FERNS Test Report
March 12, 2007

Summary

As-Delivered Configuration (FERNS-1.0)   August 2006
- Excellent sample exchange and cooling (10K in 10 minutes; 6K ultimate)
- Heating and temperature control needs improvement

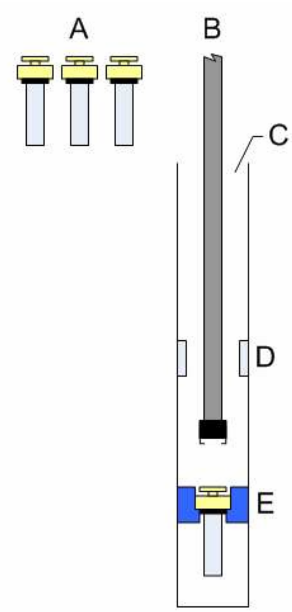
Heater Modification (FERNS-1.1)   ~28 August 2006 – October 2006
- Cartridge heater installed on cold ring
- Good heat transfer and temperature control using cold ring sensor, but huge offset between sample and control temperature
- Poor control using sample sensor
- Note: compressor troubles delayed test completion

Heater Modification (FERNS-1.2)   ~15 November 2006
- Place cartridge heater closer to sample
- Used aluminum bracket for low-mass heater mounting fixture
- Heater fixture began to melt! (poor thermal contact with sample tube)

Heater Modification (FERNS-1.3)   ~20 November 2006 – present
- Replaced aluminum heater assembly with integrated heater/sensor assembly made of Copper
- Good heating and control
- Small offset between sample region and integrated heater/sensor assembly
- Still have excellent sample cooling and exchange

