FERMILAB ENGINEERING NOTE	SECTION PPD/ETT	PROJECT BTeV/C0	SERIAL - CATAGORY	PAGE 1
SUBJECT Outgassing Rate in Good Vacuum Side of Vertical Pixel Design		NAME Mayling Wong		
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Purpose

To calculate the required outgassing rate of the surfaces in the beam line (good) vacuum side of the BTeV Vertex Detector in order to achieve a vacuum pressure of 10^{-7} torr at the collision point C0.

Summary

As of December 2001, an alternate design for the BTeV vertex detector was introduced. Figure 1 shows the cross section of one half of the detector. The newer design calls for the pixel substrates to be moved vertically to allow adjustment of the beam. The newer design is an alternative way to have two completely sealed vacuum chambers, where the pixel vacuum is completely isolated from the beam vacuum. A rectangular bellows provides the means to move the pixel detector and separate the two vacuum chambers.

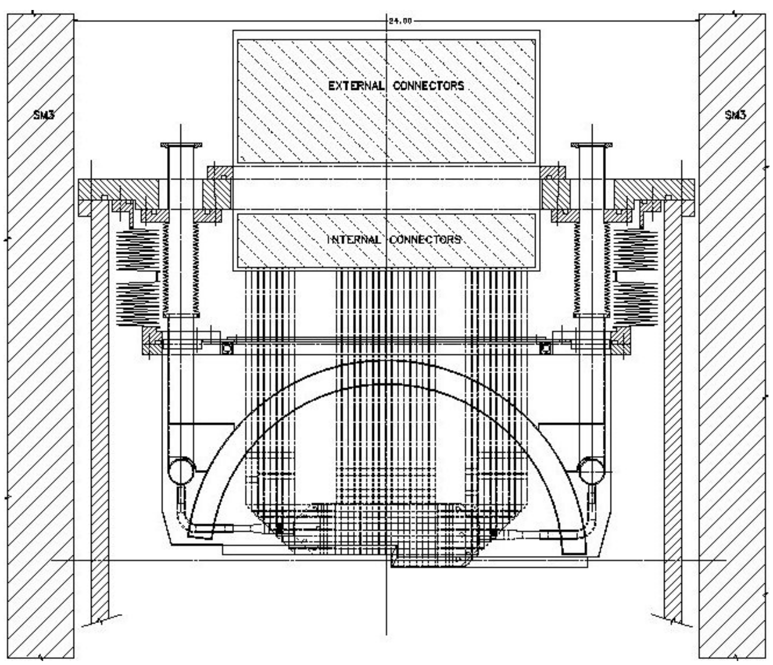

Figure 1 – Schematic of One Half of the Pixel Detector Design for Movement in Vertical Direction

The beam vacuum is still required to be less than 10^{-7} torr. Non-evaporable getters are added to the design by placing them at the ends of the vacuum vessel near the entrance of the beam pipe. The design also takes into account additional pumping speed by coating the side walls of the vessel with a non-evaporable getter material Ti-Zr-V. With the additional surface area due to the bellows in the good vacuum side, the required outgassing rate of the surfaces is calculated to be on the order of 10^{-10} torr-L/sec-cm^2. In order to achieve such low outgassing rates of the aluminum RF shield and the stainless steel bellows, the surfaces may have to be treated by baking *in situ* at temperatures of 200-300°C.

Dimensions of the new design

The RF shield design at the beam area remains the same as in the previous design [1]. The surface area of the convoluted section of one RF shield is about 34,400 cm^2. The convoluted section of one rectangular bellows has a surface area of about 80,000 cm^2. Taking into account two RF shields, two rectangular bellows, and additional flat surface area of the vessel wall, the RF shields, and the bellows, the total surface area of the good vacuum side is about 23 m^2.
The horizontal distance from the side of the RF shield to the vacuum vessel wall is 2 inches. The vertical distance from the collision point to the vacuum vessel wall is 14 inches.

Required outgassing rate for NEGs at the ends of the vacuum vessel

Figure 2 is a schematic of the good vacuum volume. The two boxes represent the enclosed pixel vacuum volumes. For simplicity, the sides of the boxes are flat. Figure 2 shows the pathway that the gas follows from the collision point in the beam area to the open area of the good vacuum volume (between the flat sides of the RF shield and the entrance to the beam pipe BP). The gas can travel in two paths from the beam area, marked BA and GAP. If the path is through GAP, then the gas has to travel along the sides of the RF shield and bellows. This path is marked SIDE.

