SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

EPTHET-1 FM and EPTHET-2 PFM
Thermal Cycling Test Plan and Procedure

Document ID: SO-EPD-KIE-TP-0036

Issue: 1

Revision: 0

Date: 28/02/2016

Signature not needed if electronically approved by route

Written	Checked	Approved Configuration Control	Approved QA	Approved Experiment Manager	Approved Principal Investigator
Ali Ravanbakhsh Date and Signature	Robert Elftmann Date and Signature	César Martín Date and Signature	Michael Richards Walter Boogaerts Date and Signature	Date and Signature	Date and Signature

DISTRIBUTION LIST

The following list indicates the individuals and agencies in receipt of review copies of the present document:

Agency / Organization	Name & Title	Contact information
SRG-UAH	Javier Rodríguez-Pacheco EPD Principal Investigator	javier.pacheco@uah.es
SRG-UAH	Manuel Prieto EPD Project Manager	manuel.prieto@uah.es
SRG-UAH	Cecilia Gordillo EPD Configuration Control Responsible	cecilia.gordillo@uah.es
SRG-UAH	Andrés Russu Berlanga EPD AIVT Responsible	Andres.Russu@uah.es
SENER	Maria Teresa Gómez EPD System Engineer	maite.gomez@sener.es
SENER	Santiago Jarabo EPD Product Assurance Manager	santiago.jarabo@sener.es
IDR/UPM	Gustavo Alonso Isabel Pérez Structural and Thermal Mathematical Models	gustavo.alonso@upm.es isabel.perez.grande@upm.es
CAU	Michael Richards Walter Boogaerts EPD/Kiel Product Assurance Manager	mlr@richards-consulting.eu WBoogaerts@gmx.net
CAU	EPD Kiel Team	solo_kiel@physik.uni-kiel.de
CAU	Robert Elftmann Thermal Vacuum Chamber Responsible	elftmann@physik.uni-kiel.de

CHANGES RECORD

Issue	Revision	Date	Modified by	Section / Paragraph modified	Change implemented
1	0	28/02/2016		All	Initial release

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Purpose

The aim of this document is to define the thermal cycling test plan and procedure. This test is performed on EPTHET1&2 to verify their functionality and performance in the hot and cold conditions.

As EPTHET-1 and EPTHET-2 are identical in design, the test margin is applied as below:

- For EPTHET-2 PFM in the hot and cold conditions, Qualification margin and 4 cycles will be applied.
- For EPTHET-2 FM in the hot and cold conditions, Acceptance margin and 4 cycles will be applied.

1.2 Scope

This document applies to all activities related to the EPTHET-1 FM and EPTHET-2 PFM thermal cycling test campaign performed by all institutions and personnel involved in the test.

Important notes:

- No thermal cycling test was performed on EPTHET PQM after vibration tests during 18.05-20.05.2015 which was unsuccessful and resulted to HW damage on electronic boards.
- During the “EPD-IQR co-location meeting” at ESTEC on 17.02.2016, due to the fact that EPTHET-1 &2 are identical, EPTHET-2 can comply with PFM approach which means qualification margin for thermal cycling tests. And EPTHET-1 can comply with FM approach which is acceptance margin for the thermal cycling tests.
- No thermal balance test is foreseen for EPTHET-1 FM and EPTHHET-2 PFM.
- The results of correlated TMM after EPTHET PQM TBT will support the TBD test temperatures indicated in Table 6-1 before the test and at the time of TRR [RD-1].

2 GLOSARY AND DEFINITIONS

2.1 Acronyms and Abbreviations

CAU	Christian-Albrechts-Universität zu Kiel
EIDA	Experiment Interface Document-Part A
EPD	Energetic Particles Detector
EPT	Electron, Proton Telescope
EUT	Equipment Under Test
FM	Flight Model
HET	High Energy Telescope
LN2	Liquid Nitrogen
MLI	Multi-layer Insulation
N/A	Not applicable
NCR	Nonconformance Report
P	Pressure
$\mathbf{P_{ambient}}$	Ambient pressure
PA	Product Assurance
PFM	Protoflight Model
PQM	Proto-Qualification Model
$\mathbf{P_{test}}$	TVC test pressure ≤ 10^{-5} Torr
QA	Quality Assurance
S/C	Spacecraft
TBC	To Be Confirmed
TBD	To Be Defined
$\mathbf{T_{ambient}}$	Ambient temperature
TMM	Thermal Mathematical Model
$\mathbf{T_{shroud}}$	TVC shroud temperature
T_URP	URP temperature
TVC	Thermal Vacuum Chamber
URP	Unit Reference Point

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable Documents

ID.	Title	Reference	Iss./Rev.	Date
AD-1	Experiment Interface Document part A	SOL-EST-RCD-0050	5/0	16/03/2015
AD-2	EPT-HET and STEP Assembly, Integration and Test Plan	SO-EPD-KIE-PL-0010	2/1	30/10/2013
AD-3	EPTHET1 FM and EPTHET-2 PFM Functional test plan and procedure	SO-EPD-KIE-TP-0038	1/0	29/02/2016
AD-4	CIDL-ABCL for EPTHET-1 FM and EPTHET-2 PFM	SO-EPD-KIE-LI-0011	1/0	29/02/2016
AD-5	EPT-HET PQM Thermal Balance Test Report	SO-EPD-KIE-TR-0013	1/0	16/09/2015

3.2 Normative Documents

ID.	Title	Reference	Iss./Rev.	Date
ND-1	Testing	ECSS-E-ST-10-03C		01/06/2012
ND-2	Safety instructions for IEAP CAU facilities	http://www.ieap.uni-kiel.de/sicherheit/		

3.3 Reference Documents

ID.	Title	Reference	Iss./Rev.	Date
RD-1	Document under preparation The results of correlated TMM after EPTHET PQM TBT to support EPTHET-1&2 TVT			Before the test and at the time of TRR

4 TEST OVERVIEW

4.1 Test objectives

The objectives of the EPTHET-1 FM and EPTHET-2 PFM thermal cycling tests are to:

- Stress the EUT at acceptance limit and check problems like loose connectors, defective solder joints after vibration tests and possible performance drift due to unpredicted reasons.
- Check the functionality of the instrument during temperature Plateaus in repeated thermal cycles.

