

Model K12

Primary Metrology Comparison Furnace
Operation and Maintenance Manual

by

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Primary Metrology Comparison Furnace

1. Background

This report documents the installation, operating and maintenance procedures for the Primary Metrology Comparison Furnace, Pond Engineering Number K12. Pond Engineering Laboratories considers information contained in this manual to be proprietary and is provided for use by the purchaser exclusively for instructional and maintenance purposes; any other uses are prohibited.

2. General Information and Operating Procedures

Figure 1, below, shows the general configuration of the furnace and provides a better visualization of its appearance, as well as, a reference for location of service points discussed later in this manual.

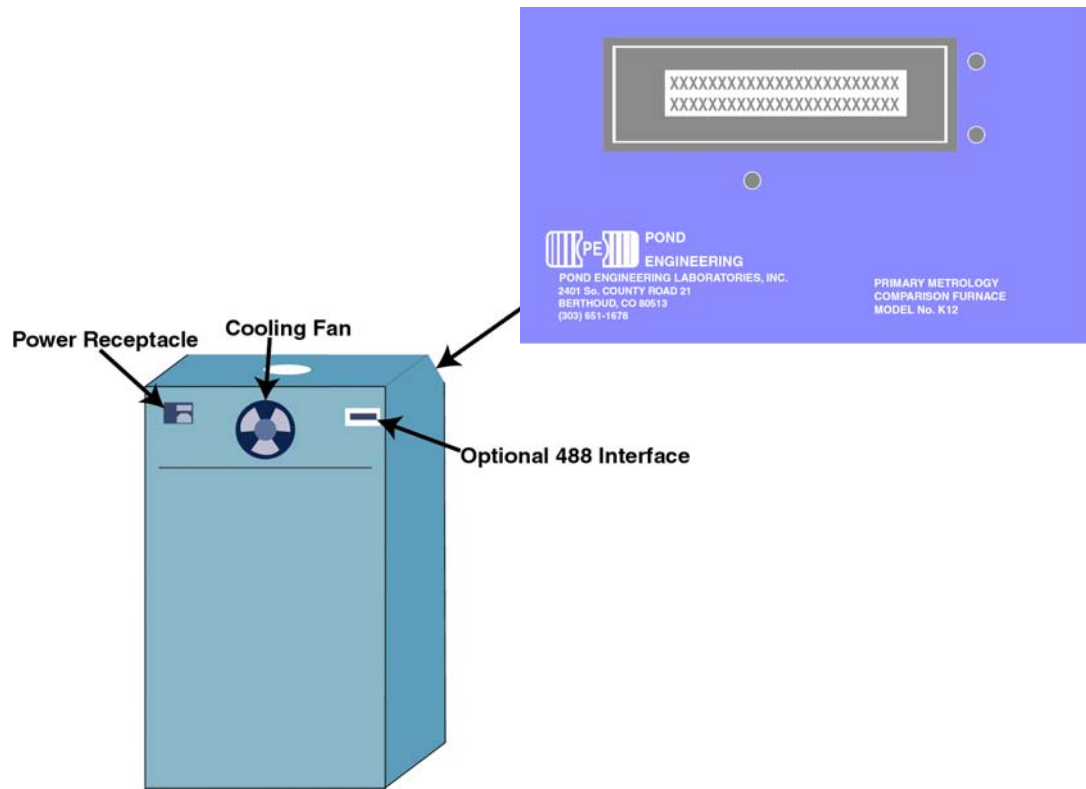


Figure 1 - System General Layout

As shown in Figure 1, the controller front panel is located on a sloping surface at the front of the outer chassis of the Furnace. The Furnace is designed to provide an extremely stable and uniform temperature environment for the comparison calibration of Standard Platinum Resistance Thermometers (SPRT's) over a range of 90°C to 662°C. The Comparison Furnace accommodates up to seven SPRT's in an arrangement of seven inconel wells 0.315" inside diameter and 16 inches deep. The temperature stability of the lower seven inches of the center well is maintained within +/- 0.0005°C over 15 minutes with six peripheral wells, uniform to each other within +/- 0.0008°C. Optional features include an IEEE-488 interface that is installed at the factory to allow operation of the Furnace as part of an integrated automatic calibration system. The furnace cabinet has a lower rear panel attached to the cabinet frame via button head screws. By removing this panel, one may gain access to the inner system components. Both side panels are also removable by actuation of the panel latches once the lower rear panel is removed. The operator interface is provided by three front panel switches, and a 2 line by 24 character Liquid Crystal Display (LCD).

