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ABSOLUTE CONTAINMENT OF A KILOCURIE 3H TARGET AT A LOW ENERGY RESEARCH ACCELERATOR

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ABSOLUTE CONTAINMENT OF A KILOCURIE  $^3\text{H}$   
TARGET AT A LOW ENERGY RESEARCH ACCELERATOR

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August 1969

Abstract

Requests are frequently made for the use of tritium targets in particle accelerators for the production of 14-MeV neutrons. Titanium tritide targets are commonly used, and publications presently available describe the techniques and handling of these targets. In our case, however, the experiment called for a gaseous tritium target containing several hundred curies that could be bombarded by a deuteron beam from the 88-inch cyclotron without accelerator contamination or personnel exposure.

The problems and hazards associated with the use of these  $^3\text{H}$  targets were investigated. Particular emphasis is placed on the use of high-speed vacuum valves activated by explosive squibs that receive their signal from a mass spectrometer; also, absorption pumps were used in order to have a complete closed pumping system.

A potential contamination problem existed due to the extremely thin windows of the  $^3\text{H}$  cell, the pressure differential between the cell and the surrounding scattering chamber, and possible sudden loss of the cyclotron vacuum.

Contamination in the cyclotron would interfere with beam development work and activities of the maintenance crew. The target cave area and the building itself are not equipped with ventilation appropriate to large quantities of radioactive gas. In addition, because of several factors, the release of tritium cannot be precisely measured. The behavior of tritium in the environment is not completely understood. The policy of this Laboratory is not to dilute and disperse, but to "concentrate and confine," and means of preventing tritium release were necessary.

The study led to the development of a long-needed fast-acting vacuum valve that could be used in the field of nuclear research. The criteria for such a valve were: Fast enough closing to stop the diffusion of the gas into the cyclotron after some sort of signal to the closing mechanism; a high degree of reliability; a large enough diameter to allow the beam to go through; and simplicity of operation and maintenance.

Commercial explosives in the form of squibs were chosen as the source of power for the valves because of their very high degree of reliability, the reproducibility of the force created by the explosion, and their compatibility with electronic firing mechanisms.

The combination of proper materials and the very high energy available from the squibs made these valves extremely positive and reliable. Even slight misfits and misalignments are overcome by the great closing force.

Two ion gauges were used to produce a signal for the explosive squibs. One, in the "rf" chamber, detected a pressure increase on the cyclotron, the second, on the scattering chamber, detected an increase of pressure that perhaps was due to a leak in the  $^3\text{H}$  cell. Since speed was of great importance in the closing of the valves, a mass spectrometer, which is more sensitive than an ion gauge, was installed in the scattering chamber to detect minute quantities of gas that might appear. Both ion gauges and the mass spectrometer were connected to a specially designed triggering device that would produce a signal for the explosive squibs.

To prevent any release of  $^3\text{H}$  into the building or the environment, a complete closed pumping system was provided by two absorption pumps. The pumps were also used to empty the  $^3\text{H}$  cell upon completion of the bombardment.

With this new approach to the problem one can run gaseous tritium targets of thousands of curies relatively safely on the cyclotron. In addition, the system can very simply be incorporated to handle the bombardment of any radioactive target.

### Introduction

Requests are frequently made for the use of tritium targets in particle accelerators for the production of neutrons. Titanium tritide targets are commonly used, and presently a number of publications are available describing the techniques and handling of these targets.<sup>1-3</sup> In our case, however, the experiment called for a gaseous tritium target containing several hundred curies that could be bombarded by a deuteron beam from the 88-inch cyclotron without accelerator contamination or personnel exposure. The purpose of this study was to investigate the problems and hazards associated with the use of these  $^3\text{H}$  targets. High-speed vacuum valves activated by explosive squibs that receive their signal from a mass spectrometer were constructed; also, absorption pumps were used in order to have a complete closed pumping system.

We feel that this is a new approach to the problem, and the study shows that one can bombard gaseous tritium targets of thousands of curies relatively safely on the cyclotron. In addition, the system can very simply be modified to handle the bombardment of any radioactive target.

