End Item Data Package (EIDP)

SPIRE - Spectrometer Calibration Source (SCal) - PFM

SPIRE Ref.: HSO-CDF-EIDP-071-UCF- SPIRE-UCF-DOC-002125
Cardiff Ref.: HSO-CDF-EIDP-071 Issue 1.0
19 August 2004

Prepared by: Peter Hargrave

Approved by: Ian Walker

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Change Record

Issue	Section	Date	Changes
1.0		12th August 2004	First issue for approval at DRB

Table of contents

SECTION 01 - Shipping Documents

SECTION 02 - Transportation, Packing, Handling & Integration Procedures

Handling

- Inspection may be carried out in class-100 clean air cabinet.
- The SCal baffle must not be removed unless by an authorised member of the SPIRE AIV team.
- ESD precautions should be observed at all times when handling SCal.

Storage

- The SCal assembly must be stored in the transport container provided.

Installation

- The SCal assembliy should be installed by trained MSSL or RAL technicians, according to the MSSL integration procedure –SPIRE Structure integration & Handling - MSSL/SPIRE/SP011.04 – section 10.2.
- The prime and redundant connectors may be identified with reference to Figure 1 below.

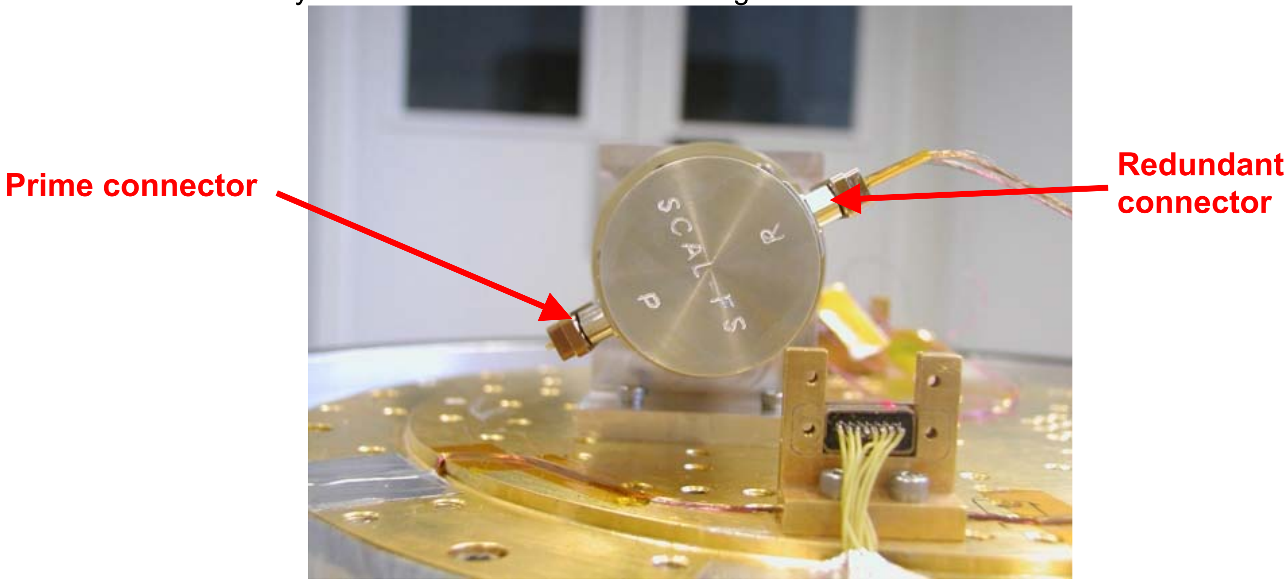


Figure 1 Identification of Prime and Redundant connectors. Note – flight spare model is shown in this view.

Cleaning & Bakeout

- Outer surface may be cleaned using a clean-room wipe impregnated with iso-propyl alcohol.
- Bakeouts should be kept to a minimum, and the temperature should NEVER exceed 80°C.

SECTION 03 - Certificate of Conformance – This will be signed after EIDP approved & PDF'd

Cardiff University Astronomy Instrumentation Group hereby certifies that the following equipment,	
Spacecraft / Project:	**Herschel**
Instrument:	**SPIRE**
Model:	**PFM**
Subsystem:	**Spectrometer Calibration Source**
Serial No:	**SCAL-PFMB-000**
As described in this End Item Data Package: **HSO-CDF-EIDP-071**	
Complies with the requirements set out in: **SPIRE Instrument Requirements Document - SPIRE-RAL-PRJ-000034** **Spectrometer Calibrator ICD – HSO-CDF-ICD-011 Issue 3.0** **Spectrometer Calibrator Specifications – HSO-CDF-SP-001 Issue 1.0**	

Responsible Authority		***Signature***
Cardiff Product Assurance	Dr I.Walker	
Cardiff SPIRE Management	Dr P.Hargrave	

SECTION 04 - Qualification Status List / Compliance Matrix

Test	Status	Applicable document	Test Institute
Dimension and tolerances to specification	Compliant	SCal ICD – HSO-CDF-ICD-011	UWC
Visual inspection (internal & external)	Passed		UWC
Mass	Compliant	SCal ICD - HSO-CDF-ICD-011	UWC
Thermal / vacuum cycles	Passed. Prior to delivery, SCal-PFM underwent a total of nine thermal / vacuum cycles to <15-K.	Section 14 & 15 Historical record & Logbook	UWC
Power consumption	Compliant, assuming maximum required source temperature is 90-K	Section 13	UWC
Vibrations 300K	Passed	AIV-2003-091-VIB, HSO-CDF-RP-078	RAL
Vibrations 4K	Passed	AIV-2003-091-VIB, HSO-CDF-RP-078	RAL
Environmental condition - Vacuum $3x10^{-1}$mBar	Compliant	Section 14 & 15 Historical record & Logbook	UWC
Differential pressure (a pumping-out rate of 10mB/sec)	Compliant	Section 14 & 15 Historical record & Logbook	RAL
Pre-bake out (not exceeding 80˚C)	Performed & compliant	Section 14 & 15 Historical record & Logbook	UWC
Outgassing	Compliant	By design	UWC
Cleanliness checks, by visual inspection.	Passed		UWC
Degradation due to high energy radiation.	Compliant	By design	UWC

Compliance with IRD

Requirement ID	Description	Value	Compliant?
IRD-CALS-R01	Radiated spectrum	Null the central maximum to accuracy of 5% (goal 2%) Replicate the dilute spectrum of the telescope to an accuracy of better than 20% (goal 5%) over 200-400 μm.	Yes – by analysis.
IRD-CALS-R03	Adjustability:	Zero - maximum in 256 steps	Yes. This is determined by the warm electronics drive – 12-bit DAC.
IRD-CALS-R04	Uniformity	The uniformity of the intensity from the cal. source across the field image at the detector shall be better than 5%	TBD – Source is at a pupil. Detectors illuminate pupil with Gaussian profile, with nominal 8-dB edge taper.

IRD-CALS-R05	Repeatability and drift	The output intensity of the calibration source shall drift by no more than 1% over one hour of continuous operation. The absolute change in the output intensity of the source shall be no more than 15% over the mission lifetime	This depends on the stability of the warm electronics drive. No drift noticeable on a day-to-day basis. At the conclusion of life tests, the source temperature increased by 3% for the same nominal applied power.
IRD-CALS-R06	Operation	The calibration source shall be capable of continuous operation for periods of up to 2 hours with no loss of operational performance.	Yes.
IRD-CALS-R07	Number of operations	The calibration source shall be capable of up to 12000 operational cycles	Yes.
IRD-CALS-R08	Operating Voltage	No more than 28 V DC	Yes
IRD-CALS-R09	Power dissipation in the focal plane	Shall be within the specification given in the systems budget document *What is this specification? Systems budget document now states that total budget for spectroscopy is 8.4mW. This does not show the breakdown for SMEC and SCAL.*	Previously quoted values were 5mW (req.) and 2mW(goal) – we are compliant with these numbers
IRD-CALS-R11	Mechanical envelope	Cylinder of 70mm diameter and 100mm length	Requirement needs updating following RAL-issued ECR to snout design. Envelope is now 50mm diameter, 121mm length.
IRD-CALS-R12	Thermal Isolation	The temperature of the SCAL housing and surrounding structure shall rise by no more than 1 K over the temperature of the FPU structure after one hour of continuous operation.	Yes
IRD-CALS-R13	Operating Temperature	< 6 K	Yes
IRD-CALS-R14	Redundancy	Fully redundant systems shall be provided for the active elements.	Yes
IRD-CALS-R15	Thermometry	Thermometers shall be provided on the spectrometer calibrator as specified in IRD	Yes
IRD-CALS-R16	Time Response	Warm-up time: Stable nominal operating temperature to be reached in less than 30 min (req.); 15 min (goal). Cool-down time from nominal operating temperature to < 10 K: 3 hrs (requirement); 30 min (goal)	Yes, if enhanced warm-up procedure is used.
SCAL-T1	Mass	< 200 gm	Yes
SCAL-SAFE-01	IRD-SAFE-R08	Failure of any sub-system, or one of its components, shall not affect the health of any other subsystem, the instrument or the interface with the satellite.	Yes
SCAL-SAFE-02	IRD-SAFE-R09	Failure of any component in a subsystem shall not damage any redundant or backup component designed to replace	Yes

		that component in the subsystem	
SCAL-REL-01	IRD-REL-R01	As far as possible the total failure of a single sub-system shall not lead to the total loss of instrument operations.	Yes
SCAL-REL-02	IRD-REL-R03	Cold redundant hardware shall be provided wherever practicable within the instrument design.	Yes

SECTION 05 - Top Level Drawings (Inc. Family Tree)

Hardware tree

The hardware tree for SCal is shown in Figure 2. Note that the part numbers are given by the general form “SCAL-XXX-nnn”, where “XXX” is the model designation (CQM, PFM etc) and “nnn” is the number given in the hardware tree. For instance, the part number for the SCal flight model rear cover would be “SCAL-PFM-105”.

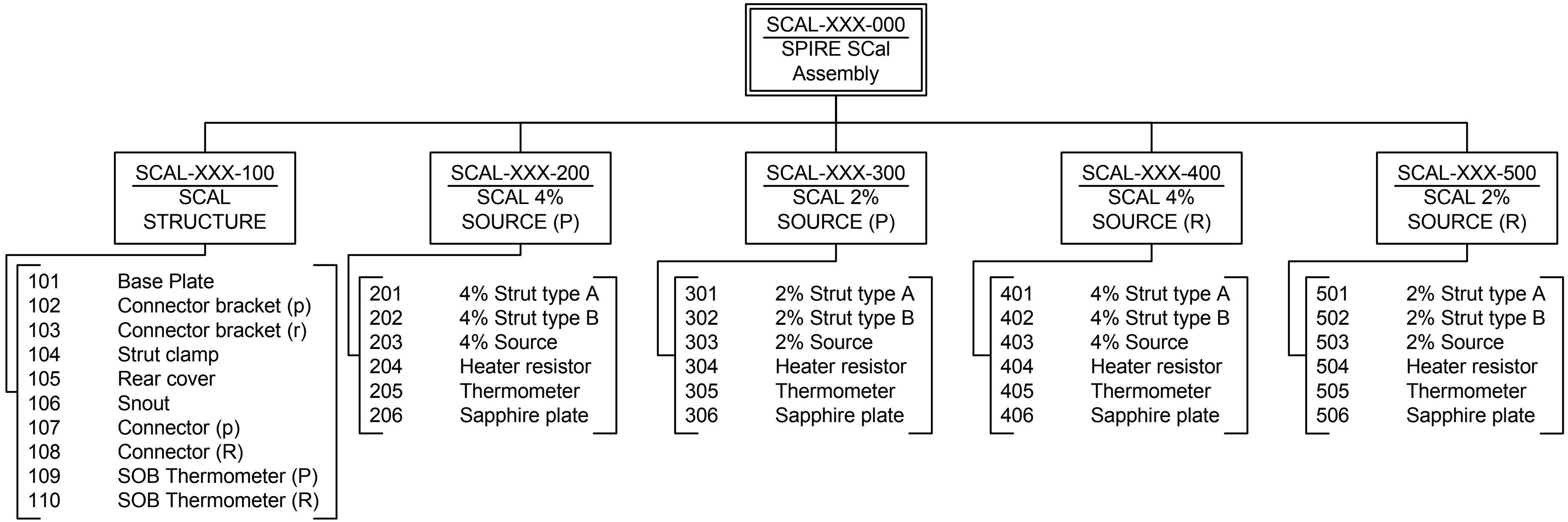
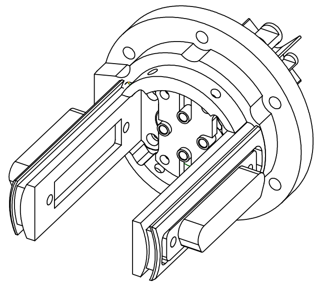


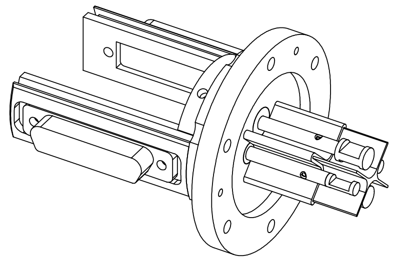
Figure 2 Hardware tree for SCal components.

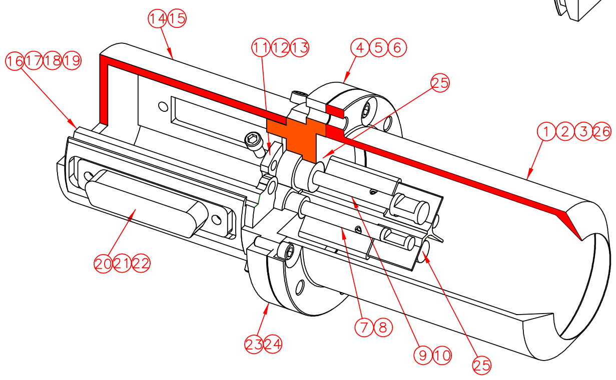
TOP LEVEL DRAWING LIST

Drawing No.	Title
SCAL-PFM-000	SPIRE SCal Assembly

CLEAN & BREAK ALL SHARP EDGES







ITEM NO.	DRAWING No.	DESCRIPTION	No. OFF	REMARKS
26	N/D	BG7	A/R	
25	N/D	BG1	A/R	
24	N/D	HELICOIL SCREWLOCK INSERTS 2-56UNCx 1.5D	1	PT. NO. 3585-02 CNX.129
23	N/D	HELICOIL SCREWLOCK INSERTS 2-56UNC x 2D	12	PT. NO. 3585-02 CNX.129
22	N/D	JACK SCREW, 2-56UNC. 12.7 LG.	4	PT. NO. MRM5254
21	N/D	BELLEVILLE SPRING WASHER	4	PT. NO. D6-20
20	PFM-102	CONNECTOR MDM37SSB	2	
19	N/D	HELICOIL SCREWLOCK INSERTS 2-56UNC x 2D	2	PT. NO. 3585-02 CNX.129
18	N/D	SCREW, 2-56UNC CP HD. 4.76 LG.	4	ST.STEEL
17	N/D	BELLEVILLE SPRING WASHER	4	PT. NO. D6-20
16	PFM-102	CONNECTOR BRACKET	2	
15	N/D	SCREW, 2-56UNC CP HD. 4.76 LG.	4	ST.STEEL
14	PFM-105	REAR COVER	1	
13	N/D	BELLEVILLE SPRING WASHER	4	PT. NO. D6-20
12	N/D	SCREW, 2-56UNC CP HD. 6.35 LG.	4	ST.STEEL
11	PFM-104	STRUT CLAMP	1	
10	PFM-203	5% SOURCE	2	
9	PFM-201	5% STRUT	2	
8	PFM-301	2% SOURCE	2	
7	PFM-301	2% STRUT	2	
6	N/D	BELLEVILLE SPRING WASHER	6	PT. NO. D6-21
5	N/D	SCREW, 4-40UNC CP HD.	6	ST.STEEL
4	PFM-101	BASE PLATE	1	
3	N/D	BELLEVILLE SPRING WASHER	3	PT. NO. D6-20
2	N/D	SCREW, 2-56UNC CP HD. 4.76 LG.	3	ST.STEEL
1	PFM-106	SNOUT	1	

CONTRACT NO.	AMENDMENT	MATERIAL & SPEC : AS LISTED	SCALE 1.5:1	TOLERANCES UNLESS OTHERWISE STATED	ASTRONOMY & INSTRUMENTATION GROUP CARDIFF UNIVERSITY QUEENS BUILDING 5 THE PARADE NEWPORT ROAD CARDIFF CF24 3YB TEL 02920 876269 FAX 02920 874056 E-MAIL Brian.Kiernan@astro.cf.ac.uk
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SECTION 06 - Interface Drawings

INTERFACE DRAWING LIST

Drawing No.	Title	Notes
SCAL-ICD-000	SCal Mechanical interface drawing	This is the ICD for SCal-PFM and SCal-FS.

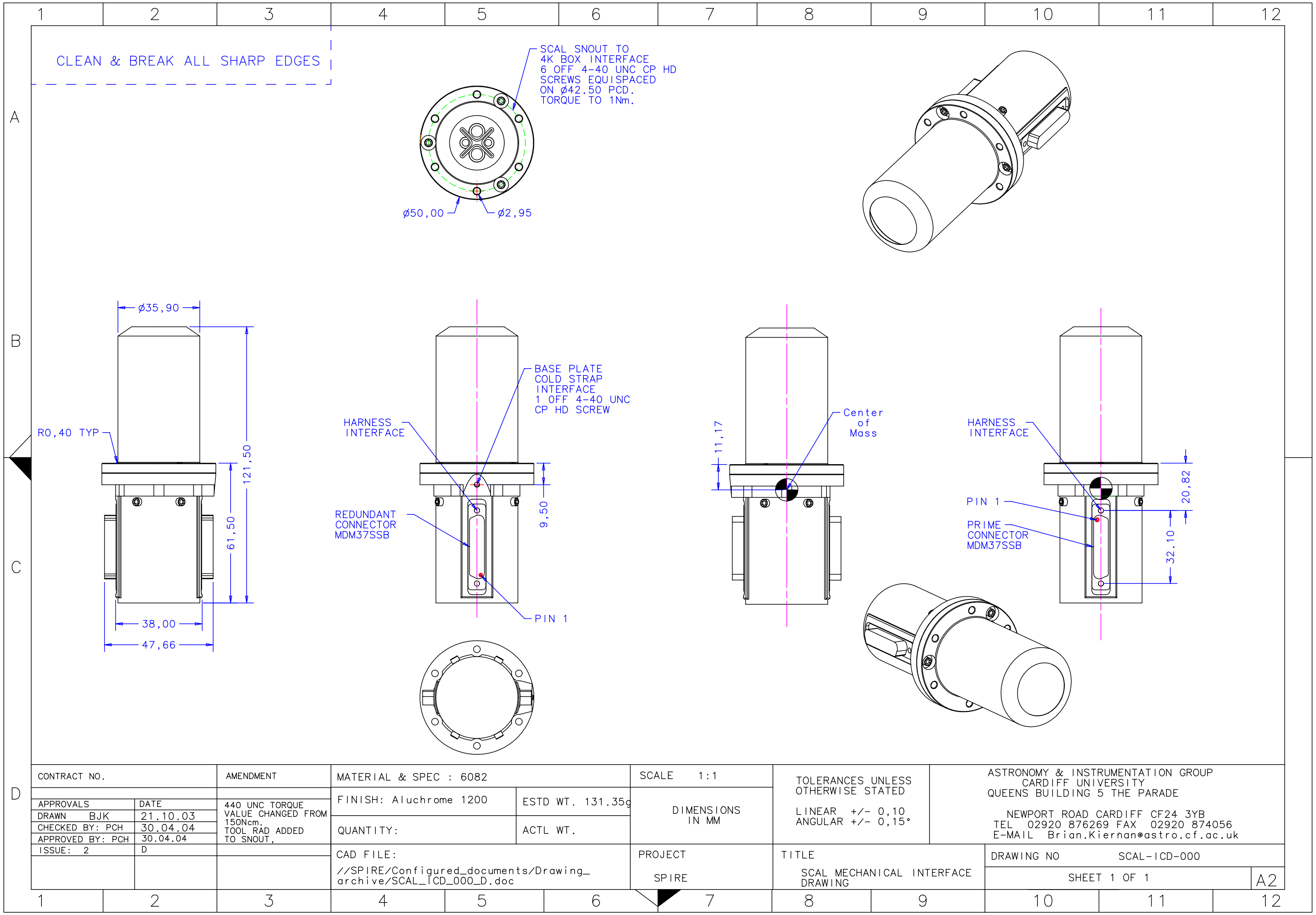


Figure 3 Mechanical interface drawing for SCal-PFM

SECTION 07 - Functional, Block & Mechanical Drawings

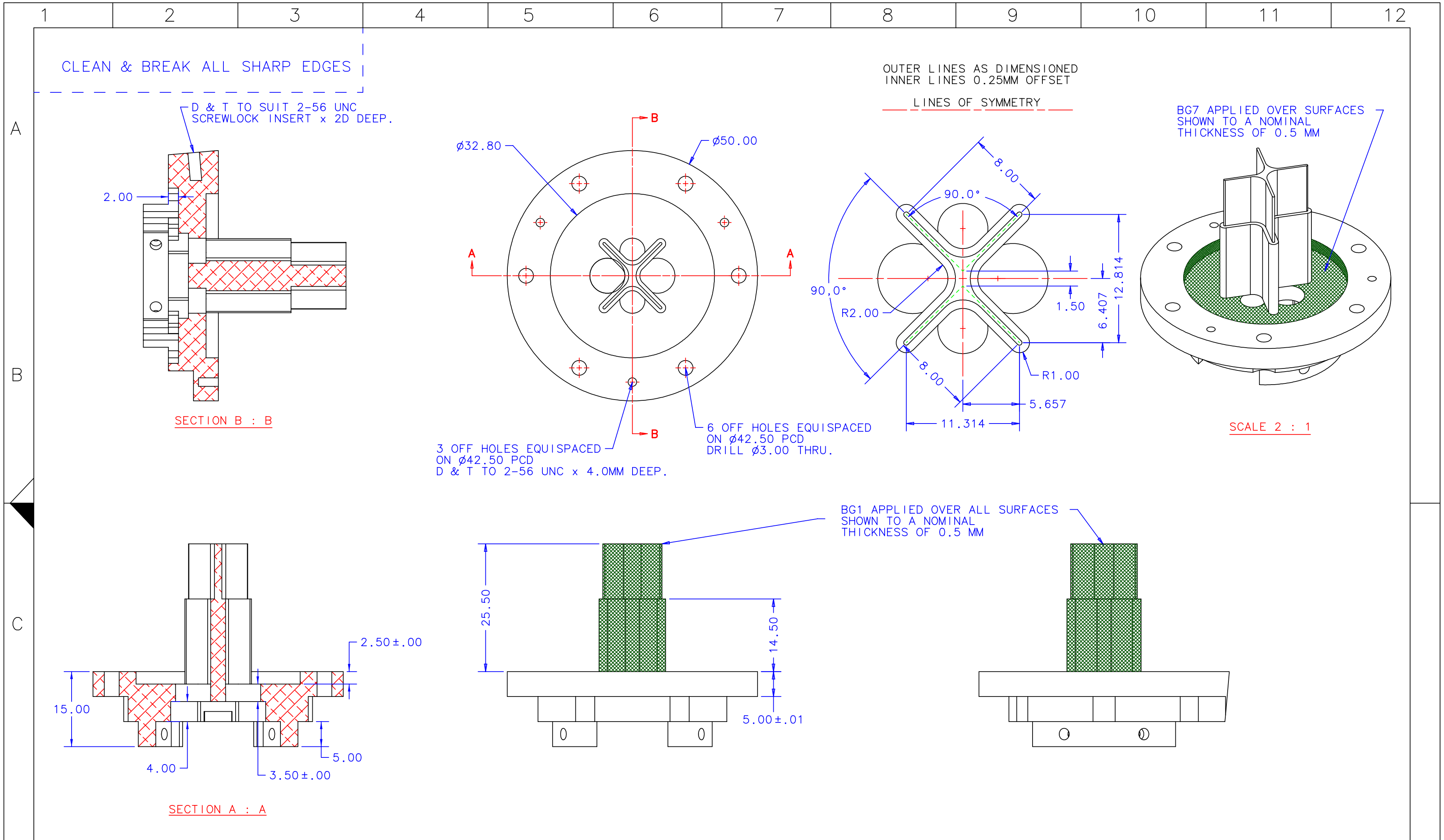
Component drawings are given in this section.

FUNCTIONAL & BLOCK DRAWING LIST

Drawing No.	Title

MECHANICAL COMPONENT DRAWING LIST

Drawing No.	Title	Notes
SCAL-PFM-101	Base plate	
SCAL-PFM-102	Connector bracket (p)	
SCAL-PFM-103	Connector bracket (r)	
SCAL-PFM-104	Strut clamp	
SCAL-PFM-105	Rear cover	
SCAL-PFM-106	Snout	
SCAL-PFM-202	4% strut type B	
SCAL-PFM-203	4% source	
SCAL-PFM-302	2% strut type B	
SCAL-PFM-303	2% source	



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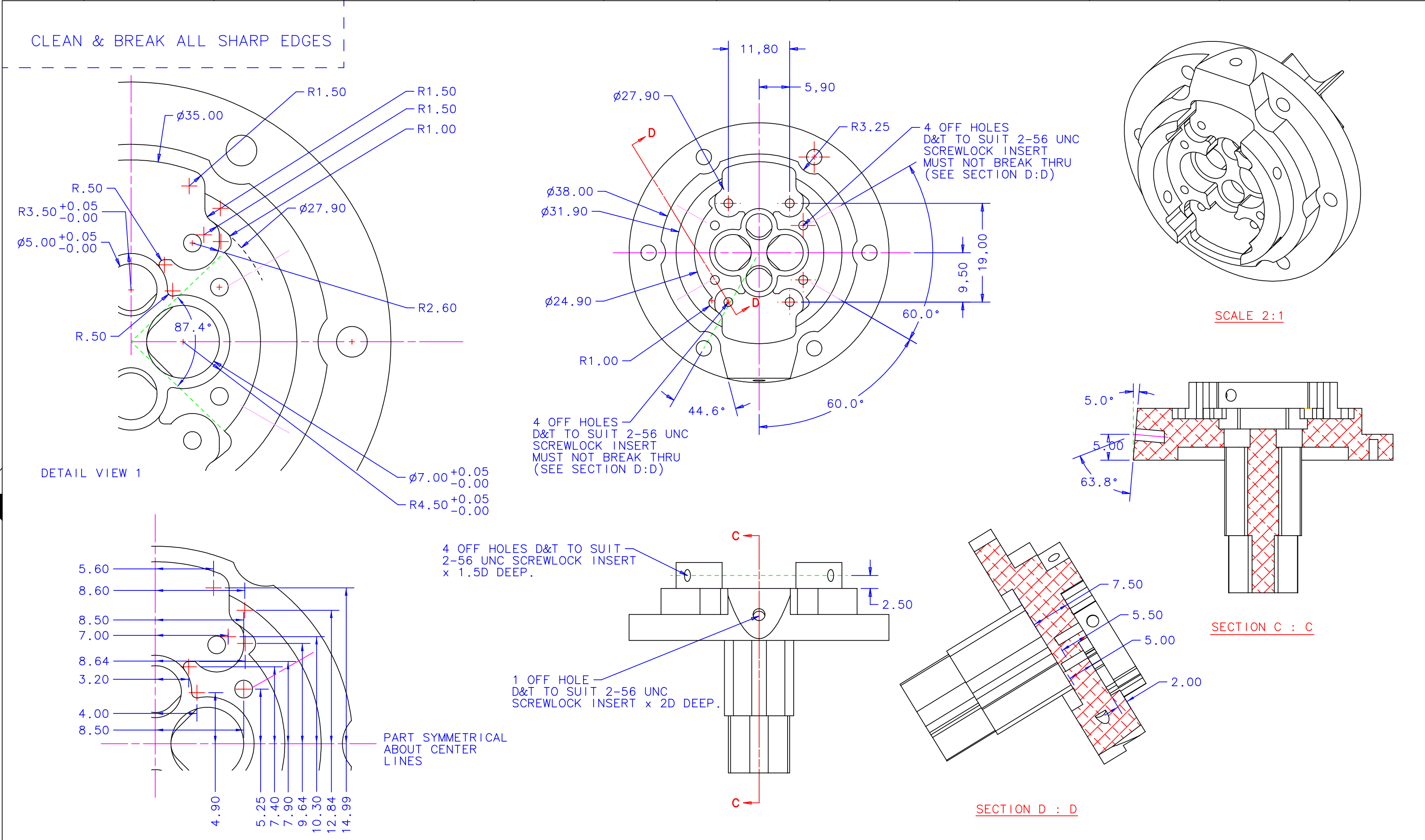

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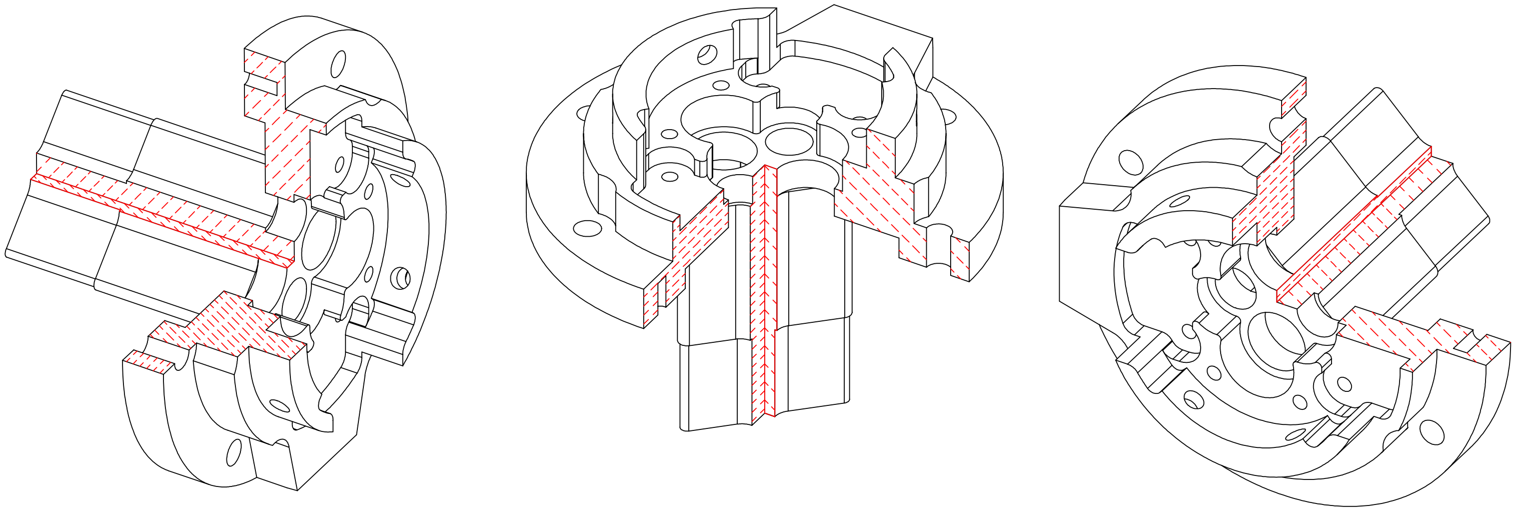

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SHEET 3 OF 3

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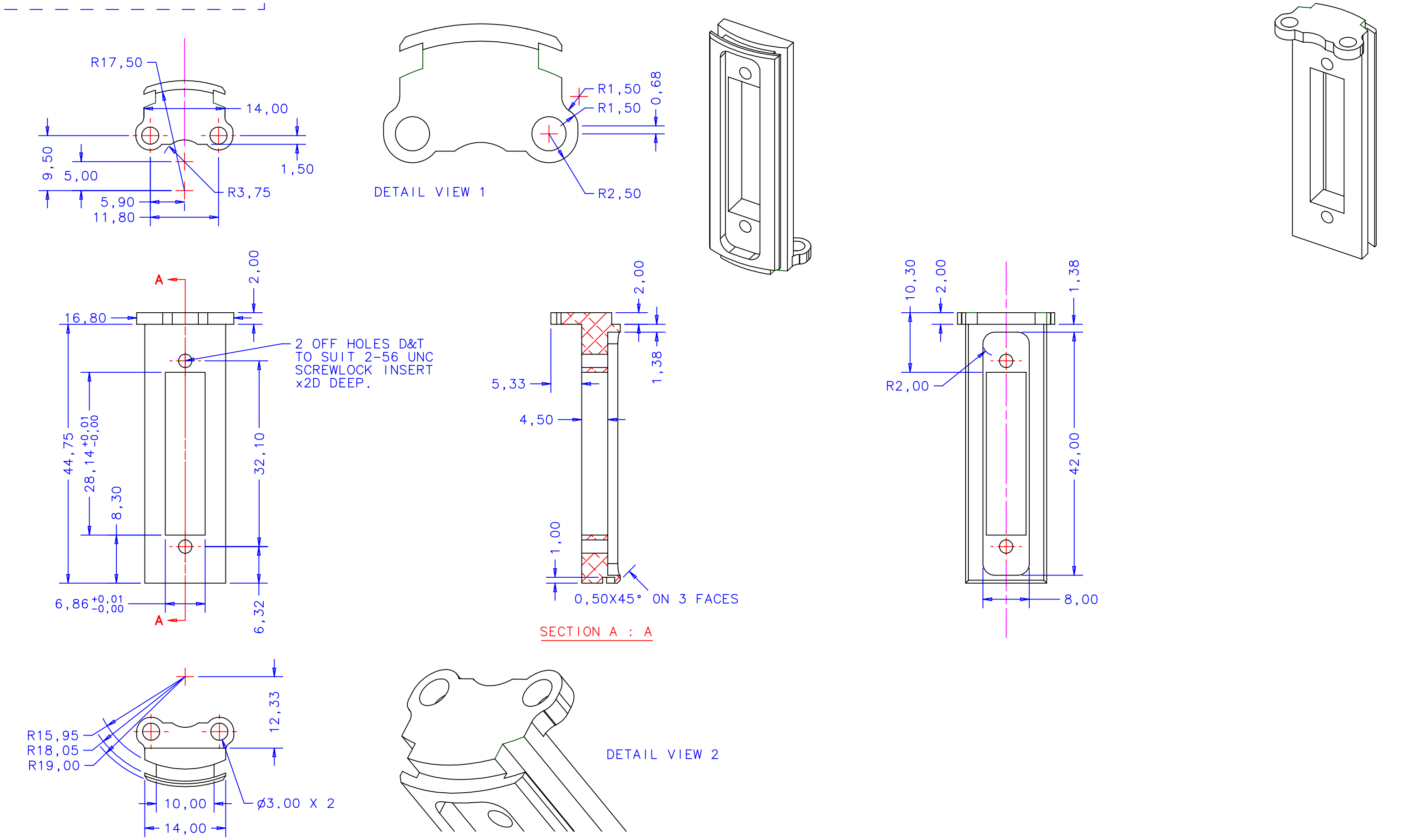

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APPROVED BY: PCH	28.10.03
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AMENDMENT
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SIDE SLOT UPDATED

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QUANTITY: | ACTL WT.

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SPIRE

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ANGULAR +/- 0,15°

TITLE CONNECTOR BRACKET(p)
- SCAL - PFM - 102

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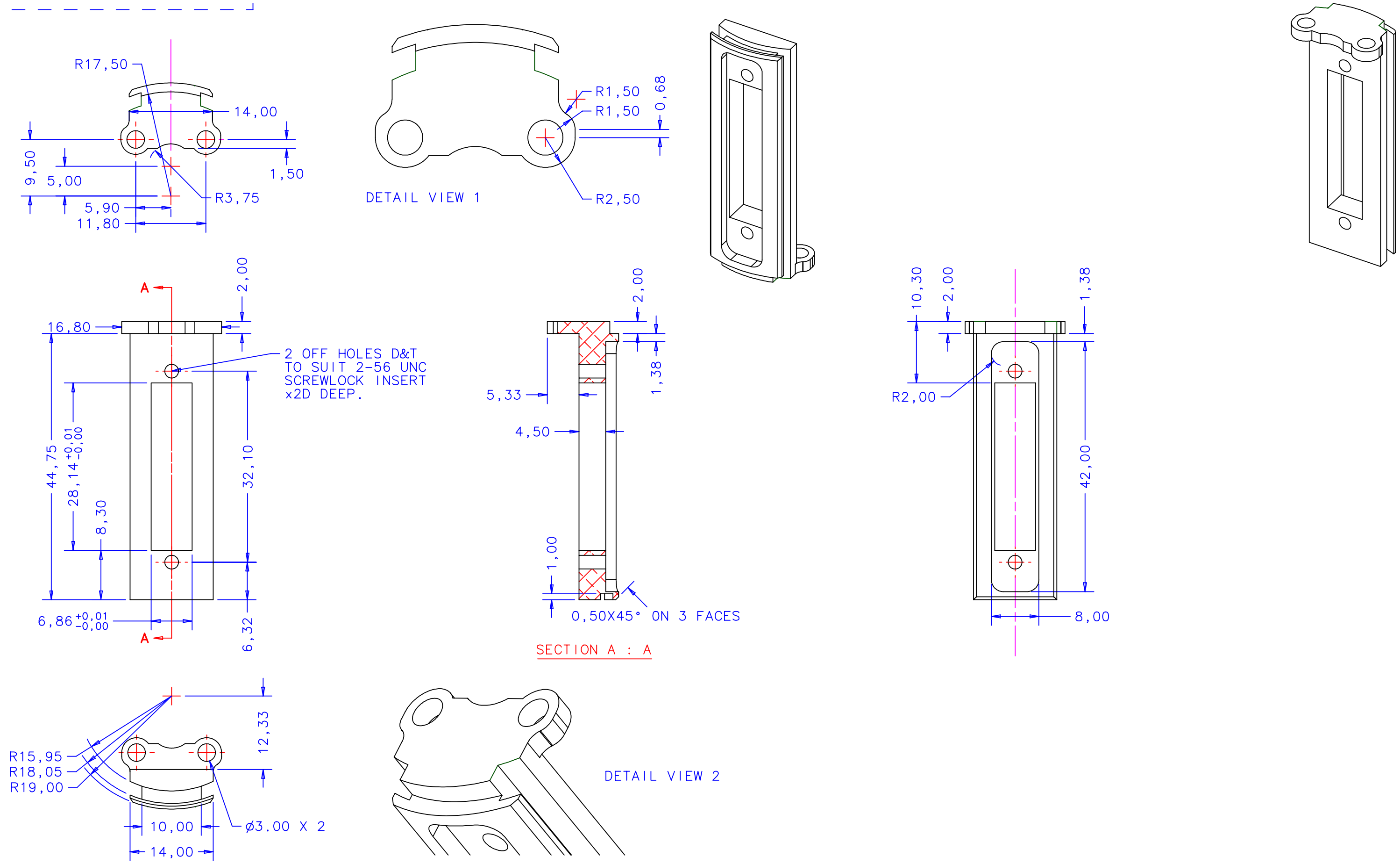

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FINISH: ALUCHROME - 1200

ESTD WT.

QUANTITY:

ACTL WT.

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SCALE 2:1

DIMENSIONS
IN MM

PROJECT
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TOLERANCES UNLESS
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LINEAR +/- 0,10
ANGULAR +/- 0,15°

TITLE CONNECTOR BRACKET(r)
- SCAL - PFM - 103

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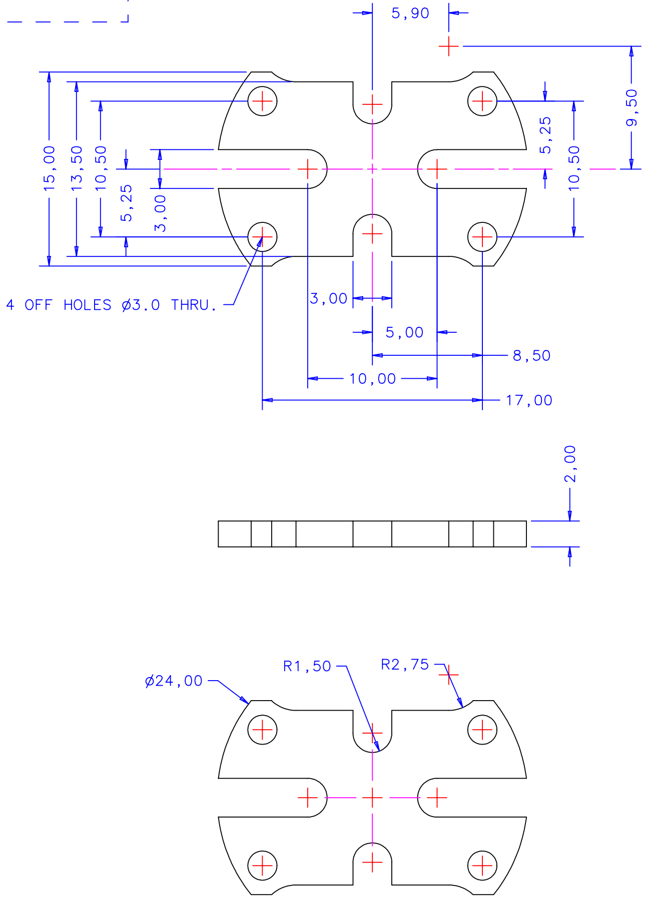

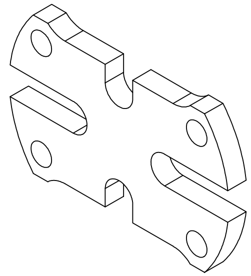

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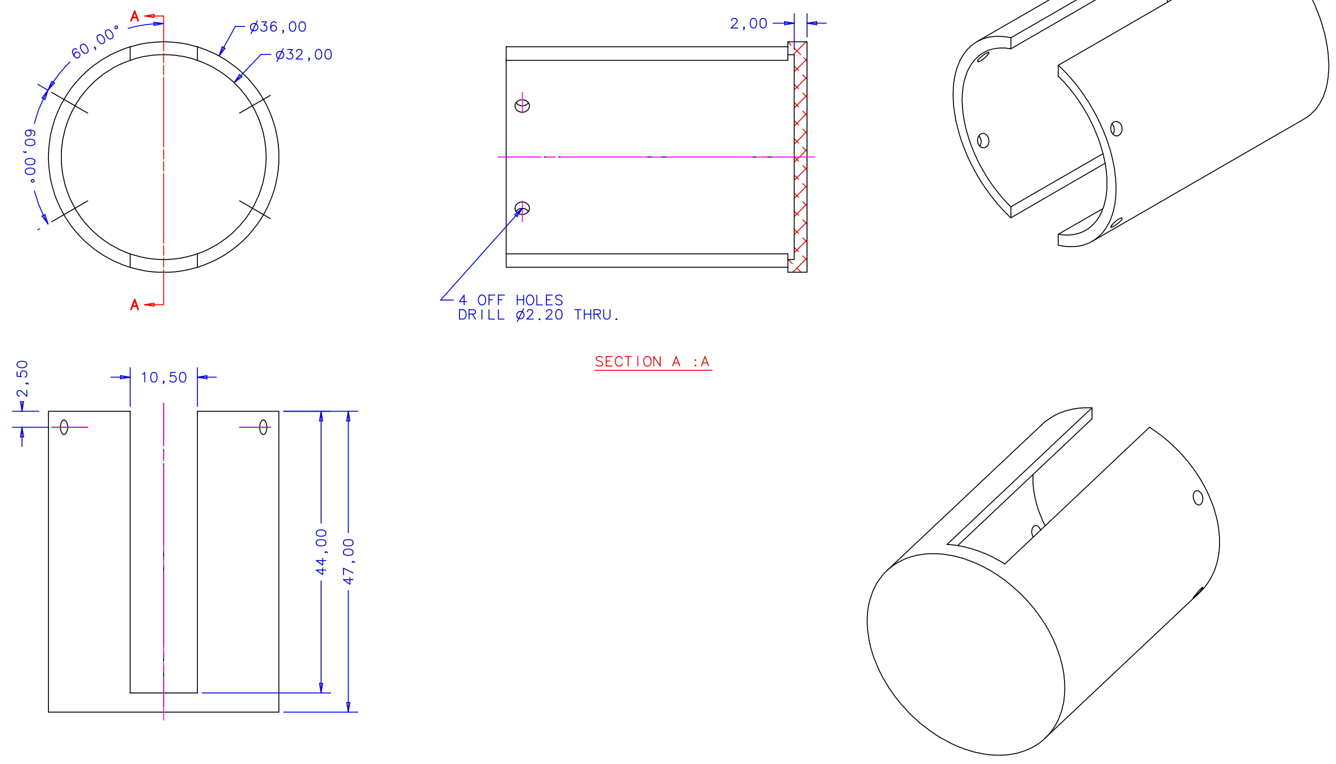

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DRAWN BJK / 22.09.03		QUANTITY: / ACTL WT.			
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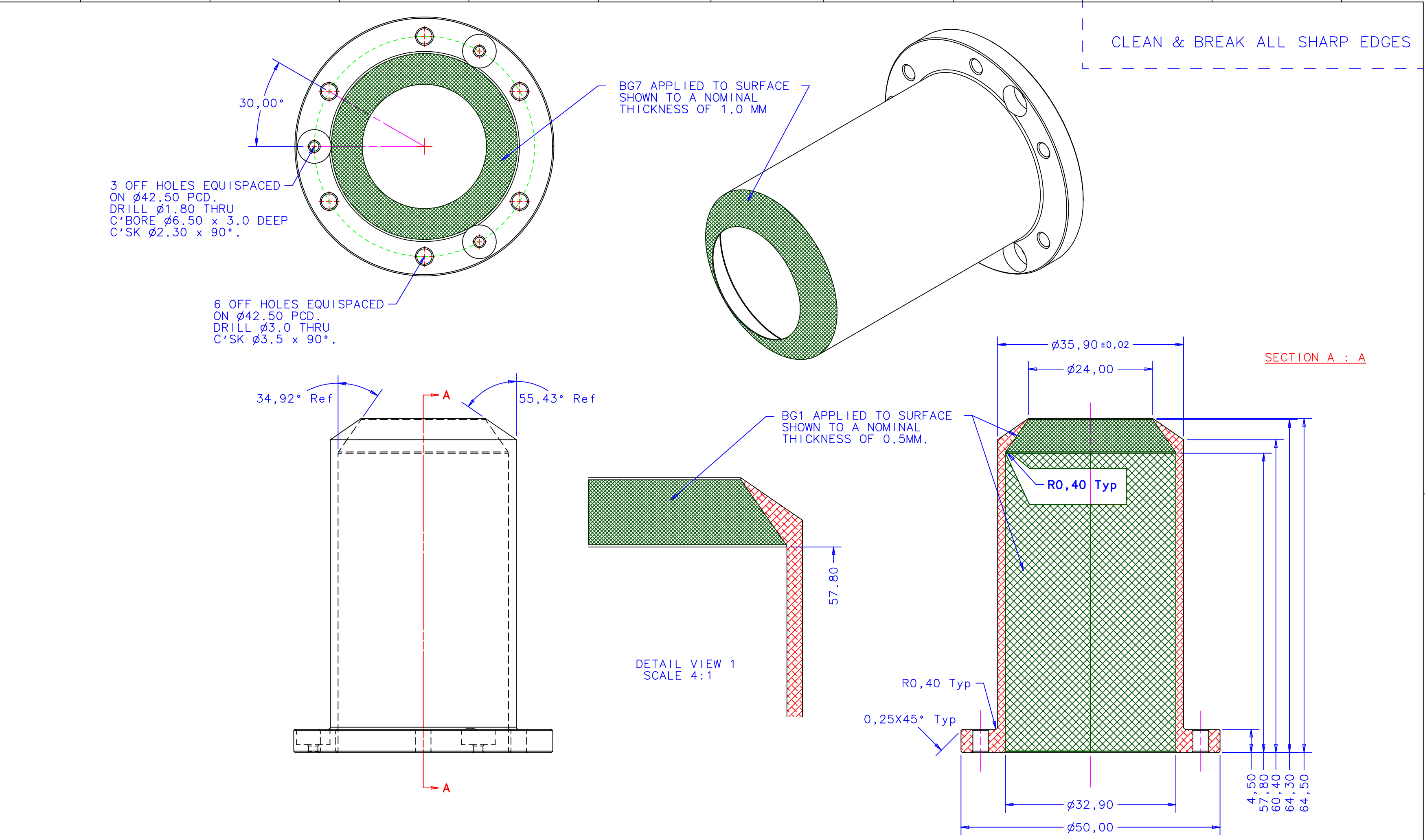

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DRAWING NO SCAL-PFM-106
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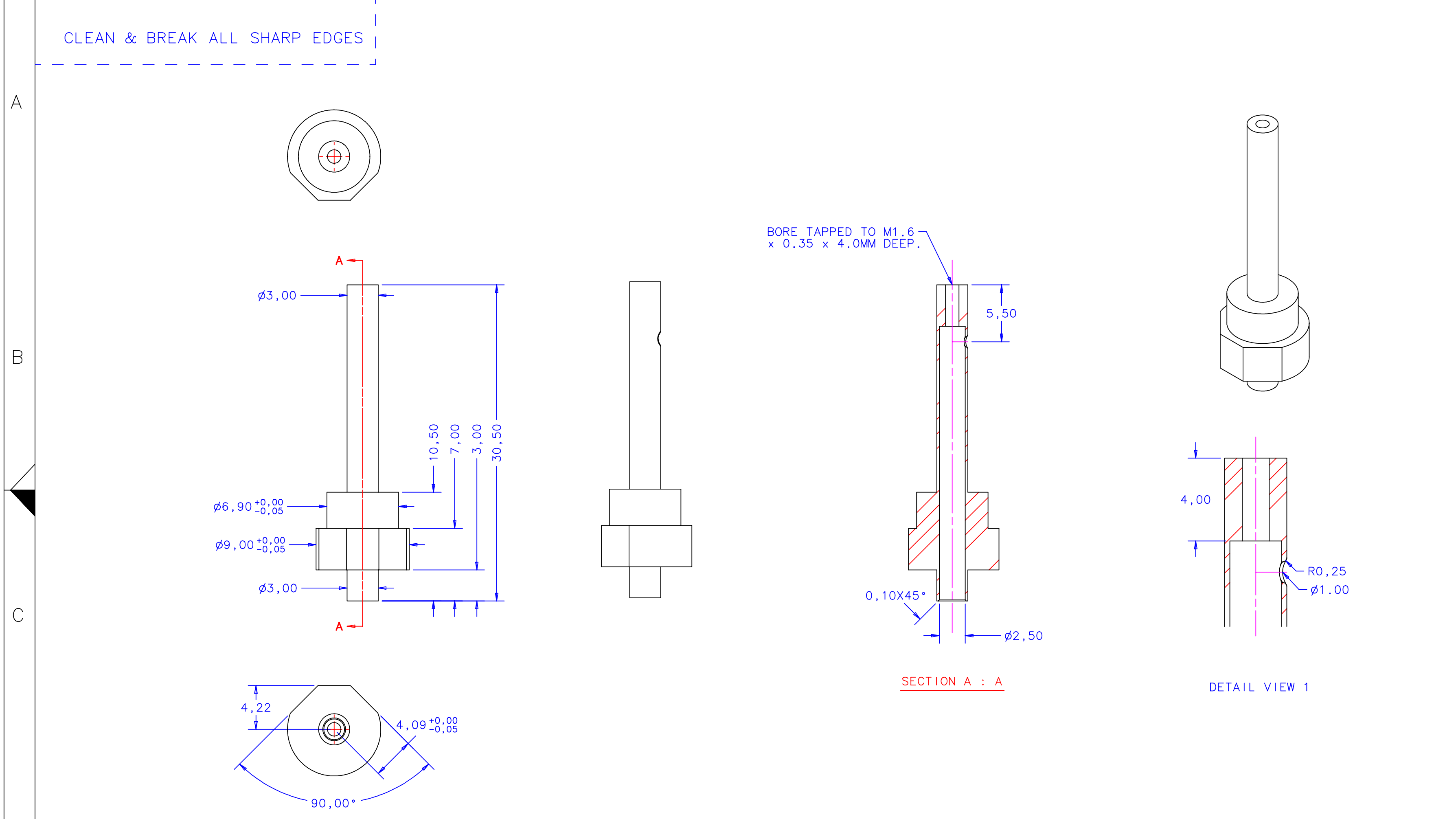

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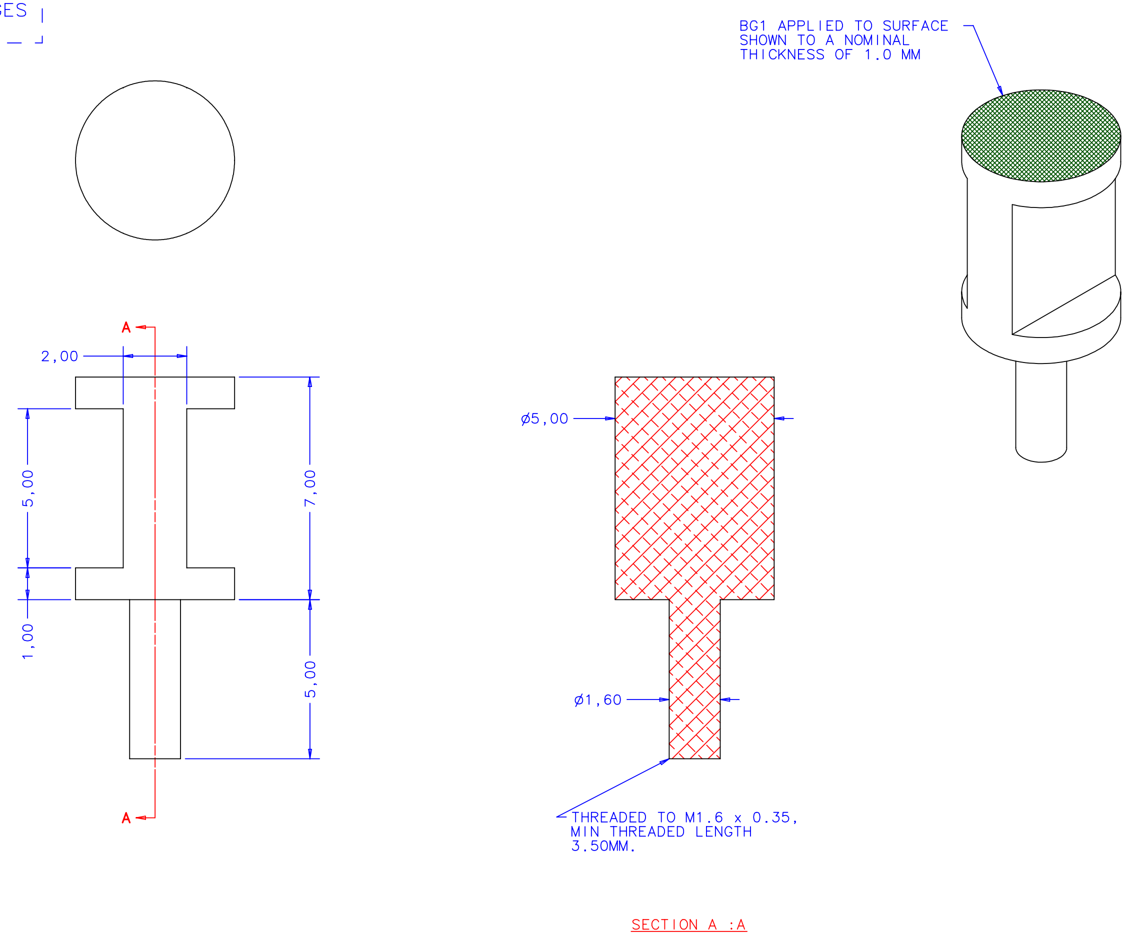
CLEAN & BREAK ALL SHARP EDGES



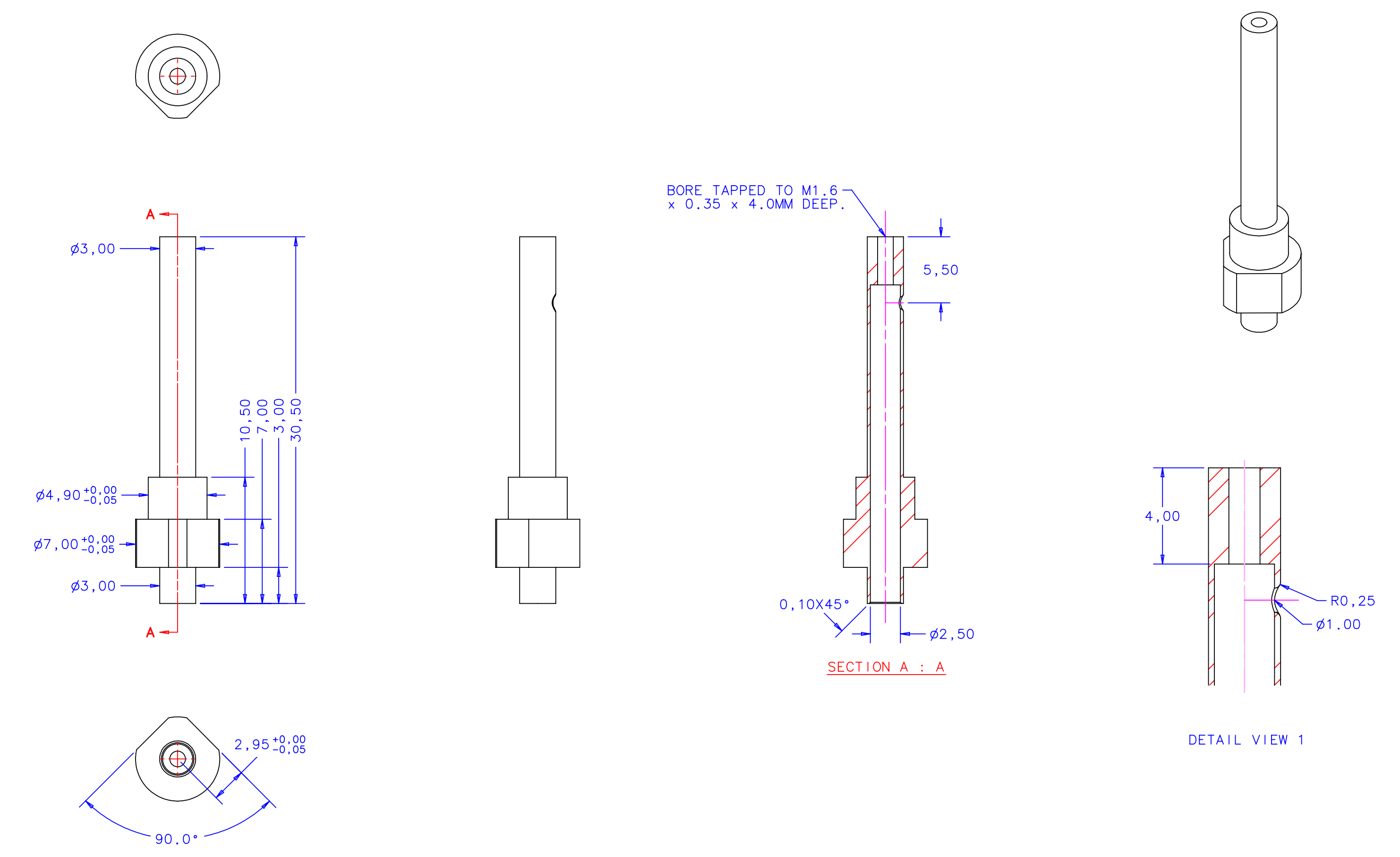
CONTRACT NO.	AMENDMENT	MATERIAL & SPEC : ALUMINIUM 6082	SCALE 10:1	TOLERANCES UNLESS OTHERWISE STATED
APPROVALS / DATE	REDRAWN, REPLACES ISSUE A	FINISH: ALUCHROME - 1200 BG1 / ESTD WT.	DIMENSIONS IN MM	LINEAR +/- 0,10 ANGULAR +/- 0,15°
DRAWN BJK / 22.09.03		QUANTITY: / ACTL WT.		
CHECKED BY: IT / 28.10.03				
APPROVED BY: PCH / 28.10.03				
ISSUE / B		CAD FILE /SPIRE/Cardiff_workpackages/Deliverables/Shipped/SCal/PFM/Drawings	PROJECT SPIRE	TITLE 5% SOURCE - SCAL - PFM - 203

ASTRONOMY & INSTRUMENTATION GROUP
CARDIFF UNIVERSITY
QUEENS BUILDING 5 THE PARADE
NEWPORT ROAD CARDIFF CF24 3YB
TEL 02920 876269 FAX 02920 874056
E-MAIL Brian.Kiernan@astro.cf.ac.uk

DRAWING NO SCAL-PFM-203

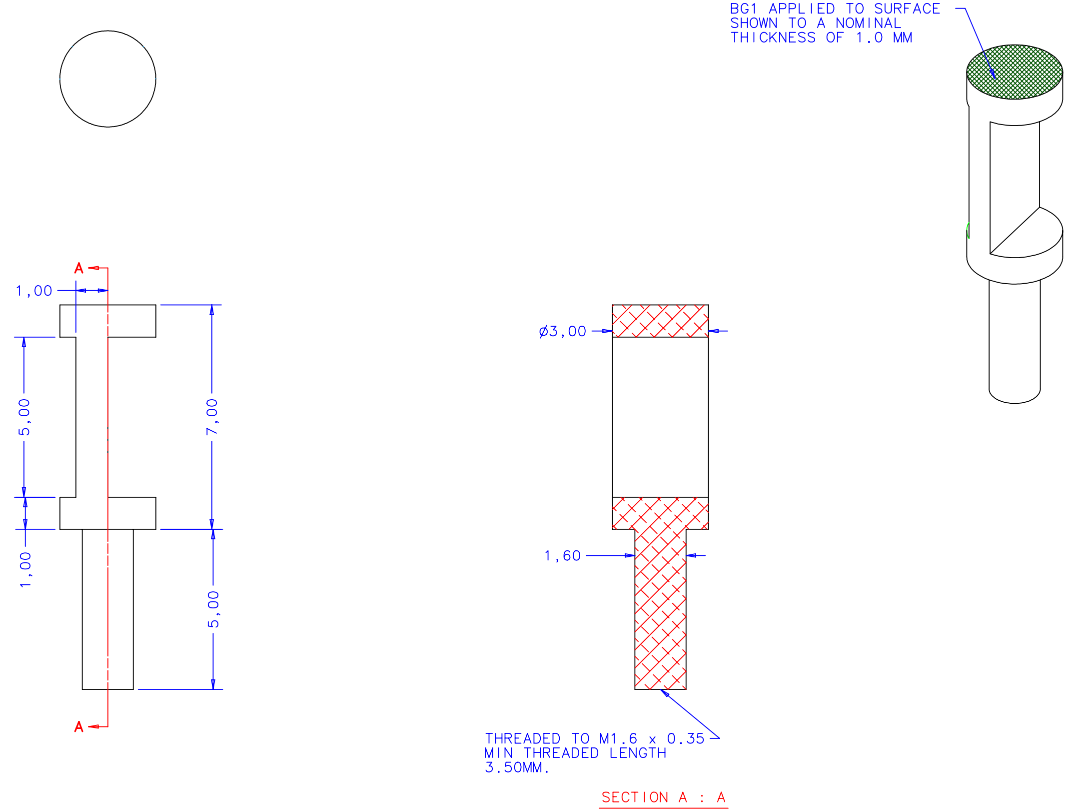
SHEET 1 OF 1 A2

CLEAN & BREAK ALL SHARP EDGES



CONTRACT NO.	AMENDMENT	MATERIAL & SPEC : TORLON	SCALE 4:1	TOLERANCES UNLESS OTHERWISE STATED LINEAR +/- 0,10 ANGULAR +/- 0,15°	ASTRONOMY & INSTRUMENTATION GROUP CARDIFF UNIVERSITY QUEENS BUILDING 5 THE PARADE NEWPORT ROAD CARDIFF CF24 3YB TEL 02920 876269 FAX 02920 874056 E-MAIL Brian.Kiernan@astro.cf.ac.uk
APPROVALS / DATE DRAWN BJK 22.09.03 CHECKED BY: IT 28.10.03 APPROVED BY: PCH 28.10.03 ISSUE B	REDRAWN, REPLACES ISSUE A	FINISH: / ESTD WT. QUANTITY: / ACTL WT.	DIMENSIONS IN MM		
		CAD FILE /SPIRE/Cardiff_workpackages/Deliverables/Shipped/SCal/PFM/Drawings	PROJECT SPIRE	TITLE 2% STRUT TYPE 'B' - SCAL - PFM - 302	DRAWING NO SCAL-PFM-302 SHEET 1 OF 1 A2

CLEAN & BREAK ALL SHARP EDGES



CONTRACT NO.	
APPROVALS	DATE
DRAWN BJK	22.09.03
CHECKED BY: IT	28.10.03
APPROVED BY: PCH	28.10.03
ISSUE	B

AMENDMENT

REDRAWN, REPLACES ISSUE A

MATERIAL & SPEC : ALUMINIUM 6082

FINISH: ALUCHROME - 1200 BG1

ESTD WT.

