SPIRE-AST-MOM-001851

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Minutes of Meeting

Herschel

Date:	03.04.03		
Doc.-No.:	HP-2-ASED-MN-0343		
Meeting place:	ASED, Friedrichshafen	Chairman:	Rüdiger Hohn
Date/Time:	03.04.03 / 14h00	Secretary	Horst Faas
Agenda dated:	25-03-03, HP-ASED-FX-0258	Close of Meeting:	04.04.03, 16h00

Subject: Instrument Thermal Interface Mtg.

Participants:	Chris Jewell, ESA/ESTEC (p/t); Carsten Scharmberg, ESA/ESTEC; Michel Pastorino, ASP; Bernard Collaudin, ASP (p/t) ; Pierre Preville, ASP (p/t) ; Jean-Michel Reix, ASP (P/T) ; J. Schubert, MPE; R. Katterloher, MPE; J. Delderfield, RAL A.S. Goizel, RAL; L. Duband, CEA (via telecon); A Hauser, ASED; K. Wagner, ASED M. Langfermann, ASED; R. Hohn, ASED; D. Schink, ASED; H. Faas, ASED	Additional Distribution:	ASP, Cannes; ESA/ESTEC; RAL; MPE

Page: 1 of 3 Page(s)

☐ Brief-Minutes (except following sheets)	☐ Summary of Results of Sheets 2 till

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Reference	Results	Remarks
	The draft Agenda was presented by H. Faas (see ASED presentation covered in Annex 1). Mr. J. Schubert presented the PACS thermal IF requirements (see Annex 2). He pointed to the PACS Change Request covering a reduction of the evaporator strap thermal IF temperature from 2.0K to 1.85K (Change Request #009). He showed the dependancy of the condensation temperature on the L1 temperature (structure temperature). Furthermore, he presented Change Request #008, covering modified mechanical loads for the cooler. The PACS thermal mechanical IF, i.e. • 2 Level-0 IF for blue and red detectors • the absorption cooler L0 IF and the • L1 I/F are currently not frozen. The cooler IF is now proposed without an adapter. The updated instrument interfaces will be shown in the configuration drawings to be issued within two weeks, i.e. 22 April 2003, excluding the PACS sorption cooler IF (see ASED AI#6) The PACS minimum temperature at the blue detectors of 1.6K was discussed. PACS agreed that a temperature of 1.65K at the detectors is acceptable as a minimal temperature. The PACS IID-B should be updated accordingly. PACS plans to use Sapphire as electrical insulation. Results of the PACS TMM (steady state) were presented (See PACS Presentation Page 9 to 13). The values were nominal and did not include uncertainties. PACS presented their modelling of the absorption cooler and the results of the transient calculations based on a tank temperature of 1.65K, i.e. without uncertainty. These calculation	

Reference	Results	Remarks
	are based on the discussion between PACS (Morgenroth) and ASED on 26/03/03. At the start of the He condensation the analysis show 2.3K (see Page 16). PACS agreed that during this phase a requirement of less that 3K would be acceptable. The analysis showed that PACS IF temperatures increase after HIFI operations (because HIFI heats up the Herschel Optical Bench). Critical points of PACS Presentation: • Get rid of adapter to the cooler • There no margins available PACS maintains the interface temperature identified in the Change Request #009. The current version of the CR does not cover a complete definition of the thermal interfaces to the Herschel EPLM. ASED requires an update of the CR#9 to include heat flows. The SPIRE presentation covering the Thermal Strap interfaces was given by John Delderfield (See Annex 3). The absorption cooler test environments were presented (prior to the EM). The thermal IF temperatures were different to those on Herschel Flight model, e.g. 4K Optical Bench temperature. The cooler peformance data have been parametrised in the SPIRE thermal model. A result of this meeting may be the recommendation to perform further non-ideal tests with the 6litre cooler model. The cooler recycling / regeneration sequence may need to be optimised. Similar to PACS, SPIRE may not require an maximum temperature of 2K during the He condensation. The requirement applies only at the enf of the condensation phase. The scaling from the 4litre cooler to the 6 litre He	Action #1: PACS to update CR#9 to include interface heat loads values for all thermal straps as agreed during the meeting (L0 and L1). Due: 15/04/03

Reference	Results	Remarks
	cooler can not done straight forward by a factor of 1.5, as the 3He tank is the only available heat capacity (He cooler structure negligible). The presented values (heat flows) were scaled from the 6 litre cooler. Due to different geometry the condensation rate will be different and may have an effect on the required IF temperatures. The design difficulties of the SPIRE thermal strap parts were presented, i.e. IF to the cooler (see PACS presentation and ground isolation of the flexible part). SPIRE presented the reasoning of the 48 hour operations period baseline. The main reason is that only at the end of the 48 hour cycle (last 12 hours) the thermal environment is stable enough to perform point source scan operations. SPIRE has currently no design of the SPIRE parts of the thermal straps that fulfils the requirements. A schedule for the finalisation of the design is not yet available. A potential idea to improve the cooler L0 IF temperatures would be to add an third L0 strap to the cooler heat shunt, which would relax the requirement on the evaporator strap. Astrium, M. Langfermann presented the design and analysis results of the H-EPLM part of the thermal straps (see Annex 1). The values of the bulk material are differing considerably, but the contact conductance are quite similar (see Page 4 of ASED presentation). It should be noted that the provided values are conservative figures. These engineering values are input for the analysis performed by Air Liquide. The tank temperature and its limits were presented. The Herschel goal is T=1.6k – 1.7K (7.5 – 11.3mbar). Due to the uncertainties a tank temperature of 1.7K should be used in the	

Reference	Results	Remarks
	analysis. The current Air Liquide Baseline design was presented (Page 7). The design is optimised for the thermal and mass requirements considering also dynamic behaviour. The thermal resistance contribution of the various thermal strap parts are shown for the ground and in-orbit case. (Page 8 and 9). The results of the ASED reference design and the assumed requirements were shown. It showed that the new requirements of PACS CR#009 can be fulfilled, but without any margins. ASED / Armin Hauser presented Agenda Item 4: H-EPLM Thermal Model status (see Annex 1, starting Page 16). For PACS the requirements for the evaporator strap were discussed. The 1.85K are required at the end of the condensation phase only (for a period of tbd minutes/seconds). The length of the period will be discussed on Friday.	
	It should be noted that the L1 temperature can be lower than 3K. During non-operating the temperature can reach 2.5K. For SPIRE L0 the heat load at the evaporator strap during recycling need to be discussed and specified. The current status with the Issue 2 HEPLM TMM were presented (Page 20) and the temperature difference of the HOB (L2) of about 1-2K and the reduction of the Spire L1 temperature were explained. The Issue 2. Of the HIFI RTMM has been delivered on 28/03/03, but the issue need to be released by ASPI and ESA. The new SPIRE RTMM is not yet released by ASPI/ESA. The timeline used during the transient calculations is shown on Page 23, consisting of 4	Action#8 PACS to check the feasibility of a non-operating temperature of 2.5K (lower limit). Due: 30/04/03

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Reference	Results	Remarks
	x 48hours, 1x 24 hours, 1x 48 hour and 1x 24 hours. Page 26: Alcatel commented that the modelling of the coolers for SPIRE and PACS should be similar. The PACS modelling may have to be changed. Page 36: The peak of the evaporator heat flux will be modified by SPIRE in the RTMM. In the current version of the model it peaks at about 1200 mW. J. Schubert presented the CEA viewgraphs concerning the modified absorption cooler interface. C. Jewell questioned the 48 hour operations (cooler hold time of 46 hours + 2 hour of recycling) of PACS. It was agreed that the baseline is 48 hours. Bernard Collaudin presented the requirements and a proposal for the way-forward how to agree on those requirements (see Annex 4) Anne-Sophie Goizel presented the dependencies of the interface temperature on the cooler hold time. She performed the analysis to show the cooler hold time of 46 hours is still achievable. The analysis showed that with an evaporator strap IF temperature of 2K the cooler hold time is achieved without margin (see Annex 5 for details and the assumptions made for the this analysis). The HOB temperatures assume an He flow of 2.2mg/sec. Via **telecon** a number of questions were discussed with Lionel Duband (qeustion see Annex 6). PACS absorption cooler (6 litre) tests are on-going. Initial results will be available at the beginning of next week (7/04/03). The test configuration was discussed. The thermal straps	Action #2 SPIRE: Update Instrument RTMM to model the heat switch as agreed in HP-2-ASED-MN-330. Due: 11/04/03 Action #3 PACS: To provide a justification for the 48 hour cycle. Due: 19/04/03

Reference	Results	Remarks
	are not representative of the SPIRE thermal straps. The surrounding temperature will be 2K. The test next week will be performed with a copper strap, but not gold plated nor using grease. The differences between the 4 and 6 litre cooler were discussed. The characterisation (e.g. heat flow as function of environmental temperatures) of the cooler was discussed. Optimisations of the cooler were discussed. The cooler mechanical IF could be changed from 2 x M3 to 2 x M4 clearance. A higher torque will be defined by CEA (> 2.2Nm). 2.2Nm were already used for the M3 interface. A better conductance for this interface is required and will improve the overall system. Another optimisation would be a modified routing of shunt strap (i.e. connecting the shunt strap to the pump). Furthermore, the switching of heat switch could be modified. This change could be implemented in the cooler FM at a later stage. The energy efficiency for a slower recycling was discussed. The impact would be a longer time required for the condensation. The rationale for the max temp T=10K pump strap requirement was discussed. The 10K is not a hard number, but it depends on the cool down time. An higher temperature could be accepted, if the cool down time is acceptable. A dedicated shunt thermal straps (i.e. 3rd strap of cooler) was discussed. Test of the cooler with Herschel representative thermal straps, i.e. test with a specified conductance. Alternatively, a heater could be used and performing the test a different temperature. This would not be representative for the transient cases.	Action #4 (SPIRE and PACS): To assess the change of cooler IF from M3 to M4 and initiate the change request to CEA. Due:10/04/03 Action #5 (SPIRE and PACS) to provide to CEA the cooler characterisation constraints for the testing (7/04/03).

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Reference	Results	Remarks
	Discussion: It agreed to discuss the critical interfaces, especially those which may affect the He II Tank interface which need to be frozen now. ASED stated that the Air Liquide proposal / contractual baseline covers only one type of thermal straps. ASED stated that ASED can not commit to new requirements. If new values are proposed during the course of the meeting, ASED has to perform an analysis to transfer those values to requirements taking into account margins. The SPIRE thermal straps interface requirements currently covered in the OBA Specs are (Evapo Strap: 0.1W/K; Pump Strap: 0.05W/K and Detector Encl Strap:0.075W/K) The following was agreed by all parties: The Spire Herschel baseline is: 1. HeII temperature is less than or equal to 1.7K 2. Each of the three existing L0 Instrument I/Fs (between He II liquid and the Industry/Instrument Thermal IF) shall have more than or equal to 100mW/K (including the contact conductance at the Instrument IF) to the He at working temperature. 3. In addition a interface take-off point shall be provided on the HeII tank, in a triangle with the two cooler interfaces, open at its centre and baselined as blanked, PACS Herschel baseline is: 1. HeII temperature is less than or equal to 1.7K 2. Each of the three (two for cooler and one for the red detector) existing L0 Instrument I/Fs (between He II liquid and the Industry/Instrument Thermal IF) shall have	

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Reference	Results	Remarks
	more than or equal to 100mW/K (including the contact conductance at the Instrument IF) to the He at working temperature. For the Red Detector the conductance is considered as soft goal. 3. The Blue Detector L0 interface is considered as less critical 4. In addition a interface take-off point shall be provided on the HeII tank, in line with the two cooler interfaces, open at its centre and baselined as blanked, Action #6 ASED: Check the feasibility of the PACS IF adapter. Due: 4/05/03 Astrium, together with Air Liquide, will perform an analysis concerning this new additional tank interface, concerning mass, eigenfrequency, etc.. PACS asked ASED to check the feasibility of the new PACS IF adapter (see PACS presentation). ASED asked Alcatel if according to S-INT-035 / HERS-800 a 20% margin has to be applied to the instrument heat flows specified by the instrument teams. Alcatel responded that a 20% margin should be added to the interface heat loads according to the applicable requirements. The PACS Cooler Pump heat load during operations is 2mW. Astrium stated that the cut-off date for Instrument TMM will be 11/04/03. All changes after this date will only be included in the next issue of the HEPLM TMM. The PACS Instrument Team stated that the agreements in these minutes apply on the assumption that the cooler adapter contact resistance is removed.	Action #6 ASED: Check the feasibility of the PACS IF adapter. Due: 4/05/03 Action #7: PACS need to justify the 2mW heat load on the cooler pump. Due: 15/04/03

Reference	Results	Remarks
	Details how to treat contractually the new baseline will be agreed between ESA/Alcatel and Astrium in a separate meeting. Based on the agreement in these minutes, the He II tank interfaces are considered frozen (one additional blind flange IF for SPIRE and PACS in the vicinity of the already existing sorption cooler L0 straps).	

Herschel
Instrument
Thermal Interface Meeting

Michael Langfermann
Armin Hauser
Horst Faas
3.04.2003

Instrument Thermal IF Meeting

Draft Agenda

- Introduction (ASED)
- Instrument Presentation of thermal IF requirements, covering nominal in-orbit operations and cooler recycling (PACS and SPIRE)
- Current design of L0, L1 and L3 thermal links (ASED)
- H-EPLM Thermal Model status (ASED)

- Presentation of Absorption Cooler IF for PACS (MPE/CEA)
- Presentation: Thermal Requirements (ASP)
- Discussion of proposed requirements for each thermal link
- Establishment of the thermal interfaces requirements
- On-ground thermal interface for EQM and PFM testing
- AOB

Friday, 08h00-09h00 (tbc):
Herschel EPLM 3D Presentation in BG8, Room 8105-8107

Instrument Thermal IF Meeting

- **Scope:**
  - Consolidate the Instrument thermal IF requirements distributed over the last few weeks
  - Present the design approach and the analysis status of the Thermal Links to the Herschel EPLM

- **Objective:**
  - **Agree the new thermal interface requirements** at the defined thermal interfaces between Instruments and H-EPLM, taking into account
    - the instrument part of the thermal strap,
    - the overall performances
    - and the feasibility of the cryostat strap

- **Background for Astrium:**
  - Freeze of thermal interface requirements as baseline for the design and qualification the cryostat thermal straps
    - for in-schedule delivery of Herschel Optical Bench Assembly and He-II Tank

Material properties

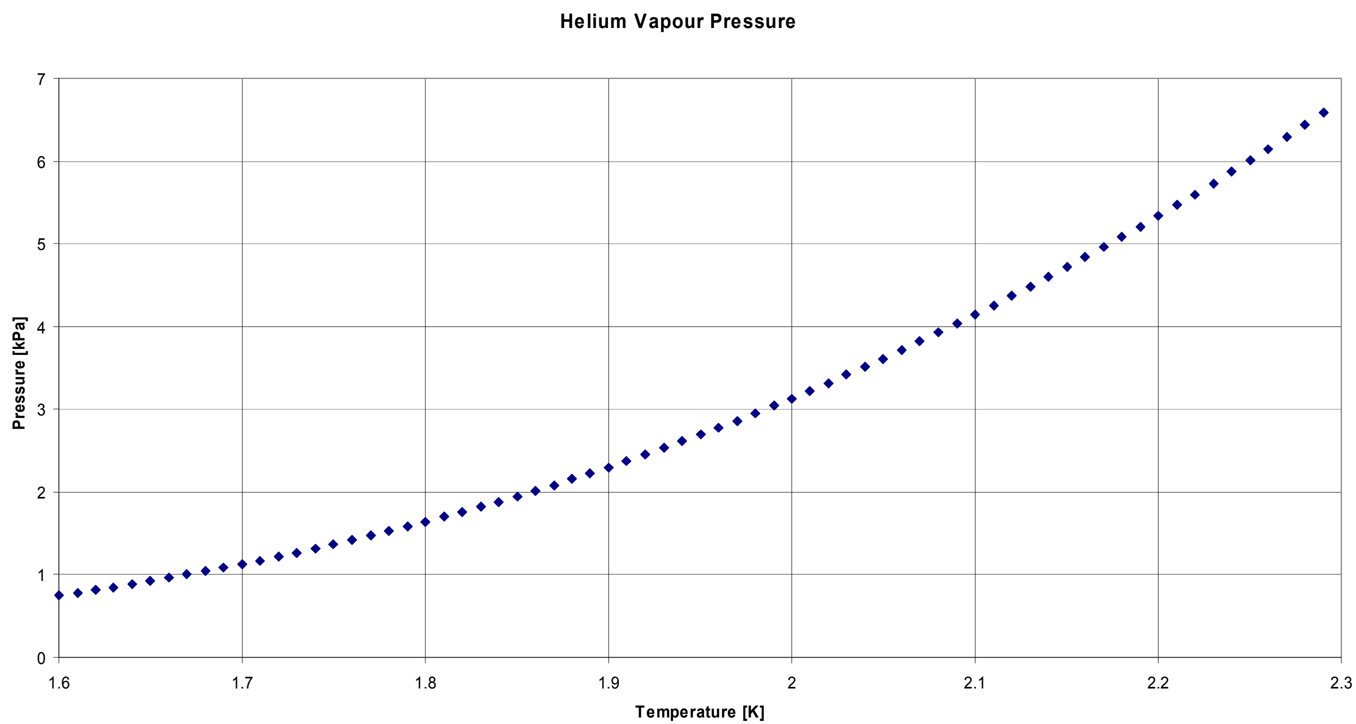
Source	Material	Properties @ 1.7K
Data measured by HIFI Design base for SPIRE?	Al 99.999% conductance Contact conductance AL/AL, 2 x M3	4000 W/m K 0.33 W/K
ASED reference design	Al 99.999% conductance Contact conductance AL/AL, 2XM4 (scaled from ISO)	390 W/m K 0.13 W/K
Air Liquide design	AA 1050 conductance OFHC copper (flex) conductance Contact conductance (CEA data from Cu/Cu 0.06 W/K kN, scaled for 2xM4)	60 W/m K 100 W/m K 0.36 W/K

HTT temperature

The in orbit tank temperature (vapour pressure) will be adjusted with a pair of nozzles as a
of a prediction based on the TMM and the extrapolated ground measurements for the whol
vent line temperature and pressure drop behavior.

ISO requirement was: 1.7 – 1.9 K -> 11.3 – 23 mbar

Herschel current goal is: 1.6 – 1.7 K -> 7.5 – 11.3 mbar



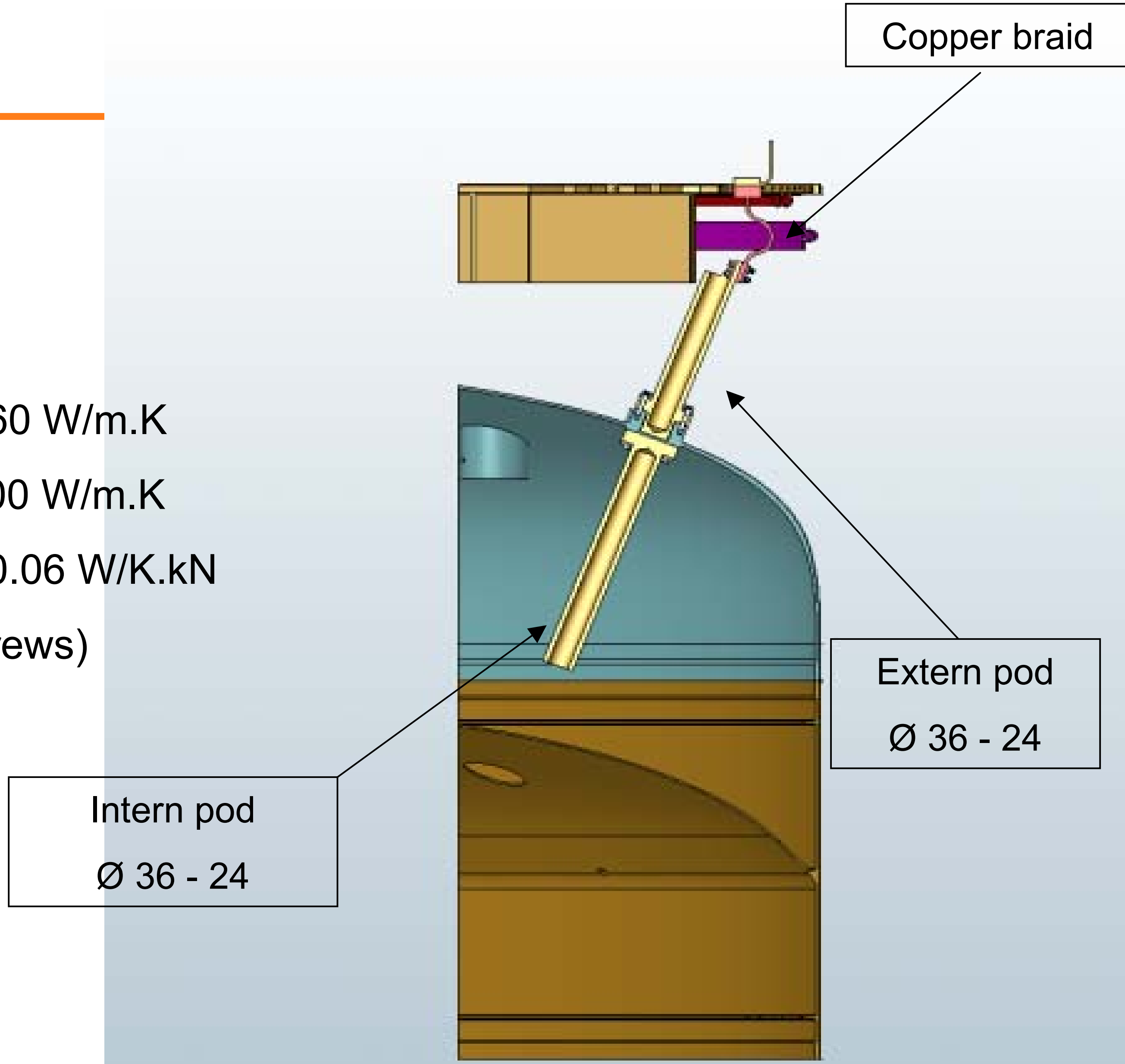
System aspects of level 0 improvements

Level 0 design	- Open/closed tank - Fluid pump - …	
Level 1 feedback to level 0	- Increased mass flow - SPIRE before PACS series	Negligible ?
HTT temperature		PACS req. >1.6K
Level 2 feedback to level 0	- SPIRE thermal decoupled from optical bench	
FPU operating cycle	24h instead of 48?	

L0 thermal links pre-design:

Hypothesis:

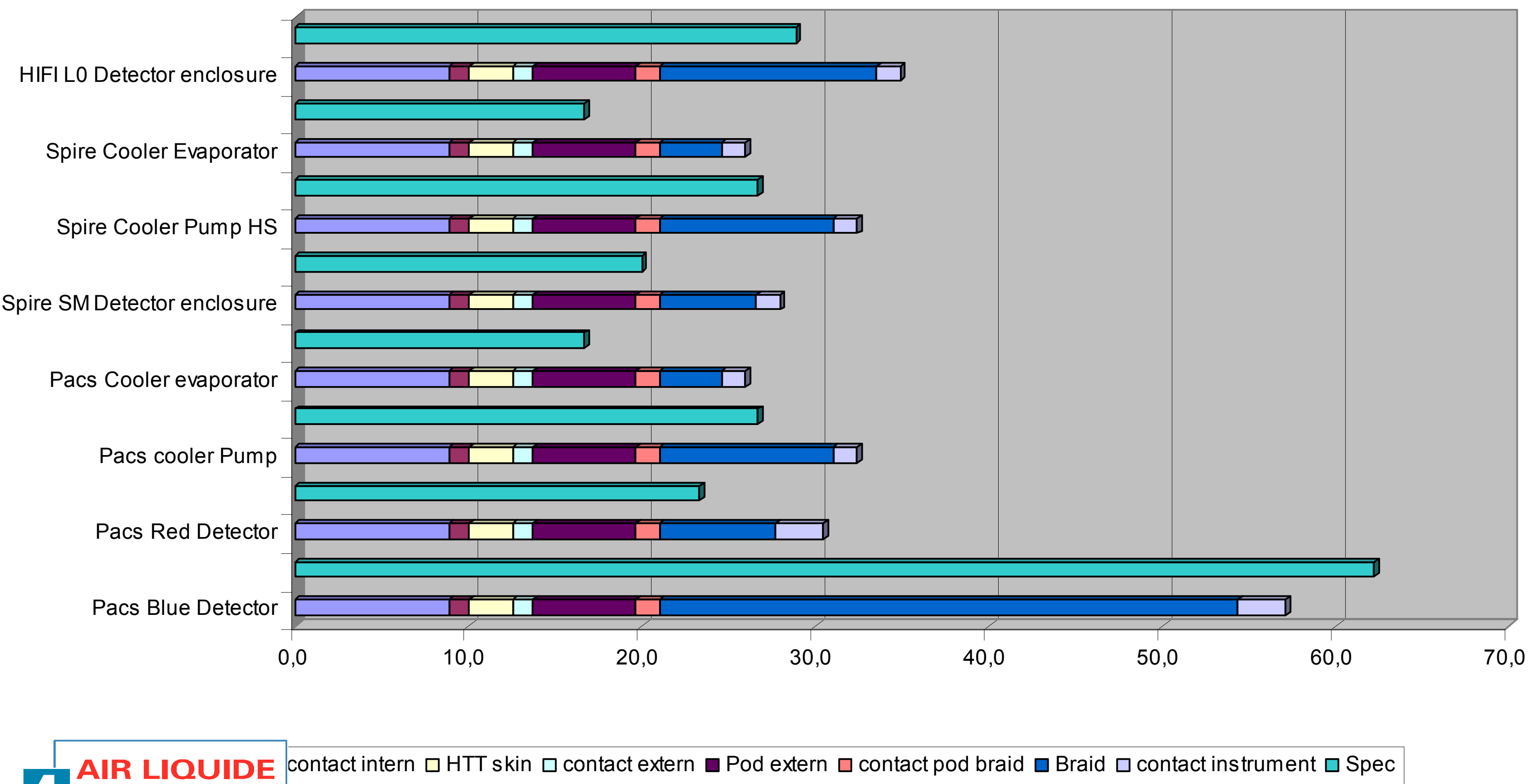
- Alu 1050 Conductivity@ 1.7°K = 60 W/m.K
- Copper conductivity @ 1.7°K = 100 W/m.K
- Contact conductance @ 1.7°K = 0.06 W/K.kN
- HTT I/F = Ø 64 flange (8 x M5 screws)
- Ground fill-in level = 70% ® 80%



Results (80%fill-in level) :

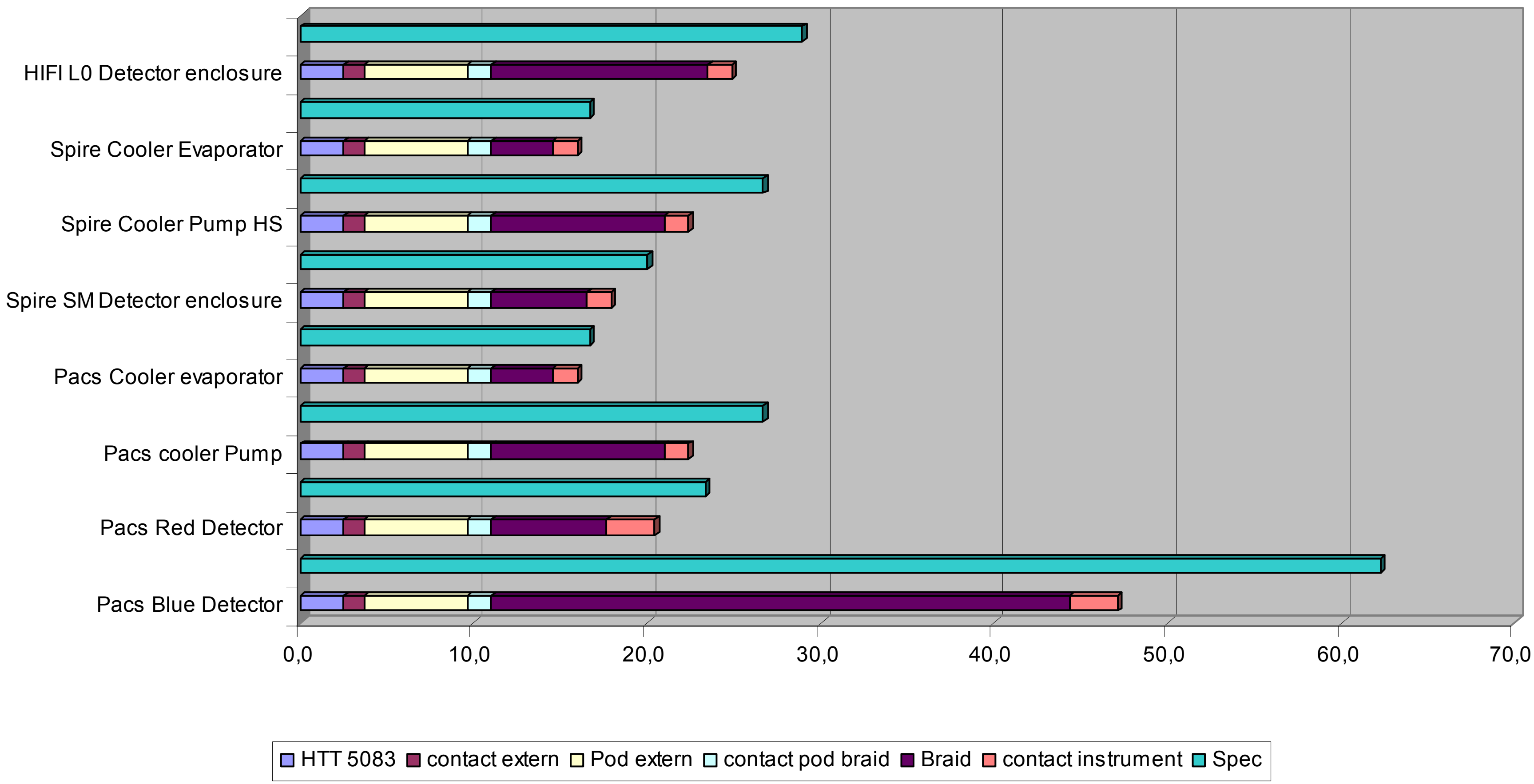
- Mass budget = 7.5 kg
- Conductance specification is fullfilled in orbit condition

THERMAL RESISTANCE (K/W)
Solution A Fill in 80% (ground condition)

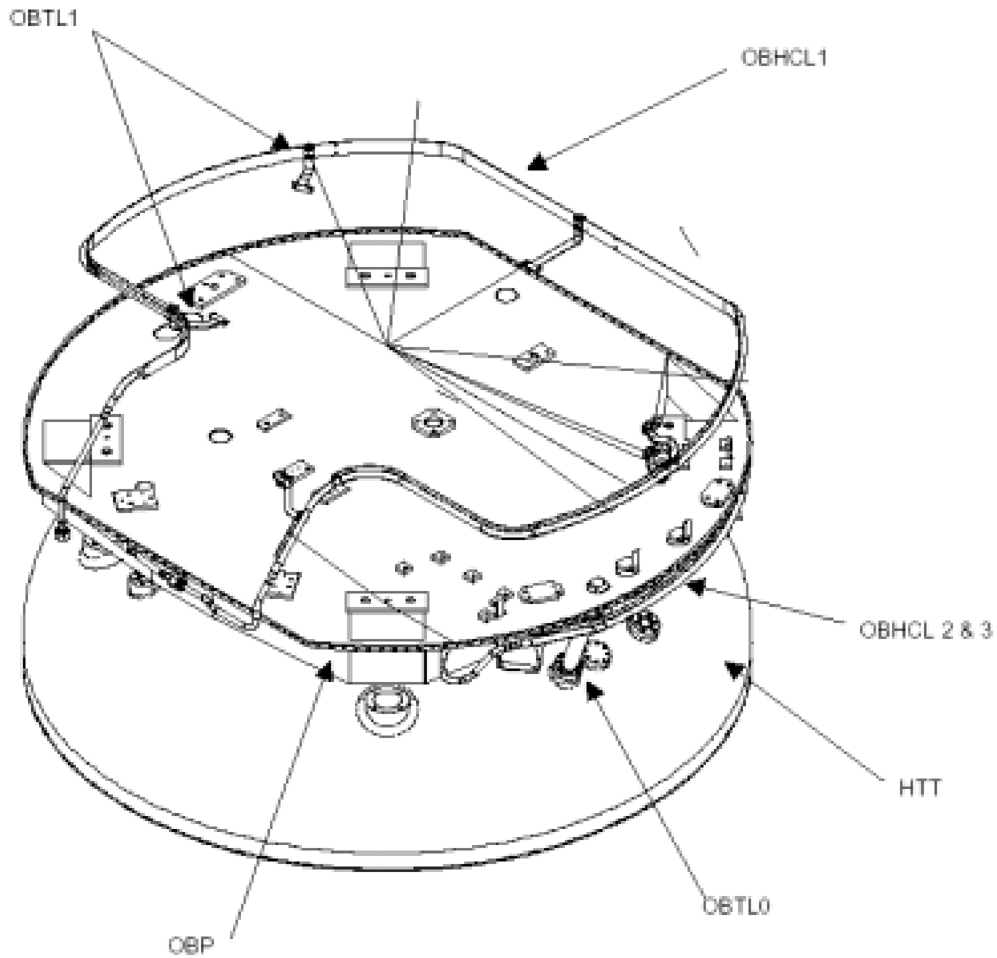


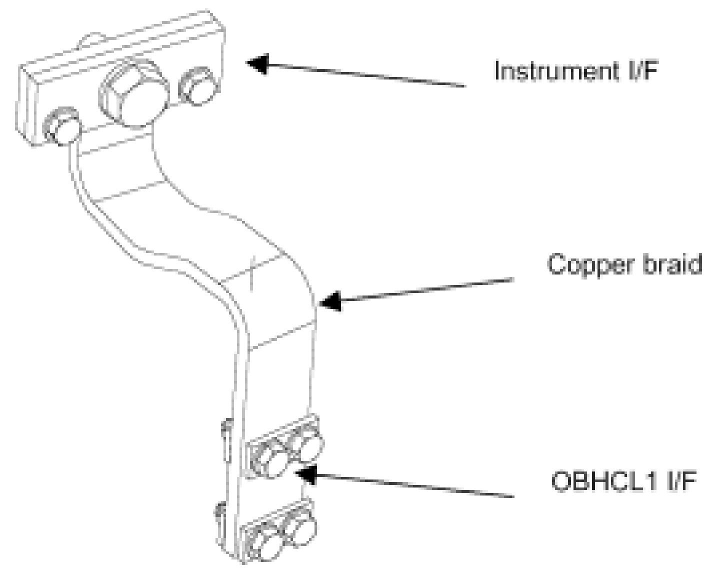
THERMAL RESISTANCE (K/W)

Solution A 80% fill in (orbit condition)



Vent line thermal contacts on optical bench



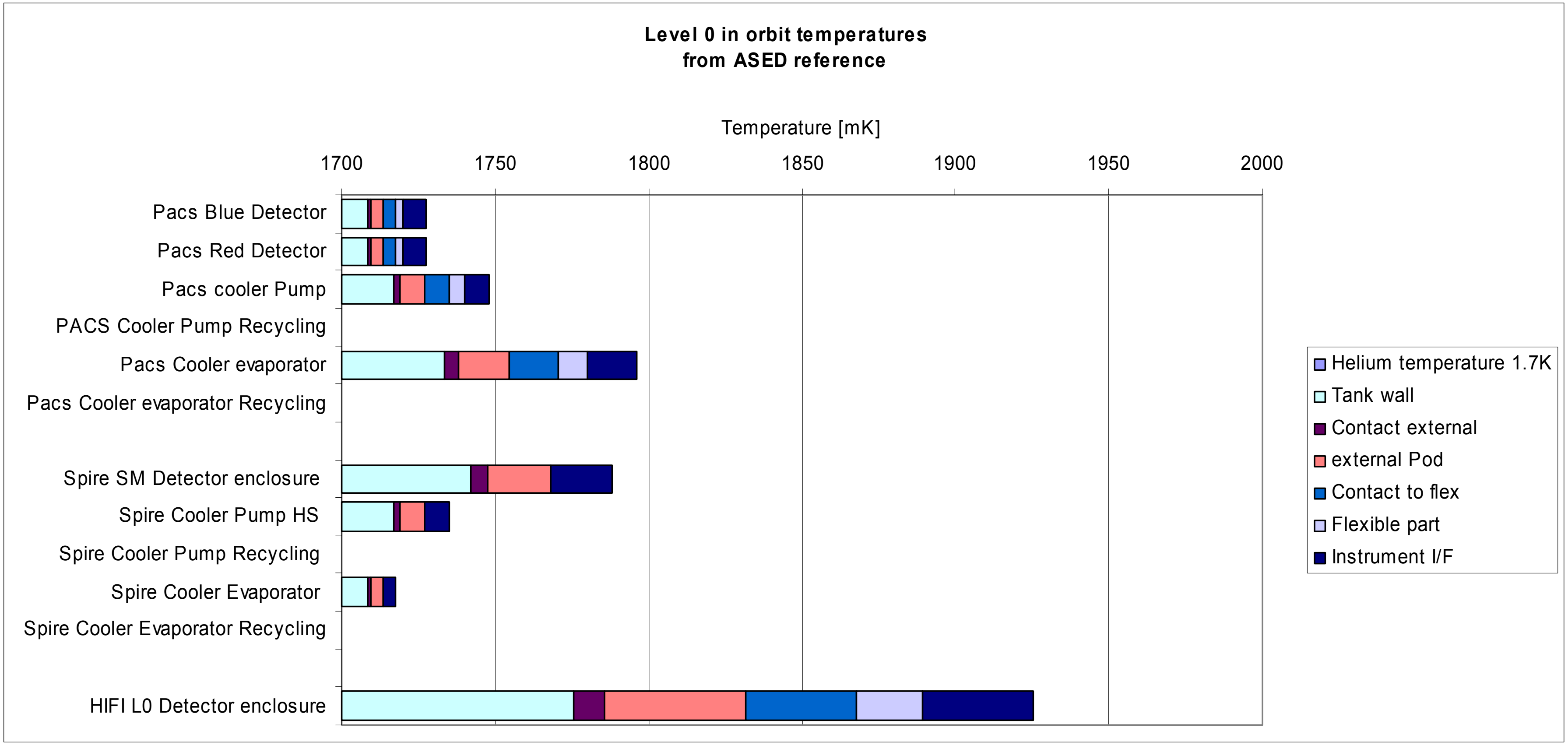


1)

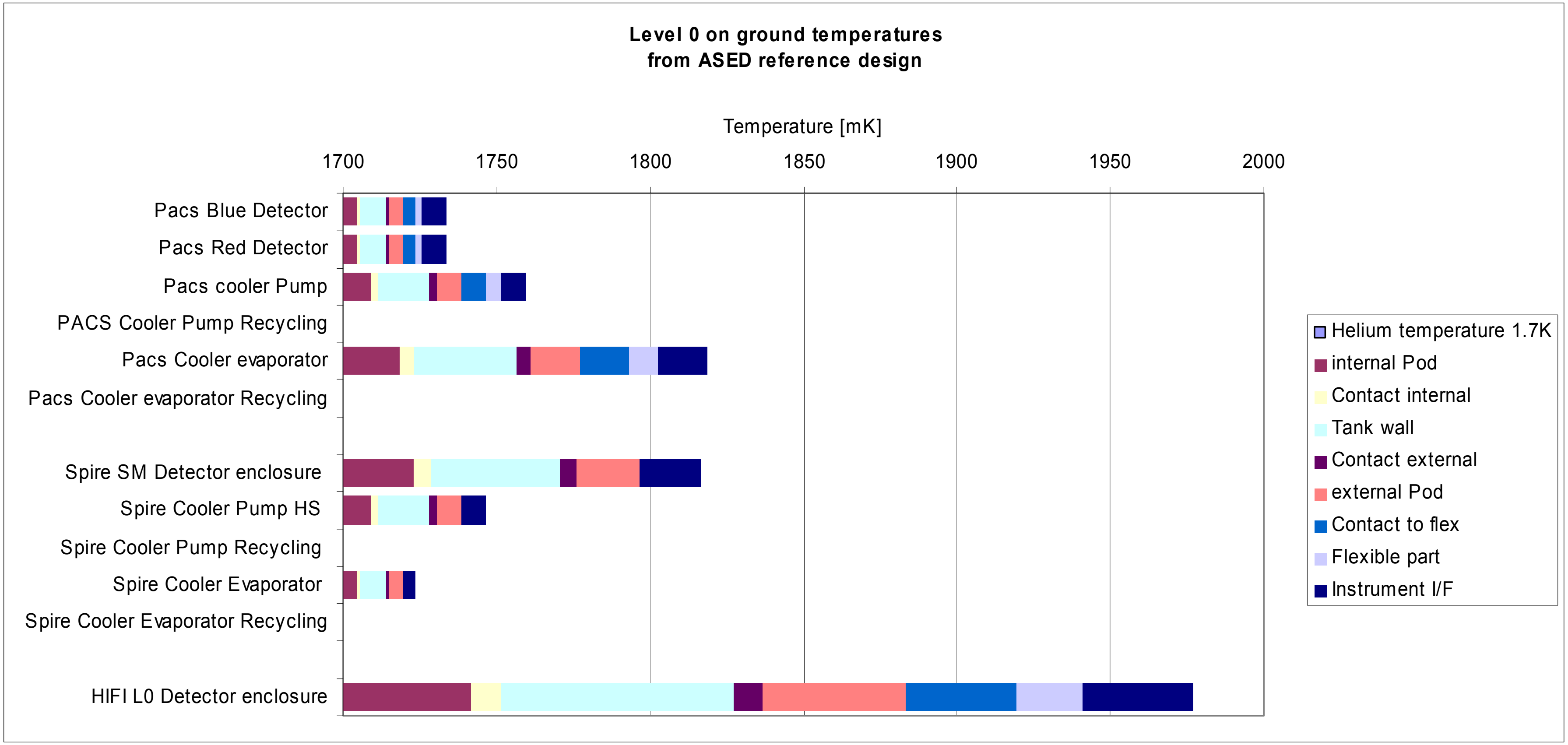
ASED reference design

Instrument I/F	Heat flux spec. To AL	Temp. Allowable	Heat flux from TMM issue 2	Remark
	[mW]		[mW]	
Pacs Blue Detector	2	**1.6-2.0K**	**0.7 / 0.3**	Photometer mode, 0.3 mW when off
Pacs Red Detector	1	**1.6-1.75K**	**0.4 / 0.8**	Spectrometer mode, temp req. unclear when off
Pacs cooler Pump	1	**1.6-2.2K**	**2.00**	
PACS Cooler Pump Recycling	450 (tbc)	**<10K**	**450 tbc**	steady state as worst case
Pacs Cooler evaporator	8	**1.6-1.85K**	**3.70**	
Pacs Cooler evaporator Recycling	?	**<2K**	**tbd**	
Spire SM Detector enclosure *	5	**<1.8K**	**5.00**	
Spire Cooler Pump HS *	2	**<1.8K**	**2.00**	1.8K wrt to PACS?
Spire Cooler Pump Recycling *	450 (tbc)	**<10K**	**450 tbc**	steady state as worst case
Spire Cooler Evaporator *	1	**<1.8K**	**1.00**	
Spire Cooler Evaporator Recycling*	?	**<2K**	**tbd**	
HIFI L0 Detector enclosure	**9.00**	**<2K**	**9.00**	Heat flux: tbc

ASED reference design



ASED reference design



On –ground testing

CQM program

- Level 0 links will be different (only level 1 -3 verification)
- temperatures adjusted by the helium bath

PFM with MTD‘s or fligth FPU‘s (except below)

- All level 0,1,2,3 temperatures will be different
- active cooling via HOT and cover will provide an operative environment (see next table)

PFM fligth FPU‘s under TB/TV testing

- orbital conditions can be achieved by active cooling of the CVV
- level 0 temperatures will be higher due to gravity
- verification of cooler hold time possible?

