FurnacePros
DIVISION OF LOCHABER CORNWALL, INC.

CONTINUOUS BELT IR FURNACE

Reference Manual

Version 2.6a

Training Guide and 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 2.6a

Part No. 675-110000-01 CD
Part No. 675-110000-02 Perfect Bound
Part No. 675-110000-03 Casewrap Hardcover

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Chapter 1

1 Introduction

1.1 Introduction

Welcome to the world of **infrared furnace thermal processing**. FurnacePros specializes in near **infrared** (0.5-5.5 µm) wavelength continuous belt dryers, ovens and furnaces worldwide. We are committed to your success. Our goal is to provide the **highest quality** thermal processing equipment, parts and service available **anywhere.** Should you have a furnace operating question, do not hesitate to contact FurnacePros Technical Support. We stand ready to help. We want **you to be successful** with the use of your IR Furnace equipment.

This "how to" manual explains the theory, operating features and techniques to assist you in achieving highly repeatable and reliable thermal processes. **Please** study this manual carefully. Experience has shown that clients 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. Achieving **high** performance and high **yields** usually elicits congratulations from your company and always from FurnacePros. Please share your successes with us. We will appreciate it.

Infrared furnaces are highly responsive to critical temperature settings. With lamps as the primary heat source, the equipment is literally heating with the speed of light. The unique gas management system provides an extremely even distribution and well regulated flow of gas throughout the process chambers. Understanding and **learning** how **to control** both the **heat and gas flow is essential** to the effective operation of the furnace. When the interaction and performance of the control elements are well understood, putting them all together to make the tool achieve its potential is a most satisfying experience. For many, 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.

There are many features in your equipment to help assure your success in achieving your goals. Many **"firsts"** involving the application of near infrared heating include: the first high temperature furnace capable of operating at 1000^{o}C with extremely tight temperature control; the first thick film furnace; the first controlled atmosphere furnace capable of <5 ppm O_2; and the first hydrogen furnace.

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

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

1.3.2 Technical Support

Department: Technical Support

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

2.2 EMO Buttons

Every FurnacePros Furnace is fitted with at least two Emergency Machine Off buttons (EMO's) Locate and insure proper function prior to regular furnace operation.

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. The following are special notes describing events associated with various furnace options.

2.2.1 UPS (Option ❒)

An uninterruptable power supply may be added as an option to the furnace. In the event that the 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.24.

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.

2.2.3 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.

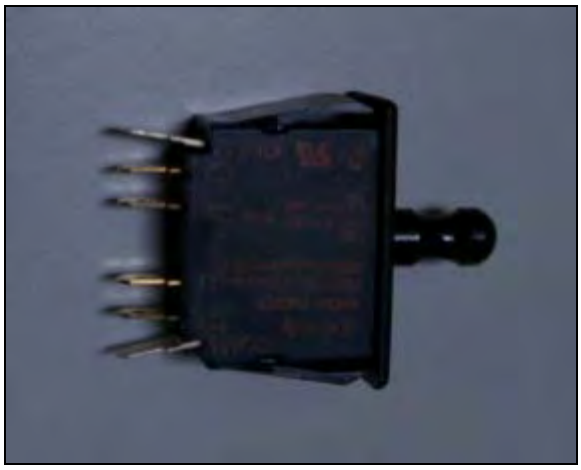


Figure 2-1: Panel Switches Showing Normal Operation Position

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

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.

