

# A ROOM TEMPERATURE TEST BED FOR EVALUATING 700-MHz RF WINDOWS AND POWER COUPLERS FOR THE SUPERCONDUCTING CAVITIES OF THE APT LINAC\*

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## Abstract

Superconducting radio frequency (SCRF) cavities are used in the high-energy portion of the Accelerator Production of Tritium (APT) linac to accelerate the beam to approximately 1700 MeV. To accelerate the 100 mA proton beam and to maintain the field levels in the cavity, up to 420 kW of CW (continuous wave) 700-MHz rf power needs to be delivered to the cavity. This is done using two rf window and power coupler assemblies that can each transmit 210 kW. To evaluate developing window-coupler designs, a Room Temperature Test Bed (RTTB) has been built that utilizes a room-temperature copper coupling cavity for mating two power couplers together. Several parameters are being tested such as: (1) power coupler matching, (2) maximum power handling, (3) rf losses in the power coupler, (4) SCRF window/power coupler matching, and (5) power coupler/cavity coupling adjustability. The RTTB is also meant to be a conditioning stand for window-coupler assemblies that will go on cryomodules [1]. The design features of the coupling cavity, test stand & layout, vacuum system & controls, data acquisition, rf controls and contamination control will be discussed.

## 1 INTRODUCTION

To evaluate the high power transmission capabilities of the APT power coupler, a Room Temperature Test Bed (RTTB) has been built. Two couplers in transmission through a copper coupling cavity will be tested simultaneously. One power coupler [2] is used to feed the power (more than 500 kW) to the cavity, while the second coupler will act to remove the rf power and direct it to a 1 MW waste load. Coaxial rf windows [3] interface the power couplers to WR-1500 waveguide.

The coupling cavity is necessary to test the couplers as-built configuration. The tip geometry (a disk slightly larger than the coaxial center conductor of the coupler) does not permit a direct coupler-to-coupler transmission test. The use of a normal conducting (rather than a superconducting) cavity is highly desirable since it reduces the complexity of the test and it separates pure rf-issues of the design from those closely related to the aspects of operation in a cryogenic environment. Finally,

the turnaround time for re-testing after adjustments or swapping of components is reduced from about a week for a superconducting test to just several hours for a room temperature test.

## 2 COPPER CAVITY DESIGN

The rf design for this configuration is aimed at maximizing  $Q_o$ , minimizing  $Q_{ext}$  (good coupling and lowered cavity fields) and maintaining a short accelerating gap for field-emitted electrons. Low cavity fields and accelerating voltages may significantly reduce or even remove shielding requirements for the high power operation of the test stand. After a trade-off study regarding the criteria mentioned above, we opted for a pillbox cavity operated in a TM010 mode with couplers attached to the two end-walls. The cavity resonates at 707.6 MHz without the couplers present. The couplers, intruding into the cavity by 14 mm, lower this frequency to the nominal 700 MHz accelerator operating frequency. Table 1 gives a number of parameters for the copper test-cavity. All field and power levels are quoted for the nominal 210 kW operation power level.

To allow for proper tuning of the cavity without the power couplers, the sensitivity of the frequency with inner diameter of the cavity was calculated (with MAFIA 2D) for resonance without the couplers. The frequency was measured between iterations of machining the inner diameter until convergence on the desired frequency. The end plates were then brazed to the cylinder. The final resonant frequency after brazing was measured and agrees with the simulations.

The power deposited in the cavity was calculated with a  $Q_{ext}$  of 31 to be 450 W. The cooling system was designed for 7500 W deposited in the cylindrical region. This was to allow for a factor of safety and flexibility in cavity temperature as cavity temperature may be used for 'fine tuning' of cavity during operation. To remove the heat from the cavity, channels were machined in the cylinder prior to final braze and tuning. Two Plenums at each end, 0.75 in. x 0.25 in., distribute and collect the cooling water, and 20,  $\varnothing$  0.25 in. holes run the length of

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the cavity parallel to its axis. A water temperature increase of 3 °C was calculated for a flow rate of 11.8 gpm for a maximum cavity temperature,  $T_{max}$ , rise of 15 °C. Coolant entrance and exit paths are at opposite sides of the cavity to balance the pressure drop through all the cooling passages to achieve a uniform flow. Channel sizes were a balance between fabricability and flexibility in  $T_{max}$  of the cavity.

