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A Very Small Ionization Pressure Gauge*

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Abstract

A very small ionization pressure gauge has been developed to operate in the pressure range 10^{-6} Torr to 100μ. A metal construction and external cooling fins result in a very rugged device with exceptionally small outgassing properties. The gauge also incorporates a replaceable filament-grid assembly on a single plug which allows the simple replacement of both the filament and the grid when needed.

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1. Introduction

Although a very large number of vacuum systems in the world operate in the pressure range 10^{-6} Torr and above, the measurement of pressure in these systems by ionization-type devices presents particular problems due primarily to the large hydrocarbon background present in these systems. These contaminents continually coat both the grid and ion collector (often a thin wire) by cracked hydrocarbon products of the ionization process producing insulating layers on the various components. These layers may during gauge operation charge, thus distorting the electron trajectories, and changing the electron energy during its trajectory. It may even allow electrons to reach the collector. The net effect is a possibility of a marked change of the gauge sensitivities from its uncomtaminated value. Some limited amount of rejuvenation may be effected by in situ "degassing" the components. However, the success of this rejuvenation process is very dependent both upon the extent and type of contamination buildup. No clear assurance can be given to the gauge sensitivity after the degassing process. Simply stated, after being operated in a contaminating environment, the ion gauge ceases to be a reliable pressure measuring instrument. It should be noted that filament burn out very often occurs much after the gauge is rendered unreliable due to the hydrocarbon contamination.

To help overcome these difficulties inherent in an ionization pressure device, a small ion gauge was developed which could be completely and easily rejuvinated. This was accomplished by mounting a very small filament-grid assembly on a 3-pin transistor socket which itself inserts into an identical socket permanently mounted in the gauge housing. Figure 1 shows a line drawing gauge housing with the insertable filament-grid assembly. It is noted that the ion collector of the device is the inner wall of the housing having the clear advantage over a device with a thin wire collector of a considerably larger surface area over which the contaminating ion layer is deposited.

To rejuvenate the device after operation in a contaminating environment, the old filament-grid assembly is taken out, any contaminating layer on the wall removed with an abrasive such as steel wool (or equivalently a wall insert replaced) and a new filament grid assembly reinserted into the device. This operation has been typically performed in less than 10 minuets and re-established a gauge to its just-purchased condition. Gauges extensively run on untrapped mechanical pumps have been repeatedly reconditioned using the above procedure. It should be noted that in manufacturing quantities the price of the entire filament grid assemblies should be approximately the cost of the 3-pin transistor socket. Thus, the device is ideally suited to systems in which gauge or filament replacement is necessitated by contaminent backgrounds.

2. Construction

The housing of the gauge is made from solid aluminum rod machined and anodized to specification. An empty transistor socket (teflon) is incorporated within the housing, the vacuum seal being made with low outgassing rate epoxy designed so that only a few mm^2 of epoxy area are exposed to the vacuum. The four wires to electrically operate the gauge extend through the back of the gauge and are attached to a standard Jones connector as seen in Figure 1. Three anodized cooling fins are afixed to the gauge body providing the heat dissipation for the approximately 4 watts of filament power, and hence help to reduce the thermal outgassing from the walls of the gauge itself. In fact, when in operation the housing temperature is only a few degrees above ambient.

The filament and grid are constructed from 0.005" diameter W wire wound around a 0.020" diameter mandrel. The filament consists of 5 turns and the grid of approximatmly 15 turns of the W wire. The ends of the filament are pressed into short stubs of 0.020" diameter Cu wire which are inserted into two of the three pins of a transistor socket indentical to the one incorporated into the housing. The grid is supported by one end in a similar fashion and inserted into the third hole. The spacing between the filament and grid is approximatley 0.080" and the wall of the housing (used as the ion collector) is of 0.408" diameter.

