Vacuum Technology Division
Room 610 - Session VT-TuM
Total and Partial Pressure Gauging
Moderator: Neil Peacock, MKS Instruments, Inc.

8:20am **VT-TuM1 Recommended Practice for Calibrating Vacuum Gauges of the Thermal Conductivity Type*, A.P. Miiller,*** National Institute for Standards and Technology*; R.E. Ellefson,* Leybold Inficon Inc.

Thermal conductivity gauges (TCGs) are used extensively in the pressure range of the order of 10@super -1@ Pa (10@super -3@ Torr) to atmosphere. This presentation summarizes the content of a recently completed Recommended Practice for calibration of thermal conductivity gauges. The recommended calibration hardware references capacitance diaphragm gauges as the transfer standard for a practical calibration gauge. The vacuum system and gas handling methods are also presented. The calibration methods recommended are similar to those used by manufacturers for factory calibrations of their TCGs. The expected accuracy of a TCG is in the range of 5 % to 20 % of reading. This recommended practice provides users with a method for their calibration as well as good practices for the use of these gauges in vacuum applications.

8:40am **VT-TuM2 The Use and Calibration of Spinning Rotor Gages at Non-Ambient Temperatures*, C.R. Tilford,*** National Institute of Standards and Technology, US*; B. Lindeanau,* FZJ-IGV, Germany

Many applications require accurate low pressure measurements at temperatures different from room temperature. These measurements are complicated by thermal transpiration effects and the thermal and chemical perturbations associated with most high vacuum gages. The use of an in situ spinning rotor gage (SRG) is a possible solution for such problems. The SRG is stable, inert, and its power disappation is in the milliwatt range. However, for the most accurate measurements it must be determined if the effective accomodation coefficient, the factor determining the sensitivity of the SRG, is temperature dependent. This talk describes the design and performance of a calibration system that corrects for thermal transpiration effects and allows the in situ calibration of SRGs for temperatures between 77 K and 400 K. This system has been used to investigate the temperature dependence of the effective accomodation coefficients for both "smooth" and deliberately roughened steel balls used as SRG rotors.

9:00am **VT-TuM3 Extension of the Spinning Rotor Gauge to Lower Pressure*, J.P. Looney,*** National Institute of Standards and Technology

The Spinning Rotor Gauge (SRG) is widely used for vacuum gauge calibration and measurement in the pressure range 0.1 Pa to somehwat below 10 @super -4@ Pa (10 @super -6@ Torr). The lower limit of presently available SRGs is due to essentially two factors (i) the ability to measure the rotor deceleration rate with a precision of better than about 10 @super -10@ s @super -1@ and (ii) large residual torques on the rotor. The first can be overcome by improved timing of the rotation rate of the ball and the second can be overcome by development of suspension heads with smaller residual torques on the spinning rotor. Together, a system can be constructed to make measurements to much lower pressures, perhaps below 10 @super -6@ Pa (10 @super -8@ Torr) with an imprecision of <1% for a four minute measurement interval. The factors which limit the useful pressure measurement range of the SRG will be dicsussed and initial performance measurements for a prototype system will be presented.

9:20am **VT-TuM4 Enhanced Bayard-Alpert Gauge with Accuracy and Stability Improved by Design and Construction*, P.C. Arnold,*** Granville-Phillips, Division of Helix Technology Corp. **INVITED**

An enhanced accuracy and stability Bayard-Alpert gauge, now in general use for over five years, is reviewed. The philosophy of its design to control electron trajectories, location of ion generation, efficiency of ion collection, and maintenance of these characteristics is described with respect to computer simulation and its resultant gauge construction. Gauge sensitivity variation with pressure, from gauge to gauge, and over five years of operation is presented. A system for multi-gauge calibration is described as well as the system for maintaining the reference standards. Analyzing commercial use of this gauge in process environments over these five years has revealed knowledge relating to degradation of the function of each gauge electrode. Also analyzed are the process cycle requirements of quickly measuring base pressure under process conditions versus backfilling to pressures well above base pressure. Many of these concepts are generally applicable to most ionization gauges and will be discussed.

10:00am **VT-TuM6 A Miniature Dual-Collector Ionization Gauge*, A.R. Filippelli,*** Granville-Phillips, Division of Helix Technology Corp.

In recent years there has been a trend to reduce the physical size of the sensors used in the semiconductor manufacturing industry. Because of the great utility of the Bayard-Alpert ionization gauge in this industry, it is natural for gauge manufacturers to ask: Can we retain its basic three-element design, operating voltages, good sensitivity, and low x-ray limit and, at the same time, significantly reduce its size? The answer is yes. This talk will introduce the basic concept that motivated a dual-collector design and will then trace the development of the miniature gauge based on this concept. Some details of the design were guided by use of a modeling program, and examples of ion and electron trajectories computed using this program will be shown. Experimental testing of prototypes, in conjunction with modeling, was used to select other design parameters such as filament length, collector diameter, and grid end geometry. Experimentally-determined test results for sensitivity and x-ray limit will also be presented. While no single design factor appears to dominate the gauge's performance, the combination of design choices has resulted in a gauge with good sensitivity as well as a significantly smaller size.

