1. Application

All LCI and RTC infrared closed atmosphere belt furnaces.

2. Scope

To provide the process engineer with guidelines for adjusting the furnace to run a desired thermal process using zone setpoint temperatures, a balanced process gas flow, appropriate zone control settings and alarm/alert levels on an operating, but empty furnace. If a heating zone is not under control in an empty furnace, it will not be under control when you try to run product.

3. 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 for 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. Summary Procedure

Tuning the furnace involves the following steps. See TEC-620 for assistance with steps marked "*".

- Identify the Process Specification required for the product. *
- Determine initial Furnace Settings. *
- Repeat the next 3 steps until an acceptable and repeatable result is achieved:
  - ✓ Run temperature profiles on product samples in a representative load using a thermal profiler.
  - ✓ Analyze product for acceptance.
  - ✓ Review profile curve and adjust Furnace Settings, if necessary. *
- Record Furnace Settings as a Recipe for production Operators. *

5. Tuning Your Furnace

A. Know Your Furnace.

Refer to your furnace documentation & drawings for details.

1. Confirm proper voltage, as shown on furnace nameplate, is connected.
2. Keep in mind that lengths of RTC and LCI furnace zones may vary.
3. Number of lamps/zone varies by zone length; more lamps mean more power in the zone.
4. Understand the sources of heat in an IR furnace are different from a convection furnace:
   a) 60-70% direct IR from the lamps.
   b) 20-30% convection via process gas heated while passing through furnace insulation.
   c) 10-20% conduction from belt and edge heaters (if present).
   d) Different materials may absorb IR energy at different rates.
   e) Parts hidden from direct IR are heated indirectly by convection and conduction.
5. Gas control flowmeters may supply process gas to more than 1 zone; check flowmeter labels.

6. Locate eductors (exhaust stacks) for flow balancing; each stack can exhaust 15x its flowmeter setting of process gas volume. Pairs of eductors control gas flow within the furnace by setting one eductor flowmeter higher/lower/same compared with the other eductor. Furnaces with a single eductor at the entrance can pull process gas forward toward the entrance at a higher/lower rate depending on its flowmeter setting.

7. Check zone control thermocouple (t/c) height: it should be the same in each zone. Replace oxidized t/c when required to maintain proper zone temperatures.

8. Determine presence/absence of under-belt edge heaters; use caution when using:

   a) Edge heaters are ***not regulated*** by the zone PID control settings.

   b) They generate constant belt edge conduction heat/unit length; amount of added heat ***varies with zone length***.

   c) Settings higher than 15% ***may affect accuracy*** of zone PID control.

9. Make sure zone SCR controllers are set properly, if adjustments are available. Some controllers require manual "zero" (minimizes SCR power leakage) and/or "span" adjustments (limits maximum voltage applied to lamps); other controllers have no adjustments.

10. Locate quartz rods/tubes supporting the belt within the furnace chamber. These supports absorb heat from the bottom lamps and belt, causing local cooling of the belt immediately above the supports. This affects only parts placed directly on the belt (i.e. not in carriers).

Note: Run parts on belt in lanes ***between*** the belt support rods/tubes.

11. No two furnaces are exactly alike, even if they have the same model number. Most furnaces are built by hand as custom assemblies, with continuous small changes due to "constant improvement" programs within the various furnace manufacturers.

Note: The "same model" furnace may need different zone PID, gas flow, edge heat and/or belt speed settings for optimal tuning to meet the process specification.

12. Don't confuse ***display resolution*** with ***display accuracy*** when tuning a furnace. K-type thermocouples are accurate of only about 2% of reading and drift over time with use.

Note: A display of 305.3C means only that the actual value may be about 305C ± 2-3C.

B. Best Control

For best control, the IR lamps must remain ON at all times with constant process gas flow into and out of the furnace. If the lamps are cycling ON/OFF during processing, the furnace is not in control and not processing parts continuously with infrared radiation (heat in the zone is varying).

C. Thermal Profile

Set up a temperature profile using the Recipe Screen. This will allow you to easily save your work to the system hard drive and to access the controls and alarm/alert settings for each zone. Remember to save your work often.

1. Start with an empty furnace, the belt running, and the default gas flowmeter settings.

2. Make sure the furnace gas inflow/outflow is balanced.

3. Enter desired zone setpoint temperatures, and click on WARM UP. Observe the results of setpoint changes on the Process Screen.

4. Conditions that cause problems:

    a) Large setpoint temperature differences between adjacent zones.

    b) Setting the next zone much cooler than the preceding zone.

5. To remedy these problems:

    a) Minimize the difference in setpoints and/or reduce belt speed. Observe the results on the Process Screen.

    b) Control direction of heated gas flow in the furnace by changing exhaust eductor flows (see Section D, below).