3. Electrical

With the gauge operating at approximately 50 μA emission current, the filament requires approximately 2 volts at approximately 2 amperes. A 6 V, 3a, d.c. supply provides the collector voltage to the output power transistor, controlled by the emission current itself. The difference between the emission voltage signal and a reference voltage is amplified (x 10) and fed into a simple integrator with time constant approximately 0.4 seconds, providing a rapid response while minimizing the thermal overshoot and being gain insensitive.

The ion collector circuit consists of a FET current amplifier with feedback resistors for each curent range switched by reed relays located on the collector board reducing noise and pickup from the rest of the controller.

4. Operation Characteristics

The gauge sensitivity is linear with respect to pressure between approximately 1.5×10^{-6} Torr and 10^{-1} Torr (100 μ) with an x-ray limit of approximately 1.5×10^{-6} Torr. In order to reduce the possibility of electron induced discharge in the pressure range 10-100μ, the electron emission is halved with an appropriate adjustment to the collector circuitry.

The sensitivity of the gauge is determined from

$$K = I_c^+/i^-p$$

where K is the sensitivity in $Torr^{-1}$, i_c is the collector current in amperes, i^- the emission current in amperes and p is the pressure in Torr. For example, for a typical tube with an emission current of 50 μA at a N_2 (air) pressure of 10μ produces a collector current of 4.7×10^{-6} amperes resulting in a sensitivity $K \simeq 9$ $Torr^{-1}$.

The apparent sensitivity of this device (microgauge) is rather remarkable when compared with the sensitivity of the Varian millitorr gauge and the Schultz-Phelps gauge both having $K \simeq 0.5$. The enhanced sensitivity of the present device over these other devices very likely results from the fact that the electrons are able to spiral around the microgauge grid, whereas they are only able to make a single pass in the above mentioned devices.

Figure 2 shows the snesitivity over a several-week period of running. Seen is that the sensitivity is stable to within ± 5%. Figure 3 shows the effect of operating approximately 18 hours on an untrapped mechanical pump for 18 hours. After a brief outgas (both the collector and the grid shared the outgas current) the sensitivity returned to its as-installed value. It should be noted that if the outgas electrons are not allowed to reach the wall, the wall must be mechanically cleaned as mentioned previously to rejuvenate the gauge.

Figure 4 shows a gauge outgas comparison. The system was pumped by an 20 l/s ion pump conductance limited to approximately

1 l/s. Initially, both a standard ion gauge and the microgauge were on. At approximately 120 seconds the ion gauge was turned off while the pressure continued to be monitored by the microgauge. A factor of approximately 17 reduction in the pressure resulted as seen in this figure.

Figure 5 shows the results of a rate-of-rise measurement in a 1 liter vessel both with the Bayard Alpert gauge and microgauge on and with the microgauge on only.

The conclusion of the last two figures is clear: the outgassing rate of the microgauge is markedly less than that of the standard ionization gauge. Thus, the material selection and construuction techniques were appropriate to a small outgassing rate device.

The gauge connection to the vacuum chamber is made through a standard 1/2" diameter snout which inserts into a "O" ring connector permanently mounted onto the system allowing for rapid insertion and removal of the device.

Discussion and Acknowledgments

The ion guage described in this report evolved over a two-year period from a considerably different device into the present one. The many encountered problems and design solutions to overcome these problems, although making an interesting story, was felt out of place in this report. In retrospect, I would like to acknowledge both Brookhaven National Laboratory and, in particular, Derek Lowenstein and Lyle Smith for their support of this

undertaking. Lastly, the extensive discussions and encouragement of Tony Wisowaty is greatly appreciated. The final result of this undertaking will, I believe, help to make reliable and economical measurements of pressure in this awkward but widely used pressure range.

