Planck Sorption Cooler

Flight Model 1 / Flight Model 2

VERIFICATION PLAN

DOC. TYPE: VERIFICATION PLAN

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DOCUMENT CHANGE LOG

CHANGE LETTER	CHANGE DATE	PAGES AFFECTED	CHANGES/ NOTES	GENERAL COMMENTS
A	5/17/2004	All	Initial Release	

REFERENCE DOCUMENTS

[1] Planck Sorption Cooler Integration and Test Plan, **JPL D-27719**

[2] Planck Sorption Cooler TMU Specification Document, **ES518265 V. B**

[3] FM Electronics Test Plan, ***LPSC***

[4] JPL Standard for System Safety, Revision C, **JPL D- 560**

[5] Problem/Failure Reporting Requirements, Herschel/Planck Project, **JPL D-19151**

List of Acronyms

AD	Applicable Document
ADC	Analog to Digital Converter
AIDS	Assembly Instruction Data Sheet
AIT	Assembly Integration & Test before delivery
AIV	Assembly Integration & Verification after delivery
ATP	Acceptance Test Procedure
AVM	Avionics Model
BOL	Begin Of Life
CDMS	Command Data Management System
CE	Compressor element
CQM	Cryogenic Qualification Model
CTF	Cryo Test Facility
DAC	Digital to Analog Converter
DMS	Document Management System
DP	Desorption Power
DPU	Data Processing Unit
DSP	Digital Signal Processing
ECR	Engineering Change Request
EBB	Engineering Bred Board
EGSE	Electric Ground Support Equipment
EOL	End Of Life
EVL	Event Logger
FM	Flight Model
FMECA	Failure Mode, Effects and Criticality Analysis
FPU	Focal Plane Unit
FS	Flight Spares
GGA	Gas-gap Actuator (Thermal Switch)
GRT	Germanium Resistance Thermometer
HFI	High Frequency Instrument
HK	Housekeeping
HP	Heatup Power
HPST	High Pressure Stabilization Tank
H/W	Hardware
I/F	Interface
IAS	Institut d'Astrophysique Spatiale
ICD	Interface Control Document
IDIS	Integrated Data and Information System
IID-A	Instrument Interface Document, Part A
IID-B	Instrument Interface Document, Part B
ILT	Instrument Level Test
IS	Instrument Scientist
ISN	Institut des Sciences Nucleaires
JPL	Jet Propulsion Laboratory
JT	Joule Thomson
KTC	Type-K Thermocouple
LEOP	Launch & Early Orbit Phase
LFI	Low Frequency Instrument
LH2	Liquid Hydrogen
LM	Local Manager
LPSC	Laboratoire de Physique Subatomique et de Cosmologie
LPSB	Low Pressure Stabilization Bed
LVHX	Liquid-Vapor Heat eXchanger
MCS	Mission Control System
MGSE	Mechanic Ground Support Equipment
MLI	Multi Layer Insulation
MOC	Mission Operations Centre
MUX	MUltipleXer
N/A	Not Applicable
NCR	Non Conformance Report
NOM	Nominal
NON-OP	Non-Operational
OBCP	On-Board Control Procedure
OBSW	On Board Software
OIRD	Operations Interface Requirement Document
OGS	Operational Ground Segment
OOL	Out Of Limit
OP	Operational
P	Pressure
PA	Product Assurance
PACE	Piping Assembly and Cold End
PCx	Pre-Cooling VGroove x
PC3a	Pre-Cooling VGroove 3 Stage a
PC3b	Pre-Cooling VGroove 3 Stage b
PC3c	Pre-Cooling VGroove 3 Stage c
PDF	Portable Document Format (Adobe Acrobat)
PDU	Power Distribution Unit
PFM	Proto-Flight Model
PFR	Problem/Failure Reporting
PI	Principal Investigator
PID	Proportional, Integral, Derivative
PLM	Payload Module
PM	Project Manager
PPL	Preference Part List
PPLM	Planck Payload Module
PRT	Platinum Resistance Thermometer
PS	Project Scientist
PSC	Planck Sorption Cooler
PSU	Power Supply Unit
QA	Quality Assurance
QLA	Quick Look Analysis
QPL	Qualified Part List
RAM	Random Access Memory
RD	Reference Document
RED	Redundant
REU	Readout Electronic Unit
RFW	Request For Waiver
RMS	Root Mean Square
ROM	Read Only Memory
RTA	Real Time Analysis
S/C	Spacecraft
SCC	Sorption Cooler Compressor
SCCE	Sorption Cooler Cold End
SCE	Sorption Cooler Electronics
SCP	Sorption Cooler Piping
SCMP	Software Configuration Management Plan
SE	System Engineer
SIP	Science Implementation Plan
SQAP	Software Quality Assurance Plan
SRR	Software Requirements Review
SS	Survey Scientist
SVM	Service Module
S/W	Software
SWCI	Software Configuration Item
T	Temperature
TBC	To Be Confirmed
TBD	To Be Determined
TBN	To Be Nominated
TBW	To Be Written
TC	Tele-Command
TM	TeleMetry
TMU	Thermo-Mechanical Unit
TRB	Test Review Board
TSA	Temperature Stabilization Assembly
URD	User Requirements Document
WP	Work Package

TABLE OF CONTENTS

Introduction

1.1 Purpose

This document is intended to contain the results of the tests outlined in the Planck Sorption Cooler Integration and Test Plan [1].
The Planck Sorption Cooler is comprised of the Thermal Mechanical Unit (TMU) and the LPSC flight electronics (SCE). JPL is directly responsible only for the testing of the TMU while providing test time for the LPSC electronics units for which LPSC is responsible.

1.2 Requirements Verification Approach

A summary of the verification approach is given in Table 1 (as from Table XX of TMU spec [2]).

Verification	TMU Spec Paragraph	Verification Method
Performance	**3.1.1**	**-**
Cold End Temperature	3.1.1.1	**T**
Cooling Capacity	3.1.1.2	**T + A**
Temperature Stability	3.1.1.3	**T + A**
Heat Lift Adaptability	3.1.1.4	**T**
Operating Period	3.1.1.7	**T**
Flight Allowable Temperatures, Operating	3.1.1.9.1	**T**
Protoflight Temperatures, Operating	3.1.1.9.2	**T**
Protoflight Temperatures, Non-Operating	3.1.1.9.3	**T+A**
Power-On	3.1.1.9.4	**T**
Electrical Interfaces	3.1.3.2	**VL+I+T**
Power	3.1.3.2.3	**T + A**
Shipping and Handling	3.1.5	**T + R**
Pressurized Structures	**3.2.4**	**A + VL + T**
Safety	**3.2.5**	**T + A + I**

Table 1. Requirements Verification

Legenda: **A** - Analysis **VH** - Verified at higher level assembly **I** - Inspection
T - Test **VL** - Verified at lower level assembly **R** - Review of Design

1.2.1 Primary performance verification

The main performance verification on the TMU FM1 and FM2 are summarized in Table 2.

TMU Requirement	Test performed on TMU	Requirement Value
Cold End Temperature	Run TMU at Min and Max Compressor Warm Radiator T (262 K - 282 K) and measure Cold End Temperatures	17.5 K < LVHX1 < 19.02 K 17.5 K < LVHX2 < 22.50 K
Cooling Power	Run the TMU in Normal Mode while applying nominal Heat Load on LVHX's	Cooling power @ LVHX1 > 190 mW Cooling power @ LVHX2 > 646 mW
Input Power	Run TMU at Min and Max Compressor Warm Radiator T (262 K - 282 K) and measure total TMU Input Power	TMU Input power < 426 W @ BOL
Cold End Temperature Fluctuations	Run TMU and measure Cold End T fluctuations for 262 and 282 K compressor radiator T *	ΔT @ LVHX1 < 450 mK ΔT @ LVHX2 < 100 mK
Heat Load Adaptability	Apply different Heat Loads on the LVHX's corresponding to the "ON" and "OFF" instrument power and verify stable TMU Operations	"ON load": 190 mW @ LVHX1 646 mW @ LVHX2 "OFF load": 10 mW @ LVHX1 346 mW @ LVHX2

Table 2. Summary of verification of performance requirements via subsystem tests

*Appropriate usage of the performance prediction model of the cooler, which was calibrated during EBB cooler testing, will be employed to ensure the overall fidelity of the test verification

NOTE: the operating period is not a direct measurement on the TMU but it comes as a by-product with all the performance measurements for a tuned TMU.

1.2.2 Data Archiving Scheme

In order to analyze cooler performance, data from both the TMU and the Cryo Test Facility (CTF) are required. Both systems store data in a binary format, archiving a new raw data file each hour of testing for data manageability. At the end of each test, two combined files containing respectively TMU and CTF data are created and then imported into a data analysis application (IGOR). The resulting IGOR total file is recorded in each test header table, together with the test start and end times which, if necessary, can be used to identify the original raw data one-hour files and/or to reconstruct the general IGOR file from them.

2 FM1/FM2 TMU Acceptance Test

2.1 *TMU FM1/TMU FM2: Acceptance Verification Matrix*

2.1.1 INITIAL VERIFICATION

Specification ID	Description	Test on	
		FM1	FM2
TMU-ACC-01	Grounding, Bonding, Isolation	✓	✓
TMU-ACC-02	Functional acceptance test	✓	✓

2.1.2 PROTOFLIGHT OPERATIONAL/NON OPERATIONAL VERIFICATION

Specification ID	Required by	Description	NON/OP	OP
TMU-ACC-03	TMU spec [1] Page 12	Non Operational cold dwell (24h) of SCC I/F (243 K)	✓	
TMU-ACC-04	TMU spec [1] Page 12	3 startup with coldest Power ON conditions on SCC I/F		✓
TMU-ACC-05	TMU spec [1] Page 12	Proto-flight verification: Cold Operation (SCC @ 252 K, PC3c @ 40 K)		✓
TMU-ACC-06	TMU spec [1] Page 12	Proto-flight verification: Hot Operation (SCC @ 292 K, PC3c @ 65 K)		✓
TMU-ACC-08	TMU spec [1] Page 12	3 startup with warmest Power ON conditions on SCC I/F		✓

2.2 TMU Acceptance Test: test description

2.2.1 INITIAL VERIFICATION

2.2.1.1 Verify "Measurement Functionality" of flight electronics (or EGSE)

Test Objective	Verify that FM Electronics or EGSE are accurately and safely connected to TMU		
Procedure	Before connecting to the flight hardware verify that what has been verified in the electrical check of PACE and SCC is pin-to-pin identical to what the EGSE has been tested to. ***This check will be performed only on documentation.***		
Pass/Fail Criteria	Pin-to-Pin connections between PACE/SCC and EGSE must be identical ✓		
Date	4/8/04	**Signature**	J. Borders [signature]

SCC End (J1):