The cavity was made of OFE ASTM F68-93 Cu, with 28% Cu – 72% Ag 0.002 in. foil braze alloy used for the Cu-Cu joints, and 50% Cu – 50% Au alloy for the SST-Cu joints. See Figure 1. Final overall internal dimensions of the cavity are  $\varnothing$  328 mm and 250 mm in length.

Table 1: Pillbox Cavity Parameters

parameter	value	comment
$f_o$	707.6 MHz	measured with no couplers in
$f_{oc}$	700 MHz	couplers present
length	328 mm	measured
diameter	250 mm	measured
$Q_o$	33500	----
R/Q	122 Ohm	----
$P_{cav}$	450 W	total rf power deposited into cavity wall
$P_{cav}$	0.4 W/cm <sup>2</sup>	maximum power density on cavity wall
voltage	0.05 MV	V across cavity gap
$E_{peak}$	0.35 MV/m	peak electric field (at coupler tip)
$Q_{ext}$	31	----

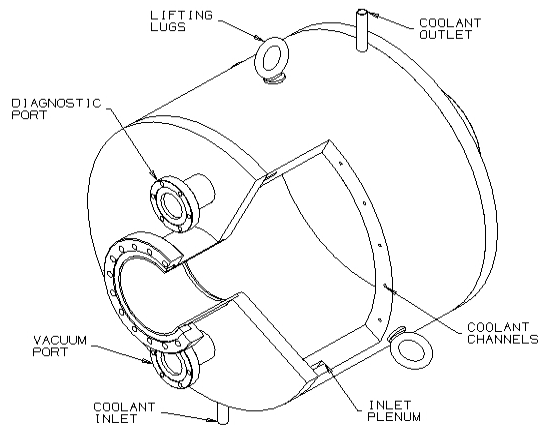


Figure 1: Pillbox Resonant Cavity View

### 3 RTTB STAND & LAYOUT

The RTTB stand was designed to accomplish several functions. See Figure 2. First, several power coupler and vacuum window assemblies will be transported from the clean room to the building where the stand is located for testing. The stand had to be able to support the components in a transfer by forklift between buildings (cavity, 250 lbs., power coupler, 150 lbs., and vacuum window assembly, 120 lbs. each). This meant that flexure of the table had to be a minimum. To assist and protect equipment during this transfer process, forklift fork guides were provided. The top of the table is a detachable aluminium mill plate, which allows flexibility for design changes later. The second attribute was to allow for a clean environment to connect assemblies to the copper cavity and for doing coupling adjustments with the power coupler tip. This requirement led to the need for a canopy that could support two ~800 cfm HEPA units, Lexan™ windows, and sufficient lighting to create a clean air, laminar flow environment for these tasks. The canopy is detachable and will also support individual components if assembly requires rigging equipment with the canopy in place. The third attribute was modularity. Adjustable feet, self contained electrical power and Instrumentation & Control distribution system, and isolation from other support equipment allows this.

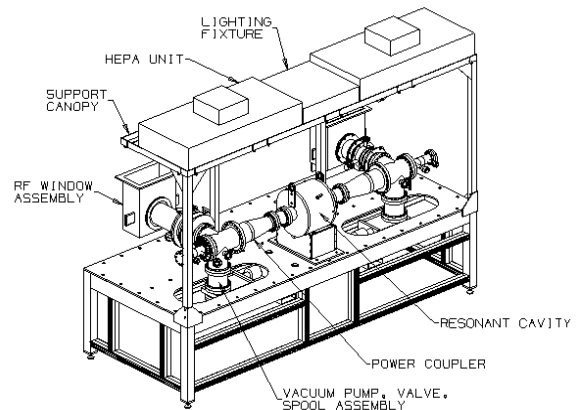


Figure 2: RTTB Test Stand

### 4 VACUUM SYSTEM & CONTROLS

The RTTB vacuum system has a Varian 300 l/sec turbomolecular pump for each of the two rf window/power coupler assemblies. There is also one Varian 70 l/sec turbomolecular pump on the copper cavity. The pumps were sized based on a vacuum model of the RTTB that was developed using MathCad™ and will provide enough pumping to meet the required operating pressure of  $1 \times 10^{-7}$  Torr. Each turbo has an electro-pneumatically actuated gate valve to isolate it from the vacuum system. Each turbo also has an electro-pneumatically actuated foreline valve and one Varian 300

1/min dry scroll pump that backs all three turbomolecular pumps.

