Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending October 20, 2018, are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery:

Center Stack Casing — A preliminary design review (PDR) for the center stack casing (CSC) was held on Oct. 16. The PDR reviewed key design modifications to the CSC and how they will impact all related system interfaces. The CSC provides structural support to the inner poloidal field (PF) coils and plasma-facing components (PFCs). It also interfaces with various vessel structures and components and a number of recovery work breakdown structures and systems.

Magnets — The updated Magnet Work Approval Form (WAF) with the Basis of Estimate (BOE) is complete and under review. An order was placed this week for improved glass tape. The electrical equipment for Corona testing on the ETI PF1A prototype coil section was set up, and the final testing procedure is complete. Work continues on the vacuum system for the corona testing, and trial testing without vacuum began. Samples have been cut from the PPPL PF1A prototype, and the test fixtures are being prepared. The drawings and traveler for the change review board were signed off, and the water fitting prototype is being fabricated.

Management — R. Feder led a safety discussion roundtable with NSTX-U Recovery Project staff as a follow-up to the Oct. 9 all-hands meeting about the Los Alamos National Lab arc flash incident.

Test Cell — The system breakdown structure and categorization for the test cell scope was completed, signed off, and documented. The labyrinth structural design calculation is completed, signed off, and documented. The Basis of Estimate for the Test Cell Recovery Scopes has been prepared and submitted.

Research:

Collaboration Activities — W. Guttenfelder presented two lectures titled, “Intro to Magnetized Plasma Turbulence,” to a graduate class at the University of Tennessee at Knoxville. He also visited Oak Ridge National Laboratory for collaborative discussions on the FY19 Theory Performance Target.

The NSTX-U collaboration on the VEST spherical torus, from Seoul National University (SNU) in Korea, confirmed that the measured magnetic fields from their ubiquitous n=1 MHD could be explained only by multiple helical currents strongly coupled to each

other. The next step is to use resistive DCON and calculate magnetic fields due to a rotating linear 2/1 mode. PPPL will continue to build the interface between the VEST data and MHD codes for more extensive collaboration in the future. The SNU fusion plasma lab has also continued the collaboration with PPPL on tokamak 3D field experiments.

S. Yang, a Ph.D. student from SNU, ran GPEC and MARS-K codes with Z. Wang to study the magnetic rotation acceleration phenomena observed in KSTAR. The conclusion of the study is that the amplified kinetic-resistive response can induce strong electron NTV in the collisional edge region and thus increase radial electric field and toroidal rotation.

U.S. ITER FABRICATION (H. NEILSON)

The Low Field Side Reflectometer (LFSR) design team submitted the last of 110 required deliverables for the preliminary design review (PDR) scheduled for Nov. 7-8 at the ITER site. This week's submissions included two structural integrity reports, for the in-vessel and ex-vessel equipment respectively. These documents report the results of structural and thermal analyses, in which the responses to multiple combinations of loads, such as nuclear heating, electromagnetic forces, and seismic acceleration, are calculated. In addition, memoranda documenting the resolution of the last two conceptual design review (CDR) chits were submitted. In all, 84 preliminary design documents and 26 chit resolutions have been delivered to the ITER organization, completing the required submissions several days ahead of the Oct. 24 deadline.

An innovative remote handling-compatible scheme for attachment of the LFSR antenna support block to the diagnostic shield module (DSM) inside the ITER equatorial port plug 11 was devised by PPPL engineer M. Duco. The new scheme will be reviewed with members of the equatorial port 11 design team during a visit to the ITER site the week of Oct. 22.

ITER & TOKAMAKS (R. NAZIKIAN)

KSTAR Control:

Fusion Flight Simulator (D. Boyer):

D. Boyer and X. Yuan continued development of the TCP/IP-based TRANSP-Simulink interface needed for the Fusion Flight Simulator, demonstrating communication of preprogrammed changes in beam-power waveforms from Simulink to TRANSP. The plasma response from predictive TRANSP were successfully communicated back to Simulink, a necessary step for closed loop control simulation. The next step will be to

close the loop by implementing a control algorithm in Simulink to adjust beam power commands based on the behavior of plasma normalized beta "measured" from TRANSP. This will provide an initial demonstration of one of the main use cases for the Flight Simulator, i.e., testing and tuning prototype control algorithms based on predictive TRANSP simulations.

