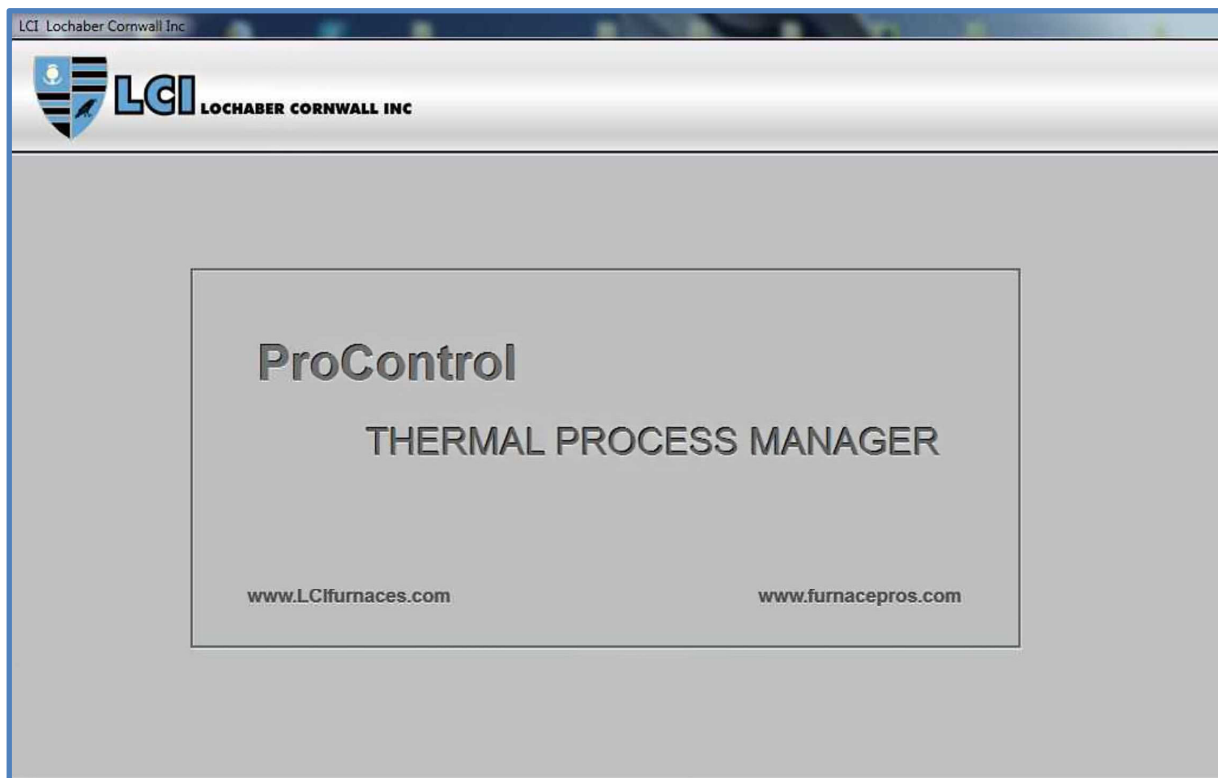




ProControl Furnace Software

Owner's Manual

Revision 1



Setup, Operation, Theory & Troubleshooting Guide

This Owner's Manual contains product information specific to the newly installed equipment and software. In addition, this manual contains information regarding features and options which may or may not be included in your furnace system.

Continuous Belt IR Furnace Software

Owner's Manual

Rev. 1

Model: ProControl

Build: 13.1218

Part No. 676-110000-01 CD

Part No. 676-110000-02 Loose Leaf

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TABLE OF REVISIONS

Rev	Sections	Description	Date
0	All	Initial Release	12/08/2017
1	All	LTSC Update	11/15/2021

WHAT IS IN THIS MANUAL

This manual covers upgrade software for computer-controlled models manufactured by RTC and controlled with a programmable logic controller (PLC). This Owner's Manual contains your product information and warranty as well as installation, startup, operating instructions specific to the equipment purchased. In addition, this manual may contain information regarding features and options which may or may not be included in your furnace system. The Owner's Manual is to be used in conjunction with the RTC Owner's Manual, RTC Continuous Belt IR Furnace Reference Manual and Dell Computer Product Information Guide to assure the equipment is installed and operated according to manufacturer's instructions.

Study this manual carefully, particularly regarding proper operation and limitations of the furnace equipment for reliable results and long life. Experience has shown that operators who master the contents of this manual can become expert in understanding the process system capabilities of our infrared furnaces. In doing so, many are able to push the initial process performance envelope and thus achieve higher degrees in both process reliability and throughput than previously anticipated.

Note that throughout this manual the equipment is generally referred to as a furnace. A dryer is a furnace with only the top lamp elements installed or operated.

The manual uses LA-309 and LA-310 interchangeably throughout. The LA-309 is an updated version of the LA-310 using the same design furnace chamber and cooling section.

EQUIPMENT LIST

The following equipment was shipped with the furnace.

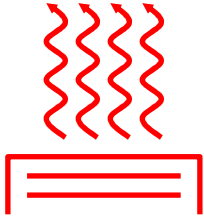
Qty	Unit	Description	Part Number
(1)	ea	ProControl Furnace Software System configured for the specific IR Furnace and consisting of the following equipment:	FO-676-110000
(1)	ea	Furnace Computer, Dell Optiplex or Precision	Required, See Service Tag
(1)	ea	Monitor, Dell Professional 17" LCD Flat Panel Monitor (std 4:3, 1024x768) VGA and/or HDMI	Required
(1)	ea	Keyboard, USB English, Black	Required
(1)	ea	Mouse, USB Optical	Required
(1)	ea	Power Supply, 5 Vdc, 5A	322-094408-103
(1)	ea	Ethernet surge protector (PoE)	Recommended option
(1)	ea	VGA or HDMI cable	Required
(1)	ea	USB A-B cable	Optional
(1)	ea	Ethernet Crossover cable	Required
(1)	ea	Ethernet Standard Cat 5 cable	Recommended option
(1)	ea	CD Media, ProControl™ Furnace software backup disk with manuals	676-110000-01
(1)	ea	Software Manual, Reference, Perfect Bound	676-110000-02 (optional)

GENERAL SAFETY GUIDELINES

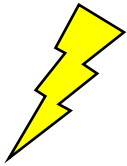
The following set of guidelines is intended to create awareness of potential health and safety hazards.

Normal Good Laboratory Practice

Normal good laboratory practices apply to the operation of IR furnaces. Do not use the space above the furnace as storage. Do not block the cabinet doors preventing the cooling of the electronic equipment inside. Do not operate with side covers off as this will prevent normal cooling of the electronic equipment thus voiding the warranty. Tuck electrical cords out of the way. Do not store flammables in the vicinity of the furnace and especially while operating the furnace with an oxygen atmosphere.



HIGH TEMPERATURES. In general, the operation of any furnace may expose operators or maintenance technicians to the risk of burns. After being processed in an infrared furnace, customer product may still be dangerous to handle. Each owner is responsible for providing a safe work environment and proper training in the handling of material being processed in a furnace.



ELECTRICAL SHOCK HAZARD. IR furnaces operate at high voltages. Operation with side covers off constitutes a safety hazard. Ensure that main power is off while side covers are removed.

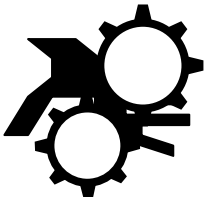
Electrical shock hazards exist for those technicians who service the furnace. High voltages are required to operate the furnace and precautions must be taken to reduce the exposure to these elements. Again, it is the responsibility of the furnace owner to assure that only properly trained service technicians, familiar with high voltage operations be allowed to service the equipment



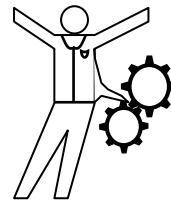
EXPLOSION Explosive dangers may exist in the high temperature process environment of the furnace. If the furnace operates with process gas containing hydrogen, measures must be taken to avoid the dangers of explosion. Furthermore, improper gas flow balance may draw oxygen rich air into the furnace, mixing with effluent gases and material from products, also creating a hazardous environment.



HAZARDOUS MATERIALS. Persons performing maintenance tasks such as replacement of lamps may become exposed to silica fiber compounds. Such tasks should be performed by qualified persons wearing gloves, eye protection and a facemask to prevent inhalation of particulates.



ROTATING EQUIPMENT. Roller dangers exist when working around the conveyor belt of the furnace. Care should be taken not to place hands or garments on or near the belt drive mechanisms when the conveyor system is operating as roller crush may occur. Operators should avoid walking near the open ends of the conveyor belt. Those who must be near the moving parts should wear close fitting clothing.



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1.1 Installation Requirements

This instruction applies to installation of replacement computer system with updated ProControl Furnace software on a Microsoft Windows 10 computer on LCI, FurnacePros and RTC IR furnaces with Opto22 LCM4 controller and SNAP or G4 racks and I/O.

1.2 Tools and Parts

Following is a list of items required for a successful installation. Some items may not be supplied with the computer, but nevertheless should be included.

Required	Optional
Furnace Computer	USB-A to USB-B Cable (optional depending on location of computer, connect computer to monitor)
Opto22 LCM4 Controller with M4SENET-100 Ethernet card	Ethernet surge protector, PoE (optional)
1024x768 Monitor (Standard 4:3) with USB (VGA or HDMI to match computer port)	Ethernet Cable, standard, 1 meter (optional to connect surge protector to LCM4)
VGA or HDMI cable (2-5 meters to run from computer to monitor)	Drill motor drill bit and screwdriver (to attach surge protector)
Ethernet Cross-over Cable (2-5 meters to run from computer to LCM4)	
USB Keyboard, USB Optical Mouse, mousepad	

1.3 Schematic

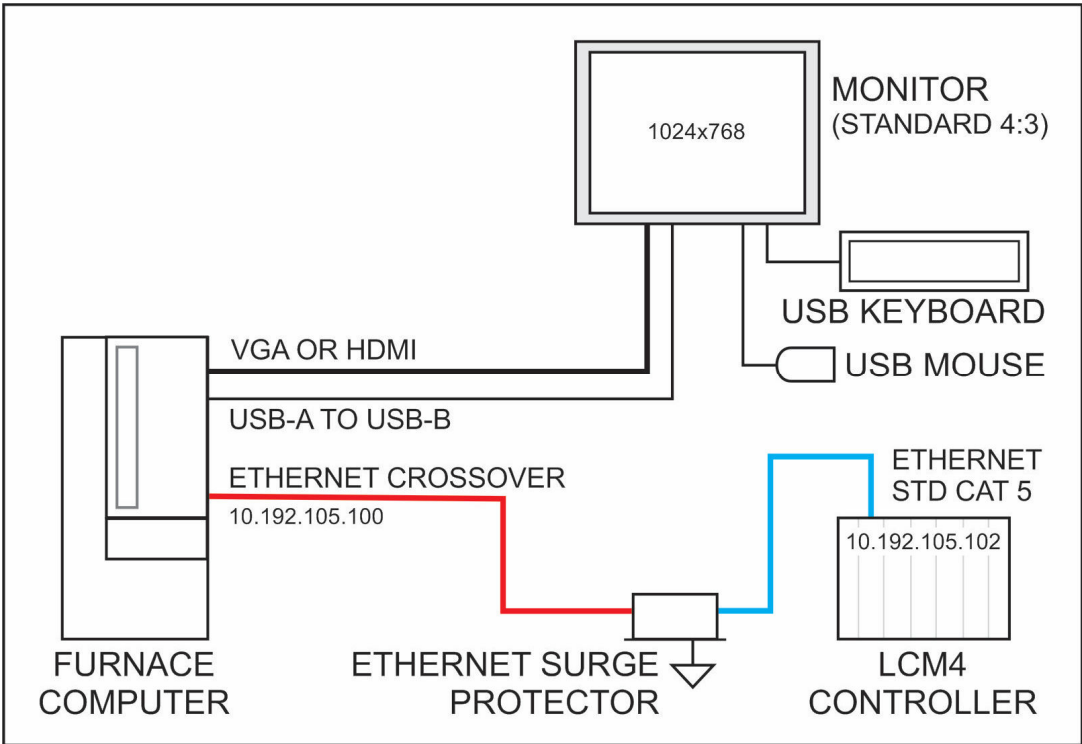


Figure 1-1 Furnace Computer Schematic

1.4 Installation

- 1) Disconnect and remove existing computer.
- 2) Position new computer and secure with ready access to power button and optical drive.
- 3) Connect standard (4:3) monitor VGA (or HDMI) and USB ports to computer (see fig 1-1).
- 4) Connect USB keyboard and USB mouse to monitor USB ports.
- 5) Connect computer and monitor to 117V power source (can be unswitched, or switched with furnace ON).

CAUTION: ELECTROSTATIC SENSITIVE DEVICE

Make sure you discharge any static charge before touching LCM4 Controller. Even a slight discharge can result in severe damage to the controller.

- 6) Connect LCM4 Controller to computer using Ethernet crossover (red or orange) cable. Plug the crossover cable into Ethernet port on computer motherboard (not aux card port). Plug other end in either an Ethernet Surge Protector (recommended) or directly into Ethernet port on the LCM4 controller. If an Ethernet Surge Protector is used, the cable between the surge protector and the LCM4 controller must be a Standard Ethernet (CAT5 or higher) cable.
- 7) Do not connect furnace computer to the internet, except if so instructed by the factory for troubleshooting.

1.5 Initial Startup

- 1) Start Furnace. Turn ON computer and monitor if they do not power up with furnace. Note Windows startup is delayed slightly to allow controller to boot first.
- 2) Furnace program loads automatically. Exit furnace program (right click on LCI app in the taskbar and select close window, Yes).
- 3) Click on Download icon (on desktop, toolbar, or start menu). Click OK to close Download Completed window.
- 4) Start Furnace program using furnace icon (on desktop, toolbar, or start menu).
- 5) Furnace program loads a factory default recipe. This is NOT the same as a default recipe that may be found in the R:\ directory.
- 6) On Security screen, select User or Engr from user. Enter password (1 for operator, 2 for engineer). Engineer level allows creation of new users at Engineer or Operator level.
- 7) On Recipe screen, in Send to Furnace window, click Send from Disk and select from list. Recipe in Furnace window will change to selected recipe.
- 8) Go to Process screen, operate furnace belt. Check belt speed. If inaccurate, go to Maintenance/Calibrate and calibrate belt (see section 3.9.3 Belt Speed Measurement and 3.9.4 Belt speed Calibration).
- 9) Go to Process screen, operate furnace normally.

1.6 Screen Resolution

The furnace program is designed for a fixed resolution of 1024x768. If the Process screen does not fill the monitor screen, right click on the desktop and select Display Settings. Use the Resolution dropdown and select 1024x768. Close Display Settings window.

1.7 Windows 10 LTSC

Microsoft Windows 10 LTSC is a Long-Term Service Channel designed for medical and industrial applications where stability and reliability are the priority. This version has a 10-year update cycle. Once properly configured, the OS does not need to be updated and, in fact, updates post installation updates can cause the computer to fail to operate with the furnace properly.

1.8 Network and Internet

The furnace uses a private network and is normally connected to the primary Ethernet port on the computer motherboard. A second Ethernet port or USB WiFi can be used to connect to a network or the internet. Only connect the computer to the internet if so instructed by the factory to facilitate remote troubleshooting. TeamViewer has been installed on the computer to allow the factory to connect to the computer remotely for troubleshooting purposes.

1.9 Troubleshooting

Download. If Download fails, perform the following, checking Download after each change:

- 1) Unplug and reinsert the Ethernet cables. Check Download.
- 2) Verify cable to furnace is a cross-over cable and is plugged into the motherboard Ethernet port.
- 3) Verify the motherboard Ethernet port is addressed 10.192.105.100 (subnet 255.255.255.0)
- 4) Make sure LCM4 controller starts and is up and running before computer furnace program loads. If both furnace and computer start together, the Opto22 controller will normally be up and running before the furnace program completes loading.

1.10 Remote Troubleshooting

If the factory is to provide remote support:

- 1) Connect furnace to internet.
- 2) Turn furnace on.
- 3) Start TeamViewer. Provide factory with ID and password.
- 4) Factory can proceed to connect to the furnace computer.

1.11 Factory Controls Upgrade Tasks

1.11.1 Prepare New Computer and PLC Interface Components

The following items were completed by FurnacePros at FurnacePros facility:

- 1) Configure Window®10 LTSC OS and load furnace control software.
- 2) Load and test furnace software on LCM4.
- 3) Collect installation cables and hardware if included in kit.

1.12 On-Site Startup Tasks

Tasks typically performed during startup by the Service technician include:

- 1) Prepare the machine for operation.
- 2) Apply power and bring up the machine to a fully operational state.
- 3) Verify PROCESS READY by starting furnace.
- 4) Verify Software operation, logging, recipes, and alarm functions.
- 5) Run through the installation test and checkout procedure.
- 6) Verify Belt Speed
- 7) Verify Warm-up and Process Ready
- 8) Verify low pressure alarm settings and alarm functions
- 9) Identify and report any deficiencies noted in the installation of the machine.
- 10) If training has been included, a manufacturer's representatives shall train the appropriate personnel in the customer's plant on furnace startup, shutdown, operation and necessary preventive maintenance at the furnace.
- 11) Replace Covers. Before operation for production, install any covers that were removed during the functional checkout.

NOTE: All functions must operate properly before continuing. Refer to the Service Information section and correct any malfunctions before proceeding.

- 12) Turn over the machine to operations.

EQUIPMENT OPERATION

2.1 Power Controls and Indicators

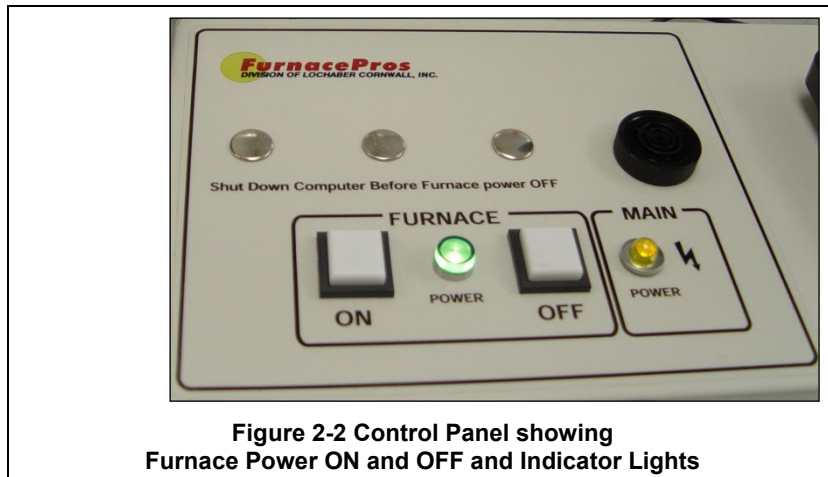
2.1.1 Power Status Indicators

A. MAIN POWER ON (White Indicator)

This lamp burns continuously whenever power is available to the furnace and the main circuit breaker (optional) is turned on.

B. FURNACE POWER ON (Green Indicator)

This lamp burns continuously when the control circuits are energized, and indicates that power is available to actuate the control circuits.



C. ALARM HORN -Black Audible Alarm

This horn provides audible feedback for furnace system alarm conditions.

D. UCD - Fill, Run & Drain Indicating Lamps – (optional equipment)

Lamps light to indicate status of Ultrasonic Cleaner Dry system.

E. USB Ports

At least two (2) USB 2.0 port are provided on professional monitors for connection of keyboard and mouse. Otherwise connect to computer tower rear USB ports. USB 2.0 ports are also provided on the front of the furnace computer for connecting profiling equipment.

2.1.2 Power Console

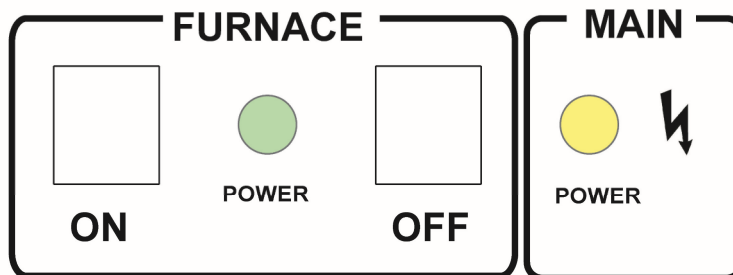


Figure 2-3 Furnace Power Control & Indication

Section 2

A. MAIN FURNACE POWER

Table 2-1 Main Furnace Power		
MODE	ON	OFF
MAIN FACILITY BREAKER	Power to TR0 only: 1. MAIN POWER light (white) on 2. PC-S1 and PC-S2 sockets live for PC and monitor	No power to furnace, computer or monitor
EMO SWITCHES  Typical EMO	Operator activated Emergency Power Off switch located at furnace entrance and exit immediately cuts power to furnace and PLC controller. Computer and monitor stay on. Rotate EMO knob to reset. FURNACE POWER ON button must be pressed to re-introduce power. Make sure all switches are in closed or furnace will not start.	
EPO PANEL SWITCHES 	For maintenance purposes only, pulling out on all exposed interlock switches will allow operation of the furnace. FURNACE POWER ON button must be pressed to re-introduce power. Make sure all switches are in closed or furnace will not start.	If a lower panel is removed, emergency power interlocks will automatically cut power to furnace, including PLC controller. Computer and monitor stay on.

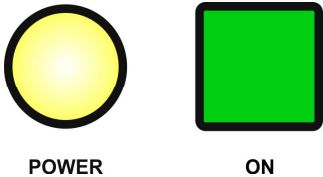
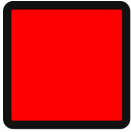
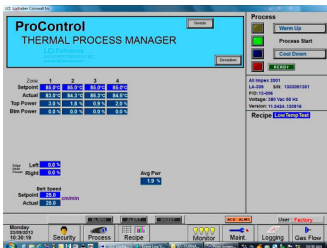
Table 2-2 Furnace Control Switches & Indicators		
MODE	ON	OFF
MAIN POWER ON  POWER	Lamp illuminates indicating that 3-phase power is connected to the furnace and the main disconnect switch is ON.	No power to furnace, computer or monitor
FURNACE CONTROLS ON 	Power to furnace and furnace PLC controller. Pressing this momentary switch causes the furnace to go through its power up sequence, providing the MAIN POWER lamp is lit and the EMOs (Emergency Power Off switches) and interlocks located in the doors are released. 24 Vac controls active only if EMO and panel interlocks allow: 1. K2 mechanical relay latches up, FURNACE POWER light (green or yellow) on.	Cuts power to furnace and furnace PLC controller. Pressing the OFF button causes the furnace to begin a timed power shutdown sequence. The heaters are shut down immediately. After Cool-Down (below 100°C), the fans, transport belt, and other functions are shut down. 1. K2 mechanical relay turns off entire control system. 2. K6 mechanical relay turns off. Belt motor, Opto22, gas supply valves, EM, and hour meter stop instantly, unless

Table 2-2 Furnace Control Switches & Indicators		
MODE	ON	OFF
FURNACE CONTROLS OFF  OFF  POWER	2. K6 mechanical relay sends switched 117 Vac power to belt motor, Opto22, gas supply valves, EM, and hour meter. 3. K3 contactor energizes phase transformers TR1, TR2 & TR3; all 117 and 24 Vac power control signals and accessories turn on.	COOL DOWN clicked on PROCESS screen prior to OFF button being pushed. 3. K3 contactor turns off. All 117 Vac and 24 Vac control signals and accessories stop instantly, unless COOL DOWN clicked on PROCESS screen prior to OFF button being pushed. 4. K1 lamp contactor shuts off, removing power to lamps and edge heaters.
POWER FAILURE		Cuts power to furnace, including computer and monitor.

2.1.3 Computer Power

The computer monitor can be wired to be switched or unswitched. In either configuration, computer should start when furnace is started.

Table 2-3 Furnace Software		
SOFTWARE MODE	WARMUP	COOL DOWN
PROCESS SCREEN 	If FURNACE POWER is ON, 1) energizes lamps and edge heaters via K1 lamp contactor, If FURNACE POWER is OFF, no effect	If furnace is in WARM UP or PROCESS READY modes, 1. provides power to K6 mechanical relay and K3 contactor until temperature reading in all zones < 100C; then 2) shuts off K6 and K3 (see FURNACE POWER button OFF), Otherwise no effect

COMPUTER SWITCHED. Computer starts when furnace ON button is pressed. Computer is disconnected when furnace OFF button is pressed. In this configuration, make sure computer is shut down first before the furnace itself is shut down or damage can occur to the computer Windows® operating system.

Caution: In the switched configuration, pressing FURNACE POWER OFF on the Furnace Console will cut power to the computer. Always shut down the computer first using normal Windows® shut down procedure.

COMPUTER UNSWITCHED. In this configuration the computer and monitor are wired to remain ON unless either is individually shut down at the computer or monitor or if main power is removed from the furnace. This mode offers the best protection for the computer operating system, files and hard drives. Power to the computer is supplied when facility power is supplied to the furnace. The computer will start automatically when power is applied to the computer. Otherwise, the momentary power button on the front of the computer must be pressed to start the computer.

Note: In the unswitched configuration, pressing FURNACE POWER OFF on the Furnace Console will not cut power to the computer or monitor. Shut down computer using normal Windows® shut down procedure.

Section 2

2.2 Starting the Furnace

2.2.1 Main Power Indicator

The MAIN POWER indicator must be lit to make sure facility power is provided to the furnace.

2.2.2 Process Gas Pressure

Assure that clean dry compressed process gas is supplied to the furnace at a minimum of 4.8 bar (70 psig). Compressed gas must be delivered to the furnace walls, exit stack venturi and belt tensioners for proper operation of the furnace. If furnace is supplied with Auto Gas Shutoff feature, process gas will flow when Furnace Power ON is pressed.

2.2.3 Power On/Startup

Follow the steps per the STARTUP table to start the furnace. See section 0 if restarting from Auto Shutdown

Table 2-4 Starting the Furnace	
1. Main Power	Verify the white Main Power ON button is lit. Furnace Disconnect switch should be ON, all panels in place and EMO switches reset.
2. Furnace ON	Press Furnace Controls ON button. Green or Yellow Furnace Controls Power light illuminates. Power is provided to the furnace controller.
4. Monitor ON	Press the power button on the monitor if the monitor ON/OFF button is not lit or you do not see the logo screen.
3. Computer ON	If the computer does not start automatically, open the computer enclosure door, press the Computer start button on the tower to start the computer. The computer boots up and the logo screen is displayed. Furnace software starts. Computer and PLC begin to communicate.
5. Start Program	Press Furnace program icon to initialize communication with the PLC and start the furnace program.
6. Log-In	Log in to furnace software. Log-in is only possible when PLC and Computer are communicating.



CAUTION: Dangerous voltages are now present throughout the electrical systems of the furnace. Make sure that any probes in the furnace are placed on the belt surface only. Probes extending over the sides of the belt may contact high voltage terminals!

2.2.4 Fans

Check that the cabinet cooling exhaust fans, and optional cooling tunnel exterior fans and product cooling fans are turning. If the exhaust for the furnace is located on the bottom of the machine, it is important to have the bottom impeller fan speed greater than or equal to the speed of the top fan to allow the cooling system to work properly.

2.2.5 Screen Menu Bar (located at bottom of screen)

The Screen Menu Bar allows operator to select the desired screen by moving the cursor and clicking on the chosen screen button. Note: Menu bar will vary according to furnace features and user log-in level.



Figure 2-4 Screen Button Menu

2.2.6 Furnace Log-on and Initial Operation

Select “Security” button to access the “Security and User Information” screen.

A. Security and User Information

The Security and User Information screen allows the operator to select access level, log-on or log-off, add or delete users, and modify password and access codes.

B. Access Level

Select Access Level by clicking on the User List, click Log-On and enter the appropriate password and select Ok.

The system is shipped with three (3) access levels, each with its own password. See the Furnace Reference Manual, Chapter 5 Software, for information on managing users and passwords.

Figure 2-5 Security Screen, Log-on

- | | |
|--------------------------|--|
| Access Level 1 password: | 1. Operator level, and allows the operator to load and run a recipe and initiate a process. (Initial password is set to “1”.) |
| Access Level 2 password: | 2. Tech/Engr level. It allows the Technician or Engineer to do all of the above, as well as changing parameters such as temperature setpoints, power distribution, and belt speed. (Initial password is set to “2”.) |
| Access Level 3 | restricted to Manufacturer’s personnel only. |

NOTE: Before turning off furnace computer, you must “Log-Off” through the Security screen and shut down Windows OS via the START button on the computer Desktop display.

2.2.7 Atmosphere Supply Gas - CDA

A. FURNACE PROCESS GAS SYSTEM

Plant supply process gas must be filtered and regulated to 4.8 bar (70 psi) before the furnace is started to assure consistent clean dry process gas is supplied during furnace operation. An internal gas reservoir with check valve further regulates gas pressure to 15 psi for the belt tensioner.

