Vacuum Technology Division
Room 329 - Session VT-TuA
Drag Pumping and Transition Flow Phenomena
Moderator: T. Sawada, Akita University, Japan

2:00pm **VT-TuA1 How Gaede Was Forgotten**, ***J.C. Helmer,*** AVS Fellow

In 1913 W. Gaede published a theory of the molecular drag pump, including data from an experimental pump which bears his name. To the author's knowledge, all reviews of this subject have reproduced Gaede's theory without qualification. However Gaede himself noted that for molecular flow his theory is off by orders of magnitude. This discrepancy was forgotten by subsequent authors. At Varian SpA, it was found in both molecular and viscous flow, that Gaede's model may be corrected with the addition of an active "pumping" leak at the end of the channel, for which there is an exact and simple theory. Design of the channel to the leak-limited compression ratio is specified by a "golden rule". We also proved that a differential velocity between adjacent channel surfaces is not necessary for the pumping action. Gaede's later designs suggest that he knew this. The modern Gaede model can now be applied to the pumping action of the Holweck pump in the direction of surface drag. What Gaede did not discuss is the possible influence of Bernoulli and inertial effects at high pressure. We will conclude with a discussion of the importance of inertial effects in the Gaede pump model.

3:20pm **VT-TuA5 Direct Simulation Monte-Carlo Method for Molecular and Transitional Flow Regimes in Vacuum Components**, ***O. Boulon***, *R. Mathes,* Alcatel High Vacuum, France; *J.-P. Thibault,* LEGI-IMG, France

With the active development of semiconductor fabrication technology, dilute gas flow phenomena are recently attracting attention. The gas flow through a vacuum component can be continuous, transitional or molecular depending on the pressure range and geometries involved. The present work proposes a method for simulating molecular and transitional flows using the direct simulation Monte-Carlo method (DSMC), first developed by Bird.@footnote 1@ DSMC codes directly simulate nature by moving computational particles through space. The computational model takes as data combinations of pressures, temperature of gas, type of gas and geometry of the vacuum components. The results of the computations are gasflow, local velocities, and molecular density distribution. The model was first tested and validated for several simples geometries such as circular and rectangular finite length tubes with static and moving walls, for different flow conditions. The molecular flow "aspect" is checked by comparing results with existing analytical values in the literature. The model was found to agree well with other published results in this field. From molecular to transitional flow, velocity profiles show the importance of viscosity effect for the different Knudsen numbers varying from 40 to 0.04 (pressure range from 5.e-03 to 5 Pa). The flow rate obtained for the smallest Knudsen number is close to the viscous value corresponding to Poiseuille's law. The aim of the study is to develop a model that we can adapt to more complicated geometries of vacuum components such as stage of turbomolecular or molecular pump and to predict the flow rate from molecular to transition flow regimes. @FootnoteText@ @footnote 1@G.A. Bird "Molecular gas dynamics and the direct simulation of gas flows". Oxford Science Publications, Clarendon Press, 1994.

3:40pm **VT-TuA6 Viscosity and Slip Measurements with a Modified Spinning Rotor Gauge**, ***J.A. Bentz***, *S.K. Loyalka, R.V. Tompson,* University of Missouri, Columbia

The spinning rotor gauge (SRG) has become a practical method in determining the coefficients of viscosity, velocity slip, and tangential momentum accommodation for rarefied gases with a high degree of accuracy. In previous papers, we discussed the use of the SRG for measurement of these quantities for noble gases (He, Ar, and Kr), polyatomic gases (N@sub2@ and CH@sub4@), and binary gas mixtures (He-Ar, He-N@sub2@, and He-Ne). In all of our previous experiments, we considered the axis of sphere rotation parallel to the axis of the cylindrical tube inside which the sphere rotates (in the MKS gauge, the sphere rotation axis is normal to the tube axis). Based on these calculations, we suggested how the results could be used for measurements of viscosity, the velocity slip and the tangential momentum accommodation coefficients. However, the theory used for our calculations required a sphere spinning co-axially to the cylinder. We have modified our experimental apparatus to achieve this geometry. A selection of experimental measurements for He and Ar gases which have been made with a modified spinning rotor gauge are reported. All of the experiments were conducted in the slip regime. Theoretical results from a previous paper on the SRG are used to extract values of the viscosity, the velocity slip coefficient and tangential accommodation coefficient from the experimentally obtained data for both gases. These are compared with previous experimental results. The measured viscosities are in excellent agreement with existing literature values.

