SOLAR ORBITER ENERGETIC PARTICLE DETECTOR

STEP FM
Thermal Cycling Test Plan and Procedure

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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 STEP FM to verify the functionality and the performance of STEP in the hot and cold conditions applying the acceptance margin.

1.2 Scope

This document applies to all activities related to the STEP FM thermal cycling test campaign performed by all institutions and personnel involved in the test.

Important notes:

Thermal cycling test has been performed successfully on STEP PQM at qualification level [AD-5] based on TMM with EIDAi4.

According to [RD-1] which is the correlated TMM results based on EIDAi5, the temperatures to be tested are colder. This is due to the fact that the environmental conditions defined in EIDAi5 in general impose a colder condition to STEP. Due to this fact, the test temperatures indicated in Table 6-1 of this document are TBC at the time of TRR in order to avoid overstressing the STEP FM.

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
$P_{ambient}$	Ambient pressure
PA	Product Assurance
PQM	Proto-Qualification Model
P_{test}	TVC test pressure ≤ 10^{-5} Torr
QA	Quality Assurance
S/C	Spacecraft
STEP	SupraThermal Electrons and Protons
TBC	To Be Confirmed
$T_{ambient}$	Ambient temperature
TMM	Thermal Mathematical Model
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	STEP FM Functional test plan and procedure	SO-EPD-KIE-TP-0043	1/0	01/02/2016
AD-4	CIDL-ABCL for STEP FM	SO-EPD-KIE-LI-0012	1/0	29/02/2016
AD-5	STEP PQM Thermal Cycling Test Report	SO-EPD-KIE-TR-0022	1/0	03/12/2015
AD-6	STEP PQM Thermal Balance Test Report	SO-EPD-KIE-TR-0021	1/0	03/12/2015

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	STEP PQM TBT correlated temperatures for STEP FM TVT	SO-EPD-IDR-TN-TH-0005	1/0	26/02/2016

4 TEST OVERVIEW

4.1 Test objectives

The objectives of the STEP FM thermal cycling test 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.

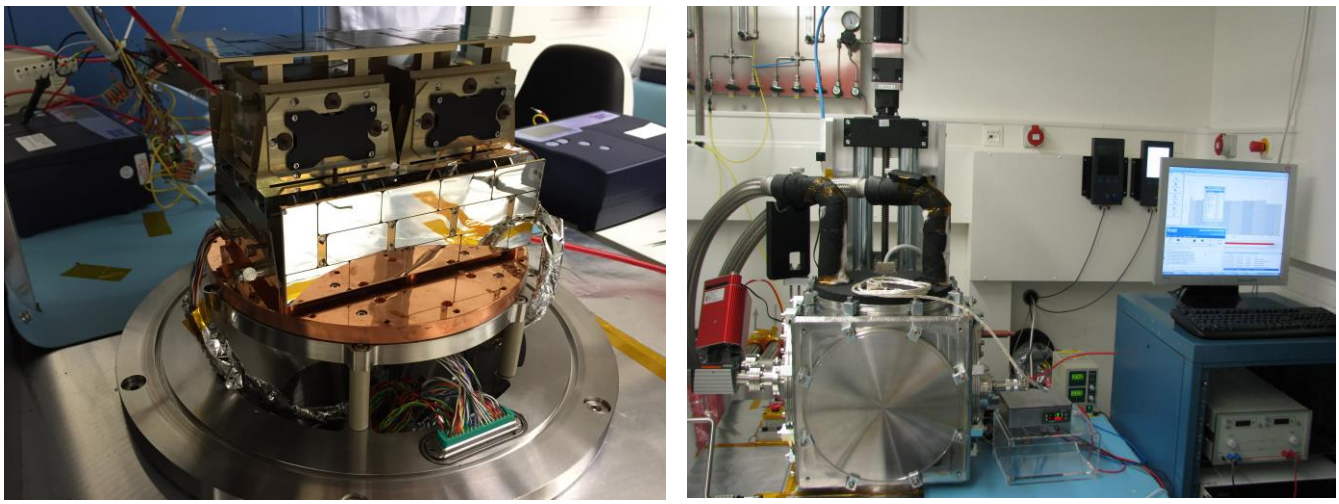

Fig. 4.1. CAU thermal vacuum chamber, STEP PQM is shown on the left in STEP PQM thermal cycling test campaign performed during 12.10-22.10.2015.

