radiant technology corporation

TRAINING MANUAL
Version 2.4e

For comments and suggestions about this manual, please contact
Radiant Technology Corporation.
1335 S. Acacia Avenue, CA 92831-5315, USA.

Email: sales@radianttech.com

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Introduction

1.1 Introduction

Welcome to the world of **R**adiant **T**echnology **C**orporation. The Company is the **leader in** the development of short-wave **infrared** conveyorized ovens and furnaces to the electronics industry worldwide. RTC's goal is to provide its customers and partners, with the **highest quality** of thermal processing equipment available **anywhere.** RTC wants you to succeed. Your success is our success. Should you have a furnace operating question, do not hesitate to talk with one of RTC's Customer Service Engineers about it. We stand ready to help. We want **you to be successful** with the use of your Radiant Technology equipment.

This "how to" Training Manual explains the theory, operating features and techniques to assist you in achieving highly repeatable and reliable thermal processes. **Please** study this manual carefully. Experience has shown that client's who thoughtfully **study** and **master** the contents of this manual **become expert** in understanding the process system capabilities of an RTC furnace. 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. Achieving **high** performance and high **yields** usually elicits congratulations from your company and always from RTC. Please share your successes with us. We will appreciate it.

RTC equipment is highly responsive to critical temperature settings. With lamps as the primary heat source, the equipment is literally heating with the speed of light. RTC's unique and patented gas management system provides an extremely even distribution and well regulated flow of gas throughout the process chambers. Understanding and **learning** how **to control** both the **heat and gas flow is essential** to the effective operation of the furnace. When the interaction and performance of the control elements are well understood, putting them all together to make the tool achieve its potential is a most satisfying experience. For many, an RTC furnace becomes regarded more than just an effective tool, it is viewed as a fine instrument that can produce wonderful results over a variety of thermal processing situations.

RTC has designed numerous features into your equipment, many of them patented, to help assure clients success in achieving their goals. Many **"firsts"** involving the application of near infrared heating include: the first high temperature furnace capable of operating at 1000^oC with extremely tight temperature control; the first thick film furnace; the first controlled atmosphere furnace capable of <5 PPM O_2; and, the first hydrogen furnace.

RTC is constantly endeavoring to improve its equipment performance and design. To this end, RTC encourages clients to suggest methods of improving designs and service. Additionally, RTC is always more than happy to discuss, in confidence, new thermal processing requirements, however difficult or mundane they may be. When needed, RTC stands ready to design new equipment to meet the special and challenging needs our partners require.

1.2 Where to Get Help

When contacting RTC, please refer to the department listed.

The general telephone number is +1 (714) 991-0200

1.2.1 Technical Support

Department: Customer Service
e-mail : service@radianttech.com

Extension: x180

1.2.2 Service Parts Ordering

Department: Parts
e-mail: general@radianttech.com

Extension: x0

1.2.3 Sales

Department: Sales/Marketing
e-mail: sales@radianttech.com

Extension: x260

1.2.4 General

Address: 1335 S. Acacia Avenue
Fullerton, California 92831
Phone: +1 (714) 991-0200
Fax: +1 (714) 991-0600
e-mail: general@radianttech.com

1.3 Website

www.radianttechnology.com

Formatting

DANGER: This signifies a potential threat to human safety.

Warning: This signifies a potential threat to equipment damage or product loss.

Note: This signifies an important fact that could affect process control.

Examples are shown in italic text.

Bold text words or phrases embedded in this document, are terms with definitions in the glossary.

<u>Underlined</u> text will be used for text in pop-up windows, button descriptions or selector button/box choices.

Cross-references to “Section Titles” are bound with quotes.

(Optional ❒) accessories will be shown in parenthesis with a checkbox. The RTC training engineer will explain which options are included with each customer furnace and can describe any options not included if requested. Please check the box as appropriate.

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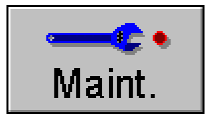
7.1 Maintenance Screen Overview

You must be logged in at the technician level to use this screen.

Click on the maintenance screen button: 

The maintenance screen presents a list of items needing service at regular intervals.

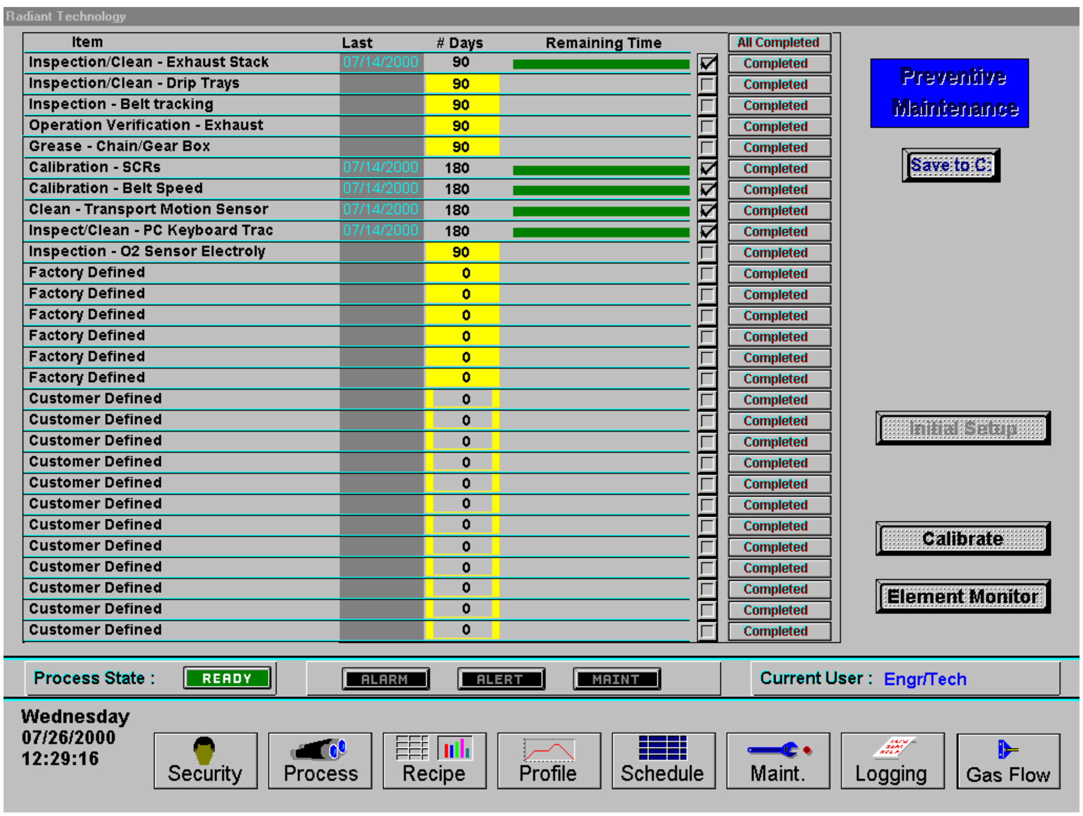


Figure 7-1 Maintenance Screen

Click on the Completed button to fill out the “Remaining Time” column for a maintenance item. The green bar decreases as the time until the next scheduled maintenance approaches. When the maintenance day arrives, the “# days” column is highlighted yellow.

Note: The time between RTC programmed maintenance activities is based upon 40 hours of operation per week, if the customer furnace is operated for more hours during the week, the regularly scheduled maintenance items may need to be performed more frequently in some cases.

7.1.1 User Defined Maintenance Items

The lower twelve rows of the Schedule Maintenance window are reserved for User Specific Maintenance Requirements.

To enter the description into the Item field, click on the desired row in the column entitled Item. The dialog box shown in Figure 7-2 will appear.

Figure 7-2 User Selectable Maintenance Description

Enter the description of the new maintenance item.

To Enter the new item's maintenance frequency, to the right of the recently added maintenance description field. Click on the area of the maintenance item to be changed under the heading "#days". The dialog box shown in Figure 7-3 below will appear.

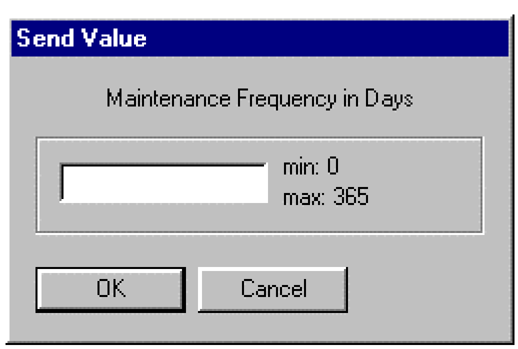


Figure 7-3: Maintenance Frequency Dialog Box

Enter the desired maintenance frequency in days.

The furnace software will start to count down the number of days until maintenance is required.

7.1.2 Furnace Calibration

To access the Calibration Screen, click on the Maintenance Screen.

Click on the Calibrate button as shown below.

The following pop-up window will appear.

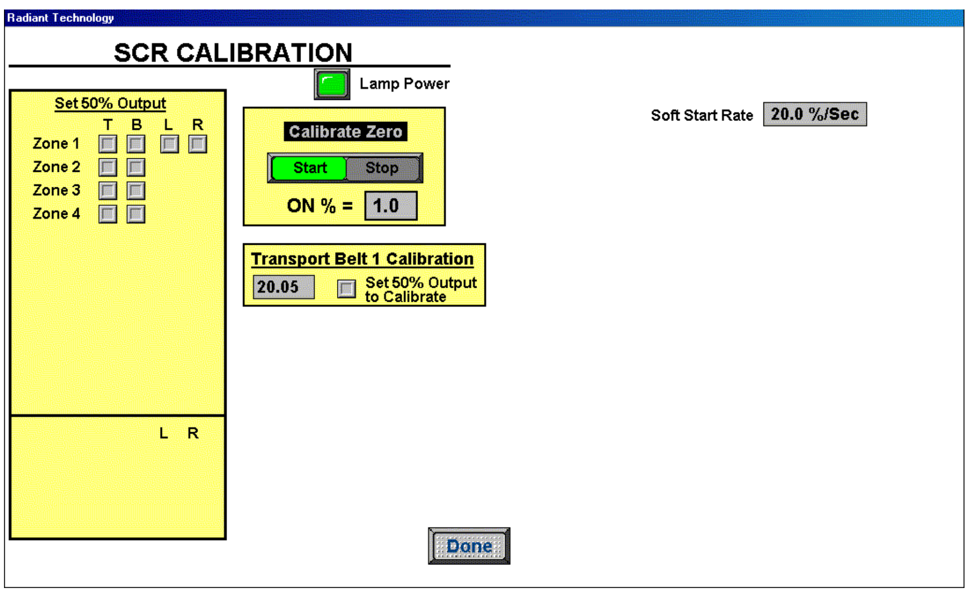


Figure 7-4: Calibration Pop-up Window

SCR Calibration

SCR Calibration is an important part of maintaining consistent thermal process profiles. To complete the calibration, each SCR will need to be zeroed and span adjusted. Please refer to Figure 7-5 below for reference.

Tools Required: True RMS Voltmeter

Step 1: Zero the SCR

From the SCR Calibration pop-up window, go to the “Calibrate Zero” box.

Set the value in the “ON %” box to 1.0.

Click on the Start button.

DANGER: High voltages are now present at the SCRs.

Go to the furnace cabinet side panel and start with one SCR. Choose an orderly pattern that will leave all SCRs adjusted.

If the LED is illuminated, turn the zero trimpot screw until the LED goes out. Do not turn the screw any further.

If the LED is not illuminated when you first observe it, turn the trimpot screw until the LED illuminates and then turn the screw until it goes out.

The correct span trimpot setting is at the point where the LED cycles between no light and partially illuminated.

If the LED never illuminates, try setting the value in the “On %” field in the “Calibrate Zero” box to 1.5. Any value between 0.5 and 2.0 is acceptable when calibrating SCRs. If the SCR still does not calibrate, the SCR may be damaged. Contact RTC for further assistance.

Repeat this process for all SCRs.

When the zero adjustments are finished for all SCRs, select the Stop button in the “Calibrate Zero” box of the Calibration pop-up window.

Step 2: Adjust the Span

From the SCR Calibration window, in the “Set 50% Output” box, select the checkbox for the first SCR; i.e. “Zone 1 - T”

Locate the SCR in the electronics cabinet and connect a voltmeter across the load. Use Figure 7-5 below as a guide.

Depending upon the supply voltage, the meter will reflect a voltage drop according to the following formula:

$$\text{RMS Voltmeter Reading} = \frac{(\text{Input Voltage})}{\sqrt{2}}$$

Example:

Supply Voltage: 480V

RMS Voltmeter Reading = 480/1.414 = 340V

Adjust the span-trimpot screw until the meter shows the correct value.

Repeat this procedure for all SCRs.

The lamps are on at this time with 50% power being supplied. Because of the possibility of overheating, power supplied to the lamps shuts off after two minutes.

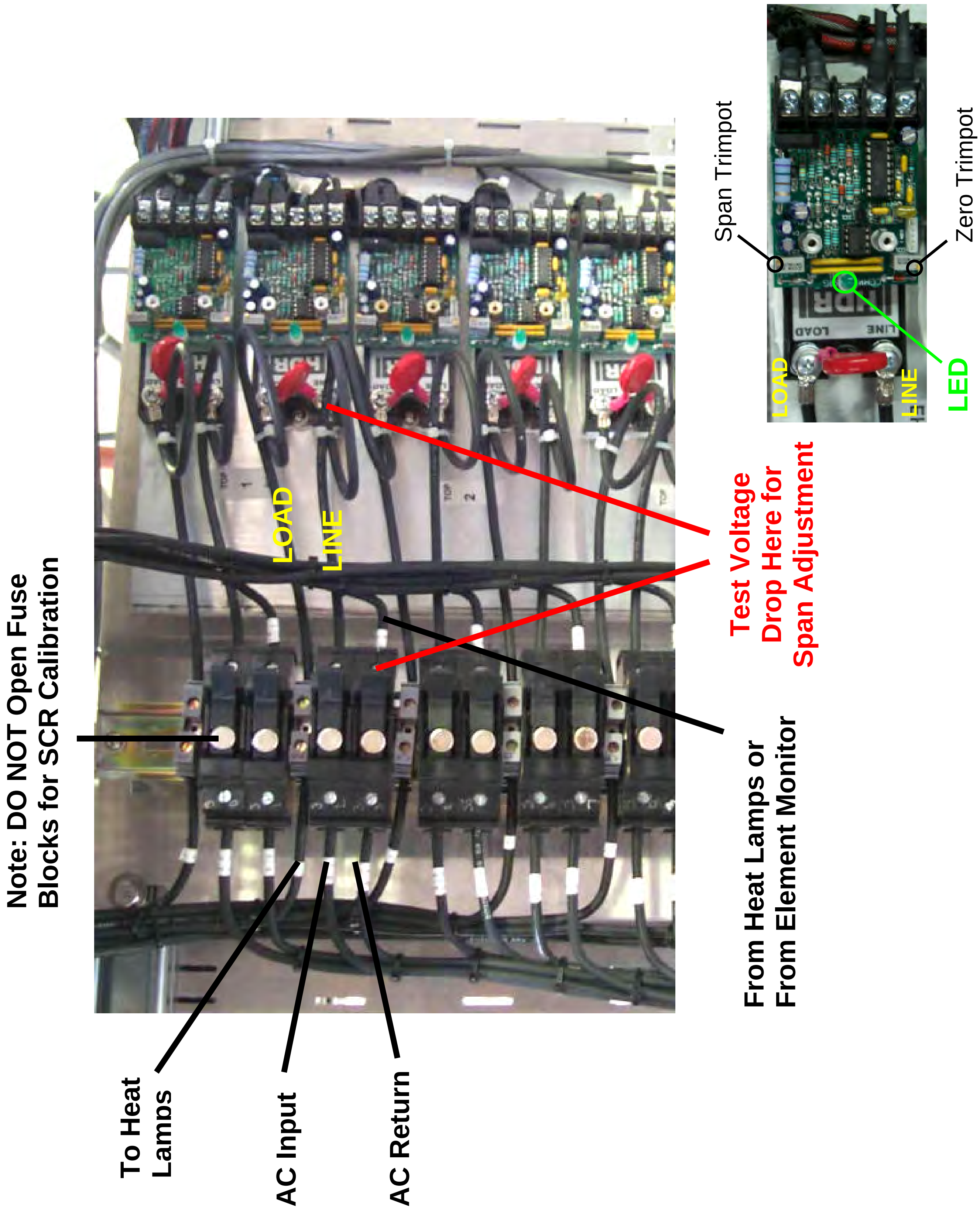

Span Trimpot
Zero Trimpot
LOAD
LINE
LED
Test Voltage Drop Here for Span Adjustment
LOAD
LINE
Note: DO NOT Open Fuse Blocks for SCR Calibration
From Heat Lamps or From Element Monitor
To Heat Lamps
AC Input
AC Return

Figure 7-5: SCR Calibration Diagram

Belt Speed Calibration

Tools Required: Tape Measure

❶ Place a small marker such as small length of wire across-the-belt at the entrance end of the furnace.

❷ Accurately measure a distance on the conveyor belt from the marker to a point on the exit belt tray.

❸ Mark the exit belt tray with a pencil or marker pen.

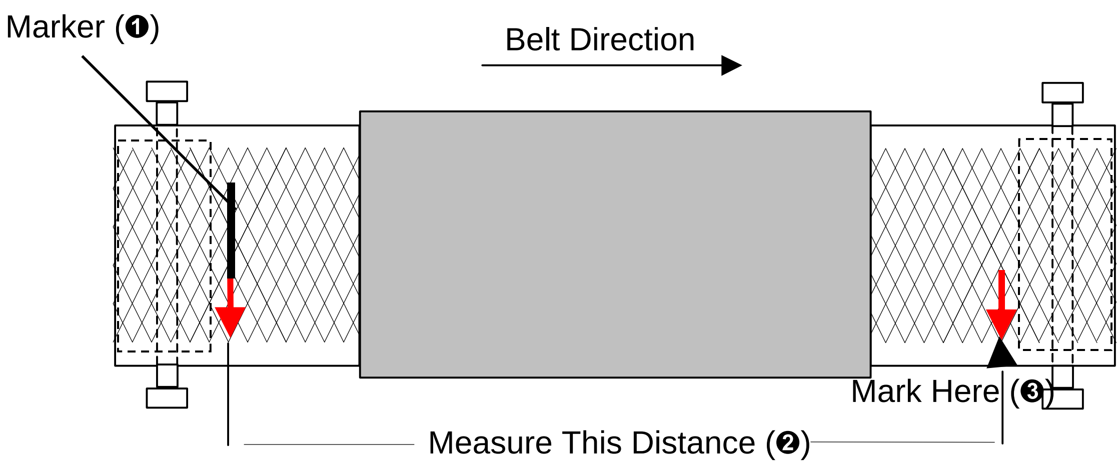


Figure 7-6: Belt Speed Calibration Diagram

❹ Click on the <u>Set 50% Output</u> checkbox in the "Transport Belt Calibration" box, and start the timer.

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

Calculate the belt speed:

Convert the measured distance from ❷ above to inches.
Convert the time from ❺ to minutes
Compute the speed according to the following equation:

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

Enter this value in the **Transport Belt Calibration** dialog box.

Select the **Done** button.

7.1.3 Element Monitor Screen (Option ❒)

The element monitor screen is the user response of the element monitor option. The listing will refer to the zone area that contains the failed element.

The element address shown under the “Addr” heading refers to the controller I/O module that checks the circuit.

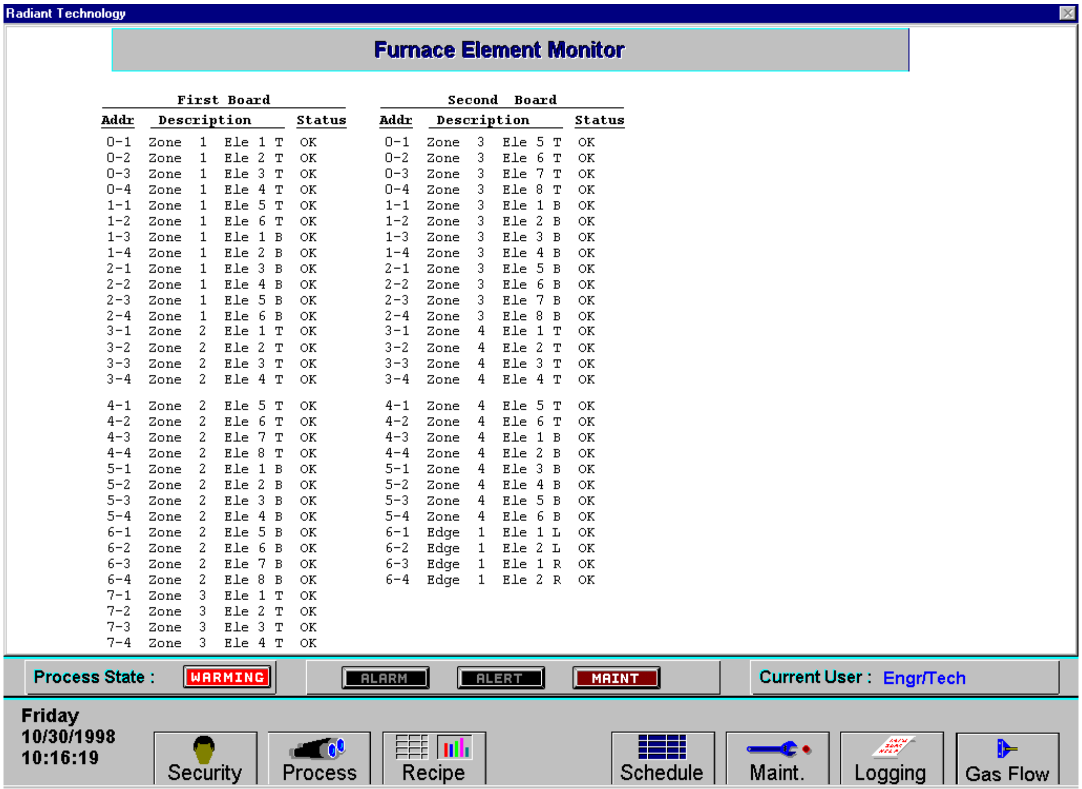


Figure 7-7: Element Monitor Screen

The RTC Furnace Opto22 controller is utilized to communicate heat lamp failures to the interface PC. A special element monitor subsystem is installed and connected to the Opto22 controller.

Figure 7-8: Opto22 Element Monitor Controller

Digital I/O modules shown in Figure 7-8 are utilized to collect element status information from Element Monitor Board shown below in Figure 7-9.

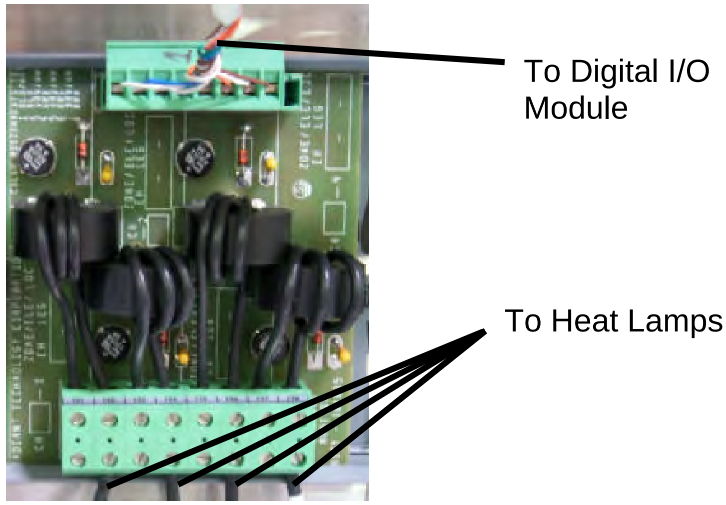


Figure 7-9: Element Monitor Circuit Board

Each Element Monitor Board has four monitoring circuits. Each circuit converts the element status with a transformer coil and rectifier network to a low voltage output signal. This output signal is received by a digital I/O module, which then relays the information through the Opto22 controller to the monitoring PC.

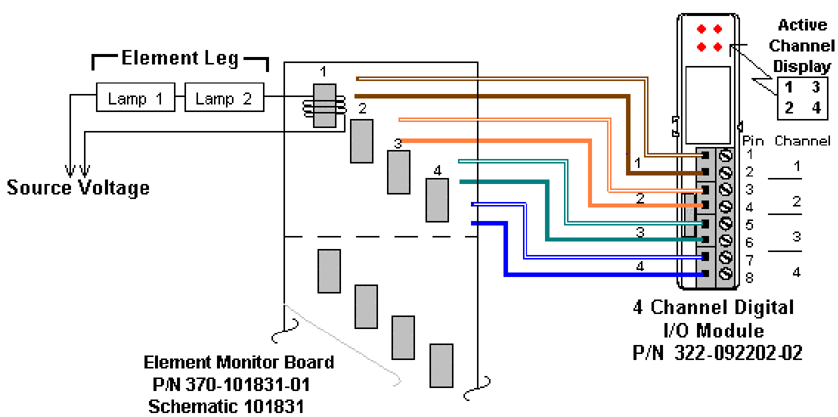


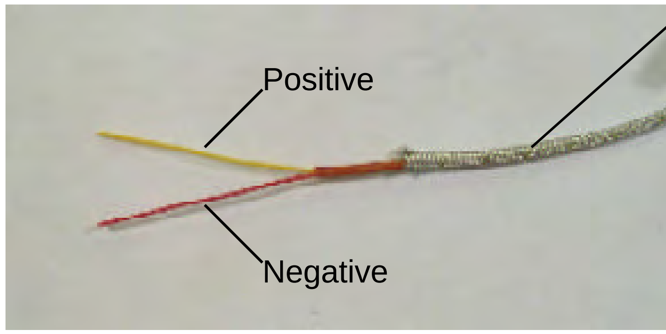
Figure 7-10: Element Monitor System Diagram

Each module also has four LED's that illuminate when its associated input is active. Input information is transmitted back to the Opto22 system controller for processing, alert notification, and display updates.

7.2 Typical Wiring Descriptions

7.2.1 Thermocouple

A thermocouple is made of a set of wires as shown below.



This set of wires is attached to the brick as follows:

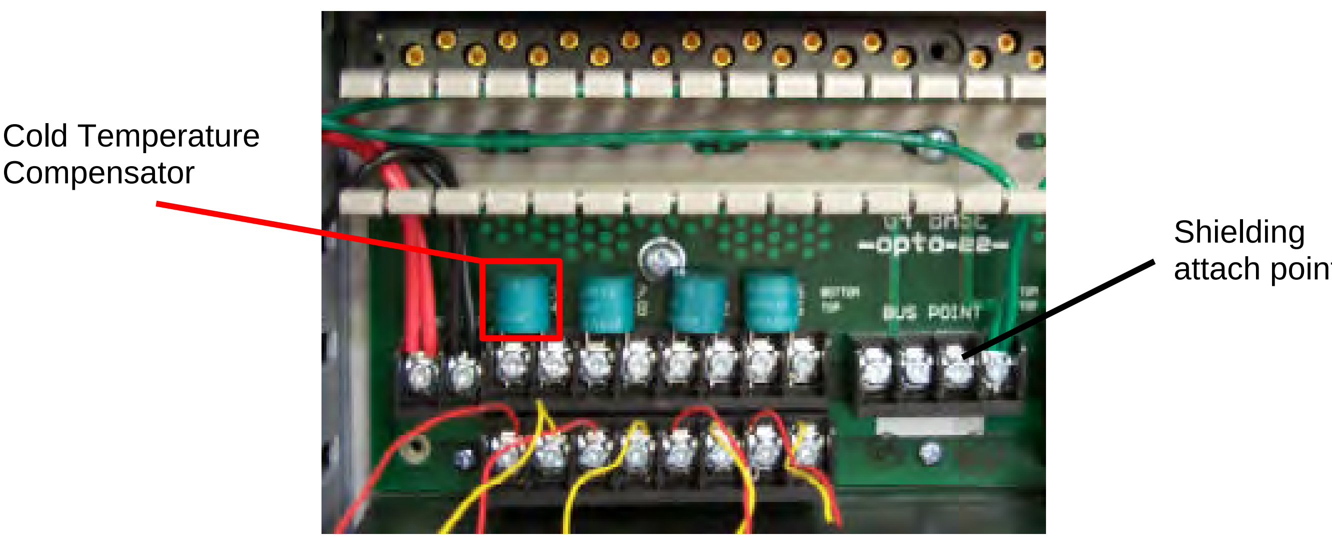


Figure 7-11: Opto22 brick wiring

At the Opto22 controller brick interface, the thermocouple wire set is attached as follows (refer to the supplied channel assignment sheet):

Red – Negative attach point for analog channel

Yellow – Positive attach point for analog channel

Braided Shielding – Attach to terminals under the “BUS POINT” label

A special cold temperature compensator is wired across the top attachpoints for the channel. See Figure 7-11 above.

At the connector end, a female connector is wired as seen below.

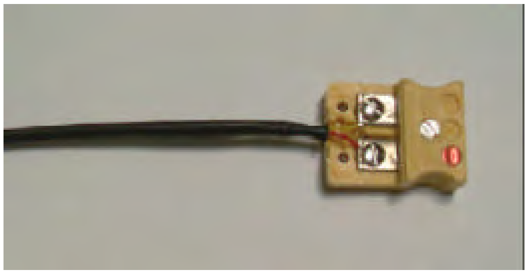


Figure 7-12: Thermocouple wiring - Female Connector

The thermocouple probe is mated to a male connector as shown below.