If the furnace air pressure drops below the set point during operation, the operator should put the furnace into Cool Down. The operator can reset the system to Warm Up when air pressure is again over 70 psig.

Table 2-5 Gas Supply Pressure		
Location	Default Setting	
Plant Process Gas Regulator supply to furnace	65-70 psig	4.5-5.0 bar
Furnace Regulator (option not supplied)	- psig	- bar
Low Gas Pressure Alarm Switch	60 psig	4.1 bar

See Section 3 for information calibration and service of the pressurized gas (N₂/CDA) system.

WARNING: The flowmeters on these furnaces are rated at 5 bar (70 psi) maximum. Operating above 70 psi exposes the operator to possible injury.

B. Flow Meter Default Settings

Select the Gas Flow button. The Gas Flow screen will be shown. Open the furnace flowmeter access panel and adjust the gas flow to the default flows indicated on the screen or per process recipe requirements. See Owner's Manual, Engineering section for default settings. See Reference Manual, Chapter 9, Balancing Gas Flow for information on setting the flow meters to balance the system gas flow.

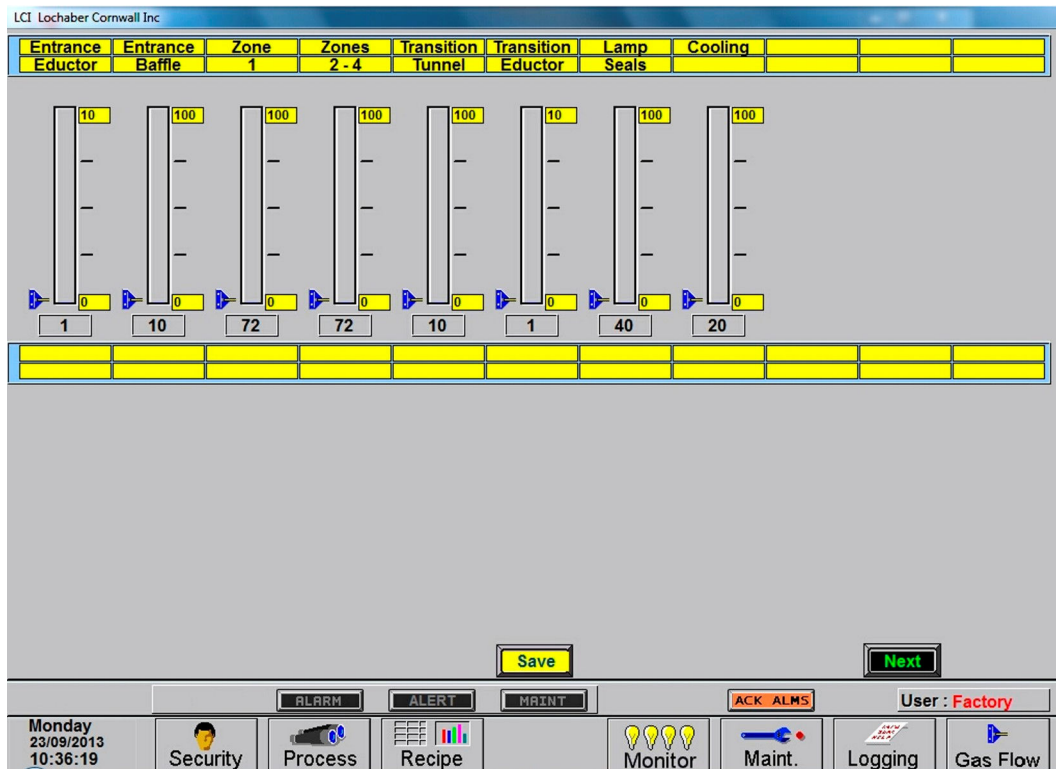


Figure 2-6 Gas Flow Screen

2.2.8 Furnace Process Screen

A. Process screen overview

Select the Process button on the menu bar view the Process screen. The Process screen displays the setpoint temperature, the current recipe, process state and status, transport speed, and other information such as percentage of power to elements and edge heaters. Alarm and alert dialog box also is displayed here along with event status.



Figure 2-7 Process Screen

B. Zone Setpoint temperature fields

To enter or change zone setpoint temperatures, click on the Setpoint field and enter the new temperature in degrees Celsius.

C. Zone Actual temperature fields

The actual temperature field shows the temperature measured in each zone by the zone thermocouple in degrees Celsius.

D. Top Power / Btm Power fields

The Top and Btm Power fields display the percent power used by each zone by the lamps above and below the belt.

Change any value by clicking on the field and entering a value from 1-100%. For values less than 100% the furnace program will multiply the entered percentage times the resulting PID control value. For example if 50% is entered into the Top Power field for Zone one, when the PID value calculates a value of 3.0% power, the actual power applied and displayed will be 1.5% for that location.

E. Edge Heat Power (option)

If edge heaters are included, enter value (0-100%) to apply linear heat to sides of furnace wall. Since edge heaters only apply the preset amount of heat to their entire length, the lowest acceptable value should be used to achieve even distribution of heat across the belt.

F. Belt Speed fields

Click on the Setpoint field to enter a new belt speed. The Actual Belt Speed field displays the belt speed determined by the motor speed as calibrated.

G. Trends button (option)

If SuperTrends are enabled, the Trends button will open a zone dialog box. Once a zone is selected the SuperTrends will open. See technical note on use of SuperTrends feature.

H. Deviation button

When on the Process Screen, the user can activate the Deviation screen by clicking on the Deviation button. The Temperature Deviation screen will show the deviation of measured temperature from set point for each zone. The vertical bars are green for process ready conditions by zone, and change color independently as the deviation in a given zone changes.

The user can drag the Deviation screen to another location on the Process Screen or close the screen at any time.

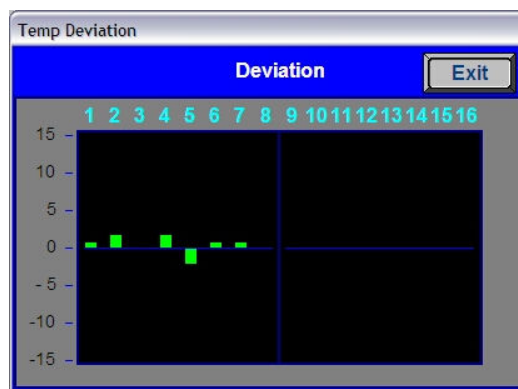


Figure 2-8 Temperature Deviation Screen

I. Avg Pwr field

The Avg Pwr field on the Process screen reflects the calculated actual power being used by the machine. This number is based on the % power applied to each zone and the lamp power of each zone. Edge heaters are not included in the calculation.

J. ALERT & ALARM buttons

Pressing the Alert or Alarm button will open list of current alerts and alarms. ALERTs are notification of an issue or potential problem, while ALARMS indicate a serious problem, shut-down the lamps and/or take the furnace out of the READY state or WARM UP state. After an ALARM has been corrected, the Furnace Controls ON button must be pressed to restart the furnace.

K. ACK ALMS button

Pressing the ACK ALMS button will “Acknowledge” or reset the alarm. If the source of the alarm is still a problem, the ALARM button will continue to blink and the alarm continue to sound.

While the machine is heating, check for alerts and alarms and listen for the alarm buzzer. In particular, check for any exhaust fan failure alarms. Check for failed elements. The effect of an element failure is generally minimal unless two failed elements are adjacent to each other.

NOTE: Allow the system to stabilize and to enter the PROCESS READY or PROCESS START mode as indicated by a green light on the screen before processing any product.

You must be in “Process Off” condition to exit (indicated by a red light).

L. Process action buttons & indicators

The Process buttons include Warm Up, Process Start, Cool Down and Ready. Press the Warm Up button to introduce power to the heating lamps. The furnace remains in Warm Up until all zones are $\pm 2\%$ of setpoint for over 60 seconds, then the green Process Start indicator and green READY box will lite. Pressing the Cool Down button starts the cool down sequence.

M. Recipe indicator

The Recipe indicator displays the recipe currently in running in the furnace controller.

N. Power Limit Feature (option)

If Power Save is enabled, the power can be limited by a “Maximum power” value entered on the Maintenance/Calibration screen. If this value is set at 0, no power is calculated and no limit is set on the power used by the machine. Any non-zero value will cause the system to calculate the power and limit it to this value.

Default maximum power is set to 100% . When enabled, the total power will then always stay below the number set by the user. Edge heaters are not included in the calculation.

WARNING: A low power limit may prevent the machine from reaching the Process Ready state, since the user value may not be high enough to reach the desired temperature. For example, setting a maximum of 30 kW will most likely not be enough to reach a steady state in a high temperature furnace when trying to go to 900°C. In this case, the machine will just stay in the Warm Up mode.

2.3 Normal Furnace Operation

A. Check for Alarms & Alerts

Check to assure that there are no active alarms or alerts. If needed, move cursor to and click on “ACK ALMS” to clear or silence an alarm/alert in order to proceed with furnace operation. If alarm/alert does not clear, see Troubleshooting in Section 3.

B. Set Process parameters

Verify correct recipe is loaded. If not, click on RECIPE button for the “Recipe” screen (Figure 2-9) or enter desired process parameters including zone set point temperatures, power, edge heater and belt speed by clicking on respective the blue fields and typing the correct values.

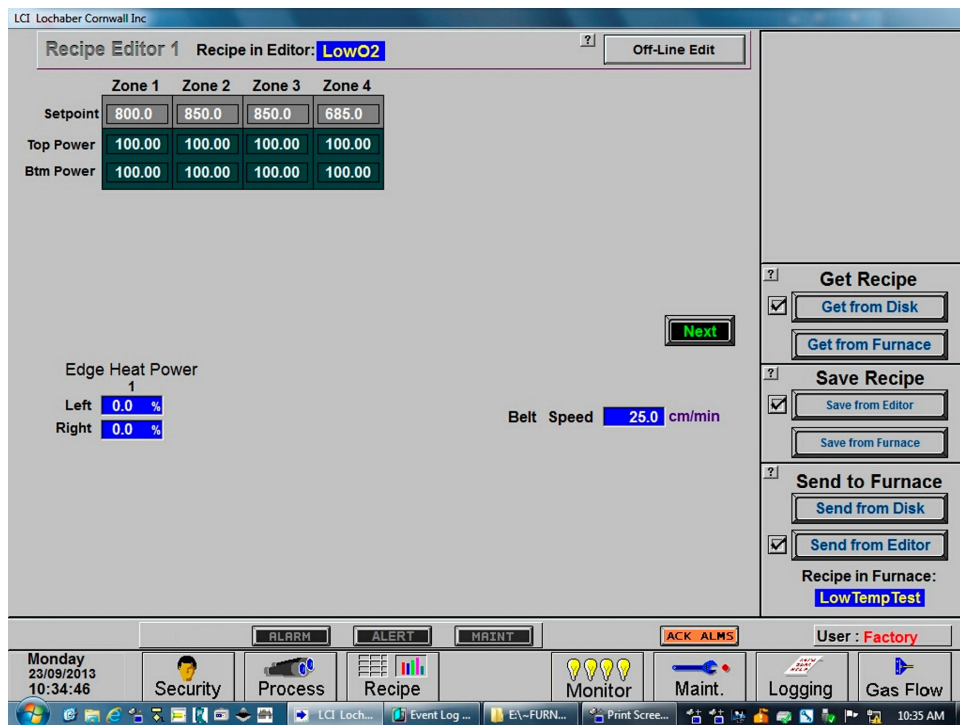


Figure 2-9 Get Recipe Menu and Editor

C. Use Existing Recipe

Two basic ways to load and run an existing recipe:

1. Get Recipe/Get from Disk loads a recipe from the disk to the editor. Then you must go to Send to Furnace/Send from Editor to run in furnace. or.
2. Send to Furnace/Send from Disk bypasses the Recipe Editor and loads the selected recipe into the furnace controller.

When the Recipe in Furnace field indicates the correct recipe go to Process and proceed as in paragraph 2.3E Select WARM UP below.

D. Create a new Recipe (see section 2.5 Modifying Control Strategies)

To create a new recipe, load an existing recipe into the recipe editor (Get Recipe/Get from Disk) and modify the Setpoint, Power and PID settings (click next to for PID and alert limits. Click on each field you want to change, and enter the new parameter. When recipe is satisfactory Save Recipe/Save from Editor and enter new recipe name and file name. Be sure to make the file name the same as the recipe name to avoid confusion.

When the Recipe in Furnace field indicates the correct recipe go to Process and proceed as in paragraph 2.3E Select WARM UP below.

E. Select WARM UP

In the Process field, select “WARM UP” to initiate the process selected (Figure 2-10). In the “WARM UP” mode, the heating elements are energized. After 20 minutes, check the system for instability or cycling, and correct if necessary.

F. Process Start

When the furnace has stabilized the green Process Start button indicator and the READY box will lite. Product man now be placed on the belt for processing (Figure 2-10).

NOTE: Allow the system to stabilize and to enter the PROCESS READY or PROCESS START mode as indicated by a green light on the screen before processing any product.

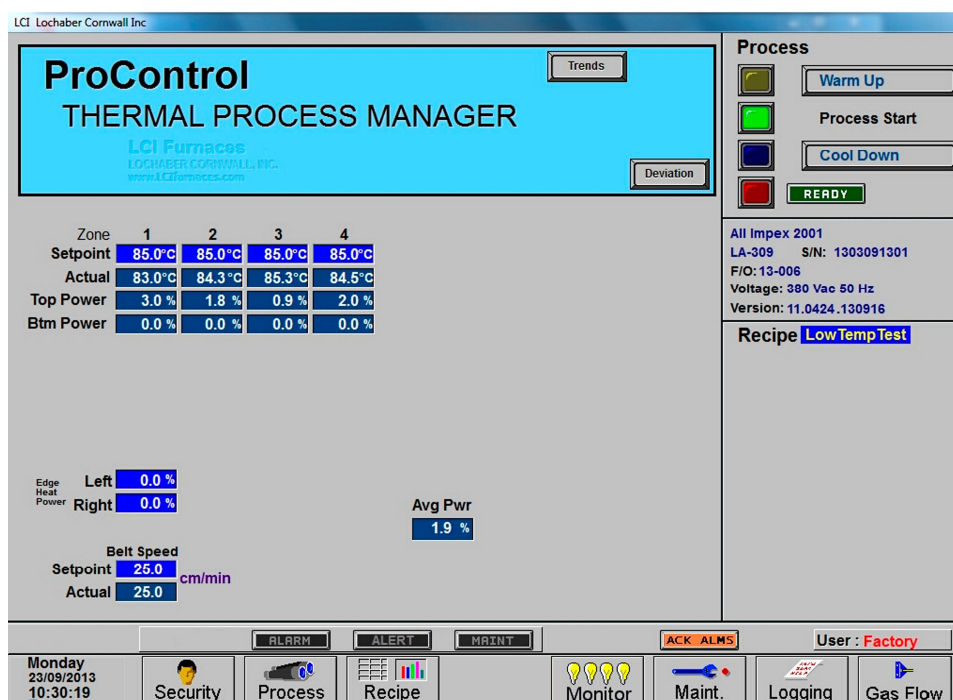


Figure 2-10 Process Start

2.4 Furnace Shut Down

2.4.1 Shut Down Modes

There are five basic levels of shut down on the furnace:

1. EMO – Emergency Off
2. Control System Off
3. Cool Down
4. Auto Shut Down
5. Complete Shut Down

Whenever possible, log out of the furnace program and shutdown the computer using the Windows operating system before pressing the OFF button on the control console. The computer is configured to start automatically when the furnace ON button is pressed on the control console.

2.4.2 EMO Shut Down

For immediate shut down of the furnace:

1. EMO - Press any of the Emergency OFF (EMO) buttons.
2. All systems will immediately shut down, except for furnace computer and monitor.

2.4.3 Furnace Control System Shut Down

For immediate shut down of the furnace:

1. Shut down furnace computer.
2. Press FURNACE POWER OFF button on Control Console .
3. All systems will immediately shut down, except for furnace computer and monitor.

2.4.4 Cool Down

To place the furnace in “standby” mode for quick restart (to load and run new recipe):

1. Using PC mouse, click the COOL DOWN button on the PROCESS screen to remove power from the heating elements. The heating elements turn off immediately. You will hear the K1 lamp power contactor release with a click. The furnace control system will continue to run the belt, cabinet cooling fans, product cooling fans, and keep process gas flowing during COOL DOWN.
2. When all zones are below 100°C, COOL DOWN is complete. The furnace may be left in this condition with belt running and process gas flowing indefinitely. You may manually turn off the process gas flow at this point without causing harm to the furnace, although you must remember to turn it back on prior to restarting the furnace.
3. To restart the furnace (after loading a new recipe or to run the current recipe again), click the WARM UP button on the Process screen , referring to item 5) in the Furnace Operation (Process Screen) section 2.3.

2.4.5 Shut Down Considerations

The furnace should be shut down when more than an hour or two will elapse between production runs. A shutdown conserves energy and prolongs the life of the furnace and elements. Follow the steps in sections 2.4.6 for short duration shutdowns.

The furnace computer is often left running if the furnace is to be down for less than 2-3 days. Leaving the computer on for longer period will not harm the system. However, always shut down the furnace computer using the Windows operating system first before the OFF button on the console is pressed.

2.4.6 Auto Shut Down

Auto Shut Down allows an operator to initiate the shutdown sequence and not have to be present when the furnace completes COOL DOWN to complete the sequence. After Auto Shut Down is complete, the furnace computer remains running, although the rest of the furnace is shut down completely and must be restarted to resume operation (see section 2.4.10).

To initiate the Auto Shut Down sequence while in PROCESS START or WARM UP mode on the PROCESS screen follow steps 1 and 2. If all furnace zones are below 100°C, go to step 2:

AUTO SHUT-DOWN STEPS:

1. Click COOL DOWN on Process screen
2. Press FURNACE POWER OFF button

COOL DOWN. Using the PC mouse, click the COOL DOWN button on the PROCESS screen to remove power from the heating elements. The heating elements turn off immediately. You will hear the K1 lamp power contactor release with a click. The furnace control system will continue to run the belt, cabinet cooling fans, product cooling fans, and keep process gas flowing during COOL DOWN.

You may move to Step 2) at any time after clicking COOL DOWN, or the furnace can be left in this condition without problem. However, until FURNACE POWER OFF is pressed, the belt and auxiliary systems will continue to run even after COOL DOWN is through.

FURNACE POWER OFF. Shut down the Windows computer. Then press the FURNACE POWER OFF button on the control console.

While still in COOL DOWN, the MAIN POWER light remains “on” and the FURNACE POWER OFF button light is “off”. All controls and accessories (belt motor, fans, light tower, etc.) remain “on”. When all zones are below 100°C, COOL DOWN is complete and the control system will stop the belt automatically and shut off any other automatic systems.

When both AUTO SHUT-DOWN steps have been initiated and are complete, the furnace will be completely shut down electrically, except for the furnace computer and monitor. If the furnace is not equipped with Auto Gas Valve Shutdown, the process gas will still be flowing to the furnace until the valve is manually closed. The furnace can be left in this state indefinitely without harm to the furnace. For complete shutdown of the furnace see section 2.4.7.

2.4.7 Complete Shut Down

For complete shutdown of all systems and power to the furnace follow steps 1-5:

1. Click COOL DOWN on Process screen
2. Computer system OFF
3. Press FURNACE POWER OFF button
4. Process Gas OFF
5. Main Power

COOL DOWN. See section 2.4.5, subsection 0.

FURNACE POWER OFF. See section 2.4.5 , subsection 0.

COMPUTER SYSTEM. The computer system is normally left ON between short to medium periods of furnace shut down. However, for Complete Shutdown, before COOL DOWN is finished, exit the Furnace program from the Process or Security screen. Then, click on Windows Start/Shut Down to turn the computer OFF. The computer will Power OFF after the operating system closes all files are closed. The furnace controller will continue to operate the cool down mode until all zones are below 100C..

PROCESS GAS. For furnaces equipped with the Auto Gas Shutoff feature, the process gas valves will close after COOL DOWN is finished. For complete shutdown, manually close process gas supply valves, but only after COOL DOWN is complete.

MAIN POWER. The main power is not automatically disconnected from the furnace. If you wish to disconnect the main power to the furnace, wait until steps 1-3 are complete before throwing the facility power breaker.

2.4.8 Turning Off Furnace PC and Monitor

Shutdown of Windows operating system and the furnace computer is only required if you are disconnecting facility power to the furnace.

1. **LOG OFF.** Using the PC mouse, go to the Security screen. Click your user name in the User List and click Log-Off. Clicking on the Exit button will take you out of furnace operation mode when all zones are below 100°C and the belt has stopped.
2. **SHUT DOWN.** From the Windows Desktop, select start, then select Shut Down. The computer will Power OFF after the operating system closes all files.

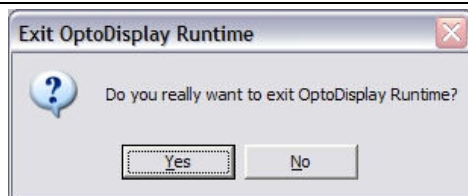
2.4.9 Exiting a Frozen Furnace Program

1. **EXIT FROZEN PROGRAM.** Using the PC keyboard, press ALT-F4 to exit the active program.
2. This method of closing the furnace program should only be used to exit a frozen program. It will not affect the program running in the furnace Controller. If still in Cool Down, the furnace will continue to run until the Cool Down sequence is complete.

Note: If communication is lost to the PLC LCM4 controller, the furnace program will freeze. To exit any frozen Windows® program, Press Alt-F4 on the keyboard.

2.4.10 Restarting the Furnace after Auto Shut Down

Auto shutdown turns off process gas and the Opto22 PLC after Cool Down. Since the computer remains on, the PLC must be re-initialized. Follow the steps per the RESTART table to start the furnace after Auto shutdown.

Table 2-6 Restarting the Furnace after Auto Shut Down		
After Auto Shutdown, the furnace computer left ON, while furnace belt, lamps and all auxiliaries are OFF. In this state the furnace program will not be communicating with the PLC and, therefore, must be closed and reopened after the furnace is restarted to re-establish communication with the furnace.		
1. Close Furnace program	Go to Security screen and select Exit. Or you can right-click on LCI button in the taskbar and select close window. Windows provides a 2nd dialog box “Do you really want to exit...? Select Yes. Note: Do not restart the furnace program until the furnace is ON and controller is running.	
2. Main Power	Verify the Main Power ON button is lit. Disconnect switch should be on, all panels in place and EMO switches reset.	
3. Furnace ON	Press Furnace Power ON button. Furnace ON light illuminates. Wait 5 minutes for the Opto22 PLC to sync with the Furnace computer.	
4. Start Furnace Program 5. Log-in	Press Furnace program icon to initialize communication with the PLC and start the furnace program. Log in to the furnace software. Log-in is only possible when PLC and Computer are communicating.	

CAUTION: Dangerous voltages are now present throughout the electrical systems of the furnace. Make sure that any probes in the furnace are placed on the belt surface only. Probes extending over the sides of the belt may contact high voltage terminals!

Section 2

2.5 Modifying Control Strategies

2.5.1 Recipe Screen (Off Line Edit)

A. Go to Recipe Screen (Recipe Editor1)

NOTE: When editing this screen the process is not changed.

Level 1 access will allow the operator to inquire, select, and run preset parameters and recipes. Level 2 access will allow the operator to edit and save recipe data.

When initializing the “Load & Run” field, the process screen is updated and the Recipe Setup screen is changed to On Line Edit.

FurnacePros

Recipe Editor 1 Recipe in Editor: **Default** Off-Line Edit

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Setpoint	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
Top Power	30.00	30.00	50.00	50.00	50.00	50.00	50.00	30.00
Btm Power	30.00	30.00	50.00	50.00	50.00	50.00	50.00	30.00

Edge Heat Power

	1	2
Left	5.0 %	5.0 %
Right	5.0 %	5.0 %

MA Alert/Alarm -25 °C -30 °C

Atmosphere Purge Time 5 min

H2 Gas Fill Time 5 min

☒ N2 ☐ H2 Process Gas

Belt Speed 0.0 in/min

Zone 4 O2 0 ppm

Pre-Purge Cycle 8.0 min

Product Length 5.0 in

Exit Transit Time 25 s

Data Log Interval 10 min

O2/MA Sampling

☐ Off ☒ On

☒ Source

☐ Zone 1

☐ Zone 4

☐ Zone 8

Get Recipe

☒ Get from Disk

Get from Furnace

Save Recipe

Save from Editor

Save from Furnace

Send to Furnace

☒ Send from Disk

Send from Editor

Recipe in Furnace: **Default**

Next

Friday 09/30/2011 14:51:01

Security Process Recipe Profile Monitor Maint. Logging Gas Flow

ALARM ALERT MAINT ACK ALMS User: FPD

Figure 2-11 Recipe Editor 1

B. Load Recipe (Access Levels 1 and 2)

C. Delete Recipe (Access Level 2)

D. Edit Stored Recipe, Save Stored Recipe (Access Level 2)

NOTE: Do not use this feature on the current recipe while in ready mode and while processing parts.

2.5.2 Changing Recipe Set points (Access Level 2)

A. Change Temperature (Access Level 2)

Place the cursor on the temperature setting to be modified. Type the new setting and press enter from the keyboard.

NOTE: Temperature display is in degrees Celsius.

B. Change Power Distribution (Access Level 2)

1. Heating Element Power distribution

Default value is 100% top and bottom.

Place the cursor on the power distribution setting to be changed. Type in the new setting and press enter from the keyboard. This can be between 0% and 100%.

Power distribution is a scaled percentage of maximum power output to the top and bottom heating elements.

The maximum power is typically set at 1.5 times the actual percentage of power used when the furnace is in the "Ready" mode.

2. Edge Heater Power Distribution (Access Level 2)

The edge heaters are located at the outer edges of the belt and run the entire length of the heated chamber. They can be used to improve the temperature uniformity across the width of the belt. Click on the blue cell to modify the percentage on. The range is 0-100% and can be set in increments of 1%. See the Reference Manual for more on using the edge heaters.

c) Change Transport Speed (Access Level 2)

Place the cursor on the Belt Speed field, click, type in the new value and press enter from the keyboard.

NOTE: Transport speed is displayed in inches per minute or cm/min.

3. O2/MA Sampling (option)

If equipped with an integrated sampling system with oxygen analyzer and/or moisture analyzer, the O2/MA sampling panel will appear in the upper right hand portion of the screen. Select default state of sampling system (ON/OFF) and sampling port (Source, Zone 1,4,8).

If an oxygen analyzer is supplied, enter alarm value for O2 ppm.

If a moisture analyzer is supplied, enter values in degrees Celsius for moisture analyzer and oxygen analyzer alerts and alarms.

4. SMEMA (option)

If equipped with SMEMA product tracking, enter length of product or product carrier in inches. Also enter the amount of time it takes from the time the part leaves the furnace until it reaches the an integrated moisture analyzer, enter values in degrees Celsius for moisture analyzer and oxygen analyzer alerts and alarms. Store in recipe file.

5. Hydrogen/FG Furnace (option)

If equipped as a hydrogen or Forming Gas furnace, you can enter setpoint time for Pre-Purge cycle (min) for the time the gas will take to purge the furnace zones with nitrogen before combustible gas can be started.

2.5.3 PID Zone Tuning

(Access Level 2)

On the recipe screen, “Next” button to view the Recipe Editor 2 screen. Enter new values for Gain, Integral and Derivative and save in recipe file.

Table 2-7 PID Initial Settings

Parameter	Initial Values
Proportional Gain	9
Integral	45
Derivative	0-1

Click on the desired Zone title pushbutton to monitor and Edit Zone PID Settings. A Zone Tuning dialog box (Figure 2-13) will appear with default values for proportional gain, integral, and derivative. Place the cursor on the value to be modified and click. Type the new setting and press enter from the keyboard. See Reference Manual, Chapter 9 for Process Engineering considerations in establishing PID parameters. Also see section 3.9.1 to completely retune a zone.

