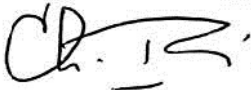



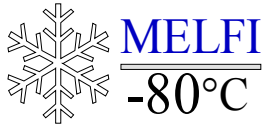
	Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01 Sept-2004 Page: i
---	---	--

<p>Title</p> <p style="text-align: center;">MELFI FLIGHT MODEL</p> <p style="text-align: center;">USER MANUAL</p>

	Name and Function	Date	Signature
Prepared by:	Ch. TADDEI	01/09/04	
Verified by:	J. CHEGANCAS	09/09/04	
Approved by:	J.L. COURTET	03/03/04	
Authorized by:	N/A		
Application Authorized by:	J.CHEGANCAS	09/09/04	



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

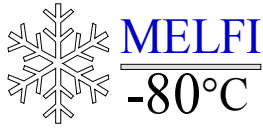
Date: 01-Sept-2004

Page: ii

SUMMARY

This document is the MELFI User Manual: equipment, sub-system and software are first described. Operating instructions are then provided for nominal operations. The preventive and corrective on-orbital maintenance is also described.

Document controlled by:



Ref: MELFI-MA-03000-0435-MMT

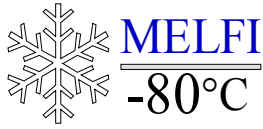
Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: iii

DOCUMENT CHANGE LOG

Issue/ Revision	Date	Modification Nb	Modified pages	Observations
01	23/01/01			First Issue; answers to CDR actions CON-1009; CON-2002; BM-1015
02	28/01/02		All	Update following system tests on FM1
03	17/12/02		All	Update following FM final launch configuration; answers to FAR RID ESA- 009; -051.
03 Rev 1	15/03/04			Update of sections 2.2, 3.5.2, 4, 5.1, 5.2.1, 5.5, 5.6, 6.3, 6.16, 7.1.1, 7.1.2, 8.2
04	01/09/04			<i>Update following FU2 Acceptance review 1 and associated RIDs: 22571, 22572, 22573, 22574, 22757, 22812, 22813, 22834, 22955, 22956, 22957, 23012</i>



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: iv

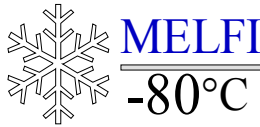
PAGE ISSUE RECORD

Issue of this document comprises the following pages at the issue shown

Page	Issue/ Rev.	Page	Issue/ Rev.	Page	Issue/ Rev.	Page	Issue/ Rev.	Page	Issue/ Rev.	Page	Issue/ Rev.
229 p	03										
229 p	03/01										
232 p	04										

TABLE OF CONTENTS

1	INTRODUCTION	13
2	DOCUMENTATION	13
2.1	APPLICABLE DOCUMENTATION	13
2.2	REFERENCE DOCUMENTATION.....	14
3	MELFI OVERVIEW	14
3.1	MELFI SUB-SYSTEM BREAKDOWN	21
3.2	BRAYTON SUBSYSTEM.....	23
3.3	DEWAR SUBSYSTEM.....	24
3.4	ELECTRICAL SUBSYSTEM.....	27
3.4.1	Power distribution and protections:	33
3.4.2	Power bus switching.....	34
3.4.3	Bonding and Grounding.....	36
3.4.4	Fire detection and isolation.....	39
3.5	RACK SUBSYSTEM.....	44
3.5.1	Mechanical supports and Ruck sack.....	45
3.5.2	MELFI Water Loop	46
3.5.3	Acoustic protections.....	49
3.6	UTILIZATION.....	51
3.6.1	Dewar outfitting.....	52
3.6.2	Interfaces for users or scientists.....	54
3.6.3	Dewar Airborne Support Equipment.....	56
3.6.4	Water bags.....	57
3.6.5	Desiccant.....	57
3.7	SOFTWARE	58
3.7.1	MELFI S/W overview and Payload Modes	59
3.7.2	Monitoring and Recovery and “Caution and Warning”	61
3.7.3	MELFI regulation algorithm.....	64
3.7.4	Management of the Dewars	65
3.7.5	Brayton Machine Motor Speed Control and Payload Power Consumption	66

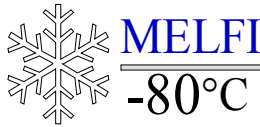


- 3.7.6 Main operations on Remote mode..... 69
- 3.7.7 Dewar activation / Invalid Dewar..... 70
- 3.7.8 Average Dewar temperature 72
- 3.7.9 Displays management..... 73
- 3.7.10 Synthesis of Crew panel behavior 74
- 3.7.11 MELFI Telemetry and Tele-commands 76

- 4 MELFI MISSION77**

- 5 MELFI OPERATING INSTRUCTIONS82**
- 5.1 MELFI CONFIGURATION FOR LAUNCH /RETURN..... 82**
- 5.2 MELFI COLD CONDITIONS SELECTION 83**
 - 5.2.1 Mode selection 83
 - 5.2.2 Standard Dewar Layout 86
 - 5.2.3 Dewar loading for 8 hour power-off : Water Bags utilization 87
- 5.3 MELFI NOMINAL OPERATIONS..... 100**
- 5.4 RULES FOR SAMPLE INSERTION 101**
- 5.5 PERFORMANCES GUIDELINES 102**
- 5.6 HANDLING /SPECIAL CARE..... 103**
- 5.7 TROUBLESHOOTING 104**

- 6 HARDWARE DESCRIPTION.....107**
- 6.1 ELECTRONIC UNIT..... 107**
 - 6.1.1 Crew Panel Interface 109
 - 6.1.2 Control and Data Handling Unit..... 112
 - 6.1.3 Power Supply Unit..... 113
 - 6.1.4 Motor Drive Electronics..... 114
 - 6.1.5 EU mechanical design 117
 - 6.1.6 ORU operations 118
- 6.2 STOWAGE COMPARTMENT 123**
- 6.3 DEWAR ASE..... 125**



6.4 NITROGEN FILL & PURGE EQUIPMENT (NFPE)..... 132

6.5 BRAYTON MACHINE EXCHANGE EQUIPMENT AND CONTAINMENT 135

6.5.1 Brayton Airborne Support Equipment..... 136

6.5.2 BMEE accommodation..... 137

6.6 COLD BOX..... 146

6.7 BRAYTON MACHINE CARTRIDGE..... 151

6.8 COLD BOX FRONT PANEL..... 161

6.9 DEWARS 163

6.9.1 Dewar Door 167

6.9.2 Cross Structure 170

6.9.3 Tray..... 172

6.9.4 Box Modules 176

6.9.5 Sample Holders 187

6.10 THERMAL BAG 191

6.11 FOAM PLUG..... 193

6.12 UTILITY INTERFACE PANEL (UIP)..... 194

6.13 PASS-THROUGH PANEL..... 194

6.14 RIU SWITCH BOX..... 197

6.15 RACK INTERFACE UNIT (RIU)..... 198

6.16 TEMPERATURE DATA RECORDER 202

6.17 TUBING..... 205

6.17.1 Cold Gas Regulation Valve 208

6.17.2 Load Heat Exchanger..... 209

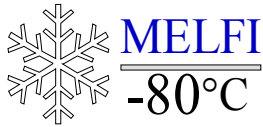
7 MAINTENANCE.....211

7.1 CORRECTIVE IN-FLIGHT MAINTENANCE..... 211

7.1.1 Electronic Unit replacement 212

7.1.2 Brayton Machine replacement..... 214

7.1.3 Dewar De-icing /De-Frosting 218



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: viii

7.1.4	Nitrogen replenishment	219
7.1.5	RIU fuse replacement	219
7.1.6	TDR battery pack replacement.	220
7.2	PREVENTIVE IN-FLIGHT MAINTENANCE	220
7.2.1	Pressure check of NFPE N2 bottle.....	220
7.3	PREVENTIVE ON-GROUND MAINTENANCE	221
8	STOWAGE AND LOOSE ITEMS	226
8.1	STATION TOOLS	226
8.2	MELFI LOOSE ITEMS	227
9	ACRONYMS	230

LIST OF FIGURES and TABLES

<i>Figure 3.1 – 1: MELFI External Interfaces description</i>	<i>16</i>
<i>Table 3.1 – 1: MPLM and ISS services for MELFI.....</i>	<i>17</i>
<i>Figure 3.1 – 2: MELFI Functional block diagram</i>	<i>18</i>
<i>Figure 3.1 – 3: MELFI Front View Schematics.....</i>	<i>19</i>
<i>Figure 3.1 – 4: MELFI Flight Model with Acoustic Pad and both Tissue Panels.....</i>	<i>20</i>
<i>Figure 3.2 – 1: Brayton Cycle Schematics.....</i>	<i>24</i>
<i>Figure 3.3 – 1: Dewar identification</i>	<i>26</i>
<i>Figure 3.3 – 2: Dewar Tray identification.....</i>	<i>26</i>
<i>Figure 3.4 – 1: MELFI Electrical S/S architecture.....</i>	<i>28</i>
<i>Figure 3.4 – 2: MELFI downstream protection characteristics</i>	<i>29</i>
<i>Figure 3.4 – 3: Over-current protection (MPLM configuration).....</i>	<i>31</i>
<i>Table 3.4 – 1: MELFI Electrical characteristics</i>	<i>32</i>
<i>Table 3.4 – 2: MAIN / AUX power bus switching</i>	<i>35</i>
<i>Figure 3.4 – 4: MELFI grounding diagram.....</i>	<i>38</i>
<i>Figure 3.4 – 5: Fire event suppression – CO2 path on Rack rear</i>	<i>43</i>
<i>Figure 3.5-1: MELFI Rack Sub-System</i>	<i>45</i>
<i>Figure 3.5-2: MELFI Water Loop Diagram</i>	<i>48</i>
<i>Figure 3.5-3: Location of acoustic protections inside the Rack.....</i>	<i>49</i>
<i>Figure 3.5-4: Acoustic protections in front of the BSS (detail).....</i>	<i>50</i>
<i>Figure 3.5-5: Acoustic protections in front of Brayton machine</i>	<i>51</i>
<i>Figure 3.6-1: Possible internal layout for a Box module.....</i>	<i>52</i>
<i>Figure 3.6-2: Empty Tray</i>	<i>53</i>
<i>Figure 3.6-3: Tray with Box Modules (1/4 size and 12 size)</i>	<i>53</i>
<i>Figure 3.6-4: Internal view of box Modules (1/4 & 1/2 sizes) when opened</i>	<i>54</i>
<i>Figure 3.6-5: Vial Card</i>	<i>55</i>
<i>Figure 3.6-6: Contact Card</i>	<i>56</i>
<i>Figure 3.6-7: Desiccant bags onto the EU</i>	<i>58</i>
<i>Figure 3.7.1-1: MELFI Modes.....</i>	<i>61</i>
<i>Table 3.7.2 - 1: Structure of Monitoring Status Word and Recovery Set-up Word.....</i>	<i>62</i>
<i>Table 3.7.2 – 2: Caution and Warning thresholds</i>	<i>63</i>
<i>Table 3.7.5 - 1: Relationship Maximum Power / Maximum Speed</i>	<i>67</i>
<i>(MELFI Beginning of Life).....</i>	<i>67</i>
<i>Table 3.7.5 - 2: Relationship Maximum Power / Maximum Speed</i>	<i>67</i>
<i>(MELFI End of Life)</i>	<i>67</i>
<i>Table 3.7.10 – 1: Synthesis of CPI behavior.....</i>	<i>75</i>
<i>Table 5.2-1. 1: On-orbit commissioning criteria for Dewar average temperature.....</i>	<i>85</i>
<i>Table 5.2-1: Minimum electrical power for each mode.....</i>	<i>87</i>
<i>Figure 5.4-1: Box Module position inside a Tray</i>	<i>101</i>
<i>Figure 6.1 - 1: Electronic Unit layout.....</i>	<i>108</i>
<i>Figure 6.1 - 2: Electronic Unit overview with its functional units.....</i>	<i>108</i>
<i>Figure 6.1 - 3: Crew Panel Interface.....</i>	<i>110</i>
<i>Figure 6.1 - 4: CPU block diagram</i>	<i>113</i>
<i>Figure 6.1 – 5: Power Supply Unit block diagram</i>	<i>114</i>
<i>Figure 6.1-6: MDE Block Diagram</i>	<i>116</i>
<i>Figure 6.1 - 7: Electronic Unit Top View</i>	<i>117</i>

Figure 6.1 - 8: Electronic Unit Side View (left side).....	118
Figure 6.1- 9: MDE Cable routing below the EU.....	119
Figure 6.1 - 10: Details of the EU connector parking	120
Figure 6.1 - 11: Details of the EU: QDs and end-stop	121
Figure 6.1 - 12: Star Handles	121
Figure 6.1 - 13: EU QD Mating Tool	122
Figure 6.1 - 14: Top view of the spare EU, showing the WED	122
Figure 6.2-1: Stowage compartment internal layout	123
Figure 6.2 - 2: Stowage compartment internal layout	124
Figure 6.2 - 3: Stowage Compartment Door	124
Figure 6.3-1: Tray Handle.....	126
Figure 6.3 - 2: Ice-scrappers set.....	127
Figure 6.3-3: Sleeve.....	128
Figure 6.3 - 4: Internal layout of the bag.....	129
Figure 6.3 - 5: TDR Battery Packs (Only one is stored into the DASE Pouch).....	130
Figure 6.3 - 6: Triple Square M6 and M4 Tools stored into the DASE Pouch.....	130
Figure 6.3 - 7: Crowfoot tool stored in the DASE Pouch.....	131
Figure 6.3 - 8: DASE Pouch inside Stowage Compartment.....	131
Figure 6.4-1: NFPE Functional Schematics.....	133
Figure 6.4-2: Nitrogen Fill and Purge Equipment Top View	134
Figure 6.5-1 : Brayton ASE Container inside Stowage Compartment.....	136
Figure 6.5 - 2: BMEE in BASE Container (Top View).....	138
Figure 6.5 - 3: FMI BMEE in BASE Container (Top View).....	139
Figure 6.5 - 4: BM ASE Interface cylinder with its black cap	140
Figure 6.5 - 5: Failed Brayton Machine Container.....	142
Figure 6.5 - 6: Brayton Machine blocking device.....	142
Figure 6.5 - 7: Gearbox Assembly.....	143
Figure 6.5 - 8: details of the gearbox.....	144
Figure 6.5 - 9: Brayton Machine Hook.....	144
(Mounted on the BM front face).....	144
Figure 6.5 - 10: BMEE mounted on the Cold Box (side view).....	145
Figure 6.6-1: Cold Box and Nitrogen Loop schematics.....	149
Figure 6.6 - 2: Cold Box internal view	150
Figure 6.7-1: Brayton Machine main parts	153
Figure 6.7 - 2 : Brayton Machine front face	154
Figure 6.7 - 3: Brayton Machine antipollution circuitry	156
Figure 6.7 - 4: Brayton Machine shaft.....	159
Table 6.7- 5: Brayton S/S Telemetry.....	160
Figure 6.8-1: Cold Box front panel.....	161
Figure 6.8-2: Acoustic protections in front of BSS after CB Front panel removal.....	162
Figure 6.8-3: Brayton machine front face access after acoustic protections removal.....	162
Figure 6.9-1: Dewar internal layout and main components.....	164
Figure 6.9 - 2: Side view of an open Dewar with extracted trays	165
Figure 6.9 - 3: Location of Dewar thermal sensors.....	167
Figure 6.9 - 4: Dewar door design	169
Figure 6.9 - 5: Dewar FMI inside Rack	170
Figure 6.9 - 6: The Internal Outfitting of a single Dewar.....	171
Figure 6.9 - 7: Internal view of a Dewar showing the cross-structure	171
Figure 6.9 - 8: Tray (without foam block)	173
Figure 6.9-9: Velcro Hooks patch on Tray.....	174
Figure 6.9-10: Cross section of Tray.....	175
Figure 6.9-11: Tray edge for sample module interface.....	176

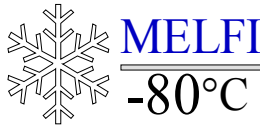


Figure 6.9-12: 1/4 size Box Module..... 177

Figure 6.9-13: 1/2 size Box Module..... 178

Figure 6.9-14: Position of Velcro on Box Module..... 178

Figure 6.9-15: Lid pivot mechanism..... 179

Figure 6.9-16: Lid locking Mechanism..... 180

Figure 6.9-17: Lid lock Dial - open and closed positions..... 180

Figure 6.9-18: Locking mechanism in open position..... 181

Figure 6.9-19: Box Module locking mechanism..... 182

Figure 6.9-20: Box Module Elastics for securing Vial Cards & Bags..... 183

Figure 6.9-21: 1/4 Receiving Box Module, internal side view..... 185

Figure 6.9-22: 1/4 Receiving Box Module, top view..... 185

Figure 6.9-23: External view of 1/4 Receiving Box Module..... 186

Figure 6.9-24: 1/4 Receiving Box Module filled with a Contact Card and 2 Fixed Bottle Holders..... 186

Figure 6.9-25: Contact Card & Fixed Bottle Holder in 1/4 Receiving Box Module..... 187

Figure 6.9-26: Vial Bag..... 189

Figure 6.9-27: Vial Card..... 189

Figure 6.9-28: Contact Card..... 190

Figure 6.10-1: Thermal Bag (shown with Tray inside)..... 191

Figure 6.10-2: Transfer of a Tray into the Thermal Bag..... 192

Figure 6.11-1: Foam Plug..... 193

Figure 6.13-1: Water valve on Pass Through panel (PTP)..... 195

Figure 6.13-2: Pass-through panel with MELFI utilities connected at UIP..... 196

Figure 6.13-3: Pass-through panel with MELFI utilities restrained (passive launch)..... 196

Figure 6.14-1: RIU Switch Box..... 197

Figure 6.15-1: Rack Interface Unit Block Diagram..... 199

Figure 6.15-2: Rack Interface Unit Power Bus Pre-selection Block Diagram..... 200

Figure 6.15-3: Power Bus Selector Block Diagram..... 201

Figure 6.15-4: Rack Interface unit inside rack FMI..... 201

Figure 6.16-1: Temperature data recorder (revolving cover is shown opened)..... 205

Figure 6.17-1: Nitrogen Tubing..... 207

Figure 6.17-2: Cold Gas Regulation Valve..... 209

Table 7.1-1: Minimum bolts on ORU..... 213



Table 7.1-2: Minimum bolts on ORU..... 215

Table 7.1-3: Filling pressures versus elapsed time since Brayton Machine failure..... 216

Figure 7.1-4: Schematics for Brayton Machine exchange operations..... 217

Figure 7.3-1: Synthesis of MELFI Ground Preventive Maintenance frequency per Flight Model Equipment:..... 222

Table 8.2 - 1: MELFI loose items list..... 227



		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: xii
---	---	--

FOREWORD

This document is the MELFI Flight Model User Manual and was written following the guidelines from the ESA Document Requirement Description E09 for Payload User Manual and E14 for Payload Operations Manual (On-board).

It describes the technical features of the MELFI and the resources supplied to the user. It also contains a description of interfaces and information relevant to the experimenter as well as the detailed instructions to perform on-orbit nominal and off-nominal operations.

The content of this document shall be available on-board in electronic format.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 13
---	---	---

1 INTRODUCTION

The Minus Eighty Degree Laboratory Freezer for the International Space Station provides low temperature cooling and storage of biological material, reagents and perishable items in the United States Laboratory on board the Space Station. It will be transferred from the Mini-Pressurized Logistics Module (MPLM) in the Space Shuttle cargo bay and be installed in the Station.

The on-orbit mission could last up to two years. MELFI features on-orbit maintainability for its main constituents (e.g. the Brayton machine and the Electronic Unit). This design allows MELFI to support up to 15 missions lasting from 3 up to 24 months.

Cold storage is maintained during pre-launch and post-landing ground processing of the experiment samples. MELFI allows quick sample retrieval using dedicated ground support equipment.

The scope of the MELFI Flight Model User Manual is to provide detailed documentation, data and instructions for nominal and off-nominal on-orbit operations of the MELFI. It also includes the necessary information to achieve on-orbit maintenance. The User manual is composed of the following sections:



- MELFI overview: payload descriptions, functional block diagrams, software description and S/S breakdown including S/W description,
- Operating instructions: cold conditions selection, performances warning, handling precautions, and troubleshooting.
- Hardware description: each MELFI H/W item or equipment is described including functional diagram or schematics,
- Maintenance instructions: instructions for preventive maintenance and corrective maintenance are provided
- Special tools: list of special tools and equipment recommended for the preventive or corrective maintenance
- Loose items: list of MELFI loose items
- Glossary and acronyms section

2 DOCUMENTATION

2.1 APPLICABLE DOCUMENTATION

The applicable documentation is listed hereafter:

- AD1: MELFI System Specification, MELFI-SP-33000-435-MMT, latest issue
- AD3: MELFI Hardware Interface Control Document, SSP 57212

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 14
---	---	---

AD4: MELFI Thermal Analysis Report, MELFI-RP-03000-0323-MMT

AD5: MELFI Flight Safety Data Package Level III, MELFI-TN-03000-0509-MMT

2.2 REFERENCE DOCUMENTATION

The reference documentation is the following one:

RD1: MELFI On- Orbit crew procedures, MELFI-PR-03000-0434-MMT

RD2: MELFI Software User Manual, MELFI-MA-03000- 0436-MMT

RD3: MELFI Design Definition Report, MELFI-DDR-03000- 0049-MMT

In case of conflict, the MELFI User Manual supersedes the MELFI Design Definition Report.

3 MELFI OVERVIEW

The Minus Eighty Degree Laboratory Freezer for the International Space Station serves as a cooling and low temperature storage facility used to preserve experiment specimen, samples and supplies until they are used on-orbit or returned to the ground to be analyzed. It is the freezer requested by NASA/ESA as a Laboratory Support Equipment (LES) of the Space Station.



The MELFI system is based on a Brayton cycle refrigeration machine, which supplies cold gaseous nitrogen to insulated cold enclosures, which are Dewar type containers.

The MELFI performances were tailored to fulfill the scientific community requirements and correspond to three selectable operating modes:

- ☐ +4°C mode
- ☐ -26°C mode
- ☐ -80°C mode

Actually, the MELFI was designed to mainly operate @ -80°C mode with capabilities to provide a Dewar at a higher operating mode, if necessary. Please refer to section 5 of this document for details on the selection of +4°C or -26°C modes.

The MELFI is integrated in a 6 post IHI – NASDA Rack and provides four independent thermally insulated units, i.e. the MELFI Dewars where the science material is stored in cold conditions. Cold

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 15
---	---	---

production is ensured by the Brayton Machine and distributed to each Dewar. Nitrogen gas at low pressure is the cooling media flowing through Dewars valves which allow thus to control the gas flow in each Dewar.

The MELFI is managed by the Electronic Unit, which houses the MELFI S/W. The payload is designed for remote control but the Crew can also operate it if necessary: directly from the Electronic Unit front panel, also called the Crew Panel Interface (CPI), or through the Portable Computer System (PCS).

The Stowage Compartment contains the Airborne Support Equipment (ASE) which is necessary to the MELFI preventive maintenance (Dewar de-icing) and corrective maintenance (spare Brayton machine).

The MELFI units will be alternately used in the USL, CAM, and JEM and in the MPLM

The ISS System Interfaces at the Utility Interface Panel (IUP) are the following:

- Main power 120 V (J1) – primary power
- Auxiliary power 120V (J2) – redundant power
- FDS / MAINT (J43) – Interface with Rack Maintenance Switch capability to disable power to rack during maintenance
- 1553B – A (J3) – Command and data bus
- 1553B – B (J4) – Redundant Command and Data bus
- Temperature thermal Control System (TCS) Low Temperature Supply Water Loop

All the external interfaces of the MELFI system are described in Figure 3.1 –1 and the Table 3.1 – 1 provides the rack resources provided by the MPLM or the ISS

The MELFI Functional block diagram is represented in figure 3.1 – 2

The MELFI accommodation inside a 6-post Rack is depicted in figures 3.1 – 3 and 3.1 – 4.

The total electrical power allocated to MELFI is between 550 W and 900W but can be extended to 950 W in transient cases.

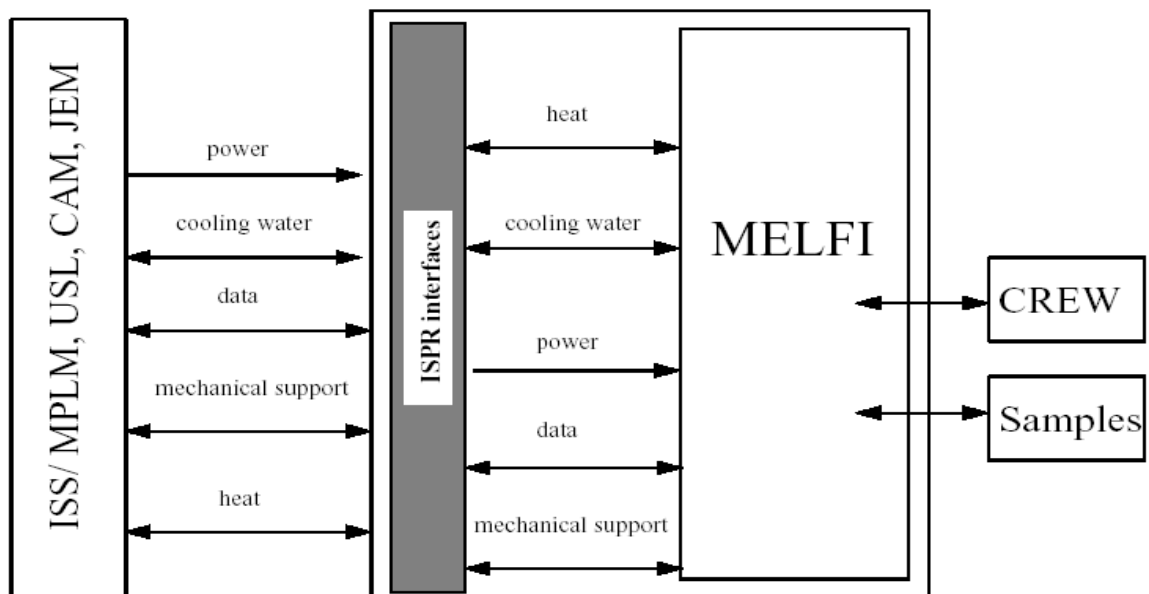
The total mass of a fully loaded MELFI is 794 kg including both ORUs and up to 100 kg for samples, distributed into 76 kg for science material and 24 kg for sample accommodation H/W (Box Modules, Contact cards, Vial bags and Vial cards).

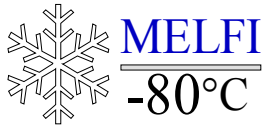
The MELFI system features safety provisions:

- Inert gas (N2) for cooling cycle gas

- Low pressure gas (close to ambient pressure) to simplify the Brayton Machine replacement operations
- Brayton Machine is physically contained for fracture control
- Thermal safety loop which switches off MELFI in case of overheating detection on electronics.

Figure 3.1 – 1: MELFI External Interfaces description





Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 17

MPLM services				
Late access	Power	Cooling	Data	Stowage
X	X	X	X	-

ISS services														
Power			UOP	Keep Alive	Data			Video	Cooling		Gases	Vacuum	Fluids	Stowage
3 kW	6 kW	12kW			LRDL	MRDL	HRDL		LTL	MTL				
X	-	-	-	X	X	-	-	-	X	-	-	-	-	-

Table 3.1 – 1: MPLM and ISS services for MELFI

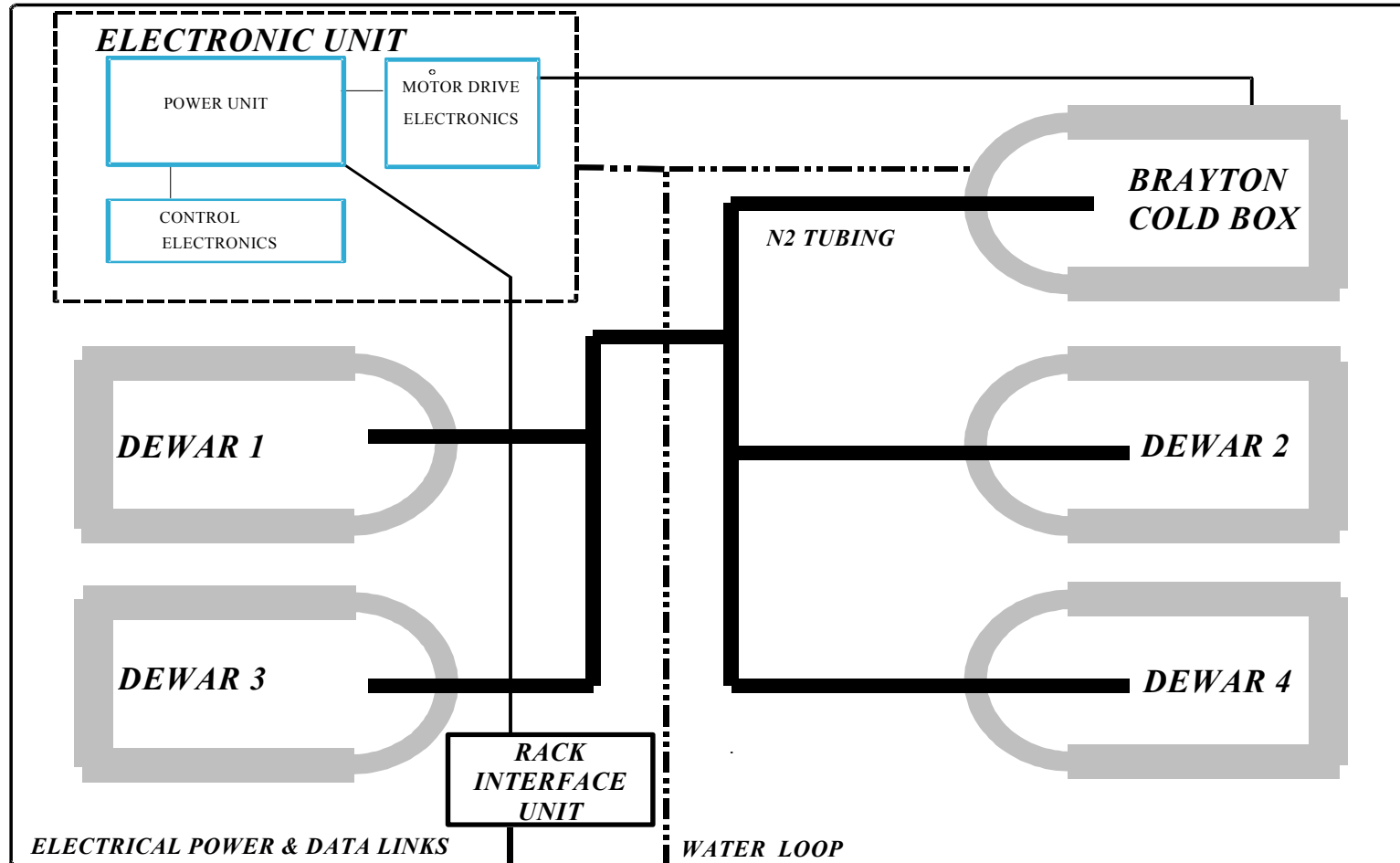


Figure 3.1 – 2: MELFI Functional block diagram

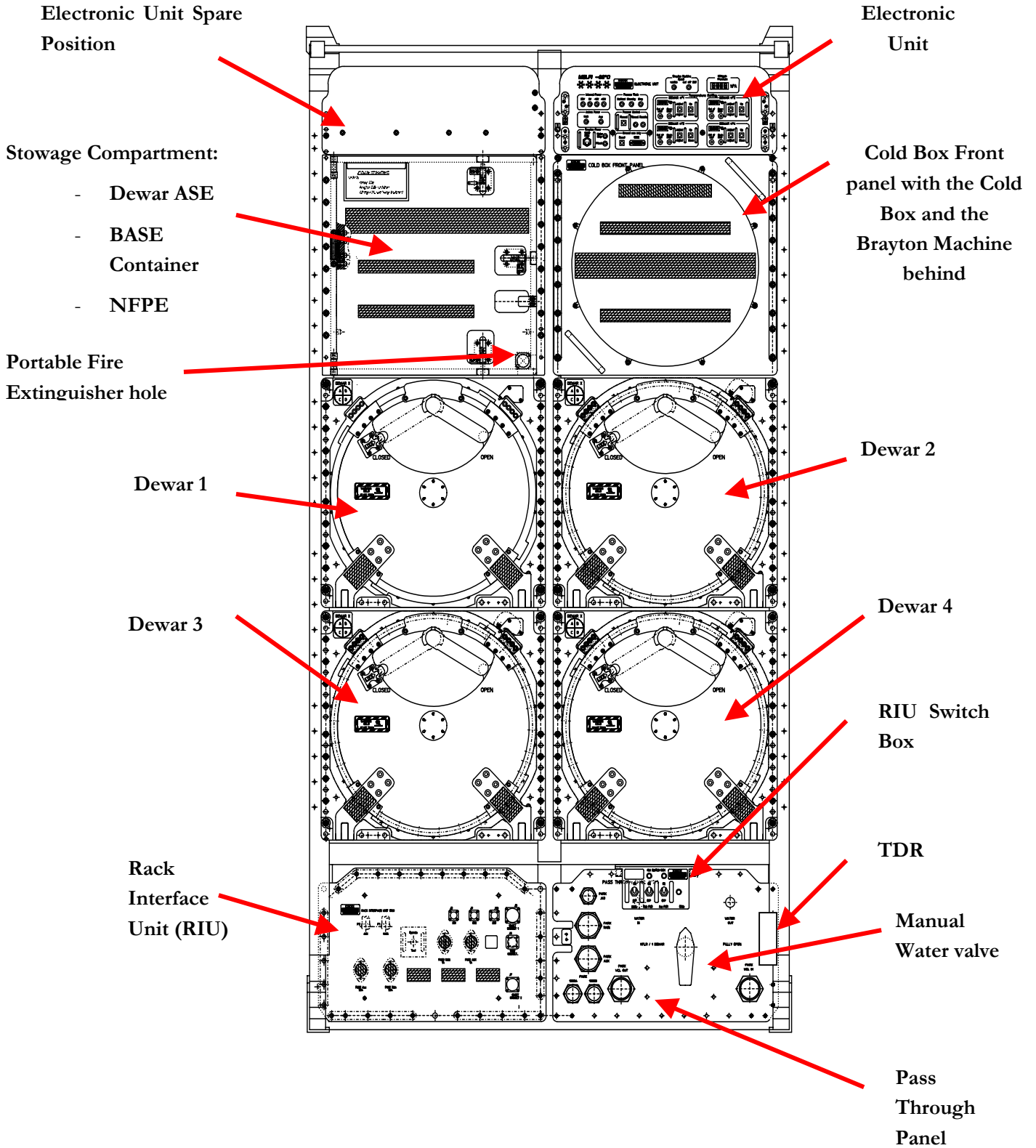


Figure 3.1 – 3: MELFI Front View Schematics

EU Tissue
Panel

Acoustic
Pad

Rack
Closeout
Tissue

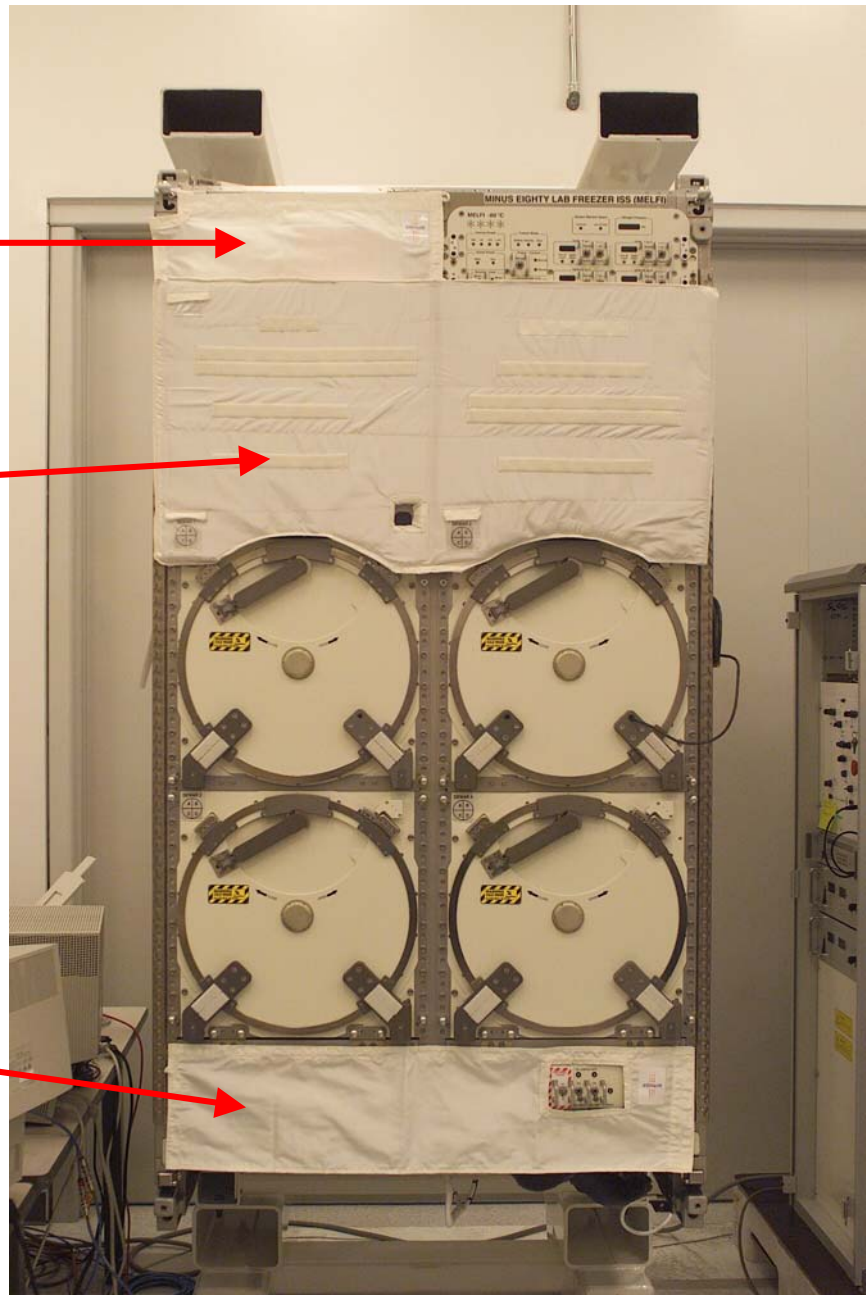


Figure 3.1 – 4: MELFI Flight Model with Acoustic Pad and both Tissue Panels

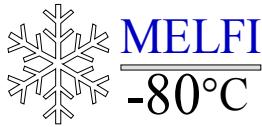
3.1 MELFI SUB-SYSTEM BREAKDOWN

The MELFI consists of the following subsystems:

- Brayton subsystem (BSS): produces cooling
- Dewar subsystem (DSS): distributes cooling and provides the cold volume
- Electrical subsystem (ESS): provides power and command / control
- Rack subsystem (RSS): provides mechanical accommodation for other sub-systems and the Stowage compartment
- Utilization (UTI): provides accommodation for samples and also supports the on-orbit crew operations
- Software (SW): centralized and housed by the electronic unit.

Each subsystems is constituted of the following equipments or H/W item as listed in the table below; storage locations are also indicated since not all the MELFI H/W is integrated into the MELFI rack:

MELFI H/W item list	Sub-system	Location
Rack IHI	RSS	MELFI Rack
Mechanical supports	RSS	MELFI Rack
Water Loop	RSS	MELFI Rack
Rucksack	RSS	MELFI Rack
Harness	RSS	MELFI Rack
Electronic Unit blind panel	RSS	MELFI Rack
Cold Box front panel	RSS	MELFI Rack
Acoustic protections	RSS	MELFI Rack
Acoustic pad	RSS	MELFI Rack
Stowage Compartment	RSS	MELFI Rack
Brayton Airborne Support Equipment (BASE) Container	RSS	MELFI Rack



Ref: MELFI-MA-03000-0435-MMT



Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 22

Brayton machine exchange equipment (BMEE)	BSS	MELFI Rack
Nitrogen Fill and Purge Equipment (NFPE)	BSS	MELFI Rack
Dewar Airborne Support Equipment (DASE) incl. tools	DSS	MELFI Rack
Cold Box	BSS	MELFI Rack
Brayton Machine	BSS	MELFI Rack
Brayton Machine spare	BSS	MELFI Rack
Tubing	DSS	MELFI Rack
Dewar (4)	DSS	MELFI Rack
Tray (16)	DSS	MELFI Rack
Box modules (8 BM ½ size and 48 BM ¼ size)	UTI	MELFI Rack
Contact cards	UTI	MELFI Rack
Vial bags	UTI	MELFI Rack
Vial cards	UTI	MELFI Rack
Electronic Unit	ESS	MELFI Rack
Electronic Unit spare	ESS	MELFI Rack
Rack Interface Unit (RIU)	ESS	MELFI Rack
Temperature Data Recorder (TDR)	ESS	MELFI Rack
RIU Switch Box	ESS	MELFI Rack
Pass-Through Panel	RSS	MELFI Rack
UIP Tissue Panel	RSS	MELFI Rack
EU Tissue Panel	RSS	MELFI Rack
Thermal bag	UTI	ISS stowage
Foam plug	UTI	ISS stowage

Each S/S is described hereafter:

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 23
---	---	---

3.2 BRAYTON SUBSYSTEM

The Brayton Subsystem consists of:

- A Brayton Machine,
- A Cold Box which houses the Brayton Machine

The electronics that drives the Brayton Machine is called the Motor Drive electronics. It is physically integrated onto the Electronic Unit and is part of the Electrical Sub-system described in section 3.4.

The hardware necessary for the on-orbit replacement of a Brayton Machine is called the Brayton Airborne Support Equipment (BASE). It is composed of:

- A Brayton Machine Exchange Equipment (BMEE) which contains the spare Brayton Machine
- A Nitrogen Fill and Purge Equipment (NFPE) which allow to flush out the Nitrogen gas (Brayton Machine extraction from the Cold Box) and to refill the cycle when the spare Brayton Machine is inserted into the Cold Box

The Brayton ASE (BASE) is accommodated inside the Stowage Compartment.

Cold power production:

A refrigeration machine based upon the Brayton cycle produces the MELFI cold power. The thermodynamical cycle utilizes nitrogen gas as the cooling fluid and operates at low pressure (Figure 3.2-1). The expander and compressor wheels are mounted on the same shaft. The shaft runs at up to 90 000 rpm to achieve the performance required.

The nitrogen gas comes into the machine at ambient pressure and temperature. It is then compressed in the turbo-compressor up to a 400-mbar-pressure increase. The heat produced by the compression is released in a Water Heat Exchanger (WHX), which cools the gas down to the ambient temperature. Then, the gas temperature is decreased by its flow through the Cycle Heat Exchanger (CHX) against the gas return flow coming back from the Dewars.

Finally, the gas expands in the turbine where its pressure drops and thus its temperature decreases down to about -90°C.

The machinery, with the Brayton Machine itself and both heat exchanges (WHX and CHX), is contained in one module called the Cold Box.

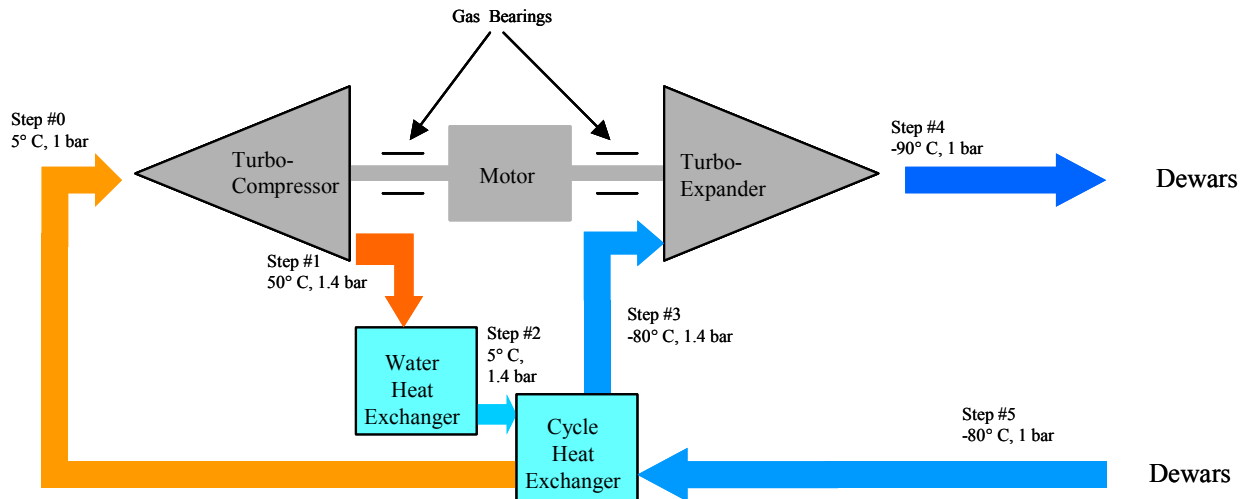


Figure 3.2 – 1: Brayton Cycle Schematics

The Brayton cycle is depicted in Figure 3.2 – 1.

The gas is dry and clean nitrogen (purity is 99.9999 %).



The gas is compressed (step 0 - 1) up to 1.4 bar, pre-cooled in a heat rejection heat exchanger (step 1 – 2), cooled further in a counter-current flow cycle heat exchanger (step 2 - 3), with the help of the low pressure circuit (step 5 – 0), expanded to low pressure in a turbine (step 3 – 4), heated as it provides the cooling power to Dewars (step 4 – 5) and heated again in the previously mentioned counter current cycle heat exchanger (step 5 – 0) as it cools down the high pressure gas (step 2 – 3).

Temperatures and pressures provided in the above diagram are indicative ones. Their exact value depends on the Brayton Machine speed and also on the Water temperature at the Water Heat Exchanger inlet and on the Dewar heat leaks.

3.3 DEWAR SUBSYSTEM

The Dewar subsystem is composed of:

- Identical Dewar assemblies (4), providing a storage temperature from -80°C up to +4°C inside thermally insulated cold enclosures

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 25
---	---	---

- An internal out fitting, i.e. a cross structure which supports four trays. Each tray will accommodate 1 or 2 types of sample box module(s),
- A cold gas loop, i.e. the nitrogen tubing, which distributes the cooling nitrogen gas to the Dewars.

Independent flow restriction valves allow separate control of each Dewar temperature. If one Dewar is empty it can be left at ambient temperature, the valve being closed so that no heat load is required from the Brayton subsystem. So the power required by MELFI can be optimized according to the number of active Dewar(s): if all the Dewars are not filled at the same time the system does not need the maximum specified power. Moreover in case of failure on one Dewar, the samples could be transferred to the other three that remain fully operational.

Each Dewar can be independently controlled with some restrictions on the number and location of Dewars @ +4°C or -26°C, according to the definition of the three operating modes:

- -80°C mode, where the temperature of contained specimens shall not in any case be higher than -68°C,
- -26°C mode, where the specimen temperature shall remain within the range -23°C to -37°C,
- +4°C mode, where the specimen temperature shall remain within the range +0.5°C to +6°C.

However, not any Dewar can be set at +4°C or -26°C mode, see section 5.2 for details.

The purpose of the cold nitrogen gas loop is to bring the refrigeration power generated in the Brayton machine into the Dewars. It consists of a vacuum insulated Tubing which connects the Brayton subsystem to the Dewars and is located in the rear of the MELFI. The tubing is ended by four cold fingers, which penetrate in the Dewars in order to provide them with refrigeration power. The external Nitrogen tubing is attached to the structure of the ISPR with specific brackets.

The Dewars are accommodated in the lower part of the rack where there is the maximum depth available. Their size has been defined in order to get the largest volume for the specimen cold storage. From left to right and top to bottom, the Dewars are referenced as Dewar 1, Dewar 2, Dewar 3 and Dewar 4(Figure 3.3 –1).

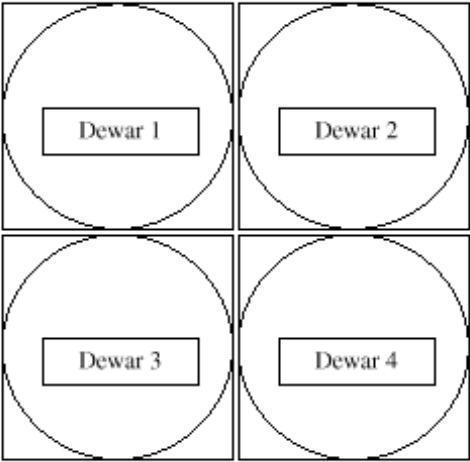


Figure 3.3 – 1: Dewar identification

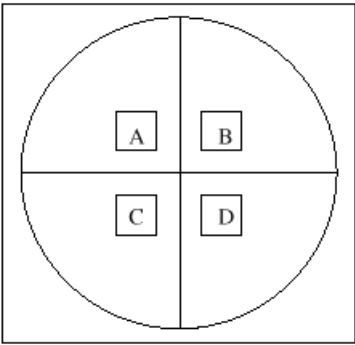




Figure 3.3 – 2: Dewar Tray identification

Each Dewar is a separate module integrated in the Rack as a self-standing unit. All Dewars are outfitted with trays, box modules, vial cards and vial bags to accommodate samples of various sizes. A Dewar houses four trays that fit to the length of the Dewar and hold the box modules and sample accommodation H/W in place. Letters (A, B, C and D) indicate each Tray slot as shown in figure 3.3 – 2.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 27
---	---	---

3.4 ELECTRICAL SUBSYSTEM

The Electrical subsystem is in charge of the control of the overall MELFI system and of the supply of electrical power to the Brayton Machine Motor and control electronics.

The MELFI electrical subsystem (ESS) is composed of the following main items:

- The Electrical Unit (EU) which gathers:
 - The Power Supply Unit (PSU),
 - The Control and Data Handling Unit (CDHU); this item includes a CPU board and I/O modules mounted on VME baseboards,
 - The Motor Drive Electronic (MDE),
 - The Crew panel Interface (CPI),
- The Rack Interface Unit (RIU)
- The RIU Switch Box
- The Temperature Data Recorder (TDR)

The Power Supply Unit, the Control and Data Handling, the Motor Drive Electronic (MDE) and the Crew panel Interface (CPI) are gathered in the Electrical Unit (EU), which is designed as an Orbit Replaceable Unit (ORU). The nominal Electronic Unit and the spare Electronic Unit are located at the top of MELFI.

The Power Supply Unit (PSU) interfaces with the Station or MPLM power bus and supplies the MELFI elements with the necessary electrical power. In case of Space Station power system reconfiguration, the electrical power supply interface automatically selects the active power bus, in order to continue nominal operations without requiring crew intervention.

The Electrical Unit interfaces software with the CPU board and provides hardware resources for code execution (memory, processor, control features as a watchdog..). The CDHU as part of the Electrical Subsystem is able to acquire and command all others MELFI subsystems (use of I/O boards) and provides this information to the software, which interfaces, to the ISS – Payload MDM.

The front panel (CPI) of the Electronic Unit is in fact the crew panel of MELFI, providing local command and monitoring of functions as power on/off, temperature setting and monitoring.

The RIU Switch Box accommodates the MAIN and AUX power switches, the RMSA switch.

The Rack Interface Unit accommodates the electrical interfaces towards Utility Interface Panel outside MELFI.

The Motor Drive Electronic (MDE) belongs functionally to the Electronic Unit but is treated apart because of its specific function. The MDE receives its commands from the Control and Data Handling Unit and sends power to the motor phases accordingly.

The TDR acquires the temperature of each Dewar during un-powered phase in order to record the temperature the science material was exposed to.

The architecture of the MELFI Electrical S/S is depicted in Figure 3.4 – 1.

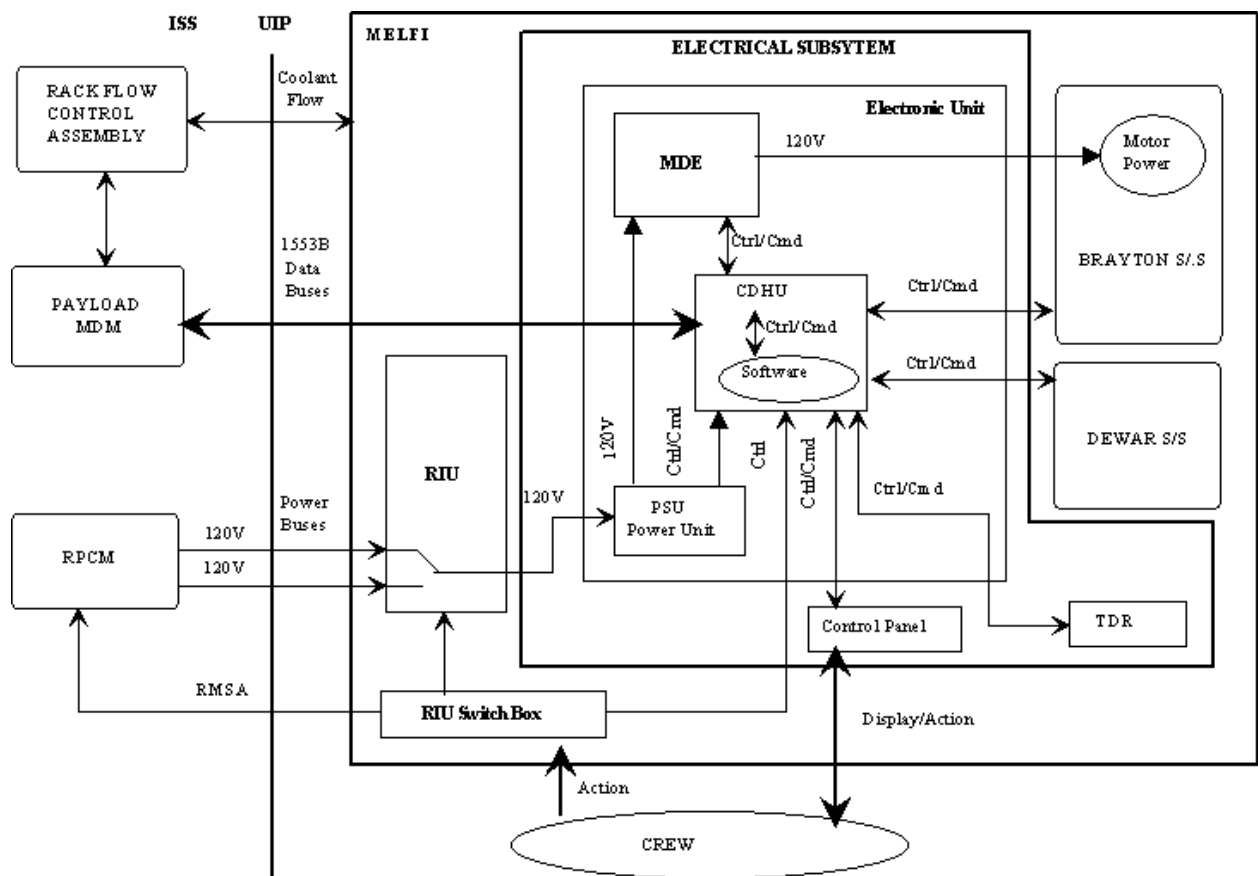


Figure 3.4 – 1: MELFI Electrical S/S architecture

The MELFI Rack power consumption and current draw is defined in Table 3.4 –1.

The MELFI downstream protection characteristics are given in the Figure 3.4 –2:

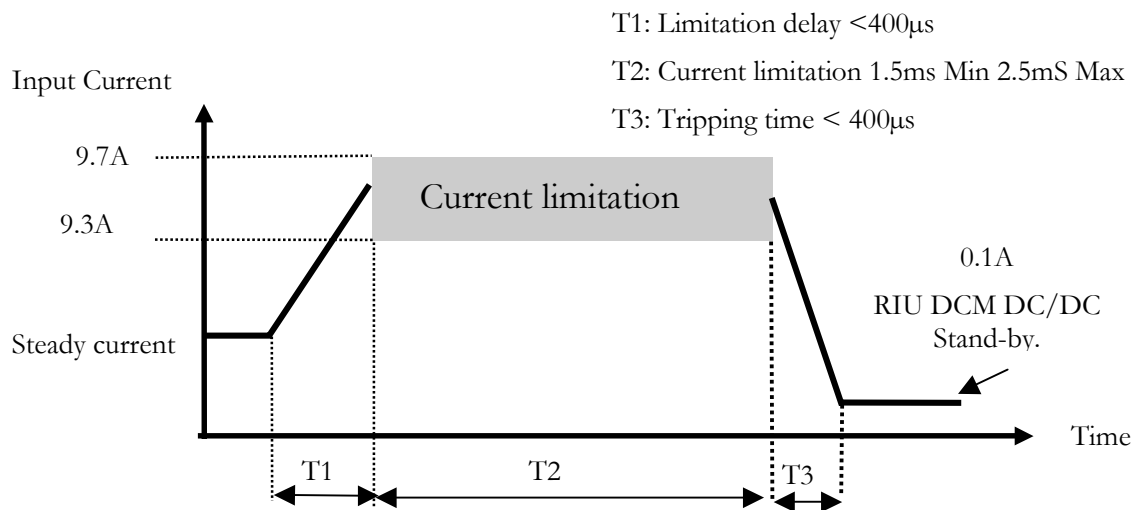



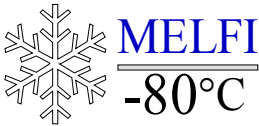
Figure 3.4 – 2: MELFI downstream protection characteristics

The MELFI design for current limitation is based upon the following constraints:

- Highest possible protections to use maximum available power in MPLM
- A single current limitation in MELFI should not induce the tripping of RPCM protections on MPLM side (MPLM protections are at a minimum of 9.8A).

This leads to the following features for the MELFI:

- A current breaker limits MELFI current to 9.5 A +/- 0.2 A as soon as there is an over-current for 1.5 to 2.5 ms
- The current breaker trips down to 0.1 A if the over-current exceeds this duration
- In case of tripping, the MELFI power switch should be set in the down position (by crew or RPCM) to restart MELFI

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 30
---	---	---

Moreover, the MELFI system interfaces with two independent 120V DC power buses: MAIN bus and AUXILIARY bus. Only one bus is active at time and power is distributed to MELFI equipment through the RIU, and the EU. Power distribution from the UIP is illustrated in figure 3.4 – 3.