Figure 7-13: Thermocouple Probe - Male Connector

The red dot on the lower part of the wire harness represents the negative side and is also stamped with the minus sign.

If a thermocouple probe needs replacement:

❶ Remove power from the RTC Furnace.
❷ Remove the side and top covers of the furnace cabinet as required.
❸ Disconnect the thermocouple connectors; See Figure 7-14 below.
❹ Mark the junction between the thermocouple probe and collar.
❺ Unscrew the friction collar just above the surface of the chamber.
❻ Remove the thermocouple probe.

When installing a new thermocouple probe, match the mark left on the old probe to the new probe and install to the same depth.

Note: Installing the thermocouple probe at a different level will result in unstable or inaccurate temperature readings.

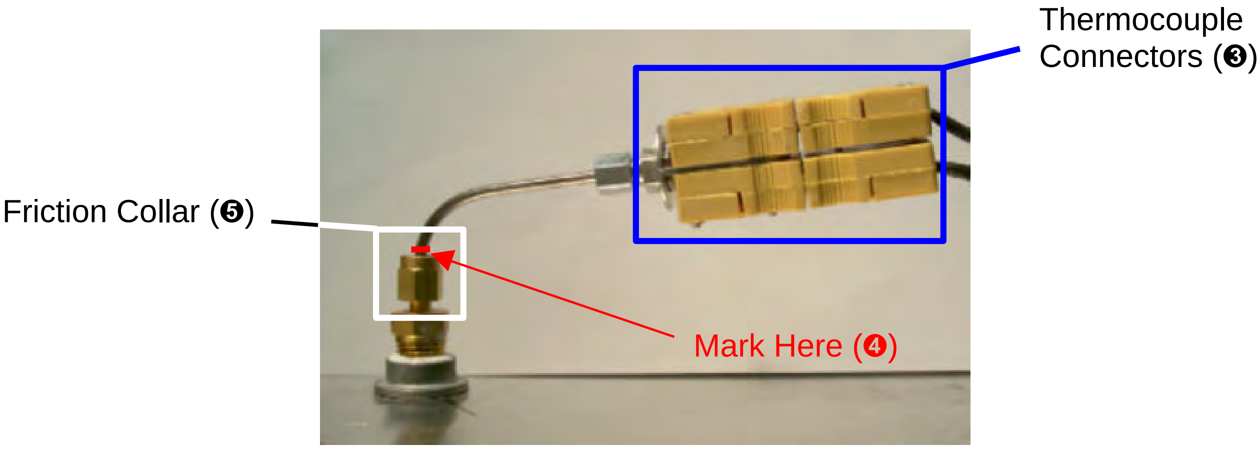


Figure 7-14: Thermocouple Installed (Overtemperature T/C Shown)

7.2.2 SCR

A Silicon Controlled Rectifier controls the level of current supplied to the heat lamp. The SCR control line is taken from an analog brick 0-5V DC Output I/O module connected to the Opto22 controller. The SCR supply power is in phase with the lamp voltage for accurate power application.

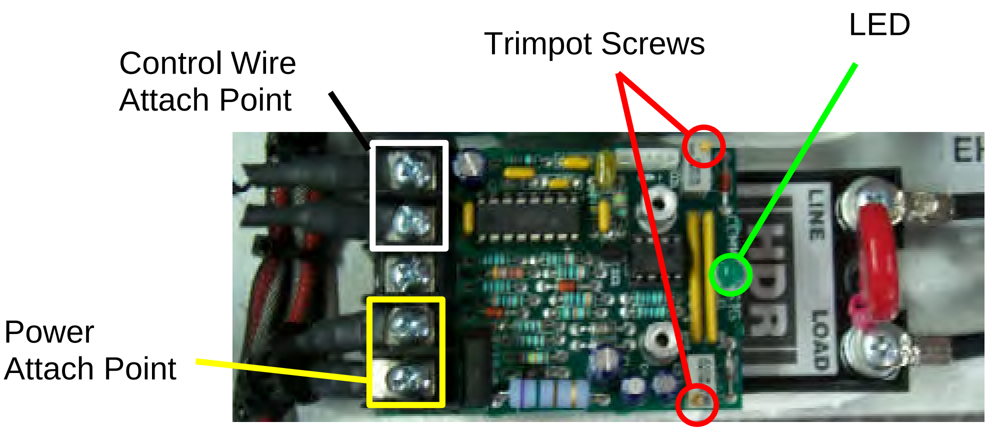


Figure 7-15: SCR

7.2.3 Fuses

Fuses are used throughout the furnace. The terminal block type of connector allows for safe and easy inspection or replacement.

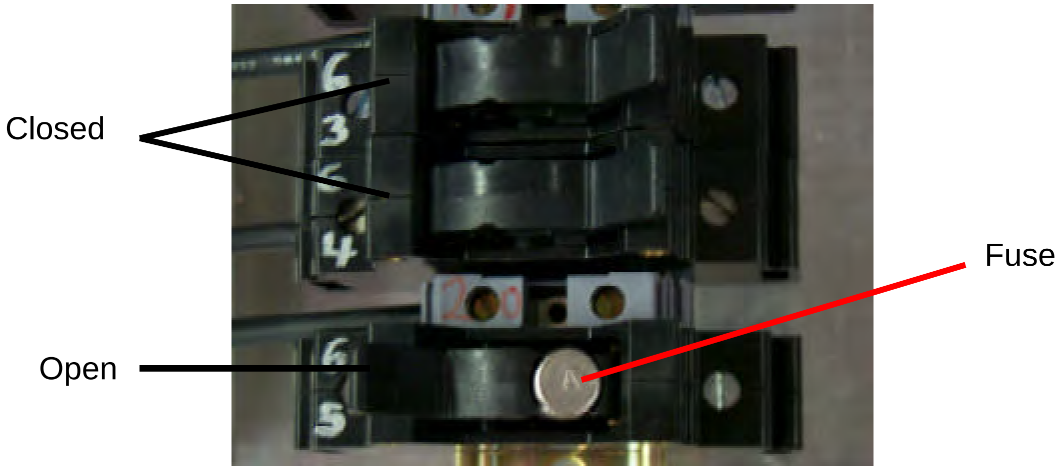


Table 7-1: Fuse Block

To inspect, flip the toggle cover and remove the fuse. Test with a multi-meter as necessary.

7.2.4 Brick

The Opto22 controller interfaces with furnace hardware through modules attached to a control brick.

The RTC Furnace controller utilizes both the digital and analog bricks. See Figure 7-16 below.

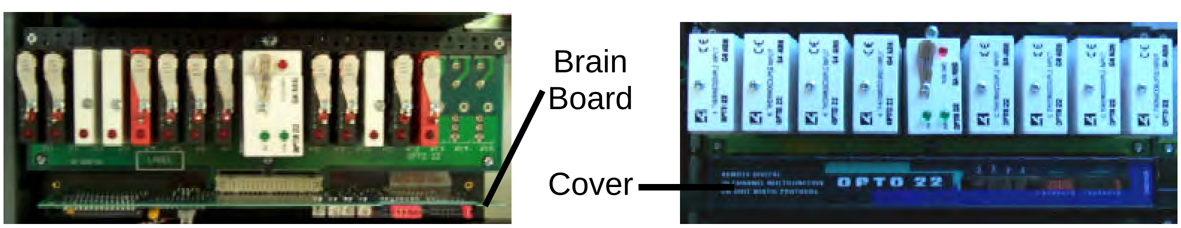


Figure 7-16: Digital Brick (L) - Analog Brick (R)

The communication interface between the bricks and the Opto22 controller is thorough a simple RS-485 communication cable which is attached to the brain board mounted below each brick.

The following figure shows the component side of the brain board and highlights the interface cable. Also notice the address jumpers on the top right of (&&& Figure below).

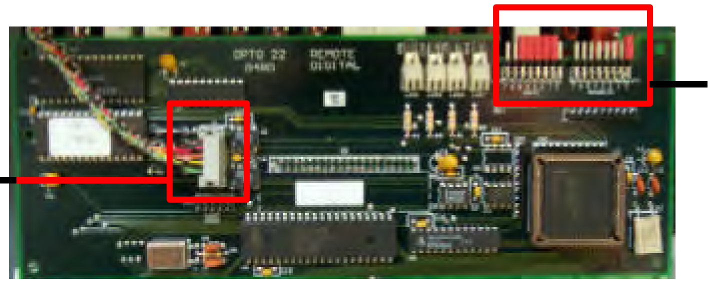


Figure 7-17: Brain Board - Component Side

The brick is attached to a base board which is wired directly to the furnace hardware.

To remove a brick:

Tools required: #1 Phillips Screwdriver
#2 Phillips Screwdriver

❶ Make sure all power is removed from the Opto22 controller.
❷ Using a #1 Phillips, unscrew the two screws holding in the brain board cover at the sides of the brick.
❸ Remove the brain board cover.
❹ Using a #2 Phillips, unscrew the two lower screws at both sides of the brick located below the brain board.
❺ Using a #2 Phillips, unscrew the top center screw holding the brick to the base board.
❻ Remove brick

To remove a regulator or I/O module or
To check a I/O module fuse:

Tools required: #1 Phillips Screwdriver

❶ Make sure all power is removed from the Opto22 controller.
❷ Unscrew the top center retaining screw of the module to be removed.
❸ Carefully pull directly outward on the module.

Warning: Pulling the module out at an angle can bend the connector pins and cause damage.

7.2.5 DC Regulator

At the center of each brick is a DC regulator. Each regulator is also equipped with individual DC monitoring LED indicators for both 5-VDC and 24-VDC source voltages. If one of the lights is out, check input supply voltage to the brick.

7.2.6 Digital I/O Module

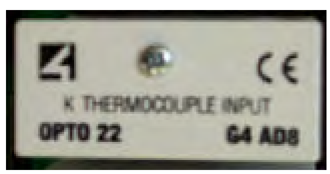
Fuse

The digital modules are used primarily for non-heat related sensory input.

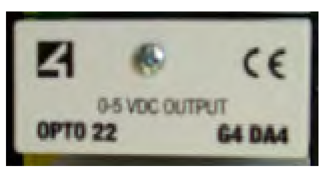
Digital I/O modules may have an independent fuse as well as a manual override control switch. If a module failure is suspected, first check the fuse.

7.2.7 Analog I/O Module

Depending upon the type of input/output assigned to the module, in most cases either a

K Thermocouple Input 

or

0-5VDC Output module 

is used.

These modules read the temperature inside the furnace and generate the control signal to the SCRs. Each primary thermocouple in the furnace is connected to an analog module. (Secondary thermocouples for the under/overtemperature option are connected to a secondary watchdog monitoring device.)
Each SCR is assigned an I/O output module also.

7.2.8 Power Supply

The power supply for the Opto22 controller is wired with 24VDC.

7.3 Mechanical System Maintenance

7.3.1 Drip Tray Cleaning

The maintenance period for drip trays depends very much on the processes being run. While some processes require drip trays to be cleaned every month, others processes may barely soil the drip trays.

Unscrew and remove the furnace side covers. If necessary, remove the cooling fan assembly.

Disconnect the T-pieces that connect the gas supply to the air-rake tubes. The T-pieces must be disconnected at the top and bottom but the connection to the air-rake tube may remain connected.

Undo the air-rake retaining nut.

Completely remove the air-rake tubes.

Undo the butterfly nuts holding the drip-tray inspection cover in place and remove the inspection cover.

Remove the drip tray being careful not to damage the attached baffle plates.

Clean the drip tray.

Re-installing the drip tray is easier if the baffle plates are tied flat against the drip tray. This is easily achieved by loosely wrapping a piece of wire around the drip tray and baffle plates.

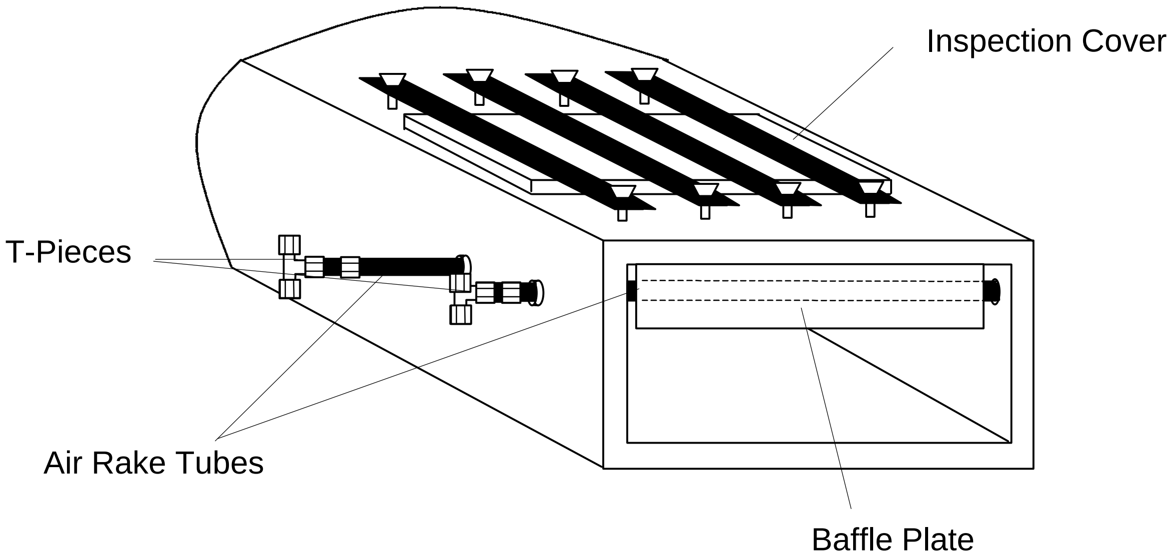


Figure 7-18: Drip Tray Cleaning Diagram

Insert the drip tray and baffle assembly. Remove the wire.

Replace the inspection cover and reattach clamps. After several hours of operation, check the butterfly nuts on the inspection cover, and tighten if necessary.

7.3.2 Stack

A visual inspection of the stack is recommended along with each drip tray cleaning.

With a flashlight, look down the furnace stack.

Contact RTC if new gasket material is required when reattaching the stack.

7.3.3 Heat Lamp Replacement

Tools Required:
- 2 - 3/8 in. open ended wrenches
- Allen wrench
- Flashlight
- Replacement kaowool packing material
- Lint free cloth or protective gloves

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

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.

Short one lamp from each zone to the furnace frame. This will remove any charge residing in the lamps.

Taking care not to disturb the ceramic insulating blocks, use one of the 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.

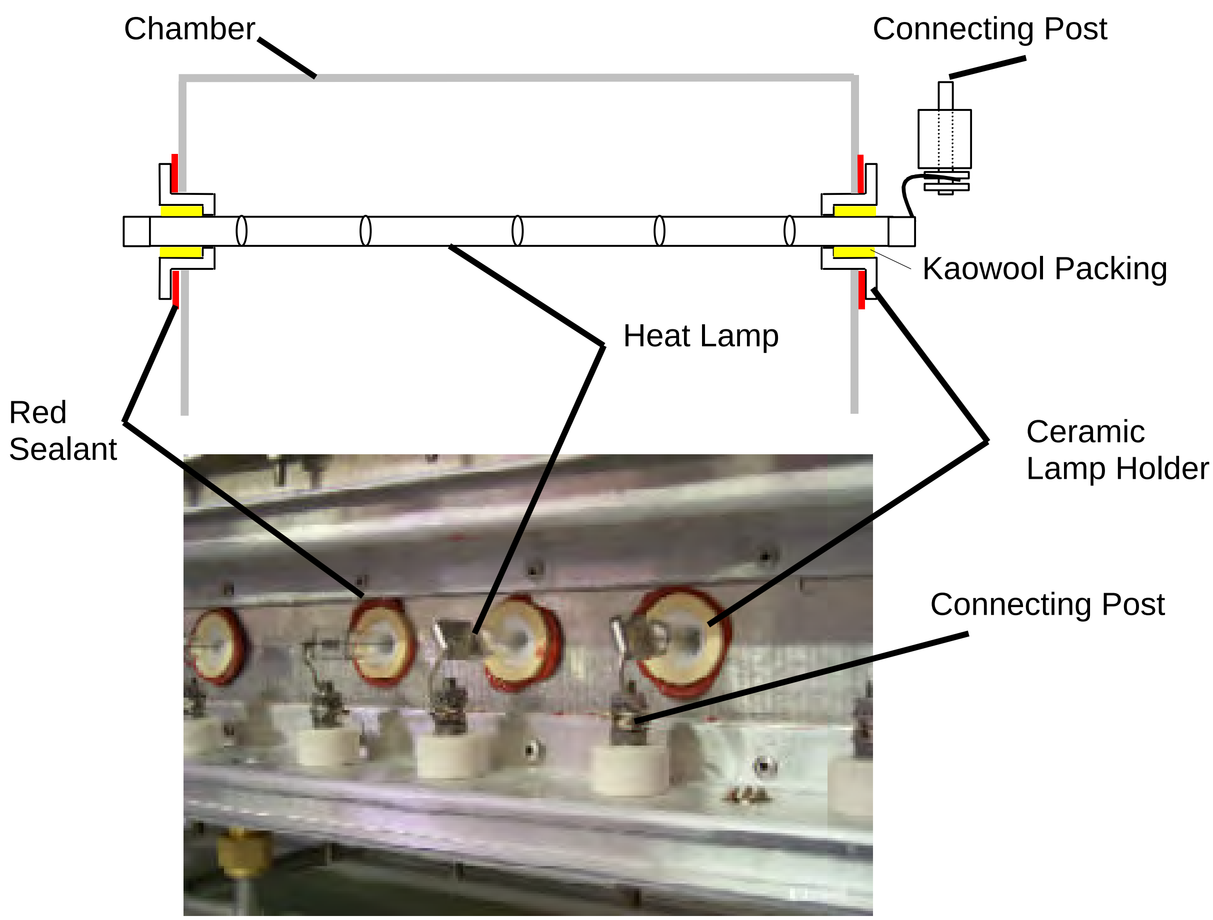


Figure 7-19: Lamp Replacement Across-the-Belt Diagram (Top), End View Picture (Bottom)

Disconnect the element lead from the insulating terminal block. Repeat this step for the opposite side.

Remove lamp and old packing material.

Make sure the red sealant securing the ceramic lamp holder is intact. Unsealed ceramic lamp holders may be resealed with kaowool packing.

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.

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.

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.

Pack the ceramic holders on both sides with the kaowool packing material.

Center the lamp to ±1/32-in. (±0.8-mm) and recheck the packing.

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.

Cut off excess connection wire.

Replace plenum covers being careful not to damage the rubber seal.

7.3.4 Drive Train / Belt Alignment

Sprocket Alignment

Unscrew the end cover at the exit end of the furnace to reveal the motor and drive mechanism. All sprockets should be perfectly aligned. Adjustments can be made by loosening the setscrews on the sprocket flanges. A straight edge can be useful for this operation.

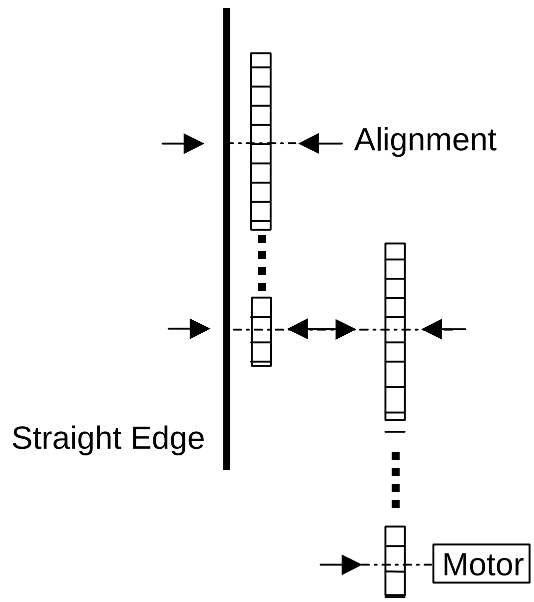


Figure 7-20: Sprocket Alignment

Motor Mount Bolts

Motor mount bolts must be checked periodically and tightened if necessary.

Sprocket Shaft Bearing Block Bolts

These shafts must be checked periodically. You will need to remove the end side covers to gain access to the bolts.

Sprocket shaft and roller shaft bearings are sealed units requiring no maintenance. The greasing points are redundant.

Chain Tension and Drive Chains

The chain tensioner is equipped with a grease fitting for lubrication. Apply sufficient grease to the tensioner so that grease can be seen squirting out along the shaft. Remove excess grease.

If the tensioner is spring loaded, no adjustment is necessary. For other types of tensioners, slacken the mounting bolts and turn the tensioner towards the chain. Tighten the bolts. A correctly tensioned chain can just be lifted from the tensioner sprocket, but cannot be lifted clear of the sprocket teeth. Drive chains should be lubricated with a non-dripping chain lubricant every 30 days.

Belt Roller Alignment

If a roller is misaligned on its shaft, loosen the setscrews that secure the roller on its shaft. Use a rubber mallet to move the roller. Rollers need to be centered within 0.125 inches so you will need a ruler or scale for this operation.

Clutch Adjustment

With the motor running, the belt should be stoppable by placing firm pressure on the entrance roller. If the belt can be stopped easily, tighten the clutch nut. If it cannot be stopped at all, slacken the clutch nut.

Belt Tracking

With the belt speed set to different values, stand at the furnace exit or entrance and look along the length of the belt. If the belt appears to be running towards one side, you will need to adjust the tracking.

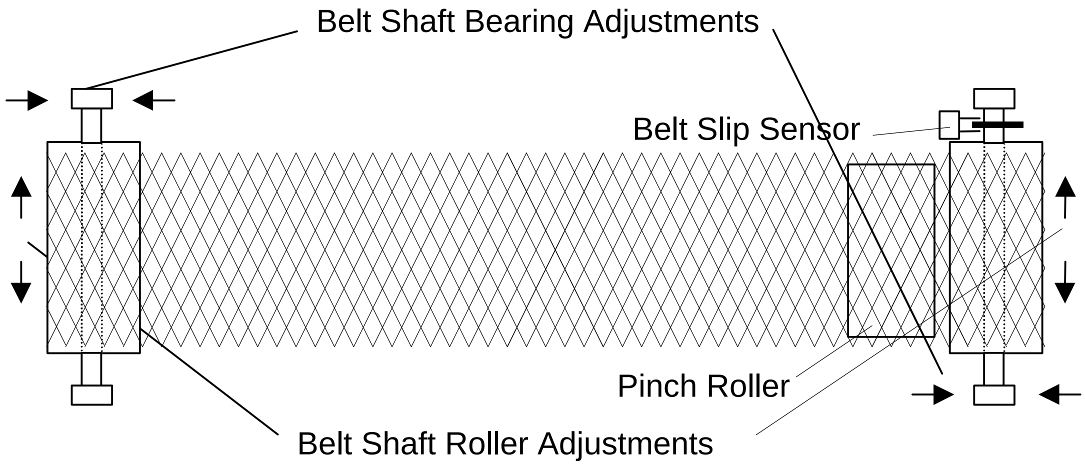


Figure 7-21: Belt Tracking Adjustment Diagram

7.3.5 Oxygen Analyzer (Option ❒)

The level of electrolyte used in the oxygen analyzer should be maintained between the high and low marks on the cup. A separate container of electrolyte is supplies with each furnace installed with this option. If additional electrolyte solution is needed, contact RTC.

Troubleshooting

Symptom	Fuse	Location
Furnace stays in warm-up mode for more than 15 min.	Gas flow contrary to zone temperatures	Adjust gas flow. See p. 110
Temperature runaway cannot be controlled by changing setpoints	The SCR has failed or needs calibrating	Calibrate SCR. If problem persists, replace SCR. See p.69
Zone Temperature fluctuates erratically	Poorly adjusted PID parameters	Adjust PID settings. See p.102
Over or under temperature alarm	Possible thermocouple malfunction	Replace thermocouple. See p.76
Hydrogen igniter alarm	Burnt our igniter	Replace
####appears in process screen where data normally appears	Computer not communicating with Controller	Check Ethernet card in PC and in Controller. Check Ethernet connectors
Data appears frozen in process screen	Bricks not communicating with controller	Check that RUN and REC LEDs are on. The TRX LED should flash periodically. Try swapping relays or brick.
Transport speed error	Slipping clutch	Tighten clutch. See p.87
Belt speed fluctuates	Worn or misaligned drive sprockets	Adjust and lubricate. See p.86
Transport motion fault	Motion sensor not working	Clean or replace motion detector gear and sensor.

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Process Engineering

9.1 Infrared Heating

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 a RTC 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** (l_{dom}) as given by Plank's distribution principle is the wavelength transmitted with the highest occurrence. So for a given temperature, only one l_{dom} exits. See Figure 9-1 below.

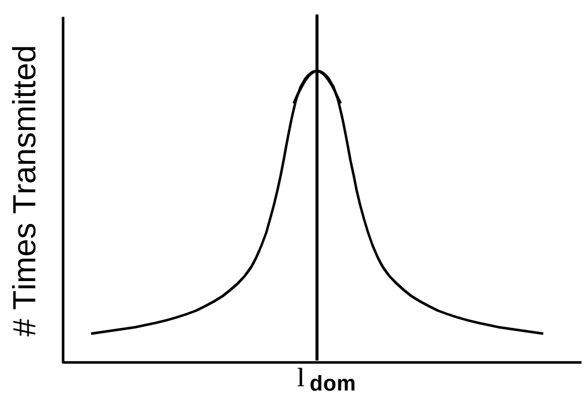


Figure 9-1: Dominant Wavelength Graph

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

$$l_{dom}\ \mu m = \frac{2897\ \mu m \cdot K}{\mathbf{T}\ K}$$

To convert from degrees Celsius (°C) to Kelvin (K) simply add 273 to the Celsius temperature value.

Example:

At 1000°C *the respective material dominant wavelength is:*

T = 1000°C + 273

T = 1273 K

Substituting back into the given equation:

λ_{dom} = 2897 μm·~~K~~ / 1273 ~~K~~

λ_{dom} = 2.28 μm

Table 9-1 shows dominant wavelengths for some common temperatures.

Furnace Setpoint (°C)	**Dominant Wavelength (μm)**
1000	2.3
900	2.5
800	2.7
700	3.0
600	3.3
500	3.7
400	4.3
300	5.1
200	6.1
100	7.8

Table 9-1: Dominant wavelengths for several temperatures.

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.

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 100ºC.

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

500 - 100 = 400

If an RTC IR furnace were heated to 500ºC, the proportional difference would be

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

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

9.2 Temperature Profiling

As discussed previously in Section 3.3 "Thermal Process", products passing through the furnace go through a set of temperatures known as a temperature profile. The process engineer must setup the furnace to achieve the temperature profile with the product. To do this, the engineer must have an idea of what the cycle of the product must look like. Looking again at the temperature profile from Chapter 3, six zones are visible labeled Z1 – Z6 (See Figure 9-2 below). Depending upon the setup of the furnace, more zones may be present.

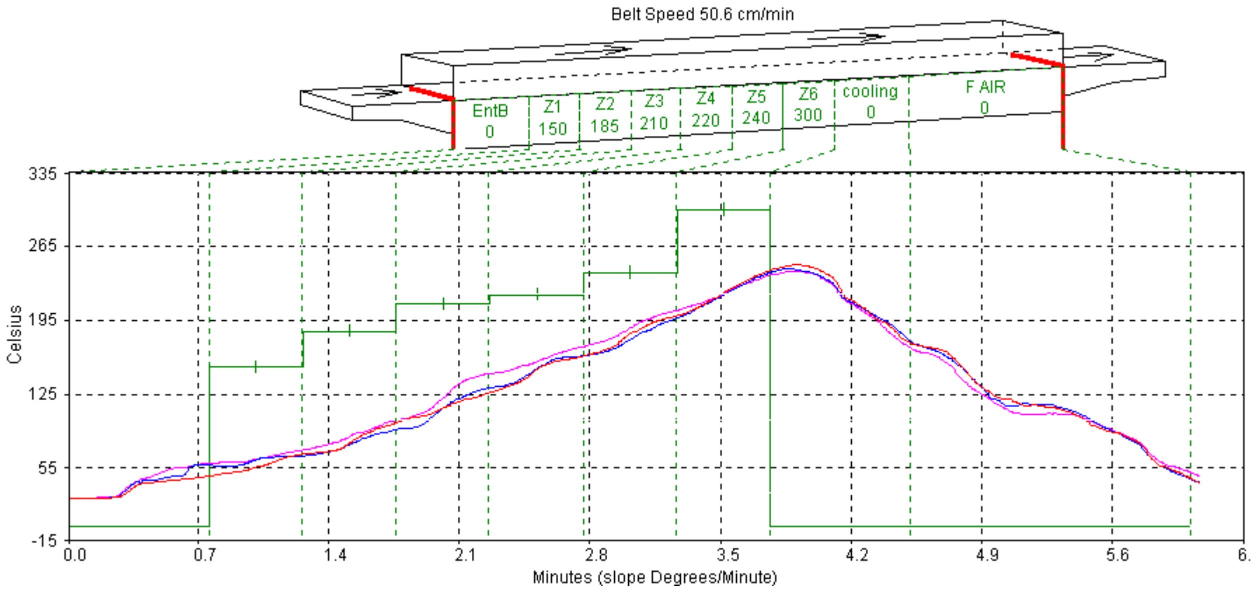


Figure 9-2: Temperature Profile

Initially, temperature profiles must be recorded from inside the furnace. To get to the point of taking a temperature profile, the following list of topics will be covered.