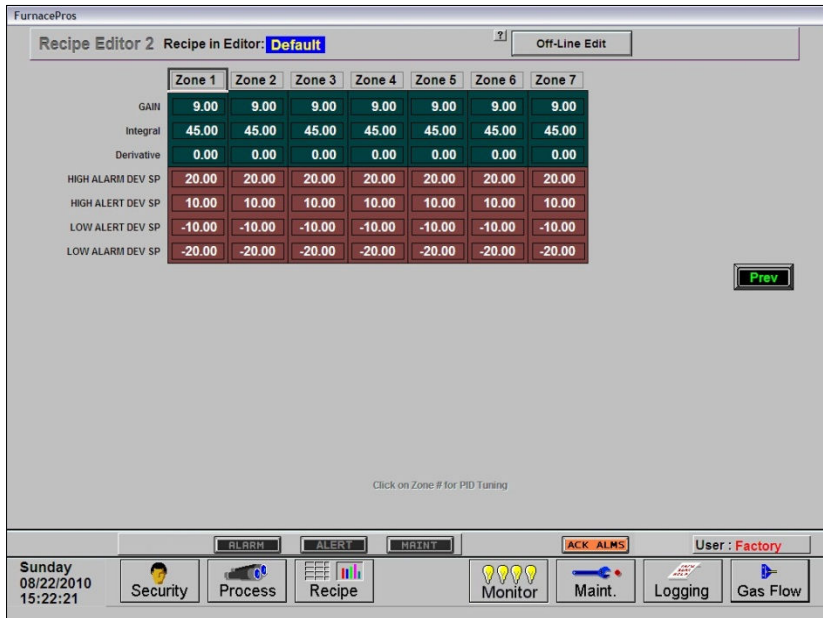


Figure 2-12 Recipe Editor2: PID Parameters

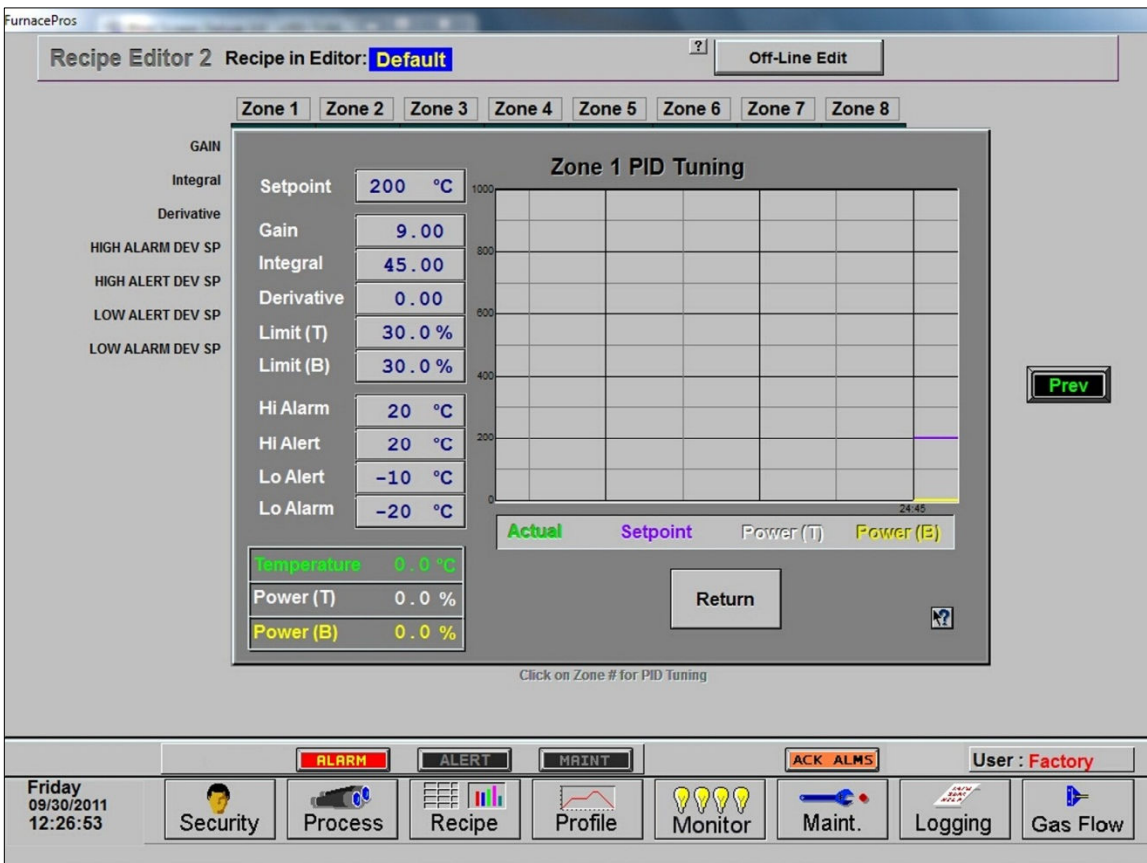


Figure 2-13 Recipe Editor 2: PID Tuning

A. Gain (Proportional)

Gain influences the proportional response of the PID by amplifying the error between set point and actual temperature to establish an output level. The proportional band, in degrees Celsius, is defined as 100 divided by the gain. An increase in the gain reduces the amount of temperature deviation required to turn the heating elements on at full distributed power or decrease it. Too small a value will cause the system to be sluggish in response. Too high a value will cause the system to overshoot and be unstable.

B. Integral

The integral (or Reset) function corrects temperature offset.

C. Derivative

Derivative is a rate function that clamps temperature overshoot/oscillation. The maximum set point for the derivative function should be $\frac{1}{4}$ of the integral value.

D. Exit

For each Zone PID Tuning popup opened, you will need to click the “Return” button until all are closed. Click “Prev” button to return to Recipe Editor 1 screen.

2.5.4 Store Gas Flow Settings

Record flowmeter settings and store for each recipe using the Gas Flow screen. Enter flowmeter values by clicking on the value in the box below each flowmeter to record new values for the recipe being edited. See section 2.2.7 for more information. If stored with the recipe file, when a recipe is later opened, the operator can verify and adjust the flowmeters to match each recipe.

The screenshot shows the 'FurnacePro' interface for gas flow settings. It features two rows of sliders and numeric input boxes. The top row contains settings for Entrance Eductor, Entrance Baffle, Transition Tunnel Ed, Transition Tunnel, Element Plenums, Cooling Gas, Exit Baffle, and Exit Eductor. The bottom row contains settings for N2 Zones (1 & 2, 3 & 4, 5 & 6, 7 & 8) and H2 Zones (1 & 2, 3 & 4, 5 & 6, 7 & 8). Each slider has a scale from 0 to a maximum value (100, 400, or 200). Below each slider is a numeric input box with a '0' and a blue arrow icon. At the bottom, there are 'Save' and 'Next' buttons, and a status bar with 'ALARM', 'ALERT', 'MAINT', 'ACK ALMS', and 'User: Engr/Tech'.

Figure 2-14 Recipe Gas Flow settings

Section 2

2.6 Super Trends

To view current or historical performance by zone:

1. Press the Trends button at the top of the Process screen,
2. Select desired zone to view.

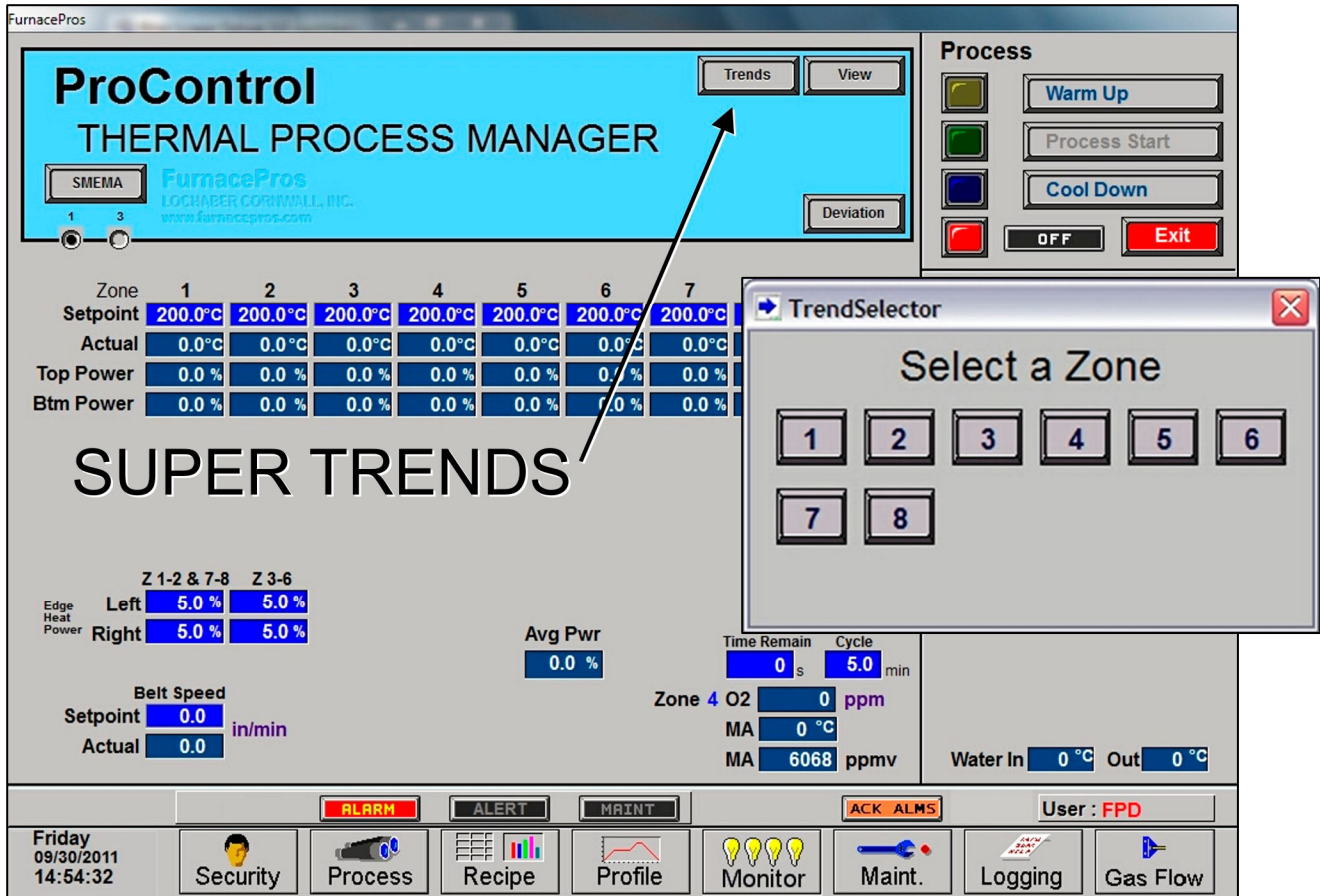


Figure 2-15 Super Trends button with Trend Selector

The Super trends graph appears as in Figure 2-16

Once the trends graph appears you can select the parameter to view. Selecting a specific parameter changes the vertical axis for that parameter. Press the  button to change the scale for the selected parameter. (see Figure 2-18). All parameters are shown on the screen at all times, although the scale is



Figure 2-16 Super Trends graph

adjusted for the selected parameter.

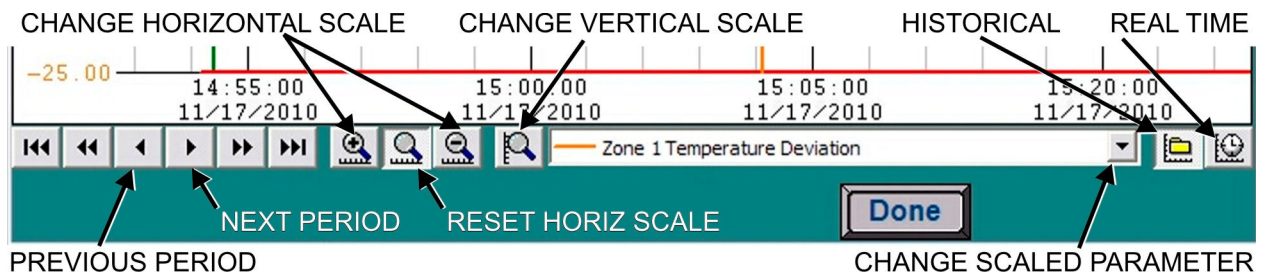


Figure 2-16 Super Trends Menu

Table 2-8 Super Trends Menu Buttons	
Button	Action
	Real Time Mode (default). Shows data currently being recorded for all 5 parameters.
	Historical Mode . Opens file from an earlier period. (See Figure 2-18). Activates Previous and Next buttons and Horiz scale buttons.
	Select Pen . Select a pen parameter and the vertical scale changes to match its set value
	Zoom Pen . Change vertical scale for selected parameter.
	Zoom Normal . Resets Horizontal scale to default (30 minutes per screen).
	Zoom Hour . Compresses horizontal scale (x-axis) to show more detail (one hour per screen).
	Zoom Day . Compresses horizontal scale (x-axis) to show longer time period in one view. (24 hours per screen)
	Log Forward (movement varies with Zoom) Zoom Normal: 5 minutes / 30 minutes / End of data Zoom In: 6 minutes / 1 hour / End of data Zoom Out: 30 minutes / 1 day / End of data
	Log Back (movement varies with Zoom) Zoom Normal: Start of data / 30 minutes / 5 minutes Zoom In: Start of data / 1 hour / 6 minutes Zoom Out: Start of data / 1 day / 30 minutes

Section 2

Enter the Historical Log Mode by pressing . The Super Trend Historical Log file popup is shown in Figure 2-18. Once an historical file has been selected, the Zoom and Log Forward/Back buttons can be used to view different time periods of furnace activity.

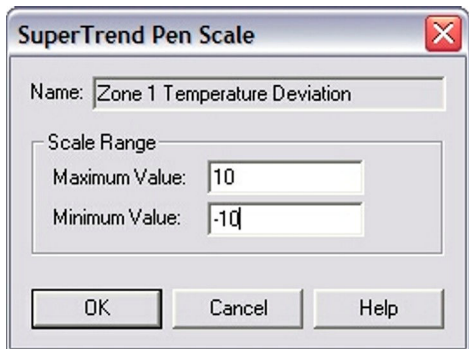


Figure 2-18 Change Vertical Scale

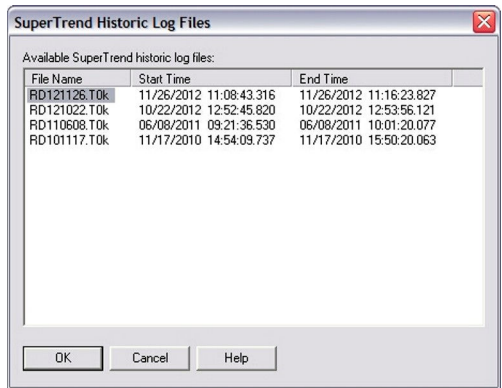


Figure 2-18 Load Historical Trend Data

2.7 Alarm Status (All Access Levels)

This is a display only feature. Any existing alarm conditions, such as transport speed error, are highlighted on the Process screen. To clear or silence an alarm/alert, move the cursor to and click on “Acknowledge Events.” See Section 3 SERVICE & MAINTENANCE for further information.

2.8 Data Log/Alarms and Alerts

2.8.1 Occurrence and Timed Logging Control (Access Levels 1 and 2)

Move the cursor to and click on “Logging” to see any occurrence.

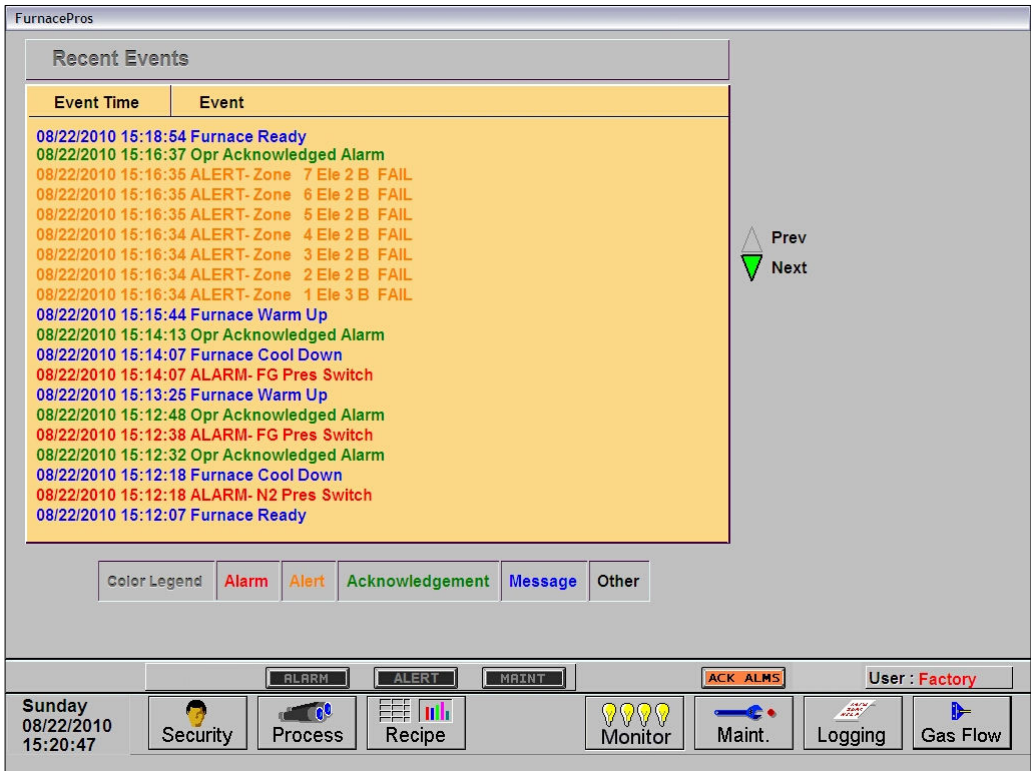


Figure 2-19 Event Logging

2.8.2 IPS Low Gas Pressure Alarms (option)

MAKE SURE THE LOW PRESSURE ALARM bypass switch on the PLC panel is in the ENABLE ALARM position. The IPS switch signals can be bypassed for service and testing using the LOW PRESSURE ALARM switch on the PLC panel. However, all alarms should be enabled during normal furnace operation.

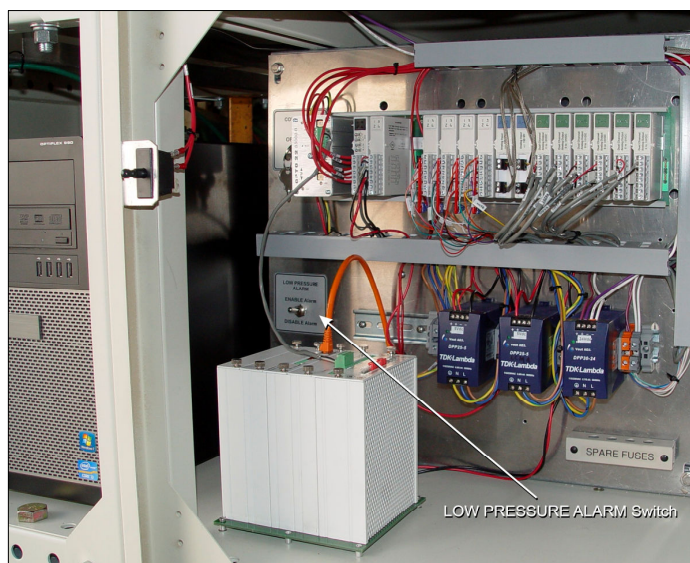


Figure 2-20 Low Pressure Alarm bypass switch location

An Inlet Pressure Switch is installed on each process gas manifold. These switches are normally open. They close when proper pressure is present in the process gas supply lines.

The current switches are set to open when pressure falls below set points in the following table:

Table 2-9 Initial Alarm Settings			
Port	Manifold	Pressure	
Gas 1	CDA or Nitrogen	55-60 psig	3.8-4 Bar
Gas 2	Nitrogen Forming Gas, or other (Option)	55-60 psig	3.8-4 Bar

The pressure switch set points can be adjusted manually. Locate the switch in the process gas supply line. To increase the set point turn the wheel clockwise. Turn the top of the switch counter clockwise to decrease the pressure set point so the alarm will not occur until the pressure drops to a lower point.



Figure 2-21 IPS Inlet Pressure Switch

2.8.3 Auto Gas Shutoff (option)

This furnace may be equipped with Auto Gas Shutoff. The Auto Gas Shutoff feature consists of solenoid valves on the process gas supply lines integrated with the furnace. These valves open and allow Process Gas to flow when Furnace ON is pressed. This feature is designed to conserve process gas. To shut down the furnace the operator need only put the system into Cool Down and press Furnace OFF. When all furnace zones reach 100°C or lower for at least one minute, the furnace shuts down and the process gas valves close.

The Auto Gas Shutoff valves fail in the closed position.

2.9 Element Monitoring System

The Element Monitoring system consists of a panel of 6-channel circuit boards which detect the location of a failed heating element. The circuit boards monitor the current to the lamps and activate an audible alarm and visible alarm upon sensing an element failure. The display shows the specific location of the lamp or lamp string (multiple lamps wired in series make up a string) containing the failed lamp. The audible alarm alerts the operator immediately if a lamp fails and allows him to discern its location and determine if process results will be appreciably affected.

Access the Monitor screen in the software to view the status of the heating element strings. Communication failure or individual lamp failure of itself will not shut down the process. The process will only shut down if a lamp failure adversely impacts the furnace ability to maintain set point temperatures.

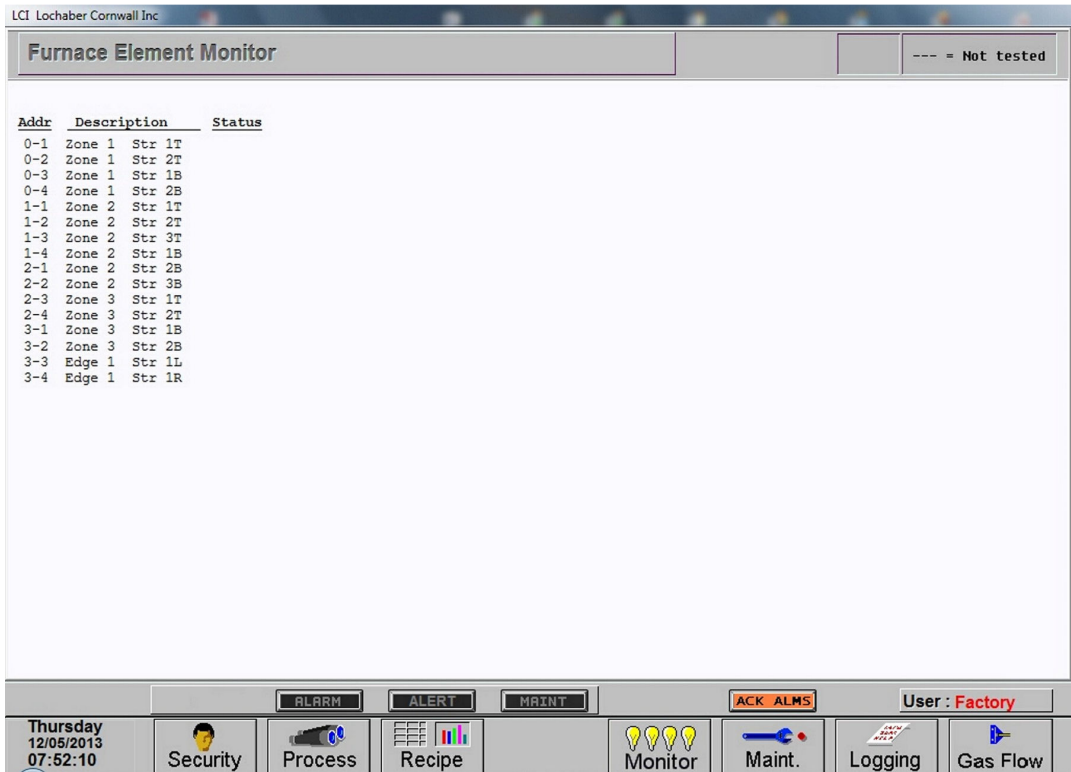


Figure 2-22 Element Monitor screen

2.9.1 EM Signal Polling (2001-2012 furnaces only)

On 2013 furnace models and later, the element monitor signals are collected from a current switch located each serial string. Visual indication of the status of each switch can be seen on the PLC digital modules assigned to the EM strings (see Figure 3-4 Furnace Controller EM I/O modules).

On pre-2013 models, the software polls the element monitor cards via a serial string. The signal sent from each channel can be viewed on the Serial EM Test popup screen (Figure 2-23). Click on the Serial EM Test button to determine if all boards are communicating properly with the PLC controller. Each board contains a dip switch which determines the digital address of a given board and the software checks each board in sequence. Boards are addressed from 0 to nn.

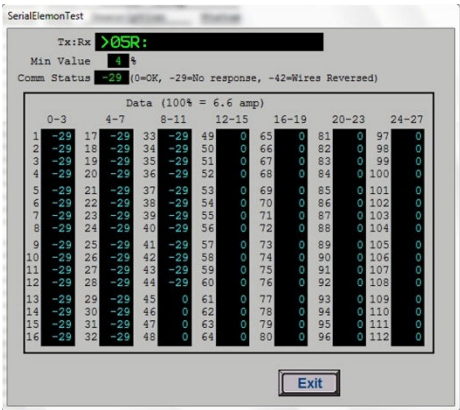


Figure 2-23 EM Serial Test screen

2.10 Over Temperature Alarm

2.10.1 Over Temperature Option (option)

The Over Temperature Alarm system consists of redundant zone thermocouples, a scanner/annunciator and digital panel meter hardware integrated into the furnace software. The scanner/annunciator and digital panel meter are mounted on top of the furnace near the flowmeter controls.

NORMAL OPERATION. The system scans each zone and passes a temperature signal to the digital panel meter. The operator can view the temperature on the panel meter and the respective zone being monitored will be indicated on the scanner

ALARM. If the temperature in any zone reaches the alarm set point, an alarm will sound in the scanner/annunciator and the furnace will go into Cool Down, the heating elements will be shut off by the controller. To silence the alarm, press ACK on the scanner/annunciator. The furnace cannot be restarted until the zone temperature drops below the alarm set point.

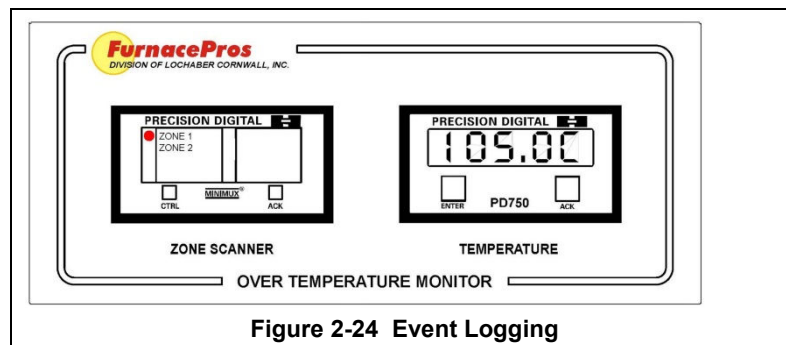


Figure 2-24 Event Logging

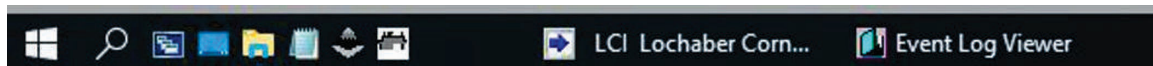
2.11 View Alternate Programs

To switch the viewing window between ProControl™ Furnace Process Software and another application (the WinKIC or DataPac Windows Applications) press and hold down the ALT key, and then press TAB repeatedly. When the title of the desired Windows Application appears, release ALT. The new application will appear in the foreground. Repeat the procedure to return ProControl™ Furnace Process Software to the active window.

2.12 Exit Furnace Program

Go to Security screen and log-out and click Exit.

If the furnace program is frozen, to exit the furnace program, click on the **LCI Lochaber Cornwall** button in the taskbar



In either case, Windows will present a dialog box asking if you are sure. Click yes to close the program.

2.13 Remote Access

In order to allow for remote diagnostics of in-process furnace operations, a 2nd network interface card (NIC) is provided as well as a modem with communication software. The remote operator, in conjunction with on-site personnel, can simultaneously view the Process screen and have access to input and control features.

Remote access can be accomplished as follows:

- Broadband connection via internet access

2.13.1 Network Connection

To connect furnace to the network:

Wired: Connect a Cat5 or higher TCP/P Cable to the RJ45 port below the entrance of the furnace. Set LAN Connection 2 to receive network signals.

Note LAN Connection 1 must be reserved for the furnace control system.

Wireless: Connect a USB wireless transmitter such as D-Link DWA-140 RangeBooster Wireless-N network adapter to the control console USB port (behind the keyboard). Setup connections to receive network signal.

2.13.2 Remote Diagnostics

A good method of connecting to the furnace remotely is to use the TeamViewer™ internet service for remote diagnostics. See Section 3.4 Remote Access for more information.

2.13.3 Connect Using TeamViewer™

Enable Teamviewer™ by clicking on blue icon on lower right of screen and enable.

Contact factory service tech and indicate system is on-line and available for troubleshooting.

SERVICE & MAINTENANCE

3.1 TROUBLESHOOTING

To troubleshoot, follow all suggested remedies sequentially to determine source of the problem.

3.1.1 No power to furnace

A. The white MAIN POWER light on Control Console is out

1. Check main facility breaker is “on”.
2. Check 3-phase disconnect switch mounted on furnace is “on” (Table 2-1).
3. Check EPO panel switches are pulled out or all furnace cover panels are in place (Table 2-1).
4. Check EMO switches are reset (Table 2-1).
5. Check fuse FA (neon light if blown) on Safety Enclosure panel per 802-101770 Power Control schematic.

