TITLE: # 4K Reference Load Test Plan

DOC. TYPE: PLAN

PROJECT REF.: PL-LFI-TES-PL-001 **PAGE:** I of V, 24

ISSUE/REV.: 1.2 **DATE:** September 2004

Prepared by	**F. CUTTAIA** **A. DE ROSA** **L. TERENZI** **L. VALENZIANO** **IASF – CNR**	**Date:** **Signature:**	September 2004
Agreed by	**C. BUTLER** **LFI** **Program Manager**	**Date:** **Signature:**	September 2004
Approved by	**N. MANDOLESI** **LFI** **Principal Investigator**	**Date:** **Signature:**	September 2004

DISTRIBUTION LIST

Recipient	**Company / Institute**	**E-mail address**	**Sent**
T. PASSVOGEL	ESA – Noordwijk	tpassvog@estec.esa.nl	Yes
G. CRONE	ESA – Noordwijk	Gerald.Crone@esa.int	Yes
J. MARTI-CANALES	ESA – Noordwijk	Javier.Marti.Canales@esa.int	Yes
M. VON HOEGEN	ESA – Noordwijk	mvhoegen@estec.esa.nl	Yes
P. OLIVIER	ESA – Noordwijk	Pierre.olivier@esa.int	Yes
N. MANDOLESI	IASF-BO – Bologna	mandolesi@bo.iasf.cnr.it	Yes
R.C. BUTLER	IASF-BO – Bologna	butler@bo.iasf.cnr.it	Yes
M. BERSANELLI	Unimi – Milano	marco.bersanelli@fisica.unimi.it	Yes
E. ALIPPI	LABEN – Vimodrone	Alippi.e@laben .it	Yes
M. BALASINI	LABEN – Vimodrone	Balasini.m@laben.it	Yes
F. MONZANI	LABEN – Vimodrone	Monzani.f@laben.it	Yes
G. CAFAGNA	LABEN – Vimodrone	Cafagna.g@laben.it	Yes
M. MICCOLIS	LABEN – Vimodrone	miccolis.m@laben.it	Yes
P. LEUTENEGGER	LABEN – Vimodrone	leutenegger.p@laben.it	Yes
4KRL TEAM	IASF-Bologna		
LFI System PCC	IASF-BO – Bologna	lfispcc@bo.iasf.cnr.it	Yes

CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	July 2004	All	First issue of this document	LFI QM AIV start
1.2	Sept 2004	All	General revision	QM-TRRR

TABLE OF CONTENTS

1 SCOPE

1.1 Purpose

The purpose of the 4 K reference load is twofold. First, the load provides the radiometer with a lower input offset (the radiometric temperature difference between the sky and the reference load). Reducing the input offset reduces the minimum achievable radiometer knee frequency (RD 5) for a given amplifier fluctuation spectrum. This minimum achievable knee frequency assumes perfect phase and gain matching in the two "legs" of the radiometer and assumes other ideal characteristics in radiometer components. An *ideal* reference load temperature would match the sky temperature (approximately 2.7 K), but there is no convenient spacecraft source of 2.7 K with sufficient cooling power, and routing reference horns through the instrument to use another part of the sky as the reference appears impractical.

The second purpose of the 4 K reference load is to maximize the probability of achieving something close to the ideal performance of the radiometer. A general rule of thumb is: the larger the input offset, the larger the potential of multiplicative systematic effects to contaminate the measurement.

The purpose of this document is to describe the tests to be performed on the QM, FM, and FS 4KRL unit .

1.2 4K Reference Load Unit Overview

The 4K Reference Load (4KRL) unit (RD 7) shall provide the 22 LFI radiometers with a stable reference signal, to allow continuous comparison with sky signal. The 4KRL will act as a cold ($T \approx 4K$) blackbody. It is composed by 22 targets (RD 11), one for each radiometer, and it is thermally connected to the HFI outer radiation shield, which provide reference temperature. Targets (RD 6), also called loads, are bonded on a support structure (separated in two sectors – upper and lower one) screwed on the HFI.

The 4KRL comprises the following functional blocks:

- Reference Horns (2 for each RCA)
- Reference Targets (2 for each RCA)
- Mounting Structure
- Thermal Link to the HFI
- Temperature Sensors

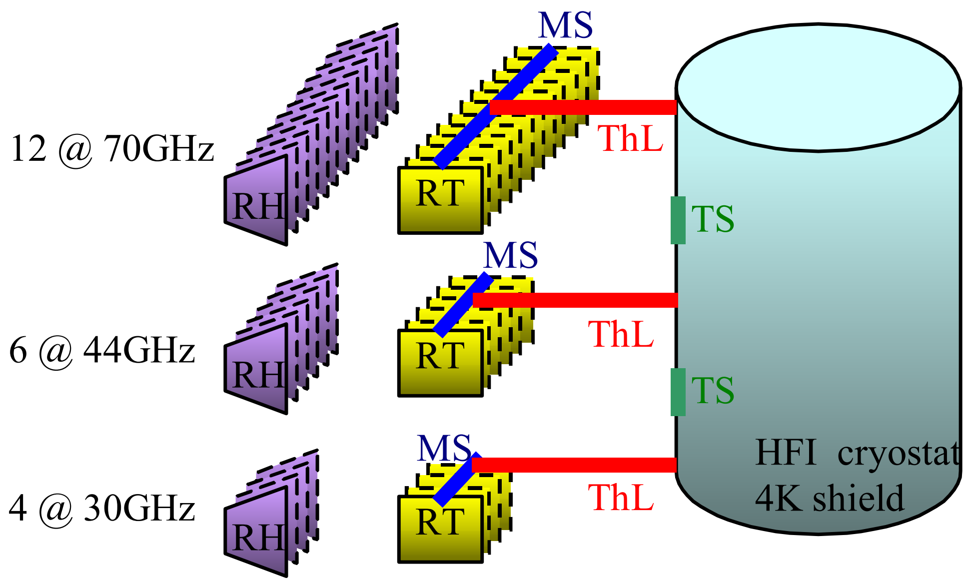


Figure 1.1: Functional Block of the 4KRL Unit. RH: Reference Horn; RT: Reference Target; ThL: Thermal Link; MS: Mounting Structure; TS: Temperature Sensors

