To be presented at the 27th National Symposium of the American Vacuum
Society, October 13-16, 1980, Detroit

BNL-28266

VTTM-6

CONF-801037--4

MASTER

THE SELECTION AND EVALUATION OF AN ULTRA HIGH VACUUM

GATE VALVE FOR ISABELLE BEAM LINE VACUUM SYSTEM

C.L. Foerster and D. McCafferty

Accelerator Department

Brookhaven National Laboratory

Upton, New York 11973

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Reg

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

THE SELECTION AND EVALUATION OF AN ULTRA HIGH VACUUM*

GATE VALVE FOR ISABELLE BEAM LINE VACUUM SYSTEM

C.L. Foerster, D. McCafferty

Accelerator Department

Brookhaven National Laboratory

Upton, New York 11973

Abstract

A minimum of eighty four (84) Ultra High Vacuum Gate Valves will be utilized in ISABELLE to protect proton beam lines from catastrophic vacuum failure and to provide sector isolation for maintenance requirements. The valve to be selected must function at less than 1×10^{-11} Torr pressure and be bakeable to 300°C in its open or closed position. In the open position, the valve must have an RF shield to make the beam line walls appear continuous. Several proposed designs were build and evaluated. The evaluation consisted mainly of leak testing, life tests, thermal cycling, mass spectrometer analysis, and 10^{-12} Torr operation. Problems with initial design and fabrication were resolved. Special requirements for design and construction were developed. This paper describes the tests on two final prototypes which appear to be the best candidates for ISABELLE operation.

*Work performed under the auspices of the U.S. Department of Energy.

1. Introduction

The Ultra High Vacuum System of ISABELLE will consist of two interlaced rings of stainless steel bore tubes in a 3.8 km circumference. The 8.8 cm diameter bore tubes will operate at less than 3×10^{-11} Torr vacuum, being pumped by a combination of Ti sublimation and 20 ltr-sec⁻¹ ion pumps. The stations containing the pumps along with UHV gauges and various beam diagnostic equipment will be spaced at 5 m intervals. With special treatment and preparation of construction materials the pressure will be maintained at less than 3×10^{-11} Torr and will consist almost entirely of hydrogen. Such a vacuum has been estimated to be adequate for operation when one considers beam life time due to nuclear scattering or multiple coulomb scattering, beam neutralization by electrons from ionized residual gas molecules, and radiation background.

The ISABELLE UHV rings will be divided up into sectors by a total of eighty four all metal gate valves. These sector valves must be compatible to the ultra high vacuum needs and to the beam requirements of ISABELLE. The bore tube will have to appear continuous to the beam with the valve in the open position. This special requirement does not allow the use of a standard all metal gate valve. The valve will also have to function in the magnetic environment and the radiation field of ISABELLE.

This sector valve will be used to isolate sectors of the beam tube and allow pressure differences of one atmosphere. This will provide some protection in case of catastrophic failure and also provide for maintenance requirements. Sections of the beam tube operating at ultra

high vacuum will be at a pressure of less than 2×10^{-11} Torr.

The integrity of the beam vacuum must be maintained and protected from contamination.

II. Sector Valve Requirements

The valve shall be capable of less than 2×10^{-11} Torr operation without adverse effects. Non-magnetic stainless steel is preferred for construction of the valve and its sub-assemblies. The residual gas composition at this very low pressure will consist primarily of hydrogen and will have traces of methane, argon, carbon dioxide and carbon monoxide (See Fig. 1). The hydrogen gas will evolve from bulk outgassing from the steel exposed to the vacuum. Outgassing of the trace constituents is strictly a surface phenomena. Total outgassing of hydrogen from the valve must be less than 1×10^{-10} Torr ltr/sec and contaminants such as hydrocarbons must be less than 1×10^{-13} Torr ltr/sec. These levels are measured after a vacuum bake.

Sector valve leakage must be less than 1×10^{-9} Torr ltr/sec helium in order to satisfy ISABELLE beam vacuum needs. Leakage through the valve must be less than 1×10^{-9} Torr ltr/sec helium with atmospheric pressure applied on either side of the gate seal. This includes after temperature and gate valve cycling. The bake out temperature will be approximately 250°C with the valve open or closed. In the open position the valve will require a shorting device to make the beam tube wall appear continuous through the valve.

III. Proposed Sector Valves

Due to the special shield requirement only a few companies made design proposals. Two proposed designs were built for evaluation. One design featured a dual gate seal in which the valve body could be pumped differentially. The other valve featured a hard metal to hard metal gate seat. Both prototype valves were of all metal construction, well within dimensional requirements, and had successfully operating RF shields. Both were electro-pneumatically actuated and met both magnetic and radiation specifications. Both should meet the thermal cycle and valve cycle requirements.

