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SERVICE BULLETIN

SUPERSEDE
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SUBJECT:
3200MP TROUBLESHOOTING

PURPOSE

This bulletin transmits our newest guide to 3200MP control troubleshooting.

MACHINES AFFECTED

17/19DK, DM, DR and 19EB Chillers and Retrofit Chillers with 3200MP Microprocessor Controls

BACKGROUND

To most of us at first, troubleshooting microprocessor electronics seems a bit mysterious, a bit intimidating. But, with a little understanding of what each board is doing in the system and some logical step-by-step use of the built-in self-diagnostics and available guides, we hope it will seem a lot less mysterious and begin to make sense.

This is also aimed at pulling together under one cover most of the basic troubleshooting information as a handy guide that a service technician can have with him on the jobsite without searching through different product Start-Up, Operation and Maintenance Instructions. It also includes a new one page guide (page 2 of the attached) to give some additional ideas aimed at first isolating whether the symptom really indicated a controls problem.

The Controls Test and The Diagnostic Codes and Troubleshooting Guide included here are "generic" to all machines. For single-compressor units, this could just as well be a DR, a DK or a DM unit. And, of course, references to movable diffuser wall units are only applicable to DM's or DR's with DM compressors.

ACTION

These same instructions will be packaged with replacement boards shipped from the Replacement Components Division under their instruction sheet number 99TA550110. This version is largely a consolidation of material from existing literature.

1.

3200MP Microprocessors Controls

This booklet is compiled in an effort to provide, in a single document, information for a basic understanding of the control system, and the correction of control system malfunctions. In many cases, replacing circuit boards is not the answer, and it is hoped this document will aid in more quickly pinpointing the problem.

Below is a description of the microprocessor control system components. A basic understanding of each board's function is needed in order to effectively troubleshoot the system.

Next is a table of software compatibility. Only the correct EPROM versions, or combination of EPROMs will send the proper instructions to the microprocessor.

This is followed on subsequent pages by troubleshooting guides and tests using the control system's built-in self-diagnostics.

Processor Board — The processor board is mounted inside the control center panel and functions as the central computing and control unit for the system. It contains the logic (CPU) and time base necessary to perform all machine control functions. The processor board controls all other system boards and monitors all analog and digital outputs. In addition, the processor board controls all digital outputs and initiates capacity overrides or safety shutdowns when required.

The processor board also contains configuration (DIP) switch banks 1 through 4, the motor current zero and span adjustment potentiometers, a refrigerant temperature set point potentiometer (for brine duty), the power-on reset (POR) pushbutton, and the serial communications port.

Analog Expansion Board (Dual Compressor Unit Only) — Dual compressor units have an A/X board that plugs into the processor board to support 5 additional analog inputs required for compressor B, and to provide additional system control configuration inputs through DIP switch banks, 5, 6 and 7 (see Table 3b).

A toggle switch for selecting the lead compressor (A or B), a pushbutton for displaying the lag compressor status, and the motor current zero and span potentiometer for compressor B are also on the A/X board.

Input/Output Board — The I/O board is mounted inside the control center panel and functions as a logical block for interfacing 115-vac input and output control signals to the low-voltage processor board. Inputs are optically isolated from the processor board. Outputs are optically coupled triac drivers. All triacs are fused to provide overcurrent protection. The I/O board contains a line voltage monitor capable of detecting high, low or loss of voltage and generating an interrupt to the processor board.

Compressor B Input/Output Board (Dual Compressor Unit Only) — The dual compressor unit has an additional I/O board that interfaces 115-vac inputs and outputs for compressor B. This board is mounted on standoffs over the compressor A (main) I/O board.

Set Point/Display Board — The S/D board is mounted in the control center gage panel and allows the operator to interface with the CPU when the local/remote switch is positioned in local. It is the input center for all local machine set points and operating commands or for a stop command during remote operation.

The following components are located on the S/D board:

1. NUMERICAL 2-DIGIT LCD for displaying diagnostic codes and operational data.
2. LOCAL/REMOTE rocker switch for selecting local or remote machine control.
3. START AND STOP PUSHBUTTONS for initiating and terminating machine operation.
4. RESET PUSHBUTTON for clearing a lockout due to a condition exceeding a safety limit (after the condition is within limits); advancing through the controls test; or overriding the 8 manual starts per 12-hour counter.
5. RECALL PUSHBUTTON for displaying up to 5 stored safety shutdown codes.
6. DEMAND LIMIT CONTROL KNOB for limiting machine motor current down to 40% of RLA.
7. TEMPERATURE CONTROL KNOB for adjusting the leaving chilled water or brine temperature set point.
8. FOUR-POSITION CAPACITY CONTROL KNOB for selecting automatic operation or manual control of guide vane position.

SOFTWARE COMPATIBILITY CHART

If an ESP is installed, all software must be from the same basic/options version.

Single Compressor Software

EPROM		Version II	Version III	Version IV	Version V	Version VI	Version VIa	Version VII
Processor Board	(Basic)	HK98EZ-003A	HK98EZ-003A	HK98EZ-004	HK98EZ-004	HK98EZ-005**	HK98EZ-005A	HK98EZ-006
M/X Board	(Options)	HK98EZ-011A	HK98EZ-012	HK98EZ-013	HK98EZ-014	HK98EZ-014C	HK98EZ-014C	HK98EZ-015
ESP Board		HK98EZ-020	HK98EZ-021	HK98EZ-022	HK98EZ-022	HK98EZ-023	HK98EZ-023	HK98EZ-023
STATUS** (Options Software)		VALID	VALID	VOID	VOID	VALID	VALID	VALID

* VERSION refers to a set of 3 EPROMs. The Basic, plus Options software needed for ESP operation
** STATUS applies only to options software within a version. If no ESP installed, all Basic software valid, except HZ98EZ-005.

Dual Compressor Software

EPROM		Version I	Version II	Version III	Version IV	Version V
Processor Board	(Basic)	HK98EZ-031	HK98EZ-034	HK98EZ-034	HK98EZ-034	HK98EZ-035
M/X Board	(Options)		HK98EZ-040	HK98EZ-040A	HK98EZ-040D	N/A
ESP Board			HK98EZ-050	HK98EZ-050	HK98EZ-050E	N/A
STATUS		VOID	VOID	VOID	VALID	VALID

2. Before initiating any troubleshooting procedure, initialize the system by pressing the P.O.R. switch (S5) on the Processor Board. If the problem persists, or if the error code does not clear, then proceed as follows:

