TECHNICAL NOTE

SPIRE 300-mK and Level-0 straps Subsystems Thermal Performances Assessment

THERMAL ENGINEERING SECTION				
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		Draft A 27/07/04	Draft A1 28/07/04	Draft A2 07/09/04	Issue 1 27/05/05	
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CHANGE RECORD

Issue	Date	Section	Change
Draft A	27/07/04	-	New Document
Draft A-1	28/07/04	Test Result	The table of copper test results has been updated with consistent data
		300-mK	A new case has been added in appendix
Draft A-2	07/09/04	All	-
		1	Scope added
		2	Added recent copper test results
		4-1	300-mK assembly thermal requirement updated
		4-2.2 and 4.2.3	Added new analyses results
		5	New section describing the Level-0 Strap sub-system thermal performances
		Appendices	New results added
Issue 1	27/05/05	-	Acronyms List added
		2	Section updated with additional reference documents.
		3	Added an introduction to this section for background information.
		3 - Eq1	Corrected formula for Wiedemann-Franz law (10^{-8} factor missing)
		Table 3.1	Added name to some of the sample and corrected for error in conductance value for brazed joints.
		4.2.1	New section for introduction
		4.2.2	Removed one bullet point from list as not really applicable.
		4.2.3	Added figure describing the 300-mK strap assembly.
		4.2.4	Reword this section for clarity. Case 4: Reword as error in initial estimation of the EPSI RRR=300 copper thermal conductivity.
		5	Re-organisation of the section for clarity Added a picture of the L0 straps

ACRONYMS

L0	Temperature Level 0 (~1.7K)
AD	Applicable Document
RD	Reference Document
RRR	Residual Resistivity Ratio
EPSI	Electronic Space Product International
5Ns	5 Nines purity copper - 99.999%
4Ns	4 Nines purity copper - 99.99%
OHFC	Oxygen Free Copper
CQM2	Cryogenic Qualification Model (Upgrade 2)
FM	Flight Model

CONTENT

LIST OF TABLES

LIST OF FIGURES

1. Scope

This document summarises the predicted performances of the SPIRE Level-0 (L0) and 300-mK strap assemblies.

A summary of the test results performed on copper samples by the University of Cardiff has been compiled and is presented in section 3.

Section 4 and 5 provides some background about the 300-mK and Level-0 strap assemblies thermal requirement and design respectively.

2. Applicable and reference documents

ID	Title	Number
AD1	Resistance Measurements on Vacuum Brazed Copper Joint for SPIRE straps	A. Woodcraft 18/08/04
AD2	Resistance Measurements	I. Didschuns 01/09/04
AD3	300 mK Hardware v1-03-1.xls	Configuration Spreadsheet AS. Goizel 09/09/04
AD4	MSSL Subsystems 5.xls	Configuration Spreadsheet AS. Goizel 09/09/04
AD5	Test Report – Thermal test of the electrical insulated Cooler Interfaces	Issue 1.0 27/08/03 I. Didschuns
AD6	Adam Woodcraft Email	27/07/04
AD7	Adam Woodcraft Email	29/04/04
AD8	Adam Woodcraft Email	12/05/04
AD9	Adam Woodcraft Email	13/05/04
AD10	Adam Woodcraft Email	04/06/04
AD11	Adam Woodcraft Email	08/06/04
AD12	Adam Woodcraft Email	21/07/04
AD13	300 mK Hardware v1-03-XXX.xls Where XXX relates to the appendices' number.	Configuration Spreadsheet AS. Goizel 26/07/04 - 09/09/04
AD14	Resistance Measurements on Copper Sample for SPIRE Straps	rrr_note3.doc 16/09/04 A. Woodcraft I. Didschuns
AD15	Thermal Update Telecon - Minutes	10/09/04

Table 2-1 – Applicable Documents

ID	Title	Number
RD1	SPIRE CQM1 Cooler test results	Report HSO-SBT-TN-091 Issue 1.1 L. Duband
RD2	Test Report – SPIRE 300-mK strap thermal tests	HSO-CDF-RP-048 Issue 1.0 09/05/04 A. Woodcraft
RD3	SPIRE Cryogenic Thermal Design Requirement	SPIRE-RAL-PJR-002075 Draft B 13/07/04 A. Goizel
RD4	Thermal Bolted Interface Conductance	Email from L. Duband 23/04/04

Table 2-2 – Reference Documents

3. Background on Copper Samples Test results

3.1 Introduction

The thermal performances of the SPIRE instrument are driven by two main thermal strap sub-systems:

- One integrated on the Level-0 stage (running at 1.7K), which consists of three copper straps, connected to the L0 detector enclosure and both the L0 pump and the evaporator interfaces of the cooler.
- The second one integrated on the 300-mK temperature stage, which consists of an arrangement of copper links connecting the five detectors to the cooler cold tip.

All straps require high purity copper in order to meet the set thermal requirements. The difficulty with copper is that its thermal conductivity is difficult to predict (as highly dependent on the purity of the copper, and other parameters such as heat treatment). Measurements of various samples of copper (from different batches) have therefore been carried out by Adam Woodcraft. The Wiedemann-Franz law has been used in this case, to estimate the thermal conductivity of the copper from its Residual Resistivity Ratio (RRR) measurement. The Wiedemann-Franz law is described in the following section and a table summarising all the measurement done by Adam is given in section 3.3.

3.2 The Wiedemann-Franz law

The Wiedemann-Franz law, described by Equation 1 below, has been used to calculate the thermal conductivity data from the RRR values measured [AD6].

$$k(RRR,T) = \frac{L0 \times T \times RRR}{r_{ROOM}}$$

Equation 1 - Wiedemann-Franz Law

Where:

- k is the thermal conductivity of the sample function of its operating temperature (T in Kelvin) and its measured Residual Resistivity Ratio (RRR)
- rho_{ROOM} is the room temperature resistivity of copper (1.679×10^{-8} ohm.m)
- The theoretical value for L0 is 2.45×10^{-8} W.ohm/K^2.

3.3 Results of the Thermal Conductivity Tests

Copper	*Supplier*	*Heat Treat*	*RRR*	*K @1.7K [W/mK]*	*K @ 0.3K [W/mK]*	*AD*
5Ns Copper 0.1mm	ESPI	As received	33	82	14	AD7
5Ns Copper 0.1mm	ESPI	As received	34	84	15	AD7
OFHC	4N?	Annealed Un-plated	190	471	83	AD7
OFHC	4N?	Un-annealed Au Plated	125-126	310	55	AD7
5Ns Copper 2 mm	ESPI	As received	510	1265	223	AD8
5Ns Copper 3 mm	ESPI	As received	465	1153	204	AD8
5Ns Copper 3 mm	ESPI	As received	530	1315	232	AD8
5Ns Copper Shim	ESPI	As received	32	79	14	AD8
5Ns Copper 1 mm rod	ESPI	As received Quite stiff	50	124	22	AD9
5Ns Copper 3 mm rod	ESPI	As received Quite stiff	50	124	22	AD9
5Ns Copper 2 mm	ESPI	Annealed after reception	>1500	3721	657	AD10
5Ns Copper 3 mm	ESPI	Annealed after reception	>1400	3473	613	AD10
5Ns Copper 3 mm	ESPI	Annealed after reception	>1400	3473	613	AD10
5Ns Copper 3 mm rod	ESPI	Annealed after reception	~300	744	131	AD10
5Ns Copper 1 mm rod	ESPI	Annealed after reception	~200	496	88	AD10
5Ns Copper 0.1 mm	ESPI	Annealed after reception	~250	620	109	AD10
5Ns Copper 0.2 mm	Leiden	Torch annealed in air	600 (1500 measured by Giorgio F)	1488 3721	263 657	AD11
5Ns Copper 0.1 mm	NORV	?	>500	1240	219	AD12

Copper	***Supplier***	***Heat Treat***	***RRR***	***K @1.7K [W/mK]***	***K @ 0.3K [W/mK]***	***AD***
5Ns Copper 0.1 mm	Advent	?	150 (TBC)	372	66	AD12
5Ns Copper 0.2 mm	NORV	Torch annealed in air	>500 (TBC)	1240	219	AD12
Brazed joint	-	-	-	-	0.0056 W/K 0.013 W/K	AD1
0.1 mm	NORV Cu Schlenk Ag [CBB_NORV10]	Vacuum Annealed	836	2200	330	AD2
1 mm rod	NOSV cu NA Ag [CBB_NORV11]	Vacuum Annealed	518	1363	204	AD2
3mm rod	NOSV cu NA Ag [CBB_NORV12]	Vacuum Annealed	504	1327	199	AD2

Table 3-1 - Copper Sample Thermal Conductivity Test Results

4. 300-mK Thermal Straps

4.1 Background Information and Thermal Requirements

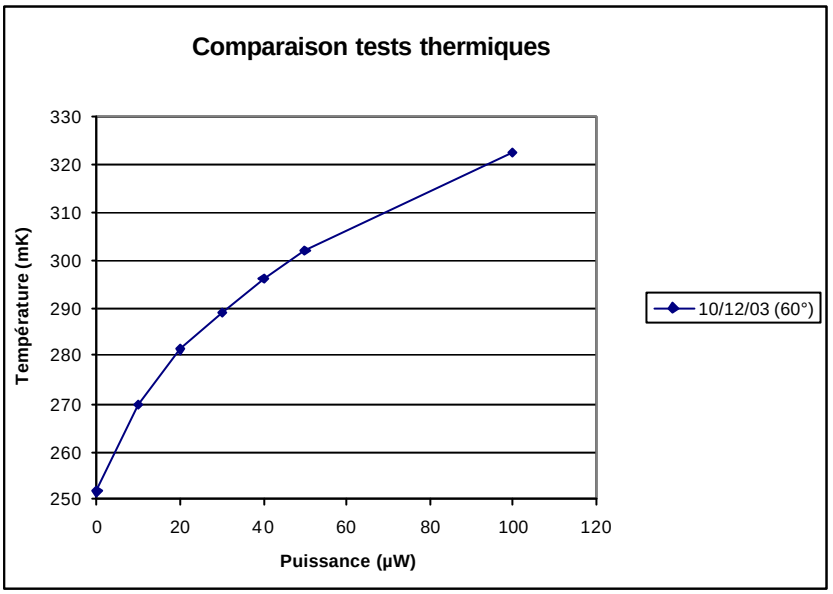


Figure 4-1 – SPIRE CQM Cooler Measured Cold Tip Temperature [RD1]

- The cooler cold tip temperature during operation can be predicted using the blue curve in Figure 4.1 [RD1].
- When no external load is applied, the temperature of the evaporator cold tip is < 255mK (for a predicted internal parasitic loads of 8 uW with the Level-1 at ~2K).
- With the Level-1 at 4-5K, the parasitic loads are close to 12uW and in operation, an additional 19.2uW (maximum design value) is expected on the cooler cold tip from the 300-mK system (parasitic loads from BDA and 300-mK Busbar supports). [RD3]
- Therefore, the cold tip temperature during operation can be predicted from this chart with an assumed applied load of 19.2uW “plus” the 4uW (missing cooler internal parasitic load when running the Level-1 at 4K) which gives a cold tip temperature around ~280-285mK (at +/- 5mK)
- The maximum temperature allowed at each of the Busbar BDA interface must be < 300mK (with a goal of <290mK) [RD3].
- Therefore the maximum allowable temperature drop from the cooler cold tip to the various 300-mK BDA interfaces should not exceed 15mK (10mK as a goal) [RD3].

4.2 300-mK Straps Thermal Performances Analysis

4.2.1 Overview

To better understand what is driving the 300-mK thermal straps performances, sensitivity analyses have been carried out by looking at the effect the following parameters:

- The copper thermal conductivity at 0.3K, for arbitrary values of 100, 400 and 30 W/mK,
- The conductance of the brazed joints, for arbitrary values of 0.01, 0.025 and 1 W/K.

Two case studies have also been analysed for the Cryogenic Qualification Model, upgrade 2 (CQM2) and the Flight Model (FM) thermal hardware configuration respectively.

For all cases, the temperature drop between the cooler cold tip and each of the detectors has been evaluated and compared with the required maximum allowable 10mK temperature drop (set as a goal).

The assumptions used for these analyses are presented in section 4.2.2 while the results are summarised in section 4.2.3. Cases for which the 10mK temperature drop isn't met have been highlighted in red in table 4.1.

4.2.2 Assumptions

The following assumptions are applicable and have been used for the sensitivity analyses on the 300-mK system:

- The 5 detectors are connected on the 300-mK system, 3 on the photometer side and 2 on the spectrometer side (see Figure 2 on next page),
- Cooler and BDA interfaces conductance set to 0.1 W/K^{-2} [RD2],
- Clamp interfaces conductance set to 0.05 W/K^{-2} [RD2],
- Both conductance must be multiplied by the interface temperature in K,
- This analysis includes the latest dimensions of the “Busbar” and “straps to cooler”.

The load observed on the different sections of the 300-mK Busbar and straps to cooler varies as described in section 6.3.2 of the SPIRE cryogenic Thermal Requirement Design document [RD3]. Those must be taken into account when assessing the thermal performances of the Busbar. It has been assumed that the parasitic load from each BDA Kevlar support is identical for all BDAs and similarly, the load from a single BDA Kapton harness is similar for all BDAs. A factor has been applied on each the parasitic load from the Kapton Harness to take into account the number of harness per BDA.

Table 4-1 on the following page provides a summary of the results obtained for each sensitivity analysis that has been carried out. A detailed description of each analysis results is given in the appendices (where the load and temperature drop along the Busbar and the strap to cooler is given for both the photometer and the spectrometer mode and for different configurations of the 300-mK system).

