1.0 Application

All LCI and RTC infrared closed atmosphere belt furnaces.

2.0 Scope

To provide the process engineer with guidelines for understanding the primary factors and considerations in adjusting the furnace to achieve a specific result.

3.0 Responsibility

It is the process engineer's responsibility to identify the performance required for each process and/or product. The process engineer must then determine the Furnace Settings required to produce consistently satisfactory process results. The Furnace Settings are recorded as a Recipe for that process so that Operators can produce results that are consistent and repeatable.

4.0 Procedure

Tuning the furnace involves the following steps.

1. Identify the Process Specification required for the product.
2. Determine initial Furnace Settings.
3. Run temperature profiles on product samples in a representative load using a thermal profiler.
4. Analyze product for acceptance.
5. Review profile curve and adjust Furnace Settings, if necessary.
6. Re-run parts profiles (steps 3-5) until an acceptable and repeatable result is achieved.
7. Record Furnace Settings as a Recipe for production Operators.

5.0 Process Specification

The Process Specification defines time and temperature factors and other atmospheric conditions that will process the product in the manner required. Primary process parameters include the following:

Temperature bandwidth durations. Product temperatures and residence times for each specified phase of the process. Units are degrees Celsius and minutes (or seconds).

Rise rates. Heating rate or temperature increase per unit of time. Units are degrees Celsius per minute (or seconds).

Decline rates. Cooling rate or temperature decline per unit of time. Units are degrees Celsius per minute (or seconds).

Oxygen levels. Processes which require an oxygen-free atmosphere may stipulate low oxygen levels. Units are parts per million by volume. Typical values are (20 ppmv, 100 ppmv or 300 ppmv). Some furnaces may be equipped with continuous monitoring systems to provide real time feedback. A cost effective approach to managing O_2 levels can be to employ an analyzer to determine the initial flowmeter settings. Once the flowmeters are adjusted and provided the supply of process gas and pressure are maintained, the Operator can be assured of consistent results.

Moisture levels. Processes which require an oxygen-free may also stipulate maximum moisture levels in the heating chamber. The furnace may be equipped with equipment to sample and display moisture content in real time.

6.0 Process Specification Examples

Following are examples of typical profiles for a number of IR furnace applications.

Profile 1 – Solder Seal

- Nitrogen atmosphere with less than 20ppm O2 levels
- 100˚C to 310˚C in 6 minutes +/- 1 minute
- Maximum temperature not to exceed 330˚C
- Temperature to exceed 305 ˚C for 1.5 to 2.5 minutes
- Temperature to fall from 300˚C to 240˚C in 2.5 minutes or less

Profile 2 – Glass Seal

- Air atmosphere
- 100 ˚C to 400 ˚C in 6 minutes +/- 1 minute
- Maintain 420 to 440 ˚C for 9 minutes +/- 1.5 minute
- Maximum temperature, 430 to 440 ˚C
- Temperature to fall from 400 to 250 ˚C in 2.5 minutes

Profile 3 – PCB Reflow

- Air atmosphere – see profile detail below.

Profile Feature	Pb-Free Assembly
Preheat/Soak Temperature Min (T_{smin}) Temperature Max (T_{smax}) Time (t_s) from (T_{smin} to T_{smax})	 150 ˚C 200 ˚C 60-120 seconds
Ramp-up rate (T_L to T_p)	3 ˚C/second max.
Liquidus temperature (T_L) Time (t_L) maintained above T_L	217 ˚C 60-150 seconds
Peak package body temperature (T_p)	T_p = 260 +/- 5
Time (t_p) within 5˚C of the specified classification temperature (T_c).	30 seconds
Ramp-down rate (T_p toT_L)	6 ˚C/second max.
Time 25 ˚C to peak temperature	8 minutes max.

7.0 Furnace Settings

The primary Furnace Settings include temperature, gas flow and belt speed.

1. **Temperature.** Infrared furnace equipment temperature setpoints are determined through profiling the furnace. Secondary parameters include EDGE HEAT%, % POWER and PID parameters. Adjustment of these secondary parameters can improve operational consistency.

   CAUTION: INFRARED FURNACE TEMPERATURE SETPOINTS AND READINGS DO NOT REPRESENT THE ACTUAL TEMPERATURE OF THE FURNCE OR OF THE PRODUCT, BUT CAN SERVE AS A RELIABLE, REPEATABLE GUIDE IN THE OPERATION OF THE FURNCE ONCE TUNING IS COMPLETE FOR A GIVEN RECIPE.

2. **Gas Flow.** Gas flow settings can have multiple rolls in furnace tuning. Initial considerations may include control of oxygen an moisture levels in low O2 firing. Additional adjustments can move heat forward or toward the exit to change the temperature profile. Finally, often a stream of gas is necessary to stabilize furnace performance by assuring the lamps are always energized during production runs.

