OPERATING INSTRUCTIONS
FOR THE
JANIS RESEARCH
SUPERTRAN-VP
CRYOSTAT SYSTEM

SERIAL NUMBER: 21394

Janis Research Company, LLC
services@janis.com
www.janis.com

Revised 5/15/2014

INTRODUCTION

The Janis Research Company's SuperTran-VP continuous flow cryostat combines a flexible transfer line with a cryostat to provide quick refrigeration from below 2 K to 300 K. Liquid helium is continuously transferred through a vacuum jacketed, superinsulated flexible transfer line to a vaporizer/heat exchanger at the bottom of the sample chamber. The liquid is then vaporized and heated to some specified temperature, and travels upwards to cool the sample and intercept the heat loads coming down the sample tube. A needle valve located at the bottom of the leg (which goes inside a storage dewar), controls the cryogen flow to the sample mount.

Temperatures below 4.2 K are achieved by reducing the pressure (using a mechanical vacuum pump) at the sample tube vent/pumping port. Temperatures above 4.2 K are obtained by sending an appropriate current through a bifilarly wound heater at the vaporizer. This heater, as well as any control thermometer supplied will be wired to an electrical feedthrough at the top of the cryostat vacuum jacket. An optional top loading sample positioner/sample mount assembly, containing an additional heater may be supplied with the system. The heater on this sample mount may be used for additional control.

UNPACKING AND SET-UP

After removal of the protective padding and shipping supports, the cryostat can be visually inspected for any damage incurred during shipment. Please report any visible damage to the crate or cryostat to your shipping/receiving department, and to Janis Research as soon as it is noticed.

Four tapped holes (newer models usually have M6, older models usually have ¼-20) are provided with standard systems, at the bottom of the vacuum jacket for rigid attachment to a laboratory bench. The cryostat head can also be supported by a standard laboratory stand and clamp(s) assembly, while the SuperTran leg may be supported inside the storage dewar.

PREPARATION FOR COOLDOWN

The SuperTran-VP is shipped with the transfer line vacuum space and the cryostat vacuum space evacuated. This is a result of the final testing at the factory, and it helps ensure clean vacuum spaces. As a precaution against deterioration of the vacuum, which arises sometimes during transit or a prolonged storage period, both vacuum spaces should be re-evacuated prior to use. This is best done with a good pumping station (e.g., a turbomolecular pumping station) capable of bringing the ultimate pressure down to approximately 10^{-4} Torr. Refer to the enclosed engineering drawing for the location of the evacuation valves. After evacuation, all valves should be firmly closed, but care should be exercised to avoid damaging the seat with too much pressure.

The vacuum jackets are protected against cold leaks with a pressure relief valve, which will vent any pressure that exceeds 2 to 4 psig. The transfer line pressure relief is located opposite the evacuation valve, while the shroud pressure relief is located on top of the cryostat vacuum jacket.

When evacuation of either vacuum space is initiated, always be sure that the pressure on the pump side of the evacuation valve is lower than the pressure in that vacuum space. This is done to avoid drawing oil vapor from the pump into the vacuum space. Thus, one should not pump any vacuum space while liquid helium is passing through the inner line, since the liquid helium could cryopump to a lower pressure than the pumping station in use.

The rigid leg of the transfer line has a built-in activated charcoal getter to help maintain excellent vacuum when this leg is inserted in the cryogen storage dewar. Thus, it is preferable to maintain this space under vacuum at all times and never allow helium gas or moist air inside this space. In the event moisture or helium does accidentally enter the space, a pumping station should be attached to the space for several days in order to bring the pressure down to an acceptable level.

SAMPLE MOUNTING AND INSTRUMENTATION

Most systems are supplied with a sample positioner/sample mount assembly that is top-loaded into the cryostat. This positioner generally contains two electrical feedthroughs for wiring a heater, any sample thermometer supplied and any other instrumentation desired. The positioner allows translation (±0.5”) and rotation (±180°) along the axis of the cryostat.

CAUTION: Do not rotate the sample positioner beyond ±180°. The wires connecting the electrical feedthrough to the heater and sensor may become wrapped around the central shaft too many times and can break.

The copper sample mount has tapped holes to allow attachment of a variety of sample holders, thus locating the sample in the flowing helium vapor. The sample need not be thermally anchored to the holder or mount, since the holder provides no cooling or heating to the sample. Any thermometer placed in the vicinity of the sample should give a very good indication of the sample’s temperature since both are being simultaneously cooled by the same helium vapor.

COOLDOWN

1. Close the needle valve at the bottom of the transfer line (storage dewar leg), by turning the knurled knob flow valve regulator (turn counter-clockwise when viewed from top).

2. Insert the “male” bayonet of the transfer line into the cryostat section and (hand) tighten the o-ring compression sealing knurled nut. Push the transfer line firmly into the female bayonet to ensure a good mechanical joint. After cooling the cryostat push the transfer line into the bayonet connection again, and re-tighten the o-ring compression seal to be sure that the brass tip fits snugly into the cryostat.

3. Attach a mechanical vacuum pump to the sample tube vent/pumping port and evacuate this space continuously during the first phase of cooldown. This will evacuate the sample tube and the inner line, and provide a path for the cryogen that is free from air and moisture.

4. Insert the SuperTran rigid leg (usually 0.5” OD) into a storage dewar very slowly (If your storage dewar leg has a hole in it, cover it with your thumb while inserting the leg into the storage dewar), while allowing the cryogen vapor to vent out of the dewar. As the foot enters into the liquid cryogen, open the flow valve and close it three of four times, and listen to the “gurgle” of the pump each time the valve is opened. This ensures that the valve does not

freeze shut during cooldown, and that the inner line is not blocked. After the leg bottoms out, lift it about 1 cm to avoid any frozen debris at the bottom.

NOTE: Disconnect the pump from the vent port before opening the needle valve if you are operating with liquid Nitrogen. Pumping on LN2 may cause it to freeze in the transfer line, which would block all flow through the transfer line.

5. Using pressurized helium gas, pressurize the storage container to about 1 psig. Please note that it is easier (and less wasteful) to increase the pressure in the storage dewar than to decrease it.

6. Open the flow regulator about two turns, and listen to the gurgle of the pump as the cryogen starts to flow through the inner line.

7. Monitor the sample mount or vaporizer temperature and/or listen to the vacuum pump carefully. In 5-15 minutes, the inner line and cryostat head will cool down (slowly at first, then very rapidly) to helium temperature. This time can be decreased by increasing both the flow valve opening (about 4 turns) and the pressure in the storage dewar (about 4 psi). At this time the vacuum pump should be disconnected from the system, and the escaping vapor vented into the atmosphere (or a gas collecting system). Be sure to allow the pump to reach atmospheric pressure before disconnecting, to avoid introducing air and moisture into the line.

8. Check that the pressure inside the storage dewar is between 1 and 4 psi, and maintain this pressure throughout this procedure.

If the experimental configuration does not allow the transfer line to be inserted into the cryostat first (due to a low ceiling height or the cryostat mounting geometry), the following steps may be substituted for steps 1 – 4 above.

1. Open the needle valve at the bottom of the transfer line (storage dewar leg) by turning the knurled knob flow valve regulator (turn clockwise when viewed from top).

2. Insert the SuperTran rigid leg (usually 0.5” O.D.) into a storage dewar very slowly and tighten the brass o-ring seal nut to form a gas tight seal. After the leg bottoms out, lift it about 1 cm to avoid any frozen debris at the bottom. Note that you will not be able to feel any gas exiting the transfer line bayonet.

3. Insert the “male” bayonet of the transfer line into the cryostat section and (hand) tighten the o-ring compression sealing knurled nut. Push the transfer line firmly into the female bayonet to ensure a good mechanical joint. After cooling the cryostat push the transfer line into the bayonet connection again, and re-tighten the o-ring compression seal to be sure that the brass tip fits snugly into the cryostat.

4. Close the needle valve and attach a mechanical vacuum pump to the sample tube vent/pumping port. This will evacuate the sample tube and the inner line, and provide a path for the cryogen that is free from air and moisture. Open the flow valve and close it three or four times, and listen to the “gurgle” of the pump each time the valve is opened. This ensures that the valve does not freeze shut during cooldown, and that the flow is not restricted.

NOTE: Disconnect the pump from the vent port before opening the needle valve if you are operating with liquid Nitrogen. Pumping on LN2 may cause it to freeze in the transfer line, which would block all flow through the transfer line.

OPERATION

For operation at 4.2 K, the flow valve should be opened just enough to maintain this temperature at the sample mount. The necessary (minimum) flow required will be a function of the heat load into the cold finger.

For temperatures above 4.2 K, using an automatic temperature controller, supply power to the vaporizer heater and monitor the temperature of the sample mount. After a short lag, the temperature of the sample mount will increase and then stabilize at a setpoint entered in the controller. IT IS IMPORTANT TO MAKE SURE THAT HELIUM IS DEFINITELY FLOWING THROUGH THE VAPORIZER PRIOR TO PASSING ANY CURRENT THROUGH THIS HEATER. IF NO FLOW EXISTS, THE VAPORIZER'S TEMPERATURE CAN INCREASE VERY RAPIDLY CAUSING HEATER BURNOUT OR DAMAGE TO THE JOINTS.

Adjustments in cryogen flow can be made at any time either to increase the cooling power (just above the cryogen boiling point), or to reduce the cryogen consumption at higher temperatures. In general, however, there is no need to change the settings of either item after the initial set-up. Control can then be entirely made through an automatic temperature controller. In either case, the sample mount temperature should never exceed 300 K.

Operation below 4.2 K is achieved by reducing the pressure at the sample tube vent/pumping port with a mechanical vacuum pump. The flow valve may be partially opened (less than ¼ turn), thus developing a pressure gradient at the needle valve and continuously transferring cold helium vapor to the sample tube. This configuration provides cooling (below 4.2 K) for extended periods of time. Lower temperatures can be achieved by filling the sample tube, closing the flow valve and then reducing the pressure on top of this helium. The low temperature will be maintained until all the superfluid helium is depleted from the sample tube. A slightly higher temperature will be reached if the needle valve is throttled to continuously replenish the liquid helium in the sample tube.

In order to change samples (temperatures above 4.2 K and above), it is only necessary to remove the sample holder from the top of the sample tube and then reinsert the holder with the new sample. During this time, the helium vapor flow in the sample tube should be maintained, or even increased, in order to preclude the admission of any air to the sample zone. When operating below 4.2 K, the temperature should be brought back to 4.2 K and the pressure to 760 Torr before removing the sample holder.

