



CONTINUOUS BELT IR FURNACE

Reference Manual

Version 2.7



**Supplemental Reference to the
IR Furnace Equipment Owner's Manual**

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Continuous Belt IR Furnace

Reference Manual

Training Guide and Supplemental Reference

Version 2.7

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1.1 Introduction

This manual pertains continuous belt closed atmosphere infrared (IR) furnaces which operate in the near infrared (0.5-5.5 μm) wavelength. Specifically it applies to IR furnaces manufactured by **FurnacePros (FPD)**, **GreenBridge Technology Inc. (GBT)** or **Radiant Technology Corporation (RTC)**.

Early History

Over 40 years ago, Radiant Technology Corporation pioneered the development of short wavelength infrared continuous belt ovens and furnaces. RTC introduced the first high-temperature infrared furnace capable of operating at 1000°C with extremely tight temperature control. From 1972 to 2006, RTC became the undisputed leader in infrared heating technology and developed precise, efficient, cost-effective, and reliable thermal processing equipment for commercial applications. These furnaces were successfully installed in many production and research facilities worldwide to perform a wide variety of thin and thick film curing, solar cell, solder reflow and electronic and component manufacturing for photovoltaic, semiconductor processing, electronics packaging and assembly technology industries, to name a few.

Furnace Characteristics

These IR furnaces were built for long life and efficient thermal processing. With infrared lamps as the primary heat source, these furnace are highly responsive to critical temperature settings. The heating chamber feature a special nonmetallic “porous muffle” design that enhances controlled atmosphere operation, with the additional benefit of a rapid heating and cool-down capability. A unique gas management system provides an extremely even distribution and well regulated flow of gas throughout the process chambers. Oxygen levels in nitrogen, hydrogen or forming gas atmospheres can be typically held to 5 ppm or less in temperature controlled zones using this unique gas management system. Analyzers and sample systems can be included to sample and monitor oxygen and moisture levels in the process atmosphere.

Over the years many advances have been made to improve performance, control and efficiency of these robust furnaces. Often simply upgrading the control system and electricals owners can extend the life of their furnace by 10 to 15 years. On newer furnaces and upgraded furnaces, operators can monitor operating parameters on a computer screen while a controller monitors the process vitals and adjusts the process environment to handle varying loads and conditions. Wireless networking can make process information available to the process engineer at remote locations. Diagnostics can be performed by factory techs over the internet.

Scope of this Manual

This updated “how to” manual explains the theory, operating features and techniques to assist owners, process engineers and operators in achieving highly repeatable, reliable and, consequently, lucrative thermal processes. Additional sections have been added to include advances in the furnace software and addition of internet access. More complete descriptions of many furnace systems have been updated. In addition, typical maintenance and troubleshooting information have been expanded to cover most situations that may be encountered.

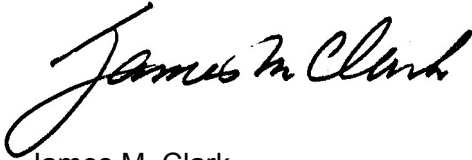
Better Results

Achieving high performance and high yields is achievable with a better understanding of the equipment. 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 can guide the tool achieve its potential. For many, our furnaces become regarded more than just an effective tool; they are viewed as a fine instrument that can produce wonderful results over a variety of thermal processing situations.

Please study this manual carefully. Experience has shown that users who thoughtfully **study** and **master** the contents of this manual **become expert** in understanding the process system capabilities of our furnaces. In doing so, many are able to push the initial process performance envelope and thus achieve higher degrees in both process reliability and throughput than previously anticipated.

Continuous Improvement

We endeavor to improve our equipment in performance and design. To this end, FurnacePros encourages users to provide data on furnace performance and suggest ideas for improving designs and service. Additionally, we are always more than happy to discuss, in confidence, new thermal processing requirements, however difficult or complex they may be. In any event, we hope that you will find this manual useful to help you operate your equipment to meet the special and challenging needs of your thermal processing endeavors.



James M. Clark
President
FurnacePros, Division of Lochaber Cornwall, Inc.

1.2 Format

This manual uses the following formatting conventions.



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.

Bold Underlined 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. If supplied, please check the box as appropriate.

1.3 Where to Get Help

1.3.1 General

Address: 675 North Eckhoff Street, Bldg. D
Orange, California 92868

Phone: +1 (714) 935-0302

Fax: +1 (714) 935-9809

e-mail: tmacias@furnacepros.com

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e-mail: service@furnacepros.com

Phone: +1 (714) 935-0302 x220

1.3.3 Service Parts Ordering

Department: Technical Support

e-mail: parts@furnacepros.com

Phone: +1 (714) 935-0302 x220

1.3.4 Upgrades & Factory Refurbishing

Department: Aftermarket

e-mail: tmacias@furnacepros.com

Phone: +1 (714) 935-0302 x220

1.3.5 Equipment Sales

Department: Sales & Marketing

e-mail: sbarber@furnacepros.com

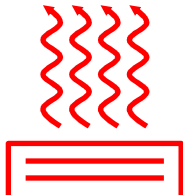
Phone: +1 (714) 935-0302 x210

1.3.6 Website

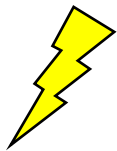
Web: www.furnacepros.com

2.1 General Precautions

Safety procedures and proper furnace installation ensuring proper ventilation and safe source gases is the responsibility of the furnace owner.



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



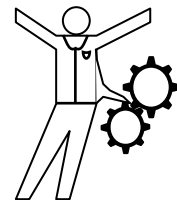
Electrical shock hazards exist for those technicians who service the furnace. High voltages are required to operate the furnace and precautions must be taken to reduce the exposure to these elements. Again, it is the responsibility of the furnace owner to assure that only properly trained service technicians,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



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. Those who must be near the moving parts should wear close fitting clothing.



2.2 EMO Buttons



Each furnace is fitted with at least two Emergency Machine Off buttons (EMO's) Locate and insure proper function prior to regular furnace operation. Newer FurnacePros brand furnaces are equipped with four (4) for SEMI compliant EMO's, one at each corner of the furnace.

Each Emergency Machine Off button (**EMO**) 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.

Chapter 3

The following special notes describe events associated with various furnace options when an EMO button is pressed.

2.2.1 UPS (Option)

An uninterruptible power supply may be added as an option to the furnace. In the event that the EMO 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 description in Section 0, p.23.

2.2.2 H2 Controlled Atmosphere (Option)

Many events occur when an EMO is tripped in a H2 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. Override this switch to allow furnace operation with the panels removed. Simply grasp the protruding switch and pull it out (See Figure 2-1) to activate the override switch setting. When the panels are replaced, the switches are reset to automatically open the circuit and kill the furnace when the panels are again removed.

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

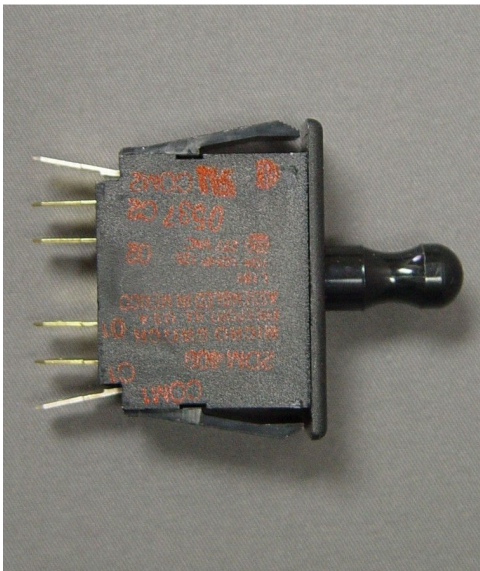


Figure 2-1: Panel Switch
Normal Operation Position



Figure 2-2: Panel Switch Installed
Override Mode Position



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 H₂ Operation Safety Overview (Option □)

The addition of hydrogen (H₂) to the heating chamber requires additional several safety considerations.

1. Care should be taken to assure that the concentration of hydrogen is always below its **Lower Explosive Limit**. LEL is the lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). At a concentration in air below the LEL there is not enough fuel to continue an explosion. Limiting oxygen to the process will increase the safe percent by volume of hydrogen.
2. The LEL for hydrogen is 4%.
3. Gas flow balance is critical to the safety of all personnel working near a furnace operating with hydrogen as a process gas. Escaping hydrogen gas, or the admission of oxygenated gas into the process section is extremely hazardous.
4. Special warm up and cool down procedures must be followed.
5. Set Nitrogen flow to each zone and then set hydrogen mixing flowmeter to assure hydrogen flowing to each zone is less than the lower explosive limit (LEL).
6. On newer furnaces, the software requires satisfaction of a list of gas permissives before the hydrogen gas valve opens including: Subsequent failure of any of them will shutdown the hydrogen operation mode.
 - Nitrogen pressure must be present at main gas manifold
 - Process is in "Ready" state
 - Exhaust eductor gas pressure or flow detected
 - Baffle gas flow detected
 - Plenum gas pressure or flow detected
 - Sample Pump is ON
 - Oxygen is not detected in the process zones
7. On newer furnaces, gas collectors at the entrance and exit of the furnace supply additional nitrogen during hydrogen operation and rapid purge cycles. This gas is evacuated by educator-jets in the furnace exhaust stacks.
8. During any hydrogen shutdown, emergency or normal, additional nitrogen gas flows to the stack eductors and collectors during the rapid purge cycle.
9. When operating in hydrogen mode, detectors mounted above gas collectors at the entrance and exit of the furnace and at other critical points on the furnace will provide audible alarm and shutdown if the presence of hydrogen at or above 50% LEL is detected.
10. Ignitors on the exhaust stacks are designed with redundant elements which are designed to safely ignite flammable concentrations of hydrogen if present in the furnace exhaust.

3 Furnace Overview

3.1 Terminology

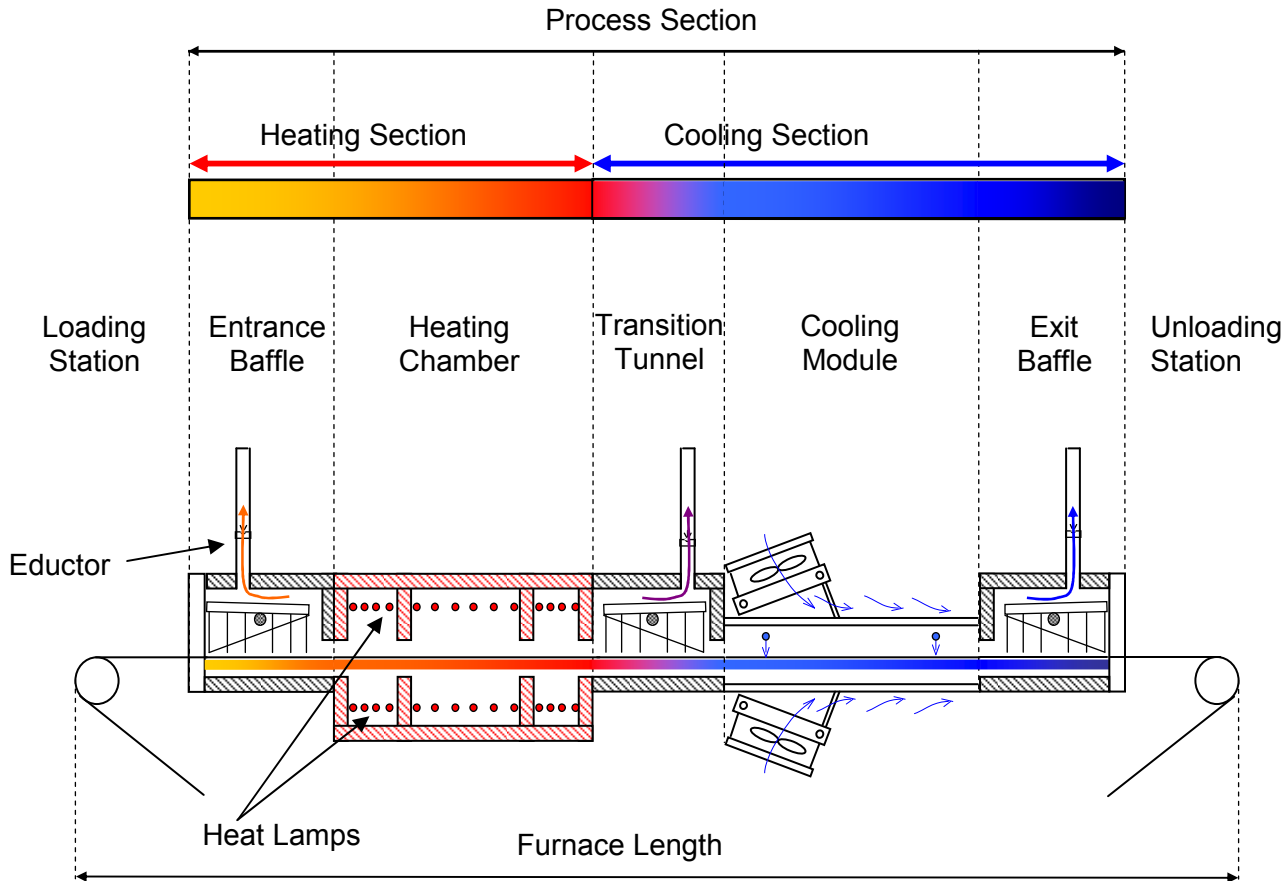


Figure 3-1: Furnace Nomenclature

Review the following terms in the glossary:

Cooling Section	Heated Length	SCR
Drip Trays	Heating Chamber	Stack
Eductor	Heating Section	Thermocouple
Entrance Baffle	Plenum	Throat
Flow Meter	Plenum Box	Transition Tunnel
Furnace Length	Process Environment	Zone
Gate	Process Gas	
Heat lamp	Process Section	

3.1.1 General Area Descriptions

Control Panel

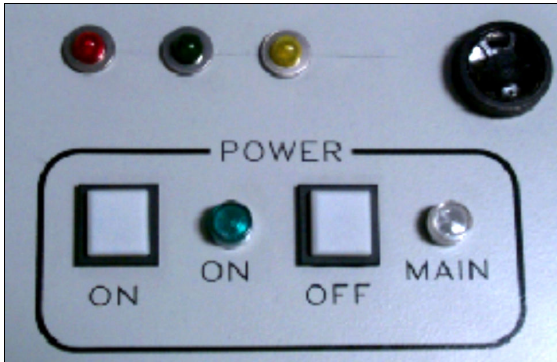


Figure 3-2: Control Panel (pre-2007)

The control panel is the central location of main power control, alarm speaker, and if so equipped, ultrasonic cleaner/dryer power lights, as well as any cooling fan power dials. The PC keyboard and mouse are also here.

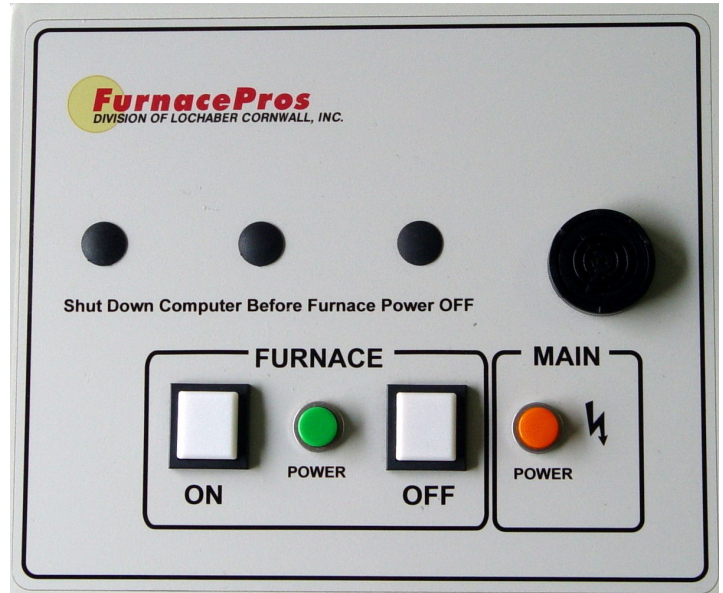


Figure 3-3: Control Panel (New)

MAIN lamp indicates high voltage power is connected to the furnace. The POWER ON lamp indicates furnace has been started and power is supplied to controller.

PLC Panel

On newer furnaces a PLC panel houses the furnace controller and input and output modules (I/O). The controller operates the furnace based on input from the Operator to the furnace Computer and feedback signals from sensors on the furnace itself.

Older furnaces have dedicated controllers or manual controls for each furnace subsystem.

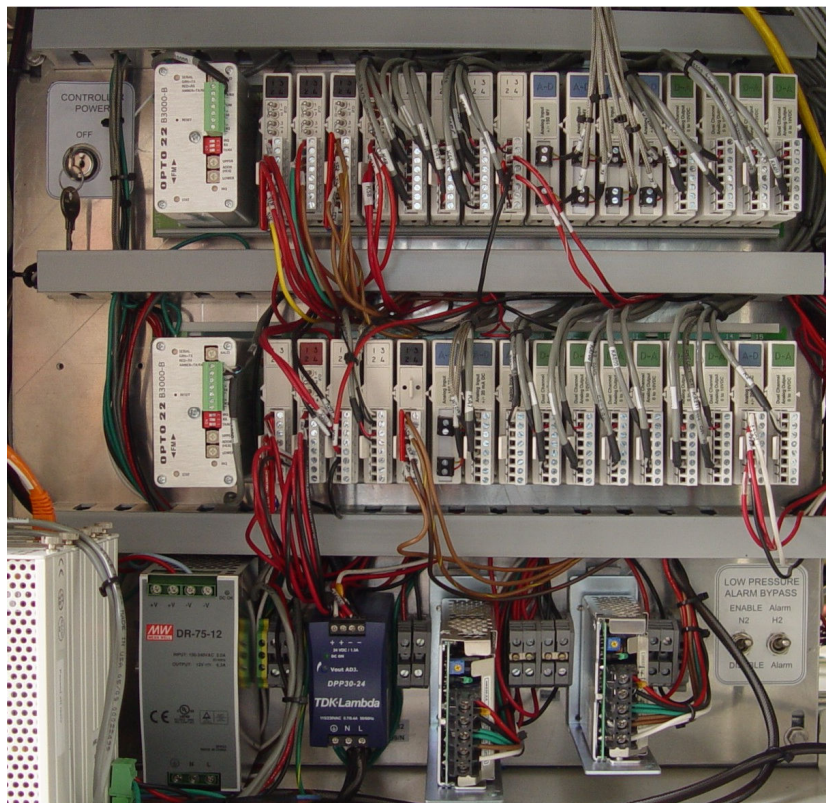


Figure 3-4: PLC Panel

SCR Panel

The SCR panel regulates the actual power applied to the heat lamps in response to signals from the PLC controller. The number of fuse relays and SCR control blocks varies based upon the furnace configuration and owner/user processes and requirements.



Figure 3-5: SCR Panel & fuses

Safety Enclosure Panel

The safety enclosure contains the system components that supply lamp and control panel power. Useable 110 VAC power for the computer is also provided here.



Figure 3-6: Safety Enclosure Panel

Power Distribution Panel (PDP)

The PDP 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.

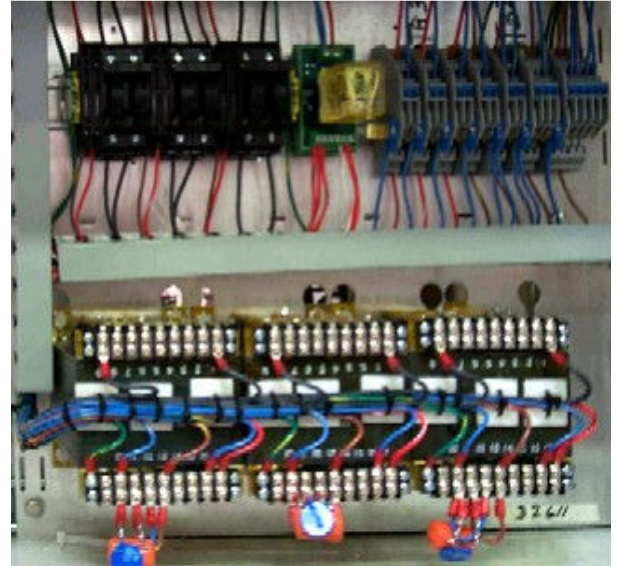


Figure 3-7: Power Distribution Panel

Element Monitor Panel

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

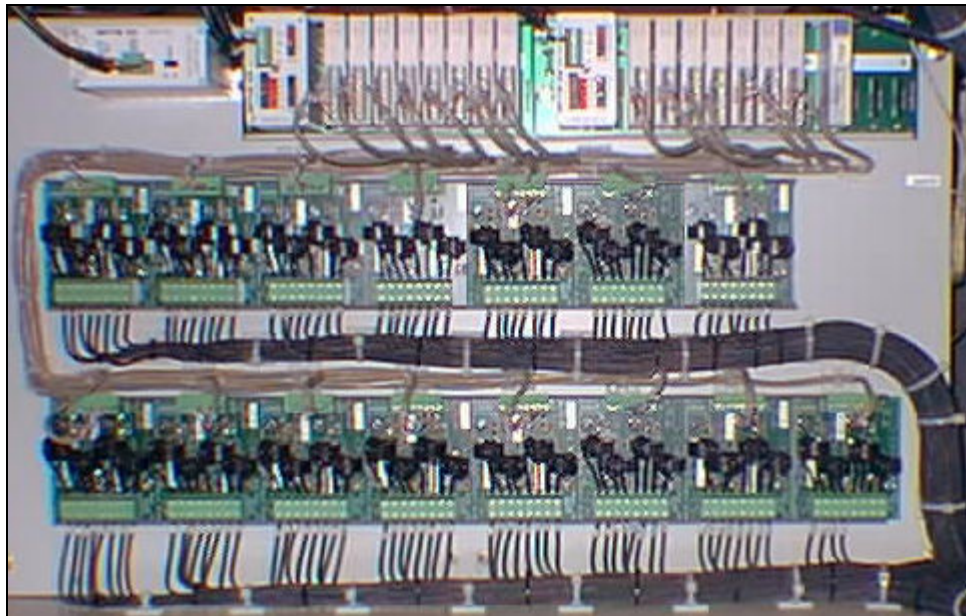


Figure 3-8: Element Monitor Installation

3.1.2 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 in Figure 3-9: Conveyor Belt Motor.



Figure 3-9: Conveyor Belt Motor

3.2 General Furnace Layout

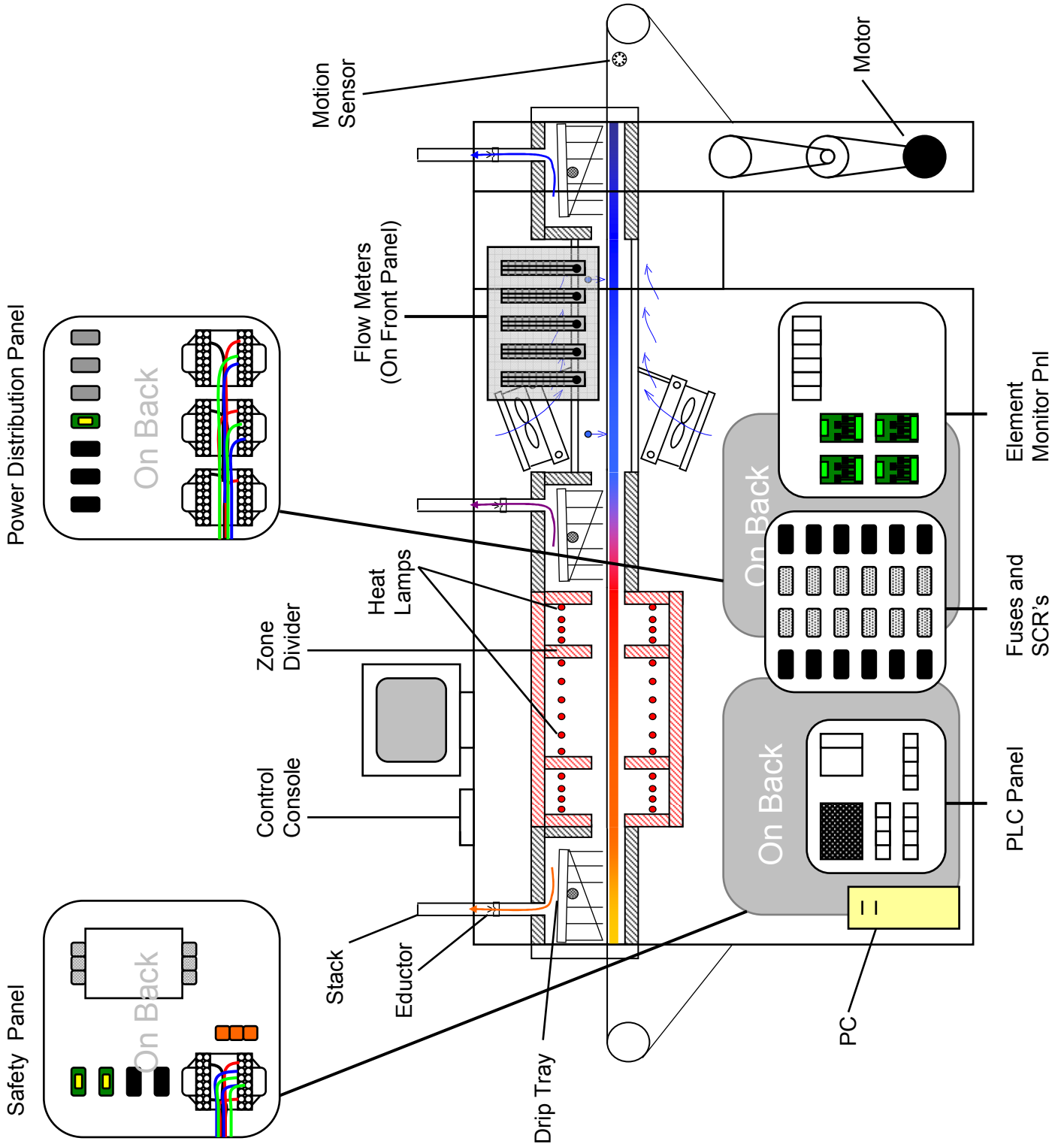


Figure 3-10: Typical Furnace Layout

3.3 Thermal Process

3.3.1 Temperature Profile

A temperature profile represents multiple temperature measurements taken at close intervals over a period of time through the length of the furnace. Figure 3-11 below shows an example temperature profile inside the 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.

