CKM Vacuum Veto System
Vacuum Pumping System

Technical Memorandum CKM-80

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TABLE OF CONTENTS

1.0 Introduction

This technical memorandum discusses two solutions for achieving the pressure specification of 1.0E-6 Torr for the CKM Vacuum Veto System (VVS). The first solution includes the use of Diffusion Pumps (DP's) for the volume upstream of the Downstream Magnetic Spectrometer (DMS) regions. The second solution uses Turbo Molecular Pumps (TMP's) for the upstream volume. In each solution, TMP's are used for each of the four DMS regions. Cryogenic Vacuum Pumping is also considered to supplement the upstream portion of the VVS. The capacity of the Roughing System is reviewed as well. The distribution of the system outgassing is first examined.

2.0 VVS Outgassing Distribution

There are several sources of outgassing in the VVS vacuum vessel. These sources are discussed in a previous note [1]. The distribution of the outgassing within the VVS is now considered.

The VVS detector total outgassing rate was determined to be 1.0E-2 Torr-L/sec. The upstream portion accounts for 54% of this rate while the downstream side is 46% of the rate. In the downstream volume there are 14 detectors, six of which are located in the DMS regions. These six detectors have a total outgassing rate of 0.2E-2 Torr-L/sec. The detectors upstream of the DMS regions have a total outgassing rate of 0.8E-2 Torr-L/sec.

The Beam Interaction Veto System (BIVS) has an outgassing rate of 1.0E-3 Torr-L/sec. This system is located directly next to the upstream beam window.

The DMS Straw Chamber leak rate totals 1.0E-3 Torr-L/sec [2]. This leak rate is primarily pumped by the TMP's designated for the DMS regions. A small portion outgases into the volume upstream of the first DMS straw plane.

The outgassing due to the VVS vessel walls, support components, and virtual leaks are assumed to be uniformly distributed along the length of the VVS while giving consideration to the vessel circumference along this length. The total outgassing rate due to these sources is equal to 0.8E-2 Torr-L/sec. It is estimated that the load in the DMS regions equals 0.15E-2 Torr-L/sec while that upstream of the DMS region is equal to 0.65E-2 Torr-L/sec.

The outgassing rates at the beam windows are assumed to be negligible.

The outgassing rates for the volume upstream of the DMS regions and for each of the DMS regions are summarized in Table 1. The values shown for the four DMS regions are based on the length of the region and the number of straw planes at each DMS station.

LOCATION	OUTGASSING RATE
VVS Upstream of DMS	1.6E-2 Torr-L/sec
DMS Region 1	1.35E-3 Torr-L/sec
DMS Region 2	1.1E-3 Torr-L/sec
DMS Region 3	1.35E-3 Torr-L/sec
DMS Region 4	0.9E-3 Torr-L/sec
TOTAL	**2E-2 Torr-L/sec**

Table 1. VVS Outgassing Distribution

From outgassing tests performed on the detector materials it is found that the gases which dominate the VVS chamber are air and water vapor [3]. In addition, the straw planes will leak the gas mixture chosen to flow through the straw tubes.

3.0 VVS High Vacuum Pumping System Solutions

The following system design solutions are based on the calculated capacities of DP's and TMP's as previously determined [1]. The reported capacities are specific to the pumping system configurations as required for the CKM VVS chamber.

3.1 Diffusion Pump System for the VVS

In a VVS vacuum system using DP's, it is assumed that the pumps available from the Fermilab K-TeV experiment would be utilized. These pumps require special manifolding in order to attach them to the CKM chamber. The throughput for each of these two DP's is 0.29E-2 Torr-L/sec totaling 0.58E-2 Torr-L/sec.

Additional DP's are required to pump the remaining 1.02E-2 Torr-L/sec from the upstream portion of the VVS. Due to pump costs and the maximum achievable port size on the VVS chamber, two smaller DP's are considered to complete the system.

It has been shown that a 20,000 L/sec DP (Leybold Model DIP 20000) [4] with a cold baffle, right angle valve, and spool piece as designed to connect to the CKM VVS chamber has a capacity of 1.4E-3 Torr-L/sec. Eight DP's of this size would be required to complete the 'upstream' vacuum system.

It has been shown that a 12,000 L/sec DP (Leybold Model DIP 12000) [4] with a cold baffle, right angle valve, and spool piece as designed to connect to the CKM VVS chamber has a capacity of 1.1E-3 Torr-L/sec. Ten DP's of this size would be required to complete the 'upstream' vacuum system.

Based on a cost estimate performed for both a 20,000 L/sec system and a 12,000 L/sec system, it was shown that the 12,000 L/sec system was slightly more cost effective. Note that both systems assume the use of the K-TeV DP's with manifolding.