Profile Specifications
Basic Variables
Type of Profiles
Examples of Profiling

9.2.1 Profile Specifications

In general, the temperature profile is defined by the following specifications:

Heating Rate: The rate of increase of temperature from room temperature.

Dwell/Hold Time: The time the product remains above a certain temperature or a range of temperatures.

Second Heating Rate: The rate of increase of temperature from the temperature reached during the hold time, as required.

Peak Temperature: The maximum temperature reached with a +/- range.

Second Hold Time: Same as hold time, as required.

Cooling Rate: The rate of decrease of temperature to a lower/critical temperature.

Product Exit Temperature: As required.

Sometimes a conveyor belt speed range is requested for a desired product speed. In this case, the above specifications are met within the specified speed range. In general, the speed range depends on the size and type of furnace. Another important consideration is to understand that many sets of belt speeds and temperature settings will meet a given set of profile specifications. Furthermore, higher belt speeds result in greater temperature deviations and lower consistency from the desired temperature profile.

9.2.2 Basic Variables

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

- Conveyor Speed: The time required to pass through the process section.
- Temperature Setpoints: 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: The rate of gas flow through the process section.

If the furnace is equipped for a controlled atmosphere, this will be an important factor to consider. Gas flow and flow meter settings will be addressed in detail later in Section 9.6 on p.110.

9.2.3 Types of Profiles

In most processes, two kinds of temperature profiles exist:

Equilibrium (flat) profiles:
- -Hybrid thick film and PTF firing
- -Glass or metal/solder sealing of IC packages
- -Die-attachment processes
- -Drying/Curing of polymeric products

Non-Equilibrium (peaked/spiked) profiles:
- -Solder reflow attachment

-Cerdip lead-frame attachment
-Solar cell firing processes

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

9.2.4 Examples of Profiling

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

Thermocouple Wires
- K-Type thermocouples are recommended.
- Depending upon operational temperatures, use a properly rated thermocouple for accurate readings. For temperatures above 300ºC, RTC recommends the use ceramic or ultra-high-temperature plastic connectors and Inconel sheath material with MgO insulation.
- Use one thermocouple for centerline profiling or three for across-the-belt profiling.

Temperature recording device
- Chart recorder
- OSP – On Screen Profiling option
- KIC temperature profiling software kit
- MOLE/SuperMOLE type of datalogger

Below temperatures of 300ºC, the thermocouple can be taped with Kapton tape to a test specimen.

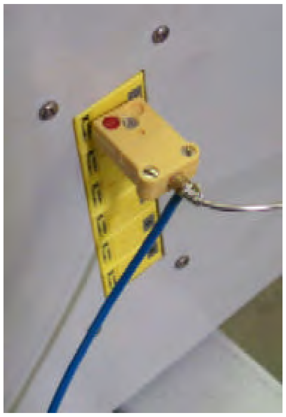
Note: Repeat testing may require new tape for accurate results.

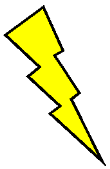
Above 300ºC, the thermocouple sensor must be cemented onto a test specimen. In cases where the product of interest is not readily available, The thermocouple may be placed inside a small length of ceramic tube called a bead.

Safety

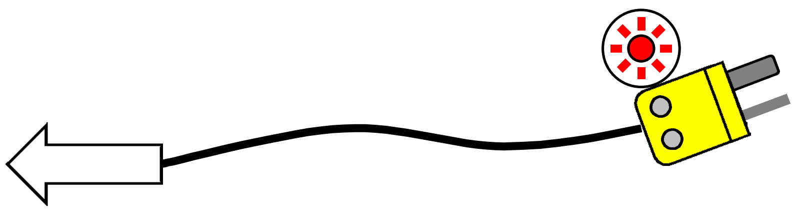
DANGER: When using metal shielded thermocouple wires inside a RTC Furnace, electrostatic energy may collect on the wires. Properly ground the shielding material to the furnace chamber by wrapping a

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.



Equilibrium 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.

Heating Chamber Length		Dwell Time			
		6 minutes		10 minutes	
(in.)	(cm)	(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

Table 9-1: Equilibrium Temperature Profile Belt Speed Recommendations

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. This will increase the resolution of the temperature profile and reveal more information about temperature uniformity and consistency.

- Set all zone temperatures to the desired peak temperature plus 5ºC. 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 nichrome 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. This will increase the heating rate at the start, while the remaining zones will maintain the temperature of the product at the peak temperature.

The slow belt speed will allow the temperature to reach the peak temperature within the first 1-2 zones. This leaves the rest of the heating chamber to 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.

Non-Equilibrium Profiles

If the type of profile requires no hold time temperatures, try the following.

- Start with a high belt speed that will result in a 2-4 minute dwell time through the heating chamber.

Heating Chamber Length		Dwell Time			
		2 minutes		4 minutes	
(in.)	(cm)	(in./min.)	(cm/min.)	(in./min.)	(cm/min.)
30	76	15	38.1	7.5	19
60	152	30	76.2	15	38.1
90	229	45	114.3	22.5	57.2
120	304	60	152.4	30	76.2

Table 9-1: Non-Equilibrium Temperature Profile Belt Speed Recommendations

- Record the temperature and observe the results.

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

  - Lower the belt speed

  - Increase zone temperatures

- Repeat the profiling until the desired temperature peak is achieved.

If the profile requires an initial hold time, follow the procedures above, listed under “Equilibrium Profiles” for the necessary hold time with the following modification.

- Increase the final zone temperature to about 30-50ºC above the desired peak temperature.

- Record the temperature and observe the results.

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

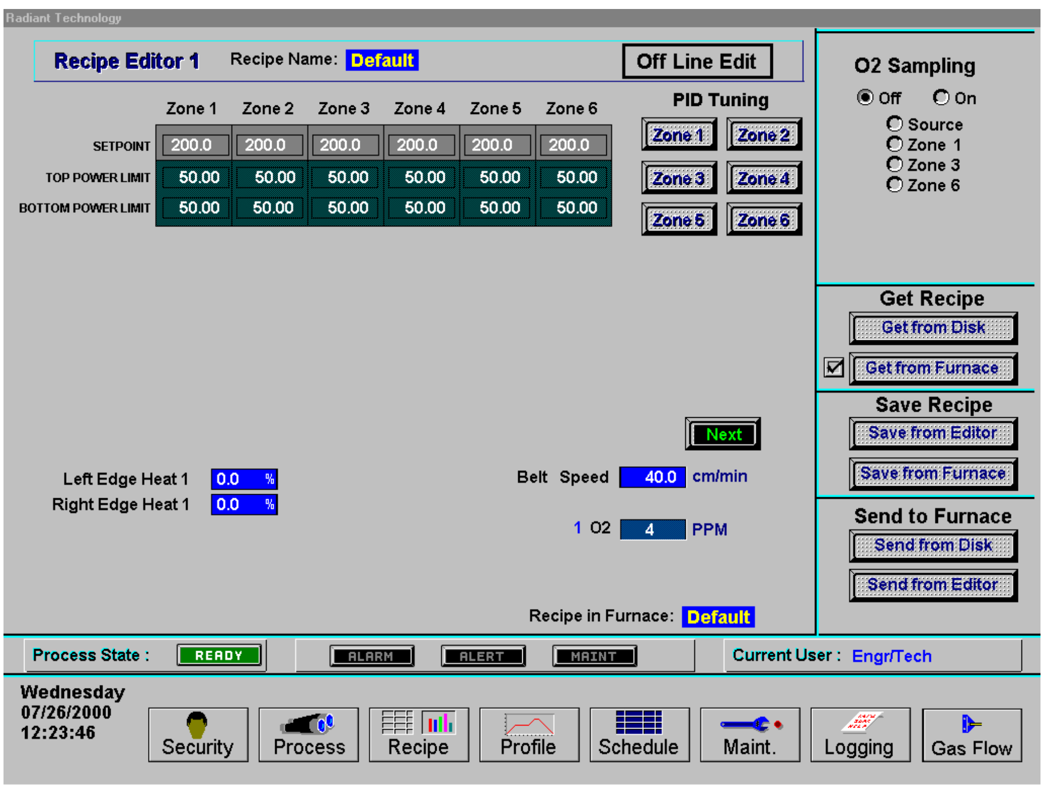
- Lower the belt speed
- Increase the final zone temperature

- Repeat the profiling until the desired temperature peak is achieved.

9.3 Creating a Recipe

For the RTC Furnace to operate, temperature setpoints, control parameters and alarm conditions must be set. Once the best parameters have been established, they can be stored in a recipe which can be used by the operator to run the furnace under those conditions.

9.3.1 Recipe Editor

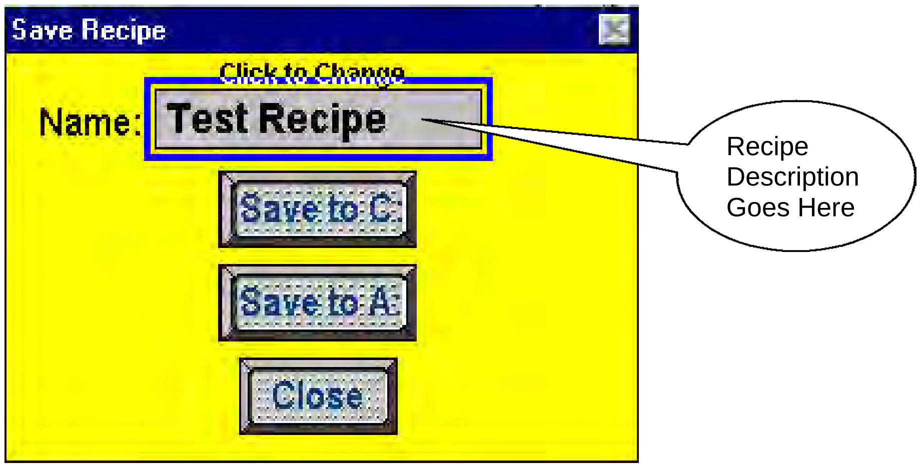


9.3.2 Recipe Handling

Recipes are handled in nearly the same way as described previously in the Recipe Loading Section under 5.5.2 on p.50.

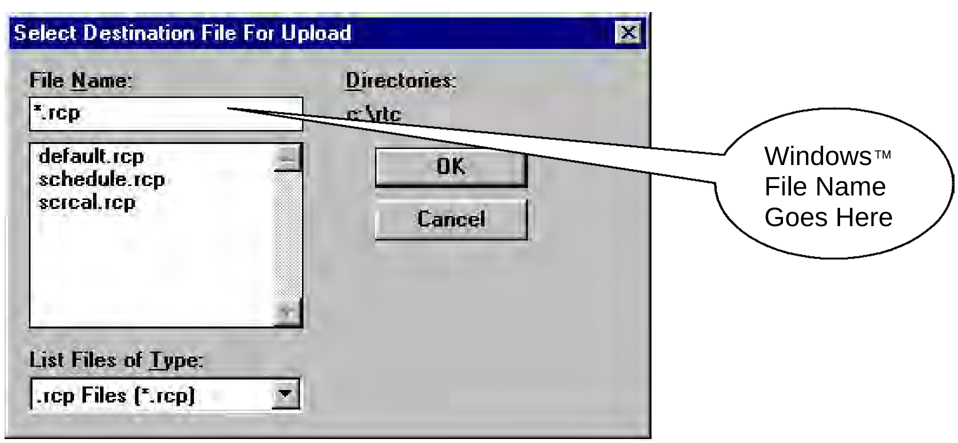
Recipe Names

The *Recipe Name* in the Save Recipe dialog box is not the same as the Windows ä file name. When saving a recipe to disk, a dialog box appears asking for the recipe name. This dialog box can be used for a recipe description. The description can be long and descriptive or the same as the Windows™ filename.



Once a recipe description has been entered in the Save Recipe dialog box, the recipe can be saved to disk.

Click on either Save to C: or Save to A: The following dialog box appears:



It is a good idea to save all your recipes to diskettes as well as to the hard drive. Recipe files can be copied using Windows Explorer or saved to a diskette by selecting the Save to A: command button in the Save Recipe dialog box.

9.3.3 PID Tuning

When the RTC 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 Proportional+Integral+Derivative and represents the three terms used in the control loop.

When in PID tuning mode, any changes that are made are sent directly to the Opto22 controller. This method of tuning the furnace allows the engineer to precisely control the temperature profile inside the furnace.

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

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

$$\mathrm{CO} = G \cdot \left\{ (S - T) + \frac{1}{I} \int_{0}^{1\,\mathrm{sec}} T \cdot dt + D \cdot \frac{dT}{dt} \right\}$$

Where:

T = Temperature

t = Time

G = Gain Term Value

S = Setpoint Temperature

I = Integral Term Value

D = Derivative Term Value

To begin, the following sections review and explain the three components of the PID equation.

Gain

The proportional band is adjusted according to the following equation

PB °C = 100 °C / Gain

Effectively, the higher the gain, the narrower the proportional band and 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 **error.** (This does not mean that anything is wrong). The error is measured continuously, (approximately 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. It can be said, therefore, that gain values greater than 1 amplify the controller's response to error. That is to say, gain values multiply the controller's response to 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.

A default value of **2** is suitable for many processes.

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

Integral

The integral value is used to home in on the setpoint.

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.

With just gain operating, and no value set for integral and derivative, the controller acts somewhat like a thermostat. When the difference between temperature and setpoint 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 results in a situation where the temperature is often away from the setpoint.

The Integral term in the PID equation is a value representing the average temperature difference over a given period of time, (approximately one second). The value is updated constantly. Another way of saying this is that the integral term accumulates error as a function of time. This means that the **integral value** entered in the recipe will be multiplying a small integral term.

The integral product (integral value x integral term) is added to the error. This integral product can make a significant difference to 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. The average difference between temperature and setpoint over a period of time (integral term), however, 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 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.

For many processes, **5** is a good default value to start with.

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 is appropriate for most processes. A derivative value is only appropriate for processes with very slow temperature deviations. This follows for a number of reasons:

Detecting an accelerating deviation from setpoint requires at least three temperature measurements. Therefore, at least two seconds elapse before a correction can be made. This response time is too slow for most processes.
RTC heat lamps are very responsive. Gain and integral values are generally sufficient to counteract temperature deviations.

The derivative is so sensitive to changes in rate that any noise on the process signal will be evaluated as a rate change – possibly sending the output on wild swings after every measurement. After one scan, for example, the output could increase by 55% and then decrease by 55% on the next scan. If the derivative is used, the process signal must be noise free or filtered before it is evaluated by the PID equation.

The derivative can show a downwards accelerating temperature deviation even though the temperature may have started increasing. This can result in an over correction.

To begin a PID tuning sequence, click on one of the Zone # buttons in the Recipe Screen.

The following pop-up box will appear. Remember, this data is pulled directly from the furnace and may not be the same as what is seen in the Recipe Screen. Any adjustments while in the PID Tuning screen occur real-time. The programmed values are sent directly to the controller and immediately affect controller values and

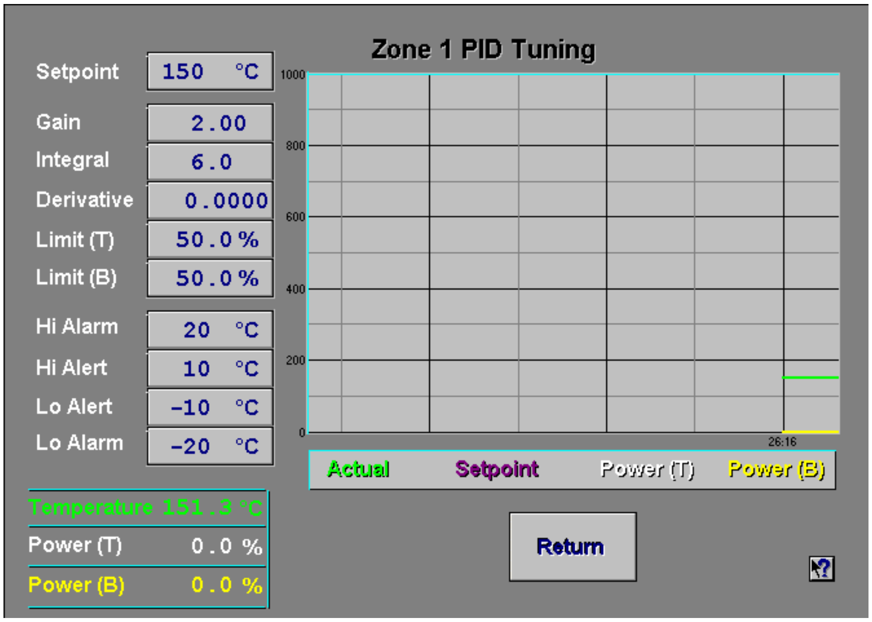


Figure 9-3: PID Tuning Screen

The values in the boxes on the left show the setpoints that are currently loaded in the furnace. The values on the bottom left reflect the numerical values of temperature in the zone as read by the thermocouple and the level of power being applied to the heat lamps in that zone as regulated by the controller and SCR. The graph on the right records these values as the graph scrolls from right to left. This gives the viewer a clear picture of the interaction of the level of power being applied to the heat lamps as the temperature deviates from the setpoint.

Power Limits

Top and bottom power limits can be set in the PID tuning screen. This value limits the amount of current that can be drawn by heat lamps. Reducing this value might increase the furnace warm-up time. A modest saving in operating costs might, however, be achieved.

9.4 Gas Flow Recap

9.4.1 Gas Flow Basics

The most important factor in creating a safe and efficient process environment is gas-flow balance. This means that 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. This would lead to alterations in the thermal process profile.

Disruptions in gas flow in the process section can be caused by the following:
- Close proximity of doors
- Close proximity fans

Placing a furnace through a wall between rooms
Attaching facility exhaust ducts directly to the RTC furnace exhaust stack

9.4.2 Process Gas

Various forms of process gas can be utilized inside RTC furnaces. Customers may want to operate a pure N_2, O_2 or H_2 environment. Others only need clean dry air (CDA). Whatever the case, RTC can configure the furnace to operate under many conditions. The following are some possible process gasses.

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 another gas in. A relatively inert gas such as nitrogen is normally used for this purpose.

Hydrogen

Other gasses 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.

Forming Gas

Forming gas is the term used to describe any mixture of N_2 and H_2 gas.

All processes with concentrations of H_2 higher than 4% mass percent require all H_2 automated safety features. When the concentration of H_2 gas required for the process falls below 4%, H_2 levels will not reach an explosive concentration inside a RTC Furnace.

9.5 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 simply calculate the volume of the furnace chamber and multiply the answer by the number of times per hour that the atmosphere needs replenishing. This will give the total gas flow per hour for the chamber.

Example:

The process engineer determines the thermal process ***replenish time*** *is 60 seconds.*

Given: *Replenishment Requirement:* 60 seconds / replenish
Belt Width: 24 in.

Process Section Dimensions
(Not including Open Air cooling modules)
The better the estimate of internal volume, the less tuning required.

Entrance Baffle
Height: 6 in.
Width: 25 in.
Length: 15 in. H x W x L = 6 x 25 x 15 = 2250

Heating Chamber
Height: 12 in. ← Includes top and bottom insulation because gas passes through this
Width: 25 in.
Length: 30 in. H x W x L = 12 x 25 x 30 = 9000

Transition Tunnel
Height: 6 in.
Width: 25 in.
Length: 15 in. H x W x L = 6 x 25 x 15 = 2250

Controlled Atmosphere Cooling Module
Height: 6 in.
Width: 25 in.
Length: 30 in. H x W x L = 6 x 25 x 30 = 4500

Exit Baffle
Height: 6 in.
Width: 25 in.
Length: 15 in. H x W x L = 6 x 25 x 15 = 2250

Total Volume: 20250 in^3

Calculations

Convert to cubic feet:

20250 ~~in~~ x ~~in~~ x ~~in~~ / [(12 ~~in~~ / ft) x (12 ~~in~~ / ft) x (12 ~~in~~ / ft)]

= 11.72 ft^3 / replenish

1 hour = 3600 seconds

3600 ~~seconds~~ / (60 ~~seconds~~ / replenish) = 60 replenishes / hr

(60 ~~replenishes~~ / hr) x (11.72 ft^3 / ~~replenish~~) = 703.1 ft^3 / hr

703.1 SCFH

From these calculations you can balance the furnace environment with a total gas flow of 703.1 SCFH.

9.6 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.

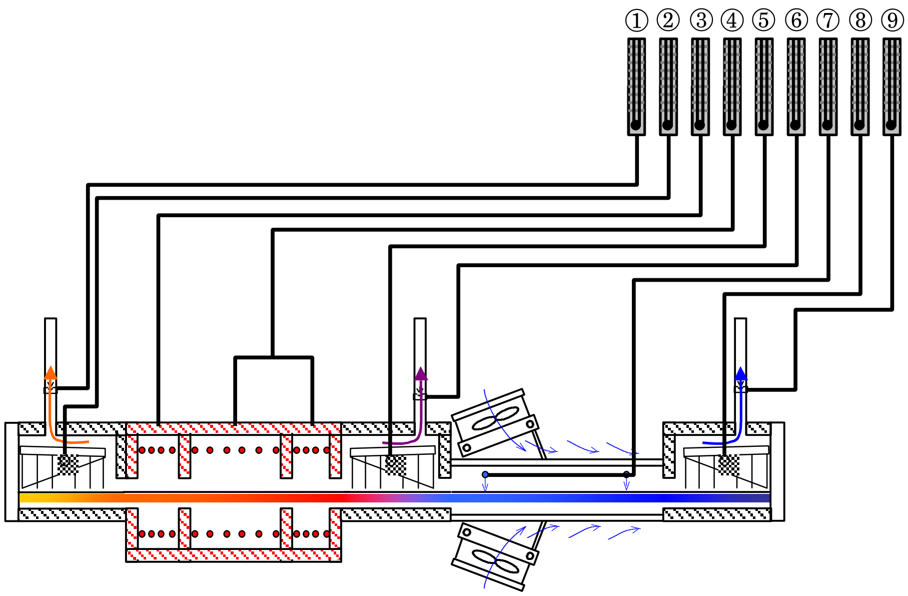
❶ First, determine how the total gas flow should be added to the heating chamber. Depending upon installation, split the total gas flow rate into flow rates for each of the heating chamber zones and baffles for which the furnace has control.

❷ Since the flow rates to exhaust stack eductors do not represent the volume of air removed from the process section, divide the total input flow rate by 10. The approximate volume of air drawn out by the venturi created by the eductor is 10 times the flow rate.

❸ Split this total into the available eductor

Refer to the example shown below.

Example:



① - Entrance Eductor
② - Entrance Baffle
③ - Zone 1
④ - Zone 2-3
⑤ - Transition Baffle
⑥ - Transition Eductor
⑦ - Cooling Section
⑧ - Exit Baffle
⑨ - Exit Eductor

Gas Entering Zones

Entrance Baffle	50	SCFH	❶
Zones 1	150	SCFH	❶
Zones 2 & 3	200	SCFH	❶
Transition Tunnel	50	SCFH	❶
Ctrl. Atm. Cooling Module	153	SCFH	❶
Exit Baffle +	50	SCFH	❶
Total Gas Flow =	703	SCFH	
Eductor Flow Divider	÷ 10		❷
Total Eductor Gas Flow =	70.3	SCFH	
Entrance Eductor	25	SCFH	❸
Transition Tunnel Eductor	22	SCFH	❸
Exit Eductor	23	SCFH	❸

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.

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.

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

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.

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.

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.

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.

9.7 Hydrogen Operation (Option ❐)

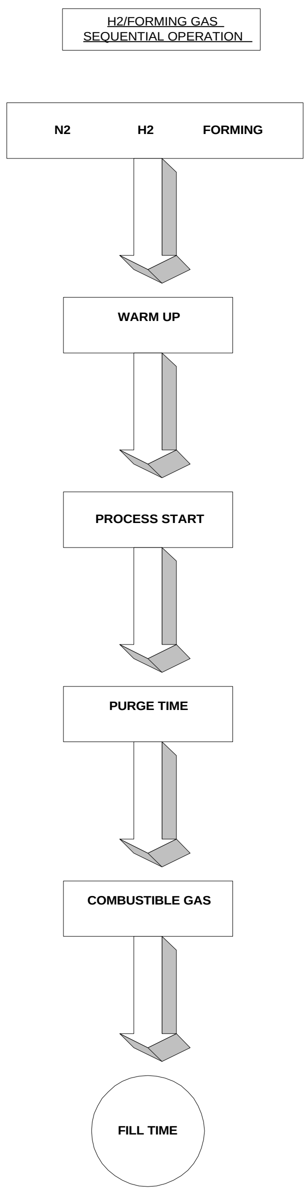
If the furnace is not equipped for hydrogen operation, skip to "Check for an Escaping Environment" Section 9.8 p.119.

DANGER: If the RTC Furnace is equipped for H_2 operation, Ozone, or another hazardous process gas, balancing gas flow is extremely important to the safety of any one working near the furnace.

9.7.1 Introduction

The hydrogen operation option is designed to provide a means of introducing a reducing atmosphere into the furnace. Because hydrogen is an extremely flammable gas and presents numerous handling and control problems, do not attempt to connect hydrogen to the machine until this section is read and understood.

9.7.2 Description



The hydrogen operation system uses existing furnace plumbing and an additional gas flow control system to introduce hydrogen into the furnace chamber. The hydrogen is introduced into the furnace by allowing it to permeate through the porous ceramic fiber insulation, which preheats the gas before it enters the process area.

Entrance and exit baffles, located at each end of the furnace chambers, generate an inert gas curtain which effectively keeps ambient air from entering the furnace chamber and mixing with the hydrogen atmosphere. Venturi assisted exhaust stacks, located in the entrance baffle or in both entrance and exit baffles, draw off the excess hydrogen and direct it into a burner assembly. The excess hydrogen, which is drawn through the exhaust stack, is directed into the burner where it is mixed with ambient air and ignited with a hot wire Igniter.

Figure 9-4 : H2 / Forming Gas Sequential Operation

9.7.3 Control System

The hydrogen control system is designed to prevent the possibility of introducing a combustible mixture of hydrogen into the furnace chamber. This is accomplished through logic which requires that nitrogen be run continuously in the exhaust venturis, entrance/exit baffles, furnace chamber, and in the transition tunnel/cooling muffle, if so equipped. The hydrogen control logic provides an automatic timed purge of from 5 to 30 minutes, with nitrogen, before hydrogen is allowed to enter the furnace. Nitrogen and hydrogen pressure switches, together with additional control logic, enhance the safety of the system by requiring that the following conditions be met.

Nitrogen Pressure

Nitrogen pressure must be present at all times during the purge cycle, as well as during straight hydrogen operation. In the event of nitrogen failure, hydrogen is automatically shut off, and the hydrogen cycle is aborted with alarm and display indication. Only after nitrogen pressure is restored can the cycle be restarted.

Hydrogen Pressure

Hydrogen pressure must be present during the purge cycle and during straight hydrogen operation. In the event of hydrogen failure, the cycle is aborted and nitrogen flow is initiated with an alarm and display indication. Only after hydrogen pressure is restored can the cycle be restarted.

Igniter

The hydrogen Igniter element(s) must start when the hydrogen burn-off operation is initiated, and run continuously during the delay cycle, as well as in the steady state. The furnace is manufactured with dual (2) igniters per stack. If both igniters in a single stack fail, the cycle is aborted with alarm and display indication. Manual restart is required to reinitiate the cycle. If only one igniter fails, the process is not aborted, but an alert occurs.

Seal or Plenum Pressure

Sensing a lack of seal pressure parts puts the machine into heat shut down with alarm and display indication.

9.7.4 Gas Flow Control

Gas flow control is accomplished manually with flowmeters. See section 2.12.4 for operating instructions.

9.7.5 Installation Requirements

Hydrogen is a flammable gas and, under certain conditions, it can be explosive. The user of this equipment must take adequate precautions to prevent the escape of hydrogen into the room air and to eliminate possible sources of ignition from the working environment. A common practice is to vent the upper part of the ceiling of the room containing the furnace, and to install a hydrogen leak detector system.

The room containing the furnace must be arranged to prevent direct air drafts from hitting the furnace. A direct air draft at the entrance or exit end of the furnace will unbalance the gas curtains and could cause hydrogen to escape into the room, or create an explosive mixture of air and hydrogen inside the furnace.

DANGER: The flow meters installed in the control panel are rated for 70 psi maximum; operating beyond 70 psi exposes the operator to possible injury.

9.7.6 Operating Instructions, OPTO22 Control System

Process Screen Controls (H_2)

Go to Process screen and click on H2 Button. Click on Warm-Up. Wait until the process start light is flashing, and click on Process Start. This starts an automatic timed purge with nitrogen and lasts from 5 to 30 minutes. When the purge cycle is complete, click on Combustible Gas On. Nitrogen will be shut off and hydrogen will be turned on.

Hydrogen/Nitrogen (Forming Gas)

Go to Process screen. Click on Forming button. Click on Warm-Up. Wait until the process start light is flashing, and click on Process Start. This starts an automatic timed purge with nitrogen and lasts from 5 to 30 minutes.

When the purge cycle is complete, click on Combustible Gas On and hydrogen will be turned on. This starts an automatic timed fill (manual set).

NOTE: Fill is defined as the amount of time required for the combustible gas to enter and fill the chamber cavity. Fill time is factory preset for 5 minutes, and can be user altered.