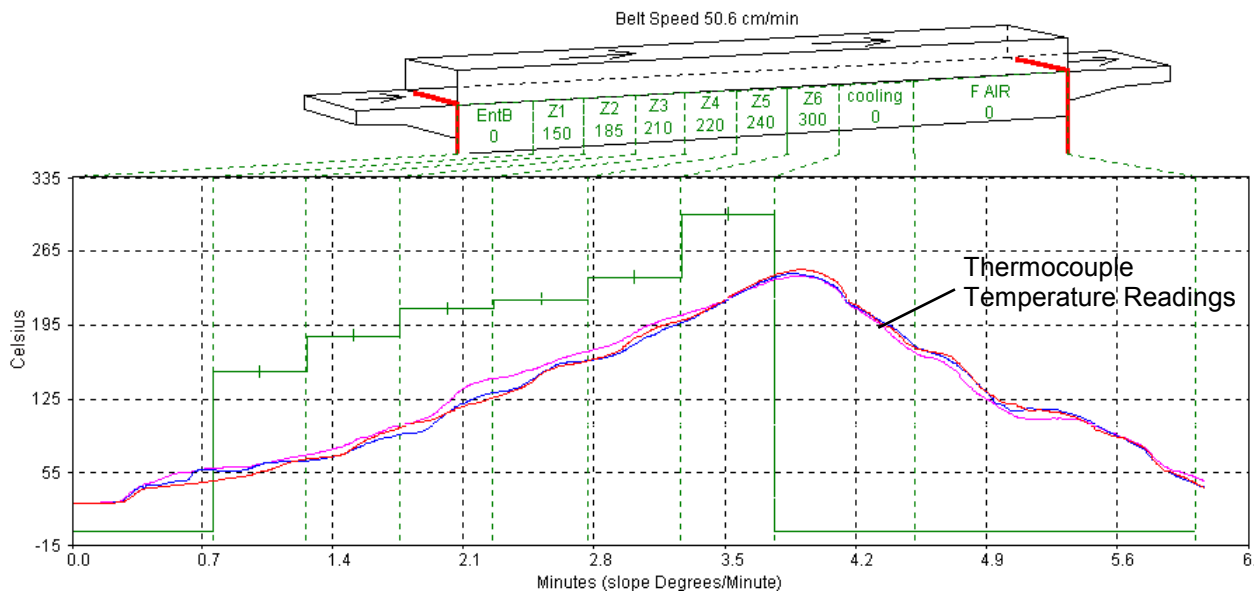


Figure 3-11: Temperature Profile Example

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

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

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 dissimilar product that passes through a FurnacePros 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 can be stored in the computer and sent to the controller to achieve the predetermined process. The recipe also defines alert and alarm conditions based on furnace owner operator requirements to maintain product quality. The uncomplicated furnace software interface on the PC facilitates changes between recipe settings as well as modifying and saving them easily.

Recipes and how they are managed is covered in more detail in Section 5.5.3 p.45.

3.3.3 Controlled Atmosphere (Option)

Many 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 ambient air at high temperatures.

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

Controlled atmosphere is discussed further in Section 4.5 p. 28 as well as presented in a detailed approach in Chapter 9: Process Engineering.

3.4 Typical Furnace Options

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 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)

Overhead sensors sense when product is present. This sensor can be used in conjunction with the SMEMA product tracking which can monitor up to three lanes, as discussed in Section 5.7.4, p.53.



Figure 3-12: SMEMA Photoelectric Product Sensor and Guides

3.4.2

3.4.3

3.4.3 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.

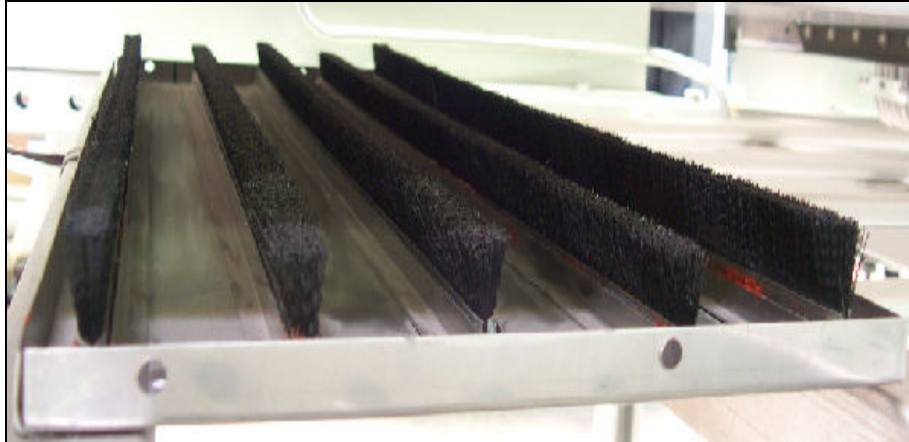


Figure 3-13: Brush Belt Cleaning System

3.4.4 Cabinet Temperature

A dedicated thermocouple is attached near the center of the heating chamber between the chamber and the upper panel. The sensor is attached to the PLC controller and software is configured allow the user to monitor the cabinet temperature and alarm when temperature exceeds a user defined limit. The cabinet thermocouple can act as an additional safeguard against furnace overheating and can show possible cabinet fan failure, or blocked air inlets or exits.

3.4.5 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.

3.4.6 European Certification (€ (Option)

A strict implementation of CE requirements is followed according to 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:

Operation Manual in European Language
Circuit Breaker
Line Filter



Figure 3-14: Circuit Breaker

3.4.7 Lexan Shields (Option)

Lexan shields can be conformed to isolate or protect selected areas of the furnace. Shields before the Safety and PDP panels are standard.

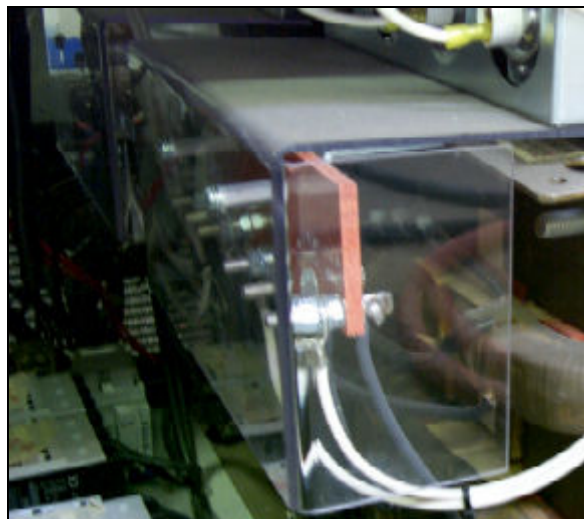



Figure 3-15: Lexan Shields

3.4.8 Light Tower

3-Light Process Ready (Option)

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

Green Light	Process Ready	
Amber Light	Furnace Warming Up Furnace Cooling Down	
Red Light	Furnace Alert or Alarm	
No Light	Process Off	
Table 3-1 Standard Light Tower		

5-Light with Process Gas Indicator (Option)

Special lights can be added to the 3-light tower to indicate selected gas operation.

White Light	CDA
Blue Light	Nitrogen Gas
Table 3-2 Standard Light Tower Process Gas Indicators	

3.4.9 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 operators who purchased CE option.

3.4.10 Low / High Belt Speed (Option)

Specified special conveyor belt speeds require specific motor speed, power and gearing for the furnace to achieve higher maximum or lower minimum operating speeds.

Most furnaces shipped through 2009 are furnished with 10:1 (Maximum : minimum) turn-down capability. Newer furnaces include an isolation board with the motor controller which allow as much as a 20:1 turn-down ratio.

Many existing furnaces can be retrofitted to achieve a 20:1 turndown ratio as well.

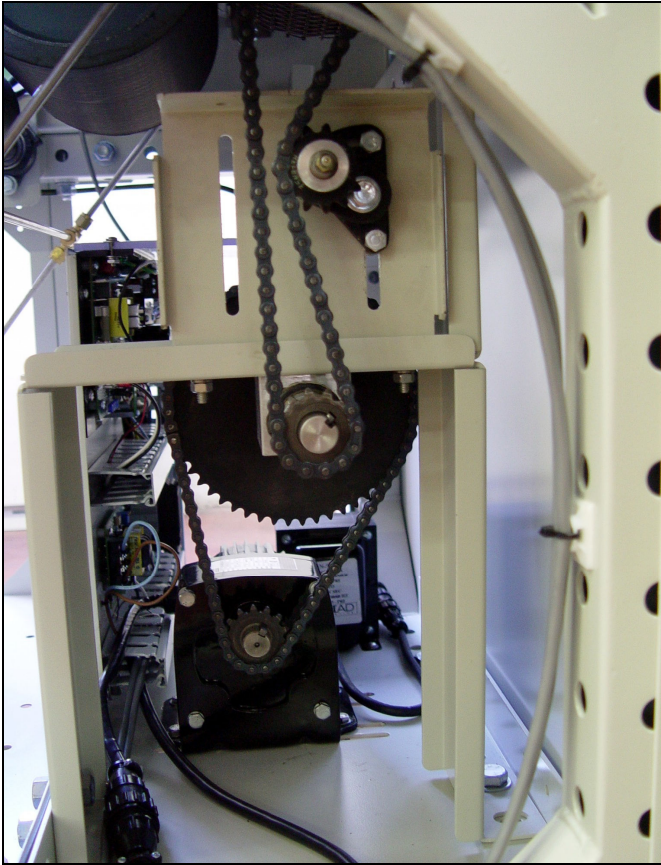


Figure 3-16: Motor Drive Gearing

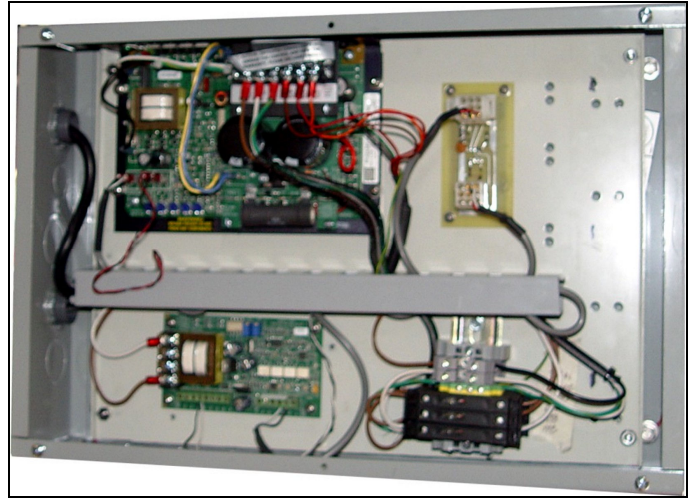


Figure 3-17: Retrofit Motor Control System

3.4.11 Quartz Standoffs (Option)

The primary purpose of 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. In this fashion, 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. See Figure 3-18 and inset.

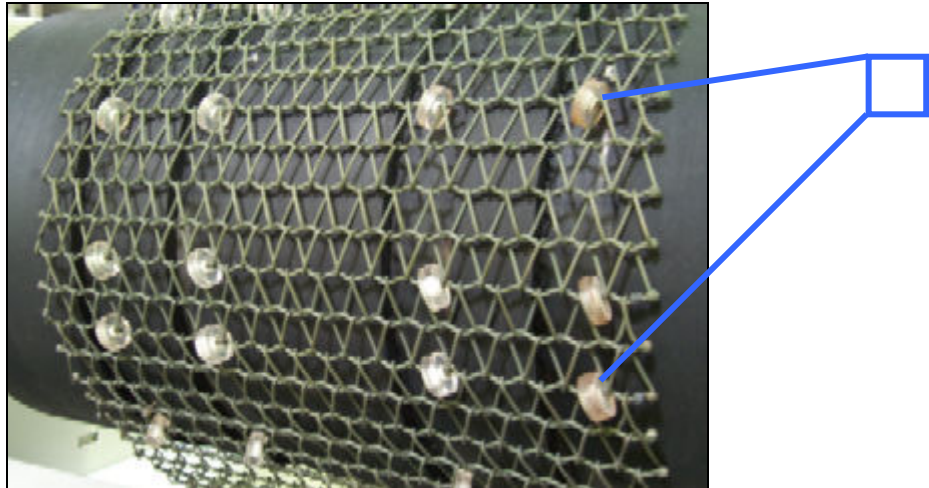


Figure 3-18: Conveyor Belt Shown with Quartz Rollers



Inset, Figure 3-18 Quartz Rollers – detail

3.4.12 Thermocouple Wheel Assembly (Option)

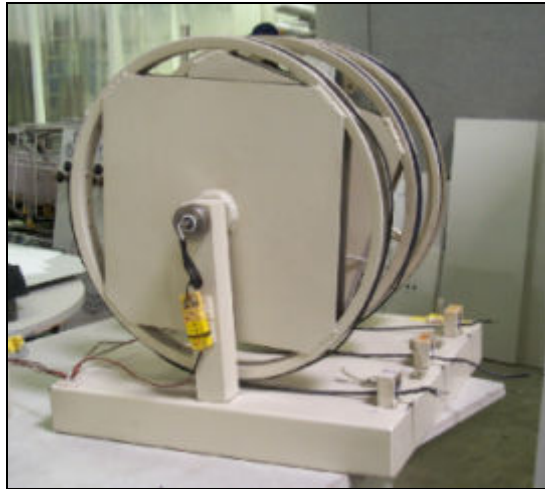


Figure 3-19: Thermocouple Wheel Assembly - 3 T/Cs

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

3.4.13 Ultrasonic Cleaner/Dryer (Option)

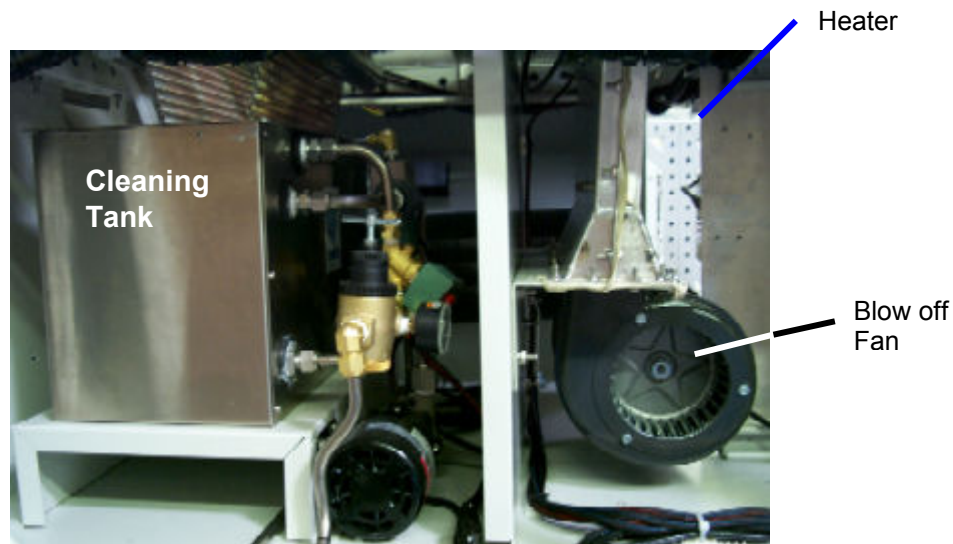


Figure 3-20: Ultrasonic Cleaner and Dryer installation

The ultrasonic belt cleaning system removes contamination that accumulates on the belt during normal furnace operation. This system includes an ultrasonic tank, belt dryer and timer system to enable automatic cleaning of the belt. A fan-driven air blow-off removes water droplets and can be provided with an optional heater to further drive moisture from the belt. The belt is drawn through an ultrasonic tank that is automatically filled and drained by a timer and control circuitry. The cleaning/drying of the belt takes place when the furnace is off-line. This option requires connection to facility water source and water drain.

3.4.14 UPS (Option)



Figure 3-21: Uninterruptible Power Supply

This option adds an uninterruptible power supply to keep 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.

4 Thermal Processing

4.1 Heating Concepts

4.1.1 Infrared Heating

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

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

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

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

4.2 Furnace Construction

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

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

4.2.1 Modules

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

For example:

Figure 3-10: Typical Furnace Layout on p.13 shows a 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. Additional controlled atmosphere cooling modules, a water cooling system, or a forced air cooling module after the exit baffle may be added.

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

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

4.2.2 Throat

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

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

4.3 Heating Chamber Design

4.3.1 Zones

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

4.3.2 Infrared Heating Chamber

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

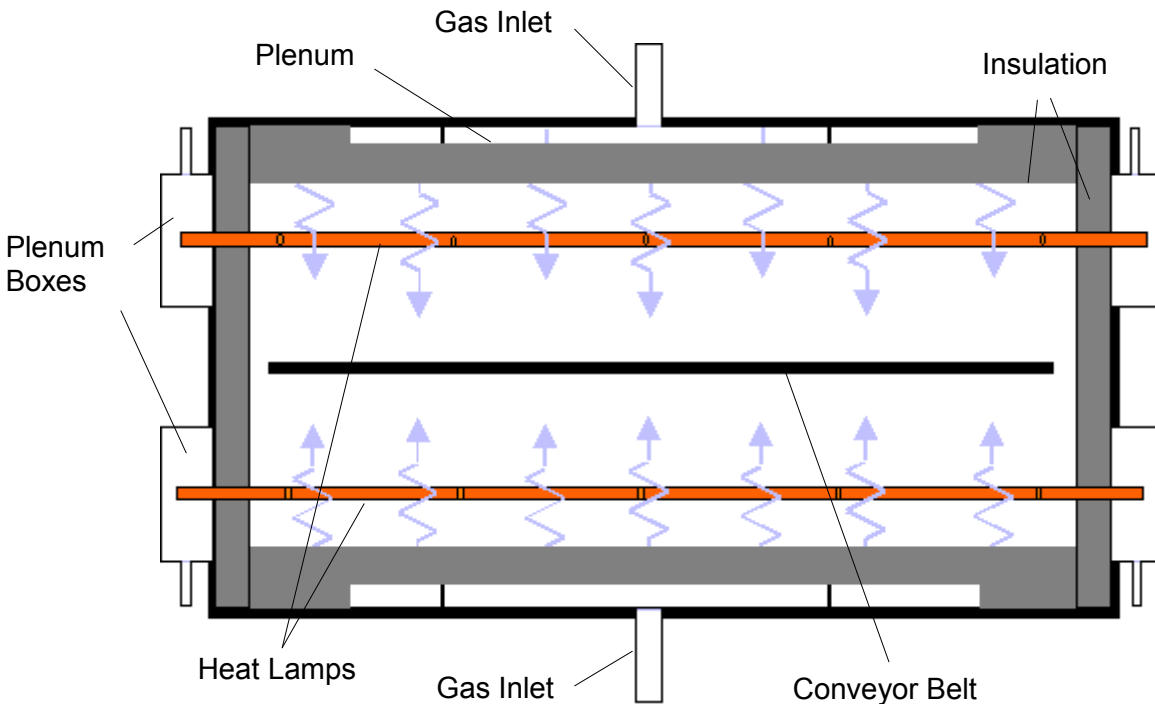


Figure 4-22: Heating Chamber Construction. End view

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

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

Incoming process gas introduced through a large displacement area provides rapid purge times and low contamination levels. Typically, a process environment atmosphere

of less than 10 parts Oxygen in 1,000,000 parts Nitrogen (<10ppm O₂) can be achieved within about 10 minutes. Rapid purge times also allow for quick process environment replenishments as well as fast cool-down times.

4.3.3 Dryer Heating Chamber

An IR Dryer heating chamber is designed the same as an IR Furnace heating chamber except that the heat lamps are only installed above the belt. Other features remain the same except thinner insulation is used for lower temperature applications.

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 handling the lamps can cause hot spots which can reduce lamp performance or cause failure.

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

4.4.1 Placement

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

4.4.2 Wiring

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

4.5 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.

Operators Please Note: When changing recipes, flow meters must be adjusted according to the levels outlined in the applied 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 the specified application requirements, the number and type of flow monitors will vary.

Flow Meters



Figure 4-23: Flow Meters

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 the furnace is used for one process only, flow meter settings can generally be left alone once the proper flow rates have been set.

4.6 Cooling Section (Option)

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 system 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 sometimes 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 can 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.

CMB30 or CMB45 Fan-driven Air Cooling (Option)

This open air cooling module is either 30 or 45 inches (76 or 114 cm) long. Axial cross-flow fans located above the belt 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 via an impeller powered exhaust duct. The top axial cross-flow fans and bottom impeller blowers are manually adjustable from the control panel.

4.6.2 Controlled Atmosphere Cooling

Where controlled atmospheres are required (typically because 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.

WC Cold-wall Water Cooling (Option)

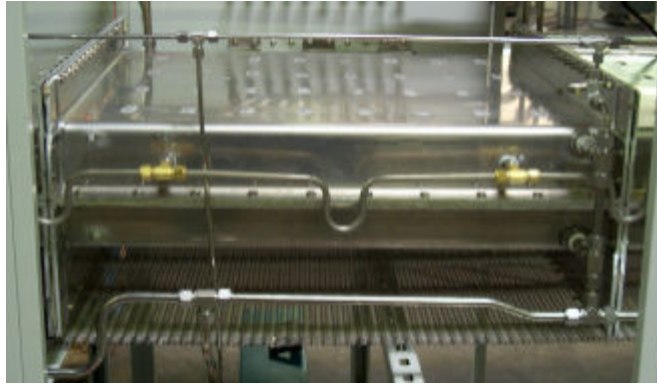


Figure 4-24: Water Cooled Controlled Atmosphere Cooling Module

Water cooling is used to ensure high rates of heat transfer while the product advances through the tunnel. The water cooled module is 20 inches long and has cold walls above and below the belt. Water plumbing lines are wrapped in insulation to prevent condensation. Water temperature at inlet source and at discharge is monitored as is water flow rate through the section. A separate flow meter (0-400 SCFH) controls the flow of gas through the air knife inside the section and, therefore, controls the cooling rate.

Owner supplied water must meet the following conditions:

- Average Flow Rate: 5 gpm
- Average Flow Pressure: 50 psig max.
- Maximum Inlet Temperature: 30°C or lower
- Water Quality: Facility supply

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 pressure (psig) specified in the installation diagram or facility drawing in the Owner's Manual.

CACT Closed Atmosphere Cooling Tunnel (Option)

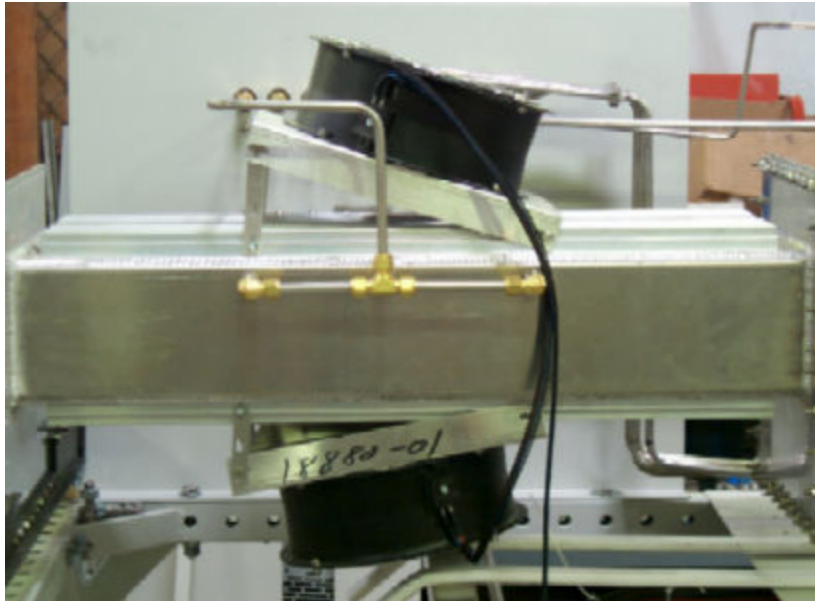


Figure 4-25: Controlled Atmosphere Air Cooled Module

Heavily finned aluminum heatsinks are attached to the outside of the cooling module which is not insulated to promote rapid heat loss. Hanging baffle gates and an air rake effectively isolate the high temperature furnace section from the controlled atmosphere cooling section. Adjustable rate fans direct air past the heat sink to remove heat transfer from the chamber. High-volume air knives inside the controlled atmosphere process section blow process gas around the parts inside to speed the cooling.