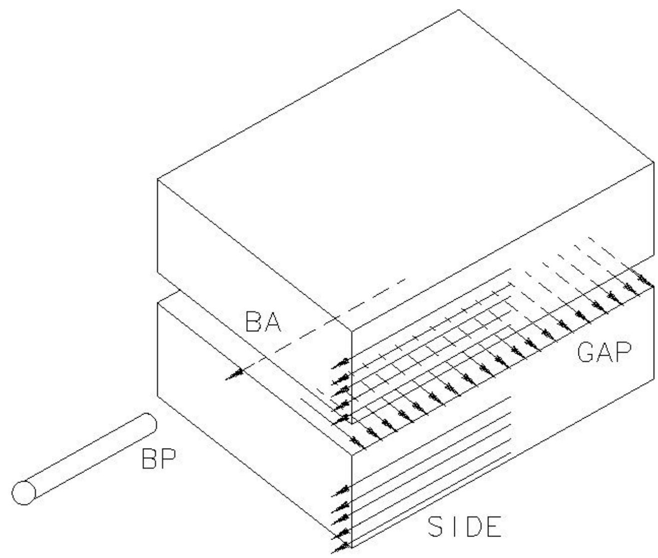

Figure 2 – Schematic of Good Vacuum Volume

The conductance path is analogous to an electrical circuit, as shown in Figure 3. The model represents the gas travel from the collision point to the entrance of the beam pipe. NEG represents non-evaporable getters that are placed in the volume between the beam pipe entrance and the pixel detector.

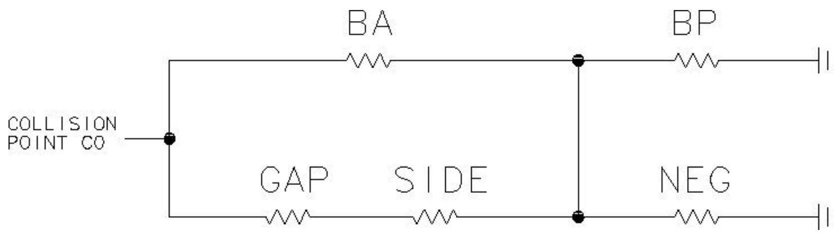

Figure 3 – Good Vacuum Model

The conductances of the paths, shown in Table 1, are calculated based on rough estimates of their geometries. For SIDE, it is assumed, quite optimistically, that the bellows is flat in nature and allows for a large gas flow rate.

Table 1 – Conductances in the Good Vacuum Side of the Vertex Detector

Path	Length (cm)	Width (cm)	Thickness (cm)	L/t	a	A (cm^2)	C (L/sec)
GAP	25	150	1	25	0.1	150	180
SIDE	36	75	5	7	0.3	375	1300
BA	70	1	1	70	0.01	1	0.1

To calculate the total conductance through the different paths, let PATH be the total conductance. The circuit in Figure 3 can be reduced to that circuit shown in Figure 4:

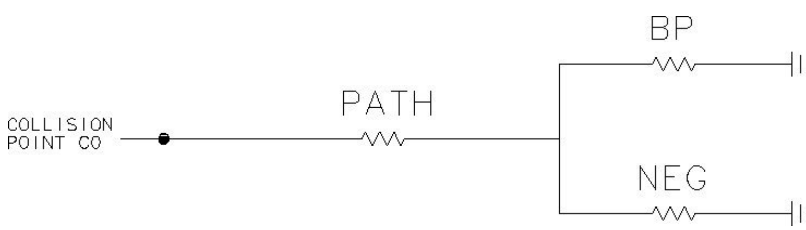

Figure 4 – Reduced Model of Vacuum System

where

$$\mathrm{PATH} = \frac{1}{\left[\dfrac{1}{\mathrm{GAP}} + \dfrac{1}{\mathrm{SIDE}}\right]} + \mathrm{BA}$$

$$\mathrm{PATH} = 158 \ \mathrm{L/sec}$$

The conductance of the beam pipe BP is 0.6 L/sec [1]. The low conductance of the beam pipe by itself is not adequate enough to be useful as a pump. Assume that the pumping speed of NEG, a non-evaporable getter near the beam pipe, is 400 L/sec. Taking into account NEG, the total conductance in the good-side vaccum is

$$C_{ttl} = \frac{1}{\left[\frac{1}{PATH} + \frac{1}{NEG}\right]}$$

$$C_{ttl} = 113 \ \mathrm{L/sec}$$

With NEGs located near the entrances of the beam pipes, to achieve a pressure of 10^{-7} torr in the good-side vacuum, the required outgassing rate for the surfaces is:

$$Q = \frac{10^{-7} * 113}{230{,}000}$$

$$Q = 5x10^{-11} \ \frac{\mathrm{torr} - \mathrm{L}}{\mathrm{sec} - \mathrm{cm}^2}$$

Required outgassing rate for NEGs at the ends and along sides of the vacuum vessel

To address the additional gas load due to the increased surface area from the bellows, the sides of the vacuum vessel wall can be coated with a NEG material in a similar manner proposed for the LHCb beam pipe [2]. LHCb's beam pipe design specifies a sputter-coated film of getter material along the entire inner wall. The design references an experiment where Ti-Zr-V is sputtered on to the wall of a test chamber [3]. The activation temperature (which is also the chamber temperature) is 150°C. A titanium sublimation/sputter-ion pumping station was attached to the chamber by way of a 25 L/sec conductance. The ultimate pressure was around 10^{-13} torr. The calculated pumping speed was 0.5 L/sec/cm^2 for hydrogen.