### Experimental Equipment

We describe only those parts of the experimental equipment that are of Health Physics interest (see Fig. 1) A 1.3-ft<sup>3</sup> vacuum chamber (scattering chamber) surrounds the  $^3\text{H}$  cell. The  $^3\text{H}$  cell was constructed from solid brass with a machined cavity of approximately 200 ml. Both ends of the cell were sealed off with 0.005-in Havar foil (see Appendix 1) that was soldered into place and later He leak-tested. A manifold connecting the  $^3\text{H}$  cell with the tritium supply cylinder came through a Wilson seal in the vacuum chamber. A 0.005-in. Havar foil separated the scattering chamber from approximately 65 to 70 ft of 4-in. beam pipe leading to the cyclotron. The scattering chamber's pumping system consisted of a mechanical and an oil diffusion pump.

### Potential Contamination Problems

There was a potential contamination problem due to two factors. One was the extremely thin windows (a necessity for the  $^3\text{H}$  cell) and the pressure differential between the cell and the surrounding scattering chamber, second, the cyclotron beam current can increase enough that the beam actually burns a hole in the cell window. Also the cyclotron could suddenly come up to air, thereby creating a blast of air rushing up the beam pipe and rupturing the foils.

Contamination in the cyclotron would be very undesirable, in particular to the beam development work (which often requires welding and brazing on the deflector parts), and would also hamper the maintenance crew that at regular intervals has to enter both the dee tank and the radio-frequency chamber. The target cave area and the building itself are not equipped with ventilation appropriate to large quantities of radioactive gas. In addition, the behavior of tritium in the environment is not completely understood. In keeping with the Laboratory's policy on contamination control, we must not dilute and disperse, but "concentrate and confine."

#### Contamination Control

Calculations showed that, in case of foil rupture, a valve in the beam pipe 35 to 40 feet upstream from the  $^3\text{H}$  cell could stop the  $^3\text{H}$  from entering the cyclotron, provided that the valve would close in 0.006 sec or less.

The requirements implied above led to development of a long-needed high-speed vacuum valve that could be used in the field of nuclear research (see Appendix 2). Two of these valves were placed in the system (Fig. 1). One was approximately 20 feet from the scattering chamber. This valve would stop the blast of air that is created when the cyclotron suddenly comes up to atmospheric pressure. The other valve was placed approximately 50 feet upstream from the scattering chamber. Both this and the other valve would prevent the  $^3\text{H}$  from entering the cyclotron in case of foil rupture in the  $^3\text{H}$  cell.

Two ion gauges were used to produce signals for the explosive squibs. One was in the "rf" chamber to detect a pressure increase on the cyclotron. Because there was a great pressure differential between the  $^3\text{H}$  cell and the scattering chamber, the second ion gauge was located on the latter and would detect any increase of pressure that was due to a leak in the  $^3\text{H}$  cell. Since speed was of the utmost importance in the closing of the valves, a mass spectrometer (see Appendix 3), which was a greater degree of sensitivity than an ion gauge, was installed in the scattering chamber to detect minute quantities of gas that might appear. Both ion gauges and the mass spectrometer were connected to a specially designed triggering device (Fig. 2) that produces a signal to the explosive squibs.

To prevent any release of  $^3\text{H}$  into the building or the environment, two absorption pumps were connected to the scattering chamber in order to have a complete closed pumping system. Upon completion of the bombardment, the pumps were also used to empty the  $^3\text{H}$  cell.

#### Operational Sequence

Prior to the filling of the  $^3\text{H}$  cell, the scattering chamber was pumped down to the desired pressure (approximately  $10^{-4}$  mm Hg), using a mechanical and a diffusion pump. When the correct vacuum was attained, the mechanical and the diffusion pumps were isolated from the scattering chamber and one of the absorption pumps sufficed to maintain the vacuum. The same absorption pump was also used to evacuate the  $^3\text{H}$  cell and the manifold connecting the  $^3\text{H}$  cell with the  $^3\text{H}$  supply cylinder (see Fig. 1). The beam pipe was evacuated by the cyclotron pumps and had a pressure of approximately  $15\mu$ . Both ion gauges and the mass spectrometer were connected to the triggering device, the explosive squibs, and the fast-acting vacuum valves. The mass spectrometer was also connected to a stripchart recorder that was monitored on a closed-circuit television in the control room during the entire bombardment. The tripping point for the explosive squibs was set at 1 mCi on the mass spectrometer. After the system had been checked for leaks and other malfunctions, the  $^3\text{H}$  cell was filled and the system was ready for the 80 hours of bombardment time.

