INPUT TO THE SPIRE

PFM4 THERMAL BALANCE TEST SPECIFICATION

THERMAL ENGINEERING GROUP				
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SPIRE PROJECT				
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CHANGE RECORD

Issue	Date	Section	Change
Draft A	31/08/06	-	New Document.
Draft B	11/09/06	3.4.6	Requirement set for BSM testing as part of Performance test.
		3.5	Step 3.3 - Test Duration increased to 2hr
			Step 4.2 - Added new sub-sections 4.2.1 and 4.2.2
			Step 4.4.2 – added requirement to run the L0 stage at 1.9K
			Step 4.5 - Added Note about L0 temperature sensors monitoring requirements during L1 test characterisation
			Step 4.6 – Add details about BSM testing
Issue 1	01/03/07	All	Remove sections that are not applicable Add detailed procedure to section 4 Formal Issue of Document

ACRONYMS

Acronym	*Definition*
AD	Applicable Document
BDA	Bolometer Detector Arrays
BSM	Beam Steering Mechanism
CBB	Cold Black Body
CQM	Cryogenic Qualification Model
DRCU	Digital Readout Control Unit
DTMM	Detailed Thermal Mathematical Model
EGSE	Electronic Ground Support Equipment
FM	Flight Model
FPU	Focal Plane Unit
FS	Flight Spare
HCSS	Herschel Common Science System
HeI	Helium I
HeII	Helium II
HOB	Herschel Optical Bench
I/F	Interface
IIDB	Instrument Interface Document Part B
IRD	Instrument Requirement Document
ILT	Instrument Level Testing
JFET	Junction Field Effect Transistor
L0	Level-0
L1	Level-1
L2	Level-2
L3	Level-3
LN2	Liquid Nitrogen
MGSE	Mechanical Ground Support Equipment
PFM	Proto Flight Model
RD	Reference Document
SMEC	Spectrometer Mechanism
SCU	Subsystem Control Unit
SOB	SPIRE Optical Bench
SPIRE	Spectral and Photometric Imaging Receiver
SVR	Science Verification Review
TBT	Thermal Balance Test

CONTENTS

LIST OF TABLES

1 SCOPE

This memo describes the thermal tests that will be carried out as part of the SPIRE PFM4 test campaign. Details about the test procedures and the thermal hardware test setup are also given.

2 DOCUMENTS

2.1 Reference Documents

ID	Title	Number
RD1	SPIRE PFM2 Thermal Balance Test Specification	SPIRE-RAL-DOC-002435 Issue 1
RD2	SPIRE Science Verification Review Thermal Performance	SPIRE-RAL-REP-002557 Issue 2
RD3	PFM3 Thermal Test Inputs	Email from A. Goizel 30/01/06
RD4	SPIRE PFM2 Thermal Test Report	SPIRE-RAL-REP-002534 Issue 1
RD5	SPIRE PFM Thermal Performance Flight Predictions	SPIRE-RAL-NOT-002588 Issue 1
RD6	SPIRE PFM3 Thermal Test Report	SPIRE-RAL-REP-002684 Issue 1
RD7	PFM4 Thermometers 0-5.xls	D. Smith 12/10/06
RD8	PFM4 Thermometer C2T Issue 0.2.xls	D. Smith 10/10/06
RD9	SPIRE Prime/Redundant Thermometry Harness Swap Procedure	SPIRE-RAL-PRC-002776 Issue 1.1
RD10	Cooler Recycle Command List Specification	SPIRE-RAL-NOT-002771 Issue 4.5
RD11	PFM4 Cold Test Master Procedure	SPIRE-RAL-PRC-002748 Issue 1
RD12	PFM As Built Configuration List	SPIRE-RAL-DOC-002326 Issue 2.8
RD13	SPIRE PFM3 Thermal Balance Test Specification	SPIRE-RAL-MEM-002563 Issue 1
RD14	Maximum Power Dissipation on sorption pump during warm recycling	L. Duband email Hot Recycling Query 01/12/06

Table 2-1 - Reference Documents

2.2 Applicable Documents

ID	Title	Number
AD1	Instrument Interface Document Part A	SCI-PT-IIDA-04624 3.3
AD2	Instrument Interface Document Part B – SPIRE Instrument	SCI-PT-IIDB/SPIRE-02124 Issue 3.2
AD3	SPIRE Instrument Requirement Document	SPIRE-RAL-PRJ-000034 Issue 1.3
AD4	SPIRE Cryogenic Thermal Design Requirements	SPIRE-RAL-PRJ-002075 Issue 1

Table 2-2 – Applicable Documents

3 PFM4 THERMAL TEST PLAN

3.1 Objectives

The primary objective of the PFM-4 test campaign is to verify that the thermal performance of the SPIRE flight model has not been degraded following the cold vibration testing at CSL in August 2006. The PFM4 test campaign will include repeats of some of the tests performed during the PFM-2/3 test campaigns to ensure the instrument is still performing as expected. It is also an opportunity to continue activities that were not successfully completed in earlier test campaigns (because of time, thermal hardware and/or test equipment limitations).

