N81-14145 D7

USE OF CRYOPUMPS ON LARGE SPACE SIMULATION SYSTEMS

L.E. McCrary*

ABSTRACT

The need for clean, oil-free space simulation systems has demanded the development of large, clean pumping systems. The assurance of optically dense liquid nitrogen baffles over diffusion pumps prevents backstreaming to a large extent, but does not preclude contamination from accidents or a control failure. Turbomolecular pumps or ion pumps achieve oil-free systems but are only practical for relatively small chambers. Large cryopumps have been developed and checked out which do achieve clean pumping of very large chambers. These pumps can be used as the original pumping system or can be retrofitted as a replacement for existing diffusion pumps.

INTRODUCTION

As spacecraft become more complicated, the need for simulation systems which more closely duplicate the space environment and prevent contamination to the spacecraft are needed. Cryogenically refrigerated surfaces have been used extensively for thermal sinks and for the creation of the vacuum environment. Hardgrove (1) discussed several existing vacuum chambers in 1972 and Wang, Collins, and Haygood (2) discussed general cryopumping in a paper in 1961. More recently, Wilson and Watts (3) evaluated the design and operational characteristics of a cryopumping system for a 2500 liter chamber.

Several other chambers at various facilities extensively use cryopumping to achieve an oil-free vacuum. However, extensive work is still being done in space simulation chambers evacuated by oil diffusion pumps which are well-trapped.

This paper discusses the development of a large 1.2 meter (48") diameter cryopump which has been developed to evacuate large space chambers. These pumps were designed to have high pumping speeds for all gases, including hydrogen and helium. They provide a vacuum environment which is oil-free and not subject to contamination from the pumping system.

The refrigeration system in the pump is supplemented by a liquid nitrogen (LN_2)-cooled shroud to prevent thermal radiation to the 15°K surface.

TYPES OF CRYOPUMPS

The common LN_2-cooled or refrigerated baffle above diffusion pumps is used to pump water and to prevent backstreaming of the oil. This is, in effect, a cryopump for water vapor.

Liquid nitrogen-cooled shrouds used in chambers for cold walls are useful for pumping water and condensibles such as solvents and plasticizers, and to provide a thermal simulation of the space environment.

*High Vacuum Equipment Corp., Hingham, Massachusetts

The third type of cryopump is the 20°K helium shrouds which are sometimes used in conjunction with the LN_2 shroud. These temperatures are obtained with a helium refrigerator and can be used with or without charcoal to supplement the pumping of H_2 and He. These cold panel pumps require large He refrigerators and are expensive to operate.

Another type of cryopump is one using liquid helium (LHe) as a refrigerant and is used most commonly in a research-size chamber.

The fifth kind of cryopump is the commercially available pump which bolts onto a flange and is used to replace or supplement other types of pumping such as diffusion pumps or turbomolecular pumps. These cryopumps have been available in sizes to 250mm (10") diameter and are now commercially available up to 500mm (20") diameter.

There is, however, a requirement for cryopumps larger than 500mm (20"). In the process of specifying and fabricating large space simulation chambers, High Vacuum Equipment Corp. has found it impractical to use many smaller cryopumps and has designed a 1.2m (48") diameter pump.

Since cryopumps normally are valved off from the system, and a multiplicity of valves and pumps add significant cost to the pumping system, it is highly desirable to use large cryopumps. If the pumps are separated from the chamber by a valve, they can be regenerated individually during long tests and can be placed back on-stream a a fresh pump.

Gate valves which seal in both directions (will hold vacuum with atmospheric pressure on either side) are preferable to poppet valves which will seal in only one direction. Poppet valves will not allow regeneration during te..., but will allow evacuation and preconditioning of the pumps before the chamber is evacuated for testing.

Neither gate valves nor poppet valves are required if the cryopumps do not require regeneration during testing. However, if the pumps should malfunction and warm up during the test, the gas which has cryocondensed onto the cold surface will be released from the pump and will return to the space chamber and possibly contaminate the test article. Therefore, valves are recommended which are automatically interlocked to close when the cryopump warms up above 25°K or if the pressure in the chamber should rise to above a few microns.

4. DESIGN OF 1.2m CRYOPUMP

Smaller cryopumps which are commercially available use the first stage refrigerator to cool the radiation shield to 70-125°K to diminish the heat load on the 15°K pumping surface. For larger pumps, this becomes impractical without the use of multiple refrigerators and compressors. High Vacuum Equipment opted to cool the radiation shield (shroud) with LN_2 since LN_2 is readily available at larger space chambers to cool the shrouds, and the additional use of a few liters per day is not detrimental. For smaller cryopumps, the use of a refrigerated radiation shield is cost effective. The elimination of LN_2 is a big selling factor for cryopumps, but elimination of LN_2 at space chambers is not possible, so therefore it is cost-effective for very large cryopumps to use LN_2.