A Modicon Programmable Logic Controller (PLC) was used to control the pumps and valves. The PLC also provides the interlocks that will prevent rf operation if the vacuum, power coupler air flow, cavity water flow or cavity temperature conditions are not met. LabView™ will be used to communicate with the PLC and will provide a graphical user interface that will be very intuitive and easy for an operator to use.

Each rf window/power coupler assembly has a Granville-Phillips Stabil-ion gauge™ and Convectron™ gauge to measure pressure. There is also a Stabil-ion gauge™ on the cavity and a Convectron™ gauge on the foreline. The process control functions on the Stabil-ion gauge™ controller are used to provide set-points to the PLC for vacuum interlocks.

There is a residual gas analyzer (RGA) mounted on the cavity that has LabView™ drivers provided by the vendor. By using LabView™ to acquire the total pressure, partial pressure, rf power, temperature of the cavity, power couplers and rf windows there will be a very good understanding of the vacuum system performance under operating conditions. The LabView™/PLC control system was successfully used on the LEDA RFQ and rf window vacuum systems [4]. It has proved to be reliable and easy to maintain. It is also a very flexible system that will allow the RTTB vacuum system to be easily reconfigured if necessary for future experiments.

## 5 DATA ACQUISITION

Data acquisition is handled by LabView™, running on a Power Macintosh™. A National Instruments SCXI™ rack contains modules for digitizing RTDs and thermocouples. Fifty RTDs are used on the exterior surfaces of the rf windows, power couplers and copper cavity. Eight thermocouples are used inside the power coupler inner conductors at various points of interest.

The LabView™ program also reads incident, reflected and transmitted rf power via a GPIB™ interface connected to two Hewlett-Packard 438A power meters. Vacuum data is recorded by SCXI™ digitization of three 0-10 volt analog voltages provided by the model 360 Granville-Phillips Stabil-ion gauge™ controllers. In addition, the Power Macintosh™ interfaces with an Allen-Bradley PLC which monitors critical waveguide and rf window locations for arcs by way of 7 fiber-optic links and arc detector units.

The data taking repetition rate is user selectable. For an extended duration test (weeks) data collection can be intentionally slowed down providing a reasonable data file size for all collected data. All the experimental data is stored on the Power Macintosh™ hard drive using a spreadsheet format. Ultimate data archiving is achieved by transferring these files to a ZIP drive.

## 6 RF KLYSTRON CONTROLS

The klystron transmitter, which can provide up to 1 MW of rf power at 700 MHz to the RTTB, is located more than 100 feet from the test bed on a second story mezzanine. For ease of operation, a remote control method was implemented at the RTTB location to allow all rf control functions without leaving the test area. A SUN Workstation™ (running the LANL EPICS control system) communicates over a serial coaxial “data highway” to an Allen-Bradley PLC at the klystron transmitter station. With this in place, all klystron functions are controlled while maintaining control over the experimental area.

There are two main klystron shutdown features, which are hardwired: (a) loss of cooling water to the 1 MW rf waste load. This will inhibit klystron operation by shutting down the high voltage to the tube and (b) occurrence of arcs at the seven monitored locations. This fault will remove the klystron drive for 100 milliseconds.

## 7 CONTAMINATION CONTROL

Contamination control is achieved by mounting two self-driven HEPA filters each providing ~800 cfm of nearly laminar flow, 0.3 micron filtered air over the power coupler/window surfaces. Support structures for the components consist of Teflon guided rails that allow flexibility in design and minimize particulate production during component change out.

## 8 CONCLUSION

The RTTB test stand is ready for testing SCRF power couplers and SCRF 700 MHz window assemblies. The new SCRF clean room is completed and will facilitate cleaning both power coupler and window assemblies before installation onto the test stand. Although testing is planned for mid-April, we're confident this configuration will be a valuable testing tool to evaluate power coupler and rf window designs. This test stand design may also be used for conditioning of assemblies prior to installation in the APT plant.

## 9 REFERENCES

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