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Analysis of the January 10th test dewar RGA data taken By Petros Rapidis

To estimate outgassing rates in the cryostat, the pumping speed delivered must be estimated. The upper range of molecular flow is approximated by $D\overline{P} \le 5\text{x}10^{-3}$ cmTorr. The diameter of the flex hose between the turbo pump and the cryostat is 3 in. or 7.62 cm. Therefore the pressure at which molecular flow begins is $\overline{P} \le \frac{5\text{x}10^{-3}\ \text{cmTorr}}{7.62\,\text{cm}} = 6.56x10^{-4}\ \text{Torr}$. The RGA data was obtained at pressures in the 10^{-6} range, thus the flow is clearly in the molecular regime. There are 3 restrictions to flow between the cryostat and the pump. The flexible hose (C_H), the isolation valve (C_V), and the aperture at the cryostat (C_A). The total conductance C_T is then $\frac{1}{C_T} = \frac{1}{C_H} + \frac{1}{C_V} + \frac{1}{C_A}$. The conductance for air thru the tube in the molecular regime is $C_H = \frac{12D^3}{L}$ with units of liters/sec where *D* and *L* are in cm. The valve is modeled as an elbow with a conductance of $C_V = \frac{12D^3}{L_{ax} + 1.33\frac{\theta}{180}D}$. The conductance of the aperature is $C_A = 11.6A$ where *A* is in cm².

$$\frac{1}{C_T} = \frac{1}{\frac{12(7.62^3)}{99.06}} + \frac{1}{\frac{12(6.05)^3}{20.93 + 1.33\frac{90}{180}6.05}} + \frac{1}{11.6\left(\frac{\pi}{4}\right)6.05^2} = \frac{1}{53.6} + \frac{1}{106.5} + \frac{1}{333.5}$$

such that C_T = 32.2 liters per sec.

The pumping speed delivered to the vessel (S_T) is significantly less than than the 160 liters/sec delivered at the pump (S_P).

$$S_T = \frac{S_P \text{x} C_T}{S_P + C_T} = \frac{160\text{x}32.2}{160 + 32.2} = 26.8\frac{liters}{\text{sec}}$$

Petros observed a pressure rise of 0.044 Torr/day when the cryostat was isolated. This pressure rise is due to internal out gassing, permeation thru the large flange and relief valve o-rings, and a known leak thru the relief valve. The pressure rise is equivalent to a leak rate of

$$0.044\frac{\text{Torr}}{\text{day}} \times \frac{1\,\text{atm}}{760\,\text{Torr}} \times \frac{178\,\text{liter}}{1\,\text{atm}} \times \frac{1\,\text{day}}{86400\,\text{sec}} \times \frac{178000\,\text{cm}^3}{1\,\text{liter}} = 1.19 \times 10^{-4}\frac{\text{cm}^3}{\text{sec}}.$$

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The relief valve has an o-ring that is presumed to be Buna-N. The air permeation rate thru the Buna-N relief valve o-ring is estimated as

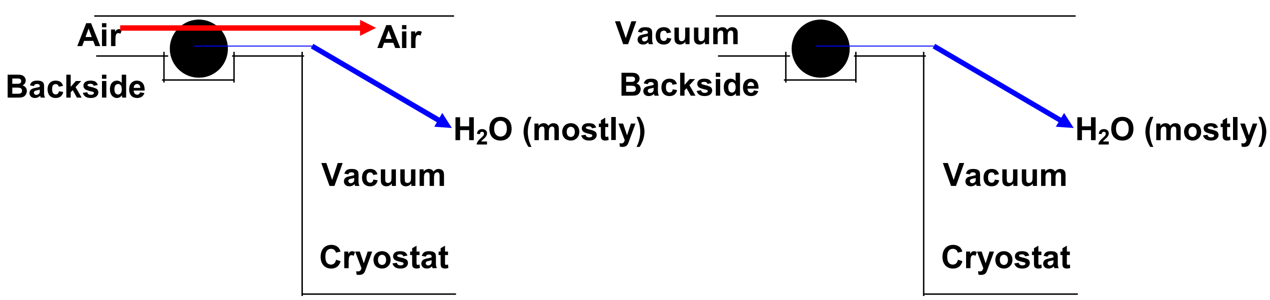
$$2.5\times10^{-7}\,\frac{\text{torr liters}}{\text{sec inch}}\times\frac{5.7\,\text{inch}}{1}=1.425\times10^{-6}\,\frac{\text{torr liters}}{\text{sec}}\;or\times\frac{1\,\text{atm}}{760\,\text{Torr}}\times\frac{1000\,\text{cm}^3}{1\,\text{liter}}=1.875\times10^{-6}\,\frac{\text{cm}^3}{\text{sec}}$$

