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HOTLINE

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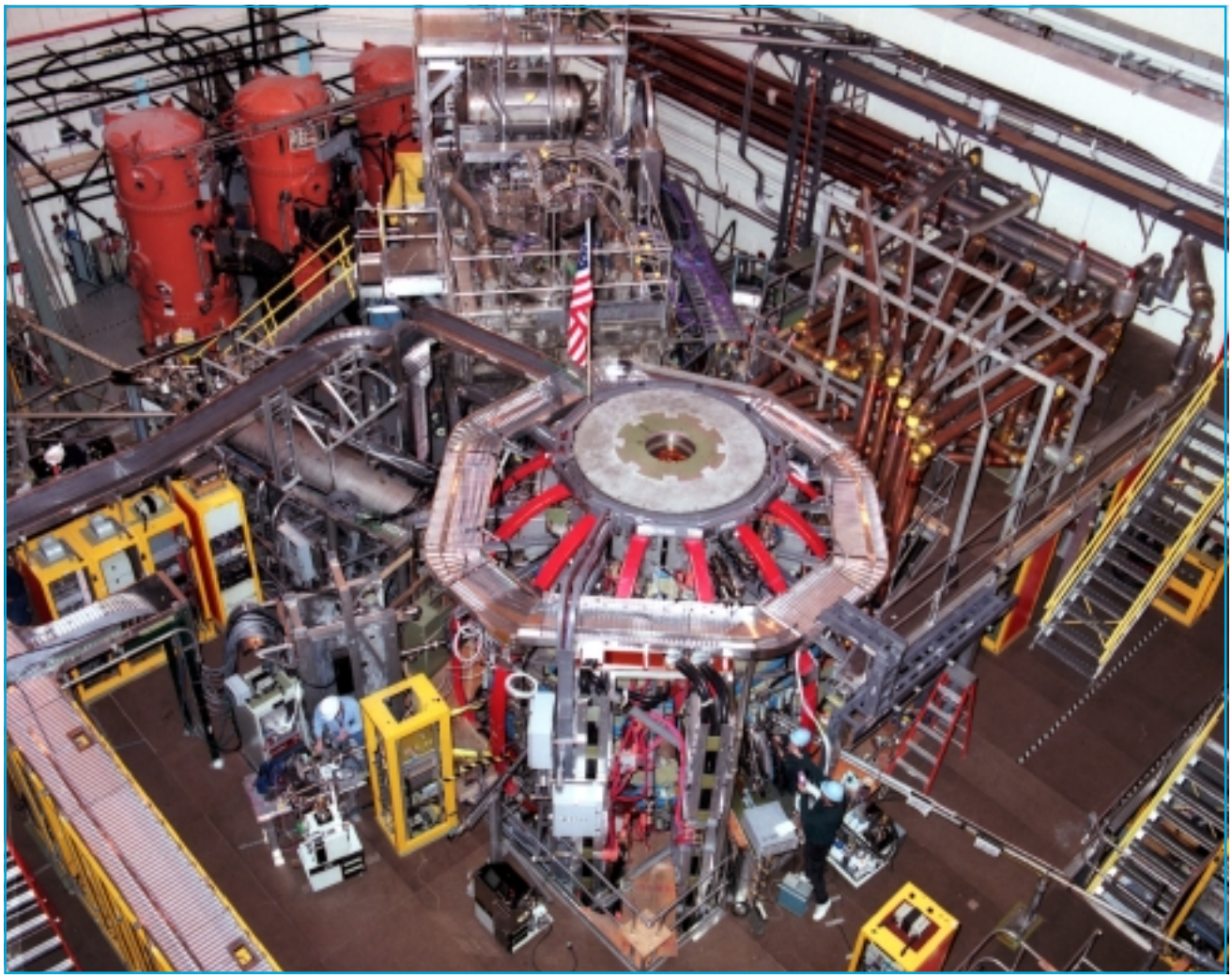
Scientists Encouraged by NSTX Results

High Beta with Good Confinement Reported



The National Spherical Torus Experiment

By Anthony De Meo

The use of neutral-beam injection heating on the National Spherical Torus Experiment (NSTX), coupled with good confinement, has allowed the NSTX National Research Team to produce a plasma toroidal beta of up to 22.5 percent. "Initial results are extremely encouraging. We hope to reach 25 percent during the next experimental campaign, more than one year ahead of schedule," noted NSTX Project Director Masa Ono.

