SEPT Thermal Vacuum Test Report
Preliminary

V1.0

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Table of contents

1 Objectives

The purpose of this document is to give a preliminary analysis of the results of the SEPT thermal vacuum tests which were carried out at ESA/ESTEC from March 4 to 17, 2004. An official report (RD1) will be issued later by the facility.

2 Applicable Documents

AD1 SEPT Thermal Vacuum Test Plan, STEREO-ETKI-006, 24-FEB-2004
AD2 SEPT Comprehensive Performance Test, STEREO-ETKI-009, January 2004
AD3 STEREO Environment Definition, Observatory, Component and Instrument Test Requirements Document, Doc. No. 7381-9003
AD4 STEREO Contamination Control Plan, Doc. No. 7381-9006
AD5 IMPACT Environmental Test Plan, Version D 2003-Dec-30
AD6 IMPACT Contamination Control Plan, Version A 2003-May-14

3 Reference documents

RD1 SEPT TV Test Facility Data Report, to be released
RD2 SEPT FM1 Test Readiness Review,
Doc. No. TOS-MCV/2004/2963/ln/BL, 2004-March-5
RD3 SEPT FM1 Post Test Review and SEPT FM2 Test Readiness Review,
Doc. No. TOS-MCV/2004/2964/ln/BL, 2004-March-11
RD4 SEPT FM2 Post Test Review
Doc. No. TOS-MCV/2004/2965/ln/BL, 2004-March-17

4 Acronyms and Abbreviations

EGSE	Electrical Ground Support Equipment
FPGA	Field Programmable Gate Array
LIVAF	Little Vacuum Facility, ESTEC Test Centre
PDFE	Particle Detector Front End
PIPS	Passivated Ion-implanted Planar Silicon detector
SEPT-E	Solar Electron and Proton Telescope – Ecliptic
SEPT-NS	Solar Electron and Proton Telescope – North/South
SSD	Solid State Detector
TC	Thermocouple
TRR	Test Readiness Review

5 Overview

5.1 Set-up

The TV chamber is located at ESA/ESTEC (Netherlands) and is shown in Fig. 1:

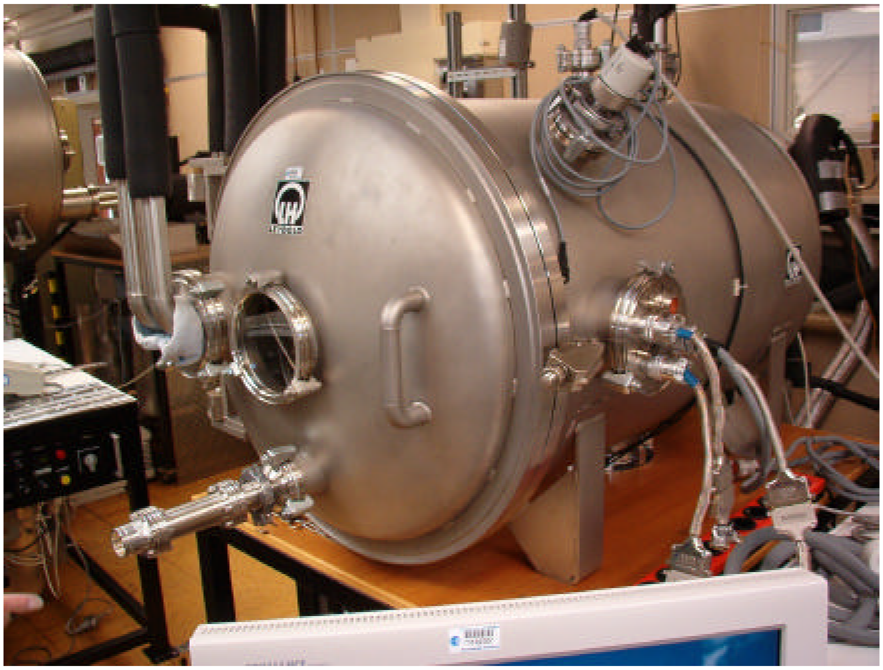

Figure 1: Little Vacuum Facility (LIVAF)

The test setup is carried out according to the test plan (see AD1): two FM1 units (SEPT-E and SEPT-NS) are mounted side by side on a thermal plate (see Figures 2 and 3). The FM2 units are tested in a separate run. The units are bagged while being transferred from the clean bench to the TV chamber (see Figure 4).