SHUT DOWN

Upon the completion of the experiment, the needle valve at the bottom of the SuperTran leg should be closed, as should the sample tube vent/pumping port. This prevents any cryogen from reaching the sample mount and allows any cryogen remaining in the inner line or sample tube to vent safely outside the cryostat via the pressure relief valve at the top of the sample tube, while stopping any air or moisture from entering. The storage dewar should then be de-pressurized, and the SuperTran leg removed in order to reduce the heat input into the liquid inside the dewar.

OPERATIONAL TECHNIQUES

In order to maintain the high performance of this cryostat, it is recommended that the following suggestions and precautions be followed:

1. Always maintain the utmost cleanliness inside the vacuum shroud. Any elastomer seals should be very lightly coated with a high vacuum grease, and evacuation of this space is best done using a turbomolecular pumping station.

2. It is preferable to maintain a vacuum in the flexible line vacuum space and cryostat vacuum space at all times. Evacuation before every cooldown is generally not necessary. The transfer line will need to be evacuated periodically using a turbomolecular pump to a level of 10^{-6} torr. This should be done while the inner line is at room temperature. Helium gas and moist air should never be allowed inside these spaces. Do not use a mechanical pumping station to evacuate the transfer line. Mechanical pumping stations do not reach a high enough vacuum level for proper operation of the transfer line.

3. Do not heat the vaporizer or sample mount to a temperature above 300 K, unless the cryostat is specially designed for this purpose.

4. Do not bend the flexible transfer line to a radius of less than 12 inches (30 cm).

5. Do not over tighten the needle (flow control) valve at the bottom of the transfer leg.

6. Do not remove the brass bayonet tip from the transfer line.

7. It is preferable to have an anti-oscillation device on your helium storage dewar, and keep the end of the transfer leg about one centimeter above the bottom of the storage dewar.

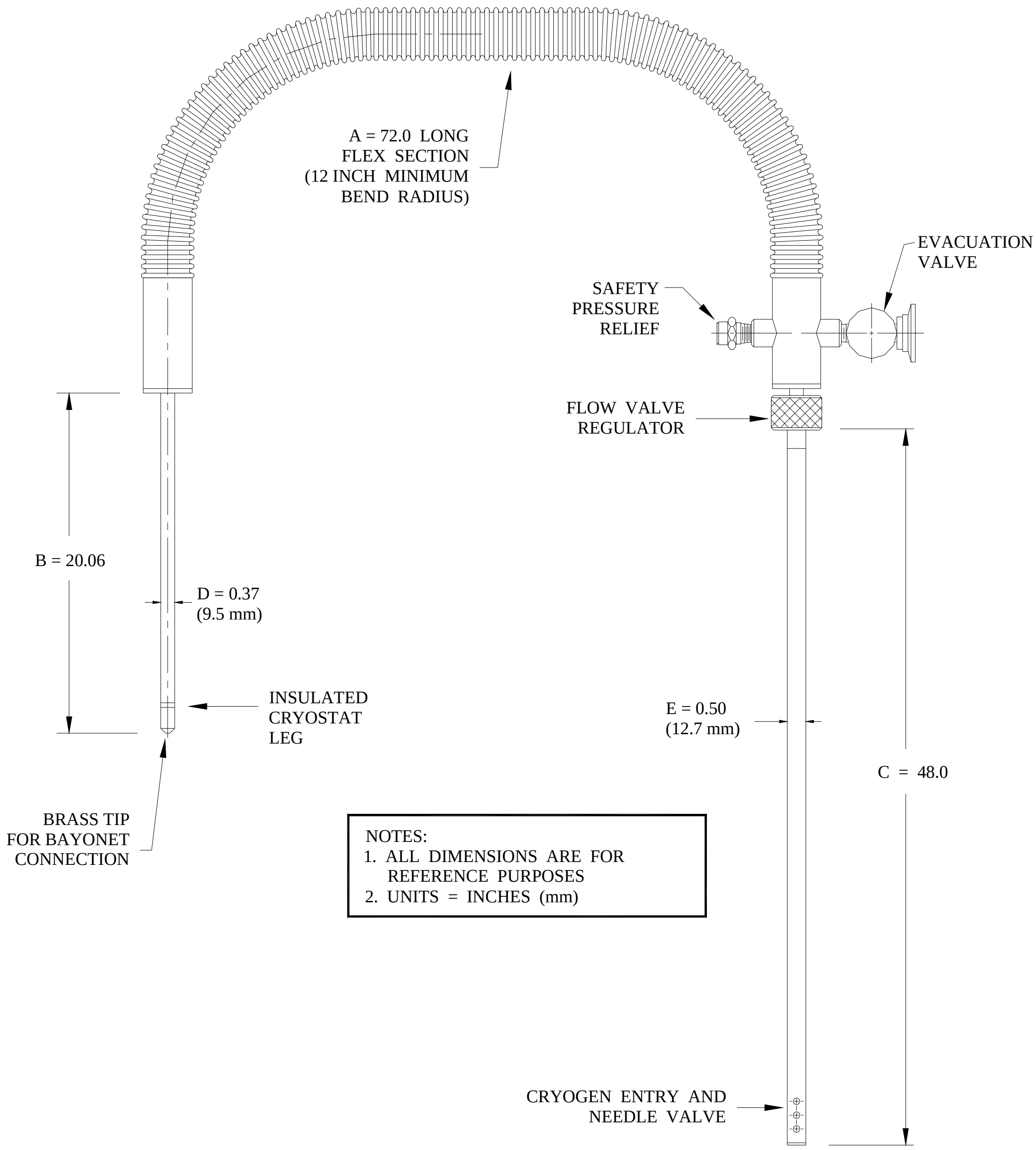


Figure 1: Model FHT-ST high efficiency flexible helium transfer line

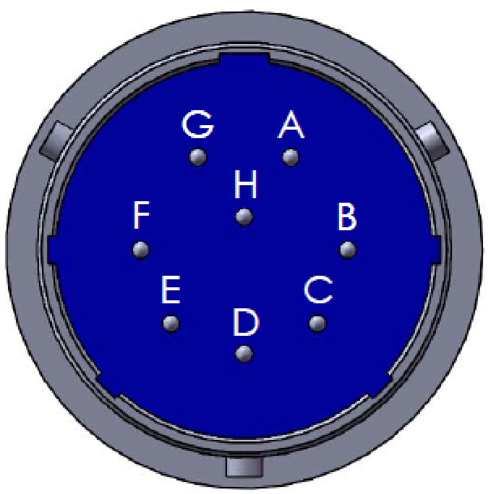
JANIS

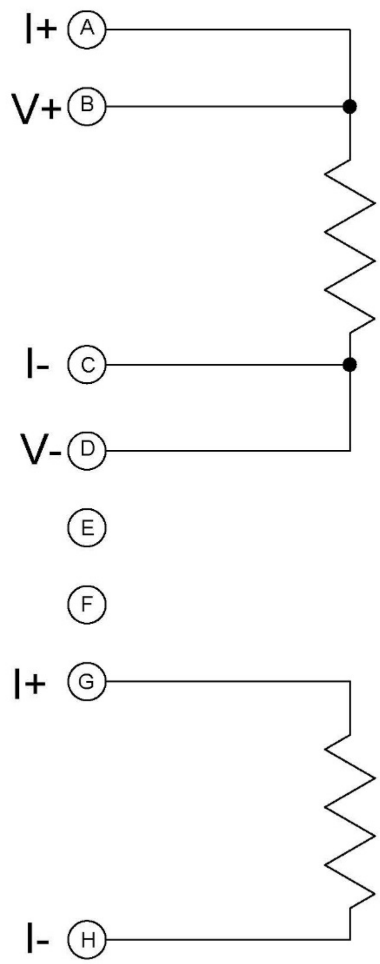
WIRING DIAGRAM FOR 8-PIN FEEDTHROUGH ON JANIS SERIAL #21394

NOTICE MAXIMUM TEMPERATURE IS 325 K

LOCATION: Top Flange

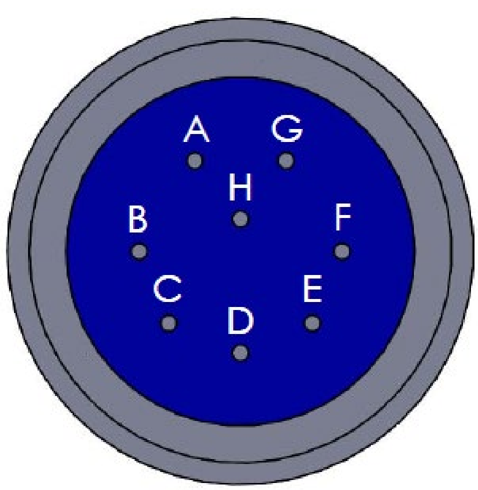
Front side (air side)





LakeShore CX-1050-CU calibrated
Cernox sensor serial number
x138113
installed on vaporizer

Back side (vacuum side)



25 Ω bifilarly wound heater
installed on vaporizer

SUPERTRAN VP TEST SHEET

(STVP-100, STVP-200, STVP-300, & STVP-400)

JOB # : 21394

CUSTOMER : PSI/Switzerland

DATE : 3/9/19

TECHNICIAN : LA

CRYOSTAT MODEL : ________

STVP INVENTORY #: ________

FHT-ST INVENTORY #: ________

INSTRUMENTATION INFORMATION

TEMPERATURE CONTROLLER — Model : 335 LAKE SHORE — S/N : LABS

VAPORIZER

TEMPERATURE SENSOR — Model : CX-1050-CU-HT-1.4H — S/N : X138113

HEATER — Type: wound htr — Resistance: 25 ohms

SAMPLE MOUNT

TEMPERATURE SENSOR — Model : ________ — S/N : ________

HEATER — Type: ________ — Resistance: ________

AUX. INPUT

LOCATION: ________ — Model : ________ — S/N : ________

AUXILIARY EQUIPMENT INFORMATION

EQUIPMENT: ________ — Model : ________ — S/N : ________

EQUIPMENT: ________ — Model : ________ — S/N : ________

EQUIPMENT: ________ — Model : ________ — S/N : ________

SUPERTRAN VP TEST

TIME		OPERATION
6:30	→	Leak test all external and internal joints using a helium leak detector at room temperature prior to cool down.. Record room temperature sensor readings below.