Terminate

Click on Cooldown (this returns the furnace to nitrogen operation), or go to Recipe Screen and load a new recipe.

Nitrogen or Manifold Pressure, Low

Low nitrogen pressure is indicated with a message and an audible alarm. The hydrogen operation cycle is aborted, and the machine goes into a heat shut down mode. The cycle cannot be restarted until nitrogen pressure is restored.

Hydrogen Pressure, Low

Low hydrogen pressure is indicated with a message and an audible alarm. The hydrogen operation cycle is aborted, and cannot be restarted until hydrogen pressure is restored.

Plenum Pressure, Low

Low seal pressure is indicated with a message and an audible alarm. The machine goes into a heat shut down mode and the hydrogen cycle is terminated.

Warning: Low plenum pressure can cause damage to the heating lamps. Do not continue to operate the machine with low plenum pressure indication. In the event of low plenum pressure indication, the machine should be shut down until the problem is found and corrected.

Igniter Failure

Igniter failure is indicated with a message and an audible alarm. If both igniters in a single stack fail, the hydrogen operation cycle is aborted and cannot be restarted until the igniters are repaired. If only one igniter fails in a single stack, the process is not aborted, but an alert occurs.

9.7.7 Hydrogen Flowmeters

Each of the hydrogen flowmeters is identified with a label as to specific function, and is adjustable from zero flow to full scale by means of an integral control valve.

Control Knob

Turning this knob clockwise decreases the flow; counterclockwise increases the flow.

9.7.8 Functional Checkout with Helium

RTC recommends that a functional checkout of the hydrogen system be made using helium gas for safety. It is further recommended that a trace oxygen analyzer and helium detector be made available for the checkout.

RTC has taken precautions to design the furnace so that it can be safely and reliably operated on hydrogen. However, if the gas flows are not properly set, air can be drawn into the machine, or the furnace atmosphere can be discharged out the entrance or exit, causing a fire hazard. If it is not possible to perform a functional checkout with helium, RTC recommends, as a minimum, a trace oxygen analyzer and combustible gas monitor be used to guide final process settings.

Furnace System Functional Check

First perform the recommended furnace system functional checkout. Correct any malfunctions, as necessary, before proceeding.

Helium Supply Gas

Temporarily connect a supply of helium gas to the hydrogen input line and adjust the input regulator to 50-psi. Make sure that the hydrogen flow meters are completely shut off at this time.

Turn On Furnace

Turn on the furnace and bring it up to a fully operational state using the suggested gas flow settings from your operation manual.

Initiate the Hydrogen Operation Cycle

Adjust the hydrogen flow meters to the same flow rates that the equivalent nitrogen flow meters were set at.

Check Oxygen Concentration

Check the oxygen concentration inside each zone of the furnace, using a trace oxygen analyzer. The oxygen concentration can vary considerably, depending on flow settings; but as long as 100 PPM, or less, is maintained in the furnace, combustion will not occur. If the concentration of oxygen is above the 100 PPM limit, increase the flow of helium in small increments and retest the oxygen level. Allow several minutes between gas flow corrections and oxygen testing for the analyzer to stabilize.

Check for Escaping Gas

Check each end of the furnace with a helium detector to see if any furnace gas is escaping. If furnace gas escapes, increase the flow to the appropriate eductor in small increments and retest.

9.7.9 Nitrogen/Hydrogen Mixing

Selecting the nitrogen/hydrogen atmosphere, with the furnace in the hydrogen mode will unbalance the ratio of input to exhaust gas. This happens because nitrogen is introduced in addition to the volume of hydrogen that is already flowing into the furnace. Before pressing nitrogen/hydrogen mixing, perform the following:

Calculate the volume of helium flowing into the furnace when the machine is running in a balanced condition.

Decide what ratio of helium to nitrogen is to be run and the volume of each gas required.

Select the nitrogen atmosphere mode to return the furnace to nitrogen operation.

Adjust the nitrogen volume to the values calculated above. Shut off the hydrogen flow meters.

Select the hydrogen atmosphere mode, and select the nitrogen/hydrogen mix mode before the purge cycle is complete.

Then adjust the hydrogen flow meters. The machine should now be operating in a balanced condition, with the proper volume of nitrogen/hydrogen.

Check the oxygen level in the furnace and ends of the furnace for helium, and correct as necessary.

This completes the functional checkout.

GAS	SP.G
Argon (A)	1.38
Carbon Monoxide (CO)	.966
Carbon Dioxide (CO_2)	1.51
Helium (He)	1.38
Hydrogen (H_2)	.070
Hydrogen Chloride (H_2Cl)	1.59
Hydrogen Sulphide (H_2S)	1.39
Methane (Me)	.553
Natural Gas	.55-.66
Nitrogen (N_2)	.966
Nitrous Oxide (N_2O)	1.52
Oxygen (O_2)	1.103
Propane (C_2H_2)	1.56-1.99
Sodium Dioxide (SO_2)	2.2-2.26
Butane-N	2.4
Butane-ISO	1.99

Table 9-1: Gas Correction Factros

9.8 Check for an Escaping Environment

If your furnace is equipped for a controlled atmosphere, the oxygen analyzer option is probably also installed and should be used to assist in establishing if a balanced gas flow has been reached. The following are some basic tests that users can apply to check for safe and healthy furnace environments.

- Check the **bezels** (exit and entrance guards) for signs of burning. If the bezels are turning brown, furnace atmosphere is probably escaping.

- Smoke exiting from either end of the furnace is an obvious sign of an escaping environment. Strong fumes in the vicinity of the bezels indicate likewise.

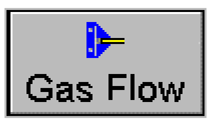
- A small smoke source close to the furnace entrance or exit will indicate if air is being drawn in, or forced out of the furnace. Smoke rising vertically indicates that gas flow is balanced. A small piece of tissue paper or light thread taped to a pencil will also work.

9.9 Plenum Gas Flow

The IR-heat lamps do not make an airtight seal with the sides of the heat chamber. For this reason, nitrogen or clean dry air **(CDA)** is pumped into the plenums where it penetrates the heat-lamp seals and enters the chamber. This technique prevents process gas escaping through the heat-lamp seals. The volume of gas entering the chamber via the plenums is minimal, and does not affect general gas-flow calculations.

9.10 Gas Flow Screen

Once gas flow has been determined by the process engineer, the values should be stored with the recipe. This provides a record of the correct process settings which can be applied when the recipe is retrieved by the operator.

Select the Gas Flow button. 

The gas-flow screen can be used to record gas-flow settings for a recipe.

Note: Depending if the customer system includes the Mass Flow Control option, the controls in this screen have no effect on the actual gas flow.

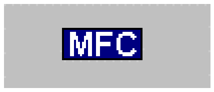
Adjust the slide indicators until the screen flow meters match the actual flow meters on the outside of the furnace. Select the Save Settings button.

A pop-up window appears, prompting the user for a recipe name. Select a recipe name you wish to associate and select Save to C.

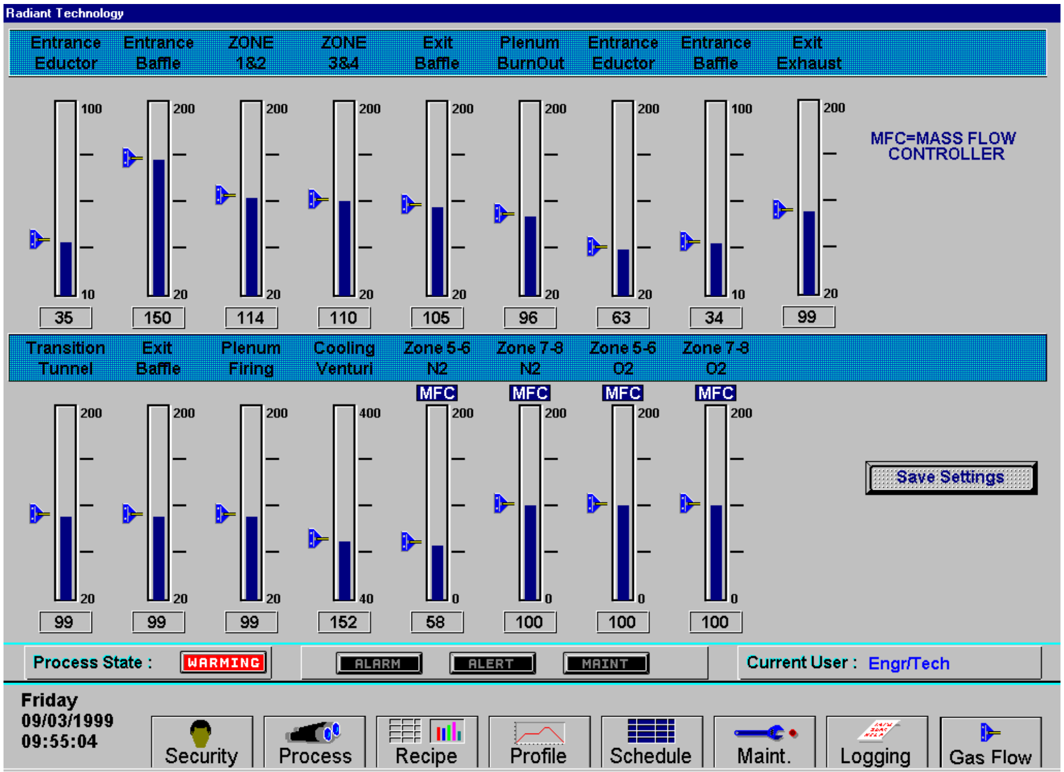
These settings are now attached to that recipe. When the operator recalls the recipe, the settings for the flow meters will be available and should be adjusted when the recipe is loaded.

9.11 Mass Flow Controller (Option ❒)

In some RTC furnaces, optional electronic mass flow control valves may be installed to allow the customer to directly control the gas flow rates in the heating chamber.

Notice the 

indicator box located above the flow meters installed with this option.



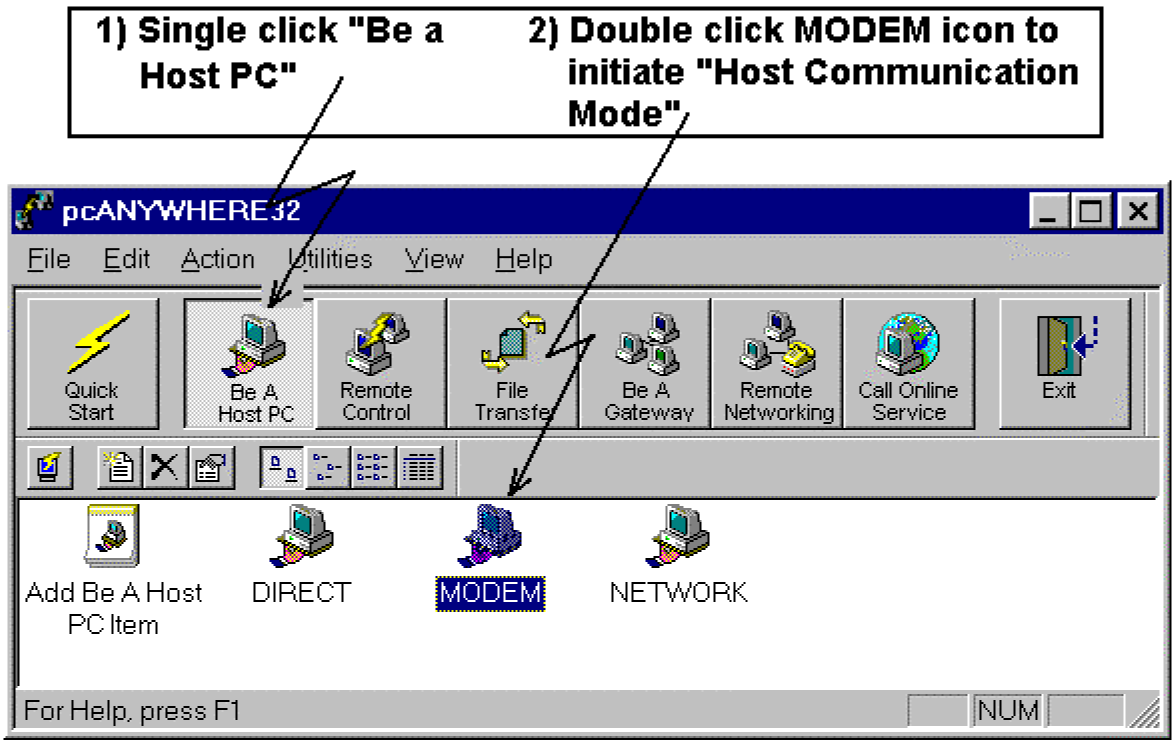
9.12 PC Anywhere

Occasionally, it may be necessary for RTC personnel to access the furnace-PC for diagnostic and maintenance purposes. Before your machine can be accessed, you need to run the **pcANYWHERE**™ software.

Double click the pcANYWHERE™ icon from the Windows desktop. 

Or the quick-launch button  or from the Windows Start Menu.

After the application opens, Select the Be A Host PC button.



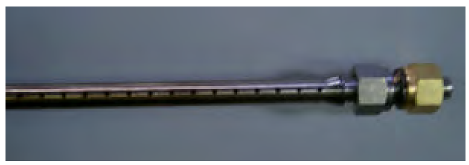
Connect the rj11 phone jack on the furnace to a direct- line phone jack. Make sure RTC technical support knows the direct dial number for this jack.

Access Level Permissions granted at time of log-on to perform certain menu operations.

Across-the-Belt In reference to an area perpendicular to the direction of travel through the furnace; the width of the conveyor belt.

Actual Temperature The instantaneous temperature in the furnace as reported by the thermocouple.

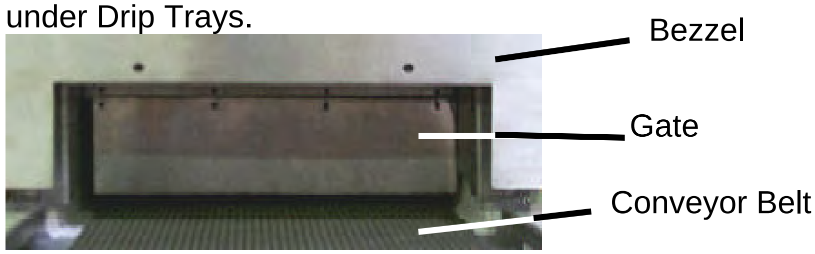
Air-Rake Long tube set across-the-belt with proportionally spaced small holes.



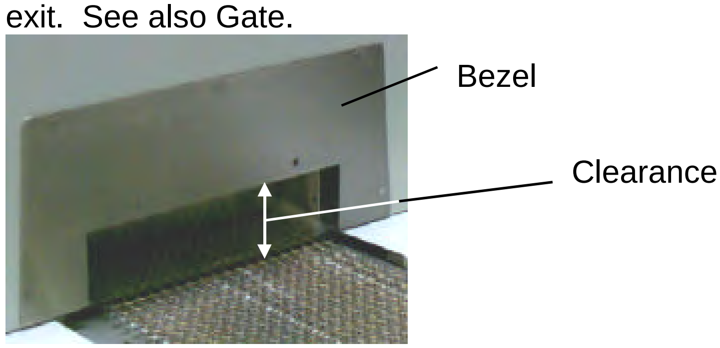
Air-Regulator Tubes Air rakes charged with air or N2 installed in the entrance and exit baffles, used in establishing a controlled atmosphere.

Arcnet Card Network interface card. PC interface talks to furnace Opto22 controller via Arcnet cards.

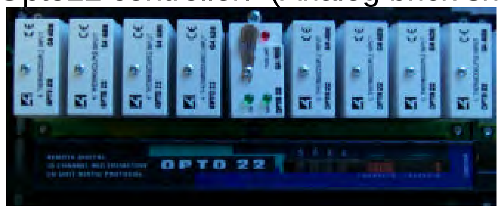
Blade Hinged flaps at entrance and exit of furnace that help prevent furnace atmosphere from escaping. See also figure under Drip Trays.



Bezel Semi-permanent entrance guard at furnace entrance and exit. See also Gate.

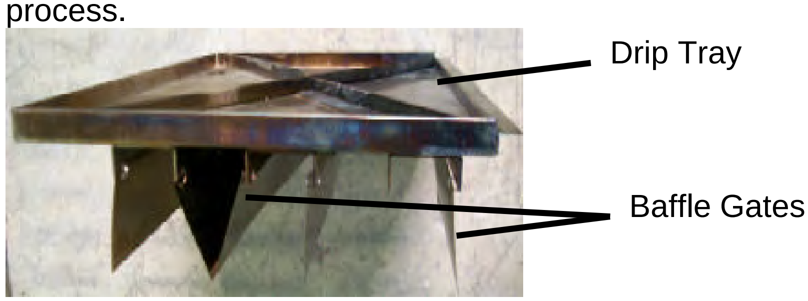


Glossary

Brick	Circuit board that connects digital or analog relays to the Opto22 controller. (Analog brick shown) 
CDA	Clean dry air – a process gas used in some furnaces
Chamber	See heating chamber.
Clearance	The distance at furnace entrance between the conveyor belt and the bezel. See diagram under bezel.
Contaminants	Anything present in the process section that could negatively impact product quality including but not limited to O_2, moisture or particulate matter.
Convection	The process of heating a product via indirect transmission of heat from adjacent high-temperature air.
Controller	Internal computer that stabilizes temperature, monitors belt speed, alarm conditions and other functions. See also Opto22.
Controlled Atmosphere	The atmosphere generated from the process gas, and gas flow patterns within the process section.
Cooling Section	The portion of the furnace that includes the transition tunnel, if any, exit baffle and any additional modules provided for the purpose of cooling the product.
Derivative	The calculated temperature rate of change; used in the PID equation.
Dilution Purge	The continuous process of adding clean gas while exhausting contaminated gas.
Dominant Wavelength	The wavelength of highest occurrence emitted by a radiating element at a specific temperature as described by Wein's Displacement Law.

Drip Trays

Trays positioned beneath stacks with attached baffle gates; used to catch condensation or residue produced by the process.

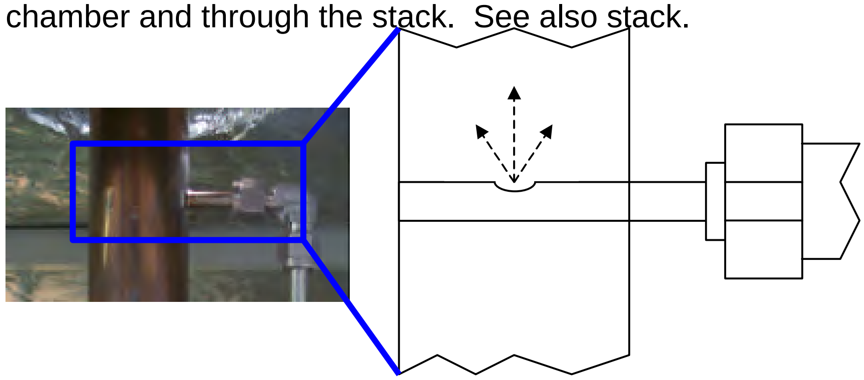


Edge Heater

Heaters along edge of chamber used to maintain uniform temperature across-the-belt in a designated part of the heating chamber.

Eductor

Metered gas exit used to draw exhaust gas out of the chamber and through the stack. See also stack.



Effluents

Contaminants expelled from a product during a thermal process. See also volatiles.

EMO

An Emergency off switch.

Glossary

Entrance Baffle — The section at the entrance of the furnace incorporating an air-regulator tube, hanging gates and an exhaust stack; used to establish a controlled atmosphere inside the process section.

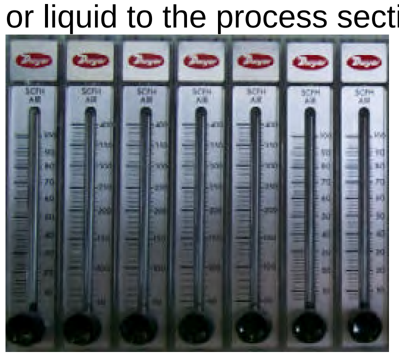
Ethernet Card — Network interface card. The PC communicates with the Opto22 controller through the use of Ethernet protocol.

Exhaust Gas — Spent process gas.

Error — Difference between actual temperature and setpoint.

Flash — The point at which organic vapors have reached the temperature and concentration necessary for spontaneous combustion.

Flow Meter — A manually adjustable gauge used to control the flow of gas or liquid to the process section.



Forming Gas — A type of process gas that consists of any mixture of H_2 and N_2 gasses.

Furnace Length — The length of the entire furnace. The sum of the process section and any loading and unloading stations.

Gain — Term in PID equation to calculate how far temperature is from setpoint.

H_2 — Hydrogen gas.

Heated Length See "Heating Chamber", next.

Heating Chamber Furnace area where heating takes place. Also referred to as the chamber, or heated length.

Heating Section The portion of the furnace including the entrance baffle and the heating chamber.

Hydrogen Detector Detect hydrogen escaping from furnace.

Integral Mathematical operation that is one term in the PID equation.

Interlocks Switches on some cabinet doors that stop furnace operation and removes power when doors are opened.

IR Electromagnetic wave. Wavelengths between 0.78 and 1000 μm in the electromagnetic spectrum.

Micron One millionth of a meter, $1.0 * 10^{-6}$ m, 1.0 μm

MMI Software development tool for creating user interface to Opto22 controller.

Module A section of the furnace designed for a specific function; may be 15, 30, 45 or 60 inches in length.

N_2 Nitrogen gas.

O_2 Oxygen gas.

Opto22 The brand of internal automatic controller used in RTC furnaces. See also controller.

Oxygen Analyzer Detects oxygen content at predetermined locations. Usually installed to read process gas source, and up to three locations in the heating chamber.

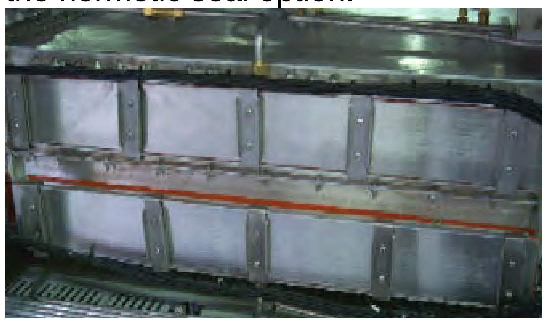
pcANYWHEREô Software allowing access to host computer by remote computer.

Phase Angle Firing Technique that activates AC power to be applied for only certain times during AC cycle.

PID Proportional+Integral+Derivative: Three-term closed loop control equation that adjusts power sent to heat lamps. See also Gain, Integral and Derivative.

Plenum
Cutout area of chamber insulation where process gas is injected.

Plenum Box
Pressurized region, enclosing ends of heat lamps, part of the hermetic seal option.



PPM
Parts per million. Useful ratio for measuring small amounts of one gas in an area dominated by another.

Process Gas
The gas used in creating a controlled atmosphere. Some examples are CDA, N_2, H_2, forming gas or other N_2/H_2 mixtures.

Process Environment
The description of the area inside the furnace at any time including the temperature, flow patterns, and the presence or absence of product, process gas, process effluents, or contaminants.

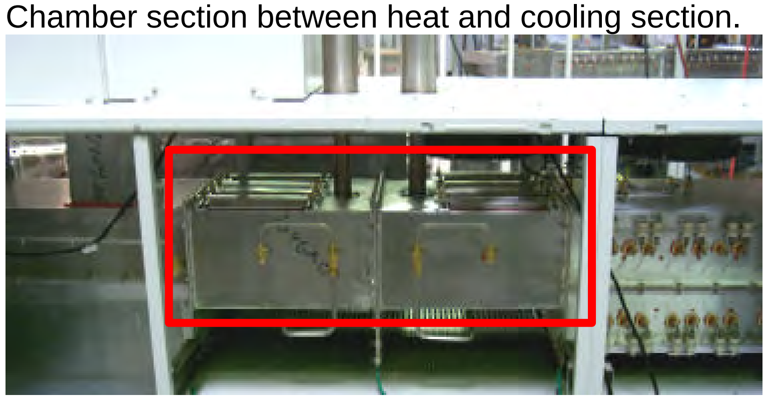
Process Section
The physical area inside the furnace from the entrance bezzel to the exit bezzel. The sum of the heating section and cooling section.

Profile
See Temperature Profile.

Proportional Band
The temperature range used in the PID equation in applying a portion of the available power to the heat lamps based on the deviation of the actual temperature from the setpoint.

Recipe
Instructions, including temperatures and belt speed that the furnace follows.

Resonant Frequency
The frequency at which the atomic structure of a material is easily excited into physical vibration resulting in excellent heat transfer characteristics.

SCFH	Standard Cubic Foot per Hour. Measurement for gas flow volume.
SCR	Silicon Controlled Rectifier. The electronic device used to regulate power to the heat lamps through signals sent by the Opto22 controller.
Setpoint	The target temperature for a zone.
Sparger Tubes	Highly porous, sintered metal tube charged with process gas; typically used in controlled atmosphere cooling modules.
Stack	Exhaust stack containing eductor. See also eductor. 
Temperature Profile	Temperature recorded over a period of time.
Thermal Process	The idealized process description for a particular product as it passes through the process section, including the product temperature profile and process environment.
Thermal Process Profile	Empirical record of the thermal process
Thermocouple	An electronic device that measures temperature.
Transition Tunnel	Chamber section between heat and cooling section. 

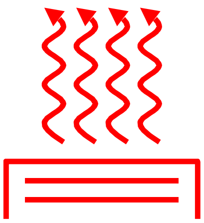
Glossary

Volatiles	Hydrocarbon based product effluents.
With-the-belt	In reference to the area of the conveyor belt that extends through the process section.
Zone	Area within the chamber where temperature can be independently controlled.

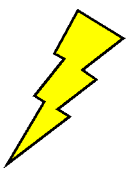
Chapter 2

Safety

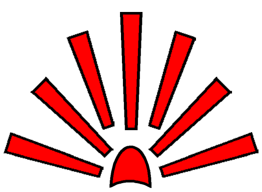
2.1 General Precautions



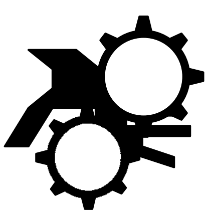
In general, the operation of any RTC Furnace may expose operators or maintenance technicians to the risk of burns. Customer product, following processing in an RTC furnace may still be dangerous to handle. Each RTC customer is responsible for providing a safe work environment and proper training in the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



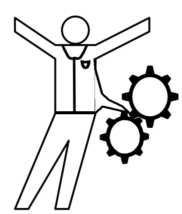
Electrical shock hazards exist for those technicians who service the furnace. High voltages are required to operate the furnace and precautions must be taken to reduce the exposure to these elements. Again, it is the responsibility of the customer to assure that only properly trained service technicians,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



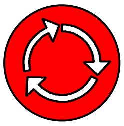
Explosive dangers may exist in the high temperature process environment of the furnace. If the furnace operates with process gas containing hydrogen, measures must be taken to avoid the dangers of explosion. Furthermore, improper gas flow balance may draw oxygen rich air into the furnace, mixing with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



Roller dangers exist when working around the conveyor belt of the furnace. Care should be taken not to place hands 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 and those who must should wear close fitting clothing.



2.2 EMOS



Every RTC Furnace is fitted with at least two Emergency Off Switches (EMOs) Locate and insure proper function prior to regular furnace operation.

Each Emergency-Shut-Off-Switch (**EMOS**) is attached directly to a switch that will automatically shut down all electrical systems inside the furnace. In many cases, non-combustible gas flow will remain on after power is shut off. The following are special notes describing events associated with various furnace options.

2.2.1 UPS (Option ❒)

An uninterruptable power supply may be added as an option to the furnace. In the event that the EMOS is tripped, the computer and conveyor belt will remain on with this option installed. The possibility of data loss is reduced. The interface PC is also less likely to experience failure under this condition. See the UPS (Option ❒) description in Section 3.4.16, p.24.

2.2.2 H_2 Controlled Atmosphere (Option ❒)

Many events occur when an EMOS is tripped in a H_2 process gas environment. The solenoid valve allowing H2 gas to enter the chamber is closed with the loss of power. The solenoid valve holding back the N2 gas supplied for rapid purge is released with the loss of power. These two events ensure that no additional H2 gas is allowed into the furnace and that the remaining H2 is diluted and removed as quickly as possible.

2.3 Panel Interlock Switches

Removable interlock switches are installed to prevent the operation of the furnace with high voltage panel covers out of place.

Customers may override this switch to allow furnace operation with the panels removed. Simply grasp the protruding switch and pull it out (See Figure 2-1 below (R)). This will activate the override switch setting.

