A TOP LOADING 2 KELVIN TEST CRYOSTAT FOR SRF CAVITIES

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Abstract

A new large 2 Kelvin test cryostat is being commissioned at Argonne National Laboratory. This system will have a full time connection to the 4.5 Kelvin Atlas refrigerator and, with a integrated J-T heat exchanger, will allow continuous 2 Kelvin operation. The large diameter was chosen to accommodate essentially all of today's superconducting cavities and the top loading design facilitates clean room assembly. The commissioning run will be with a coaxial half wave cavity to be followed by testing with a 1.3 GHz single-cell elliptical cavity

INTRODUCTION

Argonne's SRF group started testing superconducting cavities in the late 1970's. The first test cryostat was a top loading vertical cryostat built specifically for split ring cavities for the ATLAS linear accelerator. This cryostat is a cylinder 3 feet wide by 6 feet high with a 50 liter helium dewar, a copper LN2 shield, and a common vacuum for the cryogenics and cavity. This first test cryostat (TC1) was used to test nearly 100 split ring cavities. In the late 1980's TC1 was modified to be able to test low beta inter-digital cavities. The cryostat was extended to accommodate the new larger sized cavities. Magnetic shielding was added to the outside of the cryostat to reduce trapped flux during cavity cool down.

In the early 1990's a new test cryostat was designed and built (TC2) to make the testing of inter-digital cavities more efficient. TC1 and TC2 were very similar structures both being top loading cylindrical cryostats. TC2 had the magnetic shielding designed to be placed inside the cryostat. The cryostat also had some LN2 plumbing changes that made assembly easier. Both Cryostats were moved to the present location where connection to the ATLAS 4.5˚ Kelvin refrigerator was possible.

The next cryostat for the SRF test facility was a horizontal cryostat for testing double and triple spoke cavities built in 2001. This cryostat had all the same features as TC1 and TC2 with the added feature of separate vacuum systems for the cavity and cryogenic spaces. The draw back of this cryostat was a tedious and time consuming installation of the cavities.

In 2003, TC2 was modified to use separate vacuum systems for the cavity and cryogenics in order to test RIA prototype half wave and quarter wave cavities. These modifications worked well and allowed the testing of a half wave and 7 quarter wave cavities for the ATLAS energy upgrade. Since clean assembly wasn't an integral design of the cryostat, cavity assembly was difficult and time consuming. TC2 was also limited to testing cavities that would fit in the limited dimensions of the cryostat. More recently the design of a new cryostat, TC3 was started, would provide easy clean assembly and testing of all the present SRF cavity types.

DESIGN

TC3 was designed to handle all classes of SRF cavities presently being built. It is a large cylindrical cryostat (See figure 1) with an interior space for cavity placement of 140 cm high by 157 cm diameter.

Figure 1: SRF Test Cryostat.

The improvements of this design over TC1 and TC2 are easy clean room assembly, improved magnetic shielding, improved 80˚K Thermal shielding, larger liquid helium vessel that is ASME code stamped, continuous 2 Kelvin operation and multi layer insulation for reduced heat load on refrigeration system.

This cryostat allows cavities to be fully assembled with pickup, movable coupler and cavity vacuum pumping system in a clean room environment then connected to the top lid for loading into the bottom vessel for testing.

Magnetic Shielding

TC2 has a one piece cylinder for magnetic shielding in the lower part of the vacuum vessel with the top of the cylinder open. The best magnetic field reading we were able to obtain was 61mG. We managed to reduce the magnetic field to 20mG by using bucking coils on the outside of the cryostat during cool down.

The magnetic shielding has been improved on TC3 by totally shielding the interior of the vessel. (See figure 2) The shield consists of two cylinders (upper and lower) and two cones (upper and lower). All four sections were made from smaller overlapping sections.