QUANTITY:

ACTL WT.

CAD FILE
/SPIRE/Cardiff_workpackages/Deliverables/Shipped/SCal/PFM/Drawings

SCALE 10:1

DIMENSIONS IN MM

PROJECT

SPIRE

TOLERANCES UNLESS OTHERWISE STATED

LINEAR +/- 0,10
ANGULAR +/- 0,15°

TITLE 2% SOURCE - SCAL - PFM - 303

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DRAWING NO SCAL-PFM-303

SHEET 1 OF 1

A2

SECTION 08 – Electrical Circuit Diagrams

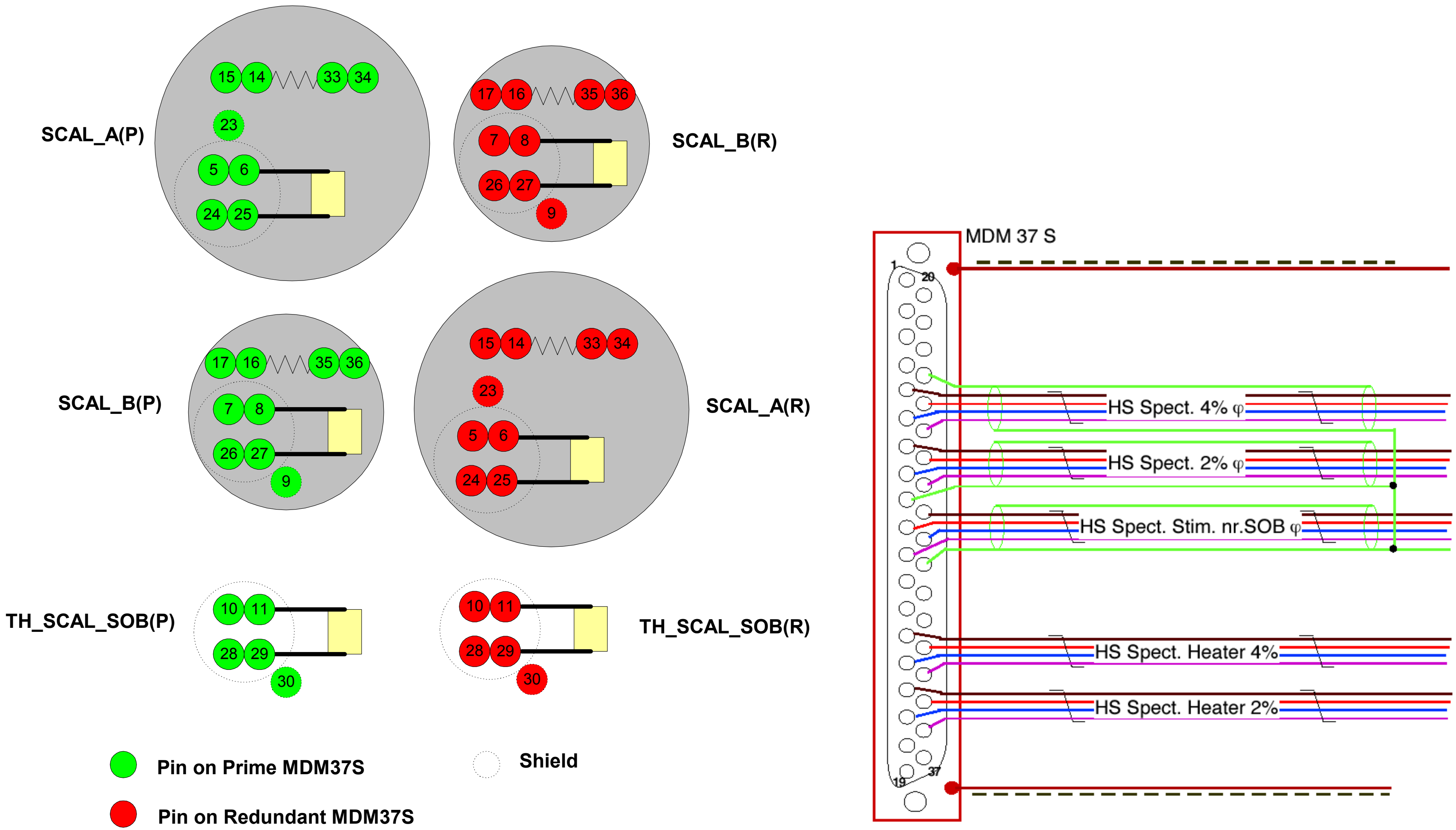


Figure 4 Schematic of pin allocations for SCal prime and redundant connectors. Both prime and redundant connectors are MDM-37 way socket connectors, with jackposts.

Table 1 Pin allocations for SCal-PFM electrical connectors.

Function	MDM-37-SSB 37-way socket	Max. current
HS Spect. 4% temperature I+	5	1 µA
HS Spect. 4% temperature V+	6	N/A
HS Spect. 4% temperature V-	24	N/A
HS Spect. 4% temperature I-	25	1 µA
HS Spect. 4% temperature shld*	23	N/A
HS Spect. 2% temperature I+	7	1 µA
HS Spect. 2% temperature V+	8	N/A
HS Spect. 2% temperature V-	26	N/A
HS Spect. 2% temperature I-	27	1 µA
HS Spect. 2% temperature shld*	9	N/A
HS Spect. Stim near SOB temperature I+	10	1 µA
HS Spect. Stim near SOB temperature V+	11	N/A
HS Spect. Stim near SOB temperature V-	28	N/A
HS Spect. Stim near SOB temperature I-	29	1 µA
HS Spect. Stim near SOB temperature shld*	30	N/A
HS Spect. 4% heater I+	14	9 mA
HS Spect. 4% heater V+	15	9 mA
HS Spect. 4% heater I-	33	9 mA
HS Spect. 4% heater V-	34	9 mA
HS Spect. 2% heater I+	16	7 mA
HS Spect. 2% heater V+	17	7 mA
HS Spect. 2% heater I-	35	7 mA
HS Spect. 2% heater V-	36	7 mA

SECTION 09 - As Built Configuration Items Status List

Files are located in the directories indicated below, and on the accompanying CD-ROM.

Item	Reference	Location	Notes
SCal drawings and manufacturing files		\\Darkstar\Astroworld\Projects\\\SPIRE\Cardiff_workpackages\Deliverables\Shipped\SCal\PFM\Drawings	
Material certificates of conformance		Attached as Appendix G	
Thermometer calibration data		\\Darkstar\Astroworld\Projects\SPIRE\Cardiff_workpackages\Deliverables\Shipped\SCal\PFM\Calibration-files\Thermometers	
Power vs Temperature calibration files		\\Darkstar\Astroworld\Projects\SPIRE\Cardiff_workpackages\Deliverables\Shipped\SCal\PFM\Calibration-files	
PFM configured documents		\\Darkstar\Astroworld\Projects\SPIRE \Cardiff_workpackages\Deliverables\Shipped\SCal\PFM\Documents	
Test reports (PFM & lifetest)		\\Darkstar\Astroworld\Projects\SPIRE \Cardiff_workpackages\Deliverables\Shipped\SCal\PFM\Test-reports	

Item	Reference	Batch number / Serial number	Quantity	Sub-Assembly	Manufacturer / supplier	C of C #	Notes
BASE PLATE	SCAL-PFM-101		1	SCAL STRUCTURE	Electromec	23959	Order ref 03/0325/PX
CONNECTOR BRACKET (P)	SCAL-PFM-102		1		Electromec	23959	Order ref 03/0325/PX
CONNECTOR BRACKET (R)	SCAL-PFM-103		1		Electromec	23959	Order ref 03/0325/PX
STRUT CLAMP	SCAL-PFM-104		1		Electromec	23959	Order ref 03/0325/PX
REAR COVER	SCAL-PFM-105		1		Electromec	23959	Order ref 03/0325/PX
SNOUT	SCAL-PFM-106		1		Electromec	23959	Order ref 03/0325/PX
CONNECTOR (P)	SCAL-PFM-107	GS83513/02-FN-429B, MRM5254	1		Glenair	676521, 626099, 589082	Order ref. 91774, 85503
CONNECTOR (R)	SCAL-PFM-108	GS83513/02-FN-429B, MRM5254	1		Glenair	676521, 626099, 589082	Order ref. 91774, 85503
SOB THERMOMETER (P)	SCAL-PFM-109	X28264	1		Lakeshore		CX-1030-SD-HT-4L Calibration data in appendix A and on accompanying CD-ROM
SOB THERMOMETER (R)	SCAL-PFM-110	X28265	1		Lakeshore		CX-1030-SD-HT-4L Calibration data in appendix A and on accompanying CD-ROM
4% STRUT TYPE B (P)	SCAL-PFM-202		1	4% PRIME SOURCE	Electromec		Order ref 03/0325/PX
4% SOURCE (P)	SCAL-PFM-203		1		Electromec		Order ref 03/0325/PX
4% HEATER RESISTOR (P)	SCAL-PFM-204	Lot 00020037/5541P7	1		Vishay	03181	Vishay 500Ω High reliability chip resistor PHR0805YB
4% THERMOMETER (P)	SCAL-PFM-205	X29754	1		Lakeshore	14200, 14119 429014	CX-1030-SD-HT-4L Calibration data in appendix A and on accompanying CD-ROM
SAPPHIRE ISOLATION PLATE	SCAL-PFM-206		2		Goodfellow		Order ref. LS236675/A J H Invoice # 131282
2% STRUT TYPE B (P)	SCAL-PFM-302		1	2% PRIME SOURCE	Electromec		Order ref 03/0325/PX
2% SOURCE (P)	SCAL-PFM-303		1		Electromec		Order ref 03/0325/PX
2% HEATER RESISTOR (P)	SCAL-PFM-304	Lot 00020037/5541P7	1		Vishay	03181	Vishay 500Ω High reliability chip resistor PHR0805YB

2% THERMOMETER (P)	SCAL-PFM-305	X29758	1		Lakeshore	14200, 14119 429018	CX-1030-SD-HT-4L Calibration data in appendix A and on accompanying CD-ROM
SAPPHIRE ISOLATION PLATE	SCAL-PFM-306		2		Goodfellow		Order ref. LS236675/A J H Invoice # 131282
4% STRUT TYPE B (R)	SCAL-PFM-402		1	4% REDUNDANT SOURCE	Electromec		Order ref 03/0325/PX
4% SOURCE (R)	SCAL-PFM-403		1		Electromec		Order ref 03/0325/PX
4% HEATER RESISTOR (R)	SCAL-PFM-404	Lot 00020037/5541P7	1		Vishay	03181	Vishay 500Ω High reliability chip resistor PHR0805YB
4% THERMOMETER (R)	SCAL-PFM-405	X29756	1		Lakeshore	14200, 14119 429016	CX-1030-SD-HT-4L Calibration data in appendix A and on accompanying CD-ROM
SAPPHIRE ISOLATION PLATE	SCAL-PFM-406		2		Goodfellow		Order ref. LS236675/A J H Invoice # 131282
2% STRUT TYPE B (R)	SCAL-PFM-502		1	2% REDUNDANT SOURCE	Electromec		Order ref 03/0325/PX
2% SOURCE (R)	SCAL-PFM-503		1		Electromec		Order ref 03/0325/PX
2% HEATER RESISTOR (R)	SCAL-PFM-504	Lot 00020037/5541P7	1		Vishay	03181	Vishay 500Ω High reliability chip resistor PHR0805YB
2% THERMOMETER (R)	SCAL-PFM-505	X29761	1		Lakeshore	14200, 14119 429023	CX-1030-SD-HT-4L Calibration data in appendix A and on accompanying CD-ROM
SAPPHIRE ISOLATION PLATE	SCAL-PFM-506		2		Goodfellow		Order ref. LS236675/A J H Invoice # 131282

SECTION 10 – Serialised Components List

As section 9.

SECTION 11 - List of Waivers

Waiver Number	Title	Status
HSO-CDF-RFW-077	Request to accept SCal flight candidate “B” as flight model assembly	Open

SECTION 12 - Copies of Waivers

See next page.

Rutherford Appleton Laboratory	REQUEST FOR WAIVER / DEVIATION (RFW/RFD)	PRODUCT ASSURANCE Space Science and Technology Department

RFW/RFD Number:	HR-SP-CDF-RFW-XXX, HSO-CDF-RFW-077

Spacecraft / Project	HERSCHEL	**Originator's Name**	Peter Hargrave	
System / Experiment / Model	SPIRE-PFM	**Signature / Date**		
Sub-System	SCal	**Request Type** (Highlight applicable request)	Waiver (RFW)	Deviation (RFD)
Assembly		**Organisation**	Cardiff University	
Sub-Assembly		**Ref. Doc. / Drwg No.**		
Item		**References**		
Serial No.	SCAL-PFMB-000			
RFW/RFD Title	**Request to accept SCal flight candidate "B" as flight model assembly**			

End Items(s) Affected (Hardware, Software)

Name	CI-Number	Model(s)
SCal flight model		Flight

Requirement / Interface Documents Affected

Specification/Drawing Title	Number	Issue	Date	App. Paragraph
SCal specification document	HSO-CDF-SP-001	1.0	07/09/01	Document will be re-written with SCal-PFMB specs.

Description of Deviation / Discrepancy / Non-Conformance

Two models of SCal were built as candidates for the flight model, one to the CQM design (SCal-PFMA), and one reduced power dissipation version (SCal-PFMB).
The reduced power dissipation version (SCal-PFMB) has passed all qualification tests and inspections, and is deemed by Cardiff as suitable for flight. However, this assembly has undergone cryogenic vibration to full flight qualification levels. This RFD is to request that this assembly be accepted as the flight model device by the project (pending successful DRB), considering that it has undergone the aforementioned vibration testing.

Other Items or Requirements (Potentially) Affected

None

Need for RFW/RFD and Rationale for Acceptance

The change request that prompted the building of the reduced power version (SCal-PFMB) was received at a late stage in the SCal development program, and after CQM delivery. Therefore the two versions of SCal mentioned above were built on the understanding that SCal-PFMA would be the default flight version, and SCal-PFMB would be upgraded to flight model (as a replacement for PFMA) on the successful completion of all qualification tests. Lifetests have been successfully completed on both candidate designs (lifetest model assemblies, not the actual SCal-PFMA or PFMB devices).
The SCal-PFMB version dissipates approximately half the power of the SCal-PFMA version for the same source temperature, with no degradation of the time constant.

	Approved	Rejected	Name	Date
Engineering:				
Product Assurance:				
CCB-Chairman:				
Principle Investigator				
Product Assurance:				
Co-Investigator				
Prime Contractor				
ESA Project Office				

Rutherford Appleton Laboratory	REQUEST FOR WAIVER / DEVIATION (RFW/RFD)	PRODUCT ASSURANCE Space Science and Technology Department

RFW/RFD Number:	HR-SP-CDF-RFW-XXX, HSO-CDF-RFW-077

Attachment One – SCal PFMB example data

Calibration curves are shown below for the SCal-PFMB prime and redundant 4% sources, as an example. These data show that there were no adverse effects on SCal-PFMB following cold vibration qualification tests.

4% prime source

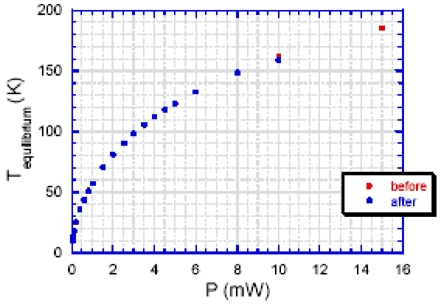


Figure 1: Comparison of the equilibrium temperature versus applied power for 4% prime source before and after cold vibration qualification.

4% redundant source

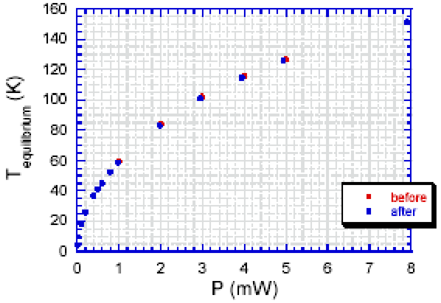


Figure 2: Comparison of the equilibrium temperature versus applied power for 4% redundant source before and after cold vibration qualification.

SECTION 13 - Operations Manual

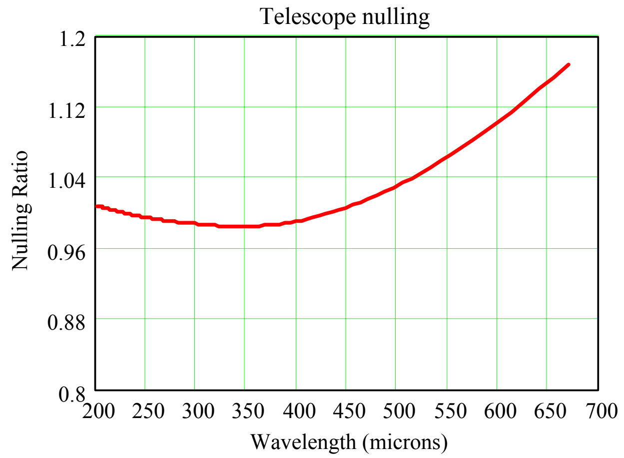
Introduction

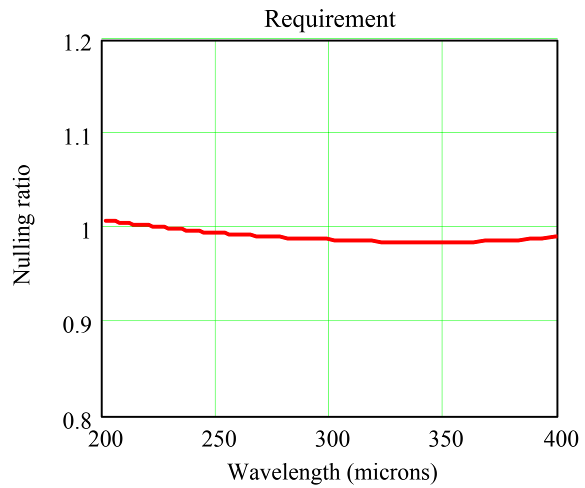
SCal is located at a pupil at the second input port to the SPIRE FTS. It has two thermal sources, with full redundancy. These sources fill ~4% and ~2% of the pupil area respectively. These sources can be heated to different temperatures in the range 4K – 200K, and be operated individually or together to suit different background conditions.
The purpose of SCal is to null the Herschel telescope emission. The nominal telescope parameters are 80K in-orbit temperature with 4% emissivity. However, the actual parameters in-orbit may be significantly different from this.

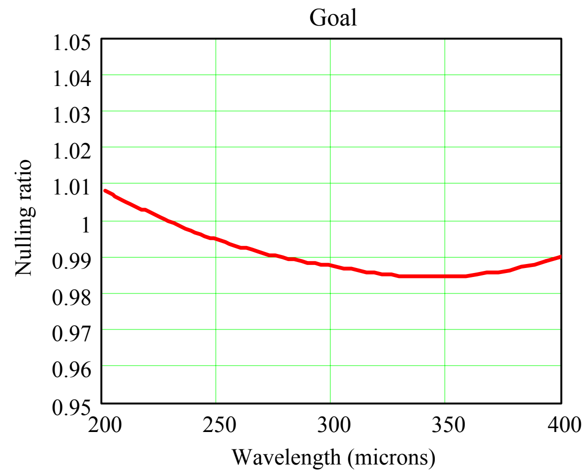
Source temperatures

This section gives recommended source temperatures for different telescope temperature / emissivity scenarios, together with the corresponding power dissipation.

Telescope Temperature (K)	Telescope Emissivity (%)	4% Source Temperature (K)	2% Source Temperature
80	4	5	88
Power applied to each source (mW)		0	2.4
Predicted nulling achievable			

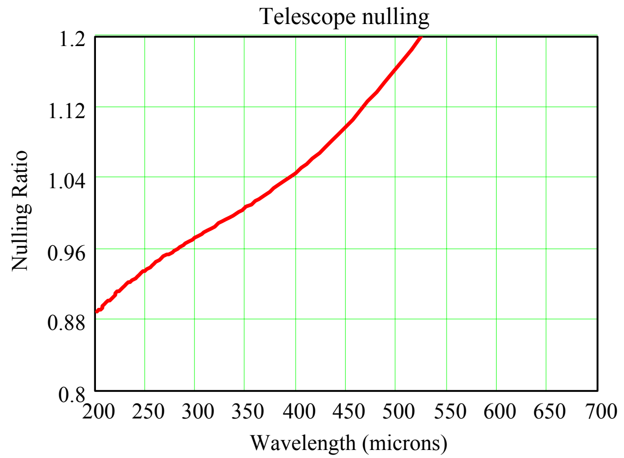


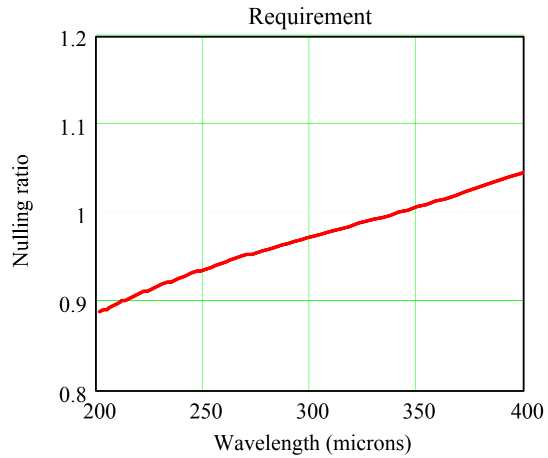


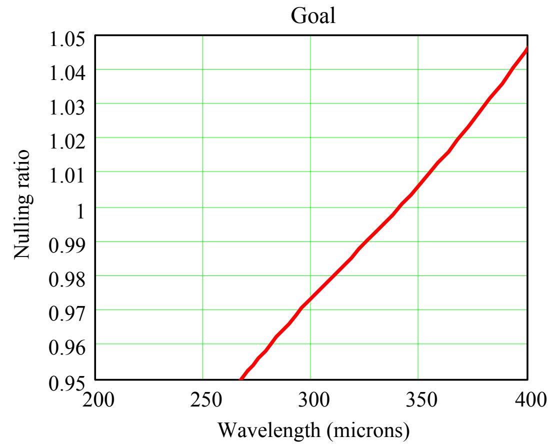


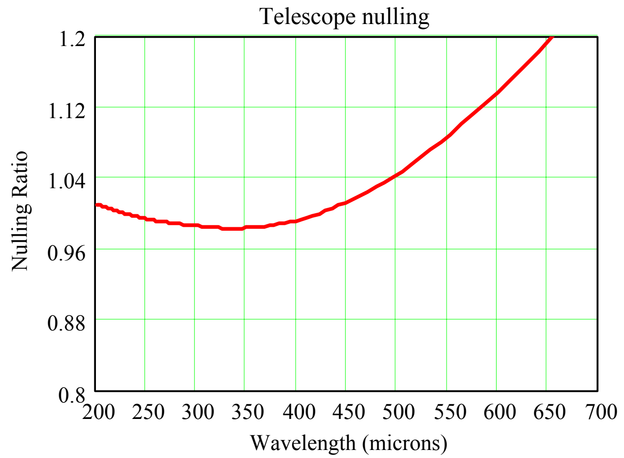
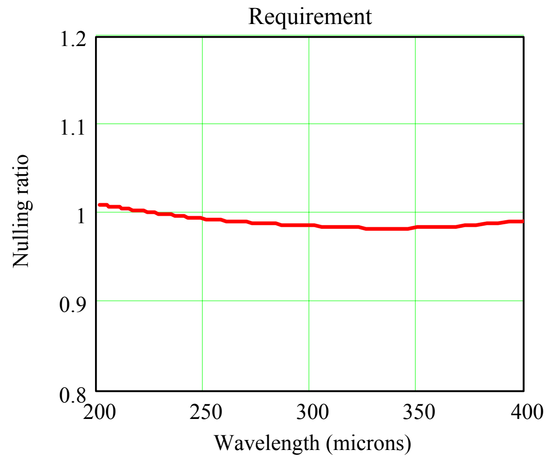
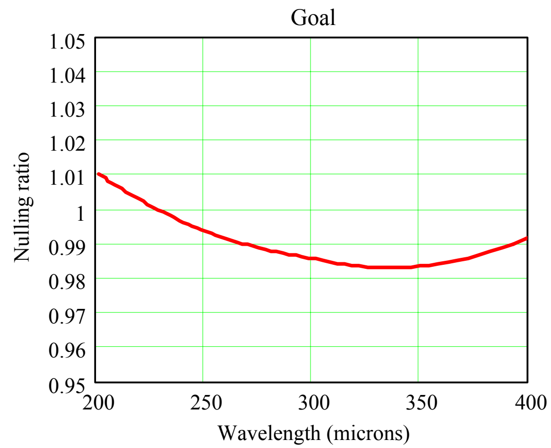
Telescope Temperature (K)	Telescope Emissivity (%)	4% Source Temperature (K)	2% Source Temperature
80	2	5	53
Power applied to each source (mW)		0	0.9

Predicted nulling achievable

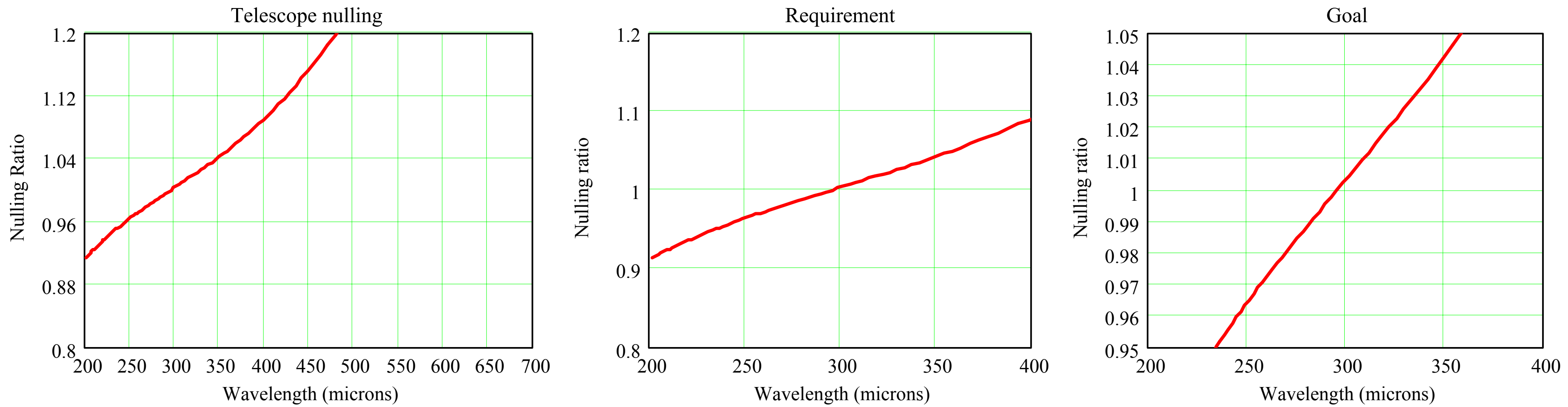




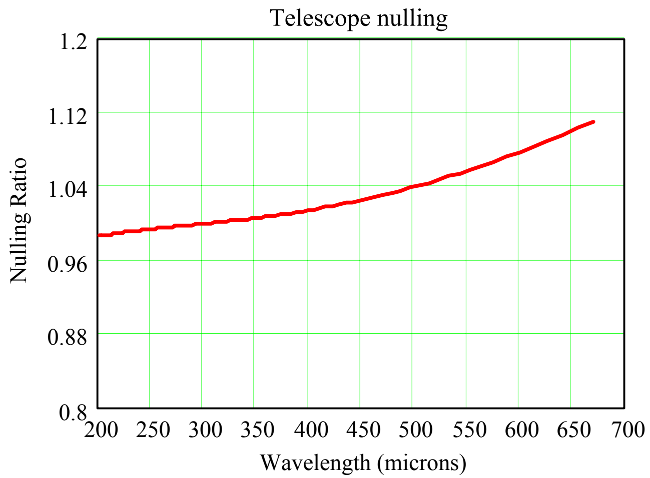


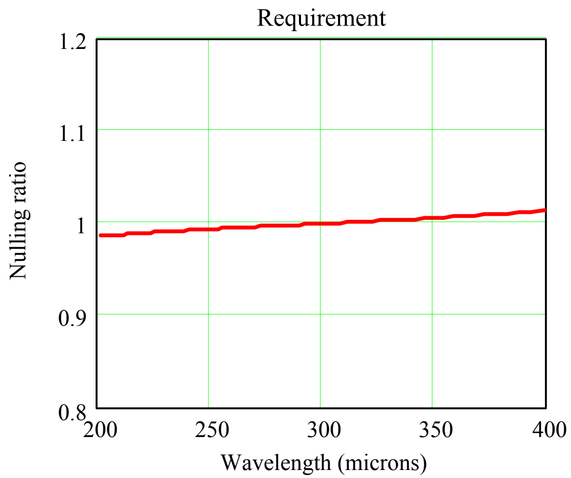
<table>
<tr><th>Telescope Temperature (K)</th><th>Telescope Emissivity (%)</th><th>4% Source Temperature (K)</th><th>2% Source Temperature</th></tr>
<tr><td>65</td><td>4</td><td>5</td><td>71</td></tr>
<tr><td colspan="2">Power applied to each source (mW)</td><td>0</td><td>1.55</td></tr>
<tr><td colspan="4">Predicted nulling achievable</td></tr>
<tr><td>
</td><td colspan="2">
</td><td>
</td></tr>
</table>

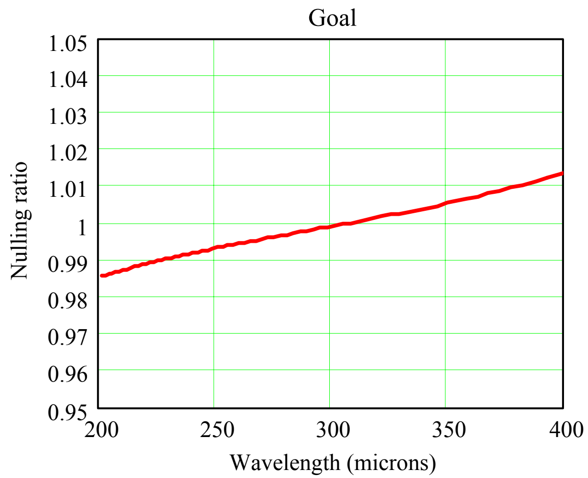
Telescope Temperature (K)	Telescope Emissivity (%)	4% Source Temperature (K)	2% Source Temperature
65	**2**	**5**	**45**
Power applied to each source (mW)		**0**	**0.65**
Predicted nulling achievable			



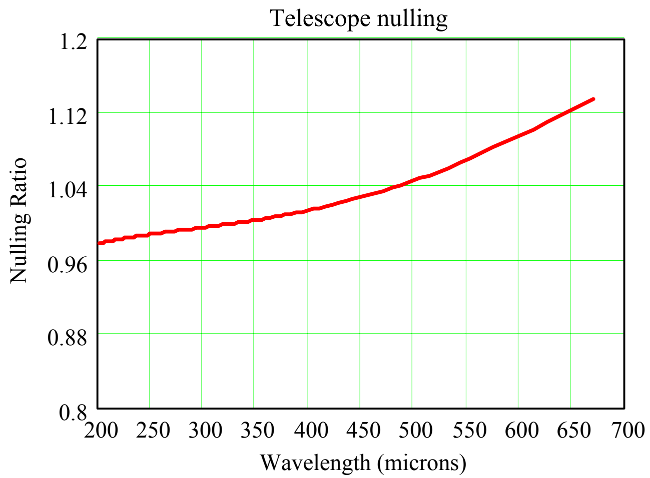
Telescope Temperature (K)	Telescope Emissivity (%)	4% Source Temperature (K)	2% Source Temperature
80	8	75	5
Power applied to each source (mW)		1.45	0
Predicted nulling achievable			

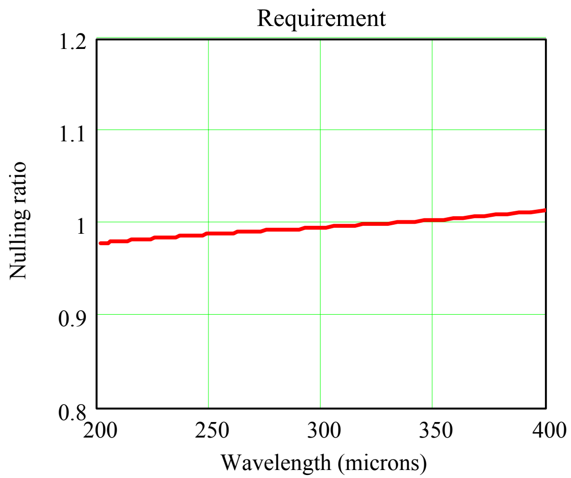


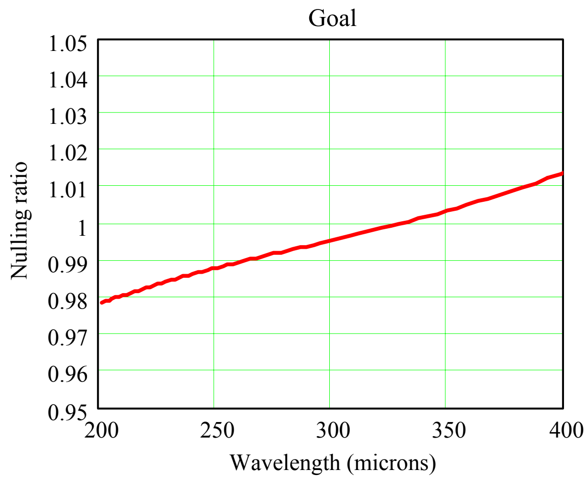




Telescope Temperature (K)	Telescope Emissivity (%)	4% Source Temperature (K)	2% Source Temperature
65	8	57	5
Power applied to each source (mW)		1.0	0
Predicted nulling achievable			

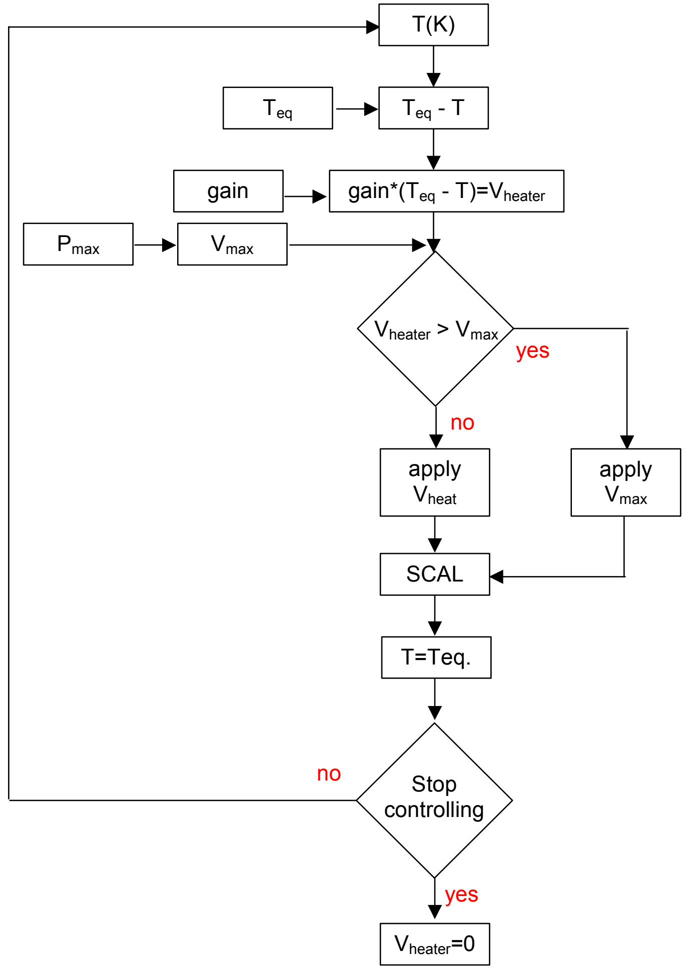






Powering up SCal sources

Although SCal may be operated by applying a constant power to the sources, the time to reach the required source temperature can be reduced by applying a higher power initially, and reducing this to the equilibrium level.
For details, see HSO-CDF-RP-083 (SCal enhanced warm-up procedure report) – Appendix F.
The recommended method is using a feedback loop, similar to that indicated in Figure 5 below.



source type	gain	P_{max} (mW)	T_{eq} (K)	$t_{warm-up}$ (min)	$t_{cool-down}$ (min)
2%	5	15	79.98	4.6	54
2%	5	15	99.99	8	61
2%	0.7	5	16.10	2	13
2%	2	5	24.51	2	—
4%	1.5	5	29.25	4.7	34
4%	0.6	5	27.25	3	21
4%	5	15	49.62	3	56
4%	5	15	79.39	6	91
4%	5	15	99.23	9.6	111

Figure 5 Implementation of a typical feedback loop for powering up SCal sources.

The table in Figure 5 gives recommended parameters to be used for the desired equilibrium temperature (T_{eq}), together with typical results from tests ($t_{warm\text{-}up}$, $t_{cool\text{-}down}$).
This method greatly reduces the time to reach equilibrium from Level-1 temperature. For instance, the time taken to reach a stable temperature of 100K for the 4% source is reduced from 56 minutes to 9.6 minutes.

It must be stressed that the loop shown above is not optimal, just an example. This method is shown as an example of the improvements achievable.
It is recommended that full PID control is implemented in software.

SECTION 14 - Historical Record

Summary. See section 15 – Logbook / Diary of events – for detailed record.
Note – "Thermal / Vacuum cycle" means one cycle 300K – 4K – 300K under vacuum in the test dewar.

Date	Event	Notes
19/01/04	Assembly of sources starts	
11/02/04	Black coating applied to SCal parts	
13/02/04	Prime sources wired	
18/02/04	Redundant sources wired	
19/02/04	Wiring QA checks carried out by P.Ade	
20/02/04	Photographic logging of all soldered joints	
09/03/04	Tests at 4K start – prime side	Thermal / Vacuum Cycle #1
16/03/04	Tests at 4K start – redundant side	Thermal / Vacuum Cycle #2
22/03/04	Taken to RAL for cold vibration qualification run	Thermal / Vacuum Cycle #3. Cryogenic vibration qualification.
31/03/04	Post shake inspection at Cardiff – no anomalies.	
06/04/04	Prime side calibration at 4K	Thermal / Vacuum Cycle #4
13/04/04	Continuing prime side calibration at 4K	Thermal / Vacuum Cycle #5
24/04/04	Begin calibration of redundant side at 4K	Thermal / Vacuum Cycle #6
26/07/04	Enhanced warm-up procedure tests start – prime side only.	Thermal / Vacuum Cycle #7
02/08/04	Enhanced warm-up procedure tests continue – prime side only.	Thermal / Vacuum Cycle #8
09/08/04	Enhanced warm-up procedure tests continue – prime side only.	Thermal / Vacuum Cycle #9
12/08/04	Final cleaning & bakeout	In vacuum oven at 350K for 24 Hrs.

SECTION 15 - Logbook / Diary of Events

Assembly & Test Log - SCAL PFMA and PFMB

This log records all events related to SCAL flight model and flight spare assembly and test. Both models will be assembled and tested together.
NOTE:- 18th August 2004 – Type B has now been accepted as the flight model. The following historical record therefore concentrates on SCal-PFMB. Details on SCal-A testing have been removed.

19/01/04

Assembly of PFM and FS sources starts.
PFMA sources have 2.0mm bores in the Torlon struts. PFMB sources have 2.5mm bores. The Al caps were bonded to the torlon struts using EpoTek-920-FL (batch# 903421, expiry 16/07/04).
Sapphire insulators were bonded using the same epoxy mix, and all were cured for 2 Hrs at 80C.
The sources were labelled as follows:-

Source	Description	Thermometer	Heater
Scal-4PA	Scal 4% prime type A	X29753, CX-1030-SD-HT	Vishay 500Ω PHR0805YB Lot 00020037/5541P7 QC# 03181
Scal-4PB	4% prime type B	X29754, CX-1030-SD-HT	“”
Scal-4RA	4% redundant type A	X29755, CX-1030-SD-HT	“”
Scal-4RB	4% redundant type B	X29756, CX-1030-SD-HT	“”
Scal-2PA	2% prime type A	X28655, CX-1030-SD-HT	“”
Scal-2PB	2% prime type B	X29758, CX-1030-SD-HT	“”
Scal-2RA	2% redundant type A	X29760, CX-1030-SD-HT	“”
Scal-2RB	2% redundant type B	X29761, CX-1030-SD-HT	“”
SCAL-SOB THERMOMETER A PRIME	On SCal baseplate	X28646, CX-1030-SD-HT	
SCAL-SOB THERMOMETER B PRIME	On SCal baseplate	X28264, CX-1030-SD-HT	
SCAL-SOB THERMOMETER A REDUNDANT	On SCal baseplate	X28651, CX-1030-SD-HT	
SCAL-SOB THERMOMETER B REDUNDANT	On SCal baseplate	X28265, CX-1030-SD-HT	

Type A is the default, qualified version for flight (2.0mm bore). Type B will be built as flight spare, will undergo qualification, and may be swapped for flight.

NOTE:- 18th August 2004 – Type B has now been accepted as the flight model. The following historical record therefore concentrates on SCal-PFMB. Details on SCal-A testing have been removed.

11/02/04

Scal base plates blackened. “Pupil area” coated with BG7 (lumpy black), inter-source baffle with non-lumpy black.
Scal sources mounted to base plates – RETAINING PLATE BOLTED USING 2-56 X 3/16 BOLTS.:-
Impedance checks – direct on terminals post-mounting & soldering:-

Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PA	Scal 4% prime type A	32.9	500
Scal-4PB	4% prime type B	35.1	500
Scal-4RA	4% redundant type A	34.7	500
Scal-4RB	4% redundant type B	33.0	500
Scal-2PA	2% prime type A	32.8	500
Scal-2PB	2% prime type B	35.4	500
Scal-2RA	2% redundant type A	35.5	500
Scal-2RB	2% redundant type B	36.8	500

12/02/04

Wired Scal-A sources to prime & redundant connectors

13/02/04

Wired Scal-B prime sources

18/02/04

Wired Scal-B redundant sources

19/02/04

Wiring checked by P.Ade. All passed.

20/02/04

Final assembly in clean room.
Photographic logging of all soldered connections.

05/03/04

put additional wire inside the BACUS cryostat
Mount SCAL B in the cryostat in semi-clean area (taking photos)
Short in cryo-harness (lines 42 & 43 as well 54 & 55 connected, but not grounded to the cryostat)
Demount SCAL B for replacing harness in semi-clean area

06/03/04

Replacing harness and mount SCAL B in semi-clean area and taking photos of assembly
4-wire-measurement of the thermometer impedances with AVS bridge (GPIB 20) at 300K
4-wire-measurement of the heater impedances with Agilent 34401A (GPIB 22) at 300K

300 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	34.64	500.14
Scal-2PB	2% prime type B (CX29758)	34.69	500.13
SCAL-SOB	body prime type B (CX28264)	42.47	--

07/03/04

cooling down to LN2 temperature

08/03/04

4-wire-measurement of the thermometer impedances with AVS bridge (GPIB 20) at 77K
4-wire-measurement of the heater impedances with Agilent 34401A (GPIB 22) at 77K

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	79.15	501.05
Scal-2PB	2% prime type B (CX29758)	73.25	500.95
SCAL-SOB	body prime type B (CX28264)	119.05	--

expected 78.8 Ω for T2% at 77 K instead we measure 73.25 Ω this is due to measuring of H2% with Agilent multimeter (0.1 mA, self heating) at the same time
cooling down to LHe temperature

09/03/04

4-wire-measurement of the thermometer impedances with AVS bridge (GPIB 20) at 4K
4-wire-measurement of the heater impedances with Agilent 34401A (GPIB 22) at 4K

4 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	439.3	500.89
Scal-2PB	2% prime type B (CX29758)	427.1	501.28
SCAL-SOB	body prime type B (CX28264)	948.8	--

measure the equilibrium temperature for various applied powers by powering up the 4% heater of the primary source of SCAL B

data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\prime source\4% source\SCAL_B_09_03_04.txt

P (mW)	$T4\%_{eq.}$ (K)	$T2\%_{eq.}$ (K)	$TSOB_{eq.}$ (K)
1	56.944	4.871	4.431
2	81.048	5.421	4.572
3	98.505	5.955	4.702

10/03/04

measure the equilibrium temperature for various applied powers by powering up the 4% heater of the primary source of SCAL B
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\prime source\4% source\SCAL_B_10_03_04.txt
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\prime source\4% source\SCAL_B_10_03_04_2.txt

P (mW)	$T4\%_{eq.}$ (K)	$T2\%_{eq.}$ (K)	$TSOB_{eq.}$ (K)
4	112.316	6.473	4.850
5	123.194	6.943	4.968

11/03/04

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B primary source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\prime source\4% source\SCAL_B_11_03_04.txt

P (mW)	$T4\%_{eq.}$ (K)	$T2\%_{eq.}$ (K)	$TSOB_{eq.}$ (K)
0.4	35.456	4.502	4.328
0.6	43.618	4.614	4.354
0.8	50.584	4.731	4.383
0.1	17.836	4.319	4.269
0.05	12.928	4.290	4.262
15	185.448	10.597	5.975
10	161.490	8.998	5.505
0.025	9.386	4.266	4.247

12/03/04

finishing calibration of SCAL B primary source

15/03/04

Prime source impedance check:-

300 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	35.11	500.81
Scal-2PB	2% prime type B (CX29758)	35.15	501.06
SCAL-SOB	body prime type B (CX28264)	41.98	--

Swap to SCAL B redundant source

300 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% red type B (C X29756)	33.14	500.81
Scal-2RB	2% red type B (C X29761)	36.50	501.06
SCAL-SOB	body red type B (CX28265)	33.97	--

16/03/04

11-00 cooling down to 77 K

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% red type B (CX29756)	70.26	501.1
Scal-2RB	2% red type B (CX29761)	78.67	501.0
SCAL-SOB	body red type B (CX28265)	77.10	--

16-00 cooling down to 4 K

4 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% red type B (CX29756)	321.3	501.9
Scal-2RB	2% red type B (CX29761)	398.1	501.5
SCAL-SOB	body red type B (CX28265)	380.8	--

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B redundant source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\4% source\SCAL_B_r_16_03_04.txt

17/03/04

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B redundant source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\4% source\SCAL_B_r_17_03_04.txt
there was a typing error in the CX29756 thermometer calibration LabView vi
problem is fixed but the data file \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\4% source\SCAL_B_r_16_03_04.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\4% source\SCAL_B_r_17_03_04.txt have to be corrected

18/03/04

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B redundant source data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\2% source\SCAL_B_r_18_03_04.txt

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
5.00	126.65	8.16	5.34
4.00	115.60	7.60	5.18
3.00	101.99	6.89	4.98
2.00	84.13	6.12	4.76
1.00	59.85	5.37	4.53

measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B redundant source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\2% source\SCAL_B_r_18_03_04_2.txt

19/03/04

measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B redundant source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\2% source\SCAL_B_r_19_03_04.txt

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
1	5.29	60.71	4.52
2	6.15	86.60	4.75
3	6.67	105.14	4.97
4	7.28	119.15	5.17
5	7.91	131.08	5.36

finishing calibration of SCAL B source
summary data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\SCAL_B_4percent_090304_summary.xls

02/03/04

SCAL-B taken to RAL for cold vibration run. Bolted on shaker plate at Cardiff.

31/03/04

Post shake inspection of SCAL-B. Visual inspection passed – no anomalies.

02/04/03

SCAL-B re-installed in Bacus dewar for post-shake test and final calibration.
Prime sources connected.

05/04/04

Prime source warm impedance check:-

300 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	34.67	500.2
Scal-2PB	2% prime type B (CX29758)	34.72	500.2
SCAL-SOB	body prime type B (CX28264)	42.50	--

06/04/04

cooling down to LN2 temperature

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	78.08	501.0
Scal-2PB	2% prime type B (CX29758)	78.64	501.1
SCAL-SOB	body prime type B (CX28264)	119.14	--

cooling down to LHe temperature

4 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	441.16	501.8
Scal-2PB	2% prime type B (CX29758)	429.23	501.9
SCAL-SOB	body prime type B (CX28264)	955.27	--

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\SCAL_B_p_06_04_04.txt

07/04/04

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\SCAL_B_p_06_04_04.txt

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
5.00	123.294	6.850	4.588
4.00	112.206	6.378	4.531
3.00	98.496	5.903	4.466

08/04/04

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\SCAL_B_p_06_04_04.txt

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
2.00	80.969	5.394	4.400
1.00	56.974	4.845	4.331
0.8	50.797	4.731	4.315
0.6	43.646	4.611	4.299

warming up the cryostat with pumping on the vacuum chamber at the same time

13/04/04

cooling down to LN2 temperature

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	78.75	501.2
Scal-2PB	2% prime type B (CX29758)	78.61	501.1
SCAL-SOB	body prime type B (CX28264)	119.01	--

cooling down to LHe temperature

4 K

Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	440.32	501.8
Scal-2PB	2% prime type B (CX29758)	428.10	501.9
SCAL-SOB	body prime type B (CX28264)	951.94	--

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\SCAL_B_p_13_04_04.txt

14/04/04

continue measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\SCAL_B_p_13_04_04.txt

15/04/04

continue measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\SCAL_B_p_13_04_04.txt

16/04/04

finishing measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\SCAL_B_p_13_04_04.txt

17/04/04

measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_17_04_04.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_17_04_04_2.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_17_04_04_3.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_17_04_04_4.txt

18/04/04

continue measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_18_04_04.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_18_04_04_2.txt

19/04/04

continue measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_19_04_04_2.txt

20/04/04

continue measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_20_04_04.txt
and
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_20_04_04_2.txt

21/04/04

finishing measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B prime source
data file: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\SCAL_B_p2percent_20_04_04_2.txt

22/04/04

warm up the cryostat by emptying all cryogenics

23/04/04

speed up the warming of the cryostat by putting some dry nitrogen gas into the vacuum chamber (TSOB=100K)

24/04/04

open cryostat and connect the redundant source

300 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% red type B (CX29756)	32.88	500.3

Scal-2RB	2% red type B (CX29761)	36.22	500.3
SCAL-SOB	body red type B (CX28265)	33.71	--

26/04/04

cooling down to LN2 temperature

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% red type B (CX29756)	70.08	501.3
Scal-2RB	2% red type B (CX29761)	78.66	501.1
SCAL-SOB	body red type B (CX28265)	77.11	--

cooling down to LHe temperature

4 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% red type B (CX29756)	70.08	501.3
Scal-2RB	2% red type B (CX29761)	78.66	501.1
SCAL-SOB	body red type B (CX28265)	77.11	--

measure the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B redundant source
data file: Test data\after cold vibration\redundant source\4% source\SCAL_FS_Br_4percent_26_04_04_2.txt

27/04/04

continue measuring the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B redundant source
data file: Test data\after cold vibration\redundant source\4% source\SCAL_FS_Br_4percent_26_04_04_2.txt

28/04/04

continue measuring the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B redundant source
data file: Test data\after cold vibration\redundant source\4% source\SCAL_FS_Br_4percent_26_04_04_2.txt

29/04/04

finishing measuring the equilibrium temperature for various applied powers by powering up the 4% heater of SCAL B redundant source
data file: Test data\after cold vibration\redundant source\4% source\SCAL_FS_Br_4percent_26_04_04_2.txt
switch to the 2% heater of SCAL B redundant source
measure the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B redundant source

data file: Test data\after cold vibration\redundant source\2% source\SCAL_FS_Br_2percent_29_04_04.txt and D:\Devlabv\acqtemp\SCAL_FS_Br_2percent_29_04_04_2.txt

30/04/04

finishing measuring the equilibrium temperature for various applied powers by powering up the 2% heater of SCAL B redundant source
data file: Test data\after cold vibration\redundant source\2% source\SCAL_FS_Br_2percent_29_04_04.txt and D:\Devlabv\acqtemp\SCAL_FS_Br_2percent_29_04_04_2.txt

31/04/04

warming up the cryostat

26/07/04

Scal-B re-installed to Bacus ready for enhanced warm-up test.
Thermometer measurements – 4-wire using AVS resistance bridge (GPIB 20). Heater measured using multimeter using 4-wire measurement.

300 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4PB	4% prime type B (CX29754)	34.48	500.10
Scal-2PB	2% prime type B (CX29758)	34.53	500.16
SCAL-SOB	body prime type B (CX28264)	42.22	--

~ 16:05: Cryostat closed
~ 16:10: On pump

27/07/04

~ 9.25: Cooling down to LN2. Display on pump gave erratic reading when switched on initially. Gives a value for the pressure inside BACUS of order 10^{-5}/ 10^{-6} mbar when switched back on again, approx. 30 min after the initial switch on. After a short period switched on gives a value of order 10^{-8}/ 10^{-9} – considered unrealistic.
~ 15:18: LN2 values for resistance:

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% prime (CX29754)	76.96	500.97
Scal-2RB	2% prime (CX29758)	77.41	501.03
SCAL-SOB	body prime (CX28264)	119.20	--

~ 16:30: Cool-down to LHe begins.
~ 18:05: Helium transfer finished. Top up LN2.

28/07/04

Morning: top up LN2, LHe.
LHe values for resistance:

4.2 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% prime (CX29754)	442.3	501.46
Scal-2RB	2% prime (CX29758)	430.2	501.57
SCAL-SOB	body prime (CX28264)	956.9	--

Test procedure
For each source:-
LabView files (for both 4% and 2% sources):-
"One_temperature_monitoring_no_scan_modev1d.vi" (Temperature monitoring)
"convert_P_in_T_from_calibration_SCALBp4percent.vi" (Conversion file)
"TtiPL330_Applied_Power_With_Rv1c.vi" (Applying power)
Data files (raw):-
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_4_P_T(K)_280704_3.txt for temperature variation of ScalB prime 4% source
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_4_P_P(mW)_280704_2.txt for power applied to Scal B prime 4% source

\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_280704_2.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_280704.txt for temperature variation of Scal B prime 2% source
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_P(mW)_280704_2.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_P(mW)_280704.txt for power applied to Scal B prime 2% source
Initial recordings: Obtaining curves for power inputs of 150 mW and 5 mW to Scal B prime 4% and 2% sources in order to derive curves for the temperature, T, obtained at time t. A slight power input was observed when connecting the power source to the illuminator box, which affected the value of the base temperature. The procedure for obtaining these measurements {may be}, therefore:

1. Check source temperature at equilibrium with cable to the power supply disconnected.
2. Enter zero power in GPIB power vi, then start program. Once started, change the power to 15 mW, but do not apply this power yet (i.e. do not click 'return', 'enter'. etc.).
3. Switch on the appropriate power button on the illuminator box.

4. Quickly connect the power supply to the illuminator box, and quickly apply the 15 mW power (by pressing 'return', etc.), so that the base temperature does not have time to rise much above 4.2419 K.
5. Monitor warm-up with LabVIEW program.
6. For the 15 mW, it was decided that only needed curve up to ~ 100 K.
7. Once curve reaches around this value, use GPIB power vi to apply zero power
8. Leave to cool-down. Wait for the temperature to reach base value with the supply connected. Once this is obtained, switch the output to 'OFF' (do not stop the program), and disconnect the power supply from the illuminator box
9. Repeat steps 1 – 8 with 5 mW applied power, leaving the source to reach approximate equilibrium (the expected equilibrium temperature can be obtained by using a convert program).
10. Repeat steps 1 – 9 with 2% source.

Glitches were observed at measurements just beyond 18 K for both 15 mW and 5 mW applied power. This was thought to be due to the AVS bridge changing range from 2 k to 200 k. Once these measurements were taken, the sources were powered-up using the adapted procedure. Initial recordings used the TTiPL330DP power supply. This supply, however, showed switching effects: no power was applied between consecutive measurements when changing the value of the applied power. {In an attempt to} avoid this problem, the power supply was switched to the DAQ card.

Power supply TtiPL330DP switching effect (does not apply power between voltage change) – switch to DAQ card to avoid problem.

Select power – use convert program to give expected equilibrium temperature, T_{eq}
Use GPIB power VI to apply 15mW until T=(T_{eq}-2) K
Use GBIP power VI to switch to required power for expected equilibrium temperature
using different program "TTiPL330_Applied_Power_With_Rv1d.vi" which can be found in
\\Darkstar\Astroworld\Projects\Spire\LabView\Applied_Power_with_control_R.llb
keeping cold at 77K over the weekend

02/08/04

cooling down 77K

~140 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% prime (CX29754)	55.78	500.68
Scal-2RB	2% prime (CX29758)	55.43	501.73
SCAL-SOB	body prime (CX28264)	75.66	--

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% prime (CX29754)	79.19	500.98

Scal-2RB	2% prime (CX29758)	78.77	501.05
SCAL-SOB	body prime (CX28264)	119.27	--

~ 14:30: Cool-down to LHe begins.
~ 16:00: Helium transfer finished. Top up LN2.

