the high-lift heat pump to Johnson Space Center. These tests were done to show that the heat pump could:

- Provide a cooling capacity of 5 kW with an ETCS inlet water temperature ranging from 10 to 91°C.
- Provide an ITCS water temperature of 4°C ±1.7°C at cooling loads as small as 1 kW.
- Operate in a fully automated mode, in which operation can switch between direct heat exchange and heat pumping, as well as between single and two-stage operation based upon system measurements only.

The first performance test consisted of operating at a constant ITCS cooling load of 5 kW while increasing the ETCS temperature from 8 to 91°C. At the highest ETCS temperature, the ITCS cooling load was reduced by lowering the inlet temperature to the heat pump to approximately 5°C. The ETCS temperature was then lowered to a final value of 52.8°C. Data were collected throughout the test.

The significant system temperatures and pressures are shown in Table 17. Figure 9 shows a plot of the ETCS and ITCS temperatures during the test. Test results showed that the heat pump was capable of providing a cooling capacity in excess of 5 kW over the range of ETCS temperatures tested. The average cooling load met during this part of the test was 5.1 kW. Figure 10 shows the values of the ITCS inlet and outlet temperatures during the test and also indicates the temperature control band limits. The ITCS outlet temperature was maintained at an average value of 4.09°C with a standard deviation of ±0.42°C. When the cooling load was lowered for the second part of the test to an average value of 2.4 kW, the average ITCS outlet temperature dropped to 3.08°C, ±0.76°C. The highest ITCS outlet water temperature measured during the test was 4.55°C, while the lowest was 1.34°C. It should be noted that the minimum value was recorded at an inlet ITCS temperature of 2.64°C, which is lower than is anticipated during operation of the ALSSIF.

The second test consisted of operating the heat pump at a minimal cooling load by limiting the heater input to the ITCS loop. The ITCS inlet water temperature varied during the test from a low of 1.04 to a high of 5.82°C. The ETCS temperature initially was set at a value of 21°C and was allowed to rise to a maximum of 90°C. The ETCS temperature was then lowered to its final value of 0.41°C.

The loop temperatures and heat pump pressures recorded during this test are shown in Table 18. Figure 11 shows the ETCS and ITCS temperatures recorded during the test. The average cooling load met by the heat pump during the test was 1.2 kW. Figure 12 shows the ITCS temperatures and the control limits for the low load test. The average ITCS outlet temperature was 3.04°C. All outlet temperatures recorded were within the desired temperature range with the exception of the first two measurements. Both of these temperatures were

Table 17. High-lift heat pump performance test, high-intermediate load testing

Data Pt	Time min	ETCS In Temp. (°C)	ITCS In Temp. (°C)	ITCS Out Temp. (°C)	Heat Pump Load (kW)	Stages	Pressure (psia) Stage 1 Suction	Interstage	Condenser
2	0	8.56	10.99	4.07	5.16	1	4.25	-	12.99
3	8	12.48	12.09	4.13	5.16	1	4.64	-	14.02
4	26	15.44	11.53	3.26	5.32	1	3.96	-	14.70
5	29	22.93	11.04	2.82	5.35	1	3.86	-	16.95
6	35	24.56	11.04	3.93	5.16	1	3.96	-	18.71
8	46	35.56	11.52	4.41	5.07	2	3.96	15.53	24.32
9	58	38.23	12.17	4.46	5.01	2	4.10	16.61	31.75
10	66	47.81	11.82	4.03	5.05	2	4.05	16.75	37.17
11	73	48.76	12.22	4.42	5.13	2	3.91	16.80	40.05
13	85	59.10	12.26	4.55	5.11	2	4.00	18.07	49.28
14	94	61.61	11.88	4.29	5.00	2	4.10	18.80	57.29
15	99	67.38	11.71	4.04	5.04	2	4.00	17.83	61.68
16	106	66.77	11.77	3.92	5.19	2	4.15	17.19	67.01
17	112	71.96	11.85	3.89	5.33	2	4.25	17.34	76.83
18	117	75.99	12.01	4.35	4.97	2	4.10	19.24	85.86
19	124	78.88	11.99	4.32	5.09	2	4.20	19.10	90.31
20	129	85.19	11.98	4.41	5.03	2	4.20	19.44	97.29
21	132	90.99	12.06	4.26	5.03	2	4.20	19.98	108.82
22	137	91.06	5.29	3.21	3.13	2	3.42	15.82	105.70
23	147	87.97	5.13	3.26	2.52	2	4.00	14.60	98.75
24	161	80.47	5.53	3.78	2.57	2	3.86	12.94	86.59
25	180	78.00	5.40	3.28	2.69	2	3.81	11.09	77.80
26	204	74.43	5.40	3.70	2.72	2	3.61	9.67	73.41
27	238	66.46	4.11	2.95	1.46	2	4.35	9.38	61.25
28	284	52.79	2.64	1.34	1.66	2	4.05	7.62	46.15

recorded at ITCS inlet temperatures that were below the desired value of the outlet temperature. This is considered a nonstandard operating situation.

Operation of the heat pump was fully automatic during both tests and the heat pump switched between single and two-stage operation as required by the discharge pressure of the first-stage compressors. The second-stage is brought on-line when this pressure exceeds 20 psia. Operation of the three first-stage compressors was fully automated with the number of compressors running determined by the value of the suction pressure. Pressure profiles for the high-intermediate load test are shown in Figure 13. Condensing pressure rises and falls with changing ETCS temperature. The interstage pressure was recorded from the point that the heat pump changed from single to two-stage operation. Interstage pressure varies slightly

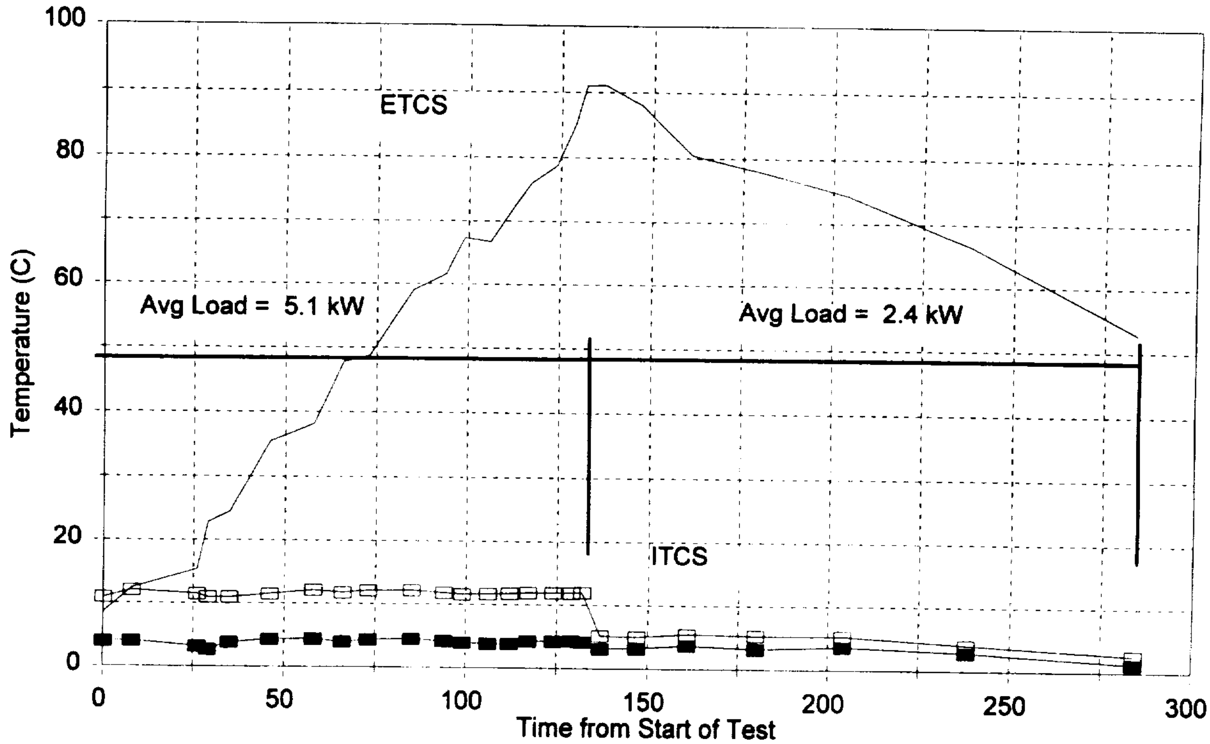


Figure 9. High-lift heat pump performance test, high-to-intermediate load test

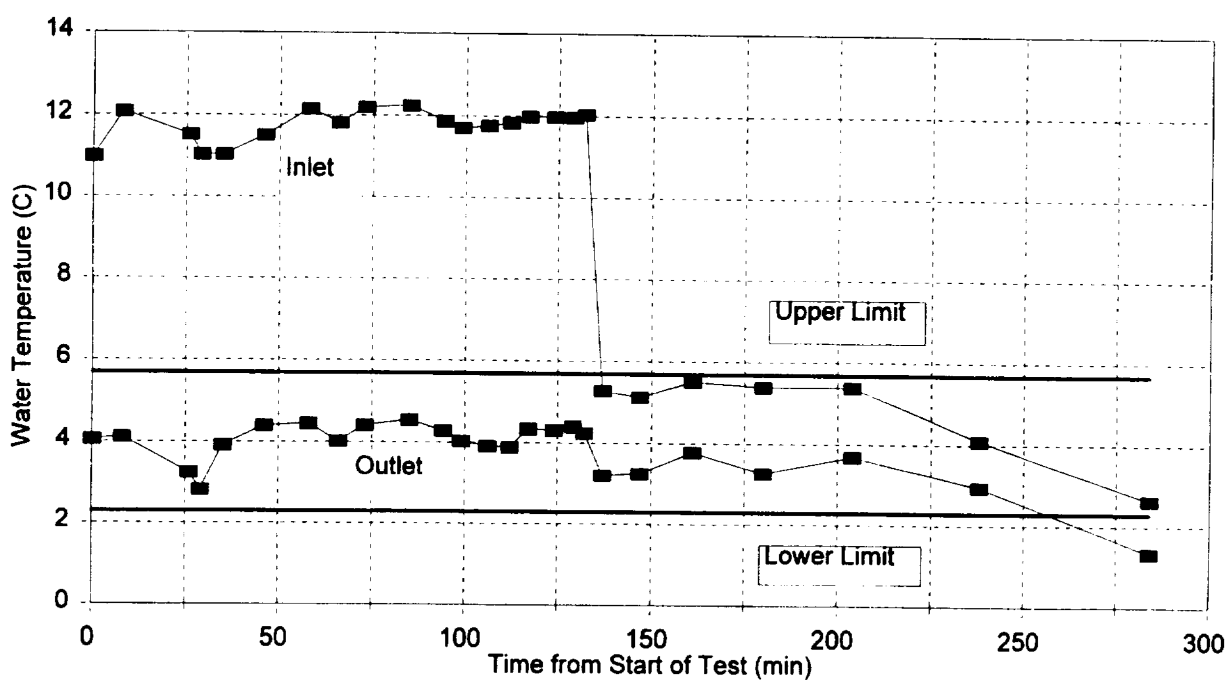


Figure 10. High-lift heat pump performance test, ITCS temperature control (full load)

Table 18. High-lift heat pump performance test, low load testing

Data Pt	Time min	ETCS In Temp. (°C)	ITCS In Temp. (°C)	ITCS Out Temp. (°C)	Heat Pump Load (kW)	Stages	Pressure (psia) Stage 1 Suction	Interstage	Condenser
1	0	21.58	1.04	0.14	1.02	1	3.50	-	15.48
2	25	21.75	2.53	1.66	0.92	1	4.20	-	15.19
3	35	22.87	3.63	2.57	1.15	1	4.44	-	15.34
4	41	20.19	4.92	3.24	1.29	1	4.20	-	14.31
5	46	22.69	4.66	3.12	1.09	1	4.49	-	15.38
6	61	30.53	4.57	3.03	1.05	1	4.44	-	17.73
7	71	39.32	4.95	2.85	1.53	2	4.15	6.15	24.37
9	87	57.98	5.04	3.24	1.34	2	4.10	7.33	42.93
10	92	64.39	5.18	3.57	1.15	2	4.30	6.64	50.55
11	100	81.39	5.13	3.38	1.20	2	4.10	18.07	80.68
12	107	85.36	5.24	3.46	1.21	2	4.05	24.47	89.77
13	110	90.01	5.16	3.66	0.90	2	4.64	21.98	100.22
14	115	84.48	5.67	3.67	1.19	2	4.54	21.34	100.95
15	118	71.82	5.82	3.62	1.46	2	3.91	15.43	72.23
16	125	69.24	5.66	3.52	1.18	2	4.25	17.00	63.25
17	130	48.76	5.18	2.88	1.67	2	3.76	10.60	40.29
18	135	37.83	4.97	3.04	1.40	2	4.25	7.96	32.72
19	139	25.54	5.07	3.68	0.93	2	4.54	5.42	25.93
20	143	15.67	5.33	3.49	1.24	2	4.49	3.91	20.37
22	150	0.41	4.91	2.98	1.25	1	4.15	9.67	14.21

with changes in condensing pressure. First-stage suction pressure is controlled by compressor operation and was found to be essentially constant. The average suction pressure value during the test was 4.2 psia with the highest and lowest pressures recorded being 4.6 and 3.5 psia, respectively.

A complete set of test data recorded during the acceptance tests is provided in Appendix C of this report.

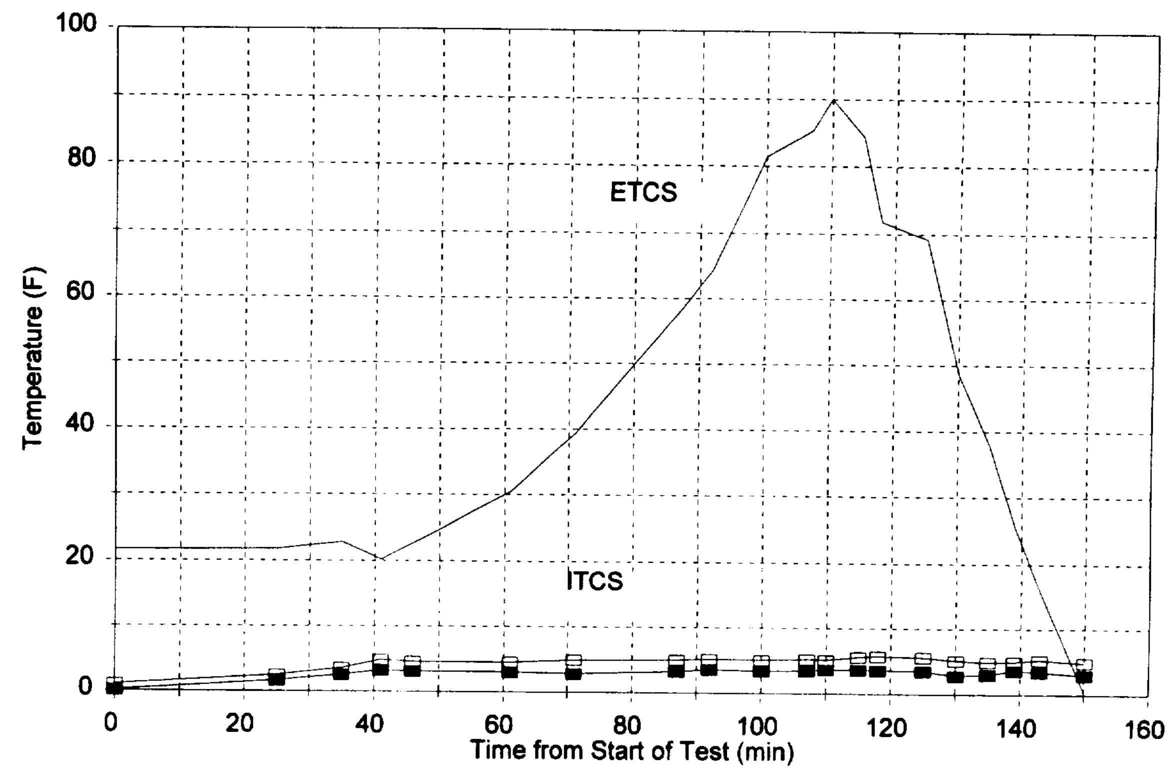


Figure 11. High-lift heat pump performance test, low load test

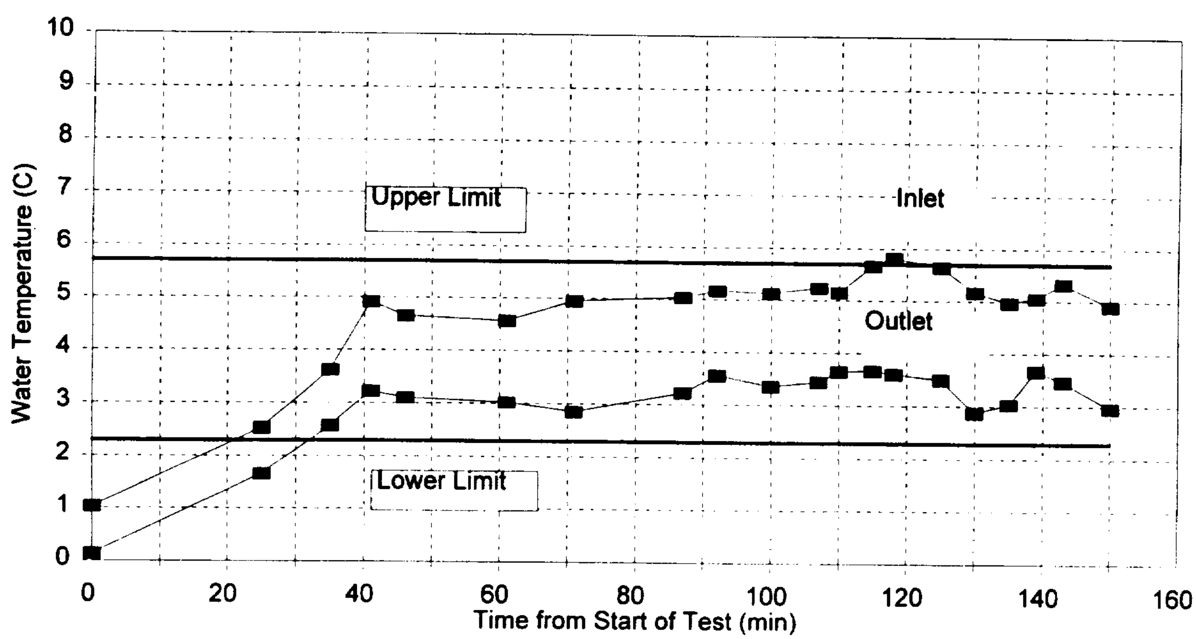


Figure 12. High-lift heat pump performance test, ITCS temperature control (low load)

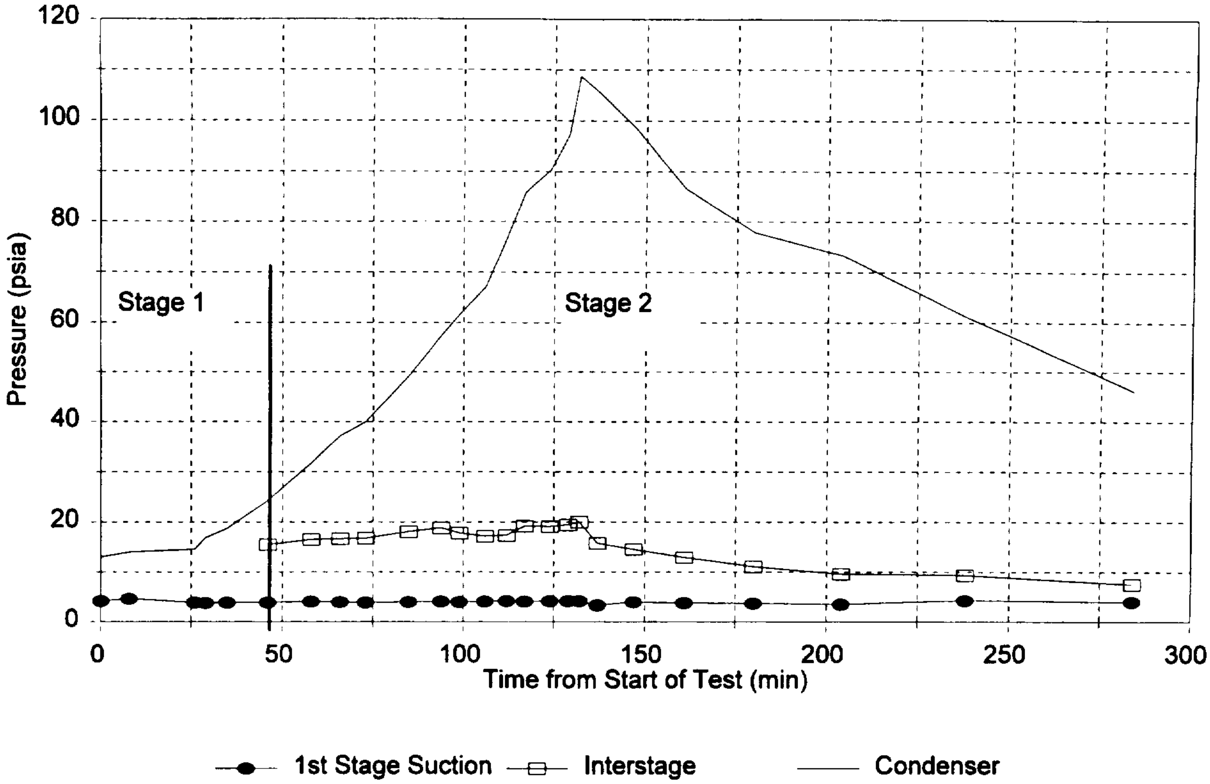


Figure 13. High-lift heat pump performance test, high-intermediate load test

6. CONCLUSIONS AND RECOMMENDATIONS

The objective of this project was to investigate the feasibility of constructing a heat pump suitable for use as a heat rejection device in applications such as a lunar base. In this situation, direct heat rejection through the use of radiators is not possible at a temperature suitable for life support systems. The temperature of the waste heat must be raised substantially before rejection can be accomplished. Initial analysis of a heat pump of this type called for a temperature lift of approximately 105°K, which is considerably higher than is commonly called for in HVAC and refrigeration applications where heat pumps are most often employed. Also because of the variation of the rejection temperature (from 100 to 381°K), extreme flexibility in the configuration and operation of the heat pump is required.

Initial design work called for the use of refrigerants with high critical temperatures, such as CFC-11 and HCFC-123, to meet the temperature lift requirement and obtain the highest heat pump COP. A three-stage compression cycle was formulated with operation possible with one, two or three stages of compression. Also, to meet the redundancy and extreme control flexibility requirements, compression was divided up over multiple compressors in each stage. A control scheme was devised that allowed these multiple compressors to be operated as required so that the heat pump could perform with variable heat loads and rejection conditions.

A prototype heat pump was designed and constructed to investigate the key elements of the high-lift heat pump concept. While the prototype used commercially available hardware, it contained all of the major elements of a flight unit including, two stages of compression and multiple compressors in each stage. The unit was configured to operate as either a one- or two-stage unit, or could provide direct heat rejection when the ETCS temperature was low enough for this purpose. Control software was written and implemented in the prototype to allow fully automatic operation. The heat pump was capable of operation over a wide range of rejection temperatures and cooling loads, while maintaining the ITCS water temperature well within the required specification of 4°C ±1.7°C. This performance was verified through testing.

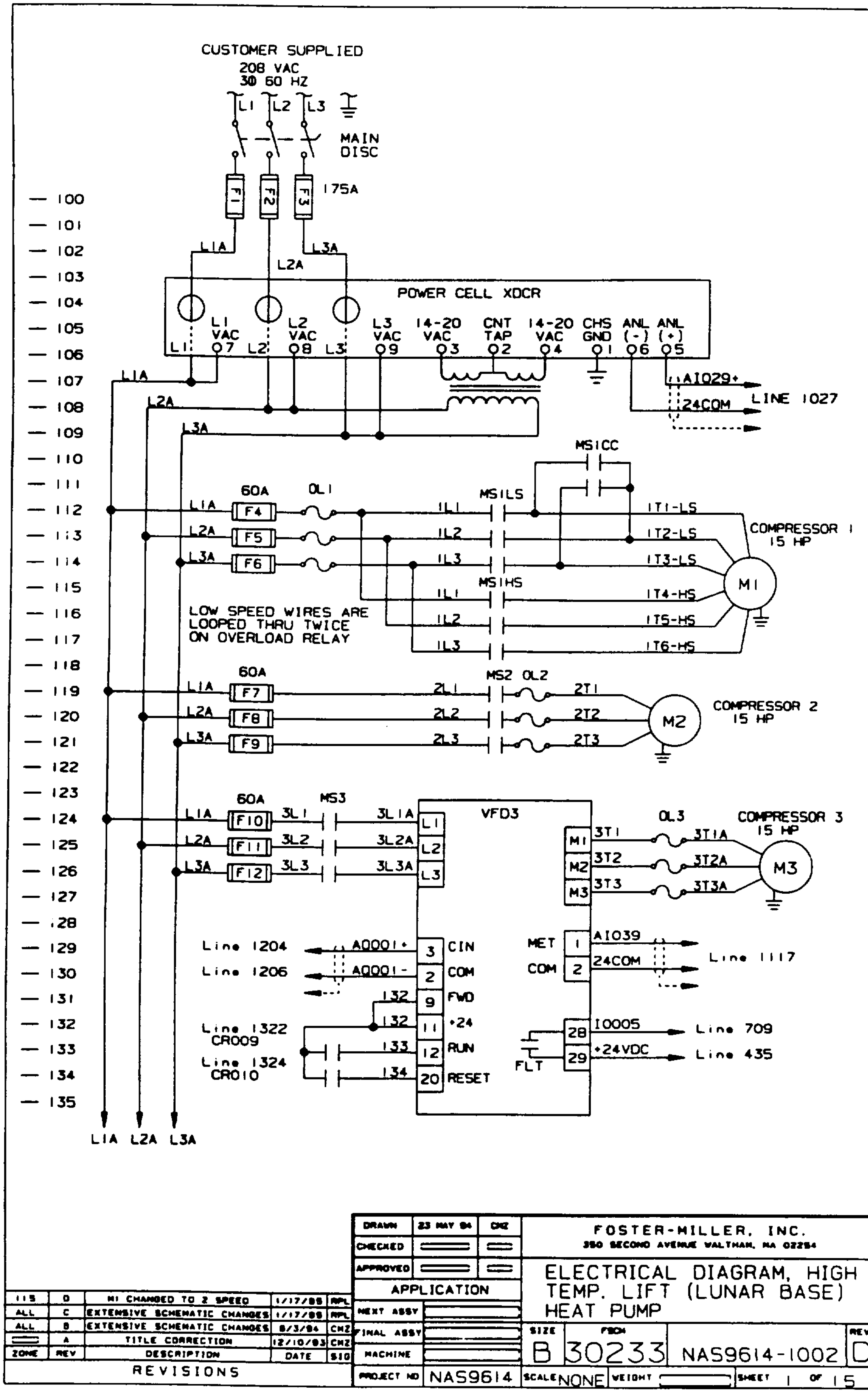
The prototype unit is now ready for installation in the LSSIF at Johnson Space Center. Valuable operating data will be obtained through this testing that will allow refinement of the heat pump design. From this point, the design requirements of flight-ready hardware can be accurately defined. Specialized compressors, heat exchangers, etc. can then be designed and fabricated.

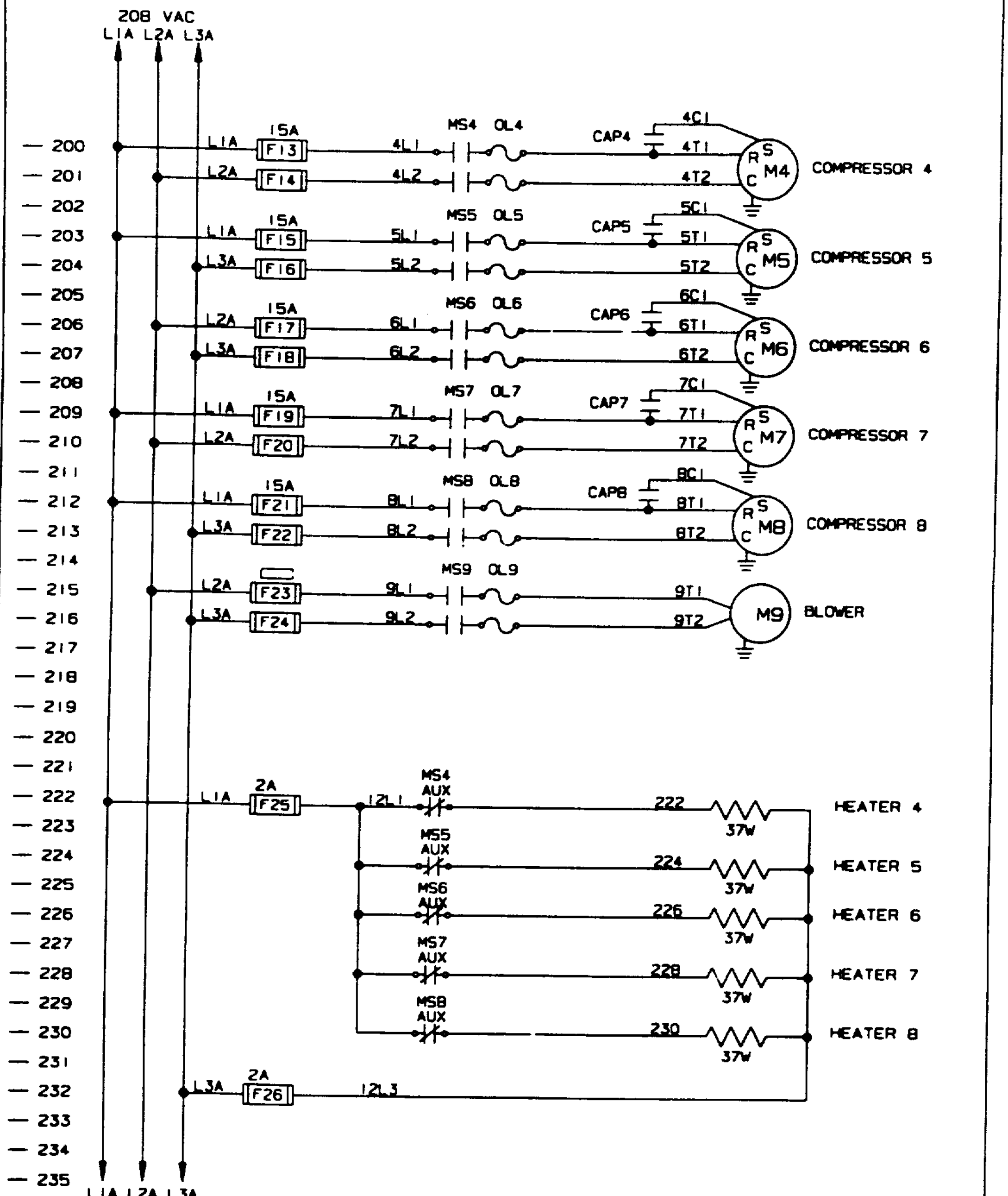
Heat pump-based heat rejection systems can be shown to be effective in other space flight applications besides interplanetary manned missions. Analysis performed by Foster-Miller comparing direct to heat-pump-based heat rejection shows that the use of a heat pump can be justified any time that the heat source is at 0°C or less. Heat pumps can also be shown as a cost-effective method of increasing heat rejection from an existing thermal control system when retrofit of additional equipment occurs. An example of such a situation would be the addition of electronics to an existing satellite design with no change to the heat rejection system or the expansion of an orbital lab, such as a space shuttle lab module or space station. Another possible application of heat pumps is in manned thermal control systems to handle specialized thermal loads such as dehumidification. Presently, dehumidification requires the lowest heat rejection temperature and strongly influences the design and sizing of the thermal control system. If a heat pump were dedicated to dehumidification, the lowest temperature of the thermal control system could be raised which could be used to increase the total thermal capacity of the radiators or reduce the total amount of radiator surface required, resulting in a substantial weight reduction.

Heat pump investigation on a terrestrial basis is now ongoing, however, little or no effort is being expended to operate heat pumps and other vapor compression systems and components at a flight level. Investigation of compressor lubrication, heat exchange with refrigerant-oil mixtures, etc., in a microgravity environment are all necessary in order to advance the use of heat pump in space flight application. Testing of this type should be initiated as soon as possible.