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	Engineering lead
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

As can be seen in figure 4.2 STEP consist of two collimator telescopes, Proton Telescope (PT) and Integral Telescope (IT) facing in the same direction and one Ebox. A passive thermal control concept is considered for STEP unit.

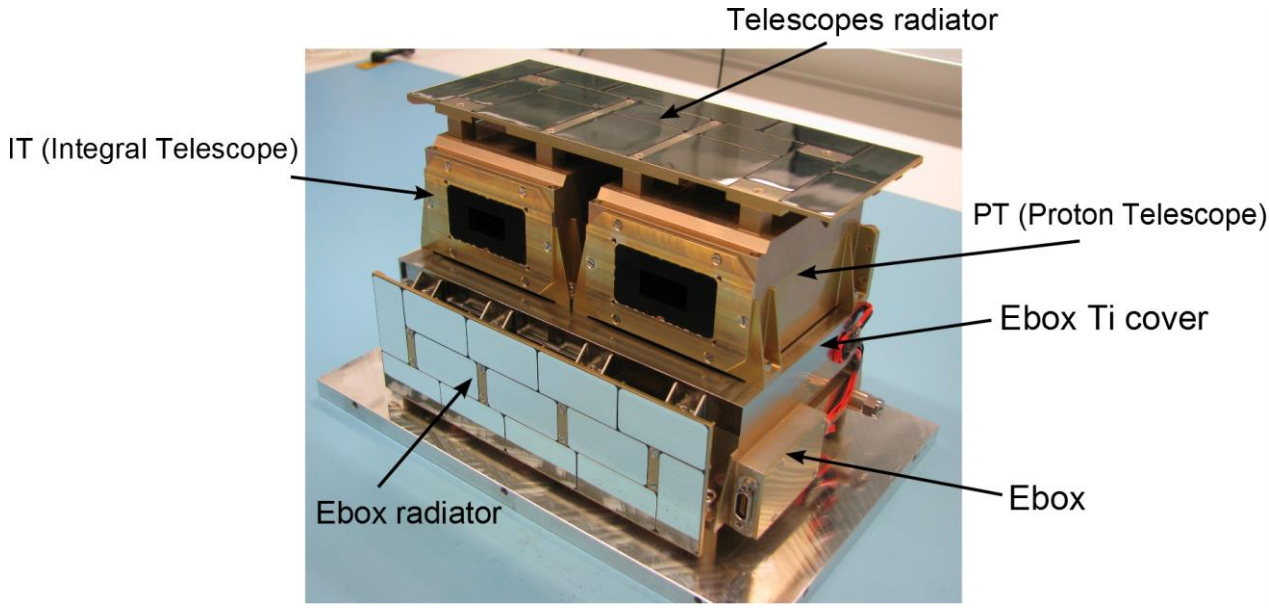

Figure. 4.2. STEP PQM is shown above, STEP FM is currently under assembly, and detail information about STEP FM can be found in [AD-4].

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5 TEST SET UP

5.1 STEP inside TVC

STEP is an externally mounted, thermally insulated unit with respect to the S/C. In order to achieve the required temperature limits for acceptance of STEP critical components which are electronic boards and detectors carriers, the set up shown in Fig.5.1 is used. As seen in Fig.5.1 for the STEP thermal cycling test no MLI is used and also copper standoffs are used instead of STEP original ULTEM insulators to increase the STEP housing thermal coupling with the TVC baseplate.

5.2 T_ref1: Reference temperature point

The T_ref1 is located on the STEP Ebox below IT (Integral Telescope) as seen in Fig.5.1.