- the multimeter HP34410A use 100μA constant current source to measure the resistance therefore 4%/2% are heating up during the measurement of the heater resistance
- to avoid this switch to use the AVS bridge for the heater resistance measurement

4.2 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% prime (CX29754)	440.6	501.8
Scal-2RB	2% prime (CX29758)	430.2	501.9
SCAL-SOB	body prime (CX28264)	957.9	--

connected ground from 25pin connector with the insulated BNC-connector "Power 3/4" inside the "Illuminator box", result after connecting the DAQ card with the "Illuminator box" the temperature jumps to 4.24K instead of 5K without ground connected.
Test procedure for each source:
LabView files (for both 4% and 2% sources):
"One_temperature_monitoring_no_scan_modev1d.vi" (Temperature monitoring) can be found in
\\Darkstar\Astroworld\Projects\Spire\LabView\temperature_monitoring_no_scan_mode_AVS.llb
"TTiPL330_Applied_Power_With_Rv1d.vi" (Applying power) can be found in \\Darkstar\Astroworld\Projects\Spire\LabView\Applied_Power_with_control_R.llb
LabView file for both 4% prime source:
"convert_P_in_T_from_calibration_SCALBp4percent.vi" (Conversion file)can be found in \\Darkstar\Astroworld\Projects\Spire\LabView\scal_calibration.llb
Data files (raw):-
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_4_P_T(K)_020804.txt
for temperature variation of Scal B prime 4% source
SCAL B 4% source: $R_{control}$=996 Ohm; R_{SCAL}=501.8 Ohm

T_{start} (K)	$P_{required}$ (mW)	$T_{eq.}$ (K)	Power factor	$P_{initial}$ (mW)	Time factor	comment
4.24	0.15	21.88	30	4.5	13	no overshoot, reach 21.1K at 66 sec, reach 21.37 at 10 min
4.24	0.15	21.88	30	4.5	13.75	no overshoot, reach 21.4K at 66sec; reach 21.52 at 10 min, shows a drop in temperature before it's rise again
4.24	0.15	21.88	33	4.95	12	no overshoot, reach 21.17K at 66sec; shows a drop in temperature before it's rise again
4.24	0.15	21.88	33	4.95	13.75	overshoot ; reach 22.04 at 66 sec; reach at 10 min 21.78

03/08/04

10-00 top up LN2

10-15 top up LHe
Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_4_P_T(K)_030804.txt
for temperature variation of Scal B prime 4% source
SCAL B 4% source: $R_{control}$=996 Ohm; R_{SCAL}=501.8 Ohm

T_{start} (K)	$P_{required}$ (mW)	$T_{eq.}$ (K)	Power factor	$P_{initial}$ (mW)	Time factor	comment
4.24	0.15	21.88	33	5.1	13.5	overshoot, reach 21.93K at 66 sec, reach 21.73 at 10 min, shows a drop in temperature before it's rise again
4.24	0.15	21.88	33	5.1	13.25	overshoot, reach 21.81K at 66 sec, reach 21.67 at 10 min
4.24	0.15	21.88	33	5.1	13	no overshoot, reach 21.69K at 66 sec, reach 21.618 at 4 min, reach 21.616 at 10 min
4.24	0.275	29.53	18	5.22	32.85	overshoot, reach 28.32K at 66 sec, reach 29.35K at 10min, shows a drop in temperature before it's rise again
4.24	0.275	29.53	18	5.22	32	no overshoot, reach 28.19K at 66 sec, reach 29.22K at 4min, reach 29.21K at 10min

Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_030804.txt
for temperature variation of Scal B prime 2% source
SCAL B 2% source: $R_{control}$=996 Ohm; R_{SCAL}=501.9 Ohm

T_{start} (K)	$P_{required}$ (mW)	$T_{eq.}$ (K)	Power factor	$P_{initial}$ (mW)	Time factor	comment
4.24	0.275	29.09	18	5.22	19.5	no overshoot, reach 28.68K at 66 sec, reach 28.72K at 4min, reach 28.78K at 10min, shows a drop in temperature before it's rise again
4.24	0.275	29.09	18	5.22	19	no overshoot, reach 28.48K at 66 sec, reach 28.56K at 4min, reach 28.70K at 10min, shows a drop in temperature before it's rise again
4.24	0.275	29.09	18	5.22	20	overshoot T_{max}= 28.99K, reach 28.88K at 66 sec, reach 28.89K at 4min, reach 28.86K at 10min
4.24	0.275	29.09	18	5.22	19.75	overshoot T_{max}= 28.87K, reach 28.78K at 66 sec, reach 28.78K at 4min, reach 28.79K at 10min, reach stable 28.8K at 15min
4.24	0.275	29.09	18	5.22	19.6	no overshoot T_{max}= 28.8K, reach 28.7K at 66 sec, reach 28.73K at 4min, reach 28.76K at 10min, shows a drop in temperature before it's rise again
4.24	0.275	29.09	19	5.5	19.7	overshoot T_{max}= 28.84K, reach 28.75K at 66 sec, reach 28.77K at 4min, reach 28.79K at 10min, shows a drop in temperature before it's rise again

04/08/04

9-45 top up LN2
10-00 top up LHe

Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_040804.txt
for temperature variation of Scal B prime 2% source
SCAL B 2% source: $R_{control}$=996 Ohm; R_{SCAL}=501.9 Ohm

T_{start} (K)	$P_{required}$ (mW)	$T_{eq.}$ (K)	Power factor	$P_{initial}$ (mW)	Time factor	comment
4.24	0.15	21.57	33	5.1	9	overshoot T_{max}= 22.03K, reach 21.84K at 66 sec, reach 21.57K at 4min, reach 21.42K at 10min
4.24	0.15	21.57	33	5.1	8	no overshoot, reach 21.1K at 66 sec, reach 21.09K at 4min, reach 21.22K at 10min, shows a drop in temperature before it's rise again
4.24	0.15	21.57	33	5.1	8.5	overshoot T_{max}= 21.67K, reach 21.48K at 66 sec, reach 21.35K at 4min, reach 21.35K at 10min
4.24	0.15	21.57	33	5.1	8.4	overshoot T_{max}= 21.6K, reach 21.42K at 66 sec, reach 21.31K at 4min, reach 21.33K at 10min, shows a drop in temperature before it's rise again
4.24	0.79	50.10	18.5	15.41	20	no overshoot, reach 42.6K at 66 sec
4.24	0.79	50.10	18.9	15.72	33	overshoot T_{max}= 50.39K, reach 48.6K at 66 sec, reach 50.34K at 4min, reach 50.11K at 10min,
4.24	0.79	50.10	18.9	15.72	30	no overshoot, reach 47.57K at 66 sec, reach 49.02K at 4min, reach 49.21K at 10min,
4.24	0.79	50.10	18.9	15.72	31.5	overshoot T_{max}= 49.7K, reach 48.17K at 66 sec, reach 49.70K at 4min, reach 49.66K at 10min,
4.24	0.79	50.10	18.9	15.72	31.25	no overshoot, reach 48.09K at 66 sec, reach 49.58 at 4min, reach 49.59K at 10min, shows a tiny drop in temperature before it's rise again, reach 49.63K at 18min
4.24	0.79	50.10	18	15.01	31.5	no overshoot, reach 47.39K at 66 sec, reach 49.05 at 4min, reach 49.24K at 10min
4.24	0.79	50.10	18	15.01	32.5	no overshoot, reach 47.79K at 66 sec, reach 49.50K at 4min, reach 49.54K at 10min, reach 49.69K at 70min

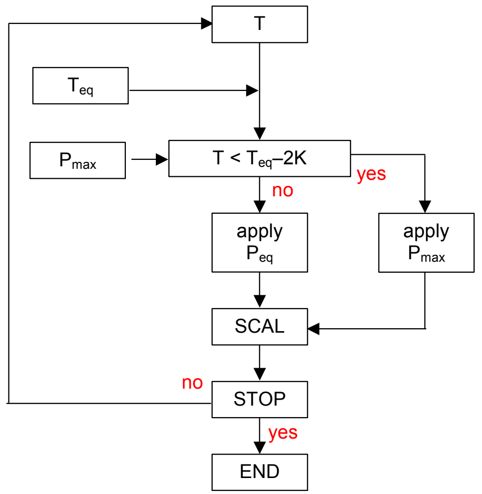
05/08/04

10-15 top up LN2
10130 top up LHe
Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_050804.txt
for temperature variation of Scal B prime 2% source
SCAL B 2% source: $R_{control}$=996 Ohm; R_{SCAL}=501.9 Ohm

T_{start} (K)	$P_{required}$ (mW)	$T_{eq.}$ (K)	Power factor	$P_{initial}$ (mW)	Time factor	comment
4.26	0.79	50.10	18	15.01	33	overshoot T_{max}= 49.67K, reach 47.88K at 66 sec, reach 49.66K at 4min, reach 49.62K at 10min,
4.25	2	81.56	6.5	15	134	overshoot T_{max}= 81.64K, reach 59.05K at 66 sec, reach 76.88K at 4min, reach 81.50K at 10min, reach 80.92K after 70min
4.25	2	81.56	6.5	15	130	overshoot T_{max}= 81.14K, reach 58.99K at 66 sec, reach 76.43K at 4min, reach 80.94K at 10min, reach 81.08K at 25min

17-05 use different method to apply power

- apply maximum power (5mW or 15mW)
- wait until temperature is 2K below the desired equilibrium power
- switch to the corresponded power for the desired equilibrium power



LabView files:
"One_temperature_monitoring_no_scan_modev1d.vi" (Temperature monitoring) can be found in
\\Darkstar\Astroworld\Projects\Spire\LabView\temperature_monitoring_no_scan_mode_AVS.llb
"TTiPL330_Applied_Power_With_Rv1e.vi" (Applying power) can be found in \\Darkstar\Astroworld\Projects\Spire\LabView\Applied_Power_with_control_R.llb

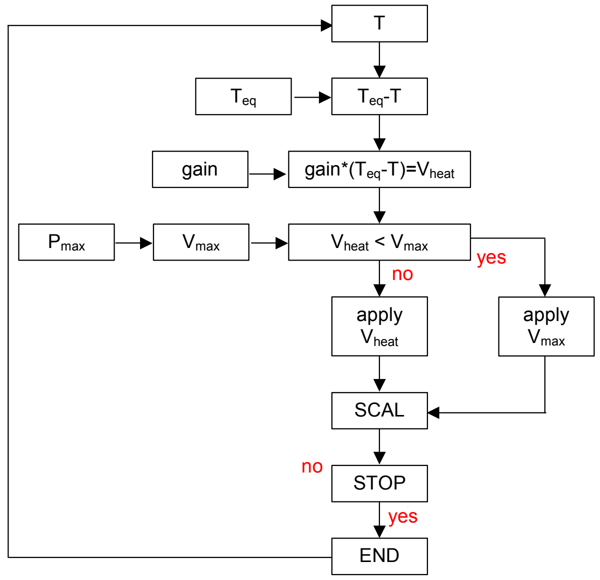
Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_050804.txt
for temperature variation of Scal B prime 2% source

T_{start} (K)	$P_{required}$ (mW)	$T_{eq.}$ (K)	P_{max} (mW)	t_{start} (mfs)	comment
4.26	2	80.82	15	393	stopped at T=77.78K, no overshoot, reach 61.42K at 66 sec, reach 77.4K at 4min, reach 78.34K at 10min, reach 80.50 at 50min

20-00 use different method to apply power

- using proportional feedback method which applies maximum power from the start and reduces the power to required power automatically to reach certain temperature in shortest time

- a difference between $T_{eq.}$ and T_{final} will be observed because only a proportional factor was used in the feed back instead of additional integrational factor



LabView files:
"SCAL_enhanced_warmup_feedbackv1.vi" (Temperature monitoring) can be found in \\Darkstar\Astroworld\Projects\Spire\LabView\scal_calibration.llb

Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_feedback_050804.txt and \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_feedback_050804_2.txt for temperature variation of Scal B prime 2% source

T_{start} (K)	$T_{eq.}$ (K)	T_{final} (K)	P_{max} (mW)	gain	comment
4.26	80.60	80	15	5	no overshoot, reach 63.72K at 66 sec, reach 79.97K at 3.3min, reach 80K at 7.7min, reach 80 at 10min

06/08/04

10-45 top up LN2

10-30 top up LHe

Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_2_P_T(K)_feedback_060804.txt for temperature variation of Scal B prime 2% source
SCAL B 2% source: $R_{control}$=996 Ohm; R_{SCAL}=501.9 Ohm

T_{start} (K)	$T_{eq.}$ (K)	T_{final} (K)	P_{max} (mW)	gain	$V_{applied}$ (V)	comment
4.24	100.75	99.99	15	5	3.77	no overshoot, reach 63.19K at 66 sec, reach 99.087K at 4min
4.25	20		5	5		overshoot because the temperature data for controlling due to AVS range change
4.25	17	16.66	5	2		overshoot Tmax=18K and undershoot, reach 16.6 at 42s
4.25	17	16.17	5	0.75	0.62	overshoot Tmax=16.86K and undershoot, reach 16.1 at 66s
4.25	17		5	0.25		not even close
4.25	17	16.10	5	0.7	0.65	overshoot Tmax=16.7K and undershoot, reach 16.05 at 66s,
4.25	25	24.51	5	2	1.03	overshoot Tmax=24.64K and undershoot, reach 24.46 at 66s, because the temperature data for controlling due to AVS range change

Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\280704\raw data\SCAL_B_4_P_T(K)_feedback_060804.txtfor temperature variation of Scal B prime 4% source
SCAL B 4% source: $R_{control}$=996 Ohm; R_{SCAL}=501.8 Ohm

T_{start} (K)	$T_{eq.}$ (K)	T_{final} (K)	P_{max} (mW)	gain	$V_{applied}$ (V)	comment
4.26	30	29.25	5	1.5	1.12	no overshoot, reach 29.02K at 66s, reach 29.25K at 4min
4.25	18	16.95	5	0.6	0.65	no overshoot, reach 16.75K at 66s, reach 29.25K at 4min
4.25	50	49.62	15	5	1.89	no overshoot, reach 49.4K at 66s, reach 49.61K at 3min
4.25	80	79.39	15	5	2.94	no overshoot, reach 51.38K at 66s, reach 77.85K at 4min, reach 79.39K at 4.3min
4.25	100	99.23	15	5	3.84	no overshoot, reach 51.40K at 66s, reach 77.86K at 4min, reach 99.23K at 8min

09/08/04

cooling down to LN2 temperature from 140K

77 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% prime (CX29754)	79.09	501.1
Scal-2RB	2% prime (CX29758)	78.80	501.3

SCAL-SOB	body prime (CX28264)	119.32	--

14-00 cooling down to LHe
15-40 every is thermalized to 4 K

4 K			
Source		Thermometer (Ohms)	Heater (Ohms)
Scal-4RB	4% prime (CX29754)	441.7	501.9
Scal-2RB	2% prime (CX29758)	430.6	501.6
SCAL-SOB	body prime (CX28264)	958.9	--

re-check calibration for few data points
LabView files:
"SCAL_calibration_v1.3.vi" (Temperature monitoring and automatically power apply) can be found in
\\Darkstar\Astroworld\Projects\Spire\LabView\scal_calibration.llb
Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\Test data\check calibration\SCAL_B_4p_09_08_04.txt for temperature variation of Scal B prime 4% source
SCAL B 4% source: $R_{control}$=996 Ohm; R_{SCAL}=501.9 Ohm

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
0.099	17.583	4.2735	4.2339
0.9936	56.363	4.764	4.2912
3.9834	111.48	6.1993	4.4619

10/08/04

Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\check calibration\SCAL_B_2p_10_08_04.txt for temperature variation of Scal B prime 2% source
SCAL B 2% source: $R_{control}$=996 Ohm; R_{SCAL}=501.6 Ohm

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
0.099			
0.9936			
3.9834			

11/08/04

- disconnect grounding of the "Power ¾" BNC socket inside the Illuminator box and repeat 0.1mW measurement for the 2% and 4% source
- T4% rise to 4.97K; T2% rise to 4.77K; TSOB stays at 4.23K
- during LHe transfer T4% drops to 4.85K; T2% rise to 4.69K; TSOB stays at 4.23K

Data files (raw):
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\check calibration\SCAL_B_2p_11_08_04.txt for temperature variation of Scal B prime 2% source
SCAL B 2% source: $R_{control}$=996 Ohm; R_{SCAL}=501.6 Ohm

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
0.099			

Data files (raw):
Test data\check calibration\4% source\raw data\SCAL_B_4p_09_08_04.txt
SCAL B 4% source: $R_{control}$=996 Ohm; R_{SCAL}=501.6 Ohm

P (mW)	T4%$_{eq.}$ (K)	T2%$_{eq.}$ (K)	TSOB$_{eq.}$ (K)
0.099			

- let the cryostat warming up on its own

SECTION 16 - Operating Time / Cycle Record

See also section 14 and section 15.
SCal-PFMB has undergone a total of nine thermal / vacuum cycles 300K – 4K – 300K.
While at 4K (baseplate temperature), the SCal sources have been heated to operating temperature (varying between 20K and 160K) and back a number of times (but less than 20 in total), as indicated in section 15 and Appendix C (Scal-B calibration report)

SECTION 17 – Connector Mating Record

Connector Mate / Demate log									
Project		**SPIRE**		**Experiment**					
Subsystem		**Spectrometer Calibration source**		**Model**	**PFM**	**ID**	***SCAL-PFM-000 – Prime Connector MDM-37S***		
ID		ID		ID		ID		ID	
Mate date 07/03/04 P. Hargrave	Demate date 15/03/04 P. Hargrave	Mate date 02/04/03 P. Hargrave	Demate date 24/04/04 P. Hargrave	Mate date 26/07/04 P. Hargrave	Demate date 12/08/04 P. Hargrave	Mate date	Demate date	Mate date	Demate date
After 5 cycles, carry out visual inspection. Record result below.									
Connect I/D		Debris	Bent pins	Remarks		Pass	Fail	Signature	
ID		ID		ID		ID		ID	
Mate date	Demate date	Mate date	Demate date	Mate date	Demate date	Mate date	Demate date	Mate date	Demate date
After 10 cycles, carry out visual inspection with magnification. Record result below.									
Connect I/D		Debris	Bent pins	Remarks		Pass	Fail	Signature	
NOTE: In case of failure, an NCR is required.									

Connector Mate / Demate log									
Project		**SPIRE**		**Experiment**					
Subsystem		**Spectrometer Calibration source**		**Model**	**PFM**	**ID**	***SCAL-PFM-000 – Redundant Connector MDM-37S***		
ID									
Mate date 15/03/04 P. Hargrave	Demate date 20/03/04 P. Hargrave	Mate date 24/04/03 P. Hargrave	Demate date 31/04/04 P. Hargrave	Mate date	Demate date	Mate date	Demate date	Mate date	Demate date
After 5 cycles, carry out visual inspection. Record result below.									
Connect I/D		Debris	Bent pins	Remarks		Pass	Fail	Signature	
ID									
Mate date	Demate date	Mate date	Demate date	Mate date	Demate date	Mate date	Demate date	Mate date	Demate date
After 10 cycles, carry out visual inspection with magnification. Record result below.									
Connect I/D		Debris	Bent pins	Remarks		Pass	Fail	Signature	
NOTE: In case of failure, an NCR is required.									

SECTION 18 – Age Sensitive Items Record

There are no age-sensitive items.

SECTION 19 – Pressure Vessel History / Test Record

N/A

SECTION 20 - Calibration Data Record

Thermometer calibration curves

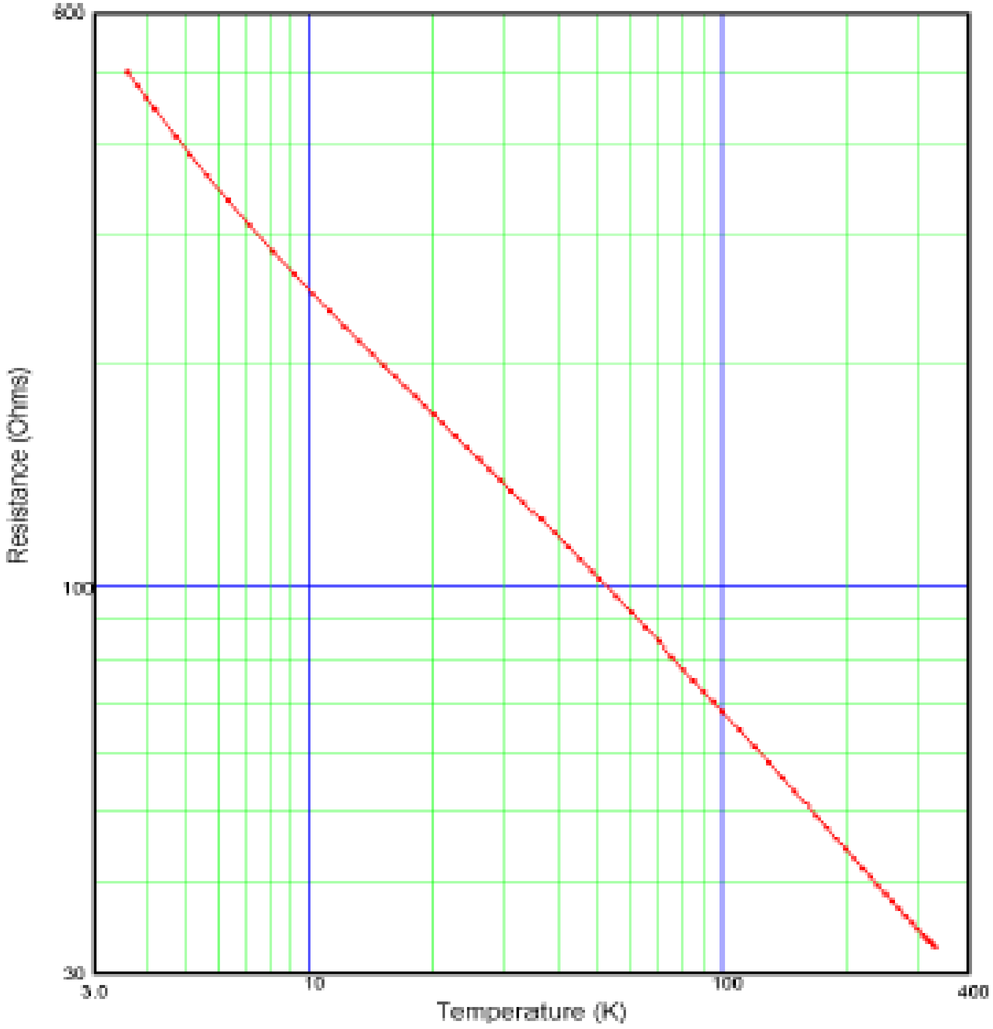
Full calibration reports for all thermometers are shown in Appendix A.

SCal-4% prime thermometer – X29754

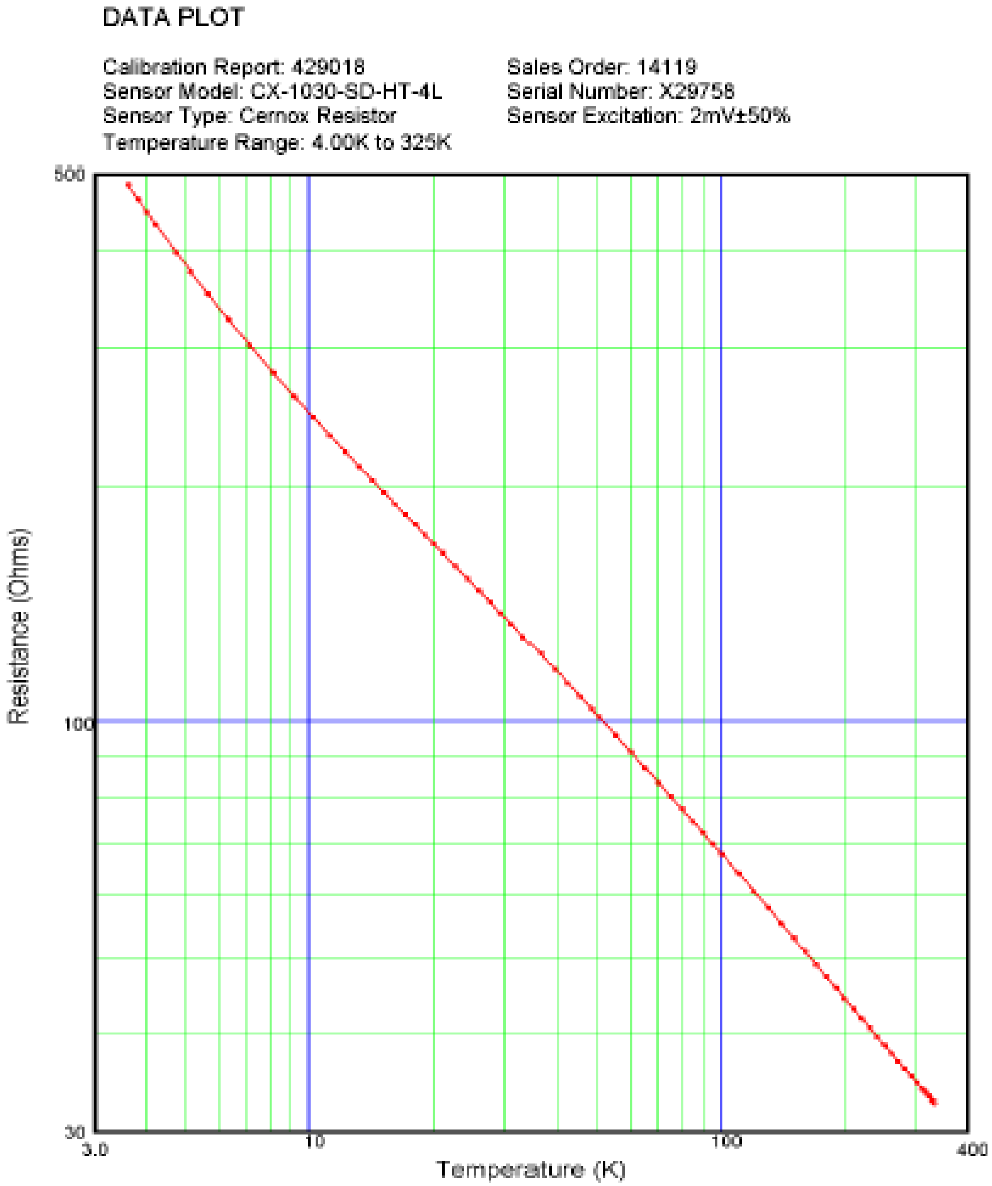
DATA PLOT

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%



SCal-2% prime thermometer – X29758

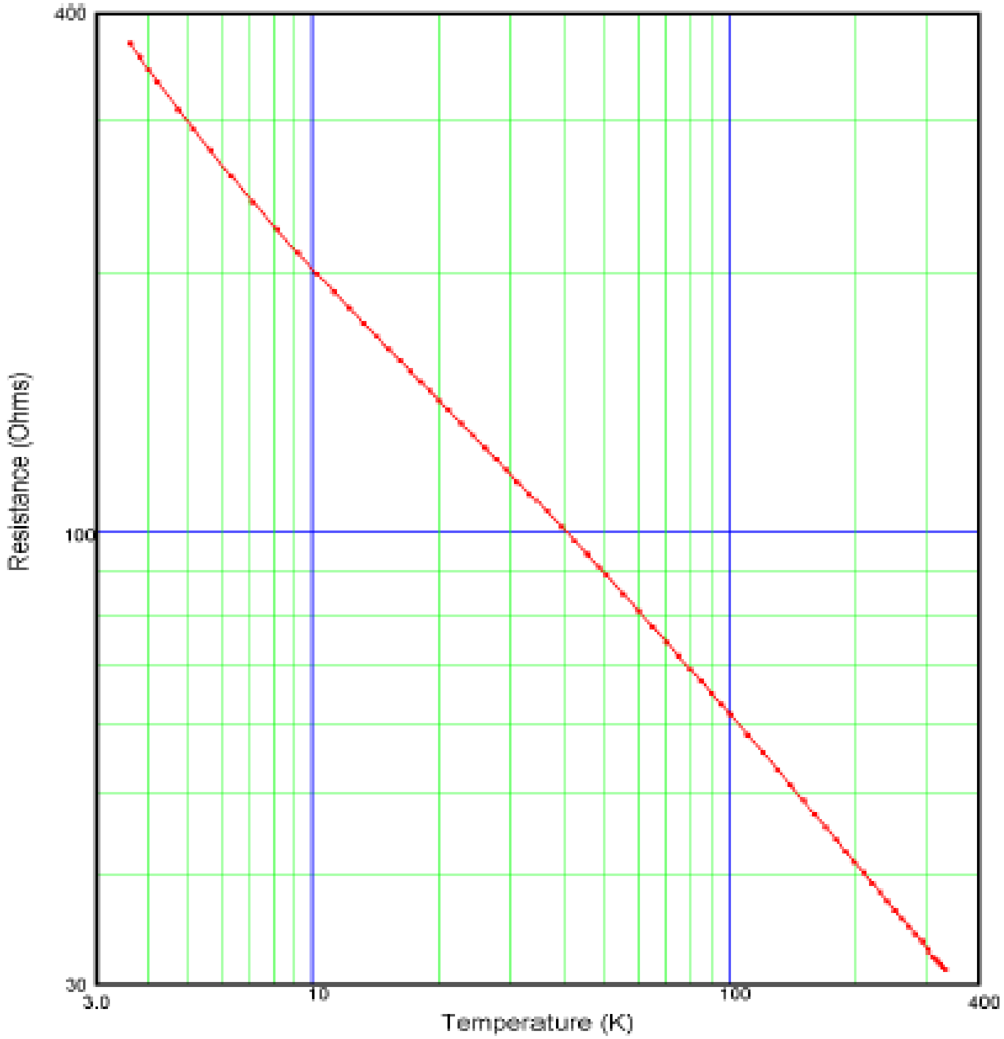


SCal-4% redundant thermometer – X29756

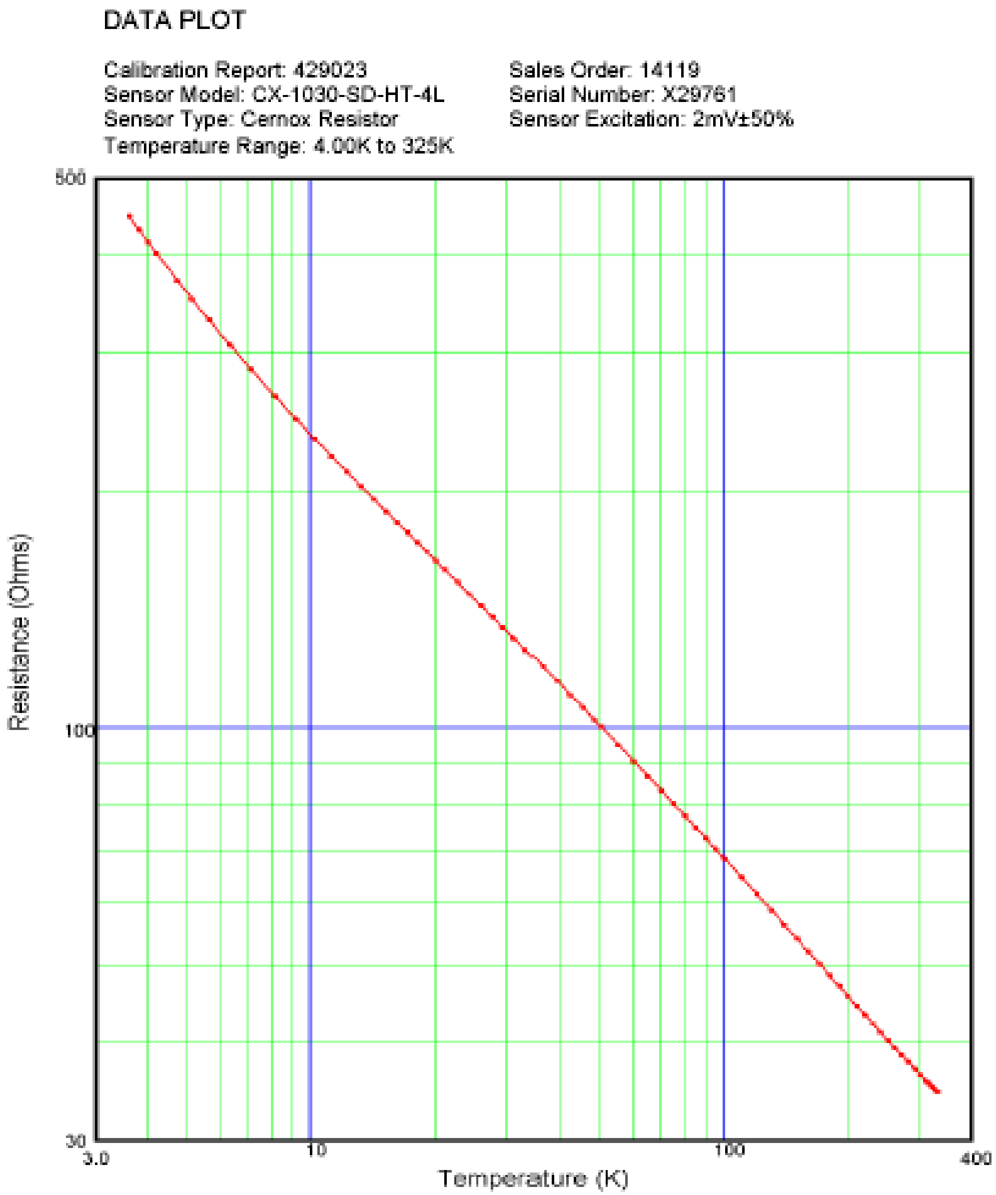
DATA PLOT

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

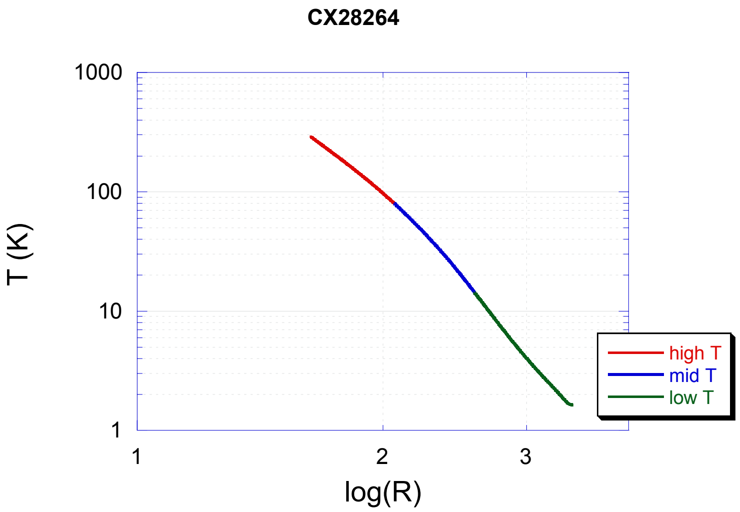
Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%



SCal-2% redundant thermometer – X29761



SCal prime near SOB Thermometer – X28264



y = m1+T1(2.0652,1.6314,m2,m...

	Value	Error
m1	168.62	0.0083204
m2	-102.91	0.01449
m3	16.25	0.01351
m4	-2.1645	0.012742
m5	0.29808	0.012521
m6	0.021492	0.011728
m7	-0.031175	0.011655
m8	0.028605	0.010032
m9	-0.015089	0.0099593
Chisq	11.227	NA
R	1	NA

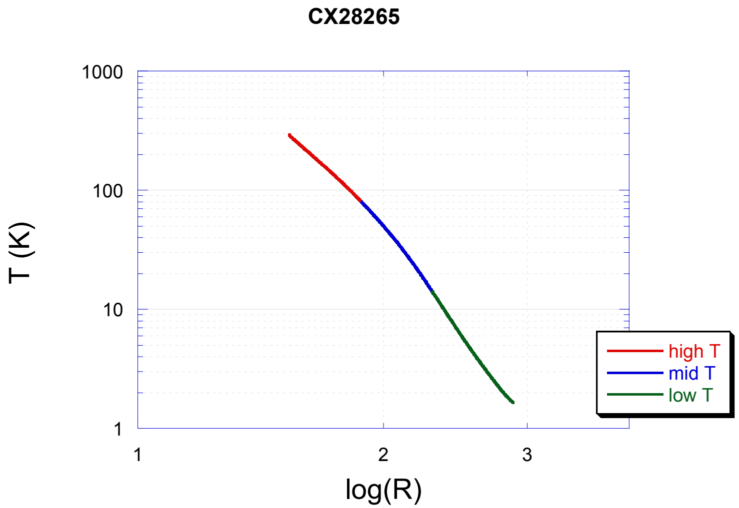
y = m1+T1(2.5937,2.0652,m2,m...

	Value	Error
m1	40.88	0.0011418
m2	-32.205	0.0019752
m3	6.1963	0.001861
m4	-0.73934	0.001746
m5	0.07258	0.0017107
m6	0.010247	0.0016082
m7	-0.0071502	0.0015767
m8	-0.0034126	0.0013834
m9	0.0028717	0.0013873
Chisq	0.18573	NA
R	1	NA

y = m1+T1(3.4133,2.5937,m2,m...

	Value	Error
m1	5.8457	0.00049434
m2	-5.7952	0.00088868
m3	1.9575	0.00075224
m4	-0.50177	0.00065247
m5	0.1068	0.0005781
m6	0.0016598	0.00055153
m7	0.010325	0.00055656
m8	0.0064626	0.00050647
m9	0.0032958	0.00044221
Chisq	0.0017067	NA
R	1	NA

SCal redundant near SOB Thermometer – X28265



y = m1+T1(1.8802,1.5328,m2,m...

	Value	Error
m1	168.08	0.011153
m2	-102.76	0.019423
m3	16.849	0.018201
m4	-2.6879	0.017167
m5	0.52093	0.016868
m6	-0.076342	0.015746
m7	0.023507	0.015599
m8	-0.008657	0.013402
m9	-0.0047288	0.013284
Chisq	20.024	NA
R	0.99999	NA

y = m1+T1(2.2951,1.8802,m2,m...

	Value	Error
m1	41.075	0.0017732
m2	-32.244	0.0030724
m3	5.9239	0.0029041
m4	-0.64916	0.0027206
m5	0.091088	0.0026679
m6	0.0024104	0.0025009
m7	-0.013718	0.0024517
m8	0.0075519	0.0021446
m9	0.010932	0.0021508
Chisq	0.44052	NA
R	1	NA

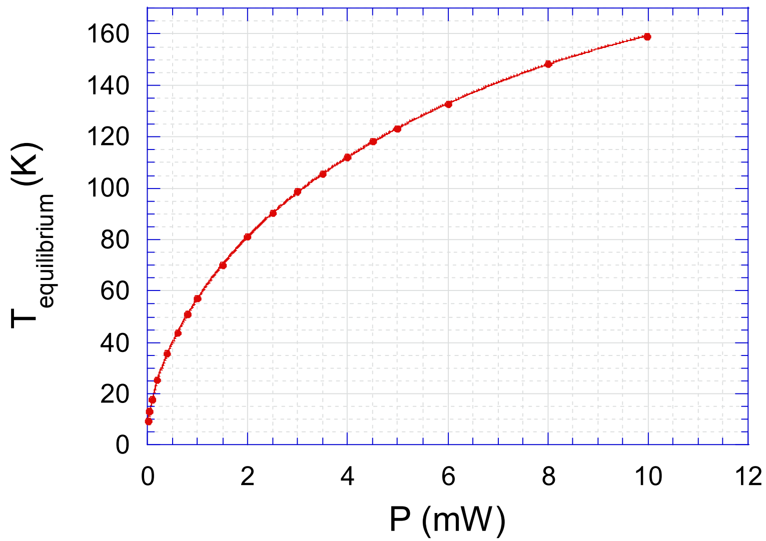
y = m1+T1(2.888,2.2951,m2,m0...

	Value	Error
m1	5.9165	0.00070635
m2	-5.8189	0.0012512
m3	1.9052	0.001078
m4	-0.4488	0.00097865
m5	0.086414	0.00091565
m6	-0.0035135	0.00086844
m7	-0.0005853	0.00082291
m8	-0.0018692	0.0007321
m9	-0.0012941	0.00065539
Chisq	0.0041611	NA
R	1	NA

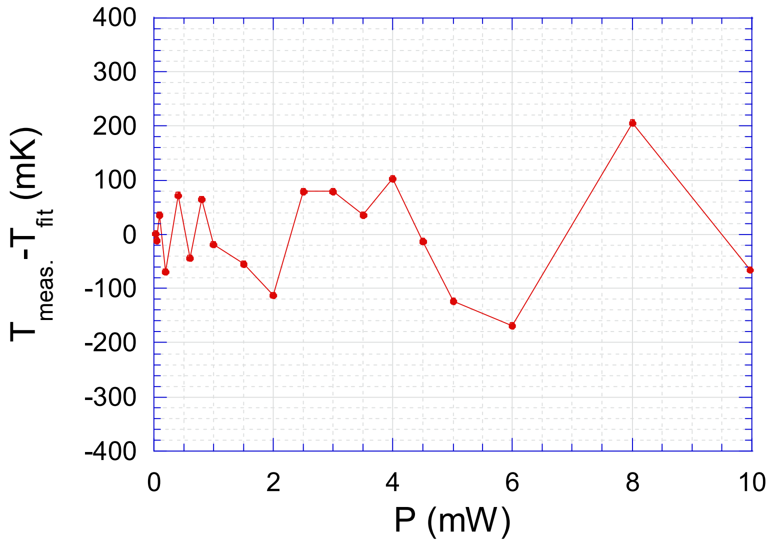
Temperature vs power calibration

The equilibrium temperature achieved for each source as a function of applied power is presented in this section.
These data were obtained in a cryostat with a liquid Helium heatsink, i.e. a 4.2K SCal base temperature. Therefore the in-orbit equilibrium temperature may vary from these data, according to the Level-1 (SPIRE Optical Bench - SOB) temperature.
For each source, the power calibration data are presented, together with a Chebychev polynomial fit to the data.
Typical times to reach equilibrium, for certain constant applied powers, are also shown.

SCal– 4% prime source – power calibration



The line is the Chebychev Fit to the data

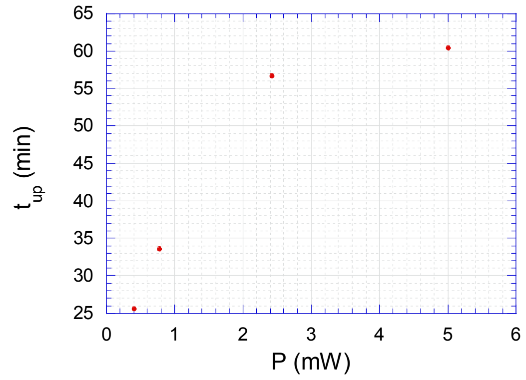


Difference between values derived using fit and data points

fit equation	coefficient	error
$$T(P)=\sum_{0}^{9} m_i \cos\left[i\cdot\cos^{-1}\left(\frac{(PU-\log P)-(\log P-PL)}{PU-PL}\right)\right]$$ PU = 0.9991 PL = -1.6021	m1 = 63.164	0.045792
	m2 = 72.736	0.071229
	m3 = 22.551	0.063424
	m4 = 2.7334	0.050699
	m5 = -0.93589	0.042519
	m6 = -0.6317	0.044712
	m7 = -0.25804	0.057828
	m8 = 0.097062	0.062944
	m9 = -0.16928	0.055977

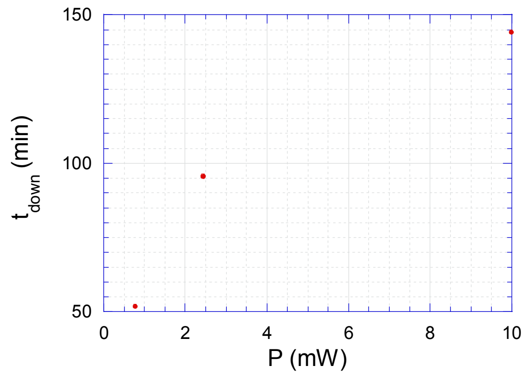
SCal– 4% prime source – Time response

Warming



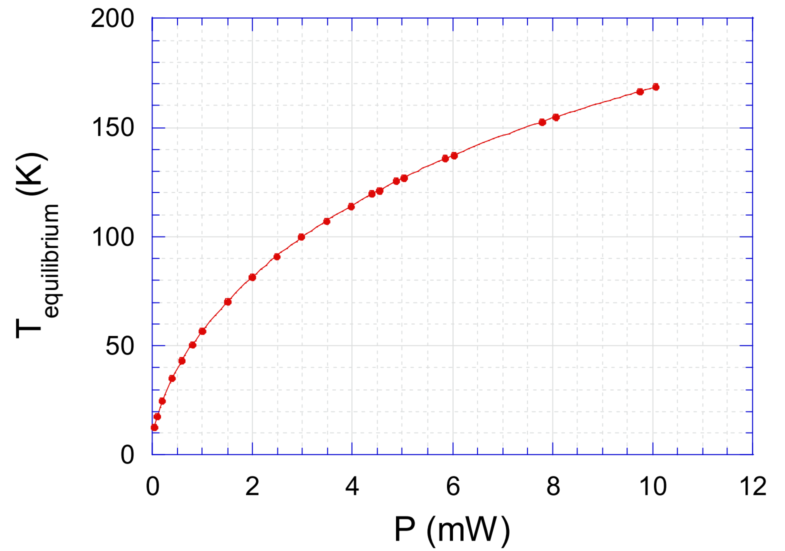
P (mW)	$time_{warm-up}$ (min)
0.400	25.58
0.774	33.57
2.424	56.70
5	60.45

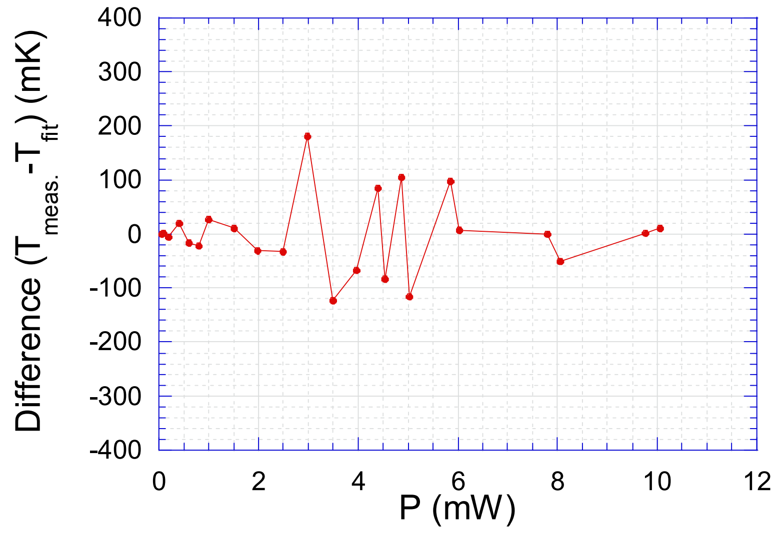
Cooling



P (mW)	$time_{cool-down}$ (min)
0.774	51.97
2.424	95.58
9.980	144.30

SCal– 2% prime source



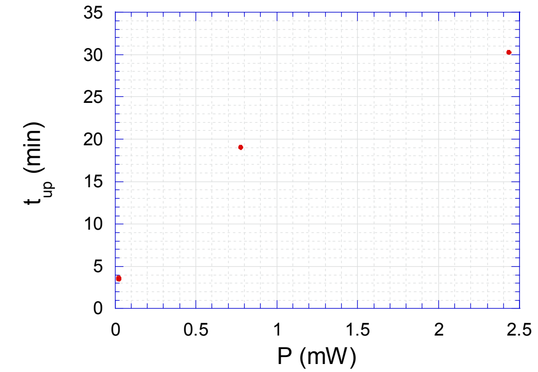


The line is the Chebychev Fit to the data	Difference between values derived using fit and data points

fit equation	coefficient	error
$T(P)=\sum_{0}^{9} m_i \cos\left[i\cdot\cos^{-1}\left(\frac{(\log P-PL)-(PU-\log P)}{PU-PL}\right)\right]$ PU = 1.0024 PL = -1.3109	m1 = 69.527	0.041256
	m2 = 75.69	0.068996
	m3 = 21.765	0.058256
	m4 = 2.5715	0.041003
	m5 = -0.72045	0.028792
	m6 = -0.37803	0.038444
	m7 = 0.017292	0.055935
	m8 = 0.037832	0.060874
	m9 = 0.022366	0.04554

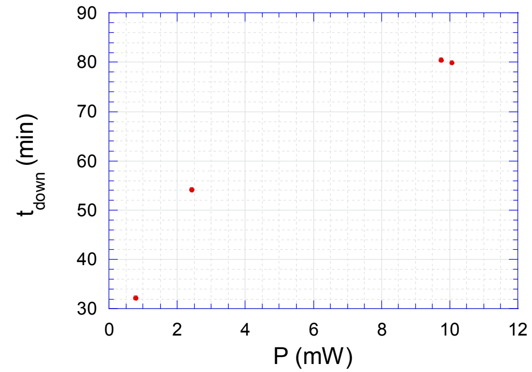
SCal– 2% prime source – Time response

Warming



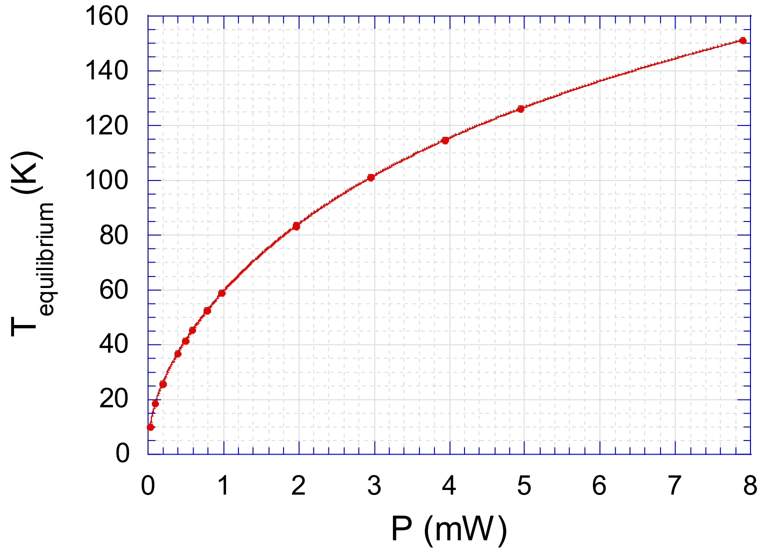
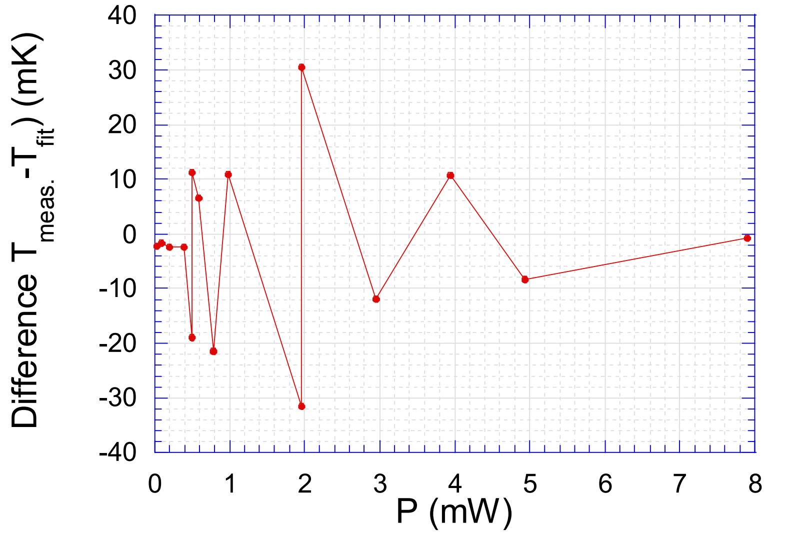
P (mW)	$time_{warm-up}$ (min)
0.024	3.467
0.024	3.675
0.776	19.045
2.432	30.32

Cooling



P (mW)	$time_{cool-down}$ (min)
0.776	32.15
2.432	54.18
9.757	80.51
10.055	79.87

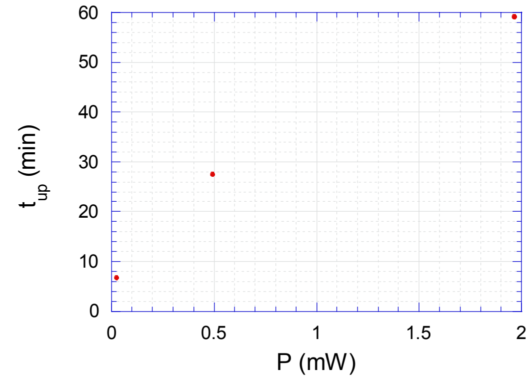
SCal– 4% redundant source

	
The line is the Chebychev Fit to the data	Difference between values derived using fit and data points

fit equation	coefficient	error
$$T(P) = \sum_{0}^{9} m_i \cos\left[i \cdot \cos^{-1}\left(\frac{(\log P - PL) - (PU - \log P)}{PU - PL}\right)\right]$$ PU = 0.8972 PL = -1.6159	m1 = 60.168	0.14263
	m2 = 68.205	0.23435
	m3 = 20.838	0.14169
	m4 = 2.8534	0.012794
	m5 = -0.58275	0.093839
	m6 = -0.41683	0.14872
	m7 = 0.00032901	0.14523
	m8 = 0.047701	0.093517
	m9 = 0.037595	0.047889

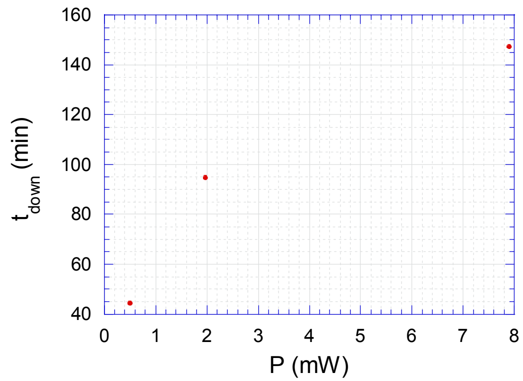
SCal– 4% redundant source – Time response

Warming



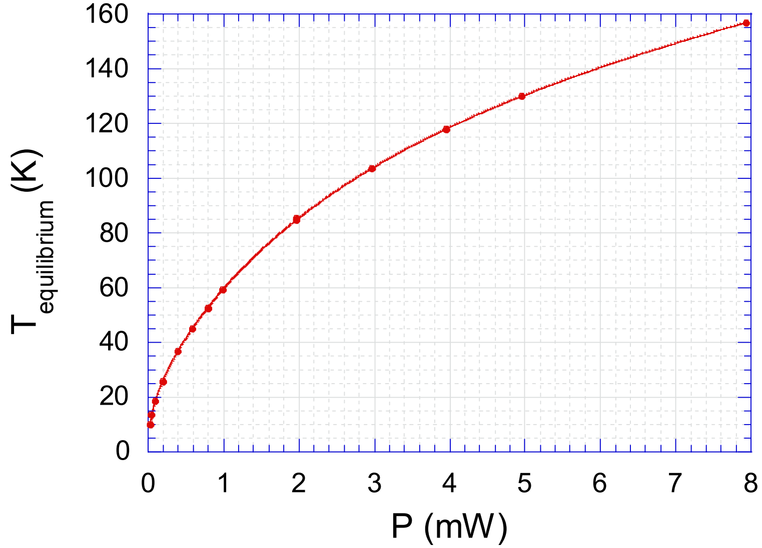
P (mW)	$time_{warm-up}$ (min)
0.023	6.74
0.492	27.61
1.965	59.19

Cooling

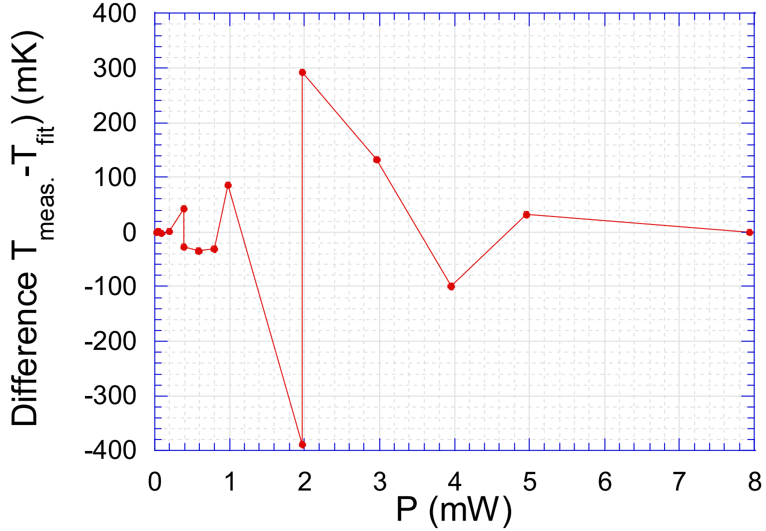


P (mW)	$time_{cool-down}$ (min)
0.492	44.46
1.965	94.76
7.893	147.34

SCal– 2% redundant source



The line is the Chebychev Fit to the data

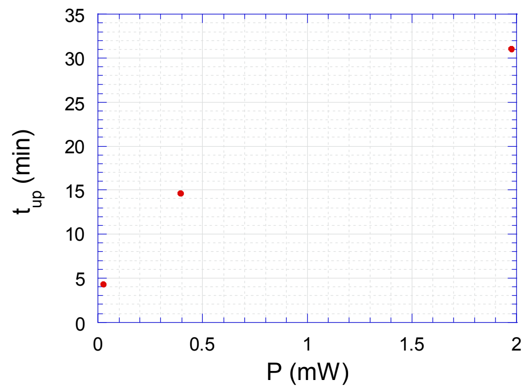


Difference between values derived using fit and data points

fit equation	coefficient	error
$T(P)=\sum_{0}^{9} m_i \cos\left[i \cdot \cos^{-1}\left(\frac{(\log P - PL)-(PU-\log P)}{PU-PL}\right)\right]$	m1 = 61.551	0.10638
	m2 = 70.52	0.14104
	m3 = 22.318	0.14428
	m4 = 3.3467	0.095438
	m5 = -0.64679	0.080251
PU = 0.8994	m6 = -0.49679	0.087555
PL = -1.6141	m7 = 0.023365	0.12297
	m8 = 0.10975	0.12033
	m9 = 0.095858	0.1425

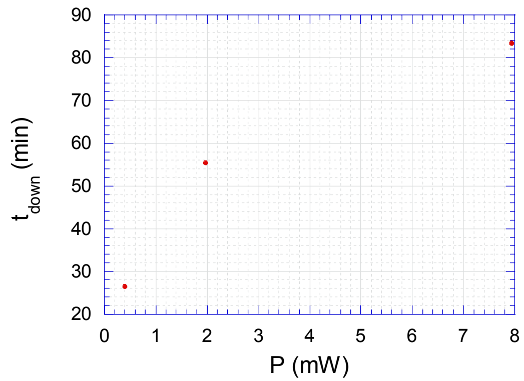
SCal– 2% redundant source – Time response

Warming



P (mW)	$time_{warm-up}$ (min)
0.024	4.31
0.395	14.65
1.975	31.07

Cooling



P (mW)	$time_{cool-down}$ (min)
0.395	26.56
1.974	55.39
7.932	83.41

SECTION 21 - Temporary Installation Record

See sections 14 & 15.

SECTION 22 - Open Work / Deferred Work / Open Tests

Optimisation of enhanced warm-up procedure. This will be done using SCal-FS and the SCal thermal model.

SECTION 23 - List of Non-Conformance Reports

None.

SECTION 24 - Copies of Non-Conformance Reports

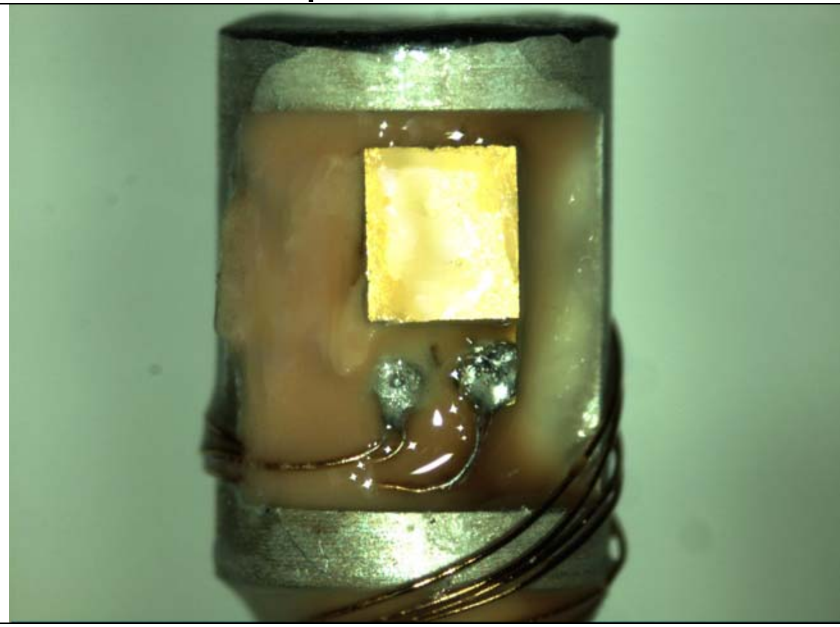
N/A

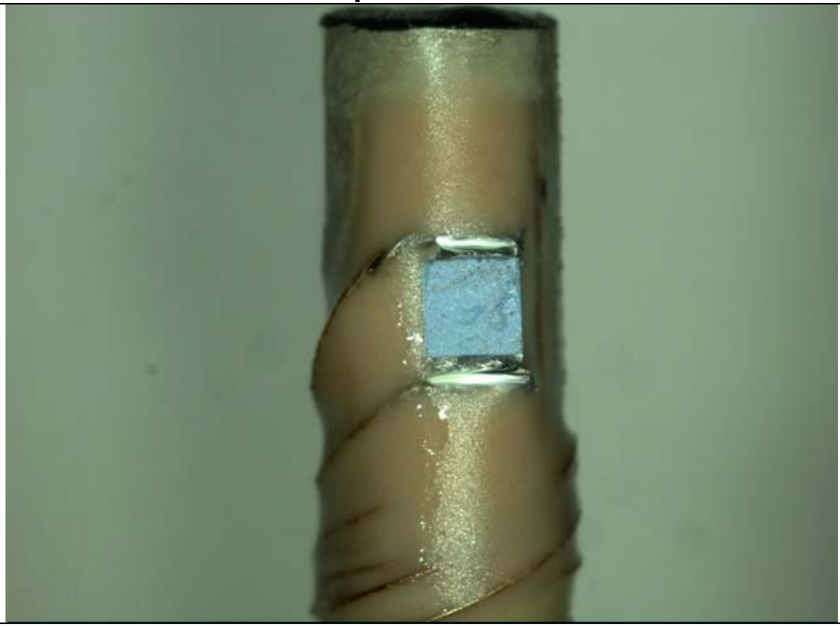
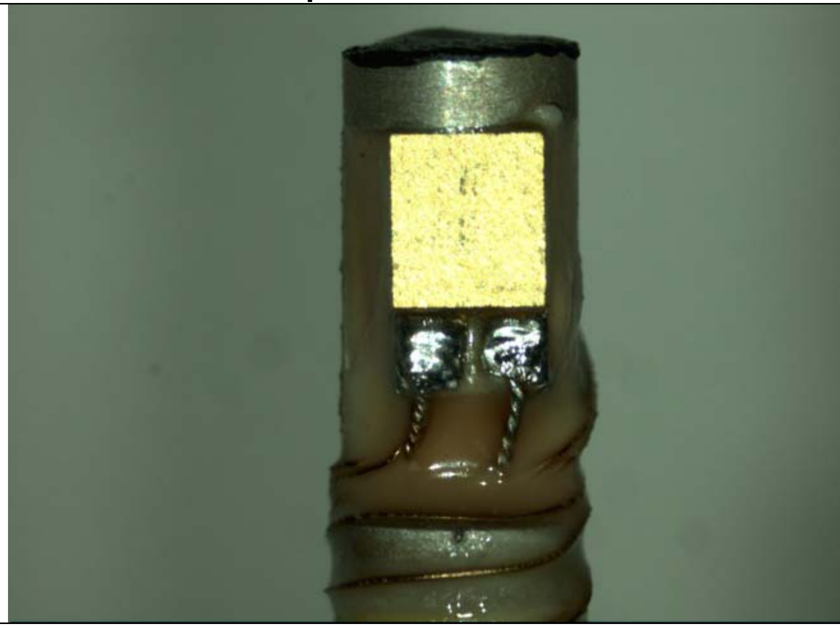
SECTION 25 - Test Reports

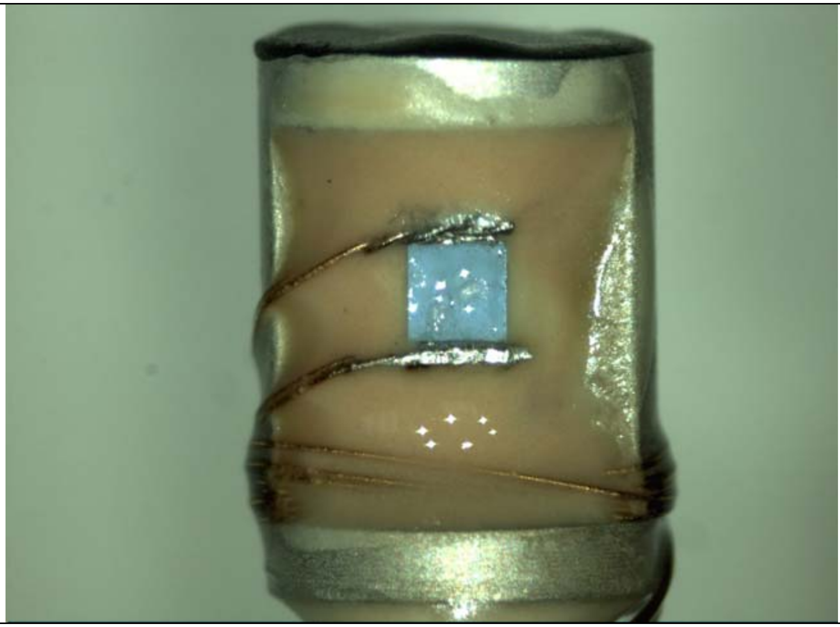
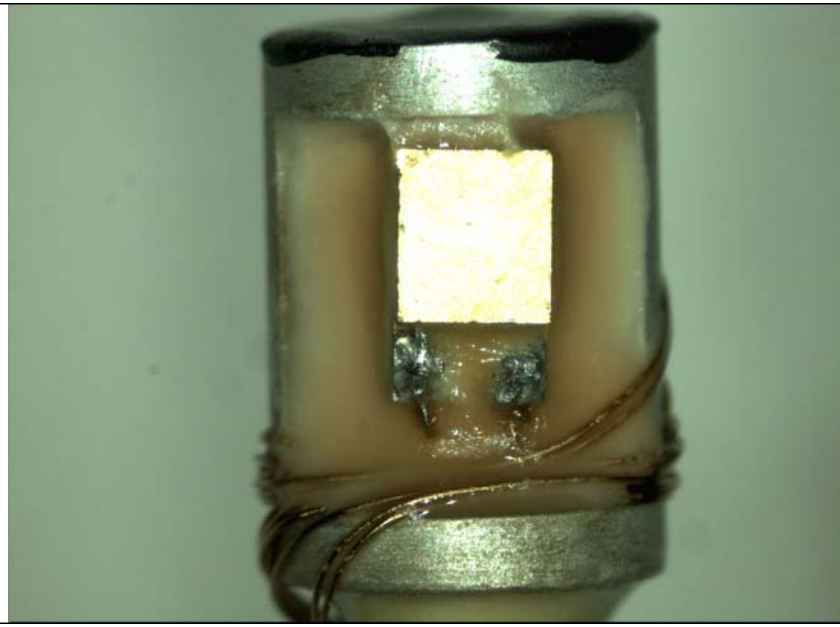
See appendices.

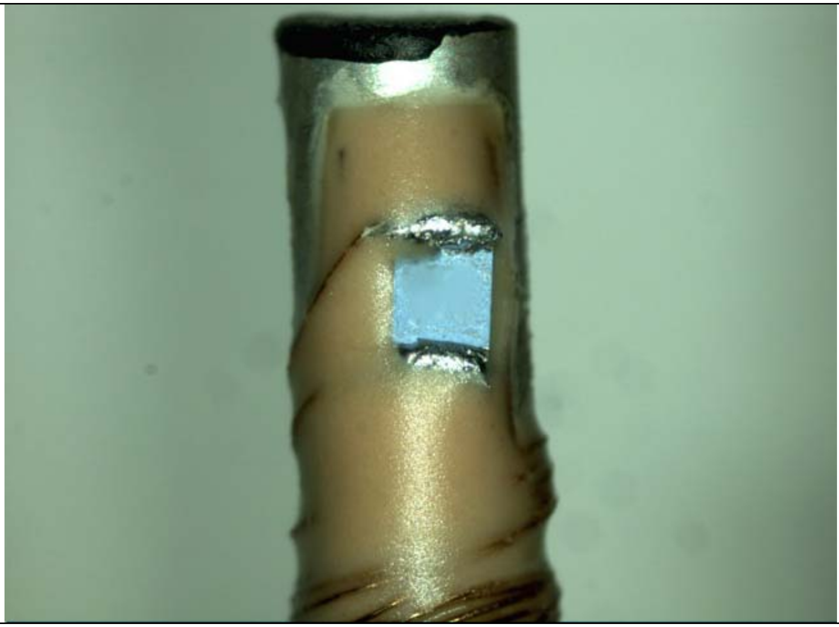
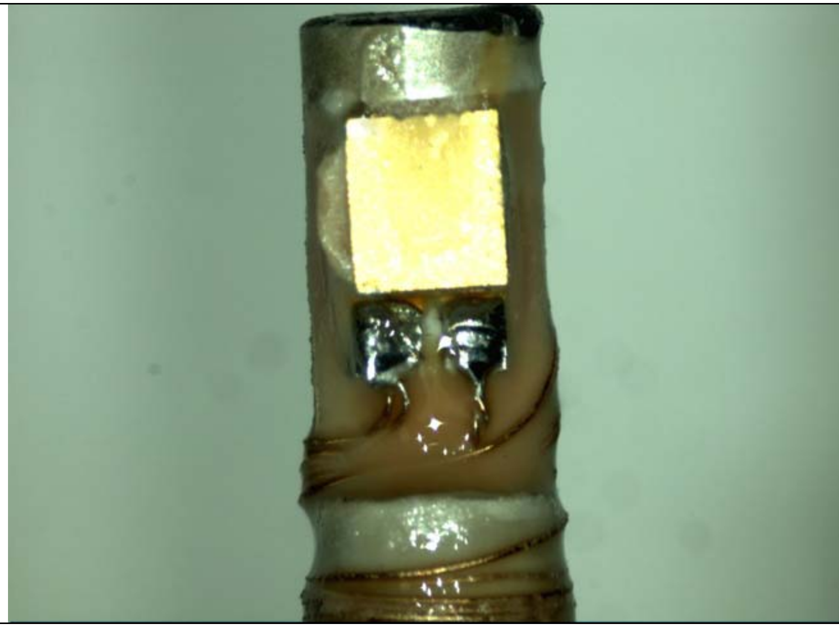
SECTION 26 – Assembly Record

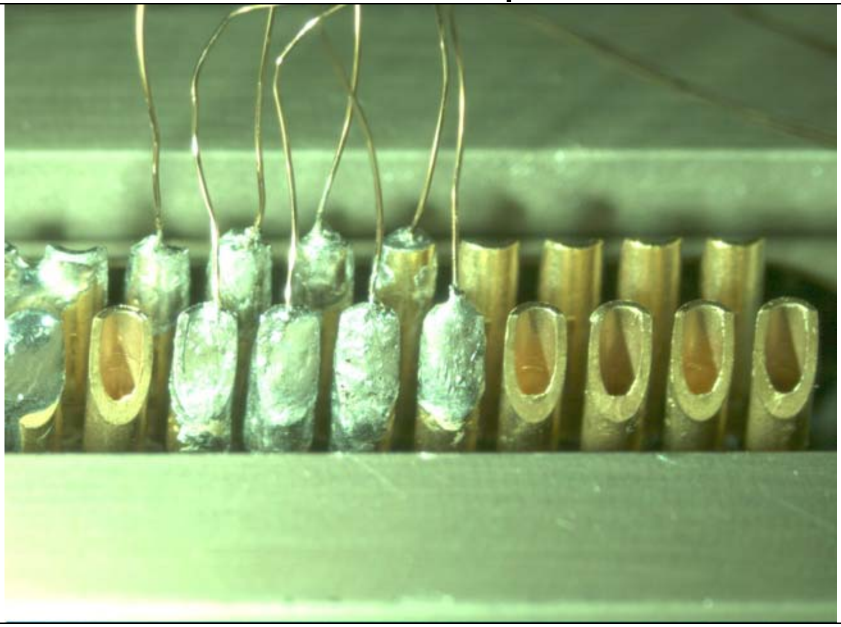
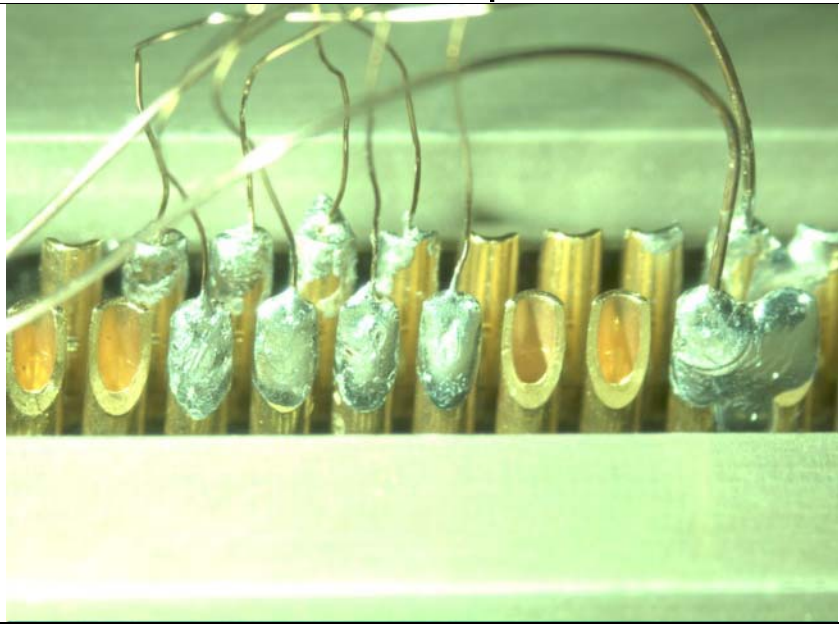
This section contains photographic records of the source assembly and connector wiring.