3.2 Changes to the Build Standard

The following changes have been implemented between the PFM3 and the PFM4 test campaigns:

- The CQM SMEC has been replaced with the PFM SMEC.
- New L0 MGSE straps will be used. These will have a representative bolted interface to the cooler heat switches and the L0 spectrometer enclosure.
- EGSE heaters will be fitted to the new MGSE straps to help with the characterisation of the instrument thermal performance following the change in L0 strap design (if necessary).
- New EGSE sensors have been procured to replace the non-working ones and some EGSE sensor locations have changed since PFM3. Please refer to [RD7] and [RD8] for additional information about the overall temperature sensors configuration.

Further details about the PFM4 master test procedure and the instrument standard build can be found in [RD11] and [RD12] respectively.

3.3 Lessons Learnt during the PFM3 Test Campaign

The following lessons have been learnt from the PFM3 test campaign [RD6]:

- A “controlled nominal cooler hold time” test case should be run at the beginning and at the end of the test campaign to allow the detection of any cooler performance degradation,
- The manostat should be operated in a consistent manner (whenever possible) to facilitate the analysis of the cooler performance during recycling.

3.4 Thermal Tests Planned for the PFM4 Test Campaign

3.4.1 Overview

Table 3.1 describes the list of thermal tests planned for the PFM4 test campaign.

Test Name	Description	Applicable Requirement	Priority
Thermal Balance Test Nominal Case	This test will ensure that the instrument thermal performance has not degraded following the cold vibration testing done at CSL.	All	High
Flight Temperature Sensors Calibration	All flight sensors (Prime and Redundant) should be checked out for DC offset and self-heating errors.	IRD-STRC-R07 IRD-CALS-R15 IRD-SMEC-R13 IRD-COOL-R18	High
300mK Subsystem Decontamination Case	Perform a cooler recycling with both cooler heat switches OFF as to allow the evaporator hence the 300mK subsystem to warm-up at or above 4K for a minimum of TBC hr.	-	High
L0 Straps Characterisation	This test would help detecting changes in the instrument thermal performance as well as help determine the L0 new straps conductance. Only if necessary.	-	TBC
Please note – the test listed below will actually be completed as part of the instrument performance testing, therefore they do not require specific time allocation.			
Automated Cooler Recycling Fine Tuning	This test will allow the fine-tuning of the control parameters that will maintain the pump temperature at or above 45K during the cooler recycling.	None	High
Mechanisms and Calibration Sources Operation	This test will assess the impact of mechanisms and source operation on the instrument internal gradients and power dissipations.	IRD-BSMP-R11 IRD-BSMP-R12 IRD-CALP-R12 IRD-CALS-R09 IRD-CALS-R12 IRD-CALS-R16 IRD-SMEC-R11	High
PTC Operation	This test will assess the impact of the PTC operation on the cooler total load and detector temperature stability.	IRD-COOL-R02 IRD-COOL-R04 IRD-COOL-R05	High

Table 3-1 – PFM4 Thermal Testing

3.4.2 Cooler Recycling

3.4.2.1 Repeatable Recyclings

The RAL calibration cryostat uses a manostat to control the temperature of the L0 temperature stage. During recycling, a large amount of heat is released by the cooler, which introduces instabilities in the L0 Helium pot unless the manostat is opened to release the heat faster. The side effect is that as the manostat is opened, the overall temperature of the L0 stage starts to drop sharply, driving the evaporator temperature as well as the L0 enclosures down. **Following the lessons learnt from the PFM3 test campaign, specific criteria should be defined to help the operators to use the manostat (time to open and close) in a controlled and consistent manner.**

When the manostat is set so that the L0 temperature stage runs at ~2K, the instabilities introduced by the recycling process are limited and the manostat only required to be opened at a late stage during the recycling i.e. it doesn't have any effect on the evaporator temperature at the end of the condensation phase. It is therefore recommended that a similar approach be used to recycle the cooler when completed as part of the Thermal Balance Test cases (whenever possible as the cryostat setup is quite a lengthy process). The following procedure should be used:

- set the manostat to operate at ~2K when closed,
- recycle the cooler and open the manostat towards the end of recycling (only if necessary),
- When the recycling is completed, open the manostat to adjust the L0 back to the temperature required for the thermal test i.e. 1.7K.

