Dual PID Temperature Controller

By: Keith G. Benedict

This article reprinted with permission of Keith G. Benedict
(Originally posted on Castboolits.com)

As part of a long term process of developing the technology and knowledge base to make custom bullet molds it was necessary to have available a means to control and monitor the temperature of a lead melting pot and a bullet mold. I decided to build a dual temperature controller using digital PID controllers, appropriate type K thermocouples, and other components supplied by Auber Instruments Inc.

A PID controller is a device that compares the set point value (what you want) to the actual process value (what you've got) from your sensor over a period of time. PID stands for Proportional-Integral-Derivative. Proportional control merely looks at the difference between set point and process values to determine whether to turn on or off an output. A simple bimetallic thermostat operates this way, but this mode of control produces overshooting/undershooting and a constant cycling of the process value above and below the set point value Derivative refers to the rate of change of the process variable over time as control action takes place. Integral control is based on the total time and magnitude of the error between the process value and the set point value. These latter two modes are designed to minimize undershoot/overshoot and improve system stabilization. These particular controllers have a discrete (on/off) output; during operation the controller cycles it on and off for certain time periods to maintain control as closely as possible.

The Auber PID controllers have a number of user-friendly features that make them work well for this type of application. They accept analog input directly from a thermocouple (and other sensors), can be operated on a range of input AC voltages, and can be had with internal relay outputs or DC outputs to operate external mechanical or Solid State Relays. They also can actuate external alarms (which I am not utilizing in this application), will auto-tune themselves, and are small and relatively inexpensive.

Parts List:
2 - PID controllers Auber #SYL-2352 $89.00
1 - Type K thermocouple w/6” probe Auber #WRNK-171 $13.50
1 - Type K thermocouple ¼ -20 probe Auber #TC-K6 $6.85
2 - 25A Solid State Relays Auber #RS1A40D25 $30.00
2 - Panel mount thermocouple connectors Auber #TCCON $9.80
1 - dual outlet 110VAC female socket $3.00
1 - cable clamp $1.00
1 - approx 48” of 1/4” x 6” 6061 aluminum plate $24.00
1 - fuse holder and box of 20A Type T fuses $5.00
1 - tube of heat sink silicone grease $4.00
1 - 110VAC three prong male plug -
1 - terminal strip -
1 - 6' 12 ga 3 conductor stranded rubber coated cable -

miscellaneous 14 ga hookup wire (red, yellow, black, white) -
miscellaneous crimp on connectors -
miscellaneous screws -
bits and pieces of repurposed shop scrap -
(un-priced items are items I had on hand) Total* $186.15

*(Total does not include the $19.50 for three orders from Auber; I should have made one order and saved $13.00)

Construction:

I wanted to make a fairly compact unit so a 3-D CAD system was used to aid the design process. The Auber site has technical information on their products, including the dimensions of the major components. Other components that were on hand were simply measured using suitable tools. Each component was turned into a simple rectangular object and locate in space to enable the box to be built around it. The overall dimensions of the box ended up being 8" long, 4-1/2" high, and 6-1/4" deep. Once this was done it was easy to take the six box panels and locate hole centers and other relevant features. Each panel was then dimensioned and printed as an individual part to take to the machine shop.

The box panels are made from 1/4” aluminum plate which was cut to size by sawing and milling. All the holes were drilled and counter bored where required using a vertical milling machine. The square holes in the front panel for the two PID controllers were milled, as were the holes for the thermocouple socket. The thermocouple sockets were designed to be mounted on 12 – 16 gauge sheet metal so these had to be recessed into the front to allow the rear spring clip to lock them in place. The area around the cable clamp hole on the inside of the right panel was also relieved for the same reason. The hole for the 110VAC socket was also milled out.

The holes were tapped using a hand tapping machine.

The bottom, front, and both sides were then clamped up to maintain size and squareness and TIG welded on the inside. The corner brackets used as attachment points for the top and back panels were then welded in place.

The box was then returned to the mill and the holes for the top and rear screw holes were drilled, again followed by hand tapping. The box was then assembled to give it rigidity and clamped into the mill vise, where the bottom vent slots were cut. The top was removed and clamped in the vise and the vent slots were cut.

All the components were given a thorough cleaning, first in a parts-washing tank, followed by a wipe down with acetone.

The terminal strip for the 110VAC connections and the fuse holder were screwed into place first, followed by the cable clamp. The 110VAC cable was then anchored into place. The black (hot) lead had a female spade lug crimped on and then it was connected to the fuse holder. The white (neutral) wire was extended to the terminal strip where it was stripped at intervals and looped around the screws on one side of the terminal strip. The green (ground) wire was connected to one of the mounting screws on the end of the terminal strip, where it would ground to the case. A jumper wire with a female spade lug crimped on one end and stripped at intervals on the other end was used to connect the fuse holder to the terminal strip.

The thermocouple wires were then cut off by about six inches to provide a length of wire to go from the thermocouple socket to the controller. The cut ends were stripped and bent into a loop. The thermocouple was connected to the male plug, and the short section was connected to the female socket., leaving the spade lugs unconnected for the moment. Polarity is very important here - my thermocouple wires were marked red positive and had a red thread in the wire covering.

The SSRs are mounted with the power terminals on the bottom, where the terminal strip makes inserting the wire difficult, so 12 gauge black jumpers wire connected before they were mounted to the case. Heat sink grease was applied to the bottom of the SSRs before mounting.