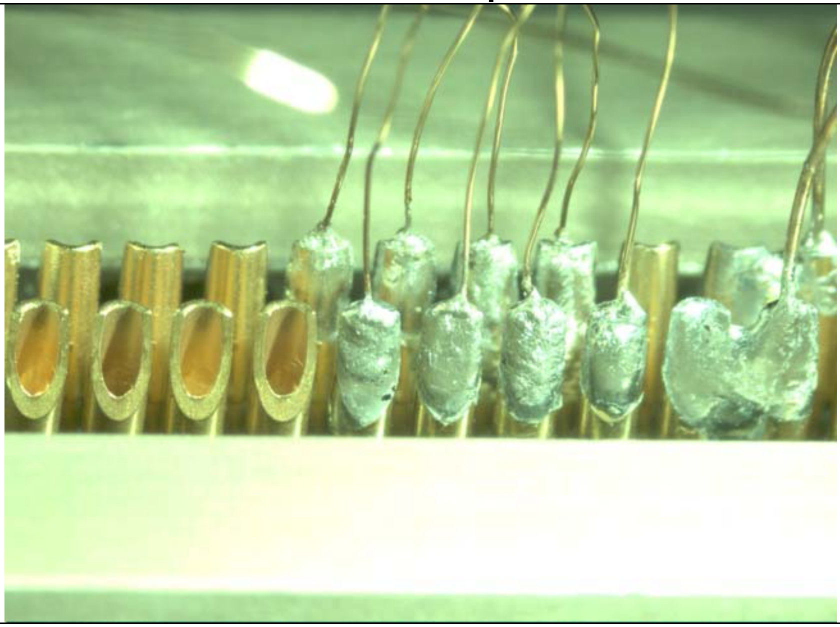
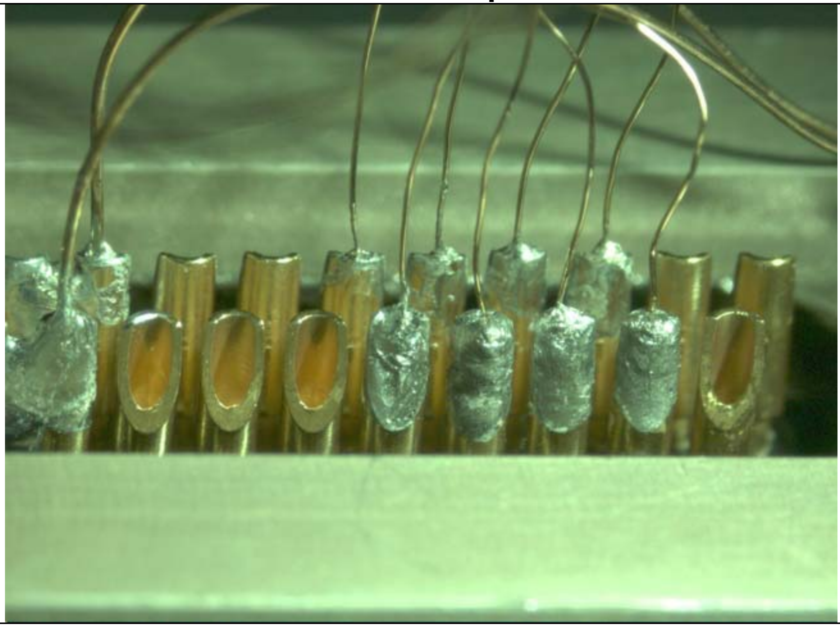
4% prime heater	4% prime thermometer
	

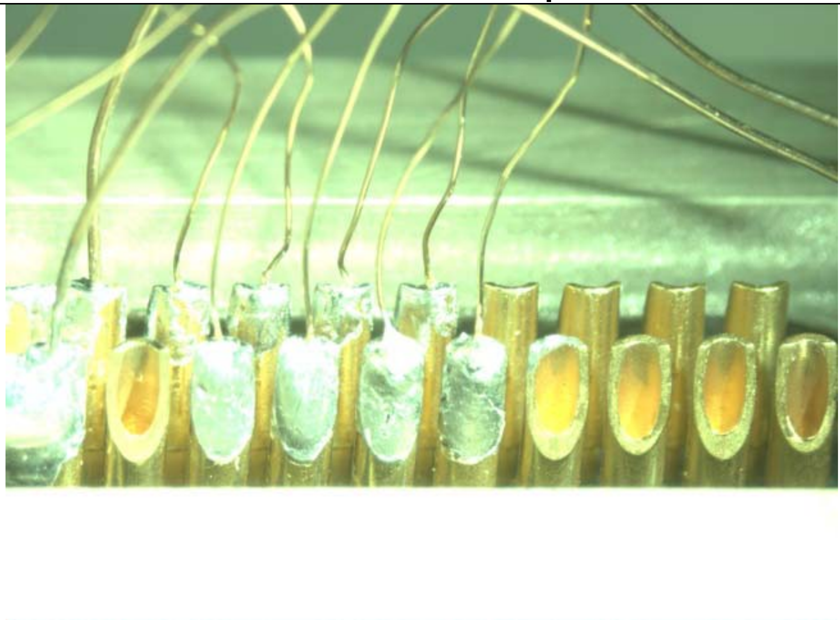
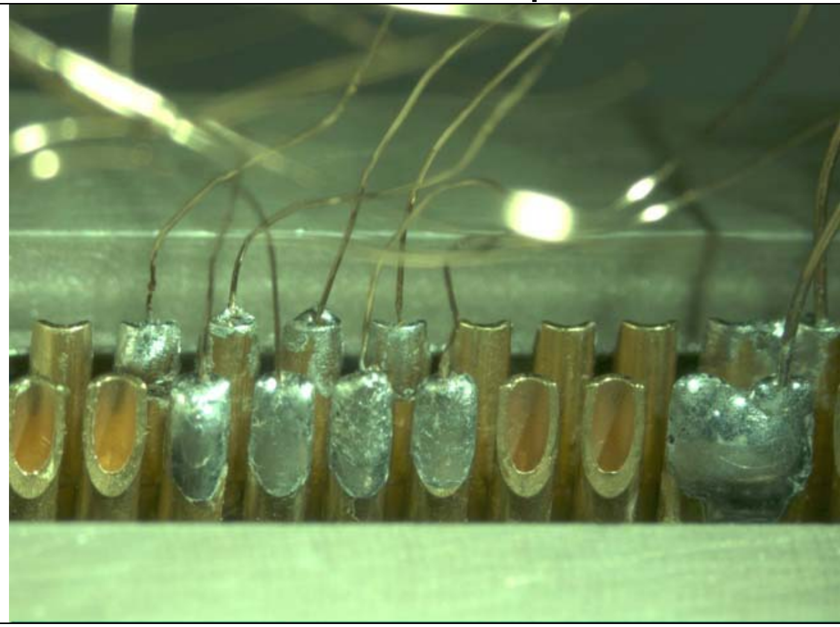
2% prime heater	2% prime thermometer
	

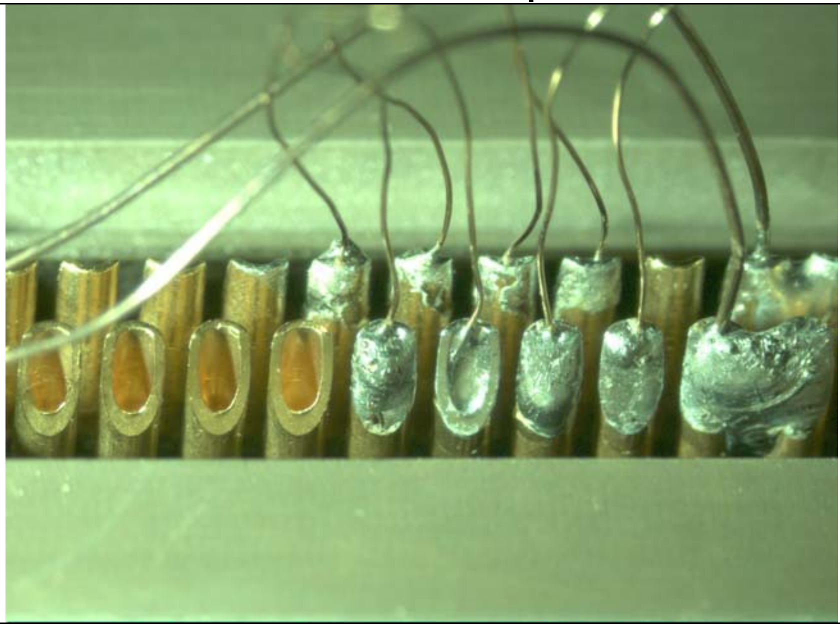
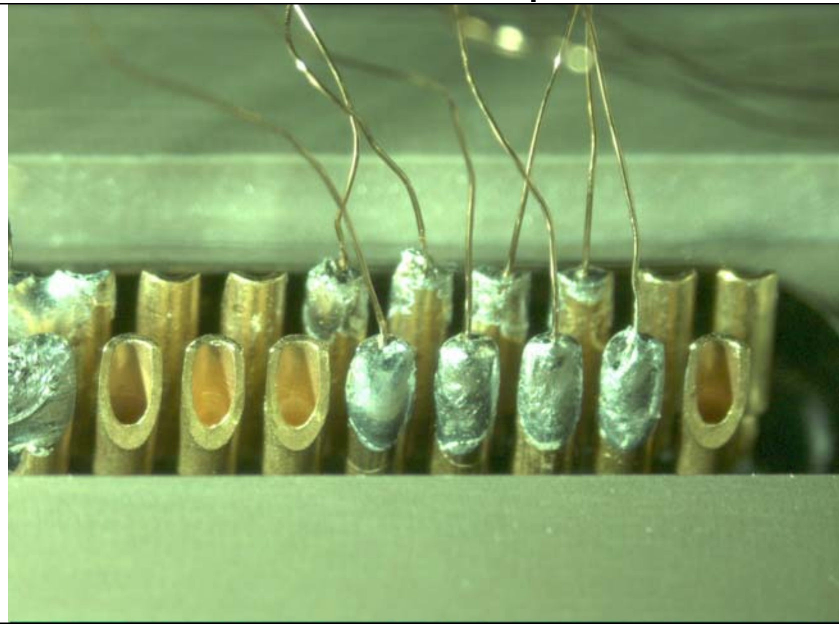
4% redundant heater	4% redundant thermometer
	

2% redundant heater	2% redundant thermometer
	

Prime connector – pins 1-9	Prime connector – pins 10-19
	

Prime connector – pins 20-29	Prime connector – pins 30-37
	

Redundant connector – pins 1-9	Redundant connector – pins 10-19
	

Redundant connector – pins 20-29	Redundant connector – pins 30-37
	

SECTION 27 - Reference List of EIDP's

Associated

Title (Listed in alphabetical order)	**ID** (Serial No.)	**Acronym**	**Document No.**	**Issue**	**Date**

Lower Level

Title (Listed in alphabetical order)	**ID** (Serial No.)	**Acronym**	**Document No.**	**Issue**	**Date**

SECTION 28 - Mass Records

Assembly	Final measured mass
SCAL-PFM-000	

SECTION 29 - Cleanliness Statement – this will be digitally signed once DRB approved version is PDF'd

Statement

The PFM Spectrometer Calibration Source assembly (SCAL-PFM-000) has been cleaned, assembled and tested within a class 1000 clean room to meet the requirements of the Cardiff PA plan (HSO-CDF-PL-007).

Signed ………………………………………….Peter Hargrave, Technical Manager, Cardiff-SPIRE deliverables.

Signed ………………………………………….Ian Walker, Programme Manager, Cardiff AIG.

Date ……………..

Extra Information

A dedicated Herschel-Planck clean room is available in the Cardiff AIG labs, class 1 000, with class 100 laminar flow cabinets.

For cooldown tests (thermal cycles) the PFM assembly was integrated to the Cardiff test dewar within the clean room annex (approx. Class 10,000 – exposure ~15 minutes per thermal cycle).

The PFM assembly was also integrated to the RAL cold vibration test facility. For the duration of this test, the Scal-PFM assembly was kept in a sealed bag with vent holes.

SECTION 30 - Other Useful Information

SECTION 31 - DPL/DML

Refer to the Cardiff-SPIRE PFM deliverables lists.

Cardiff-SPIRE-DML	HSO-CDF-LI-074
Cardiff-SPIRE-DMPL	HSO-CDF-LI-075
Cardiff-SPIRE-DPL	HSO-CDF-LI-076

SECTION 32 – List of Appendices/Attachments

Appendix #	Title (Listed in alphabetical order)	Document No.	Issue	Date	Notes
A	Thermometer Calibration Reports	Calibration Report_CX28264.doc Calibration Report_CX28265.doc X29754.pdf X29756.pdf X29758.pdf X29761.pdf			
B	Report from Cryogenic Vibration Tests	HSO-CDF-RP-078			**Will be added/modified in time for DRB**
C	SCal-B Calibration Report	HSO-CDF-RP-080			
D	SCal Lifetest Report	HSO-CDF-RP-081			
E	SCal Lifetest procedure & record	HSO-CDF-PR-082			
F	SCal enhanced warm-up test report	HSO-CDF-RP-083			

Appendix A

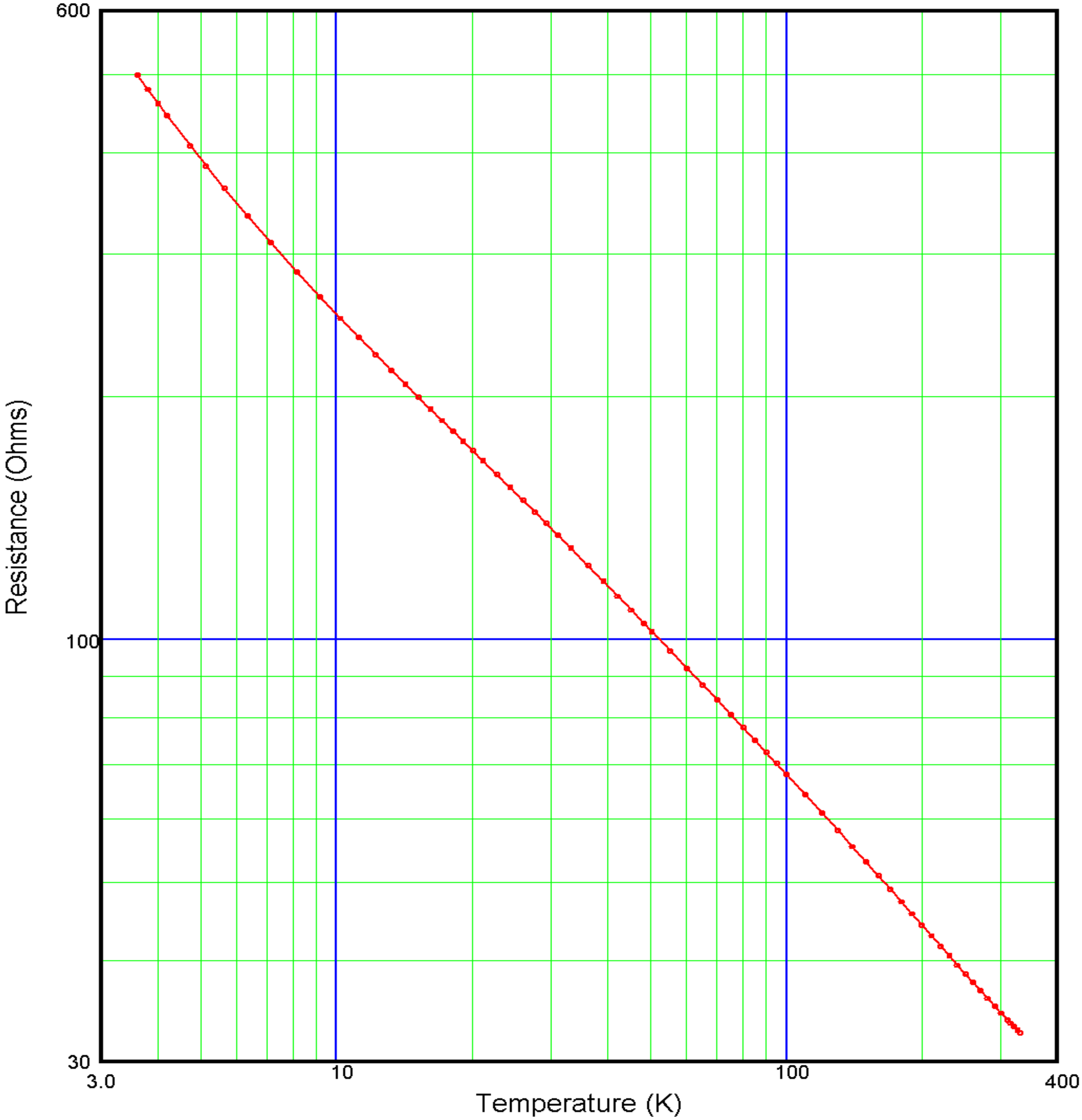
Thermometer Calibration Reports

X29754
SCAL-B 4% prime thermometer

DATA PLOT

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%



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

TEST DATA

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%

Index	Temperature (K)	Resistance (Ω)	Index	Temperature (K)	Resistance (Ω)
1	3.60593	499.991	41	75.1487	80.7769
2	3.80499	479.519	42	80.1400	77.7497
3	4.00700	460.937	43	85.1343	75.0063
4	4.20193	444.764	44	90.1253	72.4999
5	4.72442	408.437	45	95.1235	70.1935
6	5.12389	385.651	46	100.113	68.0643
7	5.62757	361.615	47	110.213	64.2175
8	6.32918	334.444	48	120.097	60.9446
9	7.13731	309.635	49	130.101	58.0186
10	8.15287	285.154	50	140.106	55.4171
11	9.17435	265.634	51	150.102	53.0881
12	10.1958	249.675	52	160.094	50.9847
13	11.2113	236.383	53	170.083	49.0829
14	12.2193	225.138	54	180.077	47.3503
15	13.2203	215.435	55	190.080	45.7618
16	14.2104	206.966	56	200.079	44.3034
17	15.1980	199.431	57	210.072	42.9641
18	16.1744	192.712	58	220.066	41.7287
19	17.1484	186.609	59	230.079	40.5804
20	18.1223	181.073	60	240.076	39.5189
21	19.0932	175.978	61	250.073	38.5292
22	20.0686	171.250	62	260.080	37.6076
23	21.1462	166.417	63	270.070	36.7475
24	22.7158	160.039	64	280.079	35.9416
25	24.3143	154.171	65	290.072	35.1915
26	25.9523	148.723	66	300.077	34.4808
27	27.5894	143.759	67	310.074	33.8149
28	29.2320	139.205	68	315.079	33.4972
29	31.0577	134.567	69	320.092	33.1898
30	33.1808	129.643	70	326.095	32.8385
31	36.1881	123.439	71	330.089	32.5963
32	39.1894	117.960			
33	42.1831	113.091			
34	45.1829	108.709			
35	48.1704	104.760			
36	50.1691	102.317			
37	55.1561	96.8279			
38	60.1600	92.0401			
39	65.1554	87.8415			
40	70.1533	84.1076			

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POLYNOMIAL EQUATION

Calibration Report: 429014
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29754
Sensor Type: Cernox Resistor
Sensor Excitation: 2mV±50%
Temperature Range: 4.00K to 325K

Polynomial Type: Chebychev
Useful Range of Fit:

4.00K	to	24.3K
461.6 Ohms	to	154.2 Ohms

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

ZL = 2.15763494798   ZU = 2.69896237717

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	12.254978	3.1570E-04	38818.89
1	-11.369745	4.8882E-04	-23259.49
2	3.284991	4.7026E-04	6985.50
3	-0.627410	4.4411E-04	-1412.74
4	0.060038	4.3313E-04	138.61
5	0.004666	4.2033E-04	11.10
6	-0.001746	4.0342E-04	-4.33

Z = Log(resistance)

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

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

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POLYNOMIAL EQUATION

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	499.9912	3.60593	3.60577	0.16
2	479.5185	3.80499	3.80493	0.06
3	460.9372	4.00700	4.00716	-0.16
4	444.7643	4.20193	4.20263	-0.70
5	408.4369	4.72442	4.72354	0.88
6	385.6510	5.12389	5.12382	0.07
7	361.6149	5.62757	5.62752	0.04
8	334.4439	6.32918	6.32965	-0.48
9	309.6347	7.13731	7.13766	-0.35
10	285.1535	8.15287	8.15221	0.67
11	265.6342	9.17435	9.17349	0.86
12	249.6747	10.19583	10.19614	-0.31
13	236.3825	11.21131	11.21352	-2.21
14	225.1382	12.21933	12.22034	-1.01
15	215.4350	13.22032	13.21958	0.74
16	206.9665	14.21038	14.20868	1.69
17	199.4308	15.19803	15.19565	2.38
18	192.7116	16.17444	16.17308	1.37
19	186.6091	17.14841	17.15113	-2.72
20	181.0726	18.12232	18.12204	0.28
21	175.9776	19.09320	19.09381	-0.62
22	171.2500	20.06857	20.06975	-1.18
23	166.4174	21.14615	21.14886	-2.70
24	160.0388	22.71581	22.71381	2.00
25	154.1708	24.31426	24.31259	1.68
26	148.7234	25.95234	25.95144	0.90
27	143.7590	27.58941	27.59075	-1.34

Order of Fit = 6 RMS error of fit = 1.30 mK
Largest absolute error = -2.72 mK at data point no. 19

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POLYNOMIAL EQUATION

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%

Polynomial Type: Chebychev
Useful Range of Fit:

24.3K	to	110.K
154.2 Ohms	to	64.22 Ohms

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

ZL = 1.76356705864 ZU = 2.22119864033

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	64.603642	1.4372E-03	44950.22
1	-53.055603	2.3370E-03	-22701.98
2	10.917440	2.1325E-03	5119.67
3	-1.428942	1.9505E-03	-732.61
4	0.101529	1.8305E-03	55.46
5	0.010150	1.8199E-03	5.58

Z = Log(resistance)

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

Temp. (K) = ΣA_i* COS(i * ARCCOS(X)), where 0 <= i <= 5
and the A_i's are the coefficients in the table above.

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POLYNOMIAL EQUATION

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
23	166.4174	21.14886	21.14822	0.64
24	160.0388	22.71381	22.71331	0.49
25	154.1708	24.31259	24.31261	-0.03
26	148.7234	25.95234	25.95179	0.55
27	143.7590	27.58941	27.59165	-2.23
28	139.2050	29.23199	29.23356	-1.57
29	134.5666	31.05770	31.05804	-0.34
30	129.6430	33.18080	33.18463	-3.83
31	123.4387	36.18806	36.18614	1.92
32	117.9604	39.18941	39.18639	3.02
33	113.0907	42.18306	42.17880	4.27
34	108.7092	45.18285	45.17697	5.88
35	104.7596	48.17036	48.16654	3.83
36	102.3166	50.16910	50.16945	-0.35
37	96.82788	55.15610	55.16312	-7.02
38	92.04011	60.15999	60.17119	-11.21
39	87.84152	65.15540	65.16325	-7.85
40	84.10762	70.15334	70.15963	-6.29
41	80.77691	75.14867	75.13214	16.53
42	77.74968	80.14005	80.13768	2.37
43	75.00634	85.13433	85.13001	4.32
44	72.49995	90.12526	90.12013	5.14
45	70.19349	95.12350	95.11850	5.00
46	68.06431	100.11258	100.11821	-5.63
47	64.21751	110.21260	110.22508	-12.47
48	60.94458	120.09683	120.09568	1.15
49	58.01858	130.10071	130.09701	3.71

Order of Fit = 5 RMS error of fit = 5.87 mK
Largest absolute error = 16.53 mK at data point no. 41

POLYNOMIAL EQUATION

Calibration Report: 429014
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29754
Sensor Type: Cernox Resistor
Sensor Excitation: 2mV±50%
Temperature Range: 4.00K to 325K

Polynomial Type: Chebychev
Useful Range of Fit:

110.K	to	325.K
64.22 Ohms	to	32.90 Ohms

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

ZL = 1.51316896149 ZU = 1.8462968374

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	194.449534	7.3511E-03	26451.87
1	-114.932390	1.1302E-02	-10168.85
2	17.711031	1.0232E-02	1731.02
3	-2.502760	9.9620E-03	-251.23
4	0.462651	9.8717E-03	46.87
5	-0.083066	9.6885E-03	-8.57

Z = Log(resistance)

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

Temp. (K) = ΣA_i* COS(i * ARCCOS(X)), where 0 <= i <= 5
and the A_i's are the coefficients in the table above.

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POLYNOMIAL EQUATION

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
45	70.19349	95.11850	95.10500	13.50
46	68.06431	100.11821	100.13120	-12.99
47	64.21751	110.22508	110.24065	-15.57
48	60.94458	120.09683	120.09526	1.57
49	58.01858	130.10071	130.08963	11.09
50	55.41712	140.10566	140.09055	15.12
51	53.08806	150.10187	150.08883	13.04
52	50.98471	160.09420	160.10459	-10.39
53	49.08292	170.08252	170.09238	-9.86
54	47.35033	180.07714	180.07869	-1.55
55	45.76180	190.07998	190.08755	-7.57
56	44.30336	200.07943	200.09897	-19.54
57	42.96412	210.07180	210.08302	-11.21
58	41.72875	220.06649	220.05657	9.92
59	40.58044	230.07864	230.07241	6.23
60	39.51887	240.07554	240.05350	22.04
61	38.52916	250.07283	250.06239	10.44
62	37.60759	260.07957	260.06703	12.55
63	36.74753	270.06965	270.06998	-0.34
64	35.94159	280.07885	280.09356	-14.71
65	35.19149	290.07200	290.04961	22.39
66	34.48083	300.07704	300.09871	-21.66
67	33.81489	310.07357	310.11513	-41.56
68	33.49720	315.07921	315.11465	-35.44
69	33.18976	320.09166	320.09743	-5.77
70	32.83850	326.09518	325.97286	122.31
71	32.59635	330.08939	330.14143	-52.04

Order of Fit = 5 RMS error of fit = 30.22 mK
Largest absolute error = 122.31 mK at data point no. 70

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INTERPOLATION TABLE

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT	Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
4.000	461.561	-87.307	-0.75663	37.00	121.887	-1.8751	-0.56921
4.200	444.971	-78.824	-0.74401	38.00	120.049	-1.8017	-0.57029
4.400	429.951	-71.556	-0.73228	39.00	118.282	-1.7328	-0.57133
4.600	416.284	-65.267	-0.72122	40.00	116.582	-1.6680	-0.57231
4.800	403.786	-59.838	-0.71133	42.00	113.367	-1.5496	-0.57409
5.000	392.305	-55.079	-0.70199	44.00	110.375	-1.4441	-0.57569
5.200	381.716	-50.893	-0.69330	46.00	107.583	-1.3498	-0.57714
5.400	371.916	-47.179	-0.68501	48.00	104.970	-1.2650	-0.57843
5.600	362.817	-43.882	-0.67731	50.00	102.518	-1.1885	-0.57966
5.800	354.340	-40.942	-0.67015	52.00	100.211	-1.1192	-0.58077
6.000	346.421	-38.290	-0.66318	54.00	98.0364	-1.0562	-0.58178
6.500	328.718	-32.758	-0.64775	56.00	95.9822	-0.99890	-0.58280
7.000	313.472	-28.396	-0.63409	58.00	94.0376	-0.94643	-0.58373
7.500	300.174	-24.914	-0.62248	60.00	92.1936	-0.89834	-0.58464
8.000	288.454	-22.065	-0.61195	65.00	87.9709	-0.79422	-0.58683
8.500	278.023	-19.728	-0.60316	70.00	84.2205	-0.70861	-0.58896
9.000	268.664	-17.766	-0.59515	75.00	80.8610	-0.63729	-0.59109
9.500	260.204	-16.115	-0.58837	77.35	79.3985	-0.60779	-0.59211
10.00	252.509	-14.702	-0.58222	80.00	77.8290	-0.57715	-0.59325
10.50	245.469	-13.490	-0.57702	85.00	75.0746	-0.52594	-0.59547
11.00	238.994	-12.435	-0.57232	90.00	72.5578	-0.48187	-0.59770
11.50	233.011	-11.515	-0.56832	95.00	70.2460	-0.44377	-0.60015
12.00	227.461	-10.704	-0.56472	100.0	68.1127	-0.41007	-0.60204
12.50	222.291	-9.9883	-0.56167	105.0	66.1389	-0.38025	-0.60367
13.00	217.459	-9.3497	-0.55893	110.0	64.3028	-0.35491	-0.60714
13.50	212.930	-8.7795	-0.55663	115.0	62.5847	-0.33260	-0.61115
14.00	208.671	-8.2661	-0.55458	120.0	60.9743	-0.31182	-0.61367
14.50	204.655	-7.8033	-0.55287	125.0	59.4636	-0.29278	-0.61546
15.00	200.860	-7.3832	-0.55137	130.0	58.0433	-0.27567	-0.61742
15.50	197.265	-7.0016	-0.55014	135.0	56.7042	-0.26017	-0.61941
16.00	193.853	-6.6527	-0.54909	140.0	55.4394	-0.24599	-0.62119
16.50	190.608	-6.3334	-0.54825	145.0	54.2424	-0.23299	-0.62283
17.00	187.516	-6.0398	-0.54756	150.0	53.1077	-0.22106	-0.62437
17.50	184.564	-5.7695	-0.54705	155.0	52.0302	-0.21007	-0.62581
18.00	181.743	-5.5196	-0.54666	160.0	51.0056	-0.19991	-0.62709
18.50	179.041	-5.2882	-0.54642	165.0	50.0299	-0.19048	-0.62821
19.00	176.452	-5.0733	-0.54628	170.0	49.0997	-0.18171	-0.62916
19.50	173.966	-4.8734	-0.54627	175.0	48.2118	-0.17354	-0.62993
20.00	171.576	-4.6870	-0.54634	180.0	47.3634	-0.16591	-0.63051
21.00	167.061	-4.3497	-0.54677	185.0	46.5519	-0.15875	-0.63090
22.00	162.863	-4.0532	-0.54751	190.0	45.7751	-0.15204	-0.63108
23.00	158.944	-3.7908	-0.54855	195.0	45.0308	-0.14573	-0.63107
24.00	155.272	-3.5567	-0.54975	200.0	44.3172	-0.13979	-0.63085
25.00	151.822	-3.3470	-0.55114	205.0	43.6324	-0.13418	-0.63044
26.00	148.571	-3.1586	-0.55276	210.0	42.9748	-0.12889	-0.62984
27.00	145.499	-2.9881	-0.55449	215.0	42.3430	-0.12389	-0.62906
28.00	142.590	-2.8325	-0.55621	220.0	41.7355	-0.11915	-0.62809
29.00	139.830	-2.6900	-0.55789	225.0	41.1510	-0.11467	-0.62696
30.00	137.206	-2.5591	-0.55955	230.0	40.5884	-0.11041	-0.62566
31.00	134.708	-2.4384	-0.56114	235.0	40.0466	-0.10637	-0.62422
32.00	132.326	-2.3267	-0.56267	240.0	39.5244	-0.10254	-0.62264
33.00	130.052	-2.2232	-0.56412	245.0	39.0208	-9.8894e-2	-0.62093
34.00	127.877	-2.1270	-0.56552	250.0	38.5351	-9.5428e-2	-0.61910
35.00	125.796	-2.0372	-0.56680	255.0	38.0663	-9.2130e-2	-0.61716
36.00	123.801	-1.9534	-0.56803	260.0	37.6136	-8.8989e-2	-0.61513

INTERPOLATION TABLE

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
265.0	37.1761	-8.5998e-2	-0.61301
270.0	36.7533	-8.3146e-2	-0.61081
273.15	36.4942	-8.1418e-2	-0.60940
275.0	36.3445	-8.0427e-2	-0.60855
280.0	35.9489	-7.7833e-2	-0.60623
285.0	35.5659	-7.5357e-2	-0.60386
290.0	35.1951	-7.2993e-2	-0.60145
295.0	34.8358	-7.0735e-2	-0.59900
300.0	34.4876	-6.8576e-2	-0.59653
305.0	34.1499	-6.6513e-2	-0.59404
310.0	33.8223	-6.4539e-2	-0.59153
315.0	33.5044	-6.2650e-2	-0.58902
320.0	33.1957	-6.0842e-2	-0.58650
325.0	32.8958	-5.9110e-2	-0.58398

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THERMAL CYCLE TESTING

Sensor Model: CX-1030-SD-HT-4L   Serial Number: X29754
Sensor Type: Cernox Resistor

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:

Room Temperature:	34.1Ω
Liquid Nitrogen:	79.4Ω
Liquid Helium:	444Ω

The nitrogen and helium values were recorded in OPEN dewars, so precision comparisons with calibration values or other dip 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 at the values listed below. In order to minimize possible self-heating errors, we suggest that these same guidelines be followed in using the sensor:

Above 1K:	1 to 3 mV
0.1 to 1K:	0.1 mV
Below 0.1K:	0.03 mV

Lead Identification:

NONE

To avoid possible damage to the sensor, do not exceed 1 Volt and do not exceed 100 mA current.

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BREAKPOINTS 340 FORMAT

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754

Name: CX-1030-SD-HT-4L
Serial number: X29754
Format: 4 ;Log Ohms/Kelvin
Limit: 325.
Coefficient: 1 ;Negative

Point 1: 1.51713,325.000
Point 2: 1.52187,319.000
Point 3: 1.52632,313.500
Point 4: 1.53086,308.000
Point 5: 1.53551,302.500

Point 6: 1.54026,297.000
Point 7: 1.54513,291.500
Point 8: 1.55011,286.000
Point 9: 1.55521,280.500
Point 10: 1.56043,275.000

Point 11: 1.56529,270.000
Point 12: 1.57026,265.000
Point 13: 1.57534,260.000
Point 14: 1.58053,255.000
Point 15: 1.58585,250.000

Point 16: 1.59129,245.000
Point 17: 1.59685,240.000
Point 18: 1.60256,235.000
Point 19: 1.60839,230.000
Point 20: 1.61437,225.000

Point 21: 1.62049,220.000
Point 22: 1.62677,215.000
Point 23: 1.63320,210.000
Point 24: 1.63980,205.000
Point 25: 1.64656,200.000

Point 26: 1.65350,195.000
Point 27: 1.66062,190.000
Point 28: 1.66792,185.000
Point 29: 1.67467,180.500
Point 30: 1.68158,176.000

Point 31: 1.68867,171.500
Point 32: 1.69593,167.000
Point 33: 1.70338,162.500
Point 34: 1.71103,158.000
Point 35: 1.71888,153.500

Point 36: 1.72695,149.000
Point 37: 1.73526,144.500
Point 38: 1.74380,140.000
Point 39: 1.75162,136.000
Point 40: 1.75964,132.000

Point 41: 1.76789,128.000
Point 42: 1.77638,124.000
Point 43: 1.78513,120.000
Point 44: 1.79415,116.000
Point 45: 1.80345,112.000

Point 46: 1.81304,108.000
Point 47: 1.82169,104.500
Point 48: 1.83060,101.000
Point 49: 1.83717, 98.500
Point 50: 1.84388, 96.000

Point 51: 1.85076, 93.500
Point 52: 1.85780, 91.000
Point 53: 1.86503, 88.500
Point 54: 1.87245, 86.000
Point 55: 1.88008, 83.500

Point 56: 1.88792, 81.000
Point 57: 1.89600, 78.500
Point 58: 1.90264, 76.500
Point 59: 1.90944, 74.500
Point 60: 1.91642, 72.500

Point 61: 1.92359, 70.500
Point 62: 1.93094, 68.500
Point 63: 1.93851, 66.500
Point 64: 1.94629, 64.500
Point 65: 1.95431, 62.500

Point 66: 1.96258, 60.500
Point 67: 1.97067, 58.600
Point 68: 1.97858, 56.800
Point 69: 1.98673, 55.000
Point 70: 1.99514, 53.200

Point 71: 2.00382, 51.400
Point 72: 2.01280, 49.600
Point 73: 2.02209, 47.800
Point 74: 2.03172, 46.000
Point 75: 2.04059, 44.400

Point 76: 2.04975, 42.800
Point 77: 2.05925, 41.200
Point 78: 2.06973, 39.500
Point 79: 2.07998, 37.900
Point 80: 2.08997, 36.400

Point 81: 2.10034, 34.900
Point 82: 2.11113, 33.400
Point 83: 2.12237, 31.900
Point 84: 2.13332, 30.500
Point 85: 2.14472, 29.100

Point 86: 2.15665, 27.700
Point 87: 2.16823, 26.400
Point 88: 2.18033, 25.100
Point 89: 2.19205, 23.900
Point 90: 2.20432, 22.700

Point 91: 2.21723, 21.500
Point 92: 2.22971, 20.400
Point 93: 2.23923, 19.600
Point 94: 2.24723, 18.950
Point 95: 2.25551, 18.300

Point 96: 2.26409, 17.650
Point 97: 2.27301, 17.000
Point 98: 2.28157, 16.400
Point 99: 2.29045, 15.800
Point 100: 2.29969, 15.200

Point 101: 2.30853, 14.650
Point 102: 2.31772, 14.100
Point 103: 2.32731, 13.550
Point 104: 2.33734, 13.000
Point 105: 2.34689, 12.500

Point 106: 2.35687, 12.000
Point 107: 2.36734, 11.500
Point 108: 2.37834, 11.000
Point 109: 2.38877, 10.550
Point 110: 2.39972, 10.100

Point 111: 2.41127, 9.650
Point 112: 2.42349, 9.200
Point 113: 2.43499, 8.800
Point 114: 2.44713, 8.400
Point 115: 2.46002, 8.000

Point 116: 2.47373, 7.600
Point 117: 2.48839, 7.200
Point 118: 2.50212, 6.850
Point 119: 2.51675, 6.500
Point 120: 2.53244, 6.150

Point 121: 2.54833, 5.820
Point 122: 2.56490, 5.500
Point 123: 2.58279, 5.180
Point 124: 2.60095, 4.880
Point 125: 2.61928, 4.600

Point 126: 2.63913, 4.320
Point 127: 2.66081, 4.040
Point 128: 2.66426, 4.000

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BREAKPOINTS 91C/93C/330 FORMAT

Calibration Report: 429014
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29754

Interpolation Method: Lagrangian
Limit: 325. (Kelvin)
Format: 4 (Log Ohms/Kelvin)
Number of Breakpoints: 47

No.	Units	Temperature (K)	No.	Units	Temperature (K)
1	1.51714	325.0	26	2.12088	32.1
2	1.51792	324.0	27	2.14812	28.7
3	1.52510	315.0	28	2.17565	25.6
4	1.53766	300.0	29	2.20332	22.8
5	1.55103	285.0	30	2.23092	20.3
6	1.56530	270.0	31	2.25814	18.1
7	1.58054	255.0	32	2.28599	16.1
8	1.59686	240.0	33	2.31268	14.4
9	1.61438	225.0	34	2.33925	12.9
10	1.63321	210.0	35	2.36738	11.5
11	1.65351	195.0	36	2.39482	10.3
12	1.67544	180.0	37	2.42076	9.3
13	1.69923	165.0	38	2.44718	8.4
14	1.72516	150.0	39	2.47380	7.6
15	1.75362	135.0	40	2.50017	6.9
16	1.78515	120.0	41	2.52566	6.3
17	1.82046	105.0	42	2.54942	5.8
18	1.86068	90.0	43	2.57602	5.3
19	1.90774	75.0	44	2.59980	4.9
20	1.95433	62.5	45	2.62630	4.5
21	1.97994	56.5	46	2.65615	4.1
22	2.01080	50.0	47	2.66423	4.0
23	2.03725	45.0			
24	2.06539	40.2			
25	2.09272	36.0			

Temperature for Resistance Decades:

Res. (Ohms)	Temp. (K)
100	52.188

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BREAKPOINTS 234 FORMAT

Calibration Report: 429014
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29754
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Maximum Temperature Error:	
1.4 - 10K:	0.005K
10 - 20K:	0.010K
20 - 40K:	0.017K
40 - 100K:	0.043K
> 100K:	0.180K

BP #	Temp. (K)	Res. (Ω)	Log10 Res.	BP #	Temp. (K)	Res. (Ω)	Log10 Res.
1	321.366	33.11311	1.520	31	32.216	131.8257	2.120
2	297.312	34.67369	1.540	32	29.678	138.0384	2.140
3	275.450	36.30781	1.560	33	27.322	144.5440	2.160
4	255.514	38.01894	1.580	34	25.140	151.3561	2.180
5	237.237	39.81072	1.600	35	23.121	158.4893	2.200
6	220.408	41.68694	1.620	36	21.256	165.9587	2.220
7	204.854	43.65158	1.640	37	19.538	173.7801	2.240
8	190.437	45.70882	1.660	38	17.959	181.9701	2.260
9	177.029	47.86301	1.680	39	16.509	190.5461	2.280
10	164.532	50.11872	1.700	40	15.182	199.5262	2.300
11	152.879	52.48075	1.720	41	13.969	208.9296	2.320
12	141.996	54.95409	1.740	42	12.861	218.7762	2.340
13	131.830	57.54399	1.760	43	11.849	229.0868	2.360
14	122.341	60.25596	1.780	44	10.929	239.8833	2.380
15	113.475	63.09573	1.800	45	10.091	251.1886	2.400
16	105.179	66.06934	1.820	46	9.328	263.0268	2.420
17	97.443	69.18310	1.840	47	8.634	275.4229	2.440
18	90.237	72.44360	1.860	48	8.002	288.4032	2.460
19	83.530	75.85776	1.880	49	7.428	301.9952	2.480
20	77.296	79.43282	1.900	50	6.904	316.2278	2.500
21	71.498	83.17638	1.920	51	6.427	331.1311	2.520
22	66.115	87.09636	1.940	52	5.992	346.7369	2.540
23	61.121	91.20108	1.960	53	5.594	363.0781	2.560
24	56.486	95.49926	1.980	54	5.230	380.1894	2.580
25	52.189	100.0000	2.000	55	4.897	398.1072	2.600
26	48.204	104.7129	2.020	56	4.591	416.8694	2.620
27	44.508	109.6478	2.040	57	4.310	436.5158	2.640
28	41.081	114.8154	2.060	58	4.052	457.0882	2.660
29	37.902	120.2264	2.080	59	3.814	478.6301	2.680
30	34.952	125.8925	2.100				

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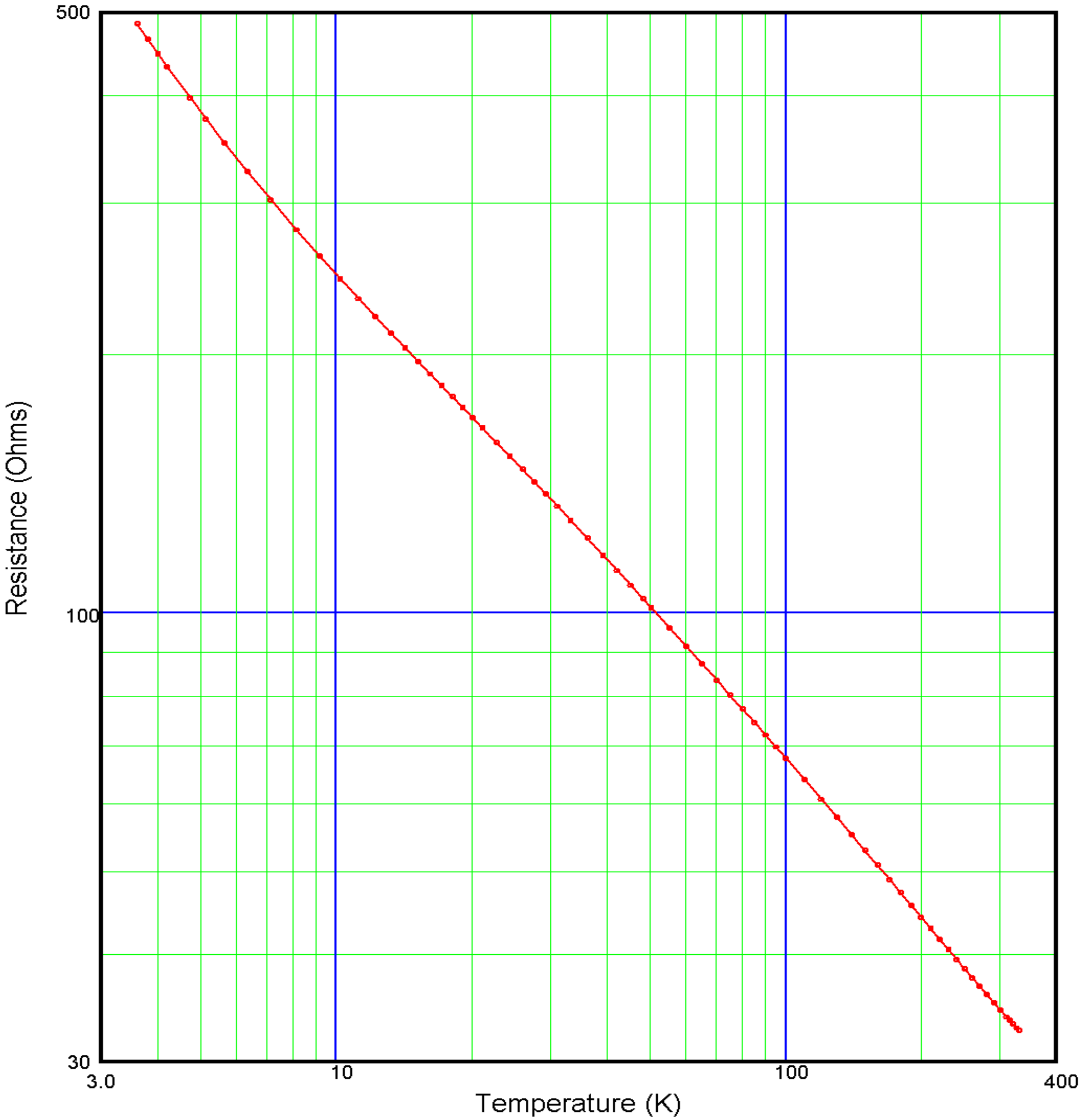
X29758
SCAL-B 2% prime thermometer

DATA PLOT

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%



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TEST DATA

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%

Index	Temperature (K)	Resistance (Ω)
1	3.60604	485.235
2	3.80519	465.676
3	4.00707	447.968
4	4.20352	432.381
5	4.72414	397.784
6	5.12455	375.921
7	5.62741	352.879
8	6.32950	326.752
9	7.13738	302.871
10	8.15264	279.288
11	9.17440	260.462
12	10.1961	245.029
13	11.2104	232.194
14	12.2201	221.264
15	13.2194	211.861
16	14.2124	203.616
17	15.2012	196.279
18	16.1742	189.792
19	17.1492	183.881
20	18.1215	178.486
21	19.0930	173.502
22	20.0679	168.916
23	21.1464	164.212
24	22.7159	157.949
25	24.3148	152.243
26	25.9494	146.923
27	27.5911	142.061
28	29.2313	137.622
29	31.0566	133.085
30	33.1811	128.241
31	36.1870	122.169
32	39.1911	116.787
33	42.1821	112.029
34	45.1813	107.723
35	48.1694	103.849
36	50.1691	101.446
37	55.1564	96.0417
38	60.1606	91.3450
39	65.1554	87.2032
40	70.1524	83.5311

Index	Temperature (K)	Resistance (Ω)
41	75.1476	80.2362
42	80.1406	77.2626
43	85.1340	74.5587
44	90.1238	72.0863
45	95.1233	69.8131
46	100.112	67.7123
47	110.212	63.9123
48	120.097	60.6798
49	130.099	57.7881
50	140.106	55.2149
51	150.102	52.9123
52	160.094	50.8370
53	170.082	48.9487
54	180.077	47.2351
55	190.080	45.6651
56	200.080	44.2251
57	210.073	42.8984
58	220.067	41.6747
59	230.078	40.5393
60	240.075	39.4857
61	250.072	38.5076
62	260.079	37.5923
63	270.070	36.7444
64	280.079	35.9449
65	290.072	35.1944
66	300.077	34.4975
67	310.072	33.8397
68	315.080	33.5258
69	320.092	33.2184
70	326.096	32.8687
71	330.092	32.6387

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POLYNOMIAL EQUATION

Calibration Report: 429018
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29758
Sensor Type: Cernox Resistor
Sensor Excitation: 2mV±50%
Temperature Range: 4.00K to 325K

Polynomial Type: Chebychev
Useful Range of Fit:

4.00K	to	24.3K
448.6 Ohms	to	152.2 Ohms

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

ZL = 2.15247379486   ZU = 2.68595222923

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	12.266048	3.1745E-04	38639.77
1	-11.377249	4.9169E-04	-23139.14
2	3.276864	4.7286E-04	6929.91
3	-0.620809	4.4652E-04	-1390.32
4	0.057461	4.3541E-04	131.97
5	0.005286	4.2275E-04	12.50
6	-0.001756	4.0566E-04	-4.33

Z = Log(resistance)

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

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

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POLYNOMIAL EQUATION

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	485.2351	3.60604	3.60585	0.20
2	465.6762	3.80519	3.80524	-0.05
3	447.9683	4.00707	4.00711	-0.04
4	432.3809	4.20352	4.20438	-0.86
5	397.7840	4.72414	4.72320	0.94
6	375.9205	5.12455	5.12409	0.46
7	352.8788	5.62741	5.62742	-0.01
8	326.7522	6.32950	6.33011	-0.61
9	302.8707	7.13738	7.13844	-1.06
10	279.2883	8.15264	8.15246	0.18
11	260.4624	9.17440	9.17279	1.61
12	245.0293	10.19610	10.19580	0.30
13	232.1945	11.21043	11.21074	-0.31
14	221.2643	12.22011	12.22091	-0.80
15	211.8606	13.21940	13.21976	-0.36
16	203.6159	14.21238	14.21232	0.06
17	196.2790	15.20121	15.20236	-1.15
18	189.7921	16.17419	16.17369	0.49
19	183.8814	17.14918	17.14762	1.56
20	178.4855	18.12147	18.11971	1.76
21	173.5017	19.09296	19.09586	-2.89
22	168.9157	20.06792	20.06750	0.42
23	164.2115	21.14637	21.14468	1.69
24	157.9489	22.71590	22.71961	-3.71
25	152.2427	24.31476	24.31212	2.64
26	146.9232	25.94943	25.94963	-0.20
27	142.0606	27.59114	27.59139	-0.25

Order of Fit = 6 RMS error of fit = 1.31 mK
Largest absolute error = -3.71 mK at data point no. 24

POLYNOMIAL EQUATION

Calibration Report: 429018
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29758
Sensor Type: Cernox Resistor
Sensor Excitation: 2mV±50%
Temperature Range: 4.00K to 325K

Polynomial Type: Chebychev
Useful Range of Fit:

24.3K	to	110.K
152.2 Ohms	to	63.91 Ohms

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

ZL = 1.76183816753 ZU = 2.21540364526

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	64.623274	1.3025E-03	49613.85
1	-53.063432	2.1181E-03	-25052.79
2	10.896525	1.9327E-03	5637.85
3	-1.423310	1.7678E-03	-805.13
4	0.100982	1.6592E-03	60.86
5	0.011061	1.6488E-03	6.71

Z = Log(resistance)

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

Temp. (K) = ΣA_i* COS(i * ARCCOS(X)), where 0 <= i <= 5
and the A_i's are the coefficients in the table above.

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POLYNOMIAL EQUATION

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
23	164.2115	21.14468	21.14510	-0.42
24	157.9489	22.71961	22.71887	0.74
25	152.2427	24.31212	24.31149	0.63
26	146.9232	25.94943	25.94965	-0.21
27	142.0606	27.59114	27.59285	-1.71
28	137.6215	29.23135	29.22934	2.01
29	133.0854	31.05655	31.05244	4.11
30	128.2406	33.18108	33.18976	-8.68
31	122.1694	36.18697	36.18812	-1.16
32	116.7872	39.19107	39.19499	-3.92
33	112.0288	42.18208	42.17549	6.59
34	107.7227	45.18125	45.17668	4.58
35	103.8485	48.16936	48.16180	7.55
36	101.4462	50.16910	50.16598	3.12
37	96.04168	55.15643	55.16745	-11.02
38	91.34499	60.16056	60.16121	-0.65
39	87.20316	65.15544	65.16406	-8.62
40	83.53112	70.15236	70.15380	-1.44
41	80.23624	75.14761	75.14772	-0.12
42	77.26257	80.14057	80.13798	2.58
43	74.55875	85.13401	85.12911	4.89
44	72.08625	90.12382	90.12083	2.99
45	69.81307	95.12333	95.11451	8.82
46	67.71228	100.11200	100.11328	-1.29
47	63.91233	110.21227	110.22601	-13.73
48	60.67984	120.09690	120.09531	1.58
49	57.78807	130.09923	130.09646	2.77

Order of Fit = 5 RMS error of fit = 5.32 mK
Largest absolute error = -13.73 mK at data point no. 47

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POLYNOMIAL EQUATION

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%

Polynomial Type: Chebychev
Useful Range of Fit:

110.K	to	325.K
63.91 Ohms	to	32.93 Ohms

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

ZL = 1.51373274759 ZU = 1.84393673895

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	194.357325	4.0527E-03	47957.22
1	-114.859138	6.2665E-03	-18329.07
2	17.739413	5.6306E-03	3150.52
3	-2.531073	5.4850E-03	-461.45
4	0.480269	5.4978E-03	87.36
5	-0.093527	5.4616E-03	-17.12
6	0.028821	5.2811E-03	5.46

Z = Log(resistance)

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

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

POLYNOMIAL EQUATION

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
45	69.81307	95.11451	95.12209	-7.58
46	67.71228	100.11328	100.10170	11.58
47	63.91233	110.22601	110.22245	3.55
48	60.67984	120.09690	120.10338	-6.49
49	57.78807	130.09923	130.10971	-10.48
50	55.21492	140.10563	140.11049	-4.86
51	52.91234	150.10170	150.09363	8.08
52	50.83703	160.09350	160.07202	21.48
53	48.94873	170.08249	170.09044	-7.95
54	47.23508	180.07739	180.07630	1.09
55	45.66506	190.07993	190.08174	-1.81
56	44.22508	200.07952	200.08018	-0.66
57	42.89836	210.07327	210.08334	-10.07
58	41.67470	220.06667	220.07143	-4.76
59	40.53926	230.07804	230.07857	-0.53
60	39.48567	240.07454	240.08198	-7.45
61	38.50763	250.07189	250.06405	7.83
62	37.59229	260.07888	260.08794	-9.07
63	36.74443	270.07040	270.03234	38.06
64	35.94490	280.07933	280.06007	19.26
65	35.19445	290.07178	290.11358	-41.80
66	34.49747	300.07718	300.07042	6.75
67	33.83975	310.07219	310.07484	-2.65
68	33.52577	315.07957	315.07775	1.82
69	33.21843	320.09156	320.12710	-35.54
70	32.86872	326.09572	326.06568	30.04
71	32.63869	330.09170	330.08957	2.14

Order of Fit = 6 RMS error of fit = 16.21 mK
Largest absolute error = -41.80 mK at data point no. 65

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INTERPOLATION TABLE

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT	Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
4.000	448.560	-83.382	-0.74355	37.00	120.652	-1.8383	-0.56373
4.200	432.711	-75.331	-0.73118	38.00	118.850	-1.7667	-0.56486
4.400	418.351	-68.433	-0.71975	39.00	117.117	-1.6995	-0.56593
4.600	405.276	-62.463	-0.70897	40.00	115.450	-1.6364	-0.56696
4.800	393.311	-57.307	-0.69937	42.00	112.295	-1.5208	-0.56881
5.000	382.311	-52.783	-0.69032	44.00	109.358	-1.4179	-0.57047
5.200	372.161	-48.802	-0.68188	46.00	106.616	-1.3257	-0.57198
5.400	362.761	-45.266	-0.67383	48.00	104.049	-1.2428	-0.57333
5.600	354.028	-42.126	-0.66635	50.00	101.640	-1.1680	-0.57459
5.800	345.888	-39.324	-0.65939	52.00	99.3723	-1.1003	-0.57575
6.000	338.281	-36.794	-0.65261	54.00	97.2345	-1.0386	-0.57678
6.500	321.260	-31.513	-0.63759	56.00	95.2143	-0.98246	-0.57783
7.000	306.586	-27.342	-0.62428	58.00	93.3015	-0.93107	-0.57879
7.500	293.777	-24.010	-0.61296	60.00	91.4872	-0.88395	-0.57972
8.000	282.477	-21.281	-0.60269	65.00	87.3312	-0.78188	-0.58194
8.500	272.413	-19.041	-0.59413	70.00	83.6383	-0.69791	-0.58410
9.000	263.377	-17.158	-0.58633	75.00	80.3289	-0.62791	-0.58625
9.500	255.204	-15.574	-0.57974	77.35	78.8877	-0.59895	-0.58727
10.00	247.766	-14.216	-0.57376	80.00	77.3410	-0.56887	-0.58843
10.50	240.956	-13.051	-0.56872	85.00	74.6256	-0.51856	-0.59065
11.00	234.690	-12.037	-0.56416	90.00	72.1436	-0.47530	-0.59294
11.50	228.897	-11.152	-0.56030	95.00	69.8631	-0.43773	-0.59523
12.00	223.520	-10.372	-0.55683	100.0	67.7581	-0.40507	-0.59782
12.50	218.510	-9.6825	-0.55390	105.0	65.8059	-0.37632	-0.60045
13.00	213.826	-9.0674	-0.55128	110.0	63.9902	-0.35044	-0.60241
13.50	209.432	-8.5181	-0.54908	115.0	62.2968	-0.32739	-0.60436
14.00	205.299	-8.0232	-0.54713	120.0	60.7116	-0.30717	-0.60714
14.50	201.400	-7.5771	-0.54552	125.0	59.2215	-0.28911	-0.61023
15.00	197.715	-7.1719	-0.54411	130.0	57.8179	-0.27256	-0.61284
15.50	194.222	-6.8037	-0.54297	135.0	56.4936	-0.25740	-0.61510
16.00	190.906	-6.4670	-0.54201	140.0	55.2418	-0.24351	-0.61713
16.50	187.750	-6.1588	-0.54125	145.0	54.0566	-0.23074	-0.61892
17.00	184.743	-5.8753	-0.54064	150.0	52.9328	-0.21894	-0.62042
17.50	181.871	-5.6142	-0.54021	155.0	51.8658	-0.20802	-0.62167
18.00	179.125	-5.3728	-0.53990	160.0	50.8513	-0.19791	-0.62271
18.50	176.496	-5.1492	-0.53973	165.0	49.8855	-0.18852	-0.62354
19.00	173.974	-4.9414	-0.53966	170.0	48.9650	-0.17979	-0.62420
19.50	171.552	-4.7482	-0.53972	175.0	48.0866	-0.17165	-0.62468
20.00	169.223	-4.5679	-0.53987	180.0	47.2476	-0.16405	-0.62500
21.00	164.822	-4.2415	-0.54041	185.0	46.4453	-0.15695	-0.62516
22.00	160.727	-3.9545	-0.54128	190.0	45.6773	-0.15030	-0.62518
23.00	156.901	-3.7020	-0.54268	195.0	44.9416	-0.14406	-0.62505
24.00	153.315	-3.4751	-0.54399	200.0	44.2362	-0.13819	-0.62477
25.00	149.944	-3.2699	-0.54519	205.0	43.5592	-0.13267	-0.62436
26.00	146.768	-3.0866	-0.54679	210.0	42.9090	-0.12746	-0.62379
27.00	143.765	-2.9210	-0.54858	215.0	42.2841	-0.12254	-0.62308
28.00	140.921	-2.7697	-0.55032	220.0	41.6831	-0.11789	-0.62222
29.00	138.221	-2.6311	-0.55203	225.0	41.1048	-0.11349	-0.62122
30.00	135.655	-2.5039	-0.55374	230.0	40.5478	-0.10931	-0.62007
31.00	133.210	-2.3865	-0.55537	235.0	40.0113	-0.10535	-0.61877
32.00	130.879	-2.2779	-0.55695	240.0	39.4940	-0.10159	-0.61733
33.00	128.652	-2.1771	-0.55845	245.0	38.9951	-9.8003e-2	-0.61574
34.00	126.522	-2.0835	-0.55989	250.0	38.5137	-9.4591e-2	-0.61401
35.00	124.483	-1.9961	-0.56122	255.0	38.0489	-9.1338e-2	-0.61214
36.00	122.528	-1.9145	-0.56250	260.0	37.6001	-8.8235e-2	-0.61014

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INTERPOLATION TABLE

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
265.0	37.1663	-8.5273e-2	-0.60801
270.0	36.7471	-8.2443e-2	-0.60575
273.15	36.4901	-8.0724e-2	-0.60427
275.0	36.3417	-7.9737e-2	-0.60337
280.0	35.9495	-7.7148e-2	-0.60088

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
285.0	35.5700	-7.4671e-2	-0.59829
290.0	35.2027	-7.2298e-2	-0.59559
295.0	34.8469	-7.0025e-2	-0.59281
300.0	34.5022	-6.7847e-2	-0.58994
305.0	34.1683	-6.5759e-2	-0.58699
310.0	33.8445	-6.3755e-2	-0.58397
315.0	33.5306	-6.1833e-2	-0.58089
320.0	33.2261	-5.9989e-2	-0.57775
325.0	32.9306	-5.8218e-2	-0.57457

THERMAL CYCLE TESTING

Sensor Model: CX-1030-SD-HT-4L   Serial Number: X29758
Sensor Type: Cernox Resistor

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:

Room Temperature:	34.1Ω
Liquid Nitrogen:	78.8Ω
Liquid Helium:	432Ω

The nitrogen and helium values were recorded in OPEN dewars, so precision comparisons with calibration values or other dip 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 at the values listed below. In order to minimize possible self-heating errors, we suggest that these same guidelines be followed in using the sensor:

Above 1K:	1 to 3 mV
0.1 to 1K:	0.1 mV
Below 0.1K:	0.03 mV

Lead Identification:

NONE

To avoid possible damage to the sensor, do not exceed 1 Volt and do not exceed 100 mA current.