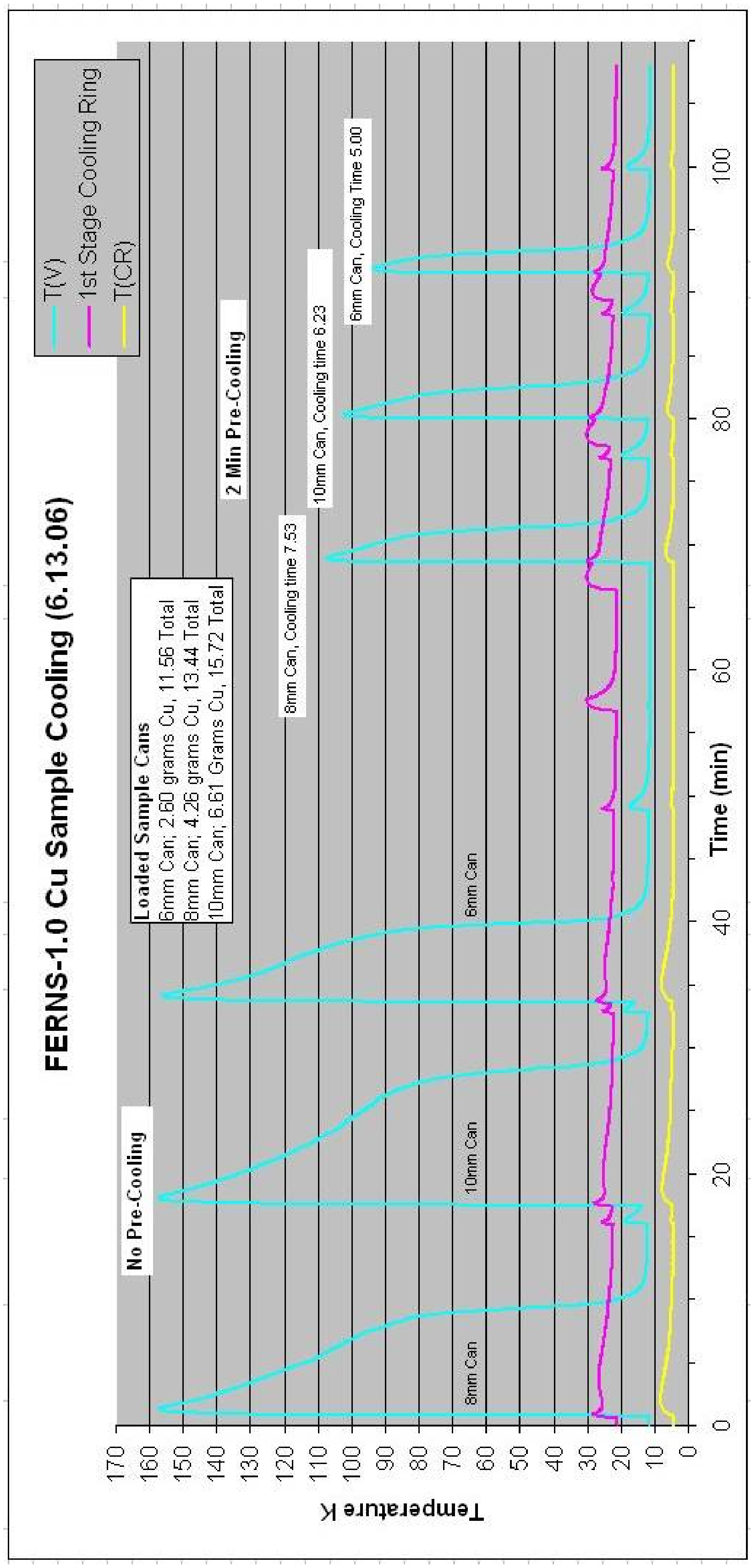
FERNS Essential Features

A. Multiple Samples (24) Stored on Carousel
B. Motorized Sample Delivery/Retrieval Stick
C. Helium Gas-Filled Sample Tube
D. Pre-Cooling Zone (linked to Displex 1st Stage)
E. Landing Pad (liked to Displex 2nd Stage)

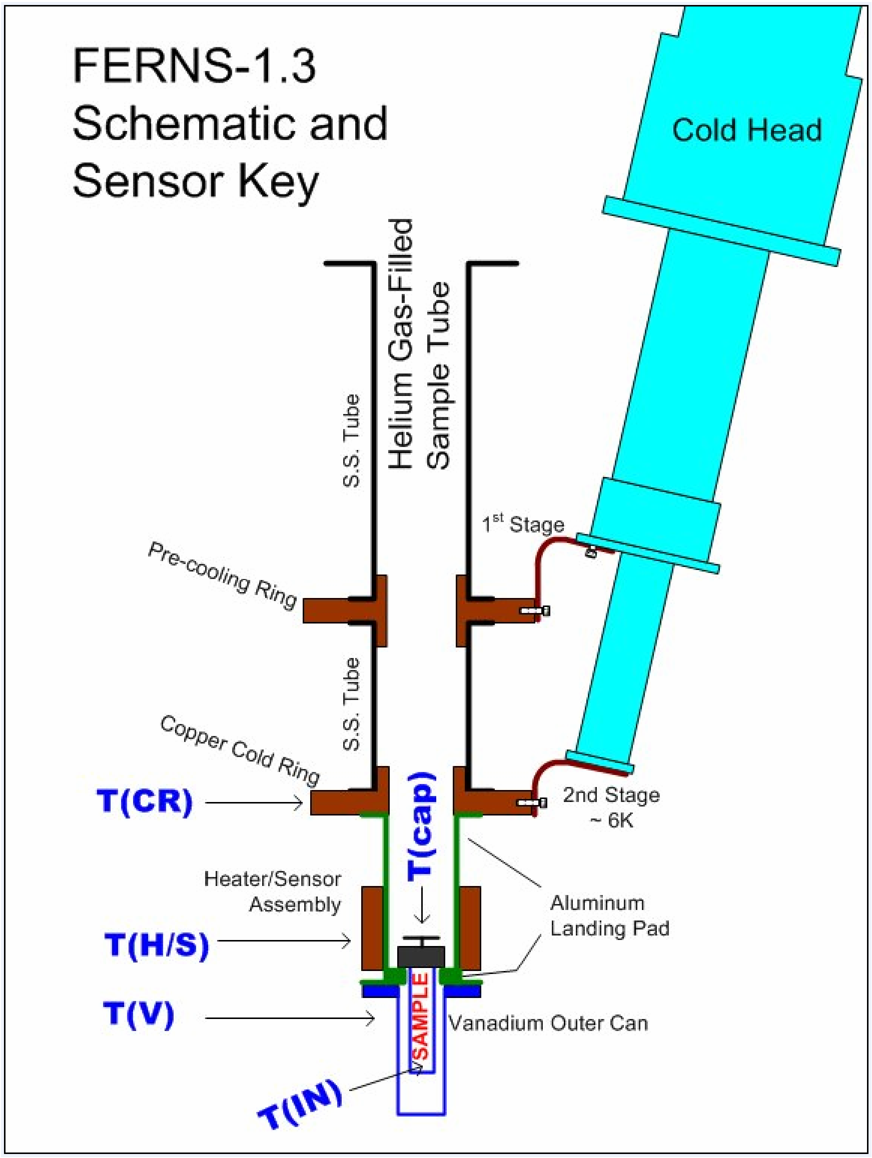


Automated Sample Delivery and Cooling Below 10K within 10 Minutes

The plot at right shows temperature response during a series of sample exchanges in the FERNS-1.0 system. The "samples" here are copper beads loaded into vanadium sample cans. Sample mass and can size are indicated on the plot. Samples are stored on a carousel within a helium gas-filled chamber at ambient temperature. Whenever a new sample is delivered into the cold sample tube, the sample tube temperature spikes but quickly recovers. Here, the temperature measured on the vanadium tail of the sample tube (T(V)) is our best indication of sample temperature (subsequent measurements confirmed this). Refer to the schematic on the next page for positions of all the sensors.

