

HIGH POWER TESTING OF THE 402.5 MHZ AND 805 MHZ RF WINDOWS FOR THE SPALLATION NEUTRON SOURCE ACCELERATOR*

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Abstract

Historically, Radio Frequency (RF) windows have been a common point of failure in cavity input power couplers; therefore, reliable RF windows are critical to the success of the Spallation Neutron Source (SNS) project. The normal conducting part of the SNS accelerator requires six RF windows at 402.5 MHz and eight RF windows at 805 MHz [1]. Each RF window will transmit up to 180 kW of average power and 2.5 MW peak power at 60 Hz with 1.2 millisecond pulses. The RF windows, designed and manufactured by Thales, were tested at the full average power for 4 hours to ensure no problems with the high average power and then tested to an effective forward power level of 10 MW by testing at 2.5 MW forward power into a short and varying the phase of the standing wave. The sliding short was moved from 0 to 180 degrees to ensure no arcing or breakdown problems occur in any part of the window. This paper discusses the results of the high power testing of both the 402.5 MHz and the 805 MHz RF windows. Problems encountered during testing and the solutions for these problems are discussed.

EXPERIMENTAL SETUP

Window Geometry

The 402.5 MHz and 805 MHz windows are planar windows, shown in Figures 1 and 2, respectively. The vacuum side of both windows is copper plated stainless steel waveguide, and the air side is aluminum waveguide. The 402.5 MHz window consists of 1/2 height WR 2100 waveguide on the vacuum side and full height WR 2100 on the air side. The 805 MHz window consists of full height WR 975 waveguide on both the air and the vacuum side. The ceramic in both windows is a high purity alumina ceramic.

Test Stand Configuration and Diagnostics

A 2.5 MW klystron was used as the RF source [2]. Assuming waveguide and circulator losses of up to 8%, 2.3 MW of peak RF power was available in the test area. In a transient condition, 2.5 MW was obtained. The steady state power was 2.3 MW peak power.

High average power testing and high peak power testing require different test configurations. In the high average power testing the forward power is transmitted through the windows into a matched load, as shown in Figure 3. The peak power test setup is the same, but instead of a load a sliding short is used. The windows are

tested at the full average power and duty factor for four hours; and then peak power tested to an effective forward

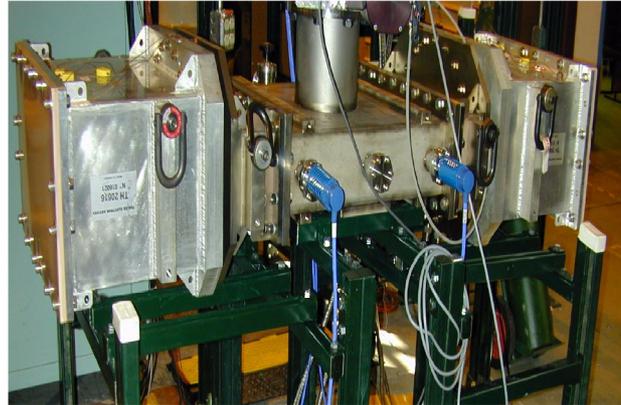


Figure 1: 402.5 MHz Windows and Vacuum Waveguide.

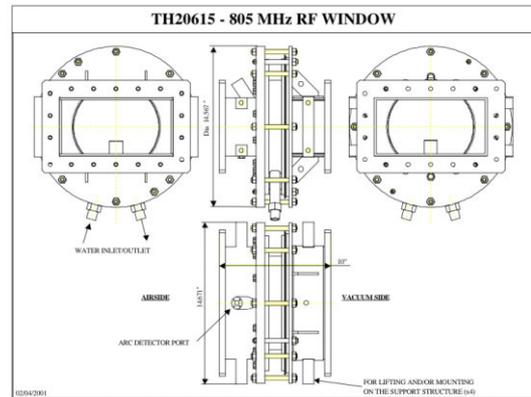


Figure 2: 805 MHz Window Schematic

power level of 10 MW by testing at 2.5 MW forward power into a sliding short and by varying the phase of the standing wave. The sliding short was moved from 0 to 180 degrees to ensure no arcing or breakdown problems occur in any part of the window.