APPENDIX A

HEAT PUMP ELECTRICAL DIAGRAM


CUSTOMER SUPPLIED
208 VAC
3Ø 60 HZ
L1 L2 L3
MAIN DISC
F1 F2 F3
175A
L1A L2A L3A
POWER CELL XDCR
L1 VAC 7
L2 VAC 8
L3 VAC 9
14-20 VAC 3
CNT TAP 2
14-20 VAC 4
CHS GND 1
ANL (-) 6
ANL (+) 5
AI029+
24COM
LINE 1027
MS1CC
60A
OL1
MS1LS
F4 F5 F6
1L1 1L2 1L3
1T1-LS
1T2-LS
1T3-LS
COMPRESSOR 1
15 HP
M1
MS1HS
1T4-HS
1T5-HS
1T6-HS
LOW SPEED WIRES ARE LOOPED THRU TWICE ON OVERLOAD RELAY
MS2 OL2
F7 F8 F9
2L1 2L2 2L3
2T1 2T2 2T3
COMPRESSOR 2
15 HP
M2
MS3
F10 F11 F12
3L1 3L2 3L3
3L1A 3L2A 3L3A
VFD3
OL3
3T1 3T2 3T3
3T1A 3T2A 3T3A
COMPRESSOR 3
15 HP
M3
Line 1204
Line 1206
A0001+
A0001-
CIN COM FWD +24 RUN RESET
Line 1322 CR009
Line 1324 CR010
132 133 134
MET COM
AI039
24COM
Line 1117
10005
+24VDC
Line 709
Line 435
FLT
100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135
L1A L2A L3A
DRAWN 23 MAY 84 CHZ
CHECKED
APPROVED
APPLICATION
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO NAS9614
FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254
ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
SIZE B
FSCM 30233
NAS9614-1002
REV D
SCALE NONE
WEIGHT
SHEET 1 OF 15
115 D M1 CHANGED TO 2 SPEED 1/17/89 RPL
ALL C EXTENSIVE SCHEMATIC CHANGES 1/17/89 RPL
ALL B EXTENSIVE SCHEMATIC CHANGES 8/3/84 CHZ
A TITLE CORRECTION 12/10/83 CHZ
ZONE REV DESCRIPTION DATE SIG
REVISIONS



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ALL	B	EXTENSIVE SCHEMATIC CHANGES	8/3/94	CHZ
—	A	TITLE CORRECTION	12/10/93	CHZ

REVISIONS

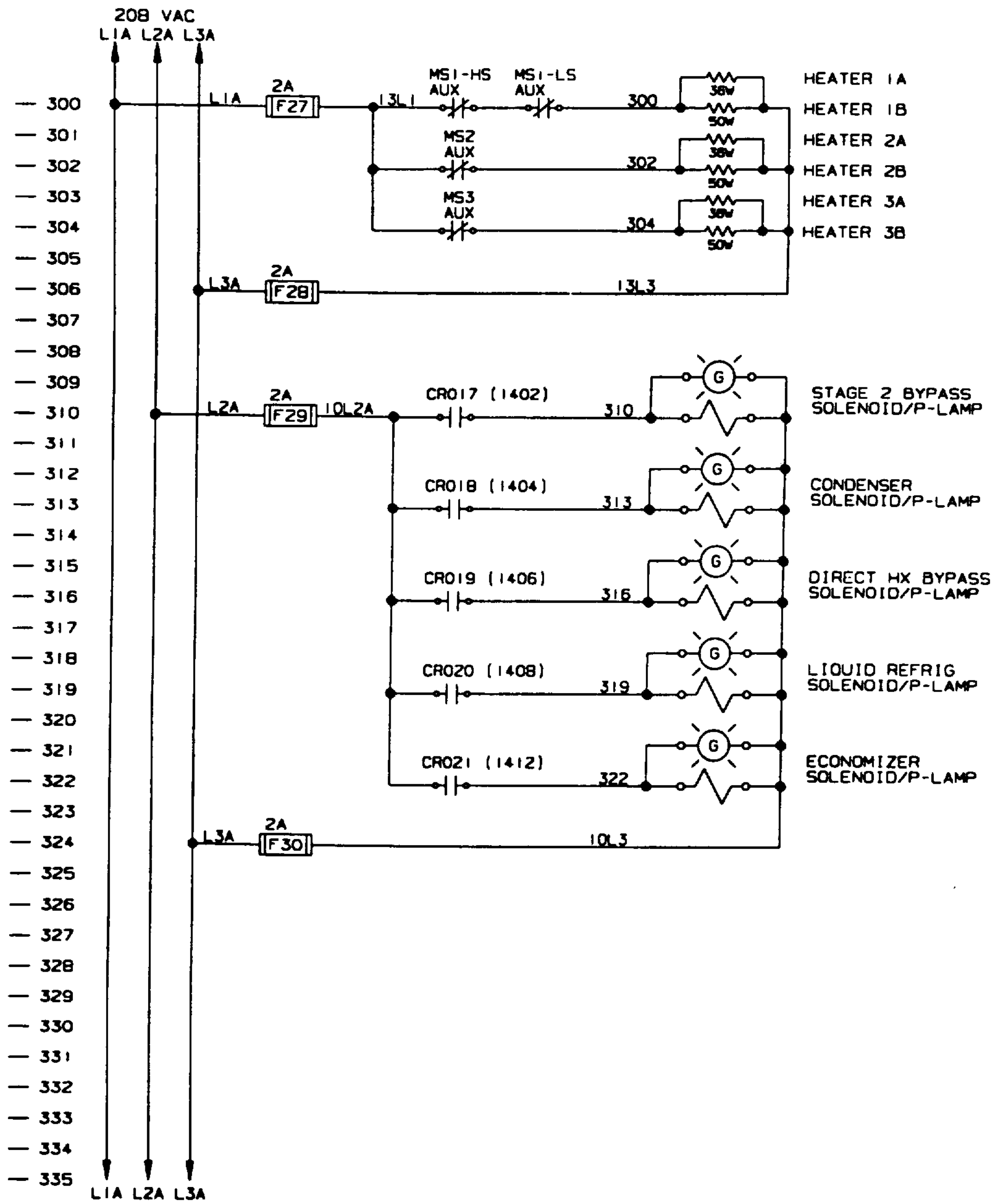
DRAWN	23 MAY 94	CHZ
CHECKED		
APPROVED		
APPLICATION		
NEXT ASSY		
FINAL ASSY		
MACHINE		
PROJECT NO	NAS9614	

FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254

ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP

SIZE	FSCM		REV
B	30233	NAS9614-1002	C

SCALE NONE WEIGHT SHEET 2 OF 15



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CHECKED			
APPROVED			ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
APPLICATION			
NEXT ASSY			
FINAL ASSY			SIZE B · FSCM 30233 · NAS9614-1002 · REV C
MACHINE			
PROJECT NO	NAS9614		SCALE NONE · WEIGHT · SHEET 3 OF 15

ZONE	REV	DESCRIPTION	DATE	
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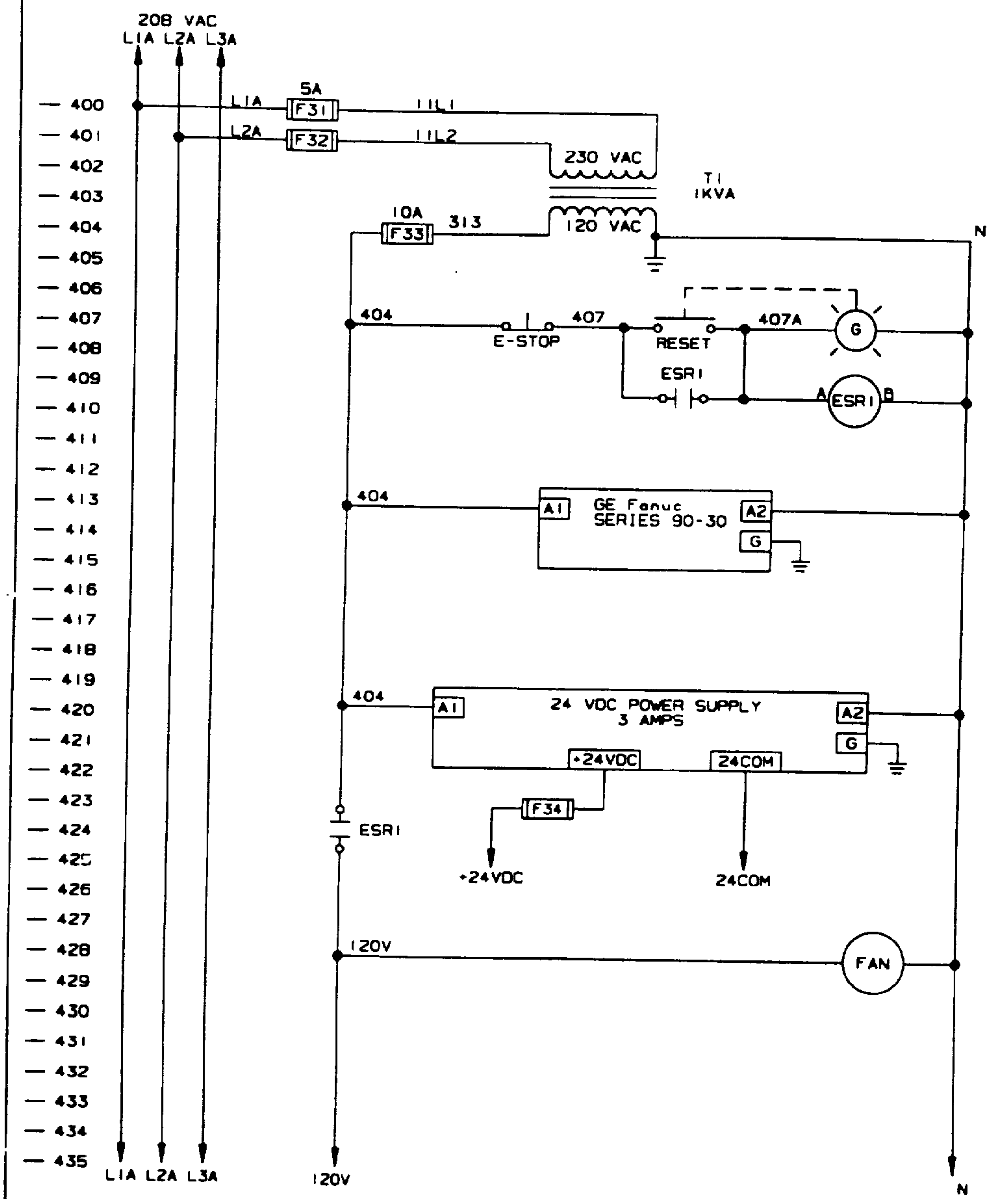
	A	TITLE CORRECTION	12/10/93	CHZ

REVISIONS



DRAWN	23 MAY 94	CHZ
CHECKED		
APPROVED		
APPLICATION		
NEXT ASSY		
FINAL ASSY		
MACHINE		
PROJECT NO	NAS9614	

FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254

ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP

SIZE	FSCM		REV
B	30233	NAS9614-1002	C
SCALE NONE	WEIGHT	SHEET 4 OF 15	

ZONE	REV	DESCRIPTION	DATE	
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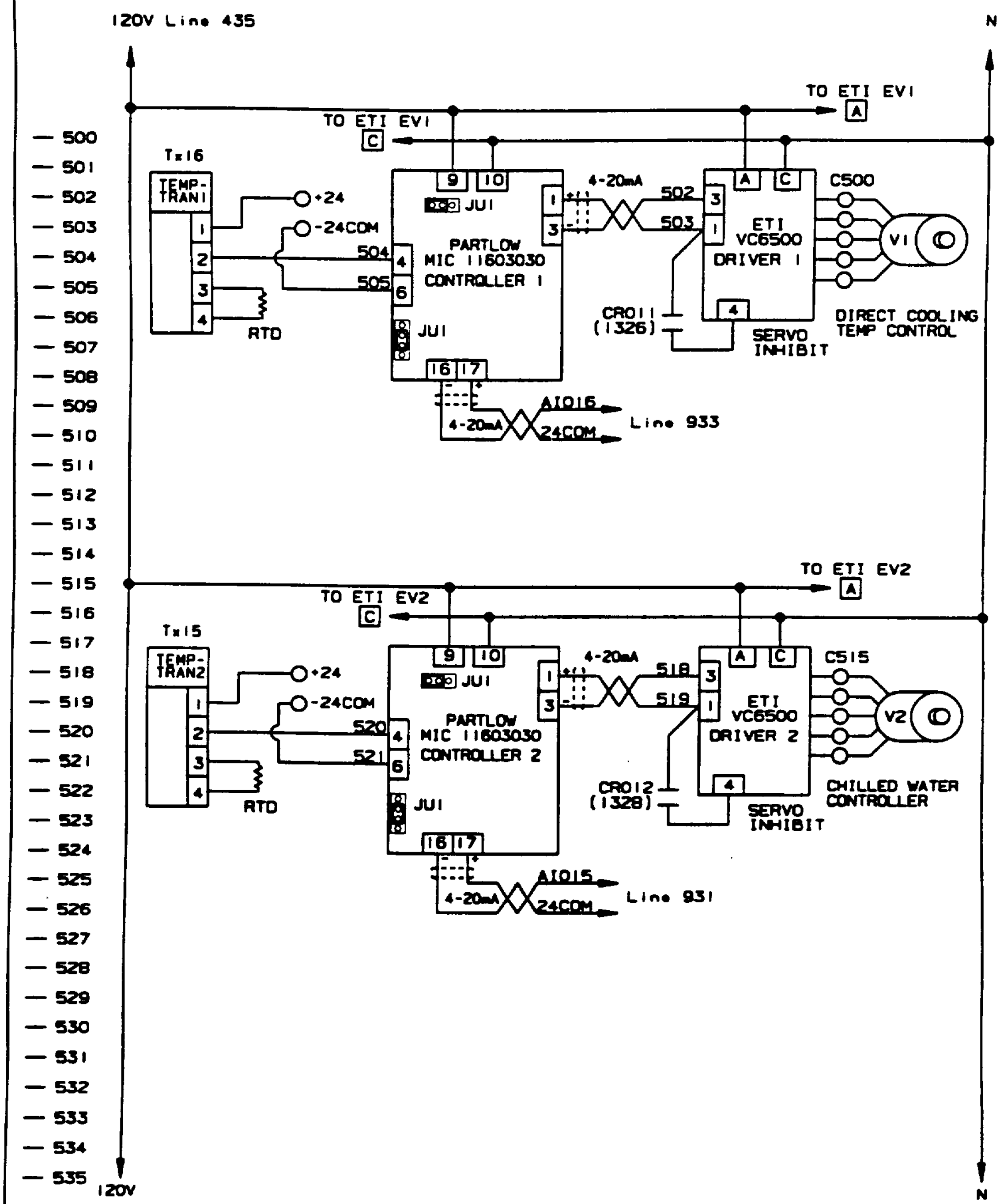
REVISIONS



ZONE	REV	DESCRIPTION	DATE	SIG
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ALL	B	EXTENSIVE SCHEMATIC CHANGES	6/3/94	CHZ
	A	TITLE CORRECTION	12/10/93	CHZ

REVISIONS

DRAWN	23 MAY 94	CHZ
CHECKED		
APPROVED		

APPLICATION

NEXT ASSY

FINAL ASSY

MACHINE

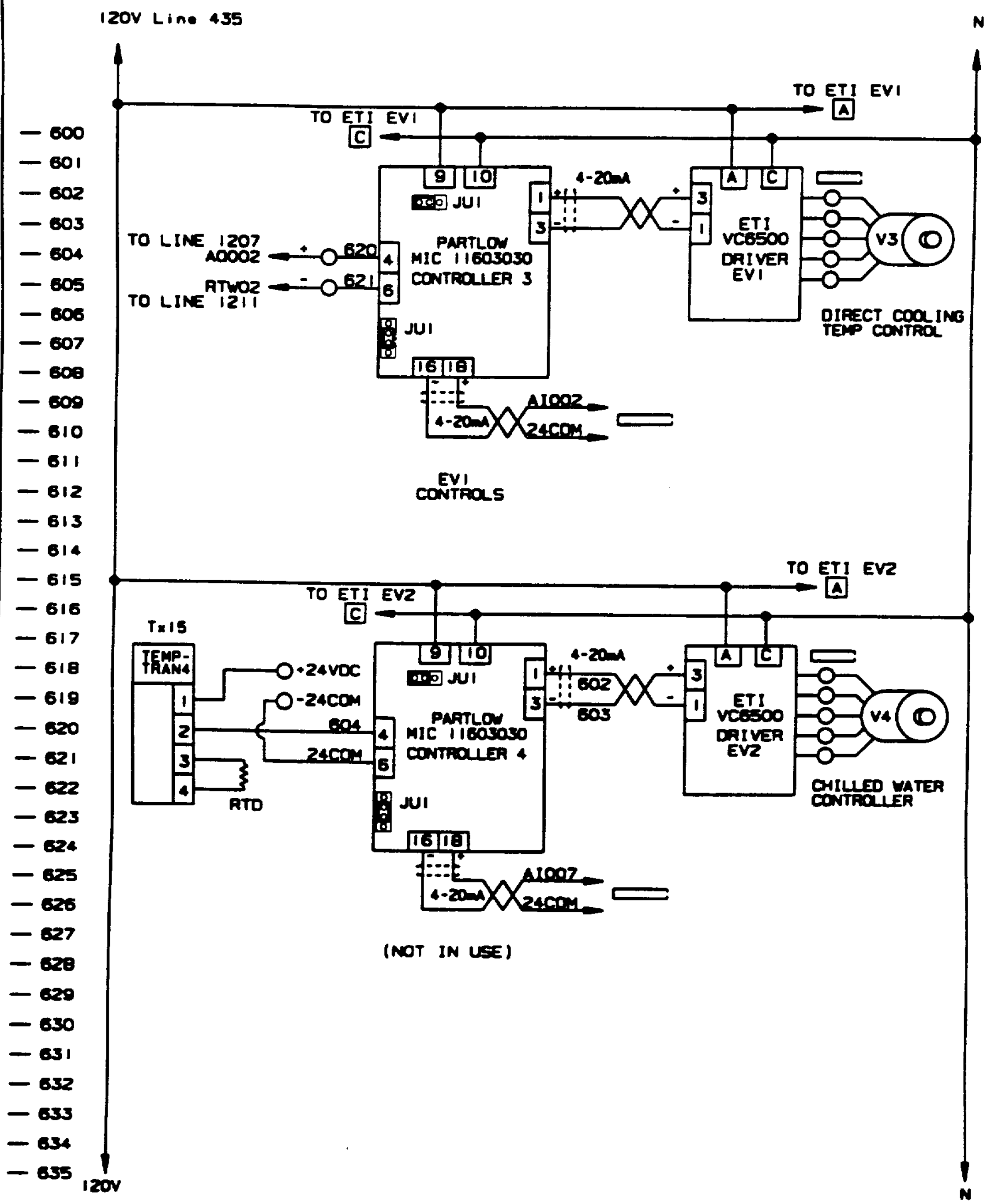
PROJECT NO NAS9614

FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254

ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP

SIZE B | FSCM 30233 | NAS9614-1002 | REV C

SCALE NONE | WEIGHT | SHEET 5 OF 15



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ALL	B	EXTENSIVE SCHEMATIC CHANGES	8/3/94	CHZ	
	A	TITLE CORRECTION	12/10/93	CHZ	
ZONE	REV	DESCRIPTION	DATE	SIG	
REVISIONS					

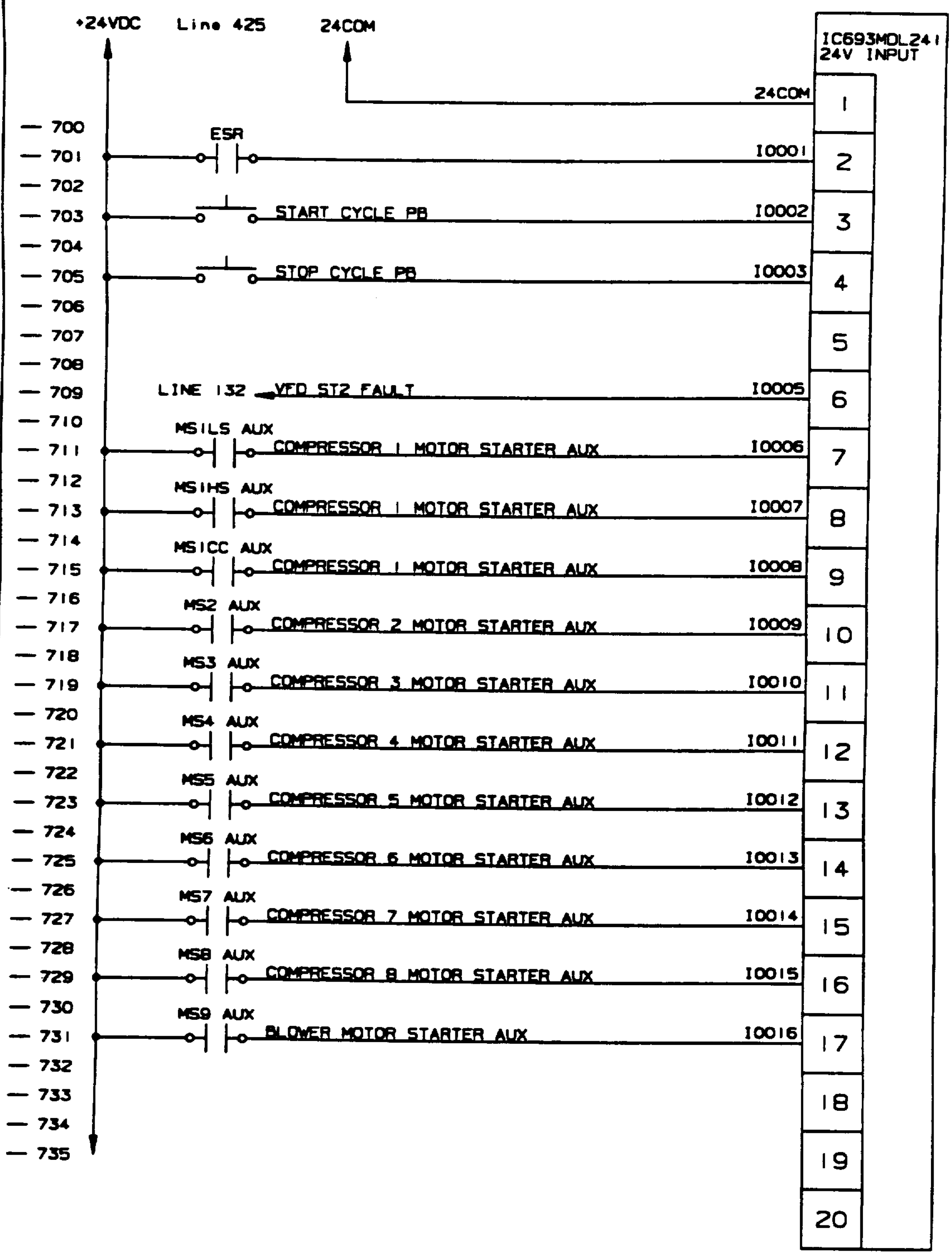
DRAWN	23 MAY 94	CHZ
CHECKED		
APPROVED		
APPLICATION		
NEXT ASSY		
FINAL ASSY		
MACHINE		
PROJECT NO	NAS9614	

FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254

ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP

SIZE	FSCM		REV
B	30233	NAS9614-1002	C
SCALE NONE	WEIGHT	SHEET 6 OF 15	

SLOT 2 24VDC INPUT MODULE



ZONE	REV	DESCRIPTION	DATE	SIG
ALL	D	ADDED MS1 HS CC AUX'S	2/15/95	RPL
ALL	C	EXTENSIVE SCHEMATIC CHANGES	1/17/95	RPL
ALL	B	EXTENSIVE SCHEMATIC CHANGES	8/3/94	CHZ
—	A	TITLE CORRECTION	12/10/93	CHZ

REVISIONS

DRAWN 23 MAY 94 CHZ
CHECKED
APPROVED
APPLICATION
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO NAS9614

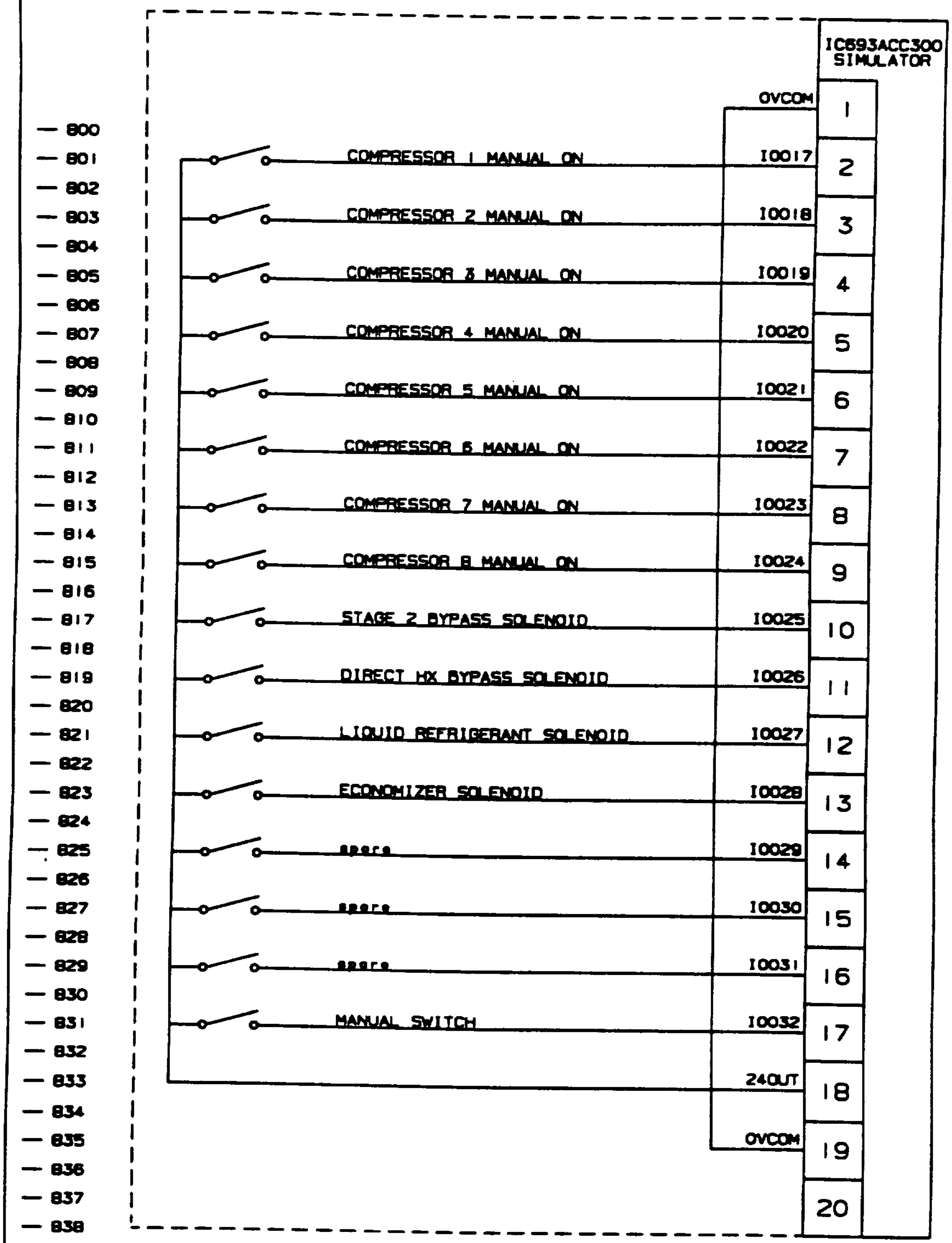
FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254

ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP

SIZE B | FSCM 30233 | NAS9614-1002 | REV D

SCALE NONE | WEIGHT | SHEET 7 OF 15

SLOT 3 I/O SIMULATOR



ZONE	REV	DESCRIPTION	DATE	SIG
ALL	C	EXTENSIVE SCHEMATIC CHANGES	1/17/95	RPL
ALL	B	EXTENSIVE SCHEMATIC CHANGES	8/3/94	CHZ
	A	TITLE CORRECTION	12/10/93	CHZ

REVISIONS

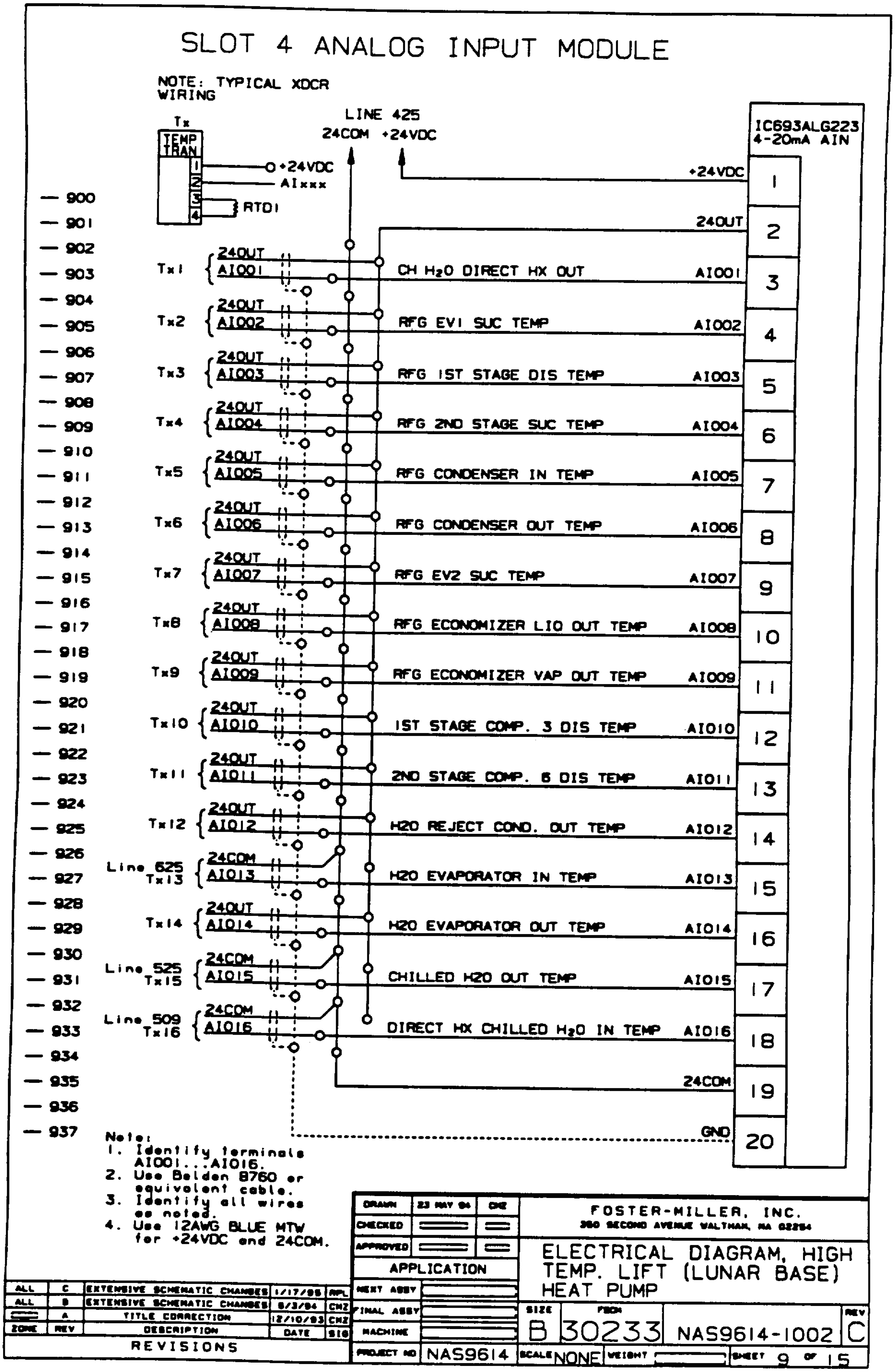
DRAWN	23 MAY 94	CHZ
CHECKED		
APPROVED		
APPLICATION		
NEXT ASSY		
FINAL ASSY		
MACHINE		
PROJECT NO	NAS9614	

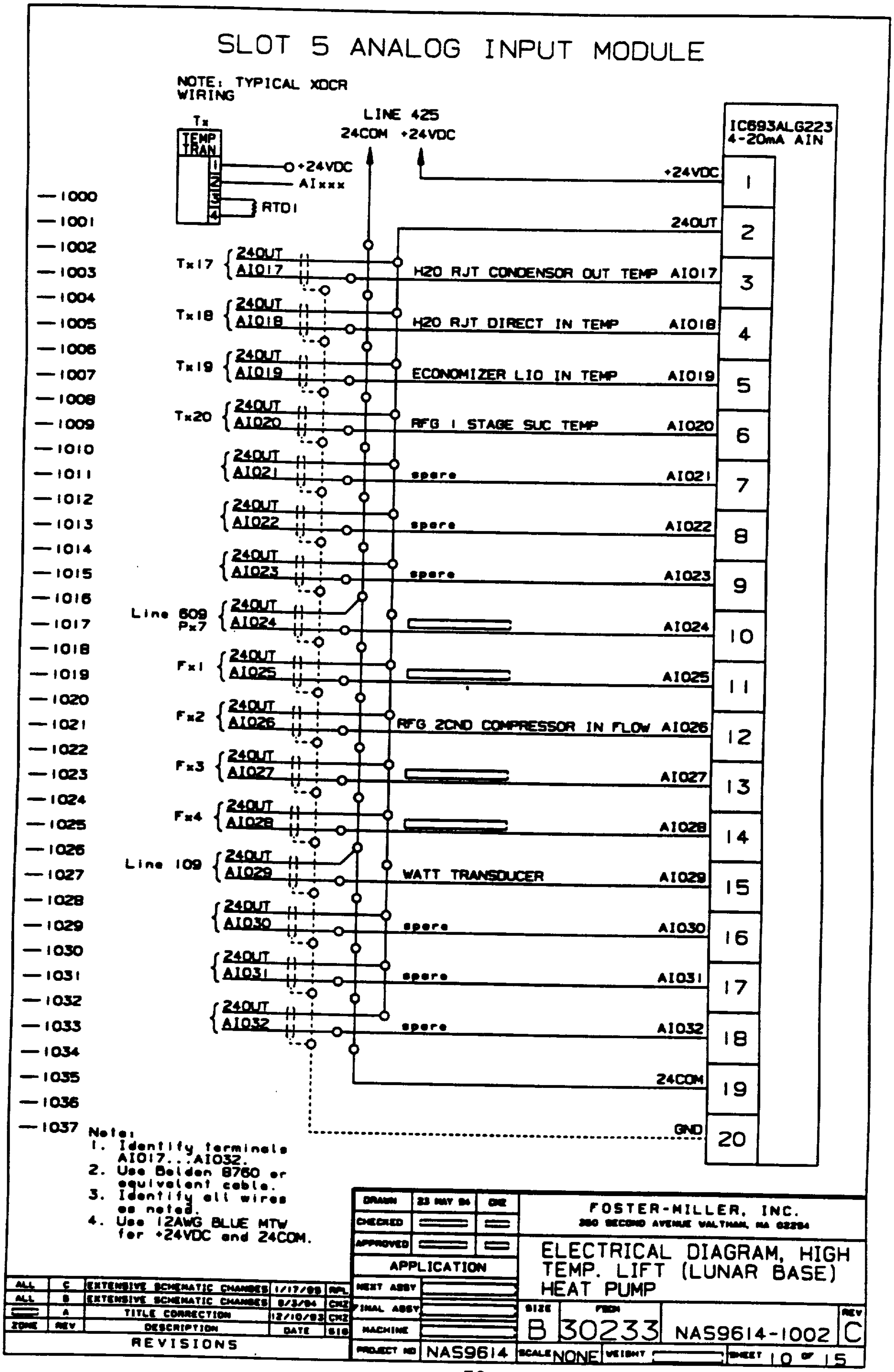
FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254

ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP

SIZE B FSCM 30233 NAS9614-1002 REV C

SCALE NONE WEIGHT SHEET 8 OF 15


SLOT 4 ANALOG INPUT MODULE
NOTE: TYPICAL XDCR WIRING
Tx
TEMP TRAN
+24VDC
AIxxx
RTDI
LINE 425
24COM +24VDC
IC693ALG223
4-20mA AIN
+24VDC 1
24OUT 2
Tx1 24OUT AI001 CH H2O DIRECT HX OUT AI001 3
Tx2 24OUT AI002 RFG EV1 SUC TEMP AI002 4
Tx3 24OUT AI003 RFG 1ST STAGE DIS TEMP AI003 5
Tx4 24OUT AI004 RFG 2ND STAGE SUC TEMP AI004 6
Tx5 24OUT AI005 RFG CONDENSER IN TEMP AI005 7
Tx6 24OUT AI006 RFG CONDENSER OUT TEMP AI006 8
Tx7 24OUT AI007 RFG EV2 SUC TEMP AI007 9
Tx8 24OUT AI008 RFG ECONOMIZER LIQ OUT TEMP AI008 10
Tx9 24OUT AI009 RFG ECONOMIZER VAP OUT TEMP AI009 11
Tx10 24OUT AI010 1ST STAGE COMP. 3 DIS TEMP AI010 12
Tx11 24OUT AI011 2ND STAGE COMP. 6 DIS TEMP AI011 13
Tx12 24OUT AI012 H2O REJECT COND. OUT TEMP AI012 14
Line 625 Tx13 24COM AI013 H2O EVAPORATOR IN TEMP AI013 15
Tx14 24OUT AI014 H2O EVAPORATOR OUT TEMP AI014 16
Line 525 Tx15 24COM AI015 CHILLED H2O OUT TEMP AI015 17
Line 509 Tx16 24COM AI016 DIRECT HX CHILLED H2O IN TEMP AI016 18
24COM 19
GND 20
900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937
Note:
1. Identify terminals AI001...AI016.
2. Use Belden 8760 or equivalent cable.
3. Identify all wires as noted.
4. Use 12AWG BLUE MTW for +24VDC and 24COM.
DRAWN 23 MAY 94 CHZ
CHECKED
APPROVED
APPLICATION
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO NAS9614
FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254
ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
SIZE B
FSCM 30233
NAS9614-1002
REV C
SCALE NONE
WEIGHT
SHEET 9 OF 15
ALL C EXTENSIVE SCHEMATIC CHANGES 1/17/95 RPL
ALL B EXTENSIVE SCHEMATIC CHANGES 8/3/94 CHZ
A TITLE CORRECTION 12/10/93 CHZ
ZONE REV DESCRIPTION DATE SIG
REVISIONS


SLOT 5 ANALOG INPUT MODULE
NOTE: TYPICAL XDCR WIRING
Tx
TEMP TRAN
+24VDC
AIxxx
RTD1
LINE 425
24COM +24VDC
IC693ALG223 4-20mA AIN
+24VDC
24OUT
H2O RJT CONDENSOR OUT TEMP AI017
H2O RJT DIRECT IN TEMP AI018
ECONOMIZER LIQ IN TEMP AI019
RFG 1 STAGE SUC TEMP AI020
spare AI021
spare AI022
spare AI023
AI024
AI025
RFG 2CND COMPRESSOR IN FLOW AI026
AI027
AI028
WATT TRANSDUCER AI029
spare AI030
spare AI031
spare AI032
24COM
GND
Tx17
Tx18
Tx19
Tx20
Line 609 Px7
Fx1
Fx2
Fx3
Fx4
Line 109
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
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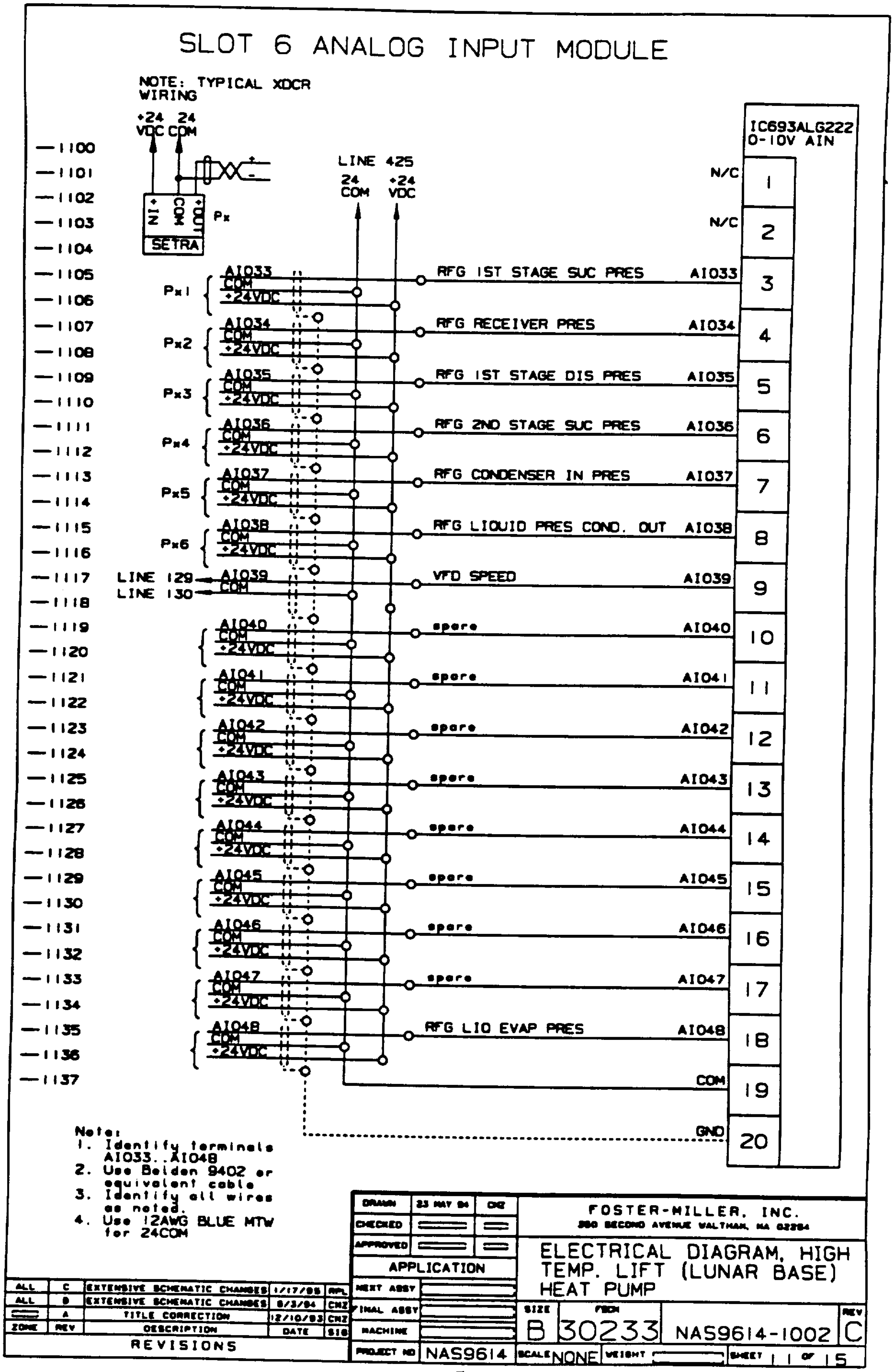
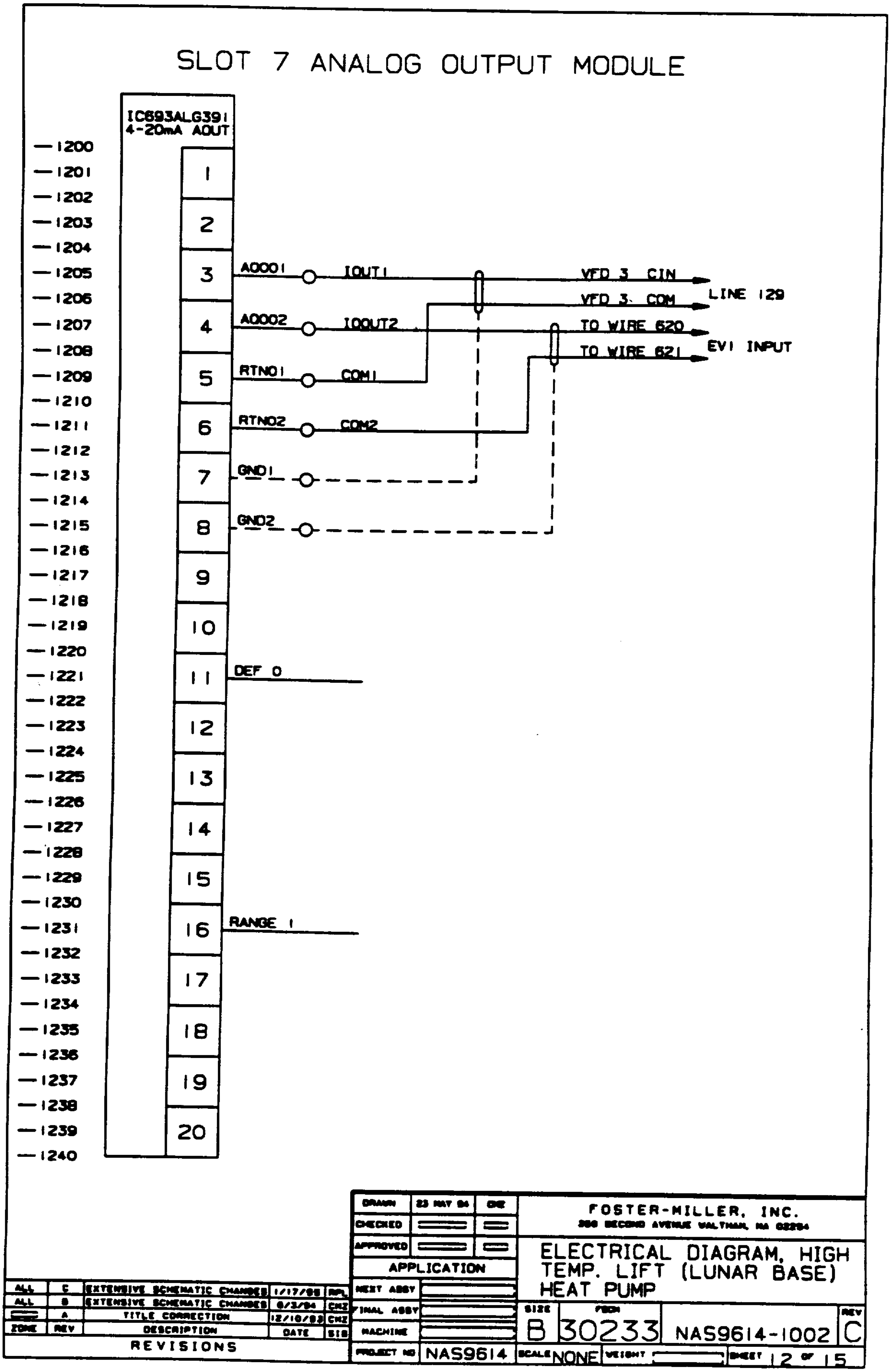
1035
1036
1037
Note:
1. Identify terminals AI017...AI032.
2. Use Belden 8760 or equivalent cable.
3. Identify all wires as noted.
4. Use 12AWG BLUE MTW for +24VDC and 24COM.
FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254
ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
DRAWN 23 MAY 94
CHECKED
APPROVED
APPLICATION
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO NAS9614
SIZE B
FSCM 30233
NAS9614-1002
REV C
SCALE NONE
WEIGHT
SHEET 10 OF 15
ALL C EXTENSIVE SCHEMATIC CHANGES 1/17/95
ALL B EXTENSIVE SCHEMATIC CHANGES 8/3/94
A TITLE CORRECTION 12/10/93
ZONE REV DESCRIPTION DATE
REVISIONS


SLOT 6 ANALOG INPUT MODULE
NOTE: TYPICAL XDCR WIRING
+24 VDC
24 COM
SETRA
Px
LINE 425
24 COM
+24 VDC
IC693ALG222
0-10V AIN
N/C
RFG 1ST STAGE SUC PRES
RFG RECEIVER PRES
RFG 1ST STAGE DIS PRES
RFG 2ND STAGE SUC PRES
RFG CONDENSER IN PRES
RFG LIQUID PRES COND. OUT
VFD SPEED
spare
RFG LIQ EVAP PRES
LINE 129
LINE 130
COM
GND
Note:
1. Identify terminals AI033..AI048
2. Use Belden 9402 or equivalent cable
3. Identify all wires as noted.
4. Use 12AWG BLUE MTW for 24COM
FOSTER-MILLER, INC.
ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
DRAWN 23 MAY 94
CHECKED
APPROVED
APPLICATION
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO NAS9614
SIZE B
FSCM 30233
NAS9614-1002
REV C
SCALE NONE
WEIGHT
SHEET 11 OF 15
ALL C EXTENSIVE SCHEMATIC CHANGES 1/17/95
ALL B EXTENSIVE SCHEMATIC CHANGES 8/3/94
A TITLE CORRECTION 12/10/93
ZONE REV DESCRIPTION DATE
REVISIONS



SLOT 7 ANALOG OUTPUT MODULE
IC693ALG391
4-20mA AOUT
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
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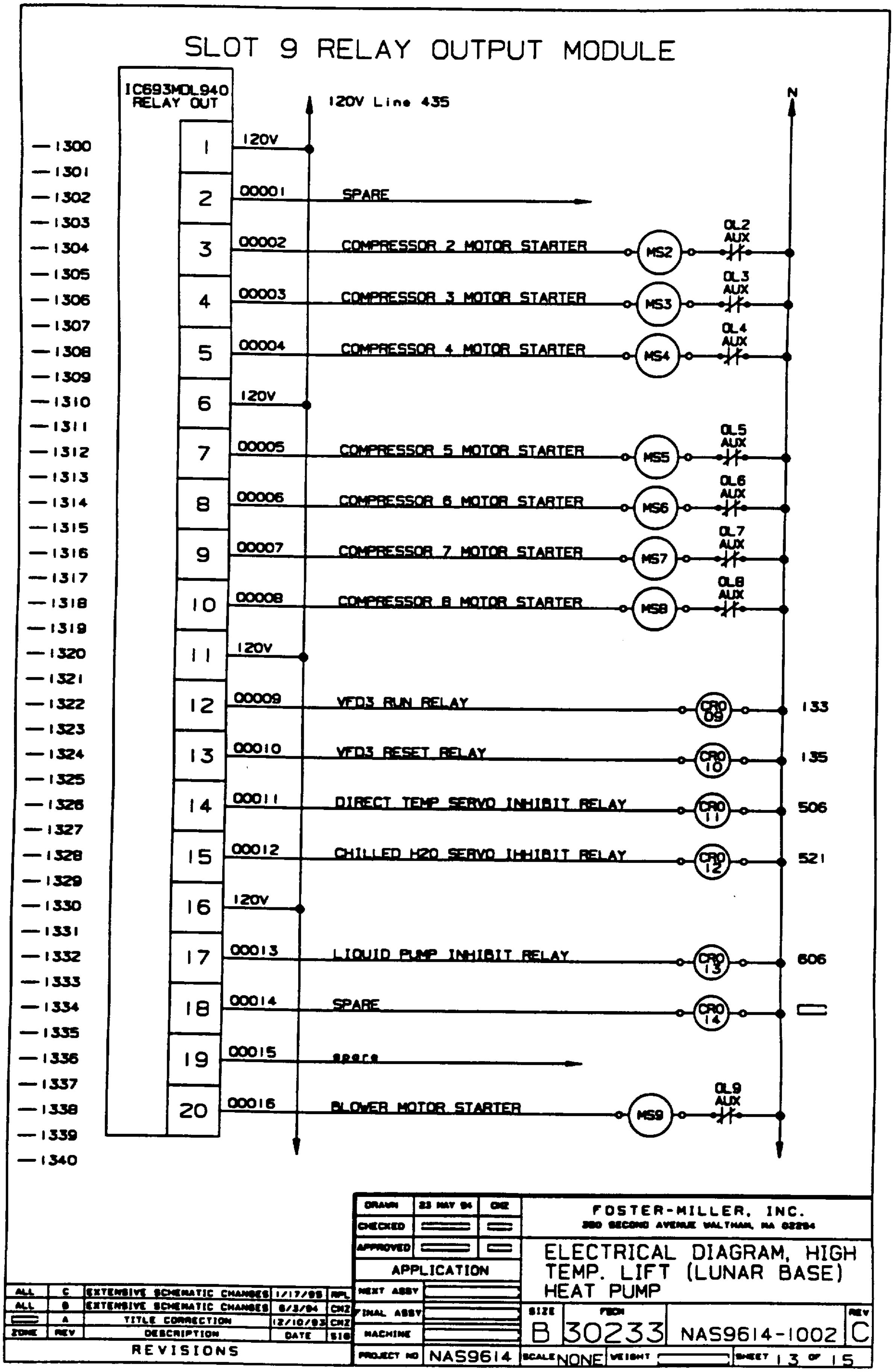
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
A0001
IOUT1
A0002
IOOUT2
RTNO1
COM1
RTNO2
COM2
GND1
GND2
DEF 0
RANGE 1
VFD 3 CIN
VFD 3 COM
LINE 129
TO WIRE 620
TO WIRE 621
EV1 INPUT
DRAWN
23 MAY 94
CHECKED
APPROVED
APPLICATION
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO
NAS9614
FOSTER-MILLER, INC.
ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
SIZE
B
FSCM
30233
NAS9614-1002
REV
C
SCALE
NONE
WEIGHT
SHEET
12 OF 15
ALL
C
EXTENSIVE SCHEMATIC CHANGES
ALL
B
EXTENSIVE SCHEMATIC CHANGES
8/3/94
A
TITLE CORRECTION
12/10/93
ZONE
REV
DESCRIPTION
DATE
REVISIONS



SLOT 9 RELAY OUTPUT MODULE
IC693MDL940 RELAY OUT
120V Line 435
N
—1300
—1301
—1302
—1303
—1304
—1305
—1306
—1307
—1308
—1309
—1310
—1311
—1312
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—1329
—1330
—1331
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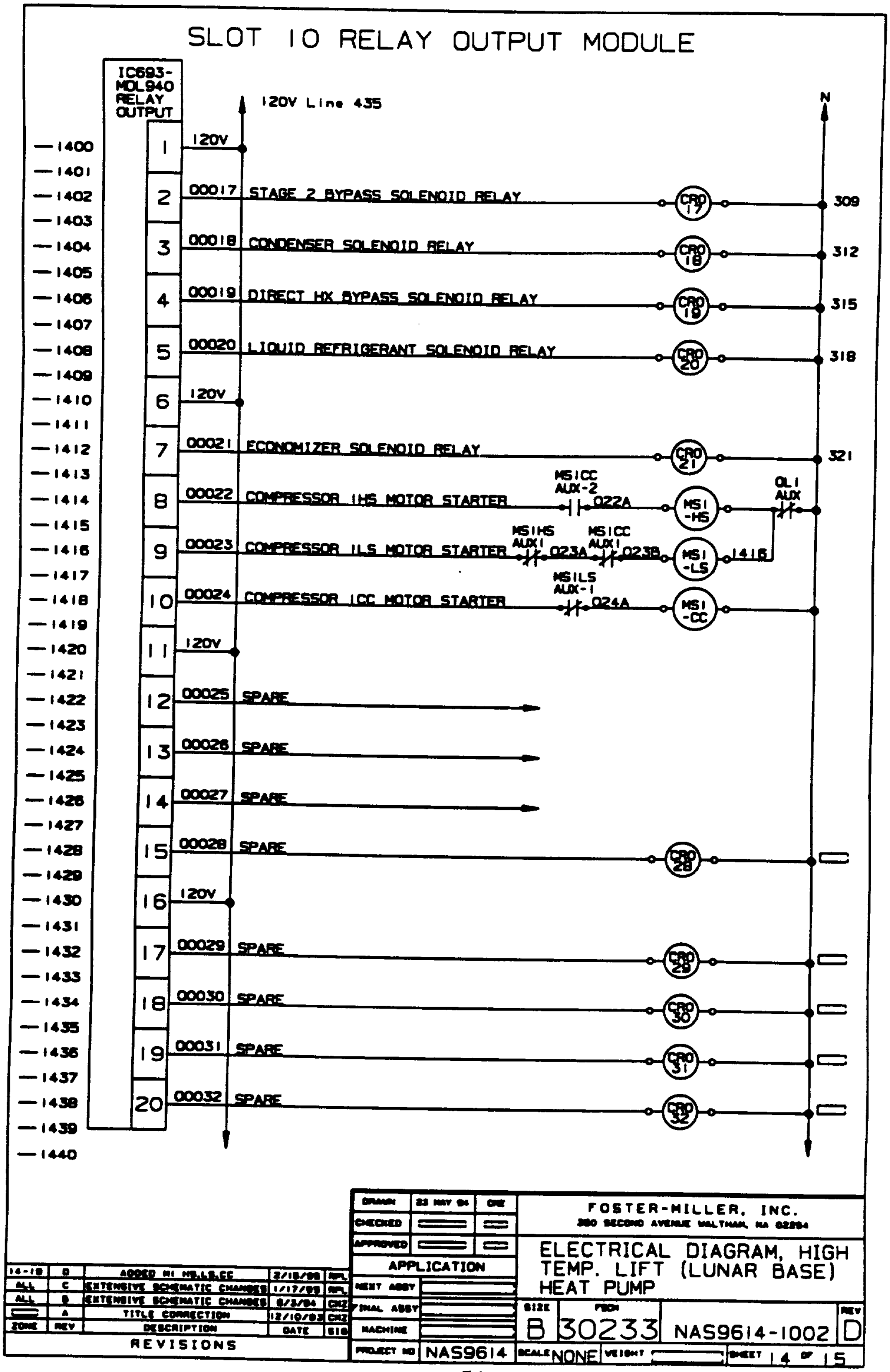
—1334
—1335
—1336
—1337
—1338
—1339
—1340
1 120V
2 00001 SPARE
3 00002 COMPRESSOR 2 MOTOR STARTER MS2 OL2 AUX
4 00003 COMPRESSOR 3 MOTOR STARTER MS3 OL3 AUX
5 00004 COMPRESSOR 4 MOTOR STARTER MS4 OL4 AUX
6 120V
7 00005 COMPRESSOR 5 MOTOR STARTER MS5 OL5 AUX
8 00006 COMPRESSOR 6 MOTOR STARTER MS6 OL6 AUX
9 00007 COMPRESSOR 7 MOTOR STARTER MS7 OL7 AUX
10 00008 COMPRESSOR 8 MOTOR STARTER MS8 OL8 AUX
11 120V
12 00009 VFD3 RUN RELAY CRO 09 133
13 00010 VFD3 RESET RELAY CRO 10 135
14 00011 DIRECT TEMP SERVO INHIBIT RELAY CRO 11 506
15 00012 CHILLED H20 SERVO INHIBIT RELAY CRO 12 521
16 120V
17 00013 LIQUID PUMP INHIBIT RELAY CRO 13 606
18 00014 SPARE CRO 14
19 00015 spare
20 00016 BLOWER MOTOR STARTER MS9 OL9 AUX
DRAWN 23 MAY 94 CHZ
CHECKED
APPROVED
APPLICATION
FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254
ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
ALL C EXTENSIVE SCHEMATIC CHANGES 1/17/95 RPL
ALL B EXTENSIVE SCHEMATIC CHANGES 6/3/94 CHZ
A TITLE CORRECTION 12/10/93 CHZ
ZONE REV DESCRIPTION DATE SIG
REVISIONS
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO NAS9614
SIZE B
FSCM 30233
NAS9614-1002
REV C
SCALE NONE
WEIGHT
SHEET 13 OF 15



SLOT 10 RELAY OUTPUT MODULE
IC693-MDL940 RELAY OUTPUT
120V Line 435
N
120V
00017 STAGE 2 BYPASS SOLENOID RELAY
CRO 17
309
00018 CONDENSER SOLENOID RELAY
CRO 18
312
00019 DIRECT HX BYPASS SOLENOID RELAY
CRO 19
315
00020 LIQUID REFRIGERANT SOLENOID RELAY
CRO 20
318
120V
00021 ECONOMIZER SOLENOID RELAY
CRO 21
321
00022 COMPRESSOR 1HS MOTOR STARTER
MS1CC AUX-2
022A
MS1 -HS
OL1 AUX
00023 COMPRESSOR 1LS MOTOR STARTER
MS1HS AUX1
023A
MS1CC AUX1
023B
MS1 -LS
1416
00024 COMPRESSOR 1CC MOTOR STARTER
MS1LS AUX-1
024A
MS1 -CC
120V
00025 SPARE
00026 SPARE
00027 SPARE
00028 SPARE
CRO 28
120V
00029 SPARE
CRO 29
00030 SPARE
CRO 30
00031 SPARE
CRO 31
00032 SPARE
CRO 32
1400
1401
1402
1403
1404
1405
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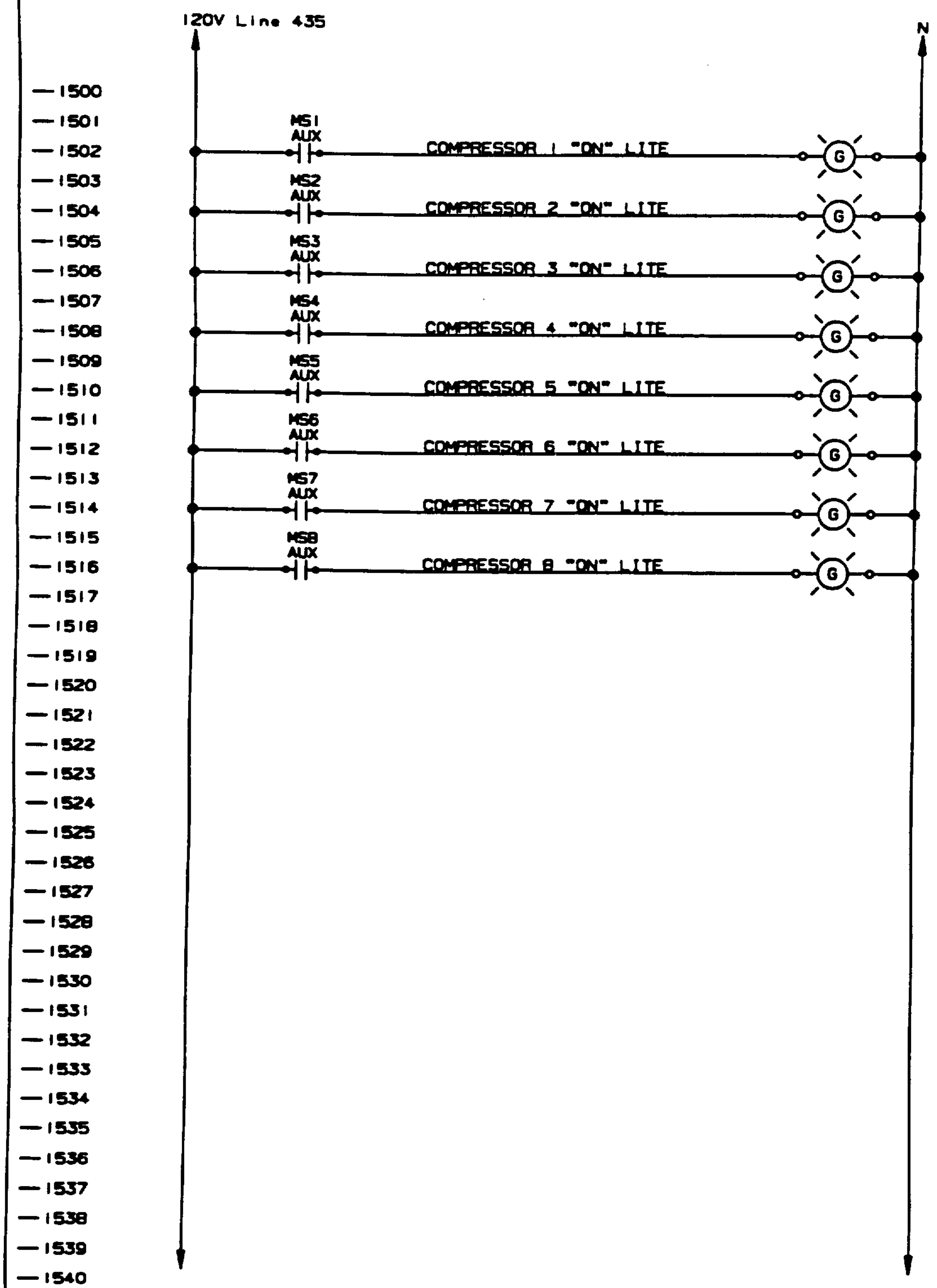
1439
1440
FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254
ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP
DRAWN 23 MAY 94
CHECKED
APPROVED
APPLICATION
NEXT ASSY
FINAL ASSY
MACHINE
PROJECT NO NAS9614
SIZE B
FSCM 30233
NAS9614-1002
REV D
SCALE NONE
WEIGHT
SHEET 14 OF 15
14-19 D ADDED M1 HS,LS,CC 2/15/95
ALL C EXTENSIVE SCHEMATIC CHANGES 1/17/95
ALL B EXTENSIVE SCHEMATIC CHANGES 6/3/94
A TITLE CORRECTION 12/10/93
ZONE REV DESCRIPTION DATE
REVISIONS



ZONE	REV	DESCRIPTION	DATE	SIG
ALL	C	EXTENSIVE SCHEMATIC CHANGES	1/17/95	RPL
ALL	B	EXTENSIVE SCHEMATIC CHANGES	6/3/94	CHZ
	A	TITLE CORRECTION	12/10/93	CHZ