Pin	Function	SCC Electrical Check AID	EGSE ATP
1	PC1 Temp T12 Excitation +	✓	✓
2	PC1 Temp T12 Signal +	✓	✓
3	PC3b Temp T09 Excitation +	✓	✓
4	PC3b Temp T09 Signal +	✓	✓
5	PC3a Temp T10 Excitation +	✓	✓
6	PC3a Temp T10 Signal +	✓	✓
7	PC3c Temp T08 Excitation +	✓	✓
8	PC3c Temp T08 Signal +	✓	✓
9	PC2 Temp T11 Excitation +	✓	✓
10	PC2 Temp T11 Signal +	✓	✓
11	Spare (Grounded)	✓	✓
12	Spare (Grounded)	✓	✓
13	Spare (Grounded)	✓	✓
14	PC1 Temp T12 Excitation -	✓	✓
15	PC1 Temp T12 Signal -	✓	✓
16	PC3b Temp T09 Excitation -	✓	✓
17	PC3b Temp T09 Signal -	✓	✓
18	PC3a Temp T10 Excitation -	✓	✓
19	PC3a Temp T10 Signal -	✓	✓
20	PC3c Temp T08 Excitation -	✓	✓
21	PC3c Temp T08 Signal -	✓	✓
22	PC2 Temp T11 Excitation -	✓	✓
23	PC2 Temp T11 Signal -	✓	✓
24	Spare (Grounded)	✓	✓
25	Spare (Grounded)	✓	✓

SCC End (J2):

Pin	Function	SCC Electrical Check AID	EGSE ATP
1	CE1 Heat Sw Heater 21A	✓	✓
2	CE1 Heat Sw Heater 21B	✓	✓
3	CE2 Heat Sw Heater 22A	✓	✓
4	CE2 Heat Sw Heater 22B	✓	✓
5	CE3 Heat Sw Heater 23A	✓	✓
6	CE3 Heat Sw Heater 23B	✓	✓
7	CE4 Heat Sw Heater 24A	✓	✓
8	CE4 Heat Sw Heater 24B	✓	✓
9	CE5 Heat Sw Heater 25A	✓	✓
10	CE5 Heat Sw Heater 25B	✓	✓
11	CE6 Heat Sw Heater 26A	✓	✓
12	CE6 Heat Sw Heater 26B	✓	✓
13	LPSB Heater 07A	✓	✓
14	LPSB Heater 07B	✓	✓
15	Spare (Grounded)	✓	✓

At SCC End (J3):

Pin	Function	SCC Electrical Check AID	EGSE ATP
A	LPSB Heater H08A	✓	✓
B	LPSB Heater H08B	✓	✓
C	CE1 Heater H01A	✓	✓
D	CE1 Heater H01B	✓	✓
E	CE1 Heater H11A	✓	✓
F	CE1 Heater H11B	✓	✓
G	CE2 Heater H02A	✓	✓
H	CE2 Heater H02B	✓	✓
J	CE2 Heater H12A	✓	✓
K	CE2 Heater H12B	✓	✓
L	CE3 Heater H03A	✓	✓
M	CE3 Heater H03B	✓	✓
N	CE3 Heater H13A	✓	✓
P	CE3 Heater H13B	✓	✓
R	CE4 Heater H04A	✓	✓
S	CE4 Heater H04B	✓	✓
T	CE4 Heater H14A	✓	✓
U	CE4 Heater H14B	✓	✓
V	CE5 Heater H05A	✓	✓
W	CE5 Heater H05B	✓	✓
X	CE5 Heater H15A	✓	✓
Y	CE5 Heater H15B	✓	✓
Z	CE6 Heater H06A	✓	✓
a	CE6 Heater H06B	✓	✓
b	CE6 Heater H16A	✓	✓
c	CE6 Heater H16B	✓	✓
d	Spare (Grounded)	✓	✓
e	Spare (Grounded)	✓	✓
f	Spare (Grounded)	✓	✓

At SCC End (J4):

Pin	Function	SCC Electrical Check AID	EGSE ATP
1	LPSB Sustain Htr. Volts (H07A)	✓	✓
2	CE1 Fixed Htr. Volts (H01A)	✓	✓
3	CE1 Adj. Htr. Volts (H11A)	✓	✓
4	CE2 Fixed Htr. Volts (H02A)	✓	✓
5	CE2 Adj. Htr. Volts (H12A)	✓	✓
6	CE3 Fixed Htr. Volts (H03A)	✓	✓
7	CE3 Adj. Htr. Volts (H13A)	✓	✓
8	CE4 Fixed Htr. Volts (H04A)	✓	✓
9	CE4 Adj. Htr. Volts (H14A)	✓	✓
10	CE5 Fixed Htr. Volts (H05A)	✓	✓
11	CE5 Adj. Htr. Volts (H15A)	✓	✓
12	CE6 Fixed Htr. Volts (H06A)	✓	✓
13	CE6 Adj. Htr. Volts (H16A)	✓	✓
14	Spare (Grounded)	✓	✓
15	Spare (Grounded)	✓	✓
16	Spare (Grounded)	✓	✓
17	Spare (Grounded)	✓	✓
18	Spare (Grounded)	✓	✓
19	Spare (Grounded)	✓	✓
20	LPSB Sustain Htr. Volts (H07B)	✓	✓
21	CE1 Fixed Htr. Volts (H01B)	✓	✓
22	CE1 Adj. Htr. Volts (H11B)	✓	✓
23	CE2 Fixed Htr. Volts (H02B)	✓	✓
24	CE2 Adj. Htr. Volts (H12B)	✓	✓
25	CE3 Fixed Htr. Volts (H03B)	✓	✓
26	CE3 Adj. Htr. Volts (H13B)	✓	✓
27	CE4 Fixed Htr. Volts (H04B)	✓	✓
28	CE4 Adj. Htr. Volts (H14B)	✓	✓
29	CE5 Fixed Htr. Volts (H05B)	✓	✓
30	CE5 Adj. Htr. Volts (H15B)	✓	✓
31	CE6 Fixed Htr. Volts (H06B)	✓	✓
32	CE6 Adj. Htr. Volts (H16B)	✓	✓
33	Spare (Grounded)	✓	✓
34	Spare (Grounded)	✓	✓
35	Spare (Grounded)	✓	✓
36	Spare (Grounded)	✓	✓
37	Spare (Grounded)	✓	✓

At SCC End (J5):

Pin	Function	SCC Electrical Check AID	EGSE ATP
1	CE1 KTC T20+	✓	✓
2	CE2 KTC T21+	✓	✓
3	CE3 KTC T22+	✓	✓
4	CE4 KTC T23+	✓	✓
5	CE5 KTC T24+	✓	✓
6	CE6 KTC T25+	✓	✓
7	Spare (Grounded)	✓	✓
8	Spare (Grounded)	✓	✓
9	CE1 KTC T20-	✓	✓
10	CE2 KTC T21-	✓	✓
11	CE3 KTC T22-	✓	✓
12	CE4 KTC T23-	✓	✓
13	CE5 KTC T24-	✓	✓
14	CE6 KTC T25-	✓	✓
15	Spare (Grounded)	✓	✓

At SCC End (J6):

Pin	Function	SCC electrical check AID	EGSE ATP
1	LPSB Temp T17 Excitation +	✓	✓
2	LPSB Temp T17 Signal +	✓	✓
3	LPSB Temp T18 Excitation +	✓	✓
4	LPSB Temp T18 Signal +	✓	✓
5	Spare (Grounded)	✓	✓
6	Spare (Grounded)	✓	✓
7	CE1 Temp T15 Excitation +	✓	✓
8	CE1 Temp T15 Signal +	✓	✓
9	CE2 Temp T16 Excitation +	✓	✓
10	CE2 Temp T16 Signal +	✓	✓
11	HPST Temp T13 Excitation +	✓	✓
12	HPST Temp T13 Signal +	✓	✓
13	HPST Temp T14 Excitation +	✓	✓
14	HPST Temp T14 Signal +	✓	✓
15	Spare (Grounded)	✓	✓
16	Spare (Grounded)	✓	✓
17	Spare (Grounded)	✓	✓
18	Spare (Grounded)	✓	✓
19	Spare (Grounded)	✓	✓
20	LPSB Temp T17 Excitation -	✓	✓
21	LPSB Temp T17 Signal -	✓	✓
22	LPSB Temp T18 Excitation -	✓	✓
23	LPSB Temp T18 Signal -	✓	✓
24	Spare (Grounded)-	✓	✓
25	Spare (Grounded)	✓	✓
26	CE1 Temp T15 Excitation -	✓	✓
27	CE1 Temp T15 Signal -	✓	✓
28	CE2 Temp T16 Excitation -	✓	✓
29	CE2 Temp T16 Signal -	✓	✓
30	HPST Temp T13 Excitation -	✓	✓
31	HPST Temp T13 Signal -	✓	✓
32	HPST Temp T14 Excitation -	✓	✓
33	HPST Temp T14 Signal -	✓	✓
34	Spare (Grounded)	✓	✓
35	Spare (Grounded)	✓	✓
36	Spare (Grounded)	✓	✓
37	Spare (Grounded)	✓	✓

At SCC End (J7):

Pin	Function	SCC electrical check AID	EGSE ATP
1	CE1 P P01A Excitation +	✓	✓
2	CE1 P P01B Signal +	✓	✓
3	CE2 P P02A Excitation +	✓	✓
4	CE2 P P02B Signal +	✓	✓
5	CE3 P P03A Excitation +	✓	✓
6	CE3 P P03B Signal +	✓	✓
7	CE4 P P04A Excitation +	✓	✓
8	CE4 P P04B Signal +	✓	✓
9	CE5 P P05A Excitation +	✓	✓
10	CE5 P P05B Signal +	✓	✓
11	CE6 P P06A Excitation +	✓	✓
12	CE6 P P06B Signal +	✓	✓
13	Spare (Grounded)	✓	✓
14	Spare (Grounded)	✓	✓
15	Spare (Grounded)	✓	✓
16	CE1 P P01D Excitation -	✓	✓
17	CE1 P P01C Signal -	✓	✓
18	CE2 P P02D Excitation -	✓	✓
19	CE2 P P02C Signal -	✓	✓
20	CE3 P P03D Excitation -	✓	✓
21	CE3 P P03C Signal -	✓	✓
22	CE4 P P04D Excitation -	✓	✓
23	CE4 P P04C Signal -	✓	✓
24	CE5 P P05D Excitation -	✓	✓
25	CE5 P P05C Signal -	✓	✓
26	CE6 P P06D Excitation -	✓	✓
27	CE6 P P06C Signal -	✓	✓
28	Spare (Grounded)	✓	✓
29	Spare (Grounded)	✓	✓
30	Spare (Grounded)	✓	✓
31	Spare (Grounded)	✓	✓
32	Spare (Grounded)	✓	✓
33	Spare (Grounded)	✓	✓
34	Spare (Grounded)	✓	✓
35	Spare (Grounded)	✓	✓
36	Spare (Grounded)	✓	✓
37	Spare (Grounded)	✓	✓

At SCC End (J8):

Pin	Function	SCC electrical check AID	EGSE ATP
1	HP P P07A Excitation +	*	✓
2	HP P P07B Signal +	*	✓
3	LP P P08A Excitation +	*	✓
4	LP P P08B Signal +	*	✓
5	CE3 Temp T26 Excitation +	✓	✓
6	CE3 Temp T26 Signal +	✓	✓
7	CE4 Temp T27 Excitation +	✓	✓
8	CE4 Temp T27 Signal +	✓	✓
9	CE5 Temp T28 Excitation +	✓	✓
10	HP P P07D Excitation -	*	✓
11	HP P P07C Signal -	*	✓
12	LP P P08D Excitation -	*	✓
13	LP P P08C Signal -	*	✓
14	CE3 Temp T26 Excitation -	✓	✓
15	CE3 Temp T26 Signal -	✓	✓
16	CE4 Temp T27 Excitation -	✓	✓
17	CE4 Temp T27 Signal -	✓	✓
18	CE5 Temp T28 Excitation -	✓	✓
19	CE5 Temp T28 Signal +	✓	✓
20	CE5 Temp T28 Signal -	✓	✓
21	CE6 Temp T29 Excitation +	✓	✓
22	CE6 Temp T29 Excitation -	✓	✓
23	CE6 Temp T29 Signal +	✓	✓
24	CE6 Temp T29 Signal -	✓	✓
25	Spare (Grounded)	✓	✓
26	Spare (Grounded)	✓	✓

* - The SCC interface agrees with the specification regarding the P07 and P08 designators. However, the functions of P07 and P08 are reversed. That is, P07 is the Low-pressure transducer and P08 is the high-pressure transducer.

