LOCKHEED MARTIN

Memorandum

Date: October 21, 2003
WBS Number: H4051300
MSAD-04-0022

To:	C. Amberboy	Dept. 3255	Mail Code: S363
Via:	E. Y. Azzi	Dept. 2I13	Mail Code: C70
	J. K. Cox	Dept. 2I13	Mail Code: C70
From:	J.D. Pantermuehl	Dept. 2I13	Mail Code: C70

SUBJECT: **Power Interface Panel (PIP) Preliminary Thermal Analysis Report**

This document presents the thermal analysis of the Power Interface Panel (PIP). This unit was analyzed for nominal operations under 14.7 psia environment pressure conditions. A thermal model was constructed and used to perform the analysis. The model considers conduction, convection, and radiation heat transfer modes. TSS was used for the geometry model, and SINDA was used for the thermal network model.

Background

The PIP is a portable power interface between the Human Research Facility (HRF) Muscle Atrophy Research and Exercise System (MARES) rack and either the Utility Interface Panel (UIP), Standard Utility Panel (SUP), or Utility Outlet Panel (UOP). The maximum capacity of the PIP is 120 Vdc at 10A. The interface concept for the UIP/SUP, PIP, and MARES is shown in Figure 1.

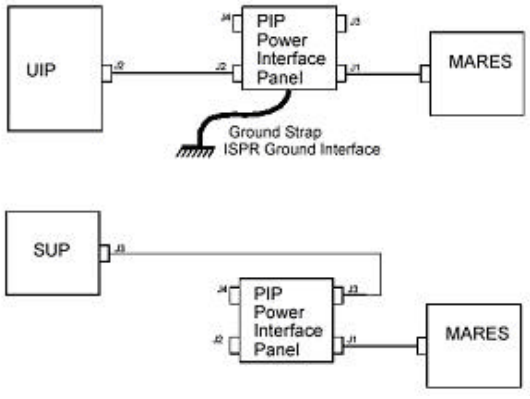

Figure 1. Power Interface Panel Connections

The PIP is mounted to the seat tracks that run vertically on either side of the HRF MARES Rack as shown in Figure 2.