4.2.3 Sensitivity Analyses Summary

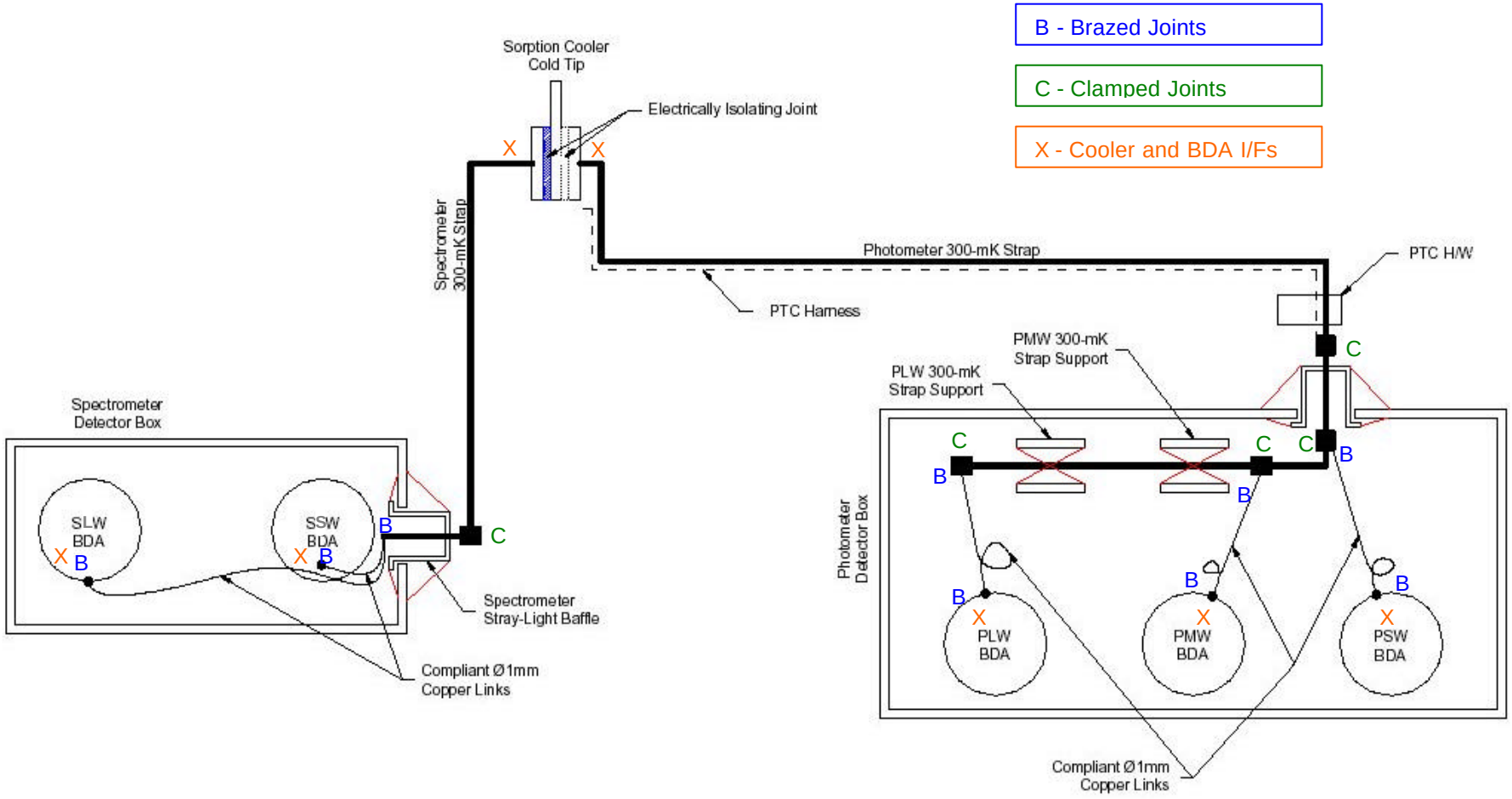


Figure 4-2 - 300mK Busbar Schematic

Description		Units	Cases									
			0	1	2	3	4	5	6	7	8	9
Inputs	Cooler Cold Tip	[mK]	285	285	285	285	285	285	285	285	285	285
	Busbar Copper Thermal Conductivity	[W/mK]	100	100	100	400	30	30	30	613 W/mK on strap to cooler 131 W/mK for 3 mm rod 88 W/mK for 1 mm rod	613 W/mK on strap to cooler 199 W/mK for 3 mm rod 204 W/mK for 1 mm rod	613 W/mK 199 W/mK 204 W/mK
	Brazed Joint Conductance	[W/K]	0.01	0.025	1	0.025	0.025	0.01	0.01	0.0065	0.0065	0.015
	Electrical Isolation Joint at photometer cooler interface	-	No	No	No	No	No	No	Yes	No	No	No
Outputs	Busbar Temperature drop to PSW	[mK]	10.2	9	8.2	4.1	24.1	25.3	-	10.3	7.5	5.7
	PSW BDA IF Temperature	[mK]	295.2	294.0	293.2	289.1	309.1	310.3	-	295.3	292.5	290.7
	Busbar Temperature drop to PMW	[mK]	10.4	8.8	7.9	4.4	22.6	24.1	-	10.2	8.3	6.1
	PMW BDA IF Temperature	[mK]	295.5	293.8	292.9	289.4	307.6	309.1	-	295.2	293.3	291.1
	Busbar Temperature drop to PLW	[mK]	11.9	10.5	9.6	4.3	27.4	28.8	53.1	11.5	9.1	7
	PLW BDA IF Temperature	[mK]	296.9	295.5	294.6	290.1	312.4	313.8	338.1	296.5	294.1	292
	Busbar Temperature drop to SSW	[mK]	7.9	7.3	6.9	4.6	15.5	16.1	-	7.5	6.2	5.3
	SSW BDA IF Temperature	[mK]	292.9	292.3	291.9	289.6	300.5	301.1	-	292.5	291.2	290.3
	Busbar Temperature drop to SLW	[mK]	9.5	9	8.7	5	21.5	22	-	9.4	6.9	6.1
	SLW BDA IF Temperature	[mK]	294.5	294.0	293.7	290	306.5	307.0	-	294.4	291.9	291.1
Appendices	Reference		A10	A11	A12	A13	B11	B12	C11	D10	D11	D12
	Graphical Representation			x		x				x	x	x

Table 4-1 – 300-mK Subsystem Thermal Performances and Sensitivity Analyses Results

4.2.4 Results Discussion

Case 0 represents an arbitrary baseline that can then be used as a reference for the sensitivity cases 1 to 5. Case 6 represents the thermal hardware configuration for the CQM2 model, while case 7 and 8 predict the performances of the flight thermal hardware of two different batches of copper.

- Sensitivity Analysis - Case 0

In this configuration, a copper with a thermal conductivity of 100 W/mK at 0.3K and a brazed interface of 0.01W/K would not allow the temperature drop to the photometer detectors to be within 10mK.

- Sensitivity Analysis - Case 1

In this configuration, a copper with a thermal conductivity of 100 W/mK at 0.3K and a brazed interface of 0.025W/K would allow most of the temperature drops to be within 10mK.

- Sensitivity Analysis - Case 2

This analysis assesses the impact of a perfect brazed interface conductance. The temperature drop is reduced by no more than 1mK, which shows that the brazed interfaces are not the most limiting factor.

- Sensitivity Analysis - Case 3

This analysis assesses what copper thermal conductivity would be required to reduce the temperature drop at each BDA interface to less than 5mK. This case shows that a copper with a thermal conductivity of 400W/mK would be required.

- Sensitivity Analysis - Case 4

This analysis assesses the impact of a 30 W/mK copper thermal conductivity at 0.3K. An important increase in temperature drop to each BDA interface was observed. Note: this 30 W/mK had initially been wrongly estimated from the RRR=300 EPSI measurement.

- Sensitivity Analysis - Case 5

Assess impact of brazed interface conductance.

- Case study for the CQM2 model - Case 6

Case study used for prediction of the temperature drop to the PLW BDA for CQM2. This analysis takes into account an increased 300-mK load to reflect Level-0 enclosures operating at 2K and an additional electrical isolation joint at the cooler photometer interface (which isn't part of the baseline anymore). Note: In the end, the EPSI (annealed after reception) 3mm and 1mm rod has been used for the CQM2.

- Case study for the flight model using EPSI Copper Batch - Case 7

The estimated thermal conductivity of the EPSI copper measured RRR (using the Wiedemann-Franz Law) has been used as an input in the spreadsheet to evaluate the Busbar performances with current in house copper material. Some temperature drops to the BDA interfaces exceed 10mK. The worse case value for the brazed joint conductance has been used for the analysis as advised by Adam Woodcraft [AD6]. Please note that the worse case value should have actually been 0.0056W/K (and not 0.0065 W/K as used in the spreadsheets).

- Case study for the flight model using NOSV Copper Batch - Case 8

The thermal conductivity predicted for a new source of copper for the 3mm and 1mm rod has been used in this case to evaluate the Busbar performances. All temperature drops to the BDA interfaces are now within the 10mK requirement, some close to 5mK. This analysis shows that a good copper has been sourced and that it should therefore be used for the manufacturing of the flight 300-mK strap thermal hardware.

- Case study for the flight model using NOSV Copper Batch - Case 9

Same as for the case 8 with the best brazed joint conductance measured to date.

4.3 300-mK Thermal Straps Performances - Conclusion

The previous analysis shows that if the NOSV copper (see Table 3-1 is used for the 3mm and 1 mm copper rod and that the EPSI 3mm sheet copper is used for the straps to the cooler, the 300-mK strap assembly thermal performance should be within the required (as a goal) 10mK. Further analysis showed that even with the correct worst value of brazed-joint conductance (0.0056 W/K) the strap assembly is still within requirement.

The predicted temperature drop along the 300-mK strap connecting to the photometer detectors is described in figure 4.3 and in figure 4.4 for the spectrometer side.

Explanatory note:

In each diagram, the temperature drop across an interface and/or a strap section is represented by a bar chart. The further from the cooler cold tip interface, the lager the temperature drop becomes as each drop across interface or strap cumulates. For example, in Figure 4.3, one can see that an initial 0.5mK temperature drop is taking place across the cooler interface. By the time it has reached the PSW BDA detector interface, the temperature drop has increased from 0.5mK to 7.5mK because additional interfaces along the thermal path.

Figure 4.2 seen earlier, provides some background as to where those interfaces and straps section are positioned in the strap assemblies.

