Vacuum Technology
Room 104C - Session VT-MoM
Vacuum Measurement, Calibration, Primary and Industry Standards

Moderators: Yulin Li, Cornell Laboratory for Accelerator-Based Sciences and Education, Joe Becker, Kurt J. Lesker Company

8:20am **VT-MoM1 Industry Practice for Using Primary Leak Standards to Validate Calibration Methods*, Jason Alfrey,*** VACUUM TECHNOLOGY INC **INVITED**

Accredited metrology labs are required to maintain traceability to a primary laboratory and periodically validate measurement methods. For calibration laboratories operating multiple systems, what is a suitable process to validate measurements and prove traceability while still being economically competitive?

Vacuum Technology, Inc (VTI) utilizes two methods for gas flow measurement of Leak Standards – both primary and comparison methods. Although these are well established methods in the industry, an accredited laboratory is always interested in proving it is linked to the "chain of metrology." The following discussion presents the methods for both inter-laboratory and intra-laboratory testing using Primary Leak Standards calibrated by NIST.

9:00am **VT-MoM3 Fixed Length Optical Cavity for Photonic Realization of the Pascal*, Jay Hendricks,*** *J. Ricker, P. Egan, J. Stone, G. Scace, G.F. Strouse,* National Institute of Standards and Technology

NIST is actively developing a new paradigm in the methodology of pressure and vacuum gauging and metrology. In a break with nearly 400 years of mercury based primary standards, NIST has developed a new standard that is based on the fundamental physics of light interacting with a gas. For the vacuum community, this represents a shift in how we think about the unit of the Pascal in that it will be directly related to the density of a gas, the temperature, the refractive index, and the Boltzmann constant. The photonic technique has now achieved important benchmarks in performance when compared to the existing primary standards based on mercury manometers: The photonic technique has a 20X smaller footprint, 100X faster sensing response time, 100X lower pressure range, and for an emerging technique has demonstrated impressive accuracy, reproducibility and hysteresis. Photonic sensing of the pascal has the potential to be further miniaturized, and has the key advantage that the light used for sensing the pressure can be transmitted over light-weight, high-speed fiber optic cables and networks. This talk will highlight the NIST efforts to replace our mercury Ultrasonic Interferometer Manometers (UIMs) with the new quantum-based, photonic technique. New data will be presented that shows that two independent Fixed Length Optical Cavities are now operating with part per million reproducibility and measurement agreement. The optical technique has now surpassed mercury manometer performance, and a new paradigm for vacuum metrology and realization of the SI unit, the pascal has begun.

9:20am **VT-MoM4 Analysis of a Quantum Based Refractometer to Replace Mercury Manometers as the Primary Standard for the United States*, Jacob Ricker,*** *J. Hendricks, P. Egan, J. Stone,* NIST

NIST has developed a technique to measure pressure using the gas refractivity of nitrogen for pressures in the range of 1 Pa to 360 kPa. This range is critical to many application including altimetry, weather, process control, etc.; all of which require high accuracy calibration of vacuum gauges. Currently the highest claimed accuracy of a primary standard is the NIST mercury Ultrasonic Interferometer Manometers (UIMs) operating at an uncertainty of $U(P_{UIM})=[(6\ \text{mPa})^2 + (5.2*10^{-6}*P)^2]^{1/2}$. NIST proposes replacement of these standards with an optical gas refractometer with an uncertainty of $U(P_{OGR}) = [(2.0\ \text{mPa})^2 + (8.8*10^{-6}*P)^2]^{1/2}$.

The optical refractometer has many benefits over the current UIMs, however we also need to show the feasibility of the fixed length refractometer as a primary standard. The two key requirements to define a primary standard are traceability of the standard back to the International System of Units (SI) and the ability to transfer the measurement/uncertainty to a high accuracy gauge or a transfer standard. The traceability and associated uncertainty will be discussed along with the derivation of the above stated uncertainty for the optical gas refractometer. Additionally, results of a calibration using the refractometer will be compared to that obtained using the NIST UIM. The capability and limitations of both the refractometer and UIM will be discussed and will show that the refractometer outperforms the UIM and will be slated to replace the mercury standards in the near future.

9:40am **VT-MoM5 Creating Vacuum Standards in the UHV and XHV to Support Cold-Atom Physics and Other Cool Stuff*, James A. Fedchak,*** *J. Scherschligt, M.S. Sefa, S. Eckel, D. Barker,* National Institute of Standards and Technology (NIST)

We are creating a program at NIST to develop new vacuum standards that cover the UHV and XHV. This addresses the needs of advanced manufacturing and research, including the semiconductor industry, accelerators, nanotechnology, and space science. NIST is also interested in developing metrological tools and other practical devices based on ultra-cold atoms, a technology pioneered at NIST that fundamentally operates in the UHV. Gravimeters, inertial sensing, and clocks are all examples of such devices, and any such device based on ultra-cold atoms will necessarily operate in UHV. To this end, we are presently developing a cold-atom vacuum standard (CAVS) to absolutely determine the vacuum level in the range of 10^{-7} torr to 10^{-12} torr. Our CAVS will use ultra-cold atoms to sense the absolute number density of gas molecules in the vacuum, and will be an SI traceable primary realization of UHV and XHV. In addition, we're developing the Cold-Core Technology program, which seeks to create a platform enabling the miniaturization of the CAVS and other practical cold-atom devices. An active UHV and XHV program is critical and necessary for this effort. This includes traditional activities such as producing and measuring low-outgassing rate materials and building dynamic expansion chambers for generating UHV pressures, as well as new efforts like building the CAVS. This talk will be an overview of these activities in light of creating the CAVS and other devices based on ultra-cold atom technology.