At SCC End (J19):

Pin	Function	SCC electrical check AID	EGSE ATP
1	T34 Excitation +	✓	✓
2	T34 Signal +	✓	✓
3	T35 Excitation +	✓	✓
4	T35 Signal +	✓	✓
5	T36 Excitation +	✓	✓
6	T36 Signal +	✓	✓
7	T37 Excitation +	✓	✓
8	T37 Signal +	✓	✓
9	T38 Excitation +	✓	✓
10	T38 Signal +	✓	✓
11	T39 Excitation +	✓	✓
12	T39 Signal +	✓	✓
13	Spare (Grounded)	✓	✓
14	Spare (Grounded)	✓	✓
15	Spare (Grounded)	✓	✓
16	Spare (Grounded)	✓	✓
17	Spare (Grounded)	✓	✓
18	Spare (Grounded)	✓	✓
19	Spare (Grounded)	✓	✓
20	T34 Excitation -	✓	✓
21	T34 Signal -	✓	✓
22	T35 Excitation -	✓	✓
23	T35 Signal -	✓	✓
24	T36 Excitation -	✓	✓
25	T36 Signal -	✓	✓
26	T37 Excitation -	✓	✓
27	T37 Signal -	✓	✓
28	T38 Excitation -	✓	✓
29	T38 Signal -	✓	✓
30	T39 Excitation -	✓	✓
31	T39 Signal -	✓	✓
32	Spare (Grounded)	✓	✓
33	Spare (Grounded)	✓	✓
34	Spare (Grounded)	✓	✓
35	Spare (Grounded)	✓	✓
36	Spare (Grounded)	✓	✓
37	Spare (Grounded)	✓	✓

At PACE End (J21):

Pin	Function	PACE electrical check AID	EGSE ATP
1	LVHX1 Temp T01 Excitation +	✓	✓
2	LVHX1 Temp T01 Signal +	✓	✓
3	LVHX1 Temp T02 Excitation +	✓	✓
4	LVHX1 Temp T02 Signal +	✓	✓
5	LVHX2 Temp T03 Excitation +	✓	✓
6	LVHX2 Temp T03 Signal +	✓	✓
7	LVHX2 Temp T04 Excitation +	✓	✓
8	LVHX2 Temp T04 Signal +	✓	✓
9	LVHX3 Temp T05 Excitation +	✓	✓
10	LVHX3 Temp T05 Signal +	✓	✓
11	JT Temp T30 Excitation +	✓	✓
12	LVHX3 Temp T06 Signal +	✓	✓
13	JT Temp T30 Signal +	✓	✓
14	JT Temp T07 Signal +	✓	✓
15	LVHX3 Heater H31A Voltage	✓	✓
16	LVHX3 Heater H32A Voltage	✓	✓
17	JT Temp T07 Excitation +	✓	✓
18	LVHX3 Temp T06 Signal +	✓	✓
19	Spare (Grounded)	✓	✓
20	LVHX1 Temp T01 Excitation -	✓	✓
21	LVHX1 Temp T01 Signal -	✓	✓
22	LVHX1 Temp T02 Excitation -	✓	✓
23	LVHX1 Temp T02 Signal -	✓	✓
24	LVHX2 Temp T03 Excitation -	✓	✓
25	LVHX2 Temp T03 Signal -	✓	✓
26	LVHX2 Temp T04 Excitation -	✓	✓
27	LVHX2 Temp T04 Signal -	✓	✓
28	LVHX3 Temp T05 Excitation -	✓	✓
29	LVHX3 Temp T05 Signal -	✓	✓
30	JT Temp T30 Excitation -	✓	✓
31	LVHX3 Temp T06 Signal -	✓	✓
32	JT Temp T30 Signal -	✓	✓
33	JT Temp T07 Signal -	✓	✓
34	LVHX3 Heater H31B Voltage	✓	✓
35	LVHX3 Heater H32B Voltage	✓	✓
36	JT Temp T07 Excitation -	✓	✓
37	LVHX3 Temp T06 Signal -	✓	✓

At PACE End (J22)

Pin	Function	PACE electrical check AID	EGSE ATP
1	LVHX3 Heater H31A	✓	✓
2	LVHX3 Heater H32A	✓	✓
3	F9 Heater H33A	✓	✓
4	JT Heater H34A	✓	✓
5	Spare (Grounded)	✓	✓
6	LVHX3 Heater H31B	✓	✓
7	LVHX3 Heater H32B	✓	✓
8	F9 Heater H33B	✓	✓
9	JT Heater H34B	✓	✓
10	Spare (Grounded)	✓	✓
11	F9 Heater H36A	✓	✓
12	JT Heater H35A	✓	✓
13	F9 Heater H36B	✓	✓
14	JT Heater H35B	✓	✓
15	Spare (Grounded)	✓	✓
16	Spare (Grounded)	✓	✓
17	Spare (Grounded)	✓	✓
18	Spare (Grounded)	✓	✓
19	Spare (Grounded)	✓	✓
20	Spare (Grounded)	✓	✓
21	Spare (Grounded)	✓	✓
22	Spare (Grounded)	✓	✓
23	Spare (Grounded)	✓	✓
24	Spare (Grounded)	✓	✓
25	Spare (Grounded)	✓	✓
26	Spare (Grounded)	✓	✓

Test Objective	Verify that all TMU sensors are read correctly within their range			
Procedure	Run *Health Monitoring* procedure specified in the flight software			
Pass/Fail Criteria	All TMU sensors must be within their expected ranges			
Start/End Date	05.18.2004	05.18.2004	**Name**	G. MORGANTE - J. BORDERS - M. PRINA
Start/End Time	12 30 P.M.	12 58 P.M.	**Signature**	GM JB
Test Data File	5-18-04 2.2.1.1 HEALTH MONITOR TEST.PXP			

Designator	Location	Type	Expected Range	Reading
T1	LVHX1	Cernox	17.5K - 323K	290.5 K
T2	LVHX1 (RED)	Cernox	17.5K - 323K	290.4 K
T3	LVHX2	Cernox	17.5K - 323K	290.2 K
T4	LVHX2 (RED)	Cernox	17.5K - 323K	290.3 K
T5	LVHX3	Cernox	17.5K - 323K	290.3 K
T6	LVHX3 (RED)	Cernox	17.5K - 323K	290.3 K
T7	JT	Cernox	17.5K - 323K	289.7 K
T30	JT	Cernox	17.5K - 323K	289.8 K
T8	PC3c	Cernox	40K - 323K	290.1 K
T9	PC3b	Cernox	40K - 323K	290.7 K
T10	PC3a	Cernox	40K - 323K	290.6 K
T11	PC2	Cernox	90K - 323K	290.8 K
T12	PC1	Cernox	150K - 323K	290.6 K
T13	HPST1	PRT	253K - 323K	291.7 K
T14	HPST4	PRT	253K - 323K	292.5 K
T17	LPSB	PRT	253K - 323K	292.0 K
T18	LPSB (RED)	PRT	253K - 323K	291.8 K
T15	CE1 Shell Temperature	PRT	253K - 323K	292.8 K
T16	CE2 Shell Temperature	PRT	253K - 323K	293.2 K
T26	CE3 Shell Temperature	PRT	253K - 323K	292.8 K
T27	CE4 Shell Temperature	PRT	253K - 323K	292.5 K
T28	CE5 Shell Temperature	PRT	253K - 323K	292.6 K
T29	CE6 Shell Temperature	PRT	253K - 323K	292.6 K
T20	CE1 Temperature	KTC	253K - 323K	293.0 K
T21	CE2 Temperature	KTC	253K - 323K	293.2 K
T22	CE3 Temperature	KTC	253K - 323K	293.0 K
T23	CE4 Temperature	KTC	253K - 323K	292.9 K
T24	CE5 Temperature	KTC	253K - 323K	292.9 K
T25	CE6 Temperature	KTC	253K - 323K	292.9 K
P1	CE1 Pressure	P Sensor	Ø PSIA - 972 PSIA	7.8 PSIA
P2	CE2 Pressure	P Sensor	Ø PSIA - 972 PSIA	7.9 PSIA
P3	CE3 Pressure	P Sensor	Ø PSIA - 972 PSIA	7.2 PSIA
P4	CE4 Pressure	P Sensor	Ø PSIA - 972 PSIA	7.0 PSIA
P5	CE5 Pressure	P Sensor	Ø PSIA - 972 PSIA	7.1 PSIA
P6	CE6 Pressure	P Sensor	Ø PSIA - 972 PSIA	6.6 PSIA
P7	HPST Pressure	P Sensor	Ø PSIA - 972 PSIA	18.3 PSIA
P8	LPSB Pressure	P Sensor	Ø Torr - 2550 Torr	327 Torr

2.2.1.2 Verify "Control Functionality" of the flight electronics (or EGSE) and the TMU

Test Objective	Verify that FM Electronics or EGSE can correctly and safely operate the TMU			
Procedure	Run *Health Check* procedure specified in the flight software			
Pass/Fail Criteria	All TMU heaters generate proper action			
Start/End Date	5-18-04	5-18-04	**Name**	J. BORDERS G. MORGANTE
Start/End Time	1:30 pm	4:24 PM	**Signature**	J.B. GM
Test Data File	5-18-04 2_2_1_2_HEALTHCHECKTEST.pxp			

