SPIRE Technical Note

SPIRE Thermal Balance Test Sequence and Requirements For EQM Testing

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CONTENT

1. Scope

This technical note provides inputs for the test sequence and thermal interface requirements for the testing of the SPIRE instrument at EQM level.

2. Documents

2.1 Applicable Documents

AD	Title	Issue	Author
1	Spire Cooler Recycling SCOS Procedure SPIRE-RAL-PRC-002267	Revised	A. Aramburu
2	SPIRE Short Performance Test sequence for EQM Testing SPIRE-RAL-NOT-002284	0.1	B. Swinyard
3	Instrument Testing on PLM EQM Level HP-2-ASED-PL-0021	3.1 Draft	S. Idler
4	NCR for Response Time of Evaporator Heat Switch HR-SP-RAL-NCR-62	-	-

Table 2-1 – Applicable Documents

2.2 Reference Documents

RD	Title	Issue	Author
1	Instrument Interface Document Part B SCI-PT-IIDB/SPIRE-02124	3.2	G. Doubrovik

Table 2-2 – Reference Documents

3. Document Changes

Issue	Date	Section	Change Description	Ref
0.1	28/01/05	All	New Document – Draft Version	-
1.0	03/02/05	3.2.1	Change the evaporator Heat Switch status to ON during test to gain time in temp stabilisation.	Point 1 in DG email on 01/02/05
		All	Typo Error corrected	BS
		3.2.3	Move the spectro mode before photo mode to get a better insight in the transient profiles.	Point 2 in DG email on 01/02/05
		3.2.6	New mode added to describe the OFF mode case.	Point 3 in DG email on 01/02/05

Table 3-1 – Document Changes

4. Thermal Interface and Test Requirements for SPIRE EQM Testing

4.1 Overview

The EQM test cryostat, which provides a thermal environment close to the Herschel cryostat flight conditions [AD3], is an opportunity to validate the thermal design of the SPIRE instrument. SPIRE will therefore be thermally tested for two different sets of interface temperatures as defined in the Instrument Interface Document, Part B or IIDB [RD1]:

- The first test will be carried out with interface temperatures as defined by the requirements in the IIDB [RD1], which represents the "worst case" thermal environment for SPIRE,

- The second test will be carried out with interface temperatures as defined by the goals in the IIDB [RD1], which represents the "best case" thermal environment for SPIRE.

A cooler recycle followed by a thermal balance test will be performed in both cases and will provide a "best case" and "worst case" set of instrument temperatures, which will be used for correlation with the thermal model. In order to verify the hold time of the cooler, the first test case will effectively end when the cooler runs out of Helium (this will not be required for the second test case). As the thermal balance test isn't expected to last more than 4 hours (time required for the temperatures to stabilise), the remaining time (until the cooler runs out) will be used to verify the instrument stability performances when switching between different operating modes. An OFF mode thermal balance test can be carried when the others instruments will be in operation.

Finally, a pump characterisation test is required as it provides a tool to evaluate the cooler total during operation.

4.2 Test Descriptions

The following tests will be carried out with the SPIRE instrument integrated into the EQM test cryostat:

- Cooler Pump Characterisation,
- Cooler Recycle 1,
- Thermal Balance Test 1 – Thermal Interfaces set to requirements defined in IIDB,
- Cooler Recycle 2,
- Thermal Balance Test 2 – Thermal Interfaces set to goals defined in IIDB,
- Thermal Balance Test 3.

EQM test specifications for the SPIRE instrument are provided in the following sections.