REVISIONS

DRAWN	23 MAY 94	CHZ
CHECKED		
APPROVED		

APPLICATION

NEXT ASSY

FINAL ASSY

MACHINE

PROJECT NO NAS9614

FOSTER-MILLER, INC.
350 SECOND AVENUE WALTHAM, MA 02254

ELECTRICAL DIAGRAM, HIGH TEMP. LIFT (LUNAR BASE) HEAT PUMP

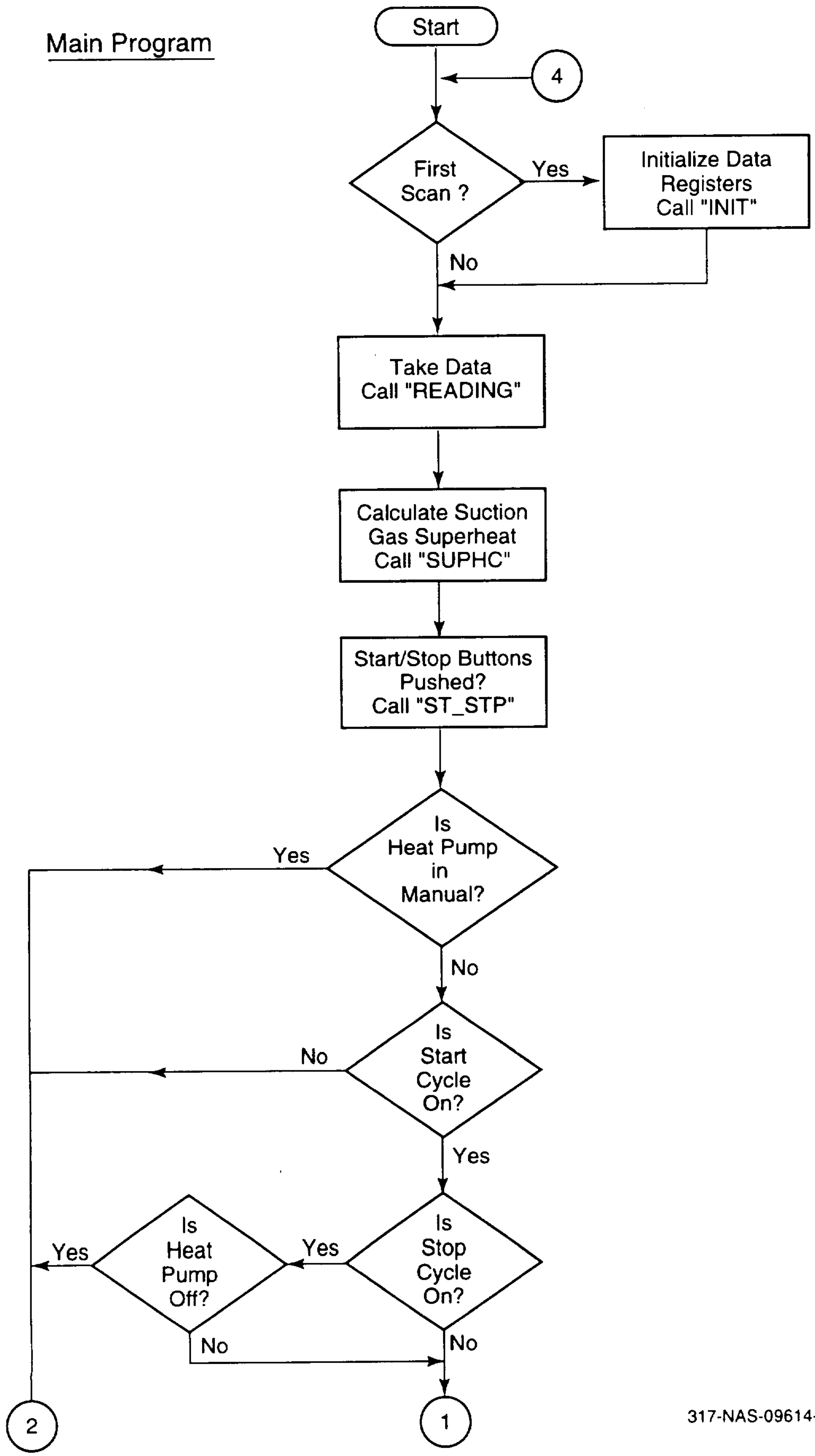
SIZE B FSCM 30233 NAS9614-1002 REV C

SCALE NONE WEIGHT SHEET 15 OF 15

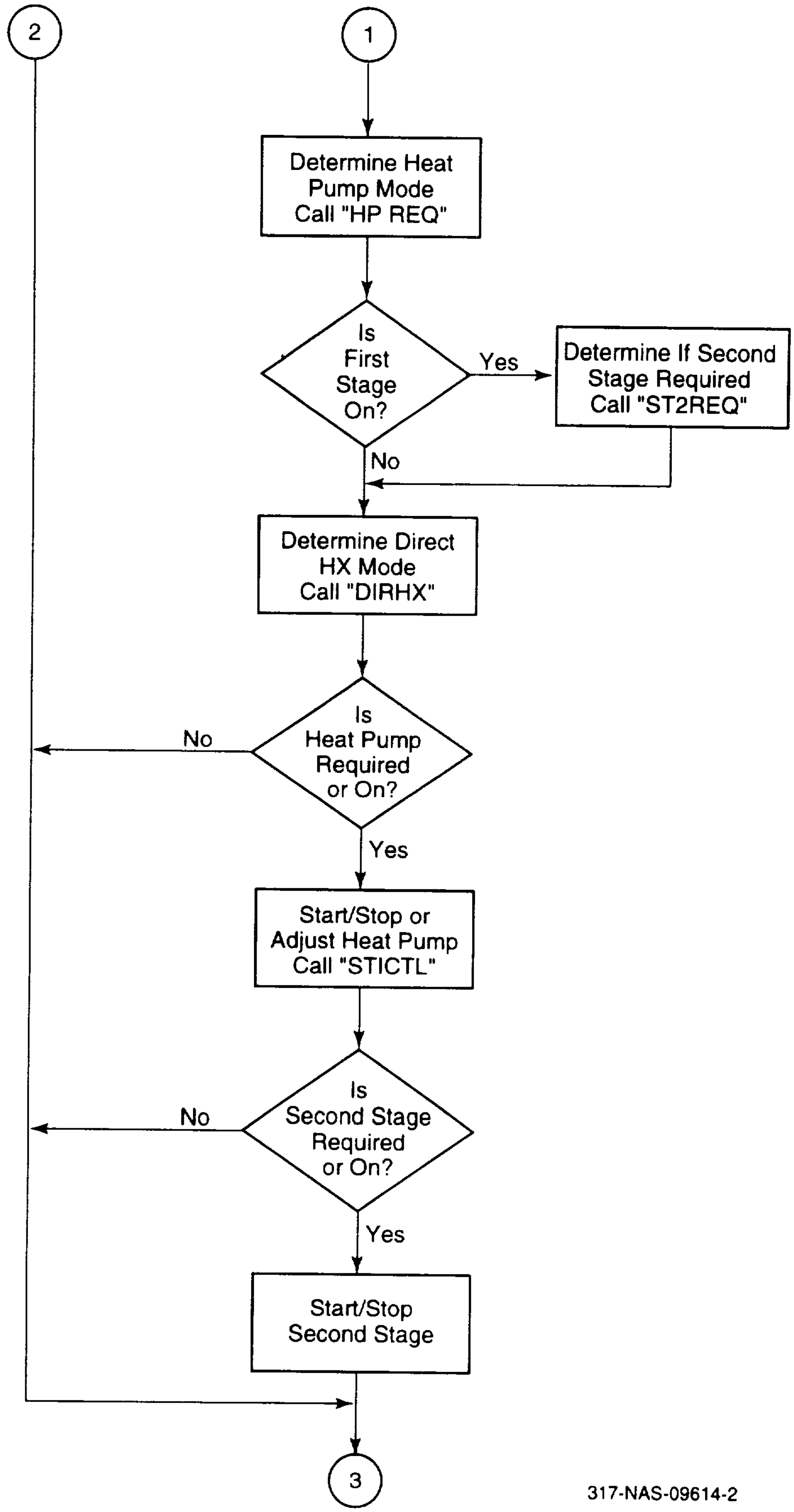
APPENDIX B

HIGH-LIFT HEAT PUMP CONTROL PROGRAM FLOW CHART

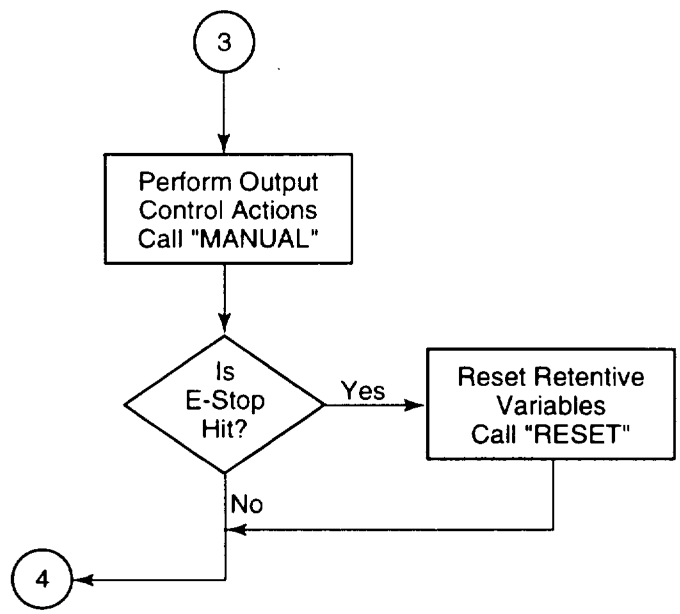
Main Program



317-NAS-09614-1

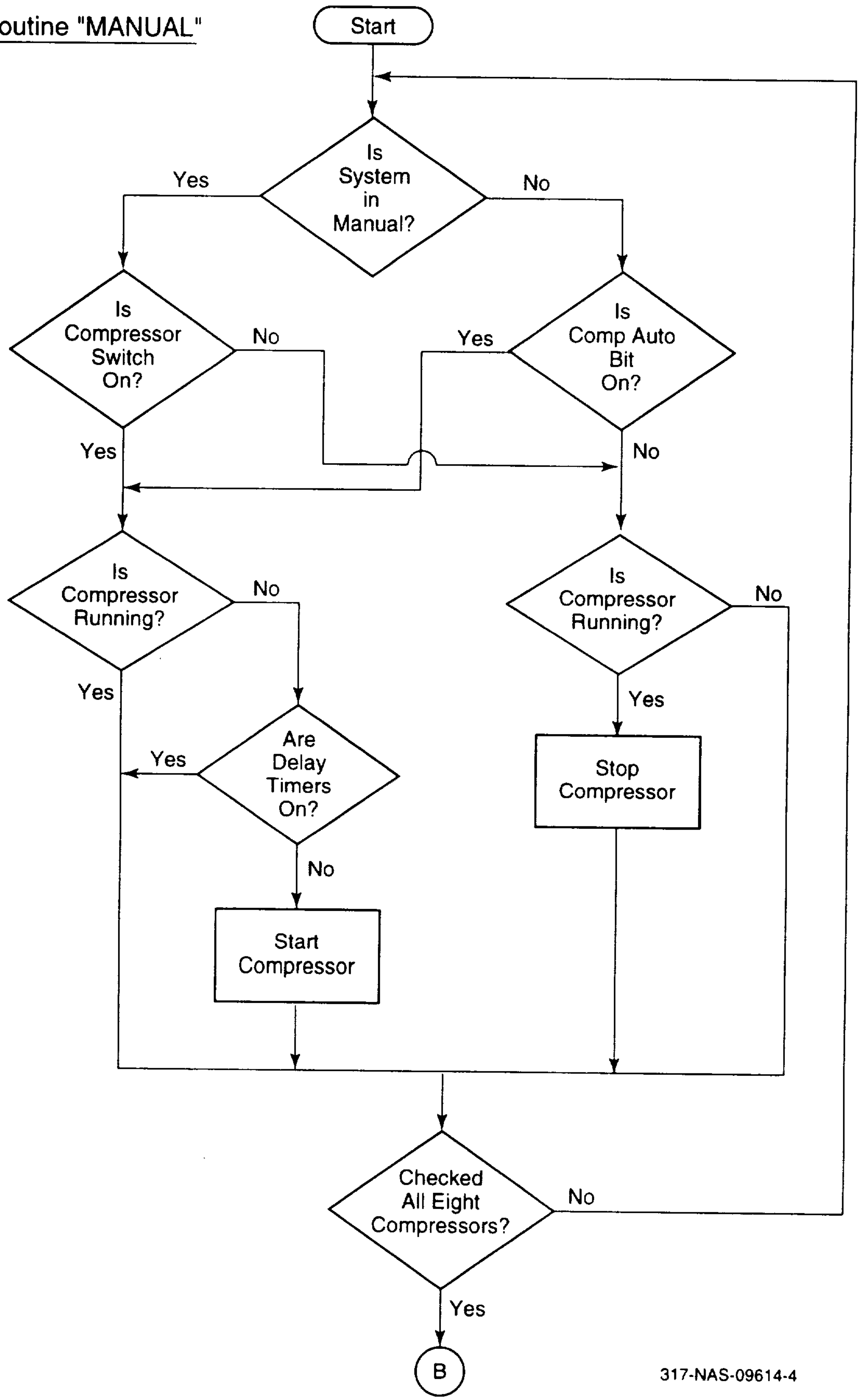


317-NAS-09614-2



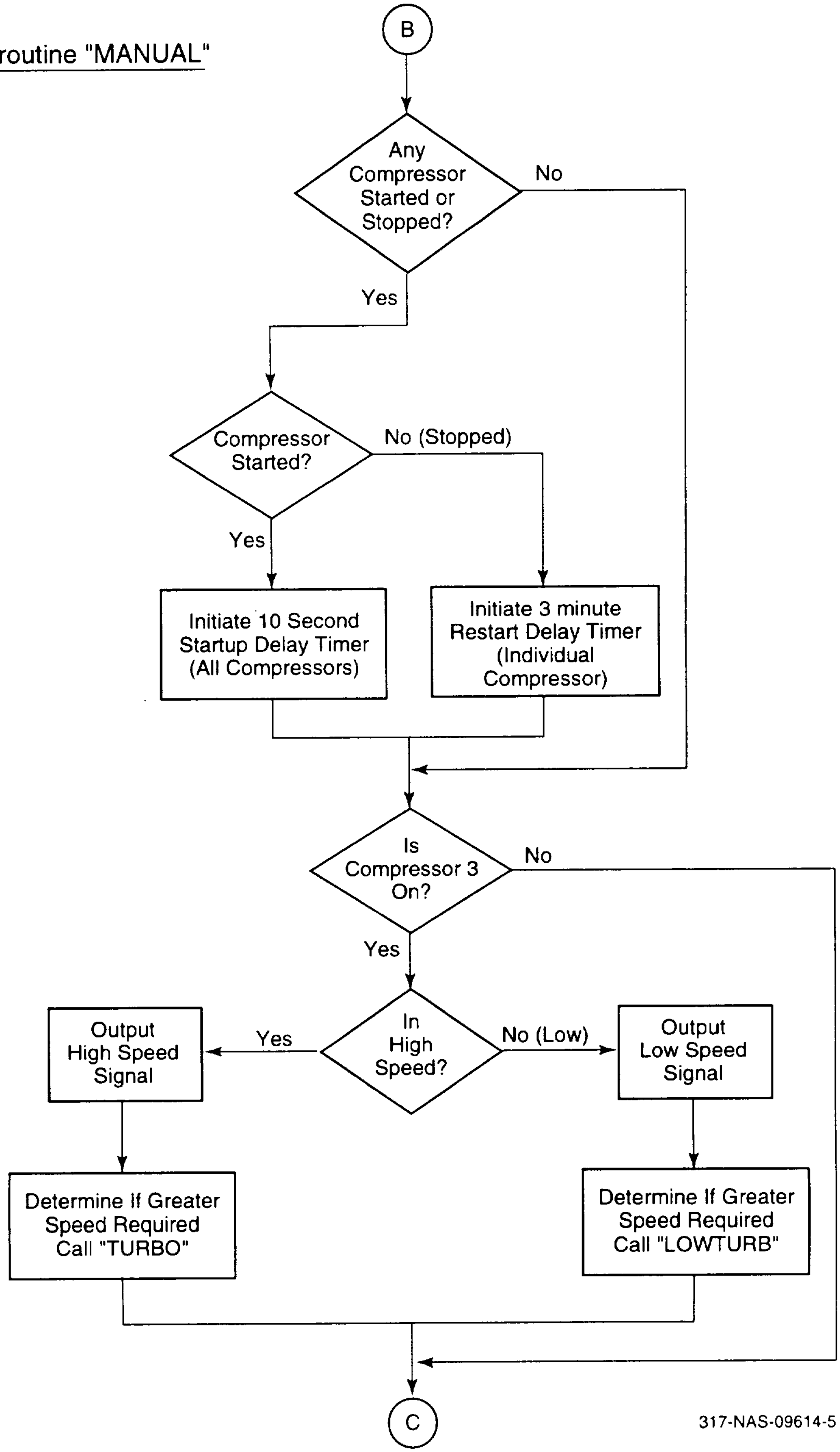
317-NAS-09614-3

Subroutine "MANUAL"



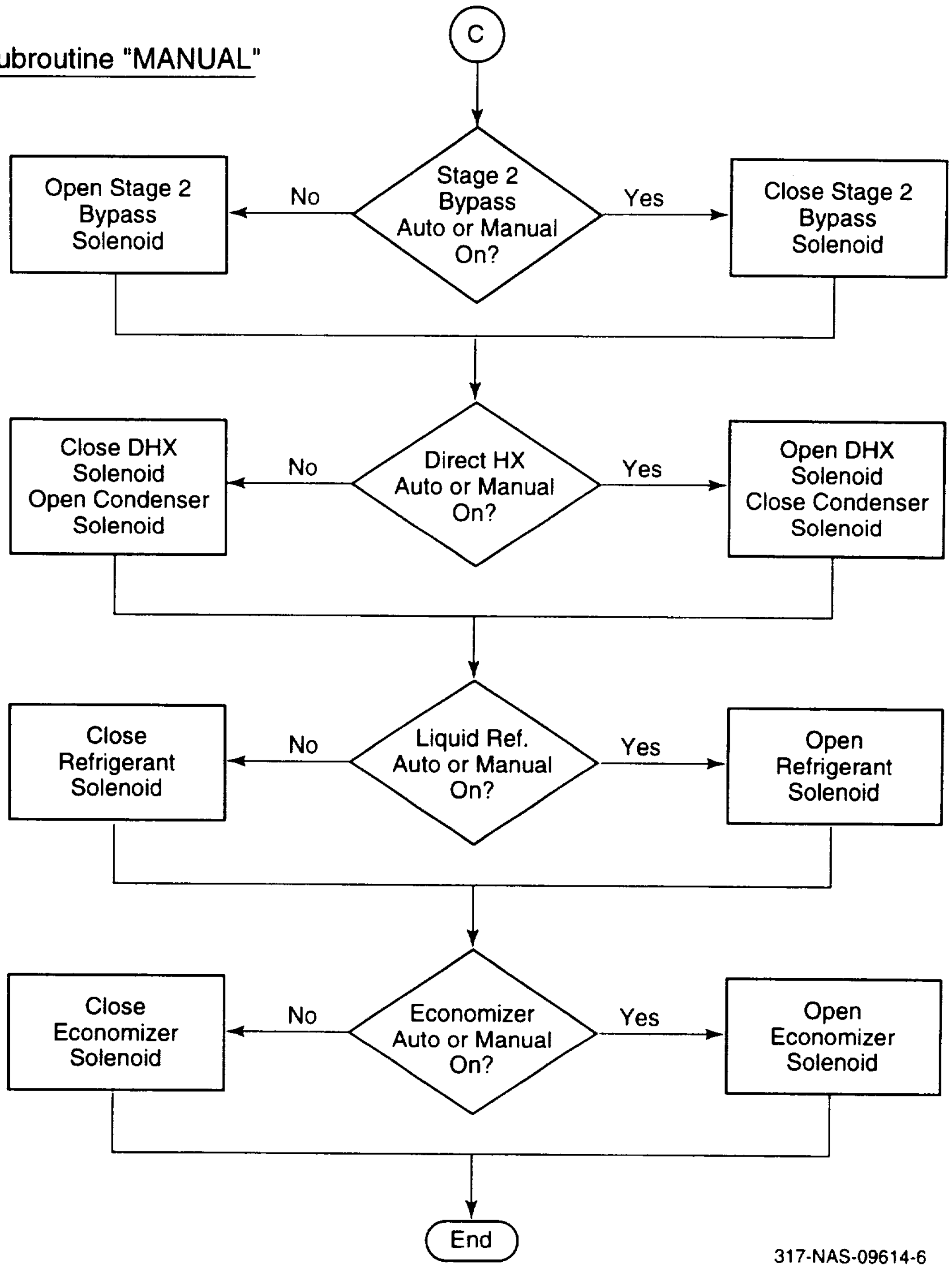
317-NAS-09614-4

Subroutine "MANUAL"

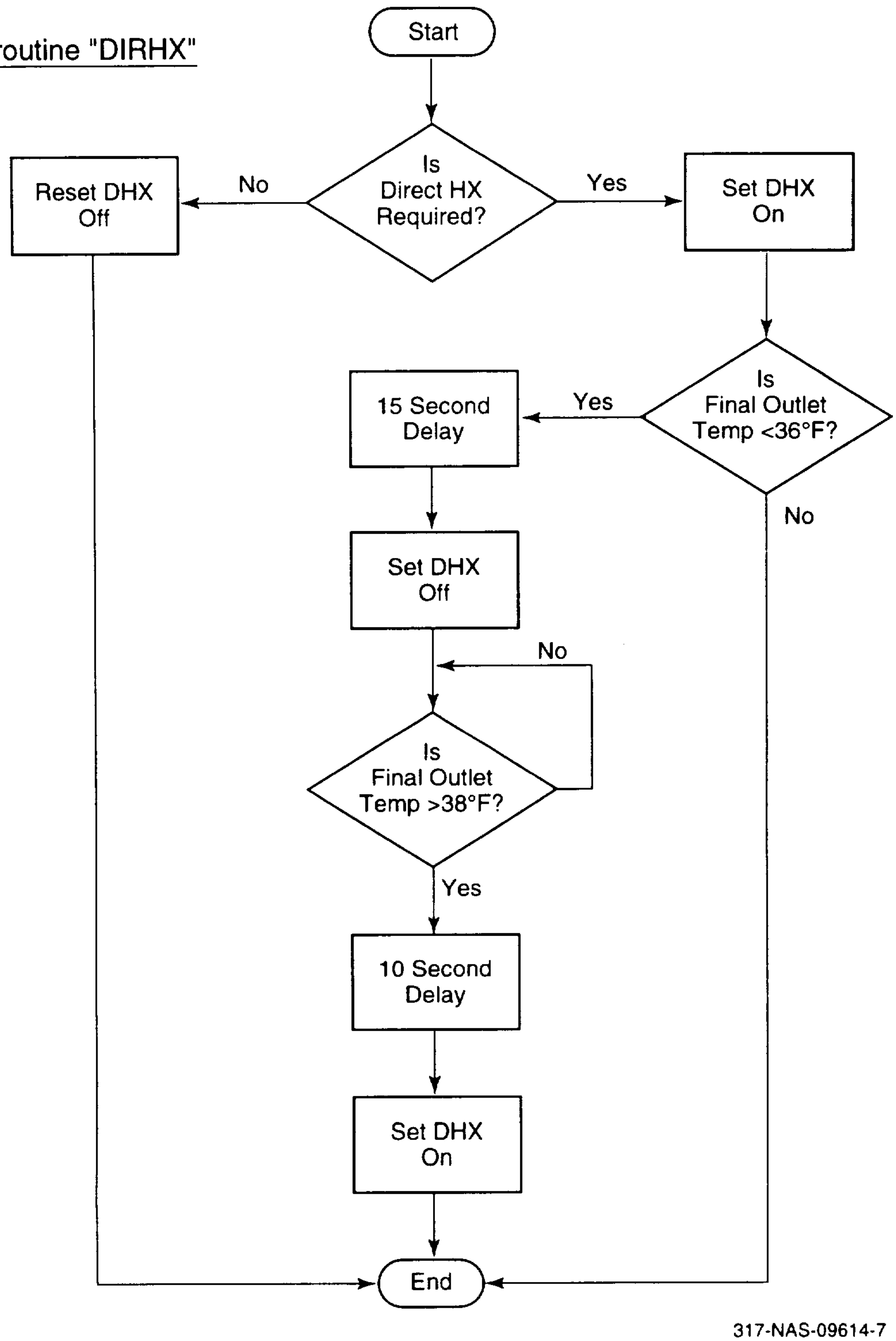


317-NAS-09614-5

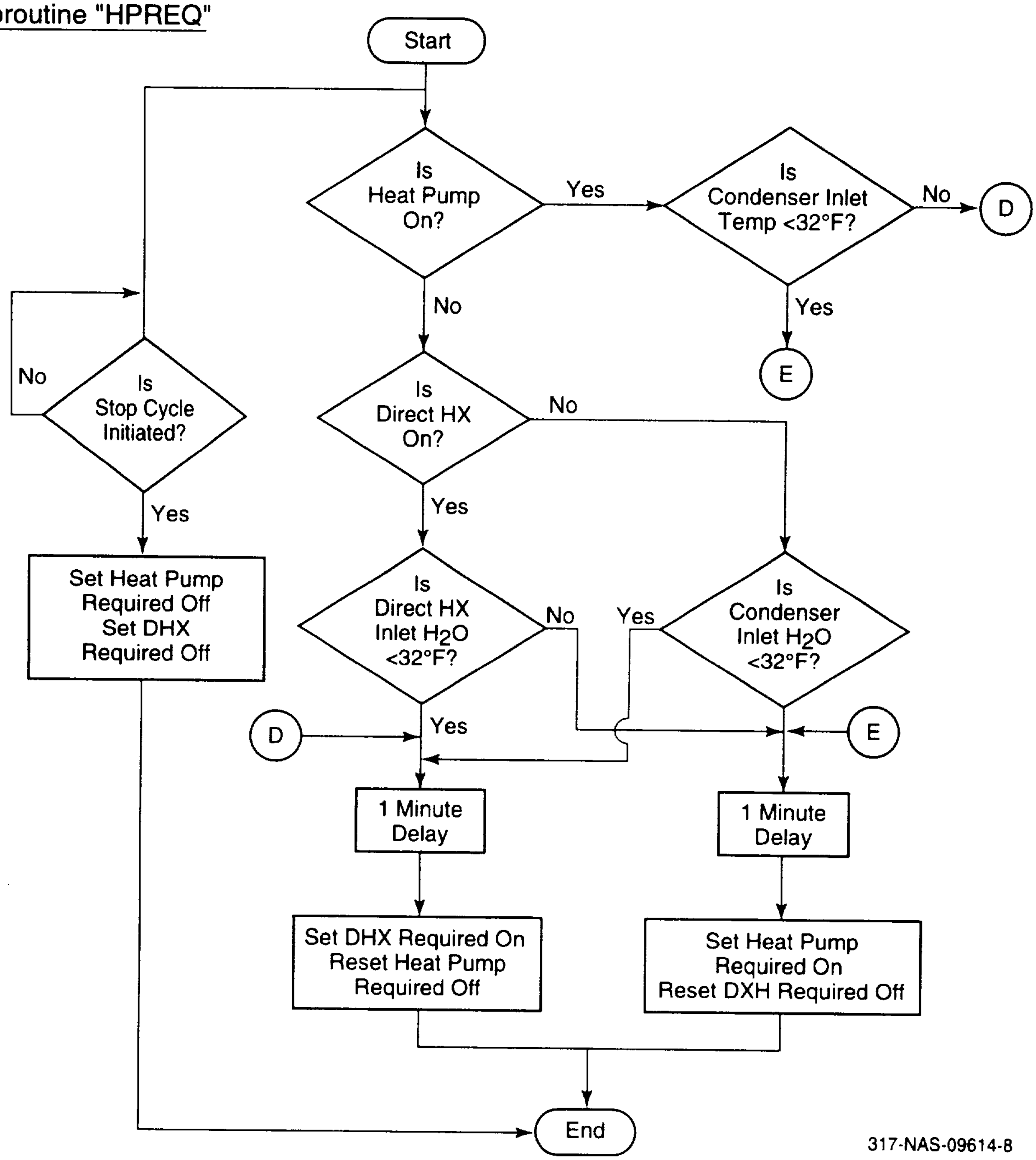
Subroutine "MANUAL"



Subroutine "DIRHX"

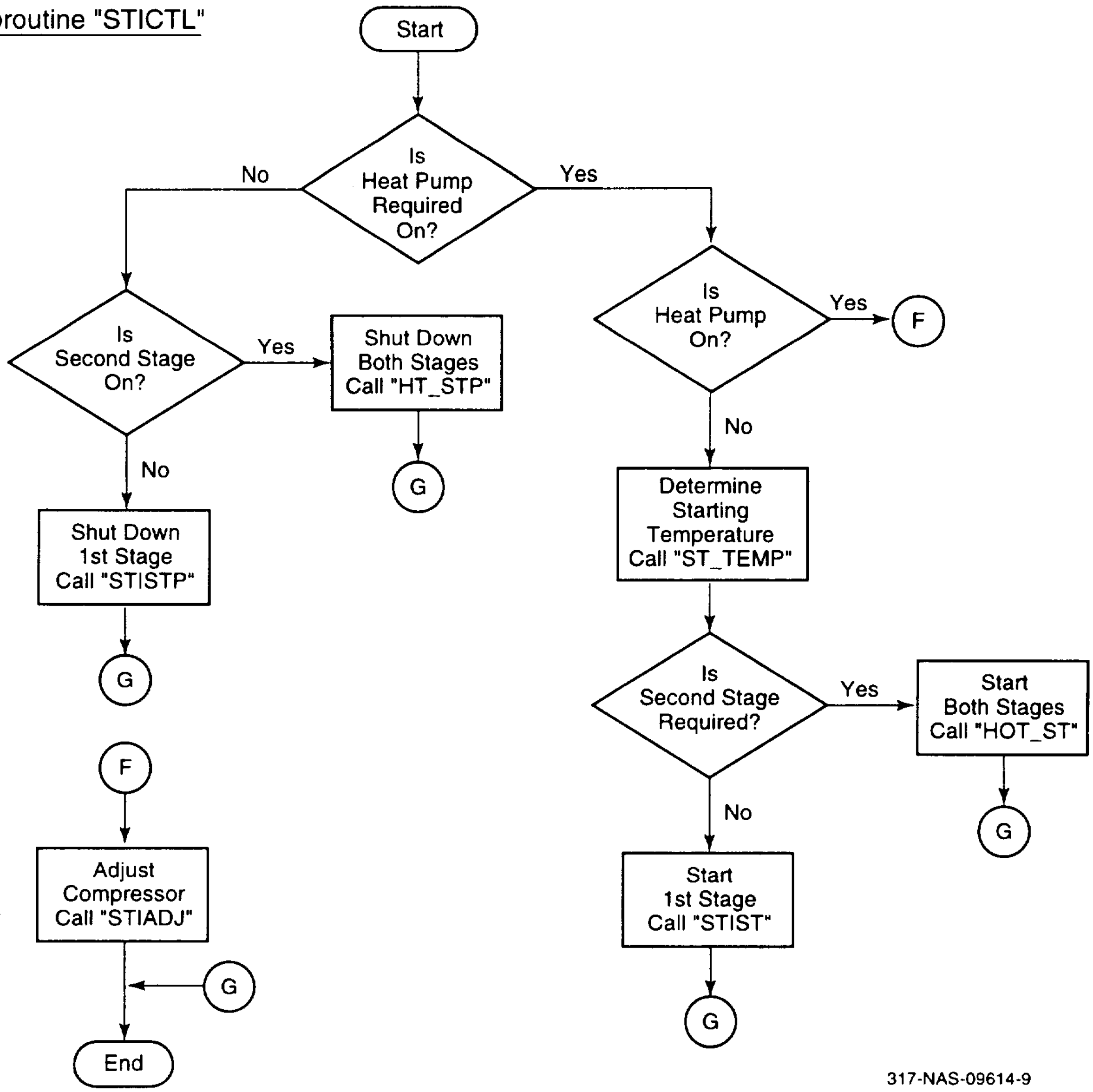


Subroutine "HPREQ"



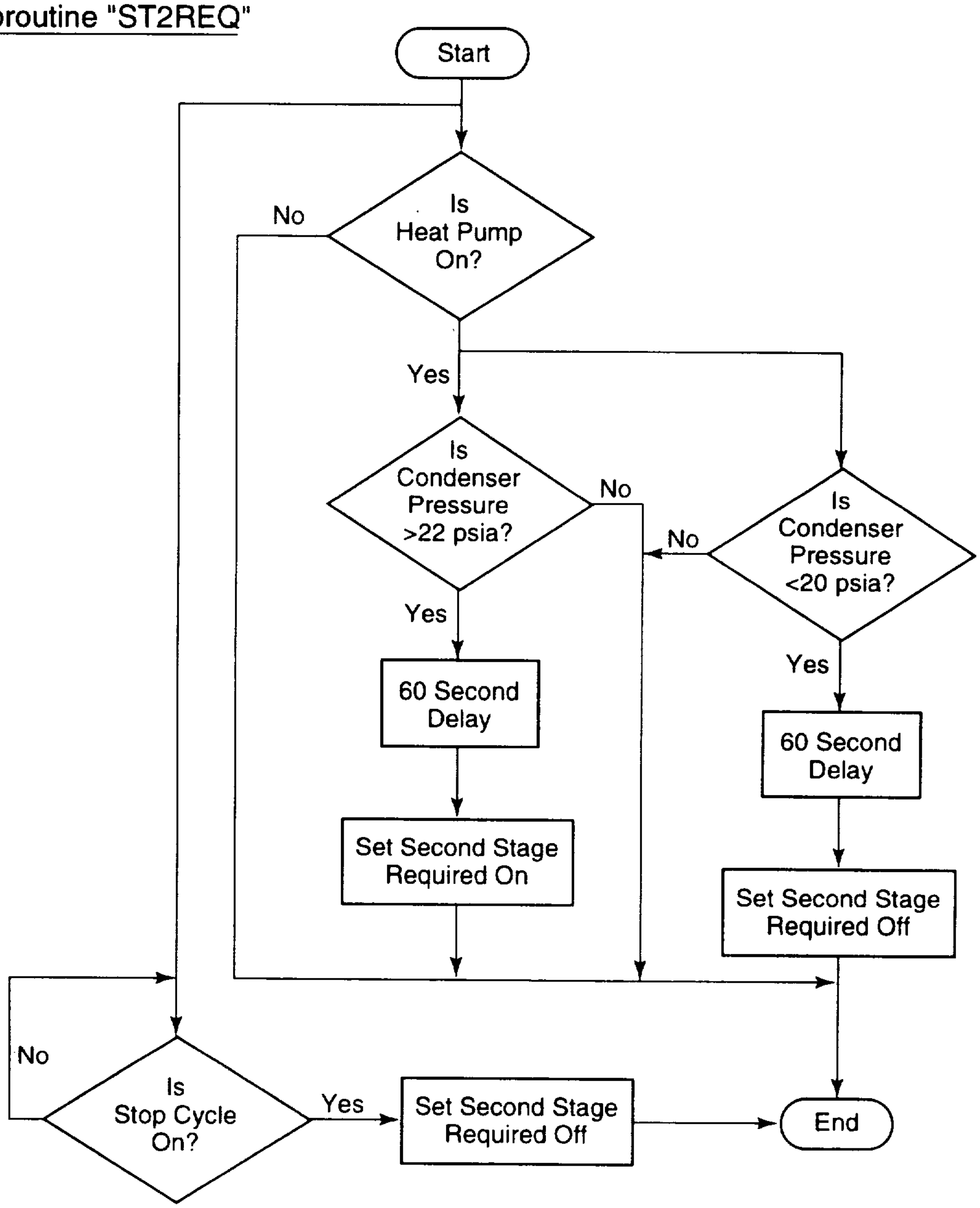
317-NAS-09614-8

Subroutine "STICTL"



