

## FURNACE EQUIPMENT

### 1.1 Furnace Description

The LA-306 is a compact, near-infrared, conveyor belt furnace for laboratory and general purpose thermal processing in the range of 100-980 °C in a controlled atmosphere, free of outside contamination. Process gas may be CDA, N<sub>2</sub> or another inert gas. Dual gas furnaces may use Nitrogen and a second gas such as Forming Gas (pre-mixed N<sub>2</sub>/H<sub>2</sub>) or another type of reducing gas injected into the heating chamber.

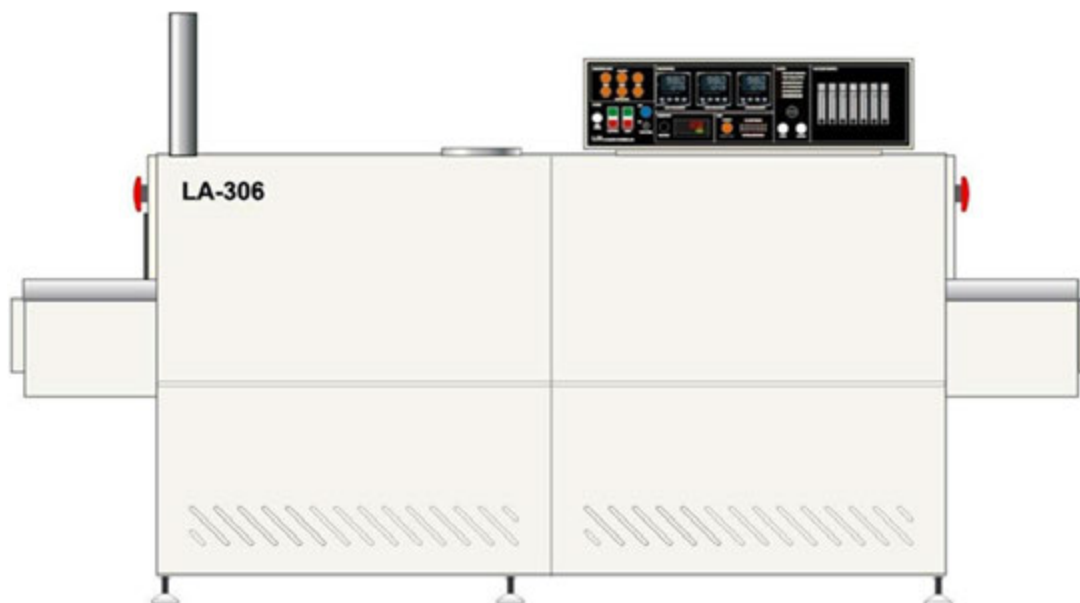


Figure 1-1 Furnace Front Elevation

The LA-306 furnace transports product on a 150 mm (6-inch) wide belt. In the standard design the chamber clearance above the belt is 50 mm (2 inches). Optionally the furnace can be ordered with 25 mm (1-inch) or 100 mm (4-inch) vertical clearance above belt. LA-306 furnaces feature a hermetically sealed heating chamber permitting control of the furnace chamber process environment. Baffle sections before and after the heating section contain curtains that hang down to just above the belt to further isolate the furnace chamber from the room atmosphere and from the cooling section.

The LA-306 can process substrates, wafers, PCBs, metal, ceramic, glass or polycarbonate parts for electronic package sealing, thermo-setting polymer curing, reflow soldering, hybrid/thick film firing, brazing, annealing, tempering and metal sintering applications, or almost any kind of general thermal processing requiring precision temperature control in a controlled atmosphere environment.

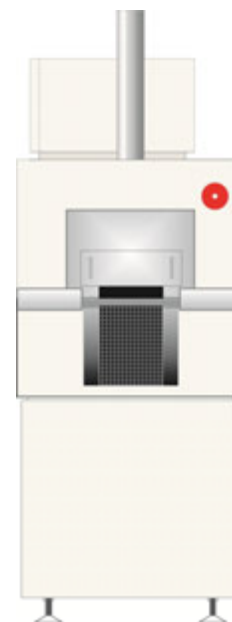


Figure 1-2 Furnace Entrance Elevation

1.2 Furnace Views



Figure 1-3 Furnace Front Elevation



Figure 1-4 Entrance Elevation



Figure 1-5 Exit Elevation



Figure 1-6 Exit Elevation (Mixing Option)