DATE : 3/9/19 JOB # 21394 CUSTOMER : PSI/Switzerland

SUPERTRAN VP TEST (Continued)

ROOM TEMPERATURE DATA			
	Vaporizer	Sample	AUX
Temperature (K) :	293.68	293.50	
Voltage (V) :	0.070	0.5745	

TIME **OPERATION**

6:45 → Attach a mechanical pump to the NW-25 vent port. Turn on the pump with the flow regulator valve closed. Start transferring liquid helium at about 1-2 psi with the needle valve open about 2-3 turns (1 turn = 360 degrees). Pumping on the vent port helps pull the liquid helium through the transfer line and reduces the cool down time. It will take 5-10 minutes before the sample mount starts to cool.

Cool down time (300K to 10K) = 12 minutes

When the cryostat reaches ~160K, close the pump valve, wait till positive pressure builds on the pump pressure gauge, then vent through the pump manifold.

6:52 → Record the time the control thermometer reaches 10 K, then wait 15 minutes for the radiation shield to cool.

7:30 → After the radiation shield is cold, record LHe sensor readings below.

LIQUID HELIUM TEMPERATURE DATA			
	Vaporizer	Sample	AUX
Temperature (K) :	4.34	4.16	
Resistance (ohms) :	3.302	1.577	

7:40 → Fully open the flow regulator valve (~2-3 turns). Wait 1 to 2 minutes for liquid helium to collect in the sample mount. Completely close the flow regulator valve. Close the vent valve on the pump manifold and start pumping on the LHe. Record static superfluid sensor readings below.

SUPERFLUID TEMPERATURE DATA			
	Vaporizer	Sample	AUX
Temperature (K) :	2.00	4.16	
Resistance (ohms) :	0.00	1.577	

DATE : 3/9/19 JOB # 21394 CUSTOMER : PSI/Switzerland

SUPERTRAN VP TEST (Continued)

5K FLOW TEST

Open the flow regulator valve about 1 turn. Close the pump valve, wait till positive pressure builds on the inlet side of the pump, then vent through the pump manifold. Maintain the control temperature by adjusting the liquid helium flow (do not use the heater). See sales order for the expected flow rate. Note: it may be easier to control the flow by controlling the pressure in the storage dewar (1-2 psi) rather than only adjusting the flow regulator valve. Record flow data ~ every 5 minutes.

TIME	MASS FLOW (SLPM)	FLOW RATE (ML/HR) 1 SLPM (LHe) = 94 ML/HR (LHe)	CONTROL SENSOR (K)	SAMPLE SENSOR (K)
8;05	18.0	16.92	5.02	4.98
8:15	17.6	16.54	5.01	4.97

TEMPERATURE CONTROLLER OPERATION

Set the flow rate at ~10 SLPM (~800 ML/HR). Reduce to ~7 SLPM (~560 ML/HR) at 150 K and 300 K.

The above flow rates are for a standard STVP system, and will have to be adjusted for larger or different systems.

	Control Set Point	Time Set	Time Stable	Temp. Stability (K)	Gain (P)	Reset (I)	Heater Power (Range / %)	Sample Tube Flow (SLPM)	Sample Tube Flow (ML/HR)
Vaporizer	13K	8:30	8:35	15.01	50	20	HI 11	8.8	827.2
Sample	15K								
Vaporizer	145K	8:35	8:50	150.01	50	20	HI 42	5.0	470
Sample	150K								
Vaporizer	295K	8:50	9:25	300.01	50	20	HI 40	4.5	423
Sample	300K								

After the final set-point, turn the heater power off, then close the evacuation valve. Record the amount of liquid helium used in this test below.

Total liquid helium usage for this test = 3 liters

Remarks or Comments:

VAPORIZER TEMP 2.0 T-UNDER

Certificate of Calibration
Report Number: 1064105

Sensor Model: CX-1050-CU-HT-1.4L	Serial Number: X138113
Sensor Type: Cernox Resistor	Calibration Date: October 06, 2018
Sensor Excitation: see *Test Data* page of report	Calibration Due:
Temperature Range: 1.40 K to 325 K	

Traceability and Calibration Method

This temperature sensor has been calibrated to the International Temperature Scale of 1990 (ITS-90) or the Provisional Low Temperature Scale (PLTS-2000) as appropriate. The calibrations are traceable to the National Institute of Standards and Technology (NIST, United States), the National Physical Laboratory (NPL, United Kingdom), the Physikalisch-Technische Bundesanstalt (PTB, Germany), or natural physical constants.

Lake Shore Cryotronics maintains ITS-90 and PLTS-2000 on standard platinum (PRT), rhodium-iron (RIRT), and germanium (GRT) resistance thermometers that have been calibrated directly by an internationally recognized national metrology institute (NIST, NPL, PTB) for T < 330 K or an ISO 17025 accredited metrology laboratory for 330 K < T < 800 K. A nuclear orientation thermometer is also used for temperatures less than 50 mK. These standards are routinely intercompared to verify consistency and accuracy of the temperature scale.

The sensor calibrations are performed by comparison to laboratory standard resistance thermometers and tested in accordance with Lake Shore Cryotronics, Inc. Quality Assurance Manual (QP-4220). The quality system of Lake Shore Cryotronics is registered to ISO 9001.

Procedures used: 021-97-02, 099-00-00, 121-96-02, 029-95-02

Notes
The calibration results in this report apply only to the specific sensor specified above.

Unless stated otherwise, the uncertainties in this report are based on an approximate 95% confidence level with a coverage factor k=2.

Reported by: Alex Cea
Calibration Engineer/Technician

Approved by: John Krause
Metrology

Lake Shore Cryotronics, Inc. • 575 McCorkle Boulevard • Westerville, OH 43082
Sales: (614) 891-2244 • Fax: (614) 891-1392 • sales@lakeshore.com • www.lakeshore.com

DATA PLOT

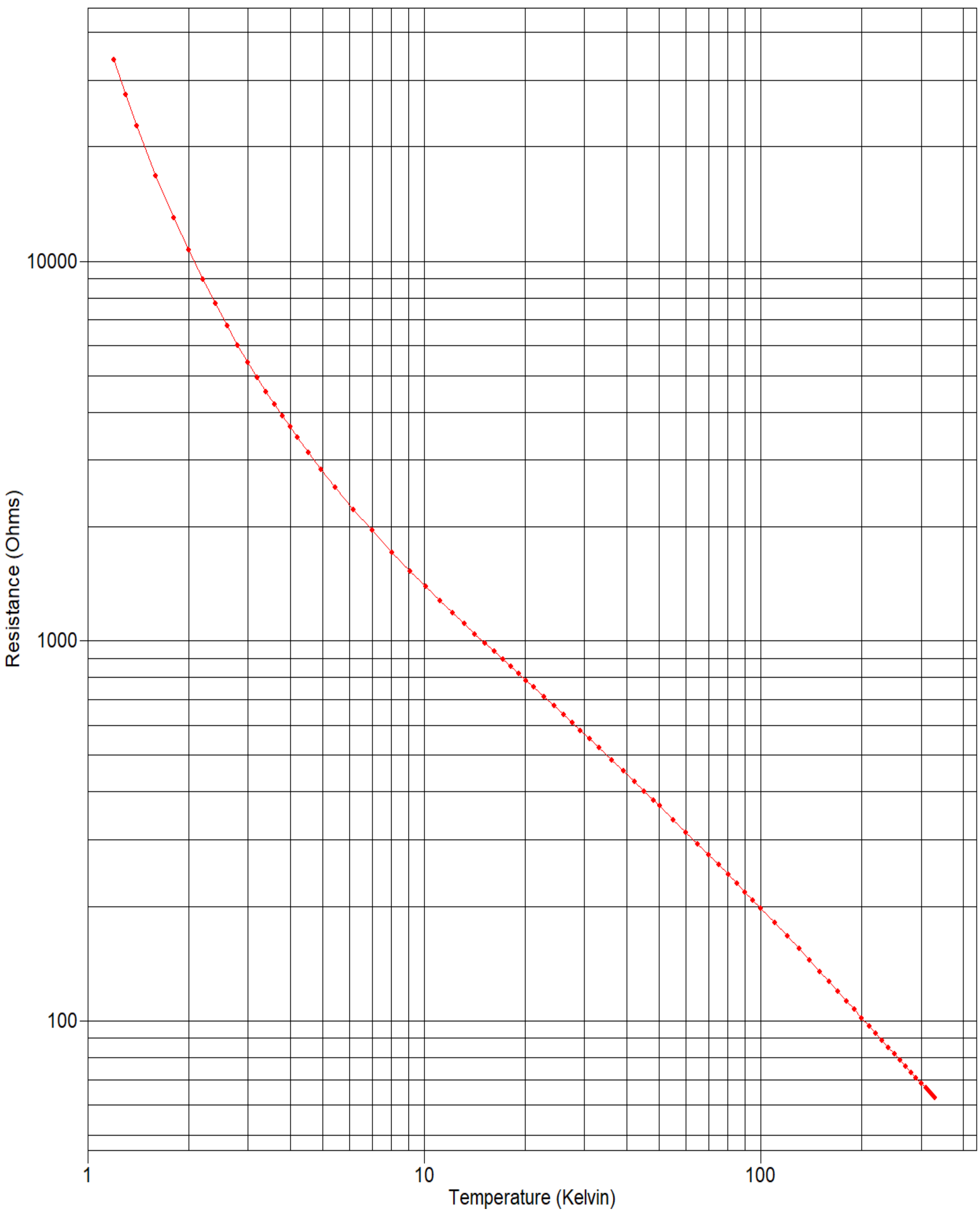
Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L