3 Furnace Overview

3.1 Terminology

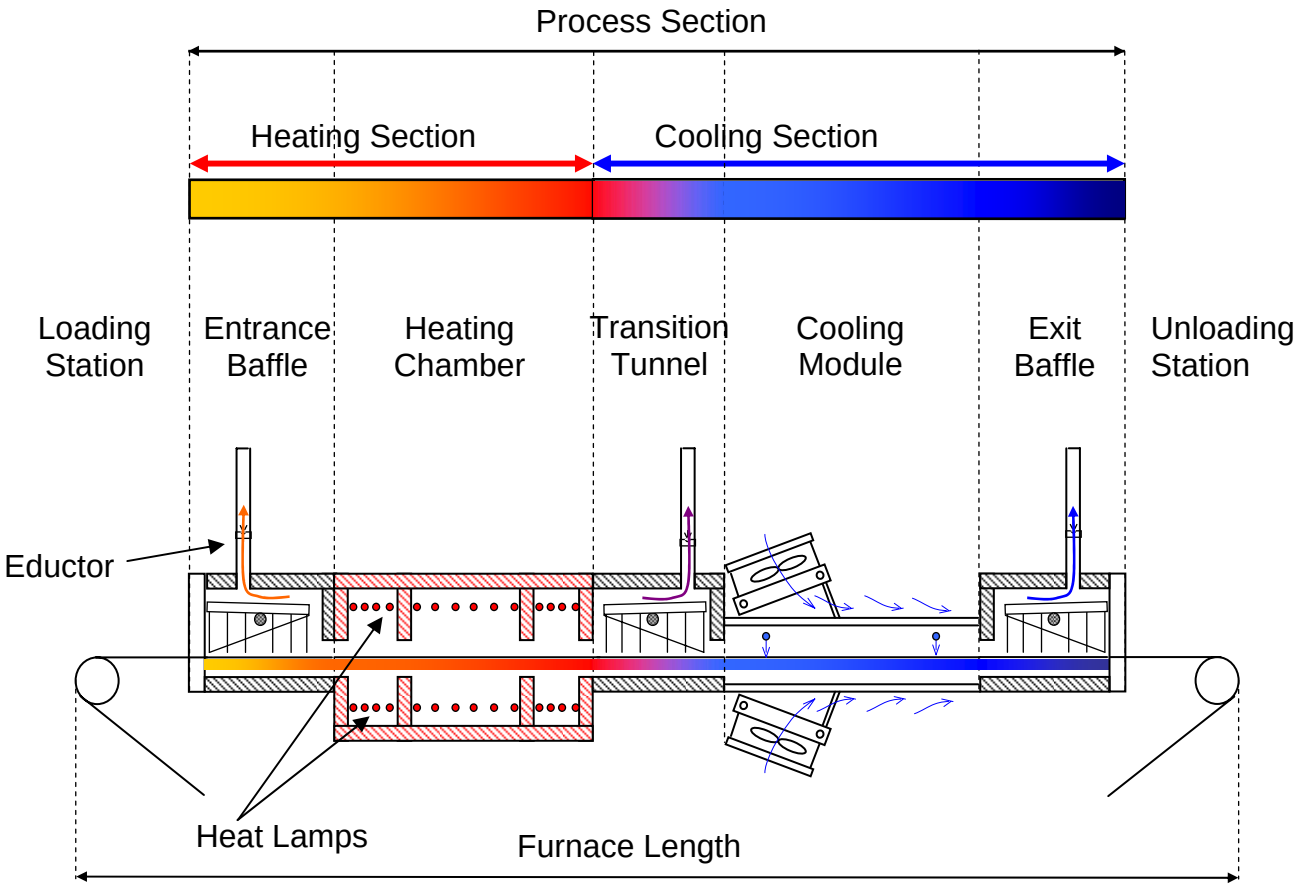


Figure 3-1: Furnace Nomenclature

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**	

3.3 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 3-9 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.*