ASED reference design

Node	Level	Label	Temperature [K] G 21 mg/s	P 60mg/s	P 100mg/s	P 1000mg/s	P 100mg/s cover cooled	**PI** 100mg/s cover cooled
811	0	SPIRE SM Detector en	2,06	1,86	1,84	1,80	1,73	1,88
819	0	SPIRE Cooler pump HS	1,82	1,75	1,75	1,74	1,72	1,91
820	0	SPIRE Cooler evap HS	1,83	1,76	1,75	1,74	1,72	1,87
760	0	PACS-Red Detector	1,76	1,74	1,74	1,73	1,71	1,86
765	0	PACS-Blue Detector	1,91	1,86	1,84	1,82	1,74	1,90
781	0	PACS-Photometer CooPu	1,78	1,76	1,75	1,75	1,72	1,94
912	0	HIFI L0 boundary node	2,05	1,79	1,77	1,75	1,73	1,90
803	1	SPIRE Optical Bench	14,73	10,25	9,54	8,14	4,38	4,66
720	1	PACS-Spectrometer	7,69	6,76	6,48	6,07	4,27	4,36
725	1	PACS-Collimator	7,69	6,76	6,48	6,08	4,27	4,36
730	1	PACS-Photometer Optic	7,69	6,76	6,48	6,08	4,27	4,36
913	1	HIFI L1 boundary node	7,81	5,07	4,71	4,27	4,22	4,27
801	2	SPIRE PM JFET ENCL	22,04	7,35	6,63	5,71	5,00	5,27
802	2	SPIRE SM JFET ENCL	21,83	7,21	6,52	5,60	4,95	5,18
910	2	HIFI FPU Structure	21,69	7,53	6,84	5,96	5,14	5,41
10		HTT	1,70	1,70	1,70	1,70	1,70	**1,85**
376		Opt. Bench centre	21,61	7,40	6,72	5,84	5,06	5,30
311		Instr. Shield Top	23,94	9,48	8,82	8,12	5,61	5,81
4061		Cryostat Cover Shield	233,94	232,43	232,25	232,19	80,00	80,00

Cases Legend:

G	GHe mass flow from HTT, Instruments off
P	GHe mass flow from HOT, Instruments off
PI	GHe mass flow from HOT, Instruments in average dissipation mode

H-EPLM Thermal Analysis

PACS L0 Interface Temperatures and Heat Loads

		Applicable and Derived Requirements (IID-B, Iss 2.1)					Non-agreed Requirements (ECR 009)					OBA Spec	
Instrument I/F		**In-Orbit Operation**			**In-Orbit Cooler Recycling**		**In-Orbit Operation**			**In-Orbit Cooler Recycling**		**to HTT**	***to He II***
		I/F Temp.	Heat load	***W/K***	I/F Temp.	Heat load	I/F Temp.	Heat load	***W/K***	I/F Temp.	Heat load	**W/K**	***W/K***
PACS Blue Detector [723]	L0	1.6 –2.0 K	1.5 mW *	***0.005***	N/A	N/A	1.6 – 2.0 K	0.8 mW**	***0.003***	N/A	N/A	**0.018**	***0.017*** ***(0.018)***
PACS Red Detector [721]	L0	1.6-1.75 K	0.7 mW *	***0.014***	N/A	N/A	1.6–1.75 K	0.7 mW**	***0.014***	N/A	N/A	**0.06**	***0.052*** ***(0.03)***
PACS Cooler Pump [761]	L0	1.6 – 2.2 K	3.9 mW *	***0.008***	= 10 K	450 mW peak	1.6 – 2.2 K	2.0 mW**	***0.004***	= 10 K	250mW **	**0.05**	***0.044*** ***(0.05)***
PACS Cooler Evaporator [762]	L0	1.6 – 2.0 K	3.9 mW *	***0.013***	< 2K	not specified	**1.6 -1.85 K**	3.7 mW**	***0.025***	**1.6-1.85 K** **< 3.0 K**	**tbd** **tbd**	**0.1**	***0.080*** ***(0.06)***

*) Interface heat flow as calculated with implemented instrument TMM's, see HP-2-ASED-RP-0011, Issue 2.1
**) Interface heat flow as calculated with implemented new PACS TMM and clarified with R. Katterloher on 11.03.03.

(used in H-EPLM TMM based on ASED Reference Design)

H-EPLM Thermal Analysis

PACS L1 Interface Temperatures and Heat Loads

		Applicable and Derived Requirements (IID-B, Iss 2.1)					Non-agreed Requirements (ECR 009)					OBA Spec	
Instrument I/F		**In-Orbit Operation**			**In-Orbit Cooler Recycling**		**In-Orbit Operation**			**In-Orbit Cooler Recycling**		**to GHe**	
		I/F Temp.	Heat load	***W/K***	I/F Temp.	Heat load	I/F Temp.	Heat load	***W/K***	I/F Temp.	Heat load		***W/K***
PACS Photom. [781]	L1	3 - 5 K	12.1 mW *		3 - 5 K	N/A	3 - 5 K	7.9 mW **		3 - 5 K	N/A	8 mW	**0.025**
PACS Collimator [782]	L1	3 - 5 K	7.2 mW *		3 - 5 K	N/A	3 - 5 K	6.7 mW **		3 - 5 K	N/A	5 mW	**0.025**
PACS Spectro-meter [783]	L1	3 - 5 K	4.1 mW *		3 - 5 K	N/A	3 - 5 K	5.2 mW **		3 - 5 K	N/A	5 mW	**0.025**

*) Interface heat flow as calculated with implemented instrument TMM's, see HP-2-ASED-RP-0011, Issue 2.1
**) Interface heat flow as calculated with implemented new PACS TMM and clarified with R. Katterloher on 11.03.03.

L1 temperature will be lower than 3K in Photometer Mode !

H-EPLM Thermal Analysis

SPIRE L0 Interface Temperatures and Heat Loads

		Applicable and Derived Requirements (IID-B, Issue 2.0)					Non-agreed Requirements (ECR 009)					OBA Spec.	
Instrument I/F		**In-Orbit Operation**			**In-Orbit Operation**		**In-Orbit Operation**			**In-Orbit Cooler Recycling**		**to HTT**	**to He II**
		I/F Temp.	Heat load	***W/K***	**W/K**	***W/K***	I/F Temp.	Heat load	***W/K***	I/F Temp.	Heat load	**W/K**	**W/K**
SPIRE SM Detector enclosure [814]	L0	≤2.0 K	3 mW	***0.01***	N/A	N/A	**≤1.8 K**	**5 mW** (2.8 mW *)	***0.05***	N/A	N/A	**0.075**	**0.063** **(0.05)**
SPIRE Cooler Pump HS [815]	L0	≤2.0 K	1.8 mW	***0.006***	≤ 10 K	450 mW peak	**≤1.8 K**	2 mW (2.2 mW *)	***0.02***	≤ 10 K	450 mW peak	**0.05 #**	**0.044** **(0.05)**
SPIRE Cooler Evaporator [816]	L0	≤2.0 K	0.6 mW	***0.002***	≤2.0 K	not specified	**≤1.8 K**	1 mW (0.4 mW *)	***0.01***	≤2.0 K	not specified	**0.1 #**	**0.080** **(0.1)**

*) Interface heat flow as calculated with implemented instrument TMM's, see HP-2-ASED-RP-0011, Issue 2.1
**) Interface heat flow as calculated with implemented newPACS TMM (Issue 28.01.03) and SPIRE TMM (Issue 2.2, delivered 06.03.03).

(used in H-EPLM TMM based on ASED Reference Design)

H-EPLM Thermal Analysis

SPIRE L1 Interface Temperatures and Heat Loads

	Applicable and Derived Requirements (IID-B, Issue 2.0)				**Non-agreed Requirements (ECR 009)**				**OBA Spec.**	
Instrument I/F	**In-Orbit Operation**		**In-Orbit Operation**		**In-Orbit Operation**		**In-Orbit Cooler Recycling**		**In Orbit**	
SPIRE L1 (two straps) [800]	≤6.0 K	18.2 mW*	not specified	not specified	**≤4.5 K**	13 mW (19 mW *)	not specified	not specified	19 mW	**0.07 W/K**

*) Interface heat flow as calculated with implemented instrument TMM's, see HP-2-ASED-RP-0011, Issue 2.1
**) Interface heat flow as calculated with implemented newPACS TMM (Issue 28.01.03) and SPIRE TMM (Issue 2.2, delivered 06.03.03).

H-EPLM Thermal Analysis

Evolution of H-EPLM TMM w.r.t. RTMM delivered to Instruments

- Refinement of Telescope GMM acc. to ASEF Catia Model
- Refinement/update of beam entrance baffles
- Refinement of ventline modelling
- Introduction of L3 interfaces (L3 patch provided to instruments)
- Update of HIFI coax cables
- Introduction of EPLM 100 mm enlargement

? Reduction of HOB (L2) temperature by about (1-2) K

? Reduction of SPIRE L1 temperature by about (0.4-0.7) K

H-EPLM Thermal Analysis

Measures to Reduce SPIRE L1 Temperature

Case	Modification	He Mass Flow	SPIRE L1 temperat.	SPIRE L1 heat flow	HOB	JFET-P	JFET-S
139	PDR Collocation Status	2.2 mg/s	M3: 4.38 K M4: 4.67 K	12.7 mW 14.9 mW	9.56 K 9.21 K	9.74 K 9.29 K	9.66 K 9.36 K
145	L3 and updated L1 introduction	2.2 mg/s	M3: 3.69 K M4: 3.92 K	12.7 mW 14.9 mW	8.17K 8.10 K	13.04 K 8.52 K	11.4 K 10.1 K
149a	as E, updated SPIRE draft TMM, 18.10.02	2.2 mg/s	M3: 3.83 K M4: 4.34 K	14.0 mW 18.8 mW	8.19K 8.36 K	13.02 K 8.76 K	11.41 K 10.32 K
172	SPIRE TMM, Iss. 2.2	2.2 mg/s	M3: 3.82 K M4: 4.46 K	12.7 mW 18.9 mW	7.83K 8.10 K	13.01 K 8.82 K	11.39 K 10.38 K
173	JFET electrical insulation	2.2 mg/s	M3: 3.83 K M4: 4.47 K	12.8 mW 18.9 mW	7.86K 8.12 K	13.30 K 8.87 K	11.36 K 10.48 K
173a	worse JFET decoupling from OBP	2.2 mg/s	M3: 4.01 K M4: 4.53 K	14.1 mW 19.3 mW	8.68K 8.38 K	12.95 K 8.97 K	11.06 K 10.31 K
		2.3 mg/s	M3: 3.83 K M4: 4.37 K	13.1 mW 18.6 mW	8.19K 7.93 K	12.43 K 8.52 K	10.50 K 9.85 K

H-EPLM Thermal Analysis

Status of H-EPLM TMM w.r.t. Instrument TMM's

- PACS RTMM, update 28.01.2003 implemented. Needs to be updated reflecting the actual L0 instrument I/F's
- SPIRE RTMM Issue 2.2 implemented. Issue 2.3 (reflecting outcome of TMM meeting) delivered 28.03.03
- HIFI RTMM Issue 2, dated 07.03.03 preliminary implemented. Updated Issue 2 delivered on 28.03.03. Final HIFI RTMM to be checked/released by ASPI and ESA.
- Overall instrument timeline (Linder/Hauser) implemented

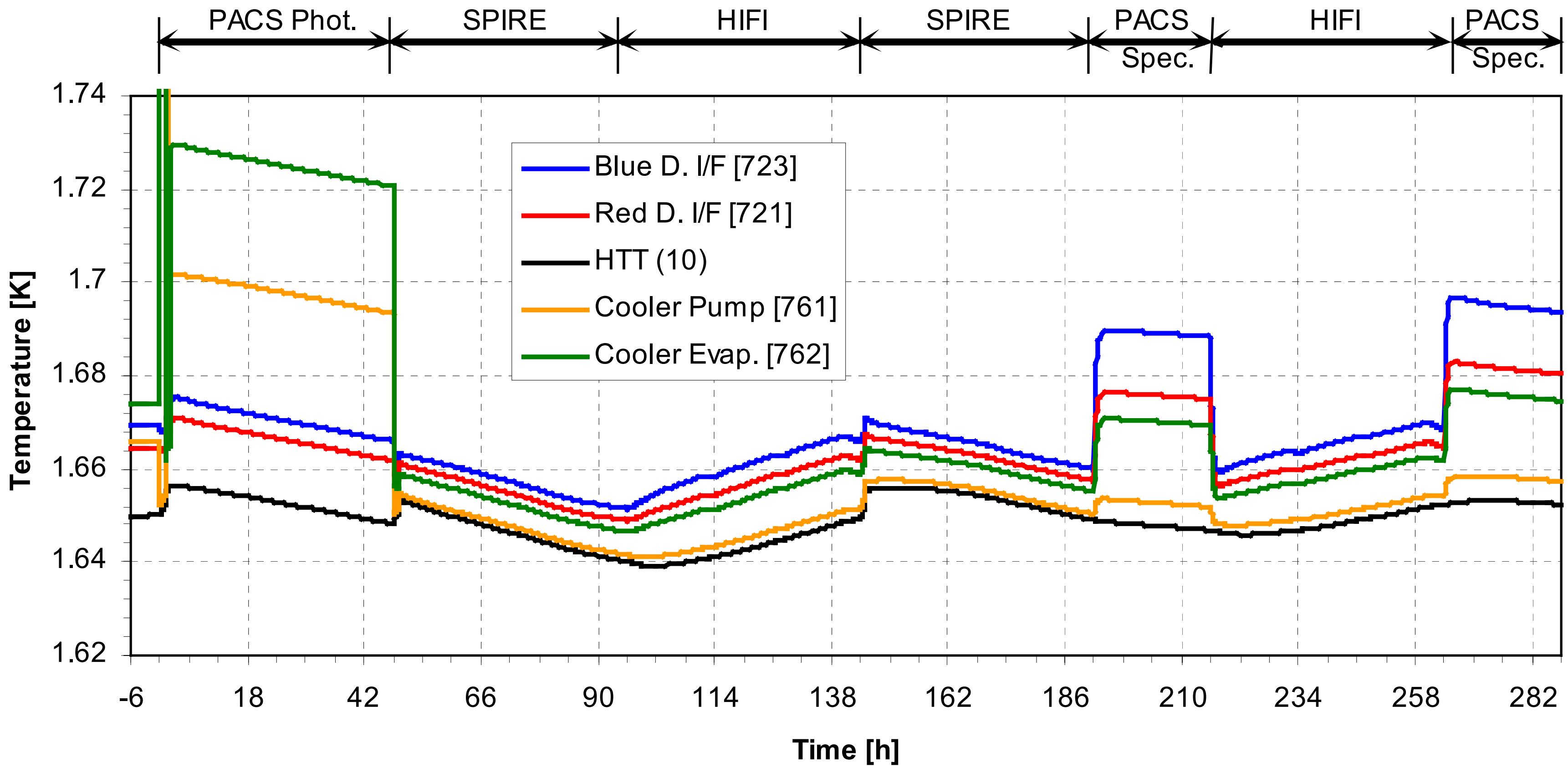
H-EPLM Thermal Analysis

Overall Instrument Timeline for Herschel Instruments

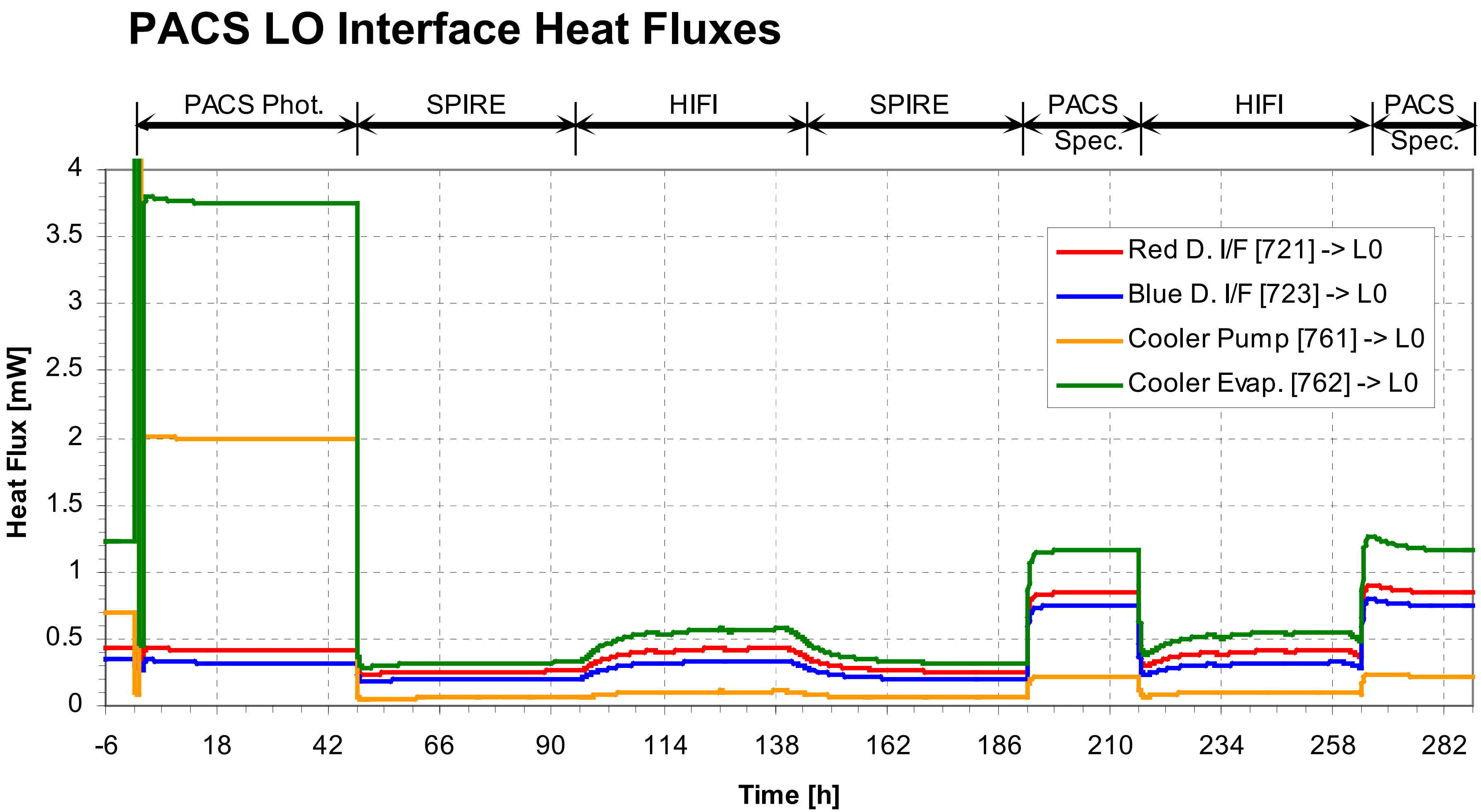
Start conditions (steady state):	Instruments average dissipation
PACS Photometer Mode (incl. sorption cooler cycle)	48 h
SPIRE	48 h
HIFI	48 h
SPIRE	48 h
PACS Spectrometer Mode (no sorption cooler cycle)	24 h
HIFI	48 h
PACS Spectrometer Mode (no sorption cooler cycle)	24 h