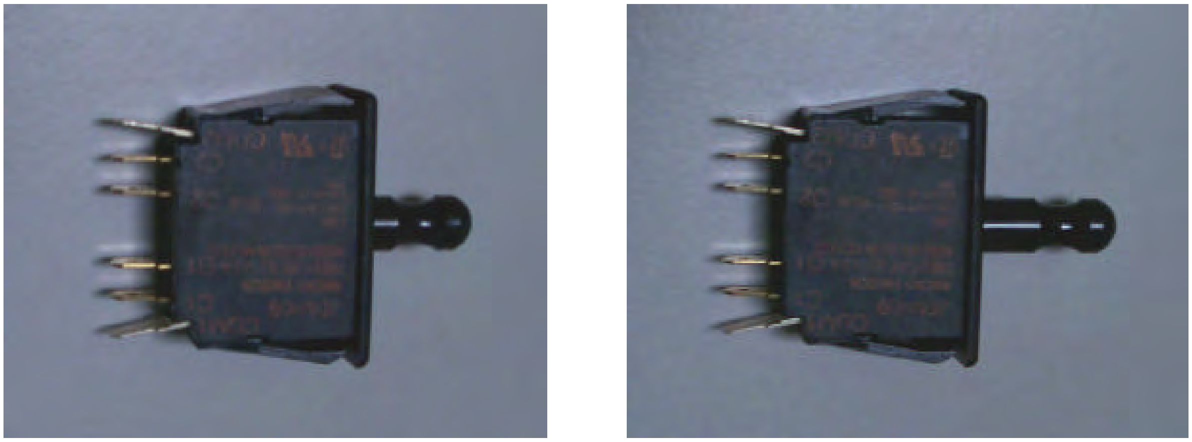


Figure 2-1: Panel Switches Showing Normal Operation (L) Override (R)

Setting the panel switches in override mode is useful when performing a SCR calibration.

Figure 2-2: Panel Switch Installed (Override Mode)

DANGER: The activation of panel switches in the override mode, increases maintenance personnel exposure to electrical hazards. The user must ensure that any panel switches that are placed in override mode are returned to normal operation following any inspection or adjustment.

2.4 H_2 Operation Overview (Option ❒)

The addition of H_2 to the heating chamber requires several safety considerations.

Special warm up and cool down procedures must be followed.

Gas flow balance is critical to the safety of all personnel working near an RTC Furnace operating with H_2 as a process gas. Escaping hydrogen gas, or the admission of oxygenated gas into the process section is extremely hazardous.

Furnace installation ensuring proper ventilation and safe source gasses is the responsibility of the customer.

Furnace Overview

3.1 Terminology

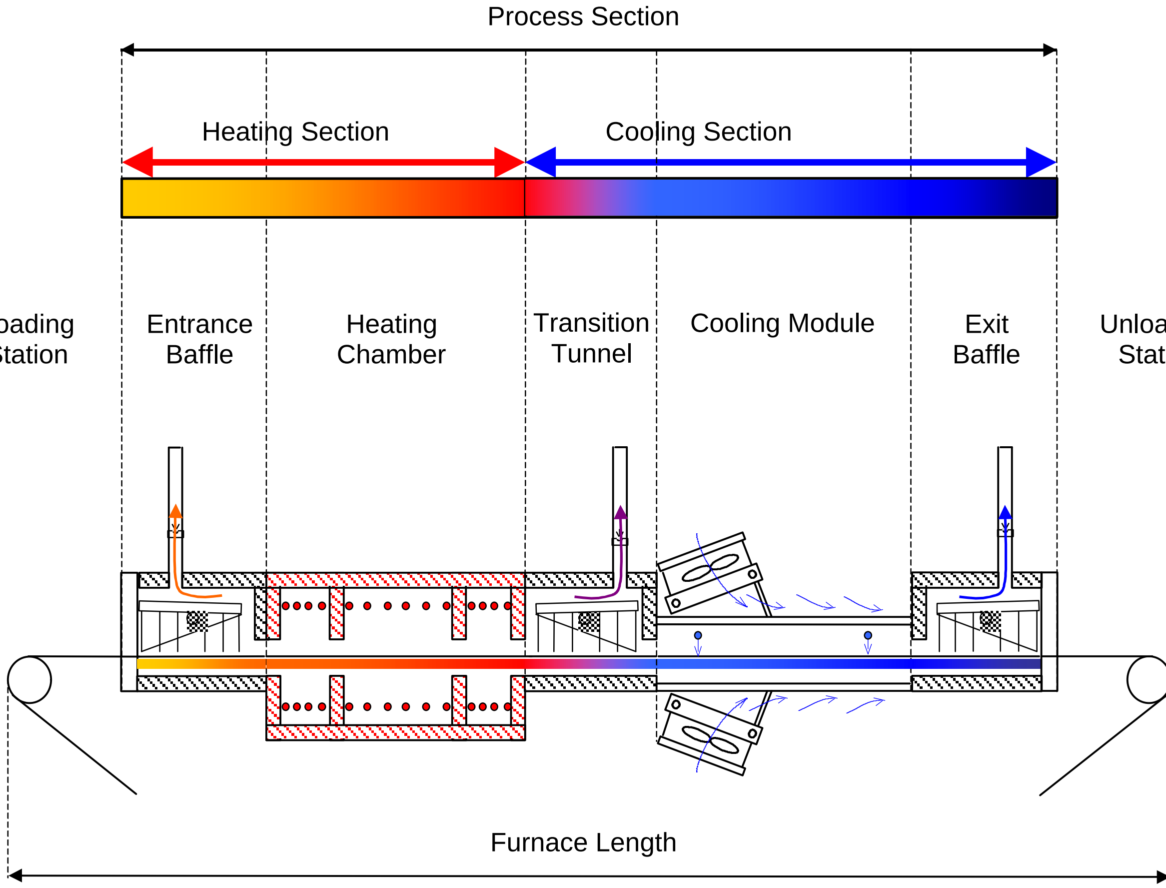


Figure 3-1: Furnace Descriptions

Below is a list of terms that should be reviewed in the glossary.

Cooling Section

Drip Trays

Eductor

Entrance Baffle

Flow Meter

Furnace Length

Gate

Heat lamps

Heated Length

Heating Chamber

Heating Section

Plenum

Plenum Box

Process Environment

Process Gas

Process Section

SCR

Stack

Thermocouple

Throat

Transition Tunnel

Zone

3.1.1 General Area Descriptions

Control Panel

The control panel is the central location of main power control, alarm speaker, ultrasonic cleaner/dryer power lights as well as any cooling fan power dials.

Figure 3-2: Control Panel

Safety Enclosure

The safety enclosure contains the system components that supply lamp and control panel power. Useable power for the computer is also provided here.

Figure 3-3: Safety Enclosure

Lower Electric Panel

The lower electric panel houses additional transformers to provide DC power throughout the furnace including any of the installed options such as an ultrasonic dryer or a light tower.

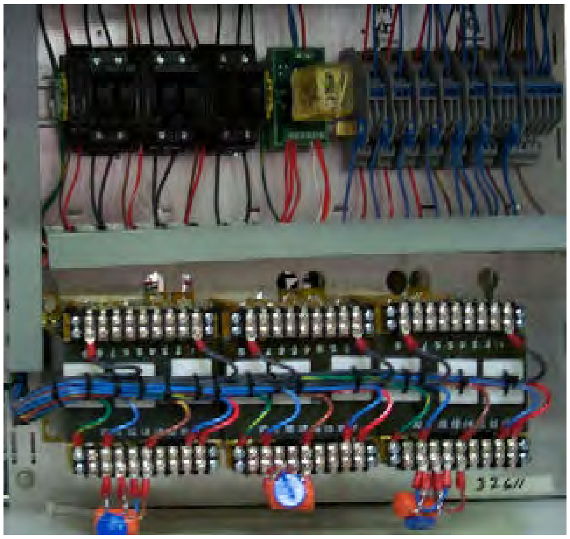


Figure 3-4: Lower Electrical Panel

Fuses and SCRs

This panel regulates the actual power applied to the heat lamps. The number of fuse relays and SCR control blocks is based upon customer processes and requirements.

Figure 3-5: Fuses and SCRs

3.1.2 Element Monitor

A panel containing the element monitor boards and controller interface hardware is typically installed on the front of the furnace next to the Opto22 controller. Depending upon the number of heat lamps installed, each will have a different number of monitor boards and control modules.

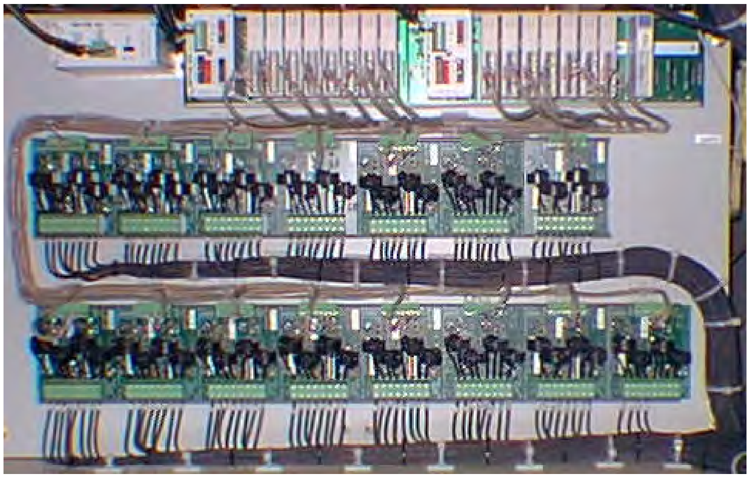


Figure 3-6: Element Monitor Installation

3.1.3 Motor

The motor assembly is typically mounted near the exit of the process section. Depending upon belt width, product mass, product number and belt speed, the motor-sprocket may appear different than the example shown below.

Figure 3-7: Conveyor Belt Motor

3.2 General Furnace Layout

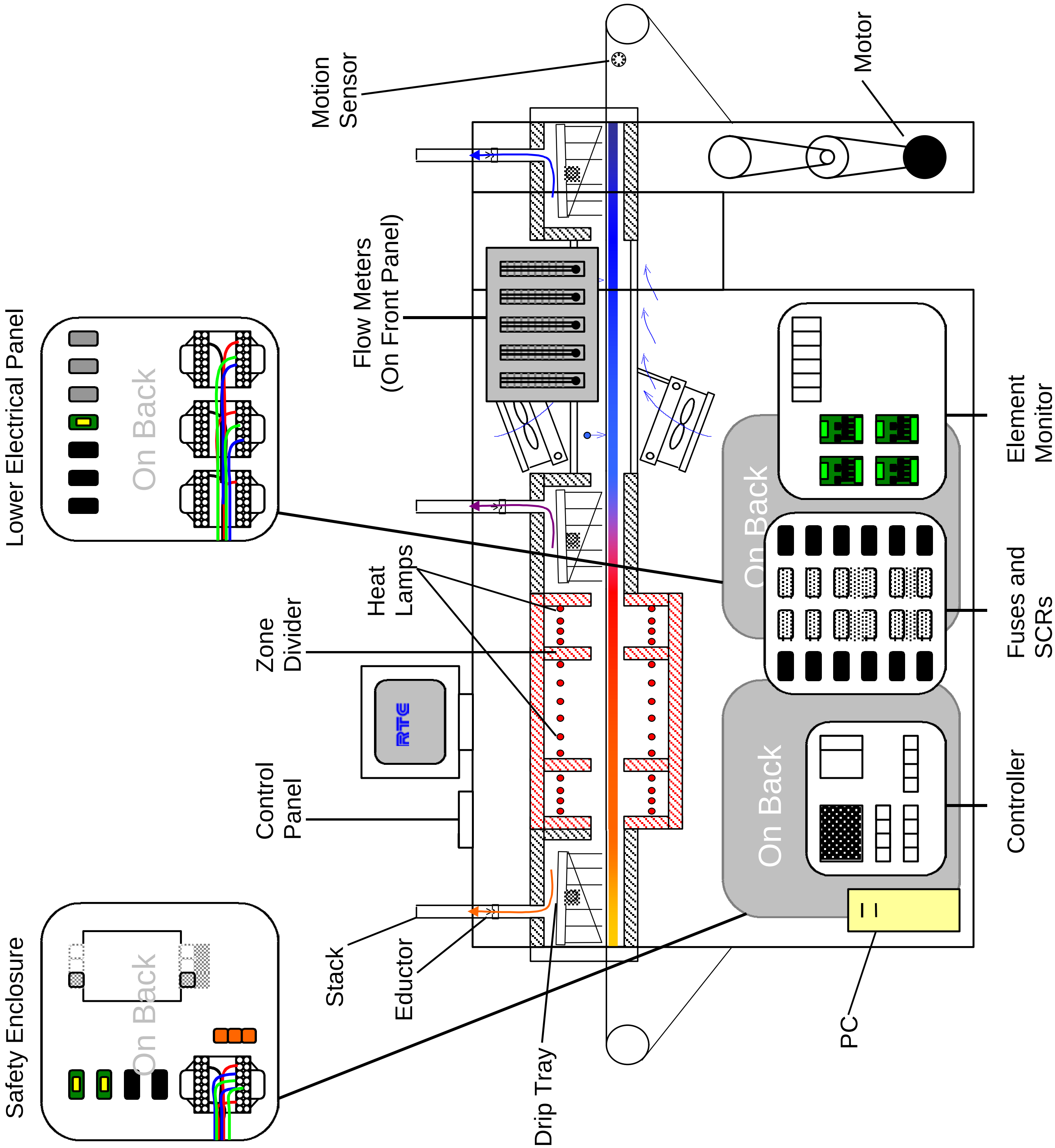


Figure 3-8: Furnace Layout

3.3 Thermal Process

3.3.1 Temperature Profile

A temperature profile represents a continuous measurement of temperature taken over a period of time. Figure 3-9 below shows an example temperature profile inside an RTC furnace.

*Notice that the green horizontal lines define the setpoint temperatures, yet the **thermocouple** (temperature recording devices) 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.*

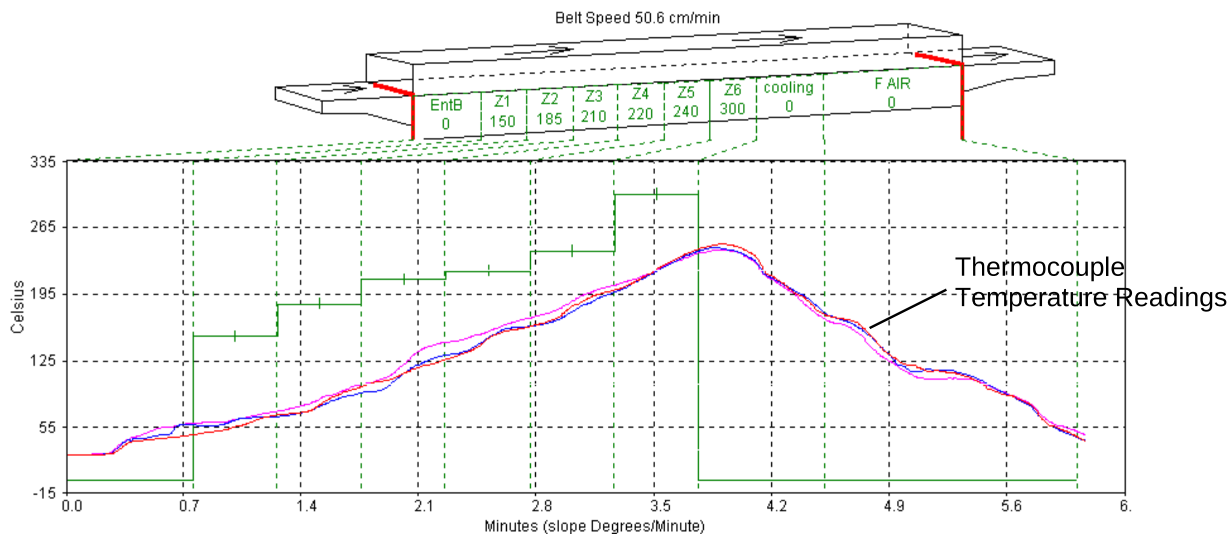


Figure 3-9: Temperature Profile Example

The temperature profile does not take into account the product material, mass or process gas. For example, a RTC 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 RTC Furnaces undergo an across-the-belt temperature profile test. In this test, three thermocouples are attached directly to the furnace conveyor belt at the center and each side. All furnace zones are programmed at the same setpoint temperature and allowed to reach steady state. The three thermocouple readings are expected to remain the same as they pass down the process section as well as be within a few degrees of one another. This test is just one of the quality assurance measures RTC takes to guarantee each furnace delivered to a customer.

3.3.2 Process Overview

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

Recipes

Once a specific thermal process has been established with correct zone setpoint temperatures, gas flow rates and conveyor belt speed, they can be stored in a recipe. The recipe is a set of instructions that is programmed into the controller to achieve the predetermined process. The recipe also defines alert and alarm conditions based on customer requirements to maintain product quality. RTC Furnaces are set up to easily change between recipe settings as well as provide a method of modifying and saving them.

Recipes and how they are handled is covered in more detail in Section 5.5.2 p.50.

3.3.3 Controlled Atmosphere (Option ❐)

Many RTC furnaces are equipped with the ability to supply constant streams of a supplied process gas. This feature allows the user to reduce product oxidation or contamination, remove process effluents or reduce other potentially negative effects of high temperature ambient air.

A controlled atmosphere also helps establish higher consistency in thermal processes. When a product travels through the process section, the slight changes in the atmospheric conditions in a non-controlled atmosphere environment will affect the stability and consistency of the product temperature profile.

This function will be discussed further in Section 4.5 p. 31 as well as a detailed approach in Chapter 9: Process Engineering.

3.4 Furnace Options Listing

3.4.1 Board Transfer Systems

SMEMA (Option ❒)

This option incorporates special protocol as outlined by the Surface Mount Equipment Manufacturers Association. The mechanical specifications outlined by this specification are consistent with standard RTC furnace equipment. Additional wiring for SMEMA electrical equipment interface standard is added to transmit signals to loading and unloading systems. Product sensors are required to perform this function.

Product Sensor (Option ❒)

An overhead sensor determines if a product is present. This sensor can be used in conjunction with the SMEMA standard option or with product tracking monitoring up to three lanes, as discussed in Section 5.7.4, p.57.

Figure 3-10: Photoelectric Product Sensor

Product Brackets (Option ❒)

Brackets are attached at a customer-specified distance to the conveyor belt in order to determine the spacing between products on the belt.

Edge Conveyor (Option ❐)

This option incorporates a raised chain that rolls along on top of the conveyor belt. Customer products or carrying trays are carried the length of the furnace.

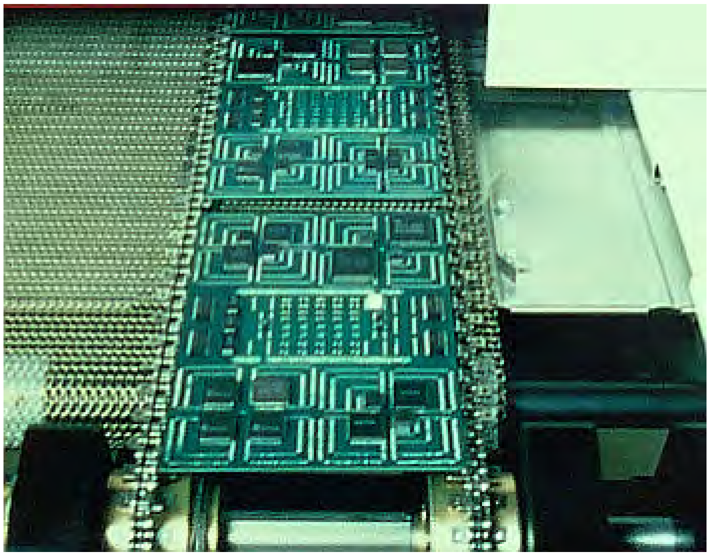


Figure 3-11: Edge Conveyor

Guide (Option ❐)

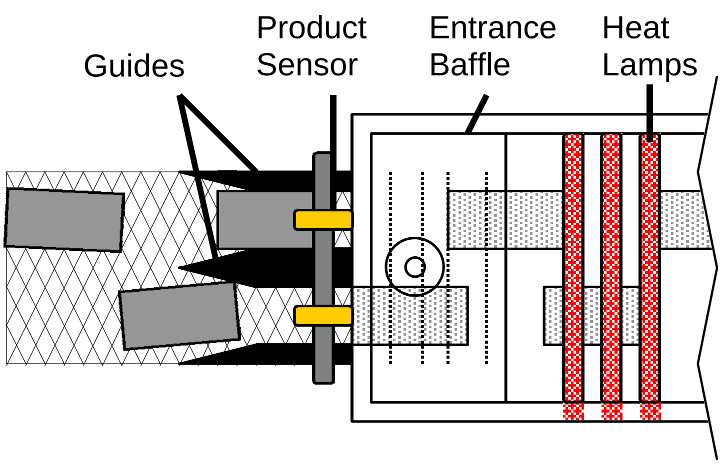


Figure 3-12: Product Guide for 2 Lanes

Guides can be installed to assist with product or boat alignment at the entrance of the process section. Guides are often used in conjunction with product sensors and the product tracking software to ensure proper lane use and control.

Edge Guides (Option ❒)

This internal protection system is used to protect the furnace walls and customer product from damage due to contact inside the process section. The guide is spring loaded to accommodate for thermal expansion inside the heating chamber.

3.4.2 Brush Belt Cleaning System (Option ❒)

This option adds a passive brush cleaner. The belt drive pulls the belt through several planar brushes to remove loose particles.

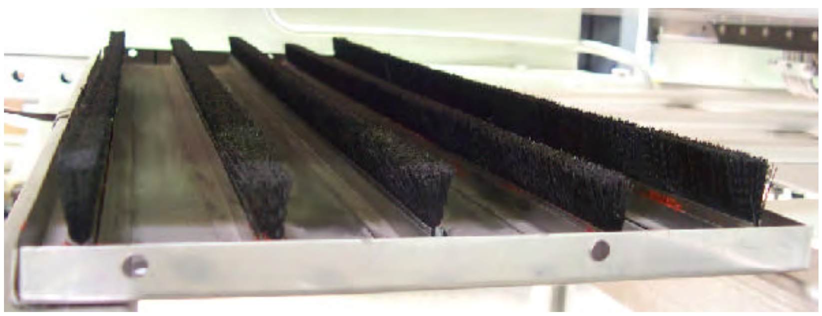


Figure 3-13: Brush Belt Cleaning System

3.4.3 Cabinet Temperature (Option ❒)

A secondary thermocouple is attached near the center of the heating chamber between the chamber and the outside panel. The sensor is attached to the Opto22 controller and software modifications allow the user to monitor the cabinet temperature, which can show possible cabinet fan failure, or blocked air inlets or exits.

3.4.4 Circuit Breaker (Option ❒)

Figure 3-14: Circuit Breaker Option

A special high-power circuit breaker is inserted in the supply power lines with access at the front of the furnace near the PC installation. Only the switch is visible from the front panel, with protective sheet metal guards surrounding it.

3.4.5 Dual Gas Input Selector, DGI (Option ❒)

This option allows the user to select between clean, dry air (CDA) or the required process gas with a special computer control and added solenoid valves.

- The default position for gas flow to the furnace is CDA. If power is removed from the furnace or if an EMOs switch is tripped, process gas-flow will stop and CDA will be supplied to the furnace chamber.
- The process-gas indicator light tower is supplied with this option. See section 3.4.12 below.

3.4.6 European Certification (Option ❒) CE

RTC follows a strict implementation of CE requirements as outlined in the following documents:

CE Compliance to Machinery Directive Annex 1, 89/392/EEC
Safety of Machinery - Electrical Equipment of Machines Part 1-EN60204-1

The following supplemental options are also added to achieve the standard:

Five Wire Electrical
Circuit Breaker
Line Filter

3.4.7 Five Wire Electrical (Option ❒)

Three phase power supply lines are implemented with a ground and added neutral wiring.

3.4.8 High Voltage Operation (Option ❒)

This option provides for operation on 380, 415, 440 or 480 V, 50/60 Hz. This requires a minimum 4 wire service, 3 phase with safety ground. Peak instantaneous power consumption required by the customer process will be met according to the specification. Lamp wiring will vary depending upon belt width and power available.

3.4.9 Lexan™ Shields (Option ❒)

Removable Lexan™ shields can be installed to provide additional protection to maintenance personnel against the electrical shock hazards associated with the high voltages used in RTC furnaces. This option is required to meet the Semi 52-98 standard.

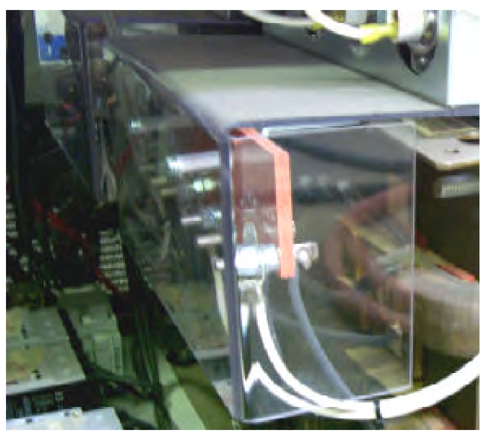


Figure 3-15: Lexan Shields Option

3.4.10 Line Filter (Option ❒)

An AC line filter reduces the electrical circuit noise by attenuating line voltage and limiting power fluctuations. This option is standard for European customers who request CE certification and is also required for use with electronic mass flow control valves.

3.4.11 Low / High Belt Speed (Option ❒)

Customer specified requirements for special conveyor belt speeds require changes to motor speed, power and gearing for this option.

3.4.12 Light Tower

Basic (Option ❒)

Figure 3-16: Standard Light Tower Option

The light tower is supplied to provide a visible indicator of the condition of the furnace.

Green Light – Process Ready

Amber Light – Furnace Warming Up
Furnace Cooling Down

Red Light – Furnace Alert or Alarm

No Light – Process Off

Process Gas Indicator (Option ❒)

A special light tower can be added to reflect N_2 gas operation.

White Light – CDA

Blue Light – N_2 gas

3.4.13 Quartz Standoffs (Option ❐)

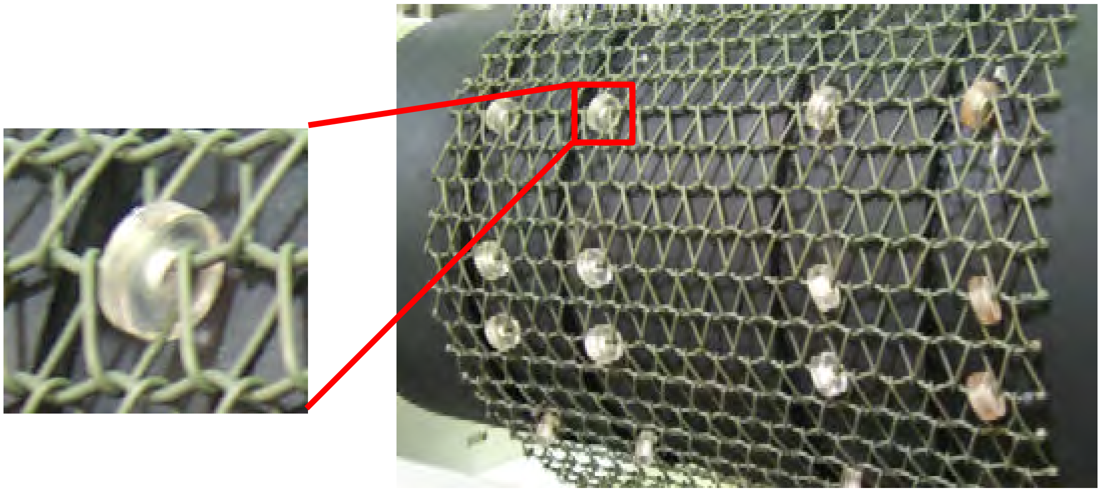


Figure 3-17: Conveyor Belt Shown with Quartz Rollers

The primary purpose of the quartz standoffs is to eliminate all contact between the customer product and the metal conveyor belt, as some substrates chemically react when in contact with metal at elevated temperatures. Additional polymer guides and rollers are added, and special, rubber coated entrance and exit drums are installed. This way, the outsides of the quartz standoffs do not contact any metal part while passing through the furnace, preventing indirect metal contamination. This option also increases belt life.

3.4.14 Thermocouple Wheel Assem. (Option ❐)

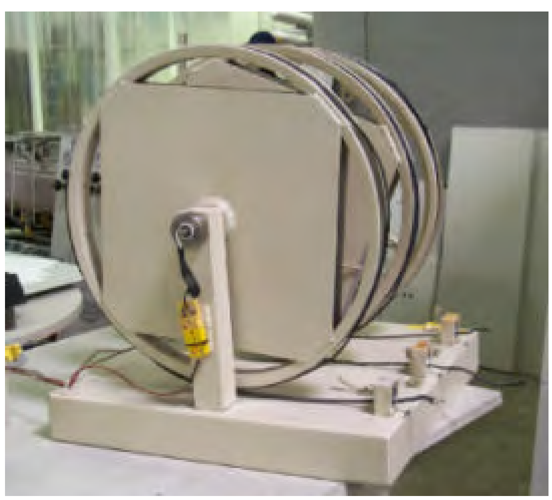


Figure 3-18: Thermocouple Wheel Assembly - 3 T/Cs

This option provides the customer with a quick and easy to use assembly of 1-3 thermocouples for use in performing temperature and thermal process profile tests. The wheel assembly can be setup at the furnace entrance and thermocouples can be drawn through the furnace automatically. Once tests are completed, the thermocouples and heated wire cables can be retrieved safely.