3. **Belt Speed.** Belt speed in closed loop systems can be used to provide a reliable and accurate representation of product residence time or time in each segment of the process. Small adjustments in belt speed can be used to increase or decrease time at temperature results in an otherwise good profile.

8.0 TEMPERATURE CONSIDERATIONS

Infrared furnaces have a thermocouple in each zone which provides feedback to the control system. Furnace systems do not measure the temperature of the product. The furnace thermocouples do provide some indication of zone temperatures; their primary function is to supply feedback so the control system can make necessary adjustments in power provided to the IR heating elements. **Therefore, the process engineer must determine the temperature setpoints for the furnace zones that will produce the required Process Parameters.**

As Product moves through each heating zone it absorbs infrared energy supplied by the zones. The product temperature can continue to increase in temperature even if successive furnace zones are set to the same temperature.

9.0 RECIPE ADJUSTMENTS

Once the initial settings have been entered and initial profile has been run, the Process Engineer must make adjustments to the furnace settings and tune the furnace to improve the result. This is an iterative process that is best completed when the end result is clearly stipulated and the deficiencies in the current results are carefully identified.

In tuning the furnace it is imperative that the settings and results are recorded for each test or Run. After a number of runs are made, the results can be compared along with the settings used to produce those results.

Each successive test run should incorporate only small changes, usually to a single parameter. For example, do not change gas flow and zone temperature setpoints all at the same time because it will be difficult to determine which adjustment improved or degraded performance. Also multiple adjustments may influence the result in a conflicting manner.

CHANGE RAMP RATE: Increase or decrease Zone 1 temperature to change the heating rate. The initial zone is often used to introduce energy to the part to get the part up to temperature rapidly. Zone 1 temperature setpoint maybe 50 to 200 C or more above the temperature expected in Zone 1 to assure a rapid rise rate.

INCREASE RESIDENCE TIME. To increase the time at temperature you can:

1. Increase temperature setpoint in the zone (introduces more energy in the problem zone), and/or
2. Increase temperature setpoint in the previous zone (introduces energy to the part earlier);
3. Increase temperature setpoint in the next zone (introduces energy to the part longer);
4. Increase gas flow to the zone (can cause lamps to stay on longer adding energy to the part)
5. Decrease belt speed (increased time part is exposed to energy applied in each zone).

If the profile shape is acceptable, but the part needs more residence time, decrease the belt speed by a small amount.

If the profile shape is acceptable, but the part needs more residence time, increase the temperature of the previous zone temperature by a small amount to achieve a faster rise time and earlier maximum temperature. Also you may be able to increase the temperature in the following zone to slightly delay the start of cooling phase.

If the profile shape is acceptable, but the maximum temperature is too low, increase the temperature setpoint of that zone.

LAST ZONE CONSIDERATIONS. The last furnace zone is often set a little higher than the previous zone to assure adequate energy is available to offset the effects of the transition tunnel and cooling sections. Alternately if peak residence time is already more than adequate and/or a slower or more controlled initial cooling rate is desired, lower the last zone below the previous zone to slow the rate of product cooling.

EDGE HEATERS. Use edge heaters to adjust for temperature variation across the belt. Make EH increases small to avoid reducing IR energy introduced via the lamps.

10.0 Using Multiple Furnaces for a Single Process

The specification for a given process describes the requirements to successfully process each part. These requirements are in terms of time, duration and atmosphere. Sometimes additional requirements can include temperature rise time and cooling rates. Additional requirements may be defined for the characteristics required of the processed part itself. The specification for the characteristics of the final processed part take precedent over all other considerations. If the processed part does not meet its requirements, the process parameters may be incorrect and have to be adjusted to assure a quality-assured result.

Each piece of equipment must be adjusted to produce the specified result. The settings on an IR furnace include zone temperature settings, gas flow rates, belt speed. Advanced settings include settings for PID parameters and applied power. Because of differences in hardware no two furnaces will have the same settings to achieve the desired result.

Differences in hardware include:

- Electronics – device tolerances vary
- Insulation - porosity, surface condition varies.
- Thermocouples and other sensing devices -performance varies within tolerance.

Differences in hardware due to age include:

- Electronics - newer devices are truer to original design, variations in both tolerances and sensitivity.
- Insulation – age affects porosity and surface condition.
- Thermocouples – age affects sensitivity and accuracy.
- Computer – newer operating systems, software and I/O respond differently to input data.

While two different pieces of equipment, even from the same manufacturer, can produce the same result, each piece of equipment must be tuned for its specific age, electronics and processing chambers.

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