1.3 TERMS and ACRONYMS

4K RL	4K Reference Load
CMB	Cosmic Microwave Background
CRT	Cross Talk
EBB	Elegant Bread Board
FEM	Front End Module
FM	Flight Model
FPU	Focal Plane Unit
FS	Flight Spare
HFI	High Frequency Instrument
I/F	Interface
IL	Insertion Loss
LFI	Low Frequency Instrument
MS	Mounting Structure
N/A	Not Applicable
PD	Prototype Demonstrator
QM	Qualification Model
RH	Reference Horn

RL	Return Loss
RT	Reference Target
SPO	Spillover
SS	Spin-Synchronous
TBC	To Be Confirmed
TBD	To Be Defined
TBR	To Be Refined
ThL	Thermal Link
WG	Waveguide

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

AD 1: *FIRST/Planck Instrument Interface Document*, Part A (SCI-PT-IIDA-04624, 3/0)
AD 2: *FIRST/Planck Instrument Interface Document,* Part B (SCI-PT-IIDB/LFI-04142, 2/0)
AD 3: *LFI Interface Control Document* (PL-LFI-PST-ID-010, 2.0)
AD 4: *LFI/HFI Interface Document* (PL-LFI-PST-ID-001, 1.0)
AD 5: *LFI Specification* (PL-LFI-PST-SP-001, 3.0)
AD 6: *Planck LFI Instrument Design and Development Plan* (PL-LFI-PST-PL-002, 2.0)
AD 7: *Planck LFI Product Assurance Plan* (PL-LFI-PST-PL-003, 3.0)
AD 8: *Planck LFI Assembly Integration* & Verification Plan (PL-LFI-PST-Pl-004, 3.0)
AD 9: *FIRST/Planck Operations Interface Requirements Document* (SCI-PT-RS-07360, 2/1)
AD 10: *LFI Configuration and Data Management CADM Plan* (PL-LFI-PST-PL-001, 3.0)
AD 11: *LFI Instrument Deliverable Documentation List* (DDL) (PL-LFI-PST-LI-007, 1.0)
AD 12: *4K Reference Load Requirement Specification* (PL-LFI-TES-SP-001, 3.1)

2.2 Reference documents

RD 1*: 4K Reference Load Horn Design* (PL-LFI-TES-TN-001, 1.0)
RD 2: *Planck LFI Mechanical Design* (PL-LFI-LAB-RP-001, 3.0)
RD 3: N. Mandolesi, G.Morgante, F. Villa ,*Low Frequency Instrument of Planck*, IR Space Telescopes and Instruments. Proceedings of the SPIE, Volume 4850, pp. 722-729 (2003)
RD 4: Burigana et al., Planck LFI: *Comparison between Galaxy Straylight Contamination and other Systematic Effects*, 2001, accepted in A&A
RD 5: M.Seiffert, A. Mennella,C. Burigana, et al 2002, A&A, 391, 1185..
RD 6: *HFI Temperature stability requirements* (SR-PH211-990141-IAS, Issue 01)
RD 7: L.Valenziano, M. Bersanelli, R.C. Butler, et al., 3rd ESA Workshop on Millimetre Wave Technology and Applications, Espoo, ESA Conf. Proc. WPP-212, 2003
RD 8*: LFI signal oscillations induced by Sorption Cooler temperature variation* (PL-LFI-PST-TN-010, Issue 1.0)
RD 9: *HFI thermometers and heaters specifications* (SP-PHAC0-100044-IAS, Issue 0/0,12.2.00)
RD 10: F. Cuttaia et al., *4KRL Reference Horn design and optimisation* (Tesre Int Rep 320, 2001)
RD 11: F. Cuttaia et al*., 4KRL Target design analysis and test* (Tesre Int Rep 321, 2001)
RD 12: F. Cuttaia, *Optimisation of the 4K Reference Load in the LFI 70 GHz band*, REPORT PL-LFI-TES-RP-002
RD 13: Adhesive data for the 4KRL (PL-LFI-TES-TN-002, 1.0)
RD 14: F. Cuttaia, L. Valenziano, M. Bersanelli, et al, *Analysis of the Radiometer - Reference Load System on Board the Planck/LFI Instrument*, Nuclear Instruments and Methods in Physics Research A 520(2004) 396-401.
RD 15: F. Cuttaia, P. Battaglia, L. Terenzi, et al, Analysis of the pseudocorrelation radiometers for the Low Frequency Instrument on board the PLANCK satellite, submitted to SPIE, 2004
RD 16: *4KRL a proposal for mechanical test on adhesives for the LFI 4K Reference Load* Collaboration TeSRE-ESA (PL-LFI-TES-TN-006, 0.1)

RD 17: *4KRL leakage test at 44 GHz* (PL-LFI-TES-TN-003, 1.1)
RD 18: *4KRL Sensitivity to displacement at 44 GHz* (PL-LFI-TES-TN-004, 1.0)
RD 19*: 4KRL a proposal for mechanical test on adhesives for the LFI 4K Reference Load Collaboration* TeSRE-ESA (PL-LFI-TES-TN-006, 0.1)
RD 20 Peterson & Richards, 1984, Int. J. Infr. Millim Waves, **5**, 12
RD 21: IASF Bo-IFP Mi experimental result (Eccosorb material properties – in preparation)
RD 22: Emerson & Cuming data sheets, 1-20 0
RD 23: The 4KRL Cryo Facility (PL-LFI-TES-TN-010, 1.0)
RD 24: Preliminary evaluation of the impact of temperature fluctuations in the HFI 4K stage on LFI (PL-LFI-PST-TN-048, 1.0)
RD 25: LFI 4K Reference Load thermal model (PL-LFI-PST-TN-049, 1.0)
RD 26: 4KRL Design Report (PL-LFI-TES-RP-001, 3.1)

3 4KRL part Identification and numbering

3.1 Model philosophy

The following models will be produced:

- Qualification Model (QM)
- Flight Model (FM)
- Flight Spares (FS)

As FS the QM shall be employed, at least for those parts that are compliant with the materials and manufacturing requirements.
For each model, the following parts will be produced and tested as reported in the Test list.

