Model K44L

Low Temperature
Precision Comparison Furnace
Operation and Maintenance Manual

by
Pond Engineering Laboratories, Inc.
2401 South County Road 21
Berthoud, Colorado 80513
(303) 651-1678

www.pondengineering.com

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POND ENGINEERING
Pond Engineering Laboratories, Inc.
2401 S. County Road 21, Berthoud, CO 80513 USA
(303) 651-1678 FAX (303) 651-1668
http://www.pondengineering.com

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Pond Engineering Laboratories, Inc.
2401 S. County Road 21, Berthoud, CO 80513 USA
(303) 651-1678 FAX (303) 651-1668
http://www.pondengineering.com

Low Temperature Precision Comparison Furnace

1. Background

This report documents the operation and maintenance procedures for the Low Temperature Precision Comparison Furnace, Pond Engineering Model Number K44L.

Information contained in this manual is considered by Pond Engineering Laboratories to be proprietary and is provided for use exclusively by the purchaser for instructional and maintenance purposes relative to the hardware delivered, any other use is prohibited.

2. General Information and Operating Procedures

Figure 1 shows the general configuration of the Metrology Comparison Furnace and provides the reader a better visualization of its appearance, as well as a point of reference in location and use of the control switches and service points discussed later in this manual.

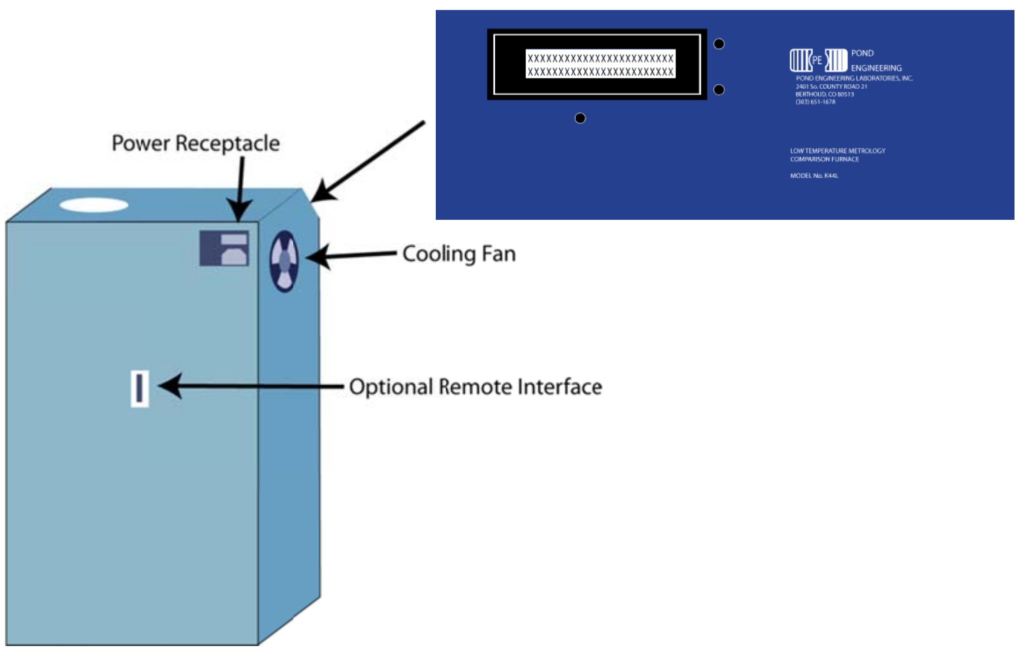

Figure 1- System General Layout, Rear View

As shown in **Figure 1**, the controller front panel is located on the sloping front surface of the Metrology Comparison Furnace. Metrology Comparison Furnace is designed to provide a stable and uniform temperature environment for the temperature range of 90 to 450°C. It provides seven test wells designed to accept up to 0.312" (7.9 mm) diameter thermometers. Overall well depth is approximately 12 inches with the Isothermal core surrounding the lower 6 inches of the wells.

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(303) 651-1678 FAX (303) 651-1668
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An optional RS-232 / USB interface can be installed at the factory to allow operation of Metrology Comparison Furnace as part of an integrated automatic calibration system. Custom software can be purchased from Pond Engineering for remote control of the Metrology Comparison Furnace. The comparison core is used to provide a uniform and stable environment for calibrating thermometers. The core also provides an environment to anneal the thermometers.

