Wasting Energy: How does your Plant rate?

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A PVC pipe manufacturer interested in energy consumption in his plant brought in the local electric power company to make some measurements. Since extruder heaters account for a large portion of the energy bill, the company logged the kilowatt-hours consumed over 24 hours on a typical barrel zone on one extruder.
A controller of a different brand with a few extra control parameters was substituted. The log was repeated under the same conditions. Here are the results and analysis

Consumption with controller 1 was 134 kWh.	Cost at $0.07/KWh was	$9.38/day.
Consumption with controller 2 was 2.4 kWh	Cost	$0.168/day

The plant has 30 such zones on five extruders. Running 330 days per year the potential saving is some $90 000 per year.

This calculation does not take into account the costs of chilling the cooling water. Five compressors, each of 30 to 35HP were in service supplying chilled water for the five lines, mostly for barrel zone and cooling trough water.

These results call for a closer look at how the control process works.
On controller 1 the heat and cool output lights were pulsing every few seconds. This revealed that the controller spent all its time alternately heating the zone then dumping the heat into the cooling water. Because it held the temperature within tolerable limits and the product was acceptable it would not normally attract much attention.
Controller 2 spent most of it's time doing nothing - but just occasionally giving a short pulse of heat or cooling water to the zone and holding temperature to within one deg F.

Let’s track all this heat. It goes into:

1. Bringing the zone up to processing temperature at start up
2. Continuous melting of incoming polymer
3. Supplying radiation, conduction and convection losses from the machine to the environment.
   Some small saving would be possible only on item 3, by using thermal insulation on the barrel heaters.
4. A fight between the heater and the cooling process. Only controller 1 is seen doing this.

Cooling water delivery should lie low until it is really needed. That is, when the controller has turned its heat output way down to zero as it tries to correct for screw-generated shear heat.
At this point and not before, should the controller start to deliver shots of water until there is just enough cool action to fight the shear heat and hold the temperature down to set point. I.e. do not let the heat and cool overlap (if overlap is selectable on your controller). Overlap means that the heating and cooling are sometimes on at the same time. This is even worse than heating and cooling the zone alternately as controller 1 is doing.

Now look at how controller adjustments influence heat/cool cycling.
If you make proportional band very small, then a small decrease of zone temperature will give an overdose of heat. This will overcorrect the temperature and bring in an overdose of cooling. This

control loop instability will continue and can bring large temperature swings. Controller 1 is seen to be unstable but with acceptable temperature swings.
Increasing the proportional band will bring a more gentle response to temperature deviations and would be your first step to achieving stability.
After you have found the heat proportional band that gives control stability in correcting for a temperature drops you need to make sure that a rise of temperature brings the same strength corrective action from the cooling system and along with it the same control stability. The parameter 'Relative Cool' serves this function. It is put into controllers because zone cooling (particularly water) is often much stronger than zone heating. Also zone cooling-water shut-off valves are sometimes left in unknown positions so the zone's full cooling capacity is not readily known.
For a high capacity cooling process you would set Relative Cool well below 1.0 (a setting of 1.0 is valid when the cool process is of equal capacity to that of the heater).

The job of integral action is to watch for and slowly correct deviations from set temperature.
A too low setting of Integral Time makes this action too eager and brings control instability. Too high a setting will make the correction of persisting deviations somewhat slow but does no harm to stability.
Derivative action, sometimes called rate action, watches for changes of temperature and puts out a dose of heat (or cool) in proportion to the rate of change of temperature but in a direction so as to oppose that change. Its contribution ceases as soon as the temperature stops changing. The parameter name is 'Derivative Time'. A larger value setting gives a stronger response but it is possible to break into large power and temperature swings and energy wastage by setting it too large.

Most controllers come with a self-tune feature, i.e. the ability to analyse the controlled process on start up or on demand and adjust the controller parameters for stable and optimum performance.
This can be a great time saver but don't let it mask your knowledge of the process and the control principles involved.
Note that the brand of controllers used in this test is less important than the provision of useful control parameters and keeping the process behaviour in mind when adjusting them.