→ MINUS EIGHTY LABORATORY FREEZER FOR ISS (MELFI)

Laboratory freezer for the International Space Station

The Minus Eighty (Degrees Celsius) Laboratory Freezer for ISS (MELFI) provides the Space Station with refrigerated volume for storage and fast-freezing of life science and biological samples. The MELFI system has been designed for an operational life of 10 years.

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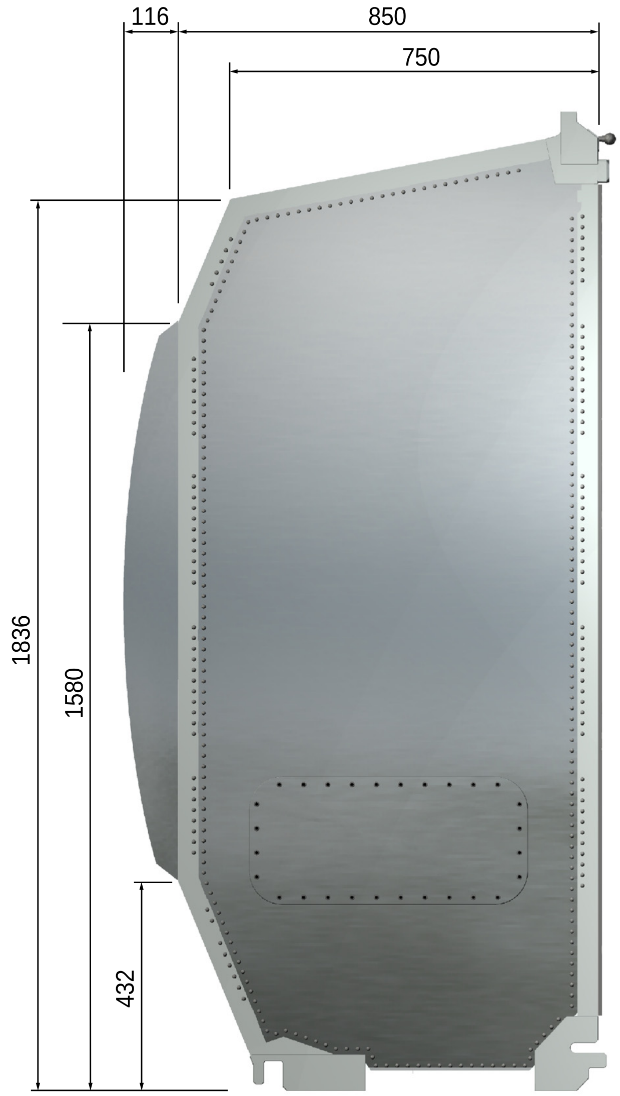