3.4.15 Ultrasonic Cleaner / Dryer (Option ❒)

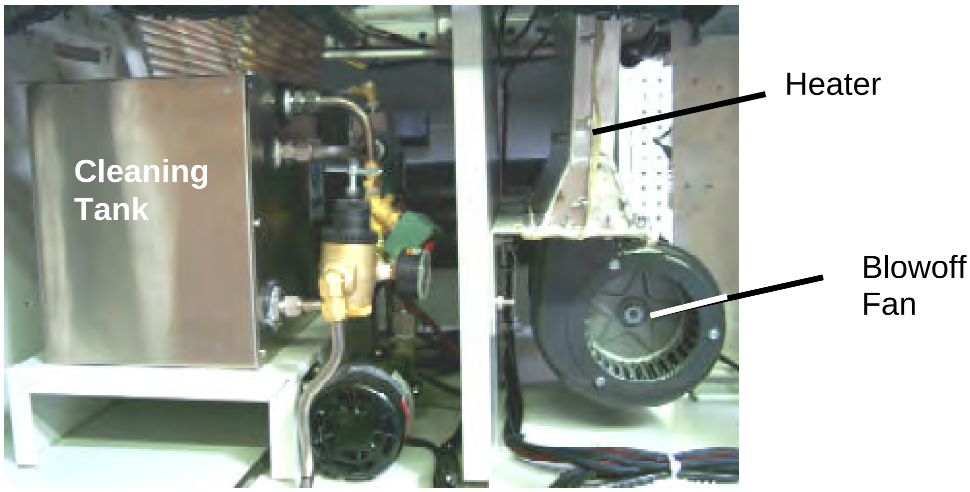


Figure 3-19: Ultrasonic Cleaner and Dryer installation (15 in., 38.1-cm)

This option adds an ultrasonic tank and timer system to provide automatic cleaning of the belt. The belt is drawn through an ultrasonic tank that is automatically filled by a timer and control circuitry for belts 10-in. (25.4-cm) and smaller. For belts above 10-in. (25.4-cm), indicator lights are added to the control panel. Facility is provided to connect the system to plant water and drains. An additional dryer system can be installed which includes a compressed air blowoff system (15, 24 and 36-inch, 38.1, 61.0 and 91.4-cm models only) and a heated belt dryer to remove all moisture from the belt following cleaning. This eliminates the introduction of moisture into the furnace at belt speeds of up to 30-in/min (76.2-cm/min.). (System requires special idler rollers for belt speeds over 30.0-in/min. (76.2-cm/min.), consult factory.)

3.4.16 UPS (Option ❒)

Figure 3-20: Uninterruptable Power Supply

This option adds an uninterruptable power supply, which keeps the belt, fans, and control system running for at least twenty minutes during a power outage. The transport belt continues to run at set speed which minimizes product loss during brief power failures. The unit automatically switches from standby to process start upon restoring power, whether provided by generator backup or city power. The control software includes modification to add automatic reset without using the normal power up and screen menu selection process, so that immediate restart is available after power interruption.

Chapter 4

Process Section Overview

4.1 Heating Concepts

4.1.1 Infrared Heating

IR heating, unlike **convection** heating, provides heat directly to objects without first heating the surrounding air. IR waves excite molecules within a substance-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 RTC furnaces occurs via IR radiation. Some heating does occur via **conduction** and convection. That is to say, heat is mainly generated by direct IR radiation and partly by contact with the heated conveyor belt and the surrounding heated gas.

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

1) The level of IR radiation emitted from the heat lamps.

2) The amount of IR absorbed by a product.

4.1.2 Ultraviolet (Option ❐)

The simultaneous placement of UV and infrared heating lamps inside the same furnace chamber is a new, patent pending, RTC technology that will work to temperatures as high as 1000ºC.

This highly complex system incorporates separate cooling and electrical systems. Depending upon installation specifications, the cooling jackets support either air or water cooling. The UV radiation is supplied by special mercury vapor lamps installed inside the cooling jackets.

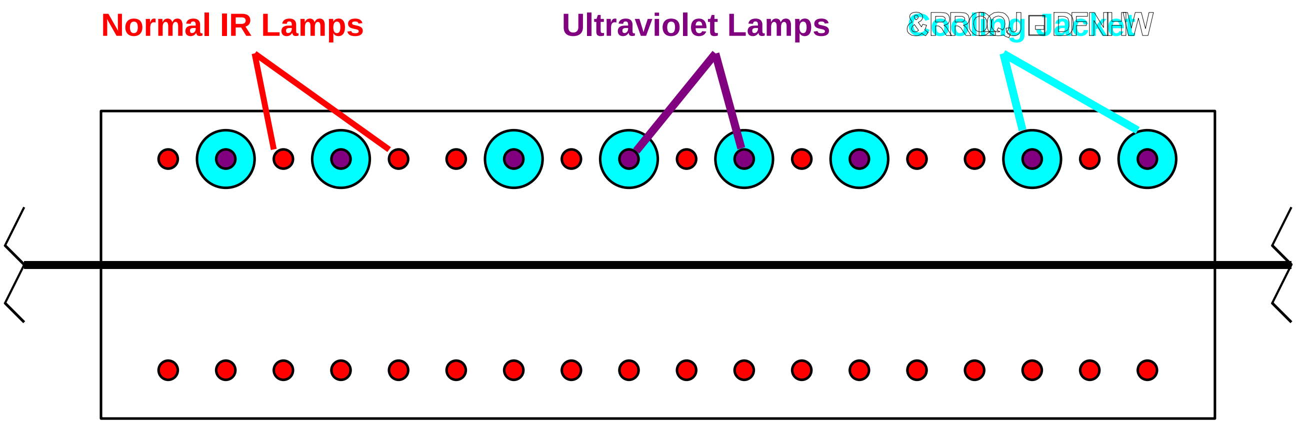


Figure 4-1: UV Heating Chamber Overview

4.1.3 Conduction Heating

In some applications, conduction heating is more desirable. RTC Furnaces can be configured to run in conduction operations where the standard IR heating lamps are placed below the conveyor belt only. A special high-density conveyor belt is cycled through the heating chamber to block the transmission of the IR radiation and absorb the transmitted energy. The energy output from the lamps is transferred directly to the conveyor belt itself. Any product in direct contact with the conveyor belt will absorb the stored heat energy via conduction. Two additional conveyor systems are used independently to avoid heat loss that would occur while the conveyor belt is in the cooling section and any baffle modules. This design also significantly reduces heating costs.

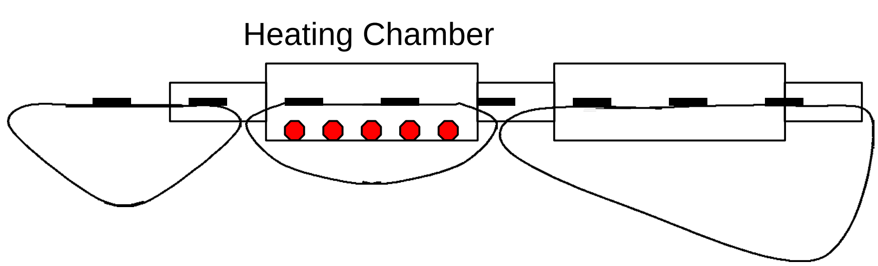


Figure 4-2: Conduction Oven Diagram

4.1.4 Convection Heating

This unique configuration is supplied to perform heat transfer through the indirect transmission of heated gas. In this type of furnace, the heating chamber temperature is maintained by heating the surrounding air. Convection is regularly used in surface mount reflow soldering when the components are different sizes. In this configuration, IR lamps are used to heat a metal chamber through which air is circulated. Currently RTC convection furnaces operate to temperatures as high as 450ºC.

4.2 Furnace Construction

The RTC heating chamber technology allows for rapid heat-up and cool-down times. Stable temperatures of up to 1000ºC can often be reached in less than 10 minutes. This allows for rapid startups and profile changes.

RTC heating chambers consist of an outer metallic shell fabricated from either aluminum or stainless steel depending upon operational temperature specifications. IR and conduction furnaces are lined with a refractory-ceramic-fiber (RCF) insulation. In these types of furnaces, controlled atmosphere sections allow process gas to pass through the RCF insulation.

4.2.1 Modules

Furnaces are constructed with basic modules, which make up the furnace length.

For example:

Figure 3-8: Furnace Layout on p.13 shows a RTC Furnace with 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 – Exit Baffle
Module 7 – Unloading Station

In some applications, longer cooling sections are required. RTC can add additional controlled atmosphere cooling modules or may add a forced air cooling module after the exit baffle.

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

Every RTC Furnace heating chamber is constructed with 30-in. (76-cm) modules. Depending upon customer requirements, RTC can manufacture any size furnace up to 16 zones. Each furnace is a custom design, laid out prior to the start of construction.

4.2.2 Throat

The throat of the furnace describes the maximum height allowable of any product through the process section. Depending upon configuration, throat clearance can range from 0.75 in. – 6 in. This 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 trough the furnace that exceed the throat will damage furnace zone separators and may reduce furnace performance.

4.3 Heating Chamber Design

4.3.1 Zones

All RTC heating chambers are divided into **zones**. Each 30” module can be divided into 1,2,3 or 4 zones. If the furnace requires more than 4 zones, additional heating chamber modules have to be added. The zone configuration of your furnace depends on the type of processes your furnace will be running and is part of the original furnace specification.

4.3.2 Infrared Heating Chamber

The insulation is 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 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.

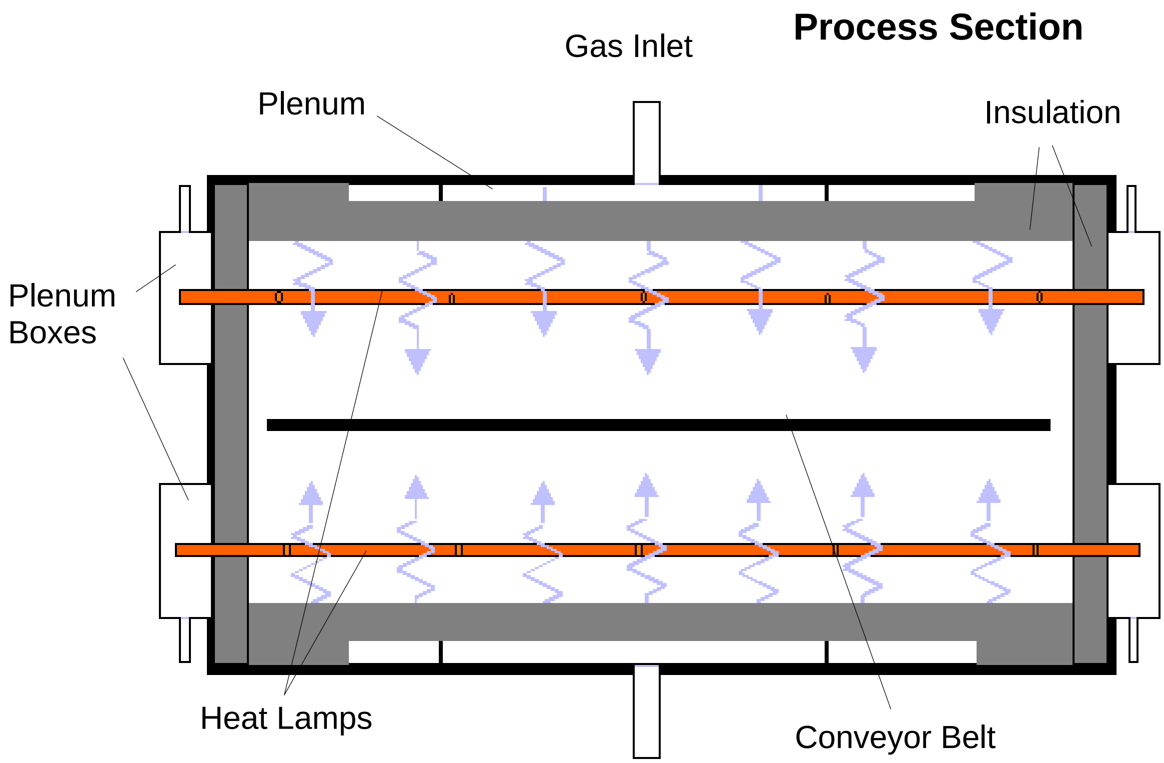


Figure 4-3: Heating Chamber Construction. End view

Plenum boxes may be added 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.
Since a high volume gas-flow is present from both top and bottom, effluents coming off the 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. This process, patented by RTC, contributes greatly to the cleanliness of the chamber.

Additionally, the usual large displacement area of the incoming process gas provides rapid purge times and low contamination levels. Typically, a process environment atmosphere of less than 10 parts oxygen in 1,000,000 nitrogen or 10 **PPM O_2** 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 Conduction Heating Chamber

A conduction heating chamber is designed the same as the IR heating chamber except that the heat lamps are only on the bottom. Furthermore, the chamber conveyor belt has a very high density to promote conductive heat transfer.

4.3.4 Convection Heating Chamber

A convection heating chamber is constructed very differently from the IR and conduction heating chambers. Heat lamp radiation is nearly isolated from the product and used to heat a gas chamber. Approximately 40% of the high temperature process gas is recirculated through the chamber to maintain the temperature profile while new process gas is introduced. By alternating the direction of gas introduction to the zones of the heating chamber, air is prevented from circulating inside the chamber and is drawn along the conveyor belt in a smooth flow.

4.4 Heating Lamps

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

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

4.4.1 Placement

Lamp configuration within each zone is determined at the time of purchase based on the type of processes specified by the customer to achieve optimal power consumption. 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.

4.4.2 Wiring

Heating lamps are wired differently for each furnace. The actual amount of power available to each lamp is based upon the wiring to the heat lamps 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. Refer to the wiring diagram for a specific customer furnace for exact heat lamp wiring details.

4.4.3 Ultraviolet Lamps (Option ❒)

UV lamps operate very differently from standard resistance IR lamps. To create the UV waves, high input current during startup vaporizes the liquid mercury into a gaseous state, which then emits the UV radiation. The UV lamps will be independently connected to a separate UV electrical system, which uses an inline capacitor during power-up. UV lamps are wired with special terminal blocks, which allow for operation at three fixed voltage levels. Furthermore, depending upon installation, air-cooled lamps have special thermocouple welds at the lamp ends.

4.5 Controlled Atmosphere (Option ❐)

A controlled atmosphere inside the furnace isolates the product from possible negative effects during chamber heating.

4.5.1 General Flow Control

By creating a balanced flow within the process section, ambient air is prohibited from entering the process section and any contaminants within the chamber are contained inside the furnace.

Note: For the operator, when changing recipes, flow meters must be adjusted according to what is outlined in the recipe.

4.5.2 Flow Rate Monitors

To control the level of gas flow inside the process section, different types of flow rate control devices are installed. Depending upon customer requirements, the number and type of flow monitors will vary.

Flow Meters

Figure 4-4: Flow Meters

These volumetric flow meters are installed with most controlled atmosphere furnaces. Manually configured, the flow meter rates need to be checked by the operator each time a recipe is changed as each thermal process may require a different replenishment time or flow rate. When customers use a RTC Furnace for one process only, flow meter settings can be left alone once the proper flow rates have been set.

Mass Flow Controller (Option ❒)

This option adopts an electronically controlled mass flow controller. Electronic mass flow controllers can be substituted for any gas flow meter in the furnace according to customer specifications. This feature is very useful in maintaining a highly consistent thermal process profile because the controller utilizes its own PID tuning which adjusts flow rate automatically to maintain consistent mass flow. Furthermore, since the monitor controls mass flow, temperature and pressure changes that affect normal flow rates are eliminated.

4.6 Cooling Section (Option ❒)

RTC Furnace cooling modules can be either **forced air** or **controlled atmosphere** types. The cooling rate is outlined by the process engineer to avoid thermal shock to the process product.

Forced-air cooling has the advantage of cooling product quickly and evenly. Air removes heat from all surfaces of a product thus ensuring even cooling. This is important where uneven cooling can cause thermal stresses and damage the product.

Controlled-Atmosphere cooling is employed when oxygen cannot be tolerated in the cooling chamber and is sometimes used when slower cooling rates are needed. Most heat is slowly removed by conduction through the conveyor belt.

4.6.1 Forced Air Cooling

Forced air cooling is used to bring large or high speed product to a low temperature very quickly. In all forced air cooling modules, powerful fans are utilized and are controlled by knobs typically located at the control panel. The following are some of the various forced air cooling modules.

Fan (Option ❒)

This module consists of several fans that force filtered ambient air over all surfaces of the product. It can be used to bring massive or high-speed product to handling temperature quickly.

Impeller (Option ❒)

This open air cooling module is either 30 or 45 inches (76 or 114 cm) long. An impeller driven assembly is located above the belt to force filtered ambient air in a downward laminar flow over the entire surface area of the cooling module. This laminar gas flow is then collected and exhausted from below the belt. A lower plenum and impeller powered exhaust duct are also provided. The top and bottom impeller style blowers are control-panel adjustable.

Impeller with Venturi Exhaust (Option ❒)

This open air cooling module is either 45 or 90 inches (114 or 228 cm) long. The first part of this cooling module consists of additional exhaust stacks followed by one or two impeller driven assemblies located above the belt. The filtered ambient air is forced in a downward laminar flow over the remaining surface area of the cooling module. This laminar air flow is then collected and exhausted from below the belt. The top impeller style blowers are control-panel adjustable, whereas the initial exhaust venturi gas flow rates are controlled by flow meters.

4.6.2 Controlled Atmosphere Cooling

Where controlled atmospheres are required, or where oxygen cannot be tolerated around the cooling product, controlled atmosphere cooling modules are necessary.

These cooling chambers can be either water-cooled or heavily finned and air-cooled. Water or airflow to the cooling chamber is regulated to optimize the chamber's cooling characteristics.

Water Cooled (Option ❒)

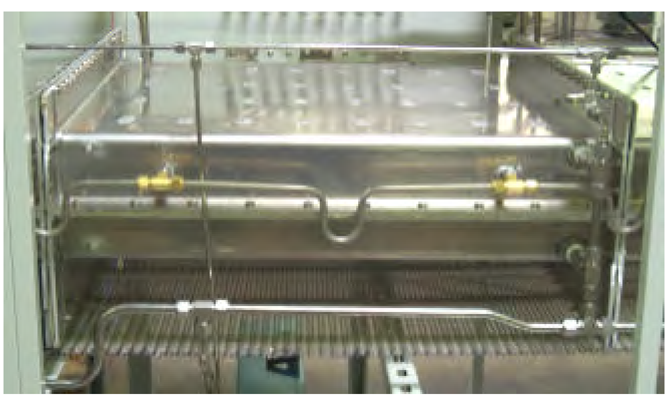


Figure 4-5: Water Cooled Controlled Atmospohere Cooling Module

Water cooling is used to ensure high rates of heat transfer while the product advances through the tunnel. The water cooled module is 30 inches long and has water jackets installed both top and bottom on the outside surfaces of the process section. To prevent condensation, water plumbing lines used to feed the jacket inside the furnace will be wrapped in insulation.

Customer supplied water must meet the following conditions:

Average Flow Rate:	4 gpm (for each 30-in module) or
	15.14 Lpm (for each 76-cm module)
Average Flow Pressure:	Set as specified
Maximum Inlet Temperature:	20°C (68°F) or lower
Water Quality:	Deionized

Warning: Using supply water different from the suggested parameters may reduce furnace performance characteristics and increase maintenance requirements or require the replacement of system components.

Water flow is controlled via flow meters next to the cooling chamber. The adjustable water regulator valve, in the base enclosure, should be set for the PSI specified in the RTC installation diagram.

Air Cooled (Option ❐)

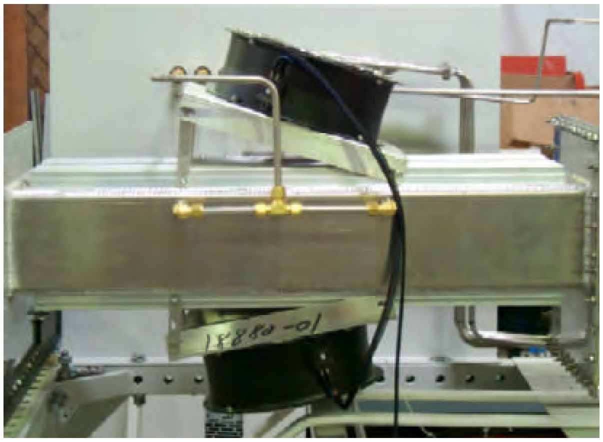


Figure 4-6: Controlled Atmosphere Air Cooled Module

Heavily finned aluminum heat sinks are attached to the outside of the cooling module. Adjustable rate fans direct air past the heat sink to remove heat transfer from the chamber.

Convection Cooling

This cooling module adds specialized high-volume air knives inside the controlled atmosphere process section. The module is constructed out of extruded aluminum heat sink material on both the inside and outside of the top and bottom of the module to assists in rapid heat transfer. Additional cooling fans are mounted on the outside of the cooling module to help remove heat from the module.

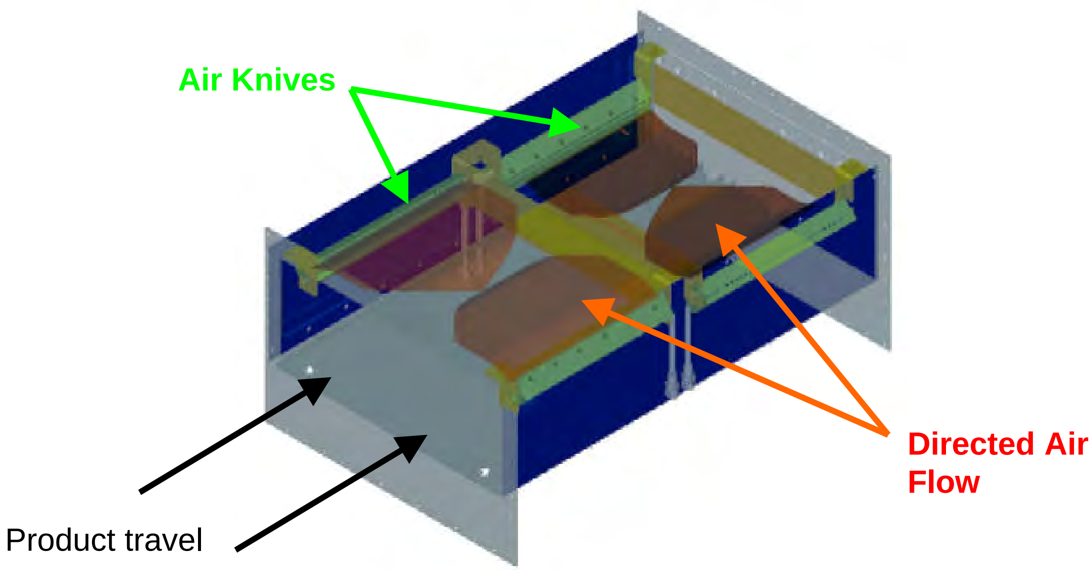


Figure 4-7: Internal View of the Controlled Atmosphere Cooling Convection Cooling Module

Controlled Cooling (Option ❒)

This type of cooling module looks like a heating chamber. These modules are added in high temperature operations where rapid heat loss could damage the product. Special software controls are used to adjust the power level in each module. Depending upon customer requirements, air rakes can be installed to assist in cooling the product. This allows the product to cool slowly to a lower temperature where additional forced-air cooling modules are typically used.

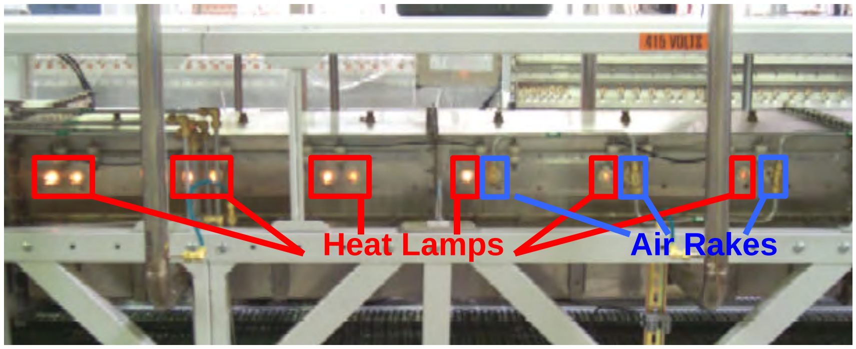


Figure 4-8: Dual Controlled Cooling Modules

4.6.3 Rapid Cool Transition Tunnel Module (Option ❐)

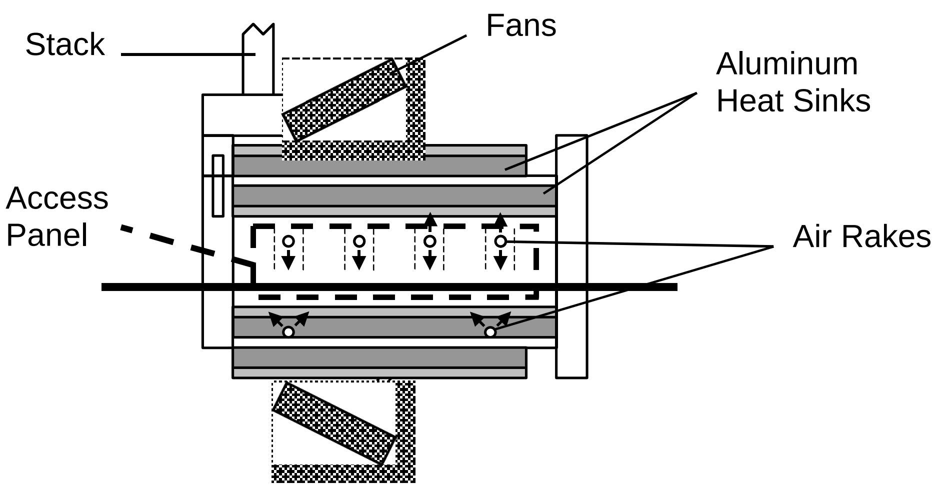


Figure 4-9: Rapid Transition Cooling Module

The 15-in. (38.1-cm) module is constructed of extruded aluminum heat sink material. Special air rakes, exhaust curtain and removable side access panel are added to this option. The exhaust curtain is placed close to the exit of the heating chamber and the module is uninsulated to isolate the chamber and promote rapid heat loss. The hanging baffle gates and air rakes effectively isolate the high temperature furnace section from the controlled atmosphere cooling section. General installation specifications are:

- Baffle gates will have 0.50-in. (1.27-cm) clearance from the mesh belt.
- Two rows of air rakes are installed, designed to cool the product rapidly and evenly.
- This feature limits the furnace operating temperature to 650^{o}C.
- (Optional ❐ external water cooling coils are available.)

4.7 Heating Chamber Options Listing

4.7.1 Air Filter (Option ❒)

Figure 4-10: Pre-filter/Regulator Shown

This option provides a filter, regulator and trap to clean and control incoming process air. The pre-filter/regulator unit includes a 0.5-micron impregnated fiber filtering element, manual drain, pressure gauge and regulator. The after filter is a 0.5-micron coalescing filter for water/oil removal with automatic drain. This combination unit reduces downstream oil contamination to .5 PPM/wt maximum.

4.7.2 Air Purification System (Option ❒)

This option provides an air dryer and filtering system, which removes moisture, oil and particulate contamination from air or nitrogen. The system alternates between two large (approximately 6-ft. / 1.83-m) storage tanks, constantly replenishing the gas in one while dispensing gas from the other. When pressure drops in the supply tank, each tank switches to the opposite supply or replenishing mode respectively.

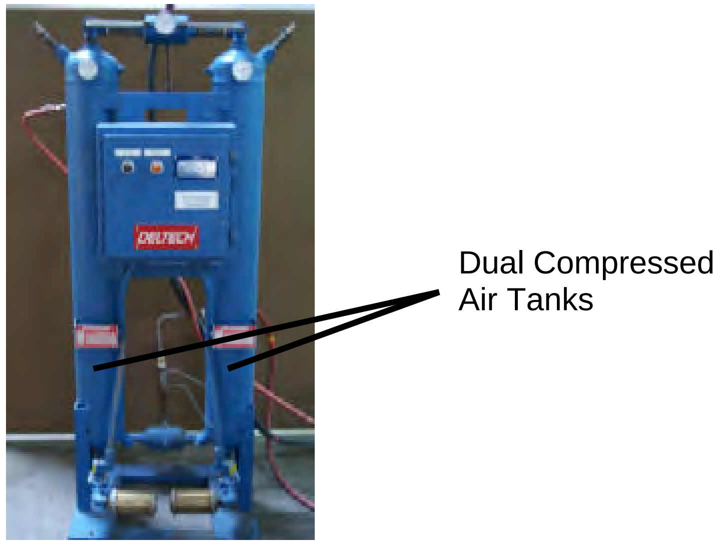


Figure 4-11: Air Purification Tanks

Performance:

- Particulate - Removes particles > 1 µm
- Oil - Reduces oil and hydrocarbons to a level below 1 PPM
- Water Removal -
  - Standard: will dry 35 SCFM to a dewpoint of -73 °C (-100°F)
  - High Capacity: will dry 56 SCFM to a dewpoint of -73°C (-100°F)

NOTE: Using flow rates higher than specified will reduce performance.

4.7.3 Edge Heat

Edge heat may be added to a furnace to provide uniform high temperature across-the-belt inside a heating chamber. Carefully tuned nichrome resistance wires are passed through added quartz tubes inside the heating section to increase the temperature at the edge of the conveyor belt. This option is critical for wide conveyor belt operations, but can be added to any furnace.

Figure 4-12: Edge Heaters

4.7.4 Element Monitor (Option ❒)

A special network is used to monitor each series of heat lamps. Return power from the lamps are passed through an inductive circuit which transmits a signal when current is lost. The signal is then relayed to the Opto22 controller which signals an alert. Lamp failure does not always shut-down the process. Until the zone temperature falls outside the alarm conditions set in the recipe, the furnace will continue to operate.

The Element Monitor Window is a part of the added software, which provides active element status. The software interface is not available to the operator, but is described in more detail in Section 7.1.3 on p.74.