H-EPLM Thermal Analysis

PACS LO Interface Temperatures EOL

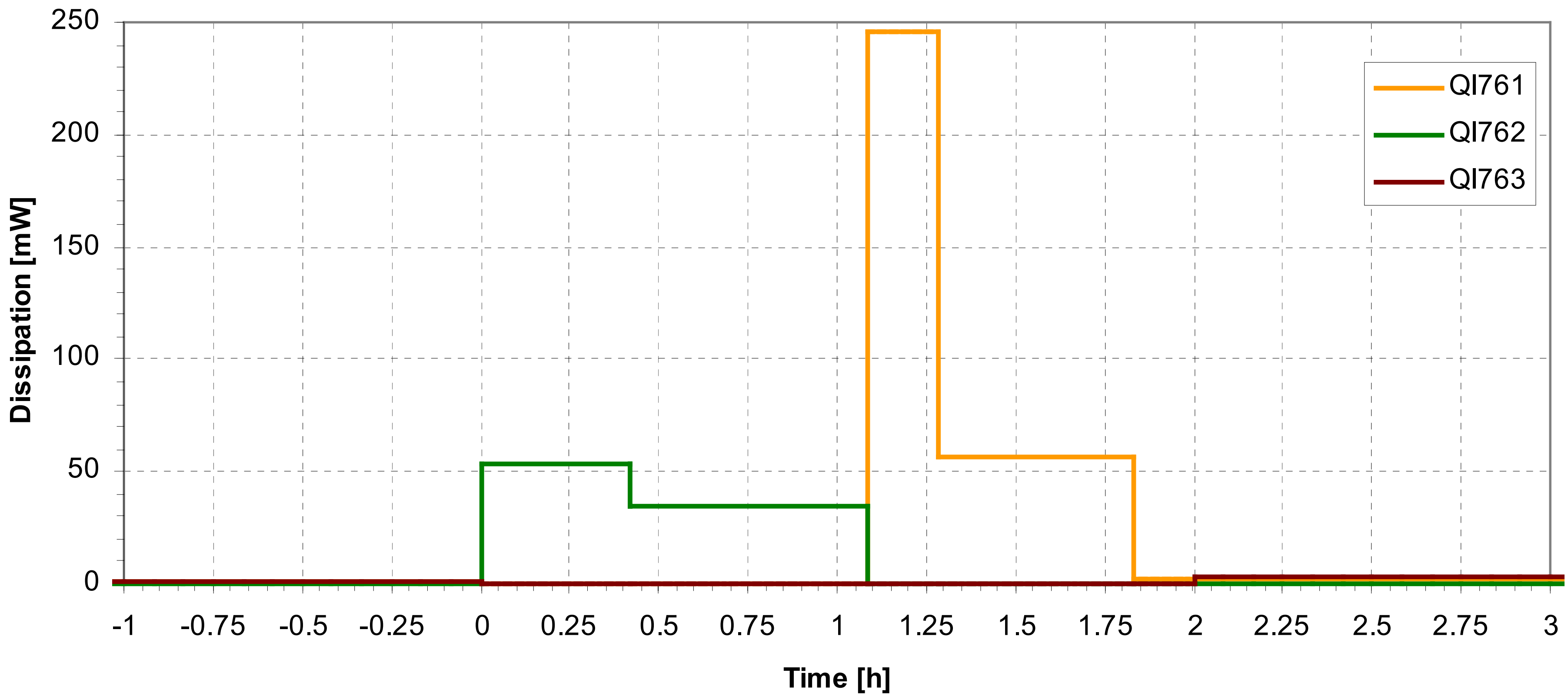


H-EPLM Thermal Analysis



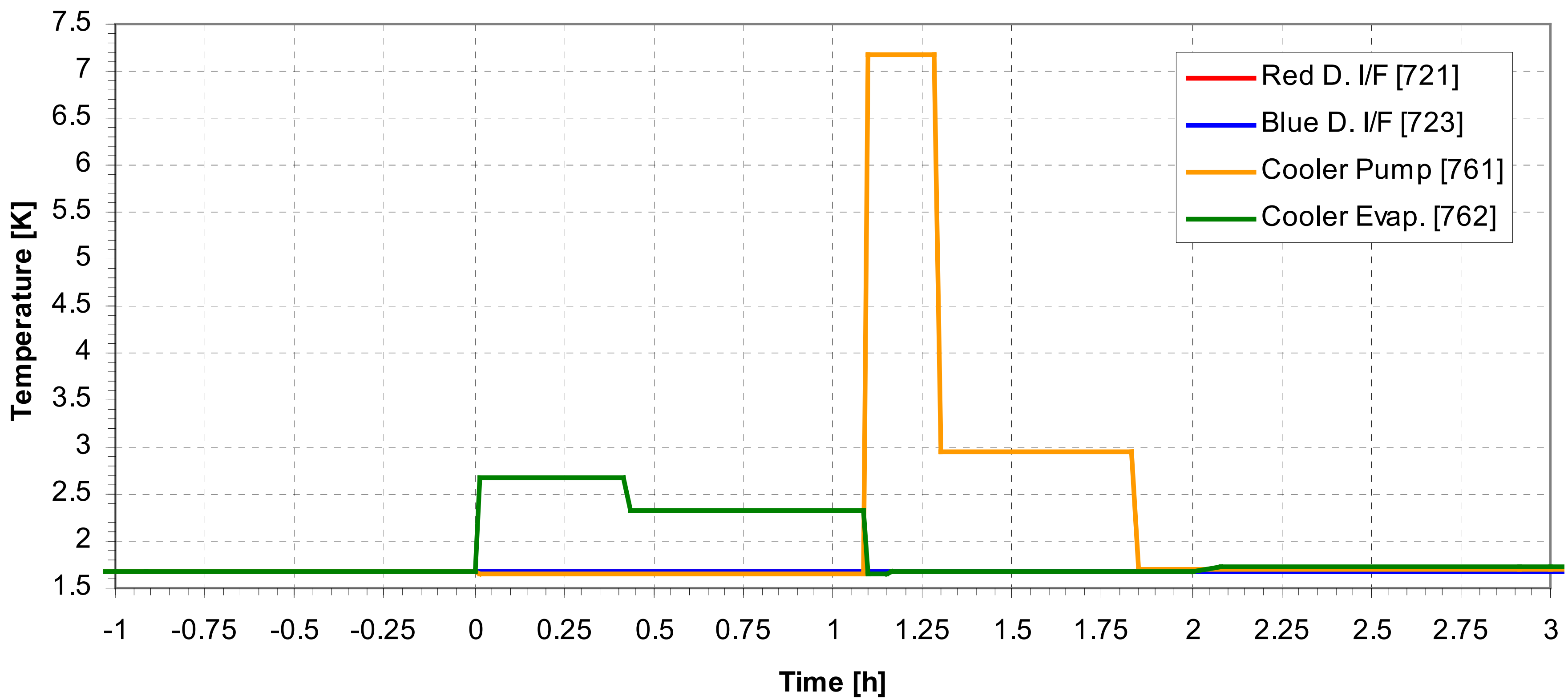
H-EPLM Thermal Analysis

PACS LO Dissipation during Recycling

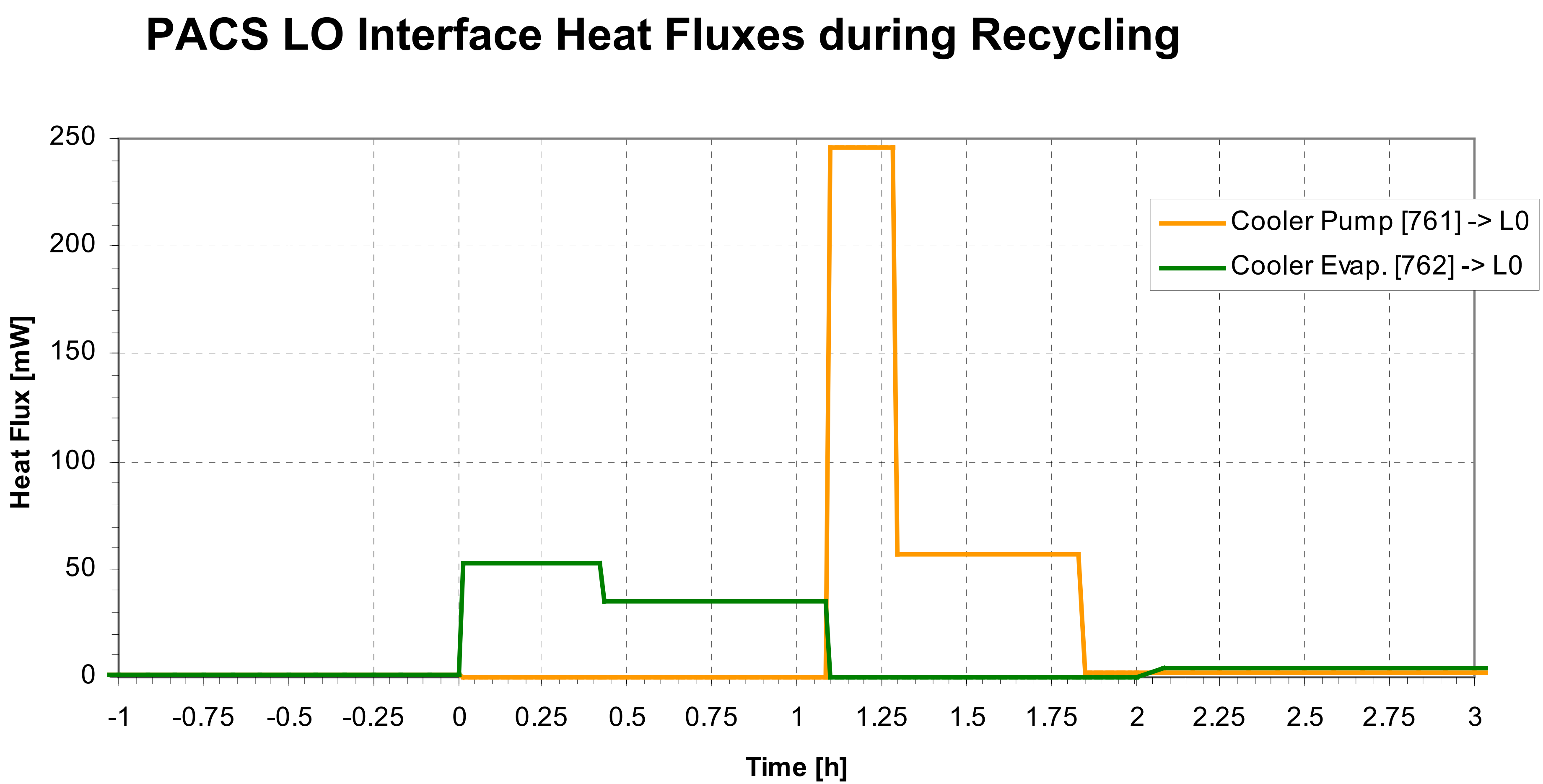


H-EPLM Thermal Analysis

PACS LO Interface Temperatures during Recycling

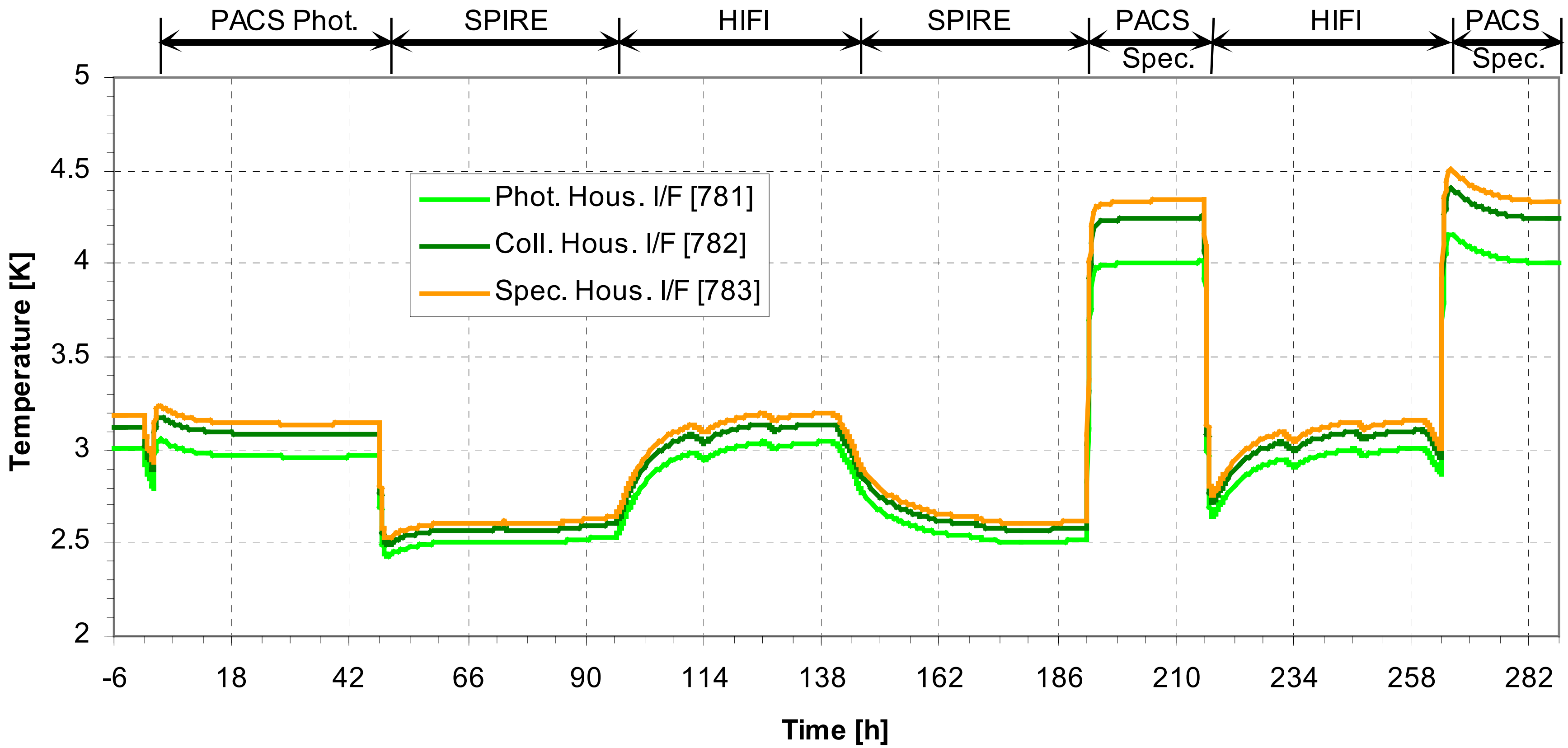


H-EPLM Thermal Analysis



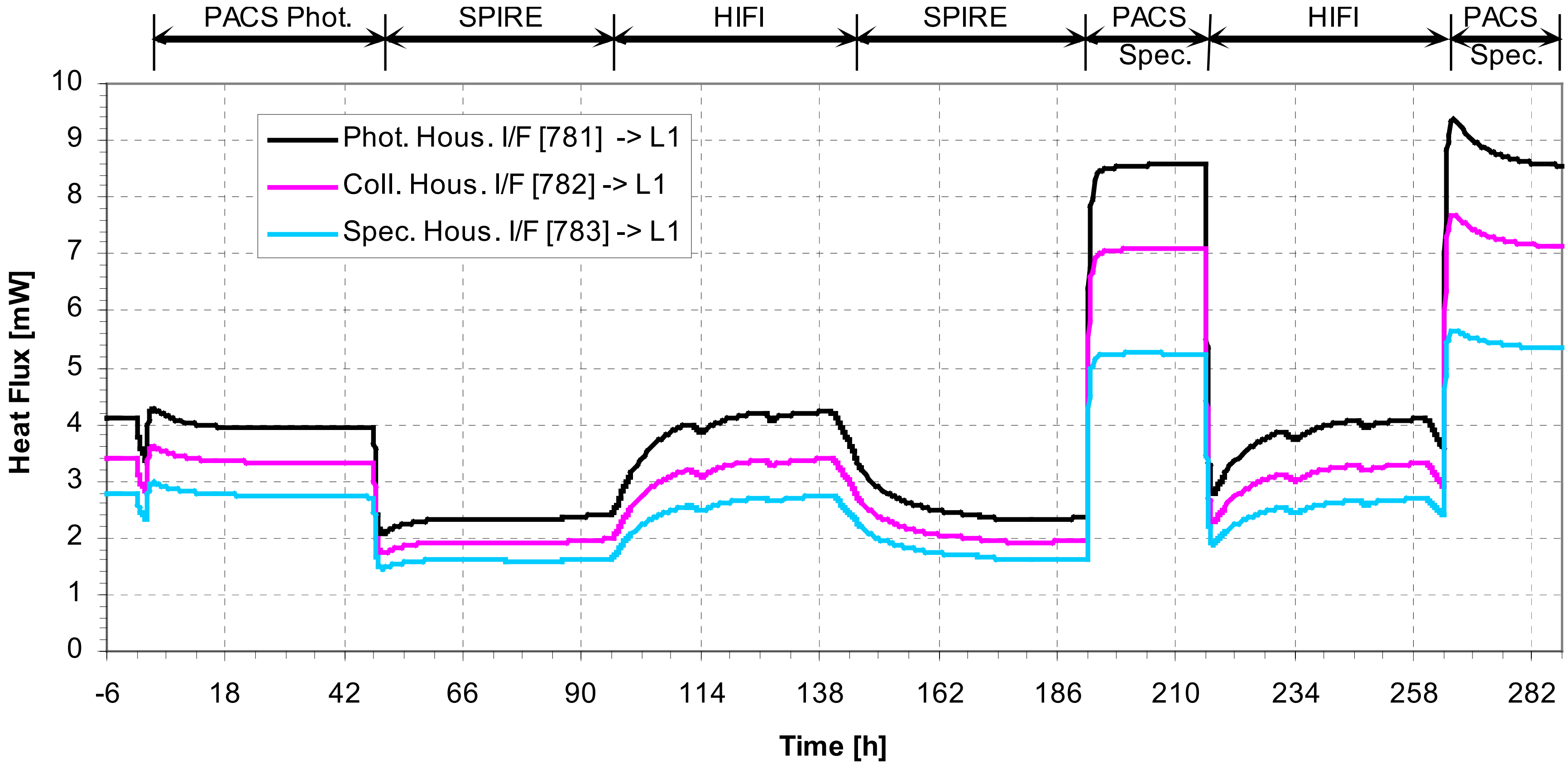
H-EPLM Thermal Analysis

PACS L1 Interface Temperatures



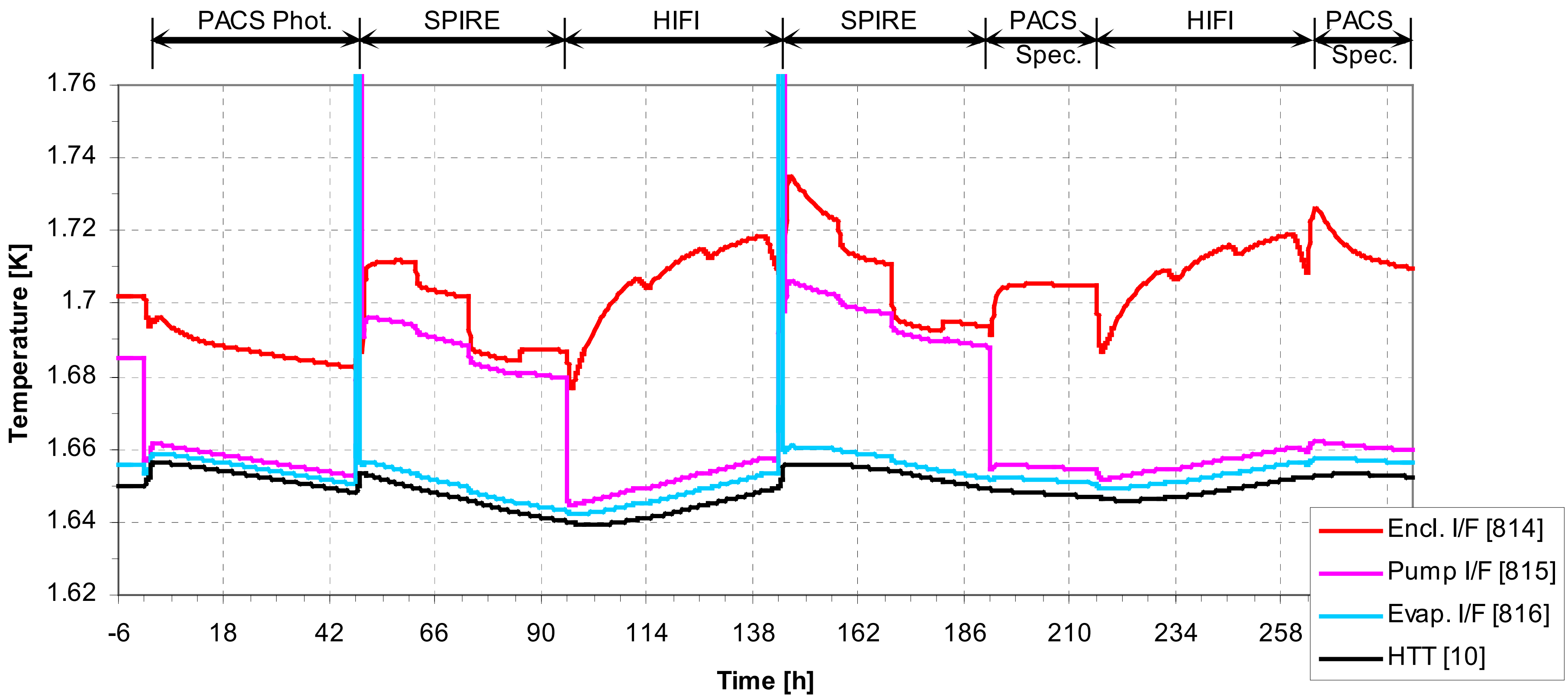
H-EPLM Thermal Analysis

PACS L1 Interface Heat Fluxes



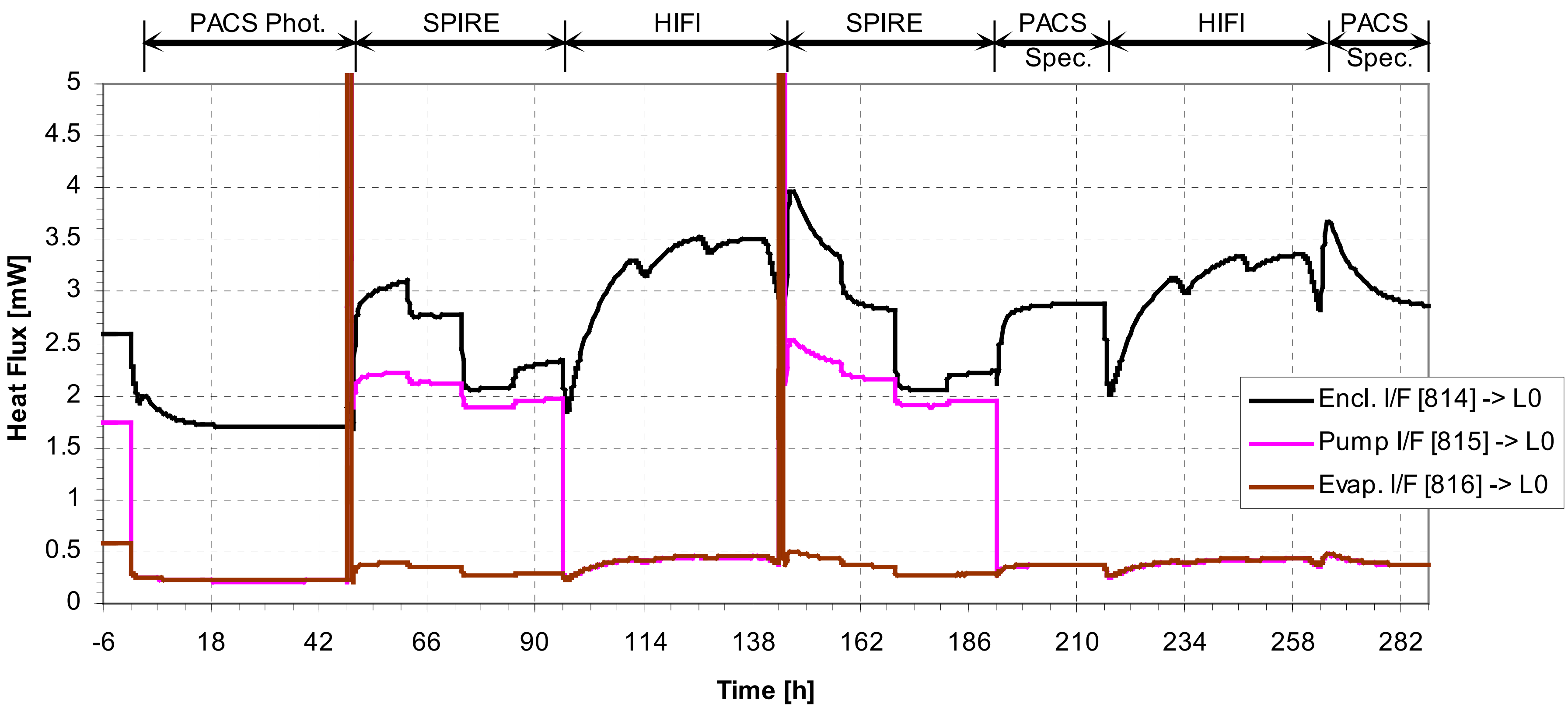
H-EPLM Thermal Analysis

SPIRE L0 Temperatures



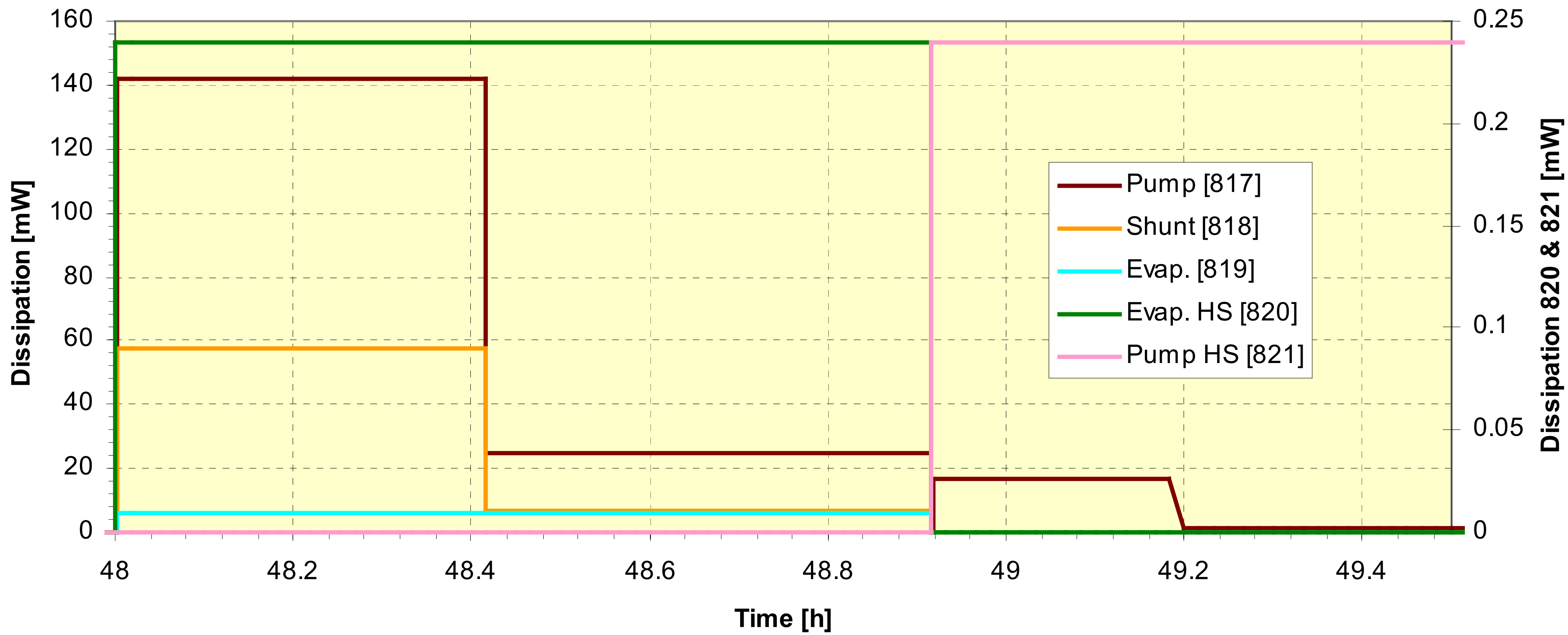
H-EPLM Thermal Analysis

SPIRE L0 Interface Heat Fluxes



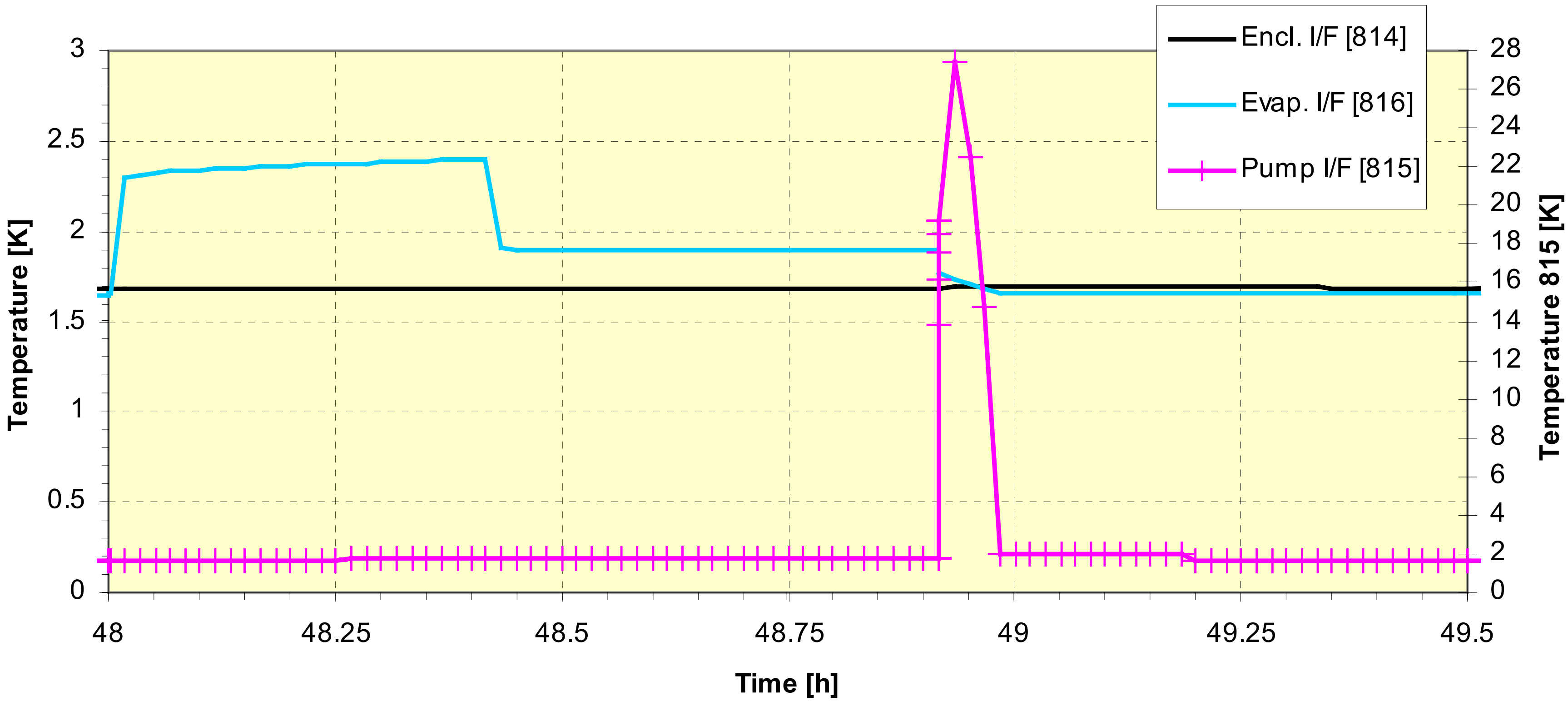
H-EPLM Thermal Analysis

SPIRE L0 Dissipation during Recycling



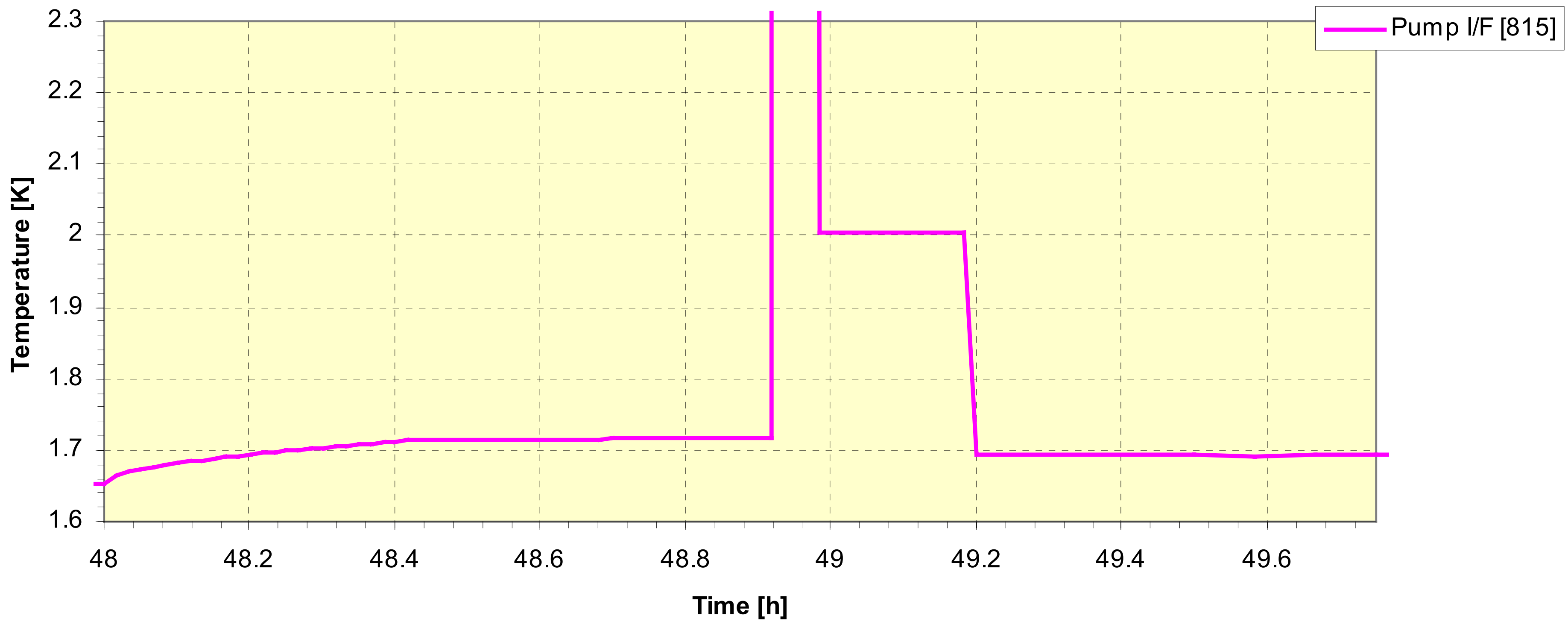
H-EPLM Thermal Analysis

SPIRE L0 Interface Temperatures during Recycling



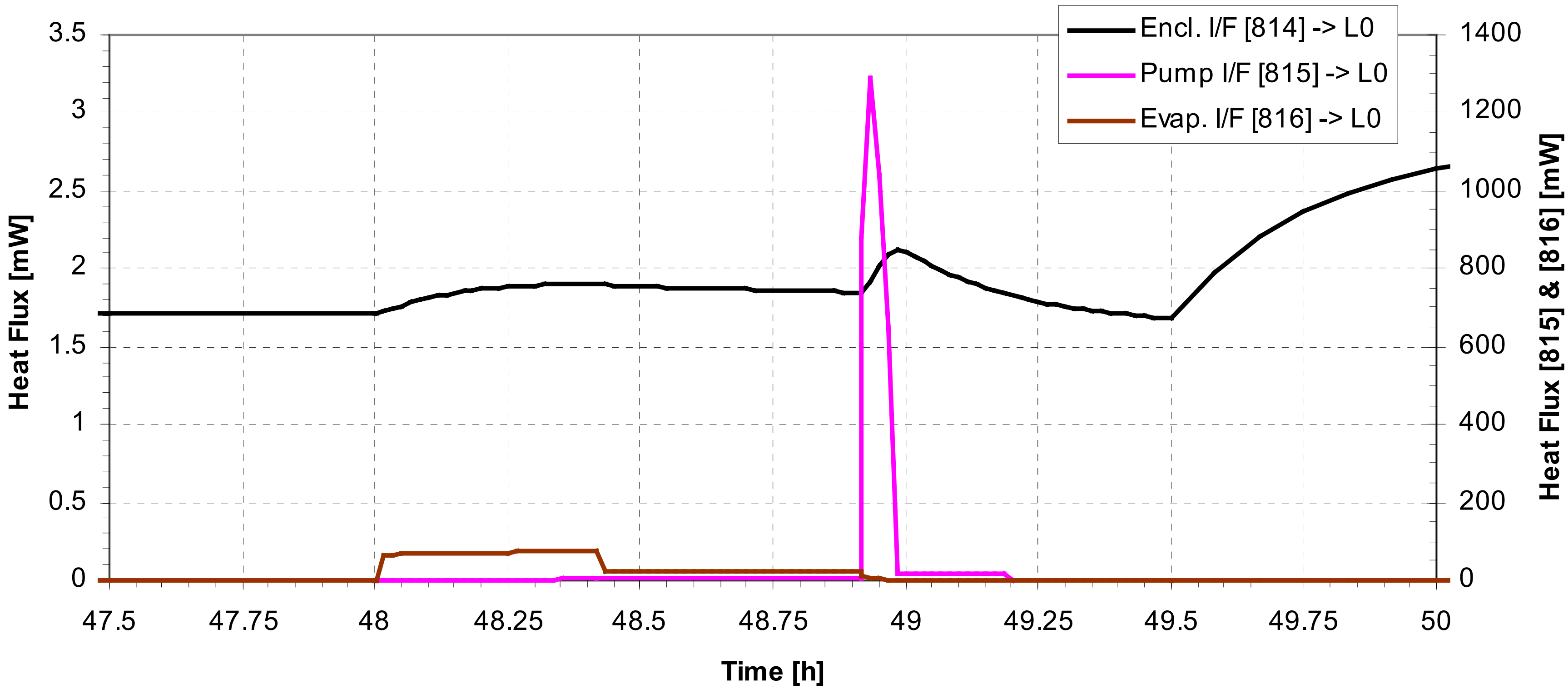
H-EPLM Thermal Analysis

SPIRE L0 Interface Temperatures during Recycling



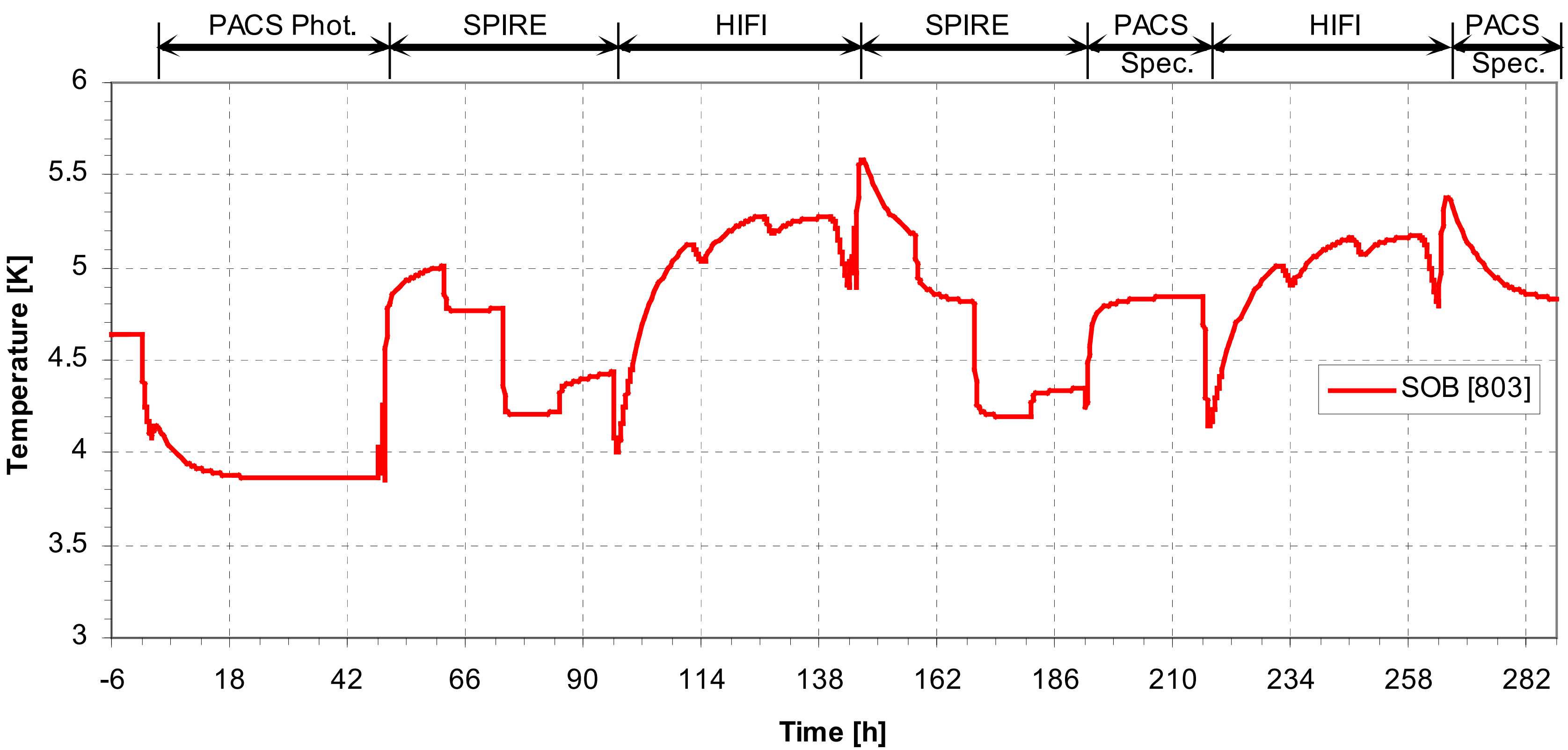
H-EPLM Thermal Analysis

SPIRE L0 Interface Heat Fluxes during Recycling



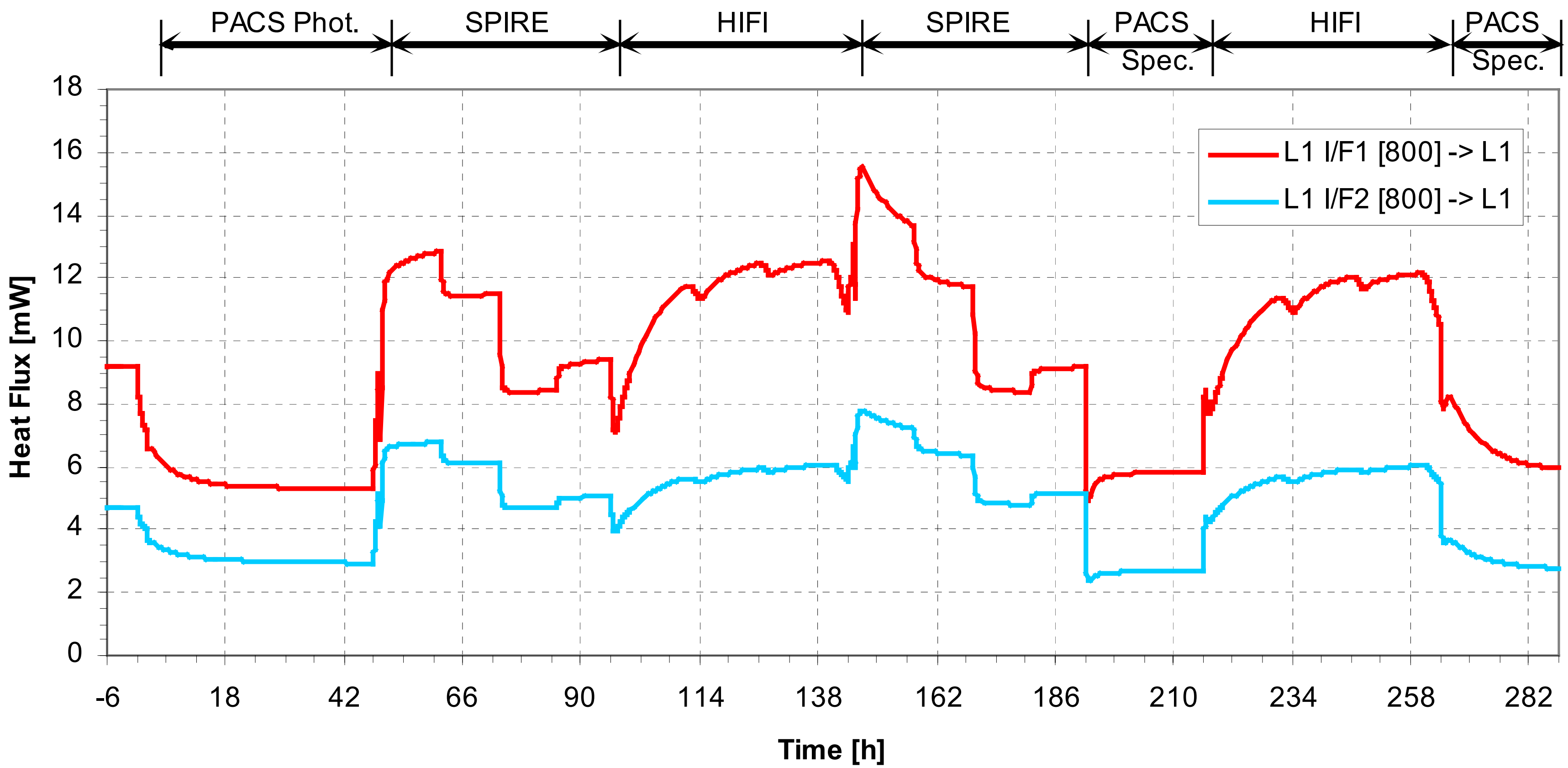
H-EPLM Thermal Analysis

SPIRE L1 Interface Temperatures

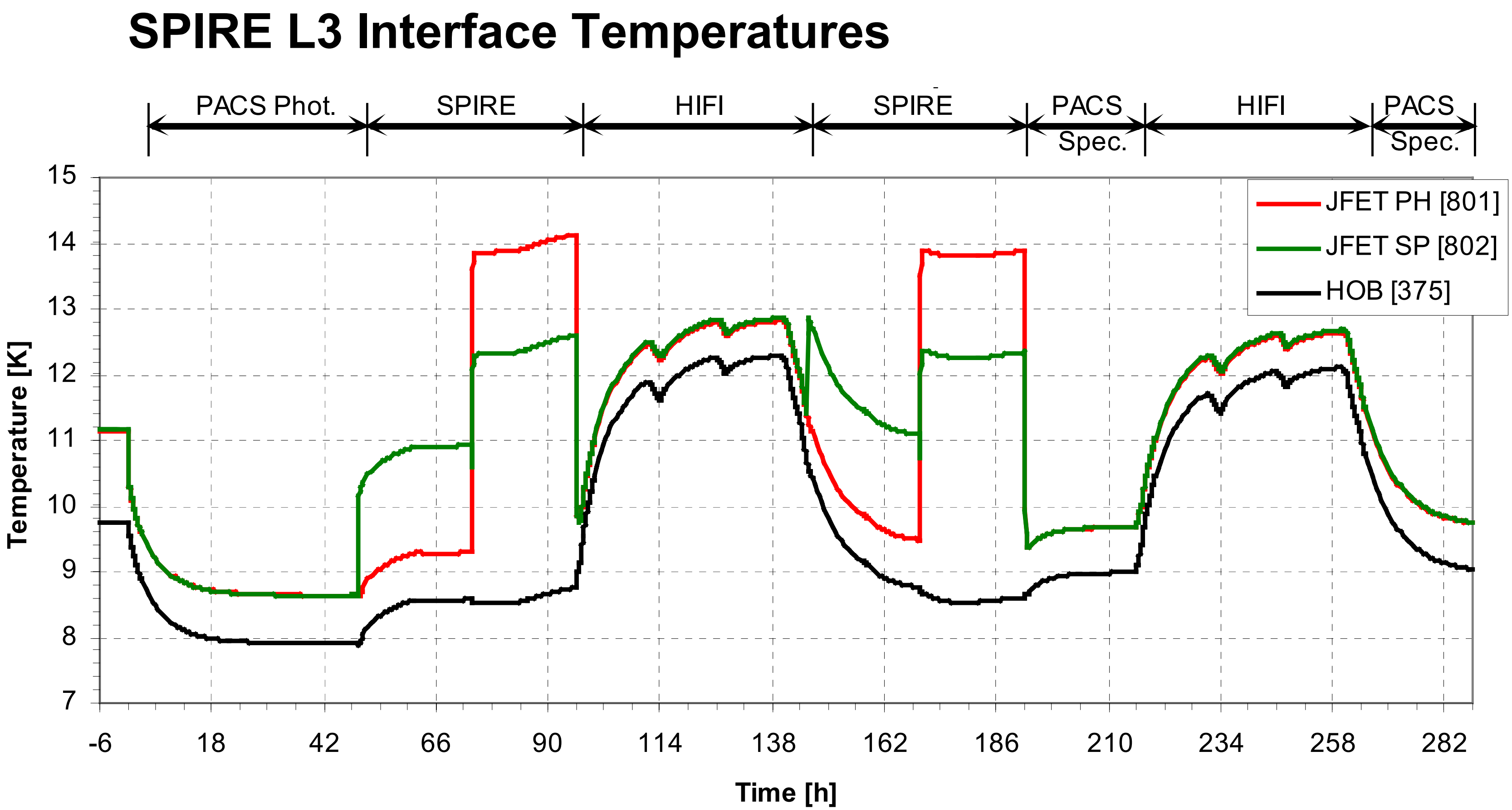


H-EPLM Thermal Analysis

SPIRE L1 Interface Heat Fluxes

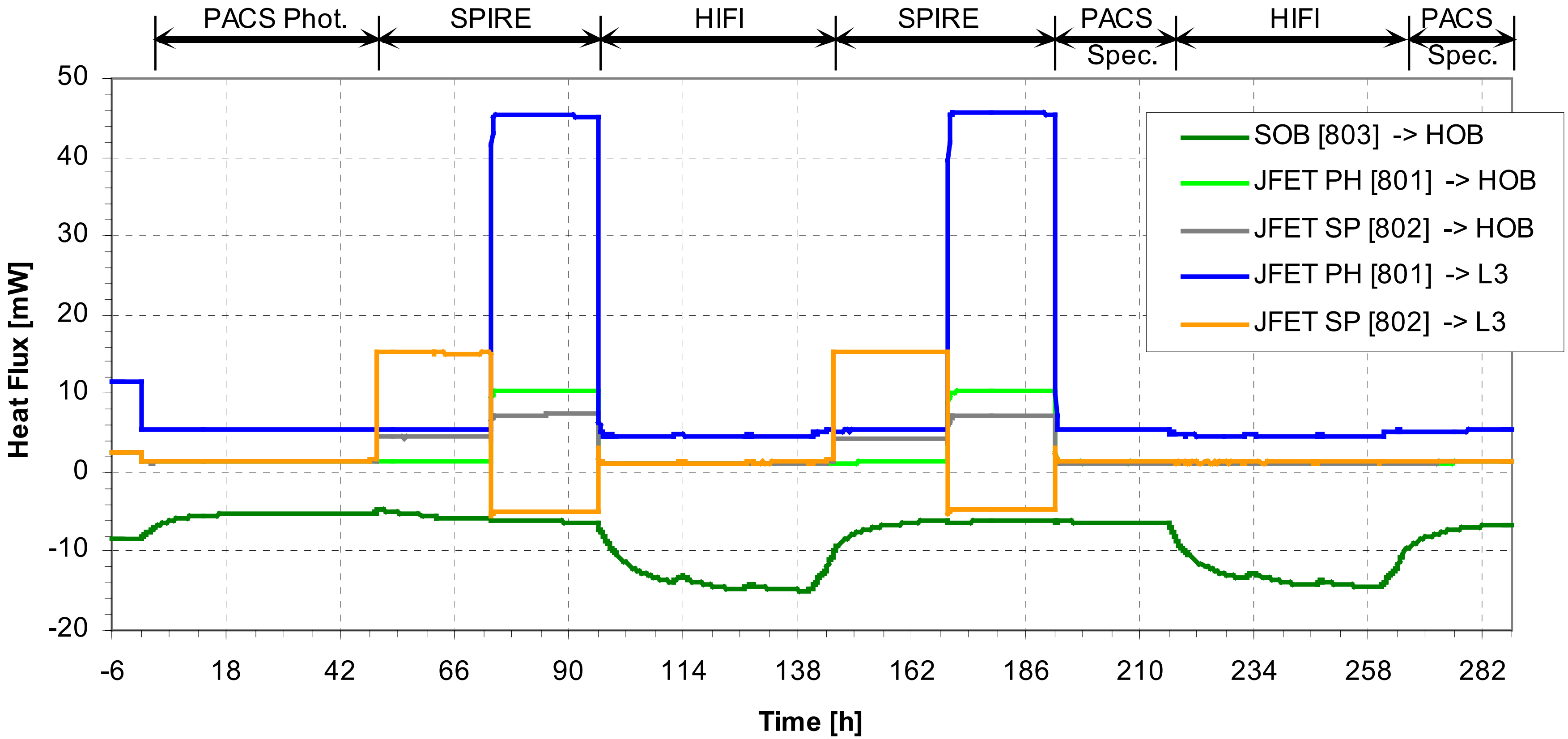


H-EPLM Thermal Analysis



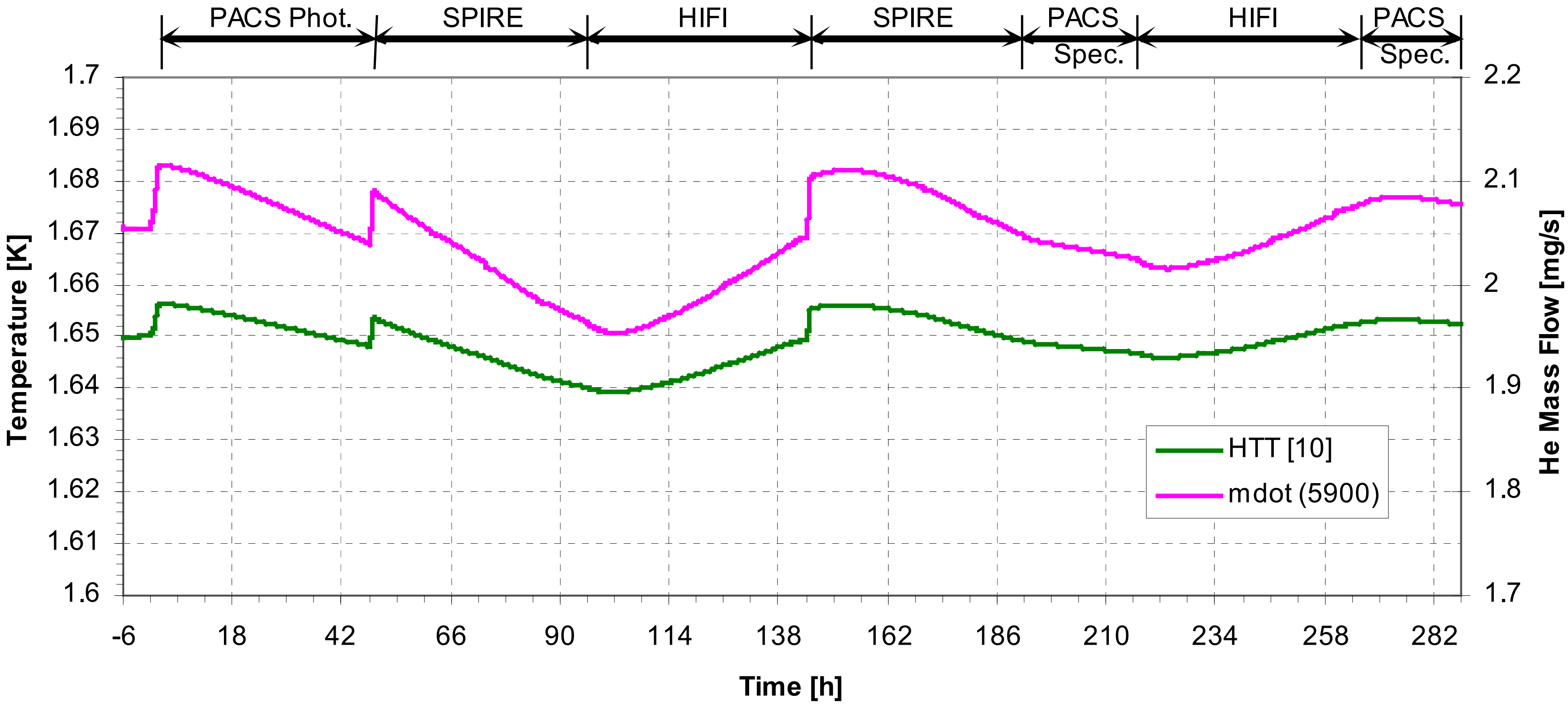
H-EPLM Thermal Analysis

SPIRE L2/L3 Interface Heat Fluxes



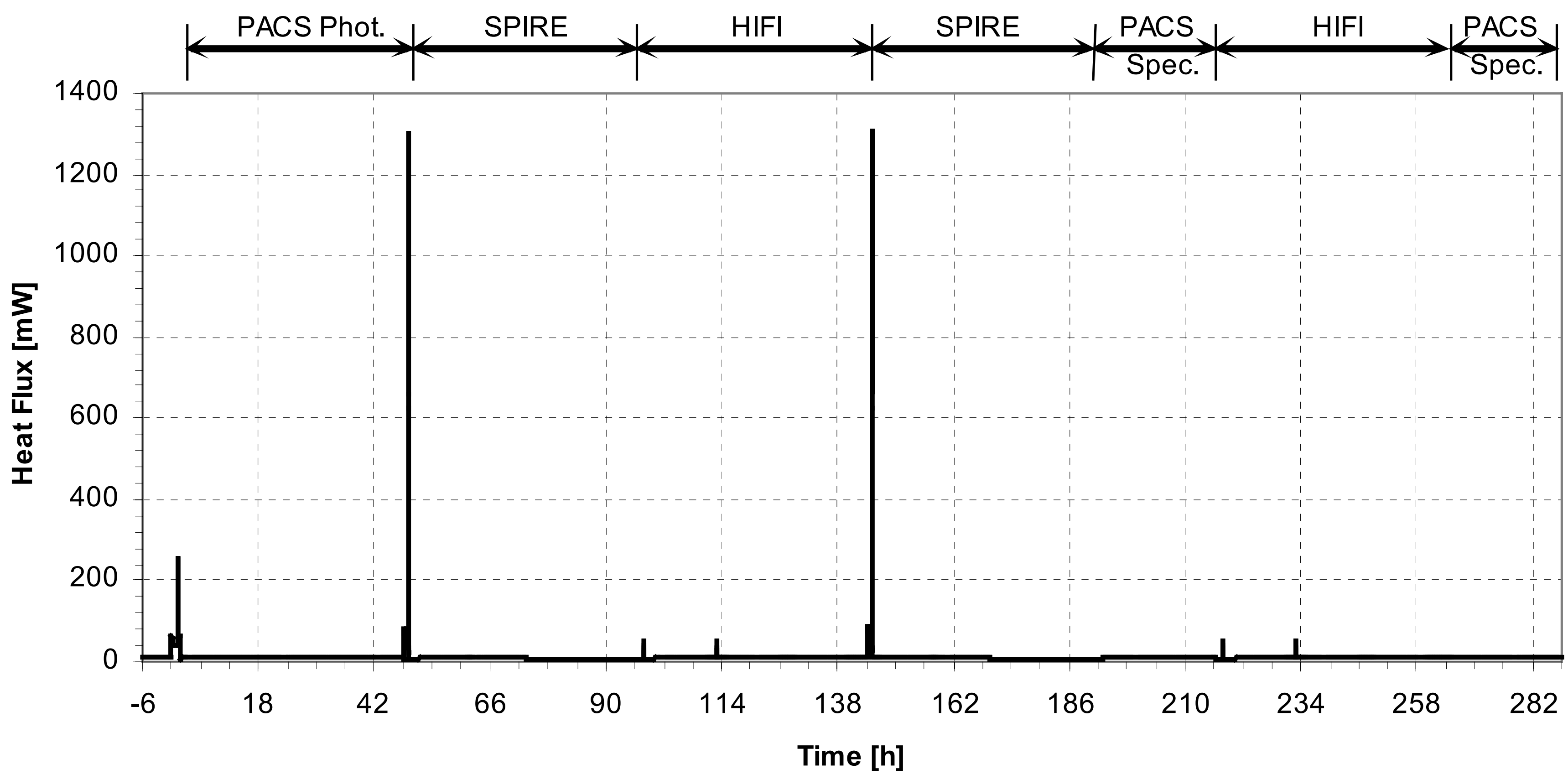
H-EPLM Thermal Analysis

HTT Temperature and He Mass Flow



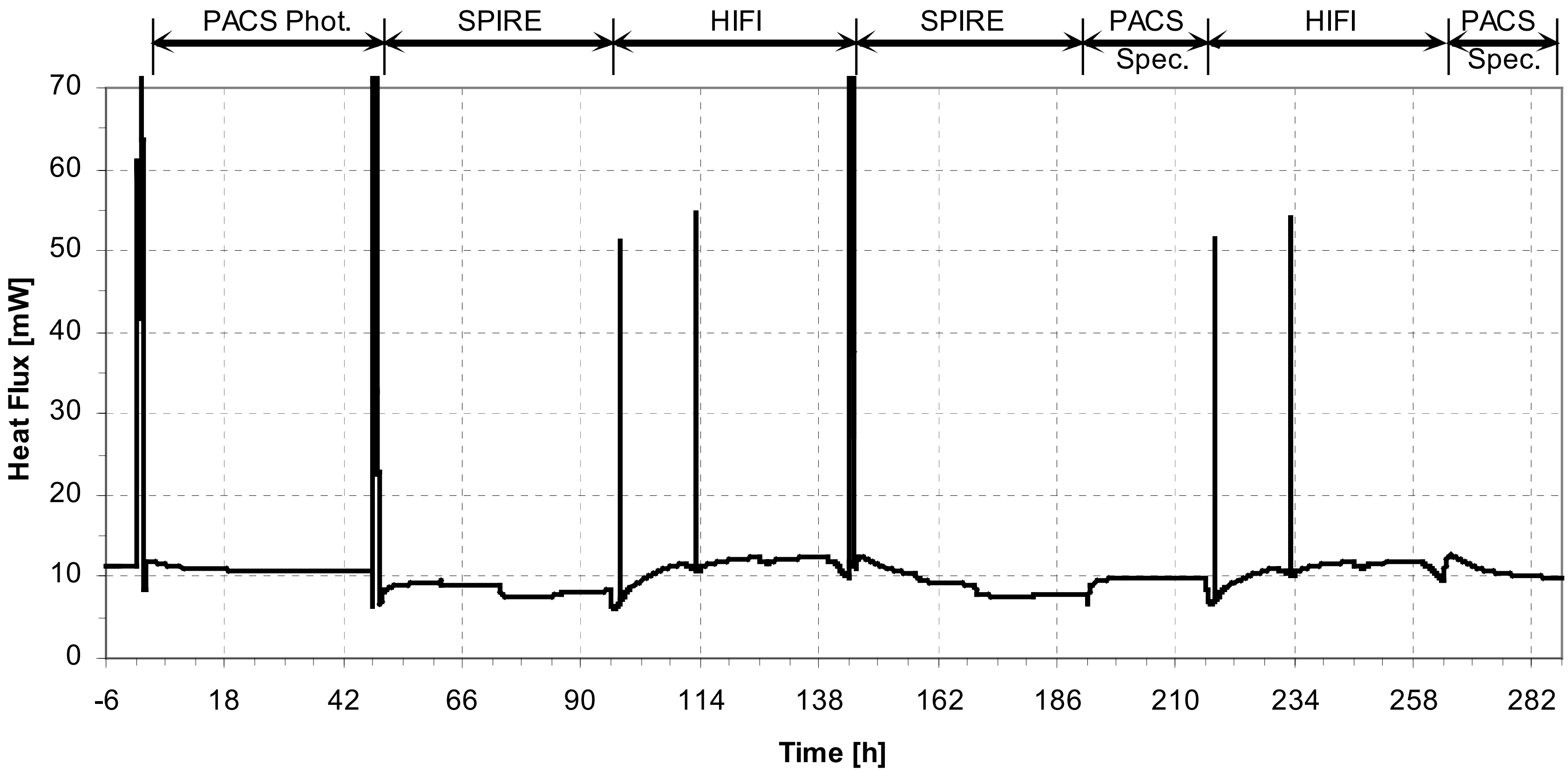
H-EPLM Thermal Analysis

Instrument L0 Instrument Heat Fluxes Summed Up



H-EPLM Thermal Analysis

Instrument L0 Instrument Heat Fluxes Summed Up



H-EPLM Thermal Analysis

Temperature Uncertainty and Margin Philosophy

	Uncertainty due to physical parameters	Uncertainty due to other parameters	Total uncertainty (Σ mean root square)	ASED design margin
L0, PACS	±0.025 K	±0.05 K (He temp.*)	±0.056 K	+ tbd K
SPIRE	±0.025 K	±0.05 K	±0.056 K	+ 0.02 K (tbc)
HIFI	±0.025 K	±0.05 K	±0.056 K	+ tbd K
L1, PACS	±0.18 K	±0.05 K (He temp.*)	±0.187 K	+ 0.2 K
SPIRE	±0.35 K	±0.05 K	±0.354 K	+ 0.3 K
HIFI	±0.32 K	±0.05 K	±0.333 K	+ 0.3 K
L2, HOB	±0.5 K	±0.22 K (orbit environ.)	±0.72 K**	+ 0.5 K (tbc)

*) HTT design temperature: 1.65K ± 0.05K
**) linear superposition

→ **Note: L1 temperature depends also on He mass flow**

H-EPLM Thermal Analysis

Conclusions:

- **Transient Herschel EPLM TMM with implemented Instrument TMMs run stable**
- **PACS and SPIRE Cooler Recycling modelling different**
- **SPIRE temperatures after HIFI operation different to those after PACS**

Instrument Thermal Link IF Meeting

PACS Thermal Interfaces

CASE / L. Morgenroth,
KT / D. Kampf, C. Körner
MPE / R. Katterloher, J. Schubert

Overview

- PACS Thermal and Mechanical Requirements to Level 0 and Level 1 I/Fs
- Mechanical Level 0 and Level 1 I/Fs to S/C
- PACS Level 0 Internal Cooling Straps
  - Ge:Ga detectors
  - Photometer
- New Thermal Results
  calculations with upgraded PACS TMM
  - Stationary
  - Transients (with old SPIRE TMM -> no SPIRE/PACS parallel mode)

PACS CR #9 (Dec. 2002) on Temperature Requirements of the PACS Sorption Cooler

PACS IIDB Convergence Meeting / Annex 1 : **26 Feb. 2002**

CR - Change Agreements Page 18 / 18

Instrument interface	Temp. Level	TMM Node (TBC)	Operating		Cooler re-cycling	Non-operating		Switch-off
			Min	**Max**	**MAX**	**Min**	**Max**	
FPFPU.OPT Optics/Structure Assy.	L1	711	3.0	5.0	5.0	N/A	60 °C *) 85 °C **) - TBC	N/A
FPFPU Red Detector	L0	701	1.6	1.75	~~1.75~~ **NA**		60 °C *) 85 °C **) - TBC	
FPFPU Blue Detector	L0	702	1.6	2.0	~~2.0~~ **NA**		60 °C *) 85 °C **) - TBC	
Cooler Pump	L0	704	1.6	2.2	10		60 °C *) 85 °C **) - TBC	
Cooler Evaporator	L0	703	1.6	~~2.0~~ **1.85**	~~2.0~~ **1.85**		60 °C *) 85 °C **) - TBC	

*) Continuous temperature limit
**) Short-duration temperature limit for bake-out during a maximum of TBD hrs.