B. The green or yellow FURNACE POWER light on Control Console is out

1. Check fuses FA & FB (neon light if blown) on Safety Enclosure panel per 802-101770 Power Control schematic.
6. Check K2 (located on Safety Enclosure panel per 802-101770 Power Control schematic) relay neon light “on” when FURNACE POWER ON button pressed.

C. The green or yellow FURNACE POWER light on Control Console is on, but the PLC has no power

1. Check fuse FB (neon light if blown) on Safety Enclosure panel per 802-101770 Power Control schematic.
7. Check Opto22 5 Vdc power supply fuses.
8. Check K6 (located on Safety Enclosure panel per 802-101770 Power Control schematic) relay light “on”.
9. See section 3.6.2. items C) and D) below.

D. The green or yellow FURNACE POWER light on Control Console is on, but the belt doesn't move

1. Check K6 (located on Safety Enclosure panel per 802-101770 Power Control schematic) relay light “on”.
10. Check that PLC has power.
11. Check fuses MA, MB, MC (neon light if blown) on Motor Control panel and on-board motor fuse on Motor Speed controller per 802-101771 Frame Wiring schematic.
12. See section 3.6.5 below.

3.1.2 Unable to log on:

A. The PLC control system does not have any power

1. Check fuses FA & FB (neon light if blown) on Safety Enclosure panel per 802-101770 Power Control schematic.
13. Check Opto22 5 Vdc power supply fuses.
14. Check the Ethernet cable between the PC and the Opto22 controller at the back of the PC and at the controller. (Ref: Frame Wiring Schematic in Documentation Section)
15. Check the setup of the installed Ethernet card. (Ref: Section 3)

3.1.3 Temperature

A. The furnace has been in "WARM UP" mode for more than 15 minutes.

On the Process screen, the zone temperature does not change. Perform the following procedures sequentially to determine cause.

1. Check K1 lamp contactor (located on Safety Enclosure panel) to be sure it is operational: on the Process screen, click on Cool Down and then click on Warm Up. You should easily hear the “snap” of the contactor points opening and then closing. If not, check:
 - Relay K5 (located on Safety Enclosure panel per 802-101770 Power Control schematic) light “on” when Warm Up mode selected. If not “on”, check fuse FD (neon light if blown), then check fuses F6 and F7 on Power Distribution panel. If K5 is “on” and the fuses are okay, check:
 - K7 Lamp_Power_Cntl relay located on Opto22 panel (Ref: Channel Assignments 802-101570 in Section 5 and PLC Configuration 802-101710 in Section 6) looking for an illuminated LED, indicating an active output.

NOTE: K7 has diagnostic circuitry by allowing the user to manually control the status of the output

Set @ 3: Automatic (Factory set)

Set @ 2: Off (Bypass)

Set @ 1: Manual On/Off

B. The heat is in a runaway condition and cannot be shut off by changing the setpoint to a lower value.

1. The SCR needs calibration. See Maintenance (“Maint”) screen for details. (Ref: Reference Manual)
2. The SCR has failed and shorted. Replace SCR.

NOTE: The following are factory typical settings:

Gain:	9
Integral:	45
Derivative:	0 or 1

3.1.4 Zone temperature fluctuates.

A. The SCR needs calibration

Calibrate SCR per section Calibrate SCRs3.9.1

B. Improper flowmeter setting(s)

Adjust flowmeters to improve furnace isolation and proper heat transfer. Generally gas flow should either be balanced or moving toward the entrance stack.

C. Adjacent zone temperature differentials are too large

Modify the adjacent temperature zones so setpoint differences are smaller to facilitate a stable furnace.

D. Improper PID setting(s)

See section 0 for initial recommendations. Also see section 3.9.1 to completely retune a zone.

3.1.5 Conveyor System

A. Transport Speed Error.

1. Check K6 (located on Safety Enclosure panel on 802-101770 Power Control schematic) relay light ON.
2. Check that PLC has power.
3. Check fuses MA, MB, MC (neon light if blown) on Motor Control panel and on-board motor fuse on Motor Speed controller per 802-101771 Frame Wiring schematic.
4. Inspect clutch for slippage.
5. Visually inspect for belt jam or snag.
6. Check the input signal on Motor Speed controller board (located in motor box); S1 is common, S2 is speed control. At maximum speed the voltage is approximately 10 Vdc.

B. Transport Motion Fault.

In addition, items in 3.1.5A, the following items should be checked:

1. **Furnaces after 2002.** Check for wear and tear or loosening of the transport motion encoder mounted on the drive roller shaft at the exit end of the furnace.
2. **Furnaces prior to 2002** may have a chopper wheel instead of a rotary encoder. Check to make sure the wheel is still turning and the optical sensor is clean.

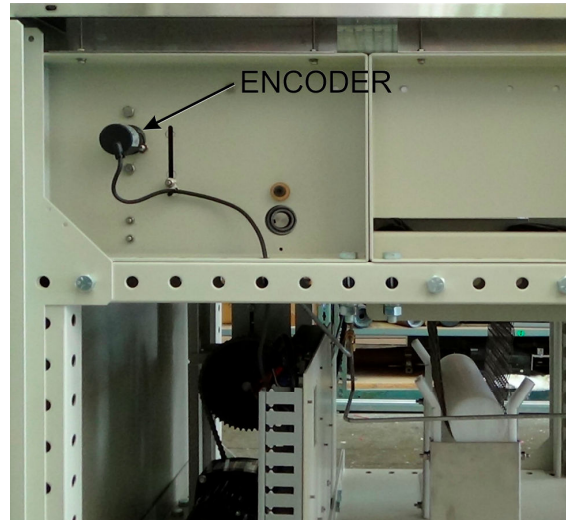


Figure 3-1 Encoder located behind furnace back exit panel

3.1.6 IPS Alarm Bypass

The furnace may be equipped with a manual ALARM BYPASS switch for each process gas pressure sensor. The switches are located on the PLC panel. Switch to Alarm Disable to manually close the pressure switch contact and bypass the alarm.

Caution: in the bypass position the software will no longer detect and alarm for low process gas pressure.

IPS Bypass switches are useful for troubleshooting the system when gas pressure is not available.

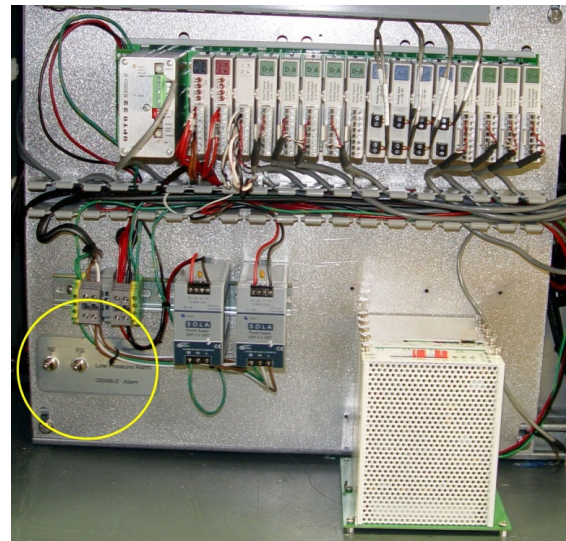


Figure 3-2 IPS Inlet Pressure Switch Location

3.2 Hardware COM Troubleshooting

3.2.1 Controller Communication

The most often seen problem is no communication between the computer and the controller and is characterized by pound signs “#####” on the screen where you should have temperature or the date or any type of data.

Check the following things in this order:

Log Event Viewer: Any event happening between the computer and the controller is logged on this screen. You can access it by “ALT-TAB”. The following are messages that are displayed:

- the normal message is “Attaching to Scanner”
- then a file download, such as the default recipe file.
- a message relating to the Ethernet card, make sure the coaxial cable is plugged in, and the controller IP address is correct.
- out of memory, switching to low scan mode; there is insufficient memory to run the software. Contact FurnacePros for additional memory.
- Incompatible gml file date/time; the source code has been changed, contact FurnacePros.

PLC: If you have communication, but it looks like some data is frozen, it may be a loss of communication between the PLC controller and the PLC modules. Check the PLC LCM4 controller module to be sure the LED’s BATT, LINE AND STAT are green.

- Line “green” indicates 5VDC power status is good.
- BATT “green” indicates CMOS battery status is good.
- STAT “green” indicates the firmware is good.
- The LED’s “TX” and “RX” indicate data is communicating between the controller and the modules.

Otherwise use the following table to troubleshoot communication problems:

Table 3-1 PLC Opto22 Troubleshooting Guide		
INDICATION	EXPLANATION	REMEDY
LINE LED is off	No Power.	Check fuses FA & FB (neon light if blown) on Safety Enclosure panel per 802-101770 Power Control schematic. Check wiring.
LINE LED is red or Controller resets.	Power may be out of specification	Check/adjust 5V DC power supply to minimum 5.0 - 5.1 Vdc limits. Do not exceed 5.2 Vdc.
STAT LED is off	Controller is faulty	Call FurnacePros Technical Support.
STAT LED blinks red	Firmware problem	Call FurnacePros Technical Support
BATT LED is red	Backup battery is low	Replace LCM4 controller battery.
RX LED is stuck on	Wiring polarity problem	Call FurnacePros Technical Support.
Controller cannot transmit to PC	Configuration jumpers were changed without cycling power.	Cycle power off/on and retry transmission.
No communication to host PC.	Communication Problems	Check serial port. Check PC IP address (10.192.105.100)
No communication to host PC. RX LED is on, but TX LED is off	Communication Problems	Check controller address (10.192.105.102), baud rate, and ASCII/binary settings.
No communication to host PC. RX and TX LEDs are on	Communication Problems	Try a slower baud rate.
No communication to I/O modules. TX LED is off while trying to communicate.	Communication Problems	Check that I/O port software is configured for correct port. If RX LEDs on I/O modules are off while trying to communicate, check for loose connections, shorts or breakage. If RX LEDs on I/O are on, check I/O address, baud rate, and protocol setting in software.
Furnace program fails to load with correct parameters, clock is wrong, or furnace controller fails to reset	Backup battery is low (battery has a 5 year life cycle)	Replace LCM4 controller battery.

If you have communication, but some variables appear as “###”, this means the controller does not know what this particular variable is. Check the Event Log viewer for more details.

3.3 Computer Troubleshooting

The Furnace computer is equipped with indicating lights and sound to provide status information and troubleshooting diagnostics. See Figure **Error! Reference source not found.** for location of lights and ports.

3.3.1 Indicating Lights

The Furnace computer lights provide basic information about the system state..

Table 3-2 Computer Indication Lights	
Controls and Lights - Front of the computer	
Power button (6)	push button
Power light (7)	blinking green — indicates that the computer is in sleep state solid green — indicates that the computer is in power-on state blinking amber — indicates a problem with the system board solid amber — indicates that the system board is unable to initialize
Drive activity light (4)	blinking green — indicates that the computer is reading data from or writing data to the hard drive
Network connectivity light (8)	green — indicates that a good connection exists between the network and the computer off (no light) — indicates that the computer is not detecting a physical connection to the network
Diagnostic lights (5)	four lights. For more information, see Diagnostics.
Controls and Lights - Back of the computer	
Link integrity light on integrated network adapter (7)	green — a good 10 Mbps connection exists between the network and the computer. orange — a good 100 Mbps connection exists between the network and the computer. yellow — a good 1000 Mbps connection exists between the network and the computer. off (no light) — the computer is not detecting a physical connection to the network.
Network activity light on integrated network adapter (6)	yellow light — A blinking yellow light indicates that network activity is present.

3.3.2 Power Button Light Codes

The diagnostic lights give much more information about the system state, but legacy power light states are also supported in your computer. The power light states are shown in following table.

Table 3-3 Computer Power Button Light Codes	
Power Light State	Description
Off 	Power is off, light is blank.
Blinking Amber 	Initial state of light at power up. Indicates system has power, but the POWER_GOOD signal is not yet active. If the Hard Drive light is off , it is probable that the power supply needs to be replaced. If the Hard Drive light on , it is probable that an onboard regulator or VRM has failed. Look at the diagnostic lights for further information.
Solid Amber 	Second state of the light at power up. Indicates the POWER_GOOD signal is active and it is probable that the power supply is fine. Look at the diagnostic lights for further information.
Blinking Green 	System is in a low power state, either S1 or S3. Look at the diagnostic lights to determine which state the system is in.
Solid Green 	System is in S0 state, the normal power state of a functioning machine. The BIOS will turn the light to this state to indicate it has started fetching op-codes.

3.3.3 Computer Beep Codes

If the monitor cannot display error messages during the POST, the computer may emit a series of beeps that identifies the problem or that can help you identify a faulty component or assembly. The following table lists the beep codes that may be generated during the POST. Most beep codes indicate a fatal error that prevents the computer from completing the boot routine until the indicated condition is corrected.

Table 3-4 Computer Beep Codes	
Code	Cause
1-1-2	Microprocessor register failure
1-1-3	NVRAM read/write failure
1-1-4	ROM BIOS checksum failure
1-2-1	Programmable interval timer failure
1-2-2	DMA initialization failure
1-2-3	DMA page register read/write failure
1-3	Video Memory Test failure
1-3-1 through 2-4-4	Memory not being properly identified or used
3-1-1	Slave DMA register failure
3-1-2	Master DMA register failure
3-1-3	Master interrupt mask register failure
3-1-4	Slave interrupt mask register failure
3-2-2	Interrupt vector loading failure
3-2-4	Keyboard Controller Test failure
3-3-1	NVRAM power loss
3-3-2	Invalid NVRAM configuration
3-3-4	Video Memory Test failure
3-4-1	Screen initialization failure
3-4-2	Screen retrace failure
3-4-3	Search for video ROM failure
4-2-1	No timer tick
4-2-2	Shutdown failure
4-2-3	Gate A20 failure
4-2-4	Unexpected interrupt in protected mode
4-3-1	Memory failure above address 0FFFFh
4-3-3	Timer-chip counter 2 failure
4-3-4	Time-of-day clock stopped
4-4-1	Serial or parallel port test failure
4-4-2	Failure to decompress code to shadowed memory
4-4-3	Math-coprocessor test failure
4-4-4	Cache test failure

3.3.4 Computer Diagnostic Lights

To help troubleshoot a problem, your computer has four lights labeled 1, 2, 3, and 4 on the bank panel. When the computer starts normally, the lights flash before turning off. If the computer malfunctions, the sequence of the lights help to identify the problem.

 **NOTE:** After the computer completes POST, all four lights turn off before booting to the operating system.

Table 3-5 Computer Diagnostic Lights		
Light Pattern	Problem Description	Suggested Resolution
	The computer is in a normal <i>off</i> condition or a possible pre-BIOS failure has occurred. The diagnostic lights are not lit after the computer successfully boots to the operating system.	- Plug the computer into a working electrical outlet. - If the problem persists, contact Dell.
	A possible processor failure has occurred.	- Reseat the processor (see Processor information for your computer). - If the problem persists, contact Dell.
	Memory modules are detected, but a memory failure has occurred.	- If two or more memory modules are installed, remove the modules, then reinstall one module and restart the computer. If the computer starts normally, continue to install additional memory modules (one at a time) until you have identified a faulty module or reinstalled all modules without error. - If available, install working memory of the same type into your computer. - If the problem persists, contact Dell.
	A possible graphics card failure has occurred.	- Reseat any installed graphics cards. - If available, install a working graphics card into your computer. - If the problem persists, contact Dell .
	A possible floppy drive or hard drive failure has occurred.	Reseat all power and data cables.
	A possible USB failure has occurred.	Reinstall all USB devices and check all cable connections.
	No memory modules are detected.	- If two or more memory modules are installed, remove the modules, then reinstall one module and restart the computer. If the computer starts normally, continue to install additional memory modules (one at a time) until you have identified a faulty module or reinstalled all modules without error. - If available, install working memory of the same type into your computer. - If the problem persists, contact Dell.

Table 3-5 Computer Diagnostic Lights

Light Pattern	Problem Description	Suggested Resolution
	Memory modules are detected, but a memory configuration or compatibility error has occurred.	• Ensure that no special requirements for memory module/connector placement exist. • Ensure that the memory you are using is supported by your computer (see the "Specifications" section for your computer). • If the problem persists, contact Dell.
	A possible expansion card failure has occurred.	• Determine if a conflict exists by removing an expansion card (not a graphics card) and restarting the computer. • If the problem persists, reinstall the card you removed, then remove a different card and restart the computer. • Repeat this process for each expansion card installed. If the computer starts normally, troubleshoot the last card removed from the computer for resource conflicts. • If the problem persists, contact Dell.
	Another failure has occurred.	• Ensure that all hard drive and optical drive cables are properly connected to the system board . • If there is an error message on the screen identifying a problem with a device (such as the floppy drive or hard drive), check the device to make sure it is functioning properly. • If the operating system is attempting to boot from a device (such as the floppy drive or optical drive), check system setup to ensure the boot sequence is correct for the devices installed on your computer. • If the problem persists, contact Dell.

3.4 Remote Access

In order to allow for remote diagnostics of in-process furnace operations, a 2nd network interface card (NIC) is provided as well as a modem with communication software. The remote operator, in conjunction with on-site personnel, can simultaneously view the Process screen and have access to input and control features.

Remote access can be accomplished as follows:

- Broadband connection via internet access
- Wireless connection via internet access

3.4.1 Connect Using TeamViewer™

A good method of connecting to the furnace remotely is to use the TeamViewer internet service for remote diagnostics:

If the computer is TeamViewer enabled:

Make sure there is an internet connection to the local network connection 2 port.

Click on the blue TeamViewer icon in the menu or next to clock on desktop menu bar.

Provide Your ID and random generated Password to remote user (factory or service tech).

Partner (factory or service tech) must have Remote User ID and TeamViewer password as well as Furnace Computer password, if any to log on the furnace computer from a remote location.

Note: For security, each time TeamViewer is enabled on the Furnace Computer, TeamViewer will generate a new password that must be provided to the remote user.

If the computer is not TeamViewer enabled, contact factory for installation instructions.

3.5 Remote Diagnostics

Enable TeamViewer™ by clicking on blue icon on lower right of screen and enable.

Contact factory service tech and indicate system is on-line and available for troubleshooting

3.6 Element Failure Indication

3.6.1 Furnace Element Monitor screen

Press the Monitor button on the menu bar to view the lamp status. Use this screen to identify whether any lamp string have a problem. The element monitoring system only detects lamp status when lamp current is above a set value (default is 4%) and sometimes may report false failures if the current is too low at the power setting.

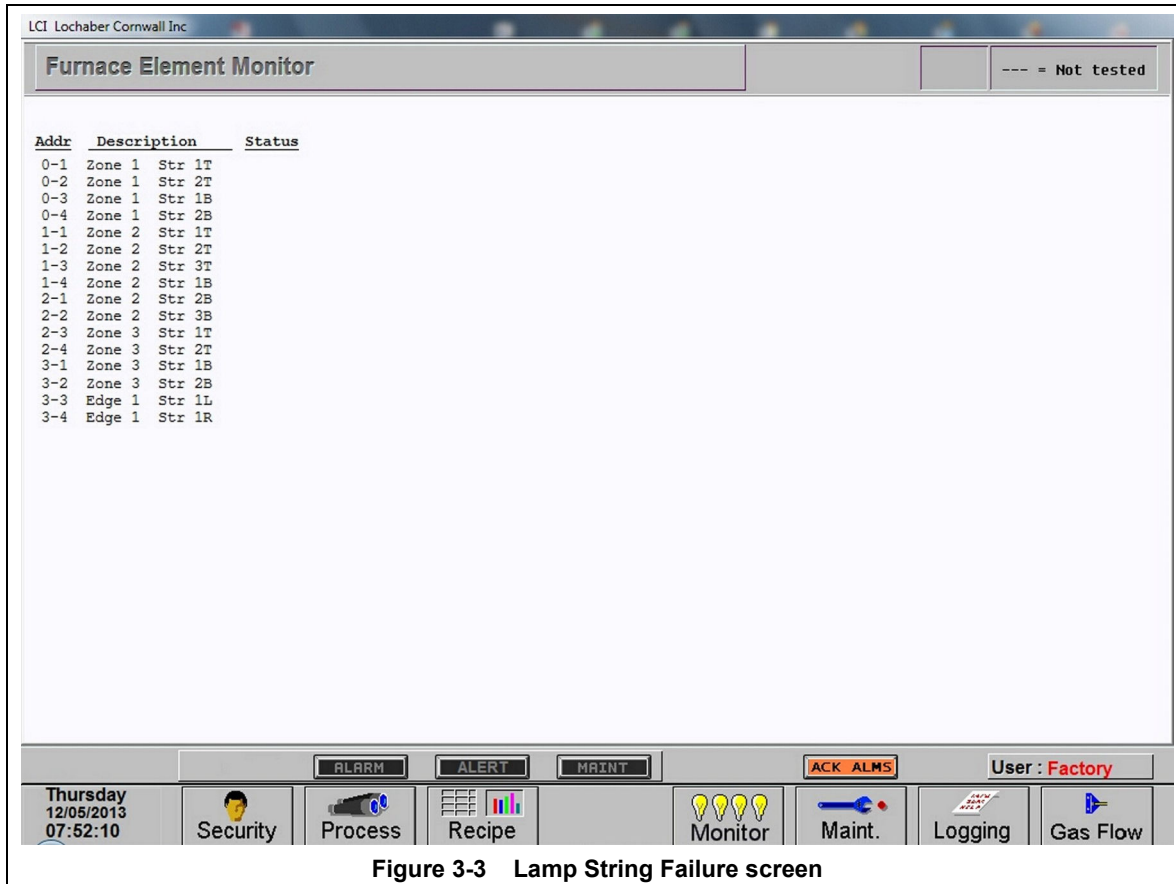


Figure 3-3 Lamp String Failure screen

Table 3-6 shows examples of EM screen readings and their meaning.

Table 3-6 Element Monitor Screen				
Addr	Zone	Str# T/B	Status	Description and Location
0	Zone 1	Ele 1T	See Table 3-7	Element monitor 0 detected a possible failed top lamp in Zone 1 in the first string from entrance.
1	Zone 1	Ele 2B	See Table 3-7	Element monitor 1 detected a possible failed bottom lamp in Zone 1 in the second string from entrance.
10	Edge 1	Ele 1 L	See Table 3-7	Element monitor 10 detected a possible failed Left Edge heater, in the first pair of edge heaters from the entrance.

Table 3-7 defines the EM screen possible Status values, description and recommended actions.

Table 3-7 Element Monitor Status		
Status	Description	Action
----	Not Tested	Lamp %power is too low to test current.
PASSED	Lamp string OK	None
FAIL	Lamp string reports faulty string	If a single string is shown as faulty, check lamp string using procedure in section 3.6.3. If all strings in a zone (top or bottom) are faulty, verify corresponding SCR is operating properly. If four strings fail, verify element monitor board is operating properly.

3.6.1 Discrete Indication (RTC retrofits and new furnaces, 2013 and after)

The Furnace controller contains a channel for each independent string of lamps. When power is applied to the lamps above a minimum value, the controller checks the status of all channels and reports any failures. When the lamps are ON, lights on the controller indicate which strings indicate current is flowing.

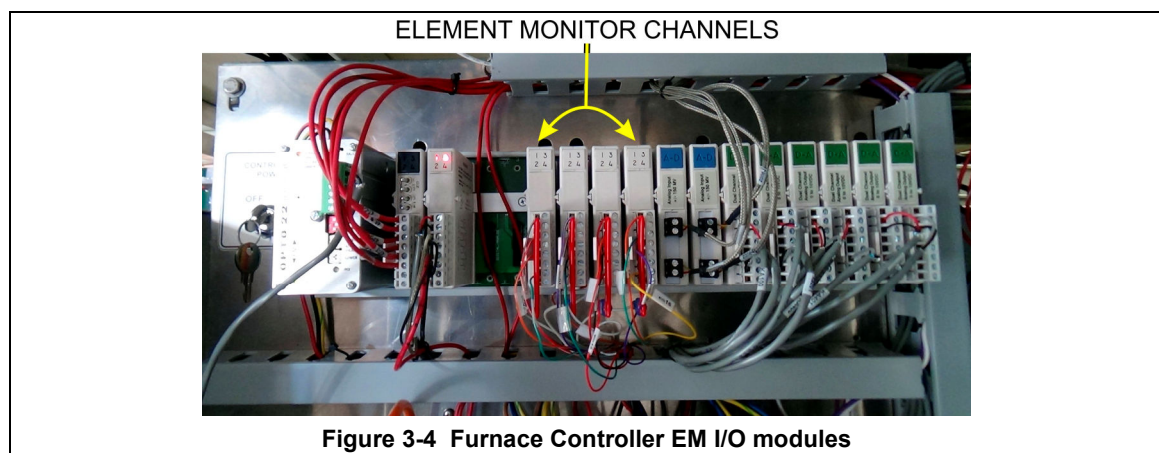


Figure 3-4 Furnace Controller EM I/O modules

3.6.2 Serial Polling (2001-2012 furnaces)

If the system returns a number of nuisance errors, from the monitor screen, you increase the minimum value below which the program will not poll the strings. To change this value, click on Serial EM Test button open the Serial Elemon Test screen (see Figure 3-5). This screen shows real time polling of the signal from the element monitor boards. Enter a higher value in the Min Value % box: Sometimes a value of 15% can provide better results if the system is falsely reporting string failures. The screen will also reveal if there is a wiring error or if there is no response from a polled system.

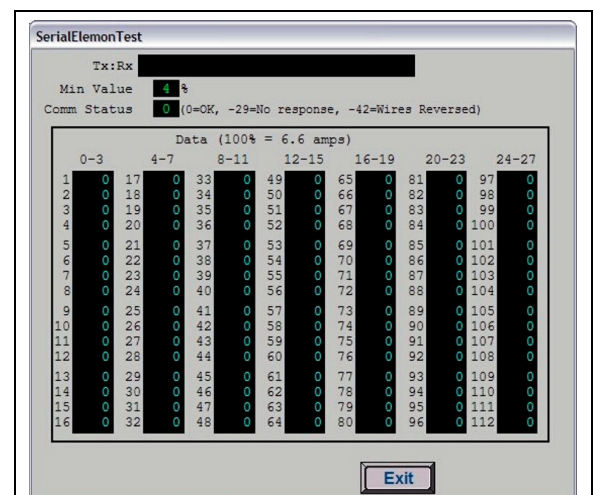


Figure 3-5 Serial Element Monitor Test screen (2001-2012 furnaces)

3.6.3 Heating Element Test Procedure

To simplify troubleshooting, the software displays the lamp strings by zone, top and bottom to indicate possible failures in each serial string of lamps. The furnace element screen displays the specific location of a suspected failed lamp string during operation. For a more reliable check, the user should perform the Testing Lamps process in this section.

Visual inspection of the lamps (either by looking down the entrance of the furnace or by removing the lamp covers) with the power on or off is not reliable. When adjacent lamps are on, reflected light will make a defective element appear okay. If the Testing Lamps process confirms that a string has failed, note the LAMP STRINGS indicator (EleT1, B1, etc.) that was OFF during the test, and use the following procedure to isolate which lamp in that identified string has failed.

This procedure is to be used to test for open heating or failed lamp heating elements.

A. Required Equipment

1. Ohmmeter (or Continuity Tester)
2. 3/8" Box or Open End Wrench
3. Control & Element Wiring Schematic 802-101814

B. Test Procedure

Remove all power from the furnace, and if a UPS or EPS is installed, locate and shut off the unit. Remove all side covers, completely exposing all lamp terminations.

Locate the identified failed string and the lamps in that string using the Element Wiring drawing.

Within each zone, the lowest numbered lamp (Ele 1) is nearest the entrance end of the furnace.

Disconnect one end of each of the 2 to 4 lamps in the suspect string and measure the resistance of each lamp. The resistance of a good lamp is $<10\ \Omega$. A higher reading identifies a defective lamp that should be replaced.

Refer to section 3.8.6 Heat Lamp Replacement for lamp replacement instructions.

Once the elements have been completely tested, replace the covers on the furnace. Turn on the EPS/UPS (if so equipped) and power to the furnace. Bring the furnace up to temperature, and, next, run a profile verifying that no leaks occurred around the lamps that were replaced.

The procedure is now complete.

3.6.4 Lamp Replacement

See furnace Reference Manual, Section 7.5.3 Heat Lamp Replacement.

3.7 Troubleshooting Process Problems

3.7.1 Belt speed

Measure the belt speed with a stopwatch. If it differs from the value on the process screen by more than 5% (1 IPM off for each 20 IPM of belt speed), re-calibrate the belt speed. Follow the Belt Speed Calibration procedure in the furnace Reference Manual, Chapter 7.

3.7.2 Resolving zone control issues

The calibration screen can be useful for use in troubleshooting and resolving zone control issues, testing lamps and checking for blown lamp fuses by isolating individual zones.