WARNING: DO NOT insert meter probes into pin connectors

CHECK THIS	POSSIBLE REMEDY
1) BLANK OR SCRAMBLED DISPLAY	
a) Check for loose display	Push display in
b) Check EPROMs for bent pins or poor contact between pins and socket	Either straighten pins or replace EPROM if pins cannot be straightened to make contact
c) Check all EPROMs per Software Compatibility Chart	Replace EPROMs
d) Check L1-L2 for 120V	Turn power on
e) Check transformer voltage at plug 1J4 1-2 9.5 VAC 2-3 9.5 VAC 5-6 18 VAC	Check transformer and fuses CAUTION: Take care to avoid shorting between terminal pins
f) Check TP1,2,4,8,9,15 on Processor Board (See CONTROL TROUBLESHOOTING: Processor Board Replacement) Note: Test pins may be coated. Use alligator clips or sharp-pointed meter test probes to penetrate	1) If test point voltages OK: a. *Turn Power Off:* Unplug Ribbon Cable on Processor Board b. Turn Power On: Recheck. If still bad, replace Processor Board 2) If test points wrong, check plug 1J4 pin connections
g) If Transformer and Processor Board OK, check following: i. CHECK I/O BOARD test point voltages.	If bad go to step g ii.
ii. *Turn Power Off:* Unplug ribbon cable on I/O Board. Turn Power back On.	If display is now OK, replace I/O Board
iii *Turn Power Off:* Replug ribbon cable on I/O Board. Turn Power back On: Check for 5 Volts across Stop Switch leads.	If bad, replace Display Board If voltage OK, replace Ribbon Cable
2) ERROR CODES	
a) Do Controls Test	See Diagnostic Codes and Troubleshooting Guide
b) Check Peripheral Devices according to Diagnostic Codes and Troubleshooting Guide.	Make prescribed corrections
c) Unplug and reconnect all plugs on I-O Board	
d) Check TP1,2,4 on I/O Board	1) Replace Cable 2) Replace I/O Board
e) See CONTROL TROUBLESHOOTING: I/O Board Replacement	
3) CHILLED WATER TEMPERATURE TOO HIGH	
a) Check Peripheral Devices (see Troubleshooting Guide)	Make prescribed corrections
4) SURGING COMPRESSOR	
a) Low refrigerant level	Add refrigerant to correct charge level
b) Air in Condenser	Purge air from system
c) High Condenser Pressure	1) Lower water temperature or increase flow rate 2) Clean Tubes
d) DM Compressor with wrong DIP Switch settings	Reset DIP Switches (See Service Bulletins or Chiller Start-Up, Operation and Maintenance Instructions)
e) Incompatible software	Install latest software
f) Sensor readings underestimate compressor lift	Reset DIP Switches for smaller impeller diameter
5) CAN'T CALIBRATE MOTOR CURRENT	
a) Check Motor Current signal (approximately .5 VAC at Full Load Amps across field terminals 23-24)	Adjust starter signal resistor to correct signal .5 (+/-.1) VAC at full load When chiller is in Run mode (Capacity Control on Hold) Calibrate Motor Current to correct % of Full Load Amps with Calibration Potentiometer on Processor Board
b) Do Controls Test Step 0.3	Calibrate Motor Current Zero (Capacity Control on Hold)
6) CONTROLS LOCK UP	
a) Display Shows 3: Doesn't change within 1 minute	Check for power at line side of fuse F1
Note: If power present at F1, then check transformer by turning off power, removing plug J6, and checking continuity with ohmmeter (should be approx. 600 ohms)	1) If open, check for bad fuse F1 2) If still open, replace I/O Board
b) Check all EPROMs per Software Compatibility Chart	Replace with latest software as required
e) Check transformer voltage at plug 1J4 1-2 9.5 VAC 2-3 9.5 VAC 5-6 18 VAC	Check transformer and fuses CAUTION: Take care to avoid shorting between terminal pins
f) Check TP1,2,4,8,9,15 on Processor Board (See CONTROL TROUBLESHOOTING: Processor Board Replacement) Note: Test pins may be coated. Use alligator clips or sharp-pointed meter test probes to penetrate	1) If test point voltages OK: a. *Turn Power Off:* Unplug Ribbon Cable on Processor Board b. Turn Power On: Recheck. If still bad, replace Processor Board 2) If test points wrong, check plug 1J4 pin connections
NOTES ON SPECIFIC ERROR CODES AND SYMPTOMS	
a) Display .8.8	1) Replace missing software 2) Check Test Point voltages 3) Check that cables are plugged in properly
b) Code 64	Add Dual Memory Expansion Board with ESP II software to get indication of specific sensor that is out of range
c) Alternates Codes 89 and 4	Check DIP Switch 1-1; Check Troubleshooting Guide
d) Code 76	Check DIP Switches 1-1 and 1-2, Check machine ID in ESP
e) Incorrect temperatures on ESP	Check DIP Switch 2-4; Sensor Voltage vs Temp. Chart
f) Pre- and Post-Lube Times wrong	Check DIP Switches for line frequency and machine type
g) Code 62	Check DIP Switch for motor sensor type
h) Code 63	Check DIP Switch for thrust bearing sensor type

3.

Controls Test — The single compressor unit controls test is a 34-step program that utilizes the LCD on the S/D board. (Dual compressor unit controls test has 44 steps.) The test verifies microprocessor controller inputs and outputs by exercising or displaying the status of peripheral control devices. The test can be initiated any time the machine is not operating by positioning the L, R switch to local and depressing the POR pushbutton. The LCD will show 03 minutes.

⚠ WARNING

Never depress the POR pushbutton while the machine is operating. Serious damage may result.

⚠ CAUTION

Depressing the POR pushbutton causes a system reset and a loss of all volatile memory. Always recall and record shutdown code history before initiating a POR.

To enter the test mode, depress the reset pushbutton within 10 seconds after the POR pushbutton has been depressed. The number of the first step (0.1) will be displayed. (For each test step, the reset pushbutton must be depressed twice. The first depression displays the number of the test step. The second depression displays the results or exercises the command for the test step number.) The results of test step number 0.1 is the display of 88. This test confirms if the elements in the LCD are operable. The test step is distinguished from the test results by a decimal point between the 2 digits in the test step number (i.e., the test step number is always a decimal fraction and the test step result is always a whole number [integer]). Flashing of a test results integer indicates a negative value. Successive depressions of the reset pushbutton will display the test numbers and results of the remaining steps as outlined in Table 4a and b.

To recheck a step while in the test mode, the test can be reinitiated with the POR and reset pushbuttons or the program can be recycled by advancing past the last test step number (3.4 for single compressor unit; 4.4 for dual compressor unit) and back to the desired test step number by depressing the reset pushbutton in succession.

To exit the controls test program, depress the POR pushbutton and allow the time on the display to decrease until it goes blank (time 0).

Table 4a — Controls Test for Single Compressor Unit

STEP NUMBER	TEST DESCRIPTION	DISPLAY CODE OR ACTION
0.1	Display 88 to verify proper operation	88 — OK XX — Faulty
0.2	Display set point of evaporator refrigerant temperature cutout	33 — Water XX — Brine Temperature (adjust with refrigerant temperature set point potentiometer and note set point displayed in LCD)
0.3	Display % RLA of compressor motor current	00 — OK XX — Faulty Calibration (end controls test, set capacity control at HOLD and adjust motor current zero potentiometer until display reads 0.0. Re-enter controls test and check reading on LCD)
0.4	Display controller identification number (00 to 07)	XX — Confirm
0.5	Display leaving chilled water sensor input status	1 — OK 0 — Faulty
0.6	Display condenser refrigerant sensor input	1 — OK 0 — Faulty (Faulty sensor may be shorted, open or poorly connected)
0.7	Display compressor discharge sensor input status	1 — OK 0 — Faulty
0.8	Display evaporator refrigerant temperature sensor input status	1 — OK 0 — Faulty
0.9	Machines with analog motor winding sensor — thermistor Display sensor input status	1 — OK 0 — Faulty 2 — Faulty Configuration
	Machines with digital motor winding sensor — Klixon Display sensor input status	2 — OK 0 — Faulty 1 — Faulty Configuration
1.0	Machines with analog thrust bearing sensor — thermistor Display sensor input status	1 — OK 0 — Faulty 2 — Faulty Configuration
	Machines with digital thrust bearing sensor — Klixon Display sensor input status	2 — OK 0 — Faulty 1 — Faulty Configuration
1.1	Display leaving chilled medium set point potentiometer input status	1 — OK 0 — Faulty
1.2	Display demand limit set point potentiometer input status	1 — OK 0 — Faulty
1.3	Machines with DM compressor — Display diffuser wall potentiometer status	1 — OK 0 — Faulty 2 — Faulty Configuration
	All machines except DM — Display configuration status	2 — OK 0 — Faulty 1 — Faulty Configuration
1.4	Energize oil pump starter relay*	14 — Response (Confirm)
1.5	Energize leaving chilled water pump starter relay*	15 — Response (Confirm)
1.6	Energize condenser water pump starter relay*	16 — Response (Confirm)
1.7	Energize tower fan starter relay*	17 — Response (Confirm)
1.8	Energize increase diffuser wall position solenoid and oil pump* (only for machines with DM compressor)	18 — Response (Confirm)
1.9	Energize decrease diffuser wall position solenoid and oil pump* (only for machines with DM compressor)	19 — Response (Confirm)
2.0	Energize increase guide vane position digital output* (capacity control switch in AUTO.)	20 — Response (Confirm)
2.1	Energize decrease guide vane position digital output* (capacity control switch in AUTO.)	21 — Response (Confirm)
2.2	Energize purge pump relay* (where applicable)	22 — Response (Confirm)
2.3	Energize alarm output indicating safety limit has been exceeded*	23 — Response (Confirm)
2.4	Machines with analog motor winding sensor — thermistor Display configuration status	1 — OK 0 — Faulty Configuration
	Machines with digital motor winding sensor — Klixon Display motor high temperature switch status	1 — OK (Closed) 0 — Faulty (Open)
2.5	Machines with analog thrust bearing sensor — thermistor Display configuration status	1 — OK 0 — Faulty Configuration
	Machines with digital thrust bearing sensor — Klixon Display switch status	1 — OK (Closed) 0 — Faulty (Open)
2.6	Display purge operating switch status (where applicable)	1 — OK (Closed) (Confirm 0 — Faulty (Open) (Confirm
2.7	Display configuration status of impeller or shaft movement switch	1 — OK 0 — Faulty Jumper Between 1J2-11 and 1J2-12 or switch open
2.8	Display spare safety input status	1 — OK (Closed) 0 — Faulty (Open)
2.9	Display chilled water flow switch contact status	1 — OK — Open, Pump Off (Confirm) 0 — Closed — Pump On (Confirm)
3.0	Display condenser water flow switch contact status	1 — OK — Open, Pump Off (Confirm) 0 — Closed — Pump On (Confirm)
3.1	Display oil pressure switch status	1 — OK — Open, Pump Off (Confirm) 0 — Closed — Pump On (Confirm)
3.2	Display 1CR auxiliary contact status	1 — OK (Closed) 0 — Faulty (Open)
3.3	Display starter run contact	1 — OK (Open) 0 — Faulty (Closed)
3.4	Cycle back to first test (depress reset pushbutton)	0.1
	End controls test (depress POR pushbutton)	03 Minutes

