

In-House Repair of a 30 Megawatt, S Band Klystron*

R. Sachtschale, P.G. O'Shea, M. Ponds, G. Swift
Duke University, Free Electron Laser Laboratory
Box 90319 Durham, NC 27708-0319

Abstract

This paper documents the repair and reconditioning of an ITT 2960 klystron that had been at atmospheric pressure for eight months due to a leak in the compression seal for the waveguide window. All work was done in the Duke FEL Vacuum Shop by laboratory staff without any external purchases. The reconditioned klystron is currently being operated at full power on the injection linac for the electron storage ring at Duke.

1 Introduction

With the passage of time since this abstract was first submitted, the Duke FEL Lab has refurbished and put into service a second 30 Megawatt ITT 2960 klystron. These tubes had never been operated and developed vacuum leaks. The leaks occurred during shipping from Stanford to Duke or during storage at Duke while facilities were being constructed. The tubes were sent back to ITT for repair evaluation. The total repair cost being \$37,000. Since the tubes have barium dispenser cathodes, rather than coated oxide cathodes, it was felt that the cathodes could be successfully reactivated once the vacuum problems were solved. See [1] for a thorough description of microwave tubes and their cathodes.

The repair process can be summarized as follows:

- Build the necessary support stands and fixtures.
- Connect vacuum hardware to support leak detection and bake-out.
- Leak detection.
- Repair or isolation of leak.
- Bake-out.
- Reactivation of cathode.
- Low-level permeance test.
- High-power testing.

The repair of the first tube (ITT serial number 4016) was started on 14 April 1994, with completion of high-power testing on 14 July 1994. Repair of the second tube (ITT serial number 4011) was begun in September 1994, with high-power testing completed on 28 February 1995. Both tubes are currently being

operated in excess of 30 Megawatts on the injection linac for the storage ring [2, 3].

2 Construction of Mechanical Support Fixtures

The first task was to build a mobile stand (similar to an engine stand) to support the tube while it was being repaired. Upon return from ITT, the pinch off port on the output waveguide of the klystron had been ground off. A convoluted bellows with a 2.75" con-flat flange was welded to the ground off port. Brackets were made from 1/8" aluminum plate to support a 20 l/s ion pump, bakeable valve and bellows. The brackets were fastened to a protrusion on the side of the klystron collector. This protrusion was originally used for mounting a bracket to support a C-magnet for the OEM 8 l/s ion pump. These components are displayed in figure 1.

3 Pump-Down, Leak-Check and Bake-out Preparation

Leak-checks were performed with helium and a mass spectrometer leak detector. The first tube worked on had a leak around the compression seal for the output waveguide window. Our lab doesn't have the necessary rf-induction hydrogen furnace for such a repair. It was decided to leave the window in place and add a waveguide elbow, with a factory installed window, from our inventory. This also required a transition piece to which a 10 l/s ion pump was attached.

The second tube had a leak in a braze joint between the vacuum side of the waveguide and the OEM 8 l/s ion pump. The ion pump and the leaky braze joint were removed using a tubing cutter. A 2-1/8" con-flat flange was welded to the remaining stub and sealed with a blank flange. The second tube did not require the addition of a second waveguide window.

Once the leaks were repaired, the tubes were stripped of all ancillary components in preparation for a vacuum bake-out. The output waveguide above the rf window was evacuated and pumped continuously by a sieve trapped roughing pump. The collector cooling jacket was purged with N_2 at very low flow. The klystron was wrapped with heater tapes and covered with foil. An auxiliary roughing cart was attached to the bakeable valve. The base pressure prior to bake-out was 3×10^{-8} torr at the 20 l/s pump with the auxiliary pump cart also pumping.