### Experimental Findings

The 80 hours of bombardment time took place without any major incidents. Two absorption pumps were available; however, only one was needed to maintain the desired pressure, thus leaving one in reserve throughout the run. During the experiment the valves were closed three times intentionally and once inadvertently because one of the mass-spectrometer elements burned out. There was no mechanical trouble. After the experiment, tests of the closed valves with a helium leak detector showed that the gates were properly closed and vacuumtight. The mass-spectrometer stripchart recorder showed a slight increase of  $^3\text{H}$  in the scattering chamber; however, the amount was so small that the tripping point for the explosive squibs needed no adjustment. The  $^3\text{H}$  appearing in the scattering chamber at the time could have been due to a very slight leak that had developed, or to diffusion through the 0.005-in. Havar foil.

### Further Tests

The arrangement shown in Fig. 3 was constructed so that the spectrometer could monitor the vacuum side of the test foil under static conditions. This would allow detection of diffusion buildup if it were to occur.

Prior to calibration of the system, the indium seal was tested by using a thick blank plate in place of the foil. Both sides of the plate were pumped down and the foil chamber back-filled to 1 atmosphere of helium. No helium was detected in the vacuum chamber. The 0.005-in. Havar foil was checked in like manner, and no leaks were detected.

With the foil removed, a helium leak ( $3.9 \times 10^{-8}$  atm cc sec) was introduced into the static vacuum chamber. Based on this measurement, a variable leak was calibrated for helium and then for tritium gas. From this it was determined that a leak rate of  $10 \mu\text{Ci sec}^{-1}$  of tritium gas was readily detectable and the signal from the spectrometer could be used to fire the fast-acting "slammer" valve.

The foil was then put in place and both sides were pumped down. The foil chamber side was back-filled to 1 atmosphere of tritium gas. With the vacuum chamber isolated from the pumps, the spectrum from mass 6 to mass 3 was observed for more than 6 hours. No significant changes were noticed, and we concluded that no tritium diffusion took place during this time.

Considerable effort was required to get the vacuum chamber to hold an acceptable vacuum in a static state. The results above were obtained with an initial pressure of  $10^{-7}$  torr and a terminal pressure of  $10^{-4}$  torr.

APPENDICES

1. Havar Foil

Havar is a corrosion-resistant nonmagnetic age-hardening type of cobalt-base alloy with good hot and cold working properties. It is characterized principally by its high fatigue resistance, high tensile strength, and high torque values. Its composition is

Cobalt	42.5%	Molybdenum	2.0%	Manganese	1.60%
Nickel	13.0%	Carbon	0.20%	Tungsten	2.80%
Chromium	20.0%	Beryllium	0.04%	Iron	Bal

2. Fast Acting Vacuum Valves

Arthur Hartwig

Fast acting vacuum valves for use in the field of nuclear research have been needed for some time. The valves described in this note (see Fig. A-1) were developed at the 88 inch cyclotron at LRL primarily because of the desire to do a scattering experiment on a tritium target. Because of the extreme problem of contamination to the cyclotron in the event of an excursion of tritium into the cyclotron and the increased difficulty of maintaining the accelerator in that event, it was thought that some protection besides isolation foils was needed.

The criteria for such a valve were:

1. To close fast enough to stop the diffusion of the gas into the cyclotron after receipt by the closing mechanism of a signal of some sort,
2. A high degree of reliability,
3. A diameter large enough to allow the beam to go through in spite of some degree of error in the optics, and
4. A simplicity of operation that would allow maintenance of the valves without undue interference with the experiment.

Commercial explosives in the form of squibs were chosen as the source of power for the valves because of their very high degree of reliability, the reproducibility of the force created by the explosion, and their compatibility with electronic firing mechanisms.

The first valve in the series had a 1-in. i. d., and was extremely simple. It was a steel block with a 1-in. bore through it in a horizontal plane and a tapered cavity at 90 deg to the bore. A Teflon wedge stored above the cavity was driven tightly across the openings by firing a squib at the top. This valve closed, with a charge of 500 mg of Bullseye Pistol powder in the squib, in 1.8 msec, including the time required by the firing mechanism. Reliability of this valve was very high, but it was inconvenient to maintain, since it had to be dismantled in order to be reset after each firing.