3.1.1 RH & WGs

The following table contains the number of parts that shall be manufactured for each of the 4KRL models:

Frequency	Number of Reference Horns		
	QM	FM	FS
30 GHz	4	4	Refurbished QM
44 GHz	2	6	Refurbished QM
70* GHz	4	12	Refurbished QM

* The 70 GHz waveguides are integrated in the FEM. Test will be performed on representative parts.

3.1.2 RT

The following table contains the number of parts that shall be manufactured for each of the 4KRL models:

Frequency	Number of Reference Targets		
	QM	FM	FS
30 GHz	4	4	Refurbished QM
44 GHz	2	6	Refurbished QM
70 GHz	8	12	Refurbished QM

3.2 4KRL ID numbers

This section contains the number of parts and their ID code. When discrepancies occurs with ADXX (CIDL), the latter applies.

3.2.1 Reference Horns &Waveguides

3.2.1.1 QM

LFI code	Frequency	4KRL part number					
PLAFB/C-C	30 GHz	PLTES023	PLTES024	PLTES025	PLTES026		
	44 GHz	PLTES027	PLTES028	PLTES029	PLTES030	PLTES031	PLTES032
N/A	70 GHz	TBI	TBI	TBI	TBI	TBI	TBI

3.2.1.2 FM

LFI code	Frequency	Reference Horns CODE/n°					
PLAFB/C-P	30 GHz	TBI	TBI	TBI	TBI	TBI	TBI
	44 GHz	TBI	TBI	TBI	TBI	TBI	TBI
N/A	70 GHz	TBI	TBI	TBI	TBI	TBI	TBI

3.2.1.3 FS

Refurbished QM

3.2.2 WGs

Experimental tests will be conducted on WGs representative on the real one. 30 and 44GHz WGs are soft soldered on the RHs. These representative WGs, one for each of the LFI frequency, will have the same design and the same manufacturing process of the FM parts. The only difference is that they will be flanges at both ends with standard flanges. This parts will allow to validate the RF model with high accuracy experimental tests.

3.2.2.1 QM

Frequency	Reference WGs CODE/n°
30 GHz	PLTES024B
44 GHz	TBI
70 GHz	*

70 GHz waveguides are included in the Front End Module and can not be tested separately.
Only one representative WG shall be tested at 30 GHz and at 44GHz..

3.2.3 Reference Target

The code relative to each reference case containing two reference targets is reported. Each target can be separately identified by the codes A and B referring to the left (A=T1) and to the right (B=T2) unit, as displayed in the picture.

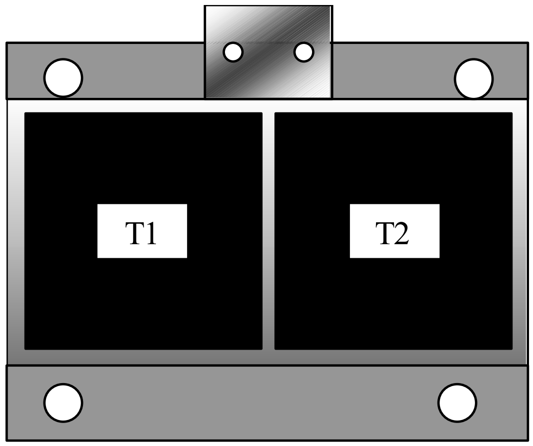


Figure 3.1: Schematic view of a case containing two RTs. Case orientation is with the vertical axis along the RDP z-axis. This sketch is valid both for upper sector and lower sector parts.

3.2.3.1 QM

LFI code	Frequency	4KRL part number			
PLAFB/B-C	30 GHz	PLTES021	PLTES022		
	44 GHz	PLTES018	PLTES019	PLTES020	
PLAFA/B-C	70 GHz	PLTES012	PLTES013	PLTES015	PLTES017

3.2.3.2 FM

LFI code	Frequency
PLAFB/B-P	30 GHz
	44 GHz
PLAFA/B-P	70 GHz

3.2.3.3 FS

Refurbished QM

4 DEVELOPMENT AND VERIFICATION

4.1 General

The elements of the 4KRL unit will be developed and verified in accordance with the requirements of AD 1, AD 6, and AD 8.
All the details are reported in AD 12, Section 9.

4.1.1 General Testing Requirements

The requirements given in AD 1, Section 9.5.1 are applicable to the unit.

4.1.2 Test Level Tolerances

The requirements given in AD 1, Section 9.5.2 are applicable to the unit.

4.2 Deliverable Tests

4.2.1 Unit Verification

The minimum agreed required unit tests to be performed during the unit development are given in AD 8, and have been based on the requirements of AD 1, Section 9.3.1.