4.7 Heating Chamber Options

4.7.1 Air Filter (Option)



Figure 4-26: 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 μm impregnated fiber filtering element, manual drain, pressure gauge and regulator. The after filter is a 0.5 μm coalescing filter for water/oil removal with automatic drain. This combination unit reduces downstream oil contamination to 0.5 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.



Dual Compressed Air Tanks

Figure 4-27: Typical Air Purification Tanks

Air Purification System 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 heaters may be added to a furnace to provide more control over temperature uniformity across-the-belt inside the heating chamber. **In critical applications, especially in furnaces greater than 14 inches wide, properly adjusted edge heaters can enable greater use of the furnace width because they make possible a flatter temperature profile across the width of the furnace.**

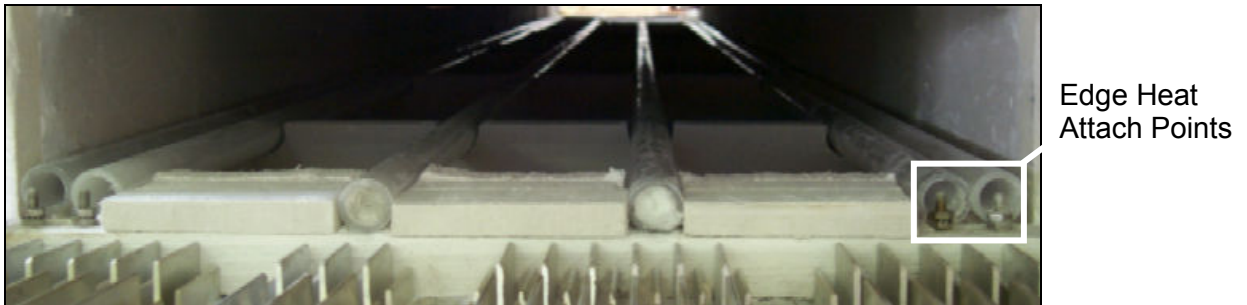


Figure 4-28: Edge Heaters

Carefully tuned nickel chromium resistance wires passed through quartz tubes inside the heating section increase the temperature at the edge of the conveyor belt. Left and right edge heaters are individually adjusted by the operator to reduce furnace delta T (temp deviation) and tune furnace performance. Edge heaters are a fine tuning device to be used in conjunction with the gas flow introduced through the chamber walls. Edge heaters are not designed to react to changes in chamber temperature and, therefore, should not be adjusted to dominate the temperature profile in any zone.

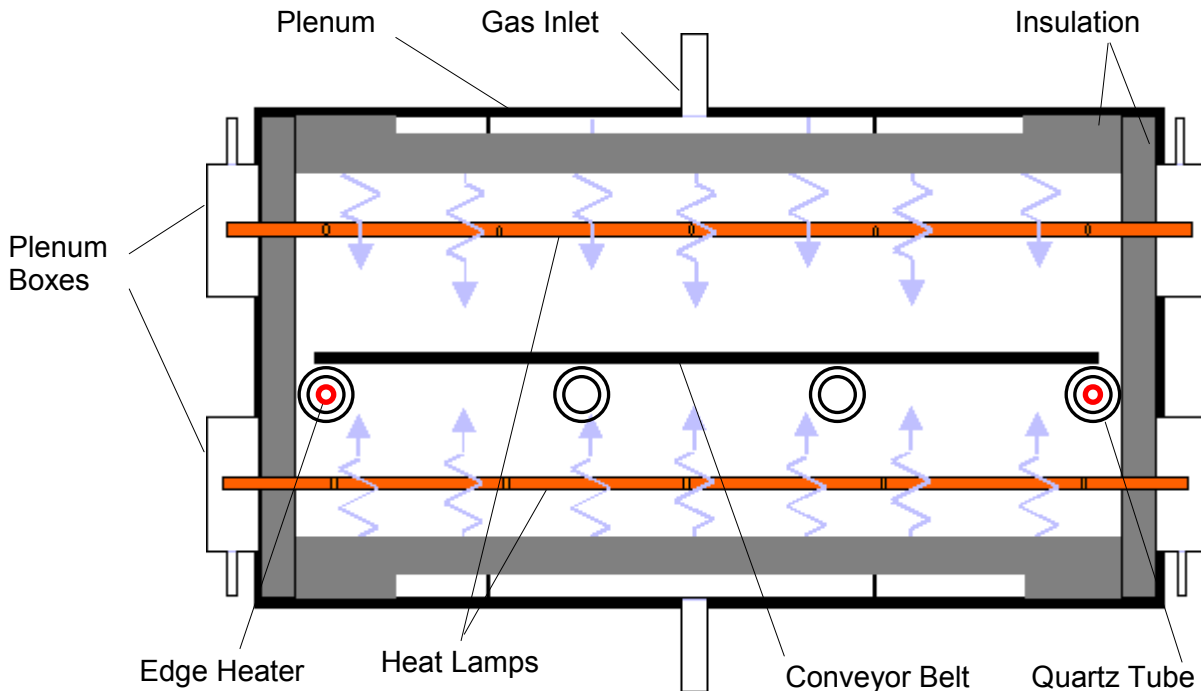


Figure 4-29: Cross Section of Furnace showing Edge Heaters

4.7.4 Element Monitor (Option)

A special network is used to monitor each heat lamp circuit. Return power from the lamps is passed through an inductive circuit which transmits a signal when current is lost. The signal is relayed to the furnace PLC controller which then signals an alert. Lamp failure is designed to not immediately shut-down the process. Until the zone temperature falls outside the alarm conditions set in the recipe, the furnace will continue to operate. However, the operator is alerted to an element (lamp) failure.

The Element Monitor Window is added furnace control software that provides active element status. Element Monitor software interface is not available to Operator level. It is described in more detail in Section 7.3.2 on p.69.

Note: The Element Monitor circuit does not function at power levels below 10% which is under the threshold of the sensor circuit. So any elements operating in this range are reported as “OK” regardless of their status.

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 each chamber to ensure that unwanted process offgas does not collect around the lamps or inside the process section. A plenum box surrounds the ends of the lamps and acts to duct controlled atmosphere gas to this area. 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.

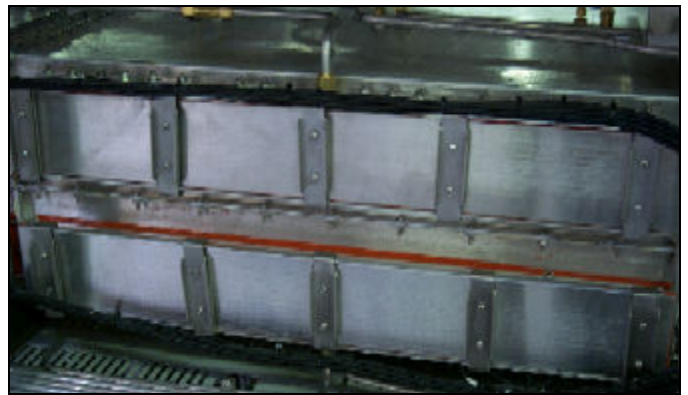


Figure 4-30: Plenum Box

4.7.6 Over Temp. Monitor (Option)

This option provides an independent zone temperature watchdog that monitors each zone and responds to set boundary conditions. A secondary thermocouple installed in each zone provides temperature sensor monitor and control redundancy. If an Over Temp condition is detected, the system is designed to automatically shut down the heat lamps, even if multiple components fail. The process engineer selects the maximum/minimum temperature. The system will shut down the heating elements if sensors detect that the temperature extends outside the predetermined range. The system factory default is set as an over-temperature alarm for 50°C above the maximum rated temperature of the furnace.

4.7.7 Oxygen Analyzer (Option)

Oxygen analyzers are regularly installed in controlled atmosphere furnaces to assist in monitoring O₂ levels at various points of the Furnace. Four sensors are installed: one to monitor the incoming source gas and three in the specified zones. O₂ levels are reported in parts per million (PPM) on the Process Screen.

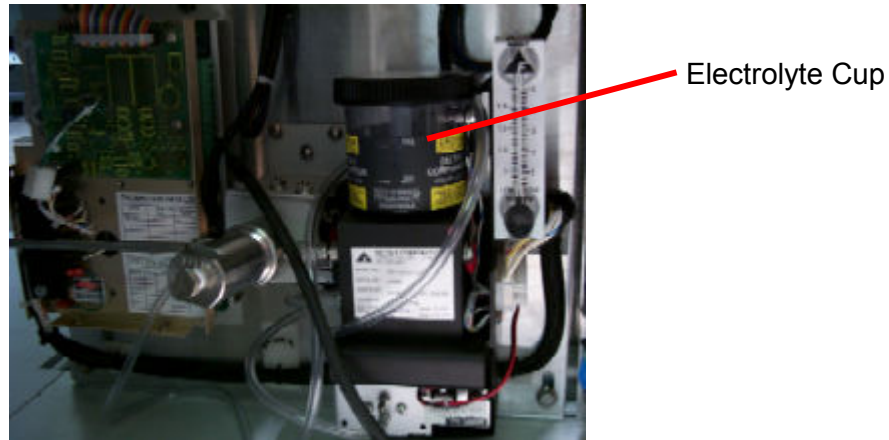


Figure 4-31: Oxygen Analyzer

Software Control (Oxygen Analyzer)

To select the sampling port:

From the Process Screen, click on the [O₂ / MA Sampling](#) button.

From the Recipe Screen, click on the [O₂ Sampling Port](#) button.

The following window will appear.



Figure 4-32: 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.

4.7.8 Moisture Analyzer (Option)



Figure 4-33: 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.

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

5.1 Windows Interface

Process parameters are entered and viewed on a computer workstation (PC) using a Microsoft Windows® operating system. 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 convenient for cycling through loaded application windows. The ProControl™ furnace software application screens 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.

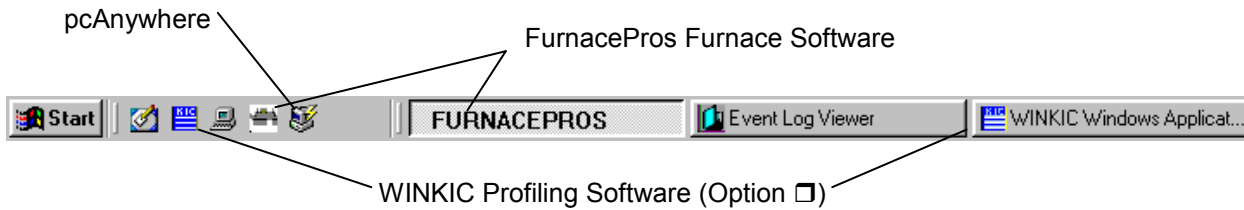


Figure 5-1: FurnacePros Furnace Windows Start Bar

The following icons should also appear on the desktop.

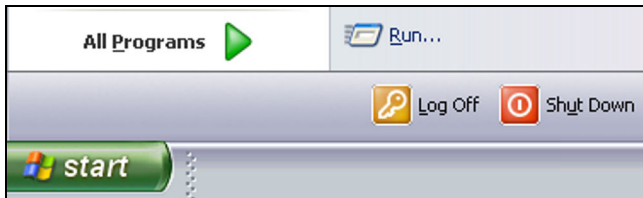


5.2 Startup Screen



When the furnace is started using Power On button to the left of the keyboard, the furnace software will automatically boot.

If the user does not want the furnace software to boot automatically, remove the furnace shortcut from the start menu. (See Windows help topic “Starting Programs at startup”). The furnace program can be accessed from the desktop by pressing the [Furnace](#) button or by selecting Windows [start\All Programs\Furnace](#).



Windows Start menu

When the furnace software boots the following screen will appear.



Figure 5-2: FurnacePros Furnace Software Startup screen

5.3 Security Screen



Before you can begin furnace operation, the user must log-on. Move to the security screen by clicking on the [Security](#) button at the bottom of the Startup screen.

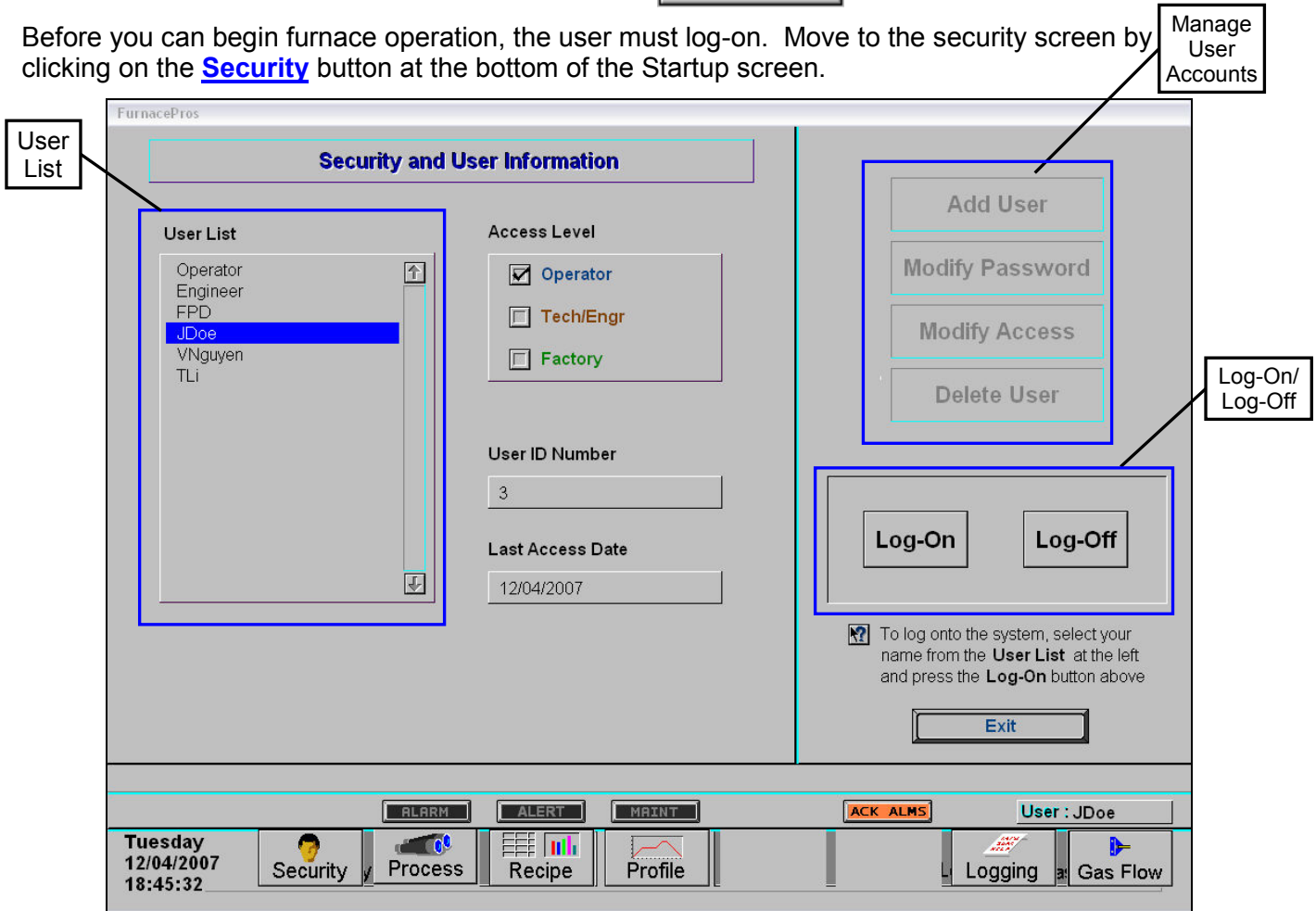


Figure 5-3: Security screen

The security screen contains the following field groups (see Figure 5-3).

Fields and Field Groups	Description
User List	A list of Users appears in the User List group. Operator, Engineer and FPD are the default settings. Change this list using Manage User Accounts .
Access Level	When a User ID is highlighted, a check-box will automatically be selected in the Access Level group indicating the level of access permitted to that user. User ID Access level control prohibits operator level access users from adjusting process recipes or making other changes to important furnace operations.
User ID Number	The software assigns a integer to each User. The logging screens track user activity by User ID Number including time of log-on and log-off.
Last Access Date	Displays date the highlighted user last accessed the software.
Manage User Accounts	Users, passwords, and access levels are modified by the User Accounts group using the Add User , Modify Password , Modify Access and Delete User buttons.
Log-On, Log Off group	Log-On to gain access to the other screens and to exit the furnace control software using the Log-Off button.
Exit	Press Exit to close the furnace program. You must first Log-Off or the program will Log-On the last user upon reboot of the furnace software.

5.3.1 Log-On & Log Off

To log on, highlight a user name in the User List and click the [Log-On](#) button.

The [Enter Password](#) pop-up window will appear.

Type in the correct User ID password and press [OK](#) to complete the login process.

To Log-Off a user: navigate to the Security screen and click the [Log-Off](#) button.

To Close the furnace program: navigate to the Security screen, Log-Off and click the [Exit](#) button.

Note: you can restart the furnace program and bypass Log-On if you do log off. In this case, the last user will be automatically be logged on.

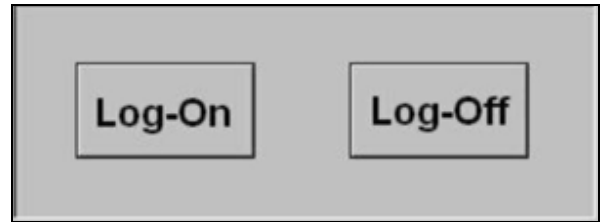


Figure 5-4: Log-On Log-Off group

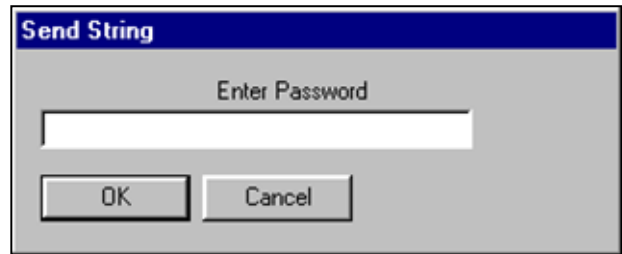


Figure 5-5: Exit button



Figure 5-6: Exit button

5.3.2 User List

When the furnace software is installed, the following default user names and passwords are installed and listed in the User List.

User Name	Password	Access Level
OPERATOR	1 or 0000	1: Operator
TECH/ENGR	2 or 0000	2: Tech/Engr
Factory	***FP access only***	3: Factory

Engr/Tech Access Level can add additional users (see following example).

User Name	Password	Access Level
JDoe	user config	1: Operator
VNnguyen	user config	1: Operator
TLi	user config	2: Tech/Engr

Use the User Account group buttons to manage changes to user names, passwords and access levels.

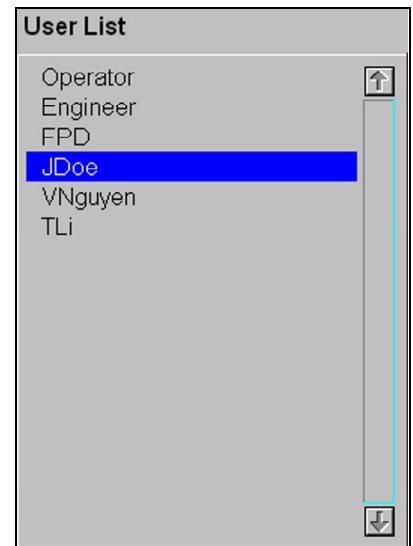


Figure 5-7: User List

5.3.3 Manage User Accounts

To access User Accounts, a User with access level 2 Tech/Engr must be logged on. The Manage User Accounts menu on the top right of the screen will appear shaded while an Operator is logged on. Through this menu, access level 2 users can designate other user names for login and recording purposes, modify passwords and access levels, and delete users.



Figure 5-8: Manage User Accounts

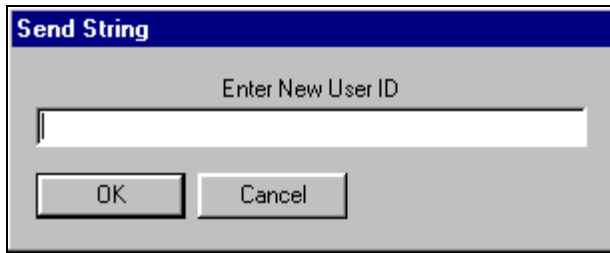


Figure 5-9: New User ID pop-up window

New user names are added by selecting the [Add User](#) button.

The [Enter New User ID](#) pop-up window will appear.

Enter the User ID (user name) and click [OK](#). The system will then assign a User ID number.

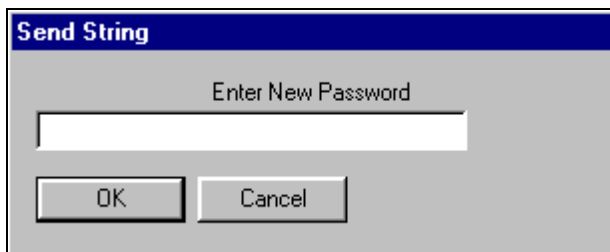


Figure 5-10: New User Password pop-up

Note: After a new user is added, the new user's password and access level must be entered.

Click [Modify Password](#) and the [Enter New Password](#) pop-up window will appear.

Enter the new User Password and click [OK](#).

Click [Modify Access](#) and the [Enter Access Level](#) pop-up window will appear. At the [Access? \(1,2,3\)](#) prompt enter the level of access the new User ID will possess according to the following table.

Level #	Access Level
1	Operator
2	Tech/Engr

The User ID's (user names) appearing in the [User List](#) will now reflect the added user ID.

To Delete a user or Modify Access level for a user press the respective button and follow the pop-up window instructions.

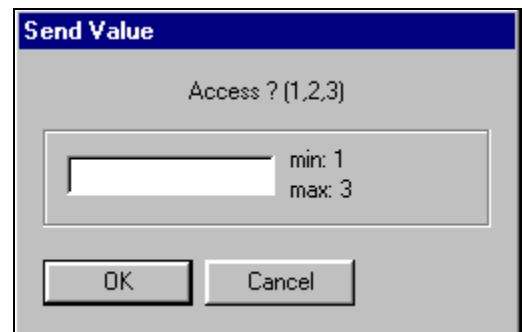


Figure 5-11: New User Security Access Level assignment window

5.4 Available Functions by Access Level

5.4.1 Operator Level Access

The following screens can be accessed with Operator level access. Operator access is restricted as noted:

<u>Screen Name</u>	<u>Restrictions</u>
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 Tech/Engr and Operator 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 will be covered later in section 7.

5.4.3 Factory Level Access

Factory level access is limited to the manufacturer. This level provides manufacturer's authorized technicians access to the system initial setup screens. Factory level access by others will void the warranty.

5.5 Operator Level Interface

5.5.1 Pre-Start Purge

The Operator should always assure that the plant air compressor is operating and the valves are open and clean dry air is supplied to the furnace. The Operator should also assure that the flow valves are properly set (factory default is provided in the Owner's manual) to assure flow to the exhaust stacks and the furnace zones.

5.5.2 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 5-12.