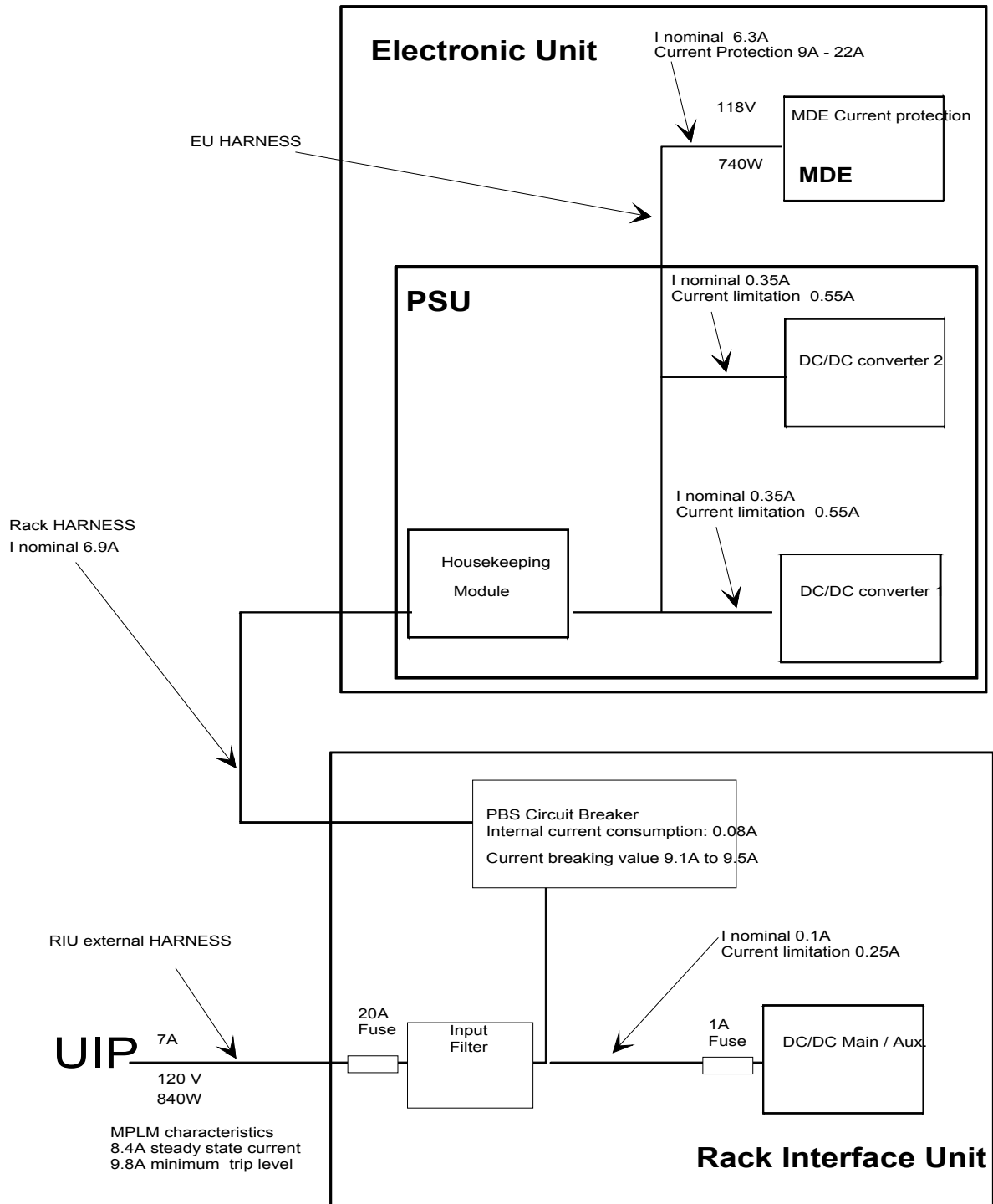
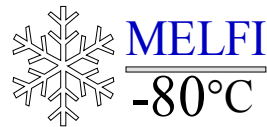


Figure 3.4 – 3: Over-current protection (MPLM configuration)



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 32



	VOLTAGE RANGE MINMAX	POWER (WATTS) MAIN FEED			P/L Characteristics	CURRENT (Amps) MAIN FEED			POWER (WATTS) AUXILIARY FEED			CURRENT (Amps) AUXILIARY FEED		
		Peak	Max Cont.	Keep Alive		Peak	Max Cont.	Surge Current	Peak	Max Cont.	Keep Alive	Peak	Max Cont.	Surge Current
Prelaunch - 1 Dewar at -80°C - 4 Dewar at -80°C	113/ 126	550† 900†	550± 900±	550† 900†	Constant	4.9 8.0	4.9 8.0	Note 1 Note 1						
Ascent - 1 Dewar at -80°C - 4 Dewar at -80°C	0/ 0													
On-Orbit in MPLM - 1 Dewar at -80°C - 4 Dewar at -80°C	113/ 126	550† 900†	550 900	550 900	Constant	4.9 8.0	4.9 8.0	Note 1 Note 1	550 900	550 900	550 900	4.9 8.0	4.9 8.0	Note 1 Note 1
On-Orbit ISS ¹ - 1 Dewar at -80°C - 4 Dewar at -80°C	113/ 126	750 900	700 900	550 900	Constant	6.6 8.0	6.2 8.0	Note 1	750 900	700 900	550 900	6.6 8.0	6.2 8.0	Note 1
Descent - 1 Dewar at -80°C - 4 Dewar at -80°C	0/ 0													
Postlanding - 1 Dewar at -80°C - 4 Dewar at -80°C	113/ 126	550† 900†	550† 900†	550† 900†	Constant	4.9 8.0	4.9 8.0	Note 1 Note 1						

Note 1: Refer to figure 3.1.3 -2 for MELFI downstream protection characteristics

†: 50 W in the MPLM increases These power allocations when the water is supplied between 7.2 and 8.3°C

¹: Assumes maximum door openings and sample insertion, keep alive assumes no door openings for 550 W



Table 3.4 - 1: MELFI Electrical characteristics

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 33
---	---	---

3.4.1 Power distribution and protections:

The MELFI system over-current protection is distributed as follows:

- The highest protection is the RPCM equipment, external to the MELFI system;
- A protection is implemented on the MELFI primary +120 VDC power bus: a current /breaker is located in the RIU after the MAIN /AUX Power Bus Selector (PBS). This protection is the nominal MELFI over-current protection and operates if the PBS current exceeds 9.3 A +/- 0.2 A. Then the over-current protection limits the MELFI input current (9.3 to 9.7 A) during 1.5 to 2.5 ms delay (see Figure 3.4 – 2). If the failure remains after this delay, a breaker is actuated. The breaker remains active as long as the input power is applied to MELFI. A crew /RPCM action is then required to disable the breaker, i.e. to switch OFF and then ON the Payload. This is mandatory to restart the MELFI. A 20 A fuse is located at the power inlet before the input filter (refer to Figure 3.4 – 3). This fuse rating was selected to protect internal wiring in case of 120 V DC failures or, in case of short circuit between the fuse and the current breaker.
- Local current limitations are also implemented for power distribution:
 - RIU DC / DC Converters: +120 V DC input power lines are current limited to 0.25 A for a nominal current of 0.1 A. Output voltage is 24 V. A 1 A fuse is located at the RIU power inlet before the input filter in order to protect internal wires in case of RIU DC/DC current limiter failure or in case of short circuit between fuse and current limiter.
 - EU DC / DC Converters: +120 V DC input power lines are current limited to 0.55A for a nominal current of 0.3 A output voltage is 28 V (for the CDHU and the MDE), +5 V, +12 V and -12 V for the CDHU.
 - MDE: +28 V input voltage line is current limited to 0.55 A for a nominal current of 0.18 A. This protection breaker is reset by the +28V switch off and can be re-actuated for +28V inrush current with the same 0.4 A level and a 3 ms trip reaction.
 - MDE: +120V input voltage line is also over current protected. When the input current is in the 9 to 22A range, the protection keeps this exceeding current for 2 to 7 ms; a breaking is actuated afterwards. Switching the +120 V power bus off or resets the protection by a local MDE reset. This protection is reserved for MDE testing. In case of internal MDE failure, it is the RIU PBS that trip removing thus power to the whole payload.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 34
---	---	---

3.4.2 **Power bus switching**

3.4.2.1 **Rack Maintenance Switch Assembly (RMSA)**

The RMSA switch is located at the bottom of the MELFI Rack on the RIU Switch Box. It actuates the external ISS/ MPLM RPCM and thus allows the removal of power for MELFI during operations at Rack level. The Crew manages this switch.

3.4.2.2 **MELFI internal switching**

Power is removed from MELFI either by activation of the ON / OFF MAIN or AUX switches located on the RIU Switch Box or by activation of the so-called MELFI safety loop.

The safety loop is build from in series contacts (normally closed), which are physically made from two thermo-switches connected in parallel for the detection of local overheating and located on the following H/W:

- Electronic Unit - PSU,
- Electronic Unit – CDHU,
- Electronic Unit – MDE,
- RIU

The over-temperature switch is common for both power buses (MAIN & AUX). The safety loop switch logics implemented in the RIU.

It can be noticed that in case of over-temperature followed by a power bus switching, a restart of MELFI is operated because power removal resets the internal restart inhibit.

3.4.2.3 MAIN / AUX Power bus switching logic



Switching between MAIN and AUX power buses is achieved in the RIU by the Pre-selection and Power Bus Selector (PBS) electronics.

Automatic switching from one bus to the other is performed within 140 ms. As internal power back up cannot be provided during this period, the payload reboots and needs afterwards to be reconfigured in order to recover nominal operations.

The table 3.4 – 2 describes the final supply source for the MELFI payload depending on the availability of both buses:

Main Bus	Aux. Bus	Supply from
Off	Off	-
Switched On	Off	Switch to Main
On	Switched On	Stay on Main
Switched Off	On	Switch to Aux.
Switched On	On	Switch to Main
On	Switched Off	Stay on Main
Switched Off	Off	Stay on Main.
Off	Switched On	Switch to Aux

Table 3.4 – 2: MAIN / AUX power bus switching

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 36
---	---	---

3.4.3 Bonding and Grounding

The electronic units, as EU and RIU, have a low impedance grounding reference plane in order to ensure a good functioning without common mode voltage between the different units. Class R requirements are applied to the unit chassis and chassis connection to the mounting plane on which they are implemented:

- Direct metal-to-metal mounting ensures a good contact.
- Surface finish is Alodine ; A bonding strap is implemented to secure the connection.
- The electrical continuity is measured after installation of the unit on the structure with a four points milli-Ohmmeter.

Rack-grounding stud (available on any ISPR rack) ensures the first bonding /grounding as documented in SSP57212 chapter Electrical power interfaces.



Second bonding/grounding through main / aux. umbilical shielding is achieved through UIP connectors back shell.

Class R requirements are applied to electrical connectors and to cable harness shielding:

- Direct mounting of the fixed connectors onto the chassis ensures contact of the connectors to the unit housing.
- The contact of the mobile connector is verified after the connection. All contacts are ensured by metal-to-metal connection.
- All external cables are shielded. The shield covers all cables of each single connector. The shield is fixed to the back-shell of the connector,
- The contact between the shield and the back shell is measured during the assembly.

Mechanical assemblies and manual switches are also grounded (*Class H requirements*):

- The rack is entirely made of aluminum. All parts are anodized in order to prevent oxidation.
- All interface surfaces are coated with Alodine that ensure surface conductivity. The contact between parts is measured after each assembly. The expected value is better than 2.5 mΩ.
- The manual switches housing are metallic and grounded to the structure. The resistance is measured on each model.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 37
---	---	---

Non-metallic parts (*Class S requirements*) have the following features:

- Few non-metallic parts (gaskets and flex water lines) are made of TEFLON.
 - Aluminum or stainless steel shielding covers the Teflon water hoses bonded to the structure.
- Primary power:
 - Both primary power busses MAIN and AUX are galvanically isolated with MELFI structure.
 - All circuits connected to the primary power are isolated from chassis: input filter, RIU breaker, and switches, DC/DC converters that use transformers.
 - The common mode filter of the units includes capacitors connected between the primary power and the chassis.
 - The DC isolation value is higher than $1M\Omega$.
 - Secondary power:
 - Secondary power is used within the different units: RIU, EU, MDE.
 - Each secondary power is locally connected to the chassis within the unit. Galvanically isolated DC/DC converters connected to the primary power generate them.
 - Tertiary power:

The tertiary power within the MDE is grounded within the MDE. It is generated by a galvanically isolated DC/DC converter from the secondary 28V provided by the RIU to the MDE.
 - 1553 bus:

The 1553 bus interface complies with the applicable documents and transformers isolate
 - Thermistors and Analogue telemetry:

The thermistors acquisition circuits are single ended and the thermistors and analogue telemetry acquisition are isolated from structure.
 - Digital telemetry and Digital command-Telemetry and command lines are isolated from structure. Opto-couplers isolate the receiving side from the transmitting side

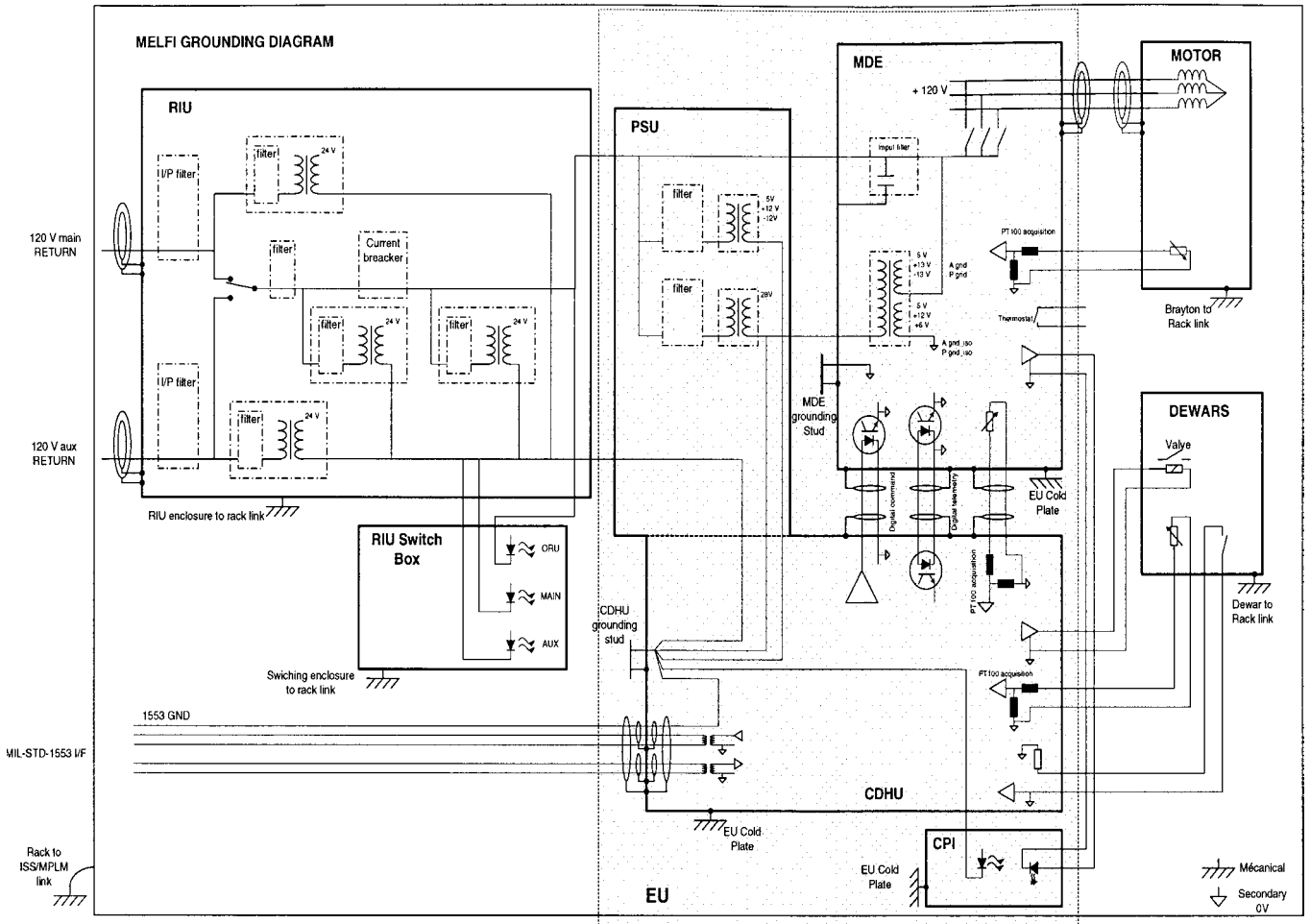




Figure 3.4 – 4: MELFI grounding diagram

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 39
---	---	---

3.4.4 Fire detection and isolation

MELFI is protected against potential fire events by design:

- Material selection,
- Over-current protections in line with application of de-rating rules

The fire detection inside MELFI is performed through an over temperature detection:

- Inside all the locations where a potential over temperature exists, both thermal sensors and thermal switches were implemented.
- The thermal switches are dedicated to automatic safing
- The thermal switches are connected to a dedicated hardware logic, called “safety loop”, which shuts MELFI power to ‘OFF’ whenever an over temperature is detected.

In the MELFI telemetry, the Caution and Warning word will be set to 3 ‘D’ Warning.


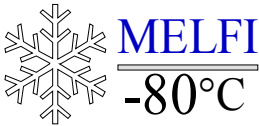
MELFI is then automatically shut down by the thermal switches, which open the safety loop.

The distribution of the thermal-switches is made among the dissipating equipment, which are the Electronic Unit (specifically for the CDHU, the PSU and the MDE) and the RIU.

- The safety loop is hardwired and independently reacts from the MELFI core controller.
- After the safety loop has been activated, even though the temperature decreases afterwards, no automatic restart of the MELFI can be performed (function implemented inside the RIU). MELFI has to be switched down (with the switches on the RIU Switch Box) and has to receive a MDM command to restart the Brayton Machine

Inside the RIU current limitation logic is implemented to protect MELFI from over-current situations.

The thermal-witches implemented to support the overheating detection function are procured according to the following specification:

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 40
---	---	---

	Temperature threshold to open	Temperature threshold to close	Location	Quantity
MDE	90°C ± 3.9°C	80°C ± 3.9°C	Close to switching transistors	1
PSU	90°C ± 3.9°C	80°C ± 3.9°C	Near DC/DC converter module 1 and 2	2
CDHU	90°C ± 3.9°C	80°C ± 3.9°C	Near side panels	2
RIU	90°C ± 3.9°C	80°C ± 3.9°C	Close to PBS	2

The switching logic using the status of the implemented thermal-switches has been implemented at RIU level, with the following characteristics:

- Hardwired logic
- Physical segregation in the command and actuator (relays)

The detection loop reacts on the power bus pre-selection circuitry and the switching mechanism is implemented by four normally open relays (AP 10 A).

The pre-selection circuitry is common for both Main and Aux power buses.

The reaction is to open the MELFI power lines.

Note: when the safety switch closes back (cooled down situation) no current can be applied to the switching relay command and the only possibility to restart the MELFI is to remove power completely from MELFI and switch on the power again.

The annunciation of a precursor event that could lead to fire is performed through the periodic MELFI housekeeping data stream sent by MELFI to the MDM.

These data contain both the Caution and Warning word and the temperature values of all the potentially hot spots.

The thermal sensors are periodically acquired and the temperature values are sent through the MELFI telemetry housekeeping data stream.

The complete set of thermal sensors is used for the MELFI internal monitoring and recovery function:

- If one of these sensors gives a temperature exceeding of the associated threshold, the Brayton Machine will be stopped (as it is the equipment which utilizes the greatest part of the electrical power)
- The thresholds for the parameters of the monitory and recovery function are defined for the nominal operational worst case. The same set of thermal sensors is also used by the logic generating the Caution and Warning word.
- The thresholds for Caution and Warning are defined between the monitoring and recovery function ones and the thermal switches ones.
- Sensors associated to water loop (gas bearings, WHX, MHX) are not associated with thermal switches.



For every potentially hot location, the alarm threshold value for the thermal sensor was chosen at 10°C or 20°C below the value at which the thermal switch opens (and activates the safety loop) to give time for annunciation before automatic safing.

In the MELFI facility case, a single unit (Electronic Unit) performs the acquisition of data used for the generation of the alarm signal.

Even with a failed Electronic Unit, the hardwired safety loop allows the system to stay in a safe state (automatic shut down action).

The next table shows the list of the thermal sensors used for the monitoring/recovery function and for the Caution/Warning word, with respective thresholds.

Thermal sensor	Default Value for Monitoring and Recovery	Default value for "Warning"
Gas Bearings temperature 1	+43°C	+60°C
Gas Bearings temperature 2	+43°C	+60°C
MDE temperature	+50°C	+70°C
Power Unit temperature 1 (DCM1)	+55°C	+70°C
Power Unit temperature 2 (DCM2)	+55°C	+70°C
Power Unit temperature 3 (Housing)	+50°C	+70°C
CDHU temperature 1 (near side panel)	+50°C	+70°C
CDHU temperature 2 (near side panel)	+50°C	+70°C
RIU temperature 1 (near Power Bus Preselector))	+80°C	+80°C
RIU temperature 2 (on Power Bus Preselector)	+80°C	+80°C

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 42
---	---	---

Thermal sensor	Default Value for Monitoring and Recovery	Default value for "Warning"
RIU temperature 3 (on Power Bus Selector)	+80°C	+80°C

Fire suppression

The MELFI facility includes provisions to enable prompt fire suppression by:

- A fire extinguisher hole for CO2 injection, that is located in the front of the Stowage Compartment with a 25mm diameter,
- A 25 mm cylindrical tube that brings the CO2 from the injection point in the front of the rack to the rear part.
- The CO2 release in the rear side of the MELFI rack through dedicated flex hoses and distribution to the identified potential fire locations (RIU and Electronic Unit)
- A continuous path of 25 mm is defined inside the rack towards the Electronic Unit and the RIU

The rear left rack post with 10 mm holes enable to prevent over pressure during the CO2 injection:

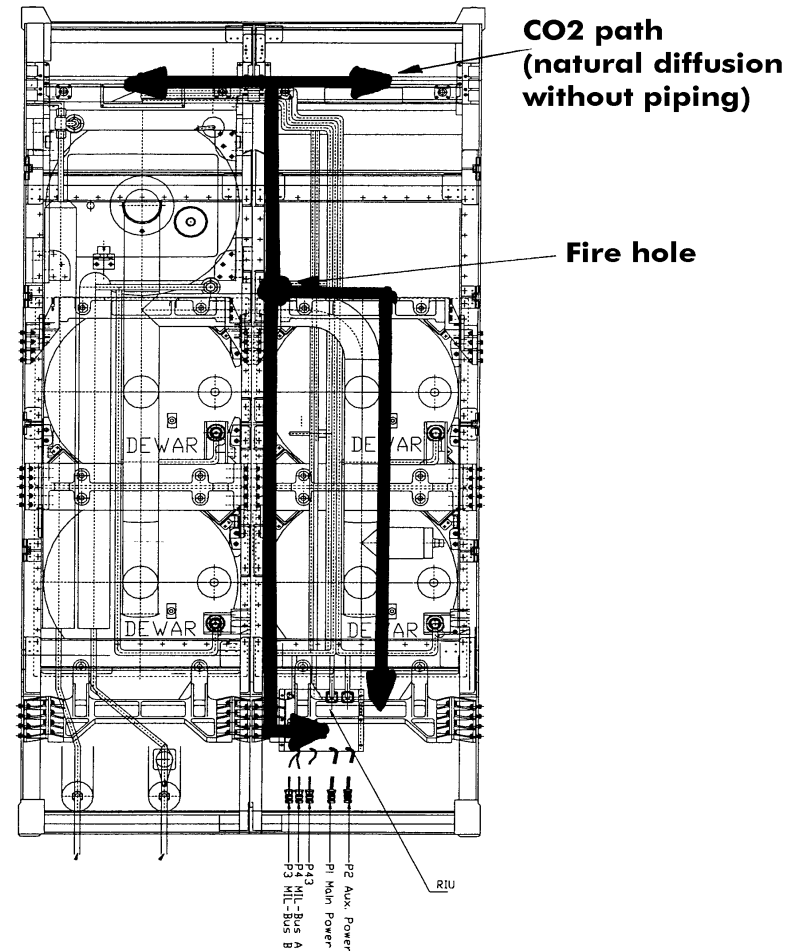
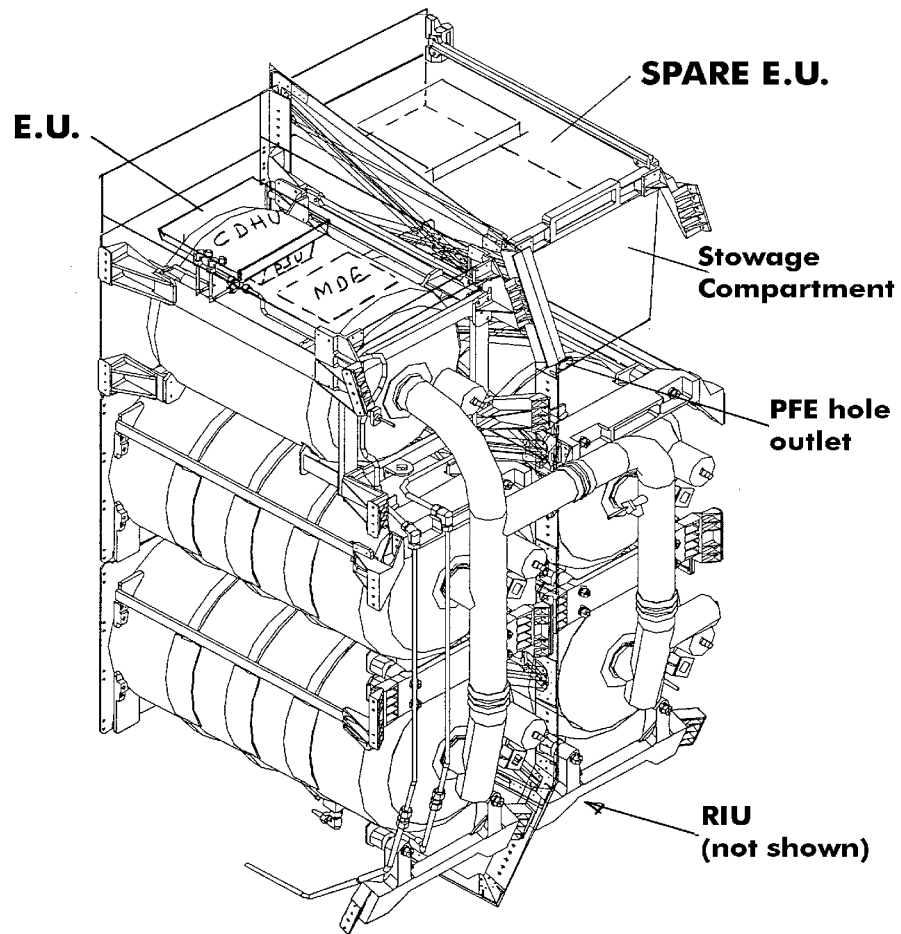
- A minimum of 10 holes gives an equivalent section identical to the injection port.
- At least 20 holes are kept uncovered, providing an acceptable venting margin.



During the CO2 injection the volumes surrounding the Electronic Unit and the Rack Interface Unit will have the Oxygen concentration lower than 10.5% in less than one minute:

- The volume inside the rack accessible to be filled with CO2 is very reduced
- More than 25 holes F7mm (equivalent section = 2 x F25mm section) are distributed over the rack height, providing an homogeneous venting path for the air from the rack

The transient increase of the rack internal pressure during the CO2 injection is compatible with the MELFI structural characteristics.

Figure 3.4 – 5: Fire event suppression – CO2 path on Rack rear



		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 44
---	---	---

3.5 RACK SUBSYSTEM

The Rack subsystem is composed of the following H/W items:

- The 6-post ISPR which is the rack primary structure,
- The mechanical supports: brackets, slides, for the attachment of the MELFI elements to the rack,
- The cooling water loop with thermal insulated tubing and a two positions calibration manual valve for the optimization of the coolant flow,
- The electrical harness installed on the rear part of the rack,
- The Stowage Compartment installed on the left of the rack.
- The Cold Box Front Panel
- The acoustic protections

The rack transportation containers, transportation trolleys and lifting devices are supplied with the ISPR.

The Rack Sub-System (RSS) interfaces with:

- o The ISS or MPLM mechanical interfaces and IUP;
- o The Brayton S/S (mechanical, Water loop and Rack harness);
- o The Dewar S/S (mechanical and Rack harness);
- o The electrical S/S (mechanical, water loop, Rack harness).

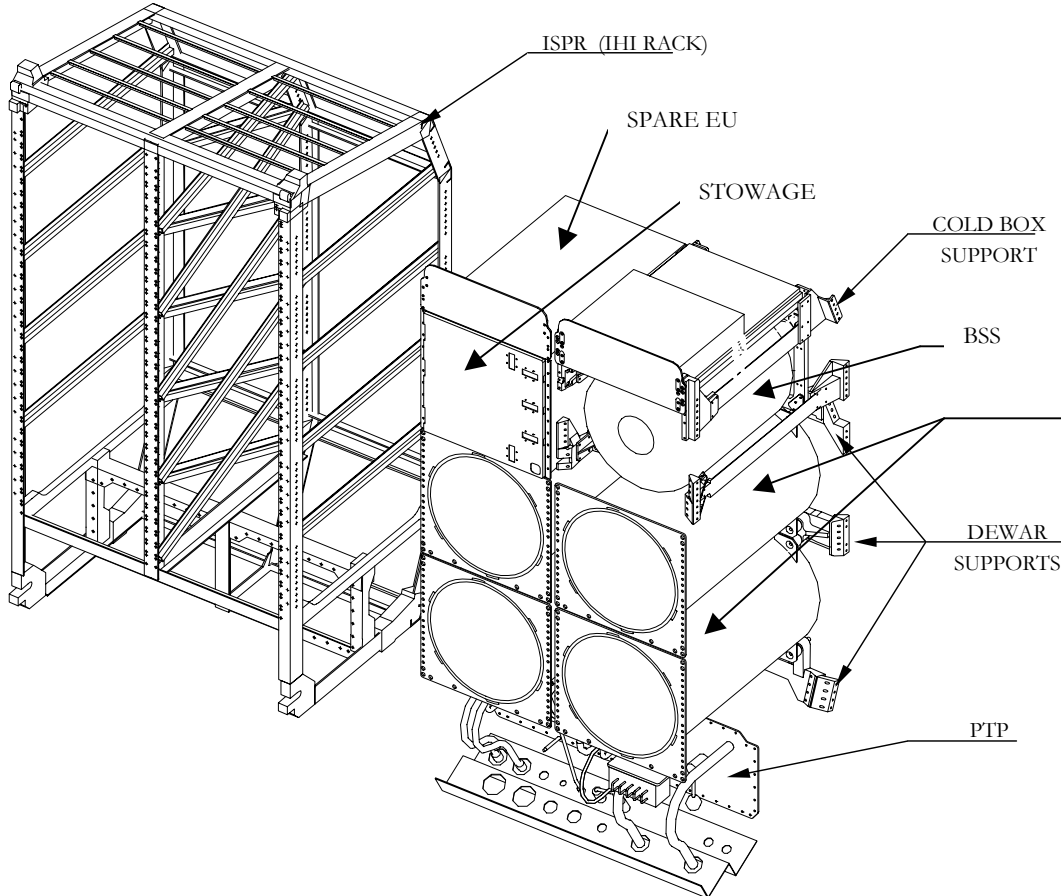




Figure 3.5-1: MELFI Rack Sub-System

3.5.1 Mechanical supports and Ruck sack

The IHI –6 posts Rack rear part was modified to allow the accommodation of the MELFI Hardware. :

- Replacement of rear center post with Dewar / Cold Box mounting structure
- Replacement of the IHI back panel with a crescent shape rack post structure (called Rucksack) in order to provide enough clearance for MELFI components.

The mechanical support structures provide the mechanical interface between the MELFI Hardware items and the ISPR:

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 46
---	---	---

- Cold Box and active EU support structure
- EU spare support structure (upper left part of the rack)
- Dewar rear support structure
- Nitrogen Tubing support Structure.
- Stowage compartment support Structure

Guide frames, support pins /bushings and bolts are used to attach the MELFI H/W to the rack

3.5.2 MELFI Water Loop

The MELFI Water cooling Loop is part of the RSS and provides heat exchange fluid to the Brayton S/S and the Electronic Unit. The schematics of the MELFI Water Loop are represented in figure 3.5 – 2.

The Low Temperature Water supply is split into two parallel branches inside the Brayton S/S: 1/3 of the inlet flow-rate is flowing through the Motor Heat Exchanger (MHX – Brayton Machine) and 2/3 of the flow-rate is passing through the Water Heat Exchanger (WHX – Cold Box).

Quick Disconnects (QDs) are implemented where required due to the On-orbit Replacement Unit capabilities, namely 2 QDs are on the Brayton Machine and 2 QDs are on the Electronic Unit.

The Manual Water Valve is a 2-positions valve and it allows adjusting the required pressure drop of the MELFI Water Loop and keeping it constant whatever the flow rate is:


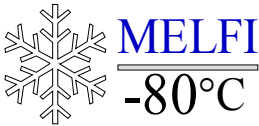
- *For the MPLM / 1 active Dewar and for all the MELFI modes inside the JEM (supply water flow rate is 13.8 g/s)*
- *For all the other situations (MPLM / 4 Dewars or all cases in ISS – Uslab), (supply water flow-rate is 22.6 g/s).*

The MELFI FM1 is delivered with a Rack Water Expansion Device as a provision for water expansion during the first ascent flight (no connection to MPLM water loop).

The spare Electronic unit and the spare Brayton Machine are both equipped with Water expansion devices.

Water Loop flow rates range:

The pressure drop across the MELFI Water interface is designed for the maximum required flow rate. It is in the MPLM 13.8 g/s for the 1 Dewar case, and 22.6 g/s for the 4 Dewar case or in the ISS.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 47
---	---	---

In the MPLM the constant pressure drop for the two required flow rates is obtained by means of a manual valve with 2 positions. As a result, the water flow available in the ISS for the 1 Dewar case is above the one in the MPLM for the same situation.

Note: MELFI water flow should be tied with MELFI power: when MELFI is powered, MELFI should receive water flow; when the water flow is off, MELFI power must be off. This implies that MELFI can be off and the water flow can be on.

When MELFI power is cut, the water shall be stopped in less than 20 minutes after power shut down.

Water Loop Temperature range:

MELFI is designed to receive water at inlet temperature ranging between 3.3°C and 7.2°C.

However, in the MPLM MELFI may receive water at temperature outside this range.

- When receiving water at temperature lower than 3.3 °C, MELFI shall not be switched off without caution: before power off, the water supply temperature shall be above 3.3°C to prevent freezing of the water inside MELFI.
- In the MPLM, when the water temperature is in the range 7.2°C to 8.3°C, MELFI shall be given 50W more power: 600W in 1 Dewar mode and 950W in the 4 Dewar modes.

After the start-up phase, MELFI shall receive water at the specified nominal conditions and will thus return the low temperature coolant at a temperature between 3.3 to 21°C, depending of the MELFI total power consumption.

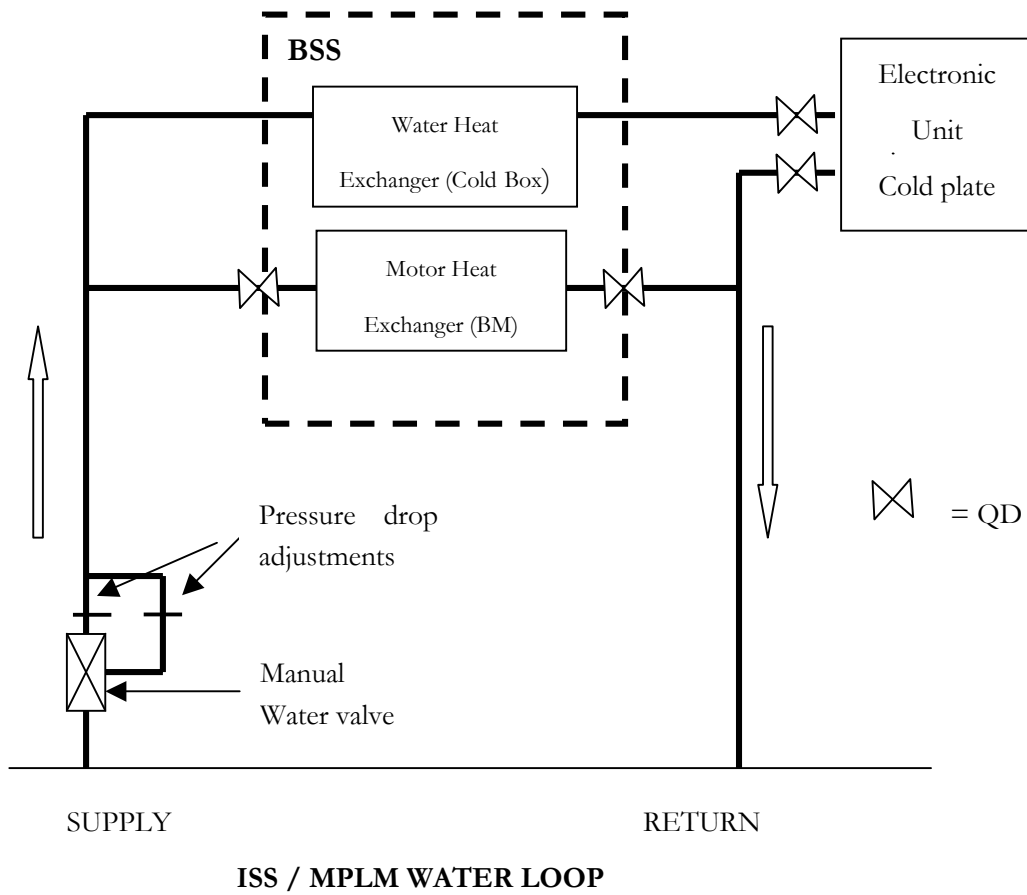


Figure 3.5-2: MELFI Water Loop Diagram

3.5.3 Acoustic protections

Following the acoustic test campaign, the implementation of acoustic protections was deemed necessary to be compliant with the NC-40 specification.

All the internal sides of the rack structure (side panels, rear panel & rucksack, center post, bottom panel) are covered with acoustic damper materials: 25 mm thick melamine plates locally reinforced with sound-foil damper material:

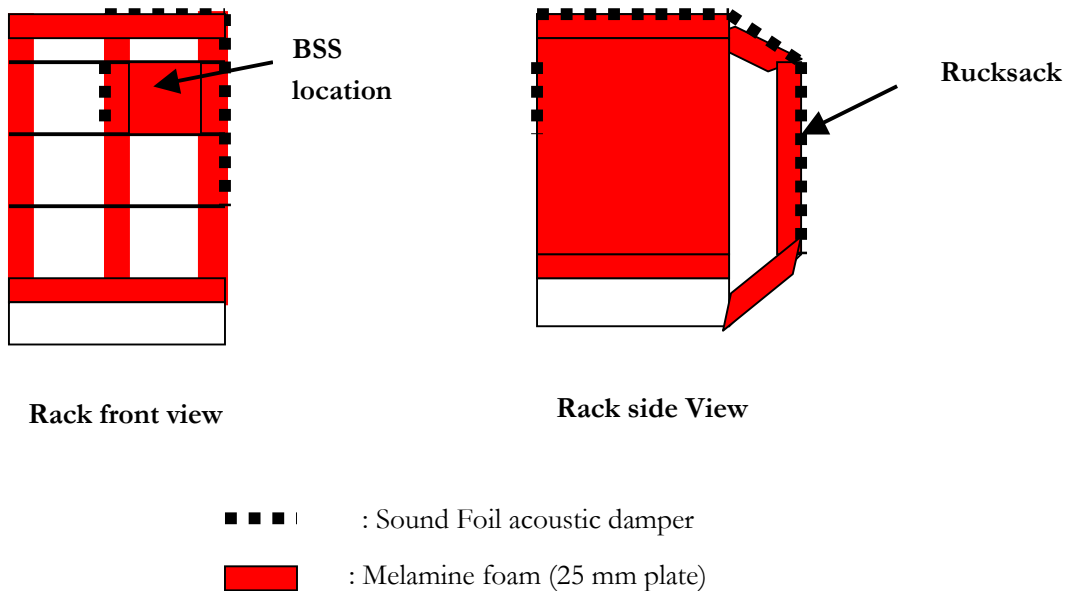


Figure 3.5-3: Location of acoustic protections inside the Rack

In addition to the above-mentioned protections, dedicated removable protections are implemented onto the tubing, the Brayton S/S and the Cold Box Front Panel:

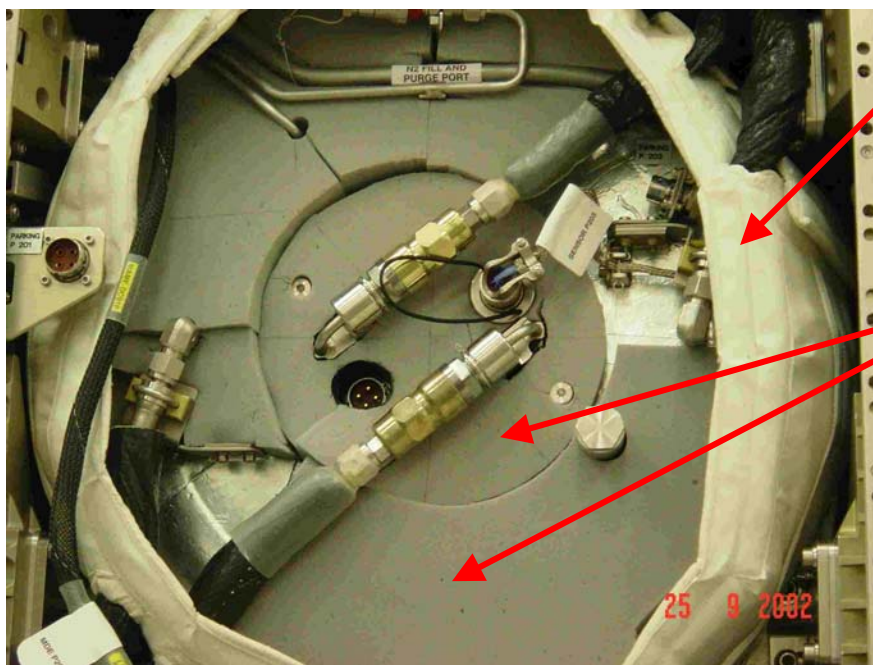
- The Cold Box external skin is covered with Sound Foil damper material and is wrapped in a multi-layer blanket made of the following materials:
 - Nomex fabric HT 90
 - 0.5 psf Bisco HT200
 - Durette felt 400-11
 - 0.5 psf Bisco HT 200

- Nomex HT 90

Velcros are part of the blanket in order to ease its installation and have it as tight as possible around the Cold Box. The objective is to contain noise as much as possible and to create a kind of box around the Cold Box.

- The Tubing is wrapped also in a multiplayer blanket made of:
 - Nomex HT 90
 - 1.5 psf Bisco HT 200
 - Nomex HT 90
- The Cold Box Front panel is equipped with 25 mm melamine (diameter close to 400 mm approx.) + a foil of 1.5 psf Bisco + a 25 mm plate of melamine

In order to contain acoustic emission as much as possible the front face of the BSS, i.e. the part accessed for the exchange of a Brayton machine is also covered with melamine panels (Figures 3.5-4 and 3.5-5):



Protection
around the
Cold Box

Melamine
Foam panels

Figure 3.5-4: Acoustic protections in front of the BSS (detail)



Figure 3.5-5: Acoustic protections in front of Brayton machine

3.6 UTILIZATION

MELFI utilization gathers all the hardware items required for the utilization of the MELFI, i.e. all the equipment to accommodate biological material inside a Dewar but also to transfer frozen samples between Dewars or Racks and to perform Dewar de-icing. In addition the utilization H/W items represent which the crewmembers will use for the nominal operations of the MELFI:

- Dewar outfitting H/W
- Thermal Bag and the foam plug to support the transfer of cold trays in between Dewars or MELFI racks within the ISS
- Gloves, sleeves for the handling of frozen samples.

3.6.1 Dewar outfitting

The Dewar is outfitted with exchangeable trays, which contains Box Modules of two sizes: $\frac{1}{2}$ size and $\frac{1}{4}$ size by comparison to the total length of a tray. Each size of Box Module exists as standard H/W, i.e. the 6 Box Module sides are perforated with holes, or as Receiving H/W. In this case some sides are plain instead of having holes in order to improve the thermal conduction towards samples installed in this Box Module. The Receiving Box Modules are designed for samples, which require to be frozen within a specified duration.

Different sample accommodation H/W are provided for samples of various volumes from 1 ml up to 100 ml. For larger volumes (up to 4 liters), the sample bag is directly installed in a Box Module and secured with Velcro straps.

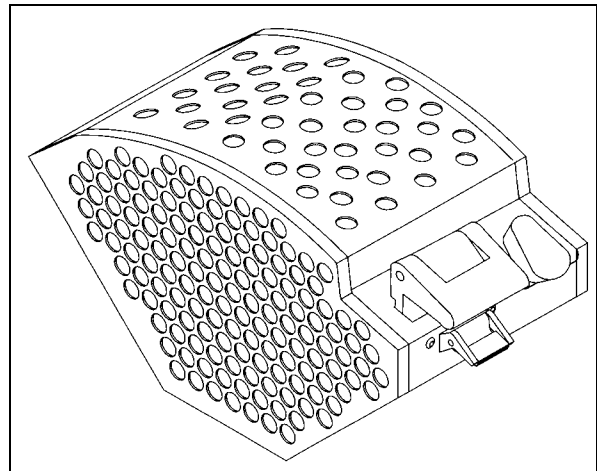


Figure 3.6-1: Possible internal layout for a Box module



Figure 3.6-2: Empty Tray

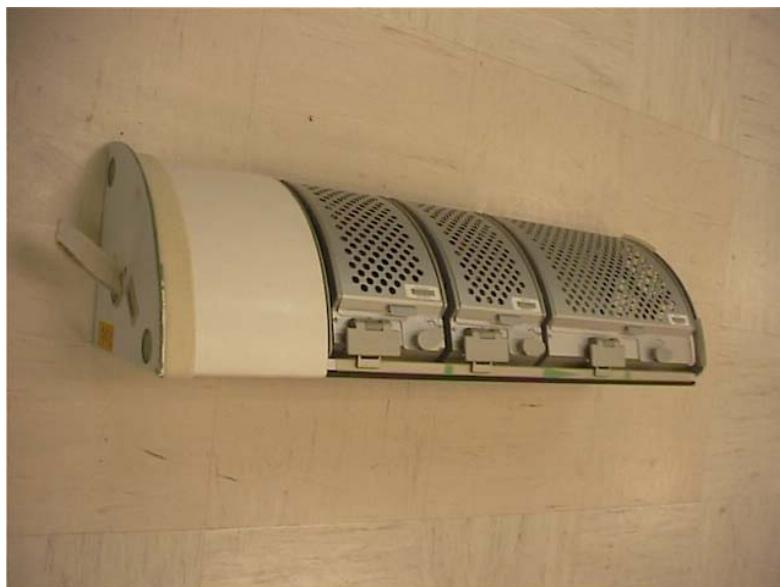


Figure 3.6-3: Tray with Box Modules (1/4 size and 12 size)

3.6.2 Interfaces for users or scientists

MELFI provides capabilities to store or freeze biological samples: Dewar temperatures can be independently set for each Dewar and within a range of $+4^{\circ}\text{C}$ down to -95°C . The total cold volume storage is 300 l equally distributed among the 4 Dewars.

Samples can be directly installed inside Box Modules or inserted on dedicated sample H/W accommodation that is then installed inside a Box Modules. The selection of a supporting H/W depends on the size /volume of the samples.

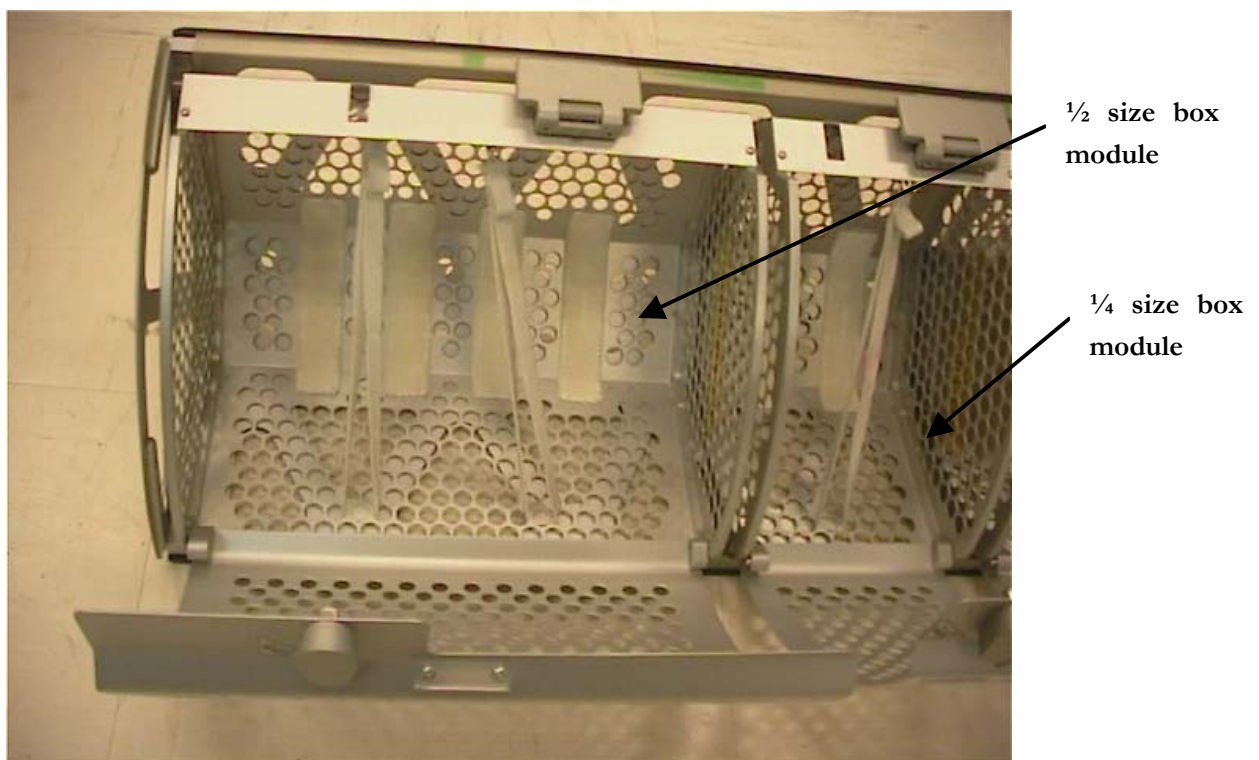


Figure 3.6-4: Internal view of box Modules (1/4 & 1/2 sizes) when opened

For samples smaller than 100 ml, it is recommended to install them on Contact Card to improve cooling down performances. Once frozen, these samples would then be transferred on Vial Cards or Vial Bags, which are inside Box Modules.

Vial Card and Contact Cards are shown in the figures below, for details refer to section 6.9.5 of this document.

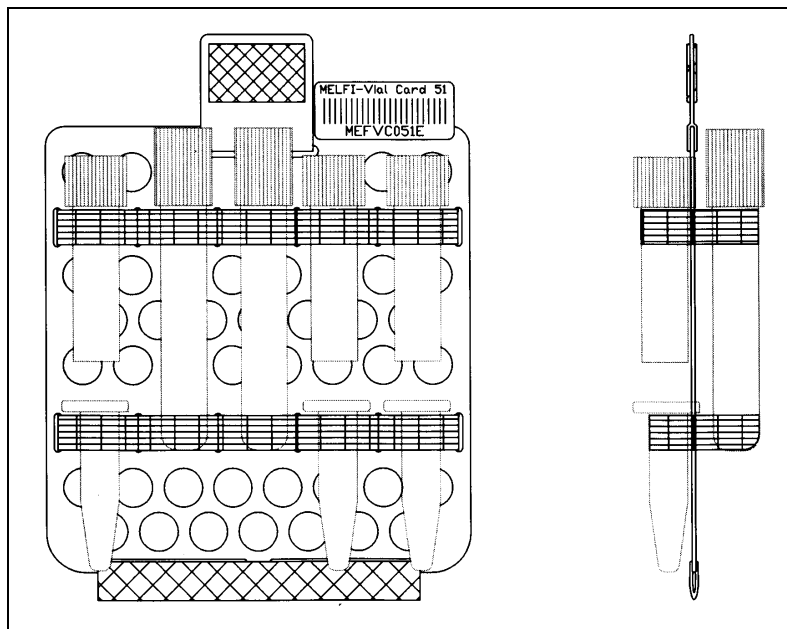


Figure 3.6-5: Vial Card.

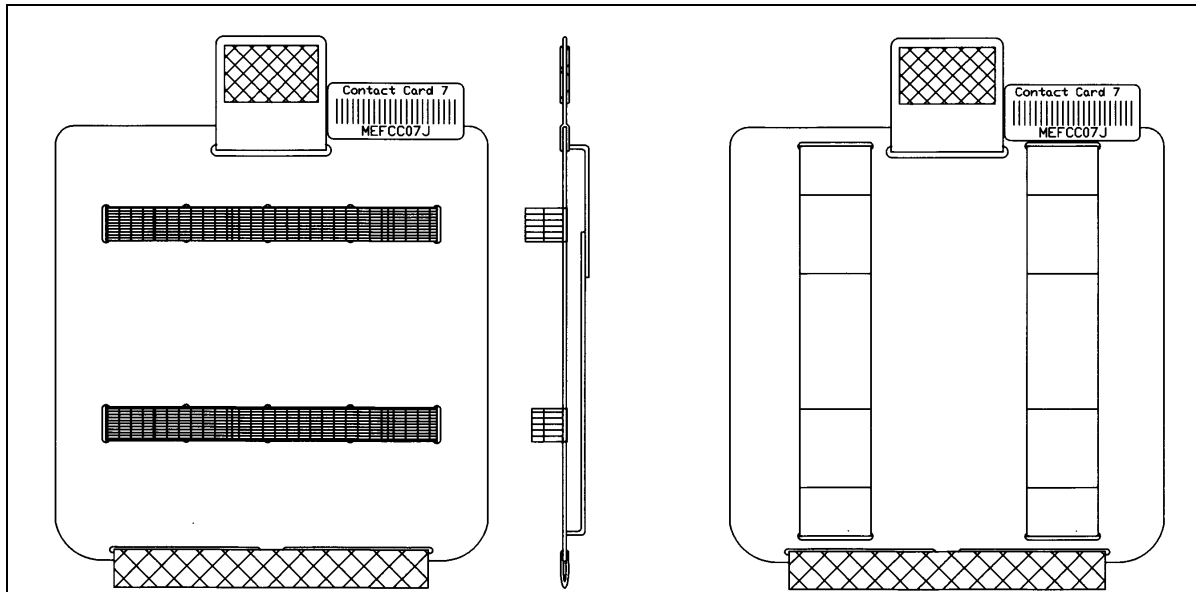




Figure 3.6-6: Contact Card

3.6.3 Dewar Airborne Support Equipment

The **Thermal Bag** is an insulated bag, which allows transferring a cold Tray in between racks if necessary. This bag has a 15-minute autonomy to keep frozen sample below -68°C .

The **Foam plug** is used to temporary replace a cold tray inside a Dewar during Tray Exchange between Racks or to support Dewar de-icing.

The **Dewar Airborne Support Equipment Pouch** is the last utilization item. It was designed like a tool box, i.e. the pouch contains all the necessary tools to allow Dewar maintenance: ice-scrappers of different shape fitting to the Dewar internal design to ease the de-icing operations, but also a few items for the on-orbit corrective maintenance. Cotton and cryogenic gloves are also provided for the nominal Dewar operations (insertion /retrieval of sample) and the preventive maintenance (de-icing).

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 57
---	---	---

3.6.4 Water bags

Water bags shall be used to reach the relevant thermal inertia in the Dewars in order to be able to cope at any moment with an 8-hour power off period. These bags could be standard bags (NUTRIPOCHE EVAM 4000 MI (LL) / Ref: FR4003STD) and contain, each one, two liters of water.

The necessary thermal inertia to cope with any situation both inside the MPLM and inside Station is 16kg of frozen water bags and 8kg of liquid water bags. The frozen water bags are used to protect the samples inside the Dewars in -80°C mode or in -26°C mode. The liquid water bags are used to protect the samples inside the Dewar in +4°C mode.

The distribution of the water bags among Dewars depends on the number of active Dewars and the selected mode of each Dewar. Details are provided in section 5.2.3.

The scenario for water bags utilization assumes that MELFI is launched active from the ground with at least one Dewar active in the -80°C mode. The frozen bags are installed in the active Dewar. The liquid water bags are stored inside one of the passive Dewars.

All the loaded box modules are cooled down in the Life Science Support Facility (LSSF). The box modules are transferred to the launch pad in Thermal Handling Containers (THC).

3.6.5 Desiccant

Desiccant bags are installed in MELFI in order to prevent internal condensation inside cold Dewars and on the Electronic Unit cold plate.

Molecular sieve Type 4A desiccant manufactured by Dessicare, Inc and supplied by Dry Pak Ind., Inc., was selected. Type 4A is the sodium form of Zeolite and is flight approved.

Desiccant inside Dewars:

One unit bag is placed in each Tray, corresponding to a total of 16 desiccant bags for a MELFI. Bags shall be replaced every 180 days (i.e. every 6 months). Each unit bag (28 grams) is wrapped with Velcro and secure to the bottom of the Box Module with a humidity indicator card: any color change from blue to pink indicates the saturation level of the desiccant.

Replacement bag of 4 each packaged in airtight bags with humidity indicator card are stowed in empty Box Modules.

Desiccant on the Electronic Unit:

Bags are pressed and secured with Velcro around the EU cold plate. Both the spare unit and the nominal unit are equipped with desiccant.

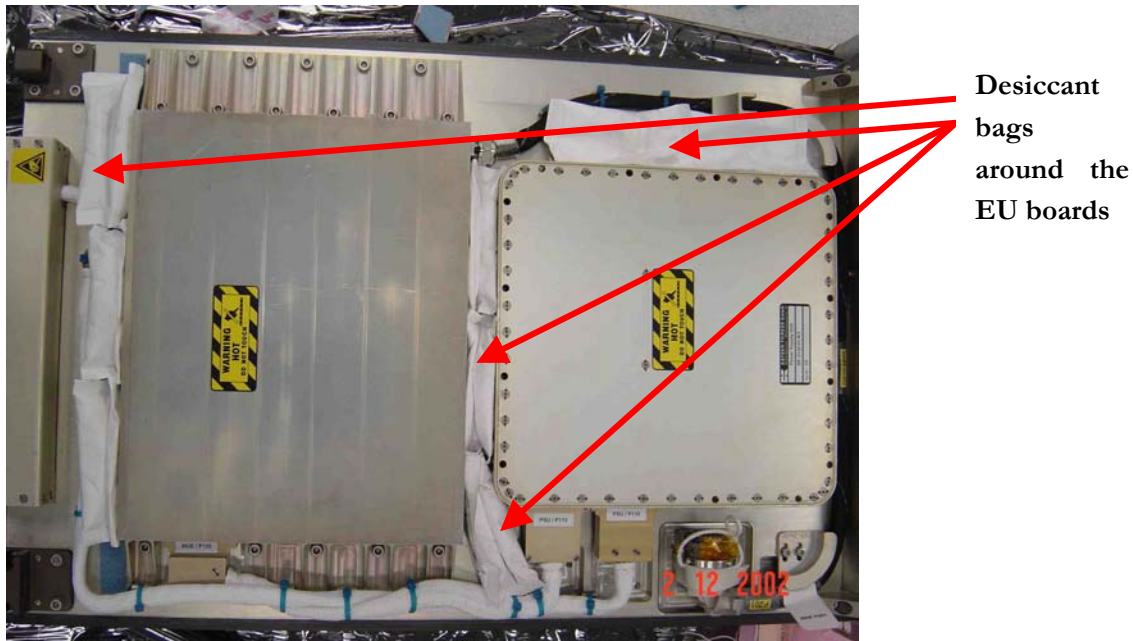


Figure 3.6-7: Desiccant bags onto the EU



3.7 SOFTWARE

The MELFI software manages all the command & data handling tasks for the MELFI control. In particular, it monitors the MELFI functions, the Dewar thermal regulation, and the Water loop regulation for freezing prevention. It also acquires all the subsystem values. The S/W also manages all the communications from or to the 1553B Bus and the internal communication between S/S.

