SPIRE

SUBJECT:	**Cold vibration test plan PFM**		
PREPARED BY:	**E Sawyer**		
DOCUMENT No:	**SPIRE-RAL-PRC-002524**		
ISSUE:	**Issue 2.1**	Date:	**23/11/05**
CHECKED BY:	…………………………………	Date:	………………………….
APPROVED BY:	…………………………………	Date:	………………………….

Distribution

Change Record

ISSUE	DATE	
Draft 1	7/10/05	New issue of plan based on CQM test plan SPIRE-RAL-PL-001955
Draft 2	31/10/05	PFM will not be vibrated with the JFETS, text altered accordingly
Draft 3	8/11/05	More accelerometer data added
Issue 1	15/11/05	First formal issue
Issue 2	17/11/05	Sine acceptance Levels changed Cooldown rate modified Accelerometer table completed All the SMEC moving carriage accelerometers coded as SMECLX, instead of SMECLX, SMECLY, SMELZ The serial number of the SMECUY is 26087 instead of 26089 The type cell for the SMECBX : it is 2272.
Issue 2.1	23/11/05	Sine test in X axis, levels after 66Hx changed from 11.5 to 6.4 g

Table of Contents

References

Applicable Documents

No	Document	Ref
AD1	Cryovibration facility Design Description Document	TN-CSL-CRYOV-01003. issue 4 rev 0
AD2	Instrument Interface Document, part A	IID-A, issue 3
AD3	Random Vibration SPIRE February 2003 issue 3.doc	Technote 9
AD4	Herschel/SPIRE Handling and integration procedure	
AD5	Instrument interface drawing	5264-300 sheet 1 to 7, issue 18

Reference Documents

RF1 Drawing describing the MGSE assemblies
RF2 Lifting the FPA from/in transport container
RF3 Lifting the FPA from/on base plate
RF4 Fax, SCI-PT/22891, dd 18th December 2003. Cryo-Qual approach.
RF5 Cold vibration test plan – CQM SPIRE-RAL-PRC-001955
RF6 Cold vibration test procedure CQM SPIRE-RAL-PRC-001956
RF7 Instrument Vibration Test Report CQM Qualification (Cold) - SPIRE-MSS-REP-002049

1. SCOPE

This document describes the cold vibration testing on the FPU to be carried out at CSL, Liege.

2. INTRODUCTION

3. PRE TEST PREPARATIONS AT RAL

As part of the preparations at RAL, instrumentation will be fitted within the FPU.
To achieve this, the following equipment will be loaned to SPIRE by CSL.

- 9 Accelerometers, consisting of three tri-ax configurations
- 9 accelerometer cables of minimum length 1.5m. This is long enough to bring the cables to the outside of the SPIRE FPU, further extension is probably required to the cryostat wall.

This equipment is required at RAL, at least two weeks before the start of the test campaign.

In addition to the CSL accelerometers, 9 accelerometers supplied by SPIRE are fitted to the SMEC subsystem, See section 6

4. DELIVERY

The following equipment will be delivered to CSL by the SPIRE project. It will be delivered by road in one shipment.

FPU, in a dedicated container
MGSE
Lifting equipment

5. PRE TEST CHECKOUT

It is not planned to do any function checks after delivery of the Instrument or before the start of the test. Only a visual inspection will be carried out.

6. INSTRUMENTATION

6.1 Accelerometers

All accelerometers will be pre-fitted before delivery, see section 3. The instrument will be delivered to CSL ready to test, no additional accelerometers on the instrument are required.

6.2 Accelerometer allocation

Channel No	Location	Type	Serial no	Code	Axis
F65	Photometer detector box	7724		PHOTX	X
F71	Photometer detector box	7724		PHOTY	Y
F53	Photometer detector box	7724		PHOTZ	Z
F66	FPU top of optics bench over cone	7724		FPUX	X
F69	FPU top	7724		FPUY	Y
F52	FPU top	7724		FPUZ	Z
F68	Spectrometer detector box	7724		SPECX	X
F73	Spectrometer detector box	7724		SPECY	Y
F54	Spectrometer detector box	7724		SPECZ	Z
	SMEC moving carriage	2222C	32974	SMECLX	X
	SMEC moving carriage	2222C	32977	SMECLY	Y
	SMEC moving carriage	2222C	32976	SMECLZ	Z
	SMEC top	2222C	32975	SMECUX	X
	SMEC top	2222C	26087	SMECUY	Y
	SMEC top	2222C	AJC49	SMECUZ	Z
	SMEC base plate	2272	YG32	SMECBX	X
	SMEC base plate	2222C	AADN7	SMECBY	Y
	SMEC base plate	2222C	32978	SMECBZ	Z