4.2.2 4KRL Scientific Performance Verification

The scientific performance verification of the 4KRL unit will done against the requirements contained in AD 12 and AD 5 at four different levels

- unit standalone level
- LFI (instrument level)
- Planck PFM System Level

5 4KRL test global description

5.1 General

The 4KRL unit performances will be verified according to the following flow chart:

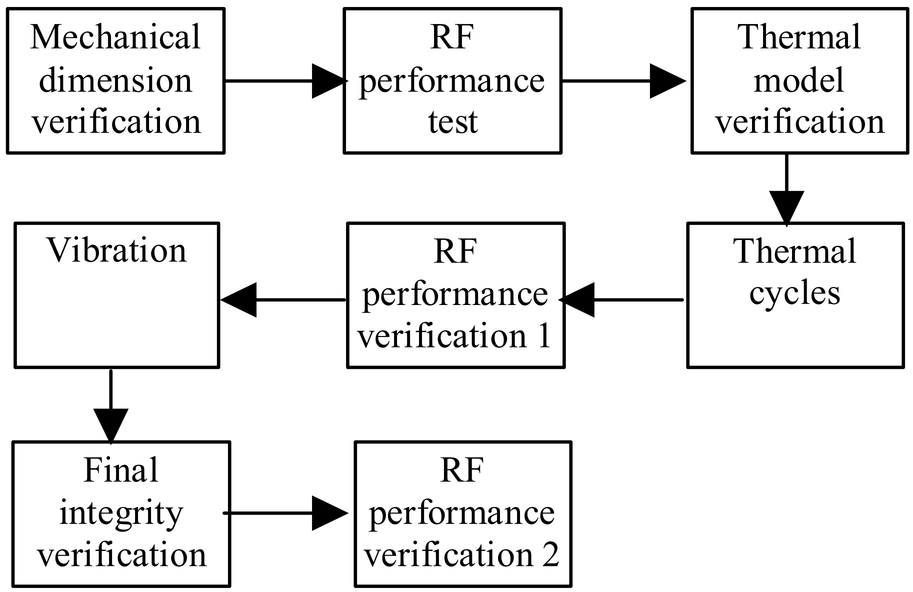


Figure 5.1: 4KRL test flow chart

5.2 QM verification approach

The different parts of the 4KRL unit are received from the supplier, cleaned and mechanical dimensions (including mass) are verified against the manufacturing drawings (Section 6). Parts are then assembled (RT are bonded with epoxy adhesive, see RD 26) in the IASF-Bo laboratories. RF performance test is then performed, as described in Section 7. Reference Targets are tested as separate sub-units and then assembled in the mounting structure.

The 4KRL thermal model is then validated and verified. Thermal cycles to 4K are then applied to the 4KRL unit (Section 8.2.1).
After these cryo tests, RF performance are checked again for a subset of the RT and for a sub-set of the overall RF test.
One sub-unit (TBD) of the 4KRL QM is then integrated in the LFI RAA and vibrated in a dedicated facility (Section 6.2). QM parts are then shipped back to IASF, RF properties are verified in a sub-set of the RT and for a sub-set of the overall RF test (Section 7.3.3.1).
A final mechanical verification and integrity check is then performed (Section 6.1).

5.3 FM verification approach

FM verification is similar to the QM activity.

Section to be completed.

5.4 FS verification approach

QM parts will be refurbished, if required, to meet the FM standard. These parts will be verified, if required, for a sub-set of the FM tests, using a TBD procedure.

Section to be completed.

6 Mechanical Verification and Testing

Mechanical testing shall be performed to show that the 4KRL unit meets the stiffness and environment mechanical requirements, and that the FM unit is acceptable for flight.
General requirements in AD 1, section 9.4.1.1 apply to this unit.

6.1 Mechanical dimensions, Mass, Moment of Inertia, and Center of Gravity

6.1.1 General remarks

In order to verify the conformity of the 4K load components with the specification required by the working of the instrument and by the strength required by the flight conditions, it is needed an accurate check of all the parts and sub-parts.
Before beginning all the checks, the manufacturing dossier must be read:
The presence of part number, material certification and the last revision of the drawing shall be checked.
Only if all these documents are present an acceptance test can be performed.
Test shall be conducted in standard laboratory conditions. Cleanliness level shall be 'visually clean'.
A log-book shall be compiled.

6.1.2 Incoming visual inspection

A first check is visual: a carefully inspection has to be conduced, eventually using a magnifier, to look for any kind of possible defect (i.e. crack, scoring, oxide and blister). Any defect shall be recorded in a log-book.

6.1.3 Mechanical dimension and mass

A check of all the dimension imposed by the drawing must be conducted to verify the respect for the tolerances required. For this analysis must be used a digital caliper with centesimal precision.
If required, a high precision measures will be obtained using a DEA machine (TBC).
Surface finishing will be visually verified when applicable.
Any non-conformity will be reported on the copy of the manufacturing drawings and listed on the log-book. Any major NC will be reported in a NCR.

The mass of each sub-part will be measured using a digital balance. These data will be compared with the design values including manufacturing tolerances.
Any non-conformity will be listed on the log-book. Any major NC will be reported in a NCR.

The mass of each of the assembled parts will be measured again after bonding.

6.1.4 Moment of Inertia and Center of Gravity

These quantities will be calculated for each of the 4KRL parts by analysis. Real dimensions and mass will be used in the model.

6.2 Mechanical model and analysis

A structural model of the complete 4KRL unit will be produced. Relevant input data will be calculated from the I/F values. Damping factors will be introduced when applicable.
Eigenfrequencies, random excitation response, sinusoidal excitation response, quasi-static load response will be calculated.