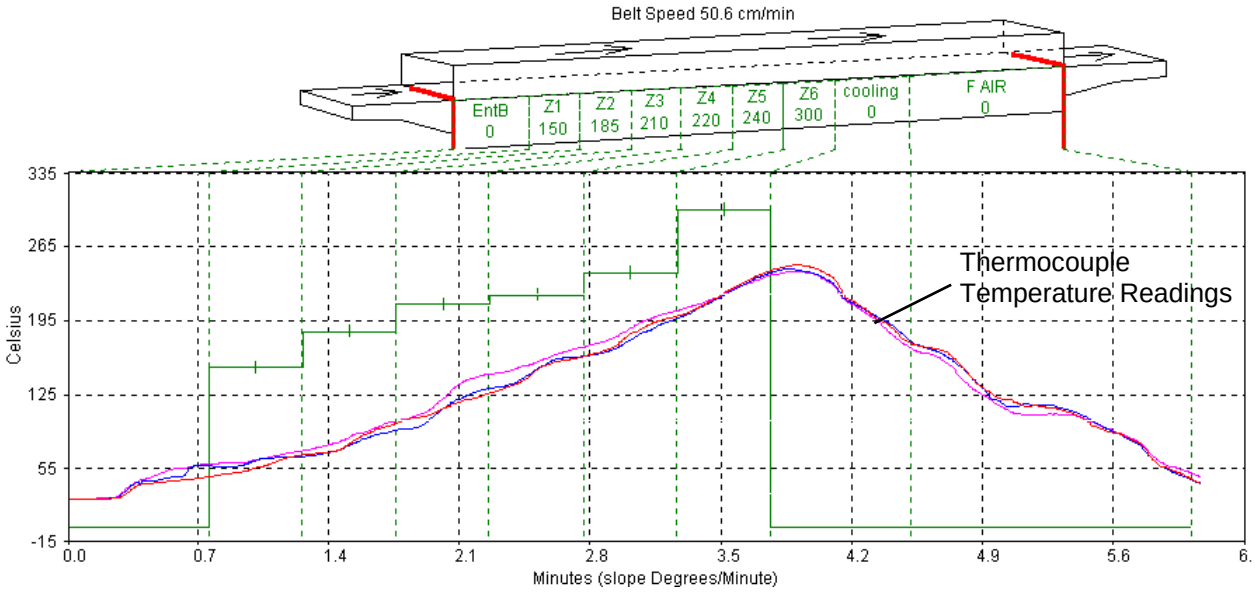


Figure 3-9: Temperature Profile Example

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.

Chapter 4

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 1000ºC 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.

5 Software

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.

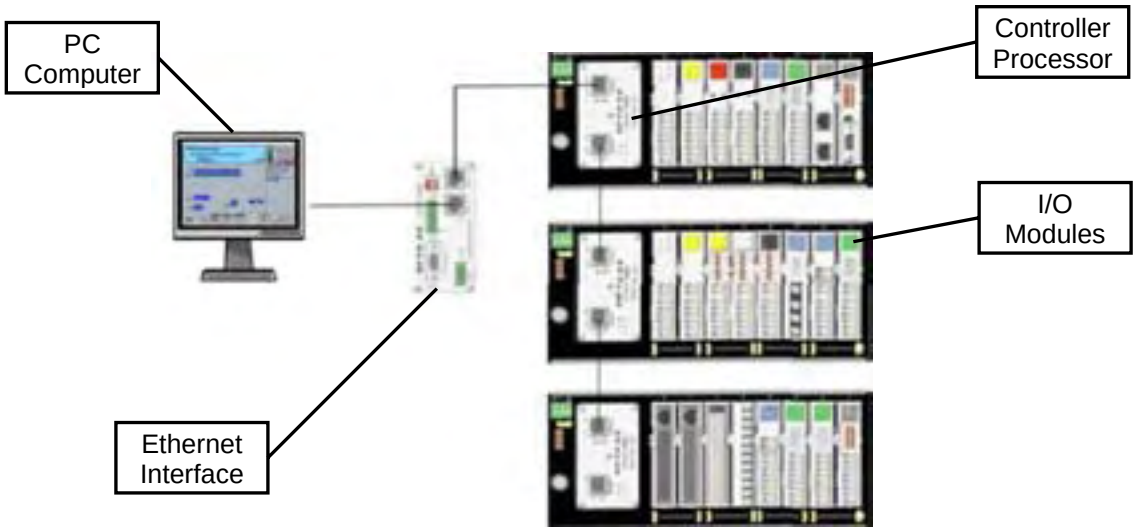
Chapter 6

6 Controller

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 a 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

7 Maintenance

7.1 Maintenance Screen Overview

You must be logged in at the Engr/Tech level, Level 2, to use this screen. Click on the maintenance screen button: The maintenance screen presents a list of items needing service at regular intervals.