3.4.2.2 Automated and Optimized Cooler Recyclings

Some unit level testing has indicated that the pump temperature has an impact on the cooler recycling efficiency i.e. the higher the pump temperature, the larger the amount of Helium desorbed and available for condensation. Overall, about n x 1% of hold time is lost for a pump temperature n x 1K lower than 45K. It is therefore of interest to try and maintain the pump temperature at or above 45K as much as possible throughout the cooler recycling condensation phase.

A bang-bang control of the pump temperature was implemented using a VM script and tested successfully during the PFM3 test campaign [RD6]. In addition to controlling the pump temperature during the condensation phase, the script has also allowed the cooler recycling to be fully automated, therefore requiring no inputs from the operators, with the exceptions of the list of parameters to use for the recycling. A flowchart describing the recycling sequence including control parameters is presented in [RD10]. It is anticipated that some of the control parameters will require additional fine-tuning as part of this test campaign.

3.4.2.3 300mK Subsystem Decontamination

The detectors have proven to be highly sensitive to helium contamination and would require to be heated up to ~4K in order for their performance to be recovered should a helium leak occur in the flight cryostat. The current detector design however does not provide this functionality and others solutions have therefore had to be considered. The detectors are thermally coupled to the cooler cold tip which warms up to 3K during a normal cooler recycling. It has been suggested that the cooler should be recycled with both heat switches opened (OFF) in order for the cold tip and hence detectors to warm up further above 3K. A "warm" recycling with both heat switches OFF will therefore be run as one of the thermal tests during the PFM4 test campaign. It is important to note that for this specific case, the heating on the pump could be safely increased up to 600mW [RD14].

3.4.3 L0 EGSE Straps Characterisation

New L0 MGSE straps have been fitted to hopefully allow the cooler to return to nominal performance during recycling. Heaters have also been fitted to the straps to help characterizing the cooler/strap interfaces performance should the new straps be unsuccessful in recovering the cooler performance.

3.4.4 PTC Operation

The Photometer Thermal Control (PTC) is used to control both the thermal stability and absolute temperature of the photometer detectors during the cold operation phase at 300mK. The following aspects of the PTC operation need to be verified during the PFM4 test campaign:

- Validation of the control scheme and script used to operate the PTC,
- Estimation of the PTC additional load on cooler evaporator for a 46hr operation period,
- 300-mK detectors performance in term of thermal stability response to disturbances.

This PTC test has been defined as a “performance” test rather than a thermal test.

3.4.5 Flight Temperature Sensors Calibration

The DC offsets of the flight temperature sensors on the mechanisms remains to be quantified and the self-heating of the cooler evaporator temperature sensor should be characterized. As this test requires disconnecting flight harnesses, a procedure has been written [RD9] to ensure the safety of the instrument during the test.

3.4.6 Mechanisms/Calibration Sources Operation

The PFM SMEC has now been fitted to the instrument and the FPU temperature gradients and internal power dissipations should be reviewed. This involves looking at the housekeeping data gathered as part of the mechanisms performance testing.

3.4.7 Thermal Balance Test – Nominal Case

The thermal balance test aims at verifying the instrument thermal performance in terms of detector absolute temperatures and cooler hold time for a L0 and L1 thermal environment as flight representative as possible. Table 3.3 described the cryostat interface temperatures which should be used during the thermal balance test:

Required Interface Temperature	Temperature Sensor	Nominal
During recycling	T_L0_ESTR1	1.9K
At end of Condensation Phase	T_CEV_1	2.1K
During low-phase operation	T_L0_DSTR1	1.7K
L1 SOB Strap Interface	T_SOB_L1STR	5K

Table 3-2 – Cryostat Setup during Thermal Balance Test Case [RD2]

Note: It is important to note that the instrument L1/L0 thermal stability performance cannot be checked in the RAL calibration cryostat.

3.5 PFM4 Thermal Test Sequence – Overview

Step	Test Name	Priority	Duration	Proc	Test Setup Requirements
1	**Warm Functional test**		**2 hr**		
1.1	Check EGSE and Cryostat Temperature Sensors				Use Air Gun to perform end-to-end check of sensors (locations and channels on Lakeshore units)
1.2	Heater Functional Check				-
2	**Cold Functional test (4K)**		**2 hr**		
2.1	Check EGSE and Cryostat Temperature Sensors				Wait for instrument temperatures to stabilise Stable cryostat temperatures required No performance testing allowed Check that temperatures are consistent and all reading 4K
2.2	Heater Functional Check				-
3	**Cold Functional test (1.7K-4K)**		**2.5 hr**		
3.1	As part of cooler SFT		-		When checking the cooler heat switches, leaves them ON until the evaporator and pump have been allowed to reach ~2K.
3.2	When SFT is completed		2hr		Leave instrument in OFF mode (Mode TBC) Stable cryostat temperatures required No performance testing allowed Wait for instrument temperatures to stabilise
3.3	Check EGSE and Cryostat Temperature Sensors		2 hr		Check that all temperatures are consistent
4	**Cold Thermal Verification**	**High**			
4.1	"Controlled" Automated Cooler Recycling	High	2 hr		**First** Cooler Recycling (Anneso to attend and check performance is nominal) Use latest PFM3 VM Script Leave cooler to run out completely
4.2	Flight Temperature Sensors Calibration (P+R)	High	8 hr		Stable cryostat temperatures required No performance testing allowed Characterize the Self-heating and DC offset on Flight and Redundant Sensors
4.3	Automated Cooler	High	2 hr x **N**		Completed as part of instrument normal operation