4.2 Test facility

The thermal cycling test is conducted in CAU facility.

NOTE:
As will be described in Sec. 5, the thermal cycling test on EPTHET-1 FM and EPTHET-2 PFM will be performed without MLI.

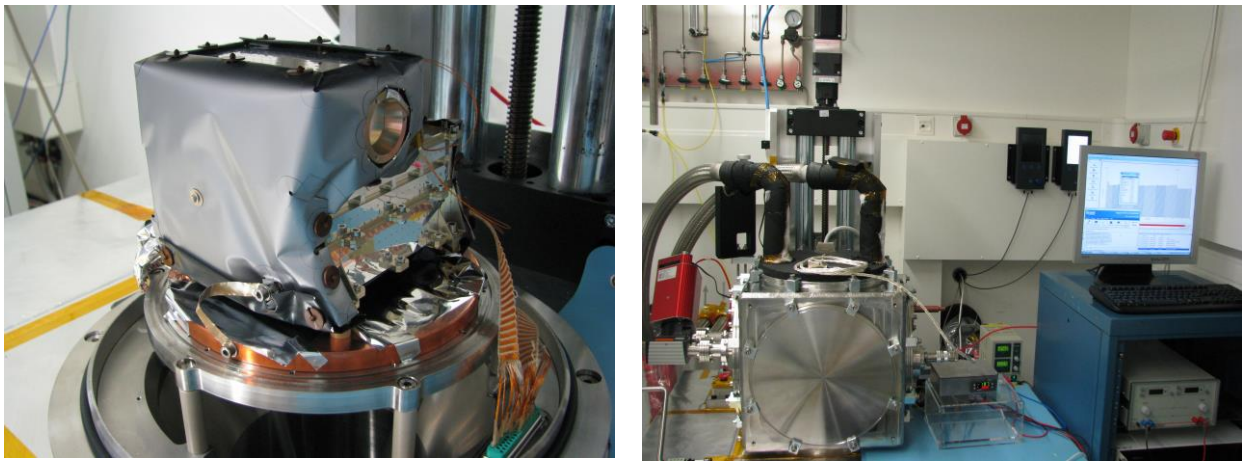


Fig. 4.1. CAU thermal vacuum chamber, EPTHET PQM is shown on the left in EPTHET PQM thermal balance test campaign performed during 10.07-22-07.2015.

4.3 Environmental conditions

- Cleanliness: ISO 8 clean room

4.4 Test documentation

A completed test report will be presented after the test. It will include the final as-run test procedure approved by the PA (Product Assurance) responsible and will be accompanied by the temperature sensor read outs from the data acquisition system. Also, appropriate discussion will conclude the success/failure of the conducted test.

4.5 Participants

The test participants and their responsibilities are defined in Table 4.1.

Table 4.1. Test participants (TBC before the test) and their responsibilities.

#	Name	Responsibility
1	Robert Elftmann	TVC and test responsible
2	Ali Ravanbakhsh	AIVT, test accountable
3	Michael Richards	Quality assurance
4	Walter Boogaerts	Quality assurance
5	Lauri Panitzsch	Instrument lead
6	Lars Seimetz	Lead mechanical engineer
7	Mahesh Yedla	Test assistance
8	Jan Steinhagen	Test assistance
9	Sebastian Boden	Test assistance

4.6 Safety

CAU facility general safety requirements shall apply during all operations [ND-2]. Handling, mounting and testing shall be performed by qualified personnel from CAU.

4.7 Equipment under test

The EPTHET-1 FM and EPTHET-2 PFM are identical units; each consists of two sensor heads and one Ebox. As seen in Fig. 4.2, the EPT and HET share a common Ebox.

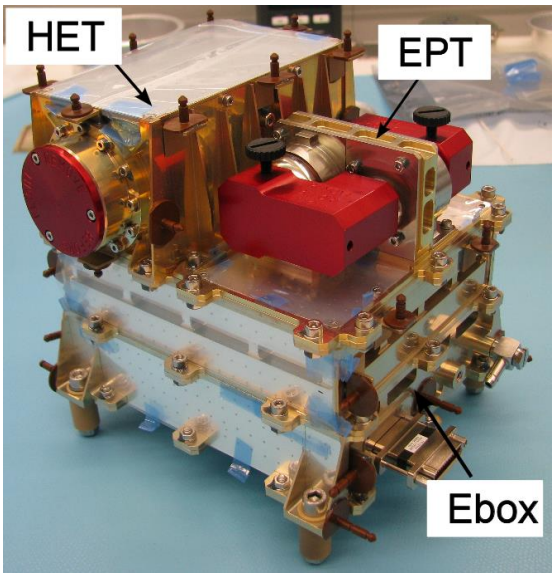


Figure. 4.2. EPTHET PQM is shown above, EPTHET-1 FM and EPTHET-2 PFM are currently under assembly, and detail information about them can be found in [AD-4].

.

5 TEST SET UP

5.1 EPTHET-1 FM or EPTHET-2 PFM inside TVC

Both EPTHET-1 FM and EPTHET-2 PFM are externally mounted, thermally insulated unit with respect to the S/C. In order to achieve the required temperature limits for qualification (EPTHET-2 PFM) and for acceptance (EPTHET-1 FM) critical components which are electronic boards and detectors, the set up shown in Fig.5.1 is used. As seen in Fig.5.1 for the EPTHET1&2 thermal cycling tests no MLI is used and also copper standoffs are used instead of the original ULTEM insulators to increase the unit housing thermal coupling with the TVC baseplate.

