LA-UR-99-5883
*Approved for public release;
distribution is unlimited.*

Title: **APT CRYOMODULE ASSEMBLY AND THE USEFULNESS OF THE MOCKUP MODEL**

Author(s): B. Campbell, K.C.D. Chan, E. Newman and R. Valicenti

Submitted to:

http://lib-www.lanl.gov/la-pubs/00796476.pdf

APT CRYOMODULE ASSEMBLY AND THE USEFULNESS OF THE MOCKUP MODEL*

B. Campbell, K.C.D. Chan, E. Newman,# and R. Valicenti
Los Alamos National Laboratory

Abstract

The cryomodule for the APT β=0.64 high-energy accelerator incorporates either two or three radio-frequency cavities, two sets of magnetic shields, one active heat shield, multi-layer insulation blankets, cryogenic plumbing for the shields and cavities, power couplers, cavity spokes, and cavity frequency tuners. Maintaining cavity cleanliness is the most important aspect of the cryomodule assembly. The clean assembly of the cryomodule is performed in a class-100 clean room. The final assembly, such as tungsten inert gas welding used to join the cryogenic plumbing, is performed in a controlled environment. To address overall design concerns and assembly issues early in the design process, a full-scale mock-up of the entire cryomodule was fabricated. The mock-up also enabled us to determine the effect of the magnetic shielding and provides a clear representation of the problems that exist. In this paper we describe the assembly process and the benefits the mock-up has provided.

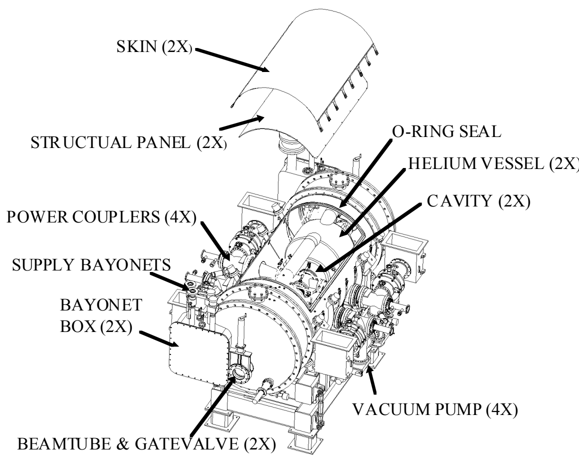

Figure 1. The β=0.64, two-cavity ED&D cryomodule.

1 INTRODUCTION

When the design of the superconducting accelerator was initiated for the APT program, the cryomodule stood out as one of the important building blocks. Success or failure of the accelerator depends on how well the cryomodule performs. Engineers decided to build a mock-up of the cryomodule before the real one would be fabricated. This mock-up would allow designers and engineers to review their designs in a full-scale model before they are implemented later. The β=0.64 engineering development and design (ED&D) cryomodule design is shown in Figure 1. The mock-up was modeled around this design.

2 CRYOMODULE/MOCK-UP DESIGN

This section will describe the current cryomodule design (shown in Figure 1) and how that design is modeled in the mock-up assembly (Figure 2).

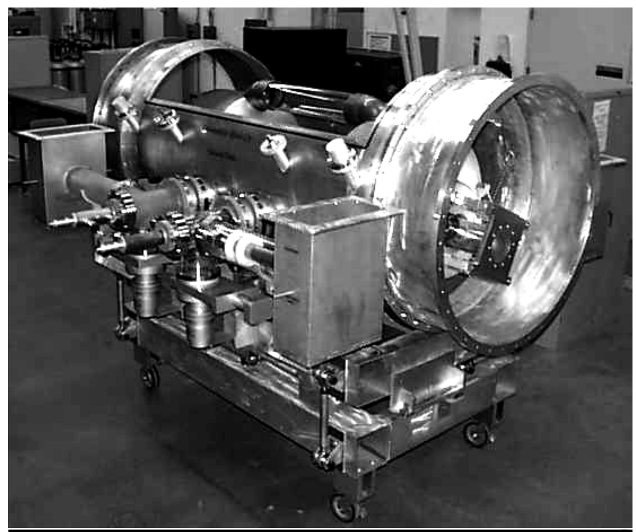

Figure 2. The β=0.64, two-cavity cryomodule mock-up.