High Vacuum Equipment developed a cryopump 1.2m (48") diameter, shown in Figure 1 This size was selected to optimize size, pumping speed, and standardization. The pump uses a LN_2-cooled entrance chevron radiation baffle, LN_2-cooled cylindrical walls, and an LN_2-cooled rear head shroud, which mates with the shield on the back head cooled by the first stage of the refrigerator. These cold surfaces completely surround the 15°K surfaces. The LN_2 surfaces pump the water in the chamber and all readily-condensible gases. The 15°K surfaces are used to pump the atmospheric gases, such as N_2, O_2, and Argon. The only gases not pumped by either the 77°K or the 15°K surfaces are the "non-condensible gases", Neon, H_2, and He. These gases are pumped by the 15°K charcoal surface which is thermally isolated behind a 15°K chevron. The charcoal covers a 250 x 650mm (10 x 25 inch) surface.

A silicon diode temperature sensor is used to monitor the temperature of the second stage sail and charcoal "box". The temperature sensor is normally attached to the sail to ensure that the thermal joint is sound between the second stage flange and the copper cold surfaces.

Eight of these pumps have been fabricated to date. One has been installed on a stainless steel, internally polished 2.1m (8' x 12') diameter x 3.7m long chamber at Rockwell International's Seal Beach facility. This chamber is the subject of another paper at this conference. One pump with a speed of approximately 38,000 l/sec has achieved an ultimate pressure in the unbaked stainless steel chamber in the mid 10^{-9} torr range with a room-temperature aluminum shroud. With a baked chamber and a 77°K shroud, it may be possible to evacuate the chamber to the 10^{-10} torr range. The shroud is a standard tube-on-sheet shroud with a chevron baffle pumping port in the vicinity of the 1.3m (52") diameter horizontal poppet valve.

Three of these cryopumps are installed on the Canadian Communications Research Centre space simulation chamber at Shirley Bay, Ottawa, Ontario, scheduled for completion in December 1980. This system is schematically shown in Figure 2. Each cryopump is isolated from the chamber with a 1.2m (48") gate valve capable of sealing with atmospheric pressure in either direction. The CRC chamber is a vertical top-loading 7.3m (24') diameter, 10.7m (35') high stainless steel chamber which is internally polished. A LN_2 shroud encloses a working space of 6.7m (22') diameter by 10.7m (35') high. Ultimate pressures and pumpdown curves are not available at this time, but an ultimate of 5 x 10^{-9} torr with a cold shroud is anticipated.

In both of the above applications, the requirement for an oil-free chamber with no possibility of contamination was the driving factor for the specification of cryopumps instead of diffusion pumps. Likewise, in existing large chambers, the decision is either being made or considered, to replace the diffusion pumps with cryopumps. This retrofit is being done for the 8.8m (29') diameter x 19.8m (65') Martin-Marietta, Denver chamber. Four 1.2m (48") oil diffusion pumps are being replaced with an improved version of the pump discussed above. The four cryopumps for Martin are larger in diameter-1.3m (52"), but will still mate with the 1.2m (48") diameter standard flange. The increased diameter and increased spacing on the entrance chevron has increased the pumping speed to approximately 48,000 l/sec. This pumping speed has not yet been measured, but conductance calculations indicate this substantial increase in pumping speed.

5. PUMPING SPEED MEASUREMENTS

The pumping speed of the pumps was measured using the AVS Standard Method 4.8, "Procedure for Measuring Speed of Pumps Without Working Fluid." An inclined manometer with silicone oil for the displacement fluid was used. Corrections were applied as defined by Stevenson (4) for the inclined manometer tube. Ion gauge corrections were made for the various gases. The pumping speed measurements are shown in Table I.

More extensive pumping speed tests are in process using the constant pressure gas flow measurement method used here and the partial pressure decay with time using a Residual Gas Analyzer (RGA). The pumping speed measurements illustrate the high pumping speeds achievable with cryopumps.

CONCLUSIONS

The use of large commercially available cryopumps is the most reliable means of achieving a vacuum environment which is assured of being free of contamination from the pumping system. To paraphrase Yarwood (5) the pump of the future is the cryopump. Cryopumps will be used instead of diffusion pumps in future systems and diffusion pumps will be replaced by cryopumps on existing systems to ensure the elimination of oil contamination.