*Energize command can be cancelled by depressing reset pushbutton within one second after test number is displayed.
XX — Represents any other numbers displayed

4.

Table 4b — Controls Test for Dual Compressor Unit

STEP NUMBER	TEST DESCRIPTION	DISPLAY CODE OR ACTION
0.1	Display 88 to verify proper operation	88 — OK XX — Faulty
0.2	Display set point of evaporator refrigerant temperature cutout	33 — Water XX — Brine Temperature (adjust with refrigerant temperature set point potentiometer and note set point displayed in LCD)
0.3	Display % RLA of compressor A motor current	00 — OK XX — Faulty Calibration (end controls test, set capacity control at HOLD and adjust motor current zero potentiometer until display reads 0.0. Re-enter controls test and check reading on LCD)
0.4	Display % RLA of compressor B motor current	00 — OK XX — Faulty Calibration (end controls test, set capacity control at HOLD and adjust motor current zero potentiometer until display reads 0.0. Re-enter controls test and check reading on LCD)
0.5	Display controller identification number (00 to 07)	XX — Confirm
0.6	Display leaving chilled water sensor input status	1 — OK 0 — Faulty
0.7	Display condenser refrigerant sensor input	1 — OK 0 — Faulty
0.8	Display compressor A discharge sensor input status	1 — OK 0 — Faulty (Faulty sensor may be shorted, open or poorly connected)
0.9	Display compressor B discharge sensor input status	1 — OK 0 — Faulty
1.0	Display evaporator refrigerant temperature sensor input status	1 — OK 0 — Faulty
1.1	Display compressor A motor winding sensor input status	1 - OK if thermistor (Faulty Configuration if Klixon) 2 - OK if Klixon (Faulty Configuration if thermistor) 0 - Faulty
1.2	Display compressor B motor winding sensor input status	1 - OK if thermistor (Faulty Configuration if Klixon) 2 - OK if Klixon (Faulty Configuration if thermistor) 0 - Faulty
1.3	Display compressor A thrust bearing sensor input status	1 - OK if thermistor (Faulty Configuration if Klixon) 2 - OK if Klixon (Faulty Configuration if thermistor) 0 - Faulty
1.4	Display compressor B thrust bearing sensor input status	1 - OK if thermistor (Faulty Configuration if Klixon) 2 - OK if Klixon (Faulty Configuration if thermistor) 0 - Faulty
1.5	Display leaving chilled medium set point potentiometer input status	1 — OK 0 — Faulty
1.6	Display demand limit set point potentiometer input status	1 — OK 0 — Faulty
1.7	Display compressor A diffuser wall potentiometer status	1 - OK if DM (Faulty Configuration if other) 2 - OK if not DM (Faulty Configuration if DM) 0 - Faulty
1.8	Display compressor B diffuser wall potentiometer status	1 - OK if DM (Faulty Configuration if other) 2 - OK if not DM (Faulty Configuration if DM) 0 - Faulty
1.9	Energize oil pump starter relay*	19 — Response (Confirm oil pump energized)
2.0	Energize leaving chilled water pump starter relay*	20 — Response (Confirm chilled water pump energized)
2.1	Energize condenser water pump starter relay*	21 — Response (Confirm condenser water pump energized)
2.2	Energize tower fan starter relay*	22 — Response (Confirm tower fan energized)
2.3	Energize compressor A increase diffuser wall position solenoid and oil pump* (if DM)	23 — Response (Confirm increase diffuser wall position solenoid and oil pump energized)
2.4	Energize compressor B increase diffuser wall position solenoid and oil pump* (if DM)	24 — Response (Confirm increase diffuser wall position solenoid and oil pump energized)
2.5	Energize compressor A decrease diffuser wall position solenoid and oil pump* (if DM)	25 — Response (Confirm decrease diffuser wall position solenoid and oil pump energized)
2.6	Energize compressor B decrease diffuser wall position solenoid and oil pump* (if DM)	26 — Response (Confirm decrease diffuser wall position solenoid and oil pump energized)
2.7	Energize compressor A increase guide vane position digital output* (Capacity control switch in AUTO.)	27 — Response (Confirm increase guide vane position digital output energized)
2.8	Energize compressor B increase guide vane position digital output* (Capacity control switch in AUTO.)	28 — Response (Confirm increase guide vane position digital output energized)
2.9	Energize compressor A decrease guide vane position digital output* (Capacity control switch in AUTO.)	29 — Response (Confirm decrease guide vane position digital output energized)
3.0	Energize compressor B decrease guide vane position digital output* (Capacity control switch in AUTO.)	30 — Response (Confirm decrease guide vane position digital output energized)
3.1	Energize purge pump relay*	31 — Response (Confirm purge pump energized)
3.2	Energize alarm output indicating safety limit has been exceeded*	32 — Response (Confirm alarm output indicating safety limit has been exceeded energized)
3.3	Display compressor A motor high temperature Klixon switch status	1 — OK 0 — Faulty Configuration if thermistor; Faulty (Open) if Klixon
3.4	Display compressor B motor high temperature Klixon switch status	1 — OK 0 — Faulty Configuration if thermistor; Faulty (Open) if Klixon
3.5	Display purge operating switch status	1 — OK (Closed) (Confirm) 0 — Faulty (Open) (Confirm)
3.6	Display spare safety input status	1 — OK (Closed) 0 — Faulty (Open)
3.7	Display chilled water flow switch contact status	1 — OK — Open, Pump Off (Confirm) 0 — Closed — Pump On (Confirm)
3.8	Display condenser water flow switch contact status	1 — OK — Open, Pump Off (Confirm) 0 — Closed — Pump On (Confirm)
3.9	Display oil pressure switch status	1 — OK — Open, Pump Off (Confirm) 0 — Closed — Pump On (Confirm)
4.0	Display compressor A 1CR auxiliary contact status	1 — OK (Closed) 0 — Faulty (Open)
4.1	Display compressor B 1CR auxiliary contact status	1 — OK (Closed) 0 — Faulty (Open)
4.2	Display compressor A starter run contact	1 — OK (Open) 0 — Faulty (Closed)
4.3	Display compressor B starter run contact	1 — OK (Open) 0 — Faulty (Closed)
4.4	Cycle back to first test (depress reset pushbutton)	0.1
	End controls test (depress POR pushbutton)	03 Minutes

*Energize command can be cancelled by depressing reset pushbutton within one second after test number is displayed.
XX — Represents any other numbers displayed

CONTROL TROUBLESHOOTING

NOTE All references to Compressor Diffuser Wall or Diffuser Wall Potentiometer in "Description/Malfunction" or "Probable Cause/Remedy" apply only to DM Chillers, or DR Chillers with DM Compressors.

These Diagnostic Codes and the Troubleshooting Guide that follows apply only to the following software versions:

Single Compressor HK98EZ-006, -015, -023 EPROMs and earlier
Dual Compressor HK98EZ-034, -C40D, -050E EPROMs and earlier

The microprocessor control system used in this unit contains extensive diagnostic capabilities. Diagnostic information is displayed on the 2-digit LCD in code form. Diagnostic codes should be used in conjunction with Table 8, Diagnostic Codes and Troubleshooting Guide, to resolve most control problems.

