Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending May 16, 2020, are as follows:

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

Recovery (J. Galayda):

Center Stack Casing (CSC) — Machining for the center stack casing continued this week at the Holtec facility in Camden, New Jersey.

Coils — Sigmaphi has restarted coil manufacturing activities in France. The first of two PF1B coils has completed vacuum pressure impregnation (VPI), is now out of the mold, and inspection results have been positive. The first PF1A coil mold is undergoing vacuum testing in preparation for VPI. In addition, the first PF1C coil is in the oven and in the early stages of vacuum testing. PF1C coil brazing setup also began this week.

Machine Core Structures — Preload transfer pins and parts were prepared for shipping at Precision Boring in Michigan. In addition, many of the PF1B hanger and base sling parts were completed or were in process. Most of the materials for the PF1C capping flanges and the PF1A and B capping and common flanges were received at Precision Boring. In South Carolina, fabrication began for the PF1A sling parts at Carolina Fabricators. In New Jersey, PF1C supports were welded together at the G. J. Oliver fabrication facility.

Personnel Safety System (PSS) — The "Red Book" for the PSS conduit system installation was submitted to the Princeton Site Office (PSO) for review and comment this week. Weekly meetings with ABB, Inc., the subcontractor for the PSS breaker refurbishment, continued with discussions on a delivery schedule and a follow-up site visit for inspection.

Mirnov Sensor Winding Fixture Peer Review — A peer review (PR) was held on May 14 to review the winding fixture design for three types of mandrels for the Mirnov sensing coils for the PFC diagnostics. These mandrels are used to hold the Mirnov mandrel in place during the winding of the Mirnov coils. The mechanical design of the sensor mounting and sensor design itself were not in this PR scope, and were the subject of a successful final design review in March 2019.

Research (S. Kaye):

An NSTX-U Program Advisory Committee (PAC) meeting was held remotely on May 13 and 14. The purpose of the meeting was to review and offer recommendations to modify the present draft of the NSTX-U Five Year Research Plan for 2021-2025, which will be formally reviewed by an external committee on June 9-11. Presentations of the

mission-oriented plan were given by S. Kaye, W. Guttenfelder, D. Battaglia, and R. Maingi. The meeting was quite successful: the PAC endorsed the main mission objectives, which position NSTX-U to contribute significantly to the development of fusion energy, and offered very much appreciated insights and recommendations on how to improve both the written plan and presentations to make the objectives and their context clearer for the formal review panel.

S. Kaye participated in the CCFE Program Advisory Committee on May 12. The CCFE PAC lasted for three days (May 12-14), but it overlapped with the NSTX-U PAC meeting on May 13-14.

U.S. ITER FABRICATION (H. NEILSON)

The ITER Electron Cyclotron Emission diagnostic is a broadband microwave receiver system that is being designed to measure the electron temperature profile. The diagnostic team, now resuming its work on this system, has reestablished ownership of the CAD model and is reviewing the current status. Work is proceeding on the layout of components, including waveguides, reflectors, *in-situ* calibration sources, and shutters, and on identifying the key design challenges. Since in-vessel components will be supported from the enclosing diagnostic shield module (DSM) structure, the design is sensitive to increased temperatures and thermal deformation of the structure under nuclear heat loads. Shutters are required in order to switch between operating states for measurement and calibration, and options for actuation mechanisms that can operate in either the presence or absence of the background toroidal magnetic field are being examined. Heating by stray microwave radiation from the ITER electron cyclotron heating (ECH) system is an issue for some ITER diagnostics; the implications for ECE are being investigated.

The Low Field Side Reflectometer (LFSR) team continues to deliver documents and drawings in preparation for a final design review (FDR) of the system's in-vessel antenna assembly. Detailed reviews of the design compliance matrix, key design analysis calculation (DAC) reports, and a structural integrity report are a current focus of the work. Based on careful assessment by the team and key stakeholders of the project's readiness for the FDR, a two-week postponement, to June 24-26, was recommended.

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ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

The paper, "Simulation of the eigenmode spectrum below the toroidicity-induced Alfvén eigenmode gap generated by the coupling of Alfvén and slow-magnetosonic waves in tokamaks," by G. Kramer was accepted for publication in *Plasma Physics and Controlled Fusion* and available online at https://doi.org/10.1088/1361-6587/ab9153. In the paper, the discrete Alfvén eigenmode spectrum below the TAE frequency is studied for hybrid and sawtooth scenarios in tokamaks whereby the full coupling between the Alfvén and slow magnetosonic waves are taken into account.