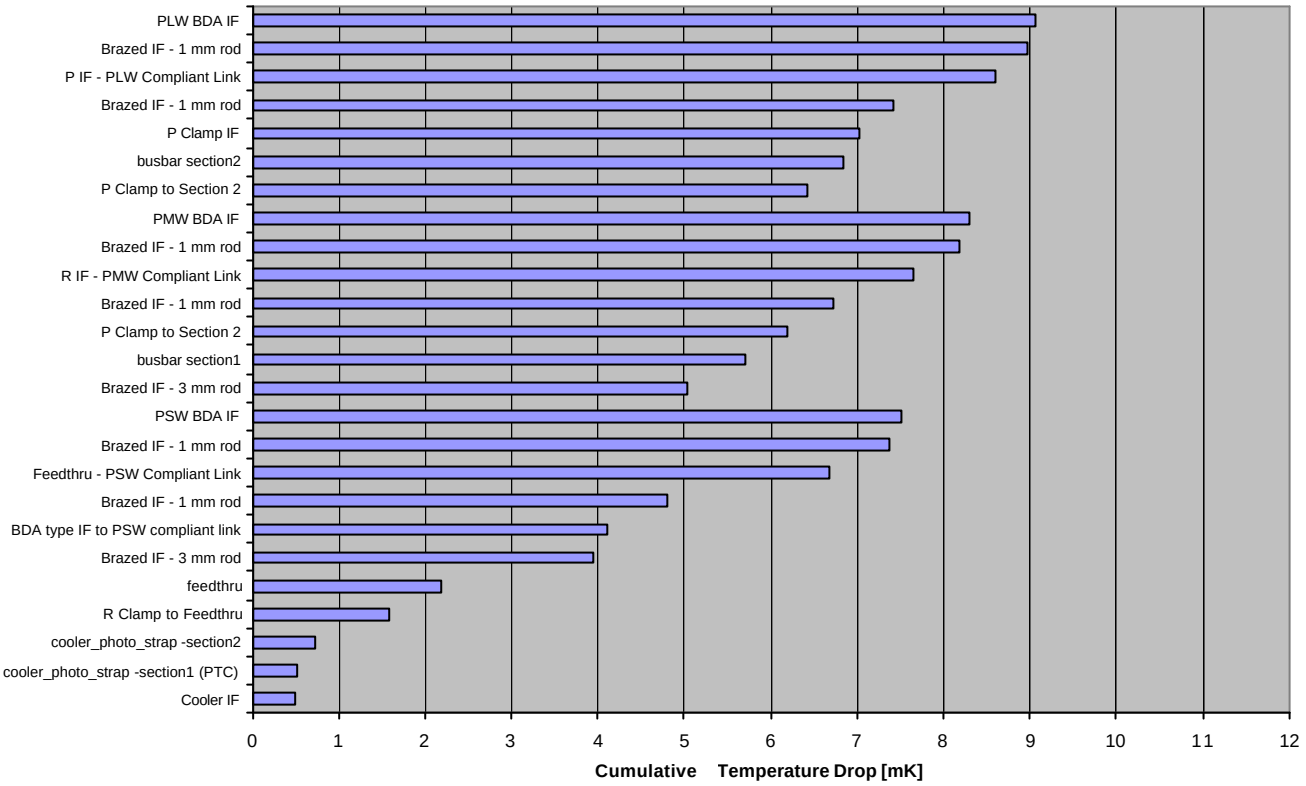


Figure 4-3 - Photometer Busbar Thermal Performance Flight Predictions

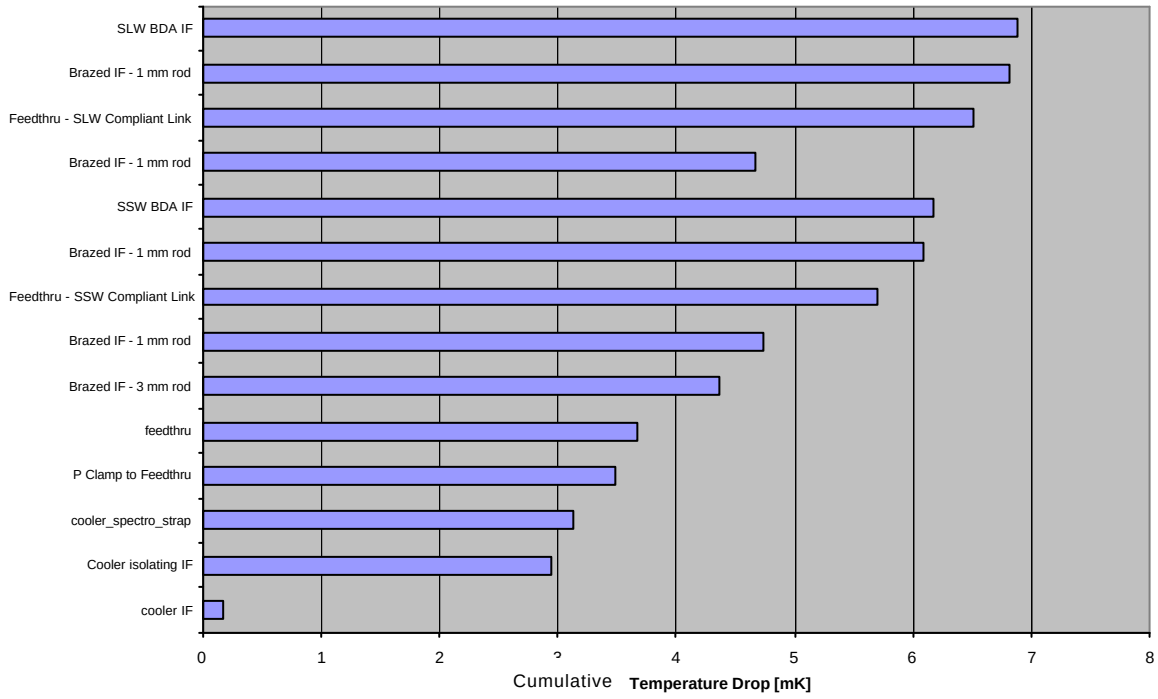


Figure 4-4 - Spectrometer Busbar Thermal Performance Flight Predictions

5. Level-0 Thermal Straps

5.1 Background Information and Thermal Requirements

5.1.1 External L0 Straps

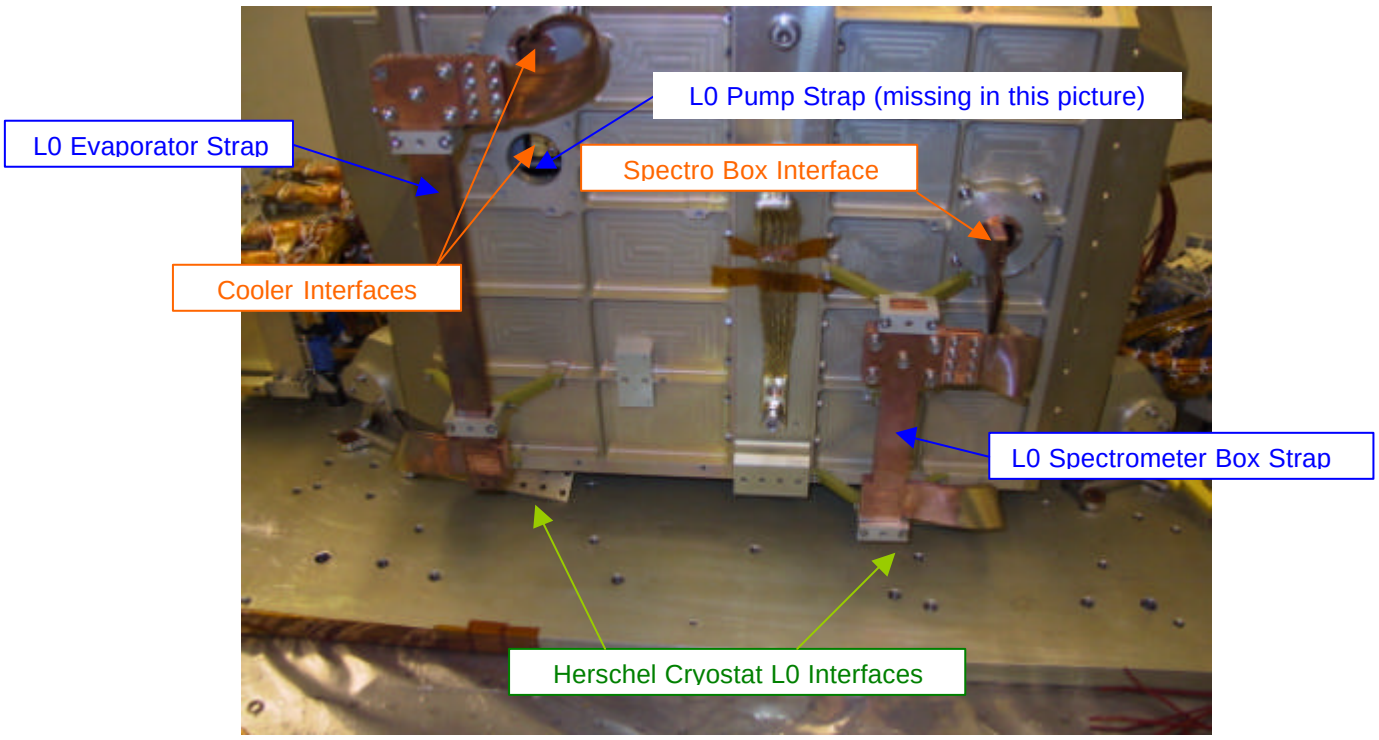


Figure 5-1 - SPIRE L0 External Evaporator (Left) and Detector (right) Straps (pump strap missing)

Three external thermal straps (two described in Figure 5-1) connect the SPIRE cooler heat switches and the spectrometer detector box to the 1.7K or Level-0 (L0) stage of the Herschel cryostat. These straps are critical to the overall thermal performances of the instrument and should have a minimum end-to-end conductance of 0.15 W/K [RD3]. Please note that this conductance should include the bolted interfaces with the cooler heat switches and with the spectrometer box. It should not include however the interfaces with the Herschel cryostat L0 stage.

5.1.2 Internal L0 Interbox Strap

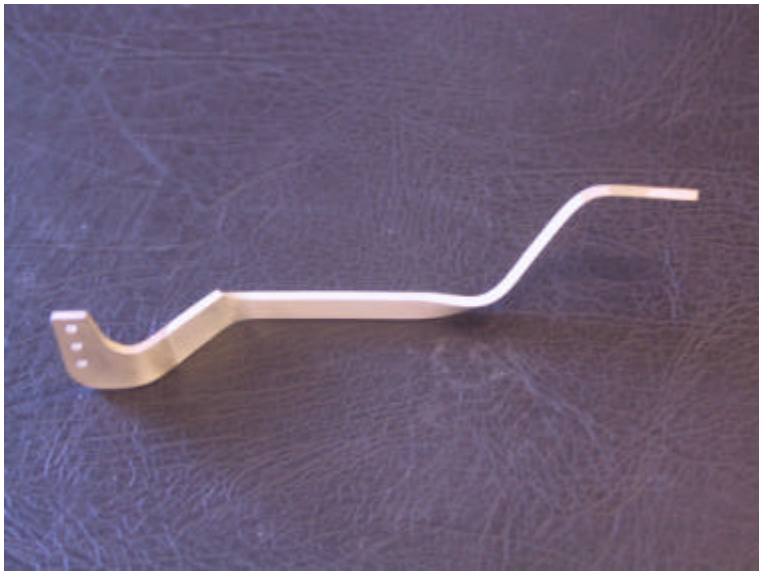


Figure 5-2 - Internal L0 Interbox Strap

The two detector enclosures are thermally coupled through an internal "interbox" strap as described in Figure 5-2. The internal interbox strap must have an overall end-to-end conductance of 0.05 W/K [RD3]. Please note that this conductance should account for the conductance across the bolted and glued interfaces at each end of the strap, on the spectrometer and the photometer boxes.

5.2 L0 Straps Thermal Performance Analysis

5.2.1 Overview

The requirements set on the L0 straps are quite challenging to achieve. In order to get a better understanding of the L0 thermal straps performances limiting factors, the conductance of each strap component has been looked at in details.

The assumptions used for this analysis are described in section 5.2.2 and the results can be found in the following sections for each L0 strap.

5.2.2 Analysis Assumptions

The following material properties have been used to predict the flight performances of the Level-0 straps:

- For each copper/copper (gold plated) bolted interface at 1.7K, a joint conductance of 0.4 W/K has been used (this value has been measured in the past by Lionel Duband at the cooler heat switches interfaces [RD4]).
- A conductance of 0.02 W/cm^{2}K has been used to compute the conductance of glued interface using stycast 1266 at 1.7K. This data has been measured by the University of Cardiff for copper/stycast 1266/copper joints and the test results are presented in AD5. It has been assumed that this data is also applicable for copper/stycast 1266/aluminium joints.
- Based on the test results obtained by Cardiff for the NORV copper 0.1mm shim samples [AD14], a 2200 W/mK thermal conductivity has been assumed for the 0.1 mm copper shim at 1.7K.
- Based on the test results obtained by Cardiff for the 3 mm copper sheet from ESPI [AD14], a 3473 W/mK thermal conductivity has been assumed for the main strap and other bulk material (adaptor and joining plates) at 1.7K.
- A thermal conductivity of 300 W/mK has been assumed for the OFHC copper pads glued on the L0 enclosures.

5.2.3 Level-0 Evaporator Strap

Subsystem/Part Description **L0 Evaporator Strap = 0.15 W/K**

Operating Temperature	1.7	K
5 Ns Copper Thermal Conductivity	3473	W/mK
5Ns shims	2200	W/mK
Copper-Epoxy-Copper Thermal Conductivity	0.02	W/cm2.K

	Type	Material	Heat Treatment	S. Finished	Nbr Off.	W (mm)	t (mm)	L (mm)	G (W/K)
Bottom Flex	bulk	Copper 5 Ns	Annealed	Au Plated	30	26	0.1	235	0.730
Bottom Flex/Main Strap	I/F	eBeam Cu-Cu	n/a	Au Plated	7	20	1	5	79.422
Main strap	bulk	Copper 5 Ns	Annealed	Au Plated	3	20	3.18	275	2.410
Electrical Isolation	I/F	Stycast1266	n/a	n/a	4	35	45	n/a	1.127
Double Plate 1	bulk	Copper 5 Ns	Annealed	Au Plated	2	34	1.3	45.5	6.748
Double Plate 2	bulk	Copper 5 Ns	Annealed	Au Plated	2	34	2	21	22.492
Double Plate / Top Flex	I/F	4-40 Bolted Cu-	n/a	Au Plated	8				1.600
Top Flex	bulk	Copper 5 Ns	Annealed	Au Plated	20	30	0.1	140	0.943
Top Flex / Adaptor IF	I/F	eBeam Cu-Cu	n/a		5	14	1	5	39.711
Adaptor 1	bulk	Copper 5 Ns	Annealed	Au Plated	1	18	6	22	16.896
Adaptor 2	bulk	Copper 5 Ns	Annealed	Au Plated	1	18	10	34	18.386
Cooler Interface	I/F	M4 Bolted Cu-Al	n/a	Au Plated	2				0.400
									0.139

Table 5-1 – Level-0 Evaporator Thermal Strap Performances [AD4]

The current estimation for the L0 Evaporator strap end-to-end conductance is 0.139 W/K. The L0 evaporator strap predicted performance is currently not fully achieving the 0.15W/K requirement. The strap components highlighted in red are currently limiting the overall strap conductance. The resistances of those components are presented in the figure below as a percentage of the overall strap resistance. To increase the overall strap conductance, the most limiting components need to be improved (either by using a better copper, larger area for glued joints and/or bigger bolted interfaces).

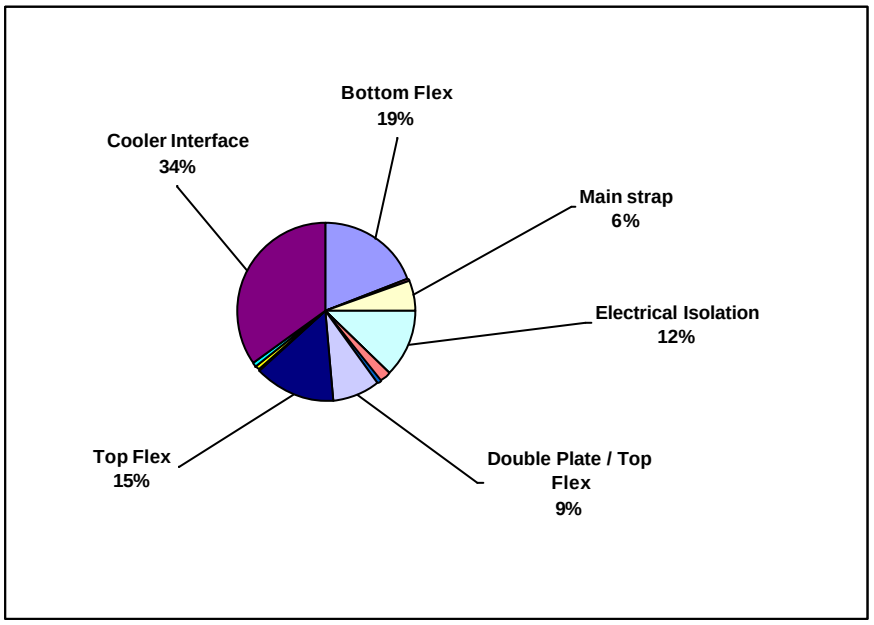


Figure 5-3 – Level-0 Evaporator Strap Components Resistance [% of overall strap conductance]

5.2.4 Level-0 Pump Strap

Subsystem/Part Description	**L0 Pump Strap = 0.15 W/K**	
Operating Temperature	1.7	K
5 Ns Copper Thermal Conductivity	3473	W/mK
5Ns shims	2200	W/mK
Copper-Epoxy-Copper Thermal Conductivity	0.02	W/cm2.K

	Type	Material	Heat Treatment	S. Finished	Nbr Off	W (mm)	t (mm)	L (mm)	G (W/K)
Bottom Flex	bulk	Copper 5 Ns	Annealed	Au Plated	30	26	0.1	200	0.858
Bottom Flex/Main Strap	I/F	eBeam Cu-Cu	n/a	Au Plated	7	20	1	5	97.244
Main strap	bulk	Copper 5 Ns	Annealed	Au Plated	3	20	3.18	185	3.582
Electrical Isolation	I/F	Stycast1266	n/a	n/a	4	35	45	n/a	1.127
Double Plate 1	bulk	Copper 5 Ns	Annealed	Au Plated	2	34	1.3	45.5	6.748
Double Plate 2	bulk	Copper 5 Ns	Annealed	Au Plated	2	34	2	21	22.492
Double Plate / Top Flex	I/F	4-40 Bolted Cu-Au-Cu		Au Plated	8				1.600
Top Flex	bulk	Copper 5 Ns	Annealed	Au Plated	20	30	0.1	150	0.880
Top Flex / Adaptor IF	I/F	eBeam Cu-Cu	n/a	Au Plated	5	14	1	5	48.622
Adaptor 1	bulk	Copper 5 Ns	Annealed	Au Plated	1	18	6	22	16.896
Adaptor 2	bulk	Copper 5 Ns	Annealed	Au Plated	1	18	10	34	18.386
Cooler Interface	I/F	M4 Bolted Cu-Au-Cu	n/a	Au Plated	2				0.400
									0.144

Table 5-2 – Level-0 Pump Thermal Strap Performances [AD4]

The current estimation for the L0 Pump strap end-to-end conductance is 0.144 W/K. Although very close, the L0 pump strap predicted performance is currently not fully achieving the 0.15W/K requirement. The strap components highlighted in red are currently limiting the overall strap conductance. The resistances of those components are presented in the figure below as a percentage of the overall strap resistance. To increase the overall strap conductance, the most limiting components need to be improved (either by using a better copper, larger area for glued joints and/or bigger bolted interfaces).