6.3 Temperature sensors

The SPIRE PFM FPU contains several sensors already fitted. These can be read out by the CSL facility.
These temperature sensor signals are available at connector J32 on the FPU. A cable to connect this to one of the CSL supplied 37 way ‘D; type connectors will be supplied by SPIRE, with pin outs as listed in AD1.

Sensor number	Location	CODE	Calibration Curve Prime	Calibration curve Redundant
1	RF filter	RF	X30977	**X31056**
2	Spectrometer 2K	SPEC	X29606	**X29592**
3	Photometer 2K	PHOT	X29601	**X29603**
4	Optical sub bench	OPSB	X30981	**X29602**
5	Input baffle	BAF	X29604	**X31033**
6	BSM/SOB interface	BSM	X29597	**X31036**

NB the redundant set will be used for this test as one of the prime set is faulty.

6.4 Heaters

To control the rate of warm up, a heater will be fitted to the FPU, a connection to outside the cryostat is required. A connector type RD37M100T2S or similar (Connector with 37 male pins Fixed female jackscrews) will be fitted to the heater harness. Pins 1 and 2 will be used for the power supply.

7. INTEGRATION AND HANDLING

The FPU will be integrated onto the fixture following the SPIRE handling and integration procedure. The salient points are extracted here for convenience.

7.1 Handling

7.1.1 General.

The FPU is a delicate optical instrument and should be handled with extreme care at all time.
For this vibration test, contamination of the optical surfaces within the instrument is prevented by a red tag cover over the aperture. This should be left in position at all times. It will not prevent the FPU from depressurising or repressurising.
WARNING: The bipod legs on two corners of the instrument are very thin section and easily damaged. Care must be taken at all times not to put side loads into these items. These are at risk at all times when the FPU is not attached to a rigid plate.
See appendix A for detailed instructions for lifting the instrument.

7.1.2 Unpacking from dedicated experiment container.

The FPU is supplied in a dedicated double container.
To remove the FPU from its container, the following procedure should be followed: -
In an area with a cleanliness of class 100,000 minimum, undo the eight latches that secure the container lid and remove the lid. This will expose the inner container
Unscrew and remove the screws that secure the baseplate to the secondary plate and the anti vibration mounts.
Attach the lifting frame RF2 to a crane. Lower the lifting frame to the baseplate and attach to the eyebolts provided on the baseplate.

The FPU, and baseplate together with the inner container can now be lifted out of the outer container with a crane.
Transport to cleanroom, minimum class 10,000.
The inner container lid can now be removed.
Upon removal of the inner container lid the FPU will be visible mounted on the baseplate and bagged in lumaloy film.
The film bagging should be left in position as long as possible during the integration into the cryostat.

7.1.3 Preparation for integration.

The following tasks need to be carried out before integration onto the spacecraft or test cryostat.

a) **Fitting of Lifting attachment**

Fit the lifting attachment to the FPU as shown in Annex A of SPIRE-RAL-PRC-001923, SPIRE FPU Handling and Integration Procedure

b) **Removal from baseplate**

WARNING: The bipod legs on two corners of the instrument are very thin section and easily damaged. Care must be taken at all times not to put side loads into these items. These are at risk at all times when the FPU is not attached to a rigid plate.

The three L0 straps and one L1 strap are also secured to the baseplate. To release these, undo the 4 off M4 fasteners on each strap and remove. NOTE. The underside of the L0 straps form the thermal interface to the spacecraft helium tank pods. Their surfaces are flat and soft gold plated, these surfaces can easily be damaged and the thermal performance of the instrument may suffer as a result.

Undo and remove the 8 fasteners that attach the bipods to the base plate, remove the M8 nut at the top of the support cone. Lift the instrument using the MGSE supports. Instrument needs to be lifted horizontally, therefore use the 4 stand offs to lift it by rotating them one by one such the instrument is slowly lifted and kept horizontal. In this way unnecessary stressing of the bipods is prevented. When instrument is disengaged from the cone, the instrument can be lifted further using the crane. The stainless steel cone remains on the base plate.