The large flange o-ring is Viton. The air permeation rate thru the Viton flange o-ring is estimated as

$$2.5\times10^{-8}\,\frac{\text{torr liters}}{\text{sec inch}}\times\frac{\pi(17)\,\text{inch}}{1}=1.335\times10^{-6}\,\frac{\text{torr liters}}{\text{sec}}\;or\times\frac{1\,\text{atm}}{760\,\text{Torr}}\times\frac{1000\,\text{cm}^3}{1\,\text{liter}}=1.757\times10^{-6}\,\frac{\text{cm}^3}{\text{sec}}$$

Despite the difference in circumference, two o-rings have about the same permeation rate because Buna-N is 10 times worse than Viton with respect to permeation.

Petros used an RGA to examine the effect of pulling a vacuum on the back side of the two o-rings which stops the permeation of air. The o-rings also outgas over time, which is mostly water vapor desorbing from the vacuum side surface. The outgassing rate decreases over time while the permeation rate is constant. A vacuum on the backside of the o-ring does not reduce outgassing.



The following table shows the partial pressures in Torr of the molecules of interest for several cases. In a high vacuum system, water and hydrogen are expected to be the major components.

Table 1: Partial Pressures in Cryostat (Torr)

2 hydrogen	18 water	28 nitrogen	32 oxygen	40 argon	Case
2.34E-07	9.65E-07	1.00E-07	2.04E-08	4.00E-09	1 - baseline - relief valve and flange o-rings @ vacuum
2.46E-07	9.03E-07	5.50E-07 (+4.5E-07)	1.27E-07 (+1.07E-07)	1.51E-08	2- relief valve o-ring @ air, flange o-ring @ vacuum
--	--	1.42E-07 (+4.20E-08)	3.16E-08 (+1.12E-08)	--	3 - relief o-ring @ air , flange o-ring @ vacuum, expected pressure rise due to air permeation
2.36E-07	9.36E-07	1.05E-07	2.32E-08	4.49E-09	4 - flange o-ring @ air, relief valve o-ring at vacuum
--	--	1.38E-07	3.05E-08	--	5 - flange o-ring @ air, relief valve o-ring at vacuum, expected pressure rise due to air permeation

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The gas load *Q* is equal to the pumping speed at the cryostat S_T multiplied by the pressure *P*. When the backside of the relief valve o-ring is changed from vacuum to air, the gas load should increase in an amount equal to the permeation of air thru the o-ring

$$\Delta P = \frac{\Delta Q}{S} = \frac{1.425\times10^{-6}\ \frac{\text{Torr liters}}{\text{sec}}}{26.8\,\frac{liters}{\text{sec}}} = 5.317\times10^{-8}\ \text{Torr}.$$

Case 3 shows the expected pressure rise from the baseline due to permeation thru the relief valve o-ring. The O2 would be expected to reach a partial pressure of 2.04E-08 + 0.21 x 5.317E-08 = 3.16E-08 Torr. However in case 2 it reached 1.27E-08 Torr, an increase 10.7 times what was expected. N2 increases in a similar fashion. The much larger than expected increase indicates that there was an air leak thru the relief valve.

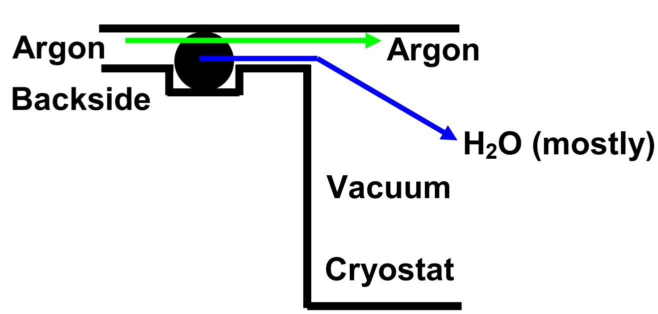
When the backside of the flange o-ring is changed from vacuum to air, the gas load should increase in an amount equal to the permeation of air thru the flange o-ring

$$\Delta P = \frac{\Delta Q}{S_T} = \frac{1.335\times10^{-6}\ \frac{\text{Torr liters}}{\text{sec}}}{26.8\,\frac{liters}{\text{sec}}} = 4.981\times10^{-8}\ \text{Torr}.$$