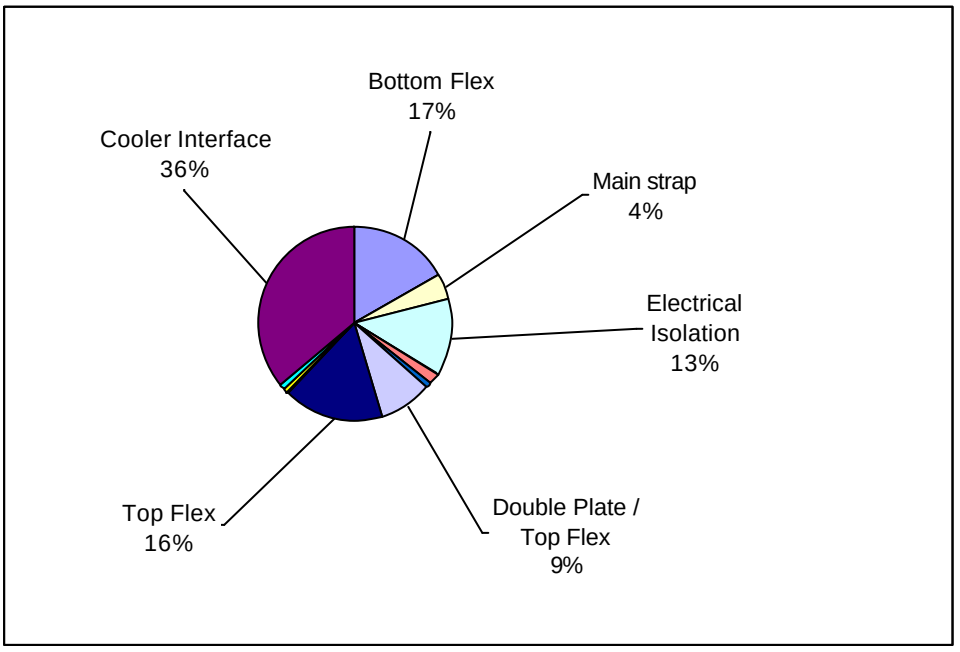


Figure 5-4 – Level-0 Pump Strap Components Resistance [% of overall strap conductance]

5.2.5 Level-0 Enclosure Strap

Subsystem/Part Description L0 Enclosure Strap = 0.15 W/K

Operating Temperature	1.7	K
5 Ns Copper Thermal Conductivity	3473	W/mK
5Ns Shims Coppper Thermal Conductivity	2200	W/mK
Copper-Epoxy-Copper Thermal Conductivity	0.02	W/cm2.K

	Type	Material	Heat Treatment	S. Finished	Nbr Off	W (mm)	t (mm)	L (mm)	G (W/K)
Bottom Flex	bulk	Copper 5 Ns	Annealed	Au Plated	30	26	0.1	205	0.837
Bottom Flex/Main Strap	I/F	eBeam Cu-Cu	n/a	Au Plated	7	20	1	5	97.244
Main strap	bulk	Copper 5 Ns	Annealed	Au Plated	3	20	3.18	151	4.388
Electrical Isolation	I/F	Stycast1266	n/a	Au Plated	4	35	45	n/a	1.127
Double Plate 1	bulk	Copper 5 Ns	Annealed	Au Plated	2	34	1.3	45.5	6.748
Double Plate 2	bulk	Copper 5 Ns	Annealed	Au Plated	2	34	2	21	22.492
Double Plate / Top Flex	I/F	4-40 Bolted Cu-Au-Cu	n/a	Au Plated	8				1.600
Top Flex	bulk	Copper 5 Ns	Annealed	Au Plated	20	30	0.1	160	0.825
Top Flex / Adaptor IF	I/F	eBeam Cu-Cu	n/a	Au Plated	5	14	1	5	48.622
Adaptor 1	bulk	Copper 5 Ns	Annealed	Au Plated	1	18	6	22	16.896
Adaptor 2	bulk	Copper 5 Ns	Annealed	Au Plated	1	18	10	31.5	19.846
Box Interface	I/F	M4 Bolted Cu-Au-Cu	n/a	Au Plated	2				0.400
									0.143

Table 5-3 – Level-0 Enclosure Thermal Strap Performances [AD4]

The current estimation for the L0 Enclosure strap end-to-end conductance is 0.143 W/K. Although very close, the L0 enclosure strap predicted performance is currently not fully achieving the 0.15W/K requirement. The strap components highlighted in red are currently limiting the overall strap conductance. The resistances of those components are presented in the figure below as a percentage of the overall strap resistance. To increase the overall strap conductance, the most limiting components need to be improved (either by using a better copper, larger area for glued joints and/or bigger bolted interfaces).

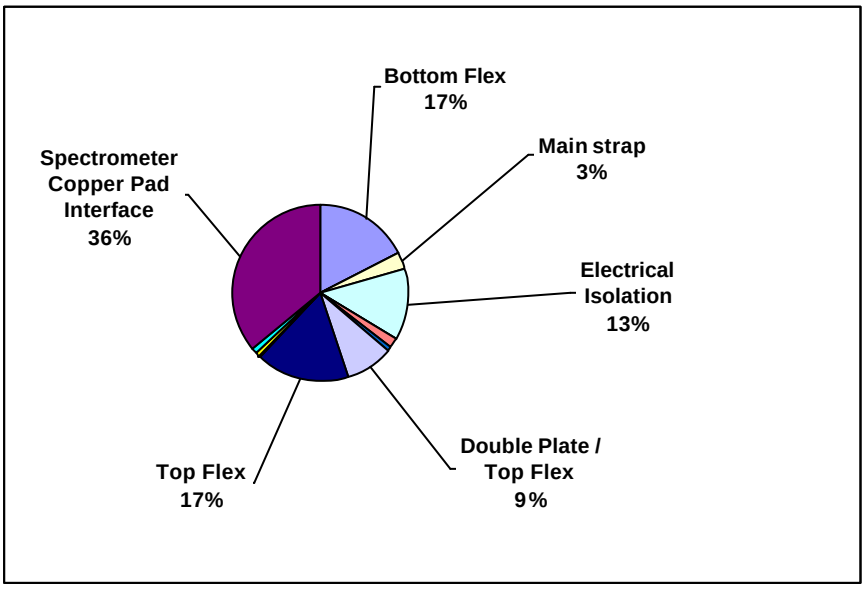


Figure 5-5 – Level-0 Enclosure Strap Components Resistance [% of overall strap conductance]

5.2.6 Level-0 Interbox Strap

	Type	Material	Heat Treatment	S. Finished	mm W (mm)	mm t (mm)	mm L (mm)	W/mK k (W/mK)	W/K G (W/K)
Spectro Copper Pad Section 1	bulk	Copper OFHC	Annealed	Au Plated	16	3	45	300	0.32
Spectro Copper Pad Section 2	bulk	Copper OFHC	Annealed	Au Plated	40	3	20	300	1.8
Spectro Copper Pad Section 3	bulk	Copper OFHC	Annealed	Au Plated	40	3	20	300	1.8
Spectro Copper Pad IF	I/F	M4 Cu-Au-Cu	n/a	Au Plated					0.4
2K strap	bulk	Copper 5 Ns	Annealed	Au Plated	3	9	200	3473	0.47
Photo Copper Pad IF	I/F	M4 Bolted Cu-Au-Cu	n/a	Au Plated					0.4
Photo Copper Pad Section	bulk	Copper OFHC	Annealed	Au Plated	40	3	20	300	1.8
Photo Copper Pad Glued Joint	I/F	Stycast1266	n/a	n/a	27.9	100		0.02	0.56
									0.0729

Table 5-4 – Level-0 Enclosure Thermal Strap Performances [AD4]

The current estimation for the L0 interbox strap end-to-end conductance is 0.073 W/K, in excess of the required 0.05 W/K conductance. The resistances of the various strap components are presented in the figure below as a percentage of the overall strap resistance.

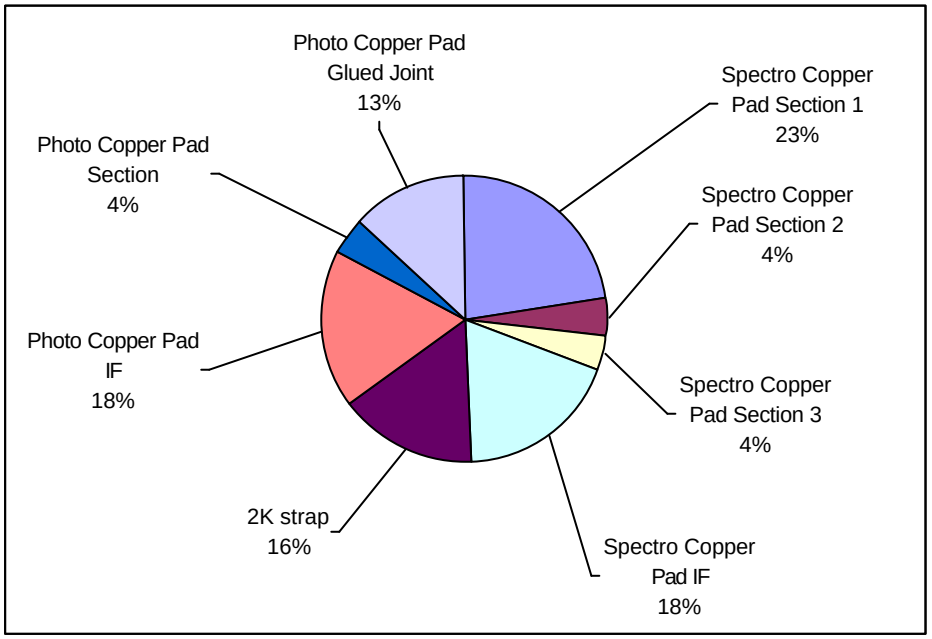


Figure 5-6 – Level-0 Enclosure Strap Components Resistance [% of overall strap conductance]

5.3 Level-0 Thermal Straps Performances – Conclusion

A summary of the predicted thermal performances of the SPIRE L0 strap is given in Table 5-5.

Components	*Requirement [W/K]*	*Prediction [W/K]*	*%*
L0 Evaporator Strap	0.15	0.139	- 8%
L0 Pump Strap	0.15	0.144	- 4%
L0 Enclosure Strap	0.15	0.143	- 5%
L0 2K Interbox Strap	0.05	0.0729	+ 46%

Table 5-5 – Summary of the predicted flight performances for the Level-0 System

- The L0 evaporator strap

It is important in order to achieve the required instrument performance (i.e. cooler hold time) that the L0 Evaporator strap meets the 0.15 W/K requirement. The design of this strap is really challenging, as it is also the longest strap to the Herschel cryostat. It isn't clear whether a further improvement of the strap conductance is possible without important changes to either its design or the instrument one. It is predicted that in order to achieve the 0.15 W/K required conductance, a thermal conductivity of 2800 W/mK is required for the 0.1 mm shim copper. Although it might be possible to find such copper, the time available to source the copper and manufacture the strap is limited. As a way forward, it had been agreed that the strap end-to-end conductance should be measured by the University of Cardiff [AD15]. Decision regarding this strap will then have to be made depending on the obtained test results.

- The L0 pump strap

The current prediction shows that the strap doesn't fully meet the required conductance although very close. This currently isn't expected to be an issue because the performance of this strap has a limited impact on the cooler performance. The University of Cardiff will carry out measurements of the overall strap conductance. Any further decision regarding this strap should be made following the test results.

- The L0 enclosure and L0 Interbox Straps

The current prediction shows that the L0 enclosure strap doesn't fully meet the required conductance although very close. The interbox strap however currently exceeds the required 0.05 W/K.

When designing the L0 enclosure straps (external and interbox straps), it is important to remember that the temperature drop from the Herschel Interface to each of the L0 enclosures is really the driving requirement, i.e. it should never exceed 0.03K for a maximum load of 1 mW [RD3]. The photometer enclosure is located at the end of the thermal path and is therefore the worst case scenario for which the L0 straps have been designed. Therefore: the 0.15 W/K of the L0 enclosure strap in series with the 0.05 W/K of the interbox strap gives an overall conductance to the L0 photometer enclosure of 0.0375 W/K, which in turn, will give a maximum temperature drop of 0.027 K for the maximum 1mW load allowed. Therefore, the interbox strap which currently exceeds the 0.05 W/K required compensates for the fact that the L0 enclosure strap conductance is slightly less than the required 0.15 W/K. The predicted overall temperature drop to each of the L0 enclosures is presented in Table 5-5 and Table 5-6. The University of Cardiff will carry out measurements of the overall strap conductance.

	Type	Material	Heat Treatment	S. Finished	W (mm)	t (mm)	L (mm)	k (W/mK)	G (W/K)	Temp Drop (mK)
L0 Enclosure Strap	n/a	n/a	n/a	Au					0.143	9
Spectro Copper Pad Section 1	bulk	OFHC Copper	annealed	Au	16	3	45	300	0.32	4
Spectro Copper Pad Section 2	bulk	OFHC Copper	annealed	Au	40	3	20	300	1.80	1
Spectro Copper Pad Glued Joint	I/F	Stycast1266	n/a	n/a	16	100		0.02	0.32	4
									0.073	18

Table 5-6 – Predicted flight temperature drop to the Spectrometer L0 Enclosure for a 1 mW load [AD4]

	Type	Material	Heat Treatment	S. Finished	W (mm)	t (mm)	L (mm)	k (W/mK)	G (W/K)	Temp Drop (mK)
L0 Enclosure Strap	n/a	n/a	n/a	Au					0.143	7
Spectro Copper Pad Section 1	bulk	OFHC Copper	annealed	Au	16	3	45	300	0.320	3
Spectro Copper Pad Section 2	bulk	OFHC Copper	annealed	Au	40	3	20	300	1.800	1
Spectro Copper Pad Section 3	bulk	OFHC Copper	annealed	Au	40	3	20	300	1.800	1
Spectro Copper Pad IF	I/F	M4 Cu-Au-Cu	n/a	Au Plated					0.400	3
2K strap	bulk	Copper 5 Ns	Annealed	Au Plated	3	9	200	3473	0.469	2
Photo Copper Pad IF	I/F	M4 Bolted Cu-Au-	n/a	Au Plated					0.400	3
Photo Copper Pad Section	bulk	Copper OFHC	Annealed	Au Plated	40	3	20	300	1.800	1
Photo Copper Pad Glued Joint	I/F	Stycast1266	n/a	n/a	27.9	100		0.02	0.558	2
									0.048	21

Table 5-7 – Predicted flight temperature drop to the Photometer L0 Enclosure for a 1 mW load [AD4]

APPENDICES

A10 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.01	*From analysis*
Copper Conductivity at 300mK	[W/mK]	100	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	100	0.1015	14.2	0.6
cooler_photo_strap -section2		9.00	100	0.090	100	0.0090	12	2.0
R Clamp to Feedthru						0.0143	12	2.8
feedthru	3	7.07	71.3	0.099	100	0.0099	12	4.0
Brazed IF - 3 mm rod						0.0100	11.5	5.2
BDA type IF to PSW compliant link						*0.0285*	4.5	5.3
Brazed IF - 1 mm rod						*0.0100*	4.5	5.8
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*100*	*0.0012*	4.5	9.6
Brazed IF - 1 mm rod						*0.0100*	4.5	10.0
PSW BDA IF						***0.0285***	4.5	**10.2**
Brazed IF - 3 mm rod						0.0100	7	5.9
busbar section1	3	7.07	133.1	0.053	100	0.0053	7	7.2
P Clamp to Section 2						0.0143	7	7.7
Brazed IF - 1 mm rod						*0.0100*	3.5	8.0
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*100*	*0.0019*	3.5	9.9
Brazed IF - 1 mm rod						*0.0100*	3.5	10.3
PMW BDA IF						***0.0285***	3.5	**10.4**
P Clamp to Section 2						0.0143	3.5	7.9
busbar section2	3	7.07	167	0.042	100	0.0042	3.5	8.8
P Clamp IF						0.0143	2.5	8.9
Brazed IF - 1 mm rod						*0.0100*	2.5	9.2
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*100*	*0.0010*	2.5	11.6
Brazed IF - 1 mm rod						*0.0100*	2.5	11.9
PLW BDA IF						***0.0285***	2.5	**11.9**

