Bulletin No. 215

Cascade Temperature Control

When precise temperature regulation is required for a difficult situation.

Cascade control is a possible solution when precise temperature regulation is required for a difficult control situation.

Background:

Proportional control adjusts the amount of power going to the heater depending upon how far away the system is from the set point. As the temperature approaches the set point, proportionally less power is provided to the heater. Parr controllers utilize time proportioning which makes this adjustment by varying the ratio of on/off time instead of varying the current.

PID (proportional, integral and derivative) control adds automatic reset to eliminate differences (called offsets) between the set point and the actual control temperature. The derivative function further allows adjustments to be made, as a function of the rate of approach (or departure), from the set point. While this requires more care in setting appropriate values for the control terms, it produces excellent control with minimum overshoot, fluctuations and drift.

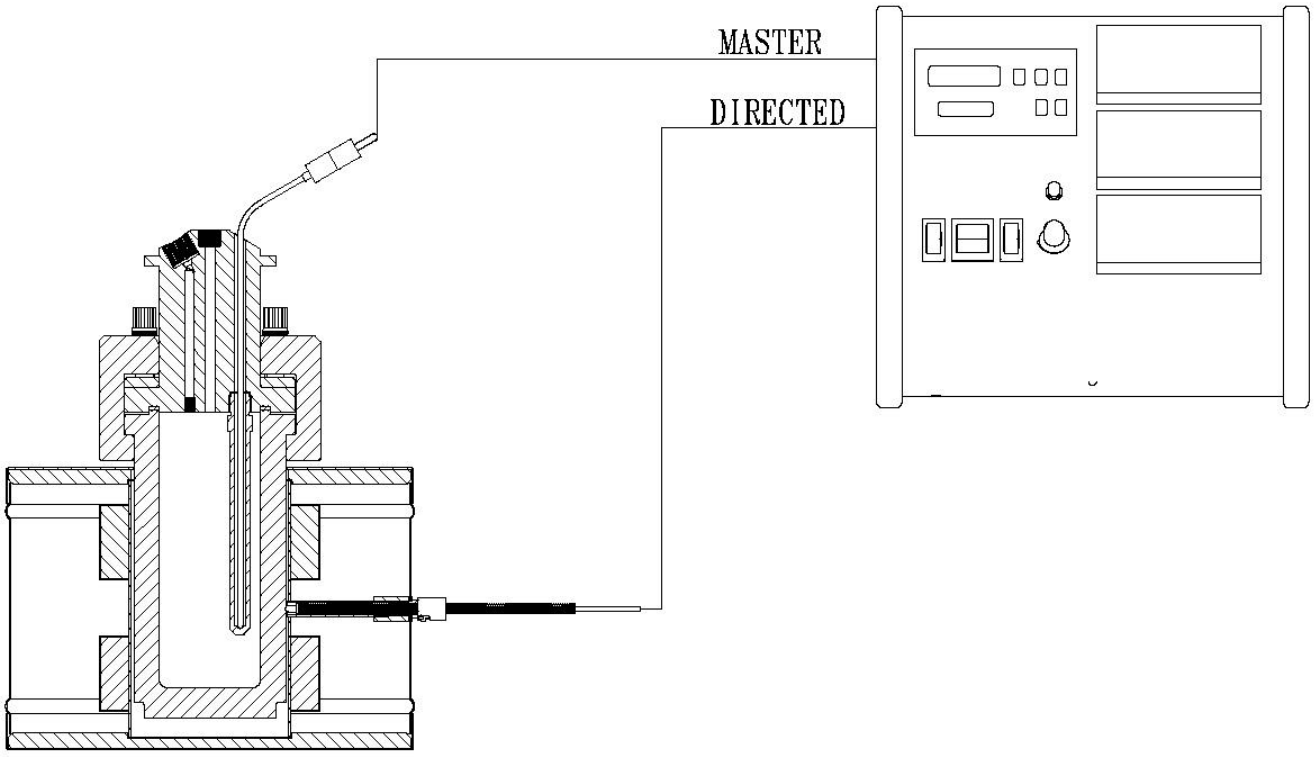
Ramp and soak programming provides two important features. First is the ability to program a series of operating temperatures and times for unattended operation. Second, it provides the ability to program specified heating and cooling rates. Ramp and soak deals with changes in the set point, not methods of control. Essentially, all ramp and soak controllers operate with PID control with the set point changing over time as specified in the program.

Difficult Control Situations

Even with all of the control capabilities discussed above, there are still certain systems that are difficult to control. Examples of these might be:

1. Systems with poor thermal conductivity through the reactants and little or no stirring.
2. Systems with large heat resistances. A vessel with thick walls and a PTFE liner can set up a system where the outside wall temperature can be 150ºC to 200ºC higher than the inside temperature.
3. A system with a very low heat capacity in the reactants as compared to the vessel. A two liter reactor containing only gasses would be an example of this.
4. Any combination of the above.

With these types of systems, a lot of heat will build up in the heater and on the outer walls of the vessel before the temperature at the inner probe will sense a change. When a standard controller does start its control action, it will be too late to compensate for the heat already in the system. This often results in a large overshoot of the set point.



Typical Cascade Application

Cascade Theory

Cascade Control utilizes two temperature sensors; one in the reactants and one on the outer wall of the vessel. There are two control loops; the master loop and the directed (or slave) loop. The master loop is the inner loop and uses the main set point of the controller to establish its heating requirements. The directed loop operates off the outer temperature sensor and receives its set point from a calculation based in the requirements of the inner loop. As an example, the following might be the directed loop set point based upon the main set point and inner temperature.

The main set point is 250ºC.

Master Temperature	Directed Set Point
50	400
100	400
150	350
200	300
225	275
250	250

Notice that as the inner temperature approaches the set point, the allowable temperature of the directed loop is reduced. The algorithm in the Cascade control system adjusts the directed loop set point continuously to provide outstanding control of these difficult systems.

Cascade Control is available in the 4844 Controller

The 4844 Cascade controller provides cascade control. This controller currently incorporates a Watlow controller which is a single set point controller.
Ramp and soak programming is not currently available, nor is the digital communications package.
To utilize the cascade option the system will need an additional thermocouple installed to monitor the outside wall temperature of the vessel. Usually this is done with a spring loaded thermocouple mounted through the heater. This is a simple option to install when a reactor is ordered, but could be more difficult to add to an existing heater.

Pseudo Cascade Control

In cases where the user may already have a PID controller or wishes to have the digital communications and Ramp and Soak Programming features offered by model 4843 controllers, we can create what we call Pseudo Cascade Control.

To do this, we add a second separate controller normally our High Temperature Module Controller, but we wire it to the heater load relay, instead of to the high temperature cut-out relay. The thermocouple sensing element is mounted on the outside surface of the vessel, and the maximum desired wall temperature is set into this controller.

With this setup, the heater will only heat when the inner temperature is below the set point AND the wall temperature is below its set maximum.

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