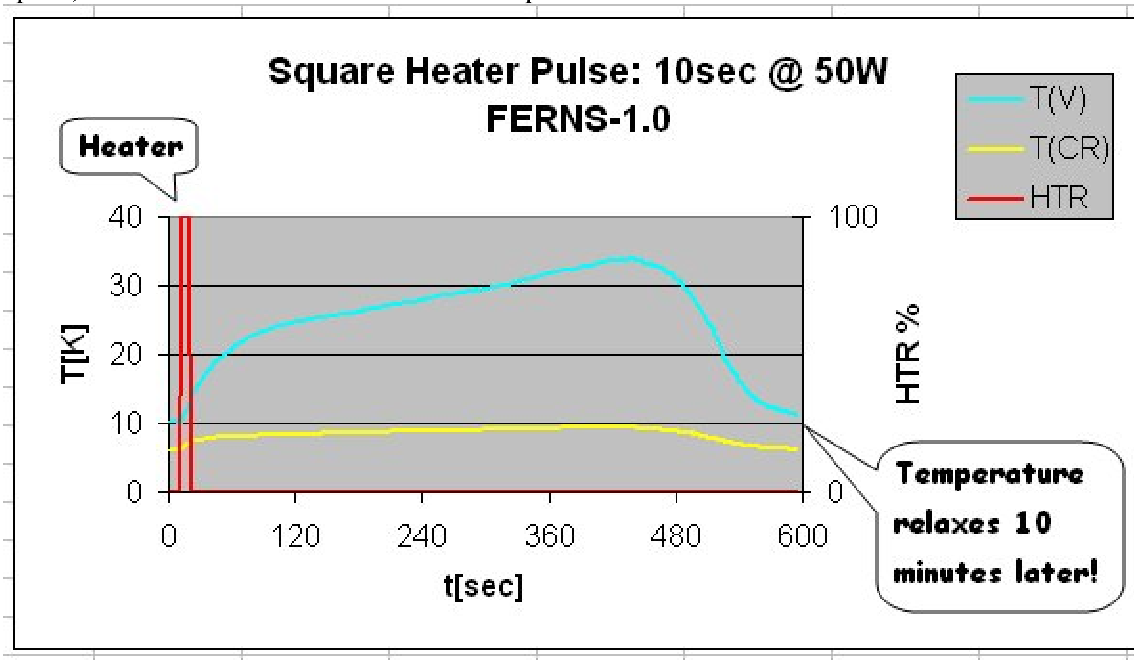


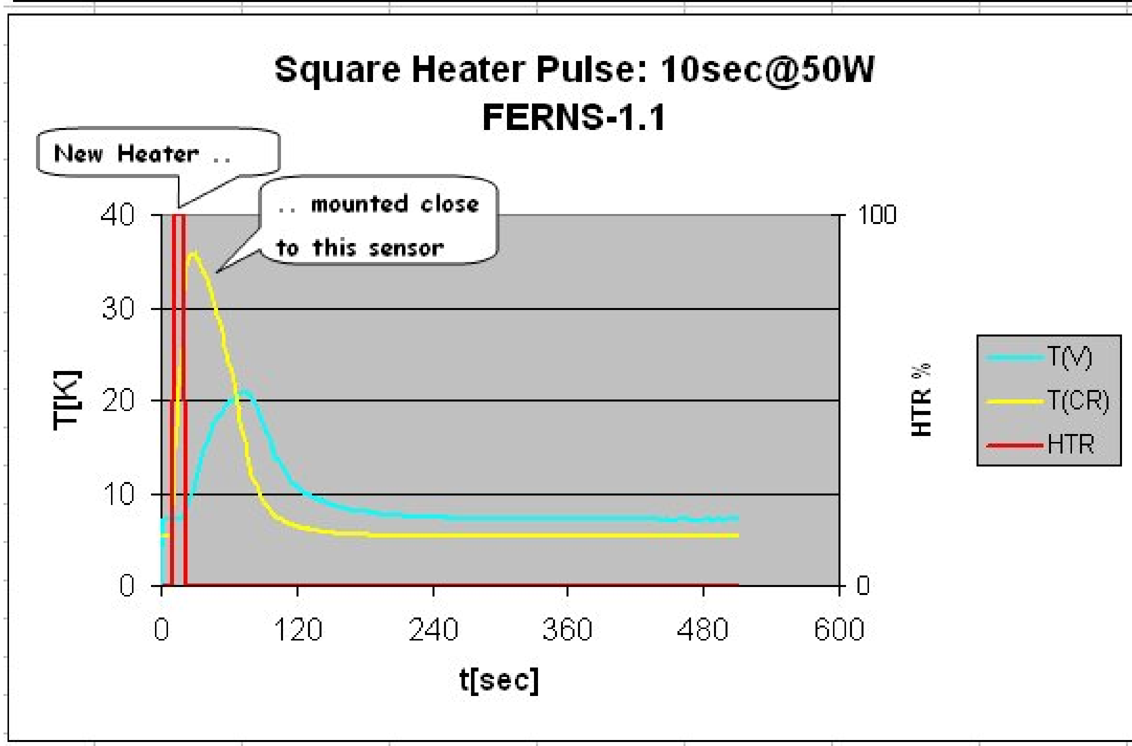
The FERNS system continues to show rapid cooling in its present configuration (FERNS-1.3). But the present configuration offers better temperature control throughout the entire operating range (6K to 300K). The remainder of the test report focuses on heating and control aspects. The figure below shows all of the temperature sensor positions. Note that the early FERNS configurations did not include all of the sensors shown below.