If a problem is suspected, use the following procedures:

1. Check display for diagnostic code and refer to Table 8.
2. Recall and record stored codes before turning off control center power or depressing the POR pushbutton.

> IMPORTANT: Displayed and stored diagnostic codes will be lost if power is turned off or a POR is performed.

3. Compare displayed code with recalled code(s) for a pattern or similarities.
4. If control center is energized and there is no diagnostic code and no stored code(s), inquire about power loss.
5. If control center is not energized or controls test malfunctions, check for loose jumper block or ribbon cable connections or blown fuses and check control center transformer as follows:
   a. De-energize control center and remove terminal plug 1J4 from the processor board. Re-energize control center transformer.
   b. Check for 19 vac ± 15% between transformer orange and blue leads (terminals 1 and 3). Replace transformer if voltage is outside these limits.
   c. Check for 18 vac ± 15% between transformer brown and red leads (terminals 5 and 6). Replace transformer if voltage is outside these limits. De-energize control center. Reconnect terminal plug 1J4 and re-energize control center.
6. Perform controls test and make visual inspection of machine and starter. If everything is correct, start machine and monitor closely. If not correct, check processor, I/O and S/D boards to determine if replacement is required.

Test Points — When checking the 3 boards to determine if replacement is required, use reference voltages given at certain test points. These test points are labeled on the particular board as TP"X", where X is the number of the test point. The voltages are listed in the following sections on board replacement. When taking readings at test points, connect ground side of DVM to negative (lower) side of large capacitor on processor board.

Processor Board Replacement — The processor board should be replaced if one or more of the following abnormalities exist with proper power supply from the control center transformer and with terminal plugs 1J1 and 1J2 disconnected.

1. The voltage at any of the following test points exceeds the range listed:

TEST POINT	VOLTAGE RANGE (vdc)
TP1	4.8 to 6
TP2	4.8 to 6
TP4	4.8 to 6
TP8	−4.8 to −6
TP9	9 to 14
TP15	11 to 17

2. Both types of inputs (analog and digital) malfunction or indicate faulty during the controls test. (See Analog Expansion Board Replacement.)
3. The display on the S/D board and outputs from the I/O board malfunction at the same time during the controls test.
4. The control sequence is not followed.
5. An out-of-range sensor reading is displayed but sensor resistance is within limits.
6. The circuit board or any component on the circuit board has been damaged.

Input/Output Board Replacement — The I/O board should be replaced if one of the following abnormalities exist and the processor board has been checked and is functioning properly.

1. The voltage at TP1 exceeds −5 ± .2 vdc; the voltage at TP2 exceeds +5 ± .2 vdc; or the voltage at TP4 exceeds +5 ± .2 vdc.
2. An input channel from a peripheral device malfunctions during a controls test when the signal from the device is correct. (Example: Microprocessor indicates flow switch open when flow switch is closed and voltage is at the input channel.)
3. An output channel to a peripheral device malfunctions during a controls test when the LCD indicates that the command is being executed. (Example: Microprocessor indicates water pump relay is energized but no power is on relay.)
4. A safety trip occurs due to a high, low or loss of power indication when the power supply is within limits. (Not applicable to compressor B input/output board on dual compressor units.)
5. A 110-vac open or close signal is applied to the guide vane actuator when the DIP switches are properly configured.
6. The circuit board or any component on the circuit board has been damaged.

Set Point/Display Board Replacement— The S/D board should be replaced if the following abnormalities exist and the processor board has been checked and is functioning properly.

1. The voltage at the center terminal on the START or STOP pushbutton exceeds +5 ± .2 vdc.
2. An 88 is not displayed on the LCD during the first-step results of the control test.
3. The demand limit or leaving chilled medium set point potentiometer status indicates faulty.

Analog Expansion Board Replacement — The A/X board should be replaced if one or more of the following abnormalities exist and the processor board has been checked and is performing properly.

1. All compressor B analog inputs malfunction or indicate faulty during the controls test.
2. The lead compressor selection switch malfunctions.
3. The lag status pushbutton malfunctions.
4. The circuit board or any component on the circuit board has been damaged.

Table 8 — Diagnostic Codes and Troubleshooting Guide

TYPE	CODE NO.	DESCRIPTION/MALFUNCTION	PROBABLE CAUSE/REMEDY
TIMER	00-15	Time Remaining Until Restart (Decreases at one-minute intervals)	15-minute or 3-minute start inhibit timers not expired.
START STATUS	24	Lag Compressor Manually Disabled	Lag compressor disable DIP switch set to ON.
	25	Recycle Restart Pending	Leaving chilled water or brine temperature too low for recycle start-up (≤ 5 F [2.8 C] above set point).
	26	Start-Up in Progress	Prestart checks being performed, water flows and oil pressure being established.

6.

Table 8 — Diagnostic Codes and Troubleshooting Guide (cont)

TYPE	CODE NO.	DESCRIPTION/MALFUNCTION	PROBABLE CAUSE/REMEDY
RUN STATUS	27	Temperature Reset Active	Indicates that either of the temperature reset options is active.
	28	Temperature Capacity Control	Machine operating normally under temperature control.
	29	Ramp Loading Capacity Control	Leaving temperature pulldown rate being limited by ramp loading
	30	Demand Limit Capacity Control	Compressor motor current > demand limit set point — check motor current calibration.
	35	Motor Temperature Override	Motor temperature > 200 F (93.3 C) — check motor temperature immediately, check sensor resistance.
	36	Refrigerant Temperature Override	Refrigerant temperature ≤ 1°F (0.56 C) above trip limit — check refrigerant temperature, check sensor resistance, check refrigerant charge.
	37	Excessive Purging	See description/malfunction Purge Cycles Often in AUTO. Position.
PRESTART FAILURE STATUS	40	Motor Winding Temperature Too High to Start	Motor temperature > 190 F (87.8 C) — check motor temperature, reset when < 190 F (87.8 C), check sensor resistance.
	41	More Than 8 Starts in Past 12 Hours	Start inhibited by 8 Starts/12-Hour counter. Depress reset pushbutton if additional start is required.
	42	Failure of Condenser Pump to Establish Flow	Check pump operation, check power supply and pilot relay, check flow switch, check water valves, check for air in water lines.
	43	Failure of Evaporator Pump to Establish Flow	Check pump operation, check power supply and pilot relay, check flow switch, check water valves, check for air in water lines
	44	Defective Oil Pump Pressure Switch	Oil pressure switch contact closed with pump de-energized; check contacts. Check setting.
	45	Out-of-Range Sensor Readings	Perform controls test to check for defective set point potentiometer(s) or open or shorted sensors; check sensor resistance
	46	Oil Pressure Switch Not Closed Within 15 Seconds After Pump is Energized (Failure to develop pressure)	Check power to pump, check oil level, check oil pressure switch setting, check for dirty oil filters.
	48	Low/High Line Voltage	Control center voltage supply < 94.3 VAC or > 135.7 VAC for one minute. Check voltage supply. Check control center transformer, check circuit loading, consult power utility if line voltage is low. See I/O Board Replacement.
SHUTDOWN STATUS	56	Lag Compressor Malfunction (Dual Compressor Units)	Safety limit exceeded on lag compressor. (Depress lag compressor status pushbutton to display diagnostic code.)
	60	Compressor Discharge Temperature > 220 F (104 C)	Check discharge temperature immediately, check sensor resistance, check for proper condenser water flow and temperature, check oil reservoir temperature, check condenser for air or water leaks.
	61	Evaporator Refrigerant Temperature < Limit	Check refrigerant temperature, check sensor resistance, check refrigerant charge.
	62	Motor Winding Temperature > 220 F (104 C) Resets at 190 F (88 C)	Check motor temperature immediately, check sensor resistance and connections at compressor junction box, check motor cooling system for restrictions.
	63	Thrust Bearing Temperature > 220 F (104 C)	Check oil reservoir temperature, check oil cooler water flow and solenoid, check oil heater thermostat setting, check sensor resistance and connections at compressor junction box, check journal and thrust bearings if other checks OK.
	64	Sensor Out-of-Range	Perform controls test to check for defective set point potentiometer(s) or open or shorted sensors; check sensor resistance. Check for motor current signal as compressor starts. Check diffuser wall feedback potentiometer calibration.
	65	Oil Pressure < Limit	Check power to pump, check oil level, check oil pressure switch setting, check for dirty oil filters, check for oil foaming at start-up, reduce ramp loading rate if oil foaming is noted.
	66	Motor Overload Trip	Check motor overload dashpots and setting (do not attempt field calibration), check motor current demand calibration. Check optional compressor motor starter protective devices (i.e., phase loss, ground fault, etc.). Check motor for open or grounded phase before attempting a restart.
	67	Temporary Loss of Line Voltage	Control center voltage < 57.5 VAC for one cycle — depress reset pushbutton and restart.
	68	Low-Line Voltage	Control center voltage < 94.3 VAC for one minute; check control center voltage, check control center transformer, check circuit loading, consult power company.
	69	High-Line Voltage	Control center voltage >135.7 VAC for one minute. Check control center voltage, check control center transformer, check power company.
	70	Loss of Chilled Water Flow	Check pilot relay, check power to pump, check flow switch, check water valves
	71	Loss of Condenser Water Flow	Check pilot relay, check power to pump, check flow switch, check water valves
	72	Faulty Jumper	Check grounded jumper wire.
	73	High Condenser Pressure	Check high condenser pressure switch setting, check for proper condenser water flow and temperature, check for fouled tubes.
	74	Failure of Starter to Complete Transition	Check starter, check run contact, check DIP switch configuration for proper starter type.
	75	Excessive Motor Acceleration Time	Check to ensure guide vane is closed at start-up, check starter transfer time, check guide vane linkage. Check DIP switch configuration for proper starter type.
	76	Illegal Configuration	Check for proper unit configuration.
	77	Run/Transition Contacts Failed to Deactivate On Shutdown	Check run contact, check 1CR relay, check starter for welded contacts. Check for 0 volts at 18, replace ribbon cable.
	78	Manual Override Shutdown	Stop pushbutton depressed with L/R switch in remote position — reset
	79	Spare Safety Limit Exceeded	Check spare safety contact(s), check spare safety operation.
	80	Recycle with Motor Current > 65% of RLA	Check for proper cooler and condenser water flows and temperatures, check leaving chilled water/brine sensor resistance, check motor current calibration, check guide vane actuator and linkage
	81*	Loss of Communication	Communication between the basic controller and the ESP not initialized or lost for more than 15 seconds after being initialized. See ESP Operating Instructions.
	85	Lag Compressor Diffuser Wall Malfunction (Dual Compressor Units)	Lag compressor diffuser wall not positioning within tolerance. Check operation of solenoid valves.
	87	Starter Run Contact Was Opened While Running	Check starter, check run contact, check field wiring connections
	88	Lag Compressor Surge Protection Shutdown	Check for air leaks, fouled tubes. Check guide vane/actuator and linkage