Figure Captions

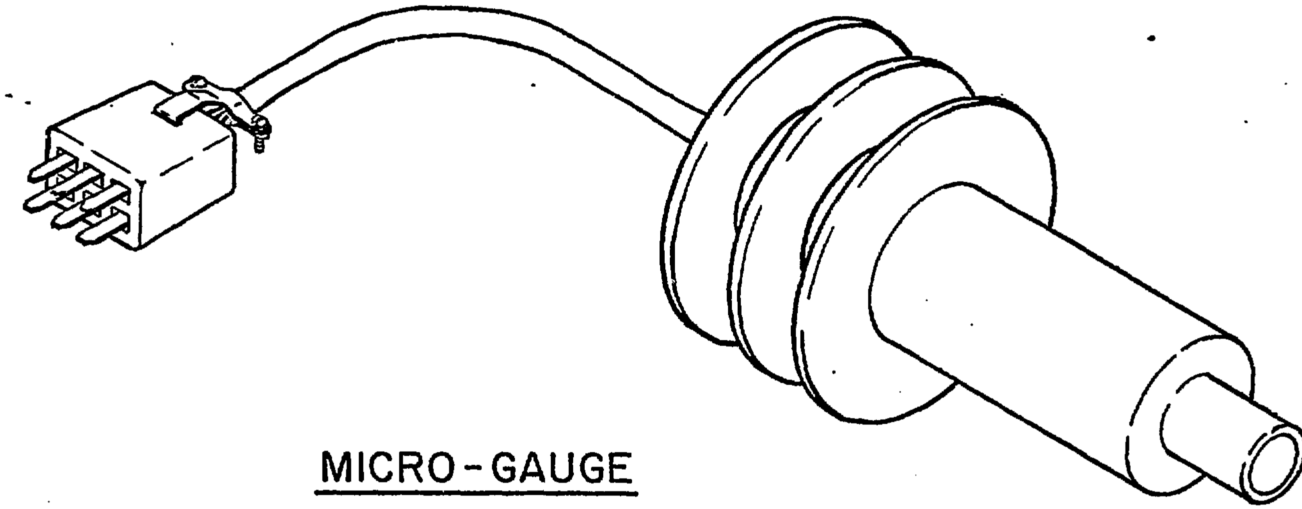
1. A line drawing of both the housing of the microgauge and the filament-grid assembly which inserts into the snout of the housing.

2. The sensitivity of the microgauge over a several-week period. The gauge sensitivity was measured after a 10 second, 10 watt outgas.

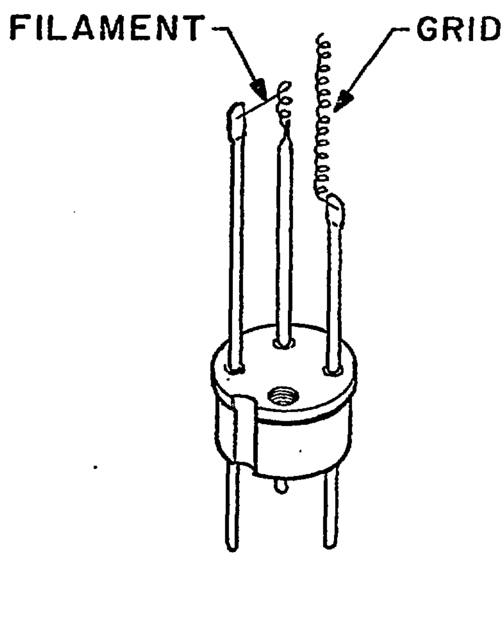
3. The gauge sensitivity decrease and re-establishment after operating on a mechanical pump for 18 hours.

4. A comparison of the respective outgassing rates of a standard Bayard-Alpert gauge and the microgauge by a direct pressure measurement.