Figure 1-7 Rear Elevation



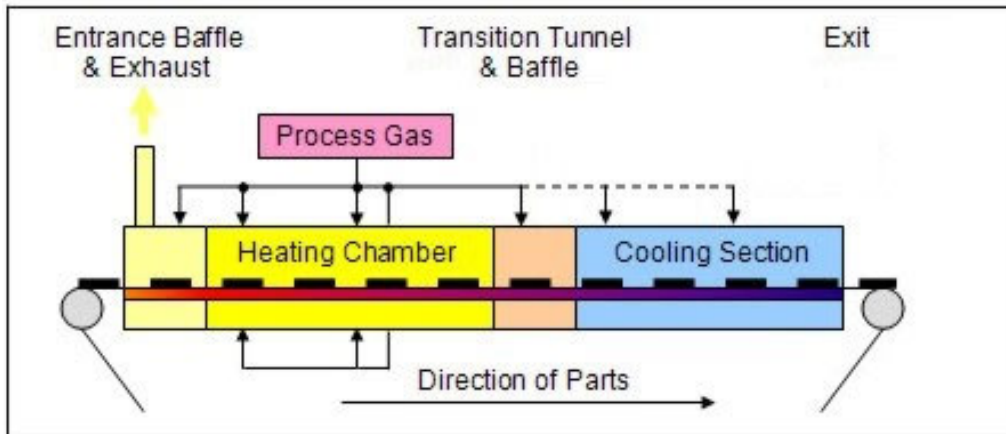
Figure 1-8 Top Front View

## Section 1

### 1.3 Furnace Elements

#### 1.3.1 Furnace Arrangement

Parts are carried from the load station through the heating and cooling sections of the furnace to the unload station on a 152 mm (6-inch) wide belt driven by an adjustable speed motor. Maximum vertical parts clearance inside the furnace is 50 mm (2 inches).



**Figure 1-9 Process Sections**

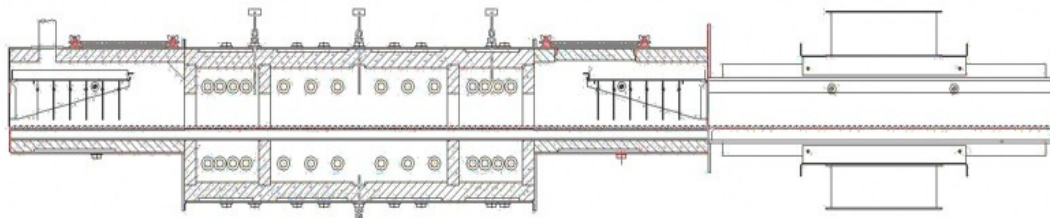
Process atmosphere is controlled much like a clean room: pressurized gas is pushed through the heating chamber insulation providing a pre-heated, laminar flow for a uniform, stable atmosphere.

The heating chamber is divided into 3 zones separated by insulation dividers so that adjacent zones can have different setpoint temperatures if required. Control starts with K-type thermocouples in each zone quickly sensing changing conditions and feeding these signals to individual digital PID controllers for each zone. The PID loop controllers drive arrays of IR quartz heating lamps inside the heating chamber so as to maintain the desired temperature setpoint in each zone.

Product cooling is by radiant cooling and CDA or N<sub>2</sub> gas convective cooling in an enclosed tunnel, with exterior fan heat removal.

#### 1.3.2 The Process Chamber

The process chamber contains an entrance baffle with an eductor equipped exhaust stack, an IR heating section, a transition tunnel between the heating and cooling sections, and a closed atmosphere cooling tunnel, arranged as shown here:



**Figure 1-10 Furnace Internals**

Together, the individual sections function as a unit to provide a carefully controlled gas atmosphere, precise temperature profile and two-stage controlled atmosphere cooling.

## 1.3.3 Entrance Baffle and Exhaust Stack

The entrance baffle isolates the heating section from the ambient air outside the furnace entrance. It is housed in a welded stainless steel shell lined with ceramic fiber insulation. An N<sub>2</sub> or CDA gas curtain and a series of hanging stainless steel baffle plates serve to act as a thermal barrier as well as purge the baffle and block ambient air from entering the furnace.

A venturi-assisted exhaust stack, known as an “eductor”, draws furnace gases across a removable drip tray to prevent exhaust condensation from falling into the baffle section and contaminating the product.

