Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending September 2, 2017, are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery

The original PF1AL coil has been mounted on the new test stand in the Field Coil Power Conversion Building for upcoming power testing. For the PF1A test VPI log, individual bars have been wrapped. The layout for the new PF1A, B, and C is underway and variations of spiral windings are being explored. Coil instrumentation, split-core testing, and coil current scenarios are also being analyzed. In the PPPL coil shop the mold for the test VPI log has passed a high-vacuum leak check. External coil fabrication vendor evaluations are complete and recommendations have been submitted.

In-vessel metrology of the upper and lower outboard divertors has been completed, and the metrology of the center-stack casing and angle tiles is now in progress. The new bellows assemblies on the Neutral Beam #2 calorimeter have successfully passed vacuum leak checking, and the assembly of drive equipment and manifolds has started.

Research

Francesca Poli has been nominated by the ITER Director General to become an ITER Scientist Fellow within the Integrated Tokamak Modeling program. She will be working with the Science and Operation Department (SCOD) on modeling ITER plasmas for the ITER Research Plan and on the exploitation of TRANSP within IMAS (the ITER Modeling and Analysis Suite) for scenario development at ITER. Part of the collaboration involves coupling the TRANSP core transport with a reduced model for the edge plasma transport, which is being developed at the ITER Organization.

A paper entitled "Liquid lithium loop system to solve challenging technology issues for fusion power plant" by M. Ono et al. was published in Nucl. Fusion 57 (2017) 116056 [https://doi.org/10.1088/1741-4326/aa7f41]. Calculations suggest that radiation-based liquid lithium divertor concepts with a modest lithium-loop of ~1 liter/s could provide a possible solution for high divertor heat flux and long term dust accumulation issues, while potentially improving reactor plasma performance. Two key technology issues were examined: (1) dust or solid particle removal and (2) real time recovery of tritium from liquid lithium while keeping the tritium inventory level to an acceptable level.

Devon Battaglia has completed a ten-week visit to the Culham Centre for Fusion Energy (CCFE) in the UK to assist in the development of startup and ramp-up scenarios for initial operations on MAST-U. For this work, Devon configured the LRDFIT code to operate on the CCFE computer system. He worked with the MAST-U team to build the

device description for MAST and MAST-U including a 2D description of the conducting structures and the position of the coils and magnetic diagnostics. The code was used to examine the vacuum field structure in a subset of discharges that used direct induction on MAST and perform predictive calculations for MAST-U. Devon provided a User's Guide and hands-on training to the MAST-U team on using and developing LRDFIT. The calculations for MAST and MAST-U provide a direct comparison to similar calculations for NSTX and NSTX-U, allowing for the shared development and optimization of the ramp-up scenario on the two ST devices.

U.S. ITER FABRICATION (H. NEILSON)

Steady State Electrical Network (J. Dellas)

Uninterruptible power supply (UPS): The factory acceptance test for the third of four UPS units, held 16-18 August, was successful with only minor punch list items noted. Verification of punch list completion for a previously tested unit was also confirmed.

Diagnostics (R. Feder)

Low field side reflectometer (LFSR): A series of three reports by PPPL's partners in the LFSR project documents the physics basis for the project. The most recent of these was a report from General Atomics (GA) on testing of a full-length transmission line with frequency-modulated transceivers. An earlier report, "High Frequency Instrument Acceptance Test," documents results of a high frequency solid state device development program resulting from a long relationship with Virginia Diodes, Inc. of Charlottesville, VA. The third report, "Recommended Configuration for the ITER LFSR Front-End Antennas," by GA, ties together the engineering, port integration, and physics of the LFSR project. The completion of these reports is an important step in the maturation of the LFSR design.

ADVANCED PROJECTS (H. NEILSON)

STELLARATORS (D. Gates)

PPPL scientists are playing key roles as the second phase of Wendelstein 7-X physics operation (OP1.2a) gets under way. Recent experiments by S. Lazerson were performed to better understand and correct error fields in the device. These experiments employed the U.S.-supplied trim coil system and a diagnostic technique, unique to stellarators, called flux surface mapping. They were performed with a specially designed magnetic configuration that is sensitive to m=1/n=1 error fields, where m and n are poloidal and toroidal mode numbers, respectively. Such error fields, if uncorrected, could change the

island divertor structure and ultimately limit plasma performance in W7-X. In the experiments, the trim coils were used to apply an error field in a controlled manner while the flux surface measurements allowed scientists to take pictures of the magnetic field structure. By changing the applied error field in a systematic manner, Lazerson was able to perform a compass scan, in which the phase of the applied error field is rotated toroidally. The underlying intrinsic error field could then be inferred from the obtained measurements.

