THE CATHODE TEST STAND FOR THE DARHT SECOND-AXIS*

C. Fortgang, C. Hudson**, D. Macy**, M. Monroe, K. Moy**, D. Prono
Los Alamos National Laboratory, Los Alamos, New Mexico 87545 USA
** Bechtel Nevada, Santa Barbara, California 93111 USA

Abstract

The injector for the DARHT second-axis will use an 8" thermionic dispenser cathode. Because the cathode is relatively large and requires a large amount of heat (5 kW) there are certain engineering issues that need to be addressed, before the DARHT injector reaches the final design stage. The Cathode Test Stand (CTS) will be used to address those concerns. The CTS is a new facility, presently under construction. The CTS will consist of a high-voltage pulse modulator, a high-vacuum diode test-chamber, and a short beam-transport section with diagnostics. This paper discusses the status of the project.

1 INTRODUCTION

The DARHT second-axis (DARHT-2) requires a 3.2 MV, 4 kA, 2 μsec injector [1]. The injector will use an 8" diameter thermionic dispenser cathode. Because such a cathode has requirements exceeding existing cathode assemblies, we are building a facility for measuring its most important engineering features. The cathode will be tested in situ as part of an operational electron-gun which has most of the design features envisioned for the DARHT-2 injector. The cathode requires 5 kW of heater power. We will measure: temperature uniformity over the cathode surface, differential thermal expansion between the cathode and focusing electrodes, and outgassing and vacuum properties. We will also test field-emission from the focusing electrodes up to an electric-field strength of 160 kV/cm. We will extract a 500 kV, 500 A beam using a PFN and a step-up transformer to generate a 1-μsec pulse. After a modest compression of the beam and a short transport section, we will measure the beam profile to assess electron-current emission-uniformity, paying particular attention to beam halo in preparation for further studies of emittance growth due to non-linear focusing forces.

2 GUN DESIGN

The electron-gun design for the CTS is very similar to that being designed for DARHT-2 by Lawrence Berkeley National Lab [2]. It is not identical because the electrical characteristics of the CTS (500 kV, 500 A) are more modest than DARHT-2 (3.2 MV, 4 kA). However, compared to the DARHT-2 design the CTS gun uses the same 8" thermionic cathode, has focusing electrodes with the same shape and is also a high perveance design (1.4 μP). The gun is designed using the computer code EGUN. The gun geometry and the electron-beam trajectory are shown in figure 1.

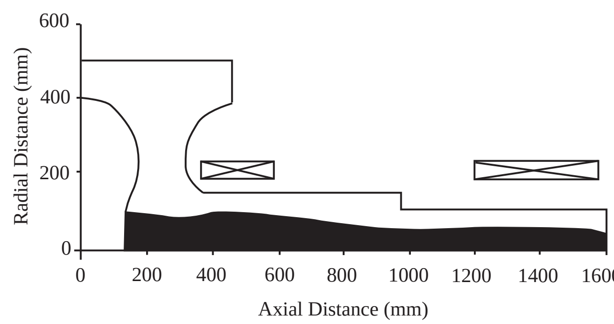

Figure 1: Electron gun design and beam envelope. Note axes are not scaled equally.

The injector uses two focusing solenoids to extract and transport the beam. Both solenoids are located down stream of the anode and have a peak magnetic field on axis of about 200 Gauss. The primary purpose of the magnetic optics is to transport the beam with a small amount of beam compression and negligible emittance growth. Under these circumstances a beam profile measurement at the end of the beam transport section can be used to determine electron-emission uniformity at the cathode.

The gun uses a M-type dispenser cathode, i.e., BaO impregnated into a tungsten matrix with a few thousand Angstrom Os/Ru coating sputtered on the surface to enhance emission and life. The cathode is heated with two counterwound filaments supplying about 5 kW of heater power. The focus electrode follows the standard Pierce diode design (67 degrees) and extends out to a large (stainless steel or molybdenum) radius shroud to minimize electric field stress.

3 EXPERIMENTAL SETUP

The configuration of the gun inside its vacuum chamber is shown in figure 2. After initial thermo-mechanical experiments, that don't require beam extraction, a beam transport line will be attached to the diode vacuum chamber. The cathode is supported by a 22" long ceramic insulator stack. Stainless steel rings are used to grade the

* Work supported by the US Department of Energy.

electrical stress along the stack. On the oil side, torlon rods under tension are used to maintain the insulator stack under compression and help support the cantilevered cathode assembly which weighs about 400 pounds. Radial and upstream heat shields surround the cathode structure to prevent heat loss and to maintain temperature uniformity. Water cooling is provided to the cathode support structure and shroud.