Sensor Type: Cernox Resistor

Serial Number: X138113

Temperature Range: 1.40 K to 325 K



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TEST DATA

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L   Serial Number: X138113

Sensor Type: Cernox Resistor   Temperature Range: 1.40 K to 325 K

Index	Temp. (K)	Resistance (Ω)	Excitation	Index	Temp. (K)	Resistance (Ω)	Excitation
1	1.19846	33943.5	2mV±25%	46	42.1345	426.092	2mV±25%
2	1.29934	27425.1	2mV±25%	47	45.1263	401.819	2mV±25%
3	1.40055	22736.7	2mV±25%	48	48.1261	380.216	2mV±25%
4	1.59794	16811.6	2mV±25%	49	50.1229	367.069	2mV±25%
5	1.80852	12993.0	2mV±25%	50	55.1182	337.976	2mV±25%
6	1.99987	10688.5	2mV±25%	51	60.1107	313.227	2mV±25%
7	2.20131	8962.21	2mV±25%	52	65.1001	291.912	2mV±25%
8	2.39623	7734.13	2mV±25%	53	70.0909	273.360	2mV±25%
9	2.60221	6746.37	2mV±25%	54	75.0779	257.040	2mV±25%
10	2.79958	6011.55	2mV±25%	55	80.0665	242.544	2mV±25%
11	2.99916	5418.86	2mV±25%	56	85.0657	229.566	2mV±25%
12	3.20089	4929.30	2mV±25%	57	90.0584	217.917	2mV±25%
13	3.39748	4534.46	2mV±25%	58	95.0588	207.370	2mV±25%
14	3.60118	4189.97	2mV±25%	59	100.057	197.765	2mV±25%
15	3.79674	3907.85	2mV±25%	60	110.036	180.989	2mV±25%
16	3.99740	3658.10	2mV±25%	61	120.031	166.762	2mV±25%
17	4.20806	3429.12	2mV±25%	62	130.032	154.544	2mV±25%
18	4.53163	3135.81	2mV±25%	63	140.040	143.930	2mV±25%
19	4.94172	2832.39	2mV±25%	64	150.035	134.665	2mV±25%
20	5.45632	2533.84	2mV±25%	65	160.028	126.473	2mV±25%
21	6.18155	2217.79	2mV±25%	66	170.022	119.211	2mV±25%
22	7.00368	1954.49	2mV±25%	67	180.019	112.711	2mV±25%
23	8.03849	1710.89	2mV±25%	68	190.029	106.878	2mV±25%
24	9.07218	1529.81	2mV±25%	69	200.034	101.620	2mV±25%
25	10.1071	1389.12	2mV±25%	70	210.041	96.8435	2mV±25%
26	11.1427	1276.03	2mV±25%	71	220.033	92.5217	2mV±25%
27	12.1659	1184.05	2mV±25%	72	230.040	88.5632	2mV±25%
28	13.1775	1107.19	2mV±25%	73	240.047	84.9446	2mV±25%
29	14.1800	1041.91	2mV±25%	74	250.035	81.6287	2mV±25%
30	15.1725	985.697	2mV±25%	75	260.048	78.5598	2mV±25%
31	16.1592	936.331	2mV±25%	76	270.045	75.7388	2mV±25%
32	17.1353	892.804	2mV±25%	77	280.054	73.1268	2mV±25%
33	18.1102	853.687	2mV±25%	78	290.044	70.7061	2mV±25%
34	19.0920	818.046	2mV±25%	79	300.053	68.4588	2mV±25%
35	20.0609	785.989	2mV±25%	80	310.033	66.3643	2mV±25%
36	21.1390	753.466	2mV±25%	81	315.044	65.3671	2mV±25%
37	22.7192	710.741	2mV±25%	82	320.047	64.4043	2mV±25%
38	24.3184	672.659	2mV±25%	83	326.043	63.2913	2mV±25%
39	25.9457	638.101	2mV±25%	84	330.052	62.5767	2mV±25%
40	27.5645	607.299	2mV±25%				
41	29.1955	579.339	2mV±25%				
42	31.0129	551.156	2mV±25%				
43	33.1320	521.726	2mV±25%				
44	36.1308	485.270	2mV±25%				
45	39.1318	453.695	2mV±25%				

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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 (± 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:

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

where

σ_{fit} = standard deviation of the fit

T_i = measured temperature for point i

T_{icalc} = 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_C

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F010-04-00_C

POLYNOMIAL EQUATION

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L

Serial Number: X138113

Sensor Type: Cernox Resistor

Temperature Range: 1.40 K to 325 K

Polynomial Type: Chebychev

Useful Range of Fit:

1.40 K	to	14.2 K
2.272e+4 ohms	to	1042 ohms

Lower and Upper limits of Log(Resistance) used in computing Chebychev coefficients:

ZL = 2.97142933052   ZU = 4.53075607575

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	5.454430	1.6400E-04	33257.82
1	-6.305936	2.6367E-04	-23915.62
2	2.863434	2.3183E-04	12351.65
3	-1.085754	2.3798E-04	-4562.34
4	0.347901	2.2415E-04	1552.06
5	-0.088921	2.0549E-04	-432.72
6	0.015681	2.0637E-04	75.98
7	0.000033	2.0840E-04	0.16
8	-0.002565	2.0891E-04	-12.28

Z = Log(Resistance)

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

Temp. (K) = ΣA_i* COS(i * ARCCOS(k)), where 0 <= i <= 8
and the A_i's are the coefficients in the table above.

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POLYNOMIAL EQUATION

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L
Serial Number: X138113

Sensor Type: Cernox Resistor
Temperature Range: 1.40 K to 325 K

Polynomial Type: Chebychev

Temp. (K) vs. Log(Resistance)

	R Meas. (W)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	33943.46	1.19846	1.19830	0.16
2	27425.09	1.29934	1.30013	-0.79
3	22736.72	1.40055	1.39956	0.98
4	16811.60	1.59794	1.59796	-0.02
5	12993.03	1.80852	1.80935	-0.83
6	10688.49	1.99987	2.00008	-0.20
7	8962.205	2.20131	2.20091	0.40
8	7734.132	2.39623	2.39532	0.91
9	6746.374	2.60221	2.60192	0.29
10	6011.555	2.79958	2.79978	-0.20
11	5418.859	2.99916	2.99929	-0.12
12	4929.305	3.20089	3.20154	-0.65
13	4534.465	3.39748	3.39802	-0.54
14	4189.972	3.60118	3.60152	-0.34
15	3907.852	3.79674	3.79684	-0.09
16	3658.103	3.99740	3.99699	0.41
17	3429.123	4.20806	4.20857	-0.51
18	3135.808	4.53163	4.52978	1.84
19	2832.386	4.94172	4.94127	0.44
20	2533.845	5.45632	5.45722	-0.90
21	2217.789	6.18155	6.18246	-0.91
22	1954.492	7.00368	7.00289	0.79
23	1710.891	8.03849	8.03830	0.19
24	1529.813	9.07218	9.07264	-0.46
25	1389.121	10.10706	10.10707	-0.01
26	1276.027	11.14269	11.14300	-0.31
27	1184.046	12.16585	12.16496	0.89
28	1107.193	13.17753	13.17786	-0.33
29	1041.912	14.17996	14.18048	-0.52
30	985.6970	15.17251	15.17182	0.69
31	936.3308	16.15918	16.15946	-0.28

Order of Fit = 8 RMS error of fit = 0.64 mK

Largest absolute error = 1.84 mK at data point no. 18

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POLYNOMIAL EQUATION

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L

Serial Number: X138113

Sensor Type: Cernox Resistor

Temperature Range: 1.40 K to 325 K

Polynomial Type: Chebychev

Useful Range of Fit:

14.2 K	to	80.1 K
1042 ohms	to	242.5 ohms

Lower and Upper limits of Log(Resistance) used in computing Chebychev coefficients:

ZL = 2.33829065649   ZU = 3.0733687146

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	42.546707	3.0844E-04	137942.09
1	-37.865627	5.0360E-04	-75189.89
2	8.455237	4.5926E-04	18410.46
3	-1.075455	4.3116E-04	-2494.32
4	0.114094	4.1252E-04	276.58
5	-0.005479	3.8823E-04	-14.11
6	-0.005284	3.8830E-04	-13.61

Z = Log(Resistance)

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

Temp. (K) = ΣA_i* COS(i * ARCCOS(k)), where 0 <= i <= 6
and the A_i's are the coefficients in the table above.

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POLYNOMIAL EQUATION

Calibration Report: 1064105
Sensor Model: CX-1050-CU-HT-1.4L
Sensor Type: Cernox Resistor
Serial Number: X138113
Temperature Range: 1.40 K to 325 K

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

	R Meas. (W)	T Meas. (K)	T Eq. (K)	T diff. (mK)
27	1184.046	12.16496	12.16419	0.77
28	1107.193	13.17786	13.17894	-1.09
29	1041.912	14.18048	14.18156	-1.07
30	985.6970	15.17251	15.17216	0.35
31	936.3308	16.15918	16.15846	0.72
32	892.8042	17.13528	17.13428	1.01
33	853.6870	18.11023	18.10972	0.52
34	818.0463	19.09203	19.09159	0.45
35	785.9890	20.06094	20.06097	-0.03
36	753.4660	21.13900	21.13901	-0.01
37	710.7411	22.71922	22.72174	-2.52
38	672.6589	24.31841	24.31853	-0.11
39	638.1009	25.94570	25.94652	-0.83
40	607.2993	27.56455	27.56533	-0.78
41	579.3389	29.19547	29.19365	1.83
42	551.1564	31.01290	31.01186	1.03
43	521.7257	33.13198	33.13128	0.70
44	485.2701	36.13076	36.12979	0.97
45	453.6950	39.13180	39.13253	-0.74
46	426.0922	42.13449	42.13555	-1.06
47	401.8192	45.12626	45.12861	-2.34
48	380.2161	48.12606	48.12362	2.44
49	367.0693	50.12288	50.12359	-0.71
50	337.9762	55.11822	55.11674	1.49
51	313.2270	60.11073	60.11096	-0.22
52	291.9123	65.10010	65.10291	-2.80
53	273.3599	70.09094	70.08961	1.33
54	257.0398	75.07791	75.07552	2.39
55	242.5442	80.06652	80.06713	-0.61
56	229.5662	85.06572	85.06784	-2.12
57	217.9168	90.05838	90.05731	1.07

Order of Fit = 6 RMS error of fit = 1.34 mK
Largest absolute error = -2.80 mK at data point no. 52

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POLYNOMIAL EQUATION

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L

Serial Number: X138113

Sensor Type: Cernox Resistor

Temperature Range: 1.40 K to 325 K

Polynomial Type: Chebychev

Useful Range of Fit:

80.1 K	to	325 K
242.5 ohms	to	63.48 ohms

Lower and Upper limits of Log(Resistance) used in computing Chebychev coefficients:

ZL = 1.79641258438   ZU = 2.43673473263

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	176.712098	1.4796E-03	119432.67
1	-126.561325	2.2835E-03	-55425.25
2	22.713199	2.1943E-03	10351.01
3	-3.291774	2.0823E-03	-1580.83
4	0.624679	1.9835E-03	314.93
5	-0.121234	1.9894E-03	-60.94
6	0.016304	1.9646E-03	8.30
7	-0.002796	1.8976E-03	-1.47

Z = Log(Resistance)

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

Temp. (K) = ΣA_i* COS(i * ARCCOS(k)), where 0 <= i <= 7
and the A_i's are the coefficients in the table above.

