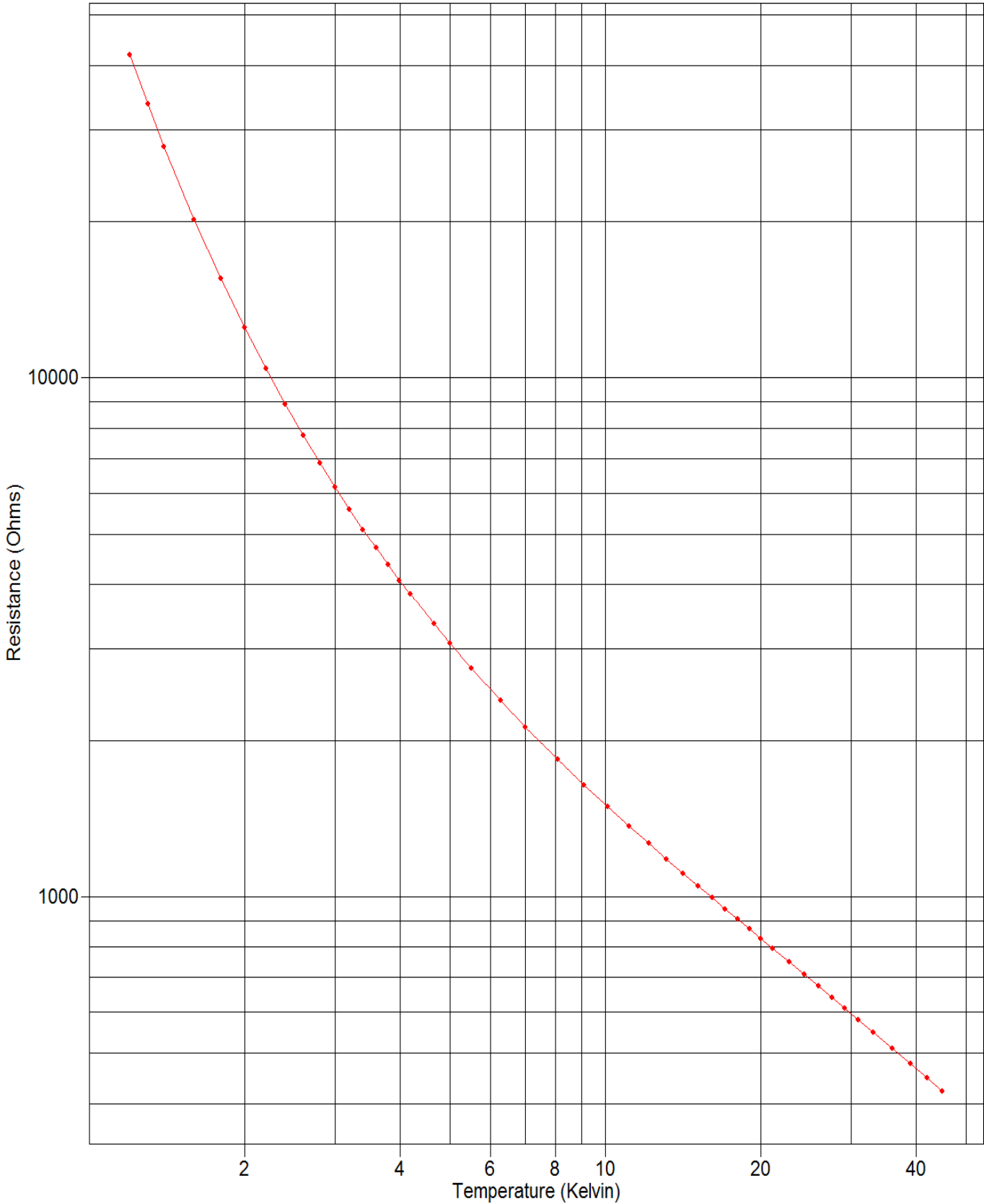


DATA PLOT

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K



TEST DATA

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K

Index	Temp. (K)	Resistance (Ω)	Excitation	Index	Temp. (K)	Resistance (Ω)	Excitation
1	1.19892	41950.5	2mV \pm 25%	31	16.1237	994.082	2mV \pm 25%
2	1.29926	33731.1	2mV \pm 25%	32	17.0994	946.672	2mV \pm 25%
3	1.39903	27849.9	2mV \pm 25%	33	18.0744	904.020	2mV \pm 25%
4	1.59929	20149.5	2mV \pm 25%	34	19.0525	865.484	2mV \pm 25%
5	1.79930	15535.2	2mV \pm 25%	35	20.0337	830.363	2mV \pm 25%
6	2.00065	12508.3	2mV \pm 25%	36	21.1091	795.310	2mV \pm 25%
7	2.20049	10420.6	2mV \pm 25%	37	22.7038	749.018	2mV \pm 25%
8	2.40023	8897.40	2mV \pm 25%	38	24.2800	708.631	2mV \pm 25%
9	2.59993	7747.89	2mV \pm 25%	39	25.8687	672.485	2mV \pm 25%
10	2.80033	6855.91	2mV \pm 25%	40	27.4740	639.777	2mV \pm 25%
11	2.99955	6148.98	2mV \pm 25%	41	29.0897	610.039	2mV \pm 25%
12	3.19875	5575.41	2mV \pm 25%	42	30.9094	579.935	2mV \pm 25%
13	3.39852	5100.75	2mV \pm 25%	43	33.0218	548.628	2mV \pm 25%
14	3.60063	4698.29	2mV \pm 25%	44	36.0242	509.846	2mV \pm 25%
15	3.79400	4370.62	2mV \pm 25%	45	39.0256	476.398	2mV \pm 25%
16	3.99900	4071.88	2mV \pm 25%	46	42.0219	447.325	2mV \pm 25%
17	4.19140	3828.06	2mV \pm 25%	47	45.0186	421.673	2mV \pm 25%
18	4.66805	3344.53	2mV \pm 25%				
19	5.01284	3067.88	2mV \pm 25%				
20	5.51662	2745.05	2mV \pm 25%				
21	6.27383	2382.10	2mV \pm 25%				
22	7.01129	2119.65	2mV \pm 25%				