10:00am **VT-MoM6 Technical Challenges of the Cold Atom Vacuum Standard*, Julia Scherschligt,*** *J.A. Fedchak, M.S. Sefa, S. Eckel, D. Barker,* National Institute of Standards and Technology (NIST)

NIST has recently launched a program combining cold-atom physics with vacuum metrology and has begun to build the Cold Atom Vacuum Standard (CAVS). Development of the cold atom vacuum standard presents a variety of technical challenges: we need a thorough understanding of the collision cross section of trapped atoms with background gas, we need to achieve excellent vacuum levels and prevent contamination of the test system with sensor alkali atoms, and we need a robust and user-friendly design if the device is ever to be practical for real-world applications. We will discuss progress that has been made in determining collision cross sections, measuring and reducing outgassing rates, as well as design considerations of the cold atom device itself.

10:40am **VT-MoM8 Investigation of a Novel Cold Cathode Ionization Gauge Geometry with Wide Range from High Vacuum to Atmosphere in a Single Gauge***, T.R. Swinney, C. Percy,* ***Gerardo Alejandro Brucker,*** Pressure & Vacuum Measurement Solutions, MKS Instruments, Inc.

Wide range vacuum gauges are in use now, however, all rely on multiple technology sensors with various mismatched pressure responses for various gases. An overview of the problems created by multiple technologies and mismatched pressure responses along with novel solutions will be presented. A new internal geometry of a cold cathode ionization gauge has been investigated and has produced a usable pressure signal from high vacuum to atmosphere, using only one gauge and only one physical electronics mechanism, namely a gaseous discharge. A redesigned electrode structure avoids mixing differences in gauge types and their responses to different gas types when using multiple gauge types over this full range. Careful choice of the anode-to-cathode spacing can sustain a gaseous discharge with the usual electric and magnetic fields. The various electrical signals used to display a pressure read-out will be presented and compared. This was accomplished during the investigation with available control circuitry.

11:00am **VT-MoM9 Advanced Manufacturing Techniques for Cold Cathode Ionization Gauges*, Clinton Percy,*** Pressure & Vacuum Measurement Solutions, MKS Instruments, Inc.

Cold cathode ionization gauges (CCIGs) have been used for decades to make high vacuum measurements on a variety of production and laboratory equipment. Interestingly, the manufacturing techniques used to produce these gauges have not appreciably changed during this same time period. Furthermore, the typical, currently marketed extended-range CCIG products involve multiple gauging technologies, which introduce additional complexity and costly design challenges. Our laboratory investigated the impact on gauge cost and performance of a variety of materials, manufacturing techniques, electronic circuit designs and sensor technologies that could be employed to produce a reduced cost CCIG that can measure an extended pressure range. The outcomes of this investigation resulted in improved design techniques which have been implemented in a prototype embodiment of a wide pressure range CCIG.

11:20am **VT-MoM10 Operation and Performance of a Wide Range Cold Cathode Ionization Gauge***, **Tim Swinney**, C. Percy,* Pressure & Vacuum Measurement Solutions, MKS Instruments, Inc.

A novel wide range cold cathode ionization gauge (CCIG), capable of measuring pressures from high vacuum to atmosphere and relying on only one gauge and only one physical electronics mechanism, was recently developed in our laboratory. Many technical challenges exist in operating a CCIG above the standard 10-2 Torr upper limit of the current CCIGs available on the market. We will present detailed operational aspects of our new sensor technology including: (1) selection criteria for the discharge characteristics used to derive pressure measurements, (2) accuracy of the pressure measurements produced and (3) long term stability and lifetime of the technology over its wide pressure range.

11:40am **VT-MoM11 Improving Process Resistance of Capacitance Diaphragm Gauges***, B. Andreaus, C. Strietzel, **Martin Wüest**,* INFICON Ltd., Liechtenstein

Process industry is constantly changing. New manufacturing processes using new chemistries are developed that can also affect sensors. Yet, quality and cost pressure demand that processes are highly reliable, repeatable and need fewer maintenance interruptions. For capacitance diaphragm gauges, process stability means that process effects on the diaphragm deflection remain in the 1 nm range for a diaphragm with 30 mm diameter. To cope with this we have investigated ways to better protect the CDGs from process related influences. We will present results from experiments performed with protective layers.

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