CRYOGENIC VERTICAL TEST FACILITY FOR THE SRF CAVITIES AT BNL

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Abstract

A vertical test facility has been constructed to test SRF cavities and can be utilized for other applications. The liquid helium volume for the large vertical dewar is approximate 2.1m tall by 1m diameter with a clearance inner diameter of 0.95m after the inner cold magnetic shield installed. For radiation enclosure, the test dewar is located inside a concrete block structure. The structure is above ground, accessible from the top, and equipped with a retractable concrete roof. A second radiation concrete facility, with ground level access via a labyrinth, is also available for testing smaller cavities in 2 smaller dewars.

INTRODUCTION

A test facility has been constructed to house a large diameter Vertical Test Dewar (large block house) and a second facility has been constructed to house two smaller full bore test dewars (small block house). The facility will be able to perform cryogenics tests from 4.5K down to 1.8K. The large dewar allows testing of SRF cavity assemblies with 2 m overall height and 0.9 m overall diameter.

SYSTEM DESCRIPTION

Radiation Block Enclosure Large Dewar

The large dewar is housed above ground in a concrete blockhouse constructed of 1.22 m wide concrete blocks of various lengths and heights. The inside space is 2.5 m x 2.5 m x 5.0 m tall volume that houses the dewar and a platform. The dewar is surrounded by an aluminum platform located at an elevation of 3.6 m which is approximately 0.4 m below the dewar's top plate. The platform is about 2.5 m x 2.5 m with a large opening for the dewar. Several smaller openings are built in to allow the piping to exit the blockhouse below the platform elevation. These openings are shadowed by additional concrete blocks outside the block house. The maximum height of the dewar and blockhouse was limited to the building's crane hook height of 9.4 m in order to lift the test article out of the dewar.

Access to the blockhouse for personnel and test article/top plate insertion is accomplished by a motorized translating roof. The roof consists of 3.66 m long concrete blocks that span the width of the blockhouse open area. The concrete blocks sit on top of a steel frame with roller bearings that roll on horizontal beams mounted on the top of the blockhouse side walls. An access stairway runs upward along the side of blockhouse and a short removable segment allows access from the top of the access stairway. See Figures 1 and 2.

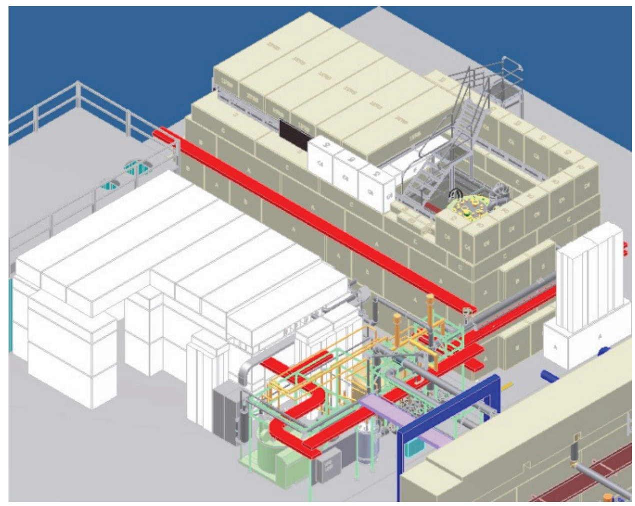

Figure 1: Vertical test facility.

LARGE DEWAR CRYOSTAT

Helium Vessel

The helium vessel has an overall height of 3.6 m and a nominal diameter of 1 m. The helium vessel is engineered, manufactured and U-stamped to ASME Section VIII Div.1 specifications. The vessel is made of stainless steel 304L with a vessel wall thickness of 4.7 mm. The cold volume is separated by a foam baffle assembly from the top plate. The cold magnetic volume in essence makes up most of the cold volume below the baffle assembly. The overall cold magnet shield volume has an overall height of 2.5 m. The overall maximum liquid level is limited by the location of the 50 mm vapor return exit line, located approximately 150 mm below the top of the cold magnet shield's top cover. See Figure 3.

Top Plate Assembly

The top plate is made of stainless steel 304 and is almost 50 mm thick. There are eight 38 mm diameter ports, two 63 mm ports, and two 150 mm ports on the top plate. All the smaller ports continue through to the bottom side of the top plate into the helium volume and terminate with Conflat flanges to allow continuation of vacuum tube connections when required for use. The circular top portion of the warm magnetic shield is mounted on the bottom side of the top plate, inside the helium volume. Four stainless steel rods sized to handle a total weight of

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1000 kg are mounted on the top plate. The mating side on the dewar for the top contains 2 o-ring grooves with the guard vacuum channel located on the top plate side. The guard vacuum port is a KF 25 for connection to a rough vacuum pump.