The second valve also had 1-in. openings, but was rebuilt from a commercial wedge valve by adding a firing chamber and piston at the top. This valve was successful and closed in 2 msec. It was always vacuumtight after closing and never failed to operate. It was somewhat self-destructive, and the housing became distorted from the force of firing the gate against the bottom of the valve body. It was, however, still operating satisfactorily after approximately 20 firings.

It became apparent that because of beam optics the 1-in. -diam valve, in its position in the beam line, was too restrictive, so it was decided to try a 2-in. one which could be installed in the beam pipe even at a position where the beam was somewhat defocused. It was thought that the 2-in. valves would close in approximately double the time required by the 1-in., and they probably would have, except that for greater reliability the size of the moving parts was increased



to a degree greater in proportion than the increase in the size of the opening. The greater proportional mass of the moving parts resulted in a closing speed of 6 msec. This speed was considered fast enough, and the gain in reliability made it worthwhile.

The apparatus used in testing is shown in Fig. A-2.

During the experiment the valves were closed three times intentionally and once inadvertently. No mechanical trouble of any kind was encountered. After the experiment was finished the valves were closed and tested with a helium leak detector which showed that the gates were properly closed and vacuumtight.

Future development will be towards lighter materials in the moving parts and some method of decelerating the gate near the end of its travel.

Choice of materials for the gate-sealing surfaces is important. Chrome-plated steel for the gate and Teflon seats were chosen. Materials other than Teflon either shattered on impact or failed to permit any loose material to be imbedded into the seat, so that the gate either was scratched or failed to seal.

The combination of proper materials and the very high energy available from the squib made these valves extremely positive and reliable. Even slight misfits and misalignments are overcome by the great closing force. Longevity of the valve depends upon the speed at which it is closed. Some deformation of the bottom of the valve body is to be expected.

### 3. Description and Specifications of Mass Spectrometer

The Model AVA1 Vacuum Analyzer measures total system pressure and scans the mass spectrum to identify gas residuals and their partial pressures when installed on a vacuum system or exhaust station. The vacuum analyzer consists of the following major components:

- Spectrometer tube AST1 - B (Bakable)
- Power supply and emission regulator
- Ion current amplifier
- Magnet set
- Interconnecting cable

The spectrometer tube is constructed on a stainless steel flange with the ion gun electrodes extending into the vacuum system in nude-type configuration. Two filaments are provided; the unit may operate on either one at a time. A degassing grid is built into the ion gun. Ions are accelerated down a stainless steel tube, deflected 60 deg in a magnetic field, and collected at the far end of the tube. The AST1-B flange is a modified Varian 2.5-in. i. d. copper seal flange which bolts to a 2.5-in. penetration with a standard Varian mating flange. Adaptors for other penetrations are available as optional accessories.

The power supply and emission regulator feeds regulated dc current to the filament, provides the accelerating potentials, operates the degassing grid, and protects the filaments from pressure surges. A motor drive scans the ion accelerating voltage over the mass number range. In addition, the drive provides an x-axis output which correlates with mass number. Manual scan can also be employed. X and Y outputs for operating a recorder are provided at the back panel. Controls on the unit select the active filament, control the mode of operation (total or partial pressure), and set emission current.

The ion current amplifier includes a meter calibrated in torr. The unit reads directly in total pressure and relative partial pressure over seven ranges ( $10^{-4}$  to  $10^{-10}$  torr).

