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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	6/7/2005	All	First issue of the document	TRB
1.1	12/7/2005	10	Conclusion section included with reference to the vibration test report	TRB

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1 SCOPE

1.1 Purpose

Purpose of the LFI 4KRL is to provide LFI radiometers of a stable reference signal. The 4KRL is mechanically and thermally connected to the lower temperature accessible in the Planck payload, the HFI outer radiation shield. This shield is cooled at the nominal temperature of 4K.
Due to changes in the LFI model philosophy and schedule constraints, a dummy unit for the 4KRL is required by the HFI for its qualification activities.
Purpose of the unit described in this document is to provide the HFI with a 4KRL dummy unit representative of the mass, volume, interface and radiative thermal load of the FM unit.

Purpose of this document is to describe the 4KRL dummy FM unit and the verification activities performed by the 4KRL development team before delivering it to the HFI.

1.2 Document Overview

1.3 TERMS and ACRONYMS

4K RL	4K Reference Load
CMB	Cosmic Microwave Background
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
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: 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: I/F drawing IAS PH 280 0182 IAS 1-2 (FM Interface)
AD 14: 4KRL FM dummy vibration test procedures ((PL-LFI-TES-PR-008, 1.0)
AD 15: 4K Reference Load Thermal Test Procedures (PL-LFI-TES-PR-003, 1.2)

2.2 Reference documents

RD 1: Drawing PL-TES-03-001, rev. 1
RD 2: Drawing PL-TES-03-002, rev. 1
RD 3: Drawing PL-TES-03-003, rev. 1
RD 4: Drawing PL-TES-03-004, rev. 1
RD 5: ECCOSORB™ CR-series revision 12/11/2002
RD 6: ECCOSORB™ MF-series revision 12/11/2002
RD 7: The 4KRL Cryo Facility (PL-LFI-TES-TN-010, 1.0)
RD 8: ECCOSORB failure analysis (PL-LFI-TES-TN-015, 1.0)
RD 9: 4KRL Bonding procedure (PL-LFI-TES-PR-010, 2.0)
RD 10:Off. Pasquali procedure, STP 317, Rev. A
RD 11:4KRL cleaning procedure (PL-LFI-TES-TN-009, 2.0)
RD 12: 4KRL FM dummy load vibration test report (PL-LFI-TES-RP-014, 1.0)

3 Dummy load design

The 4KRL FM dummy is designed to be representative of the volume, mass and thermal properties of the 4KRL FM design. Parts have been manufactured according to configured drawings RD 1, RD 2, RD 3 and RD 4.

3.1 Interface

The 4KRL FM dummy is designed according to the I/F drawing AD 13. Thermal properties of the interface are not representative of the 4KRL thermal interface to the HFI.

3.2 Dimensions

The 4KRL FM dummy is representative of the occupied volume of the 4KRL FM. However, to be representative of the 4KRL mass, the dummy load detailed design is different from the FM. The position of the center of gravity of each part is as close as possible to the FM.

3.3 Mass

The 4KRL FM dummy mass is representative of the true 4KRL FM mass. Details of the mass of each part is reported in Table 1.

LFI PART NUMBER	4KRL PART NUMBER	PART NAME	ACTUAL WEIGHT
PLAFC/A-P	PLTES033	UPPER SECTOR FM DUMMY	117.3
PLAFC/B-P	PLTES034	44GHz FM DUMMY LOAD	52.8
PLAFC/B-P	PLTES035	44GHz FM DUMMY LOAD	53
PLAFC/B-P	PLTES036	44GHz FM DUMMY LOAD	52.8
PLAFC/B-P	PLTES037	30GHz FM DUMMY LOAD	225

Table 1: Mass of the 4KRL FM dummies.

3.4 Absorbing surface

The absorbing surface is made of the same ECCOSORB™ material the real 4KRL are made of and is representative of the true ECCOSORB™ area. The upper sector absorbing surface was separated in three areas, whose overall surface is representative of the FM surface.

