Monday Afternoon, September 22, 2025

Vacuum Technology
Room 205 ABCD W - Session VT1-MoA

Vacuum for Fusion and Large Systems I

Moderators: Sol Omolayo, Lawrence Berkeley National Laboratory, **Charles Smith**, Oak Ridge Natinal Laboratory

1:30pm **VT1-MoA-1 Advanced Roots Pumping Solutions for Demanding Applications in Fusion and Nuclear Research: The New Okta 1500 GM**, ***Nico Völker,*** Pfeiffer Vacuum GmbH, Germany **INVITED**

Abstract:

Fusion and nuclear research facilities impose stringent requirements on vacuum technology, including high pumping speeds, reliability, and contamination-free operation under extreme conditions. Pfeiffer Vacuum's latest addition to its high-performance Roots pump portfolio, the **Okta 1500 GM**, addresses these challenges with enhanced efficiency and flexibility tailored for scientific and industrial applications.

The Okta 1500 GM combines a robust design with an integrated magnetic coupling, ensuring absolute gas-tightness. This feature eliminates the risk of cross-contamination and significantly reduces maintenance, making the pump ideal for radioactive and toxic media handling.

This presentation will highlight key technical innovations, such as the mechanical seals and advanced thermal management, as well as application examples from recent fusion and nuclear research projects. Special emphasis will be placed on the pump's contribution to operational safety, system uptime, and reduced lifecycle costs in demanding R&D and pilot-scale environments.

2:00pm **VT1-MoA-3 Neutron Resistant Vacuum Systems for Fusion Energy Applications**, ***J.R. Gaines,*** Kurt J. Lesker Company

Fusion energy, the process that powers the stars, offers unique potential for sustainable, clean electricity without many of the harmful by-products of fission reactors. But nuclear fusion is not without issues, specifically the high-energy neutron fluxes and associated radiation damage threaten the integrity, performance, and longevity of critical components of these complex systems through deformation, swelling, embrittlement, and the loss of mechanical integrity.

The presentation will explore the intersection of fusion energy and vacuum technology with special attention to strategies to mitigate radiation damage in vacuum systems. Topis reviewed include specialized vacuum system metal alloys engineered for improved radiation resistance, modular system designs, shielding approaches using multi-layered thin films and neutron reflectors.

Attendees may gain insights into material science, design considerations and innovative, multi-disciplinary, approaches that will shape the future of commercial fusion energy technology.

2:15pm **VT1-MoA-4 Vacuum Roughing Pump System's Role in ITER's Fuel Cycle**, ***Jared Tippens,*** Oak Ridge National Laboratory

The ITER Torus Cryopumps (TCPs) are located adjacent to the machine and allow the 1,400 m^3 vacuum vessel to reach the high vacuum pressures needed for operation. They also allow for the high throughput of the hydrogen isotopes via cryopumping. The TCPs themselves have a high surface area and are cooled via supercritical helium at 4 K in order to condense the hydrogen isotopes. The six TCPs are positioned in parallel and will operate in cycles, where they are regenerated at elevated temperatures one at a time after the capacity of each cryopump is filled.

The RPS located at an adjacent building, consists of a series of tritium compatible pumps and supporting equipment to remove the regenerated process gas from the TCPs and deliver them downstream to tritium processing where the helium ash is separated from the hydrogen isotopes (Tokamak Exhaust Processing), and eventually the hydrogen isotopes are separated and prepared again to fuel the fusion reaction.

The RPS used for the ITER fuel cycle consists of a total of 15 tritium compatible scroll pumps and 3 roots pumps. These are evenly divided into 3 different cells, called the Torus Cryopump Regeneration System (TCRS) cells. Each cell consists of 3 pumping stages. The first stage consists of an all-metal roots pump, the second stage of four scroll pumps in parallel, and the third stage a single scroll pump that backs the other four. The process gas regenerated from the TCPs is pumped through the TCRS cells into a buffer tank, where the process gas then flows to Tokamak Exhaust Processing at a controlled rate.

An overview of the RPS and its role in the ITER fuel cycle will be provided, as well as insight to the pumping performance of the system. Additionally, several of the key operational scenarios of the system are outlined, showing the flexibility of this type of pumping arrangement in a complex fusion machine such as ITER.

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The ITER project has the goal to demonstrate the feasibility of fusion and to advance the scientific and engineering understanding of fusion for future commercial reactors. In the reactor, heat is created through the fusion of hydrogen isotopes, primarily Deuterium and Tritium. To maintain the reaction, the fuel needs to be continuously supplied to and removed from the tokamak at a high rate. ITER's Roughing Pump System (RPS) drives this flow of fuel that makes the continuous fusion reaction possible.