23	8.09013	1836.63	2mV \pm 25%				
24	9.09941	1641.35	2mV \pm 25%				
25	10.1144	1488.51	2mV \pm 25%				
26	11.1357	1365.33	2mV \pm 25%				
27	12.1497	1264.61	2mV \pm 25%				
28	13.1550	1180.65	2mV \pm 25%				
29	14.1521	1109.25	2mV \pm 25%				
30	15.1421	1047.69	2mV \pm 25%				



UNCERTAINTY ANALYSIS

Calibration Report: 631805
 Sensor Model: CX-1050-SD-1.4B
 Sensor Type: Cernox Resistor

Sales Order: 65301
 Serial Number: X70245
 Temperature Range: 1.40K to 40.0K

Calibration Data Uncertainty

The uncertainties of the measured calibration data for Lake Shore's sensors are summarized in the table below. The values given are the combined uncertainty of the temperature measurement and the resistance or voltage measurement expressed as an equivalent temperature uncertainty in millikelvin (mK). Note that the values are the calibration uncertainty only and do not include the stability of the temperature sensor. The uncertainty analysis has followed the guidelines for determining measurement uncertainty as outlined in the ISO Guide to the Expression of Uncertainty in Measurement, NIST Technical Note 1297, and ANSI/NCSL Z540-2-1997. Since the uncertainty varies with temperature due to the variation of the sensor sensitivity and excitation, the table gives typical values at several different temperatures throughout the range of the calibration. The uncertainty is based on an approximate 95% confidence level with a coverage factor $k = 2$.