Interior access to the system cabinet is provided by a removable back panel attached to the frame by button head screws. **CAUTION: High voltage is present inside the furnace cabinet even when the power switch is in the off position.**

Operator interface is provided by three front panel switches and a 2 line by 24 character Liquid Crystal Display (LCD) located in the front panel of the Metrology Comparison Furnace as shown in **Figure 2**.

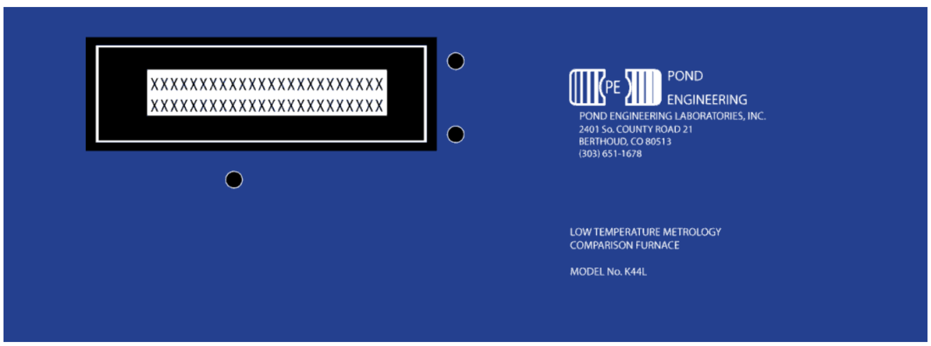

Figure 2 - Front Panel Layout

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 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.

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 prompting 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 is provided in the following text and figures, providing a detailed description of the prompts and user actions necessary to set up the system, edit configurations and operate the system manually.

Because of the multitude of functions which each switch will be called upon to 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 3** are for the benefit of the reader in understanding the documentation herein. Such labels do not appear on the device front panel.)

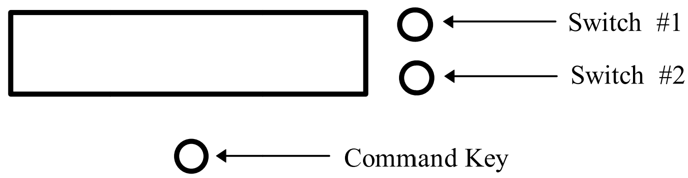

Figure 3 - Front Panel Switch Layout

3.1. Normal Operating Mode

In normal operation, the furnace controller will continuously display the current temperature set point for the controller and the measured core temperature on the first and second lines of the display, as shown in **Figure 4**. Measurements are taken at approximately 3-second intervals and the lower line of the display is updated following 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.

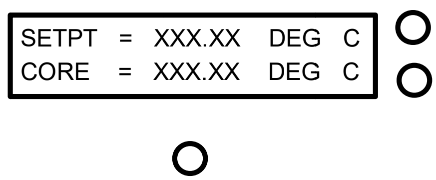

Figure 4 - Normal Operating Mode Display

3.2. The "Command Functions"

In order to perform the many functions necessary for operation, the user must leave the normal operating mode and enter the COMMAND FUNCTIONS mode. 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 and 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 should press and hold the Command Key until the words "COMMAND FUNCTIONS" disappear and then release the key.

****Note:** The system has been designed such that control functions operate normally even when the user is accessing the command functions.

3.2.1. Change Setpoint Temperature

The first command function accessed is CHANGE SETPOINT TEMPERATURE. This function is provided to allow the user to change the setpoint to one of three user adjustable memory setpoint temperatures or manually adjust the Setpoint Temperature. The three memory setpoint temperatures allow the user to customize their system by programming the memory setpoints to the three most frequently used setpoint temperatures. The memory setpoints are provided to allow the user to quickly change the setpoint temperature to one of these preset values (Adjusting memory setpoints is discussed in section **3.2.2.1.** Adjust Memory Setpoint Temperatures). When changing the setpoint to a value not preprogrammed in one of the memory setpoints the user may adjust the setpoint manually. The setpoint value may be set within the range of 90.00 to 450.00°C.

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(303) 651-1678 FAX (303) 651-1668
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As shown in **Figure 5**, 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 6** will be presented on the LCD.