The Ultem bushings below the lugs are replaced by aluminium washers (1 mm thick) to provide good thermal contact to the cold plate and sufficient clearance for the reference point thermocouple on the bottom plate of the E-Box. The Ultem bushings above the lugs are retained. SEPT-NS is mounted without brackets.

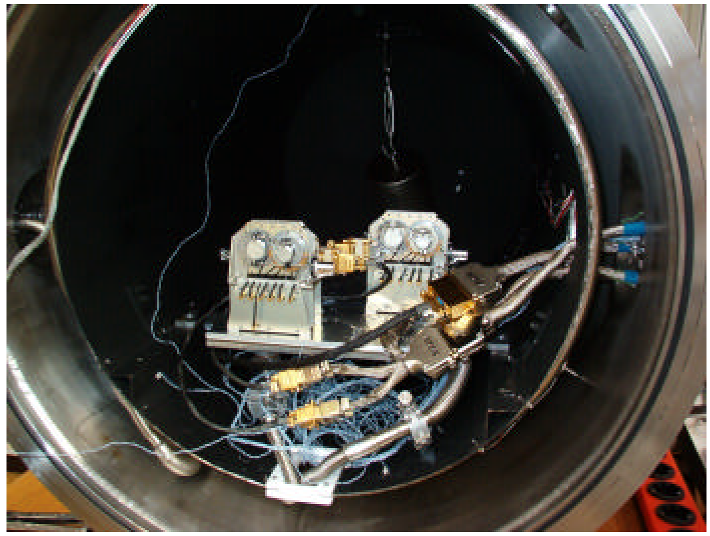

Figure 2: Configuration of the FM1 units (left: SEPT-NS rear view, right: SEPT-E front view)

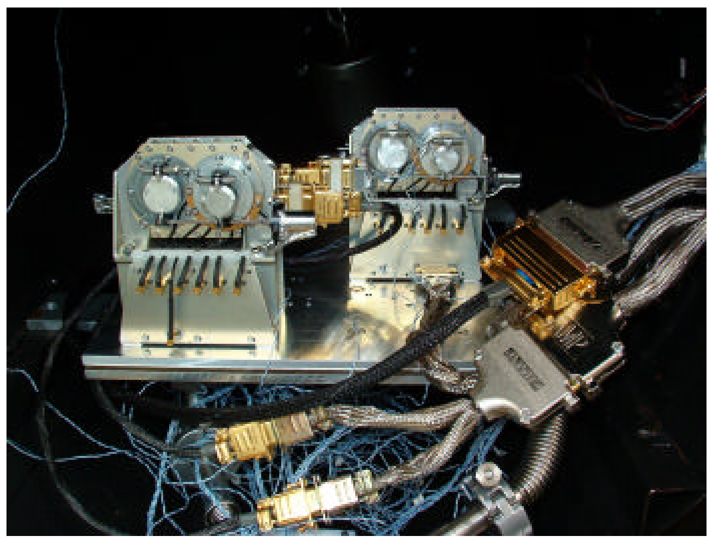

Figure 3: Note locations of the SEPT-E sensor thermocouple TC1 outside the detector housing and the cold plate thermocouple TC6 between SEPT-E and -NS.

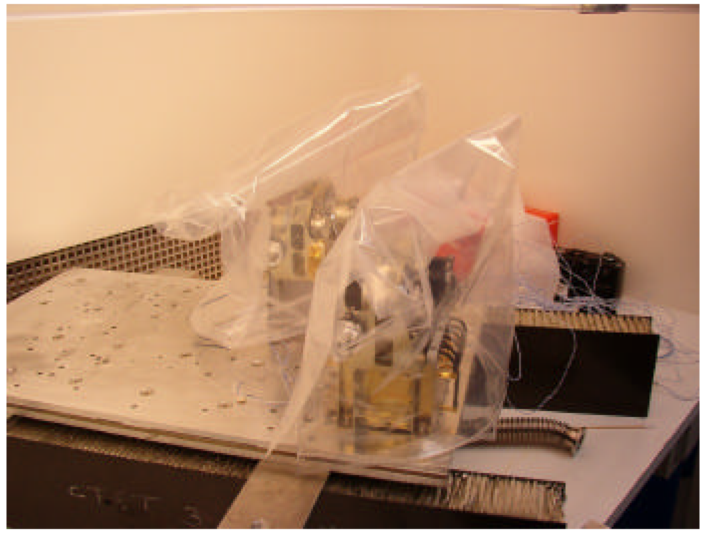

Figure 4: FM1 on cold plate with protection bag during transfer

5.2 Thermocouples

The test facility provided 8 thermocouples:

TC No.	Task	Location
1	Critical temperature	SEPT-E sensor, front side, close to detector housing
2	Reference temperature	SEPT-E Ebox, bottom surface, close to mounting lug
3	Critical temperature	SEPT-NS sensor, front side, close to detector housing
4	Reference temperature	SEPT-NS Ebox, bottom surface, close to mounting lug
6	Control temperature	Cold plate (averaged with TC 7)
7	Control temperature	Cold plate (averaged with TC 6)
8	Shroud	LIVAF chamber shroud door
9	Shroud	LIVAF chamber shroud cylinder

5.3 Test sequence

The test sequence is carried out according to the test plan (see AD1), however, with some deviations as described below. These deviations are made in response to several non-conformances/failures which occurred during the thermal cycling. No failures are observed during Pre- and Post-TV CPTs.

5.3.1 FM1

Activities prior to TV Test	
2004-03-02	Remove covers, lubricate with MoS_2, clean clevis, install new hinge-bolts (diameter 2.95 ±0.01)
2004-03-03	Measure clevis gap, mount covers, clean FM1 for TV test (400 W black light, cotton buds, IPA), clean EM for TV harness test, take photos of sliding surfaces
2004-03-04	Install EM into LIVAF, check TV harness (power/data and actuator), remove EM, install FM1 into LIVAF, check 2 E pinpullers, check 2 NS pinpullers, perform E CPT, perform NS CPT, check thermistor readings, check thermocouple readings, hold TRR, close chamber, start pump down

Cycle 1 (Survival)	
2004-03-05	Pressure < 3 x 10^{-6} mbar, switch on FM1 at ambient, SEPT counting rates show occasional noise bursts which can be correlated with pumping/cold trap cycles.
08:50	Start hot ramp (Step 5)
09:34	Switch off FM1, ready for survival hot soak
11:30	End of survival hot soak, switch on FM1, perform E CPT, perform NS CPT, switch off FM1
12:00	Start cold ramp (Step 7)
15:30	End of survival cold soak, switch on FM1, failure of SEPT-E: current on -80V supply is 22.3 µA, should be 4.3 µA. Leakage currents of detector 2 center segment and guard ring are saturated. Perform E CPT: high noise counts in CS2 and GR2. Perform NS CPT. Switch off NS, E remains powered, ramp up to ambient, bias current gets nominal again! Switch off E.
17:56	Start hot ramp (Step 9)
19:02	Start bake-out at 49 ±1 °C for weekend (Step 34)

Cycles 2, 3	
2004-03-08	Finish bake-out at 48.6 °C after 60 hours
07:15	Switch on FM1, perform NS CPT, perform E CPT (Step 10)
09:17	Start cold ramp (Step 11), SEPT-E leakage problem reappears
12:23	End of cold soak (Step 12), perform NS CPT, perform E CPT, NS threshold scan
14:38	Start hot ramp (Step 13), SEPT-E leakage problem disappears at -22.6 °C
17:02	End of Hot soak (Step 14), perform E CPT, perform NS CPT
18:16	Start cold ramp (Step 15), SEPT-E leakage problem reappears at -21 °C
20:35	End of cold soak (Step 16), perform NS CPT, perform E CPT
21:36	Ramp up to ambient for the night

Cycles 4, 5	
2004-03-09	Start hot ramp
09:00	Hot soak (Step 18), perform E CPT, perform NS CPT
09:45	Start cold ramp (Step 19), SEPT-E leakage problem reappears
13:09	Cold soak (Step 20), perform NS CPT with power supply (±5%): 5.3 V_D, 5.035 V, 5.565 V (nominal, min, max)