Actually the MELFI S/W autonomously controls all functions needed to operate within the specification.

MELFI may be controlled through two different interfaces:

- The data interface through the 1553B bus (also called in present document data bus); which provides the full control on MELFI, but requires some understanding on the behavior of the payload, including software structure. This is the Remote Mode for the MELFI control.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 59
---	---	---

- The Crew panel Interface (CPI), which provides the crew with limited control on the payload. This corresponds to the Manual Mode for the MELFI control.

In addition, remote power activation / de-activation is limited to motor activation/deactivation.

The description of the CPI is given in section 5.

The control of MELFI through the 1553B bus is made by constantly checking the telemetry given every second by the payload, and sends the allowed commands.

Here after the minimum knowledge on MELFI software structure required to control the MELFI through the 1553B bus is described.



3.7.1 MELFI S/W overview and Payload Modes

The first information needed to control the MELFI, either from the data bus, or the CPI, is the Payload Mode. The allowed operations and actions are related to the Payload Mode; some actions are authorized in some modes and not in others.

Permanently, the Payload Mode can be obtained both from the telemetry received from MELFI and from the CPI displays.

The management of MELFI is based upon five payload modes:

- The **Configuration mode** is in charge of the initial configuration of the payload resources.
- The **Standby mode** performs a test of the Brayton Machine motor and of the Dewar valves (Motor and Valves test), before operating the payload in the Remote or Manual modes.
- The **Remote mode** is the nominal payload operational mode: operation and control from the ground station
- The crew, through the use of the Crew Panel Interface, dedicates **the Manual mode** to the control of the payload:
 - The Manual mode may be either enabled (following reception of the Enable Manual Mode command) or inhibited (following reception of the Inhibit Manual Mode command),
 - The Manual mode is initially enabled, and is systematically enabled following any detection of 1553B synchronization loss.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 60
---	---	---

- The **Stop mode** manages the Brayton Machine motor stop, either on request (STOP LED is red illuminated on the CPI) or in case of failure detection (STOP LED is blinking on CPI).

The allowed mode transitions are identified in figure 3.7.1-1:

- T1 (Configuration mode transition to Standby mode) is automatically performed when all “Conf” mode operations are completed.
- T2 (Standby mode transition to Remote mode) is performed following reception of the Set Remote Mode command, on condition that:
 - No Brayton Machine Motor and no Valves test session is in progress,
 - The Brayton Machine motor is stopped.
- T3 (Standby mode transition to Manual mode) is performed following the actuation of the Manual switch (on the Crew Panel Interface), on condition that:
 - The Manual mode is enabled,
 - No Brayton Machine Motor and no Valves test session is in progress,
 - The Brayton Machine motor is stopped.
- T4 (Remote mode transition to Manual mode) is performed following the actuation of the Manual switch, on condition that the Manual mode is enabled.
- T5 (Manual mode transition to Remote mode) is performed following reception of the Set Remote Mode command.
- Any T6, T7, or T8 transition (to Stop mode) is performed following:
 - Either the reception of the Set Stop Mode command,
 - Or the actuation of the Motor Stop switch (on the CPI),
 - Or the management of an anomaly (by the Recovery function).
- T9 (Stop mode transition to Standby mode) is performed following reception of the Set Standby Mode command, on condition that:

- The Brayton Machine motor is stopped,
- The Motor Stop switch is released.

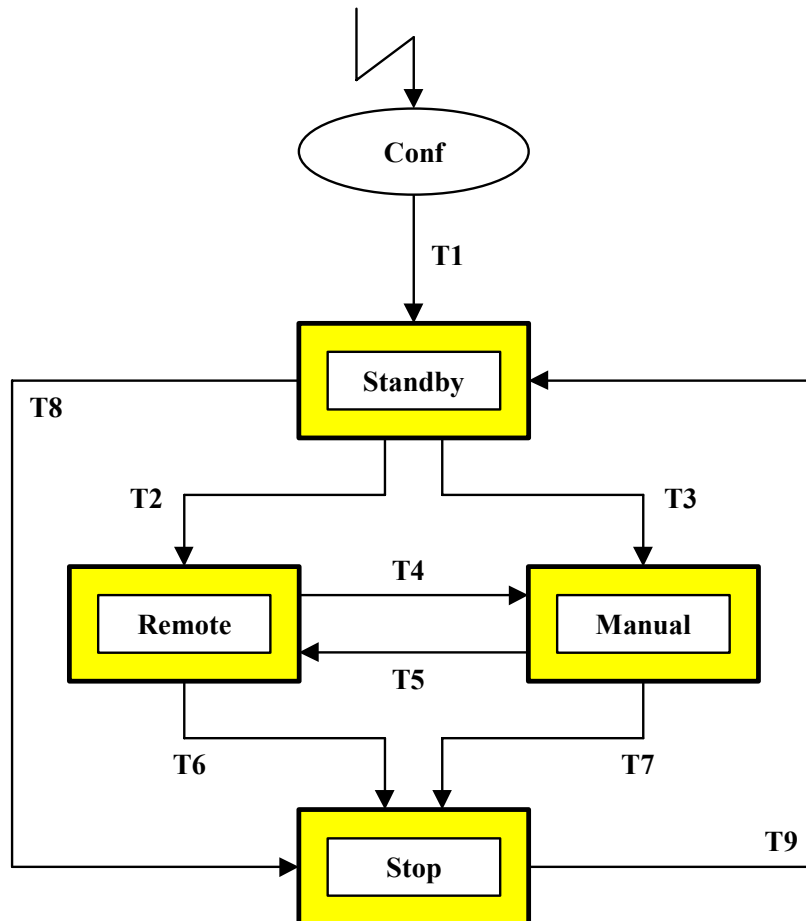


Figure 3.7.1-1: MELFI Modes

3.7.2 Monitoring and Recovery and “Caution and Warning”

MELFI Software continuously performs internal checks on a set of technological data and some internal statuses; this is the monitoring function.

The technological data is compared to a range defined by two (minimum and maximum) thresholds. All monitoring thresholds are System Parameters

An anomaly is detected when a monitored technological data is out of the specified range or when any monitored status is set to '1'B.

The anomalies are given in the Monitoring Status Word inside the Telemetry.

If the anomaly is to be considered in the recovery function, the payload will enter the Stop mode (Auto Stop sub mode) with the consequence to stop the motor. Hence, in case of failure the MELFI is automatically configured in a safe state, i.e. the STOP Mode.

The anomalies to be considered for the recovery function are given in the Recovery Set-up Word inside the Telemetry.

Both the Monitoring Status Word and the Recovery Set-up Word have the same structure, which is detailed in Table 3.7.2 - 1. *The details of both words are given in MELFI Software User Manual (RD2).*

The Recovery Set-up Word may be modified by command. This offers the possibility to activate or deactivate the recovery function for a given failure.

Table 3.7.2 - 1: Structure of Monitoring Status Word and Recovery Set-up Word

Bit	Operand #1		Operand #2	
B15	Gas bearing temperature 1	X	MDE driver failure status	X
B14	Gas bearing temperature 2	X	MDE over voltage failure status	X
B13	MDE temperature	X	MDE over current failure status	X
B12	PSU temperature 1 (DCM1)	X	Motor over temperature failure status	X
B11	PSU temperature 2 (DCM2)	X	MDE over temperature failure status	X
B10	PSU temperature 3 (housing)	X	MDE watchdog failure status	X
B9	CDHU temperature 1	X	MDE telemetry link failure status	X
B8	CDHU temperature 2	X	MDE command link failure status	X
B7	WHX outlet temperature	X	Motor speed regulation failure status	X
B6	MHX outlet temperature	X	Main Slave I/O VME failure status	X

B5	RIU temperature 1 (DCM1)	X	Spare	
B4	RIU temperature 2 (DCM2)	X	Spare	
B3	RIU temperature 3 (PBS)	X	Spare	
B2	Spare		Spare	
B1	Spare		Spare	
B0	Spare		Spare	

The Caution and Warning function is implemented in the MELFI S/W and is part of the telemetry. The processing of the Caution & Warning word uses the same sensors as the Monitoring and Recovery function (even though neither Gas Bearing Temperatures 1 & 2, nor MHX & WHX Temperatures are needed for safety).

Only the sensors that are considered as valid by the Monitoring and Recovery function are taken into account to generate the Caution and Warning Word. This implies that the sensors discarded by the Recovery function are also discarded by the Caution and Warning function.

When a valid sensor gives a temperature value higher than the associated C&W threshold, the Caution and Warning word is set to a class 3 alarm representing “Warning”. The value for a “Warning” is ‘3’D according to the MELFI S/W ICD.

The thresholds for the Caution and Warning function are the following:

Table 3.7.2 – 2: Caution and Warning thresholds

Identifier	Equipment	Name	Default value
20H	Brayton	Gas bearing temperature 1 - C&W threshold	+ 60°C
21H	Brayton	Gas bearing temperature 2 - C&W threshold	+ 60°C
22H	MDE	MDE temperature - C&W threshold	+ 70°C
23H	Power Unit	PSU temperature 1 (DCM1) - C&W threshold	+ 70°C
24H	Power Unit	PSU temperature 2 (DCM2) - C&W threshold	+ 70°C
25H	Power Unit	PSU temperature 3 (housing) - C&W threshold	+ 70°C
26H	CDHU	CDHU temperature 1 - C&W threshold	+ 70°C
27H	CDHU	CDHU temperature 2 - C&W threshold	+ 70°C

28H	Brayton	WHX outlet temperature - C&W threshold	+ 60°C
29H	Brayton	MHX outlet temperature - C&W threshold	+ 60°C
2AH	RIU	RIU temperature 1 (DCM1) - C&W threshold	+ 80°C
2BH	RIU	RIU temperature 2 (DCM2) - C&W threshold	+ 80°C
2CH	RIU	RIU temperature 3 (PBS) - C&W threshold	+ 80°C

3.7.3 MELFI regulation algorithm

The MELFI regulation algorithm aims at reaching a pre-selected low temperature inside a Dewar controlling both the Brayton Machine speed, which will produce the cold gas, and the Dewar valve opening, which will circulate more or less cold gas to the Dewar (s). In addition, the higher the Brayton machine speed, the higher the rack power consumption and the colder the gas temperature. This is why there is an obvious limitation to the Brayton machine speed, which is the maximum power, allocated to the MELFI, since 80 to 90% of the power consumption is required for the Brayton Machine and its driver (MDE).


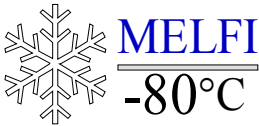
MELFI will start regulating the temperature inside the Dewars as soon as a Dewar temperature set has been accepted. The Brayton Machine motor will then automatically start.

The commands required for a Dewar Set-Up are explained in RD2.

The regulation of the Dewars temperature involves two algorithms:

- A Brayton Machine Motor Control algorithm (regulating the production of the cooling power),
- A Dewar Valve Control algorithm (for regulating the distribution of the cooling power through the Dewars).

The algorithm takes into account the Brayton Return Temperature, which is measured and rounded inside the Cold Box on the gas return line from the Dewar. In case of failure of both cold Box sensors, a predictor will automatically derive the Brayton Return Temperature from Dewar's temperatures and activation statuses. This predictor is activated in Manual or Remote mode. The mathematical function for this predictor can be tuned through some dedicated system parameters: DH, D6, D7, D8, D9, DA to DH, E0, C3H and C4H (refer to RD2 for details).

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 65
---	---	---

Default values of those system parameters have been chosen for accuracy on the prediction compatible with MELFI needs.

To initiate or control the regulation, a Dewar set-up may be generated in two different ways:

- Either as a Remote set-up, through the use of the Set One Dewar or Deactivate One Dewar commands,
- Or as a Manual set-up, through the use of the CPI.

Any Remote or Manual set-up refers to only one Dewar at the time.

A Dewar set-up may imply:

- The activation of a Dewar (with a Dewar Temperature Set-Up),
- The modification of the Dewar Temperature Set-up of an active Dewar,
- The deactivation of a Dewar.



Before starting any thermal regulation, one must check that all the four valves are valid thanks to the telemetry data flow. If a valve is not valid, one may have to use the command “Validate /Un-validate One Valve” as described in RD2 in order to allow the validation of a valve that became invalid.

3.7.4 Management of the Dewars

The management of the Dewars uses the status of the 4 Dewars, which are known through their associated statuses gathered inside 3 Dewar Status words. The most important statuses considered for the Dewars regulation are:

- Dewar Valve Validity Status: “valid” if the valve has the nominal behavior with the end switches actuated as expected;
- Dewar Validity Status: “valid” if, at least one Dewar temperature sensor is detected as valid AND the Dewar Valve Validity Status is “valid”;
- Dewar Activation Status;
- Cold Dewar Status: “cold” if temperature setting and Dewar temperature allow deciding that this Dewar can be used as main path for the Nitrogen flow in the MELFI regulation laws.

Dewar average temperature is the average of the Dewar temperatures given by valid sensors (4 temperature sensors are implemented in each Dewar for the thermal regulation). The sensors validity is given in the Dewar Temperature Status (see RD2 for details).

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 66
---	---	---

A command to change a Dewar setup is accepted with some conditions: the Dewars configuration shall always contain at least one Dewar detected as “cold Dewar”, to ensure enough valves opening for the Brayton Machine to start or to keep running.

A Dewar is declared as “cold Dewar” with the following logic:

All Dewars which average temperature and temperature set-up are both below the Cold Dewar set-up parameter are declared as “cold Dewars”.

If no Dewar complies with previous condition, the “cold Dewars” are those which temperature set-up is below the Cold Dewar set-up parameter.

In the Telemetry data, Dewar Status #1 and #2 give the status on Activation, Validity, Dewar Doors (open/close) and Valves end switches status.

Dewar Status #3 provides some technological data on the valves hardware status.

Dewar Temperature Status gives the validity of the temperature sensors inside the Dewars.

Valves positions, Dewar temperatures and Dewar Set Temperatures are also given in the Telemetry.

3.7.5 Brayton Machine Motor Speed Control and Payload Power Consumption

The motor regulation controls the speed of the motor through the Motor Speed Set-up. The real speed is given in Motor Speed.

When the difference between set and actual Brayton Machine motor speed exceeds the system parameter preset value (Motor Speed Regulation Gap), the Motor Speed Out of Limit Status is set. This out of limit may be “ON” during the starting of the Brayton Machine motor from the ambient conditions.

The Motor Drive Electronics (MDE) receives every second a speed set, even though the motor algorithm initiates no change in speed.

When a speed change is required, the speed set up is increased/decreased by the value in Speed Increase/Decrease (System Parameter). Thus the motor speed changes smoothly.

In addition, the motor speed is limited in order to limit the power consumption of the payload. The speed cannot exceed the value in Maximum Motor Speed (System Parameter). If the Motor algorithm requires a motor speed exceeding the Maximum Motor Speed, the motor speed is limited to the Maximum Motor Speed and the Motor Speed Screening Status #1 is set. (The same logic applies also for the Minimum Motor Speed (System Parameter).

Moreover, when the motor speed is higher than the difference Maximum Motor Speed - Motor Speed Screening Gap (defined by a system parameter), during the actuation of the Dewar valves the motor speed is reduced to the value Maximum Motor Speed - Motor Speed Screening Gap. This is needed so that the payload does not exceed the limitation on power consumption. During this limitation, the Motor Speed Screening Status #2 is set.

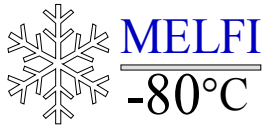
If the user wants to limit the payload power consumption during some phases of MELFI mission, the system parameter Maximum Motor Speed may be changed (see RD2 to modify the motor speed command). The relationship between maximum motor speed and MELFI maximum power consumption is given in following tables:

MELFI Maximum Power (W)	550	700	750	800	850	900	950	1000
Motor Maximum Speed (RPM)	71000	78000	80000	83000	85000	87000	92000	94000

Table 3.7.5 - 1: Relationship Maximum Power / Maximum Speed (MELFI Beginning of Life)

MELFI Maximum Power (W)	550	700	750	800	850	900	950	1000
Motor Maximum Speed (RPM)	66000	73000	75000	78000	80000	82000	85000	87000

Table 3.7.5 - 2: Relationship Maximum Power / Maximum Speed (MELFI End of Life)



The MELFI beginning of Life relationship between the maximum power and maximum speed is the one used by the MELFI S/W. When the power consumption increases gradually over MELFI's lifetime, the ground station team will have to adjust the maximum speed to an intermediate figure taking into both tables.

For the first starting of the motor when the Brayton Sub-System is at ambient temperature, a smooth speed increase is required from the minimum speed to the maximum speed. This is needed in order to keep an acceptable temperature distribution for the Brayton Machine motor gas bearings.

The gas bearings temperature has to be constantly checked during this initial cooling down of the Cold Box, if started from ambient.

The Speed Limitation For Motor Protection function is implemented in the Motor Starting logic S/W in order to limit the Motor speed that is computed by the Brayton Machine regulation algorithm:



Then, at the period of this regulation (by default 30 seconds), before applying the speed computed by the regulation, the function Speed Limitation For Motor Protection is activated. The speed finally requested for the machine to reach is the output of this limitation function.

Reminder: Actually, the speed finally requested by the motor regulation, before being applied, has to go through the limitation due to the electrical power available for MELFI: the limitation is the System Parameter "Maximum Motor Speed".

The Motor starting logic is the following:

- If the gas bearings temperatures are below + 2°C or above + 41°C, the Brayton Machine speed has to be limited to 25000 rpm;
- If not and if the gas bearings temperatures are below + 4°C or above + 40 °C, the machine speed has to be limited to 40000 rpm,
- If not, in function of the Brayton gas return temperature, the Machine speed has to be limited according to the next table:

Brayton Temperature (T5)	+15°C	+9°C	+2°C	-5°C	-11°C	-18°C	-25°C	-31°C	-54°C	-83°C
Speed limit (RPM)	45000	50000	55000	60000	65000	70000	75000	80000	87000	96000

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 69
---	---	---

3.7.6 Main operations on Remote mode

The Remote mode operations are introduced through two procedures:

- Generation of a **first set-up**, when the execution of the thermal regulation algorithms is not yet initiated, i.e. when:
 - All four Dewars are inactive,
 - The BM motor is not running.

- Generation of **further set-up**, when the execution of the algorithms is initiated i.e. when:
 - At a minimum one Dewar is active,
 - The BM motor is running.

Note:

Any Dewar set-up, either from the Set One Dewar command or from the CPI, is processed as follows:



- Any Dewar set-up requiring the activation of an invalid Dewar is rejected (see next chapter)
- The first Dewar set-up is accepted only if the Dewar Temperature Set-Up is lower than or equal to the ‘Cold Dewar Set-Up’ (system parameter).

The “Cold Dewar Set-Up” corresponds to the setting of a Dewar temperature equal or lower than **- 85°C**. Nevertheless this figure is a system parameter, which can be changed if necessary.

The concept of “Cold Dewar” is implemented to:

- Protect the samples stored inside cold Dewar, while warm Dewars are activated;
- Recognize, after a power-off period, the Dewars, which have to be protected because they are supposed to contain samples.

Advice: If samples have to be protected, wait for all active Dewars to reach their temperature set-up before sending a new command to activate an additional Dewar.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 70
---	---	---

If no Cold Dewar has reached the “Cold Dewar Set-Up” temperature, any additional Dewar with a set-up below the “Cold Dewar Set-Up” temperature will become an additional Cold Dewar. As a consequence, the new Dewar will have its valve opening quite fast.

If a Cold Dewar has reached the “Cold Dewar Set-Up” temperature, any additional Dewar with a set-up below the “Cold Dewar Set-Up” temperature will not be declared as a Cold Dewar until it reaches a temperature below the “Cold Dewar Set-Up”. As a consequence, this new Dewar will have its valve opening very slowly so that the Dewars declared, as an active new warm Dewar does not impact Cold Dewars.

3.7.7 Dewar activation / Invalid Dewar

Three Dewar modes are possible for a MELFI; these are respectively:

- -80°C mode
- -26°C mode
- $+4^{\circ}\text{C}$ mode

According to the MELFI S/W, both the -26°C and the $+4^{\circ}\text{C}$ Dewar modes are considered as “non-cold” Dewars in contrast to the “cold” Dewars corresponding to the -80°C mode.

The cold power for MELFI being produced by a single source, the Brayton Machine, it is mandatory to always have 1 Dewar at least operating at the -80°C mode.



The MELFI software recognizes internally the “Cold Dewar” among the temperature settings of all Dewars. This terminology is thus transparent regarding the procedures. Moreover the set points were defined to survive power-off conditions with respect to Dewar modes. This is why -35°C is the recommended set point for a -26°C mode Dewar (and $+2^{\circ}\text{C}$ for a $+4^{\circ}\text{C}$ mode Dewar).

Once there is a Cold Dewar (-80°C mode) it is possible to select Dewars at $+4^{\circ}\text{C}$ or -26°C mode. A Dewar is recognized as a “Cold Dewar” when its temperature setting is $\leq -85^{\circ}\text{C}$. This is the default value of this system parameter.

The Brayton Machine only starts cold production if there is at least one Dewar set-up with temperature set below the Cold Dewar Temperature (i.e. -85°C).

As soon as a Dewar is activated, the execution of both Motor Control and Valve Control algorithms is initiated, this implies:

- The actuation of the valves of the activated Dewar,

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 71
---	---	---

- The initiation of the BM motor start-up, as soon as the overall valve opening (restricted to the only valid valves) is greater than or equal to the “Minimum Overall Valve Opening”.

Activation of a Dewar in Manual Mode:

Any Manual set-up shall be managed as follows:

- (1) If (the Manual set-up is related to the activation of a first Dewar (i.e. the three other Dewars being inactive)),

The allowed range for the Dewar Temperature Set-Up is limited to [-99°C, ‘Cold Dewar Set-Up’]

Out of this range, the Dewar Temperature Set-Up is set to off (non activation of the Dewar)

- (2) Else if (the Manual set-up is related to the only active Cold Dewar)

The allowed range for the Dewar Temperature Set-Up is strictly limited to [-99°C, ‘Cold Dewar Set-Up’]

The deactivation of the Dewar is inhibited

Else

The allowed range for the Dewar Temperature Set-Up is [-99°C, +10°C]

Out of this range, the Dewar Temperature Set-Up is set to Off (deactivation of the Dewar)

note: the Cold Dewar Set-Up is a System Parameter.

When an Adjust switch is actuated, a Manual set-up shall be managed as follows:

- **Every time the related Up switch is actuated,**

If (the Dewar Temperature Set-Up is Off)

The Dewar Temperature Set-Up is set to the minimum value of the allowed range

Else

The Dewar Temperature Set-Up is increased by 1°C

(Up to the maximum value of the allowed range, then [if allowed] to the additional ‘Off value)



- **Every time the related Down switch is actuated,**

If (the Dewar Temperature Set-Up is Off)

The Dewar Temperature Set-Up is set to the maximum value of the allowed range

Else

The Dewar Temperature Set-Up is decreased by 1°C

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 72
---	---	---

(Down to the minimum value of the allowed range, then [if allowed] to the additional 'Off' value)

- **Every time the related Up/Down] switch is kept actuated for two seconds**, the Dewar Temperature Set-Up is automatically managed (as described above) every 200 ms, as long as the Up/Down switch is kept actuated.

Note: it should be noted that in case the maximum/minimum value (or the additional 'Off' value, if allowed) is reached, the automatic management of the Set-Up stops: no rollover is implemented. Refer to Annex1 for default values.

Through telemetry and also on CPI, the status of Dewars, active or inactive or invalid, is provided.

A Dewar is active when there is cold power distributed to that Dewar. Checking if there is a set point for that Dewar could check this on CPI.

A Dewar is inactive when there is no cold distributed to it. This can be observed on the CPI by pushing on the ADJUST switch, the message OFF is displayed. Otherwise the set-point temperature is displayed when a Dewar is active.

A Dewar is invalid when there is a valve failure or the 4 temperature sensors are out of use. Hence the Dewar cannot be controlled any longer by the MELFI S/W and is declared "invalid". In this case, the message "---" is displayed when the ADJUST switch is pushed on.

When the last Dewar gets "invalid", either because all Dewar sensors are invalid or the Dewar valve is invalid, the Brayton Machine will continue to operate at the last commanded speed by MELFI S/W and will remain in the current mode. Additionally, the valve position will remain the same as before the invalidation. The objective is to preserve samples in the last Dewar.

3.7.8 Average Dewar temperature

The Dewar temperature displayed on CPI is the average of the 4 thermal sensors located inside each Dewar. If one or more had failed, the average will be calculated on the remaining valid ones. There is no monitoring and recovery function for the failure of a Dewar thermal sensor; it will only be detected through the processing of the telemetry.

In Remote or Manual mode, the Dewar Temperature 'Out Of Limit' Status shall be managed as follows:

If the Dewar is active:

If $-99^{\circ}\text{C} < \text{Dewar temperature set-up} \leq -50^{\circ}\text{C}$,

The Status is 'out of limit' if the Average Dewar Temperature is out of the range defined by:

- Dewar set temperature + 'minimum temperature gap ([-99°C, -50°C] range)'
- Dewar set temperature + 'maximum temperature gap ([-99°C, -50°C] range)'

Else the Status is 'nominal'

If $(-50^{\circ}\text{C} < \text{Dewar temperature set-up} \leq -10^{\circ}\text{C})$

The Status is 'out of limit' if the Average Dewar Temperature is out of the range defined by:

- Dewar set temperature + 'minimum temperature gap ([-50°C, -10°C] range)'
- Dewar set temperature + 'maximum temperature gap ([-50°C, -10°C] range)'

Else the Status is 'nominal'

If $(-10^{\circ}\text{C} < \text{Dewar temperature set-up} \leq +10^{\circ}\text{C})$

The Status is 'out of limit' only if the Average Dewar Temperature is out of the range defined by:

- Dewar set temperature + 'minimum temperature gap ([-10°C, +10°C] range)'
- Dewar set temperature + 'maximum temperature gap ([-10°C, +10°C] range)'


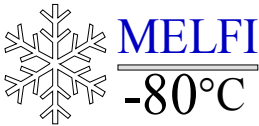
Else the Status is 'nominal'

Else the Status is 'nominal'.

Note: all Minimum and Maximum Temperature Gaps are System parameters; the minimum temperature gaps are negative values.

3.7.9 Displays management

- The Nitrogen Pressure Display shall be managed as follows:
If (the Average Gas Loop Pressure value is valid (i.e. $\neq 0$ hPa))
Display the rounded value of the Average Gas Loop Pressure
Else

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 74
---	---	---

Display the '---' (three minus signs) message

- The display of an Average Dewar Temperature shall be managed as follows:
If (the Average Dewar Temperature value is valid (i.e. $\neq +127^{\circ}\text{C}$))

Display the rounded value of the Average Dewar Temperature

Else

Display the '---' (three minus signs) message

- The display of a Dewar Temperature Set-Up shall be managed as follows:

If (a Manual set-up is in progress)

 If (the Dewar Temperature Set-Up value is in the $[-99^{\circ}\text{C}, +10^{\circ}\text{C}]$ range)

 Display the value of the Dewar Temperature Set-Up

 Else

 Display the 'OFF' message

 Else

 If (the Dewar is activated)

 Display the value of the Dewar Temperature Set-Up

 Else

 If (the Dewar is valid)

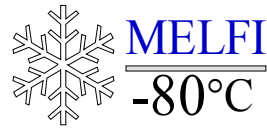
 Display the 'OFF' message

 If (the Dewar is invalid)

 Display the '---' (three minus signs) message

3.7.10 Synthesis of Crew panel behavior

The table 3.7.10 – 1 gathers all the information related to the actuation of CPI switches.



Ref: MELFI-MA-03000-0435-MMT


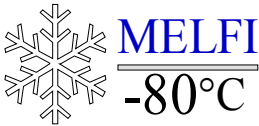
Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 75

Actuated switch (es)	Dewar configuration	Any mode but Manual	Manual mode only
None	Valid Average Dewar Temperature	Display Average Dewar Temperature	Display Average Dewar Temperature
	Invalid Average Dewar Temperature	Display “---”	Display “---”
Up/Down only	Valid or Invalid Dewar	No action: display Average Dewar Temp or “---”	No action: display Average Dewar Temp or “---”
Adjust only	Valid Dewar	Display current set-up (Temperature set-up or “OFF”)	Display current set-up (Temperature set-up or “OFF”)
	Invalid Dewar	Display “---”	Display “---”
	One specific case: at least one active Dewar but no Cold Dewar	Display current set-up (Temperature set-up or “OFF” or “---”)	Displayed current set-up is blinking (Temperature set-up or “OFF” or “---”)
Adjust then Up/Down	Valid Dewar (no Dewar is active yet)	No action: display current set-up (Temperature set-up or “OFF”)	Set-up allowed within [-99°C, Cold Set-Up] Non-activation is allowed
	Valid Dewar (this is the only active Cold Dewar)	No action: display current set-up (Temperature set-up)	Set-up allowed within [-99°C, Cold Set-Up] Deactivation is not allowed
	Valid Dewar (another Dewar is an active Cold Dewar)	No action: display current set-up (Temperature set-up or “OFF”)	Set-up allowed within [-99°C, +10°C] Activation or deactivation is allowed
	Invalid Dewar	No action: display current set-up (“---”)	No action: display current set-up (“---”)
	One specific case: at least one active Dewar but no Cold Dewar	No action: display current set-up (Temperature set-up or “OFF” or “---”)	No action: displayed current set-up is blinking (Temperature set-up or “OFF” or “---”)

Table 3.7.10 – 1: Synthesis of CPI behavior



		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 76
---	---	---

3.7.11 MELFI Telemetry and Tele-commands

The structure and list of the Health and Status Data Packets (MELFI Telemetry) is given in the MELFI Software User manual (RD2).

The nominal values for the health data given in last column are only for indication to help constructing the ground software controlling MELFI. The values given are the default values in MELFI flight software that may be changed through system parameters modification.

The list of MELFI telecommands is detailed in the RD2 document.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 77
---	---	---

4 MELFI MISSION

The MELFI mission consists of the following phases:

- Installation of MELFI in the MPLM
- Pre-launch operations including loading of samples,
- Launch and transportation of MELFI to ISS (MELFI being located inside the MPLM)
- Transfer of the MELFI rack from MPLM to MELFI final location in ISS
- Operational phase (up to 24 months in orbit)
- Transfer of the MELFI rack from its ISS location into MPLM
- Transfer of MPLM from ISS to Shuttle Cargo Bay and
- Return of Shuttle to earth
- Post-landing operations including samples retrieval
- MELFI rack dismounting.


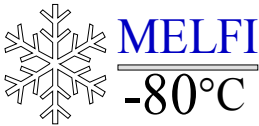
MELFI checkout and integration into MPLM (in SSPF building at KSC) consists of:

- Post-shipment inspection
- Off-line testing (functional test and interfaces verification)
- Configure MELFI for cold conditions
- MELFI rack integration into MPLM (Assumption: MPLM in horizontal position in SSPF building)
- Interface verification with MPLM (standard)
- MPLM transported to launch pad

MELFI on launch pad:

- At Launch minus 8 days (L - 8 days): MELFI is powered-on and starts cooling down the empty Dewars (may last 2 or 3 days).
- At L - 4 days: to fill one Dewar, 4 Thermal Handling Containers (THC) with cold Box Modules containing cold samples are transported to the launch pad

The 4 THC are transferred on top of MPLM and are installed one by one in front of MELFI (standard operation) using the PLAK/PLAP. Each THC contains the Box

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 78
---	---	---

Modules to fill one tray; when in front of MELFI, the THC is opened and the Box Modules with cold samples are installed in the dedicated tray:

- For loading one tray with the cold Box Modules, each Dewar door opening is to be limited to duration of 2 minutes.
 - This operation has to be repeated for the 4 THC associated with one Dewar. Wait 4 hours minimum for MELFI to recover cold temperatures and bring to the launch pad another package of 4 THC for the next Dewar to be filled
- o The last Dewar has to be loaded at L-2 days so that the samples are cold enough for next power-off during ascent
 - o At L- 70 minute power is removed from MPLM hence from MELFI.

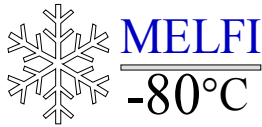
MELFI launch & transportation to ISS:

- o At L + 1 hour and 30 minutes MPLM is powered on, after Cargo Bay Doors are opened.
- o During the 2 hours and 40 minutes of power-off MELFI will maintain the samples temperature inside the specified temperature ranges by thermal inertia
- o During the On Orbit Post Ascent phase MELFI receives power for 63 hours to recover the minimum temperatures During MPLM removal from the Shuttle to CBM on Node 2, MELFI is not powered for 8 hours
- o While MPLM uses ISS Node 2 power and cooling water, MELFI is powered for 24 hours to recover temperature in preparation for the next power-off phase
- o MELFI is powered-off, disconnected from Node 2 and connected to its final location in ISS; power off duration is 50 minutes
- o MELFI cools down during 80 hours until starting of nominal operations with the first Dewar door opening

Operations from ground through MDM (Remote operation)

For every power-on or power-off of MELFI, ground operators intervene through the MDM to command MELFI. A typical sequence is:

- o Power on to MELFI
- o Acquire and verify MELFI housekeeping data
- o Set Dewar temperatures



- Start cooling down
- Wait until activated Dewars reach set temperature

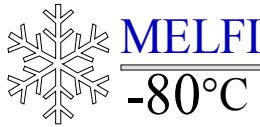
Once installed inside MPLM, MELFI can be powered up and will then start cooling itself. If the Dewars are empty, the cool down time assuming 900 W of input power, is given in the following table (figures are given for on-ground operations only):

Number of active Dewars @ -80°C	Cool down times (hours)
1	20
2	30
3	40
4	50

Transfer of MELFI from ISS to MPLM and return

- At Return minus 3 days and 15 hours (R - 3 days 15 hours), MELFI is powered-off, and transported from ISS to MPLM:
- Maximum expected duration of power-off is 4 hours
- One hour later, nominally, MELFI is powered-on inside MPLM and will continuously receive power during 24 hours.
- MPLM and MELFI are powered off for MPLM transfer to Payload Bay; duration of power off is 6 hours and 30 minutes maximum. MELFI is powered continuously during 43 hours
- At Return minus 3 hours and 30 minutes MPLM and MELFI are powered off
- At R - 1 hour Shuttle performs De-orbit Burn
- At R + 1 hour power is given to MPLM then MELFI: duration of power off was 4 hours and 30 minutes

Note: MELFI has to remain powered during 80 hours minimum before first cold cargo unloading



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004


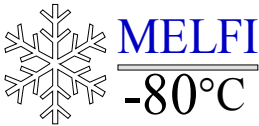
Page: 80

Ground Operations after landing: KSC landing site

- At R+2 hrs: Power restored via Payload Support Vehicle and MELFI Housekeeping Data is monitored
- At R+9hrs: Orbiter to Orbiter Processing Facility (OPF)
 - Removable and Access Platform (REAP) is installed
- At R + 4 days: early access for removal of samples
 - Samples inside their Box Modules are loaded into Thermal Handling Containers
- Thermal Handling Containers containing the samples are transported to the ground labs (LSSF)
- In LSSF, samples are loaded into ground freezers. In parallel, de-integration of MPLM from Shuttle
- MPLM transported to the SSPF
- De-integration of MELFI from MPLM.

Ground Operations after landing: Dryden landing site

- At R+2 hrs: Power restored via Dryden Payload Support Vehicle and MELFI Housekeeping Data is monitored
- At R+9 hrs: Orbiter to Dryden Orbiter Processing Facility
 - Dryden Early Access Platform (DEAP) is installed
- At R + 4 days: early access for removal of samples
 - Samples inside their Box Modules are loaded into Thermal Handling Containers
- Thermal Handling Containers containing the samples are transported to the Ground Transportation freezer l Orbiter to the Dryden Orbiter Processing Facility (DOPF)
MELFI wipeout
- Orbiter ferry flight to KSC
- De-integration of MPLM from Shuttle
MPLM to the SSPF
- De-integration of MELFI from MPLM.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 81
---	---	---



Post-flight refurbishment:

After landing, the following operations should be performed regarding maintenance:

- MELFI Dewar de-icing
- TDR dump
- MELFI Complete inspection, based on the inputs for MELFI Maintenance between flights.

After the first mission a complete inspection of all MELFI items is required.

- This will require dismounting the Rucksack, the Cold Box front panel, the EU and the spare EU for inspection down to board level.
- Replacement of parts that might be dirty or worn down: cotton gloves, some Velcros, some Labels ...
- Cleaning of all front panels, including CPI and all parts that were manipulated on-orbit.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 82
---	---	---



5 MELFI OPERATING INSTRUCTIONS

The MELFI on-board operating instructions are detailed in the MELFI On-Orbit crew procedures (RD1). The main steps for MELFI configuration for Launch / Return are first described. Then the MELFI cold conditions selection is described, followed by performances guidelines with a focus on the sample loading for cooling down, handling /special care and troubleshooting.

5.1 MELFI CONFIGURATION FOR LAUNCH /RETURN

Before launch or Return, the following points should be checked:

- Samples /specimen and sample accommodation H/W are secured by the bungee cord in the Box Modules
- For an active flight, there is enough thermal inertia inside Dewars to cope with power-off periods (refer to section 5.2.3 of this document)
- Box Modules are properly attached to the trays
- Dewar doors are locked
- Inside the Stowage Compartment, the BASE and the NFPE are locked
- The Dewar ASE items are all inside the pouch and the pouch, located in the Stowage Compartment, is closed
- The Stowage Compartment door is locked
- A spare EU or the Blind panel is installed on the left side of the active EU
- The active flight Brayton Machine must be off the latest possible regarding the launch count-down
- The Dewar valves shall be put in the intermediate position before launch: use of the command “Valves_Middle_Position” to be sent when there is no test session.
- The MELFI Water Loop valve should be switched to the MPLM position (active flight)

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 83
---	---	---

- In case of a passive flight, the Rack Water Expansion Device, the Water Loop Inlet and outlet, the UIP cables are all mounted and restrained onto the Pass Through Panel, at the bottom of the MELFI Rack.

The MELFI Rack transfer from MPLM to ISS is limited to the mechanical de-installation from the MPLM, transportation and re-installation in the ISS, including UIP connections and these operations shall last less than one hour.

Important Note: DO NOT MOVE MELFI WHEN IT IS ACTIVE AND THE BRAYTON MACHINE IS RUNNING

5.2 MELFI COLD CONDITIONS SELECTION

5.2.1 Mode selection

The MELFI system is capable to control Dewars in different cold conditions, however some pre-requisite are necessary to be taken into account before the activation of a Dewar:

A single Brayton Machine produces cold power for the 4 Dewars. Each Dewar can be active or non-active depending on the cold gas distribution valve open /closed position dedicated to each Dewar.



Each Dewar temperature can be independently controlled in order to meet the following mode / temperature range:

- - 80°C mode: sample temperature \leq -68°C
- - 26°C mode: - 37°C \leq specimen temperature \leq -23°C
- + 4°C mode: + 0.5°C \leq specimen temperature \leq + 6°C

In the MELFI system, the Brayton Machine is designed to produce cold gas at cold temperature (-90 / -105°C). There shall be at least one Dewar at - 80°C, the other Dewar temperatures can then be set at +4°C or -26°C. The Dewar temperature is adjusted at +4°C or -26°C by throttling the cold gas flow-rate to each Dewar and not by significantly changing the cold gas flow-rate from the Brayton Machine.

Tests performed at system level have revealed that a few configurations are forbidden, whatever the MELFI orientation (vertical or horizontal). Restrictions in utilization of Dewars at +4°C and -26°C are the following ones:

- **Dewar 2 never at +4°C or -26°C**

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 84
---	---	---

- Dewar 1 not at +4°C when Dewar 3 is at -26°C or - 80°C
- Dewar 1 not at - 26°C when Dewar 3 is at -80°C.

The thermal regulation being under S/W control, the MELFI automatically recognizes if there is a “Cold Dewar” among the temperature settings of all Dewars. This “Cold Dewar set-up” is a system requirement in the MELFI S/W and its default value is - 85°C. A Dewar is automatically recognized by the S/W as a “Cold Dewar” when its temperature setting is $\leq -85^{\circ}\text{C}$.

The Brayton Machine will only start cold production when there is at least one Dewar set-up with a temperature setting below the “Cold Dewar set-up”. The Brayton Return temperature set-up limits the Brayton Machine cold production. This System parameter is set to -97°C by default.

Cold Dewar temperature set-up is selected to withstand the whole mission. Not any temperature can be chosen to meet all the requirements for MELFI: cooling down time for samples, recovery after 8h power-off periods ...

The regulation algorithm will always converge to a temperature lower than the cold Dewar set-up. However, the samples will remain in the range as defined by the users /operators.

In order to meet the thermal performances requirements, Dewar set points should be the following ones:

- -35°C for a - 26°C mode Dewar;
- + 2°C for a + 4°C mode Dewar
- -95°C for a -80°C mode Dewar.

The alarm ranges for Dewar temperatures (out-of-limit LED light-on, CPI) depends on the selected Dewar modes:

- +/- 2°C for a Dewar @ + 4°C
- +/- 5°C for a Dewar @ - 26°C
- + 5°C / - 3°C for a Dewar @ -80°C

Cooling down times for a Dewar

Depending on the ambient conditions, about 20 hours is required to get a Dewar from ambient to stabilized cold conditions (-80°C). For the cooling down of 2 or 3 Dewars from ambient, it is preferred to activate one Dewar at the time and activate the 2nd once the first is already cold (below -70°C) and so on.

This is applicable to empty Dewars. When warm samples are already in a Dewar @ ambient conditions, the cooling down of this Dewar must be achieved (i.e. stationary cold conditions are reached) before activating a next Dewar. The estimated on-orbit cooling down times are indicated in the table below:

Number of active Dewars @ -80°C	On-Orbit Cool down times (hours)
1	20
2	40
3	60
4	80

Once a cold Dewar is deactivated, several hours (48h) are necessary to warm it up to ambient temperature. The exact duration depends also upon the ambient temperature.

Note: These cooling down or warming up durations from and to ambient have to be taken into account for the timeline of on-ground and on-orbit procedures.

On-Orbit criteria for Dewar temperature stabilization



Stationary thermal conditions of a Dewar depend on ambient temperature, available electrical power, water flow rate and also the number of active Dewars. It is however possible to estimate an expected temperature range so that the operator would know if the observed Dewar behaves correctly:

Assumptions:

- Ambient temperature: 25°C
- Water flow: 13.8g/s in the single dewar case and 22.6g/s in the other cases
- Water temperature: 7.2°C

	Single dewar at -80°C (550W)	Combined case (two dewars at -80°C, one at -26°C & one at +4°C) (900W)			Four dewars at -80°C (900W)
Dewar mode	-80°C	-80°C	-26°C	+4°C	-80°C
Min acceptable temperature	-99°C	-99°C	-36°C	+1°C	-99°C
Max acceptable temperature	-82.4°C	-90.4°C	-32.7°C	+3.2°C	-90.6°C

Table 5.2-1. 1: On-orbit commissioning criteria for Dewar average temperature

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 86
---	---	---

5.2.2 Standard Dewar Layout

The MELFI is equipped with four Dewars. Each Dewar is delivered with a set of Trays, Box Modules (both standard and receiving ones) and sample accommodation H/W. The recommended allocation of this H/W for each Dewar is called the standard Dewar layout that is:

- 4 trays,
- 1 ½ size Box Module
- 9 ¼ size Box Modules
- 1 ½ size Receiving Box Module
- 3 ¼ size Receiving Box Module

There is a Receiving Box Module in position 1 of each tray (just behind the foam block).

Each ¼ size Receiving Box Module is equipped with one Contact Card.

The rest of the sample accommodation H/W (Vial Bags and Vial Cards) is distributed in the remaining Box Modules.

The Sample Loading / Transfer procedure (PR-09 in RD1) is based upon the Standard Dewar Layout.

Samples requiring cooling down from ambient within a specified duration should be installed in Receiving Box Module, position 1 just behind the foam block.

The standard layout is a generic one which meets most of the utilization scenario; however each mission could have its own Dewar layout depending on the mission definition and objectives.

Dewar Box Modules reconfiguration:

Box Modules, sample accommodation H/W and trays are **exchangeable** between Dewars and/or MELFI units.

Minimum electrical power for Dewar mode selection

Each of the 12 functioning modes is associated to a minimum electrical power to ensure the samples preservation throughout the mission and allow sample insertion. The table below provides the definition of the different modes whatever the Dewar location in the MELFI Rack (1, 2, 3 or 4):

MELFI MODE	Dewar W	Dewar X	Dewar Y	Dewar Z	Min allocated power
<i>1</i>	OFF	-80°C	OFF	OFF	700 W
<i>2</i>	OFF	-80°C	OFF	+4°C	750 W
<i>3</i>	OFF	-80°C	OFF	-26°C	800 W
<i>4</i>	OFF	-80°C	OFF	-80°C	850 W
<i>5</i>	+4°C	-80°C	OFF	-26°C	900 W
<i>6</i>	OFF	-80°C	-80°C	+4°C	900 W
<i>7</i>	-80°C	-80°C	OFF	-26°C	900 W
<i>8</i>	OFF	-80°C	-80°C	-80°C	900 W
<i>9</i>	-26°C	-80°C	+4°C	-80°C	900 W
<i>10</i>	-80°	-80°C	-80°C	+4°C	900 W
<i>11</i>	-80°C	-80°C	-80°C	-26°C	900 W
<i>12</i>	-80°C	-80°C	-80°C	-80°C	900 W (*)

(*) Preferably 1000W

Note: Power consumption figures are applicable to on-orbit conditions

Table 5.2-1: Minimum electrical power for each mode

5.2.3 Dewar loading for 8 hour power-off : Water Bags utilization

During the MELFI mission, there might be configuration for which Dewars are not sufficiently loaded to ensure that the samples will remain below -68°C throughout the mission, in particular during power-off periods.

For each temperature mode and according to the available electrical power, a minimum thermal inertia shall be installed in each Dewar to preserve the samples throughout the mission.

To be able to cope at any moment with an 8-hour power off period, a minimum thermal inertia is brought into station. Water bags shall be used to reach the relevant thermal inertia in the Dewars. These bags are standard bags (NUTRIPOCHE EVAM 4000 MI (LL) / Ref: FR4003STD) and contain, each one, two liters of water.

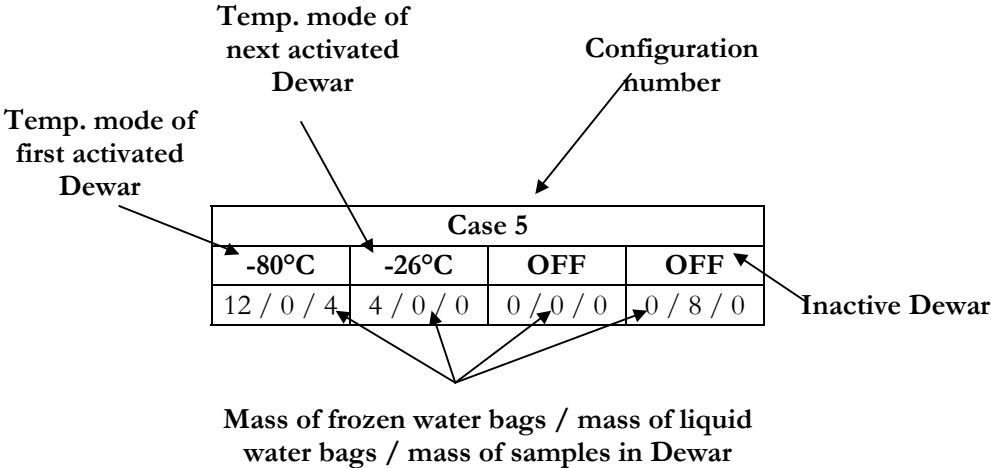
As defined in MELFI Thermal analysis report (AD 4), the necessary thermal inertia to cope with any situation both inside the MPLM and inside Station is **16kg of frozen water bags and 8kg of liquid water bags**. The frozen water bags are used to protect the samples inside the Dewars in -80°C mode or in -26°C mode. The liquid water bags are used to protect the samples inside the Dewar in +4°C mode.

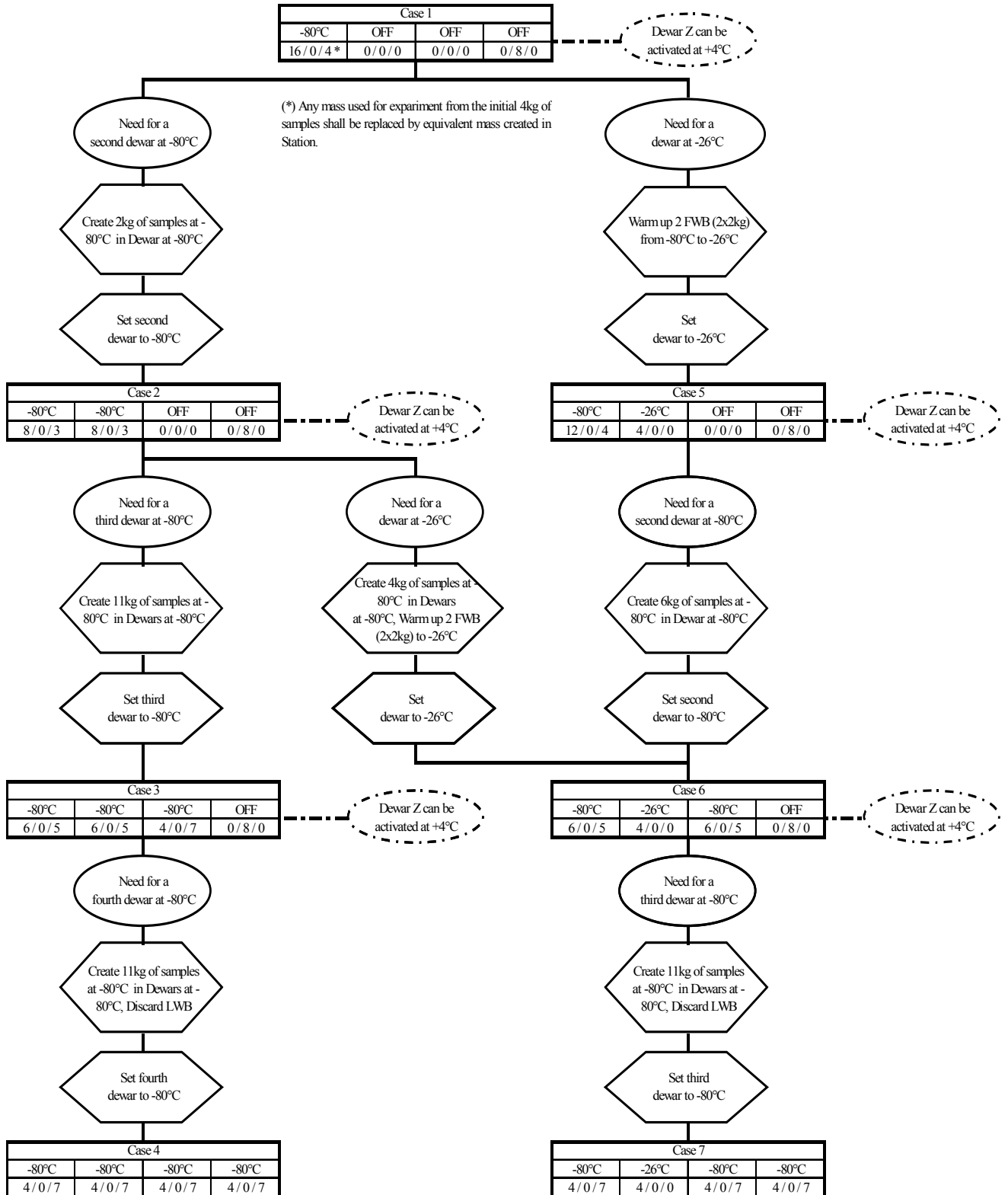
The scenario for water bags utilization assumes that MELFI is launched active from the ground with at least one Dewar active in the -80°C mode. The frozen bags are installed in the active Dewar. The liquid water bags are stored inside one of the passive Dewars.

All the loaded box modules are cooled down in the Life Science Support Facility (LSSF). The box modules are transferred to the launch pad in Thermal Handling Containers (THC).

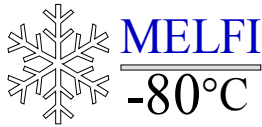
Note: In the following pages, the Dewars are numbered W, X, Y and Z (with {W, X, Y, Z} ⊂ {1, 2, 3, 4}). The Dewars are interchangeable but shall respect the restriction rules established for utilization of Dewars at +4°C and -26°C.

In the diagram below, MELFI possible configurations are identified as follows:





The Dewars are numbered W, X, Y and Z (with $\{W, X, Y, Z\} \subset \{1, 2, 3, 4\}$). The Dewars are interchangeable but shall respect the restriction rules established for utilization of Dewars at +4°C and -26°C.



At any time, the Dewar (Dewar Z in the diagram above), which contains the liquid water bags, can be activated and set to +4°C.

If all the Dewars are active and set to -80°C or -26°C (cases 4 and 7), the liquid water bags shall be removed from MELFI.

For each of the cases, the figures hereafter explain how to physically distribute the water bags in MELFI.

Case 1

-80°C	OFF	OFF	OFF
16 / 0 / 4	0 / 0 / 0	0 / 0 / 0	0 / 8 / 0

DEWAR W *
Dewar at -80°C
 20kg thermal inertia (16kg of frozen water bags + 4kg of samples)

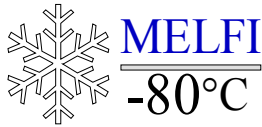
	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A		FWB	FWB		
TRAY B		FWB	FWB		
TRAY C		FWB	FWB		
TRAY D		FWB	FWB		

DEWAR X,
Inactive Dewar
 Empty

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A					
TRAY B					
TRAY C					
TRAY D					

DEWAR Y
Inactive Dewar
 Empty

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A					
TRAY B					
TRAY C					
TRAY D					



DEWAR Z
Inactive Dewar
 8kg of liquid
 water bags

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A		LWB			
TRAY B			LWB		
TRAY C			LWB		
TRAY D		LWB			



Standard box module with 2kg frozen
 Water Bag



Box module filled with required samples
 mass

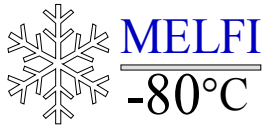


Standard box module with 2kg liquid
 Water Bag



Receiving box module

In ISS, as soon as 900W are available for MELFI, a second Dewar can be cooled down. Dewar Z containing the liquid water bags can be set to +4°C or a second Dewar at -80°C can be activated. In that case (case 2), 22kg of thermal inertia are needed. Thus, two (2) additional kilograms of samples shall be created in Dewar W. When the needed mass of thermal inertia is available in the first active Dewar, the 22kg of samples and water bags shall be spread between the two Dewars respecting the configuration described hereafter:



Case 2

-80°C	-80°C	OFF	OFF
8 / 0 / 3	8 / 0 / 3	0 / 0 / 0	0 / 8 / 0

DEWAR W

Dewar at – 80°C

11kg thermal inertia (8kg of frozen water bags + 3 kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B			FWB		
TRAY C			FWB		
TRAY D	FWB				

DEWAR X

Dewar at – 80°C

11kg thermal inertia (8kg of frozen water bags + 3kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B			FWB		
TRAY C			FWB		
TRAY D	FWB				

DEWAR Y

Inactive Dewar
Empty

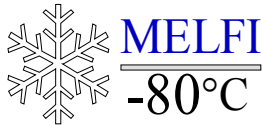
	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A					
TRAY B					
TRAY C					
TRAY D					

DEWAR Z

Inactive Dewar

8kg of liquid water bags

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	LWB				
TRAY B			LWB		
TRAY C			LWB		
TRAY D	LWB				



When a third Dewar is cooled down to -80°C (case 3) and when 33kg of thermal inertia are available in the two active Dewar (i.e. when eleven (11) kilograms of new samples are created), the 33kg of samples and water bags shall be spread among the three Dewars as described hereafter:

Case 3

-80°C	-80°C	-80°C	OFF
6 / 0 / 5	6 / 0 / 5	4 / 0 / 7	0 / 8 / 0

DEWAR W

Dewar at -80°C
 11kg thermal inertia
 (6kg of frozen water bags + 5kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B		FWB			
TRAY C					
TRAY D	FWB				

DEWAR X

Dewar at -80°C
 11kg thermal inertia
 (6kg of frozen water bags + 5kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B		FWB			
TRAY C					
TRAY D	FWB				

DEWAR Y

Dewar at -80°C
 11kg thermal inertia
 (4kg of frozen water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR Z

Inactive Dewar
 8kg of liquid water bags

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	LWB				
TRAY B		LWB			
TRAY C		LWB			
TRAY D	LWB				

When a fourth Dewar is cooled down to -80°C (case 4) and when 44kg of thermal inertia are available in the three active Dewar (i.e. when eleven (11) kilograms of new samples are created), the 44kg of samples and water bags shall be spread among the four Dewars as described hereafter.