T (K)	Uncertainty (\pm mK)												
	GR	Cernox (CX)					RX			Platinum		RF-800	Diode
		1010	1030	1050	1070	1080	102A	103A	202A	100 Ω	25 Ω	27 Ω	
1.4	4	4	4	4			4	4	4			5	7
4.2	4	4	4	4	4		4	6	5			5	5
10	4	5	5	4	4		10	15	12			7	6
20	8	10	9	8	8	8	35	35	28	9	10	13	9
30	9	13	11	9	9	9	76	61	46	9	9	14	31
50	11	18	14	12	12	11				10	10	13	37
100	20	29	22	17	16	14				11	12	12	32
300		78	60	46	45	36				24	24	25	35
400		124	94	74	72	60				45	45	45	49
500										51	51		54

Polynomial Fit Uncertainty

When a sensor is used to measure temperature, a polynomial fit to the measured calibration data is often used to convert the sensor resistance (R) or voltage (V) to a temperature (T). How well the polynomial represents the sensor calibration data is another source of uncertainty when using the sensor. In the polynomials provided with this set of calibration data, the standard deviation of the fit can be used as an estimate of this additional temperature uncertainty. The standard deviation of fit is determined from the following equation:

$$\sigma_{fit}^2 = \frac{\sum_{i=1}^N (T_i - T_{i,calc})^2}{N - n} = \frac{N}{N - n} (\Delta T_{RMS})^2$$

where

- σ_{fit} = standard deviation of the fit
- T_i = measured temperature for point i
- $T_{i,calc}$ = the temperature calculated from the polynomial equation for point i
- N = number of data points in fit range
- n = number of fit coefficients
- ΔT_{RMS} = root mean square deviation of fit

A value of ΔT_{RMS} is given for each range of fit.

F008-04-00_B (01/17/11)



POLYNOMIAL EQUATION

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K

Polynomial Type: Chebychev
Useful Range of Fit:

1.40 K to 9.10 K
2.780e+4 Ohms to 1641. Ohms

Lower and Upper limits of Log(Resistance) used in computing Chebychev coefficients:
ZL = 3.13523792394 ZU = 4.62273732301

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	4.215453	1.1574E-04	36420.83
1	-4.305307	1.9157E-04	-22473.90
2	1.754838	1.6926E-04	10367.72
3	-0.612244	1.6901E-04	-3622.55
4	0.186517	1.5693E-04	1188.50
5	-0.049184	1.4375E-04	-342.15
6	0.010356	1.4193E-04	72.97
7	-0.001860	1.5467E-04	-12.02
8	0.000087	1.5584E-04	0.56
9	0.000252	1.5161E-04	1.66

$Z = \text{Log}(\text{Resistance})$

$k = ((Z-ZL)-(ZU-Z))/(ZU-ZL)$

Temp. (K) = $\sum A_i \cdot \text{COS}(i \cdot \text{ARCCOS}(k))$, where $0 \leq i \leq 9$
and the A_i 's are the coefficients in the table above.



POLYNOMIAL EQUATION

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K

Polynomial Type: Chebychev
Temp. (K) vs. Log(Resistance)

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	41950.52	1.19892	1.19891	0.01
2	33731.09	1.29926	1.29931	-0.05
3	27849.88	1.39903	1.39896	0.07
4	20149.50	1.59929	1.59929	0.00
5	15535.22	1.79930	1.79943	-0.14
6	12508.33	2.00065	2.00061	0.04
7	10420.64	2.20049	2.20023	0.25
8	8897.404	2.40023	2.40020	0.03
9	7747.893	2.59993	2.60027	-0.34
10	6855.911	2.80033	2.80029	0.05
11	6148.977	2.99955	2.99961	-0.06
12	5575.408	3.19875	3.19879	-0.03
13	5100.755	3.39852	3.39834	0.18
14	4698.293	3.60063	3.60040	0.23
15	4370.625	3.79400	3.79385	0.14
16	4071.877	3.99900	3.99916	-0.16
17	3828.062	4.19140	4.19229	-0.89
18	3344.530	4.66805	4.66672	1.33
19	3067.885	5.01284	5.01307	-0.23
20	2745.052	5.51662	5.51737	-0.75
21	2382.101	6.27383	6.27366	0.17
22	2119.652	7.01129	7.01099	0.30
23	1836.635	8.09013	8.09036	-0.23
24	1641.349	9.09941	9.09922	0.19
25	1488.511	10.11442	10.11459	-0.17
26	1365.331	11.13565	11.13559	0.06