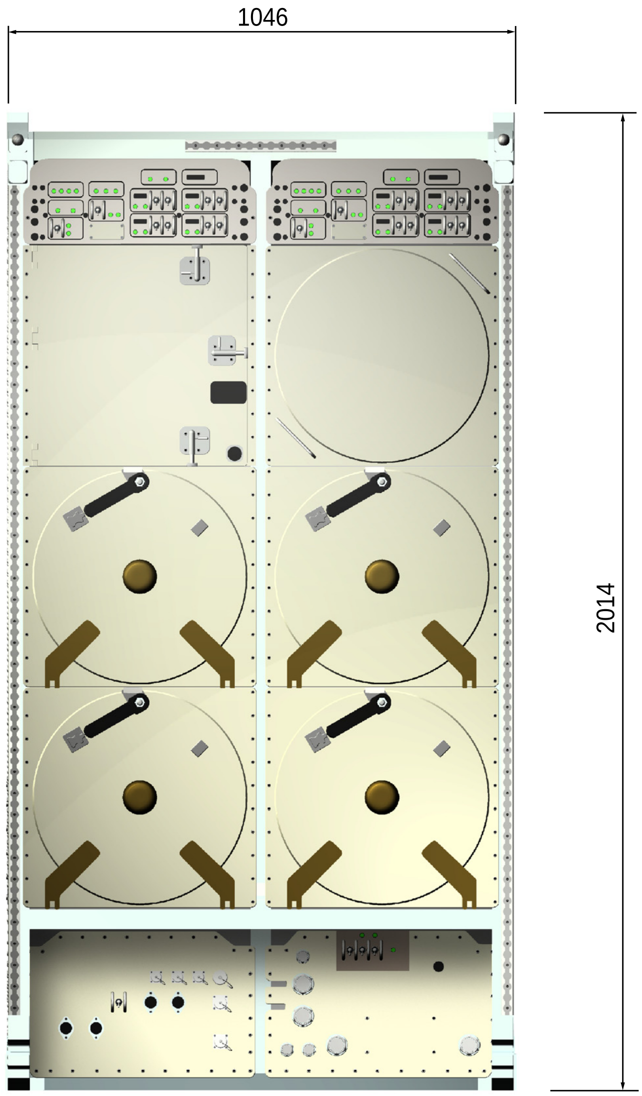

DIMENSIONS:
in mm

Facility Description

The Dewar System includes the cold volume, made by four separate compartments (dewars), and a nitrogen distributing system, consisting of piping and control valves. Each dewar is a cylindrical vacuum insulated container with a total capacity of about 75 litres. Its internal volume is divided in four parts by a cross structure, having two functions: the support function for the specimen containers and the heat transport function, from the heat exchanger to the specimen.

The centralised cooling system is based on a reverse Brayton cycle using very pure nitrogen as the working fluid. The basic machine was developed under ESA's Technology Research Programme (TRP), and then modified to satisfy MELFI's specific and stringent requirements. The Brayton expander and compressor wheels are mounted on the same shaft, running at up to 96,000 rpm. At that speed, the system produces 90 W of cooling power at - 97º C. The heat exchangers needed to implement the Brayton thermodynamic cycle are integrated in a closed container called the Cold Box. The Brayton Machine is inserted into the Cold Box, forming an integrated assembly called the Brayton Subsystem. The cooling distribution to the Dewars is via vacuum-insulated nitrogen lines running from the machine. A distribution valve on each Dewar stabilises the temperature within the required range by modulating the cold nitrogen flow. The valves can also isolate each Dewar independently, shutting down one or more enclosures when the storage capacity is not needed.
In this way, the temperature in the dewars can be controlled independently at three operating modes (-80, -26 and +4° C). Control of - 26º C and + 4º C is achieved with good overall efficiency when at least one dewar is working at - 80º C. The upper temperature limit for the - 80º C mode is fixed at - 68º C. This gives a 12º C safety margin. The temperature is continously monitored and recorded even in power-off phases. Notification of out-of-limit conditions is performed.

The dewars are designed to improve the thermal coupling between the samples and the cold fingers. The external surfaces and internal volumes where the nitrogen flows at different temperatures require a very efficient thermal insulation to reduce the thermal leaks. To achieve this the double walls are covered with MLI sheets and pumped out to very high vacuum levels. The very low leakage requirement requires a "Getter pump" that keeps the vacuum by molecular pumping at the desired level.
The Cold Box design features an axi-symmetric configuration with all the components integrated around the housing of the Brayton Machine.
The electrical subsystem provides the overall control of the MELFI system and supplies electrical power to the BM motor and control electronics. It is integrated in two main boxes: the Electronic Unit and the Rack Interface Unit. The Electronic Unit includes the Power Supply Unit, the Control and Data Handling Unit (built around the commercial Intel 386 processor and including the I/O boards and the VME boards), the Motor Drive Electronics and the Control Panel Interface. The Rack Interface Unit interfaces directly to the ISS power supply. It provides electrical protection, filtering and the automatic switching between the ISS Main and Auxiliary power supplies. It also selects automatically the active bus. A battery driven Temperature Data Recorder records the temperature in the dewars when MELFI is not powered.

MELFI uses International Standard Payload Rack interfaces such as:

- 120 V Electrical Power from the Main and Auxiliary buses
- Cold Water Loop (nominally 3.3 to 10.ºC) for cooling the EU and the BM, and removing heat from the Brayton cycle
- the US Lab Payload 1553B bus for controlling MELFI

Being a freezer, the continuous availability of MELFI is a key parameter for the success of the mission. Therefore, several key components of MELFI are designed as Orbital Replaceable Units.

