Low Temperature Calibration Service

Lake Shore Cryotronics provides calibration services for all types of cryogenic temperature sensing elements. Lake Shore maintains a complete low temperature calibration facility capable of performing calibrations from 0.05 kelvin to well above room temperature.

Beginning 1 January 1990, the International Temperature Scale of 1990 (ITS-90) became effective, and all Lake Shore calibrations above 0.65 K are based on this scale. At lower temperatures, a cerium magnesium nitrate magnetic thermometer has been used in conjunction with National Institute of Standards and Technology (NIST) superconducting fixed points SRM768 to generate a scale.

Calibration Method

The sensors to be calibrated are mounted, along with appropriate known standards, in a copper block designed to accommodate a variety of sensor styles. This block is enclosed within a quasi-adiabatic copper radiation shield which, in turn, is thermally isolated within an outer vacuum jacket.

Constant temperature of the block is achieved by an appropriately mounted heater and precision temperature controller. The electrical, mechanical, and thermal designs of the calibration probe provide extremely stable and uniform temperatures within the copper block.

All thermometers to be calibrated, whether two-lead or four-lead elements, are connected in a four-wire configuration. A comparison calibration is then performed by measuring the resistance, forward voltage, as appropriate, of both the standard and the sensor being calibrated. The typical number of data points collected is listed in Table 1.

The calibration process above 1.2 K is computer controlled and the calibration data collected automatically. Data points are usually not at integer temperatures since the primary concern is temperature stability near a data point rather than the specific value. The precise temperature for each data point is subsequently determined.

Raw data is provided for each calibration, along with a computer generated smoothed interpolation table which is listed as a function of temperature. For resistance sensors, the raw data is given as T and R; the interpolation table shows T, R, dR/dT and with the figure of merit d(log R)/d(log T). For diode sensors, the raw data is given as T and V_f, and the interpolation table presents T, V f and dV_f/dT.

The specific techniques for generating and controlling calibration temperatures vary, depending on the temperature involved.

Calibrations performed over a wide temperature span frequently entail the consecutive use of a variety of procedures and equipment. In these cases, data points are routinely overlapped to assure integrity of the calibration. The sections that follow describe the specific techniques utilized for the various temperature ranges.

Table 1. Calibration Data Points and Printouts

Range (K)	Typical Number of Data Points	Interpolation Calibration Printout Interval
0.05 – 0.1	6	0.005
0.1 – 0.3	9	0.01
0.3 – 0.5	5	0.02
0.5 – 1.0	7	0.05
1 – 4	18	0.1
4 – 10	18	0.2
10 – 20	40	0.5
20 – 40	40	1
40 – 60	40	2
60 – 100	40	5
100 – 300	28	5
300 – 380	28	5

Calibration Method – 1.2 K to 330 K

Temperatures from 1.2 K to 4.2 K are achieved by filling a He^4 subpot attached to the copper sensor block and pumping on the subpot through a vacuum regulator valve. Temperatures above 4.2 K are achieved by applying controlled power to a heater while the entire probe assembly remains immersed in liquid helium. In either case, the sensors themselves are maintained in a vacuum.

Extreme care is taken to ensure that the sensor block is thermally stable before calibration data is collected. The computer examines successive and interposed measurements of both the known standards and the sensors being calibrated at each data point to verify temperature stability.

Once temperature has stabilized, an appropriate DC excitation current is applied to the thermometer, and the resultant voltage is measured. In the case of resistance sensors, currents from 0.25 µA to 5 mA are selected in steps of 1, 2.5, and 5 as required. Sensor voltage is maintained between 1 and 3 mV for Carbon-Glass™, Germanium, Cernox™, Rox™, and Thermox™ elements up to 30 kΩ. Higher resistances are measured using a fixed current of 0.1 µA. Sensor power is held between 1 and 100 µW for platinum and rhodium-iron resistors.

Successive voltage readings taken with the current applied in opposite polarities are averaged together to eliminate thermal EMFs from the data. The resistance of the sensing element is determined and reported to five significant figures at each temperature.