4.2.1 Cooler Pump Characterisation

Thermal Test ID	**#Char**		
Description	**Cooler Pump Characterisation**		
Objective	This test allows the cooler pump thermal behaviour to be characterised from which the evaporator total load can be estimated.		
Method	- Set the pump heater to a known power dissipation, - Wait for the pump temperature to stabilise and log it.		
Total Test Duration (estimated)	4.5 hr Max.		
Outputs	Curve of pump temperature increase versus pump heater power.		
Cryostat Interface Temperature Setup	**Case 1**	**Case 2**	**Case 3**
Level-0 Detector Box	2K	2K	2K
Level-0 Pump	2K	2K	2K
Level-0 Evaporator	1.85K	1.85K	1.85K
Cryostat Mass Flow Rate	N/A	N/A	N/A
Applicable Temp. Stability Crit.	Pump, Pump IF	Pump, Pump IF	Pump, Pump IF
Performance Testing allowed	No	No	No
Estimated Test Case Duration	1.5 hr	1.5 hr	1.5 hr
SPIRE Instrument Setup	**Case 1**	**Case 2**	**Case 3**
Cooler			
Cooler State at Beginning of Case	Discharged	Discharged	Discharged
Pump Heater [mW]	0	40	20
Pump Heat Switch State / Heater [mW]	ON / 0.8 [1]	ON / 0.8	ON / 0.8
Evaporator Heat Switch State / Heater [mW]	ON	ON	ON
Mechanisms			
Instrument Operating Mode	OFF	OFF	OFF
SCAL [mW]	0	0	0
PCAL [mW]	0	0	0
SMEC [mW]	0	0	0
BSM [mW]	0	0	0
JFETs			
Photometer JFET [mW]	TBC	TBC	TBC
Spectrometer JFET [mW]	0	0	0
Monitoring Requirement			
Required Temperature Readout Frequency	10 sec	10 sec	10 sec
Additional Notes			

- The evaporator temperature must have stabilised at the predefined L0 temperature stage.
- The requirement and the goal temperatures at the pump cryostat interface are identical, so this test will be applicable for both Thermal Balance Tests #TBT1 and #TBT2.
- The Pump HS will only be tested at a lower value (0.4mW) during the recycling #Rec2 and therefore will not compromise these test results.
- The slope of the output curve and the final temperatures of the pump both depend on the L0 Pump strap conductance and therefore are expected to differ from the values measured during the CQM test campaign.
- Data that needs logging at the end of each test case are the pump, the cryo pump IF, pump HS heater current, pump heater current, cryostat mass flow rate.

Table 4-1 – Cooler Pump Characterisation

[1] For optimum operation, the Pump HS should be open as soon as possible after the cryostat interface temperatures have been setup.

4.2.2 Cooler Recycle 1

Thermal Test ID	**#Rec1**		
Description	**Cooler Recycle 1**		
Objective	Test the SPIRE Cooler recycling in flight like conditions (as defined per the requirements in the IIDB).		
Method	See AD1.		
Total Test Duration (estimated)	2 hr		
Outputs	Cooler Recycling Timeline		
Cryostat Interface Temperature Setup	**Case 1**		
Level-0 Detector Box	2K		
Level-0 Pump	2K		
Level-0 Evaporator	1.85K		
Cryostat Mass Flow Rate	Controlled to 2.2 mg/s		
Applicable Temp. Stability Crit.	N/A		
Performance Testing allowed	No		
Estimated Test Case Duration	2 hr		
SPIRE Instrument Setup	**Case 1**		
Cooler			
Cooler State at Beginning of Case	Discharged		
Pump Heater [mW]	See Proc.		
Pump Heat Switch State / Heater [mW]	0.8 - See Proc.		
Evaporator Heat Switch State / Heater [mW]	0.8 - See Proc.		
Mechanisms			
Instrument Operating Mode	PHOT STBY (TBC)		
SCAL [mW]	TBC		
PCAL [mW]	TBC		
SMEC [mW]	TBC		
BSM [mW]	TBC		
JFETs			
Photometer JFET [mW]	TBC		
Spectrometer JFET [mW]	0		
Monitoring Requirement			
Required Temperature Readout Frequency	1 sec		
Additional Notes			
▪ Known non-compliance: the evaporator heat switch takes approximately 40 min to switch ON [AD4]. ▪ The conditions to change the states of both heat switches at the end of the condensation phase should either be when the evaporator reaches 2K or at the latest, an hour[2] after the start of the recycling (whichever occurs first).			

Table 4-2 – Cooler Recycle 1

2 This will allow a direct comparison to be performed with the CQM test results where the evaporator was reaching 2K after an hour.

