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PPPL News

The Princeton Plasma Physics Laboratory is a United States Department of Energy Facility

TFTR Reaches Historic Milestone

Team Plans for Final Run on the Tokamak Fusion Test Reactor

The TFTR Outage Team

By Anthony DeMeo

In August, 1996, the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory (PPPL) completed its longest and most exciting run period, embodying the world's first extensive series of deuterium-tritium (D-T) magnetic fusion experiments. Since November, 1993, nearly 20,000 plasma pulses have been logged, including shots that produced record-breaking levels of fusion power, with advances in other key plasma parameters as well. "It is unprecedented that a tokamak has been operated so successfully, for such a long period of time, without a major outage," said Richard Hawryluk, Head of PPPL's Tokamak Confinement Systems Department.

The TFTR outage completed in December was also unique. It was the first time that work was performed inside the vacuum vessel following the extensive use of tritium. Substantial amounts of the radioisotope remained in the vessel at the end of the run, so work had to be carefully planned with all the necessary precautions. Before the vessel ports were opened, tritium was removed by a combination of techniques including bakeout, pulse discharge cleaning, and glow discharge cleaning. The gas was then processed by the tritium cleanup system and trapped in special containers.

"Preparations for this outage worked extremely well. We were able to keep tritium concentrations very low, enabling us to open ports and make major modifications to internal hardware. This was a major technical challenge, entailing close coordination and cooperation among a whole host of organizations within the Laboratory," noted Hawryluk.

One of the major accomplishments during the outage was the replacement of three major radio frequency (RF) launchers. These are radio antennas which introduce RF

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TFTR

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waves into the plasma. The waves heat the plasma directly, or drive plasma currents that help confine the plasma. One of the older vertical antennas was replaced with a new one which runs horizontally to produce the so-called Ion Bernstein waves, studied extensively on the Princeton Beta Experiment-Modification (PBX-M) project by PPPL physicists Masayuki Ono and Ben LeBlanc, but never on TFTR. The other two vertical launchers were upgraded to improve the efficiency of RF current drive.

Promising Physics

The key objective of magnetic confinement is to prevent particles and energy from being transported out of the plasma. During TFTR's last run period, TFTR physicists were able to create powerful transport barriers using the enhanced reversed shear (ERS) mode of operation. ERS involves the use of a novel magnetic field configuration which dramatically reduces plasma turbulence, resulting in a three-fold increase in the central plasma density and the reduction of particle leakage by a factor of fifty. So far ERS has been successful in taming instabilities in only part of the plasma for a limited range of conditions. During the ERS experiments, physicists noted that the barriers created steep pressure gradients, i.e., regions in the plasma where the pressure changes rapidly with position.

"We have been looking for a way to control the location and magnitude of these pressure gradients," said Hawryluk. "We believe that Ion Bernstein waves can do that for us, therefore we plan to repeat the PBX-M experiments on TFTR with hotter, more powerful plasmas. The Ion Bernstein experiments will be challenging, but if this technique works, it will have major ramifications for the design and operation of fusion power reactors," he continued.

The Ion Bernstein wave experiments will be the highest priority for the run period. Initially these studies will be conducted with deuterium plasmas to allow greater flexibility with a large number of plasma shots. If successful, the waves will be launched into high-power D-T plasmas later in the run period.

Plans for the run period were developed in early December by means of a series of "run assessments" meetings in which TFTR staff discussed the upcoming run. Since then, staff conditioned the neutral beams and the RF systems, and otherwise prepared the machine for the exciting work that began after the holidays. ●

Princeton University and DOE Sign Five-year Contract for the Operation of PPPL

Officials from Princeton University and the U.S. Department of Energy (DOE) recently signed a newly negotiated performance-based, five-year contract for the management and operation of PPPL.

The Thursday, December 19, contract signing ceremony took place at Princeton University's Nassau Hall. Cherri Langenfeld, manager of the DOE's Chicago Operations Office, signed on behalf of the DOE and University Provost Jeremiah Ostriker signed for Princeton University.