Zone Control. If heat in any zone increases rapidly into a “runaway” condition even if the zone controller OUT1 LED indicator is dark (the controller output is OFF), but the heat can be stopped by shutting off the affected zone top and bottom switches, the zone SCR probably has failed with a shorted output and needs to be replaced.

If the heat in any zone steadily stays above the setpoint value, but is not in a “runaway” condition, enter zero on the Process Screen for power for the affected zone top and bottom and see if the heat decreases. If it does not, the furnace has a process gas flow problem or the setpoint value in adjacent zones may need to be lowered.

Types of Energy. The ability to turn banks of lamps off and on via the % Power fields on the Process or Recipe Editor screens allows the user great flexibility in applying energy to each zone. Use just the top lamps in each zone for drying moisture or volatile organic compounds from the top surface of substrates or trays, or curing thermosetting compounds or coatings on wafers or polycarbonate materials. Use both top and bottom lamps in traditional furnace applications. Use just the bottom lamps to emphasize conduction heating of parts from the transport belt and from IR radiation on the bottom of metallic or ceramic parts carriers.

3.7.3 Temperature or large power fluctuations

If the temperature is slow to respond to large deviations from setpoint temperature, it may be a problem with the PID settings. If you need to modify a particular zone, see the procedures in section 0. Also see section 3.9.1 to completely retune a zone.

At low temperatures (<100°C) or near the maximum temperature, if there is an unacceptable deviation from setpoint, the SCR may need to be calibrated. If the SCR is out of calibration, most likely it will not be noticeable in the medium range of the temperature. If necessary, calibrate the SCR Calibration using the procedure in section 3-26 Calibrate SCRs.

NOTE: PID tuning should only be attempted by qualified personnel. Unreasonable PID parameters can stress the components of the system and cause premature failure of some electrical systems.

3.7.4 Unstable zone temperatures

If the temperature fluctuates by more than 5 degrees in less than 20 seconds after you reached ready state, it might be a problem with the PID settings. If you notice unstable behavior in a certain zone, you may need to modify the PID loop parameters for that particular zone. Follow the procedures in section 0 to retune the PID loop parameters. Also see section 3.9.1 to completely retune a zone.

If the SCR is out of calibration, most likely it will not be noticeable in the medium range of the temperature. Only at low temperature (<100°C) or near the maximum temperature, will there be deviation from the setpoint. See the SCR Calibration procedure in the Furnace Reference Manual.

NOTE: PID tuning should only be attempted by qualified personnel. Unreasonable PID parameters can stress the components of the system and cause premature failure of some electrical systems.

3.7.5 Abnormal sensor behavior

There are numerous sensors (standard and optional) on the furnace, from thermocouple to a board counter, gas analyzer, and so on. If one particular sensor seems to behave erratically, you will need to look into the value reported by the control subsystem.

The errors could be

1. • a temperature with a negative value,
2. • a gas analyzer readout that never changes value,
3. • a board counter that doesn't count.

For the digital sensors, first locate the relay module connected to that sensor on the OPTO panel, using the Channel Assignment configuration sheet. The red LED should toggle every time the sensor changes state. If it doesn't, the problem is with the sensor or the wiring. Most unlikely the relay module itself.

If the relay does toggle, make sure the module is talking to the controller; the TX LED should be flashing.

The analog inputs cannot be checked visually.

3.8 Control System Installation and Setup

3.8.1 LCM4 Furnace Controller Installation

Connect the various cables between the modules, the controller, the computer and the I/O racks. Newer systems have a surge protector on the network cable between the computer and the controller.

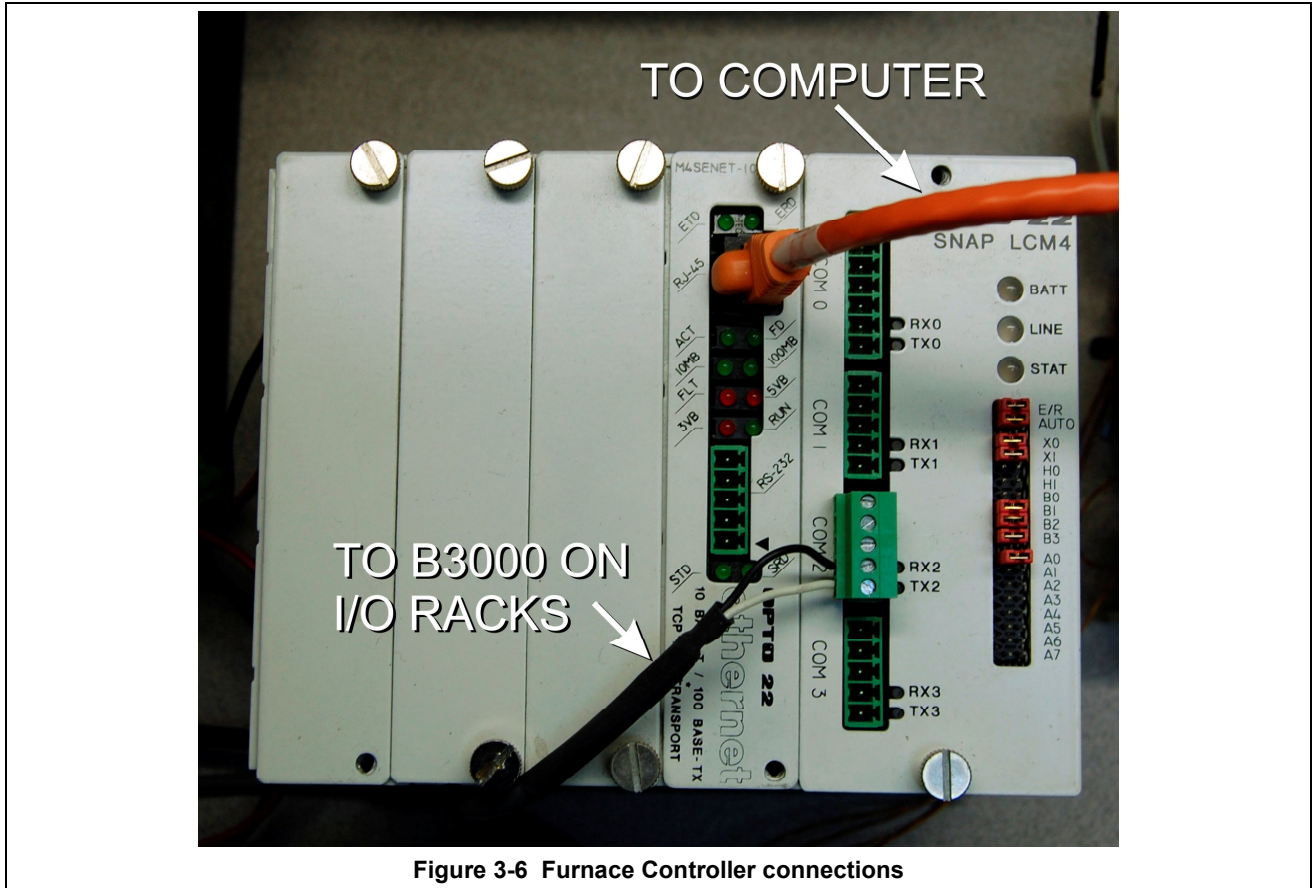


Figure 3-6 Furnace Controller connections

INITIALIZE: Open computer access door and turn ON the computer. When the WINDOWS® logo comes up, hold down the shift key to prevent the MMI from starting, since the controller is not ready yet. If it started, exit using ALT +F4.

The first time the controller is turned on, its memory is empty, and the software has to be downloaded. Double click on the download icon in the furnace group in Windows or the furnace icon on the desktop.

FURNACE SOFTWARE. The furnace icon or menu item will download the kernel (the Operation System for the controller) and the ProControl™ furnace software, and start running it.

You can now start the MMI software by double clicking on the Furnace icon. From now on, startup will be automatic.

You should see the correct date and day in the bottom left corner. If not, go to the Ethernet Installation and troubleshooting section.

LOG-IN. Check the log-in dialog box for one of the 3 proposed users: operator, tech and Factory (FPD). Enter appropriate password for the level selected.

3.8.2 Verify configuration of the external jumpers of the LCM4 Controller

Refer to Figure 3-6 for board jumper settings.

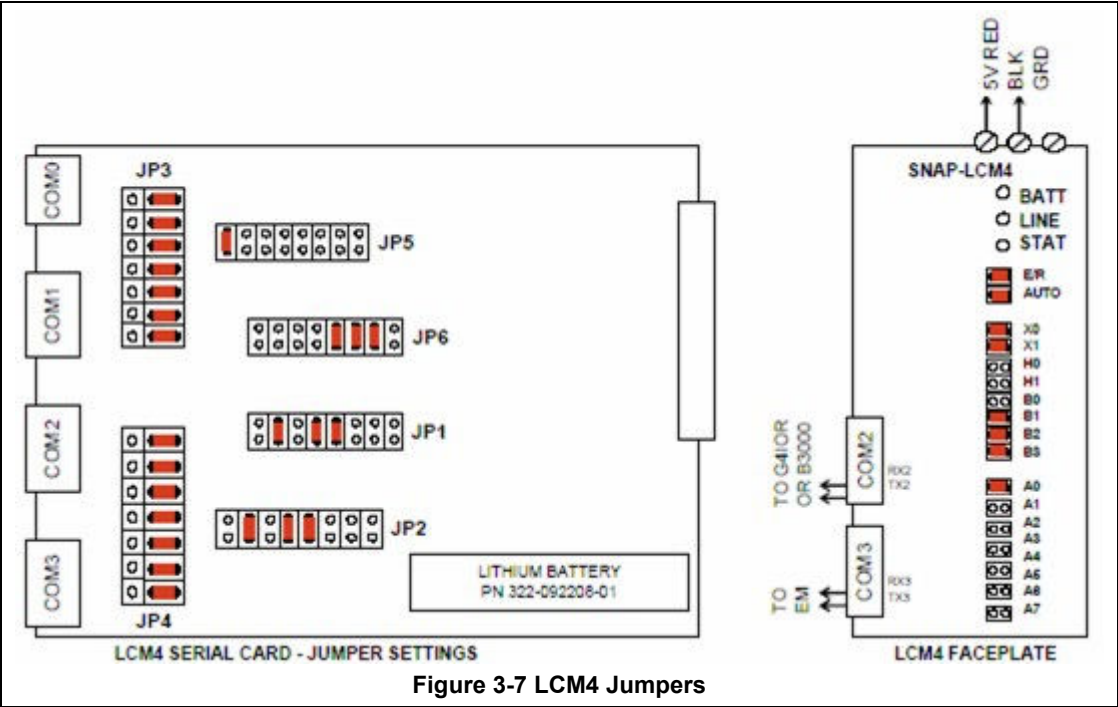


Figure 3-7 LCM4 Jumpers

3.8.3 Windows10® Setup of Furnace Computer Ethernet Connection

- a. Open the Windows Start . Click on the Settings icon . Select Network & Internet. Then select Ethernet/Change adapter settings (Figure 3-9 Select Change adapter settings)

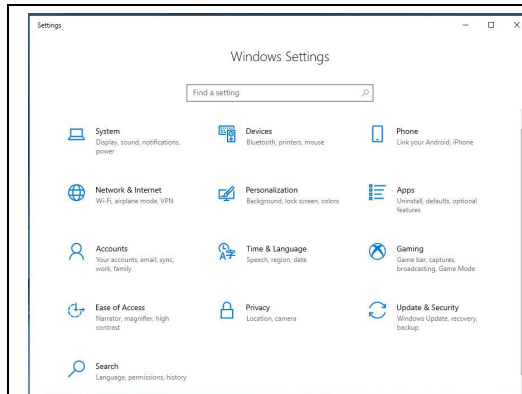


Figure 3-8 Open Network & Internet

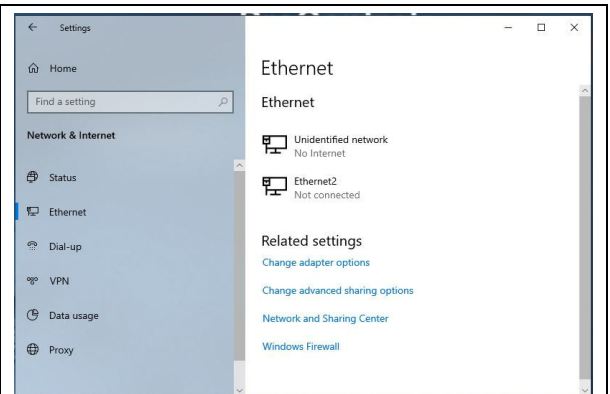


Figure 3-9 Select Change adapter settings

- b. From Network Connections window, select Ethernet-Furnace, the connection that corresponds to the furnace network (it may say “Unidentified network, No Internet”), Figure 3-10.
- c. Select **Properties** button from the Ethernet-Furnace Status window, Figure 3-11.

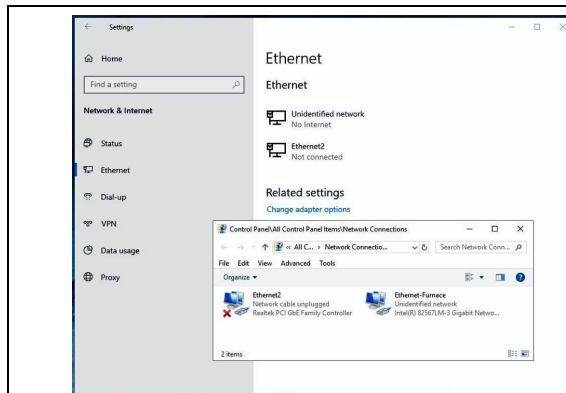


Figure 3-10 Select Select Ethernet-Furnace

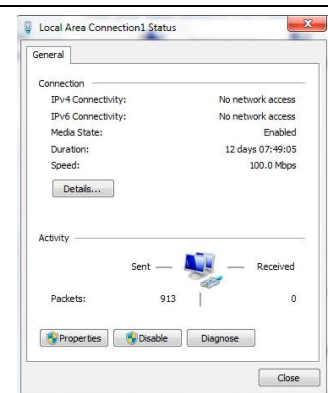


Figure 3-11 Select Properties

- d. Double-click **Internet Protocol Version 4 (TCP/IPv4)** from the Properties screen Figure 3-12. Verify IP address **10.192.105.100** and subnet mask **255.255.255.0**, Figure 3-13. **Revise if incorrect.**

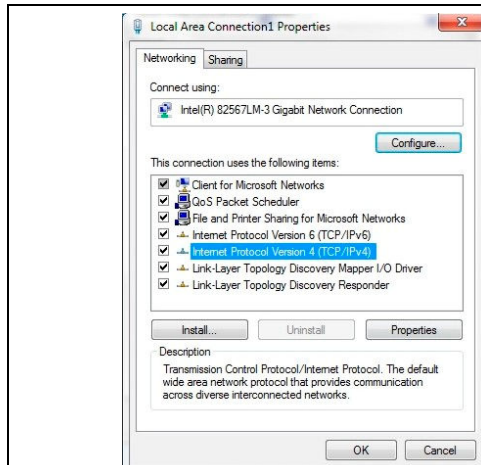


Figure 3-12 Select Internet Protocol 4

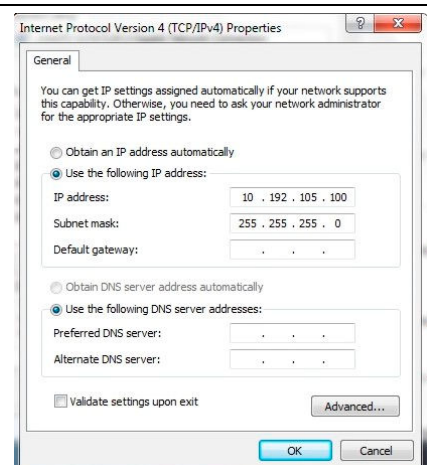


Figure 3-13 Verify IP Address

Section 3

- e. Click Ok. And close all windows.

3.8.4 Reset & Assign an IP Address to the Controller's Ethernet Adapter Card.

- a. Remove power from the controller chassis box.
- b. Remove the controller's Ethernet adapter card from the controller chassis.

Note: Follow standard anti-static dissipative procedures when removing and handling the card.

- c. Remove Ethernet and RS-232 connectors
- d. Release (4) front panel set screws and (2) covers

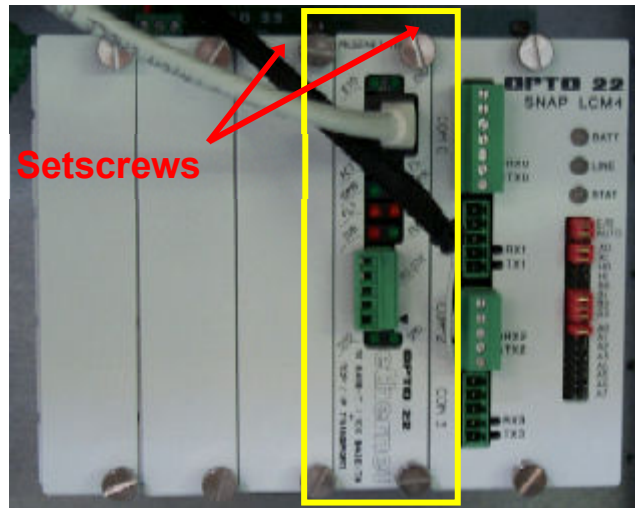


Figure 3-14 Remove Card from chassis. (See figure below)

- e. Remove the Ethernet adapter card

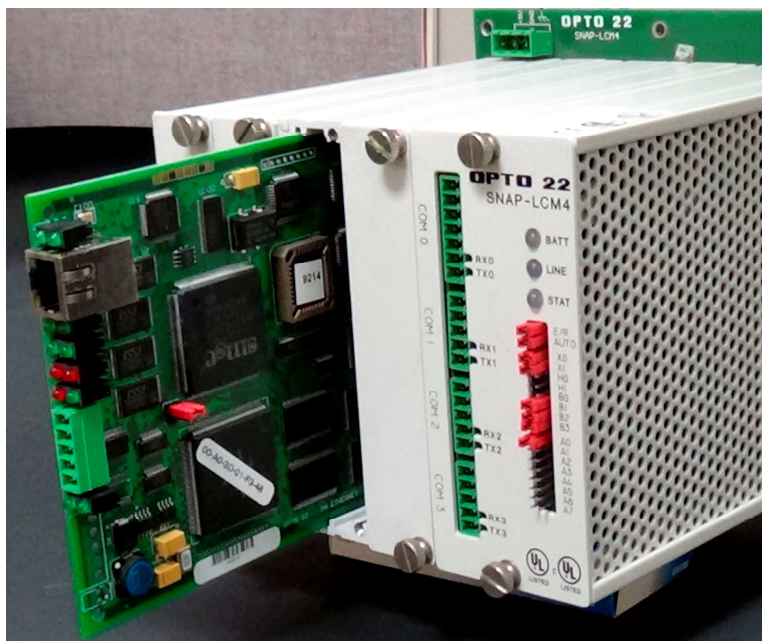
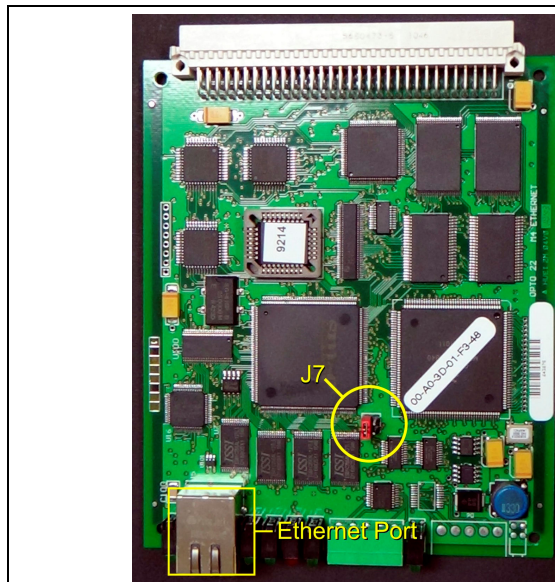


Figure 3-15 Removal of Ethernet Card

- f. Move the J7 Jumper to the Module Reset Position as shown in the following pictures.



**Figure 3-16 Location of J7 Jumper
J7 in Normal RUN Position**

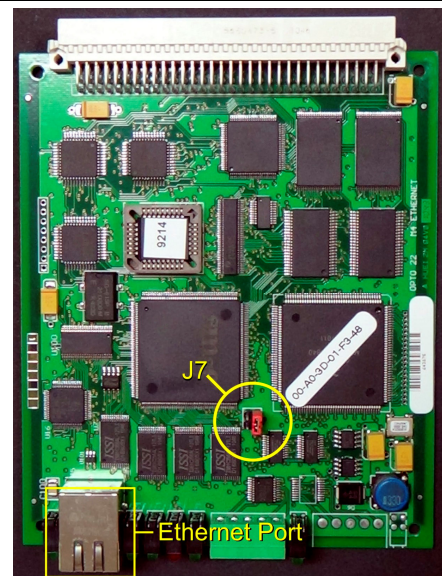


Figure 3-17 J7 Jumper at Module RESET

- g. Reinstall the Ethernet adapter card into the Opto22 controller chassis box.
h. Wait for the STD LED on the Ethernet adapter card to stop blinking, and then turn off, or remove power from the system.

Note: The power switch on the PC may need to be initialized.

- i. Apply power to the controller system.

Note: This procedure resets the Ethernet Adapter Card to its factory default settings.

- j. After removing power from the controller system, again remove the Ethernet Adapter card and restore the J7 Jumper to its original position as shown at right

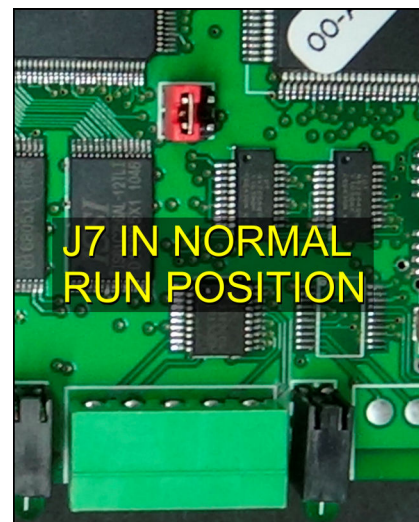


Figure 3-18 Original J7 Position

Section 3

- k. Reinstall the Ethernet Adapter card into the Opto22 controller chassis box making sure the covers and set screws are in place. Connect the network cable to the Ethernet port on the Ethernet adapter card. Make sure the green I/O connector is connected to COM2 port on the LCM4 (do not connect to the Ethernet card).

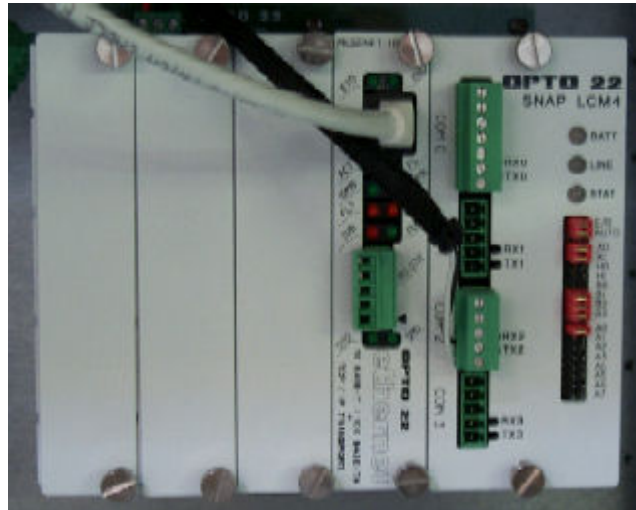


Figure 3-19 LCM4 Controller with Ethernet Adapter (on left)

- l. From the Windows® Toolbar, Select <Start/Programs\Opto22\OptoUtil\OptoBootP Utility>
- m. On the “OptoBoot Tool” dialog box, click the “Listen” pushbutton located at the upper right.
- n. After a few seconds, in the dialog box’s data window, a Mac address will be listed followed by 0.0.0.0 IP Address and a ??.?.?. Subnet Mask.

Double Click on the 0.0.0.0 field to assign an IP Address

Enter “**10.192.105.102**” for the IP Address and “**255.255.255.0**” for the Subnet Mask. Leave the Gateway field **0.0.0.0**.

Click the “Send” pushbutton to assign the entered address.

The data window should now be updated to display a “Yes” under the “Sent” Column.

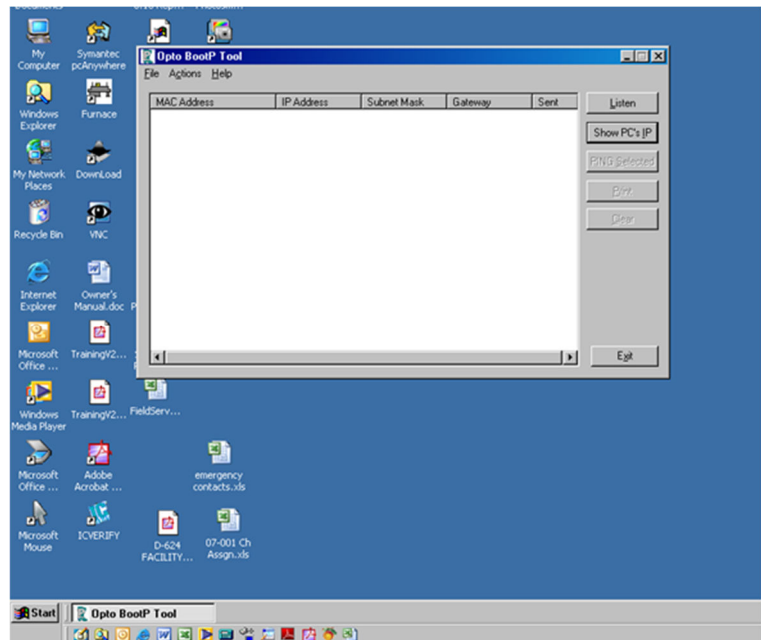


Figure 3-20 OptoBoot Screen

- o. Click on “Exit” to leave the OptoBoot tool application.

3.8.5 Replacing SCR Control Modules

A. SCR REMOVAL

To remove the entire SCR assembly, disconnect the 10Vdc and the 24 Vac wire pairs. Unscrew the Line and Load wires. If you are only replacing the firing board, remove the (2) firing board screws. If you are removing the entire assembly, remove the (2) SCR Mounting screws. See **Figure 3-21 SCR installed**

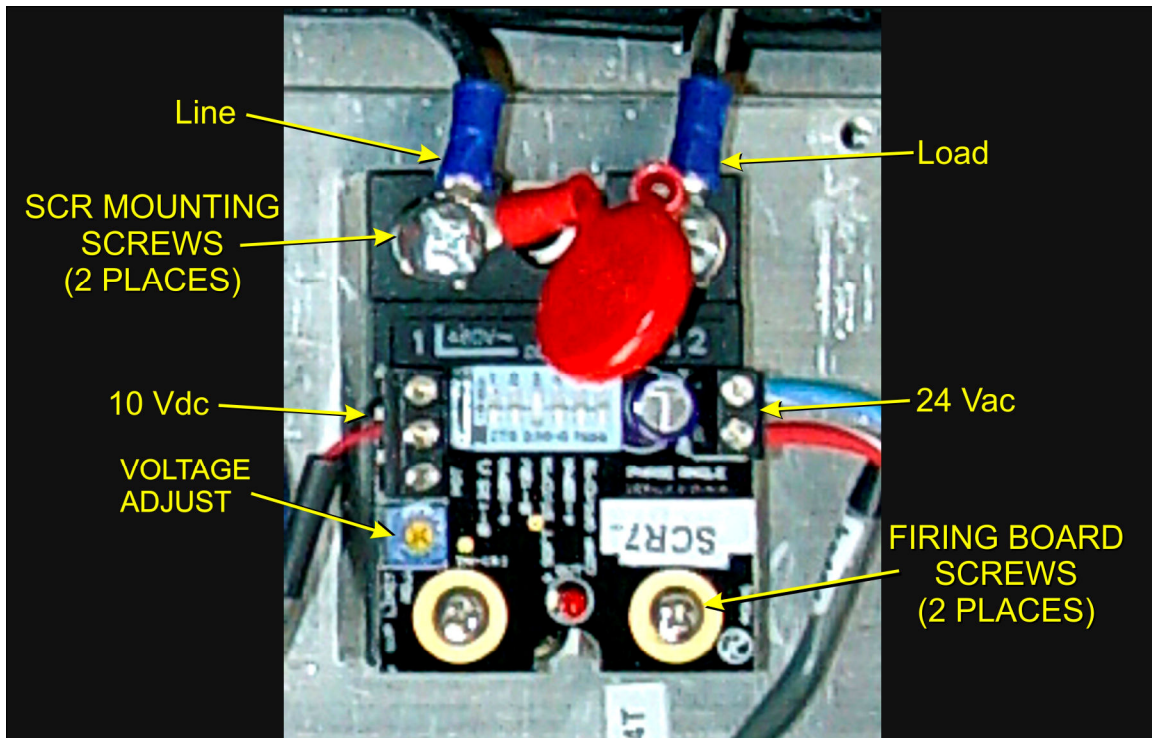


Figure 3-21 SCR installed

B. SCR INSTALLATION

Install an entire SCR assembly, by first checking that thermal paste is applied to the back of the SCR and the heat sink (aluminum plate) in the location where it will be mounted. Screw the assembly to the heat sink. Connect the 10 Vdc control wires, the 24 Vac control voltage wires and the Line and Load wires with red capacitor in place. Make sure the dip switch is set as shown in Table 3-10. Then follow the procedure on page 3-26, section **3.9.1 Calibrate SCRs** to calibrate the SCR.