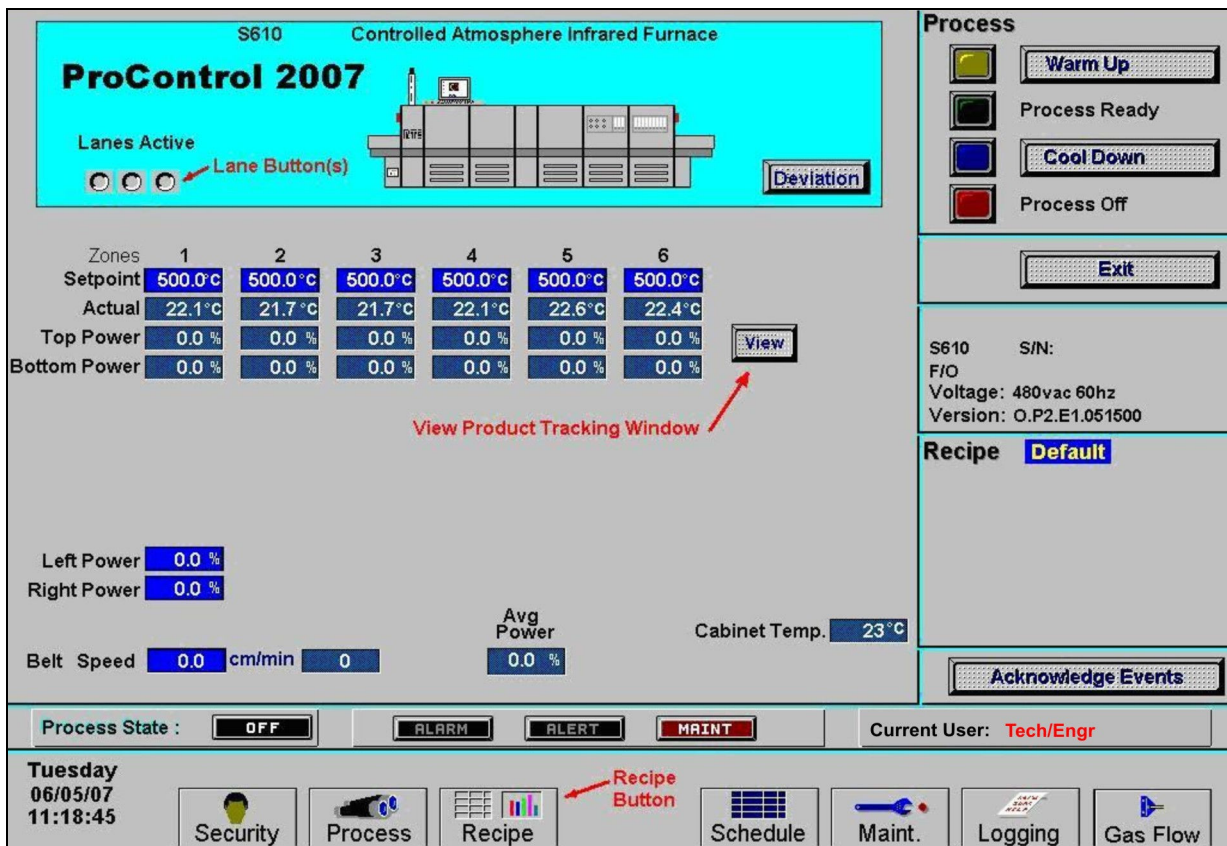


Figure 5-12: Process Screen

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. In the example below the recipe name is **Default**. Please refer to “Saving and Retrieving Recipes” under Section 5.5.3 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.

5.5.3 Recipe Screen



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 5-13.

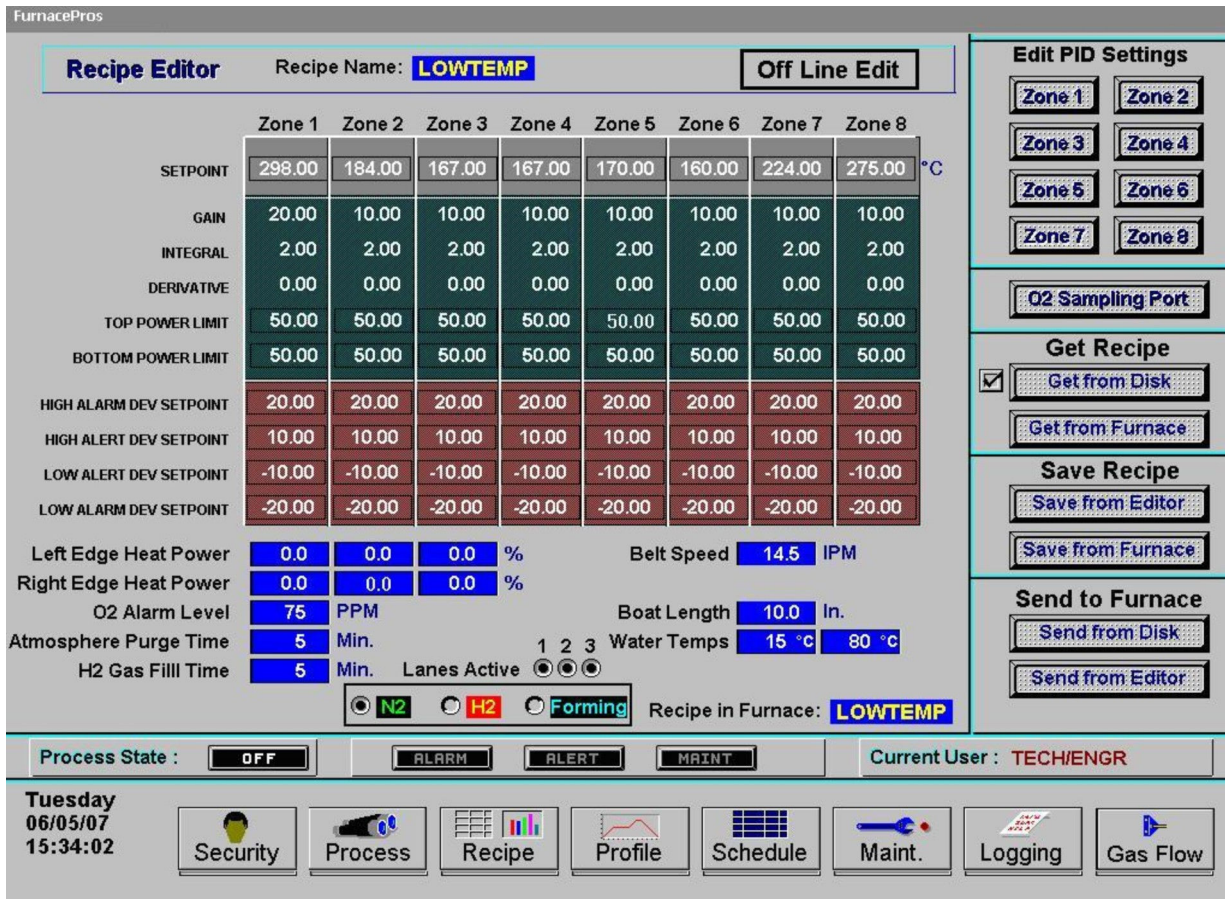


Figure 5-13: Recipe Screen (Operator Level Access)

Recipe Overview

In order to start a thermal process, an operator must load the appropriate recipe to the furnace programmable logic controller (PLC). The recipe contains all the information for operation of the furnace for a particular process or product. The computer is used to create, modify and load a recipe onto the PLC. However, once a recipe is loaded into the furnace, the computer (PC) is not critical to the operation of the furnace. The independent PLC installed inside the furnace will follow the recipe instructions, start and continue the process. If a parameter outlined in the recipe creates an alarm with shutdown 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.

As seen in Figure 5-13, 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 current operating temperature setpoints.

Saving and Retrieving Recipes

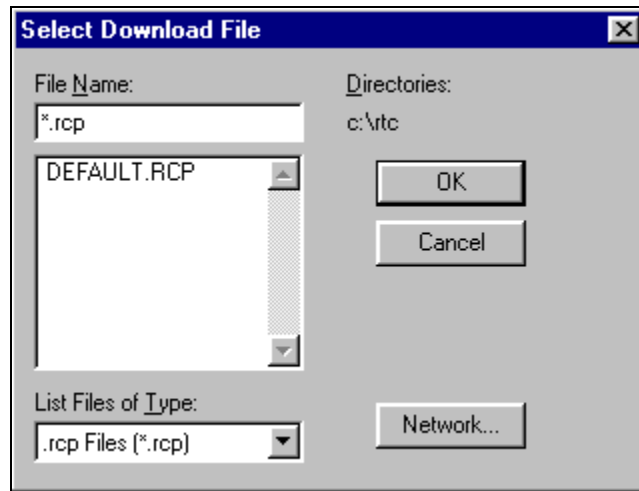


Figure 5-14: MS Windows Browsing Pop-up

Recipes can be stored on the computer hard disk or on one of the following portable mediums: a USB jump drive, removable disk (drive A:) or compact disc (CD).

On the right side of the Recipe Screen are buttons for saving and retrieving recipes. To load a recipe, the operator must know the name of the recipe file. Furnace software recipes are listed with a Windows extension of (*.rcp).

To view a recipe before loading it to the furnace PLC controller, click the [Get from Disk](#) button. The window in Figure 5-14 will appear.

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

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

To load a recipe to the furnace without first looking at it, click the [Send from Disk](#) button.

The same window pictured in Figure 5-14 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 PLC controller.

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


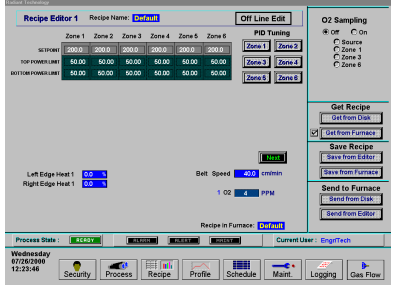

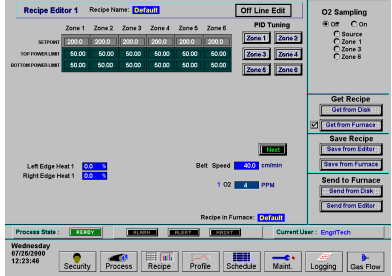



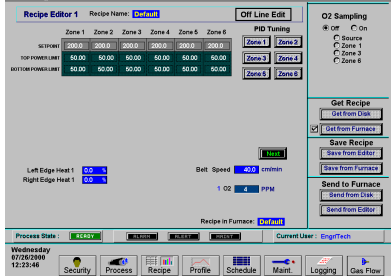

ACTION	FROM	TO
<p>Get Recipe To Load recipe to the editor, press:</p> <p>Get from Disk</p> <p>Loads recipe to editor from selected source. Choices include from removable disk or hard drive.</p>		 <p>Recipe Editor</p>
<p>Get from Furnace</p> <p>Loads recipe to Editor that is currently stored in the furnace PLC controller”</p>		
<p>Save Recipe To Save recipe to computer:</p> <p>Save from Editor</p> <p>Saves recipe on screen to selected destination: removable disk or hard drive.</p>		
<p>Save from Furnace</p> <p>Saves recipe running on furnace PLC controller to selected removable disk or hard drive.</p>		<p>Hard disk or removable disk</p>
<p>Send to Furnace To load a recipe into the Furnace controller:</p> <p>Send from Disk</p> <p>Copies a user selected recipe from the hard drive or portable medium directly to the furnace PLC controller.</p>		
<p>Send from Editor</p> <p>Copies the recipe currently displayed in the Editor to the furnace PLC controller.</p>		 <p>Furnace PLC Controller</p>

Figure 5-15: Recipe Storage and Retrieval


5.5.4 Logging Screen



The furnace is supplied with logging software. The Logging function allows the owner to keep a detailed record of furnace events. The following is a list of the events that are recorded in the “Event” file.

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 in Figure 5-16.

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.

5.5.5 Viewing Logged Data

Each day a furnace is in full operation, the interface PC creates two files, and places them in the C:\FP 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.

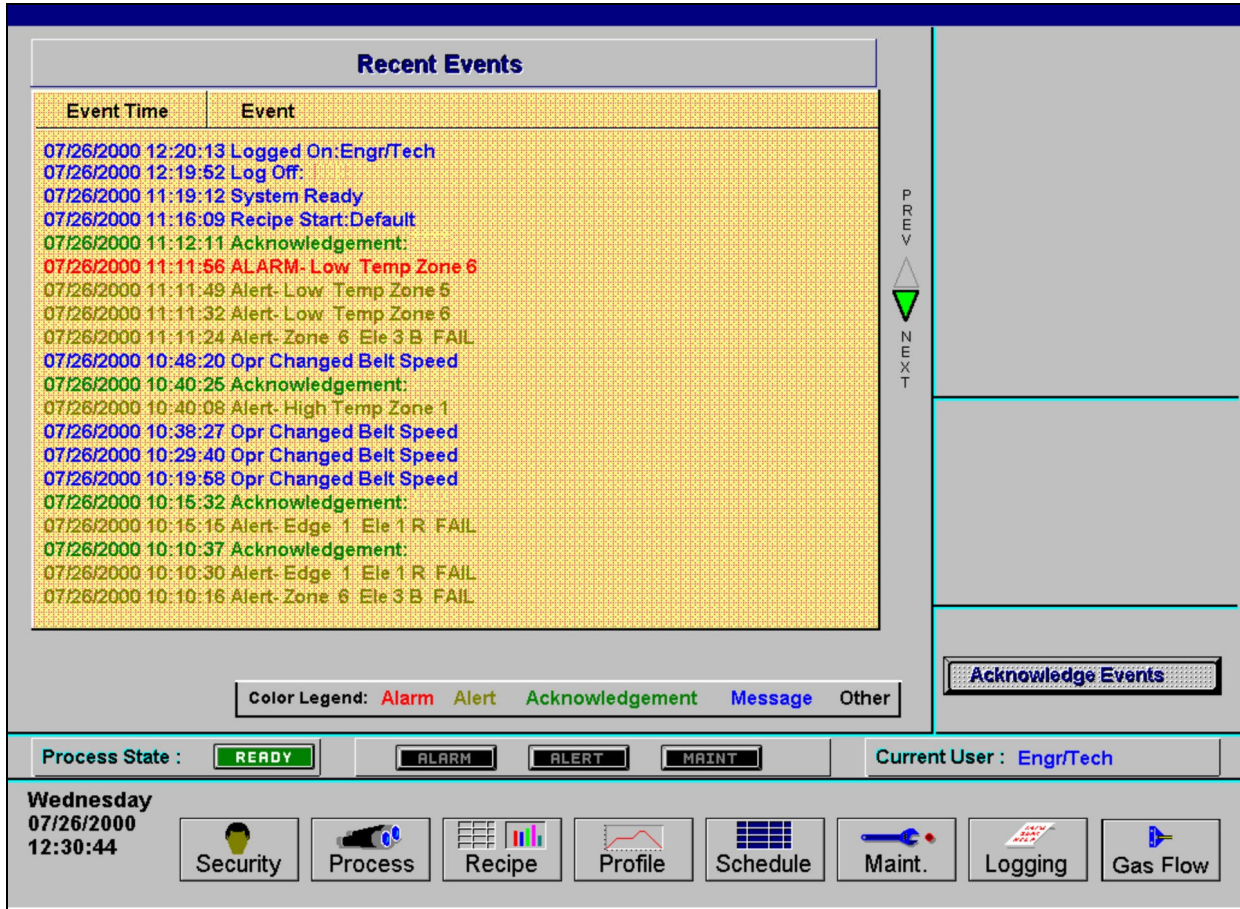


Figure 5-16: Logging Screen

5.5.6 Text Editing

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

5.5.7 Excel Import

The log files can also be conveniently imported into Microsoft Excel®.

5.6 Alarms

Alarms are audible and visual signals that the furnace has reached a state where the operator's attention is required.

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 in Figure 5-17: Alarm Monitor Pop-up Window.

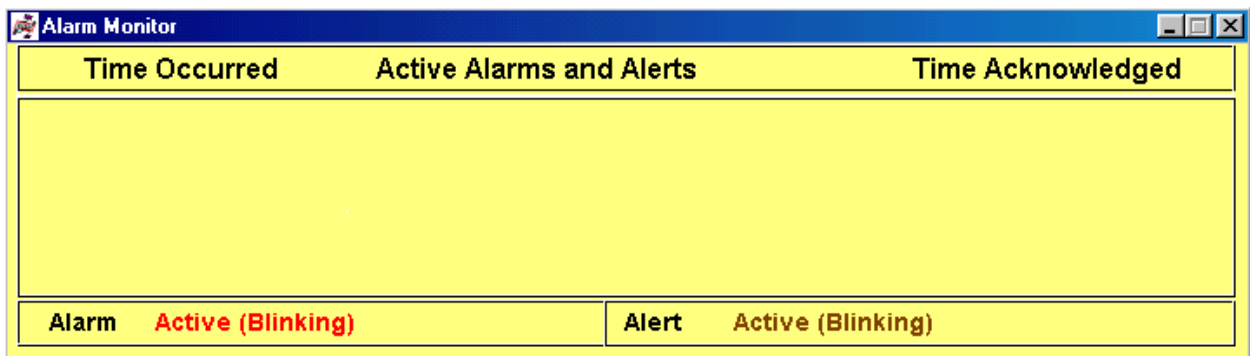


Figure 5-17: Alarm Monitor Pop-up Window

If you click on the pop-up window, the furnace software will automatically bring up the Logging screen behind the [Alarm Monitor](#).

Acknowledge Events



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 only available from the maintenance screen and is not accessible the operator. Details of this option are discussed further in Section 7.3.2 on p.69.

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 engineer or operator 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 5-18.



Figure 5-18: Thermocouple Interface

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

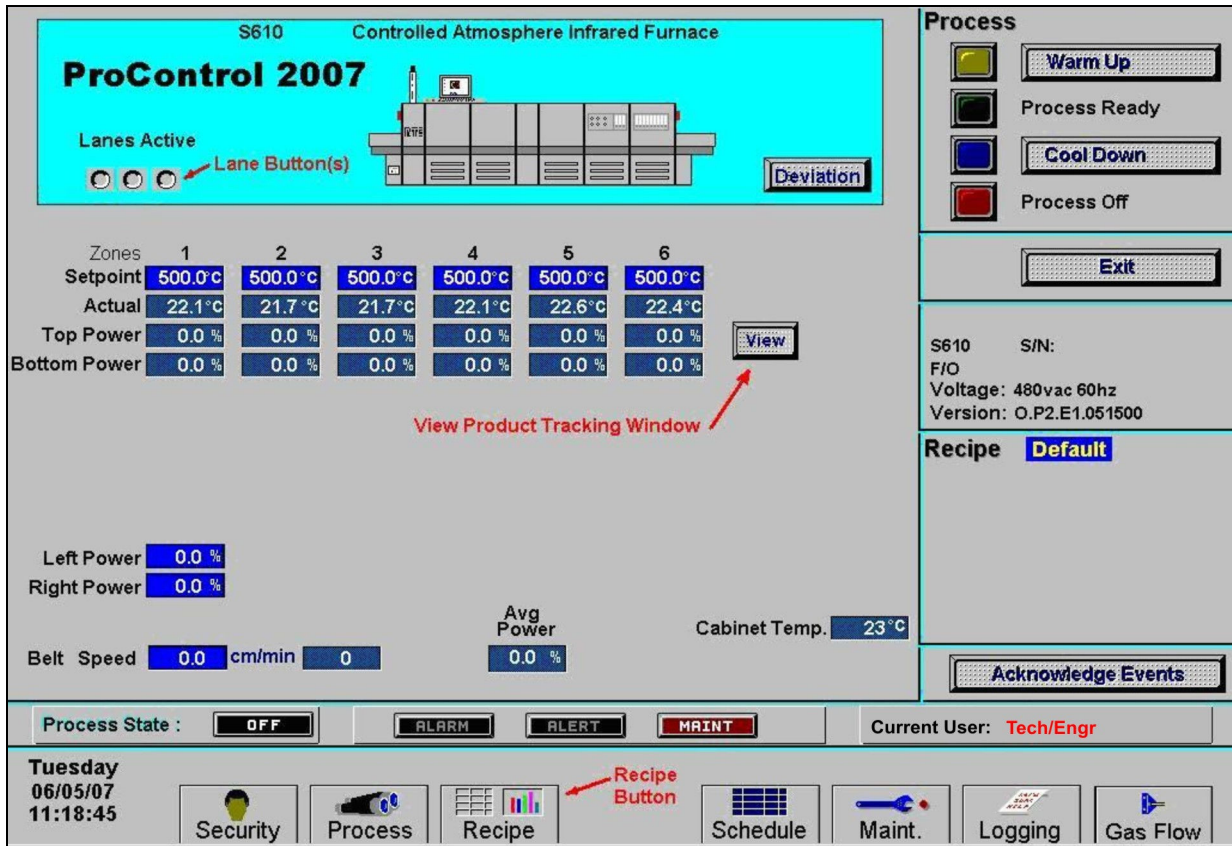


Figure 5-19: Process Screen Highlighting Lane Button, View Button and Recipe Button

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](#) (Figure 5-20).

Recipe Editor 1 Recipe Name: **Default** **Off Line Edit**

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
SETPOINT	270.0	245.0	245.0	245.0	245.0	285.0
TOP POWER LIMIT	60.00	60.00	60.00	60.00	60.00	60.00
BOTTOM POWER LIMIT	10.00	20.00	20.00	15.00	15.00	20.00

PID Tuning

Zone 1 Zone 2
Zone 3 Zone 4
Zone 5 Zone 6

Next

Left Edge Heat 1 **0.0** %
Right Edge Heat 1 **0.0** %

Belt Speed **17.0** in/min

Product Length Box → **Product Length** **5.5** in

Recipe in Furnace: **Default**

Get Recipe
Get from Disk
 Get from Furnace

Save Recipe
Save from Editor
Save from Furnace

Send to Furnace
Send from Disk
Send from Editor

Figure 5-20: Recipe Screen Highlighting Product Length input field box

A pop-up window labeled [Send Value](#) will appear as seen in Figure 5-21. Define the product-unit length in the product length window, and click [OK](#).

Send Value

Enter Product Length

5.5 min: 0 max: 100

OK Cancel

Figure 5-21: Send Value window

5.7.5 View Product Tracking



To view the product tracking window, return to the recipe screen shown in Figure 5-19 above and click the [View](#) button. Figure 5-22 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.

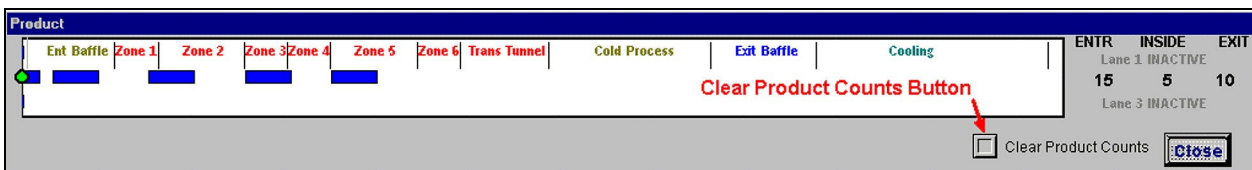
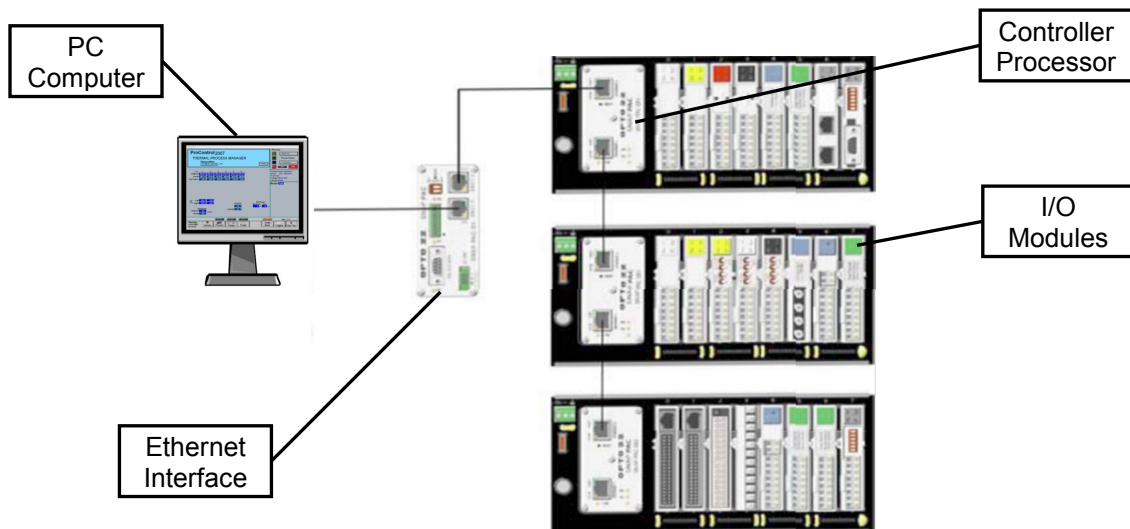


Figure 5-22: Product Tracking Window
Highlighting the [Clear Product Counts](#) Button

6.1 Conceptual Overview

An industrial controller is installed to organize signals throughout the furnace and relay information to the interface PC. The controller is the communication center for all furnace operations. Analog and digital relays provide sensory and feedback information via I/O modules to the controller which then regulates power, changes settings and sounds alarms.

Figure 6-1: Controller Overview



6.2 Terminology

6.2.1 PLC

The furnace controller is an industrial programmable logic controller or PLC. The software logic that the controller employs is downloaded from the PC to the controller memory. The PLC receives data from the furnace, sends information to the PC and controls the furnace. Thermocouple sensors and gas sensors are the main inputs to the PLC. The PLC 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.