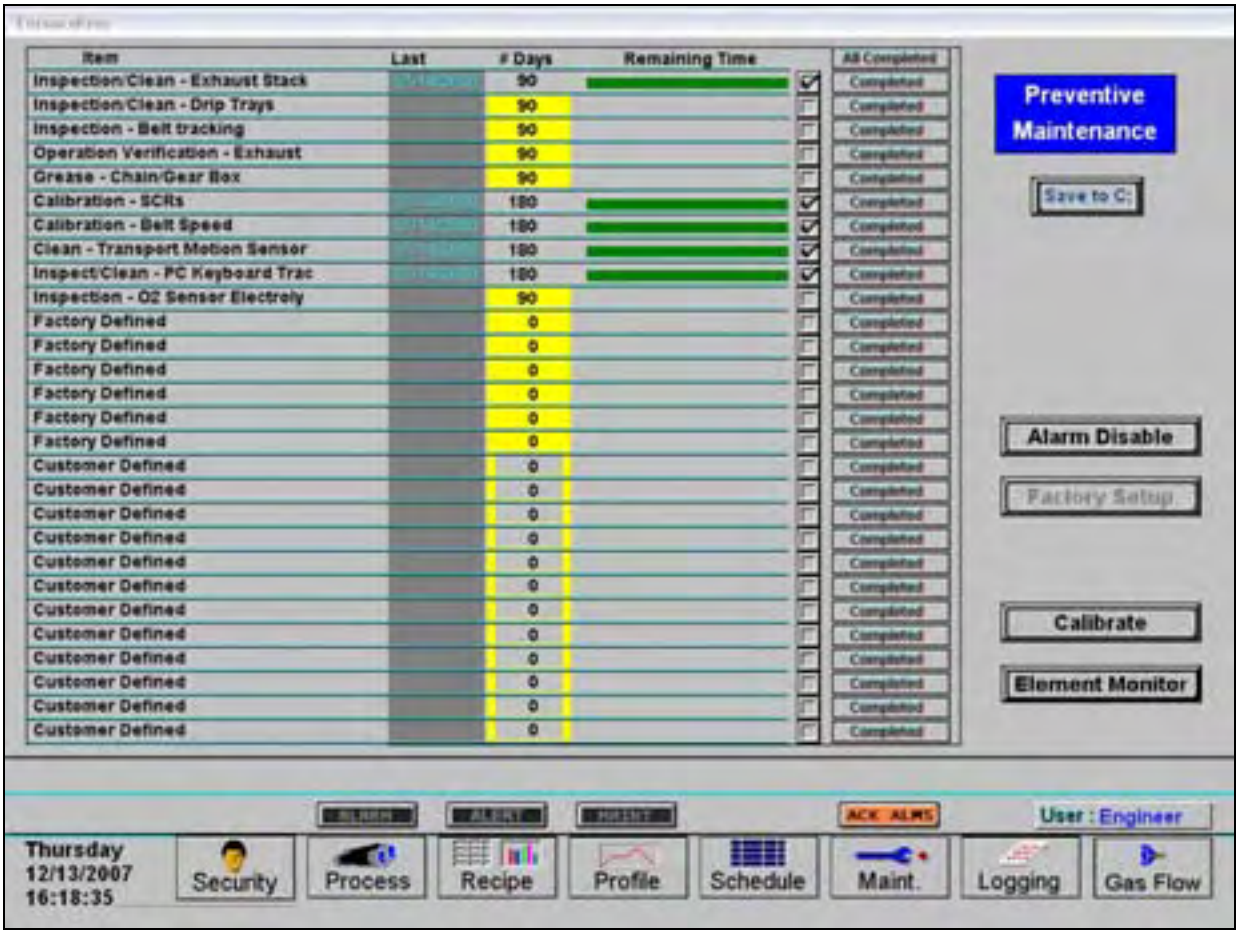


Figure 7-1 Maintenance Screen

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

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

7.3 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.