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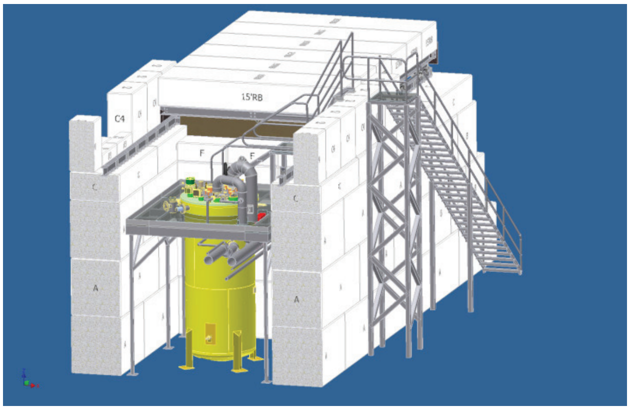


Figure 2: Large test dewar / large block house.

Heat Leak

The heat leak is summarized in Table 1.

Table 1: Helium Volume Heat Leak

Vessel wall Conduction	7 W	
Vessel wall Conduction with 5K Intercept		1.5 W
Radiant Load	1.8 W	1.8 W
Baffle	8 W	
Baffle with baffle intercept flow		~2 W
Relief pipe	0.8 W	0.8 W
Total	17.6 W	6.1 W

5K Intercept

Some 4.6K flow from the helium supply line is taken upstream from the recovery heat exchanger to flow through the second intercept. The cold intercept is engineered to intercept 5.5 W along the helium vessel wall at a flowrate of 0.1 g/s. Because the flow rate used and the heat leak intercepted are less than or equal to the Carnot equivalent between the refrigeration load of the heat leak and the liquefaction for the intercept flow, the intercept flow will primarily be useful when operating at e.g. 2K.

80K Intercept

A liquid nitrogen cooled intercept is located on the helium vessel approximately 350 mm from the warm end of the helium vessel to intercept conduction heat leak from the top. Flow comes from the nitrogen shield around the helium vessel.

Thermal Shield

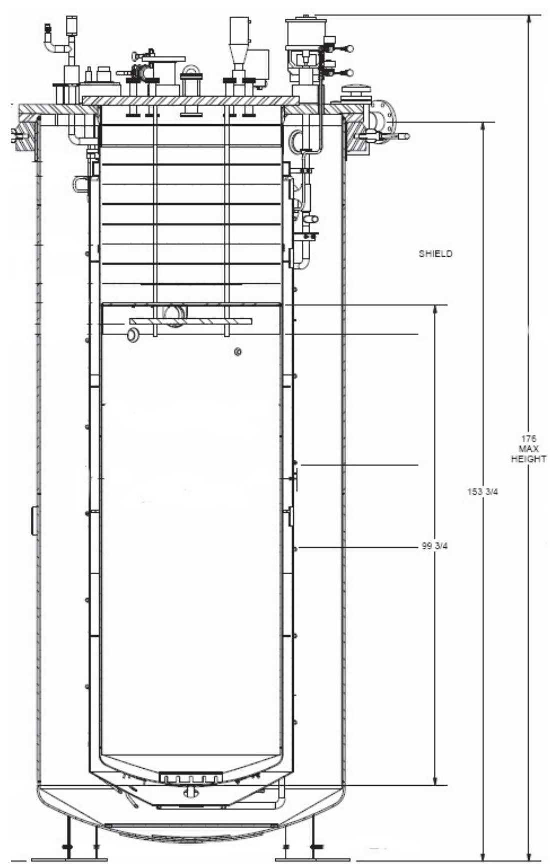
The liquid nitrogen cooled thermal shield surrounding helium vessel is made out of aluminum with the cooling passages made from extruded 3003 aluminum D-shaped tubing. MLI is wrapped on the outside of the heat shield to minimize radiation heat loads.

Baffle Assembly

The baffle assembly consists of nine 100 mm thick layers of Rohacell-51 (51 kg/m^3) foam supported on circular aluminum plates. The baffle assembly is supported by the same support rods that support the test article.

Magnetic Shielding

Shielding of the test article is accomplished by 2 layers of magnetic shielding. The inner magnetic shield is located inside the helium vessel and is thus submerged in the liquid helium bath. The inner shield, with a nominal diameter of 0.97 m is made from a 1 mm thick Cryoperm® sheet. The outer shield is constructed of 1 mm thick Mu metal mounted in the insulating vacuum space on the vacuum vessel wall. The nominal diameter is 1.63 m. Room temperature measurements made with both shields in place gave attenuation of approximately 126 with an APS Three Axis Fluxgate Magnetometer with Three Axis Probe along the centerline of the cold volume. Expected attenuation will increase with the Cryoperm cold at 4K we should comfortably be under 10 mG. Saturation margin, using a saturation value of Amu metal of 8000 mG and sheet thickness of 1.5 mm in an ambient field of 0.5G gives a theoretical factor of 24.