2.1 Vacuum Tank

This vacuum tank uses the same design approach as that used in the CERN-LEP *wrap-up* cryomodule [1],[2]. The approach maximizes accessibility to the cryomodule. The CERN-LEP wrap-up design has one fixed stave on which all of the penetrations to the cryomodule are mounted. The stave is welded at each end to the vacuum vessel end bulkheads. The vessel is sealed to the atmosphere using an elastomer O-ring. Removable staves are added around the circumference of the vessel to keep the thin cover from collapsing. A thin stainless steel cover is wrapped around the vessel covering the O-ring. Buckles, with one end mounted to the cover and the other to the stave, are

* Work supported by the US Department of Energy; LA-UR-99-5883.
# Email: enewman@lanl.gov

tightened, causing the cover to compress the O-ring. This design has worked very well, providing maximum accessibility to the cavities inside when the removable staves are removed. APT adopted this approach because of the accessibility to the cavities and the success CERN has had with the design.

There are some differences between the CERN and LANL design approaches. The CERN cryomodule has one power coupler per cavity, whereas APT will have two. The CERN power coupler penetrates the upper quadrant of the cryomodule through the only permanent stave. The two APT couplers are on opposite sides of the cavity and are on the horizontal plane. This requires the APT vessel to have 2 permanent staves. The thin stainless steel cover is split into two pieces, one on top as shown in Figure 1, and one on the bottom. Two separate O-ring grooves will be machined into the vessel.

The APT cryomodule vacuum tank will have a top opening that will be approximately 120° of the circular annulus. A similar large opening will be in the bottom. This provides excellent access for assembly and laminar airflow in the clean room. This is shown in Figure 1 where the structural panel and vacuum skin are raised above and the magnetic heat shields and the multilayer insulation are removed. This design also enables easy cleaning of the vacuum tank before it is moved into the clean room.

The main vacuum vessel of the mock-up was fabricated out of 6061 aluminium and maintains the same material thickness and sizes as the actual design, which is 310 stainless steel plate. It is barely tack welded together for structural integrity and, therefore, is not intended to be vacuum leak-tight. This represents the overall design, including the vacuum-sealing techniques used on the large top and bottom openings.

2.2 Support Stand

The support stand is fabricated out of 8-inch-square 6061 aluminium tubing with 0.18-inch wall thickness. The overall dimensions are the same as the real stand, but unlike the final design in that total weight of the mock-up is approximately 3,000 pounds compared to the approximate 10,000-pound weight of the real cryomodule. The mounting legs have been replaced with heavy-duty casters for ease of movement.

2.3 Cavity and Helium Vessel

The APT 5-cell, β=0.64 cavity is fabricated from RRR (Residual Resistivity Ratio) 250 niobium for the cavity cells and RRR 40 niobium tubing for everything else [3]. The two ends of the cavity, as well as all ports protruding from the beamtubes, have stainless steel ConFlat® flanges brazed to them. A titanium liquid helium vessel encloses the cavity to provide the 2.15 K environment in which the cavity will operate. Each cavity assembly is supported with eight diagonal spokes from the vacuum vessel wall. The mock-up cavity assemblies are constructed out of a combination of aluminium and wood. This assembly only represents the outer contour of the helium vessel and cavity, including the tuner mechanism. The eight diagonal spokes are included and are mocked-up using threaded brass rod,

2.4 Power Coupler

The APT power couplers are designed to deliver a maximum of 250 kW per coupler to the cavity [4]. There are two couplers per cavity. A WR1500 waveguide section is transitioned to a coax line. There will be two coaxial windows in the line to make the air-to-vacuum transition. The coax line will go through a right-angle transition into the power coupler. The power coupler is a coaxial line with the outer conductor fabricated from copper-plated stainless steel. The inner conductor is fabricated from oxygen-free copper. The assembly is supported from the cryomodule using a flexure, which constrains the unit in five degrees of freedom. The transverse direction is left to permit contraction during cool-down.