The agreement took effect on December 30, 1996, and will extend through September 30, 2001.

The new contract is a product of the DOE's Contract Reform Initiative and includes several characteristics that distinguish it from the management and operating contract that it replaces. Among the more significant distinguishing features are objective performance-based metrics against which the Laboratory's performance will be measured and increased liability of Princeton University for unallowable expenses. The initiative is expected to improve efficiency and reduce costs for both the DOE and the University.

"Princeton University has been actively involved with the Department of Energy in implementing the Department's Contract Reform Initiative," said Allen J. Sinisgalli, Associate Provost for Research and Project Administration for the University. "I believe the signing of this contract attests to the success of those efforts, and we look forward to continued cooperation between the University and the Department of Energy."

Added Ronald C. Davidson, who was Director of the Lab at the time of the signing, "I would like to thank the members of the negotiating teams for their extraordinary efforts during the past several months and the imaginative solutions that they brought to bear on some very challenging issues. We can now devote our energy to being the nation's preeminent center for excellence in fusion science."

From left are: (front row) DOE Chicago Operations Office Manager Cherri Langenfeld and Princeton University Provost Jeremiah Ostriker; (back row) Milton Johnson, Deputy Associate Director of the DOE's Office of Fusion Energy Sciences, former PPPL Director Ronald C. Davidson, Princeton University Professor of Physics William Happer, who is also Chair of the Princeton University Research Board, PPPL Deputy Director Dale Meade, and PPPL Interim Director John Schmidt.

In addition to Princeton University, DOE officials signed contracts during the same week with Ames Laboratory at Iowa State University in Ames, Iowa, and with Fermi National Accelerator Laboratory near Chicago.

Langenfeld said, "In signing these three contracts, the DOE Chicago Operations Office becomes one of the department's first field organizations to successfully implement Contract Reform by placing all its major facilities under performance-based contracts. This will help us achieve our goal of reducing administrative costs in DOE and contractor organizations, leaving more resources available to fund research and development that delivers important technical and economic benefits to the nation." ●

Davidson Steps Down as Director

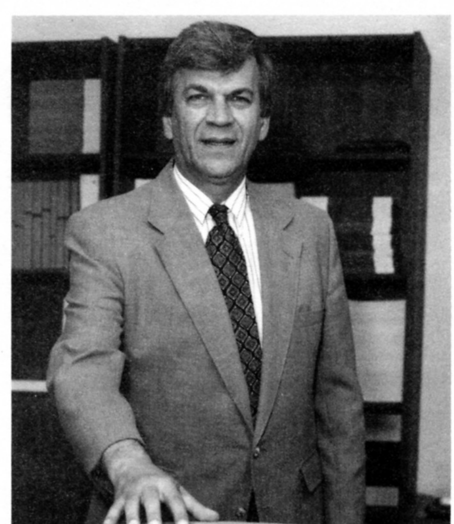
PPPL Director Ronald C. Davidson has stepped down as Director of the Laboratory. Davidson, a professor of astrophysical sciences at Princeton, returned to research and teaching on a full-time basis on January 1, 1997.

In a message to staff, Davidson said, "I feel very fortunate to have had the opportunity to lead PPPL through a period of unprecedented scientific productivity during the past six years, and I ask for your continued strong support and dedicated efforts."

Princeton University President Harold Shapiro lauded Davidson for providing "exceptional leadership" for PPPL and for the national fusion effort. "We are very grateful to him for his outstanding service as Director of the Lab, and we are delighted that he will be remaining as a member of the Princeton faculty," said Shapiro in a press release.

Davidson, who came to the Lab in 1991 as PPPL's fourth director, said his decision is a consequence of a strong personal desire to return to research and teaching on a full-time basis.

