TITLE:

4K Reference Load Thermal Test Procedures

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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	Sept. 2004	All	First issue of the document	QM TRR
1.1	Nov. 2004	§ 8.2	Updated: Thermal control with LS 340.	QM TRB
1.2	May 2005	§ 8.2	Updated: temperature ranges relaxed	LFI IQR

TABLE OF CONTENTS

1 ABSTRACT

This document contains the procedures for the cryogenic tests of the QM and FM 4 K Reference Load parts.

2 KEYWORDS/ACRONYMS

RL	Reference Load
DUT	Device Under Test
SUT	Sample Under Test
RF	Radio Frequency
QM	Qualification Model
FM	Flight Model

3 INTRODUCTION

The 4 K Reference Load model philosophy implies the requirement verification of both qualification and flight models. From the thermal point of view, the main requirements of the 4 K Reference Load are the heat load upon the HFI 4 K shield and the temperature stability observed by the LFI radiometers. The tests described in this document are aimed to verify this properties.

3.1 PURPOSE AND SCOPE

The purpose of this document is to provide procedures to perform cryogenic tests, verifying the 4 K Reference Load thermal requirements

3.2 STRUCTURE OF THE DOCUMENT

Section 5 is dedicated to the description of the general condition of the testing laboratory environment, the personnel involved in tests and instrumentation list.
Section 6 includes test control sheets summarizing the objective and methodology of the tests.
Section 7 describes the pre-test activities of experimental setup and cryofacility cooldown.
Section 8 provides procedures for thermal balance tests, while Section 9 provides procedures for thermal cycles.

4 APPLICABLE AND REFERENCE DOCUMENTS

4.1 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)
[AD 13] *4K Reference Load Test Plan* (PL-LFI-TES-PL-001)

4.2 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] *HFI Temperature stability requirements* (SR-PH211-990141-IAS, Issue 01)
[RD 4] *LFI signal oscillations induced by Sorption Cooler temperature variation* (PL-LFI-PST-TN-010, Issue 1.0)
[RD 5] *HFI thermometers and heaters specifications* (SP-PHAC0-100044-IAS, Issue 0/0,12.2.00)
[RD 6] The 4KRL Cryo Facility (PL-LFI-TES-TN-010, 1.0)
[RD 7] *Preliminary evaluation of the impact of temperature fluctuations in the HFI 4K stage on LFI* (PL-LFI-PST-TN-048, 1.0)
[RD 8] *LFI 4K Reference Load thermal model* (PL-LFI-PST-TN-049, 1.0)
[RD 9] *LakeShore Model 340 Temperature controller user's manual,* Rev. 1.8

5 GENERAL REQUIREMENTS

5.1 RESPONSIBILITIES

The test engineer is responsible for the correct execution of the test program, for the fulfilment of the requirements, for measurement and recording and for the preparation of the test report.
IASF P.A. personnel are responsible to ensure that all operations and test are performed in accordance with the Project P.A. Plan.
Any measurements which departs from the nominal value shown in this procedure will be declared by an N.C.R. and following the procedure as indicated in applicable P.A. document.

5.2 ENVIRONMENTAL CONDITIONS

Tests will be performed in a dedicated cryo chamber (described in [RD 6]) in the IR laboratory at IASF-CNR in Bologna. The cleanliness standard of the laboratory is that of a “visible clean”.
Table 5.2.1 environmental conditions shall apply.

Parameter	Nominal value	Measured value
Relative Humidity [RH %]	20-60 %	
Temperature [°C]	22°± 4° C	

Table 5.2.1 Laboratory environmental conditions applicable to tests

5.3 PERSONNEL REQUIREMENT

The table below shows the responsibilities during the test realisation.
Fill in blank cells.

TABLE 5.3.1- PERSONNEL REQUIREMENT

COMPANY	RESPONSIBILITY	NAME	REMARKS
IASF	TEST CONDUCTOR		
IASF	TEST ENGINEER		
IASF	P.A. ENGINEER		

5.4 INSTRUMENT REQUIREMENT LIST

In the following table all the laboratory equipment requested has to be listed. Fill in blank cells.

TABLE 5.4.1- INSTRUMENTS LIST

EQUIPMENT LABEL (e.g. name)	QUANTITY	MANUFACT. TYPE	INVENTOR. No.	NEXT CALIBRATION DATE	ACCURACY	REMARKS

6 TEST CONTROL SHEETS

6.1 TEST IDENTIFICATION CODE

Each test to be performed will be uniquely identified by a test identification code with the format shown in the test matrix ([AD 13]).