6.3 Vibration and mechanical testing

Section to be completed

6.3.1 Facility requirements

6.3.2 Test Fixture requirements

6.3.3 Vibration facility

6.3.4 Test condition

6.3.5 Failure criteria

6.3.6 Test sequence

6.3.7 Sine vibration tests

6.3.8 Random vibration tests

6.3.9 Shock tests

7 RF Verification and Testing

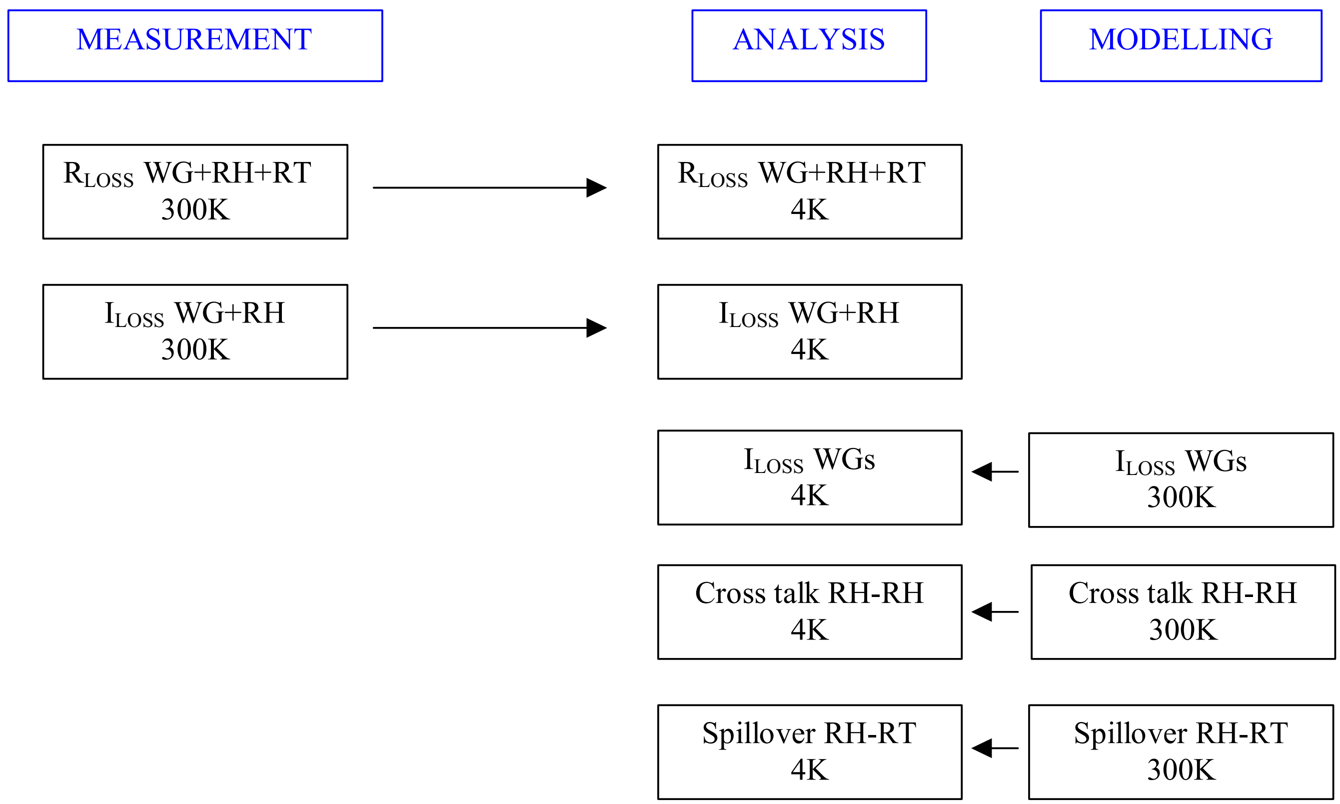
7.1 General

7.1.1 Test approach

Tests will be performed at room temperature. Results can be extrapolated to cryogenic temperatures by analysis (RD 20).
Only some tests, can be directly performed on samples as laboratory tests; in all the remaining cases, the performances will be evaluated by analysis or by similarity. Each case is separately detailed in the test matrix.

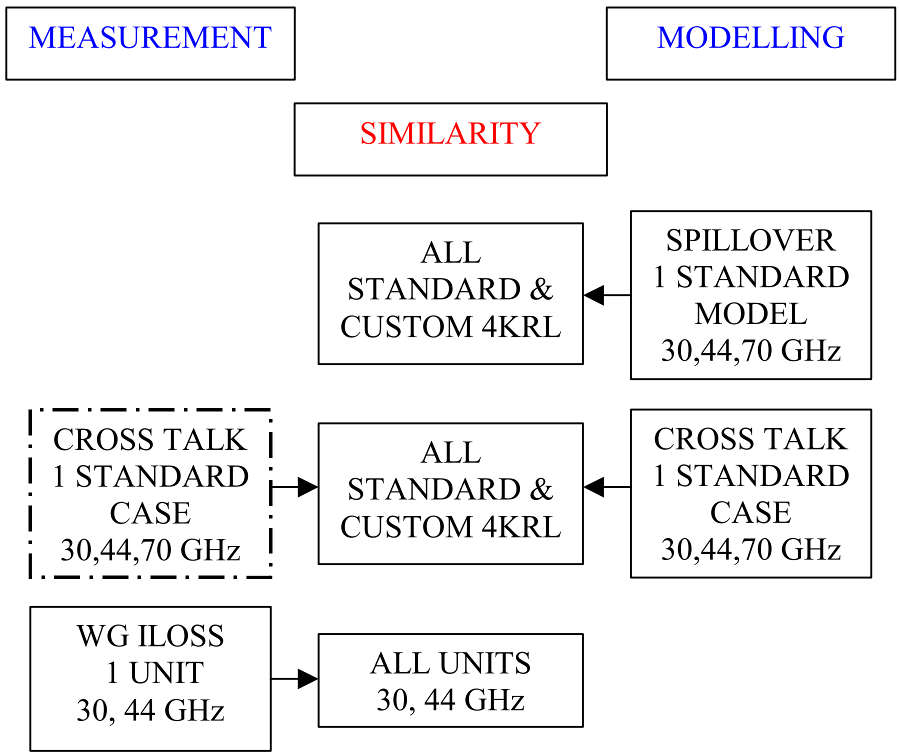
7.1.2 Test flow

The following diagram describes the test flow, detailing which test shall be performed in laboratory and which test shall be performed by modelling tools or by analytical extrapolation from experimental results (RD 21) or from model results (RD 15).



The Cross-Talk (RD 17 , RD 12) measurement is facultative: it will be performed only, if possible, for representative 4KRL systems.

Some modelling or laboratory tests shall base on a similarity approach. The performances shall be verified on a representative standard model or sample and extended to all the other units, provided that fundamental differences do not exist between the units.
The similarity flow diagram follows.



*As in the previous flow diagram, the cross talk laboratory measurement is facultative: it will depend on the instrumentation and on the time available.