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F010-04-00_C

POLYNOMIAL EQUATION

Calibration Report: 1064105
Sensor Model: CX-1050-CU-HT-1.4L
Serial Number: X138113
Sensor Type: Cernox Resistor
Temperature Range: 1.40 K to 325 K

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

	R Meas. (W)	T Meas. (K)	T Eq. (K)	T diff. (mK)
53	273.3599	70.08961	70.08915	0.46
54	257.0398	75.07552	75.07638	-0.86
55	242.5442	80.06713	80.06700	0.13
56	229.5662	85.06572	85.06718	-1.46
57	217.9168	90.05838	90.05812	0.26
58	207.3701	95.05879	95.05359	5.20
59	197.7653	100.05715	100.05790	-0.75
60	180.9889	110.03618	110.04107	-4.89
61	166.7621	120.03122	120.03228	-1.06
62	154.5436	130.03155	130.02998	1.57
63	143.9299	140.04026	140.04186	-1.60
64	134.6652	150.03522	150.02523	9.99
65	126.4725	160.02766	160.03236	-4.70
66	119.2111	170.02202	170.01978	2.23
67	112.7115	180.01942	180.02714	-7.71
68	106.8781	190.02909	190.03044	-1.35
69	101.6196	200.03376	200.02696	6.80
70	96.84350	210.04067	210.05125	-10.59
71	92.52168	220.03307	220.02705	6.02
72	88.56321	230.04046	230.04047	-0.01
73	84.94455	240.04662	240.04140	5.22
74	81.62868	250.03517	250.02262	12.54
75	78.55978	260.04770	260.05782	-10.12
76	75.73882	270.04475	270.05322	-8.48
77	73.12678	280.05427	280.05623	-1.95
78	70.70611	290.04356	290.05243	-8.88
79	68.45882	300.05305	300.03724	15.81
80	66.36432	310.03280	310.02874	4.06
81	65.36706	315.04374	315.04145	2.29
82	64.40426	320.04656	320.04924	-2.67
83	63.29130	326.04269	326.05630	-13.61
84	62.57669	330.05150	330.04341	8.09

Order of Fit = 7 RMS error of fit = 6.65 mK
Largest absolute error = 15.81 mK at data point no. 79

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INTERPOLATION TABLE

Calibration Report: 1064105
Sensor Model: CX-1050-CU-HT-1.4L
Serial Number: X138113
Sensor Type: Cernox Resistor
Temperature Range: 1.40 K to 325 K

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT	Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
1.400	22719.3	-39846	-2.4554	15.50	968.620	-51.028	-0.81656
1.500	19315.6	-29085	-2.2587	16.00	943.870	-48.025	-0.81409
1.600	16765.7	-22454	-2.1429	16.50	920.546	-45.315	-0.81223
1.700	14753.7	-18000	-2.0740	17.00	898.515	-42.846	-0.81065
1.800	13128.8	-14655	-2.0093	17.50	877.664	-40.593	-0.80939
1.900	11796.3	-12104	-1.9495	18.00	857.891	-38.530	-0.80842
2.000	10689.3	-10119	-1.8934	18.50	839.105	-36.638	-0.80777
2.100	9758.65	-8550.9	-1.8401	19.00	821.228	-34.895	-0.80733
2.200	8968.84	-7290.6	-1.7883	19.50	804.188	-33.286	-0.80712
2.300	8292.55	-6270.0	-1.7390	20.00	787.922	-31.796	-0.80710
2.400	7708.59	-5437.3	-1.6929	21.00	757.491	-29.130	-0.80756
2.500	7200.21	-4751.6	-1.6498	22.00	729.546	-26.813	-0.80855
2.600	6754.41	-4182.1	-1.6098	23.00	703.770	-24.784	-0.80998
2.700	6360.70	-3705.5	-1.5729	24.00	679.899	-22.994	-0.81168
2.800	6010.84	-3303.2	-1.5387	25.00	657.714	-21.406	-0.81366
2.900	5698.06	-2961.2	-1.5071	26.00	637.030	-19.988	-0.81579
3.000	5416.96	-2668.3	-1.4778	27.00	617.690	-18.715	-0.81804
3.100	5163.05	-2415.8	-1.4505	28.00	599.559	-17.567	-0.82038
3.200	4932.68	-2196.7	-1.4250	29.00	582.521	-16.527	-0.82275
3.300	4722.79	-2005.5	-1.4013	30.00	566.474	-15.581	-0.82517
3.400	4530.82	-1837.6	-1.3790	31.00	551.331	-14.718	-0.82757
3.500	4354.60	-1689.6	-1.3580	32.00	537.013	-13.928	-0.82997
3.600	4192.34	-1558.3	-1.3382	33.00	523.453	-13.203	-0.83234
3.700	4042.45	-1441.6	-1.3194	34.00	510.589	-12.535	-0.83470
3.800	3903.62	-1337.2	-1.3017	35.00	498.366	-11.917	-0.83695
3.900	3774.67	-1243.5	-1.2848	36.00	486.738	-11.346	-0.83920
4.000	3654.61	-1159.1	-1.2687	37.00	475.659	-10.817	-0.84144
4.200	3437.79	-1013.9	-1.2387	38.00	465.091	-10.325	-0.84357
4.400	3247.38	-893.84	-1.2111	39.00	454.999	-9.8662	-0.84567
4.600	3078.92	-793.76	-1.1859	40.00	445.349	-9.4386	-0.84775
4.800	2928.85	-709.24	-1.1624	42.00	427.263	-8.6640	-0.85167
5.000	2794.37	-637.58	-1.1408	44.00	410.630	-7.9832	-0.85542
5.200	2673.15	-576.06	-1.1206	46.00	395.278	-7.3814	-0.85900
5.400	2563.38	-523.04	-1.1018	48.00	381.061	-6.8461	-0.86237
5.600	2463.46	-477.15	-1.0847	50.00	367.855	-6.3686	-0.86564
5.800	2372.14	-436.86	-1.0681	52.00	355.553	-5.9401	-0.86874
6.000	2288.39	-401.46	-1.0526	54.00	344.066	-5.5538	-0.87165
6.500	2106.34	-330.21	-1.0190	56.00	333.313	-5.2055	-0.87458
7.000	1955.29	-276.53	-0.98998	58.00	323.223	-4.8892	-0.87734
7.500	1827.76	-235.21	-0.96517	60.00	313.737	-4.6016	-0.88003
8.000	1718.61	-202.70	-0.94356	65.00	292.322	-3.9868	-0.88650
8.500	1623.96	-176.80	-0.92538	70.00	273.672	-3.4901	-0.89269
9.000	1541.02	-155.67	-0.90917	75.00	257.272	-3.0829	-0.89871
9.500	1467.65	-138.32	-0.89535	77.35	250.226	-2.9165	-0.90154
10.00	1402.23	-123.81	-0.88298	80.00	242.728	-2.7452	-0.90477
10.50	1343.45	-111.62	-0.87242	85.00	229.731	-2.4612	-0.91063
11.00	1290.31	-101.21	-0.86286	90.00	218.046	-2.2196	-0.91614
11.50	1241.98	-92.302	-0.85466	95.00	207.478	-2.0127	-0.92158
12.00	1197.81	-84.585	-0.84739	100.0	197.871	-1.8342	-0.92695
12.50	1157.23	-77.872	-0.84115	105.0	189.098	-1.6787	-0.93214
13.00	1119.81	-71.921	-0.83494	110.0	181.052	-1.5425	-0.93718
13.50	1085.19	-66.658	-0.82923	115.0	173.646	-1.4225	-0.94208
14.00	1053.04	-62.060	-0.82508	120.0	166.805	-1.3160	-0.94674
14.50	1023.04	-58.027	-0.82245	125.0	160.466	-1.2211	-0.95118
15.00	994.953	-54.362	-0.81956	130.0	154.578	-1.1360	-0.95535

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INTERPOLATION TABLE

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L

Serial Number: X138113

Sensor Type: Cernox Resistor

Temperature Range: 1.40 K to 325 K

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT	Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
135.0	149.092	-1.0594	-0.95927	235.0	86.7294	-0.36180	-0.98033
140.0	143.971	-0.99022	-0.96290	240.0	84.9589	-0.34654	-0.97895
145.0	139.180	-0.92747	-0.96626	245.0	83.2625	-0.33216	-0.97739
150.0	134.687	-0.87037	-0.96932	250.0	81.6359	-0.31860	-0.97568
155.0	130.468	-0.81824	-0.97210	255.0	80.0752	-0.30580	-0.97381
160.0	126.497	-0.77051	-0.97458	260.0	78.5768	-0.29369	-0.97179
165.0	122.756	-0.72670	-0.97678	265.0	77.1372	-0.28225	-0.96965
170.0	119.225	-0.68638	-0.97869	270.0	75.7533	-0.27141	-0.96737
175.0	115.887	-0.64918	-0.98032	273.15	74.9087	-0.26488	-0.96587
180.0	112.728	-0.61479	-0.98168	275.0	74.4221	-0.26115	-0.96497
185.0	109.735	-0.58293	-0.98276	280.0	73.1409	-0.25141	-0.96247
190.0	106.895	-0.55337	-0.98358	285.0	71.9071	-0.24218	-0.95986
195.0	104.198	-0.52587	-0.98414	290.0	70.7184	-0.23341	-0.95716
200.0	101.633	-0.50026	-0.98445	295.0	69.5723	-0.22508	-0.95437
205.0	99.1922	-0.47637	-0.98452	300.0	68.4669	-0.21715	-0.95150
210.0	96.8668	-0.45405	-0.98435	305.0	67.4001	-0.20962	-0.94856
215.0	94.6493	-0.43317	-0.98397	310.0	66.3701	-0.20244	-0.94555
220.0	92.5329	-0.41360	-0.98336	315.0	65.3752	-0.19560	-0.94249
225.0	90.5112	-0.39525	-0.98255	320.0	64.4136	-0.18909	-0.93937
230.0	88.5785	-0.37801	-0.98153	325.0	63.4838	-0.18287	-0.93620

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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 295 K:	69.5 Ω
Liquid Nitrogen:	250 Ω
Liquid Helium:	3422 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 Lake Shore, the current to the sensor is adjusted to maintain the sensor output voltage or power at the values listed on the Test Data page.