10:20am **VT-TuM7 A Compact Wide-Range Cold-Cathode Gauge*, B.R.F. Kendall,*** Elvac Laboratories*; E. Drubetsky,* The Fredericks Company

Cold-cathode ionization gauges offer many advantages for routine high-vacuum measurements. They are simple and robust. Thermal outgassing and electron-stimulated desorption, both significant problems in hot-cathode gauges, are negligible. There are no x-ray effects to cause errors at low pressures. New design techniques have largely eliminated stray-field and starting problems. The design, development and testing of a compact wide-range cold-cathode gauge are discussed. Demountable and all-metal versions have small internal volumes ranging from 5 to 15 cm@super 3@, yet the sensitivity can exceed 10A Torr@super -1@ at 10@super -6@ Torr. Double inverted magnetron geometry and shielding rings reduce the external magnetic fields to very low levels. The anode contains thorium for easier starting at normal pressures. For UHV applications, Americium 241 or a carbon film cold emitter can be used for instant starting. Test data are given which illustrate the effects of varying anode voltages and magnetic fields upon sensitivity and starting time. Factors affecting stability and freedom from discharge discontinuities are also discussed. Design features allowing stable operation down to 10@super -11@ Torr and above 10@super -2@ Torr are described.

10:40am **VT-TuM8 New Enhanced Performance Low Pressure Capacitance Manometer*, C.P. Grudzien,*** MKS Instruments

The measurement performance of low pressure capacitance manometers has traditionally been influenced to varying degrees by many factors including barometric pressure, ambient temperature change, shock, vibration, material creep and rapid pressure excursions. Many improvements and developments have occurred since the original capacitance manometer technology was invented over forty years ago. Previous capacitance manometer designs address several of these pressure independent influences, but in the process, trade off performance in other areas. A new enhanced performance design is described here that incorporates several unique approaches to reducing these influences and provides for a practical, robust platform. The unique radial 'spoke' geometry isolates the sensitive capacitance elements from unwanted body forces and thermal transients, yielding stable zero and span performance. Experimental data and computer simulation show that measurements using instruments with full scale ranges of 100 mTorr (~10 Pa) and below are superior to that of previous state-of-the-art methods. The enhanced performance capacitance manometer design establishes a basis for continual improvement and a path to meet the future requirements of the vacuum community.

11:00am **VT-TuM9 A Review of Thermal Transpiration Corrections in Capacitance Diaphragm Gauges*, J. Setina,*** Institute of Metals and Technology, Slovenia

Capacitance diaphragm gauges (CDGs) play important role in vacuum metrology because of their accuracy and resolution. They are widely used in calibration laboratories as reference and transfer standards for calibration of other pressure measuring devices in the pressure range from 0.01 Pa to 100 kPa. CDGs are inherently susceptible to ambient temperature variations. Operating CDGs at stabilised elevated temperature greatly improves the zero stability and enables relative resolution of few ppm of gauge full-scale but also introduces nonlinearities, which are known as thermal transpiration (TT) effect. In applications, where the uncertainty of measurements must be reduced to less than one percent, the response of CDG has to be corrected for TT effect if measured pressure is below 100 Pa. TT effect had been studied in detail by Takaishi and Sensui,@footnote 1@ and their empirical formulas are widely accepted for corrections of CDG measurements. In the present paper we will address the accuracy of this formulas which were published four decades ago. We have done some accurate calibrations of CDGs in the pressure range from 0.01 to 133 Pa in four gases: N@sub 2@, Ar, He and H@sub 2@. For He we found discrepancy of our data from Takaishi and Sensui empirical formula as large as 0.3 % in the range of pressures from 0.5 to 5 Pa. Scaling of thermal transpiration curves for different gases with the inverse of Knudsen number was also observed. This has not been reported by other authors. Vacuum metrology greatly advanced since the work of Takaishi and Sensui. The improvement in measurement accuracy at primary laboratories in the past ten years allows much more precise measurements in the range from 0.01 to 100 Pa. Therefore we suggest a thorough re-evaluation of the TT effect that should include a variety of gases with which CDGs are commonly used as well as the influence of momentum exchange of gas molecules on the surface of the tube that connects a CDG to the vacuum system. @FootnoteText@ @footnote 1@ Takaishi T., Sensui Y.,Trans.Faraday Soc., 1963, 59, p. 2503

11:20am **VT-TuM10 Partial Pressure Analyzers in the Relativistic Heavy Ion Collider***, **L.A. Smart**, D. Loughlin, R.J. Todd, R.C. Lee,* Brookhaven National Laboratory

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory incorporates large-scale high and ultrahigh vacuum systems. Partial pressure analyzers (PPAs) are employed to monitor the gas composition of these volumes remotely. PPAs with faraday cup detectors are placed along cryostat vessels that are up to 480 meters long. Data trends in both displacement and time are used to indicate helium or air leaks into the system and their probable locations. Electron multiplier units are employed to peer into the ultrahigh vacuum beam chambers near the interaction region detectors, where beam-on-beam collisions occur. The acquisition, testing, installation and control of the PPAs will be discussed with a summary of the system performance in the first few months of RHIC operation.

11:40am **VT-TuM11 The Modern and Flexible Upstream Controller***, **H.-Ch. Gehlhar**,* Leybold Inficon, Liechtenstein

The modern vacuum applications ask more and more for constant pressures in chambers and reactors or constant gas flow to maintain certain atmospheres in those chambers. This can be done in different ways, e.g. downstream control, massflow control or as we would like to discuss now by upstream control. A very simple version of upstream control could be a limit switch controlled valve operation by just opening or closing the valve. A simple and inexpensive method with all pros and cons concerning any system requirement. As an improvement to this, modern upstream controllers are flexible and give various opportunities to justify the pressure control circle in a vacuum system. The parameters to take care of like: chamber size, pumping speed, response times, time requirements etc. are very well known by everyone who has ever designed such a control circle. The user requirements of the vacuum system combined with all these parameters result in a level of requirements of a controller and a valve as well as for the applied gauges. Those requirements may vary in such a wide range that many pressure controllers are by far out of their limits. Modern solutions for pressure controllers or upstream controllers may not cover every extreme requirement. These new and advantageous controllers give flexibility in choosing out of various gauges and allow to justify the PID parameters in a wide range that nearly most of the known applications are covered in a satisfying way.

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