Case 4

-80°C	-80°C	-80°C	-80°C
4 / 0 / 7	4 / 0 / 7	4 / 0 / 7	4 / 0 / 7

DEWAR W
Dewar at -80°C
11kg thermal inertia
(4kg of frozen water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR X
Dewar at -80°C
11kg thermal inertia
(4kg of frozen water bags + 7kg of samples)

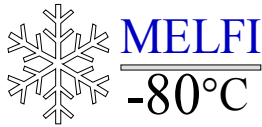
	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR Y
Dewar at -80°C
11kg thermal inertia
(4kg of water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR Z
Dewar at -80°C
11kg thermal inertia
(4kg of water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				



When in ISS and only one active Dewar (at -80°C), a second Dewar can be cooled down: Dewar Z can be set to $+4^{\circ}\text{C}$ or a second Dewar at -26°C can be activated. In that case (case 5), 3.5kg of thermal inertia are needed in Dewar at -26°C . Thus, two water bags (2x2kg) shall be transferred from -80°C to the Dewar at -26°C and warmed up to -26°C . Samples and water bags shall be distributed between both Dewars respecting the configuration described hereafter:

Case 5

-80°C	-26°C	OFF	OFF
12 / 0 / 4	4 / 0 / 0	0 / 0 / 0	0 / 8 / 0

DEWAR W
Dewar at -80°C
16kg thermal inertia (12kg of frozen water bags + 4 kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	■	FWB	FWB		
TRAY B	■		FWB		
TRAY C	■		FWB		
TRAY D	■	FWB	FWB		

DEWAR X
Dewar at -26°C
4kg thermal inertia (4kg of frozen water bags)

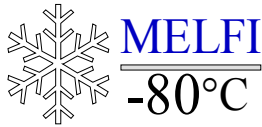
	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	■	FWB			
TRAY B	■				
TRAY C	■				
TRAY D	■	FWB			

DEWAR Y
Inactive Dewar
Empty

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	■				
TRAY B	■				
TRAY C	■				
TRAY D	■				

DEWAR Z
Inactive Dewar
8kg of liquid water bags

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	■	LWB			
TRAY B	■		LWB		
TRAY C	■		LWB		
TRAY D	■	LWB			



When a third Dewar is cooled down (to -80°C , case 6) and when 22kg of thermal inertia at -80°C are available in the first Dewar at -80°C (i.e. when six kilograms of new samples are created), the 22kg of samples and water bags shall be spread among the two Dewars at -80°C as described hereafter:

Case 6

-80°C	-26°C	-80°C	OFF
6 / 0 / 5	4 / 0 / 0	6 / 0 / 5	0 / 8 / 0

DEWAR W

Dewar at -80°C
 11kg thermal inertia
 (6kg of frozen water
 bags + 5kg of
 samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B			FWB		
TRAY C					
TRAY D	FWB				

DEWAR X

Dewar at -26°C
 4kg thermal inertia
 (4kg of frozen water
 bags)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR Y

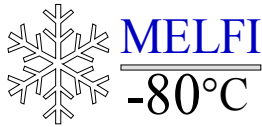
Dewar at -80°C
 11kg thermal inertia
 (6kg of frozen water
 bags + 5kg of
 samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B			FWB		
TRAY C					
TRAY D	FWB				

DEWAR Z

Inactive Dewar
 8kg of liquid water
 bags

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	LWB				
TRAY B			LWB		
TRAY C			LWB		
TRAY D	LWB				



When a fourth Dewar is cooled down (to -80°C , case 7) and when 33kg of thermal inertia at -80°C are available in the two Dewars at -80°C (i.e. when eleven kilograms of new samples are created), the 33kg of samples and water bags shall be distributed among the three Dewars at -80°C as described hereafter. All the liquid water bags shall be emptied and eliminated.

Case 7

-80°C	-26°C	-80°C	-80°C
4 / 0 / 7	4 / 0 / 0	4 / 0 / 7	4 / 0 / 7

DEWAR W
Dewar at -80°C
 11kg thermal inertia (4kg of frozen water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR X
Dewar at -26°C
 4kg thermal inertia (4kg of frozen water bags)

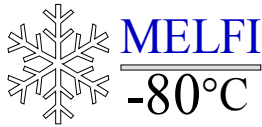
	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR Y
Dewar at -80°C
 11kg thermal inertia (4kg of water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR Z
Dewar at -80°C
 11kg thermal inertia (4kg of water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				



This additional case presents the utilization of the liquid water bags in the **mode at +4°C**.

-80°C	-80°C	-80°C	+4°C
6 / 0 / 5	6 / 0 / 5	4 / 0 / 7	0 / 8 / 0

DEWAR W
Dewar at -80°C
 11kg thermal inertia (6kg of water bags + 5kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B			FWB		
TRAY C					
TRAY D	FWB				

DEWAR X
Dewar at -80°C
 11kg thermal inertia (6kg of water bags + 5kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B			FWB		
TRAY C					
TRAY D	FWB				

DEWAR Y
Dewar at -80°C
 11kg thermal inertia (4kg of water bags + 7kg of samples)

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	FWB				
TRAY B					
TRAY C					
TRAY D	FWB				

DEWAR Z
Dewar at +4°C
 8kg of liquid water bags

	Foam block	Box 1	Box 2	Box 3	Box 4
TRAY A	LWB				
TRAY B			LWB		
TRAY C			LWB		
TRAY D	LWB				

The frozen water bags shall remain frozen in the Dewars at -80°C or -26°C as long as the thermal inertia is not sufficient to cope with an unexpected power off period. Once enough thermal inertia is obtained with real samples for all Dewars, the water bags may be discarded respecting the following procedure:

- Remove the box modules containing the water bags from the Dewars
- Wait for the defrosting of the bags
- Remove the water bags from the box modules
- Reinsert the empty box modules inside the Dewars
- Discard the water from bags.

In the same way, the liquid water bags shall remain in the Dewar at $+4^{\circ}\text{C}$ as long as the needed thermal inertia is not reached. Once the minimum thermal mass needed to cope with an 8h power off period is needed, the water bags may be discarded following the procedure:

- Remove the box modules containing the water bags from the Dewar
- Remove the water bags from the box modules
- Reinsert the empty box modules inside the Dewar
- Discard the water from bags.

For passive launches or if more than 9kg of samples have to be brought to ISS while power limitation is 550W, water bags would have to be frozen on orbit.

Once the method to freeze water bags on orbit have been validated, one Dewar in -80°C mode shall be dedicated to water bags freezing on orbit. So that the already cold samples in the cold Dewars remain protected, the water bags freezing shall be performed in a staggered manner (one box modules with 2kg frozen per day).

5.3 MELFI NOMINAL OPERATIONS

The list of procedures for nominal operations is given below:

Nominal operations

- MELFI Rack Power Up PR-01
- MELFI Rack Power Down PR-02
- Configure for operations PR-03
- Set/Change Dewar temperature PR-04
- Transfer spares from Old Rack to New Rack: spare EU, BMEE, NFPE PR-05
- Tray Exchange between MELFI Racks PR-06
- Tray Exchange between Dewars PR-07
- Box Module Exchange PR-08
- Sample loading /transfer PR-09
- Configure for Return PR-10

Each step-by-step procedure is provided in the “On-Orbit Crew Procedure” (RD1).

For safety reasons, the use of protective equipment is mandatory when the crew accesses cold parts: goggles for de-icing (ISS-provided), cryogenic and cotton gloves plus sleeves if necessary for de-icing and also nominal operations with cold trays and Box modules. This protective equipment is stored inside the MELFI DASE pouch located into the Stowage Compartment.

Cue Cards should be used to keep track of the Dewars settings and parameters which values were changed from default values.

5.4 RULES FOR SAMPLE INSERTION

Rules are defined for sample insertion in a cold Dewar (-80°C mode) in order to ensure the cooling down performances and to protect the already frozen samples. The definition of the Box Module position inside a Tray is recalled in the figure below:

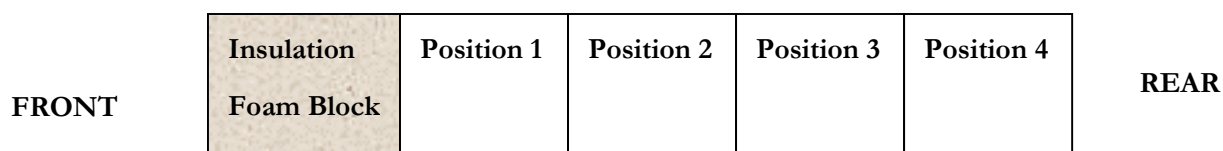




Figure 5.4-1: Box Module position inside a Tray

RULE 1: Samples insertion

1. Warm samples are inserted alternating the Dewars: Dewar 1, then Dewar 2, then Dewar 1 ... or Dewar 1, then Dewar 2, then Dewar 3, then Dewar 1
2. In each Dewar, samples are inserted alternating the trays where Receiving Box Modules are located : Dewar 1-Tray A ; Dewar 2 –Tray A ; Dewar 1- Tray B ; Dewar 2-Tray B ; Dewar 1-Tray A ...
3. Warm samples are always inserted in the receiving Box Module in Tray position 1
4. If there is a frozen sample in the Box Module where the warm sample has to be installed, please move the frozen sample at the rear of the Tray to the Box module position 4. If position 4 is already full of sample, move to position 3 or position 2 if Box Module Position 3 and 4 are full.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 102
---	---	--

RULE 2: Minimum elapsed time between consecutive insertions into the same Dewar

This rule was established to both ensure the cooling down performance and protect already frozen samples, including samples stored in Tray position 2. The minimum elapsed time depends on the sample volume:

1. If sample volume is ≤ 250 ml, the sample is installed in a $\frac{1}{4}$ size Receiving Box Module
 - a. Minimum elapsed time is 30 min for sample volume ≤ 30 ml
 - b. Minimum elapsed time is X min for $30 \text{ ml} < \text{sample volume} \leq 250 \text{ ml}$; X is the figure for the sample volume (for instance the minimum elapsed time is 100 min for a 100 ml sample)
2. If sample volume is > 250 ml, the sample is thus inserted in a $\frac{1}{2}$ size Receiving Box Module; for an X ml sample, the minimum elapsed time is X min.

RULE 3: Minimum elapsed time between consecutive sample insertions in the same Dewar and without any cooling down performances and an empty position 2 Box Module



In this case, the frozen samples are in position 3 & position 4 Box Modules:

1. If sample volume is ≤ 250 ml, the sample is installed in a $\frac{1}{4}$ size Receiving Box Module
 - a. Minimum elapsed time is 15 min for sample volume ≤ 30 ml
 - b. Minimum elapsed time is X/2 min for $30 \text{ ml} < \text{sample volume} \leq 250 \text{ ml}$; X is the figure for the sample volume (for instance the minimum elapsed time is 100 min for a 100 ml sample)
2. If sample volume is > 250 ml, the sample is thus inserted in a $\frac{1}{2}$ size Receiving Box Module; for an X ml sample, the minimum elapsed time is X min.

5.5 PERFORMANCES GUIDELINES

The main guidelines for MELFI operations are listed below:

- The **duration of a Dewar door opening** is limited to 60 s on an active MELFI. This constraint should be taken into account for all the operations that requires opening of a Dewar door.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 103
---	---	--

□ The **performance of the MELFI** system (electrical power consumption versus cold power production) is ensured if the pressure of N2 is 1600 hPa +/- 20 Pa. at 20°C (= **mean gas cycle temperature**).

□ *In the MPLM/ISS, when the **water temperature** is in the range 7.2°C to 8.3°C, MELFI power allocation should be increased by **50W**: 600W for the 1 Dewar mode and 950W for the 4 Dewars mode.*

If the Water temperature is within the range of 8.3°C to 10.0°C, 100 W to keep the margins in performances should increase power allocation.

When MELFI is on the launch Pad, inside MPLM, the cooling down should be started with the maximum motor speed (parameter 09H) at the value of 92 000 rpms. This will allow MELFI to use up to 1000 W on ground before launch.

Once in-orbit, parameter 09H will recover the default value or value associated with the available power for MELFI.



□ The **Foam Plug** is designed to replace a Tray in a Cold Dewar and in particular for the exchange of a cold tray between MELFI racks or during de-icing operations which cannot be done within the 60 s allocation.

5.6 HANDLING /SPECIAL CARE

□ Cotton **gloves**, cryogenic gloves and sleeves are provided to prevent injury from touching the cold surfaces inside the Dewars and items removed from the cold Dewars. Cotton gloves are required for sample loading and removal. Cryogenic gloves, sleeves and goggles are required for the Dewar de-icing operations.

□ The handling of **trays** during insertion / extraction into or from a Dewar should be done carefully. Avoid force on a tray because it could get twisted or damaged. If there are difficulties, interrupt the insertion or extraction and check if there is no element impeding the tray insertion/extraction.

□ The **Thermal bag** is made of tissue and thermal blankets that can be damaged if not handled with care.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 104
---	---	--

☐ No traces of **moisture or liquids** should be inserted in a cold Dewar otherwise there is a risk of uncontrolled ice build-up, which may jeopardize the utilization of a Dewar. It is therefore necessary to wipe-off the surface of cold or warm Box Modules or Trays, which are inserted into a Cold Dewar. This should in particular be taken into account for the training of the on-orbit procedures with the MELFI TRM.

☐ **Samples containment:** verify that the samples are not leaking before their insertion; in particular traces of NaCl should be avoided for Dewar internal wall corrosion prevention. The choice of sample containers is beyond ASTRIUM responsibility and it is recommended to only use material for cryogenic application in order to avoid leaky samples in MELFI.

☐ The Rack should never be moved when the Brayton Machine is running (risk of Brayton Machine failure).

On-orbit, the Brayton Machine shall be stopped during the following events:


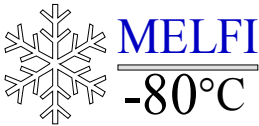
- MPLM docking to the Station or de-docking from the Station
- Station Re-boost phase.

5.7 TROUBLESHOOTING

☐ It is recommended to keep in mind the **priority management between MAIN and AUX buses** before performing a Power-Up or Power-Down. As soon as the MAIN bus is available, MELFI will automatically switch to that bus going through a complete reset, losing thus the last current configuration. MELFI will perform the initialization steps and if everything is OK the payload will be in STANDBY Mode (or STOP Mode incase an anomaly is detected).

☐ MELFI goes automatically to **MANUAL** Mode if telemetry is lost.

☐ The **Commands** allowed for the Crew should all commands except level 2 commands, so that the Crew can restart MELFI after a power-off and bringing it back to the previous configuration.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 105
---	---	--

□ The duration of the **MELFI initialization** (Self-test mode) lasts about 3 minutes, which means that the CPI display is locked during 20s (same status as before the power-off) and then MELFI goes to initialization phase which lasts about 3 minutes before going to Standby Mode or the Stop mode.

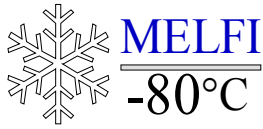
□ The **STOP** mode is either the result of an anomaly detection by the S/W (see the Recovery and monitoring chapter in the S/W section), and in this case the STOP LED on the CPI is blinking either the result of an external action from the Crew through the Brayton Motor Switch activation on CPI or from a command sent through the 1553 bus to MELFI S/W. The Payload will remain in the STOP Mode as long as the anomaly is not recovered.

□ If a **tray is blocked** inside a Dewar or if the Nomex sling to push/pull the Tray is damaged, there is a handle tool available to help the tray extraction from a Dewar. The Tray handle is stored in the Dewar ASE and should be screwed on the front side of the foam block. Its “T-shape” will ease to grip it to extract the tray.

□ If performances are degraded, one must check the pressure of the Nitrogen gas cycle, taking into account the average gas temperature and the rotational speed of the Brayton Machine. Actually the MELFI is designed to operate with a pressure of $1600 \pm 20\text{mbar}$ @ 20°C.

Malfunctions:

- MAIN Power loss from Switch Box MAL-01
- AUX Power loss from Switch Box MAL-02
- MAIN or AUX power loss from CPI MAL-03
- Abnormal loss of +28V internal power on CPI MAL-04
- Abnormal loss of +5V, +12V and -12V internal power on CPI MAL-05
- Loss of Telemetry MAL-06
- Brayton Machine out-of-limit speed MAL-07
- Abnormal Dewar door Open indication MAL-08
- Dewar out-of-limit temperature MAL-09
- Abnormal off status of CPI LEDs MAL-10



Ref: MELFI-MA-03000-0435-MMT



Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 106

- Failure of CPI segment displays MAL-11
- Switch failure MAL-12
- Payload in STOP Mode MAL-13
- Unexpected STANDBY Mode MAL-14

Each step-by-step procedure is provided in the "On-Orbit Crew Procedures" document (RD1).

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 107
---	---	--

6 HARDWARE DESCRIPTION.

The description of the MELFI H/W items is provided hereafter starting from top to bottom of the rack:

6.1 ELECTRONIC UNIT

The Electronic Unit (EU) is an Orbit Replaceable Unit (ORU). The active location of the EU in the MELFI Rack is at the Rack top right corner.

A spare EU is located beside the active one on the top left corner. A Tissue panel covers the spare EU in order to avoid any misleading situation for the crew. In case there is no spare EU integrated in a flight model, its slot is closed by a Blind Panel. The operations related to the on-orbit replacement of a failed EU are described at the end of this chapter.

The Electronic Unit receives power from the Station (or MPLM) and through the MELFI RIU and distributes it to the MELFI sub-units. The EU also controls and commands the MELFI either through the Crew I/F panel (manual mode) or through the 1553 bus for remote control (remote mode).

The EU is composed of the following elements (Figures 6.1 – 1 and 6.1 - 2):

- A Crew Panel Interface (CPI) which is the front panel of the EU where commands switches and displays are located,
- A Control and Data Handling Unit (CDHU) where the MELFI Software resides; the CDHU is made from three boards: a Central Processing Unit (CPU) and two I/O modules mounted onto a VME baseboard,
- A Motor Drive Electronics (MDE) which allow to drive the Brayton Machine
- A Power Supply Unit (PSU)
- A cold plate connected to the MELFI Water Loop
- A set of electrical connectors interfacing to the MELFI internal harness at the Rack.

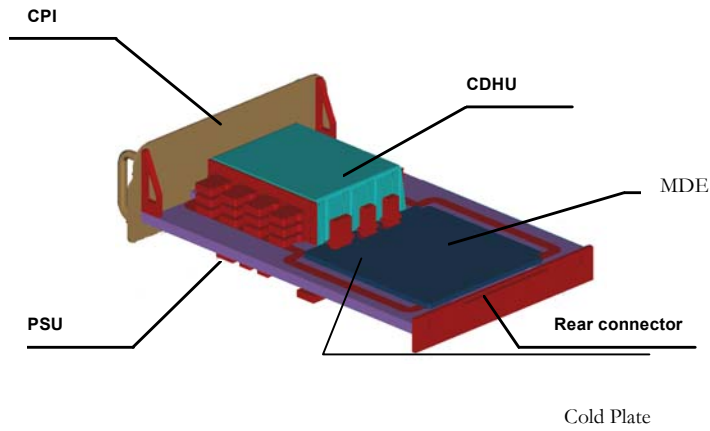


Figure 6.1 - 1: Electronic Unit layout

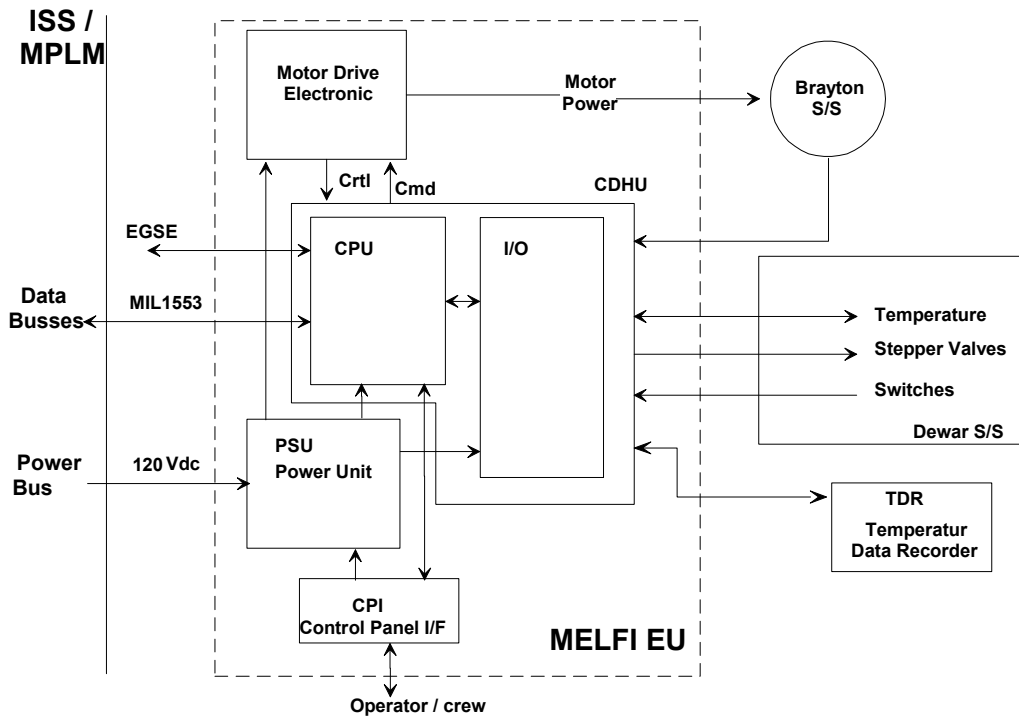

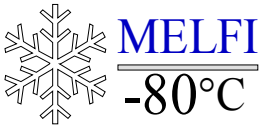


Figure 6.1 - 2: Electronic Unit overview with its functional units

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 109
---	---	--

6.1.1 Crew Panel Interface

The MELFI S/W manages the CPI: refer to section 3.7 of this document for details.

The CPI supports crew interface for local mode operation and provides MELFI payload status, mode and displays. These are described hereafter:

- Internal Power
 - 28V LED (hardware driven and indicates 28V power status, illuminated green)
 - +12V LED (hardware driven and indicates +12V power status, illuminated green)
 - 12V LED (hardware driven and indicates -12V power status, illuminated green)
 - 5V LED (hardware driven and indicates 5V power status, illuminated green)
- Active Power
 - MAIN (hardware driven and indicates Main power status, illuminated green)
 - AUX. (hardware driven and indicates Aux. power status, illuminated green)
- Brayton Power
 - MOTOR STOP Switch (2-position lever lock ON-STOP)
 - MOTOR STOP LED (hardware driven and indicates Motor Stop Switch has been selected ON, illuminated green)
 - POWER LED (hardware driven and indicates Brayton power status, illuminated green)

The four power lines are all light on as soon as MELFI is ready for operation.

When the power LED is illuminated, this means that the Brayton Machine motor is running (speed > system parameter figure for minimum speed). Either the Brayton Machine NOMINAL

Speed or the OUT-OF-LIMIT Speed LED shall be illuminated when the Brayton POWER LED is light on.

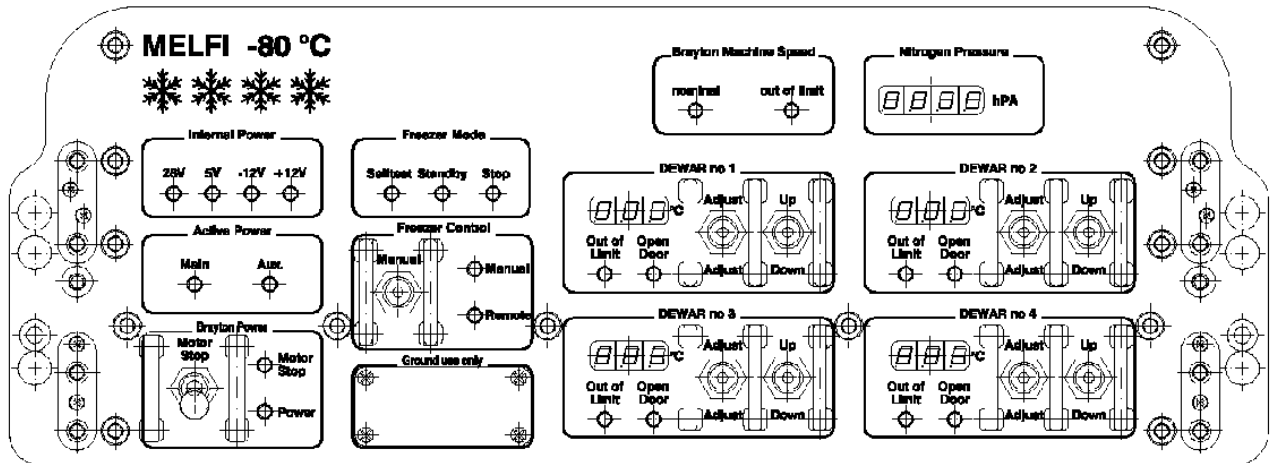


Figure 6.1 - 3: Crew Panel Interface

- Freezer Mode
 - SELF-TEST LED (software driven and indicates Self-test Mode, illuminated yellow)
 - STANDBY LED (software driven and indicates Standby Mode, illuminated yellow)
 - STOP LED (software driven and indicates Stop Mode, illuminated red).

The SELFTEST is only illuminated during the MELFI initialization phase, which lasts 3 minutes. When initialization is completed and no anomaly detected, the SELF-TEST is light – off and the STANDBY LED is light – on.

The STOP Mode is blinking when the MELFI software recovery function has detected an anomaly. If the STOP Mode is the result of a decision external to the Payload (Telecommand or Brayton STOP switch activated in emergency by crew), the STOP Mode is illuminated but not blinking.

- Freezer Control
 - MANUAL Switch (2-position momentary switch, parked position is the center)
 - MANUAL LED (software driven and indicates Manual Mode, illuminated green)

- REMOTE LED (software driven and indicates Remote Mode, illuminated green)

During nominal operations, either the MANUAL LED or the REMOTE LED is illuminated depending on the type of MELFI Control mode.

The activation of the MANUAL Mode from CPI can be inhibited by the S/W. In this case, the activation of the MANUAL Switch will lead to a temporary blinking of the Manual Mode LED (duration of switch activation + 5 sec) to inform crew that the operation is not possible.

- Ground Use Only

This part of the CPI is covered with a protective cap during flight, and crew access is not possible.

- Brayton Machine Speed



- NOMINAL LED (software driven and indicates BM speed is nominal, illuminated green)
- OUT OF LIMIT LED (software driven and indicates BM speed is out of limit, illuminated yellow)

The OUT OF LIMIT LED is illuminated when the difference between the actual Brayton Machine Speed and the expected speed (estimated from Motor Drive Electronics power supply) is exceeded. This information is also acquired by the S/W as part of the Monitoring and Recovery function. As soon as an anomaly is detected, MELFI will switch to the STOP Mode. The OUT OF LIMIT LED can only be illuminated if there is an anomaly and the corresponding information is no longer monitored by the S/W (for instance, it was inhibited as a ground decision to operate in degraded conditions).

- Nitrogen Pressure

- PRESSURE DISPLAY (software driven and indicates N₂ cycle pressure; 4 digit, seven segment display, illuminated red). The figure displayed is the average of the 2 pressure sensors.

- Temperature Setting - Dewars 1 - 4, identical controls

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 112
---	---	--

- TEMPERATURE DISPLAY (software driven and indicates Dewar temperature or set-point; 3 digit, seven segment, illuminated red). The figure displayed is the average of the 4 temperature sensors implemented in each Dewar.
- OUT OF LIMIT LED (software driven and indicates Dewar temperature out of limit, illuminated yellow)
- OPEN DOOR LED (software driven and indicates Dewar door open, illuminated yellow)
- ADJUST Switch (3-position momentary switch, neutral position is the center; direction commands set-point adjustment direction)
- UP/DOWN Switch (3-position momentary switch, neutral position is the center; direction commands set-point adjustment direction)

The range of temperature setting from CPI depends on the number of active cold Dewars and is managed by the software (refer to the S/W section).

6.1.2 Control and Data Handling Unit

The Control and Data Handling Unit (CDHU) is the central data processing unit of MELFI. It controls and monitors functions of sub-systems and handles 1553B data interface with MPLM and /or ISS.

The CDHU comprises a processing unit with associated analogue data acquisition electronics to measure temperatures, pressure, rotational speed and electrical power. The CPU block diagram is represented in figure below.

It reads the Dewars temperature at four different locations in each Dewar. Then analogue to digital converter (ADC) digitizes the temperature signals. The software reads the converted values and applies a processing algorithm to determine the set points for each cold valve, thus controlling the amount of cold gas distributed to each Dewar.

The MELFI has to accommodate various freezer loads. This is done through the adjustment of the Brayton machine speed. The speed set point and the current rotational speed are exchanged by digital command words between the CDHU and the MDE via a serial synchronous data link comprising an enable, a clock and a data line.

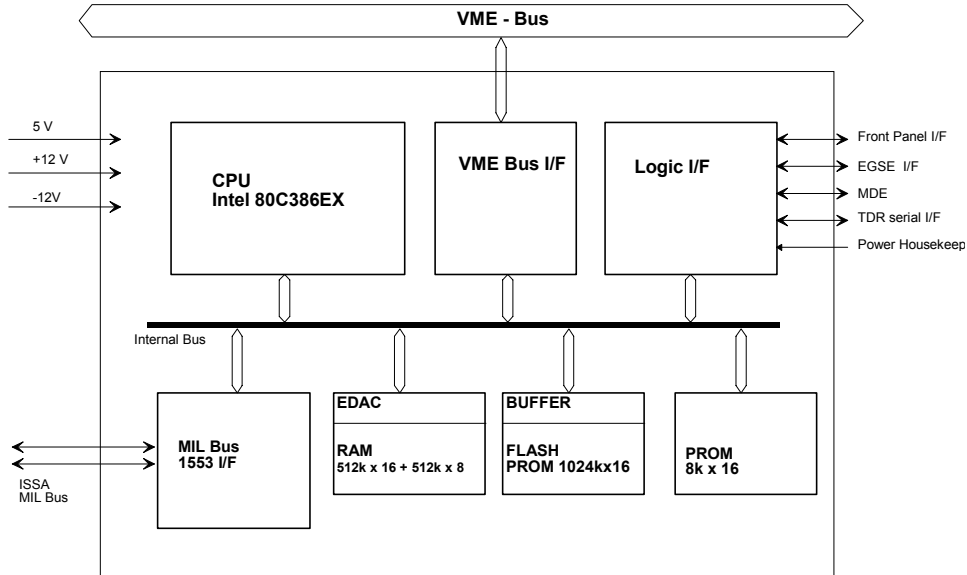


Figure 6.1 - 4: CPU block diagram

6.1.3 Power Supply Unit

The Power Supply Unit is in charge of supplying power to the CDHU, CPI and also to the stepper motors controlling the N2 valves in the Dewars, the Brayton S/S via the MDE and the Temperature Data Recorder (TDR) located in the rack. It thus conditions ISS or MPLM supplied power to RIU before routing it to other components inside the EU.

The power supply module basically consists of three components (two DC converter modules and a housekeeping module) mounted in one box. It converts the primary input voltage (120V DC) to the voltages needed in the other components of the EU (+5, +12, -12 and +28V DC) and measures the input voltage and the input currents on the primary side. The PSU block diagram is shown in figure 6.1-5.

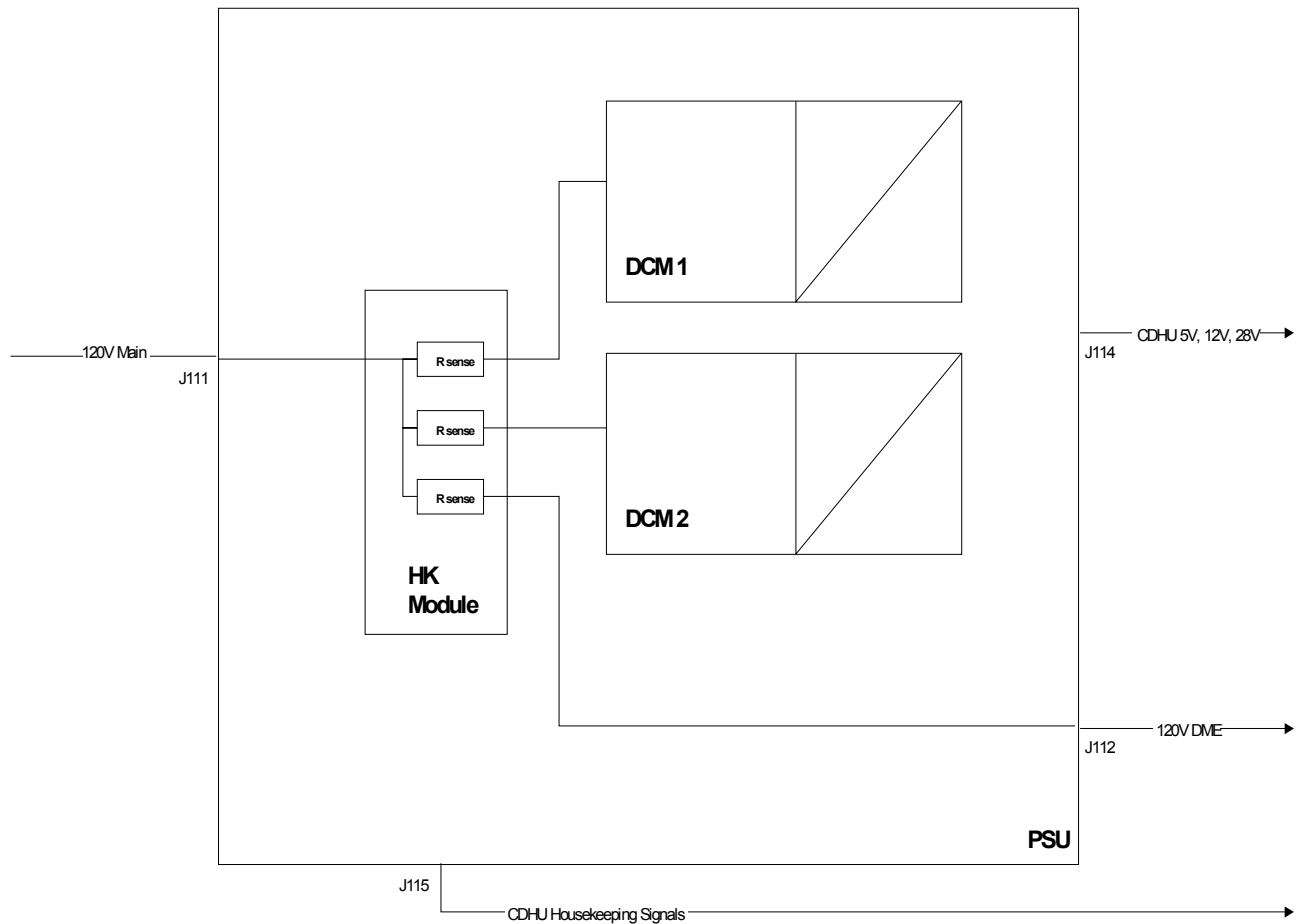




Figure 6.1 – 5: Power Supply Unit block diagram

6.1.4 Motor Drive Electronics

The Motor Drive Electronics (MDE) has the following functions:

- To supply the Brayton Machine motor from the +120V power bus line
- To control the motor speed according to set points computed by the MELFI Software and sent by the CDHU. The control logic resides in a FPGA device.
- To monitor the MDE internal status
- To protect the motor against over-temperature

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 115
---	---	--

- To protect the MDE against external over-voltage or internal over-temperature and also against the lack of speed command (internal H/W watchdog)

The overall architecture is based upon one power input for the MDE DC/DC converters and another one for the motor power. This allows the TM / TC to be active when no power is applied to the BM motor.

The MDE design is distributed over two printed circuit boards: one board comprises the motor power bridge, MosFets drivers and motor telemetry bus /protection circuits, while the second board houses the logic and the DC/DC converter and the isolated circuit for the motor temperature control.

The MDE block diagram is represented in figure 6.1-6.

6.1.5 EU mechanical design

The CDHU, PSU, CPI and MDE form one single structural unit. The boxes are mounted on both sides of a base plate in order to provide adequate cooling to the electronics. This base plate acts as a cold plate and is connected to the water loop with QDs to allow on orbital exchange of the EU.

The Electronic Unit is attached to the Rack using guiding rails, self-mating connectors at the rear and captive screws to attach the front panel (CPI) to the rack. The 120V cable from the MDE to the Brayton Machine is directly routed from the EU to the Brayton S/S for EMC reasons. In case of EU exchange, this cable will have to be separately de-mated once the Cold Box front panel is removed.

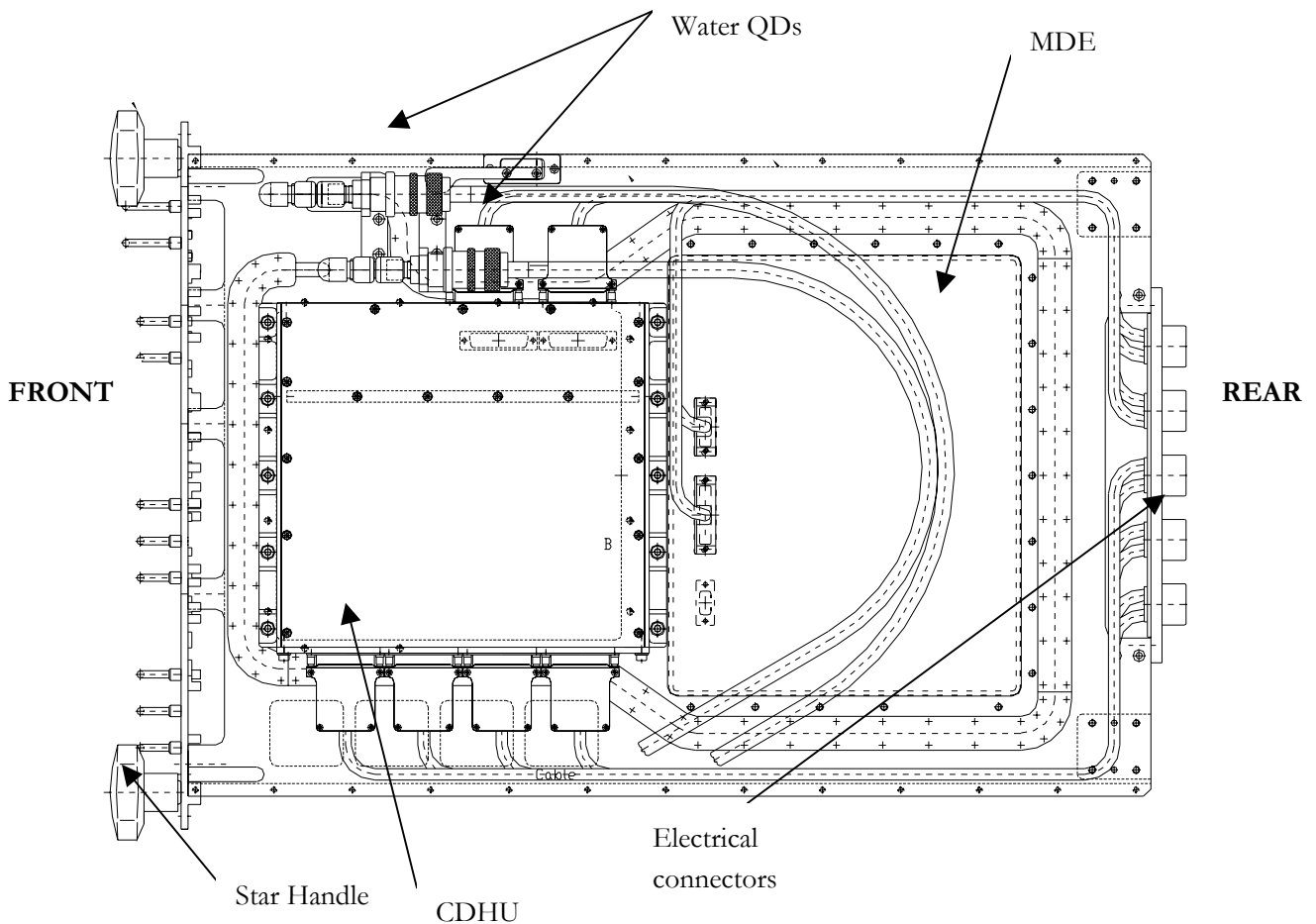


Figure 6.1 - 7: Electronic Unit Top View

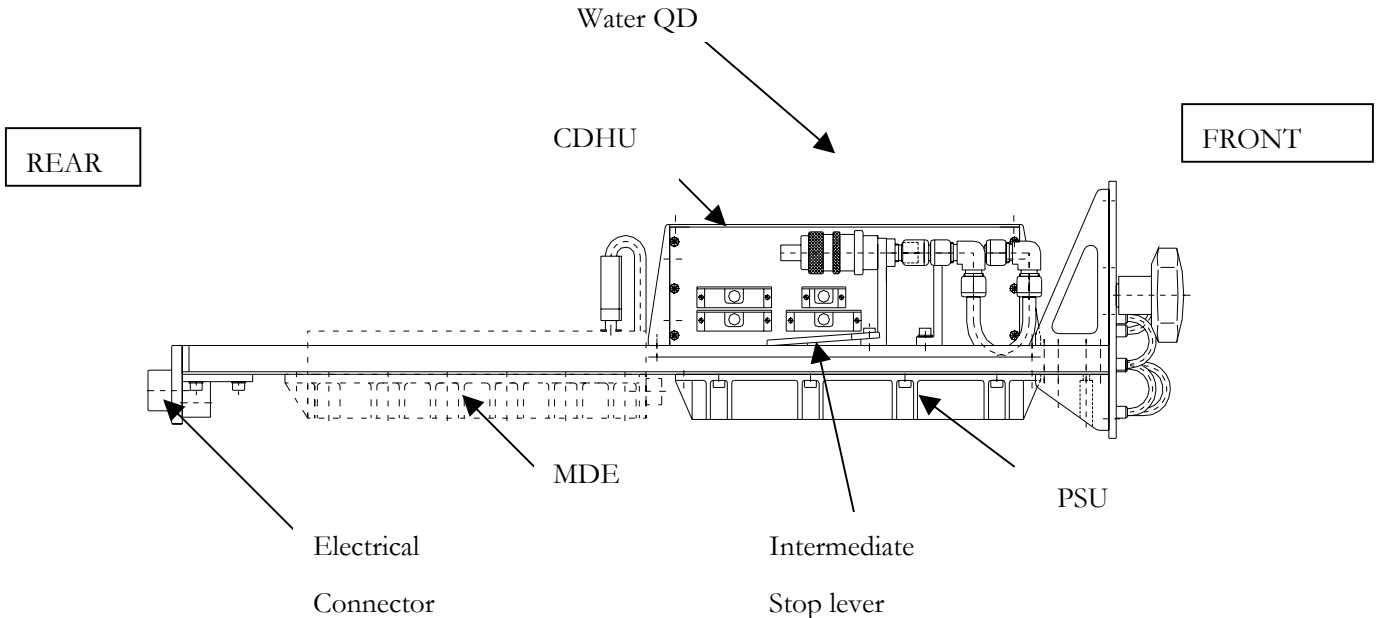


Figure 6.1 - 8: Electronic Unit Side View (left side)

6.1.6 ORU operations

In order to meet the reliability requirements, two Electronic Units can be installed in the MELFI rack, only one being active. In case of failure, the spare unit can thus replace this EU.

The in-flight replacement of the Electronic Unit is a two crewmembers operation. The different parts accessed by the crew for this operation are listed below:

- EU front panel captive screws to be loosen using the Triple Square M6 Tool stored in the DASE Pouch,
- Cold Box front panel to dismount (captive screws), using the same tool as above, to access the MDE cable connected to the Brayton Machine

- Water Quick Disconnects (2 QDs) for the EU connection to the MELFI Water Loop;
- The utilization of 2 Star Handles to help the extraction and insertion of the EU from the Rack.
- The utilization of the Triple Square M4 Tool to dismount the EU WED from the Spare Unit and screw it to the failed EU.
- The utilization of the EU QD mating tool to ease the connection of the Water loop flex hoses to the Spare EU Quick Disconnects
- The routing of the MDE cable below the EU is shown in Figure 6.1-9. This activity is performed when a failed EU is removed from the Rack.

The five electrical connectors located at the rear of the EU are automatically de-mated during EU replacement. The crew does not access them.

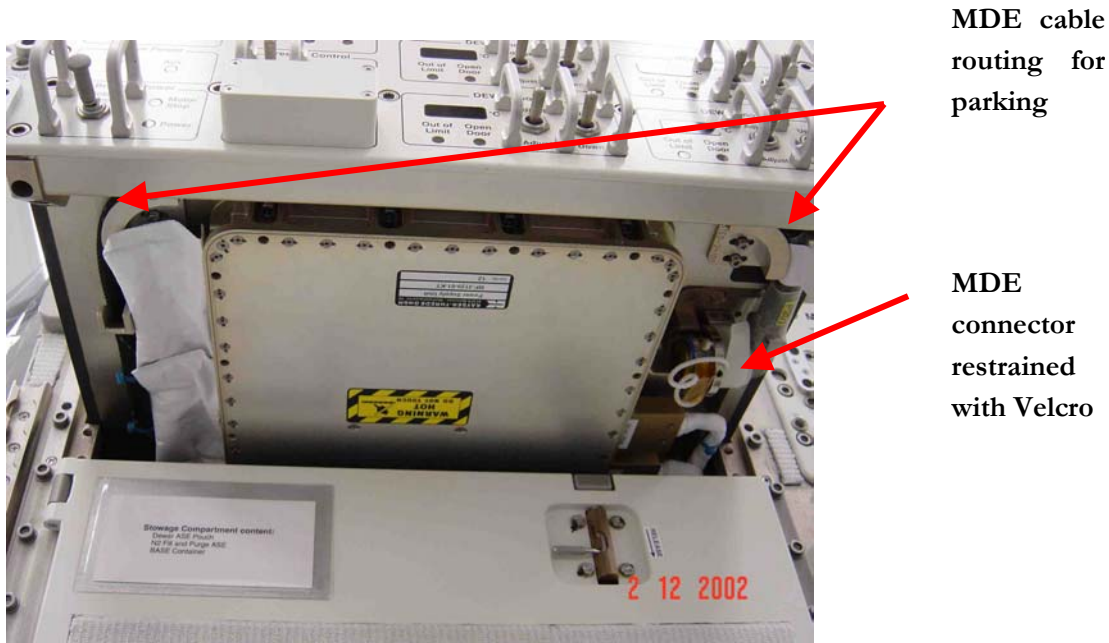


Figure 6.1- 9: MDE Cable routing below the EU

Both water QD's are located on the left side of the EU (Figure 6.1-8).

MDE
Connector
parking

MDE cable
parking

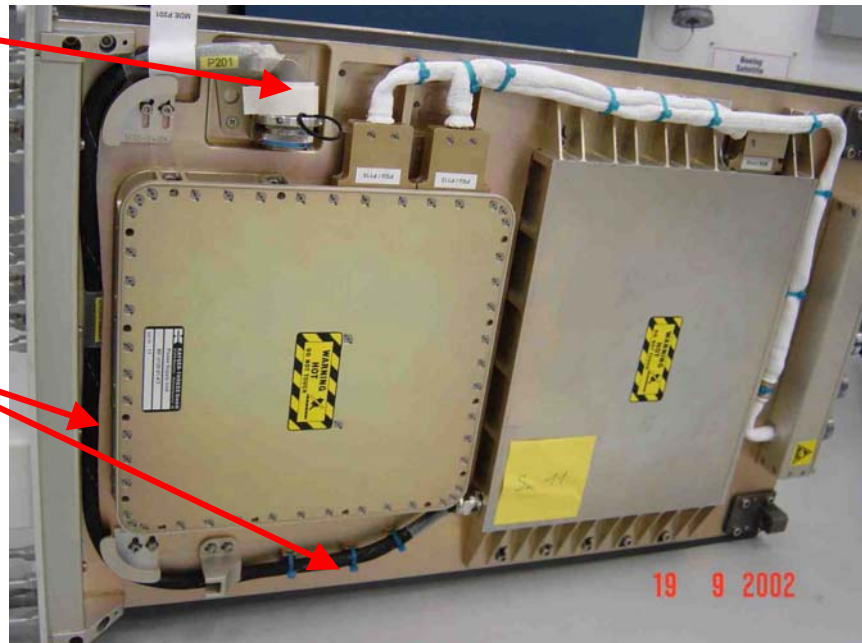


Figure 6.1 - 10: Details of the EU connector parking

For the EU exchange, captive screws on both sides of the front panel must be fastening. Two Star Handles (Figure 6.1-12) are necessary for the EU extraction from the Rack. They are located on the pass-through panel for launch and landing configuration and stored in the Dewar ASE during the in-orbit mission. Each Star Handle is mounted on dedicated holes to help the extraction and / or insertion of the EU in its slot. These are located on the left side and the right side of the EU front panel. Both Star Handles must be **clockwise** rotated slowly and smoothly to allow a straight extraction of the EU. When the EU is partially extracted, it is necessary to deactivate the intermediate end-stop located on the left side of the EU to allow the complete extraction (Figure 6.1-11). This intermediate end-stop protects the Water Loop components from damage in case of complete extraction without having them disconnected first.

The EU Water Expansion Device (WED) is on the EU Spare Unit. It is necessary to use the Triple Square M4 Tool, stored in the MELFI DASE Pouch, to dismount the WED and connect it to the failed EU. The WED is depicted on figure 6.1-14.

The EU QD mating Tool, also stored in the DASE Pouch, is a pinch-like tool (figure 6.1-13). This tool is used to ease the connection of the Water QDs (no tool is deemed necessary for the disconnection).

Water QDs

End-stop



Figure 6.1 - 11: Details of the EU: QDs and end-stop



Figure 6.1 - 12: Star Handles



Figure 6.1 - 13: EU QD Mating Tool

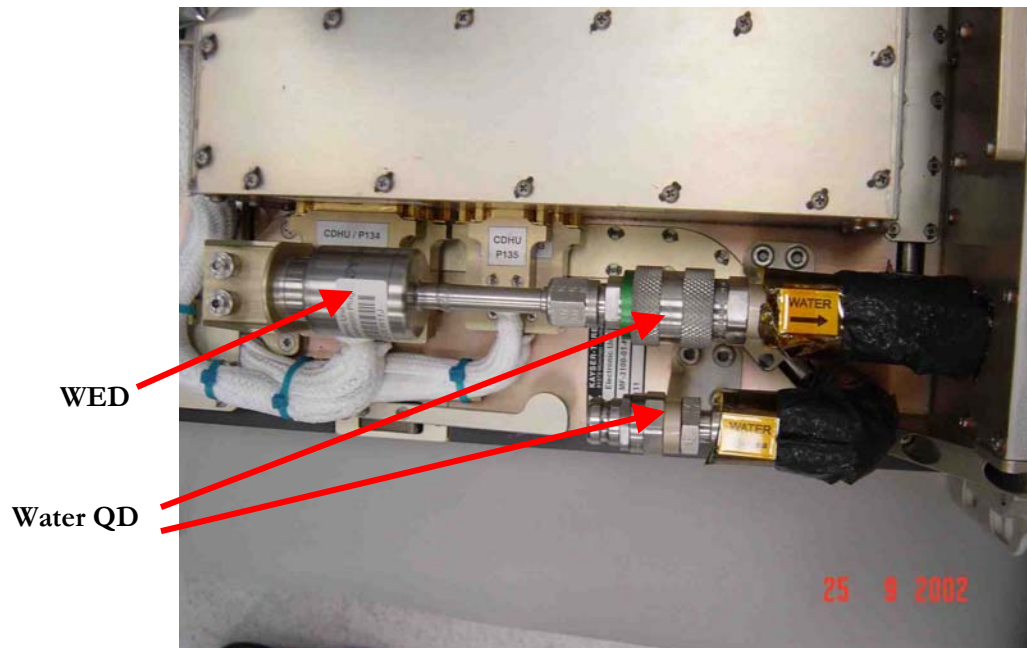

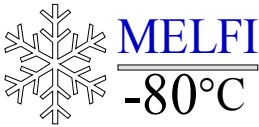


Figure 6.1 - 14: Top view of the spare EU, showing the WED

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 123
---	---	--

6.2 STOWAGE COMPARTMENT

The Stowage Compartment is a large and deep compartment which accommodates 3 elements dedicated to on-orbit maintenance operations:

- Dewar ASE
- Brayton ASE
- Nitrogen Fill and Purge Equipment

The internal layout of the stowage Compartment is shown in Figures 6.2-1& 6.2-2.

The Stowage compartment is equipped with a hinged door, closed by three latches (Figure 6.2-3).

The Dewar ASE is the first unit accessible when the door is open. The two remaining units are behind the Dewar ASE.

A CO₂ port for fire extinguisher is located at the right bottom corner of the stowage compartment.

In order to allow the CO₂ venting through the stowage Compartment, 25 mm diameter holes (Portable Fire Extinguisher Interface) are drilled respectively in the front door and the rear box panel:

- o A 25 mm tube is kept in the right bottom corner of the box,
- o The rear side of the rack is equipped with flex hoses which routes the CO₂ flow towards the electrical units,
- o CO₂ is provided by the Portable Fire Extinguisher

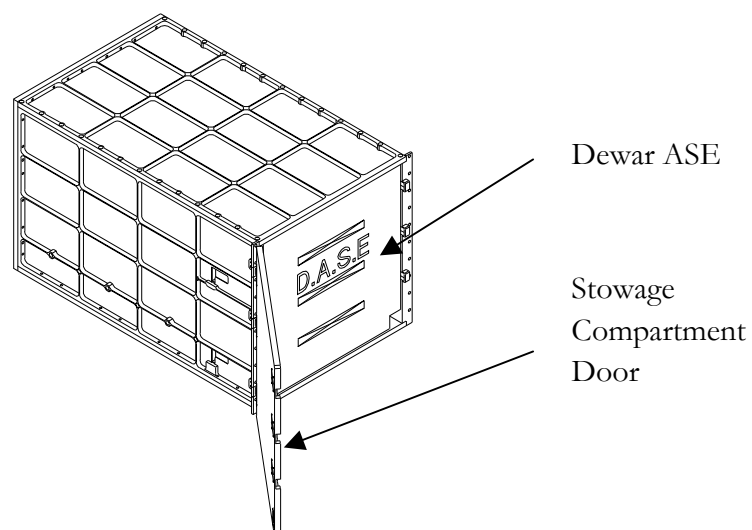


Figure 6.2-1: Stowage compartment internal layout

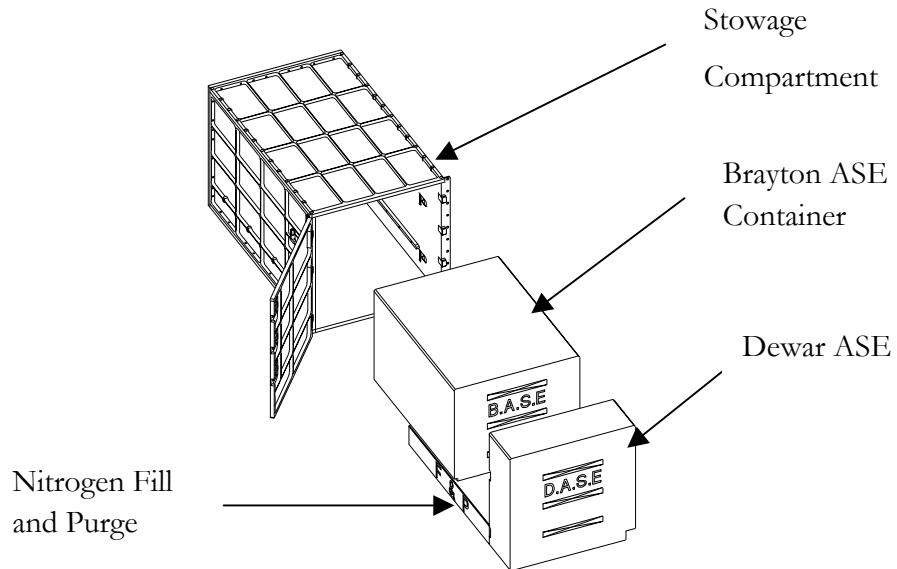




Figure 6.2 - 2: Stowage compartment internal layout



Figure 6.2 - 3: Stowage Compartment Door

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 125
---	---	--

6.3 DEWAR ASE

The Dewar Airborne Support Equipment is a set of tools for the operation of the MELFI accommodated inside a pouch made of Nomex tissue:

- 1 Ice Scraper Shaft - Long.
- 1 Ice Scraper Shaft - Short.
- 7 Ice Scraper heads.
- Cryogenic Gloves (2 pairs).
- Cotton Gloves (4 sizes of 2 pairs)
- 2 Sleeves.
- 4 Tray straps (2 long, 2 short).
- 1 Tray Handle.
- 2 Star Handles
- Spare fuses
- 1 EU QD mating tool
- TDR Battery pack
- Triple Square M6 Tool
- Triple Square M4 Tool
- Dewar door bolt (only as part of On Orbit commissioning)
- 24 mm Crowfoot ¼ drive

Goggles are ISS provided.

Tray Handle

The Tray Handle, shown in Figure 6.3 - 1, allows removal of the Trays from the Dewar when the sling handle is broken or unusual additional forces are necessary to extract a Tray from the Dewar. The Tray Handle may be operated by a one-handed procedure. The removal of a Tray from a Dewar requires two functions to be carried out. First, the Dewar door must be opened; the Tray Handle can then be inserted (by turning it into the thread) at the interface thread on the isolation block located under the sling handle. An end-stop ensures that the handle cannot be screwed too far in. Once the Tray Handle is in place, pulling the handle can retract the Tray. The Tray Handle can be disengaged from the Tray by unscrewing it.

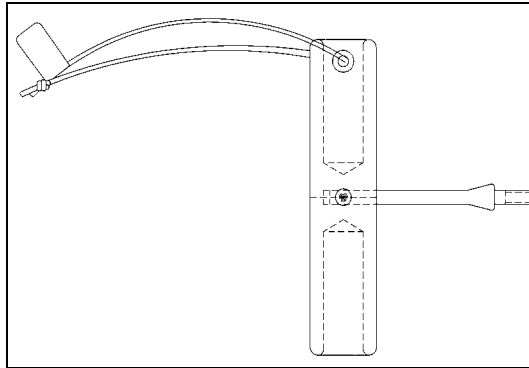


Figure 6.3-1: Tray Handle.

De-icing tools

The function of the de-icing tool is to allow removal of ice deposits inside the Dewars. The de-icing tool is a simple mechanical scraper, designed to access the areas of the internal outfitting where ice build-up would hinder the ability of the internal outfitting to function properly. The areas most sensitive to ice-formations are:

- a) The surface of the cold finger housing where the sliding wedges slides,
- b) The inner edge where the sliding rails slide on the cross-plate,
- c) The sliding rails on the Trays,
- d) The outer surface of the isolation block at the end of the Trays,
- e) The bottom corners at the end on the sliding edges on the cross-plates,
- f) The gaskets,

The de-icing tool consists of an ice-scraper handle used with gloves. It has an inner thread at one end for insertion of one of the different ice-scraper heads listed below. On the other end it has a small bungee loop with a Velcro hook patch for intermediate attachment of the tool. The Handle is provided in a short and a long version:

- Short: 22,3 cm (End-to-end, including Handle)

- Long: 54,0 cm (End-to-end, including Handle)

Seven different ice-scraper heads are provided for the de-icing of the internal outfitting:

1. C-shaped tool for the area a),
2. I-shaped tool for area d) and other large flat surfaces,
3. Small I-shaped tool for small and narrow flat surfaces,
4. ⊥-Shaped tool for areas b) and c),
5. V-shaped tool for area e) and other corners and inner edges.
6.)-Shaped tool for the inner Dewar wall.
7. A flexible flat head for gasket areas.