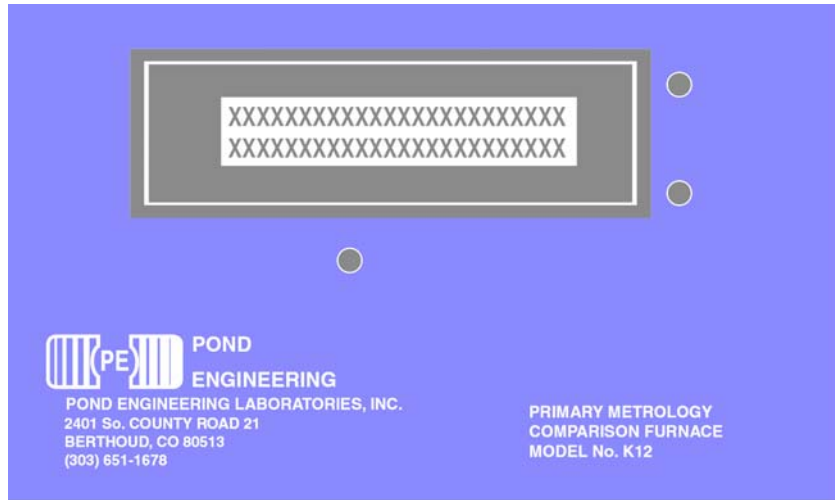


Figure 2 - Front Panel Layout

In the normal operating mode this display presents the current temperature setpoint for the controller and the measured core temperature on the first and second lines of the display, respectively. Measurements are taken at approximately 3-second intervals and the lower line of the display is updated following the measurement, indicating the measured core temperature. Additional controller functions (for the purpose of providing diagnostic information, sensor calibration etc.) are accessed through the use of the front panel switches and messages presented by the LCD display as outlined in the following sections.

2.1 Primary and Secondary Alarms

The Furnace system has a primary alarm and a secondary alarm. The primary alarm is adjustable by the user (see 3.2.2.2) and is used to set an alarm if the temperature reaches an undesired value.

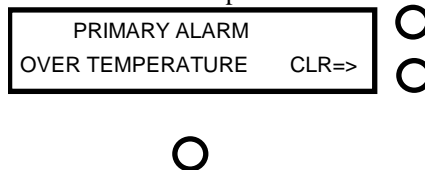


Figure 3 - Primary Alarm

Simply pressing the switch next to CLR=> can clear this alarm.

The secondary alarm is used when the system has a catastrophic error. This alarm is a failsafe device to prevent the system from overheating. When this alarm is activated, the following will appear on the display.

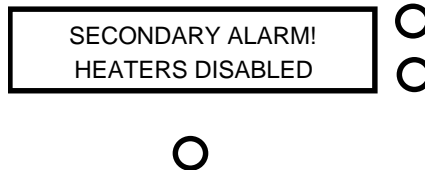


Figure 4 - Secondary Alarm

When this alarm is activated the heaters will be disabled. This alarm can only be cleared is by turning the system off and then back on again.

3. System Controller

In an effort to provide simplicity, while maintaining flexibility to accommodate optional features, the operator interface is based largely on user interactive software control. The software provides prompts to the user through a set of COMMAND FUNCTIONS, including ADJUST SETPOINT TEMPERATURE, and ADJUST SYSTEM VARIABLES. In a user-interactive manner, the software displays messages on the LCD to prompt the user as necessary to perform all command functions through the use of the three front panel switches surrounding the LCD. An outline of the user interface, a detailed description of prompts, how to edit configurations and operate the system manually are explained in this manual. Because of the multitude of functions that each switch will perform, all “labeling” of the switches is provided by the system software and presented to the user via the LCD display. The labels attached to the switches in Figure 5, below, are for the benefit of the reader in understanding the documentation herein. Such labels do not appear on the device front panel.

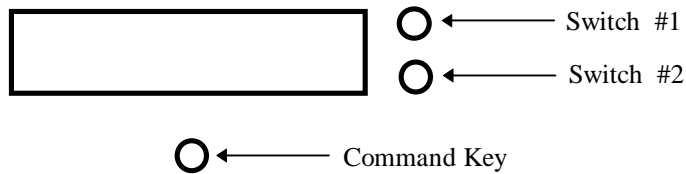


Figure 5 - Front Panel Switch Layout

3.1 Normal Operating Mode

In normal operation, the Furnace controller will continuously display the setpoint temperature and the current measured core temperature, as shown in Figure 6. Measurements are taken at approximately 3-second intervals and the lower line of the display updated following the measurement. This information is removed from the display when the user presses and holds the “Command Key” for a period of 2 to 3 seconds which allows entry to the COMMAND FUNCTIONS portion of the program. .