Performance of the PACS and SPIRE Sorption coolers under various operating conditions.

Same as Table A, except it is assumed the heat sink to the cryostat drops back down to 1.8 K once the condensation phase is completed

Table C (12 µW net heat lift)		Condensation temperature (K)		
		1.8	**2**	**2.2**
Structure temperature (K)	**4**	54	51	47.5
	5	49	46	42.5
	6	43	40.5	37.5

[Hold time given in hours)

Same as Table B except it is assumed the heat sink to the cryostat drops back down to 1.8 K once the condensation phase is completed

Table D (46 hours hold time)		Condensation temperature (K)		
		1.8	**2**	**2.2**
Structure temperature (K)	**4**	17	15	13
	5	14	12	9.5
	6	9.5	7.5	5.5

[Net heat lift given in µW)

PACS CR #8 (Nov. 2001) on Mechanical Requirements of the PACS Sorption Cooler

Loads on Level 0 Cooling Straps

A) I/F for the distribution boards 1 and 2 (Ge:Ga detectors)

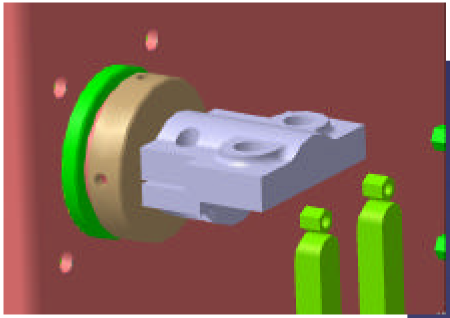
The sum of the static and dynamic loads shall not exceed the values given below.

Lateral:	108 N
Axial:	2680 N
Torque:	1,8 Nm

B) I/F for the cooler pump and cooler evaporation switches (Photometer)

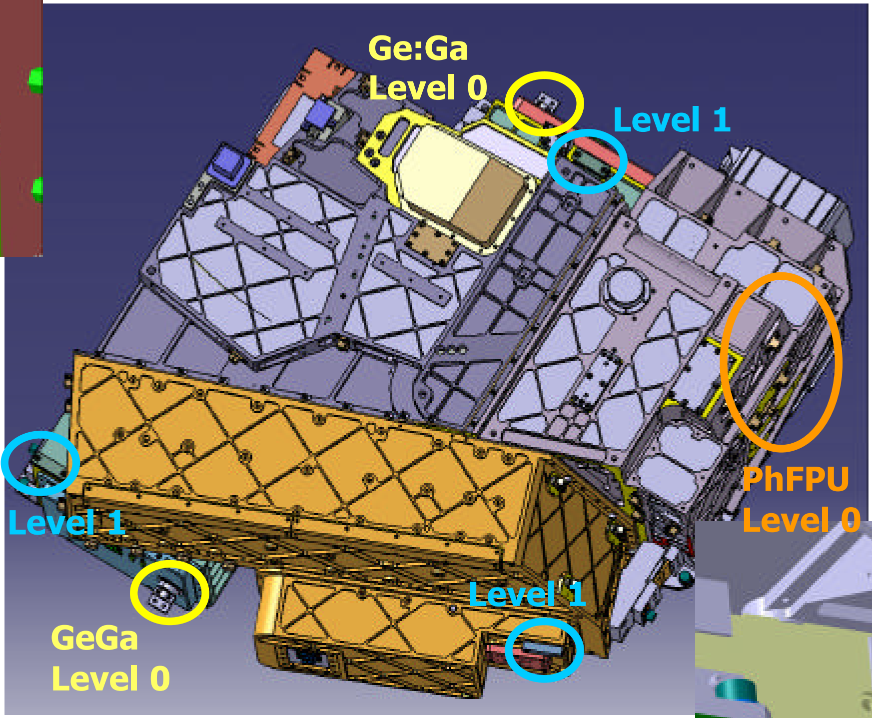
Static load:	50 N
Dynamic load:	50 additional grams providing 20.8G rms random spec.

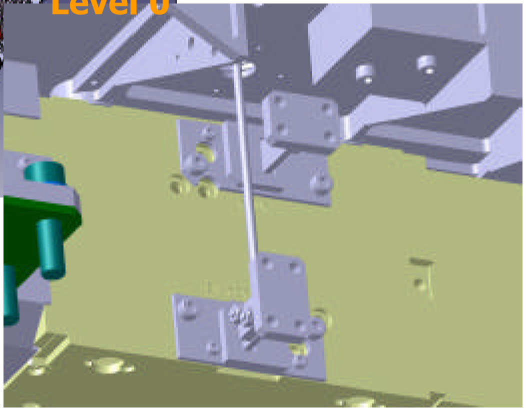
PACS Thermal I/Fs to SC



GeGa Level 0 I/F (2x)

Pin I/F changed to rectangular I/F, soldered to pin; **I/F to blue detector thermally variable to minimize heating**

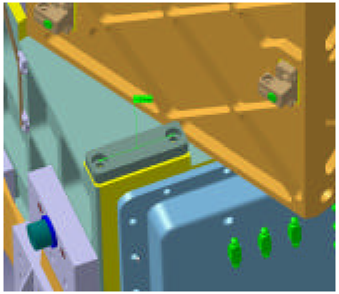




PhFPU/Cooler Level 0 I/F (2x)

Adapter to overcome mounting problems and baffled to insure light tightness

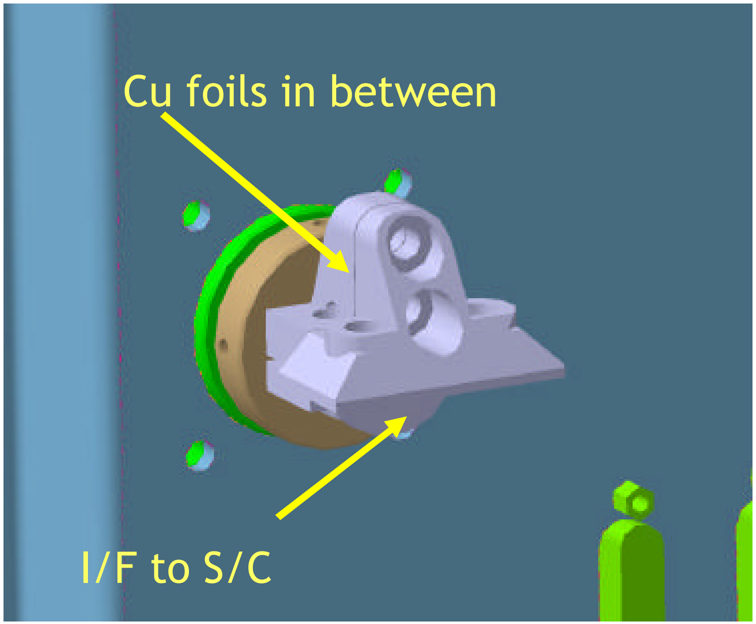
BUT !!!

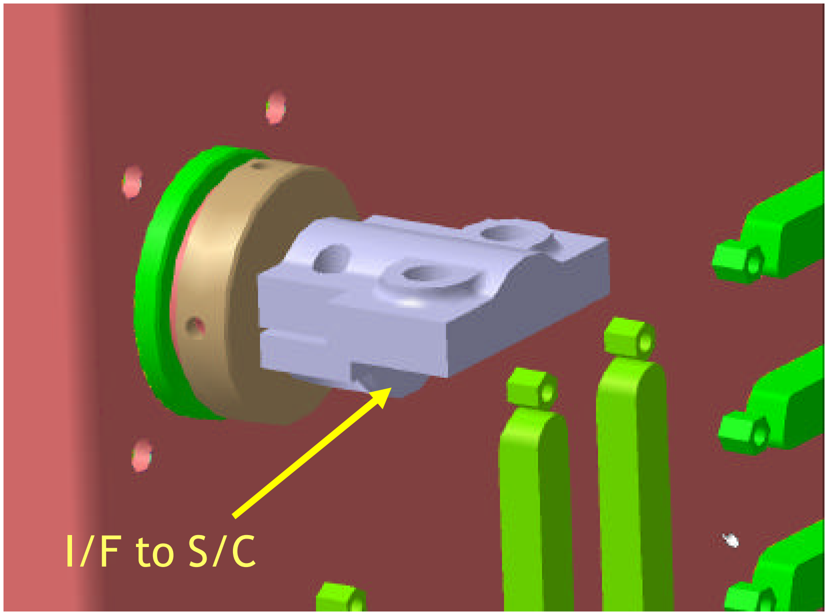


Level 1 I/F (3x)

Thread distance changed from 33 mm to 37 mm

PACS Thermal I/Fs to GaGa Detectors

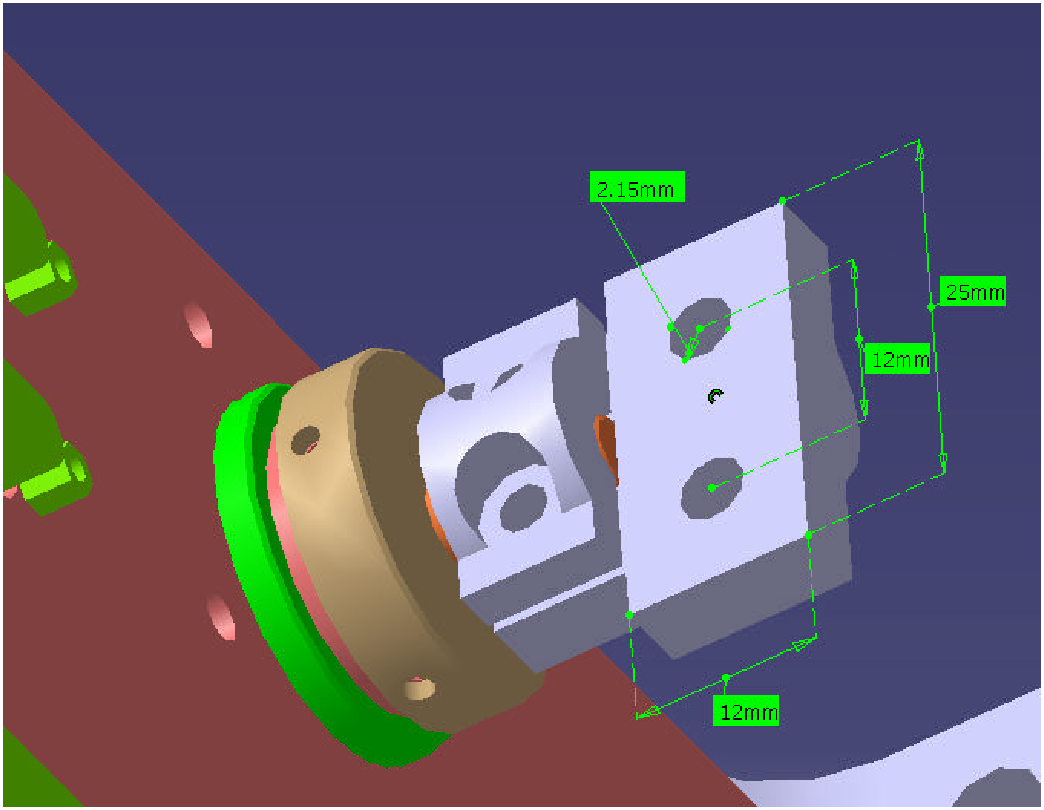




Blue GeGa Detector, **thermally tuneable**

Red GeGa Detector

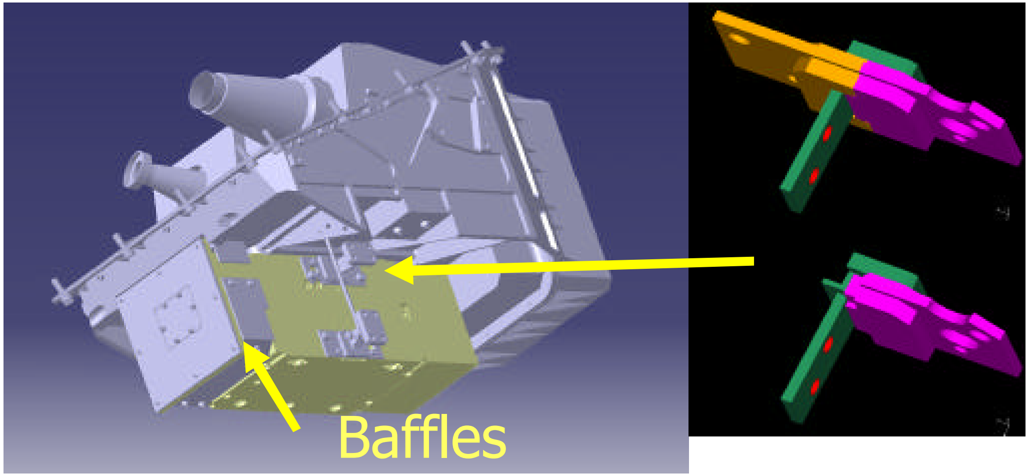
PACS Thermal I/Fs to GaGa Detectors (cont.)



Common Blue/Red GeGa Detector I/F to S/C, view from below

Photometer Cooler IF to Level 0

- Bolometer Cooler mounted externally to the PACS FPU with shortest possible distance to the OB
- Strap mounting tools to protect sensitive switches during 2K strap mounting will be provided
- Cooler covered by a closed 4K-baffle to reduce radiation load. Baffle at the Cooler I/Fs is cut in two parts. This allows to mount them after the straps are screwed on the Cooler switches thermal I/F



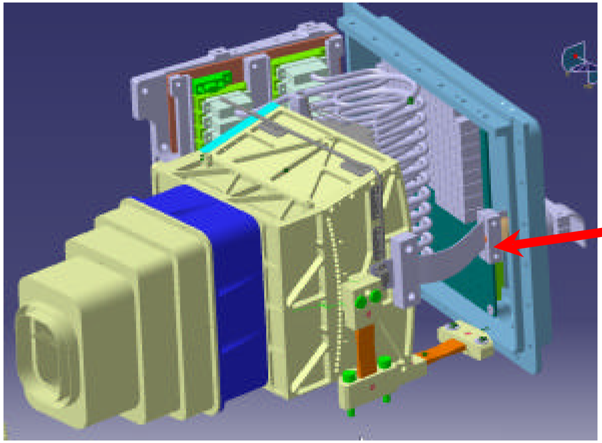
Photometer Cooler IF to Level 0 (cont.)

- Current design with I/F adapter and cooler switches
- **CEA suggests to change the Cooler I/F (no adapter) to avoide the additional thermal contact resistance between cooler switches and adapter**

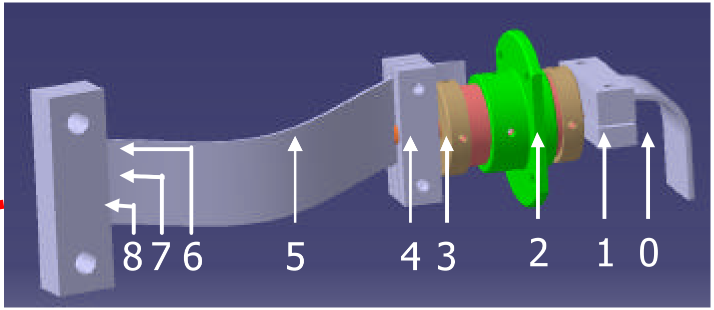
  CEA presentation tomorrow

- Current results with PACS TMM **do not include the additional contact resistance of the "'former" cooler I/F adapter!**

Ga:Ga internal Detector Cooling Strap (I)



Blue Detector with Distribution Board



0) TR: ESA IF to clamp, screwed
1) TR: ext. Cu clamp to Cu Pin feed through
2) HC: Cu pin 2K feed through
3) TR: Cu pin feed through to Cu int. clamp
4) TR: int. clamp to Cu strap
5) HC: Cu strap
6) TR: Cu to Sapphire, screwed
7) HC: Sapphire
8) TR: Sapphire to Al I/F at detector, screwed

TR: Thermal Resistance HC: Heat Conduction

Requirements:

Level 0 IF Temperature to Space Craft:

Min: 1.6K Max: 1.75K (Red Det.) 2.0K (Blue Det.)

Detector Operation Temperature

Blue Detector 1.8K ….. 2.6K

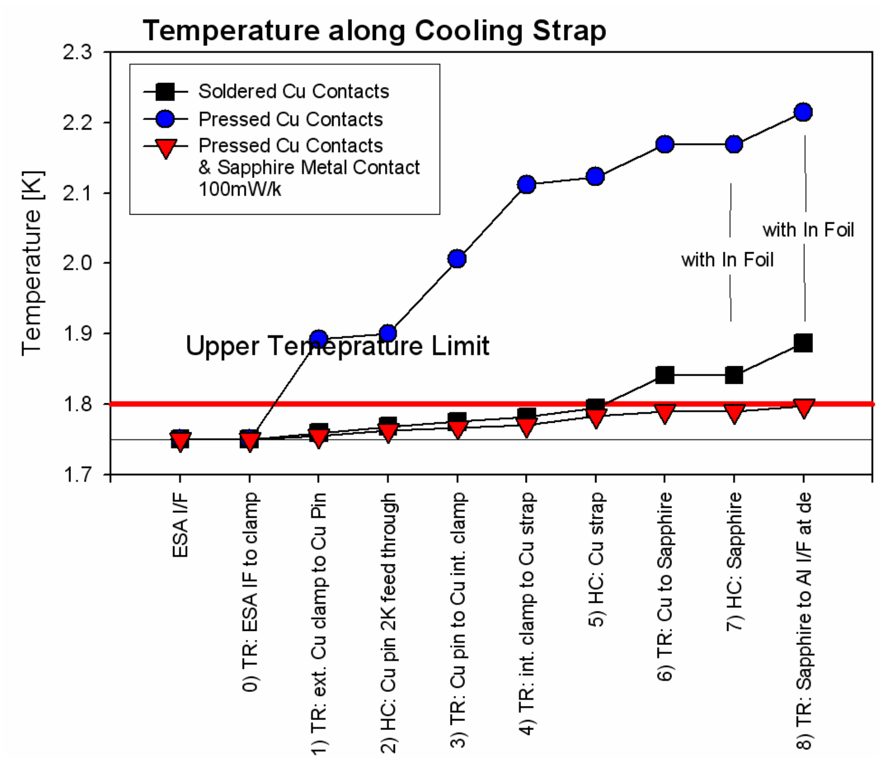
Red Detector 1.8K

→ **DT of 50 mK allowed**

Elect. isolated via Sapphire Slice

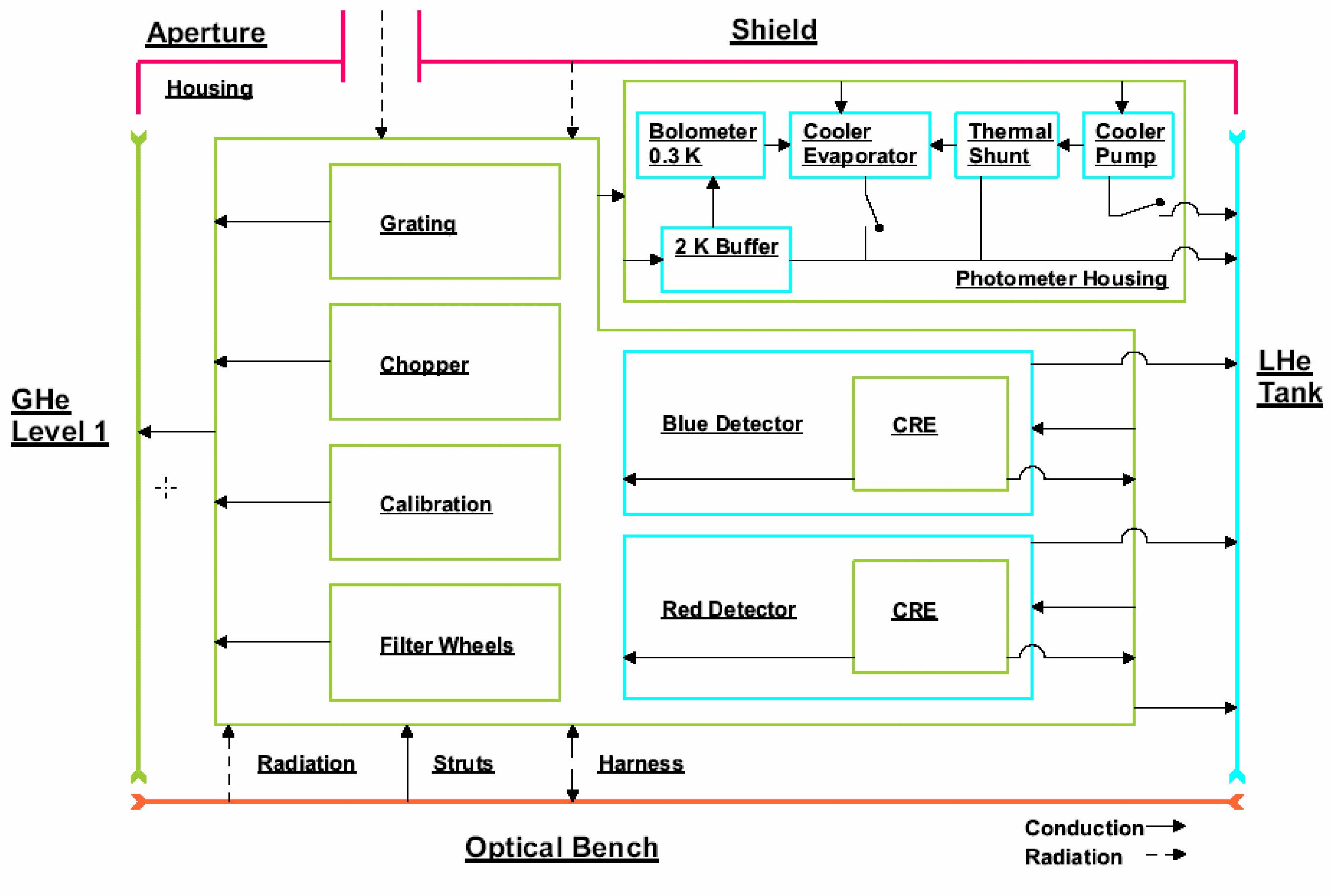
Ga:Ga Detector Cooling Strap (II)

- 400mW/K assumption on thermal contact conductance at 2K (ISO value) is by far to optimistic



Assumed Thermal Contact Conductance			
	mW/K	mW/K	mW/K
	not soldered	soldered	required
ESA I/F		**used in TMM**	
1) TR: ext. Cu clamp to Cu Pin	6.5")	100	200
3) TR: Cu pin to Cu int. clamp	6.5")	100	200
4) TR: int. clamp to Cu strap	6.5")	100	200
6) TR: Cu to Sapphire	15*)	15*)	**100**
8) TR: Sapphire to Al I/F at det.	15*)	15*)	**100**
Heat Flux	6.5") Cu machiend @2k, 1400N		
Red Detector: 0.69 mW	*) Cu-IndiumFoil-Cu @2K, 670N		
2K Feed-Through: 0.23 mW			

New Calculation with upgraded PACS TMM



I/F Temperatures, Stationary Calculation

Instrument IF	**Spectrometer Mode**		**Photometer Mode (without Recycling)**	
Tank Temparature: 1.7K	**I/F Temperature [K]**	**IF Heat Flux [mW]**	**I/F Temperature [K]**	**IF Heat Flux [mW]**
PACS Blue Detector	1.796	1.63	1.721	0.361
PACS Red Detector	1.715	0.801	1.708	0.399
PACS Cooler Pump	1.705	0.202	1.745	1.998
PACS Cooler Evaporator	1.713	1.078	1.746	3.713
PACS Level 1.1	3.288	9.626	2.570	4.701
PACS Level 1.2	3.705	7.675	2.771	3.711
PACS Level 1.3	3.965	5.297	2.930	2.931

I/F Temperatures, Stationary Calculation (cont.)

Photometer Mode

Flux PACS	->LHe 1.7K	6.471 mW
Flux PACS	->Level 1	11.343 mW
Flux Opt. Bench	->PACS	7.270 mW
Flux w/o Harness-Diss		7.216 mW
Rad Cryostat	->PACS	1.996 mW

Avg.House-Temp: 3.234 K

Opt_Bench-Te_6: 9.275 K

Spectrometer Mode

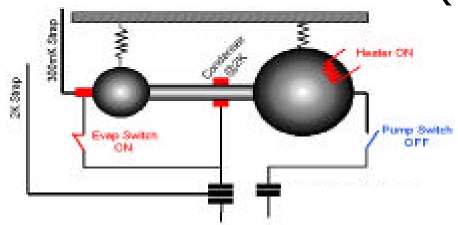
Flux PACS	->LHe 1.7K	3.711 mW
Flux PACS	->Level 1	22.598 mW
Flux Opt. Bench	->PACS	8.829 mW
Flux w/o Harness-Diss		8.805 mW
Rad Cryostat	->PACS	2.063 mW

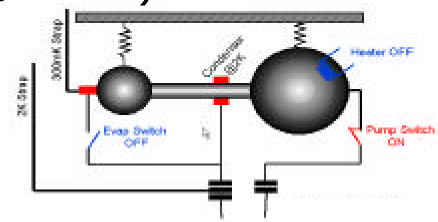
Avg.House-Temp: 4.359 K

Opt_Bench-Te_6: 10.256 K

PACS TMM Transient Calculations

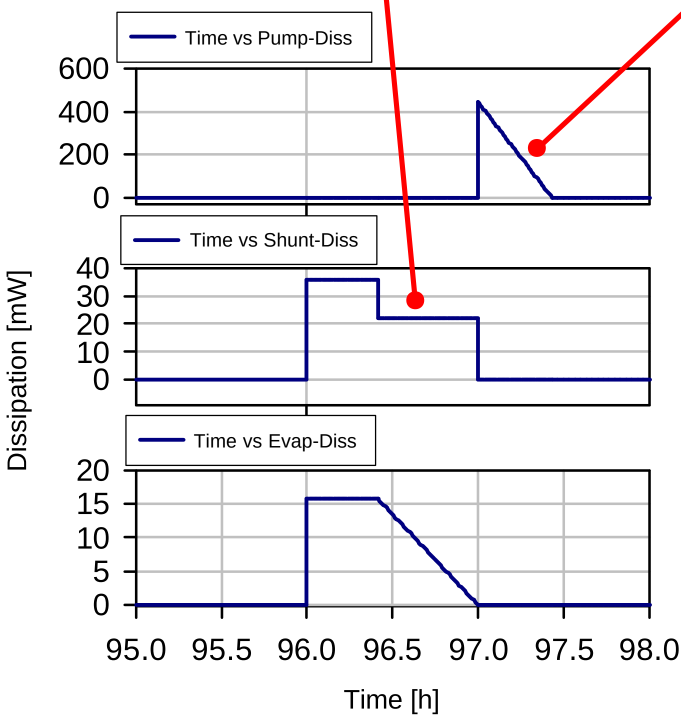
(Tank @ 1.65K)

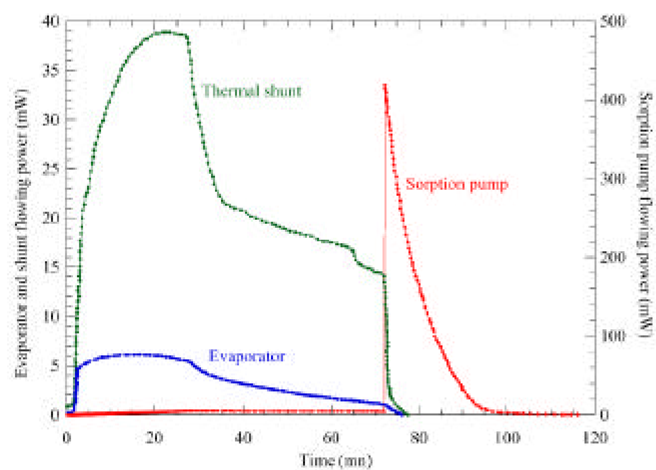




Pump heating up

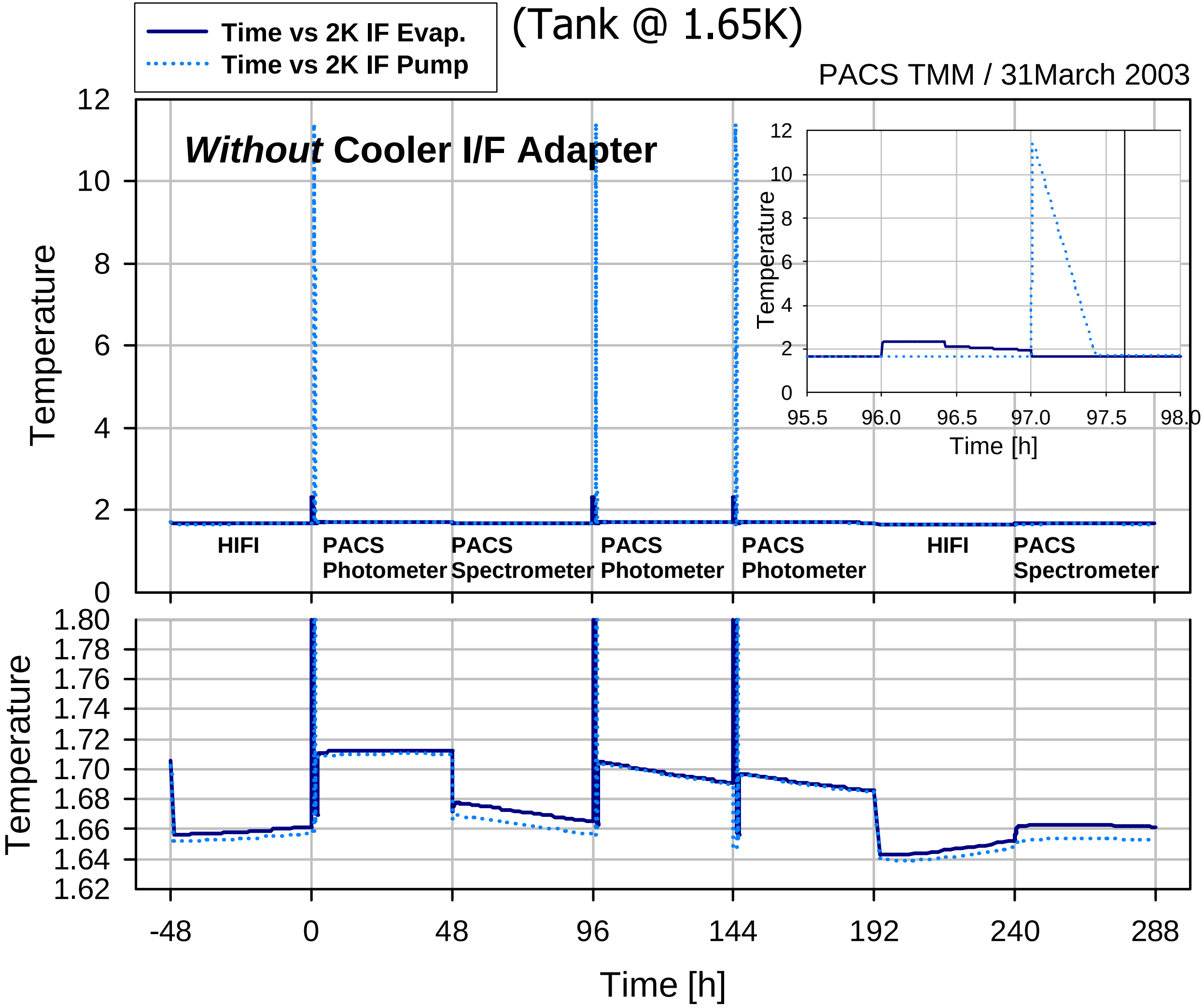
Pump cooling down





PACS TMM Transient Calculations

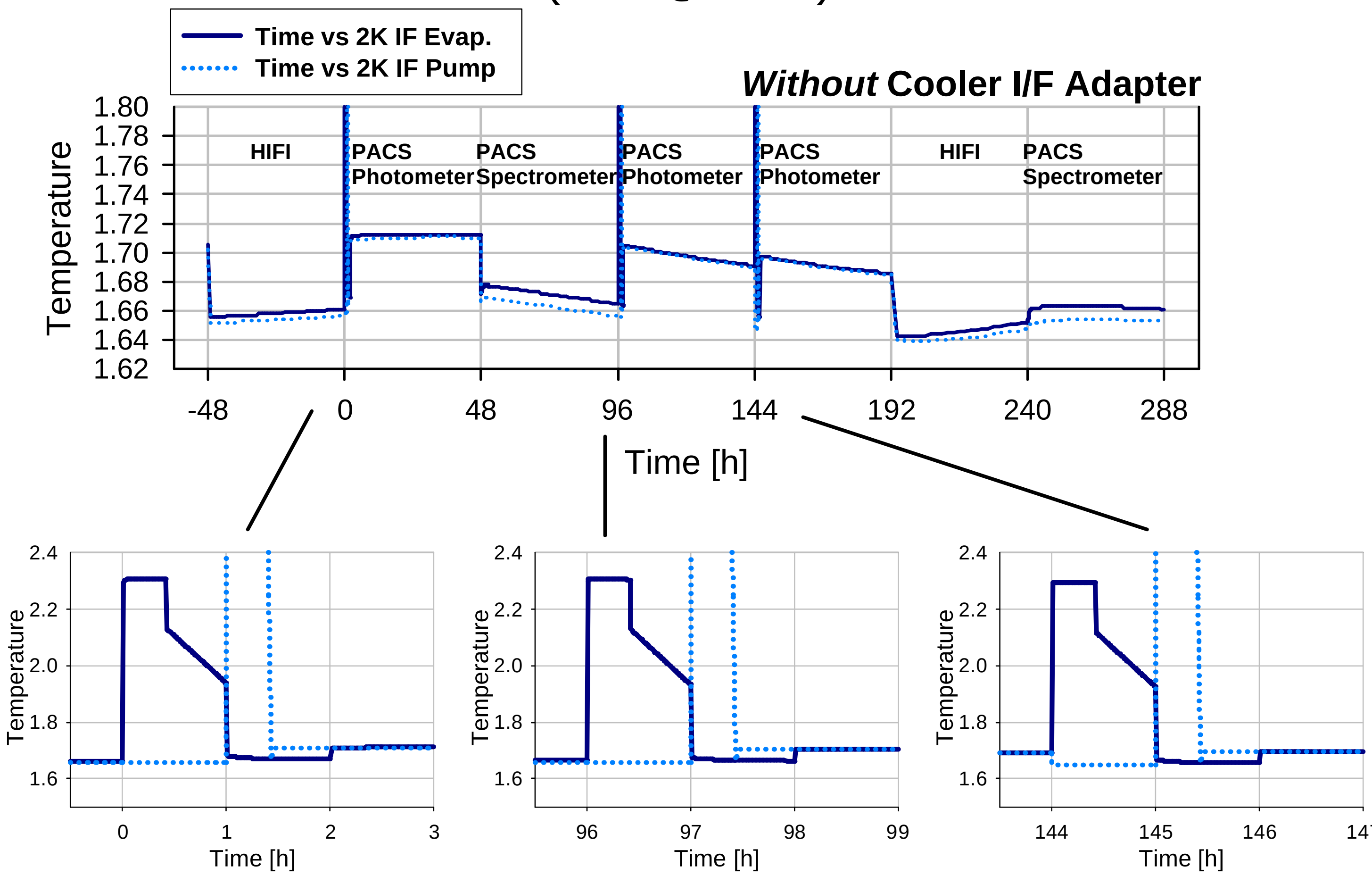
(Tank @ 1.65K)



St

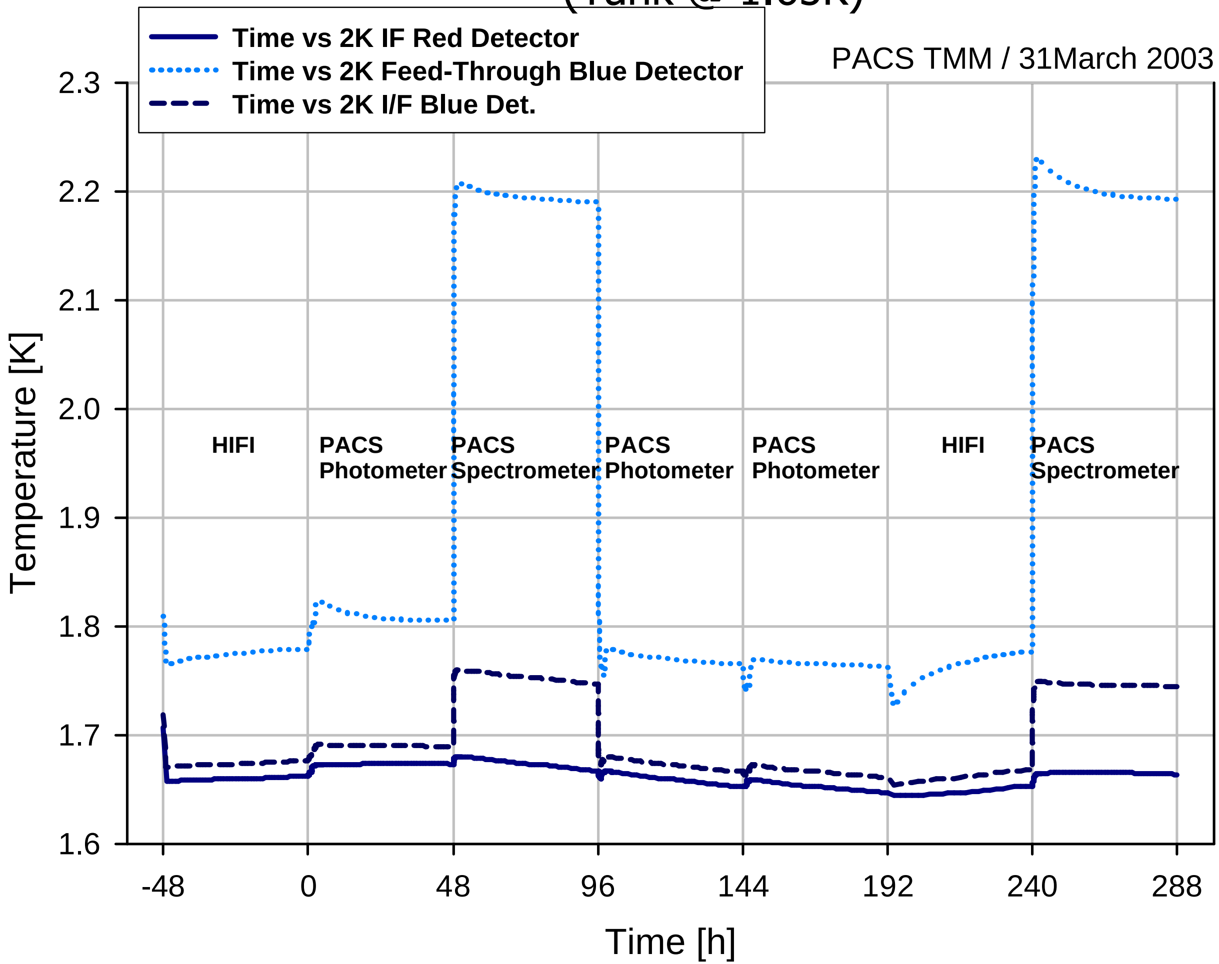
PACS TMM Transient Calculations

(Tank @ 1.65K)