5. The rate-of-rise of the pressure in a 1 liter system (no real pumps present) measured for the two respective gauges.



MICRO-GAUGE



PLUG

Figure 1

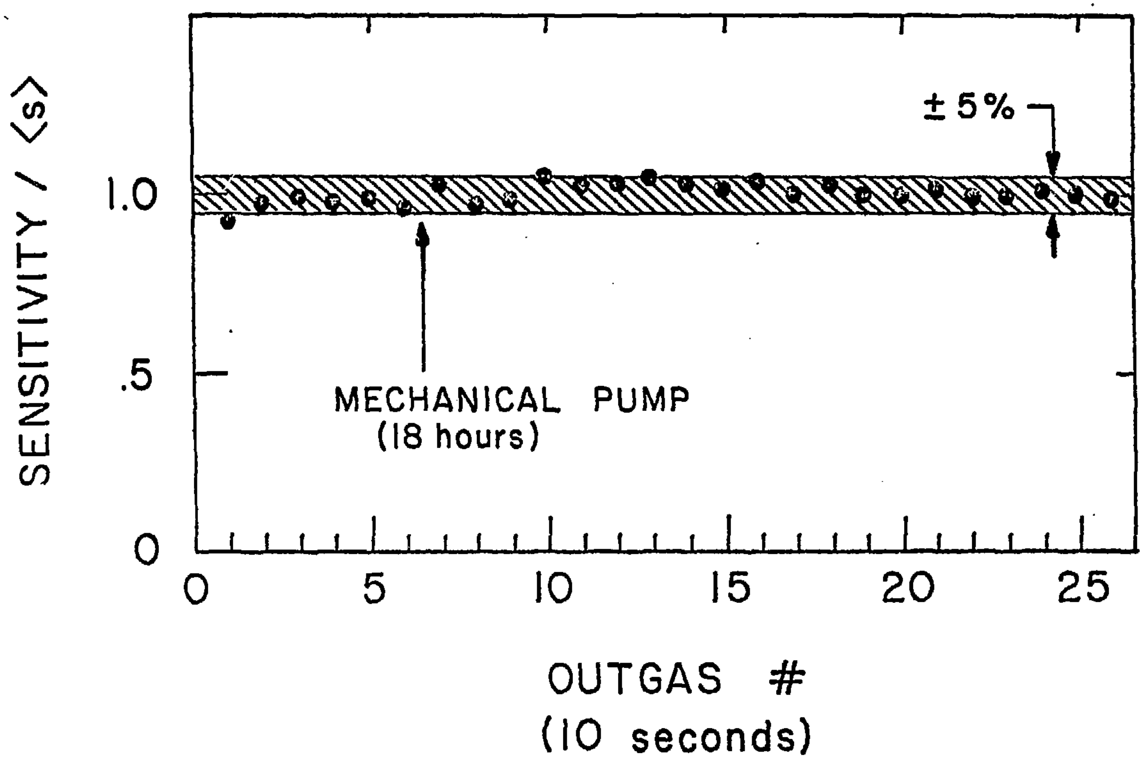

SENSITIVITY / ⟨s⟩
1.0
.5
0
± 5%
MECHANICAL PUMP
(18 hours)
0
5
10
15
20
25
OUTGAS #
(10 seconds)