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BREAKPOINTS 340 FORMAT

Calibration Report: 429018
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29758

Name: CX-1030-SD-HT-4L
Serial number: X29758
Format: 4 ;Log Ohms/Kelvin
Limit: 325.
Coefficient: 1 ;Negative

Point 1: 1.51759,325.000
Point 2: 1.52226,319.000
Point 3: 1.52664,313.500
Point 4: 1.53112,308.000
Point 5: 1.53572,302.500

Point 6: 1.54042,297.000
Point 7: 1.54523,291.500
Point 8: 1.55017,286.000
Point 9: 1.55476,281.000
Point 10: 1.55945,276.000

Point 11: 1.56424,271.000
Point 12: 1.56915,266.000
Point 13: 1.57416,261.000
Point 14: 1.57929,256.000
Point 15: 1.58454,251.000

Point 16: 1.58991,246.000
Point 17: 1.59541,241.000
Point 18: 1.60103,236.000
Point 19: 1.60679,231.000
Point 20: 1.61269,226.000

Point 21: 1.61872,221.000
Point 22: 1.62491,216.000
Point 23: 1.63125,211.000
Point 24: 1.63775,206.000
Point 25: 1.64441,201.000

Point 26: 1.65125,196.000
Point 27: 1.65826,191.000
Point 28: 1.66546,186.000
Point 29: 1.67212,181.500
Point 30: 1.67893,177.000

Point 31: 1.68591,172.500
Point 32: 1.69308,168.000
Point 33: 1.70043,163.500
Point 34: 1.70798,159.000
Point 35: 1.71574,154.500

Point 36: 1.72371,150.000
Point 37: 1.73191,145.500
Point 38: 1.74034,141.000
Point 39: 1.74903,136.500
Point 40: 1.75697,132.500

Point 41: 1.76513,128.500
Point 42: 1.77352,124.500
Point 43: 1.78216,120.500
Point 44: 1.79104,116.500
Point 45: 1.80021,112.500

Point 46: 1.80968,108.500
Point 47: 1.81825,105.000
Point 48: 1.82707,101.500
Point 49: 1.83487, 98.500
Point 50: 1.84153, 96.000

Point 51: 1.84835, 93.500
Point 52: 1.85534, 91.000
Point 53: 1.86251, 88.500
Point 54: 1.86987, 86.000
Point 55: 1.87744, 83.500

Point 56: 1.88522, 81.000
Point 57: 1.89323, 78.500
Point 58: 1.89982, 76.500
Point 59: 1.90656, 74.500
Point 60: 1.91348, 72.500

Point 61: 1.92059, 70.500
Point 62: 1.92788, 68.500
Point 63: 1.93539, 66.500
Point 64: 1.94311, 64.500
Point 65: 1.95106, 62.500

Point 66: 1.95925, 60.500
Point 67: 1.96728, 58.600
Point 68: 1.97512, 56.800
Point 69: 1.98320, 55.000
Point 70: 1.99154, 53.200

Point 71: 2.00015, 51.400
Point 72: 2.00904, 49.600
Point 73: 2.01825, 47.800
Point 74: 2.02780, 46.000
Point 75: 2.03659, 44.400

Point 76: 2.04567, 42.800
Point 77: 2.05508, 41.200
Point 78: 2.06546, 39.500
Point 79: 2.07561, 37.900
Point 80: 2.08617, 36.300

Point 81: 2.09648, 34.800
Point 82: 2.10719, 33.300
Point 83: 2.11835, 31.800
Point 84: 2.12921, 30.400
Point 85: 2.14054, 29.000

Point 86: 2.15237, 27.600
Point 87: 2.16387, 26.300
Point 88: 2.17588, 25.000
Point 89: 2.18752, 23.800
Point 90: 2.19971, 22.600

Point 91: 2.21253, 21.400
Point 92: 2.22492, 20.300
Point 93: 2.23437, 19.500
Point 94: 2.24232, 18.850
Point 95: 2.25054, 18.200

Point 96: 2.25907, 17.550
Point 97: 2.26793, 16.900
Point 98: 2.27643, 16.300
Point 99: 2.28525, 15.700
Point 100: 2.29444, 15.100

Point 101: 2.30322, 14.550
Point 102: 2.31236, 14.000
Point 103: 2.32190, 13.450
Point 104: 2.33187, 12.900
Point 105: 2.34138, 12.400

Point 106: 2.35131, 11.900
Point 107: 2.36173, 11.400
Point 108: 2.37269, 10.900
Point 109: 2.38308, 10.450
Point 110: 2.39400, 10.000

Point 111: 2.40552, 9.550
Point 112: 2.41771, 9.100
Point 113: 2.42920, 8.700
Point 114: 2.44133, 8.300
Point 115: 2.45422, 7.900

Point 116: 2.46795, 7.500
Point 117: 2.48077, 7.150
Point 118: 2.49438, 6.800
Point 119: 2.50893, 6.450
Point 120: 2.52452, 6.100

Point 121: 2.53984, 5.780
Point 122: 2.55629, 5.460
Point 123: 2.57406, 5.140
Point 124: 2.59211, 4.840
Point 125: 2.61033, 4.560

Point 126: 2.63009, 4.280
Point 127: 2.65009, 4.020
Point 128: 2.65182, 4.000

BREAKPOINTS 91C/93C/330 FORMAT

Calibration Report: 429018
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29758
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Interpolation Method: Lagrangian
Limit: 325. (Kelvin)
Format: 4 (Log Ohms/Kelvin)
Number of Breakpoints: 46

No.	Units	Temperature (K)	No.	Units	Temperature (K)
1	1.51760	325.0	26	2.12925	30.4
2	1.51837	324.0	27	2.15677	27.1
3	1.53031	309.0	28	2.18362	24.2
4	1.54304	294.0	29	2.21040	21.6
5	1.55663	279.0	30	2.23803	19.2
6	1.57115	264.0	31	2.26519	17.1
7	1.58668	249.0	32	2.29136	15.3
8	1.60333	234.0	33	2.31928	13.6
9	1.62119	219.0	34	2.34532	12.2
10	1.64041	204.0	35	2.37273	10.9
11	1.66113	189.0	36	2.39909	9.8
12	1.68358	174.0	37	2.42631	8.8
13	1.70800	159.0	38	2.45098	8.0
14	1.73471	144.0	39	2.47894	7.2
15	1.76412	129.0	40	2.50264	6.6
16	1.79676	114.0	41	2.52928	6.0
17	1.83357	99.0	42	2.55427	5.5
18	1.87592	84.0	43	2.58242	5.0
19	1.92605	69.0	44	2.60775	4.6
20	1.96347	59.5	45	2.64388	4.1
21	1.99487	52.5	46	2.65182	4.0
22	2.01984	47.5			
23	2.04744	42.5			
24	2.07500	38.0			
25	2.10217	34.0			

Temperature for Resistance Decades:

Res. (Ohms)	Temp. (K)
100	51.433

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BREAKPOINTS 234 FORMAT

Calibration Report: 429018 Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L Serial Number: X29758
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Maximum Temperature Error:	
1.4 - 10K:	0.006K
10 - 20K:	0.011K
20 - 40K:	0.018K
40 - 100K:	0.039K
> 100K:	0.187K

BP #	Temp. (K)	Res. (Ω)	Log10 Res.	BP #	Temp. (K)	Res. (Ω)	Log10 Res.
1	321.886	33.11311	1.520	31	31.589	131.8257	2.120
2	297.495	34.67369	1.540	32	29.070	138.0384	2.140
3	275.439	36.30781	1.560	33	26.734	144.5440	2.160
4	255.325	38.01894	1.580	34	24.574	151.3561	2.180
5	236.914	39.81072	1.600	35	22.576	158.4893	2.200
6	219.968	41.68694	1.620	36	20.735	165.9587	2.220
7	204.305	43.65158	1.640	37	19.039	173.7801	2.240
8	189.791	45.70882	1.660	38	17.483	181.9701	2.260
9	176.309	47.86301	1.680	39	16.056	190.5461	2.280
10	163.771	50.11872	1.700	40	14.751	199.5262	2.300
11	152.089	52.48075	1.720	41	13.559	208.9296	2.320
12	141.189	54.95409	1.740	42	12.472	218.7762	2.340
13	131.011	57.54399	1.760	43	11.483	229.0868	2.360
14	121.497	60.25596	1.780	44	10.583	239.8833	2.380
15	112.599	63.09573	1.800	45	9.764	251.1886	2.400
16	104.300	66.06934	1.820	46	9.021	263.0268	2.420
17	96.575	69.18310	1.840	47	8.345	275.4229	2.440
18	89.372	72.44360	1.860	48	7.730	288.4032	2.460
19	82.674	75.85776	1.880	49	7.172	301.9952	2.480
20	76.448	79.43282	1.900	50	6.663	316.2278	2.500
21	70.667	83.17638	1.920	51	6.201	331.1311	2.520
22	65.301	87.09636	1.940	52	5.779	346.7369	2.540
23	60.325	91.20108	1.960	53	5.393	363.0781	2.560
24	55.711	95.49926	1.980	54	5.041	380.1894	2.580
25	51.433	100.0000	2.000	55	4.718	398.1072	2.600
26	47.471	104.7129	2.020	56	4.422	416.8694	2.620
27	43.797	109.6478	2.040	57	4.150	436.5158	2.640
28	40.390	114.8154	2.060	58	3.901	457.0882	2.660
29	37.233	120.2264	2.080	59	3.670	478.6301	2.680
30	34.302	125.8925	2.100				

X28264
SCAL-B prime SOB thermometer

Calibration Report
(CX28264)

Document Ref.:
Cardiff Ref.:
Issue: 1.0

Prepared by: Iris Didschuns
Last Modified on: 19 August 2004
Approved by:

Distribution list

Table of Contents

Calibration Report– (CX28264)

1. Scope

This document describes the calibration procedure and results for the Lakeshore Cernox High temperature thermometer (type: CX-1030-SD-HT; Serial No.: X28264).

2. Overview of experimental set-up

2.1 Cryostat set-up

The thermometer calibration was carry out under vacuum in a Helium 4 cryostat. The temperature range was from room temperature down to 4.2 K and through pumping on the He4 bath it was extend to 1.5 K. Therefore the three thermometers where mounted onto the 4 K plate next to the calibrated thermometers see Figure 1. The thermometers are calibrated against a calibrated Lakeshore Cernox thermometer (type: CX-1030-SD-HT-1.4L; Serial No.: X25820). The Lakeshore Cernox thermometer is calibrated from 1.4 K up to 325 K.

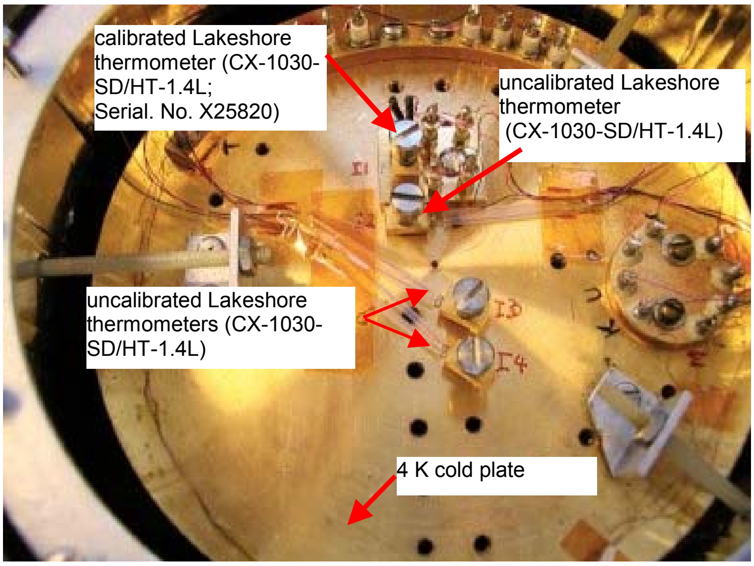


Figure 1: experimental set-up inside the cryostat

A 4 K and 77 K radiation shield was mounted over all temperature sensors to significantly decrease the radiation input form the surrounding. The data were taken during the warming up period of the cryostat to ensure a good thermal equilibrium of the sensor. The warming up rate until 4 K was 1K per 68min (Figure 2) and from 4 K until 300 K was 1K per 5min (Figure 3).

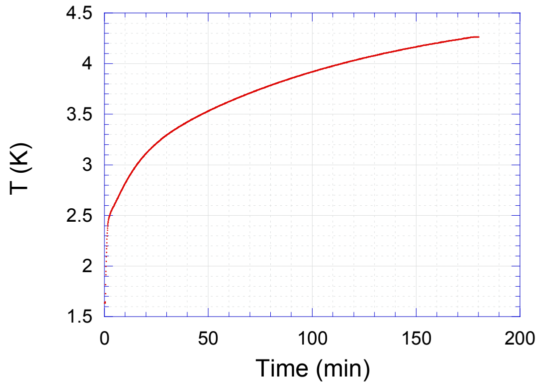


Figure 2: Typical warming up curve in temperature range between 1.5 K and 4.2 K

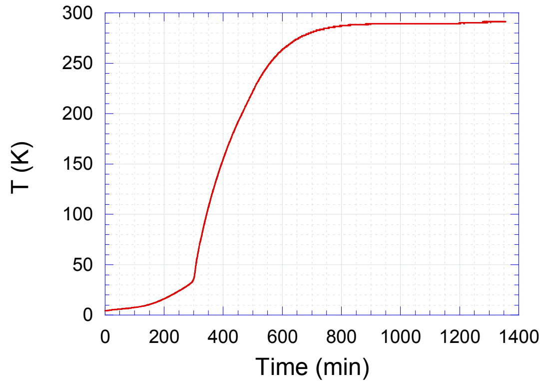


Figure 3: Typical warming up curve in temperature range between 4.2 K and 300 K

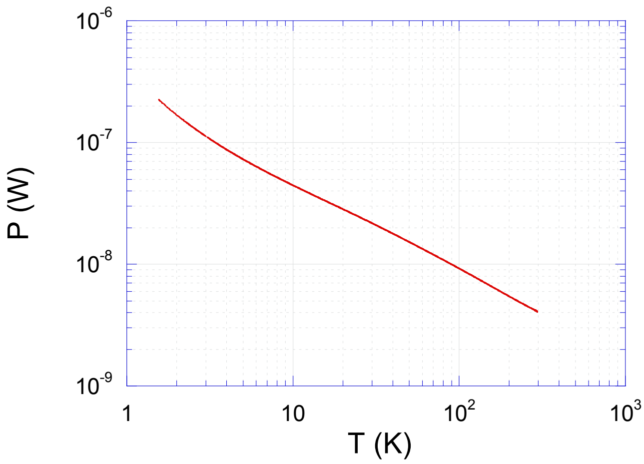


Figure 4: Power dissipation of the Lakeshore Temperature Monitor LS218E at the calibrated CERNOX thermometer

2.2 Data Acquisition

The resistance of all temperature sensors were monitor with the Lakeshore Temperature Monitor Model 218. The Lakeshore Temperature Monitor was used according to the manual. This means on each of the two groups of four inputs was the same type sensor connected. The calibrated CERNOX thermometer (CX25820) was connected to the 1st input and the to calibrate Cernox thermometer were connected to the 2nd, 3rd and 4th inputs. These inputs were configured for the sensor type "Cernox RTD" (see below). A LabVIEW program was used to control the temperature monitor as well to record the resistance data.

Calibration Report– (CX28264)

Lake Shore Model 218 Temperature Monitor User's Manual

Table 1-2. Model 218 Sensor Input Performance Chart

Sensor Type	Silicon Diode	GaAlAs Diode	100Ω Platinum RTD 500Ω Full Scale	1000Ω Platinum RTD	Cernox™ RTD
Temperature Coefficient	Negative	Negative	Positive	Positive	Negative
Sensor Units	Volts (V)	Volts (V)	Ohms (Ω)	Ohms (Ω)	Ohms (Ω)
Input Range	0 – 2.5 V	0 – 7.5 V	0 – 500 Ω	0 – 5000 Ω	0 – 7500 Ω
Sensor Excitation (Constant Current)	10 µA ±0.01%	10 µA ±0.01%	1 mA ±0.3%	1 mA ±0.3%	10 µA ±0.01%
Display Resolution (Sensor Units)	100 uV	100 uV	10 mΩ	100 mΩ	100 mΩ
Example LSCI Sensor	DT-470-CO-13 with 1.4H Cal.	TG-120SD with 1.4H Cal.	PT-103 with 14J Cal.	PT-1001[2] with 1.4J Cal.	CX-1050-SD with 4L Cal.
Temperature Range	1.4 – 475 K	1.4 – 475 K	30 – 800 K	30 – 800 K	3.5 – 400 K
Standard Sensor Curve	LSCI Curve 10	Requires Calibration	DIN 43760	Scaled from DIN 43670	Requires calibration
Typical Sensor Sensitivity	-30 mV/K at 4.2 K -1.9 mV/K at 77 K -2.4 mV/K at 300 K -2.2 mV/K at 475 K	-180 mV/K at 10 K -1.25 mV/K at 77 K -2.75 mV/K at 300 K -2.75 mV/K at 475 K	0.19 Ω/K at 30 K 0.42 Ω/K at 77 K 0.39 Ω/K at 300 K 0.35 Ω/K at 675 K 0.33 Ω/K at 800 K	1.9 Ω/K at 30 K 4.2 Ω/K at 77 K 3.9 Ω/K at 300 K 3.3 Ω/K at 800 K	-770 Ω/K at 4.2 K -1.5 Ω/K at 77 K -0.1 Ω/K at 300 K
Measurement Resolution: Sensor Units Temperature Equivalence	20 uV 1 mK at 4.2 K 11 mK at 77 K 10 mK at 300 K 10 mK at 475 K	20 uV 1 mK at 10 K 16 mK at 77 K 10 mK at 300 K 10 mK at 475 K	2 mΩ 10.6 mK at 30 K 10 mK at 77 K 10 mK at 300 K 10 mK at 675 K 10 mK at 800 K	20 mΩ 10.6 mK at 30 K 10 mK at 77 K 10 mK at 300 K 10 mK at 800 K	50 mΩ 1 mK at 4.2 K 33.3 mK at 77 K 500 mK at 300 K
Electronic Accuracy: Sensor Units Temperature Equivalence	±160 uV ±0.01% RDG ±11 mK at 4.2 K ±138 mK at 77 K ±88 mK at 300 K ±77 mK at 475 K	±160 uV ±0.02% RDG ±6 mK at 10 K ±300 mK at 77 K ±150 mK at 300 K ±110 mK at 475 K	±0.004 Ω ±0.02% RDG ±25 mK at 30 K ±18 mK at 77 K ±70 mK at 300 K ±162 mK at 675 K ±187 mK at 800 K	±0.06 Ω ±0.04% RDG ±40 mK at 30 K ±33 mK at 77 K ±135 mK at 300 K ±370 mK at 800 K	±0.1 Ω ±0.04% RDG ±1 mK at 4.2 K ±88 mK at 77 K ±1.144 K at 300K
Temperature Accuracy including electronic accuracy, CalCurve™ and calibrated sensor	±31 mK at 4.2 K ±193 mK at 77 K ±138 mK at 300 K ±177 mK at 475 K	±21 mK at 10 K ±390 mK at 77 K ±140 mK at 300 K ±210 mK at 475 K	±45 mK at 30 K ±38 mK at 77 K ±105 mK at 300 K ±262 mK at 675 K ±287 mK at 800 K	±60 mK at 30 K ±53 mK at 77 K ±170 mK at 300 K ±470 mK at 800 K	±9 mK at 4.2 K[1] ±138 mK at 77 K[1] ±1.284 K at 300K[1]
Magnetic Field Use	Recommended for T ≥ 60 K & B ≤ 3 T	Recommended for T > 4.2 K & B ≤ 5 T	Recommended for T > 40 K & B ≤ 2.5 T	Recommended for T > 40 K & B ≤ 2.5 T	Recommended for T > 2 K & B ≤ 19 T

[1] Specified accuracy includes no effects of thermal EMF voltages. An error of 3 mΩ results from each 1 µV of thermal EMF voltage. In well-designed systems, thermal EMF voltage should be less than 10 µV.
[2] No longer available from Lake Shore.

1-4 Introduction

2.3 Data Calibration

A polynomial equation based on the Chebychev polynomials has been fit to the calibration data. This equation is of the form:

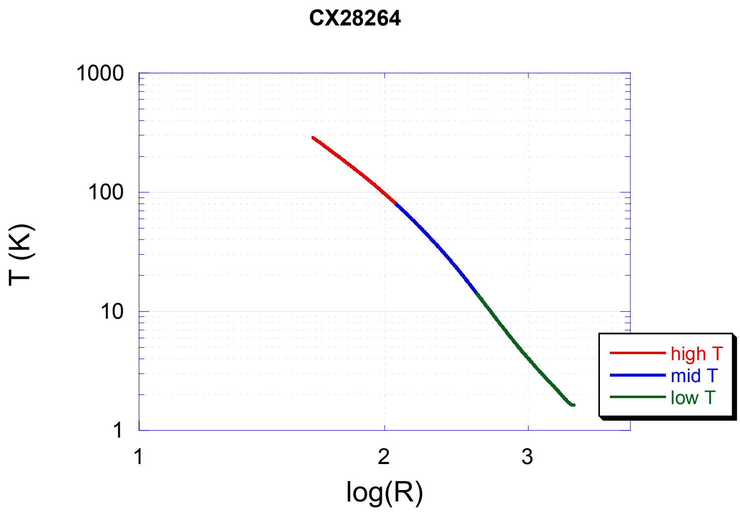
$$T(x) = \sum_{i=0}^{n} a_i \cdot \cos(i \cdot \arccos(x))$$

where *T(x)* represents the temperature in Kelvin and a_i represents the Chebychev coefficients. The parameter x is a normalized variable given by:

$$x = \frac{(Z-Zl)-(ZU-Z)}{(ZU-ZL)}$$

Z is $Z = log_{10}(R)$. ZL and ZU designate the lower and upper limit of the variable Z over the fit range.

3. Results



y = m1+T1(2.0652,1.6314,m2,m...

	Value	Error
m1	168.62	0.0083204
m2	-102.91	0.01449
m3	16.25	0.01351
m4	-2.1645	0.012742
m5	0.29808	0.012521
m6	0.021492	0.011728
m7	-0.031175	0.011655
m8	0.028605	0.010032
m9	-0.015089	0.0099593
Chisq	11.227	NA
R	1	NA

y = m1+T1(2.5937,2.0652,m2,m...

	Value	Error
m1	40.88	0.0011418
m2	-32.205	0.0019752
m3	6.1963	0.001861
m4	-0.73934	0.001746
m5	0.07258	0.0017107
m6	0.010247	0.0016082
m7	-0.0071502	0.0015767
m8	-0.0034126	0.0013834
m9	0.0028717	0.0013873
Chisq	0.18573	NA
R	1	NA

y = m1+T1(3.4133,2.5937,m2,m...

	Value	Error
m1	5.8457	0.00049434
m2	-5.7952	0.00088868
m3	1.9575	0.00075224
m4	-0.50177	0.00065247
m5	0.1068	0.0005781
m6	0.0016598	0.00055153
m7	0.010325	0.00055656
m8	0.0064626	0.00050647
m9	0.0032958	0.00044221
Chisq	0.0017067	NA
R	1	NA

Figure 5: A polynomial equation based on the Chebychev polynomials has been fit to the calibration data and the coefficients are shown for each temperature range.

Calibration Report– (CX28264)

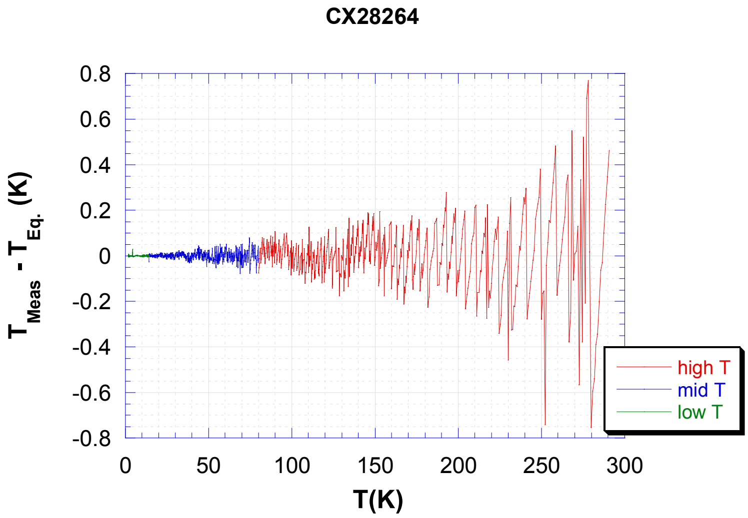


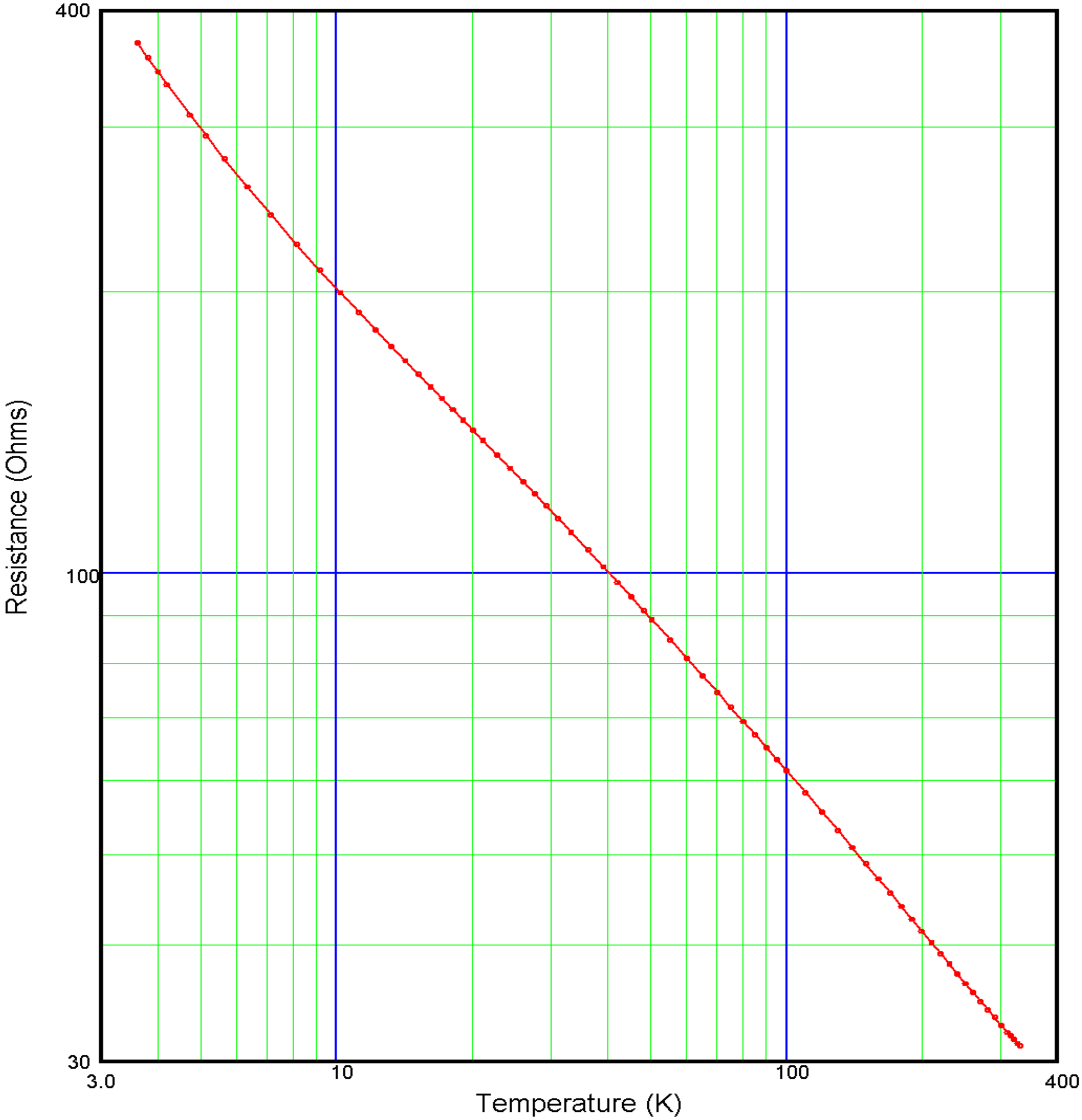
Figure 6: This graph shows the difference between calculated temperature and measured temperature.

X29756
SCAL-B 4% redundant thermometer

DATA PLOT

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%



LakeShore

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TEST DATA

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%

Index	Temperature (K)	Resistance (Ω)	Index	Temperature (K)	Resistance (Ω)
1	3.60616	369.666	41	75.1478	71.8923
2	3.80505	356.290	42	80.1401	69.4295
3	4.00698	344.127	43	85.1341	67.1857
4	4.20190	333.384	44	90.1259	65.1200
5	4.72419	309.351	45	95.1232	63.2156
6	5.12413	294.010	46	100.112	61.4547
7	5.62727	277.719	47	110.212	58.2579
8	6.32901	259.116	48	120.097	55.5216
9	7.13744	241.974	49	130.100	53.0668
10	8.15252	224.896	50	140.106	50.8700
11	9.17388	211.071	51	150.102	48.8982
12	10.1957	199.727	52	160.094	47.1103
13	11.2113	190.220	53	170.083	45.4865
14	12.2198	182.070	54	180.077	44.0033
15	13.2208	175.016	55	190.079	42.6412
16	14.2122	168.814	56	200.079	41.3867
17	15.1980	163.285	57	210.073	40.2352
18	16.1742	158.332	58	220.067	39.1622
19	17.1501	153.839	59	230.078	38.1678
20	18.1218	149.720	60	240.075	37.2435
21	19.0929	145.934	61	250.073	36.3833
22	20.0681	142.394	62	260.079	35.5832
23	21.1460	138.755	63	270.069	34.8298
24	22.7159	133.948	64	280.079	34.1250
25	24.3146	129.507	65	290.072	33.4668
26	25.9497	125.374	66	300.078	32.8398
27	27.5938	121.581	67	310.072	32.2606
28	29.2319	118.092	68	315.080	31.9834
29	31.0574	114.509	69	320.092	31.7155
30	33.1817	110.709	70	326.096	31.3972
31	36.1874	105.877	71	330.090	31.1979
32	39.1901	101.611			
33	42.1827	97.7798			
34	45.1824	94.3152			
35	48.1697	91.1877			
36	50.1692	89.2498			
37	55.1561	84.8701			
38	60.1602	81.0258			
39	65.1559	77.6359			
40	70.1529	74.6098			

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POLYNOMIAL EQUATION

Calibration Report: 429016
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29756
Sensor Type: Cernox Resistor
Sensor Excitation: 2mV±50%
Temperature Range: 4.00K to 325K

Polynomial Type: Chebychev
Useful Range of Fit:

4.00K	to	24.3K
344.5 Ohms	to	129.5 Ohms

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

ZL = 2.08486652641 ZU = 2.56780974922

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	12.294818	3.2454E-04	37883.89
1	-11.392262	5.0283E-04	-22656.36
2	3.251466	4.8330E-04	6727.62
3	-0.606381	4.5647E-04	-1328.41
4	0.054590	4.4516E-04	122.63
5	0.005033	4.3256E-04	11.64
6	-0.001275	4.1513E-04	-3.07

Z = Log(resistance)

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

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

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POLYNOMIAL EQUATION

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	369.6662	3.60616	3.60599	0.17
2	356.2897	3.80505	3.80499	0.07
3	344.1269	4.00698	4.00668	0.29
4	333.3837	4.20190	4.20372	-1.81
5	309.3506	4.72419	4.72235	1.84
6	294.0101	5.12413	5.12363	0.50
7	277.7187	5.62727	5.62765	-0.38
8	259.1155	6.32901	6.33038	-1.37
9	241.9739	7.13744	7.13788	-0.44
10	224.8964	8.15252	8.15042	2.10
11	211.0710	9.17388	9.17510	-1.22
12	199.7275	10.19568	10.19605	-0.37
13	190.2199	11.21127	11.21005	1.22
14	182.0696	12.21985	12.22021	-0.36
15	175.0158	13.22080	13.22004	0.76
16	168.8137	14.21224	14.21200	0.24
17	163.2849	15.19800	15.19895	-0.95
18	158.3317	16.17420	16.17670	-2.51
19	153.8389	17.15005	17.14959	0.46
20	149.7195	18.12179	18.12181	-0.02
21	145.9337	19.09287	19.09011	2.76
22	142.3944	20.06814	20.06659	1.55
23	138.7554	21.14598	21.14922	-3.24
24	133.9475	22.71587	22.71500	0.86
25	129.5072	24.31455	24.31404	0.51
26	125.3737	25.94971	25.95097	-1.27
27	121.5812	27.59380	27.59321	0.59

Order of Fit = 6 RMS error of fit = 1.34 mK
Largest absolute error = -3.24 mK at data point no. 23

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POLYNOMIAL EQUATION

Calibration Report: 429016
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29756
Sensor Type: Cernox Resistor
Sensor Excitation: 2mV±50%
Temperature Range: 4.00K to 325K

Polynomial Type: Chebychev
Useful Range of Fit:

24.3K	to	110.K
129.5 Ohms	to	58.26 Ohms

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

ZL = 1.72482278171 ZU = 2.14225003518

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	64.731028	1.4486E-03	44684.49
1	-53.094861	2.3549E-03	-22546.73
2	10.796985	2.1486E-03	5025.03
3	-1.390311	1.9656E-03	-707.33
4	0.093317	1.8469E-03	50.53
5	0.012139	1.8333E-03	6.62

Z = Log(resistance)

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

Temp. (K) = ΣA_i* COS(i * ARCCOS(X)), where 0 <= i <= 5
and the A_i's are the coefficients in the table above.

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POLYNOMIAL EQUATION

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
23	138.7554	21.14922	21.14830	0.92
24	133.9475	22.71500	22.71509	-0.08
25	129.5072	24.31404	24.31463	-0.59
26	125.3737	25.94971	25.95078	-1.07
27	121.5812	27.59380	27.59121	2.59
28	118.0924	29.23193	29.23148	0.44
29	114.5091	31.05742	31.06208	-4.66
30	110.7094	33.18171	33.18437	-2.66
31	105.8770	36.18736	36.19207	-4.71
32	101.6112	39.19009	39.18070	9.39
33	97.77980	42.18274	42.17716	5.58
34	94.31525	45.18240	45.18125	1.15
35	91.18767	48.16971	48.16876	0.96
36	89.24982	50.16917	50.16710	2.08
37	84.87010	55.15613	55.15784	-1.71
38	81.02580	60.16017	60.16697	-6.80
39	77.63589	65.15585	65.16358	-7.73
40	74.60981	70.15289	70.16135	-8.46
41	71.89228	75.14776	75.14910	-1.34
42	69.42952	80.14005	80.13614	3.91
43	67.18573	85.13411	85.11744	16.67
44	65.12000	90.12593	90.11789	8.04
45	63.21558	95.12316	95.12040	2.76
46	61.45472	100.11153	100.11707	-5.54
47	58.25787	110.21209	110.22358	-11.48
48	55.52161	120.09697	120.10063	-3.66
49	53.06679	130.10035	130.09436	5.99

Order of Fit = 5 RMS error of fit = 5.92 mK
Largest absolute error = 16.67 mK at data point no. 43

POLYNOMIAL EQUATION

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%

Polynomial Type: Chebychev
Useful Range of Fit:

110.K	to	325.K
58.26 Ohms	to	31.46 Ohms

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

ZL = 1.49412539875 ZU = 1.80082409976

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	194.431541	6.2938E-03	30892.40
1	-114.838107	9.7294E-03	-11803.17
2	17.641752	8.7457E-03	2017.19
3	-2.530510	8.5190E-03	-297.04
4	0.489222	8.5386E-03	57.30
5	-0.097158	8.4839E-03	-11.45
6	0.033193	8.2031E-03	4.05

Z = Log(resistance)

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

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

POLYNOMIAL EQUATION

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
45	63.21558	95.12040	95.12993	-9.54
46	61.45472	100.11707	100.10256	14.50
47	58.25787	110.22358	110.21837	5.21
48	55.52161	120.09697	120.10931	-12.33
49	53.06679	130.10035	130.10677	-6.42
50	50.86996	140.10581	140.11150	-5.70
51	48.89819	150.10195	150.08970	12.26
52	47.11034	160.09390	160.08907	4.83
53	45.48647	170.08275	170.07900	3.75
54	44.00333	180.07742	180.07016	7.26
55	42.64116	190.07948	190.07862	0.87
56	41.38668	200.07878	200.09655	-17.77
57	40.23522	210.07313	210.05618	16.95
58	39.16218	220.06718	220.08085	-13.67
59	38.16779	230.07828	230.09143	-13.15
60	37.24354	240.07539	240.09491	-19.52
61	36.38326	250.07315	250.08523	-12.08
62	35.58315	260.07924	260.03568	43.56
63	34.82985	270.06916	270.05367	15.49
64	34.12503	280.07855	280.06447	14.07
65	33.46680	290.07238	290.03470	37.68
66	32.83980	300.07833	300.15339	-75.05
67	32.26055	310.07168	310.10038	-28.70
68	31.98343	315.08033	315.08108	-0.75
69	31.71546	320.09163	320.04330	48.34
70	31.39717	326.09554	326.13406	-38.53
71	31.19790	330.08993	330.06148	28.45

Order of Fit = 6 RMS error of fit = 25.19 mK
Largest absolute error = -75.05 mK at data point no. 66

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INTERPOLATION TABLE

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT	Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
4.000	344.510	-57.407	-0.66653	37.00	104.675	-1.4641	-0.51752
4.200	333.577	-52.069	-0.65559	38.00	103.239	-1.4092	-0.51871
4.400	323.632	-47.491	-0.64567	39.00	101.856	-1.3576	-0.51983
4.600	314.541	-43.516	-0.63640	40.00	100.523	-1.3091	-0.52091
4.800	306.189	-40.075	-0.62824	42.00	97.9953	-1.2199	-0.52286
5.000	298.484	-37.044	-0.62054	44.00	95.6365	-1.1403	-0.52462
5.200	291.348	-34.365	-0.61335	46.00	93.4286	-1.0688	-0.52622
5.400	284.719	-31.977	-0.60647	48.00	91.3567	-1.0043	-0.52765
5.600	278.540	-29.847	-0.60007	50.00	89.4075	-0.94592	-0.52899
5.800	272.765	-27.940	-0.59411	52.00	87.5695	-0.89291	-0.53022
6.000	267.352	-26.213	-0.58829	54.00	85.8328	-0.84455	-0.53133
6.500	255.190	-22.588	-0.57534	56.00	84.1884	-0.80046	-0.53245
7.000	244.643	-19.705	-0.56383	58.00	82.6285	-0.75999	-0.53347
7.500	235.389	-17.389	-0.55404	60.00	81.1462	-0.72282	-0.53446
8.000	227.187	-15.481	-0.54515	65.00	77.7407	-0.64204	-0.53681
8.500	219.851	-13.909	-0.53776	70.00	74.7025	-0.57530	-0.53908
9.000	213.238	-12.582	-0.53102	75.00	71.9696	-0.51945	-0.54132
9.500	207.234	-11.460	-0.52536	77.35	70.7765	-0.49628	-0.54238
10.00	201.751	-10.496	-0.52023	80.00	69.4937	-0.47218	-0.54357
10.50	196.716	-9.6657	-0.51592	85.00	67.2364	-0.43177	-0.54584
11.00	192.069	-8.9404	-0.51203	90.00	65.1667	-0.39692	-0.54818
11.50	187.760	-8.3065	-0.50876	95.00	63.2597	-0.36657	-0.55049
12.00	183.750	-7.7454	-0.50582	100.0	61.4945	-0.34015	-0.55315
12.50	180.004	-7.2485	-0.50336	105.0	59.8529	-0.31686	-0.55586
13.00	176.493	-6.8040	-0.50116	110.0	58.3223	-0.29571	-0.55773
13.50	173.192	-6.4060	-0.49934	115.0	56.8920	-0.27683	-0.55957
14.00	170.081	-6.0467	-0.49773	120.0	55.5500	-0.26036	-0.56242
14.50	167.140	-5.7221	-0.49641	125.0	54.2855	-0.24565	-0.56565
15.00	164.354	-5.4267	-0.49527	130.0	53.0916	-0.23212	-0.56837
15.50	161.708	-5.1576	-0.49437	135.0	51.9625	-0.21967	-0.57071
16.00	159.192	-4.9111	-0.49360	140.0	50.8932	-0.20823	-0.57282
16.50	156.794	-4.6851	-0.49303	145.0	49.8787	-0.19768	-0.57468
17.00	154.504	-4.4768	-0.49258	150.0	48.9150	-0.18791	-0.57623
17.50	152.314	-4.2846	-0.49227	155.0	47.9984	-0.17884	-0.57754
18.00	150.217	-4.1066	-0.49207	160.0	47.1255	-0.17042	-0.57862
18.50	148.206	-3.9415	-0.49200	165.0	46.2932	-0.16259	-0.57951
19.00	146.274	-3.7878	-0.49201	170.0	45.4987	-0.15529	-0.58021
19.50	144.416	-3.6447	-0.49213	175.0	44.7395	-0.14847	-0.58075
20.00	142.628	-3.5108	-0.49231	180.0	44.0133	-0.14210	-0.58112
21.00	139.241	-3.2684	-0.49294	185.0	43.3179	-0.13613	-0.58136
22.00	136.081	-3.0545	-0.49381	190.0	42.6514	-0.13052	-0.58145
23.00	133.124	-2.8634	-0.49471	195.0	42.0121	-0.12526	-0.58141
24.00	130.347	-2.6940	-0.49604	200.0	41.3983	-0.12031	-0.58122
25.00	127.729	-2.5438	-0.49788	205.0	40.8085	-0.11564	-0.58090
26.00	125.255	-2.4074	-0.49971	210.0	40.2415	-0.11123	-0.58045
27.00	122.911	-2.2832	-0.50155	215.0	39.6958	-0.10706	-0.57985
28.00	120.685	-2.1699	-0.50343	220.0	39.1705	-0.10311	-0.57911
29.00	118.568	-2.0658	-0.50526	225.0	38.6644	-9.9365e-2	-0.57824
30.00	116.551	-1.9699	-0.50705	230.0	38.1765	-9.5809e-2	-0.57721
31.00	114.626	-1.8812	-0.50877	235.0	37.7060	-9.2428e-2	-0.57605
32.00	112.786	-1.7990	-0.51042	240.0	37.2520	-8.9209e-2	-0.57474
33.00	111.026	-1.7226	-0.51200	245.0	36.8137	-8.6141e-2	-0.57328
34.00	109.339	-1.6514	-0.51351	250.0	36.3904	-8.3216e-2	-0.57169
35.00	107.722	-1.5847	-0.51490	255.0	35.9813	-8.0422e-2	-0.56995
36.00	106.168	-1.5224	-0.51624	260.0	35.5859	-7.7752e-2	-0.56808

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INTERPOLATION TABLE

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
265.0	35.2036	-7.5199e-2	-0.56607
270.0	34.8338	-7.2756e-2	-0.56394
273.15	34.6069	-7.1270e-2	-0.56253
275.0	34.4759	-7.0416e-2	-0.56168
280.0	34.1294	-6.8175e-2	-0.55931

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
285.0	33.7940	-6.6026e-2	-0.55683
290.0	33.4690	-6.3965e-2	-0.55424
295.0	33.1542	-6.1987e-2	-0.55155
300.0	32.8490	-6.0089e-2	-0.54878
305.0	32.5532	-5.8267e-2	-0.54592
310.0	32.2662	-5.6517e-2	-0.54299
315.0	31.9879	-5.4836e-2	-0.53999
320.0	31.7178	-5.3220e-2	-0.53694
325.0	31.4556	-5.1667e-2	-0.53383

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THERMAL CYCLE TESTING

Sensor Model: CX-1030-SD-HT-4L   Serial Number: X29756
Sensor Type: Cernox Resistor

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:

Room Temperature:	32.5Ω
Liquid Nitrogen:	70.7Ω
Liquid Helium:	333Ω

The nitrogen and helium values were recorded in OPEN dewars, so precision comparisons with calibration values or other dip 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 at the values listed below. In order to minimize possible self-heating errors, we suggest that these same guidelines be followed in using the sensor:

Above 1K:	1 to 3 mV
0.1 to 1K:	0.1 mV
Below 0.1K:	0.03 mV

Lead Identification:

NONE

To avoid possible damage to the sensor, do not exceed 1 Volt and do not exceed 100 mA current.

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BREAKPOINTS 340 FORMAT

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756

Name: CX-1030-SD-HT-4L
Serial number: X29756
Format: 4 ;Log Ohms/Kelvin
Limit: 325.
Coefficient: 1 ;Negative

Point 1: 1.49769,325.000
Point 2: 1.50166,319.500
Point 3: 1.50535,314.500
Point 4: 1.50912,309.500
Point 5: 1.51298,304.500

Point 6: 1.51691,299.500
Point 7: 1.52094,294.500
Point 8: 1.52505,289.500
Point 9: 1.52926,284.500
Point 10: 1.53356,279.500

Point 11: 1.53795,274.500
Point 12: 1.54245,269.500
Point 13: 1.54704,264.500
Point 14: 1.55175,259.500
Point 15: 1.55655,254.500

Point 16: 1.56147,249.500
Point 17: 1.56651,244.500
Point 18: 1.57166,239.500
Point 19: 1.57693,234.500
Point 20: 1.58233,229.500

Point 21: 1.58786,224.500
Point 22: 1.59352,219.500
Point 23: 1.59932,214.500
Point 24: 1.60526,209.500
Point 25: 1.61136,204.500

Point 26: 1.61760,199.500
Point 27: 1.62401,194.500
Point 28: 1.63059,189.500
Point 29: 1.63734,184.500
Point 30: 1.64357,180.000

Point 31: 1.64996,175.500
Point 32: 1.65651,171.000
Point 33: 1.66323,166.500
Point 34: 1.67012,162.000
Point 35: 1.67720,157.500

Point 36: 1.68447,153.000
Point 37: 1.69194,148.500
Point 38: 1.69963,144.000
Point 39: 1.70753,139.500
Point 40: 1.71567,135.000

Point 41: 1.72312,131.000
Point 42: 1.73076,127.000
Point 43: 1.73863,123.000
Point 44: 1.74671,119.000
Point 45: 1.75503,115.000

Point 46: 1.76362,111.000
Point 47: 1.77138,107.500
Point 48: 1.77938,104.000
Point 49: 1.78762,100.500
Point 50: 1.79490, 97.500

Point 51: 1.80112, 95.000
Point 52: 1.80749, 92.500
Point 53: 1.81402, 90.000
Point 54: 1.82071, 87.500
Point 55: 1.82759, 85.000

Point 56: 1.83466, 82.500
Point 57: 1.84193, 80.000
Point 58: 1.84942, 77.500
Point 59: 1.85558, 75.500
Point 60: 1.86188, 73.500

Point 61: 1.86836, 71.500
Point 62: 1.87500, 69.500
Point 63: 1.88183, 67.500
Point 64: 1.88885, 65.500
Point 65: 1.89607, 63.500

Point 66: 1.90352, 61.500
Point 67: 1.91158, 59.400
Point 68: 1.91872, 57.600
Point 69: 1.92606, 55.800
Point 70: 1.93364, 54.000

Point 71: 1.94145, 52.200
Point 72: 1.94952, 50.400
Point 73: 1.95787, 48.600
Point 74: 1.96651, 46.800
Point 75: 1.97547, 45.000

Point 76: 1.98373, 43.400
Point 77: 1.99227, 41.800
Point 78: 2.00111, 40.200
Point 79: 2.01028, 38.600
Point 80: 2.01982, 37.000

Point 81: 2.02910, 35.500
Point 82: 2.03875, 34.000
Point 83: 2.04878, 32.500
Point 84: 2.05925, 31.000
Point 85: 2.06944, 29.600

Point 86: 2.08006, 28.200
Point 87: 2.09117, 26.800
Point 88: 2.10197, 25.500
Point 89: 2.11327, 24.200
Point 90: 2.12422, 23.000

Point 91: 2.13571, 21.800
Point 92: 2.14783, 20.600
Point 93: 2.15688, 19.750
Point 94: 2.16403, 19.100
Point 95: 2.17142, 18.450

Point 96: 2.17909, 17.800
Point 97: 2.18704, 17.150
Point 98: 2.19466, 16.550
Point 99: 2.20257, 15.950
Point 100: 2.21080, 15.350

Point 101: 2.21937, 14.750
Point 102: 2.22757, 14.200
Point 103: 2.23610, 13.650
Point 104: 2.24503, 13.100
Point 105: 2.25352, 12.600

Point 106: 2.26237, 12.100
Point 107: 2.27166, 11.600
Point 108: 2.28141, 11.100
Point 109: 2.29063, 10.650
Point 110: 2.30031, 10.200

Point 111: 2.31051, 9.750
Point 112: 2.32128, 9.300
Point 113: 2.33269, 8.850
Point 114: 2.34347, 8.450
Point 115: 2.35486, 8.050

Point 116: 2.36698, 7.650
Point 117: 2.37991, 7.250
Point 118: 2.39201, 6.900
Point 119: 2.40488, 6.550
Point 120: 2.41868, 6.200

Point 121: 2.43306, 5.860
Point 122: 2.44761, 5.540
Point 123: 2.46329, 5.220
Point 124: 2.47918, 4.920
Point 125: 2.49636, 4.620

Point 126: 2.51380, 4.340
Point 127: 2.53276, 4.060
Point 128: 2.53724, 4.000

BREAKPOINTS 91C/93C/330 FORMAT

Calibration Report: 429016
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29756
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Interpolation Method: Lagrangian
Limit: 325. (Kelvin)
Format: 4 (Log Ohms/Kelvin)
Number of Breakpoints: 46

No.	Units	Temperature (K)	No.	Units	Temperature (K)
1	1.49770	325.0	26	2.04610	32.9
2	1.49841	324.0	27	2.07096	29.4
3	1.49985	322.0	28	2.09613	26.2
4	1.51105	307.0	29	2.12055	23.4
5	1.52299	292.0	30	2.14581	20.8
6	1.53575	277.0	31	2.17086	18.5
7	1.54939	262.0	32	2.19533	16.5
8	1.56399	247.0	33	2.22013	14.7
9	1.57963	232.0	34	2.24506	13.1
10	1.59641	217.0	35	2.26980	11.7
11	1.61447	202.0	36	2.29384	10.5
12	1.63395	187.0	37	2.31888	9.4
13	1.65505	172.0	38	2.34213	8.5
14	1.67801	157.0	39	2.36547	7.7
15	1.70313	142.0	40	2.38853	7.0
16	1.73078	127.0	41	2.41075	6.4
17	1.76147	112.0	42	2.43579	5.8
18	1.79614	97.0	43	2.45935	5.3
19	1.83611	82.0	44	2.48038	4.9
20	1.88358	67.0	45	2.51005	4.4
21	1.91514	58.5	46	2.53720	4.0
22	1.94682	51.0			
23	1.97048	46.0			
24	1.99612	41.1			
25	2.02106	36.8			

Temperature for Resistance Decades:

Res. (Ohms)	Temp. (K)
100	40.402

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BREAKPOINTS 234 FORMAT

Calibration Report: 429016
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29756

Maximum Temperature Error:	
1.4 - 10K:	0.007K
10 - 20K:	0.013K
20 - 40K:	0.020K
40 - 100K:	0.046K
> 100K:	0.222K

BP #	Temp. (K)	Res. (Ω)	Log10 Res.	BP #	Temp. (K)	Res. (Ω)	Log10 Res.
1	321.801	31.62278	1.500	31	25.737	125.8925	2.100
2	295.658	33.11311	1.520	32	23.461	131.8257	2.120
3	272.210	34.67369	1.540	33	21.372	138.0384	2.140
4	250.995	36.30781	1.560	34	19.466	144.5440	2.160
5	231.656	38.01894	1.580	35	17.726	151.3561	2.180
6	213.936	39.81072	1.600	36	16.144	158.4893	2.200
7	197.618	41.68694	1.620	37	14.709	165.9587	2.220
8	182.576	43.65158	1.640	38	13.409	173.7801	2.240
9	168.655	45.70882	1.660	39	12.233	181.9701	2.260
10	155.762	47.86301	1.680	40	11.173	190.5461	2.280
11	143.794	50.11872	1.700	41	10.216	199.5262	2.300
12	132.670	52.48075	1.720	42	9.354	208.9296	2.320
13	122.320	54.95409	1.740	43	8.578	218.7762	2.340
14	112.680	57.54399	1.760	44	7.880	229.0868	2.360
15	103.738	60.25596	1.780	45	7.249	239.8833	2.380
16	95.449	63.09573	1.800	46	6.681	251.1886	2.400
17	87.769	66.06934	1.820	47	6.169	263.0268	2.420
18	80.662	69.18310	1.840	48	5.706	275.4229	2.440
19	74.096	72.44360	1.860	49	5.287	288.4032	2.460
20	68.033	75.85776	1.880	50	4.907	301.9952	2.480
21	62.442	79.43282	1.900	51	4.561	316.2278	2.500
22	57.285	83.17638	1.920	52	4.247	331.1311	2.520
23	52.535	87.09636	1.940	53	3.962	346.7369	2.540
24	48.155	91.20108	1.960	54	3.701	363.0781	2.560
25	44.120	95.49926	1.980				
26	40.404	100.0000	2.000				
27	36.974	104.7129	2.020				
28	33.814	109.6478	2.040				
29	30.899	114.8154	2.060				
30	28.213	120.2264	2.080				

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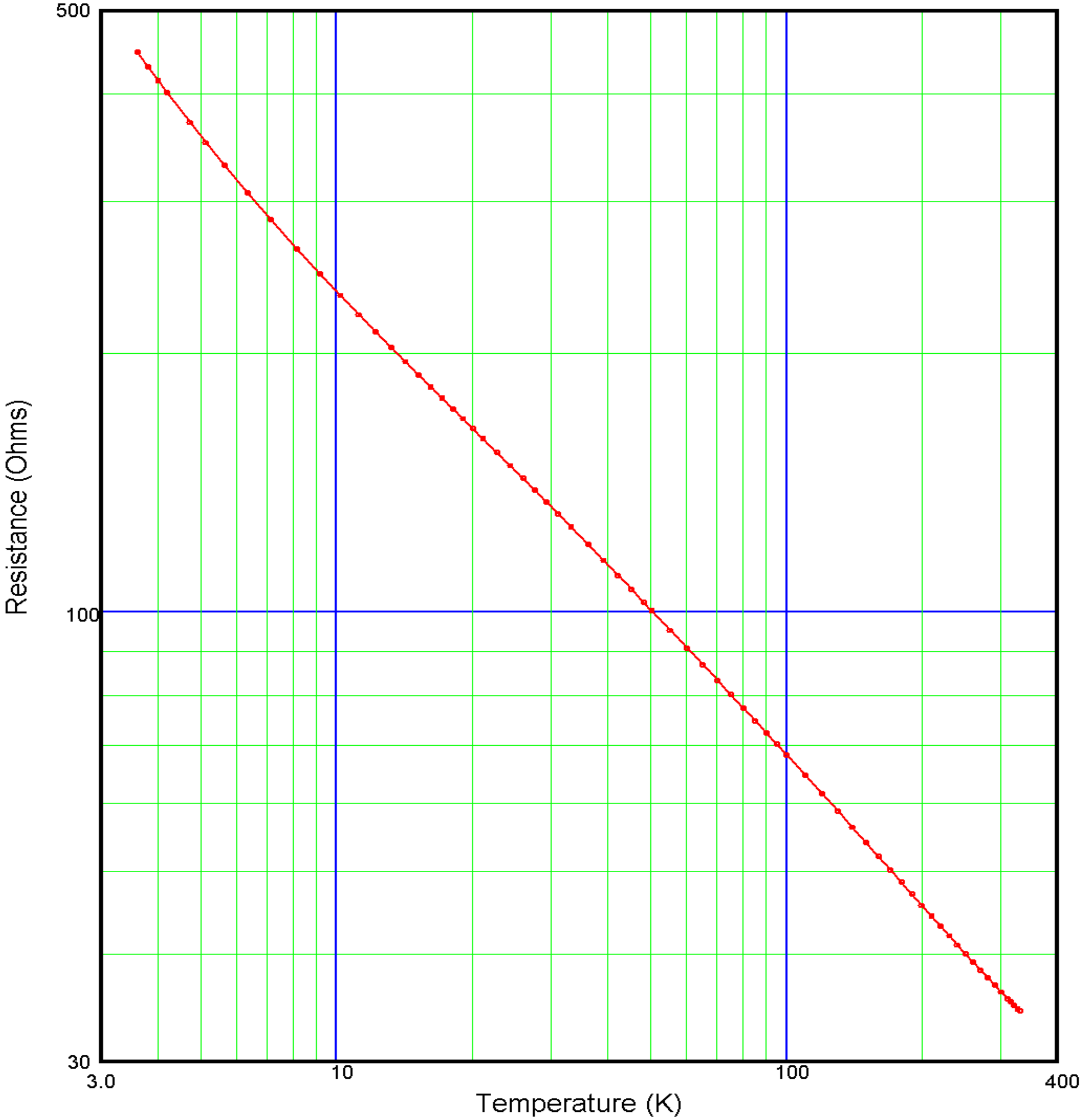
X29761
SCAL-B 2% redundant thermometer

DATA PLOT

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%



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TEST DATA

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

Index	Temperature (K)	Resistance (Ω)	Index	Temperature (K)	Resistance (Ω)
1	3.60625	447.904	41	75.1471	80.1893
2	3.80527	430.752	42	80.1405	77.3496
3	4.00697	415.162	43	85.1340	74.7693
4	4.20283	401.488	44	90.1246	72.4077
5	4.72405	370.747	45	95.1220	70.2307
6	5.12442	351.270	46	100.112	68.2174
7	5.62776	330.679	47	110.213	64.5763
8	6.32975	307.347	48	120.097	61.4721
9	7.13722	285.809	49	130.099	58.6955
10	8.15277	264.509	50	140.105	56.2170
11	9.17411	247.432	51	150.102	53.9960
12	10.1958	233.421	52	160.094	51.9967
13	11.2105	221.666	53	170.083	50.1770
14	12.2203	211.692	54	180.078	48.5182
15	13.2230	203.061	55	190.080	46.9982
16	14.2114	195.501	56	200.080	45.6021
17	15.1988	188.762	57	210.072	44.3174
18	16.1739	182.769	58	220.066	43.1343
19	17.1501	177.323	59	230.079	42.0338
20	18.1219	172.330	60	240.075	41.0104
21	19.0924	167.748	61	250.074	40.0606
22	20.0679	163.477	62	260.081	39.1773
23	21.1462	159.123	63	270.070	38.3508
24	22.7168	153.331	64	280.082	37.5757
25	24.3139	148.007	65	290.073	36.8537
26	25.9477	143.053	66	300.078	36.1714
27	27.5954	138.525	67	310.072	35.5330
28	29.2311	134.365	68	315.079	35.2302
29	31.0573	130.113	69	320.093	34.9345
30	33.1816	125.597	70	326.097	34.5900
31	36.1875	119.898	71	330.090	34.3696
32	39.1903	114.838			
33	42.1820	110.337			
34	45.1818	106.273			
35	48.1695	102.609			
36	50.1685	100.342			
37	55.1571	95.2215			
38	60.1605	90.7581			
39	65.1556	86.8255			
40	70.1517	83.3291			

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POLYNOMIAL EQUATION

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

Polynomial Type: Chebychev
Useful Range of Fit:

4.00K	to	24.3K
415.7 Ohms	to	148.0 Ohms

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

ZL = 2.1415292157   ZU = 2.65118527504

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	12.274101	3.7295E-04	32910.74
1	-11.379432	5.7755E-04	-19702.84
2	3.269299	5.5544E-04	5885.95
3	-0.618780	5.2462E-04	-1179.49
4	0.057863	5.1174E-04	113.07
5	0.004750	4.9700E-04	9.56
6	-0.001625	4.7683E-04	-3.41

Z = Log(resistance)

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

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

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POLYNOMIAL EQUATION

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	447.9043	3.60625	3.60618	0.07
2	430.7519	3.80527	3.80530	-0.03
3	415.1623	4.00697	4.00711	-0.14
4	401.4877	4.20283	4.20308	-0.25
5	370.7475	4.72405	4.72316	0.89
6	351.2702	5.12442	5.12456	-0.14
7	330.6787	5.62776	5.62853	-0.77
8	307.3467	6.32975	6.32874	1.01
9	285.8095	7.13722	7.13877	-1.56
10	264.5094	8.15277	8.15260	0.17
11	247.4321	9.17411	9.17322	0.89
12	233.4206	10.19581	10.19390	1.91
13	221.6655	11.21049	11.21270	-2.20
14	211.6919	12.22025	12.22068	-0.43
15	203.0613	13.22300	13.22096	2.04
16	195.5012	14.21140	14.21221	-0.80
17	188.7616	15.19879	15.20086	-2.07
18	182.7688	16.17390	16.17494	-1.05
19	177.3232	17.15006	17.14772	2.34
20	172.3301	18.12194	18.12166	0.28
21	167.7482	19.09236	19.09204	0.33
22	163.4770	20.06786	20.06946	-1.60
23	159.1226	21.14617	21.14541	0.76
24	153.3306	22.71684	22.71478	2.05
25	148.0066	24.31395	24.31341	0.54
26	143.0531	25.94766	25.95221	-4.55
27	138.5253	27.59541	27.59310	2.31

Order of Fit = 6 RMS error of fit = 1.54 mK
Largest absolute error = -4.55 mK at data point no. 26

POLYNOMIAL EQUATION

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

Polynomial Type: Chebychev
Useful Range of Fit:

24.3K	to	110.K
148.0 Ohms	to	64.58 Ohms

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

ZL = 1.76860451763   ZU = 2.20173184503

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	64.545267	1.1559E-03	55837.83
1	-53.007161	1.8805E-03	-28188.14
2	10.956697	1.7114E-03	6402.11
3	-1.475195	1.5664E-03	-941.77
4	0.117342	1.5015E-03	78.15
5	0.008713	1.4616E-03	5.96
6	0.003256	1.4486E-03	2.25

Z = Log(resistance)

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

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

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POLYNOMIAL EQUATION

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
23	159.1226	21.14541	21.14892	-3.51
24	153.3306	22.71478	22.71194	2.85
25	148.0066	24.31341	24.30924	4.17
26	143.0531	25.94766	25.94852	-0.85
27	138.5253	27.59541	27.59055	4.86
28	134.3646	29.23106	29.23412	-3.06
29	130.1127	31.05730	31.06238	-5.07
30	125.5975	33.18162	33.18891	-7.30
31	119.8982	36.18745	36.18603	1.42
32	114.8383	39.19030	39.18904	1.26
33	110.3365	42.18197	42.17934	2.64
34	106.2730	45.18179	45.17869	3.09
35	102.6093	48.16951	48.16440	5.10
36	100.3425	50.16854	50.16246	6.08
37	95.22149	55.15711	55.16324	-6.13
38	90.75811	60.16050	60.16365	-3.15
39	86.82548	65.15559	65.16173	-6.14
40	83.32911	70.15173	70.15384	-2.11
41	80.18932	75.14707	75.14788	-0.81
42	77.34965	80.14055	80.14299	-2.45
43	74.76926	85.13401	85.13034	3.67
44	72.40770	90.12457	90.11682	7.75
45	70.23074	95.12197	95.11375	8.22
46	68.21740	100.11170	100.11551	-3.81
47	64.57626	110.21301	110.22198	-8.97
48	61.47205	120.09664	120.09669	-0.05
49	58.69546	130.09851	130.09621	2.30

Order of Fit = 6 RMS error of fit = 4.60 mK
Largest absolute error = -8.97 mK at data point no. 47

POLYNOMIAL EQUATION

Calibration Report: 429023
Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L
Serial Number: X29761
Sensor Type: Cernox Resistor
Sensor Excitation: 2mV±50%
Temperature Range: 4.00K to 325K

Polynomial Type: Chebychev
Useful Range of Fit:

110.K	to	325.K
64.58 Ohms	to	34.65 Ohms

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

ZL = 1.53617408827 ZU = 1.84652722919

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff./Std Dev.)
0	193.900732	2.9905E-03	64839.77
1	-114.656643	4.6122E-03	-24859.60
2	18.135919	4.1639E-03	4355.49
3	-2.715954	4.0231E-03	-675.10
4	0.536736	4.0332E-03	133.08
5	-0.103940	4.0440E-03	-25.70
6	0.024621	3.9739E-03	6.20
7	-0.010242	3.7776E-03	-2.71

Z = Log(resistance)

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

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

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POLYNOMIAL EQUATION

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

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

	R Meas. (Ω)	T Meas. (K)	T Eq. (K)	T diff. (mK)
45	70.23074	95.11375	95.11123	2.52
46	68.21740	100.11551	100.12036	-4.85
47	64.57626	110.22198	110.22153	0.45
48	61.47205	120.09664	120.09272	3.92
49	58.69546	130.09851	130.09226	6.24
50	56.21703	140.10534	140.11255	-7.22
51	53.99603	150.10184	150.11613	-14.29
52	51.99667	160.09364	160.08499	8.65
53	50.17700	170.08297	170.07840	4.57
54	48.51824	180.07766	180.07072	6.94
55	46.99816	190.08014	190.07745	2.69
56	45.60212	200.07973	200.08672	-6.99
57	44.31738	210.07230	210.08702	-14.72
58	43.13431	220.06609	220.05444	11.65
59	42.03380	230.07899	230.06369	15.31
60	41.01042	240.07472	240.09004	-15.32
61	40.06062	250.07416	250.09187	-17.70
62	39.17735	260.08083	260.06821	12.62
63	38.35077	270.07030	270.06401	6.29
64	37.57573	280.08230	280.08463	-2.33
65	36.85366	290.07256	290.05112	21.43
66	36.17145	300.07773	300.09095	-13.22
67	35.53302	310.07241	310.09801	-25.59
68	35.23017	315.07944	315.07097	8.47
69	34.93446	320.09290	320.07759	15.31
70	34.59003	326.09722	326.10730	-10.08
71	34.36957	330.09006	330.08479	5.27

Order of Fit = 7 RMS error of fit = 11.55 mK
Largest absolute error = -25.59 mK at data point no. 67

INTERPOLATION TABLE

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
4.000	415.684	-73.521	-0.70747
4.200	401.693	-66.577	-0.69611
4.400	388.988	-60.609	-0.68557
4.600	377.397	-55.428	-0.67560
4.800	366.770	-50.942	-0.66669
5.000	356.984	-46.997	-0.65826
5.200	347.940	-43.518	-0.65038
5.400	339.552	-40.423	-0.64286
5.600	331.748	-37.669	-0.63586
5.800	324.465	-35.207	-0.62934
6.000	317.650	-32.982	-0.62299
6.500	302.372	-28.325	-0.60889
7.000	289.167	-24.636	-0.59638
7.500	277.612	-21.681	-0.58574
8.000	267.398	-19.255	-0.57608
8.500	258.284	-17.260	-0.56803
9.000	250.086	-15.580	-0.56069
9.500	242.659	-14.163	-0.55448
10.00	235.890	-12.947	-0.54885
10.50	229.683	-11.902	-0.54410
11.00	223.966	-10.991	-0.53980
11.50	218.673	-10.195	-0.53616
12.00	213.755	-9.4923	-0.53289
12.50	209.167	-8.8707	-0.53012
13.00	204.873	-8.3153	-0.52764
13.50	200.842	-7.8189	-0.52556
14.00	197.047	-7.3712	-0.52372
14.50	193.464	-6.9672	-0.52219
15.00	190.073	-6.6000	-0.52085
15.50	186.858	-6.2659	-0.51976
16.00	183.803	-5.9602	-0.51884
16.50	180.894	-5.6802	-0.51811
17.00	178.119	-5.4224	-0.51752
17.50	175.468	-5.1848	-0.51710
18.00	172.931	-4.9649	-0.51679
18.50	170.500	-4.7612	-0.51661
19.00	168.167	-4.5717	-0.51652
19.50	165.926	-4.3954	-0.51655
20.00	163.770	-4.2311	-0.51671
21.00	159.691	-3.9320	-0.51707
22.00	155.894	-3.6695	-0.51784
23.00	152.339	-3.4458	-0.52024
24.00	148.998	-3.2377	-0.52151
25.00	145.860	-3.0420	-0.52139
26.00	142.905	-2.8729	-0.52270
27.00	140.108	-2.7225	-0.52465
28.00	137.456	-2.5839	-0.52635
29.00	134.937	-2.4571	-0.52807
30.00	132.538	-2.3409	-0.52986
31.00	130.252	-2.2335	-0.53157
32.00	128.069	-2.1340	-0.53321
33.00	125.982	-2.0415	-0.53476
34.00	123.984	-1.9555	-0.53625
35.00	122.069	-1.8750	-0.53761
36.00	120.232	-1.7998	-0.53890
37.00	118.468	-1.7294	-0.54012
38.00	116.772	-1.6632	-0.54123
39.00	115.140	-1.6010	-0.54228
40.00	113.568	-1.5424	-0.54326
42.00	110.593	-1.4350	-0.54499
44.00	107.821	-1.3392	-0.54650
46.00	105.230	-1.2532	-0.54783
48.00	102.802	-1.1758	-0.54898
50.00	100.522	-1.1058	-0.55004
52.00	98.3745	-1.0424	-0.55099
54.00	96.3485	-0.98456	-0.55181
56.00	94.4328	-0.93195	-0.55266
58.00	92.6178	-0.88372	-0.55341
60.00	90.8952	-0.83949	-0.55415
65.00	86.9455	-0.74358	-0.55590
70.00	83.4312	-0.66460	-0.55761
75.00	80.2777	-0.59869	-0.55933
77.35	78.9033	-0.57140	-0.56015
80.00	77.4272	-0.54303	-0.56108
85.00	74.8338	-0.49555	-0.56287
90.00	72.4608	-0.45465	-0.56469
95.00	70.2784	-0.41912	-0.56655
100.0	68.2622	-0.38803	-0.56844
105.0	66.3919	-0.36063	-0.57033
110.0	64.6507	-0.33638	-0.57234
115.0	63.0237	-0.31477	-0.57437
120.0	61.4994	-0.29528	-0.57616
125.0	60.0677	-0.27770	-0.57788
130.0	58.7196	-0.26183	-0.57966
135.0	57.4470	-0.24742	-0.58143
140.0	56.2434	-0.23423	-0.58305
145.0	55.1029	-0.22213	-0.58452
150.0	54.0205	-0.21097	-0.58579
155.0	52.9918	-0.20064	-0.58686
160.0	52.0129	-0.19105	-0.58770
165.0	51.0802	-0.18213	-0.58831
170.0	50.1906	-0.17381	-0.58870
175.0	49.3412	-0.16603	-0.58887
180.0	48.5295	-0.15876	-0.58884
185.0	47.7529	-0.15193	-0.58861
190.0	47.0094	-0.14553	-0.58820
195.0	46.2970	-0.13951	-0.58761
200.0	45.6137	-0.13385	-0.58687
205.0	44.9580	-0.12851	-0.58598
210.0	44.3281	-0.12347	-0.58494
215.0	43.7228	-0.11872	-0.58377
220.0	43.1405	-0.11422	-0.58247
225.0	42.5802	-0.10996	-0.58105
230.0	42.0405	-0.10592	-0.57950
235.0	41.5206	-0.10209	-0.57784
240.0	41.0193	-9.8456e-2	-0.57606
245.0	40.5357	-9.4996e-2	-0.57416
250.0	40.0690	-9.1701e-2	-0.57215
255.0	39.6184	-8.8562e-2	-0.57002
260.0	39.1832	-8.5568e-2	-0.56778

INTERPOLATION TABLE

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761
Sensor Excitation: 2mV±50%

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
265.0	38.7625	-8.2709e-2	-0.56544
270.0	38.3559	-7.9976e-2	-0.56298
273.15	38.1066	-7.8317e-2	-0.56138
275.0	37.9626	-7.7363e-2	-0.56042
280.0	37.5821	-7.4862e-2	-0.55775

Temp (K)	Res. (Ω)	dR/dT (Ω/K)	dlogR/dlogT
285.0	37.2138	-7.2466e-2	-0.55497
290.0	36.8572	-7.0169e-2	-0.55210
295.0	36.5119	-6.7966e-2	-0.54914
300.0	36.1774	-6.5852e-2	-0.54608
305.0	35.8533	-6.3822e-2	-0.54293
310.0	35.5391	-6.1873e-2	-0.53970
315.0	35.2344	-5.9999e-2	-0.53640
320.0	34.9390	-5.8197e-2	-0.53302
325.0	34.6523	-5.6465e-2	-0.52958

THERMAL CYCLE TESTING

Sensor Model: CX-1030-SD-HT-4L   Serial Number: X29761
Sensor Type: Cernox Resistor

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:

Room Temperature:	35.8Ω
Liquid Nitrogen:	78.8Ω
Liquid Helium:	401Ω

The nitrogen and helium values were recorded in OPEN dewars, so precision comparisons with calibration values or other dip 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 at the values listed below. In order to minimize possible self-heating errors, we suggest that these same guidelines be followed in using the sensor:

Above 1K:	1 to 3 mV
0.1 to 1K:	0.1 mV
Below 0.1K:	0.03 mV

Lead Identification:

NONE

To avoid possible damage to the sensor, do not exceed 1 Volt and do not exceed 100 mA current.

