PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending June 24, 2016 are as follows:

U.S. ITER FABRICATION (C. NEUMEYER):

Instructions were issued by the U.S. ITER project office concerning budget profiles and planning documents that are to be prepared for an upcoming Independent Project Review (IPR) and an Independent Cost Review (ICR), in support of DOE's objective to achieve approval of a CD2A/3A baseline by December. The team has been directed to submit draft documents (spending plan, schedule, revised WBS dictionary, revised cost estimates, and revised risk analysis, and revised procurement plan) by July 15. The plan is to subdivide the scope of the project into First Plasma, and Post-First Plasma elements. The First Plasma scope includes the R&D and design of all systems, and the fabrication of items required for First Plasma. The Post-First Plasma scope includes fabrication of all remaining components not included in the First Plasma scope.

Steady State Electric Network (SSEN):

Power Transformers: Lot #1 and Lot #2 oil-filled units (eight @ 35MVA and four @ 7MVA) are ready for shipment from the Schneider Electric factory near Istanbul, Turkey, on July 18. The release for shipping documentation package is in final review.

6.6kV Switchgear: The 48 cubicles in Lot #2 were shipped from the Schneider Electric factory in Manisa, Turkey on June 23. Factory Acceptance Testing (FAT) of the remaining 110 cubicles in Lot #3 and #4 was completed on June 17.

Diagnostics:

ITPA Diagnostics Working Group Meeting: This week R. Feder attended ITER Diagnostic and Port Plug Engineering meetings hosted by the Russian Federation Domestic Agency (RFDA) at the Budker Institute in Novosibirsk, Russia. The first meeting was for the International Tokamak Physics Activity (ITPA) Diagnostics Working Group. The ITPA provides a framework for internationally coordinated fusion research activities in support of the ITER project and the Diagnostics Working Group focuses on coordinating research and development activities that help solve challenging diagnostics issues. There were several sub-sessions including updates on Mirror Cleaning technology developments and efforts to characterize the expected high background reflected light levels inside ITER that will flood diagnostic signals. R. Feder, with the help of Dr. David Brower from UCLA, gave the U.S. ITER Diagnostics progress report, which was very well received. The second meeting was the gathering of the Port Integration Coordinating Team (PICT). The PICT was organized by ITER to ensure the Domestic Agencies

and IO Port Plug Engineering teams are working efficiently, have open communication and are focused on solving critical port plug engineering problems.

One reason the fourth meeting of PICT was held at the RFDA is that the Russian Equatorial Port 11 (EP11) is a First Plasma (FP) port plug. ITER recently proposed some new Diagnostic Shield Module (DSM) design guidelines that are targeted at helping the RFDA be ready in time for FP. The USDA has two of seven diagnostic systems, the Low Field Side Reflectometer (LFSR) and the Diagnostic Residual Gas Analyzer (DRGA), hosted by the RFDA in EP11. The U.S. is also delivering five Upper Port Wide Angle View Visible-IR Camera systems to ITER and two of these are hosted or integrated in to RFDA Upper Port Plugs. R. Feder had several private meetings with various RFDA engineers to help coordinate the integration of all these U.S. systems in to the RFDA ports. A few good ideas for improving this relationship were discussed as well as technical design issues. For example, the RFDA team is concerned about maintenance access to the EP11 diagnostic vacuum windows and suggested design features for portions of the LFSR diagnostic that will help open up access. The next ITPA Diagnostics and PICT meetings are at the IO in December.

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): A subcontract for the Design of Software and Detectors for the Upper Wide Angle View Visible-IR Camera Systems (UWAVs) was awarded this week to Bertin Technologies. This is the second subcontract in support of the UWAVs project and the final major subcontract that the U.S. ITER project has been trying to place for the diagnostic scope. General Atomics (GA) along with the Dutch company TNO have been working on the complex optical-mechanical design of the UWAVs system. The optical system transmits light to visible and infrared cameras that Bertin will be selecting. This raw high speed data is then sent to data acquisition and computing hardware that will use Bertin's software for image processing. The UWAVs system has a critical machine protection role on ITER. A key feature of the software is to rapidly recognize locations on the ITER divertor surfaces that are overheating and then feed this data back to machine control centers. Another important activity will be the selection and placement of visible and infrared cameras to minimize the impact of the high radiation environment. Bertin is also heavily involved in the European DA Equatorial Port Wide Angle View Visible-IR camera program. In working with Bertin, the U.S. DA will be able to achieve some economies of scale between the two high speed imaging systems.

