September 1975 B75-10185

NASA TECH BRIEF

Lewis Research Center

Characteristics and Performance Study of Mass Spectrometer Residual Gas Analyzers

The operation and properties of various mass-spectrometer residual gas analyzers for use in vacuum measurements were analyzed in terms of efficiencies of ion extraction, ion separation and transmission, and ion collection. Types of instruments studied were magnetic sector, omegatron, quadrupole, and monopole. Experimental results obtained included absolute sensitivity to argon, relative sensitivity to 10 gases (hydrogen, helium, neon, nitrogen, carbon monoxide, oxygen, argon, carbon dioxide, krypton, and xenon), and cracking patterns for these gases. Tests were performed at a pressure level of about 2×10^{-7} torr.

In many high vacuum applications, it is important to identify the gas species present as well as to know the approximate pressure level. Examples where such information is useful are materials research, spacecraft and space power system tests, thin-film processing, and outgassing, gettering, and pumping studies. Such measurements are commonly made with mass-spectrometer residual gas analyzers (RGAs). To determine pressures and identities of individual gases, knowledge of three major RGA characteristics is required. These are absolute sensitivity to a reference gas, relative sensitivity to other gases, and the cracking pattern of the measured gases. The cracking pattern denotes the total spectrum of ions that appear when a particular gas is ionized, expressed as percentages of the principal ion. The cracking phenomenon results from the presence of isotopes and from the processes of dissociation and single and multiple ionizations. Absolute sensitivity is the ratio of indicated output current contributed by either the principal ion, or the sum of all ions in the gas cracking pattern, to the partial pressure of the gas (amperes/torr).

Relative sensitivity is the ratio of absolute sensitivity for a particular gas to that for a standard gas, such as nitrogen or argon. Argon was used in the present work.

For total-pressure measurements made with ionization gages, relative sensitivity is substantially invariant with gage type and closely correlated with gas ionization cross section. However, for RGAs, relative sensitivity also depends on efficiencies of ion separation and collection. These properties are unique to individual RGA design and operating parameters.

Much information is available on absolute and relative gas sensitivity as a function of upstream or sample reservoir pressure in analytical chemistry applications. However, it is difficult to use this information to measure absolute partial pressures in a vacuum environment unless the flow characteristics of both the gas inlet and the vacuum system under consideration are accurately known. Only a limited amount of information exists in the literature on RGA relative sensitivities for partial-pressure measurement. This is especially true for the intercomparison of different types of RGAs on the same vacuum system.

Test results showed a day-to-day variation in absolute sensitivity to argon was about 10 percent, even when voltage and current settings were repeated as closely as the standard control units allowed. Shift in absolute sensitivity after prolonged exposure to oxygen was inconsistent among the RGAs, and varied from 30 to 300 percent; some instruments recovered slowly after exposure, and others retained a permanent shift. Absolute gas sensitivity can change considerably for the same RGA when the mass range is changed. The change in argon sensitivity varied from 0 to 800 percent for the four RGAs which had multiple ranges.

Overall collection efficiency for the omegatron, as measured, was considerably higher than the others, due to the low electron emission current and absence of beam-forming slits or apertures. No single parameter was found that would permit the prediction of an instrument's relative sensitivity for various gases. However, the values of relative sensitivity, as measured, may be used with an in-place calibration with a reference gas such as argon or nitrogen to obtain absolute sensitivity to other gases. A calibration ion gage may be used as a standard in such a calibration with a reference gas.

The accuracy obtainable for relative sensitivity may be judged from the variation in nitrogen-to-argon relative sensitivity obtained over the time period of investigation (165 days). This ranged from ±2 to ±8 percent for RGAs with Faraday cup detectors, to about ±15 percent for those with electron-multiplier detectors.

(continued overleaf)

The cracking pattern data emphasize the fact that cracking patterns differ widely for different types of RGAs and even differ moderately for different ranges of the same RGA. Both sensitivity and cracking pattern depend on the type of RGA, operating parameters of ion sources, transmission efficiencies of the different separators, and relative gain of electron multiplier detectors.

Notes:

1. Further information is available in the following report:
   NASA TN-D-7554 (N74-19084), Characteristics and Performance of Several Mass Spectrometer Residual Gas Analyzers
   Copies may be obtained at cost from:
   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B75-10185
2. Specific technical questions may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B75-10185

Source: William W. Hultzman
Lewis Research Center
(LEW-12393)