Fusion power production is roughly proportional to the square of the plasma pressure. Toroidal beta is the ratio of plasma pressure to magnetic field pressure applied in

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NSTX

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the long direction of the spherical torus. A higher beta means that greater plasma pressure, thus substantially more fusion power output, is achieved with a given magnetic field strength. The cost of a fusion reactor will rise with the strength and size of the magnetic field coils. Consequently, higher betas in NSTX could lead to the development of smaller, more economical fusion reactors. The highest beta value produced by a tokamak stands at about 13 percent.

PPPL physicists, their colleagues from 13 other U.S. institutions comprising the NSTX team, and collaborators from Japan, Korea, and the United Kingdom, worked together on the recent experiments. The 22.5 percent beta was achieved with only three million watts of neutral-beam heating power. Five million watts of heating power will be applied during the next campaign to enable the physics studies at increased plasma pressures.

Quite surprisingly, the observed energy containment efficiency of the NSTX plasma improved by as much as a factor of two as neutral-beam heating was added to the resistive heating. This bodes well for the prospect that NSTX eventually will have adequate heating power to test the theoretically predicted toroidal beta values in the range of 40 percent. In the coming months, the NSTX National Research Team and the PPPL Theory Department will use results now emerging from NSTX to refine and expand models for high-beta spherical torus plasmas, enabling a better understanding of the plasma stability and confinement properties.

Ono attributes the recent success to the December 1999 achievement of one million amperes of plasma current, nine months ahead of schedule, which set the stage for the current experiments. He also noted that NSTX is building on previous results from machines such as PPPL's Tokamak Fusion Test Reactor and the DIII-D tokamak at General Atomics in San Diego. For example, the NSTX neutral-beam injection system, which became operational on September 13 within budget and ahead of schedule, draws heavily on TFTR design, hardware, and operating experience. The system cost $6 million and took two years to complete.

Using techniques developed on TFTR and other tokamaks, researchers have been able to minimize plasma impurities in NSTX, especially heavy metals, which absorb energy from the plasma and release it as ultraviolet light and X-rays. Such foreign matter enters the plasma when it interacts with walls of the vacuum vessel. To minimize this infiltration, large portions of the NSTX vacuum vessel walls and center column were covered with protective graphite tiles. Just prior to the neutral-beam experiments, the vacuum vessel and tiles were heated to 150˚C and the center stack to 300˚C to drive out water vapor. A helium glow discharge was used to reduce the influx of hydrogen bound up in the walls. The reduction of hydrogen helps make plasma operation more reliable and improves performance. A glow discharge is a tenuous plasma produced in the vacuum vessel using an electrode. The vacuum vessel wall being cleaned is biased negatively against the electrode. This causes the ions in the glow plasma to bombard and "scrub" the wall surface free of contaminants. Finally, all the walls and graphite tiles were coated with a thin layer of boron using trimethyl boron gas, which also helps keep heavy metals from entering the plasma.

Other Work Underway

While striving to understand the physics behind NSTX's excellent plasma confinement and high-beta performance, physicists are working on other fundamental goals. Among the most important of these are experiments relating to Coaxial Helicity Injection (CHI) and High Harmonic Fast Waves (HHFW). If successfully applied, CHI could lead eventually to the elimination of the central solenoid, resulting in smaller, more powerful fusion reactors. HHFW will heat plasma electrons to high temperatures and sustain plasma current needed for steady-state fusion reactors.

