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 National 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 SPARC Tokamak Status and Inter-Pulse Pumping Projections**, ***Matt Fillion,*** *Oliver Mulvany,* Commonwealth Fusion Systems; *Shaun Hughes, Ant Hollingsworth,* Commonwealth Fusion Systems, UK; *Chris Chrobak, Adam Kuang,* Commonwealth Fusion Systems

The SPARC tokamak is a compact, high-field, deuterium-tritium fueled magnetic confinement device, aimed at demonstrating net energy gain. The SPARC vacuum pumping systems (VACP) comprises three subsystems: the cryostat pumping system provides superconducting component vacuum insulation, the leak detection system provides interspace pumping of vulnerable double-walled vacuum components, and the torus pumping system integrates with the fueling system to enable plasma operations.

A significant portion of each VACP subsystem will be installed and commissioned this year as part of a major SPARC milestone. Concurrently, VACP development progresses to enable SPARC final assembly and integrated commissioning, culminating in the initial pump-down of SPARC and beginning of plasma operations.

This talk will provide an update on the SPARC vacuum pumping systems and associated challenges. Additionally, we will discuss vacuum performance on plasma operations in more detail.

2:30pm **VT1-MoA-5 ITER Roughing Pump System Within the Fuel Cycle**, ***Ainsley Hart***, *Jared Tippens, Lisa Batsch-Smith, David vanderVeen,* Oak Ridge National Laboratory **INVITED**

The ITER Project is an international collaboration consisting of the United States, European Union, China, Russia, South Korea, Japan, and India, with the goal of demonstrating the scientific and technological feasibility of fusion energy for peaceful purposes. The ITER machine is being constructed in Cadarache, France and is a large Tokamak device.

The Roughing Pump System (RPS) design is being completed by US ITER, the United States Domestic Agency, and is vital to the fuel cycle system. The fuel cycle system includes the Pellet Injection System, RPS, and the Tokamak Exhaust Processing (TEP) System. This presentation will cover the RPS only, and its role in the fuel cycle.

The RPS is vital for regeneration of the Torus Cryopumps (TCPs), as well as other functions outside of the fuel cycle. RPS is currently being designed using first-of-a-kind, all-metal roughing pump trains composed of scroll and roots pumps to manage the gas load between the TCPs and the TEP System. Originally, a bespoke cryogenic-based system was required for regeneration, but as vacuum pumping technology has advanced the commercially available pumps now provide the opportunity for the all-metal pump trains.

The TCPs evacuate large vacuum volumes in the ITER facility. They accumulate various gas species during operations, leading to the need for regeneration at varying levels of temperature. This gas volume will then be evacuated through the Torus Cryopump Regeneration System (TCRS) Cells, consisting of 1 roots pump and 5 scroll pumps, to the TEP System for processing. There are three TCRS cells, where a roots pump is backed by 3 scrolls in parallel, which is backed by two scroll pumps in series.

The RPS system's Eumeca scroll pumps are based on the tritium compatible Normatex scroll pumps that have been evaluated with protium and deuterium at the Karlsruhe Institute of Technology [1]. Recently, the Eumeca pumps have successfully completed protium and deuterium testing at the United Kingdom Atomic Energy Authority, leading to the proposed 3-1-1 scroll pump configuration backing the roots pump.

This presentation will highlight the role of RPS in ITER's fuel cycle, the results of the scroll pump characterization testing, and analysis of the TCP regeneration cycle from VacTran analysis.

[1]Berndt, U.,et. al (1991). Performance Characteristics of Large Scroll Pumps. *Fusion Engineering and Design, 18.* 73-77.https://doi.org/10.1016/0920-3796(91)90110-C

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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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