KSTAR MSE (S. Scott):

Accurate calibration of the MSE system on KSTAR is essential for obtaining precise information on the current profile in KSTAR experiments. Calibration is performed by injecting neutral beams into a gas-filled torus. In the latest calibration performed on KSTAR by Steve Scott and the KSTAR team, it was found that secondary beam emission was complicating the calibration. To obtain an accurate MSE calibration in the presence of secondary beam emission, additional data will be needed at two or more values of the gas pressure. In order to verify that secondary emission was contributing to the first round of calibration measurements, a numerical model was developed to simulate its effects. The model predicted signal contamination by secondary beam emission on MSE channels in the middle of the diagnostic view, consistent with the calibration data. The modeling provides strong support for the need for additional calibration data. Efforts will be made to obtain the additional calibration data at different torus pressure during the 2018 experimental campaign.

Control (K. Erickson):

K. Erickson worked with S. Sabbagh to make progress on the real-time MHD monitoring system for KSTAR. The project requirements for passive real-time MHD monitoring has been communicated to the vendors chosen to build the signal buffer chassis. KSTAR engineering has given design approval. This job is expected to be completed in the first half of 2019.

International 3D and stability (J-K. Park):

T. Markovic, a Ph.D. student from the Czech Academy of Sciences and a member of the COMPASS research team, continued the collaboration with N. Logan and J.-K. Park on 3D field optimization for MHD stability control. Markovic utilized the GPEC package through the OMFIT interface to predict n=1 core and edge resonant coupling in response to a subset of non-axisymmetric coils in COMPASS. By increasing edge resonance while holding core resonance under the locking thresholds, similarly to work on KSTAR [J.-K. Park, Nat. Phys (2018)], the optimal coil set configurations for ELM

control was successfully identified for various q95 target plasmas. These optimal coil configurations will be tested in the coming months on COMPASS.

DIII-D Research (B. Grierson):

Scientific staff are preparing for two upcoming major meetings: the IAEA-FEC and APS-DPP. The PPPL-DIII-D collaboration activities will be featured in a wide range of invited talks and posters next week in Ahmedabad, India. A lead author talk by M. Podesta and poster presentations by B. Grierson, A. Diallo, D. Boyer, F. Laggner, M. Okabayashi, and R. Hager will be presented during the week.

R. Maingi visited DIII-D to discuss continuing R&D with the impurity powder and granule droppers. Discussions focused on DIII-D needs and opportunities, but connections to the international dropper programs were also made. An additional meeting organized by A. Bortolon was held with the multi-institutional group modeling the powder injection experiments for wall conditioning on DIII-D.

DIII-D Operations and Control:

Facility (A. Nagy):

PPPL is developing switches that can rapidly reverse the toroidal field on DIII-D in order to allow for experiments to use both toroidal field directions in a single run day. Work on the toroidal field reversing switch is progressing well with the position indicator micro-switches received onsite. Discussion on the optimal design for the switches is ongoing with a PDR and FDR expected before the end of the calendar year.

J. Hernandez has joined the PPPL collaboration as a technician and will contribute to the LTO activity assembling high-voltage transmission lines.

International PMI (R. Maingi):

E. Kolemen presented a seminar during the liquid metal PFC strategy seminar series titled, “Development of Fast Flowing Liquid Metal Concept For Fusion Reactor Divertor.” This seminar covered pros and cons of fast-flowing LM PFCs, the R&D needs for fast-flowing PFC designs for next-step devices, details of a design concept to test fast-flowing PFCs (the FLowing Liquid Metal Torus or FLIT), and recent results from the Liquid Metal eXperiment (LMX) at PPPL. The seminar was attended by 30 people onsite and online.

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ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

An article titled, "Error fields in the Wendelstein 7-X stellarator" by S. Lazerson has been accepted for publication in *Plasma Physics and Controlled Fusion*. This article details the use of the U.S.-supplied trim coil system on Wendelstein 7-X (W7-X) to measure and correct n=1 error fields. In this work, a compass scan technique is used to assess the phase and amplitude of the n=1 component of the error field. Flux surface measurements confirm the effectiveness of this technique in compensating error fields. Measurements of the temperature rise in the island divertor modules demonstrate the utility of the method and trim coils. This paper will be published in a special issue of *Plasma Physics and Controlled Fusion* dedicated to the 21st International Stellarator and Heliotron Workshop.