University officials are in the middle of a search for a new director. ●



Ronald C. Davidson

Schmidt Named Interim Director

John Schmidt, Head of PPPL's Advanced Projects Department, became the Interim Director of the Laboratory on January 1.

Schmidt succeeds Ronald C. Davidson, who had served as Director of PPPL since 1991. Davidson has returned to research and teaching on a full-time basis. Schmidt's appointment will last until a permanent director can be found. Princeton University Provost Jeremiah Ostriker, a professor of astrophysical sciences, and Professor of Physics William Happer, Chair of the University Research Board, are leading the search process.

John Schmidt

A member of the PPPL staff for 27 years, Schmidt has led efforts to design tokamaks that would carry future research on magnetic fusion. As Head of Advanced Projects, he has been responsible for several projects, including the construction of the National Spherical Torus Experiment; consultation with Korean scientists on a new tokamak that would use superconductivity and apply advanced techniques for confining and handling fusion plasmas; and PPPL involvement in the engineering design of the International Thermonuclear Experimental Reactor.

Schmidt joined PPPL after earning his Ph.D. in physics from the University of Wisconsin in 1969. He worked variously as a researcher and project manager before 1977, when he became head of a group to provide physics input to the design for TFTR, which began operations in 1983.

Schmidt served as Head of the Applied Physics Division at PPPL from 1980 to 1988, then led three successive efforts to design a machine to succeed TFTR, including the Compact Ignition Tokamak, the Burning Plasma Experiment, and the Tokamak Physics Experiment. Because of funding constraints, none of these machines were built. Schmidt became Head of Advanced Projects in 1996.

"We are delighted that John Schmidt has assumed the leadership of PPPL at this critical moment in its history," said Ostriker. "John is universally respected as a person and as a scientist. He and the Laboratory will have the complete support of Princeton University as they go forward into the post-TFTR era." •

NSTX Project is On The Boards

By Patti Wieser

In another two years, a new toroidal device will start operations at PPPL. Construction of the National Spherical Torus Experiment (NSTX) — a national fusion science project to be sited at PPPL — is expected to begin this year.

The new experiment is designed to reach mega-amp-level plasma currents and investigate the physics of spherically shaped toroidal plasmas. Such plasmas (also known as "low-aspect-ratio plasmas") resemble spheres with holes through their centers, which are different from the donut shape of tokamak plasmas. The spherical torus (ST) configuration is expected to have several physics advantages, a major example being the ability to confine high plasma pressure for a given magnetic field. Since the amount of fusion power produced is proportional to the square of the plasma pressure, this alternate concept could play an important role in the development of smaller and more economical fusion reactors.

Former Laboratory Director Ronald C. Davidson said, "The NSTX is a highly innovative experiment that will advance our understanding of plasma science and provide an important focus for experimental research here at PPPL. My congratulations to our collaborators and the entire NSTX team."

The program planning efforts for NSTX are moving ahead following DOE approval to begin construction in fiscal year 1997, said Martin Peng, NSTX Program Director.

"We are holding an NSTX Research Forum February 5-7 at PPPL and engaging NSTX working groups to

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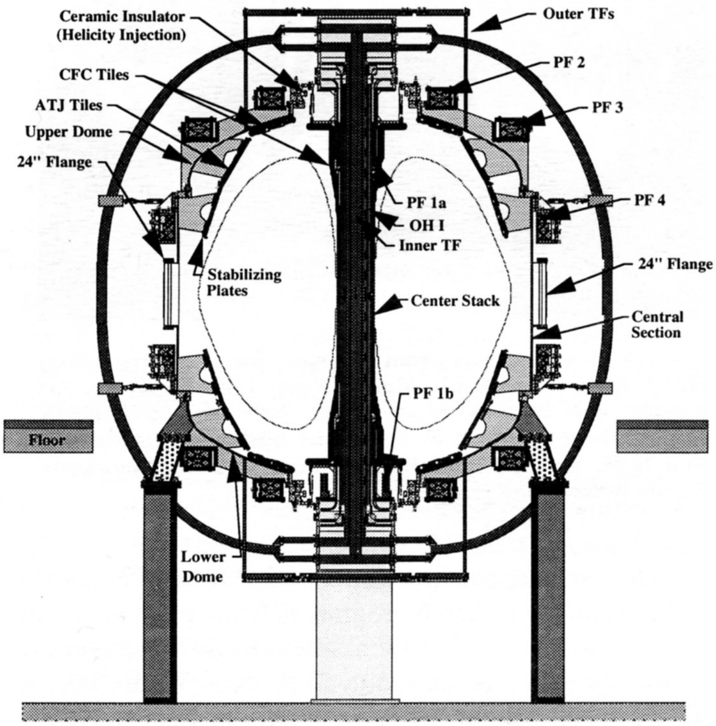