Note: to avoid over stressing the telescope detectors just in case for the cold cases, the instrument survival heaters were considered as test heaters to be switched on when T_URP is colder than -82°C. This is not foreseen to happen during the test and can be considered as a safety measure.

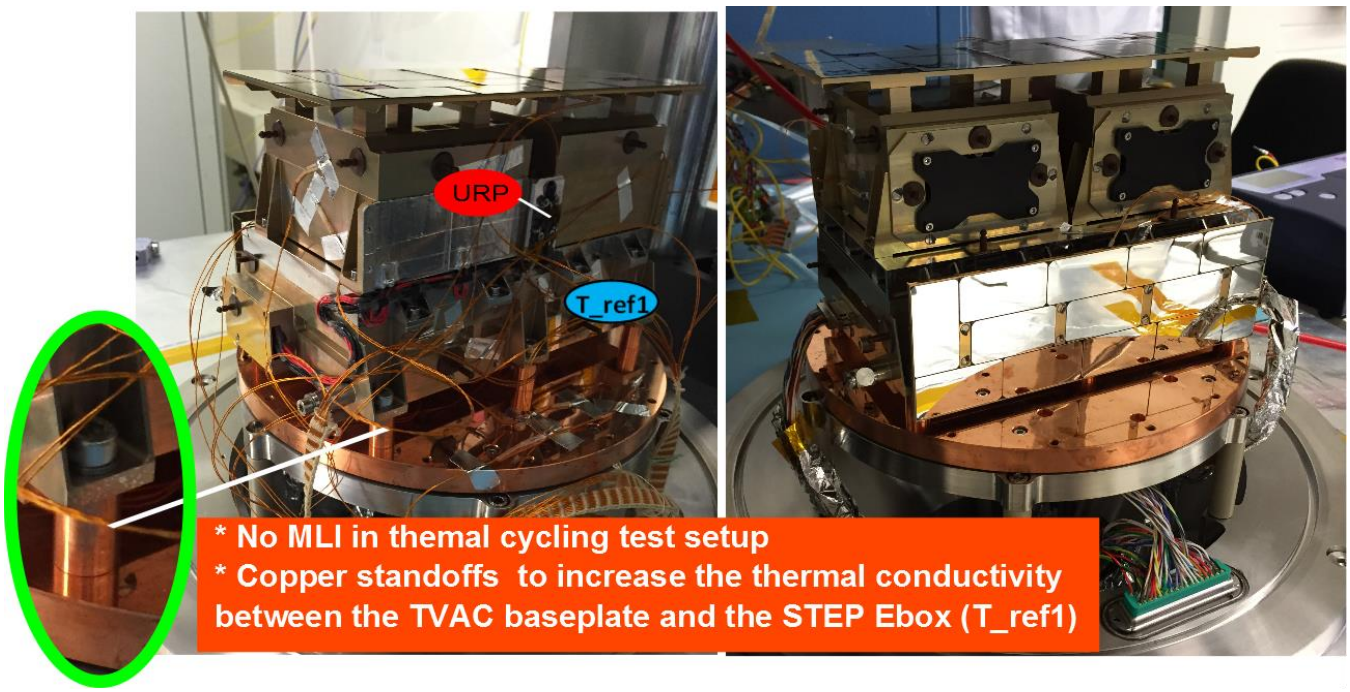


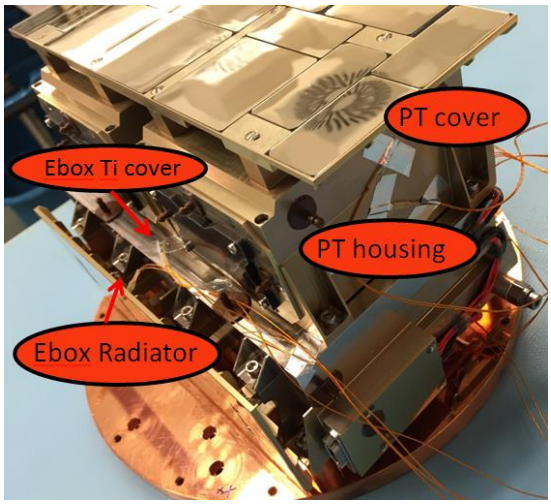
Figure. 5.1. T_ref1 and URP location on STEP PQM for thermal cycling test, the same set up is applicable for STEP FM.