6.2 TEST CONTROL SHEETS

For each test, a test control sheet is given which identifies all the requirements.
It has to be compiled and attached to the test report as cover sheet. We give here examples of test sheets applicable for each test to all frequency channels so that a white space (“__”) is to be filled with frequency tested

<table>
<tr><td colspan="2">Test title: Thermal Balance steady state at __ GHz</td><td>Date:</td></tr>
<tr><td>Test N°: PLTES-___-TB-SS-__</td><td colspan="2">Conductor:</td></tr>
<tr><td colspan="3">Requirements: see [AD 12]/VCN-025</td></tr>
<tr><td colspan="3">DUT name: __ GHz QM/FM Reference Target ID ___</td></tr>
<tr><td colspan="3">Objective: To verify that the reference target outer parts temperatures and heat load on HFI shield at steady state are compliant with specifications</td></tr>
<tr><td colspan="3">Test methodology: The QM/FM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. Temperatures are measured after the system has thermalized and heat load is evaluated as indicated in [AD 13]</td></tr>
<tr><td colspan="3">Notes:</td></tr>
<tr><td colspan="3">Conductor Signature:

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

Test title: Thermal Balance transient state at __ GHz		**Date:**
Test N°: PLTES-___-TB-TS-__	**Conductor:**	
Requirements: [AD 12]/VCN-022, VCN-023, VCN-024		
DUT name: __ GHz QM/FM Reference Target ID ____		
Objective: To verify that the reference target fluctuation damping at different frequencies is compliant with specifications:		
Test methodology: The QM/FM Reference targets and mounting structure are cooled down in the cryo facility in presence of a conductive and radiative heat transfer representative of in flight conditions. An oscillating temperature boundary is provided at the interface with the 4 K stage and pyramid tip temperatures are measured in order to evaluate the fluctuation transfer function as indicated in [AD 13]. The test is repeated for different oscillation frequencies.		
Notes:		
Conductor Signature: ________________________		

Test title: Thermal cycles at __ GHz	**Date:**
Test N°: PLTES-____-TC-__	**Conductor:**
Requirements: No relevant change in DUT after visual inspection. See [AD 12]/VCN-035	
DUT name: __ GHz QM/FM Reference Target ID ____	
Objective: To verify that the reference target mechanical properties are unchanged after 15 thermal cycles, including cycles performed during other tests.	
Test methodology: The QM/FM Reference targets and mounting structure are continously cooled down and warmed up in the cryo facility for 15 times.	
Notes:	
Conductor Signature: ______________________	

7 PRE TEST ACTIVITIES

This section is intended to describe the instrumentation used during the tests and a number of experimental steps, which are common to all kind of tests, to be performed before the goal measurements.

7.1 INSTRUMENTATION DESCRIPTION

As far as these measurements are concerned, the instrumentation can be regarded as composed of:

1. A number and type of temperature sensors and heaters, depending on the test to be performed
2. A thermo-vacuum chamber with a 4 K cryo-cooler
3. One (or two TBC) temperature monitor(s) and controller(s)
4. One personal computer with dedicated operation control software
5. One dry pump and pressure monitor
6. One voltage function generator
7. One digital oscilloscope for quick visual control of voltage function

7.1.1 TEMPERATURE SENSORS AND HEATERS DESCRIPTION

Lakeshore temperature sensors Germanium GR200, Cernox CX1050, silicon diodes DT670 are used. Sensor packages SD and CU will be used. Main features of these devices coupled with our readout system are reported in [AD 13] (Table 1 in Section 8.2.2).
Minco film heaters will be used.

7.1.2 CRYO FACILITY DESCRIPTION

The 4K RL cryo facility is described in [RD 6].

7.1.3 TEMPERATURE CONTROLLER DESCRIPTION

The LakeShore 340 Temperature Controller will be used for readout and control of the temperature of our system. In Fig. 1 and Fig. 2, front and back panels of the instrument are shown.
Many configurations options are available through the acquisition software. Her we give a short description of some options the operator have to adjust directly on the instrument.

- **Input setup** button [key 7 on the panel]: set the type of sensor, for each channel, and the curve to use for converting electrical signal in temperature
- **Display format** button [key 9]: set the channel and units to appear in the instrument display.
- **Control setup** button: in the first screen enables heater output and set the channel to control the kind of control and the heater resistance. Pushing [**More**] button, enter the second screen with the Max current settings and max heater range .