Order of Fit = 9 RMS error of fit = 0.38 mK
Largest absolute error = 1.33 mK at data point no. 18



POLYNOMIAL EQUATION

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K

Polynomial Type: Chebychev
Useful Range of Fit:

9.10 K to 40.0 K
1641. Ohms to 466.5 Ohms

Lower and Upper limits of Log(Resistance) used in computing Chebychev coefficients:
ZL = 2.62497629933 ZU = 3.32626457253

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	21.536535	3.2622E-04	66017.76
1	-18.402009	5.4083E-04	-34025.37
2	4.441748	4.6806E-04	9489.74
3	-0.595158	3.9911E-04	-1491.20
4	0.034148	3.7179E-04	91.85
5	-0.006528	3.6817E-04	-17.73
6	0.003504	3.8984E-04	8.99
7	-0.000490	3.8593E-04	-1.27
8	-0.000813	3.9560E-04	-2.05

$Z = \text{Log}(\text{Resistance})$

$k = ((Z-ZL)-(ZU-Z))/(ZU-ZL)$

Temp. (K) = $\sum A_i * \text{COS}(i * \text{ARCCOS}(k))$, where $0 \leq i \leq 8$
and the A_i 's are the coefficients in the table above.

POLYNOMIAL EQUATION

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K

Polynomial Type: Chebychev
Temp. (K) vs. Log(Resistance)

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
22	2119.652	7.01099	7.01094	0.05
23	1836.635	8.09036	8.09070	-0.34
24	1641.349	9.09922	9.09866	0.56
25	1488.511	10.11442	10.11453	-0.11
26	1365.331	11.13565	11.13560	0.06
27	1264.609	12.14966	12.14992	-0.26
28	1180.646	13.15496	13.15493	0.03
29	1109.250	14.15208	14.15281	-0.73
30	1047.690	15.14214	15.14291	-0.77
31	994.0823	16.12370	16.12272	0.97
32	946.6721	17.09937	17.09715	2.22
33	904.0199	18.07443	18.07472	-0.29
34	865.4839	19.05245	19.05281	-0.36
35	830.3632	20.03373	20.03391	-0.18
36	795.3098	21.10911	21.11026	-1.15
37	749.0181	22.70383	22.70371	0.12
38	708.6311	24.28003	24.28141	-1.39
39	672.4850	25.86868	25.86870	-0.02
40	639.7772	27.47397	27.47206	1.91
41	610.0388	29.08971	29.08992	-0.21
42	579.9351	30.90942	30.90788	1.54
43	548.6276	33.02185	33.02318	-1.33
44	509.8459	36.02419	36.02452	-0.34
45	476.3977	39.02556	39.02691	-1.35
46	447.3247	42.02190	42.01984	2.06
47	421.6735	45.01861	45.01931	-0.70

Order of Fit = 8 RMS error of fit = 0.99 mK
Largest absolute error = 2.22 mK at data point no. 32



INTERPOLATION TABLE

Calibration Report: 631805
 Sensor Model: CX-1050-SD-1.4B
 Sensor Type: Cernox Resistor