Figure 2

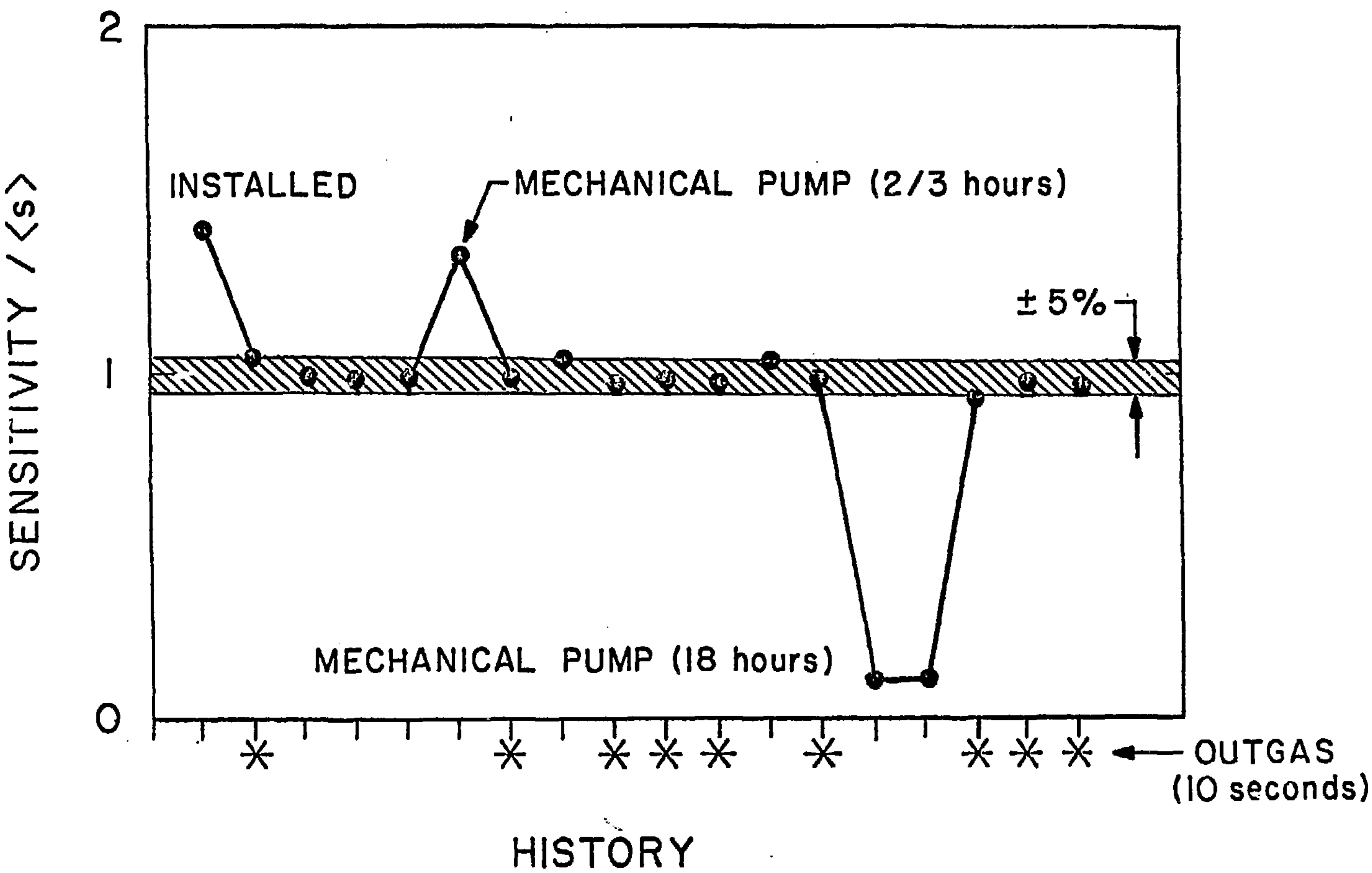