4.2.3 Thermal Balance Test 1

Thermal Test ID	**#TBT1**			
Description	**Thermal Balance Test 1**			
Objective	- Perform a Thermal Balance test in Photo mode in flight like conditions (as defined per the requirements in the IIDB). - Analyse the effect of mode change on instrument stability. - Test the cooler hold time for flight like recycling and operation conditions.			
Method	Set specific power dissipation in mechanisms.			
Total Test Duration	Until the Cooler runs out of Helium (46 hr max). [3]			
Outputs	Set of instrument temperatures that will be used for the correlation of the instrument thermal model.			
Cryostat Interface Temperature Setup	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Level-0 Detector Box	2K	2K	2K	2K
Level-0 Pump	2K	2K	2K	2K
Level-0 Evaporator	1.85K	1.85K	1.85K	1.85K
Cryostat Mass Flow Rate	N/A	N/A	N/A	N/A
Applicable Temp. Stability Crit.	All	N/A	N/A	N/A
Performance Testing allowed	(TBC)	(TBC)	(TBC)	(TBC)
Estimated Test Case Duration	4 hr	4 hr	4 hr	4 hr
SPIRE Instrument Setup	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Cooler				
Cooler State at Beginning of Case	Recycled	Recycled	Recycled	Recycled
Pump Heater [mW]	0	0	0	0
Pump Heat Switch State / Heater [mW]	ON / 0.8	ON / 0.8	ON / 0.8	ON / 0.8
Evaporator Heat Switch State / Heater [mW]	OFF	OFF	OFF	OFF
Mechanisms				
Instrument Operating Mode	PHOT STBY	SPEC SCAN	PHOT SCAN	PHOT CHOP
SCAL [mW]	0 (TBC)	2.3 (TBC)	TBC	TBC
PCAL [mW]	0 (TBC)	TBC	TBC	TBC
SMEC [mW]	0 (TBC)	0 – 8 (TBC)	0 (TBC)	0 (TBC)
BSM [mW]	0 (TBC)	0 (TBC)	3 (TBC)	0 -3, 1Hz (TBC)
JFETs				
Photometer JFET [mW]	42 (TBC)	TBC	60 (TBC)	TBC
Spectrometer JFET [mW]	0	0	0	TBC
Monitoring Requirement				
Required Temperature Readout Frequency	1 min	1 sec	1 min	1 sec
Additional Notes				
▪ All power dissipation settings will be updated following PFM1 testing, as to be as flight like as possible. ▪ The setting of the SMEC and BSM power dissipation will be done manually using 2-wire measurements and an EGSE Power Supply, the procedure will be updated as soon as the above information are available.				

Table 4-3 – Thermal Balance Test 1

[3] *The cooler is expected to hold between 27-32 hours (depending on L0 interface temperatures). This allows for 4.5 hr of cooler pump characterisation before any thermal testing.*

4.2.4 Cooler Recycle 2

Thermal Test ID	**#Rec2**		
Description	**Cooler Recycle 2**		
Objective	Test the SPIRE Cooler recycling in flight like conditions (as defined per the goals in the IIDB). Assess impact of the pump thermal link overall conductance on cooler recycling timeline.		
Method	See AD1.		
Total Test Duration	2 hr		
Outputs	Cooler Recycling Timeline		
Cryostat Interface Temperature Setup	**Case 1**		
Level-0 Detector Box	1.71K		
Level-0 Pump	2K		
Level-0 Evaporator	1.75K		
Cryostat Mass Flow Rate	Controlled to 2.2 mg/s		
Applicable Temp. Stability Crit.	N/A		
Performance Testing allowed	No		
Estimated Test Case Duration	2 hr		
SPIRE Instrument Setup	**Case 1**		
Cooler			
Cooler State at Beginning of Case	Discharged		
Pump Heater [mW]	See Proc.		
Pump Heat Switch State / Heater [mW]	0.4/0.8 - See Proc.		
Evaporator Heat Switch State / Heater [mW]	0.8 - See Proc.		
Mechanisms			
Instrument Operating Mode	PHOT STBY (TBC)		
SCAL [mW]	TBC		
PCAL [mW]	TBC		
SMEC [mW]	TBC		
BSM [mW]	TBC		
JFETs			
Photometer JFET [mW]	TBC		
Spectrometer JFET [mW]	0		
Monitoring Requirement			
Required Temperature Readout Frequency	1 sec		
Additional Notes			
▪ Known non-compliance: the evaporator heat switch takes approximately 40 min to switch ON [AD4]. ▪ The conditions to change the states of both heat switches at the end of the condensation phase should either be when the evaporator reaches 2K or at the latest, an hour[4] after the start of the recycling (whichever occurs first). ▪ This recycle will differ from the first recycle in terms of the way the pump heat switch will be operated during the cryo-pumping phase. This will provide an additional insight with regards to the cooler recycling timeline and heat loads profile.			