A10 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.01	*From analysis*
Copper Conductivity at 300mK	[W/mK]	100	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler spectro strap		9.00	217.6	0.041	100	0.0041	5	4.1
P Clamp to Feedthru						0.0143	5	4.5
feedthru	3	7.07	50.6	0.140	100	0.0140	5	4.9
Brazed IF - 3 mm rod						0.0100	4.5	5.3
Brazed IF - 1 mm rod						*0.0100*	2.5	5.6
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*100*	*0.0013*	2.5	7.5
Brazed IF - 1 mm rod						*0.0100*	2.5	7.8
SSW BDA IF						***0.0285***	2.5	**7.9**
Brazed IF - 1 mm rod						*0.0100*	2	5.5
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*100*	*0.0005*	2	9.3
Brazed IF - 1 mm rod						*0.0100*	2	9.5
SLW BDA IF						***0.0285***	2	**9.5**

A11 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

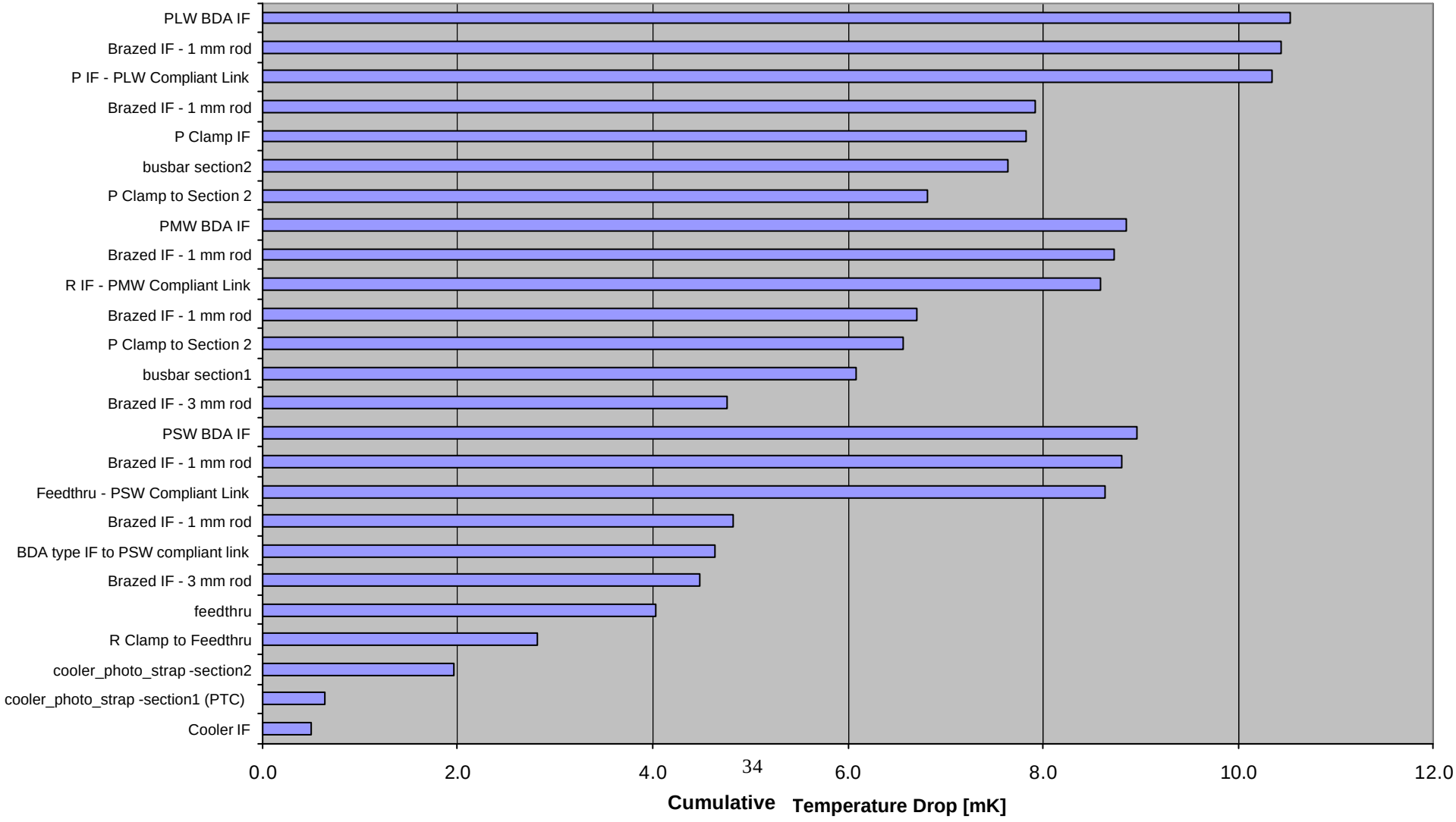
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.025	*From analysis*
Copper Conductivity at 300mK	[W/mK]	100	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	100	0.1015	14.2	0.6
cooler_photo_strap -section2		9.00	100	0.090	100	0.0090	12	2.0
R Clamp to Feedthru						0.0143	12	2.8
feedthru	3	7.07	71.3	0.099	100	0.0099	12	4.0
Brazed IF - 3 mm rod						0.0250	11.5	4.5
BDA type IF to PSW compliant link						*0.0285*	4.5	4.6
Brazed IF - 1 mm rod						*0.0250*	4.5	4.8
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*100*	*0.0012*	4.5	8.6
Brazed IF - 1 mm rod						*0.0250*	4.5	8.8
PSW BDA IF						***0.0285***	4.5	**9.0**
Brazed IF - 3 mm rod						0.0250	7	4.8
busbar section1	3	7.07	133.1	0.053	100	0.0053	7	6.1
P Clamp to Section 2						0.0143	7	6.6
Brazed IF - 1 mm rod						*0.0250*	3.5	6.7
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*100*	*0.0019*	3.5	8.6
Brazed IF - 1 mm rod						*0.0250*	3.5	8.7
PMW BDA IF						***0.0285***	3.5	**8.8**
P Clamp to Section 2						0.0143	3.5	6.8
busbar section2	3	7.07	167	0.042	100	0.0042	3.5	7.6
P Clamp IF						0.0143	2.5	7.8
Brazed IF - 1 mm rod						*0.0250*	2.5	7.9
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*100*	*0.0010*	2.5	10.3
Brazed IF - 1 mm rod						*0.0250*	2.5	10.4
PLW BDA IF						***0.0285***	2.5	**10.5**

A11 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]



A11 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

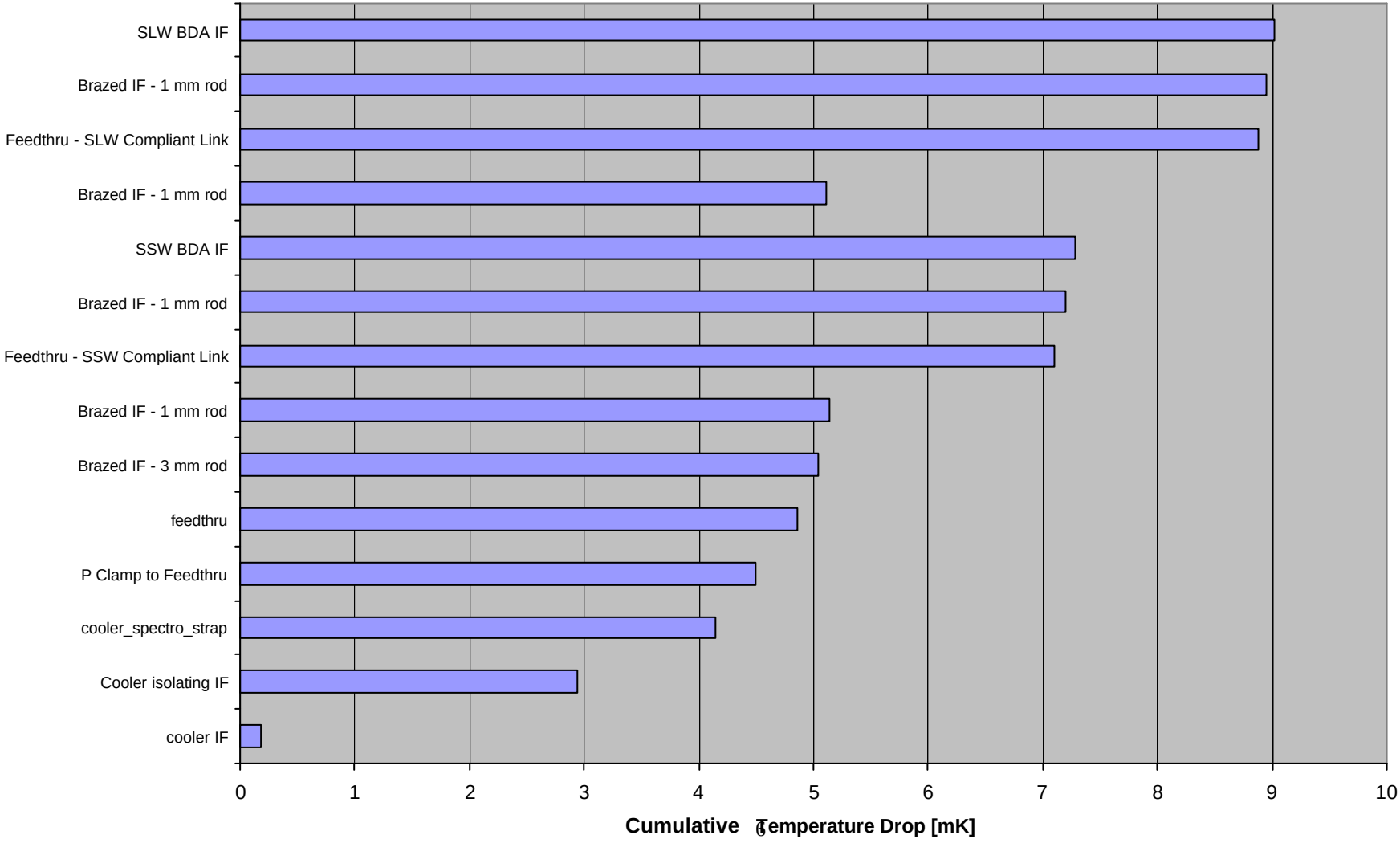
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.025	*From analysis*
Copper Conductivity at 300mK	[W/mK]	100	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	100	0.0041	5	4.1
P Clamp to Feedthru						0.0143	5	4.5
feedthru	3	7.07	50.6	0.140	100	0.0140	5	4.9
Brazed IF - 3 mm rod						0.0250	4.5	5.0
Brazed IF - 1 mm rod						*0.0250*	2.5	5.1
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*100*	*0.0013*	2.5	7.1
Brazed IF - 1 mm rod						*0.0250*	2.5	7.2
SSW BDA IF						***0.0285***	2.5	**7.3**
Brazed IF - 1 mm rod						*0.0250*	2	5.1
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*100*	*0.0005*	2	8.9
Brazed IF - 1 mm rod						*0.0250*	2	9.0
SLW BDA IF						***0.0285***	2	**9.0**

A11 – Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]



A12 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	1	*From analysis*
Copper Conductivity at 300mK	[W/mK]	100	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	100	0.1015	14.2	0.6
cooler_photo_strap -section2		9.00	100	0.090	100	0.0090	12	2.0
R Clamp to Feedthru						0.0143	12	2.8
feedthru	3	7.07	71.3	0.099	100	0.0099	12	4.0
Brazed IF - 3 mm rod						1.0000	11.5	4.0
BDA type IF to PSW compliant link						*0.0285*	4.5	4.2
Brazed IF - 1 mm rod						*1.0000*	4.5	4.2
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*100*	*0.0012*	4.5	8.0
Brazed IF - 1 mm rod						*1.0000*	4.5	8.0
PSW BDA IF						***0.0285***	4.5	**8.2**
Brazed IF - 3 mm rod						1.0000	7	4.0
busbar section1	3	7.07	133.1	0.053	100	0.0053	7	5.4
P Clamp to Section 2						0.0143	7	5.9
Brazed IF - 1 mm rod						*1.0000*	3.5	5.9
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*100*	*0.0019*	3.5	7.7
Brazed IF - 1 mm rod						*1.0000*	3.5	7.7
PMW BDA IF						***0.0285***	3.5	**7.9**
P Clamp to Section 2						0.0143	3.5	6.1
busbar section2	3	7.07	167	0.042	100	0.0042	3.5	6.9
P Clamp IF						0.0143	2.5	7.1
Brazed IF - 1 mm rod						*1.0000*	2.5	7.1
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*100*	*0.0010*	2.5	9.5
Brazed IF - 1 mm rod						*1.0000*	2.5	9.5
PLW BDA IF						***0.0285***	2.5	**9.6**

A12 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	1	*From analysis*
Copper Conductivity at 300mK	[W/mK]	100	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	100	0.0041	5	4.1
P Clamp to Feedthru						0.0143	5	4.5
feedthru	3	7.07	50.6	0.140	100	0.0140	5	4.9
Brazed IF - 3 mm rod						1.0000	4.5	4.9
Brazed IF - 1 mm rod						*1.0000*	2.5	4.9
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*100*	*0.0013*	2.5	6.8
Brazed IF - 1 mm rod						*1.0000*	2.5	6.8
SSW BDA IF						***0.0285***	2.5	**6.9**
Brazed IF - 1 mm rod						*1.0000*	2	4.9
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*100*	*0.0005*	2	8.6
Brazed IF - 1 mm rod						*1.0000*	2	8.6
SLW BDA IF						***0.0285***	2	**8.7**