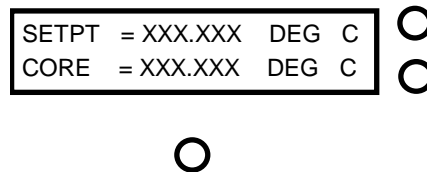


Figure 6 - Normal Operating Mode Display

3.2 The “Command Functions”

In order to perform the many functions necessary, the user must leave the normal operating mode and enter COMMAND FUNCTIONS. To do this, the user should depress and hold the Command Key. As the key is pressed, the words COMMAND FUNCTIONS will be immediately displayed on the lower line of the display. If the key is released the normal operation screen will again be displayed and normal operation will continue. In order to proceed to “Command Functions”, the operator must press and hold the “Command Key” until the words COMMAND FUNCTIONS disappear at which time the operator may release the key.

****Note: The system has been designed such that control functions operate normally even when the user is accessing the command functions. The IEEE-488 commands will not work however, until the system is returned to normal operating mode. Attempting to send 488 commands while in COMMAND FUNCTIONS will cause a 488 error that will clear itself in 10 to 30 seconds.**

3.2.1 Change Setpoint

The first command function accessed is CHANGE SETPOINT TEMPERATURE. This function is provided to either change the setpoint to one of three user defined memory setpoint temperatures or to manually adjust the setpoint temperature. Manual adjustment of the Setpoint Temperature may be accomplished within the range of 90.00 to 662.00°C. As shown in Figure 7, the YES is located adjacent to the top switch, which was identified earlier in Figure 3 as “Switch #1”. The NO is adjacent to the switch identified as “Switch #2”. If the NO selection is made, the program will continue on to allow access to the next function.

If the user selects YES by pressing the corresponding switch, the display shown in Figure 8 will be presented on the LCD.

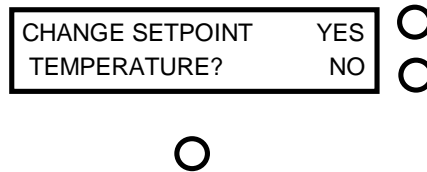


Figure 7 - Setpoint Access Prompt

The system controller is equipped with three memory SETPOINT temperatures (MEMORY 1 - MEMORY 3). The user may choose to select one of the memory setpoint temperatures by pressing the corresponding YES switch.

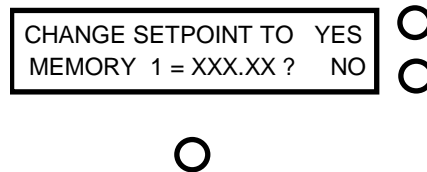


Figure 8 - Memory Setpoint Change Prompt

A NO selection will advance the system to the next memory setpoint. A NO response to all three memory setpoint temperatures will allow the user to change the setpoint manually, as shown in Figure 9. Manual adjustment of the SETPOINT may be accomplished by using the two switches on the side corresponding to the labels UP and DN displayed on the LCD. The cursor starts in the hundred’s position. Choosing UP will cause the value to increase by 100 until it reaches a maximum of 662 degrees C. Choosing DN will cause the value to decrease by 100 until it reaches 90 degrees C. The COMMAND switch, located directly below the LCD, is used to advance the cursor to the ten’s digit and so on. The number presented on the display is used as the current setpoint as soon as one advances the cursor past the last digit.

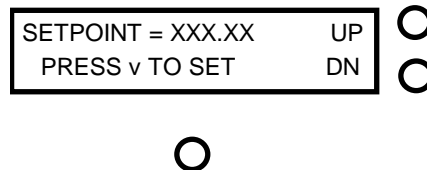


Figure 9 - Manual Setpoint Change Prompt

Once the cursor is scrolled past the last digit, setpoint adjustment is completed and the user is allowed access to the next Command Function as described in the following section.

3.2.2 Adjust System Variables

This command function is provided to allow user examination and adjustment of the system variables used by the controller.

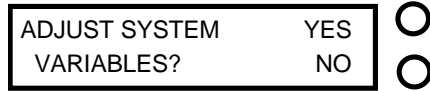


Figure 10 - System Variables Access Prompt

Pressing the switch by the display YES will allow access to the first system variable by presenting the messages shown in Figure 11, while responding with a NO command will terminate the function.

3.2.2.1 Adjust Memory Temperatures

The first variable accessed is MEMORY 0 as shown in Figure 11. The MEMORY 0 variable is the system startup setpoint temperature. Responding YES to the prompt will allow the user to adjust the setpoint as shown in Figure 12, a NO response will access the remaining three memory setpoint temperatures (MEMORY 1 - MEMORY 3). A NO response to all four memory setpoint temperatures accesses the next system variable described in the following section.

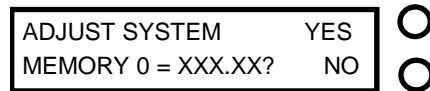


Figure 11 - System Memory Setpoint Prompt

The adjustment of MEMORY 0 may be accomplished by using the two switches on the side corresponding to the labels UP and DN displayed on the LCD shown in Figure 12. The COMMAND switch, located directly below the LCD, is used to advance the cursor to each of the digits.