Table 3-8 SCR Firing Board DIP Switch Settings						
Dip Switch	1	2	3	4	5	6
Position	OFF	OFF	ON	OFF	OFF	OFF

3.8.6 Heat Lamp Replacement

A. Tools Required:

Table 3-9 Tools needed for replacing Lamps	
(2) 3/8 in. open ended wrenches	Replacement Kaowool packing material
Allen wrench	Lint free cloth or protective gloves
Flashlight	

B. Handling Heating Lamps

Warning: Whenever handling furnace heat lamps, special care must be taken not to touch the surface of the lamp. Leftover salt from handling the lamps can cause hot spots which can reduce lamp performance or cause failure.

If the cleanliness of a heat lamp is suspect, clean the lamp with isopropyl alcohol and wipe with a lint-free cloth prior to use.

C. Lamp Removal

All power should be removed from the furnace before replacing lamps.

1. If Plenum covers are supplied, remove the setscrews securing the plenum clamps and carefully remove plenum covers. Care must be taken not to damage the rubber seal between the plenum chamber and the chamber cover.
16. Short one lamp from each zone to the furnace frame to remove any charge residing in the lamps.
17. Taking care not to disturb the ceramic insulating blocks, use one of the 3/8" wrenches to hold the base nut while you loosen the fastening nut.

Warning: If the furnace is equipped with the hermetic seal (Option □), any cracks to the insulating block will result in furnace chamber leaks and should be replaced if broken.

18. Disconnect the element lead from the insulating terminal block. Repeat this step for the opposite side.
19. Remove lamp and old packing material.

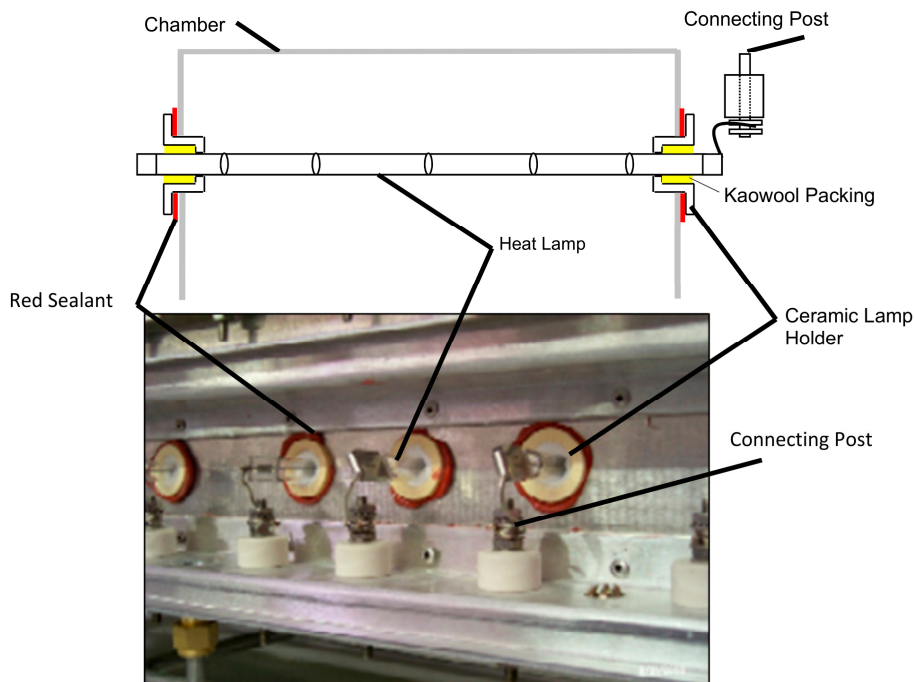


Figure 3-22 Lamp Replacement

Cross-section Across-the-Belt Diagram (top), End View Picture (bottom)

D. Lamp Installation

1. Make sure the red sealant securing the ceramic lamp holder is intact. Unsealed ceramic lamp holders may be resealed with Kaowool packing.
2. Using a lint free cloth or protective gloves, remove the lamp from its carton being very careful not to touch the glass with bare hands.
3. Straighten the connecting lead on one end of a new lamp and slide it into place. You may need the flashlight to locate the opposite side's ceramic holder. Once the lead appears from the ceramic holder, you may carefully pull the lamp through the furnace chamber.

If threading the lamp is difficult. Thread a dowel or stiff wire through the furnace. Tape the lead to the dowel or wire and then pull the lamp into position.

5. Pack the ceramic holders on both sides with the Kaowool packing material.
6. Center the lamp to $\pm 1/32$ -in. (± 0.8 -mm) and recheck the packing.
7. Wrap the connection leads around the connection terminals in the same direction as the nut will be tightened. Use two wrenches, as you did when removing the connection, to ensure the connection post is not disturbed.
8. Cut off excess connection wire.
9. Replace plenum covers being careful not to damage the rubber seal.

3.9 Calibration

Consult the Reference Manual Section 7.3 for most calibration procedures.

3.9.1 Calibrate SCRs

Follow the calibration procedure described in section 7.3 of the Reference Manual.

Calibration of the SCRs is usually necessary only if an SCR or SCR controller is replaced. Good maintenance practice, however, is to check SCR calibration every 6 months or so, or if the furnace seems to be slower than usual to reach operating temperature.

This calibration procedure will require use of an RMS responding voltmeter/multimeter and a thin blade screwdriver, and will require that the access cover to the control enclosure be opened.

3.9.2 PID tuning

PID parameters can be varied for each zone. Typical initial values for PID parameters in high temperature applications are shown in Table 3-10. Alternate values can be used for a low temperature application to provide more constant application if IR energy. Use the SuperTrends screen to evaluate performance in each zone for you process.

Table 3-10 Typical PID Initial Factory Settings			
Symbol	Parameter	Initial Value	Alt Initial Value
P	Proportional Gain	9	18
I	Integral	45	45
D	Derivative	0	1

See Furnace Reference manual for theory and description of PID Tuning.

If you notice unstable behavior in a certain zone, use the following procedure to retune the PID:

NOTE: This procedure should only be attempted by qualified personnel. Unreasonable PID parameters can stress the components of the system and cause premature failure of some electrical systems.

First go the Process screen an open the Super Trends chart for the zone to be tuned (see section 2.6 Super Trends). Go to the recipe screen and select the PID tuning for the zone of interest. Write down the values of Gain and Integral before you start changing them! If all else fails, you can return to the factory default.

Set the integral to the maximum possible value (180), the Derivative to 0 and the Gain to 1. Wait until the temperature stabilizes. Increase the Gain by 10%. Repeat until the temperature starts oscillating. Always wait for at least 5 oscillations before changing any parameters again. The temperature will be oscillating at a value BELOW the setpoint. This is normal. The temperature will be anywhere between 5° and 50°C below the setpoint.

Now set the Integral to the period of previous oscillations (usually between 5 and 15 seconds). Round up to the nearest integer. The temperature will slowly drift to a new value. Reduce the Integral term for faster convergence.

At that point, the system may start oscillating again. Decrease the Gain by an additional 10% until stable.

If the heating process inside the chamber is a first order process with very little lag time. This means that the PID does not need a Derivative value to operate ($D = 0$).

Oscillations are caused by gain too high, integral too short, or rate too long. Never set rate to more than one-fourth of integral time. Sluggish response is caused by gain too low, integral too long, or rate too short.

The PID values will work over a rather wide range of temperature. However, on a High Temperature furnace, the PID might require tuning for the low range of temperature, around 200°C, and different set of parameters above 500°C. The machines are set up for one set of PID parameters at the factory. For furnace fine tuning, it is the responsibility of owner's process engineer to determine the final settings.

3.9.3 Belt Speed Measurement

The belt speed has been calibrated at the factory. The actual belt speed can be verified by the following procedure.

Tools Required: Tape Measure & Stop Watch.

- ❶ Measure the distance from the furnace entrance gate to the exit gate.
- ❷ Set the belt to the desired speed. (Set belt to the maximum speed if you plan to reprogram the Belt Speed Display meter.).
- ❸ Place an object on the belt to act as a marker
- ❹ Start the timer as the marker enters the entrance gate.

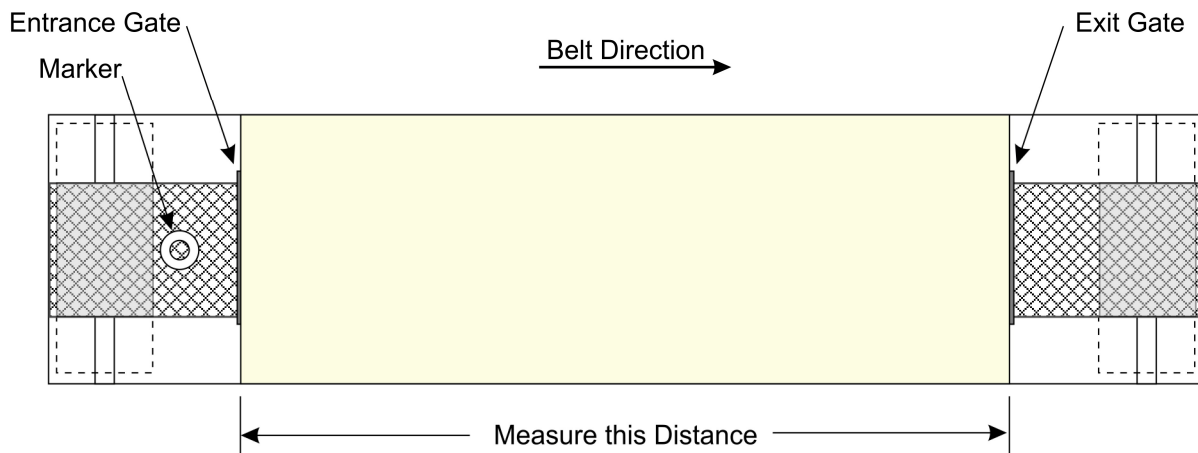


Figure 3-23 Belt Speed Calibration Diagram

- ❺ When the marker on the belt reaches the exit belt tray, stop the timer. Record the time in seconds.

CALCULATE ACTUAL BELT SPEED:

Convert the measured distance from **step ❶** above to inches.

Convert the time from **step ❺** to minutes.

Compute the actual belt speed according to the following equation:

$$\text{Speed} = \frac{\text{Distance (in.)}}{\text{Time (min.)}}$$

3.9.4 Belt speed Calibration

Go to the calibration screen. Check the box 50% output. Using a stopwatch, time the belt speed over a known distance, and calculate the actual belt speed. Enter the number in the Actual speed field. Un-check the 50% output box. See Reference Manual Chapter 7.3 for more detail.

3.9.5 Thermocouples

The thermocouples are pre-calibrated. They do not require any additional calibration.

3.9.6 IPS - Low Gas Pressure Switch Calibration (optional equipment-not installed)

Inlet Pressure Switches are installed on the process gas manifolds. These switches are normally open. They close when proper pressure is present in the process gas supply lines.

The switches are set to open when pressure falls below set points in the following table:

Table 3-11 Initial Alarm Settings			
Port	Manifold	Pressure	
Gas 1	CDA or Nitrogen	55-60 psig	3.8-4 Bar
Gas 2	Nitrogen Forming Gas, or other (Option)	55-60 psig	3.8-4 Bar

The pressure switch set points can be adjusted manually. Locate the switch in the process gas supply line. To increase the set point turn the wheel clockwise. Turn the top of the switch counter clockwise to decrease the pressure set point so the alarm will not occur until the pressure drops to a lower point.



Figure 3-24 IPS Inlet Pressure Switch

A. Gas Supply Low Pressure Switch Calibration

The process gas pressure switch is located on the gas supply manifold for each gas supplied.

If a reservoir tank is supplied, the pressure switch is located at or near the compressed air receiver. See drawing 802-101780-01.

B. Calibration

To calibrate each switch:

- 1) Verify that the Low Pressure Alarm switch is enabled.
- 2) Close all flowmeter valves.
- 3) Set inlet air pressure to desired set point pressure. Read pressure on supply gage.
- 4) Rotate the Adjusting Wheel: Clockwise to increase the pressure set point, counterclockwise to decrease. You can hear a faint click when the micro switch changes state. Below this point below which the switch will activate the alarm when enabled.
- 5) Start the furnace system without power to the lamps. Close the facility process gas valve to the furnace. Open the flowmeter valves and verify that the alarm trips when the pressure drops below the new set point.
- 6) Readjust as necessary and retest.

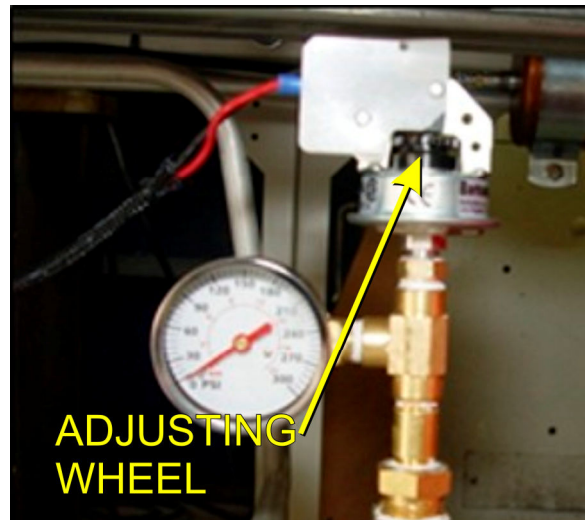
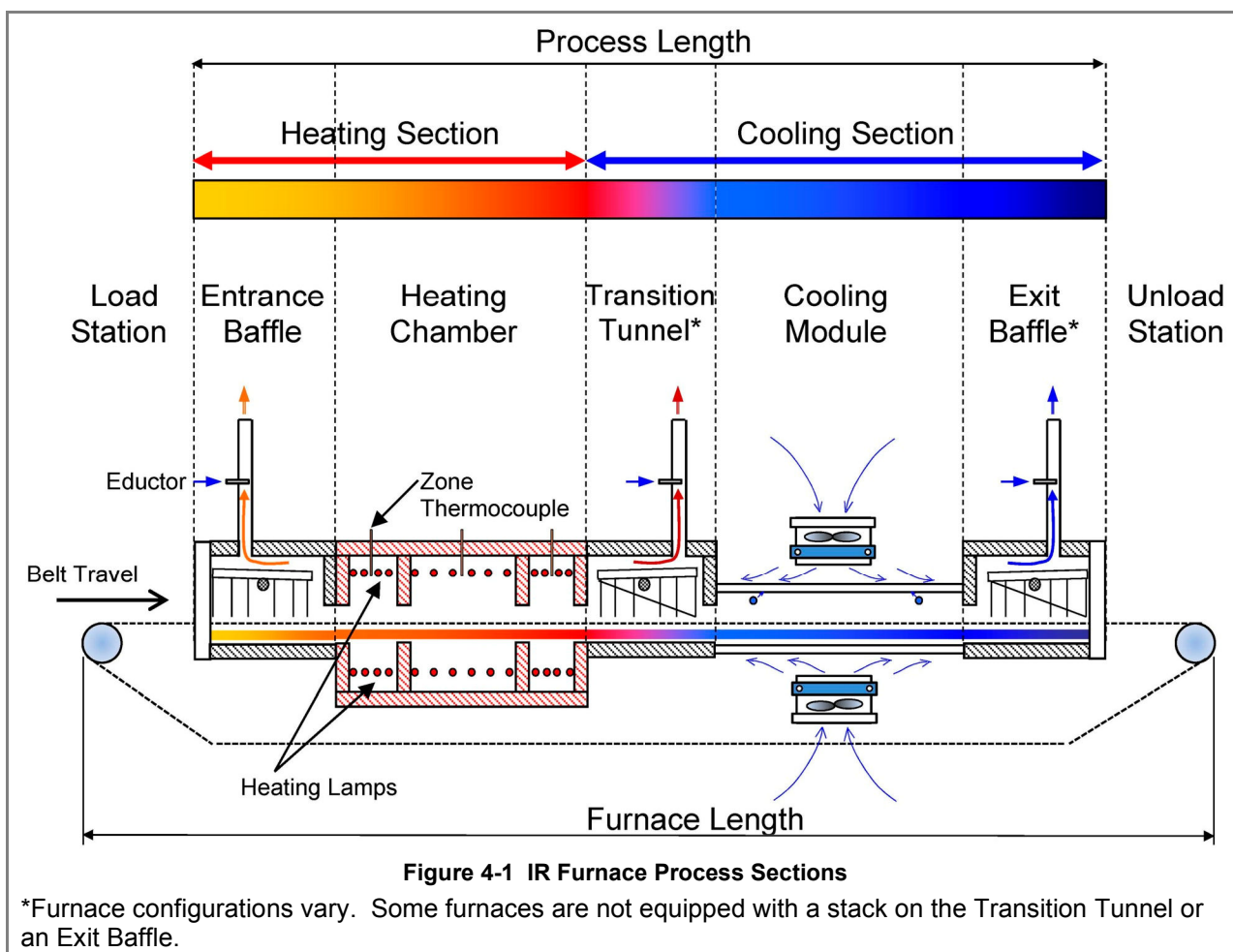


Figure 3-25 Air Pressure sensor

PROCESS ENGINEERING

4.1 IR Furnace Process

The infrared furnace continuously processes product on a moving belt. Each product moves through the same areas and is exposed to the same process elements. The furnace process sections are shown in Figure 4-1.



Continuous IR Processing is generally characterized by rapid ramping rates, ability to vary temperatures greatly from zone to zone and consistent processing performance in a controlled atmosphere. Establishing an acceptable profile and stabilizing the furnace are key to successful thermal processing. This is done by managing the following:

- Zone Temperatures
- Belt Speed
- Process Gas inflow
- Balancing the Gas flow using exhaust venturi flow
- PID Loop and Zone Power adjustments

Section 4

4.1.1 Zone Temperatures

Set zone temperature controllers so that the furnace can easily achieve the required temperatures in each heating zone.

4.1.2 Belt Speed

If the profile temperatures are acceptable, but the period is too long or short, vary the belt speed to achieve the required retention time. Increasing belt speed reduces process time, reducing belt speed increases time at temperature. Adjusting belt speed will also affect ramping time. Be careful to keep belt speed low enough to assure the product has adequate time to cool before it reached the exit belt roller.

4.1.3 Process Gas Inflow

Process gas introduced into the furnace through the chamber walls serves to keep the lamps ON and thereby improving process control. Too much gas will force lamps ON and use more power than may be necessary. Too little gas will allow the lamps to shut OFF. While the furnace is coasting, it is out of control and may result in uneven results.

The process gas flow can be adjusted to replenish the gas in each zone by multiples of the volume of that zone. Replenish rates for normal processing are 1-2x. If processing requires very low moisture and/or oxygen concentrations below 20 ppmv, higher replenish rates in the zones may be required to achieve good results. See section 4.5 Gas Flow through 4.5.8 Process Gas Flow Guidelines for detailed information of gas flow replenish rates and balancing the furnace.

4.1.4 Balancing the Gas Flow

Once the process gas inflows are set, the exhaust stacks must be adjusted for the type of environment desired. If the process being run requires very low moisture and/or oxygen concentrations, the furnace atmosphere should be positive (internal pressure higher than the pressure of the room). To establish a positive atmosphere in the furnace, sum the inflows, subtract excess gas amount (typically 50-200 Lpm) and divide by 15 to determine the stack exhaust flow settings.

If the process may give off volatile or poisonous gas, set the furnace to neutral or negative atmosphere (furnace internal pressure lower than room atmospheric pressure). To achieve a negative atmosphere, sum the inflows, add excess gas amount (typically 50-200 Lpm), and divide by 15 to determine the stack exhaust flow settings.

The furnace eductors are designed to extract the process gas from the furnace and cooling section internals at approximately 15 times the flow to the stack eductor. For example, to extract 250 Lpm from the furnace via the stack, set the stack flow to 17 ($250/15 = 16.67$). See sections 8.5 through 8.8 for process engineering considerations.

4.1.5 PID and Zone Power

While the furnace PID settings are preset at the factory, sometimes a process requires adjustment of these parameters to achieve desired results. In addition, on computer controlled furnaces, adjusting the zone power settings can dampen furnace performance. Increasing zone power will increase furnace responsiveness.

In furnaces with independent zone controllers, the Autotune feature can aid in optimizing zone controller performance. See 4.4 PID Tuning for more details.

4.2 Furnace Construction

The heating chamber technology allows for rapid heat-up and cool-down times. Stable temperatures of up to 1000°C can often be reached in less than 20 minutes. Radiant heating allows for rapid startups and profile changes and system stabilization.

The heating chambers consist of an outer metallic shell fabricated from either aluminum or stainless steel, lined with a refractory-ceramic-fiber (RCF) insulation. Controlled atmosphere heated sections allow process gas to pass through the RCF insulation.

4.2.1 Modules

The furnace is constructed from a number of basic modules which make up the furnace length.

For example, the standard ProControl is comprised of 7 modules

Module 1 – Loading Station

Module 2 – Entrance Baffle

Module 3 – 3-Zone Heating Chamber Module

Module 4 – Transition Tunnel

Module 5 – Controlled Atmosphere Cooling Module

Module 6 – Unloading Station

In some applications, longer cooling sections are required. Additional controlled atmosphere cooling modules, a water cooling system, or a forced air cooling module after the exit baffle may be added.

Another application may call for a longer heating section with an additional 4-Zone heating chamber module.

Every furnace heating chamber is constructed with 30-in. (76-cm) modules. Depending upon application requirements, the furnace can be configured for any size up to 16 zones. Each furnace is a custom arrangement from standard design modules, the layout and overall design is completed prior to the start of fabrication.

4.2.2 Throat

The throat of the furnace describes the maximum height of any product allowable through the process section. Depending upon configuration, throat clearance can range from 0.75 to 4 inches. The throat height has a significant impact on the thermal process profile as gas flow between chambers is significantly increased as the throat is increased.

Warning: Feeding items through the furnace that exceed the throat clearance will damage furnace zone separators and may reduce furnace performance.

4.3 Heating Chamber Design

4.3.1 Zones

The heating chambers are divided into individually controlled **zones**. Each 30" chamber module can be divided into 1, 2, 3 or 4 zones. If the furnace requires more than 4 zones, additional heating chamber modules must be added. The zone configuration of your furnace depends on the type of processes your furnace will be running and is part of the project furnace design specification.

4.3.2 Infrared Heating Chamber

The chamber is insulated with a porous material and if the furnace is used in a controlled atmosphere application, pressurized process-gas entering **plenums** at the top and bottom diffuses through the porous insulation and enters the process area. The gas enters in high volume and with low velocity. As the gas diffuses, it becomes heated to the bulk temperature of the zone.

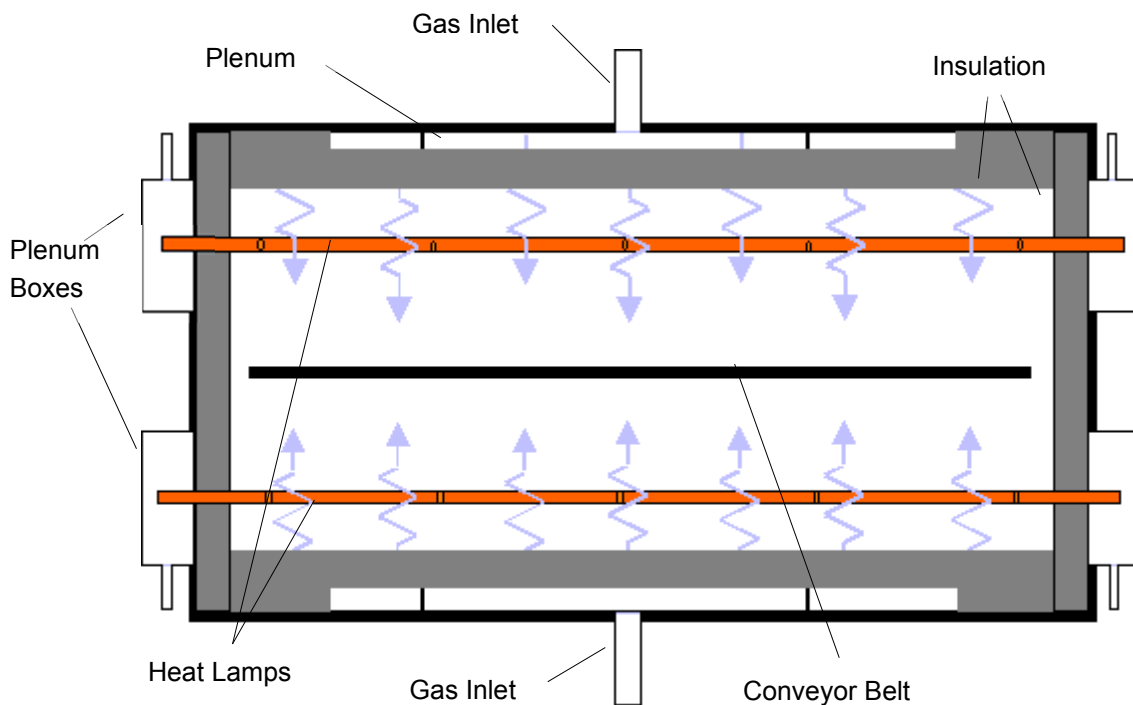


Figure 4-2 Heating Chamber Cross-section

Plenum boxes may be specified and included as part of the hermetic seal option, which allows a light positive pressure to be applied to the ends of the heat lamps forming a highly controlled atmosphere condition.

Correctly balancing the airflow contributes greatly to the cleanliness of the chamber. When properly balanced, a high volume gas-flow is present from both top and bottom of the chamber. Effluents released from your product are swept along the centerline of the chamber to the exhaust ports, and do not rise to contact the upper surfaces or fall to contaminate lower surfaces.

Incoming process gas introduced through a large displacement area provides rapid purge times and low contamination levels. Typically, a process environment atmosphere of less than 10 parts Oxygen in 1,000,000 parts Nitrogen (<10ppm O₂) can be achieved within about 10 minutes. Rapid purge times also allow for quick process environment replenishments as well as fast cool-down times.

4.3.3 Energy Type for Applications

Types of Energy. The ability to turn banks of lamps off and on via the zone switches on the ENERGIZE LAMPS panel allows the user great flexibility in applying energy to each zone. Use just the top lamps in each zone for drying moisture or volatile organic compounds from the top surface of substrates or trays, or curing

thermosetting compounds or coatings on wafers or polycarbonate materials. Use both top and bottom lamps in traditional furnace applications. Use just the bottom lamps to emphasize conduction heating of parts from the transport belt and from IR radiation on the bottom of metallic or ceramic parts carriers.

4.3.4 Placement

Lamp configuration within each zone is determined to achieve optimal power consumption based on the type of processes specified by the owner operator. Heat lamps can be packed closely together where high temperatures need to be reached quickly. For Holding Zones where rapid rises to high temperatures are not required, lamps are usually spaced further apart.

4.3.5 Wiring

Heating lamps are wired differently for each furnace. The actual amount of power available to each lamp is based upon the heat lamp wiring configuration and the AC input voltage. Lamps may be wired in parallel providing the highest available power to the individual lamp or in series, splitting the power with other lamps. Most systems are wired in a series-parallel configuration to optimize the use of available voltage and minimize current flow. Refer to the wiring diagram in the Operating Manual for heat lamp wiring details for a specific furnace.

4.4 PID Tuning Concepts

When the furnace is in operation, the power supplied to the lamps is under constant control. A special performance control is used to maintain consistent zone temperatures by adjusting the current allowed to reach the heat lamps. The control is referred to as a PID control loop. The name PID stands for **P**roportional + **I**ntegral + **D**erivative and represents the three terms used in the control loop.

When PID tuning, any changes that are made are sent directly to the controller modifying the way the controller responds to deviations from setpoint. Tuning the furnace allows the engineer to precisely control the temperature profile inside the furnace.

A complete understanding of how a PID loop works and how to tune it will greatly benefit the owner operator and product results.

In general, the PID equation takes on the following form:

$$CO = G \cdot \left\{ (S - T) + \frac{1}{I} \int_0^{1\text{sec}} T \cdot dt + D \cdot \frac{dT}{dt} \right\}$$

Where:

T = Temperature

t = Time

G = Gain Term Value

S = Setpoint Temperature

I = Integral Term Value

D = Derivative Term Value

The output from the three terms, the proportional, the integral and the derivative terms are summed to calculate the output of the PID controller. The following paragraphs review and explain the three components of the PID equation.