Sales Order: 65301
 Serial Number: X70245
 Temperature Range: 1.40K to 40.0K

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT	Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
1.400	27797.6	-50265.	-2.5315	10.50	1438.98	-123.41	-0.90049
1.500	23436.9	-37716.	-2.4139	11.00	1380.28	-111.69	-0.89012
1.600	20128.9	-28957.	-2.3017	11.50	1327.00	-101.68	-0.88119
1.700	17561.5	-22732.	-2.2005	12.00	1278.38	-93.018	-0.87315
1.800	15524.9	-18243.	-2.1151	12.50	1233.79	-85.500	-0.86623
1.900	13874.6	-14914.	-2.0424	13.00	1192.72	-78.900	-0.85997
2.000	12515.9	-12372.	-1.9771	13.50	1154.75	-73.095	-0.85454
2.100	11381.3	-10397.	-1.9185	14.00	1119.52	-67.943	-0.84965
2.200	10422.7	-8834.6	-1.8648	14.50	1086.72	-63.361	-0.84543
2.300	9604.09	-7581.1	-1.8155	15.00	1056.08	-59.257	-0.84166
2.400	8898.70	-6561.4	-1.7696	15.50	1027.39	-55.574	-0.83843
2.500	8285.76	-5723.6	-1.7269	16.00	1000.45	-52.247	-0.83557
2.600	7749.24	-5028.1	-1.6870	16.50	975.088	-49.237	-0.83316
2.700	7276.37	-4445.9	-1.6497	17.00	951.165	-46.499	-0.83107
2.800	6857.04	-3954.4	-1.6147	17.50	928.548	-44.005	-0.82934
2.900	6483.03	-3536.6	-1.5820	18.00	907.125	-41.721	-0.82787
3.000	6147.73	-3178.8	-1.5512	18.50	886.795	-39.628	-0.82670
3.100	5845.63	-2870.6	-1.5223	19.00	867.470	-37.701	-0.82575
3.200	5572.25	-2603.4	-1.4951	19.50	849.069	-35.924	-0.82504
3.300	5323.80	-2370.7	-1.4695	20.00	831.524	-34.280	-0.82451
3.400	5097.15	-2166.7	-1.4453	21.00	798.749	-31.342	-0.82400
3.500	4889.64	-1987.2	-1.4225	22.00	768.710	-28.794	-0.82406
3.600	4699.02	-1828.5	-1.4008	23.00	741.053	-26.569	-0.82462
3.700	4523.35	-1687.5	-1.3804	24.00	715.485	-24.609	-0.82549
3.800	4361.00	-1561.9	-1.3610	25.00	691.759	-22.875	-0.82669
3.900	4210.54	-1449.4	-1.3425	26.00	669.672	-21.329	-0.82810
4.000	4070.74	-1348.3	-1.3249	27.00	649.048	-19.944	-0.82964
4.200	3818.98	-1175.2	-1.2925	28.00	629.738	-18.697	-0.83133
4.400	3598.63	-1032.6	-1.2626	29.00	611.614	-17.569	-0.83306
4.600	3404.33	-913.97	-1.2350	30.00	594.565	-16.546	-0.83484
4.800	3231.73	-814.84	-1.2103	31.00	578.493	-15.612	-0.83663
5.000	3077.40	-730.71	-1.1872	32.00	563.314	-14.759	-0.83841
5.200	2938.63	-658.84	-1.1658	33.00	548.951	-13.976	-0.84019
5.400	2813.20	-596.97	-1.1459	34.00	535.340	-13.257	-0.84194
5.600	2699.26	-543.66	-1.1279	35.00	522.420	-12.592	-0.84358
5.800	2595.30	-496.99	-1.1107	36.00	510.140	-11.978	-0.84524
6.000	2500.09	-455.96	-1.0943	37.00	498.450	-11.409	-0.84688
6.500	2293.74	-373.66	-1.0589	38.00	487.309	-10.880	-0.84843
7.000	2123.07	-311.91	-1.0284	39.00	476.677	-10.389	-0.84997
7.500	1979.46	-264.46	-1.0020	40.00	466.520	-9.9309	-0.85149
8.000	1856.91	-227.26	-0.97911				
8.500	1750.90	-197.76	-0.96006				
9.000	1658.26	-173.57	-0.94204				
9.500	1576.61	-153.67	-0.92597				
10.00	1504.03	-137.17	-0.91202				