In a state-of-the-art spherical torus, the plasma current essential for start-up, heating, and confinement is induced by rapidly reversing the current in a solenoid running through the hole at the center of the vacuum vessel. This coil occupies space, which could be used more productively for additional toroidal windings, yielding a stronger toroidal magnetic field. For example, doubling the toroidal magnetic field could result in as

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Staff responsible for the installation of the third and final long-pulse ion source on the NSTX neutral beam are (from left) Paul Ernst, Len Halvorsen, Martin Wisowaty, Mark Cropper, Kris Gilton, and Ed Bush.

much as 16 times the fusion power output. CHI, a method of noninductive start-up, involves the establishment of voltage between the center column and the vacuum vessel outer wall. Electrical breakdown occurs propelling a plasma ring into the chamber resulting in the creation of a toroidal plasma. Separation of the plasma from the wall occurs by means of magnetic reconnection, a phenomenon under study in PPPL's Magnetic Reconnection Experiment, as well in NSTX. To date, NSTX researchers have been able to start up a plasma current of 0.26 million amperes. Their goal is 0.50 million amperes or more.

NSTX is the first device of its size to test the physics of HHFW. HHFW heats electrons and maintains plasma current using a plasma wave at many times the frequency with which ions gyrate around the magnetic field. Strong electron heating using HHFW was observed for the first time in recent NSTX experiments. Electron temperature was increased from about 4 million degrees to above 10 million degrees Centigrade using 2 megawatts of power. NSTX Program Director Martin Peng said, "It is encouraging to have achieved good electron heating and we look forward to exploring the new and rather intriguing properties of HHFW and learning how to utilize this method in spherical torus and other high-beta plasmas."

In the mid-1980s, experiments on TFTR verified the existence of the theoretically predicted bootstrap current, which can sustain itself when the plasma pressure is high. If NSTX experiments establish the effectiveness of CHI, it may be used in conjunction with bootstrap plasma current and HHFW to allow steady-state operation of a fusion power plant. NSTX researchers hope to determine if the bootstrap current will start automatically, or will require a small seed current of a few percent of the total. Bootstrap current may ultimately account for as much as 70 percent of the total plasma current flowing in NSTX.

The next NSTX experimental campaign is scheduled to begin in February. "With many intriguing experimental results coming out of NSTX, as well as new capabilities being implemented, clearly there are far more experiments we would like to conduct than the available machine time and resources will permit. Obviously we would like to explore and increase our understanding of the high-beta plasma regime. We must continue the development of key spherical torus reactor tools, such as CHI and HHFW. So we must choose carefully to come up with an optimized run plan," Ono said.

To help in this planning process, the NSTX project is hosting its annual Research Forum January 15-18. ●

PPPL's Sauthoff Becomes IEEE-USA President

PPPL's Ned Sauthoff became President of The Institute of Electrical and Electronics Engineers-United States of America (IEEE-USA) on January 1. He served the past year as President-elect of the organization.

Sauthoff, Head of PPPL's Off-site Research Department, began his career at the Lab after he earned a Ph.D. in astrophysics from Princeton University in 1975. He has headed numerous departments at PPPL, including the Physics Department from 1992-1994, and the Plasma Science and Technology Department from 1994-1997.

As President of IEEE-USA, Sauthoff is the highest-ranking volunteer member and will chair the organization's Board of Directors. He will also serve at the international level on the IEEE Executive Committee and Board of Directors. He succeeds Merrill Buckley of Springfield, Pennsylvania, and will work closely with Buckley and 2002 President-elect LeEarl Bryant of Richardson, Texas.

Sauthoff said he plans to work with IEEE-USA volunteers and staff to realize the great potential for electrotechnology and information technology to improve the quality of life.

Ned Sauthoff

Building Careers and Shaping Public Policy

"We will address that mission both by building careers and by shaping public policy," he said. "IEEE, as the leading technological professional society in the world, has a responsibility to serve by providing both authoritative perspectives to decision makers and professional development tools to our members. IEEE-USA provides those services to U.S. decision makers and to its more than 230,000 members. In 2001, we will provide improved tools to a greater number of our members and will enhance our public-policy grassroots outreach by engaging our geographically dispersed membership in all U.S. Congressional districts."

