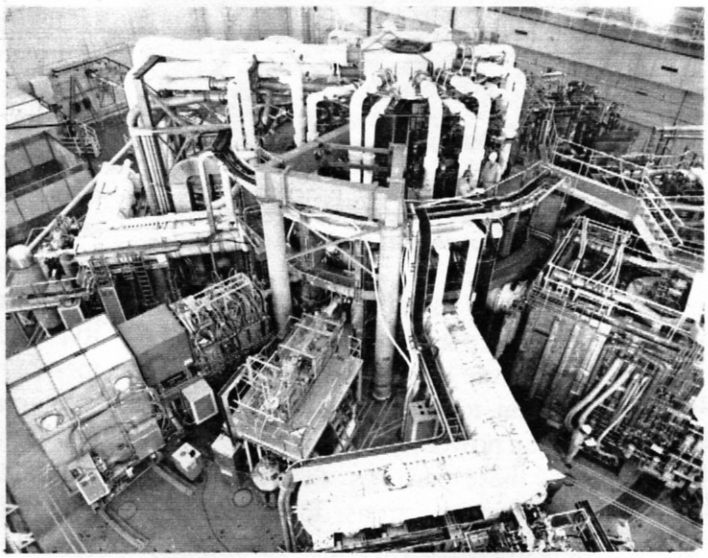
Princeton University • Plasma Physics Laboratory Vol. 16, No. 5 • December 20, 1994

Hotline

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

TFTR Breaks Own World Record



With a dream in sight and a sense of adventure at heart, the TFTR team led PPPL to another world record on November 2. The Tokamak Fusion Test Reactor generated 10.7 million watts of fusion power — the highest ever achieved by magnetic confinement — in a burst of energy equivalent to the amount of electrical power consumed by about 3,000 homes.

The record represents another leap toward delivering a commercial fusion reactor to the world and surpasses the goal of 10 million watts set for the TFTR project.

"There's no question that the achievements on TFTR in the last year have been major milestones in the fusion energy program," said PPPL Director Ronald Davidson during the TFTR celebration for PPPL employees on November 28. "I'd like to thank the entire staff here at the Laboratory for this monumental effort ... literally everyone here has played a significant role in the success of TFTR."

Preparations leading to the accomplishment featured a "Technical Superbowl" in which teams of PPPL physicists, engineers, and technicians developed innovative solutions. To reach the new highs, the neutral-beam system and the toroidal field were pushed beyond their original design limits, which led to better physics results.

TFTR Special Edition

Double Round of Applause

And when the results were announced at the annual meeting of the American Physical Society's (APS) Division of Plasma Physics in Minneapolis in November, PPPL physicists basked in the glory as their colleagues offered a double round of applause.

"Kevin McGuire gave an enthusiastic and excellent presentation at the APS meeting that was extremely well received," said TFTR Project Head Richard Hawryluk. "At the end of a talk, there is always a round of applause. One of the members of the audience from General Atomics stood up and asked the audience to give a second round of applause to acknowledge the important, historic nature of this work."

Davidson said the understanding of high-temperature fusion plasmas developed in the experiments represents a significant advance toward practical applications of fusion energy.

Explained Hawryluk, "These experiments have demonstrated our ability to predict — as we change machine conditions — how the plasma will respond. Indeed, as we increased the plasma current and toroidal field in our experiments last December and then in May and November, the plasma did what we expected it to do."

The most recent record-breaking experiments fall on the heels of two previous TFTR records — that of producing 6.2 million watts of fusion power last December and 9.3 million watts in May. The December experiments were the first using a fuel mixture of equal amounts of deuterium and tritium (D-T).

Hawryluk noted that even though about 300 D-T experiments have been

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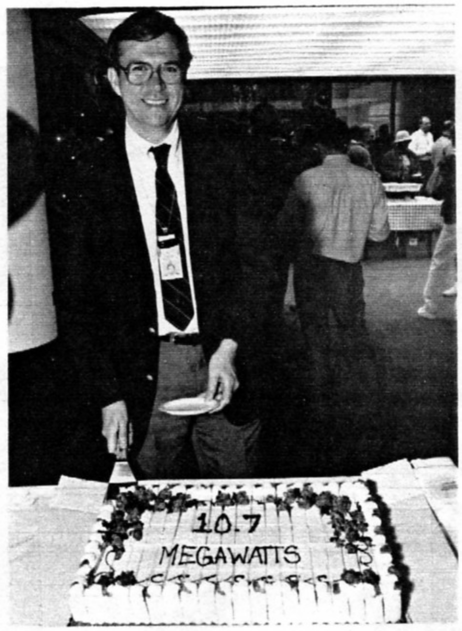
done on TFTR, there is still excitement over new results. "While the novelty has worn off, the sense of adventure is still there," he said.