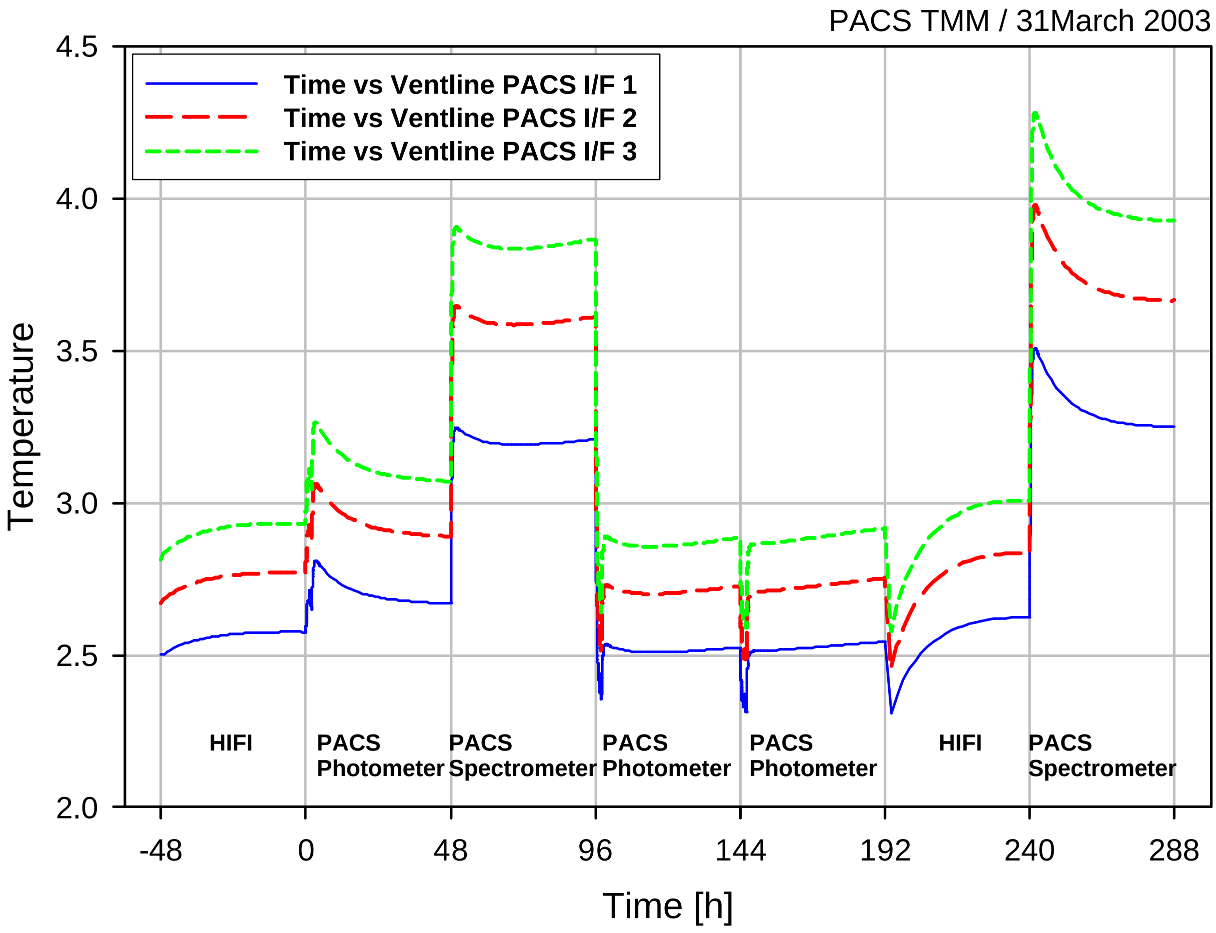
PACS TMM Transient Calculations

(Tank @ 1.65K)



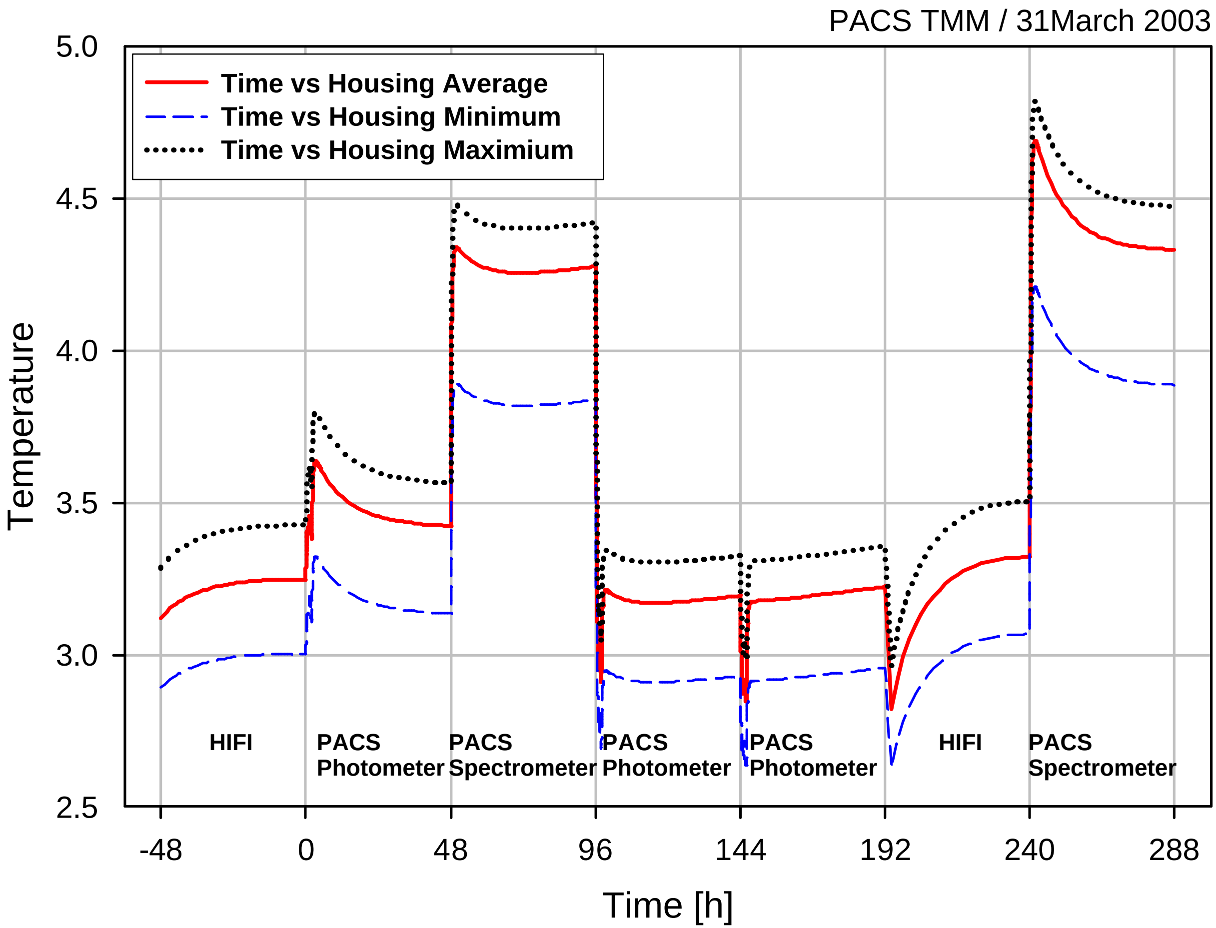
PACS TMM Transient Calculations

(Tank @ 1.65K)



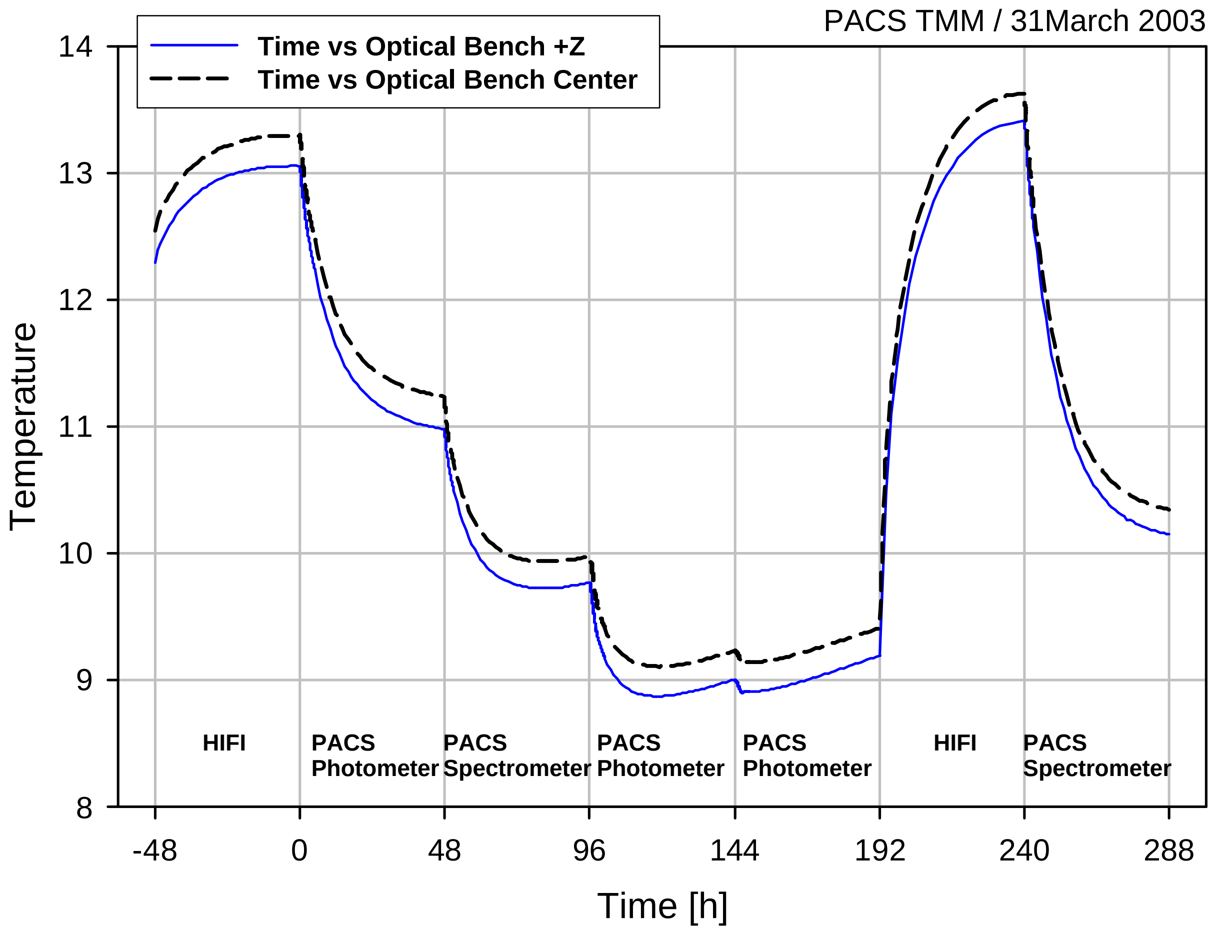
PACS TMM Transient Calculations

(Tank @ 1.65K)



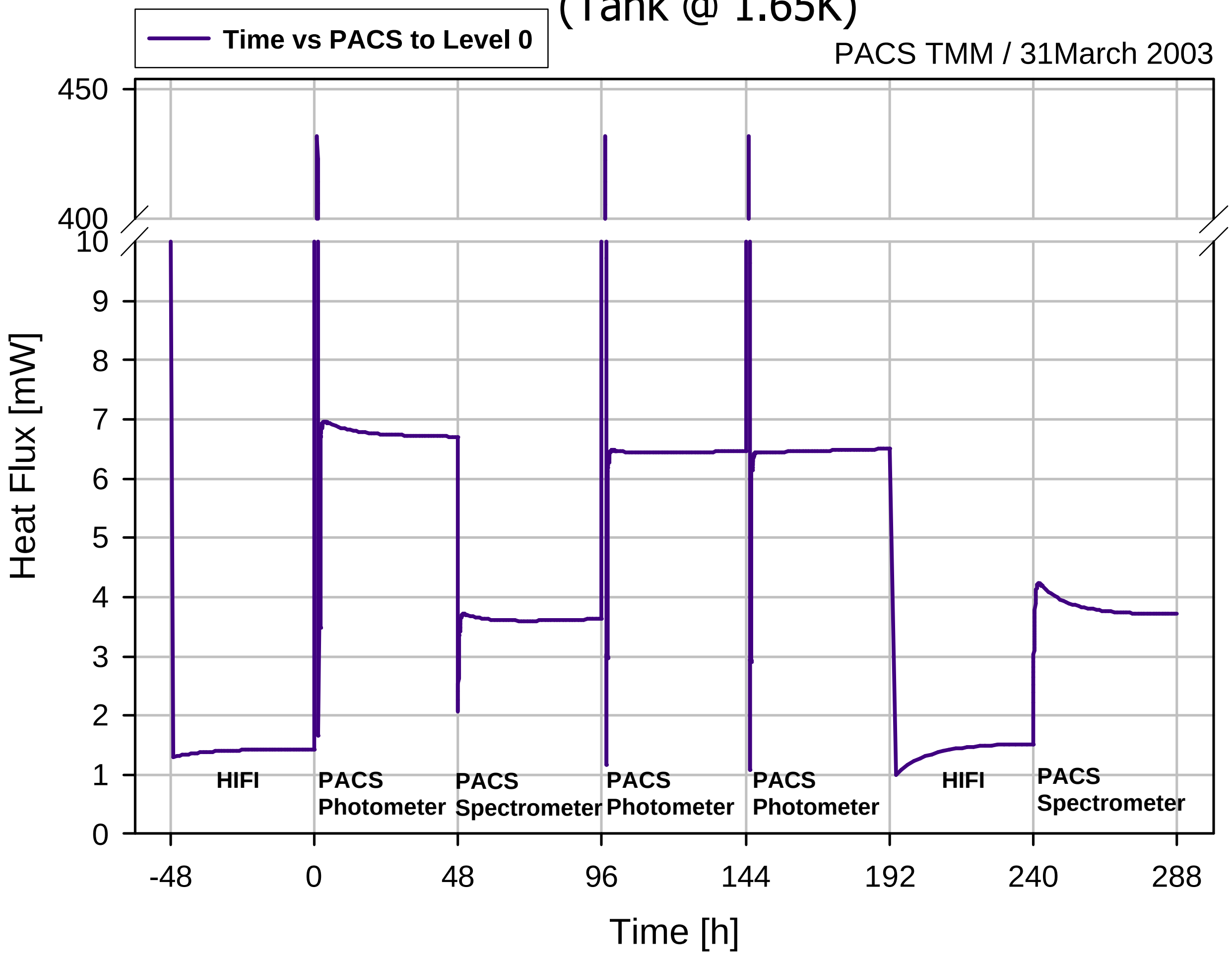
PACS TMM Transient Calculations

(Tank @ 1.65K)



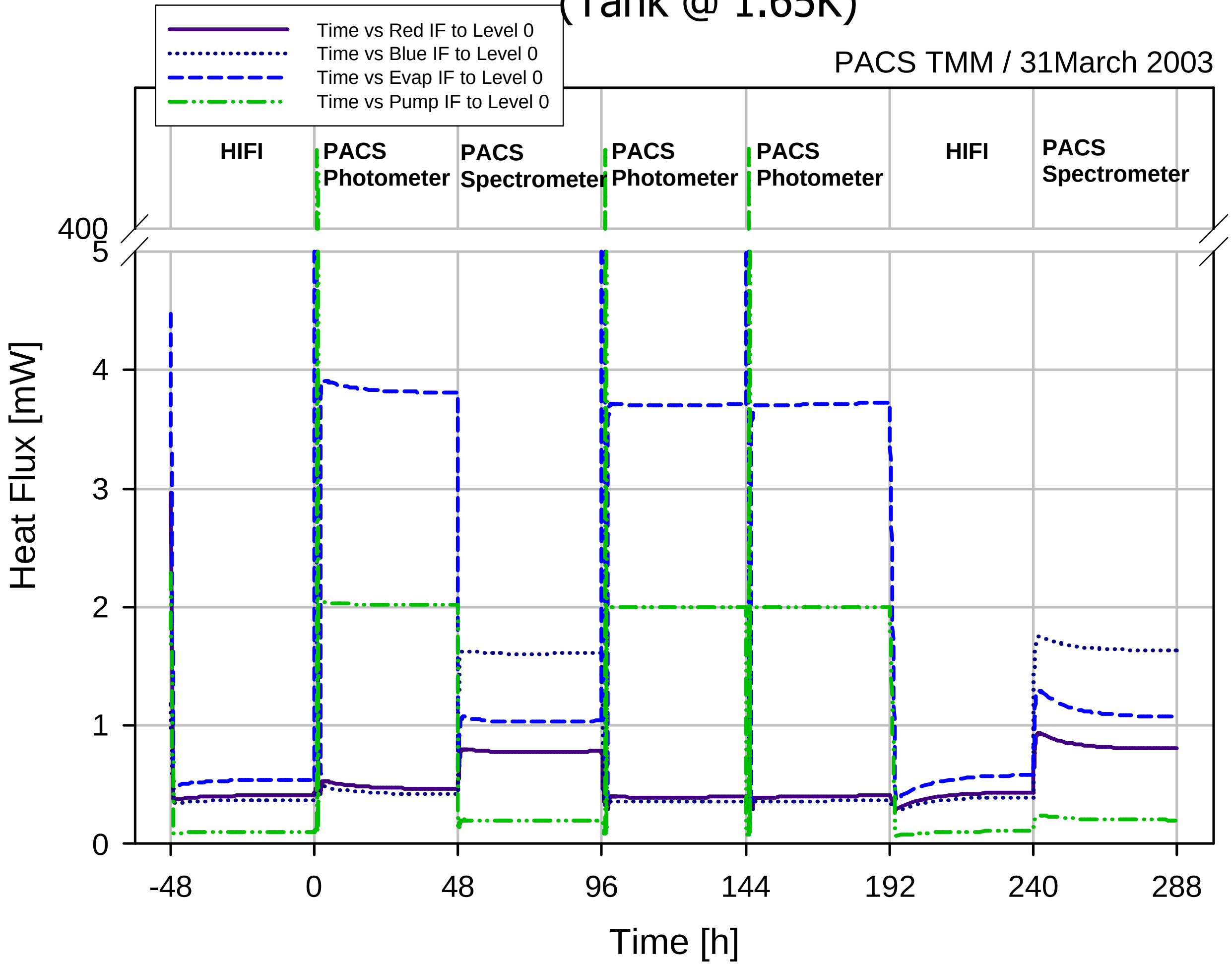
PACS TMM Transient Calculations

(Tank @ 1.65K)



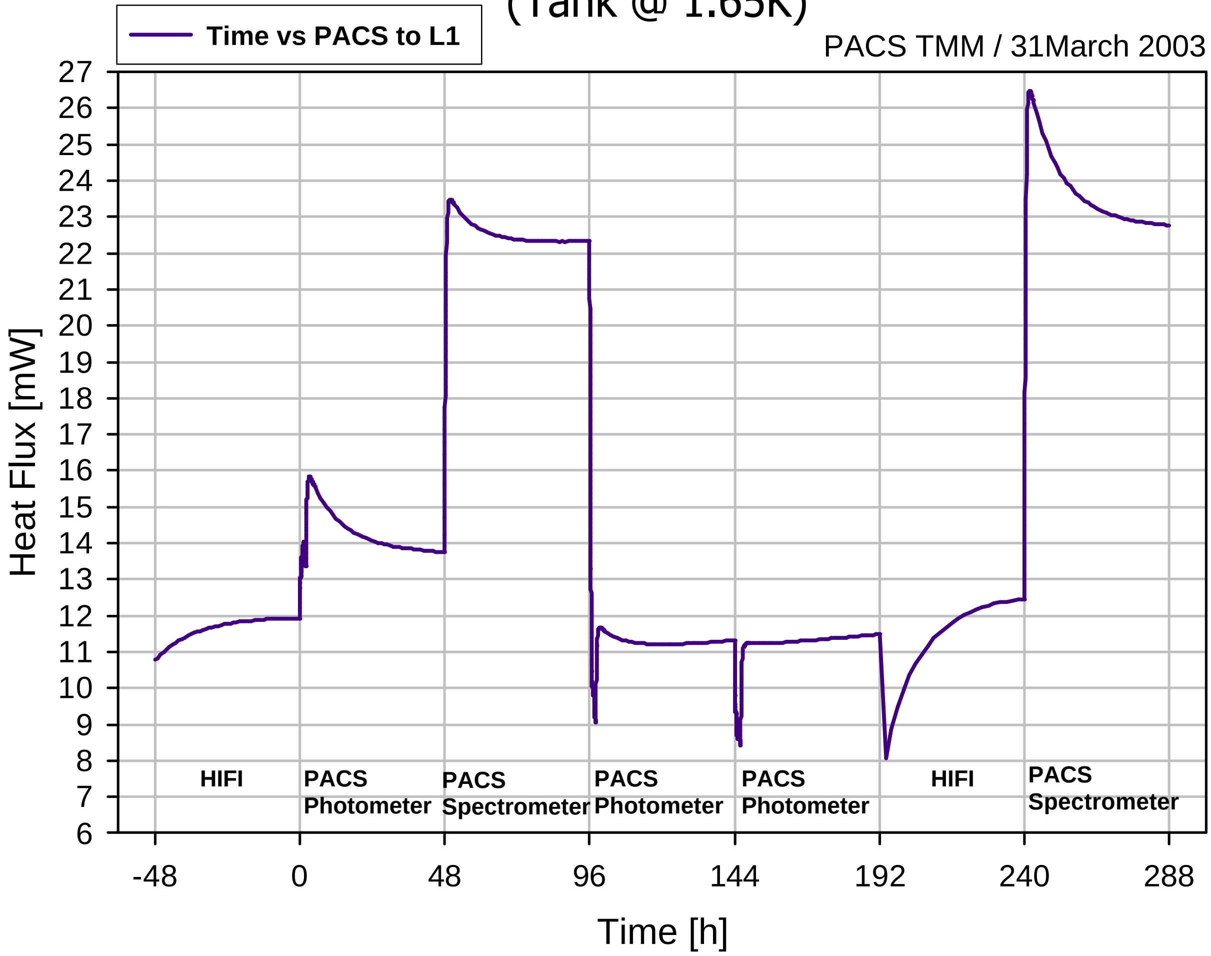
PACS TMM Transient Calculations

(Tank @ 1.65K)



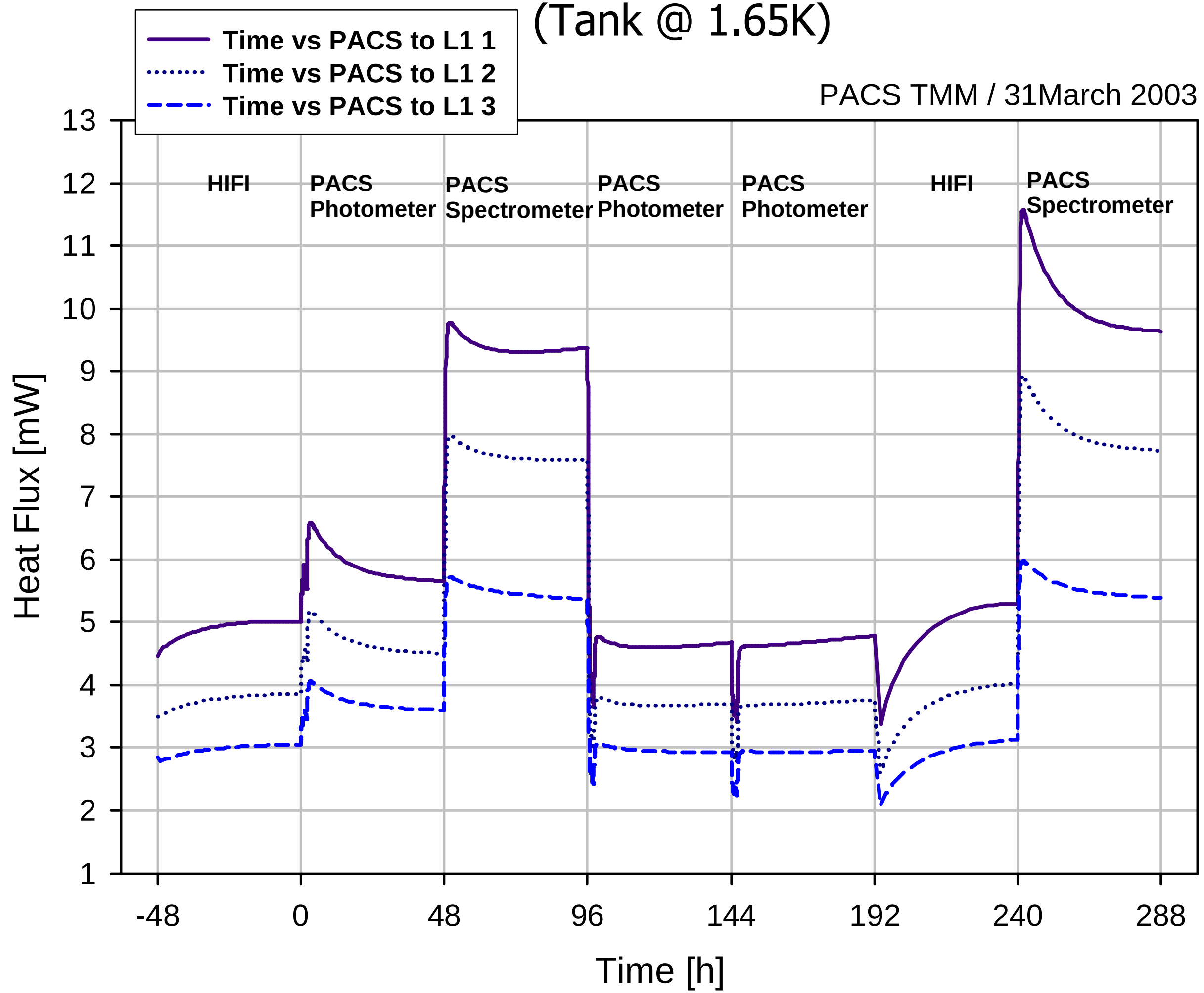
PACS TMM Transient Calculations

(Tank @ 1.65K)



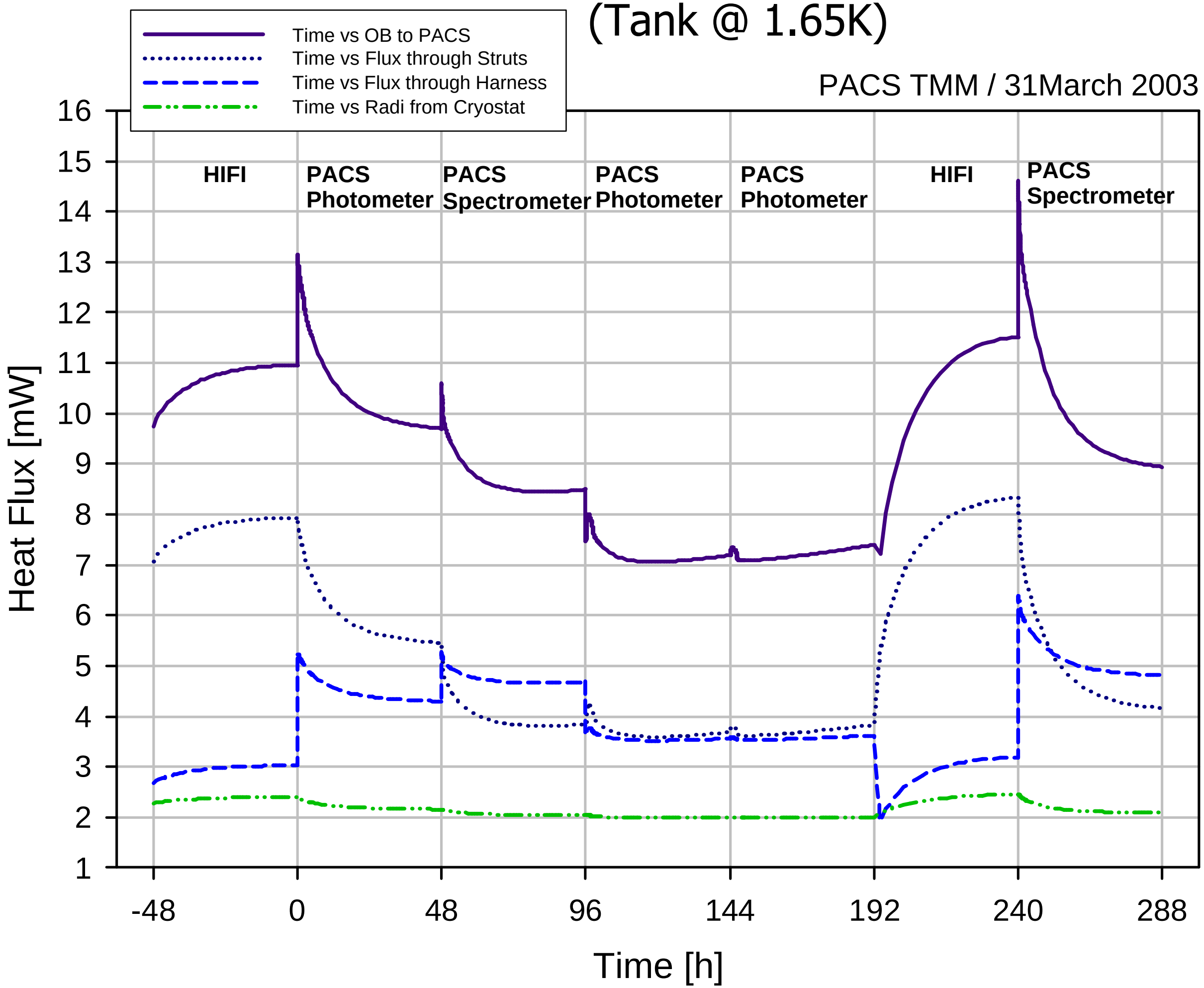
PACS TMM Transient Calculations

(Tank @ 1.65K)



PACS TMM Transient Calculations

(Tank @ 1.65K)



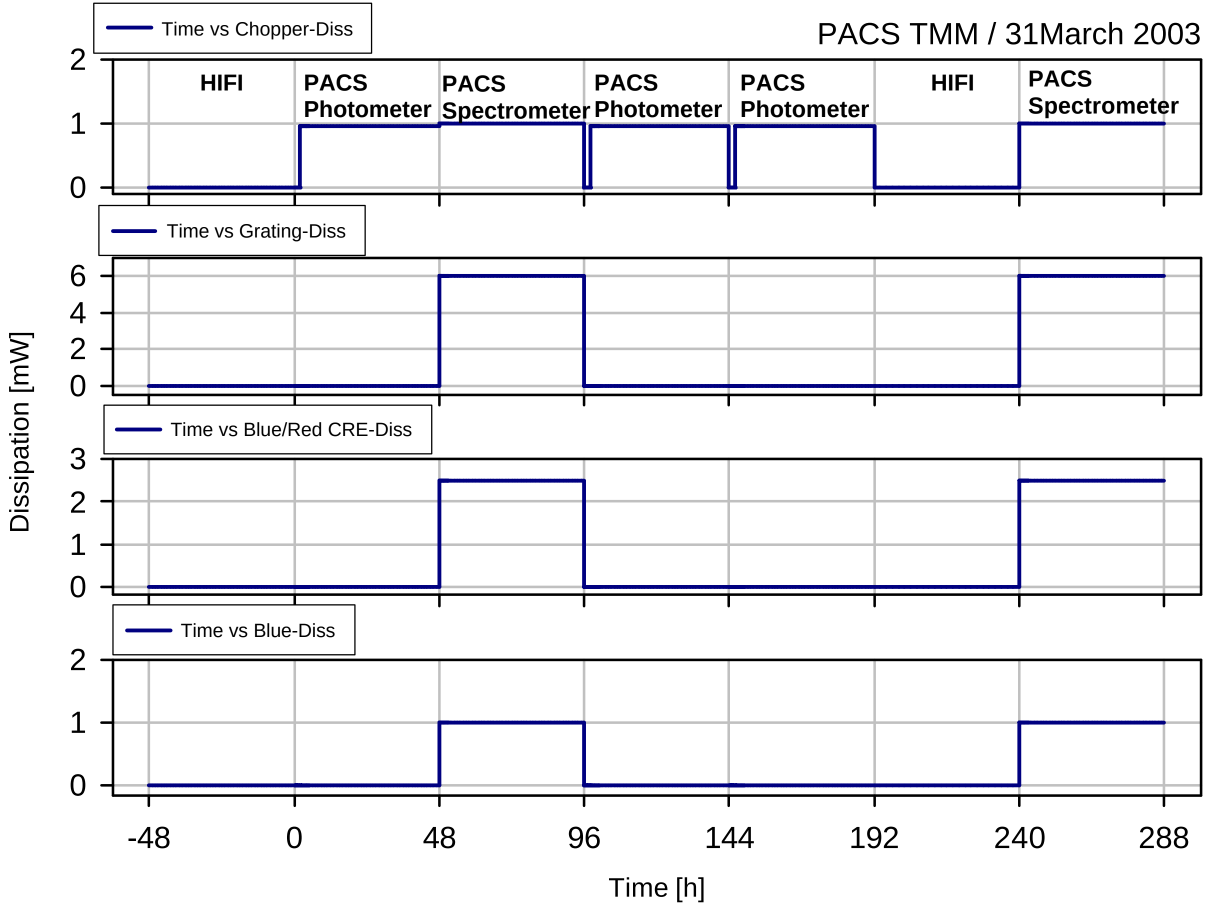
PACS TMM Transient Calculations

(Tank @ 1.65K)

ANNEX

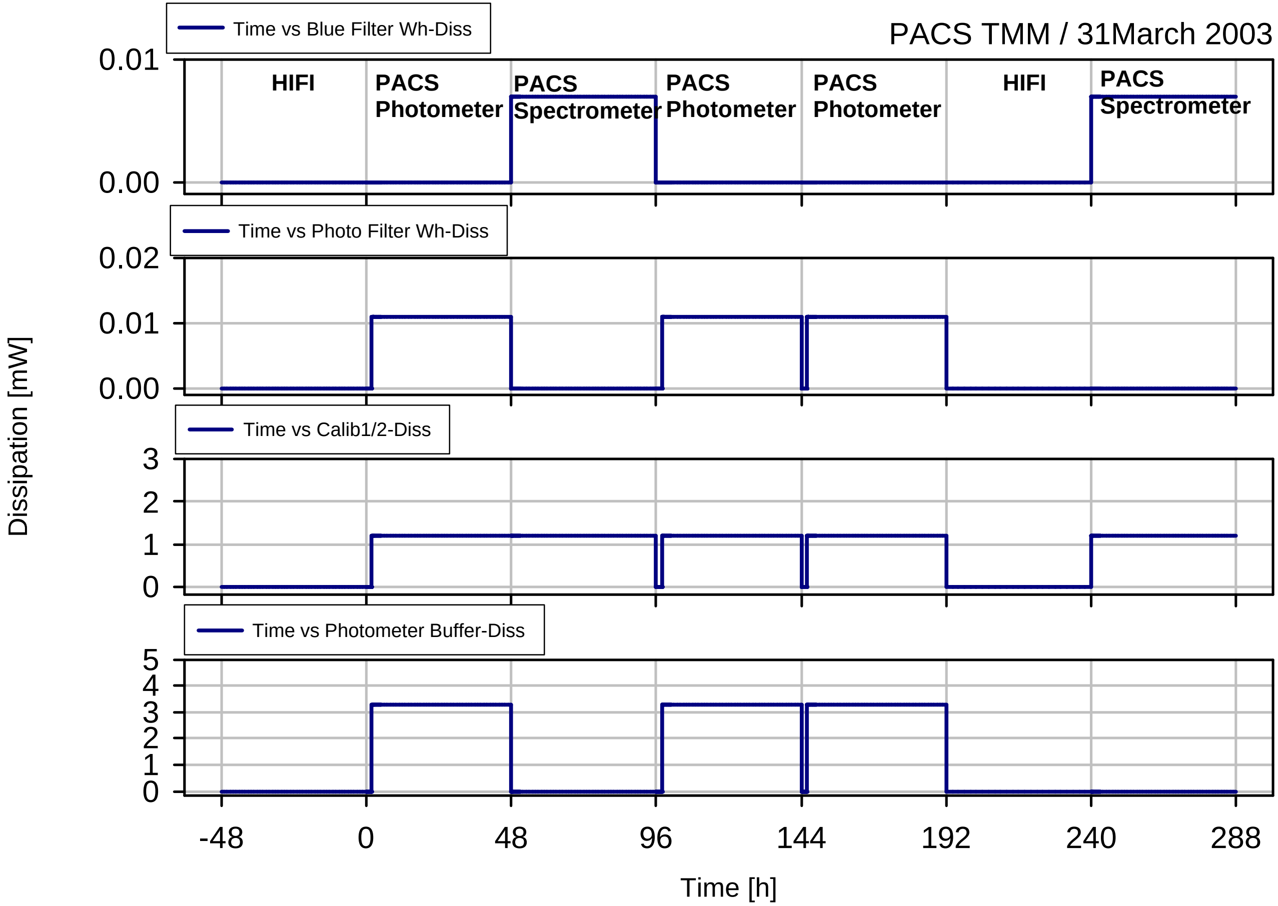
PACS TMM Transient Calculations

(Tank @ 1.65K)



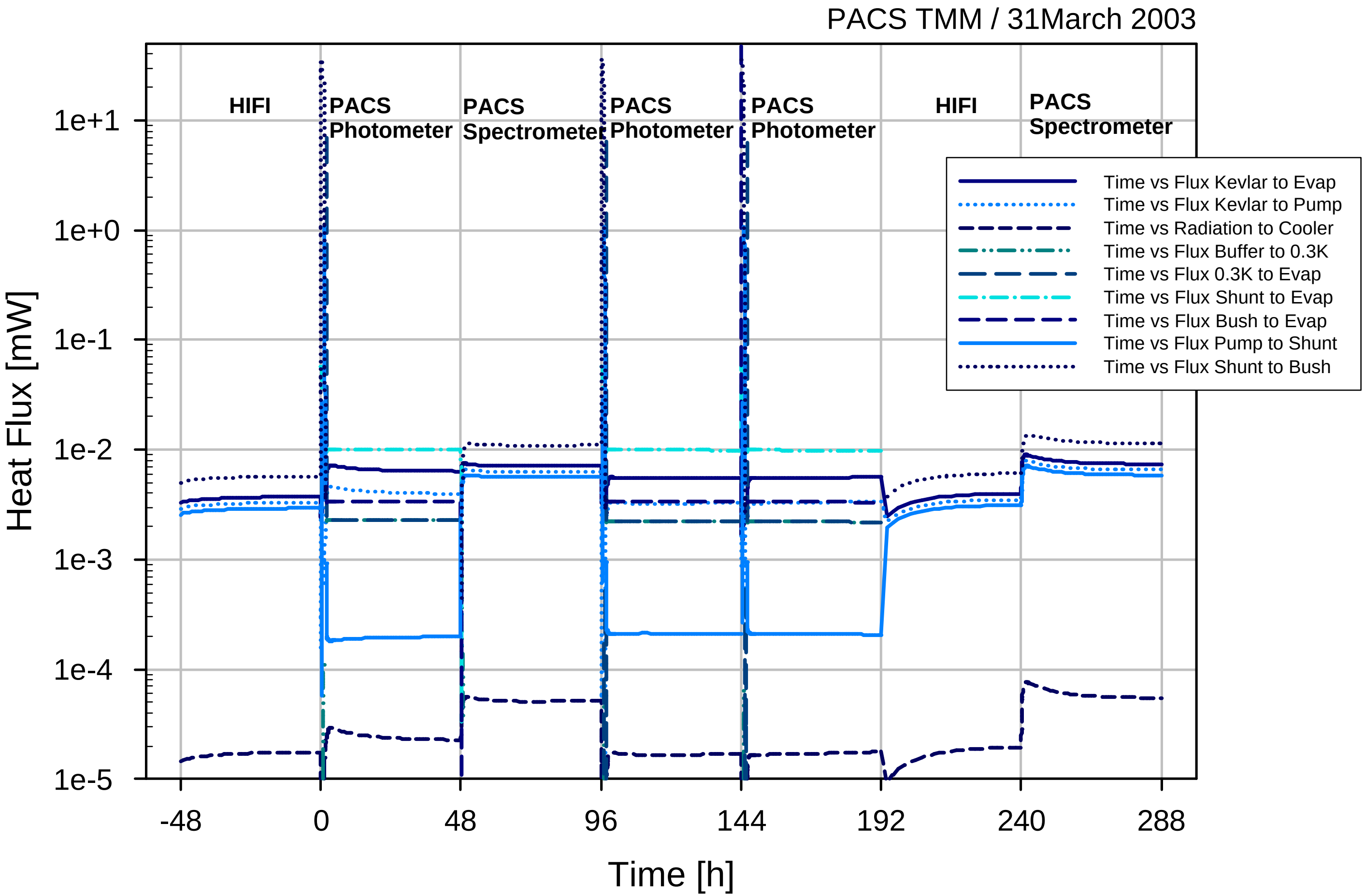
PACS TMM Transient Calculations

(Tank @ 1.65K)