Sauthoff pointed out that in the area of building careers, IEEE-USA sponsors conferences and symposia; develops and disseminates career-development tools; argues for a strong U.S. engineering workforce through programs ranging from pre-college to continuing education, to permanent immigration; and supports pension portability for a mobile workforce. In the area of technology policy, IEEE-USA works for reliable restructuring of the electric supply industry; strong research and development through both industrial tax incentives and federal funding; fair intellectual property rights in today's economy; and privacy and reliability of the information infrastructure.

In 1998-1999, Sauthoff served as IEEE-USA Vice President of Technology Policy Activities. He began his work with IEEE-USA's Technology Policy Council (TPC) in 1988 and by 1997 had risen to TPC Vice Chair. He was presented the IEEE-USA Divisional Professional Leadership Award in 1996 in recognition of his accomplishments as Chair of the organization's Energy Policy Committee from 1994-1995.

Sauthoff received a bachelor's degree in physics in 1971 and a master's degree in nuclear engineering in 1972, both from the Massachusetts Institute of Technology. He has held his current position at PPPL since 1997.

IEEE-USA is an organizational unit of the IEEE created in 1973 to promote the careers and public-policy interests of the more than 230,000 electrical, electronics, computer, and software engineers who are U.S. members of the IEEE, the world's largest technical professional society. For more information, visit http://www.ieeeusa.org. ●

— Provided by IEEE-USA

PPPL Raises $26K for the 2000 United Way Campaign

PPPL employees continued their generosity toward the United Way in 2000, donating a total of $26,566 for the Lab's annual campaign. More than 32 percent of the PPPL's staff participated. A special thanks goes to all those who helped to make the 2000 Campaign such a success! ●

PPPL's 2001 Science-on-Saturday Series Kicks Off

From mechanical and real birds to twin-star systems, plasma rockets, the Hubble, and space travel, to contemporary medical diagnostic tools and genomics, this year's Science-on-Saturday series at PPPL promises a diverse array of scientific topics. The series kicked off its 17th year of operation on January 13 with a talk about the discovery of the binary pulsar by PPPL's Russell Hulse, who shared the 1993 Nobel Prize in Physics with Joseph Taylor.

"This year, we have a varied group of speakers discussing a broad range of scientific subjects. Many of the students who attend the talks have never been in contact with scientists before and this gives them an opportunity to see that scientists are real people. It also inspires some to consider careers in science," said PPPL engineer Ronald Hatcher. Hatcher is co-organizing the series this year, along with PPPL physicist Janardhan Manickam and PPPL Science Education Program administrator James Morgan.

Different Avenues to Explore

Added Morgan, "The series exposes students to a variety of scientific subjects, giving them different avenues to explore, possibly as potential careers. One regular attendee from the past is now a university student pursuing a career in science. As a high school student, she called the organizers to suggest topics for the series or to comment on those lectures she attended. She still keeps in touch, offering ideas for Science-on-Saturday talks."

Science on Saturday is a series of eight free lectures geared toward high school students, but open to everyone. The talks are given by scientists and other professionals who are leaders in their field. The annual wintertime series began nearly two decades ago at PPPL, and now attracts more than 300 people each Saturday.

Students, teachers, parents, and community members are welcome to attend any or all of the series. In the past, attendees have ranged in age from 8 to 80.

Manickam said, "This program has evolved from its narrow focus on high school students to become a valuable resource to people of all ages who wish to be exposed to the intellectual stimulation of new scientific ideas. I encourage all like-minded people to take advantage of this opportunity and attend these lectures."

All talks are scheduled in the MBG Auditorium at PPPL and begin at 9:30 A.M. Each lecture usually lasts about two hours. For more information, go to the PPPL web site at www.pppl.gov or call the Science-on-Saturday Hotline at (609) 243-2121.