THERMAL CYCLE TESTING

Sensor Model: CX-1050-SD-1.4B

Sensor Type: Cernox Resistor

Serial Number: X70245

This sensor was tested for repeatability through rapid thermal cycles from room temperature into liquid helium. During this test, the following four lead resistance values were recorded:

Approximately 305 K:	72.0 Ω
Liquid Nitrogen:	263 Ω
Liquid Helium:	3830 Ω

The nitrogen and helium values were recorded in OPEN dewars, so precision comparisons with calibration values or other thermal cycle test values should not be made.

Recommended Operating Parameters:

For sensors calibrated by LSCI, the current to the sensor is adjusted to maintain the sensor output voltage or power at the values listed on the Test Data page.



BREAKPOINTS 340 FORMAT

Calibration Report: 631805

Sensor Model: CX-1050-SD-1.4B

Sensor Type: Cernox Resistor

Sales Order: 65301

Serial Number: X70245

Temperature Range: 1.40K to 40.0K

Name: CX-1050-SD-1.4B

Serial number: X70245

Format: 4 ;Log Ohms/Kelvin

Limit: 40.0

Coefficient: 1 ;Negative

Point 1: 2.66881, 40.000 Point 56: 3.72411, 3.310
Point 2: 2.68486, 38.300 Point 57: 3.75610, 3.150
Point 3: 2.69957, 36.800 Point 58: 3.78852, 3.000
Point 4: 2.71484, 35.300 Point 59: 3.82355, 2.850
Point 5: 2.73074, 33.800 Point 60: 3.86165, 2.700

Point 6: 2.74730, 32.300 Point 61: 3.90042, 2.560
Point 7: 2.76342, 30.900 Point 62: 3.94265, 2.420
Point 8: 2.78023, 29.500 Point 63: 3.98561, 2.290
Point 9: 2.79781, 28.100 Point 64: 4.03256, 2.160
Point 10: 2.81490, 26.800 Point 65: 4.08432, 2.030

Point 11: 2.83277, 25.500 Point 66: 4.13718, 1.910
Point 12: 2.85009, 24.300 Point 67: 4.19063, 1.800
Point 13: 2.86822, 23.100 Point 68: 4.24969, 1.690
Point 14: 2.88731, 21.900 Point 69: 4.31583, 1.580
Point 15: 2.90577, 20.800 Point 70: 4.38348, 1.480

Point 16: 2.92074, 19.950 Point 71: 4.44366, 1.400
Point 17: 2.93261, 19.300
Point 18: 2.94489, 18.650
Point 19: 2.95763, 18.000
Point 20: 2.97086, 17.350

Point 21: 2.98357, 16.750
Point 22: 2.99677, 16.150
Point 23: 3.01052, 15.550
Point 24: 3.02366, 15.000
Point 25: 3.03734, 14.450

Point 26: 3.05163, 13.900
Point 27: 3.06659, 13.350
Point 28: 3.08083, 12.850
Point 29: 3.09573, 12.350
Point 30: 3.11138, 11.850

Point 31: 3.12783, 11.350
Point 32: 3.14345, 10.900
Point 33: 3.15985, 10.450
Point 34: 3.17718, 10.000
Point 35: 3.19346, 9.600

Point 36: 3.21062, 9.200
Point 37: 3.22880, 8.800
Point 38: 3.24811, 8.400
Point 39: 3.26869, 8.000
Point 40: 3.28788, 7.650

Point 41: 3.30827, 7.300
Point 42: 3.33006, 6.950
Point 43: 3.35342, 6.600
Point 44: 3.37858, 6.250
Point 45: 3.40582, 5.900

Point 46: 3.43110, 5.600
Point 47: 3.45836, 5.300
Point 48: 3.48798, 5.000
Point 49: 3.51811, 4.720
Point 50: 3.54854, 4.460

