Thursday Morning, November 7, 2002

Vacuum Technology
Room: C-104 - Session VT-ThM

Gas Dynamics and Flow
Moderator: R. Dobrozemsky, University of Vienna, Austria

8:20am **VT-ThM1 Cryopump Pumping Performance Estimation Using Flow Meter Method**, *H.-P. Cheng*, ***Y.-C. Lu***, National Taipei University of Technology, Taiwan, *M.-K. Hsu*, World Hold Engineering Consultants, LTD

The pumping performance of cryopump, ULVAC CRYO-U10PU, is estimated by the flow meter method, which is widely used in the estimation of the pumping capacity of the turbo molecular pump for inlet pressure greater than 1.0E-04 Pa. The test dome is designed according to the instruction of JVIS-005 and connected directly with the cyropump. The inner diameter of the test dome is the same as the inlet port of the pump. The PIRANI gauge (ULVAC GP-1000, range 0.4 to 2700 Pa) and the ION gauge (ULVAC GI-1000 WIT, range 1.3E-05 to 6.7E-01 Pa) are equipped on the peripheral of the test dome to measure the test dome pressure according to the instruction of the JVIS-005. Four flow meters (Sierra 820 series, ranges 25 SCCM, 500 SCCM, 10 SLM, and 50 SLM) hybrid the needle valves are used to control the inlet gas throughput of the pump and two types of gas, nitrogen and argon are introduced. The variations of the temperature of the first stage (80K) of the cryopump and the test dome pressure relative to the operating time of cryopump are discussed. The pumping speed and throughput of the cryopump versus to the test dome pressure that is considered as the inlet pressure of cyropump are plotted and compared to the values described in the catalog of ULVAC. Finally, the residual gas analysis is made to investigate the residual gas in the whole system. And the temperature recovery time is recorded after the cryopump is turned off. According to the measurements, the temperature of the first stage of cryopump is in the steady state condition after two hundred minutes of the starting of the cryopump. The pumping speed for nitrogen is near to the value shown in the catalog of ULVAC and the argon is nearly twice than the catalog. The main residual gases are hydrogen and water at the status of the ultimate pressure operating condition. The recovery time from normal operating temperature of the cryopump to the room temperature is over three hundred minutes after the pump turned off.

8:40am **VT-ThM2 Developing of Calculation Methods of Diffusion Vacuum Pumps' Characteristics**, *M.G. Sapeshinsky*, Bauman Moscow State Technical University, Russia, ***B.N. Kemenov***, NPK INTELVAC, Russia

Results on 3-dimensional mathematic simulations of processes in an inlet chamber of diffusion vacuum pumps, of interaction between pumped out gas and steam molecules are presented. Description of algorithmus and of a calculation programs complex for characteristics of diffusion vacuum pumps is given. Using the developed calculation programs the influence of parameters and form of a steam flow, geometry of a body, as well as of an oil reflector and protecting screens, on operation rate and on reverse oil flow of diffusion pumps is investigated. Rated and experimental data are compared. The concept of optimisation of an inlet chamber of diffusion pumps is developed

9:00am **VT-ThM3 Comparison between Monte Carlo and Analytical Calculation of the Conductance of Cylindrical and Conical Tubes**, ***J. Gómez-Goñi***, *P.J. Lobo*, Universidad Politécnica de Madrid, Spain

The accurate calculation of transmission probabilities of ducts in the molecular flow regime has become a need of vacuum standards on the ultra high vacuum region. The usual approach is to simulate a molecular flow of molecules with a Monte Carlo method, because of the difficulties that arise trying to find a solution of the Clausing integral equation in a system of a given geometry. As modern computers increase their speed, the accuracy of Monte Carlo methods is higher and higher. So it becomes important to compare simulation results with data obtained by other methods to check that random number generators used in the Monte Carlo are not biased. Moreover, with numerical methods we can obtain the density of molecules along the tube. This density is important in molecular beam formation studies. We have applied both a Monte Carlo method and numerical solutions of the Clausing integral equation for cylindrical and conical tubes. In the case of cylinders, we have found very accurate transmission probabilities solving numerically Clausing integral equations. The method consists in an approximation of the Clausing function with Chebyshev polynomials using a subroutine made by the Numerical Algorithm Group (NAG).[1] Comparing with other values found in the literature[2] made by a variational method, we have obtained values near the upper bound and quite far away from the lower bound. In the case of cones, we obtain values which agree with values found in the Literature[3] to a high degree of accuracy.