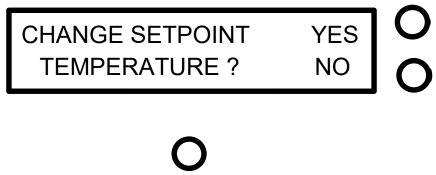

Figure 5 - Setpoint Access Prompt

The user may choose to select one of the memory setpoint temperatures by pressing the corresponding “YES” switch. A “NO” selection will advance the system to the next memory setpoint. A “NO” response to all of the three memory setpoint temperatures will allow the user to change the setpoint manually.

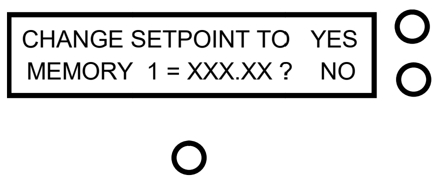

Figure 6 - Memory Setpoint Change Prompt

The 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 Command Key, located directly below the LCD, is used to advance the cursor to each of the digits. The current number presented on the display is used by the system controller as the current setpoint even while in the command functions mode.

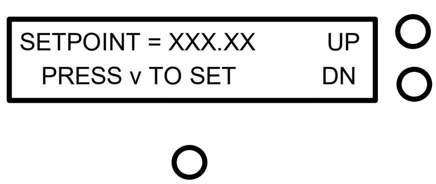

Figure 7 - Manual Setpoint Change Prompt

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

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(303) 651-1678 FAX (303) 651-1668
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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 as well as the calibration variables for the system core temperature measurement.

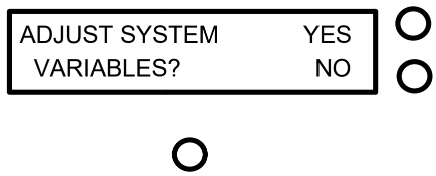

Figure 8 - System Variable Access Prompt

Pressing the switch by the display "YES" will allow access to the first system variable by presenting the messages shown in **Figure 9**, responding with a "NO" command will terminate the function and advance to the next command function.

3.2.2.1. Adjust Memory Setpoint Temperatures

The first variable accessed by the "adjust system variables" function is the "Memory 0" as shown in **Figure 9**. The "Memory 0" variable is the system startup setpoint. Responding "YES" to the prompt will allow the user to adjust the setpoint, a "NO" response will move to the next memory setpoint.

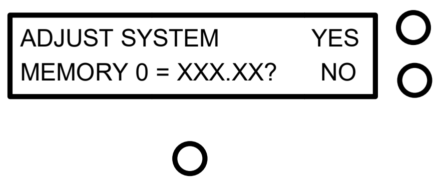

Figure 9 - Adjust Setpoint Memory 0 Prompt

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. The "COMMAND" switch, located directly below the LCD, is used to advance the cursor to each of the digits.

As the cursor is scrolled past the last digit, memory setpoint adjustment is completed and the user is advanced to the next memory setpoint. When all memory setpoint adjustments have been presented, the system advances to the next Command Function as described in the following section.

3.2.2.2. Adjust Alarm Temperature

The next variable accessed by this function is ALARM TEMPERATURE, the temperature at which the controller turns off the heater to prevent overheating the core. Adjustment is accessed by displaying the messages shown in **Figure 10**.

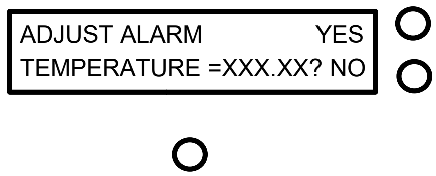

Figure 10 - Adjust Alarm Temperature Access Prompt

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

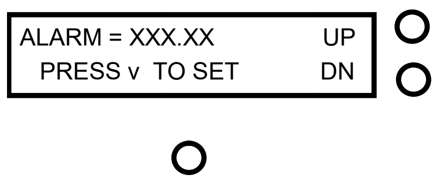

Figure 11 - Alarm Temperature Adjust Prompt

Modification of the variable is accomplished by pressing the two switches on the right of the LCD. The command key, located directly below the LCD, is used to advance the cursor to each of the digits. Pressing the switch adjacent to the "UP" prompt will cause the value of the selected digit to increment by one, while pressing the switch adjacent to the "DN" will cause it to decrement by one. The range of the variable is 100 to 460 degrees C. As the cursor passes the last digit the value is stored as a temporary system variable.