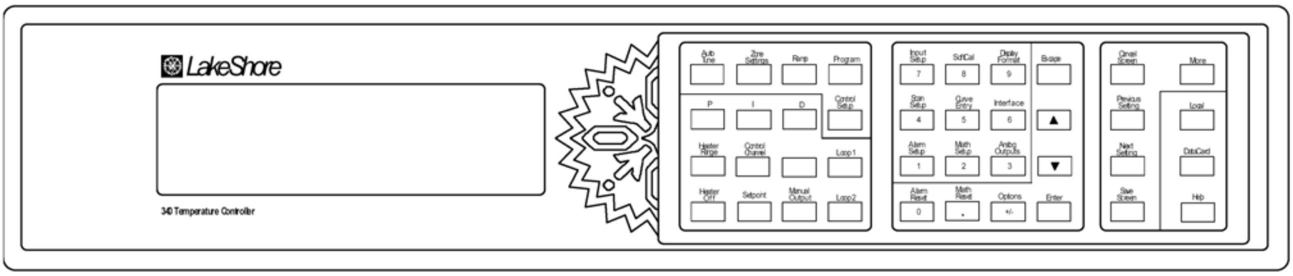

Fig. 1 LakeShore 340 front panel

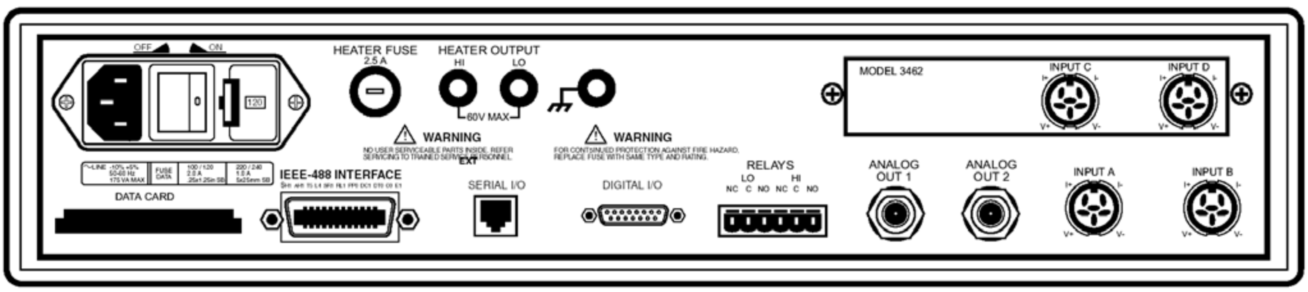

Fig. 2 LakeShore 340 back panel

In the back panel, input connector for sensor are evident in the option 3462. In this options it is possible to monitor four independent sensors (channels A, B, C, D). When option 3468 is mounted,

inputs C and D are substituted by two 25-pin Cannon connectors, each connecting four sensors of the same kind read in sequential scanning (channels C1, C2, C3, C4 and D1, D2, D3, D4).
Other important connections are the IEEE-488 interface connector and the Heater output plug.

7.1.4 DRY PUMP DESCRIPTION

Fig. 3 Vacuum dry pump Boc Edwards XDS5 (left) and connection to the facility by its valve (right)

The vacuum pump is shown in Fig. 3 (left panel). The red hose which outputs outdoor and the vacuum flexible hose, connected to the facility through the vacuum valve (right panel), are also visible. The switch is on the left of the red hose clamping collar. The vacuum valve have to be closed before both switching on and off the pump. This dry pump permits to reach a level of $5 \cdot 10^{-2}$ mBar, so it is useful to close the valve and switch off the pump when the pressure drops below this value,under the effect of cryogenic pumping.

7.1.5 VOLTAGE FUNCTION GENERATOR AND DIGITAL OSCILLOSCOPE DESCRIPTION

The voltage function generator (Fig. 4) will be used in the generation of a sinusoidal input to the heaters, in order to create temperature fluctuations in the shields during the transient test.

Fig. 4 Philips PM5134 function generator front view

Fig. 5 HP Digital Oscilloscope front view

The oscilloscope (Fig. 5) is used to check and measure the parameters set with the generator.

In order to do that connect, by a BNC connector, the output of the generator to the input 1 of the oscilloscope.
The main operations to be performed are

- **Setting Frequency:** to set the frequency of our signal
    1. Switch the frequency display
    2. Set the frequency range
    3. Tune the frequency
    4. Push in sequence the Blue button and the [**9**] on the oscilloscope panel, then select the [1] channel and check the frequency set.
- **Setting DC Offset:**
    1. Pull the DC OFFSET control and tune the offset checking the V_{AVG} display on the oscillator (Blue button and then [**ns**] key).
- **Setting the amplitude:**
    1. Switch the amplitude display
    2. Tune the amplitude
    3. Check the peak-to-peak amplitude by the $V_{p\text{-}p}$ function in the oscillator (Blue button and then [**1**] key).

