Thermometer calibrations pose a difficult problem at high magnetic fields [1]. Commercially available Cernox chips are very useful resistance thermometers at low temperatures, but display a high sensitivity to magnetic fields. Few good standards exist that are: (1) Easy to use, (2) Suitably field independent, and (3) inexpensive, with which to calibrate magnetic field sensitive thermometers. These difficulties are more pronounced at temperatures below the boiling point of $^3$He. In this report, we have tested a method of calibrating Cernox thermometers at $^3$He temperatures using the pulsed field facility at NHMFL-LANL. We utilize the short time of the magnet pulse to keep the thermometer temperature constant while monitoring the field dependent resistance in the thermometer. This method has been used successfully in a number of high magnetic field experiments done at the DC facility (NHMFL-FSU). We have, for the first time here, tested this same calibration method at $^3$He temperatures. The results, however, are not as promising, for it seems to be difficult to achieve a constant temperature during the field pulse, judging from the hysteresis present between 10 T and 45 T magnet pulses.

The 50 T mid-pulse magnet was utilized for subjecting Cernox 1010 thermometers to high magnetic fields. A standard $^3$He refrigerator available at LANL was used to reach temperatures as low as 0.5 K. Lock-in detection at a frequency of around 100 kHz was used to measure the thermometer resistance. The lock-in reference voltage output was followed by a homemade ratio transformer in order to provide signal isolation and constant-current regulation to the thermometer.

A typical $R$ vs. $B$ plot at base temperature (~0.5 K) is shown in Fig. 1. In the main panel, two curves are shown: (black) the full, 45 T shot, and (red) a 10 T shot, taken at nominally the same temperature. The main problem with this experiment was that the 10 T and 45 T shots do not overlap (at low fields). This is what is referred to as “hysteresis” in the introduction. Since the magnet pulse is of the same duration for both maximum field values, the 10 T shot occurs with a smaller value of $d\theta/dt$, where $t$ is time and $B$ is magnetic field. Thus, one may ascribe the difference between the two shots to the larger amount of heating that occurs at the higher field shot. This is an unfavorable circumstance since one cannot know how much heating may be occurring at the thermometer. Since these thermometers become very sensitive at lower and lower temperatures, calibration data of this quality becomes very difficult to use. Nevertheless, we checked this hysteresis at various temperatures. The inset of Fig. 1 shows the number of calibration points taken in about a week in the mid-pulse magnet. The hysteresis seemed to persist above the boiling point of $^4$He, so that the poor thermal conductivity of $^3$He liquid may at first, be identified as the source of the problem. However, we have not checked this behavior in detail as of this writing.

Although this pulse field method for calibrating Cernox thermometers at high fields has worked well in the pumped $^4$He range, it appears that more work will be required to allow satisfactory results in the $^3$He range. Future work should be focused on a better way of heat sinking the thermometer at these low temperatures if this method is to be used for high field, low temperature calibration. If successful, this is a quick and convenient way of calibrating thermometers at low temperatures and very high magnetic fields.

Acknowledgements
This work was supported by the NSF through the NHMFL, the State of Florida and the Department of Energy.

References