3.2.2.5. Change Upper/Lower Guard Temperature Offsets

These functions allow the user to adjust the upper and lower guard block setpoints by applying an offset to the system setpoint. The purpose of these offsets is to allow the user to adjust the temperature of the guard blocks positioned above and below the isothermal core in order to minimize or eliminate any gradients that may exist in the isothermal core. Changing these offsets results in a change in core temperature of approximately 1% of the offset value.

For example, measuring the core at 232°C and ~10.5" immersion measured 50mK warmer than the core at 12" immersion. Applying a lower guard offset of +5°C caused the temperature at 12" immersion to more closely match the temperature at 10.5" immersion.

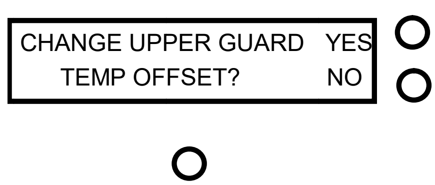

Figure 12 – Change Upper Guard Offset Prompt

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

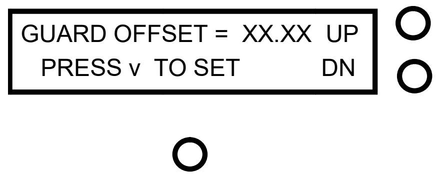

Figure 13 – Guard Offset Adjust Prompt

Modification of the variable is accomplished by pressing the two switches on the right of the LCD. The command key, located directly below the LCD, is used to advance the cursor to each of the digits. Pressing the switch adjacent to the “UP” prompt will cause the value of the selected digit to increment by one, while pressing the switch adjacent to the “DN” will cause it to decrement by one. The range of these offsets is -10 to +10 degrees C. As the cursor passes the last digit the value is stored as a temporary system variable.

3.2.2.5. 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 section **4.2.** System Variable List). 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.

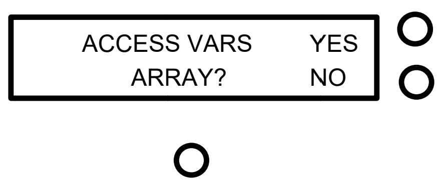

Figure 14 - Access Variables Array Prompt

Responding YES will cause the display shown in **Figure 15** 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.

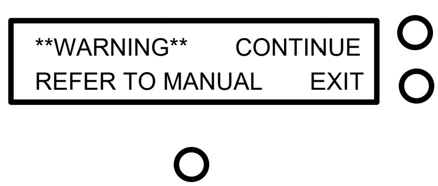

Figure 15 - Warning Prompt

Variables can be viewed and changed as shown below. The variables are not labeled. Please refer to the chart in section **4.2.** System Variable List for information about each variable.

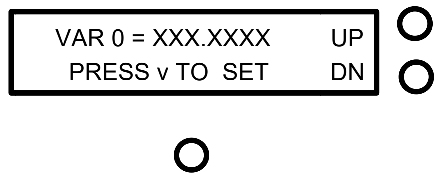

Figure 16 - Variable Adjustment Prompt

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 16** 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.**

3.2.2.6. Save changes to Variables

Here the user is given the opportunity to 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 the non-volatile memory within the system controller. The variables will then be utilized as the system’s power on defaults.

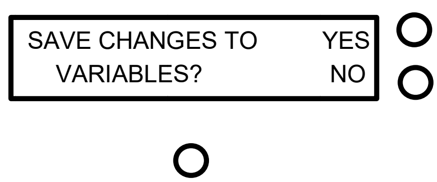

Figure 17 - Save Variables Prompt

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 in the non-volatile memory, then the newly established values would be lost and the system would utilize the default values. Following verification of performance of the newly established variable values, they may be stored by entering the “ADJUST SYSTEM VARIABLES” routine, stepping through the prompts and responding “YES” to the “SAVE CHANGES” prompt.

3.2.2.7. 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 control function to allow display of “DIAGNOSTIC INFORMATION” by answering YES to the command function prompt.