Industrial PLC

6.3 Data Flow

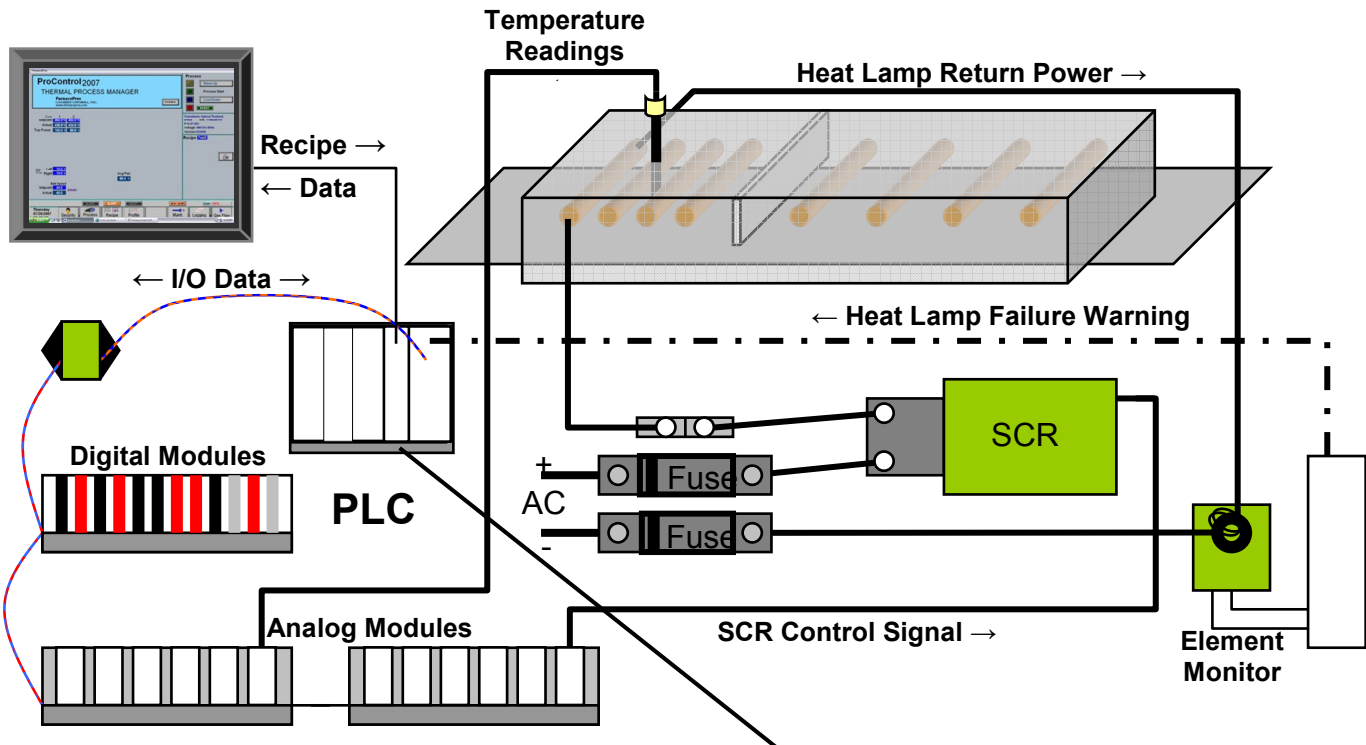


Figure 6-2: Control Data Flow

6.4 Ethernet Location

An Ethernet interface is provided as the communication device between the furnace Controller and the interface PC. The Ethernet card inside the controller is installed just to the left of the Controller in the Controller housing (Figure 6-3).

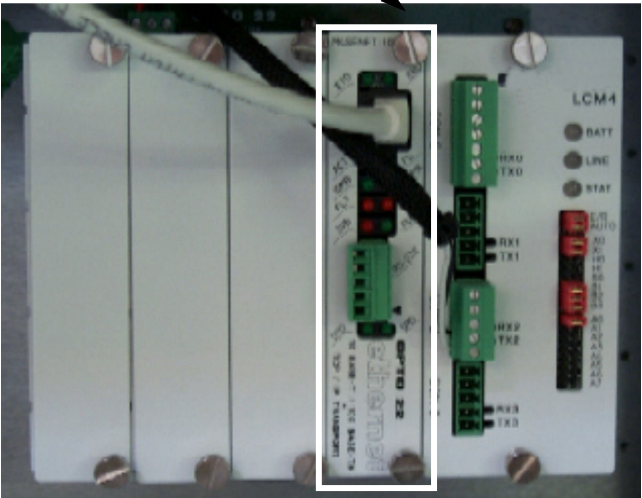


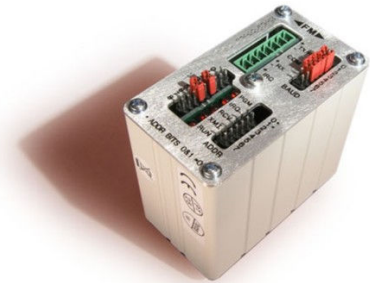
Figure 6-3: PLC Controller Ethernet Interface

6.5 PLC Components

6.5.1 PLC CPU

The CPU is a high-performance processor used to remotely control analog and digital I/O modules. The CPU connects to the controller over an RS-485 serial link. CPU functions include PID loop control, latching, counting, totalizing, thermocouple linearization, and waveform generation.

The CPU is mounted on a rack with up to 8-16 analog, digital, and serial I/O modules.



PLC CPU
322-094410-01

6.5.2 PLC Power Supply

The power supply (120 VAC input) can provide 5 VDC power for loads up to 4 amps. This compact, sturdy supply includes a built-in fuse, an LED status indicator, and an ON/OFF power switch for ease of use.

The SNAP-PS5 provides 5 VDC power for a SNAP PAC rack with an I/O processor and I/O modules mounted on the rack.



PLC Power Supply
322-094408-01

6.5.3 PLC Communication

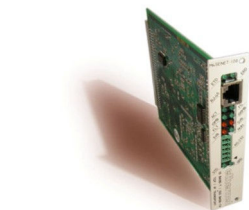
The LCM4 is a powerful industrial controller that provides real-time control and communication to input/output (I/O) systems, serial devices, motion controllers, and networks.



LCM4 Controller
322-092246-03

6.5.4 Ethernet Interface

The Ethernet Module provides an Ethernet interface for the LCM4 Controller. Connection is via a 10Base-T or 100Base-TX link, and standard TCP/IP transport is used for all transactions between the furnace Computer and the PLC Controller.



Ethernet Module
322-092246-04

6.5.5 PLC I/O

Furnace devices communicate analog and digital signals with PLC Controller input and output or I/O modules. Input modules receive furnace status data from sensors. The controller sends signals to the furnace via output modules to control furnace operation and provide audible and visual alarm indication.

Analog In

Specially calibrated analog input modules accept analog temperature input from type K thermocouples mounted in the chambers and furnace cabinet.

Analog Out

Analog output modules provide analog voltage signals to control power supplied to the heating elements, edge heaters (if supplied) and belt drive motor.

Digital In

Digital In modules provide four channels of high-speed digital input. Each channel senses the on/off status for DC voltages from sources such as transport motion fault and belt speed feedback. Each module has removable top-mounted connectors for easy access to field wiring, as well as channel-specific LED's for convenient troubleshooting.

Digital Out – AC

Four channels of 12-250 VAC digital output are supplied from each Digital Out module, each switching a separate AC load including light tower lamps. AC outputs use zero voltage turn on and zero current turn off for transient-free switching. The module has removable top-mounted connectors to provide easy access to field wiring and features channel-specific LED's for troubleshooting.

Digital Out – DC

Digital Out modules supply four isolated channels of 5-60 VDC digital output, each switching a separate DC load such as the alarm horn. Each module features manual-on/manual-off/automatic switches that override output from the application and are ideal for testing field device wiring.



**Analog In Thermocouple Module
PN 322-094405-01**



**Analog Out Module
PN 322-094402-01**



**Digital In Module
PN 322-094406-01**



**Digital AC Output Module
PN 322-094401-01**



**Digital DC Output Module
PN 322-094412-01**

Chapter 6

6.5.6 Channel Assignments

Standard channel assignments are listed in Figure 6-4 Typical Channel Assignments - Windows Environment. This listing shows the assignment, channel number and function of the PLC inputs and outputs (I/O). See the Owner's Manual Drawings section for the as delivered equipment settings.

FURNACEPROS
DIV LOCHABER CORNWALL

FurnacePros
675 N. Eckhoff St. Bldg. D
Orange, CA 92868

Furnace Channel Assignments

Customer: ****Customer****

LAYOUT			Factory Order: 326xx		
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

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 6-4 Typical Channel Assignments - Windows Environment

Notes:

7.2 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.

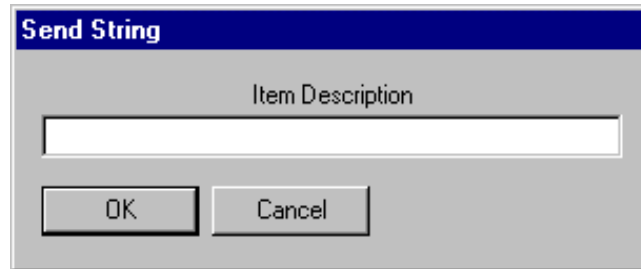


Figure 7-2 User Selectable Maintenance Description

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.

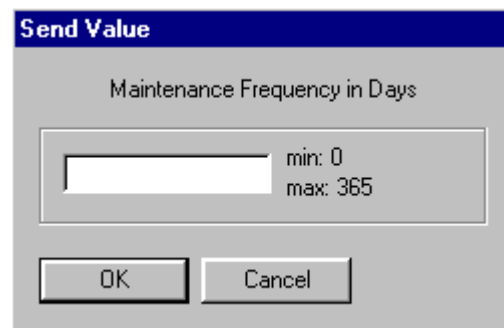


Figure 7-3: Maintenance Frequency Dialog Box

Enter the desired maintenance frequency in days.

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

7.3 Furnace Calibration

To access the Calibration Screen, go the [Maintenance](#) Screen.



Click on the [Calibrate](#) button as shown below.



The following pop-up window will appear.

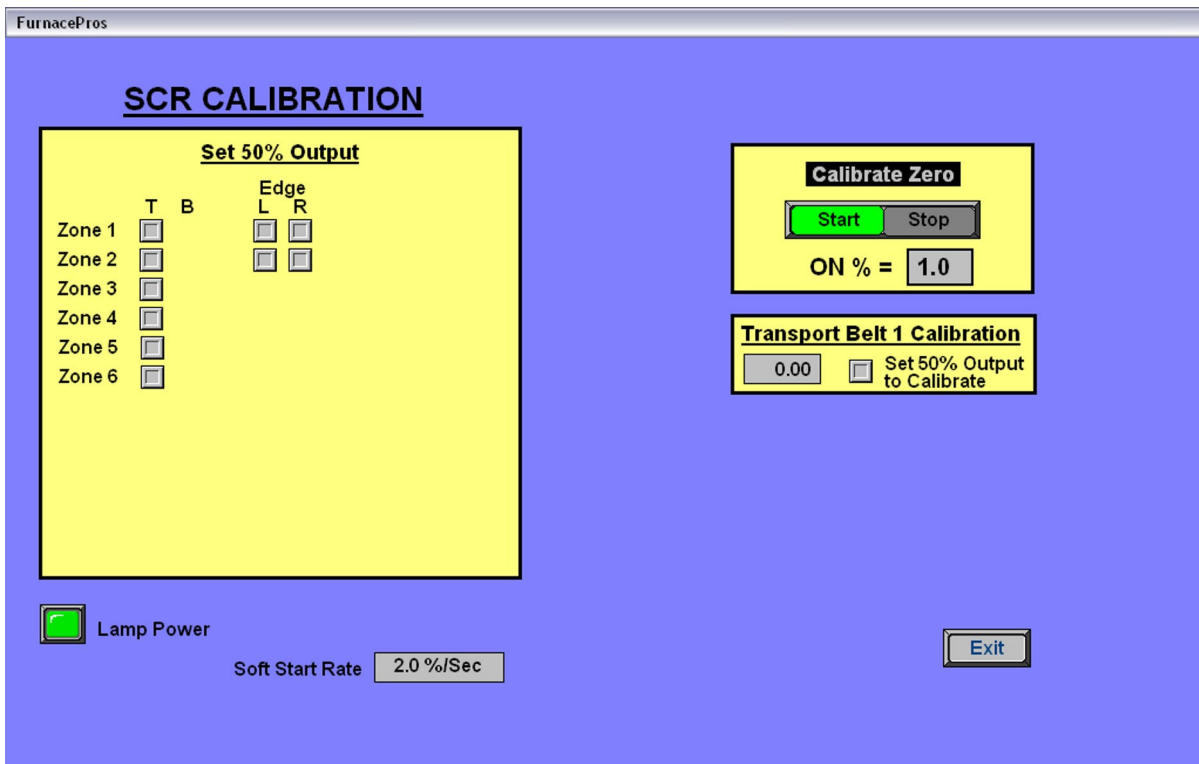


Figure 7-4: Calibration pop-up window

7.3.1 SCR Calibration

SCR calibration is an important part of maintaining consistent thermal process profiles. To complete the calibration, each SCR will need its ZERO trimpot and SPAN trimpot adjusted. ZERO and SPAN controls allow the user to calibrate each SCR output to the process command signals from its respective PLC Analog Output module. Due to some interaction between the ZERO and SPAN controls, it may be necessary to repeat these adjustments several times.

Tools Required: True RMS or Peak-Responding Voltmeter

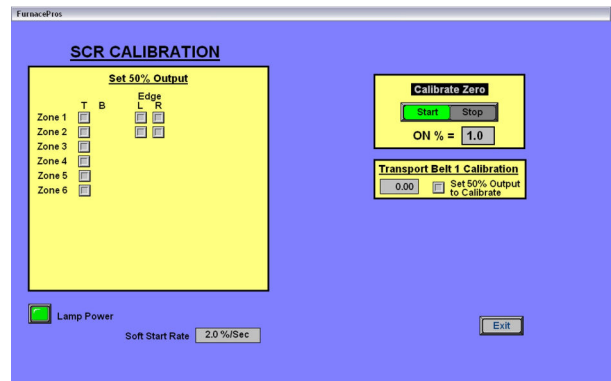
Step 1: ZERO the SCR

From the on-screen 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 voltage is now present at the SCR's!



- Go to the furnace cabinet side panel and start with one SCR. It is recommended that you choose an orderly pattern that will leave all SCR's adjusted.
- Locate the Command Indicator, a green Light Emitting Diode (LED) located between the ZERO trimpot and SPAN trimpot on the SCR module. The intensity of this LED will vary with the output of the unit. The correct ZERO trimpot setting is at the point where the LED cycles between no light and partially illuminated.

If the LED is illuminated:

Turn the ZERO trimpot screw until the LED goes out. Do not turn the screw any further. Go to the next SCR.

If the LED is not illuminated when you first observe it:

Turn the ZERO trimpot screw until the LED illuminates and then turn the screw the opposite direction until the LED goes out. Go to the next SCR.

If the LED never illuminates:

Try setting the value in the [On %](#) field in the [Calibrate Zero](#) box to any value between 0.5 and 2.0 and go back to step e) above. If the SCR still does not calibrate, the SCR may be damaged. Contact FurnacePros Technical Support for further assistance.

- Repeat this process for all SCR's.
- When the ZERO adjustments are finished for all SCR's, select the [Stop](#) button in the [Calibrate Zero](#) box of the Calibration pop-up window. This action will remove the high voltage from the SCR's.

Step 2: Adjust the SPAN

The PLC Analog Out modules apply a DC signal over a range of 0-5 Vdc or 0-10 Vdc to the command input on each SCR module. The RMS voltage applied to the lamps from the SCR Output varies linearly with this DC command signal applied from the Analog Out.

Chapter 7

Calculate the full scale RMS voltage by multiplying the peak or supply voltage by 0.707.

$$\text{RMS Voltmeter Reading} = (\text{Peak Voltage}) \times 0.707$$

For Example:

$$170V_{rms} \approx 240V_{AC} \times 0.707$$

$$270V_{rms} \approx 380V_{AC} \times 0.707$$

$$340V_{rms} \approx 480V_{AC} \times 0.707$$

$$390V_{rms} \approx 550V_{AC} \times 0.707$$



DANGER: High voltage is now present at the SCR's!

Remember: this RMS value is your target for setting the SPAN on each SCR.

a) From the SCR Calibration window, in the [Set 50% Output](#) box, select the checkbox for the first SCR (Zone 1-T). See the following examples to understand how the SCR's are referenced:

Zone 1, column T is the SCR controlling the top lamps in Zone 1

Zone 1, column B is the SCR controlling the bottom lamps in Zone 1

Edge (row 1, column L) is the SCR controlling the first edge heater on the left side of the furnace (facing the furnace entrance).

Edge (row 2, column R) is the SCR controlling the second edge heater on the right side of the furnace (facing the furnace entrance).

b) Locate the selected SCR in the electronics cabinet and connect a true RMS or peak-responding voltmeter across the load.

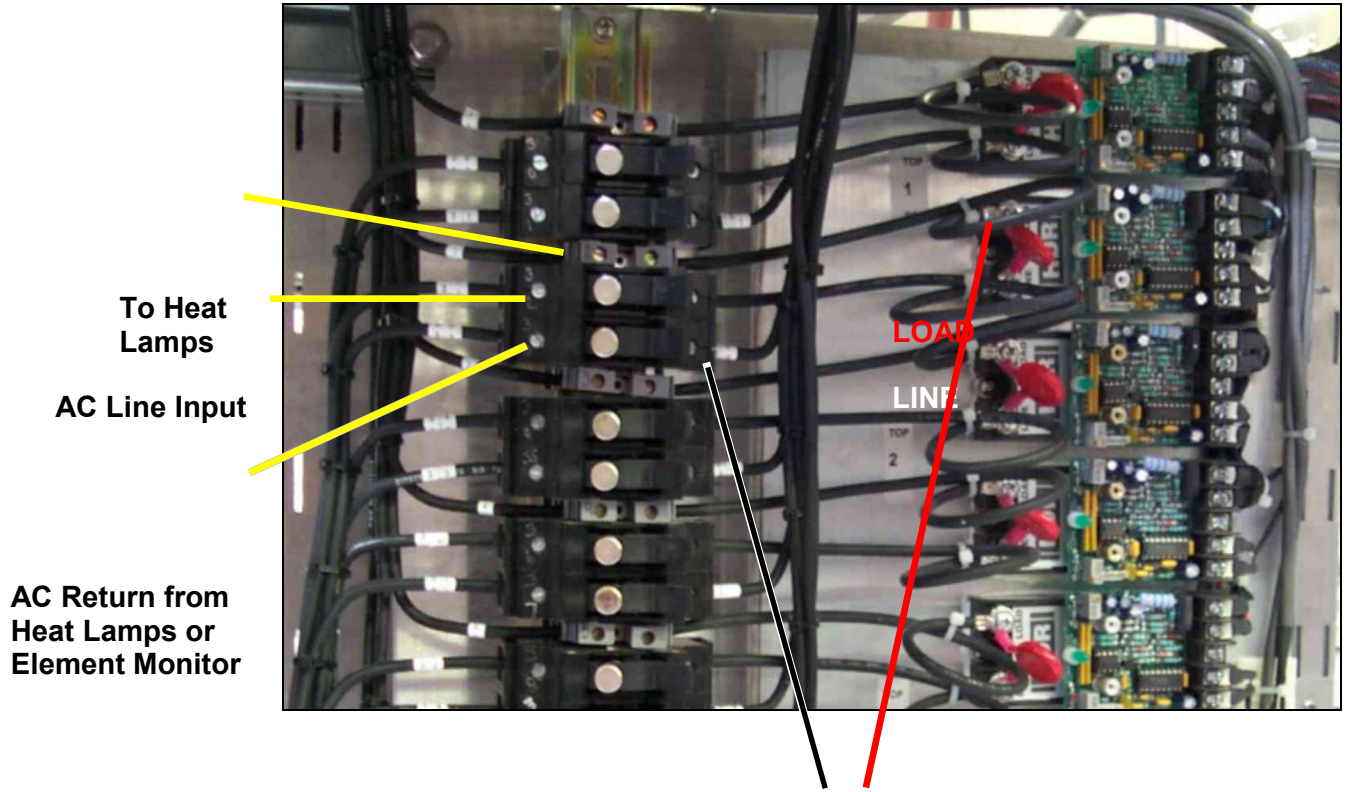
c) Adjust the SPAN trimpot screw until your meter shows the correct RMS target value (remember to adjust for the RMS value – not peak! – if you are using a peak-responding voltmeter). Clockwise adjustment increases the output while counter-clockwise adjustment decreases the output.

d) Repeat this procedure for all SCR's, selecting the SCR's one at a time as was performed in step a) above.

e) During this process, the lamps are on with 50% power being supplied. Because of the possibility of overheating, power supplied to the lamps will shut off after two minutes. Please note that while the PLC is applying a command signal for 50% power to the lamps, you should be setting the SPAN for the full RMS target value.

Note: DO NOT open Fuse Blocks for SCR Calibration





**Test Voltage Drop Here
For Span Adjustment**

Span Trimpot

LOAD

LINE

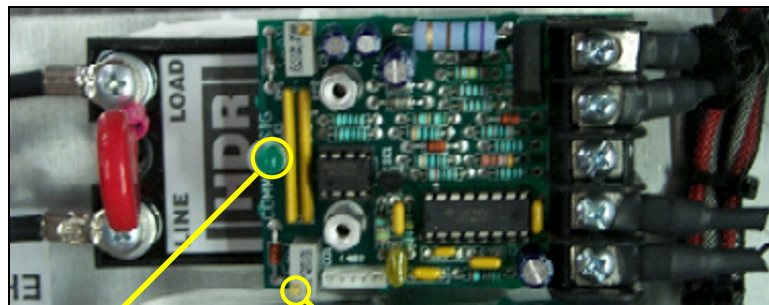


Figure 7-5: SCR Calibration Diagram & SCR Detail

LED

Zero Trimpot

Belt Speed Calibration

Tools Required: Tape Measure & Stop Watch

- 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.

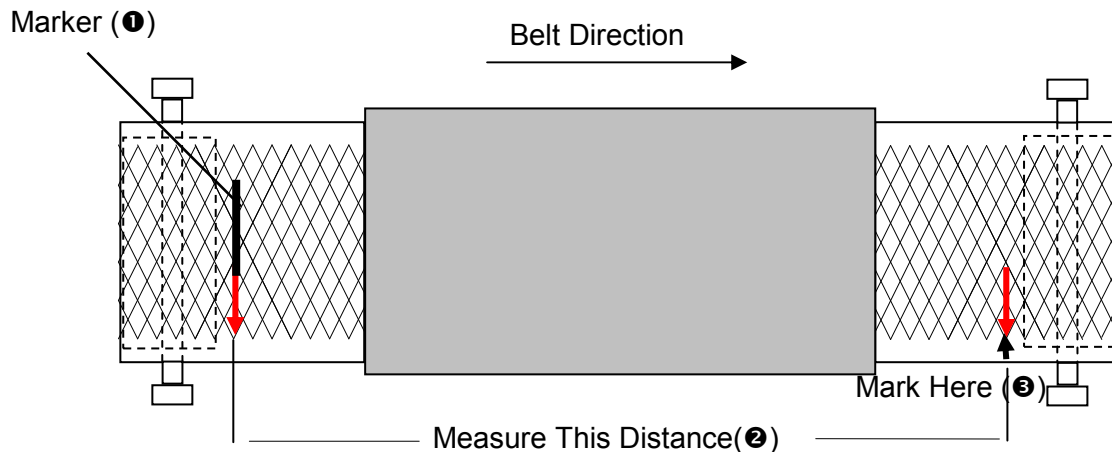


Figure 7-6: Belt Speed Calibration Diagram

- ❹ Click on the [Set 50% Output](#) 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 **step ❷** above to inches.

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

Compute the speed according to the following equation:

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

Enter this value in the [Transport Belt Calibration](#) dialog box.

Select the [Done](#) button.

7.3.2 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.