7.2 Test facilities

7.2.1 Laboratory Instrumentation

Tests will be performed in a dedicated zone of the IASF-BO Microwave Laboratory. The instrumentation required is the standard one used for radiometric measurements in the millimeter range. It will basically comprise a Scalar or Vector Network Analyser (depending on the availability), detectors and detectors adapters at the three operating bandwidth, Head adapters, RF cables, directional couplers, multipliers, matched loads, linear and rotation stages with metric micrometers, other various components depending on the contingent necessity.

7.2.2 Instruments certification

All the main instruments employed (i.e. network analyser, detectors, etc.) shall be certified from the manufacturer. The ordinary instrumentation (i.e. cables, matched loads, etc.) do not require it. In all the cases the accuracy of the instrumentation employed will be periodically checked by proper internal calibration procedures.

7.2.3 DATA ACQUISITION

It will be performed via a GPIB board installed on a laboratory computer. A dedicated software, able to download and save data will be employed.

7.2.4 MODELLING TOOLS

Modellisation shall be performed by a Finite Elements Method approach using a dedicated software (HFSS Ansoft). Calculations can be performed employing electro magnetic parameters at 300 K from literature or measured (REF**measurements IASF-IFP): performances at 4K can be extrapolated by referring to materials behaviours from literature.

7.2.4.1 VALIDATION OF THE RADIOMETRIC MATHEMATICAL MODELS

The modelling shall be validated by comparing Return Loss measurements on a representative RH and on complete systems RH-RT with simulated data. Spillover modelling can be validated by comparing simulated data with measurements on principal cut planes (E-plane, H-plane) at a specified frequency. Being the total spillover the power integrated over the whole solid angle (i.e over the all possible cuts) for similarity the validation shall be also extended to it.

7.2.5 Test tolerances

Test tolerances depend on the specific test to be performed: unless otherwise specified, the following tolerances applies for tests instrumentation.

Measurement	Measurement range	tolerances
Return Loss	Dynamic range >30 dB	+/- 1dB on the operative band
Cross talk (isolation)	Dynamic range >35 dB	+/- 1dB on the operative band
Insertion loss	0 dB ÷ 1 dB	+/- 0.1dB on the operative band
Frequencies	>10 MHz	1 ppm

Temperature	10 °C ÷ 22 °C	+/- 3°C
Pressure	**÷** mbar	+/- **%
Relative Humidity	5-70%	+5% / -1%

7.2.6 Documentation

For each test, results will be documented in a test report sheet. Each test report shall be completed with the test's conductor signature and the date of the test execution. For results obtained by modelling, the test report will indicate the method followed, the software employed, the analysis performed and the uncertainty associated to it.

7.2.7 Personnel

The testing activities will be conducted by IASF-Bo with its own personnel. If necessary, some test will be performed in an external facility keeping the same environmental and instrumental requirements.

7.3 RF Test description and test matrix

7.3.1 General

The present chart presents an overview of the qualification and acceptance tests to be conducted. The tests to be performed are:

⇒ Return Loss Test
⇒ Insertion Loss Test
⇒ Cross talk test
⇒ Spillover tests

They have to be performed both on the Qualification Model (QM) and in the Flight Model (FM) . The QM, depending on the test, could comprise only some representative parts.

7.3.2 TEST IDENTIFICATION CODE

Each test will be identified by a code, taking into account the part under test, the subsystem part, the test name, the test methodology, the frequency.
The code will be composed as follows:

Part identifier:
- PLTES**

Subsystem part (if is given) identifier letter:
- A,B, *, etc

Test typology :
- RL : Return Loss Measurement
- IL: Insertion Loss Measurement
- CRT: Cross Talk Measurement
- SPO: Spillover Measurement

Test Methodology:
- EXP: laboratory test
- MOD: modelling test
- ANY: mathematical analysis
- SIM: similarity analysis with the previous test result

Frequency:
- 30: 30 GHz
- 44: 44 GHz
- 70: 70 GHz

Frequency range:
- WB : wide band (20%)
- SF: single frequency

For example, the Return Loss Test on the right unit of the system RH (PLTES021) + RT (PLTES023), performed as experimental test at the frequency 30GHz over the full 20% range, shall have the identification test code:

PLTES-021-023-RL-EXP-30-WB

7.3.3 Reference Horn test list

7.3.3.1 QM

Test Description	Test id.	Ref.Doc.
RH+WG Insertion Loss @30GHz	PLTES-023-IL-EXP-30-WB	
	PLTES-024-IL-EXP-30-WB	
	PLTES-025-IL-EXP-30-WB	
	PLTES-026-IL-EXP-30-WB	
RH+WG Insertion Loss @44GHz	PLTES-027-IL-EXP-44-WB	
	PLTES-028-IL-EXP-44-WB	
	PLTES-029-IL-EXP-44-WB	
	PLTES-030-IL-EXP-44-WB	
	PLTES-031-IL-EXP-44-WB	
	PLTES-032-IL-EXP-44-WB	
RH+WG Insertion Loss @70GHz	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	

7.3.3.2 FM

Test Description	Test id.**	Ref.Doc.
RH+WG Insertion Loss @30GHz	PLTES-XXX-IL-EXP-30-WB	
	PLTES-XXX-IL-EXP-30-WB	
	PLTES-XXX-IL-EXP-30-WB	
	PLTES-XXX-IL-EXP-30-WB	
RH+WG Insertion Loss @44GHz	PLTES-XXX-IL-EXP-44-WB	
	PLTES-XXX-IL-EXP-44-WB	
	PLTES-XXX-IL-EXP-44-WB	
	PLTES-XXX-IL-EXP-44-WB	
	PLTES-XXX-IL-EXP-44-WB	
	PLTES-XXX-IL-EXP-44-WB	
RH+WG Insertion Loss @70GHz	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	

	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	
	PLTES-XXX-IL-EXP-70-WB	

** Where identifier codes are not still available, numbers are replaced by XXX; codes shall be included when available.

7.3.3.3 FS

Test on refurbished QM will be performed when applicable.