Artist's rendition of the NSTX.

discuss and clarify the scientific elements of the NSTX research program," said Peng, who is on assignment at PPPL from the Oak Ridge National Laboratory (ORNL).

National Collaboration

The design and construction of the NSTX Project is a national collaboration among several institutions, including PPPL, ORNL, Columbia University, and the University of Washington at Seattle. PPPL has primary responsibility for the Project. ORNL, which will lead the power and particle handling activities, already contributes in several key physics design activities. The University of Washington will lead the physics design of the co-axial helicity injection, an important test on NSTX to find out if the ST devices can be freed from relying on inductive startup. Columbia University will contribute in the area of plasma stabilization at high pressures.

The Program Director said the Engineering, Cost and Schedule Review Committee (ECSR), headed by Professor Bruce Montgomery of the Massachusetts Institute of Technology, recently endorsed the NSTX Project and provided a number of constructive suggestions.

Incorporating many of the ECSR recommendations, the detail of the center stack design is being finalized and its final design review is scheduled for late February. Plans are also in place to complete the final designs of the vacuum vessel, plasma facing components and the high harmonic fast wave antenna this fiscal year.

Peng said the NSTX device will be able to use many of the existing facilities and equipment at PPPL. "NSTX will have a tremendous potential for delivering powerful high performance plasmas utilizing the facilities at PPPL," he said.

"The NSTX is a highly innovative experiment that will advance our understanding of plasma science and provide an important focus for experimental research here at PPPL."

—Ronald Davidson

Analysis indicates that the ST configuration could permit small, cost-effective devices for fusion research and development. Offered Peng, "For example, the present center stack in NSTX will give us the ability to produce plasmas of high currents for aspect ratios as low as 1.25, an important capability for investigating the ST plasma properties. NSTX, with an upgraded center stack and additional auxiliary drive power, could allow us to produce plasmas comparable in pressure to TFTR and the Joint European Torus. Initial tests on NSTX will provide

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The NSTX physics team, from left, includes, Wonho Choe, Neil Pomphrey, Henry Kugel, Bob Kaita, Jon Menard, Dick Majeski, Steve Jardin, Stanley Kaye, NSTX Program Director Martin Peng, and NSTX Project Director Masa Ono.

NSTX

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the data needed for us to take this next step." Aspect ratio is the ratio of the major radius of a plasma to its minor radius.

Broad Vision

Project Director Masayuki Ono said, "We are particularly fortunate to have Martin Peng with us on NSTX. Martin's background as the originator of the modern-day-ST concept and his broad vision for the ST future make him uniquely qualified to direct the NSTX Program."

The recently formed NSTX Program Advisory Committee, made up of senior fusion researchers in the U.S. and the European Community, will regularly review and advise the PPPL Director on the direction of the NSTX Research Program.

The evaluation of NSTX began in 1993, when the project was called the Princeton Spherical Tokamak Experiment. National ST workshops in 1994 at Oak Ridge and in 1995 at PPPL provided important forums for formulating the scientific mission and design concept for the NSTX. During the same period, ST experiments complementary in research mission and device design to the NSTX were also successfully developed. Most notable are the GLOBUS-M in Russia and the MAST in the United Kingdom, which recently began construction.