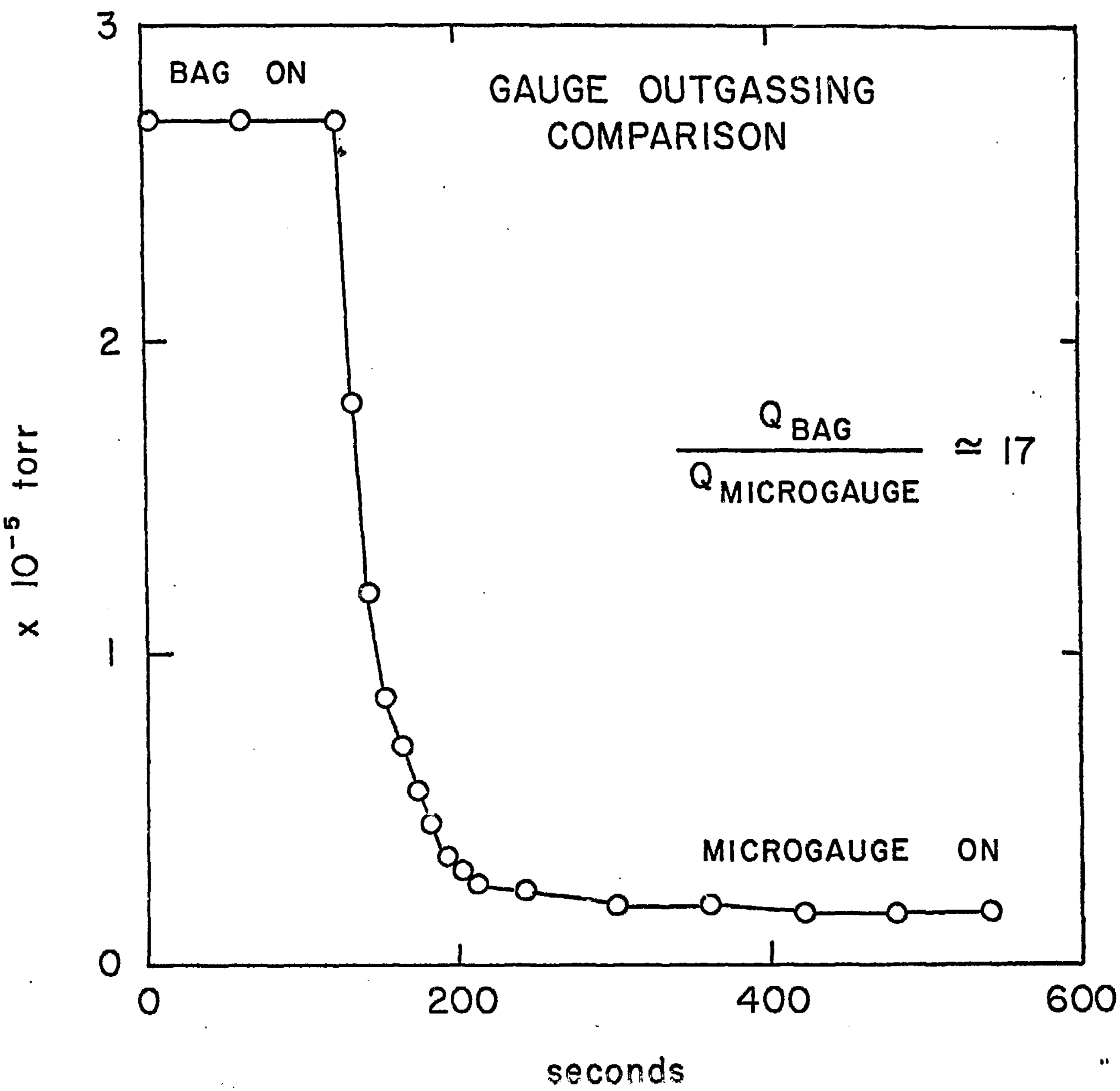

