VTM-12

BNL-28267

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.

MASTER

A Water Vapor Pressure Gauge*

CONF-801037--7

D. Edwards, Jr. and D. Gillette
Brookhaven National Laboratory
Upton, New York 11973

Abstract

An inexpensive pressure gauge, able to measure the N_2 and H_2O components within a vacuum system in the pressure range 1μ to 400μ is described and results of tests of the device are reported.

1. Introduction

One of the major problems in leak detection is the ability to know when in fact a leak is present in a vacuum system. This problem is particularly manifest in complex or extended systems in which parts of the system are reasonably inaccessible to an external helium spray.

A reliable indication of the presence of a leak or leaks in the vacuum system is the presence of N_2 in the system after pumpdown. Although several techniques exist for testing N_2 in a vacuum system (mass spectrometer, Varian cold cathode discharge gauge) they tend to be both costly and not suited to leak detecting applications in the pressure range 1μ to 400μ .

It was the object of the present program to design a simple instrument capable of distinguishing air (N_2 , O_2) from H_2O in a pressure range 1μ to 400μ , determine the characteristics of the device and test the gauge on a typical system.

2. Instrument

The gauge together with the system used for its testing is shown schematically in Fig. 1. Briefly the water vapor gauge consists of two thermocouple gauges (P1 and P2) separated by a cold trap one side of which is connected through V1 to the system to be tested. An additional valve V2 was also included in order to be able to independently evacuate the gauge.

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

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 test system, shown also in Fig. 1, allowed various partial pressures of air and water vapor to be established which could then be measured by the water vapor gauge.

3. Description

The gauge operation can be described in the following way. With the trap separating P1 and P2 cold and V2 closed V1 is opened to the system under study. P1 measures the total (air plus H₂O) pressure. The cold trap acts as a filter of the water vapor allowing the N₂, O₂ components to reach P2. Hence P2 will measure only the N₂, O₂ component of the total pressure. Thus with these two quantities both the air and water vapor components can be determined.

It was originally planned to operate the cold trap at LN₂ (77 K) temperature since LN₂ is readily available and the trap is more than sufficiently cold to trap H₂O and the vapor pressure of N₂ at 77K is ~ 1 atm. However, it was soon realized that the adsorbing H₂O film in the cold trap is able to effectively pump the N₂ coming in with the water vapor. In fact with 20μ of N₂ mixed with 300μ of H₂O, P2 measured less than 1μ. Thus the growing H₂O film effectively trapped all of the incoming N₂.

In view of this difficulty the cold trap temperature was changed to ~ 200K, the temperature of a solution of dry ice and methanol. It should be noted that the vapor pressure of H₂O at this temperature is less than 0.1μ. No evidence of pumping of the incoming N₂ by the water vapor film was observed at the 200K trap temperature.

4. Operation

The gauge was operated in two modes: i) a static mode, and ii) a dynamic mode.

4.1 Static Mode

In the static mode the gauge was evacuated through V2 with the trap warm (at room temperature) and V1 closed. V2 was then closed and V1 opened allowing the gas mixture to enter the gauge (with the trap still warm). V1 was then closed and the trap cooled to ~ 200K. The water vapor would then condense on the trap walls leaving the N₂, O₂ components remaining, and measured by either P1 or P2. It typically took between 5 to 10 minutes to adsorb 400μ of H₂O onto the trap walls. Said slightly differently, additional waiting past the 5-10 minute interval would not further reduce the gauge pressure.

4.2 Dynamic Method

The second method used to operate the gauge was the dynamic method. In this mode of operation the gauge would be evacuated through V2 with the trap at room temperature and V1 closed. V2 would then be closed and the trap cooled to $\sim 200\text{K}$ which took from 2 to 5 minutes. V1 would then be opened and the change in P2 measured. With the total pressure less than 30μ (see further discussion) the N_2 component could be determined with a sensitivity of $\sim .1\mu$ in this operating mode.

4.3 Tests

The gauge was tested at two N_2 (air) pressures of $\sim 2\mu$ and $\sim 15\mu$ mixed with water vapor at pressures between 0μ and 400μ . The results of these tests are shown in Figs. 2 and 3.

The most significant effect is observed in the dynamic measurement mode at water vapor pressures above 100μ . Seen in these figures is that as the water vapor pressure is increased above 100μ the N_2 pressure read by P2 is markedly enhanced. This effect is very likely due to a diffusion pump like effect; i.e., the H_2O carries the N_2 into the cold trap where the H_2O is adsorbed on the walls. However, the migration of the N_2 back into the system is greatly impeded at the higher pressures by the inflowing gases and hence an enhancement of the N_2 pressure on the downstream side of the trap is expected.

A small effect slightly influencing the N_2 pressure in the test system is the enhanced conductance of V3 connecting the system to the mechanical pump through a LN_2 trap. This effect would tend to decrease the N_2 pressure in the test system for a given N_2 leak rate and is as seen in the static mode case, i.e. a diminution of the N_2 pressure as the water vapor pressure is increased.

The conclusions of the above tests are summarized below:

1. The static method is able to determine the N_2 component of the pressure in H_2O pressures up to 400μ with a sensitivity of about 1μ .
2. For total pressures below 30μ the static and dynamic methods are in agreement as to the N_2 component of the total pressure.
3. For pressures below 30μ the dynamic method is able to rapidly and easily determine the N_2 component of the $\text{N}_2\text{-H}_2\text{O}$ mixture with a sensitivity of $\sim .1\mu$.

Thus the gauge operation is restricted in the following way:

- i) For total pressures above 30μ use the device in the static method only.
- ii) For total pressures less than 30μ either the static method or dynamic method may be used, the dynamic method being preferred for operating ease and N_2 sensitivity.

5. Pumpdown of the Test System

The gauge was used to monitor the N_2 component in the pumpdown of the test system after the system had a 5 minute atmospheric exposure. The trap on the mechanical pump on the test system was left at room temperature during this study.

Figure 4 shows a rather continuous record of the total pressure during the pumpdown and a few discrete N_2 pressures. Seen is that after ~ 6 minutes of pumping the N_2 component comprises less than 0.5% of the total pressure and after 10 minutes of pumping the actual N_2 pressure in the system is less than 0.1μ , although the H_2O pressure is still $\sim 30\mu$.

Thus if one were observing the total pressure during pumpdown (after say 10 minutes of pumping) in an attempt to determine the presence of real leaks, only a few per cent change in the total pressure would correspond to a rather large leak and would be essentially not be determinable from a pumpdown observation. However with the present simple device, a few per cent N_2 in the H_2O background is easily measured and hence the presence of a real leak in the vacuum system definitely established after a very short pumping period.

Acknowledgments

It is a pleasure to acknowledge the continuous and helpful cooperation of Mr. W. Jacobs and Mr. A. Wisowaty during the course of this study.

Figure Captions

1. A schematic of both the water vapor gauge and test system.
2. The N_2 pressure of $\sim 2\mu$ mixed with various water vapor pressures for the two measurement methods. It is noted that the dynamic measurement was made 5 minutes after V1 was opened.
3. The N_2 pressure of $\sim 16\mu$ again mixed with various water vapor partial pressures. The dynamic measurement was also made after a 5 minute wait after V1 was opened.
4. The pumpdown of the test system showing a continuous record of the total (mainly H_2O) pressure and several discrete N_2 measurement points.

Fig. 1

Fig. 2

Fig. 3

Fig. 4