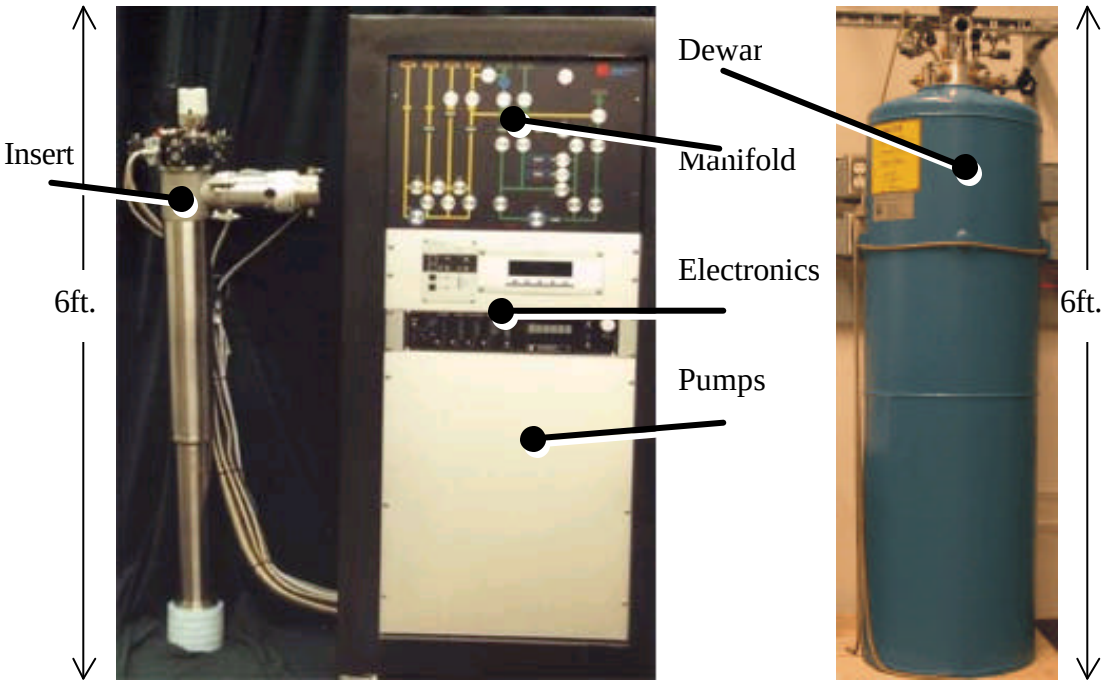
SPECIFICATIONS
DILUTION REFRIGERATOR

INTRODUCTION

The function of a dilution refrigerator is to provide a cold temperature (from approximately a few mili-Kelvin and up) environment for the characterization of devices. A typical dilution refrigerator system is about 12 feet tall, 3 feet wide, and consists of vacuum tight stainless steel chambers, pumps, valves, gas manifolds, temperature sensors, heaters, etc. The operation --- maintaining a fixed temperature, for example --- is computer-controlled for convenience. A picture shown below can provide a general idea. To the left, the picture shows the **insert** and a **rack** full of supporting components, including electronics, pumps, manifolds, and valves. The **insert** is to be put into a liquid helium **dewar,** shown at right. The actual height of the **rack** and the **dewar** is approximately 6 feet. Since the insert has to be lifted to be above the top of the dewar, approximately 12 feet of ceiling height is therefore needed for operating this dilution refrigerator system. Inside the liquid helium **dewar**, there is a superconducting magnet, magnet support, liquid helium level sensor, and other miscellaneous parts.



The dilution refrigerator shall meet or exceed the following specifications:

SPECIFICATIONS

The dilution refrigerator system shall be comprised of (1) a **dilution refrigerator insert**, (2) a **controlling rack** with essential electronic and mechanical components, (3) a liquid **helium dewar** with a superconducting magnet, and (4) **miscellaneous items** for the operation of the dilution refrigerator.

1) Dilution Refrigerator Insert

The dilution refrigerator insert shall include:

A) Dilution refrigerator insert with an outer diameter between 125mm to 130 mm and with an inner vacuum chamber (IVC) diameter between 105-110mm.

B) Minimum (or Base) temperature on the base of the mixing chamber shall be less than 6mK (at least 9mK shall be guaranteed).

