

# Vacuum System Design of the MIT-Bates South Hall Ring

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## Abstract

The MIT-Bates Linear Accelerator Center is now in the commissioning stage for the new South Hall Ring (SHR). The SHR is a 1 GeV electron storage/stretcher ring with a 190 meter circumference and is designed for circulating beams of 80 mA. The SHR vacuum system was completed in January 1993 with commissioning starting in February. This paper describes the design of the vacuum system, hardware developed and operational performance during commissioning.

## I. INTRODUCTION

The vacuum system for the SHR is an all metal system which is designed and constructed to operate in the Ultra High Vacuum (UHV) regime. The following parameters have been used in the design of the vacuum system:

1. Energies from .3 to 1 GeV, maximum circulating currents of 100 mA, bending radius of 9.14 m. This yields a maximum synchrotron power loss of approximately 1 kW.
2. Design goal of static pressures less than  $5 \times 10^{-10}$  torr. Dynamic pressures of  $2 \times 10^{-9}$  torr with a stored beam after 100 Ah of operation.
3. Ability to recover one quadrant of the ring in a 24 hr period from planned or accidental venting.
4. Ability to monitor pressures with a computer interface and to log data. Use of residual gas analyzers (RGA) to

leak check and diagnose problems.

5. Minimum service life of 10,000 cycles or 10,000 hours on all equipment.
6. Use of 316L stainless steel and Conflat type flanges in most construction. Very large flanges use Helicoflex Delta Seals.
7. Ability to perform in situ bakeout to 150 C.
8. All vacuum equipment including pumping ports, chambers, valves, beam monitors, bellows, and transition sections are designed with a smooth internal bore to limit beam induced RF wake fields.

## II. OPERATION

From atmosphere, only one quadrant at a time may be roughed out. First, a dry diaphragm pump is used to get to 27 in. Hg and then a large liquid nitrogen cooled sorption system with capacity of 1.7 million torr-liters is used to provide a totally oil free pump out from atm. to  $5 \times 10^{-4}$  torr. At this pressure, the starcell triode ion pumps easily start and quickly achieve  $5 \times 10^{-7}$  torr. All dipole ion pumps and dipole vacuum chambers have a direct current heated ST 707 non-evaporable getter pumps (NEGs). We then activate the NEGs for one hour at 400 C while monitoring the Ion pump current to keep the entire system in the  $10^{-5}$  torr range. After all the ion pumps and NEGs are operating, the base static pressure

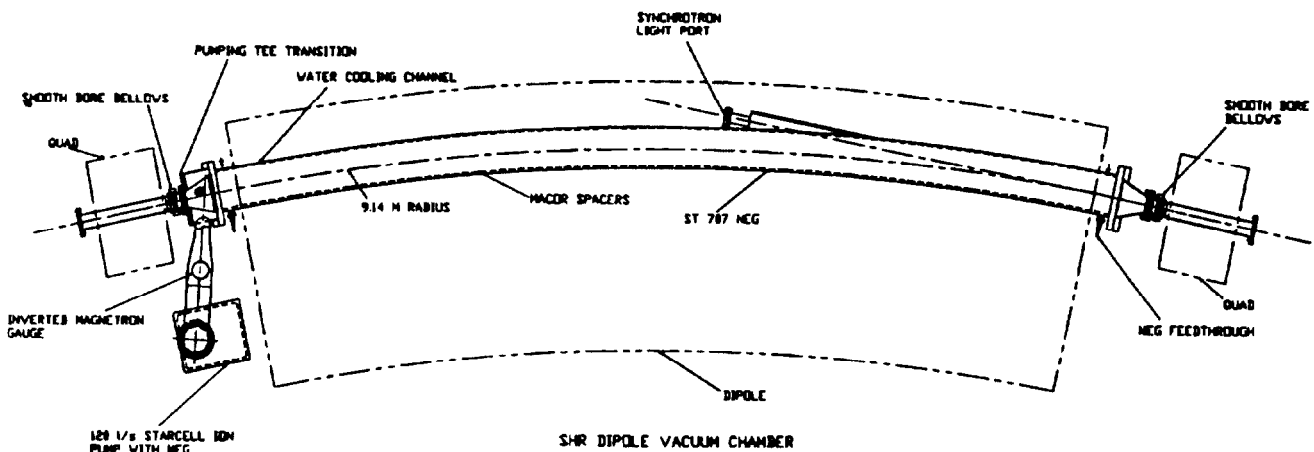


Figure 1.

quickly drops to  $5 \times 10^9$ . After about a week, the pressure decreases to between  $3 \times 10^9$  and  $8 \times 10^{10}$  unbaked.