	5.6 V_A, 5.32 V, 5.88 V 2.6 V_D, 2.47 V, 2.73 V perform E CPT with power supply (± 5%)
14:50	Start hot ramp (Step 21), SEPT-E leakage problem disappears at -17.5°C
16:13	Start hot soak (Step 22), perform NS CPT, perform E CPT
17:09	Start cold ramp (Step 23)
18:56	Start cold soak (Step 24), perform NS CPT, perform E CPT
20:36	Ramp up to ambient for the night

Cycles 6, 7	
2004-03-10	Study SEPT-E leakage problem
08:30	repressurize, disconnect SEPT-E detector 2 (3 coax: CS2, GR2, XT2) from FM1 E-box and connect via feedthrough to EM E-box outside the chamber
11:00	Start pumping down
11:15	Pressure < 4.4 x 10^{-6} mbar
11:44	Start hot ramp (Step 25)
13:02	Start hot soak (Step 26), perform NS CPT with power supply ± 5%, perform E CPT with power supply ± 5%
	Pinpuller test at I_{min} during TV (V_{supply} = 8.3 Ohm x 0.79 A = 6.6 V) Open cover SEPT-E front: success, but pinpuller function time not recorded as oscilloscope did not trigger Open cover SEPT-NS rear: Not Okay, both covers did not open, measurement of pinpuller function on test point of GSE: no current flowing! Measurement of pinpuller (SN 5054) resistance: > 10 MOhm, should be 5 Ohm Open cover SEPT-NS front instead: success, 40 ms at 0.8 A
15:30	Start cold ramp (Step 27) with SEPT-E detector connected to EM E-box outside the chamber. SEPT-NS rear side pinpuller resistance changed from > 10 MOhm to 5 Ohm during cold ramp.
16:05	EM -80 V rail shows high bias current at -14 °C, i.e. the problem is located in the sensor, not in the electronics box! FM -80 V current is nominal.
16:57	Start cold soak (Step 28) Open cover SEPT-E rear: Not Okay, proton cover opened, but electron cover did not! But pinpuller success, 98 ms at 0.8 A Open cover SEPT-NS rear: now success, 90 ms at 0.8 A
17:10	Perform E CPT, perform NS CPT
18:20	Start hot ramp (Step 29), SEPT-E rear electron cover opened by itself somewhere below -15 °C
19:55	Start hot soak (Step 30), perform NS CPT, perform E CPT
20:38	Switch off FM1, ramp down to ambient for the night.
2004-03-11	Start cold ramp (Step 31)
09:30	Start cold soak (Step 32), switch on FM1, perform NS CPT, perform E CPT
10:23	Ramp up to ambient
11:08	Switch off FM1 and EM
12:25	pressure = 1 bar, perform E CPT, perform NS CPT, open chamber, remove FM1 from chamber, close covers.
2004-03-12	Pinpuller test at I_{max} after TV (V_{supply} = 8.3 Ohm x 1.4 A = 11.7 V) Open cover SEPT-E front: success, 14.8 ms at 1.4 A

	Open cover SEPT-E rear: success, 20.0 ms at 1.4 A Open cover SEPT-NS front: success, 15.6 ms at 1.4 A Cover SEPT-NS rear: pinpuller resistance shows open circuit
	Study pinpuller problem SEPT-NS rear (SN 5054): cables are OK, 5 Ohm appear/disappear when pin is moved, no changes are seen when cables are moved.

5.3.2 FM2

Activities prior to TV Test	
2004-03-11	Install FM2 into LIVAF, check 2 E pinpuller, check 2 NS pinpuller, perform E CPT, perform NS CPT, check thermistor readings, check thermocouple readings, hold TRR, close chamber
17:45	Start pump down

Cycle 1 (Survival)	
2004-03-12	Pressure < 3 x 10^{-6} mbar
06:40	Switch on FM2 at ambient (17.3 °C), perform E and NS CPT, switch off FM2
07:30	Start hot ramp (Step 5)
08:42	Start survival hot soak (Step 6)
09:52	End of survival hot soak, switch on FM2, perform E and NS CPT, switch off FM2, check E and NS pinpuller resistance: 5 Ohm at +50 °C
	Start cold ramp (Step 7), check E and NS pinpuller resistance: 5 Ohm at -40 °C
13:05	End of survival cold soak, switch on FM2, failure of SEPT-E: current on -80V supply is 24.8 µA, should be 4.3 µA! Leakage currents of detector 1 center segment and guard ring are saturated. Perform E and NS CPT, switch off NS, E remains powered.
13:35	Start hot ramp (Step 9), SEPT-E detector 1 leakage current is nominal again at -10.6 °C! Switch off E.
15:13	Pre-bake-out test: perform E and NS CPT. Start bake-out at 49 ±1 °C for weekend (Step 34)