The gaskets and other smooth surfaces with snow formation can be cleaned with a soft cloth and the flexible flat tool with silicone rubber sole. Each ice-scraper head has an outer thread that fits to the ice-scraper handle. Furthermore, most of them have a slight bend (approx. 20 degrees) to allow for easier operation inside the Dewar. The ice-scraper handle and heads are shown in Figure 6.3 - 2.

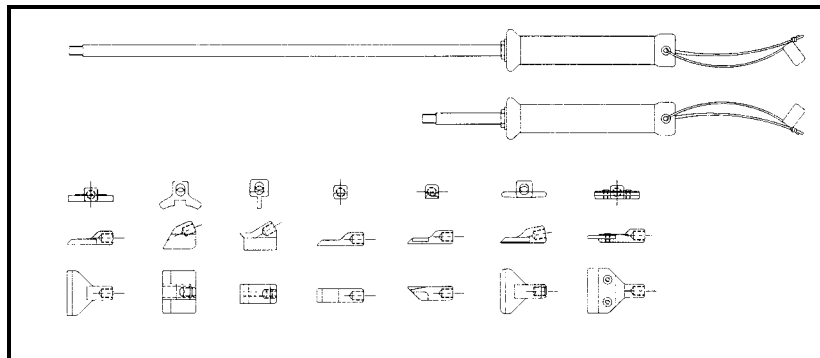

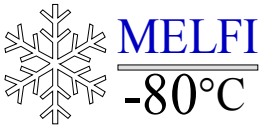


Figure 6.3 - 2: Ice-scrappers set

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 128
---	---	--

Head 7 and head 1 are used to remove hard snow; Head 2 is for the cold finger housing, Head 6 (with the little handle) is for the inner cylinder de-icing, Head 3 is for the cross-plates, head 4 is suitable both the cold finger housing and the cross plates, Head 5 is mainly for the corners.

Gloves

Cotton gloves are provided for any operations in the vicinity of the exposed cold surfaces. The gloves are provided in four sizes. The gloves are standard cotton type as used in the ground-based laboratories for operation of -80 degrees freezers. Two sets of cryogenic gloves are provided for de-icing operation. These gloves have a Velcro patch for attachment.

Sleeves

Two arm sleeves are provided for protection during the de-icing operation at the bottom of the Dewar. The sleeve is made from a double layer of Nomex. At one end it has a Velcro hook patch, which can overlap the cryogenic de-icing gloves (either left or right). At the other end it has a Velcro closing strap for closing. The sleeve is 64 cm long and 23 cm in diameter at the widest location. A drawing of the sleeve is shown in Figure 6.3 – 3.

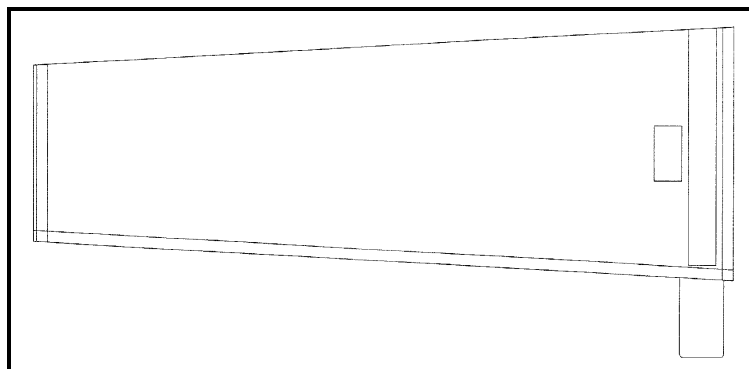


Figure 6.3-3: Sleeve.

Tray Straps

Two sets of Tray straps are provided for attachment of the Trays during de-icing. The straps consist of Hi-Air Velcro loops on one side and Hooks on the other side. The long version is 150 cm and the short 50 cm.

Dewar ASE Pouch

All the De-icing tools are stowed in the Dewar ASE Pouch, attached inside with either Velcro or elastic straps. The Internal layout of the bag is shown in Figure 6.3 - 4 and the external design in Figure 6.3 - 8.

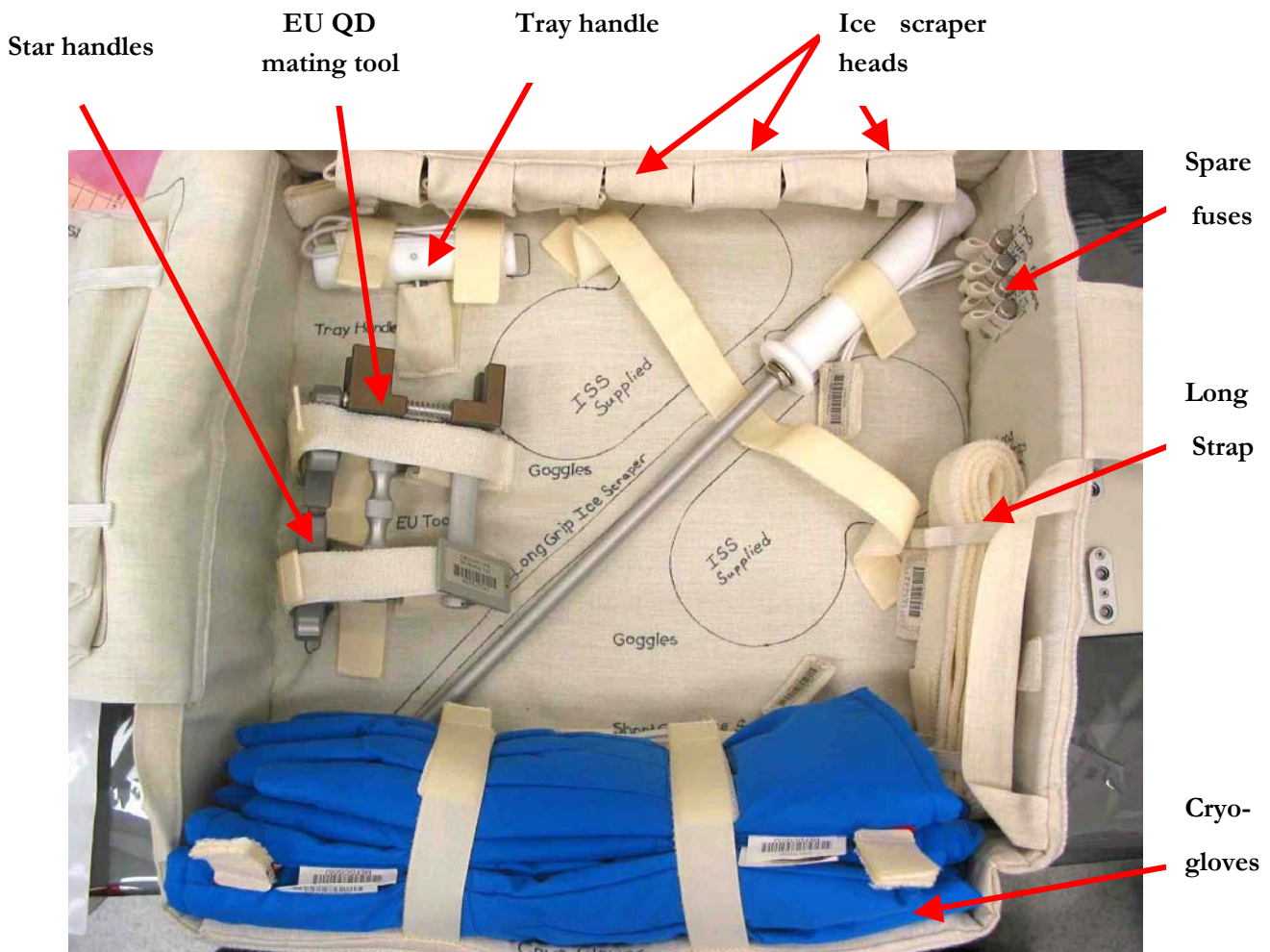


Figure 6.3 - 4: Internal layout of the bag.



Figure 6.3 - 5: TDR Battery Packs (Only one is stored into the DASE Pouch)



Figure 6.3 - 6: Triple Square M6 and M4 Tools stored into the DASE Pouch



Figure 6.3 - 7: Crowfoot tool stored in the DASE Pouch.

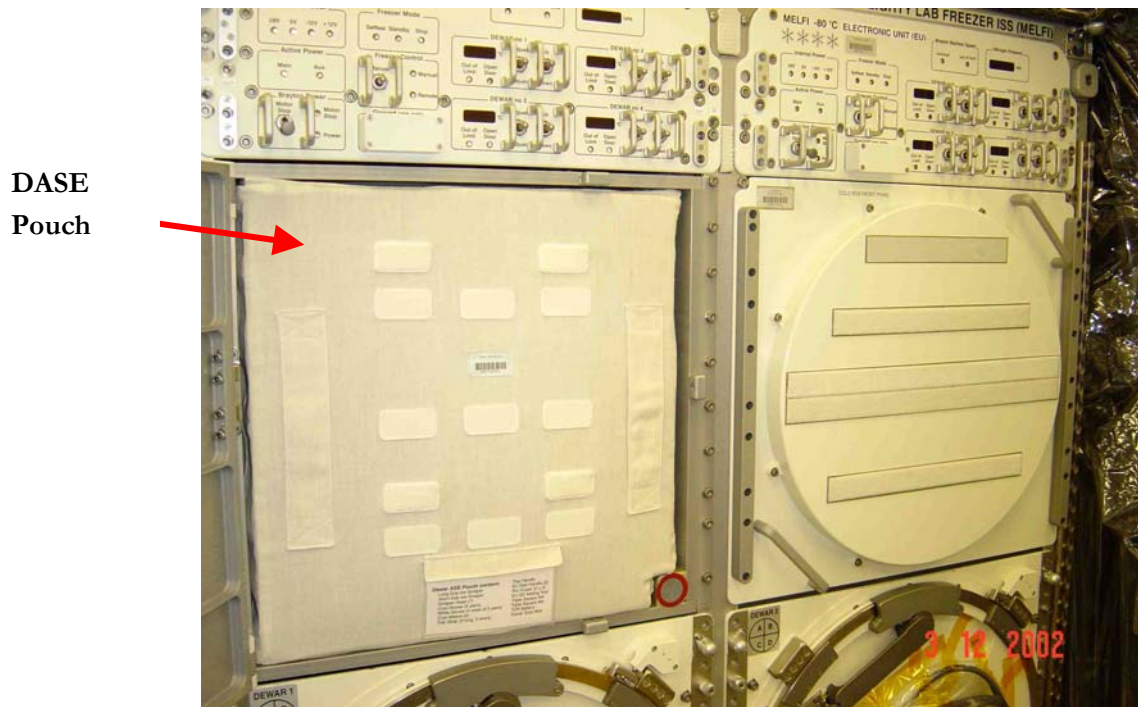




Figure 6.3 - 8: DASE Pouch inside Stowage Compartment.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 132
---	---	--

6.4 NITROGEN FILL & PURGE EQUIPMENT (NFPE)

The Nitrogen Fill and Purge Equipment is used to purge the N₂ from the Cold Box prior to the Brayton Machine (BM) replacement and to fill it at the correct pressure afterwards. It can also be used to complete the pressure of the gas cycle if necessary.

The NFPE is mounted inside an aluminum frame, which is stored in MELFI stowage compartment. The frame can slide in and out by pulling on a manual hook. It is a standalone drawer containing the following components (all attached as a single unit):

- A valve V2 to purge the gas in the Cold Box,
- A valve V1 to refill the Cold Box,
- A 1 meter long wounded flexible hose for connection to the Cold Box using a Swagelok QD,
- Redundant relief valves to prevent the NFPE from exceeding its MDP,
- A 0.5 l pressurized bottle containing N₂ at about 100 bars,
- A manometer for checking the pressure in the bottle. The crew will have access to the NFPE manometer by partly extracting the drawer until the display is visible.

Valves V1 and V2 are self-locking central pivot-type valves.

The crew shall never manipulate valve V3 but only by ground staff when refilling the N₂ bottle. It shall remain open in-orbit.

When connecting the CB to the NFPE via a dedicated port on the CB and via the flex hose, the pressure in the CB (always below 2.1 bar) can be reduced to the ambient pressure + 20 kPa, through the 20 kPa relief valve and by opening V2. About 50 liters of gas are then released slowly (due to large pressure drops in a filter located on the CB) in the rear of the rack.

Once V2 is closed, the CB can be refilled using V1. A calibrated orifice between V1 and the pressurized bottle creates a low pressure and slow mass flow. The system can be refilled in about 15 minutes (pressure drops in the filter slow down the process). Such elapsed time allows a precise filling at the correct pressure. The pressure depends on the thermal map in MELFI. Tables are provided to set up the pressure with respect to temperatures displayed on MELFI's front face.

The mass of gas in the bottle has been calculated such as even if the crew empties it in the CB, the CB maximum design pressure will never be exceeded.

Two redundant 400 kPa valves prevent from exceeding the NFPE maximum design pressure. They only protect the NFPE components. The CB is protected by procedure during nitrogen gas filling up.

The NFPE is shown in Figure 6.4 –1 and 6.4-2. An IMS label is stuck to its front face: MEFNFPxxJ.

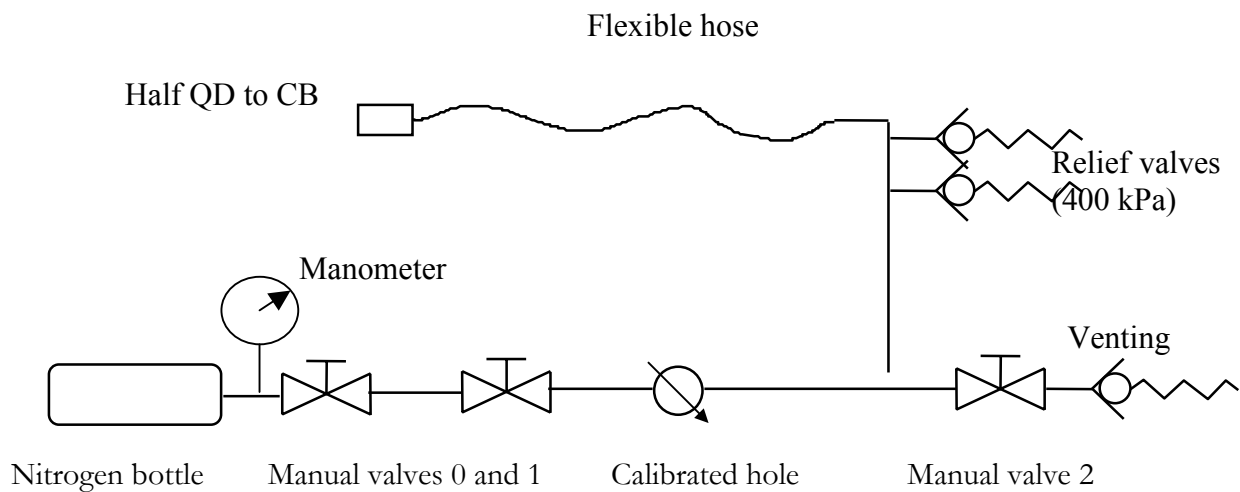


Figure 6.4-1: NFPE Functional Schematics

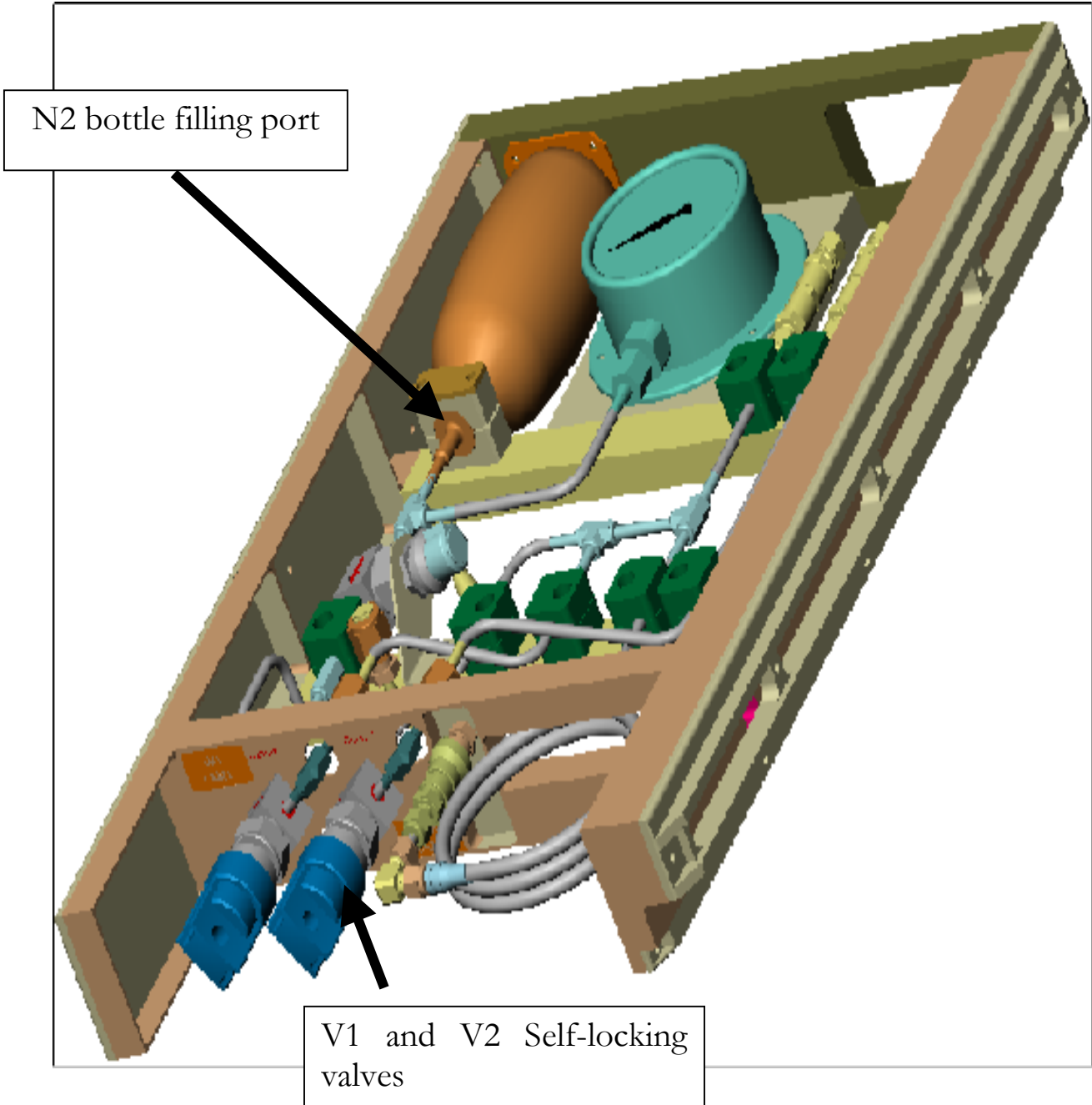




Figure 6.4-2: Nitrogen Fill and Purge Equipment Top View

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 135
---	---	--

6.5 BRAYTON MACHINE EXCHANGE EQUIPMENT AND CONTAINMENT

The Brayton Machine Exchange Equipment (BMEE) is used to extract a machine out of the Cold Box and to replace it, i.e. to insert the BM into the CB. It must ensure the following functions:

- Extraction of the used Brayton Machine (BM) from the Cold Box
- Insertion of the spare BM in the Cold Box
- Isolation of the BSS during the exchange versus the outer environment
- Storage within the required conditions of the spare BM until it can be directly connected to the BSS nitrogen cycle
- Storage of the failed BM after exchange

The BMEE is composed of five main elements:

- The BM ASE Interface to be mounted on to the Cold Box; it is equipped with a sealed shutter and protected by a cap;
- The Spare Brayton Machine Container which provides a sealed containment for the spare Brayton Machine and is also equipped with a sealed shutter; the Spare BM is equipped with a Water Expansion Device (WED) and a Brayton MACHINE Front Cap to hold the Spare BM.
- The Failed Brayton Machine Container, which is empty in launch configuration and will receive the failed Brayton Machine. It is identical to the Spare Brayton machine container except that its shutter is not gas tight;
- A removable Brayton Machine Gear Box to be mounted on the BM Containers for pulling / pushing the failed /spare Brayton Machines inside the Containers during the replacement operations.
- Two Shutter Gearbox in order to open and close the shutters during the operations required for a BM exchange.

These elements are accommodated inside the Brayton Airborne Support Equipment (BASE) Container and are equipped with protective caps and securing flanges.

All screws are captive and are actuated by using standard IVA metric wrenches.

6.5.1 Brayton Airborne Support Equipment

The BMEE parts are accommodated in a Container named Brayton Airborne Support Equipment Container, stored in the Stowage Compartment.

It is locked to the Stowage Compartment by the means of 4 devices implemented on each side of the front face of the Container. A foldable handle is implemented to pull out the BMEE container.

The internal volume of this container is equipped with foam, which allows keeping the BMEE parts in place.

A cover fixed with 3 Velcro bands closes the Container (See figure below).

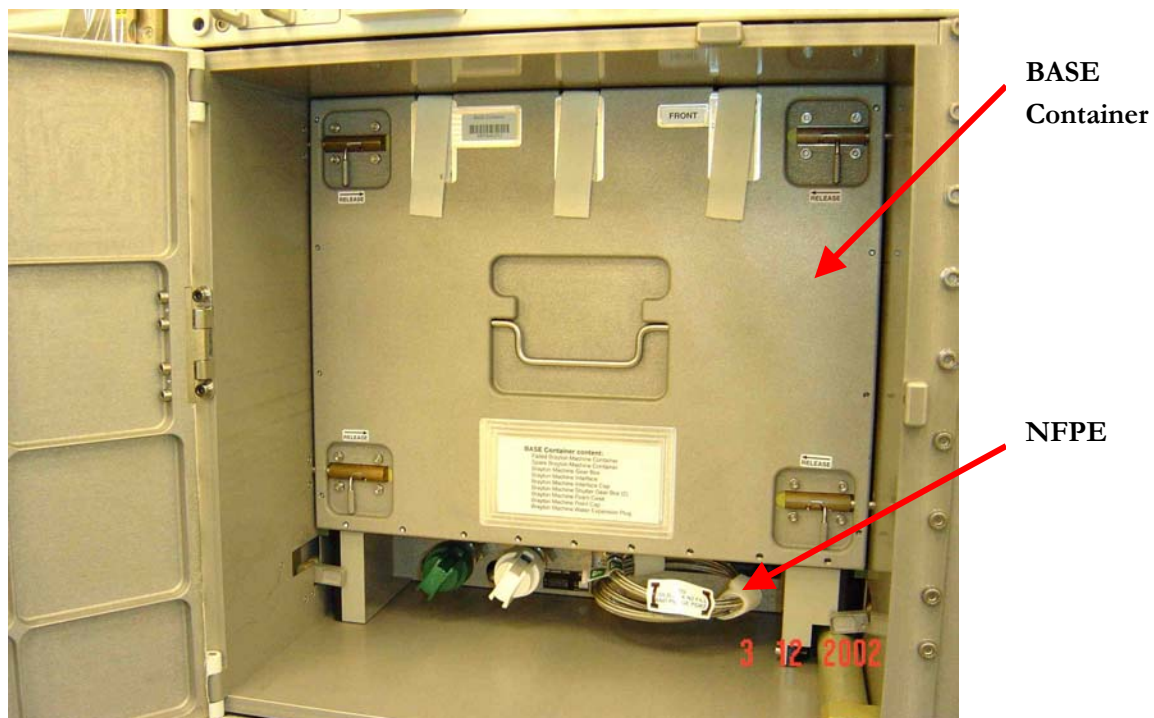




Figure 6.5-1 : Brayton ASE Container inside Stowage Compartment

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 137
---	---	--

6.5.2 BMEE accommodation

The Brayton Machine Exchange Equipment accommodated in the BASE Container comprehends (see figures hereafter):

- One Spare Brayton Machine Container with the Spare Brayton Machine with a shutter. It is stowed at the “Loaded Container” location in the BASE Container. The spare BM is equipped with a WED.
Once the BM has been replaced, this container is empty and must be stowed at the “ Empty Container” location in the BASE Container.
- One empty Failed Brayton Machine Container stowed at the “Empty Container” location in the BASE Container.
Once the BM has been replaced, this container is loaded with the Failed BM and must be stowed at the “ Loaded Container” location in the BASE Container.
- One Brayton Machine Gear Box stored in fully extracted position in the BASE Container
- One Brayton Machine Interface cylinder equipped with a shutter.
- Two Shutter Gear Boxes.

The BMEE parts accommodation in the BASE Container is shown in figure below. Both Tubes and the Interface Cylinder are set at the bottom of the container and covered by a foam block. On top, there is the Gearbox, and both Shutter Gearboxes stored in a Foam case.

For the launch configuration, the Spare Machine is inside the Spare BM Container and is equipped with the Water Expansion device. The failed container is empty.

For the Return configuration, and in case of a BM replacement, the Failed Brayton Machine is inside the Failed container and the Water Expansion device is now mounted on this Machine. The Spare Container is empty.

Brayton
Machine
Gearbox

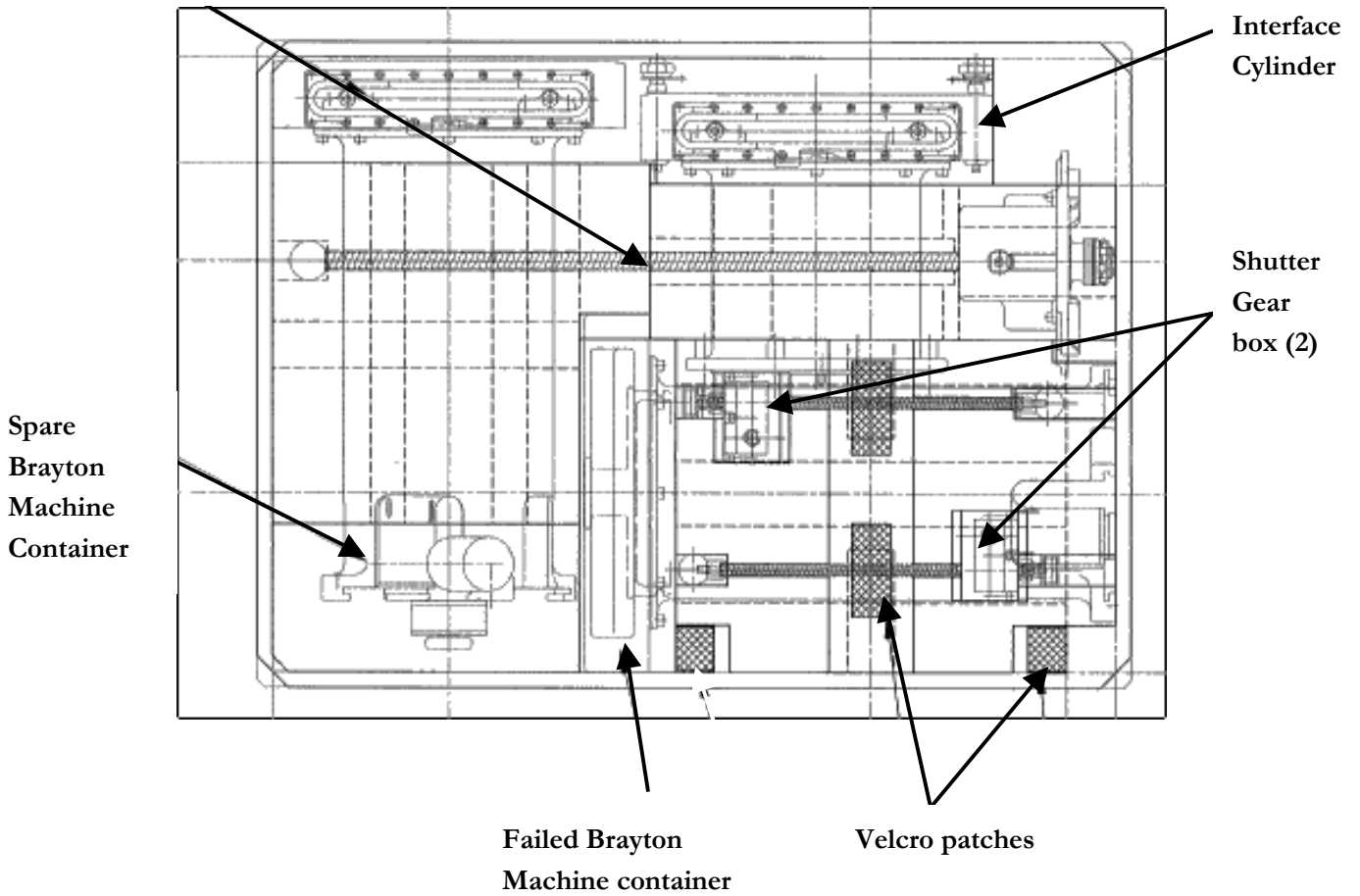


Figure 6.5 - 2: BMEE in BASE Container (Top View)

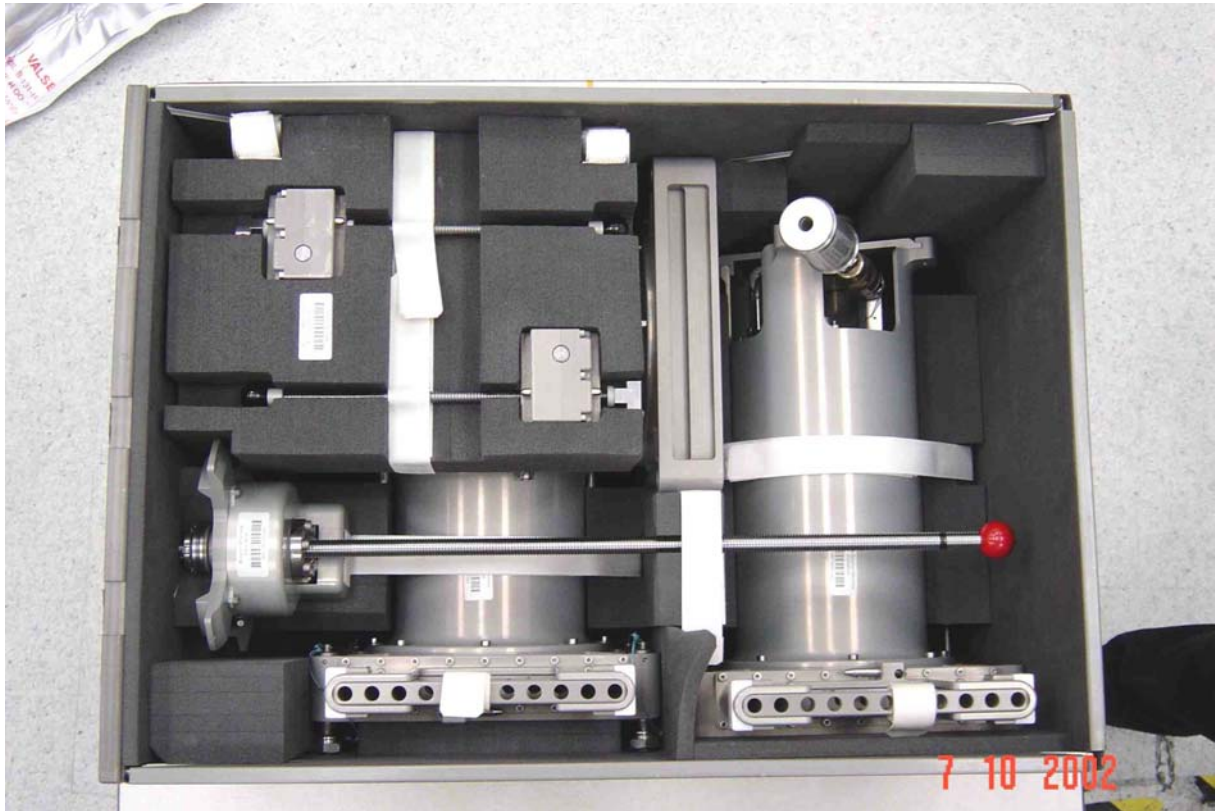


Figure 6.5 - 3: FM1 BMEE in BASE Container (Top View)

6.5.2.1 Interface Cylinder

The interface cylinder is an intermediate part between the CB and the BMEE Containers that will be sequentially mounted on to this part. The main function of the I/F cylinder is to insure the tightness of the Cold Box during the container exchange. It also enables shutters to be located outside the rack when manipulated. Its mechanical strength shall be able to support the weight of one container with the Brayton Machine and the extraction / insertion gear for on ground Brayton Machine exchange purposes.




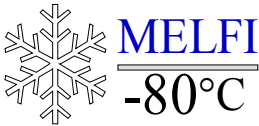
Figure 6.5 - 4: BM ASE Interface cylinder with its black cap

The interface cylinder is stored with its shutter locked. After having been installed on the Cold Box, the shutter is opened after the connection of the used Brayton Machine container. The used Brayton Machine is removed and placed in its container. The shutter is then closed and locked. When the used Brayton Machine container is removed, this shutter insures the tightness of the nitrogen inside the BSS.

6.5.2.2 Spare Brayton Machine Container

The spare Brayton Machine container has several different functions:

- Spare Brayton Machine storage for 2 years in nitrogen, inside the defined environments in MPLM and ISS
- To protect the spare Brayton Machine against damage when submitted to the launch loads
- To avoid contamination of the nitrogen surrounding the spare Brayton Machine for 2 years
- To enable the insertion of the spare Brayton Machine into the Cold Box, without contamination of the cycle nitrogen
- To respect the angular position of the BM when inserted in the CB.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 141
---	---	--

AIR LIQUIDE inserts the spare BM in this container with respect to the required angular position.

The leak rate of the contained nitrogen will be insured on one hand by the shutter gear and on the other hand by the Brayton Machine external O-ring seal (same as the one used in the BSS for the front side tightness).

Note: The Spare BM Container is filled with 70kPa (700 mbar) absolute pressure of dry and pure Nitrogen. The locking device shall not be removed before shutter opening to prevent the BM from being pressed against the shutter by pressure difference.

6.5.2.3 Failed Brayton Machine Container

This container, presented in figure 6.5-5, is designed to store the failed Brayton Machine and to enable its extraction.

This container is connected on one side to the interface cylinder (same interface as the spare Brayton Machine container) and shall enable the installation of the extraction gear on the other side.

Since the failed Brayton Machine will require corrective maintenance, there is no need to store it in a high quality nitrogen atmosphere. Consequently, this container is not equipped with a shutter gear but a cap will be installed for protection. The blocking device, which maintains the spare Brayton Machine, will be used on the other side to secure the failed Brayton Machine in the container.

The container is not tightening; consequently its inner pressure is always close to the outer atmosphere pressure when stored.

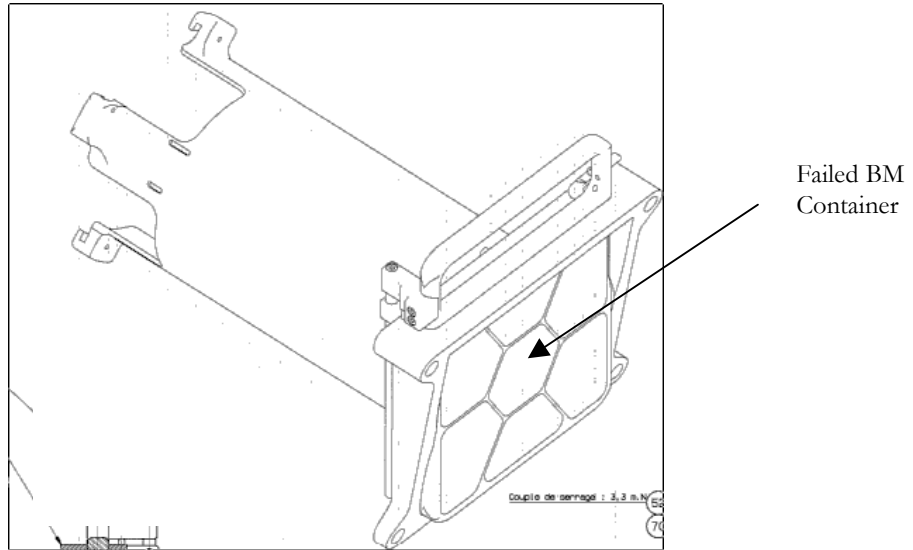


Figure 6.5 - 5: Failed Brayton Machine Container

A locking device secures the BM after insertion inside a container (spare or failed BM).

The BM is kept in place by a T-shape hook (as for the extraction device). By activating the manual screw, the BM is secured inside a container.

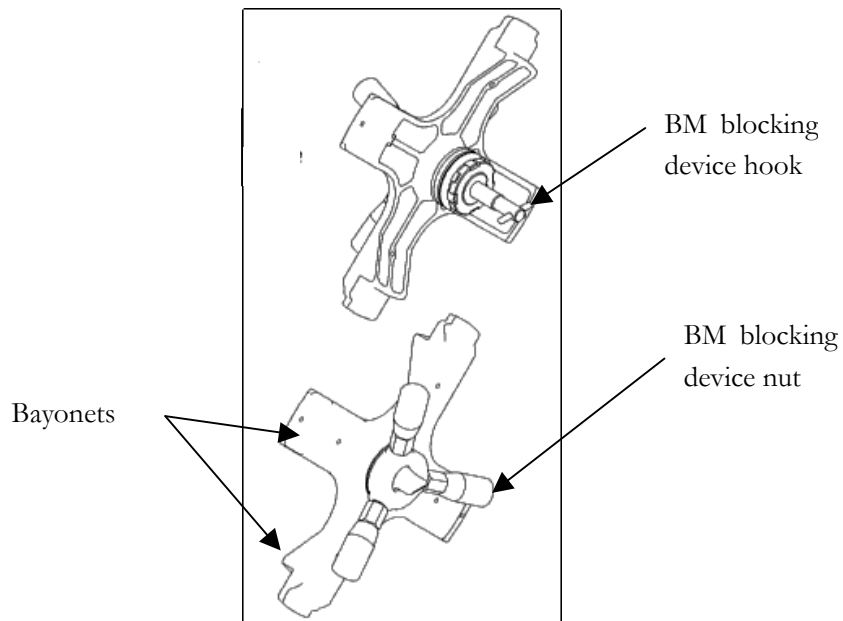


Figure 6.5 - 6: Brayton Machine blocking device

6.5.2.4 Insertion / Extraction Gear

The insertion / extraction gear shall enable the extraction of the Brayton Machine from the BSS.

A drawing of the gear can be found in figure 6.5-7.

It is mainly made of two major components: the threaded rod which hooks and pushes the Brayton Machine, and a driving gearbox which enables the translation of the screw and which is fixed to the container. The gearbox is equipped with a rotating nut which, when rotating, translates the screw. The ISS Power Tool drives the rotational movement of the nut. The number of turns necessary to extract the used Brayton Machine or to insert the spare Brayton Machine is 390. The accurate positioning of the spare Brayton Machine in the BSS requires a low translation per turn (approx. 1 mm per turn). In order to preserve the integrity of the BM external O-rings, the rotational speed of the power tool shall be limited to 200 rpm.

The threaded rod hooks the Brayton Machine with a T-shape device placed on its tip. This T is locked by a 90° turn of the screw into a locking device placed on the Brayton Machine front face (see figure 6.5-8). Since the screw is translated without rotation, there is no risk to loose the Brayton Machine.

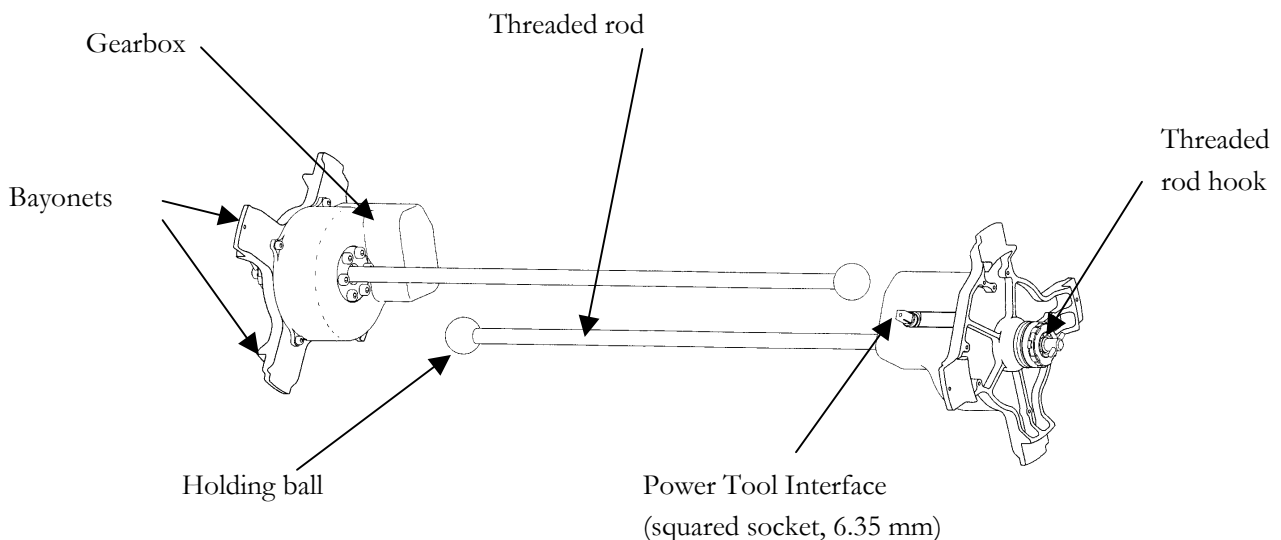


Figure 6.5 - 7: Gearbox Assembly

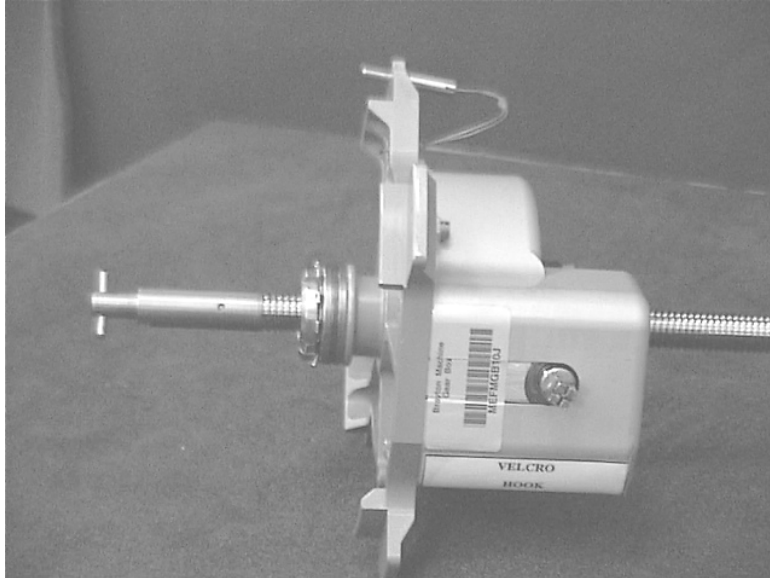
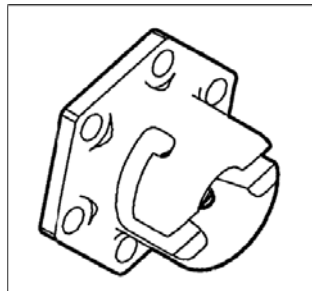


Figure 6.5 - 8: details of the gearbox



*Figure 6.5 - 9: Brayton Machine Hook
(Mounted on the BM front face)*

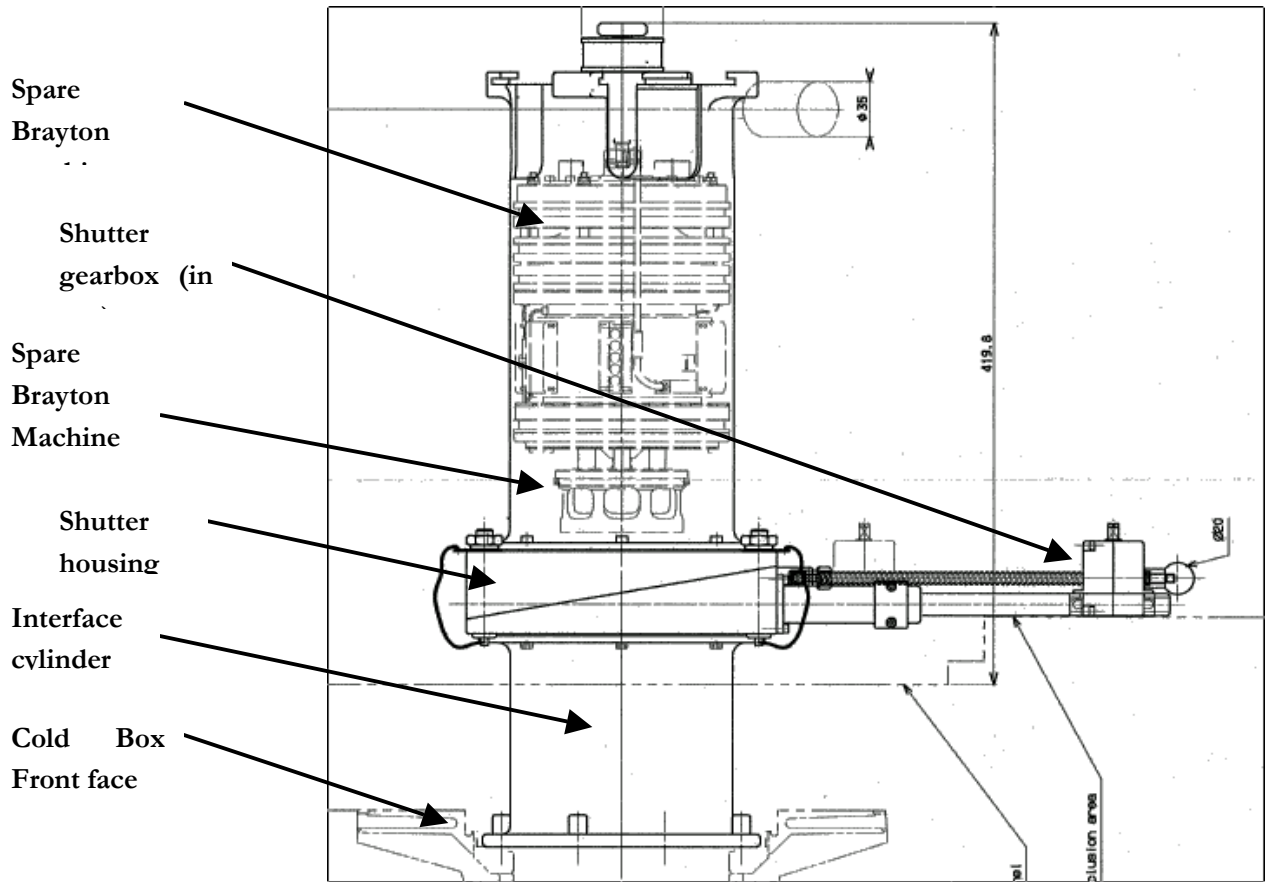




Figure 6.5 - 10: BMEE mounted on the Cold Box (side view)

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 146
---	---	--

6.6 COLD BOX

The Cold Box houses the Brayton Machine and contributes to the cold power production. The Cold Box schematics is depicted in Figure 6.6-1

High-pressure nitrogen from compressor outlet is directed across an annular tube to the Water Heat Exchanger (WHX). The heat of compression of the N₂ gas is extracted by this counter-flow coil heat exchanger: cooling water is flowing inside the coil and N₂ gas is circulating outside the coil and in reverse direction.


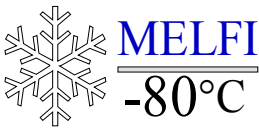
Downstream the WHX, the cycle heat exchanger (CHX) is connected directly to the shell side outlet volume of the WHX. Inside the CHX tubes, the nitrogen is cooled down further. An annular tube feeds the gas via a conical filter to the turbine. The expanded nitrogen leaves the Cold Box (CB) at low temperature via the coupling of the Tubing to the Dewars.

The Dewar return gas re-enters the CB via the annular shaped return line, connected to the shell side of the CHX. In counter flow to the high-pressure nitrogen, the return gas is warmed-up within the CHX. From CHX outlet, another annular pipe feeds the gas through a second conical shaped filter to the compressor suction side.

The overall design of the CB is strongly influenced by the radial compressor in-/outlet and the turbine inlet connections of the BM. This leads, in combination with the necessity of a volume optimized overall arrangement, compulsory to a centric arrangement of the BM with annular shaped components (WHX, CHX, filters) surrounding the Brayton Machine.

The centric turbine outlet requires a centric connection tube to the external Tubing. This connection has to be located at the CB rear side as the exchangeability of the BM from the front is compulsive. With the exception of the Dewar return temperature measurement feed through, all other feed-through (nitrogen, Phase Change Material and cooling water) are arranged on the front side.

The CB including its internal components and associated connections is an overall welded / brazed construction to ensure maximum strength and leak tightness of all single volumes to and from the surroundings. The only exception is the connection between CB and Tubing: because of the removability requirement of the CB a double o-ring (ORS) with a helium leak tightness of 1.5×10^{-6} mbar l / sec each perform the sealing between ambient and the nitrogen cycle.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 147
---	---	--

With some exceptions, the CB and its components/ parts are manufactured of stainless steel. The CB vessel via different ways supports the internal components of the CB. The main power flux, resulting from the masses of BM and CHX, is directed via the warm end plate of the CHX and a perforated cylindrical plate (PCP) to the front end of the CB outer shell.

All components of the CB and - where necessary the CB tubing - are surrounded by vacuum to reduce heat leaks between volumes of different temperatures or within volumes with a temperature gradient, in particular:

- For the nitrogen flow channels to and from the compressor (high temperature difference),
- Along the WHX (partially) and CHX (temperature gradient).

The vacuum volume between the CB outer shell and inner shell is equipped with up to 20 layers of multi-layer super-insulation (MLI) to reduce radiative heat input.

Because of the annular arrangement inside the CB several separated vacuum volumes have to be connected.

A getter pump maintains the vacuum at high level, down to 10^{-6} mbar. The pumping capacity of the getter is in accordance with an on-orbit operation of 24 months. After this period the getter might have to be reactivated. Two pumping ports to prepare the basic vacuum for the getter are provided.

During non-operating phases as e.g. power-off the temperatures of the different CB components will equalize at a level below 0 °C. To avoid damage by freezing, components filled with cooling water are protected by the use of a phase change material (PCM), called n-tetradecane C₁₄ H₃₀, so that the temperature remains well above 0 °C.

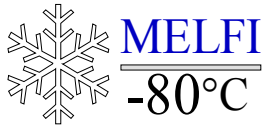
The volume inside the WHX core tube is sufficient to store the necessary amount of PCM.

During the manufacturing of the Cold Box, the PCM volume is connected to ambient via a filling and a pumping port. Once the PCM has been filled inside the PCM compartment, a sealed tube closes this pumping port after filling.

The PCM volume is connected to ambient via a filling and a pumping port. The mass of PCM is 2.6 kg approximately with glass fleece (0.4 kg) spiral wounded in the PCM cavity.

The CB instrumentation consists of:

- 1 Pt 1000, at measuring location 5 (Dewar return gas at CB coupling inlet),
- 1 Pt 1000 at the same location for redundancy.



Ref: MELFI-MA-03000-0435-MMT

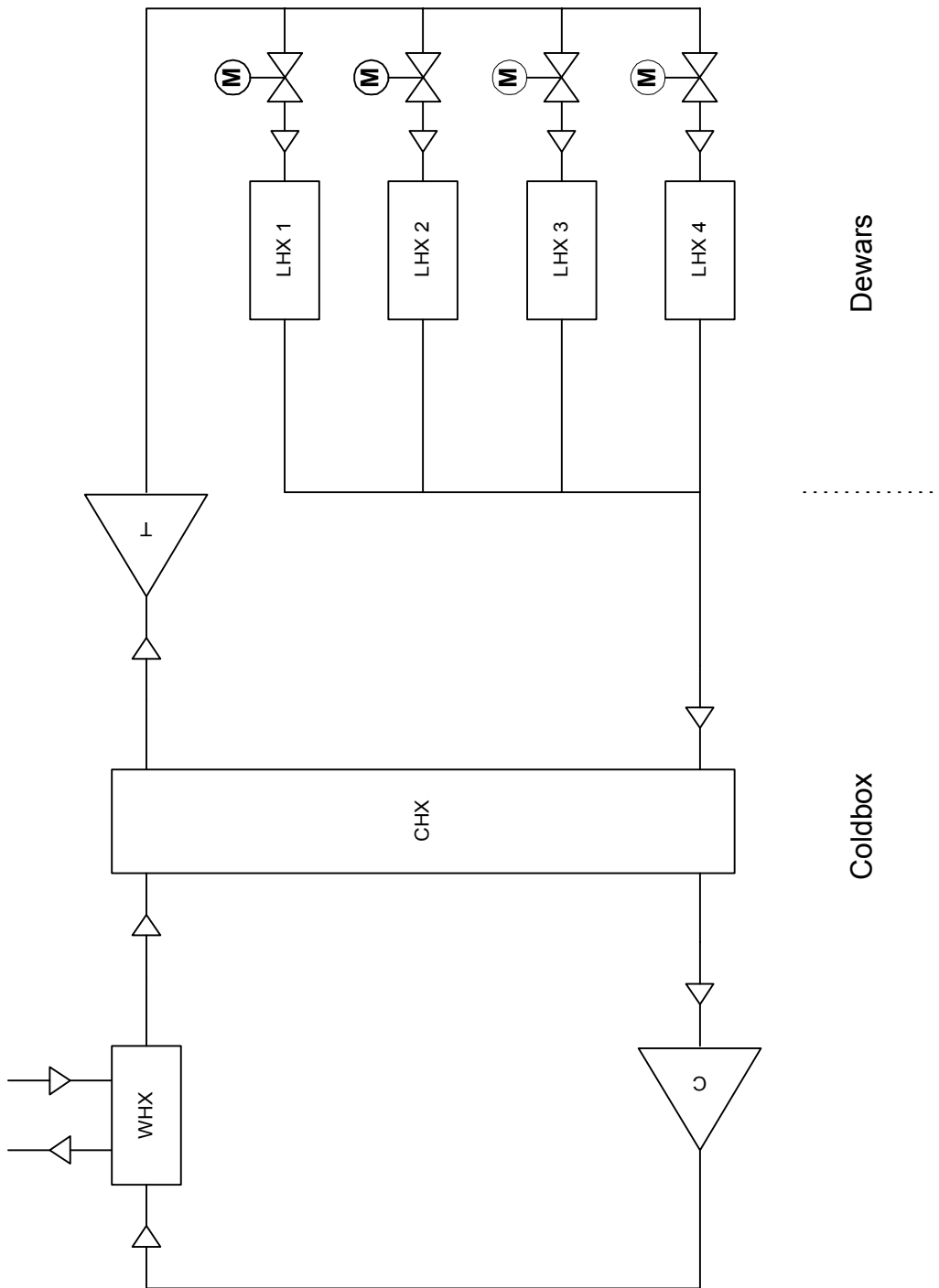
Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 148

- 1 pressure sensor measuring the compressor outlet pressure inside the N2 high-pressure purge-in pipe,
- 1 pressure sensor at the same location for redundancy

Both Pt 1000 sensors are mounted inside an enveloping tube, which is routed through the coupling outer flange to the CB rear side. In case of need they are replaceable.



Note: LHX stands for Load Heat Exchangers, part of the N2 Tubing

Figure 6.6-1: Cold Box and Nitrogen Loop schematics

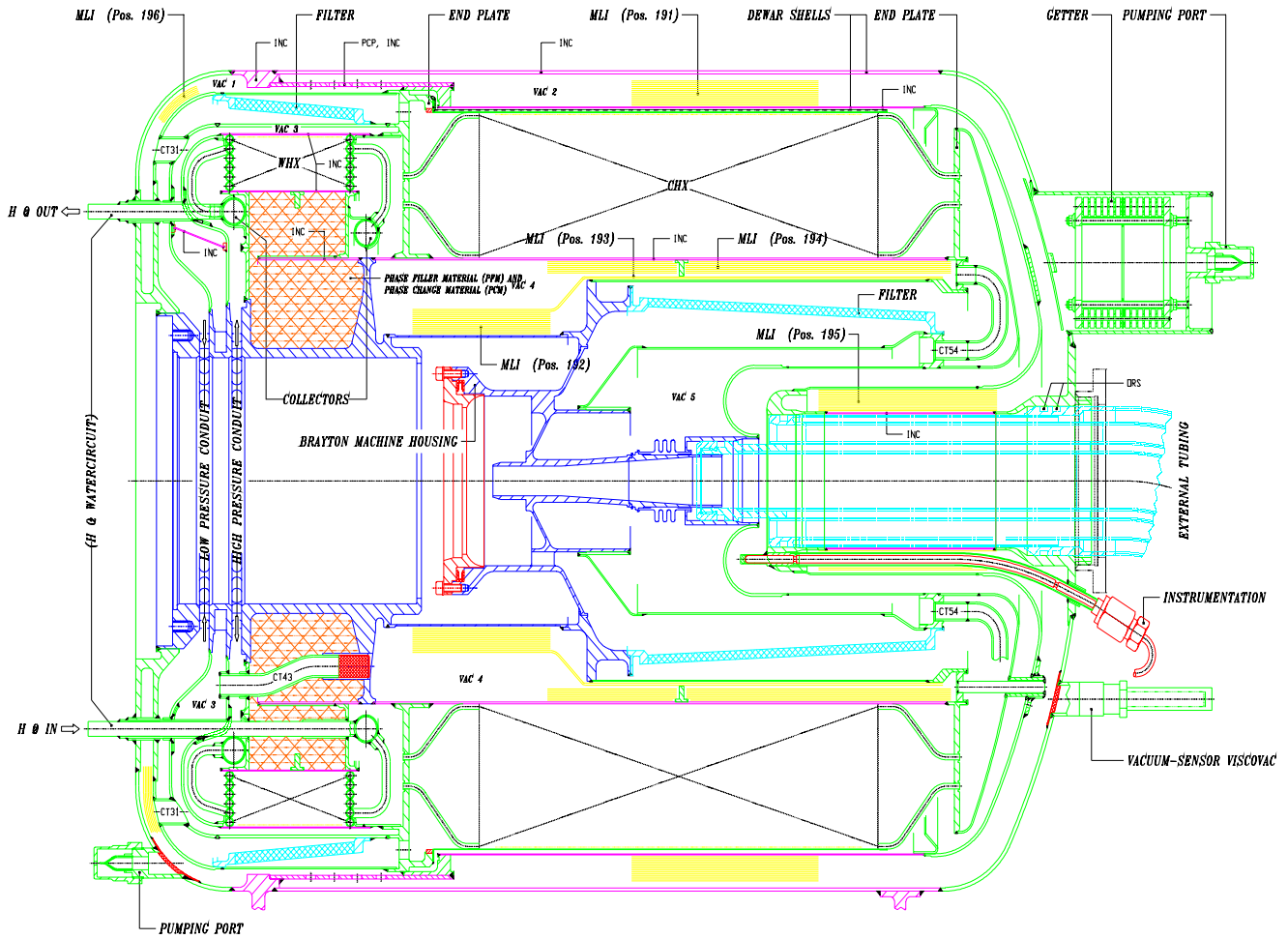




Figure 6.6 - 2: Cold Box internal view

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 151
---	---	--

6.7 BRAYTON MACHINE CARTRIDGE

The Brayton Machine cartridge is integrated in the Cold Box. It is designed to produce cold power in the range [60 W – 90 W] depending on the Dewar configuration. The cartridge is an Orbit Replaceable Unit that requires specific equipment, i.e. the Brayton Machine Exchange equipment, for its on-orbit exchange.