5.2 T_ref1: Reference temperature point

The T_ref1 is located on the EPTHET-1 FM and EPTHET-2 PFM URP as seen in Fig.5.1.

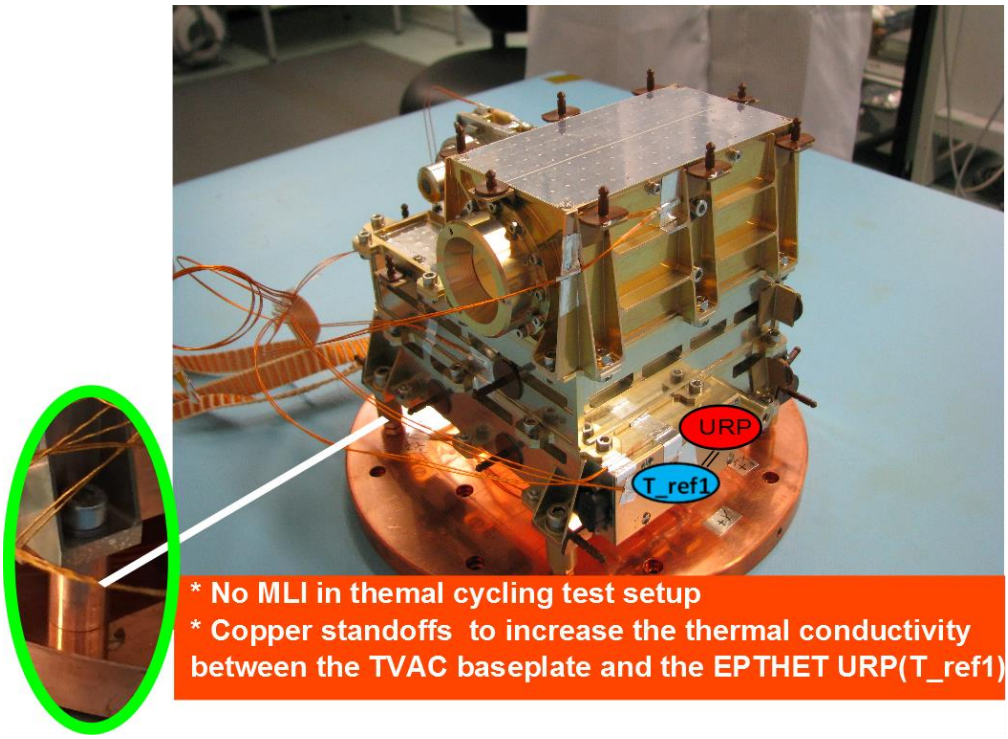


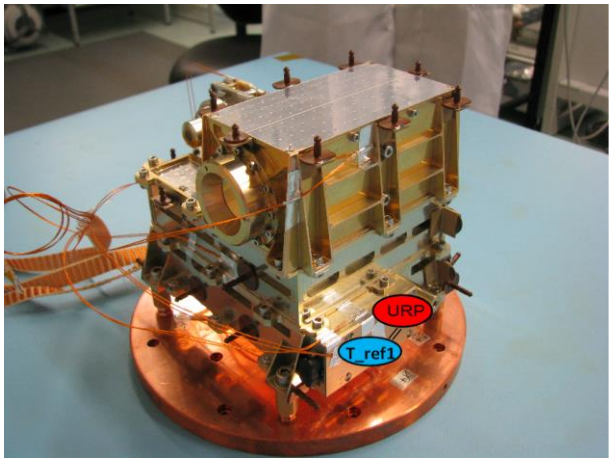
Figure. 5.1. T_ref1 (the same as URP) location on EPTHET PQM, the same location is considered to be used for thermal cycling tests of EPTHET-1 FM and EPTHET-2 PFM.

5.3 Temperature sensors

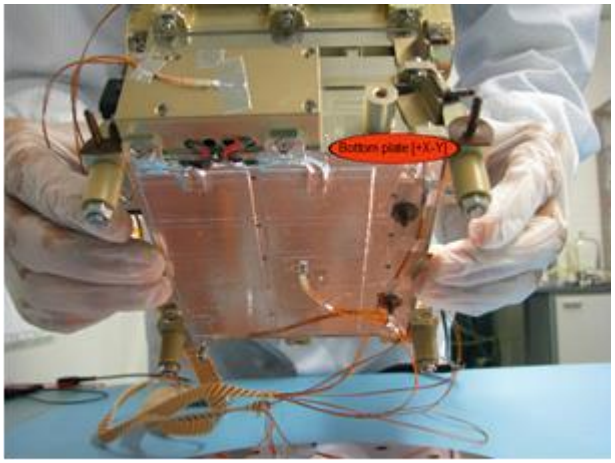
For monitoring the temperature of different parts on EPTHET-1 FM and EPTHET-2 PFM during the test the external temperature sensors are positioned in different locations as indicated in Table 5-1 and Fig. 5.1.

Table 5-1. Temperature sensors allocation for the thermal cycling test of EPTHET-1 FM and EPTHET-2 PFM.