The NSTX engineering team includes, from left, (standing) NSTX Program Director Martin Peng, John Robinson, Art Brooks, Bob Parsells, Mike Kalish, Judy Malsbury, NSTX Project Director Masa Ono, Dwight Bashore, John Citrolo, and H.M. Fan; (seated) John Spitzer, Charles Neumeyer, Randy Wilson, and Jerry Levine.

Design and construction of NSTX will cost $20 million and the research program is being planned for an annual budget of $25 million. The NSTX research effort is anticipated to be at about 50 percent of the present TFTR level. About 40 percent of the annual NSTX research budget will be devoted to facility operation, which will be a PPPL responsibility. The remaining 60 percent of the budget will be devoted to scientific research activities.

Two-thirds from PPPL

Two-thirds of the research team will be from PPPL while the remaining one-third will be from the collaborating institutions. "Instrumentation control and diagnostics data acquisition can be made accessible through the Internet," commented Peng.

NSTX's first plasma is scheduled for April, 1999. "We will have a national research team ready to begin the experiments," said Peng. ●

The management team for NSTX includes, from left, (seated) PPPL Associate Director for Research Rob Goldston, NSTX Project Director Masa Ono, NSTX Program Director Martin Peng, and NSTX Physics Manager Stanley Kaye; (standing) PPPL Deputy Director Dale Meade, PPPL Interim Director John Schmidt, DOE's Greg Pitonak, NSTX Project Control Manager Tom Egebo, NSTX Engineering Manager Charles Neumeyer, and former PPPL Director Ronald C. Davidson.

For additional information on NSTX, see the August, 1996, Information Bulletin, which is available through PPPL Information Services.

PPPL Collaborates with Korea on Fusion Energy Research

Through a collaborative research agreement signed this summer, PPPL received $540,000 for the remainder of fiscal year 1996 from the Korea Basic Science Institute (KBSI) to assist in the planning and design for the Korean Superconducting Tokamak Advanced Research (KSTAR) facility to be constructed in Korea. The Lab expects to receive $3 million for the collaboration in fiscal year 1997.

"This collaboration combines the expertise of U.S. fusion researchers with Korea's quest for a world-class fusion research facility during the next decade," said Former PPPL Director Ronald C. Davidson.

Expanding Partnership

Officials from PPPL, Princeton University, and KBSI inked the pact in June, which falls under an umbrella agreement signed earlier by U.S. Secretary of Energy Hazel O'Leary and then Korean Minister of Science and Technology Dr. KunMo Chung. The umbrella agreement is for expanding a partnership in nuclear energy and fusion energy research between the U.S. Department of Energy and the Korean Ministry of Science and Technology.

Through the Princeton-KBSI collaboration, a team of Korean physicists and engineers from the KSTAR Project are at PPPL to work closely with a U.S. team comprised of scientists who formerly developed the design for the canceled Tokamak Physics Experiment (TPX) Project. The KSTAR is a research program for the construction and operation of a tokamak with superconducting magnets. It is presently being organized by the KBSI in Taejeon sciencetown as part of a plan to become the leader in fusion science and technology in Korea.

The TPX Project was designed to be a superconducting advanced tokamak and had characteristics similar to those envisioned for the KSTAR. The TPX was a national research project funded by the Department of Energy that was to be sited at PPPL with participants from many of the U.S. plasma physics research laboratories, universities, and industrial firms. It was canceled in 1995 due to a 32% cut in funding for magnetic fusion research in the United States.

Exchanges of Scientists

The U.S. team involved in the collaboration with Korea includes researchers from PPPL, the Lawrence Livermore National Laboratory and General Atomics Corporation in California, the Oak Ridge National Laboratory in Tennessee, the Massachusetts Institute of Technology, and Northrup Grumman. Collaborative research activities on plasma physics and fusion science between the national team at PPPL and KBSI include exchanges of

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Members of the former TPX team who will be working with Korean scientists on the KSTAR project are, from left (seated), James Sinnis and Wayne Reiersen and (standing) Robert Simmons and John Schmidt. Not pictured is G.H. Nielson.

