Tech Note

Partial Pressures vs. Total Pressure for an Open Ion Source RGA

Residual Gas Analyzers (RGAs) have been used in vacuum research applications for 25 years. Their role has changed in the last 10 years, as they have evolved from purely a research instrument to a production tool. As a production tool, the RGA can increase productivity, improve product yield, increase throughput and reduce costs, all of which ultimately increases profits.

However, it is up to the user to determine how the tool can best meet the needs of a specific application. This Tech Note is concerned with the total pressure and partial pressure readings of an RGA.

How an RGA is Used

Many production vacuum systems work at two distinct pressure ranges. The first, typically called base pressure, is a method of cleaning the vacuum chamber and its parts before the process begins. If the base pressure of the vacuum system is less than 1E-4 Torr, a standard RGA can be mounted to the vacuum system to monitor the base pressure. The second pressure range, process pressure, is typically several decades higher and is created by adding various gases used in the particular process.

When using an RGA for quantitative measurements, it is important to understand, and work within, the physical limitations of the instrument. Dalton's Law states that the total pressure of a mixture of gases is equal to the sum of its parts ($P_T = P_1 + P_2 + \ldots + P_x$). This law does not fully correlate with the output of an RGA and corrections such as ionization probabilities, fragmentation factors, and transmission factors must be considered.

should be considered as an approximation of the total pressure. A more accurate total pressure measurement can be made with an ion gauge which can be displayed via the RGA software.

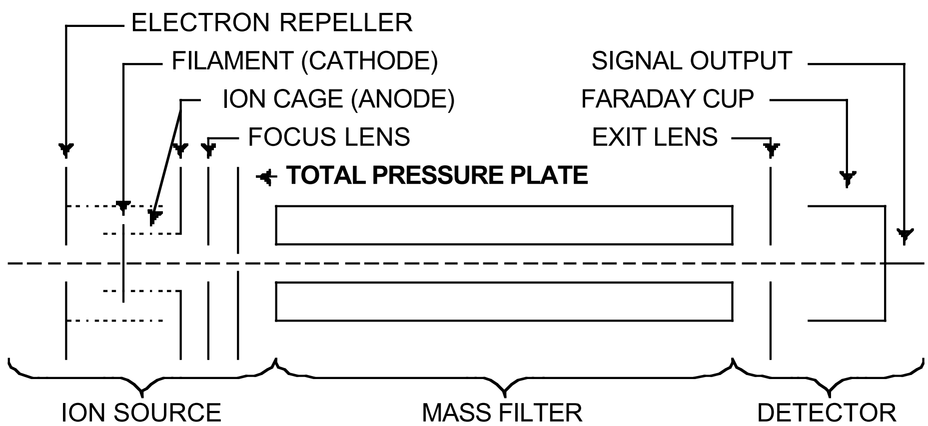

Figure 1: RGA drawing that shows the total pressure plate

Total Pressure

The total pressure reading as measured with a Leybold Inficon RGA is taken from a total pressure plate mounted in the ion source of the sensor, as seen in Figure 1. This plate measures the current produced from the ions that collide with the plate on their path to the analyzer portion of the quadrupole sensor. By measuring total pressure in this manner we have a continuous total display and continuous over pressure protection of the sensor. The total pressure reading

Partial Pressure

The partial pressure mode displays the absolute pressure of a component, or the relative amount of each gas expressed as a percentage of the total. Unfortunately, the peak height also depends on other parameters such as the ionization probability (how easy it is to make an ion), the fragmentation factor (how many fragments are produced when an ion is created and the amplitude of each), a transmission factor (how many ions actually reach the detector) and finally the sensitivity of the detector. An algorithm is used to determine the partial pressure specific to each gas. The formula for determining the partial pressure of gas A based upon a peak at mass B is given in Equations 1 and 2.

Equation 1:

$$PP_A = \frac{(I_{AB})x(FF_{N28})}{(FF_{AB})x(XF_A)x(TF_B)x(DF)x(S)}$$

PP_A = Partial Pressure of Gas A

I_{AB} = Current of the Peak at Mass B from Gas A (peak height in amps)

FF_{N28} = Fragmentation Factor for Nitrogen (Mass 28) (usually taken as 1.0)

FF_{AB} = Fragmentation Factor for Gas A at Mass B (from a table such as Table A)

XF_A = Ionization Probability of A (from a table such as Table A)

TF_B = Transmission Factor for Mass B (pre-programmed in software)

DF = Detection Factor or Relative Current per Ion (usually taken as 1.0)

S = Sensitivity for Nitrogen at Mass 28 in Amps/Torr (from an instrument calibration)

We can then simplify the calculation by setting FF_{N28} and DF equal to 1.0 and removing the Transmission Factor TF_B to get Equation 2.

Equation 2:

$$PP_A = \frac{(I_{AB})}{(FF_{AB})x(XF_A)x(S)}$$

It must be noted that the calculation is based upon the current produced by one gas at a specific mass. If there are overlapping peaks, such as the presence of both carbon monoxide (CO) and nitrogen (N_2) at mass 28, then the calculation is complicated further. Sensitivity is also a concern when determining the partial pressures of gasses. Since the sensitivity of a RGA can change with time it is important that the sensor is calibrated frequently. It is also important to note that a RGA's sensitivity typically increases dramatically when an electron multiplier is used instead of a Faraday cup and the sensitivity value must be changed accordingly. Lastly, the RGA tuning of resolution will also play a key role in accurate partial pressure calculations and measurements.

TABLE A

FRAGMENTATION FACTORS AND IONIZATION PROBABILITIES FOR COMMON GASSES

Substance	Ionization Probability	Most Intense Peak	Fragmentation Factor	Substance	Ionization Probability	Most Intense Peak	Fragmentation Factor
ACETONE	3.6	43	0.58	HYDROGEN	0.44	2	0.98
AIR	1.0	28	0.71	HYDROGEN SULFIDE	2.2	34	0.52
AMMONIA	1.3	17	0.53	KRYPTON	1.7	84	0.57
ARGON	1.2	40	0.88	METHANE	1.6	16	0.46
BENZENE	5.9	78	0.53	METHYL ALCOHOL	1.8	31	0.43
CARBON DIOXIDE	1.4	44	0.85	NEON	0.23	20	0.90
CARBON MONOXIDE	1.05	28	0.91	NITROGEN	1.0	28	0.94
CARBON TETRACHLORIDE	6.0	117	0.28	OXYGEN	1.0	32	0.95
ETHYL ALCOHOL	3.6	31	0.49	TOLUENE	6.8	91	0.53
HALOCARBON 12	2.7	85	0.62	WATER	1.0	18	0.75
HELIUM	0.14	4	1.00	XENON	3.0	132	0.27
HEXANE	6.6	41	0.21				

LEYBOLD INFICON

The Instrumental Difference™

Two Technology Place
East Syracuse, NY 13057 USA
(315) 434-1100
TFX(315) 437-3803
E-mail: reachus@inficon.com

P.O. Box 1000
FL-9496 Balzers, Liechtenstein
(+41) 75-388-4525
TFX (+41) 75-388-5431
E-mail: reachkh@bi.balzers.net

Bonner Strasse 498
D-50968 Cologne, Germany
(+49) 221347-0
TFX (+49) 221-347-1250
E-mail: reachus@leyboldvac.de

Visit our website for sales offices worldwide. http://www.leyboldinficon.com

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