The 2001 Science-on-Saturday schedule follows:

January 13 "The Discovery of The Binary Pulsar"
Dr. Russell Hulse
1993 Nobel Prize Winner in Physics
Princeton Plasma Physics Laboratory

January 20 "Plasma Rockets
for Future Space Missions"
Yevgeny Raitses
Princeton Plasma Physics Laboratory

January 27 SATs — No Program

February 3 "Fanciful Fliers — A Different
Approach to Small Aircraft Design"
David A. Cylinder
Plasma Science and Technology
Princeton Plasma Physics Laboratory

February 10 "Exploiting the Genomics Revolution
for the Discovery of New Medicines"
Dr. F. Raymond Salemme
3-D Pharmaceuticals, Exton, PA

February 17 "What's up with the Hubble"
Dr. Edward Groth, Physics Department
Princeton University

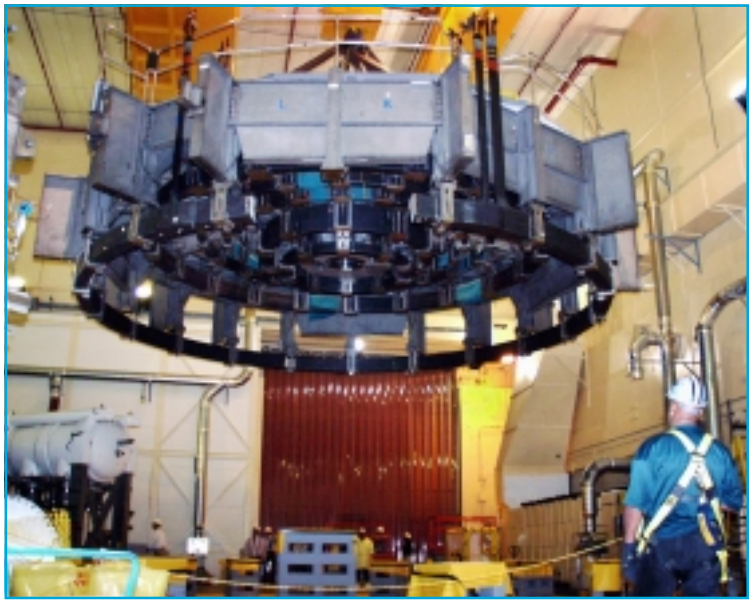
February 24 New Jersey Regional Science Bowl®
— No Program

March 3 "Biology and Conservation
of North American Songbirds"
Rachael Winfree
Department of Ecology
and Evolutionary Biology
Princeton University

March 10 "The Use of Echo-Cardiography
in Diagnosing Heart Disease"
Dr. Andrew Costin, Cardiologist,
Princeton Medical Group
Adjunct Faculty, Hospital of the
University of Pennsylvania

March 17 NASA Astronaut Talk —
Speaker and Title to be announced
Contact the Science-on-Saturday Hotline