	Recycling Fine-Tuning				Use updated VM script Check whether control parameters need updating as part of the fine-tuning exercise Use the manostat is a controlled/consistent manner
4.4	Thermal Balance Test Nominal Case	High	52 hr		Preferably run over a week-end
4.4.1			2 hr		Cryostat setup
4.4.2			2 hr		Cooler Recycling with L0 interface at 1.9K to confirm interface issue has been solved
4.4.3			2 hr		Cryostat setup
4.4.4			46 hr		Cooler Left to run out
4.6	Mechanisms Operations	High			Completed as part of performance testing.
4.7	300mK Subsystem Decontamination Case	High	4 hr		Special case of cooler recycling with both heat switches OFF => use manual script
4.8	"Controlled" Automated Cooler Recycling	High	2 hr		**Last** Cooler Recycling (Anneso to attend and check performance is nominal) Use latest PFM3 VM Script Leave cooler to run out completely
5	**Cold Thermal Verification**	**Medium**			
5.1	L0 Straps Characterisation	Medium TBC	8 hr		Stable cryostat temperatures required No performance testing allowed

Note: The duration of each thermal test has been defined in hours to help with the planning of the various tests within a day's shift pattern. Please note that the durations are applicable only once the cryostat has reached stable conditions i.e. as cryostat top-ups are required every morning, thermal tests are not expected to start before lunch time.

3.6 Additional Information

3.6.1 Steady-State Criteria

The completion of a thermal balance test is defined by a steady state criterion, which describes the maximum allowable temperature rate of change over a period of time for a given temperature sensor. Each temperature stage of the instrument has a different requirement as described in Table 3.4.

Stage	Rate of Change	Period	Applicable Sensor	Equivalent TMM Node
300mK	0.1 mK/hr	2 hr	T_PLW	2750
			SUBTEMP	4300
Level 0	9 mK/hr	2 hr	T_PL0_1	2400
			T_SL0_1	3400
Level 1	120 mK/hr	2 hr	T_SOB_L1STR	1130
			T_FPU_MXAF	1600
			T_FPU_PXAF	1500
			T_SOB_CONE	1300
Level 2	70 mK/hr	2 hr	T_PJFS_CHAS	5040
			T_SJFS_CHAS	5530

Table 3-3 - Thermal Steady State Criteria

3.6.2 Team Support and Tasks Breakdown

Tasks/Operations	Support
Cryostat, Lakeshores and Heaters	Dave/Anneso
Instrument/Mechanisms	Sunil/Ed/Tim/Davide
PTC	Ken/Doug/Anneso Sunil/Ed/Tim/Davide
Automated Recycling	Dave/Anneso Sunil/Ed/Tim/Davide

Table 3-4 – Tasks Breakdown and Team Support

4 FM4 THERMAL TEST PROCEDURE

The procedure described in the following pages should be used during the PFM4 thermal balance test campaign. It describes the thermal test setup for the various tests and also provides information regarding the types of information that should be logged during each test phase.

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
6.1	**Temperature Sensors Functional Check**						
6.1.1	**Room Temperature Check**						
6.1.2	**4K Temperature Check**						**0.3**
6.1.2.1	Wait for instrument temperatures to stabilise at 4K						
6.1.2.2	Log all instrument and cryostat temperature below, identify possible discrepancies and write observations in provided space.	Temperature	Resistance/Count				**0.3**
	HSFPU Harness Filter Bracket						
	M3,5,7 Optical Sub Bench						
	Input Baffle						
	BSM/SOB I/F (SOB side)						
	SCAL Structure						
	SCAL 4%						
	SCAL 2%						
	BSM						
	SMEC						
	SMEC/SOB I/F						
	Cooler Pump						
	Cooler Shunt						
	Cooler Evap						
	Cooler Pump Heat Switch (sieve)						
	Cooler Evap Heat Switch (sieve)						
	Photometer Level 0 Enclosure						
	Spectrometer Level 0 Enclosure						
	Photometer JFET Chassis						
	Spectrometer JFET Chassis						