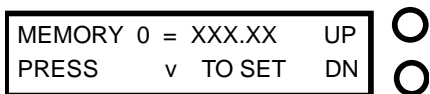


Figure 12 - Adjust System Memory Setpoint Prompt

Modification of the variable is accomplished by pressing either of the two switches to the right of the LCD. Pressing the switch adjacent to the UP prompt shown in Figure 12 will cause the value of the selected digit to increment one, while pressing the switch adjacent to the DN will cause it to decrement one. As the cursor is scrolled past the last digit, memory setpoint adjustment is completed and the user is allowed access to the next memory setpoint. When all memory setpoint adjustments have been presented, the system advances to the next system variable as described in the following section.

3.2.2.2 Change Primary Alarm Temperature

The next variable accessed by this function is ALARM TEMPERATURE, the temperature at which the controller turns off the heater drive to prevent overheating of the core.

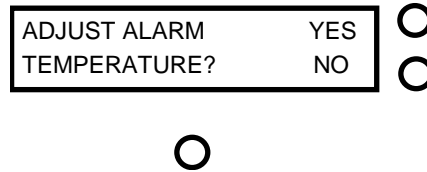


Figure 13 - Change Primary Alarm Temperature Access Prompt

Responding YES to the prompt will allow user access to the variable modification function as described below, while a NO response will allow access to the next system variable in the sequence, as described in the following section.

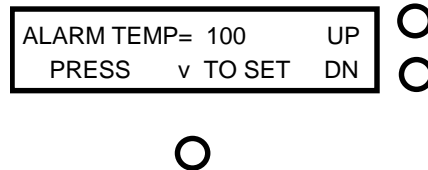


Figure 14 - Primary Alarm Temperature Adjust Prompt

Modification of the variable is accomplished by pressing either of the two switches to the right of the LCD. The command switch located directly below the LCD is used to advance the cursor to each of the digits. Pressing the switch adjacent to the UP prompt shown in Figure 15 will cause the value of the selected digit to increment one, while pressing the switch adjacent to the DN will cause it to decrement one. The range of the variable is 100.0 to 670.0 °C. As the cursor passes the last digit the value is stored as a temporary system variable.

If for any reason the measured core temperature exceeds the primary alarm temperature the following display will appear.

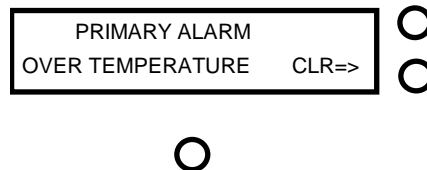


Figure 15 - Primary Alarm Display

When the primary alarm is exceeded the system immediately shuts off all power to the core heaters. The user must press Switch 2 in order to exit the above display and return the system to normal operation.

****Note: The Furnace is provided with an isolated secondary alarm. The secondary alarm is provided to prevent a catastrophic system failure. The secondary alarm is discussed in detail in section 2.1 Primary and Secondary Alarms.**

3.2.2.3 Set IEEE - 488 Address

The next variable presented is, SET IEEE-488 ADDRESS, the parameter that determines the address at which the system can be accessed over the IEEE-488 Buss. This is an optional accessory to the Furnace system that will not be accessed if not installed. Please skip this section if the IEEE-488 feature has not been installed.

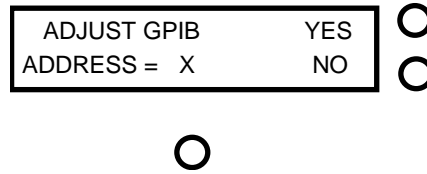


Figure 16 - IEEE-488 Address Adjust Prompt

This variable may be examined or adjusted by the user by responding YES to the prompt, while a NO response will allow access to the next Command Function in the sequence as described in the following section.

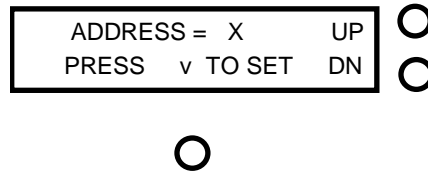


Figure 17 - Address Adjust Prompt

Here the user has the ability to choose the address at which the IEEE-488 can be located as shown in Figure 17. The adjustment of address may be accomplished by using either of the two switches on the side corresponding to the labels UP and DN displayed on the LCD shown in Figure 17. This variable can be set within the range of 1 to 30. The COMMAND switch, located directly below the LCD, is used to advance the cursor to each of the digits. Pressing the switch adjacent to the UP prompt shown in Figure 17 will cause the value of the selected digit to increment one, while pressing the switch adjacent to the DN will cause it to decrement one. As the cursor passes the last digit the value is stored as a temporary system variable.