The Brayton machine is interchangeable between different MELFI Flight Models, both during ground and on-orbit maintenance operations.

Note: DO NOT MOVE THE RACK WHILE THE BRAYTON MACHINE IS RUNNING

Brayton Machine main parts:

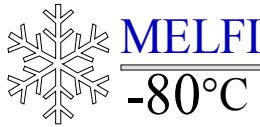
The main parts of the BM are listed below and presented on the following figure (Figure 6.7 – 1):

- The cold head.
- The front face of the BM including the electrical wire connector, the sensor connector and the water inlet/outlet Quick Disconnects (QD).
- The aluminum casing and its bearing supports with the anti-pollution circuit (particulate filters)
- The motor stator.
- The Motor Heat exchanger around the aluminum casing in order to dissipate the drag losses generated by the bearings, the stator and the turbine wheels.
- The rotating shaft and associated bearings that is composed of a very complex and high precision assembly
- The turbine and compressor wheels and the inlet/outlet volutes. Brayton Machine main parts are presented in figure 6.7-1.

The BM front face is a circular plate fixed to the CB by the front flange.

The front face of the Brayton Machine (figure 6.7 –2) is constituted of:

- The front flange that fixes the Brayton Machine inside the Cold Box with screws,
- The compressor flange for the inlet circuit,



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 152

- The electrical motor wire connector that enables connections between the BM stator and the electronic supply,
- The electrical connector that enables connections between the three temperature sensors (two for the bearings and one for the BM stator)
- The electrical connector that provides power supply to the BM,
- The two water Quick Disconnects (QD's) that enable connections between the BM MHX and the MELFI water loop,
- One locking device for the insertion / extraction of the BM from the CB with the ASE supply. It is implemented at the center of the front face. A single T-shape nut allows the locking function.

If a BM has to be replaced, the flange has to be dismounted from the cold Box once the N2 gas pressure has been released. Eight screws (M6 screws) have to be unfastening to remove the flange. Both grasp handles have to be used to pull out the flange from its slot. In case the flange remains stuck, the grasps handles should be rotated to help extracting the flange.

The BSS is completely wrapped in an acoustic blanket in order to limit noise emission from the BM. The front part of this blanket is removable in order to let access to the BM front face for corrective maintenance, i.e. BM exchange or EU exchange.

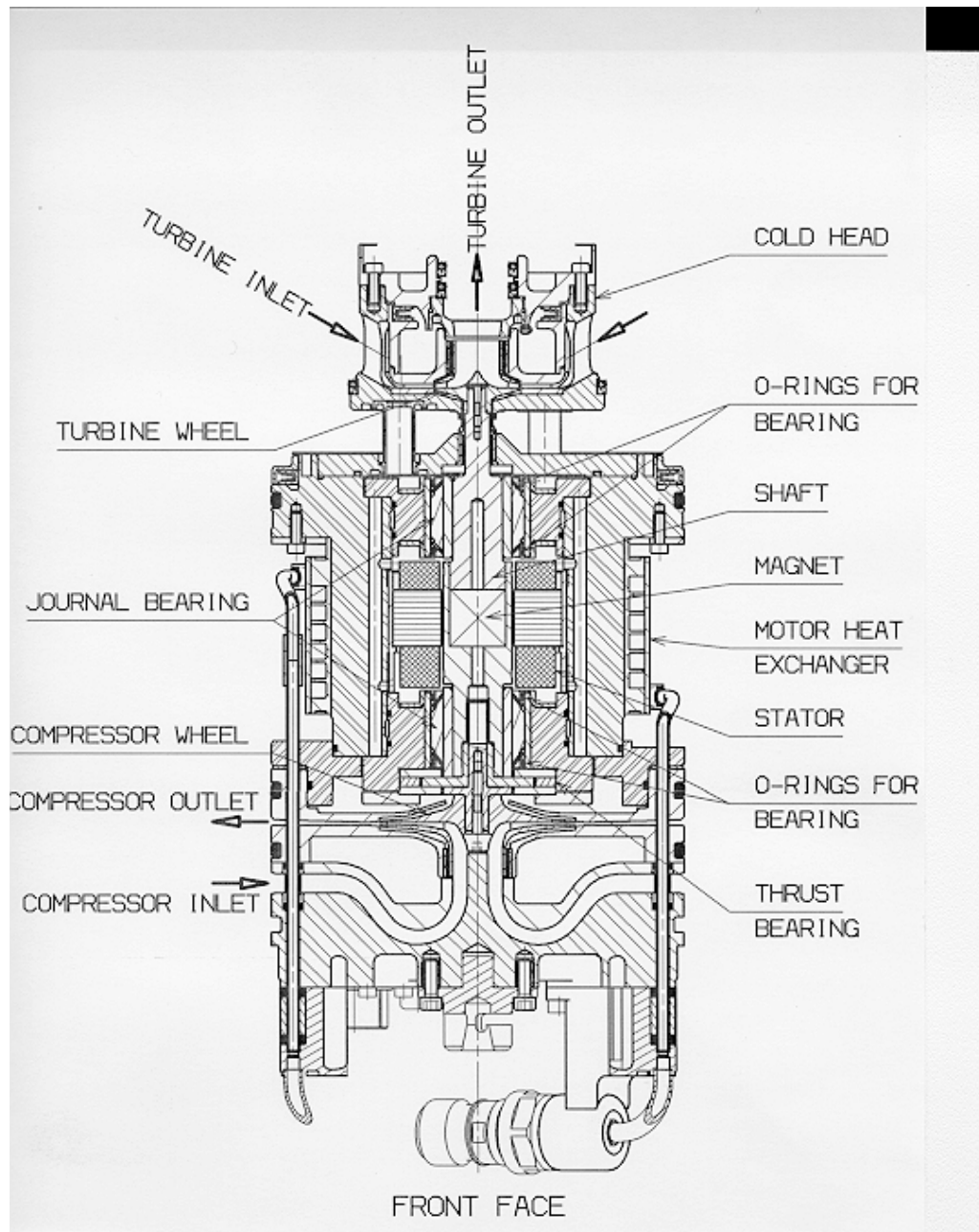


Figure 6.7-1: Brayton Machine main parts

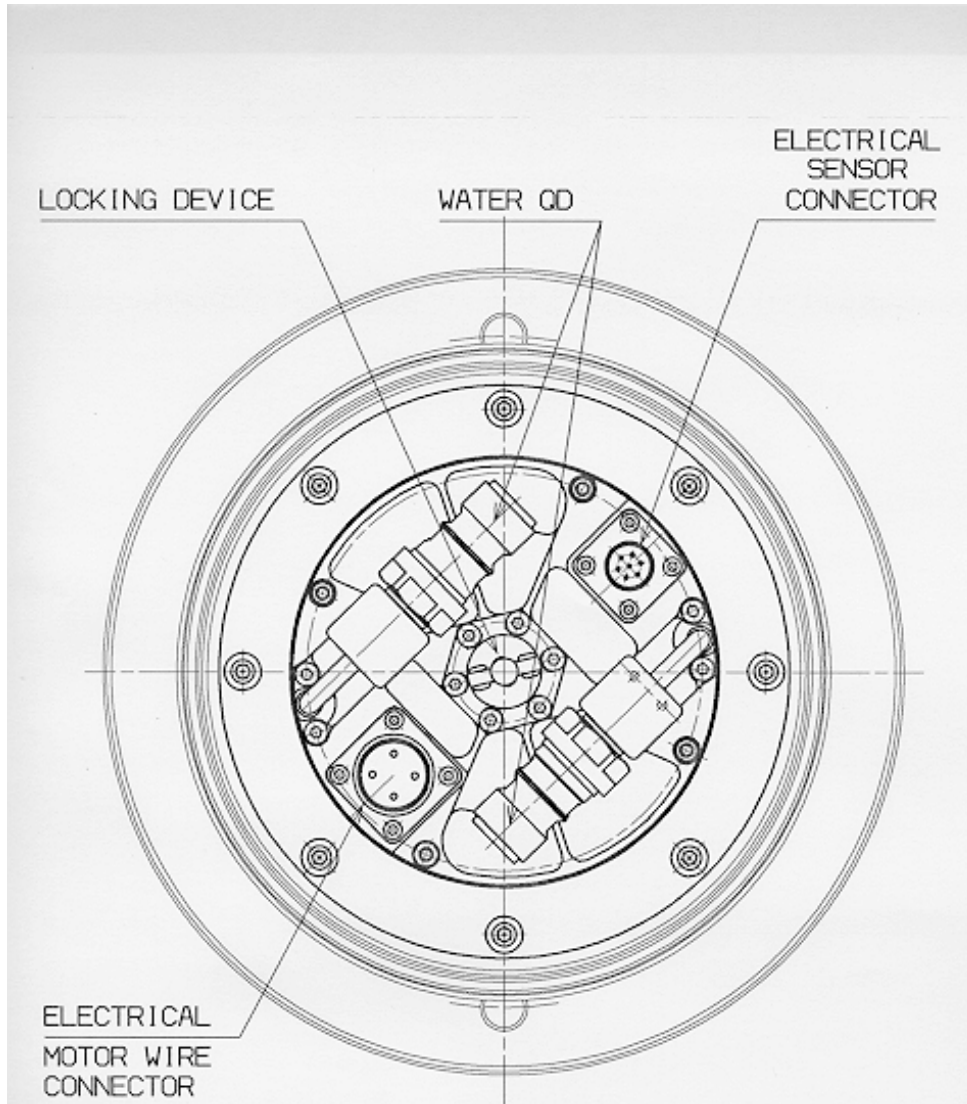

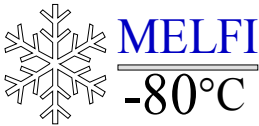


Figure 6.7 - 2 : Brayton Machine front face

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 155
---	---	--

Brayton Machine casing design

The casing material is in aluminum in order to improve the heat transfer from the warm sources to the MHX. It is treated with a BF5 coating (anodizing).

Antipollution circuit:

The anti-pollution circuit is implemented in the BM and constituted of several particle filters. Its main function is to prevent any particle entering the bearing zone.

The circuit description is given below (Figure 6.7– 3):

- A small amount of the gas mass flow coming from the compressor outlet (part ①) is used for the anti-pollution circuit since it is the part of the cycle where the pressure is the highest. This gas is at high temperature in the range [20°C; 60°C] according the shaft rotational speed,
- 6 holes in the BM casing conduct the gas in the chamber part ② where it is cooled by the MHX,
- 16 holes x 22.5 deg with an inlet filter in front of each hole (filtration rate = 1 µm) (see part ③) in order to protect the gas bearing circuit from any particle. The pressure drops due to these filters is reduced and has no effect on the Brayton cycle performances.
- Dedicated holes in the Brayton Machine casing conduct the gas to the stationary gas bearing bushes (see part ④),
- The gas flow is injected at the boundary of the active gas bearing clearance (see part ⑤) and limits the number of particles to penetrate in the 10 µm critical operating bearing clearance.

A return circuit has been also implemented to conduct the N2 from the gas bearing bushes to the compressor inlet (Low Pressure circuit).

Finally, the overall circuit has been designed such that the mass flow represents less than 1 % of the total cycle mass flow in order to not affect the cycle cooling performances. The pressure drops in the circuit have been calculated in order to guaranty a sufficient gas velocity at the gas bearing bush outlet.

Note: other filters have been implemented in the CB in order to protect the bearings from the potential particles in the gas cycle:

- Two filters are arranged in the CB at the turbine inlet and compressor inlet.

- A filter is implemented in the N2 Fill and purge line on the Cold Box side.

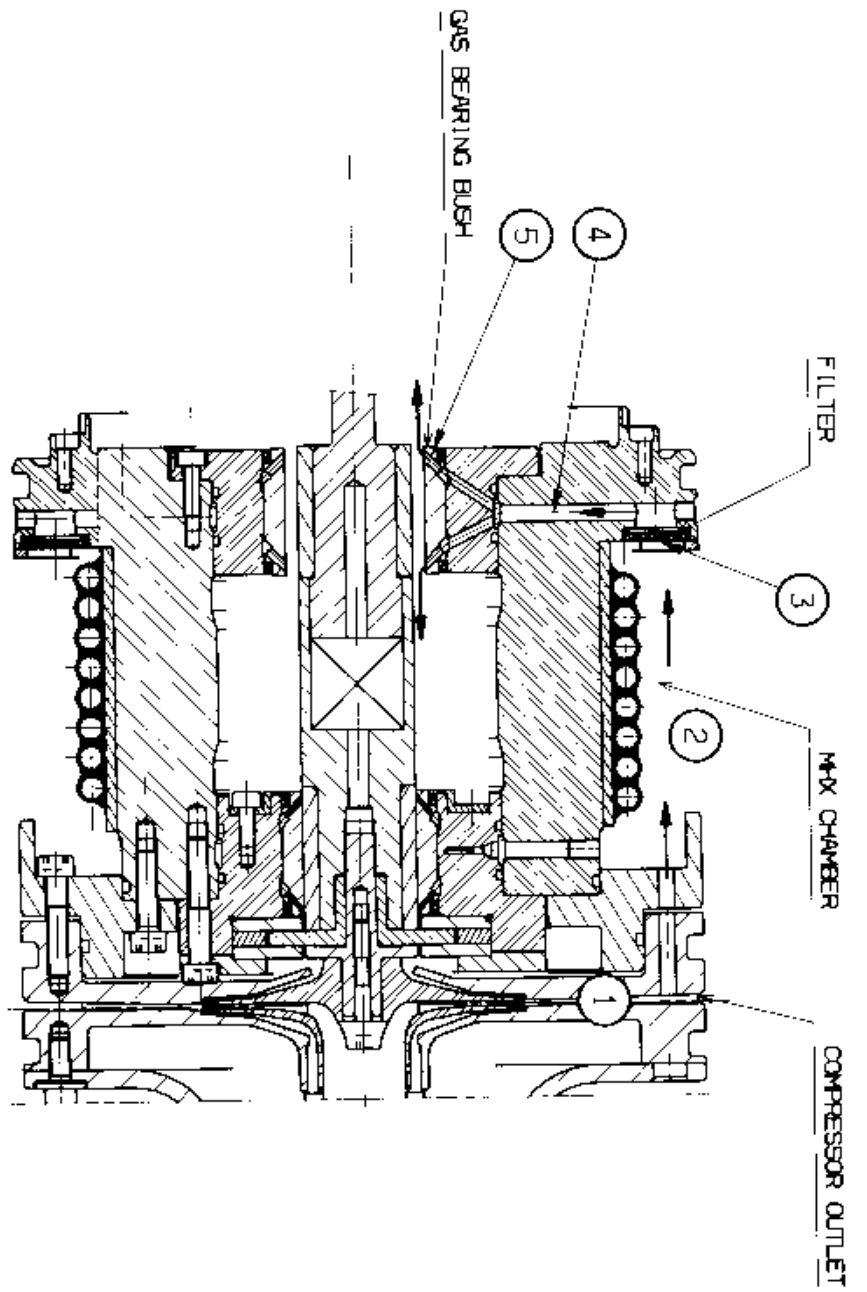




Figure 6.7 - 3: Brayton Machine antipollution circuitry

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 157
---	---	--

Brayton Machine Motor:

The work required for the compression of the gas cycle is supplied by the expansion turbine and by the additional electrical motor. The associated electronic driver (MDE) provides power to this motor.

The motor is a synchronous brush less motor with a permanent magnet. For the rotor assembly, the most important stress is the high centrifugal force on the magnet and, in this respect; the rotor concept is a hollow shaft with magnet inside. A three-phase sensor less driver has been chosen due to the small motor dimensions.


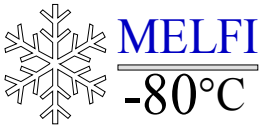
There is a protection implemented in the MELFI S/W to prevent the stator to reach 70°C.

Brayton Machine shaft:

The gas-bearing shaft is mainly composed of the following parts (see figure 6.7 – 4):

- The stainless steel part for the compressor side
- Motor's magnet shrunk fitted in the stainless steel plug
- The titanium plug for the turbine side that is shrunk fitted in the stainless steel part. This material was selected for its lower thermal conductivity in order to minimize the heat conduction through the shaft to the expansion unit. A whole titanium shaft was not possible due to its relatively low elasticity modulus (11000 kg/mm² instead of 20000 kg/mm² for stainless steel) that led to a too low first bending mode. As a result, the shaft design was a compromise between heat conduction and critical frequency requirements.
- The thrust bearing assembling that is relatively complex due to drastic constraints (manufacturing, grooving, positioning...). Exhaustive calculations have been carried out in order to demonstrate that this assembly shall fulfill the requirements, especially in terms of stresses and deformations. This assembly includes the screwed plug that fixes the thrust runner into the shaft. The compressor wheel is directly mounted on it.
- The turbine and compressor wheels already described above. Their design is fully independent on the bearing choice.

The shaft design has a direct influence on the two bearing critical frequencies and the shaft first bending mode. To have a sufficient safety margin, the first bending mode has to be at least 20 % above the

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 158
---	---	--

maximal rotational speed (120 krpm for our application). On the contrary, the frequencies of the two rigid modes shall have to be below the speed operating range of the shaft. This speed operating range was confirmed to be [60 krpm; 90 krpm] by the tests.

In addition, the MELFI Rack Interface Unit (RIU) limitations do not allow a speed above 93000 rpm. Even with the maximum input voltage of 126 V, the MELFI input power is limited to 1150 W, and then speed is limited to 93000 rpm. With the nominal input voltage of 120 V, MELFI power is limited to 1100 W and the speed is then limited to 91000 rpm.

The mission constraints applied to MELFI impose a speed of less than 87000 rpm (power limited to 950 W).

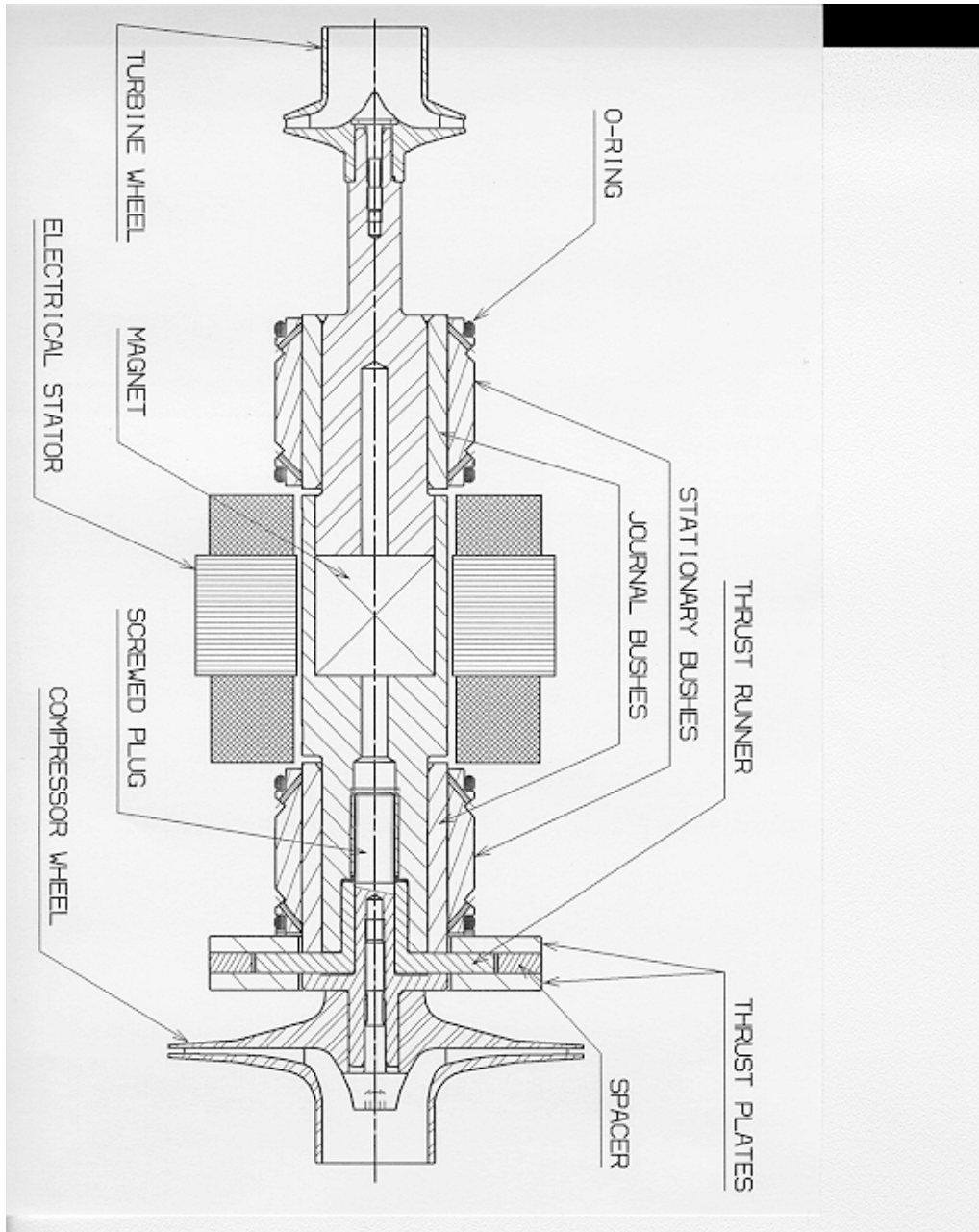
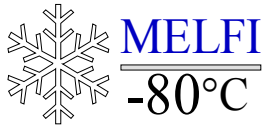


Figure 6.7 - 4: Brayton Machine shaft



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 160

From	To	Sensor type	Sensor Functional Range	Sensor Accuracy	Comments
BS/S	CDHU then MDE	PT100	0 to +100°C	+/-1°C	Motor Temperature without redundancy in order to detect any over-temperature in the stator. Stopping of the Brayton Machine if the temperature exceeds 85 ± 15°C. (Only available at MDE level)
BS/S	CDHU	KULITE HK- 375M	0 to 0.4 MPa	+/-2%	N2 Gas loop pressure 1 (compressor outlet in the Cold Box). The CB MDP shall never be exceeded.
BS/S	CDHU	KULITE HK- 375M	0 to 0.4 MPa	+/-2%	N2 Gas loop pressure 2 (compressor outlet in the Cold Box). The CB MDP shall never be exceeded.
BS/S	CDHU	PT100	-20 to +80°C	+/-1°C	Gas Bearing temperature 1 (turbine's side). Stopping of the Brayton Machine if the temperature exceeds 37°C.
BS/S	CDHU	PT100	-20 to +80°C	+/-1°C	Gas Bearing temperature 2 (compressor's side). Stopping of the Brayton Machine if the temperature exceeds 37°C.
BS/S	CDHU	PT1000	-100°C to +20°C	+/-1°C	Brayton N2 Return temperature 1 at the inlet of the BS/S (outlet of the DS/S at Cold Box coupling inlet)
BS/S	CDHU	PT1000	-100°C to +20°C	+/-1°C	Brayton N2 Return temperature 2 at the inlet of the BS/S (outlet of the DS/S at Cold Box coupling inlet)

Table 6.7- 5: Brayton S/S Telemetry

6.8 COLD BOX FRONT PANEL

The Cold Box front panel is fixed to the Rack in front of the BSS. It is necessary to dismount it (10 M6 captive screws on each side of the panel) to access the Cold Box and the Brayton Machine, to typically perform corrective maintenance: Brayton machine Exchange, Electronic Unit replacement or N2 cycle replenishment. The Triple Square M6 Tool, stored in the DASE Pouch, is necessary to dismount the CB Front Panel captive screws.

The Cold Box front panel is shown in Figure 6.8 –1. Its front face is equipped with Velcro: velvet and hook types. The internal side of the Cold Box front panel is covered with foam for acoustic damping.

The different parts accessible after Cold Box front panel dismounting are depicted in figure 6.8 –2 and 6.8-3.

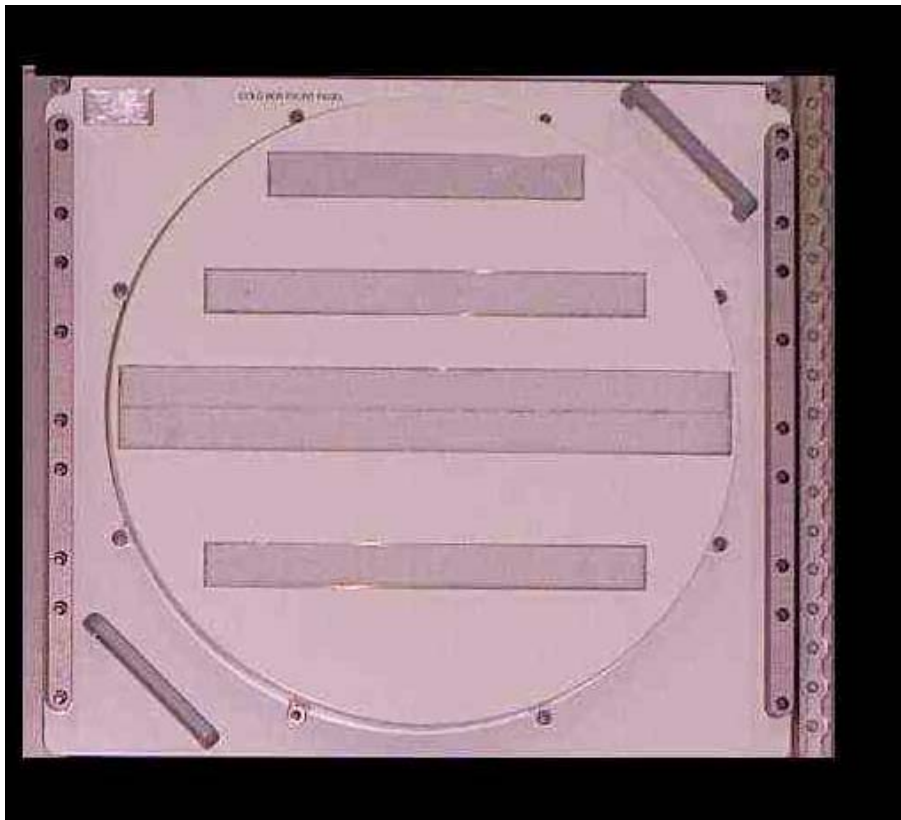


Figure 6.8-1: Cold Box front panel



Figure 6.8-2: Acoustic protections in front of BSS after CB Front panel removal

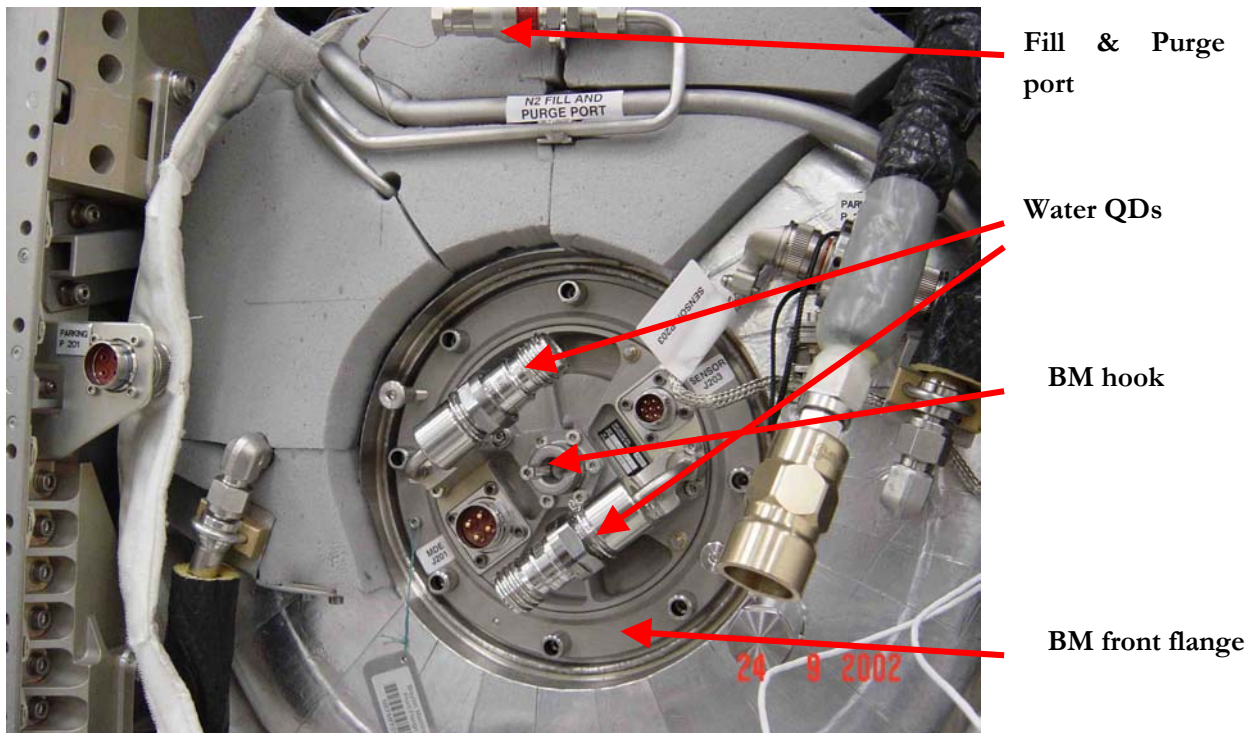




Figure 6.8-3: Brayton machine front face access after acoustic protections removal

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 163
---	---	--

6.9 DEWARS

Four identical Dewars are accommodated in the MELFI. They are all equipped with trays and Box Modules, however there is some internal layout flexibility regarding the size and type of Box Modules that can outfit a Dewar.

The cold volume provided by each Dewar is 75 liters.

The science material, including samples packaging, is up to 25 kg/ Dewar.

Each Dewar is independently controlled thanks to distribution valves and can be operated in any cold conditions provided that there is always one Dewar at least at a temperature close to -80°C .

Design and internal layout:

The MELFI Dewar is a vacuum insulated, double walled metal vessel, which is equipped with internal outfitting incl. trays and sample boxes for biological samples, a load heat exchanger (LHX) and the necessary instrumentation to monitor the actual status, i.e. 5 temperature sensors inside the Dewar and 2 door position switches to monitor the door open or closed status. The overall arrangement of the Dewar is depicted in figs. Below.

A flange connects the inner and outer cylindrical walls. On the other side two bulkheads form the bottom of the Dewar. The space between the two walls is filled with multi-layer insulation and the volume is evacuated to reduce heat input.

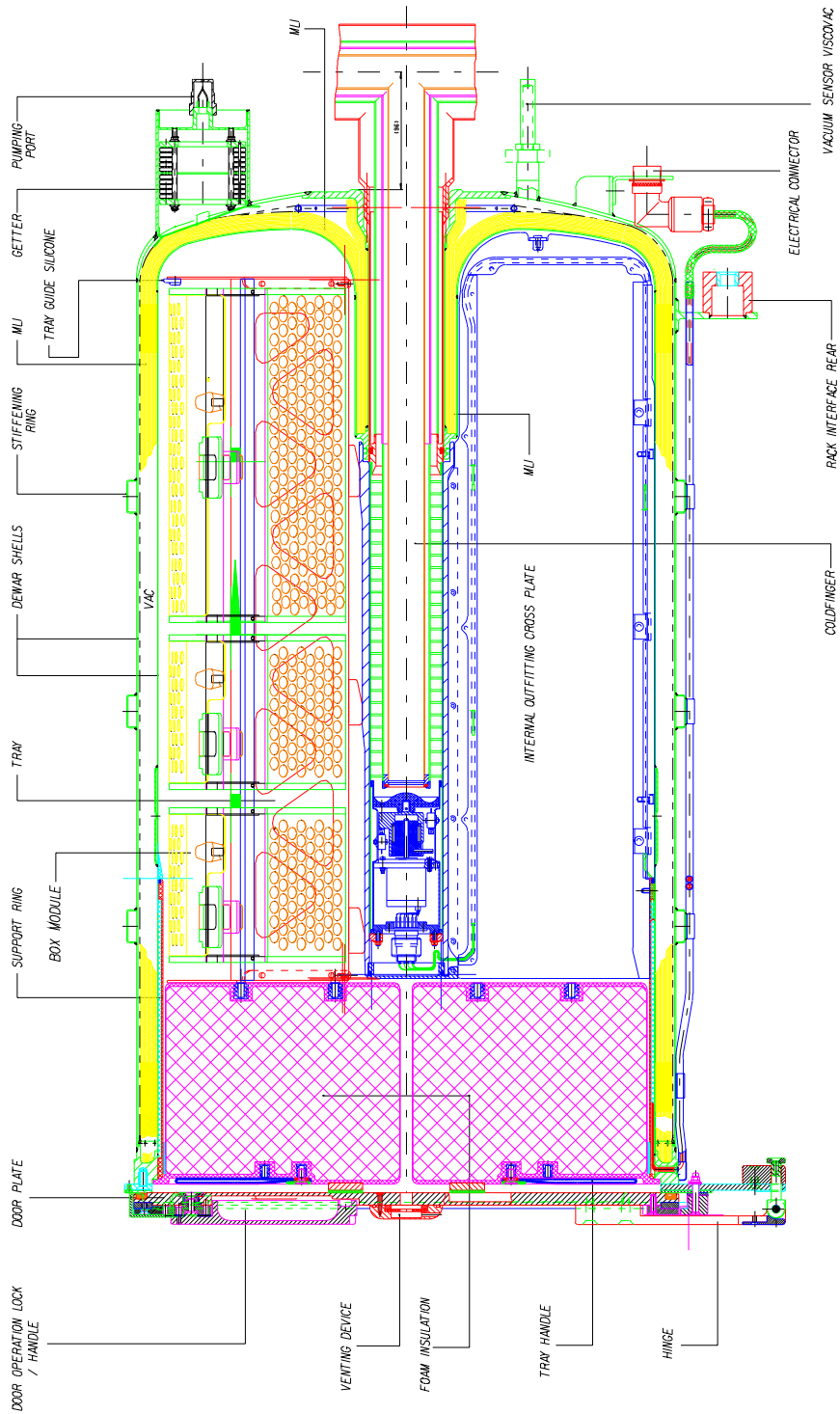


Figure 6.9-1: Dewar internal layout and main components

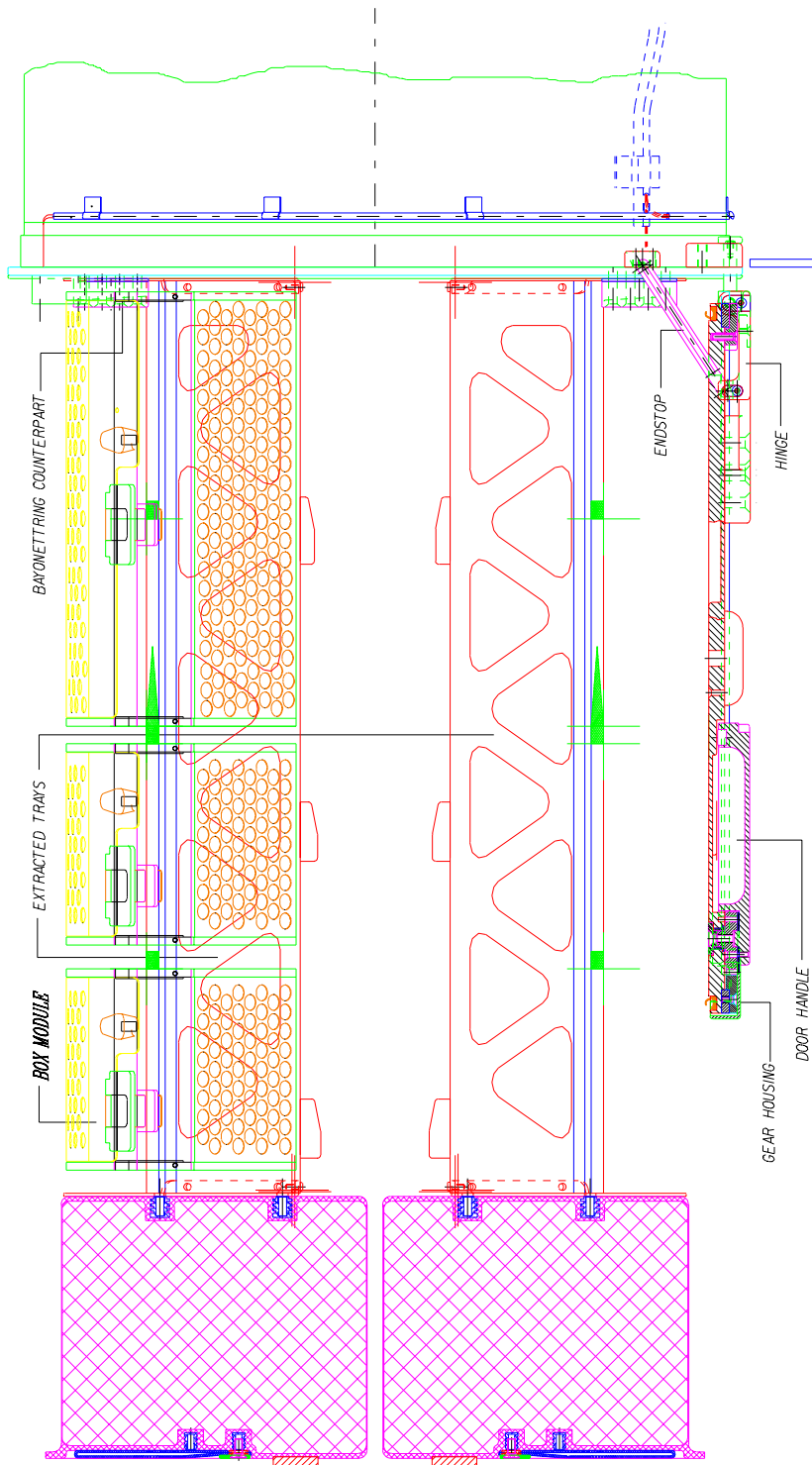


Figure 6.9 - 2: Side view of an open Dewar with extracted trays

At the rear dome the housing for a getter pump is located, which is used to maintain a high vacuum level over the required 10 years of operation plus additional margin. At the getter housing there is the evacuation nozzle to evacuate the vacuum volume on ground during the MAIT. A sensor tube for a VISCOVAC pressure sensor is also located at the rear dome, which allows pressure monitoring of the vacuum pressure on ground during maintenance.

To maintain a low insulation vacuum pressure over the required operation period a getter made of zirconium-vanadium-iron is implemented in the insulation vacuum space. The vacuum pressure in the Dewar insulation is permanently kept below 1×10^{-4} mbar.

The Dewar door closed /open position is monitored by micro switches located near the closure mechanism.

Five Pt 1000 temperature sensors are accommodated in each Dewar to monitor the internal temperature. These sensors are mounted at the outside respectively the inside of the cross plates close to the inner cylinder wall, and close to the cold finger, glued into a groove. Four temperatures signals are sent to the electronics, where the Dewar temperatures are recorded. One additional temperature sensor is connected to the temperature data recorder, TDR. In addition the electronics control the cold gas flow to the individual Dewars by a stepper motor driven cold gas regulation valves.

The location of the five temperature sensors is the following:

- TI 1 is in the outside groove of the cross plate 270° about 400 mm from the front of the cross plate
- TI 2 is in the outside groove of the cross plate 0° about 100 mm from the front
- TI 3 is in the outside groove of the cross plate 90° about 100 mm from the front
- TI 4 is in the inside groove of the cross plate 270° about 400 mm from the front
- TI 5 is in the inside groove of the cross plate 90° about 200 mm from the front.

The axial location of the temperature sensors has been selected on the basis of the thermal analysis results.

The schematic location of the sensors is depicted in fig. 6.9 -3.

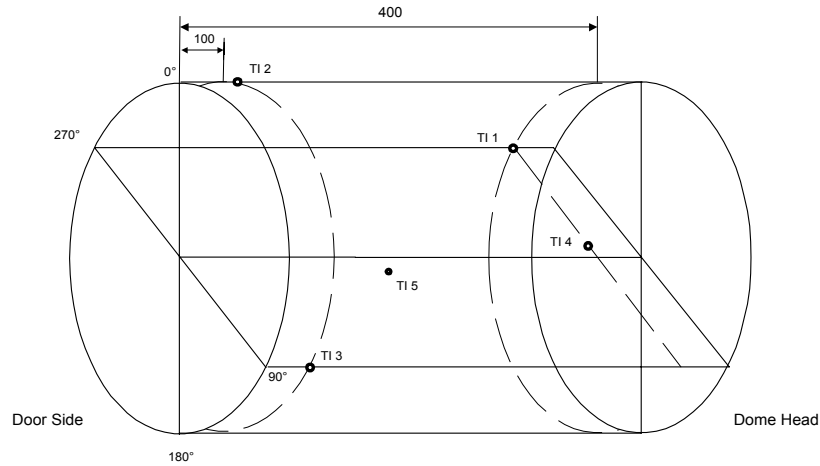


Figure 6.9 - 3: Location of Dewar thermal sensors

The read out of the temperature is the following:

- TI 1 to TI 3 monitor maximum Dewar temperatures
- TI 4 – TI 5 monitor lowest Dewar temperatures



The nominal Dewar temperature for controlling of the regulation is determined by the electronics/software as the mean value of the 4 sensor readings of TI 1, TI 3, TI 4, and TI 5.

The TI 2 is used as temperature signal for the TDR. This sensor is located at the outside of the cross plate close to the door and monitors the highest Dewar temperature.

Their cables are routed from the door end in the groove along the alignment rail. There are two cables per temperature sensor.

6.9.1 Dewar Door

The door of the Dewar seals the cold internal volume from the ambient temperature. It consists of a flat round aluminum plate with two hinges at the bottom side and a bayonet locking mechanism, which is

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 168
---	---	--

attached to the Dewar front flange. The door-locking handle is equipped with an additional lock for fixation of the door.

Locking can be done by shifting the lock into a recess of the door handle, which prevents the door-locking handle from moving. This lock and unlock shall be verified before launch and before return to earth. This operation is part of the configuration procedure for Return (see RD1).

On one side of the door a soft dock mechanism keeps the door in 90° open position. On the other side a bonding strap connects the Dewar a door with the front flange to avoid electrical charge of the door. The bonding strap is integrated near one of the hinges. The front view of the door is shown in fig. 6.9 – 4 and 6.9 –5.

When the door is closed the trays are axially kept in position by small glass fiber pads with additional silicone pads, which are located between the door and the tray insulation blocks.

The door is axially sealed by a silicone sealing which is embedded in the Dewar door.

To allow pressure balance between Dewars and cabin/ambient a breathing device is foreseen at the door front. It consists of a housing with a silicone membrane. A cross cut in the membrane opens at small differential pressures and closes again, when there is no pressure gradient across the membrane.

The thermal insulation of the Dewar enclosure is ensured by poliimide foam, which is embedded in a glass fiber housing for structural reasons.

The insulation foam is just behind the Dewar door and is attached to the Tray structure. These insulation foam blocks interfaces to the trays on one side and to a Nomex sling to push /pull the tray.

To hold the Dewar door closed in normal utilization an operation lock device is provided at the upper side of the door. This locking bar has to be opened by a 120 ° rotation before opening of the Dewar door.

The handle rotation is transmitted to a gear bar by a gear drive to rotate a bayonet ring in the door. This ring engages with its 4 segments in dedicated counter parts on the door front flange. While the Dewar door handle is rotated by 120° the Dewar door is pulled towards the front flange by 2 mm compressing the door seal, which is located on the inside of the door plate. When the door touches the front flange the sealing is compressed to the nominal value and the door is locked.

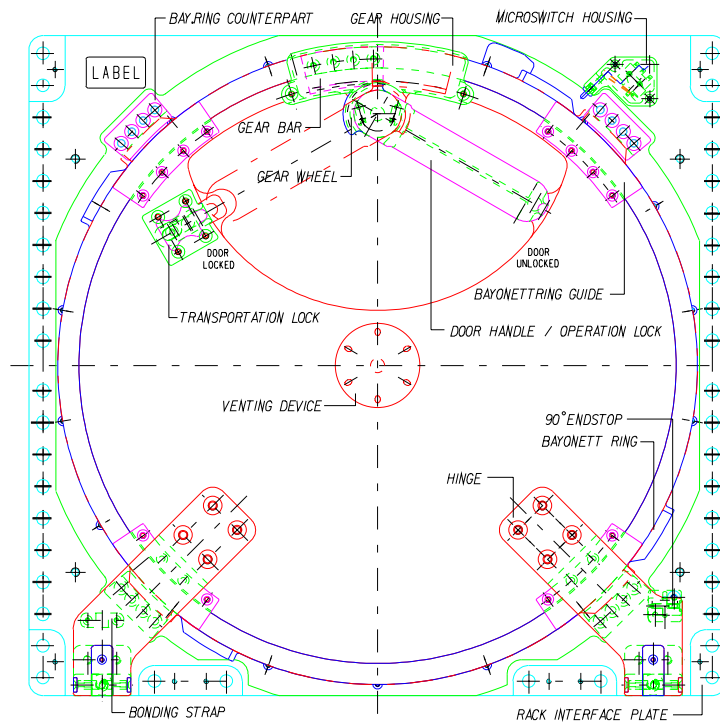


Figure 6.9 - 4: Dewar door design

The door locked position will be detected by one micro switch. The micro switch is activated by a cam profile, which is attached to the bayonet ring. When the door handle is rotated and thus rotates the bayonet ring, the cam profile actuates the pin of the micro switch. Due to that design it is ensured that the door switch is only activated when the door is properly closed.

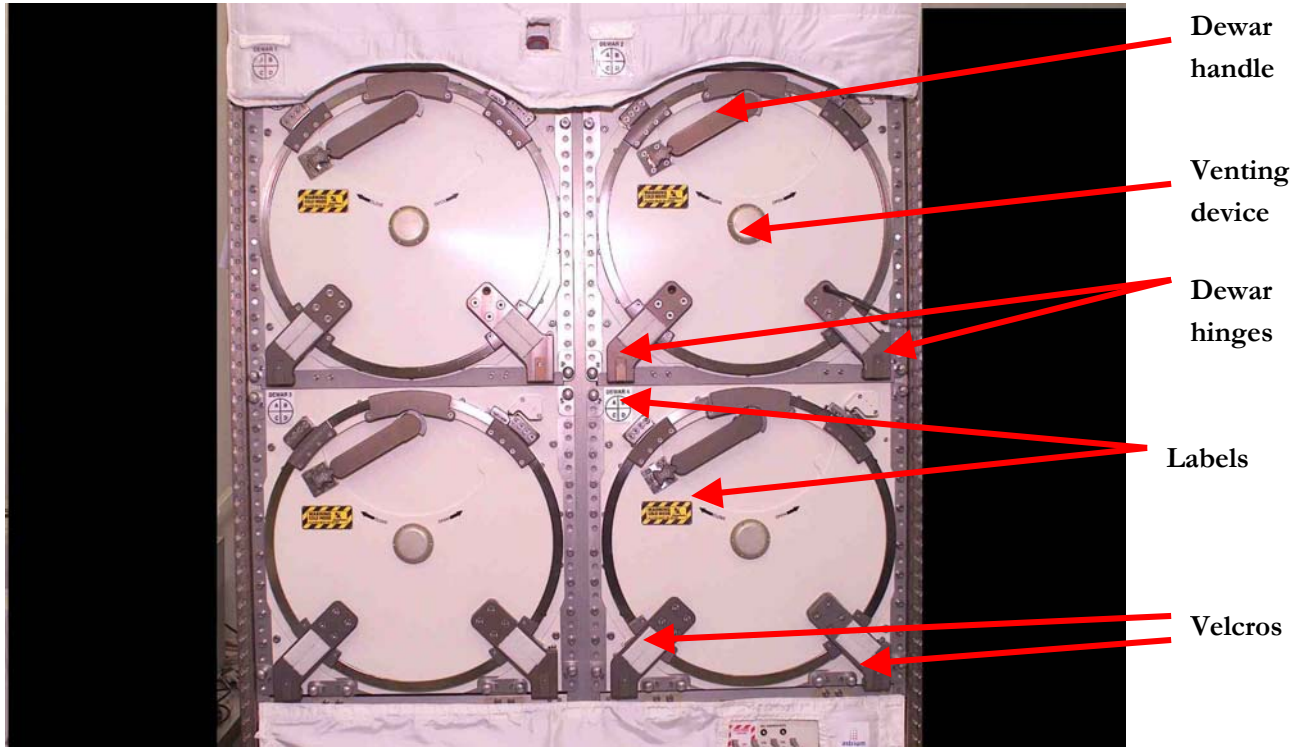


Figure 6.9 - 5: Dewar FM1 inside Rack

6.9.2 Cross Structure

Each Dewar is divided into four sections by a cross structure.

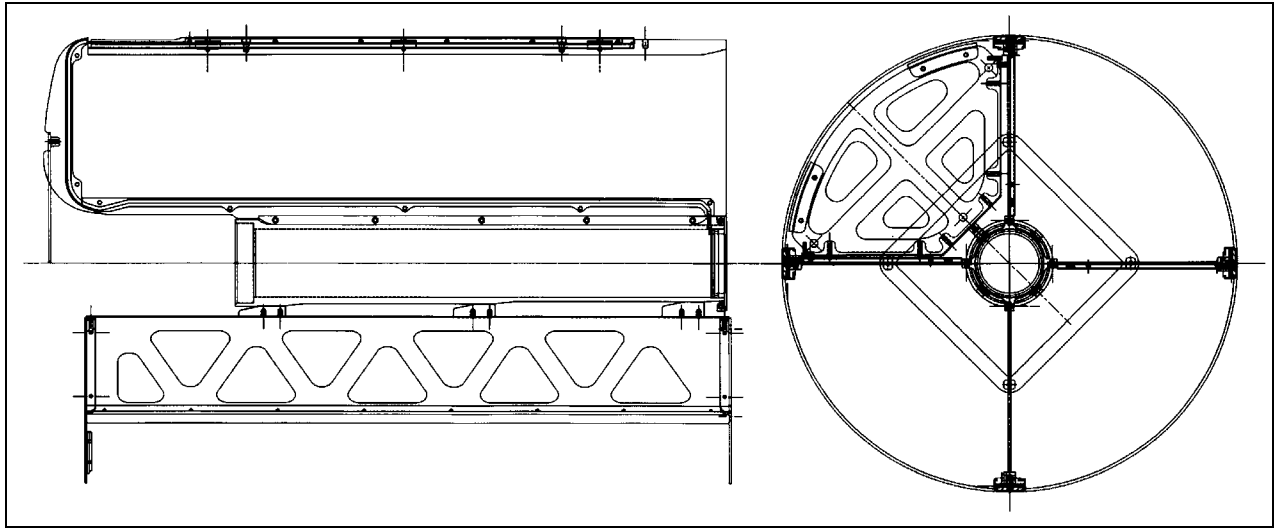


Figure 6.9 - 6: The Internal Outfitting of a single Dewar.

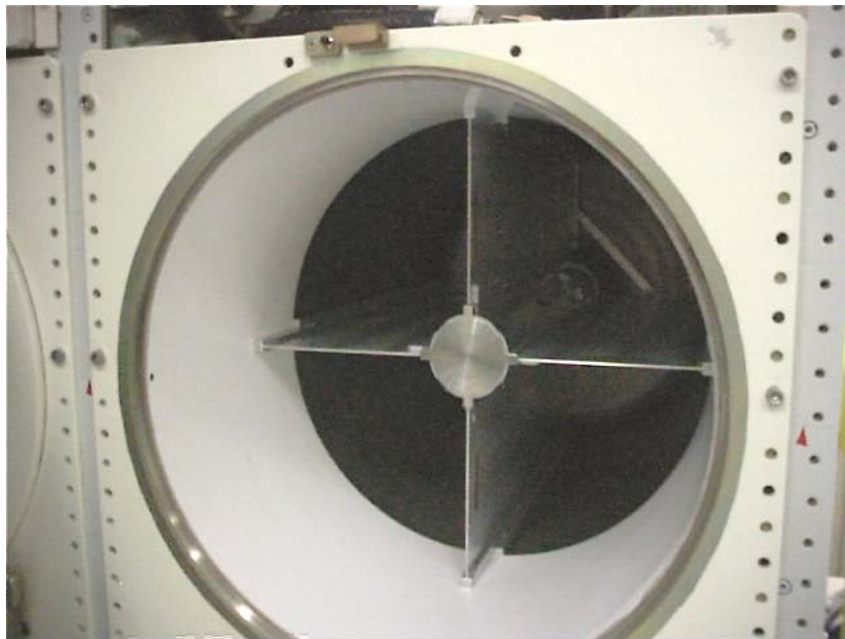

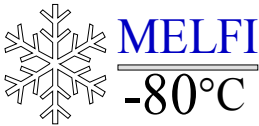


Figure 6.9 - 7: Internal view of a Dewar showing the cross-structure

The Cross Structure supports and guides the four Trays in each Dewar; it is fixed to the internal wall of the Dewar and allows the Trays to slide out when the Dewar door is opened.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 172
---	---	--

The Cross Structure contributes to the distribution of the cold production from the cooling element (cold-finger) to the internal volume of the Dewar.

The Cross Structure is coated for protection against moisture and corrosion, which might be caused by potential spillage of saline solutions. The coating forms a low surface tension film with excellent repellent properties to water, hydrocarbons, synthetic fluids and various other aqueous solutions. It should be inspected every two years and re-applied if necessary.

6.9.3 Tray

The function of the Tray is to safely and efficiently store the sample Box Modules, while allowing easy access to the sample modules during crew operations. The Trays are shown in Figure 6.9 - 8.

There are 4 trays per Dewar; each tray is individually removable.

Tray features:

- Glide smoothly with tray braking mechanism to prevent un-wanted extraction; no tray stop but tray marking to prevent complete extraction
- Foam insulation block is hard attached to the tray metallic structure
- Soft handle for the nominal removal/insertion operation
- Tray extraction tool for Off-nominal Ops (see sections 4.3 and 5.4)
- Silicon rubber friction strip to prevent Box Modules from moving
- Alignment marks to aid module placement by crew
- Four module positions, numbered front to back.

The crew can access any Box modules stored in a Tray, when the Tray is withdrawn from the Dewar. A Tray may be retrieved (partly or fully) from the Dewar by pulling onto the handle.

However, not any operation can be done with trays. In particular no overstress during handling should affect the tray because there might be a risk of twisting the tray. This is a warning regarding the operations.

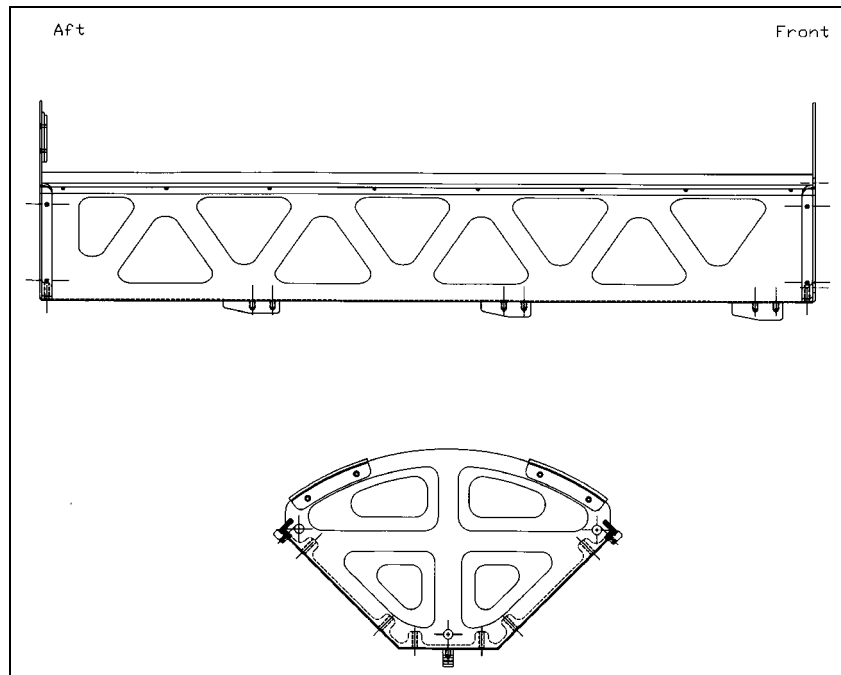


Figure 6.9 - 8: Tray (without foam block)

Tray design

Each Tray consists of three main parts; the Tray side walls, the Tray front and end plate. The Tray side is fitted with sliding rails and sliding wedges to interface with the Cross Structure. The sliding rails and wedges are manufactured from a reinforced low-friction material (Fluoro-seals) to allow the Trays to glide smoothly as they are inserted or removed from the Dewar.

The Tray side profile is fitted with a silicone rubber friction strip to ensure that the sample modules stored within the Trays are not able to move around within the Tray, when they are exposed to various forces and vibrations.

Green square alignment markings are on the top of the tray sides and are used to ease the correct positioning or distribution of Box modules inside a Tray. There is also a green arrow marking to indicate the maximum distance beyond the Tray will be completely extracted from the Dewar.

The Tray carries a Velcro Hook patch at the rear end plate. The Hook patch allows to temporary attaches the Tray to the MELFI rack front face. The position of the Velcro patch is shown in Figure 6.9 - 9.

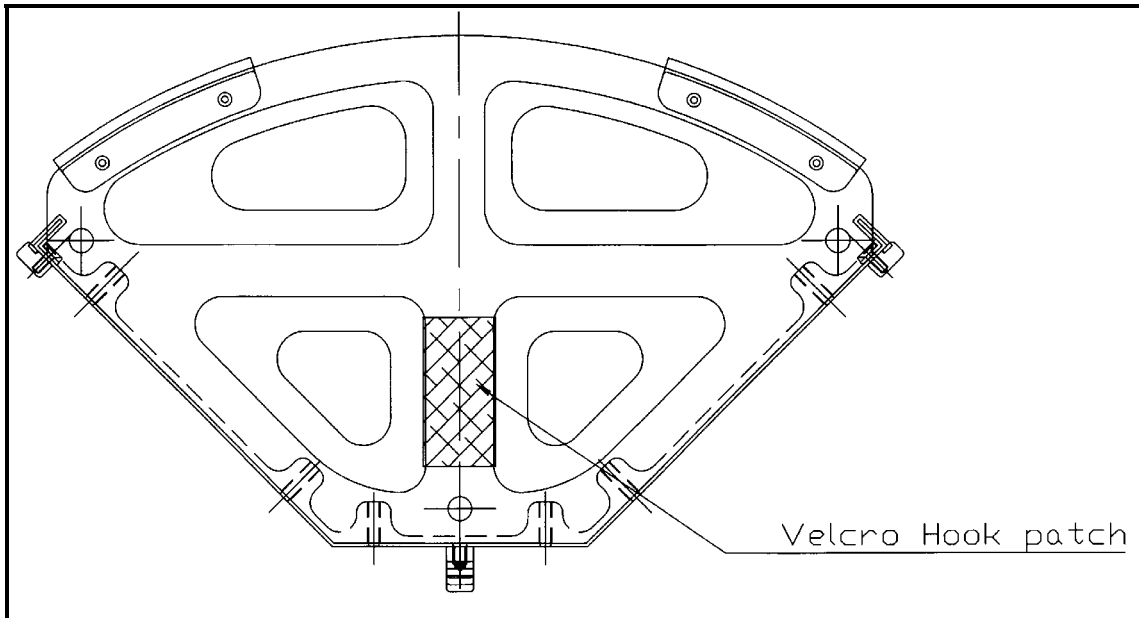


Figure 6.9-9: Velcro Hooks patch on Tray.