2
1
0
SENSITIVITY / <s>
INSTALLED
MECHANICAL PUMP (2/3 hours)
± 5%
MECHANICAL PUMP (18 hours)
OUTGAS
(10 seconds)
HISTORY

Figure 3



GAUGE OUTGASSING COMPARISON
BAG ON
MICROGAUGE ON
$\frac{Q_{BAG}}{Q_{MICROGAUGE}} \cong 17$
x 10⁻⁵ torr
seconds
0
1
2
3
0
200
400
600

Figure 4

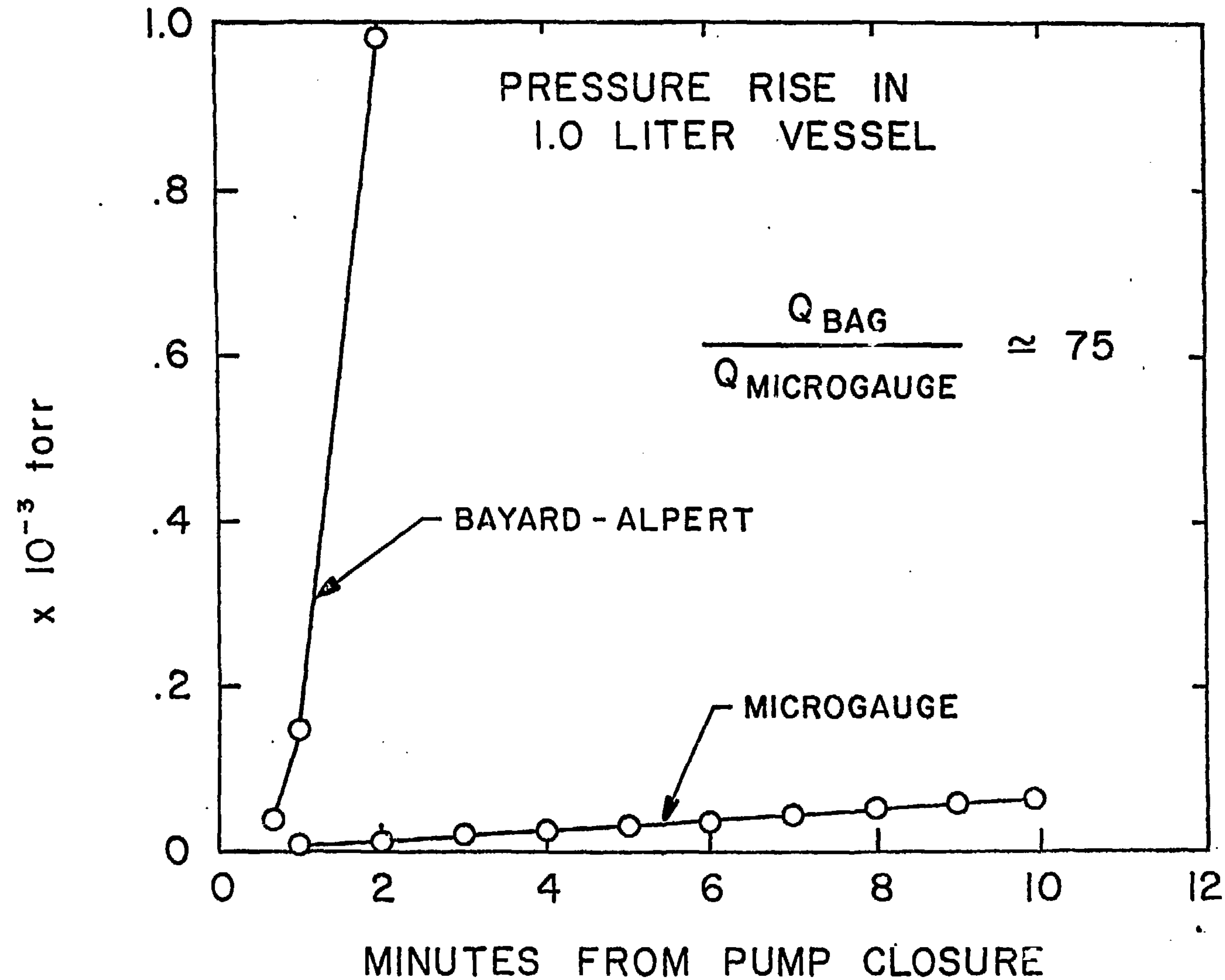

PRESSURE RISE IN
1.0 LITER VESSEL
$\frac{Q_{BAG}}{Q_{MICROGAUGE}} \simeq 75$
BAYARD - ALPERT
MICROGAUGE
x 10^{-3} torr
1.0
.8
.6
.4
.2
0
0
2
4
6
8
10
12
MINUTES FROM PUMP CLOSURE

Figure 5