7.2 ACTIVITY DETAILED DESCRIPTION

7.2.1 TEST SETUP

The SUTs will be mounted in the cryofacility according to Fig. 6. Stainless steel thermal washers are visible around the screws of the shields, in order to increase the stability and control of their temperature.

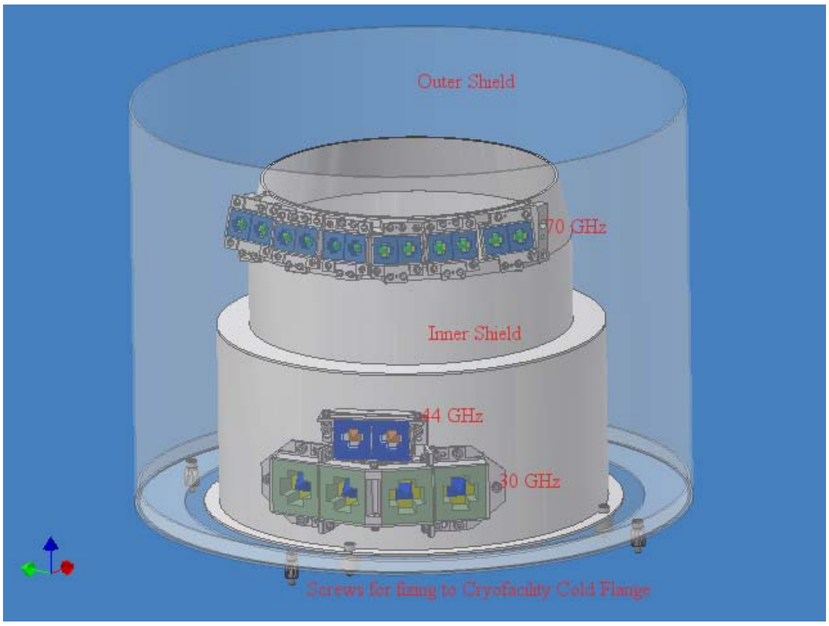

Fig. 6 Experimental setup with 20 K outer shield, HFI inner shield and target mounted in the right position

The integration steps are reported in the table below. For thermal cycles the dedicated thermally stable environment is not needed. DUTs will be mounted on adedicated copper support and directly linked to the cryofacility cold flange.

The operator is requested to wear dustless gloves during the handling of the samples under test.
Fill in blank cells in the following table.

Step No.	Action	Expected Output	Notes/Result	Date
0	Clean all facility and SUTs			
1	Mount the inner shield (mount the copper support in case of thermal cycles)			
2	Fix the SUT in its corresponding position			
3	Mount sensors and heaters			
4	Mount the outer shield (skip in case of thermal cycles)			
5	Mount the facility 4 K shield			
6	Mount the facility 50 K shield			
7	Acquisition and control test run			

Test Engineer	Test Conductor
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7.2.2 CRYOFACILITY CLOSURE AND VACUUM

Step No.	Action	Expected Output	Notes/Result	Date
0	Clean the facility o-ring and its groove			
1	Spam vacuum grease on the o-ring homogeneously and locate it			
2	Pull down the facility cover in such a way that the o-ring and groove fit correctly.			
3	Mount the closure screws			
4	Close the facility vacuum valve			
5	Connect the pump tube to the valve by DN25			
6	Connect the pressure sensor to the facility and switch on pressure monitor	The monitor display measures the atmospheric pressure		
7	Switch on the pump			
8	Wait two minutes and then open gradually the facility valve until it is completely open			
9	Wait until the pressure reaches a value of 0.12 mBar			

7.2.3 CRYOCOOLER ACTIVATION AND FACILITY COOLDOWN

In case of thermal cycles refer directly to Section 9.1.

Step No.	Action	Expected Output	Notes/Result	Date
0	Start the “Cooldown.vi” LabView acquisition file.			
1	Set the proper filename for storing cooldown data and readout sampling time (in ms) in the corresponding input forms			
2	Switch on the control tab.			
3	Start acquisition and then switch the cooler on.			

4	When the facility pressure drops down to less than 10^{-2} mBar close the facility vacuum valve and switch off the pump.			
5	When the system has thermalized, stop acquisition.			

8 THERMAL BALANCE TEST

8.1 STEADY STATE TEST

The goal of the steady state test is to study the temperature distribution of the reference load in the radiative and conductive conditions representative of the in-flight ones. High accuracy calibrated sensors have to be used in this kind of tests because we are interested in the absolute temperature of different regions of our setup.