5.3 Temperature sensors

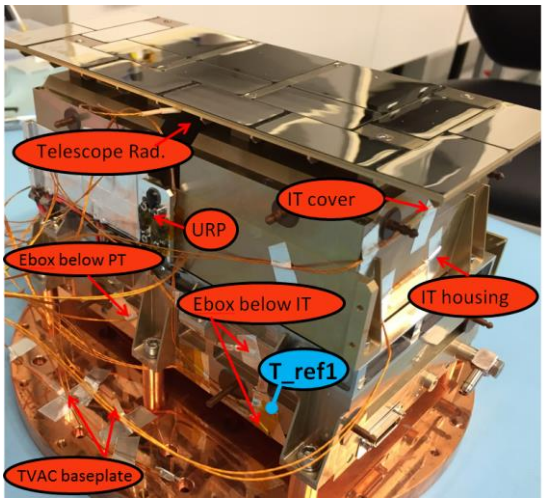
For monitoring the temperature of different parts on STEP FM during the test the external temperature sensors are positioned in different locations as indicated in Table 5-1 and Fig. 5.1.

Table 5-1. Temperature sensors allocation for the thermal of STEP PQM, the same is applicable for STEP FM.

URP: Unit Reference Point		Location	Name of temperature sensor
Thermal Vacuum Chamber		TVAC shroud	Shroud
Thermal cycling test Reference point		Fig.5-1(b)	T_ref1 (STEP Ebox below IT)
STEP FM	**External**	Fig.5-1(b)	TVAC baseplate
		Fig.5-1(b)	Bottom plate
		Fig.5-1(a)	PT housing
		Fig.5-1(b)	Ebox below PT
		Fig.5-1(b)	IT housing
		Fig.5-1(b)	Ebox below IT
		Fig.5-1(a)	PT cover
		Fig.5-1(b)	IT cover
		Fig.5-1(b)	URP
		Fig.5-1(b)	Telescopes Radiator
		Fig.5-1(a)	Ebox Radiator
		Fig.5-1(a)	Ebox Ti cover
	Internal (MDM25)	Fig.5-1(c), (d)	Analog board
		Fig.5-1(d)	Ebox Ti cover inner side NTC1, NTC2, NTC3
		Fig.5-1(c), (e)	Digital board
		Fig.5-1(c), (f)	Power board
		Fig.5-1(g)	IT detector carrier
		Fig.5-1(g)	PT detector carrier



(a)



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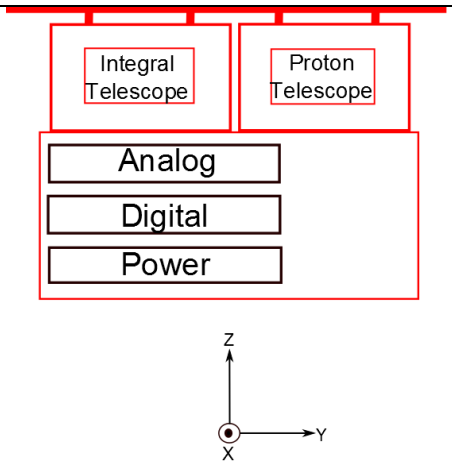