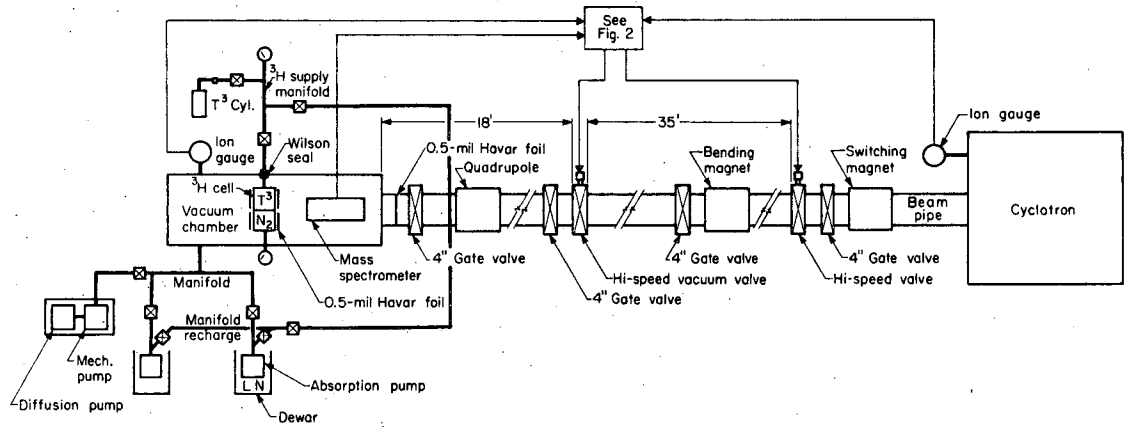
The magnet set consists of two magnets, one for scanning masses 2 to 11, and one (which we did not use) for masses 12 to 70. Total pressure may be read on either mass range. Magnets are easily changed.

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2. L. K. Akers and H. E. Banta, Solid Tritium Target Quality Studies, ORINS International Report, Oak Ridge, Tenn., 1963.
3. I. L. Morgan, Tritiated Targets of Sc, Ti, Zr, Er, Y, and U, presented at the Second International Meeting on Accelerator Targets Designed for the Production of Neutrons, Grenoble, France, June 2, 1965.

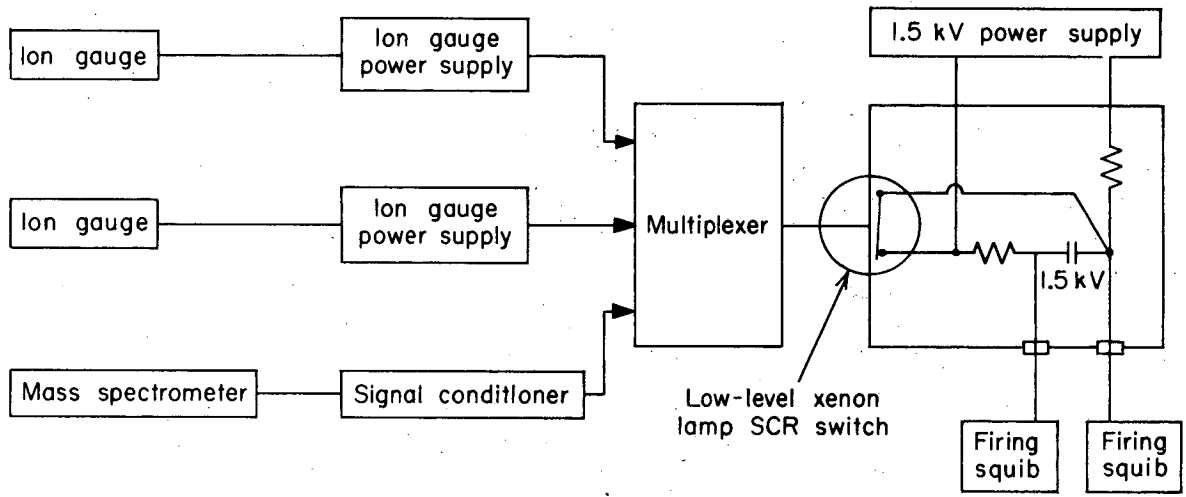
Figure Captions

- Fig. 1. Schematic diagram of the experimental arrangement.
- Fig. 2. Triggering device.
- Fig. 3. Diffusion testing apparatus.
  
- Fig. A-1. Two-inch fast-acting valve, Mk III.
- Fig. A-2. Apparatus for testing high-speed vacuum valves.  
Operational sequence:
  1. Foil is ruptured and helium enters.
  2. Ion gauge signals squib power supply (not shown).
  3. High-speed valve closes.
  4. Helium gets to first Annie, but not to second.