NSTX-U (M. ONO):

A FY2016 NSTX-U plasma operations update: The department has completed 9.66 run weeks and 1016 plasma shots. The total operation target is 18 run weeks.

NSTX-U plasma operations resumed this past week after completing a prescribed set of combined field test shots and inspections as a final verification of the PF coil lead supports. Operations this week included experiments on plasma inner gap control, H-mode access and diverted shape control utilizing neutral beam injection, and error field correction utilizing the Resistive Wall Mode (RWM) coils driven by the Switching Power Amplifier (SPA) system. All six neutral beam ion sources were conditioned at an average 90kV. Protective relaying upgrades to the upstream switchgear of the RF sources has been completed, and all six RF sources are operational. Vacuum conditioning of the High Harmonic Fast Wave (HHFW) antennas has

resumed. Lithium evaporator (LITER) probes have been relocated such that the F2 and K2 probes are now mounted on the Fill Stand to undergo lithium testing/prep for filling, and the F1 and K1 probes are on the vessel for pre-operational testing. Arrangements are being made to vacuum bake the probes this weekend. Also this week, laser alignments of the Diagnostic Neutral Beam were performed, as well as a neon glow for diagnostic calibrations. Data was collected from the recently installed FISO outer leg bending strain gauges. Two sets of three legs were monitored. In each group a new leg and two old legs were selected. The stable signals yielded strains with magnitudes consistent with predictions. There were some erratic signals, which are being investigated by swapping connections to the signal conditioner. The strain gauge measurements are part of efforts to build confidence that the new and old outer legs are acceptable for increased toroidal field.

The morning of June 22 was dedicated to XMP-153 (control development for early H-mode access). The first task was to integrate inner gap control into the H-mode scenario. This control tool made progress in maintaining a diverted shape that is independent of the timing of the LH transition. Neutral beams were in great shape and provided routine injection with three beams at about 2MW each. Routine H-mode access was achieved, however an issue was identified in controlling drsep at the time of diverting, which is important for H-mode access.

Following these activities, shots were taken toward XMP-141 (early ramp-up error field correction, C. Myers). During this XMP, pre-programmed error field correction was turned on very early in the discharge (5-10 ms) at various phases and amplitudes. Interesting asymmetries in the core rotation and the density were observed, indicating that the required error field correction early in the discharge may differ from the required flattop error field correction as established by XP-1506. Additional discharges to explore this trend are planned.

June 23 was dedicated to continuing XMP-141 (early ramp-up error field correction, C. Myers). Three additional error field correction scans were conducted. First, the core rotation asymmetry observed on June 22 was reestablished, further supporting the hypothesis that the required ramp-up error field correction differs from the required flattop error field correction. Second, in order to investigate the possible role of the OH coil in producing the error fields, the core rotation asymmetry scan was repeated at a different OH pre-charge (8kA versus 20kA). A similar (but possibly weaker) asymmetry was observed in the core rotation during this second scan. Finally, a traditional ramping-current compass scan was conducted in the 8kA OH pre-charge scenario. This compass scan produced an inferred flattop error field that is very similar in amplitude and phase to the flattop error field determined by previous compass scans conducted in the 20kA scenario. This result indicates that the OH coil is not likely to be the source of the flattop error field, and that further experiments are required to identify the error field source.

About two hours was spent toward XMP-153 (improved control for H-mode access) on June 24. A few tasks were completed to establish a DN shape at the time of diverting. The issue appears to be associated with starting X-point control with finite current in the PF2 divertor coils. The cause of this behavior of the control system is under investigation, but a scenario was established where the discharge diverted into the requested DN shape.