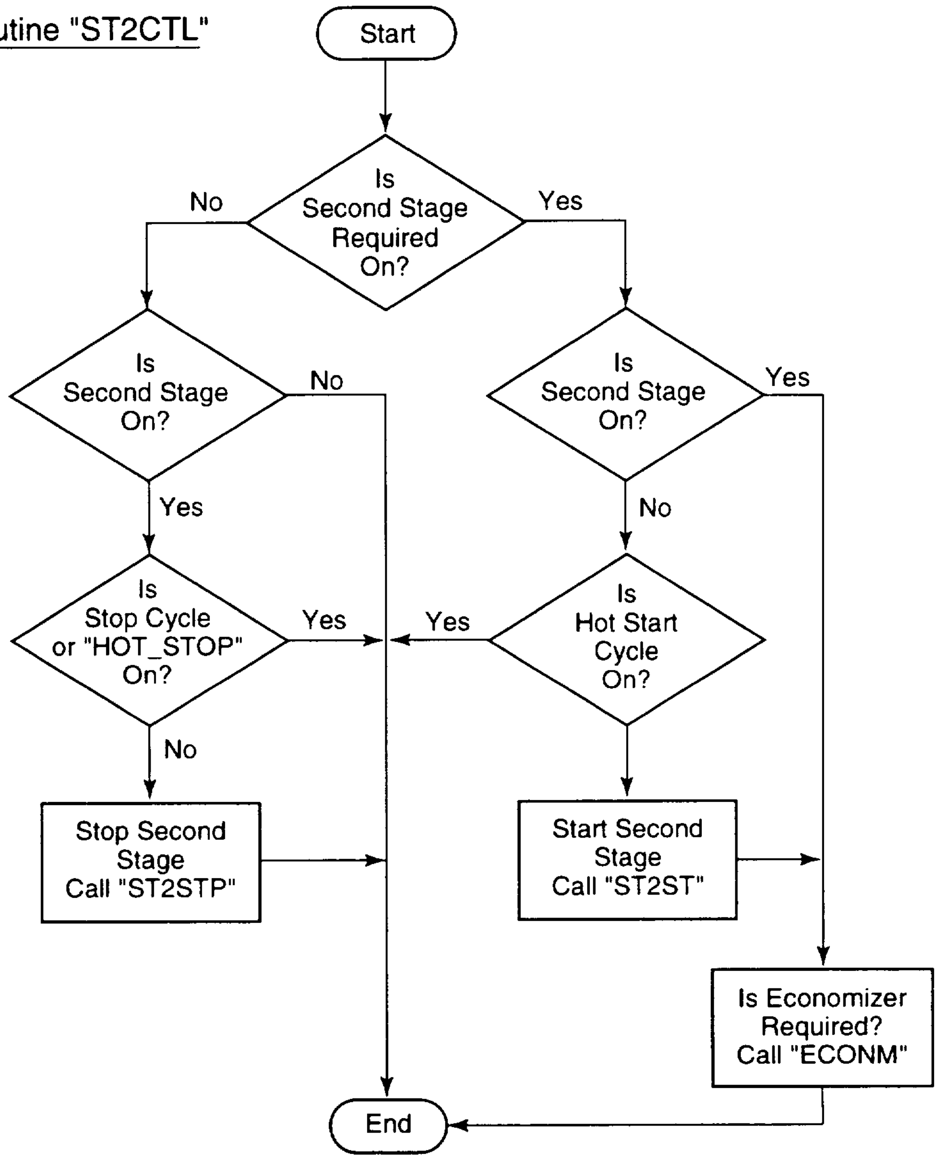
317-NAS-09614-9

Subroutine "ST2REQ"



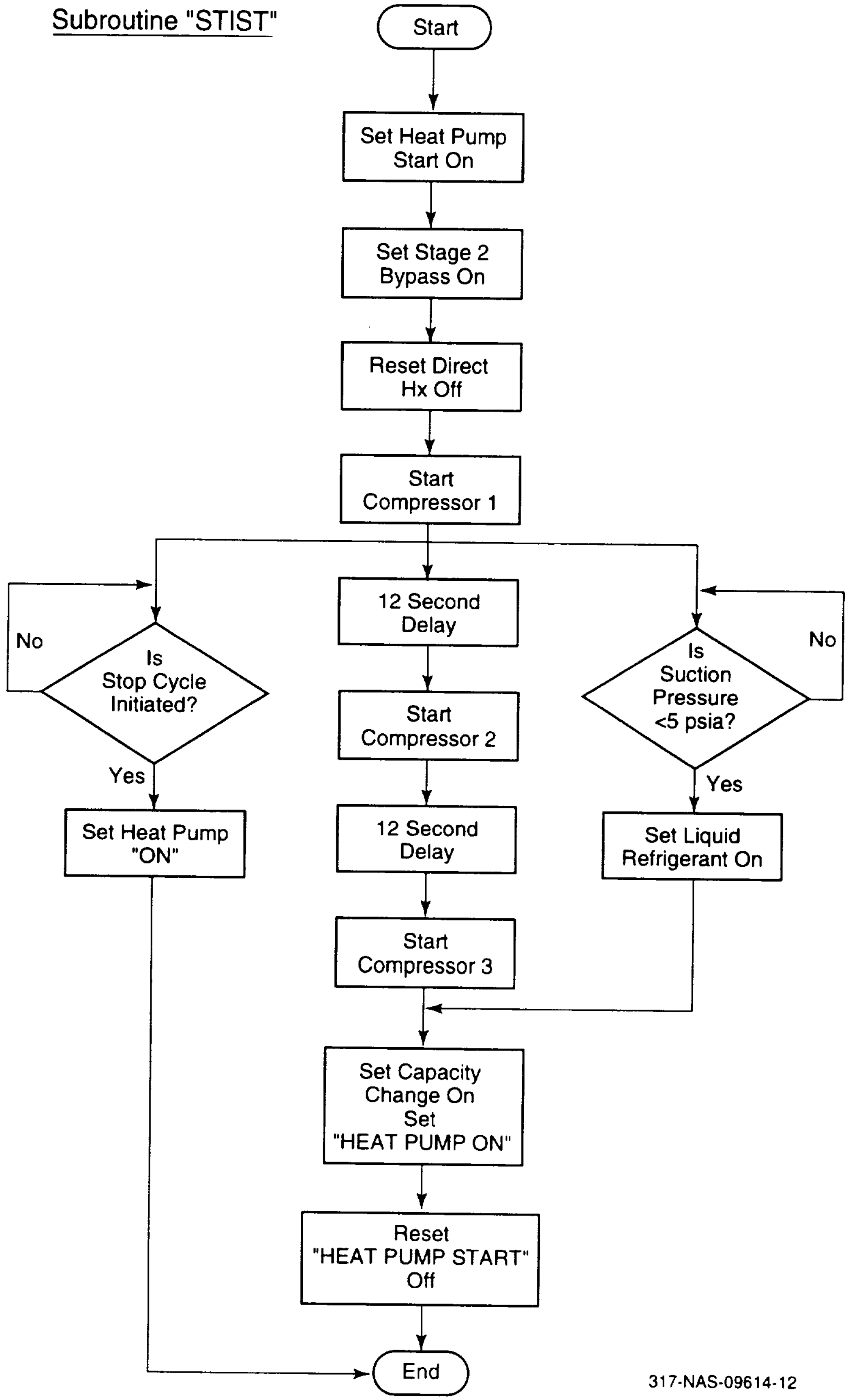
317-NAS-09614-10

Subroutine "ST2CTL"



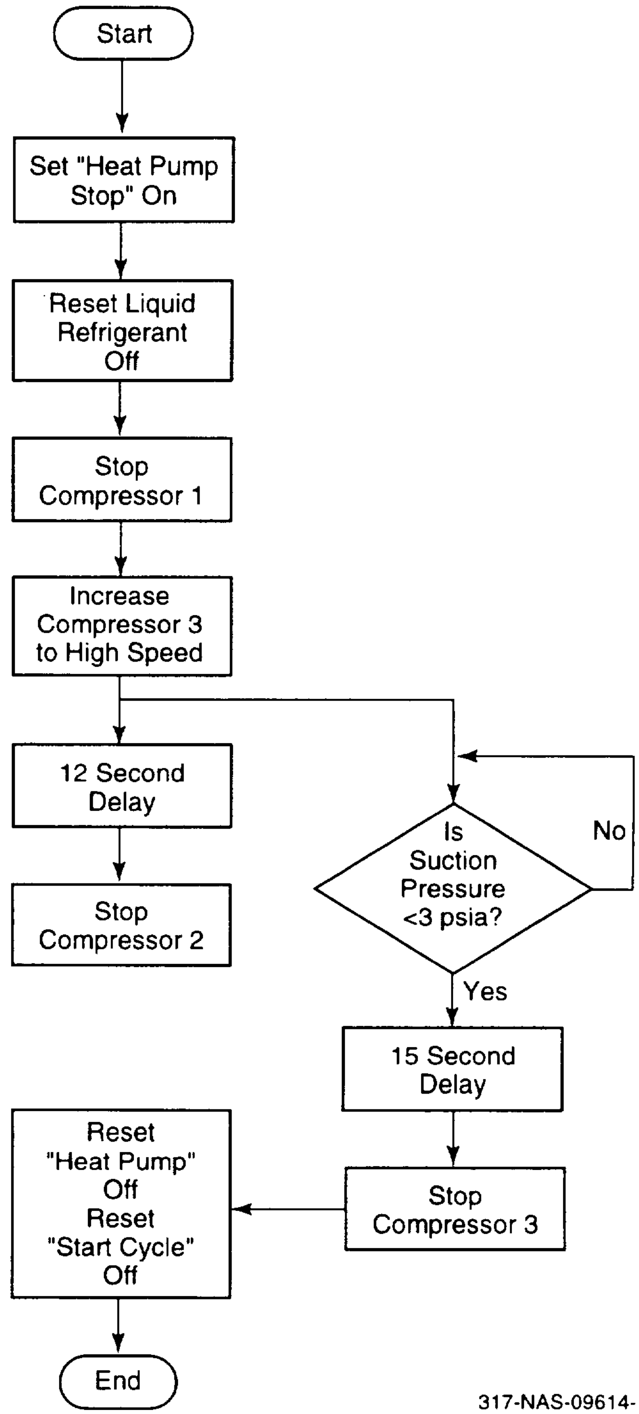
317-NAS-09614-11

Subroutine "STIST"



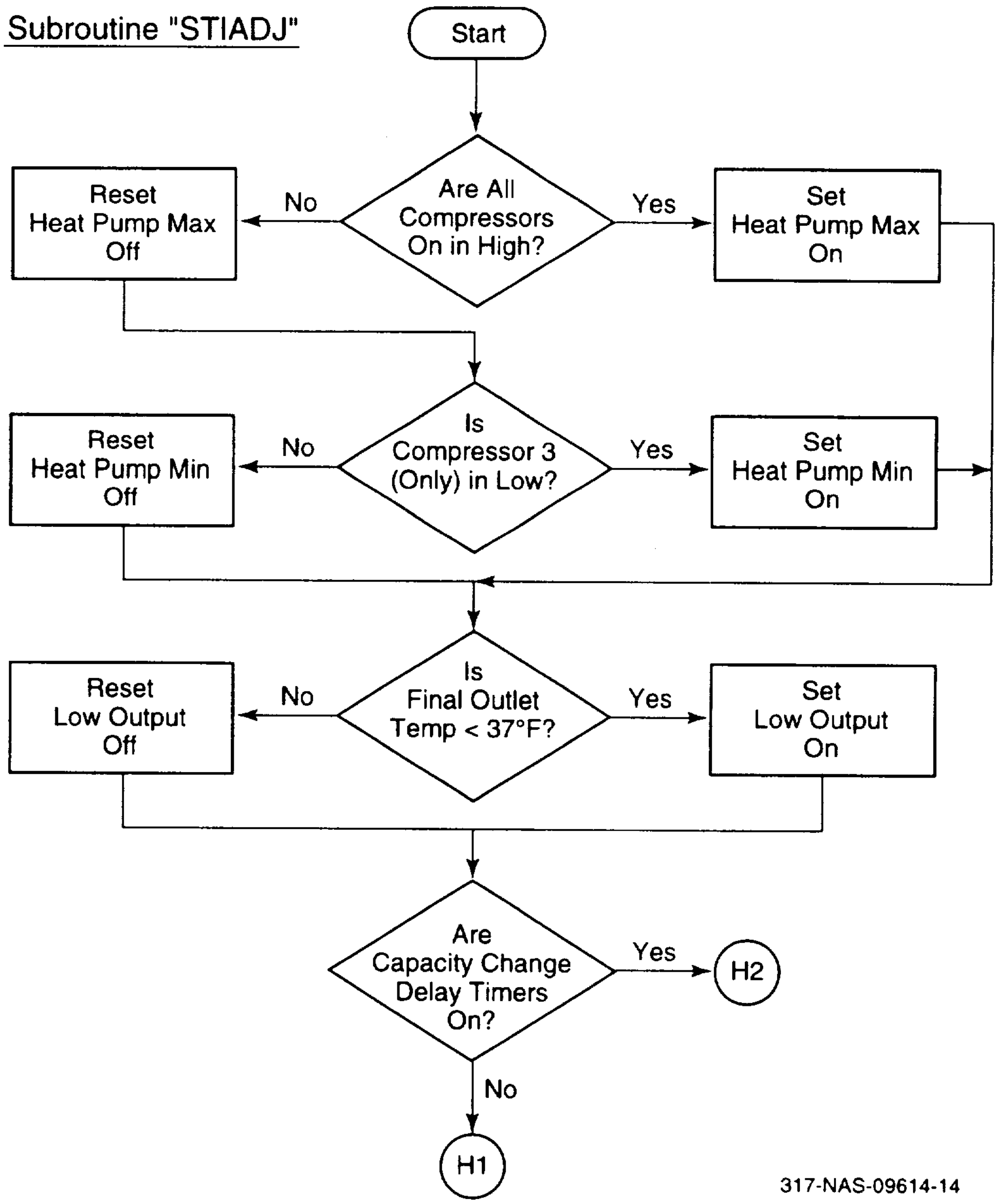
317-NAS-09614-12

Subroutine "STISTP"



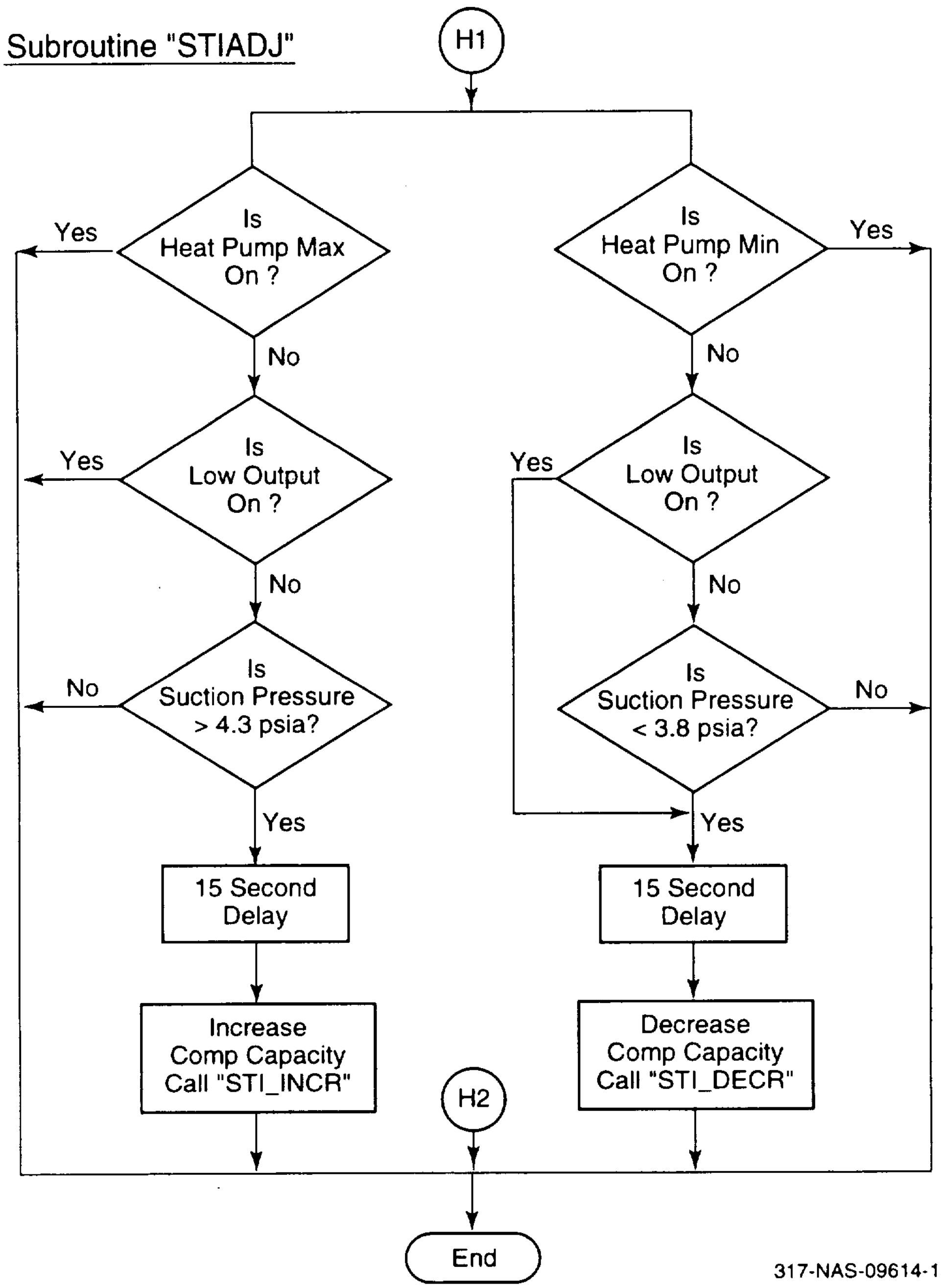
317-NAS-09614-13

Subroutine "STIADJ"



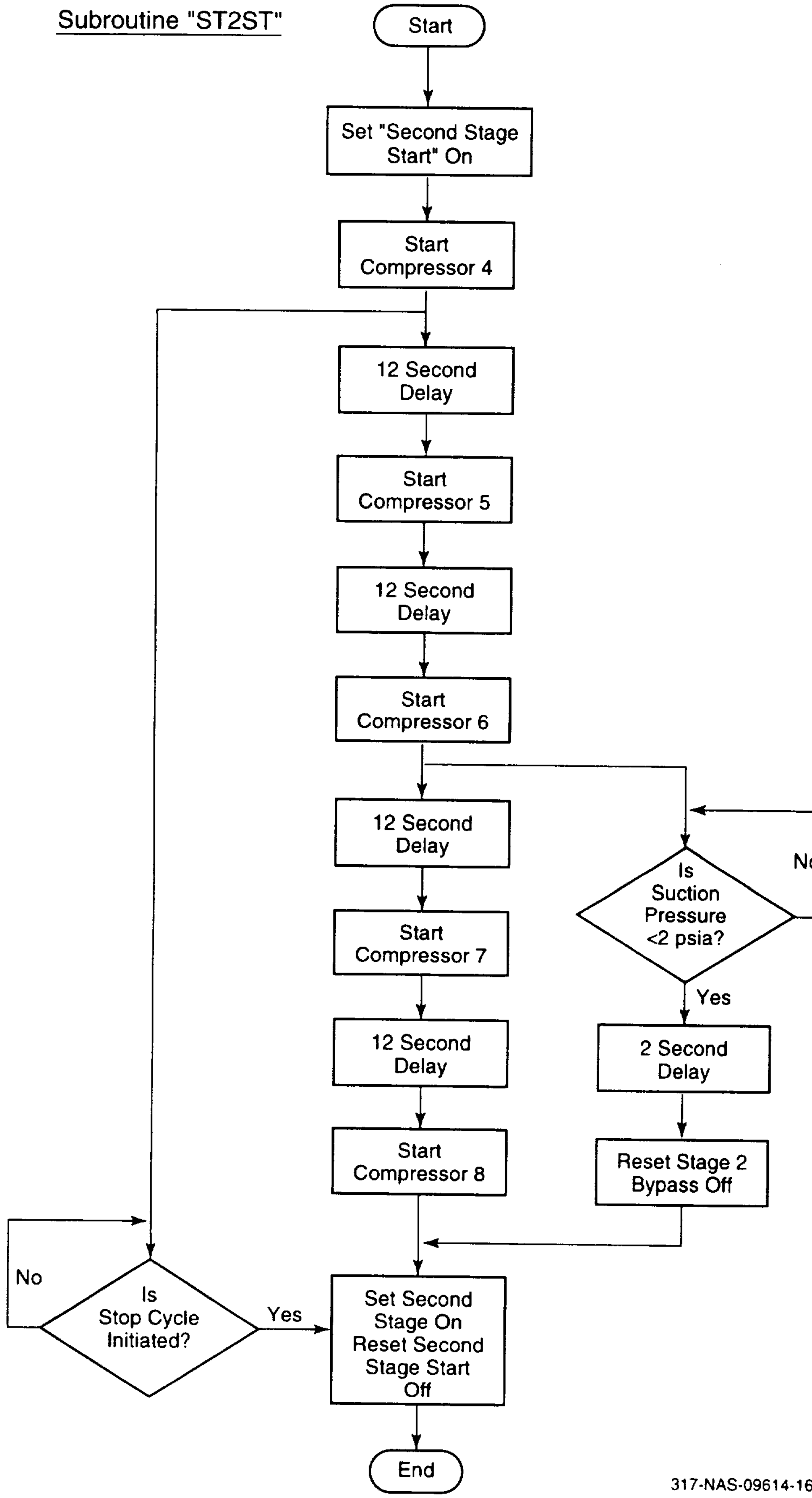
317-NAS-09614-14

Subroutine "STIADJ"

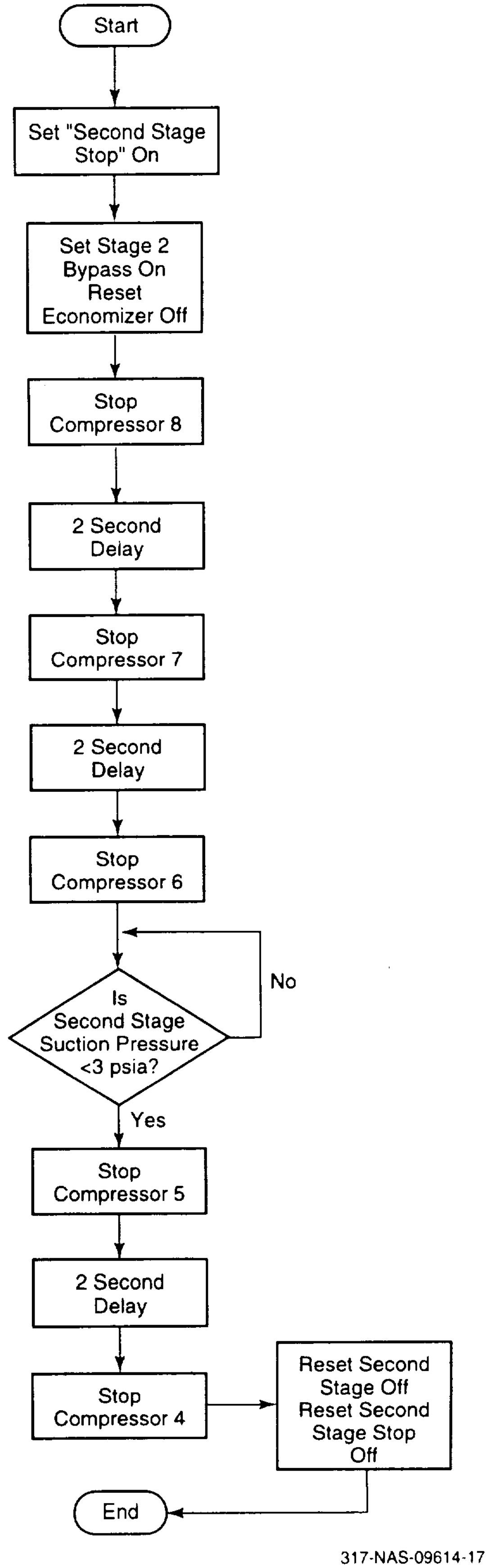


317-NAS-09614-15

Subroutine "ST2ST"



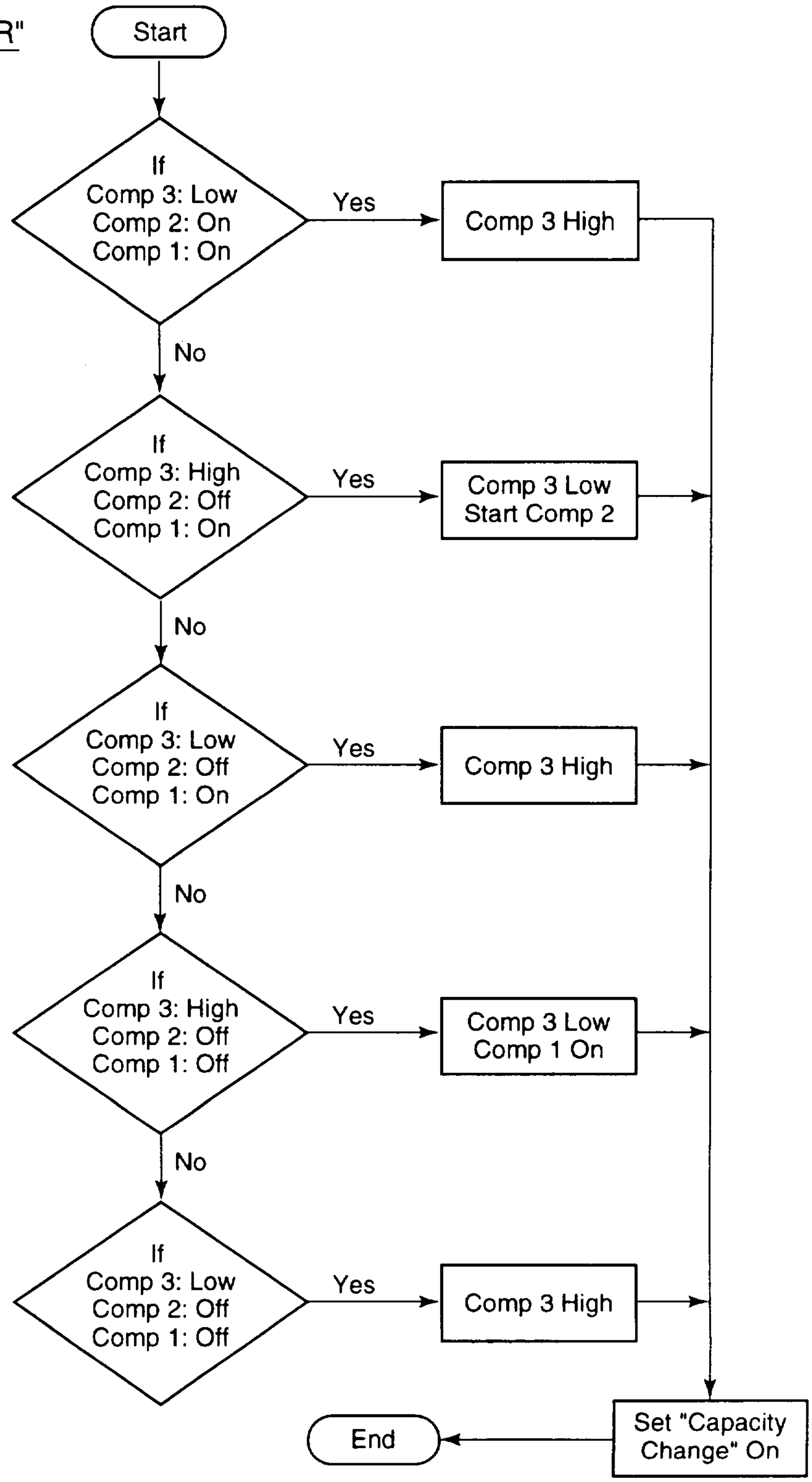
Subroutine "ST2STP"



Subroutine "ST2ADJ"

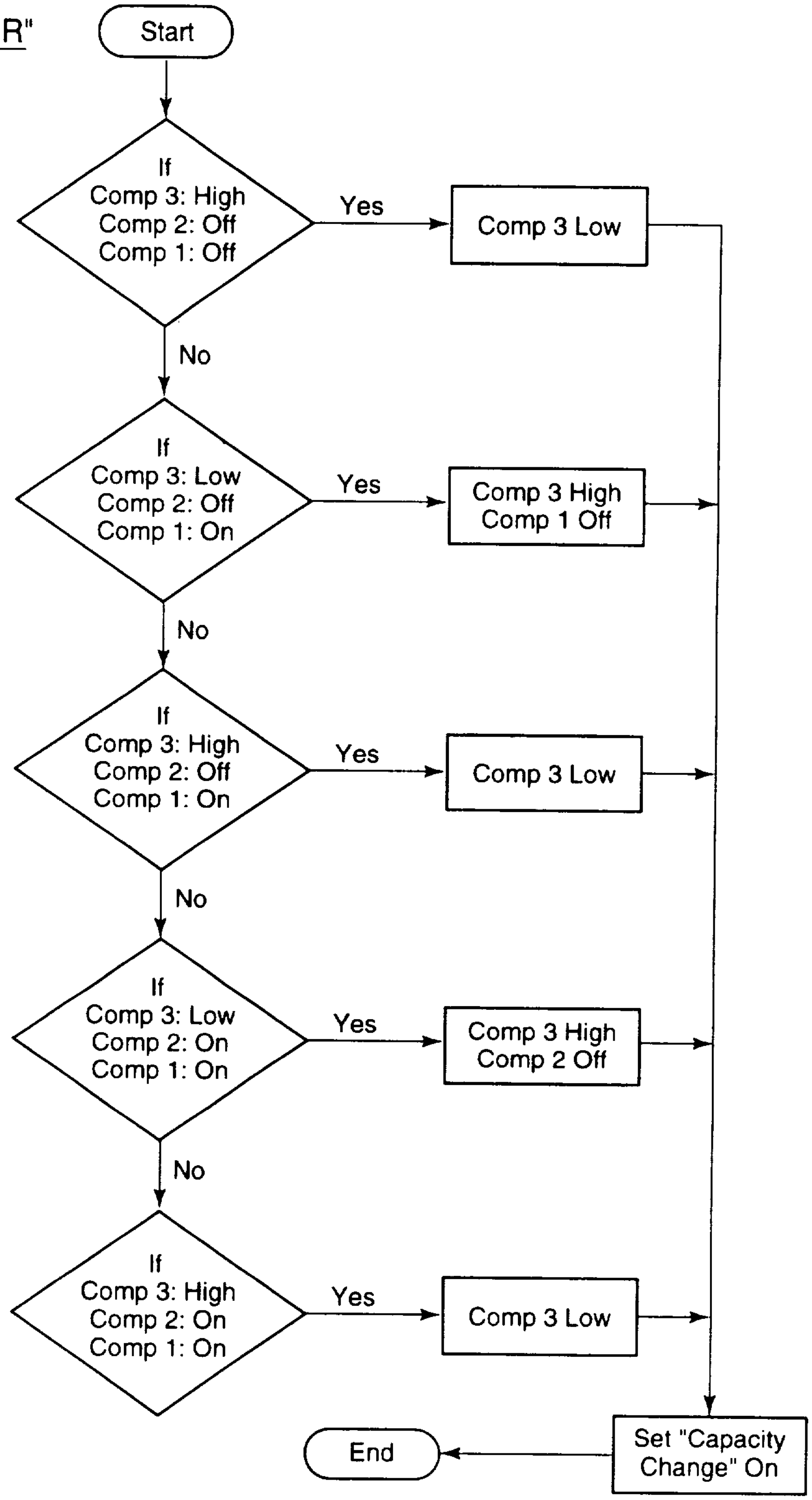
Not Used in Program

Subroutine "ST1INCR"



317-NAS-09614-18

Subroutine "STIDECR"

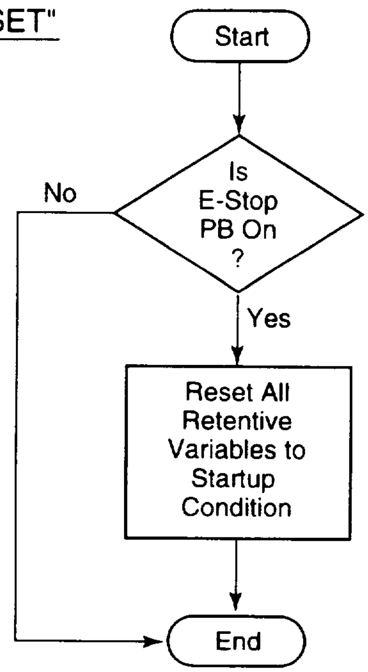


317-NAS-09614-19

Subroutines "ST2INCR", "ST2DCER"

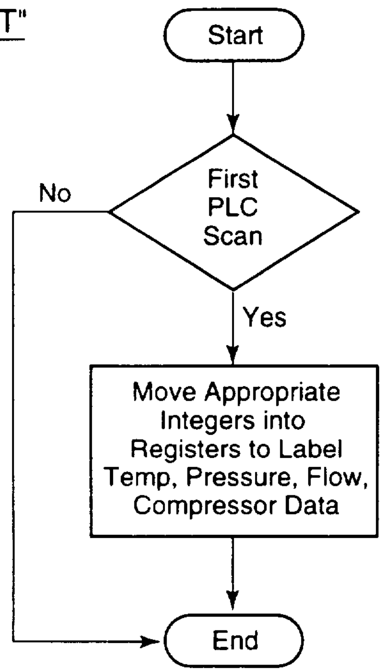
Not Used in Program

Subroutine "RESET"