Diode thermometers are normally excited with a 10 µA current (±0.02%) and the resultant forward voltage reported to five significant figures.

The Lake Shore calibration facility and procedures for diode and resistance sensor calibrations above 1.2 k are maintained traceable in accordance with MIL-STD-45662A.

Calibration Method – Below 1.2 K

Calibration temperatures from 0.05 K to 1.2 K are produced in a dilution refrigerator. Techniques similar to those for higher temperatures are followed to ensure reliable calibration data. The need for increased care at these lower temperatures, however, requires greater involvement on the part of a skilled system technician and less reliance on automation.

Sensors are measured with a self-balancing resistance bridge operated at 15 Hertz. Germanium sensors are maintained at a nominal excitation voltage of 30 µV RMS (0.05 to 0.1 K) or 100 µV RMS (0.1 to 1.2 K). Cernox™ sensors are maintained at a nominal excitation voltage of 30 mV RMS (0.3 to 0.6 K) or 100 mV RMS (0.6 to 1.2 K).

Accuracy Considerations

The accuracy of Lake Shore calibrations is a combined function of temperature stability and instrumentation precision. Those, in turn, are a function of temperature and sensor signal. Additionally, basic uncertainties in traceability of a scale must be taken into account. As a result, calibration accuracy varies with both temperature range and sensor type. The table below summarizes the accuracies of the raw data of calibrations performed at Lake Shore. A summary of the calibration accuracy for selected Lake Shore sensors at specific temperatures is given in the table below. Errors in each case are expressed in millikelvin deviation from ITS-90. Shown are (1) the typical error of a given calibration, and (2) the worst case column represents the maximum allowable deviation or worst case possible error that could result—the value could occur only in the unlikely event that all standards and instrumentation maximum tolerance limits are reached simultaneously at the end of a recalibration cycle, and all error sources are linearly added. The accuracies listed in the table below reflect a combination of the overall calibration system accuracy and the sensitivity of the sensor in a given temperature range. A sensor with low sensitivity [(1/R)(dR/dT)] in a given temperature range will have low accuracy in that range due to the low signal-to-noise ratio. Note: typical error and worst case error accuracy are in units of mK.

Table 2. Accuracy Of Lake Shore Calibrations

	Germanium 1000 ohm		Carbon-Glass™ 1000 ohm		Rox™ (RX-102A)		Rox™ (RX-103A)		Rox™ (RX-202A)		Thermox™		Cernox™ (CX-1050)	
Temp (K)	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case
1.0	4	5	4	5	5	6	5	6	5	6	–	–	4	5
4.2	4	5	4	5	10	15	7	11	10	13	–	–	4	6
10	4	5	4	5	24	31	15	24	26	33	–	–	4	8
20	8	15	10	20	83	102	40	64	61	77	–	–	8	20
30	12	25	20	30	178	212	72	112	98	123	–	–	12	30
50	20	35	30	65	–	–	–	–	–	–	–	–	20	35
100	45	90	65	125	–	–	–	–	–	–	16	21	30	50
300	–	–	250	450	–	–	–	–	–	–	35	60	50	140
400	–	–	–	–	–	–	–	–	–	–	–	–	180	230

Table 2. Accuracy Of Lake Shore Calibrations (Continued)

	Platinum 100 ohm		Rhodium-Iron 27 ohm wire wound		Rhodium-Iron 100 ohm thin film		Silicon Diode		Galium-Aluminum Arsenide Diode	
Temp (K)	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case	Typical Error	Worst Case
1.0	–	–	8	15	4	8	12	20	10	15
4.2	–	–	10	17	4	9	12	20	10	15
10	–	–	12	20	4	10	12	20	10	15
20	15	25	20	35	10	20	15	25	10	15
30	10	20	20	35	12	25	25	45	13	20
50	10	20	20	35	10	20	30	55	35	50
100	10	20	15	30	10	25	25	50	35	90
300	20	35	20	35	20	35	25	50	50	110
400	30	45	40	70	–	–	35	55	50	75
475	35	50	–	–	–	–	30	40	45	65