The PEP-II Lower Pressure HER vacuum chamber

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Abstract

This new vacuum chamber has been installed from 12 to 21 meters upstream of the BaBar detector in the PEP-II High Energy Ring (HER) to reduce lost particle backgrounds. The backgrounds from HER now dominate the backgrounds in the BaBar detector and the present vacuum pressure is 1 x 10^{-9} Torr. The new chamber will increase the pumping significantly by adding 18 x 2000 l/s titanium sublimation pumps to the existing 5 x 440 l/s ion pumps, and is expected to reduce the pressure by about a factor of five. Features of the chamber include improved water cooling, improved vacuum conductance through copper RF screens featuring over 15,000 small square holes and the ability to sublimate titanium while the beam is still on.

1. INTRODUCTION

It is critical to keep the pressure as low as possible in the region of PEP-II [1] occupied by this vacuum chamber in order to minimize the production of bremsstrahlung scattered beam gas particles which cause BaBar detector backgrounds and lead to radiation damage. The chamber that has just been removed had 6 ion pumps, approx. 1m apart which proved inadequate for the task, having a total pumping speed of 2640 l/s. The chamber area cooled by water was increased to fully accommodate the powerful SR fans (5.5 kW) generated by the High Energy Ring (HER) as it goes through the upstream B2 and B3 magnets and from the Low Energy Ring (LER) as it goes through the two B1 magnets near the collision point.

2. THE NEW CHAMBER DESIGN

We chose a design that incorporated a plenum chamber underneath the beam chamber in order to maximize the screen area (and hence conductance) and to maximize the number of Titanium Sublimation Pumps (TSP's) that would fit in between 5 of the existing ion pumps (which remain to handle the non getterable gasses). The final pump count was 18 x 2000 l/s TSP's and 5 x 440 l/s ion pumps = 38200 l/s. Ideally, we would have chosen to make the chamber out of copper to maximize heat transfer but this proved impractical to manufacture within the time available, so stainless steel was chosen, with 15 copper RF screens brazed in to the underside of the chamber.