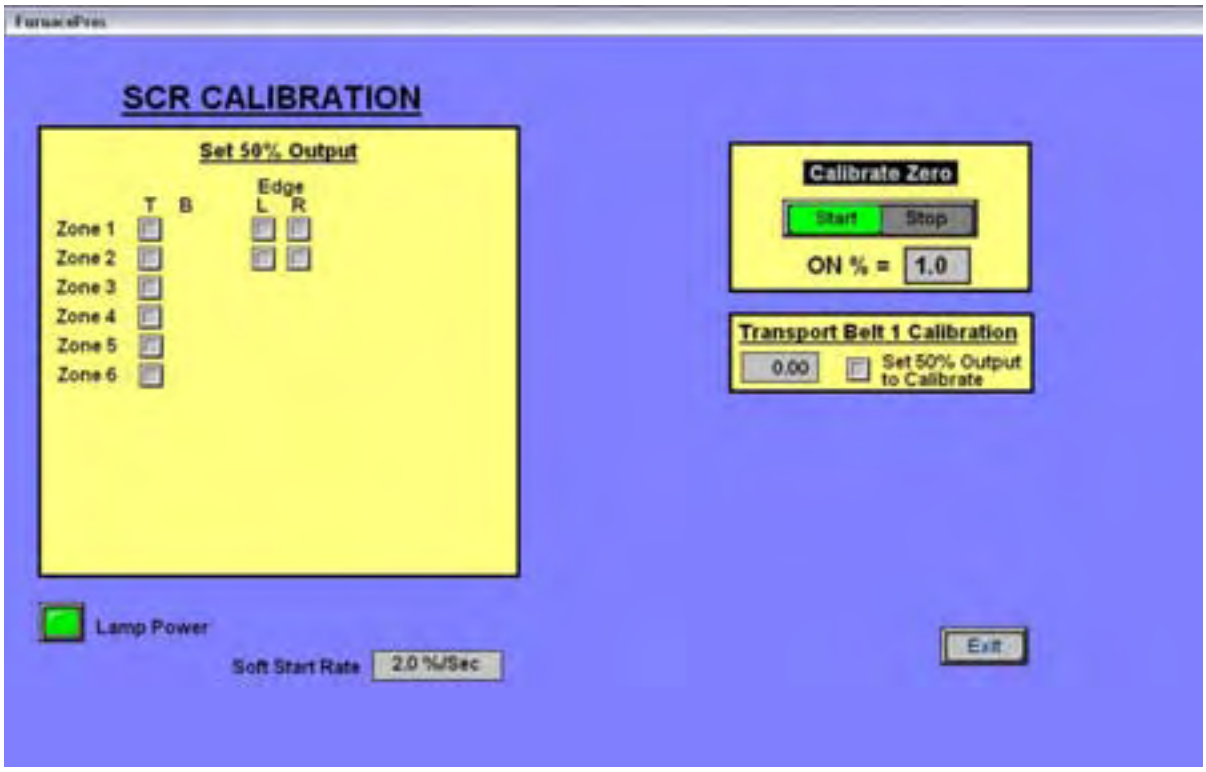


Figure 7-4: Calibration pop-up window

9 Process Engineering

9.1 Infrared Heating

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

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

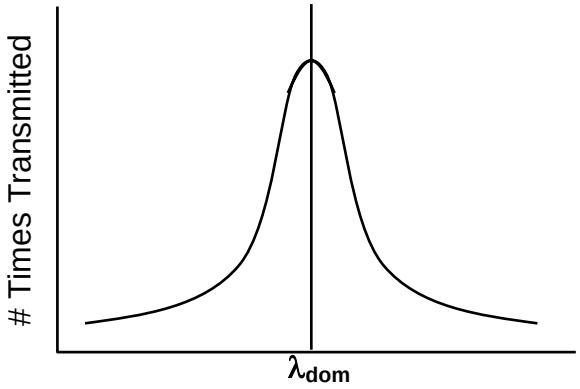


Figure 9-1: Dominant Wavelength Graph

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

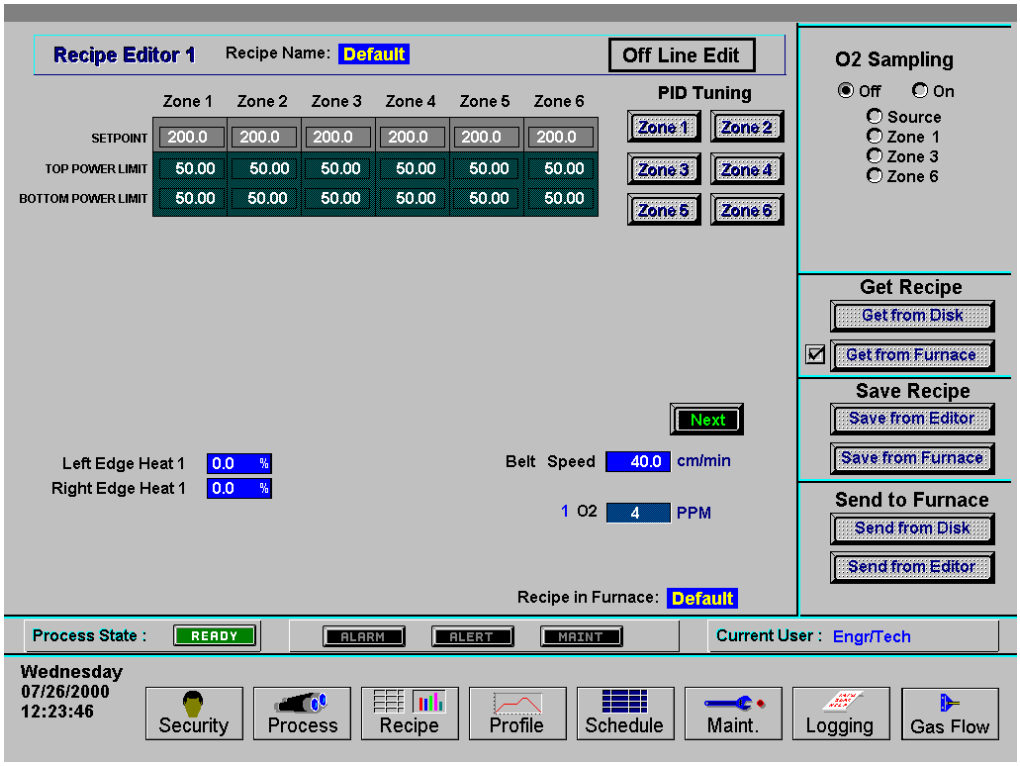


Figure 9-3: Recipe Editor screen

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.47.

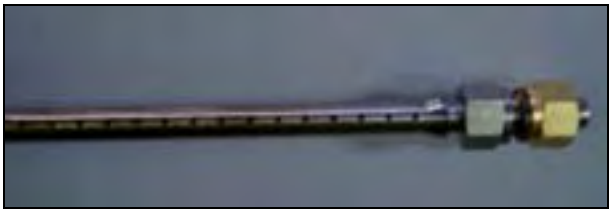
Glossary

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.

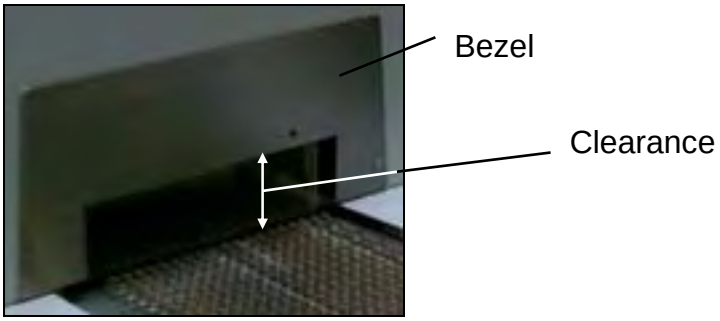
Air-Rake — Long tube set across-the-belt with proportionally spaced small holes.



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.

Contaminants — Anything present in the process section that could negatively impact product quality including but not limited to O_2, moisture or particulate matter.

Convection — The process of heating a product via indirect transmission of heat from adjacent high-temperature air.

Controller — Internal computer that stabilizes temperature, monitors belt speed, alarm conditions and other functions. See also PLC.

Controlled Atmosphere — The atmosphere generated from the process gas, and gas flow patterns within the process section.