D. Balance Gas Flow

A balanced gas flow means the same volume of gas that enters the furnace chambers exits the furnace chambers, helping ensure furnace control stability.

1. Gas flow in any zone must carry away heat when that zone's lamps are off.

2. Be aware that adjacent zones may contribute heat to the affected zone via gas flow.

3. When the zone lamps are OFF and the actual zone temperature stays the same or rises, the zone is not under control.

4. To remedy this condition, try the following adjustments either singly or in combination while observing the results on the Process Screen. Keep in mind that a properly balanced furnace will meet the criteria in item 3, above.

    a) Confirm that the SCR(s) controlling the zone have properly set "Zero" trim pots as per Section A.9, above.

    b) Raise affected zone setpoint temperature so that control of the actual zone temperature depends only on the power delivered to its lamps.

    c) Lower adjacent zone setpoint temperatures to remove excess heat transfer to the affected zone.

    d) Increase gas flowmeter settings to affected zone (more gas gets rid of heat).

    e) Control direction of gas flow in furnace (toward nearest exhaust, toward entrance, toward exit) by changing exhaust eductor flows. Make these changes in small increments, say 3-5%, keeping in mind the 15:1 effect of the exhaust eductors.

        (1) A higher entrance exhaust flow vs. the transition tunnel/exit exhaust flow will pull gas flow toward the entrance of the furnace. Effects include:

            (a) Added heat to zones near the entrance for maximum ramp up in temperature.

            (b) Any zone setpoint that is much cooler than the preceding zone.

            (c) Faster initial cooling in cooling section.

        (2) Conversely, a higher transition tunnel/exit exhaust flow will pull flow toward the exit of the furnace. Principal effect:

            (a) Pulling heat away from entrance may allow higher temperatures to be maintained with less power in zones nearer to the furnace exit.

        (3) Remember to keep the total furnace gas inflow/outflow in balance when you make any gas flow adjustments.

f) Get in the habit of storing your gas flow settings on the Gas Flow screen with each recipe so that they will be available for operator adjustment when the recipe is recalled from storage.

E. Stability

While the default zone PID control settings entered at the factory may be sufficient for most profiles, the furnace allows fine tuning of these settings, if needed. This tuning should be performed only if Sections C & D above are completed.

1. Observe the effect of your changes on the Trends screen for the selected zone and correct PID settings as required. Allow enough time (2-3 minutes) to let the zone controls settle.

2. What happens when "Gain" is adjusted:

   a) The higher the number, the bigger the amount of correction. If gain is too big, the actual temperature will oscillate above/below the setpoint. Reduce gain until the actual temperature settles quickly onto the setpoint temperature with little overshoot.

   b) **Never set gain to 0!** On RTC furnaces, typical settings are 6-30. Factory default is 9.

3. What happens when "Integral" is adjusted:

   a) The smaller the number, the quicker the correction is applied.

   b) **Never set integral to 0!** On RTC furnaces, typical settings are 25-90. Factory default is 45.

4. What happens when "Derivative" adjusted:

   a) Derivative acts on the "rate of change" of the temperature deviation and gives an anticipatory response. May be set to 0 (Derivative has no effect) for a continuous stream of similar parts entering a zone. A setting of 1 or 2 may help a furnace zone respond more quickly to an uneven flow of parts.

   b) On RTC furnaces, typical settings are 0-2; use with caution as the **IR lamps in the furnace respond quickly**. Factory default is 0.

Note: Zone control settings for this recipe are stored with the recipe when it is saved. These control settings load when the recipe loads: there is no involvement required by the operator.

F. Process Alerts and Alarms. Set up alert and alarm levels.

1. Be smart about alerts and alarms

   a) Always leave the audible horn ON . If you are getting Alerts, check temperature settings, observed deviation from setpoint, rate of recovery from the alert and current power to the lamps for the affected zone on the Process screen. Alerts are giving you and your process people valuable information -- they are not nuisances.

   b) On RTC furnaces with PLC control, use the Deviation window on the Process screen to review Alert and Alarm levels for each zone. A furnace under control will show short, green bars or no bars at all in each zone.

   c) Avoid unnecessary furnace shutdowns due to brief temperature deviations (due to uneven furnace loading, etc.). Once in the process READY mode, the control system will shut off the lamps and enter COOL DOWN whenever any zone actual temperature reaches its Alarm limit. Increasing the Alarm limits for sensitive zones from their default setting of ± 20C to ± 30C can make a big difference; the same is true for Alerts.

G. Examples of Zone Control

Analysis on An RTC or LCI furnace with PLC control.