3.2.2.4 Access Vars Array

This function allows access to variables stored in the system's memory. It is strongly recommended that before responding YES one carefully reviews what each variable represents (see chart below). It is strongly recommended that only experienced users familiar with this system and its limitations exercise this option.

****DO NOT ADJUST VARS ARRAY WITHOUT FIRST CONSULTING FACTORY!!!** Doing so can cause severe damage to the Furnace and could be very dangerous! If the message UNABLE TO LOAD VARIABLES should appear on the front panel display call Pond Engineering immediately for service.

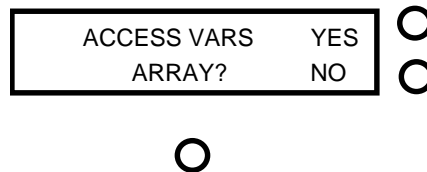


Figure 18 - Access Variables Array Prompt

Responding YES will cause Figure 19 to appear. This is to warn the user of the danger if this function is not used properly. Press Switch #1 to continue or Switch #2 to exit to the next function.

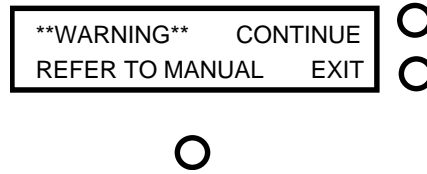


Figure 19 - Warning Prompt

Variables can be viewed and changed as shown below. The variables are not labeled. Please refer to the following chart for information about each variable.

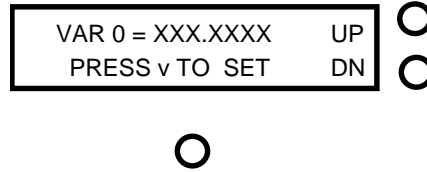


Figure 20 - Variable 0 Adjustment Prompt

Scrolling through the variables is accomplished by pressing either of the two switches to the right of the LCD, the switch adjacent to UP increments the variable number and the switch adjacent to DN decrements it. The command key located directly below the LCD is used to start the adjustment of the selected variable by advancing the cursor through the digits. Pressing the switch adjacent to the UP prompt shown in Figure 20 will cause the value of the selected digit to increment one, while pressing the switch adjacent to the DN will cause it to decrement by one. As the cursor passes the last digit the value is stored as a temporary system variable. ****WARNING** Software checking is not done for these entries and inputting values outside the recommended ranges can result in permanent damage to the system if utilized for operating the system.**

The following is a list of the variables and their locations.

#	Variable \Description	Default Values	Recommend Range
0	Setpoint Temperature	90.0000 degrees C	90 to 662 degrees C
1	Memory 0 Setpoint Temperature	90.0000 degrees C	90 to 662 degrees C
2	Memory 1 Setpoint Temperature	156.0000 degrees C	90 to 662 degrees C
3	Memory 2 Setpoint Temperature	232.0000 degrees C	90 to 662 degrees C
4	Memory 3 Setpoint Temperature	419.0000 degrees C	90 to 662 degrees C
5	Alarm Temperature	662.0000 degrees C	100 to 670 degrees C
6	GPIB Primary Address	6.0000	1.0000-30.0000
8	Hold core int at zero below threshold value		
9	Stable status indicator 0 to 3		
10	Core RTPW	See 6. Calibration Log	
11	Core A Coefficient	See 6. Calibration Log	
12	Core B Coefficient	See 6. Calibration Log	
13	Core C Coefficient	See 6. Calibration Log	
14	Shell RTPW	See 6. Calibration Log	
15	Shell A Coefficient	See 6. Calibration Log	
16	Shell B Coefficient	See 6. Calibration Log	
17	Shell C Coefficient	See 6. Calibration Log	
18	System Status		
20	ACCESS CODE for protected variables	0.0000	Call Factory