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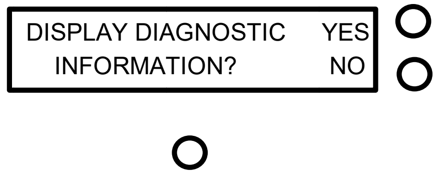

Figure 18 - Diagnostics Mode Display Prompt

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

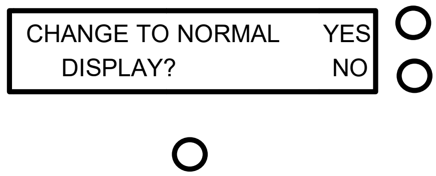

Figure 19 - Normal Mode Display Prompt

The “DIAGNOSTIC INFORMATION” display presents an array of numeric information for system diagnostics for the “CORE” zone as well as the “UPPER GUARD” and “LOWER GUARD” zones. An example of the core diagnostic information is shown below in **Figure 20**.

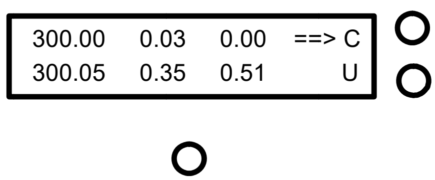

Figure 20 - Core Diagnostics Display

The information presented by this display is described in **Table 1**. Pressing switch #2 will allow the user to scroll through the next diagnostics displays. For example, while in the core diagnostics pressing the switch opposite the Letter “U” will allow the user to scroll to the upper guard diagnostics.

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Table 1 - Diagnostic Data Layout

Core Diagnostics				
	Left Position	**Center Left Position**	**Center Right Position**	**Right Position**
Top Row	Furnace Setpoint (°C)	Core Proportional Signal (V)	Core Derivative Signal (V)	==>C
Bottom Row	Measured Core Temperature (°C)	Core Integrator Signal (V)	Core Heater Voltage (V)	U

Upper Guard Diagnostics				
	Left Position	**Center Left Position**	**Center Right Position**	**Right Position**
Top Row	Upper Guard Setpoint (°C)	Upper Guard Proportional Signal (V)	Upper Guard Derivative Signal (V)	==>U
Bottom Row	Measured Upper Guard Temperature (°C)	Upper Guard Integrator Signal (V)	Upper Guard Heater Voltage (V)	L

Lower Guard Diagnostics				
	Left Position	**Center Left Position**	**Center Right Position**	**Right Position**
Top Row	Lower Guard Setpoint (°C)	Lower Guard Proportional Signal (V)	Lower Guard Derivative Signal (V)	==>L
Bottom Row	Measured Lower Guard Temperature (°C)	Lower Guard Integrator Signal (V)	Lower Guard Heater Voltage (V)	C

****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" option as described above.**

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

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4. Operating the Temperature Calibration Furnace Using Remote Interface Commands

The Model K44L Temperature Calibration Furnace can be equipped with an RS-232/USB remote interface connection. Any computer, with a compatible port may be used to operate the furnace over this interface. Pond Engineering has software available for reading the furnace variables using an IBM compatible or Macintosh computer with a USB or RS-232 port. Custom software packages are also available to integrate the furnace into an automated lab. The system variables which can be accessed over the remote interface and the command set recognized by the furnace are in the following sections.

4.2. System Variable List

Below is a list of all system variables, their default values, and the recommended value range. Refer to this list when making any variable changes.

#	Variable/ Description	Default Values	Units	Recommended Range
00	System Setpoint Temperature	--	°C	90.00 to 450.00°C
01	Memory 0 Setpoint Temperature	90.00	°C	90.00 to 450.00°C
02	Memory 1 Setpoint Temperature	156.00	°C	90.00 to 450.00°C
03	Memory 2 Setpoint Temperature	232.00	°C	90.00 to 450.00°C
04	Memory 3 Setpoint Temperature	419.00	°C	90.00 to 450.00°C
05	Alarm Temperature	460.00	°C	100.00 to 460.00°C
06	*Unused*	--	--	--
07	Upper Guard Offset	0.00	°C	-50 to 50 °C
08	Lower Guard Offset	0.00	°C	-50 to 50 °C
20	Protected Variable Access Code	0.00	--	Contact Pond Engineering
21	Core PRT Resistance at TPW	0	ohms	Calculated – See Cal Log
22	Core Calibration Coefficient A	0	--	Calculated – See Cal Log
23	Core Calibration Coefficient B	0	--	Calculated – See Cal Log
24	Core Calibration Coefficient C	0	--	0
30	U Guard PRT Resistance at TPW	0	ohms	Calculated – See Cal Log
31	U Guard Calibration Coefficient A	0	--	Calculated – See Cal Log
32	U Guard Calibration Coefficient B	0	--	Calculated – See Cal Log
33	U Guard Calibration Coefficient C	0	--	0
39	L Guard PRT Resistance at TPW	0	ohms	Calculated – See Cal Log
40	L Guard Calibration Coefficient A	0	--	Calculated – See Cal Log
41	L Guard Calibration Coefficient B	0	--	Calculated – See Cal Log
42	L Guard Calibration Coefficient C	0	--	0
83	U Guard Heater Max Voltage	45	V	0 to 48V
85	L Guard Heater Max Voltage	26	V	0 to 48V
87	Core Heater Max Voltage	45	V	0 to 48V
90	Sensor Calibration Mode Select	0	--	0 = inactive, 1 = active

