Vacuum Technology
Room 321 - Session VT-ThA

Vacuum Technology Flow and Pumps

Moderators: Dr. Marcello Juni Ferreira, ESS, **Marcy Stutzman**, Jefferson Lab

2:15pm **VT-ThA-1 Vacuum Technology in Cork Science: From Permeability to TCA Desorption**, ***Orlando Teodoro,*** Nova School of Science and Technology, Portugal **INVITED**

Natural cork has been used for centuries as a high–performance sealing material for wine bottling due to its elasticity, durability, tightness to liquids, and naturally low gas transmission. In addition to being a renewable and recyclable material, cork combines mechanical resilience with a unique cellular structure that enables long-term sealing performance. However, the cork industry has historically faced important challenges related to the variability of sealing performance at the cork–bottle interface and to the presence of trace contaminants responsible for wine defects, particularly 2,4,6–trichloroanisole (TCA), the main compound associated with cork taint. TCA is of particular concern because it can migrate from cork to wine, producing sensory defects at concentrations as low as 2–3 ng/L.

This work presents several applications of vacuum technology developed and introduced for cork science and industrial processing over the last two decades. The first topic addresses the characterization of gas and vapor permeation through cork using vacuum-based methods. Permeability measurements performed under controlled pressure conditions enabled the study of transport mechanisms in natural cork and supported the development of transport models accounting for the permeation of gases and vapors through the cellular cork structure.

The second topic focuses on the sealing performance of cork stoppers in bottlenecks and on the role of surface treatments and lubricants. Vacuum-based leak testing methods were used to characterize sealing performance at the cork–glass interface, revealing leak rates ranging from below 10^{-7} mbar·L/s for well-sealed stoppers to above 10^{-5} mbar·L/s for poor sealing conditions.

The third topic concerns the interaction of TCA with cork and the development of large-scale vacuum-based thermal desorption processes for contaminant removal. Experimental studies combining controlled heating, vacuum exposure, and gas analysis provided insight into the desorption behavior of TCA and its interaction with the cork structure. These studies contributed to the development of industrial processes capable of efficiently reducing TCA contamination while preserving the physical integrity and performance of the cork.

The work illustrates how vacuum technology evolved from a laboratory research tool into an enabling industrial technology in the cork sector. These developments contributed to substantial improvements in cork quality control, contaminant removal, and sealing consistency, playing a significant role in the modernization of the cork industry over the last decades.

2:45pm **VT-ThA-3 Gas Transport in 3D-Printed Polymers: Linking Microstructure to Outgassing and Permeation Behavior**, ***Sefer Avdiaj,*** University of Prishtina, Kosovo*; Zgjim Rrustemi,* University of Prishtina. Department of Physics, Kosovo*; Ramiz Hoti,* University of Prishtina. Department of Chemistry, Kosovo*; Partizan Malkaj,* Polytechnic University of Tirana. Department of Physics, Albania*; Zeqe Tolaj,* University of Prishtina. Department of Physics, Kosovo*; Makfire Sadiku,* University of Prishtina. Department of Chemistry, Kosovo

Additive manufacturing is opening new possibilities for producing polymer components with complex and customized geometries. However, their use in vacuum environments is still limited by gas transport effects such as diffusion, permeation, and outgassing. In this study, we investigate how the microstructure created during 3D printing influences gas transport behavior in commonly used polymers.

Samples are being fabricated using fused deposition modeling (FDM), with systematic variation of key printing parameters such as infill density, layer thickness, and raster orientation. These parameters are expected to significantly affect the internal structure of the materials, including porosity, interlayer bonding, and anisotropy. Gas diffusion and permeation are being measured using steady-state and time-lag methods, while outgassing behavior is evaluated under controlled vacuum conditions.

Preliminary results indicate that gas transport properties are strongly influenced by printing-induced microstructure. Early observations suggest that increased porosity and weaker interlayer bonding lead to higher permeation and outgassing, while optimized processing conditions reduce gas release. Ongoing work is focused on obtaining quantitative relationships between processing parameters, microstructure, and transport properties.

The expected outcomes of this study will provide a deeper understanding of gas transport mechanisms in 3D-printed polymers and establish guidelines for improving their performance in vacuum and low-pressure applications. This work aims to support the development of additively manufactured components suitable for vacuum technology.