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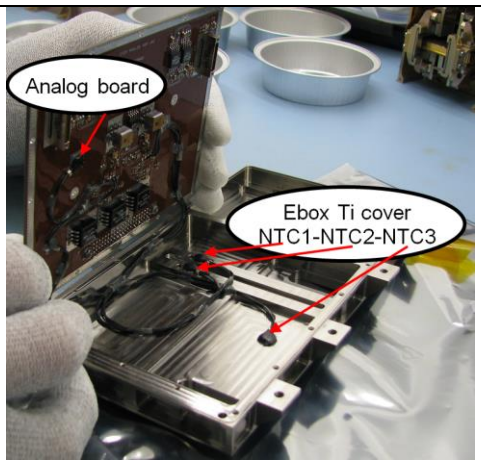

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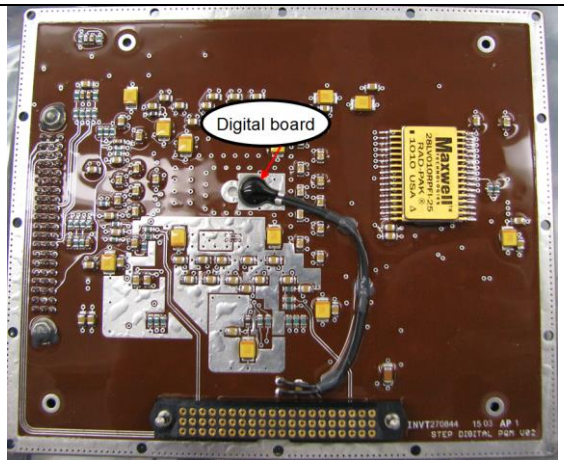
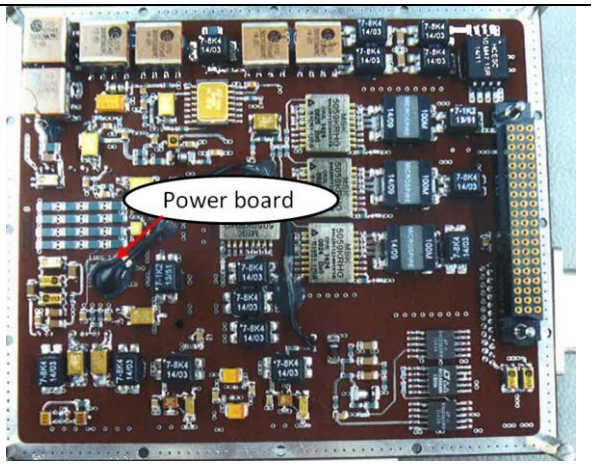


(e)



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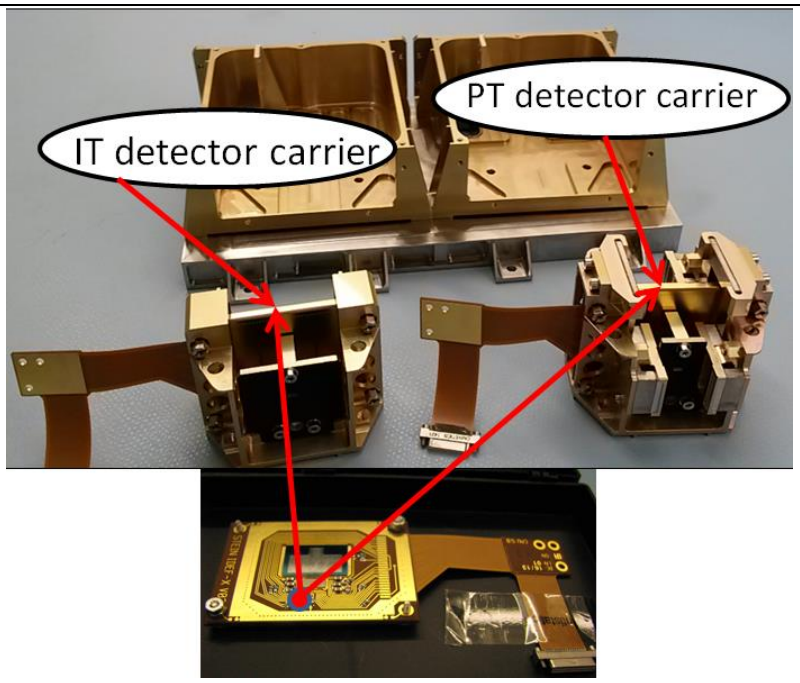


(g)

Fig. 5.1. (a) to (g): Temperature sensors location on STEP PQM, the same is applicable for STEP FM.