*Applies only to options available with the ESP (Expanded Services Panel).

Table 8 — Diagnostic Codes and Troubleshooting Guide (cont)

TYPE	CODE NO.	DESCRIPTION/MALFUNCTION	PROBABLE CAUSE/REMEDY
—	—	Chilled Water Temperature Too High (Machine Running)	THERMOSTAT SET TOO HIGH — Return thermostat to proper setting
			CAPACITY OVERRIDE OR EXCESSIVE COOLING LOAD (Machine at Capacity) — Check for diagnostic code, check for infiltration of outside air into conditioned spaces.
			CONDENSER TEMPERATURE TOO HIGH — Check condensing water flow. Check condensing water temperature; examine cooling tower operation. Check for air and water leaks, check for fouled tubes
			REFRIGERANT LEVEL LOW — Check for leak; repair. Add refrigerant and trim charge
			LIQUID BYPASS IN WATER BOX — Examine division plates and gaskets for leaks.
			GUIDE VANE FAILS TO OPEN — Check for defective actuator — replace.
			GUIDE VANES FAIL TO OPEN FULLY — Be sure that capacity control switch is in *AUTO*. position. If vanes will not open with switch at *INC*, check for excessive cooling load (see above). Check chilled water or brine sensor resistance. Check guide vane linkage. Check limit switch in actuator, check that sensor is connected to proper terminals.
			LAG COMPRESSOR NOT STAGING ON (DUAL COMPRESSOR UNITS) — Check lag compressor status. Check that start requirements have been met.
—	—	Chilled Water or Brine Temperature Too Low (Machine Running)	THERMOSTAT SET TOO LOW — Return thermostat to proper setting.
			GUIDE VANES FAIL TO CLOSE — Be sure that capacity control switch is in *AUTO*. position. Check chilled water sensor resistance, check guide vane linkage. Check for defective actuator — replace, check that sensor is connected to proper terminals.
			DEFECTIVE SENSOR — Check sensor resistance.
			EVAPORATOR REFRIGERANT TEMPERATURE SET POINT IMPROPERLY SET (Brine Chilling Only) — Check refrigerant temperature set point.
—	—	Chilled Water Temperature Fluctuates; Vanes Hunt	DEADBAND TOO NARROW (Erratic Flow or Temperature) — Configure DIP switch for 2 F (1°C) deadband.
			PROPORTIONAL BAND TOO NARROW (Erratic Flow or Temperature) — Configure DIP switch for 15 F (8.3 C) proportional band.
			LOOSE GUIDE VANE LINKAGE — Adjust guide vane linkage.
			DEFECTIVE VANE ACTUATOR — Replace actuator.
			DEFECTIVE SENSOR — Check sensor resistance.
—	—	Oil Reservoir Temperature Too Low	OIL COOLER WATER FLOW TOO HIGH — Throttle water to reduce flow
			THERMOSTAT IMPROPERLY SET OR DEFECTIVE — Check voltage across thermostat while adjusting; if contacts do not close, replace thermostat.
			OIL HEATER DEFECTIVE — If light indicates power but unit does not heat, check unit for open or short. Replace unit if required.
—	—	Oil Reservoir Temperature Too High	THERMOSTAT IMPROPERLY SET — Adjust thermostat.
			OIL COOLER WATER FLOW TOO LOW — Open plug valve.
			OIL COOLER SOLENOID VALVE OPERATING IMPROPERLY — Check electrical operation of solenoid. Inspect valve; if screen is fouled, clean and install a 20-mesh strainer ahead of valve.
			OIL COOLER COIL FOULED — Clean coil; replace cooler if required
—	—	Purge Cycles Often in AUTO. Position	Purge valves not tightly closed. Check valve settings per purge valve chart (see Fig. 6). Close applicable valves securely.
			Solenoid valve leaking. Allow smoke to drift past connection B (Fig. 11). If smoke is drawn into line, repair or replace valves.
			Incorrect purge operating switch setting. Check switch per Table 7 with metered supply of air. Recalibrate or replace as required.
			Excessive air leakage into machine. Check machine for leaks
			Purge condensing chamber float valve stuck in closed position or return line plugged. (Refrigerant level will be above sight glass.)
			Purge liquid supply orifice blocked or excessive flashing in the line ahead of the orifice.
—	—	Excessive Refrigerant Loss	Purge pump cycles often. See Purge Cycles Often in AUTO. Position, above.
—	—	Purge Does Not Operate in AUTO. Position	Normal. Purge pump does not operate unless purge pressure is within 2 to 4 psi (14 to 28 kPa) of condenser pressure. Check gage readings. See Purge Operation.
			Blown fuse. (On some units.) Check 15-amp fuse inside purge electrical switch box (on some units)
			Loose connections or broken wires. Check purge control switch connections
			Check circuit to purge motor, indicator light, solenoid switch and solenoid valve by switching to MANUAL.
			Check purge operating switch and K1 relay connections.
			Purge inhibited, check display for code
			Incorrect purge or operating switch settings. Check switch per Table 7 with metered supply of air. Recalibrate or replace as required.
			Purge condensing chamber float valve stuck in open position (indicated by low refrigerant level).
			The difference between suction temperature and condensing temperature is less than 24 F (13.3 C)

8.

PURGE CYCLE

The purge removes water, air or other noncondensable gases from the refrigerant system. It indicates air and water leaks and may be used to evacuate or pressurize the machine.