Step	Action		Parameter	Value
LPSB-1	Initial Pressure LPSB		P	302 Torr
LPSB-2	Initial LPSB Temperature		T	290.7 K
LPSB-3	Sustain LPSB heater ON	Power (W): 3.92	Δt	667 s
LPSB-4	Final Pressure LPSB		P	308 Torr
LPSB-5	Final LPSB Temperature		T	291.2 K
LPSB-6	Startup heater ON	Power (W): 38.7	Δt	610 s
LPSB-7	Final Pressure LPSB		P	360 Torr
LPSB-8	Final LPSB Temperature		T	296.1 K
CE-1-1	Temperature CE1		T	292.0 K
CE-1-2	Pressure CE1		P	7.5 PSIA
CE-1-3	Pressure HPST		P	17.4 PSIA
CE-1-4	Turn ON CE1 Heater Max Power	Power (W): 242.0	Δt	480 s
CE-1-5	Temperature CE1		T	390.0 K
CE-1-6	Pressure CE1		P	136.0 PSIA
CE-1-7	Pressure HPST		P	125.0 PSIA
CE-1-8	Turn ON CE1 Heater Min Power	Power (W): 6.9	Δt	667 s
CE-1-9	Temperature CE1		T	385 K
CE-1-10	Pressure CE1		P	130.3 PSIA
CE-1-11	Pressure HPST		P	130.7 PSIA
CE-1-12	Turn OFF CE heater, Turn ON GGA heater		Δt	667 s
CE-1-13	Temperature CE1		T	281.0 K
CE-1-14	Pressure CE1		P	5.2 PSIA
CE-1-15	Pressure HPST		P	160.6 PSIA
CE-2-1	Temperature CE2		T	292.7 K
CE-2-2	Pressure CE2		P	7.6 PSIA
CE-2-3	Pressure HPST		P	129.8 PSIA
CE-2-4	Turn ON CE2 Heater Max Power	Power (W): 244	Δt	354 s
CE-2-5	Temperature CE2		T	390.0 K
CE-2-6	Pressure CE2		P	169.9 PSIA
CE-2-7	Pressure HPST		P	159.6 PSIA
CE-2-8	Turn ON CE2 Heater Min Power	Power (W): 6.9	Δt	667 s
CE-2-9	Temperature CE2		T	385.5 K
CE-2-10	Pressure CE2		P	159.0 PSIA
CE-2-11	Pressure HPST		P	173.1 PSIA

CE-2-12	Turn OFF CE heater, Turn ON GGA heater		Δt	667 s
CE-2-13	Temperature CE2		T	279.7 K
CE-2-14	Pressure CE2		P	5.0 PSIA
CE-2-15	Pressure HPST		P	171.1 PSIA
CE-3-1	Temperature CE3		T	290.7 K
CE-3-2	Pressure CE3		P	6.4 PSIA
CE-3-3	Pressure HPST		P	159.2 PSIA
CE-3-4	Turn ON CE3 Heater Max Power	Power (W): 237	Δt	330 s
CE3-5	Temperature CE3		T	390.0 K
CE3-6	Pressure CE3		P	174.2 PSIA
CE3-7	Pressure HPST		P	173.2 PSIA
CE3-8	Turn ON CE3 Heater Min Power	Power (W): 6.83	Δt	667 s
CE3-9	Temperature CE3		T	384.7 K
CE3-10	Pressure CE3		P	172.1 PSIA
CE3-11	Pressure HPST		P	171.3 PSIA
CE3-12	Turn OFF CE heater, Turn ON GGA heater		Δt	667 s
CE3-13	Temperature CE3		T	275.4 K
CE3-14	Pressure CE3		P	3.2 PSIA
CE3-15	Pressure HPST		P	193.7 PSIA
CE-4-1	Temperature CE4		T	287.6 K
CE-4-2	Pressure CE4		P	5.6 PSIA
CE-4-3	Pressure HPST		P	171.2 PSIA
CE-4-4	Turn ON CE4 Heater Max Power	Power (W): 247	Δt	348 s
CE-4-5	Temperature CE4		T	390.0 K
CE-4-6	Pressure CE4		P	194.9 PSIA
CE-4-7	Pressure HPST		P	194.7 PSIA
CE-4-8	Turn ON CE4 Heater Min Power	Power (W): 7.1	Δt	667 s
CE-4-9	Temperature CE4		T	384.4 K
CE-4-10	Pressure CE4		P	192.2 PSIA
CE-4-11	Pressure HPST		P	192.3 PSIA
CE-4-12	Turn OFF CE heater, Turn ON GGA heater		Δt	667 s
CE-4-13	Temperature CE4		T	275.2 K
CE-4-14	Pressure CE4		P	3.0 PSIA
CE-4-15	Pressure HPST		P	217.1 PSIA
CE-5-1	Temperature CE5		T	288.2 K
CE-5-2	Pressure CE5		P	6.1 PSIA
CE-5-3	Pressure HPST		P	192.9 PSIA
CE-5-4	Turn ON CE5 Heater Max Power	Power (W): 243	Δt	365 s
CE-5-5	Temperature CE5		T	390.0 K
CE-5-6	Pressure CE5		P	223.8 PSIA
CE-5-7	Pressure HPST		P	218.0 PSIA
CE-5-8	Turn ON CE5 Heater Min Power	Power (W): 6.92	Δt	667 s
CE-5-9	Temperature CE5		T	385.0 K
CE-5-10	Pressure CE5		P	216.6 PSIA
CE-5-11	Pressure HPST		P	216.6 PSIA

CE-5-12	Turn OFF CE heater, Turn ON GGA heater		Δt	694 s
CE-5-13	Temperature CE5		T	275.5 K
CE5-14	Pressure CE5		P	3.1 PSIA
CE5-15	Pressure HPST		P	243.7 PSIA
CE-6-1	Temperature CE6		T	287.6 K
CE-6-2	Pressure CE6		P	5.1 PSIA
CE-6-3	Pressure HPST		P	216.9 PSIA
CE-6-4	Turn ON CE6 Heater Max Power	Power (W): 243	Δt	393 s
CE-6-5	Temperature CE6		T	390.0 K
CE-6-6	Pressure CE6		P	249.5 PSIA
CE-6-7	Pressure HPST		P	245.2 PSIA
CE-6-8	Turn ON CE6 Heater Min Power	Power (W): 6.96	Δt	667 s
CE-6-9	Temperature CE6		T	385.7 K
CE-6-10	Pressure CE6		P	241.8 PSIA
CE-6-11	Pressure HPST		P	242.4 PSIA
CE-6-12	Turn OFF CE heater, Turn ON GGA heater		Δt	667 s
CE-6-13	Temperature CE6		T	275.1 K
CE-6-14	Pressure CE6		P	2.6 PSIA
CE-6-15	Pressure HPST		P	237.6 PSIA
CE-1-1	Temperature CE1		T	284.3 K
CE-1-2	Pressure CE1		P	4.4 PSIA
CE-1-3	Pressure HPST		P	242.9 PSIA
CE-1-4	Turn ON CE1 Heater Max Power	Power (W): 239	Δt	323 s
CE-1-5	Temperature CE1		T	392.0 K
CE-1-6	Pressure CE1		P	179.9 PSIA
CE-1-7	Pressure HPST		P	240.8 PSIA
CE-1-8	Turn ON CE1 Heater Min Power	Power (W): 6.9	Δt	667 s
CE-1-9	Temperature CE1		T	390.4 K
CE-1-10	Pressure CE1		P	173.6 PSIA
CE-1-11	Pressure HPST		P	236.1 PSIA
CE-1-12	Turn OFF CE heater, Turn ON GGA heater		Δt	667 s
CE-1-13	Temperature CE1		T	276.5 K
CE-1-14	Pressure CE1		P	3.7 PSIA
CE-1-15	Pressure HPST		P	231.4 PSIA

NOTE: *Do not perform Health-Check Procedure on PACE when PACE is warm*

11 ANNEX

11.1 Health Procedure

JPL

Jet Propulsion Laboratory
California Institute of Technology

INTEROFFICE MEMORANDUM

DATE: 2/10/2002

HEALTHCHECK PROCEDURE

OBJECTIVE

The purpose of this document is to provide the procedure needed to check the status of the Planck Sorption Cooler System both in flight and on the ground. The check consist in verifying that all the heater circuits (CE, LPSB, JT etc) are functioning properly (current goes through the heater circuit and, if possible, the respective temperature or pressure is changed as expected). The health check procedure will perform all the verifications on the heating circuit but will not make any system decision on its results. The ground operator, comparing those data with previous run and with proper parameter ranges will decide on the status of the system and decide on how to operate the cooler.

THE PROCEDURE

The health status of the Planck Sorption Cooler System combines two previous procedures, the ground and the flight health check) to simplify the software structure. When the system enters into Ready Mode, the health monitoring process is automatically performed (see Fig.1): it consists in the readout of all the system sensors (T and P), checking that all the values result are within the limits relative to the coolers present condition (i.e. first start or re-start).

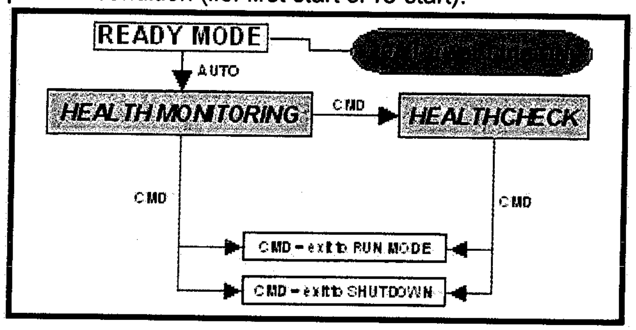

Fig.1

Once the health monitoring process has confirmed the functionality of the system sensors, the health check procedure can be started by *command.* If one or more sensors fails the monitoring test they, will be excluded from the health check procedure: a flag will be raised and a message generated to communicate the failure in order to establish the appropriate actions. During the whole health check procedure the cooler safety limits needs to be continuously monitored in order to ensure the safety of the system.

The healthcheck will test the Compressor Assembly and the Cold End status by performing the actions described in the following list (to be performed in sequence). The limits indicated in the processes are summarized in a dedicated uplink table (see Tab.1): its values might be changed depending on whether the cooler is on the ground or in flight.

Compressor Assembly

All sensors OK from health monitoring process? If NOT exclude the subsystem from healthcheck and inform operator.