A13 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

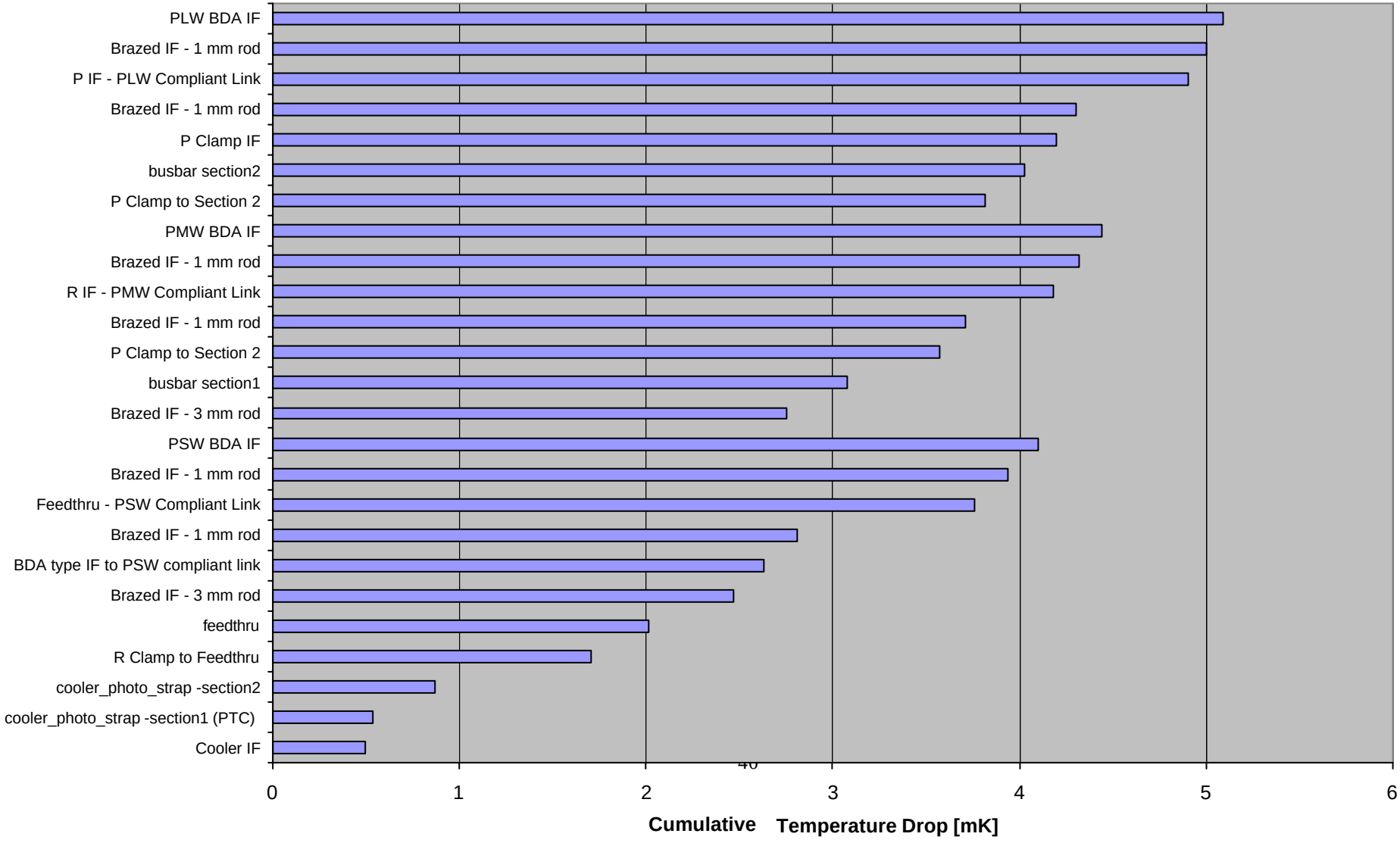
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.025	*From analysis*
Copper Conductivity at 300mK	[W/mK]	400	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	400	0.4062	14.2	0.5
cooler_photo_strap -section2		9.00	100	0.090	400	0.0360	12	0.9
R Clamp to Feedthru						0.0143	12	1.7
feedthru	3	7.07	71.3	0.099	400	0.0397	12	2.0
Brazed IF - 3 mm rod						0.0250	11.5	2.5
BDA type IF to PSW compliant link						*0.0285*	4.5	2.6
Brazed IF - 1 mm rod						*0.0250*	4.5	2.8
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*400*	*0.0047*	4.5	3.8
Brazed IF - 1 mm rod						*0.0250*	4.5	3.9
PSW BDA IF						***0.0285***	4.5	**4.1**
Brazed IF - 3 mm rod						0.0250	7	2.8
busbar section1	3	7.07	133.1	0.053	400	0.0212	7	3.1
P Clamp to Section 2						0.0143	7	3.6
Brazed IF - 1 mm rod						*0.0250*	3.5	3.7
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*400*	*0.0075*	3.5	4.2
Brazed IF - 1 mm rod						*0.0250*	3.5	4.3
PMW BDA IF						***0.0285***	3.5	**4.4**
P Clamp to Section 2						0.0143	3.5	3.8
busbar section2	3	7.07	167	0.042	400	0.0169	3.5	4.0
P Clamp IF						0.0143	2.5	4.2
Brazed IF - 1 mm rod						*0.0250*	2.5	4.3
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*400*	*0.0041*	2.5	4.9
Brazed IF - 1 mm rod						*0.0250*	2.5	5.0
PLW BDA IF						***0.0285***	2.5	**5.1**

A13 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]



A13 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

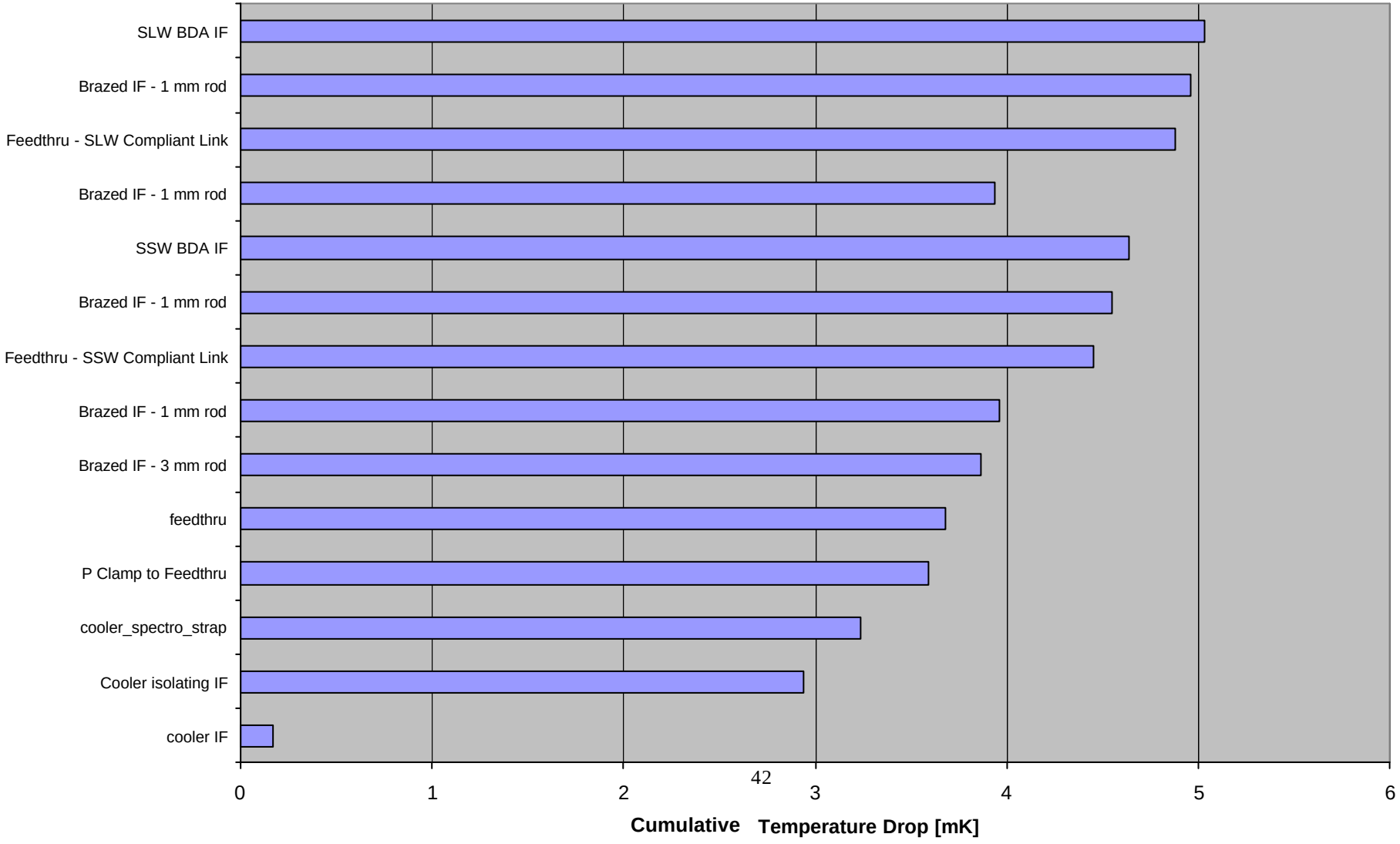
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.25	*From analysis*
Copper Conductivity at 300mK	[W/mK]	400	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	400	0.0165	5	3.2
P Clamp to Feedthru						0.0143	5	3.6
feedthru	3	7.07	50.6	0.140	400	0.0559	5	3.7
Brazed IF - 3 mm rod						0.2500	4.5	3.7
Brazed IF - 1 mm rod						*0.2500*	2.5	3.7
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*400*	*0.0051*	2.5	4.2
Brazed IF - 1 mm rod						*0.2500*	2.5	4.2
SSW BDA IF						***0.0285***	2.5	**4.3**
Brazed IF - 1 mm rod						*0.2500*	2	3.7
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*400*	*0.0021*	2	4.6
Brazed IF - 1 mm rod						*0.2500*	2	4.7
SLW BDA IF						***0.0285***	2	**4.7**

A13 – Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]



B11 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.025	*From analysis*
Copper Conductivity at 300mK	[W/mK]	30	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	30	0.0305	14.2	1.0
cooler_photo_strap -section2		9.00	100	0.090	30	0.0027	12	5.4
R Clamp to Feedthru						0.0143	12	6.3
feedthru	3	7.07	71.3	0.099	30	0.0030	12	10.3
Brazed IF - 3 mm rod						0.0250	11.5	10.7
BDA type IF to PSW compliant link						*0.0285*	4.5	10.9
Brazed IF - 1 mm rod						*0.0250*	4.5	11.1
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*30*	*0.0004*	4.5	23.8
Brazed IF - 1 mm rod						*0.0250*	4.5	23.9
PSW BDA IF						***0.0285***	4.5	**24.1**
Brazed IF - 3 mm rod						0.0250	7	11.0
busbar section1	3	7.07	133.1	0.053	30	0.0016	7	15.4
P Clamp to Section 2						0.0143	7	15.9
Brazed IF - 1 mm rod						*0.0250*	3.5	16.1
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*30*	*0.0006*	3.5	22.3
Brazed IF - 1 mm rod						*0.0250*	3.5	22.4
PMW BDA IF						***0.0285***	3.5	**22.6**
P Clamp to Section 2						0.0143	3.5	16.2
busbar section2	3	7.07	167	0.042	30	0.0013	3.5	18.9
P Clamp IF						0.0143	2.5	19.1
Brazed IF - 1 mm rod						*0.0250*	2.5	19.2
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*30*	*0.0003*	2.5	27.3
Brazed IF - 1 mm rod						*0.0250*	2.5	27.4
PLW BDA IF						***0.0285***	2.5	**27.4**

B11 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.025	*From analysis*
Copper Conductivity at 300mK	[W/mK]	30	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	30	0.0012	5	7.0
P Clamp to Feedthru						0.0143	5	7.3
feedthru	3	7.07	50.6	0.140	30	0.0042	5	8.5
Brazed IF - 3 mm rod						0.0250	4.5	8.7
Brazed IF - 1 mm rod						*0.0250*	2.5	8.8
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*30*	*0.0004*	2.5	15.3
Brazed IF - 1 mm rod						*0.0250*	2.5	15.4
SSW BDA IF						***0.0285***	2.5	**15.5**
Brazed IF - 1 mm rod						*0.0250*	2	8.8
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*30*	*0.0002*	2	21.3
Brazed IF - 1 mm rod						*0.0250*	2	21.4
SLW BDA IF						***0.0285***	2	**21.5**

B12 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.01	*From analysis*
Copper Conductivity at 300mK	[W/mK]	30	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	**Dia**	**A**	**L**	**A/L**	**K**	**G**	**Load**	**Total Drop**
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	30	0.0305	14.2	1.0
cooler_photo_strap -section2		9.00	100	0.090	30	0.0027	12	5.4
R Clamp to Feedthru						0.0143	12	6.3
feedthru	3	7.07	71.3	0.099	30	0.0030	12	10.3
Brazed IF - 3 mm rod						0.0100	11.5	11.4
BDA type IF to PSW compliant link						*0.0285*	4.5	11.6
Brazed IF - 1 mm rod						*0.0100*	4.5	12.0
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*30*	*0.0004*	4.5	24.7
Brazed IF - 1 mm rod						*0.0100*	4.5	25.2
PSW BDA IF						***0.0285***	4.5	**25.3**
Brazed IF - 3 mm rod						0.0100	7	12.1
busbar section1	3	7.07	133.1	0.053	30	0.0016	7	16.5
P Clamp to Section 2						0.0143	7	17.0
Brazed IF - 1 mm rod						*0.0100*	3.5	17.4
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*30*	*0.0006*	3.5	23.6
Brazed IF - 1 mm rod						*0.0100*	3.5	24.0
PMW BDA IF						***0.0285***	3.5	**24.1**
P Clamp to Section 2						0.0143	3.5	17.3
busbar section2	3	7.07	167	0.042	30	0.0013	3.5	20.0
P Clamp IF						0.0143	2.5	20.2
Brazed IF - 1 mm rod						*0.0100*	2.5	20.4
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*30*	*0.0003*	2.5	28.5
Brazed IF - 1 mm rod						*0.0100*	2.5	28.8
PLW BDA IF						***0.0285***	2.5	**28.8**

B12 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.01	*From analysis*
Copper Conductivity at 300mK	[W/mK]	30	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	30	0.0012	5	7.0
P Clamp to Feedthru						0.0143	5	7.3
feedthru	3	7.07	50.6	0.140	30	0.0042	5	8.5
Brazed IF - 3 mm rod						0.0100	4.5	9.0
Brazed IF - 1 mm rod						*0.0100*	2.5	9.2
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*30*	*0.0004*	2.5	15.8
Brazed IF - 1 mm rod						*0.0100*	2.5	16.0
SSW BDA IF						***0.0285***	2.5	**16.1**
Brazed IF - 1 mm rod						*0.0100*	2	9.2
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*30*	*0.0002*	2	21.7
Brazed IF - 1 mm rod						*0.0100*	2	21.9
SLW BDA IF						***0.0285***	2	**22.0**

C11 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]		*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	*0.3*	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	*2.25*	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	*1.5*	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	*2.25*	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	*3*	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	*2.25*	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	*4.5*	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	*0.75*	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.01	*From analysis*
Copper Conductivity at 300mK	[W/mK]	30	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Electrical isolation						*0.0018*	*18.3*	*10.2*
Cooler IF						0.0285	18.3	*10.8*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	30	0.0305	18.3	11.4
cooler_photo_strap -section2		9.00	100	0.090	30	0.0027	18	18.1
R Clamp to Feedthru						0.0143	18	19.3
feedthru	3	7.07	71.3	0.099	30	0.0030	18	25.4
Brazed IF - 3 mm rod						0.0100	17.25	27.1
BDA type IF to PSW compliant link						*0.0285*	6.75	27.4
Brazed IF - 1 mm rod						*0.0100*	6.75	28.0
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*30*	*0.0004*	6.75	47.1
Brazed IF - 1 mm rod						*0.0100*	6.75	47.7
PSW BDA IF						***0.0285***	6.75	**48.0**
Brazed IF - 3 mm rod						0.0100	10.5	28.2
busbar section1	3	7.07	133.1	0.053	30	0.0016	10.5	34.8
P Clamp to Section 2						0.0143	10.5	35.5
Brazed IF - 1 mm rod						*0.0100*	5.25	36.0
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*30*	*0.0006*	5.25	45.4
Brazed IF - 1 mm rod						*0.0100*	5.25	45.9
PMW BDA IF						***0.0285***	5.25	**46.1**
P Clamp to Section 2						0.0143	3.5	35.7
busbar section2	3	7.07	167	0.042	30	0.0013	5.25	39.9
P Clamp IF						0.0143	3.75	40.1
Brazed IF - 1 mm rod						*0.0100*	3.75	40.5
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*30*	*0.0003*	3.75	52.6
Brazed IF - 1 mm rod						*0.0100*	3.75	53.0
PLW BDA IF						***0.0285***	3.75	**53.1**