3:00pm **VT-ThA-4 Study on the Influence of Different Combinations of Roots Pump Sets on Flow Characteristics**, ***Shengquan Yang,*** *Kun Liu,* Northeastern University, China

Abstract: The multi-stage series Roots pump set has broad application prospects in fields such as nuclear fusion vacuum systems, semiconductor manufacturing, aerospace environment simulation, and large-scale scientific devices due to its advantages of high pumping speed, high compression ratio, no oil pollution, and suitability for high flow gas transportation. By operating in series with multi-stage pump bodies, the working pressure range of the pump group can be significantly expanded, the ability to extract light gases can be improved, and the demand for efficient pumping under complex working conditions can be met. However, the internal flow process of multi-stage Roots pump sets is complex, and phenomena such as gas transport, pressure distribution, and reflux leakage between stages are coupled with each other. The matching relationship between different stages has a significant impact on the pumping speed, compression ratio, and operational stability of the pump set. Especially under conditions of high speed, large pressure difference, and light gas, significant issues such as increased flow loss, uneven inter stage flow field, and local temperature rise are prone to occur within the pump unit, which in turn affects the overall pumping performance and long-term operational reliability. This study is based on computational fluid dynamics methods to establish a transient flow model for multi-stage Roots pump sets. Numerical simulations were conducted on the inter stage flow field, pressure distribution, and gas transport process of the pump sets, and the flow characteristics and pressure distribution laws of different combinations of pump sets under different operating conditions were analyzed. The research results indicate that as the compression ratio increases from 10 to 1000, the inter stage pressure difference significantly increases, and the clearance reflux velocity and reflux rate significantly increase; The heat generation effect of gas compression is enhanced, and the inter stage temperature at a compression ratio of 1000 is significantly higher than that at a compression ratio of 10; And the highest temperature occurs in the stage before the exhaust stage, not in the final exhaust stage, indicating that this stage has undergone the strongest gas compression and thermal accumulation; The gap between Roots rotors decreases, resulting in a decrease in leakage, but the reflux velocity increases, leading to an increase in inter stage pressure. This study provides a theoretical basis

3:15pm **VT-ThA-5 NAVAC Vacuum Technology: Old Problems. New Architecture. NAVAC HelixDrive Screw Pumps and NAVAC ShieldDrive Mag-Coupled Rotary Vane Pumps**, ***Evan Sawyer,*** NAVAC

Part One: HelixDrive Series — Dry Screw Technology Reimagined

Dry screw vacuum technology has existed for decades. Two intermeshing rotors trap and compress gas without contact — no oil, no sealing fluid. The concept is sound. The execution has historically been the problem. Traditional dry screw pumps are large, thermally complex machines with gearboxes and couplings that demand as much management attention as the processes they serve.

The HelixDrive series starts differently. Its coaxial design integrates motor and pump along a shared axis, eliminating mechanical interfaces and achieving the smallest dry screw form factor at this performance level.

The HD series reaches an ultimate pressure of 7.5×10^{-4} torr — challenging oil-sealed rotary vane pumps and exceeding most dry screw designs. A proprietary internal coating provides chemical resistance in corrosive, moisture-laden environments, sustaining performance over time. Thermal management is integrated: smaller models use onboard air cooling; the HD100 uses water cooling limiting surface temperature rise to under 50°F, keeping performance predictable.

Maintenance is largely eliminated. No tip seals means no wear, no particulate, no contamination risk. No oil means no changes, no mist filters, no backstreaming.

Part Two: ShieldDrive SDi Series — Rotary Vane Done Right

Oil-sealed rotary vane technology is proven but carries known liabilities: shaft seal leakage, oil mist in the workspace, messy maintenance, and degradation in chemically aggressive environments.

The SDi series engineers those problems away. A magnetic drive coupling replaces the dynamic shaft seal entirely, creating a hermetic boundary with no leakage path. An integrated oil mist filter — built into the pump body — captures exhaust droplets and doubles as an exhaust muffler, with tool-free quick-change access. An integrated drip tray handles maintenance mess. A detachable oil reservoir replaces drain plugs with a clean swap. Due to the magnetically coupled seals, there is no need for the "Cookie sheets" underneath the rotary pump. Additionally, the simple addition of the oil reservoir allows for a quick oil change without having to move the pump or use a separate container to trap the oil.

Gas ballast is adjustable for condensable vapor processes. The variable-frequency drive enables Eco Mode, reducing speed, energy draw, and noise during lower-demand operation. Another innovation that allows for lower energy consumption when the pump doesn't need to run at full capacity.

3:30pm **VT-ThA-6 From Experiment to Grid: A Systems Engineering Approach to Vacuum Pumping Systems in Stellarators***, **Danah Garcia**,* Type One Energy Group, Inc.