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BREAKPOINTS CUBIC SPLINE FORMAT

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L   Serial Number: X138113
Sensor Type: Cernox Resistor   Temperature Range: 1.40 K to 325 K

Sensor Model:	CX-1050-CU-HT-1.4L	
Serial Number:	X138113	
Data Format:	7	(Ohms/Kelvin)
Setpoint Limit:	325	

Measurement (ohms)	Temp (K)	Curvature
6.25767E+01	3.30043E+02	2.08808E-01
6.32913E+01	3.26056E+02	2.00754E-01
6.44043E+01	3.20049E+02	1.88211E-01
6.53671E+01	3.15041E+02	1.78397E-01
6.63643E+01	3.10029E+02	1.68694E-01
6.84588E+01	3.00037E+02	1.50730E-01
7.07061E+01	2.90052E+02	1.34290E-01
7.31268E+01	2.80056E+02	1.19174E-01
7.57388E+01	2.70053E+02	1.05357E-01
7.85598E+01	2.60058E+02	9.27838E-02
8.16287E+01	2.50023E+02	8.13356E-02
8.49446E+01	2.40041E+02	7.10468E-02
8.85632E+01	2.30040E+02	6.17638E-02
9.25217E+01	2.20027E+02	5.34328E-02
9.68435E+01	2.10051E+02	4.60199E-02
1.01620E+02	2.00027E+02	3.93958E-02
1.06878E+02	1.90030E+02	3.35481E-02
1.12711E+02	1.80027E+02	2.83884E-02
1.19211E+02	1.70020E+02	2.38592E-02
1.26473E+02	1.60032E+02	1.99103E-02
1.34665E+02	1.50025E+02	1.64713E-02
1.43930E+02	1.40042E+02	1.35049E-02
1.54544E+02	1.30030E+02	1.09469E-02
1.66762E+02	1.20032E+02	8.76636E-03
1.80989E+02	1.10041E+02	6.91106E-03
1.97765E+02	1.00058E+02	5.36658E-03
2.07370E+02	9.50536E+01	4.70668E-03
2.17917E+02	9.00581E+01	4.07305E-03
2.29566E+02	8.50672E+01	3.51095E-03
2.42544E+02	8.00671E+01	2.97270E-03
2.57040E+02	7.50755E+01	2.52468E-03
2.73360E+02	7.00896E+01	2.10624E-03
2.91912E+02	6.51029E+01	1.73620E-03
3.13227E+02	6.01110E+01	1.40803E-03
3.37976E+02	5.51167E+01	1.12056E-03
3.67069E+02	5.01236E+01	8.75960E-04
3.80216E+02	4.81236E+01	7.91062E-04
4.01819E+02	4.51286E+01	6.68120E-04
4.26092E+02	4.21356E+01	5.59862E-04
4.53695E+02	3.91325E+01	4.62982E-04
4.85270E+02	3.61298E+01	3.77658E-04
5.21726E+02	3.31313E+01	3.03940E-04
5.51156E+02	3.10119E+01	2.58371E-04
5.79339E+02	2.91936E+01	2.22541E-04
6.07299E+02	2.75653E+01	1.93355E-04
6.38101E+02	2.59465E+01	1.66777E-04
6.72659E+02	2.43185E+01	1.42519E-04
7.10741E+02	2.27217E+01	1.20918E-04
7.53466E+02	2.11390E+01	1.01670E-04
7.85989E+02	2.00610E+01	8.97361E-05
8.18046E+02	1.90916E+01	7.95512E-05
8.53687E+02	1.81097E+01	6.99434E-05
8.92804E+02	1.71343E+01	6.09206E-05
9.36331E+02	1.61585E+01	5.28314E-05
9.85697E+02	1.51722E+01	4.39858E-05
1.04191E+03	1.41805E+01	3.79487E-05
1.10719E+03	1.31779E+01	3.06306E-05
1.18405E+03	1.21650E+01	2.45944E-05
1.27603E+03	1.11430E+01	1.90811E-05
1.38912E+03	1.01071E+01	1.42803E-05
1.52981E+03	9.07264E+00	1.02293E-05
1.71089E+03	8.03830E+00	6.90236E-06
1.95449E+03	7.00289E+00	4.33095E-06
2.21779E+03	6.18246E+00	2.79013E-06
2.53384E+03	5.45722E+00	1.75502E-06
2.83239E+03	4.94127E+00	1.20451E-06
3.13581E+03	4.52978E+00	8.50889E-07
3.42912E+03	4.20857E+00	6.31958E-07
3.65810E+03	3.99699E+00	5.10350E-07
3.90785E+03	3.79684E+00	4.09369E-07
4.18997E+03	3.60152E+00	3.25140E-07
4.53446E+03	3.39802E+00	2.51015E-07
4.92930E+03	3.20154E+00	1.91463E-07
5.41886E+03	2.99929E+00	1.41095E-07
6.01155E+03	2.79978E+00	1.01305E-07
6.74637E+03	2.60192E+00	7.00446E-08
7.73413E+03	2.39532E+00	4.53793E-08
8.96221E+03	2.20091E+00	2.84071E-08
1.06885E+04	2.00008E+00	1.63385E-08
1.29930E+04	1.80935E+00	8.98960E-09
1.68116E+04	1.59796E+00	4.36385E-09
2.27367E+04	1.39956E+00	2.00580E-09
2.74251E+04	1.30013E+00	1.11321E-09
3.39435E+04	1.19830E+00	-1.27776E-10

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BREAKPOINTS 340 FORMAT

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L
Serial Number: X138113
Sensor Type: Cernox Resistor
Temperature Range: 1.40 K to 325 K

Name: CX-1050-CU-HT-1.4L
Serial Number: X138113
Format: 4 ;Log Ohms/Kelvin
Limit: 325.0
Coefficient: 1 ;Negative

Point 1: 1.80265,325.000
Point 2: 1.81024,319.000
Point 3: 1.81736,313.500
Point 4: 1.82462,308.000
Point 5: 1.83204,302.500

Point 6: 1.83963,297.000
Point 7: 1.84738,291.500
Point 8: 1.85530,286.000
Point 9: 1.86340,280.500
Point 10: 1.87169,275.000

Point 11: 1.88017,269.500
Point 12: 1.88884,264.000
Point 13: 1.89772,258.500
Point 14: 1.90681,253.000
Point 15: 1.91612,247.500

Point 16: 1.92479,242.500
Point 17: 1.93365,237.500
Point 18: 1.94271,232.500
Point 19: 1.95197,227.500
Point 20: 1.96145,222.500

Point 21: 1.97116,217.500
Point 22: 1.98110,212.500
Point 23: 1.99128,207.500
Point 24: 2.00170,202.500
Point 25: 2.01239,197.500

Point 26: 2.02335,192.500
Point 27: 2.03459,187.500
Point 28: 2.04613,182.500
Point 29: 2.05797,177.500
Point 30: 2.06891,173.000

Point 31: 2.08011,168.500
Point 32: 2.09160,164.000
Point 33: 2.10338,159.500
Point 34: 2.11548,155.000
Point 35: 2.12790,150.500

Point 36: 2.14066,146.000
Point 37: 2.15379,141.500
Point 38: 2.16729,137.000
Point 39: 2.18120,132.500
Point 40: 2.19394,128.500

Point 41: 2.20701,124.500
Point 42: 2.22047,120.500
Point 43: 2.23433,116.500
Point 44: 2.24861,112.500
Point 45: 2.26335,108.500

Point 46: 2.27858,104.500
Point 47: 2.29235,101.000
Point 48: 2.30245, 98.500
Point 49: 2.31276, 96.000
Point 50: 2.32332, 93.500

Point 51: 2.33413, 91.000
Point 52: 2.34521, 88.500
Point 53: 2.35657, 86.000
Point 54: 2.36823, 83.500
Point 55: 2.38021, 81.000

Point 56: 2.39253, 78.500
Point 57: 2.40520, 76.000
Point 58: 2.41562, 74.000
Point 59: 2.42628, 72.000
Point 60: 2.43721, 70.000

Point 61: 2.44843, 68.000
Point 62: 2.45996, 66.000
Point 63: 2.47181, 64.000
Point 64: 2.48399, 62.000
Point 65: 2.49654, 60.000

Point 66: 2.50947, 58.000
Point 67: 2.52282, 56.000
Point 68: 2.53522, 54.200
Point 69: 2.54798, 52.400
Point 70: 2.56116, 50.600

Point 71: 2.57476, 48.800
Point 72: 2.58884, 47.000
Point 73: 2.60340, 45.200
Point 74: 2.61851, 43.400
Point 75: 2.63243, 41.800

Point 76: 2.64682, 40.200
Point 77: 2.66175, 38.600
Point 78: 2.67725, 37.000
Point 79: 2.69235, 35.500
Point 80: 2.70802, 34.000

Point 81: 2.72434, 32.500
Point 82: 2.74021, 31.100
Point 83: 2.75672, 29.700
Point 84: 2.77397, 28.300
Point 85: 2.79072, 27.000

Point 86: 2.80820, 25.700
Point 87: 2.82654, 24.400
Point 88: 2.84432, 23.200
Point 89: 2.86298, 22.000
Point 90: 2.88099, 20.900

Point 91: 2.89471, 20.100
Point 92: 2.90623, 19.450
Point 93: 2.91814, 18.800
Point 94: 2.93048, 18.150
Point 95: 2.94329, 17.500

Point 96: 2.95557, 16.900
Point 97: 2.96831, 16.300
Point 98: 2.98157, 15.700
Point 99: 2.99423, 15.150
Point 100: 3.00739, 14.600

Point 101: 3.02112, 14.050
Point 102: 3.03546, 13.500
Point 103: 3.04910, 13.000
Point 104: 3.06337, 12.500
Point 105: 3.07833, 12.000

Point 106: 3.09405, 11.500
Point 107: 3.10895, 11.050
Point 108: 3.12457, 10.600
Point 109: 3.14105, 10.150
Point 110: 3.15847, 9.700

Point 111: 3.17486, 9.300
Point 112: 3.19215, 8.900
Point 113: 3.21049, 8.500
Point 114: 3.23000, 8.100
Point 115: 3.25083, 7.700

Point 116: 3.27034, 7.350
Point 117: 3.29111, 7.000
Point 118: 3.31336, 6.650
Point 119: 3.33731, 6.300
Point 120: 3.36400, 5.940

Point 121: 3.38806, 5.640
Point 122: 3.41401, 5.340
Point 123: 3.44215, 5.040
Point 124: 3.47075, 4.760
Point 125: 3.50187, 4.480