The all metal dual gate seal valve used internal roller bearings for opening and closing motion. These bearings are specially lubricated with a very low vapor pressure material. The volume captured between the two gate seals in the closed position is approximately two liters. This volume can be pumped by some means not included with the valve. Operation with this method will be tricky due to possible contamination of the pump and subsequent beam vacuum requirements when the valve is re-opened. The advantage of the dual gate design is that by pumping between gates or with static vacuum and a time limit, total through leak rate is much lower than either individual seat leak rate.

The hard metal to hard metal gate seat valve is an all metal single gate design. It utilizes a swing gate pendulum design which avoids bearings and sliding surfaces in the vacuum. One hard metal surface of the gate seat is plated to avoid sticking after high temperature vacuum bake. The swing gate design requires a logic

control unit to insure correct operation. The advantage of this hard metal to hard metal seat is that it should be less susceptible to contaminant leaks typical to the hard metal to soft metal seal design.

IV. Testing Description

A program to evaluate the proposed sector valves was established. Individual seat leak rates, total leak rate for the dual gate seats, valve enclosure leak rates, location of leaks, multiple cycle reliability, residual contaminant levels, and physical characteristics were examined. The basic test system consisted of a balzer TSH 100 tubromolecular pump connected to the lower side of the sector valve through a 10 ltr/sec helium aperture and a bypass valve (See Fig. 2). The turbo pump was used to initially evacuate the system, pump during bake outs, maintain constant aperture speed for mass spectrometer calibration or measurement and to maintain vacuum on the lower section of the valve when closed.

Two different quadrupole mass spectrometers were used for helium leak rate measurements and for measurement of residual contamination levels. A Varian VGA-100 was installed between the 10 ltr/sec aperture and the lower test valve. Helium sensitivity was 5.1×10^{-4} amps/Torr. This M.S. was used to determine total test valve leakage, external leakage, and residual contaminants. The second M.S. utilized was an Ion pumped UTI model 100 G connected through an auxiliary port. Helium sensitivity with its multiplier off, was 0.97×10^{-4} amps/Torr. Ion pumping was through a 1 liter/sec nitrogen aperture. This system was used to determine top gate seat leakage on the dual gate valve, test for external leak rates, and make sensitive measurements of valve contaminants using its multiplier. Measurements with both mass spectrometers were made at room temperature, at 100°C, and at 200°C.

External leakage was measured using both mass spectrometers with the valve open or closed. The whole valve or sections of the valve were helium bagged with the mass spec. tuned to helium. If a leak was detected the area was helium probed to find its location. After completion of testing the valves were removed from the test system and examined visually. Wear characteristics, design, construction and materials were examined.

V. Test Results

The dual gate valve had been cycled approximately fifty times prior to delivery. The valve was installed in the test system and gate seals helium leak tested. The top seal was initially 5.6×10^{-7} Torr ltr/sec and the lower seal was 2.9×10^{-4} Torr ltr/sec helium. Total leakage through both seats was initially low 10^{-9} Torr ltr/sec and rose to low 10^{-8} Torr ltr/sec helium after 24 hours without interseal pumping. Top seal leakage and total both seal leakage did not change drastically with additional cycles and vacuum bakes at temperatures of 300°C or less. After the test valve was heated to 350°C to reduce a high hydrocarbon residual, its gate seal integrity was deminished. Individual and total leakage rates were unacceptable. The OFC copper seals had lost their mechanical sealing properties due to the high temperature bake⁽¹⁾.

The hard metal to hard metal seat swing gate valve had been cycled eighty times including six heating cycles to 300°C prior to delivery. After installation in the test system and the gate seal leak tested. The seal showed an initial leak rate of 7.5×10^{-5} Torr ltr/sec helium. The test valve was cycled several times, retested, and found

to have worsened to 2.0×10^{-4} Torr ltr/sec helium. Additional cycling did not improve the leak rate. The valve was returned to the vendor for rework.

The initial high leak rate of the lower seat of the dual gate valve had changed to 10^{-5} range on the lower seat after several cycles. Individual seat leak rates stayed in the 10^{-6} to 10^{-5} leak rate range for additional cycling until after the 350°C bake (See Table 1 and Fig. 3).