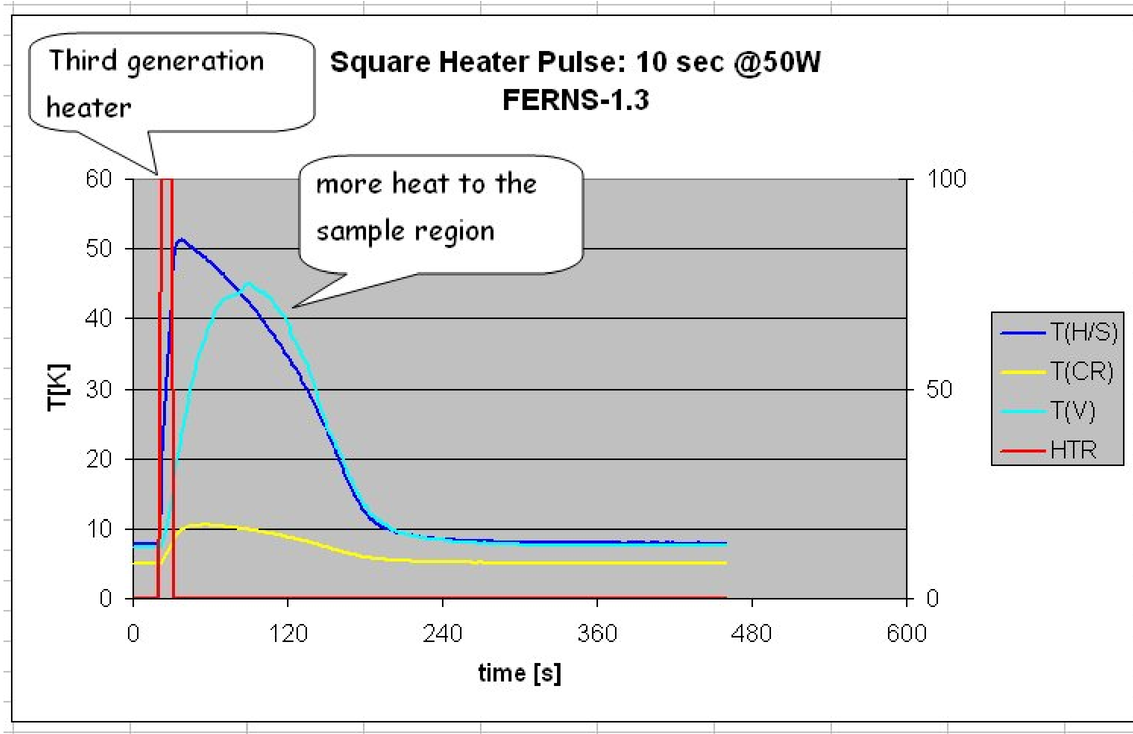


Heater Response Comparison

Good temperature control (fast temperature changes and equilibration) requires fast heat exchange. The tests shown below were used to evaluate various FERNS heater configurations. The test procedure is simple: spike the heater while recording the temperature response. The longer the delay between the heater spike and temperature spike, the harder it will be to control temperature.