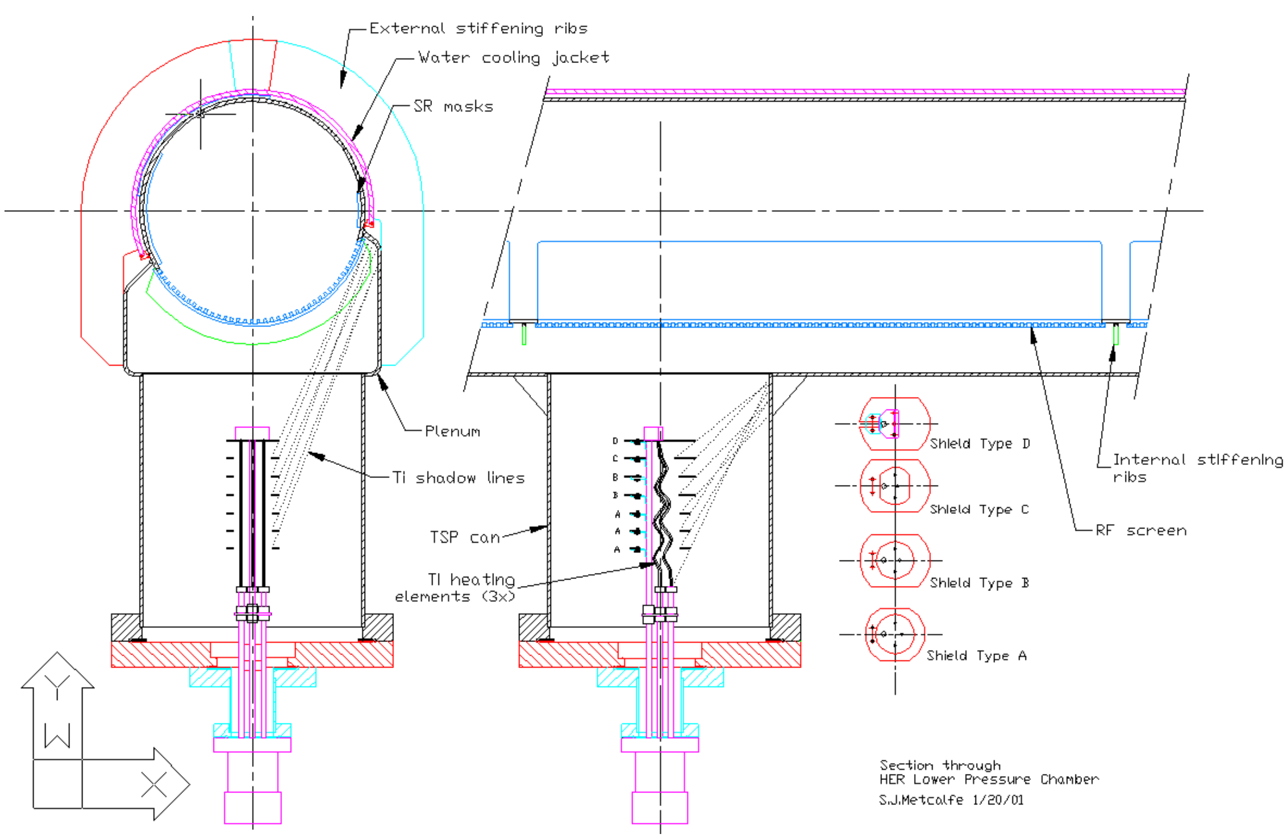

Figure 1: Typical cross sections through the chamber through 'X' and 'Z' axes.

The overall length of the chamber is 882.22 cm. It was desirable but impractical to manufacture this in one piece so it was decided to make the chamber in 3 separate sections, each with a length of 288.74 cm.

A plenum design maximizes the number of pumps and area of screen hence maximizing pumping speed, however it reduces the chamber area that can be 'scrubbed' by synchrotron radiation (SR) photons, so beam conditioning is not expected to be as effective although this should be more than compensated for by the increased pumping speed.

A 2D analysis of the chamber and plenum identified high stress areas in the welds joining the plenum to the chamber so external ribs were added to stiffen up the structure and to counteract the 'bourdon tube' effect of the pressure in the water jacket. Together with the internal stiffening ribs between the RF screens, these measures result in a very rigid structure which shows no significant deflection during vacuum and pressure testing.

The velocity of the water through the cooling jacket will be relatively low, so a set of water diverter rods were welded to the outside of the vacuum vessel before the jacket was attached in order to continuously mix the warmer water at the sides with the cooler water at the top. The attachments for the water supply and return in the water jacket are adjacent to the SR masks to ensure maximum water flow at these critical areas. These copper masks are tapered from 0 to 0.35 cm high and brazed to the inside of the vacuum vessel at appropriate locations to shield valves and bellows from the SR fans.

Thermocouples were placed at the edge of the water jacket on both sides of the chamber at 2 m intervals. These would abort the beam if a SR fan should stray from its predicted path, below the water cooled area. Thermocouples were also placed on the return cooling water manifold.

The TSP cartridges (Thermionics Sierra Inc, model SB-275-3) carry 3 Ti heating elements connected to a common power socket outside the chamber. Each cartridge is fitted with 7 shield plates which were placed to ensure that Ti would not be deposited in the path of the beam, allowing regeneration to take place while the beam is still on - see the shadow lines on Fig 1. The total Ti covered surface is 131000 cm^2. Water cooling coils are fitted around the outside of this surface to improve pumping efficiency. The TSP's are regenerated by preheating at 35amps for 5 minutes and flashed at 44 amps for 3 minutes.