1. Process In Control

a) On the Process screen, issues with zones out of control can be spotted quickly via the Deviations window. Use the Trends display assess the zone behavior and to identify a solution.

b) Table 5-1 is a Trends display of a **zone under control**. Here the zone gas flow is being replenished at an appropriate rate and the lamps are on continuously adding energy to the entering gas and belt. The furnace was placed briefly in COOL DOWN mode, then returned to WARM UP to check the control response.

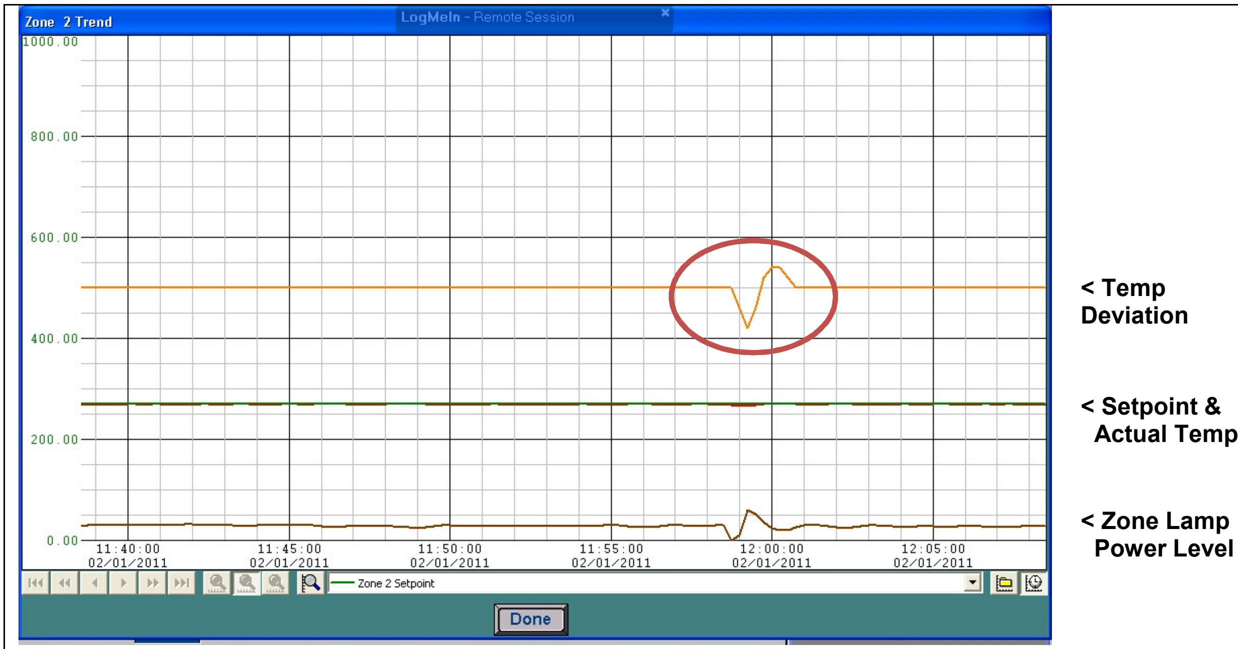

Table 5-1

Observation: This is a stable zone with a balanced gas flow. Note the smooth response in the Temp Deviation trace (circled) to the COOL DOWN command followed by the WARM UP command.

Recommendation: No further adjustment required.

2. Process Needs Adjustment

   a) Table 5-2 is a Trends display of Zone 1 out of control due to **gas flow imbalance**. Here the entrance exhaust eductor flow is higher than the transition tunnel exhaust eductor flow causing a net flow of gas toward the entrance of the furnace. This flow is dragging heat from the hotter Zone 2 (setpoint 270C) into Zone 1 (setpoint 210C) on its way to the entrance exhaust stack. Even with the lamps in Zone 1 off, heated gas is entering Zone 2, raising Zone 1 actual temperatures.

