Study of the Sensitivity of a Quadrupole Mass Analyzer and a Bayard Alpert Gauge with Changes in Temperature and Gas Composition.

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Abstract: The quadrupole mass analyzer (QMA) and the Bayard Alpert (BA) gauge are used widely in Tokamaks (fusion devices) to study the composition of residual gases and to measure the total pressure inside the vacuum chambers of these devices. The partial pressure analysis of the spectra provides useful information about the sources of impurities or leaks in these chambers. Cryostat chamber of SST-1 Tokamak encloses cold masses like liquid nitrogen panels and liquid helium cooled coils. A QMA or a BA gauge mounted on the cryostat chamber is therefore subjected to gases at low temperatures. An experiment was performed to study the behaviour of these gauges under these conditions. The results will be presented in this paper.

1. Introduction
Steady State Superconducting Tokamak – 1 (SST-1) is being commissioned at IPR for fusion experiments. Its vacuum chamber comprises of the vacuum vessel and the cryostat [1]. Vacuum vessel is an ultra high vacuum (UHV) chamber in which plasma will be produced and confined. Cryostat is a high vacuum (HV) chamber, which houses superconducting magnetic field coils and liquid nitrogen cooled panels. Superconducting coils are maintained at ~ 5°K by flowing supercritical liquid helium through them. Liquid nitrogen cooled panels are mounted on the inside surface of the cryostat and the outside surface of the vacuum vessel to provide radiation shielding around the coils. These panels are maintained at ~ 77 °K. The accurate measurement of total pressure and the partial pressures of the impurities inside the cryostat are very much important to determine whether the leaks are developed in the magnet coils or in the LN2 panels during cool down phase. The total and partial pressure measurements in the cryostat of SST-1 will be done using a BA gauge [2] and a Quadrupole Mass Analyser (QMA) [3] respectively. Since these gauges will be subjected to gases at cold temperatures inside the cryostat, therefore it is necessary to study their behavior at these temperatures.

2. Experimental Setup
The experimental setup is shown in Figure – 1 below. A copper enclosure with brazed copper tube for cooling is connected at one end of the UHV chamber having a turbo-molecular pump of effective pumping speed of 500 l/s. QMA / BA gauge which is to be studied is mounted inside this copper
A reference BA gauge is connected to the test chamber identically opposite to the test QMA / BA gauge as shown in fig. (1). Different gases are fed inside the cold surface through a copper tube connected to a variable leak valve. Three Pt-102 temperature sensors are mounted at three different locations, two of them near the two gauges and one somewhere inside the copper enclosure, to measure the temperatures of the fed gases.

![Experimental setup to study the behaviour of gauges at low temperatures.](image)

**Figure – 1: Experimental setup to study the behaviour of gauges at low temperatures.**

### 3. Experimental Procedure
The test chamber was pumped down to an ultimate pressure of $1.0 \times 10^{-7}$ mbar measured with the reference B.A. gauge. A minimum gas temperature of 150 °K was achieved by flowing Liquid nitrogen through the copper tubes when the gauges were switched off. After switching on the filaments of the two gauges, the minimum gas temperature rose to 220 °K. Different gases like Nitrogen, Helium and Argon were fed into the test chamber and their temperatures were maintained at 325 °K, 300 °K, 273 °K, 250 °K and 220 °K respectively by flowing LN$_2$ into the copper chamber. For each gas temperature, the gas pressure was varied from $5.0 \times 10^{-7}$ mbar to $1.0 \times 10^{-4}$ mbar and the pressure readings were taken with respect to the reference and test BA gauges. The same procedure was repeated for QMA.

### 4. Results and Discussions
For each gas, the test gauge pressure is plotted as a function of the reference gauge pressure for all the five temperatures as shown in the figure – 2, figure – 3 and figure – 4. For all these gases at these five temperatures, it was observed that the test BA gauge pressure varied linearly with the reference gauge pressure over the entire pressure range whereas the QMA showed non-linearity above $1.0 \times 10^{-5}$ mbar. This non-linear behaviour of QMA above $1.0 \times 10^{-5}$ mbar is due to the ion space charge effect in the ion source of the QMA. The difference in the behaviour of the QMA and the BA gauge arises due to the differences in their ion source geometries [4-5].
Figure – 2: Variation of test gauge pressure as a function of reference gauge pressure for Nitrogen gas.

Figure – 3: Variation of test gauge pressure as a function of reference gauge pressure for Helium gas.
Figure – 4: Variation of test gauge pressure as a function of reference gauge pressure for Argon gas.

b) For a given reference BA gauge pressure, no significant variation was observed in the test BA gauge/QMA pressures with changes in the gas temperature. This effect was due to the fact that the temperature of the gas molecules rose to higher values as they reached the gauge filament.

5. Conclusion
A quadrupole mass analyzer is not reliable at pressures above $1.0 \times 10^{-5}$ mbar whereas a BA gauge shows reliability up to $1.0 \times 10^{-4}$ mbar. These effects are independent of the variation in gas temperature. Since there isn’t much variation in the pressure readings with gas temperature, therefore the temperature correction for the sensitivity is not required for both BA gauge and QMA.

6. References
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