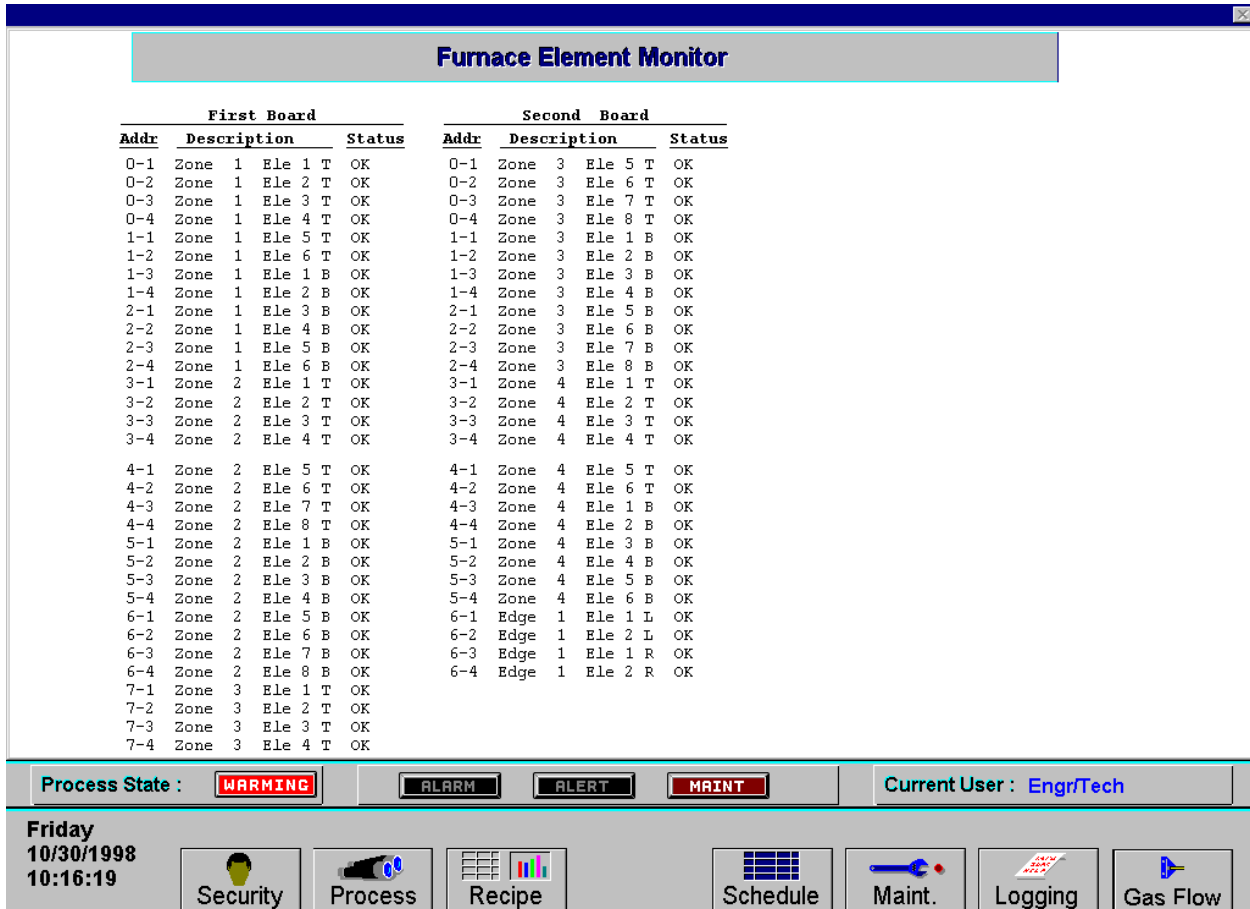


Figure 7-7: Element Monitor Screen

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



Figure 7-8: Element Monitor Controller

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

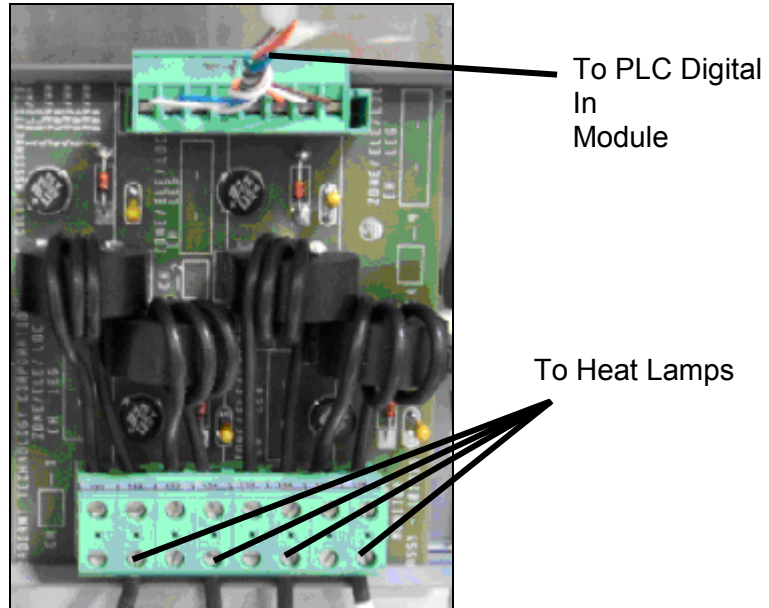


Figure 7-9: Element Monitor Circuit Board

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 PLC controller to the monitoring PC.

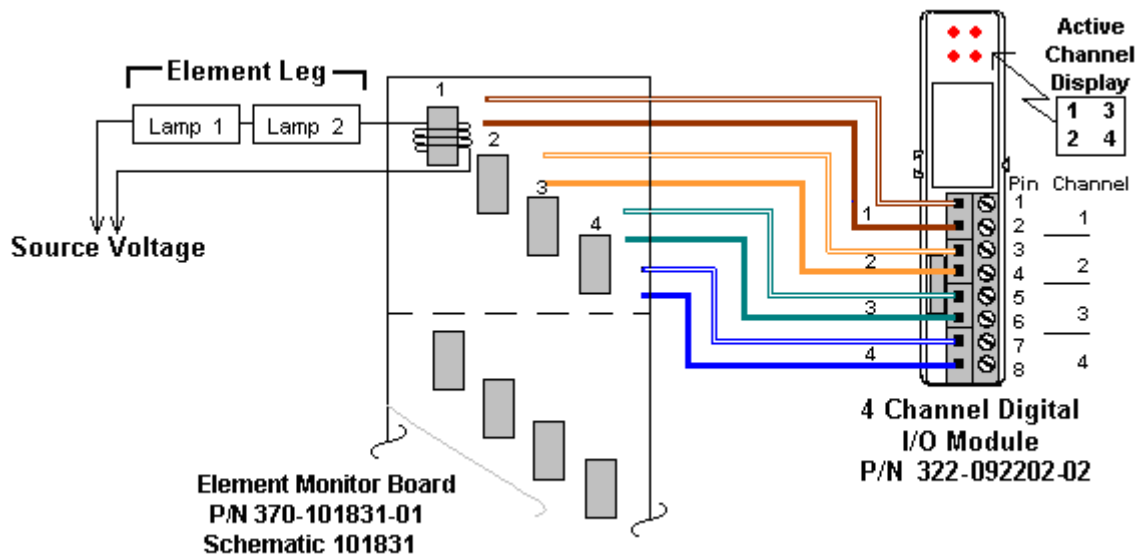


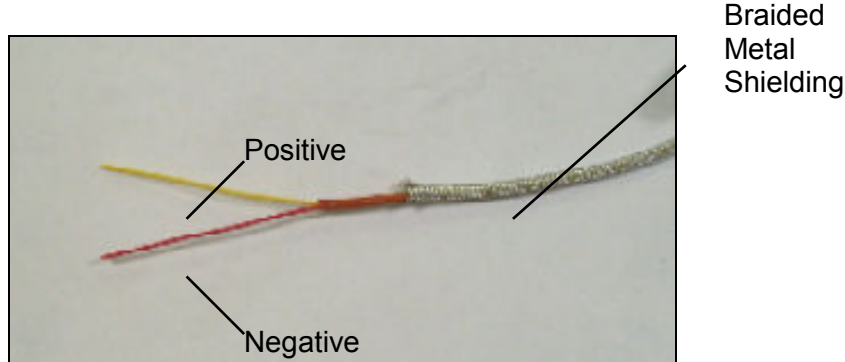
Figure 7-10: Element Monitor System Diagram

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

7.4 Typical Wiring

7.4.1 Thermocouple

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



This set of wires is attached to the PLC module as shown below:

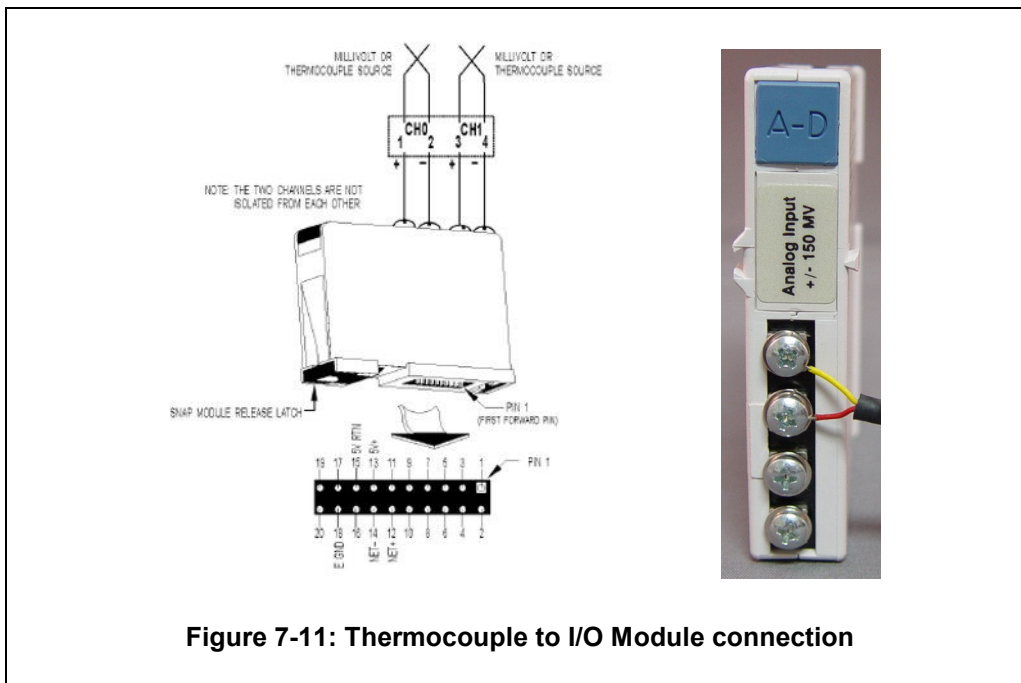


Figure 7-11: Thermocouple to I/O Module connection

The thermocouple wire set is attached to the PLC Analog input module 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 the common ground terminal

Cold junction temperature compensation is automatic when used with the furnace PLC.

At the connector end, a female connector is wired (see Figure 7-12). The thermocouple probe is mated to a male connector (see Figure 7-13). The red dot on the lower part of the connector represents the negative side and is also stamped with a minus sign.

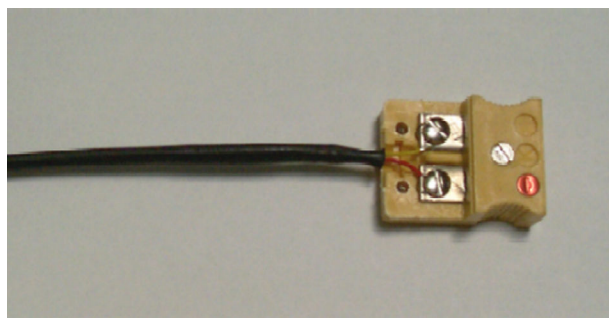


Figure 7-12 Thermocouple Female Connector

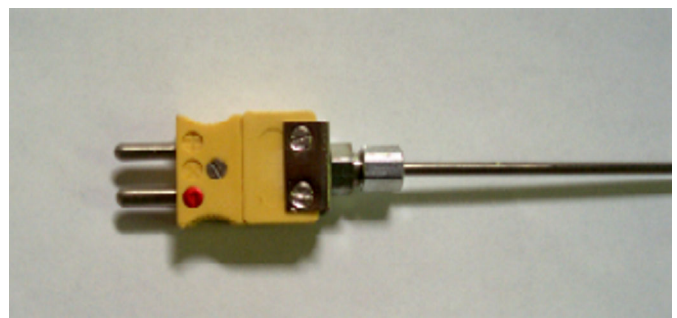


Figure 7-13 Thermocouple Male Connector

7.4.2 Replacing a Thermocouple

If a thermocouple probe needs replacement:

1. Remove power from the furnace.
2. Remove the side and top covers of the furnace cabinet as required.
3. Disconnect the thermocouple connectors; See Figure 7-14 below.
4. Mark the junction between the thermocouple probe and collar.
5. Unscrew the friction collar just above the surface of the chamber.
6. 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 height will result in unstable or inaccurate temperature readings.

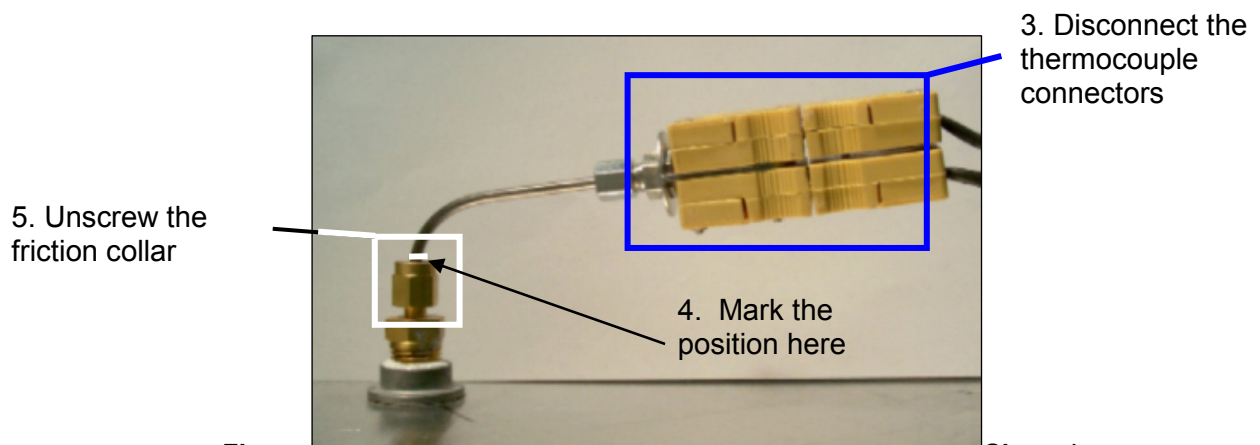


Figure 7-14: Thermocouple installed (Over Temperature T/C Shown)

7.4.3 SCR

A silicon-controlled rectifier (SCR) controls the level of current supplied to the heat lamp. The SCR control line is taken from an analog brick 0-5 V DC Output module connected to the PLC controller. The SCR supply power is in phase with the lamp voltage for accurate power application.

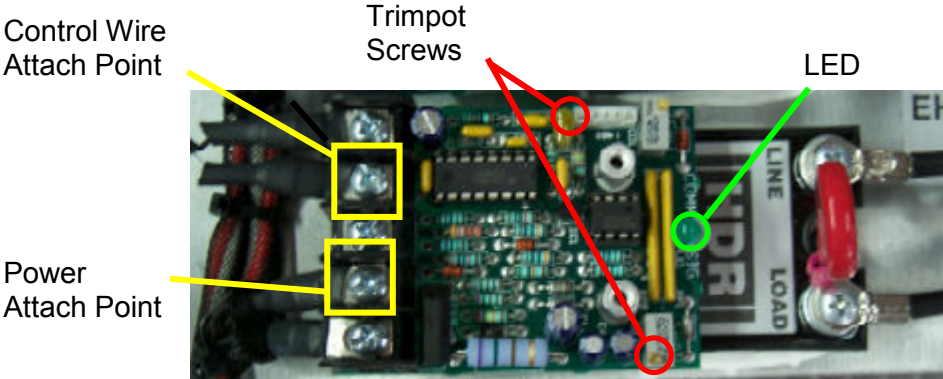


Figure 7-15: Silicon-Controlled Rectifier (SCR)

7.4.4 Fuses

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

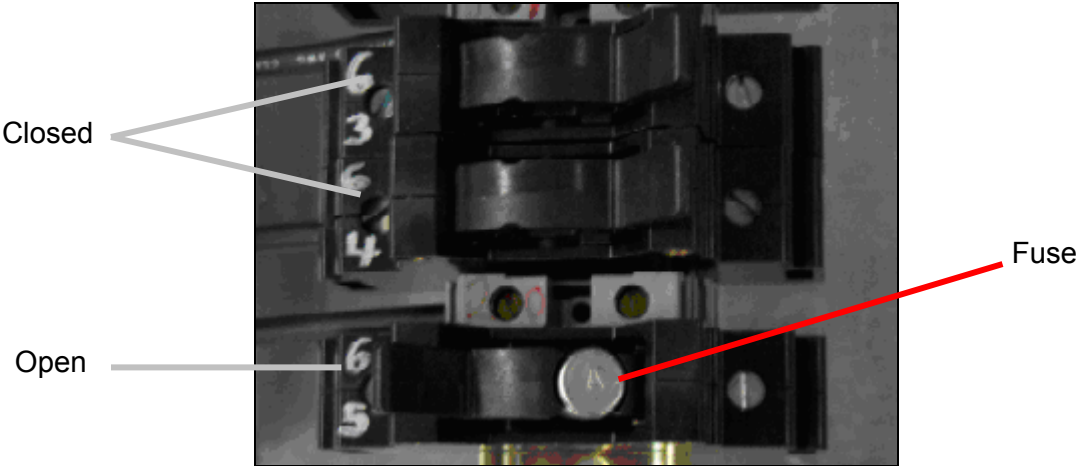


Figure 7-1: Fuse Block

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

7.4.5 PLC

Figure 7-16: PLC with Digital and Analog modules

The PLC controller interfaces with furnace hardware through input modules attached to the PLC rack. The furnace controller utilizes both the digital and analog modules. See



Figure 7-16 above.

7.4.6 Communication

Communication interface between the PC and the PLC controller is through a simple TCP/IP crossover communication cable which is attached to the computer network interface card (NIC) and the PLC Ethernet Interface module.

7.4.7 Power Supply

The power supply for the PLC controller is wired with 5 VDC.

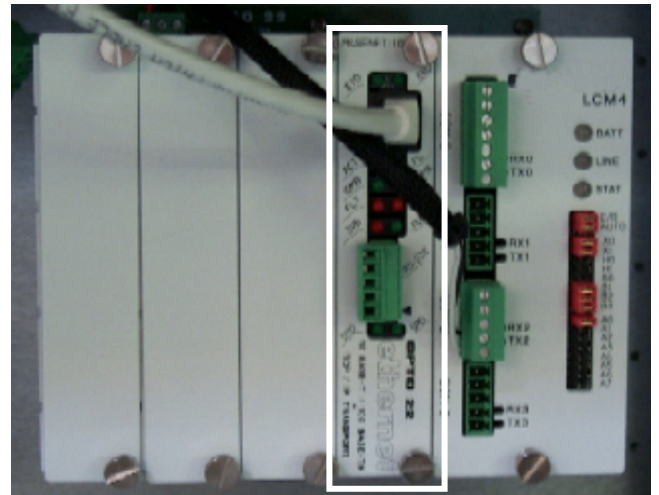


Figure 7-17: PLC Controller Ethernet Interface

7.4.8 Module Removal

The modules are attached to a rack mounted on the furnace. To remove a module:

- Tools required: #1 Phillips screwdriver
1. Make sure all power is removed from the PLC controller.
 2. Using a small round screwdriver, raise the black retainer tab to release the module from the rack.
 3. Carefully pull directly outward on the module to remove it.

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

7.4.9 Analog I/O Modules

Analog input modules (322-094405-01) receive changes



Figure 7-18: I/O Module Removal

in voltage from type K thermocouples. After processing by the furnace program, a 0-10 VDC output voltage is sent to the SCR's via analog output modules (322-094402-01).

These modules essentially read the temperature inside the furnace and generate a control signal to the SCR's. Each primary thermocouple in the furnace is connected to an analog input module. (Each SCR is assigned an analog output module.

Secondary thermocouples for the over temperature monitor option are connected to a secondary temperature indicator mounted on the furnace enclosure.

Additional monitoring may be provide by thermocouples mounted inside the cabinet. These thermocouples are connected to the Analog In modules (322-094405-01) also.



**Analog In Type K T/C Module
PN 322-094405-01**



**Analog Out SCR Module
PN 322-094402-01**

7.4.10 Digital I/O Modules

Digital I/O modules are used primarily for non-heat related sensory input or output. Digital Output modules may be equipped with override control switches. Switch positions are manual-on, manual-off/automatic (default). These switches can be toggled to manually operate the module. Top-mounted connectors are removable without tools providing access to wiring connections to the module.

Digital In. Each digital input channel senses the on/off status for DC voltages from sources such as transport motion fault and belt speed feedback.

Digital Out – AC. Four channels of 12-250 VAC digital output from each Digital Out module, each switches a separate AC load. This module is used to control the light tower lamps.

Digital Out – DC. Digital output modules supply four isolated channels of 5-60 VDC digital output, each switching a separate DC load such as the alarm horn.



**Digital In Motion Fault/Belt Speed Module
PN 322-094406-01**



**Digital Out AC Lamp Tower Module
PN 322-094401-01**



**Digital DC Output Alarm Module
PN 322-094412-01**

7.5 Mechanical System Maintenance

7.5.1 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.

1. Unscrew and remove the furnace side covers. If necessary, remove the cooling fan assembly.
2. 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.
3. Undo the air-rake retaining nut.
4. Completely remove the air-rake tubes.
5. Undo the butterfly nuts holding the drip-tray inspection cover in place and remove the inspection cover.
6. Remove the drip tray being careful not to damage the attached baffle plates.
7. Clean the drip tray.

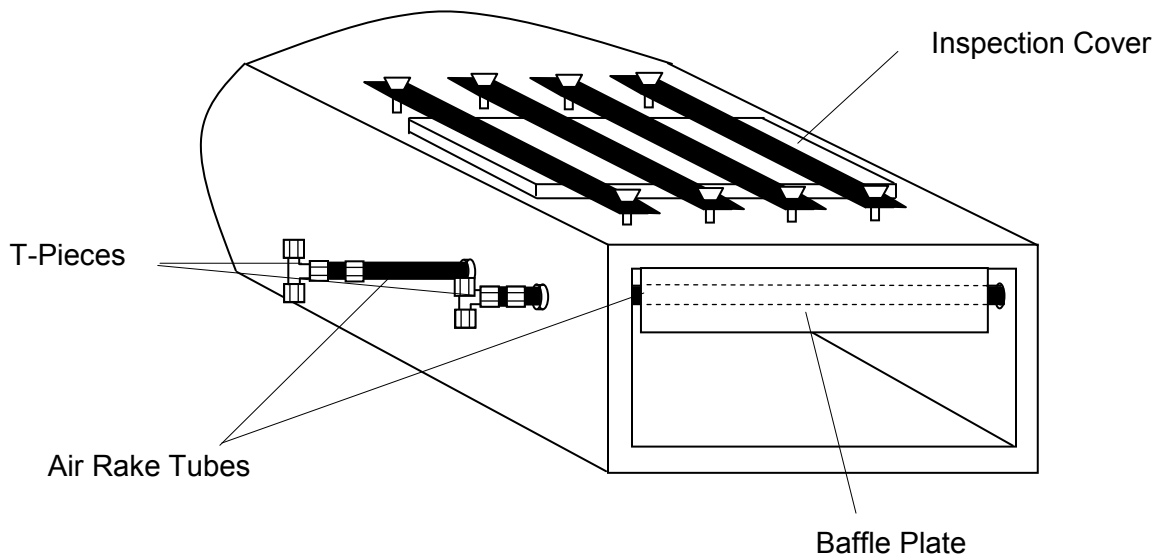


Figure 7-19: Drip Tray Cleaning Diagram

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.

1. Insert the drip tray and baffle assembly. Remove the wire.
2. Replace the inspection cover and reattach clamps. After several hours of operation, check the butterfly nuts on the inspection cover, and tighten if necessary.

7.5.2 Stack

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

1. With a flashlight, look down the furnace stack.

Contact FurnacePros if new gasket material is required to reattach the stack.