Cycles 2, 3, 4	
2004-03-15	Finish bake-out at 49.5 °C after 64 hours
07:05	Switch on FM2, perform E CPT, perform NS CPT (Step 10)
07:43	Start cold ramp (Step 11), SEPT-E leakage problem reappears at 0.5 °C, switch off FM2
09:15	End of cold soak (Step 12), cold start-up, Leakage current of SEPT-E detectors 0 and 1 (both center segments and guard rings) are saturated! Current on -80 V supply is 42.9 µA, should be 4.3 µA!
	Perform E CPT: high noise counts in CS0, GR0, CS1, GR1. Perform NS CPT and NS threshold scan. Switch off NS, leave E powered on.
10:27	Start hot ramp (Step 13), SEPT-E detector 0 leakage current again nominal at -32 °C, SEPT-E detector 1 leakage current nominal at +0.5 °C. Switch off E.

12:28	Hot soak (Step 14), perform E and NS CPT, test SEPT-E at min/max voltages in power rails.
13:30	Start cold ramp (Step 15)
14:03	SEPT-E detector 1 leakage problem reappears at +0.7 °C
14:40	SEPT-E detector 0 leakage problem reappears at -33.3 °C
15:19	Cold soak (Step 16), perform E and NS CPT.
16:20	Start hot ramp (Step 17)
16:32	Detector 0 leakage problem disappears at -23.5 °C
16:44	Detector 1 leakage problem disappears at +4.6 °C
18:13	Hot soak (Step 18), perform E and NS CPT, switch off FM2
18:29	Start cold ramp (Step 19)
20:42	Cold coak (Step 20), perform E and NS CPT, observe known high noise counts due to leakage current problem, test SEPT-NS at min/max voltages in power rails, switch off FM2.
21:34	Ramp to ambient for the night

Cycles 5, 6, 7	
2004-03-16	Start hot ramp (Step 21)
08:20	Hot soak (Step 22), perform E and NS CPT, test SEPT-NS at min/max voltages in power rails, E and NS threshold scan at nominal voltages, switch off NS, leave E powered on.
09:22	Start cold ramp (Step 23)
10:05	SEPT-E detector 1 leakage problem reappears at +4.2 °C
10:29	SEPT-E detector 0 leakage problem reappears at -25.5 °C
11:21	Cold soak (Step 24), perform E and NS CPT, test SEPT-E at min/max voltages inpower rails.
12:22	Start hot ramp (Step 25)
12:45	Detector 0 leakage problem disappears at -12.2 °C
12:54	Detector 1 leakage problem disappears at +7.7 °C
14:06	Hot soak (Step 26), perform E and NS CPT Open cover SEPT-E front: success, 35.6 ms at 0.8 A Open cover SEPT-NS rear: success, 40.0 ms at 0.8 A
15:10	Start cold ramp (Step 27) with E and NS powered on
15:29	SEPT-E detector 1 leakage problem reappears at +5.2 °C
15:46	SEPT-E detector 0 leakage problem reappears at -21.9 °C
16:32	Cold soak (Step 28), perform E and NS CPT Open cover SEPT-E rear: success, 93.2 ms at 0.8 A Open cover SEPT-NS front: success, 78 ms at 0.8 A Switch off FM2
	Start hot ramp
19:59	Hot soak (Step 30), perform E and NS CPT, switch off FM2
20:40	Ramp down to ambient for the night
2004-03-17	Start cold ramp (Step 31)
08:41	Cold soak (Step 32), perform E and NS CPT
	Start hot ramp with E and NS powered
10:18	Detector 0 leakage problem disappears at -12.3 °C
10:31	Detector 1 leakage problem disappears at +9.2 °C
	Switch off FM2