An initial set of nine shots was then taken on June 24 for XMP-114, “CHERS analysis with modulated NBI.” A good set of data has been obtained for the first step of the XMP, requiring scenarios with one source modulated from NB line #1 and with combinations of two sources

from NB line #1 (one modulated and the other one steady ON). The next steps in the XMP requires more reliable operation of sources from NB line #2, including modulation.

J. Caughman and C. Lau from ORNL visited NSTX-U this week. They performed diagnostic tests on the microwave electronics for the SOL reflectometer. The system is ready to acquire raw data. They also participated in HHFW vacuum conditioning.

Work continues to prepare the MSE-LIF system for operation. Beam-into-gas calibrations of the diagnostic neutral beam were performed, and spectra were obtained and analyzed for the 10 planned sightlines. Doppler shift measurements estimated from the spectra were used to do interference filter selections for the detector assemblies, and optical assemblies for detectors were completed. Data acquisition hardware and a test APD were installed in the NSTX-U mezzanine. Testing and shakedown of software and hardware for the data acquisition is ongoing. The MSE-LIF laser system has also been successfully aligned through the diagnostic neutral beam acceleration grids and onto the beam dump.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

B. Grierson presented a live demonstration of data preparation, submission, and visualization for TRANSP analysis enabled by OMFIT. Colleagues from JET, ASDEX, and JAEA attended the demo that was broadcast live to the 2016 EUROfusion code camp in Prague on integrated modeling. The camp covered MSE-constrained EFIT, profile analysis, TRANSP, and kinetic (pressure and current constrained) equilibrium reconstruction. The OMFIT integrated modeling workflow also seamlessly transitions to model validation by using TGLF embedded into PTSOLVER. Discussions are ongoing for collaboration between OMFIT developers and JET for using OMFIT to manage TRANSP analysis.

L. Cui presented a talk at the DIII-D Pedestal/ELM meeting on transport modeling of RMP ELM suppressed plasmas in DIII-D. The analysis attempted to explain the long-term recovery of confinement in RMP plasmas on DIII-D and the implications for ITER. Cui used the OMFIT workflow to fit time dependent profiles, run TRANSP and predictive TGLF runs to compare to experiment. Results indicate that the confinement recovery following density pumpout is driven by the increase in the edge Ti and core transport stiffness. The increase in the edge Ti is understood qualitatively from the increase in the ion thermal heat flux due to the reduction in the plasma density.

The 210 Off Axis Neutral Beam (OANB) project, led by A. Nagy, continues to make progress on DIII-D. The OANB carriage design required for rotating the beam is progressing. A CDR is scheduled for next week. Modeling of the collimator and calorimeter are underway for thermal analysis. The requirements documents are being developed for the calorimeter with PPPL.

ADVANCED PROJECTS (H. NEILSON):

The Laboratory is conducting LDRD-funded studies building on recent stellarator physics and engineering advances. These new developments, together with opportunities available through collaboration with Wendelstein 7-X, could set the directions for a new U.S. stellarator initiative. One study is exploring the potential to significantly improve stellarator designs using theoretical methods pioneered by PPPL and Max Planck Institute for Plasma Physics (IPP) scientists for designing stellarator configurations to have significantly reduced turbulent transport, "turbulence optimization" for short. A new paper by IPP's P. Xanthopoulos, et al., Phys. Rev. X 6, 021033 (2016), discussing physical mechanisms of turbulence stabilization intrinsic to modern optimized stellarators, is the latest encouraging development in this area of research. In the current PPPL study, researchers have identified a family of previously developed quasi-symmetric plasma configurations, including both quasi-axisymmetric (QA) and quasi-helically symmetric (QH) configurations. The aim of the project is to determine the degree to which their turbulent transport metrics can be improved through turbulence optimization. As a precursor to that step, the candidate configurations have been analyzed and, in some cases, are being re-optimized for neoclassical and MHD stability metrics, using up-to-date versions of the physics analysis tools. The work has benefited from collaboration with Dr. W. A. Cooper, retired from the Swiss Federal Polytechnic Institute (EPFL) in Lausanne, the author of a key stability analysis code, TERPSICHORE.