REFERENCES

1. W.F. Hardgrove, "Cryogenic Applications for Environment Simulation", AIChE Symposium Series No. 125, Vacuum Technology at Low Temperatures, S.Alexander, editor, 1972, pp.31-39.

2. E.S.J. Wang, J.A. Collins, J.D. Haygood, "General Cryopumping Study," Advances in Cryogenic Engineering, Vol. 7, Plenum Press, N.Y., 1961.

3. N.G. Wilson, K.N. Watts, "Design and Operational Characteristics of the Cryopump High Vacuum System for the 2500-1 Target Chamber of the Helios Test Facility," J. Vac. Sci. Tech., Vol. 17, No.1, Jan/Feb. 1980, pp. 270-273.

4. D.L. Stevenson, "Improving the Accuracy of Metering Gas Flow and Computing Throughput," Vacuum Symposium Transactions, 1961, pp. 555-559.

4. J. Yarwood, "The Production of Vacuum: Past, Present, and Future," Vacuum, Vol. 29, No.8/9, Aug/Sept. 1979, pp. 313-317.

TABLE I

Gas	Pumping Speed 1/sec.
Nitrogen	39,278 (Avg. of [illegible] meas.)
Argon	30,575 (Avg. of 3 meas.)
Helium	5,729 (Avg. of 2 meas.)