2000: The Year in Pictures

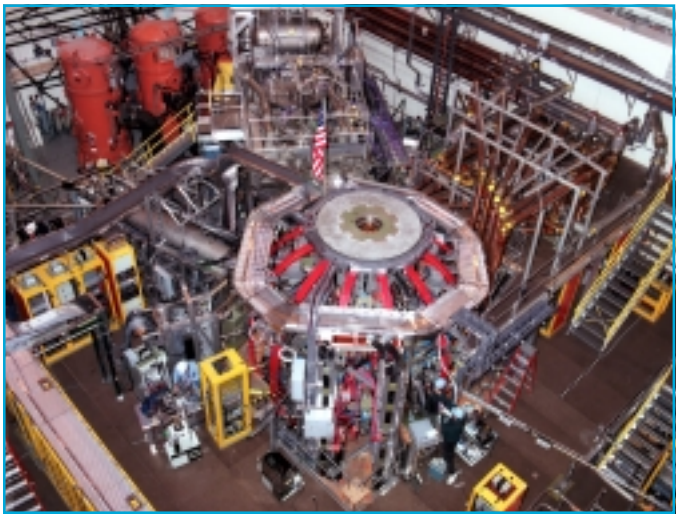


The disassembly of the Tokamak Fusion Test Reactor (TFTR) at PPPL progressed. On November 8, the umbrella structure and upper magnetic poloidal-field coils were lifted off the top of TFTR. Workers used the 110-ton capacity overhead bridge crane to make this 92-ton lift. Preparation for this critical lift began several months earlier. The structure and coils were removed as part of the disassembly of TFTR, which is expected to be completed by September, 2002.

PPPL's June 3 Open House was a smash, drawing about 2,400 people. The Lab's visitors, ranging from tots to seniors, walked around NSTX, toured the experimental areas, learned about the physics behind sports, crawled into a portable planetarium, and participated in safety activities, as well as tabletop demonstrations about electromagnetism, thermodynamics, and common plasmas. Above, PPPL's Marianne Tyrrell has a "hair raising" experience while trying out the Van de Graaff generator during the event's hands-on science demonstrations. The generator develops an electrostatic charge, making the hair of anyone who touches it stand on end. Behind Tyrrell is her husband, PPPL's Mike Viola (wearing white T-shirt), and at left is PPPL's Bob Simmons (in cap).

During the summer and fall, PPPL Director Rob Goldston and his wife, Ruth, hosted four staff picnics at their home. More than 200 employees enjoyed the soirees, which included dips in the pool, grilled hot dogs, refreshments, and plenty of conversation.

During the summer, Pamela Lucas was named Head of PPPL's Science Education Program. Lucas, who joined the Laboratory's Science Education staff six years ago, had been Acting Head for eight months prior to being named Head.



On October 25, U.S. Energy Secretary Bill Richardson (above) brought welcome news to PPPL, announcing a five-year extension of the contract between Princeton University and the U.S. Department of Energy for the operation of the Laboratory. Richardson made the announcement to a large assembly of PPPL personnel, media, and visitors at the MBG Auditorium. Above left, experiments continued on the National Spherical Torus Experiment (NSTX). By the end of 2000, a plasma toroidal beta of up to 22.5 percent was reached on the machine. At left, Al Planeta and his children Sarah, Brian, and Rachel tour NSTX during the Lab's "Take Our Daughters to Work Day" program on April 27. The Lab's Director's Advisory Committee on Women (DACW) hosted 28 children of employees for the day, which included a talk, "How Fusion Will Protect Our Natural Resources," by PPPL Director Rob Goldston; a tour; and mentoring sessions with staff members and parents.

Former PPPL Director Melvin B. Gottlieb, an international leader in the field of research on fusion energy, died on December 1 in Haverford, Pennsylvania, at the age of 83. Gottlieb, Director of PPPL from 1961-1980, was known for his tireless dedication to the fusion concept and for his constant inspiration to the fusion program worldwide, as well as for his leadership and for being the consummate "people person."

On November 2, PPPL Director Rob Goldston delivered his annual "State-of-the-Lab" address to staff in a packed MBG Auditorium. Goldston lauded the Lab's research accomplishments, as well as the goals and successes of our external relations efforts and operations, stressing that PPPL's programs were "off and flying." The talk was followed by an ice-cream reception in the Lobby.

PPPL'ers Rock at Holiday Bash

On December 22, the Laboratory held its annual Holiday Party for all staff in the LSB Lobby. Entertainment was provided by The Rhythm Kings. Clockwise from bottom left are: Larry Guttadora at the dessert buffet; Sonja Patterson at the raffle prize table; staffers in the chow line; from left, Wilbert Barlow, James Nah, and Sharlena Coles taking part in the festivities; the Rhythm Kings, with PPPL physicist Ed Synakowski playing trombone; from left, Joanne Savino, Rob Goldston, and Stephane Ethier enjoying the entertainment; and Marisol Rivas.