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BREAKPOINTS 340 FORMAT

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761

```
Name: CX-1030-SD-HT-4L
Serial number:  X29761
Format: 4          ;Log Ohms/Kelvin
Limit: 325.
Coefficient: 1     ;Negative
Point   1: 1.53972,325.000
Point   2: 1.54367,319.500
Point   3: 1.54733,314.500
Point   4: 1.55108,309.500
Point   5: 1.55491,304.500

Point   6: 1.55883,299.500
Point   7: 1.56283,294.500
Point   8: 1.56693,289.500
Point   9: 1.57112,284.500
Point  10: 1.57541,279.500

Point  11: 1.57979,274.500
Point  12: 1.58428,269.500
Point  13: 1.58887,264.500
Point  14: 1.59357,259.500
Point  15: 1.59837,254.500

Point  16: 1.60330,249.500
Point  17: 1.60834,244.500
Point  18: 1.61350,239.500
Point  19: 1.61879,234.500
Point  20: 1.62421,229.500

Point  21: 1.62976,224.500
Point  22: 1.63545,219.500
Point  23: 1.64129,214.500
Point  24: 1.64727,209.500
Point  25: 1.65342,204.500

Point  26: 1.65972,199.500
Point  27: 1.66619,194.500
Point  28: 1.67218,190.000
Point  29: 1.67830,185.500
Point  30: 1.68458,181.000

Point  31: 1.69101,176.500
Point  32: 1.69762,172.000
Point  33: 1.70440,167.500
Point  34: 1.71135,163.000
Point  35: 1.71850,158.500

Point  36: 1.72584,154.000
Point  37: 1.73339,149.500
Point  38: 1.74116,145.000
Point  39: 1.74915,140.500
Point  40: 1.75646,136.500

Point  41: 1.76397,132.500
Point  42: 1.77169,128.500
Point  43: 1.77963,124.500
Point  44: 1.78781,120.500
Point  45: 1.79625,116.500

Point  46: 1.80496,112.500
Point  47: 1.81396,108.500
Point  48: 1.82210,105.000
Point  49: 1.83048,101.500
Point  50: 1.83790, 98.500

Point  51: 1.84423, 96.000
Point  52: 1.85072, 93.500
Point  53: 1.85738, 91.000
Point  54: 1.86421, 88.500
Point  55: 1.87122, 86.000

Point  56: 1.87843, 83.500
Point  57: 1.88585, 81.000
Point  58: 1.89349, 78.500
Point  59: 1.89977, 76.500
Point  60: 1.90621, 74.500

Point  61: 1.91281, 72.500
Point  62: 1.91959, 70.500
Point  63: 1.92656, 68.500
Point  64: 1.93372, 66.500
Point  65: 1.94110, 64.500

Point  66: 1.94869, 62.500
Point  67: 1.95653, 60.500
Point  68: 1.96420, 58.600
Point  69: 1.97170, 56.800
Point  70: 1.97943, 55.000

Point  71: 1.98740, 53.200
Point  72: 1.99564, 51.400
Point  73: 2.00416, 49.600
Point  74: 2.01297, 47.800
Point  75: 2.02211, 46.000

Point  76: 2.03053, 44.400
Point  77: 2.03924, 42.800
Point  78: 2.04825, 41.200
Point  79: 2.05820, 39.500
Point  80: 2.06793, 37.900

Point  81: 2.07804, 36.300
Point  82: 2.08791, 34.800
Point  83: 2.09817, 33.300
Point  84: 2.10886, 31.800
Point  85: 2.11926, 30.400

Point  86: 2.13009, 29.000
Point  87: 2.14141, 27.600
Point  88: 2.15241, 26.300
Point  89: 2.16389, 25.000
Point  90: 2.17503, 23.800

Point  91: 2.18673, 22.600
Point  92: 2.19899, 21.400
Point  93: 2.21085, 20.300
Point  94: 2.21989, 19.500
Point  95: 2.22750, 18.850

Point  96: 2.23537, 18.200
Point  97: 2.24353, 17.550
Point  98: 2.25201, 16.900
Point  99: 2.26015, 16.300
Point 100: 2.26859, 15.700

Point 101: 2.27739, 15.100
Point 102: 2.28579, 14.550
Point 103: 2.29454, 14.000
Point 104: 2.30367, 13.450
Point 105: 2.31322, 12.900

Point 106: 2.32232, 12.400
Point 107: 2.33182, 11.900
Point 108: 2.34179, 11.400
Point 109: 2.35228, 10.900
Point 110: 2.36222, 10.450

Point 111: 2.37267, 10.000
Point 112: 2.38369,  9.550
Point 113: 2.39535,  9.100
Point 114: 2.40633,  8.700
Point 115: 2.41793,  8.300

Point 116: 2.43025,  7.900
Point 117: 2.44337,  7.500
Point 118: 2.45562,  7.150
Point 119: 2.46862,  6.800
Point 120: 2.48252,  6.450

Point 121: 2.49741,  6.100
Point 122: 2.51203,  5.780
Point 123: 2.52773,  5.460
Point 124: 2.54468,  5.140
Point 125: 2.56189,  4.840

Point 126: 2.57926,  4.560
Point 127: 2.59808,  4.280
Point 128: 2.61711,  4.020
Point 129: 2.61876,  4.000
```


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

BREAKPOINTS 91C/93C/330 FORMAT

Calibration Report: 429023
Sensor Model: CX-1030-SD-HT-4L
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Sales Order: 14119
Serial Number: X29761

Interpolation Method: Lagrangian
Limit: 325. (Kelvin)
Format: 4 (Log Ohms/Kelvin)
Number of Breakpoints: 46

No.	Units	Temperature (K)	No.	Units	Temperature (K)
1	1.53973	325.0	26	2.11853	30.5
2	1.54044	324.0	27	2.14478	27.2
3	1.55146	309.0	28	2.16576	24.8
4	1.56325	294.0	29	2.19385	21.9
5	1.57585	279.0	30	2.21877	19.6
6	1.58934	264.0	31	2.24420	17.5
7	1.60381	249.0	32	2.27006	15.6
8	1.61933	234.0	33	2.29620	13.9
9	1.63604	219.0	34	2.32049	12.5
10	1.65405	204.0	35	2.34596	11.2
11	1.67353	189.0	36	2.37034	10.1
12	1.69468	174.0	37	2.39540	9.1
13	1.71771	159.0	38	2.42100	8.2
14	1.74293	144.0	39	2.44686	7.4
15	1.77073	129.0	40	2.47256	6.7
16	1.80168	114.0	41	2.49749	6.1
17	1.83666	99.0	42	2.52081	5.6
18	1.87699	84.0	43	2.54701	5.1
19	1.92481	69.0	44	2.57051	4.7
20	1.96055	59.5	45	2.59681	4.3
21	1.99059	52.5	46	2.61876	4.0
22	2.01450	47.5			
23	2.04093	42.5			
24	2.06672	38.1			
25	2.09268	34.1			

Temperature for Resistance Decades:

Res. (Ohms)	Temp. (K)
100	50.474

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Sales: (614) 891-2244 • Fax: (614) 891-1392 • sales@lakeshore.com • www.lakeshore.com

BREAKPOINTS 234 FORMAT

Calibration Report: 429023 Sales Order: 14119
Sensor Model: CX-1030-SD-HT-4L Serial Number: X29761
Sensor Type: Cernox Resistor
Temperature Range: 4.00K to 325K

Maximum Temperature Error:	
1.4 - 10K:	0.006K
10 - 20K:	0.013K
20 - 40K:	0.020K
40 - 100K:	0.046K
> 100K:	0.240K

BP #	Temp. (K)	Res. (Ω)	Log10 Res.	BP #	Temp. (K)	Res. (Ω)	Log10 Res.
1	324.621	34.67369	1.540	31	27.777	138.0384	2.140
2	298.036	36.30781	1.560	32	25.437	144.5440	2.160
3	274.269	38.01894	1.580	33	23.288	151.3561	2.180
4	252.845	39.81072	1.600	34	21.309	158.4893	2.200
5	233.381	41.68694	1.620	35	19.493	165.9587	2.220
6	215.600	43.65158	1.640	36	17.830	173.7801	2.240
7	199.292	45.70882	1.660	37	16.312	181.9701	2.260
8	184.279	47.86301	1.680	38	14.928	190.5461	2.280
9	170.414	50.11872	1.700	39	13.670	199.5262	2.300
10	157.581	52.48075	1.720	40	12.527	208.9296	2.320
11	145.668	54.95409	1.740	41	11.489	218.7762	2.340
12	134.610	57.54399	1.760	42	10.550	229.0868	2.360
13	124.327	60.25596	1.780	43	9.700	239.8833	2.380
14	114.771	63.09573	1.800	44	8.930	251.1886	2.400
15	105.897	66.06934	1.820	45	8.233	263.0268	2.420
16	97.669	69.18310	1.840	46	7.602	275.4229	2.440
17	90.038	72.44360	1.860	47	7.031	288.4032	2.460
18	82.971	75.85776	1.880	48	6.514	301.9952	2.480
19	76.431	79.43282	1.900	49	6.044	316.2278	2.500
20	70.385	83.17638	1.920	50	5.616	331.1311	2.520
21	64.797	87.09636	1.940	51	5.228	346.7369	2.540
22	59.637	91.20108	1.960	52	4.874	363.0781	2.560
23	54.873	95.49926	1.980	53	4.550	380.1894	2.580
24	50.476	100.0000	2.000	54	4.255	398.1072	2.600
25	46.415	104.7129	2.020	55	3.984	416.8694	2.620
26	42.667	109.6478	2.040	56	3.736	436.5158	2.640
27	39.203	114.8154	2.060				
28	36.003	120.2264	2.080				
29	33.043	125.8925	2.100				
30	30.306	131.8257	2.120				

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X28265
SCAL-B redundant SOB thermometer

Calibration Report
(CX28265)

Document Ref.:
Cardiff Ref.:
Issue: 1.0

Prepared by: Iris Didschuns
Last Modified on: 19 August 2004
Approved by:

Distribution list

Table of Contents

1. Scope

This document describes the calibration procedure and results for the Lakeshore Cernox High temperature thermometer (type: CX-1030-SD-HT; Serial No.: X28265).

2. Overview of experimental set-up

2.1 Cryostat set-up

The thermometer calibration was carry out under vacuum in a Helium 4 cryostat. The temperature range was from room temperature down to 4.2 K and through pumping on the He4 bath it was extend to 1.5 K. Therefore the three thermometers where mounted onto the 4 K plate next to the calibrated thermometers see Figure 1. The thermometers are calibrated against a calibrated Lakeshore Cernox thermometer (type: CX-1030-SD-HT-1.4L; Serial No.: X25820). The Lakeshore Cernox thermometer is calibrated from 1.4 K up to 325 K.

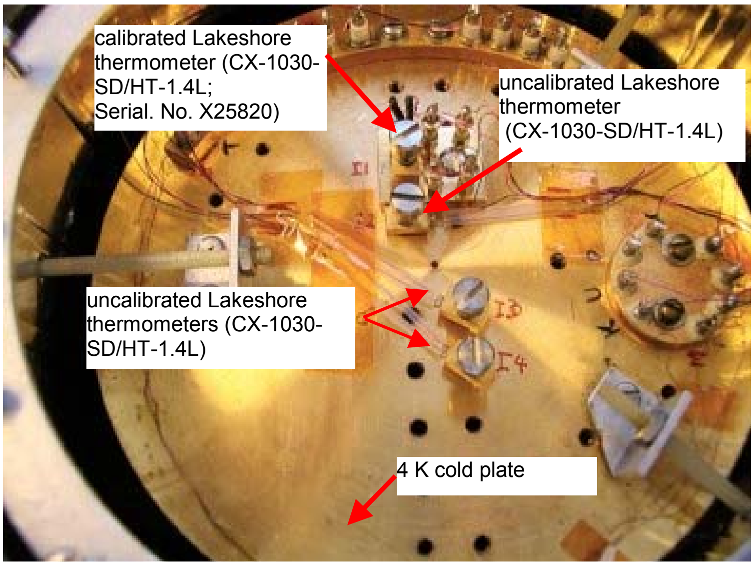


Figure 1: experimental set-up inside the cryostat

A 4 K and 77 K radiation shield was mounted over all temperature sensors to significantly decrease the radiation input form the surrounding. The data were taken during the warming up period of the cryostat to ensure a good thermal equilibrium of the sensor. The warming up rate until 4 K was 1K per 68min (Figure 2) and from 4 K until 300 K was 1K per 5min (Figure 3).

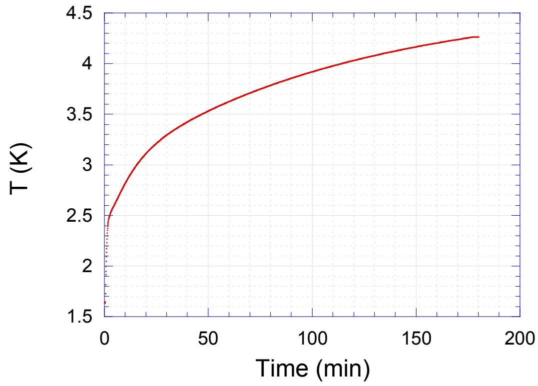


Figure 2: Typical warming up curve in temperature range between 1.5 K and 4.2 K

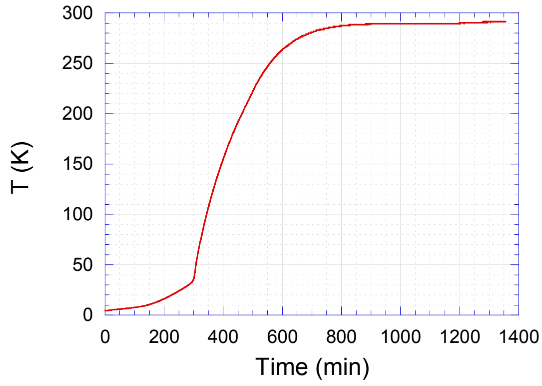


Figure 3: Typical warming up curve in temperature range between 4.2 K and 300 K

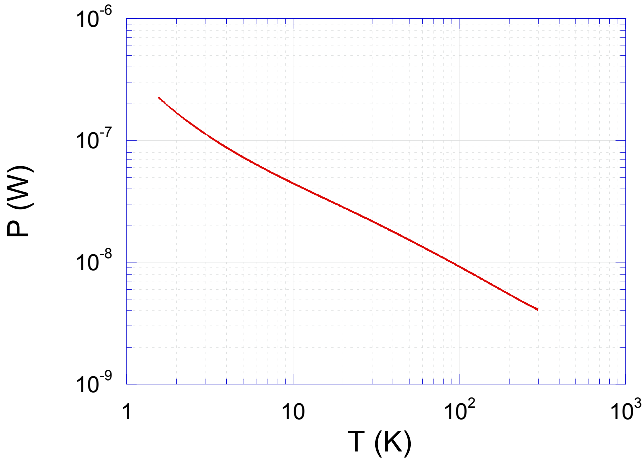


Figure 4: Power dissipation of the Lakeshore Temperature Monitor LS218E at the calibrated CERNOX thermometer

2.2 Data Acquisition

The resistance of all temperature sensors were monitor with the Lakeshore Temperature Monitor Model 218. The Lakeshore Temperature Monitor was used according to the manual. This means on each of the two groups of four inputs was the same type sensor connected. The calibrated CERNOX thermometer (CX25820) was connected to the 1st input and the to calibrate Cernox thermometer were connected to the 2nd, 3rd and 4th inputs. These inputs were configured for the sensor type "Cernox RTD" (see below). A LabVIEW program was used to control the temperature monitor as well to record the resistance data.

Lake Shore Model 218 Temperature Monitor User's Manual

Table 1-2. Model 218 Sensor Input Performance Chart

Sensor Type	Silicon Diode	GaAlAs Diode	100Ω Platinum RTD 500Ω Full Scale	1000Ω Platinum RTD	Cernox™ RTD
Temperature Coefficient	Negative	Negative	Positive	Positive	Negative
Sensor Units	Volts (V)	Volts (V)	Ohms (Ω)	Ohms (Ω)	Ohms (Ω)
Input Range	0 – 2.5 V	0 – 7.5 V	0 – 500 Ω	0 – 5000 Ω	0 – 7500 Ω
Sensor Excitation (Constant Current)	10 µA ±0.01%	10 µA ±0.01%	1 mA ±0.3%	1 mA ±0.3%	10 µA ±0.01%
Display Resolution (Sensor Units)	100 uV	100 uV	10 mΩ	100 mΩ	100 mΩ
Example LSCI Sensor	DT-470-CO-13 with 1.4H Cal.	TG-120SD with 1.4H Cal.	PT-103 with 14J Cal.	PT-1001[2] with 1.4J Cal.	CX-1050-SD with 4L Cal.
Temperature Range	1.4 – 475 K	1.4 – 475 K	30 – 800 K	30 – 800 K	3.5 – 400 K
Standard Sensor Curve	LSCI Curve 10	Requires Calibration	DIN 43760	Scaled from DIN 43670	Requires calibration
Typical Sensor Sensitivity	-30 mV/K at 4.2 K -1.9 mV/K at 77 K -2.4 mV/K at 300 K -2.2 mV/K at 475 K	-180 mV/K at 10 K -1.25 mV/K at 77 K -2.75 mV/K at 300 K -2.75 mV/K at 475 K	0.19 Ω/K at 30 K 0.42 Ω/K at 77 K 0.39 Ω/K at 300 K 0.35 Ω/K at 675 K 0.33 Ω/K at 800 K	1.9 Ω/K at 30 K 4.2 Ω/K at 77 K 3.9 Ω/K at 300 K 3.3 Ω/K at 800 K	-770 Ω/K at 4.2 K -1.5 Ω/K at 77 K -0.1 Ω/K at 300 K
Measurement Resolution:					
Sensor Units	20 uV	20 uV	2 mΩ	20 mΩ	50 mΩ
Temperature Equivalence	1 mK at 4.2 K 11 mK at 77 K 10 mK at 300 K 10 mK at 475 K	1 mK at 10 K 16 mK at 77 K 10 mK at 300 K 10 mK at 475 K	10.6 mK at 30 K 10 mK at 77 K 10 mK at 300 K 10 mK at 675 K 10 mK at 800 K	10.6 mK at 30 K 10 mK at 77 K 10 mK at 300 K 10 mK at 800 K	1 mK at 4.2 K 33.3 mK at 77 K 500 mK at 300 K
Electronic Accuracy:					
Sensor Units	±160 uV ±0.01% RDG	±160 uV ±0.02% RDG	±0.004 Ω ±0.02% RDG	±0.06 Ω ±0.04% RDG	±0.1 Ω ±0.04% RDG
Temperature Equivalence	±11 mK at 4.2 K ±138 mK at 77 K ±88 mK at 300 K ±77 mK at 475 K	±6 mK at 10 K ±300 mK at 77 K ±150 mK at 300 K ±110 mK at 475 K	±25 mK at 30 K ±18 mK at 77 K ±70 mK at 300 K ±162 mK at 675 K ±187 mK at 800 K	±40 mK at 30 K ±33 mK at 77 K ±135 mK at 300 K ±370 mK at 800 K	±1 mK at 4.2 K ±88 mK at 77 K ±1.144 K at 300K
Temperature Accuracy including electronic accuracy, CalCurve™ and calibrated sensor	±31 mK at 4.2 K ±193 mK at 77 K ±138 mK at 300 K ±177 mK at 475 K	±21 mK at 10 K ±390 mK at 77 K ±140 mK at 300 K ±210 mK at 475 K	±45 mK at 30 K ±38 mK at 77 K ±105 mK at 300 K ±262 mK at 675 K ±287 mK at 800 K	±60 mK at 30 K ±53 mK at 77 K ±170 mK at 300 K ±470 mK at 800 K	±9 mK at 4.2 K[1] ±138 mK at 77 K[1] ±1.284 K at 300K[1]
Magnetic Field Use	Recommended for T ≥ 60 K & B ≤ 3 T	Recommended for T > 4.2 K & B ≤ 5 T	Recommended for T > 40 K & B ≤ 2.5 T	Recommended for T > 40 K & B ≤ 2.5 T	Recommended for T > 2 K & B ≤ 19 T

[1] Specified accuracy includes no effects of thermal EMF voltages. An error of 3 mΩ results from each 1 µV of thermal EMF voltage. In well-designed systems, thermal EMF voltage should be less than 10 µV.
[2] No longer available from Lake Shore.

1-4 Introduction

2.3 Data Calibration

A polynomial equation based on the Chebychev polynomials has been fit to the calibration data. This equation is of the form:

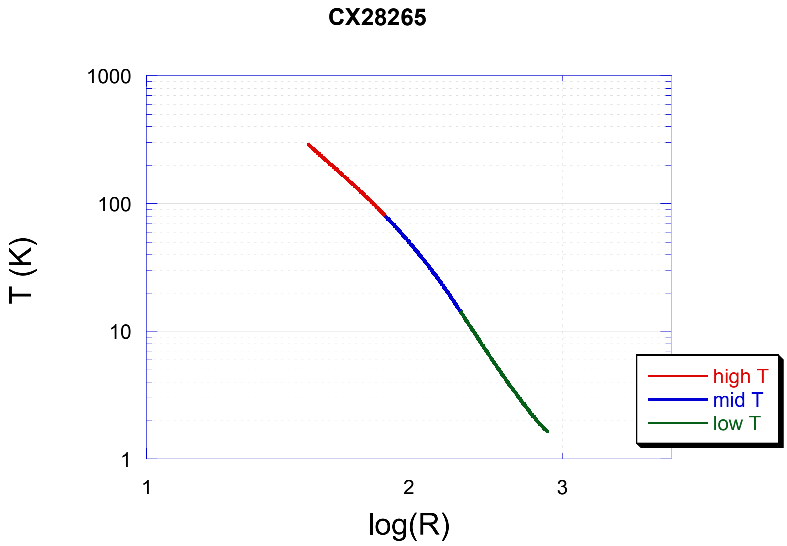
$$T(x) = \sum_{i=0}^{n} a_i \cdot \cos(i \cdot \arccos(x))$$

where *T(x)* represents the temperature in Kelvin and a_i represents the Chebychev coefficients. The parameter x is a normalized variable given by:

$$x = \frac{(Z - ZI) - (ZU - Z)}{(ZU - ZL)}$$

Z is $Z = log_{10}(R)$. ZL and ZU designate the lower and upper limit of the variable Z over the fit range.

3. Results



y = m1+T1(1.8802,1.5328,m2,m...

	Value	Error
m1	168.08	0.011153
m2	-102.76	0.019423
m3	16.849	0.018201
m4	-2.6879	0.017167
m5	0.52093	0.016868
m6	-0.076342	0.015746
m7	0.023507	0.015599
m8	-0.008657	0.013402
m9	-0.0047288	0.013284
Chisq	20.024	NA
R	0.99999	NA

y = m1+T1(2.2951,1.8802,m2,m...

	Value	Error
m1	41.075	0.0017732
m2	-32.244	0.0030724
m3	5.9239	0.0029041
m4	-0.64916	0.0027206
m5	0.091088	0.0026679
m6	0.0024104	0.0025009
m7	-0.013718	0.0024517
m8	0.0075519	0.0021446
m9	0.010932	0.0021508
Chisq	0.44052	NA
R	1	NA

y = m1+T1(2.888,2.2951,m2,m0...

	Value	Error
m1	5.9165	0.00070635
m2	-5.8189	0.0012512
m3	1.9052	0.001078
m4	-0.4488	0.00097865
m5	0.086414	0.00091565
m6	-0.0035135	0.00086844
m7	-0.0005853	0.00082291
m8	-0.0018692	0.0007321
m9	-0.0012941	0.00065539
Chisq	0.0041611	NA
R	1	NA

Figure 5: A polynomial equation based on the Chebychev polynomials has been fit to the calibration data and the coefficients are shown for each temperature range.

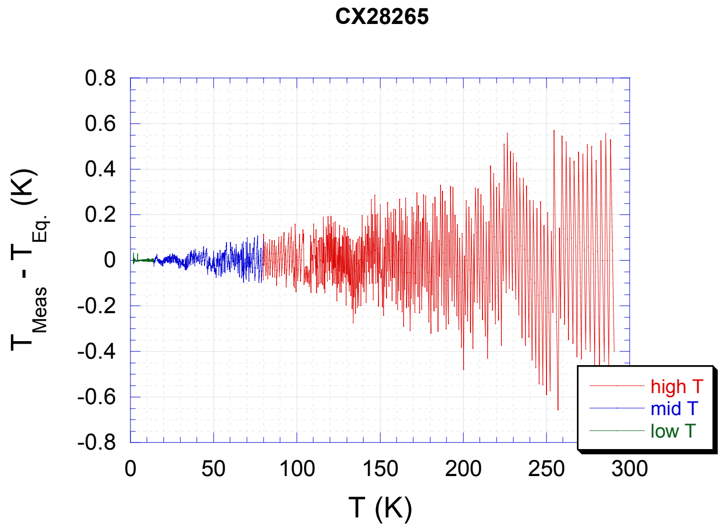


Figure 6: This graph shows the difference between calculated temperature and measured temperature.

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Appendix B

Report from Cryogenic Vibration Tests

022

SST DEPARTMENT

VIBRATION TEST FACILITY

REPORT REF: AIV-2003-091-VIB

HERSCHEL : CARDIFF COMPONENTS

RUTHERFORD APPLETON LABORATORY
Vibration Facility
Chilton, Didcot,
Oxfordshire OX11 OQX

Tel: 44 (0) 1235 446617

CONTENTS

1) TEST ITEM DESCRIPTION

The test items consisted of :-

- Scal-B - nominal flight spare, reduced power option - SCAL-FS-000-FLIGHT COMPONENT
- Pcal DM – lifetest source in DM structure – non-flight, but flight replica
- 300mK System – 1 photometer support & 1 light baffle – both DM, but flight replica. Configuration as per previous shake.
- 2 additional Pcal sources (in sealed chambers). One mica device, one sapphire device.
- Beam divider in CQM Mount (flight replica)
- Black tiles
- Representative hot-pressed filter material in SPIRE-type mount

Testing would be carried out on the head of the shaker within the Cryostat.

2) TEST SPECIFICATION

The components were to be tested to Spire Qualification levels. A sine survey was to be initially carried out at ambient temperature/atmospheric pressure. A further sine survey followed by a random and post random sine survey would be carried out at sub 10 Kelvin/ Vacuum. A final sine survey at ambient temperature/atmospheric pressure would be undertaken.

A single axis accelerometer was to be used for monitoring.

SINE SURVEY TEST

One sweep @ 0.25g from 10 Hz to 2000 Hz at 2 octaves per minute.

RANDOM

FREQUENCY (Hz)	TEST LEVEL
20 - 100	+3 dB/oct
100 – 138.5	0.06 g^2 / Hz
138.5 - 170	0.06 – 0.7 g^2 / Hz
170 - 200	0.7 g^2 / Hz
200 - 220	0.7 – 0.1 g^2 / Hz
220 - 300	0.1 g^2 / Hz
300 - 2000	-9 dB/oct

Overall Test Level = 8.0 g rms. for 30 Seconds

3) ACCELEROMETER CALIBRATION STATUS

SINGLE AXIS - ENDEVCO 2272 & B&K 4393

SERIAL NUMBER	CALIBRATION PC/g	Date	SIGNAL CONDITIONER
A66B	12.67	11/03/04	ENDEVCO 2775A
YG32	13.77	11/03/04	
1434587	3.16	N/A	

NOTE

Due to the temperature effects, a reduction of 10% in the sensitivity values was used during all cold testing.

See test summary for details on S/N 1434587

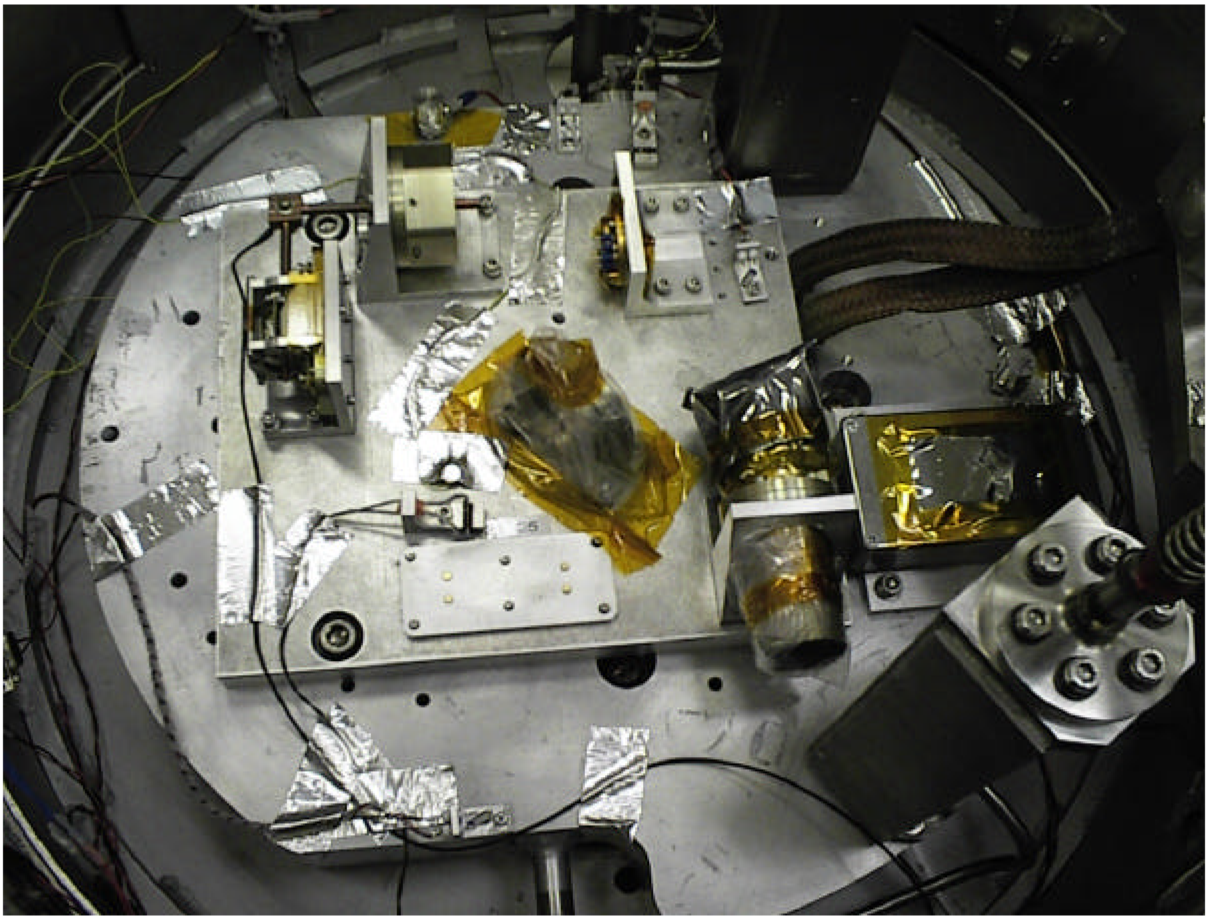
Signal Conditioners: Endevco 2775A
Calibrated on: September 2002

4) CLEANLINESS

Approved cleanroom gloves to be worn when handling the test items.

5) FIXTURE DETAILS

FIXTURE CONFIGURATION



A view of the test items mounted on their vibration fixture. The control strategy implemented involved taking the average response from the two accelerometers attached to the fixture.

6) TEST SUMMARY

Test Dates: 23 March 2004 to 25 March 2004

Observers: Dr. Peter Hargrave and Facility Staff

Organisation : Cardiff University

CHANNEL ALLOCATION:

CONTROL:-

Channel No.	Accelerometer Type/Serial No.	Testing Axis	Mounting Position
1	Endevco A66B	**N/A**	Fixture
2	Endevco YG32	**N/A**	Fixture

MONITORING:-

Channel No.	Accelerometer Type/Serial No.	Testing Axis	Mounting Position
3	B&K 1434587	**N/A**	300mK Busbar

NOTE

Accelerometer B&K 1434587 was an uncalibrated unit, which was not specified to have a working temperature range at the low temperatures it would be subjected too. As such the data collected should only be viewed as an indication of frequency response. The amplitude data has no relevance.

ACTION	DATE	TIME
Pumpdown Started	23/03/04	16:45
Cooldown Started	23/03/04	21:30
Cold Vib. Testing	24/03/04	11:30
Start Warm Up	24/03/04	12:00
Ambient Testing	25/03/04	08:40
Test Item Removed	25/03/04	11:00

ACCELEROMETER TEST PLOTS

ATMOSPHERIC/AMBIENT TEST CONDITIONS 23/03/04

RUN 00002 SINE SURVEY *FIG 1*

COLD TEST CONDITIONS 24/03/04

RUN 00003 SINE SURVEY *FIG 2*

RUN 00001 RANDOM *FIG 3*

RUN 00005 SINE SURVEY *FIG 4*

ATMOSPHERIC/AMBIENT TEST CONDITIONS 25/03/04

RUN 00006 SINE SURVEY *FIG 5*

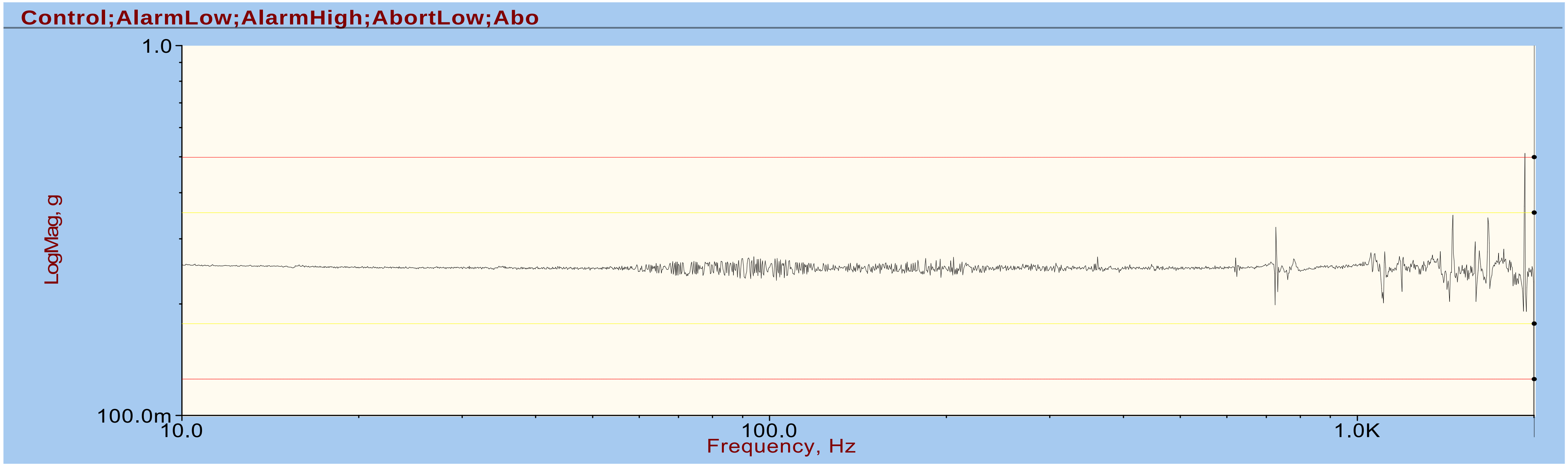
7) CONCLUSION

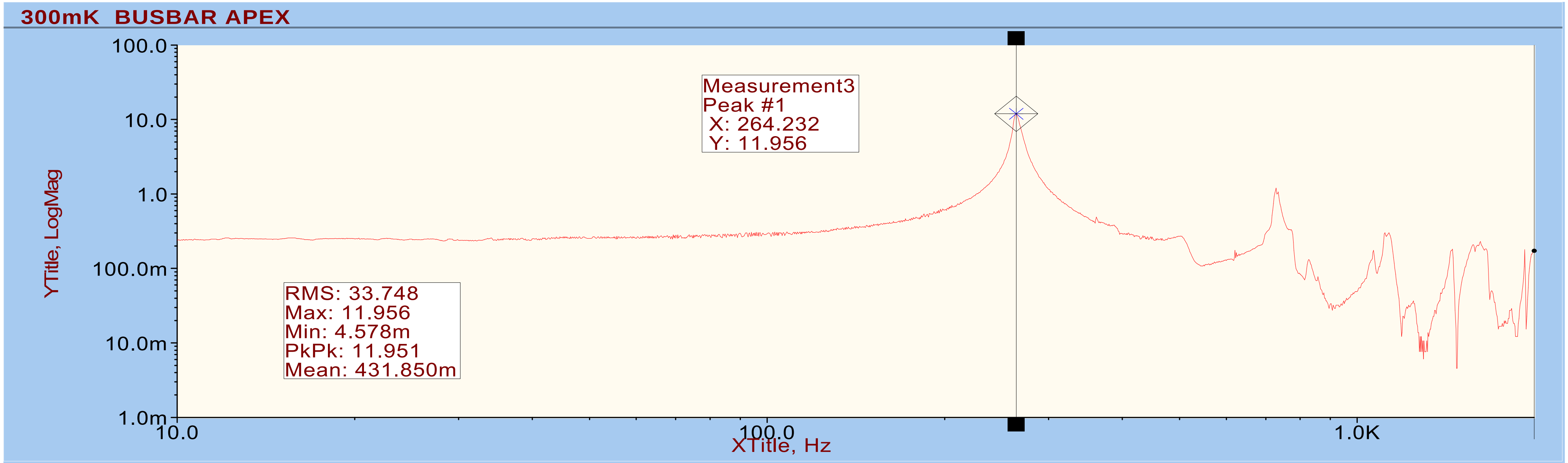
The test items were subjected to the Spire Qualification levels of vibration. On inspection, post vibration testing, it was discovered that 3 of the 4 fasteners securing the photometer support to the fixture were loose. These had been torqued too 0.2 NM prior to testing.

A visual inspection revealed no further problems with any other components.

FACILITY OPERATOR: -

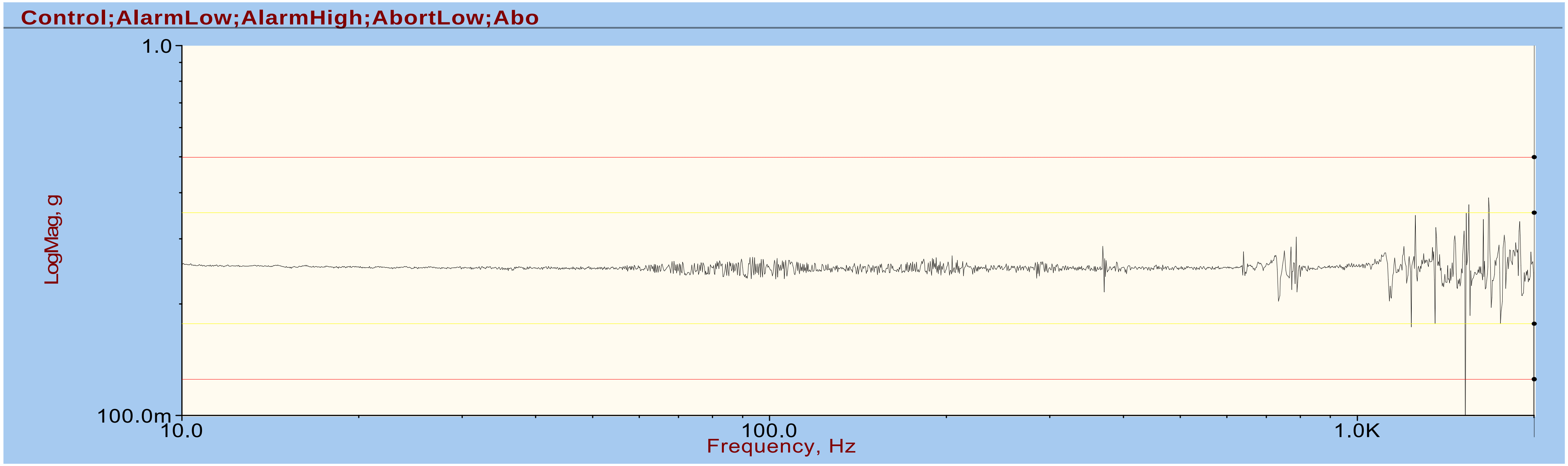
ANNEX: A   ACCELEROMETER PLOTS
ANNEX: B   COOLDOWN/WARM-UP GRAPH

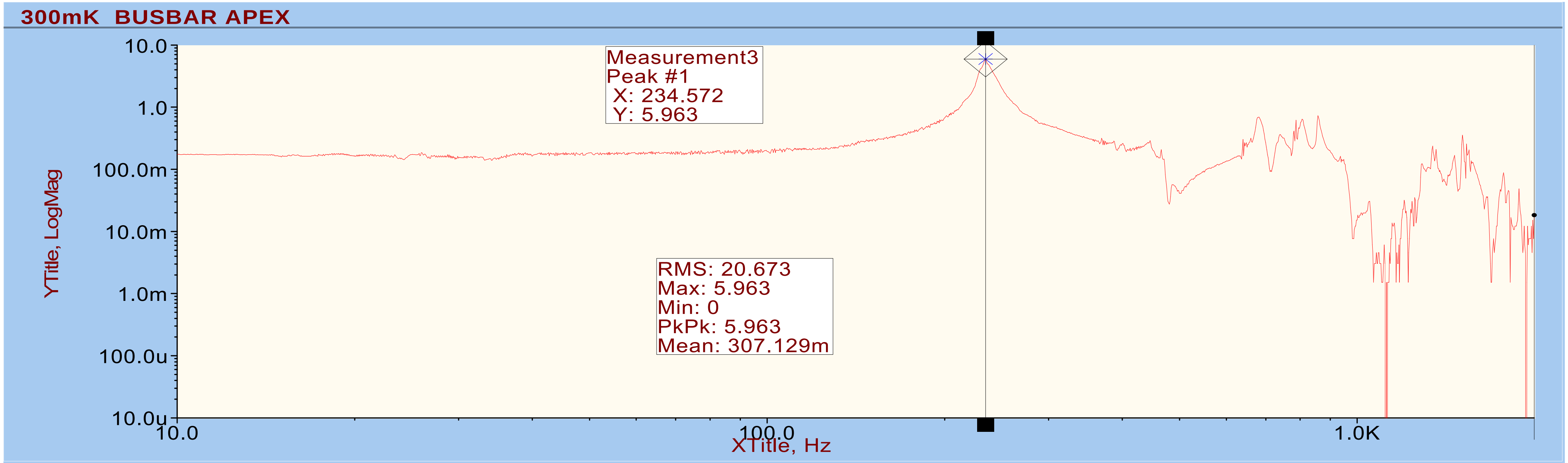




SPIRE CARDIFF COMPONENTS SINE SURVEY AMBIENT/ ATMOSPHERE
RUN 00002
N/A AXIS 16:01:23 23/03/2004

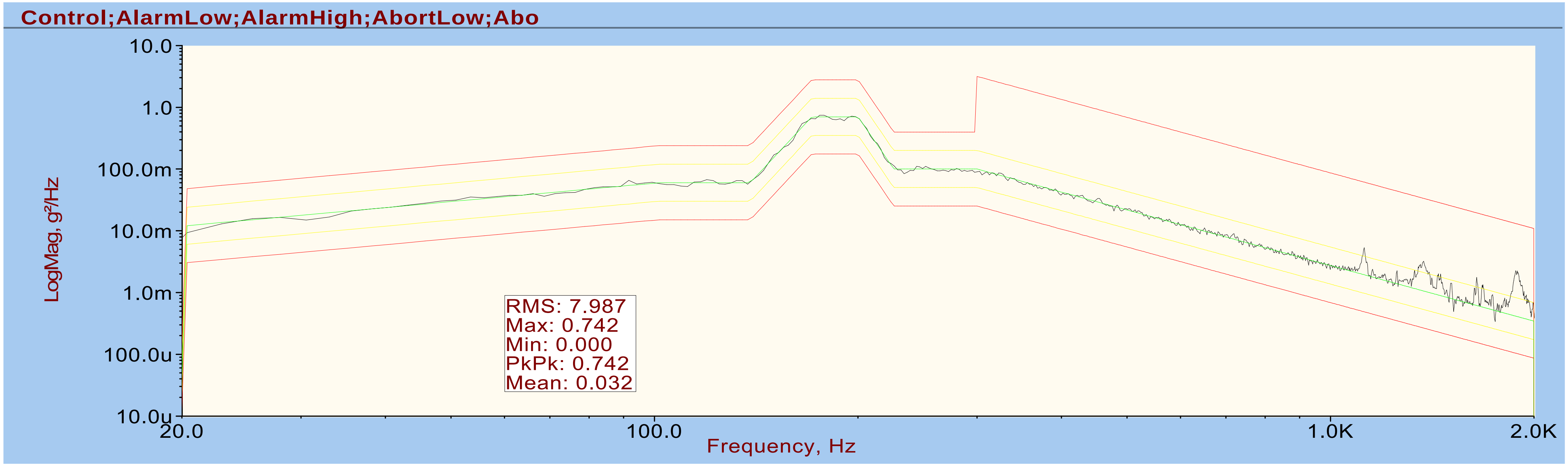
Fig 1

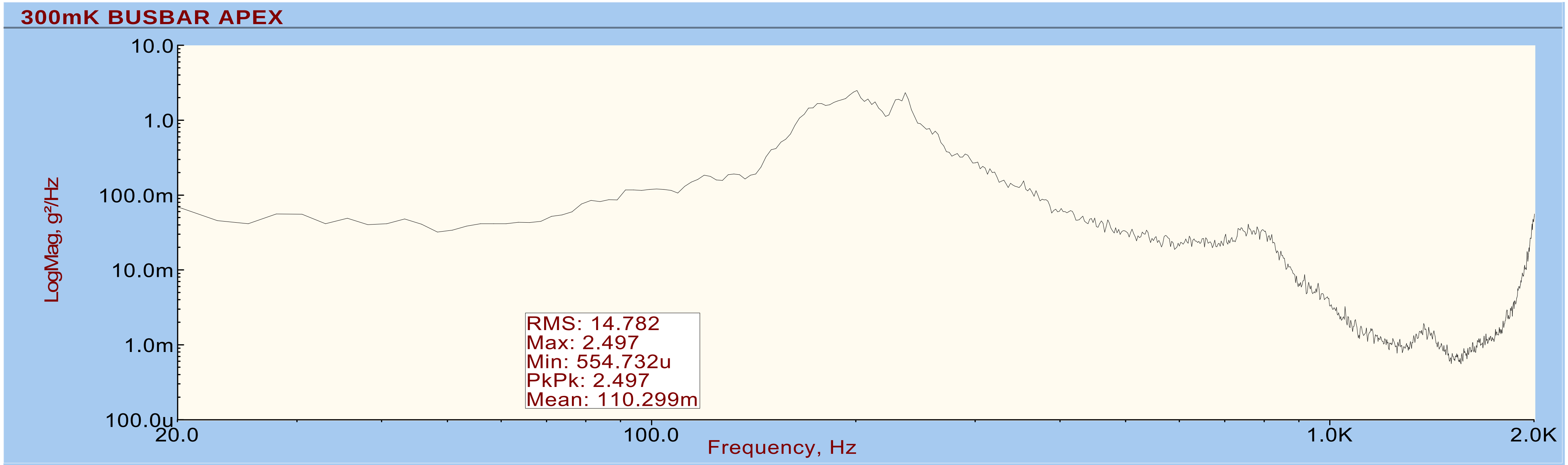




SPIRE CARDIFF COMPONENTS SINE SURVEY 7 Kelvin 5.8E-6mBAR
RUN 00003
N/A AXIS 11:37:40 24/03/2004

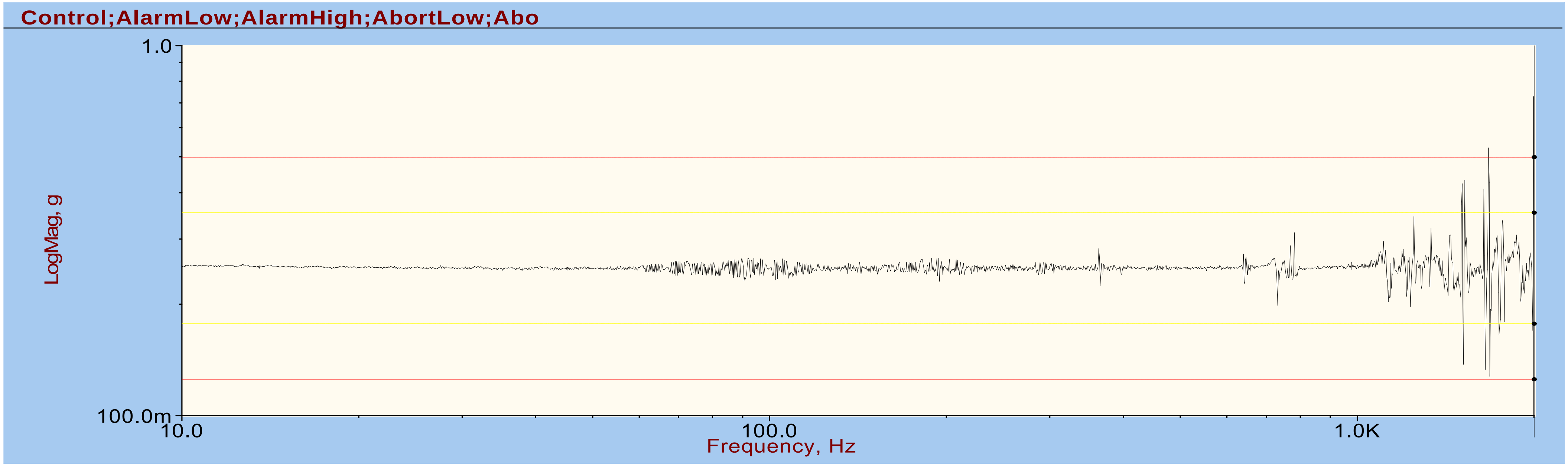
Fig 2

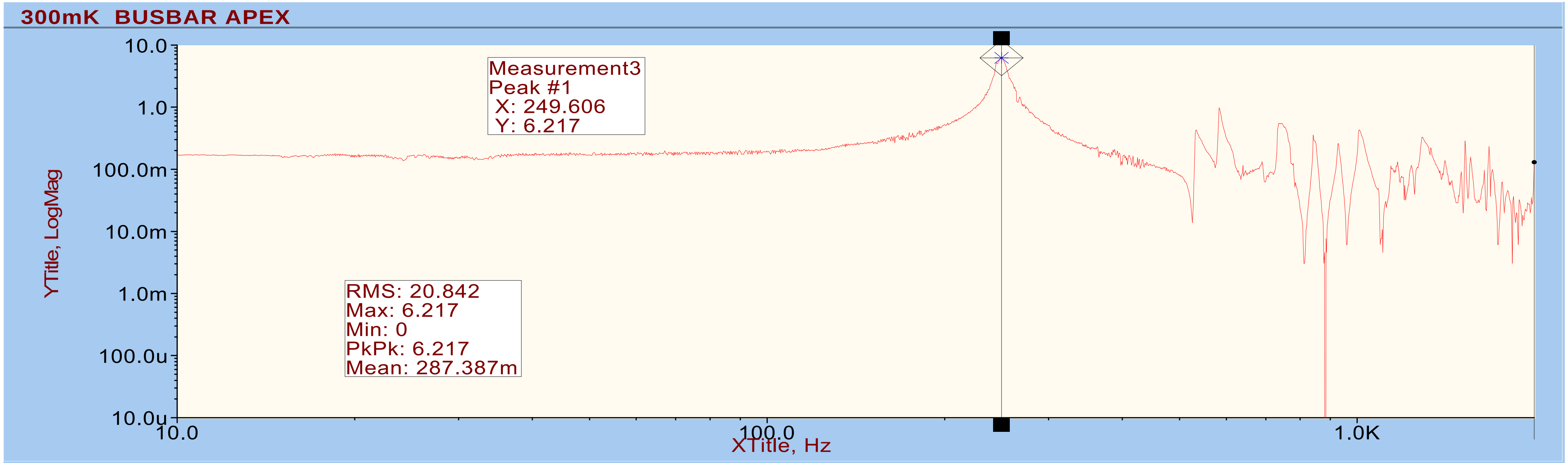




SPIRE CARDIFF COMPONENTS RANDOM 7 KELVIN @ 5.6e-6mBAR
RUN 00001
N/A AXIS 11:46:44 24/03/2004

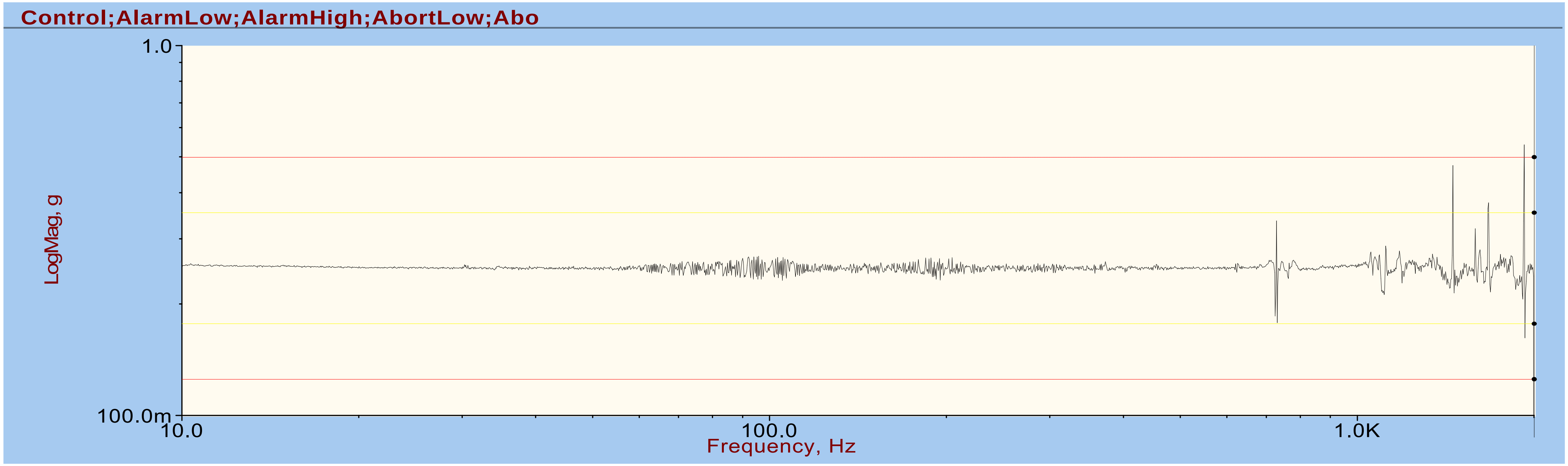
Fig 3

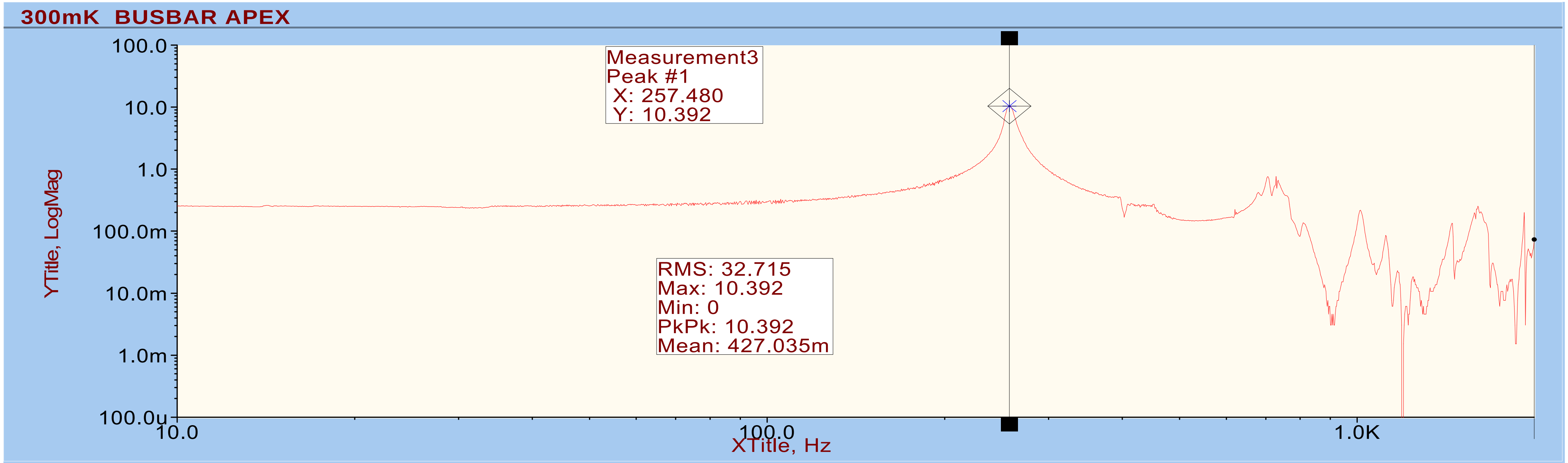




SPIRE CARDIFF COMPONENTS POST RANDOM SINE SURVEY 7 Kelvin 5.8E-6mBAR
RUN 00005
N/A AXIS 11:55:48 24/03/2004

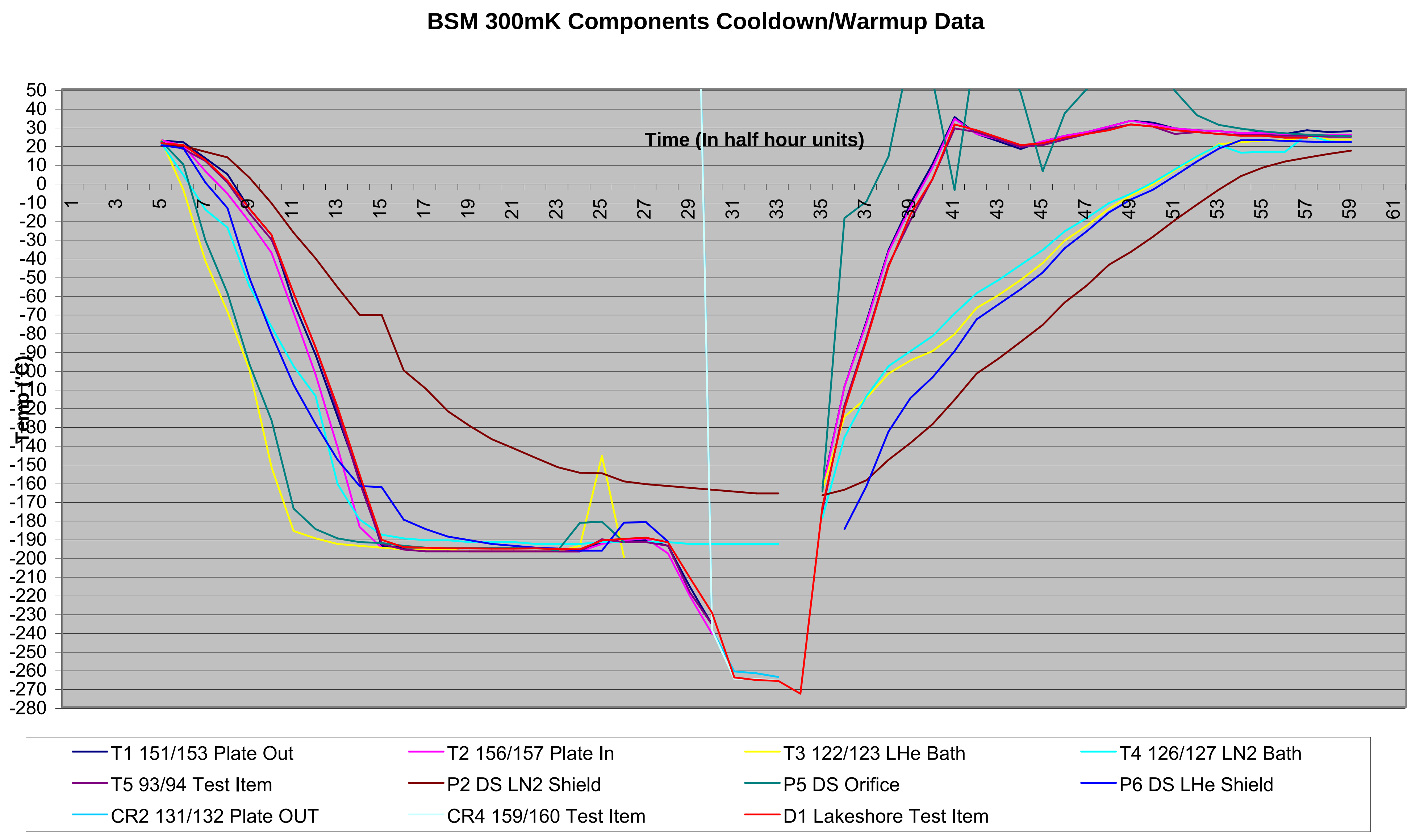
Fig 4





SPIRE CARDIFF COMPONENTS POST RANDOM SINE SURVEY AMBIENT/ATMOSPHERE
RUN 00006
N/A AXIS 08:38:48 25/03/2004

Fig 5


BSM 300mK Components Cooldown/Warmup Data
Time (In half hour units)
Temp (°C)
T1 151/153 Plate Out
T2 156/157 Plate In
T3 122/123 LHe Bath
T4 126/127 LN2 Bath
T5 93/94 Test Item
P2 DS LN2 Shield
P5 DS Orifice
P6 DS LHe Shield
CR2 131/132 Plate OUT
CR4 159/160 Test Item
D1 Lakeshore Test Item

Appendix C

SCal-B Calibration Report

Results

(Calibration - SCAL B)
7 May 2004

Document Ref.: HSO-CDF-RP-080
Issue: 1.0
Test Date

Prepared by: Iris Didschuns
Last Modified on: 6 August 2004
Approved by:

Distribution list

The equilibrium temperatures for all sources of SCAL B were determine in the same way. A constant power was applied to the heater until the thermometer showed a stable temperature (equilibrium temperature) with ΔT=±0.1K.
The warm-up time was determine by using the time until the temperature reach 90% of the equilibrium temperature with an base temperature is 4.2 K. The cool down time was determine similar only the time until the temperature drops by 90% from equilibrium temperature was used. There are only some complete warm-up/cool-down curves due to the way the measurements were carried out. The main goal of the measurements were to determine the equilibrium temperature at a certain power for each source of SCAL B.