7.5.3 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

Lamp Removal

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

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

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

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

Lamp Installation

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

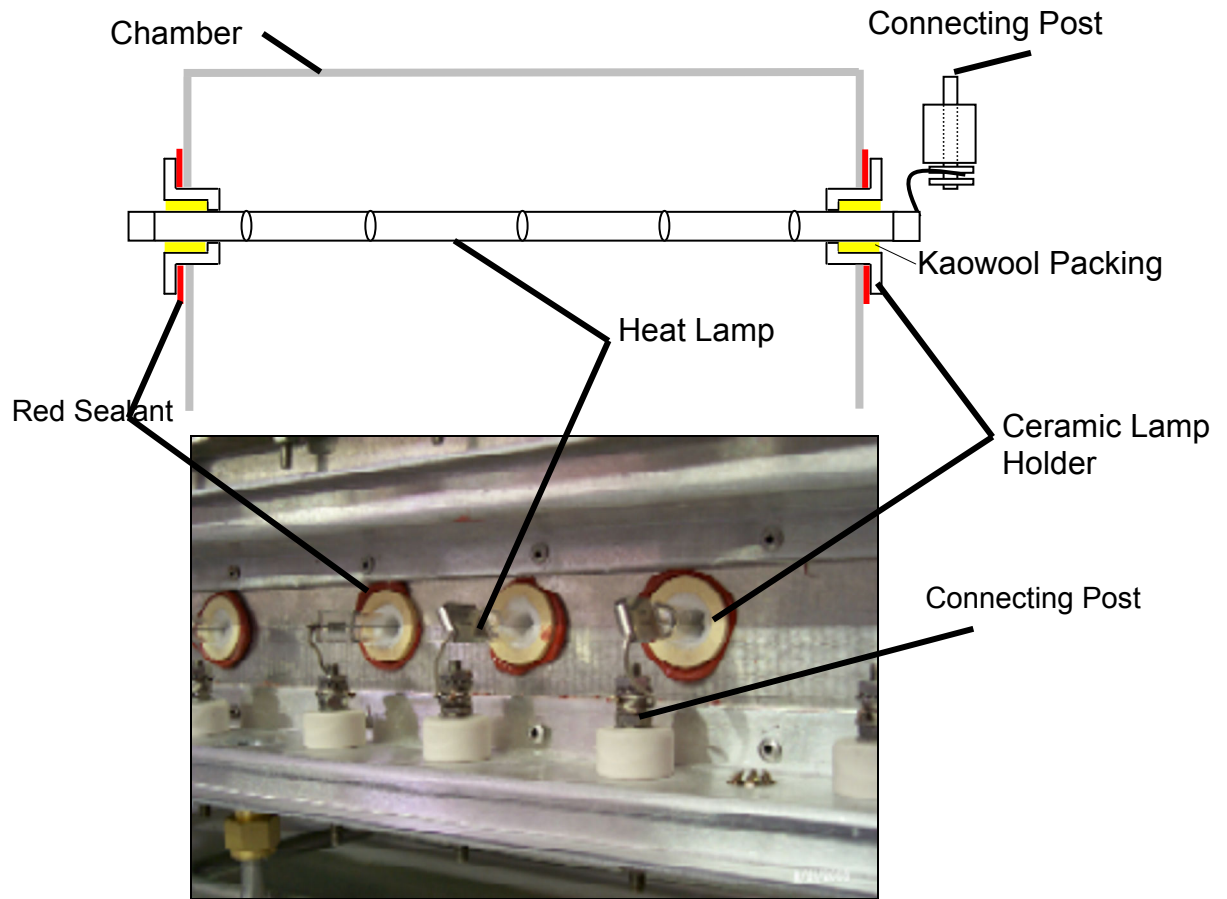


Figure 7-20: Lamp Replacement

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

4. If threading the lamp is difficult. Thread a dowel or stiff wire through the furnace. Tape the lead to the dowel or wire and then pull the lamp into position.
5. Pack the ceramic holders on both sides with the kaowool packing material.
6. Center the lamp to $\pm 1/32$ -in. (± 0.8 -mm) and recheck the packing.
7. Wrap the connection leads around the connection terminals in the same direction as the nut will be tightened. Use two wrenches, as you did when removing the connection, to ensure the connection post is not disturbed.
8. Cut off excess connection wire.
9. Replace plenum covers being careful not to damage the rubber seal.

7.5.4 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.

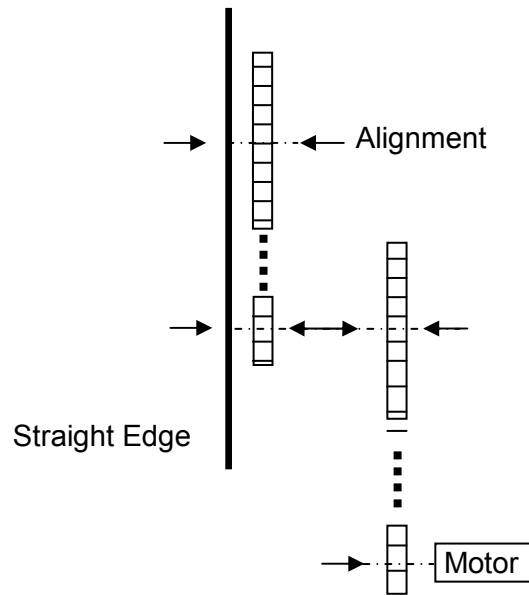


Figure 7-21: Sprocket Alignment

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 too 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.

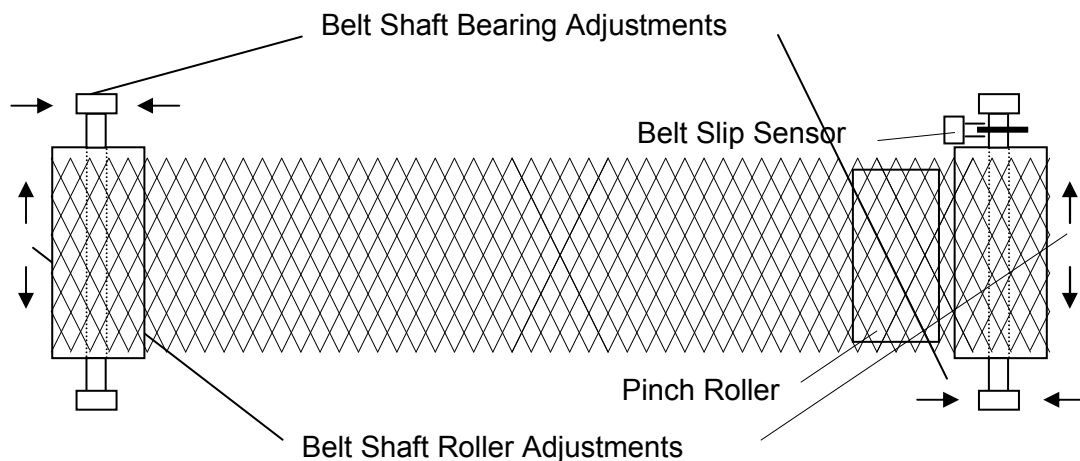


Figure 7-22: Belt Tracking Adjustment Diagram

7.5.5 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 supplied with each furnace installed with this option. If additional electrolyte solution is needed, contact FurnacePros.

8 Troubleshooting

Symptom	Possible Cause	Location
Furnace stays in warm-up mode for more than 15 min.	Gas flow contrary to zone temperatures	Adjust gas flow. See p. 108
Temperature runaway cannot be controlled by changing setpoints	The SCR has failed or needs calibrating	Calibrate SCR. If problem persists, replace SCR. See p.65
Zone Temperature fluctuates erratically	Poorly adjusted PID parameters	Adjust PID settings. See p.100
Over or under temperature alarm	Possible thermocouple malfunction	Replace thermocouple. See p.72
Hydrogen igniter alarm	Burnt our igniter	Replace igniter
#### 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	I/O modules not communicating with PLC	Check that RUN and REC LED's are on. The TRX LED should flash periodically. Try swapping relays or I/O module.
Transport speed error	Slipping clutch	Tighten clutch. See p.83
Belt speed fluctuates	Worn or misaligned drive sprockets	Adjust and lubricate. See p.82
Transport motion fault	Motion sensor not working	Clean or replace motion detector gear and sensor.

9.1 Infrared Heating

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

When using infrared lamps, higher heat-lamp temperatures emit higher radiant energy. This elevated energy translates to a shorter electromagnetic wavelength of emitted IR radiation. While the IR waves of a heat lamp come from a continuous range of wavelengths, the **dominant wavelength** (λ_{dom}) as given by Plank's distribution principle is the wavelength transmitted with the highest occurrence. So for a given temperature, only one λ_{dom} exists. See Figure 9-1 below.

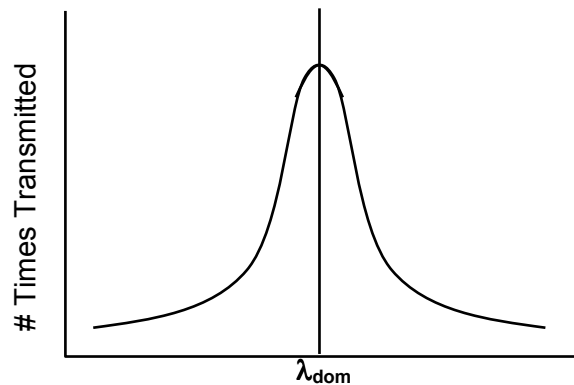


Figure 9-1: Dominant Wavelength Graph

Chapter 9

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

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

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

Example:

At 1000°C the respective material dominant wavelength is:

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

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

Substituting back into the given equation:

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

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

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 Wavelength vs. Temperature

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 100°C.

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

$$500 - 100 = 400$$

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

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

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

9.2 Temperature Profiling

As discussed previously in Section 3.3 “Thermal Process”, product passing through the furnace go through a set of temperatures known as a temperature profile. The process engineer must configure 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 **Error! Reference source not found.**, six zones are visible labeled Z1 – Z6 (See Figure 9-2 below). Depending upon the configuration of the furnace, more zones may be present.

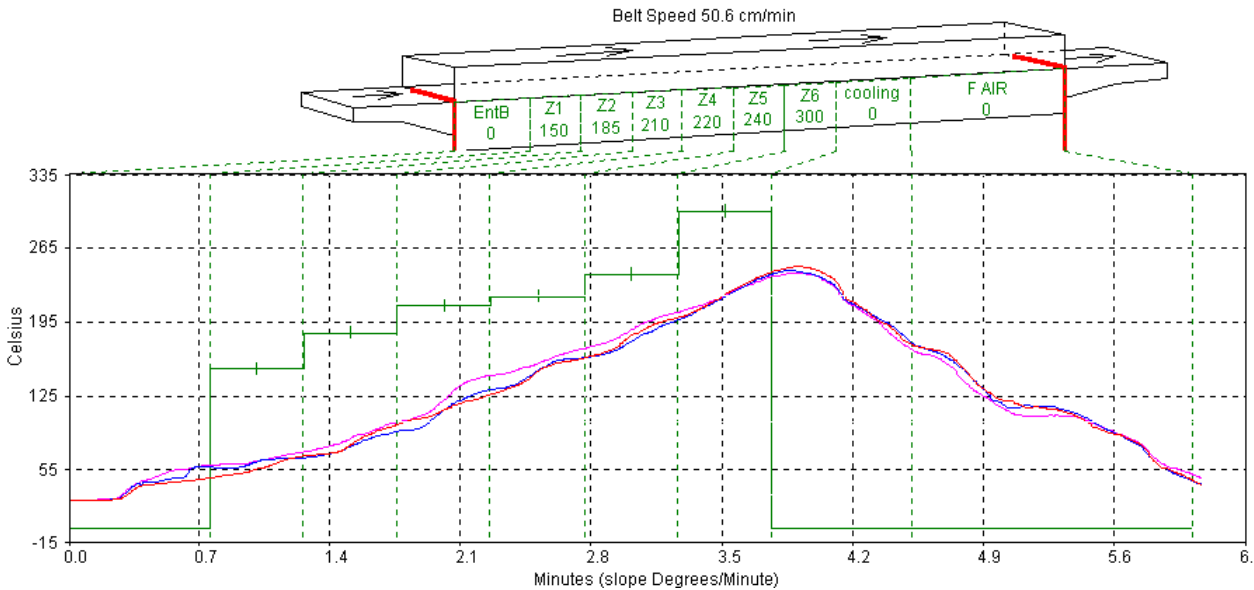


Figure 9-2: Temperature Profile

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 parameters:

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

When a conveyor belt speed range is requested for a desired product speed the above specifications are met within the specified speed range. In general, the speed range depends on the size and type of furnace. However, many sets of belt speeds and temperature settings can 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.108.

9.2.3 Types of Profiles

In most processes, two kinds of temperature profiles exist:

Equilibrium (flat) profile applications:

- 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) profile applications:

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

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

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 300°C, we recommend 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

DATAPAQ Data Logger

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

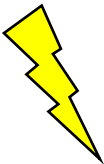
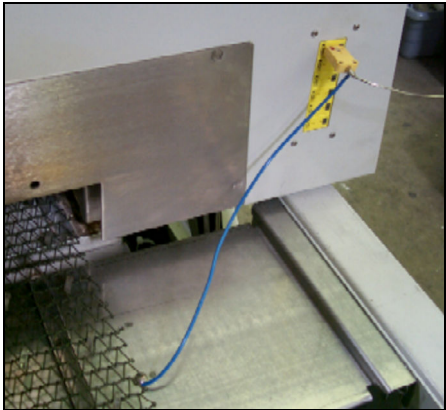
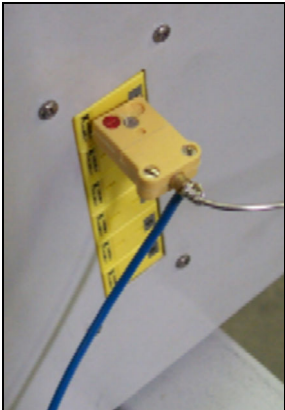
Note: Repeat testing may require new tape for accurate results.

Above 300°C, 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.

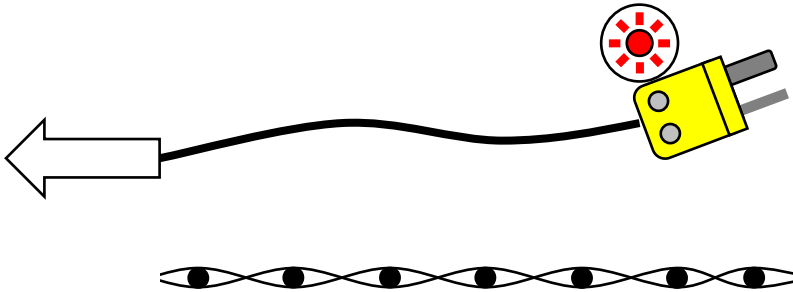


Safety

DANGER: When using metal shielded thermocouple wires inside a 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

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

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 9-2: Equilibrium 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. A slower rate increases the resolution of the temperature profile and can reveal more information about temperature uniformity and consistency.

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

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

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

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

- Record the temperature and observe the results.

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

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

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

For slower initial heating rates:

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

For faster belt speeds:

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

For slower belt speeds:

- Lower the belt speed 5%
- Decrease zone 1-2 setpoint temperatures by 7%

- Record a new temperature profile

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

Non-Equilibrium Profiles

For non-equilibrium (peaked or spiked) temperature 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			
(in.)	(cm)	2 minutes		4 minutes	
		(in./min)	(cm/min.)	(in./min)	(cm/min)
30	76	15	38.1	7.5	19.0
60	152	30	76.2	15.0	38.1
90	229	45	114.3	22.5	57.2
120	304	60	152.4	30.0	76.2

Table 9-3: Non-Equilibrium 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 listed under “Equilibrium Profiles” for the necessary hold time with the following modification:

- Increase the final zone temperature to about 30-50°C 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 furnace to operate, temperature setpoints, control parameters and alarm conditions must be entered. 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

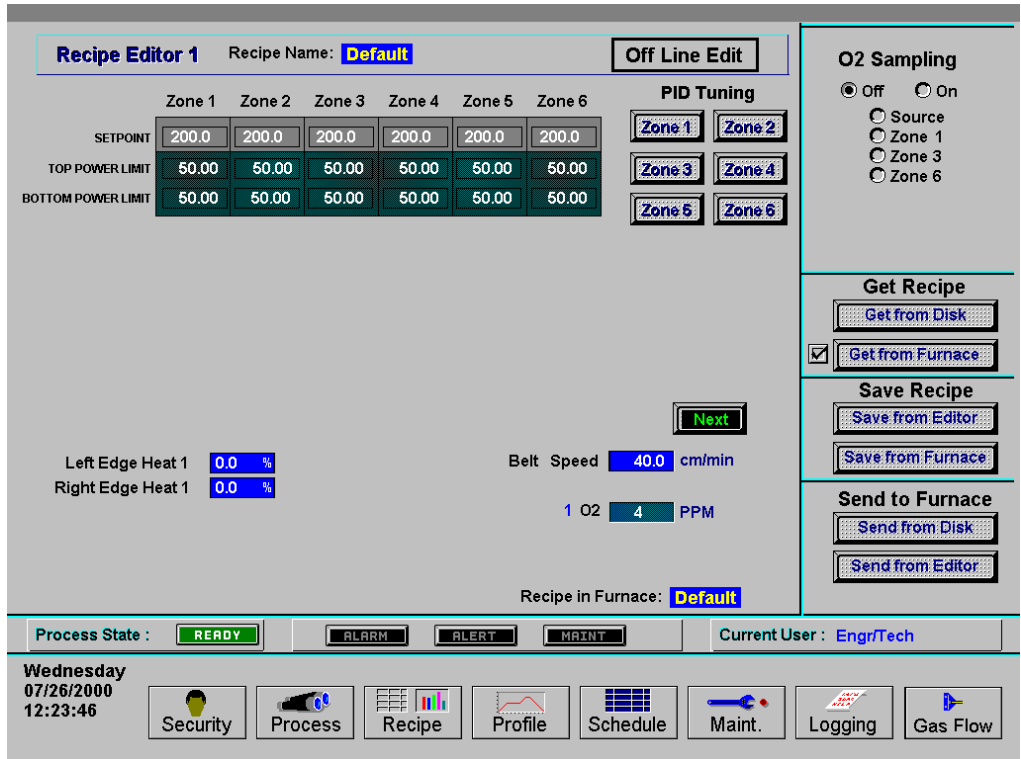


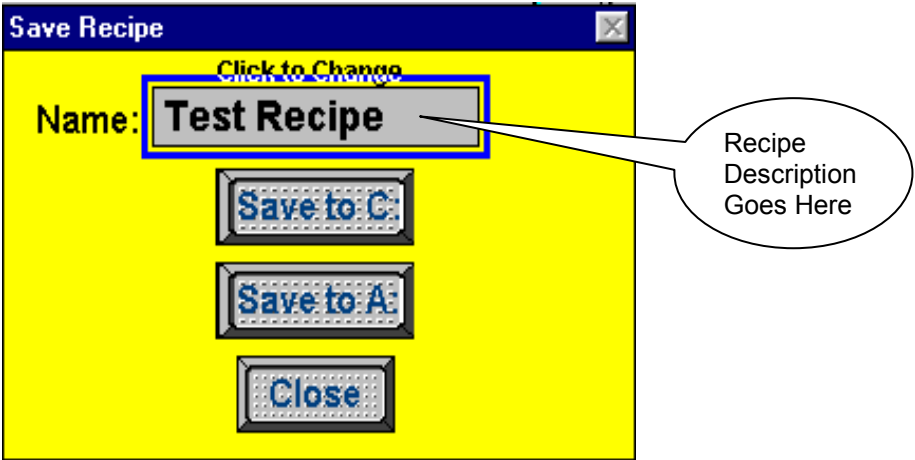
Figure 9-3: Recipe Editor screen

9.3.2 Recipe Handling

Recipes are handled in nearly the same way as described previously in the Saving and Retrieving Recipes Section under 5.5.3 on p.45.

Recipe Names

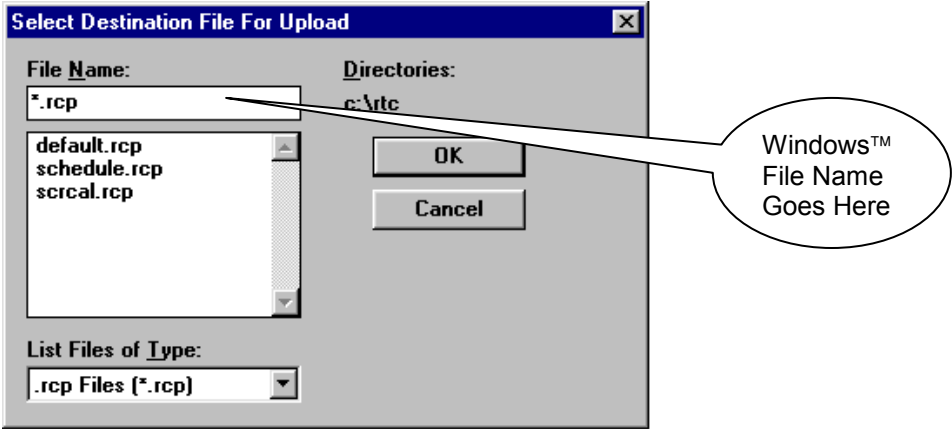
The **Recipe Name** in the **Save Recipe** dialog box is not the same as the Windows™ file name. When saving a recipe to disk, a dialog box appears asking for the recipe name. This dialog box can be used for a recipe description. The description can be long and descriptive



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 a diskette or USB removable media as well as to the hard drive. Recipe files can be copied using Windows Explorer or saved to a diskette or removable media by selecting the **Save to A:** command button in the **Save Recipe** dialog box.

9.3.3 PID Tuning

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

When in PID tuning mode, any changes that are made are sent directly to the PLC 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 loop works and how to tune it will greatly benefit the owner operator and product results.

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

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

Where:

T = Temperature

t = Time

G = Gain Term Value

S = Setpoint Temperature

I = Integral Term Value

D = Derivative Term Value

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

Gain

The proportional band is adjusted according to the following equation

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

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

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

values greater than 1 amplify the controller's response to error (differences between temperature and setpoint).

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

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

A default value of **9** is suitable for many processes.

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

Integral

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

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

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

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

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

Think of it this way: The difference between temperature and setpoint at any given time could be zero, but the average difference between temperature and setpoint over the length of time represented by the integral term is never likely to be zero. With an integral value of zero, power will be maintained at its current level even though the temperature is about to decrease. With an integral value greater than zero, multiplying the integral term, power will be increased slightly and the impending temperature drop will be not be as profound. With a Gain and an Integral value entered in a recipe, the PID equation will always be adjusting the controller's output unless the both the **current difference** and **average difference** between temperature and setpoint is zero.

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

For many processes, start with an initial value of **45** for the integral.

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 many processes with constant furnace loading (a continuous stream of similar parts entering the furnace).

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

In such uneven loading situations, a derivative term of **2** is a good initial value.

Care must be taken when entering derivative terms higher than 2 due to the fast response of the IR furnace.

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

If furnace loading is constant, Gain and Integral values are generally sufficient to counteract temperature deviations and the Derivative may be set to **zero**.

To begin a PID tuning sequence, click on one of the Zone # buttons in the Recipe Screen. The following pop-up box will appear (Figure 9-4). 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.

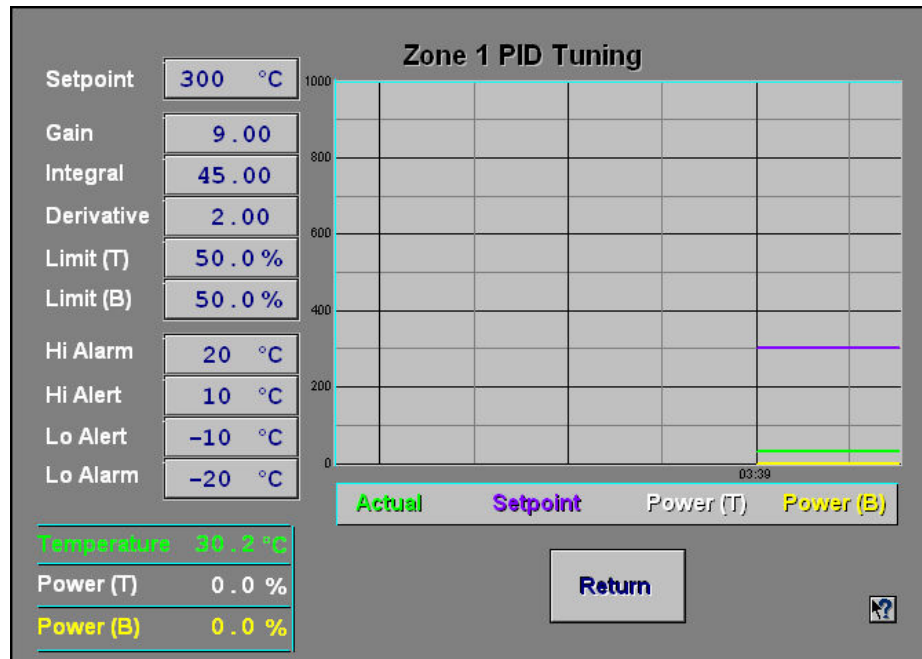


Figure 9-4: PID Tuning screen

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 screen should give 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 with lower limits.

9.4 Gas Flow

9.4.1 Gas Flow Basics

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

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

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

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

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

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

9.4.2 Process Gas

Various forms of process gas can be utilized inside furnaces. Users may want to operate a pure N_2 , O_2 or H_2 environment. Others will only need clean dry air (CDA). Whatever the case, the furnace can be factory configured in different ways to meet specific requirements. The following are some possible process gases.

Nitrogen

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

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

Calculate the Internal Volume of the Furnace Chamber

Example 1:

*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, H: 6 in.

Width, W: 25 in.

Length, L: 15 in.

Volume, V = H x W x L = 6 x 25 x 15 = 2250 in³

Heating Chamber

Height, H: 12 in. ← *Includes top and bottom insulation because gas passes through this*

Width, W: 25 in.

Length, L: 30 in.

Volume, V = H x W x L = 12 x 25 x 30 = 9000 in³

Transition Tunnel

Height, H: 6 in.

Width, W: 25 in.

Length, L: 15 in.

Volume, V = H x W x L = 6 x 25 x 15 = 2250 in³

Controlled Atmosphere Cooling Module

Height: 6 in.