Tray Sliding Mechanism

Sliding wedges and sliding rails facilitate the Tray insertion and / or removal from the Dewar. The T-shape of the cross-plates acts as a guide for the sliding rails. As the Tray is inserted into the Dewar, an initial clearance between the Cross Structure and the stepped plane on the cold-finger housing and the sliding wedges gradually reduces the Tray, until a slight interference fit is created in the fully inserted position. The material of the sliding rails and wedges is Fluoro-seals (a Teflon and Carbon composite), which ensures that the frictional resistance is kept to a minimum. An exception is the front sliding wedge, which is made of aluminum in order to provide thermal contact between the Tray and the Cold-finger Housing. The sliding rails are round at the aft end in order to ensure proper alignment when inserted into the Cross Structure. A cross section of a Tray with sliding rails and sliding wedges is shown in Figure 6.9 - 10.

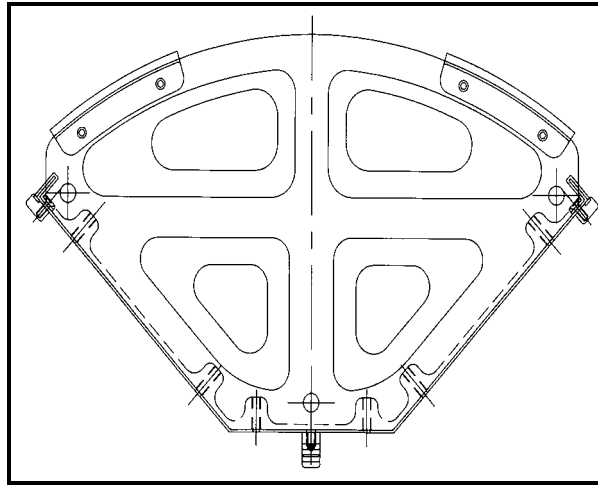


Figure 6.9-10: Cross section of Tray.

Tray Guide Mechanism

A Tray Guide mechanism is implemented at the rear of all Trays. The mechanism consists of two flaps of silicone, which protrude upwards from the Tray in the radial direction towards the inner Dewar wall. The 2 mm thick silicone is 0,3 mm from the inner Dewar shell when the Tray is in its nominal position in the Dewar. When the Tray is extracted, the silicone remains free until it meets the edge of the inner Glass fiber ring of the Dewar. Then the silicone flap slides with a small friction against the Glass fiber ring, until the Tray is completely extracted.

When inserted, the Tray uses the sloped ends of the sliding rails to be aligned and the silicone flat for guiding.

Tray/Sample Module interfaces

The interface between the sample modules and the Tray is an edge, which allows the box module to grip on it. The edge is covered with a strip of silicone rubber to allow for absorption of some of the gripping effect. A detailed drawing of this Tray edge is shown in Figure 6.9 – 11.

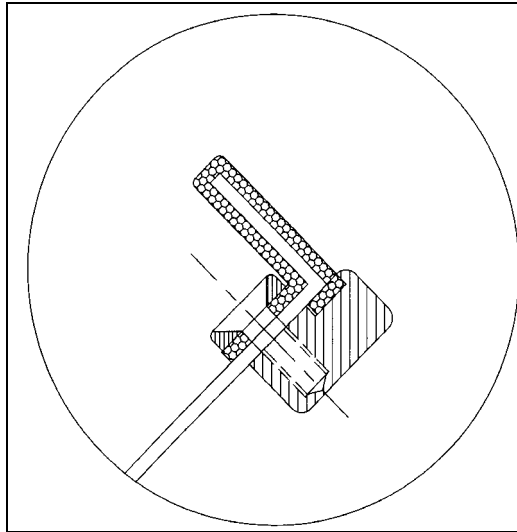


Figure 6.9-11: Tray edge for sample module interface.

6.9.4 Box Modules

The experimental material will be filled in vials of various sizes (ranging from 2 ml to 10 ml) or bags and transferred to the Dewar for storage.

This biological or science material can be accommodated in various types of MELFI H/W: Vial Bags, Vial Cards, Holders, Contact cards for sample size < 100 ml. For larger samples, bags will be directly inserted into the Box modules.

The sample accommodation H/W is located inside Box Modules. The Box Modules are available in two configurations and two sizes:

- Standard Box Modules: $\frac{1}{4}$ size and $\frac{1}{2}$ size
- Receiving Box Modules: $\frac{1}{4}$ size and $\frac{1}{2}$ size

6.9.4.1 Standard Box module

The Standard Box Module, shown in Figures below, can be used to store a large variety of samples. The design allows samples to be added to a box module for storage while the module is locked on position to the Tray irrespective of the location of other sample modules in the Tray.

Perforated plate is used in the construction to reduce the mass of the box module.

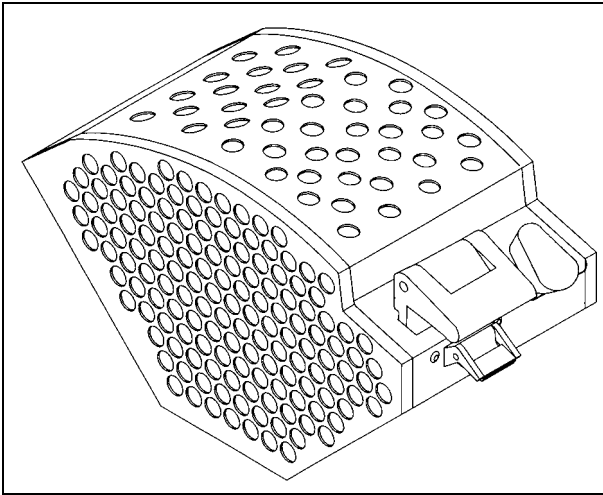


Figure 6.9-12: 1/4 size Box Module.

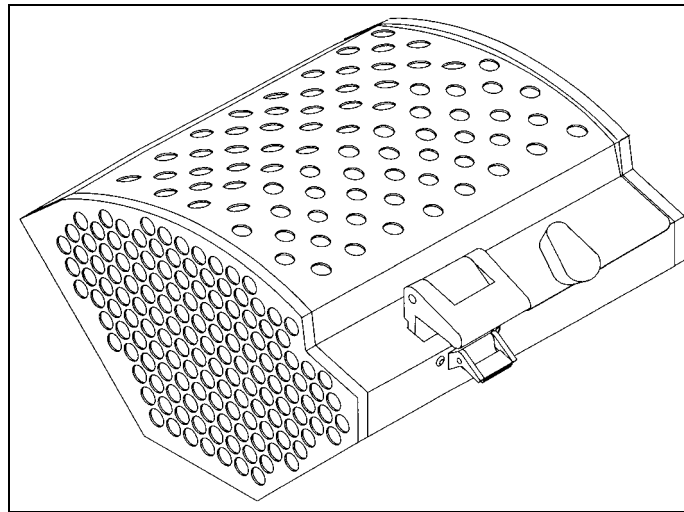


Figure 6.9-13: 1/2 size Box Module.

The Box construction consists of two opposite end frames which provide rigidity and strength to the structure. The bottom profiles, reinforcement plates and inner cover plates and lids are manufactured from perforated aluminum plate, to ensure a strong but light construction.

The Box Modules have two strips of Velcro Loops on the inside, at the bottom plate, for fixation of the Vial Bags and Vial Cards. Opposite, on the outside of the bottom plate the Box Module will have two strips of Velcro hooks which allows to attach Box Modules to any surface when removed from the Tray.

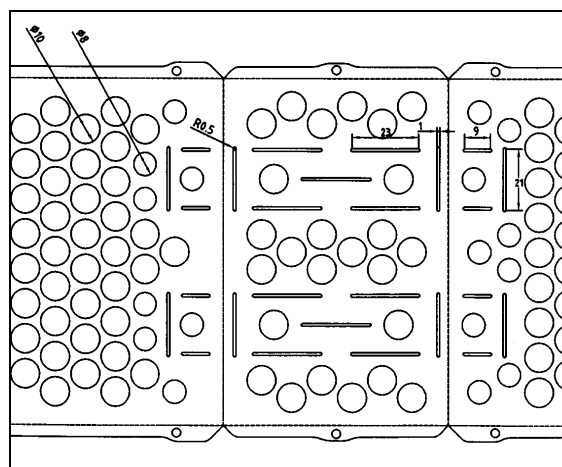


Figure 6.9-14: Position of Velcro on Box Module.

Box Module closure Mechanism

The lid is hinged to the Box Modules frames by two pivots. One of the pivots is passive, while the other has a small spring contraction mechanism, which matches an indent in the corresponding frame. When the lid is fully opened the mechanism maintains it in the open position, until it is actively forced back and the lid is closed. When in the closed position it is locked.

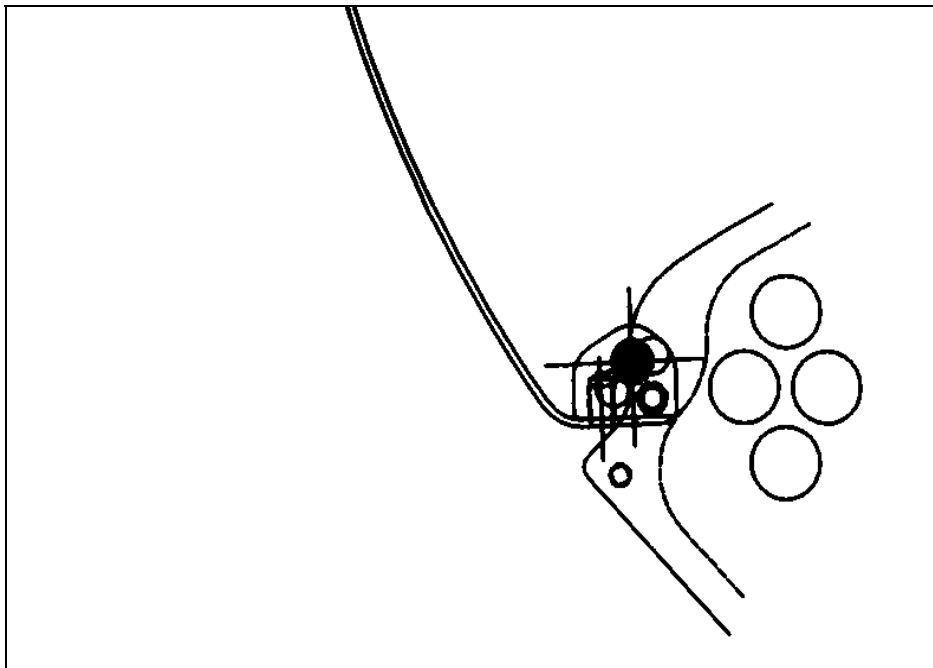


Figure 6.9-15: Lid pivot mechanism.

The lid of the Box Module pivots around one side of the module, allowing samples to be inserted or retrieved when the lid is open. A single turn dial is used to lock the lid to the reinforcement plate. The lid is closed when the dial is turned 90° clockwise. The dial is conical in order to allow for a proper grip. On the bottom an L-shaped bar maintains the lid in the closed position when turned 90° clockwise.

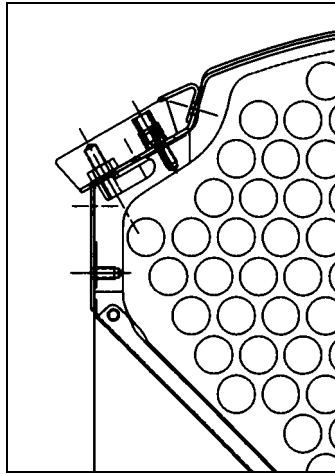


Figure 6.9-16: Lid locking Mechanism.

A small spring contraction and two recesses in the lid provide two defined end-stop positions, open and closed. A small pin on the dial ensures that the dial only can rotate between 0° and 90° (see Figure below). When the lid is opened the end-stop contraction maintains the dial in the open position and prevents it from unintentionally shifting to the closed position (which would require turning the dial 90° clockwise to engage the reinforcement plate).

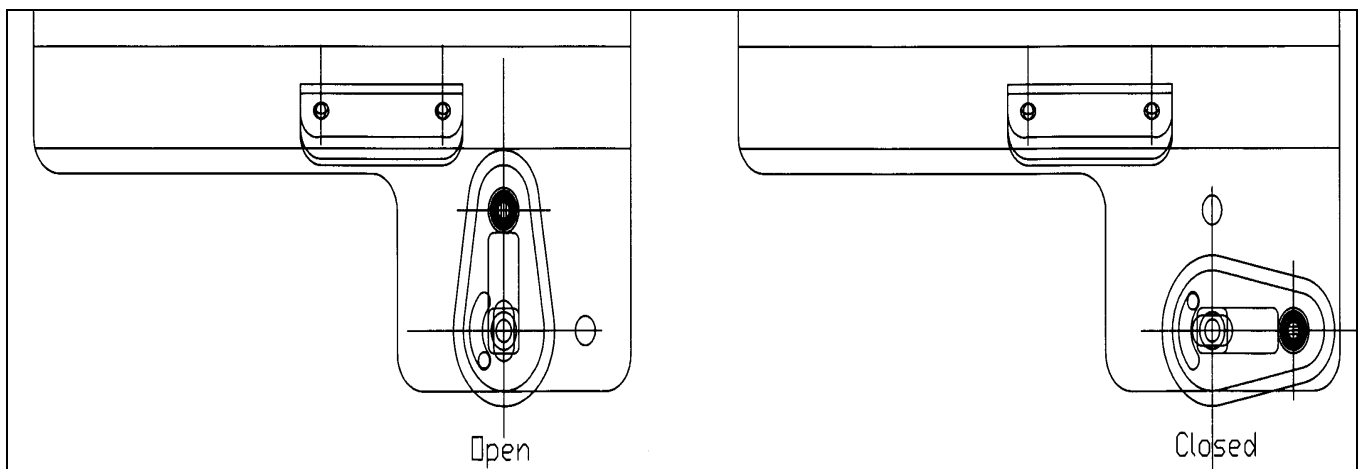


Figure 6.9-17: Lid lock Dial - open and closed positions.

Box Module Locking Mechanism

The locking mechanism for fixation of the Box Modules within the Trays is identical for all types of Box modules. Figure 6.9 - 18 shows the locking mechanism, which secures the sample modules within the Trays. The locking mechanism is operated by hand, while the crew is wearing gloves.

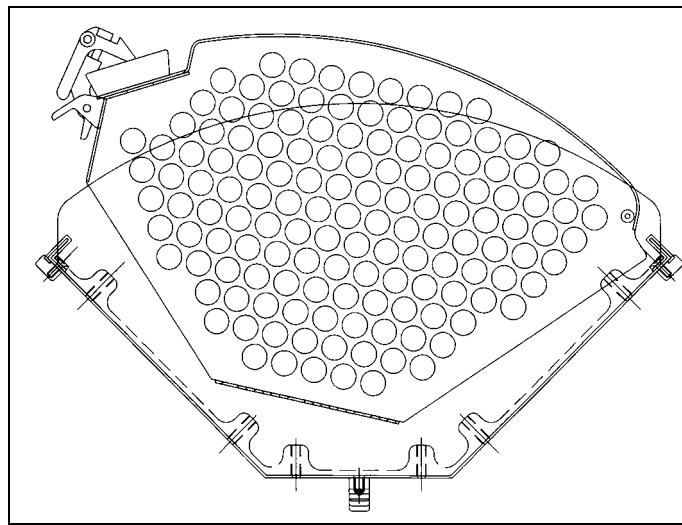


Figure 6.9-18: Locking mechanism in open position.

The edges of the Tray side-profile have a small inward fold, which effectively holds the Box Modules in place when they are locked to the Tray. The locking mechanism is fitted on one side of the Box Module, to the reinforcement plate. When inserting the module into the Tray, the side of the module opposite the locking mechanism fits into the angle produced by the fold at the end of the Tray side profile. At the locking mechanism, the upper fixed part of the clamp grip rests on the Tray side profile fold. The module is locked to the Tray by means of a clamp, which grips the folded edge of the Tray side-profile. When released a spring ensures that the locking mechanism always ready in position for locking.

The clamp handle is pressed down allowing the clamp to rotate about a pivot, causing the two grips of the clamp to lock onto the fold on the Tray side-profile. A spring fixed to the clamp presses the clamp handle, ensuring that a catch on the handle locks the position of the clamp. The clamp is released by gripping the handle and pulling upwards, this presses the spring back and releases the clamp. A spring ensures that the clamp stays in the open position when released. The Clamp Handle is equipped with two fins for better grip, and it is slightly wedge shaped to give more room for the fingers below.

The rubber strips on the Tray provide a slightly elastic interface, which yields as the sample module is pressed against the Tray and between the clamp fingers and the Tray fold. The rubber strips also provide additional friction at the interface to eliminate movement of the Box Modules due to vibrations.

An Inner cover Plate is placed inside the Box Module protecting the locking mechanism, so it is not released accidentally when Vial Cards are inserted. Furthermore, it offers protection for the mechanism so nothing can be trapped in it.

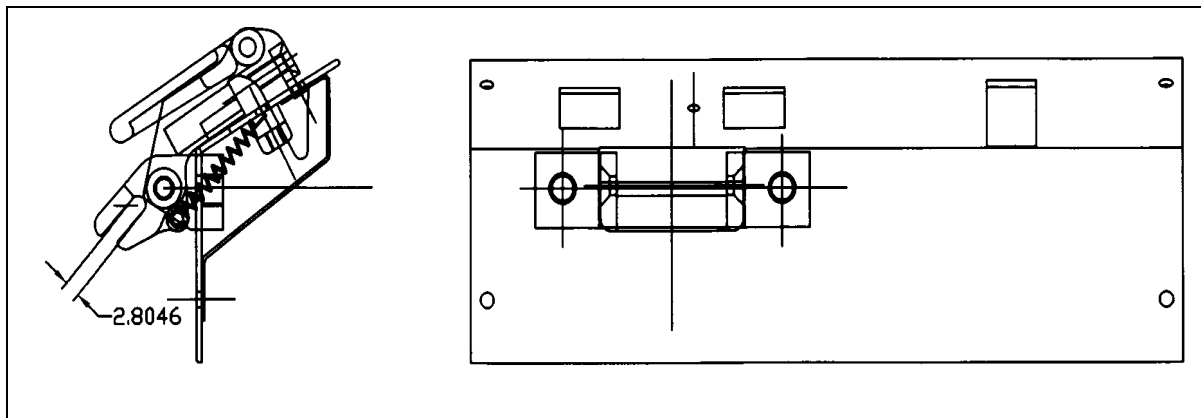

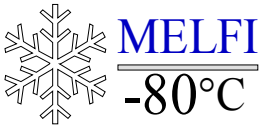


Figure 6.9-19: Box Module locking mechanism.

Elastic Strap

All Box Modules are outfitted with an elastic strap inside to secure the Vial Cards and Vial Bags during Launch and landing. The strap is attached at one end to the Box Module bottom plate (6 cm above the bottom) and has in the other a small metal hook, which can be attached to the holes in the Inner Cover plate. At the hook end the strap has a small handle to allow for gripping. The ½ size Box Models has two of these straps installed.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 183
---	---	--

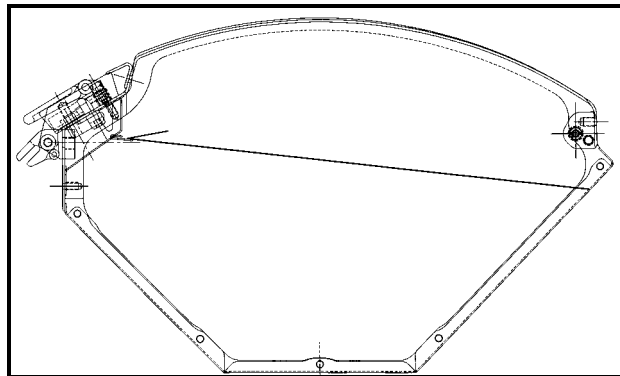


Figure 6.9-20: Box Module Elastics for securing Vial Cards & Bags.

6.9.4.2 Receiving Box Modules


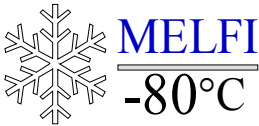
MELFI have 2 types of Receiving Box Modules, $\frac{1}{4}$ and $\frac{1}{2}$ sizes dedicated for cool down of samples. Both types of Receiving Box Modules have the features installed permanently but can be used as standard Box Modules with minimal impact on the usable volume if necessary.

The Receiving Box Module was developed to provide a cooling capability equivalent to the cooling of **100 ml** saline solution from 23°C to -68°C in less than **170 minutes**.

$\frac{1}{4}$ RECEIVING BOX MODULE:

Each $\frac{1}{4}$ Receiving Box Module is based on a standard $\frac{1}{4}$ size Box Module with added contact areas in order to improve the contact to both the Box Module and the samples. The contact areas have been realized in three positions. The first is the vertical close to the locking mechanism of the Box Module and are for the dedicated Contact Cards. The second and third are on each side profiles of the Box Module and are for the Fixed Bottle Holders.

The mechanism in the first position has the height of approximately 120 mm and consists of 2 aluminum bars fixed on each side profile of the Box module. A stainless steel spring is mounted parallel to each bar

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 184
---	---	--

and will press the 1 mm Contact Card towards the bars in order to give a good thermal contact. The bar and spring is round at the top so it is easy to insert the Contact Cards from the top.

The mechanisms in the second and third position are the same. They consist of two 90 mm Bottle Holder attachments made of spring of stainless steel. The 2 attachments are placed vertically, 60 mm apart, on the side profile. The attachments press the Bottle Holders against the side profile for good thermal contact.

Each Receiving ¼ Box Module can accommodate for cooling down either one Contact Card and some standard Vial cards and Vial Bags attached with Velcro or 2 Bottle Holders (for 2 pcs. 100 ml bottles). Even with the 2 Bottle Holders there will be room for a few additional Standard Vial Cards and Vial Bags. Other combinations are also possible. If the Receiving ¼ Box Module is utilized as a standard Box Module the Contact Cards and Bottle Holders can be removed.

The ¼ Receiving Box Modules has three positions of which the two are identical for cooling down of samples. The spring half is made from 0,3 mm stainless Steel.

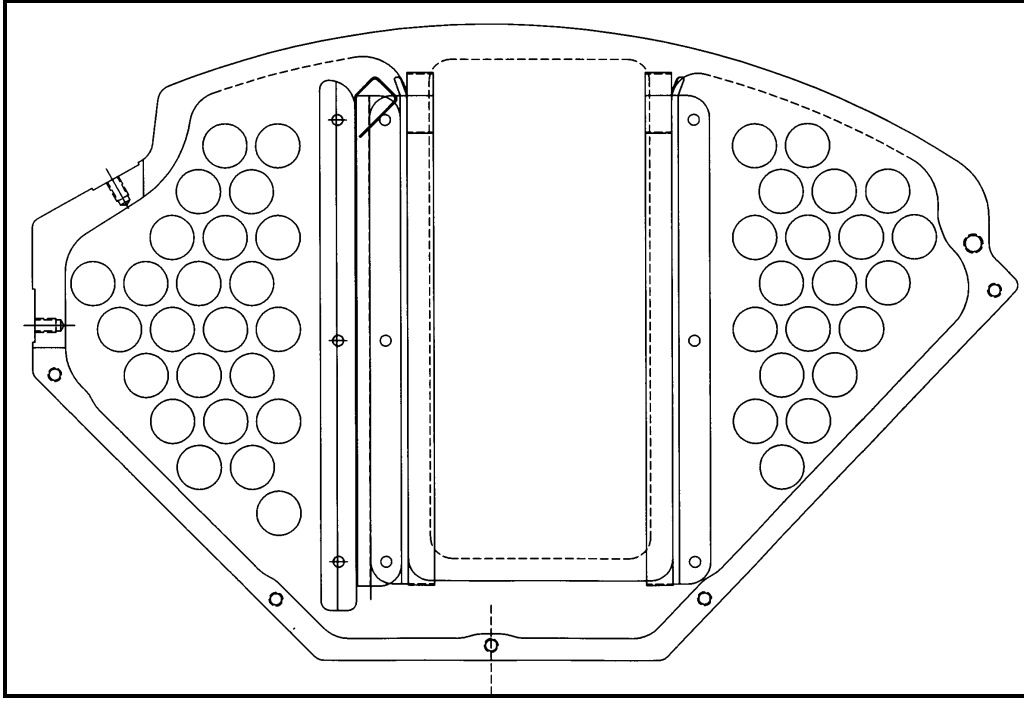


Figure 6.9-21: 1/4 Receiving Box Module, internal side view

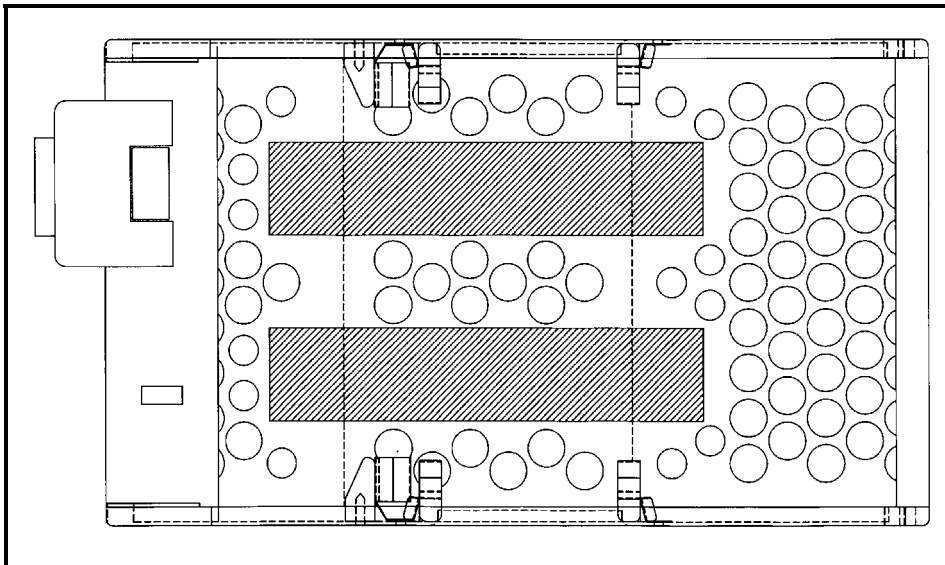


Figure 6.9-22: 1/4 Receiving Box Module, top view

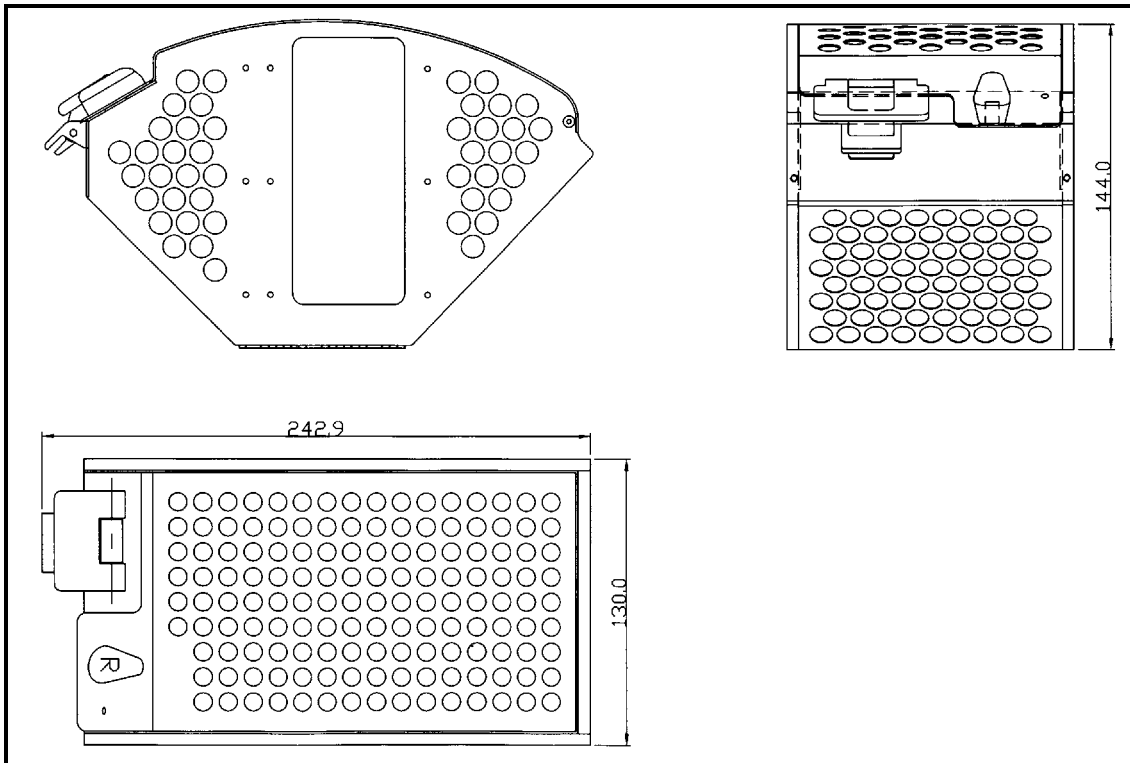


Figure 6.9-23: External view of 1/4 Receiving Box Module

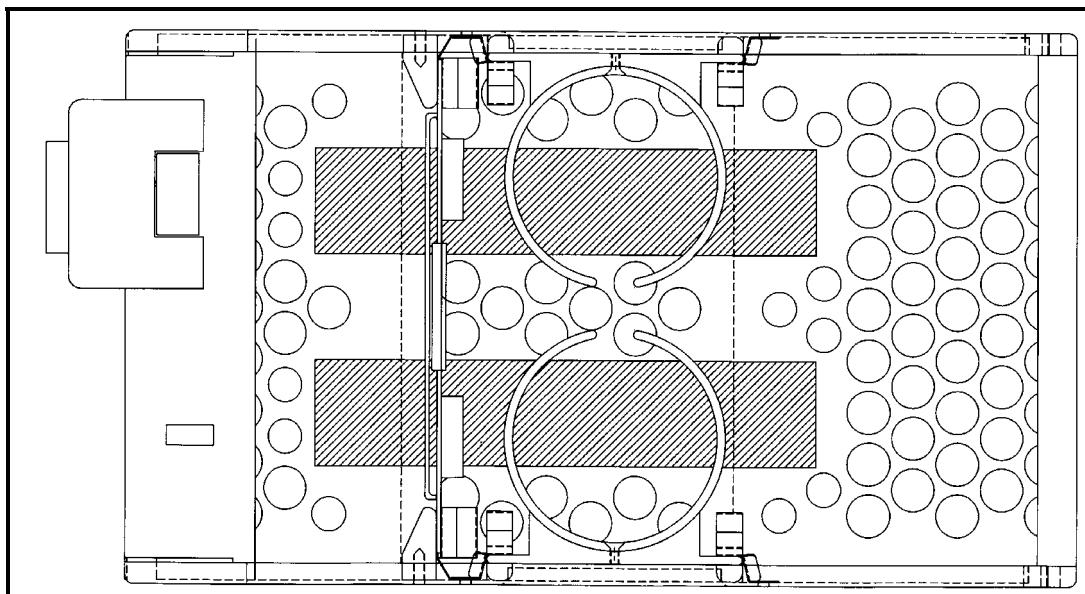


Figure 6.9-24: 1/4 Receiving Box Module filled with a Contact Card and 2 Fixed Bottle Holders.

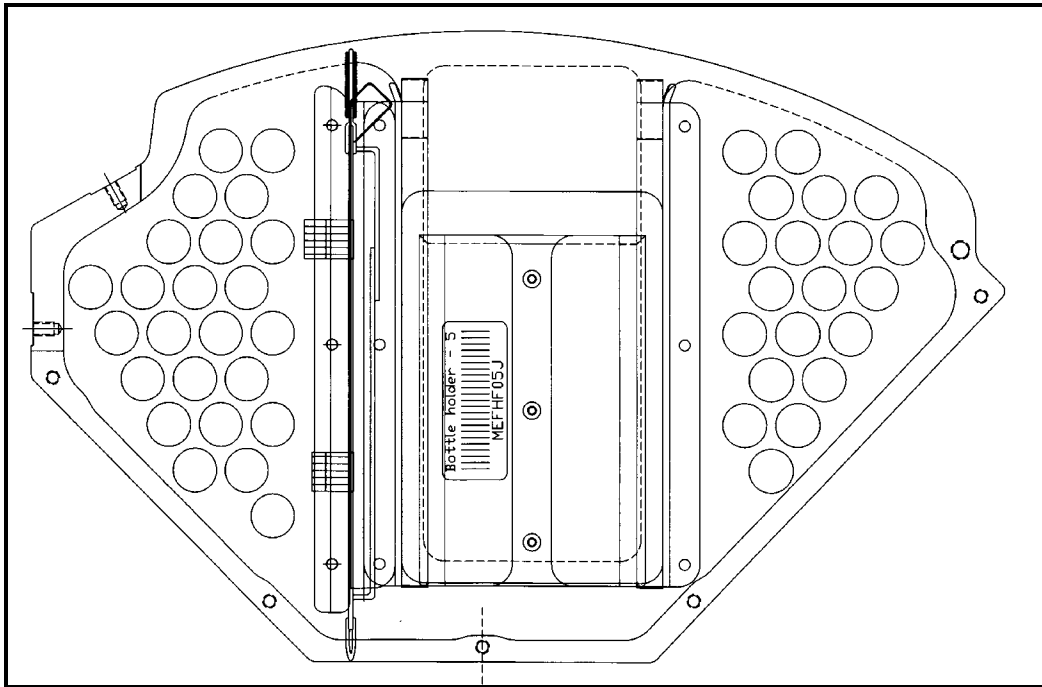


Figure 6.9-25: Contact Card & Fixed Bottle Holder in 1/4 Receiving Box Module.



1/2 RECEIVING BOX MODULE

The 1/2 size Receiving Box Modules only have two modifications compared to the Standard 1/2 size Box Module. The bottom profile is made without holes in order to give an improved contact areas for larger e.g. 500 ml samples. Furthermore, it has two Hi-Air Velcro Hook Straps mounted for securing good thermal contact between the sample and the bottom profile.

6.9.5 Sample Holders

Four types of sample holders are provided as inserts for the Box Modules:

- Vial Bag
- Vial Card
- Contact Card

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 188
---	---	--

The Vial Bag and the Vial Cards types can be accommodated in any type of Box Modules. They are both capable of accommodating a wide range of vials and sample types. A Box Module can be outfitted with nearly any combination of Vial Cards and Vial Bags depending on their filling. A maximum of 4 Vial Card or 6 Vial Bags is possible in a ¼ size Box module.

The Contact Cards and holder (100 ml Bottle) can only be accommodated in ¼ size Receiving Box Module because they were made to improve cooling down times for samples. However these H/W items can be stowed in regular Box Modules if necessary.

Vial Bags

The Vial Bag is a bag manufactured from a mesh type fabric. It measures 10 cm x 12 cm. At the bottom edge it has a Velcro hook patch, which will hold it in place inside the Box Module. At the top end it is outfitted with a Velcro closing mechanism, which will prevent the vials from escaping. Each Vial Bag is labeled with a unique serial number. A Vial Bag is shown in Figure 6.9 - 26. The Vial Bag has Velcro Hooks on the Tab for attachment outside MELFI, and two identical, but opposite facing labels. The bag mesh has large holes, which allows the crew to easily identify a sample to be retrieved from the bag.

Vial Cards

The Vial Card has approximately the same size as the Vial Bag, 10 x 11 cm. It is manufactured from an aluminum plate, which contains holes for mass saving purposes, and fastening of elastic bands and Velcro. On each side it has two rows of elastic straps. The straps have loops for accommodating the individual vials. In total a Vial Card can accommodate 20 small vials (10 on each side) or 10 large vials (5 on each side). At the bottom corners it has two Velcro hook patches, which will hold it in place inside the Box Module. Each Vial Card is labeled with a unique serial number. A Vial Card is shown in Figure 6.9 - 27.

The Vial Card has Velcro Hooks on the Tab for attachment outside MELFI, and two identical, but opposite facing labels.

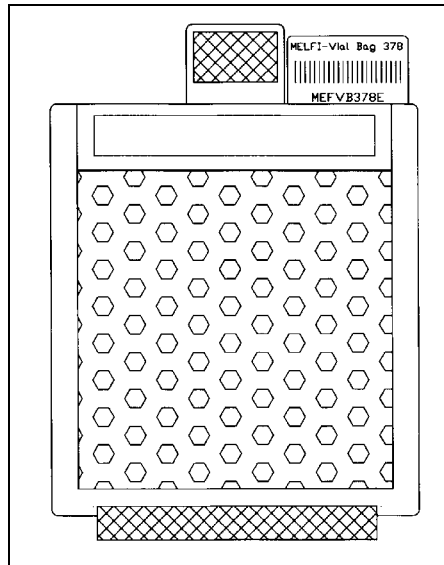


Figure 6.9-26: Vial Bag.

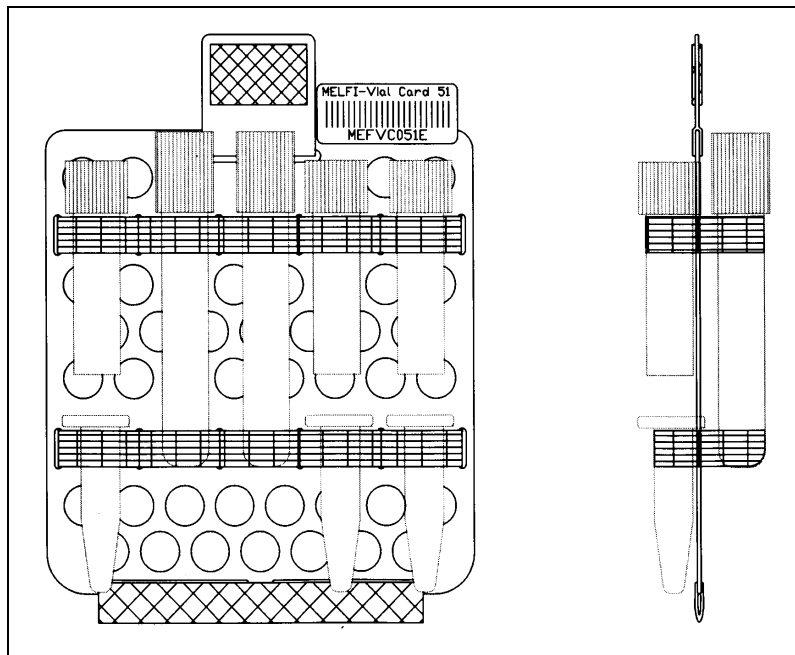


Figure 6.9-27: Vial Card.

Contact Card

Dedicated Contact Cards are provided for small samples of irregular shapes and for large samples up to 100 ml of non-rounded shapes, mainly with one or more flat sides. The size of the Contact Card is similar to the Vial Cards. The only exception is that it is 5 mm wider in order to provide better thermal contact to the receiving Box Module. On each side they have an unused zone, which fits into the bar & spring mechanism on the Receiving Box Module and provides the contact between the Card and the Module.

The Card is made of aluminum. On one side the Card has straps to hold 4 long or 8 short Vials (up to 12 mm diameter). The other side has Velcro straps attached to fixate larger square samples. The card is equipped with the standard Nomex handle with Hi-Air Velcro and it has Hi-Air Velcro at the bottom to attach it in the normal fashion inside the Box Module. It has two identical, but opposite facing labels.

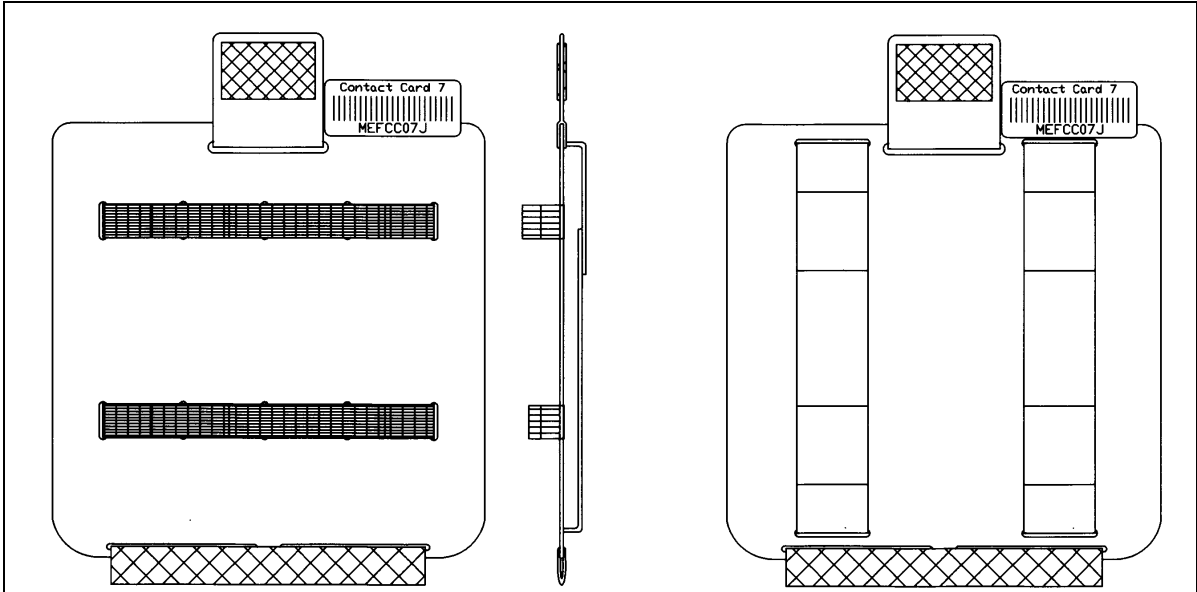


Figure 6.9-28: Contact Card

6.10 THERMAL BAG

The Thermal Bag is used for intermediate storage of a cold Tray. The bag ensures that the sample temperature in the Tray remains below minus 68°C for 15 minutes after extraction from a Dewar at minus 80°C (when 2,4 kg of samples are installed). The Thermal Bag concept is based on a collapsible design, made from foam pads at each Tray end and two layers of Nomex in between. The layers are gold/silver coated Polyester foil and leave an air gap for thermal insulation purpose. The two 50 mm foam pads located at both bag extremities have the overall dimensions of a Tray enlarged by 50 mm in order to leave an air gap all around the Tray inside the Bag. The inner bag consists of five layers. A silk layer facing the Tray to protect the foil layers against abrasion. Layers provide protection against heat radiation.

To aid the crew to insert a Tray into the bag, a rigid frame made of glass fiber is attached to the bag front end. Guiding the rigid frame over the Tray until it is completely inside the Thermal Bag does inserting a Tray. The foam pad at the front end is closed, pressing slightly onto the Tray and consequently stretching the two Nomex layers. The closing mechanism consists of Nomex flaps with Velcro all the way around, sealing the slit between the outer Nomex layer and foam pad.

The two foam pads each have a Nomex handle on top for use during transportation. The Thermal Bag is equipped with four straps for storage. When applied, these straps pull the two foam pads together and thereby collapsing the bag.

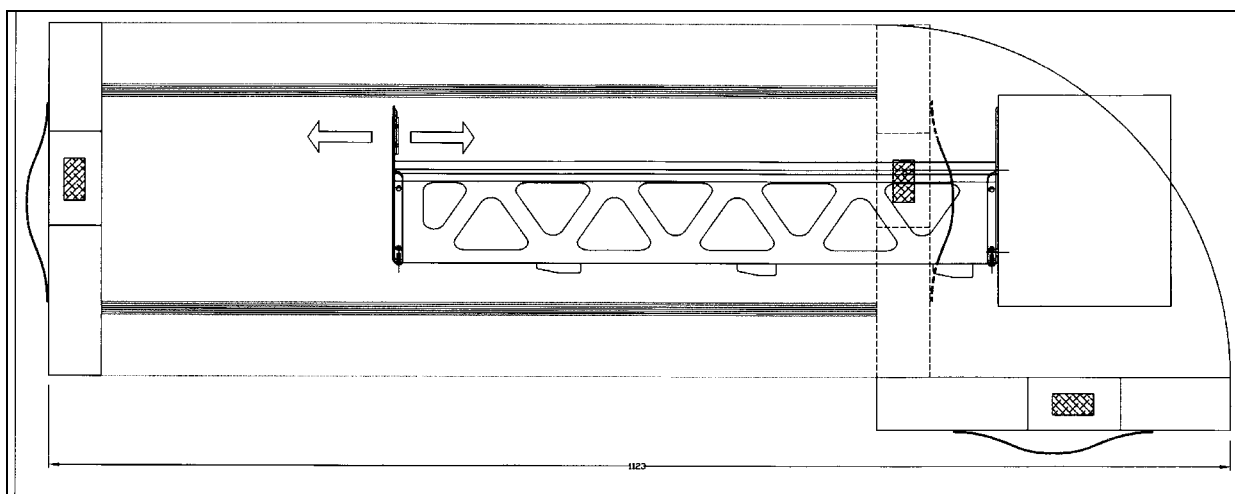


Figure 6.10-1: Thermal Bag (shown with Tray inside)


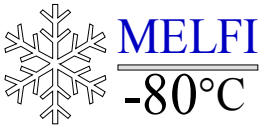
This design provides sufficient insulation and low stowage volume at the same time. However some operational constraints should be applied. Trays should be transferred to the Thermal Bag swiftly as the heat flux is intense when the cold Tray is fully exposed. The transfer of a cold tray from a Dewar into the Thermal bag is shown in figure 6.10 - 2.



Figure 6.10-2: Transfer of a Tray into the Thermal Bag.

The Thermal Bag is made from thin quality Nomex panels that are sewn. **It is rather fragile and must be handled with care in particular during the insertion of a cold tray.**

The Thermal bag is stored in the ISS apart from MELFI.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 193
---	---	--

6.11 FOAM PLUG

A foam plug is provided for each MELFI flight Unit for the operations related to the on-orbit exchange of cold trays between MELFI Racks.

The function of the foam plug is to provide thermal insulation of a Cold Dewar when a tray does not occupy one of the Dewar partition.

The foam plug is shown in Figure 6.11 – 1.

It is stored in the ISS apart from the MELFI.

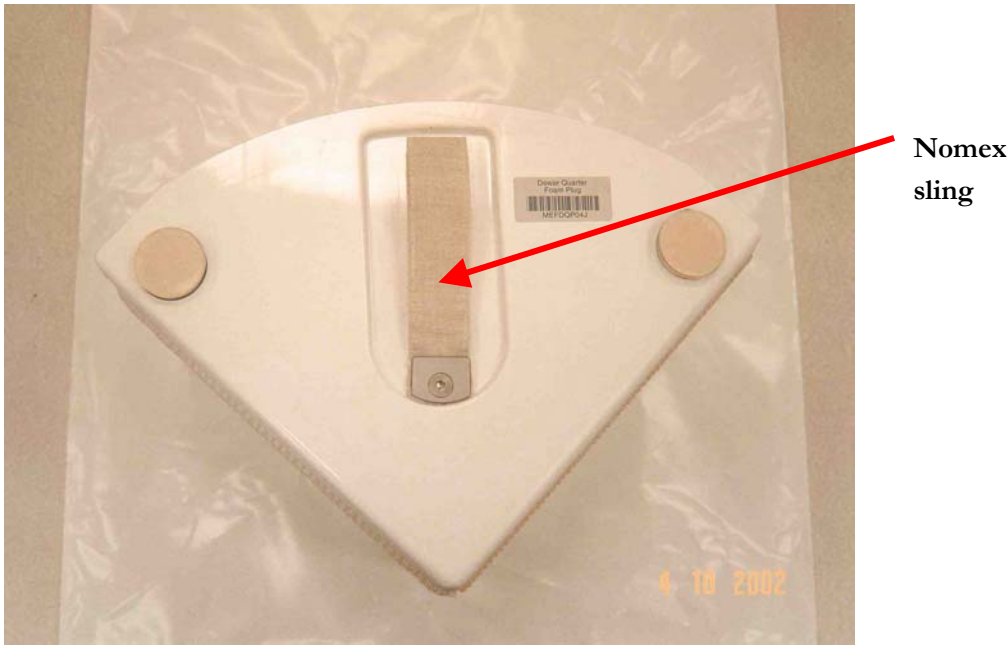




Figure 6.11-1: Foam Plug

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 194
---	---	--

6.12 UTILITY INTERFACE PANEL (UIP)

The Utility Interface Panel is located at the bottom of the Rack, and MELFI utilities from ISS /MPLM are provided to MELFI through it: power, data bus, water Loop. These connections are described below:

Two primary power buses are available at UIP interface:

- The Main 120V power buses (J1), interfaces with Interface B 3 kilowatt and 6 kilowatt feeder in USL configuration or with Interface C according to MPLM definition in MPLM configuration (connectors NAT06G25LN3PN).
- The Auxiliary 120V power buses (J2) Interface C 1.44kW feeder. This interface is not used inside the MPLM (connectors NAT06G25LN3PA).

MELFI provides a Maintenance Switch connected to J43 at UIP interface (connector NATC06G13N35PA).

Two data buses are available at UIP interface (pin allocation is compliant applicable documentation AD2 section 3.2.2.1):

- The nominal 1553 payload bus A (J3) (connectors NATC06G15N35PN),
- The redundant 1553 payload bus B (J4) (connectors NATC06G15N35PA),

6.13 PASS-THROUGH PANEL

The Pass-Through panel is located at the bottom right side of the Rack and accommodates some utilities depending on the flight type: active or passive launch on MPLM.

The baseline for the accommodation of umbilical is depicted in figure 6.13 – 1 for active launch: MELFI utilities are connected to UIP (power and data) and water lines are connected between the UIP and the pass-through panel. For passive launches, power and data cables are restrained on the Pass-Through Panel (figures 6.13 –2 and - 3, showing the labels for connectors parking).

The current MELFI baseline assumes the connection of the interface utilities to the mating connector located in the UIP of the MPLM (exception being the Auxiliary Power and the Maintenance Switch connectors not available in the MPLM). The early flights of the MPLM will not be active (MPLM water loop will be empty).

It is foreseen to implement for the First Flight Unit of MELFI (FM1) of the following features:

- Necessary restraints of all the MELFI utilities compatible with the required launch environments and envelope requirements;
- Provide an expansion device to compensate the water expansion in the MELFI water loop during the temperature limits required in the MPLM.

The restrain mechanism shall allow an easy operation by the crew, and minimize the mass increase.

An option will be given to implement the same features in other MELFI Flight Units (FM2, FM3, FM4).

The Water Valve is also mounted on to the pass-through panel. The valve imposes the flow rate in the MELFI Water Loop and has 2 positions that need to be selected by the crew:

- Fully open
- MPLM / 1 Dewar

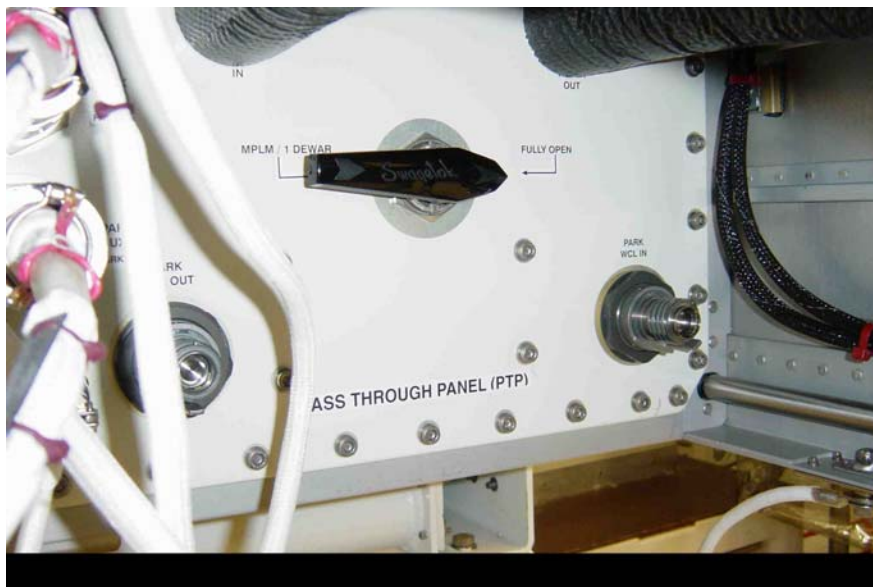


Figure 6.13-1: Water valve on Pass Through panel (PTP)

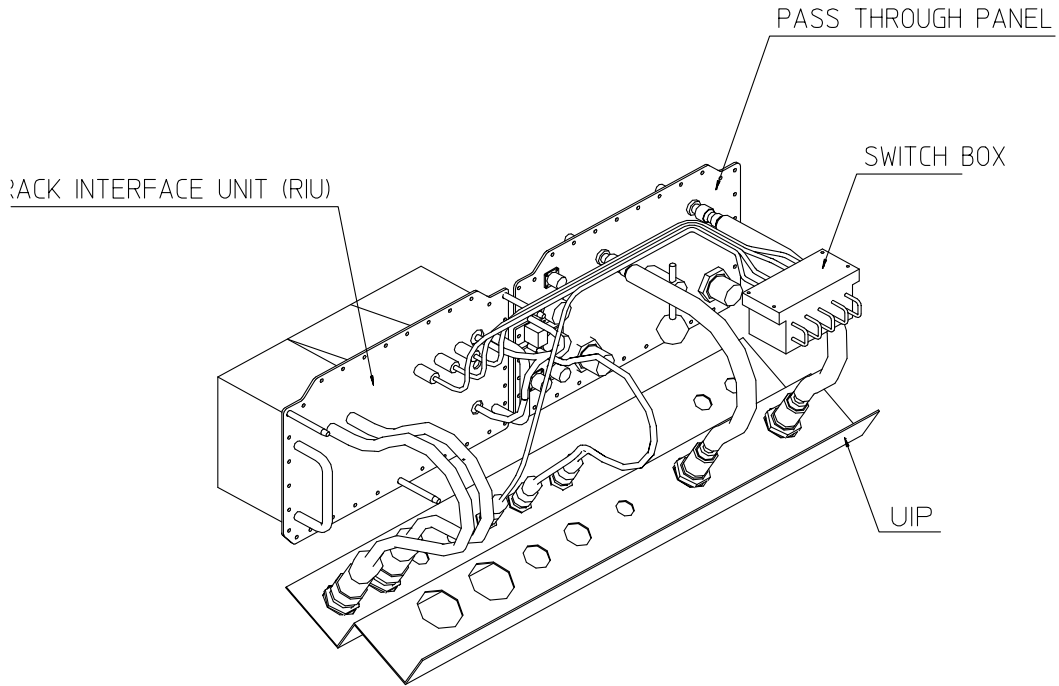


Figure 6.13-2: Pass-through panel with MELFI utilities connected at UIP

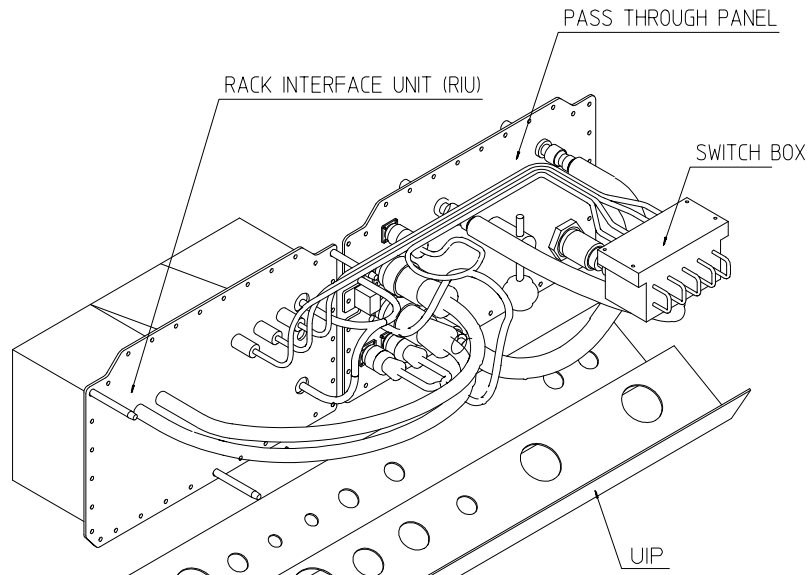


Figure 6.13-3: Pass-through panel with MELFI utilities restrained (passive launch)

6.14 RIU SWITCH BOX

The RIU Switch Box is located at the bottom of the rack. The activation of power switches (MAIN and AUX) located on this equipment provides power to the MELFI.

The RIU Switch Box is depicted in Figure 6.14 – 1.



The Switch Box holds:

- The MELFI Rack power Maintenance Switch Assembly (RMSA), which provides the electrical power removing capability upstream MELFI at RPCM level.
- The power bus MAIN/AUX switches with a monitoring LED (showing that power is applied downstream the relay contact at K1 to K4, which allows MELFI to remove power upon crew action on the two power bus.
- The ORU LED which monitors the output voltage of the RIU.

Any action on these switches removes power from the MELFI. The associated LED's monitors the switch action.



Figure 6.14-1: RIU Switch Box

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 198
---	---	--

6.15 RACK INTERFACE UNIT (RIU)

The Rack Interface Unit (RIU) is a dedicated electronic unit located at the bottom of the MELFI rack close to the UIP panel.

The unit incorporates the following features:

- Interface to ISS UIP for power (input filter IPF) and data
- Interface to RIU Switch Box (RMSA switch routing between the UIP and the Switch Box)
- Over voltage protection.
- Thermal overload protection logic and safety switch off function
- Main & Aux power bus interface of two 120V DC buses (only one has to be used for MELFI; main bus with priority)
- Automatic power bus selection

Power from power buses is removed in case of:

- User action on the Main/Aux switches located on the Switch Box. Power removal leads to the reset of the overload current tripper and the safety loop shutdown protection.
- Overheating conditions locally detected on the MELFI based upon the use of thermo-switches throughout the payload. The safety loop detection function (Power bus Pre-selection & Power Bus selector i.e. PBS) is implemented and drives actuators (K1 to K4 in Pre-selector) in order to interrupt power hot and return line thus allowing failure insulation by power removal. For each power bus, an electronic sub-unit (RIU DC/DC Converter Module) provides energy to the power relays.