A sampling line from the condenser (Fig. 11) continually brings refrigerant gas, and any contaminants, into the purge condensing chamber. Here the gas-vapor mixture passes over a cooling coil. Since the refrigerant liquid within the coil is colder than the mixture surrounding it, the refrigerant gas and water are condensed to liquid.

Water, if present, separates from and floats on the heavier refrigerant. The water level may be observed through a sight glass and the water may be withdrawn manually at the water drain valve (Fig. 7). The liquid refrigerant flows through a U-trap and a float valve back to the cooler.

Purge Operation — The standard operating mode is AUTOMATIC. The purge MANUAL-OFF-AUTO. switch is placed at AUTO. position. As the machine starts up, the purge operating switch will open.

As air and other noncondensable gases accumulate in the upper part of the condensing chamber, raising the chamber pressure to within 2 psi (14 kPa) of machine condenser pressure, the purge operating switch closes, sending a signal to the microprocessor. (See Table 7.) At this point, if the compressor has operated a minimum of 2 minutes and the condensing temperature is at least 24 degrees F (13.3 degrees C) higher than the suction temperature, the microprocessor energizes the purge pump and opens the purge vent solenoid. The air is then discharged through connection B (item 12), Fig. 7. When

Table 7 — Purge Operating Switch Settings

SWITCH	NORMAL POSITION	DIFFERENTIAL PRESSURE SETTING		CONNECTION
		Cutout	Cut-in	
Purge Oper (P2)	Closed	4 psi (28 kPa)	2 psi (14 kPa)	Purge Cond-Machine Cond

the pressure difference increases to 4 psi (28 kPa), the purge operating switch opens, de-energizing the purge. The compressor must be energized for the purge to discharge while in AUTO. mode.

Since machine condenser pressure and purge chamber pressure also equalize at machine shutdown, air and then refrigerant could be discharged each time the machine stops. To prevent this, K1 relay opens whenever cooler and condenser temperature difference drops below 24 degrees F (13.3 degrees C). The K1 relay deactivates the purge AUTO. circuit until machine operation again builds up temperature differences within the refrigerant system.

When the chamber pressure drops during air discharge, the pump and solenoid valve will be de-energized by the purge operating switch. Excessive purging will be prohibited by the microprocessor as described under Excessive Purge Pump Run Time.

If the control switch is placed at the MANUAL position, the purge pump will operate continuously without regard to whether K1 or the purge operating switch is closed. Manual operation is used for removing air from the machine after service work or for pressurizing the machine for leak testing.

	OPERATION	VALVE NUMBER			SWITCH
		1	2	3	Purge
1	Automatic	Close	Open	Close	Auto.
2	Remove water (See Note)	Open	Close	Close	Off

NOTE: Start machine and allow purge pressure to rise above atmospheric. Open valve No. 1 and allow water to drain from top of refrigerant. Close valve No. 1 after removing water.

Fig. 6 — Purge Valve and Switch Settings

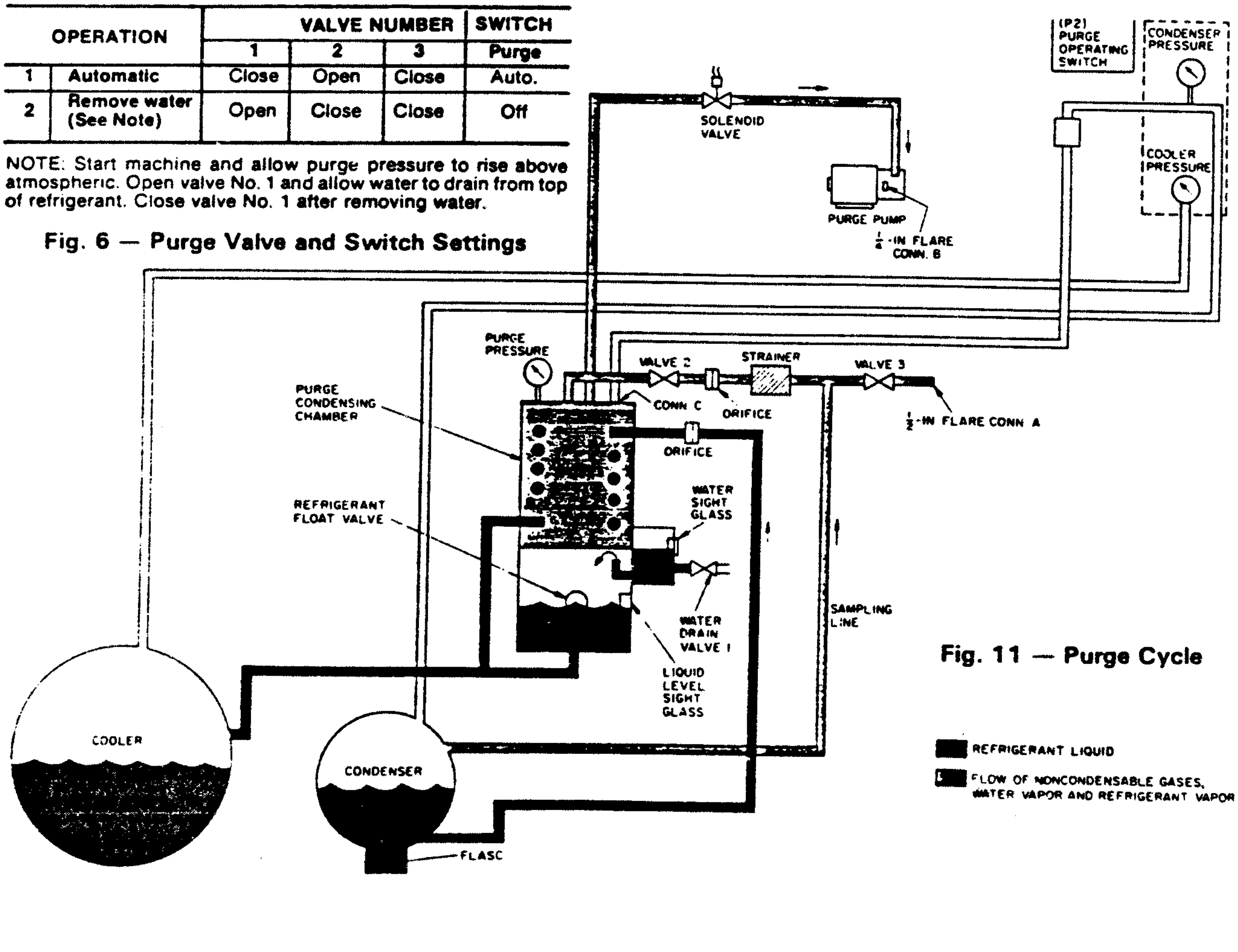

Fig. 11 — Purge Cycle

9.

Table 6a — Sensor Resistance and Temperature (F)