Point 51: 3.58170, 4.200
Point 52: 3.61242, 3.980
Point 53: 3.63943, 3.800
Point 54: 3.66682, 3.630
Point 55: 3.69446, 3.470



BREAKPOINTS 91C/93C/330 FORMAT

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K

Interpolation Method: Lagrangian
Limit: 40.0 (Kelvin)
Format: 4 (Log Ohms/Kelvin)
Number of Breakpoints: 22

No.	Units	Temperature (K)	No.	Units	Temperature (K)
1	2.66887	40.0	16	3.70733	3.4
2	2.66980	39.9	17	3.78871	3.0
3	2.71907	34.9	18	3.88926	2.6
4	2.77541	29.9	19	3.98246	2.3
5	2.84139	24.9	20	4.09746	2.0
6	2.92167	19.9	21	4.24456	1.7
7	3.02614	14.9	22	4.44401	1.4
8	3.10983	11.9			
9	3.18937	9.7			
10	3.25833	8.2			
11	3.32696	7.0			
12	3.39796	6.0			
13	3.46814	5.2			
14	3.54388	4.5			
15	3.62434	3.9			

Temperature for Resistance Decades:

Res. (Ohms)	Temp. (K)
1000	15.997
10000	2.250



BREAKPOINTS 234 FORMAT

Calibration Report: 631805
Sensor Model: CX-1050-SD-1.4B
Sensor Type: Cernox Resistor

Sales Order: 65301
Serial Number: X70245
Temperature Range: 1.40K to 40.0K

Maximum Temperature Error:

1.4 - 10K: 0.010K
10 - 20K: 0.020K
20 - 40K: 0.008K
40 - 100K: 0.009K
> 100K: -

<u>BP #</u>	<u>Temp. (K)</u>	<u>Res. (Ω)</u>	<u>Log10 Res.</u>	<u>BP #</u>	<u>Temp. (K)</u>	<u>Res. (Ω)</u>	<u>Log10 Res.</u>
1	43.241	436.5158	2.640	26	7.793	1905.461	3.280
2	40.970	457.0882	2.660	27	7.110	2089.296	3.320
3	38.813	478.6301	2.680	28	6.508	2290.868	3.360
4	36.761	501.1872	2.700	29	5.974	2511.886	3.400
5	34.811	524.8075	2.720	30	5.501	2754.229	3.440
6	32.958	549.5409	2.740	31	5.080	3019.952	3.480
7	31.197	575.4399	2.760	32	4.705	3311.311	3.520
8	29.523	602.5596	2.780	33	4.369	3630.781	3.560
9	27.935	630.9573	2.800	34	4.068	3981.072	3.600
10	26.427	660.6934	2.820	35	3.797	4365.158	3.640
11	24.996	691.8310	2.840	36	3.553	4786.301	3.680
12	23.641	724.4360	2.860	37	3.332	5248.075	3.720
13	22.357	758.5776	2.880	38	3.132	5754.399	3.760
14	21.142	794.3282	2.900	39	2.950	6309.573	3.800
15	19.993	831.7638	2.920	40	2.785	6918.310	3.840
16	18.908	870.9636	2.940	41	2.633	7585.776	3.880
17	17.884	912.0108	2.960	42	2.494	8317.638	3.920
18	16.918	954.9926	2.980	43	2.367	9120.108	3.960
19	16.008	1000.000	3.000	44	2.250	10000.00	4.000
20	14.347	1096.478	3.040	45	1.994	12589.25	4.100
21	12.880	1202.264	3.080	46	1.783	15848.93	4.200
22	11.587	1318.257	3.120	47	1.606	19952.62	4.300
23	10.448	1445.440	3.160	48	1.458	25118.86	4.400
24	9.447	1584.893	3.200	49	1.332	31622.78	4.500
25	8.567	1737.801	3.240	50	1.222	39810.72	4.600