2:30pm **VT1-MoA-5 Advanced UHV Sealing Solutions with HELICOFLEX® TEXEAL®**, ***Ryan Widejko,*** Technetics Group - An Enpro Company **INVITED**

As a leader in high-performance sealing for demanding environments, Technetics Group is consistently pushing the boundaries of Ultra High Vacuum (UHV) sealing technology. This presentation focuses on the development and application of HELICOFLEX® TEXEAL®, a patented texturized technology integrated into metallic seals, designed to lower the required seating load and enhance UHV performance. By applying TEXEAL® technology to its HELICOFLEX® metal seals, Technetics has achieved a significant reduction in clamping load while maintaining superior sealing integrity, even under extreme conditions.The HELICOFLEX® TEXEAL® solution minimizes the contact area without reducing the seal track width, promoting optimal conformity to flange roughness. This approach eliminates the need for softer sealing materials by selecting materials with better thermomechanical properties. Comparative test data indicate that the texturized seal exhibits lower linear loads (lbs/inch) and improved sealing rates compared to non-texturized and traditional seals. Additional benefits include improved reusability, lower sensitivity to surface defects, and minimal requirement for flange redesign, resulting in increased equipment uptime and simplified assembly processes. These innovations render the HELICOFLEX® TEXEAL® ideal for applications in semiconductor manufacturing, accelerator and fusion research, and other areas that demand ultra-high vacuum stability and reliability.This discussion will detail design principles, test methodologies, and performance metrics associated with HELICOFLEX® TEXEAL®, while outlining manufacturing capabilities and real-world applications. The session aims to provide UHV professionals with novel insights into reducing hardware stresses and operational costs, thereby advancing the state-of-the-art in UHV sealing technologies—a critical component in today's increasingly demanding vacuum systems.

3:00pm **VT1-MoA-7 Space Simulator – Thermal-Vacuum Chambers**, ***Juan Pablo Romero,*** INOVOAL Corp, Argentina **INVITED**

Satellites and systems orbiting the Earth are affected by the extreme conditions of space, where vacuum and sudden thermal amplitude affect materials and hardware systems. To ensure their correct performance, in INOVOAL we are specialists in design and manufacturing Space Simulators, Thermal Vacuum Chamber systems for testing satellites and space components that validate the resistance and functionality of systems under controlled conditions prior to their launch. This equipment allows engineers to identify and correct potential failures, thus maximizing the lifespan and performance of space missions.

Vacuum System: The vacuum system includes Dry Mechanical Pump for the first stage and a turbo-molecular pump for the second stage. Optionally, the equipment is prepared to add a cryogenic pump as a third vacuum stage. Throughout the vacuum system and chamber sections, there are control points to sense the performance and allow the opening and closing of vacuum valves and the start of thermal sequences. Turbo and Cryogenic pumps are directly connected to the chamber through gate valves. Electrically operated right-angle valves are configured to control the approximate vacuum and the counter-vacuum of the turbo (and cryogenic) valves.

Mechanical Sub-System: Most of the SP vessels are based on a horizontal cylindrical design, with a cylinder central body and two semi-elliptical caps, one rear and one front as a door. The design is based on and verified according to ASME Sec. VIII Div. I standards.

Shroud: The Shroud is of the 304L stainless steel pillow plate type. The Shroud is divided into three sections: The main cylinder (located along the central axis of the Simulator's main vessel) and rear cover, the front cover or door, and the cold table.

INTERIOR SURFACE: The interior surface of the Shroud has an Emissivity higher than 0.9. It is internally painted with black polyurethane with thermal and optical characteristics suitable for thermo-vacuum tests. The painting is MAP PU1 or similar with equal or better characteristics. The paint is tested and certified to ensure that it does not out gas in high vacuum and thermal cycles.

EXTERIOR SURFACE: The external side of the Shroud is mirror polished with "Electropolish" or a similar process and has an emissivity rate lower than 0.15. Optional for the interior surface of the chamber: Shot peening with glass bead blasting.

3:30pm **VT1-MoA-9 Alternative Method for Large Vacuum Systems Bake-Out***, **Freek Molkenboer**, Han Veldhuis, Herman Bekman, Andrey Ushakov, Veronique De Rooij, Thom Oosterveen, Michael Dekker, Corne Rijnsent, Willem van Werkhoven, Dirk van Baarle,* TNO Science and Industry, the Netherlands

Thermal bake-out is a well-known and commonly used method for removing contaminants from the inner surface of a vacuum system. However, the economic and practical scalability of this method for very large systems or systems with a high thermal mass poses quite some challenges.

The Einstein Telescope will be the largest vacuum system on Earth and will require the removal of water and hydrocarbons after installation underground. The currently foreseen method is thermal bake-out using Joule heating of the beam tube. The beam-pipes have a diameter of 1 meter, and due to the layout of the Einstein Telescope, a total of 120 kilometers of beam-pipe is needed.

In a dedicated study, TNO will investigate the technical feasibility of using plasma techniques to remove water and hydrocarbons from the inner surface of the beam tube. For this study, a dedicated setup will be designed and built to assess whether plasma-assisted cleaning can achieve the low partial pressure specifications needed for the Einstein Telescope.

During the presentation, we will discuss the considerations and realization of the setup, as well as the first validation experiments.

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