## 1.3.4 Heating Chamber

The furnace chamber is similar in construction to the entrance baffle and may be hermetically sealed with plenum box covers over the lamp ends. Inside this section, arrays of tungsten filament quartz heating lamp tubes located above and below the belt, generate intense near-wave (sometimes called “short-wave”) infrared light with a color temperature of 2500 K (peak wave length of 1.16 μm). These lamps are very efficient heaters with very fast response times, producing up to 600W per lamp at full power and capable of heating the furnace chamber to a state of equilibrium within minutes.

**Lamp Arrangement.** The lamps are arranged symmetrically above and below the belt. The top and bottom lamps may be used independently or together to provide the best possible heating configuration for any particular process. **Table 1-1 Furnace Arrangement** shows the distribution of lamps and available power in each zone.

Table 1-1 Furnace Arrangement					
Zone	Length (mm)	# of Lamps Top / Btm	Lamp Spacing (mm)	Standard Furnace Max. Available Zone Power (W)	High Power Furnace Max. Available Zone Power (W)
1	190	4 / 4	30	4800	4800
2	380	6 / 6	58	3800 – 4800*	7200
3	190	4 / 4	30	4800	4800
*Depends on power line voltage; 208 Vac: 3800W; 220 Vac: 4200W; 230 Vac: 4500W; 240 Vac: 4800W					

**Standard and High Power Configurations.** LA-306 furnaces are wired in standard configuration or high power configuration. In the standard configuration Zones 1 and 3 are wired with two (2) parallel strings, each consisting of two (2) lamps in series. Zone 2 is wired with two (2) parallel strings, each string consisting of three (3) lamps in series. High power models differ only in Zone 2 which is wired with three (3) parallel strings, each string consisting of two (2) lamps in series. Lamps within the furnace are arranged as follows: Either model will perform well throughout the design temperature range of the furnace (100-1000<sup>o</sup>C), the standard model is optimized for 100-500<sup>o</sup>C operation, while the high power model is optimized for 500-1000<sup>o</sup>C operation. Each configuration is summarized in Table 1-2.

Table 1-2 Furnace Lamps Wiring Configuration				
Zone	Standard Configuration		High Power Configuration	
	Strings Top/Btm	Lamps per String Top/Btm	Strings Top/Btm	Lamps per String Top/Btm
1	2	2	2	2
2	2	3	3	2
3	2	2	2	2

**Chamber Process Gas.** Process gas (CDA, N<sub>2</sub>, FG or other gas) is preheated before reaching the furnace interior by allowing it to permeate through the hot porous ceramic fiber insulation. This method of gas distribution does not affect the temperature profile and helps keep the furnace interior clean.

## Section 1

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**Zones.** The heating chamber is partitioned into 3 separate zones using ceramic fiber dividers. The dividers are designed with the smallest possible opening consistent with the part parts clearance specifications. This partitioning assures very high thermal isolation between zones. Although the heating profile across the belt is extremely uniform, heat losses through the furnace side walls and at the belt edge supports produce a temperature drop near the edges of the transport belt. Away from the extreme edges of the belt, overall temperature uniformity across the belt will be  $\pm 3^{\circ}\text{C}$ .

**Temperature Measurement.** Inside the furnace chamber, at the top center of each zone a type K thermocouple measures the temperature in that zone and provides feedback to each respective zone PID controller to determine the amount of power necessary to maintain setpoint temperatures. However useful these thermocouples are for controlling the temperature in each zone, the actual part is exposed to three heat transfer methods. As with any furnace, the most accurate way to determine what temperature product on the belt actually sees from these three methods of heat is to profile the furnace with a thermocouple placed directly on the product surface.

**Heat Transfer Methods.** Transfer of heat in the furnace is by three different methods: Radiation, Convection and Conduction. In order of their contribution to heating the product, these methods are:

### A. Radiation

The furnace lamps emit infrared electromagnetic waves which, when striking and absorbed by product on the belt, cause its temperature to rise. This is the way “heat lamps” and microwave ovens work, and also the way the sun heats the Earth. The infrared radiation does not directly heat the process gas within the furnace.

### B. Convection

During operation, lamp radiation heats the chamber top, bottom and side wall insulation. As the process gas enters the furnace through the porous ceramic insulation, it is heated to near the setpoint temperature of the zone. This flow of heated gas transfers heat to the product on the belt. This is how a hair dryer or home forced air heating works.