4:00pm **VT-TuA7 Two Point Calibration Scheme for the Linearization of the Spinning Rotor Gauge at High Pressures**, ***J. Setina,*** Fotona d.d., Slovenia

Commercial spinning rotor gages (SRGs) use a special linearization procedures to compensate for a vanishing pressure dependence of the rotor deceleration rate in the transition regime from 0.1 to 100 Pa. These procedures have been found to have large errors above 10 Pa,@footnote 1@ but can be significantly improved. An extensive set of experimental data of rotor deceleration rate versus gas pressure up to 130Pa was acquired. A group of six SRGs and four gases (N@sub 2@, Ar, He and H@sub 2@) were used in the study. Temperature measurements where also included to account for heating effects. The data shows that the differences between rotor/thimble combinations are large enough to cause differences of several % if one uses the linearization functions currently in use without adjustable parameters. To get the best accuracy, one parameter is left in our linearization procedure to be determined by calibration. We call it the Knudsen length of the rotor/thimble assembly. This is the second calibration constant of SRG that needs to be determined for accurate pressure measurements above 1Pa. The method to determine the second calibration constant at 100Pa will be proposed. The first calibration constant is the already well-known rotor accommodation coefficient and is determined in molecular regime below 0.01Pa. Achievable accuracy of the new linearization procedure with the two calibration parameters is better than 1% over the entire range from molecular regime up to 130Pa. The effect of thimble temperature on this linearization procedure will also be discussed. @FootnoteText@ @footnote 1@J.Setina and J.P.Looney, Vacuum, 44,1993, p.577

4:20pm **VT-TuA8 Design and Characterization of High Capacity NEG Pumps Embedded Inside the Interaction Regions of DA@PHI@NE**, ***R. Giannantonio***, *P. Manini, F. Mazza, R.M. Caloi, D. Dominoni,* SAES Getters S.p.A., Italy; *A. Clozza,* Infn Lnf, Italy; *L. Zanin,* DG Technology Service, Italy

The DA@PHI@NE @PHI@-factory is a twin ring 510 MeV e@super +@e@super -@ collider facility under commissioning at INFN-LNF in Frascati. With a stored beam current of 5.3 A, a mean pressure of 1*10@super -9@ Torr is required in each ring. To cope with a total gas load, mainly consisting of CO, of 1.2*10@super -4@ Torr*l*s@super -1@ for each of the electron/positron ring, sputter ion pumps and titanium sublimation pumps with a total pumping speed of about 1.2*10@super 5@ l*s@super -1@ were installed on each ring. For the KLOE interaction region, where a mean pressure of the order of 1*10@super -10@ Torr is required, an embedded Non Evaporable Getter (NEG) pump with a CapaciTorr@super TM@-type structure was chosen mainly because of the unavailability of room for the installation of lumped pumps and to take advantage of the utmost sorption capability of the NEG pump for CO in the UHV operating conditions of the machine. A NEG pumping system of the kind discussed in this paper seemed to be particularly suitable for the KLOE experiment, where limited servicing and high reliability is required. In this paper we report on pumping speed measurements performed on a first pump prototype, fitted with St-172 NEG alloy, featuring sorption rates as high as 5*10@super 3@ l*s@super -1@. We also discuss on the design and characteristics of the final pump version, where St-185 NEG alloy is used. Computer simulations of the pressure distribution inside the interaction beam pipe are also shown, demonstrating the effectiveness of the selected technical solutions.

4:40pm **VT-TuA9 Hydrogen Pumping Simulation for Cryopumps**, *S. Nesterov, J. Vasiliev,* Moscow Power Engineering Institute, Russia; ***L.C. Wagner***, *M. Boiarski,* IGC-APD Cryogenics Inc.

Cryopumps are an effective way to create clean, high vacuum. When designing a new cryopump, it is desirable to have some tool to predict cryopump performance for the different cryopanel geometries that are being considered. Monte Carlo simulation is a method that has been used for evaluating the pumping speed of a cryopump when it has not yet accumulated any gas. The simulation of hydrogen pumping has its own challenges due to the typical location of the hydrogen pumping sites and interactions with other gases. As gases accumulate on the pumping surfaces, the passageways for hydrogen gas are restricted. This paper describes the work that was done, using Monte Carlo simulation, to study the hydrogen pumping speed and capacity of a typical cryopump as it accumulates hydrogen, water and argon. The hydrogen pumping speed is predicted as a function of the amount of other gases that have been accumulated.

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