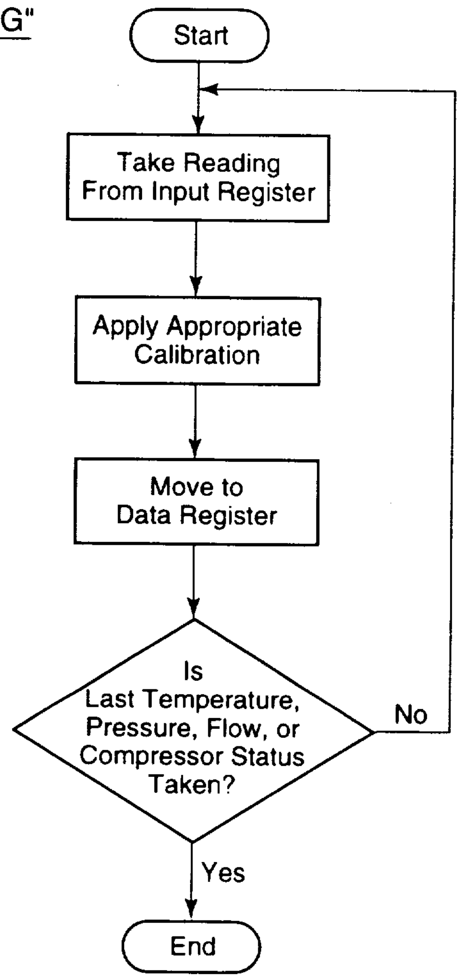
317-NAS-09614-20

Subroutine "INIT"



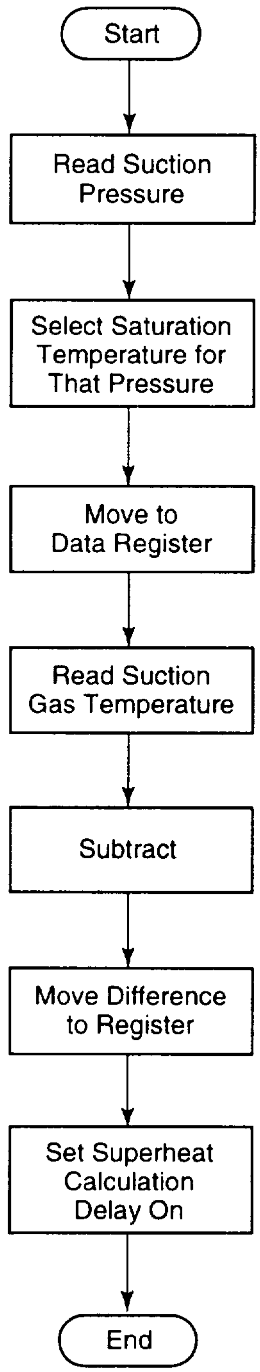
317-NAS-09614-21

Subroutine "READING"



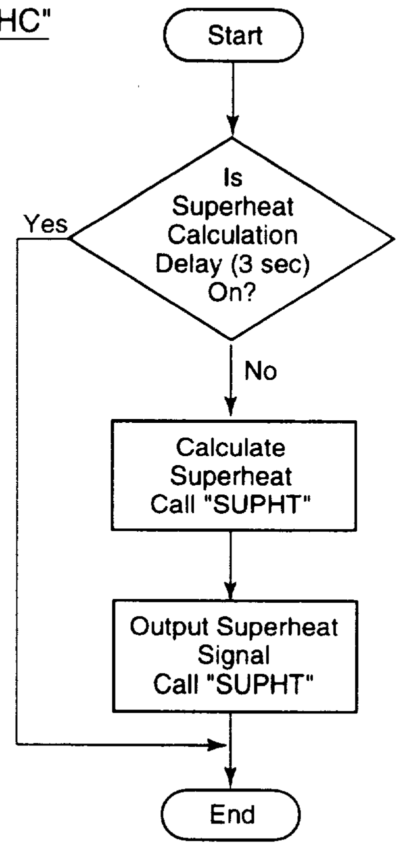
317-NAS-09614-22

Subroutine "SUPHT"



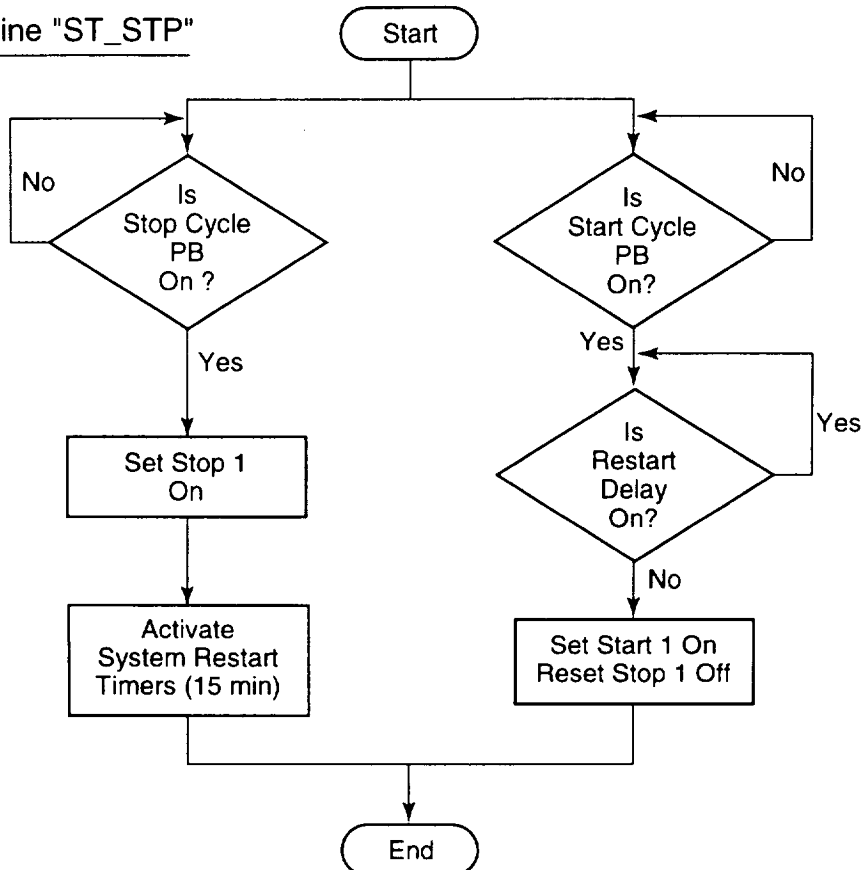
317-NAS-09614-23

Subroutine "SUPHC"



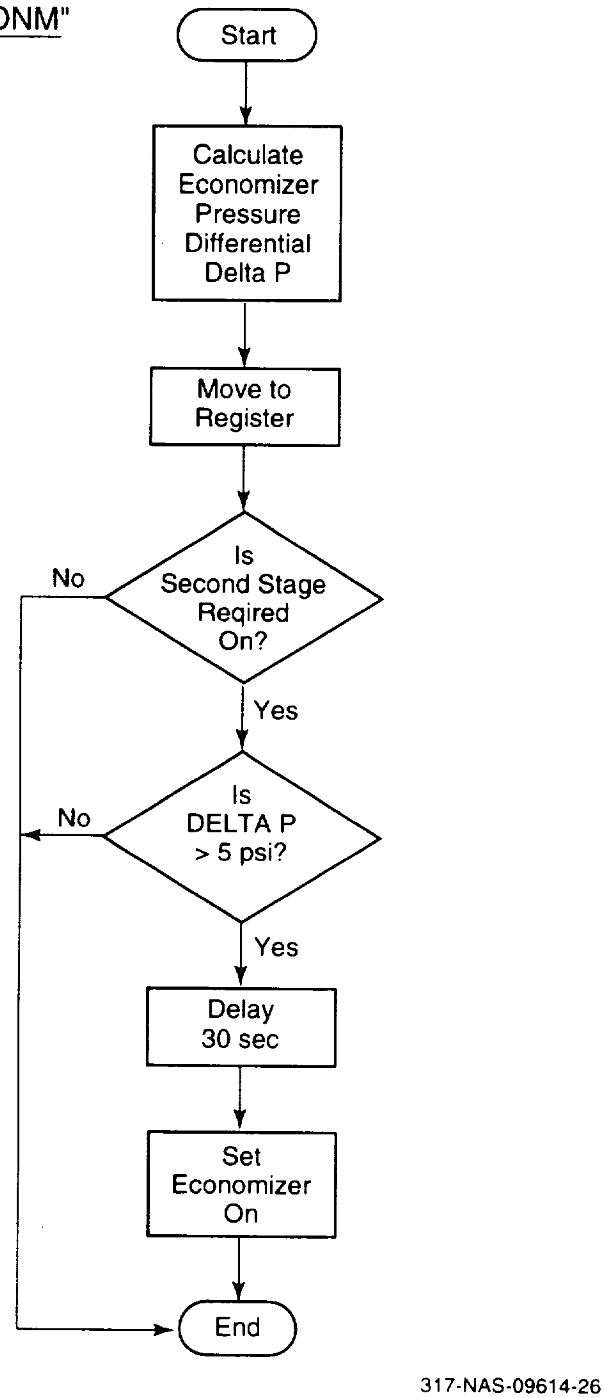
317-NAS-09614-24

Subroutine "ST_STP"

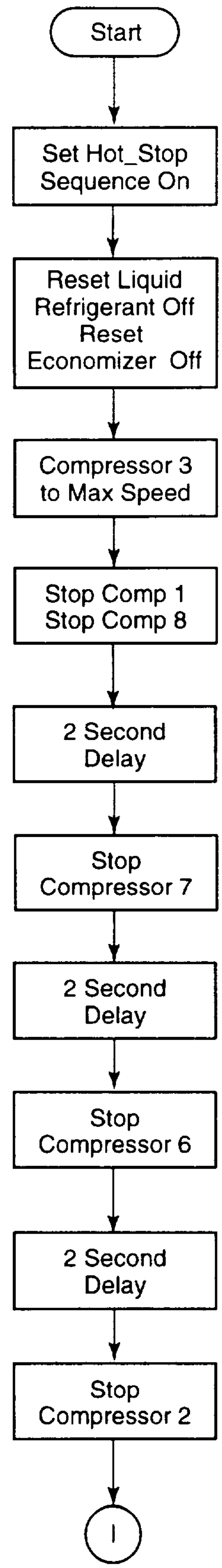


317-NAS-09614-25

Subroutine "ECONM"

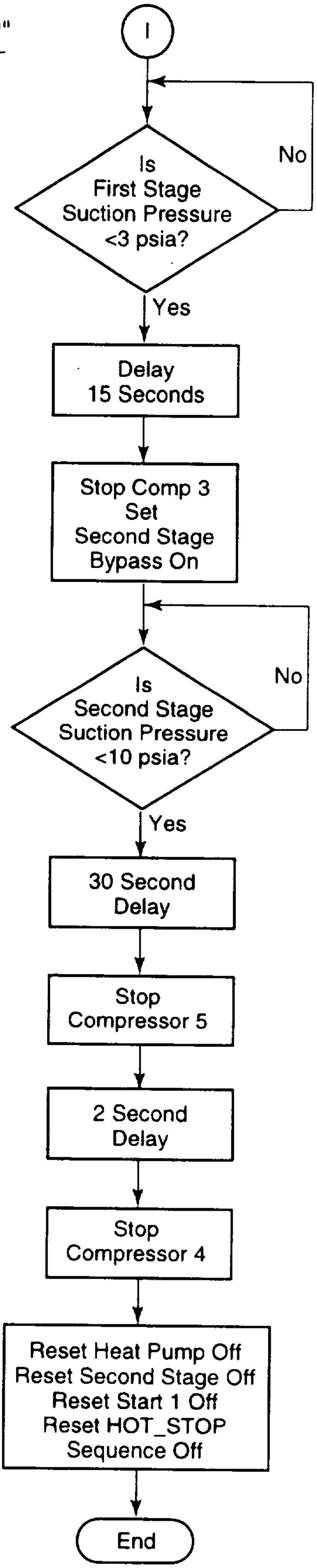


Subroutine "HOT_STP"



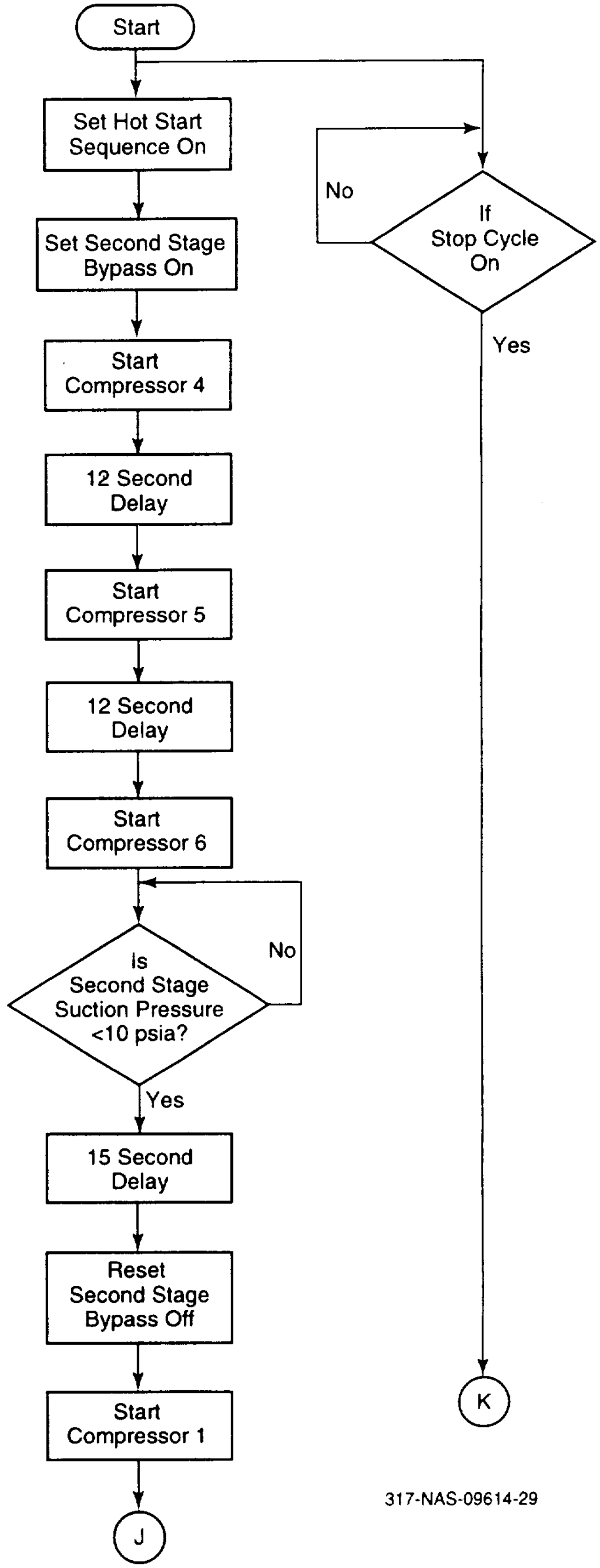
317-NAS-09614-27

Subroutine "HOT_STP"



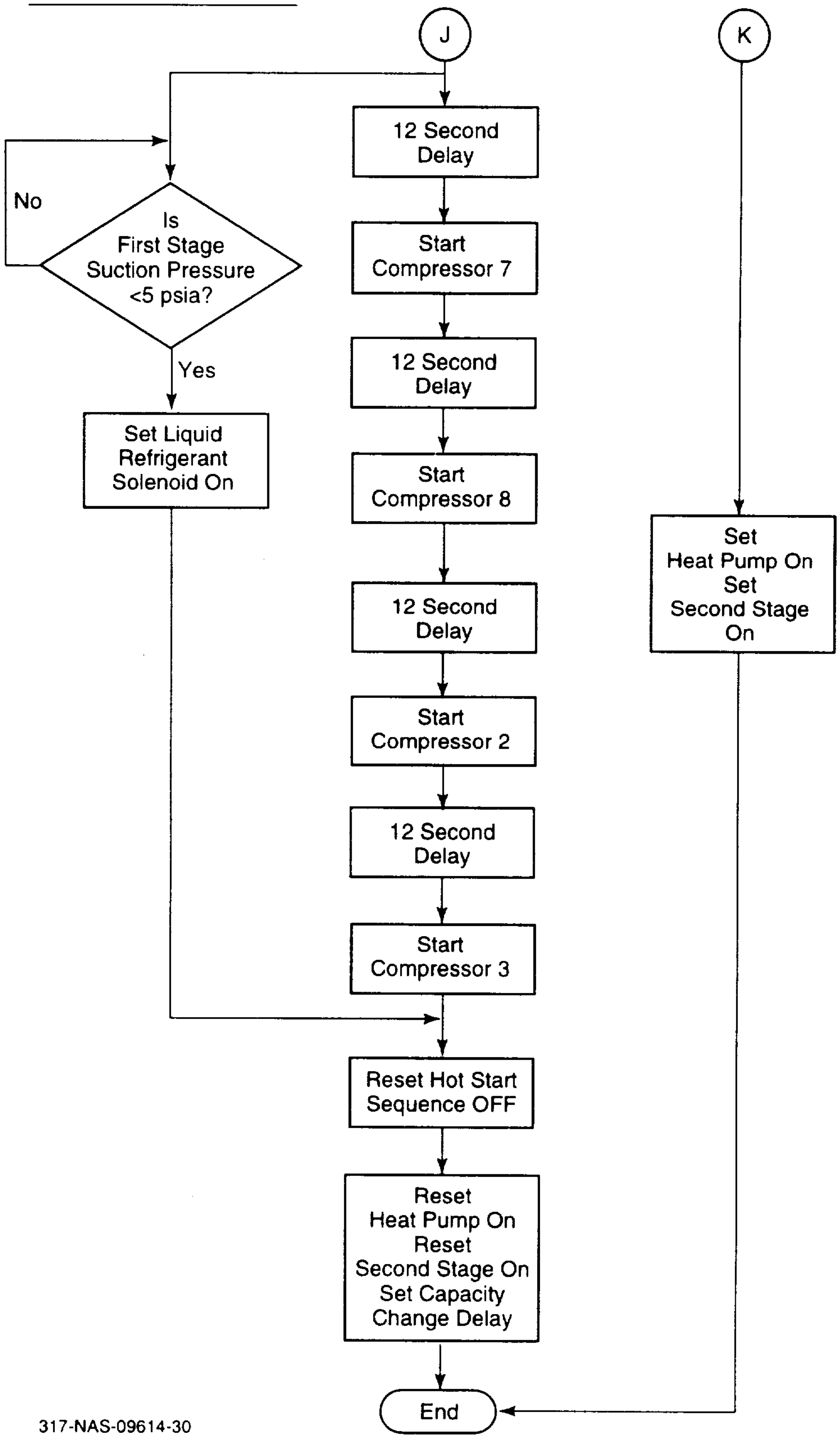
317-NAS-09614-28

Subroutine "HOT_ST"



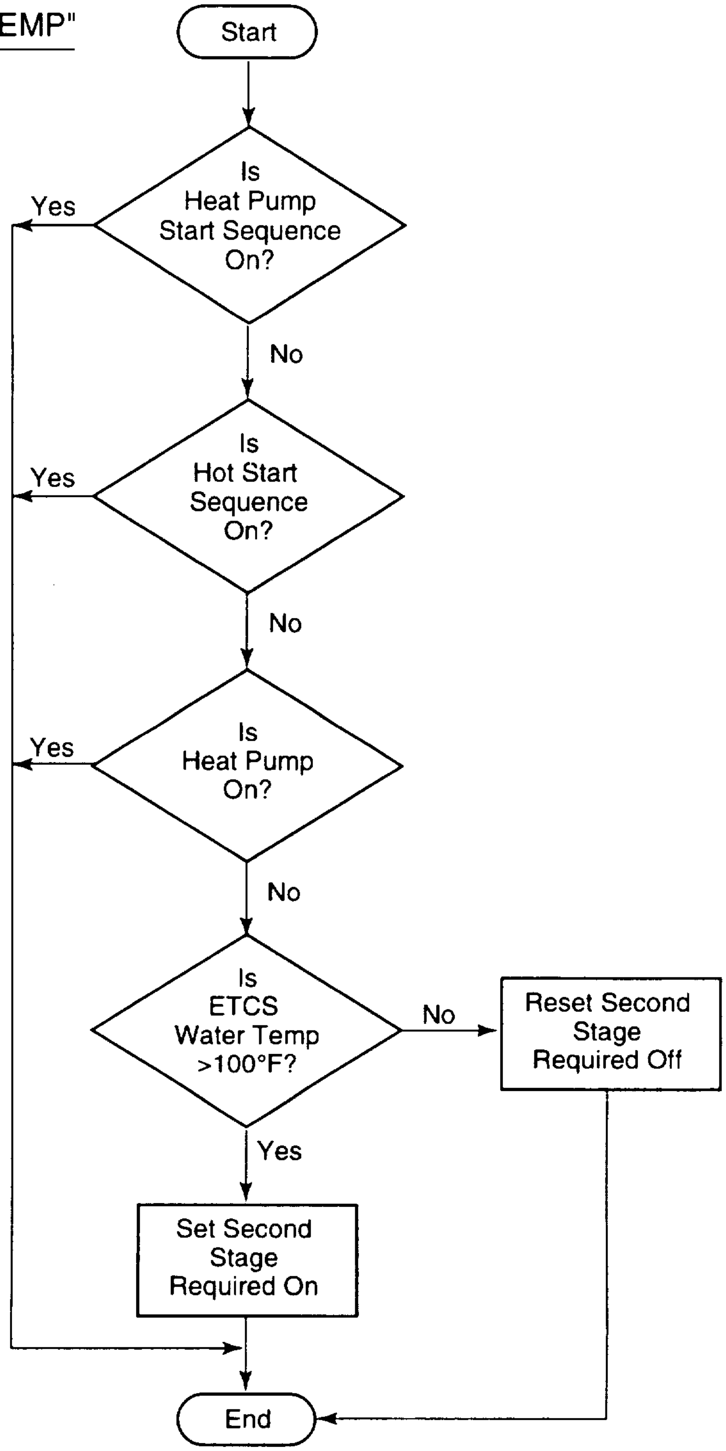
317-NAS-09614-29

Subroutine "HOT_ST"



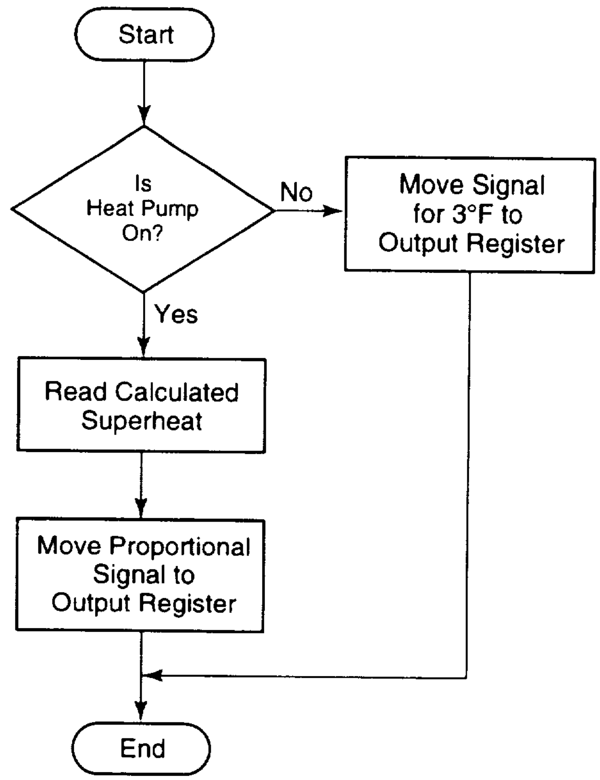
317-NAS-09614-30

Subroutine "ST_TEMP"



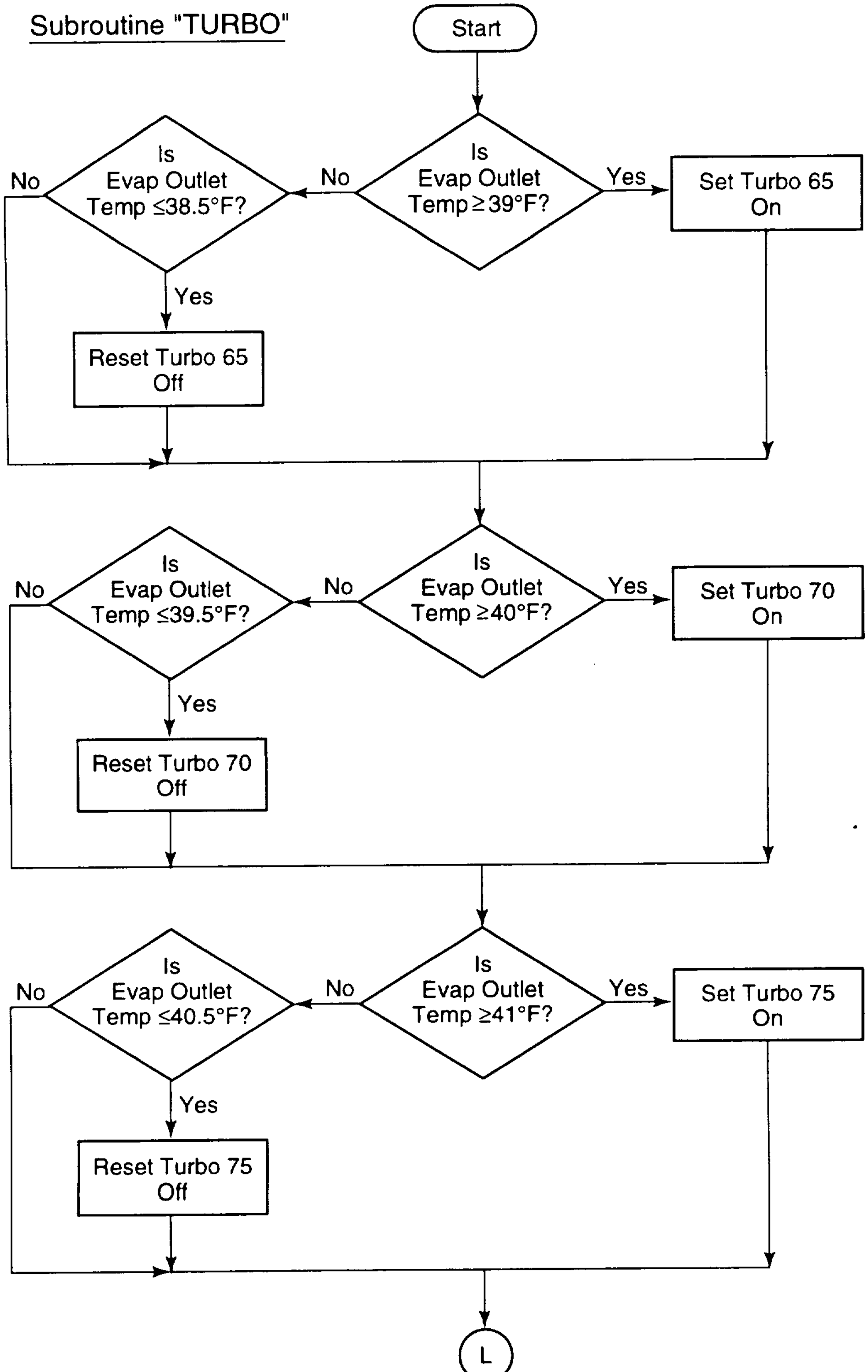
317-NAS-09614-31

Subroutine "SUPHOUT"



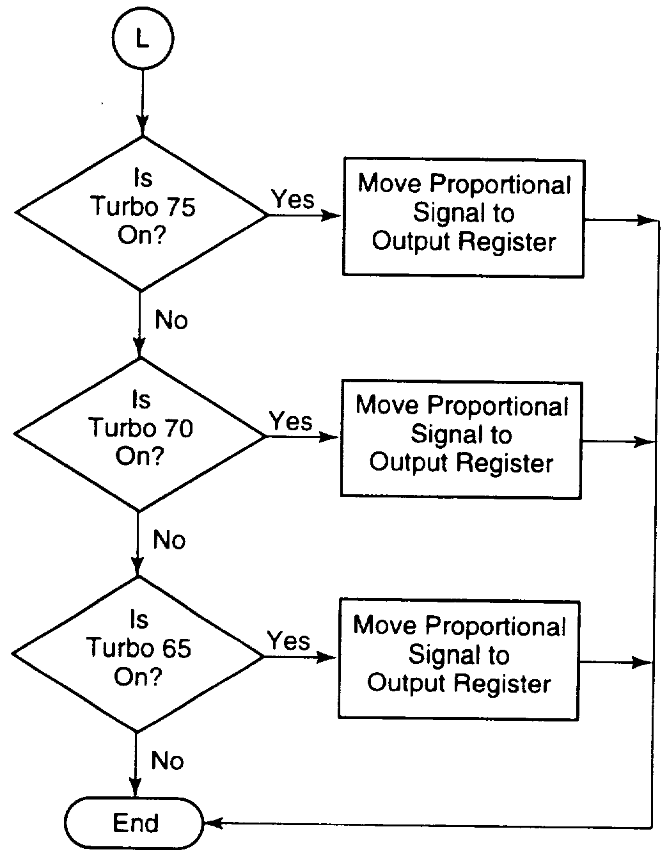
317-NAS-09614-32

Subroutine "TURBO"



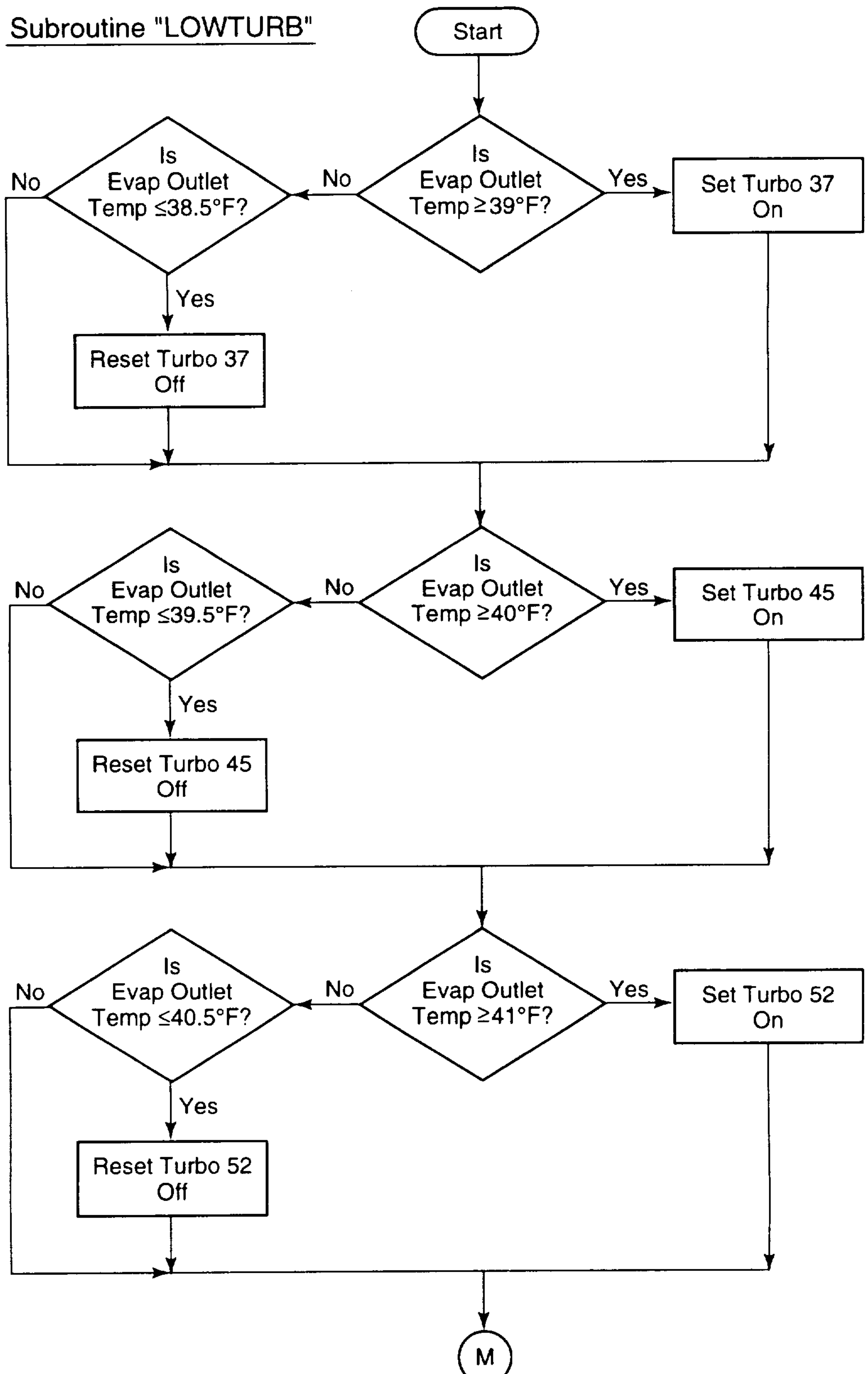
317-NAS-09614-33

Subroutine "TURBO"