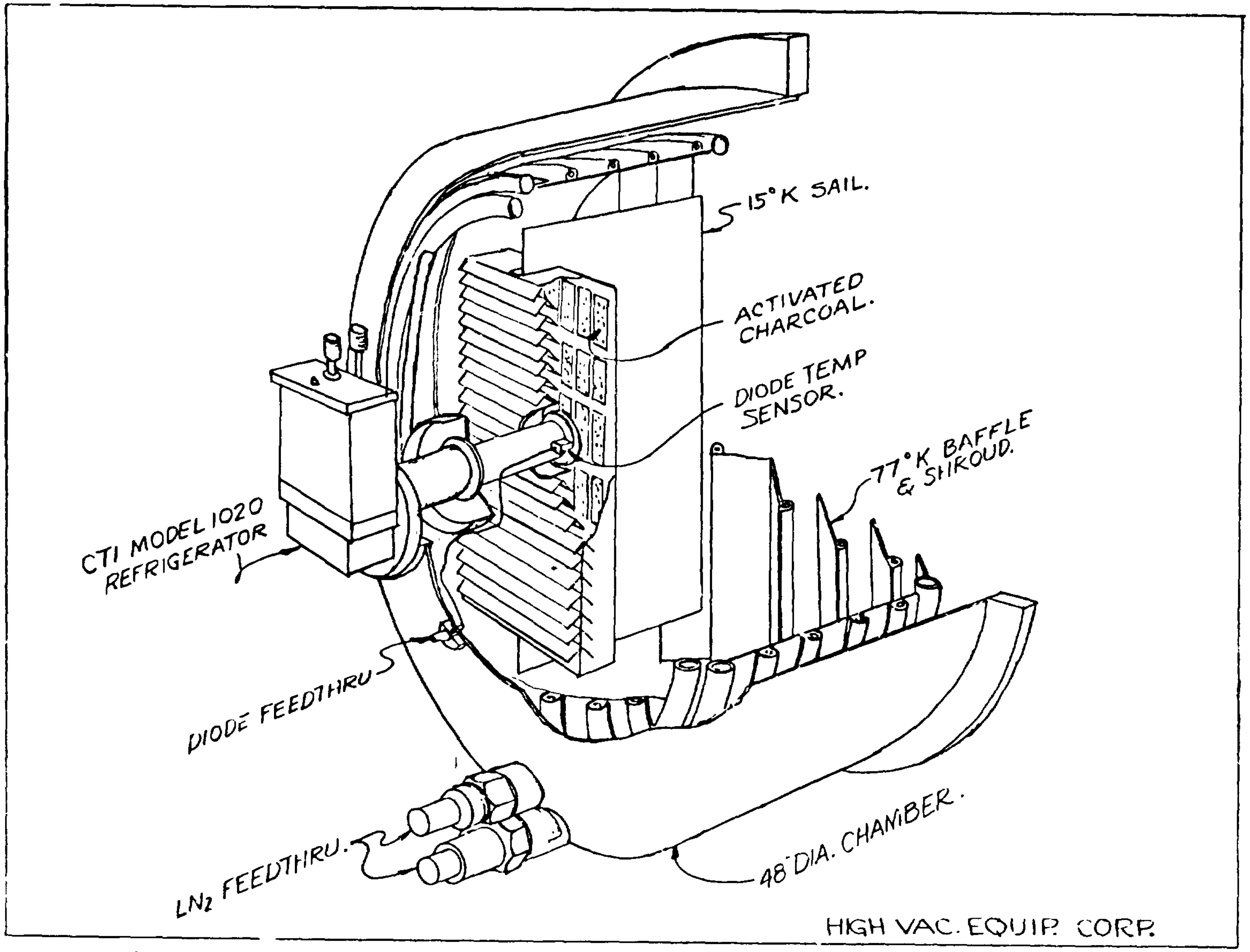

Figure 1 Schematic of 1.2 Meter Diameter Cryopump

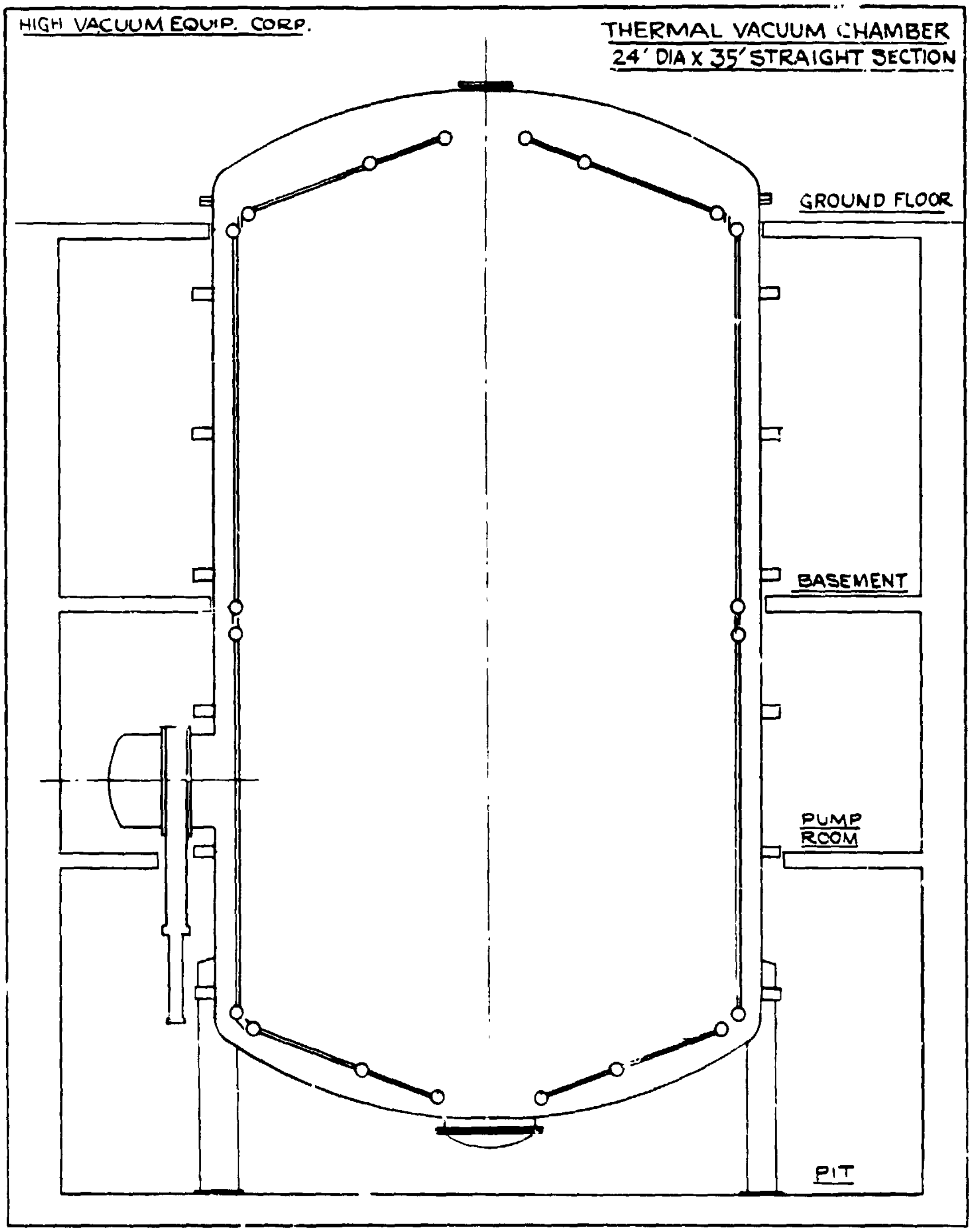

Figure 2 CRC Thermal Vacuum Chamber