5.4 Electrical interface

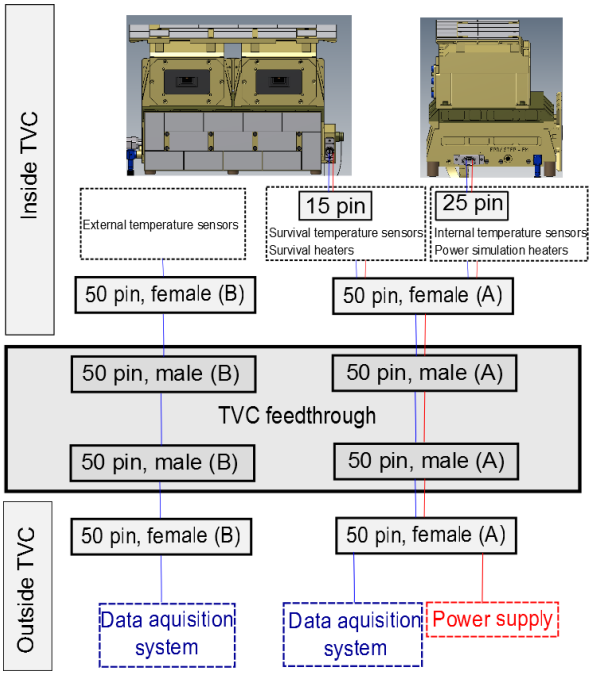


Figure. 5.3. Electrical interface and harness for STEP PQM thermal cycling test, the same is applicable for STEP FM.

The STEP PFM 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 STEP FM is indicated.

Table 5.2. Heat loads calculated for power dissipation of STEP FM.

STEP FM	Heat load (W) nominal operational mode
Total nominal power consumption	3
Operational heaters for Cold Operational Case	2
Survival heater (50% duty cycle) During STEP PQM TBT, the duty cycle obtained in CNOC test was 65%, see [AD-6], This is still under evaluation; see [RD-1].	6

6 TEST PARAMETERS

6.1 Test requirements

Important notes:

Thermal cycling test has been performed successfully on STEP PQM at qualification level [AD-5] based on TMM with EIDAi4.

According to [RD-1] which is the correlated TMM results based on EIDAi5, the temperatures to be tested are colder. This is due to the fact that the environmental conditions defined in EIDAi5 in general impose a colder condition to STEP. Due to this fact, the test temperatures indicated in Table 6-1 of this document are TBC at the time of TRR in order to avoid overstressing the STEP FM.

***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
T_ref1 which is the controlled temperature reference point on the EUT Ebox below IT. Note that T_ref1 is not T_URP. See section 5.	According to [RD-1] the predicted temperatures from correlated TMM for the electronic boards and the detector carriers in different thermal cases are as below (the temperature from [RD-1] are rounded): HOC: STEP URP= -12 °C STEP Ebox structure = +5 °C STEP boards(max)= +10 °C STEP detector carriers(max)= -4 °C COC: STEP URP= -58 °C STEP Ebox structure = -54 °C STEP boards(min)= -44 °C STEP detector carriers(max)= -56 °C HNOC: STEP URP= +60 °C STEP Ebox structure = +66 °C	

	STEP boards(max)= +65 °C STEP detector carriers(max)= +59 °C CNOC: STEP URP= -61 °C STEP Ebox structure = -62 °C STEP boards(max)= -61 °C STEP detector carriers(max)= -65 °C To achieve the above temperatures with ±5 °C acceptance margin, the controlled T_ref1, i.e., "STEP Ebox structure", for the test is selected as below: TBC at TRR and before test HOC= +10 °C COC= -59 °C HNOC= +71 °C CNOC= -65 °C	
Temperature rate of change	dT/dt = 1…5 °C/min	
Dwell time	$t_E \geq 2$ h	
Stabilization criterion	ΔT/ dt ≤ 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 STEP FM there is risk for the unit in case of URP temperature violation in the range of -70°C to +70 °C. The T_ref1 should not violate the temperature profile shown in Fig. 7-1.