An RF screen design was required that maximized vacuum and thermal conductance whilst being economic to manufacture. Most designs did not meet the latter requirement given that 15 screens were required, each 50 cm x 23 cm. The final solution involved slotting a flat copper plate on both sides with one cut at 90 deg. to the other to just break through (the inner slot will be parallel to the beam direction), followed by forming the plate on a tool to the required radius. The resulting vacuum conductance of the screens is 24500 l/s, almost 10 times greater than the previous chamber.

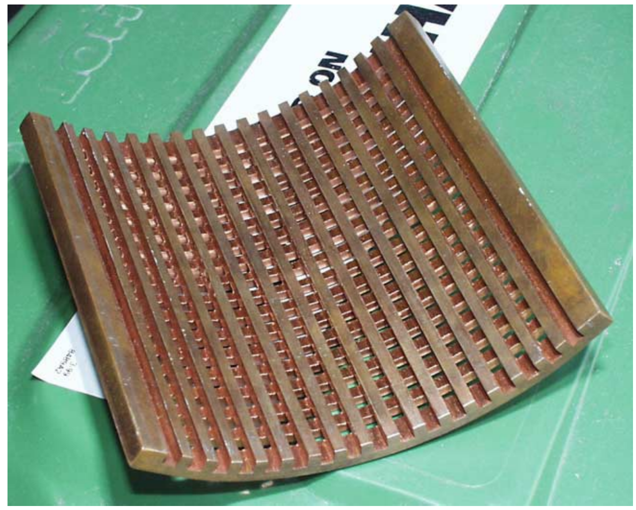

Figure 2: The prototype screen.

A pair of RF screened, 20.3 cm ID, all metal gate valves, with double acting pneumatic actuators were fitted at both ends of the third chamber. This new valve design was supplied by VAT Inc, model 47146-CE77-X. The valves were added to enable chamber 3 to be removed for future maintenance without venting the entire beamline.

3. VALVE CONTROLS

The air to the VAT valves is controlled by electrically actuated 24V 4-way pneumatic control valves located on a panel where the radiation levels are lower than the levels at the valve itself. The air is nominally 100 psi "house air" with a local backup supply bottle. There is a pressure regulator and air pressure switch on each panel. The valves are equipped with IN and OUT position switches, the status of which is reported to the control system via the valve controller. The OUT switch status is also reported to the Beam Abort Trigger System to prevent beam damage to the valve. The solenoids are actuated from a programmable multi-valve controller capable of controlling up to 6 valves. Each valve can be programmed to close when the desired combinatorial logic of up to 16 inputs, such as gauges or pumps, is realized. The mode of operation for each valve is controlled by key actuated switches where the key can be removed from any of 4 positions :

1. CAMAC Control via the PEPII control system.
2. LOCAL Control from the front panel of the controller.
3. J-BOX Control from a key box located on the solenoid panel near the valve.
4. CLOSE Valve closed

4. MANUFACTURING

The vacuum chamber proved difficult to manufacture, mainly as a result of distortion due to welding. Tooling jigs were manufactured to hold the chamber during machining and to straighten it after each stage of the machining/welding process. Also cleaning and stress relieving was required prior to, and following, welding.

The first chamber to be delivered from the vendor was accidentally pressure tested to a higher pressure than the requested 150 psi. Failure of the inner chamber occurred at 190 psi, causing a bubble along the weakest (thinnest) section of the tube. This bubble was repaired by the application of heat, vacuum in the water jacket and considerable force along the fault line, however, the end result was a chamber that was excessively bent and twisted and we decided to make a new one.

Ultrasonic measurements of the vacuum chamber wall thickness (from the inside - the outside was covered by the water jacket) showed that there were variations due to the tube manufacturing process. Unfortunately, one of the remaining chambers had it's thinnest section in a high stress location and could have caused another, similar failure so we decided to limit the water pressure in the channel to 50 psi, requiring a pressure regulated water supply with check valves and pressure relief valves to eliminate the possibility of overpressurising the system.