4.4.1 Gain

The proportional band is adjusted according to the following equation

$$PB \text{ } ^\circ\text{C} = 100 \text{ } ^\circ\text{C} / \text{Gain}$$

The higher the gain, the narrower the proportional band; the lower the gain, the wider the proportional band.

The gain value multiplies the difference between the setpoint and actual temperature. The difference between these two values is referred to as the **error**. (This does not mean that anything is wrong). The error is measured continuously, about once a second. When this difference is large, power to the heat lamps will be increased, or decreased, accordingly. When the error is small, power to the heat lamps will be maintained at present levels. Gain values greater than 1 amplify the controller's response to error (differences between temperature and setpoint).

Setting the gain too high will result in temperature over and under shoots. It is possible that the temperature will never reach a stable state. The temperature might oscillate around the setpoint.

Setting the gain too low will result in a slow response to temperature changes. The furnace will take longer to reach operating temperatures and will be slower to recover from temperature drops as the product soaks up heat.

Note: Since the gain value is a multiplier, it should not be set to zero.

Default values for gain vary for each zone and temperature setpoint range. Gain is typically set at default values from **40** to **95** for most applications.

4.4.2 Integral

With only gain operating, and no value set for integral and derivative, the controller acts somewhat like a thermostat. When the difference between temperature and setpoint (error) is zero, power to the heat lamps is maintained at current levels. When the temperature drops below the setpoint, power is increased until the temperature returns to the setpoint. This PID setting results in an operating condition where the measured temperature is often inappropriately far from the temperature setpoint.

The integral value is used to rapidly converge on the set point.

The **integral value** refers to the integer value entered in the recipe screen. The **integral term** is calculated automatically by the controller. The integral value multiplies the integral term.

The Integral term in the PID equation represents the average error (temperature difference) over a time interval of about one second and is updated continuously, accumulating error as a function of time.

The integral product (**integral value** multiplied by **integral term**) is added to the error. This integral product can make a significant difference to the PID control output signal especially if the current error is small.

Think of it this way: The difference between temperature and setpoint at any given time could be zero, but the average difference between temperature and setpoint over the length of time represented by the integral term is never likely to be zero. With an integral value of zero, power will be maintained at its current level even though the temperature is about to decrease. With an integral value greater than zero, multiplying the integral term, power will be increased slightly and the impending temperature drop will be not be as profound.

With a Gain and an Integral value entered in a recipe, the PID equation will always be adjusting the controller's output unless the both the **current difference** and **average difference** between temperature and setpoint is zero.

Larger integral values generate smaller responses from the controller. A value of 1, for instance, will use the entire average difference between temperature and setpoint for the correction value. A value of 2 will use half the average difference for the calculation. Entering very large integer values will have the same effect as entering zero.

Default values for integral vary for each zone and temperature setpoint range. Integral is typically set at default values from **8 to 15** for most applications.

4.4.3 Derivative

The derivative term of the PID equation is a value representing the rate of change of the temperature setpoint deviation. If, for example, the temperature deviation is accelerating away from the setpoint, the derivative term attempts to predict what the deviation will be some short time in the future. This behavior allows the derivative to sense a change in load early and attempt to counteract its effect ahead of time.

Suppose, for example, that the zone temperature is deviating downwards from the setpoint at 10°C/second. At the next measurement, the temperature is deviating downwards at a rate of 20°C/second. The derivative term will sense this acceleration away from the setpoint and counteract it by increasing the PID signal to the controller. The larger the derivative value entered in the recipe screen, the larger the correction.

A zero value may be appropriate for many processes with constant furnace loading (a continuous stream of similar parts entering the furnace).

For processes where furnace loading is uneven, such as when parts arrive from screen printers or non-buffered processes in an automated line, a non-zero derivative term may help the furnace respond more quickly when parts suddenly enter the heating zones.

Care must be taken when entering derivative terms higher than 4 due to the fast response of the IR furnace.

Detecting an accelerating deviation from setpoint requires at least three temperature measurements. Therefore, at least two seconds elapse before a correction can be made. Heat lamps are very responsive and very little amplification is needed to correct the lamp output. The derivative can show a downwards accelerating temperature deviation even though the temperature may have started increasing. This condition can result in an over correction.

Even when furnace loading is fairly constant, Derivative can vary for each zone and temperature setpoint range. Derivative is typically set at default values of **1 to 3** for most applications.

4.5 Gas Flow

4.5.1 Gas Flow Basics

The most important factor in creating a safe and efficient process environment is gas-flow balance. The volume of process gas entering the system should be equal to the volume of exhaust gas leaving the system.

Gas flow entering the oven is controlled by **flow meters**. The flow meter arrangement is different for every furnace. A flow meter can be installed to supply gas for each individual zone or for various combinations of zones.

All furnaces are equipped with gas power exhausts. Compressed gas (usually air or nitrogen) is forced through a small hole in a small tube creating a venturi effect inside the exhaust stack. The forced high-speed gas flow drags the furnace atmosphere out with it. To regulate the rate of exhaust, each venturi is supplied by its own flow meter.

Correct gas flow through the venturi is a critical factor in achieving stable temperature profiles. For this reason, exhaust stacks cannot be connected to facilities ducting. Changes in facilities-ducting pressure would change exhaust pressure that would in turn change the gas flow within the furnace. The condition will lead to alterations in the thermal process profile.

Disruptions in gas flow in the process section can be caused by the following influencers:

- Close proximity of doors
- Close proximity fans
- Placing a furnace through a wall between rooms
- Attaching facility exhaust ducts directly to the furnace exhaust stack

4.5.2 Process Gas

Various forms of process gas can be utilized inside furnaces. Users may want to operate a pure N₂, O₂ or H₂ environment. Others will only need clean dry air (CDA). Whatever the case, the furnace can be factory configured in different ways to meet specific requirements. The following are some possible process gases.

4.5.3 Nitrogen

Many processes require the process environment be free, or almost free, of oxygen as the products would either burn or oxidize. Removing oxygen involves forcing the oxygen out by pumping in another gas. A relatively inert gas such as nitrogen is normally used for this purpose.

4.5.4 Forming Gas

Forming gas is the term used to describe any mixture of N₂ and H₂ gas. Without the Hydrogen option, only non-combustible gas can be used safely with the ProControl.

4.5.5 Hydrogen

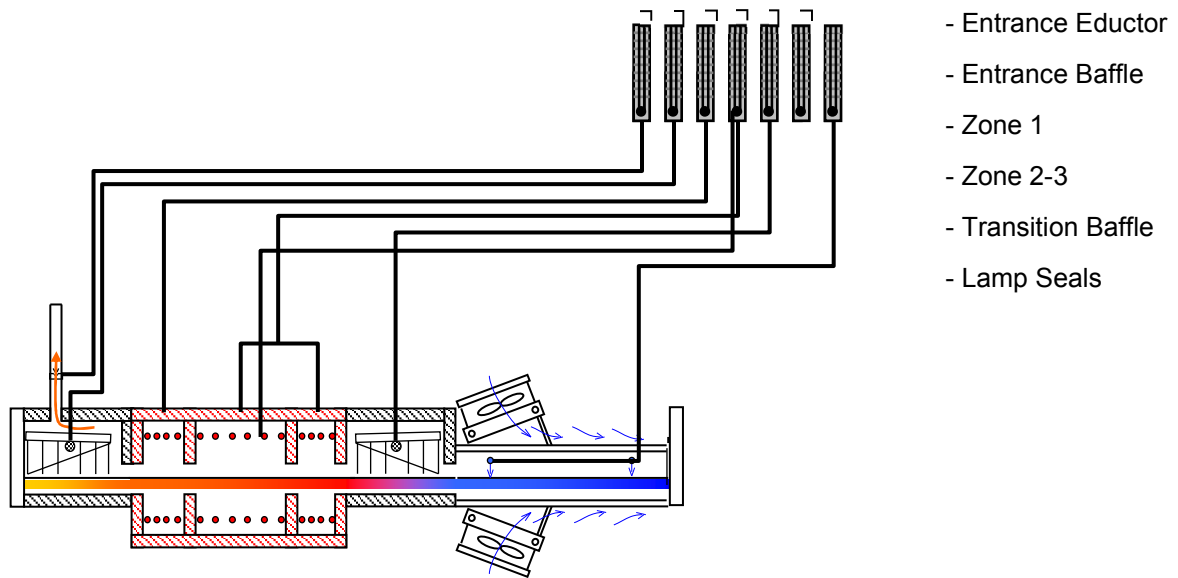
Other gases having a beneficial effect on a process can also be introduced into the process environment. Hydrogen, for example, is commonly used in reflow soldering processes to facilitate solder flow. Without the Hydrogen option, only non-combustible gas can be used safely with the ProControl.

All processes with concentrations of H₂ higher than 4% mass percent require all H₂ automated safety features. When the concentration of H₂ gas required for the process falls below 4%, H₂ levels will not reach an explosive concentration inside a furnace.

4.5.6 Creating an Optimum Process Environment

To establish a process environment, the engineer will need to start with the number of times the air surrounding the product will need to be replenished. This figure depends very much on the process requirements and costs. Some processes give off large quantities of volatiles that will need to be removed, requiring higher gas flow rates than other, cleaner processes. The cost of the process gas will also need to be taken into account, as quick replenishment times will use significant volumes of gas. For new processes, it may be safest to start with a high gas flow rate that can be adjusted downwards until the test product stops coming out clean.

The first step in calculating the flow rates will be to calculate the internal volume of the furnace chamber and multiply the answer by the number of times per hour that the atmosphere needs replenishing. The result is the total gas flow per hour for the chamber.



A. Calculate the Internal Volume of an ProControl Furnace

Example 1:

The process engineer determines the thermal process replenish time is 30 seconds.

Given: Replenishment Requirement: 30 seconds / replenish

Belt Width: 6 in.

Process Section Dimensions (Not including Open Air cooling modules)

The better the estimate of internal volume, the less tuning required.

	L (cm)	W (cm)	H (cm)	V (cm ³)
Entrance Baffle	38	17.8	15.2	10 324
Zone 1	19	17.8	22.9	7 8743
Zone 2	38	17.8	22.9	15 486
Zone 3	19	17.8	22.9	7 743
Trans Tunnel	38	17.8	15.2	10 324
Cooling	76	17.8	15.2	20 648
Lamp Seals	305	2.5	5.1	3 933
Total Internal Volume				72 267

Section 4

B. Calculate Replenish Rate

Convert furnace Volume from cubic centimeters to liters:

$$\begin{aligned} 72\,267 \text{ cm}^3 / 1000 \text{ cm}^3/\text{L} \\ = 72 \text{ L / replenish} \end{aligned}$$

Convert to L/min

$$1 \text{ minute} = 60 \text{ seconds}$$

$$60 \text{ seconds/min} / (30 \text{ seconds / replenish}) = 2.0 \text{ replenishes / min}$$

$$(2.0 \text{ replenishes / min}) \times (100 \text{ L / replenish}) = 144 \text{ L / min}$$

Balancing Gas Flow, Q = 144 L/min (actual liters per minute)
--

From these calculations you can balance the furnace environment with a total gas flow of 1,444 L/min.

Note: although the above result is not true Lpm, it can be used to balance the furnace. The flowmeter scales are labeled in Lpm, but are not corrected for actual conditions. To calculate true Lpm, convert using Boyles law:

Correct for temperature and pressure to convert from CFH to standard cubic feet per hour (SCFH), assuming the inside of the furnace is at 1 atmosphere:

$$s\text{Lpm} = a\text{Lpm} \times \frac{(\text{Std Temperature} \times \text{Actual Pressure})}{(\text{Act Temperature} \times \text{Std Pressure})}$$

$$\text{Actual Furnace Temperature, } T_1 = 38\text{C} + 273 = 311 \text{ K}$$

$$\text{Actual Pressure, } P_1 = 0 \text{ kPa} + 101.3 \text{ kPa} = 101.3 \text{ kPa}$$

$$\text{Standard Temperature, } T_s = 21\text{C} + 273 = 294 \text{ K}$$

$$\text{Standard Pressure, } P_s = 101.3 \text{ kPa}$$

$$s\text{Lpm} = 144 \times \frac{(294 \text{ K} \times 101.3 \text{ kPa})}{(311 \text{ K} \times 101.3 \text{ kPa})}$$

$$\text{True Standard Gas Flow, } Q_s = 137 \text{ sLpm (21C, 101.3 kPa)}$$

Standard liters per minute can be used to determine plant compressed air requirements.

4.5.7 Balancing Gas Flow

Once the total gas flow has been determined for the process, the process engineer can then determine the balance of the gas flow.

Balanced gas flow means that the same volume of gas enters the chamber as exits.

- ❶ First to determine the quantity of gas that should be introduced to the each heating chamber: Divide the Balancing Gas Flow among each of the heating chamber zones and baffles for which the furnace has control.
- ❷ To determine the total gas flow to the eductors, first subtract the volume excess gas flow (flow to exit from entrance and exit openings) and then divide the result by 15. The approximate volume of air drawn out by the venturi created by the eductor is 15 times the flow rate.
- ❸ Divide the total eductor gas flow among the available eductors.
- ❹ The sum of the eductor gas flow and the Balancing Gas Flow is the gas consumed by the furnace.

Refer to Example 2 example shown on the following page.

Note: A balanced gas flow does not guarantee the best or most economical environment for your process. After following this procedure, gas flow may still need adjusting to achieve an optimum and safe environment.

A. Calculate the Balancing Flow

Example 2:

Given: Desired Excess Gas Flow = 100 Lpm

Balancing Gas Flow = 144 Lpm (from Example 1)

Gas Entering Zones

Entrance Baffle	20 Lpm	}	①
Zones 1	20 Lpm		
Zones 2 & 3	30 Lpm		
Transition Tunnel	15 Lpm		
Lamp Seals	20 Lpm		
Cooling	+ 20 Lpm		
Balancing Gas Flow in =	125 Lpm		
- Excess Gas Flow =	80 Lpm	}	②
Evacuation Gas Flow =	45 Lpm		
Eductor Flow Divider	÷ 15	}	
Total Eductor Gas Flow =	3 Lpm		
Entrance Stack Eductor	1.5 Lpm	}	③
Transition Stack Eductor	1.5 Lpm		

Gas Consumption

Total Gas Flow in	125 Lpm	←	④
Eductor Gas Flow	3 Lpm		
Total Gas Consumption =	128 Lpm		

This method provides a good starting point for balancing the gas flow in your furnace. It is, however, an approximate method so additional tuning will be required.

4.5.8 Process Gas Flow Guidelines

The following are guidelines for some common processes performed in furnaces.

1. If faster cooling is required – increase flow to the entrance eductor while reducing flow to the transition or exit eductor. This will prevent hot air from the heating chamber from carrying over into the cooling section.
2. For equilibrium profiles – set the flow to the zones at about the same rate. This will assist in keeping a steady flow of process gas around the product during heating.
3. For peaked or non-equilibrium profiles (i.e. solder reflow or solar cell firing) – increase flow to the middle zones and reduce flow at the beginning and ending zones, also increase flow to cooling sections. This will help the product achieve high temperature under IR radiation and allow for quick cooling.
4. In a long steady peak profile – increase flow to exit or transition eductor while reducing flow to the entrance eductor. This will draw the air to the end of the heating chamber using convection heating to assist in raising the product to its final temperature.

THERMAL PROCESSING THEORY

5.1 Infrared Waves

Infrared waves form part of the electromagnetic spectrum. Electromagnetic waves with wavelengths from 0.78 μm to 1000 μm are called infrared waves. You are already familiar with electromagnetic waves of different wavelengths. Microwaves, X-rays, radio waves and visible light are all electromagnetic waves. Infrared waves produced inside the furnace lie predominately in the near and medium infrared range with wavelengths ranging between 0.5 and 3.0- μm .

When using infrared lamps, higher heat-lamp temperatures emit higher radiant energy. This elevated energy translates to a shorter electromagnetic wavelength of emitted IR radiation. While the IR waves of a heat lamp come from a continuous range of wavelengths, the **dominant wavelength** (λ_{dom}) as given by Plank's distribution principle is the wavelength transmitted with the highest occurrence. So for a given temperature, only one λ_{dom} exists. See Figure 5-1 below.

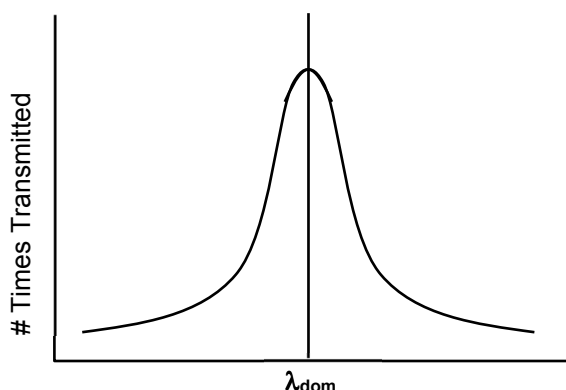


Figure 5-1 Dominant Wavelength Graph

The relationship between heat-lamp filament temperature T and λ_{dom} is given by the fixed relationship:

$$\lambda_{\text{dom}} \mu\text{m} = \frac{2897 \mu\text{m} \cdot \text{K}}{T \text{ K}}$$

To convert from degrees Celsius ($^{\circ}\text{C}$) to Kelvin (K) add 273 to the Celsius temperature value.

For example:

At 1000 $^{\circ}\text{C}$ the respective material dominant wavelength is:

$$T = 1000^{\circ}\text{C} + 273$$

$$T = 1273 \text{ K}$$

Substituting back into the given equation:

$$\lambda_{\text{dom}} = 2897 \mu\text{m} \cdot \text{K} / 1273 \text{ K}$$

$$\lambda_{\text{dom}} = 2.28 \mu\text{m}$$

5.2 Infrared Heating

Infrared (IR) heating is electromagnetic radiation emitted from the surface of IR lamps or emitters. Thermal radiation is generated when heat from the movement of charged particles within atoms is converted to electromagnetic radiation. In the furnace, radiant heating from IR lamps provides heat directly to objects without first heating the surrounding air. IR waves excite molecules within a substance (product) thus generating heat, but pass generally undisturbed through the surrounding atmosphere. Other substances such as glass, ceramics and some organic materials are also transparent to IR waves. Objects suspended in these media can, therefore, be heated directly by IR waves without directly heating the supporting media.

Not all heating in the furnaces occurs via direct IR radiation. The belt and air inside the furnace are heated via the IR lamps. Also edge heaters (resistance heaters installed along the furnace length) can introduce heat into the furnace. Your product also acquires heat from the edge heaters, conveyor belt and surrounding heated gas in the chamber via **conduction**.

The amount of direct heating via IR radiation is determined by three factors:

- 1) The level of IR radiation emitted from the heat lamps.
- 2) The amount of IR absorbed by a product.
- 3) The level of edge heat introduced into the furnace

If you know the **resonant frequency** of a particular substance, matching the furnace dominant wavelength the product resonant frequency ensures maximum energy transfer via IR radiation. In most cases, rapid product heating can be achieved more efficiently through frequency matching rather than with temperature increases.

5.2.1 Advantages of IR Heating

Heating via conduction and convection operates by transferring heat to object surfaces. Heat is then transferred from the surface to the layers beneath. Heat transfer, however, is not uniform, causing temperature differences and unequal expansion across an object. The unequal expansion due to the uneven heating is called thermal stress and can cause objects to fracture called thermal shock.

IR radiation heats molecules below an object's surface and allows for more uniform heat distribution than can be provided by conduction and convection heating alone.

Rapid heat up time is also achieved with IR technology due to the high energy-transfer rate of IR waves. The speed of conduction and convection heating is proportional to the temperature difference between the object and heating environment, whereas the speed of IR heating is proportional to the difference between the fourth powers of the object and environment temperatures.

For example:

Suppose the temperatures of an object were 100°C.

If a convection heating furnace were heated to 500°C, the proportional difference would be

$$500 - 100 = 400$$

If an IR furnace were heated to 500°C, the proportional difference would be

$$500^4 - 100^4 = 6.25 \times 10^{10} - 1.00 \times 10^8 = 6.24 \times 10^{10}$$

Other factors such as the emissivity of objects are taken into account when calculating energy transfer rates.

5.3 Thermal Process

The **thermal process** is the idealized process description for a particular product as it passes through the process section, including the product temperature profile and process environment. When establishing the thermal process, a consistent temperature profile is just as important as establishing the correct process environment.

Each dissimilar product that passes through a continuous belt Infrared furnace will likely utilize a different thermal process. Engineering design and empirical testing are the best methods of achieving the best thermal process.

5.4 Temperature Profiling

The proper thermal process is usually verified by performing a temperature profile. A temperature profile represents multiple temperature measurements taken at close intervals over a period of time through the length of the furnace. Product passing through the furnace go through a set of temperatures known as a temperature profile.

Notice in Figure 5-2 that the green horizontal lines define the setpoint temperatures, yet the thermocouple readings do not reach the actual setpoint temperature inside each zone. Also notice that the product peak temperature may be achieved well inside the cooling section.

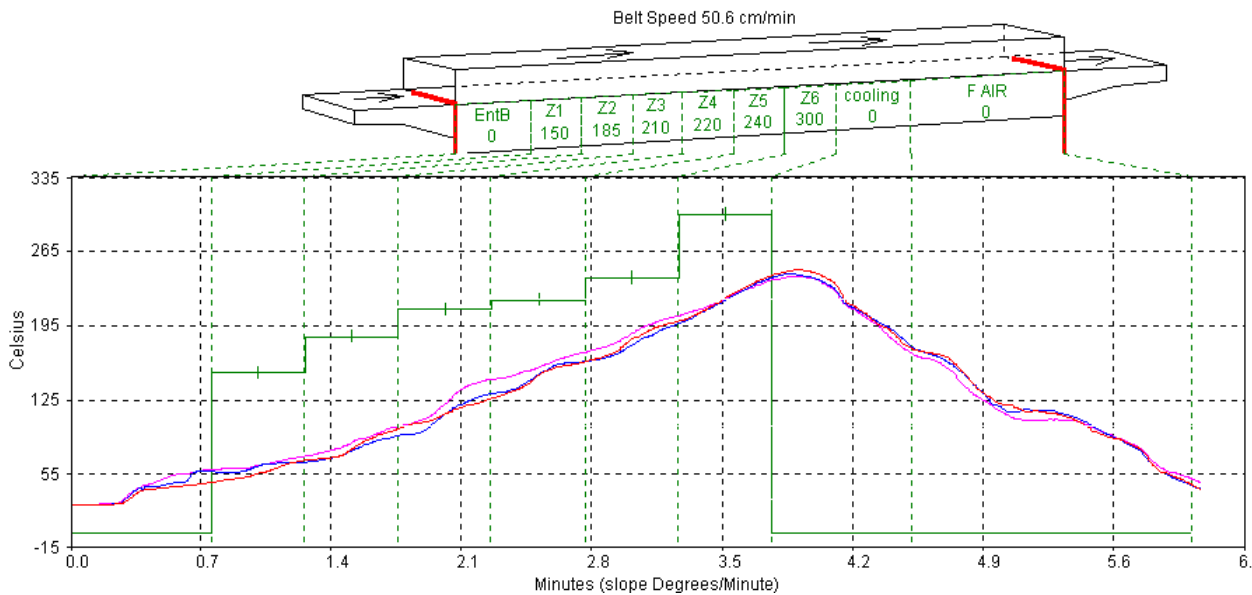


Figure 5-2 Temperature Profile

The temperature profile will be affected by the product material, mass and process gas. For example, a furnace with a controlled atmosphere cooling module installed can cool the product while in a pure nitrogen gas environment. The same temperature profile could be achieved with a forced-air cooling module, but could subject the product to a potentially hazardous oxidizing environment at elevated temperatures.

Prior to shipment, all furnaces undergo a temperature profile test. In this test, typically one or three (on furnaces with 15-inch or wider belt) thermocouples are sent through the furnace located on sample product on the conveyor belt at the center and, if three are used, one each side. All furnace zones are programmed to produce the furnace owner's prescribed setpoint temperature and allowed to reach steady state. The thermocouple readings are expected to remain within 5% of one another. While this test is performed at the factory, it should also be performed at startup and periodically thereafter to assure that the desired temperature profile can be maintained.

5.4.1 Profiling Responsibilities

The process engineer must set the furnace process parameters to achieve the desired temperature profile with the product. To do this, the engineer must have an idea of the process cycle of the product and the important process parameters and limitations. Looking again at the temperature profile from Figure 5-2, six zones are visible labeled Z1 – Z6. Depending upon the configuration of the furnace, fewer or more zones may be present. Standard and high power ProControl models are 3-zone furnaces. Initially, temperature profiles must be recorded from temperatures measured inside the furnace.

5.4.2 Profile Specification

In general, the temperature profile is defined by a combination of the following parameters:

- a. Heating Rate: The rate of increase of temperature from room temperature.
- b. Dwell/Hold Time: The time the product remains above a certain temperature or range of temperatures.
- c. Second Heating Rate: The rate of increase of temperature from the temperature reached during the hold time (if required).
- d. Second Hold Time: Dwell/Hold time for 2nd heating (if required).
- e. Peak Temperature: The maximum temperature reached with a +/- range and time at peak.
- f. Cooling Rate: The rate of decrease of temperature to a lower/critical temperature.
- g. Product Exit Temperature: As required.

If across the belt temperature distribution is a critical factor, use of three thermocouples attached in a similar fashion in the same line across the belt can reveal the temperature stratification during furnace processing.

If the parts are of great thickness as in a brass forging part, two thermocouples can be used to measure the temperature differences at different locations on the sample part.

For production work, the required specification must be achievable at a single speed setpoint within the specified furnace speed range. In general, the speed range depends on the factory gearing for the size and type of furnace and the specified requirements. Many sets of belt speeds and temperature settings can meet a given set of profile specifications. Furthermore, higher belt speeds can result in greater temperature deviations and lower consistency from the desired temperature profile. Also higher speeds shortens the cooling retention time and the parts may exit the furnace too hot.

5.4.3 Basic Profiling Variables

The two most influential and basic variables in setting up a temperature profile are:

- Retention Time: The time required to pass through the process section. Retention time is influenced by belt speed and zone temperature setpoints.
- Temperature Setpoints: Determines the energy level in each zone.

The combination of the time-temperature exposure of the product determines the temperature profile. The temperature settings in each zone set the heating rate and hold times of the product.

A third and less influential factor in the temperature profile is:

- Flow Meter Settings: Controls the rate of gas flow through the process section. Can influence heating and cooling rates and furnace IR stability.

If the furnace is equipped for a controlled atmosphere, this will be an important factor to consider. Gas flow and flow meter settings is addressed in detail in Sections 4.1.3 and 4.1.4.

5.4.4 Types of Profiles

In most processes, two kinds of temperature profiles exist:

Equilibrium (flat) profile applications:

- Annealing
- Brazing
- Die-attachment processes
- Drying/Curing of polymeric products
- Glass or metal/solder sealing of IC packages
- Hybrid thick film and PTF firing

Non-Equilibrium (peaked/spiked) profile applications:

- Cerdip lead-frame attachment
- Solar cell firing processes
- Solder reflow attachment

Most microelectronic and semiconductor thermal processes fall into one of the above categories, or some combination of the two. Set the furnace parameters according to the type of process that will be used with the furnace.

Examples of the two fundamental types of profiles are illustrated in Figure 5-3 and Figure 5-4.

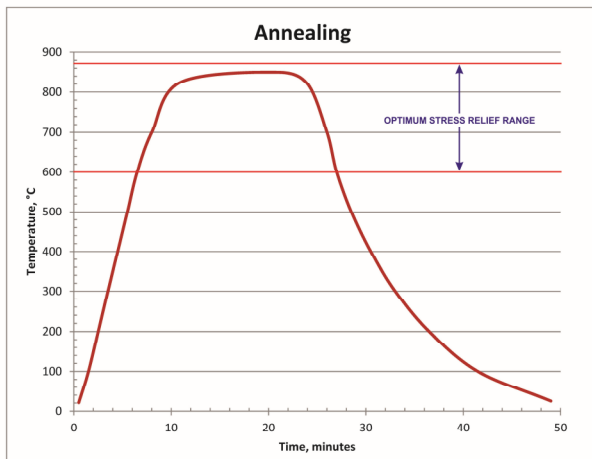


Figure 5-3 Equilibrium Profile

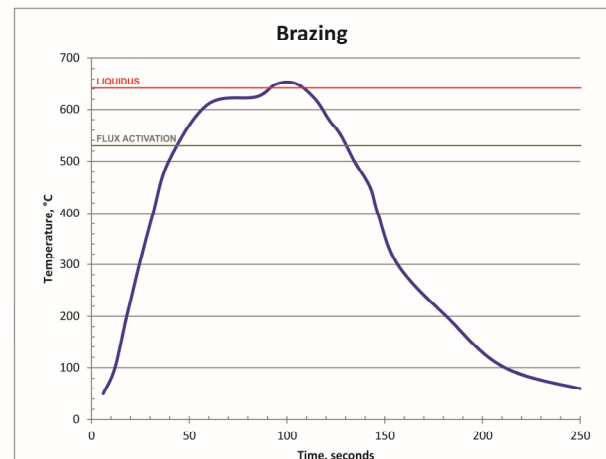


Figure 5-4 Non-equilibrium profile

5.4.5 Profiling Apparatus

A typical setup for profiling an infrared furnace is depicted on an LA-306 in Figure 5-5 and includes a computer and data logger positioned at the entrance of the furnace. For profiling, a type K thermocouple is placed on the surface of a part or representative sample which can be placed on the belt or in a parts boat. The thermocouple is plugged into a data logger connected to the computer. Figure 5-6 shows a close-up of a high speed high temperature type K thermocouple, a wire basket or parts boat, and a DataPaq Q18 data logger. As the part travels through the furnace, the computer graphs the temperature as a function of time and distance traveled.