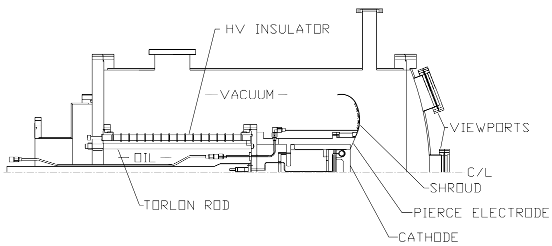

Figure 2: An assembly drawing of the gun and vacuum test chamber.

The vacuum chamber for the gun has 1 cryopump (4000 liters/sec) and 2 turbo pumps (500 liters/sec each). Because the cathode can be easily poisoned by contaminants (e.g. water, hydrocarbons) only metal seals are used and all components are to be baked for 10^{-9} Torr vacuum operation. There are several viewports on the vacuum chamber to be used for instrumentation. Ports are also available to insert quartz heating elements for in situ baking.

4 HIGH VOLTAGE MODULATOR

The HV modulator consists of a solid-state switching power supply, two 7-section PFNs wired in parallel, and a HV step-up (13:1) transformer. The modulator is presently being commissioned using a 1 kΩ dummy load. Each PFN has a characteristic impedance of about 11 Ω. An example of the modulator output and a simulation of the output are shown in figure 3.

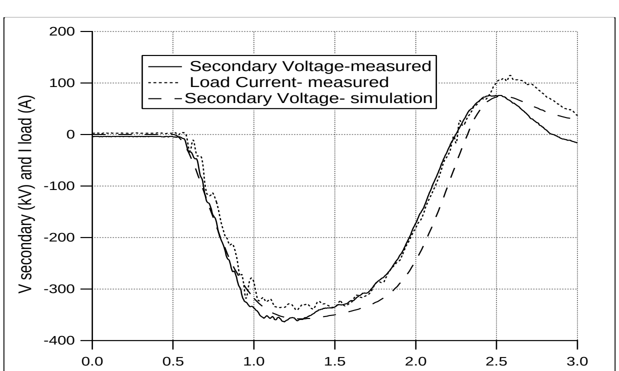

Figure 3: Modulator output waveforms compared with a circuit model simulation.

The modulator output voltage shown in figure 3 has unacceptable droop. We are in the process of replacing the PFN inductors with variable inductors. This will give us the ability to vary the waveform pulse shape and make it more constant. The modulator is capable of running at 10 Hz but we envision running the gun between 0.1 Hz and 1.0 Hz.

5 PLANNED EXPERIMENTS

The experiments to be performed on the CTS can be grouped into two categories, those without beam and those with beam. Experiments without beam will consist of measuring thermal, mechanical, and vacuum properties of the gun. Because of the high heat load (5 kW) some differential thermal expansion of components is expected. In particular, we will measure relative movement between the cathode, Pierce electrode, and shroud. EGUN simulations indicate that relative displacements of ~1mm have adverse effects on the beam quality. Pyrometers will be used to measure thermal uniformity on the cathode surface. The cathode is heated to 1100 degrees centigrade and a temperature uniformity of ±5 degrees is desired to maintain electron emission uniformity to a few percent over the 324 cm^2 cathode surface area. If we find that the temperature uniformity is greater than desired the 2 cathode filaments will be reconfigured to run off independent power supplies to gain more control of the heat deposition profile.

Another important experiment for the CTS regards field emission from the shroud. Field emission can cause breakdown and contamination of the cathode. The peak electric field at the shroud surface for the DARHT-2 injector is 160 kV/cm. The peak electric field during beam extraction for the CTS gun is only 39 kV/cm. Therefore to test for field emission from the shroud we plan to use a small grounded electrode placed close to the shroud to locally enhance the electric field. The experiment will be performed using a HV pulser with little energy storage. In this way we will achieve a high-electric field with negligible current emission from the cathode. This experiment will be performed with a hot cathode providing the same vacuum environment (dominated by the barium outgassing from the cathode) that is present when the gun is being pulsed normally.

After the first phase of experiments are complete a short beam line (~ 1m) will be installed to transport the beam to a beam profile diagnostic (see figure 1). Simulations show that with two solenoids (20 cm and 40 cm long) the beam can be transported with negligible emittance growth. By measuring current density at the end of the transport section with a beam profile diagnostic we will assess beam current-emission uniformity at the cathode surface.

6 SUMMARY

The CTS is a new facility under construction. It will be used to investigate critical engineering issues for the DARHT-2 electron gun. The modulator is built and operating. The gun is in the final design stage and fabrication of some parts has begun.

7 REFERENCES

[1] H. Rutkowski, An Induction Linac for the Second Phase of DARHT, presented at this conference.

[2] E. Henestroza, et al., Physics Design of the DARHT Electron Beam Injector , presented at this conference.