The mock-up power coupler outer conductors are modeled from acrylic tubing. One station is clear to view the internal components. All vacuum flanges are commercially available ConFlat-type knife-edge seals. The gate valves and turbo pumps are of wood.

2.4 Magnetic Shielding

Two layers of 1-mm-thick Amumetal (80% nickel high-permeability shielding alloy) have been assembled inside the vacuum tank to reduce the effect of external magnetic forces. This shielding is cylindrical, and one layer is placed just inside the vacuum tank ID (43 inches ∅) with the second layer mounted over the thermal shielding at a ∅ of 37 inches. This provides an approximate space of 3 inches between the layers and reduces the internal permeability to well below the required 10 milligauss.

3 ASSEMBLY PROCEDURE

The assembly procedure for the cryomodule is complex and important. Having the mock-up greatly enables visualization of this entire process and allows for testing and developing these procedures. The superconducting cavity is extremely sensitive to dust and any type of contamination on its interior surface. Therefore, the assembly of the cavity and its components must be done in a very clean environment. A class-100 clean room will be used for assembly. To minimize the number of components to be brought into the clean room, the assembly is divided into two phases. The first phase, the clean assembly, includes the components that have to be assembled in order to seal the cavity. Once sealed, contaminants cannot enter the cavity. The cavity can then be moved outside the clean room into phase 2 of the final assembly. The remainder of the equipment would then be installed without concern for contaminating the cavity.

3.1 Clean Assembly

The assembly in the clean room would consist of the vacuum tank, 2 cavity/helium vessel assemblies, 4 power coupler assemblies, 4 high-order-mode couplers, 2 rf pick-up probes, an intercavity spool piece, 16 spokes, 2 gate-valves, and all of the assembly hardware. This assembly has been demonstrated on the mock-up. The mock-up clearly shows that it is impossible to approach the vacuum tank from either side. The location of the power couplers in the APT design blocks access to the center of the cryomodule. The mock-up shows the need for a tool to support the vacuum vessel. It also provides access from underneath.

3.2 Final Assembly

Final assembly of two magnetic shields, one active heat shield, multi-layer insulation blankets, extensive cryo-genic plumbing, and remaining components are then installed outside the clean room. The power couplers do not allow access to the cryomodule during this process. A rotating fixture was developed so the cryomodule can be rotated 90° to allow access to the center (Figure 3).

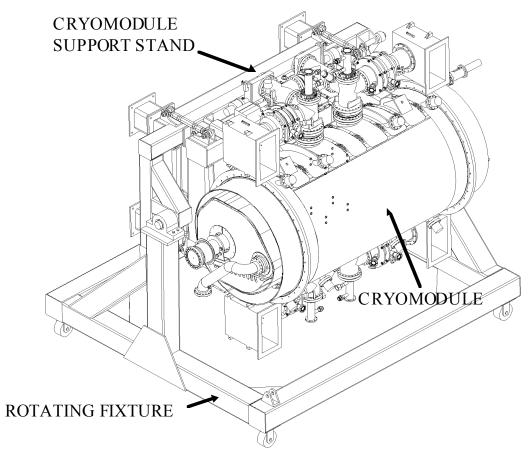

Figure 3. Rotating assembly fixture.

4 CONCLUSION

One never appreciates the value of a mock-up until after it has been built. It is a very useful and inexpensive tool for evaluating ideas and designs. It is also very useful as a tool to aid others in visualizing the concepts being proposed by the designers and engineers.

By highlighting shortfalls early in the fabrication cycle, it helps prevent schedule delays caused by redesign.

REFERENCES

[1] B.M. Campbell, “Design Status of the Cryomodules for the APT Linac,” Padoua, Italy (October 1998).

[2] B.M. Campbell, "Engineering Design of the APT Cryomodules," for LINAC98, Chicago, Illinois (1998).

[3] R. Gentzlinger, "Design, Analysis, and Fabrication of the APT Cavities, for PAC99, New York City (March 1999).

[4] R. E. Lujan, "Development of the SCRF Power Coupler for the APT Accelerator," for PAC99, New York City (March 1999).

[5] E.Newman, "APT Cryomodule Assembly Process and Mock-Up Model," for PAC99, New York City (March 1999).