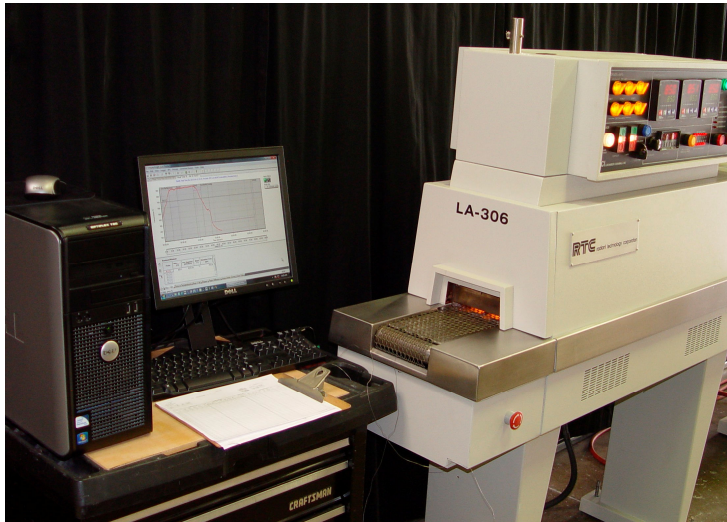


Figure 5-5 Temperature Profiling Apparatus

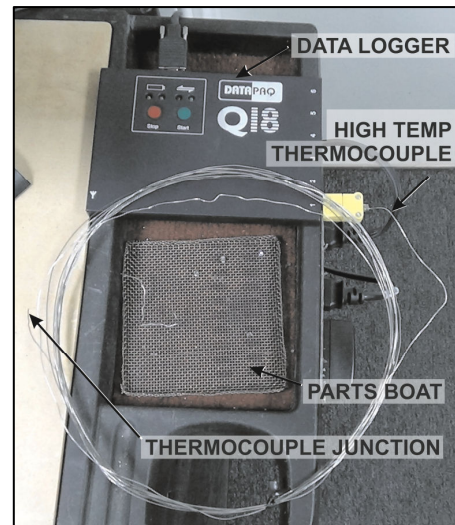


Figure 5-6 Data Logger

To produce a temperature profile, the following components are needed:

- Thermocouple
- Data Logger
- Sample part
- Computer

A. Thermocouple Wires

- K-Type thermocouples are recommended.

Depending upon operational temperatures, use a properly rated thermocouple for accurate readings. For temperatures above 300°C, we recommend the use of ultra-thin high speed type K thermocouples. Make sure exterior sheath is grounded to furnace frame.

Use one thermocouple for centerline profiling or three for across-the-belt profiling.

B. Data Loggers

A data logger or temperature data collection device. Examples are:

- Chart recorder
- DATAPAQ data logger (Q18 or similar)
- KIC temperature profiling kit
- MOLE/SuperMOLE data logger

Figure 5-6 shows a DataPaq Q18 six-channel data logger with one high temperature thermocouple attached to channel 1.

Another data collection method involves sending a data logger down the belt inside an insulated enclosure. A short thermocouple is connected to the data logger through a sealed opening in the enclosure. The data logger collects the data for later transfer to a computer for graphing and analysis.

C. Sample Part

The part can be an actual production part, or something of similar material, mass, size and shape. The closer the sample is to an actual production part, the more representative the results will be. If parts boats or carriers are to be used in production, use a similar boat for the test. Figure 5-7 and Figure 5-8 depict different samples with high temperature thermocouples in position.

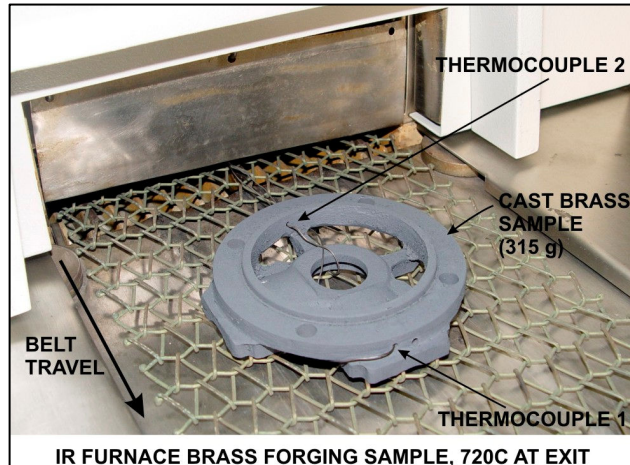


Figure 5-7 Brass Forging Sample With 2 thermocouples

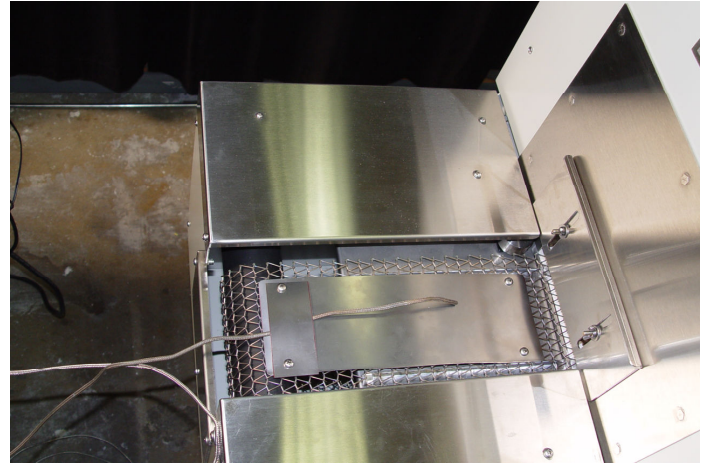


Figure 5-8 Metal Plate Sample with Wire Sheath Type K Thermocouple

5.4.6 Profiling Procedure

A. Operate furnace to steady state or READY.

B. Connect the thermocouple to the part and place on Load table.

1. Below temperatures of 300°C, the thermocouple can be taped with Kapton tape to a test specimen. Repeat testing may require new tape for accurate results.
2. Above 300°C, the thermocouple sensor can be cemented onto a test specimen if direct contact is not otherwise possible. In cases where the product of interest is not readily available, the thermocouple may be placed inside a small length of ceramic tube called a bead or other piece of material similar in shape and mass to the actual product.

C. For real time viewing, ready profiling software on the computer.

D. Place sample on belt. As thermocouple junction in the part passes furnace entrance, start data logger (click on start button on computer screen).

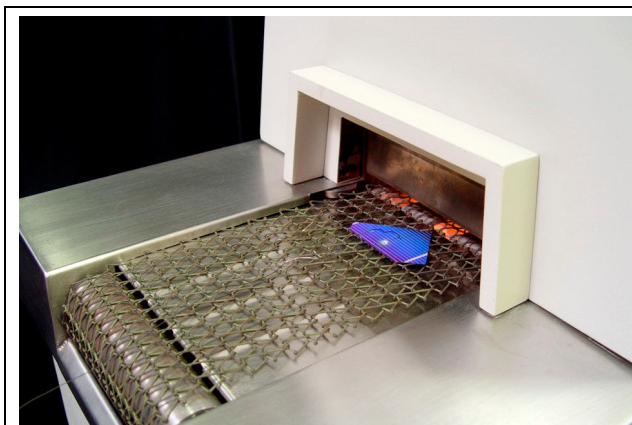


Figure 5-9 Silicon Wafer Entering Furnace

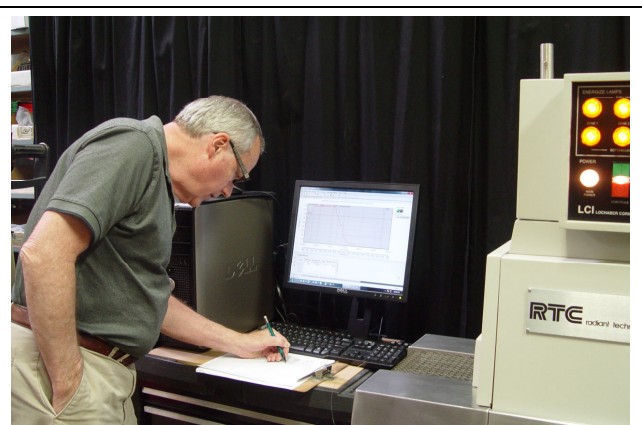


Figure 5-10 Recording Setpoints

Section 4

- E. Place sample on belt. As part passes furnace entrance (Figure 5-9), start data logger.
- F. Record temperature setpoints and process gas flowmeter setpoints in a log (Figure 5-10)
- G. As thermocouple junction passes exit of furnace, stop data logger.

Note: If the start and the stop times coincide with the furnace entrance and exit, the actual belt speed can be verified in the profiling software and graph.

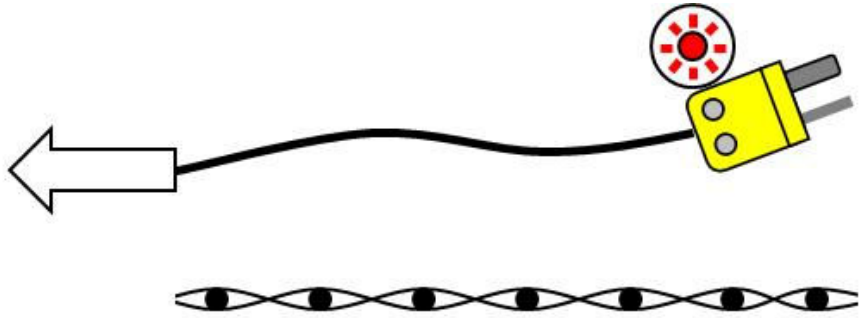


Figure 5-11 Brass forging sample exiting



Figure 5-12 Sample plate exiting furnace

5.4.7 Safety Tips

	DANGER: When using metal shielded thermocouple wires inside a furnace, electrostatic energy may collect on the wires. Properly ground the shielding material to the furnace chamber by wrapping a wire around the sheath and attaching one end to an unpainted portion of the furnace cabinet.
DANGER: 	Extreme caution must be taken when pulling thermocouple wires through the process section. Connectors may bounce inside the chamber and break a lamp exposing the handler to high voltage and current, which could cause serious injury or death. 

5.4.8 Equilibrium Profile Settings

For equilibrium profiles (flat temperatures profiles), set a belt speed that will result in at least a 6-10 minute dwell time inside the heating chamber. The following table shows some belt speeds for various heating chamber lengths.

Table 5-1 Equilibrium Belt Speed Recommendations					
Heating Chamber Length		Dwell Time			
(inches)	(cm)	6 minutes		10 minutes	
		(in/min)	(cm/min)	(in./min)	(cm/min)
30	76	5	12.7	3	7.6
60	152	10	25.4	6	15.2
90	229	15	38.1	9	22.9
120	304	20	50.8	12	30.4

For across-the-belt temperature profiles, set the belt speed to a minimum. The slow rate of the conveyor belt will result in a larger number of recorded temperature readings. A slower rate increases the resolution of the temperature profile and can reveal more information about temperature uniformity and consistency.

Set all zone temperatures to the desired peak temperature plus 5°C.

If edge heaters are installed, a setpoint of 30% power is a good starting point. Also, for edge heat, allow a few minutes to pass between setting adjustments, as the nickel chromium edge heat wires do not respond as quickly as the IR heat lamps.

If faster heating rate is desired with a longer dwell time at the peak temperature, increase the first 1-2 zone temperature setpoints by about 10-20% of the peak temperature. The heating rate will be higher at the start, while the remaining zones will maintain the temperature of the product at the peak temperature.

A slow belt speed will allow the temperature to reach the peak temperature within the first 1-2 zones. The rest of the heating chamber will hold the temperature for the remainder of the profile.

- Record the temperature and observe the results.

If the desired temperature and hold time is not achieved, begin tuning the belt speed and zone setpoint temperature variables. The following are some guidelines:

For faster initial heating rates, try one of the following:

- Lower the belt speed
- Raise the first 1-2 zone temperature setpoints

For slower initial heating rates:

- Raise the belt speed
- Lower the first 1-2 zone temperature setpoints

For faster belt speeds:

- Raise the belt speed 5%
- Increase zone 1-2 setpoint temperatures by 7%

For slower belt speeds:

- Lower the belt speed 5%
- Decrease zone 1-2 setpoint temperatures by 7%
- Record a new temperature profile

Go back and retune as necessary until the desired temperature profile is achieved.

5.4.9 Profiling Results – Typical Curves

Following are examples of actual profiles run at the factory on different machines with product samples for a wide range of applications. Figures 9-13, 9-15 and 9-16 were performed on LCI LA-306 models. Figures 9-14, 9-17 and 9-18 were performed on LCI retrofitted RTC LA-306 furnaces. LA-309P performance will be similar.

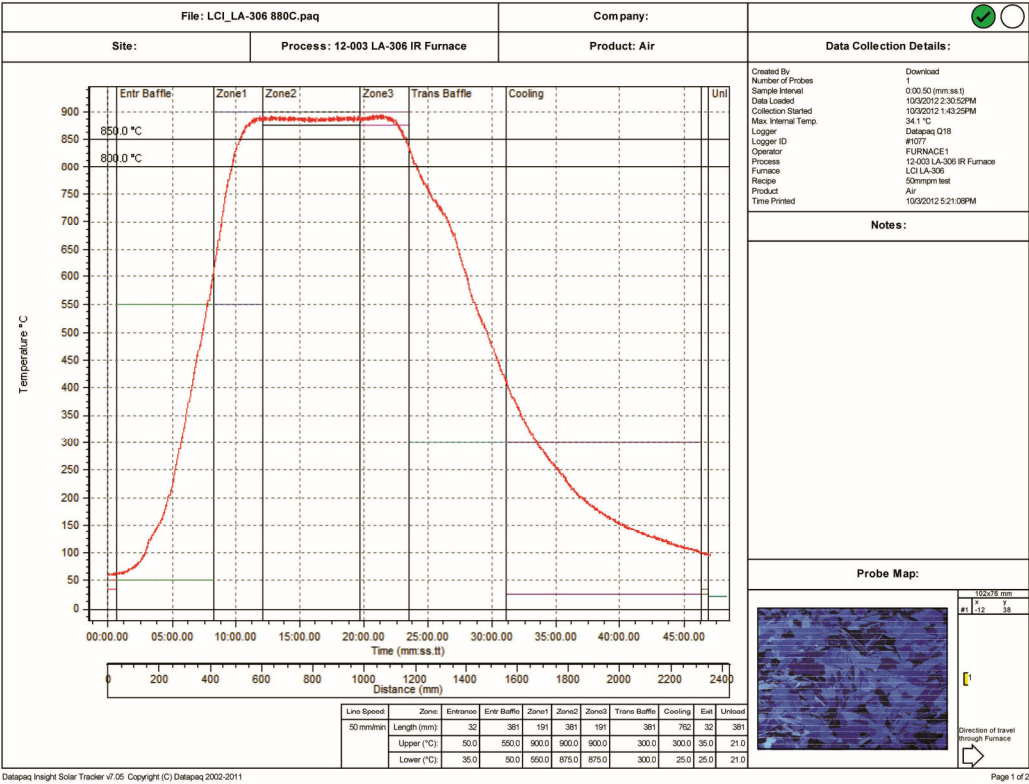


Figure 5-13 880 °C Annealing profile

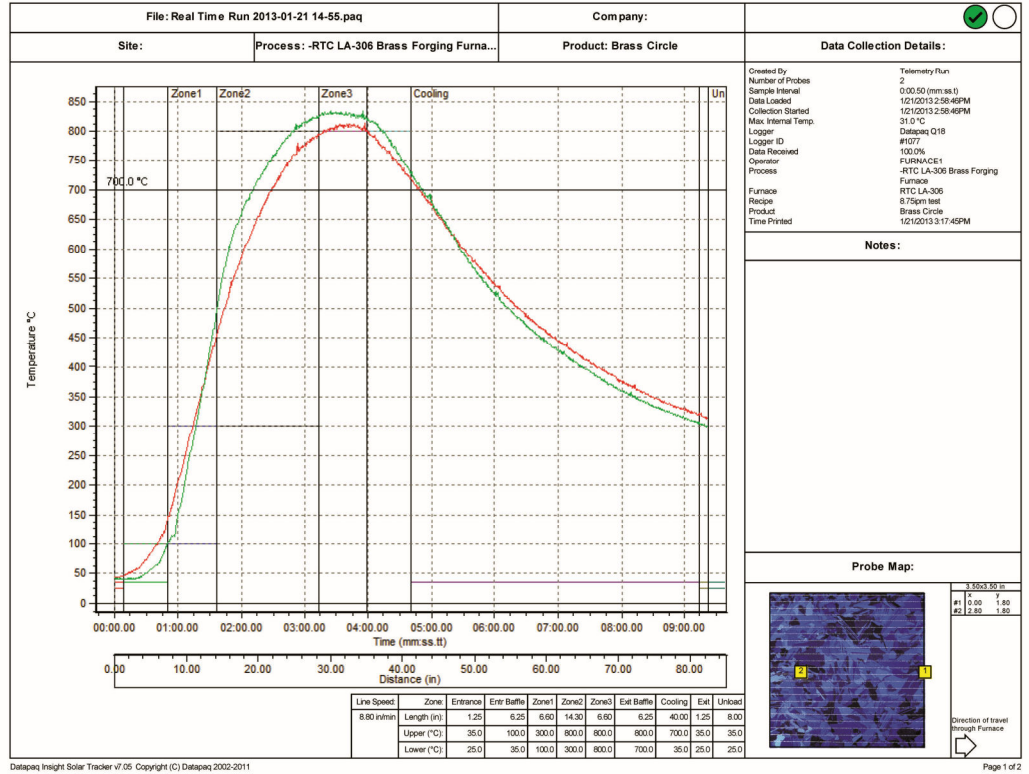


Figure 5-14 880 °C Brass Forging profile

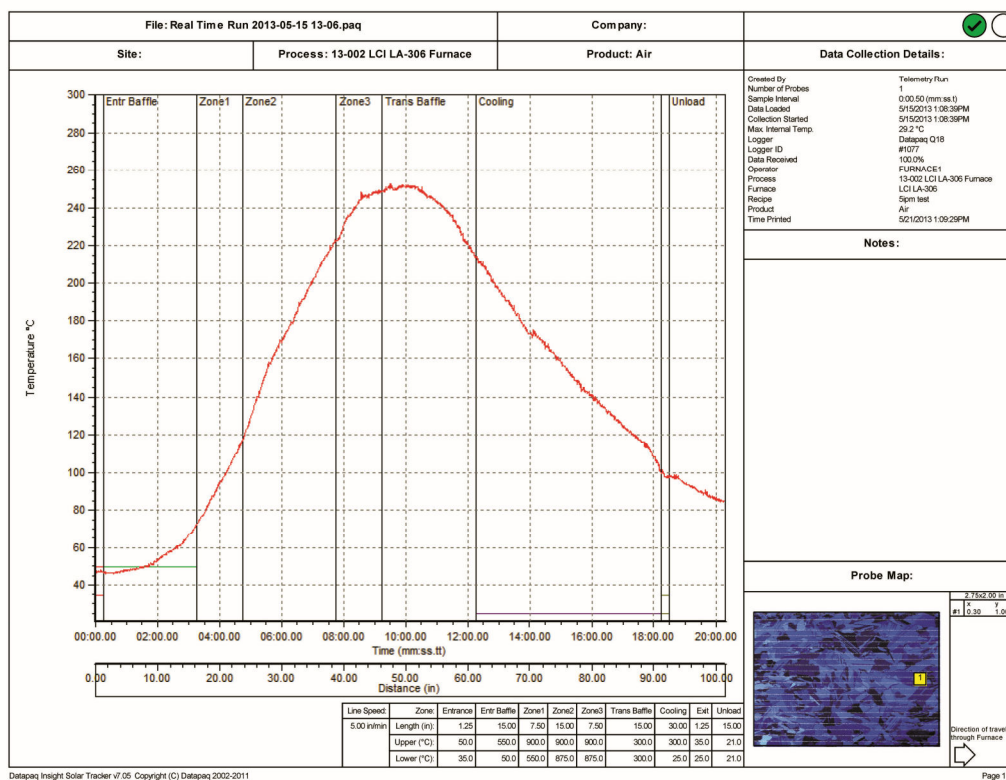


Figure 5-15 250 °C Curing Profile

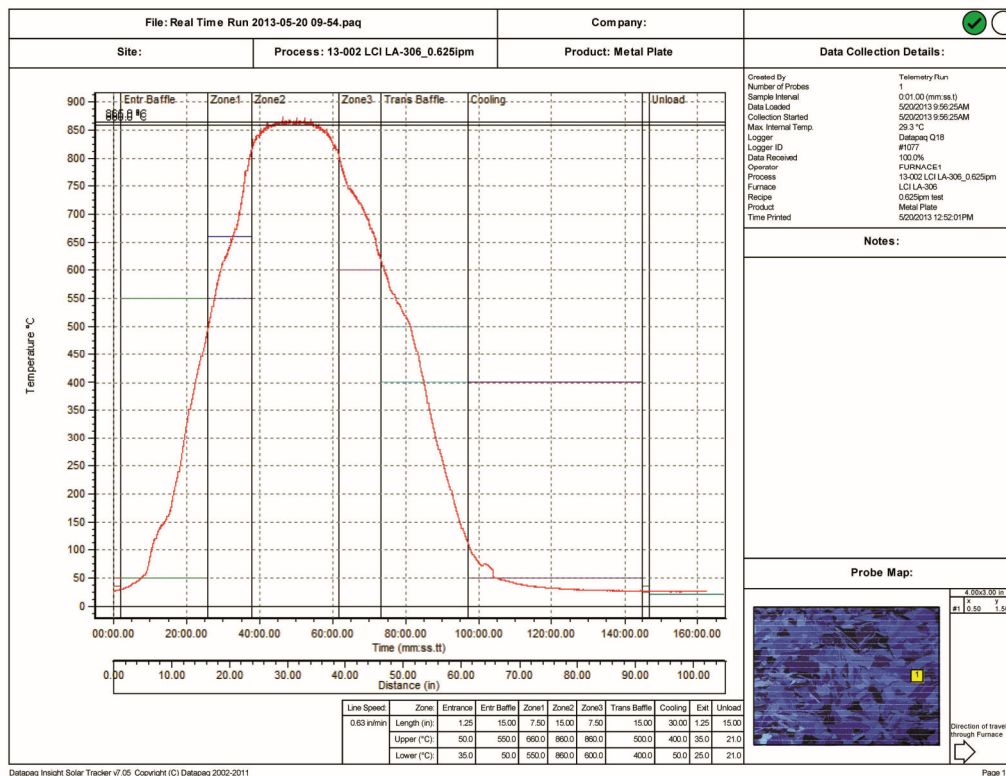


Figure 5-16 860 °C Thick Film profile

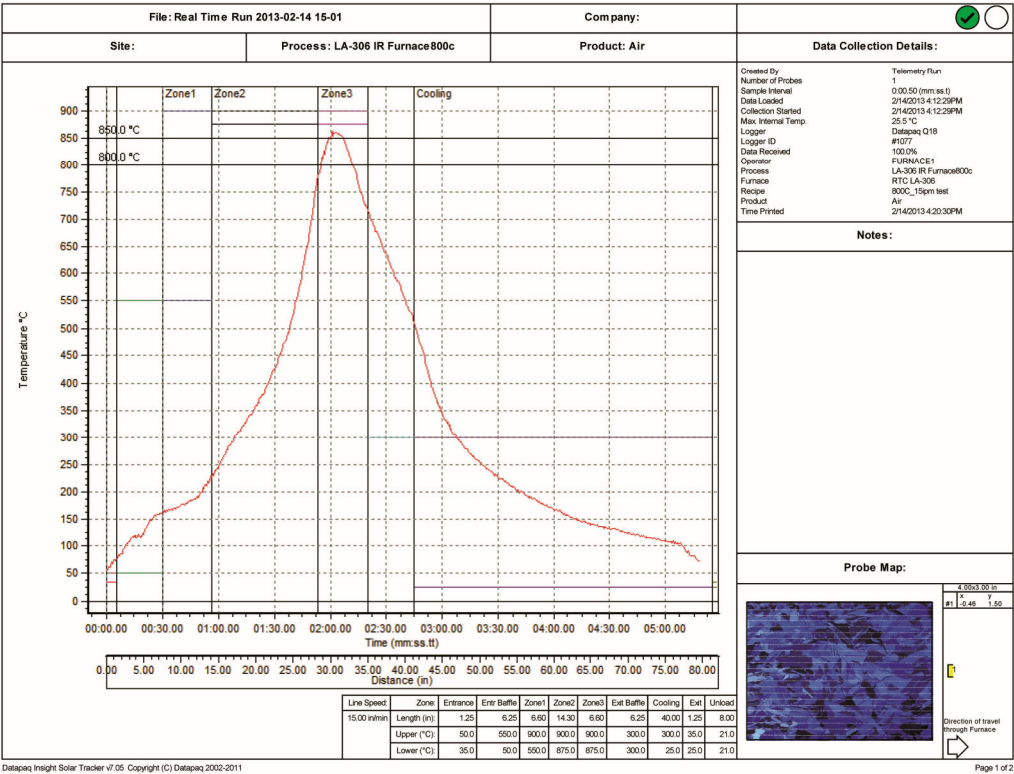


Figure 5-17 860 °C Spike profile

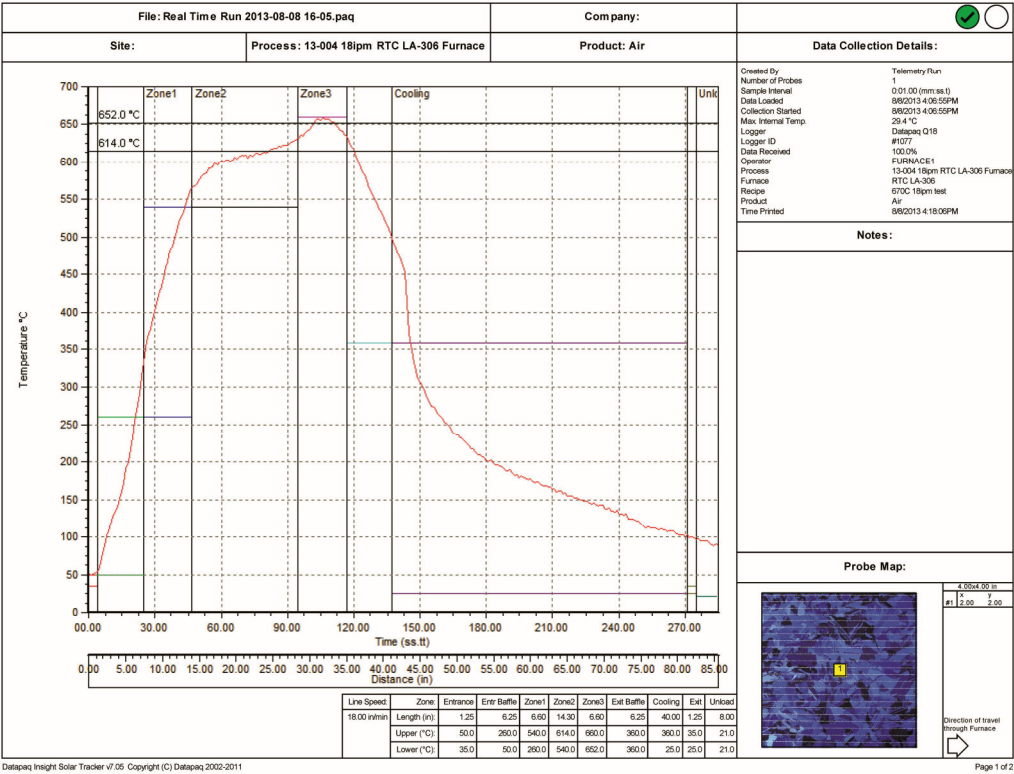


Figure 5-18 652 °C 1205 Brazing profile



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