3.2 Turbo Molecular Pump System for the VVS

A TMP system for the upstream portion of the VVS would offer system uniformity and remove concerns of oil migration to the detectors. The TMP connection to the VVS can be closer because of its smaller size relative to that of a DP. A 2000 L/sec TMP (Varian Model Turbo-V2000HT) [5] is considered in this analysis as it is one of the largest TMP's sold that allows mounting in any orientation. If, for example, a TMP was chosen that only allowed mounting in a vertical orientation, manifolding would be required to connect the pump to the CKM chamber which would severely reduce the pumping capacity of the TMP. This configuration would quickly make a TMP system cost prohibitive.

The capacity of the Varian 2000 L/sec TMP was calculated in [1] and found to be 0.75E-3 Torr-L/sec assuming no gate valve between the pump and the chamber. 22 TMP's would be required in the upstream VVS to remove the estimated gas load.

If a gate valve is included, the TMP capacity is reduced to 0.72E-3 Torr-L/sec. In this case, 23 TMP's are required.

3.3 Turbo Molecular Pump System for the DMS Region

DMS Region 1 has an estimated outgassing rate equal to 1.35E-3 Torr-L/sec. Two TMP's are required to remove the gas load in this region.

DMS Region 2 has an estimated outgassing rate equal to 1.1E-3 Torr-L/sec. Two TMP's are required to remove the gas load in this region. Manifolding to the TMP's are required in this location due to the proximity of the DMS magnet.

DMS Region 3 has an estimated outgassing rate equal to 1.35E-3 Torr-L/sec. Two TMP's are required to remove the gas load in this region.

DMS Region 4 has an estimated outgassing rate equal to 0.9E-3 Torr-L/sec. One TMP's will be adequate to remove the gas load in this region.

The total number of Varian 2000 L/sec TMP's [5] required for the DMS regions is seven. TMP's are chosen as they have a greater efficiency in pumping the heavy gases leaking from the DMS straw chambers.

3.4 VVS Cryogenic Vacuum Pumping System

Some portion of the outgassing from the detectors and VVS vessel components has been shown to be water vapor [3]. Water vapor can be pumped at very high pumping speeds onto surfaces cooled to cryogenic temperatures. Liquid nitrogen can be used as the coolant. The pumping speed of a surface cooled to liquid nitrogen temperatures has been previously measured and found to be 9.06 L/(sec-cm^2) [6]. At a design pressure of 1.0E-6 Torr, this is equivalent to 9E-6 Torr-L/(sec-cm^2).

For the CKM VVS, it is estimated that at least 25% of the outgassing is in the form of water vapor. Given the above rate, a one square foot surface would be capable of pumping at a rate of 8.3E-3 Torr-L/sec. This assumes that the cryo-surface is installed directly into the VVS vessel and the conductance to the surface is high.

4.0 Roughing System

The Roughing System which was used for K-TeV has an appropriate capacity for CKM also. This system is described in [1]. The design pressure for the foreline during steady state operation is 1.0E-2 Torr. The estimated throughput from the CKM system is only a fraction of the roughing system capacity at 1.0E-2 Torr. The maximum permissible forevacuum pressure for the Diffusion Pumps [4] is 0.45 Torr. The maximum permissible forevacuum pressure for the Turbo Molecular Pumps [5] is 1.0 Torr. A 10 inch diameter foreline pipe is planned to manifold the high vacuum pumps together to the roughing system. A cold trap system may be used at the roughing system inlet to prevent oil migration to the VVS chamber from the roughing pumps.

5.0 Summary

The VVS volume must be maintained at or below 1E-6 Torr for the CKM experiment. The volume upstream of the DMS has two possible system solutions. The first system considered utilizes Diffusion Pumps. The DP system would include the two pumps previously used at K-TeV with special manifolding added, plus 10 additional pumping systems, each with a nominal capacity of 12,000 L/sec. The second solution uses Turbo Molecular Pumps. Given TMP's with a nominal capacity of 2000 L/sec, 22 pumps are required for the upstream VVS volume. In both solutions, TMP's are planned for the DMS regions. A total of seven TMP's are needed for these regions. Using liquid nitrogen cooled surfaces in the upstream volume of the VVS would improve the system pumping speed for water vapor. The roughing system used in the K-TeV experiment is suitable for either the DP or TMP high vacuum pumping system.

The solutions presented are based on a total outgassing rate of 2E-2 Torr-L/sec. If design changes are made that increase the gas load, additional pumps will be required.

6.0 References

1. Allspach, "Vacuum Conductance Analysis of the CKM Vacuum Veto System," Technical Memorandum CKM-79, March, 2003

2. Kendziora, et al, "A Straw Drift Chamber for Operaton in Vacuum," CKM Technical Memorandum, September, 2002

3. Allspach, et al, "CKM Vacuum Veto System Detector Outgassing Studies," Technical Memorandum CKM-81, March, 2003

4. Leybold Vacuum USA Inc., Export, PA, USA

5. Varian Vacuum Technologies, Lexington, MA, USA

6. Kendziora, et al, "Outgassing Measurement of the BTeV 5% Model of the Pixel Detector," BTeV Document 812, June, 2002