The RF power was measured with four directional couplers, as illustrated in Figure 3. The vacuum pressure was measured with two ion gauges that are interlocked to turn off the RF power if the pressure rises above 1×10^{-7} Torr. The water inlet and outlet temperatures and surface temperatures are also measured. Fiber optic arc detectors are used on both the air side and the vacuum side of the ceramic. If an arc is detected, an interlock turns off the RF power for 1.6 seconds. A LabVIEW data acquisition system is used to monitor, display and record the RF power, pressure, water inlet and outlet temperatures, surface temperatures and the total number of arcs

detected. The control racks for the test stand are shown in Figure 4. The racks are, from left to right, the 805 MHz arc detection rack, two 805 MHz transmitter racks; the computer rack for LabVIEW data acquisition program; a rack containing the HV ready/ crowbar interlock chassis, the ion gauges for the window vacuum; a scope displaying HV pulse waveform, pulse generator and RF signal generator; and a rack with 402.5 MHz arc detectors, the vacuum interlocks and the gate valve controllers.

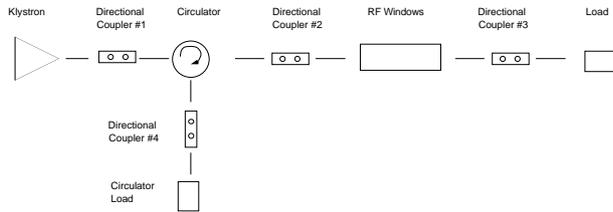


Figure 3: Test Block Diagram for Average Power Testing.



Figure 4: Control Racks for RF Window Test Stand.

EXPERIMENTAL RESULTS

High Temperature Bake Out Results

A high temperature vacuum bake out is done to release particles and water vapor embedded in the ceramic and vacuum waveguide surfaces. During the bake out, the windows are held between 150 BC to 200 BC until the pressure drops below 5×10^{-7} Torr as shown in Figure 5 and Figure 6. It typically takes 5 hours for the windows to reach the required temperature. It takes 10 to 15 hours, once the windows are at the required temperature, for the vacuum level to decrease to below 5×10^{-7} Torr. Because of safety regulations, the bake out is not allowed to run unattended. The bake out requires 3 to 4 days.

Experiments done to validate the need for the bake out showed that the bake out is essential to conditioning the windows successfully and expediently. Testing of two unbaked 402.5 MHz windows was attempted, but it was not successful because the vacuum pressure was too high.

These two windows were then baked out and then successfully conditioned and tested. Two 402.5 MHz windows were baked out, vented to nitrogen, exposed to air, and then re-pumped and tested at high power. There was not a second bake out after the windows were exposed to air. The windows were still successfully conditioned and tested.

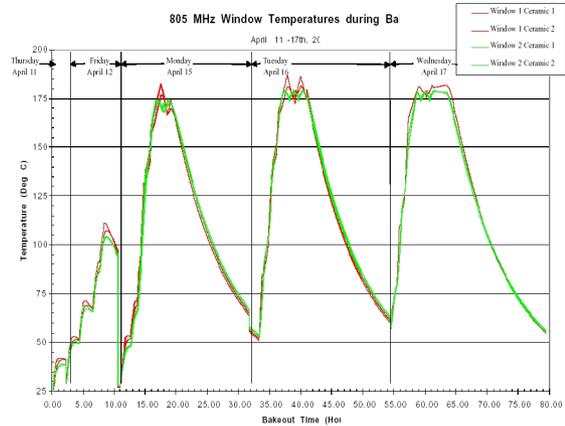


Figure 5: Temperature vs. Time during Bake Out

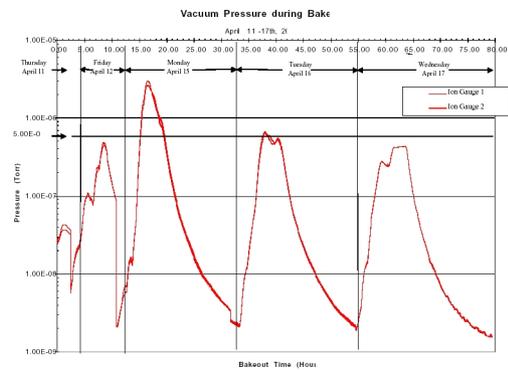


Figure 6: Pressure vs. Time during Bake Out

High Power Test Results

The conditioning procedure consists of beginning with a low duty factor and gradually increasing the power level. Next, the peak power level is lowered, the duty factor is increased and then the peak power level is gradually raised at the new duty factor. For the 805 MHz windows, a graph of the peak power verses time is shown in Figure 8. Once the windows are conditioned, the four hour heat run is done at full power and duty factor, also illustrated in Figure 8. It took about 10 hours to condition the two 805 MHz windows to the full power and duty factor. There were only a few arcs and the conditioning rate was limited by the pressure, as expected.