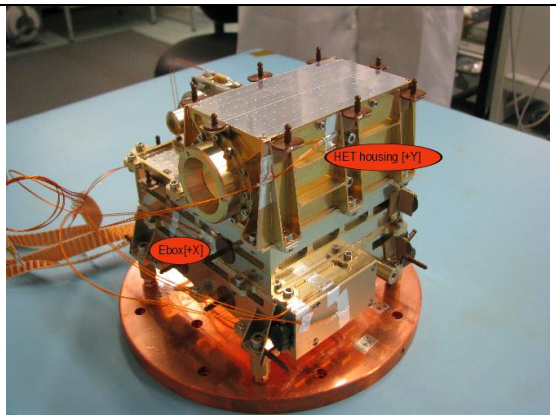
URP: Unit Reference Point		Location	Name of temperature sensor
Thermal Vacuum Chamber (TVC)		TVAC shroud	Shroud
Thermal cycling test Reference point		Fig.5-2 (a)	T_ref1 (EPTHET1&2 URP)
EPTHET-1 FM EPTHET-2 PFM	External	Fig.5-2 (b)	Bottom plate [+X-Y]
		Fig.5-2 (c)	Ebox [+X]
		Fig.5-2 (c)	HET housing [+Y]
		Fig.5-2 (d)	EPT housing top
		Fig.5-2 (d)	Ebox [-Y]
	Internal (MDM25)	Fig.5-2 (f)	Power board
		Fig.5-2 (g)	Digital board
		Fig.5-2 (h)	Analog board
		Fig.5-2 (i)	HET preamp board
		Fig.5-2 (j)	EPT preamp board
		Fig.5-2 (k)	Crystal package
		Fig.5-2 (k)	HET housing [+X]
		Fig.5-2 (l)	EPT baseplate [inner]



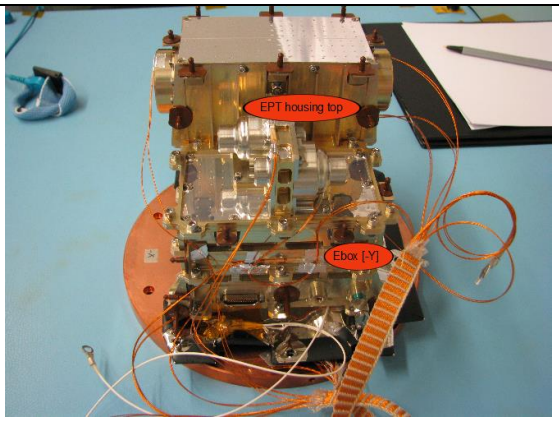
(a)



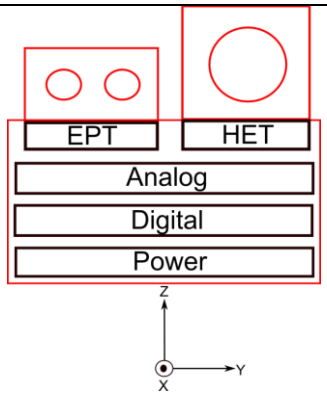
(b)


HET housing [+Y]
Ebox [+X]

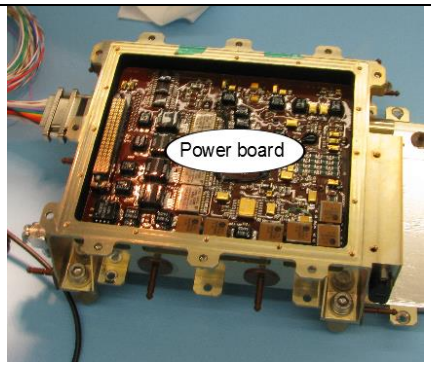
(c)


EPT housing top
Ebox [-Y]

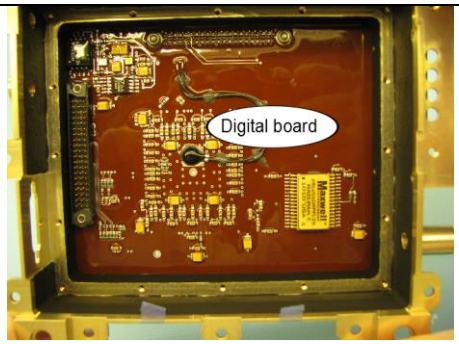
(d)


EPT
HET
Analog
Digital
Power
Z
Y
X

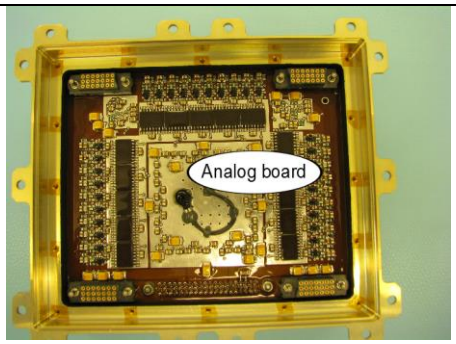
(e)


Power board

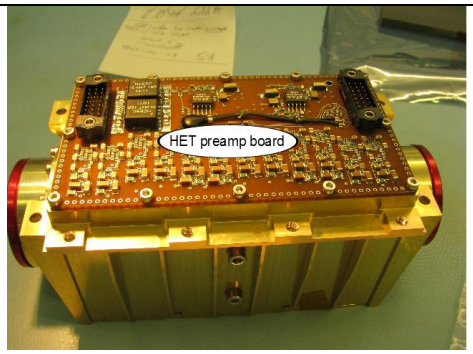
(f)


Digital board

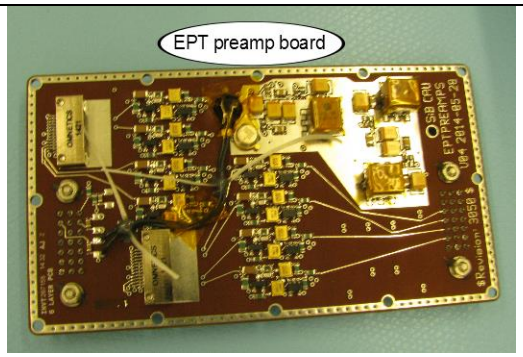
(g)