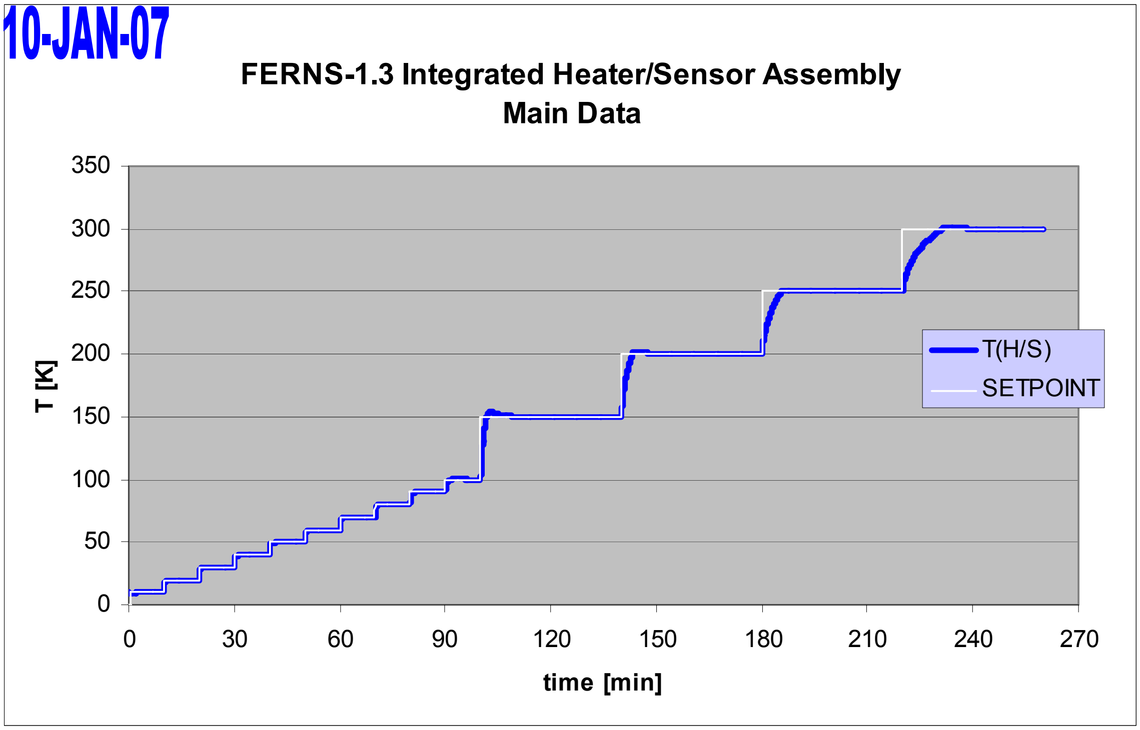


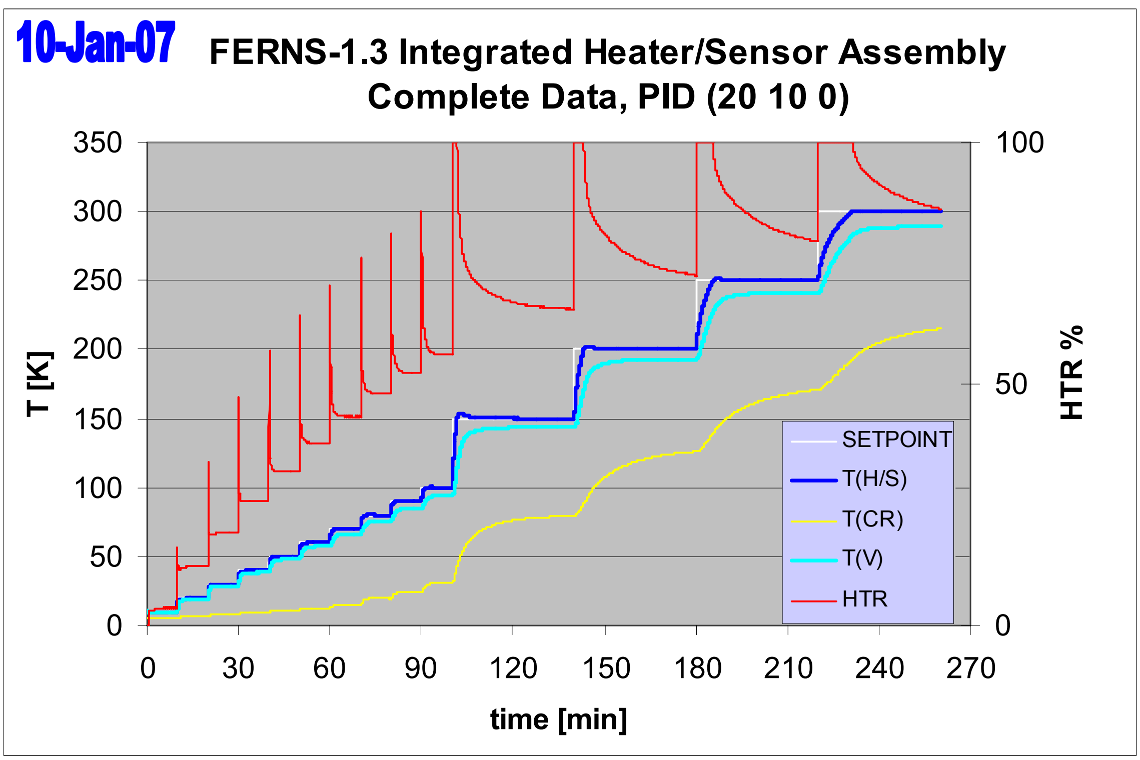
The original FERNS heater (FERNS-1.0) consisted of resistive wire wound around the aluminum landing pad fixture, and potted with epoxy. It showed very slow heat transfer, so it was replaced with a commercial cartridge heater. The first cartridge heater modification (FERNS-1.1) involved mounting the cartridge to a convenient spot on the cold ring. Heater pulse tests showed a much improved thermal response, but (not surprisingly) the cold ring was heated more than the sample region. In FERNS-1.2, an aluminum cartridge heater mounting bracket was fabricated and clamped onto the landing pad. Aluminum was chosen for low thermal mass, but this assembly overheated and even began to melt! Note that the temperature