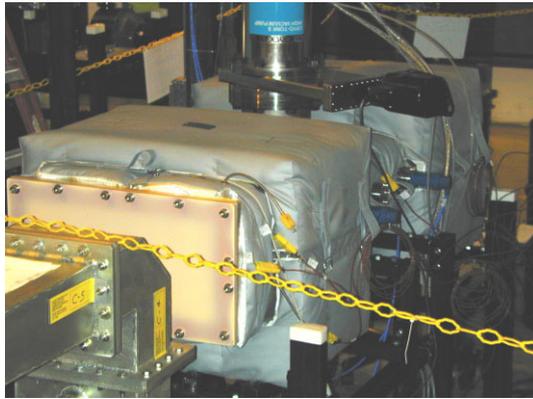


Figure 7: Windows in Heat Blankets during Bake Out.

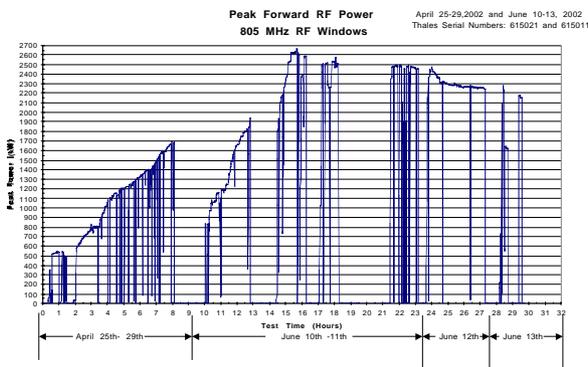


Figure 8: 805 MHz Window Peak Power vs. Test Time

It took 5 hours to condition the first two 402.5 MHz windows to 500 kW. The available power supply voltage was limited, thus they were run at 500 kW for seven more hours. Once the full power supply capacity was available, they were conditioned up to full power in two hours. This results in a total conditioning time of 7 hours. The second two 402.5 MHz windows were conditioned up to 500 kW in 4 hours and then once the full power supply capacity was available, they were conditioned up to full power in 3 hours. Thus, the average conditioning time for all 6 windows was 8 hours.

Problems Encountered during Testing

Two separate problems were encountered while testing the 402.5 MHz windows. The first problem was that a RF leak was found on the top surface of the waveguide in the region of the ceramic. The leak was measured at 9.7 mW/cm² at a distance of 10 cm from the surface at 6.4 kW average power. At 2.5 MW peak power and 180 kW average power, this extrapolates to 272 mW/cm². This exceeded the specified maximum leak rate of 1 mW/cm² at a distance of 10 cm. This window was sent back to Thales, where it was repaired, but has not yet been re-tested. The leak was due to an inadequate RF seal caused by loose bolts around the ceramic, as shown in Figure 9.

The Thales assembly procedure was modified and additional post-delivery inspections were implemented. The second problem encountered during testing is that the second pair of 402.5 MHz windows are arcing during the peak power test with the sliding short. This pair of windows does not arc at all when run into a matched load. When run into a sliding short, both circulator and window arcs occur at the same time. This problem has not yet been resolved and it may be due to arcs in the waveguide run and/or circulator and not due to window arcs. To help isolate the arcing problem, air will be blown through the waveguide to reduce window arcs during the next sliding short window tests.

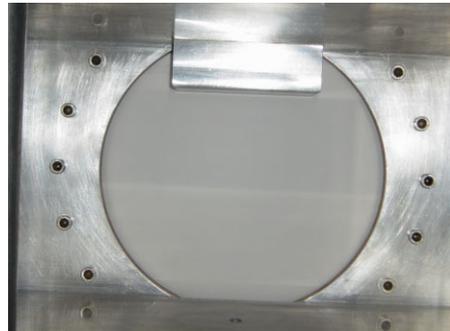


Figure 9: 402.5 MHz Inner Bolt Circle

CONCLUSIONS

Two of the eight 805 MHz windows and four of the six 402.5 MHz windows have been successfully baked out, conditioned and tested. The test results are very important for four different reasons: First, they prove the design concept of the windows. Second, they have shown that the bake out is an essential part of the testing process. Windows could not be conditioned and tested without a bake out. Third, if a window is baked out and then vented to nitrogen, it retains the benefits of the bake out and does not need to be re-baked out. Previous work has indicated that if a window is baked, conditioned, and then vented to air, it can be reconditioned quickly [3]. Fourth, we have learned that the average conditioning time for the windows is 8 hours. Hence it is not feasible to condition windows while conditioning the accelerator. Therefore, the bake out and the conditioning of the windows on the test stand is absolutely essential to the success of the SNS project.

REFERENCES

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