Analog board

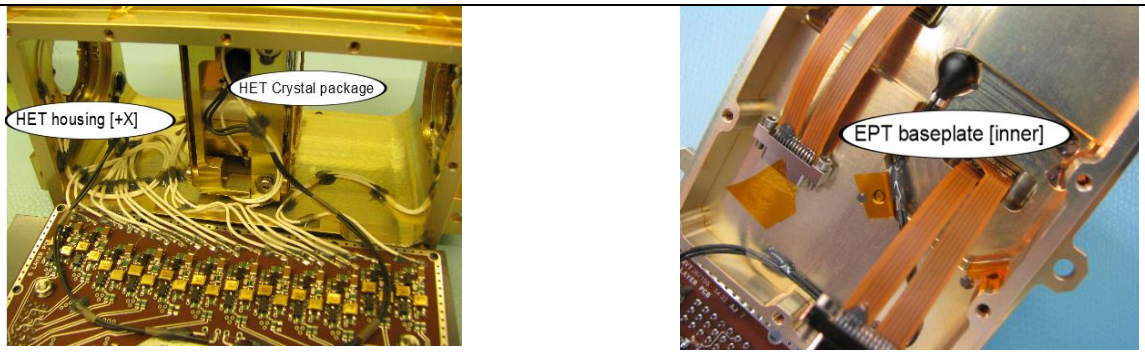
(h)


HET preamp board

(i)


EPT preamp board

(j)



(k) (l)

Fig. 5.2. (a) to (l): Some of the temperature sensors locations on EPT-HET PQM for TBT and they are going to be used as a reference for EPTHET-1 FM and EPTHET-2 PFM thermal cycling test.

5.4 Electrical interface

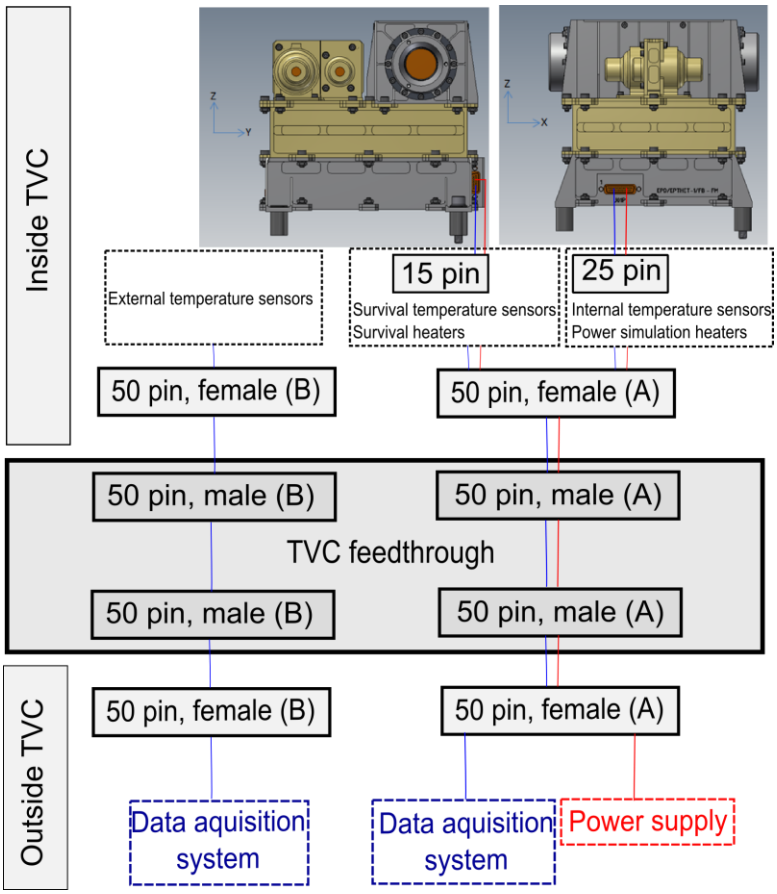


Figure. 5.3. Electrical interface and harness for EPTHET-1 FM and EPTHET-2 PFM in thermal cycling test.

The EPTHET has two connectors. The main MDM25 connector provides the power and data. The MDM15 connector supports the 3 temperature sensors for survival compartment as well as power lines for the nominal and redundant survival heaters. Fig. 5.3 shows the harness diagram inside and outside the TVC.

Inside the TVC:

- Both MDM25 and MDM15 connectors are connected to the 50 pin, female (A) connector and then to the first feedthrough of the TVC which is the 50 pin, male (A) connector.
- The external temperature sensors will be connected to the 50 pin, female (B) connector and then to the second feedthrough of TVC which is the 50 pin, male (B) connector.

Outside the TVC:

- The 50 pin, male (A) connector is connected to another 50 pin, female (A) connector. From this connector appropriate pin outs go to the data acquisition system and power supply respectively.
- The 50 pin, male (B) connector is connected to another 50 pin, female (B) connector. From this connector the pin outs go to the data acquisition system.

In Table 5.2 the calculated power dissipation in EPTHET-1 FM and EPTHET-2 PFM is indicated.

Table 5.2. Heat loads calculated for power dissipation of EPT-HET PQM.

EPT-HET PQM	Heat load (W) nominal operational mode
Total nominal power consumption	5.05
Survival heater (50% duty cycle) During EPTHET PQM TBT, the duty cycle obtained in CNOC test was 49%, see [AD-5]. This is still under evaluation; see [RD-1].	4.50

6 TEST PARAMETERS

6.1 Test requirements

Important notes:

- No thermal cycling test was performed on EPTHET PQM after vibration tests during 18.05-20.05.2015 which was unsuccessful and resulted to HW damage on electronic boards.
- During the "EPD-IQR co-location meeting" at ESTEC on 17.02.2016, due to the fact that EPTHET-1 &2 are identical, EPTHET-2 can comply with PFM approach which means qualification margin for thermal cycling tests. And EPTHET-1 can comply with FM approach which is acceptance margin for the thermal cycling tests.
- No thermal balance test is foreseen for EPTHET-1 FM and EPTHHET-2 PFM.
- The results of correlated TMM after EPTHET PQM TBT will support the TBD test temperatures indicated in Table 6-1 before the test and at the time of TRR [RD-1].