After the 350°C bake the leak rate changed to above 1×10^{-4} Torr ltr/sec helium. The total number of cycles at this time was approximately one hundred. The dual gate valve was then cycled to a total of one thousand cycles to see if mechanical failure would occur. None did. Total leakage was measured during the cycling (See Fig. 4).

Initial mass scans of the dual gate test valve indicated an unidentified hydrocarbon oil contaminant inside the valve. The level was too high for successful 10^{-11} Torr operation. The unidentified oil was not one of the refined types used in vacuum systems. Its major peak was found at m/e 41. After several bakes up to 300°C the level was reduced to 8.0×10^{-12} Torr ltr/sec. A 350°C bake was employed to reduce this level an order of magnitude but an air leak in a foil seal developed along with loss of gate seal integrity.

The valves under test had been initially tested after installation and pump down in the test system. No leaks were detected to a sensitivity of 5×10^{-10} Torr/Division helium. The valves were again tested after initial bakes up to 300°C . No leaks were detected.

TABLE I
TEST VALVE SEAT HELIUM LEAK RATE RESULTS

Total Cycles	Top Gate Seat ¹	Both Seats ^{1,2}	Comment ¹
53	5.6×10^{-7}	2.9×10^{-9}	2.9×10^{-4} Lower Seat
55	2.0×10^{-6}	--	--
56	9.2×10^{-6}	2.0×10^{-9}	4.3×10^{-5} Lower Seat After 4½ Hr. Bake 200°C
57	5.5×10^{-6}	6×10^{-10}	After 4 Hr. Bake 250°C
67	1.2×10^{-5}	1×10^{-9}	--
68	5.3×10^{-6}	--	After 1 Week 300°C Bake
70	3.9×10^{-6}	1×10^{-9}	
100	3.0×10^{-4}	1.4×10^{-7}	After 3 Day 350°C Bake
150	$> 5 \times 10^{-4}$	9.0×10^{-8}	
200	$> 5 \times 10^{-4}$	1.2×10^{-8}	
300	$> 5 \times 10^{-4}$	5.6×10^{-8}	
420	$> 5 \times 10^{-4}$	5.0×10^{-8}	
500	$> 5 \times 10^{-4}$	2.8×10^{-8}	
680	$> 5 \times 10^{-4}$	1.4×10^{-8}	
900	$> 5 \times 10^{-4}$	6.0×10^{-8}	
1000	$> 5 \times 10^{-4}$	2.2×10^{-7}	

Note: 1) Helium Leak Rates in Torr-Liters/Sec.

2) Both Seat Leak Rate measured within one half hour after valve closure and with static vacuum between seats.

The foil leak in the dual gate valve which resulted from the 350°C bake was measured at 8.6×10^{-8} Torr ltr/sec helium.

The foil leak was repaired and the copper seals were replaced by the dual gate valve vendor. Additional background and leak rate testing was performed. Results were good until after an additional two hundred cycles. After the additional cycles the leak rate drastically increased. Individual seat leak rates were in the 10^{-3} range.

External dimensions and configurations were within ISABELLE requirements. Either valve would fit in the space available. Internal surfaces in both valves were clean and no visual contamination could be found. Several blind holes in the dual gate valve were not vented. As blind holes⁽²⁾ can lead to virtual leaks in the valve they were later reworked by the vendor.

VI. Conclusion

The test results revealed problems with both proposed sector valves. These problems will have to be resolved prior to an acceptance of any final design. The major difficulty appears to be with the gate seal. Several standard all metal valves of similar size had been tested prior to fabrication of the sector valve prototypes. Gate seal and internal contamination problems were also encountered.

A welded seal will replace the foil seal in a new dual gate seal prototype. Also all blind holes will be vented and improved techniques will eliminate the internal contamination problem. Additional tests will be necessary prior to any acceptance for the ISABELLE vacuum system.

References

1. CERN Report - CERN-ISR-VA/77-46, CLOSED DISTRIBUTION.
2. F. Rosebury, Handbook of Electron Tube and Vacuum Technique,
Addison Wesley, 1965, pp 113-4

Acknowledgements

The authors would like to thank H. Halama, R. Skelton, P. Stattel,
and A. Hoffmann for their valuable contributions.

Figure Captions

- Figure 1. Residual Gas During Normal Operation of ISABELLE Vacuum First Cell.
- Figure 2. Test valve evaluation system. System is all metal except for the turbo port.
- Figure 3. Plot of test valve top seat leak rate versus number of closures. Dual Gate Valve.
- Figure 4. Plot of total test valve leakage thru both gate seats, with static vacuum between seats, versus time after valve closure. Plots after different numbers of total valve cycles open to closed position. Dual Gate Valve.