Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending October 10, 2020, are as follows:

NSTX-U RECOVERY (J. GALAYDA) AND RESEARCH (S. KAYE)

Recovery (J. Galayda):

Management — DOE has chosen a date for the next project review: March 9-11, 2021. The review charge is not yet final; however, the overall objective is clear: to review the overall project status and assess progress against the baseline plan. Adequacy of the total project cost (TPC) will be evaluated in light of project cost-to-go and remaining risks.

Coils — All six production coils (PF1B#1, PF1C#1, PFC#2, PF1A#1, PF1A#2, and PF1B#2) are at PPPL. The sixth coil arrived the week of Oct. 8. Three coils passed low-power electrical tests on site and the remaining three coils underwent tests as well. In France at Sigmaphi, coil PF1C-S (spare) was demolded and underwent electrical testing. Coils PF1A-S and PF1B-S were prepped for brazing.

Center Stack Casing (CSC) — The CSC was in Camden, New Jersey, for the final six weeks of finish machining. Additionally, welding of the organ pipes occurred at Turtle Creek, along with welding of the mockup bellows to the flange. Post-machining vacuum testing of the production bellows was completed and the bellows were shipped to Turtle Creek for installation.

IVPS — IVPS parts were cleaned in the vacuum prep lab and leak testing was completed. Installation was started and will continue for approximately four weeks.

Machine Core Structure (MCS) — Many fabrication activities continued at the three facilities currently making sling parts. Precision Boring in Michigan continued fabrication of the PF1A and PF1B capture and common flanges. The lower PF1C capping flange arrived at PPPL and the upper PF1C capping flange was in final documentation review prior to shipping. In South Carolina, Carolina Fabricators continued production of PF1A sling parts. Hanger parts were shipped on Oct. 8. Also, G. J. Oliver added components to the machined PF1C supports and will ship the supports out for coating in the near term; delivery of the lower PF1C support is scheduled for early October. The on-site mockup activities continued as preload was applied to slings and the engineers and techs fine-tuned the application of the preload. PF1B lower slings were welded together, with PF1A lower slings to follow.

PFC Inboard Divertor Horizontal (IBDH) Tile Support Frame Modification Peer Review — A peer review (PR) was held Oct. 1 to review additional segmentation proposed to ensure that design modifications would meet the flatness requirements for the Inboard Divertor Horizontal (IBDH) Heat Transfer Plate (HTP). During the in-house fabrication of the IBDH tile frame prototype, it was found that flatness of the subscale metal frame prototyped in a 15-degree segment was not maintained after machining. This IBDH tile support frame is in direct contact with the diverter HTP, so it is important that the design meet the flatness requirements set forth during the final design review.

Passive Plate Helium Tube Bracket Mounting Plate Modification Peer Review — A peer review was held Oct. 2 to evaluate necessary modification of the helium tube bracket mounting plate for the tube so it would pass through without interference in the lower Bay G & Bay H installation. The review also included the NCR and revised calculation report required to qualify and document the new mounting plate.

Recovery Cooling Water System Startup Scope Final Design Review — A final design review (FDR) was held Oct. 6 to review changes to the recovery cooling water system that will satisfy design verification and validation review (DVVR) recommendations, and to ensure all requirements are sufficiently met for the final design and completion of the cooling startup scope. Plans were presented during the FDR for modifications to the water system programmable logic controller in response to the latest SRD requirements. The cooling water system is a closed loop deionized water system used to cool experimental components of NSTX-U.

