Enclosure D

Dilution-Refrigerator-Specifications 3-31-2021

Low-vibration dilution refrigerator with optical fiber and free-space ports

System:

- Bluefors LD-400 UHV with Ultra High Vacuum (10^-10 at base temperature) or approved equivalent
- Base temperature: < 10mK (<8mK typical)
- Cooling power: >14μW at 20mK (>16μW typical)
- Cooling power: >400μW at 100mK (>500μW typical)
- Cooling power: >575μW at 120mK (>650 μW typical)
- Pressure: On the top flange <1e-9 mbar at base temperature (<5e-10 mbar expected)
- Integrated features include:
    - edge-welded bellow assembly for mounting pulse tube for reduced vibration amplitudes
    - temperature controller
- System Main Voltage: 115V 60Hz. Must be NRTL approved
- 3yr warranty for all manufactured parts that is not conditional to any maintenance being carried out. Service-free for the first 3 years.
- Unlimited telephone customer support. Support must be provided by technical personnel who are scientists, experienced with the system and who will reply within one business day.
- Manufacturer must have demonstrated experience providing an equivalent system
- Must deliver no later than 12mos from date of purchase order

Pulse Tube Configuration:

- Standard configuration with PT415-RM pulse tube cryocooler
- Voltage specification: 440/480V 3Ph 60Hz

Temperature Controller:

- 8-channel resistive temperature measurement
- Four heater controls operational in manual or closed-loop mode
- Intuitive device touchscreen and web interface
- API enabled via ethernet connection

Control Unit:

- Standalone control unit with 610 x 645 mm table size

Vacuum can specification:

- 3-section vacuum can

4K Heater Kit

Resistive heater at the 4K flange for faster warm-up

- 40W (10 Ohm, 2A max)
- All cabling and heat sinking

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• Integrated with system control software

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1. General description

1.1. Continuously-operating He-3/He-4 dilution refrigerator

1.2. Cooling power of 15 µW @ 20 mK (with 18L of He3) measured directly on the sample plate

1.3. The base temperature is below 10 mK and is guarantee with all factory installed wiring.

1.4. Precooling provided by a pulse tube cryocooler (i.e. a "Dry" refrigerator)

1.5. Single vacuum space: Separate IVC/OVC designs excluded

1.6. Standard vertical orientation

1.7. Modular design and in case of parts failure they are to be promptly replaced

1.8. A fully-welded main heat exchanger that basically provides indefinite trouble-free operation

1.9. All electrical components must be NRTL approved.

2. Helium-3 isotope

2.1. He-3 for running the dilution unit is not part of the purchase and will be provided by the user

2.2. Maximum amount: 18L STP (liters at standard temperature and pressure)

3. Installation

3.1. User will prepare the laboratory space with reasonable utilities connections as requested by the supplier

3.2. Supplier is responsible for commissioning of the refrigerator at the user's site

3.3. Base temperature and cooling power as specified below must be demonstrated on-site after installation by the supplier

4. Mechanical envelope

4.1. Maximum footprint of the dilution fridge unit

4.1.1. 2m x 2m floor area

4.1.2. 98" room height to drop ceiling (2489 mm)

4.2. The cryocompressor, mixture tanks, and pumps located in an adjacent room

5. Mechanical vibrations

5.1. Ceiling- or floor-anchored support structure the for pulse tube cryocooler that is separate from the support for the main body of the dilution fridge

5.2. Thermal contact between the pulse tube and fridge stages through flexible thermal links: Cu braid or similar

5.3. Flexible vacuum seal between the pulse tube and the fridge frame: Bellows or a similar

6. Cryocooler

6.1. The system delivery must include all required components for running the cryocooler

7. Electrical isolation

7.1. All connections (including vacuum and electrical) to the dilution refrigerator must be galvanically isolated in such a manner that the dilution refrigerator frame, in normal operating status, is electrically floating with respect to the building ground unless grounded through an external, user-supplied connection

7.1.1. Verification: After installation, an electrical power supply will be connected between the cryostat and the building ground. The cryostat will be raised to a potential +- 10V with respect to the building ground. The current provided by the supply must be less than 5 mA (> 2000 Ohm isolation).

8. Pumps and dilution circuit

8.1. The system must include a pumping system that allows evacuating the main vacuum and running the dilution unit

8.2. The dilution circuit can include a LN2 (liquid nitrogen) trap and a LN2 dewar

8.3. All pumps must be oil-free

9. Control system

9.1.1. Must have temperature sensors and readouts at all temperature stages except cold plate. System's thermometry wiring harness prepared to add up to four additional sensors, two on 50 K or 4 K and two on or below still.

9.1.2. Thermometers must be delivered installed in the cryostat

9.1.3. Each thermometer must have a valid calibration covering its normal operating temperature range

9.2. The pumping system must be computer-controllable

9.2.1. The computer interface provides access to at least the following functions

9.2.1.1. Opening and closing valves

9.2.1.2. Turning pumps on and off

9.2.1.3. Reading pressure gauges

9.2.1.4. Reading thermometers

9.2.2. The user can provide a standard desktop PC available for controlling the cryostat if requested by the supplier

9.2.2.1. All other control electronics must be provided by the supplier

10. Cooldown and warm-up time

10.1. Cooldown time from room temperature to within 10% of specified base temperature < 24h following standard procedure

10.2. Warm-up time from base temperature to room temperature < 12h following standard procedure

10.2.1. The allotted time (12h) must include mixture collection

11. Experimental space dimensions

11.1. Minimum available unobstructed experimental space at base temperature

11.1.1. A cylinder of diameter 303 mm and height 337 mm

12. Cooling power / Base temperature**

12.1. MXC stage base temperature <20 mK with specified wiring installed

12.2. MXC stage base temperature <20 mK with >12 uW heat to the MXC stage

12.3. Requirement will be verified by applying the specified amount of heating electrically