4KRL part	FM dummy absorbing area – mm^2
Upper sector	3 x 900.00
44 GHz loads	3 x 2 x 5.16
30 GHz load	4 x 1035.00
Total area	6871

Table 2: Absorbing area of the 4KRL FM dummies

3.5 Material

The 4KRL FM dummy made of Aluminum 6061 and ECCOSORB™ CR110 (see RD 5, RD 6 for details). The 4KRL FM is made of Al6061 and ECCOSORB™ CR110 and CR117. Stainless Steel screws and bolts will be used in the FM. Aluminum surface is polished to obtain a reflectivity which is representative of the FM unit.

3.6 Non conformity reported and recovery actions

3.6.1 Mass

The 30GHz dummy load mass, when measured, resulted far too high than the value required. This was due to an error in the design of the dummy load. The part was re-worked on the back part. Some Al was milled out to recover a mass value representative of the 4KRL FM mass.

3.6.2 Cracks on ECCOSORB

After the first thermal cycle, some cracks on the ECCOSORB surface were observed. The cause of this behavior is the different thermal contraction coefficient between ECCOSORB and Al. ECCOSORB was directly casted on the Al, being ‘glued’ not only on the back surface but also on the sides. Moreover, the overall dimension of the 30GHz ECCOSORB surface was larger than in the QM dummy loads.

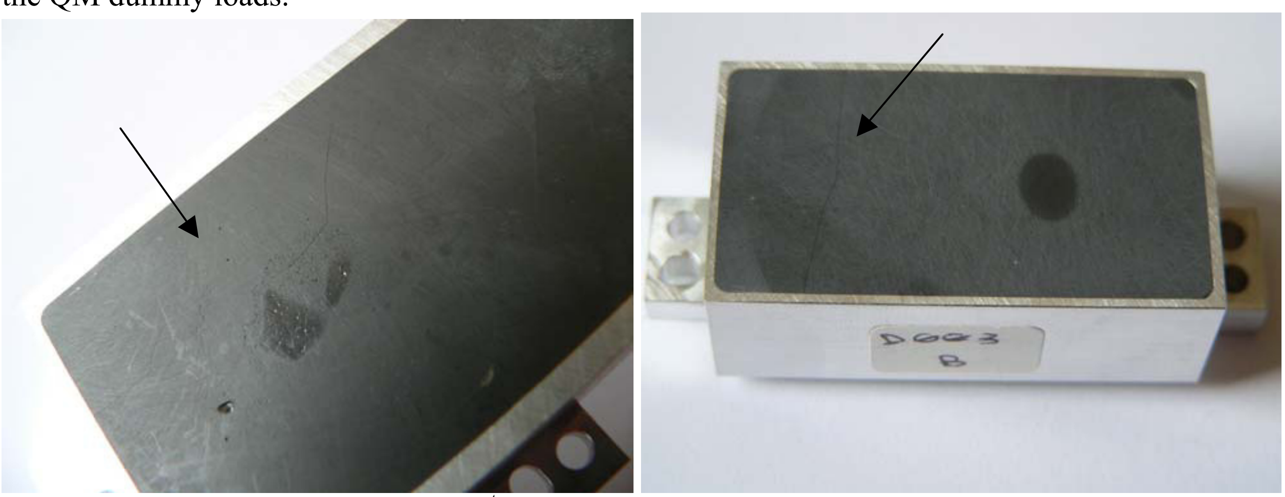

Figure 1: Cracks reported after the 1st thermal cycle. Left: 30GHz load; right 44GHz load. Cracks are marked with an arrow.

We then applied the same manufacturing approach as for the FM ‘true’ loads: ECCOSORB parts are casted (as for RD 10) separately and then bonded (as for RD 9) with Hysol 9394EA on the Al. Epoxy glue is located on the back part only (see RD 8).
Moreover, to reduce the surface of each ECCOSORB block, the central part of the loads was milled out.
Parts have then been submitted to vibrations and four thermal cycles to 4K.