Research (S. Kaye):

C. Liu of PPPL gave a Monday Physics Meeting presentation entitled, “Study of energetic particle interaction with MHD using the M3D-C1 code.” The abstract of the talk is as follows:

“In NSTX-U, MHD activities including Alfvén eigenmode instabilities and kink instabilities can interact with energetic particles from beam injection, affecting the confinement and plasma stability. Studying nonlinear interactions between MHD activities and energetic particles using first-principle simulation is an important and challenging task. Recently, a new kinetic module of M3D-C1 code has been developed to address this issue. The code utilizes GPU to accelerate particles pushing. Both drift-kinetic and gyro-kinetic schemes for delta-f calculations and both pressure coupling and current coupling schemes for MHD-kinetic interaction have both been implemented. Several linear and nonlinear benchmarks have been conducted, and good agreements with other codes have been obtained. The code has been used to study the nonlinear frequency chirping of

Reversed Shear Alfvén Eigenmode (RSAE). It is found that during the frequency chirping, the mode will shift radially, and the two branches (upward and downward chirping) will separate in space. We plan to use this new code to simulate the instabilities in NSTX-U like Alfvén avalanche in the future."

ITER PROJECTS (H. NEILSON)

Equatorial Port Integration — EP03/09 (A. Basile):

The equatorial port integration team is working with tenant systems to negotiate space allocations among diagnostics and port structures, currently emphasizing the in-port structures and the closure plates. A current focus is the integration of the Charge Exchange Recombination Spectroscopy (CXRS) diagnostic, for which Russia is responsible, in EP03. A presentation by the CXRS team showed that the system requires mirrors and shutters in two of the three diagnostic shield modules (DSM) in EP03. The design requires large cutouts in the DSM structures and currently has localized space conflicts with the Motional Stark Effect diagnostic. The Laboratory's CAD team is exploring possible solutions.

Upper Wide Angle Viewing — UWAV (M. Smith):

The UWAV team is investigating options for adapting the in-port optics design to the Upper Port 17 DSM, whose design is unique among the five UWAV installations and therefore precludes having a common design for all locations. However, the team has identified and is exploring a solution that could minimize the differences.

Electron Cyclotron Emission — ECE (G. Paraiso):

In its shutter actuation development efforts, the ECE team is currently performing a baseline review of the 2017 pushrod mechanism for adapting it to the new DSM structure, identifying issues and modeling design modification concepts. The team is studying options for actuating the pushrod, starting with the 2017 pneumatic concept. Alternatives to the pushrod are also being explored. Finally, the team continues its design work on the supports for mounting the fixed mirrors to the DSM structural elements.

Low Field Side Reflectometer — LFSR (A. Zolfaghari, S. Shirey):

Manufacturing development efforts are proceeding on several fronts, including welding trials and investigations into welding and gun drilling inspection methods. Material specifications are under critical review, in preparation for ordering long lead materials including ITER grades of stainless steel and copper chrome zirconium alloys. These two

refined materials were developed specifically for ITER. Under the newly authorized manufacturing program, partner General Atomics will be procuring the necessary material to manufacture in-vessel LFSR components so that upon reaching manufacturing readiness approval, the manufacturing can begin immediately.

ITER & TOKAMAKS (R. NAZIKIAN)

A new paper by E.-H. Kim, et al. titled, "Helicon wave coupling optimization and possible parasitic excitation of slow waves near the edge plasma of KSTAR" was published in *AIP Conference Proceedings*: https://doi.org/10.1063/5.0013978. The research presented one-dimensional wave simulations to examine the excitation and propagation of helicon and slow-wave modes. The authors show that the excitation from the antenna and subsequent propagation to the core plasma of the helicon and slow modes are strongly affected by the angle between normal antenna current and static magnetic field, which is used for optimizing plasma conditions for helicon wave coupling to the plasma core in KSTAR.

DIII-D (B. Grierson):

Research:

A review article titled, "Turbulence dynamics during the pedestal evolution between edge localized modes in magnetic fusion devices" by A. Diallo and F. Laggner has been accepted for publication in *Plasma Physics and Controlled Fusion*: https://doi.org/10.1088/1361-6587/abbf85. The paper reviews the experimentally observed signatures of instabilities during the pedestal parameter evolution made in between edge localized modes in multiple tokamaks. A key emphasis made in the review is that potential future research avenues will require multiscale-nonlinear-gyrokinetic analyses to study the nonlinear interaction between these instabilities, and which pedestal conditions facilitate such nonlinear interactions, as well as the relationship with the formation of the pedestal through transport.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

D. Gates gave a talk to members of the Flatiron Institute and the Simons Institute entitled, "Stellarator Simplification with Permanent Magnets" on Sept. 30. The main purpose of the meeting was to inform the attendees of the status of a new project (of the same name) at PPPL that is about to begin. In addition to technical content, the long-range vision and plans for stellarator research in the U.S. was discussed.