D10 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

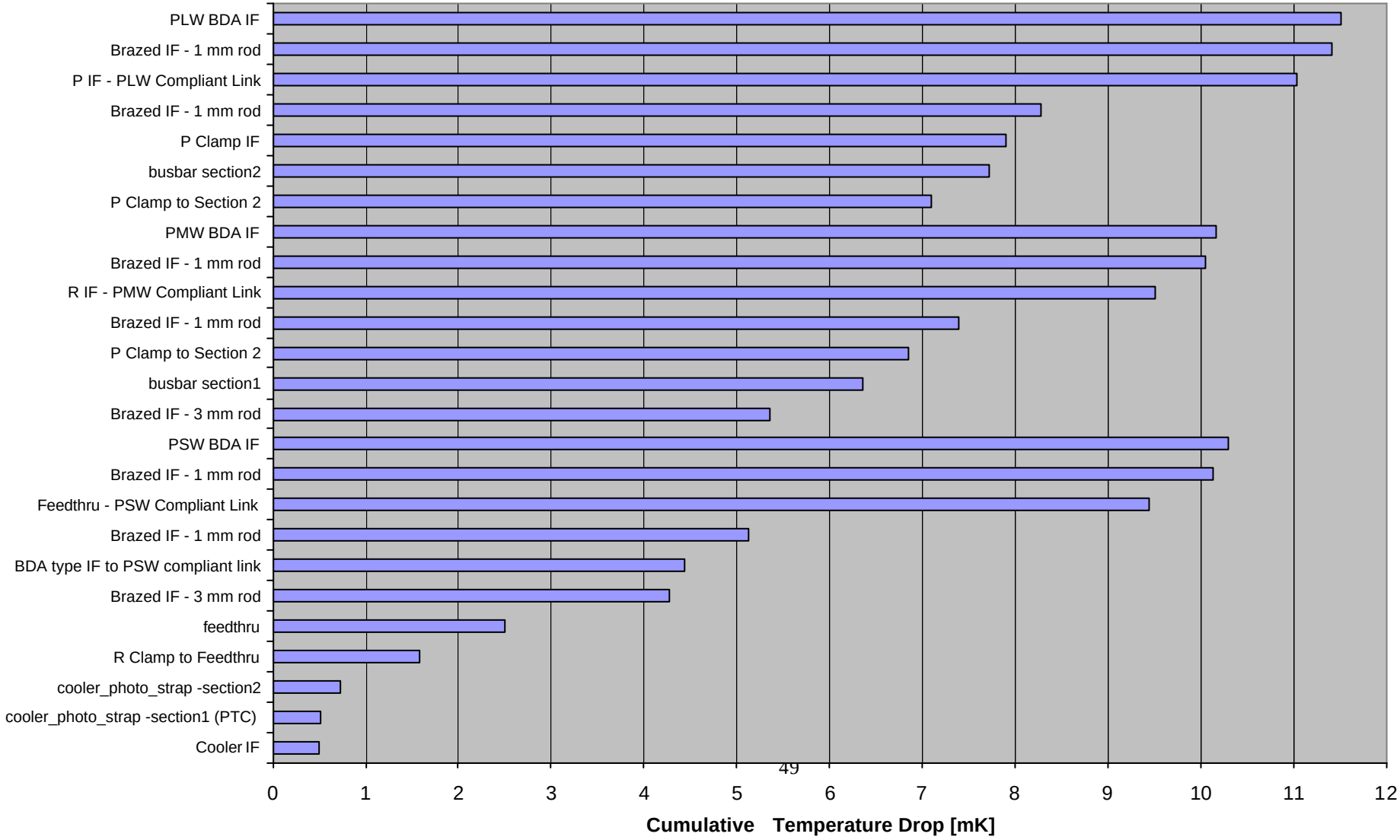
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.0065	*From analysis*
Copper Conductivity at 300mK	[W/mK]	-	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	613	0.6224	14.2	0.5
cooler_photo_strap -section2		9.00	100	0.090	613	0.0552	12	0.7
R Clamp to Feedthru						0.0143	12	1.6
feedthru	3	7.07	71.3	0.099	131	0.0130	12	2.5
Brazed IF - 3 mm rod						0.0065	11.5	4.3
BDA type IF to PSW compliant link						*0.0285*	4.5	4.4
Brazed IF - 1 mm rod						*0.0065*	4.5	5.1
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*88*	*0.0010*	4.5	9.4
Brazed IF - 1 mm rod						*0.0065*	4.5	10.1
PSW BDA IF						***0.0285***	4.5	**10.3**
Brazed IF - 3 mm rod						0.0065	7	5.4
busbar section1	3	7.07	133.1	0.053	131	0.0070	7	6.4
P Clamp to Section 2						0.0143	7	6.8
Brazed IF - 1 mm rod						*0.0065*	3.5	7.4
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*88*	*0.0016*	3.5	9.5
Brazed IF - 1 mm rod						*0.0065*	3.5	10.1
PMW BDA IF						***0.0285***	3.5	**10.2**
P Clamp to Section 2						0.0143	3.5	7.1
busbar section2	3	7.07	167	0.042	131	0.0055	3.5	7.7
P Clamp IF						0.0143	2.5	7.9
Brazed IF - 1 mm rod						*0.0065*	2.5	8.3
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*88*	*0.0009*	2.5	11.0
Brazed IF - 1 mm rod						*0.0065*	2.5	11.4
PLW BDA IF						***0.0285***	2.5	**11.5**

D10 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]



D10 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

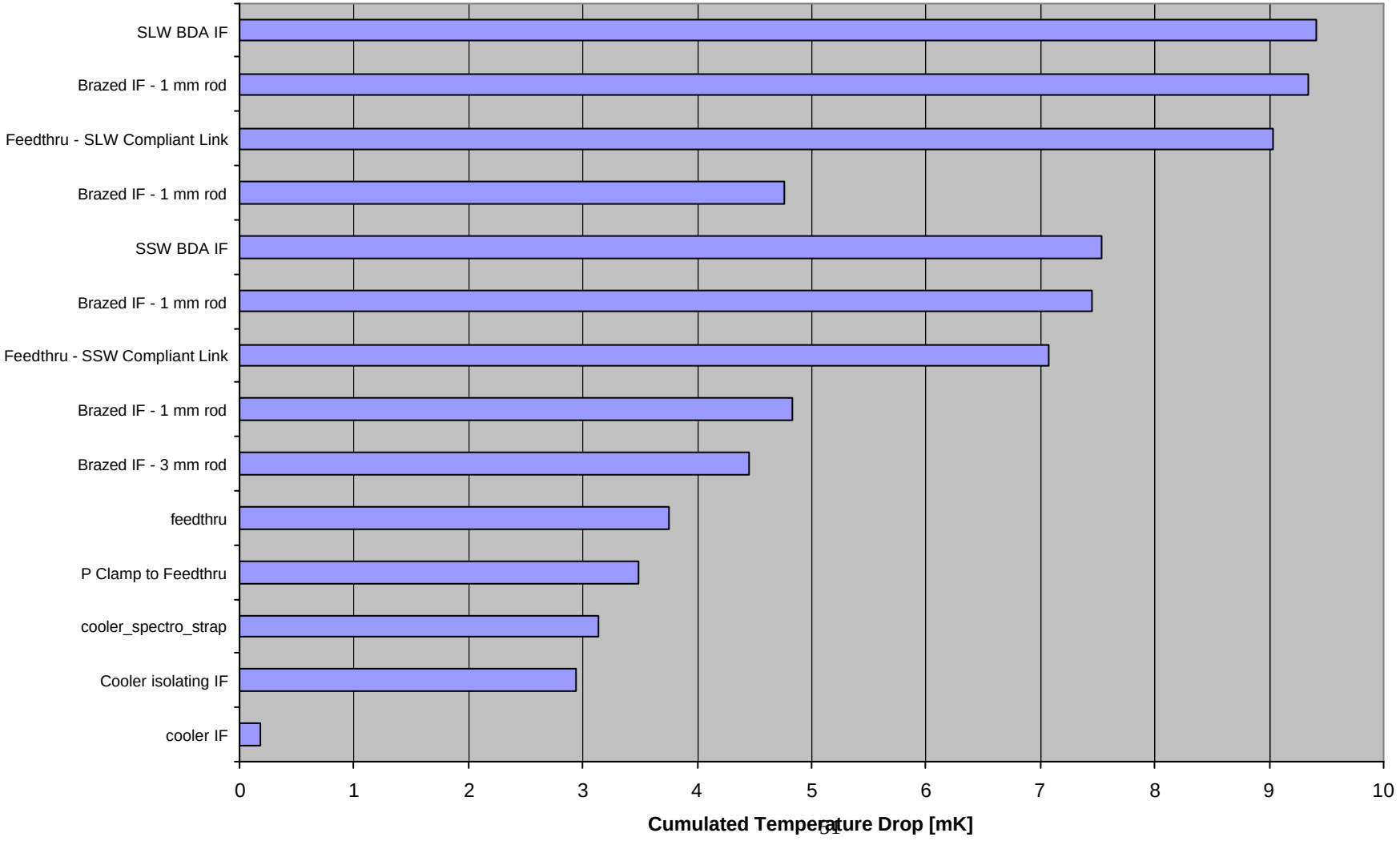
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.0065	*From analysis*
Copper Conductivity at 300mK	[W/mK]	-	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	613	0.0254	5	3.1
P Clamp to Feedthru						0.0143	5	3.5
feedthru	3	7.07	50.6	0.140	131	0.0183	5	3.8
Brazed IF - 3 mm rod						0.0065	4.5	4.5
Brazed IF - 1 mm rod						*0.0065*	2.5	4.8
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*88*	*0.0011*	2.5	7.1
Brazed IF - 1 mm rod						*0.0065*	2.5	7.5
SSW BDA IF						***0.0285***	2.5	**7.5**
Brazed IF - 1 mm rod						*0.0065*	2	4.8
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*88*	*0.0005*	2	9.0
Brazed IF - 1 mm rod						*0.0065*	2	9.3
SLW BDA IF						***0.0285***	2	**9.4**

D10 – Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]



D11 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

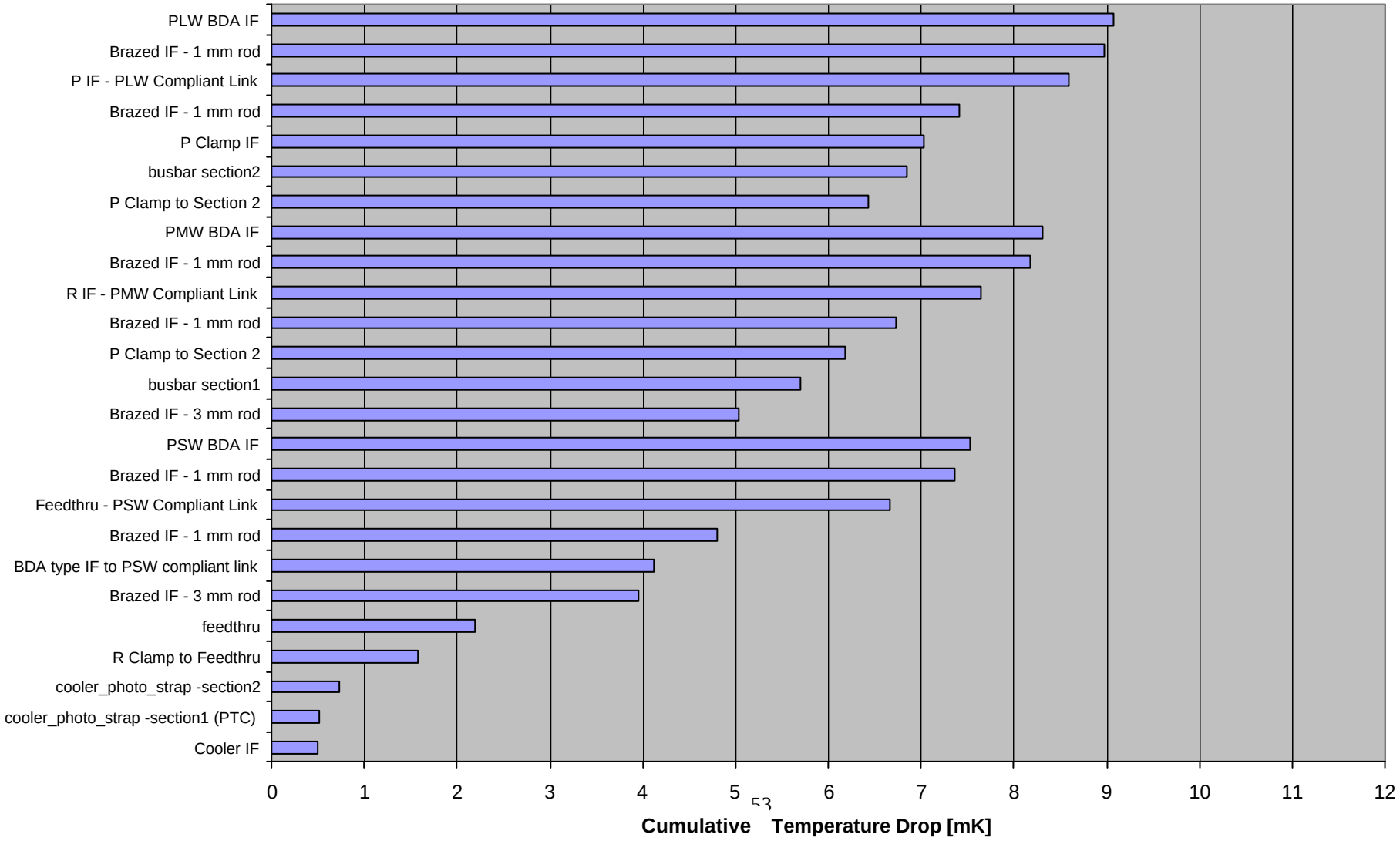
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.0065	*From analysis*
Copper Conductivity at 300mK	[W/mK]	-	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	613	0.6224	14.2	0.5
cooler_photo_strap -section2		9.00	100	0.090	613	0.0552	12	0.7
R Clamp to Feedthru						0.0143	12	1.6
feedthru	3	7.07	71.3	0.099	199	0.0197	12	2.2
Brazed IF - 3 mm rod						0.0065	11.5	4.0
BDA type IF to PSW compliant link						*0.0285*	4.5	4.1
Brazed IF - 1 mm rod						*0.0065*	4.5	4.8
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*204*	*0.0024*	4.5	6.7
Brazed IF - 1 mm rod						*0.0065*	4.5	7.4
PSW BDA IF						***0.0285***	4.5	**7.5**
Brazed IF - 3 mm rod						0.0065	7	5.0
busbar section1	3	7.07	133.1	0.053	199	0.0106	7	5.7
P Clamp to Section 2						0.0143	7	6.2
Brazed IF - 1 mm rod						*0.0065*	3.5	6.7
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*204*	*0.0038*	3.5	7.6
Brazed IF - 1 mm rod						*0.0065*	3.5	8.2
PMW BDA IF						***0.0285***	3.5	**8.3**
P Clamp to Section 2						0.0143	3.5	6.4
busbar section2	3	7.07	167	0.042	199	0.0084	3.5	6.8
P Clamp IF						0.0143	2.5	7.0
Brazed IF - 1 mm rod						*0.0065*	2.5	7.4
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*204*	*0.0021*	2.5	8.6
Brazed IF - 1 mm rod						*0.0065*	2.5	9.0
PLW BDA IF						***0.0285***	2.5	**9.1**