Width: 25 in.
Length: 30 in. $H \times W \times L = 6 \times 25 \times 30 = 4500 \text{ in}^3$

Exit Baffle

Height, H: 6 in.
Width, W: 25 in.
Length, L: 15 in.
Volume, V = H x W x L = 6 x 25 x 15 = 2250 in³

Total Internal Volume: 20250 in³

Calculate Replenish Rate

Convert furnace Volume from cubic inches to cubic feet:

$$20250 \text{ in} \times \text{in} \times \text{in} / [(12 \text{ in} / \text{ft}) \times (12 \text{ in} / \text{ft}) \times (12 \text{ in} / \text{ft})]$$

$$= 11.72 \text{ ft}^3 / \text{replenish}$$

Convert to CFH

1 hour = 3600 seconds

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

(60 replenishes / hr) x (11.72 ft³ / replenish) = 703.1 ft³ / hr

Balancing Gas Flow, Q = 703.1 CFH (actual cubic feet per hour)
--

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

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

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

$$\text{SCFH} = \text{ACFH} \times \frac{(\text{Std Temperature} \times \text{Actual Pressure})}{(\text{Act Temperature} \times \text{Std Pressure})}$$

Actual Furnace Temperature, T₁ = 100F + 460 = 560 K

Actual Pressure, P₁ = 0 psig + 14.7 = 14.7 psia

Standard Temperature, T_s = 70F + 460 = 530 K

Standard Pressure, P_s = 14.7 psia

$$\text{SCFH} = 703.1 \times \frac{(530 \text{ K} \times 14.7 \text{ psia})}{(560 \text{ K} \times 14.7)}$$

True Standard Gas Flow, Q_s = 665.4 SCFH

True SCFH can be used to determine plant compressed air requirements.

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 to determine the quantity of gas that should be introduced to the each heating chamber: Divide the Balancing Gas Flow among each of the heating chamber zones and baffles for which the furnace has control.
- ❷ To determine the total gas flow to the eductors, divide the Balancing Gas Flow by 10. The approximate volume of air drawn out by the venturi created by the eductor is 10 times the flow rate.
- ❸ Divide the total eductor gas flow among the available eductors.
- ❹ The sum of the eductor gas flow and the Balancing Gas Flow is the gas consumed by the furnace.

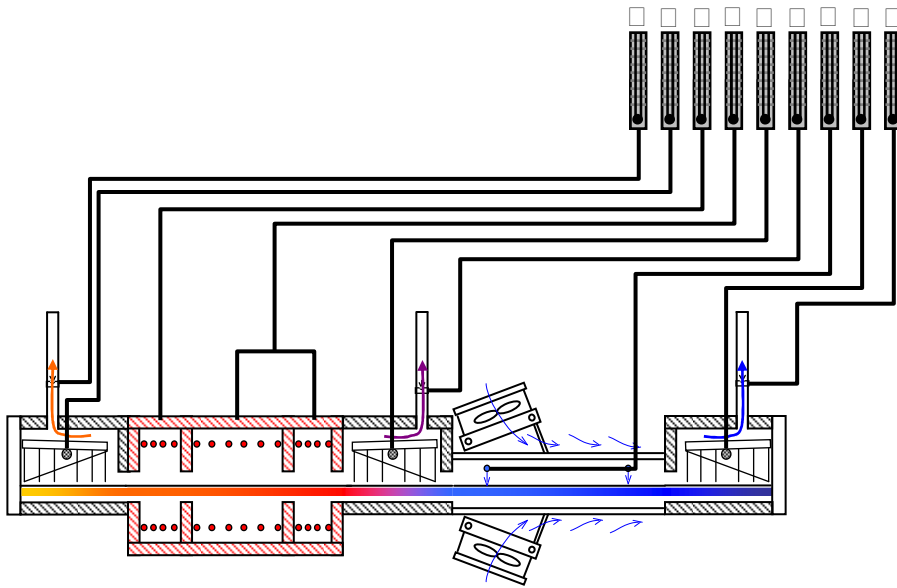
Refer to Example 2 example shown on the following page.

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

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

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

Example 2:



- - Entrance Eductor
- - Entrance Baffle
- - Zone 1
- - Zone 2-3
- - Transition Baffle
- - Transition Eductor
- - Cooling Section
- - Exit Baffle
- - Exit Eductor

Gas Entering Zones

<i>Entrance Baffle</i>	50 SCFH	} ①
<i>Zones 1</i>	150 SCFH	
<i>Zones 2 & 3</i>	200 SCFH	
<i>Transition Tunnel</i>	50 SCFH	
<i>Ctrl. Atm. Cooling Module</i>	153 SCFH	
<u><i>Exit Baffle</i></u>	+ 50 SCFH	
Total Gas Flow =	703 SCFH	
<u><i>Eductor Flow Divider</i></u>	<u>÷ 10</u>	← ②
Total Eductor Gas Flow =	70.3 SCFH	
<i>Entrance Eductor</i>	25 SCFH	} ③
<i>Transition Tunnel Eductor</i>	22 SCFH	
<u><i>Exit Eductor</i></u>	<u>23 SCFH</u>	
Gas Consumption	773.3 SCFH	← ④

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.

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.116.



DANGER: If the furnace is equipped for H₂ 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.

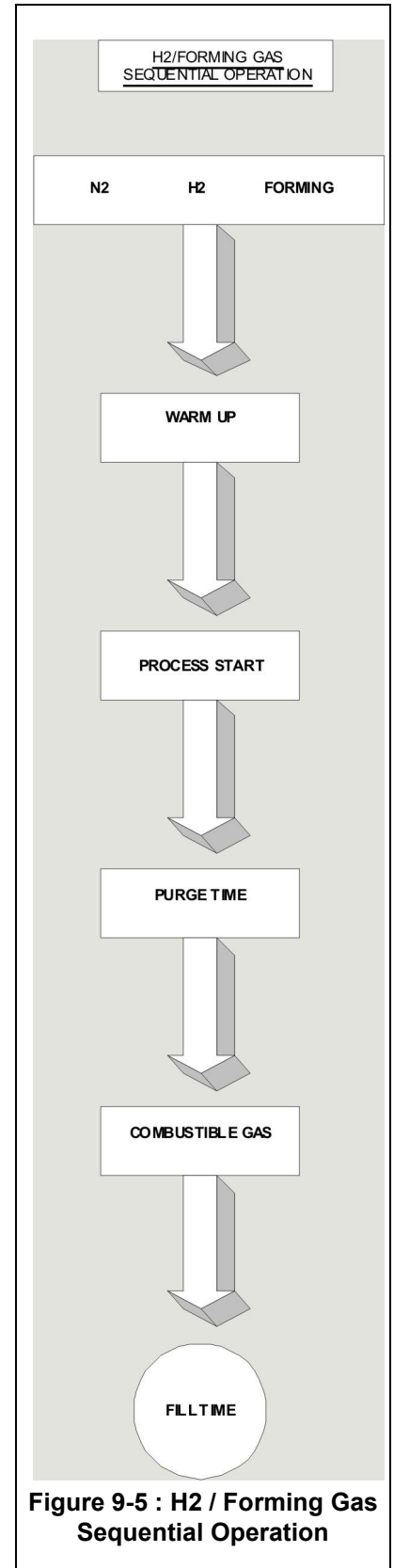


Figure 9-5 : H₂ / Forming Gas Sequential Operation

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. The furnace software control logic requires that nitrogen be run continuously in the exhaust venturi, entrance/exit baffles, furnace chamber, and in the transition tunnel/cooling muffle, if so equipped. The hydrogen control logic provides an user configurable 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 Variable Area Flowmeters. To start system open valve slowly to avoid possible damage. Control valves are turned clockwise to reduce flow and counter-clockwise to increase flow.

The standard technique for reading a Variable Area Flowmeter is to locate the highest point of greatest diameter on the float, and then align that with the theoretical center of the scale graduation. In the event the float is not aligned with a grad, extrapolation of the float location must be made by the operator as to its location between the two closest grads.

The furnace flowmeters are calibrated to operate at standard conditions:

Standard pressure, $P_s = 14.7$ psia (101.3 kPa)

Standard temperature, $T_s = 70^\circ\text{F}$ (21.1°C)

Deviation from standard conditions will require correction for the calibration to be valid. In practice, the reading taken from the flowmeter scale must be corrected to standard conditions to be used with the scale units. The correct location to measure the actual pressure and temperature is at the exit of the flowmeter. The equation to correct the flowmeter observed reading to standard flow, Q_s in SCFH.

$$Q_s = Q_a \times \text{SQRT} [(P_a \times T_s) / (P_s \times T_a)]$$

Where:

P_s = Standard Pressure = 14.7 psia

T_s = Standard Temperature = $70^\circ\text{F} + 460 = 530$ R

Q_a = Observed flowmeter graduation reading

P_a = Pressure at exit of flowmeter, (Gage pressure + 14.7 psia)

T_a = Temperature at exit of flowmeter (use $100^\circ\text{F} + 460 = 560$ R)

Example 1: An Exhaust Stack flowmeter with a scale of 10-200 SCFH Air. The float is sitting at the 100 grad on the flowmeter scale. Assume at the exit of the flowmeter that the pressure is -2.0 inches H₂O and temperature is 100F.

$$P_a = 14.7 \text{ psia} + (-2 \text{ in. H}_2\text{O} / 27.68 \text{ in./psi}) = 14.6 \text{ psia}$$

$$Q_a = 100 \text{ grad} \times \text{SQRT} [(14.6 \times 530) / 14.7 \times (100+460)] = 96.95 \text{ SCFH}$$

Example 2: An Zone flowmeter with a scale of 10-400 SCFH Air. The float is sitting at the 200 grad on the flowmeter scale. Assume at the exit of the flowmeter that the pressure is 55 psig and temperature is 100F.

$$P_a = 14.7 + 55 \text{ psig} = 69.7 \text{ psia}$$

$$Q_a = 200 \text{ grad} \times \text{SQRT} [(69.7 \times 530) / 14.7 \times (100 + 460)] = 897.5 \text{ SCFH}$$

Caution: Do not completely unscrew valve stem. Removal while in service will allow gas or liquid to flow from the front of the valve body and could result in serious personal injury.

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, Furnace Software & Control

Process Screen Controls (H₂)

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

We recommend 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.

The furnace is designed 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, we recommend, 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:

1. Calculate the volume of helium flowing into the furnace when the machine is running in a balanced condition.
2. Decide what ratio of helium to nitrogen is to be run and the volume of each gas required.
3. Select the nitrogen atmosphere mode to return the furnace to nitrogen operation.
4. Adjust the nitrogen volume to the values calculated above. Shut off the hydrogen flow meters.
5. Select the hydrogen atmosphere mode, and select the nitrogen/hydrogen mix mode before the purge cycle is complete.
6. Then adjust the hydrogen flow meters. The machine should now be operating in a balanced condition, with the proper volume of nitrogen/hydrogen.

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

This completes the functional checkout.

<u>GAS</u>	<u>SP.G</u>
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 ₂ Cl)	1.59
Hydrogen Sulphide (H ₂ S)	1.39
Methane (Me)	.553
Natural Gas	.55-.66
Nitrogen (N ₂)	.966
Nitrous Oxide (N ₂ O)	1.52
Oxygen (O ₂)	1.103
Propane (C ₂ H ₂)	1.56-1.99
Sodium Dioxide (SO ₂)	2.2-2.26
Butane-N	2.4
Butane-ISO	1.99

Table 9-4: Gas Correction Factors

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: If the furnace does not include a Mass Flow Control, the controls in this screen have no effect on the actual gas flow. With a Mass Flow Controller, the flow can be controlled through the software from this screen.

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 furnaces, optional electronic mass flow control valves may be installed to allow the operator or engineer to directly control the gas flow rates in the heating chamber.



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

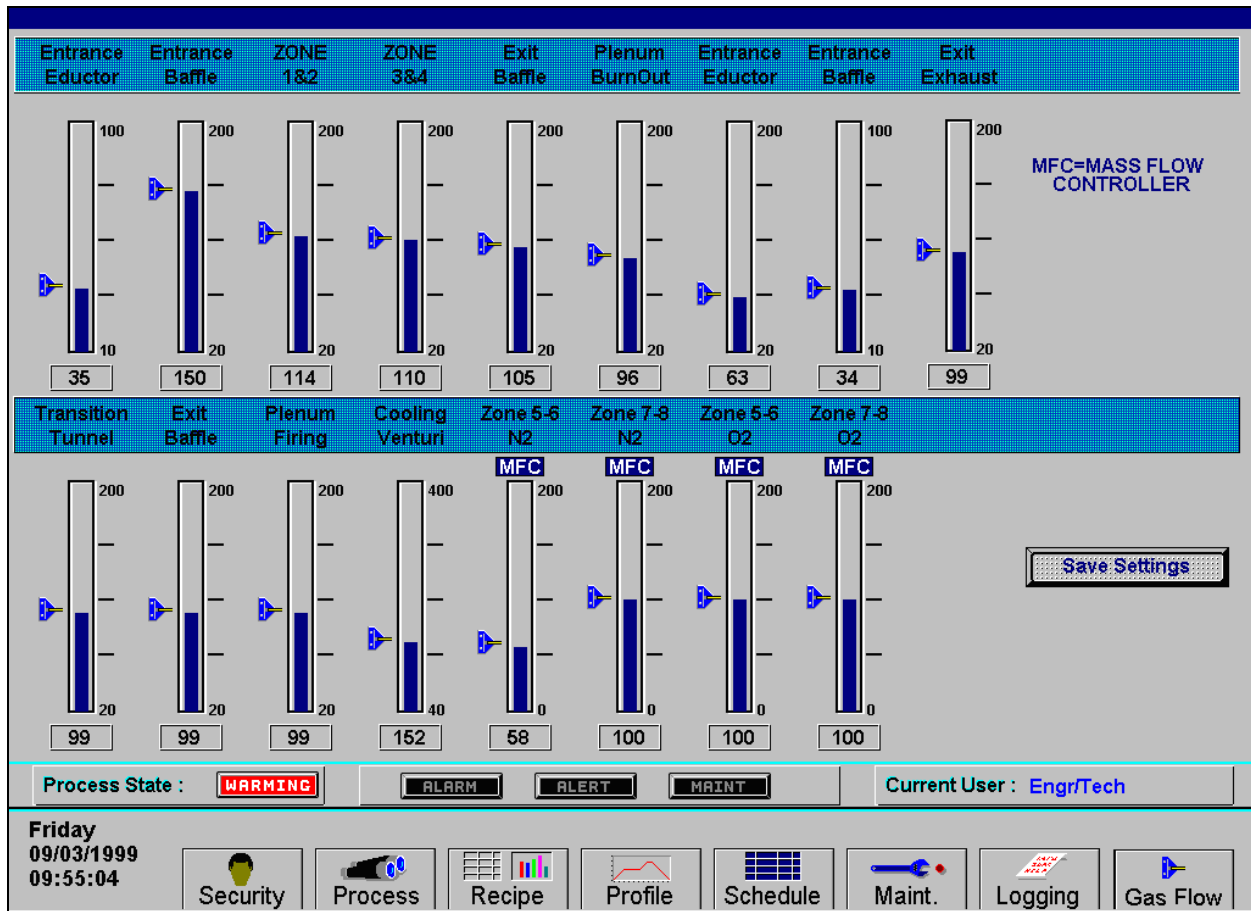
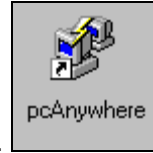



Figure 9-6: Mass Flow Control Valve Settings Screen

9.12 PC Anywhere

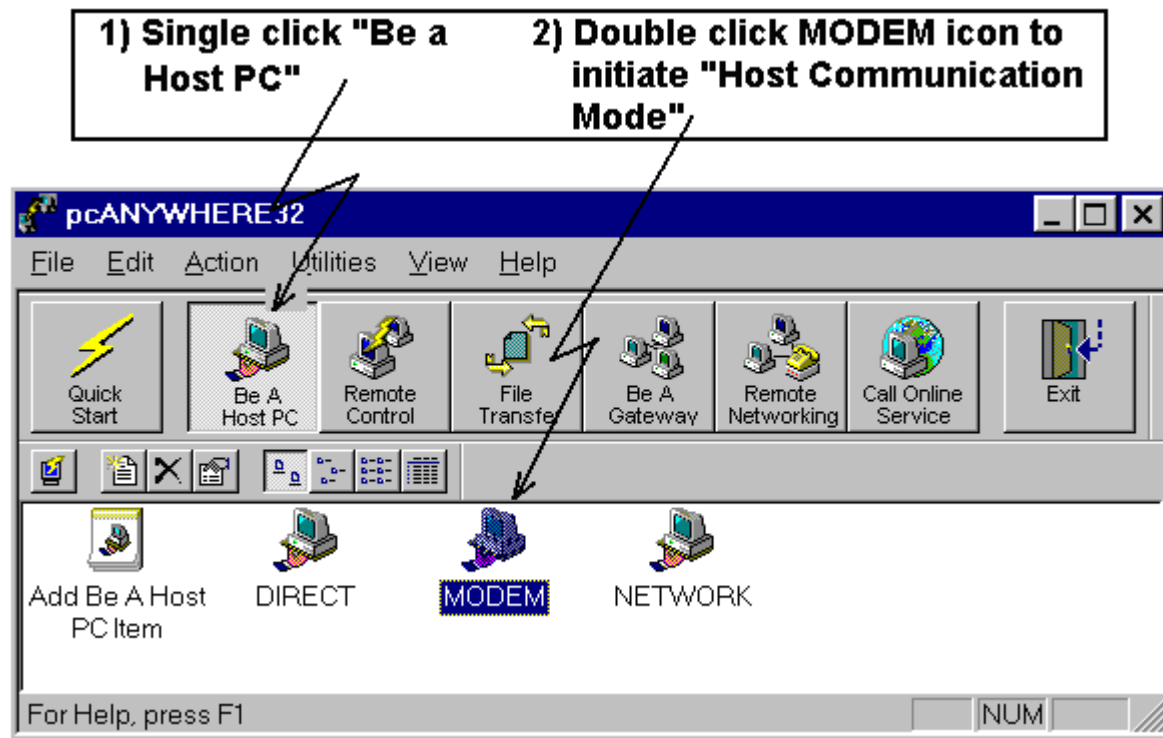
If it is necessary for the manufacturer to access the furnace-PC for diagnostic and maintenance purposes, before your machine can be accessed, you need to run the **pcANYWHERE™** software.



Double click the pcANYWHERE™ icon from the Windows desktop.

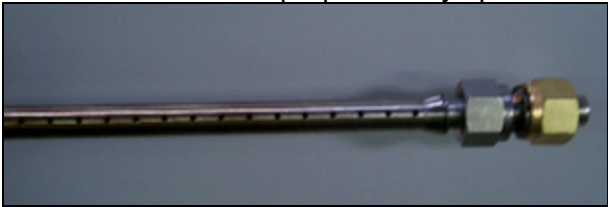
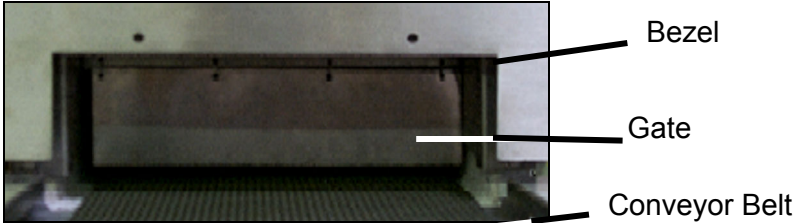
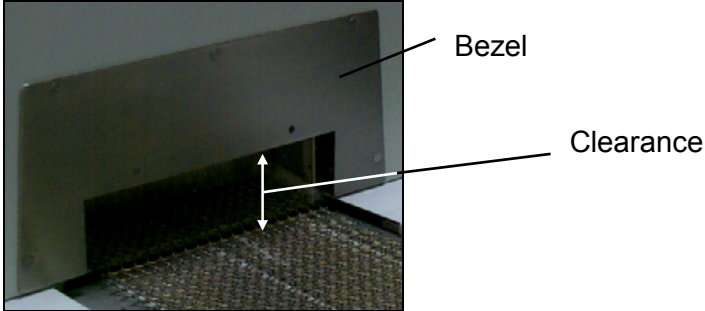
Or the quick-launch button  or from the Windows Start Menu.

After the application opens, Select the [Be A Host PC](#) button.



Connect a phone line from the RJ11 phone jack on the furnace to a direct-line phone jack. Make sure the accessing party knows the direct dial number for this jack.

Glossary

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.
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. 
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.

Glossary

Contaminants

Anything present in the process section that could negatively impact product quality including but not limited to O₂, 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 PLC.

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

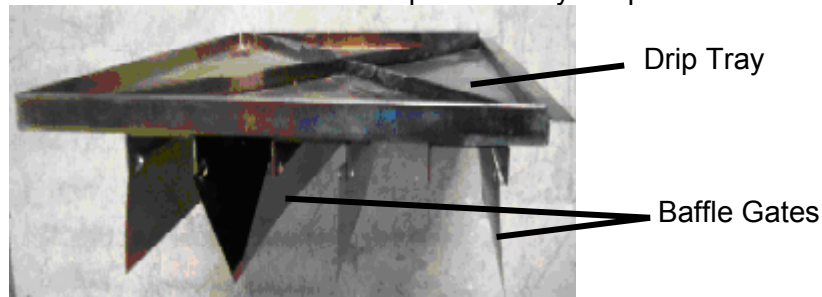
The continuous process of adding clean gas while exhausting contaminated gas.

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.

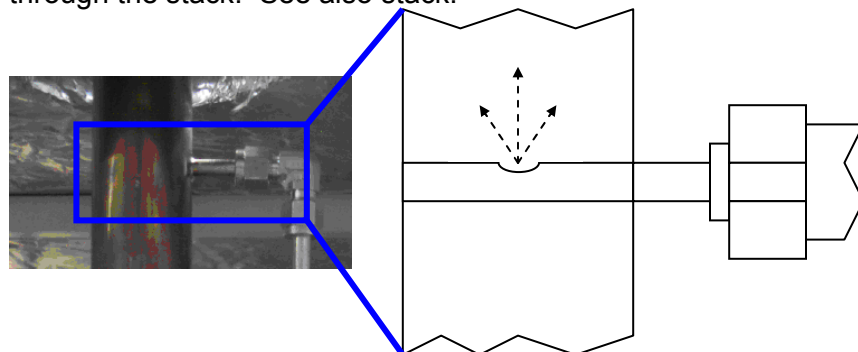


Edge Heater

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.

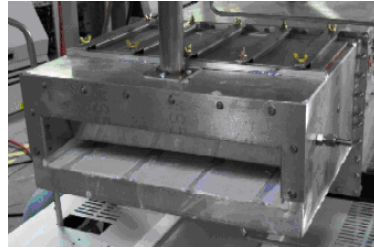


Effluents Contaminants expelled from a product during a thermal process. See also volatiles.

EMO An Emergency off switch.



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 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.



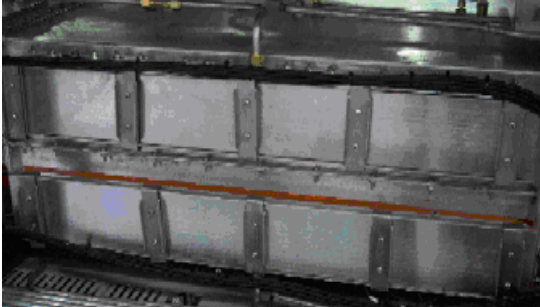
Forming Gas A type of process gas that consists of any mixture of H₂ and N₂ gasses.

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

Glossary

Gain	Term in PID equation to calculate how far temperature is from setpoint.
Gate	Plate that divides furnace into sections that can allow better control of the processing environment. See Blade and Drip Trays for picture.
H₂	Hydrogen gas.
Heat Lamp	Double ended metal sleeve clear quartz infrared (IR) heat lamp element or emitter.
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	Man machine interface software development tool for creating user interface to PLC controller.
Module	A section of the furnace designed for a specific function; may be 15, 30, 45 or 60 inches in length.
N₂	Nitrogen gas.
O₂	Oxygen gas.
Oxygen Analyzer	Detects oxygen content at predetermined locations. Usually installed to read process gas source, and up to three locations in the heating chamber.
pcANYWHERE™	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.
PC	Personal computer. The PC provides the main operator interface for operating the furnace. The PC interfaces with the PLC.

PID	Proportional+Integral+Derivative: Three-term closed loop control equation that adjusts power sent to heat lamps. See also Gain, Integral and Derivative.
PLC	Programmable Logic Controller. An industrial computer which provides input and output control of the furnace.
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 bezel to the exit bezel. 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 PLC controller.
Setpoint	The target temperature for a zone.

Glossary

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

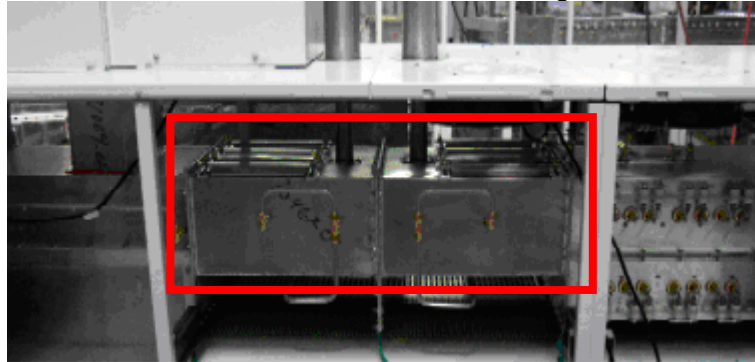
An electronic device that measures temperature.

Throat

The throat of the furnace describes the maximum height of any product allowable through the process section.

Transition Tunnel

Chamber section between heat and cooling section.



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.