6.4 Abortion criteria

In case of temperature violation of FM URP temperature tolerance [-70°C, +70°C], 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 STEP FM is indicated in the table 7-1 and the test sequence profile is shown in Fig. 7-1.

Table 7-1: Step-by-step test procedure for STEP FM thermal cycling test.

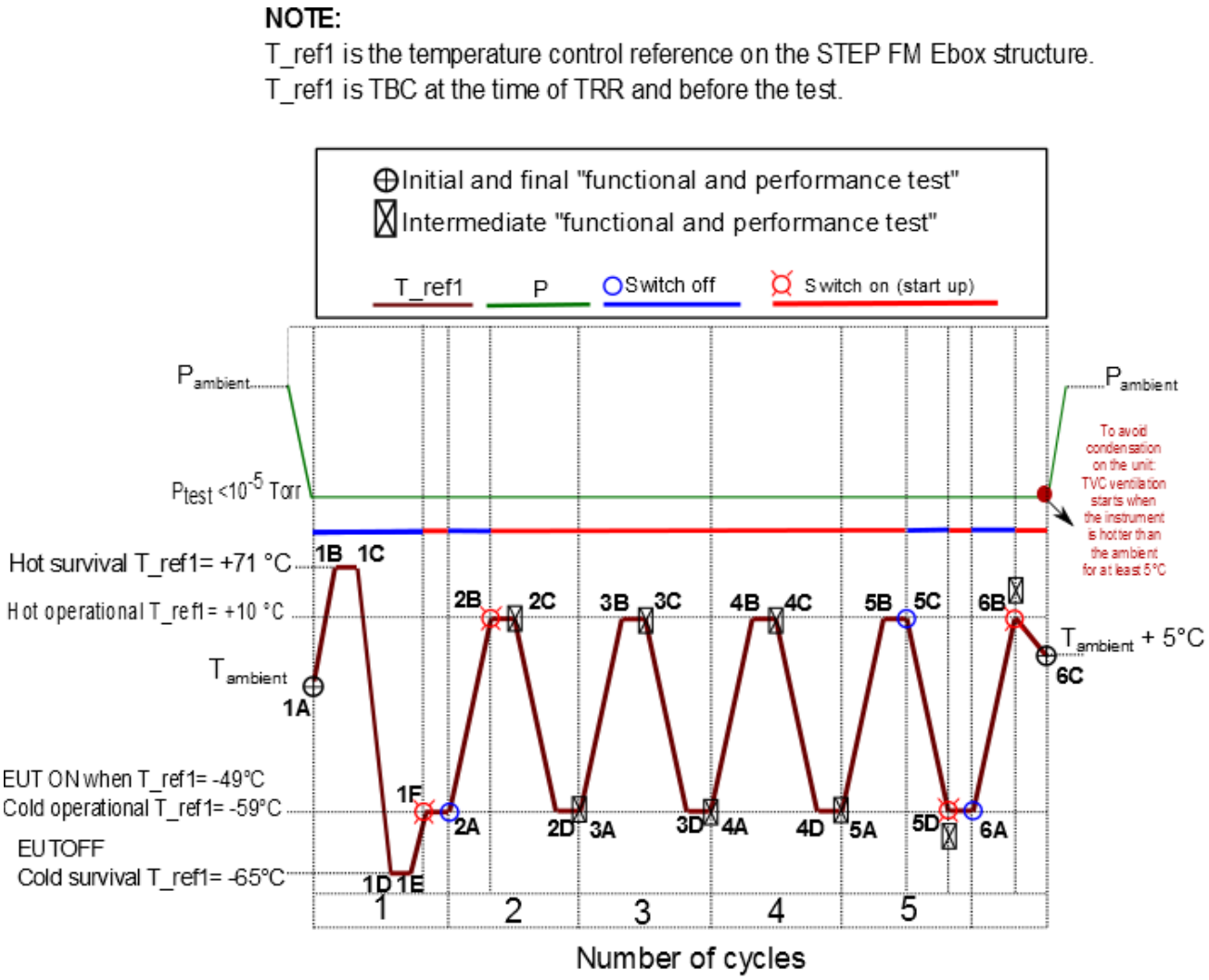
Step		Description	Criteria	Date/Time	Sign	Comment
00		Set up the test item • Mounting the temperature sensors. The test set up inside TVAC is such to achieve the required thermal plateaus in a reasonable time (will be documented in the test report). • Torque value of 3.5 N.m can be used for the interface 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. STEP 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 STEP FM • Set T_ref1 (Huber)= +71 deg TBC • Shroud heaters ON (max. 2.5A)	T_ref1 = 71 °C TBC $P \leq 10^{-5}$ Torr			
	1B→1C	• Dwell time	$T_{Dwell} \geq 2$ hours $\Delta T/dt \leq 1$ °C/hour			