4 Parts manufacturing

4.1 Manufacturer

FM Dummy load parts have been manufactured by the Officine Pasquali, using the same procedure used for the 4KRL FM manufacturing.

Dummy 4KRL parts have then been delivered to IASF-Bo for mechanical properties verification and thermal cycling.

4.2 Handling

No particular care is required in handling the 4KRL FM dummies. Use of gloves is suggested to prevent contamination. Cleaning shall be made with Isopropyl alcohol only. Parts can be stored in standard laboratory environment.

5 Parts verification

4KRL dummies were verified before delivery.
Purpose of these activity is:

- to verify the conformity with respect to drawings' dimensions
- to verify the manufacturing

5.1 Cleaning

Parts have been cleaned using IsoPropyl Alcohol. Gloves have been used for handling (see RD 11).

5.2 Mechanical dimensions

Parts have been measured with an accuracy of ±0.1 mm with a digital gage. All dimensions are found as specified in the configured drawings.
Mass was measured with a digital balance with an accuracy of ±0.1 g. Data are reported in Table 1.

5.3 Vibrations

The 4KRL FM dummy has been vibrated following the procedures in AD 14. Parts passed successfully the test, as reported in RD 12.

5.4 Thermal cycling

Parts were mounted in the 4KRL cryo facility (see RD 7 for details), using the 4KRL I/F points. The 44 GHz dummies were mounted on the cryo facility cold flange. The 30 GHz and 70 GHz dummies were mounted on the HFI dummy shield used in the QM 4K RL thermal tests.

5.4.1 Cycles procedures

Applied thermal cycle procedures, reported in the following table, are the same used in the QM 4K RL thermal tests (AD 15).

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			
10	Start the "Cooldown.vi" LabView acquisition file.			
11	Set the proper filename for storing cooldown data and readout sampling time (in ms) in the corresponding input forms			
12	Start acquisition and then switch the cooler on.			
13	When the facility pressure drops down to less than 10^{-2} mBar close the facility vacuum valve and switch off the pump.			
14	When the system has reached a temperature lower than 5 K since more than two hours stop acquisition.			
15	Switch on the control tab and set the heater value at 95% of 10 W			
16	Start acquisition and then switch the cooler on.			
17	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.			
18	Repeat steps 10-18 until the desired number of cycles is reached.			

5.4.2 Cycle 1

Test started May, 30th. All units were cleaned and mounted in the facility. Two calibrated sensors were mounted on the 30 GHz (Cernox CX1050) and 70 GHz (DT670 silicon diode) aluminum cases to monitor cooldown and warm up behavior (shown in Fig. 1).

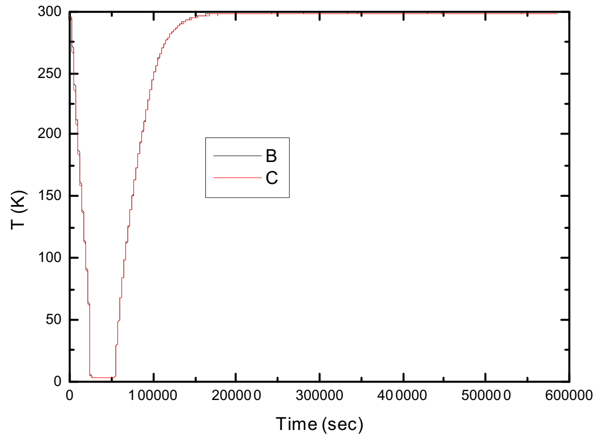

Fig. 1 Cool-down and warm-up temperature curve for the first cycle.