TEMP (F)	RESISTANCE (Ohms)	VOLTAGE DROP (v)	TEMP (F)	RESISTANCE (Ohms)	VOLTAGE DROP (v)	TEMP (F)	RESISTANCE (Ohms)	VOLTAGE DROP (v)	TEMP (F)	RESISTANCE (Ohms)	VOLTAGE DROP (v)
-25.0	98009.6	4.684	38.0	13825.5	3.373	101.0	2834.9	1.500	164.0	765.3	0.527
-24.0	94707.1	4.673	39.0	13449.2	3.343	102.0	2773.2	1.476	165.0	749.5	0.518
-23.0	91521.5	4.662	40.0	13084.2	3.312	103.0	2713.1	1.453	166.0	734.2	0.509
-22.0	88448.9	4.651	41.0	12730.1	3.281	104.0	2654.7	1.430	167.0	719.2	0.501
-21.0	85485.5	4.640	42.0	12386.6	3.250	105.0	2597.8	1.407	168.0	704.6	0.493
-20.0	82627.2	4.628	43.0	12053.3	3.219	106.0	2542.3	1.385	169.0	690.4	0.484
-19.0	79870.6	4.616	44.0	11730.0	3.187	107.0	2488.3	1.362	170.0	676.6	0.476
-18.0	77212.0	4.604	45.0	11416.1	3.156	108.0	2435.8	1.341	171.0	663.3	0.468
-17.0	74647.9	4.591	46.0	11111.5	3.124	109.0	2384.5	1.319	172.0	650.3	0.461
-16.0	72175.1	4.578	47.0	10815.8	3.093	110.0	2334.6	1.298	173.0	637.7	0.453
-15.0	69790.3	4.565	48.0	10528.7	3.061	111.0	2285.9	1.277	174.0	625.5	0.446
-14.0	67490.4	4.551	49.0	10250.0	3.029	112.0	2238.5	1.256	175.0	613.8	0.438
-13.0	65272.4	4.537	50.0	9979.3	2.997	113.0	2192.2	1.236	176.0	602.3	0.431
-12.0	63133.3	4.523	51.0	9716.5	2.965	114.0	2147.0	1.216	177.0	591.3	0.424
-11.0	61070.3	4.509	52.0	9461.3	2.933	115.0	2103.0	1.196	178.0	580.7	0.417
-10.0	59080.6	4.494	53.0	9213.4	2.901	116.0	2060.0	1.176	179.0	570.3	0.410
- 9.0	57161.7	4.479	54.0	8972.6	2.869	117.0	2018.0	1.157	180.0	560.5	0.403
- 8.0	55310.9	4.463	55.0	8738.6	2.837	118.0	1977.0	1.138	181.0	550.9	0.397
- 7.0	53525.8	4.448	56.0	8511.4	2.805	119.0	1936.9	1.120	182.0	541.7	0.390
- 6.0	51804.0	4.431	57.0	8290.6	2.772	120.0	1897.8	1.101	183.0	532.9	0.384
- 5.0	50143.2	4.415	58.0	8076.1	2.740	121.0	1859.5	1.083	184.0	524.4	0.378
- 4.0	48541.1	4.398	59.0	7867.7	2.708	122.0	1822.1	1.065	185.0	516.2	0.371
- 3.0	46995.6	4.381	60.0	7665.1	2.676	123.0	1785.5	1.048	186.0	508.4	0.365
- 2.0	45504.7	4.363	61.0	7468.3	2.644	124.0	1749.7	1.030	187.0	500.8	0.360
- 1.0	44066.3	4.345	62.0	7277.1	2.612	125.0	1714.7	1.013	188.0	493.6	0.354
0.0	42678.5	4.327	63.0	7091.2	2.581	126.0	1680.4	0.997	189.0	486.5	0.348
1.0	41339.3	4.308	64.0	6910.6	2.549	127.0	1646.8	0.980	190.0	479.9	0.342
2.0	40047.1	4.289	65.0	6735.1	2.517	128.0	1613.8	0.964	191.0	473.4	0.337
3.0	38800.0	4.270	66.0	6564.4	2.486	129.0	1581.6	0.948	192.0	467.2	0.332
4.0	37596.4	4.250	67.0	6398.6	2.454	130.0	1550.0	0.932	193.0	461.2	0.326
5.0	36434.7	4.230	68.0	6237.5	2.423	131.0	1519.0	0.917	194.0	455.6	0.321
6.0	35313.3	4.209	69.0	6080.8	2.391	132.0	1488.6	0.902	195.0	450.0	0.316
7.0	34230.7	4.188	70.0	5928.6	2.360	133.0	1458.8	0.887	196.0	444.5	0.311
8.0	33185.4	4.167	71.0	5780.6	2.329	134.0	1429.6	0.872	197.0	439.2	0.306
9.0	32176.2	4.145	72.0	5636.8	2.299	135.0	1400.9	0.857	198.0	434.4	0.301
10.0	31201.5	4.123	73.0	5497.0	2.268	136.0	1372.7	0.843	199.0	429.2	0.297
11.0	30260.1	4.101	74.0	5361.2	2.237	137.0	1345.1	0.829	200.0	424.1	0.292
12.0	29350.9	4.078	75.0	5229.1	2.207	138.0	1318.0	0.815	201.0	419.4	0.288
13.0	28472.5	4.055	76.0	5100.8	2.177	139.0	1291.3	0.802	202.0	414.6	0.283
14.0	27623.8	4.032	77.0	4976.0	2.147	140.0	1265.2	0.788	203.0	410.2	0.279
15.0	26803.7	4.008	78.0	4854.8	2.117	141.0	1239.5	0.775	204.0	405.3	0.274
16.0	26011.2	3.984	79.0	4736.9	2.088	142.0	1214.3	0.762	205.0	400.8	0.270
17.0	25245.1	3.959	80.0	4622.4	2.058	143.0	1189.5	0.750	206.0	396.2	0.266
18.0	24504.6	3.934	81.0	4511.1	2.029	144.0	1165.2	0.737	207.0	391.2	0.262
19.0	23788.7	3.909	82.0	4402.9	2.000	145.0	1141.3	0.725	208.0	386.4	0.258
20.0	23096.4	3.883	83.0	4297.7	1.972	146.0	1117.8	0.713	209.0	381.6	0.254
21.0	22426.9	3.858	84.0	4195.5	1.943	147.0	1094.8	0.701	210.0	376.7	0.250
22.0	21779.3	3.831	85.0	4096.1	1.915	148.0	1072.2	0.689	211.0	371.6	0.247
23.0	21152.8	3.805	86.0	3999.6	1.887	149.0	1049.9	0.678	212.0	366.1	0.243
24.0	20546.7	3.778	87.0	3905.7	1.859	150.0	1028.1	0.666	213.0	360.7	0.239
25.0	19960.2	3.751	88.0	3814.4	1.832	151.0	1006.8	0.655	214.0	355.6	0.236
26.0	19392.5	3.723	89.0	3725.8	1.805	152.0	985.8	0.644	215.0	349.8	0.232
27.0	18843.0	3.696	90.0	3639.5	1.778	153.0	965.2	0.634	216.0	343.7	0.229
28.0	18311.0	3.668	91.0	3555.7	1.751	154.0	945.0	0.623	217.0	337.6	0.225
29.0	17795.8	3.639	92.0	3474.2	1.725	155.0	925.3	0.613	218.0	331.7	0.222
30.0	17297.0	3.611	93.0	3395.0	1.699	156.0	905.9	0.602	219.0	325.0	0.219
31.0	16813.8	3.582	94.0	3318.0	1.673	157.0	887.0	0.592	220.0	318.4	0.215
32.0	16345.7	3.553	95.0	3243.1	1.647	158.0	868.3	0.582	221.0	311.4	0.212
33.0	15892.2	3.523	96.0	3170.3	1.622	159.0	850.2	0.573	222.0	304.4	0.209
34.0	15452.7	3.494	97.0	3099.4	1.597	160.0	832.4	0.563	223.0	296.9	0.206
35.0	15026.7	3.464	98.0	3030.5	1.572	161.0	815.1	0.554	224.0	289.4	0.203
36.0	14613.9	3.434	99.0	2963.5	1.548	162.0	798.1	0.545	225.0	282.1	0.200
37.0	14213.6	3.404	100.0	2898.4	1.523	163.0	781.5	0.536			
38.0	13825.5	3.373	101.0	2834.9	1.500	164.0	765.3	0.527			

10.

Table 6b — Sensor Resistance and Temperature (C)