LPSB

a. Read initial low pressure sensor (LP_{INI}); Sustain heater ON (Max Power) until low pressure greater than $LP_{INI}+\Delta P_{LP}$ Low P OR time heater ON>$time_{limit}$; heater OFF

b. Startup heater ON until T_{17} OR T_{17} greater than $T_{LP\text{-}LIMIT}$ OR time heater ON> $time_{limit}$; heater OFF

Compressor Elements

c. All CE Heaters OFF, all GGA OFF

d. CE#1 heaters ON (max power(CE)) until temperature of the bed>$T_{BED\text{-}LIMIT}$ OR pressure of the bed>$P_{BED\text{-}LIMIT}$ OR time heater ON>$time_{limit}$; heater OFF

e. CE#1 heater ON (min power, only on variable heater circuit) until time heater ON>$time_{limit}$; heater OFF

f. CE#1 gas gap heater ON until time heater ON>$time_{limit}$; heater OFF

g. Repeat step a,b,c,d for each CE (2,3,4,5,6, and again 1)

Cold End

Read initial JT temperature sensor $T_{7initial}$ and $T_{30initial}$; turn JT heater H34 ON UNTIL $T_7>T_{7initial}+\Delta T_{COLD}$ OR $T_{30initial}+\Delta T_{COLD}$ OR time heater ON>$time_{limit\text{-}cold}$, H34 heater OFF

Read initial JT temperature sensor $T_{7initial}$ and $T_{30initial}$; turn JT heater H35 ON UNTIL $T_7>T_{7initial}+\Delta T_{COLD}$ OR $T_{30initial}+\Delta T_{COLD}$ OR time heater ON>$time_{limit\text{-}cold}$, H35 heater OFF

PF heater H33 ON: time heater ON>$time_{limit\text{-}cold}$, H33 heater OFF

PF heater H36 ON: time heater ON>$time_{limit\text{-}cold}$, H36 heater OFF

Read initial LR3 temperature sensor $T_{5initial}$ and $T_{6initial}$; turn LR3 heater H1 ON UNTIL $T_5>T_{5initial}+\Delta T_{COLD}$ OR $T_{6initial}+\Delta T_{COLD}$ OR time heater ON>$time_{limit\text{-}cold}$, H1 heater OFF

Read initial LR3 temperature sensor $T_{5initial}$ and $T_{6initial}$; turn LR3 heater H2 ON UNTIL $T_5>T_{5initial}+\Delta T_{COLD}$ OR $T_{6initial}+\Delta T_{COLD}$ OR time heater ON>$time_{limit\text{-}cold}$, H2 heater OFF

Healthcheck Limits

The limits to be used for all the above-listed processes are summarized in the following table:

Sensor or parameter	Value	Range
ΔP_{LP}	50 Torr	10-800 Torr
$time_{limit}$	667 s	100-1000 s
$T_{LP\text{-}LIMIT}$	5K abv. ~~310 K~~ +5K	290-323 K
max power(CE)	220 W	See TMU spec.
Min power (CE)	~7 ~~5-10~~ W	0-30 W
$T_{BED\text{-}LIMIT}$	390 K	310-450 K
$P_{BED\text{-}LIMIT}$	750 psia	0-750 psia
ΔT_{COLD}	0.5 K	0.1-2 K
$time_{limit\text{-}cold}$	2 s	0-667 s

Tab.1

2.2.2 PROTOFLIGHT OPERATIONAL/NON OPERATIONAL VERIFICATION

2.2.2.1 Cold Dwell, NON-OP

Test Objective	Verify that Compressor can survive Proto-Flight cold conditions of the I/F's (warm radiator at 243 K) for 24 hrs			
Procedure	Run *Health Monitoring* procedure recording T readings for 24 hrs.			
Pass/Fail Criteria	Sensors readings must comply with expected values			
Start/End Date	5-20-04	5-21-04	**Name**	G. MORGANTE
Start/End Time	7[15] PM	7:20 PM	**Signature**	[signature]
Test Data File	5-21-04 2.2.2.1 ColdDwell Non_Op.pkp			

Designator	Location	Type	Expected Range	Reading
T13	HPST1	PRT	≤243K	241.6 K
T14	HPST4	PRT	≤243K	240.3 K
T17	LPSB	PRT	≤243K	239.3 K
T18	LPSB (Redundant)	PRT	≤243K	239.1 K
T15	CE1 Shell Temperature	PRT	≤243K	235.1 K
T16	CE2 Shell Temperature	PRT	≤243K	235.0 K
T26	CE3 Shell Temperature	PRT	≤243K	234.8 K
T27	CE4 Shell Temperature	PRT	≤243K	234.6 K
T28	CE5 Shell Temperature	PRT	≤243K	234.7 K
T29	CE6 Shell Temperature	PRT	≤243K	234.9 K
T20	CE1 Temperature	KTC	≤243K	236.2 K
T21	CE2 Temperature	KTC	≤243K	236.1 K
T22	CE3 Temperature	KTC	≤243K	235.9 K
T23	CE4 Temperature	KTC	≤243K	235.7 K
T24	CE5 Temperature	KTC	≤243K	235.9 K
T25	CE6 Temperature	KTC	≤243K	236.1 K

Note — pressure sensors were turned off

2.2.2.2 Two Start up Sequences at Minimum I/F's Temperature Conditions

Test Objective	Verify that the TMU can startup in the coldest environment (warm radiator at 252 K and PC3c at 40 K) provided by the S/C			
Procedure	Run *twice* the *Start-up* procedure specified in the flight software			
Pass/Fail Criteria	Pressure in HPST after 3 cycles* must be above 10 atm (147 PSI)			
Start/End Date	6/16/04	6/17/04	**Name**	BURT ZHANG
Start/End Time	7:00 AM	8:00 AM	**Signature**	[signature]
Test Data File	6-16-04 2-2-2-2 Two Start up sequences at min interface T. PXP			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	145	W
CE1 Desorption Power	130	W
CE1 GGA Advance Decoupling	60	s
CE1 GGA Cooldown Delay	0	s
CE2 Heatup Power	145	W
CE2 Desorption Power	130	W
CE2 GGA Advance Decoupling	60	s
CE2 GGA Cooldown Delay	0	s
CE3 Heatup Power	145	W
CE3 Desorption Power	130	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	145	W
CE4 Desorption Power	130	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	145	W
CE5 Desorption Power	130	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	145	W
CE6 Desorption Power	130	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	Variable	s
LPSB Sustain Power	0.0031	~~s~~ W
GGA Power (average total)	27.8	W
Average TSA power	0	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	74.5	K
PC3b Temperature	75.0	K

* Cycles refer to cooler cycle - ~~[illegible]~~ all six beds.

PC3c Temperature	37.8	K
PC2 Temperature	75.8	K
PC1 Temperature	84.8	K
FACILITY INTERFACES		
SCC radiator (measured at the inlet plenum, for indication only)	245 / 243.7	K

Run	HPST Pressure at the end of 3 cycles (atm)	Requirement (atm)
1st	27.8	10.0
2nd	12.8	10.0

2.2.2.3 Full Start up at Minimum I/F's Temperature Conditions

Test Objective	Verify that the TMU can produce LH_2 in the coldest environment provided by the S/C (warm radiator at 252 K, PC3c at 40 K)			
Procedure	Run *Start-up* procedure specified in the flight software			
Pass/Fail Criteria	Produce LH_2, temperature of LVHX1 lower than 19.0 K			
Start/End Date	6/18/04	6/19/04	**Name**	BURT ZHANG
Start/End Time	7:00 AM	9:00 AM	**Signature**	Burt Zhang
Test Data File	6-18-04 2_2_2_3 Full Start up at Min IF.pxp			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	137	W
CE1 Desorption Power	130	W
CE1 GGA Advance Decoupling	60	s
CE1 GGA Cooldown Delay	0	s
CE2 Heatup Power	137	W
CE2 Desorption Power	130	W
CE2 GGA Advance Decoupling	60	s
CE2 GGA Cooldown Delay	0	s
CE3 Heatup Power	137	W
CE3 Desorption Power	130	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	137	W
CE4 Desorption Power	130	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	137	W
CE5 Desorption Power	130	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	137	W
CE6 Desorption Power	130	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	940	s
LPSB Sustain Power	0	s
GGA Power (average total)	27.81	W
Average TSA power	0	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	72.52	K
PC3b Temperature	73.05	K

PC3c Temperature	37.92	K
PC2 Temperature	73.84	K
PC1 Temperature	94.93	K
FACILITY INTERFACES		
LVHX1 load	0	W
LVHX2 load	0	W
LFI – I/F Temperature (average, for indication only)	16.87	K
HFI – I/F Temperature (average, for indication only)	16.38	K
SCC radiator (measured at the inlet plenum, for indication only)	251.4	K

LVHX1 Temperature (K)	Requirement (K)
16.38	< 19.0

2.2.2.4 Minimum Temperature Proto-Flight Operational Conditions

Test Objective	Verify that the TMU can operate in the coldest proto-flight conditions (warm radiator at 252 K and PC3c at 40 K) of the I/F's			
Procedure	Run TMU in Normal Operation for 24 hours			
Pass/Fail Criteria	Stable conditions (TMU continuously in Normal Operation) after 24 h			
Start/End Date	7-6-04	7-7-04	**Name**	James Borders
Start/End Time	9:30 AM	11:00 AM	**Signature**	[signature]
Test Data File	7-7-04 2-2-2-4 Min T Proto-flight Op. pxp			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	115	W
CE1 Desorption Power	130	W
CE1 GGA Advance Decoupling	60	s
CE1 GGA Cooldown Delay	0	s
CE2 Heatup Power	115	W
CE2 Desorption Power	130	W
CE2 GGA Advance Decoupling	60	s
CE2 GGA Cooldown Delay	0	s
CE3 Heatup Power	115	W
CE3 Desorption Power	130	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	115	W
CE4 Desorption Power	130	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	115	W
CE5 Desorption Power	130	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	115	W
CE6 Desorption Power	130	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	940	s
LPSB Sustain Power	1.67	~~s~~ W
GGA Power (average total)	27.4	W
Average TSA power	0	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	75.85	K
PC3b Temperature	76.39	K

PC3c Temperature	39.97	K
PC2 Temperature	78.19	K
PC1 Temperature	148.25	K
FACILITY INTERFACES		
LVHX1 load	0.195	W
LVHX2 load	0.311	W
HFI – I/F Temperature (average, for indication only)	16.89	K
LFI – I/F Temperature (average, for indication only)	18.29	K
HFI – I/F ΔT (peak-to peak, for indication only)	0.850	K
LFI – I/F ΔT (peak-to peak, for indication only)	0.675	K
SCC radiator (measured at the inlet plenum, for indication only)	254.5	K

	YES	NO
TMU continuously in Normal Operation for 24 hrs.	✓	

2.2.2.5 Two Start up Sequences in Maximum I/F's Temperature Conditions

Test Objective	Verify that TMU can startup in the warmest environment (warm radiator at 292 K, PC3c 65 K) provided by the S/C			
Procedure	Run twice the *Start-up* procedure specified in the flight software			
Pass/Fail Criteria	Pressure in HPST after 3 cycles must be above 10 atm			
Start/End Date	6/21/04	6/21/04	**Name**	BURT ZHANG
Start/End Time	8:00 AM	2:00 PM	**Signature**	[signature]
Test Data File	6-21-04 2_2_2_5			

Two Startup Sequences in MAX IF T Conditions

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	115	W
CE1 Desorption Power	130	W
CE1 GGA Advance Decoupling	0	s
CE1 GGA Cooldown Delay	0	s
CE2 Heatup Power	115	W
CE2 Desorption Power	130	W
CE2 GGA Advance Decoupling	0	s
CE2 GGA Cooldown Delay	0	s
CE3 Heatup Power	115	W
CE3 Desorption Power	130	W
CE3 GGA Advance Decoupling	0	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	115	W
CE4 Desorption Power	130	W
CE4 GGA Advance Decoupling	0	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	115	W
CE5 Desorption Power	130	W
CE5 GGA Advance Decoupling	0	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	115	W
CE6 Desorption Power	130	W
CE6 GGA Advance Decoupling	0	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	Variable	s
LPSB Sustain Power	0.453	W
GGA Power (average total)	27.48	W
Average TSA power	0	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	73.34	K
PC3b Temperature	73.87	K

PC3c Temperature	70.83	K
PC2 Temperature	75.72	K
PC1 Temperature	189.1	K
FACILITY INTERFACES		
SCC radiator (measured at the inlet plenum, for indication only)	295.4	K