"Drawing courtesy of PHPK Technologies".

Figure 3: Large vertical test dewar section view.

Relief System

To handle upsets during normal operations, a smaller pilot operated relief valve with a capacity of 750 Nm^3/hr air equivalent is provided, which would handle almost 100 g/s of room temperature helium. To handle catastrophic failure for loss of insulating vacuum or loss of vacuum on the test article side, a 100 mm diameter burst disk is provided. The size of the burst disk is large due to the low design pressure of the cavities. Because the surface area of the test article can be very large, a restriction for port size used on the test article's beam vacuum side for pump out ports is set at the equivalent to a standard 38 mm vacuum tube port. This corresponds to a 55 kW condensing heat load for choked flow of air through this size port. The relief valve is set at 1.36 bar and the burst disk at 1.56 bar.

PROCESS AND OPERATIONS

A 12 mm diameter liquid helium supply line, a 12 mm diameter liquid nitrogen supply line, and a 76mm diameter cold vapor return line connects to the cryostat through a common vacuum jacketed transfer line system with a 250 mm jacket pipe diameter. The supply helium from the cryogenic system [1] flows through a recovery heat exchanger, where the 4.7K helium is cooled to below 3K in a counterflow heat exchanger against the returning low pressure cold vapor ranging in temperature from 1.8K to 4.4K, prior to throttling into the helium vessel by the top fill valve. Filling and cooldown is done via a separate cooldown valve that supplies the bottom of the helium vessel, see figure 3. A small supply line (not shown) that is connected to the plant high pressure ambient supply provides clean helium to the cooldown line for warmup and mixing for controlled cooldown of the test article if required.

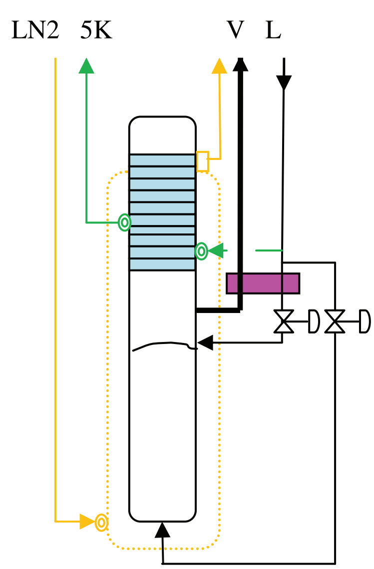


Figure 4: Process flow diagram large dewar.

Instrumentation and Controls

A 100 W heater is mounted on the bottom of the helium vessel on the insulating vacuum side for boil-off and warmup and load testing. Temperature sensors are mounted at the bottom, midpoint, and at the 5K intercept on the vessel wall insulating vacuum side of the dewar. A 2 m long superconducting level probe is mounted inside the cold magnetic shield volume.

SMALL BLOCK HOUSE

The small blockhouse is located next to the large blockhouse and can accommodate a small vertical test dewar. The small block house is built from ground level with a roof height of approximately 2.4 m. Access to the small block house is via a double door, and shielding is accomplished by a labyrinth tunnel arrangement between the door and test space.

Two small vertical test dewars are available for testing of smaller cavities or experiments: a 0.35m diameter dewar and a 0.70m diameter dewar. The 0.7m dewar has an overall helium vessel straight depth of 1.6 m and with a baffle space of 0.5 m. The working cold height is around 1.1 m. The 0.7m diameter dewar is also an ASME VIII Div 1 U-stamped vessel. Both dewars are used as boil-off dewars with no cold recovery; that is, the boil-off is used as the heat intercept along the baffles and dewar walls as the flow moves upwards and exits at the top of the dewar to the plant's compressor suction return line. The dewar vapor return is cross connected to the cryogenic system's sub-atmospheric pumping system line to allow capability to test at 2K. The test dewar is supplied from a portable dewar outside the blockhouse.

STATUS AND SUMMARY

The cryogenic transfer lines installation between the large vertical test dewar and the cryo plant's sub components is currently near completion. Controls and instrumentations wiring are also nearing completion. The Vertical Test Facility will allow onsite testing of SRF cavities with a maximum overall envelope of 0.9 m diameter and 2.1 m height in the large dewar and smaller SRF cavities and assemblies with a maximum overall envelope of 0.66 m diameter and 1.6 m height.

ACKNOWLEDGEMENTS

Many thanks to C. Sylvester from Fermi Lab for help on the baffle material and the cold magnetic shield information, and T. Peterson for the recovery heat exchanger. Many thanks to PHPK Technologies for the use of the figure 3 test dewar cross section diagram.

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