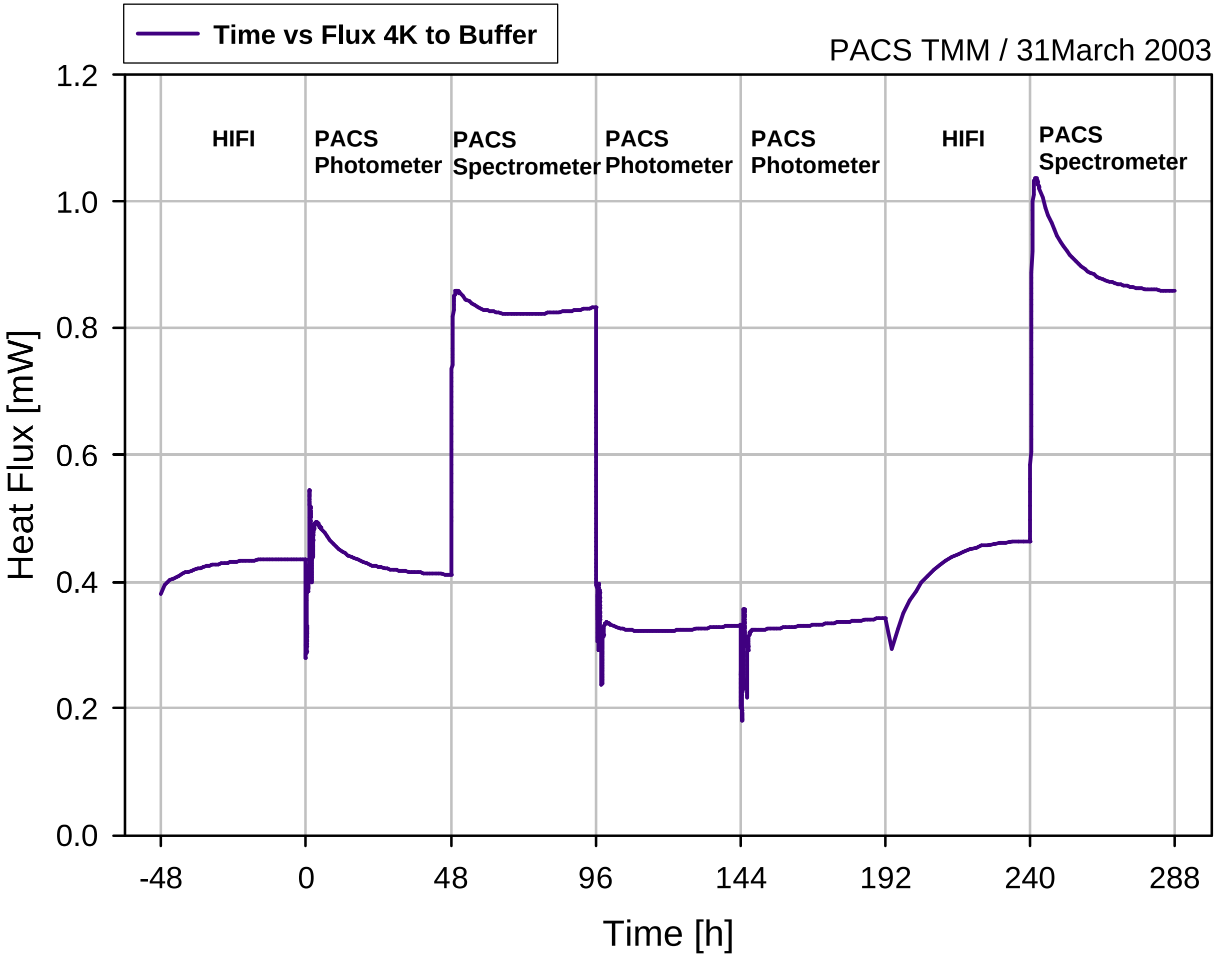
PACS TMM Transient Calculations

(Tank @ 1.65K)



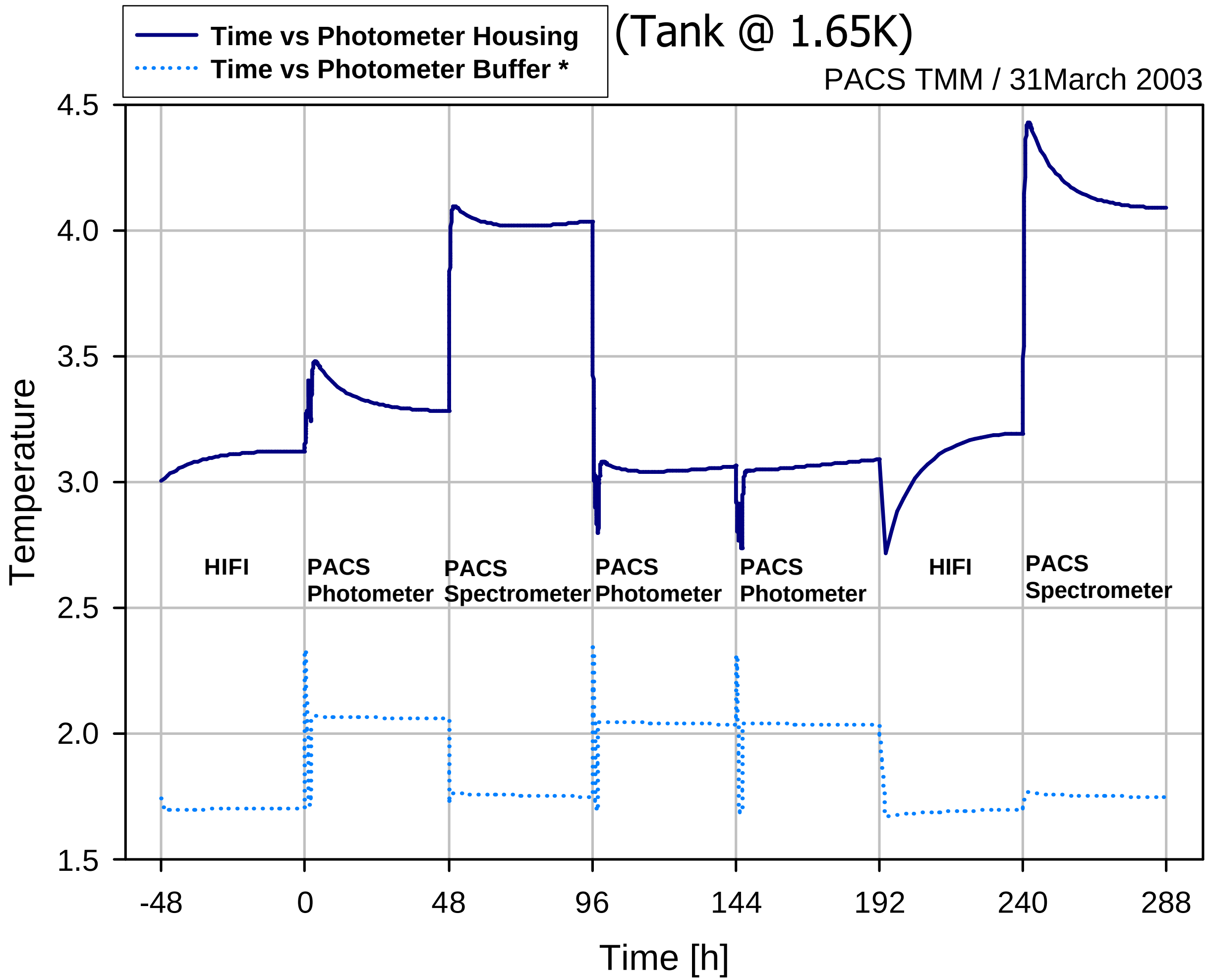
PACS TMM Transient Calculations

(Tank @ 1.65K)

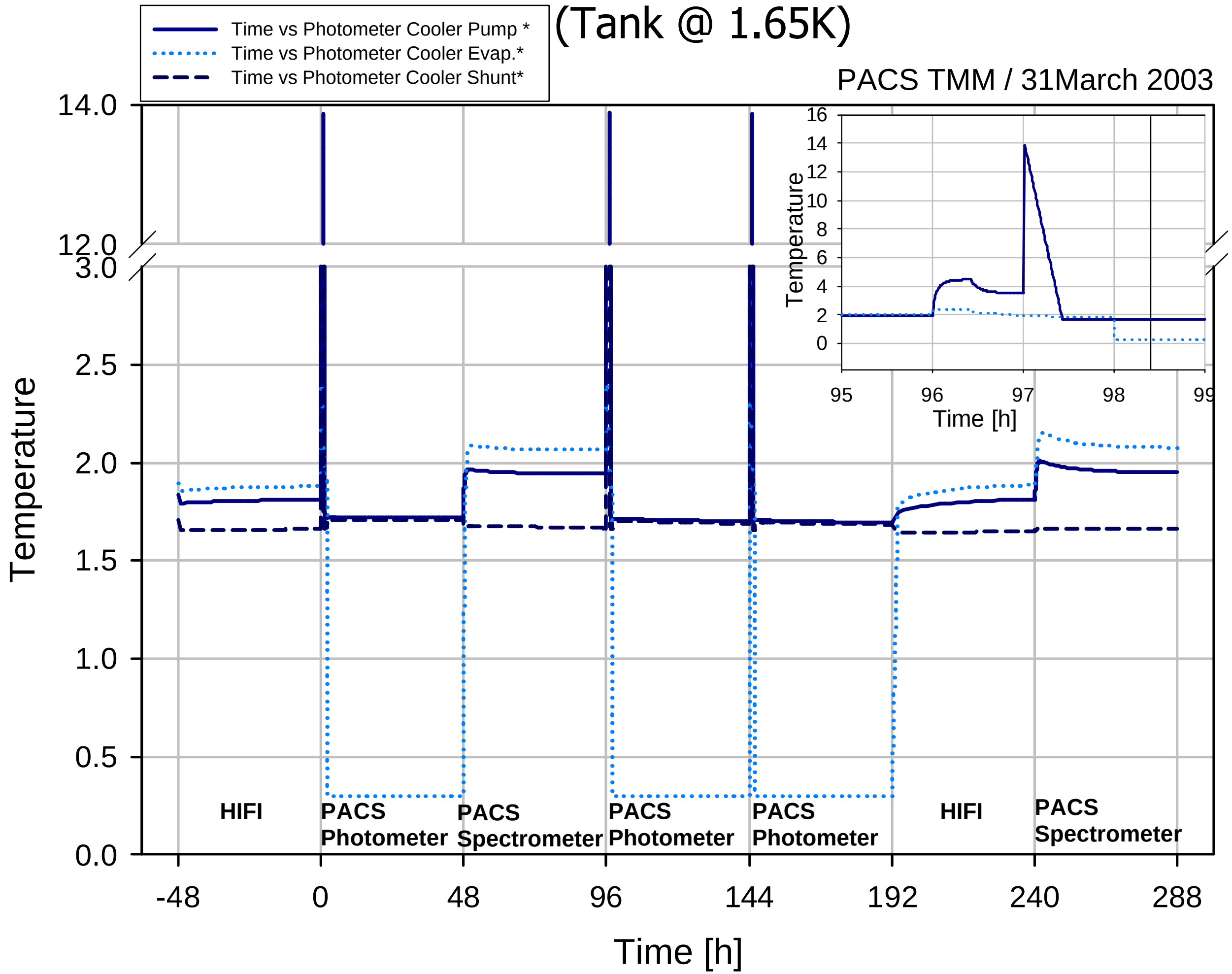


PACS TMM Transient Calculations

(Tank @ 1.65K)

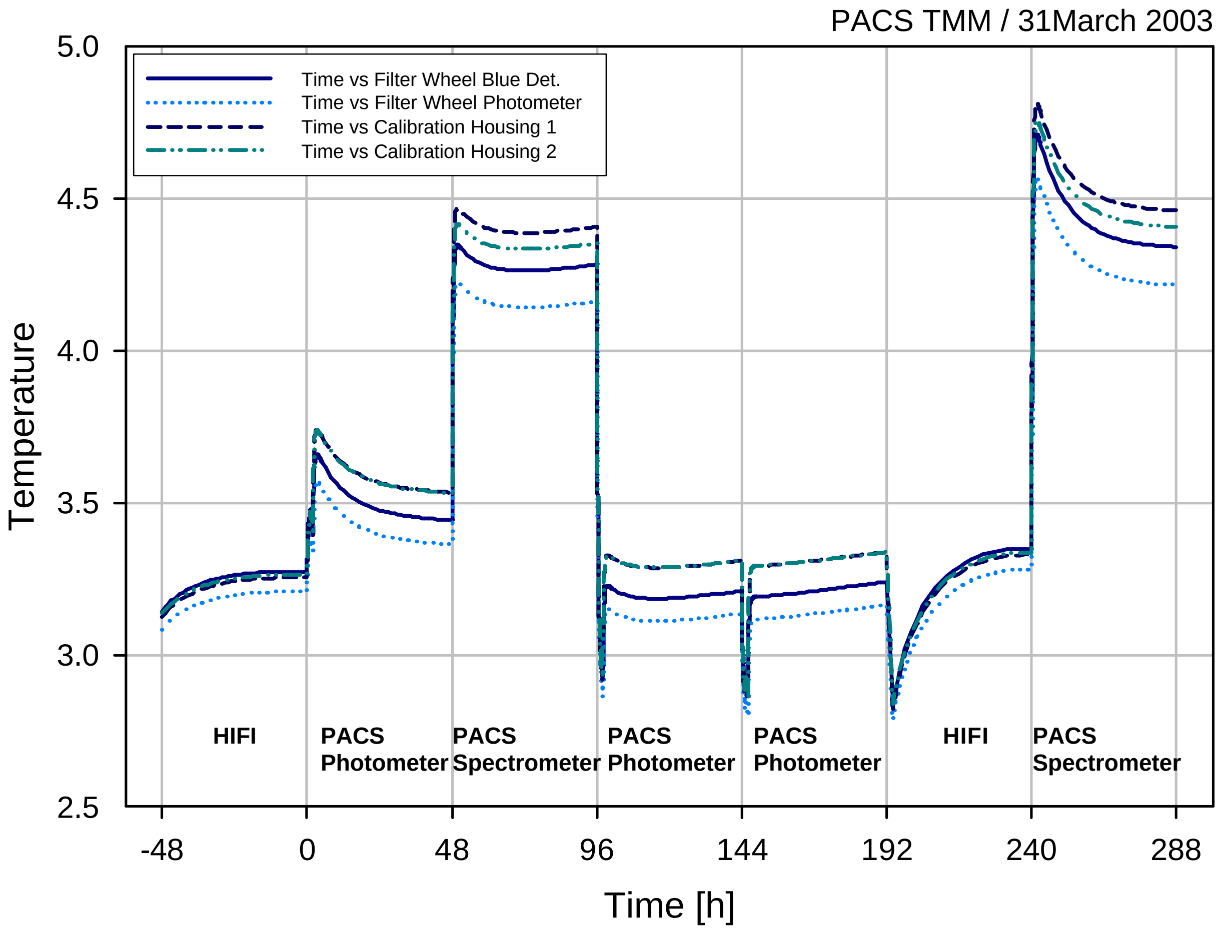


PACS TMM Transient Calculations



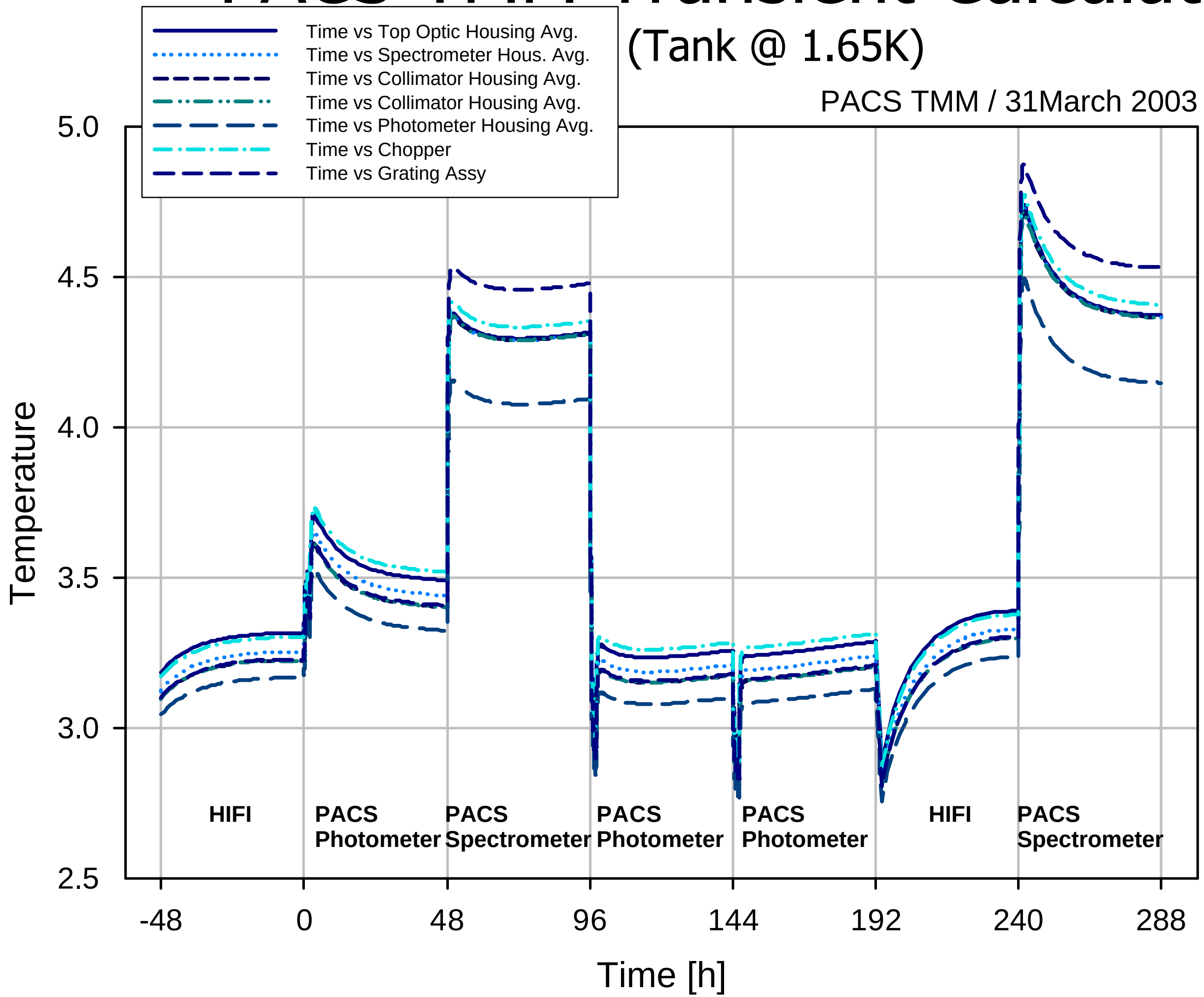
PACS TMM Transient Calculations

(Tank @ 1.65K)



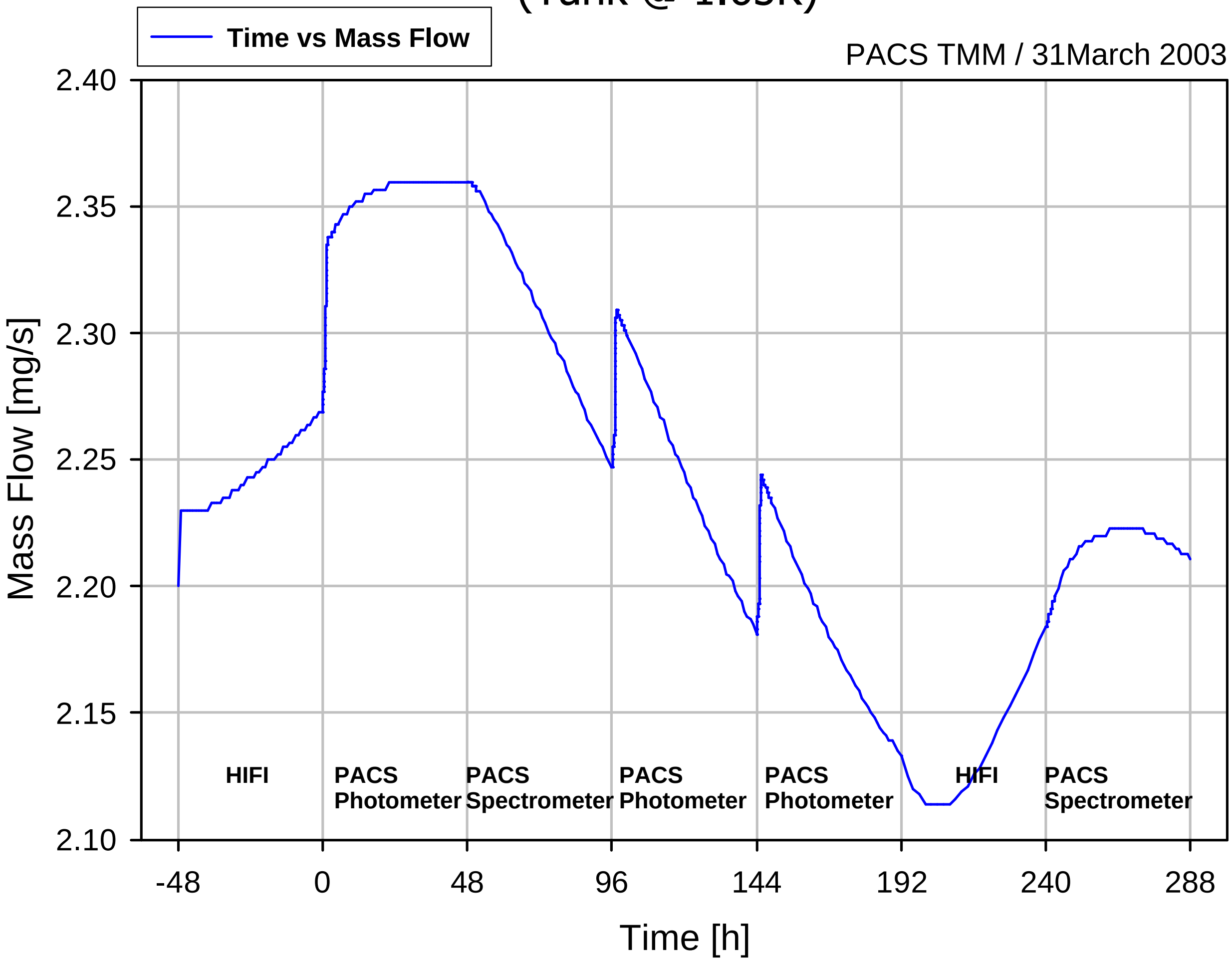
PACS TMM Transient Calculations

(Tank @ 1.65K)



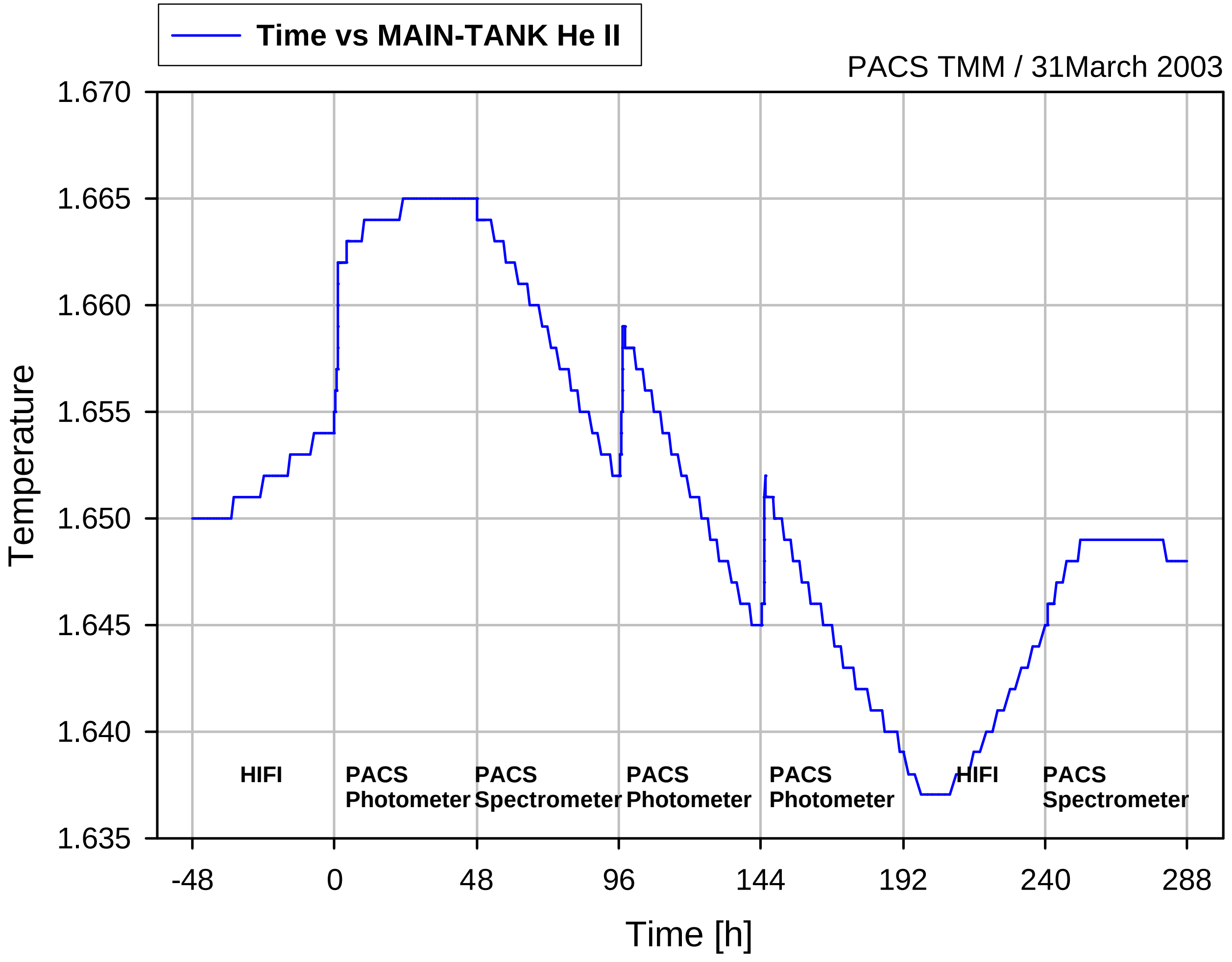
PACS TMM Transient Calculations

(Tank @ 1.65K)



PACS TMM Transient Calculations

(Tank @ 1.65K)



Herschel Cooler Meeting

SPIRE PERSPECTIVE

Freidrichshafen 3&4 April 2003

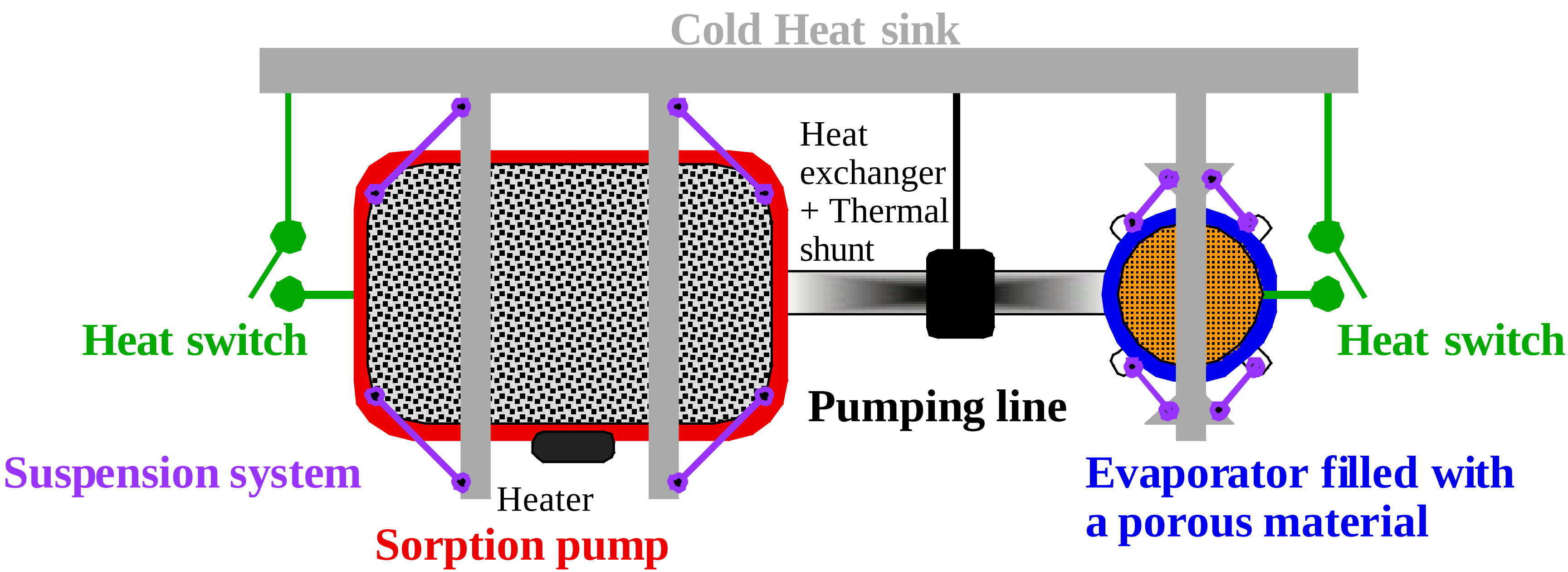
J.Delderfield

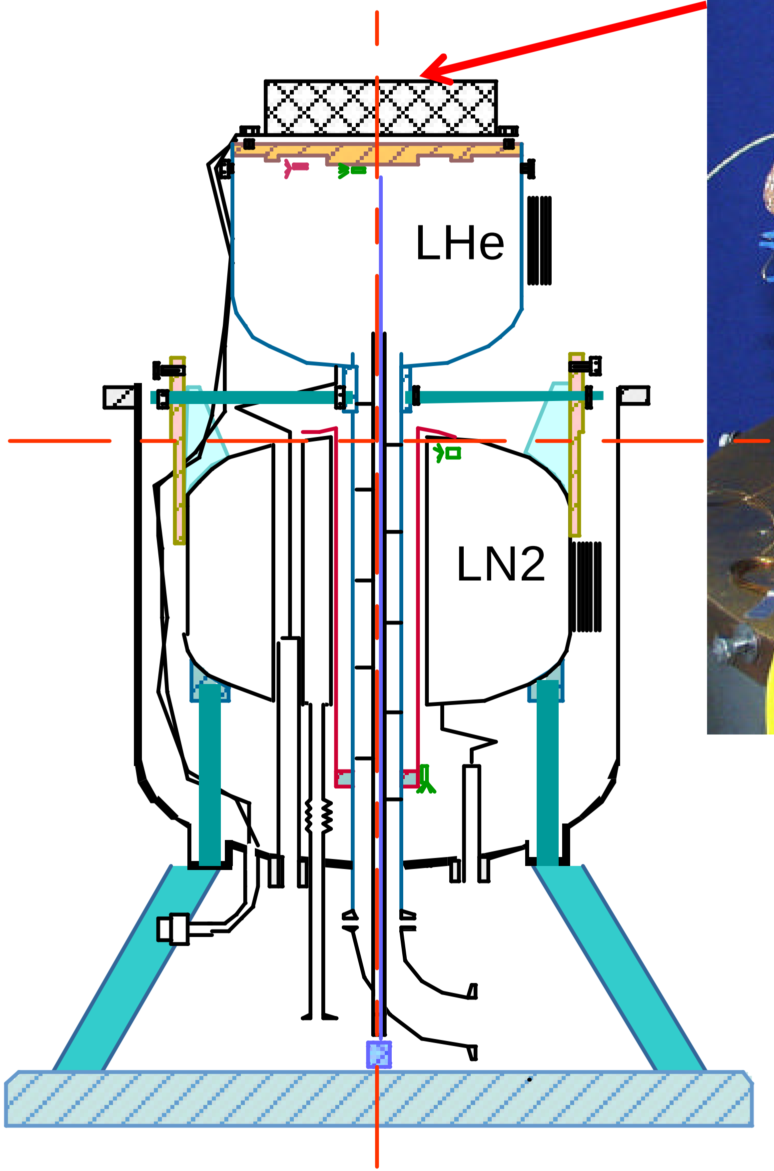
To outline material formally issued in Spire technical notes:

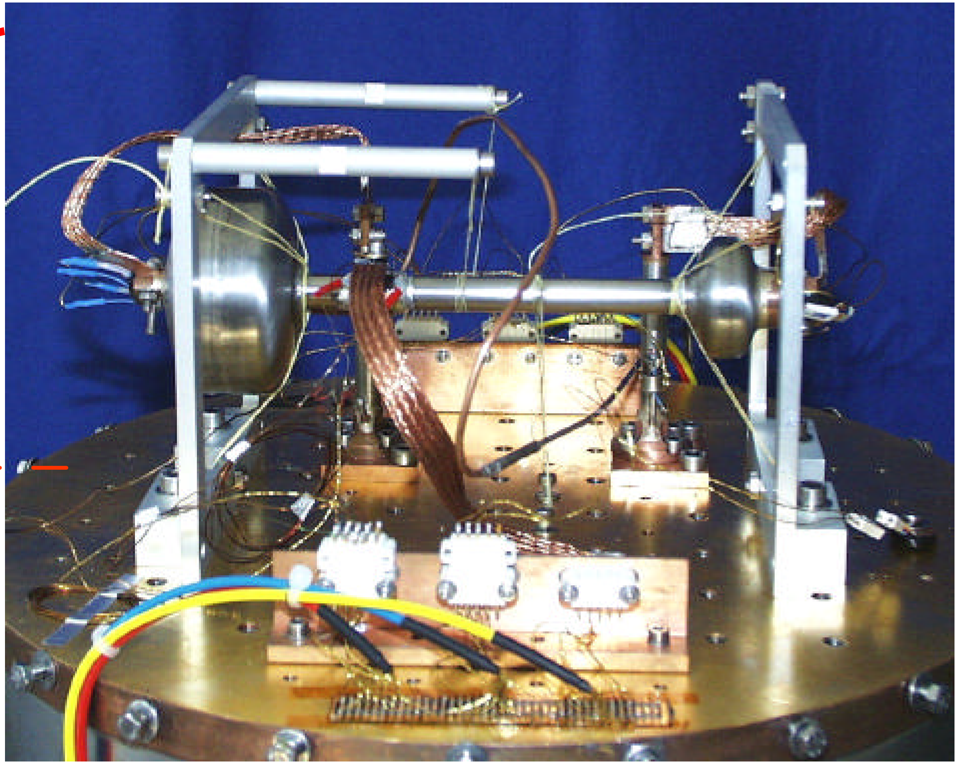
- COOLER ACCOMMODATION
- LIMITING CASES
- SPIRE SHORTCOMINGS

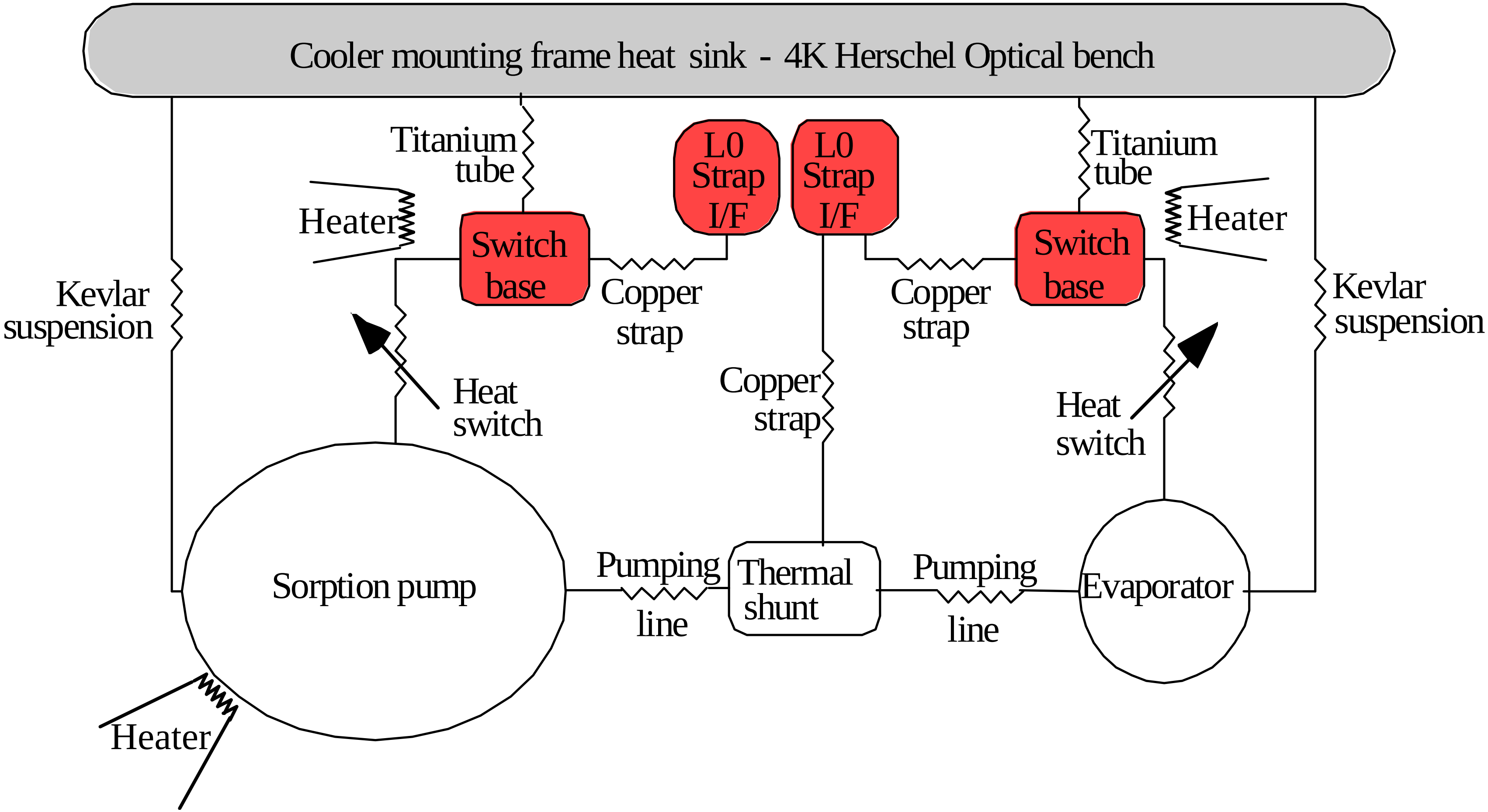
- TEST/DEVELOPMENT CONFIGURATION

Cooler conceived as intimately attached to its cold heatsink



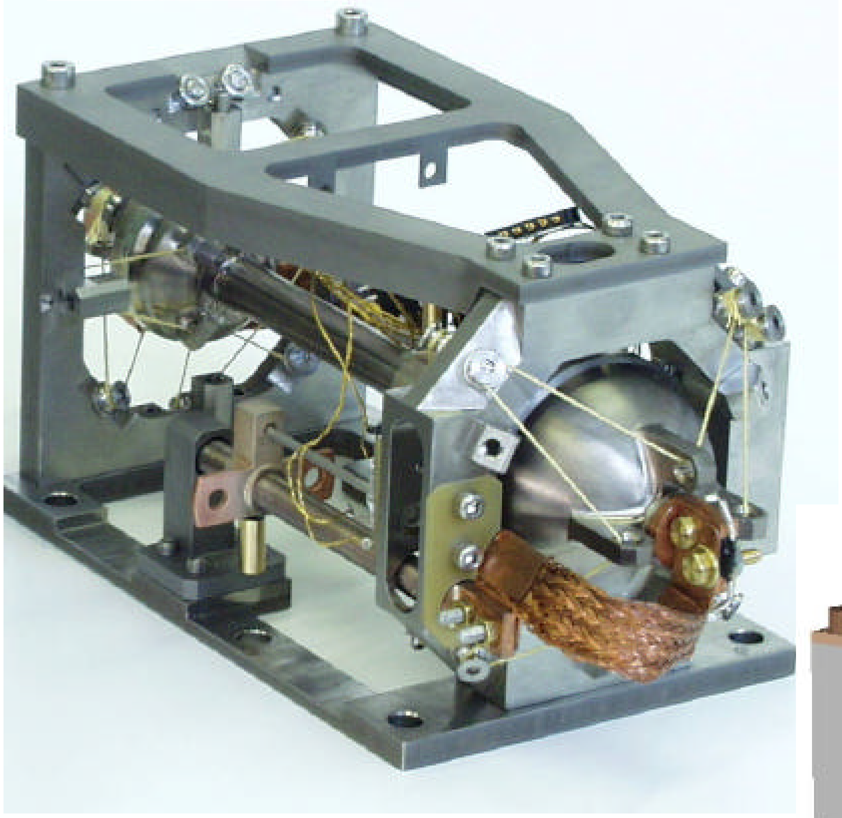

LHe
LN2





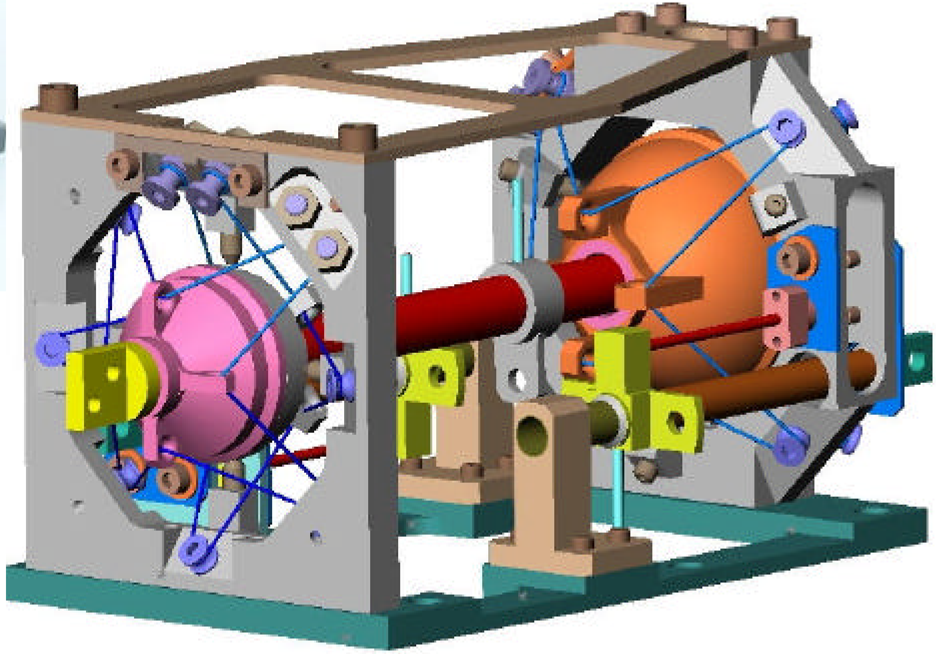
The L0 straps from heatswitches and shunt are still essentially thought of as straight to ^{4}He II.