READ ONLY VARIABLES

#	Variable/ Description	Default Values	Units	Recommended Range
57	Measured Core Resistance	--	ohms	--
58	Measured L Guard Resistance	--	ohms	--
59	Measured U Guard Resistance	--	ohms	--
63	Measured Core Temperature	--	°C	--
64	Measured Core Temperature	--	°C	--
65	Measured Core Temperature	--	°C	--

4.3. Metrology 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).

4.3.1. 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 time-out, 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

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 remote commands for as long as 500 ms. 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.

4.3.2. 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 be decimal 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 300 °C, the user would send:

W05,300

and the alarm temperature variable would then be set to 300 °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 users 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 variable. All other variables can be set to any value received over the remote interface. **Extreme** caution must be used when setting any variable over the remote interface. The user should read back any variable after setting it to insure the variable was received by the furnace correctly. This is especially important when setting the RTPW's and calibration coefficients, since an errant RTPW or coefficient may cause the furnace to overheat and damage the furnace core.

POND ENGINEERING
Pond Engineering Laboratories, Inc.
2401 S. County Road 21, Berthoud, CO 80513 USA
(303) 651-1678 FAX (303) 651-1668
http://www.pondengineering.com

6. Calibration Procedure

In the event that the internal temperature sensors drift out of calibration, they can be field-calibrated by following the procedure outlined in this section.

6.1 Enabling Calibration Mode

To start the calibration procedure, it is necessary to access the Vars Array and enable calibration mode. Calibration mode causes the system to disable the heaters in the lower guard while the lower guard sensor is used in the calibration.

Calibration mode is enabled by changing variable 90 from a value of 0 to a value of 1. Note that this is a protected variable, and the password (variable 20) must be entered and saved in order to change the calibration mode variable.

After saving the variables and exiting the command functions, the system will return to the normal display. In calibration mode, the normal display shows the current measured resistances of each of the three control sensors. At this point, the calibration procedure may begin.

6.2 Calibrating the Core and Lower Guard Sensors

Once calibration mode is enabled, the lower guard sensor should be moved to be at the same immersion as the core sensor – approximately 9.5" from the top of the cabinet. A working standard should also be inserted in the center well with the sensing element centered at this same depth.

Calibration is then performed using a two-point calibration at 232°C and 419°C. Once the calibration resistances and coefficients are calculated and verified, they are loaded into the appropriate variables and saved.

6.3 Calibrating the Upper Guard Sensor

Due to the shallow immersion depth of the upper guard block, it is very difficult to perform the calibration of the upper guard sensor using a working standard as a reference. To minimize the effect of stem conduction, the upper guard calibration is performed using the lower guard sensor as the calibration standard.

To calibrate the upper guard sensor, both the upper and lower guard sensors must be placed near the bottom of the guard block. To do this, the upper guard sensor must be pulled up ~0.25", and the lower guard placed at ~5.25" below the top of the cabinet.

Calibration is again performed using a two-point calibration at 232°C and 419°C, this time using the lower guard sensor as the calibration standard. Once the calibration resistance and coefficients are calculated and verified, they are loaded into the appropriate variables and saved.

6.3 Returning to Normal Operation

Once the calibration is complete, the system can be returned to normal operation mode by changing variable 90 back to a value of 0 and saving the variable. Be sure to re-protect and save the variables once finished.

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2401 S. County Road 21, Berthoud, CO 80513 USA
(303) 651-1678 FAX (303) 651-1668
http://www.pondengineering.com

7. Calibration Record

Core	Date	Upper Guard	Date	Lower Guard	Date	Comments

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(303) 651-1678 FAX (303) 651-1668
http://www.pondengineering.com

8. K44 System Schematic

The following page contains a schematic of the overall system.