The FPU can now be lifted from the baseplate.

The FPU is now ready for integration.

7.1.4 Required tools/MGSE

SPIRE supplied tools/MGSE:-	FPU handling frame.	
	JFET support beam	
	FPU/JFET/baseplate lifting gear	
	Fixation bolts,	
	FPU	M6 12 off
	L0 straps	M4 16 off
	L1 strap	M6 8 off
	L3 strap	Not required
	Thermal strap interface plate and bolts	
	Torque wrench	
	Allan key, spanners etc	
Supplied by facility	Crane, with slow speed capability	

7.2 Integration on to fixture

FPU
Fit the thermal strap interface plate (SPIRE supplied) to the fixture with the 8 off M6 bolts supplied.
Assuming activities described unpacking and preparation sections have been carried out, and the FPU is supported on a crane.
Fix the CFRP cone to the vibration fixture using the four M6x21 cap head screws. Note: there are special washers (part number A3/5264/302-3) under the head of each screw and also Vespel insulating bushes (A3/5264/302-2) either side of the mounting flange.
Torque the screws to 8.1 Nm.
Lift the FPU using the lifting gear as described in section 6.
Very gently lower the assembly onto the fixture, ensuring that the cone mount engages in its location on the FPU.
The flexible ends of the L0 straps are unsupported at this stage and will need to be guided into place as the FPU is lowered.
NOTE: the cone is very thin walled section and large moments can be applied if the unit is not lowered with its interface plane parallel to the fixture
When all units are resting on the fixture, fit the attachment screws (M6X21) to the bipod feet as for the cone mount.
Fit the two Bellville washers and the M8 Kaylock nut to the cone mount. Torque to 8.25Nm.
Remove the lifting/handling fixture.

L0 straps
The L0 straps should be fitted to the interface plate which has been previously fitted to the fixture, using 4 off M4 bolts per strap.

L1 straps.
For this test a non flight representative straps will be supplied to thermally short the FPU optical bench to the test fixture. This short strap fits between the interface plate and the FPU.

L3 straps.
Not required

7.3 Removal from fixture

WARNING: The bipod legs on two corners of the instrument are very thin section and easily damaged. Care must be taken at all times not to put side loads into these items. These are at risk at all times when the FPU is not attached to a rigid plate.
Remove all electrical connections,
Attach the FPU lifting devices as detailed in section 'preparation for integration'
Undo the 4 off M4 fasteners on each L0 strap and remove, separate the cold strap from the interface plate. NOTE. The underside of these straps form the thermal interface to the spacecraft helium tank pods. Their surfaces are flat and soft gold plated, these surfaces can easily be damaged and the thermal performance of the instrument may suffer as a result.
Undo and remove the 4 off M4 screws which secure L1 cold strap to the interface plate, separate the cold strap from the interface plate

Undo and remove the 8 fasteners that attach the FPU bipods to the baseplate.
Undo and remove the M8 nut that secures the FPU to the cone mount.
NOTE: the cone is very thin walled section and large moments can be applied if the unit is not raised with its interface plane parallel to the fixture.

The FPU can now be lifted from the HOB

7.3.1 Preparation for packing

All units should be wrapped in clean film and replaced in their transit containers. The FPU should be refitted to its baseplate using the following procedure:

Assuming activities described in section above have been carried out, and the FPU is supported on a crane.
The cone is already fitted to the SPIRE baseplate using the four M6x21 cap head screws. Note: there are special washers (part number A3/5264/302-3) under the head of each screw and also Vespel insulating bushes (A3/5264/302-2) either side of the mounting flange.
Torque the screws to 8.1 Nm.
Lift the FPU using the lifting gear as described in section 6.
Very gently lower the assembly onto the baseplate, ensuring that the cone mount engages in its location on the FPU.
NOTE: the cone is very thin walled section and large moments can be applied if the unit is not lowered with its interface plane parallel to the baseplate
When all units are resting on the baseplate, fit the attachment screws (M6X21) to the bipod feet as for the cone mount, torque the screws to 8.1 Nm.
Remove the lifting/handling fixture.
Secure the L0 straps to the baseplate using M4X20 socket head cap screws. Torque the screws to 1.5 Nm.
Cover the FPU with a double layer of clean lumaloy film and secure each one with tape to the baseplate.
Fit the lifting frame RF2 to the four eyebolts in the plate.