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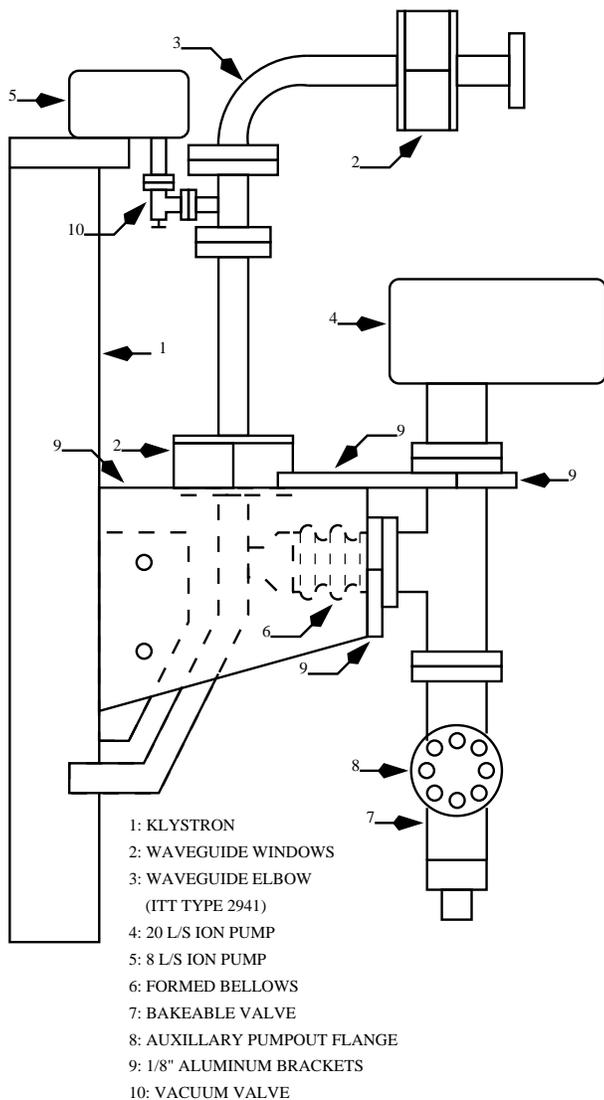


Figure 1: Mounting of Hardware for Klystron Repair

4 Bake-Out

The first klystron was slowly heated over a period of 10 days, reaching a peak of 400°C for 72 hours. The vacuum was kept below 10^{-6} torr during bake-out. The temperature was lowered at a maximum rate of 1°C/min. Two days after bake-out the pressure was $2 * 10^{-10}$ torr at room temperature.

Due to faulty heater tapes, the second tube was heated for 21 days and reached a peak temperature of 380°C for 6 days. Following bake-out the pressure at the 20 l/s ion pump was too high ($5 * 10^{-6}$ torr) with the auxiliary pump cart valve closed. The auxiliary pump cart contains a residual gas analyzer (RGA). The pump cart was valved in and the klystron was helium leak checked using the RGA as a detector. A leak was found in the ceramic to metal braze of the 20 l/s ion pump high voltage feed-through. The leak was sealed with Vac Seal (a silicone resin).

5 Reactivation of the Cathode

Following bake-out the cathode filament was slowly powered up while monitoring vacuum pressure. Pressure was maintained in the 10^{-7} torr range. RGA spectra showed H_2 to be the major gas component. To assist in the pumping of the H_2 a Titanium Sublimation Pump on the pump cart was activated daily for 1 minute. At 450W of cathode filament power, it has taken several months for the pressure to come down into the 10^{-9} torr range. The tube was operated at full power in this condition while keeping a daily record of the ion pump current.

Once the cathode filament was at full power, a low level permeance test was done at -500 volts. The μ perveance was found to roll off at 2.0 for a filament power of 200W.

At this point the tube is ready for reassembly and high-power testing.

6 High-Power Testing

For high-power testing the tubes were installed in 300kV, 2μ sec. modulators. First the ion pumps and cathode filaments were restarted. The μ perveance was checked and plotted against filament power. The results of both tubes are shown in figure 2. #4016 is the first tube we reconditioned and #4011 was done second. We believe that much of the offset results from differences in measuring devices between the two modulators. Principally the high voltage capacitive dividers and the calibration of the filament power supplies.

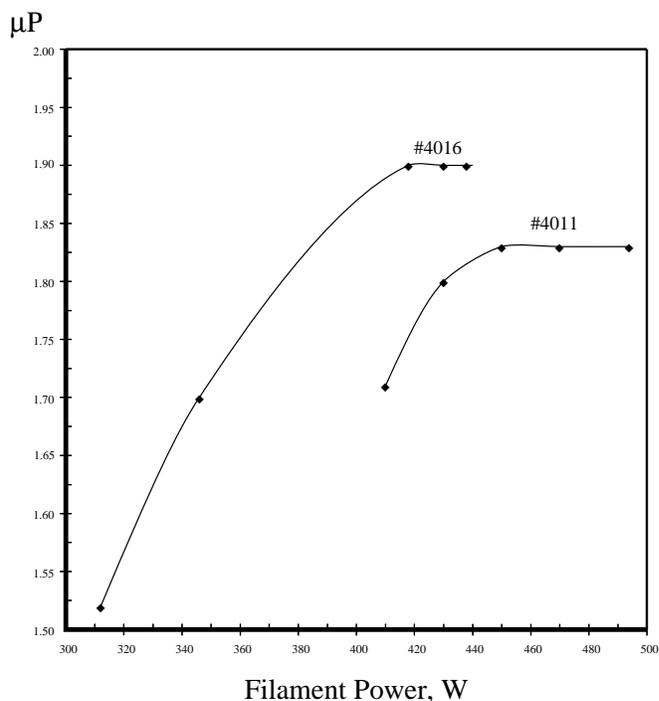


Figure 2: Micro-Perveance vs. Filament Power

It took the better part of a day to get the tubes up to 300kV. The tubes were operated at various drive voltages and the input

power was increased until the output began to saturate. Plots of this data for tube #4011 are shown in figure 3.