For comparison to the pixel vacuum, one of the vessel's side-walls is 1.5m long by 28 cm in height. In theory, if the wall is coated with same getter material, the total pump speed would be 2100 L/sec. The model of the good vacuum side would be modified, as shown in Figure 5, where WALL represents the pump speed of the NEG-coated wall:

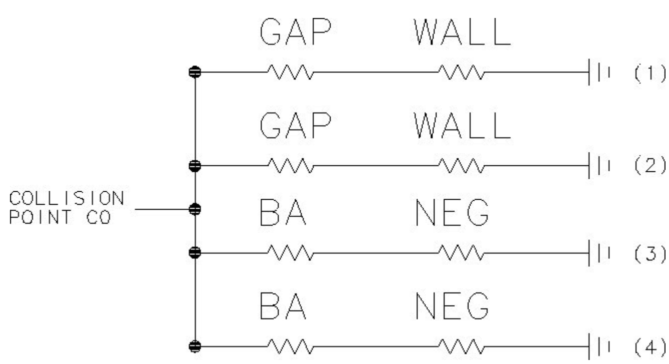

Figure 5 – Model of Good Vacuum Side with NEG-coated Walls

Each "circuit" is numbered so that the total conductance of the vacuum system can be calculated as shown:

$$C_1 = C_2 = \frac{1}{\left[\frac{1}{180} + \frac{1}{2100}\right]} = 166 \ \text{L/sec}$$

$$C_3 = C_4 = \frac{1}{\left[\frac{1}{0.1} + \frac{1}{400}\right]} = 0.1 \ \text{L/sec}$$

$$C_{ttl} = C_1 + C_2 + C_3 + C_4 = 332 \ \text{L/sec}$$

The required outgassing rate of the RF shield and bellows to obtain 10^{-7} torr at the collision point would then be:

$$Q = \frac{10^{-7} * 332}{230{,}000}$$

$$Q = 1.4x10^{-10} \ \frac{\text{torr} - \text{L}}{\text{sec} - \text{cm}^2}$$

This assumes that the sources of the entire gas load are the surfaces of the RF shield and the bellows. In reality, the gas load traveling in the path between the RF shields (designated as GAP) comes only from the RF shield. The model changes again, as shown in Figure 6:

To simplify the problem, the outgassing rate for the good vacuum can be calculated by taking into account only the surface area of the RF shield, thus ignoring the effects of the bellows. Assuming the total surface area of the RF shields is 68,800 cm^2, the required outgassing rate is:

$$Q_{best} = \frac{10^{-7} * 332}{68{,}800} = 4.8x10^{-10} \ \frac{\text{torr} - \text{L}}{\text{sec} - \text{cm}^2}$$

Thus, even in the most optimistic situation of having four NEG pumps and only the gas load from the RF shields, the required outgassing rate is on the order 10^{-10} torr-L/sec-cm^2. It is clear that the small conductance of the gap between the RF shield results in low pumping speed from the collision point.

Conclusions

A NEG pump can be placed at the ends of the vacuum vessel and the sides of the vessel can be coated with NEG material. The collision point would then see 10^{-7} torr as long as the outgassing rate of the aluminum RF shield and the stainless steel bellows is on the order of 10^{-10} torr-L/sec-cm^2. The small conductance of the path between the RF shield is the cause of low pumping speed from the collision point. According to various measurements of outgassing rates [4], both aluminum and stainless surfaces should be cleaned with solvents and baked *in situ* at temperatures greater than 150°C to obtain rates of 10^{-10} torr-L/sec-cm^2. By surveying the measurements of outgassing rates, it is clear that there is a wide range measured rates for each type of surface preparations and cleaning methods Tests would be have be completed to better understand how to best obtain such low outgassing rates for the our applications.

References

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2. LHCb Vertex Locator Technical Design Report, May 2001.
3. Benevnuti, C., et al, “A novel route to extreme vacua: the non-evaporable getter thin film coatings.” Vacuum, vol 53, 1999.
4. Wong, M. “Review of papers regarding vacuum system and materials.” http://home.fnal.gov/~mlwong/outgas_rev.htm