In addition to the 3 flight units, the MELFI project includes the following ground units:

- Laboratory Ground Model
- MELFI Training Unit
- MELFI Engineering Unit

Specifications

Facility size and mass:	Double size International Standard Payload Rack. Maximum mass about 800 kg, including spares and up to 100 kg cold payload.
Modular Stowage Volume:	Total stowage volume of 300 litres, in four independently controlled dewars
Minimum Active Configuration:	At least 1 dewar at - 80º C
Multiple Mission Configurations:	Combinations of dewars at three different temperature modes (- 80, - 26 and + 4º C) Up to 2 dewars at - 26º C and/or + 4º C are allowed at any given time.
Controlled Temperatures:	- 80º C Mode: samples maintained below - 68º C - 26º C Mode: samples maintained in - 37º C to - 23º C range + 4º C Mode: samples maintained in the + 0.5º C to + 6º C range
Type of Samples Stowed	
Cell Culture:	of 1 to 10 ml size
Fluid Samples (blood, media, etc.):	of 1 to 500 ml size
Specimens/Dissection Tissues:	of 2 to 10 ml size
Specimens (whole):	of 10 to 500 ml
Loading capabilities:	Sample mass equivalent to 100 ml saline solution each 45 minutes, up to 2 kg of samples per day from ambient temperature to - 80º C.
Typical Specimen Cooling Time	(from + 23º to - 68º C) in 0-g conditions:
Samples of 2 ml:	18 to 25 minutes
Samples of 5 ml:	29 to 41 minutes
Samples of 10 ml:	44 to 56 minutes
Samples of 100 ml:	165 minutes
Samples of 500 ml:	460 minutes maximum
Power-Off Survival:	Temperature conditions maintained for at least 8 hours without electrical power
Power Supply:	Main and Auxiliary bus automatic switching provided
Power Consumption:	Ranging from 550 W to 900 W depending on the active configuration
Heat Rejection:	Water cooled
Facility Control:	From ground or from the ISS Laptop through the payload MIL Bus 1553B, and manually from the control panel

Operations and Utilisation

ACCOMMODATION AND TRANSPORT

The MELFI system has been designed for an operational life of 10 years. The operational life has been extended via provision of refurbishment tools and spares for the BM and EU.

It has been qualified for 15 launches flying active in the MPLM. Although MELFI was originally designed for utilisation within the Destiny laboratory, it is also accommodated into the Japanese module, KIBO.

OPERATIONAL CONCEPT

MELFI can be controlled in two ways: in remote mode through the US Lab 1553B payload bus from either the ground or the ISS laptop, or in manual local mode from the CPI (Control Panel Interface). The MELFI software provides overall control and monitoring of the MELFI subsystems. In particular, it implements the algorithms that control the speed of the machine and cold power to each dewar. The algorithms minimise the power consumption for a selected configuration (dewar mode and temperature set point).

UTILISATION SCENARIO

Many different utilisation scenarios are possible. MELFI provides the required heat lift to each of the dewars. The basic accommodation hardware provided by MELFI is the tray. Each dewar includes four trays that can be extracted without disturbing the samples in the other three. In addition to the trays, MELFI provides standard accommodation hardware for the insertion of samples of different sizes and shapes.

Users can design their own accommodation hardware, based on defined interface requirements and their cooling needs. MELFI is a ‘contact freezer’ to allow selection of the cooling speed. For fast cooling, the samples must be held against the Dewar trays and have a large, conductive surface. Conversely, samples requiring slow cooling need small, isolating interface surfaces.

SCHEDULE

MELFI has been developed by ESA under different Barter Agreements that ESA formalised with NASA and JAXA. Under those agreements ESA has delivered two MELFI flight units to NASA and one flight unit to JAXA. The first MELFI freezer was launched on board STS - 121 (Utilisation Flight ULF 1.1), in July 2006.

The final Melfi unit was flown to the ISS on board Space Shuttle Discovery during the STS-131 mission in 2010.

In addition, ESA has agreed to deliver to NASA the necessary spares and sustaining engineering to maintain the NASA MELFI units for up to 10 years of MELFI operations. Additional agreements are being settled to extend the lifetime up to 2020.

ESA astronaut Thomas Reiter commissioned the first MELFI freezer.

ESA astronaut Paulo Nespoli working with MELFI

ESA astronaut Frank de Winne working with MELFI