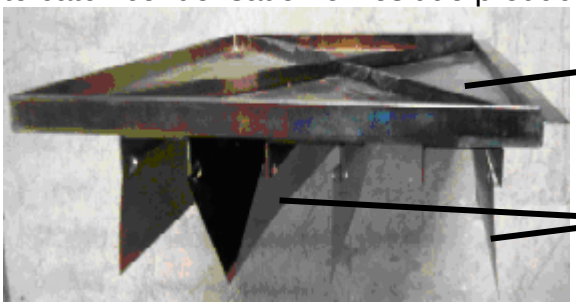
Cooling Section — The portion of the furnace that includes the transition tunnel, if any, exit baffle and any additional modules provided for the purpose of cooling the product.

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.

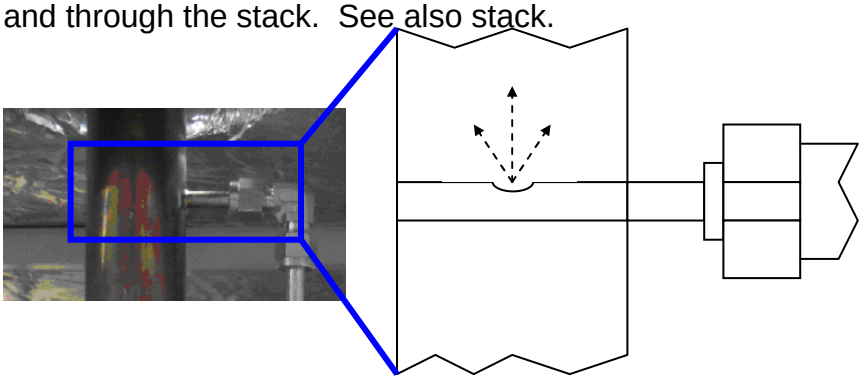
Drip Trays — Trays positioned beneath stacks with attached baffle gates; used to catch condensation or residue produced by the process.



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

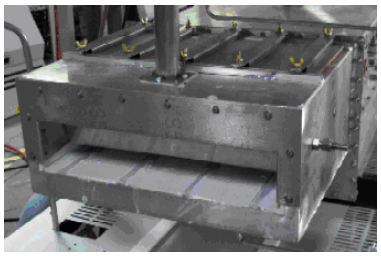
Contaminants expelled from a product during a thermal process. See also volatiles.

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 H_2 and N_2 gasses.

Furnace Length

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

Gain

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

Gate

Plate that divides furnace into sections that can allow better control of the processing environment. See Blade and Drip Trays for picture.

H_2

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

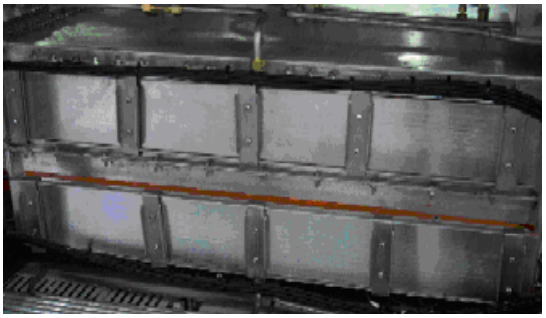
Mathematical operation that is one term in the PID equation.

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.
N_2	Nitrogen gas.
O_2	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.

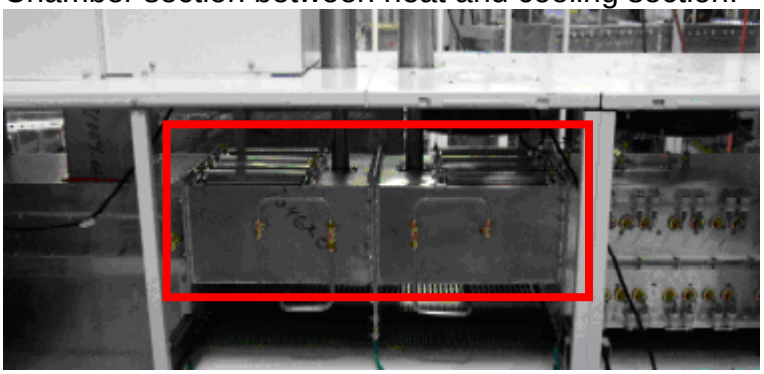
Sparger Tubes Highly porous, sintered metal tube charged with process gas; typically used in controlled atmosphere cooling modules.

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.