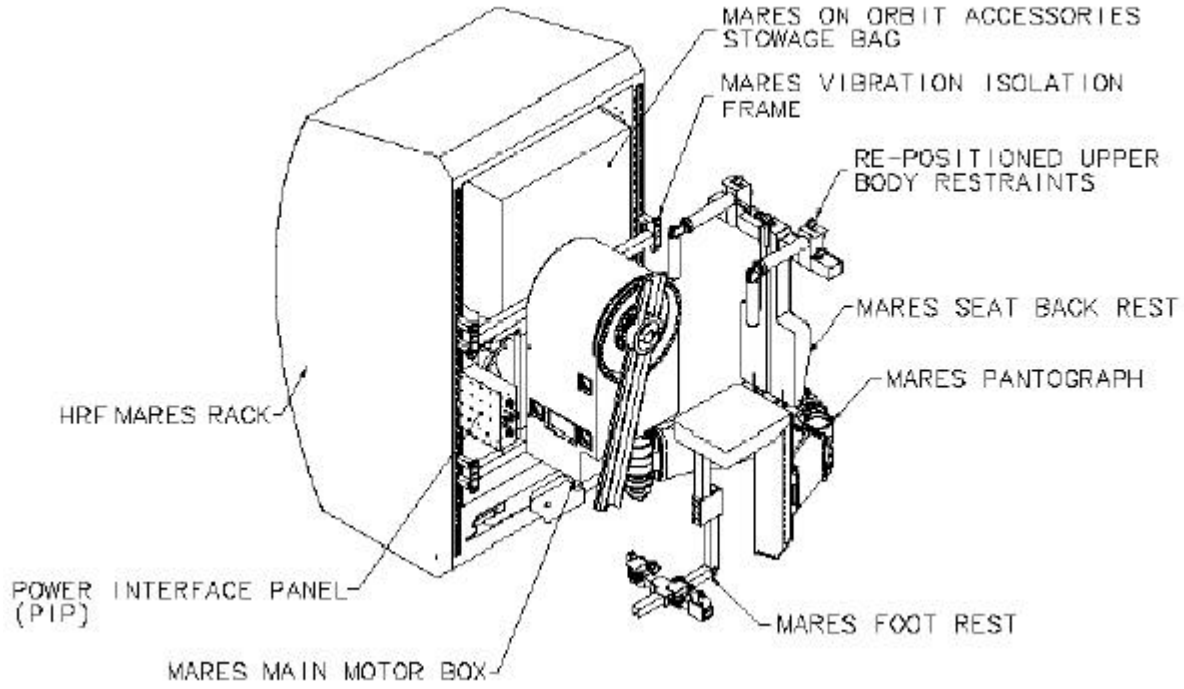

Figure 2. HRF MARES Rack Deployed Position

Analysis Method and Modeling

This section of the report contains the following: thermal interface requirements, analysis assumptions, thermal design, heat dissipation, and convection coefficient determination. The Power Interface Panel was analyzed based on nominal for 14.7 psia environment pressure conditions.

Thermal Interface Requirements

When integrated rack surfaces, which are subject to continuous or incidental contact, exceed 49°C (120°F) and are exposed to crewmember's bare skin contact, protective equipment shall be provided to the crew and warning labels shall be provided at the surface site [1]. This limit is applicable to the external walls of the PIP.

Normal on-orbit internal operating environments are defined as temperatures in the range of 63°F to 82°F and pressures in the range of 13.9 to 14.9 PSIA [1]. The convection coefficient is 0.2 BTU/hr-°F-ft^2 for a 14.7 psia module pressure. The mean radiant environment is specified to be 86 °F [2].

Assumptions

The following assumptions were used for the PIP Thermal Analysis:

1. The cabin air temperature was assumed to be 82 °F (28.0 °C).
2. The mean radiant environment was assumed to be 86 °F (30.0 °C).
3. Cooling is done via external wall convection and radiation to cabin air and walls.

4. Aluminum box surfaces are blue anodized with an assumed emissivity of 0.85.
5. The external wall convection coefficient was assumed to be 0.20 BTU/hr-°F-ft^2 for 14.7 psia module pressure.
6. Components mounted directly to box walls were assumed to have a contact conductance of 100 BTU/hr-sq ft-°F (see page 4-25, reference 3).

Power Interface Panel Thermal Design

The PIP box dimensions are 9.0"W x 3.5"H x 10.5"L. The PIP unit has 32.08 Watts of heat dissipation located on three circuit boards [4]. The control board and the switch board are thermally sunk to the top and bottom plates, respectively, via an aluminum heat sink sandwiched by thermal interface material. The filter board is attached to the control board via standoffs. The external walls are cooled via radiation and convection to the cabin air and walls. The outer walls of the unit are blue anodized with an emissivity of 0.85. In order to meet the touch temperature requirements on the external walls, it was necessary to add fins to the top and bottom plates.

The PIP is equipped with a thermal cut-off switch, which is located on the aluminum heat sink that is attached to the bottom panel. The thermal switch has a set point of 122 °F (50 °C). The tolerance is +/- 3 °F (+/- 1.7 °C).

Heat Dissipation

The PIP consists of a single module, with heat dissipating components located internally on three circuit boards. The three boards are the Switch Board, Control Board and the Filter Board. The heat dissipation for each of the boards is listed in Table 1. The heat dissipation was assumed to be continuous with a maximum of 32.08 Watts [4].

Table 1. Power Interface Panel Heat Dissipation

Component	Heat Dissipation (W)	Quantity	Total Heat Dissipation
Switch Board		1	13.326
Diodes (D1, D2)	1.845 each	2	3.690
Fets	0.803 each	12	9.636
Control Board		1	16.800
Filter Board		1	1.950
Total			**32.080**

Convection Coefficient Determination

There is no internal forced convection associated with the PIP. The external convection coefficients used in the thermal model for 14.7 psia module pressure was assumed to be 0.2 Btu/hr ft^2 F.