R. Shousha (E. Kolemen Plasma Control Group, Princeton University) conducted a new set of experiments on DIII-D testing the improved Relay Feedback 3D MHD Spectroscopy setup. When the plasma is close to MHD instabilities, its response to 3D perturbations applied to the plasma by the Relay Feedback setup is amplified. This phenomenon can be used to track the stability margin in real-time. Building on previous experiments at DIII-D (by E. Kolemen, F. Laggner, and R. Shousha), the setup has been improved to minimize the vacuum response contribution to the sensor measurement by choosing a specific sensor in combination with a specific 3D perturbation field (n=1, 180 deg). The improved setup was optimized during the first two days of the experiments with a focus on stability tracking during the pulse by repeatedly re-estimating the so-called transfer function. The final day was used to deploy the optimized set-up in shots that go from low power L-mode to high power H-mode. This sudden increase in plasma pressure was reflected in the data obtained during the experiments and further analysis to validate our concept is ongoing.

R. Conlin, a graduate student working in the Kolemen group, performed further testing and validation of the real-time MHD plasma stability analysis using DCON/STRIDE achieving calculation times between 250-300 ms over dozens of discharges during the recent DIII-D startup. Parallelized calculations run on the 72 core "RTstab" CPU system, recently installed by the Kolemen group as part of the DIII-D control system. After profiling the code on the real-time computers, improvements are underway to reduce this calculation time further, making it more useful for real time control, with the eventual goal to use the code for instability prediction and prevention later this year.

International PMI and FES LM PFC Development Program (R. Maingi):

A paper titled, "Results from a new flowing liquid Li limiter with TZM substrate during high-confinement plasmas in the EAST device," by G. Zuo, C. Li, R. Maingi, X. Meng, Z. Sun, *et al*., was published in *Physics of Plasmas*: https://aip.scitation.org/doi/10.1063/1.5143179 This paper presents technical results from the solid molybdenum flowing-liquid-lithium limiter experiment conducted on EAST and reported at the 2019 APS conference in an invited talk.

A periodic meeting of the liquid metal PFC development program was conducted on May 15. S. Smolenstev (UCLA) summarized recent calculations and the group discussed near-term directions for the R&D.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

A manuscript entitled, "Topology optimization of permanent magnets for stellarators," was submitted to *Nuclear Fusion* (also available at https://arxiv.org/abs/2005.05504). The authors are C. Zhu, K. Hammond, T. Brown, D. Gates, M. Zarnstorff, K. Corrigan, M. Sibilia, and E. Feibush. This work is closely related to the new ARPA-E Award for a permanent magnet stellarator. In the manuscript, a topology optimization method to design permanent magnets for advanced stellarators is introduced. Three different permanent magnet designs together with planar TF coils for a half-Tesla NCSX configuration have been obtained for demonstrations. The designs have good accuracy in generating the desired equilibrium and offer considerably large plasma access on the outboard side. The results show that the new method is a flexible, advanced numerical tool for future permanent magnet stellarator designs.

At this week's national Fusion Energy Systems Studies (FESS) meeting, Y. Zhai and P. Titus reported progress in the Laboratory's study of the potential of high-temperature superconductors (HTS) for fusion machines. Zhai provided updated information on the status of commercially available HTS conductors and cable designs, including their achieved performance and other characteristics. For purposes of the study, ReBCO cabled conductor was chosen for tokamak toroidal field (TF) coils. A range of cable and winding pack design options was examined to elucidate the tradeoffs. Titus reported on winding pack structural studies, with a focus on the compressive stresses on various HTS conductor types in the TF coils in a high-field variant of the 4.8 m Fusion Nuclear Science Facility (FNSF) design developed by the FESS team a few years ago. The meeting was chaired by FESS team leader C. Kessel (ORNL).

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DIRECTOR'S OFFICE (S. COWLEY)

Laboratory leadership has been communicating ongoing updates to staff regarding the COVID-19 virus and PPPL.

On May 14, a virtual seminar with Director General B. Bigot of the ITER organization was hosted by Princeton University's Andlinger Center for Energy and the Environment. S. Cowley and E. Kolemen participated as panelists.

On May 15, S. Cowley participated in the weekly National Laboratory Director's Council COVID-19 Coordination conference call.

On May 15, J. Menard participated in the monthly National Laboratory Chief Research Officer (NLCRO) conference call and weekly National Virtual Biotechnology Laboratory (NVBL) working group call.

This report is also available on the following web site:

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