### III. DIPOLE VACUUM CHAMBERS

There are sixteen 22.5° dipole vacuum chambers in the SHR lattice (see Figure 1). They are fabricated from commercially available 6" x 2" x .120 wall 316L stainless steel rectangular tubing. 316L was chosen for its low magnetic permeability. The tubing is bent the hard way in 20 foot sections to a radius of 9.14 m. The bent tube is then machined for the NEG electrical feedthroughs, synchrotron light ports and to final length. After a chemical cleaning, the flanges and ports are TIG welded using argon as a backing gas. After a final clean, all the chambers were mounted to test setup where they were pumped down, leak and RGA checked, and baked at 200 C for 48 hr. All chambers reached  $5 \times 10^{10}$  torr before being removed from the test setup and installed in the ring.

Incorporated into the dipole vacuum chambers is a NEG strip which gives localized pumping to desorbed getterable gases (for example  $H_2, N_2, O_2, Co$ ). The strips are held to the inside radius of the chamber on Macor spacers and connected to the outside by two high current feedthroughs. The NEG is a non-magnetic Constantan strip with a Zr-V-Fe composition sintered on to it. The NEG is activated by passing 50 A through it causing resistive heating to 400 C. The strips have a high pumping speed of .71/s/cm<sup>2</sup> for  $H_2$ . At pressures envisioned in the ring, activation will only be needed twice a year.

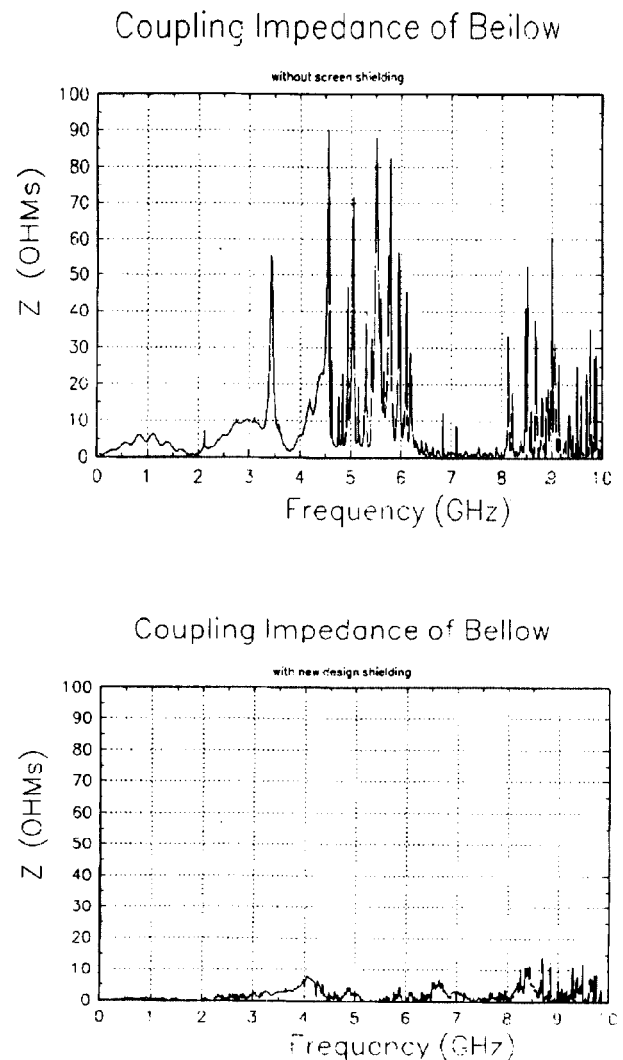
Attached to the exterior of the dipole chamber are water cooling channels to dissipate the thermal load caused by synchrotron radiation. The cooling is provided to limit the temperature rise caused by the very localized heating. With a synchrotron power loss of 1 kW distributed around the ring, the linear power flux would be .17 W/cm. With a minimum beam height of 1.15 mm, the local power flux is 1.5 W/cm<sup>2</sup>. The water cooling channel is capable of dissipating this load.

### IV. VACUUM HARDWARE

This section gives a brief summary of hardware in the SHR vacuum system as well as operation experiences. The ion pumps were purchased on the basis of cost. The Starcell ion pumps are three different sizes, 60 l/s for straight sections, 120 l/s with direct heated ST 707 NEG for the arc sections and 230 l/s for the septum magnets and kickers. There are a total of 51 ion pumps in the ring. These pumps are extremely easy to start off a sorption pump. Ion pumps are started with large power supplies and then switched to 3 mA holding power supplies developed for MIT by a local company, Kernco Inc. All power supplies are monitored and controlled by a computer in the ring control room. Twenty eight HPS inverted magnetron gauges monitor the vacuum and provide setpoints to operate the valves. These gauges read

from  $1 \times 10^{-3}$  to  $5 \times 10^{10}$  torr. These units have performed well. Ten RGA heads are also installed in the ring.