Run	HPST Pressure at the end of 3 cycles (atm)	Requirement (atm)
1st	18.1	10.0
2nd	16.1	10.0

2.2.2.6 Full Start up in Maximum I/F's Temperature Conditions

Test Objective	Verify that the TMU can produce LH_2 when started in the warmest I/F's flight conditions (warm radiator at 292 K and PC3c at 65 K)			
Procedure	Run *Start-up* procedure specified in the flight software			
Pass/Fail Criteria	Produce LH_2, temperature of LVHX1 lower than 19.0 K			
Start/End Date	7.7.04	7.7.04	**Name**	Burt Zhang
Start/End Time	14 50	17 20	**Signature**	[signature]
Test Data File	7-7-04 2-2-2-6 Full Start-up in Max IF T Conditions.pxp			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	160.0	W
CE1 Desorption Power	185.0	W
CE1 GGA Advance Decoupling	0	s
CE1 GGA Cooldown Delay	0	s
CE2 Heatup Power	160.0	W
CE2 Desorption Power	185.0	W
CE2 GGA Advance Decoupling	0	s
CE2 GGA Cooldown Delay	0	s
CE3 Heatup Power	160.0	W
CE3 Desorption Power	185.0	W
CE3 GGA Advance Decoupling	0	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	160.0	W
CE4 Desorption Power	185.0	W
CE4 GGA Advance Decoupling	0	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	160.0	W
CE5 Desorption Power	185.0	W
CE5 GGA Advance Decoupling	0	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	160.0	W
CE6 Desorption Power	185.0	W
CE6 GGA Advance Decoupling	0	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	N.A.	s
LPSB Sustain Power	N.A.	s
GGA Power (average total)	27.77	W
Average TSA power	0.0	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	76.38	K
PC3b Temperature	76.83	K

PC3c Temperature	64.49	K
PC2 Temperature	78.51	K
PC1 Temperature	148.2 ~~149.8~~	K
FACILITY INTERFACES		
LVHX1 load	0.0	W
LVHX2 load	0.0	W
LFI – I/F Temperature (average, for indication only)	28.2	K
HFI – I/F Temperature (average, for indication only)	18.59	K
SCC radiator (measured at the inlet plenum, for indication only)		K

LVHX1 Temperature (K)	Requirement (K)
19.2	<25.0

2.2.2.7 Maximum Temperature Proto-Flight Operational Conditions

Test Objective	Verify that the TMU can operate in the warmest proto-flight conditions (warm radiator at 292 K and PC3c at 65 K) of the I/F's			
Procedure	Run TMU in Normal Operation for 24 hours			
Pass/Fail Criteria	Stable conditions (TMU continuously in Normal Operation) after 24 h			
Start/End Date	6/22/04	6/23/04	**Name**	BURT ZHANG & JAMES BORDERS
Start/End Time	12:00PM	1:25 PM	**Signature**	[signature]
Test Data File	6-22-04 2-2-2-7 Max T Proto-Flight OP.PXP			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	115	W
CE1 Desorption Power	130	W
CE1 GGA Advance Decoupling	60	s
CE1 GGA Cooldown Delay	0	s
CE2 Heatup Power	115	W
CE2 Desorption Power	130	W
CE2 GGA Advance Decoupling	60	s
CE2 GGA Cooldown Delay	0	s
CE3 Heatup Power	115	W
CE3 Desorption Power	130	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	115	W
CE4 Desorption Power	130	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	115	W
CE5 Desorption Power	130	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	115	W
CE6 Desorption Power	130	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	940	s
LPSB Sustain Power	0.74	W
GGA Power (average total)	27.3	W
Average TSA power	0.085	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	79.70	K
PC3b Temperature	80.23	K

PC3c Temperature	66.39	K
PC2 Temperature	82.47	K
PC1 Temperature	176.3	K
FACILITY INTERFACES		
LVHX1 load	0	W
LVHX2 load	0	W
LFI – I/F Temperature (average, for indication only)	20.19	K
HFI – I/F Temperature (average, for indication only)	19.43	K
SCC radiator (measured at the inlet plenum, for indication only)	295.2	K

	YES	NO
TMU continuously in Normal Operation for 24 hrs.	✓	

3 FM1/FM2 TMU Performance Verification

3.1 TMU FM1/TMU FM2: Performance Verification Approach

The TMU is run to meet all its performances in terms of cooling power, LVHX's temperature, temperature fluctuations and input power while optimizing them based on the thermal interfaces provided by the spacecraft. It is recognized that it is not convenient (a) in terms of cooler lifetime and (b) whole spacecraft performances to run the TMU at full input power and to evaporate excess liquid hydrogen at LVHX2. The mission operations of the TMU are based on providing enough cooling (by measuring the excess cooling power) with the minimum power required. The minimal amount of excess cooling power depends on the specific performance of the TSA and will be determined in agreement with the instruments. The initial estimate of the minimal excess cooling is 150 mW (ref. LFI ECR 102829). Considering the exposed operation rationale, the cooling power provided by the TMU is kept fixed by adjusting the power profile of the TMU. The test to verify the performance of the TMU is performed using the same operational procedures intended for the mission operations and will be validated extensively on the TMU FM1 and verified on the TMU FM2.

3.2 TMU FM1/TMU FM2: Performance Test Matrix

Spec ID	Required by	Description	Performed on		PC3 T [K]	SCC Radiator T [K]		
			FM1	FM2		260	270	280
TMU-PER-01	TMU spec (p. 12) [1]	Min LVHX's T	✓		45	✓		
TMU-PER-02	TMU spec (p. 12) [1]	Max LVHX's T	✓	✓	60			✓
TMU-PER-03	TMU spec (p.17) [1]	Min TMU Input Power (HP/ DP, LPSB Power)	✓	✓	45			✓
TMU-PER-04	TMU spec (p.17) [1]	Max TMU Input Power (HP/ DP, LPSB Power)	✓	✓	60	✓		
TMU-PER-05	TMU spec (p.13) [1]	Heat Lift Adaptability	✓	✓	60-45	✓		
TMU-PER-06	TMU spec (p.12) [1]	Nominal Operational point	✓		52		✓	
TMU-PER-07	TMU spec [1]	Min TSA Setpoint *(goal)*	✓	✓	45-60			✓

NOTES

a) the cooling power is constantly measured by the TSA during ground test. The temperature fluctuations of the LVHX1 and at the TSA will be measured in all the cases specified in the performance matrix.

b) the transition between different thermal interfaces (SCC radiator temperature and PC3c temperature) will be accommodated in the TMU operations following the TMU operating procedure that will be used mission operations and that will be part of the TMU operating manual.

3.3 *FM1/FM2 TM: tests descriptions*

3.3.1 Performance Characterization Test Description

3.3.1.1 Run startup sequence

Test Objective	Verify that the TMU can cool down the LVHX's and transition to Normal Operations			
Procedure	Run *Start-up* procedure then transition into *Normal Operation* as specified in the flight software			
Pass/Fail Criteria	Automatic transition into Normal Operation State			
Start/End Date	5/24/04	5/25/04	**Name**	BURT ZHANG
Start/End Time	8:00 AM	12:00 AM	**Signature**	Burt Zhang
Test Data File	5-24-04 3-3-1-1 Run Startup Sequence.pxp			

Automatic transition into Normal Operation	Yes/No	Time needed (hrs.)
	Yes	14

3.3.1.1 Run startup sequence

NOTES

3.3.1.2 Maximum LVHX's Temperature with warm radiator @ 282 K, PC3c @ 60 K

Test Objective	Measurement of Max LVHX's Temperature		
Procedure	Run *Normal Operation* as specified in the flight software		
Pass/Fail Criteria	TMU performance must be within specifications in terms of input power, cooling power, LVHX's temperature and temperature fluctuations		
Start/End Date	5/29/2004 / 6/1/2004	**Name**	B. ZHANG & G. MORGANTE
Start/End Time	12:00 AM / 9:00 AM	**Signature**	[signature]
Test Data File	~~FINAL280-60~~ 5-29-04 3_3_1_2 MAX LVHX T. PXP		

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	170	W
CE1 Desorption Power	185	W
CE1 GGA Advance Decoupling	80	S
CE1 GGA Cooldown Delay	0	S
CE2 Heatup Power	170	W
CE2 Desorption Power	185	W
CE2 GGA Advance Decoupling	80	S
CE2 GGA Cooldown Delay	0	S
CE3 Heatup Power	170	W
CE3 Desorption Power	185	W
CE3 GGA Advance Decoupling	80	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	170	W
CE4 Desorption Power	185	W
CE4 GGA Advance Decoupling	80	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	170	W
CE5 Desorption Power	185	W
CE5 GGA Advance Decoupling	80	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	170	W
CE6 Desorption Power	185	W
CE6 GGA Advance Decoupling	80	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	667	s
LPSB Sustain Power	1.38	W
GGA Power (average total)	26.95	W
Average TSA power	0.147	W
Pressure Transducers Power Supply (constant)	3.789 ~~8~~	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	44.5	K
PC3b Temperature	44.54	K

PC3c Temperature	60.05	K
PC2 Temperature	48.95	K
PC1 Temperature	173.6	K
FACILITY INTERFACES		
LVHX1 load	0.214	W
LVHX2 load	0.754	W
LFI – I/F Temperature (average, for indication only)	18.64	K
HFI – I/F Temperature (average, for indication only)	21.79	K
SCC radiator (measured at the inlet plenum, for indication only)	282	K

	Measured Value	Requirement
LVHX1 T (K)	18.62	< 19.02 K
LVHX2 T (K)	19.0	< 22.50 K
LVHX1 ΔT [1] (K)	351	< 450 mK
LVHX2 ΔT [2] (K)	153	< 100 mK
TSA Power [3] (W)	147	< 150 mW
Cooling Power [4] (W)	1,115	≥ 836 mW
Input Power [5] (W)	~~393.3~~ 387.28	< 426 W

Notes:
[1] Peak-to-Peak, when compressor radiator performs according to the TMU spec
[2] Peak-to-Peak, measured @ TSA Stage
[3] When Instruments load is ON (646 mW for LFI + 190 mW for HFI) the TSA average Power indicates the extra heat lift available
[4] Total Cooling Power = LVHX Loads+TSA Average Power
[5] Input Power = HU Power + DE Power + GGA's Power + LPSB Sustain + TSA Power + P Sensors Supply

3.3.1.2 Maximum LVHX's Temperature with warm radiator @ 282 K, PC3c @ 60 K

NOTES

* Average Working P is 702 psia

*

3.3.1.3 Minimum TSA Setpoint (goal is 21.8 K) with 60 K PC3c

Test Objective	Verify the minimum setpoint at which the TSA can be run			
Procedure	Lower TSA setpoint until the control is not able to keep the temperature fluctuations within 100 mK			
Pass/Fail Criteria	TSA setpoint should be at 21.8 K while T fluctuations remain below 100 mK. If not, record minimum TSA setpoint that keeps ΔT < 100 mK			
Start/End Date			**Name**	
Start/End Time			**Signature**	
Test Data File				

Minimum TSA setpoint that keeps ΔT < 100 mK (K)	