Collaboration

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scientists and engineers, as well as of ideas and information. PPPL's contribution is to provide the physics and engineering expertise and design information that was developed as part of the TPX design activity.

In July, researchers from the Korean institute began working with the U.S. national team at PPPL. The Princeton activity complements design and research and development tasks being carried out as part of the project in Korea. Seven Korean researchers joined the team at PPPL by the end of 1996. The collaborating group is advancing the conceptual design of the Korean tokamak and is helping develop Korean expertise in tokamak design and technology. The U.S. team is based at PPPL under the direction of G.H. Nielson, Acting Advanced Projects Department Head. In 1997, the conceptual design phase of the project will begin. The collaboration should continue into operation of the KSTAR tokamak.

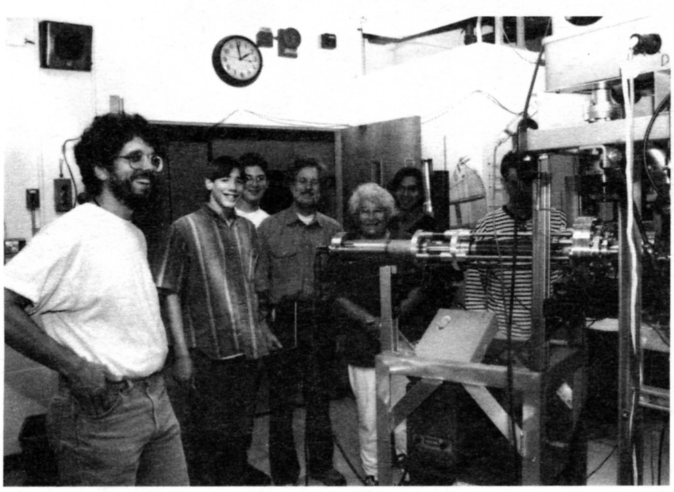
"This collaboration combines the expertise of U.S. fusion researchers with Korea's quest for a world-class fusion research facility."
—Ronald C. Davidson

Korea anticipates the KSTAR tokamak to produce its first plasma in 2002 specifically on August 15 of that year — to coincide with Korea's Independence Day and with the year that the World Cup Soccer Tournament, co-hosted by Korea and Japan, is to be held for the first time in Asia. •

PPPL Open House was a Smash!

Science, sunshine, and a chance to visit the world's most powerful fusion device — the Tokamak Fusion Test Reactor — attracted close to 2,000 people to the Open House at the PPPL on Saturday, October 26. The Laboratory's visitors, ranging from youngsters to seniors, walked around the record-setting TFTR, crawled into a portable planetarium, watched tabletop demonstrations in electromagnetism, thermodynamics, and common plasmas, and participated in hands-on science education activities.

Throughout the day, which coincided with the 250th Anniversary of Princeton University, visitors were able to talk to PPPL scientists about fusion and the Laboratory's accomplishments while taking self-guided tours of TFTR and smaller fusion machines. The event also featured activities and displays ranging from a flexible fuel vehicle powered by a new nonpetroleum motor fuel to tensile testing to a demonstration on music, sound, and resonance. Popular sites and features — in addition to the heavily visited TFTR — included a special lecture, "A Scientific Adventure: The Discovery of the Binary Pulsar," by 1993 Nobel Laureate and PPPL scientist Russell Hulse; the PPPL Fire Engine, where children could sit behind the wheel and try on firefighting protection gear; and the Star Lab, a portable planetarium in which visitors could observe nature's fusion engines. •



Matthew Goeckner (left) describes hyperthermal neutral beams and plasma processing to a group of visitors during the PPPL Open House on October 26.

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