7.3.2 Packing in containers.

Fit the inner lid.
Lift the plate into the outer container.
Remove lifting frame.
Secure baseplate.
Fit container lid.

8. BUILD STANDARD

This unit is a full PFM, but has one subsystem at DM level.

- Spectrometer Mechanism (full structure but no electronics), This unit has nine accelerometers fitted to monitor its behaviour and limit the response levels.

The mass of the PFM model of the SPIRE instrument is 38.7Kg.

9. TEST OBJECTIVES

- To perform acceptance tests on the SPIRE instrument and its critical subsystems, at a temperature typical of the launch environment.
- To monitor the dynamic behaviour of the instrument and some critical subsystems at cold temperature so that it can be compared with the results of previous test campaigns.

10. TESTING

10.1 General

The SPIRE FPU will be subjected to the following vibration tests.

Note the detectors within SPIRE are supported on highly tensioned Kevlar fibres. These fibres are at a higher tension when at room temperature that they are when cold. Consequently no vibration tests shall be carried out when the FPU is above 100K, with the exception of low level resonance searches.

In each axis:

- Low level resonance search
- Sine test
- Low level resonance search
- Random test
- Low level resonance search

The order of axis is not important.

NOTE. Due to the low natural frequency of the fixture, high levels may be encountered within the FPU at modest input levels.
Accelerometers mounted on the detector boxes will be monitored and used to limit the vibration levels applied to the FPU.

11. PUMP DOWN RATE

SPIRE has thin filters in various locations within the FPU. These can be damaged if the cryostat is pumped down too quickly.

Max pump down or re-pressurisation rate is 50mb/min

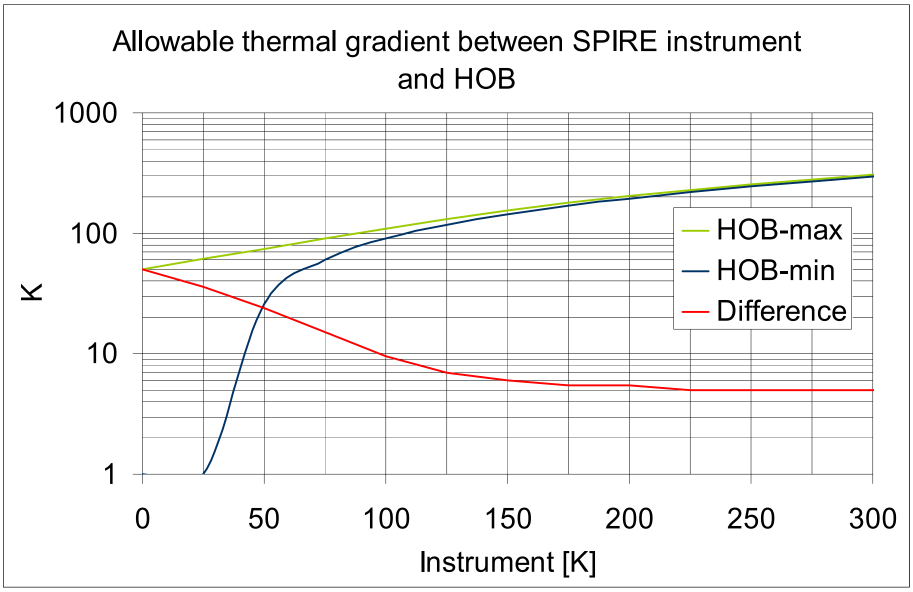
12. COOL DOWN RATE

To avoid damage to the FPU cool down/warm up rate should not exceed to following:
5K/hour, between room temperature and 200K,
10K/hour, between 200K and 100K.
50K/hour below 100K

This is very critical because the flex pivots in the Spectrometer mechanism are likely to be damaged if this rate is exceeded.

13. TEMPERATURE GRADIENTS

The SPIRE FPU incorporates CFRP feet on the FPU and detector boxes and these are very sensitive to temperature gradients, Maximum permissible gradients are listed below.



Temperature gradient between the detector boxes (sensors 2 and 3) and the optical bench (sensor 6) also need to be monitored, here the restriction is more relaxed at a factor two greater than the curve above.