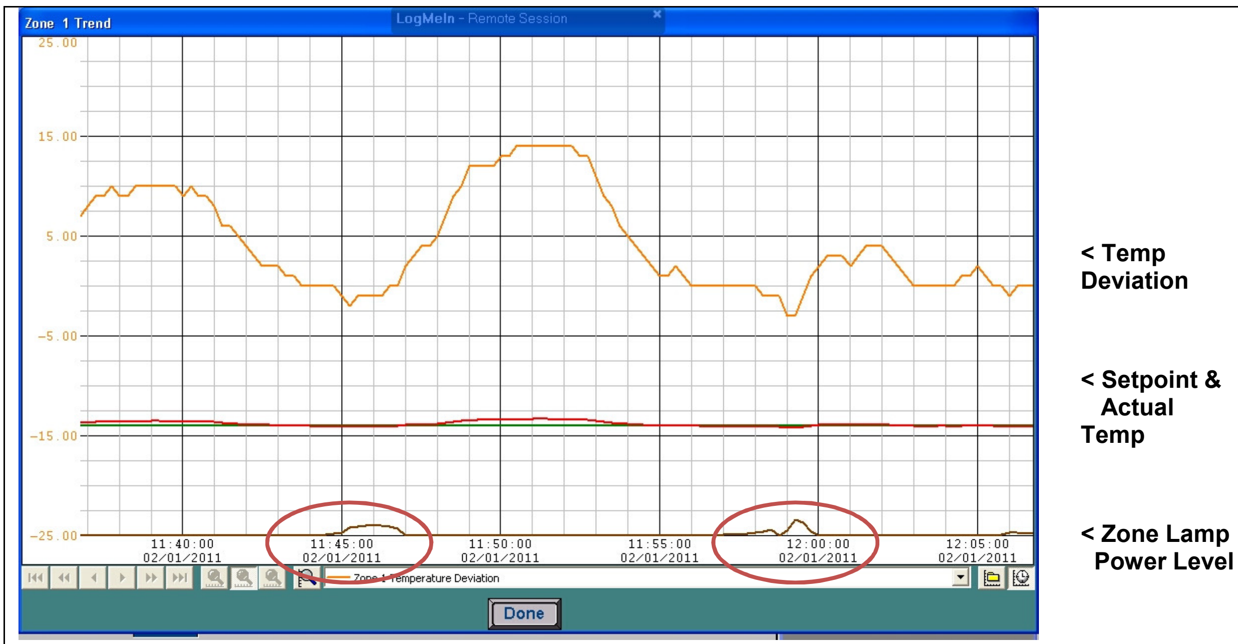

Table 5-2

Observation: Temperature deviation (difference between setpoint and actual) from -2C to + 14C observed. Lamps are on (circled areas, bottom trace) only when deviation is below 0C. During 10 minutes lamps are off, temperature rises due to gas entering from Zone 2.

Recommendation: raise transition exhaust eductor flow (while reducing entrance exhaust eductor flow) to move heated gas toward exit end of furnace. Lamps in both zones will add appropriate heat as required and the zones will be under control.

3. Effect of Changing PID Settings

a) Table 5-3 is a Trends display of the effect of a **change to the control PID settings** in a zone.

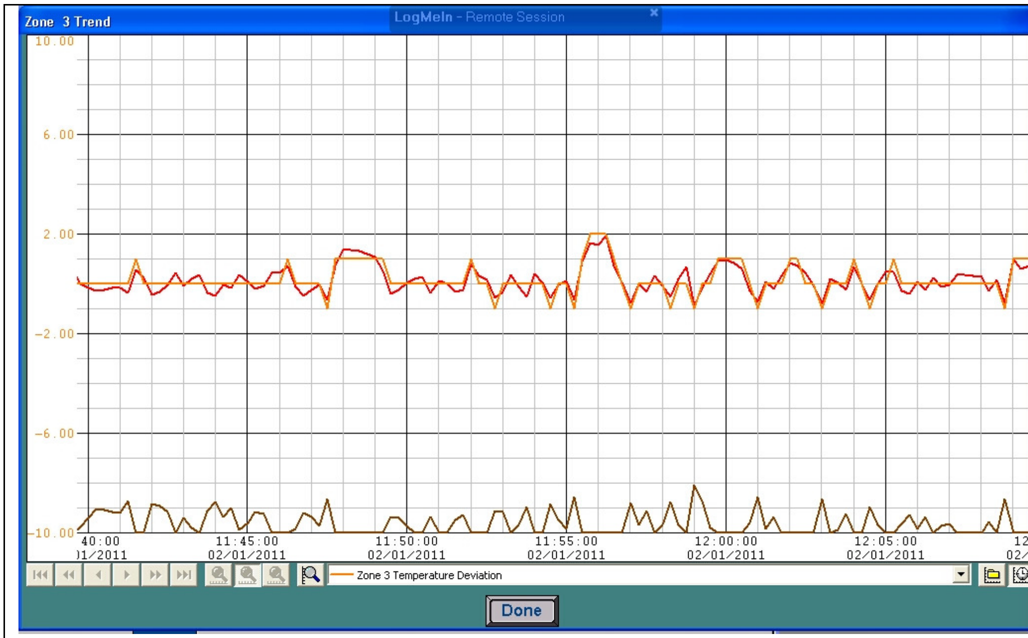

Table 5-3

Observation: Temperature deviations of ± 5C (difference between setpoint and actual) were observed.

Recommendation: by increasing the gain setting from 9 to 18, and reducing the integral setting from 45 to 30, larger and faster corrections reduced temperature deviations in this zone from ±5C to mostly ± 1C.

Additional recommendation: To further improve stability, add slightly more gas flow into the zone or adjust the exhaust eductors at either end of the furnace section to move more heated process gas out of the zone (see 5.D. Balance Gas Flow above).