As part of PPPL's collaboration with the Wendelstein 7-X (W7-X) project at Germany's Max Planck Institute for Plasma Physics (IPP), a joint project has been established with the aim of significantly improving remote collaboration capabilities for U.S. participants. A project team was formed and has begun meeting on a bi-weekly basis and are working toward implementing a set of improvements that were identified in an April 2016 workshop on this topic. In a recent meeting, IPP representatives announced a decision to adopt ZOOM, a convenient cloud-based remote meeting tool that is already widely used in the U.S. community, as a W7-X project standard. In addition, IPP has made progress toward defining modifications to their systems and protocols intended to facilitate access to W7-X data archives and reported status of a technical specification now being prepared.

THEORY (A. BHATTACHARJEE):

On June 23, B. Scott (Max-Planck-IPP, EURATOM Association) presented a theory seminar on the physics of tokamak flow relaxation to equilibrium: "The theorem for toroidal angular momentum conservation within gyrokinetic field theory is used as a starting point for consideration of flow equilibration at low frequencies (less than fast-Alfvén or gyrofrequencies). Quasineutrality and perpendicular MHD force balance are inputs to the theory and therefore never violated. However, the gyrocenter densities are not ambipolar in equilibrium, since the flow vorticity is given by their difference. From an arbitrary initial state, flows evolve acoustically and via Landau damping into divergence balance, in which radial force balance of the electric field is a part. On collisional time scales, which in the tokamak core are longer, the neoclassical electric field is brought into balance by collisions, and it is only on these slow time scales that the collisional transport is ambipolar (i.e., the time derivative of the vorticity is small). Computations from 2014 showing the relaxation on tokamak core spatial scales are displayed. I will also give relevant cases of edge-layer relaxation and discuss the dependence on the finite

poloidal gyroradius. Total-f two-species gyrokinetic relaxation cases from 2009/10 are available to show that the basic processes in fluid and gyrokinetic models are the same for these purposes."

On June 24, M. Yamada gave Theory Department Research Review Seminar entitled, "Is there a fundamental principle for energy partitioning in a proto-typical reconnection layer." The abstract reads: "Recently, a quantitative inventory of magnetic energy conversion during magnetic reconnection was carried out in the MRX reconnection layer with a well-defined boundary. This study concluded that about half the inflowing magnetic energy is converted to particle energy, 2/3 of which is ultimately transferred to ions and 1/3 to electrons. This observation was found to be consistent with numerical simulation results based on VPIC codes. It was also found that features of energy conversion and partitioning do not strongly depend on the size of the analysis region over the tested range of scales. So a question arises, whether there is a fundamental principle in the energy partitioning in a proto-typical reconnection layer. This talk describes my physics understanding of the energy conversion processes in the magnetic reconnection layer of two-fluid physics regime and leads to a general quantitative evaluation of energy partitioning."

ENVIRONMENT, SAFETY, & HEALTH (J. LEVINE):

Safety Division:

An all hands safety meeting was held on June 20 to hear Betsy Dunn, Director of Environment, Safety and Quality Assurance at Argonne National Laboratory, speak about a fatal accident that occurred last October at the Florida State University National High Magnetic Field Laboratory. Ms. Dunn led the team that investigated the accident, which has broad implications for work here and elsewhere. In the weeks following this all hands meeting, PPPL workgroups are holding small group safety meetings to talk about how something similar could happen here and what we can do to avoid it.

Environmental Services Division (ESD):

NJDEP Division of Water Quality representatives conducted a routine compliance inspection for PPPL's New Jersey Pollution Discharge Elimination System (NJPDES) Surface Water Discharge Permit covering the detention basin outfall and canal pumphouse filter backwash. A recent exceedance of the permit limit for Chlorine Produced Oxidants (CPO) was discussed. No other issues were found.

DIRECTOR'S OFFICE (C. AUSTIN):

On June 24, Professor Hojong Kim, Pennsylvania State University, presented a colloquium entitled, "Liquid Metal Batteries for Large-Scale Energy Storage."

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