Laboratory Tube Furnace SOP – Supplementary Material

* + Temperature Profiles and Nomenclature - an introduction
  + Temperature-Profile Development Worksheets

**Temperature Profiles & Nomenclature** - an introduction

Temperature controllers are used on tube furnaces to make them follow a predetermined temperature profile over time. These commonly look like the following:

Temperature

Time

The various segments of the profile are identified as shown here:

temp

dwell

ramp

ramp

final temp

dwell

start temp

The three parameters repeated during the profile are relatively straightforward:

**Temp** You can see 3 different temperatures in the diagram above. The temp controller’s algorithm attempts to achieve each of the temperatures during the execution of the profile with minimal overshoot (in temp) so that the process tracks the desired profile closely.

**Ramp** This parameter defines the rate at which the temperature increases and decreases. The temp controller attempts to change the furnace temperature according to the rate (ramp) desired. Although the diagram above is symmetric, ramp rates may be different.

**Dwell** defines the amount of time that the furnace holds at any given temperature.

To achieve a process that follows the simple profile shown above, a temperature controller is typically programmed with seven parameters (three temp values, two dwells, and two ramp values).

While the above example can make a useful process for a simple operation, often an added set of steps are necessary…

This figure shows a profile with one additional pair of each parameter (**R**amp, **T**emp, & **D**well). Furnace tubes often shouldn’t be ramped at the same rate above a certain temperature (800oC is common), so a lower rate-of-change must be added. This results in a “double ramp” profile:

D2

R2

D1

D3

R3

T1

R1

R4

T4

D4

T2

T3

Notice in the example that two dwell times (D1 & D3 - highlighted) are essentially zero. This means that the ramp rate will change when the temperature set points T1 and T3 are reached without spending any time at these temperatures (T1 & T3). This is not always necessary or desirable; these dwells may be nonzero values, resulting in the following profile (not to scale):

T1

D2

R1

R4

T4

D4

T2

T3

R2

D1

D3

R3

T0

The profile is symmetric, but all parameters can be changed to suit your desired process. In many cases the last dwell time (D4 in this example) will be set to a non-numerical value to signal the end of the program being run by the temperature controller. When programming a temp controller this is commonly done by entering a value < 0. More detail is practical only in the context of a specific temperature controller. The instruction manual for your temp controller will describe how to enter a program into its memory and how to execute (run) it when you are ready to start your process.

Looking at the example above, it is necessary to enter 12 or 13 parameters into the controller to ‘run’ that temperature profile. Regardless of the number of steps, the use of a worksheet with this information can be useful when entering the numerous parameters into the controller’s memory. The example worksheets shown here presume temperature units in **oC** and time units in **Hours.** They were developed for use with a high temperature furnace but can easily be customized to your controller **and** furnace.

**Temperature-Profile Development Worksheet**

**LIMITATIONS**

R1 & R4 < = 200oC/hr (typ.) and **NEVER** > 500oC/hr

R2 & R3 < = 100oC/hr (**MANDATORY**)

T1 & T3 < = 800oC. (800oC typical)

T2 > 800oC. T2 < 1700oC (**ALWAYS**)

D1 & D3 = 0 (typ.) T0: room temp presumed

T1

D2

R1

R4

T4

D4

T2

T3

R2

D1

D3

R3

T0

**R**amp **T**emp  
**D**well

R1 oC/hr T1 oC D1 hrs

R2 oC/hr T2 oC D2 hrs

R3 oC/hr T3 oC D3 hrs

R4 oC/hr T4 *30* oC D4 *END* hrs

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D1 & D3 = 0 (typ.) T0: room temp presumed

T1

D2

R1

R4

T4

D4

T2

T3

R2

D1

D3

R3

T0

**R**amp **T**emp  
**D**well

R1 oC/hr T1 oC D1 hrs

R2 oC/hr T2 oC D2 hrs

R3 oC/hr T3 oC D3 hrs

R4 oC/hr T4 *30* oC D4 *END* hrs