Controlling the Temperature of Slow Cooker

For long duration sous-vide cooking, water bath temperature stability can be easily achieved with a slow cooker. Almost any PID parameters' settings will hold the set temperature within one degree, if given enough time. However, the time needed for a slow cooker to stabilize at the set temperature is sensitive to the settings of the PID parameters. A slow cooker normally takes 1-2 hours to reach the set temperature from a cold start; during this period a slight temperature overshoot is expected. If food pouches are added to water bath at set temperature, you may need to wait another hour for temperature to stabilize again. You may want to shorten this long stabilizing period by using appropriate PID settings according to your applications.

We used two slow cookers for this study, a 4-quart 200 watt unit made by Crockpot, and a 7-quart 400 watt unit made by Euro Prox. These two cookers represent the majority of the slow cookers on the market.

Based on the temperature controlling method, we can classify the slow cooker control method into two classes, PID and PD (when I=0, No I). We will discuss the advantages and limitations of each method.
A) Proportional and Derivative (PD) control mode.
When I (Integral) action is removed (I=0), the temperature controller becomes a PD controller. The advantage of PD control mode is that you can reduce the temperature overshoot to a minimum. If the food pouches are placed in the cooker with water (hot or cold) and ramped (heated) up together, you would observe no temperature overshoot. This is really the best cooking approach. However, if you add the food pouches after the temperature has reached (or is close) to the set point, this would make the cooker longer time to stabilize. The PD control mode is very fast to reach set point from a cold or warm start. It is very slow to stabilize the temperature when there is temperature disturbance caused by sudden temperature drop (adding cold food pouches).
The following parameters worked well from our study.

Symbol	P	I	d	C-F
Display	P	I	d	C-F
Slow cooker, 4 quart	40	0	40	°F
Slow cooker, 4 quart	17	0	40	°C
Slow cooker, 7 quart	40	0	40	°F
Slow cooker, 7 quart	17	0	40	°C

Depending on the amount of water in the cooker, the performance may vary slightly. If the temperature still overshoots too much, increase the P value. If the temperature stabilizes one degree below the set point, reduce the P value.

Technical explanation

For people used to a conventional thermocouple or RTD sensor based PID controller, they may think a PD controller can't hold the temperature within one degree, because a few degree temperature offset is needed for the controller to output enough power to maintain stability. However, this is not true for a thermistor sensor based controller, because a thermistor sensor is much more sensitive. A 0.3 degree offset is sufficient for the controller sending enough power to maintain the temperature within one degree of set point.

B) Proportional, Integral and Derivative (PID) mode. The advantage of using the PID mode is fast action and no temperature offset (<1 degree) in long duration cooking. The disadvantage of PID mode is that there will be a small temperature overshoot. Depending on the parameters used, the temperature may oscillate several times before it settles to the set temperature. Because the very slow response of the slow cooker, it is very difficult to not have any temperature overshoot when PID mode is used. However, if you are making sous-vide and want to drop the food pouches into the pot after temperature is close to the set point, this small temperature overshoot actually will help the cooking and is preferred by many cooks. This is because in most cases, the overshoot is not high enough and long enough to bring the food temperature above the set point. It will help to bring the food temperature reach desired temperature faster.
The following parameters worked well for our test.

Symbol	P	I	d	C-F
Display	P	I	d	C -F
Slow cooker, 4 quart	54	60	15	°F
Slow cooker, 4 quart	30	60	15	°C
Slow cooker, 7 quart	180	700	40	°F
Slow cooker, 7 quart	100	700	40	°C

It should be noted that these parameters are not optimized if the amount of water in the pot is different. In general, weaker parameters (i.e., higher P and I) should be used when a larger mass is heated (except that the derivative action should be lower). Larger mass has larger heat inertia, so it needs to be moved more slowly to control. For the derivative action, strong action will reduce the overshoot. In terms of long term temperature precision, the difference in these parameters will have very little effect.

This study is preliminary. It will give you a guide on how to achieve a good stability control. We will keep you updated when better results are obtained from our tests or from our customers.