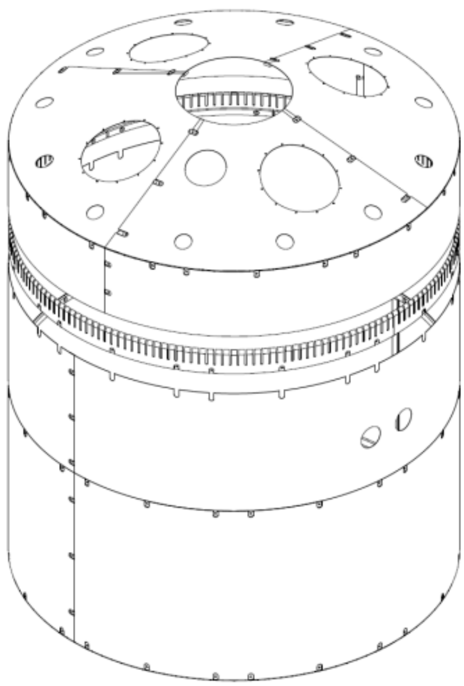

Figure 2: Magnetic Shield.

Threaded studs were spot welded to the interior of the vacuum vessel then each shield section is mounted on to the studs with one over lapping the next. Then stainless steel strips compress a lap joint to make a good mechanical and magnetic seam. Conical sections are tabbed to mate with cylinders using fasteners. The top shield is attached to the lid and overlaps the bottom when the two sections are mated. The material used to make the shield is AD-MU-80 sheets 1 mm thick. The end result of this shield construction is a measured magnetic field from 8mG to 17mG inside the vacuum vessel.

80K Copper Thermal Shield

There are two improvements to the 80K shield that TC1and TC2 did not have. The first is a liquid nitrogen phase separator which ensures good quality liquid to the shields (see figure 3) and any secondary nitrogen systems. The second is 35 layers of MLI wrapped around the outside of both the upper and lower shield sections. The helium dewar is also wrapped in MLI reducing total cryogenic static heat load of the cryostat.

The copper shielding has been constructed with two main assemblies, an upper and a lower. Each section was made of smaller pieces welded together to form both shield sections. Both upper and lower sections have a ½" OD tube brazed to the outside of the shields (see figure 4). Liquid nitrogen is force flowed through the upper shield then out of the top lid through a removable vacuum insulated line to the lower shield. The LN2 then exits the lower vacuum vessel through an external heater and is exhausted to room air. The upper shield is fastened to the helium dewar neck through a copper ring that is brazed on to the neck; this also serves as an 80k intercept for the helium dewar. The lower shield is on G10 spacers which thermally insulated it from the magnetic shield. There are 35 layers of MLI in between the magnetic and LN2 shields.

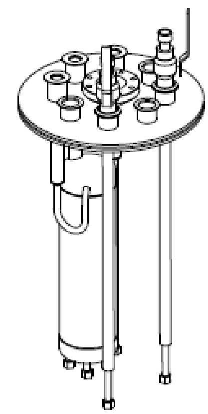

Figure 3: LN2 Phase Separator.

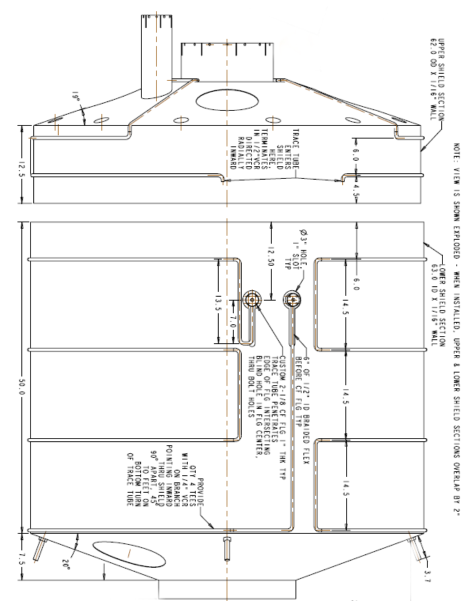

Figure 4: 80K copper Shield.