3.3.1.3 Minimum TSA Setpoint (goal is 21.8 K) with 60 K PC3c

NOTES

3.3.1.4 Maximum TMU input power: 262 K warm radiator, 60 K PC3c

Test Objective	Measurement of Max TMU Input Power			
Procedure	Run *Normal Operation* as specified in the flight software			
Pass/Fail Criteria	TMU performance must be within specifications in terms of input power, cooling power, LVHX's temperature and temperature fluctuations			
Start/End Date	8/20/04	8/26/04	**Name**	BURT ZHANG
Start/End Time	4:30PM	3:00PM	**Signature**	Burt Zhang
Test Data File	8-20-04 3_3_1_4 Max TMU INPUT POWER TEST.PXP			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	187	W
CE1 Desorption Power	188	W
CE1 GGA Advance Decoupling	60	S
CE1 GGA Cooldown Delay	0	S
CE2 Heatup Power	187	W
CE2 Desorption Power	188	W
CE2 GGA Advance Decoupling	60	S
CE2 GGA Cooldown Delay	100	S
CE3 Heatup Power	187	W
CE3 Desorption Power	188	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	100	s
CE4 Heatup Power	187	W
CE4 Desorption Power	188	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	187	W
CE5 Desorption Power	188	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	100	s
CE6 Heatup Power	187	W
CE6 Desorption Power	188	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	100	s
Cycle Time	667	s
LPSB Sustain Power	1.93	W
GGA Power (average total)	27.28	W
Average TSA power	0.149	W
Pressure Transducers Power Supply (constant)	3.78	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	47.45	K
PC3b Temperature	47.52	K

PC3c Temperature	61	K
PC2 Temperature	51.81	K
PC1 Temperature	173.6	K
FACILITY INTERFACES		
LVHX1 load	0.207	W
LVHX2 load	0.657	W
LFI – I/F Temperature (average, for indication only)	19.75	K
HFI – I/F Temperature (average, for indication only)	17.2	K
SCC radiator (measured at the inlet plenum, for indication only)	259.6	K

	Measured Value	Requirement
LVHX1 T (K)	17.13	< 19.02 K
LVHX2 T (K)	17.34	< 22.50 K
LVHX1 ΔT [1] (K)	421	< 450 mK
LVHX2 ΔT [2] (K)	73	< 100 mK
TSA Power [3] (W)	149	< 150 mW
Cooling Power [4] (W)	1,013	≥ 836 mW
Input Power [5] (W)	408	< 426 W

Notes:
[1] Peak-to-Peak, when compressor radiator performs according to the TMU spec
[2] Peak-to-Peak, measured @ TSA Stage
[3] When Instruments load is ON (646 mW for LFI + 190 mW for HFI) the TSA average Power indicates the extra heat lift available
[4] Total Cooling Power = LVHX Loads+TSA Average Power
[5] Input Power = HU Power + DE Power + GGA's Power + LPSB Sustain + TSA Power + P Sensors Supply

3.3.1.4 Maximum TMU input power: 262 K warm radiator, 60 K PC3c

NOTES

* Temperature sensors T08 — T12 for pre-coolers PC3C, 3b, 3a and PC2, PC1 went bad shortly before 7:00AM, 8/22/04. No adjustment was made to these pre-coolers through the test. Steady temperature reading from facility sensors indicates that these pre-coolers remained at the temperatures recorded prior to 7:00AM, 8/22/04.

* ΔT at LVHX1 and control stage taken over a full cooler cycle (6 bed cycles) between data points 521671 and 525689.
These temperature differences do not meet the requirement over some other cooler cycles. Over a 67-hour period, ΔT LVHX1 ~ 485 mK peak to peak and 35 ~ 426 mK,

3.3.1.5 Heat adaptability test (262 K warm radiator, 60 K PC3c)

Test Objective	Verify that TMU remains in stable conditions when Instruments are switched OFF/ON			
Procedure	Run *Normal Operation* as specified in the flight software, switch Instrument loads OFF then ON again			
Pass/Fail Criteria	The sum of the Instrument loads and TSA power (i.e. the total cooling power) must remain constant within ±30 mW after switching OFF/ON Instruments			
Start/End Date			**Name**	
Start/End Time			**Signature**	
Test Data File				

	LVHX1 Load (W)	LVHX2 Load (W)	TSA (W)	Total[1] (W)
Cooling Power *before* switching OFF Instruments				
Cooling Power *after* switching OFF Instruments				
Cooling Power *after* switching ON Instruments				

Notes: [1] the cooler total cooling power is given by the sum of the Instrument loads on the LVHX's and the average TSA power

3.3.1.5 Heat adaptability test (262 K warm radiator, 60 K PC3c)

NOTES

9/9/04 7 Am Drop input powers to parasitic levels LFI ≈ 400 mW HFI ≈ 10 mW

12 Pm Increase input powers to nominal 650 mW, 200 mW (LFI, HFI)

3.3.1.6 Minimum LVHX temperature: 262 K warm radiator, 45 K PC3c

Test Objective	Measurement of Min LVHX's Temperature			
Procedure	Run *Normal Operation* as specified in the flight software			
Pass/Fail Criteria	TMU performance must be within specifications in terms of input power, cooling power, LVHX's temperature and temperature fluctuations			
Start/End Date	6/6/04	6/7/04	**Name**	B. ZHANG & M PRINA
Start/End Time	6:00 PM	9:00 AM	**Signature**	[signatures]
Test Data File	6-7-04 3_3_1_6 MINIMUM LVHX TEMPERATURE TEST.PXP			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	134	W
CE1 Desorption Power	130	W
CE1 GGA Advance Decoupling	60	S
CE1 GGA Cooldown Delay	0	S
CE2 Heatup Power	134	W
CE2 Desorption Power	130	W
CE2 GGA Advance Decoupling	60	S
CE2 GGA Cooldown Delay	60	S
CE3 Heatup Power	134	W
CE3 Desorption Power	130	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	80	s
CE4 Heatup Power	134	W
CE4 Desorption Power	130	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	134	W
CE5 Desorption Power	130	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	60	s
CE6 Heatup Power	134	W
CE6 Desorption Power	130	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	940	s
LPSB Sustain Power	1.35	W
GGA Power (average total)	28.0	W
Average TSA power	0.28	W
Pressure Transducers Power Supply (constant)	3.78	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	42.12	K
PC3b Temperature	42.15	K

PC3c Temperature	44.9	K
PC2 Temperature	45.48	K
PC1 Temperature	149.5	K
FACILITY INTERFACES		
LVHX1 load	0.196	W
LVHX2 load	0.655	W
LFI – I/F Temperature (average, for indication only)	19.48	K
HFI – I/F Temperature (average, for indication only)	16.73	K
SCC radiator (measured at the inlet plenum, for indication only)	~~269.4~~ 261.3	K

	Measured Value	Requirement
LVHX1 T (K)	16.72	< 19.02 K
LVHX2 T (K)	18.4	< 22.50 K
LVHX1 ΔT [1] (K)	430	< 450 mK
LVHX2 ΔT [2] (K)	130	< 100 mK
TSA Power [3] (W)	280	< 150 mW
Cooling Power [4] (W)	1,131	≥ 836 mW
Input Power [5] (W)	~~301.5~~ 297.4	< 426 W

Notes:
[1] Peak-to-Peak, when compressor radiator performs according to the TMU spec
[2] Peak-to-Peak, measured @ TSA Stage
[3] When Instruments load is ON (646 mW for LFI + 190 mW for HFI) the TSA average Power indicates the extra heat lift available
[4] Total Cooling Power = LVHX Loads+TSA Average Power
[5] Input Power = HU Power + DE Power + GGA's Power + LPSB Sustain + TSA Power + P Sensors Supply

3.3.1.6 Minimum LVHX temperature: 262 K warm radiator, 45 K PC3c

NOTES

3.3.1.7 Heat adaptability test (262 K warm radiator, 45 K PC3c)

Test Objective	Verify that TMU remains in stable conditions when Instruments are switched OFF/ON			
Procedure	Run *Normal Operation* as specified in the flight software, switch Instrument loads OFF then ON again			
Pass/Fail Criteria	The sum of the Instrument loads and TSA power (i.e. the total cooling power) must remain constant within ±30 mW after switching OFF/ON Instruments			
Start/End Date	6/7/04	6/7/04	**Name**	BURT ZHANG
Start/End Time	8:32 AM	12:16 PM	**Signature**	Burt Zhang
Test Data File	6-7-04 3-3-1-7 Heat Adaptability. PXP			

Heat Lift Measurement	LVHX1 Load (W)	LVHX2 Load (W)	TSA (W)	Total[1] (W)
Cooling Power *before* switching OFF Instruments	0.196	0.655	0.289	1.140
Cooling Power *after* switching OFF Instruments	0.0.	0.413	0.547	0.96
Cooling Power *after* switching ON Instruments	0.196	0.655	0.305	1.156

Notes: [1] the cooler total cooling power is given by the sum of the Instrument loads on the LVHX's and the average TSA power

3.3.1.7 Heat adaptability test (262 K warm radiator, 45 K PC3c)

NOTES

3.3.1.8 Minimum TMU input power: 282 K warm radiator, 45 K PC3c

Test Objective	Measurement of Min TMU Input Power			
Procedure	Run *Normal Operation*, as specified for the flight software			
Pass/Fail Criteria	TMU performance must be within specifications in terms of input power, cooling power, LVHX's temperature and temperature fluctuations			
Start/End Date	6/9/04	6/11/04	**Name**	BURT ZHANG
Start/End Time	12:10 PM	8:50 AM	**Signature**	Burt Zhang
Test Data File	6-11-04 3_3_1_8 MINIMUM TMU INPUT POWER TEST. PXP			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	115	W
CE1 Desorption Power	130	W
CE1 GGA Advance Decoupling	60	S
CE1 GGA Cooldown Delay	0	S
CE2 Heatup Power	115	W
CE2 Desorption Power	130	W
CE2 GGA Advance Decoupling	60	S
CE2 GGA Cooldown Delay	0	S
CE3 Heatup Power	115	W
CE3 Desorption Power	130	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	115	W
CE4 Desorption Power	130	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	115	W
CE5 Desorption Power	130	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	115	W
CE6 Desorption Power	130	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	940	s
LPSB Sustain Power	0.7584	W
GGA Power (average total)	27.34	W
Average TSA power	0.1635	W
Pressure Transducers Power Supply (constant)	3.78	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	43.22	K
PC3b Temperature	43.26	K

PC3c Temperature	44.93	K
PC2 Temperature	47.02	K
PC1 Temperature	173.8	K
FACILITY INTERFACES		
LVHX1 load	0.1954	W
LVHX2 load	0.6554	W
LFI – I/F Temperature (average, for indication only)	20.42	K
HFI – I/F Temperature (average, for indication only)	17.98	K
SCC radiator (measured at the inlet plenum, for indication only)	283.2	K

	Measured Value	Requirement	
LVHX1 T (K)	17.97	< 19.02 K	
LVHX2 T (K)	18.20	< 22.50 K	
LVHX1 ΔT [1] (K)	433	< 450 mK	
LVHX2 ΔT [2] (K)	92.33 *	< 100 mK	– See notes
TSA Power [3] (W)	163.5	< 150 mW	– See notes
Cooling Power [4] (W)	1,014	≥ 836 mW	
Input Power [5] (W)	277.0	< 426 W	

Notes:
[1] Peak-to-Peak, when compressor radiator performs according to the TMU spec
[2] Peak-to-Peak, measured @ TSA Stage
[3] When Instruments load is ON (646 mW for LFI + 190 mW for HFI) the TSA average Power indicates the extra heat lift available
[4] Total Cooling Power = LVHX Loads+TSA Average Power
[5] Input Power = HU Power + DE Power + GGA's Power + LPSB Sustain + TSA Power + P Sensors Supply

3.3.1.8 Minimum TMU input power: 282 K warm radiator, 45 K PC3c

NOTES

Lakeshore Power Source and controller ~~were~~ used for cold end Heaters in this test.