C) Cooling power measured on the base of the mixing chamber shall be 700 micro-Watt (μW) at 120mK (at least 600μW shall be guaranteed at 120mK).

D) Insert and dilution unit with stepped tails to suit magnet, which has a 78mm bore diameter.

E) At least three access ports on top flanges with clear shot tubes to IVC.

F) Thermometry
Resistance thermometers with nominal calibration at the 1K pot and still.
Calibrated resistance thermometer for the mixing chamber with an accuracy better than ±0.3% at 4.2K.
Calibrated Ruthenium oxide thermometer for the sample space (with data down to at least 9mK) with an accuracy better than ±5mK at 50mK.

G) Wiring
48 shielded brass wires in twisted pairs anchored at the 50mK plate or the mixing chamber.
10 brass low-frequency coax cables anchored to the 1K plate (2 coax cables for the still level gauge).

H) Heaters
6 shielded brass wires for still, mixing chamber, and sorb heaters anchored at the still plate.

I) Circuit
Double 1K pot circuit with bypass valve and double He3 condensing circuit.

J) Four ports for 4 high-frequency coaxial cables
Four semi rigid high-frequency coaxial cables (cables to be furnished by NRL) from room temperature to the 1K pot, open port with o-ring groove at room temperature and 2.4mm connectors anchored at 1K pot. Superconducting cables from 1K pot to the mixing chamber terminated with 2.4mm connectors.

K) Sample rotator
Axis of rotation shall be perpendicular to the field.
Angle of rotation shall be at least 180º.

2) **Controlling Rack** (including the gas handling manifold, control electronics, and pumps)

The controlling rack shall include:

A) Automatic He3 gas handling system and automatic pumping system for 1K stage and IVC (automatic operation under LabView).
B) Microprocessor controlled electrical valves with manual and automatic operation.
C) Ceramic bearing oil-free turbo pump(s) mounted inside the cabinet, backed by oil-free dry pump.
D) He4 gas handling system for 1K pot, including pump.
E) IVC vacuum system uses He3 circulation turbo pumps for pre-evacuation and sorb pump for final vacuum.
F) Electro-pneumatic gate valve for insert.
G) Two external nitrogen cold traps including nitrogen dewar.
H) Two helium traps inside insert.
I) Vacuum gauges and flow meters for monitoring the gas flow.
J) Sorb pump.
K) Separate power supplies for still, mixing chamber, and sorb heaters with LabView drivers.
L) Thermometry system to monitor, display and control the temperature of the system.
M) Complete testing of the insert and all of the supporting components with document and demonstration to meet the specifications. (NRL reserves the right to be present during the final testing).
N) The height of the controlling rack shall not exceed 7 feet.

3) **Helium Dewar with a Superconducting Magnet**

The helium dewar with a superconducting magnet shall include:

A) Vapor shielded stainless steel dewar, with 100 liters reservoir, mounted on wheels with a He4 boiling rate less than 0.7 liter per hour.
B) Stainless steel flange with all of the necessary ports; sliding seal, including radiation shields.
C) High field superconducting magnet with or 78 mm clear bore for housing the tail of the dilution refrigerator, 11 tesla at 4.2K, 13 tesla at 2.2K, 0.1% homogeneity over a 10mm cubic volume. In addition, diode/resistor protection circuit is wired, as an integral part of the magnet assembly.
D) Superconducting compensation coil around the mixing chamber.
E) Magnet support assembly with a lambda plate.
F) Vapor cooled magnet current leads.
G) Liquid helium level gauge and probe in glass fiber tube.
H) Complete testing of the superconducting magnet with test results provided to demonstrate compliance with the specifications. (NRL reserves the right to be present during the final testing).

I) The height of the helium dewar shall not exceed 7 feet.

4) **Miscellaneous items** (all are necessary for the operation of the dilution refrigerator)

The miscellaneous items necessary for the operation of the dilution refrigerator shall include:

A) Bipolar power supply, at least 120 ampere, 5 V dc (or higher), with programmer that can sweep the magnetic field up and down at adjustable rate --- this power supply matches with the superconducting magnet, so that the maximum field (13 tesla) can be reached.
B) Optimized He3 and He4 mixture.
C) Flexible liquid helium transfer tube with demountable coupling for the dewar in item (3).