7.3.4 Reference waveguides test list

Test Description	Test id.**	Ref.Doc.
WG Insertion Loss @30GHz	PLTES024B-IL-EXP-30-WB	
WG Insertion Loss @44GHz	PLTES-XXX-IL-EXP-44-WB	
WG Return Loss @30GHz	PLTES024B-RL-EXP-30-WB	
WG Return Loss @44GHz	PLTES-XXX-RL-EXP-44-WB	

** Waveguides @70GHz are included in the FEM and can not tested separately.

7.3.5 Reference Horn + Reference Target test matrix

7.3.5.1 QM

Test Description	Test id.	Ref.Doc.
RH+RT Return Loss @30GHz	PLTES-023-021A-RL-EXP-30-WB	
	PLTES-024-021B-RL-EXP-30-WB	
	PLTES-025-022A-RL-EXP-30-WB	
	PLTES-026-022B- RL-EXP-30-WB	
RH+RT Return Loss @44GHz	PLTES-027-018A-RL-EXP-44-WB	
	PLTES-028-018B-RL-EXP-44-WB	
	PLTES-029-019A-RL-EXP-44-WB	
	PLTES-030-019B-RL-EXP-44-WB	
	PLTES-031-020A-RL-EXP-44-WB	
	PLTES-032-020B-RL-EXP-44-WB	
RH+RT Return Loss @70GHz	PLTES-XXX-012A-RL-EXP-70-WB	
	PLTES-XXX-RL-012B-EXP-70-WB	
	PLTES-XXX-RL-013A-EXP-70-WB	
	PLTES-XXX-RL-013B-EXP-70-WB	
	PLTES-XXX-RL-015AEXP-70-WB	
	PLTES-XXX-RL-015B-EXP-70-WB	
	PLTES-XXX-RL-017A-EXP-70-WB	

	PLTES-XXX-RL-017B-EXP-70-WB	
RH+RT Spillover @30GHz	PLTES-023-021A-SPO-MOD-30-WB	
	PLTES-024-021B-SPO-SIM-30-WB	
	PLTES-025-022A-SPO-SIM-30-WB	
	PLTES-026-022B- SPO-SIM-30-WB	
RH+RT Spillover @44GHz	PLTES-027-018A-SPO-MOD-44-WB	
	PLTES-028-018B-SPO-SIM-44-WB	
	PLTES-029-019A-SPO-SIM-44-WB	
	PLTES-030-019B-SPO-SIM-44-WB	
	PLTES-031-020A-SPO-SIM-44-WB	
	PLTES-032-020B-SPO-SIM-44-WB	
RH+RT Spillover @70GHz	PLTES-XXX-012A-SPO-MOD-70-WB	
	PLTES-XXX-SPO-012B-SIM-70-WB	
	PLTES-XXX-SPO-013A-SIM-70-WB	
	PLTES-XXX-SPO-013B-SIM-70-WB	
	PLTES-XXX-SPO-015ASIM-70-WB	
	PLTES-XXX-SPO-015B-SIM-70-WB	
	PLTES-XXX-SPO-017A-SIM-70-WB	
	PLTES-XXX-SPO-017B-SIM-70-WB	
RH+RT Cross Talk @30GHz	PLTES-023-021A-024-021B-CRT-MOD-30-WB	
	PLTES-025-022A-026-022B-SPO-SIM-30-WB	
RH+RT Cross Talk @44GHz	PLTES-027-018A-028-018B-CRT-MOD-44-WB	
	PLTES-029-019A-030-019B-CRT-SIM-44-WB	
	PLTES-031-020A-032-020B-CRT-SIM-44-WB	
RH+RT Cross Talk @70GHz	PLTES- MLB-A -012A- MLB-B-012B-CRT-EXP-70-WB	
	PLTES- MLB-A -013A- MLB-B-013B-CRT-SIM-70-WB	
	PLTES- MLB-A -014A- MLB-B-014B-CRT-SIM-70-WB	
	PLTES- MLB-A -017A- MLB-B-017B-CRT-SIM-70-WB	

7.3.5.2 FM

TBI

7.3.5.3 FS

Test on refurbished QM will be performed when applicable.

7.4 TEST CONTROL SHEETS

7.4.1 TEST CONTROL SHEETS STRUCTURE

For each test, a corresponding proper control sheet will be prepared. It shall contain all the information regarding the test identifying it univocally; its scope is double: to trace and collect all the high level info regarding the test and to allow the responsible personnel to easily prepare the test report.

The standard test control sheet shall contain:

<table>
<tr><td colspan="2">Test title: Name of the test</td><td>Date: day, month, year</td></tr>
<tr><td>Test N°: identifying code of the test</td><td colspan="2">Conductor: first name, second name</td></tr>
<tr><td colspan="3">Requirements: brief description of the requirements to be verified</td></tr>
<tr><td colspan="3">DUT mod: Model of the device under test</td></tr>
<tr><td colspan="3">DUT name: Name of the device under test</td></tr>
<tr><td colspan="3">Objective: scope of the test</td></tr>
<tr><td colspan="3">Test methodology: method used for the test</td></tr>
<tr><td colspan="3">Notes:</td></tr>
<tr><td colspan="3">Conductor Signature:

______________________</td></tr>
</table>

8 Thermal Verification and Testing

8.1 Thermal Verification Requirements

8.1.1 General Requirements

Compliance with requirement specifications, namely temperature difference and heat load, together with fluctuations damping.

8.1.2 Definition of the Thermal Environment

Thermal verification tests will be performed in the 4K Reference Load cryo-facility (described in the RD 23). The reference targets will be mounted on a support, at 4 K representative of the HFI outer shield. An aluminum shield, at 20 K, in front of the targets will create the radiative environment surrounding the reference load. Stability of these stage of temperature is TBD.

8.1.3 Thermal Models and Analyses

4K Reference Load thermal model and analysis are described in RD 25. An additional analysis, performed to evaluate the impact of 4K stage fluctautions on CMB measurements, is reported in RD 24.