Analysis Results

The PIP thermal model was used to determine the temperature distribution of the PIP. It should be noted that in the PIP module is equipped with a thermal switch. The thermal switch is located on the Switch Board heat sink. The switch is set to trip at 122 °F with a +/- 3 °F tolerance. The unit was analyzed for nominal operations for 14.7 environment pressure conditions. Temperature results for nominal operations are summarized in Table 2.

The results for the nominal operation case indicate that there are no touch temperature or component temperature limit violations for 14.7 environmental pressures. The external walls are a maximum of 119.0 °F (14.7 psia) with a touch temperature limit of 120 °F. Individual components were not modeled, however, the heat dissipation associated with each component has been taken into account on a board level basis. The board temperatures are based on the total heat dissipation for the components on that board. Component temperatures are going to be higher than the predicted board temperatures. However, based on engineering judgment there are no components in danger of violating their temperature limits.

Table 2. PIP Analysis Temperature Results (14.7 psia)

Component	Max. Operating Temperature (°F)	Temperature Results (°F) Nominal Operations
Outer Walls	120 F (49 C)	119.0
Switch Board	212 F (100 C)**	161.0 (max)
Switch Board (Near Diodes 1&2)		161.0
Switch Board (Avg.)		128.0
Heat Sink (Avg.)		119.0
Heat Sink (Near Thermal Switch)	122 F (50 C)*	119.0
Control Board	158 F (70 C)**	124.0
Heat Sink		120.0
Filter Board	185 F (85 C)**	126.0

* Set point temperature for the Thermal Switch is 122 F +/- 3 F
** Lowest component temperature limit for that board.

A heat balance was performed on the PIP unit as a system check of the thermal model. A total of 32.08 Watts of heat is dissipated inside the unit. The heat balance was performed based on the nominal case for 14.7 psia pressure condition. The heat is removed from the unit by radiation and convection from the outer panels. The heat balance summary is shown in Table 3.

Table 3. 120 Vdc IPPS Heat Balance Summary (14.7 psia)

Heat Balance Summary	Heat Dissipation (W)
Heat Input	32.08
Heat Removed	
Radiation Outer Panels	-26.06
Convection Outer Panels	-5.53
Conduction (via seat track mounts)	-0.49
Net (Watts)	**0.00**

Summary
A thermal model of the Power Interface Panel (PIP) was used to predict the temperature distribution of the unit under 14.7 psia environmental pressure conditions. The PIP has a total heat dissipation of 32.08 Watts, which is located primarily on three circuit boards. In order to meet the touch temperature requirements on the external walls, it was necessary to add fins to the top and bottom plates of the PIP.

The PIP module is equipped with a thermal switch. The thermal switch is located on the Switch Board heat sink, which is mounted to the bottom external wall of the PIP. The switch is set to trip at 120 °F with a +/- 3 °F tolerance. The PIP unit does not violate touch temperature limits under normal operations for 14.7 psia pressure conditions.

Jerry D. Pantermuehl
Thermal Analysis Section

References:

1. Hardware Requirements Document (HRD) for the Human Research Facility (HRF) MARES Integration, Deployment, Assembly, and Stowage (MIDAS), LS-71090-1, Sect. 3.3.6.9, NASA JSC, December 2002.

2. Expedite the Processing of Experiments to Space Station (EXPRESS) Rack Payloads Interface Definition Document, SSP 52000-IDD-ERP, Sect 5, NASA JSC, May 1998.

3. Satellite Thermal Control Handbook, David G. Gilmore, The Aerospace Corporation Press, 1994

4. Email received from Ronald Bennett listing the heat dissipation for the three circuit boards located in the PIP module, July 11, 2003

Distribution:

C. J. Amberboy	/ LM	/	S363
R. Bennett	/ LM	/	S363
TDIC			S362
J. K. Cox	/ LM	/	C70
A. H. Milliken	/ LM	/	C70
E. Y. Azzi	/ LM	/	C70
J. D. Pantermuehl	/ HEI	/	C70

Task Order File