sensors never recorded unusually high temperatures, and no other components of the FERNS rig were damaged. Perhaps the problem was bad thermal contact between the aluminum bracket and the aluminum landing pad.

The next modification (FERNS-1.3) involved remaking the heater bracket using copper, and mounting a temperature sensor directly on the heater bracket. This integrated heater/sensor assembly has given us our best results to date.

Temperature Control

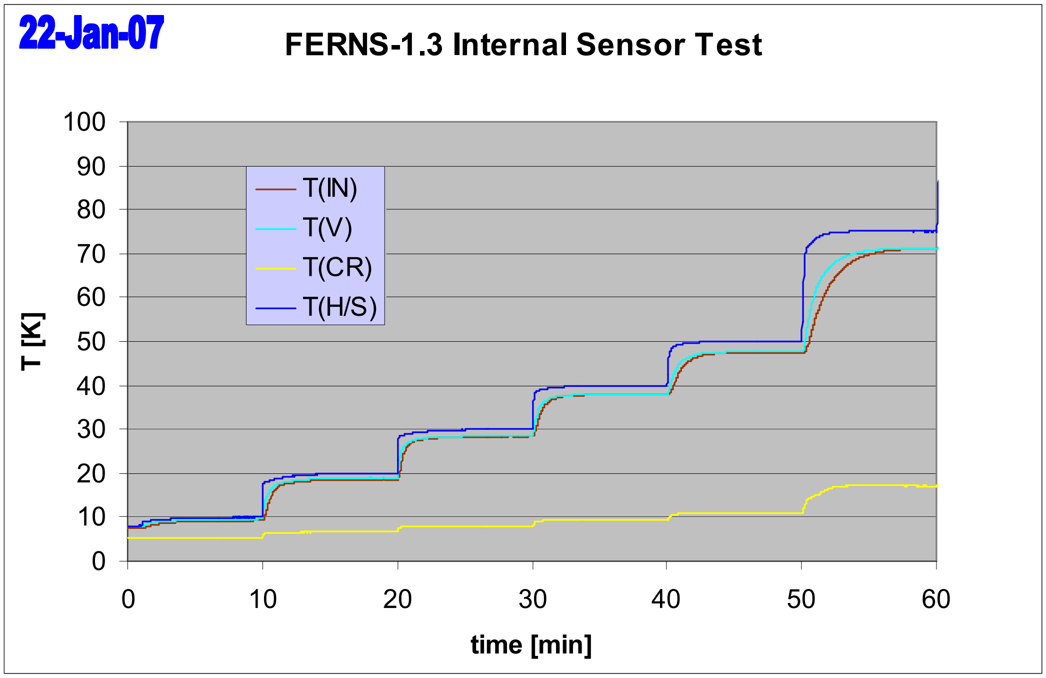
The two plots below show the best set point control to date with FERNS-1.3, where T(H/S) is used as the control sensor (*i.e.* determines heater output of temperature controller). The top plot shows simply the set point and control sensor, and the bottom plot shows complete data from the same test.