Note: The Element Monitor circuit does not function at power levels of less than 10%, the threshold of the sensor circuit. Element legs operating in this range are reported as OK.

4.7.5 Hermetic Seal (Option ❒)

The hermetic seal option provides a positive pressure gas flow to the outside of the ends of the lamps on the furnace. This ensures that no process gas collects around the lamps or inside the process section. The box created around the end of the lamps is referred to as a plenum box. An added benefit to this option is the protection of the ends of the lamps from overheating. By allowing process gas to flow around the ends of the heat lamps, heat is carried away from each lamp.

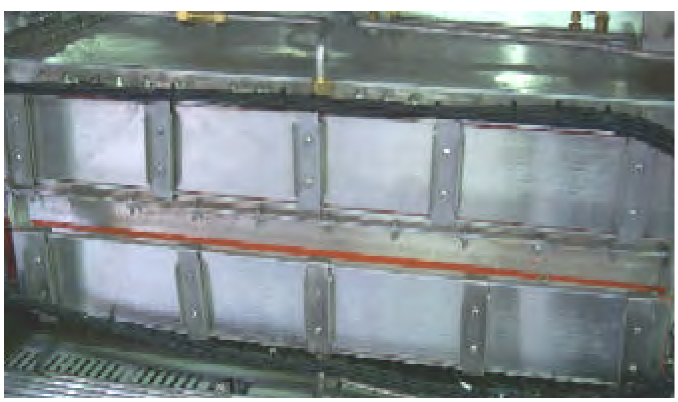


Figure 4-13: Plenum Box

4.7.6 Independent Top/Bottom Temp. Control (Option ❒)

Typically, zone temperature is set by adjusting power to all lamps in that zone. This option allows for independent control of the top and bottom elements of a particular zone.

4.7.7 Over Temp. Monitor (Option ❒)

This option provides an independent zone temperature watchdog to monitor each zone and respond to set boundary conditions. A secondary thermocouple is installed in each zone for monitoring and control. The redundancy in the sensors is designed automatically shut down the heat lamps in the event of multiple component failures. The temperature shut down system allows the process engineer to select the maximum/minimum temperature and will shut down the heating elements if the temperature is exceeded. The system factory default is set as an overtemperature alarm for 50°C above the maximum rated temperature of the furnace.

4.7.8 Oxygen Analyzer (Option ❒)

Oxygen analyzers are regularly installed in controlled atmosphere furnaces to assist in monitoring O_2 levels at various points of the RTC Furnace. Four sensors are installed including one to monitor the incoming source gas as well as three specified zones. O_2 levels are reported in PPM on the Process Screen.

Figure 4-14: Oxygen Analyzer

Software Control

To select the sampling port,

From the Process Screen, click on the <u>O2 / MA Sampling</u> button

From the Recipe Screen, click on the <u>O2 Sampling Port</u> button

The following window will appear.

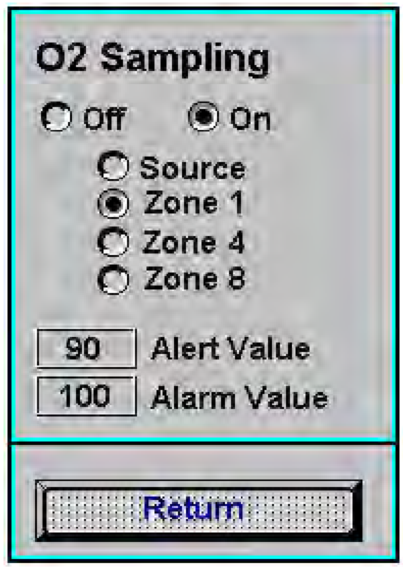


Figure 4-15 Oxygen Analyzer

Click the appropriate selector button to see the oxygen content at various positions within the furnace chamber. If the selector button for the Source is selected, the analyzer will sample the incoming gas.

Note: When switching between sampling ports, several seconds must pass to clear the sampling line and establish an accurate reading. Furthermore, upon system startup, the oxygen analyzer lines must be purged of residual air that is in the system prior to gas hook-up. Initial readings may take as long as a minute but will not occur again unless the oxygen supply is disconnected.

4.7.9 Moisture Analyzer (Option ❒)

Figure 4-16: Moisture Analyzer

The moisture analyzer provides accurate moisture readings at four locations in the supplied process gas. Typically, a source and three heating chamber process gas supply lines are sampled.

Process Section Overview

Note: Moisture analyzer saturation can cause false readings until the sensor is dried out. The drying process may take as long as 45 minutes. Avoid allowing high levels of moisture into the process air supply lines.

Chapter 5
Software Overview

5.1 Windows Interface

Process parameters are entered on a PC using the Microsoft Windows environment. If the operator is not familiar with basic Windows techniques, run a Windows training tutorial before trying to run a process.

The ALT+TAB key combination is useful for cycling through loaded application windows. The RTC Furnace software application screen cannot be minimized or maximized so this shortcut is particularly useful for switching away from or to the furnace software screen.

The following figure shows the Windows start bar with the furnace software running. The quick start buttons on the left will launch the software with one click of the mouse. WINKIC will only appear if the furnace is equipped with profiling software.

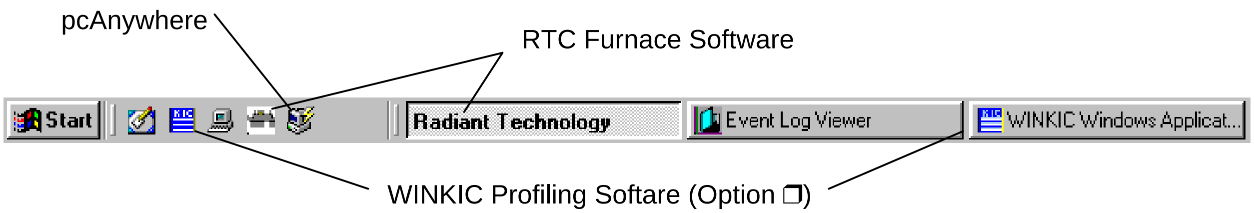
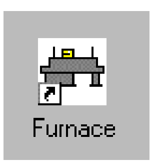


Figure 5-1: RTC Furnace Windows Start Bar

The following icons should also appear on the desktop.



5.2 Startup

When the RTC furnace boots up, the furnace software will automatically start. If the user does not want the furnace software to boot automatically, remove the file from the start menu. (See Windows help topic “Starting Programs at startup”)

When the furnace software boots up, the following screen will appear.

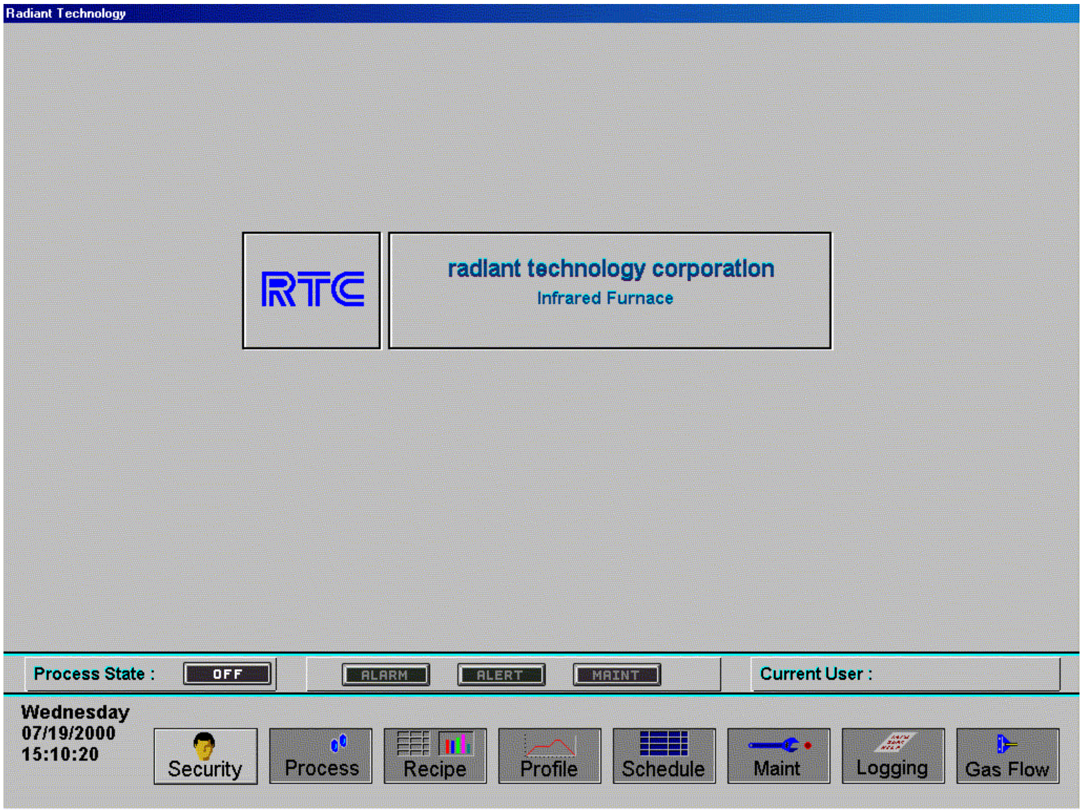


Figure 5-2: RTC Furnace Software Startup Screen

5.3 Log-On

Before you can begin furnace operation, the user must log-on.

Move to the securit screen by clicking on the Security button at the bottom of the screen.

The security screen will appear as seen below in Figure 5-3.

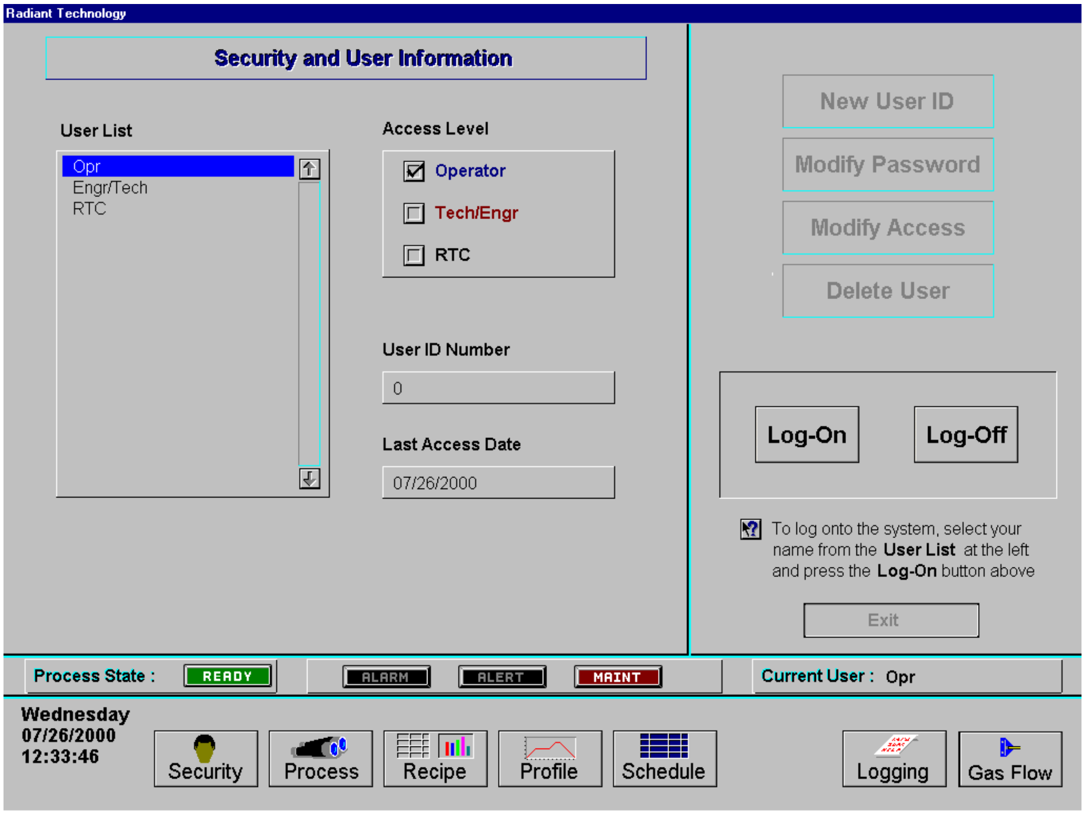


Figure 5-3 Security Screen Showing Password Pop-up Screen

In the large area to the left, a list of user names will appear under the heading "User List". When selected, a check-box will automatically be highlighted under the "Access Level" heading. This check-box indicates the level of access permitted to that user.

Access level control prohibits operator level access users from adjusting process recipes or making other changes to important furnace operations.

To log on, simply highlight the user name and click the Log-On button

The "Enter Password" pop-up window will appear.

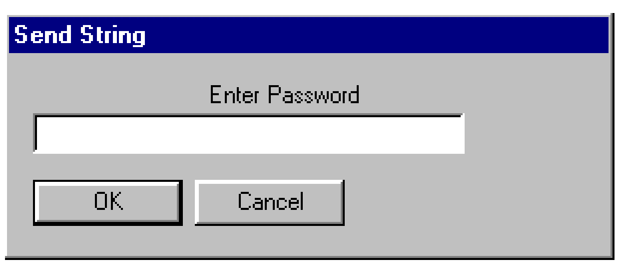


Figure 5-4: Enter Password Pop-up Window

Type in the correct User ID password to complete the login process.

5.3.1 Furnace Software Default Passwords

When the furnace software is installed, the following default user names and passwords are entered.

User Name	Password	Access Level
OPERATOR	1	Operator
TECH/ENGR	2	Tech/Engr
RTC	****RTC Access Only****	

5.3.2 User ID Menu

The menu on the top right of the screen will appear shaded until a user with Tech/Engr level access is logged on. This menu allows those users to designate other user names for login and recording purposes.

If several operators run processes at the customer facility, it might be convenient to add different names to the user list. The logging screen will track user ID's and list the time of sign-on and sign-off. New user ID's can be added by selecting the New User ID button.

The following pop-up window will appear

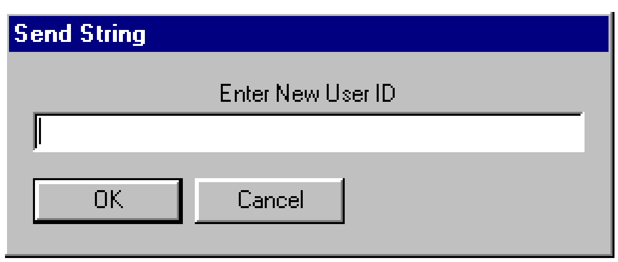


Figure 5-5: New User ID Pop-up Window

Enter the User ID label and click the OK button.

The following pop-up window will appear

Figure 5-6: New User Password Pop-up Window

Enter the new user password

The following pop-up window will appear

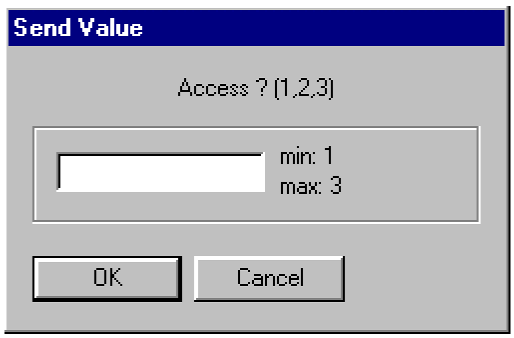


Figure 5-7: New User Security Access Level Assignment Window

Enter the level of access the new User ID will possess according to the following table.

Number	Access Level
1	Operator
2	Tech/Engr
3	RTC

Only an authorized RTC Service Engineer can add a level 3 access.

The names appearing under the “User List” heading will reflect the added user ID.

5.4 Available Screens / Functions

5.4.1 Operator Level Access

The following list of screens is allowed with Operator level access with various restrictions listed below:

Screen Name	Restrictions
Security	No user list additions allowed
Process	No changes allowed
Recipe	Loading Only
Profile	All Functions
Logging	Viewing Only
Gas Flow	Read Only

5.4.2 Tech/Engr Level Access

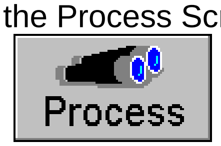
All functions are available with Tech/Engr level security access. This level of access allows the user to make several modifications to the operation of the furnace and other maintenance tasks. Furthermore, the user can add user names to the “Security” screen.

The maintenance screen button does not appear when signed on with Operator level access. The Maintenance screen and the associated features of the will be covered later in **Error! Reference source not found.**.

Process engineering features including detailed process control and recipe development will be covered in Chapter 9.

5.5 Operator Level Interface

5.5.1 Process Screen

Access the Process Screen by clicking the Process button at the bottom of the screen. 

Depending upon furnace configuration, the process screen will appear like that pictured in Figure 5-8 shown below.

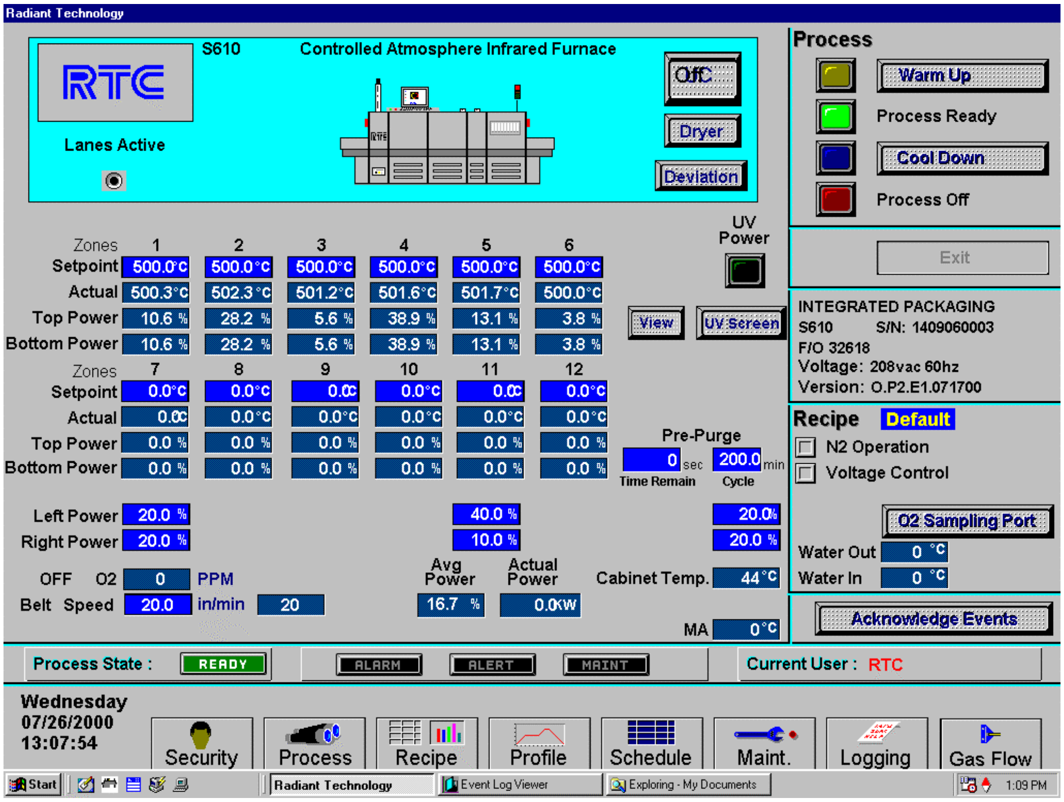


Figure 5-8: Process Screen

Operators will have the ability to start and stop the furnace operation, but will not be able to change the settings in the process screen.

On/Off Procedures

First make sure that the correct recipe is loaded into the furnace and that the setpoint values in the blue boxes for each zone are set correctly for the process to be run. Check the recipe name near the lower right hand corner as seen below. Please refer to “Recipe Loading” under Section 5.5.2 below if help is needed to load a recipe.

When starting furnace operations, click the Warm Up button in the “Process” box at the top right hand side of the Process Screen, as seen below.

The light to the left of the button should begin to blink yellow and the furnace should make an audible click. This is the power contact connecting inside the safety enclosure. The furnace will start to warm up as indicated in the "Process State" box in lower left hand corner.

The numbers shown below the setpoint temperature values will indicate the status of power and furnace temperature. Once the temperature has stabilized around the setpoint values, the "Process State" box and "Process window will light up as shown below.

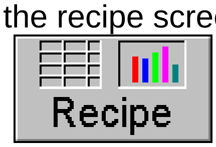
Hydrogen Operation (Option ❒)

If the furnace is equipped with H2 gas, a special pop-up screen will appear listing a set of required parameters for system warm up.

5.5.2 Recipe Screen

Recipe Overview

In order to start a thermal process, an operator must load the appropriate recipe. The recipe contains all the information for the correct operation of the furnace with a particular product. Once a recipe is loaded into the furnace, the computer is not critical to the operation of the furnace. The independent controller installed inside the furnace will follow the recipe instructions, start and continue the process. If a parameter outlined in the recipe creates an alarm condition, the furnace will automatically shut down. An alarm message is transmitted to the PC, but the furnace does not require the PC to respond for the condition response to take place.

Access the recipe screen by clicking the Recipe button at the bottom of the screen. 

Depending upon furnace configuration, the recipe screen will appear like that pictured in Figure 5-9 shown below.

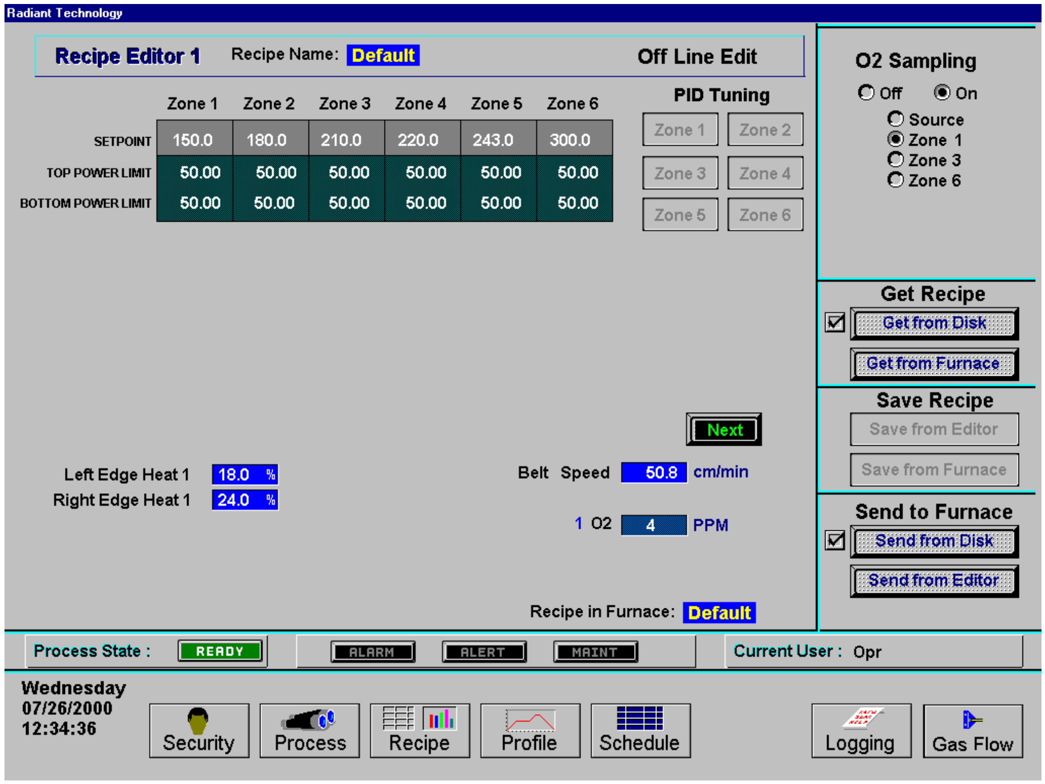


Figure 5-9: Recipe Screen (Operator Level Access)

As seen above, the “PID tuning” and “Save Recipe” screen area buttons are not available.

Also notice the bar across the top of the window where it shows the following.

Off Line Edit

Operators can only use the Recipe Screen in the “Off Line Edit” mode which does not allow the user to change the furnace temperature setpoints.

Recipe Loading

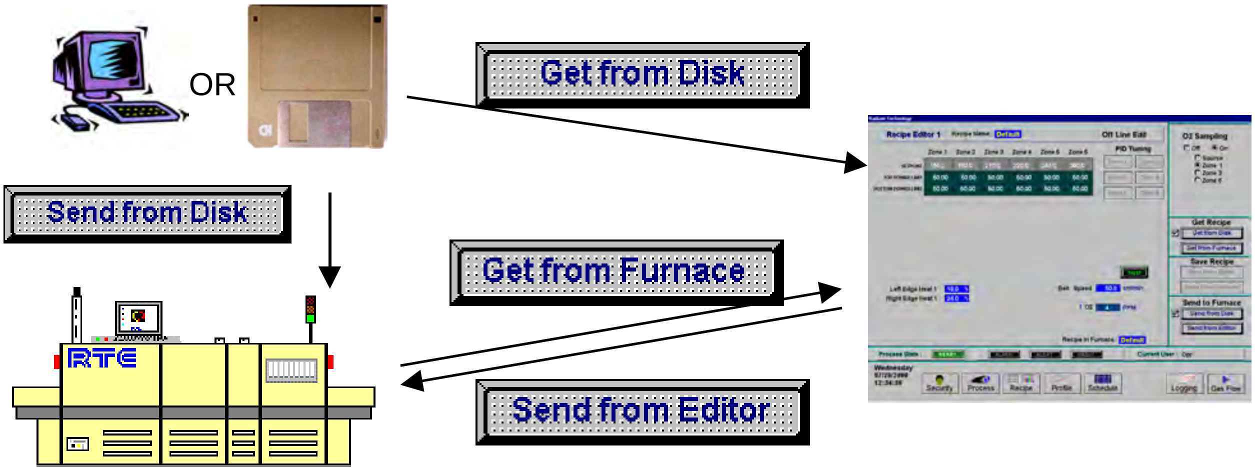


Figure 5-10: Recipe Loading Overview

To load a recipe, the operator must know the name of the recipe file. RTC Furnace software recipes are listed with a Windows extension of (*.rcp).

Recipes can be saved on floppy disk or on the PC hard disk.

To view a recipe before loading it to the furnace controller, click the Get from Disk button. The following window will appear.

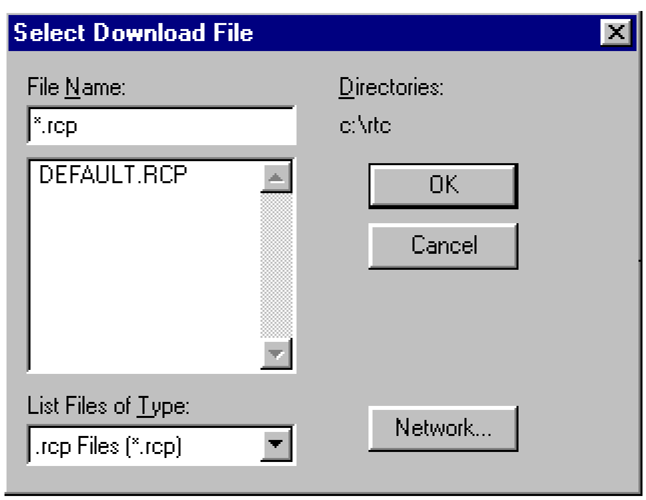


Figure 5-11: MS Windows Browsing Pop-up window

Browse through the directories using standard Windows point and click methods.

Once selected, the recipe can be viewed in the Recipe Screen.

To simply load a recipe to the furnace without first looking at it, click the Send from Disk button. The same window pictured in Figure 5-11 above will appear.

Browse through the directories using standard Windows point and click methods.

Once selected, the recipe will be directly loaded into the furnace Opto22 controller.

To check what recipe is currently loaded in the furnace, click the Get from Furnace button. This will download the current recipe in the furnace memory to the Recipe Screen for viewing.

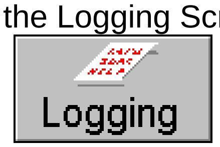
5.5.3 Logging Screen

All RTC Furnaces are supplied with logging software. This allows the customer to keep a detailed record of any furnace event. The following is a list of the events that are recorded.

Item Recorded	Other Information Noted with Item
User log on	User ID
User log off	User ID
System Alert:	“Alert Condition Description”
System Alarm:	“Alarm Condition Description”
System Ready	
Recipe Loaded:	“Recipe Name”
Alert/Alarm Acknowledgment:	“User ID”
Furnace Activity	“Activity Description” e.g. Change belt speed

The logging screen allows any operator to view the last 40 recorded log items.

Access the Logging Screen by clicking the Logging button at the bottom of the screen.



The Logging Screen will appear like that pictured below in Figure 5-12.