### C. Conduction

Lamp radiation heats the transport belt which becomes a heat source for the product supported on the belt. This is how a hot plate heater works.

## 1.3.5 Controlled Atmosphere

LCI 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.

## 1.3.6 Transition Tunnel

The transition tunnel separates the furnace chamber from the closed atmosphere cooling tunnel. The transition tunnel is constructed using the same materials as the furnace section to minimize thermal stresses to the product caused by excessive cooling rates. Convective gas cooling of product is produced by the controlled flow of process gas into this tunnel. A series of hanging stainless steel baffle plates serve to act as a thermal barrier and help contain the furnace atmosphere.

## 1.3.7 Closed Atmosphere Cooling Tunnel (CACT)

This section is constructed of extruded aluminum heat sink material and is not insulated. Inside, a carefully controlled atmosphere of CDA or N<sub>2</sub> gas is maintained to cool the product to a safe temperature. Fans mounted on the exterior of the CACT transfer heat to the air inside of the furnace cabinet. This cabinet air is then exhausted by cabinet fan through an opening in the furnace top cover into the room or for removal by facility exhaust ducting.

To prevent drafts and ambient air from entering the CACT, a hanging stainless steel baffle plate is mounted directly to the CACT exit.

## 1.3.8 Cabinet Fans

**Cabinet Fan.** The furnace is equipped with one (1) 10-inch diameter fan mounted on the underside of the top of the furnace cabinet. This fan exhausts heat emitted from the outside of the furnace chamber and cooling tunnel into the room or customer installed exhaust system.

**Enclosure Fan.** The control enclosure is cooled by fan(s) mounted under the enclosure. These fans pull cool air from the room into the enclosure through vents in the enclosure base. Room air flows into opening in the back panel and across the heat sinks where the SCR's are mounted and exhausts out the top of the rear panel door.

**Cooling System Fans.** The CACT cooling tunnel is cooled by fans mounted outside the top and bottom of the tunnel. Cabinet air is forced over the cooling tunnel to remove heat transferred from the tunnel interior. This air is evacuated via the cabinet fan.

## 1.3.9 Transport Belt

The LA-306 standard conveyor belt for high temperature applications is a close weave Nichrome-V belt manufactured from high temperature wire comprised of 80% nickel and 20% chromium. This belt offers fast heat-up times, more uniform operating temperatures and excellent mechanical stability. This belt exhibits minimum shrinkage, growth, sag or distortion in use.

## 1.3.10 Motor

The transport drive 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 1-11 Transport Drive Motor.



Figure 1-11 Transport Drive Motor

## 1.4 Console Controls & Indicators

### 1.4.1 Control Console

Control of the furnace is via the control console (Figure 1-12 LA-306 Control Console) mounted over the cooling section of the furnace. Independent control of each furnace zone is provided by type K sensing thermocouples, located above the belt in each zone, coupled to digital temperature controllers that control the power output of the lamps and sense alarm or alert conditions in each zone.



Figure 1-12 LA-306 Control Console

## Section 1

### 1.4.2 POWER Panel

#### A. MAIN POWER lamp

When this WHITE light is ON, the furnace is connected to the power line.

#### B. CONTROLS pushbuttons with indicator

Pressing the green switch applies power to the furnace controls, belt motor and cooling fans.

Pressing the red switch shuts off power to the furnace and acts electrically in the same way as pushing an EMO button.

Between the switches is an indicator light that stays ON while the control system is ON.

#### C. LAMPS pushbuttons with indicator

These buttons work only when CONTROLS indicator is ON.

Pressing the green switch applies power to the lamps and SCRs.

Pressing the red switch shuts off power to the lamps and SCRs.

Between the switches is an indicator light that stays ON while the lamps and SCRs are ON.

#### D. COOL DOWN pushbutton with lamp

Pressing this switch begins a timed, power shut down sequence. The furnace lamps and SCRs shut down immediately.

If the operator also presses the red CONTROLS switch, the control system shuts off, but the COOL DOWN circuits keep the zone controllers, transport belt, and cooling fans ON to help cool the furnace until the timer expires.

While in COOL DOWN, the blue indicator in the pushbutton is lighted until time expires.