Parts have been de-mounted from the cryo facility and carefully observed:

- Some cracks were observed in 30 and 44 GHz units.
- No deformation was observed
- No flaking was observed
- No change in color was observed

Parts have then been re-worked (see Section 3.6.2 for details)

5.4.3 Cycle 1 for new 30 and 44 GHz dummy units

Test started on June, 16th. All units were cleaned and mounted in the facility (Fig. 2). Two calibrated sensors were mounted on the 30 GHz (Cernox CX1050) and 44 GHz (DT670 silicon diode) aluminum cases to monitor cool-down and warm up behavior.

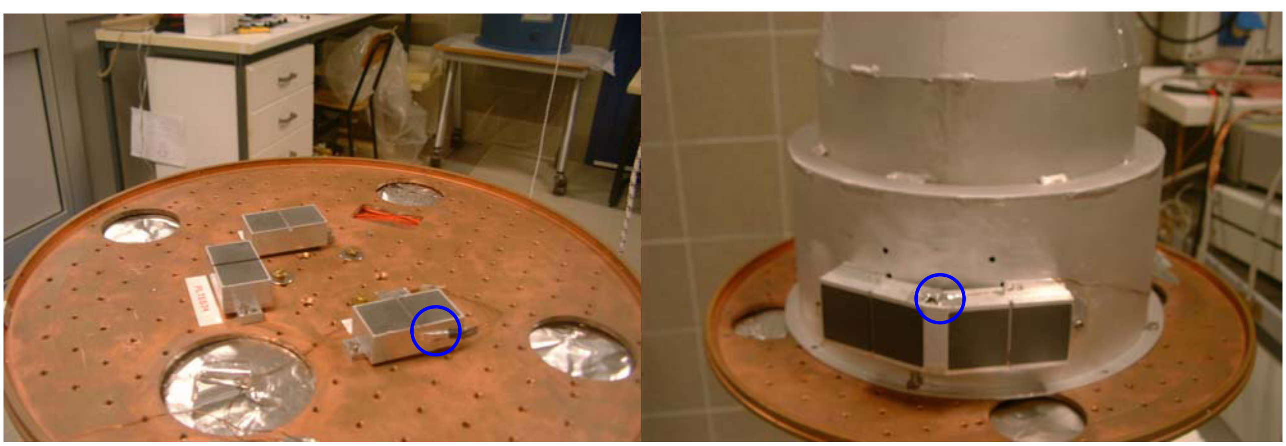

Fig. 2 Dummies mounting. 44 GHz are mounted on the cold flange (left), while 30 GHz assembly is mounted on the HFI dummy shield (right). Temperature sensors are visible (blue circles).

Parts have been de-mounted from the cryo facility and carefully observed:

- No cracks were observed
- No deformation was observed
- No flaking was observed
- No change in color was observed

5.4.4 Cycles 2-4

Test started on June, 23th. All units were cleaned and mounted in the facility. Two calibrated sensors were mounted on the 30 GHz (Cernox CX1050) and 70 GHz (DT670 silicon diode) aluminum cases to monitor cooldown and warm up behaviour. During cycles 2 and 3 problems with the environmental temperature of the cooler compressor made cooldown cooler slightly irregular. Cycles data are shown in Fig. 4 and following.