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
	FPU +X A-Frame Interface						
	FPU –X A-Frame Interface						
	SOB Cone Interface						
	SOB L1 Strap Interface						
	L1 photo connector bracket						
	Detector Box L0 Strap Adaptor						
	Pump L0 Strap Adaptor						
	Evaporator L0 Strap Adaptor						
	Phot JFET L3 I/F Block						
	Spect JFET L3 I/F Block						
	HOB Cone I/F (Rear)						
	HOB +Y A-Frame I/F						
	HOB -Y A-Frame I/F						
	FPU L1 Adaptor						
	Detector Box L0 Strap on Adaptor 2						
	Pump L0 Strap 2 on Adaptor 2						
	Evaporator L0 Strap 2 on Adaptor 2						
6.1.3	**1.7K/4KTemperature Check**						**1.0**
6.1.3.1	Wait for instrument L1 temperatures to stabilise at 4K and L0 temperatures to stabilise at 1.7K.						
6.1.3.2	Make sure the cooler is discharged.					Discharged while the cryostat is stabilising if needed	
6.1.3.3	Make sure the Lakeshore 370 is using a 1uA excitation current setting						
6.1.3.4	Log all instrument and cryostat temperature (and resistance when applicable) below, identify possible discrepancies and write observations in provided space.						**0.3**

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
		Temperature	Resistance/Count				
	HSFPU Harness Filter Bracket						
	M3,5,7 Optical Sub Bench						
	Input Baffle						
	BSM/SOB I/F (SOB side)						
	SCAL Structure						
	SCAL 4%						
	SCAL 2%						
	BSM						
	SMEC						
	SMEC/SOB I/F						
	Cooler Pump						
	Cooler Shunt						
	Cooler Evap						
	Cooler Pump Heat Switch (sieve)						
	Cooler Evap Heat Switch (sieve)						
	Photometer Level 0 Enclosure						
	Spectrometer Level 0 Enclosure						
	Photometer JFET Chassis						
	Spectrometer JFET Chassis						
	FPU +X A-Frame Interface						
	FPU –X A-Frame Interface						
	SOB Cone Interface						
	SOB L1 Strap Interface						
	L1 photo connector bracket						
	Detector Box L0 Strap Adaptor						
	Pump L0 Strap Adaptor						
	Evaporator L0 Strap Adaptor						
	Phot JFET L3 I/F Block						

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
	Spect JFET L3 I/F Block						
	HOB Cone I/F (Rear)						
	HOB +Y A-Frame I/F						
	HOB -Y A-Frame I/F						
	FPU L1 Adaptor						
	Detector Box L0 Strap on Adaptor 2						
	Pump L0 Strap 2 on Adaptor 2						
	Evaporator L0 Strap 2 on Adaptor 2						
	Photometer Level 0 Enclosure (redundant)						
	Spectrometer Level 0 Enclosure (redundant)						
6.1.3.5	Change the Lakeshore 370 from 1uA to 10uA excitation current setting						0.1
6.1.3.6	Wait for 20 min for the temperature to stabilise						0.3
6.1.3.7	Log all the temperature and resistance for the following sensors, identify possible discrepancies and write observations in provided space.	Temperature	Resistance				0.3
	SOB L1 Strap Interface						
	Detector Box L0 Strap Adaptor						
	Pump L0 Strap Adaptor						
	Evaporator L0 Strap Adaptor						
	FPU L1 Adaptor						
	Detector Box L0 Strap on Adaptor 2						
	Pump L0 Strap 2 on Adaptor 2						
	Evaporator L0 Strap 2 on Adaptor 2						
6.1.3.8	Change the Lakeshore 370 from 10uA to 1uA excitation current setting						0.1

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
6.1.3.9	Wait for 20 min for the temperature to stabilise						0.3
6.1.3.10	Log all the temperature and resistance for the following sensors, identify possible discrepancies and write observations in provided space.	Temperature	Resistance				0.3
	SOB L1 Strap Interface						
	Detector Box L0 Strap Adaptor						
	Pump L0 Strap Adaptor						
	Evaporator L0 Strap Adaptor						
	FPU L1 Adaptor						
	Detector Box L0 Strap on Adaptor 2						
	Pump L0 Strap 2 on Adaptor 2						
	Evaporator L0 Strap 2 on Adaptor 2						
6.2	**Cooler Recycling**						**2.0**
6.2.1	Make sure the cryostat temperature stages have been set at ~1.7K.						
6.2.2	Make sure the 370 AC bridge excitation current is set to 1uA.						
6.2.3	Define and update list of control parameters for script as necessary					See "Cooler Recycle Command List Specification" for details of control parameters required (SPIRE-RAL-NOT-002771, Issue 4.5)	
6.2.4	Run VM script for cooler recycling and log the recycling start time in the AIV log						
6.2.5	Log the evaporator cold base temperature and recycling end time in the AIV log once it has stabilised at subk temperature.						
6.3	**Warm Cooler Recycling (Manual)**						**3.0**