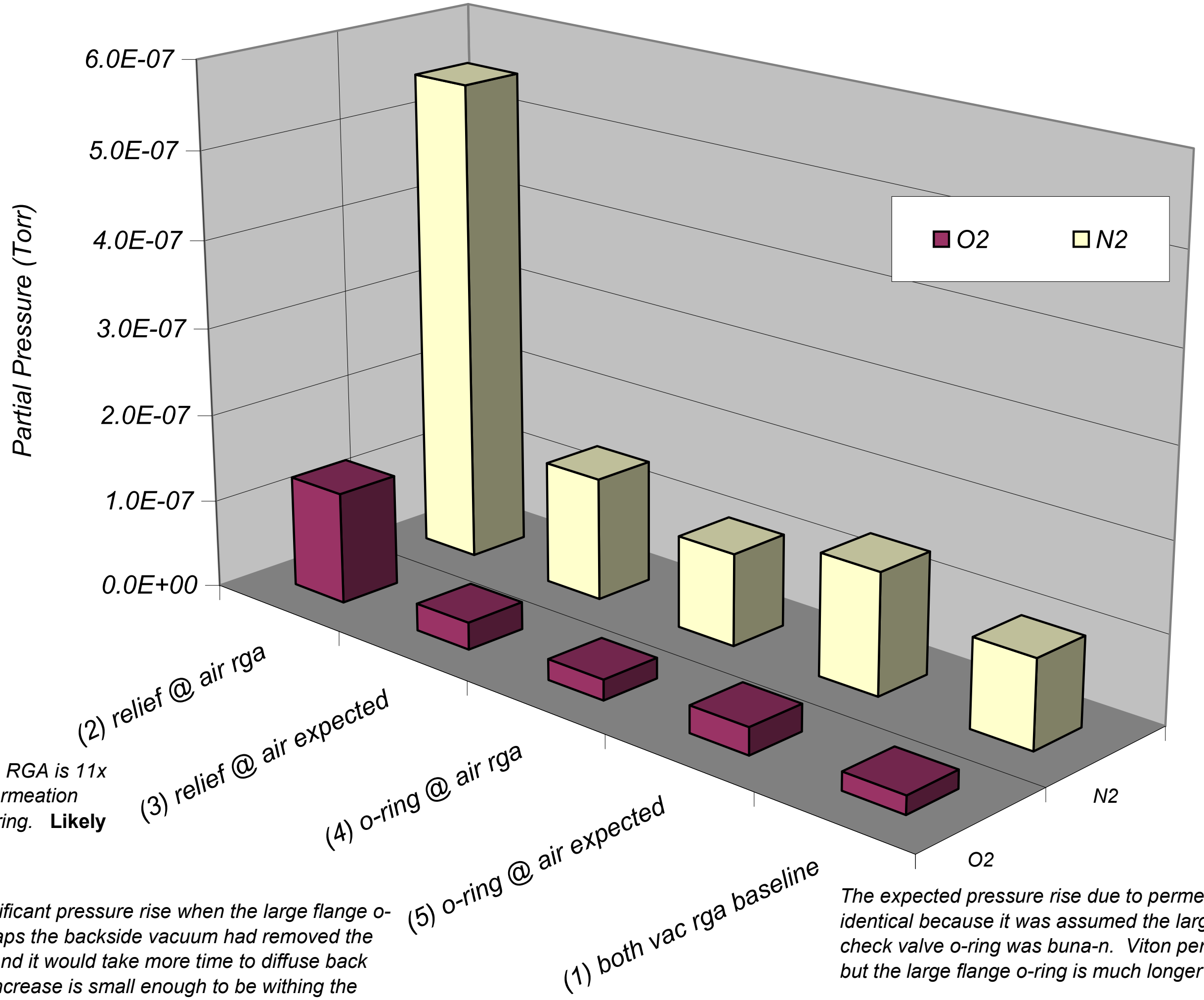
Case 5 shows the expected pressure rise from the baseline due to permeation thru the flange o-ring. The O2 would be expected to reach a partial pressure of 2.04E-08 + 0.21 x 4.981E-08 = 3.09E-08 Torr. However, case 4 shows that the O2 partial pressure only increased to 2.32E-08 Torr. Either the small increase is within the calculation and experimental error, or it may take more time for air to permeate thru the o-ring than allowed.

Plot 1 compares the partial pressures for this o-ring study.

Plot 2 shows the partial pressures for all cases. It indicates that an argon gas purge on the backside of the o-ring has the same effect as a vacuum. Argon gas permeates thru the o-rings and thru the relief valve leak while O2 stays at the same level as the baseline case where vacuum is created on the backside of both o-rings.