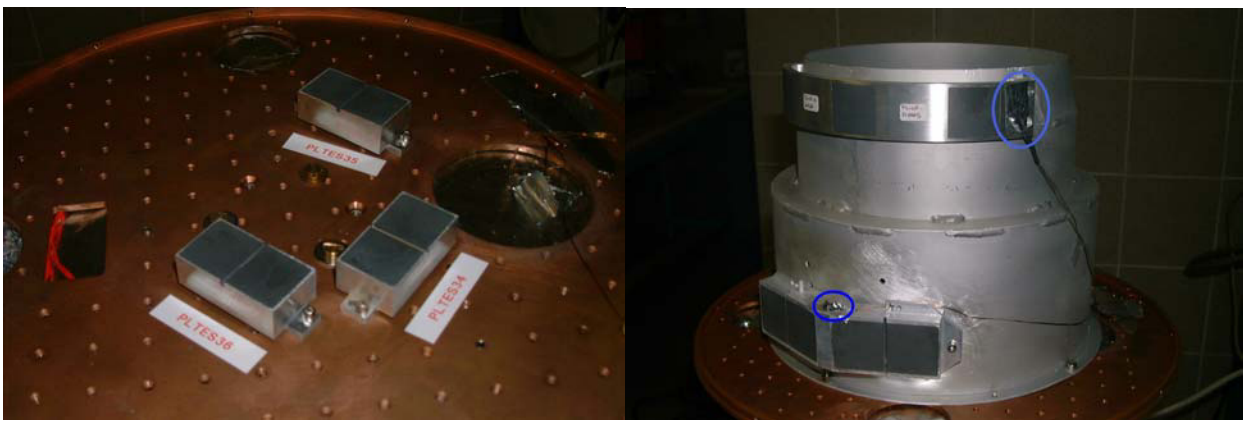

Fig. 3 Cycles 2-4: 44 GHz are mounted on the cold flange (left), while 30 and 70 GHz assemblies are mounted on the HFI dummy shield (right). Temperature sensors are visible (blue circles).

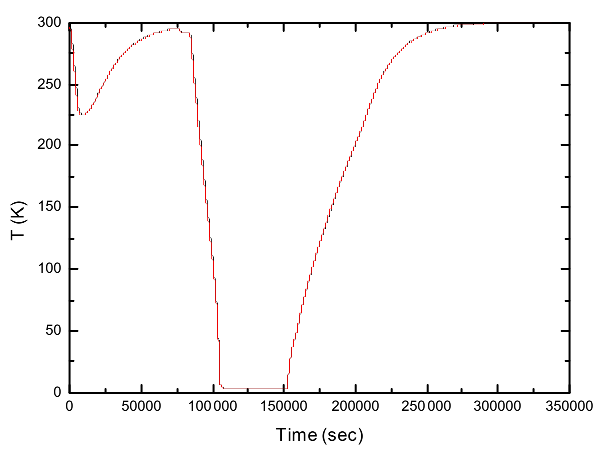

Fig. 4 Cycle 2 cooldown and warm up data; a temporary cooler failure is visible.

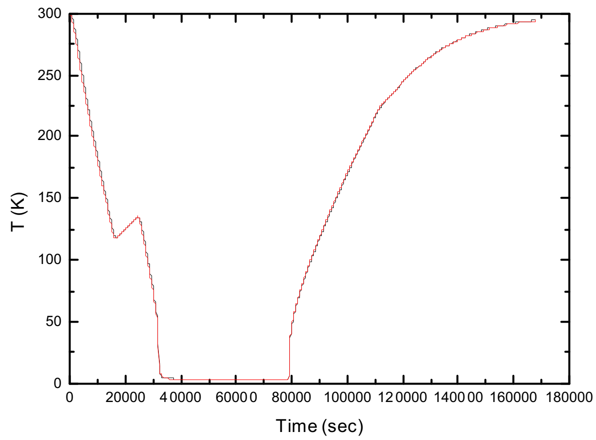

Fig. 5 Cycle 3 cooldown and warm up data; a temporary cooler failure is visible

Parts have been de-mounted from the cryo facility and carefully observed:

- No cracks were observed
- No deformation was observed
- No flaking was observed
- No change in color was observed

6 Conclusions

4KRL FM dummy parts have been verified.
Mechanical dimensions have been verified are successfully (see Section 5.2)
Vibration test is successful, see Test report RD 12: 4KRL FM dummy load vibration test report (PL-LFI-TES-RP-014, 1.0)
Thermal cycles are successfully (see Section 5.4)

Since all tests have been passed successfully, parts are ready for integration on the HFI.