#### E. COOL TIME knob

This knob sets the cool down time over a range from 1.2 minutes (fully CCW) to 120 minutes (fully CW). Set enough cool down time so that each zone process temperature (red PV) falls below 100°C. When the timer expires, all displays, the belt and fans shutoff automatically..

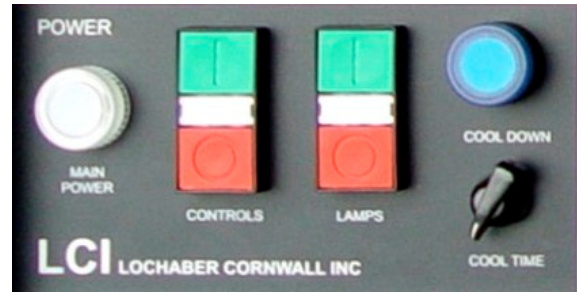


Figure 1-13 Power Panel Controls

### 1.4.3 ENERGIZE LAMPS Panel

#### A. Zone Switches with Lamps

These zone selection switches turn top and bottom heating elements in each zone ON or OFF. When a switch is turned CW, those elements are selected to be ON, and the switch light will turn ON. Turning a lighted switch CCW will turn those elements OFF.

Selected zones will remain selected even when furnace power is OFF.



Figure 1-14 Energize Lamps Controls

**Note:** Change zone selection only with LAMPS OFF to maximize zone selection switch life.



1.4.4 TEMPERATURE Panel



Figure 1-15 Zone Temperature Controllers

The temperature control for each zone’s heating elements is by a digital single-loop PID controller with loop Autotune and 3 alarm functions. The controller’s closed loop temperature control system uses K-type thermocouples for feedback and is preprogrammed to provide excellent furnace performance.

	<p><b>PV Display:</b> process value or parameter type  <b>SV Display:</b> setpoint or parameter value  <b>AT:</b> flashes when Autotuning operation is ON  <b>OUT1:</b> lights when control output is ON  <b>ALM1-ALM3:</b> alert/alarm LEDs, light when ON  <b>°F, °C:</b> temperature units selected  <b>SET:</b> press to select mode or set parameter value  <b>ROTATE:</b> selects next parameter within a mode  <b>DOWN:</b> press to decrease displayed SV values  <b>UP:</b> press to increase displayed SV values</p>
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## Section 1

### 1.4.5 STATUS Panel

#### A. READY lamp

When all zones have heated to their SV setpoint values and the controllers have reported all PV process temperatures as within temperature deviation limits, the process READY light (green) on the STATUS panel will turn ON. The furnace is then ready to process parts.

#### B. ALARMS

When lighted, these red LED indicators show what condition caused the alert or alarm. An alert condition will only produce an audible and visual warning; an alarm condition will produce an audible and visual warning and shut off the lamps as well. Any alert or alarm condition will shut off the READY Lamp.

#### C. ZONE TEMP DEVIATION alert indicator

A zone has experienced a process temperature outside the setpoint temperature +/- the ALM1 limits set in the zone controller. Factory setting is +/- 10<sup>0</sup>C.

#### D. OVER TEMPERATURE alarm indicator

A zone has experienced a process temperature higher than the ALM2 limit set in the zone controller and the lamps have been turned OFF. Factory setting is 1005 °C.

#### E. AIR PRESSURE LOW alert indicator (optional)

The CDA (clean, dry air) gas manifold has insufficient gas pressure, effecting operation. Setpoint mechanically set at the factory.

#### F. N2 PRESSURE LOW alert indicator (optional)

The N2 (nitrogen) gas manifold has insufficient in gas pressure, effecting operation. Setpoint mechanically set at the factory.

#### G. FG PRESSURE LOW alert indicator (optional)

The FG (forming gas, H2/N2 mix) gas manifold has insufficient gas pressure, effecting operation. Setpoint mechanically set at the factory.

#### H. CLEAR pushbutton with lamp

This red lamp lights with any alert or alarm condition.

Pressing the button will clear all alerts and alarms and will immediately shut off the CALIBRATE function, if active, on the TEST panel.

Persisting alert and alarm conditions will re-light the lamp, however, so it is best to correct the cause of the alert or alarm condition before pressing the CLEAR button.

#### I. BUZZER

This is an audible signal of any alert or alarm condition.

SILENCE pushbutton with lamp

Press the SILENCE button to silence the buzzer. This will also turn on the SILENCE red lamp as a reminder to the operator that the buzzer is off.