The fusion industry sits at a pivotal point in its trajectory from experimental reactors to power plant devices. The Infinity Two Stellarator is currently in design by Type One Energy. Part of the risk mitigation platform on Infinity Two will be conducted with the Infinity One device, a smaller scale stellarator that will help reduce physics and engineering uncertainties in fusion power plant design. Employing systems engineering fundamentals is crucial for mobilization of the industry, and special attention should be paid to systems that are integral to the power output of the device, namely the vacuum pumping system (VPS). The VPS interfaces with the plasma chamber and the tritium plant, linking the fuel processing system with the main reaction chamber of the device. As this link, the VPS is responsible for continuous exhaust of deuterium, tritium, helium and other plasma impurities, and helps maintain a burning plasma in the reactor, which is necessary for net energy out of the power plant. Type One Energy's VPS on the Infinity One fusion device will serve as an integrated design verification testbed for the Infinity Two stellarator, with demonstration of plasma particle exhaust as a key objective. The Wendelstein 7-X (W7-X) stellarator is the largest, most technologically advanced stellarator in the world, however its design is best suited for exploration of magnetic configurations, rather than particle exhaust. Demonstration of enhanced particle exhaust in Infinity One over W7-X will help solidify Infinity One's purpose of risk reduction, with emphasis on increased particle flux out of the plasma chamber and achieving target subdivertor pressures. With respect to the VPS, advancing the technology readiness level of high throughput vacuum pumping systems with fusion fuel present is critical. This work will demonstrate the scalability of the VPS from the Infinity One device to a reactor-scale device, exemplifying the need for risk mitigation in the transition of the fusion industry from the laboratory to the grid.

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3:45pm **VT-ThA-7 Measuring Rf Surface Resistance of Non-Evaporable Getter Coatings***, **Eleni Marshall**, Oleg Malyshev, Daniel Seal, Reza Valizadeh,* STFC Daresbury Laboratory, UK

A new method for measuring the RF surface resistance of non-evaporable getter (NEG) coatings on tubular samples has been developed at Daresbury laboratory.

NEG coatings are vital for achieving good pressures in vacuum systems with limited conductivity but will reduce the RF surface conductivity of the vacuum chamber when compared with the substrate material. For purposes such as particle accelerator chambers, this is important as the increased surface resistance can cause a loss in beam energyand increase in beam energy spread.

With this method, both the surface resistance and the NEG pumping properties can be measured from the same sample, allowing a full quantification of NEG properties.

This study compares samples of TiZrV of different thickness and microstructure, to see the relationship between NEG surface resistance and pumping properties.

4:00pm **VT-ThA-8 Feasibility of Turbomolecular Deceleration as an Intrinsic Measurement of System Pressure***, **Andrew Chew**, Paul Smith, Sam Lodge,* Edwards Ltd, UK*; James Healy,* University of Bristol, UK

When the drive power to a turbomolecular pump (TMP) is halted the TMP decelerates at a rate dependent upon various parameters/variables. These include TMP impeller mass, original rotational speed, suspension type, inlet and exhaust pressure and pumped gas type. Also and crucially, the TMP pumping configuration in terms of number of turbomolecular blade rows and drag stage numbers and types. We will report measurements of dependency of different TMPs on these variables and the feasibility of indicative pressure readings.

Patent Application: GB1902564.2

4:15pm **VT-ThA-9 Single-Stage Vacuum Pump Performance Measuring Method***, **Xiaoyu Chi**, Kun Liu, Dechun Ba, Yuanhua Xie,* Northeastern University, China

Traditional dry pump measurement devices usually focus on the entire vacuum pump performance parameters other than vacuum pump interior flow situation .This paper propose a performance test method for testing a single stage of a vacuum pump, concentrating on four basic physical quantities ; flow, vacuum degree ,temperature and rotating speed. For a better description of the measurement method , this test method is divided into six modules: the pump inlet test doom module, the pump outlet test doom module, the pressure measurement module, the temperature measurement module,the flow measurement module and the rotating speed measurement module. This method ensures the normal operation and parameter measurement of the single-stage vacuum pump by adjusting the pressure range of the front and rear vacuum dooms so that we can measure the flow field inside the single rotor and the specific measurement parameters to fit pumping speed - pressure curve and other parameter curves. The pressure, flow, temperature and rotating speed measurement ranges of the test method are 10^{-3}~10^{5} Pa, 20 SCCM~5000 SLM , 20℃~300℃and 100 rad/s~3000 rad/s. Compared with the traditional vacuum pump measurement method, the measurement method of the single-stage vacuum pump proposes a performance parameter to measure the internal flow field of the first-stage rotor of the multi-stage vacuum pump and the related parameters to provide design reference and experimental data support and rotor profile design for the rotor combination of the multi-stage vacuum pump.

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