Step		Description	Criteria	Date/Time	Sign	Comment
	1C→1D	Start the Cold survival • Set T_ref1 (Huber)= -65 deg TBC • Open shroud LN2 line (T_{shroud} < -150°C) • Make sure that the temperature controlled switch connected to STEP survival heaters is ON. It should be set in such a way that in case T_URP is colder than -82deg it is ON which allows survival heaters to heat up the STEP telescopes.				
	1D→1E	• Dwell time	T_{Dwell} ≥ 2 hours $\Delta T/dt \leq 1$ °C/hour			
	1E→1F	• Set T_ref1 (Huber)= -49 deg • Shroud remains LN2 • Switch ON STEP FM when T_ref1= -49 deg TBC • Right after switching ON STEP FM set T_ref1= -59 deg TBC				
	1F→2A	• Dwell time	T_{Dwell} ≥ 2 hours $\Delta T/dt \leq 1$ °C/hour			
Cycle 2	2A	**Cycle 2: Start** • Switch OFF STEP FM • Set T_ref1(Huber) = +10 deg TBC • Close shroud LN2 line • Shroud heaters ON (max. 2.5A)				
	2B	• Switch ON STEP FM when T_ref1= +10 deg TBC • From this step the STEP FM remains switched ON till step 8C continuously. See Fig. 7-1.				
	2B→2C	• Dwell time	T_{Dwell} ≥ 2 hours $\Delta T/dt \leq 1$ °C/hour			
	2C	• Short functional test • Set T_ref1= -59 deg TBC • Open shroud LN2 line (T_{shroud} < -150°C)				
	2D→3A	• Dwell time	T_{Dwell} ≥ 2 hours $\Delta T/dt \leq 1$ °C/hour			
Cycle 3	3A	**Cycle 3: Start** • Short functional test				

Step		Description	Criteria	Date/Time	Sign	Comment
		• Set T_ref1= +10 deg TBC • 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= -59 deg TBC • 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)= +10 deg TBC • 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)= -59 deg TBC • 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)= +10 deg TBC • 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)= -59 deg TBC • Open shroud LN2 line (T_{shroud} < -150°C) • Switch OFF STEP FM • Switch ON STEP FM when set T_ref1(Huber)= -49 deg TBC • 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 STEP FM • Set T_ref1(Huber)= +10 deg TBC • Close shroud LN2 line • Shroud heaters ON (max. 2.5A)				
	6B	• Switch ON STEP FM when T_ref1(Huber)= +10 deg TBC • Short functional test				
	6B→6C	• Set T_ref1(Huber)= +25 deg				
	6	• Full functional test	T_ref1 = $T_{ambient}$ +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. STEP FM thermal cycling test profile.



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		