Pressing the SILENCE button again will enable the audible buzzer and turn off the SILENCE lamp.

#### J. SILENCE switch with red lamp

Turn the SILENCE switch CW to silence the buzzer. This will also turn the SILENCE red lamp ON as a reminder to the operator that the buzzer is OFF.

Silencing alerts is useful when changing setpoint temperatures, calibrating the SCRs, or auto tuning a zone.

Turning the lighted SILENCE switch CCW will enable the audible buzzer and turn the SILENCE lamp OFF.



Figure 1-16 Status Panel and Alarm Controls

## 1.4.6 GAS FLOW CONTROL Panel

Atmosphere control is accomplished manually with flowmeters calibrated in liters per minute. The meters are arranged to control gas flow into the various parts of the furnace and to control gas flow out the exhaust stack to achieve overall gas flow balance within the furnace. See Figure 1-17 Gas Flow Control Panel



**Figure 1-17 Gas Flow Control Panel**

Each flowmeter is identified with a label as to specific function and is adjustable from zero flow to full scale by means of a control knob. Turning this knob CW decreases flow; CCW increases flow. Flow is read on the graduated scale at the mid-point of the bead. Meters supplied are:

### A. STACK

Controls flow to the exhaust stack venturi. This flow has the capacity to exhaust a volume 15 times the venturi flow setting from the furnace atmosphere (for example, 10 L/m of exhaust removes 150 L/m of furnace atmosphere).

### B. ENTR BAFFLE

Controls flow to the entrance baffle isolating the furnace from room air.

### C. ZONE 1

Controls flow to zone 1.

### D. ZONES 2 & 3

Controls flow to zones 2 and 3.

### E. LAMP SEALS

Controls flow to the sealed lamp plenum boxes on each side of the furnace heating chamber.

**Note:** LA-306 furnaces equipped with a LAMP SEALS flowmeter should have at least 20 L/m flow through the meter while operating to prevent damage to the element seals and to avoid premature lamp failure.

### F. TRANS TUNNEL

Controls flow to the transition tunnel isolating the heating chamber from the cooling chamber.

### G. COOLING

Controls flow to the CACT closed atmosphere cooling tunnel.

## Section 1

### 1.4.7 TEST Panel

#### A. CALIBRATE pushbutton with lamp

Whenever the LAMPS button is on, this button applies 25% power directly to the lamps selected on the ENERGIZE LAMPS panel, allowing a reliable check for failed lamps on the TOP LAMP STRINGS and BOTTOM LAMP STRINGS indicators, or to adjust the SCR line voltage settings during SCR maintenance.



Figure 1-18 Test Panel

The built-in 2-minute timer, or pressing the LAMPS OFF button and pressing the CLEAR button, will end the CALIBRATE mode and return SCR control to the zone controllers.

#### B. TOP LAMP STRINGS indicators

A lamp “string” is 2 or 3 IR heating lamps wired in series to maximize each lamp’s efficiency. Whenever the LAMPS button is on, furnace lamp strings T1 through T7 above the belt (“top” lamps) are continuously monitored for lamp failure. String T1 is closest to the furnace entrance, and T7 is closest to the exit.

If the indicator is lit, the lamps in the string are fine. If unlit, the commanded power may be too low for an accurate assessment (a situation most likely during actual operation of the furnace), one of the lamps in the string may have failed, or the string may not be in the group of lamps selected on the ENERGIZE LAMPS panel.

For a more accurate assessment, use the CALIBRATE mode to check the lamps before running product in the furnace or during maintenance checks.

#### C. BOTTOM LAMP STRINGS indicators

Similar in operation to the TOP LAMPS STRINGS above, these indicators monitor the IR heating lamp strings below the belt (“bottom” lamps) in each zone.

### 1.4.8 TRANSPORT Panel

#### A. SPEED ADJUST

The Transport Speed Adjust knob controls the speed of the transport belt. CW rotation increases belt speed, CCW rotation decreases belt speed. There are approximately 10 turns between minimum and maximum speed settings.

To the right, a **Belt Speed** digital display meter shows the belt speed in inches per minute (ipm), or millimeters per minute (mm/m), or centimeters per minute (cm/min).

The **PAR**, **▼** and **▲** are only used to change the display settings and should be disabled during normal furnace operation.

The **PAR**, **▼** and **▲** are disabled during normal furnace operation.



Figure 1-19 Transport Panel