The following block diagram Figure 6.15 – 1 shows the RIU with its main functional units

- Over voltage Protection
- Power Bus Pre-selection
- Power Bus Selector

The following block diagrams show the Pre-selection and PBS in detail:

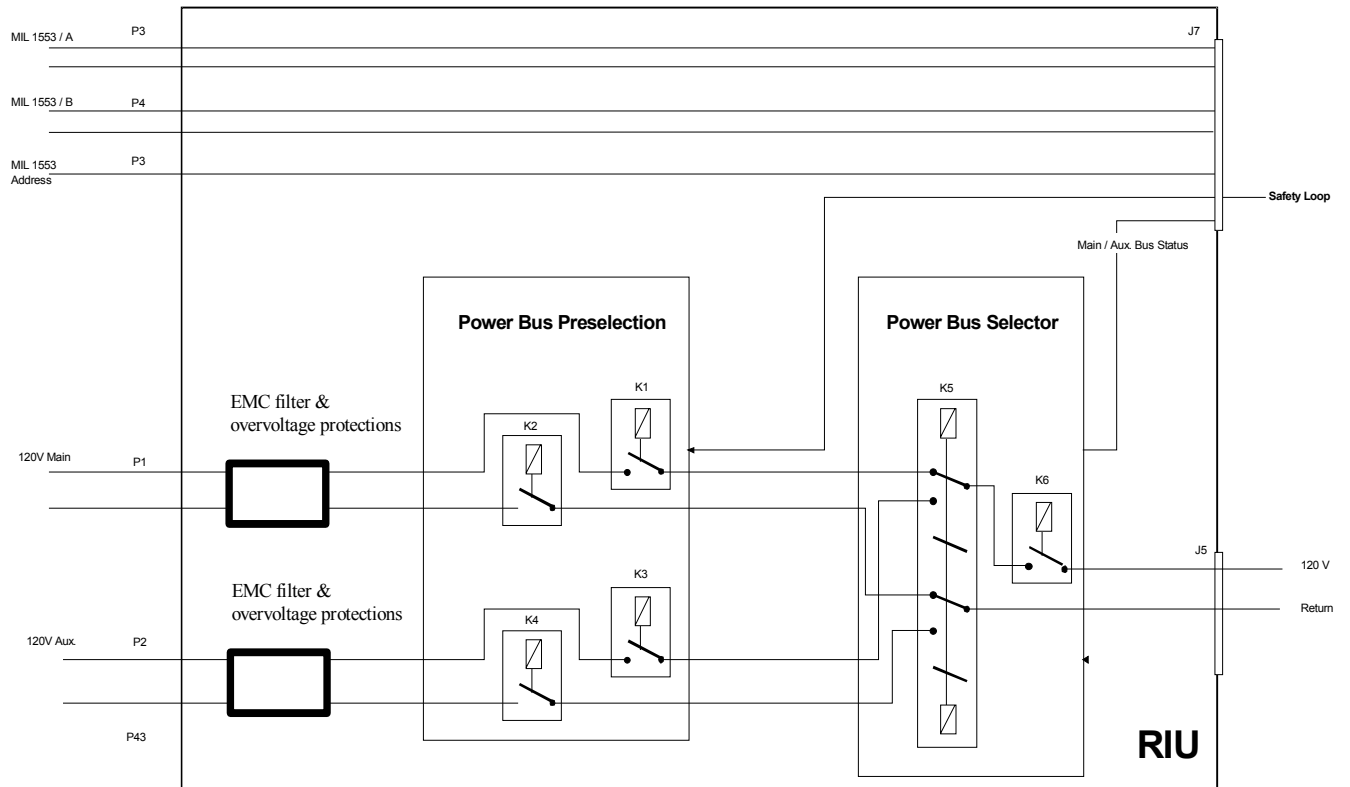


Figure 6.15-1: Rack Interface Unit Block Diagram

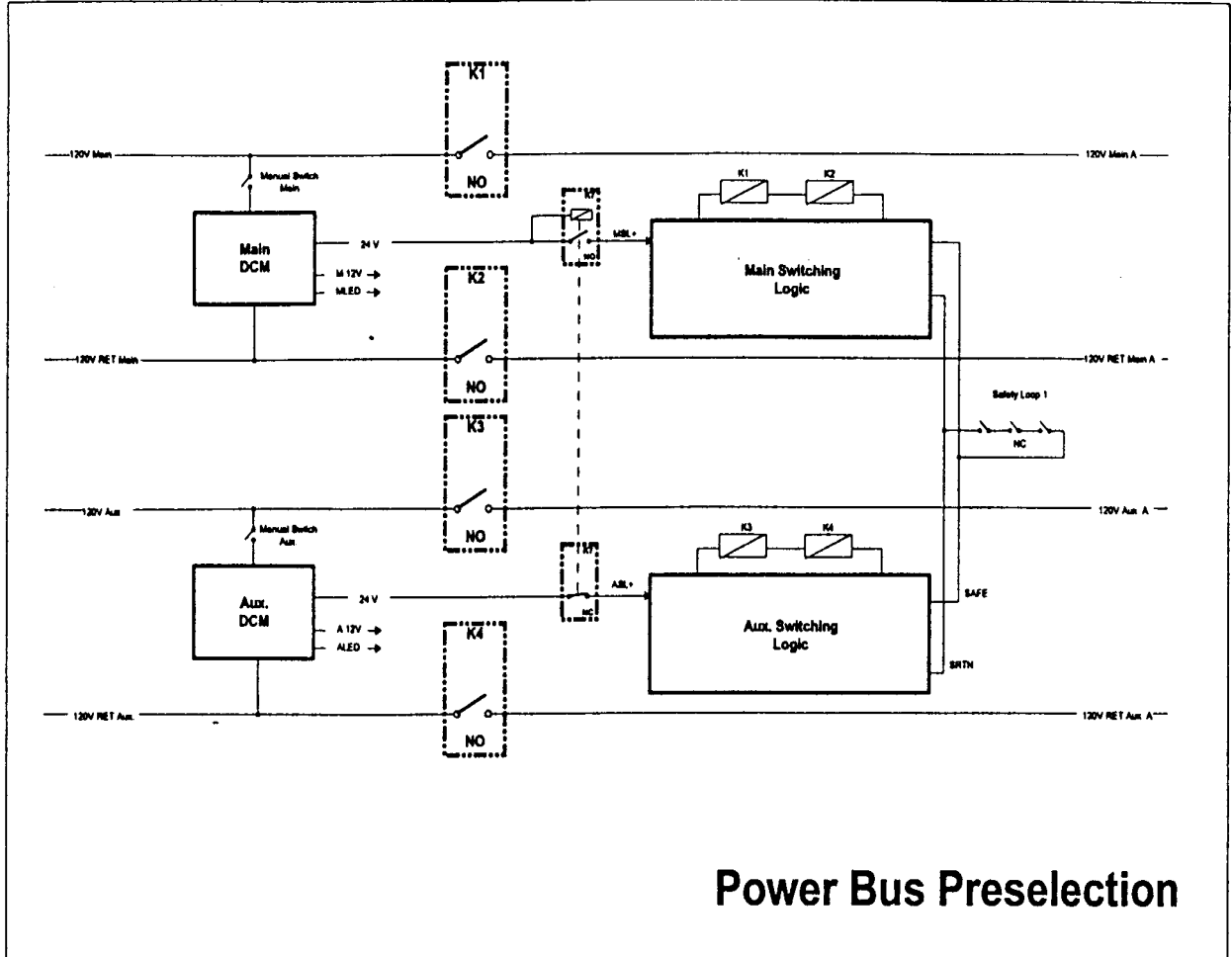


Figure 6.15-2: Rack Interface Unit Power Bus Pre-selection Block Diagram

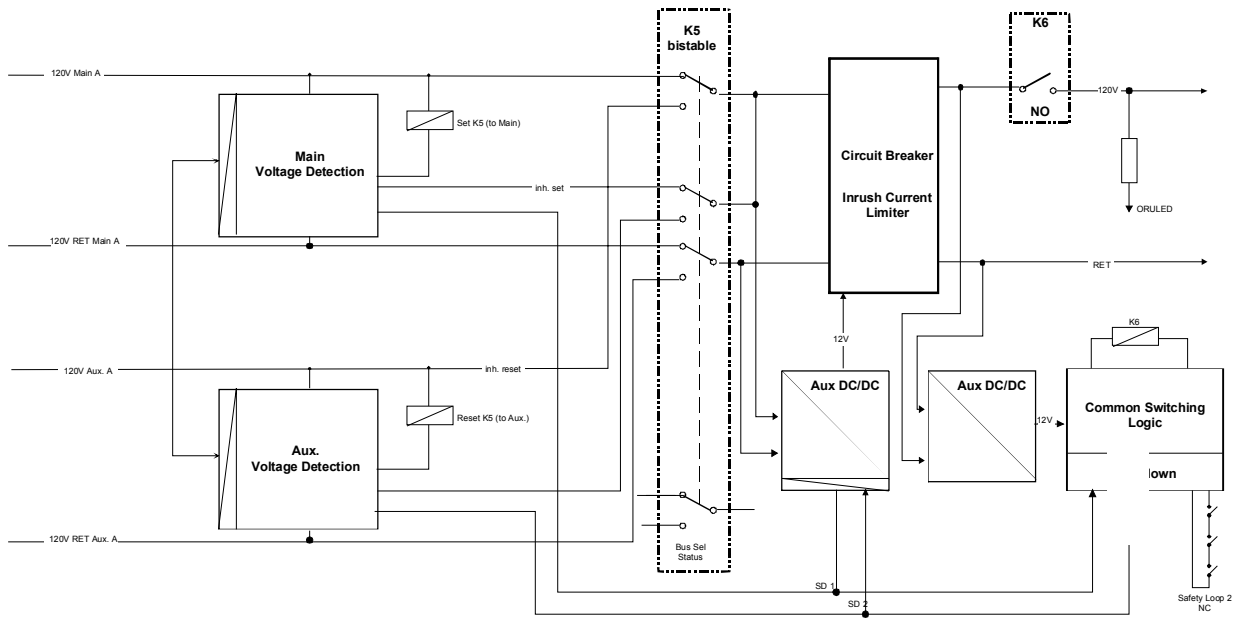


Figure 6.15-3: Power Bus Selector Block Diagram

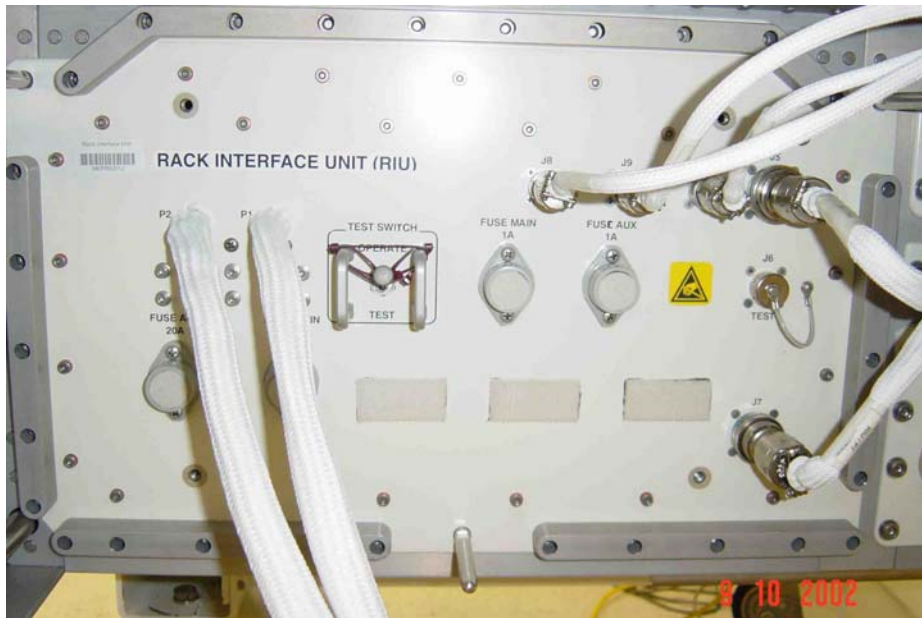

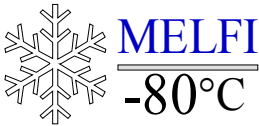


Figure 6.15-4: Rack Interface unit inside rack FM1

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 202
---	---	--

6.16 TEMPERATURE DATA RECORDER

The Temperature Data Recorder is an autonomous temperature recorder unit. It is mounted at the bottom right side of the Rack, attached to the internal face of the right Panel of the Rack and in front of the Pass-through panel.

The TDR records Dewar temperatures, using one of the sensors (PT1000) implemented at the highest temperature location in each of the four Dewars, including throughout MELFI powered-off periods.

The TDR is a commercial item with following characteristics:

- *Power Supply:*

TDR is powered by E.U. when MELFI is ON and is battery powered during MELFI OFF phases. (Switch over to the battery supply occurs automatically as soon as the external voltage is below 6.2V)

The internal battery is composed of 8 cells 1.5V – 145mAh and divided in 2 sections: 2 cells are used for the system clock and the 6 other cells are used for the logger module. When battery powered, only a small part of the TDR is supplied between 2 acquisitions.

Battery lifetime is estimated to 24 months. Replacement of the TDR battery pack requires having the MELFI OFF.



- *First activation of the TDR:*

When a new battery pack is installed, the MELFI must be OFF. When the MELFI will be powered on, the TDR will have to be initialized to start the acquisitions, i.e. the crewmember (through the PCS) or the ground team has to send a TDR Reset Command. Until this first reset command, the TDR remains idle and the battery consumption is idle.

- *Acquisitions:*

Once the TDR starts acquiring data, it will never stop and keep on going at acquisition period given by the System parameter 13h; the default value is 600 seconds but it can be set between 60 and 1800 seconds.

Each acquisition contains the 4 Dewar temperature sensors, one for each Dewar. The TDR buffer can contain 90000 words of 16 bits equal to 30000 acquisitions of the 4 Dewars temperatures (3 words are used for the 4 temperatures); when the buffer is full; the TDR stops its acquisitions (no ring mode).

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 203
---	---	--

To prevent the acquisitions to reach the maximum storing capability, a Reset TDR is automatically performed:

The TDR data are erased periodically each 168 hours by default if no “Reset” command has been sent during this period; this period can be modified by mean of system parameter #14h and can be set between 24 hours and 720 hours. This counter is reset at each “Reset” command or automatically when MELFI is powered on. This means that after a power-off period, the TDR data remain available only during 168 hours

- *Communication:*

The TDR has a data interface with CDHU in order to:

- Get data from TDR upon CCSDS request
- Change time/configure TDR in flight upon reset CCSDS command.

Software uses the asynchronous SIO features of the processor and manages a serial UART (1 start bit, 8 data bits, odd parity, 1 stop bit) at a 9600 bps. Once data is collected and stored inside MELFI SRAM, it is transmitted to the ISS (activity not done in MPLM) with Low Rate Science Telemetry service. This induces a delay of 100 seconds between TDR dump request and first TDR data sent by MELFI payload.

- *Payload Operations:*

After a power-off period, the P/L MDM has to send “Dump TDR” command before the TDR is automatically erased.

After the reception of this command, MELFI will store the TDR data inside a specific internal memory location, and will then ask for the LRT service request.


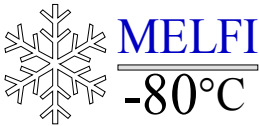
Once the LRT Service is obtained, the MELFI will send the TDR data to P/L MDM.

When P/L MDM has completely acquired the TDR data, a “Reset TDR” command is sent.

Following the TDR data dump through the LRT, the ground team shall confirm that the dump is complete and if necessary repeat the dump. Upon successful retrieval of the TDR data, a TDR Reset command has to be sent afterwards.

After a MELFI power-off period, the recovery of the TDR data acquired during this period has to be performed before the next automatic TDR Reset. Even though this reset will happen 168 hours after power recovery, it is recommended to dump the data after 48 hours.

The data recovered after a TDR Dump command starts from the moment when the last TDR Reset command had been sent and extends to the moment of the TDR Dump command. The data related

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 204
---	---	--

to a given period, i.e. a power-off period is selected using the date/time of the last measurement also given by the TDR data, and the TDR acquisition period existing in the MELFI software.

Note: All explanations rely on the default values of both System parameters 13H and 14h, which use less than 4% of the storage memory of the TDR. If the user intends to modify the default values of those parameters, both parameters have to be modified in conjunction. For example, one cannot choose a minimum acquisition period and the highest reset period because the storage capability will be exceeded.

- **Stop Command**

A TDR Stop Command shall be used only when no data will have to be recovered from the TDR, with the objective to spare the TDR battery. This command shall not be sent when a TDR dump is in progress.

- ***Rules for exchanging the TDR Battery Pack:***

As soon as a TDR starts acquisition, the battery pack allows data storage throughout three cumulated months (TDR power only provided by the battery, the MELFI is thus OFF). This figure is suitable for nominal mission duration of two years on-orbit.

If the cumulated power-off duration exceeds three months or the MELFI is used for more than 24 months, the TDR battery pack has to be replaced: a spare one is stored inside the DASE Pouch.

If the MELFI is expected to be powered-off for a long duration, while the TDR has already started acquisition, the crewmember may remove the battery pack and temporarily store it in order to save the battery energy. The battery will be installed back into the TDR just before the MELFI power-on.

- ***Battery exchange:***

- Open battery compartment: relieve securing clamp, lift and turn cover lid
- Remove battery container from compartment: pull 2 flexible stripes thereby disconnecting the electrical connector
- Install a new battery container in the compartment
- Close the battery compartment and secure the clamp





Figure 6.16-1: Temperature data recorder (revolving cover is shown opened)

6.17 TUBING

The external tubing of MELFI connects the Cold Box with the 4 Dewars. It is designed to minimize pressure drop and heat leak. The overall arrangement of the tubing is adapted to the constraints of the MELFI configuration inside the ISPR.

The N₂ transfer line is consisting of 2 gas flow channels and 2 vacuum volumes, which are concentric to the centerline, see Fig. 6.17 - 1.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 206
---	---	--

Within the innermost tube cold nitrogen gas is supplied from the Cold Box / Brayton Machine to the Dewars. The tube branches are arranged in parallel to the individual Dewars. The outer surface of this colds gas supply tube is vacuum insulated.

The return line is insulated to the environment with a multi-layer vacuum insulation consisting of aluminum foils with glass fleece spacers in a vacuum space.

The external tubing is an overall stainless steel construction and allows a high leak tightness of the insulation vacuum space. The connections to the Dewars are special cryogenic couplings, which are O-ring sealed at the warm end. Thus the gas cycle can be kept closed and the Dewar can be easily assembled onto the cold finger tube.

No contamination of the N2 cycle gas is possible.

On the upper most branch of the external tubing the coupling to the Cold Box is located. This connection is double O-ring sealed and closes the nitrogen cycle. Both types of couplings for Dewars and Cold Box are based on cryogenic couplings for transfer of low temperature gas. These so called Johnston couplings allow to connect two vacuum insulated coupling parts with a minimum heat loss.

The external tubing provides 4 parallel branches of cold finger type tube ends with a load heat exchanger (LHX) at each end. To provide gas flow regulation to the four cold fingers, each extremity is equipped with a cold gas regulation valve for temperature control of the four individual Dewars. The regulation valves will regulate the cold gas flow coming from the Cold box. The Dewar temperature control algorithm regulates throttling.

On the outer most tube a Viscovac pressure-measuring device is foreseen to provide means to monitor the insulation vacuum pressure on ground with a special GSE.

On the lower part of the tubing a tube is implemented for the getter material. This is to maintain a high insulation vacuum over the required lifetime.

The tubing is fixed to the rack at 3 locations at the two vertical branches and the horizontal branch where brackets are used to hold the tubing in the rack. These areas are also used as electrical bonding locations.

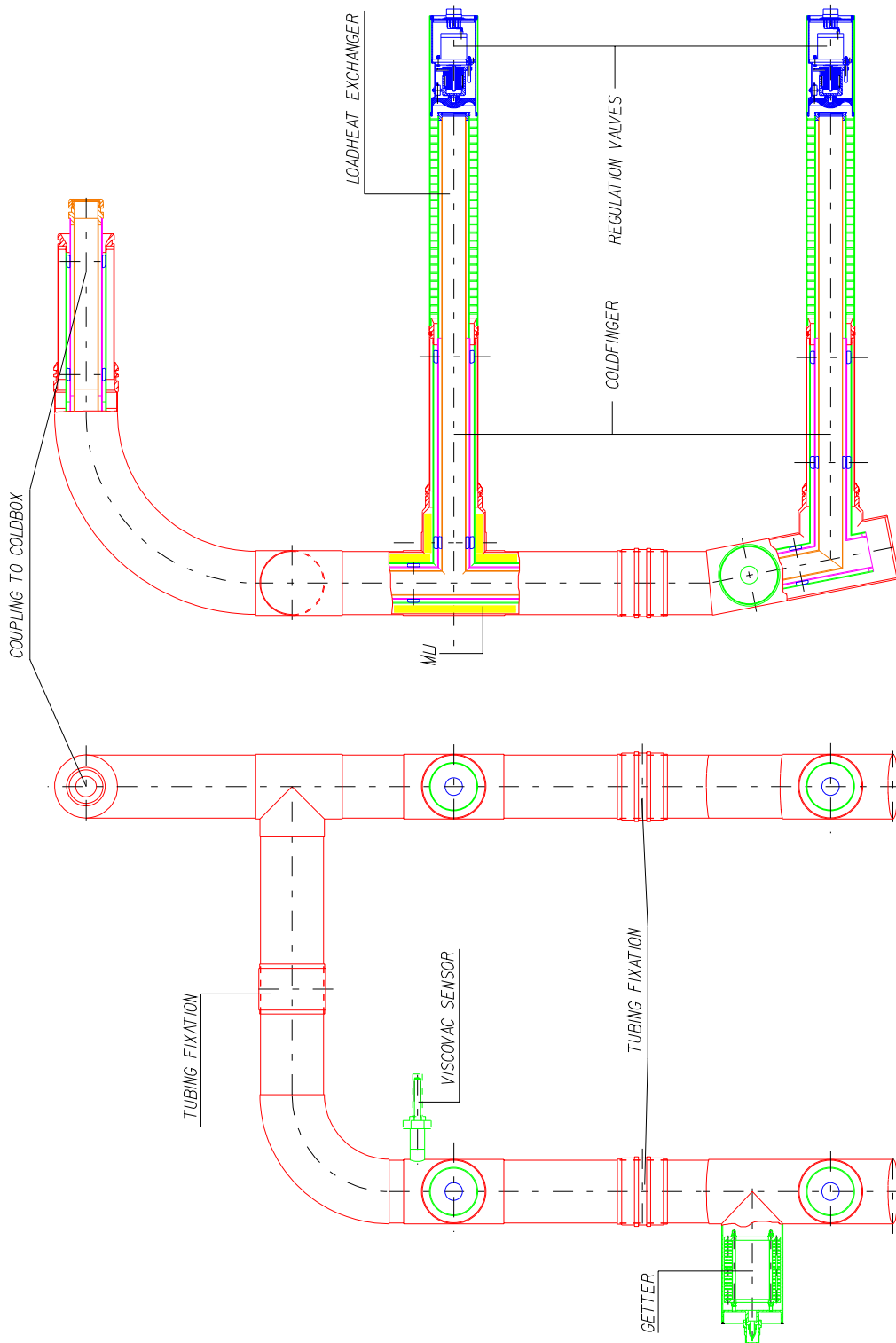

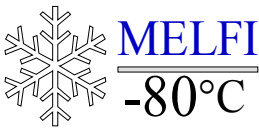


Figure 6.17-1: Nitrogen Tubing

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 208
---	---	--

6.17.1 Cold Gas Regulation Valve

The External Tubing supplies cooling energy to the so-called Dewar cold finger. The cold gas flows to the Dewar in the center tube of this cold finger and is directed backwards into the circular load heat exchanger by means of a control valve. Each cold finger is equipped with a Cold gas regulation valve.

This valve regulates the cold gas flow to the Dewar and thus controls the Dewar temperature. It also acts as a flow distribution valve, which is used for every Dewar to establish proper flow conditions and homogeneous flow distribution between the four parallel Dewars. A stepper motor drives this regulation valve. The valve is depicted in fig. 6.17 - 2.

The stepper motor is actuating the valve spindle, which moves the valve poppet. This allows axial movement of the "Mexican hat" - like valve poppet and acts to direct the flow from the inner line to the concentric return line and acts also as a throttle to reduce flow rate.

The full valve stroke is 12 mm plus 2 mm to compress a spring at the popped for proper closing. For the +4°C mode, the valve is almost closed while it is fully open for the -80°C mode.

The electrical connection to the regulation valve is via the front plate of the cold finger, where an electrical connector is located. The connector will be mated when the Dewar has been mounted onto the cold finger during integration into the rack. Afterwards an end cap will close the cold finger housing.

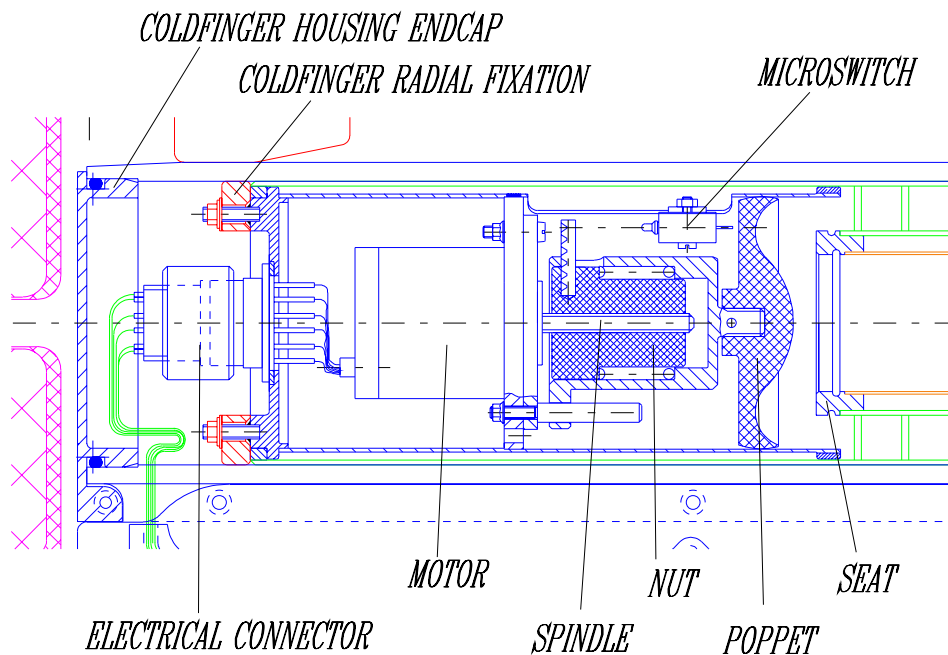


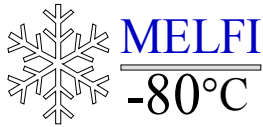
Figure 6.17-2: Cold Gas Regulation Valve

6.17.2 Load Heat Exchanger

The load heat exchanger LHX is part of the External Tubing and comes inside the Dewar to provide refrigeration of samples inside a Dewar. It shall pump heat from the internal volume of the Dewar such that the Dewar internal temperature will not exceed $-68\text{ }^{\circ}\text{C}$ for the $-80\text{ }^{\circ}\text{C}$ Dewar mode. It also provides cooling for the $-26\text{ }^{\circ}\text{C}$ and the $+4\text{ }^{\circ}\text{C}$ operation mode.

The load heat exchanger is located at the end of the cold finger, which penetrates into the Dewar from the rear side. It consists of an inner and outer tube forming a concentric tubular gap. Within this gap, a helical coiled corrugated strip is soldered to the outer tube. The looped ribs show a circular outer contour. This shape is to increase the heat transfer coefficient.

The LHX is made of copper for good thermal transfer capabilities. A layer of aluminum to avoid galvanic corrosion between the cold finger covers the outside of the LHX and its housing, on the Dewar side. On one side it is brazed to the external tubing. On the other side, the outer tube is



Ref: MELFI-MA-03000-0435-MMT


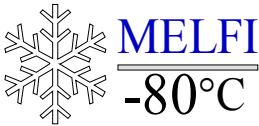
Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 210

extended to accommodate the cold gas distribution valve. A plate to seal the nitrogen volume closes the end of the LHX.

The cold gas supplied by the Cold Box enters the LHX in the center tube. On the side where the cold gas valve is arranged the cycle gas enters the LHX after having turned flow direction by 180° because of the regulation valve shape. After heat absorption within the LHX the gas is fed back into the external tubing and back to the Cold Box where the Brayton Machine and the Cycle Heat exchanger (CHX) will cool it down again.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 211
---	---	--

7 MAINTENANCE

The MELFI maintenance operations are divided into:

- Corrective in-flight maintenance
 - EU Exchange
 - BM Exchange
 - Trays de-icing
 - Dewar de-icing
 - Nitrogen cycle replenishment
 - RIU fuse replacement
 - TDR Battery pack replacement

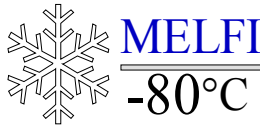
The in-flight maintenance procedures are detailed in RD 2.

- Preventive in-flight maintenance
 - Pressure check of NFPE N2 bottle: to be performed every 6 months
- Preventive maintenance (on-ground only):
 - Replacement of life limited items such as sealing, gaskets ...

7.1 CORRECTIVE IN-FLIGHT MAINTENANCE

The MELFI corrective in-flight maintenance is also applicable to the corrective ground maintenance, except the Brayton Machine Replacement, that requires the use of a GSE on –ground although it is the N2FPE that is used in-flight to refill the cycle. The on-orbit procedure is less complex and doesn't call for vacuum pumping of the cycle to remove traces of humidity. It thus provides a N2 cycle dew point higher but still compatible to the operation of a Brayton Machine.

Recommendations from the Flight safety review have been implemented into the step-by-step crew procedures and are recalled for each corrective operation whenever applicable.



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 212

In-Flight Maintenance Ops:

- Electronic Unit replacement IFM-01
- Brayton machine cartridge replacement IFM-02
- Nitrogen replenishment IFM-03
- Pressure check of NFPE N2 bottle IFM-04
- Dewar de-frosting /de-icing IFM-05
- RIU fuse replacement IFM-06
- TDR battery pack replacement IFM-07

The step-by-step procedures are described in the MELFI on-orbit Crew procedures. The following chapters describe the main steps for ORU replacement and/or on orbit maintenance.

7.1.1 Electronic Unit replacement

The Electronic Unit is designed as an On-orbit Replaceable Unit and if a failure is detected the failed equipment can be replaced by a spare one.

In case of EU failure, crewmembers must wait 0.5 hour before dismounting the EU provided that water has been flowing for at least 30 minutes since the MELFI is OFF. If there is a water shortage and water flow cannot be re-established through the MELFI, crewmembers must wait 8 hours before accessing the failed EU (hot temperature hazard: MELFI Hazard Report MEL-U-07).


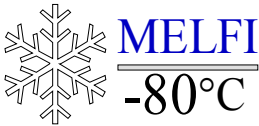
Safety panel also requires the inspection of Water QDs before and after connection to verify that there is no leak (MELFI Hazard Report MEL-U-05).

The exchange of the failed EU by the spare unit requires to shut down the MELFI, the dismounting of the Cold Box front panel to access power cable and the complete extraction of the failed EU to replace it by the spare one which requires to dismount it from its stowage location.

Additionally, the crewmembers shall pay attention to the routing of the MDE cable before disconnecting it from the Brayton machine front face. This is to ensure that the cable will be properly routed after EU exchange and reconnection to the Brayton machine front face.

The typical replacement sequence is as follows:

1. Shut down the Payload
2. Remove and temp. stow the acoustic Pad
3. Remove the Cold Box front Panel (use of the Triple Square M6 Tool)

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 213
---	---	--

4. Remove the acoustic protections to access the MDE connector
5. Loosen the spare EU rack mounting screws and pull it out using the Star Handles
6. Loosen the failed EU mounting screws and disconnect the MDE power cable located below the EU from the BM front face and pull out the failed EU until an intermediate stop
7. Disconnect both water QD from the EU and completely extract the Failed EU
8. Swap the Water Expansion device (use of the triple square M4 Tool) from the spare EU to the failed one
9. Swap and tighten both EU
10. *Connect the MDE cable carefully and verify that it is correctly routed to avoid any damage or pinching*
11. Re-install the CB Front Panel

- Required tooling: Triple Square M6 Tool, Triple Square M4 Tool, the Star handles (2) and the EU QD mating tool. All are MELFI provided tool stored in the DASE Pouch.
- Crew resource requested: Two astronauts, 30 minutes

Notes/comments, as part of the procedure:



- When EU is removed from the rack, crew shall not reach into the accommodation slot.
- Spare EU is filled with Water and equipped with a Water expansion device that must be swapped to the failed EU. Spare EU must be extracted with precautions (rigid MDE cable).
- Watch for MDE-power cable routed outside EU towards the Brayton Machine front face

During operation the EU external surfaces remain below the maximum allowed touch temperature. In addition, the monitoring function gives the real temperature.

Minimum bolts on EU for Safe Return:

ORU equipment	Nominal Number of I/F bolts	Minimum Number of I/F bolts for return
Spare electronic Unit	8	7
Electronic Unit	8	7
Cold box front Cover	20	19

Table 7.1-1: Minimum bolts on ORU

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 214
---	---	--

7.1.2 Brayton Machine replacement

The exchange of the failed BM by a spare unit requires the shut down of the MELFI, the dismounting of the Cold Box front panel to access power cable and the utilization of the BMEE and the NFPE which are both stored in the MELFI Stowage Compartment.

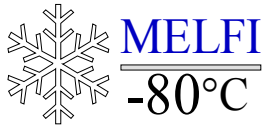
According to MELFI Hazard Report (MEL-U-09), the risk of Brayton Machine expulsion, when the BM flange is removed, is avoided by depressurizing the N2 cycle prior to the dismounting. This is achieved by procedure.

In addition, water QDs must be inspected before and after connection to verify that they are not leaky (MELFI Hazard Report MEL-U-05).

The routing of the MDE cable must be checked after re-mating of the electrical connector to the Brayton machine Front face to avoid any potential damage due to bad routing.

The Brayton Machine is an ORU and a spare machine could be located inside the MELFI Stowage Compartment to replace it in case of on-orbit failure:

1. Set MELFI Payload in STANDBY MODE in order to fully open the 4 Dewar valves and to stop Water Flow in MELFI
2. On EU CPI, activate the MOTOR Switch
3. Check that the pressure of NFPE N2 bottle is sufficient to re-fill MELFI after the exchange
4. Remove and temp. stow the acoustic Pad
5. Dismount the CB Front Panel
6. Remove the acoustic protections
7. Connect the NFPE to the CB Fill & Purge port and flush out the cycle down to the ambient pressure (check on CPI the pressure decrease)
8. Shut down MELFI – Disconnect both Water QDs – De-mate both electrical connectors
9. Dismount the BM flange
10. Install the BMEE and proceed with the extraction of the failed BM and replacement by the spare one
11. Dismount the BMEE parts and re-install the BM flange
12. Connect both electrical connectors and both QDs *and verify correct routing for the MDE cable to the BM front face*
13. Power-up MELFI
14. Fill and pressurize the cycle up to its nominal value



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 215

Tools required from ISS:

- All tools are metric
- IVA Power Tool with a squared socket (6.35 mm, 1/4 inch)
- 1 torque wrench
- 1 M6 (#10) and 1 M10 (#19) hexagonal sockets for the torque wrench
- 2 #24 flat hexagonal wrenches
- 1 #6 elbowed Allen wrench

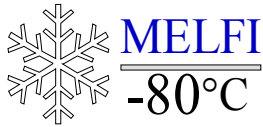
Tools provided:

- 2 shutter extraction Tools, stored in the MELFI BASE container
- Triple Square M6 Tool, stored into the DASE Pouch.
- 24 mm Crowfoot 1/4 drive

Minimum bolts on BM for Safe Return:

ORU equipment	Nominal Number of I/F bolts	Minimum Number of I/F bolts for return
Brayton machine	8	7
Stowage compartment door	3 latches	3 latches
Base container	4 latches	4 latches
Cold box front Cover	20	19

Table 7.1-2: Minimum bolts on ORU



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 216

Time after stopping (h)	Filling Pressure (kPa)
0	128.0
1	130.5
2	132.5
3	134.1
4	135.5
5	136.6
6	137.7
7	138.6
8	139.5
9	140.3
10	141.1
11	141.8
12	142.4
13	143.0
14	143.6
15	144.2
16	144.7
17	145.2
18	145.8
19	146.3
20	146.8

Table 7.1-3: Filling pressures versus elapsed time since Brayton Machine failure

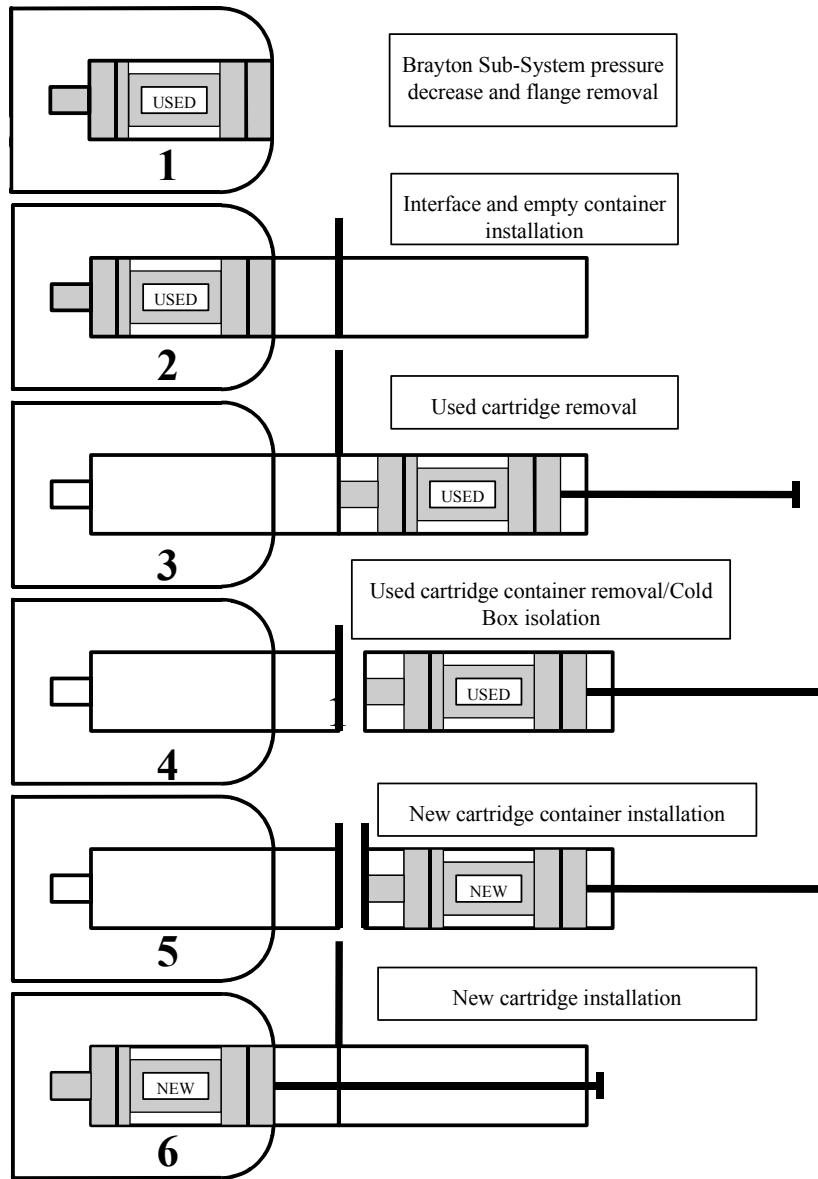

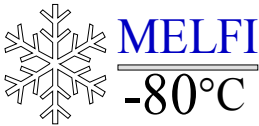


Figure 7.1-4: Schematics for Brayton Machine exchange operations

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 218
---	---	--

7.1.3 Dewar De-icing /De-Frosting

De-icing of Dewars is required when the Dewar door is not easy to open /close because of high quantity of ice /frost or ice build-up is observed around the tray insulation foam block or along the cross-plates. All other de-icing activities should be deferred to ground operation after MELFI return if possible.

It requires the use of the de-icing tools stored in the DASE pouch inside the MELFI stowage Compartment and protective equipment (refer to MELFI Hazard Report MEL-U-06 and MEL-U-07): Cryogenic gloves and sleeves stored in the DASE Pouch and also goggles stored in the ISS

The de-icing procedure is using different ice scrapers and de-icing tools depending on the location of the ice/frost inside a Dewar:

- **PARTIAL DEWAR DE-ICING**

A cold Tray is temporary removed from the Dewar and stored in the thermal Bag meanwhile the cold finger and cross plate are de-iced.

Items required: Thermal Bag, Foam Plug, Zip lock bag, towel, Ice scrapers (head #2 and 3)

- **DEWAR DOOR GASKETS AND TRAY FOAM BLOCK DE-ICING**



The cold tray is only partially extracted from the Dewar in order to access the foam block and the Dewar gasket for de-icing

Items required: Zip lock bag, towel, Ice scrapers (head #7 and 1)

- **COMPLETE DEWAR DE-ICING**

A complete Dewar de-icing shall only be performed if a vacant Dewar at equal temperature is available to hold the frozen samples. This procedure only applies to -80°C Dewars.

Items required: Zip lock bag, towel, Ice scrapers (head #7 and 1)

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 219
---	---	--

7.1.4 Nitrogen replenishment

Diagnosis: The pressure of the N₂ cycle is below the expected figure (1600+/-20 mbar at 20°C), this would affect the MELFI power consumption; the pressure has to be increased by re-filling the cycle using the NFPE

It requires to stop the Brayton Machine and to remove the Cold Box front panel to connect the NFPE flex hose to the Cold Box Fill and Purge port. The CPI displays the N₂ cycle pressure during the Nitrogen replenishment procedure.

The procedure is a subset of the BM exchange procedure:



1. Set MELFI in STOP MODE and fully open the 4 Dewar regulation valves (TC to MELFI)
2. Switch OFF the BM MOTOR
3. Remove and temp. stow the acoustic Pad
4. Dismount the Cold Box Front Panel (use of Triple Square M6 Tool)
5. Remove the acoustic protections
6. Connect the NFPE flex hose to the CB Fill and Purge Port
7. Open the NFPE valve to fill the cycle up to its nominal value, i.e. 1600 mbar at 20°C (pressure is displayed on the CPI)
8. Close the NFPE valve
9. Disconnect the NFPE Flex hose and stow back the NFPE
10. Re-install the CB front panel and fasten the captive screws

7.1.5 RIU fuse replacement

This corrective maintenance procedure has to be performed as a result of fuse blow on the RIU.

- If MAIN fuses blow and AUX Power is available, MELFI must be powered down to replace MAIN Fuses
- If AUX fuses blows, this means that AUX was the active bus and that MAIN Power was no longer available. MELFI is thus OFF. MAIN and AUX Switches must be in OFF position.

It requires to shut down the MELFI payload and to set OFF both switches (MAIN and AUX) on the RIU Switch Box. The spare fuses are stored in the MELFI stowage compartment, inside the DASE Pouch.

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 220
---	---	--

Tools required:

- A red marker must be available to identify the failed fuse
- A multimeter

7.1.6 TDR battery pack replacement.

It requires to shut down the MELFI payload and to set OFF both switches (MAIN and AUX) on the RIU Switch Box.

The spare TDR battery Pack is stored in the DASE Pouch, inside the MELFI Stowage Compartment.

Main steps are as follows (refer to TDR battery cells exchange procedure, MELFI-PR-03400-0501-MMT):

- Open TDR battery compartment: relieve securing clamp, lift and turn cover lid
- Remove battery container from compartment: pull 2 flexible stripes thereby disconnecting the electrical connector
- Install a new battery container in the compartment
- Close the battery compartment and secure the clamp

7.2 PREVENTIVE IN-FLIGHT MAINTENANCE

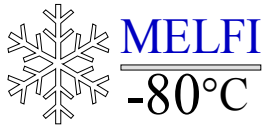
The only preventive in-flight maintenance procedure deals with the N2 bottle of the NFPE. The bottle is filled with pure Nitrogen on ground before the flight. It is then recommended to check every 6 months or so the pressure of that bottle. This is to be sure that there will be enough Nitrogen to refill the cycle in case the Brayton Machine has to be replaced.

7.2.1 Pressure check of NFPE N2 bottle

The periodic maintenance of the gas bottle requires opening the Stowage Compartment in order to access the NFPE and read the N2 bottle pressure on the manometer.

To be performed **every 6 months.** :

1. Remove the Acoustic Pad. Open the Stowage Compartment
2. Remove the DASE Pouch to access the NFPE
3. Unlock the NFPE and extract it in order to read the pressure figure displayed on the manometer



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 221

4. Verify that the pressure is still in the nominal range and inform the ground
5. Set the NFPE back in its slot and lock it.
6. Re-install the DASE Pouch. Close the Stowage Compartment and re-position the Acoustic Pad.

No tool required.

7.3 PREVENTIVE ON-GROUND MAINTENANCE

Replacement of life limited items such as sealing, gaskets are ground preventive maintenance and are summarized in the table below including the operation frequency, and the potential impact regarding safety in case the operation is not achieved. Mandatory inspection post-flight are also indicated.


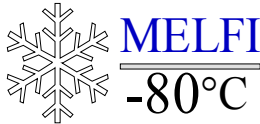
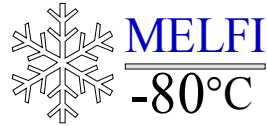
		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 222
---	---	--

Figure 7.3-1: Synthesis of MELFI Ground Preventive Maintenance frequency per Flight Model Equipment:

Equipment /Task description	Recommended task frequency						Impacts if the task is not performed
	6 months	1 year	3 years	6 years	Before mission	After mission	
1. Cold Box – Vacuum check	-	Y ⁽¹⁾	-	-	Y	Y	Impact on performances
2. Cold Box – Replacement of pressure sensors o-rings	-	-	-	Y	-	-	Impact on performances
3. Cold box – Pressure sensors control	-	Y ⁽¹⁾	-	-	-	Y	Impact on performances
4. Cold Box – Temperature sensors control	-	Y ⁽¹⁾	-	-	-	Y	Impact on performances
5. Brayton machine (nominal) – O-rings replacement & maintenance	-	-	Y ⁽²⁾	-	-	-	Impact on performances
6. Brayton ASE – NFPE bottle (pressure control)	-	Y	-	-	Y	Y	Impact on mission success
7. Brayton ASE – Spare Machine Container (reconditioning)	-	-	Y ⁽³⁾	-	-	-	Impact on mission success
8. Dewar – Vacuum check	-	Y ⁽¹⁾	-	-	Y	Y	Impact on performances
9. Dewar – Door mechanism inspection	-	-	-	Y	Y	Y	Potential safety impact
10. Dewar – Venting device: replacement of membrane	-	-	-	Y	-	-	Potential safety impact
11. Dewar – Temperature sensors check	-	Y ⁽¹⁾	-	-	Y	Y	Impact on mission success



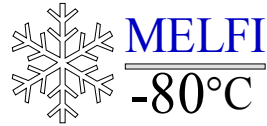
Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 223

Equipment /Task description	Recommended task frequency						Impacts if the task is not performed
	6 months	1 year	3 years	6 years	Before mission	After mission	
12. Dewar door – Sealing replacement	-	-	-	Y	-	-	Impact on mission success
13. Dewar – inspection of foam insulation block for trays	-	-	Y	-	Y	Y	Impact on mission success
14. Dewar - Cross-structure de-icing	Y ⁽⁴⁾	-	-	-	Y ⁽⁴⁾	Y	Impact on mission success
15. Box Modules – Mechanisms inspection	-	-	-	-	-	Y	Potential safety impact + Impact on mission success
16. Dewar ASE – Cotton gloves replacement	-	-	-	-	-	Y	Potential safety impact
17. Tubing - Vacuum check	-	Y ⁽¹⁾	-	-	Y	Y	Impact on performances
18. Tubing – Valves check	-	Y ⁽¹⁾	-	-	-	Y	Impact on mission success
19. Tubing – Replacement of coldfinger end cap sealing	-	-	-	Y	-	-	Impact on mission success
20. Tubing – Replacement of O-rings & gaskets	-	-	-	Y	-	-	Impact on mission success
21. TDR – Replacement of battery pack	-	-	Y ⁽⁵⁾	-	Y	Y	Impact on mission success
22. Electronic Unit – Inspection of boards	-	-	-	-	-	After 1 st mission	Impact on mission success
23. RIU – Fuses replacement	-	-	-	-	-	Y	Impact on mission success
24. Water Loop – Thermal insulation replacement	-	-	-	-	-	After 3 missions	Impact on mission success



Ref: MELFI-MA-03000-0435-MMT



Issue: 04 Rev.: 00

Date: 01-Sept-2004



Page: 224

Equipment /Task description	Recommended task frequency						Impacts if the task is not performed
	6 months	1 year	3 years	6 years	Before mission	After mission	
25. <i>Water loop – Flex lines inspection</i>	-	-	-	-	-	Y	Potential safety impact
26. <i>Integrated equipments – verification of mounting screws torque</i>	-	-	-	-	-	Y	Potential safety impact
27. <i>Utilization accessories inspection (Box modules, Contact cards ...)</i>	-	-	-	-	-	Y	Impact on mission success
28. <i>MELFI gas loop maintenance (refill with pure dry gas)</i>	-	Y ⁽¹⁾	-	-	Y	-	Impact on performances
29. <i>ORU water filling</i>	-	-	-	-	Y	-	Impact on mission success
30. <i>Acoustic damper visual inspection</i>	-	-	Y	-	-	Y	Impact on mission success
31. <i>Inspection of IHI rack upper attachment bracket pin (fracture life limited item)</i>	-	-	-	-	-	After 12 missions	Potential safety impact
32. <i>NFPE- manometer check</i>	-	-	Y	-	-	Y	Impact on mission success
33. <i>NFPE- relief and venting valve check</i>	-	-	Y	-	-	Y	Potential safety impact
34. <i>Dewar Cross structures coating inspection</i>	-	-	Y	-	-	Y	Potential long-term corrosion

(1) : Verified through a MELFI functional test (cold conditions) in case MELFI is not used

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 225
---	--	--

- (2) : *Extended by ESA to 5 years*
- (3) : *Could be extended to 4 years (3 years+1 year margin on container tightness)*
- (4) : *Every 6 months of continuous operations*
- (5) : *Remove battery pack if MELFI is planned to be OFF during 6 months or more*

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 226
---	---	--

8 STOWAGE AND LOOSE ITEMS

All items required for MELFI operations are contained in MELFI with the exception of:

- MELFI Thermal Bag
- MELFI Foam Plug
- Regular tools from the ISS Tool Box that are necessary to support ORU operations

All the MELFI loose items have IMS labels with bar code to ease their identification on-orbit.

8.1 STATION TOOLS

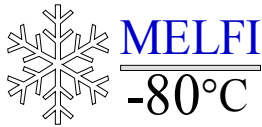
4 mm-Hex Head Driver 1/4" Drive TMAM4
5mm Hex Head Driver 1/4" Drive TMAM5
24 mm Combination Wrench OEXM240B
19 mm Combination Wrench SOEXM19
10" Adjustable Wrench AD10
Driver Drill Kit SJG33109829-301
1/4" Drive Ratchet 528-20145-24
19 mm-Shallow Socket 3/8" Drive FSM191
6" Extension 1/4" Drive TMXK60
3/8" to 1/4" Adaptor 528-20147-29
Driver Handle 1/4" Drive 528-20146-6
Hex Shank 1/4" Drive 00005-24J
(30-200"lb) Torque Wrench 3/8" Drive SEG39128571-301
Portable Utility Light (Flashlight) SEG33107306-301

8.2 MELFI LOOSE ITEMS

All the MELFI loose items are identified with IMS labels and listed in the table 8.2-1. IMS labels are also on samples or specimen that are inserted in the MELFI. The astronaut will use a barcode reader to identify locations within MELFI, and to know at any time where is what in MELFI. Details of IMS method implementation are under NASA responsibility.

Table 8.2 - 1: MELFI loose items list

MELFI loose item	Part Number	Quantity per MELFI	Dimensions (mm)
¼ size Standard Box Module	03227	40	130x243x144
¼ size Receiving Box Module	03329	8 ⁽¹⁾	130x243x144
½ size Standard Box Module	03226	7	272x243x144
½ size Receiving Box Module	03222	1 ⁽²⁾	272x243x144
Standard Vial Card	03219	48	146x110x10
Contact Card	03221	8	146x115x10
BASE Container	03133	1	579x416x335
Failed Brayton Machine Container	03123-1	1	347x229x198
Spare Brayton Machine Container	03123-2	1 ⁽³⁾	347x229x198
Interface Cylinder	03123-3	1	210x229x198
Interface Cylinder cap	03123-5	1	20x229x198
Gearbox sub-assembly	03123-4	1	510x162x162
Brayton Machine Foam Case	03123-7	1	220x70x150
Shutter Gearbox	03123-6	2	250x60x20
Brayton Machine Front Cap	03123-8	1	198x30
Brayton Machine Water Expansion device	03154	1 ⁽³⁾	30x100
Brayton machine flange	03153	1	Φ 120
Nitrogen Fill and Purge Equipment	03113	1	575x417x78




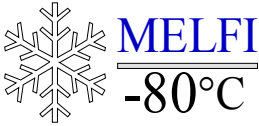
Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

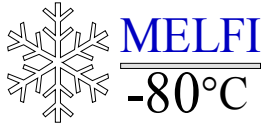
Page: 228

MELFI loose item	Part Number	Quantity per MELFI	Dimensions (mm)
Electronic Unit (active +spare)	03301	1 ⁽⁴⁾	686x485x177
EU Water Expansion device	03307	1 ⁽⁵⁾	25x110
Thermal Bag	03295	1	180x425x180 (packed) 840x425x334 (unfolded)
DASE Pouch	03298	1	420x420x150
Tray handle	03294	1	83x115x25
Sleeves	03292	2	640x230x10
Ice Scraper Handle- Short Shaft	03293-12	1	223x37x37
Ice Scraper Handle- Long Shaft	03293-13	1	540x37x37
Ice Scraper Head 1	03293-21	1	41x40x12
Ice Scraper Head 2	03293-22	1	38x25x30
Ice Scraper Head 3	03293-23	1	33x26x17
Ice Scraper Head 4	03293-24	1	42x12x12
Ice Scraper Head 5	03293-25	1	41x12x12
Ice Scraper Head 6	03293-26	1	41x40x15
Ice Scraper Head 7	03293-27	1	51x40x12
Cotton Gloves (4 sizes, two sets of each)	03291	8 pairs	230x90x10
Cryogenic gloves (2 sizes)	03291	2 pairs	372x149x25
Tray Strap - Long	0397-1	1	1500x25x5
Tray Strap - Short	03297-2	1	500x25x5
Star Handles	03305	2	Φ 70x104
Spare RIU Fuses	03296	4	20x8
EU QD mating Tool	03306	1	120x80x25
Triple Square M6 Tool	03308	1	60x Φ 20
Triple Square M4 Tool	03309	1	40x Φ 15
Dewar Bolt	-	1 ⁽⁶⁾	10x4

		Ref: MELFI-MA-03000-0435-MMT Issue: 04 Rev.: 00 Date: 01-Sept-2004 Page: 229
---	---	--

MELFI loose item	Part Number	Quantity per MELFI	Dimensions (mm)
24 mm Crowfoot ¼ drive	03310	1	50x30x3
Cold Box Front panel	03408	1	480x480x30
Acoustic Pad	03409-8	1	1020x510x30
Foam Block	03205	1	207x292x171
Rack Close-out Tissue Panel	03409-9	1	990x240x 5
EU Tissue Panel	03302	1	535x205x5
EU blind Panel	03304	1	485x177x12
TDR Battery Pack	03370	1	20x50x15

- Notes:
- (1): No receiving ¼ size Box Module delivered for FU2; Replaced by 8 additional ¼ size standard Box Modules.
 - (2): No receiving ½ size Box Module delivered for FU2; Replaced by 1 additional ½ size standard Box Module.
 - (3): The Spare Brayton Machine Container houses a Spare Brayton machine only for FU1. The Brayton Machine Water Expansion device equips the Spare Brayton Machine
 - (4): A Spare EU is only delivered for MELFI FU1
 - (5): The EU Water Expansion device equips the spare EU, which is inside the MELFI Rack.
 - (6): A loose Dewar bolt is only for FU1 as a result of the on-orbit commissioning activity.



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 230

9 ACRONYMS

ASE: Airborne Support equipment

AUX: Auxiliary Power Bus

BASE: Brayton Airborne Support Equipment

BSS: Brayton Sub-System

BM: Brayton Machine

BMEE: Brayton Machine Exchange equipment

CAM: Centrifuge Accommodation Module

CB: Cold Box

CDHU: Control and Data Handling Unit

CPI: Crew Panel Interface

C&W: Caution and Warning

DASE: Dewar ASE

DSS: Dewar Sub-System

ESS: Electrical Sub-System

EU: Electronic Unit

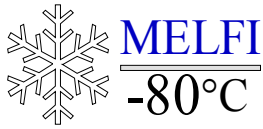
Exit: External Tubing

FM: Flight Model

GSE: Ground Support equipment

HAS: Health And Status data

hPa: hectoPascal



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 231

HW: Hardware

IIP: ISPR-mounted Interface Panel

ISS: International Space Station

LHX: Load Heat eXchanger

LRDL: Low Rate Data Link

LTL: Low Thermal Loop

MAIN: Main Power bus

MDE: Motor Drive Electronics

MOP: Maximum Operating Pressure

MPLM: Mini Pressurized Logistics Module

N2: Nitrogen

NFPE: Nitrogen Fill and Purge

ORU: Orbit replaceable Unit

PBS: Power Bus Selector

PCM: Phase Change Material

PCS: Portable Computer System

PSU: Power Supply Unit

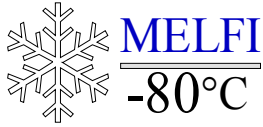
QD: Quick Disconnect

RIU: Rack Interface Unit

RMSA: Rack Maintenance Switch Assembly

RPCM: Remote Power Control Module

RSS: Rack Sub-System



Ref: MELFI-MA-03000-0435-MMT

Issue: 04 Rev.: 00

Date: 01-Sept-2004

Page: 232

Stowage Compartment: Stowage Compartment

S/S: Sub-System

SW: Software

TC: Tele-command

TCS: Thermal Control System

TDR: Temperature Data Recorder

TM: Telemetry

UIP: Utility Interface Panel

USL: US Laboratory

WHX: Water Heat Exchanger