****Protected Variables****

#	Variable \Description	Default Values	Recommend Range
21	Proportional 1 Gain	5.0000	1.25 to 20.00
22	Integral 1 Gain	0.3000	0.075 to 1.200
23	Derivative 1 Gain	-150.0000	-600 to -50
24	Initialization Variable – Code Version 1.1	12.15	
25	Core Tight Control Band	0.0060	0.003 to 0.012
26	Drift Stability Test	0.0010	0.0005 to 0.0020
27	Integral 1 Maximum Increment	0.2000	0.1 to 0.4
28	Second Control Group Limit	10.0000	5 to 20
29	Core Clip Hold Off	4.0000	2 to 8
30	Proportional 2 Gain	0.5000	0.125 to 2.000
31	Integral 2 Gain	0.0300	0.0075 to 0.1200
32	Derivative 2 Gain	-15.0000	-60.00 to -3.75
33	Integral 2 Increment Maximum per ISR	0.0004	0.0001 to 0.0016
34	Time Average Gain	0.0300	0.0075 to 0.1200
35	Proportional 2 Limit	10.0000	2.5 to 40.0
36	Integral 2 Limit	10.0000	2.5 to 40.0
37	Clip Limit for Core Integral 1	0.0500	0.0125 to 0.2000
38	Core Feedback Gain to Integral 2	0.0003	0.000075 to 0.001200
39	Clip Limit for Core Derivative 1	100.0000	50 to 200
40	First Band for Gain Shift	0.3000	0.075 to 1.200
41	Integral 2 Offset	-2.0000	-8.0 to -0.5 degrees C
42	Configuration Variable- 488 Interface	0.0000	0 to 600
43	Gain Shift in Sec P&D at (.05 times normal)	0.0500	0.025 to 0.100
44	Integral 2 Gain Shift in Ultimate Stability Mode	0.3000	0.15 to 0.60
45	Ultimate Temperature Band	0.0020	0.001 to 0.004
46	Clip Limit for Feedback Variable	0.0050	0.0025 to 0.0100
47	Proportional 2	(current reading)	
48	Integral 2	(current reading)	
49	Derivative 2	(current reading)	
50	Core Proportional Gain 1	20.0000	10 to 40
51	Core Integral Gain 1	0.3000	0.15 to 0.60
52	Core Derivative Gain 1	-500.0000	-1000 to -250
53	Power Feedback	2.0000	0.5 to 8.0
54	Average Shell Temperature	(current reading)	
55	Core Proportional Signal	(current reading)	
56	Core Integral	(current reading)	
57	Core Derivative Signal	(current reading)	
58	Core Feedback to Shell Setpoint →Int 2	(current reading)	
59	Average Core Temperature	(current reading)	
60	Measured Core Temperature	(current reading)	
61	Measured Shell Temperature	(current reading)	
62	Measured Guard Temperature	(current reading)	
63	Measured Core Sensor Resistance	(current reading)	
64	Measured Shell Sensor Resistance	(current reading)	
65	Measured Guard Sensor Resistance	(current reading)	
66	Proportional Signal	(current reading)	
67	Integral Signal	(current reading)	
68	Derivative Signal	(current reading)	
69	PID2 sum, the Total Shell Setpoint Offset	(current reading)	

3.2.2.5 Save Changes to Variables

The user can now save the newly established system variables as the power-up default values. As mentioned earlier, the newly established system variables are stored as temporary system variables at this point, responding YES to this prompt causes the variables to be stored in non-volatile memory within the system controller to be utilized as the system variables the next time the system is turned on.

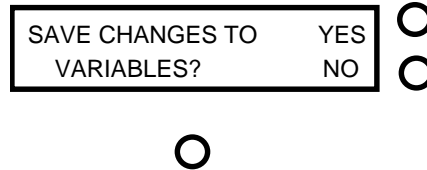


Figure 21 - Save Variables Prompt

Responding NO to this prompt causes the system to exit the function without saving the variables to non-volatile memory, allowing the user to temporarily establish new values for the system variables without permanently altering the default values. If the power were to be shut off or interrupted before the new information was stored into the non-volatile memory, the newly established values would be lost and the system would utilize the default values previously stored in non-volatile memory for the system variables at the time power was restored to the system. Following verification of performance of the newly established variable values, they may be stored by entering the ADJUST SYSTEM VARIABLES routine and responding YES to the SAVE CHANGES prompt when presented.

3.2.3 Diagnostics Display Mode Select

Here the user is given the opportunity to choose which set of information is presented by the display during operation. Two choices are presented, NORMAL DISPLAY and DIAGNOSTIC INFORMATION. The NORMAL DISPLAY mode is always presented upon system power up and is changed through this command function to allow display of DIAGNOSTIC INFORMATION by answering YES to the command function prompt shown in Figure 22.

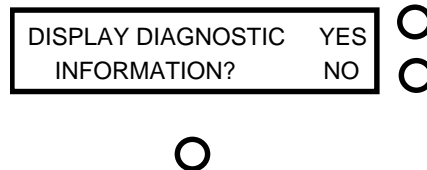


Figure 22 - Diagnostics Mode Display Prompt

If the system is currently displaying DIAGNOSTIC INFORMATION, the prompt will be modified to allow the user to toggle back to the NORMAL DISPLAY mode by answering YES to the command function prompt shown in Figure 23.

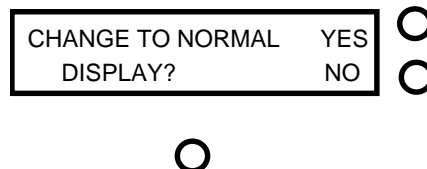


Figure 23 - Normal Mode Display Prompt

The DIAGNOSTIC INFORMATION display presents an array of numeric information for system diagnostics for the Primary and Secondary system control loops.