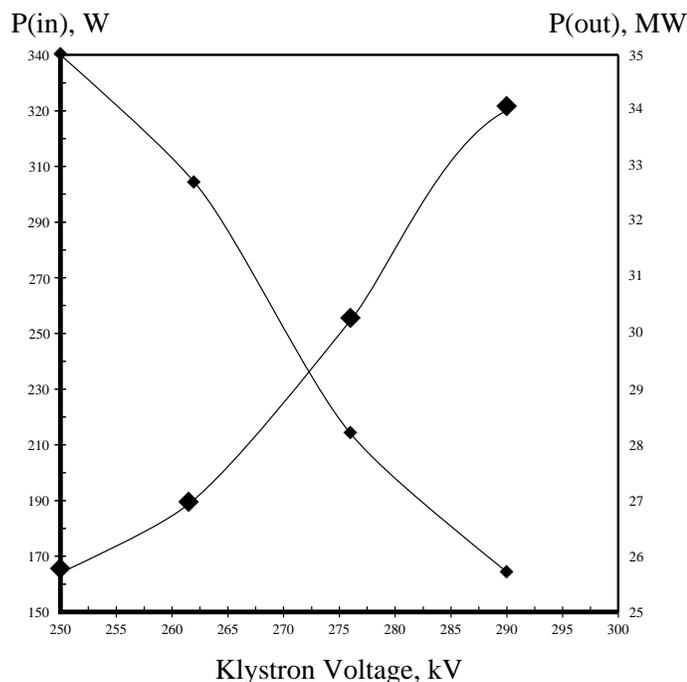


Figure 3: Saturated Input and Output RF Power vs. Klystron Beam Voltage

Finally klystron output power is plotted against rf input power for a fixed beam voltage. A plot from the data for tube #4011 is shown in figure 4.

7 Conclusion

The repair of our ITT 2960 klystrons has been a great success. The skills that were gained will enhance our abilities to resurrect klystrons used in old accelerators or obtained from government surplus lists. Future plans include the repair of an inoperable RCA klystron. The plan is to remove the oxide cathode and replace it with a new dispenser cathode. If successful, we should be able to upgrade the cathodes in all of our old RCA klystrons. These tubes can't provide more than 20 megawatts of power with their vintage oxide cathodes. The installation of dispenser cathodes should yield 30 megawatts of rf power.

8 Acknowledgements

We would like to acknowledge the dedication of the entire team of people at the Duke FEL Lab. Their dedication, to the many requests in attempting the impossible, has resulted in an astonishing and ongoing string of success.

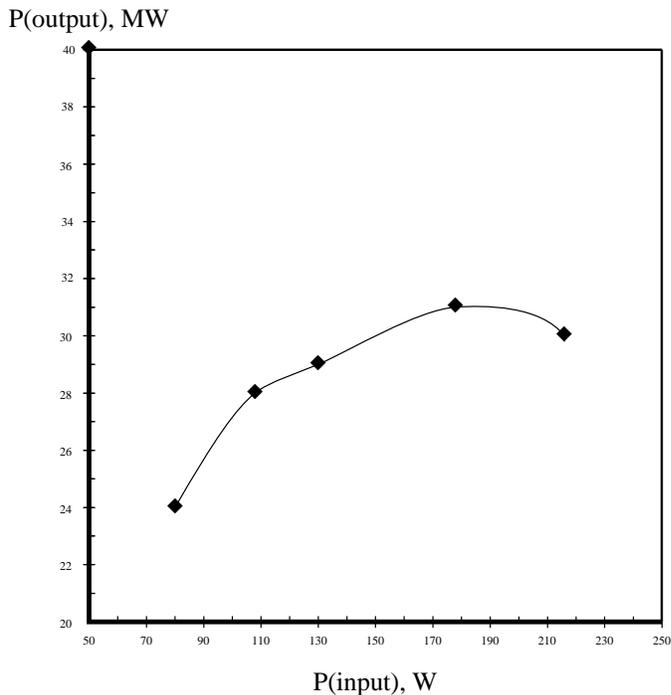


Figure 4: Klystron Output Power vs. RF Input Power at 290kV

References

- [1] A.S. Gilmour, Jr. *Microwave Tubes*. Copyright 1986, Artech House, Inc. Dedham, MA 02026 ISBN: 0-89006-181-5.
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- [3] V.N. Litvinenko et al. *Commissioning of the Duke Storage Ring*. In these proceedings.