The Laboratory has joined a collaboration to develop the conceptual design of a continuous pellet fueling system for Wendelstein 7-X. A kickoff meeting of the project team, attended by staff from the Max Planck Institute for Plasma Physics, the Oak Ridge National Laboratory (ORNL), and PPPL, was held recently. The collaboration, whose ultimate goal is to investigate the physics and technology of continuous pellet fueling for stellarators, also includes Japan's National Institute for Fusion Science. At the kickoff meeting, it was decided to base the conceptual design on pellet fueling technology developed by ORNL including a screw-type frozen hydrogen extruder and a repeating pneumatic injector. It was agreed that PPPL's H. Neilson will serve as project manager, consistent with the Laboratory's role as U.S. technical coordinator for the W7-X collaboration.

SYSTEM STUDIES (C. Kessel)

At a recent project meeting of the national Fusion Energy Systems Studies team, members of PPPL staff presented work in support of the liquid metal plasma facing component (PFC) study. The study is currently focusing on concepts embodying a liquid plasma facing surface in a fusion reactor. M. Hvasta presented his findings on liquid metal impurities, corrosion processes and modeling, whole liquid metal loops effects, solubility data for metals in liquid metals, status of purification schemes. A. Khodak presented his progress in using ANSYS/CFX for computational fluid dynamics simulation of liquid metal flows (both in-duct and free-surface), and verification of these simulations with benchmark cases in the literature and from experiments. M. Jaworski presented information about the capillary porous concepts for the divertor and first wall as part of a discussion session on the concepts for these applications. D. Majeski and E. Kolemen also made presentations on concepts to contribute to the characterization of these proposals. Other presentations included nuclear analysis of liquid metal PFC/blanket breeder combinations, solid materials issues, temperature constraints for the liquid metal PFCs, divertor analysis of the lithium vapor box concept, transient loading to liquid metals, tritium processing, tritium/liquid metal modeling progress, and liquid metal simulations of first wall flowing concepts.

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THEORY (A. BHATTACHARJEE)

A special issue of *Physics of Plasma* containing invited papers presented at *"Gyrokinetic Particle Simulation: A symposium in honor of Wei-li Lee"*, held at Uni. California, Irvine (July 18-22,2016) has been published online: (http://aip.scitation.org/doi/10.1063/1.5000231). The issue has 9 papers, including W.W. Lee & R. B. White's paper "Equilibrium potential well due to finite Larmor radius effects at the tokamak edge," Phys. Plasma **24**, 081204 (2017). A link to this paper can be found on the Theory Department webpage, http://theory.pppl.gov/news/seminars.php?scid=4&n=publications.

The paper "Pedestal and edge electrostatic turbulence characteristics from an XGC1 gyrokinetic simulation" by R.M. Churchill, C.S. Chang *et al*., was published Plasma Phys. Control. Fusion **59**, 105014 (2017), A link to the paper can be found on the Theory Department webpage, http://theory.pppl.gov/news/seminars.php?scid=4&n=publications.

On Wednesday August 29, Caoxiang Zhu (University of Science and Technology of China, Hefei) presented a special theory seminar on a new coil design code FOCUS for designing stellarator coils without the winding surface. The abstract and presentation are available on the Theory Department webpage, http://theory.pppl.gov/news/seminars.php?scid=1&n=research-seminars.

On Thursday August 30, Liang Wang (University of New Hampshire) presented a Theory Seminar on the role of electron physics in 3D, two-fluid, 10-moment simulations of the Ganymede's magnetosphere. The abstract and presentation are available on the Theory Department webpage, http://theory.pppl.gov/news/seminars.php?scid=1&n=research-seminars.

ENGINEERING & INFRASTRUCTURE (V. RICCARDO)

Power Engineering:
Processing of the XST-1 transformer oil was completed this week. XST-1 is critical to NSTX-U operations as it provides the 13.8kV primary power for D-Site experimental operations. This maintenance activity was driven by measured soluble water levels within the transformer oil that, left unattended, could degrade the winding insulation to failure. The transformer's 6,000 gallons of oil was processed on-site to remove soluble water by heat and vacuum, and to remove oil oxidation contaminants by filtering through fuller's earth clay. Oxidation inhibitors were also added as part of the processing.

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DIRECTOR'S OFFICE (R. HAWRYLUK)

August 29-30, M. Zarnstorff attended the ARPA-E ALPHA Program Review in San Francisco, California.

This report is also available on the following web site:

http://www.pppl.gov/publication-type/weekly-highlights