Plot 1: Cryostat RGA Study (No Purity Monitor)

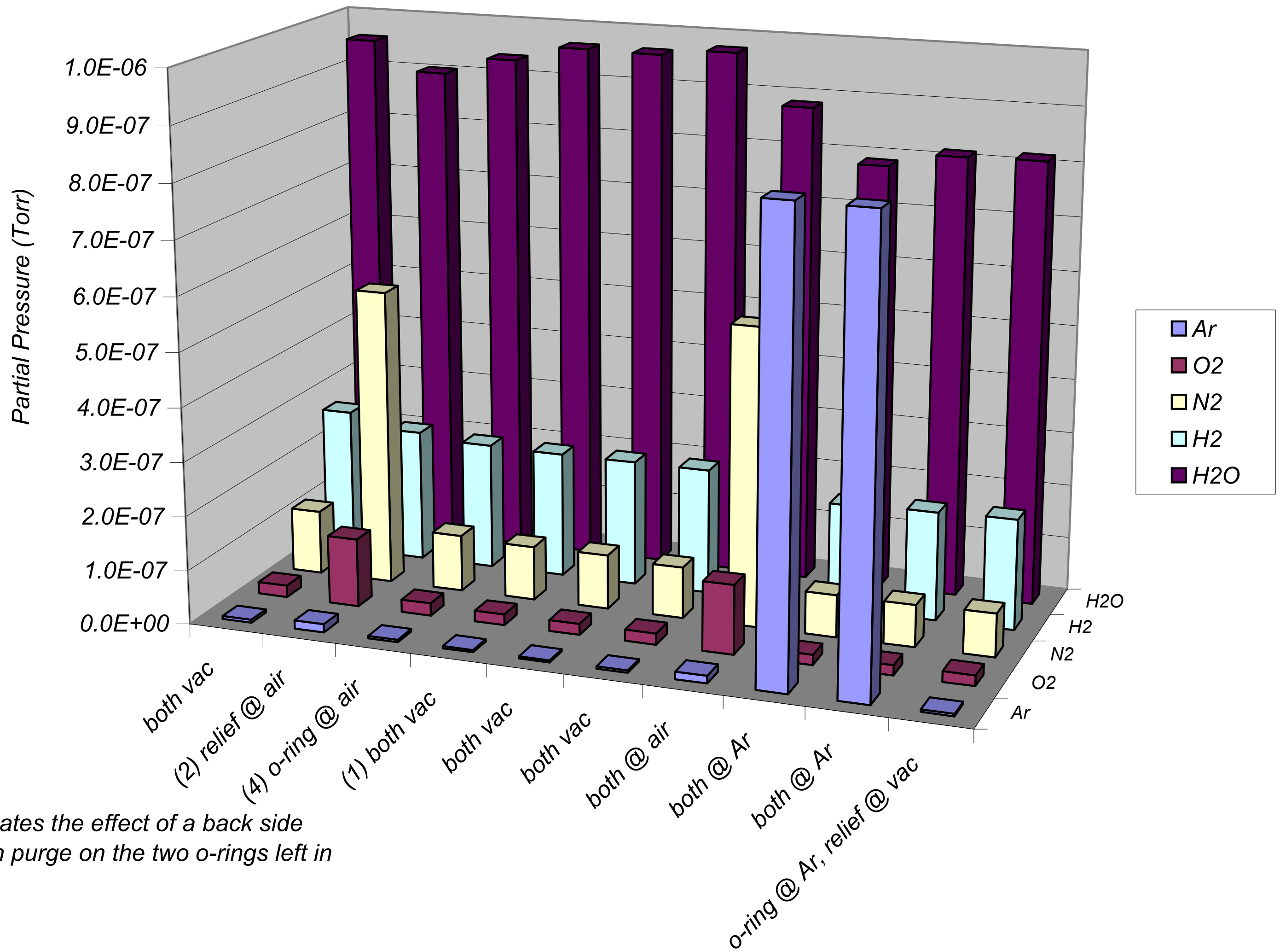


Pressure rise observed by the RGA is 11x what is expected due to air permeation thru the relief valve buna-n o-ring. **Likely there is a small leak.**

The RGA did not record a significant pressure rise when the large flange o-ring was exposed to air. Perhaps the backside vacuum had removed the air from the bulk of the o-ring and it would take more time to diffuse back thru into the cryostat. Or the increase is small enough to be withing the error of the experiment.

The expected pressure rise due to permeation thru the two o-rings is nearly identical because it was assumed the large flange o-ring was viton and the check valve o-ring was buna-n. Viton permeation is much less than buna-n, but the large flange o-ring is much longer than the relief valve o-ring.

Plot 2: Cryostat RGA Study - All Cases (No Purity Monitor)



The study investigates the effect of a back side vacuum and argon purge on the two o-rings left in the system.