	Ramp up to ambient, repressurize, perform E and NS CPT
12:13	Open chamber, remove FM2 from chamber, close covers
	Pinpuller test at I_{max} after TV Open cover SEPT-E front: success, 15.2 ms at 1.5 A Open cover SEPT-E rear: success, 19.6 ms at 1.5 A Open cover SEPT-NS front: 16.0 ms at 1.5 A Open cover SEPT-NS rear: 18.8 ms at 1.5 A Close covers

6 Results

The tests were performed as planned, however with some modifications to the step by step procedure. These deviations were made in response to three problem areas which have been detected in the course of the tests:

- detector leakage current problem
- pin puller contact problem
- door opening problem

All CPTs were successful except for deviations related to the leakage current problem and for occasional noise bursts due to EMI from pumps and cold trap which operated in a 5 minute cycle. This cycle was visible also in the instrument background rate. Switching off pumps and cold trap for a while produced quiet instrument performance.

6.1 Detector leakage current problem

SEPT comprises 4 detectors per telescope, two telescopes per spacecraft, hence there were 16 detectors total subjected to TV testing. Three detectors produced high leakage currents. The detector leakage current problem was observed during cold soak.

- FM1 SEPT-E detector 2 showed leakage current in saturation after 1^{st} cold turn on.
- FM2 SEPT-E detector 1 showed leakage current in saturation after 1^{st} cold turn on
- FM2 SEPT-E detector 0 showed leakage current in saturation after 2^{nd} cold turn on

The onset of the failure is sudden like a switch, it is temperature dependent: below a certain trigger temperature, the failure is continually present and absent above this temperature. The trigger temperature is different for the three detectors and is observed to move to higher temperatures in the course of the thermal cycling.

Simultaneously the current on the -80 V bias supply switches from 4.3 µA to 22 µA in the case of a one-detector failure (FM1), and in a second step to 43 µA in the case of a two-detector failure (FM2). Note that this current is not the detector leakage current but current through protection resistor chains. Nominal detector leakage currents are in the range of 1 – 10 nA per detector at ambient, and not measurable at cold soak temperatures of - 40 °C!

In the case of FM1 SEPT-E, the origin of the failure could be located inside SEPT sensor. The failure signature in FM2 SEPT-E is identical. The suspected cause of this failure is the detector mount and wire-bonding which might lead to short-circuiting to analogue ground. This can be a possible failure mode for all detectors. The detector manufacturer Canberra delivered to Kiel 15 stacks, each comprising two detectors separated by 700 µm and premounted with their coax cables in a nickel-plated aluminium housing. A failure review board is set up with Canberra, and a review will be held in week 14.

6.2 Pinpuller contact problem

SEPT comprises 2 pinpullers per telescope, two telescopes per spacecraft, hence there were 8 pinpullers total subjected to TV testing. One pinpuller produced an open circuit during hot soak. When ramping down to cooler temperatures, the pinpuller automatically re-established the nominal 5 Ohm resistance.

By manually manipulating the extended output shaft at ambient temperatures, it was possible to let the 5 Ohm resistance appear/disappear. The pinpuller (SN 5054) is dismounted and will be returned to the manufacturer TiNi for inspection. We will use the spare pinpuller for the flight model.

TiNi allows two methods to manually restow a pinpuller which had been previously actuated: push by way of special TiNi supplied tool, or pull on the shaft extension. As STEREO requests conducting outer surfaces, we have wrapped the pinpuller with aluminium tape thereby blocking the access holes for the special tool. Hence we pull on the pinpuller rod.

6.3 Door opening problem

SEPT comprises 4 covers per telescope, two telescopes per spacecraft, hence there were 16 covers total subjected to TV testing. One cover (FM1 SEPT-E rear electron aperture) failed to open at cold soak, although the associated pinpuller performed nominally and the partner cover (FM1 SEPT-E rear proton aperture) opened correctly. When ramping up to warmer temperatures, the cover opened by itself.

We envisage that the SEPT sensors will have to be disassembled again to install working detector stacks. In this process, the covers, collimators, and pinpuller rods will be made available for rework and surface treatment (e.g. tiodize titanium surfaces). The exact steps of the recovery procedure will need further discussion with the failure review board.

7 Conclusion

The four SEPT units were tested according to AD1. The SEPT electronics boxes performed flawlessly. The three failure areas are concentrated in the SEPT sensor. Problem/failure reports will be issued and submitted to the Project. After rework a (partial) re-qualification in thermal vacuum will be necessary.