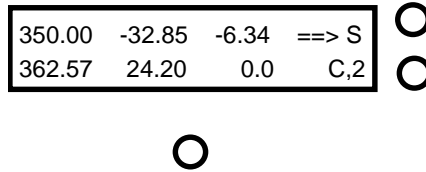


Figure 24 - Shell Loop Diagnostics Display

The information presented by this display is as follows. Top row from left to right: shell setpoint, shell proportional signal, shell derivative signal. Bottom row left to right: measured shell temperature, shell integrator signal, shell PID sum.

Pressing the button opposite the letters “C,2” on the display will allow the user to scroll to the next diagnostics display. An example of a core loop diagnostics display is shown in the figure below.

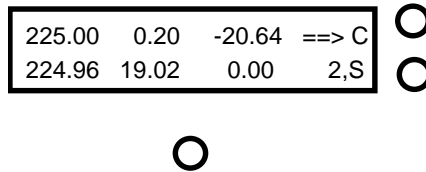


Figure 25 - Core Loop Diagnostics Display

The information presented by the core loop diagnostics display is as follows. Top row left to right: current setpoint, core proportional signal, core derivative signal. Bottom row left to right: measured core temperature, core integrator signal, and core PID sum.

Pressing the button opposite the letters “2,S” on the display will allow the user to scroll to the next diagnostics display. An example of a second loop diagnostics display is shown in the figure below.



Figure 26 - Second Loop Diagnostics Display

The information presented by the second loop diagnostics display is as follows. Top row left to right: current setpoint, second loop proportional signal, second loop derivative signal. Bottom row left to right: measured core temperature, second loop integrator signal, and second loop PID sum.

****Note: Once the DIAGNOSTIC INFORMATION mode has been entered the display will only present the diagnostic information; normal display mode can be obtained through the COMMAND FUNCTIONS options as described above.**

After completing all of the command functions as described above, the Furnace system will again return to the normal operating mode as described earlier.

4. Operating the Furnace Using a Remote Interface

If the Furnace has been equipped with an IEEE-488 Remote Interface any host computer that can be set up as a system controller may be used to operate the Furnace over the interface. Pond Engineering has software available for reading the Furnace variables by a IBM compatible or Macintosh computer with a National Instruments 488 interface card. Custom software packages are also available to integrate the Furnace into an automated lab. The system variables that can be accessed over the 488 and the command set recognized by the Furnace are listed below.

4.1 System Variable List

Please refer to section 3.2.2.4 *Access Vars Array* for a list of the system variables.

4.2 Furnace Command Set

The command set for the Furnace is outlined in the following paragraphs. The commands are issued from the host computer that acts as the controller. The Furnace acting as the slave listens when addressed as a listener, talks when addressed as a talker, and does not issue a service request (SRQ).

4.2.1 Read System Variable

The “READ “ command, called by sending a “R” (upper or lower case) followed by the two digit address of the variable, enables the user to read or interrogate the current values for system variables. The syntax for the read command is “Rxx”, where xx is the address of the variable to interrogate. The address must be two digits in length, therefore addresses less than 10 MUST HAVE LEADING ZEROS.

After receiving a read command, the Furnace will wait to be addressed as a talker to return the data at the read location over the bus. The Furnace has a one-second-write timeout, thus the controller in charge must read from the Furnace within one second after sending the R command to receive data. For example: If the user wants to see the value stored as the systems alarm temperature, the user would send the character string:

```
R05<cr>
```

The controller in charge would then address the Furnace as a talker and wait for the data to be returned.

****Note: The Furnace must maintain control of the Furnace core as the highest priority and may put off responding to 488 commands for as long as 500ms. The Furnace being addressed as a talker and not in the control cycle would return the alarm temperature (variable address 05), as follows:**

```
+4.300000e+02(space)05
```

The values returned are always in the above scientific format followed by a space and address number for the given value.

4.2.2 Write System Variable

The “WRITE” command, called by sending a “W” (upper or lower case) followed by the two digit address, a comma, and the desired new value, enables the user to write or set the values for system variables. The syntax for the write command is “Wxx,(value)”, where xx is the address of the variable and (value) is the new desired value for the variable. The format for (value) must have a positive or negative sign followed by a decimal number with at most seven significant digits not to exceed 15 digits in length.