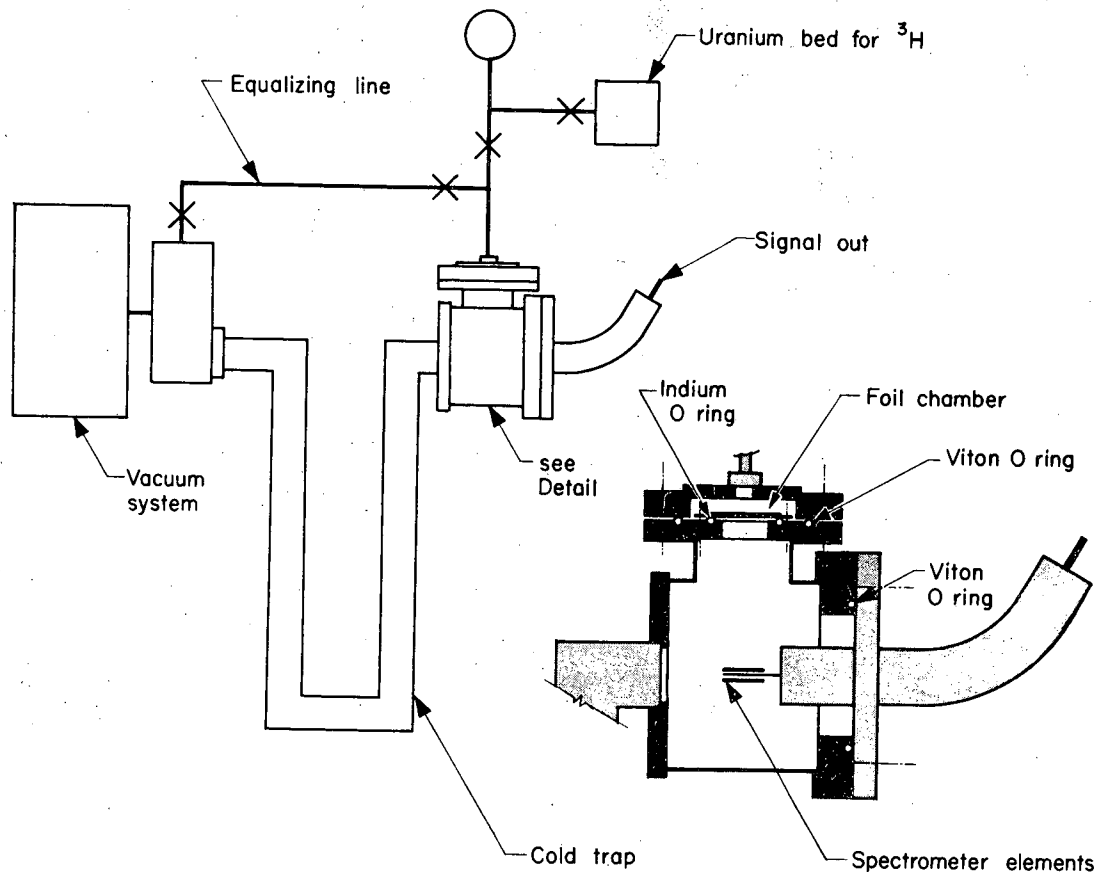
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Fig. 1