Table 4-4 – Cooler Recycle 2

4 This will allow a direct comparison to be performed with the CQM test results where the evaporator was reaching 2K after an hour.

4.2.5 Thermal Balance Test 2

Thermal Test ID	**#TBT2**			
Description	**Thermal Balance Test 2**			
Objective	- Perform a Thermal Balance test in Photo mode in flight like conditions (as defined per the goals in the IIDB).			
Method	Set specific power dissipation in mechanisms.			
Total Test Duration (estimated)	4 hr			
Outputs	Set of instrument temperatures that will be used for the correlation of the instrument thermal model.			
Cryostat Interface Temperature Setup	**Case 1**			
Level-0 Detector Box	1.71K			
Level-0 Pump	2K			
Level-0 Evaporator	1.75K			
Cryostat Mass Flow Rate	N/A			
Applicable Temp. Stability Crit.	All			
Performance Testing allowed	(TBC)			
Estimated Test Case Duration	4 hr			
SPIRE Instrument Setup	**Case 1**			
Cooler				
Cooler State at Beginning of Case	Recycled			
Pump Heater [mW]	0			
Pump Heat Switch State / Heater [mW]	ON / 0.8			
Evaporator Heat Switch State / Heater [mW]	OFF			
Mechanisms				
Instrument Operating Mode	PHOT STBY			
SCAL [mW]	(TBC)			
PCAL [mW]	(TBC)			
SMEC [mW]	(TBC)			
BSM [mW]	(TBC)			
JFETs				
Photometer JFET [mW]	(TBC)			
Spectrometer JFET [mW]	(TBC)			
Monitoring Requirement				
Required Temperature Readout Frequency	1 min			
Additional Notes				
▪ All power dissipation settings will be updated following PFM1 testing, as to be as flight like as possible. ▪ The setting of the SMEC and BSM power dissipation will be done manually using 2-wire measurements and an EGSE Power Supply, the procedure will be updated as soon as the above information are available.				

Table 4-5 – Thermal Balance Test 2

4.2.6 Thermal Balance Test 3

Thermal Test ID	**#TBT3**			
Description	**Thermal Balance Test 3**			
Objective	Perform a Thermal Balance test with the instrument in OFF mode.			
Method	This test can be done at any time when the instrument is in OFF mode, even if others instruments (PACS, HIFI) are in operation.			
Total Test Duration (estimated)	Until temperatures are stable enough to be used for correlation.			
Outputs	Set of instrument temperatures that will be used for the correlation of the instrument thermal model.			
Cryostat Interface Temperature Setup	**Case 1**			
Level-0 Detector Box	N/A			
Level-0 Pump	N/A			
Level-0 Evaporator	N/A			
Cryostat Mass Flow Rate	N/A			
Applicable Temp. Stability Crit.	All			
Performance Testing allowed	yes			
Estimated Test Case Duration	N/A			
SPIRE Instrument Setup	**Case 1**			
Cooler				
Cooler State at Beginning of Case	Discharged			
Pump Heater [mW]	0			
Pump Heat Switch State / Heater [mW]	OFF			
Evaporator Heat Switch State / Heater [mW]	OFF			
Mechanisms				
Instrument Operating Mode	OFF			
SCAL [mW]	0			
PCAL [mW]	0			
SMEC [mW]	0			
BSM [mW]	0			
JFETs				
Photometer JFET [mW]	0			
Spectrometer JFET [mW]	0			
Monitoring Requirement				
Required Temperature Readout Frequency	1 min			
Additional Notes				
▪				

Table 4-6 - Thermal Balance Test 3