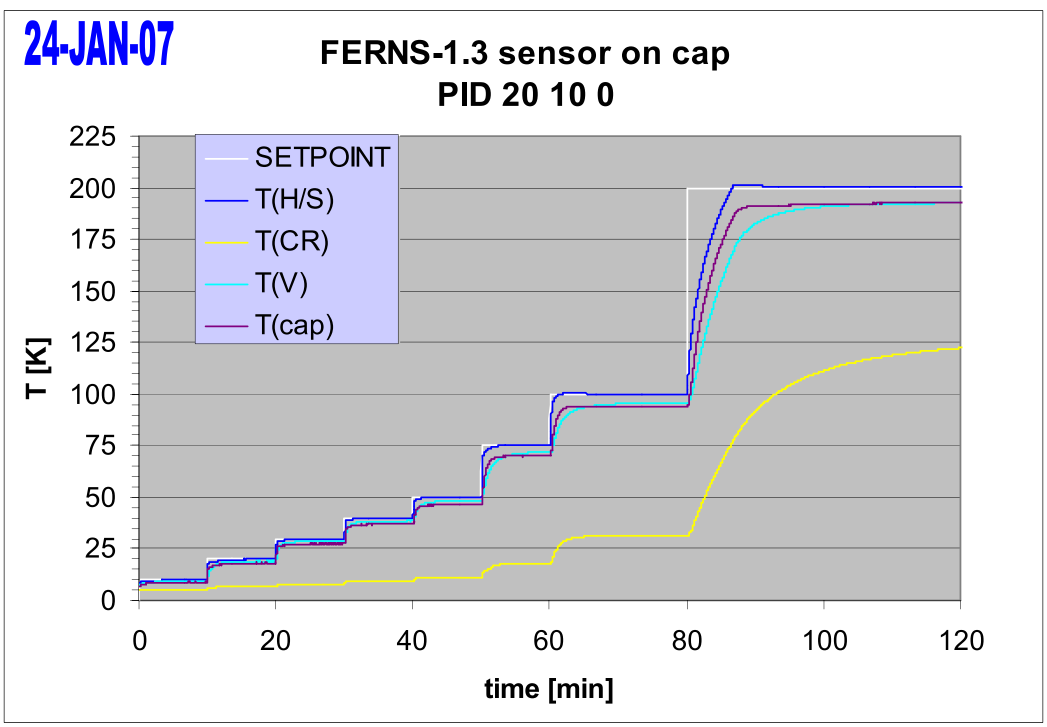




While T(H/S) gives the best control, the sensor T(V) gives a better indication of sample temperature (see below). But using T(V) as the control sensor gives much poorer temperature control. For many experiments, it may be best to use T(H/S) as the control sensor, with the understanding that there will be a measurable offset.

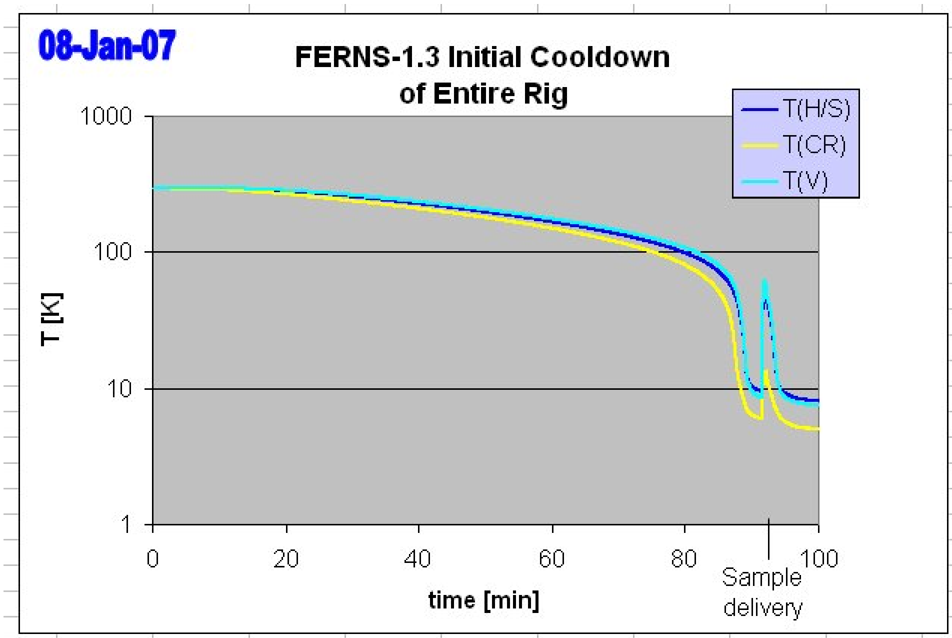
The test below verified that there is agreement (after equilibration) among the temperatures inside the sample can (T(IN)), on the cap of the can (T(CAP)), and at the permanently mounted senor on the exterior of the vanadium tube (T(V)). During transitions, there are lags between sensors.