***EIDA R-520*:** The PI shall ensure that the equipment is tested in a thermal vacuum environment having a pressure of 0.0013 Pa (10^{-5} Torr) or less.

***EIDA R-525*:** The PI shall ensure that the test item is a fully thermally representative configuration. In particular the thermal hardware shall be flight representative as far as any critical interface.

***EIDA R-537*:** The PI shall apply the values specified in the table below:

Table 6-1. Test parameters values for thermal vacuum test according to ***EIDA R-537***.

Requirement		Comments
Note that T_ref1 is representative as T_URP. See section 5.	Test temperatures are TBD brfore the test at the time of TRR based on [RD-1]	
Temperature rate of change	dT/dt = 1…5 °C/min	
Dwell time	$t_E \geq 2$ h	
Stabilization criterion	$\Delta T / dt \leq 1°C/h$	
Number of cycles	n = 4 for acceptance	

EIDA R-534: The PI shall apply to the units externally mounted the following:
· equipment bolted to a mounting panel, using the correct bolts, bolt torques and insulation H/W as specified in the MICD.
· Temperature-controlled mounting device able to maintain the URP temperature values.
· Unit baseplate radiatively insulated from the mounting device.

· panel(s) temperature-controlled to a fixed temperature in order to achieve the acceptance / qualification temperature level on the URP temperature
· shroud(s) providing the specified radiative environment (Annex 3) modified by the acceptance/qualification margins.

EIDA R-536: See [AD-1]. This test sequence in this requirement is implemented in the thermal cycling profile indicated in section 7 and can be seen in Fig. 7-1.

6.2 Test tolerances

EIDA R-440: The PI shall respect the following test tolerances, unless otherwise specified.

According to ***EIDA R-440*** the relevant test level tolerances are as below:

Temperature:

- Tmax: 0 to +3°C
- Tmin: 0 to -3°C
- Within the temperature range: -55°C to +150°C

Pressure:

- Equal or above 0.1 mbar 10%
- Below 0.1 mbar 50%

6.3 Test temperatures

For EPTHET there is risk for the unit in case of URP temperature violation in the range of TBD Temperature. The T_ref1 should not violate the temperature profile shown in Fig. 7-1 and Fig 7-2.

6.4 Abortion criteria

In case of temperature violation of PQM URP temperature tolerance TBD Temperature, the test will be aborted in such a way to result the instrument temperatures as fast as possible inside the tolerable temperature margin again. An NCR (Non Conformance Report) will be considered if the test is aborted prior to the successful completion of thermal cycling test.

6.5 Test success criteria

- ✓ No visual damages.
- ✓ Availability of all temperature sensors data.
- ✓ No degradation in the instrument functionality during the repeated cycles.

7 STEP-BY-STEP TEST PROCEDURE

The step-by-step thermal cycling test procedure for EPTHET-1 FM and EPTHET-2 PFM is indicated in the table 7-1 and the test sequence profile is shown in Fig. 7-1 and Fig. 7-2. In Table 7-1, EUT(Equipment Under Test) is referred to either EPTHET-1 FM or EPTHET-2 PFM.

Table 7-1: Step-by-step test procedure for EPTHET-1 FM and EPTHET-2 PFM thermal cycling tests.

Step		Description	Criteria	Date/Time	Sign	Comment
00		Set up the test item • Mounting the temperature sensors. The test set up inside TVAC is such to achieve the required thermal plateaus in a reasonable time (will be documented in the test report). • Torque value of 3.5 N.m can be used for the interface screws to the copper plate. • Grounding strap should be connected for the proper bonding. • Red tag covers should be removed after the EUT is inside the chamber.				
05		Check test set up ✓ Electrical interface (grounding, bonding, isolation) ✓ Harness inside TVC ✓ Check connectivity after closing the TVC ✓ Check the EGSE required communications to be monitored during the test.				
10		Start test See: Fig. 7-1. EPTHET-2 PFM thermal cycling test profile See: Fig. 7-2. EPTHET-1 FM thermal cycling test profile				
15		• Pump down the TVC • Perform an initial functional test. • Start to monitor the temperatures • Start to monitor the Rest Gas Analyzer (RGA)	$P \leq 10^{-5}$ Torr			
Cycle 1	1A→1B	**Cycle 1: Start** Start the hot survival • Switch OFF EUT • Set T_ref1 (Huber)= TBD deg • Shroud heaters ON (max. 2.5A)	T_ref1 = TBD °C $P \leq 10^{-5}$ Torr			

Step		Description	Criteria	Date/Time	Sign	Comment
	1B→1C	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
	1C→1D	Start the Cold survival • Set T_ref1 (Huber)= TBD deg • Open shroud LN2 line (T_{shroud} < -150°C) • Make sure that the temperature controlled switch connected to EUT survival heaters is ON. It should be set in such a way that in case T_URP is colder than TBD deg it is ON which allows survival heaters to heat up the EUT telescopes.				
	1D→1E	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
	1E→1F	• Set T_ref1 (Huber)= TBD deg • Shroud remains LN2 • Switch ON EUT when T_ref1= TBD deg • Right after switching ON EUT set T_ref1= TBD deg				
	1F→2A	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
Cycle 2	2A	**Cycle 2: Start** • Switch OFF EUT • Set T_ref1(Huber) = TBD deg • Close shroud LN2 line • Shroud heaters ON (max. 2.5A)				
	2B	• Switch ON EUT when T_ref1= TBD deg • From this step the EUT remains switched ON till step 8C continuously. See Fig. 7-2.				
	2B→2C	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
	2C	• Short functional test • Set T_ref1= TBD deg • Open shroud LN2 line (T_{shroud} < -150°C)				
	2D→3A	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
C yc	3A	**Cycle 3: Start**				