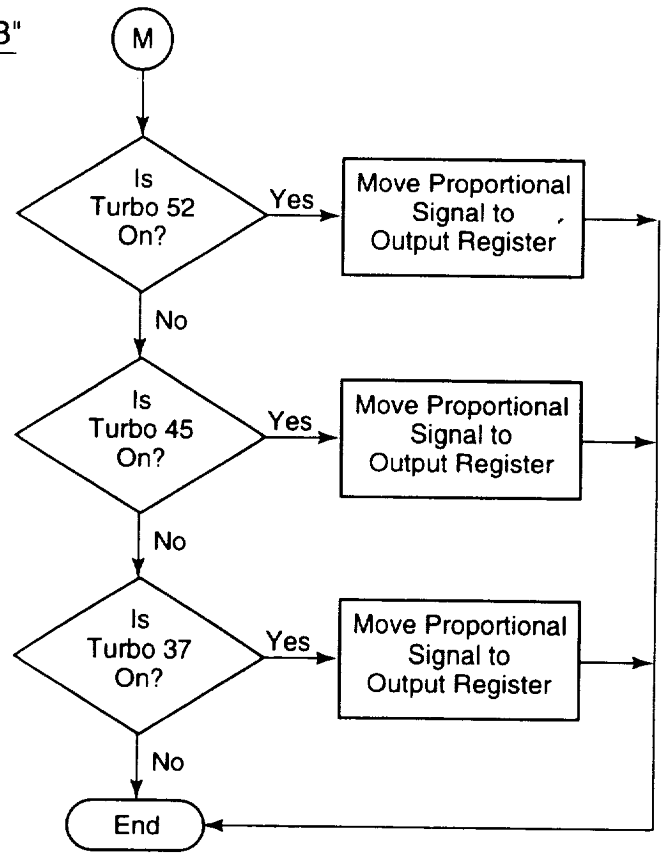
317-NAS-09614-34

Subroutine "LOWTURB"



317-NAS-09614-35

Subroutine "LOWTURB"



317-NAS-09614-36

APPENDIX C

PERFORMANCE TEST DATA

HIGH-INTERMEDIATE LOAD TEST

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.25	Refrigerant	Direct HX Out	Tx1	50.06	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	11.09	Refrigerant	EV1 Suction	Tx2	32.38	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	15.78	Refrigerant	1st Stage Discharge	Tx3	112.42	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	5.42	Refrigerant	2nd Stage Suction	Tx4	75.54	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	12.99	Refrigerant	Condenser In	Tx5	106.12	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	11.77	Refrigerant	Condenser Out	Tx6	50.00	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	9.33	Refrigerant	EV2 OUT	Tx7	31.83	Refrigerant
Compressor 7(2)	0	0			KW	4.31		Economizer Liq Out	Tx8	56.90	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.46	Chill Water	Economizer Vap Out	Tx9	75.56	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	127.44	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	75.40	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.43	Cool Water	Condenser Out	Tx12	57.40	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	51.79	Chill Water
DIR VALVE1				Condenser in	Tx17	47.45	Cool Water	Evaporator Out	Tx14	37.24	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	44.64	Cool Water	Final Outlet Temp	Tx15	39.33	Chill Water
manual switch	0			Econom Liq In	Tx19	57.57	Refrigerant	Direct HX In (chilled)	Tx16	50.11	Chill Water
10/11/95								1st STAGE SUCTION		30.93	
002				LOAD (kW)	5.16			Superheat		2.00	
3:46PM				REJECT(kW)	12.09						
1st stage				DIRECT HX(kw)	-0.60						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.64	Refrigerant	Direct HX Out	Tx1	52.21	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	11.77	Refrigerant	EV1 Suction	Tx2	35.27	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	17.34	Refrigerant	1st Stage Discharge	Tx3	128.88	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	5.47	Refrigerant	2nd Stage Suction	Tx4	75.64	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	14.02	Refrigerant	Condenser In	Tx5	122.43	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	12.41	Refrigerant	Condenser Out	Tx6	61.43	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	9.62	Refrigerant	EV2 OUT	Tx7	34.67	Refrigerant
Compressor 7(2)	0	0			KW	4.43		Economizer Liq Out	Tx8	57.29	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.55	Chill Water	Economizer Vap Out	Tx9	75.51	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	144.35	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	75.65	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.45	Cool Water	Condenser Out	Tx12	66.20	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	53.76	Chill Water
DIR VALVE1				Condenser in	Tx17	54.47	Cool Water	Evaporator Out	Tx14	39.73	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	47.52	Cool Water	Final Outlet Temp	Tx15	39.43	Chill Water
manual switch	0			Econom Liq In	Tx19	58.74	Refrigerant	Direct HX In (chilled)	Tx16	51.87	Chill Water
10/11/95								1st STAGE SUCTION		33.94	
003				LOAD (kW)	5.16			Superheat		1.00	
3:54PM				REJECT(kW)	14.28						
1st stage				DIRECT HX(kw)	-0.70						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.96	Refrigerant	Direct HX Out	Tx1	51.18	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	13.24	Refrigerant	EV1 Suction	Tx2	30.12	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	16.85	Refrigerant	1st Stage Discharge	Tx3	127.51	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	5.62	Refrigerant	2nd Stage Suction	Tx4	76.42	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	14.70	Refrigerant	Condenser In	Tx5	122.24	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	13.72	Refrigerant	Condenser Out	Tx6	63.24	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	11.67	Refrigerant	EV2 OUT	Tx7	30.19	Refrigerant
Compressor 7(2)	0	0			KW	4.29		Economizer Liq Out	Tx8	65.20	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.48	Chill Water	Economizer Vap Out	Tx9	76.34	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	125.60	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	76.38	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.53	Cool Water	Condenser Out	Tx12	69.74	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	52.75	Chill Water
DIR VALVE1				Condenser in	Tx17	59.79	Cool Water	Evaporator Out	Tx14	37.87	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	51.87	Cool Water	Final Outlet Temp	Tx15	40.03	Chill Water
manual switch	0			Econom Liq In	Tx19	66.12	Refrigerant	Direct HX In (chilled)	Tx16	50.94	Chill Water
10/11/95								1st STAGE SUCTION		31.18	
004				LOAD (kW)	5.32			Superheat		8.00	
4:12PM				REJECT(kW)	12.24						
1st stage				DIRECT HX(kw)	-0.65						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.86	Refrigerant	Direct HX Out	Tx1	50.31	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	15.24	Refrigerant	EV1 Suction	Tx2	28.92	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	18.61	Refrigerant	1st Stage Discharge	Tx3	131.78	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	5.67	Refrigerant	2nd Stage Suction	Tx4	76.52	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	16.95	Refrigerant	Condenser In	Tx5	125.73	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	15.87	Refrigerant	Condenser Out	Tx6	79.11	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	13.43	Refrigerant	EV2 OUT	Tx7	28.50	Refrigerant
Compressor 7(2)	0	0			KW	4.44		Economizer Liq Out	Tx8	71.65	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.51	Chill Water	Economizer Vap Out	Tx9	76.39	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	130.67	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	76.63	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.59	Cool Water	Condenser Out	Tx12	78.29	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	51.87	Chill Water
DIR VALVE1				Condenser in	Tx17	73.28	Cool Water	Evaporator Out	Tx14	37.08	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	53.50	Cool Water	Final Outlet Temp	Tx15	38.23	Chill Water
manual switch	0			Econom Liq In	Tx19	73.64	Refrigerant	Direct HX In (chilled)	Tx16	50.09	Chill Water
10/11/95								1st STAGE SUCTION		27.35	
005				LOAD (kW)	5.35			Superheat		3.00	
4:15PM				REJECT(kW)	6.20						
1st stage				DIRECT HX(kw)	-0.64						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.98	Refrigerant	Direct HX Out	Tx1	50.33	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	17.34	Refrigerant	EV1 Suction	Tx2	29.47	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	20.37	Refrigerant	1st Stage Discharge	Tx3	137.23	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	5.67	Refrigerant	2nd Stage Suction	Tx4	76.76	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	18.71	Refrigerant	Condenser In	Tx5	130.61	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	17.53	Refrigerant	Condenser Out	Tx6	87.07	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	15.48	Refrigerant	EV2 OUT	Tx7	29.39	Refrigerant
Compressor 7(2)	0	0			KW	4.60		Economizer Liq Out	Tx8	77.51	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.53	Chill Water	Economizer Vap Out	Tx9	76.53	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	138.43	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	76.99	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.61	Cool Water	Condenser Out	Tx12	88.73	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	51.87	Chill Water
DIR VALVE1				Condenser in	Tx17	76.21	Cool Water	Evaporator Out	Tx14	37.71	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	54.51	Cool Water	Final Outlet Temp	Tx15	39.08	Chill Water
manual switch	0			Econom Liq In	Tx19	79.89	Refrigerant	Direct HX In (chilled)	Tx16	50.09	Chill Water
10/11/95								1st STAGE SUCTION		34.07	
006				LOAD (kW)	5.16			Superheat		9.00	
4:21PM				REJECT(kW)	15.53						
1st stage				DIRECT HX(kw)	-0.65						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.96	Refrigerant	Direct HX Out	Tx1	51.18	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	22.47	Refrigerant	EV1 Suction	Tx2	30.25	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	17.00	Refrigerant	1st Stage Discharge	Tx3	146.41	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	15.53	Refrigerant	2nd Stage Suction	Tx4	87.56	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	24.32	Refrigerant	Condenser In	Tx5	112.47	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	23.49	Refrigerant	Condenser Out	Tx6	100.55	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	21.25	Refrigerant	EV2 OUT	Tx7	29.54	Refrigerant
Compressor 7(2)	0	0			KW	6.29		Economizer Liq Out	Tx8	83.08	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.48	Chill Water	Economizer Vap Out	Tx9	84.59	Refrigerant
2nd Stage bypas	0	0			Fx2 CFM	22.75		Comp 1 (1 stage) disc	Tx10	148.32	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	125.91	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.63	Cool Water	Condenser Out	Tx12	100.27	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	52.73	Chill Water
DIR VALVE1				Condenser in	Tx17	96.00	Cool Water	Evaporator Out	Tx14	38.55	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	56.04	Cool Water	Final Outlet Temp	Tx15	39.93	Chill Water
manual switch	0			Econom Liq In	Tx19	90.68	Refrigerant	Direct HX In (chilled)	Tx16	50.96	Chill Water
10/11/95								1st STAGE SUCTION		28.90	
008				LOAD (kW)	5.07			Superheat		3.00	
4:32PM				REJECT(kW)	5.32						
2nd stage				DIRECT HX(kw)	-0.63						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.10	Refrigerant	Direct HX Out	Tx1	52.33	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	30.67	Refrigerant	EV1 Suction	Tx2	33.38	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	18.61	Refrigerant	1st Stage Discharge	Tx3	146.85	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	16.61	Refrigerant	2nd Stage Suction	Tx4	91.12	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	31.75	Refrigerant	Condenser In	Tx5	128.53	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	30.96	Refrigerant	Condenser Out	Tx6	107.68	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	29.26	Refrigerant	EV2 OUT	Tx7	32.23	Refrigerant
Compressor 7(2)	0	0			KW	6.85		Economizer Liq Out	Tx8	91.28	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.51	Chill Water	Economizer Vap Out	Tx9	90.11	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	24.43		Comp 1 (1 stage) disc	Tx10	158.09	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	142.40	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.59	Cool Water	Condenser Out	Tx12	112.18	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.91	Chill Water
DIR VALVE1				Condenser in	Tx17	100.82	Cool Water	Evaporator Out	Tx14	40.03	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	56.80	Cool Water	Final Outlet Temp	Tx15	39.71	Chill Water
manual switch	0			Econom Liq In	Tx19	111.78	Refrigerant	Direct HX In (chilled)	Tx16	53.87	Chill Water
10/11/95								1st STAGE SUCTION		31.44	
009				LOAD (kW)	5.01			Superheat		4.00	
4:44PM				REJECT(kW)	14.06						
2nd stage				DIRECT HX(kw)	-0.02						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.05	Refrigerant	Direct HX Out	Tx1	51.75	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	35.21	Refrigerant	EV1 Suction	Tx2	32.25	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	18.85	Refrigerant	1st Stage Discharge	Tx3	150.71	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	16.75	Refrigerant	2nd Stage Suction	Tx4	92.00	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	37.17	Refrigerant	Condenser In	Tx5	136.90	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	36.43	Refrigerant	Condenser Out	Tx6	114.76	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	33.85	Refrigerant	EV2 OUT	Tx7	31.23	Refrigerant
Compressor 7(2)	0	0			KW	6.90		Economizer Liq Out	Tx8	92.36	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.54	Chill Water	Economizer Vap Out	Tx9	90.35	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	25.17		Comp 1 (1 stage) disc	Tx10	165.85	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	148.99	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.84	Cool Water	Condenser Out	Tx12	123.05	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.28	Chill Water
DIR VALVE1				Condenser in	Tx17	118.05	Cool Water	Evaporator Out	Tx14	39.48	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	57.83	Cool Water	Final Outlet Temp	Tx15	39.26	Chill Water
manual switch	0			Econom Liq In	Tx19	121.65	Refrigerant	Direct HX In (chilled)	Tx16	56.83	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	30.56	
010				LOAD (kW)	5.05			Superheat		4.00	
4:52PM				REJECT(kW)	6.23						
2nd stage				DIRECT HX(kw)	1.30						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.91	Refrigerant	Direct HX Out	Tx1	52.38	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	38.58	Refrigerant	EV1 Suction	Tx2	32.38	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	18.80	Refrigerant	1st Stage Discharge	Tx3	154.08	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	16.80	Refrigerant	2nd Stage Suction	Tx4	91.47	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	40.05	Refrigerant	Condenser In	Tx5	141.85	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	39.22	Refrigerant	Condenser Out	Tx6	123.65	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	37.36	Refrigerant	EV2 OUT	Tx7	30.54	Refrigerant
Compressor 7(2)	0	0			KW	6.95		Economizer Liq Out	Tx8	93.09	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.54	Chill Water	Economizer Vap Out	Tx9	90.40	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	25.05		Comp 1 (1 stage) disc	Tx10	173.48	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	153.39	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.59	Cool Water	Condenser Out	Tx12	132.09	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.99	Chill Water
DIR VALVE1				Condenser in	Tx17	119.76	Cool Water	Evaporator Out	Tx14	39.96	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	58.27	Cool Water	Final Outlet Temp	Tx15	39.43	Chill Water
manual switch	0			Econom Liq In	Tx19	127.22	Refrigerant	Direct HX In (chilled)	Tx16	59.51	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	31.08	
011				LOAD (kW)	5.13			Superheat		5.00	
4:59PM				REJECT(kW)	15.27						
2nd stage				DIRECT HX(kw)	2.02						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.00	Refrigerant	Direct HX Out	Tx1	52.41	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	47.23	Refrigerant	EV1 Suction	Tx2	32.28	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	19.88	Refrigerant	1st Stage Discharge	Tx3	159.21	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	18.07	Refrigerant	2nd Stage Suction	Tx4	95.86	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	49.28	Refrigerant	Condenser In	Tx5	154.37	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	48.50	Refrigerant	Condenser Out	Tx6	137.81	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	45.86	Refrigerant	EV2 OUT	Tx7	31.68	Refrigerant
Compressor 7(2)	0	0			KW	7.25		Economizer Liq Out	Tx8	97.34	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.55	Chill Water	Economizer Vap Out	Tx9	94.31	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	24.34		Comp 1 (1 stage) disc	Tx10	183.37	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	163.10	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.55	Cool Water	Condenser Out	Tx12	143.82	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	54.06	Chill Water
DIR VALVE1				Condenser in	Tx17	138.38	Cool Water	Evaporator Out	Tx14	40.19	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	59.29	Cool Water	Final Outlet Temp	Tx15	39.73	Chill Water
manual switch	0			Econom Liq In	Tx19	139.43	Refrigerant	Direct HX In (chilled)	Tx16	62.37	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	30.88	
13.00				LOAD (kW)	5.11			Superheat		4.00	
5:11pm				REJECT(kW)	6.70						
2nd stage				DIRECT HX(kw)	3.06						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.10	Refrigerant	Direct HX Out	Tx1	51.75	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	55.78	Refrigerant	EV1 Suction	Tx2	33.31	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	20.76	Refrigerant	1st Stage Discharge	Tx3	164.04	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	18.80	Refrigerant	2nd Stage Suction	Tx4	98.50	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	57.29	Refrigerant	Condenser In	Tx5	163.40	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	56.46	Refrigerant	Condenser Out	Tx6	159.11	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	54.21	Refrigerant	EV2 OUT	Tx7	32.58	Refrigerant
Compressor 7(2)	0	0			KW	7.58		Economizer Liq Out	Tx8	100.12	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.54	Chill Water	Economizer Vap Out	Tx9	96.46	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	25.12		Comp 1 (1 stage) disc	Tx10	189.97	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	171.89	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.56	Cool Water	Condenser Out	Tx12	156.64	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.38	Chill Water
DIR VALVE1				Condenser in	Tx17	142.90	Cool Water	Evaporator Out	Tx14	39.73	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	59.80	Cool Water	Final Outlet Temp	Tx15	39.68	Chill Water
manual switch	0			Econom Liq In	Tx19	150.02	Refrigerant	Direct HX In (chilled)	Tx16	63.71	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	31.89	
014				LOAD (kW)	5.00			Superheat		5.00	
5:20pm				REJECT(kW)	16.95						
2nd stage				DIRECT HX(kw)	3.78						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.00	Refrigerant
Compr 1 High(1)	0	1		Receiver	Px2 PSI	59.73	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	19.68	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	17.83	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	61.68	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	60.95	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	58.41	Refrigerant
Compressor 7(2)	0	0			KW	7.49	
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.53	Chill Water
2nd Stage bypass	0	0			Fx2 CFM	26.32	
Direct HX bypass	0	0	1		Fx3 GPM	0.00	
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.53	Cool Water
Economizer sol.	0	1			FLOW	0.00	
DIR VALVE1				Condenser in	Tx17	153.28	Cool Water
CHILL VALVE2	0			Direct HX in	Tx18	60.00	Cool Water
manual switch	0			Econom Liq In	Tx19	155.40	Refrigerant
10/11/95							
015				LOAD (kW)	5.04		
5:25pm				REJECT(kW)	7.36		
2nd stage				DIRECT HX(kw)	4.29		

Direct HX Out	Tx1	51.48	Chill Water
EV1 Suction	Tx2	32.15	Refrigerant
1st Stage Discharge	Tx3	165.41	Refrigerant
2nd Stage Suction	Tx4	102.06	Refrigerant
Condenser In	Tx5	168.05	Refrigerant
Condenser Out	Tx6	154.91	Refrigerant
EV2 OUT	Tx7	30.54	Refrigerant
Economizer Liq Out	Tx8	97.53	Refrigerant
Economizer Vap Out	Tx9	93.77	Refrigerant
Comp 1 (1 stage) disc	Tx10	191.44	Refrigerant
Comp 6(2 stage) disc	Tx11	177.15	Refrigerant
Condenser Out	Tx12	159.27	Cool Water
Evaporator In	Tx13	53.08	Chill Water
Evaporator Out	Tx14	39.28	Chill Water
Final Outlet Temp	Tx15	39.38	Chill Water
Direct HX In (chilled)	Tx16	64.84	Chill Water
1st STAGE SUCTION	Tx20	30.28	
Superheat		4.00	

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.15	Refrigerant	Direct HX Out	Tx1	51.62	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	66.08	Refrigerant	EV1 Suction	Tx2	31.85	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	19.24	Refrigerant	1st Stage Discharge	Tx3	165.07	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	17.19	Refrigerant	2nd Stage Suction	Tx4	118.82	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	67.01	Refrigerant	Condenser In	Tx5	173.05	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	66.28	Refrigerant	Condenser Out	Tx6	169.51	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	65.05	Refrigerant	EV2 OUT	Tx7	30.94	Refrigerant
Compressor 7(2)	0	0			KW	7.49		Economizer Liq Out	Tx8	96.85	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.53	Chill Water	Economizer Vap Out	Tx9	92.75	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	27.25		Comp 1 (1 stage) dis	Tx10	191.56	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	183.50	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.58	Cool Water	Condenser Out	Tx12	167.63	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.18	Chill Water
DIR VALVE1				Condenser in	Tx17	152.18	Cool Water	Evaporator Out	Tx14	38.95	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	60.15	Cool Water	Final Outlet Temp	Tx15	39.06	Chill Water
manual switch	0			Econom Liq In	Tx19	161.36	Refrigerant	Direct HX In (chilled)	Tx16	65.62	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	30.31	
016				LOAD (kW)	5.19			Superheat		3.00	
5:32pm				REJECT(kW)	19.10						
2nd stage				DIRECT HX(kw)	4.53						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.25	Refrigerant	Direct HX Out	Tx1	51.75	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	74.97	Refrigerant	EV1 Suction	Tx2	32.81	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	19.39	Refrigerant	1st Stage Discharge	Tx3	165.56	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	17.34	Refrigerant	2nd Stage Suction	Tx4	121.31	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	76.83	Refrigerant	Condenser In	Tx5	181.05	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	76.24	Refrigerant	Condenser Out	Tx6	179.38	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	74.24	Refrigerant	EV2 OUT	Tx7	31.53	Refrigerant
Compressor 7(2)	0	0			KW	7.66		Economizer Liq Out	Tx8	98.66	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.55	Chill Water	Economizer Vap Out	Tx9	100.71	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	27.63		Comp 1 (1 stage) disc	Tx10	192.66	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	191.50	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.61	Cool Water	Condenser Out	Tx12	177.47	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.33	Chill Water
DIR VALVE1				Condenser in	Tx17	161.53	Cool Water	Evaporator Out	Tx14	38.82	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	60.29	Cool Water	Final Outlet Temp	Tx15	39.01	Chill Water
manual switch	0			Econom Liq In	Tx19	168.29	Refrigerant	Direct HX In (chilled)	Tx16	66.20	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	31.36	
017				LOAD (kW)	5.33			Superheat		2.00	
5:38pm				REJECT(kW)	19.78						
2nd stage				DIRECT HX(kw)	4.73						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.10	Refrigerant	Direct HX Out	Tx1	52.01	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	84.54	Refrigerant	EV1 Suction	Tx2	32.30	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	21.20	Refrigerant	1st Stage Discharge	Tx3	167.95	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	19.24	Refrigerant	2nd Stage Suction	Tx4	104.51	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	85.86	Refrigerant	Condenser In	Tx5	189.97	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	85.23	Refrigerant	Condenser Out	Tx6	187.39	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	83.71	Refrigerant	EV2 OUT	Tx7	31.33	Refrigerant
Compressor 7(2)	0	0			KW	8.16		Economizer Liq Out	Tx8	103.10	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.49	Chill Water	Economizer Vap Out	Tx9	97.53	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	26.81		Comp 1 (1 stage) disc	Tx10	195.95	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	201.21	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.65	Cool Water	Condenser Out	Tx12	185.34	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.61	Chill Water
DIR VALVE1				Condenser in	Tx17	168.79	Cool Water	Evaporator Out	Tx14	39.76	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	60.51	Cool Water	Final Outlet Temp	Tx15	39.83	Chill Water
manual switch	0			Econom Liq In	Tx19	175.67	Refrigerant	Direct HX In (chilled)	Tx16	66.86	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	30.23	
018				LOAD (kW)	4.97			Superheat		3.00	
5:43pm				REJECT(kW)	20.63						
2nd stage				DIRECT HX(kw)	4.75						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.20	Refrigerant	Direct HX Out	Tx1	52.06	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	89.38	Refrigerant	EV1 Suction	Tx2	32.51	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	21.05	Refrigerant	1st Stage Discharge	Tx3	170.44	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	19.10	Refrigerant	2nd Stage Suction	Tx4	124.68	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	90.31	Refrigerant	Condenser In	Tx5	196.75	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	89.67	Refrigerant	Condenser Out	Tx6	191.10	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	88.60	Refrigerant	EV2 OUT	Tx7	31.48	Refrigerant
Compressor 7(2)	0	0			KW	8.25		Economizer Liq Out	Tx8	104.47	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.53	Chill Water	Economizer Vap Out	Tx9	105.20	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	27.18		Comp 1 (1 stage) disc	Tx10	198.15	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	208.60	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.54	Cool Water	Condenser Out	Tx12	189.01	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.58	Chill Water
DIR VALVE1				Condenser in	Tx17	173.98	Cool Water	Evaporator Out	Tx14	39.63	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	60.81	Cool Water	Final Outlet Temp	Tx15	39.78	Chill Water
manual switch	0			Econom Liq In	Tx19	183.58	Refrigerant	Direct HX In (chilled)	Tx16	67.52	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	30.91	
019				LOAD (kW)	5.09			Superheat		3.00	
5:50pm				REJECT(kW)	18.49						
2nd stage				DIRECT HX(kw)	5.09						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.20	Refrigerant	Direct HX Out	Tx1	52.01	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	95.82	Refrigerant	EV1 Suction	Tx2	32.25	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	21.34	Refrigerant	1st Stage Discharge	Tx3	171.32	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	19.44	Refrigerant	2nd Stage Suction	Tx4	131.90	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	97.29	Refrigerant	Condenser In	Tx5	202.18	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	96.65	Refrigerant	Condenser Out	Tx6	192.71	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	94.75	Refrigerant	EV2 OUT	Tx7	30.94	Refrigerant
Compressor 7(2)	0	0			KW	8.35		Economizer Liq Out	Tx8	104.96	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.53	Chill Water	Economizer Vap Out	Tx9	104.32	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	27.15		Comp 1 (1 stage) disc	Tx10	198.76	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	213.66	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.60	Cool Water	Condenser Out	Tx12	193.22	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.56	Chill Water
DIR VALVE1				Condenser in	Tx17	185.34	Cool Water	Evaporator Out	Tx14	39.78	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	60.85	Cool Water	Final Outlet Temp	Tx15	39.93	Chill Water
manual switch	0			Econom Liq In	Tx19	183.92	Refrigerant	Direct HX In (chilled)	Tx16	67.79	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	30.86	
020				LOAD (kW)	5.03			Superheat		3.00	
5:55pm				REJECT(kW)	9.77						
2nd stage				DIRECT HX(kw)	5.19						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.20	Refrigerant	Direct HX Out	Tx1	52.11	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	106.96	Refrigerant	EV1 Suction	Tx2	32.76	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	21.88	Refrigerant	1st Stage Discharge	Tx3	172.59	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	19.98	Refrigerant	2nd Stage Suction	Tx4	132.10	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	108.82	Refrigerant	Condenser In	Tx5	206.82	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	107.99	Refrigerant	Condenser Out	Tx6	205.21	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	105.93	Refrigerant	EV2 OUT	Tx7	31.63	Refrigerant
Compressor 7(2)	0	0			KW	8.64		Economizer Liq Out	Tx8	106.08	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.51	Chill Water	Economizer Vap Out	Tx9	99.83	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	26.86		Comp 1 (1 stage) disc	Tx10	199.68	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	217.76	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.62	Cool Water	Condenser Out	Tx12	202.81	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	53.71	Chill Water
DIR VALVE1				Condenser in	Tx17	195.79	Cool Water	Evaporator Out	Tx14	39.83	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	60.93	Cool Water	Final Outlet Temp	Tx15	39.66	Chill Water
manual switch	0			Econom Liq In	Tx19	188.56	Refrigerant	Direct HX In (chilled)	Tx16	68.01	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	30.71	
021				LOAD (kW)	5.03			Superheat		2.00	
5:58pm				REJECT(kW)	8.72						
2nd stage				DIRECT HX(kw)	5.18						

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.42	Refrigerant	Direct HX Out	Tx1	40.10	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	103.88	Refrigerant	EV1 Suction	Tx2	25.03	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	16.85	Refrigerant	1st Stage Discharge	Tx3	168.73	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	15.82	Refrigerant	2nd Stage Suction	Tx4	86.73	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	105.74	Refrigerant	Condenser In	Tx5	206.76	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	105.05	Refrigerant	Condenser Out	Tx6	195.84	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	103.20	Refrigerant	EV2 OUT	Tx7	25.51	Refrigerant
Compressor 7(2)	0	0			KW	6.88		Economizer Liq Out	Tx8	96.75	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.20	Chill Water	Economizer Vap Out	Tx9	87.67	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	22.04		Comp 1 (1 stage) disc	Tx10	188.44	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	220.14	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.61	Cool Water	Condenser Out	Tx12	200.73	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.52	Chill Water
DIR VALVE1				Condenser in	Tx17	195.91	Cool Water	Evaporator Out	Tx14	31.66	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	59.90	Cool Water	Final Outlet Temp	Tx15	37.78	Chill Water
manual switch	0			Econom Liq In	Tx19	193.05	Refrigerant	Direct HX In (chilled)	Tx16	40.39	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	26.94	
022				LOAD (kW)	3.13			Superheat		6.00	
6:03pm				REJECT(kW)	5.99						
2nd stage				DIRECT HX(kw)	-0.36						
1 kW Load											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.00	Refrigerant	Direct HX Out	Tx1	40.42	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	97.53	Refrigerant	EV1 Suction	Tx2	29.44	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	15.53	Refrigerant	1st Stage Discharge	Tx3	169.95	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	14.60	Refrigerant	2nd Stage Suction	Tx4	82.58	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	98.75	Refrigerant	Condenser In	Tx5	199.25	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	98.17	Refrigerant	Condenser Out	Tx6	198.03	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	96.51	Refrigerant	EV2 OUT	Tx7	28.80	Refrigerant
Compressor 7(2)	0	0			KW	6.08		Economizer Liq Out	Tx8	91.67	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.20	Chill Water	Economizer Vap Out	Tx9	83.76	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	22.67		Comp 1 (1 stage) disc	Tx10	186.00	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	215.13	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.62	Cool Water	Condenser Out	Tx12	196.21	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.24	Chill Water
DIR VALVE1				Condenser in	Tx17	190.35	Cool Water	Evaporator Out	Tx14	33.30	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	58.10	Cool Water	Final Outlet Temp	Tx15	37.83	Chill Water
manual switch	0			Econom Liq In	Tx19	189.34	Refrigerant	Direct HX In (chilled)	Tx16	40.90	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	31.23	
023				LOAD (kW)	2.52			Superheat		5.00	
6:08pm				REJECT(kW)	7.28						
2nd stage				DIRECT HX(kw)	-0.11						
1 kW Load											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.86	Refrigerant	Direct HX Out	Tx1	40.83	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	87.42	Refrigerant	EV1 Suction	Tx2	29.17	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	13.72	Refrigerant	1st Stage Discharge	Tx3	166.14	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	12.94	Refrigerant	2nd Stage Suction	Tx4	76.42	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	86.59	Refrigerant	Condenser In	Tx5	195.04	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	86.11	Refrigerant	Condenser Out	Tx6	189.78	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	86.54	Refrigerant	EV2 OUT	Tx7	28.25	Refrigerant
Compressor 7(2)	0	0			KW	5.70		Economizer Liq Out	Tx8	83.03	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.25	Chill Water	Economizer Vap Out	Tx9	77.26	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	21.85		Comp 1 (1 stage) disc	Tx10	178.49	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	210.61	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.56	Cool Water	Condenser Out	Tx12	185.77	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.95	Chill Water
DIR VALVE1				Condenser in	Tx17	176.85	Cool Water	Evaporator Out	Tx14	34.03	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	57.14	Cool Water	Final Outlet Temp	Tx15	38.81	Chill Water
manual switch	0			Econom Liq In	Tx19	183.63	Refrigerant	Direct HX In (chilled)	Tx16	41.90	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	31.64	
024				LOAD (kW)	2.57			Superheat		7.00	
6:12pm				REJECT(kW)	11.00						
2nd stage				DIRECT HX(kw)	-0.01						
1 kW Load											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.81	Refrigerant	Direct HX Out	Tx1	40.95	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	78.63	Refrigerant	EV1 Suction	Tx2	29.59	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	11.92	Refrigerant	1st Stage Discharge	Tx3	160.33	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	11.09	Refrigerant	2nd Stage Suction	Tx4	72.08	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	77.80	Refrigerant	Condenser In	Tx5	187.77	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	77.36	Refrigerant	Condenser Out	Tx6	180.99	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	78.29	Refrigerant	EV2 OUT	Tx7	28.15	Refrigerant
Compressor 7(2)	0	0			KW	5.41		Economizer Liq Out	Tx8	76.04	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.22	Chill Water	Economizer Vap Out	Tx9	69.79	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	23.16		Comp 1 (1 stage) disc	Tx10	171.65	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	204.20	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.63	Cool Water	Condenser Out	Tx12	177.47	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.72	Chill Water
DIR VALVE1				Condenser in	Tx17	172.40	Cool Water	Evaporator Out	Tx14	33.30	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	56.12	Cool Water	Final Outlet Temp	Tx15	37.91	Chill Water
manual switch	0			Econom Liq In	Tx19	173.57	Refrigerant	Direct HX In (chilled)	Tx16	40.71	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	27.92	
025				LOAD (kW)	2.69			Superheat		4.00	
6:17pm				REJECT(kW)	6.31						
2nd stage				DIRECT HX(kw)	-0.32						
1 kW Load											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.61	Refrigerant	Direct HX Out	Tx1	40.44	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	72.28	Refrigerant	EV1 Suction	Tx2	26.61	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	10.55	Refrigerant	1st Stage Discharge	Tx3	153.20	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	9.67	Refrigerant	2nd Stage Suction	Tx4	67.39	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	73.41	Refrigerant	Condenser In	Tx5	177.94	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	72.92	Refrigerant	Condenser Out	Tx6	176.54	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	71.26	Refrigerant	EV2 OUT	Tx7	25.56	Refrigerant
Compressor 7(2)	0	0			KW	5.10		Economizer Liq Out	Tx8	68.82	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.22	Chill Water	Economizer Vap Out	Tx9	64.18	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	24.07		Comp 1 (1 stage) disc	Tx10	165.73	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	202.43	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.62	Cool Water	Condenser Out	Tx12	175.45	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.72	Chill Water
DIR VALVE1				Condenser in	Tx17	165.98	Cool Water	Evaporator Out	Tx14	33.23	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	55.46	Cool Water	Final Outlet Temp	Tx15	38.66	Chill Water
manual switch	0			Econom Liq In	Tx19	163.06	Refrigerant	Direct HX In (chilled)	Tx16	41.10	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	28.75	
026				LOAD (kW)	2.72			Superheat		7.00	
6:22pm				REJECT(kW)	11.77						
2nd stage				DIRECT HX(kw)	-0.20						
1 kW Load											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.35	Refrigerant	Direct HX Out	Tx1	38.22	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	60.17	Refrigerant	EV1 Suction	Tx2	32.48	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	10.01	Refrigerant	1st Stage Discharge	Tx3	141.33	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	9.38	Refrigerant	2nd Stage Suction	Tx4	63.87	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	61.25	Refrigerant	Condenser In	Tx5	179.89	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	60.85	Refrigerant	Condenser Out	Tx6	164.24	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	59.05	Refrigerant	EV2 OUT	Tx7	31.73	Refrigerant
Compressor 7(2)	0	0			KW	4.36		Economizer Liq Out	Tx8	69.55	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.23	Chill Water	Economizer Vap Out	Tx9	64.13	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	25.08		Comp 1 (1 stage) disc	Tx10	172.20	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	204.14	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.53	Cool Water	Condenser Out	Tx12	163.60	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	39.40	Chill Water
DIR VALVE1				Condenser in	Tx17	151.63	Cool Water	Evaporator Out	Tx14	34.87	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	55.26	Cool Water	Final Outlet Temp	Tx15	37.31	Chill Water
manual switch	0			Econom Liq In	Tx19	154.27	Refrigerant	Direct HX In (chilled)	Tx16	38.02	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	33.47	
027				LOAD (kW)		1.46		Superheat		5.00	
6:32pm				REJECT(kW)		14.72					
2nd stage				DIRECT HX(kw)		-0.44					
1 kW Load											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.05	Refrigerant	Direct HX Out	Tx1	35.68	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	46.06	Refrigerant	EV1 Suction	Tx2	29.44	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	8.21	Refrigerant	1st Stage Discharge	Tx3	141.48	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	7.62	Refrigerant	2nd Stage Suction	Tx4	92.98	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	46.15	Refrigerant	Condenser In	Tx5	167.86	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	45.67	Refrigerant	Condenser Out	Tx6	136.69	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	44.93	Refrigerant	EV2 OUT	Tx7	29.79	Refrigerant
Compressor 7(2)	0	0			KW	3.97		Economizer Liq Out	Tx8	53.92	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	2.22	Chill Water	Economizer Vap Out	Tx9	93.82	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	27.54		Comp 1 (1 stage) disc	Tx10	169.51	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	198.70	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.53	Cool Water	Condenser Out	Tx12	139.30	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	36.75	Chill Water
DIR VALVE1				Condenser in	Tx17	127.02	Cool Water	Evaporator Out	Tx14	31.56	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	54.85	Cool Water	Final Outlet Temp	Tx15	34.41	Chill Water
manual switch	0			Econom Liq In	Tx19	141.09	Refrigerant	Direct HX In (chilled)	Tx16	35.26	Chill Water
10/11/95								1st STAGE SUCTION	Tx20	31.89	
028				LOAD (kW)	1.66			Superheat		5.00	
6:44pm				REJECT(kW)	15.09						
2nd stage				DIRECT HX(kw)	-0.48						
1 kW Load											