1. Before cold vibration

1.1 4% primary source

The raw data can be found:
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\prime source\4% source\

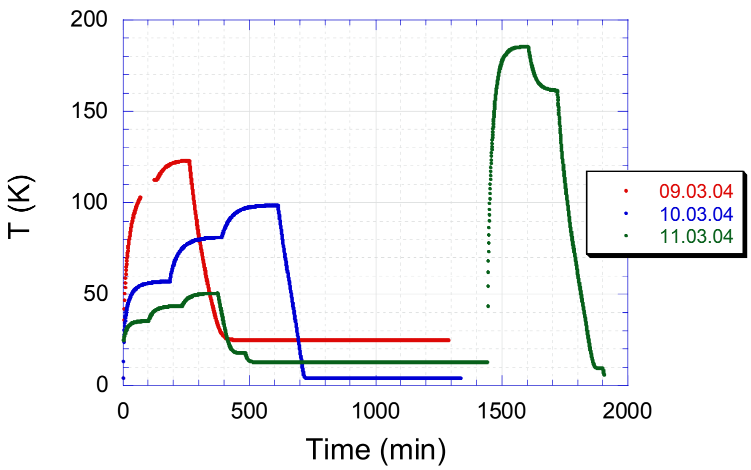
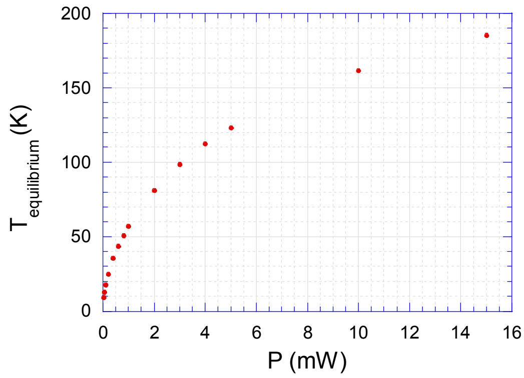


Figure 1: Temperature versus time data of the 4% prime source measured at different days and before the cold vibration test.

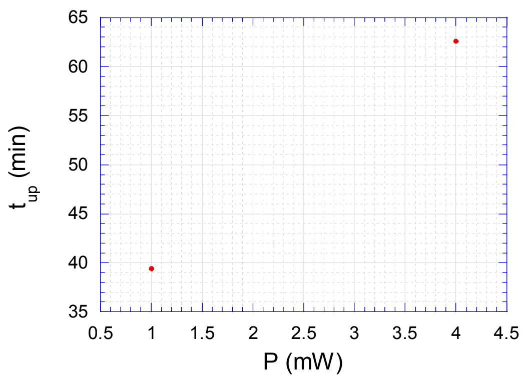
equilibrium temperature:



P (mW)	$T_{equilibrium}$ (K)
0.025	9.39
0.050	12.93
0.100	17.84
0.200	24.92
0.400	35.46
0.600	43.62
0.800	50.58
1.000	56.94
2.000	81.05
3.000	98.51
4.000	112.32
5.000	123.19
10.000	161.49
15.000	185.45

Figure 2: Equilibrium temperature for different applied power value of the 4% prime source measured before the cold vibration test.

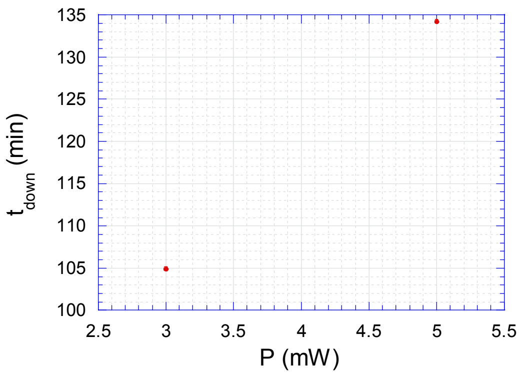
warming-up time:



P (mW)	$time_{warm-up}$ (min)
1.000	39.42
4.000	62.61

Figure 3: Warming up time which is the time between 4.2K and 90% of $T_{eq.}$ for different applied power value of the 4% prime source measured before the cold vibration test.

cooling-down time:



P (mW)	$time_{cool\text{-}down}$ (min)
3.000	104.94
5.000	134.27

Figure 4: Cooling down time which is the time between $T_{eq.}$ and 10% of $T_{eq.}$ for different applied power value of the 4% prime source measured before the cold vibration test.

1.2 2% primary source

No measurement were carry out for the 2% prime source.

1.3 4% redundant source

The raw data can be found:
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\4% source\

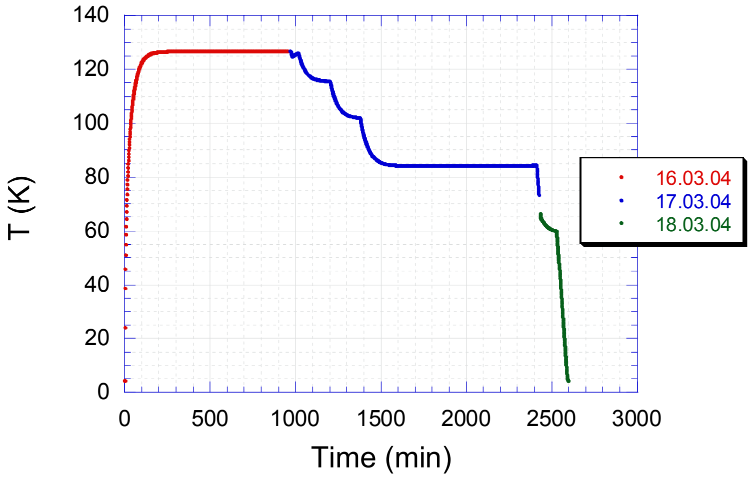
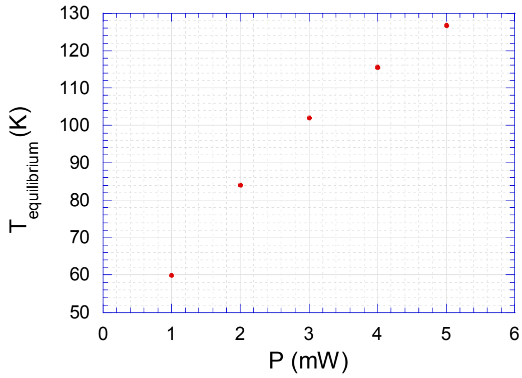


Figure 5: Temperature versus time data of the 4% redundant source measured at different days and before the cold vibration test.

equilibrium temperature:



P (mW)	$T_{equilibrium}$ (K)
1.000	59.85
2.000	84.13
3.000	101.99
4.000	115.60
5.000	126.65

Figure 6: Equilibrium temperature for different applied power value of the 4% redundant source measured before the cold vibration test.

warming-up and cooling-down time:

P (mW)	$time_{cool-down}$ (min)	P (mW)	$time_{warm-up}$ (min)
1	66.215	5	60.522

1.3.1 2% source

The raw data can be found:
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\before cold vibration\redundant source\2% source\

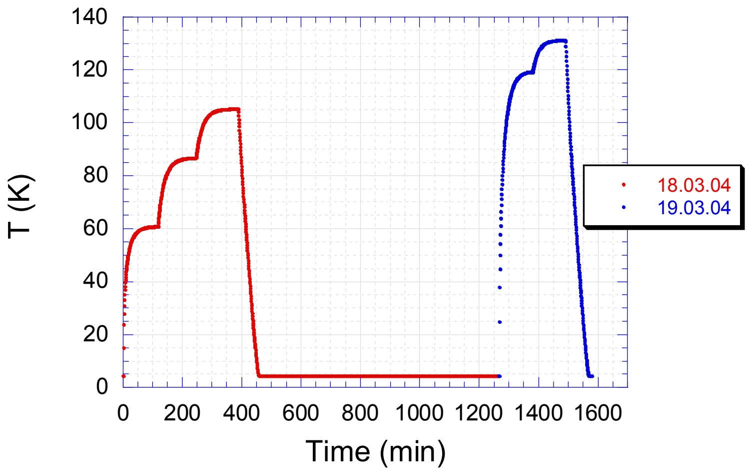
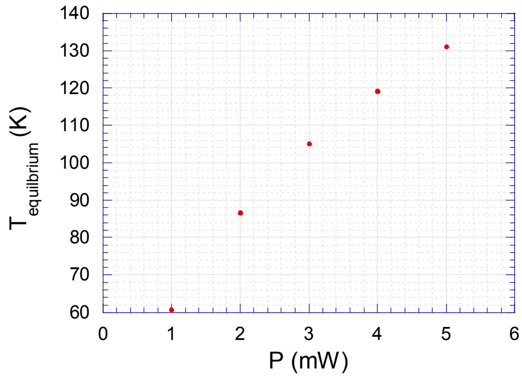


Figure 7: Temperature versus time data of the 2% redundant source measured at different days and before the cold vibration test.

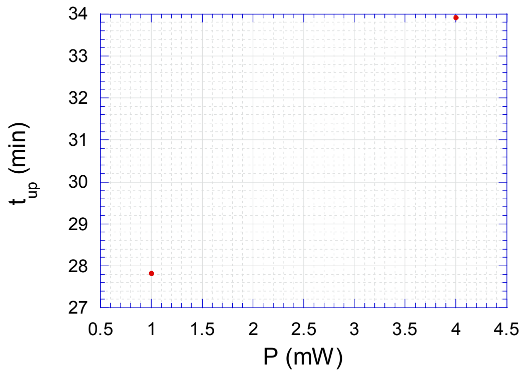
equilibrium temperature:



P (mW)	$T_{equilibrium}$ (K)
1.000	60.71
2.000	86.60
3.000	105.14
4.000	119.15
5.000	131.08

Figure 8: Equilibrium temperature for different applied power value of the 2% redundant source measured before the cold vibration test.

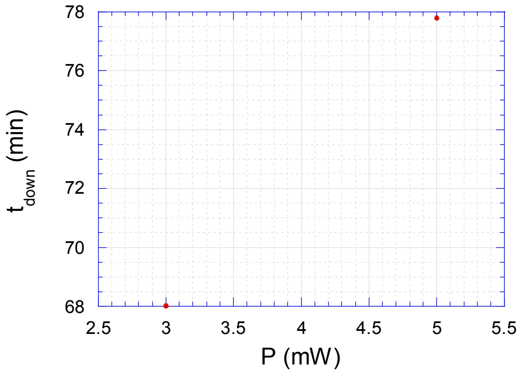
warming-up time:



P (mW)	$time_{warm-up}$ (min)
1.000	27.83
4.000	33.91

Figure 9: Warming up time which is the time between 4.2K and 90% of $T_{eq.}$ for different applied power value of the 2% redundant source measured before the cold vibration test.

cooling-down time:



P (mW)	$time_{cool-down}$ (min)
3.000	68.03
5.000	77.78

Figure 10: Cooling down time which is the time between $T_{eq.}$ and 10% of $T_{eq.}$ for different applied power value of the 2% redundant source measured before the cold vibration test.

2. After cold vibration

2.1 4% primary source

The raw data can be found in:
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\4% source\

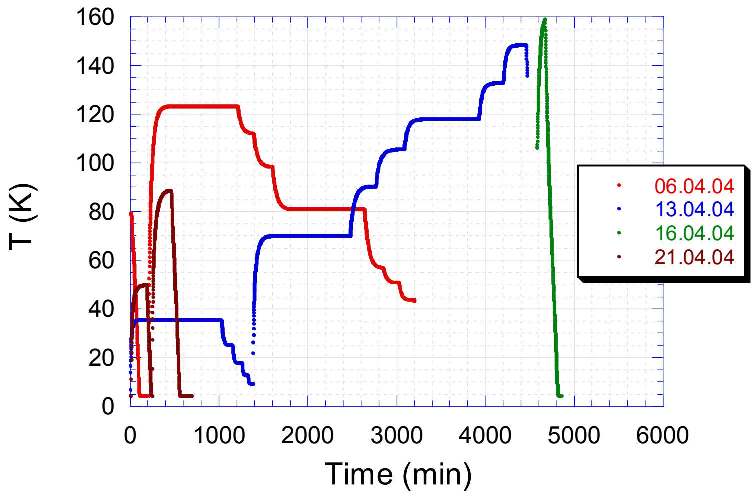
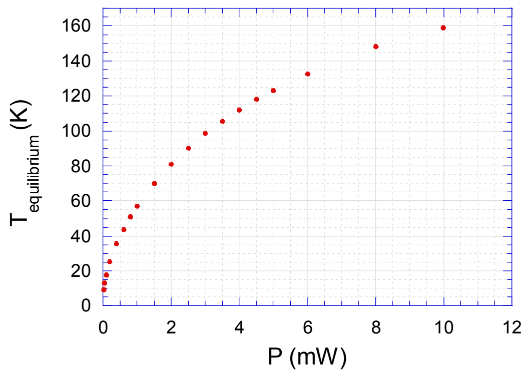


Figure 11: Temperature versus time data of the 4% prime source measured at different days and after the cold vibration test.

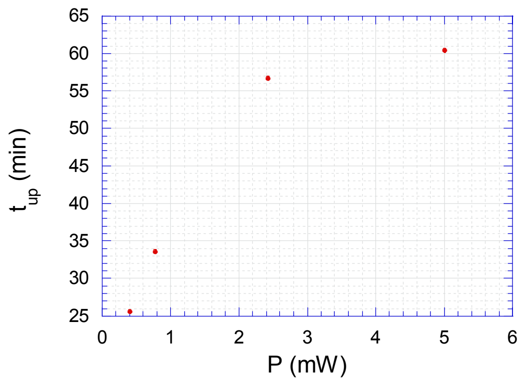
equilibrium temperature:



P (mW)	$T_{equilibrium}$ (K)
0.025	9.42
0.050	12.95
0.100	17.81
0.200	25.19
0.400	35.62
0.600	43.65
0.800	50.80
1.000	56.97
1.500	70.17
2.000	80.97
2.500	90.41
3.000	98.50
3.500	105.65
4.000	112.21
4.500	118.00
5.000	123.29
6.000	132.82
8.000	148.42
9.980	159.22

Figure 12: Equilibrium temperature for different applied power value of the 4% prime source measured at different days and after the cold vibration test.

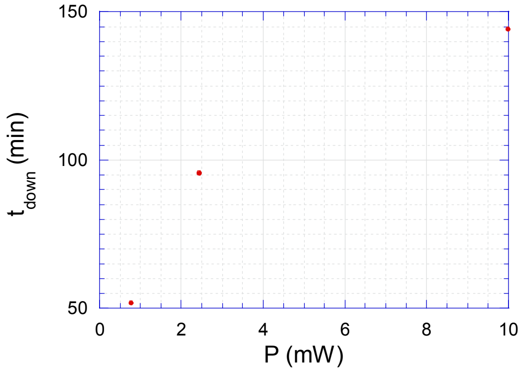
warming-up time:



P (mW)	$time_{warm-up}$ (min)
0.400	25.58
0.774	33.57
2.424	56.70
5	60.45

Figure 13: Warming up time which is the time between 4.2K and 90% of $T_{eq.}$ for different applied power value of the 4% prime source measured after the cold vibration test.

cooling-down time:



P (mW)	$time_{cool-down}$ (min)
0.774	51.97
2.424	95.58
9.980	144.30

Figure 14: Cooling down time which is the time between $T_{eq.}$ and 10% of $T_{eq.}$ for different applied power value of the 4% prime source measured after the cold vibration test.

2.2 2% primary source

The raw data can be found in:
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\prime source\2% source\

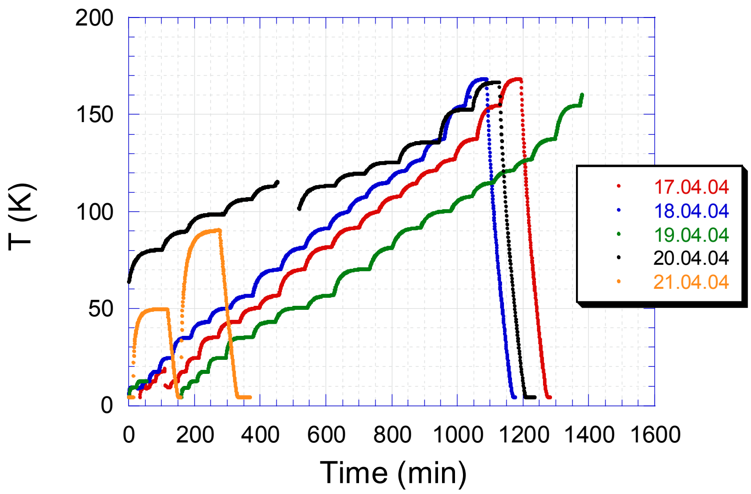
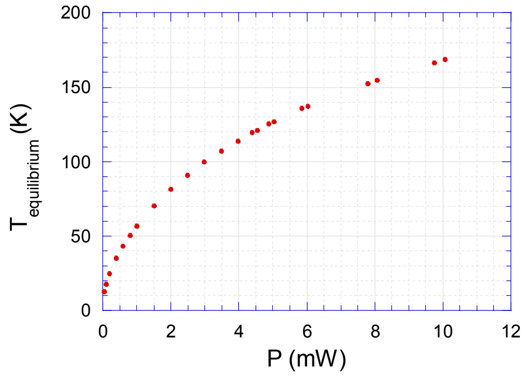


Figure 15: Temperature versus time data of the 2% prime source measured at different days and after the cold vibration test.

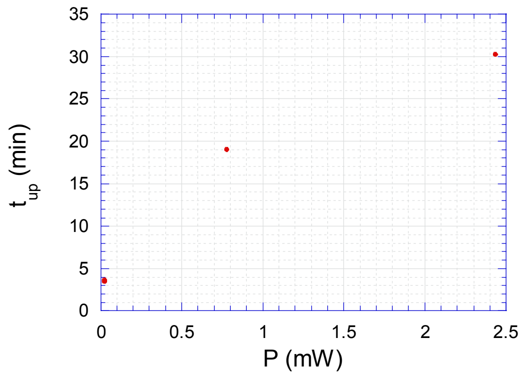
equilibrium temperature:



P (mW)	$T_{equilibrium}$ (K)
0.049	12.69
0.099	17.65
0.199	24.76
0.401	35.21
0.599	43.29
0.801	50.44
1.003	56.85
1.504	70.37
1.990	81.32
2.488	91.09
2.982	99.84
3.489	107.36
3.965	114.07
4.394	119.74
4.532	121.26
4.875	125.48
5.0236	126.92
5.848	135.79
6.030	137.48
7.796	152.75
8.061	154.73
9.757	166.63
10.055	168.54

Figure 16: Equilibrium temperature for different applied power value of the 2% prime source measured at different days and after the cold vibration test.

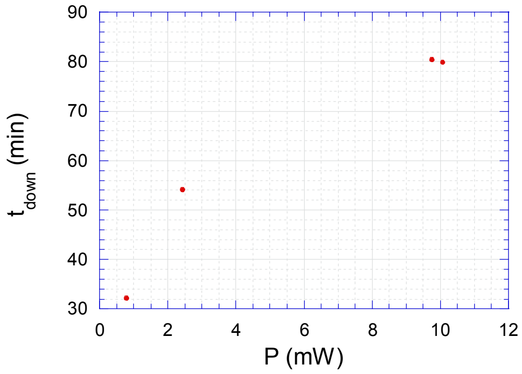
warming-up time:



P (mW)	$time_{warm-up}$ (min)
0.024	3.467
0.024	3.675
0.776	19.045
2.432	30.32

Figure 17: Warming up time which is the time between 4.2K and 90% of $T_{eq.}$ for different applied power value of the 2% prime source measured after the cold vibration test.

cooling-down time:



P (mW)	$time_{cool\text{-}down}$ (min)
0.776	32.15
2.432	54.18
9.757	80.51
10.055	79.87

Figure 18: Cooling down time which is the time between $T_{eq.}$ and 10% of $T_{eq.}$ for different applied power value of the 2% prime source measured after the cold vibration test.

2.3 4% redundant source

The raw data can be found in:
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\redundant source\4% source\

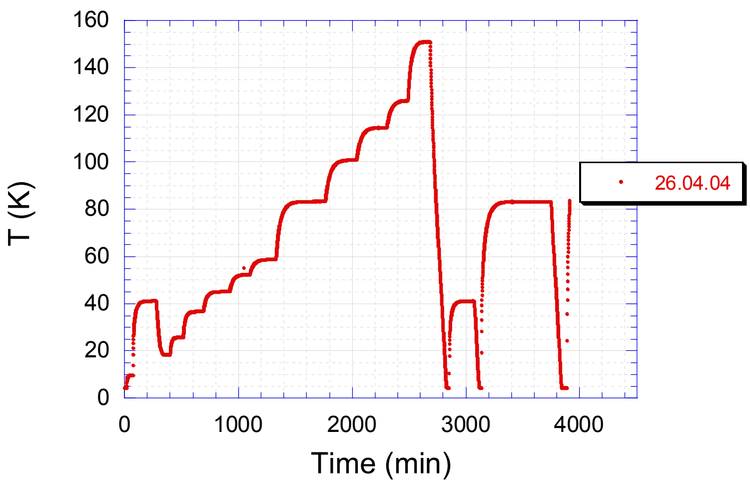
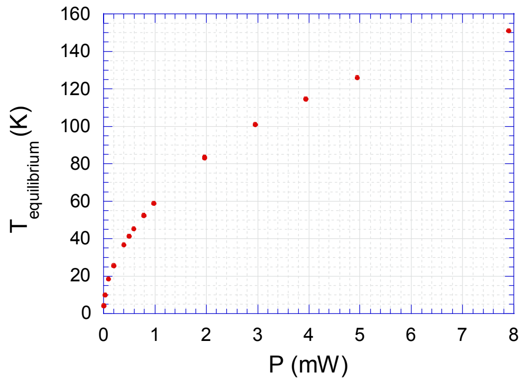


Figure 19: Temperature versus time data of the 4% redundant source measured after the cold vibration test.

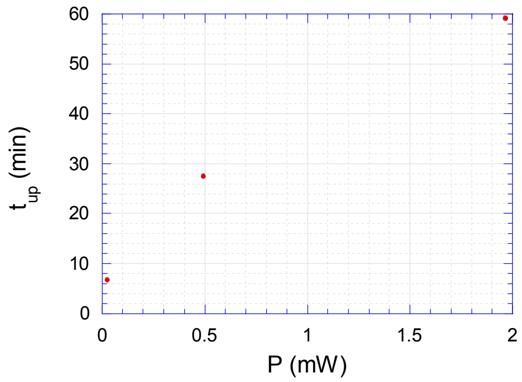
equilibrium temperature:



P (mW)	$T_{equilibrium}$ (K)
0.024	9.77
0.096	18.33
0.194	25.77
0.393	36.75
0.492	41.195
0.492	41.23
0.589	45.19
0.789	52.51
0.983	58.82
1.965	83.31
1.965	83.371
2.954	100.99
3.939	114.71
4.937	126.03
7.893	151.15

Figure 20: Equilibrium temperature for different applied power value of the 4% redundant source measured at different days and after the cold vibration test.

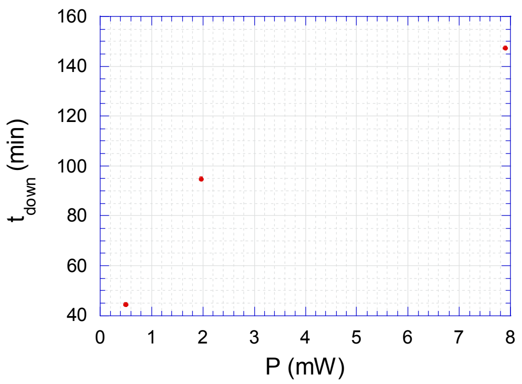
warming-up time:



P (mW)	$time_{warm-up}$ (min)
0.023	6.74
0.492	27.61
1.965	59.19

Figure 21: Warming up time which is the time between 4.2K and 90% of $T_{eq.}$ for different applied power value of the 4% redundant source measured after the cold vibration test.

cooling-down time:



P (mW)	$time_{cool\text{-}down}$ (min)
0.492	44.46
1.965	94.76
7.893	147.34

Figure 22: Cooling down time which is the time between $T_{eq.}$ and 10% of $T_{eq.}$ for different applied power value of the 4% redundant source measured after the cold vibration test.

2.4 2% redundant source

The raw data can be found in:
\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\after cold vibration\redundant source\2% source\

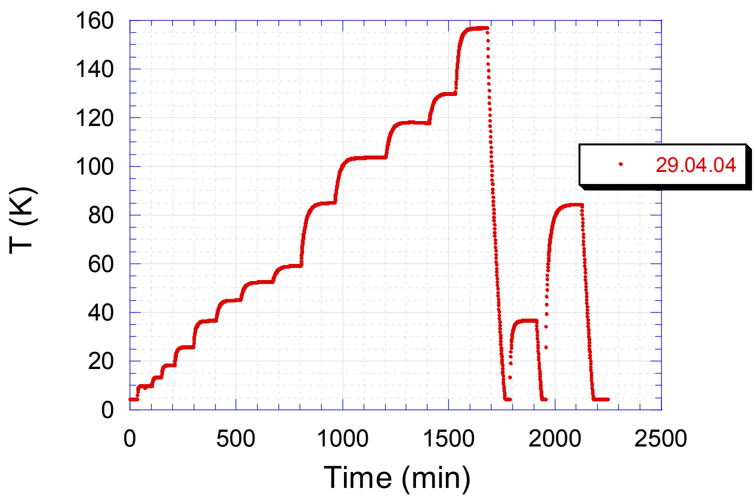
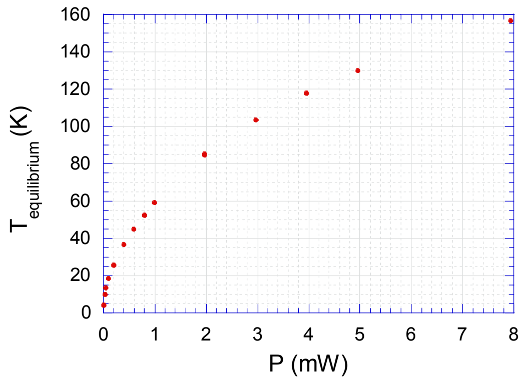


Figure 23: Temperature versus time data of the 2% redundant source measured after the cold vibration test.

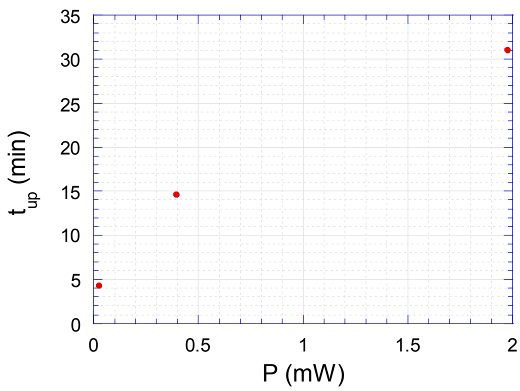
equilibrium temperature:



P (mW)	$T_{equilibrium}$ (K)
0.024	9.86
0.049	13.40
0.096	18.36
0.194	25.71
0.395	36.67
0.395	36.60
0.592	45.06
0.793	52.52
0.987	59.11
1.974	84.41
1.974	85.09
2.968	103.66
3.959	117.90
4.962	129.96
7.932	156.82

Figure 24: Equilibrium temperature for different applied power value of the 2% redundant source measured at different days and after the cold vibration test.

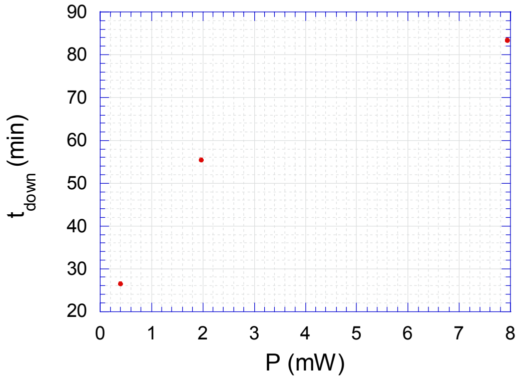
warming-up time:



P (mW)	$time_{warm-up}$ (min)
0.024	4.31
0.395	14.65
1.975	31.07

Figure 25: Warming up time which is the time between 4.2K and 90% of $T_{eq.}$ for different applied power value of the 2% redundant source measured after the cold vibration test.

cooling-down time:



P (mW)	$time_{cool\text{-}down}$ (min)
0.395	26.56
1.974	55.39
7.932	83.41

Figure 26: Cooling down time which is the time between $T_{eq.}$ and 10% of $T_{eq.}$ for different applied power value of the 2% redundant source measured after the cold vibration test.

3. Summary

3.1 4% primary source

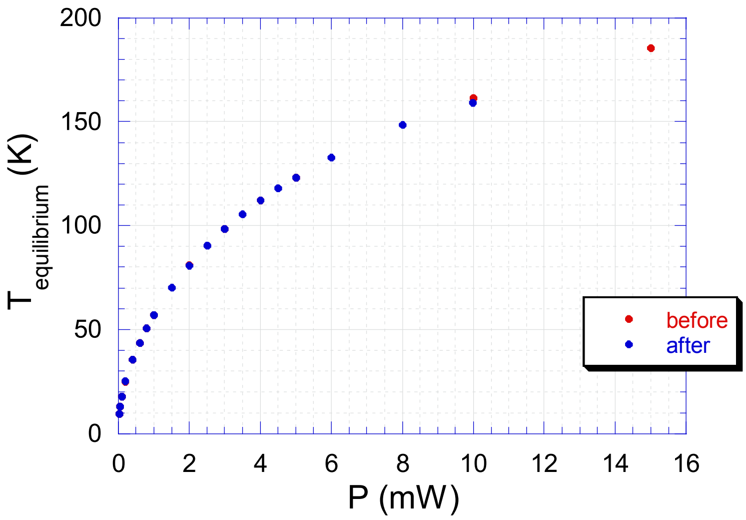
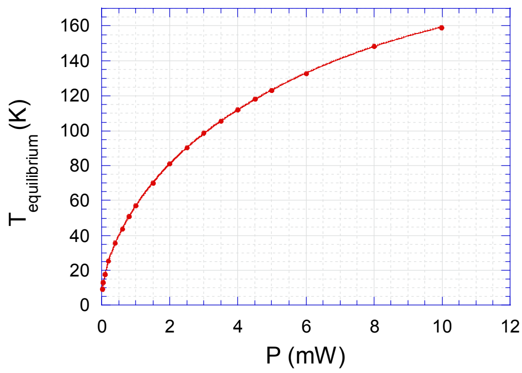
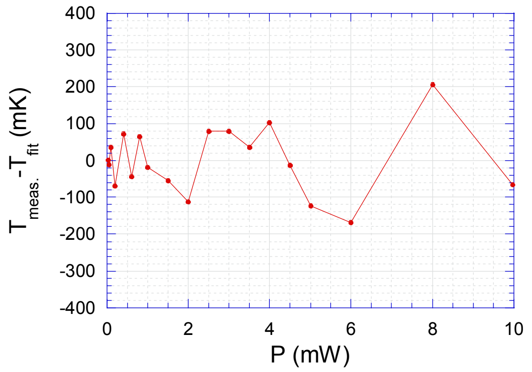


Figure 27: Comparison of the equilibrium temperature versus applied power for 4% prime source before and after the cold vibration test.



The line is the Chebychev Fit to the data



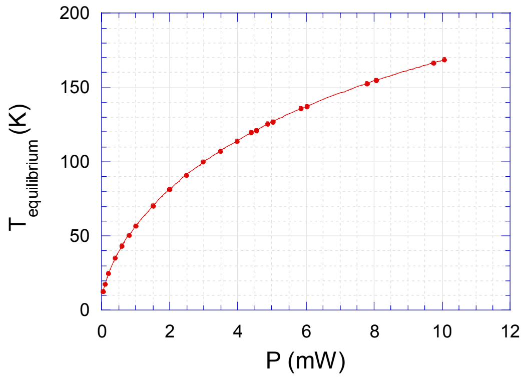
Difference between values derived using fit and data points

fit equation	coefficient	error
$$T(P)=\sum_{0}^{9} m_i \cos\left[i\cdot\cos^{-1}\left(\frac{(PU-\log P)-(\log P-PL)}{PU-PL}\right)\right]$$	m1 = 63.164	0.045792
	m2 = 72.736	0.071229
	m3 = 22.551	0.063424
	m4 = 2.7334	0.050699
	m5 = -0.93589	0.042519
	m6 = -0.6317	0.044712
PU = 0.9991	m7 = -0.25804	0.057828
PL = -1.6021	m8 = 0.097062	0.062944
	m9 = -0.16928	0.055977

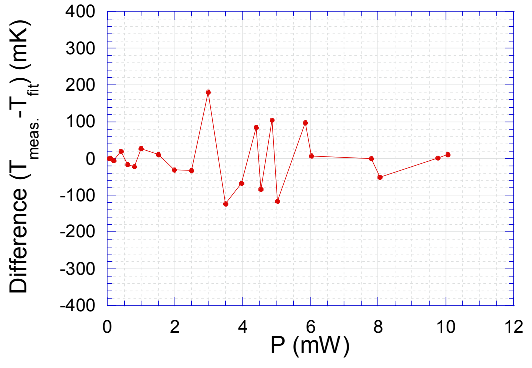
Table 1: Parameters and coefficients of the Chebychev fit for 4% prime source after the cold vibration test.

3.2 2% primary source

The was no measurement taken for 2% prime source before the cold vibration test.



The line is the Chebychev Fit to the data



Difference between values derived using fit and data points

fit equation	coefficient	error
$T(P)=\sum_{0}^{9} m_i \cos\left[i\cdot\cos^{-1}\left(\frac{(\log P - PL)-(PU-\log P)}{PU-PL}\right)\right]$ PU = 1.0024 PL = -1.3109	m1 = 69.527	0.041256
	m2 = 75.69	0.068996
	m3 = 21.765	0.058256
	m4 = 2.5715	0.041003
	m5 = -0.72045	0.028792
	m6 = -0.37803	0.038444
	m7 = 0.017292	0.055935
	m8 = 0.037832	0.060874
	m9 = 0.022366	0.04554

Table 2: Parameters and coefficients of the Chebychev fit for 2% prime source after the cold vibration test.

3.3 4% redundant source

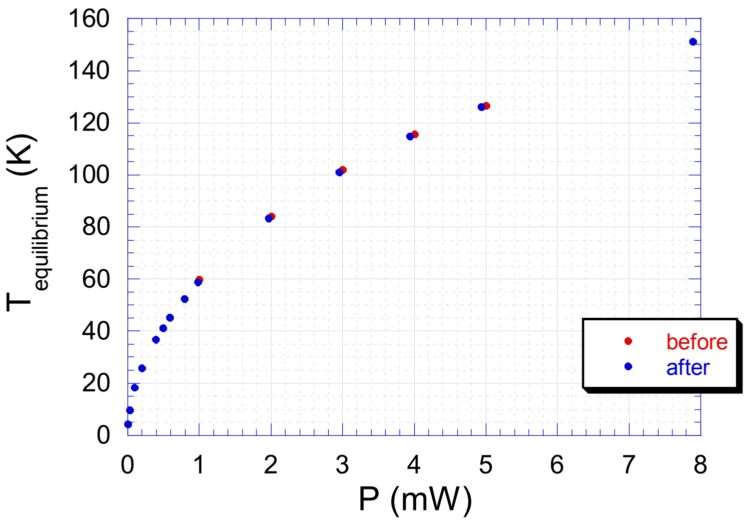
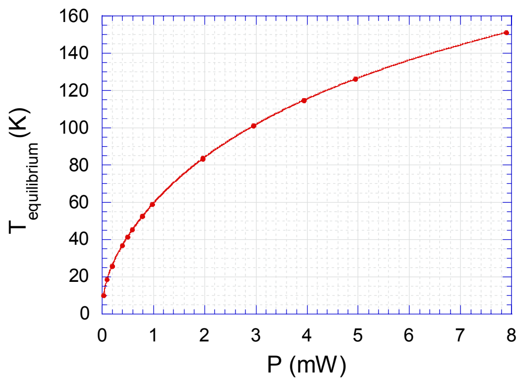
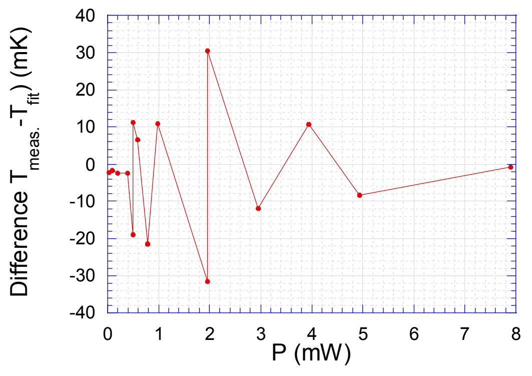


Figure 28: Comparison of the equilibrium temperature versus applied power for 4% redundant source before and after the cold vibration test.



The line is the Chebychev Fit to the data



Difference between values derived using fit and data points

fit equation	coefficient	error
$T(P)=\sum_{0}^{9} m_i \cos\left[i\cdot\cos^{-1}\left(\frac{(\log P - PL)-(PU-\log P)}{PU-PL}\right)\right]$	m1 = 60.168	0.14263
	m2 = 68.205	0.23435
	m3 = 20.838	0.14169
	m4 = 2.8534	0.012794
	m5 = -0.58275	0.093839
PU = 0.8972	m6 = -0.41683	0.14872
PL = -1.6159	m7 = 0.00032901	0.14523
	m8 = 0.047701	0.093517
	m9 = 0.037595	0.047889

Table 3: Parameters and coefficients of the Chebychev fit for 4% redundant source after the cold vibration test.

3.4 2% redundant source

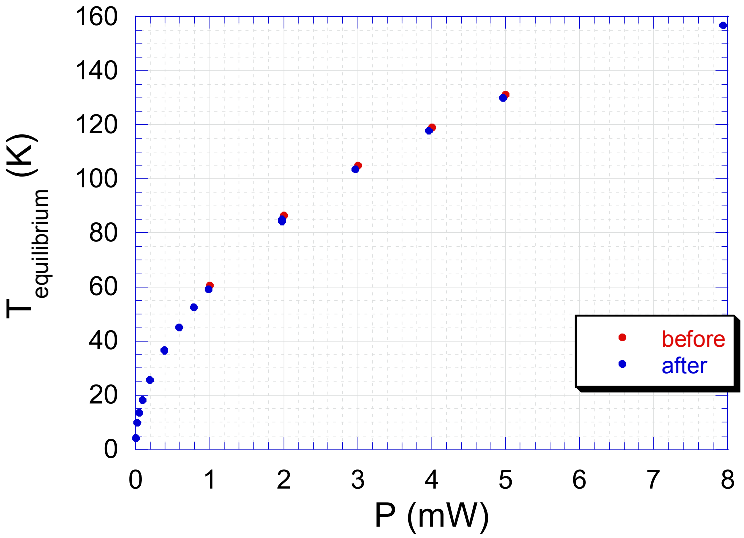
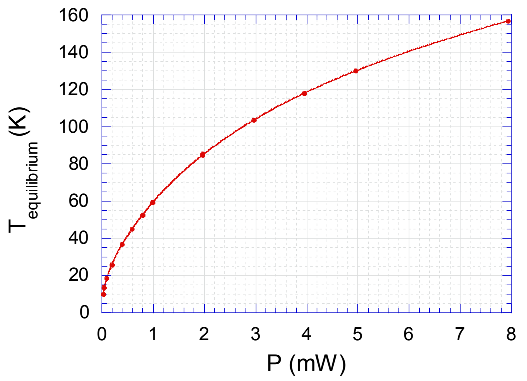
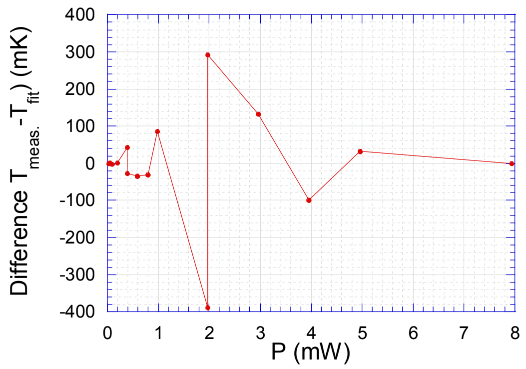


Figure 29: Comparison of the equilibrium temperature versus applied power for 2% redundant source before and after the cold vibration test.

	
The line is the Chebychev Fit to the data	Difference between values derived using fit and data points

fit equation	coefficient	error
$$T(P)=\sum_{0}^{9} m_i \cos\left[i \cdot \cos^{-1}\left(\frac{(\log P - PL)-(PU-\log P)}{PU-PL}\right)\right]$$ PU = 0.8994 PL = -1.6141	m1 = 61.551	0.10638
	m2 = 70.52	0.14104
	m3 = 22.318	0.14428
	m4 = 3.3467	0.095438
	m5 = -0.64679	0.080251
	m6 = -0.49679	0.087555
	m7 = 0.023365	0.12297
	m8 = 0.10975	0.12033
	m9 = 0.095858	0.1425

Table 4: Parameters and coefficients of the Chebychev fit for 2% redundant source after the cold vibration test.

Appendix D

SCal Lifetest Report

SCAL life test

(Results)

27 July 2004

Document Ref.: HSO-CDF-RP-081

Issue: 1.0

Prepared by: Iris Didschuns

Last Modified on: 27 July 2004

Distribution list

Table of Content

1. Introduction

The life test was carried out to demonstrate that the internal SPIRE spectrometer calibrator (SCAL) was capable of 3,000 operational cycles (SPIRE IHDR) during the mission lifetime. The actual number of cycles in the life test was increased by a factor of 1.5 to 4500 operational cycles to ensure a reliable performance well above the requirement.

Results from tests with the SCAL CQM model showed that SCAL had a long time constant during warm-up (t_{80K}=185 min) and cool-down (t_{80K}=80 min). With such long time constants, the life test would take 29 months. A SCAL life test model (SCAL LTM) with significantly shorter Torlon legs than the flight model (Figure 1) and, consequently, an improved cool-down time, was, therefore, used in the life test. The interface to the aluminium head was exactly the same as in the SCAL flight model, so SCAL LTM was considered to be a representative model in crucial properties.

The warm-up time was reduced further to seconds by applying power pulses of 100 mW, which were 30 times higher then normally used, but still recommend maximum power for heater by the manufacture.

The SCAL LTM had a 4% source (S1) on top of a thin Torlon leg (bore Ø 2.0 mm, length 7 mm) and a 4% source (S2) on top of an ultra thin Torlon leg (bore Ø 2.5 mm, length 10 mm). A 2% source was not included in the SCAL LTM because the interface between the aluminium head and the Torlon leg was the same.

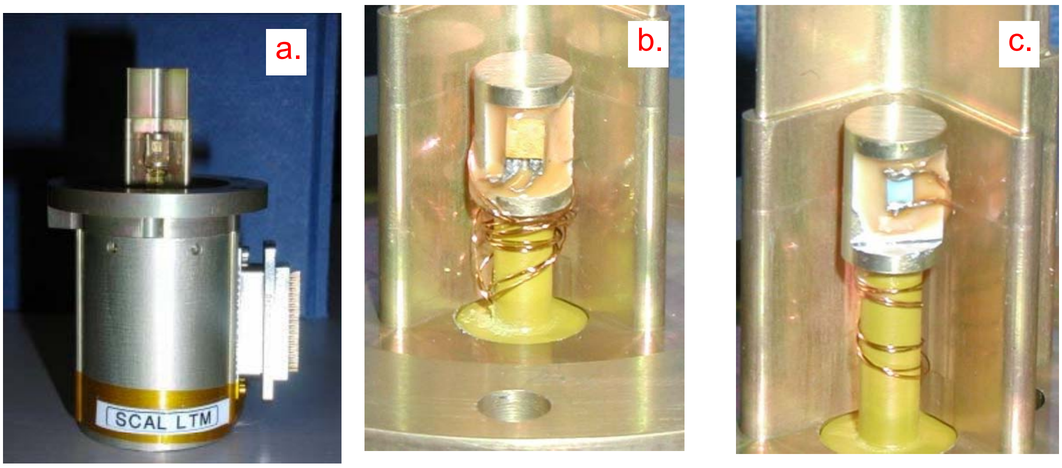


Figure 1: SCAL LTM (a. used in the life test with an close-up view of both sources (b. – S1 on top of the thin Torlon leg; c. – S2 on top of the ultra thin Torlon leg).

The heaters for the S1 and S2 source were identical, and their resistances differed only by 0.04% at 4 K. Due to technical problems during the assembly of SCAL LTM, S2 was only equipped with the heater chip but no thermometer. This was not expected to cause any problems because during the life test the heater voltage was continuously measured and compared with the heater voltage measured from S1. So any problems with the S2 heater, potentially caused by electrical or mechanical failure, could be immediately detected. Due to the longer and thinner-walled Torlon leg it can be assumed that S2 reached at least the same target temperature (80K) then S1 most likely even higher. The temperature of S2 would be as well 80K if use as SCAL flight model. Therefore if S1 shows no problems with the components (interface torlon to aluminium head, interface heater to aluminium head via Epo-Tek layer) the assumption if S1 survive then S2 despite not having a thermometer is justified.

A detailed description of the test procedure and test record can be found in: \\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\SCAL life test\Test procedure and record.doc.

2. Characterization before the life test

The SCAL source was characterised before the life test by applying a constant power to the heater and simultaneously measuring the temperature.

The warm-up time was defined as the time taken for the temperature to reach 90% of its equilibrium value, with the base temperature remaining at 4.2 K. The cool down time was defined similar as the time taken for the temperature to drop by 90% from this equilibrium once the power over the heater was switched off.

Figure 2 shows the complete temperature curves (warming-up and cooling-down) at different levels of applied power. These power levels were chosen to cover the predicted temperature range necessary to null the telescope background with the SCAL calibrator. The time scale of the different temperature curves has been normalized to zero for clarification.

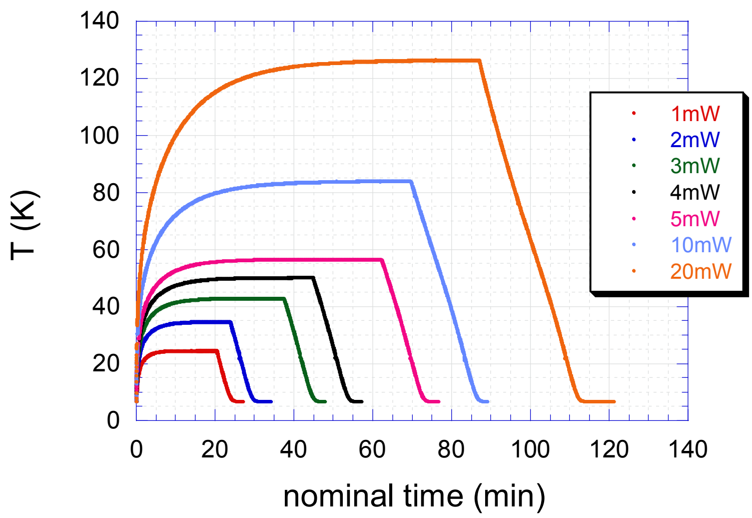


Figure 2: Temperature response curves for different levels of power applied to the SCAL LTM 4% source before the life test was carried out.

The equilibrium temperatures for certain power levels were determined from these results and can be found in Figure 3 and Table 1.

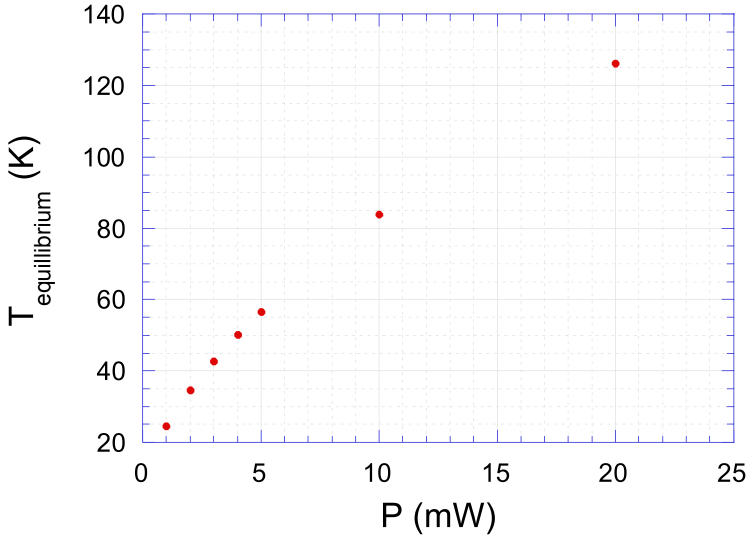


Figure 3: Equilibrium temperatures at different levels of power applied to the SCAL LTM 4% source calculated from Figure 2

P (mW)	$T_{eq.}$ (K)	t_{down} (min)	t_{up} (min)
0.999	24.53	4.03	2.85
1.998	34.68	6.08	3.87
2.994	42.88	8.10	5.27
3.991	50.06	9.47	6.62
4.988	56.59	10.99	7.90
9.967	83.87	16.73	13.16
19.912	126.44	25.60	18.66

Table 1: Equilibrium temperatures and the time constants at various levels of applied power for S1 source.

Since the warming-up and cooling-down time constants were still quite long an enhanced warm-up procedure was employed. This involved powering up the S1 source with 100mW (the recommended power (P_{max}=200mW) to be use for this type of heater by manufacture) for a short time (seconds rather than minutes). Figure 4 shows the temperature response of this enhanced warm-up for 100mW, 150mW and 200mW.

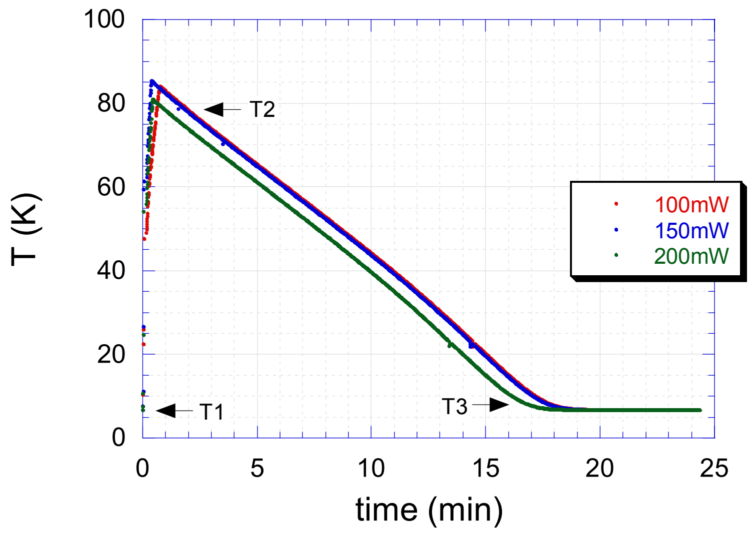


Figure 4: Enhanced warm-up by applied higher power level for a short time of the SCAL LTM S1 source

P (mW)	$\Delta T=T_2-T_1$ (K)	t_{up} (sec)	$\Delta T=T_3-T_2$ (K)	t_{down} (min)	t_{80K} (min)	T_{max} (K)
100	72.45=79.92-7.47	37.4	72.43=79.92-7.49	17.54	0.65	84.06
150	72.54=80.08-7.54	24.6	72.59=80.08-7.49	16.73	0.42	80.89
200	72.35=80.01-7.66	18.54	72.52=80.01-7.49	17.74		85.29

The same temperature range was used to compare time constants for each applied power. The different maximum temperatures were a result of the power being switched off manually. The cool-down times varied slightly, therefore, with the maximum temperature.

Figure 5 shows the time S1 source need until it reaches 80 K for different applied power values. The time is reduced by a factor of 30 when using 100 mW instead of 10 mW.

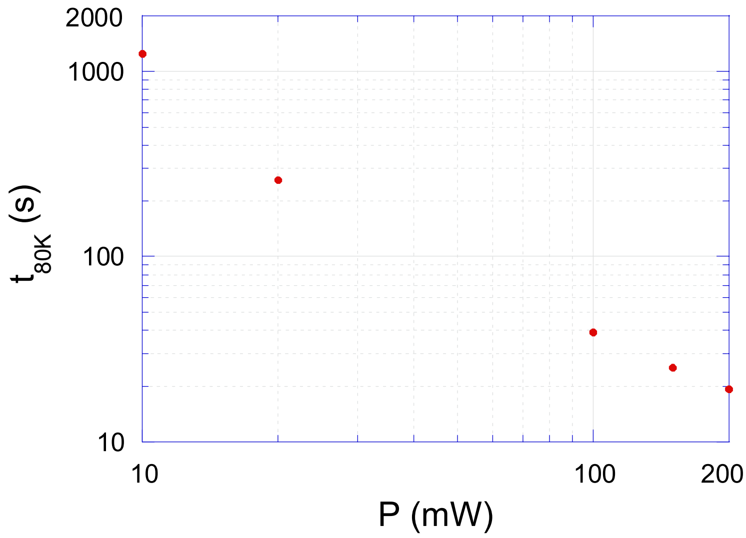


Figure 5: Time until S1 source reached 80K for different applied power values taken from Figure 4.

3. Life test

The life test was carried out by applying a continuous series of on/off power pulses with constant excitation to the SCAL sources. The time, the voltage across S1 heater (V_{S1}), the voltage across the S2 heater (V_{S2}) and the cycle number were measured and to reduce the size of the data file, however, only every 10th cycle was recorded.

The resistance values of the S1 and S2 heaters as well the S1 thermometer were measure during the first cryostat cool-down (Table 2). The resistances were measured using the 4 wire measurement method and a HP34410 multimeter for the heater a AVS-47 resistance bridge for the thermometer.

T (K)	R_{S1} (Ω)	R_{S2} (Ω)	$R_{CX28257}$ (Ω)
300	500	500	35.06
77	501	501	87.4
4.2	501.5	501.3	451.7

Table 2:Resistance values of the S1 and S2 heaters as well the S1 thermometer during the cool-down

This method of running the life test used the TTi PL330DP power supply to provide the applied Voltage (V_{app}). The temperature of the S1 source was measured and recorded at the beginning, middle and end of the life test to prove that the SCAL source was still functional (Figure 6). The data were stored in separated files for S1 source.

The three curves in Figure 6 were obtained at 3 week intervals during the life test. The data was monitored to reveal signs of changes in SCAL LTM that may have manifested themselves as temperature drop due, for example:

- Minimize power output of the heater due, possibly, connection failure
- Epo-Tek interface between Aluminium head and heater/thermometer due, possibly change of the interface properties (thermal conductance)
- Interfaces between the Torlon leg and Aluminium head due, possibly change mechanical properties (less good heat sink).

There were, however, no significant observable changes.

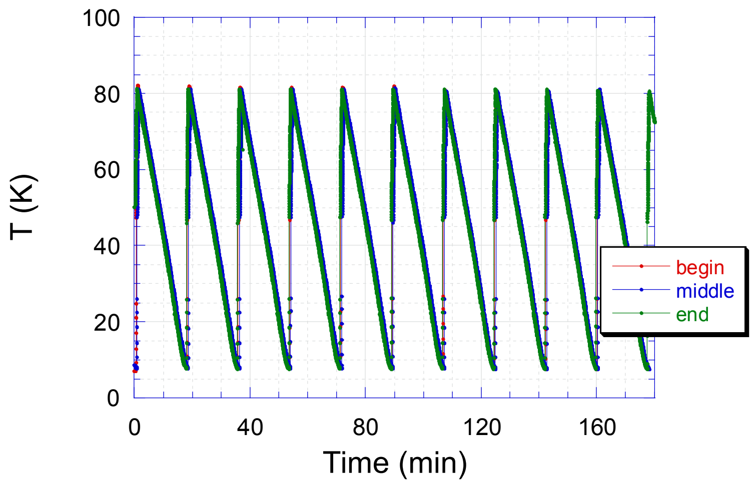


Figure 6: Temperature respond for 10 cycles measured at the beginning, middle and end of the life test to prove that the SCAL source was still functional.

The amount of current applied to the heater was determining by making daily measurements of the voltage drop over the control resistor (996 Ω). From these measurements the resistance values (Figure 7, Figure 8) were calculated. The calculated resistances show digitisation because the measurements were carried out using a handheld multimeter (Fluke), which only had a 2-digit resolution. The fluctuations of 0.2% for S1 and 0.3% for S2 most likely caused by different base temperature and noise induced in system. Other than this, there were no significant changes in the resistance of either source measured during the life test.

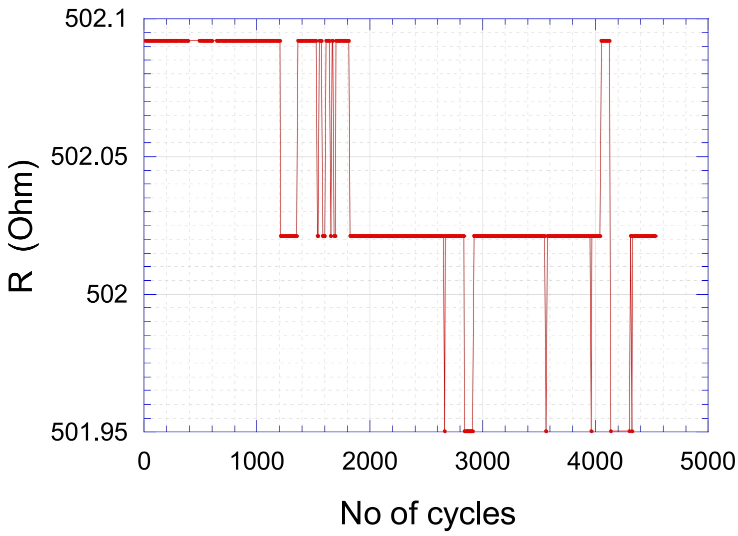


Figure 7: Heater resistance of SCAL LTM S1 source during the life test

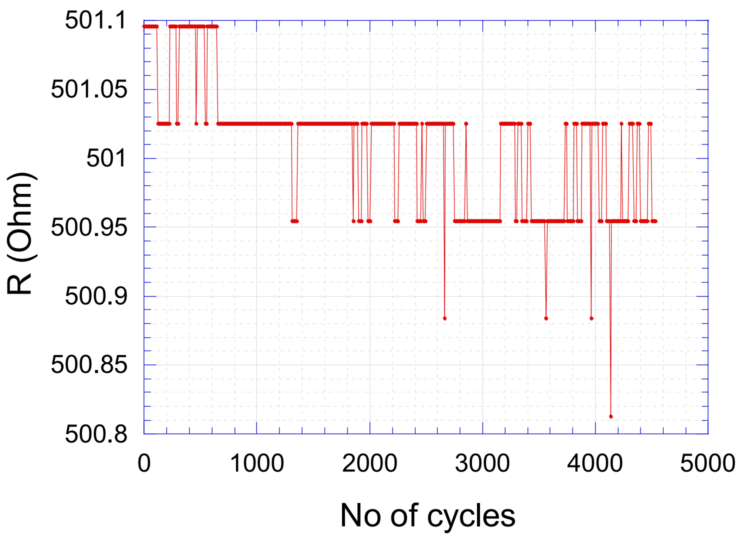


Figure 8: Heater resistance of SCAL LTM S2 source during the life test

4. Characterization after the life test

The SCAL source was characterised again after the life test to determine if there had been any changes in the source caused by the life test. The characterization was carried out in the same way as the characterization before the life test by applying a constant power to the heater and simultaneously measuring the temperature.