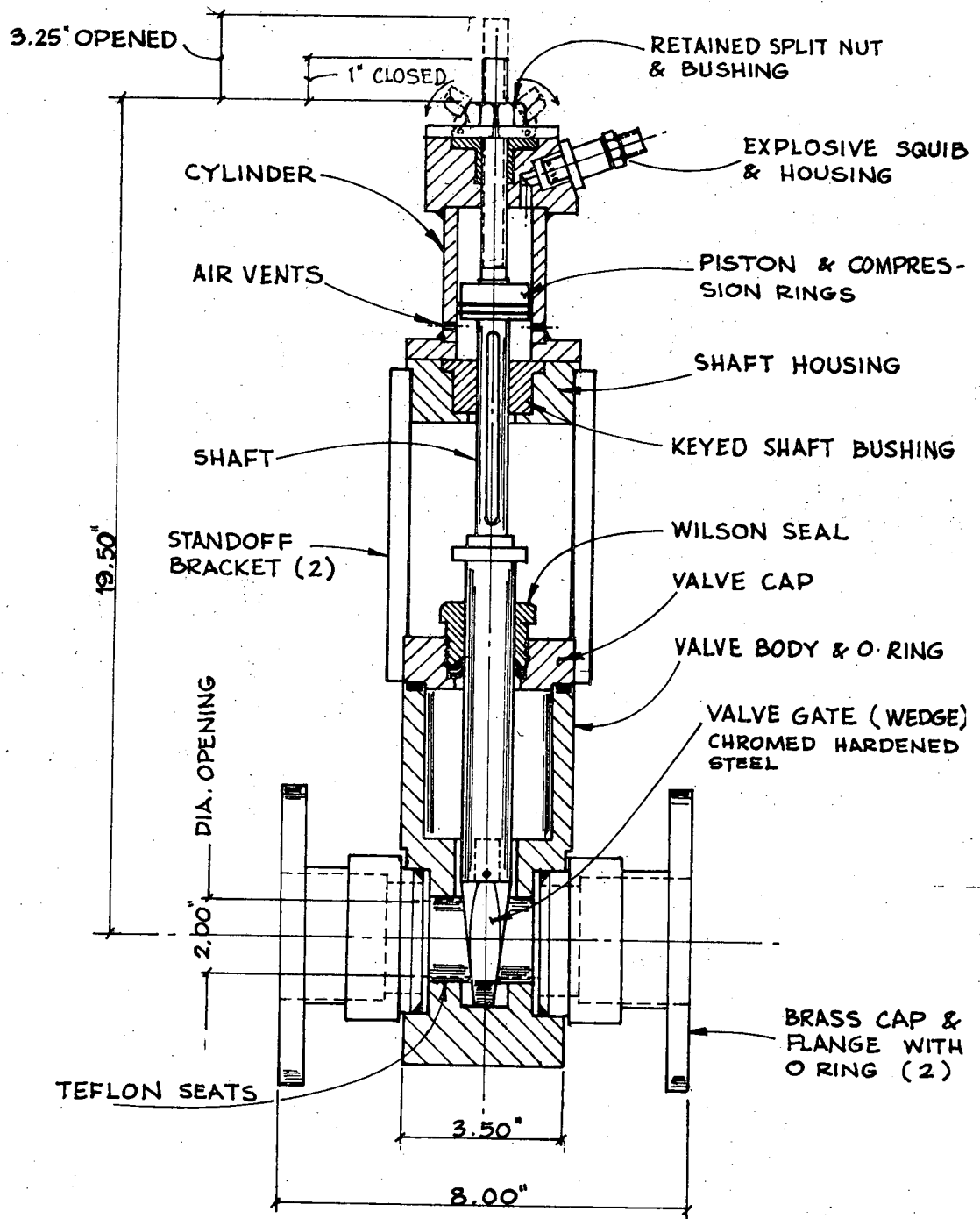
XBL 691-38

Fig. 2



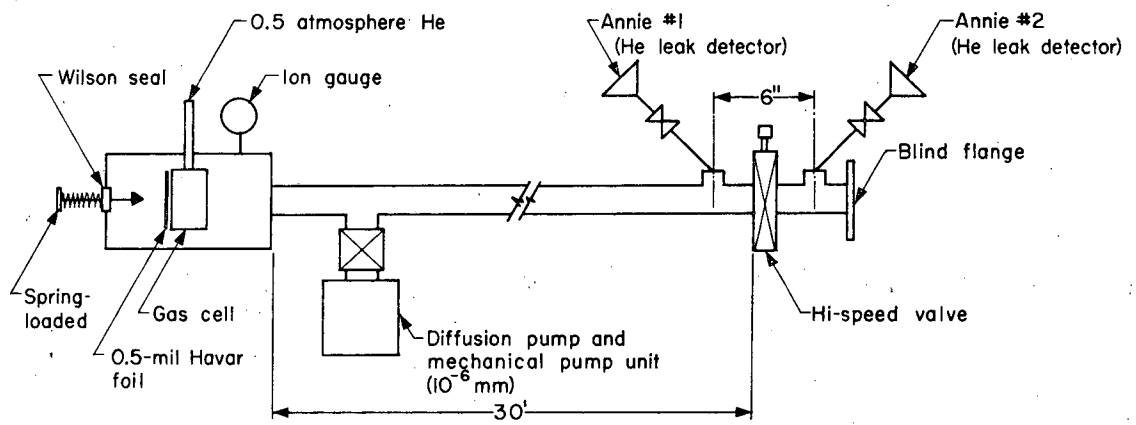
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Fig. 3



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Fig. A-1



XBL 691-39

Fig. A-2



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