[1] NAG Subroutine D05AAF.
[2] R.J. Cole, J. Inst. Maths. Applics. 20, 107-115 (1977).
[3] R.P. Iczkowski, J.L Margrave and S.M. Robinson, J. Phys. Chem. 67,229 (1963)

9:20am **VT-ThM4 Modeling Molecular Drag Pumping in the 20th Century: A Personal View**, ***J.C. Helmer***, Consultant **INVITED**

In the last decade we have had a renaissance in molecular drag pumping, led by the design of hybrid turbopumps that exhaust at pressures above 10 Torr, to oil-free forepumps. The exhaust stages, which operate in laminar flow, may be of the Gaede, Holweck, or Siegbahn type. While Gaede provided the underlying model in 1913, upon which all are based, the Gaede design was not developed as a commercial pump until it was revived by Varian SpA, in Turin, in 1992. The neglect of the Gaede design was accompanied by 80 years neglect of the molecular drag model, in deficiencies which Gaede himself identified in his original papers. Pumps operate in continuum flow, which is a new field in vacuum science, extending the classical field of molecular flow. The appropriate mathematical tools have been developed in the fields of fluid mechanics (CFD), aerodynamics (RGD) and molecular simulation (DSMC). It is a challenge to extract from these fields a subset of theory that is appropriate and useful to molecular pumping. Many papers miss the fact that molecular drag pumps operate in the classic analytic regime of Couette-Poiseuille flow, and results need to be compared with the characteristics of this type of flow. Even G.A. Bird, author of the famous DSMC method, recommends that numerical simulations be guided by analytic models. Useful theory has been developed in the design of gas (journal) bearings, and floating magnetic recording heads. For molecular pumping, the inertial term in the viscous equations should not be neglected. Some papers calculate solutions with a form of slip-flow that has no physical correspondence, since in practice the molecules have full accomodation to the surface. This is an emerging field which has many opportunities for student research.

10:00am **VT-ThM6 Mathematic Simulation of Processes in Flow Parts of Hybrid Turbomolecular Vacuum Pumps**, ***M.G. Sapeshinsky***, *A.V. Ponomarev*, Bauman Moscow State Technical University, Russia

Results on 3-dimensional mathematic simulation of processes in flow parts of hybrid turbomolecular pumps (TMP) are presented. Description of algorithms and of a calculation programs complex for characteristics of hybrid turbomolecular pumps with molecular and drum forcing channels is given. The influence of geometric parameters of a flow part on an operation rate and a maximal compression degree of pump channels is investigated. The concept of optimisation of hybrid pumps under restrictions of controlled parameters is developed.The optimal variants of a flow part are given. Rated and experimental data are compared. There is developed an algorithm of optimization of a TMP flow part with axial and axial-radial gas flow under functional restrictions on controlled parameters, ensuring the desired TMP operation rate at fixed suction pressure for a chosen gas, and also the desired operation rate for several gases using the algorithm of slipping access and the absolute penalty functions metod. It is found out, that within the investigated operation rate's range an axial-radial scheme has better mass-size characteristics compared to that of an axial scheme. Decrease in volume of a flow part with optimal geometric parameters makes from 36 % (S=0.5 m^3/sec) to 53 % (S=20 m^3/sec) due to decreasing the axial rotors number. Here the external diameter of axial rotors increased from 35 % (S=0.5m^3/sec) to 5 % (S=20m^3/sec). More preferable is the axial-radial scheme with periphery-center flow direction. It is found out, that if ensuring the desired raised evacuation characteristic for light gases, the flow part volume of all the three schemes increases due to increase in axial rotors number and smoother changing of geometric parameters over rotors, and mass-size characterictics of axial-radial schemes come worse. Decrease in the flow part volume comparing to that of an axial scheme makes for the scheme with periphery-center flow 24 % (S=20m^3/sec, P=10^{-5} Pa, S=15 m^3/sec and P=10^{-3} Pa). The volume of an axial scheme raised on 93 %, of axial-radial schemes - on 163 % and 150 % compared to the computation results when ensuring the desired operation rate only for nitrogen.