Point 126: 3.53352, 4.220
Point 127: 3.55998, 4.020
Point 128: 3.58398, 3.850
Point 129: 3.60961, 3.680
Point 130: 3.63711, 3.510

Point 131: 3.66493, 3.350
Point 132: 3.69483, 3.190
Point 133: 3.72511, 3.040
Point 134: 3.75777, 2.890
Point 135: 3.79326, 2.740

Point 136: 3.82935, 2.600
Point 137: 3.86867, 2.460
Point 138: 3.90868, 2.330
Point 139: 3.95240, 2.200
Point 140: 4.00056, 2.070

Point 141: 4.04957, 1.950
Point 142: 4.10343, 1.830
Point 143: 4.16313, 1.710
Point 144: 4.22396, 1.600
Point 145: 4.28532, 1.500

Point 146: 4.34818, 1.410
Point 147: 4.35639, 1.400

BREAKPOINTS 91C/93C/330 FORMAT

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L   Serial Number: X138113

Sensor Type: Cernox Resistor   Temperature Range: 1.40 K to 325 K

Interpolation Method: Lagrangian
Limit: 325.0 (Kelvin)
Format: 4 (Log Ohms/Kelvin)
Number of Breakpoints: 53

No.	Units	Temperature (K)	No.	Units	Temperature (K)
1	1.80266	325.0	31	3.06051	12.6
2	1.80392	324.0	32	3.12109	10.7
3	1.80898	320.0	33	3.17916	9.2
4	1.82866	305.0	34	3.24034	7.9
5	1.84953	290.0	35	3.29741	6.9
6	1.87170	275.0	36	3.35953	6.0
7	1.89529	260.0	37	3.41779	5.3
8	1.92045	245.0	38	3.47738	4.7
9	1.94733	230.0	39	3.53628	4.2
10	1.97612	215.0	40	3.59147	3.8
11	2.00704	200.0	41	3.65618	3.4
12	2.04034	185.0	42	3.71291	3.1
13	2.07637	170.0	43	3.75573	2.9
14	2.11550	155.0	44	3.80351	2.7
15	2.15828	140.0	45	3.85735	2.5
16	2.20538	125.0	46	3.91869	2.3
17	2.25780	110.0	47	3.95274	2.2
18	2.31697	95.0	48	4.02895	2.0
19	2.38512	80.0	49	4.07175	1.9
20	2.46586	65.0	50	4.11823	1.8
21	2.51280	57.5	51	4.16890	1.7
22	2.56568	50.0	52	4.28591	1.5
23	2.60509	45.0	53	4.35639	1.4
24	2.64870	40.0			
25	2.69755	35.0			
26	2.75318	30.0			
27	2.81804	25.0			
28	2.87771	21.1			
29	2.93933	17.7			
30	3.00018	14.9			

Temperature for Resistance Decades:

Res. (Ohms)	Temp. (K)
100	203.320
1000	14.908
10000	2.072

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BREAKPOINTS 234 FORMAT

Calibration Report: 1064105

Sensor Model: CX-1050-CU-HT-1.4L　　Serial Number: X138113

Sensor Type: Cernox Resistor　　Temperature Range: 1.40 K to 325 K

Maximum Temperature Error:	
1.4 - 10 K:	0.010 K
10 - 20 K:	0.019 K
20 - 40 K:	0.008 K
40 - 100 K:	0.016 K
> 100 K:	0.065 K

BP #	Temp. (K)	Res. (W)	Log10 Res.	BP #	Temp. (K)	Res. (W)	Log10 Res.
1	311.494	66.06934	1.820	46	32.898	524.8075	2.720
2	296.740	69.18310	1.840	47	31.122	549.5409	2.740
3	282.803	72.44360	1.860	48	29.434	575.4399	2.760
4	269.616	75.85776	1.880	49	27.830	602.5596	2.780
5	257.119	79.43282	1.900	50	26.307	630.9573	2.800
6	245.259	83.17638	1.920	51	24.861	660.6934	2.820
7	233.990	87.09636	1.940	52	23.491	691.8310	2.840
8	223.268	91.20108	1.960	53	22.192	724.4360	2.860
9	213.056	95.49926	1.980	54	20.963	758.5776	2.880
10	203.318	100.0000	2.000	55	19.800	794.3282	2.900
11	194.025	104.7129	2.020	56	18.702	831.7638	2.920
12	185.149	109.6478	2.040	57	17.667	870.9636	2.940
13	176.666	114.8154	2.060	58	16.690	912.0108	2.960
14	168.552	120.2264	2.080	59	15.772	954.9926	2.980
15	160.789	125.8925	2.100	60	14.908	1000.000	3.000
16	153.357	131.8257	2.120	61	13.333	1096.478	3.040
17	146.240	138.0384	2.140	62	11.948	1202.264	3.080
18	139.424	144.5440	2.160	63	10.731	1318.257	3.120
19	132.894	151.3561	2.180	64	9.664	1445.440	3.160
20	126.639	158.4893	2.200	65	8.728	1584.893	3.200
21	120.646	165.9587	2.220	66	7.907	1737.801	3.240
22	114.906	173.7801	2.240	67	7.186	1905.461	3.280
23	109.408	181.9701	2.260	68	6.552	2089.296	3.320
24	104.144	190.5461	2.280	69	5.994	2290.868	3.360
25	99.105	199.5262	2.300	70	5.501	2511.886	3.400
26	94.284	208.9296	2.320	71	5.064	2754.229	3.440
27	89.672	218.7762	2.340	72	4.676	3019.952	3.480
28	85.263	229.0868	2.360	73	4.330	3311.311	3.520
29	81.048	239.8833	2.380	74	4.021	3630.781	3.560
30	77.021	251.1886	2.400	75	3.743	3981.072	3.600
31	73.174	263.0268	2.420	76	3.494	4365.158	3.640
32	69.502	275.4229	2.440	77	3.269	4786.301	3.680
33	65.996	288.4032	2.460	78	3.065	5248.075	3.720
34	62.652	301.9952	2.480	79	2.881	5754.399	3.760
35	59.463	316.2278	2.500	80	2.714	6309.573	3.800
36	56.422	331.1311	2.520	81	2.562	6918.310	3.840
37	53.523	346.7369	2.540	82	2.423	7585.776	3.880
38	50.760	363.0781	2.560	83	2.296	8317.638	3.920
39	48.128	380.1894	2.580	84	2.180	9120.108	3.960
40	45.619	398.1072	2.600	85	2.072	10000.00	4.000
41	43.231	416.8694	2.620	86	1.838	12589.25	4.100
42	40.955	436.5158	2.640	87	1.643	15848.93	4.200
43	38.789	457.0882	2.660	88	1.479	19952.62	4.300
44	36.727	478.6301	2.680	89	1.345	25118.86	4.400
45	34.765	501.1872	2.700	90	1.232	31622.78	4.500

