Introduction

μSR oven temperature control with CAMP instrument controller a processor for active PID control of other CAMP devices.

Set up of CAMP instrument controller

Path: /Tcontrol

setpoint	875.00000000	
readback	875.00000000	
output	3000000.0000	
function	Stop	! Turn active control on or off
status	idle	

setup_read/ →		! Set readback device and parameters
device	/TC/temp	! Identify Camp Variable to use for readback
min	300.00000000	
max	1100.0000000	
interval	60	! Number of seconds between each readback/control iteration
num_ave	3	! Number of instrument readings to average for each readback iteration
stable_tol	2.0000000000	! The maximum range of readings in each iteration for the readback to be declared ”stable”

setup_out/ →		! Set up control of output device
device	/DAC/dac_set	! Identify Camp Variable to set for output
min	0.0000000000	
max	3000000.0000	
max_change	22000.000000	! The maximum allowed change in output at each control iteration
interval	60	! Number of seconds between each readback/control iteration
Kp	6000	! Proportional Gain: Coefficient for P term (0 is off) (may be function of $rb)
Ki	1200	! Coefficient for I term (1/xnmr_cal) (0 is off) (may be function of $rb)
Kd	0.0	! Coefficient for D term (0 is off) (may be function of readback $rb)
scale_func	sqrt($x)	! Function of $x to rescale the control output, e.g. ”sqrt($x)”
inverse_func	$x*$x	! Enter the inverse of the scale_func function, e.g. ”$x*$x”
learn		! Automatically determine (tune) control parameters.
lconfig/ →		! Configure details of learning process
internal/ →		! Internal control variables

Set up of power supply and oven

The power supply is set up to give 5 A current when the input is 2000 DAC. The output of the controller is in power 4×10^6 DAC^2 corresponds to 5 A. At low temperature the oven response is much better if an exchange gas is introduced into the vacuum jacket. In this test 0.5 atm of air was used between room temperature and 700 K. Above 700 K the gas should be pumped out. Figure 1 shows the oven temperature from the time a constant power was applied to the oven. The solid lines are with 0.5 atm air and the dotted line in vacuum. The dashed line shows the cool down time in 0.5 atm air. All the curves show that a stable temperature is obtained in about 40 min. Fig. 2 shows the oven cool down time in vacuum which becomes very slow at low temperature.

Temperature control

Figure 3 is a plot of power vs. temperature. Below 700 K with 0.5 atm air in the oven the temperature range can be divided into three zones. The slope of the power curve in the three zones and the parameters used to control the temperature are given in Table 1. Above 700 K the vacuum range is also divided into three zones and the slope of the power curve and control parameters are also given in Table 1.

With the parameters given in Table 1 changing the temperature should take between 10 and 15 min for a 10 K change and about 30 min for a 50 K change. Some examples of temperature changes are shown in Fig. 4,5 and 6. It is best to change the control parameters to the values needed in the final zone at the start of the temperature change.

Test in preparation for Oxygen flow

In January 2006 the temperature of some critical parts were measured as required for safety approval to use the oven with Oxygen flow. During the first day the oven was tested in air at 1 atm. For the next two days tests at high temperature were done with 1 LPM Oxygen flow. With the oven at 850 K the T of the various parts are given in Table 2. The T of the window flange increases as the Ti foil becomes less reflective, at these high T one should replace the foil after each use. With the flange at 340 K the top of the water pipe was at 335 K and with a bit of air cap the T was 328 K. The T at the center of the Kapton window was well below the max operating T for Kapton. At about 5 mm away at the normal location of the muon counter the T was 330 K. Plastic scintillators softening point is about 70 C or 343 K. Therefore setting the trip of the water cooling flange at 340 K should be safe but one should make sure none of the counters touch the oven shell and that the air compressor is connected and on. Teflon melts a 600 K and its physical properties starts degrading at 533 K its ignetion temperature in pure Oxygen is above 700 K, so a temperature of 430 to 440 K at the teflon insulation is safe.

Oven trip

This section describes how to setup the trip system to shut off the power to the oven if the temperature of the oven or water cooling exceeds a preset value. The trip value for the oven temperature should be set at 855 K and for the water cooling flange at 340 K. The DAC controlling the output of the KEPCO power supply can be shut off by either the LakeShore 218 temperature monitor measuring the temperature of the water cooling flange or the ISeries thermocouple reader measuring the oven temperature. A Platinum resistor is used to measure the water temperature below it is shown how to set input 1 of the LakeShore 218 to read the temperature and use relay 1 to control the trip. If needed more relays can be added in series and controlled by other inputs.

LakeShore 218:
Relay 1 contacts 1 and 2 normally closed.
Alarm Setup:
Input 1
Alarm on
Units K
Low alarm point 280 K
High alarm point **340 K**
Deadband 0
Latching on (Alarm Reset will reset a latched active alarm after the alarm condition has been corrected by the operator(water turned on))
Audible on
Relay Setup
Relay 1
Alarms
Input 1
Both (insure power is turned off if temperature sensor is unplugged or stop working)

The oven temperature is measured by a type N thermocouple read by an ISeries Omega controller. In the paragraph below it is described how to setup Alarm 2 to trip the power supply if the oven temperature exceeds a safe value.

Iseries:
Alarm 2 contacts 1 and 3 normally closed.
Display color: Normal GREEN; Alarm RED
Press Cycle (Cy) until **Config**. menu then Enter (En)
Cy **Alarm 2** En
Enabl
(! Can be changed only when flashing press En to enter submenu)
Abso
UnLt (relay remains latched only as long as the alarm condition is true, TC unplugged or max T exceeded)

N.C. 'Fail safe mode'
Hi.Lo.
Alr. L 5 C
Alr. H. **580 C**

Table 1: Oven zones and control parameters.

zone	temperature	oven condition	Kp	Ki	max–change	watt/K
1	300–499	0.5atm N_2	3500	400	6000	0.20
2	500–599	0.5atm N_2	3500	600	9000	0.28
3	600–699	0.5atm N_2	3500	800	12000	0.42
4	700–824	vacuum	3500	800	18000	0.40
5	825–924	vacuum	3500	1200	20000	0.62
6	925–1000	vacuum	3500	1600	22000	1.02

Table 2: Test with Oxygen flow.

	1 atm air	1 LPM O_2 flow day 1	1 LPM O_2 flow day 2
Oven T	850.5 K	850 K	849.7 K
Window flange	330.5 K	336 K	340.5 K Top of water pipe 335/328 K
Kapton window	413 K max operating T 673 K	418 K	414 K 5 mm away 330 K
Power lead teflon	431 K max operating T 533 K	437 K	439 K
DAC	1917	1976	2000
Power	3.65 M	3.9 M	4.0 M Should change Ti foil