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
6.3.1	Make sure the 370 AC bridge excitation current is set to 1uA.						
6.3.2	The cooler must be discharged to start with and the evaporator temperature at ~1.7K.						
6.3.3	Log the "warm" recycling start time in the AIV log						
6.3.4	Turn the pump Heat Switch OFF if previously turned ON.						
6.3.5	Turn the evaporator Heat Switch OFF if previously turned ON.						
6.3.6	Wait for both heat switches temperature to stabilise back to ~3.6K.						
6.3.7	Apply 400mW to the pump					**Up to 600mW could be used for this specific test as a maximum.**	
6.3.8	Monitore the evaporator temperature and record the peak value recorded in the AIV test log.					This completes the warm recycling test which aim was to find out what the warmest temperature the evaporator could get to during this "warm" recycling with both heat switches OFF.	
6.4	**PRIME Flight Thermometry Calibration**						**4.0**
6.4.1	Make sure the instrument temperatures are stable before starting the test						
6.4.2	Follow procedure given in "SPIRE Prime/Redundant Thermometry Harness Swap Procedure" to connect the PRIME flight instrument sensors to the Lakeshore AC bridge					SPIRE-RAL-PRC-002776, Issue 1.1	

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
6.4.3	Make sure the Lakeshore 370 is using a 1uA excitation current setting (with the exception of the SUBKtemp which should be monitored with a 3.16nA excitation current)						
6.4.4	Log all instrument flight temperatures (and resistance when applicable) for this excitation current					Note: this measurement cannot be performed for the evaporator heat switch sensor.	
	HSFPU Harness Filter Bracket						
	M3,5,7 Optical Sub Bench						
	Input Baffle						
	BSM/SOB I/F (SOB side)						
	SCAL Structure						
	SCAL 4%						
	SCAL 2%						
	Cooler Pump						
	Cooler Shunt						
	Cooler Evap						
	Cooler Pump Heat Switch (sieve)						
	Photometer Level 0 Enclosure						
	Spectrometer Level 0 Enclosure						
	BSM						
	SMEC						
	SMEC/SOB I/F						
6.4.5	Set the Lakeshore 370 to use a 10uA excitation current setting (with the exception of the SUBKtemp which should be monitored with a 31.6nA excitation current)					Note: this measurement cannot be performed for the evaporator heat switch sensor.	
	HSFPU Harness Filter Bracket						

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
	M3,5,7 Optical Sub Bench						
	Input Baffle						
	BSM/SOB I/F (SOB side)						
	SCAL Structure						
	SCAL 4%						
	SCAL 2%						
	Cooler Pump						
	Cooler Shunt						
	Cooler Evap						
	Cooler Pump Heat Switch (sieve)						
	Photometer Level 0 Enclosure						
	Spectrometer Level 0 Enclosure						
	BSM						
	SMEC						
	SMEC/SOB I/F						
6.4.6	Follow procedure given in "SPIRE Prime/Redundant Thermometry Harness Swap Procedure" to connect the instrument back to flight electronics					SPIRE-RAL-PRC-002776, Issue 1.1	
6.5	**REDUNDANT Flight Thermometry Calibration**						**4.0**
6.5.1	Make sure the instrument temperatures are stable before starting the test						
6.5.2	Follow procedure given in "SPIRE Prime/Redundant Thermometry Harness Swap Procedure" to connect the REDUNDANT flight instrument sensors to the Lakeshore AC bridge					SPIRE-RAL-PRC-002776, Issue 1.1	

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
6.5.3	Make sure the Lakeshore 370 is using a 1uA excitation current setting (with the exception of the SUBKtemp which should be monitored with a 3.16nA excitation current)						
6.5.4	Log all instrument flight temperatures (and resistance when applicable) for this excitation current					Note: this measurement cannot be performed for the evaporator heat switch sensor.	
	HSFPU Harness Filter Bracket						
	M3,5,7 Optical Sub Bench						
	Input Baffle						
	BSM/SOB I/F (SOB side)						
	SCAL Structure						
	SCAL 4%						
	SCAL 2%						
	Cooler Pump						
	Cooler Shunt						
	Cooler Evap						
	Cooler Pump Heat Switch (sieve)						
	Photometer Level 0 Enclosure						
	Spectrometer Level 0 Enclosure						
	BSM						
	SMEC						
	SMEC/SOB I/F						
6.5.5	Set the Lakeshore 370 to use a 10uA excitation current setting (with the exception of the SUBKtemp which should be monitored with a 31.6nA excitation current)					Note: this measurement cannot be performed for the evaporator heat switch sensor.	
	HSFPU Harness Filter Bracket						