TEMP (C)	RESIST-ANCE (Ohms)	VOLTAGE DROP (v)	TEMP (C)	RESIST-ANCE (Ohms)	VOLTAGE DROP (v)	TEMP (C)	RESIST-ANCE (Ohms)	VOLTAGE DROP (v)	TEMP (C)	RESIST-ANCE (Ohms)	VOLTAGE DROP (v)	TEMP (C)	RESIST-ANCE (Ohms)	VOLTAGE DROP (v)
-32.0	100049.0	4.690	-4.0	20075.9	3.756	24.0	5203.2	2.201	52.0	1694.0	1.003	80.0	602.4	0.431
-31.5	97006.4	4.680	-3.5	19560.8	3.732	24.5	5088.1	2.174	52.5	1663.5	0.988	80.5	592.4	0.425
-31.0	94060.8	4.671	-3.0	19060.6	3.707	25.0	4976.0	2.147	53.0	1633.5	0.974	81.0	582.8	0.418
-30.5	91209.3	4.661	-2.5	18574.8	3.682	25.5	4866.8	2.120	53.5	1604.1	0.959	81.5	573.4	0.412
-30.0	88449.0	4.651	-2.0	18102.9	3.656	26.0	4760.2	2.094	54.0	1575.2	0.945	82.0	564.4	0.406
-29.5	85777.0	4.641	-1.5	17644.5	3.631	26.5	4656.4	2.067	54.5	1546.9	0.931	82.5	555.7	0.400
-29.0	83190.7	4.630	-1.0	17199.1	3.605	27.0	4555.2	2.041	55.0	1519.0	0.917	83.0	547.2	0.394
-28.5	80687.1	4.620	-0.5	16766.3	3.579	27.5	4456.6	2.015	55.5	1491.6	0.903	83.5	539.1	0.388
-28.0	78263.9	4.609	0.0	16345.7	3.553	28.0	4360.4	1.989	56.0	1464.7	0.890	84.0	531.2	0.383
-27.5	75918.3	4.597	0.5	15936.9	3.526	28.5	4266.7	1.963	56.5	1438.3	0.876	84.5	523.6	0.377
-27.0	73648.0	4.586	1.0	15539.5	3.500	29.0	4175.4	1.938	57.0	1412.3	0.863	85.0	516.2	0.371
-26.5	71450.6	4.574	1.5	15153.1	3.473	29.5	4086.3	1.912	57.5	1386.8	0.850	85.5	509.2	0.366
-26.0	69323.7	4.562	2.0	14777.5	3.446	30.0	3999.6	1.887	58.0	1361.6	0.837	86.0	502.3	0.361
-25.5	67265.0	4.550	2.5	14412.2	3.419	30.5	3915.0	1.862	58.5	1336.9	0.825	86.5	495.7	0.355
-25.0	65272.4	4.537	3.0	14056.9	3.392	31.0	3832.5	1.837	59.0	1312.6	0.812	87.0	489.4	0.350
-24.5	63343.7	4.525	3.5	13711.4	3.364	31.5	3752.1	1.813	59.5	1288.7	0.800	87.5	483.2	0.345
-24.0	61476.9	4.512	4.0	13375.3	3.337	32.0	3673.7	1.789	60.0	1265.2	0.788	88.0	477.4	0.340
-23.5	59670.0	4.499	4.5	13048.3	3.309	32.5	3597.3	1.764	60.5	1242.1	0.776	88.5	471.6	0.335
-23.0	57920.9	4.485	5.0	12730.1	3.281	33.0	3522.9	1.741	61.0	1219.3	0.765	89.0	466.1	0.331
-22.5	56227.9	4.471	5.5	12420.5	3.253	33.5	3450.2	1.717	61.5	1196.9	0.753	89.5	460.8	0.326
-22.0	54589.1	4.457	6.0	12119.2	3.225	34.0	3379.4	1.693	62.0	1174.8	0.742	90.0	455.6	0.321
-21.5	53002.7	4.443	6.5	11826.0	3.197	34.5	3310.4	1.670	62.5	1153.2	0.731	90.5	450.6	0.317
-21.0	51467.0	4.428	7.0	11540.5	3.169	35.0	3243.1	1.647	63.0	1131.8	0.720	91.0	445.7	0.312
-20.5	49980.4	4.413	7.5	11262.7	3.140	35.5	3177.5	1.624	63.5	1110.9	0.709	91.5	440.9	0.308
-20.0	48541.1	4.398	8.0	10992.1	3.112	36.0	3113.4	1.602	64.0	1090.2	0.698	92.0	436.3	0.303
-19.5	47147.7	4.383	8.5	10728.8	3.083	36.5	3051.0	1.579	64.5	1069.9	0.688	92.5	431.8	0.299
-19.0	45798.6	4.367	9.0	10472.3	3.054	37.0	2990.1	1.557	65.0	1050.0	0.678	93.0	427.4	0.295
-18.5	44492.4	4.351	9.5	10222.6	3.026	37.5	2930.7	1.536	65.5	1030.3	0.667	93.5	423.0	0.291
-18.0	43227.6	4.334	10.0	9979.3	2.997	38.0	2872.8	1.514	66.0	1011.0	0.657	94.0	418.8	0.287
-17.5	42002.9	4.318	10.5	9742.5	2.968	38.5	2816.2	1.492	66.5	992.1	0.648	94.5	414.5	0.283
-17.0	40816.9	4.301	11.0	9511.7	2.939	39.0	2761.1	1.471	67.0	973.4	0.638	95.0	410.3	0.279
-16.5	39668.3	4.283	11.5	9287.0	2.911	39.5	2707.2	1.450	67.5	955.1	0.628	95.5	406.0	0.275
-16.0	38555.9	4.266	12.0	9068.0	2.882	40.0	2654.7	1.430	68.0	937.1	0.619	96.0	401.8	0.271
-15.5	37478.4	4.248	12.5	8854.7	2.853	40.5	2603.4	1.409	68.5	919.4	0.609	96.5	397.6	0.267
-15.0	36434.7	4.230	13.0	8646.9	2.824	41.0	2553.3	1.389	69.0	902.1	0.600	97.0	393.3	0.264
-14.5	35423.7	4.211	13.5	8444.5	2.795	41.5	2504.4	1.369	69.5	885.1	0.591	97.5	389.0	0.260
-14.0	34444.2	4.193	14.0	8247.2	2.766	42.0	2456.6	1.349	70.0	868.4	0.582	98.0	384.7	0.257
-13.5	33495.2	4.174	14.5	8055.0	2.737	42.5	2410.0	1.330	70.5	852.0	0.574	98.5	380.3	0.253
-13.0	32575.6	4.154	15.0	7867.7	2.708	43.0	2364.4	1.311	71.0	836.0	0.565	99.0	375.8	0.250
-12.5	31684.6	4.135	15.5	7685.1	2.680	43.5	2319.9	1.292	71.5	820.2	0.557	99.5	371.1	0.246
-12.0	30821.0	4.115	16.0	7507.2	2.651	44.0	2276.3	1.273	72.0	804.8	0.548	100.0	366.5	0.243
-11.5	29984.0	4.094	16.5	7333.9	2.622	44.5	2233.8	1.254	72.5	789.8	0.540	100.5	361.6	0.240
-11.0	29172.7	4.074	17.0	7164.9	2.593	45.0	2192.2	1.236	73.0	775.0	0.532	101.0	356.7	0.236
-10.5	28386.3	4.053	17.5	7000.3	2.565	45.5	2151.5	1.218	73.5	760.6	0.524	101.5	351.5	0.233
-10.0	27623.8	4.032	18.0	6839.8	2.536	46.0	2111.7	1.200	74.0	746.5	0.516	102.0	346.3	0.230
- 9.5	26884.4	4.010	18.5	6683.4	2.508	46.5	2072.8	1.182	74.5	732.6	0.508	102.5	341.1	0.227
- 9.0	26167.5	3.989	19.0	6530.9	2.479	47.0	2034.7	1.165	75.0	719.2	0.501	103.0	335.3	0.224
- 8.5	25472.2	3.967	19.5	6382.3	2.451	47.5	1997.4	1.148	75.5	706.1	0.493	103.5	329.7	0.221
- 8.0	24797.8	3.944	20.0	6237.5	2.423	48.0	1960.9	1.131	76.0	693.3	0.486	104.0	323.8	0.218
- 7.5	24143.6	3.922	20.5	6096.3	2.395	48.5	1925.1	1.114	76.5	680.8	0.479	104.5	317.9	0.215
- 7.0	23509.0	3.899	21.0	5958.7	2.367	49.0	1890.1	1.098	77.0	668.6	0.472	105.0	311.6	0.212
- 6.5	22893.2	3.876	21.5	5824.6	2.339	49.5	1855.7	1.081	77.5	656.8	0.465	105.5	305.3	0.209
- 6.0	22295.6	3.852	22.0	5693.9	2.311	50.0	1822.1	1.065	78.0	645.2	0.458	106.0	298.6	0.206
- 5.5	21715.7	3.829	22.5	5566.4	2.283	50.5	1789.1	1.049	78.5	634.0	0.451	106.5	292.1	0.204
- 5.0	21152.8	3.805	23.0	5442.2	2.256	51.0	1756.8	1.034	79.0	623.2	0.444	107.0	285.2	0.201
- 4.5	20606.4	3.781	23.5	5321.2	2.228	51.5	1725.1	1.019	79.5	612.6	0.437			
- 4.0	20075.9	3.756	24.0	5203.2	2.201	52.0	1694.0	1.003	80.0	602.4	0.431			