A large amount of detailed engineering effort was put into developing smooth bore hardware which meets the requirements of low higher order mode losses. The hardware includes: 16 smooth bore pumping tee transition which allows for ion pumping in a region which switches from 6" x 2" rectangular to 2 1/2" circular cross section, 14 smooth bore intercepting beam targets, 22 button beam position monitors (BPMs), 12 smooth bore stripline BPMs, 6 RF shielded gate valves, 60 smooth bore bellows and a RF cavity collimator pumping tee. Some designs were modeled by accelerator physics using MAFIA<sup>(1)</sup> to study unwanted modes which could lead to coupled bunch instabilities. Also, all hardware was measured for longitudinal impedance on a test setup which looked at frequencies to 10 GHz. Figures 2 and 3 below show measurements of bellows without shield and with shield.



Figures 2 and 3.

The smooth bore bellows (Figures 2,3,4) is similar in design to a unit designed by Duke University<sup>[2]</sup> at the FEL lab. It features a welded bellows which is shielded by an inner tube which makes solid contact on both ends with a beryllium copper Amp Products Louvertac strip which make a solid RF contact on both ends. RF tests showed the contact on both ends to be the most important criteria for a good design.

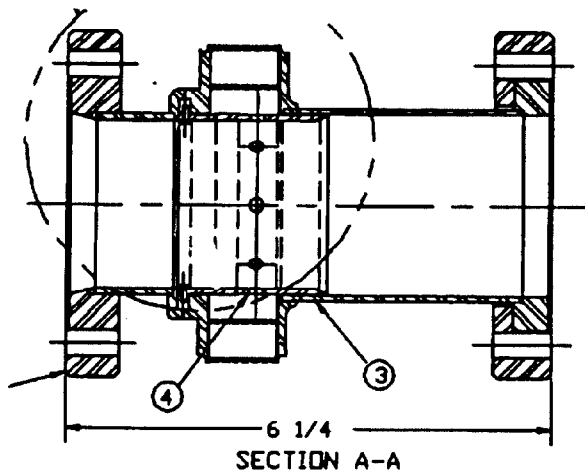


Figure 4.

Other detailed vacuum design work was on the Energy Compression System dipole vacuum chambers. They were modeled using SDRC Ideas FEA code (Figure 5). The parts were CNC laser cut from 316L stainless steel and TIG welded together.

LOAD SET: 1 - VAC LOAD  
 DISPLACEMENT - NORMAL MIN: 0.00 MAX: 0.033838  
 ECS DIPOLE VACUUM CHAMBER, REV 1.

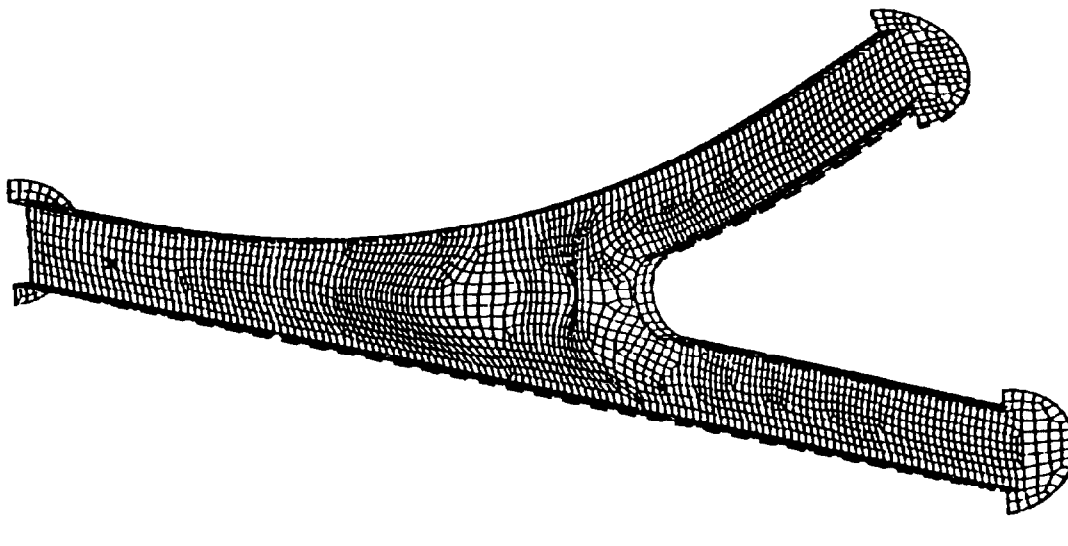


Figure 5.

## V. COMMISSIONING TESTS

The vacuum system for the SHR was completed in January 1993 and commissioning started in February. Base vacuum around the ring was in the high  $10^{-10}$  - low  $10^{-9}$  torr range. Initial operation was at 300 MeV with very low currents at 1-3 mA, in the storage mode without RF. Storage times were limited by losses due to synchrotron radiation. The vacuum remained unchanged throughout these tests. After successful storage at low currents, the ring was brought to 40 mA, half the design current, and the vacuum in the arc sections rose to about  $2 \times 10^{-8}$  torr. Base pressures continued to improve after beam was shut off. Although the vacuum system is designed for in situ bakeout, we have not baked any components after installation. More section vacuum valves are to be installed so to limit the amount of beamline which needs to be vented to work on a section.

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## VII. REFERENCES

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