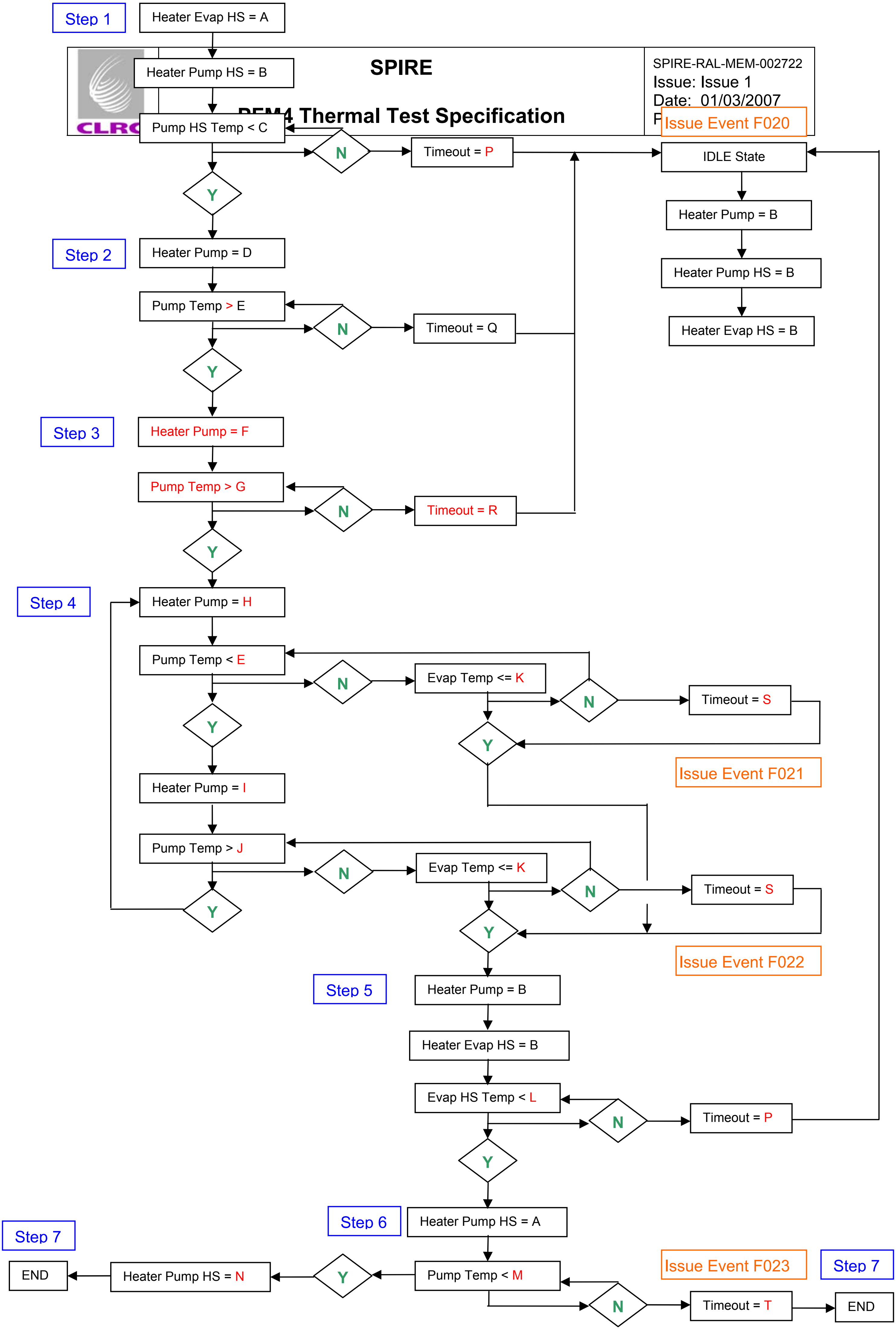
Test	Actions	Data			Task Completed	Comments	Duration [Hr]
	M3,5,7 Optical Sub Bench						
	Input Baffle						
	BSM/SOB I/F (SOB side)						
	SCAL Structure						
	SCAL 4%						
	SCAL 2%						
	Cooler Pump						
	Cooler Shunt						
	Cooler Evap						
	Cooler Pump Heat Switch (sieve)						
	Photometer Level 0 Enclosure						
	Spectrometer Level 0 Enclosure						
	BSM						
	SMEC						
	SMEC/SOB I/F						
6.5.6	Follow procedure given in "SPIRE Prime/Redundant Thermometry Harness Swap Procedure" to connect the instrument back to flight electronics					SPIRE-RAL-PRC-002776, Issue 1.1	
6.6	**Thermal Balance Test (Nominal Flight Environment)**						**55.5**
6.6.1	The cryostat temperature stages should be set as follows:						
	L2	~15K					
	L1 at SOB L1 I/F	~5K				Use the temperature from the "SOB L1 Strap Interface" (T_SOB_L1STR) to monitor the temperature setting.	