D11 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]



D11 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

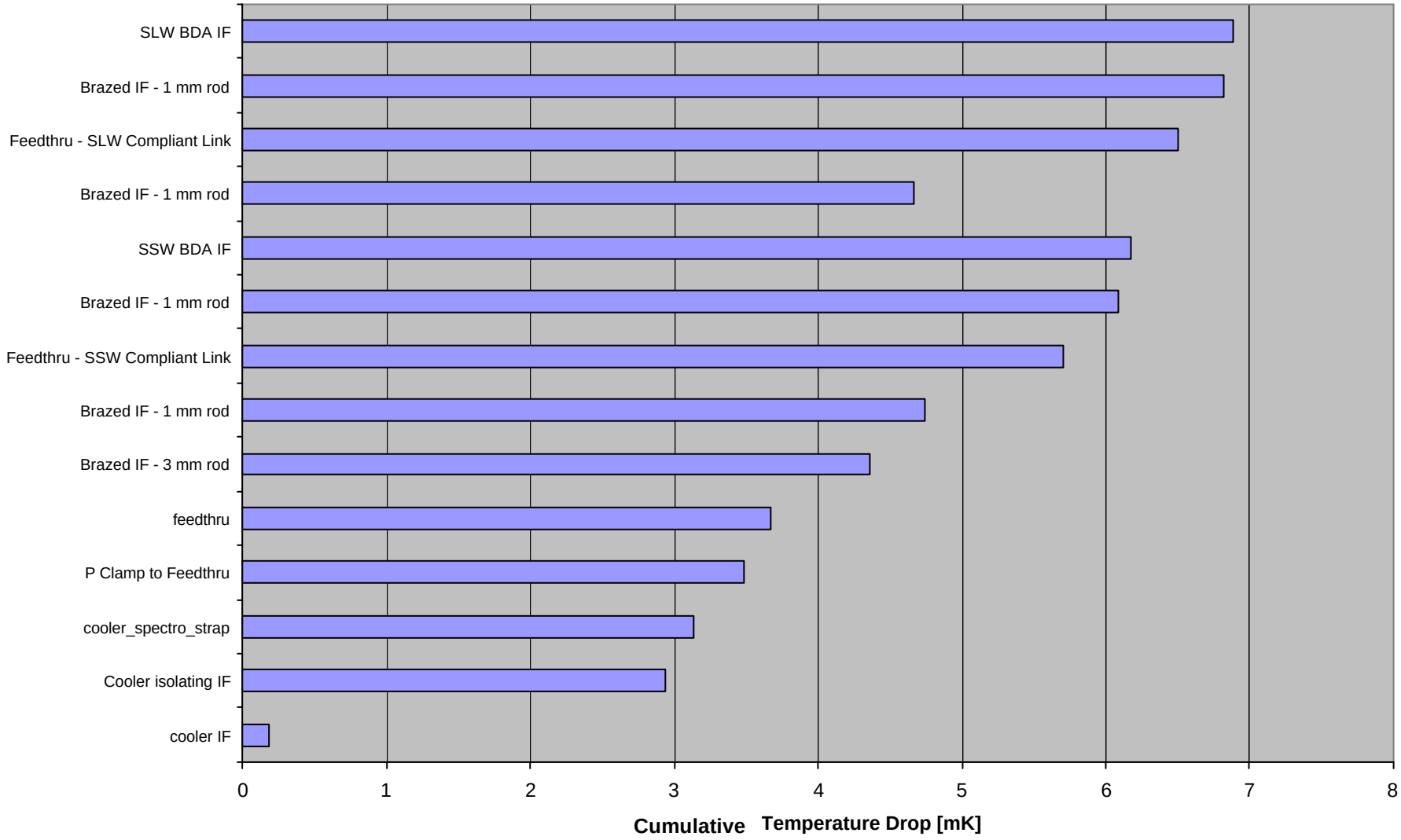
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.0065	*From analysis*
Copper Conductivity at 300mK	[W/mK]	-	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	613	0.0254	5	3.1
P Clamp to Feedthru						0.0143	5	3.5
feedthru	3	7.07	50.6	0.140	199	0.0278	5	3.7
Brazed IF - 3 mm rod						0.0065	4.5	4.4
Brazed IF - 1 mm rod						*0.0065*	2.5	4.7
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*204*	*0.0026*	2.5	5.7
Brazed IF - 1 mm rod						*0.0065*	2.5	6.1
SSW BDA IF						***0.0285***	2.5	**6.2**
Brazed IF - 1 mm rod						*0.0065*	2	4.7
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*204*	*0.0011*	2	6.5
Brazed IF - 1 mm rod						*0.0065*	2	6.8
SLW BDA IF						***0.0285***	2	**6.9**

D11 – Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]



D12 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]

Subsystem Description 300mK Photometer Busbar **5264-306B**

Input to Spreadsheet for calculation of temperature drop along the 300 mK Photometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
PTC Power Dissipation	[uW]	2	*From BDA total Load Requirement*
PTC Harness Parasitic Load	[uW]	0.2	*From BDA total Load Requirement*
PLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PLW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
PMW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PMW Kapton Load [4 harnesses]	[uW]	2	*From BDA total Load Requirement*
PSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
PSW Kapton Load [6 harnesses]	[uW]	3	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
R Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

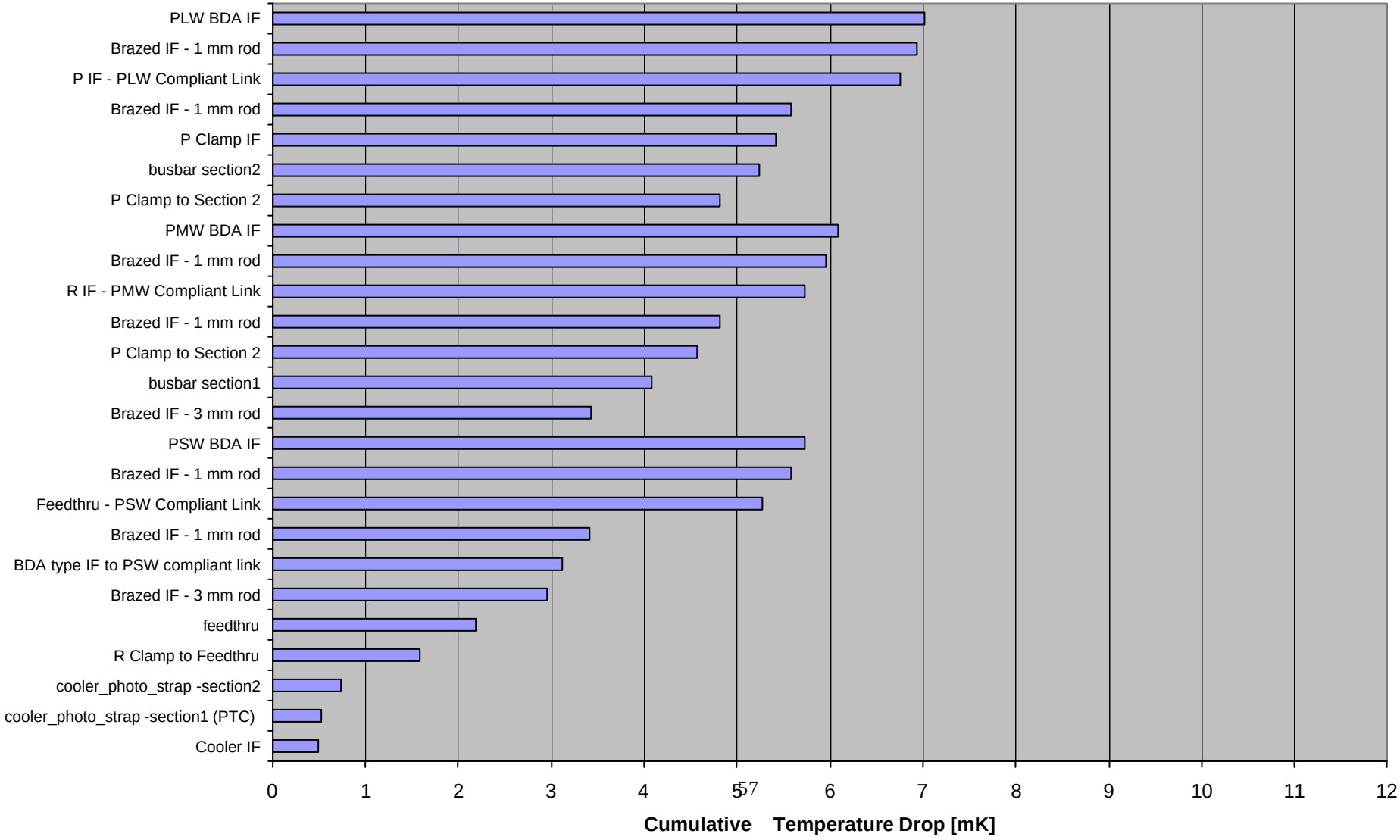
Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.015	*From analysis*
Copper Conductivity at 300mK	[W/mK]	-	*From analysis*
photo cooler strap - section 1	[mm]	39	*5264-302-30*
photo cooler strap - section 2	[mm]	100	*5264-302-30*
feedthru Length	[mm]	71.3	*5264-306-20*
PSW compliant link	[mm]	66.4	*5264-306-18*
Busbar section 1	[mm]	133.1	*5264-306-8*
PMW compliant link	[mm]	42	*5264-306-17*
Busbar section 2	[mm]	167	*5264-306-7*
PLW compliant link	[mm]	76	*5264-306-16*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
Cooler IF						0.0285	14.2	*0.5*
cooler_photo_strap -section1 (PTC)		39.60	39	1.015	613	0.6224	14.2	0.5
cooler_photo_strap -section2		9.00	100	0.090	613	0.0552	12	0.7
R Clamp to Feedthru						0.0143	12	1.6
feedthru	3	7.07	71.3	0.099	199	0.0197	12	2.2
Brazed IF - 3 mm rod						0.0150	11.5	3.0
BDA type IF to PSW compliant link						*0.0285*	4.5	3.1
Brazed IF - 1 mm rod						*0.0150*	4.5	3.4
Feedthru - PSW Compliant Link	*1*	*0.79*	*66.4*	*0.012*	*204*	*0.0024*	4.5	5.3
Brazed IF - 1 mm rod						*0.0150*	4.5	5.6
PSW BDA IF						***0.0285***	4.5	**5.7**
Brazed IF - 3 mm rod						0.0150	7	3.4
busbar section1	3	7.07	133.1	0.053	199	0.0106	7	4.1
P Clamp to Section 2						0.0143	7	4.6
Brazed IF - 1 mm rod						*0.0150*	3.5	4.8
R IF - PMW Compliant Link	*1*	*0.79*	*42*	*0.019*	*204*	*0.0038*	3.5	5.7
Brazed IF - 1 mm rod						*0.0150*	3.5	6.0
PMW BDA IF						***0.0285***	3.5	**6.1**
P Clamp to Section 2						0.0143	3.5	4.8
busbar section2	3	7.07	167	0.042	199	0.0084	3.5	5.2
P Clamp IF						0.0143	2.5	5.4
Brazed IF - 1 mm rod						*0.0150*	2.5	5.6
P IF - PLW Compliant Link	*1*	*0.79*	*76*	*0.010*	*204*	*0.0021*	2.5	6.8
Brazed IF - 1 mm rod						*0.0150*	2.5	6.9
PLW BDA IF						***0.0285***	2.5	**7.0**

D12 – Sensitivity Analysis for Photometer 300-mK Busbar [AD13]



D12 –Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]

Subsystem Description 300mK Spectrometer Busbar 5264-307B

Input to Spreadsheet for calculation of temperature drop along the 300 mK Spectrometer Busbar

		Goal	Ref
Thermal Data below are stated at	[mK]	285	*Cooler Test report - HSO-SBT-TN-091 Issue 1.1*
SLW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SLW Kapton Load [1 harnesses]	[uW]	0.5	*From BDA total Load Requirement*
SSW Kevlar Load	[uW]	1.5	*From BDA total Load Requirement*
SSW Kapton Load [2 harnesses]	[uW]	1	*From BDA total Load Requirement*
Load / Busbar Support	[uW]	0.5	*From Busbar total Load Requirement*
Cooler Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
Isolating Joint IF	[W/cm2K]	0.001	*SPIRE - Electrical Insulated Cooler Interfaces [Issue1.0 on 06/05/04]*
BDA Joint IF	[W/K-2]	0.1	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*
P Joint IF	[W/K-2]	0.05	*HSO-CDF-RP-048 [Issue 1.0 on 09/05/04]*

Assumption: these given interface conductances are temperature dependent and use cooler cold tip temperature as worse case.

Brazed Joint IF	[W/K]	0.015	*From analysis*
Copper Conductivity at 300mK	[W/mK]	-	*From analysis*
spectro cooler strap area IF	[mm2]	181	*5264-302-31*
spectro cooler strap	[mm]	217.6	*5264-302-31*
feedthru Length	[mm]	50.6	*5264-307-06*
SSW compliant link	[mm]	61.7	*5264-307-8*
SLW compliant link	[mm]	147.6	*5264-307-9*

Assumption: the given lengths are a worse case as they account for the section of the wire inside the joint.

Thermal Links	Dia	A	L	A/L	K	G	Load	Total Drop
	mm	*mm2*	*mm*	*mm*	*W/mK*	*W/K*	*uW*	*mK*
cooler IF						*0.0285*	5	*0.2*
Cooler isolating IF		181				0.0018	5	*2.9*
cooler_spectro_strap		9.00	217.6	0.041	613	0.0254	5	3.1
P Clamp to Feedthru						0.0143	5	3.5
feedthru	3	7.07	50.6	0.140	199	0.0278	5	3.7
Brazed IF - 3 mm rod						0.0150	4.5	4.0
Brazed IF - 1 mm rod						*0.0150*	2.5	4.1
Feedthru - SSW Compliant Link	*1*	*0.79*	*61.7*	*0.013*	*204*	*0.0026*	2.5	5.1
Brazed IF - 1 mm rod						*0.0150*	2.5	5.3
SSW BDA IF						***0.0285***	2.5	**5.3**
Brazed IF - 1 mm rod						*0.0150*	2	4.1
Feedthru - SLW Compliant Link	*1*	*0.79*	*147.6*	*0.005*	*204*	*0.0011*	2	5.9
Brazed IF - 1 mm rod						*0.0150*	2	6.1
SLW BDA IF						***0.0285***	2	**6.1**

D12 – Sensitivity Analysis for Spectrometer 300-mK Busbar [AD13]