Magnetic Shielding

Both TC1 and TC2 are capable of continuous 4.5K operation connected to the ATLAS refrigerator. For 2K operation the cryostats needed to be disconnected and batch filled. This limits the amount of time that an experiment can run due to the 50 liter dewar capacity. TC3 has an integral JT heat exchanger that allow continuous 2 Kelvin operation while connected to the

ATLAS refrigerator. When not connected to the refrigerator the large 400 liter Dewar allows for many hours of 2K operation.

JT Heat Exchanger

The JT heat exchanger (HX) in TC3 is based on the CERN design. (See table 1) This heat exchanger has 1.5 g/s flow which equals 35 watts of capacity at 1.8K

Table 1: JT heat exchanger specs

	CERN HX	**Argonne HX**
Helium mass flow	4.5g/s	1.5g/s
High pressure stream (SC)		
Inlet temperature	4.5K	4.5K
Outlet temperature	<2.2K	<2.2K
Pressure	240 to 360 kPA	240 to 360 kPA
Pressure drop	<20KPA	<20KPA
Low pressure stream (VLP)		
Inlet temperature	1.8K	1.8K
Pressure	1.64KPa	1.64KPa
Pressure drop	<100Pa	<100Pa
Overall dimension		
Length	450 mm	450 mm
Width	150 mm	150 mm
Height	150 mm	100 mm

The heat exchanger works by sub-cooling the LHe supply to 2.2K with counter flow boil-off vapor before being throttled to low pressure by the JT expansion valve. The result of this is approximately 90% liquid supplied to helium Dewar. (See figure 5)

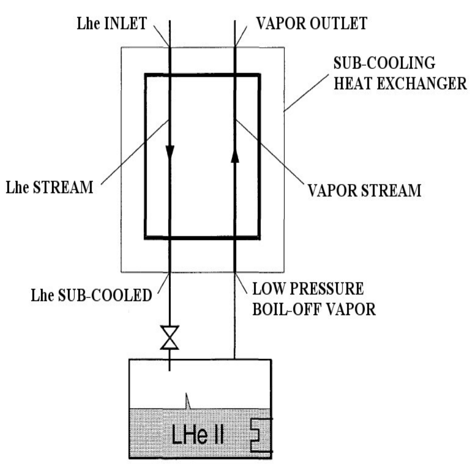

Figure 5: Heat exchanger flow schematic.

Summary

TC3 is the latest in single cavity cryostat design. The large internal volume lets us test all classes of today's SRF cavities. The connection to the ATLAS refrigerator along with the JT heat exchanger allows long term testing of cavities from 4.5˚K to below 2˚K. The improvements to the magnetic shield will reduce the trapped magnetic flux in cavities during cool down allowing the measurement of intrinsic cavity Q. The addition of the LN2 phase separator and the MLI reduces the static heat load as seen by the refrigerator allowing the use of more RF power during tests.

The fall of 2009 will be the first engineering cool down of the cryostat followed by a half wave cavity then a 1.3 GHz single-cell elliptical cavity.

Shown below is a 169 MHz half wave cavity (see figure 6) and 1.3 GHz 9 cell elliptical cavity (see figure 7) as they would be assembled in TC3.

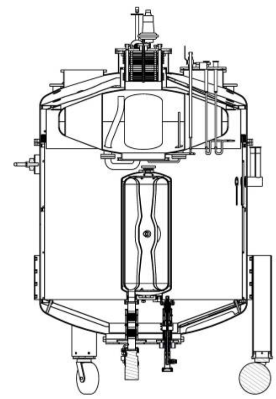

Figure 6: Half wave cavity in TC3.

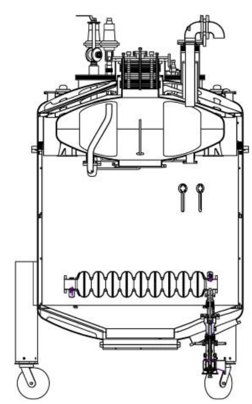

Figure 7: 9 cell elliptical cavity in TC3.

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