The PID controllers each had four eight inch long 14 gauge jumper wires connected – black and white to the AC power terminals, red to the positive SSR coil output, yellow to the negative SSR coil output.

The thermocouple sockets were inserted and anchored into place with the supplied spring clips. The PID controllers were inserted into the face and the retaining clips were put on loosely. The thermocouple wires were connected to the proper terminals on the PID controller, which was then securely anchored with the spring clip. The yellow and red wires hooked to the proper polarity terminals of the SSR, and the white and black wires connected to the 110VAC terminal strip.

One of the power wires of the SSR was connected to a black (hot) terminal on the terminal strip. The other was connected to one of the brass terminals on the 110VAC socket. The 20A socket had the connector strip on the side removed so that each plug-in was controlled separately. The silver (neutral) side of the socket was not altered so only one white wire was needed to connect it to the terminal strip. No ground wire was used as the socket grounds to the box.

The 110VAC socket was then mounted to the top panel and a metal cover was secured in place. A fuse was inserted into the fuse holder and the top and back panels were then mounted to the box. A three prong male plug was connected to the end of the power cable, completing the assembly.

Operation:

The thermocouples were plugged in and the unit was plugged into a heavy duty extension cord on a 20A branch circuit. It was thrilling when nothing exciting happened and everything powered up normally. The units were preset at 50F and the thermocouples were exposed to ambient air temperature and within a few minutes both stabilized within one degree of the same 67-68F temperature reading.

With everything working normally it was time to test the unit. A simple thermocouple holder for the Lyman 20 pound bottom pour lead pot was made from shop scrap. It allows the thermocouple probe to be inserted into the melt to a consistent depth and can be swung out of the way for fluxing when the probe is removed.

Since a bullet mold was not available for preheating, a one pound lead ingot was drilled and tapped with a 1/4-20 thread and the other thermocouple was screwed into it. A protective aluminum plate was placed over the hot plate used for preheating and eight ingots, including the instrumented one, were placed on top.

The Lyman furnace and hot plate were plugged into the appropriate sockets and both units were turned all the way one, effectively cutting out the thermostats built into each unit and allowing the PID controller to cycle the power to the devices. Again nothing exciting happened.

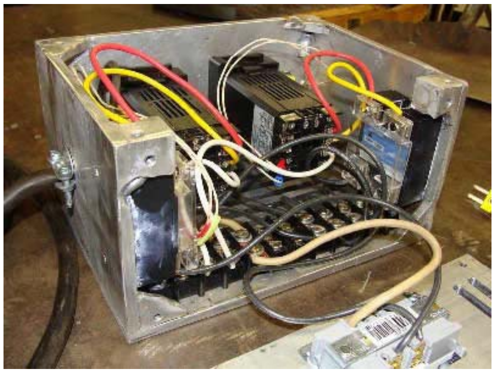
The set point value of the controllers were then entered. The lead pot was set to 725F, the hot plate to 325F. Within a minute or two the temperature reading began to increase. Within 10 – 12 minutes the hot plate was approaching the desired temperature and the auto-tune function was engaged. It overshot the temperature by about 40F the first time but settled down within a few minutes and held temperature within about +/- 10F after a while. This was not unexpected, as it is a system with a powerful input to a low thermal mass with a lot of surface area exposed to air currents.

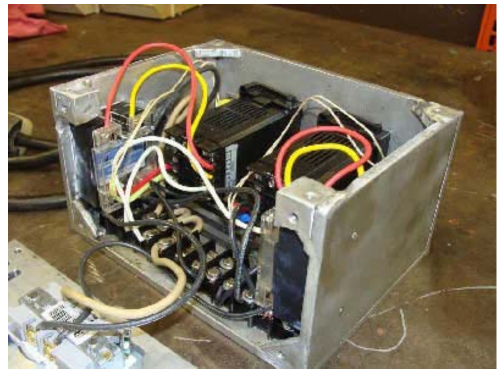
Within about 20 minutes the lead pot was approaching the set point value and the auto-tune was engaged. It overshot by about 30F at first but stayed within +/-5F after that, with +/- 2F control most of the time. No material was added or removed from the pot at this time so how good control will be during operation is yet to be determined. It is expected that temperature swings can be minimized by preheating ingots to a consistent temperature on the hot plate.

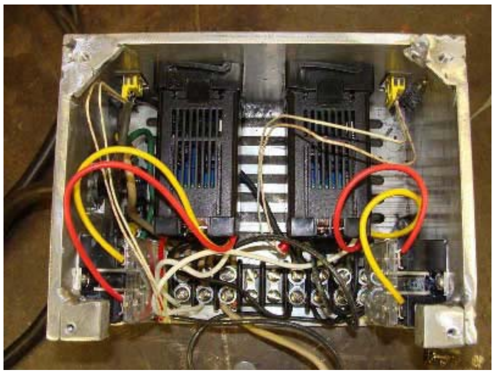
In the future I plan to attach a thermocouple to several special molds, but I do not plan to drill and tap all my molds. I think that putting a mold in the middle of a bunch of ingots held at a specific temperature on a hot plate would work just fine.

The system was operated at steady-state conditions for several hours. At no time did the area of the side panels under the SSRs get warm enough to feel. No heat was felt coming through the air vents on the top. Despite the small size of the unit it runs cool. So far I am pleased with the results.

Pictures Included here are various shots of the completed unit:







The Los Angeles Silhouette Club Front Page   Index to all LASC Articles