LOW LOAD TEST

Compr 1 High(1)	0	0		Receiver	Px2 PSI	14.51	Refrigerant	EV1 Suction	Tx2	27.69	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	15.63	Refrigerant	1st Stage Discharge	Tx3	132.30	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	9.13	Refrigerant	2nd Stage Suction	Tx4	72.91	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	15.48	Refrigerant	Condenser In	Tx5	120.78	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	14.99	Refrigerant	Condenser Out	Tx6	74.13	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	13.19	Refrigerant	EV2 OUT	Tx7	26.96	Refrigerant
Compressor 7(2)	0	0			KW	1.72		Economizer Liq Out	Tx8	72.67	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.84	Chill Water	Economizer Vap Out	Tx9	73.65	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	160.60	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	74.31	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.45	Cool Water	Condenser Out	Tx12	77.13	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	33.87	Chill Water
DIR VALVE1				Condenser in	Tx17	70.84	Cool Water	Evaporator Out	Tx14	30.03	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	54.75	Cool Water	Final Outlet Temp	Tx15	32.26	Chill Water
manual switch	0			Econom Liq In	Tx19	74.32	Refrigerant	Direct HX In (chilled)	Tx16	32.67	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	27.17	
001				LOAD (kW)	1.02			Superheat		3.00	
9:45am				REJECT(kW)	7.66						
1st stage				DIRECT HX(kw)	-0.32						
start											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.20	Refrigerant	Direct HX Out	Tx1	35.48	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	14.16	Refrigerant	EV1 Suction	Tx2	31.10	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	15.29	Refrigerant	1st Stage Discharge	Tx3	123.80	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	8.94	Refrigerant	2nd Stage Suction	Tx4	73.00	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	15.19	Refrigerant	Condenser In	Tx5	107.77	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	14.85	Refrigerant	Condenser Out	Tx6	73.00	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	12.80	Refrigerant	EV2 OUT	Tx7	31.48	Refrigerant
Compressor 7(2)	0	0			KW	1.20		Economizer Liq Out	Tx8	72.23	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.84	Chill Water	Economizer Vap Out	Tx9	73.65	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	154.73	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	74.92	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.45	Cool Water	Condenser Out	Tx12	73.59	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	36.55	Chill Water
DIR VALVE1				Condenser in	Tx17	71.15	Cool Water	Evaporator Out	Tx14	33.10	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	51.55	Cool Water	Final Outlet Temp	Tx15	34.98	Chill Water
manual switch	0			Econom Liq In	Tx19	73.35	Refrigerant	Direct HX In (chilled)	Tx16	35.29	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	33.07	
002				LOAD (kW)	0.92			Superheat		5.00	
10:10am				REJECT(kW)	2.98						
1st stage				DIRECT HX(kw)	-0.33						
start											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.44	Refrigerant	Direct HX Out	Tx1	37.36	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	14.41	Refrigerant	EV1 Suction	Tx2	33.03	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	15.53	Refrigerant	1st Stage Discharge	Tx3	123.99	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	8.79	Refrigerant	2nd Stage Suction	Tx4	72.91	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	15.34	Refrigerant	Condenser In	Tx5	106.31	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px8 PSI	15.09	Refrigerant	Condenser Out	Tx6	74.86	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	12.84	Refrigerant	EV2 OUT	Tx7	33.32	Refrigerant
Compressor 7(2)	0	0			KW	1.22		Economizer Liq Out	Tx8	72.28	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.85	Chill Water	Economizer Vap Out	Tx9	73.26	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	158.09	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	75.10	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.51	Cool Water	Condenser Out	Tx12	75.30	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	38.54	Chill Water
DIR VALVE1				Condenser in	Tx17	73.16	Cool Water	Evaporator Out	Tx14	34.24	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	51.06	Cool Water	Final Outlet Temp	Tx15	36.63	Chill Water
manual switch	0			Econom Liq In	Tx19	73.64	Refrigerant	Direct HX In (chilled)	Tx16	37.22	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	35.57	
003				LOAD (kW)	1.15			Superheat		5.00	
10:20am				REJECT(kW)	2.62						
1st stage				DIRECT HX(kw)	-0.35						
start											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.20	Refrigerant	Direct HX Out	Tx1	39.46	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	14.41	Refrigerant	EV1 Suction	Tx2	31.38	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	14.65	Refrigerant	1st Stage Discharge	Tx3	129.85	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	8.69	Refrigerant	2nd Stage Suction	Tx4	72.95	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	14.31	Refrigerant	Condenser In	Tx5	110.70	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	13.92	Refrigerant	Condenser Out	Tx6	74.62	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	13.09	Refrigerant	EV2 OUT	Tx7	30.84	Refrigerant
Compressor 7(2)	0	0			KW	1.71		Economizer Liq Out	Tx8	72.19	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.08	Chill Water	Economizer Vap Out	Tx9	73.36	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	167.25	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	75.10	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.50	Cool Water	Condenser Out	Tx12	73.16	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	40.86	Chill Water
DIR VALVE1				Condenser in	Tx17	68.34	Cool Water	Evaporator Out	Tx14	32.60	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	51.23	Cool Water	Final Outlet Temp	Tx15	37.83	Chill Water
manual switch	0			Econom Liq In	Tx19	73.54	Refrigerant	Direct HX In (chilled)	Tx16	39.34	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	32.11	
004				LOAD (kW)	1.29			Superheat		4.00	
10:26am				REJECT(kW)	5.91						
1st stage				DIRECT HX(kw)	-0.24						
start											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.49	Refrigerant	Direct HX Out	Tx1	39.07	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	14.36	Refrigerant	EV1 Suction	Tx2	32.96	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	15.43	Refrigerant	1st Stage Discharge	Tx3	132.49	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	8.69	Refrigerant	2nd Stage Suction	Tx4	73.10	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	15.38	Refrigerant	Condenser In	Tx5	113.27	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	15.09	Refrigerant	Condenser Out	Tx6	73.00	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	12.99	Refrigerant	EV2 OUT	Tx7	32.78	Refrigerant
Compressor 7(2)	0	0			KW	1.17		Economizer Liq Out	Tx8	72.28	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.08	Chill Water	Economizer Vap Out	Tx9	73.65	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	163.40	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	75.59	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.49	Cool Water	Condenser Out	Tx12	74.56	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	40.38	Chill Water
DIR VALVE1				Condenser in	Tx17	72.85	Cool Water	Evaporator Out	Tx14	33.43	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	51.58	Cool Water	Final Outlet Temp	Tx15	37.61	Chill Water
manual switch	0			Econom Liq In	Tx19	73.59	Refrigerant	Direct HX In (chilled)	Tx16	38.78	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	34.77	
005				LOAD (kW)	1.09			Superheat		4.00	
10:31am				REJECT(kW)	2.09						
1st stage				DIRECT HX(kw)	-0.25						
start											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.44	Refrigerant	Direct HX Out	Tx1	38.80	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	16.31	Refrigerant	EV1 Suction	Tx2	32.61	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	17.92	Refrigerant	1st Stage Discharge	Tx3	136.30	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	8.60	Refrigerant	2nd Stage Suction	Tx4	73.44	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	17.73	Refrigerant	Condenser In	Tx5	118.15	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	17.00	Refrigerant	Condenser Out	Tx6	86.39	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	15.63	Refrigerant	EV2 OUT	Tx7	32.38	Refrigerant
Compressor 7(2)	0	0			KW	1.23		Economizer Liq Out	Tx8	73.16	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.05	Chill Water	Economizer Vap Out	Tx9	73.89	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	169.08	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	76.14	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.58	Cool Water	Condenser Out	Tx12	88.49	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	40.23	Chill Water
DIR VALVE1				Condenser in	Tx17	86.96	Cool Water	Evaporator Out	Tx14	33.33	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.21	Cool Water	Final Outlet Temp	Tx15	37.46	Chill Water
manual switch	0			Econom Liq In	Tx19	75.10	Refrigerant	Direct HX In (chilled)	Tx16	38.56	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	34.45	
006				LOAD (kW)	1.05			Superheat		4.00	
10:46am				REJECT(kW)	1.89						
1st stage				DIRECT HX(kw)	-0.25						
start											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.15	Refrigerant	Direct HX Out	Tx1	39.63	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	22.76	Refrigerant	EV1 Suction	Tx2	29.84	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	6.64	Refrigerant	1st Stage Discharge	Tx3	140.16	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	6.15	Refrigerant	2nd Stage Suction	Tx4	50.00	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	24.37	Refrigerant	Condenser In	Tx5	107.83	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	23.83	Refrigerant	Condenser Out	Tx6	106.46	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	21.93	Refrigerant	EV2 OUT	Tx7	29.79	Refrigerant
Compressor 7(2)	0	0			KW	2.95		Economizer Liq Out	Tx8	51.23	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.07	Chill Water	Economizer Vap Out	Tx9	43.42	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	9.19		Comp 1 (1 stage) disc	Tx10	162.31	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	121.57	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.56	Cool Water	Condenser Out	Tx12	105.40	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	40.91	Chill Water
DIR VALVE1				Condenser in	Tx17	102.78	Cool Water	Evaporator Out	Tx14	31.01	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.33	Cool Water	Final Outlet Temp	Tx15	37.13	Chill Water
manual switch	0			Econom Liq In	Tx19	81.65	Refrigerant	Direct HX In (chilled)	Tx16	39.00	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	30.81	
007				LOAD (kW)	1.53			Superheat		2.00	
10:56am				REJECT(kW)	3.24						
2nd stage				DIRECT HX(kw)	-0.30						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.10	Refrigerant	Direct HX Out	Tx1	39.78	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	41.22	Refrigerant	EV1 Suction	Tx2	30.27	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	8.01	Refrigerant	1st Stage Discharge	Tx3	129.17	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	7.33	Refrigerant	2nd Stage Suction	Tx4	50.54	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	42.93	Refrigerant	Condenser In	Tx5	140.87	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	42.10	Refrigerant	Condenser Out	Tx6	140.16	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	40.34	Refrigerant	EV2 OUT	Tx7	29.79	Refrigerant
Compressor 7(2)	0	0			KW	3.90		Economizer Liq Out	Tx8	49.67	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.02	Chill Water	Economizer Vap Out	Tx9	50.35	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	14.53		Comp 1 (1 stage) disc	Tx10	157.11	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	151.98	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.67	Cool Water	Condenser Out	Tx12	139.18	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.07	Chill Water
DIR VALVE1				Condenser in	Tx17	136.37	Cool Water	Evaporator Out	Tx14	31.89	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.43	Cool Water	Final Outlet Temp	Tx15	37.83	Chill Water
manual switch	0			Econom Liq In	Tx19	117.11	Refrigerant	Direct HX In (chilled)	Tx16	39.51	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	31.16	
009				LOAD (kW)	1.34			Superheat		4.00	
11:12am				REJECT(kW)	3.51						
2nd stage				DIRECT HX(kw)	-0.23						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.30	Refrigerant	Direct HX Out	Tx1	39.90	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	49.38	Refrigerant	EV1 Suction	Tx2	33.13	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	8.21	Refrigerant	1st Stage Discharge	Tx3	125.46	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	6.64	Refrigerant	2nd Stage Suction	Tx4	50.00	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	50.55	Refrigerant	Condenser In	Tx5	151.80	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	50.16	Refrigerant	Condenser Out	Tx6	151.05	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	48.35	Refrigerant	EV2 OUT	Tx7	33.92	Refrigerant
Compressor 7(2)	0	0			KW	4.17		Economizer Liq Out	Tx8	49.04	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.21	Chill Water	Economizer Vap Out	Tx9	44.69	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	12.75		Comp 1 (1 stage) disc	Tx10	146.98	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	162.61	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.72	Cool Water	Condenser Out	Tx12	150.47	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.32	Chill Water
DIR VALVE1				Condenser in	Tx17	147.91	Cool Water	Evaporator Out	Tx14	34.69	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.31	Cool Water	Final Outlet Temp	Tx15	38.43	Chill Water
manual switch	0			Econom Liq In	Tx19	131.17	Refrigerant	Direct HX In (chilled)	Tx16	39.71	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	34.85	
010				LOAD (kW)	1.15			Superheat		5.00	
11:17am				REJECT(kW)	3.22						
2nd stage				DIRECT HX(kw)	-0.28						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.10	Refrigerant	Direct HX Out	Tx1	39.83	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	79.07	Refrigerant	EV1 Suction	Tx2	31.45	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	18.41	Refrigerant	1st Stage Discharge	Tx3	132.59	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	18.07	Refrigerant	2nd Stage Suction	Tx4	95.03	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	80.68	Refrigerant	Condenser In	Tx5	184.53	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	79.80	Refrigerant	Condenser Out	Tx6	182.75	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	78.24	Refrigerant	EV2 OUT	Tx7	30.49	Refrigerant
Compressor 7(2)	0	0			KW	5.98		Economizer Liq Out	Tx8	93.92	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.00	Chill Water	Economizer Vap Out	Tx9	92.16	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	7.16		Comp 1 (1 stage) disc	Tx10	159.92	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	193.78	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.81	Cool Water	Condenser Out	Tx12	182.35	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.24	Chill Water
DIR VALVE1				Condenser in	Tx17	178.50	Cool Water	Evaporator Out	Tx14	32.95	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.41	Cool Water	Final Outlet Temp	Tx15	38.08	Chill Water
manual switch	0			Econom Liq In	Tx19	171.61	Refrigerant	Direct HX In (chilled)	Tx16	39.27	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	31.59	
011				LOAD (kW)	1.20			Superheat		4.00	
11:25am				REJECT(kW)	4.89						
2nd stage				DIRECT HX(kw)	-0.28						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.05	Refrigerant	Direct HX Out	Tx1	40.05	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	87.62	Refrigerant	EV1 Suction	Tx2	31.35	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	25.05	Refrigerant	1st Stage Discharge	Tx3	131.22	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	24.47	Refrigerant	2nd Stage Suction	Tx4	110.71	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	89.77	Refrigerant	Condenser In	Tx5	193.76	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	89.18	Refrigerant	Condenser Out	Tx6	191.34	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	86.89	Refrigerant	EV2 OUT	Tx7	30.54	Refrigerant
Compressor 7(2)	0	0			KW	7.54		Economizer Liq Out	Tx8	110.18	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.03	Chill Water	Economizer Vap Out	Tx9	110.09	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	10.42		Comp 1 (1 stage) disc	Tx10	159.74	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	201.88	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.82	Cool Water	Condenser Out	Tx12	189.86	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.44	Chill Water
DIR VALVE1				Condenser in	Tx17	185.65	Cool Water	Evaporator Out	Tx14	33.30	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.43	Cool Water	Final Outlet Temp	Tx15	38.23	Chill Water
manual switch	0			Econom Liq In	Tx19	186.80	Refrigerant	Direct HX In (chilled)	Tx16	39.68	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	30.46	
012				LOAD (kW)	1.21			Superheat		3.00	
11:32am				REJECT(kW)	5.36						
2nd stage				DIRECT HX(kw)	-0.26						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.64	Refrigerant	Direct HX Out	Tx1	39.90	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	98.51	Refrigerant	EV1 Suction	Tx2	35.94	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	22.52	Refrigerant	1st Stage Discharge	Tx3	138.40	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	21.98	Refrigerant	2nd Stage Suction	Tx4	103.48	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	100.22	Refrigerant	Condenser In	Tx5	200.90	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	99.54	Refrigerant	Condenser Out	Tx6	198.77	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	98.22	Refrigerant	EV2 OUT	Tx7	35.46	Refrigerant
Compressor 7(2)	0	0			KW	6.73		Economizer Liq Out	Tx8	105.20	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.26	Chill Water	Economizer Vap Out	Tx9	102.86	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	11.06		Comp 1 (1 stage) disc	Tx10	164.50	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	208.53	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.68	Cool Water	Condenser Out	Tx12	198.23	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.29	Chill Water
DIR VALVE1				Condenser in	Tx17	194.02	Cool Water	Evaporator Out	Tx14	36.35	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.55	Cool Water	Final Outlet Temp	Tx15	38.58	Chill Water
manual switch	0			Econom Liq In	Tx19	195.64	Refrigerant	Direct HX In (chilled)	Tx16	39.76	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	36.48	
013				LOAD (kW)	0.90			Superheat		4.00	
11:35am				REJECT(kW)	5.27						
2nd stage				DIRECT HX(kw)	-0.28						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.54	Refrigerant	Direct HX Out	Tx1	40.90	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	99.73	Refrigerant	EV1 Suction	Tx2	34.99	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	22.22	Refrigerant	1st Stage Discharge	Tx3	137.28	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	21.34	Refrigerant	2nd Stage Suction	Tx4	110.07	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	100.95	Refrigerant	Condenser In	Tx5	203.28	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	100.17	Refrigerant	Condenser Out	Tx6	199.55	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	98.75	Refrigerant	EV2 OUT	Tx7	34.22	Refrigerant
Compressor 7(2)	0	0			KW	7.38		Economizer Liq Out	Tx8	117.75	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.41	Chill Water	Economizer Vap Out	Tx9	109.06	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	20.31		Comp 1 (1 stage) disc	Tx10	159.37	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	210.61	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.77	Cool Water	Condenser Out	Tx12	197.37	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	42.20	Chill Water
DIR VALVE1				Condenser in	Tx17	184.06	Cool Water	Evaporator Out	Tx14	36.35	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.50	Cool Water	Final Outlet Temp	Tx15	38.61	Chill Water
manual switch	0			Econom Liq In	Tx19	193.49	Refrigerant	Direct HX In (chilled)	Tx16	40.73	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	34.27	
014				LOAD (kW)	1.19			Superheat		3.00	
11:40am				REJECT(kW)	16.84						
2nd stage				DIRECT HX(kw)	-0.30						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.91	Refrigerant	Direct HX Out	Tx1	41.05	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	72.63	Refrigerant	EV1 Suction	Tx2	30.95	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	16.61	Refrigerant	1st Stage Discharge	Tx3	140.79	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	15.43	Refrigerant	2nd Stage Suction	Tx4	85.07	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	72.23	Refrigerant	Condenser In	Tx5	179.89	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	71.75	Refrigerant	Condenser Out	Tx6	175.81	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	71.60	Refrigerant	EV2 OUT	Tx7	29.15	Refrigerant
Compressor 7(2)	0	0			KW	6.47		Economizer Liq Out	Tx8	95.73	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.24	Chill Water	Economizer Vap Out	Tx9	86.01	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	21.91		Comp 1 (1 stage) disc	Tx10	146.85	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	196.38	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.70	Cool Water	Condenser Out	Tx12	171.60	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	42.48	Chill Water
DIR VALVE1				Condenser in	Tx17	161.28	Cool Water	Evaporator Out	Tx14	34.31	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	52.58	Cool Water	Final Outlet Temp	Tx15	38.51	Chill Water
manual switch	0			Econom Liq In	Tx19	170.10	Refrigerant	Direct HX In (chilled)	Tx16	40.56	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	30.26	
015				LOAD (kW)	1.46			Superheat		5.00	
11:43am				REJECT(kW)	12.94						
2nd stage				DIRECT HX(kw)	-0.34						
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.25	Refrigerant	Direct HX Out	Tx1	40.49	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	60.56	Refrigerant	EV1 Suction	Tx2	31.35	Refrigerant
Compressor 2(1)	0	1		1st stage disch	Px3 PSI	18.51	Refrigerant	1st Stage Discharge	Tx3	124.33	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	17.00	Refrigerant	2nd Stage Suction	Tx4	93.81	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	63.25	Refrigerant	Condenser In	Tx5	174.15	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	62.52	Refrigerant	Condenser Out	Tx6	163.36	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	59.63	Refrigerant	EV2 OUT	Tx7	31.04	Refrigerant
Compressor 7(2)	0	0			KW	7.05		Economizer Liq Out	Tx8	103.10	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.04	Chill Water	Economizer Vap Out	Tx9	90.89	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	25.96		Comp 1 (1 stage) disc	Tx10	137.39	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	188.87	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.68	Cool Water	Condenser Out	Tx12	161.22	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	42.18	Chill Water
DIR VALVE1				Condenser in	Tx17	156.64	Cool Water	Evaporator Out	Tx14	34.31	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	53.33	Cool Water	Final Outlet Temp	Tx15	38.33	Chill Water
manual switch	0			Econom Liq In	Tx19	156.96	Refrigerant	Direct HX In (chilled)	Tx16	40.10	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	30.86	
016				LOAD (kW)	1.18			Superheat		2.00	
11:50am				REJECT(kW)	5.73						
2nd stage				DIRECT HX(kw)	-0.31						
going down											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	3.78	Refrigerant	Direct HX Out	Tx1	39.78	Chill Water
Compr 1 High(1)	0	1		Receiver	Px2 PSI	41.27	Refrigerant	EV1 Suction	Tx2	28.34	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	11.62	Refrigerant	1st Stage Discharge	Tx3	131.07	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	10.60	Refrigerant	2nd Stage Suction	Tx4	67.00	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	40.29	Refrigerant	Condenser In	Tx5	160.11	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	39.90	Refrigerant	Condenser Out	Tx6	129.80	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	40.34	Refrigerant	EV2 OUT	Tx7	27.65	Refrigerant
Compressor 7(2)	0	0			KW	4.79		Economizer Liq Out	Tx8	75.80	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.06	Chill Water	Economizer Vap Out	Tx9	67.79	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	21.82		Comp 1 (1 stage) disc	Tx10	119.19	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	177.94	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.67	Cool Water	Condenser Out	Tx12	128.49	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.32	Chill Water
DIR VALVE1				Condenser in	Tx17	119.76	Cool Water	Evaporator Out	Tx14	30.38	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	55.73	Cool Water	Final Outlet Temp	Tx15	37.18	Chill Water
manual switch	0			Econom Liq In	Tx19	133.47	Refrigerant	Direct HX In (chilled)	Tx16	39.44	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	27.15	
017				LOAD (kW)	1.67			Superheat		3.00	
11:55am				REJECT(kW)	10.92						
2nd stage				DIRECT HX(kw)	-0.29						
going down											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.25	Refrigerant	Direct HX Out	Tx1	39.34	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	31.65	Refrigerant	EV1 Suction	Tx2	31.12	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	8.60	Refrigerant	1st Stage Discharge	Tx3	107.58	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	7.98	Refrigerant	2nd Stage Suction	Tx4	55.18	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	32.72	Refrigerant	Condenser In	Tx5	151.01	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	32.33	Refrigerant	Condenser Out	Tx6	100.94	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	30.23	Refrigerant	EV2 OUT	Tx7	30.59	Refrigerant
Compressor 7(2)	0	0			KW	3.75		Economizer Liq Out	Tx8	61.44	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.09	Chill Water	Economizer Vap Out	Tx9	54.16	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	21.21		Comp 1 (1 stage) disc	Tx10	111.37	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	172.32	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.55	Cool Water	Condenser Out	Tx12	105.40	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	40.94	Chill Water
DIR VALVE1				Condenser in	Tx17	100.09	Cool Water	Evaporator Out	Tx14	32.07	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	56.87	Cool Water	Final Outlet Temp	Tx15	37.48	Chill Water
manual switch	0			Econom Liq In	Tx19	116.08	Refrigerant	Direct HX In (chilled)	Tx16	38.95	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	31.69	
018				LOAD (kW)	1.40			Superheat		3.00	
12:00noon				REJECT(kW)	6.55						
2nd stage				DIRECT HX(kw)	-0.31						
going down											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.54	Refrigerant	Direct HX Out	Tx1	39.58	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	25.45	Refrigerant	EV1 Suction	Tx2	33.83	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	8.84	Refrigerant	1st Stage Discharge	Tx3	98.69	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	5.42	Refrigerant	2nd Stage Suction	Tx4	50.00	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	25.93	Refrigerant	Condenser In	Tx5	138.31	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	25.69	Refrigerant	Condenser Out	Tx6	79.55	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	24.42	Refrigerant	EV2 OUT	Tx7	33.22	Refrigerant
Compressor 7(2)	0	0			KW	3.01		Economizer Liq Out	Tx8	46.15	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.06	Chill Water	Economizer Vap Out	Tx9	37.61	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	22.21		Comp 1 (1 stage) disc	Tx10	98.61	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	167.13	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.53	Cool Water	Condenser Out	Tx12	81.04	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.12	Chill Water
DIR VALVE1				Condenser in	Tx17	77.98	Cool Water	Evaporator Out	Tx14	35.04	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	58.71	Cool Water	Final Outlet Temp	Tx15	38.83	Chill Water
manual switch	0			Econom Liq In	Tx19	104.11	Refrigerant	Direct HX In (chilled)	Tx16	39.51	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	34.52	
019				LOAD (kW)	0.93			Superheat		4.00	
12:04pm				REJECT(kW)	3.76						
2nd stage				DIRECT HX(kw)	-0.25						
going down											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.49	Refrigerant	Direct HX Out	Tx1	40.07	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	19.88	Refrigerant	EV1 Suction	Tx2	32.38	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	8.84	Refrigerant	1st Stage Discharge	Tx3	94.59	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	3.91	Refrigerant	2nd Stage Suction	Tx4	50.00	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	20.37	Refrigerant	Condenser In	Tx5	132.26	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	20.17	Refrigerant	Condenser Out	Tx6	64.51	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	18.41	Refrigerant	EV2 OUT	Tx7	32.23	Refrigerant
Compressor 7(2)	0	0			KW	2.90		Economizer Liq Out	Tx8	32.87	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.09	Chill Water	Economizer Vap Out	Tx9	28.23	Refrigerant
2nd Stage bypass	0	0			Fx2 CFM	25.77		Comp 1 (1 stage) disc	Tx10	95.50	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	165.85	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.43	Cool Water	Condenser Out	Tx12	61.01	Cool Water
Economizer sol.	0	1			FLOW	0.00		Evaporator In	Tx13	41.60	Chill Water
DIR VALVE1				Condenser in	Tx17	60.21	Cool Water	Evaporator Out	Tx14	33.71	Chill Water
CHILL VALVE2	0			Direct HX in	Tx18	60.17	Cool Water	Final Outlet Temp	Tx15	38.28	Chill Water
manual switch	0			Econom Liq In	Tx19	90.00	Refrigerant	Direct HX In (chilled)	Tx16	39.71	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	33.92	
020				LOAD (kW)	1.24			Superheat		3.00	
12:08pm				REJECT(kW)	0.96						
2nd stage				DIRECT HX(kw)	-0.30						
going down											
new low load control											

Compr 1 Low (1)	0	0		1st stage suct	Px1 PSI	4.15	Refrigerant	Direct HX Out	Tx1	39.32	Chill Water
Compr 1 High(1)	0	0		Receiver	Px2 PSI	13.28	Refrigerant	EV1 Suction	Tx2	30.12	Refrigerant
Compressor 2(1)	0	0		1st stage disch	Px3 PSI	14.41	Refrigerant	1st Stage Discharge	Tx3	98.99	Refrigerant
Compressor 3(1)	0	1	n	2nd stage suct	Px4 PSI	9.67	Refrigerant	2nd Stage Suction	Tx4	61.77	Refrigerant
Compressor 4(2)	0	0		Condenser in	Px5 PSI	14.21	Refrigerant	Condenser In	Tx5	97.88	Refrigerant
Compressor 5(2)	0	0		Condenser out	Px6 PSI	13.97	Refrigerant	Condenser Out	Tx6	50.00	Refrigerant
Compressor 6(2)	0	0		Liq Ref In	Px7 PSI	11.77	Refrigerant	EV2 OUT	Tx7	29.69	Refrigerant
Compressor 7(2)	0	0			KW	1.72		Economizer Liq Out	Tx8	67.55	Refrigerant
Compressor 8(2)	0	0		Evap water Flow	Fx1 GPM	1.03	Chill Water	Economizer Vap Out	Tx9	60.66	Refrigerant
2nd Stage bypass	0	1			Fx2 CFM	0.00		Comp 1 (1 stage) disc	Tx10	111.37	Refrigerant
Direct HX bypass	0	0	1		Fx3 GPM	0.00		Comp 6(2 stage) disc	Tx11	125.11	Refrigerant
Liquid solenoid	0	1		Cond water Flow	Fx4 GPM	8.23	Cool Water	Condenser Out	Tx12	36.70	Cool Water
Economizer sol.	0	0			FLOW	0.00		Evaporator In	Tx13	40.84	Chill Water
DIR VALVE1				Condenser in	Tx17	32.73	Cool Water	Evaporator Out	Tx14	32.45	Chill Water
CHILL VALVE2	0			Direct HX In	Tx18	62.27	Cool Water	Final Outlet Temp	Tx15	37.36	Chill Water
manual switch	0			Econom Liq In	Tx19	68.61	Refrigerant	Direct HX In (chilled)	Tx16	38.73	Chill Water
10/12/95								1st STAGE SUCTION	Tx20	29.65	
022				LOAD (kW)	1.25			Superheat		2.00	
12:15pm				REJECT(kW)	4.71						
1st stage				DIRECT HX(kw)	-0.31						
going down											
new low load control											

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13. ABSTRACT *(Maximum 200 words)*

The objective of this project was to investigate the feasibility of constructing a heat pump suitable for use as a heat rejection device in applications such as a lunar base. In this situation, direct heat rejection through the use of radiators is not possible at a temperature suitable for life support systems. Initial analysis of a heat pump of this type called for a temperature lift of approximately 378°K, which is considerably higher than is commonly called for in HVAC and refrigeration applications where heat pumps are most often employed. Also because of the variation of the rejection temperature (from 100 to 381°K), extreme flexibility in the configuration and operation of the heat pump is required.

A three–stage compression cycle using a refrigerant such as CFC–11 or HCFC–123 was formulated with operation possible with one, two or three stages of compression. Also, to meet the redundancy requirements, compression was divided up over multiple compressors in each stage. A control scheme was devised that allowed these multiple compressors to be operated as required so that the heat pump could perform with variable heat loads and rejection conditions.

A prototype heat pump was designed and constructed to investigate the key elements of the high–lift heat pump concept. Control software was written and implemented in the prototype to allow fully automatic operation. The heat pump was capable of operation over a wide range of rejection temperatures and cooling loads, while maintaining cooling water temperature well within the required specification of 4°C ±1.7°C. This performance was verified through testing.

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