Step		Description	Criteria	Date/Time	Sign	Comment
		• Short functional test • Set T_ref1= TBD deg • Close shroud LN2 line • Shroud heaters ON (max. 2.5A)				
	3B→3C	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
	3C	• Short functional test • Set T_ref1= TBD deg • Open shroud LN2 line (T_{shroud} < -150°C)				
	3D→4A	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
Cycle 4	4A	**Cycle 4: Start** • Short functional test • Set T_ref1(Huber)= TBD deg • Close shroud LN2 line • Shroud heaters ON (max. 2.5A)				
	4B→4C	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
	4C	• Short functional test • Set T_ref1(Huber)= TBD deg • Open shroud LN2 line (T_{shroud} < -150°C)				
	4D→5A	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
Cycle 5	5A	**Cycle 8: Start** • Short functional test • Set T_ref1(Huber)= TBD deg • Close shroud LN2 line • Shroud heaters ON (max. 2.5A)				
	5B→5C	• Dwell time	T_{Dwell} ≥ 2 hours ΔT/dt ≤ 1 °C/hour			
	5C & 5C→5D	• Short functional test • Set T_ref1(Huber)= TBD deg • Open shroud LN2 line (T_{shroud} < -150°C) • Switch OFF EUT • Switch ON EUT when set T_ref1(Huber)= TBD deg • Short functional test				

Step		Description	Criteria	Date/Time	Sign	Comment
	5D→6A	• Dwell time	T_{Dwell} ≥ 2 hours $\Delta T/dt$ ≤ 1 °C/hour			
Cycle 6 (Ending)	6A	• Switch OFF EUT • Set T_ref1(Huber)= TBD deg • Close shroud LN2 line • Shroud heaters ON (max. 2.5A)				
	6B	• Switch ON EUT when T_ref1(Huber)= TBD deg • Short functional test				
	6B→6C	• Set T_ref1(Huber)= +25 deg				
	6	• Full functional test	$T_{Ref} = T_{ambient}$ +5°C			
	20	Open TVC and visual inspection (take photos)				
	25	Dismount EUT and test set up				
	30	Check the instrument on clean bench				

Fig. 7-1. EPTHET-2 PFM thermal cycling test profile.

NOTE:
T_ref1 is the temperature control reference on the EPTHET-2 PFM URP with ± 10°C Acceptance margin.
T_ref1 is TBD at the time of TRR and before the test.