In order to obtain the right thermal environment it is needed to adjust the temperature of the two shields at 4.5 and 20 K. This operation, according to the stability described in [AD 13], requires a number of steps whose definition is not applicable univocally. Procedures for a correct PID tuning are well described in the [RD 9], Chapter 6, we will refer to in our table of actions. The mechanical setup was thought in order to damp passively cooler cold end fluctuations, so that a PID tuning will be needed only in case of residual fluctuations.

8.1.1 STEADY STATE TEST PROCEDURE

Step No.	Action	Expected Output	Notes/Result	Date
0	Start the “Steady_State.vi”			
1	Set the temperature of the outer shield at 20 ± 1 K, with a stability of 50 mK. Start with a constant power load (Open Loop) of 53% in Loop 2. If residual fluctuations are present, then tune the Manual PID parameters ([RD 9])			
2	Set the temperature of the HFI representative shield at 4.5 ± 0.5 K with a stability of 5 mK. Start with a constant power load (Open Loop) of 12% of 60mW in Loop 1. If residual fluctuations are present, then tune the Manual PID parameters ([RD 9])			
3	Acquire data for 5 minutes.			
4	Evaluate the heat load from Reference Targets to the HFI shield as in [AD 13].			

Test engineer   Project leader   Product assurance

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8.2 TRANSIENT TEST

The goal of the transient analysis is to verify the damping efficiency of the reference load with respect to the 4.5 K shield fluctuations. The temperature of the HFI shield has to be stabilized at 4.5 K and then, by means of the voltage function source an 100 mK amplitude fluctuation is provided at different frequencies. Since we are interested in the ratio between interface fluctuation and target fluctuation amplitudes, the requirement on the HFI shield stability is not applicable.

8.2.1 TRANSIENT STATE TEST PROCEDURE

Step No.	Action	Expected Output	Notes/Result	Date
0	Start the "Transient_State.vi"			
1	Set the temperature of the outer shield at 20 ± 1 K, with a stability of 50 mK. Start with a constant power load (Open Loop). If residual fluctuations are present, then tune the Manual PID parameters ([RD 9])			
3	Start the function generator. Set the offset in order to reach at the interface a temperature of 4.5 K.			
4	Set the sinusoidal function at 1 Hz; measure amplitude and frequency of the function by means of the digital oscilloscope.			
5	Set the filename and acquire data at least for 5 periods.			
6	Stop acquisition.			
7	Disconnect the heater plugs from function generator and connect them to the LSCI 340 heater output. Set the temperature of the HFI representative shield at 4.5 ± 0.5 K with a stability of 5 mK. Start with a constant power load (Open Loop). If residual fluctuations are present, then tune the Manual PID parameters ([RD 9])			
8	Set the offset and amplitude of the power sinusoidal fuction and set the period to 60 sec in the dedicated input forms			

9	Set the filename and acquire for at least five periods			
10	Stop acquisition			
11	Repeat the steps 7-10, changing the period at 600 sec.			
12	Repeat the steps 7-10, changing the period at 667 sec.			
13	Repeat the steps 7-10, changing the period at 1000 sec.			
14	Evaluate the peak-to-peak amplitude of fluctuations at the level of pyramid tip and targets' outer face. The damping factor is the ratio between these values and the fluctuations p-p amplitude at the interface with the HFI shield ([AD 13])			

Test engineer	Project leader	Product assurance
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9 THERMAL CYCLES

The scope of this test is to perform a number of continous cooldowns and warm-ups of the DUTs in the cryofacility.

9.1 THERMAL CYCLES PROCEDURES

Step No.	Action	Expected Output	Notes/Result	Date
1	Start the "Cooldown.vi" LabView acquisition file.			
2	Set the proper filename for storing cooldown data and readout sampling time (in ms) in the corresponding input forms			
3	Start acquisition and then switch the cooler on.			
4	When the facility pressure drops down to less than 10^{-2} mBar close the facility vacuum valve and switch off the pump.			

5	When the system has reached a temperature lower than 5 K since more than two hours stop acquisition.			
6	Switch on the control tab and set the heater value at 95% of 10 W			
7	Start acquisition and then switch the cooler on.			
8	When temperature has reached a temperature greater than 280 K for more than two hours, stop acquisition, switch off the control tab and switch off the heater.			
9	Repeat steps 1-8 until the desired number of cycles is reached.			

Test engineer	Project leader	Product assurance
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10 END OF TEST

At the end of each test activity warm up the facility and open gradually the vacuum valve in order to refill it with air until the atmospheric pressure is reached, before opening it and de-mount the DUTs. The operator has to wear dustless gloves. Store the DUTs in the dedicated spaces.