10:20am **VT-ThM7 Two-Dimensional and Three-Dimensional Monte Carlo Simulation on the Pumping Performance of a Turbomolecular Pump with Rough-Surface Blades**, *M. Yabuki,* ***T. Sawada****, W. Sugiyama,* Akita University, Japan, *M. Watanabe*, Osaka Vacuum Ltd., Japan

The elements of a turbomolecular pump (TMP) are sometimes coated with ceramic (SiO_2) film for the purpose of preventing corrosion on the TMP. The blades coated with SiO_2 have relatively rough surfaces, and it has been confirmed by previous experiments that the SiO_2-coated TMP gives a higher maximum-compression ratio than the non-coated TMP. This paper describes the Monte Carlo simulation on the effects of the surface roughness of blades on the pumping performance of a TMP. The surface roughness was measured by SEM, and then the distribution of roughness slope angles was obtained from the surface roughness data. The surface roughness was modeled by statistically located circular-conic peaks and dimples of the same base radius and various base angles. The base angles were sampled in a statistical manner so as to accord with the measured slope angle distribution. Both the 2D and 3D Monte Carlo simulations were done in the free molecule flow regime and the simulated maximum-compression ratios were compared with the previously measured values. The 3D simulation naturally showed a better agreement with the measured values than the 2D simulation. However, it was proved that the 2D simulation gave reasonable results with much less computation time than the 3D simulation when the ratio of blade height to pitch was larger than the unity.

10:40am **VT-ThM8 Experimental Analysis of Tapered Gaede Pumps**, ***S. Giors****, R. Gotta, J.C. Helmer,* Varian S.p.A., Italy

In 1993 Varian S.p.A. revived the Gaede design and developed it for commercial hybrid turbomolecular pumps. The Gaede stages exhaust at pressures above 10 Torr, operating in laminar viscous flow. Classical Gaede stages are characterized by uniform cross section of the channel, from inlet to exhaust. Both modelling and experimental analysis agrees in showing that the maximum compression in the viscous regime is inversely proportional to the square of the height h between disk and channel surface, while channel pumping speed is proportional to the inlet cross section of the channel and hence to h. From this reasoning comes the simple idea that tapering the height h of the channel from inlet to exhaust, keeping the same entrance section, can greatly increase compression, without compromising the pumping speed of the channel. An experiment was designed to test these concepts. A uniform channel and one with a 3:1 taper, with the same inlet channel section, are compared in viscous conditions. Results show that the channels must be compared not just in terms of maximum compression and maximum speed, but in terms of the complete speed vs. compression characteristics. Actually the tapered channel shows a slight decrease in maximum pumping speed, but that is highly compensated by increased compression and improved shape of the speed vs. compression characteristics. Another promising advantage of the tapered channel with respect to the uniform one, is reduction in power dissipation with the same exhaust pressure and flow. Comparison of experimental results with model calculations, indicates some ways in which the Couette-Poiseuille model needs to be improved.

11:00am **VT-ThM9 Pumping Performance Investigation of a Turbo Booster Vacuum Pump Equipped with Spiral-Grooved Rotor and Inner Housing by CFD Method**, ***H.-P. Cheng****, C.-P. Chien,* National Taipei University of Technology, Taiwan, *C.-P. Lee*, China Engineering Consultants, INC

This paper estimates the pumping performance of a turbo booster vacuum pump equipped with spiral-grooved rotor and inner housing by CFD method. The computational domain hybrids the flow channels in the rotor and inner housing, thus the gas can flow continuously from the inlet of rotor through the outlet then into the inlet of inner housing and exist. The pumping characteristics for the spiral angle of the rotor, and the groove number and the spiral angle of the inner housing are detailed investigated. The spiral angle, 15 degrees, of rotor can adequately increase the effective pumping length of the flow channel and overcome the following increased friction force, therefore the pumping performance can be enhanced. Similarly, the spiral-grooved inner housing with 5 grooves and spiral angle 27 degrees can also have the better pumping performance. The results also indicate that there is an axial vortex dominated the spiral-grooved flow channel of both rotor and inner housing. The back stream from rotor channel to the vacuum chamber is evident. Otherwise, the detailed three-dimensional velocity vector, axial velocity contour, and pressure fields are shown in the paper. The arithmetic axial pressure distribution, compression ratio are also discussed. The pumping performance of two prototypes are also measured and shown in the paper. The discrepancies among experiments, simulation, and expected target are discussed.

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