The TFTR Head said the latest results on TFTR enable researchers to study the physics they will eventually encounter with a fusion reactor.

New Studies

New studies at PPPL focus on alpha particles and how well they are confined. Each fusion reaction produces an alpha particle (helium nucleus) and a neutron. In fusion power plants, the energy of the alpha particles would sustain the fuel temperature, while the neutron energy would be converted into heat for the generation of electricity.

"In the months ahead, we will be studying in considerable detail whether the alphas are as well confined as the recent experiments indicate or whether there are regimes of operation in which there is enhanced loss," said Hawryluk, noting that PPPL, along with General Atomics, the University of Wisconsin, and the Ioffe Physical-Technical Institute (Russian Federation), are collaborating on the development of new diagnostic techniques that enable researchers to measure and probe the

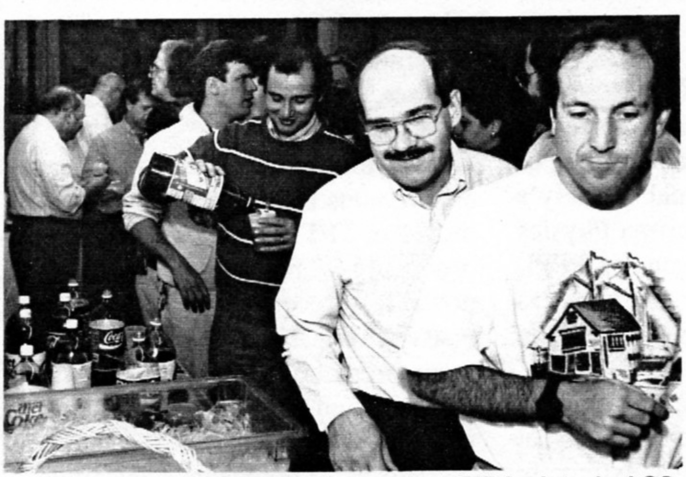


TFTR Project Head Richard Hawryluk prepares to cut cake at the TFTR Celebration.

details of the alpha particles in the plasma core.

While heating by alpha particles is vital to achieving self-sustained fusion power production, it is critical that these particles, the "ash" from the fusion reactions, do not accumulate in the fuel. A major accomplishment of the recent D-T experiments is that measurements of the alpha particles in the plasma show that ash accumulation would not occur in a fusion reactor with similar confinement characteristics to TFTR.

Said Dr. Martha Krebs, Director of the U.S. Department of Energy's Office of Energy Research, "Achieving 10 million watts of fusion power is a long-standing goal of the TFTR program ... just as important as the power level is the result that the helium produced by the fusion reactions does not accumulate in the fuel and quench the reaction. This means that the prospects for achieving sustained fusion reactions in a device like the International Thermonuclear Experimental Reactor (ITER) are good."



Lab employees enjoyed the fare at the TFTR bash in the LOB Lobby. In the foreground, from left, are Phil Efthimion (with soda bottle), Kevin McGuire, and Mike Vocaturo.

In addition to studying alphas and alpha confinement, PPPL researchers will be examining Ion-Cyclotron Radio-Frequency Heating (ICRH) of a D-T plasma. "We're interested in seeing how things change as we go from deuterium operation to D-T. We are now able to heat the ions effectively in D-T plasmas with ICRH and we'd like to go further in those studies," said Hawryluk.

"TFTR is a unique fusion facility in the world at this stage. It's the only one that can routinely run D-T to study the physics of the alpha particles and of the D-T plasma itself. That's really a very exciting capability," added the TFTR Head, who remembers that TFTR was just being conceptualized by Harold Furth — the "father and architect of TFTR" — when Hawryluk joined the Lab 20 years ago.

Engineering

The record results are largely credited to the feats accomplished by the engineering and technical staffs, who pushed the neutral-beam system and magnetic fields beyond their design objectives.

Dale Meade

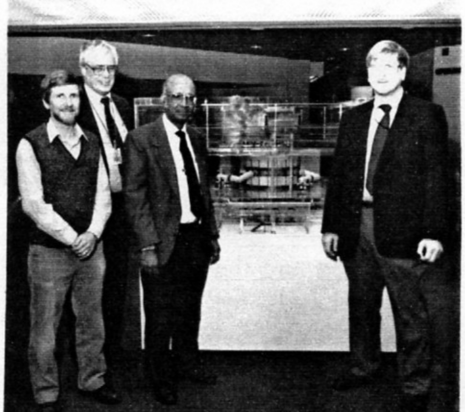
Laboratory Deputy Director Dale Meade said, "During the last several months PPPL engineers have devised ways to extend the performance of the TFTR magnetic field and plasma heating power. For these experiments, the magnetic field was increased by 8 percent and 39.5 million watts of neutral-beam power was used to heat the plasma."