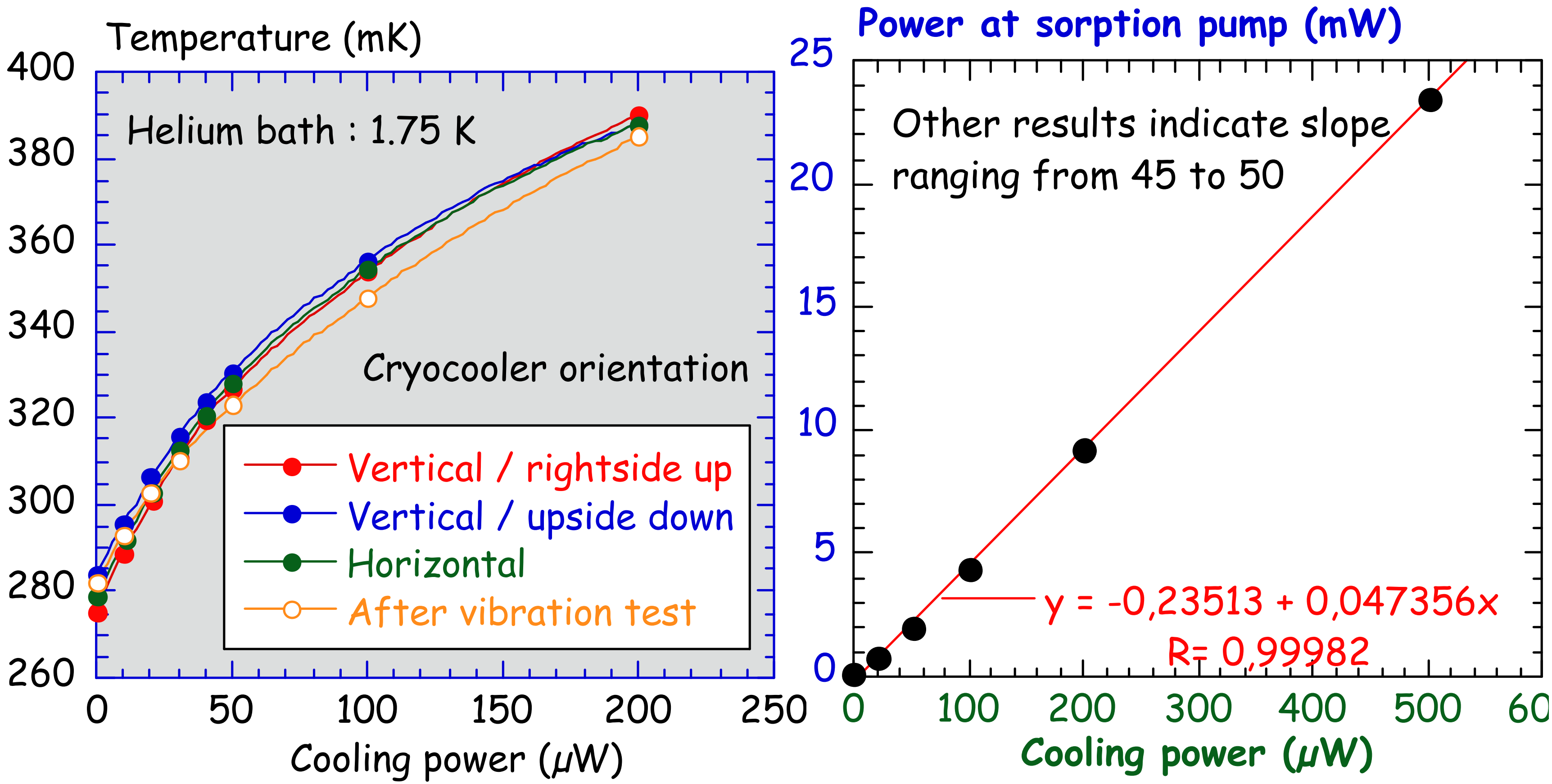
Herschel Cooler Meeting 3&4/4/03



ESA TRP contract : 12942/98/NL/PA

4Litre STP He3, now using 6 for 48hour





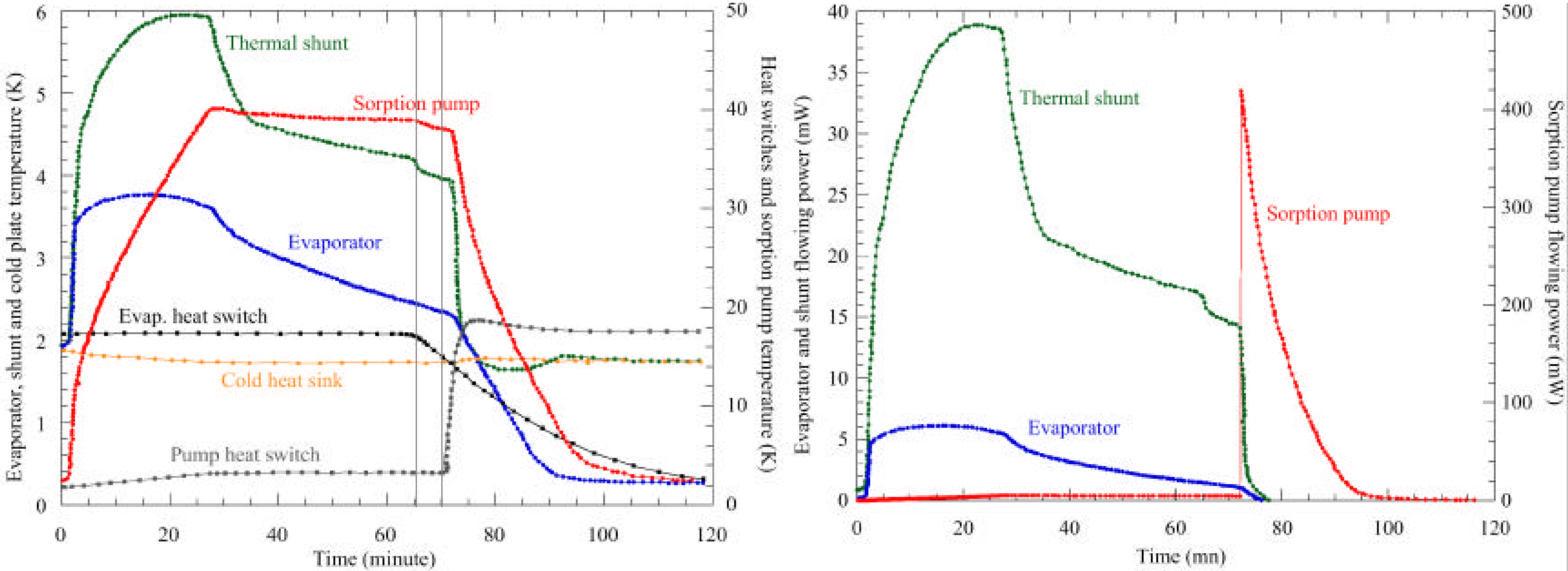
We have cooler performance data, and they are approximately parameterised into the Spire cooler thermal model.

- The cooler is supplied to Requirements Document number HSO-SBT-SP-001, at issue 3.3 after its DDR:

"*The sorption cooler will be mounted off a 4 K plate (level 1) and 1.7 K (level 0) thermal paths will be provided for the heat switches and thermal shunt for the operation of the cooler. The radiative environment will be 4K.*"

- The pertinent question is, 'How necessary are these ideal temperatures and what happens if they are not achieved?"

COOLER REYCLING/REGENERATION



a. 65 minutes “condensation” with the sorption pump heater on (the first 27mins with ~200mW and the remainder~25mW), also with the evaporator heat switch on.

b. Then there’s 5minutes with neither switch on.

c. Finally 50minutes are taken to “cool down” again, for the sorption pump to reach <2K.

Pump strap

- A triangular heatflow profile peaks up at 420mW near the start of regeneration cooling phase.

- Tstrap interface must be <10K at this point.

- A strap with 50mW/K end-to-end conductance gives a temperature of 10.1K at the pump interface if the helium surface temperature is 1.7K, a slight **negative** margin.

Evaporator Strap

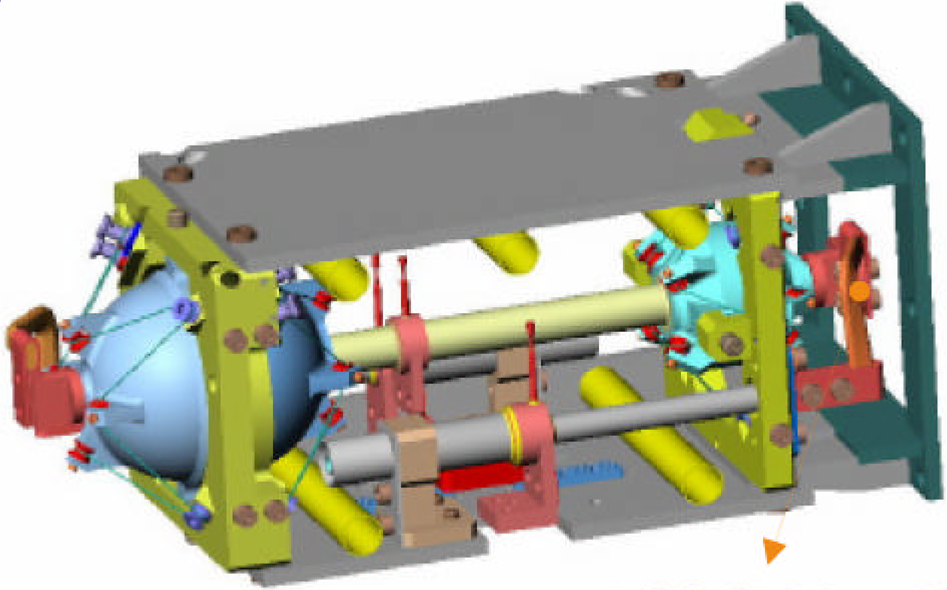
- The power from the evaporator drops to <2mW at the end of the condensation phase, but there is still 15-25mW from the heat shunt coming down the strap.

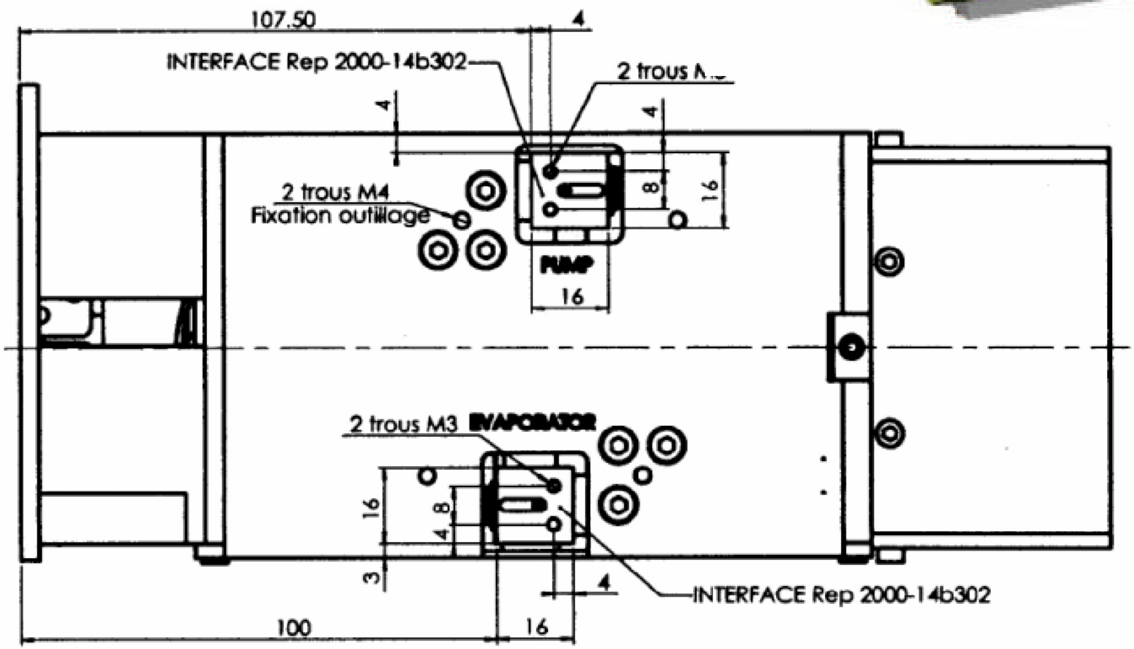
- The <2K evaporator temperature requirement is to guarantee that most of the ^{3}He is condensed in the evaporator at the end of the process.

- Taking a worst case 27mW and 1.7K ^{4}Helium liquid surface, 75mW/K gives a temperature of 2.06K, a slight **negative** margin.

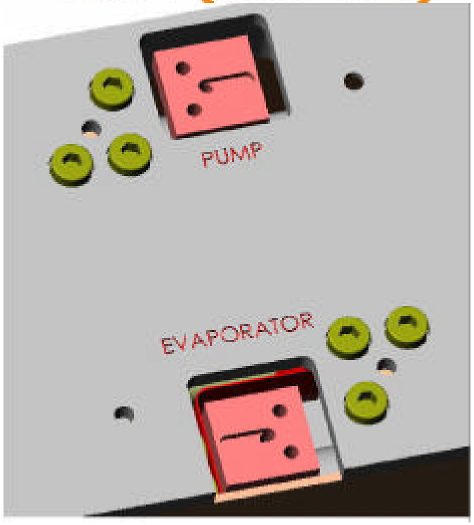
- Because there are unavoidable impedances within the cooler, in order to achieve 75mW/K from the evaporator itself to the Herschel ^{4}Helium liquid surface, CEA and Spire have specified a total strap impedance of 100mW/K.

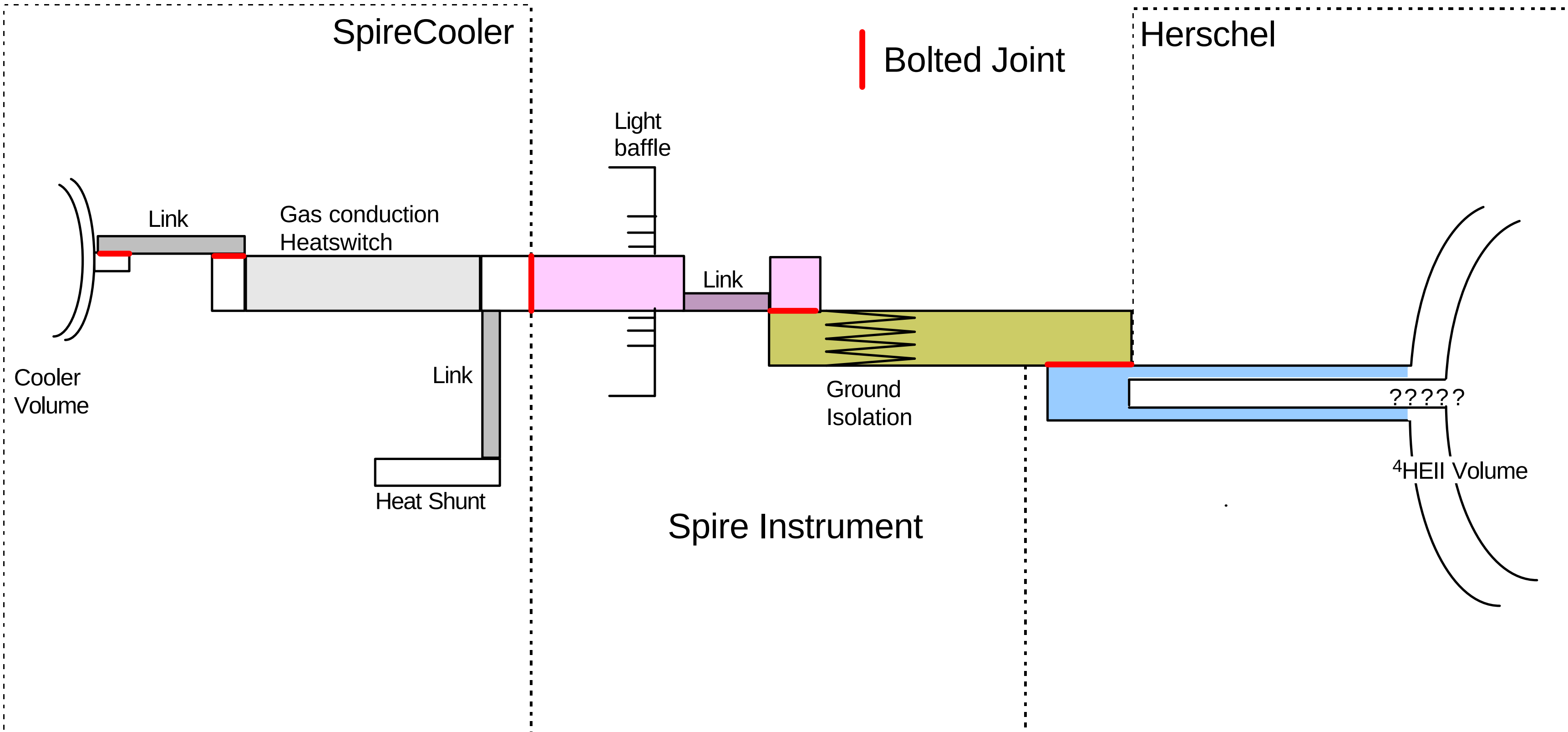
Cooler L0 Interfaces





Cold (300 mK)





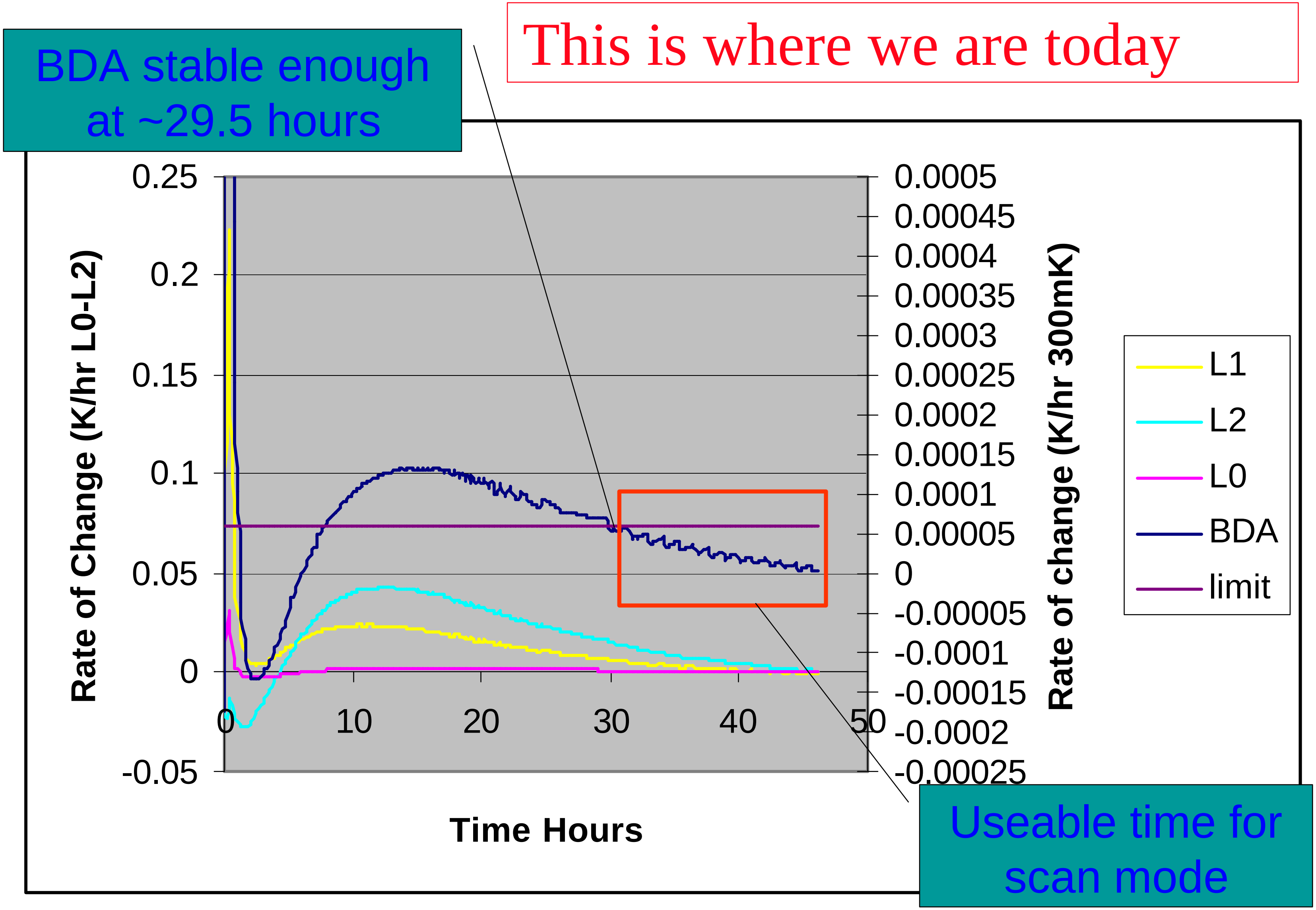
Spire has proposed a specification that each of the coloured sections (with its bolted joint) needs to be 300mW/K for the evaporator link.

Slide presented at IIDR in April 2001

Radiation Detection System -temperature stability

- **The detectors place the following constraints on the temperature stability of the SPIRE instrument temperature levels:**
  - **300 mK - 0.6 to 1.2 mK/Hz$^{1/2}$ (depending on band)**
  - **Translates to BDA 0.06 mK/hr linear drift for scan mode point source detection (see TN-000623)**
  - **Level 0 no strong requirement**
  - **Level 1 - drift scanning point source detection 5 mK/Hz$^{1/2.}$ This translates to <0.3 K per hour**
  - **Level 1 - drift scanning extended emission mapping 0.8 mK/Hz$^{1/2}$. This translates to <4e-3 K per hour**
  - **The last is probably unachievable and calibration methods will have to be employed to remove any temperature drift effects for extended emission mapping**

Scan Mode Point Source Detection is not a “nice to have”, it really is a Spire core Science objective.


BDA stable enough at ~29.5 hours
This is where we are today
Useable time for scan mode
Rate of Change (K/hr L0-L2)
Rate of change (K/hr 300mK)
Time Hours
0.25
0.2
0.15
0.1
0.05
0
-0.05
0.0005
0.00045
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
-0.00005
-0.0001
-0.00015
-0.0002
-0.00025
0
10
20
30
40
50
L1
L2
L0
BDA
limit

There are at least two **less important** reasons for not going from 48hours to 24hours cooler recycling:

1. The integrated cooler heat dissipation associated with recycling will essentially double, as energy saving by only doing a partial regeneration is very TBC. ESA/Alcatel could assess impact.

2. Supposing Spire nominally operates for 365 days out of the three year mission, the reduction of the time available for observing is 15days, just from time alone, i.e. in addition to the other factors.

Spire shortcomings:

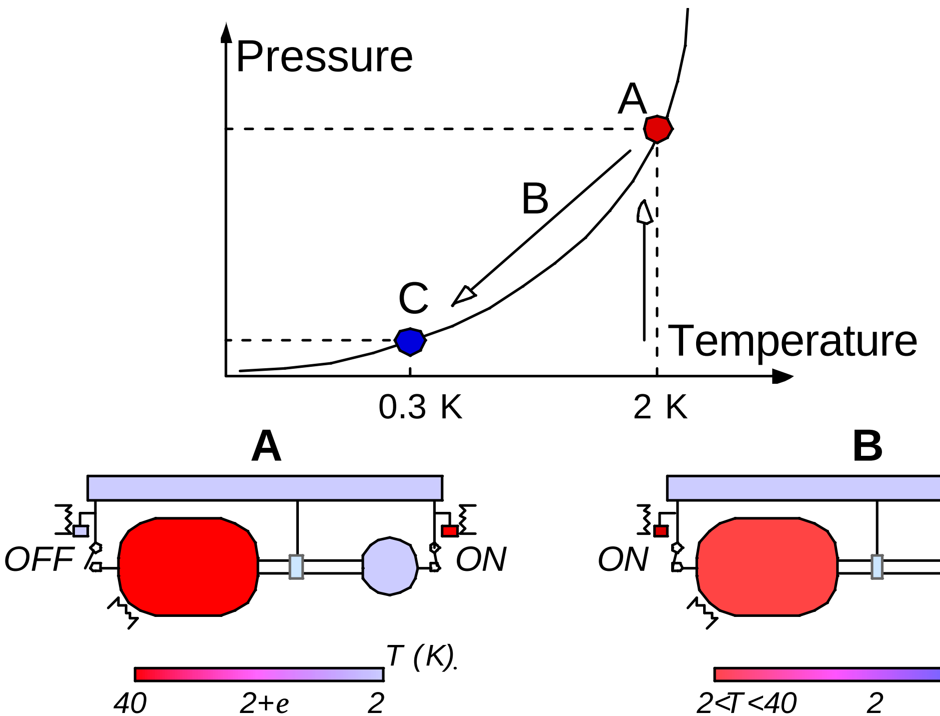
- IID-B open
- Thermal calculations only recently converging
- No full thermodynamic cooler model
- 6 litre cooler measurements needed to confirm extrapolation from 4 litre ones + recycle definition
- Instrument implementation of straps to fulfil our side of proposed conductance not yet in place

MEETING OBJECTIVES:

- Can we agree technically where to put the Spire to Herschel L0 cooler Interface, how many straps, and the target thermal impedances from cooler to this interface + from this interface to the ^{4}HeII surface?
- Then measurable temperatures assuming computed heatflows can be put into I/F specifications.

End

PRINCIPLE OF OPERATION

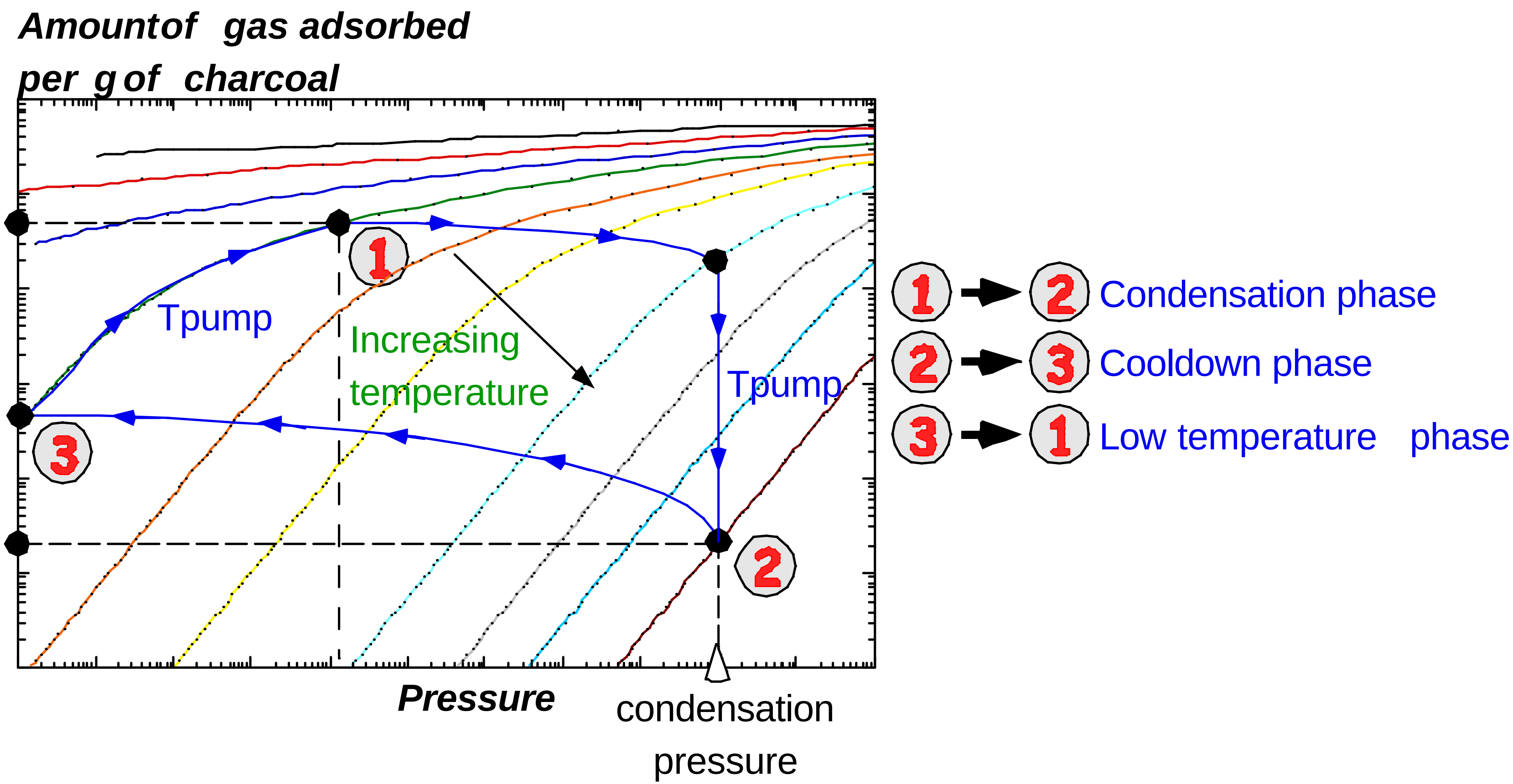


A : Condensation phase

B : Cooldown phase

C : Low temperature phase

Control {
- thermal gradient : gas gap heat switch
- cooler internal pressure : sorption pump
- liquid position : confinement by capillary attraction (evaporator)


Amountof gas adsorbed
per g of charcoal
Tpump
Increasing
temperature
Tpump
Pressure
condensation
pressure
1
2
3
1 → 2 Condensation phase
2 → 3 Cooldown phase
3 → 1 Low temperature phase

Thermal requirements

Thermal Requirements

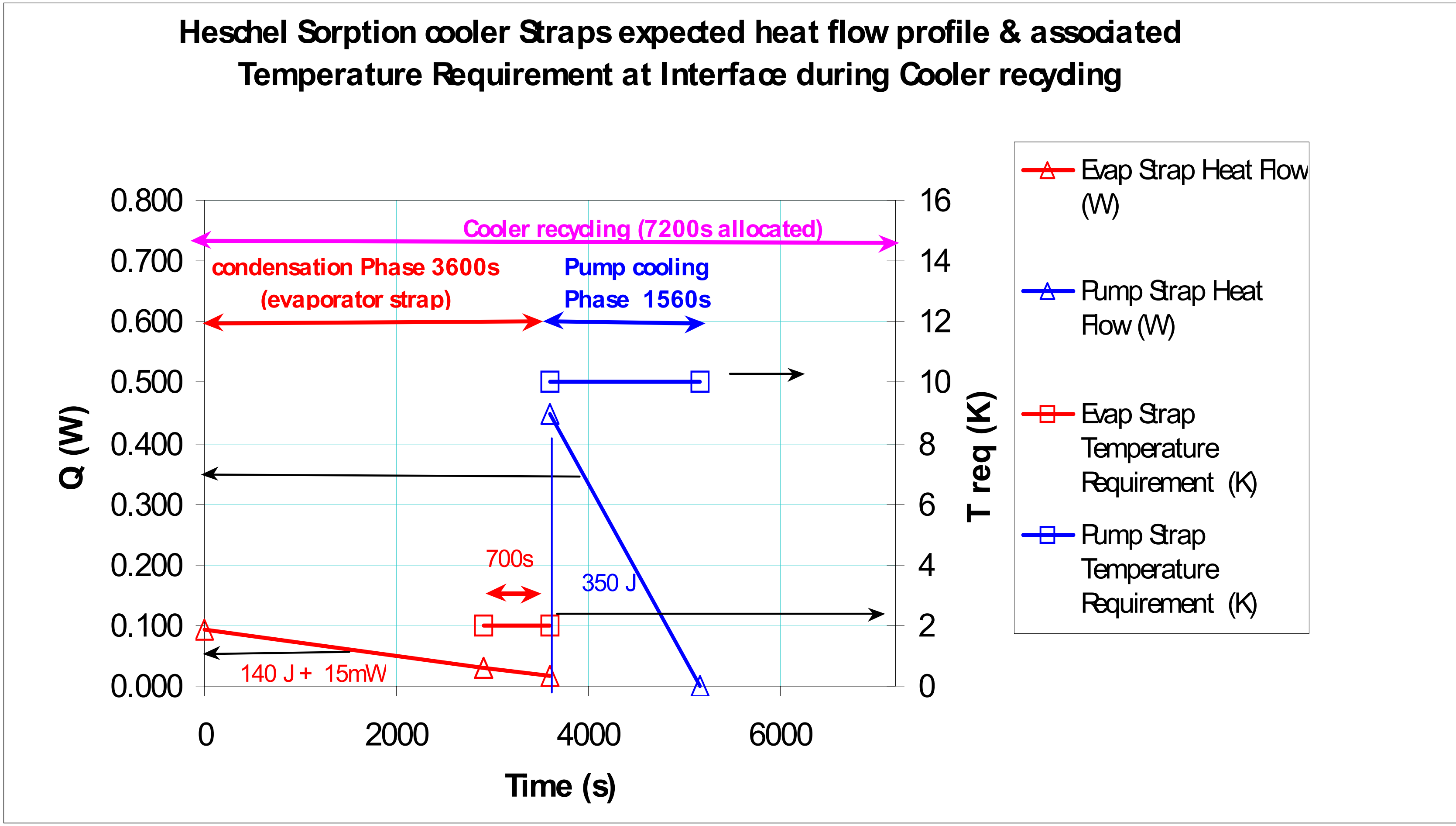
- Current agreement to have requirement on Max Temperature & design heat flow at thermal interface.
- (could have been also He Temperature & Strap conductances, together with max Helium bath temperature)
- Base objective is to guarantee 48h cooler cycle operation
  - Allow to desorb 3He from pump, & condense in evaporator (Tevap < 3He critical point (3.2K)
  - Condense enough 3He to guarantee 48h cycle (ie T<2K (TBC) at heat switch at end of condensation) while conducting the pump line losses (15mW) through evaporator strap.
  - Optimum use of the 2h allocated for cooler recycling (no oversize, optimum management of margins
  - Critical aspect is Evaporator Strap

Thermal Requirements

Alcatel/Astrium understanding

- Pump strap: 350J/1560s , triangular pulse (peak 450mW), T interface <10K (rationale ?)
- Evaporator strap: 140J (condensation heat from shunt (100J) & Evaporator 40J)/3600s, triangular pulse + 15mW heat conduction from pump to shunt, T < 2K (TBC) during last 20% (700s) .
- This lead to sizing heat flow of 30mW, and an industry Strap conductance of 0.1W/K (assuming Helium at 1.7K)
- Rem This last requirement (2K) could also apply when all 3He is condensed (ie relevant heat flow =pump losses only= 15mW), allowing to increase condensation efficiency by modifying the recycling procedure

Requirements



Assumptions

Helium bath temperature	1.7	K			
Evaporator Strap	3He Condensation in Evaporator	3He Condensation on Thermal shunt	Conduction from pump to thermal shunt	Total	unit
shape of pulse	triang |\\	triang |\\	rectang []		
Duration of condensation phase	3600	3600	3600	3600	s
Energy	40	100	54	194	J
Peak	0.022	0.056	0.015	0.093	W
Contribution to Average dissipation on 48h				0.0011	W
				1.12	mW

Evaporator Strap					Rem
	time (s)	Evap Strap Heat Flow (W)	Evap Strap Temperature Requirement (K)	Estimated needed thermal strap conductance (W/K)	
	0	0.093			
	2900	0.0301			
700	2900	0.0301	2	0.100	
	3600	0.015	2		
temperature requirement applies to the last 700s of the condensation phase					

Pump Strap				Cooling of the pump	
shape of pulse				triang	
Duration of pum cooling phase				1560	s
Energy				350	J
Peak				0.4487	W
Contribution to Average dissipation on 48h				0.0020	W
				2.03	mW

Pump Strap					
	time (s)	Pump Strap Heat Flow (W)	Pump Strap Temperature Requirement (K)	Estimated needed thermal strap conductance (W/K)	
0	3600	0.4487	10	0.054	
1560	5160	0	10		
Temperature requirement applies during all pump cooling phase					

System Aspects Evaporator Strap

- 1: Clarify the real needs:
  - Heat flow & temperature
    - 30mW sizing heat flow or 15mW
    - Where & When Temperature < 2K needed
  - Conductance
    - 0.1W/K between Helium and Heat switch + tank at 1.7K
- In case conductance 0.1W/K is confirmed to be required, a First approach for Sharing can be:
  - Industry: 0.2W/K --> lead to interface at 1.85K instead of 2K
  - Instrument 0.2W/K

Level 0 complete strap

- **Thermal path for evaporator Strap is composed of**

Industry

Instrument

  - Helium (1.7K)
  - (ground test: Internal strap)
  - (ground test: Contact K=0.3W/K)
  - Helium tank (5053)
  - Contact (6 x M6 screws TBC, area=?, K= 0.3W/K
  - Astrium /Air Liquide Pod (copper bulk, L=340mm)
  - Contact (4 x M4 screws, area=?, K=0.3W/K)
  - THERMAL INTERFACE
  - SPIRE Rigid Strap (25mmx3mmx322.5mm), Aluminum RRR=2200 !!!
  - Contact TBD screws, area=?, K=0.4W/K
  - SPIRE flexible Strap (10mmx3mmx76mm) Aluminum RRR=2200 !!!
  - Contact 0.4W/K (TBC, M3 screws)
  - electrical insulation (not in model)
  - Contact
  - Heat switch (0.2W/K ?)
  - Contact (0.4W/K)
  - Evaporator
- **Better reduce the number of screwed contact along path**
  - large uncertainty on conductance
  - 6 contacts @0.4W/K --> 60mW/K already

Level 0 complete strap

Global SPIRE Evaporator Strap

T	1.8
RRR Copper	800
RRR Al	800

	Diameter	width	thickness	Length	Material ref	material	Section	S/L	K	screw	M	Contact Force	Conductance	Conductance
	m	m	m	m			m2	m				N	W/K	W/K
Helium tank	0.05			0.003	50	Al 5083-T0 Alum	0.00196	0.654	1.2915				0.8453	0.0669
Contact										6	6		0.4	
Astrium pod				0.308	1	Copper	0.0001	3E-04	352.08				0.1141	
contact										4	4		0.4	
SPIRE rigid strap		0.025	0.003	0.323	2	Aluminum	7.5E-05	2E-04	1416.1				0.3293	0.0577
contact													0.4	
Spire flexible strap		0.01	0.003	0.076	2	Aluminum	0.00003	4E-04	1416.1				0.559	
Contact										3	3		0.4	
Heat switch open													0.2	
Contact													0.4	
Evaporator														

K	0.0310	
Q	0.03	0.05
delta T	0.97	1.61

Way forward

- Agree today on interface data (temperature/Heat flows or temperature/conductances
- Options:
  - Optimise existing system design
    - reduce number of contacts
    - use pure copper (high RRR)+ external mechanical support for soft material
  - Oversize Industry strap
    - More room available
    - keep design simple (no holes in tank preferred)
  - Split Evaporator strap to Shunt strap & Evaporator strap (add 1 thermal interface)
  - Use coupled analysis
    - Consistent set of assumption on materials (RRR) and contact conductances
    - Include all contacts & electrical insulation

Herschel Cooler Meeting

SPIRE PERSPECTIVE

Freidrichshafen 3&4 April 2003

A.Goizel

- Initial Astrium results have shown that the HOB temperature can be as low as 8.11K in spectrometer mode with the SPIRE ITMMv22.

- SPIRE Improvements currently being analysed:
  - L1 and L0 supports optimisation (1/4 reduction in heat leaks)
  - Cooler Evaporator Kevlar support back to 0.29 diam
  - Reduction in SCAL Power Dissipation
  - L0 straps design

- Analysis has been performed to demonstrate that 46 hrs hold time is still achievable by:
  - Holding the HOB temperature at 8.11K in spectrometer mode with other interface temperatures as calculated by HERSCHEL RTMM (PDR Status)
  - Implementing the changes in SPIRE as described previously

- The hold time has been calculated for various temperatures of the evaporator at the end of the condensation phase
- The hold time estimation also accounts for the He lost during cryo-pumping to allow for the 300mK system to cooldown to 0.3K

Temp HOB (K)	Temp Vent1 (K)	Qcooler (microW)	Hold Time Tevap @2.4K	Hold Time Tevap @2.2K	Hold Time Tevap @2K	Hold Time Tevap @ 1.8K
8.11	3.859	29.97	43.4	45.26	46.48	48.56
9.11	4.05	30.34	42.88	44.7	46.41	47.97
10.11	4.26	30.79	42.26	44.1	45.73	47.27

- Cooler model based on 4 litres test results, scaled for 6 litres – actual performance tbc following testing
- The need for the evaporator temperature to be as close as 1.7K at the end of condensation phase is shown above.