The temperature response curves obtained in the post-life-test characterization are shown in Figure 9, with the data points displayed in Table 3.

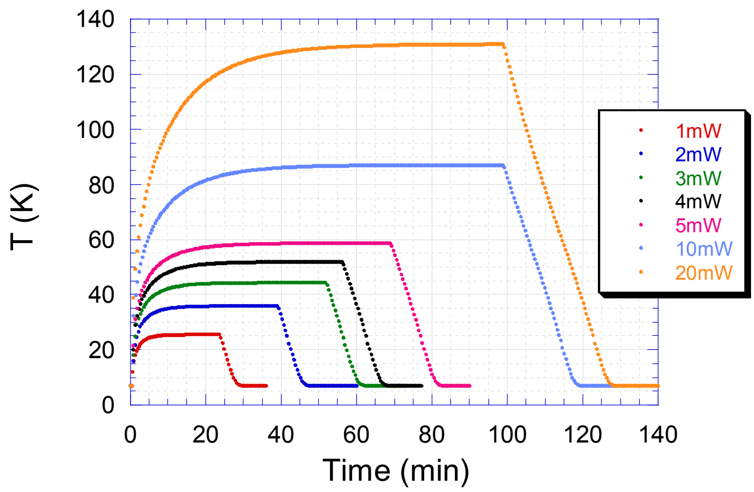


Figure 9: Temperature response curves for different values of power applied to the SCAL LTM S1 source after the life test was carried out.

P (mW)	$T_{eq.}$ (K)	t_{down} (min)	t_{up} (min)
1.001	25.51	5.47	3.27
1.999	35.94	7.73	4.99
2.998	44.39	9.73	6.54
4.016	51.96	11.57	8.07
5.018	58.71	13.26	9.47
10.019	87.08	20.13	15.18
20.019	130.90	29.12	20.57

Table 3: Equilibrium temperatures and the time constants at various levels of applied power for SCAL LTM S1 source.

A comparison between the temperature response curves obtained in the characterizations before and after the life test is given in Figure 10, and Figure 11 compares the values of equilibrium temperature obtained by applying various levels of power to the heater before and after the life test.

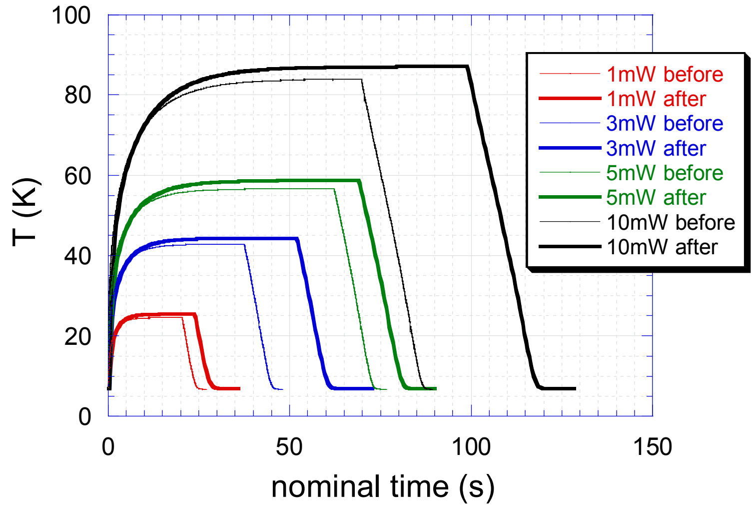


Figure 10: Comparison of the temperature response at different levels of power applied to the SCAL LTM S1 source before and after the life test

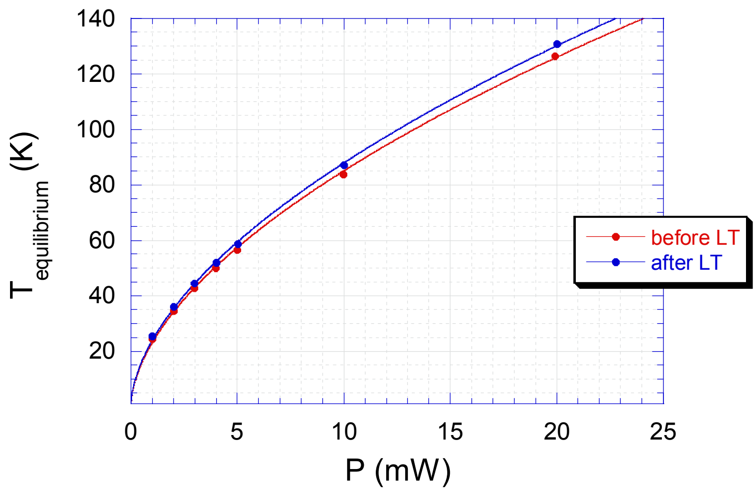


Figure 11: Comparison of equilibrium temperature for certain applied powers of the SCAL LTM S1 source before and after the life test. The solid lines are power fit curves.

The power curve fits in Figure 11 are characterized by the following equations:

- $T_{eq}(P) = (23.018 \pm 0.399) \cdot P^{(0.56752 \pm 0.00705)}$ (red curve)
- $T_{eq}(P) = (23.876 \pm 0.409) \cdot P^{(0.56597 \pm 0.00696)}$ (blue curve).

The equilibrium temperature of the S1 source before and after the life test was calculated from given power values by using the above equation and the result can be seen in Table 4. Table 4 shows as well the fraction difference between the calculated $T_{eq.}$ before and after the life test.

P (mW)	$T_{eq.}^{b}$ (K) before LT	$T_{eq.}^{a}$ (K) after LT	fractional difference between $T_{eq.}^{b}$ and $T_{eq.}^{a}$
1	23.018	23.876	0.037275
2	34.112	35.346	0.036161
3	42.938	44.463	0.03551
4	50.553	52.325	0.035049
5	57.378	59.369	0.034691
10	85.033	87.888	0.03358
20	126.02	130.11	0.03247

Table 4: Calculated equilibrium temperatures for given power values of the S1 source before and after the life test.

Figure 10 and Figure 11 show a difference in the equilibrium temperature before and after the life test. The equilibrium temperature from S1 source is a 3% higher after the life test then before.

5. Summary

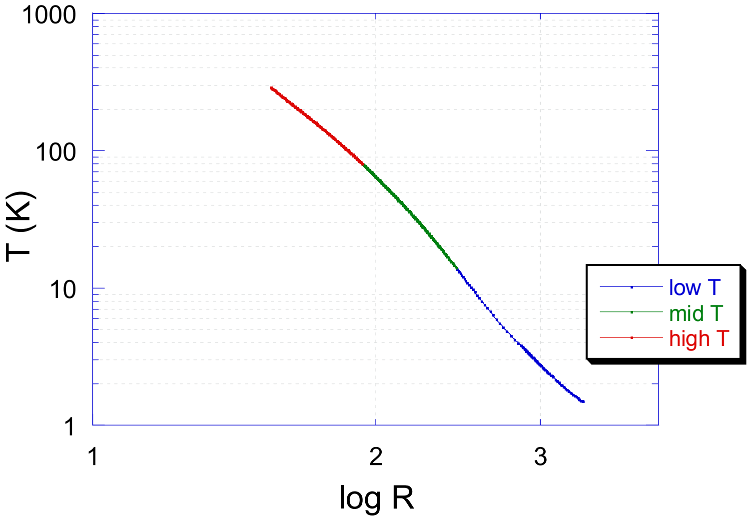
The SCAL sources S1 and S2 survived 4500 cycles of constant powering on and off and, therefore, survived the life test. This number of cycles corresponds to a 4.5 years mission lifetime.

By applying 100mW for a short time (40s), the required maximum temperature was reached very quickly. This enhanced warm-up procedure did not decrease the performance of the heater during the life test.

During the life test there was not significant change in the heaters properties. The heater resistance varies a little ($R_{S1} = 502.02 \pm 0.04\ \Omega$, $R_{S2} = 501.030 \pm 0.075\ \Omega$)

The only notable different was the 3% increase in the equilibrium temperature for applied powers after the life test, which may be explained by a change in the thermal conductance of the use EPO-TEK 920FL over time (settling down effect).

6. Appendix – CX28257 thermometer calibration



TU=3.3272; TL=2.439		
	Value	Error
m1	5.5004	0.00188
m2	-5.6064	0.0028849
m3	2.0933	0.002599
m4	-0.64197	0.002721
m5	0.16943	0.0025047
m6	-0.011071	0.002664
m7	-0.013387	0.0025709
m8	-0.00097751	0.0025812
m9	0.014891	0.0024562
Chisq	0.034762	NA
R	0.99999	NA

TU=2.439; TL=1.939		
	Value	Error
m1	40.587	0.0018976
m2	-32.186	0.0035042
m3	6.3379	0.0031502
m4	-0.80543	0.0028897
m5	0.10238	0.0027599
m6	-0.014318	0.0025109
m7	0.019571	0.00233
m8	-0.011692	0.0017188
m9	0.0091089	0.001482
Chisq	0.67983	NA
R	1	NA

TU=1.939; TL=1.5465		
	Value	Error
m1	168.45	0.0070628
m2	-103.2	0.012162
m3	17.055	0.011548
m4	-2.8043	0.010857
m5	0.67016	0.010638
m6	-0.13803	0.0099678
m7	-0.042202	0.0098392
m8	0.062814	0.0087243
m9	-0.046955	0.008496
Chisq	7.2511	NA
R	1	NA

Figure 12: Temperature versus resistance curve for Cernox sensor (serial #28257) used during the life test and the solid line are Chebychev curve fits.

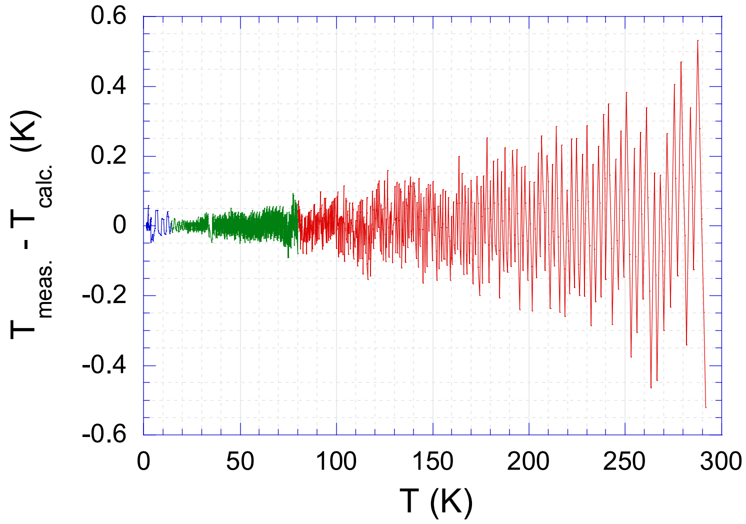


Figure 13: Absolute difference between values derived using fit and data points with temperature.

Appendix E

SCal Lifetest Procedure & Record

Test procedure and record

(SCAL life test)

9 August 2004

Document Ref.: HSO-CDF-PR-082

Issue: 1.0

Test Date

Prepared by: Iris Didschuns

Last Modified on: 9 August 2004

Approved by:

Distribution list

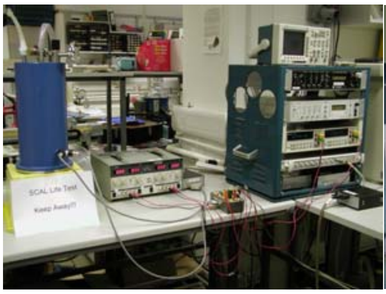
Table of contents

1. Introduction

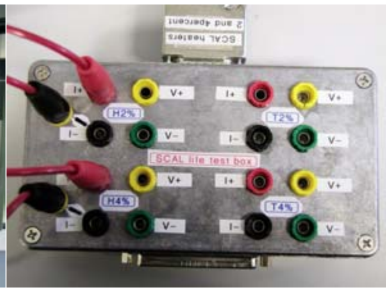
This document described the test plan for SCAL life test which included the experimental set-up, the preliminary tests, the room temperature, 77 K and 4 K checks as well the data acquisition.

The SCAL LTM had a 4% source (S1) on top of a thin Torlon leg (bore Ø 2.0 mm, length 7 mm) and a 4% source (S2) on top of an ultra thin Torlon leg (bore Ø 2.5 mm, length 10 mm). A 2% source was not included in the SCAL LTM because the interface between the aluminium head and the Torlon leg was the same.

2. Test Equipment & Set-Up


Test set-up


TTi PL330DP


SCAL life test box

- Helium4-cryostat (Oxford Instruments No: 38586, provided by QMC instruments)

Temperature measurement

- "AVS 2" Picowatt (RV-Elektroniikka Oy) AC-resistance bridge (AVS-47) with a two-stage IEEE-488 computer interface (AVS47-IB) (GPIB address 19)
- Description below

Life test

- Power supply TTi PL330DP (GPIB address: 12)
- Digital multimeter HP 34401A (GPIB address 22)
- Digital multimeter Agilent 34401A (GPIB address 21)
- Connector box labelled "SCAL life test box"
- Description below

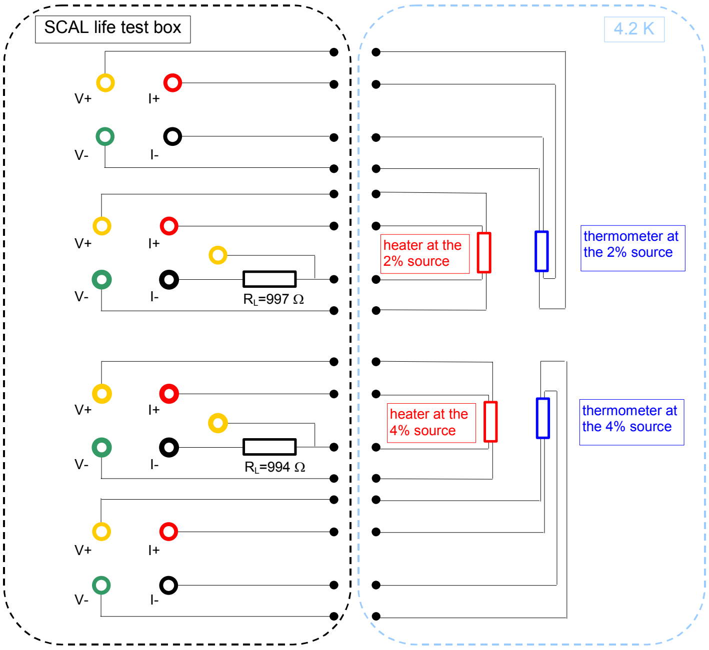


Figure 1: Schematic diagram of the "SCAL life test box" and the corresponding connection inside the cryostat.

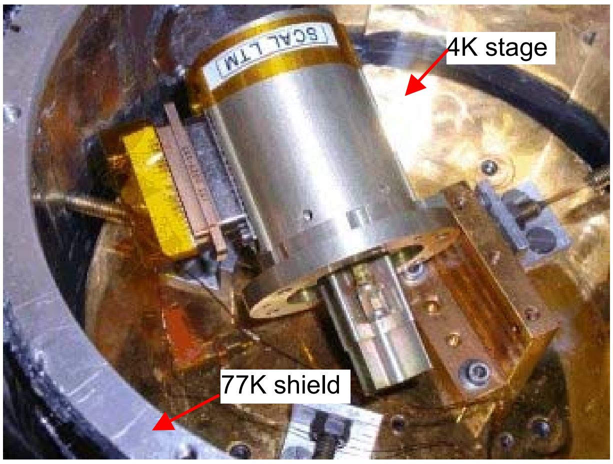


Figure 2: Inside view of the test cryostat which also will be use to carry out the SCAL life test.

3. Life test options

Total No. cycles (According to SPIRE IHDR)	4500
Total time for life test (Appendix A)	53 days
Time for warm-up (According to test from 12.01.2004 q.v. Appendix B)	40 s
Total time for one cycle (According to test from 12.01.2004 q.v. Appendix B)	17 min
Excitation	V_{max}=10V I_{max}=20mA
Temperature min	10 K
Temperature max	80 K
Estimated hard disk space for data files	3 MB

4. Data Acquisition

The life test will be controlled via computer (Windows2000) and the data acquisition software was written in LabVIEW 6. All LabVIEW programs can be found at \\Darkstar\Astroworld\Projects\SPIRE\LabVIEW\.

5. Test structure

Parameters marked TBD will be constrained after initial tests and all entries in red are records taken during the life test.

5.1 Room temperature checks

- Check for short circuits
- 4-wire-resistance measurement of both heaters
- Connect the cable "SCAL heaters 2% and 4% source" from the cryostat via 10pin Oxford connector "connector 2" to the 15pin connector at the "SCAL life test box"
- From the "SCAL life test box" connect the cables
  "SCAL LT 4% V-",
  "SCAL LT 4% I-",
  "SCAL LT 4% V+",
  "SCAL LT 4% I+",
  with HP34401A Digital multimeter

HP34401A settings	
4-wire-mode	ON
Autorange	ON

- From the "SCAL life test box" connect the cables
  "SCAL LT 2% V-",
  "SCAL LT 2% I-",
  "SCAL LT 2% V+",
  "SCAL LT 2% I+",
- with Agilent34401A Digital multimeter

Agilent34401A settings	
4-wire-mode	ON
Autorange	ON

In this life test the 2% source is replaced by a second 4% source which has a ultra thin Torlon leg. This source is referred to as "S2" in this test plan.

date: 08/01/04

H4% "S1"	H4% "S2"
R_{300K}= 500 Ω	R_{300K}= 500 Ω

- 4-wire-resistance measurement of the calibrated thermometer
- Connect the cable "SCAL thermometers 2% and 4% source" from the 10 pin Oxford connector "connector 1" with the AVS-47 bridge
- Convert the impedance value into temperature by using the LabVIEW program "convert_R_to_T(CX28257).vi"
- The calibration data can be found in "Calibration Report_CX2857.doc" which is stored in \\Darkstar\Astroworld\projects\spire\Cardiff_workpackages\thermmometer calibration\Cernox-CX-1030-SD-HT\Cx28257\.

date: 08/01/04

T4% "S1"
R_{300K}= 35.06 Ω

5.2 77 K checks

- Check for short circuits
- Check the resistance of the heaters:

date: 08/01/04

H4% "S1"	H4% "S2"
R_{77K}= 501 Ω	R_{77K}= 501 Ω

- Check thermometer resistance:

date: 08/01/04

T4% "S1"
R_{77K}= 87.4 Ω
T= 79.4 K

5.3 4 K checks

- Check for short circuits
- Check the resistance of the heaters:

date: 16/01/04

H4% "S1"	H4% "S2"
R_{4K}= 501.5 Ω	R_{4K}= 501.3 Ω

- Check thermometer resistance:

date: 16/01/04

T4% "S1"
R_{4K}= 451.7 Ω
T= 6.64 K

5.4 Preliminary test

The SCAL source S1 is characterised by applying a constant power to the heater and measuring simultaneously the temperature.

- Connect the cable "SCAL thermometers 2% and 4% source" from the 10 pin Oxford connector "connector 1" with the AVS-47 bridge
- Open LabVIEW program "One_temperature_monitoring_no_scan_modev1d.vi" which can be found in \\Darkstar\Astroworld\Projects\SPIRE\Labview\temperature_monitoring_no_scan_mode_AVS.llb
- Run the program

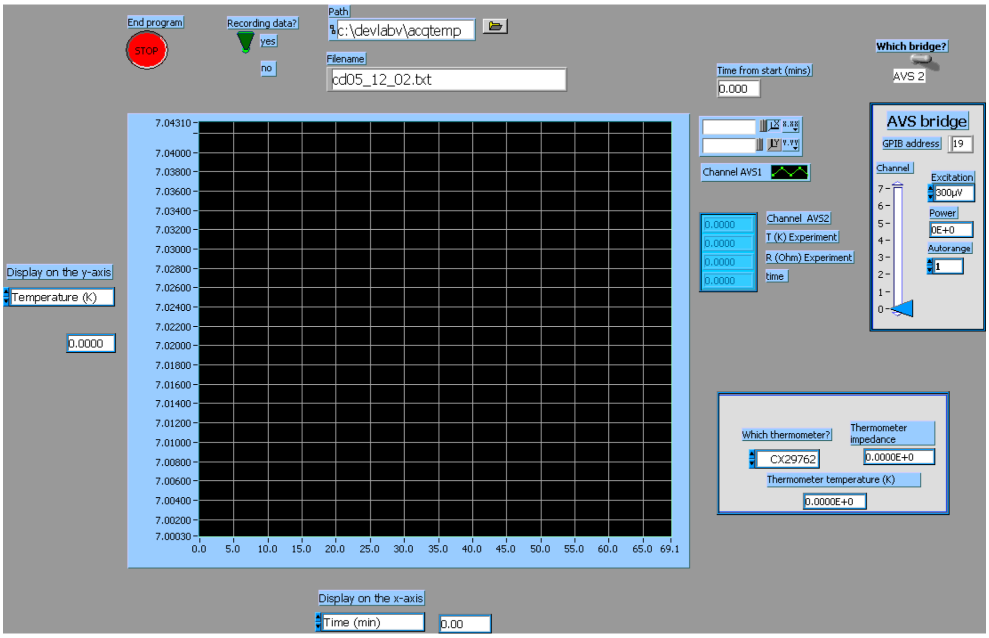


Figure 3: Program window of "One_temperature_monitoring_no_scan_modev1d.vi" which is monitoring and recording the temperature at T4%.

Program settings:

Function	
Channel	0
Excitation	300µV
Autorange	1
Which thermometer?	CX28257
Which AVS bridge?	AVS 2

File name:

scal_ltm_4percent_09_01_04.txt
scal_ltm_4percent_12_01_04.txt

- Turn the power supply TTi330DP "ON" (switch 1)
- Turn at the power supply TTi330DP the switch 3 to "remote", the switch 2 and switch 4 to "ON"
- Connect the current leads from Output 1 of the Power Supply TTi330DP to I+ (red socket) and I- (black socket) of H2%
- Connect the current leads from Output 2 of the Power Supply TTi330DP to I+ (red socket) and I- (black socket) of H4%
- Connect the voltage leads from Digital multimeter Agilent 34401A (GPIB address 21) to V+ (yellow socket) and V- (green socket) H2%

- Connect the voltage leads from Digital multimeter HP 34401A (GPIB address 22) to V+ (yellow socket) and V- (green socket) H4%
- Open program "TTiPL330_Applied_Power_with_Rv1.vi" which can be found in \\Darkstar\Astroworld\Projects\SPIRE\Labview\Applied_Power_with_control_R.llb
- run the program and apply various power values to the determine the correspond equilibrium temperature

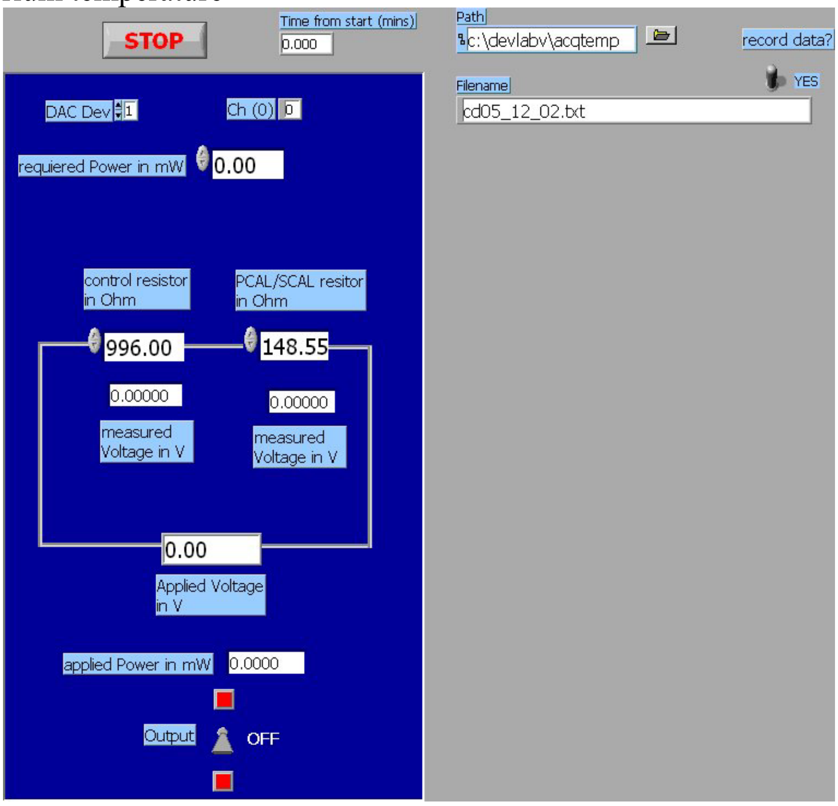


Figure 4: Program window of "TTiPL330_Applied_Power_with_Rv1.vi" which is controlling as well applying the required power values.

Program settings:

Function	
Output	OFF
Control Resistor	994 Ω
SCAL resistor	501 Ω
Max. Power (According to heater specification)	200 mW
Recommended Power (According to heater specification)	100 mW

File name:

scal_ltm_4percent_09_01_04_summary.txt
scal_ltm_4percent_12_01_04_summary.txt

5.5 *Life test*

The life test is carry out by applying a continuous series of on/off pulses with constant excitation to the SCAL sources. The time, V_{S1}, V_{S2} and the No. of cycles are measured and every 10^{th} cycle recorded to reduce the data file size. This method is using the TTi PL330DP power supply to provide "V_{app}". The temperature of the S1 measured & recorded at the beginning, the middle and the end of the life test in order to prove that the SCAL source is still functional. The data are been stored in two separated files for each source.

Expected values				
P (mW)	V_{app} (V)	I_{app} (mA)	V_{S1} (V)	V_{drop} (V)
200	31.22	20	10	19.89
5	4.94	3.16	1.58	3.14

- Turn at the power supply TTi330DP the switch 3 to "remote", the switch 2 and switch 4 to "ON"
- Connect the current leads from Output 1 of the Power Supply TTi330DP to I+ (red socket) and I- (black socket) of H4%
- Connect the current leads from Output 2 of the Power Supply TTi330DP to I+ (red socket) and I- (black socket) of H2%
- Connect the voltage leads from Digital multimeter HP 34401A (GPIB address 22) to V+ (yellow socket) and V- (green socket) H4%
- Connect the voltage leads from Digital multimeter Agilent 34401A (GPIB address 21) to V+ (yellow socket) and V- (green socket) H2%
- Running life test program "SCAL_life_test_part_A.vi" from \\Darkstar\Astroworld\Projects\SPIRE\Labview\SCAL_life_test.llb\ where both source are powered up

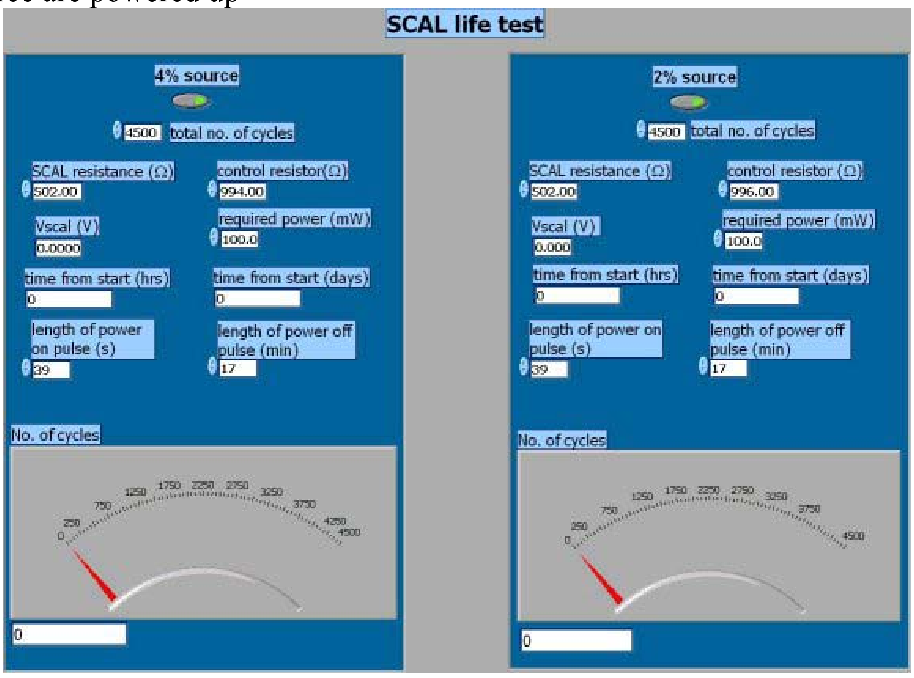


Figure 5: Program window of "SCAL_life_test_part_A.vi" which is controlling as well monitoring the life test.

Program settings:

4% source		2% source	
Total No. Of cycles	4500	Total No. Of cycles	4500
SCAL resistance (Ω)	994	SCAL resistance (Ω)	996
Required power (mW)	100	Required power (mW)	100
Length of power on pulse (s)	39	Length of power on pulse (s)	39
Length of power off pulse (min)	17	Length of power off pulse (min)	17

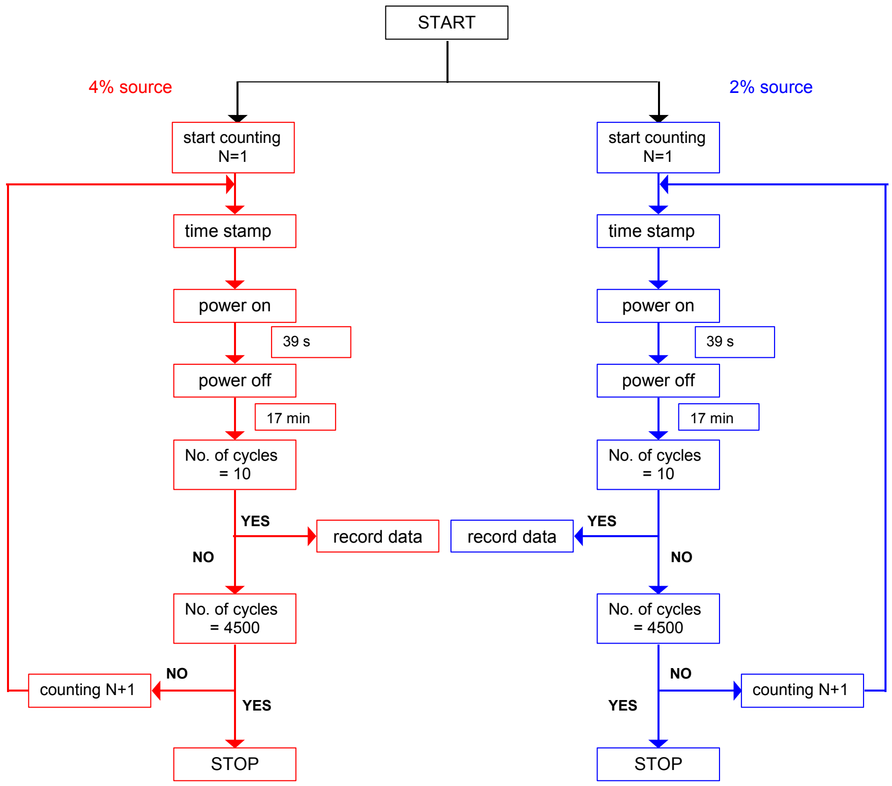


Figure 6: The flow chart of the main program shows that both sources are controlled at the same time.

The temperature versus time curve is measured at the beginning, the middle and the end of the life test to prove that the S1 source still works normally and to do so run the program "SCAL_life_test_part_b.vi" which can be found in:

\\Darkstar\Astroworld\Projects\SPIRE\Labview\SCAL_life_test.llb\.

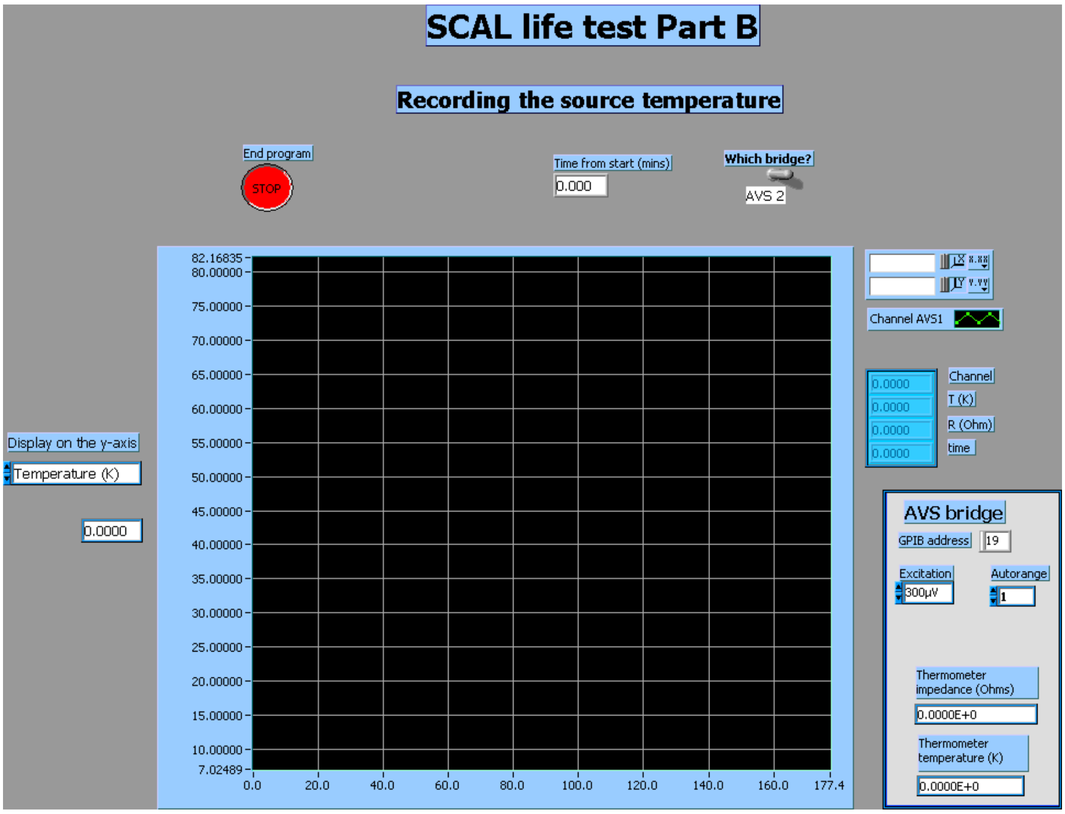


Figure 7: This is the 2nd program for the SCAL life test, which the user will run at the beginning, the middle and the end of the life test for the S1 source. This program measures the temperature vs. time from the S1 source.

Program settings:

Function	
Channel	0
Excitation	300µV
Autorange	1
Which AVS bridge?	AVS 2

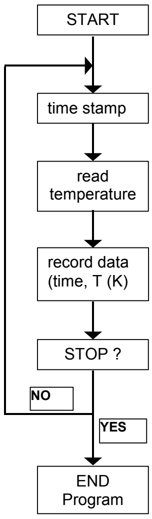


Figure 8: Flow chart of the program, which records the temperature vs. time of the 4% source.

	File name
Main life test data from S1 source	scal_LTM_4percent_source_16_01_04.txt
Main life test data from S2 source	scal_LTM_2percent_source_16_01_04.txt
T(K) vs. time data from S1 source at begin of life test	scal_LTM_4percent_source_T(K)_16_01_04.txt
T(K) vs. time data from S1 source at middle of life test	scal_LTM_4percent_source_T(K)_11_02_04.txt
T(K) vs. time data from S1 source at end of life test	scal_LTM_4percent_source_T(K)_11_03_04.txt

- Check once a day the thermometer CX28257 and the voltage at control resistor V_{drop} of S1 source

1st week					2nd week					3rd week				
Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S1}$ (V)	Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)	Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)
16/01	14:08	85.57	7.98	7.98	23/01	14:56	85.57	14.05	14.09	30/01	10:50	89.04	14.04	14.09
17/01	12:34	90.84	7.97	7.97	24/01	13:22	87.77	14.05	14.09	31/01	11:56	86.07	14.04	14.09
18/01	12:29	89.84	7.97	7.98	25/01	11:45	89.99	14.05	14.09	01/02	12:06	86.02	14.05	14.09
19/01	12:29	90.25	14.04	14.1	26/01	12:13	86.28	14.05	14.09	02/02	11:30	89.45	14.04	14.09
20/01	11:58	91.36	14.04	14.09	27/01	11:25	86.33	14.05	14.09	03/02	10:30	86.38	14.04	14.09
21/01	11:35	90.5	14.04	14.08	28/01	11:02	89.01	14.04	14.1	04/02	10:20	89.86	14.04	14.09
22/01	12:00	86.66	14.04	14.1	29/01	10:00	86.3	14.05	14.09	05/02	10:32	98.9	14.04	14.09
4th week					5th week					6th week				
Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)	Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)	Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)
06/02	11:55	86.44	14.05	14.09	13/02	10:40	86.15	14.04	14.08	20/02	13:08	86.84	14.05	14.09
07/02	11:30	86.15	14.04	14.08	14/02	12:55	86.13	14.05	14.09	21/02	12:19	86.7	14.04	14.08
08/02	12:20	86.16	14.05	14.09	15/02	12:33	86.46	14.05	14.09	22/02	12:30	86.27	14.05	14.09
09/02	10:45	86.2	14.05	14.09	16/02	11:35	86.89	14.05	14.09	23/02	12:05	86.15	14.05	14.09
10/02	11:33	86.07	14.05	14.09	17/02	11:16	86.02	14.04	14.09	24/02	12:35	85.71	14.04	14.08
11/02	10:15	86.45	14.05	14.09	18/02	11:05	85.97	14.04	14.09	25/02	19:20	91.5	14.05	14.09
12/02	11:58	86.39	14.05	14.09	19/02	10:42	85.99	14.04	14.08	26/02	11:14	85.92	14.04	14.08
7th week					8th week					9th week				
Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)	Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)	Date	Time	T_{S1} (Ω)	$V_{drop\ S1}$ (V)	$V_{drop\ S2}$ (V)
2/02	10:50	86.26	14.05	14.09	05/03	11:20	86.48	14.04	14.09	12/03	11:00	86.17	14.04	14.09
28/02	11:55	86.48	14.03	14.08	06/03	11:50	86.38	14.04	14.09					
29/02	12:15	87.48	14.04	14.08	07/03	12:40	86.86	14.05	14.09					
01/03	11:32	86.7	14.05	14.09	08/03	10:45	87.1	14.04	14.09					
02/03	11:40	86.47	14.04	14.08	09/03	11:35	86.34	14.04	14.08					
03/03	10:20	86.67	14.04	14.09	10/03	10:50	86.26	14.04	14.09					
04/03	10:30	86.34	14.04	14.09	11/03	11:05	86.15	14.05	14.09					

The blue value are V_{scal} (Voltage across the heater) and not V_{drop} (voltage across the warm control resistor).

5.6 *Final test*

- According to 5.4

File name:

SCAL_LTM_22_04_04.txt

- According to 5.1
- Check the resistance of the heaters:

date: 15/03/04

H4% S1"	H4% S2
R_{4K}= 500.1 Ω	R_{4K}= 500.1 Ω

- Check thermometer resistance:

date: 15/03/04

T4% "thin"
R_{4K}= 34.82 Ω

6. Appendix A

SCAL_Life_Test_Options.mcd **13 Janurary 2004**

Mission lifetime (yrs)	Life := 4.5	Revised requirement
	Life2 := Life·365.25 Life2 = 1644	days
Fraction of SPIRE time	f_spire := 0.33	
Fraction of SPIRE time used by FSS	f_FTS := 0.5	
Operational hours per day	hrs_day := 21	
No. of hours per operation	hrs_op := 2	
Margin factor	M := 1.5	Revised requirement

No. of operation per day: $op\_day := \frac{hrs\_day}{hrs\_op}$ $op\_day = 10.5$

No. of operations for test: $N\_ops := \frac{Life2 \cdot hrs\_day \cdot f\_spire \cdot f\_FTS}{hrs\_op} \cdot M$ $N\_ops = 4271$

$N\_ops := 4500$ according to SPIRE-IHDR

Time per cycle (min.): $t\_cycle := 17$

Total time needed (days) assuming 100% efficiency: $t\_tot := N\_ops \cdot \frac{t\_cycle}{60} \cdot \frac{1}{24}$ $t\_tot = 53.1$

Latent heat of He at 4.2 K and 1.01285 bar (J gm^{-1}): $C\_He := 20.91$ R.A. Haefer:"Kryo-Vakuumtechnik:Grundlagen und Anwendungen", Springer-Verlag, Berlin 1981

Density of liquid He at 4.2 K and 1.01285 bar (gm cm^{-3}): $\rho\_He := 0.1248$

Dewar capacity (Oxford cryostat) (ltr)	Vol := 1.9	
Mass of Helium (gm)	M_He := Vol·1000·ρ_He	M_He = 237.12
Total available energy (J)	Energy := M_He·C_He	Energy = 4958.179
Heater resistance (Ω)	R_heat := 500	

Warm-up time vs. applied power
(from SCAL LTM measurements 09-01-04 12-01-04.mcd)

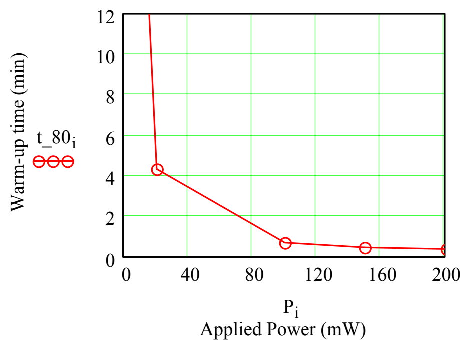
Parameters:
Wire length = 30 mm
Torlon strut: length = 10 mm; bore = 2 mm

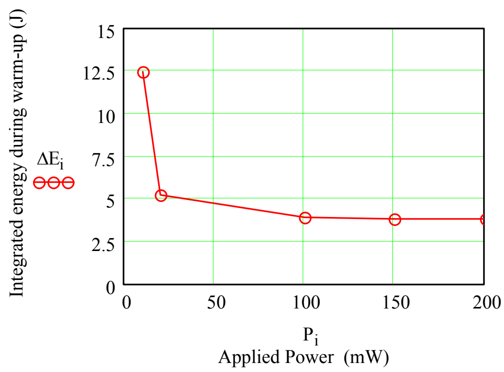
$i := 0, 1 .. 4$

Applied Power (mW) $P_i :=$	Time for which power applied (min) $t\_80_i :=$
10	20.7
20	4.3
100	0.65
150	0.42
200	0.32

Life test for one source at the time

Integrated energy (J)	Required current (mA)	Required voltage (V)	Average power (mW)
$\Delta E_i := \frac{P_i \cdot 1}{1000} \cdot t\_80_i \cdot 60$	$I_i := \left(\frac{P_i \cdot 1000 \cdot 1}{R\_heat}\right)^{0.5}$	$V_i := \frac{I_i}{1000} \cdot R\_heat$	$P\_avg_i := P_i \cdot 1 \cdot \frac{t\_80_i}{t\_cycle}$
$\Delta E_i =$	$I_i =$	$V_i =$	$P\_avg_i =$
12.42	4.5	2.2	12.2
5.16	6.3	3.2	5.1
3.9	14.1	7.1	3.8
3.78	17.3	8.7	3.7
3.84	20.0	10.0	3.8





Comments:

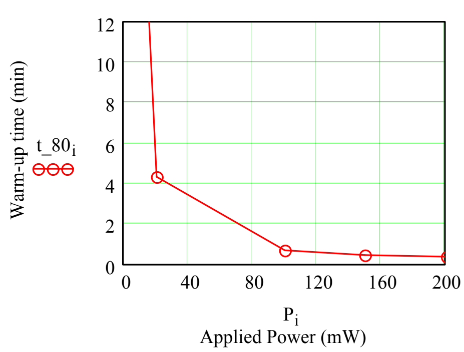
For large applied power, the required total energy becomes insensitive to the applied power because the warm-up time is so short that little or no energy leaks away during warm-up

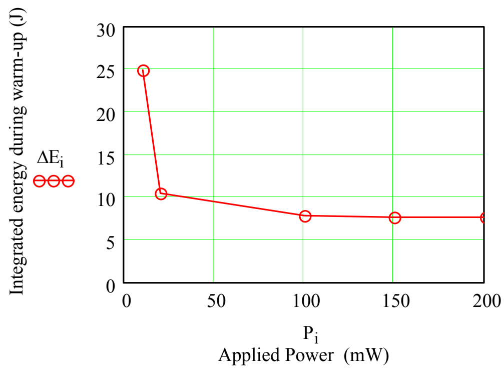
With a cool-down time on the order of 10 minutes, there is little to be gained by going above 200 mW applied power since the warm-up time is already less than one minute.

Number of cycles per helium fill	Hold time per helium fill (days)	Check
$N\_cyc_i := \frac{Energy}{\Delta E_i}$	$t\_hold_i := \frac{N\_cyc_i \cdot t\_cycle}{60 \cdot 24}$	$t\_hold\_check_i := \frac{Energy}{\frac{P\_avg_i}{1000} \cdot 3600 \cdot 24}$
$N\_cyc_i =$	$t\_hold_i =$	$t\_hold\_check_i =$
399	4.7	4.7
961	11.3	11.3
1271	15.0	15.0
1312	15.5	15.5
1291	15.2	15.2

Life test for both sources at the time

Integrated energy (J)	Required current (mA)	Required voltage (V)	Average power (mW)
$\Delta E_i := \frac{P_i \cdot 2}{1000} \cdot t\_80_i \cdot 60$	$I_i := \left(\frac{P_i \cdot 1000\,2}{R\_heat}\right)^{0.5}$	$V_i := \frac{I_i}{1000} \cdot R\_heat$	$P\_avg_i := P_i \cdot 2 \cdot \frac{t\_80_i}{t\_cycle}$
$\Delta E_i =$	$I_i =$	$V_i =$	$P\_avg_i =$
24.84	6.3	3.2	24.4
10.32	8.9	4.5	10.1
7.8	20.0	10.0	7.6
7.56	24.5	12.2	7.4
7.68	28.3	14.1	7.5





Number of cycles per helium fill	Hold time per helium fill (days)	Check
$N\_cyc_i := \frac{Energy}{\Delta E_i}$	$t\_hold_i := \frac{N\_cyc_i \cdot t\_cycle}{60 \cdot 24}$	$t\_hold\_check_i := \frac{Energy}{\frac{P\_avg_i}{1000} \cdot 3600\,24}$
$N\_cyc_i =$	$t\_hold_i =$	$t\_hold\_check_i =$
200	2.4	2.4
480	5.7	5.7
636	7.5	7.5
656	7.7	7.7
646	7.6	7.6

Appendix F

SCal Enhanced Warm-up Test Report

SCAL B

(Enhanced warm-up procedure)

19 August 2004

Document Ref.: HSO-CDF-RP-083

Issue: 1.0

Prepared by: Iris Didschuns

Last Modified on: 19 August 2004

Approved by:

Distribution list

1. Introduction

This document describes three different methods to reach the equilibrium temperatures as quick as possible. In all three method an initial maximum power value is applied and the reduced to required equilibrium power value via different methods.

These tests were only carry out for 4% and 2% primary source. It is not necessary to carry out the test with redundant sources due to the identical design of the primary and redundant sources.

A record of all tests carried out on SCAL B can be found in:

\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\SCAL_build-test-log-pfm-fs.doc

2. Method One

The data can be found in:

\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\enhanced warmup\method one\raw data\

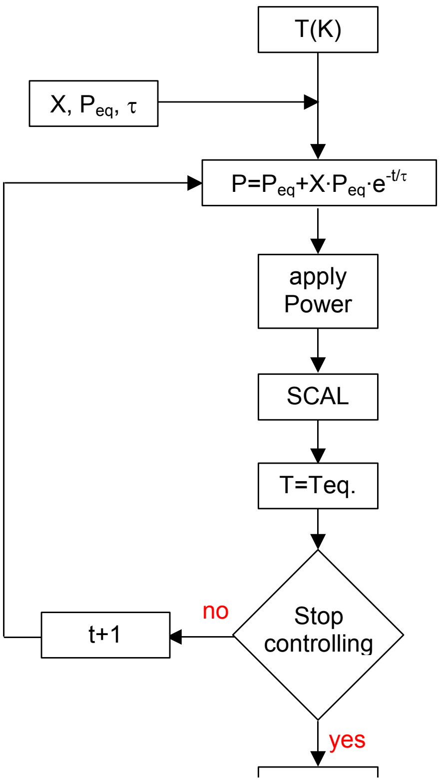


Figure 1: Flow chart of the LabVIEW program that applies constant maximum power and exponential reduces the power until reach the equilibrium power.

2.1 4% primary source

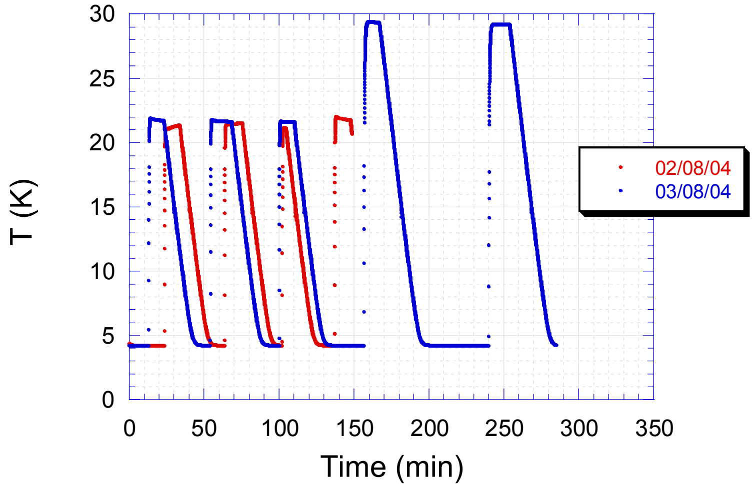


Figure 2: Temperature versus time curve during the enhanced warm-up at different maximum power values and parameter of SCAL B 4% prime source.

2.2 2% primary source

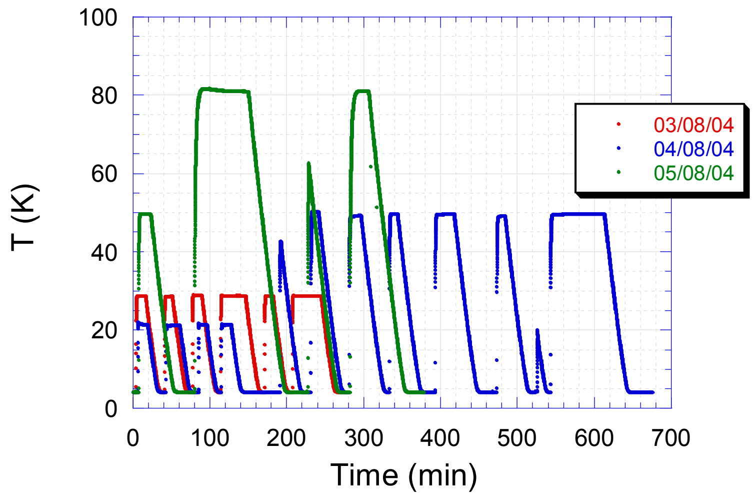


Figure 3: Temperature versus time curve during the enhanced warm-up at different maximum power values and parameter of SCAL B 2% prime source.

3. Method Two

The data can be found in:

\\Darkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\enhanced warmup\method two\raw data\

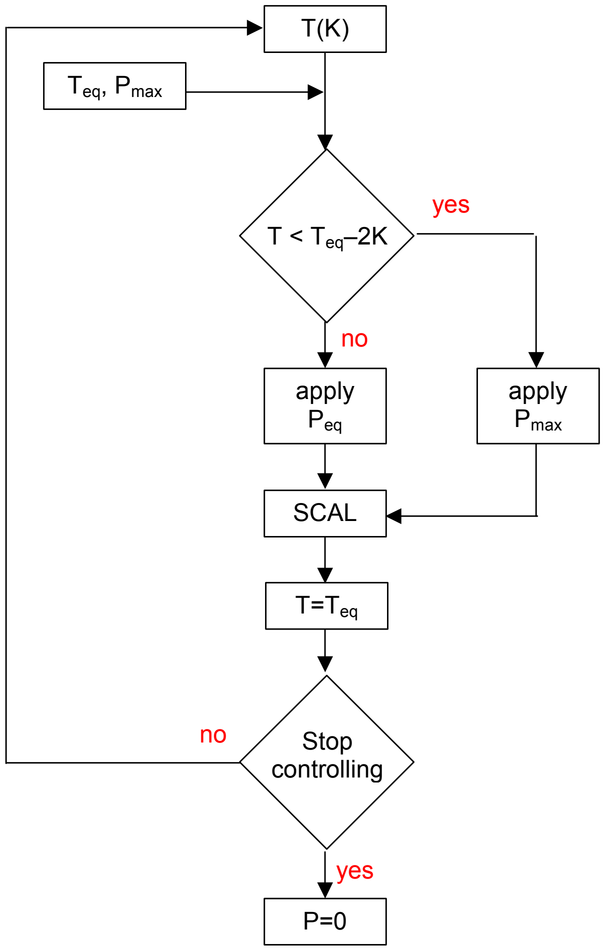


Figure 4: Flow chart of the LabVIEW program which applies constant maximum power until $T=T_{eq}$-2K and then the equilibrium power.

3.3 2% primary source

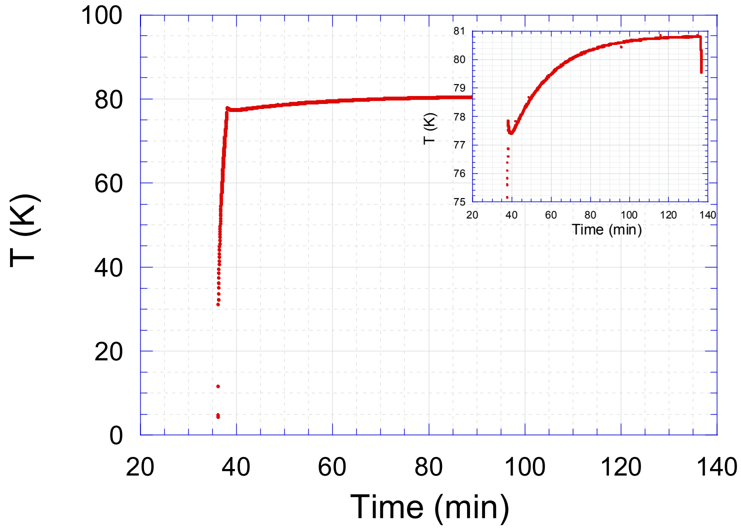


Figure 5: Temperature versus time curve during the enhanced warm-up where the maximum power was switch to the required power at T_{eq}-2K SCAL B 2% prime source.

P_{max} (mW)	T_{eq} (K)	T_{start} (K)	T_{end} (K)	$t_{warm-up}$ (min)	$t_{cool-down}$ (min)
15	80.82	4.28	—	120	95

4. Method Three

The data can be found in:

\arkstar\Astroworld\Projects\Spire\Cardiff_workpackages\SCAL\Assembly&test\SCAL_PFM_FS\Test data\enhanced warmup\method three\raw data\

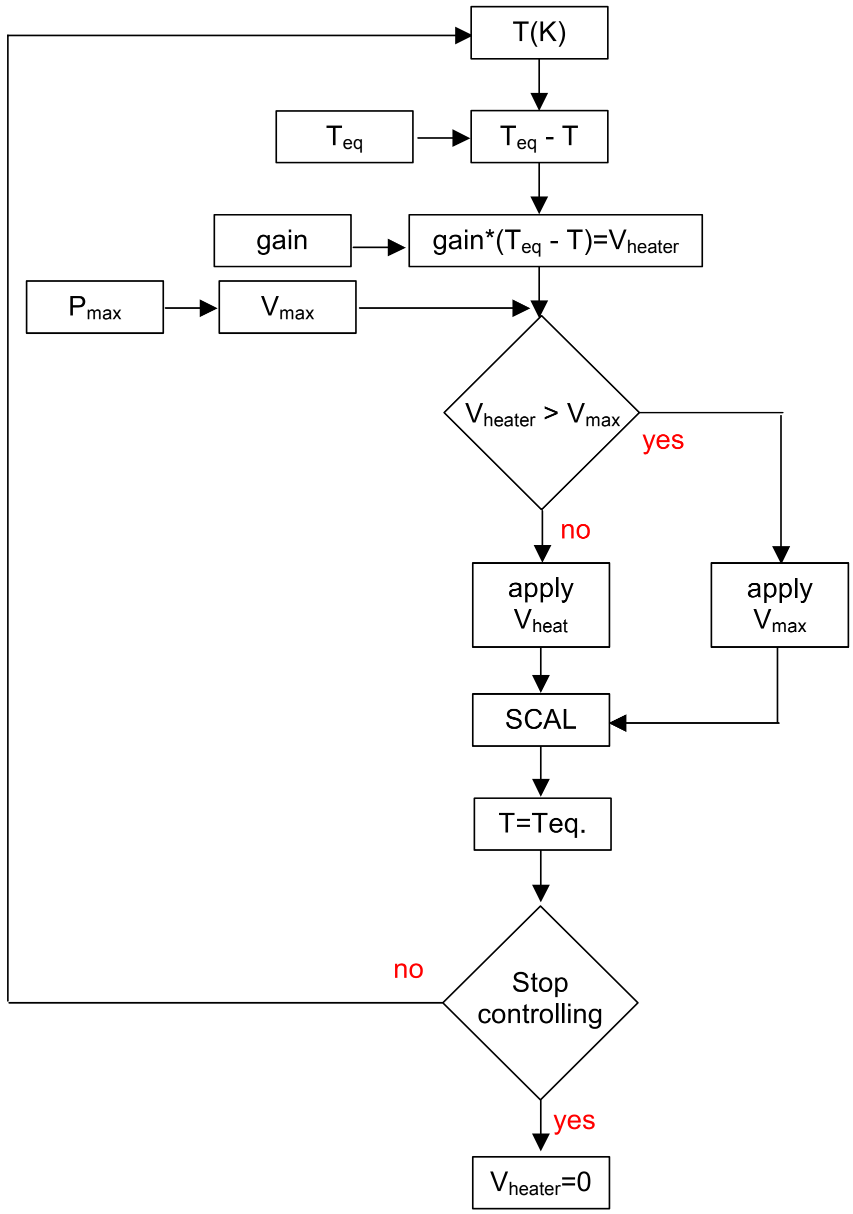


Figure 6: Flow chart of the LabVIEW program that uses a proportional feedback loop to reach equilibrium temperature fast as possible.

4.4 4% primary source

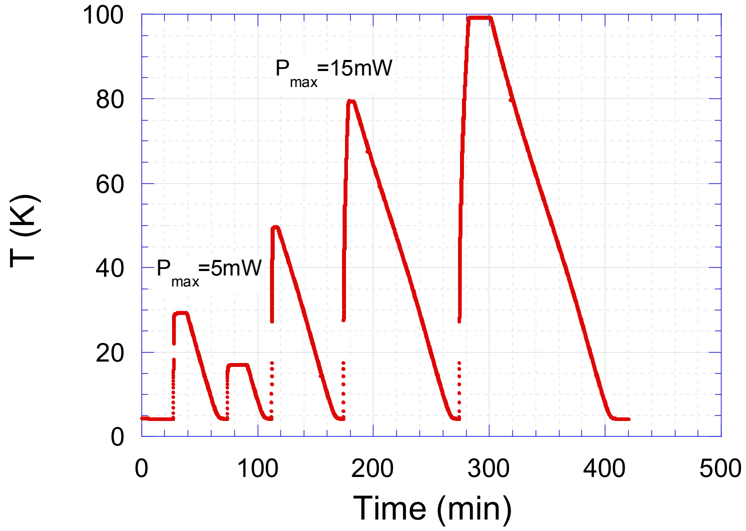


Figure 7: Temperature versus time curve during the enhanced warm-up at different maximum power and gain values of SCAL B 4% prime source.

4.5 2% primary source

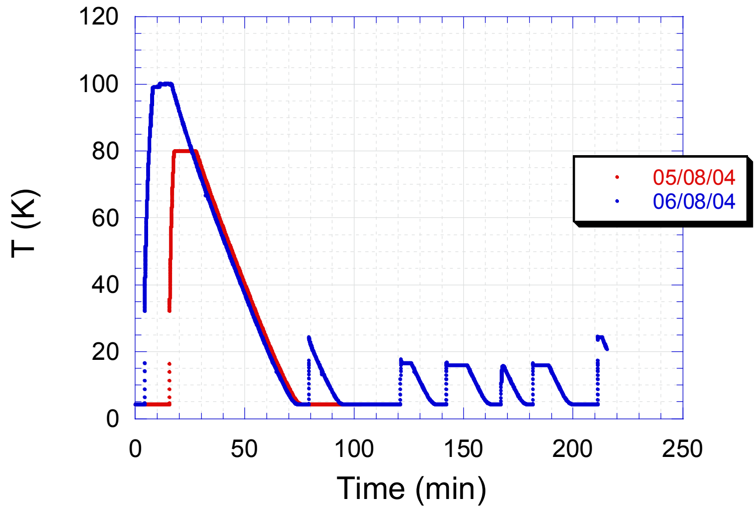


Figure 8: Temperature versus time curve during the enhanced warm-up at different maximum power and gain values of SCAL B 4% prime source.

5. Conclusion

All three method can be used to speed up the time until the temperature reaches equilibrium but not every method is optimal to use.

For all three methods we found that 5mW maximum power is suitable to reach the equilibrium temperatures up to 30K and 15mW for higher equilibrium temperatures. This is due the fact that the time constant temperatures up to 30K with 15mW maximum power is below 3 seconds. The data acquisition system that we use hat problems to work with those short time constant.

During the first test we observed that the temperature rise quickly (seconds) with maximum applied power and then when the power is switch to the required equilibrium power the temperature drops (1-2K below T_{eq}) initially before it start to rise again until it reaches the equilibrium temperature. This temperature drop followed by a the rise takes a long time, due to long time constant of the SCAL sources effect, and counteracts the quick warm-up through the initial power boost. This effect we believe is caused by the big heat capacity of the Torlon leg. The Torlon leg stay at a low temperature while the aluminium head warm up very quickly. So when the power is reduce to the required equilibrium power straight away the Torlon leg acts as a heat sink and the temperature drops below the equilibrium temperature. This is can be seen in Figure 5. The use of different ways of switching from the maximum power to the equilibrium power can avoid this effect.

Method One decrease exponential the maximum power to the equilibrium power. For this method it is necessary to determine the right parameters and this process takes a long time and also there will be a small temperature overshoot. The following table shows some parameter we found working best for this algorithm:

$$P(t) = P_{required} + P_{\max} \cdot e^{-\frac{t}{\tau}} \text{ with } P_{\max} = X \cdot P_{required}.$$

source type	$P_{required}$ (mW)	power factor X	Pmax (mW)	time factor τ	T_{eq} (K)	$t_{warm-up}$ (min)	$t_{cool-down}$ (min)
4%	0.15	33	5.1	13	21.6	5	29
4%	0.275	18	5.22	32	29.2	12	—
2%	0.15	33	5.1	8.5	21.35	4	18
2%	0.79	18.9	15.01	31.5	49.67	6	47
2%	2	6.5	15	130	81.1	13	53

Method Three use a simply proportional feedback to control the heater power. This method was the fastest of all three and showed no overshoot if the right gain value was chosen (Figure 7, Figure 8). A small off-set from the chosen set point (equilibrium temperature T_{eq}) was observed but this can be cancel out by using a additional integrational term in the feedback. At low temperature we observed that our data acquisition system was not fast enough controlling to avoid a temperature overshoot. One way to eliminate the overshoot is decreasing the maximum power from 5mW to probably 4mW or another way is the have a faster control system. The following table shows some parameter we found working best for this algorithm.

source type	gain	P_{max} (mW)	T_{eq} (K)	$t_{warm-up}$ (min)	$t_{cool-down}$ (min)
2%	5	15	79.98	4.6	54
2%	5	15	99.99	8	61
2%	0.7	5	16.10	2	13
2%	2	5	24.51	2	—
4%	1.5	5	29.25	4.7	34
4%	0.6	5	27.25	3	21
4%	5	15	49.62	3	56
4%	5	15	79.39	6	91
4%	5	15	99.23	9.6	111

Appendix G

Certificates of Conformance & Calibration