A (virtual) kickoff meeting for a new project entitled, “Stellarator Simplification with Permanent Magnets” was held on Oct. 7. The project, which is jointly funded by the Advanced Research Projects Administration-Energy (ARPA-E) and Fusion Energy Sciences (FES) aims to demonstrate the construction techniques required to build a prototype permanent magnet assembly that is capable of generating the complex 3D magnetic shaping fields for a quasi-axisymmetric stellarator. The meeting was attended by staff from PPPL, from the private industry partner on the project (SABR Industries), and members of a team from Ansys. The Ansys group was in attendance as part of a parallel project to develop virtual engineering capabilities at PPPL. The topic of the meeting was the methods and use of the FAMUS code for designing permanent magnet distributions with a talk given by C. Zhu. Several additional tutorial-style meetings are planned for the coming weeks so that the team has a common knowledge base.

THEORY (S. HUDSON)

The Final Report detailing the successful completion of the FES 2020 Theory Milestone “Modeling of Fully 3D Vertical Displacement Event Disruptions” was submitted to the Office of Fusion Energy Sciences on Sept. 30. The final report, as well as three quarterly reports, can be found here: https://m3dc1.pppl.gov/2020TheoryMilestone.html.

A paper by A. Khrabry, et.al. entitled, “Analytical model of low and high ablation regimes in carbon arcs” has been published in the *Journal of Applied Physics* :https://doi.org/10.1063/5.0016110. The paper presents an accurate analytical model explaining nonlinear behavior of ablation rate of a graphite electrode in carbon arcs. The paper was chosen to be promoted as an editor's pick.

C. Liu published a paper in *Physics of Plasmas* titled, “Structure and overstability of resistive modes with runaway electrons:” https://aip.scitation.org/doi/pdf/10.1063/5.0018559

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted three press releases to the PPPL website. One reported on the students attending PPPL’s third annual graduate summer school virtually to get a broad overview of the field of plasma physics. Another noted that PPPL physicist E. Belova has been elected a 2020 Fellow of the American Physical Society. The third reported that PPPL physicist E. Gilson won third place at the Princeton University Keller Center’s 15th Annual Innovation Forum for his invention with a team of PPPL

researchers of an advanced liquid centrifuge. All stories were also posted to the *Newswise* and *EurekAlert* press release distribution services.

L. Bernard participated remotely in the U.S. Department of Energy Office of Science Communications and Public Affairs monthly meeting on Oct. 8. Office of Science Director C. Fall was the featured speaker.

DIRECTOR'S OFFICE (S. COWLEY)

M. Zarnstorff, J. Menard, and S. Cowley participated in a virtual public forum on a regulatory framework for fusion on Oct. 6. The forum was co-facilitated by the U.S. Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), and the Fusion Industry Association. The purpose of the forum was to begin a dialogue on a regulatory framework for any type of fusion energy reactor system supported by either the public sector or private sector with domestic and international regulating bodies.

M. Zarnstorff, J. Menard, and S. Cowley participated in a virtual meeting on Oct. 7 hosted by the National Academies Fusion Pilot Plant Panel titled, "Key Goals and Innovations Needed for a U.S. Fusion Pilot Plant." S. Cowley presented in a panel discussion about national laboratories and fusion pilot plants.

J. Menard participated in a virtual meeting "InnovationXLab Quantum Information Science & Technology Summit" on Oct. 7 and S. Cowley and J. Menard participated in the same meeting on Oct. 8.

This report is also available on the following web site:

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