14. CONTROL PHILOSOPHY

The accelerometers mounted inside the instrument on the SOB and the detector boxes should not exceed the response measured during the warm vibration test at RAL in April 2002. Furthermore the responses should be limited to 10 g-rms maximum for sensitive subsystems, following RF4. A SPIRE mechanical engineer will be present during the cold vibration tests to specify the notches. The instrument is not allowed to exceed the equivalent quasi-static interface force for each axis in any direction. Readings from accelerometers mounted near the CoG can be used to monitor the overall interface force at frequencies below the first instrument or fixture resonance.

15. TEST SPECIFICATION

15.1 Resonance search

A resonance search shall be conducted at approximately 0.25 g input between 5 and 2000 Hz to identify any changes in the primary resonances. The will serve as the structure's health check.

The sweep rate shall be 4 Oct/min, the monitor accelerometers shall be located on the SPIRE vibration fixture near the mounting locations of the instrument. The resonance search will be performed before and after a test run. No nuts or bolts should be tightened or loosened between these verification runs.

15.2 Sine vibration test

As stated in IID-A, AD (1) the acceptance levels are:

X axis

Frequency Range Hz		Acceptance level
5 - 20.1		+/- 8mm
20.1 – 100		14.4 g

Y and Z axis

Frequency Range Hz		Acceptance level
5 - 13.5		+/- 8mm
13.5 – 100		6.4 g

Test sweep rate 4 Oct/min,

For SPIRE PFM the following modifies inputs are to be used

X axis

Frequency Range Hz		Acceptance level
5 - 20.1		+/- 2mm
20.1 – 100 for 1000 cycles *	Up to 66Hz	14.4 g
20.1 – 100 for remaining cycles		6.4 g TBC

Test sweep rate 4 Oct/min, the input will be limited to equivalent quasi static interface force.

Y and Z axis

Frequency Range Hz		Acceptance level
5 - 13.5		+/- 2mm
13.5 – 100 for 1000 cycles *	Up to 66Hz	6.4 g
13.5 – 100 for remaining cycles		4.8 g TBC

Test sweep rate 4 Oct/min, the input will be limited to equivalent quasi static interface force.

* To avoid fatigue damage, the level specified above should be carried out for a maximum of 1000 cycles, after that the level should be reduced to 6.4 g

15.3 Random vibration test

As stated in IID-A, AD (1) the acceptance levels are:

Y and Z axis

Frequency Range Hz	Qualification level For reference only	Acceptance levels
20-100	+3dB/Oct	+3dB/Oct
100-150	0.02 g^2/Hz	0.0128 g^2/Hz
150-300	0.0125g^2/Hz	0.008 g^2/Hz
300-2000	-7 dB/Oct	-12 dB/Oct
Global	2.54 g RMS	2.0 g RMS

Test duration 1 minute in each axis

X axis

Frequency Range Hz	Qualification level For reference only	Acceptance levels
20-100	+3dB/Oct	+3dB/Oct
100-150	0.05 g^2/Hz	0.032 g^2/Hz
150-300	0.02g^2/Hz	0.0128 g^2/Hz
300-2000	-7 dB/Oct	-12 dB/Oct
Global	3.47 g RMS	2.77 g RMS

Test duration 1 minute

These levels will be used for the SPIRE PFM test, but modified with notches as required after analysis of the low level runs.

15.4 Test Sequence

The test sequence can be adjusted to suit the planning of the facility

16. REJECTION AND RETEST

If a failure, malfunction or out of tolerance performance occurs during or after test as appropriate the test shall be discontinued. This also includes test equipment qualification. the deficiency, including any design defect, shall be corrected and the applicable procedures repeated until successfully completed. If the corrective action subsequently affects the significance of results of previously completed test in the sequence, such test shall be repeated.

17. DOCUMENTATION

A test report shall be produced logging all events and the results of the visual inspections. Also all main resonances shall be reported and the worst case responses at the subsystem interfaces. The rest report shall also contain the environmental measurement data (taken during the test) and the calibration/qualification certificates of the test facility.

18. PRODUCT ASSURANCE

Before a test can proceed a Test Readiness Review (TRR) shall be convened by the SPIRE project manager. All the relevant test and facility documentation will be made available. The TRR must give approval before the test can commence. The TRB will convene between each reconfiguration of the test set-up. The test set up can be dismantled after the TRB is convened and agrees.

The test review board will consist of the designated SPIRE representative and the test facility manager or their representatives.