For example: If the user wants to change the value stored as the alarm temperature to 225.345 °C, the user would send:

```
W05,+225.345<cr>
```

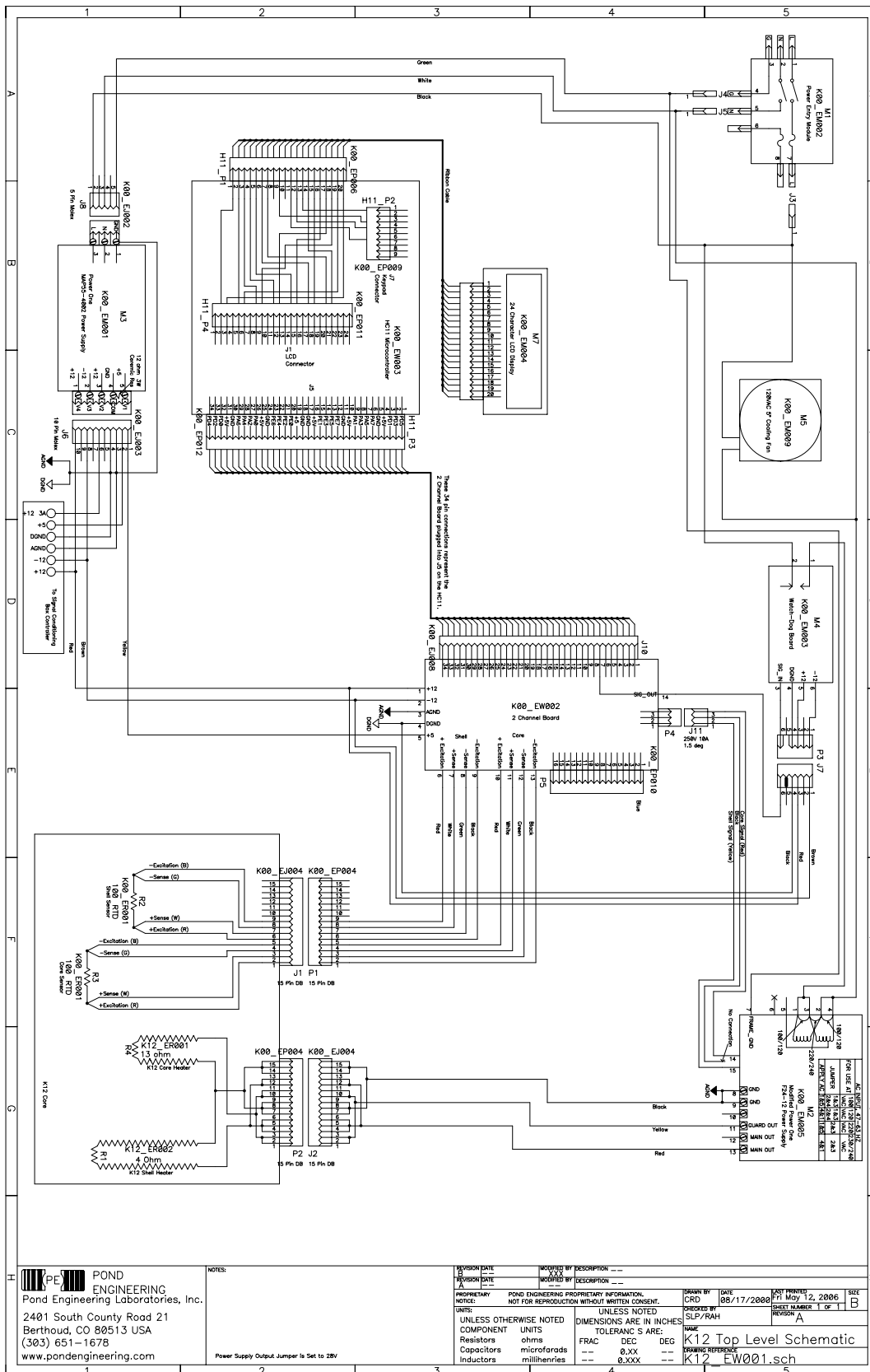
and the alarm temperature variable would then be set to 225.345°C.

****Note: As variables are written to the system the new value is immediately used by the system. However this new value is not stored as a permanent system variable until the user saves the variable using the “Save variables” command through the front panel. IMPORTANT! SAVING**

CHANGED VARIABLES WILL PERMANENTLY CHANGE THE SYSTEMS VARIABLES.
Pond Engineering strongly recommends the user keep a log of any changed variables. Also, Pond Engineering is in no way responsible for any damage caused by the failure to use these commands properly. DO NOT set a variable outside the recommended range.

In order to maintain flexibility the only variables that are limit checked are the Setpoint variables and the Alarm variables. All other variables can be set to any value received over the 488. Extreme caution must be used when setting any variable over the 488. The user should read back any variable after setting it to insure the Furnace received the variable correctly. This is especially important when setting the calibration RTPW and calibration coefficients, since an errant RTPW or coefficient may cause the Furnace to overheat and damage the Furnace core.

5.4 Schematic



6. Calibration Log

<u>Date</u>		<u>RTPW</u>	<u>Coef. A</u>	<u>Coef. B</u>	<u>Coef. C</u>
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				
	CORE				
	SHELL				