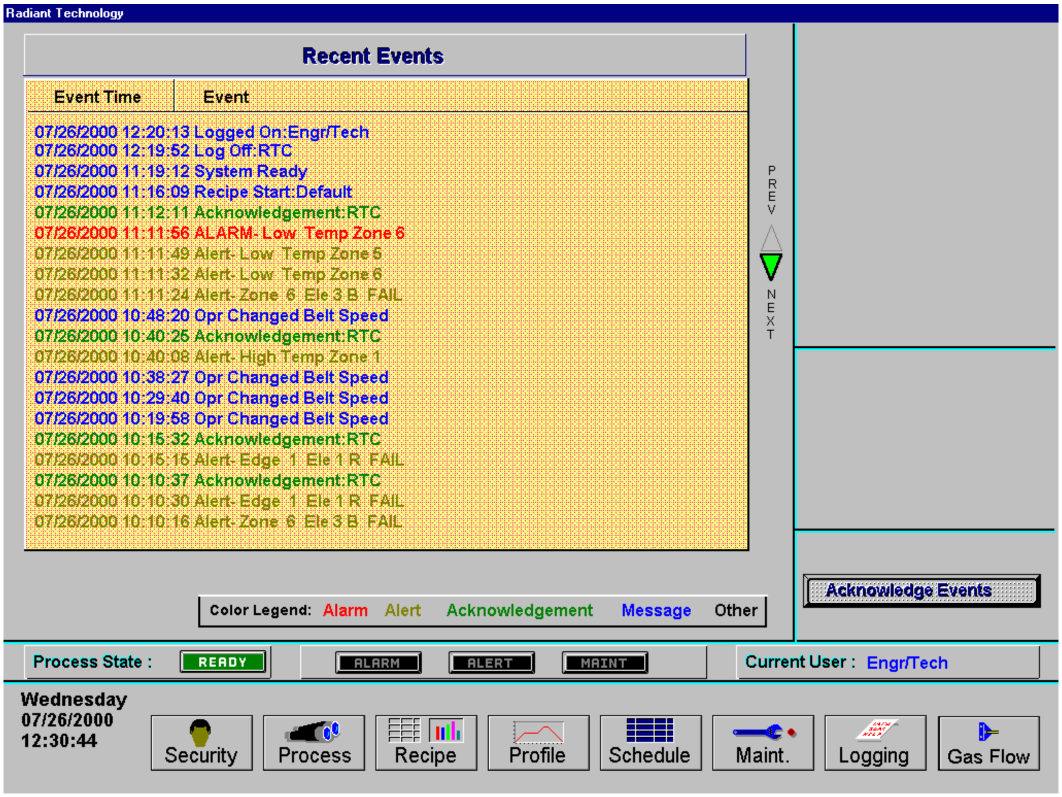


Figure 5-12: Logging Screen

The most recent event is listed at the top of the screen. To view an additional screen of recorded events, click the NEXT down arrow to the right. 

The color legend at the bottom helps determine the event type.

5.5.4 Viewing Logged Data

Each day a RTC Furnace is in full operation, the interface PC creates two files, and places them in the C:\RTC directory. The files follow the following naming format:

yymmdd.h01

yyddmm.evt

The first file, called the “History” file, includes a status of the furnace every three seconds. The following data are recorded:

- Thermocouple temperature readings, PID input values
- PID output levels as a function of available power
- Process State, warming, process ready, cool down, process off
- Belt Speed, inches per minute

- Current user
- Date
- Time

The second file, called the “Event” file, records furnace event data as seen in the Logging Screen. See Section 5.5.3 above.

Text Editing

A quick method of viewing the information presented in the file is to open a simple text editor such as Microsoft Word Pad.

Excel Import

The log files can also be conveniently imported to Microsoft Excel.

5.6 Alarms

Alarms are signals to the operator that the furnace has reached a state where

5.6.1 Events

When an alarm sounds, the following events occur

An audible alert will be heard from the furnace control panel.

The alarm box near the bottom of the process screen will light up.

Moving the mouse pointer over the bar across the bottom of the screen will highlight it in red as seen below.

Clicking on this bar will bring up the “Alarm Monitor” pop-up window as shown below.

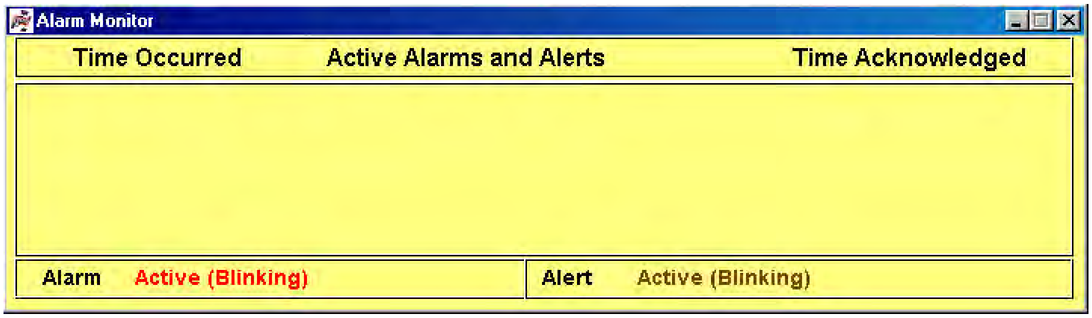


Figure 5-13: Alarm Monitor Pop-up Window

If you click on the pop-up window, the furnace software will automatically bring up the Logging screen behind the “Alarm Monitor”.

To silence the audible alert and acknowledge the alarm, click on the Acknowledge Events button from the Process or Logging Screen.

5.7 Other Options

5.7.1 Element Monitor (Option ❒)

Furnaces can be outfitted with element monitors used to trace continuity through each heat lamp. This option is available from the maintenance screen and is not accessible to an operator. Details of this option are discussed further in Section 7.1.3 on p.74.

5.7.2 WINKIC Prophet (Option ❒)

The WINKIC prophet is a system of high-temperature thermocouples that are placed inside the quartz tubes along the bottom of the process section. These thermocouples allow the customer to continuously monitor several points of the temperature profile at all times.

5.7.3 WINKIC On Screen Profiling (Option ❒)

On screen profiling is a useful feature allowing the user to observe a temperature profile of a thermocouple as it travels through the furnace.

When installed as an option with the furnace, six female thermocouple connectors are available near the entrance of the process section as shown below in Figure 5-14.

Figure 5-14: Thermocouple Interface

A separate manual is provided with the WINKIC interface board and software for on screen profiling. RTC will initially setup the software to match the process section of each customer furnace.

5.7.4 Product Tracking (Option ❒)

The purpose of the product sensor and on-screen tracking feature is to count the number of product-units traveling through the furnace. A set of sensors at the entrance and exit detect the leading edge of a product-unit leaving the loading station or arriving at the unloading station. The tracking feature sets off an alert if the exit sensor does not detect the arrival of an expected product-unit at the unloading station.

To initiate the count, activate one or more tracking lanes by clicking the lane button(s) on the upper left corner of the process screen.

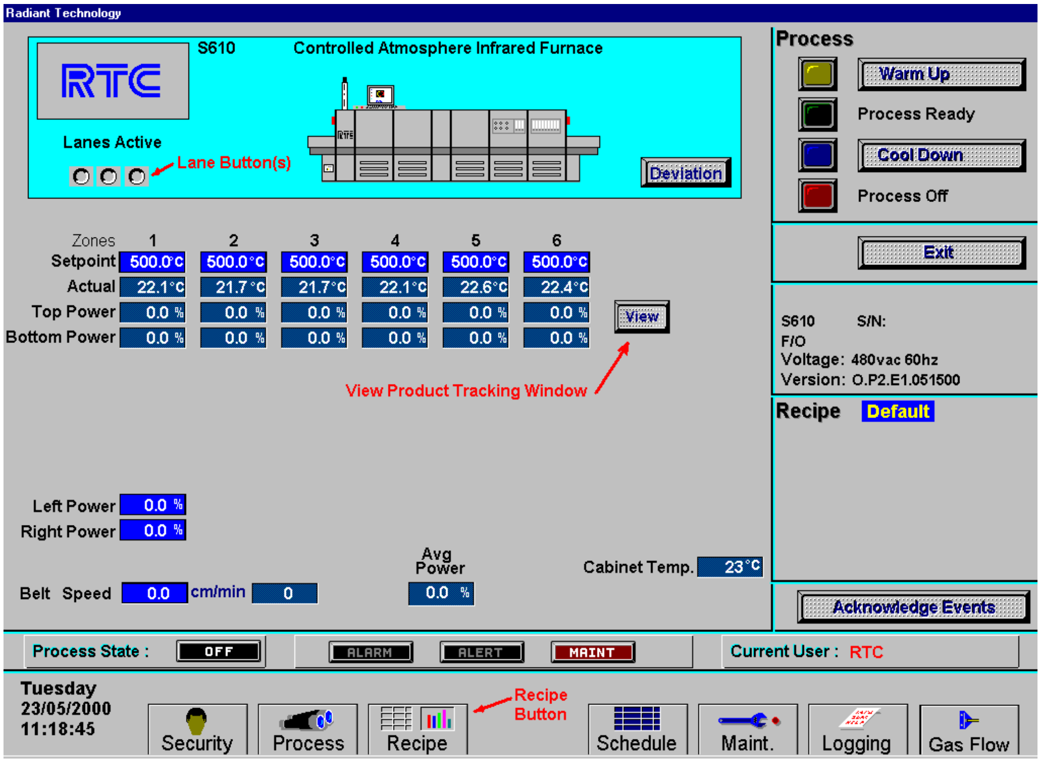


Figure 5-15: Process Screen Highlighting Lane Button, View Button and Recipe Button

The product-unit length must be set in the Recipe Screen.

Once in the Recipe Screen, double-click on the box next to the label "Product Length". See Figure 5-16 below.

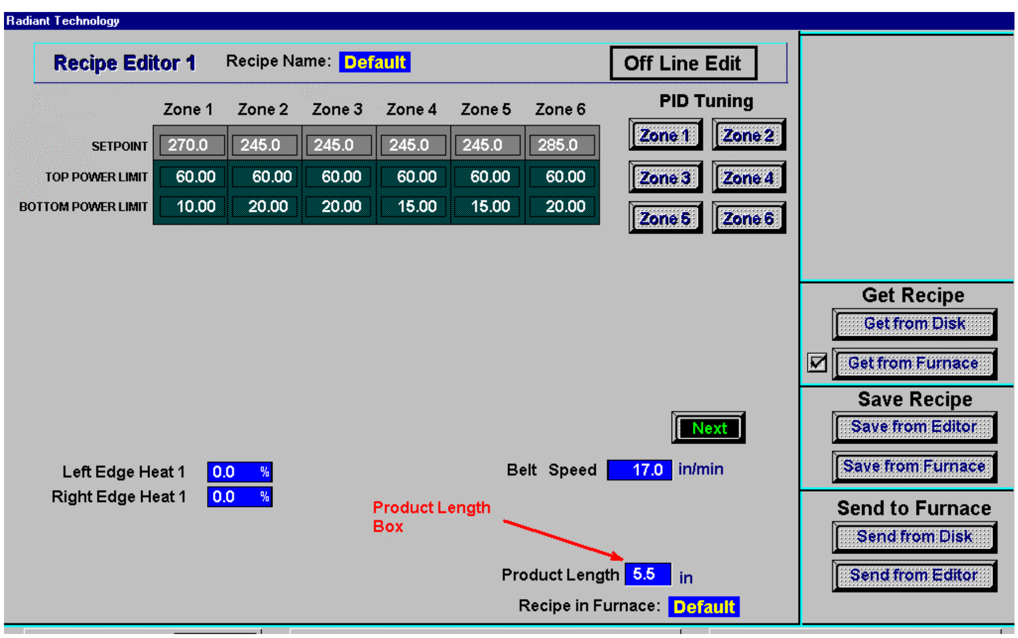


Figure 5-16: Recipe Screen Highlighting Product Length Box

A pop-up window labeled “Send Value” will appear as seen in Figure 5-17. Define the product-unit length in the product length window, and click OK.

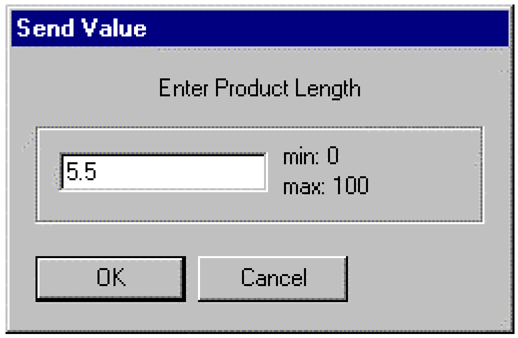


Figure 5-17: Send Value Window

To view the product tracking window, return to the recipe screen shown in Figure 5-15 above and click the View button. Figure 5-18 shows the product tracking window labeled “Product”. Rectangular representations of the defined product-unit length will scroll this screen at the set belt speed. The number of units, which have entered the furnace, will appear in the “ENTR” column. The number of units processed through the furnace will appear in the “EXIT” column. The number of units still in process will appear in the “INSIDE” column. Click on the Clear Product Counts button to reset the count to zero.

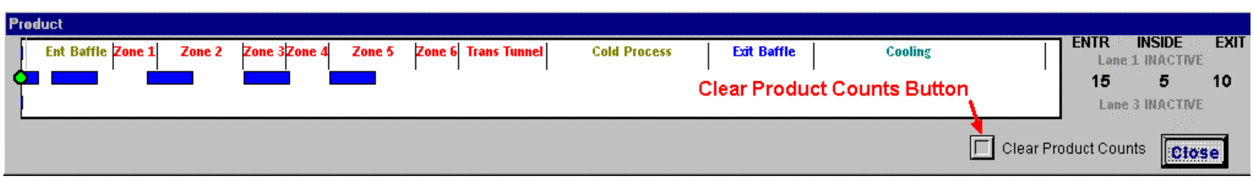


Figure 5-18: Product Tracking Window Highlighting the Clear Product Counts Button

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Controller Overview

6.1 Conceptual Overview

Figure 6-1: Controller Overview

The controller is the communication center for all furnace operations. The Opto22 industrial controller system is implemented to organize signals throughout the furnace and relay information to the interface PC. Analog and digital relays provide sensory and feedback information to the controller, which then regulates power, changes settings and sounds alarms.

6.2 Terminology

6.2.1 PLC

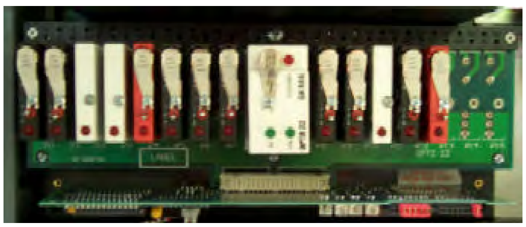
Programmable Logic Controller
The Opto22 controller is a PLC. The program software that is utilized by the controller is downloaded from the PC to the controller memory, describing the logic during certain events. Thermocouple sensors and gas sensors are the

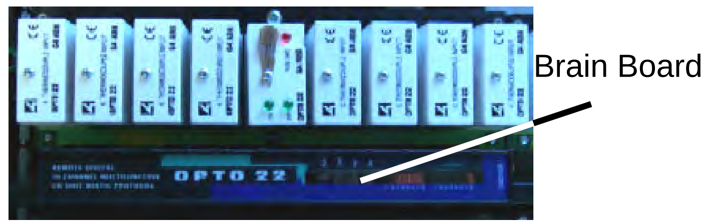
main inputs to the PLC. The PLC then controls the power the heat lamps and solenoid gas valves. In the event of an alarm, the controller will automatically shutdown the furnace based on the user programmed setpoints.

6.2.2 Brick

The Opto22 controller interfaces with furnace hardware through modules attached to a brick. The brick is attached to a base board which is wired directly to the furnace hardware.

The RTC Furnace controller utilizes both the digital and analog bricks. See the figures below.





The communication interface between the bricks and the Opto22 controller is thorough a simple RS-485 communication cable which is attached to the brain board mounted underneath each brick.

6.2.3 Channel Assignments

A channel assignment sheet will accompany every RTC Furnace. This listing shows brick assignment, channel number and function of each Opto22 channel.

Radiant Technology Corporation
1335 S. Acacia Ave.
Fullerton, California 92831-5315

Furnace Channel Assignments

Customer: ****Customer****

LAYOUT

Addr	Power Supply	322-092210-01	Addr	Controller	322-092246-01
21	Analog1	322-092212-01		Analog1_Expansion	322-092226-01
22	Analog2	322-092212-01	1	Digital1	322-092213-01
32	EleMon1_01_TO_16	322-092226-02 322-092246-02	33	EleMon2_17_TO_32	322-092226-02

Factory Order: **326xx**
Date: **DD-Mmm-YY**
Model Number: **XX**
Serial Number: ******
Power: **480vac, 60hz**

Chn	Signal	Part Number	Module Description	Model Number	Signal Description
	Analog1				
0	TEMPERATURE_ZONE_1_K	322-092204-01	Type K analog input	G4AD8-K	KA103 Thermocouple Inputs TC1
1	TEMPERATURE_ZONE_2_K	322-092204-01	Type K analog input	G4AD8-K	KA203 Thermocouple Inputs TC2
2	TEMPERATURE_ZONE_3_K	322-092204-01	Type K analog input	G4AD8-K	KA303 Thermocouple Inputs TC3
3	TEMPERATURE_ZONE_4_K	322-092204-01	Type K analog input	G4AD8-K	KA403 Thermocouple Inputs TC4
4	TEMPERATURE_ZONE_5_K	322-092204-01	Type K analog input	G4AD8-K	KA503 Thermocouple Inputs TC5
5	TEMPERATURE_ZONE_6_K	322-092204-01	Type K analog input	G4AD8-K	KA603 Thermocouple Inputs TC6
6	ZONE_1_TOP	322-092201-01	Analog dc out 0-5v	G4AD4	KA100 Top SCR Signal Control
7	ZONE_1_BOTTOM	322-092201-01	Analog dc out 0-5v	G4AD4	KA101 Bot SCR Signal Control
8	ZONE_2_TOP	322-092201-01	Analog dc out 0-5v	G4AD4	KA200 Top SCR Signal Control
9	ZONE_2_BOTTOM	322-092201-01	Analog dc out 0-5v	G4AD4	KA201 Bot SCR Signal Control
10	ZONE_3_TOP	322-092201-01	Analog dc out 0-5v	G4AD4	KA300 Top SCR Signal Control
11	ZONE_3_BOTTOM	322-092201-01	Analog dc out 0-5v	G4AD4	KA301 Bot SCR Signal Control
12	ZONE_4_TOP	322-092201-01	Analog dc out 0-5v	G4AD4	KA400 Top SCR Signal Control
13	ZONE_4_BOTTOM	322-092201-01	Analog dc out 0-5v	G4AD4	KA401 Bot SCR Signal Control
14	ZONE_5_TOP	322-092201-01	Analog dc out 0-5v	G4AD4	KA500 Top SCR Signal Control
15	ZONE_5_BOTTOM	322-092201-01	Analog dc out 0-5v	G4AD4	KA501 Bot SCR Signal Control
	Analog2				
0	ZONE_6_TOP	322-092201-01	Analog dc out 0-5v	G4AD4	KA600 Top SCR Signal Control
1	ZONE_6_BOTTOM	322-092201-01	Analog dc out 0-5v	G4AD4	KA601 Bot SCR Signal Control
2	RIGHT_EDGE_HEAT1	322-092201-01	Analog dc out 0-5v	G4AD4	KA111 Edge Heat 1 Left SCR Signal Control
3	LEFT_EDGE_HEAT1	322-092201-01	Analog dc out 0-5v	G4AD4	KA112 Edge Heat 1 Right SCR Signal Control
4	BELT_SPEED_OUTPUT	322-092203-01	Analog Out 0-10vdc	G4AD5	KA2 Motor Speed Control Signal
5	CABINET_TEMP	322-092204-01	Type K analog input	G4AD8-K	KA1703 Cabinet Temperature input
6-15	Not Used				
	Digital1				
0	MAIN_POWER_LATCH	322-092200-01	Digital AC Out 12-140vac	G40AC5MA	K4 Delay Power OFF, Ref: 802-101770
1	LAMP_POWER_CTRL	322-092200-01	Digital AC Out 12-140vac	G40AC5MA	K7 Process Power On, Ref: 802-101770
2	SPEED_FEEDBACK	322-092207-01	Digital In 2.5-16v	G41IDC5K	K11 Transport Motor Tach Feedback, Ref: 802-101771
3	TRANSPORT_MOTION_FAULT	322-092207-01	Digital In 2.5-16v	G41IDC5K	K8 Transport Motion Sensor, Ref: 802-101771
4	ALARM_HORN	322-092227-01	Digital DC Out 5-60vdc	G40DC5MA	K14 Alarm Horn, Ref: 802-101772
5	PRES_SW_N2_MANIFOLD	322-092202-01	Digital input 2.5-28v	G41DC5D	K? N2 pres. Sensors
6	ENTRANCE_SENSOR_MIDDLE	322-092202-01	Digital input 2.5-28v	G41DC5D	K81 SMEMA Center Sensor Int. Ref: 802-101777
7	EXIT_SENSOR_MIDDLE	322-092202-01	Digital input 2.5-28v	G41DC5D	K84 SMEMA Center Sensor Exit Ref: 802-101777
8	FlowSwitchN2	322-092202-01	Digital input 2.5-28v	G41DC5D	N2 Flow Sensor
9	PrePurgeProcess	322-092227-01	Digital DC Out 5-60vdc	G40DC5MA	N2 Pre-Purge Process Active
10	DiffusionInterlockSwitch	322-092202-01	Digital input 2.5-28v	G41DC5D	Diffusion Interlock Input
11	OzoneFailSafeSwitch	322-092202-01	Digital input 2.5-28v	G41DC5D	Ozone Fail Input
12-15	Not Used	322-092227-01	Digital DC Out 5-60vdc	G40DC5MA	Spare Output
	EleMon1_01_TO_16				
0	EM01	322-092207-02	10-32 vac/vdc digital input	Snap-IDC5	-| Input 1 of 4, Elem. Mon Z1-1-T
1	EM02	322-092207-02	10-32 vac/vdc digital input	Snap-IDC5	| Input 2 of 4, Elem. Mon Z1-2-T
2	EM03	322-092207-02	10-32 vac/vdc digital input	Snap-IDC5	| Input 3 of 4, Elem. Mon Z1-1-B
3	EM04	322-092207-02	10-32 vac/vdc digital input	Snap-IDC5	-| Input 4 of 4, Elem. Mon Z1-2-B

Figure 6-2 Channel Assignments Windows Environment

6.3 PLC Layout

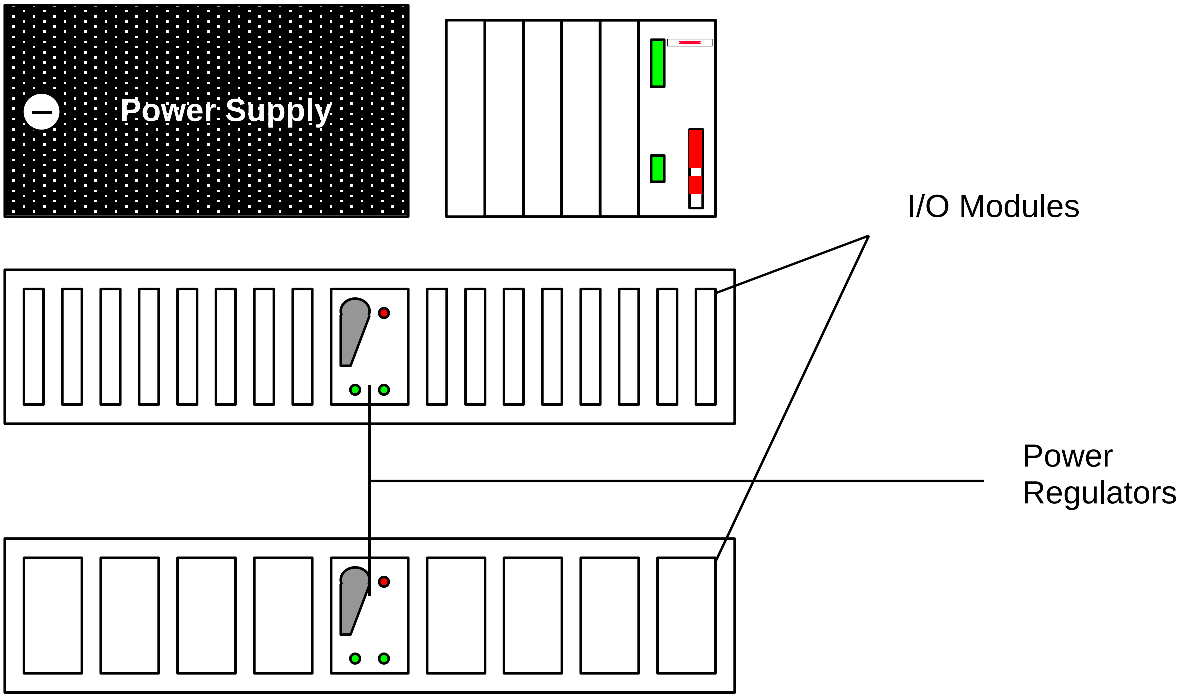


Figure 6-3: PLC Layout

6.3.1 Power

The power supply for the Opto22 controller supplies power to the control system, bricks and ethernet interface. Supplemental power supplies may be added to other installed components such as Opto22 Snap brains that are used to interface with element monitor boards.

6.3.2 Controller

The controller is responsible for maintaining steady temperature through adjustments to SCR power transmission, as well as communication of system information to the user interface PC.

6.4 Ethernet

An ethernet interface is provided as the communication device between the Opto22 controller and the interface PC. The ethernet card inside the controller is installed just to the left of the controller in the controller housing. See Figure 6-4 below.

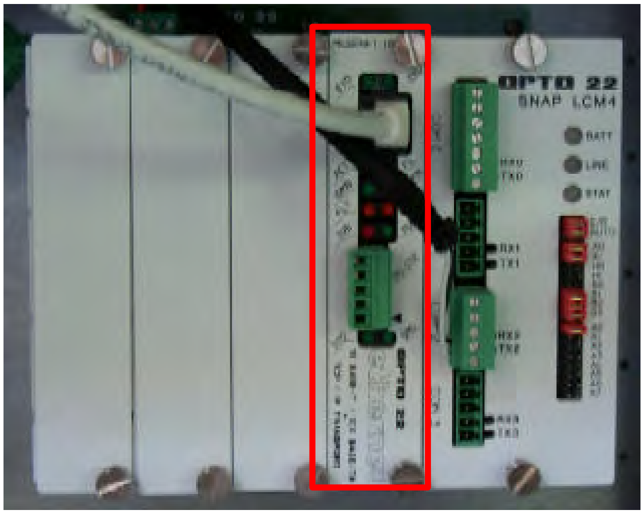
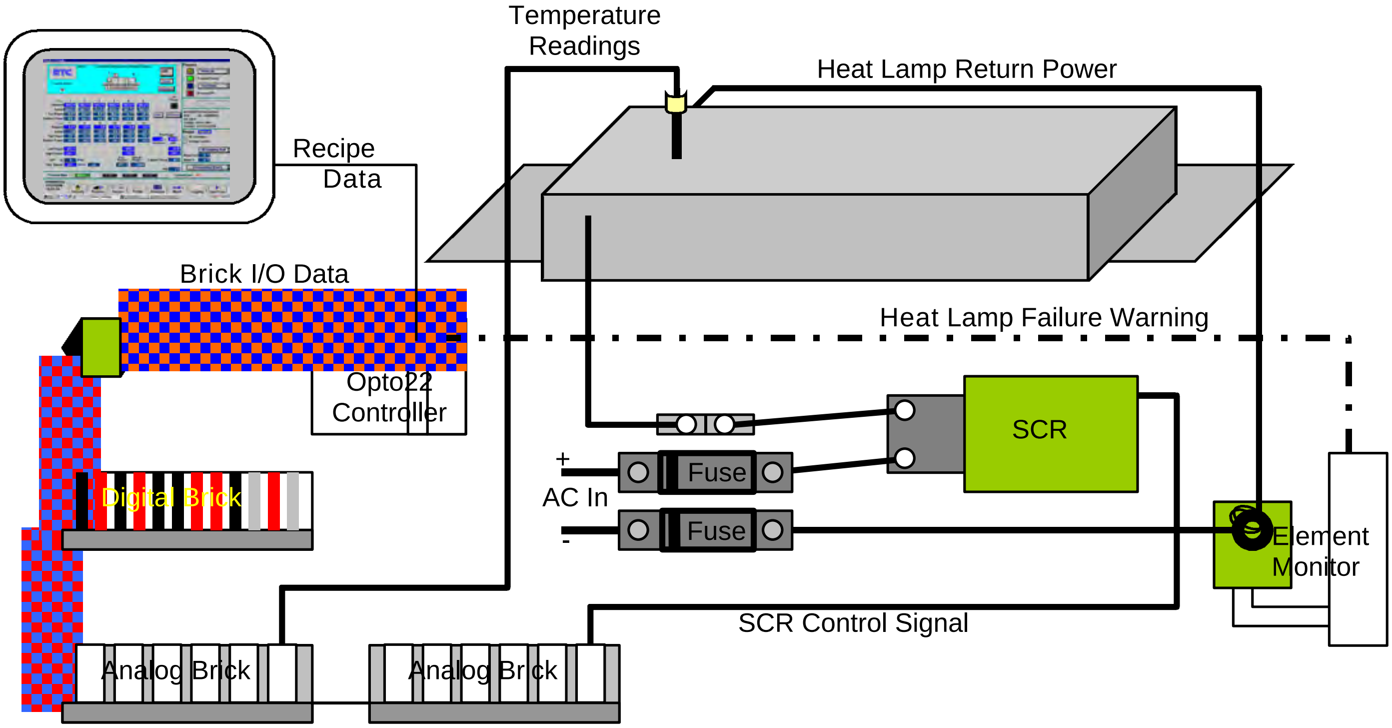


Figure 6-4: Opto22 Controller Ethernet Interface

6.5 Overall PLC Communication



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