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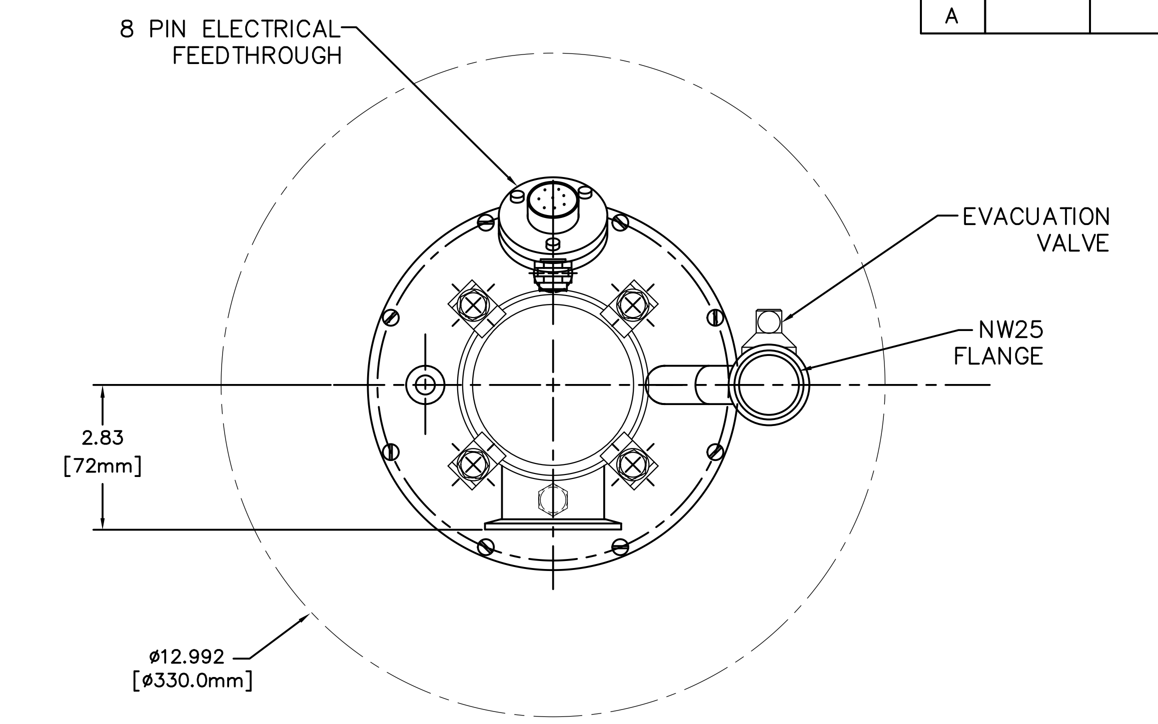
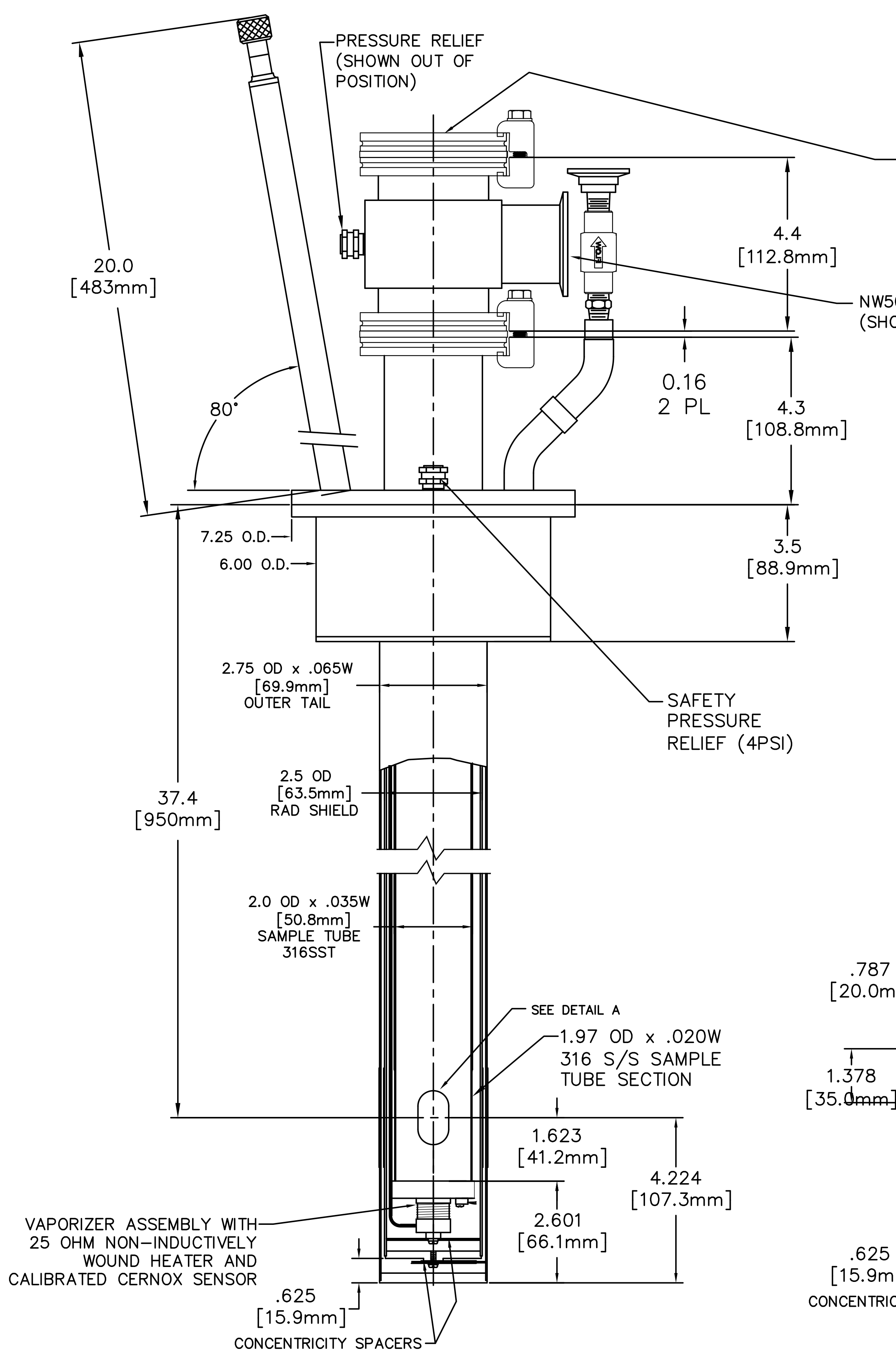
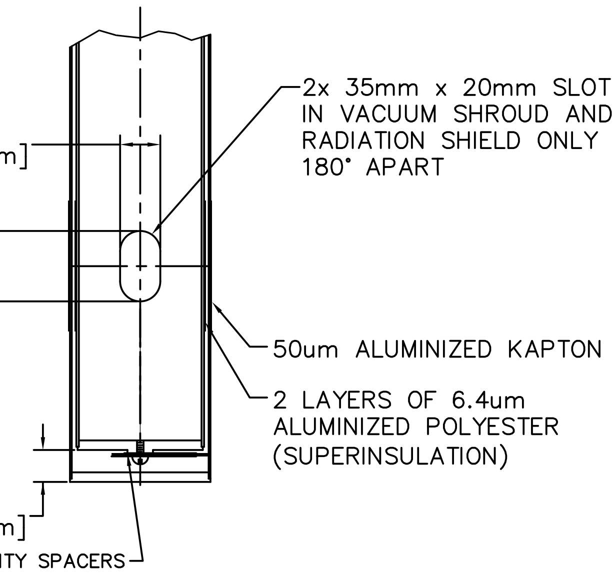
REV.	ECO #	REVISION DESCRIPTION	DATE	INITIALS	APP'D
A		INITIAL RELEASE	10/17/18	MG	



TOP VIEW



(1) BLANK NW63 FLANGE SHIPPED AS SPARE



DETAIL A

JANIS
A World Leader in Cryogenics since 1961

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
REMOVE ALL SHARP EDGES AND CORNERS
MACHINED SURFACES 32

THIRD ANGLE PROJ. — TOLERANCE: .X ± .1, .XX ± .02, .XXX ± .005, .XXXX ± .0005, FRAC. ± .1, ANGLE ± 0°30'
DRAWING ANSI Y14.5

MATL:		DRAWN / DATE	LFB 02/16/17
ASS'Y:		APP'D / DATE	
	STOCK	JOB NO.	21394
	WELDING	FINISH:	
	MODIFY	QT'Y REQ'D	

TITLE:	ASSY, STVP–NMR		
SIZE: D	DRAWING NO: D02–15–17A		REV. A
SCALE: –	ITEM NO.		SHEET 1 OF 2

JANIS RESEARCH COMPANY, LLC
Manufacturer of high-quality, easy-to-use cryogenic equipment since 1961.
225 Wildwood Avenue • Woburn, MA 01801-2025 • USA
Tel: +1 781 491-0888 • Fax: +1 781 491-0889 • www.janis.com • sales@janis.com

Limited Warranty Statement

What products are covered?
The Janis Research Co. LLC (Janis) limited warranty covers defects in material or workmanship in new products manufactured by Janis (the "Product" or "Products"). The warranty applies only to those Products sold directly by Janis, or through an authorized Janis representative, distributor or original equipment manufacturer (OEM). The warranty extends only to the original Purchaser, and is not transferable or assignable.

What is the warranty period?
The Janis limited warranty is three years (36 months) from:

- The date of shipment from Janis if no system installation is purchased
  -OR-
- The completion of installation and operational verification at the Purchaser facility, if installation has been purchased from Janis or Janis authorized representative, distributor, or OEM. If installation scheduling is delayed by the Purchaser for more than 30 days, the warranty will begin on the 31st day after receipt of the equipment at the Purchaser's facility.

Repairs that have been paid for by the Purchaser (for example after the original limited warranty has expired) will be covered by the Janis warranty for one year (12 months) from the date of shipment of the repaired Product from Janis. The one year warranty applies only to the part(s) for which repair was purchased, not to any other part of the repaired Product.

Any other warranty duration or condition must be specified by Janis in writing in a quotation or expressly approved by Janis in writing.

What products are not covered?

- Non-Janis branded products integrated or delivered with the Product, including but not limited to cryogenic refrigerators, superconducting magnets, electromagnets, magnet power supplies, vacuum pumps, and electronic instruments. These and all other non-Janis branded products will be covered by the factory warranty of their respective manufacturers or for one year, whichever is longer.
  - The Janis labor cost to remove and re-install any failed non-Janis branded product will be paid by Janis only during the first year (12 months) of the warranty period.
  - The one year period begins when the Janis limited warranty begins (according to the "What is the warranty period" section above.)
- Window materials other than quartz, sapphire, and wrapped mylar ("Other Material").

- If a window of Other Material should fail (crack or break) within the warranty period, the Purchaser will be responsible for all costs (materials, labor, and freight charges) to repair the Product.
- If a window of Other Material develops a leak within the warranty period but does not crack or break, Janis will perform the labor to replace the window at no cost to the Purchaser (in accordance with other standard warranty terms). However, the Purchaser will bear the cost of the replacement window material.

Other warranty exclusions

Excluded from this warranty are any Products that fail due to accidental damage, abuse, neglect, mechanical shock, electrostatic discharge, wear and tear, heat or humidity, unapproved component modifications, incorrect assembly or installation (unless installation service was provided by Janis or Janis authorized personnel), misuse or other operation contrary to the instructions in the user manual, operation exceeding rated specifications, natural disasters such as flood, fire, wind, or earthquake. This warranty does not cover consequential damages, incidental damages, and costs related to removal and installation at the Purchaser facility.

How do you make a warranty claim?

The Purchaser must contact Janis or the authorized Janis representative, distributor, or original equipment manufacturer (OEM) within the warranty period. The Purchaser should include name, address, phone number, email address, and product serial number, along with a description of the problem. Products are not to be returned to Janis without receiving prior authorization and a Return Merchandise Authorization (RMA). Once the RMA has been received, the Product must be properly packaged in its original packaging (or packaging that provides the Product with protection equivalent to the original packaging). The Product should be shipped freight prepaid to Janis, with the RMA clearly marked on the outside of the packaging.

What will Janis do?

Upon receipt of the Product, Janis will evaluate the Product to determine whether the failure is due to a factory defect in materials or workmanship. If found defective, Janis will either repair or replace the Product (at its sole discretion) without charge for materials, labor, or return freight charges to the Purchaser. Replacement for the Product may include either new parts or equivalent in performance to new parts. Replacement or repaired parts, or replacement Product, will be warranted for the unexpired portion of the original warranty or for 90 days (whichever is greater).

In the case of a returned Product in which no fault is found, the Purchaser will be responsible for all costs associated with the evaluation and testing of the Product, as well as the return packaging and freight charges.

Miscellaneous

The foregoing warranties are expressly in lieu of and exclude all other expressed or implied warranties, including but not limited to warranties of merchantability and of fitness for particular purpose, use or application, and all other obligations or liabilities on the part of Janis, unless such other warranties, obligations or liabilities are expressly agreed to in writing by Janis.

Statements made by any person, including representatives of Janis, which are inconsistent or in conflict with the terms of these warranties shall not be binding upon Janis unless reduced to writing by an authorized official of Janis.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, OF MERCHANTABILITY, FITNESS FOR PARTICULAR PURPOSE, PERFORMANCE, OR OTHERWISE. Neither Janis nor any of its subsidiaries or affiliates shall be held liable for incidental, consequential or other damages (including lost profit, lost data, or downtime costs) arising out of the use or inability to use the product, whether based in warranty, contract, tort or other legal theory, regardless of whether or not Janis has been advised of the possibility of such damages. Janis is not an expert in the customer's technical field and therefore does not warrant the suitability of its products for the applications selected by the customer. Janis accepts no responsibility for misuse, misapplication or unauthorized modification of its products. Use of the Product is entirely at Purchaser’s risk.