- Emphasis has been made on the need for a 46 hrs hold time (to allow proper operation of SPIRE in photometer mode).
- This is achievable but margins are very small
- It definitely requires a low Tevap at end of condensation period to allow this hold time to be achieved

PhFPU
2K Thermal Straps

J. Martignac

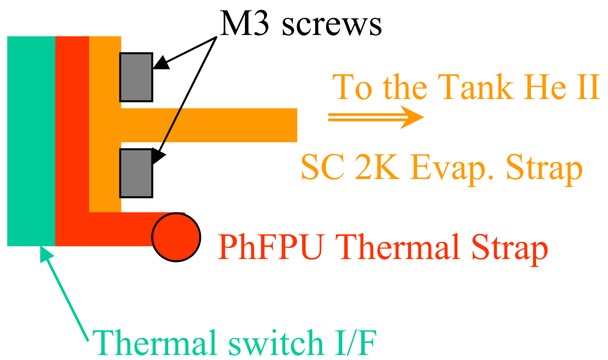
CEA/DSM/DAPNIA

Service d'Astrophysique

Introduction

- PhFPU 2K Thermal I/F historic;
- ^{3}He Cooler Thermal & Mechanical requirements;
- Thermal Boundary Resistance of mechanical contacts between solids around 2K;
- Possible Solutions : Advantages & Unpleasantness
- Thermal Interface description
- Conclusion : Best way !?

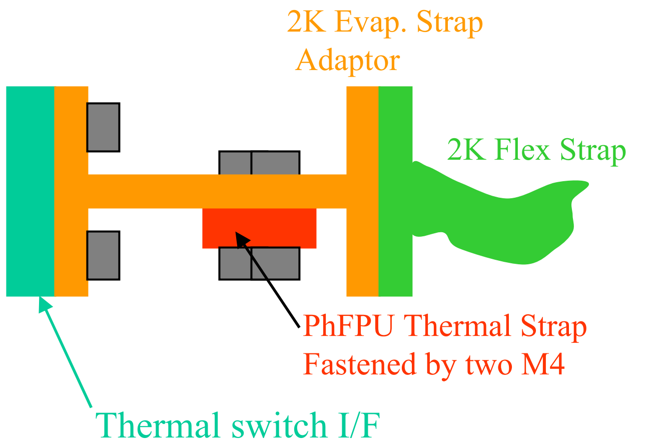
PhFPU 2K Thermal I/F Historic



First design : The PhFPU 2K strap was fastened between the thermal switch interface and the SC 2K strap.

⇒ Problems during integration on the space craft in terms of :

- responsibility vs cooler
- accessibility of the cooler thermal switch interfaces



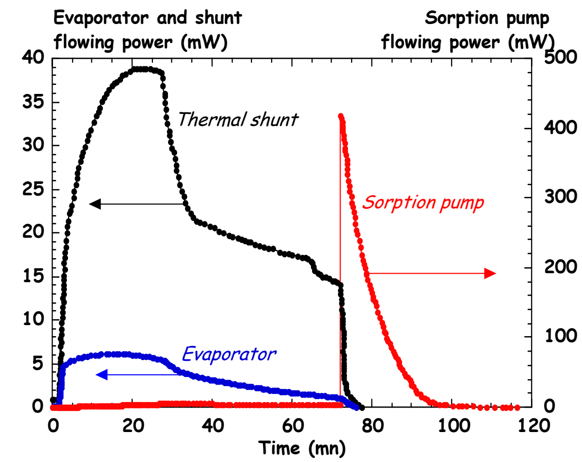
Evolution: An extra 2K strap adaptor was designed just to see the compatibility with the PhFPU design and was proposed to the instrument.

In this design the PhFPU 2K strap is directly linked to the 2K strap adaptor.

^{3}He Cooler Thermal Requirements

The size of the 2K evaporator Strap is driven by the dissipated energy during the condensation phase. The energy to be considered are the following:

	Pulse	Duration	Energy / J	Peak / W
Condensation in Evaporator	triangle	3600	40	0,022
Condensation on Thermal Shunt	triangle	3600	100	0,056
Conduction from Pump to the thermal shunt	rectangle	3600	54	0,015
Total		3600	194	0,093

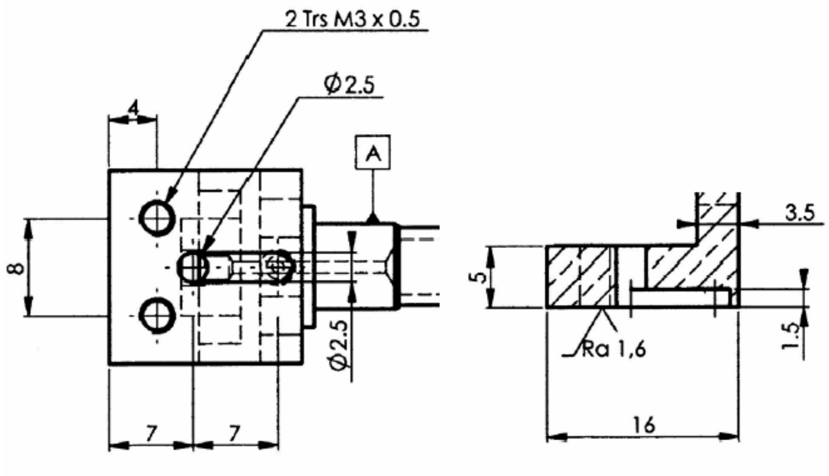


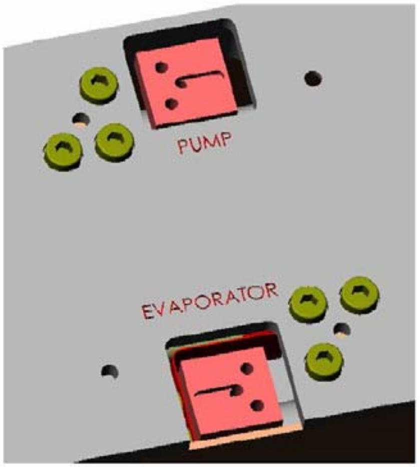
The temperature requirement on the cooler evaporator switch interface is applied only to the last 700 s. (TBC) of the condensation phase. During this time the power trough the strap is 30mW. Assuming a HeII bath temperature of 1,75K and an admissible maximum temperature of 2 K at the cooler interface level, we find a thermal strap conductance of about 0,12 $W.K^{-1}$.

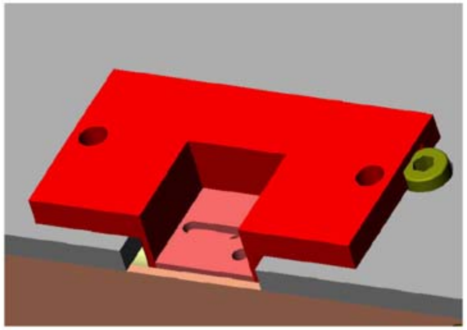
So, if we want to maximize the 300mK hold time the evaporator thermal strap (between the cooler switch evaporator thermal interface and the He II tank) should have a thermal conductance better than 0,12 $W.K^{-1}$.

Concerning the 2K Pump Strap, the peak power at the beginning of the pump cooling phase is 450 mW. Assuming an admissible maximum temperature of 10 K at the cooler switch pump interface level, **the pump thermal strap should have a thermal conductance better than 0,054 $W.K^{-1}$.**

^{3}He Cooler Mechanical Requirements *







* : SPIRE & PACS Sorption Coolers Interface Control Document (ICD)

The cooler comprises two gas gap heat switches located inside the structural box. The box then features two cut to provide access to the switch interface. Each heat switch interfaces with a thermal strap (connected to the superfluid cryostat). The mechanical interface for both switches is similar and is a copper plate gold plated 16 mm x 16 mm featuring two M3 holes (helicoil screw lock type). The maximum recommended torque for the screws is 0.33 Nm. The maximum additionnal mass which can be supported is 50 grams. This interface also features a tool designed to prevent any excessive torque on the gas gap heat switch when mounting the thermal strap. ***This tool is intended to be used only while screwing the strap and must be removed before cooler operation – the drawing hereafter shows this tool in place***.

It is important to note that any excessive mechanical load on this interface must be avoided and shall in any case never exceeds 50 N in any directions.

Thermal Boundary Resistance of mechanical contacts between solids around 2K

The requirements on the 2K thermal straps especially for the evaporator one, implies to look on detail the thermal performances that we can reach at the interface between the solid parts.

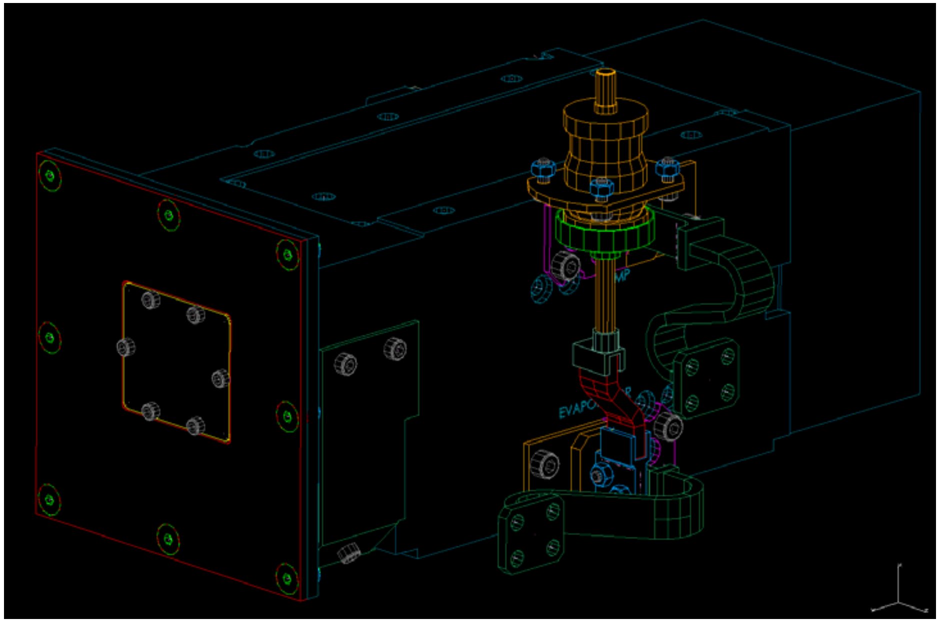
The thermal conductance of mechanical contacts is driven by many parameters :

- Thermal depedance : $h \approx \alpha T^n$ $n \approx 1$ for metals
  $n \approx 3$ for insulators
- True area of contact : $A_t << A$ (total area of contact)
- Pressure P applied to the contact : $At \approx P/\sigma_y$, where σ_y is the yield strength
  $h \approx \beta P^n$, with $n \leq 1$ (for the copper data show $n \approx 0,89$)
- Roughness dependance : In general, whichever the material is, the thermal conductance have a maximun for a surface roughness around 0.4µm (assuming operating temperature around 2K).

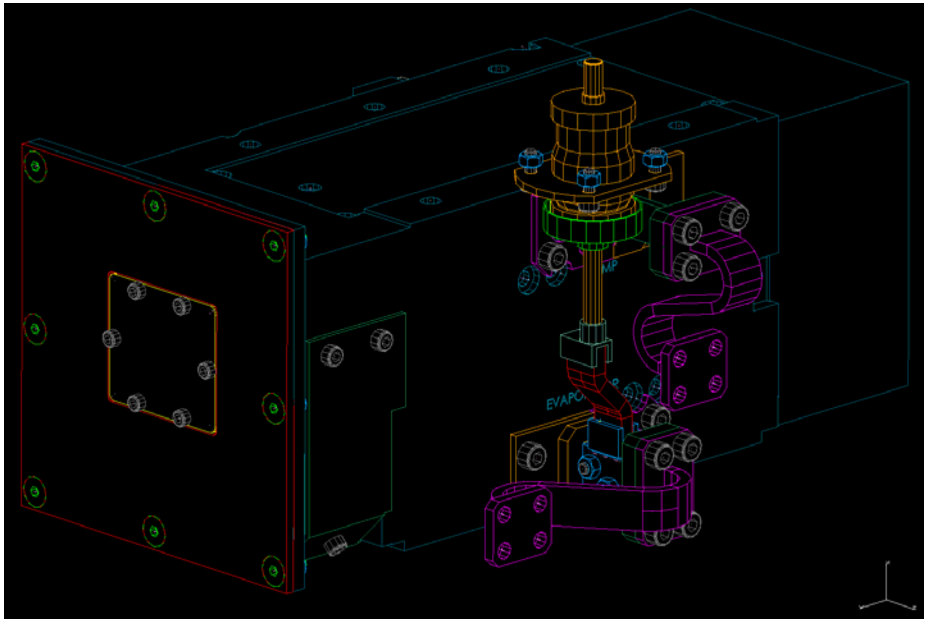
<u>Different values from bibliography:</u>

Author	Material	Contact	Temp / K	Applied Force / N	Conductance / $W.K^{-1}$
Berman	Cu/Cu		4.2	670	$1{,}46.10^{-2}$
“	“		“	892	$1{,}9.10^{-2}$
“	“		“	1115	$2{,}3.10^{-2}$
“	“	machined	1,8-4,2	280	$4.10^{-4}.T^2$
“	“	machined	1,8-4,2	1400	$1{,}67.10^{-3}.T^2$
ISO	?	?		?	0,4

Possible Solutions



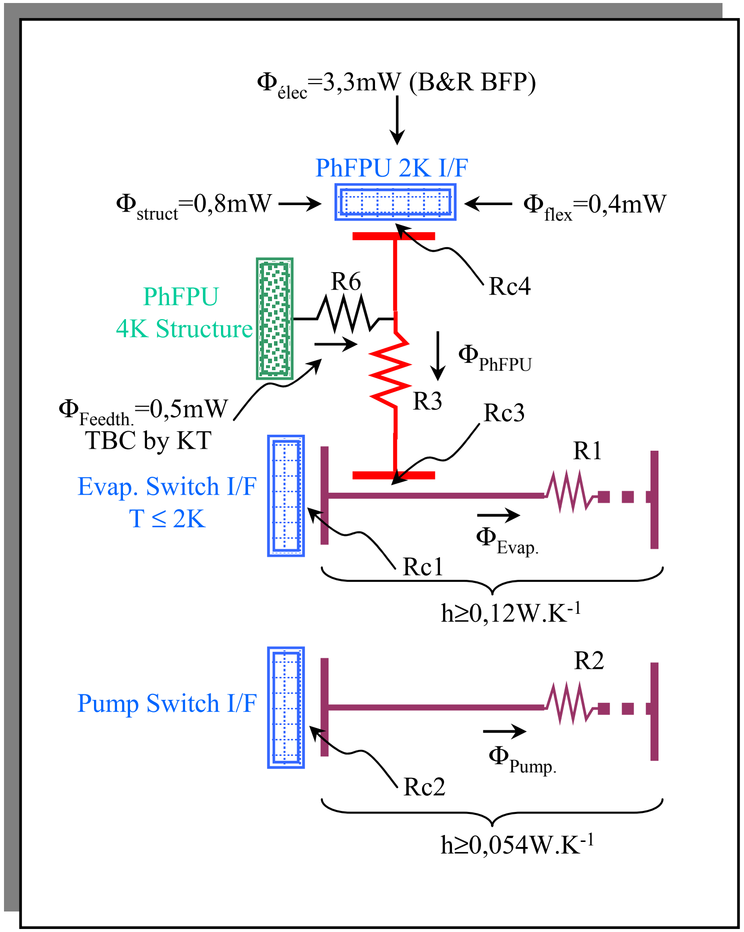
Strap : Flex part + Rigid part whithout extra thermal interface



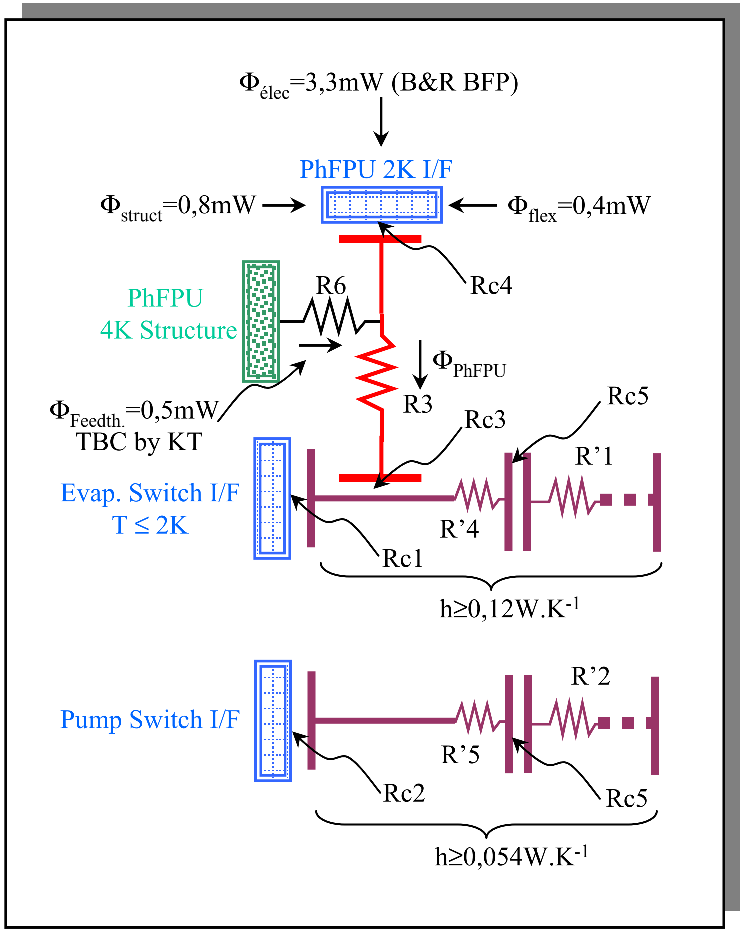
Strap composed by an adaptor + Flexible Strap with an extra thermal interface

The CEA/SAp consider that the Space Craft 2K Straps are linked from the HeII tank to the cooler switches I/F, and this whatever the configuration.

PhFPU Thermal I/F Equivalent Scheme



First Configuration : Single Strap



Second Configuration : Flex Strap + Adaptor

Thermal data summarize

	Description	Value	Status
Φ_{elec}	Electrical power on BFPs	$3{,}3.10^{-3}$W	
Φ_{struct}	2K/4K Structure	8.10^{-4}W	
Φ_{flex}	Flex ribbon cables	4.10^{-4}W	
Φ_{feedth}	2K Feedthrough	5.10^{-4}W (TBC)	
Φ_{Evap}	Cooler Evap	3.10^{-2}W peak during recycling phase	
Φ_{Pump}	Cooler Pump	$4{,}5.10^{-1}$W peak during recycling phase	
R1	SC Evaporator Strap thermal resistance	33 K.W^{-1} for S=0,33cm^2 9 K.W^{-1} for S=1cm^2	Non admissible ΔT= 1K Lower limit ΔT= 0,27K
R2	SC Pump Strap thermal resistance	33 K.W^{-1} for S=0,33cm^2 18,3 K.W^{-1} for S=0,6cm^2	Non admissible ΔT= 14,8K Lower limit ΔT= 8,2K
R3	2K PhFPU Strap thermal resistance	77 K.W^{-1}	ΔT= 0.38K
R6	2K Feedthrough thermal resistance	?	Non applicable

R'1	SC Flex Evaporator Strap thermal resistance	24,3 $K.W^{-1}$ for $S=0{,}33cm^2$ 8 $K.W^{-1}$ for $S=1cm^2$	Non admissible $\Delta T= 0{,}73K$ Lower limit $\Delta T= 0{,}24K$
R'2	SC Flex Pump Strap thermal resistance	24,3 $K.W^{-1}$ for $S=0{,}33cm^2$ 13,3 $K.W^{-1}$ for $S=0{,}6cm^2$	Non admissible $\Delta T= 0{,}73K$ Lower limit $\Delta T= 0{,}27K$
R'4	Adaptor Evaporator Strap thermal resistance	9,1 $K.W^{-1}$ for $S=0{,}33cm^2$ 3 $K.W^{-1}$ for $S=0{,}33cm^2$	Non admissible $\Delta T= 1K$ Lower limit $\Delta T= 0{,}09K$
R'5	Adaptor Pump Strap thermal resistance	9,1 $K.W^{-1}$ for $S=0{,}33cm^2$ 5 $K.W^{-1}$ for $S=0{,}6cm^2$	Non admissible $\Delta T= 1K$ Lower limit $\Delta T= 0{,}09K$
Rc1	Evaporator Switch thermal resistance contact	…. $K.W^{-1}$ (to be measured)	
Rc2	Pump Switch thermal resistance contact	…. $K.W^{-1}$ (to be measured)	
Rc3	PhFPU 2K strap thermal resistance contact with the SC strap	2,5$K.W^{-1}$ with $S=1cm^2$, $h=0{,}4\ W.cm^{-1}.K^{-1}$ (ISO data)	
Rc4	PhFPU 2K strap thermal resistance contact with the PhFPU 2K Structure	2,5$K.W^{-1}$ with $S=1cm^2$, $h=0{,}4\ W.cm^{-1}.K^{-1}$ (ISO data)	
Rc5	Strap Adaptor thermal resistance contact	30$K.W^{-1}$ with $S=5cm^2$, $h_c=1{,}9.10^{-3}T^{1{,}4}$, $F=1400N$ 16,8$K.W^{-1}$ with $S=5cm^2$, $F=3000N$ 0,5$K.W^{-1}$ with $S=5cm^2$, $h=0{,}4\ W.cm^{-1}.K^{-1}$ (ISO data)	Non admissible $\Delta Tevap= 0{,}9K$ Non admissible $\Delta Tpump= 13{,}5K$ Non admissible $\Delta Tevap= 0{,}5K$ Non admissible $\Delta Tpump= 7{,}5K$ OK $\Delta Tevap= 0{,}015K$ $\Delta Tevap= 0{,}22K$

Advantages & Unpleasantness

Advantages :

• Significant gain in term of mass : 30% (estimated), permit to fit with the cooler requirements : 50 g. max;

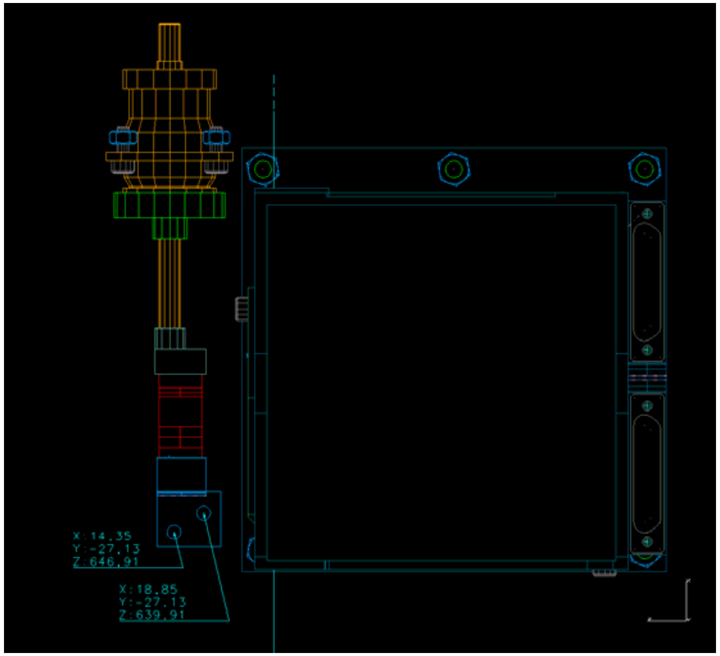
• Improvement of the thermal conductance which is the most critical item, an extra thermal interface is permitted only if we can achieve a thermal conductance at the interface better than : h_{min} = 0,31 $W.cm^{-2}.K^{-1}$ which represent 10 times the thermal srap conductance;

• Reduction of the number of parts and number of interfaces ⇒ anomaly reduction.

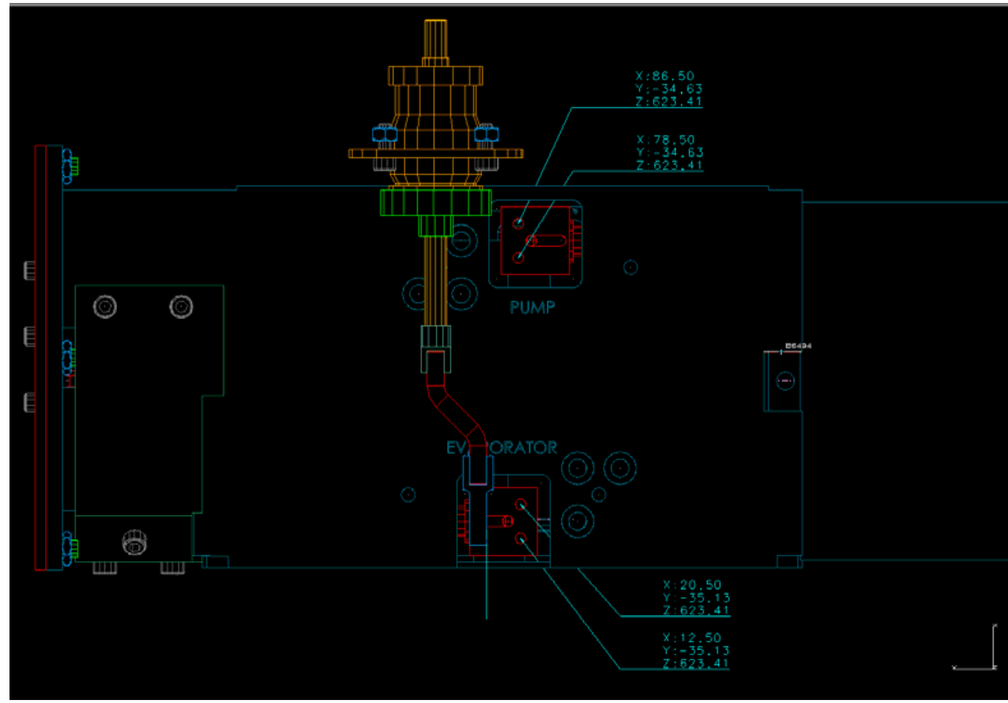
Unpleasantness :

• Mechanical manufacturing will be a little bit more complicated, but I think really that is not a real problem.

2K Thermal Interfaces Location



PhFPU 2K thermal Strap I/F

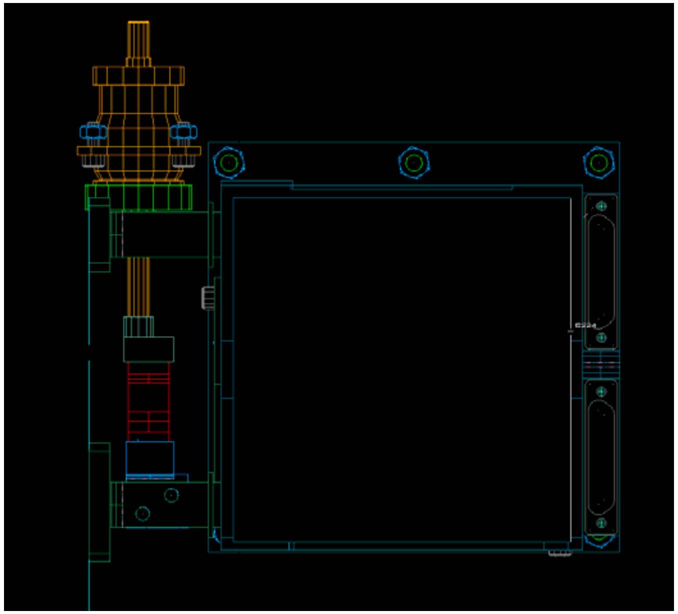


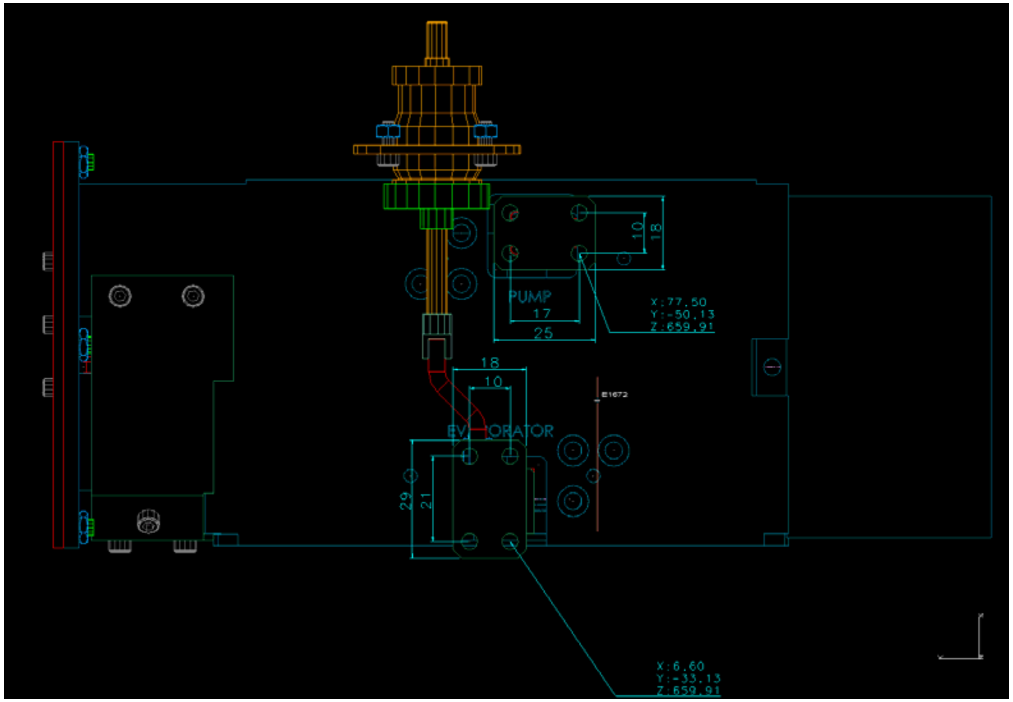
Cooler Switches thermal Straps I/F

The foreseen rougthness for this contact area is 0,4µm (S ≈ 1cm^2). It will be fastened by two M4 screws (Max. admissible torque :2 N.m ⇒ F ≈ 2500 N.)

The rougthness of this contact area is 1,6µm (S≈2cm^2). Each strap is fastened by two M3 Z2-CN18-10 screws (ICD : torque ≈ 0,33 N.m ⇒ F ≈ 650 N., to be measured & TBC)

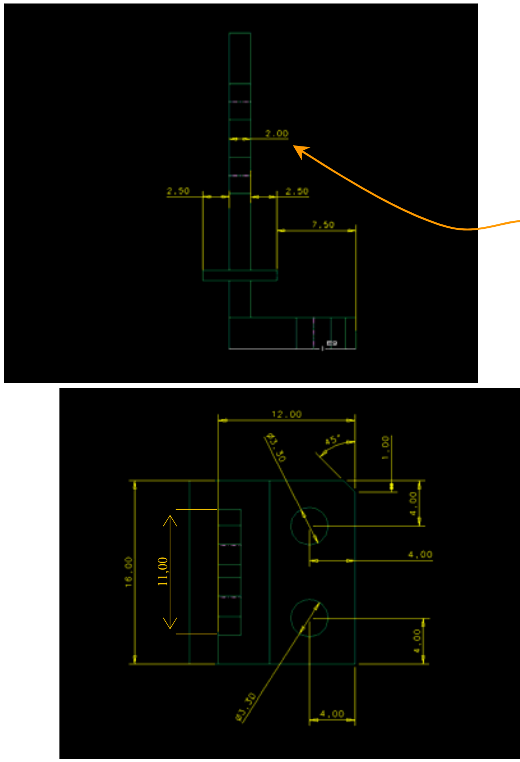
Intermediate 2K Thermal Interfaces Location with Strap Adaptors





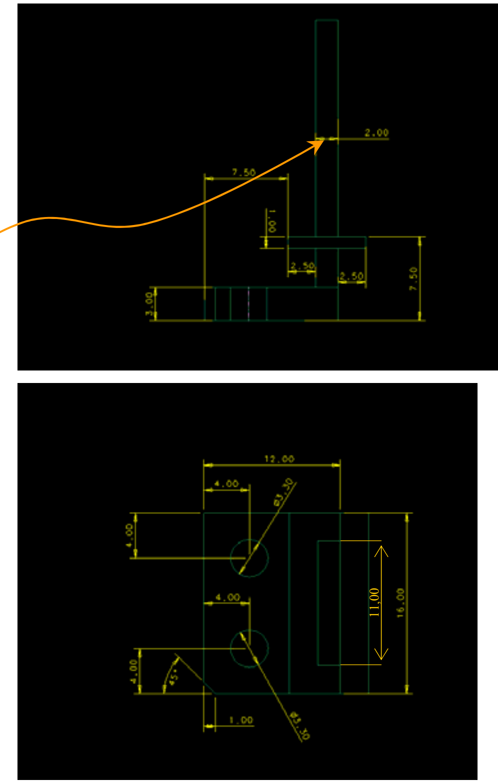
Nota : This design is a proposal and it is not contractual

SC Straps ending detail



2K SC Strap Evaporator ending

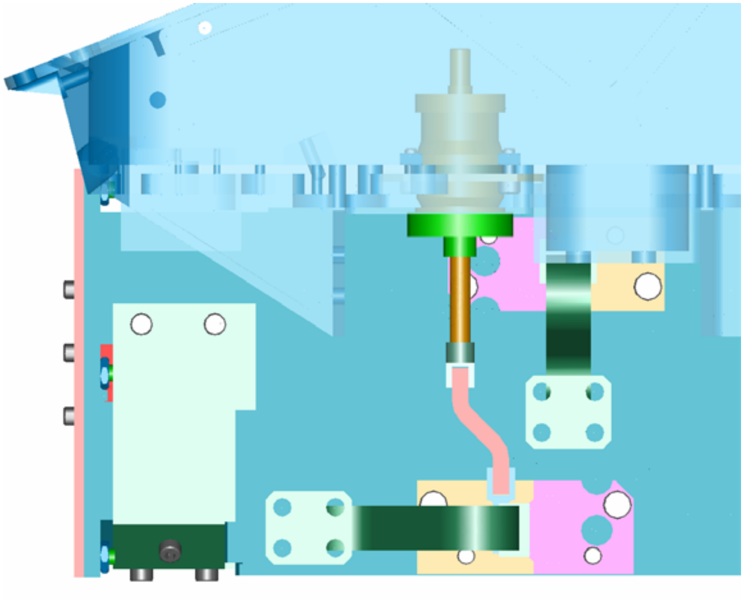
The strap thickness should be adapted to the required thermal conductance.
The cooler optical baffles can be modified

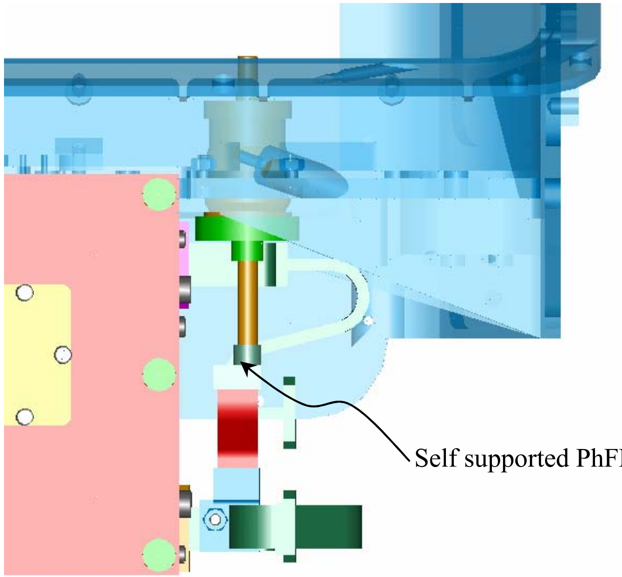


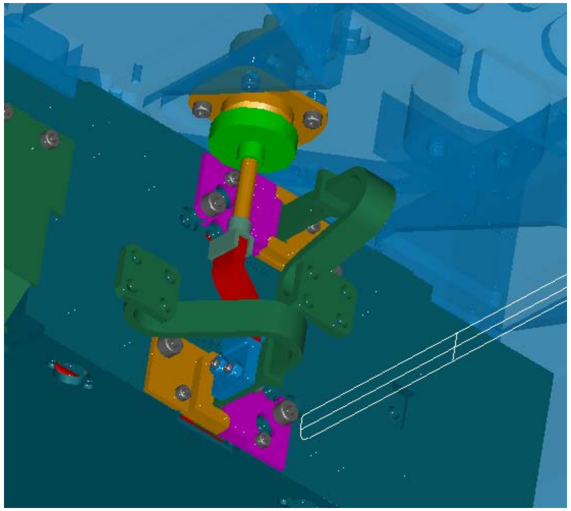
2K SC Strap Pump ending

This design is applicable whatever the adopted configuration : single strap or adaptor + flex strap

2K SC Straps mounting accessiblity







Whatever the adopted configuration, it will preferable to mount the 2K SC Straps during the assembly phase of the PhFPU, **even if Adaptors are used.**

Actions vs Adopted Configuration

Solution N°1: **SC 2K Strap in one part**

-Design definition to adapt the optical baffles fastened to the cooler, particularly to fit with the required thickness of the strap.

Solution N°2: **SC 2K Strap in two parts : Adaptor + Flexible part**

-Design definition of the Strap Adaptors to adapt the optical baffles ….

For accessibility reasons and maximun admissible torque on switches I/F, whatever the adopted configuration, the CEA/SAp offer to mount the SC 2K Straps on the PhFPU during its assembly.
The PhFPU will be delivered with a special tool designed to maintain the SC Straps on this tank I/F.

- What are present time-scales for baseline 6 litre performance measurements?
- Can they be extended to assess over a range of L0 (which is nominally 1.7K) and L1 (4.2K nom. in cooler spec.) temperatures & straps? Note Herschel environment is wider than cooler spec.
- Is it likely that the 6 litre unit will differ in required recycle temperatures versus % recycle.
- Do you include testing with the alternative position of heat shunt strap testing?
- Could one cut an aperture in the cooler side between the existing switch interfaces with 4 tapped holes around it, either to secure a cover or to an instrument provided steady to an externally fed shunt strap?
- If we want to use a somewhat slower regeneration than you now propose, i.e. to use the full 2 hour regeneration (minimum heat pulse, supposedly easiest straps) how could this impact energy efficiency?
- If the 10K pump cooler I/F after switching spec. were relaxed, what would be the impact?
-

	Name	Dep./Comp.		Name	Dep./Comp.
x	Alberti von Mathias Dr.	SM 34	x	Schink Dietmar	ED 422
	Alo Hakan	OTN/IP 35	x	Schlosser Christian	OTN/EN 64
	Barlage Bernhard	ED 11		Schweickert Gunn	SM 34
	Bayer Thomas	ED 541	x	Stauss Oliver	SM 33
x	Faas Horst	EA 65		Steininger Eric	ED 422
	Fehringer Alexander	SM 33		Stritter Rene	ED 11
	Frey Albrecht	ED 422	x	Suttner Klaus	SM 32
	Gerner Willi	ED 11		Tenhaeff Dieter	SM 34
	Grasl Andreas	OTN/EN 64		Thörmer Klaus-Horst Dr.	OTN/ED 65
	Grasshoff Brigitte	ED 521		Wagner Adalbert	OTN/IP 35
	Hartmann Hans Dr.	ED 422	x	Wagner Klaus	SM 31
x	Hauser Armin	SM 31	x	Wietbrock, Walter	ED 521
x	Hinger Jürgen	SM 31		Wöhler Hans	SM 34
x	Hohn Rüdiger	ED 541		Zipf Ludwig	ACE 32
x	Hölzle Edgar	ED 421			
	Huber Johann	ED 543		Alcatel	ASP
	Hund Walter	SE 76	x	ESA/ESTEC	ESA
x	Idler Siegmund	ED 432		**Instruments:**	
	Ivády von András	ACE 32	x	MPE (PACS)	MPE
	Jahn Gerd Dr.	SM 31	x	RAL (SPIRE)	RAL
	Kalde Clemens	ED 532		SRON (HIFI)	SRON
	Kameter Rudolf	OTN/EN 64		**Subcontractors:**	
	Kersting Stefan	OTN/EN 63		Air Liquide, Space Department	AIR
x	Kettner Bernhard	SM 34		Air Liquide, Space Department	AIRS
	Knoblauch August	ED 531		Air Liquide, Orbital System	AIRT
	Koelle Markus	ED 533		Alcatel Bell Space	ABSP
x	Kroeker Jürgen	ED 542		Astrium Sub-Subsyst. & Equipment	ASSE
	Kunz Oliver	SM 31		Austrian Aerospace	AAE
	Lamprecht Ernst	OTN/SM 222		Austrian Aerospace	AAEM
	Lang Jürgen	SE 76		APCO Technologies S. A.	APCO
x	Langfermann Michael	ED 541		Astrium GmbH Space Infrastr.	ASIP
	Mack Paul	OTN/EN 64		Bieri Engineering B. V.	BIER
x	Moritz Konrad Dr.	ED 65		BOC Edwards	BOCE
	Müller Lutz	OTN/EN 64		Dutch Space Solar Arrays	DSSA
	Muhl Eckhard	OTN/EN 64		EADS CASA Espacio	CASA
x	Pastorino Michel	ASPI Resid.		EADS CASA Espacio	ECAS
	Peitzker Helmut	ED 65		Eurocopter	ECDE
	Peltz Heinz-Willi	SM 33		HTS AG Zürich	HTSZ
	Peters, Gerhard	ED 531		Linde	LIND
	Pietroboni Karin	ED 65		Patria New Technologies Oy	PANT
	Puttlitz Joachim	OTN/EN 64		Phoenix, Volkmarsen	PHOE
	Rebholz Reinhold	ED 541		Prototech AS	PROT
	Reuß Friedhelm	ED 62		Rembe, Brilon	REMB
x	Rühe Wolfgang	ED 6		SENER Ingenieria SA	SEN
	Runge Axel	OTN/EN 64		Stöhr, Königsbrunn	STOE
	Sachsse Bernt	ED 21		Rosemount Aerospace GmbH	ROSE
	Schäffler Johannes	OTN/EN 64		RYMSA, Radiación y Microondas S.A.	RYM