This week, PPPL received the first prototype fast-ion loss detectors being developed for W7-X. Manufactured by Reynard Corp., these detectors are similar in function to traditional thin-film-style detectors, but they have different internal structures. In traditional thin-film detectors, thin conducting films separated by large vacuum gaps discriminate particle energies based on which film a particle is captured in. Higher particle energies penetrate father into the detector layers. In these new prototype detectors, the large vacuum gaps are replaced by insulating material. This reduces the thickness of the detector to only a few millimeters (mostly attributed to the substrate thickness). This is made possible through an additive manufacturing process known as thin film vapor deposition, allowing sub-micron layer thickness control. The end goal is to allow instrumentation of wall tiles in W7-X with fast-ion loss detectors. The detectors received by PPPL will now undergo acceptance testing to verify manufacture and preparation for testing in a 150 keV tunable accelerator.

Lazerson presented an overview of initial results from neutral-beam injection (NBI) experiments performed on W7-X at the Wendelstein science meeting. These experiments explored plasmas supported solely by NBI heating, and demonstrated five seconds of continuous operation of the W7-X NBI system. These plasmas demonstrated a path to access high-density configurations with peaked density profiles. Once this scenario was established, tests of ECRH heating in the plasmas were conducted. These tests demonstrated that small amounts of ECRH could heat both ions and electrons. The increased temperatures were maintained during the 1000ms of ECRH injection. Additionally, impurity transport studies with the NIFS TESPEL system were conducted. These experiments were carried out during the OP1.2b contingency period as part of Lazerson's duties as the Scenario and Integration Task Force Leader.

The Laboratory conducted an internal cost and schedule review (Work Authorization Review) for its contributions to the W7-X Continuous Pellet Fueling System in the instrumentation and controls (I&C) area. Plant I&C Group leader G. Tchilinguirian presented a detailed breakdown of the tasks involved in developing the control hardware and software that PPPL will develop to integrate the pellet injector and its associated vacuum and cryogenic systems with the W7-X control infrastructure. Tchilinguirian described the estimates, their basis, and the applicable risk-based contingencies on a task-by-task basis. The review, which was conducted by members of PPPL's engineering and project management organizations, was judged successful and authorization to proceed with the work was approved.

THEORY (S. HUDSON)

V. Duarte published a paper titled, "Resonances between high energy particles and ideal magnetohydrodynamic modes in tokamaks," in *Physics of Plasmas*, online here: https://aip.scitation.org/doi/abs/10.1063/1.5046655

H. Qin presented a *Lunch with Hamilton* seminar on Sept. 12 at the Mathematical Sciences Research Institute, as part of the Program on Hamiltonian Systems, from topology to applications through analysis. The presentation is described in a recent paper titled, "A necessary and sufficient condition for the stability of linear Hamiltonian systems with periodic coefficients," online here: arXiv:1810.03971.

A paper entitled "Role of the Plasmoid Instability in Magnetohydrodynamic Turbulence," was recently published in *Physical Review Letters*. Authors include C. F. Dong, L. Wang, Y.-M. Huang, L. Comisso, and A. Bhattacharjee. The paper can be found here: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.121.165101

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. BERNARD)

The Office of Communications posted one press release to the PPPL website. It focused on research by graduate student E. Evans and physicist S. Cohen indicating that a process that occurs within field-reversed configuration fusion devices could remove ash and make the fusion reactions more efficient. The story was also posted to the *Newswise* press release distribution service.

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DIRECTOR'S OFFICE (S. COWLEY)

S. Cowley attended the National Laboratory Director's Council Diversity and Inclusion meeting in Chicago on Oct. 16-17.

S. Cowley attended the Mega Amp Spherical Tokamak (MAST) Upgrade re-opening at the Culham Centre for Fusion Energy, Oxfordshire, UK on Oct. 18.

This report is also available on the following web site:
http://www.pppl.gov/publication-type/weekly-highlights