The vacuum furnace brazing process was carried out using standard SLAC procedures. The screens and masks were clamped into place on the chamber using a 35Au/65Cu filler material and soaked for 4 minutes at 1025^{O}C. It was necessary to ensure that braze filler material on the screens did not contaminate the adjacent area where the plenum would subsequently be welded.

The chamber is instrumented with three nude hot-filament gauges (Varian UHV-24) which measure the pressure distribution and which are used to calibrate a Residual Gas Analyzer (MKS Orion Compact). Two Pirani gauges (HPS) are used as interlock switches to permit opening of the adjacent VAT valves.

Final preparation for assembly comprised glow discharge cleaning followed by a 200 ^{O}C bakeout for 4 days.

Figure 3: Upstream half of the assembled chamber.

From start of design to end of installation took exactly 12 months: 5 months to complete the design and produce shop drawings of the chamber, 6 months to manufacture and 1 month to install.

5. EARLY RESULTS

It will take some time to prove the effectiveness of this new chamber but the early signs are very encouraging. The graphs below compare the recent startup with a similar graph taken a year earlier. The latest graph shows the same vacuum pressure even though it has had less scrubbing time and more beam current.

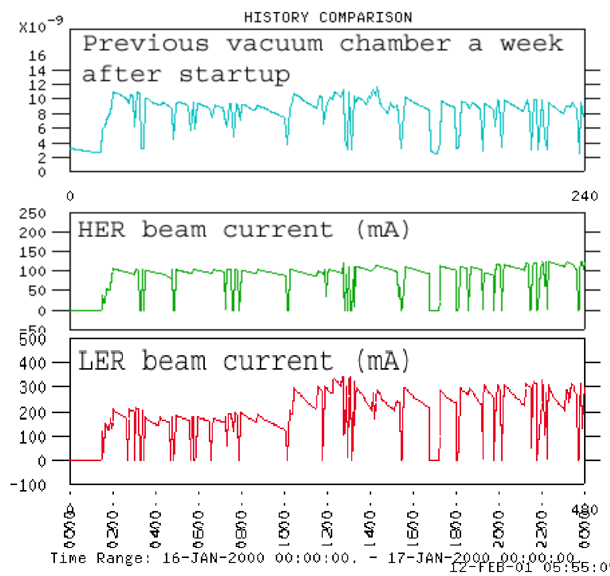

Figure 4: Year 2000 startup

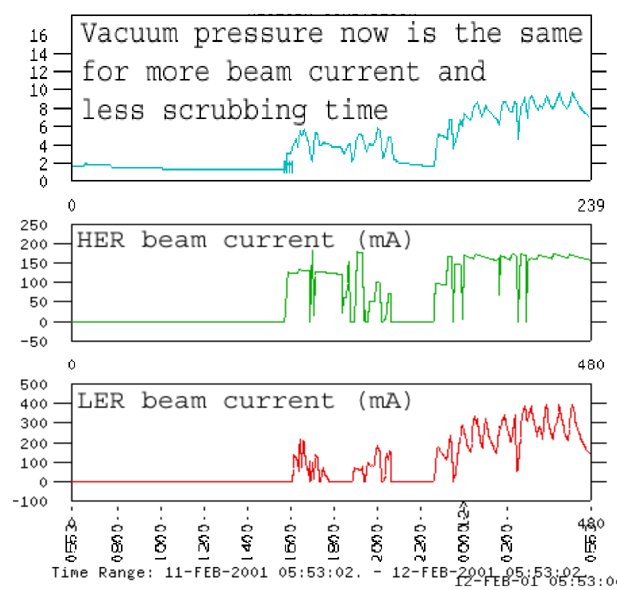

Figure 5: Year 2001 startup

6. REFERENCE

[1] "PEP-II Conceptual Design Report", SLAC report 418, LBL-PUB-5379, June 1993