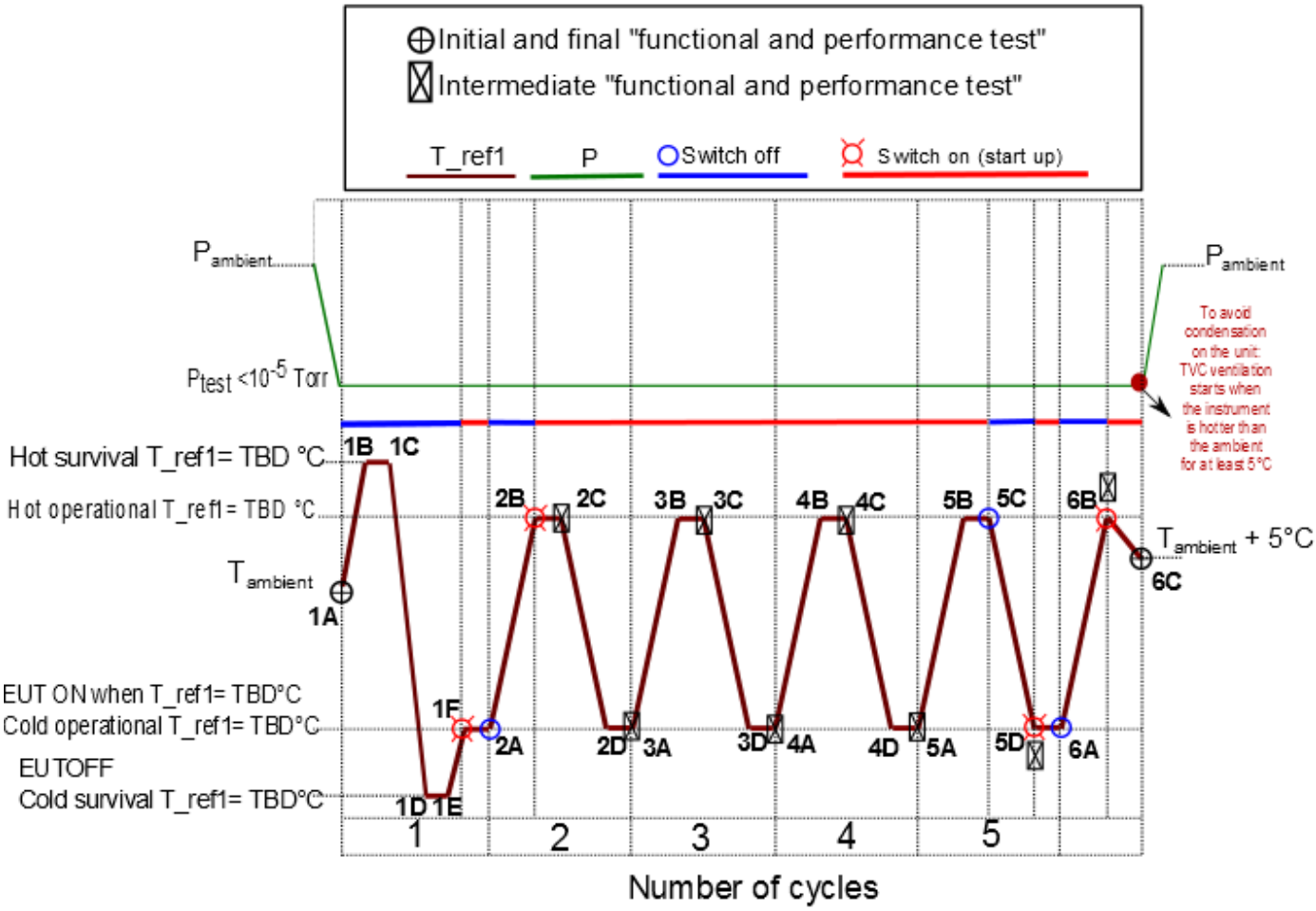
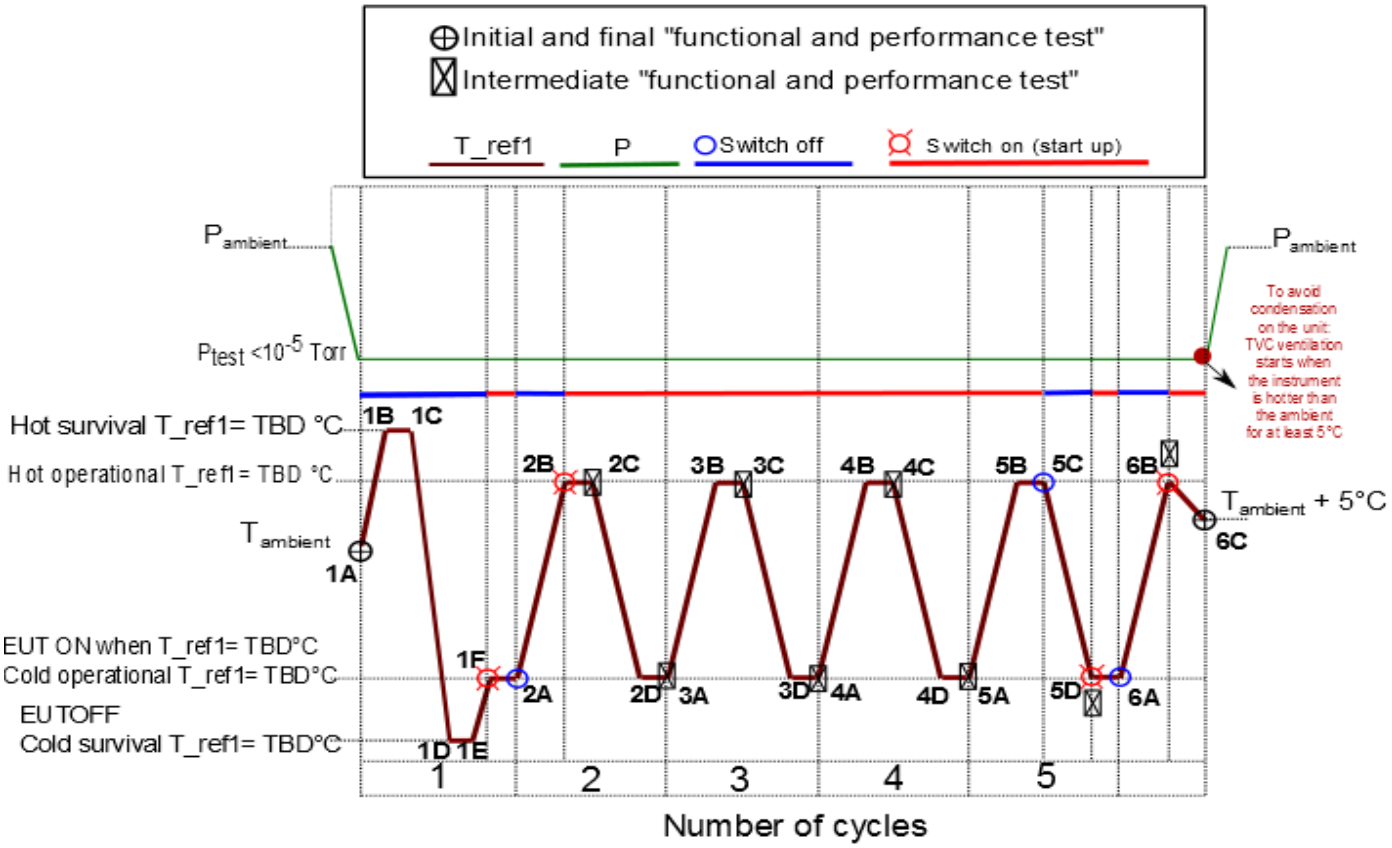


Fig. 7-2. EPTHET-1 FM thermal cycling test profile.

NOTE:

T_ref1 is the temperature control reference on the EPTHET-1 FM URP with ± 5°C Acceptance margin.
T_ref1 is TBD at the time of TRR and before the test.



8 GSE

The complete list of GSE items to be used during the test is indicated in Table 8-1.

Table 8-1: GSE items.

#	Item	Manufacturer	Serial Number	Calibration status
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

9 SPECIAL REMARKS

9.1 Anomalies

Anomalies will be reported in the final approved as-run test procedure as part of the test documentation.

Table 9-1-1: List of anomalies.

#	Anomalous	Comment
1		
2		
3		
4		
5		

9.2 Test deviations

Test deviations will be reported in the final approved as-run test procedure as part of the test documentation.

Table 9-2-1: List of test deviations.

#	Test deviation	Comment
1		
2		
3		
4		
5		