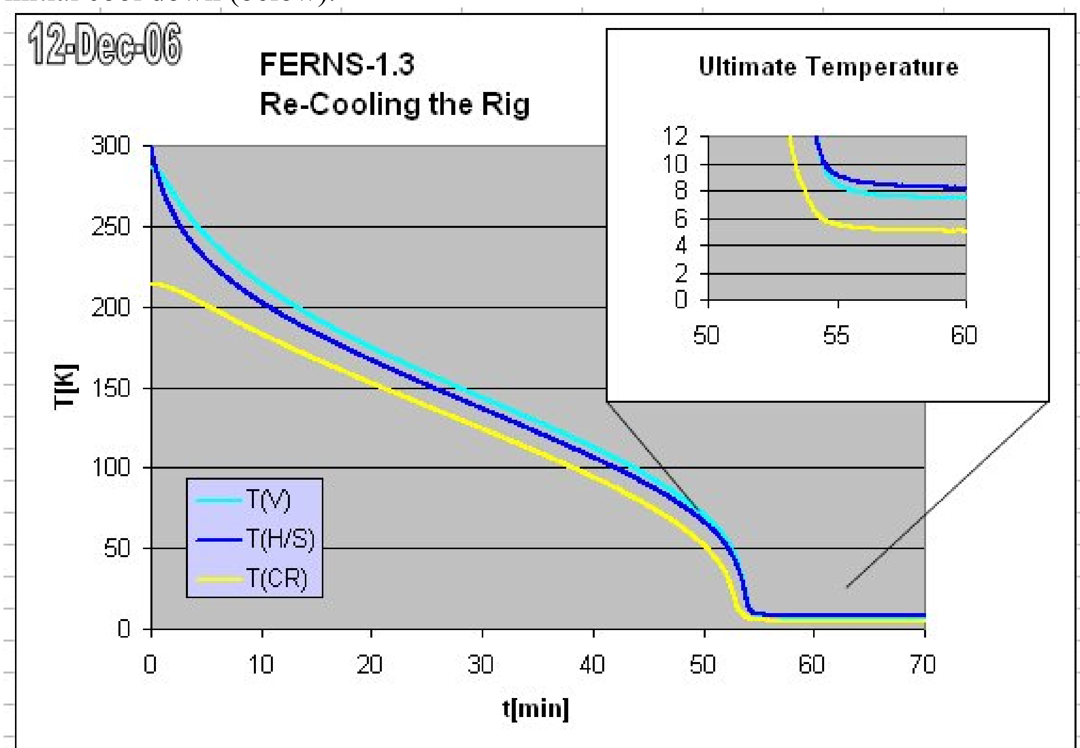




Initial System Cool Down

Once the FERNS system is cold, individual samples can be delivered and cooled in about 10 minutes. But when the system is first turned on, it takes about 90 minutes to cool the cold ring (CR) and pre-cooling ring (PCR) to their ultimate temperature (presently T(CR) reaches 6K). The ultimate temperature at the sample position approaches that of the cold ring only if the amount of helium "exchange" gas in the sample tube is properly adjusted (charge to 1 Bar at room temperature, and isolate so that low temperature level is ~0.5 Bar) and the heat shielding is sufficient. Several layers of "super-insulation" (aluminized mylar sheet) are wrapped around the sample tube above the beam path, and an actively-cooled aluminum heat shield surrounds the sample region. Note that re-cooling the system after heating the sample region is faster than initial cool down (below).





"Heat-Up" Test

With the present configuration, it takes much longer to heat samples than it does to cool them. Note that the cool down time is exceptional, but the heat up time is typical for this class of device (top loading closed cycle refrigerator). It may be possible to significantly improve the heat-up performance without degrading the cool down. But the SNS has no short term plans to modify the system again. Overall, we are very happy with the performance.