8.1.4 Validation of the Thermal Mathematical Models

Following the thermal analysis performed in the RD 25 and RD 24, a set of thermal specifications are obtained, described in AD 12. Thermal balance tests will check the conformity of performance with thermal model analysis. Results will be included in the global thermal model

8.2 Thermal Verification and Testing

8.2.1 General Test Requirements and Test Arrangement

The cold stage of the 4K Reference Load cryofacility will be operative at a temperature less than 4 K. The mounting structure of the targets will be at 4.5 ± 0.2 K, while optical shield will operate at 20 ± 1 K. An adequate thermal resistance will be put between the cooler cold end and the two structures in order to rise their temperatures at the required values by means of a heating system. Details of a temperature active control implementation to optimize the two stage stability and to perform thermal fluctuation studies are TBD.

8.2.2 General Test Condition and Instrumentation

Tests will be performed in the cryofacility mounted in the IR laboratory at IASF Bologna.
The main environmental conditions of the laboratory zone outside the cryofacility are:

- Cleanliness class: visible cleaning
- Relative humidity: 50% ± 10%
- Temperature: 22º C ± 5º C
- Pressure: 900 to 1050 hPa

The instrumentation will consist of :

- 2 (TBC) LakeShore 340 temperature monitors and controllers

- 8 (TBC) LakeShore GR200A germanium and CX1050 cernox resistances
- 8 (TBC) LakeShore DT670 silicon diodes
- 4 (TBC) Minco heater films
- 1 Alcatel Pirani manometer
- 1 BOC Edwards Active Gauge Controller D386 series
- One dry pump and a turbo-rotative pump

Table 1 reports main sensor characteristics according to 340 readout system.

Sensor type	T range	Accuracy	Sensitivity
Silicon diode DT670	1.4 – 500 K	No cal: 0.25 K (at 2-100 K) 0.5 K (at 100-300 K)	0.3 mK at 4.2 K 5 mK at 20 K 70 mK at 77 K
		Cal: 12 mK at 1.4-10 K 22 mK at 77 K 32 mK at 300 K	
Germanium GR200A	0.3 – 40 K	25 mK at 4.2 50 mK at 6 K	0.3 mK at 4.2 0.6 mK at 6 K
Cernox	1.4 – 300 K	7 mK at 4.2 K 110 mK at 77 K	0.1 mK at 4.2 K 0.5 mK at 77 K

Table 1 **Main sensor characteristic with LSCI 340 readout apparatus**

8.2.3 Thermal Vacuum and Balance Test

8.2.3.1 Thermal Vacuum Test

All the samples under test will be mounted in the cryo-facility and will reach a minimum temperature of 4.0 ± 1.0 K at a minimum pressure of less than 10^{-4} mBar. The samples will be mechanically checked after the low temperature tests.

8.2.3.2 Thermal Balance Test

The thermal balance test will check the thermal requirement specification according to AD 12 and will verify the thermal model described in RD 25.
The test is divided in two main parts: the steady state verification and the transient state verification.

8.2.3.2.1 Steady state analysis

In the steady state verification, the temperature distribution of the reference load parts will be measured in order to compare with the specifications

1. the temperature difference between the target outer face (and pyramid) and the HFI shield interface
2. the power load of the 4 K Reference Load on the HFI shield

The scheme of the measurements will be as follows.
After the system thermalization at less than 4 K, the HFI representative structure temperature will be risen, by means of electrical heaters, to a value of 4.5 ± 0.2 K. The stability of this temperature will be less than TBD K. The temperature of the outer shield, representative of the LFI, will be risen, by means of electrical heaters, to a stable value of 20 ± 1 K. The stability of this temperature will be less than TBD K.
The temperatures of the target face in front of the LFI, T_{face}, of the pyramid tip, T_{pyr}, and of the HFI interface, T_{HFI}, will be measured with an accuracy better than 25 mK.
The differences, $\Delta T_{face\text{-}HFI}$ and $\Delta T_{pyr\text{-}HFI}$, between the two target temperature and the HFI shield will be evaluated.
Finally, the heat load on the HFI shield will be evaluated, according to the well known relation:
$W = K \cdot \Delta T$ where K is the conductance, evaluated from the model.

8.2.3.2.2 Transient state analysis

The scope of the test is to evaluate and compare with model predictions the transfer function of temperature fluctuations between HFI and LFI shield and the reference target, in order to verify the 4K RL temperature stability specifications.
The scheme of the measurements will be as follows.
After the system thermalization at less than 4 K, the HFI representative structure temperature will be risen to a value of 4.5 ± 0.25 K. The temperature of the outer shield, representative of the LFI, will be risen to a value of 20 ± 2 K.
Temperature fluctuations, $T_{HFI} = T_0 + \Delta T_{HFI} \sin(2\pi\nu t + \phi)$ with different frequencies, ν, will be applied to the HFI shield; the temperatures of the target face in front of the LFI, T_{face}, and of the pyramid tip, T_{pyr}, will be measured with a sensitivity better than 5 mK. The test will be performed at least for 1s, 60s, 667s and 4000s periods of fluctuations.
Transfer functions, $T_f(\nu)$, will be evaluated as $T_f(\nu)=\Delta T_{HFI}/\Delta T_{pyr}$.
They will be applied to the TBD HFI 4 K stage so that reference load stability at different frequency will be evaluated.

8.2.4 Thermal Cycling Tests

The 4K Reference Load parts will furtherly perform a number of thermal cycles between room temperature and cryogenic temperatures in order to reach a total number of 15, which is about three times the number of cycles the flight model will undergo during its lifetime.
The cycles will start at a temperature of 290 ± 10 K and reach a minimum temperature of 4 ± 1 K. The rate of cooldown and warm up will be of less than 3 K/min and the total duration of each cooldown and warmup phase will be not less than 10 hours (including at least 2 hours of thermalization at a constant temperature).

8.2.5 Thermal Shock Test

TBD