TSA power is ~~too~~ high - wrote PFR.

3.3.1.9 Minimum TSA Setpoint (goal is 21.8 K) with 45 K PC3c

Test Objective	Verify the minimum setpoint at which the TSA can be run			
Procedure	Lower TSA setpoint until the control is not able to keep the temperature fluctuations within 100 mK			
Pass/Fail Criteria	TSA setpoint should be at 21.8 K while T fluctuations remain below 100 mK. If not, record minimum TSA setpoint that keeps ΔT < 100 mK			
Start/End Date			**Name**	
Start/End Time			**Signature**	
Test Data File				

Minimum TSA setpoint that keeps ΔT < 100 mK (K)	

3.3.1.9 Minimum TSA Setpoint (goal is 21.8 K) with 45 K PC3c

NOTES

3.3.1.10 Nominal TMU thermal interfaces: 272 K warm radiator, 52 K PC3c

Test Objective	Verification of TMU performance in *nominal* conditions of thermal I/F's			
Procedure	Run *Normal Operation*, as specified for the flight software			
Pass/Fail Criteria	TMU performance must be within specifications in terms of input power, flow generated, high-pressure and low-pressure produced and their fluctuations			
Start/End Date	8/26/04	9/8/04	**Name**	Burt Zhang
Start/End Time	3:30PM	7:00AM	**Signature**	Burt Zhang
Test Data File	8-26-04 3-3-1-10 Nominal TMU IF.PXP			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	151	W
CE1 Desorption Power	162	W
CE1 GGA Advance Decoupling	60	S
CE1 GGA Cooldown Delay	0	S
CE2 Heatup Power	151	W
CE2 Desorption Power	162	W
CE2 GGA Advance Decoupling	60	S
CE2 GGA Cooldown Delay	0	S
CE3 Heatup Power	151	W
CE3 Desorption Power	162	W
CE3 GGA Advance Decoupling	60	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	151	W
CE4 Desorption Power	162	W
CE4 GGA Advance Decoupling	60	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	151	W
CE5 Desorption Power	162	W
CE5 GGA Advance Decoupling	60	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	151	W
CE6 Desorption Power	162	W
CE6 GGA Advance Decoupling	60	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	760	s
LPSB Sustain Power	1.363	W
GGA Power (average total)	27.01	W
Average TSA power	0.085	W
Pressure Transducers Power Supply (constant)	3.78	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	45.64	K
PC3b Temperature	45.7	K

PC3c Temperature	51.91	K
PC2 Temperature	49.38	K
PC1 Temperature	158.68	K
FACILITY INTERFACES		
LVHX1 load	0.206	W
LVHX2 load	0.657	W
LFI – I/F Temperature (average, for indication only)	19.67	K
HFI – I/F Temperature (average, for indication only)	17.24	K
SCC radiator (measured at the inlet plenum, for indication only)	269	K

	Measured Value	Requirement
LVHX1 T (K)	17.23	< 19.02 K
LVHX2 T (K)	17.44	< 22.50 K
LVHX1 ΔT [1] (K)	360	< 450 mK
LVHX2 ΔT [2] (K)	97	< 100 mK
TSA Power [3] (W)	85	< 150 mW
Cooling Power [4] (W)	948	≥836 mW
Input Power [5] (W)	345.2	< 426 W

Notes:
[1] Peak-to-Peak, when compressor radiator performs according to the TMU spec
[2] Peak-to-Peak, measured @ TSA Stage
[3] When Instruments load is ON (646 mW for LFI + 190 mW for HFI) the TSA average Power indicates the extra heat lift available
[4] Total Cooling Power = LVHX Loads+TSA Average Power
[5] Input Power = HU Power + DE Power + GGA's Power + LPSB Sustain + TSA Power + P Sensors Supply

3.3.1.10 Nominal TMU thermal interfaces: 272 K warm radiator, 52 K PC3c

NOTES

Sept 6 - To test cooling power, add 150 mW to LVHX1 for a total of 350 mW

Sept 8 try James's open loop

ΔT's at LVHX1 and TSA stage are taken over a complete cooler cycle between data points 910646 and 915255. Over a time period of 100 hours, ΔT at LVHX1 ~ 456 mK and ΔT LVHX2 (TSA) ~ 178 mK w/ 3σ = 0.032

(3σ = 0.171)

3.3.1.11 Recharge TMU

Test Objective	Refresh H_2 gas of TMU			
Procedure	Remove H_2 gas from TMU and recharge it with same amount of H_2			
Pass/Fail Criteria	N/A			
Start/End Date	8-2-04	8-5-04	**Name**	BURT ZHANG
Start/End Time			**Signature**	Burt Zhang
Test Data File	N/A			

Quantity of H_2 removed (SL)	700
Quantity of H_2 refilled (SL)	709

3.3.1.11 Recharge TMU

NOTES

3.3.1.12 H_2 gas charge verification (warm radiator at 282 K, 60 K) (ONLY FM1)

Test Objective	Verification of TMU proper H_2 gas recharge			
Procedure	Run *Startup* and *Normal Operation*, as specified in the flight software			
Pass/Fail Criteria	TMU performance with warm radiator at 282 K must be replicated (ref. **3.3.1.2**)			
Start/End Date	8/14/04	8/17/04	**Name**	BURT ZHANG
Start/End Time	3:00 PM	11:00 AM	**Signature**	Burt Zhang
Test Data File	~~FM1gasRecharge 8-17-04~~ PXP 8-14-04 3_3_1_12 H2 GAS CHARGE VERIFICATION PXP			

TMU NORMAL OPERATIONS PARAMETERS	VALUE	UNITS
CE1 Heatup Power	170	W
CE1 Desorption Power	185	W
CE1 GGA Advance Decoupling	80	S
CE1 GGA Cooldown Delay	0	S
CE2 Heatup Power	170	W
CE2 Desorption Power	185	W
CE2 GGA Advance Decoupling	80	S
CE2 GGA Cooldown Delay	0	S
CE3 Heatup Power	170	W
CE3 Desorption Power	185	W
CE3 GGA Advance Decoupling	80	s
CE3 GGA Cooldown Delay	0	s
CE4 Heatup Power	170	W
CE4 Desorption Power	185	W
CE4 GGA Advance Decoupling	80	s
CE4 GGA Cooldown Delay	0	s
CE5 Heatup Power	170	W
CE5 Desorption Power	185	W
CE5 GGA Advance Decoupling	80	s
CE5 GGA Cooldown Delay	0	s
CE6 Heatup Power	170	W
CE6 Desorption Power	185	W
CE6 GGA Advance Decoupling	80	s
CE6 GGA Cooldown Delay	0	s
Cycle Time	667	s
☆ LPSB Sustain Power	1.88	W
GGA Power (average total)	26.72	W
Average TSA power	0.162	W
Pressure Transducers Power Supply (constant)	3.78	W
FACILITY I/F's (all measured on TMU thermometers)		
PC3a Temperature	47.86	K
PC3b Temperature	47.95	K

PC3c Temperature	60.59	K
PC2 Temperature	52.26	K
PC1 Temperature	173.6	K
FACILITY INTERFACES		
LVHX1 load	0.199	W
LVHX2 load	0.658	W
LFI – I/F Temperature (average, for indication only)	18.40	K
HFI – I/F Temperature (average, for indication only)	20.75	K
SCC radiator (measured at the inlet plenum, for indication only)	281.6	K

	Measured Value	Requirement
LVHX1 T (K)	18.39	< 19.02 K
LVHX2 T (K)	18.59	< 22.50 K
LVHX1 ΔT [1] (K)	386	< 450 mK
LVHX2 ΔT [2] (K)	98.3	< 100 mK
TSA Power [3] (W)	162	< 150 mW
Cooling Power [4] (W)	1,019	≥836 mW
Input Power [5] (W)	387.5	< 426 W

Notes:
[1] Peak-to-Peak, when compressor radiator performs according to the TMU spec
[2] Peak-to-Peak, measured @ TSA Stage
[3] When Instruments load is ON (646 mW for LFI + 190 mW for HFI) the TSA average Power indicates the extra heat lift available
[4] Total Cooling Power = LVHX Loads+TSA Average Power
[5] Input Power = HU Power + DE Power + GGA's Power + LPSB Sustain + TSA Power + P Sensors Supply

3.3.1.12 H_2 gas charge verification (warm radiator at 282 K, 60 K) (ONLY FM1)

NOTES

R1 =

R2 = 1.52 K/W

* LPSB sustain power was set at 1.34 W for ~ 46 hours. HPST pressure gradually built up to 688 psia.

* LPSB sustain power was ramped up incrementally to 1.88 W, which brought HPST pressure up to 703.7 psia. This action shifted H_2 inventory from LPSB to the beds while keeping the LPSB sustain power within spec.

* Active control on LVHX3 heater started at 7:00 AM on 8/17/04. LH_2 was depleted within 3 hours. This amount of H_2 further increased the HPST pressure.

3.3.1.13 FM Electronics testing

The FM Electronics Test objectives, Procedures, Pass/Fail Criteria are indicated in the documentation that has to be produced by *Laboratoire de Physique Subatomique et de Cosmologie* (LPSC), France (see [3]).

4 Documentation

4.1 Test Documentation

Documentation for planning and reporting testing shall meet the requirements of the ERD, D-19155. The test documentation will include all the documents of the subassemblies test previously performed, and the EBB test report.

4.2 Operating Procedures

The integration/handling/test procedures are specified and called out in the assembly and test plan [1]. A summary of all the procedures can be found in Table 3.

Procedure	Use	Relative Documentation
Safe to Mate Procedure	MGSE, SCC, PACE	Verification Plan
Health check monitoring	TMU performance test	TMU Operation Document
Health check procedure	TMU performance test	TMU Operation Document
TMU Tuning	TMU performance test	User Manual
Recharge Procedure	Recharge operation	AIDS

Table 3. Summary of the procedures to be used in the test of the TMU

4.3 Disposition of non conforming items

The JPL system for problem/failure reporting (PFR) will be used to report and dispose the non-conforming items. Reporting shall follow the Herschel/Planck Project Problem/Failure Reporting Requirements, D-19151.

4.4 Safety requirements/processes/documentation

Testing at JPL shall follow all safety standards as dictated in the JPL Standards for System Safety, D-560. A test readiness review shall be conducted prior to each test to verify compliance.