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
	L0 at top of Evaporator L0 Strap Interface	~1.9K				Use the temperature from the top of "Evaporator L0 Strap Interface" (T_L0_ESTR1 IF) to monitor the temperature setting.	**2.0**
6.6.2	The cryostat temperatures must be stable.						
6.6.3	The CBB should be closed.						
6.6.4	Make sure the 370 AC bridge excitation current is set to 1uA.						
6.6.5	The instrument mechanisms should be left OFF						
6.6.6	Recycle cooler according the procedure 6.2.						**2.0**
6.6.7	When the recycling has been completed, open the manostat to reset the L0 stage temperature as follows:						**2.0**
	L0 at L0 enclosure adaptor	~1.7K				Use the temperature from the "Detector L0 Strap Adaptor" (T_L0_DSTR1) to monitor the manostat temperature settings.	
6.6.8	Wait for the temperatures reached steady-state criteria and make sure no performances testing is carried out during this period.						**2.0**
6.6.9	When steady-state criteria are met, run a DC load curve to measure the phot detectors temperature [AD7] as well as the PTC.						**0.5**
6.6.10	When steady-state criteria are met, mesured all the flight temperature sensors on the AC bridge						**0.5**

Test	Actions	Data			Task Completed	Comments	Duration [Hr]
6.6.11	Write down the time at which the steady state condition has been met for future reference. This completes the thermal balance test case.						
6.6.12	Leave the cooler to run out during the week-end to assess the cooler total load and hold time performance for the nominal conditions						**46.0**
6.6.13	Log the time at which the evaporator started warming-up back from ~300mK to 1.7K and take note of the cooler hold time. This completes the cooler hold time characterisation.						**0.5**

APPENDIX – SPIRE Script for Automated Recycling Version 4.5

Param	Description	Setting	Current	Voltage	Hex
A	Heater Heat Switch ON (during Recycling)	0.8 mW	1.4 mA	0.56V	0x0DEB
B	Heaters OFF	0 mW	0.0 mA	0V	0x0000
C	Pump Heat Switch – Actuation Temperature	12 K	-	-	0xBF9B
D	Heater Pump Dissipation 1	400 mW	31.54 mA	12.7V	0x0A25
E	Pump Temperature Condensation 1	45 K	-	-	0x8E76
F	Heater Pump Dissipation 2	100mW	15.77mA	TBC	0x0513
G	Pump Temperature Condensation 2	46K	-	-	TBC
H	Heater Pump Dissipation 3	10mW	4.987mA	2V	0x019C
I	Heater Pump Dissipation 4	70mW	13.197mA	5.3V	0x043F
J	Pump Temperature Condensation Threshold	45.1K	-	-	0x8E49
K	Evap Temperature Condensation	2 K	-	-	0x7EBE
L	Evaporator Heat Switch Actuation Temperature	15K	-	-	0xB764
M	Pump Temperature Threshold	2 K	-	-	0xEFAE
N	Heater Heat Switch ON (during Recycling)	~ 0.4 mW	1.022 mA	0.41V	0x0A2A
O	Loop Sampling (microsecs)	10 sec	-	-	10000000
P	Heat Switch Timeout (min)	½ hr	-	-	1E
Q	Pump Heating Timeout 1 (min)	1hr	-	-	3C
R	Pump Heating Timeout 2 (min)	1hr	-	-	3C
S	Evaporator Timeout (min)	1 hr	-	-	3C
T	Pump Cooling Timeout (min)	1hr	-	-	3C
U	Global Timeout (min)	2hr	-	-	78


Step 1
Heater Evap HS = A
Heater Pump HS = B
Pump HS Temp < C
N
Timeout = P
Y
Issue Event F020
IDLE State
Heater Pump = B
Heater Pump HS = B
Heater Evap HS = B
Step 2
Heater Pump = D
Pump Temp > E
N
Timeout = Q
Y
Step 3
Heater Pump = F
Pump Temp > G
N
Timeout = R
Y
Step 4
Heater Pump = H
Pump Temp < E
N
Evap Temp <= K
N
Timeout = S
Y
Y
Issue Event F021
Heater Pump = I
Pump Temp > J
N
Evap Temp <= K
N
Timeout = S
Y
Y
Issue Event F022
Step 5
Heater Pump = B
Heater Evap HS = B
Evap HS Temp < L
N
Timeout = P
Y
Step 6
Heater Pump HS = A
Pump Temp < M
Y
Heater Pump HS = N
END
Step 7
N
Timeout = T
END
Issue Event F023
Step 7