Hawryluk said the TFTR team realized the machine capabilities had to be increased to achieve 10 megawatts of fusion power and to provide better physics results for study.

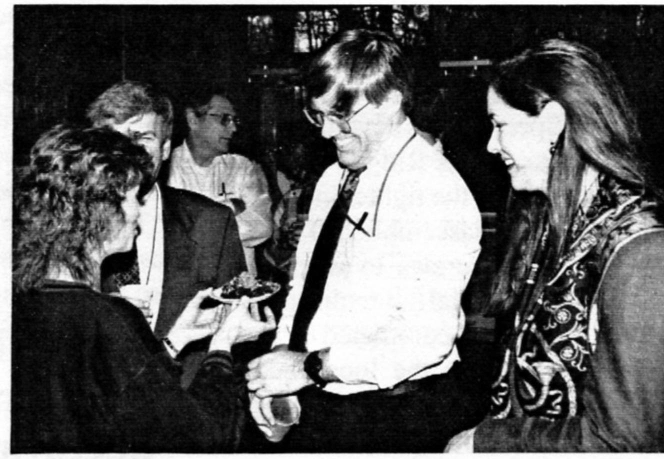
Magnetic Field

"We felt the single parameter that would give us the biggest change was to increase the toroidal field. This was based upon work done by Jim Strachan and Michael Bell," Hawryluk added, noting that the Lab's Engineering Division did an extensive series of analysis to be certain the machine could take the additional stresses. "Earlier studies done by Michael Bell indicated the magnetic-field level strongly affected fusion power. When the magnetic field was pushed to 5.6 tesla during the November experiments, the plasma actually behaved better, leading to higher fusion power production."

Said Bell, "The experiments in May had shown us that the fusion power from TFTR was being limited by the ability of the magnetic field to contain the large pressure created by the neutral beams in the center of the plasma. Increasing the toroidal magnetic field provided a stronger magnetic bottle to contain the plasma pressure, and the higher the pressure, the more fusion reactions occur. It is a very simple but important result for fusion research."



Key contributors in the six tesla effort are, from left, Michael Bell, Norman Fromm, S. (Raki) Ramakrishnan, and Robert Woolley. A photograph of the entire group contributing to pushing the magnetic field to six tesla is on page five.



Sally Connell presents a piece of cake to Engineering Head Michael Williams during the TFTR Celebration. To the right of Williams is Lori Meade, daughter of PPPL Deputy Director Dale Meade. At the left of Williams is Lab Director Ronald Davidson.

Engineer Robert Woolley said TFTR was designed to work with a maximum toroidal field of 5.2 tesla, although original plans gave it the capability of going to six tesla. Woolley said the magnetic-field level reached is directly proportional to the electric current. "It's not enough to have a coil strong enough to go to the higher field. You must also have enough energy to power it," he explained.

"Literally everyone here has played a significant role in the success of TFTR." —Ronald Davidson

About a year and a half ago, Woolley identified a way of using some power supplies that had been used in other coil systems. These would allow TFTR to go to higher fields. Raki Ramakrishnan and Norm Fromm developed an inexpensive and safe way for using these power supplies.

Laszlo Lontai led a group of engineers who analyzed the capabilities of the magnetic coils. "There was a lot of analysis done to calculate the stresses and strains inside the coils. The forces on these coils are pretty amazing. We have 20 of these toroidal-field coils on the machine arranged symmetrically. The forces are produced when current runs through the coils," said Woolley.

The higher coil current also increases currents and stresses in TFTR's Motor Generators (MG), prompting additional monitoring by MG engineers Mounir Awad, Gene Baker, and the MG staff.

Coil Pressure Increased

He said that at the 5.2 design field, the overall net force on each coil is six million pounds. This is equivalent to the weight of 100 large trucks, each filled with 30 tons of rock. "That's the amount of pressure on each coil pushing toward the middle of the machine. Since we're raising the current through the coils, we wanted to make sure they weren't going to break," said Woolley, noting that Irving Zatz and others in Lontai's group used computer models of the coils to predict their stresses and strengths. The net force on each coil was raised to seven million pounds during the latest experiments.

One problem the analysis failed to predict was the previous loosening of large bolts in the sides of the coils. In addition, some of the coils' interior cooling channels had sprung leaks. "So a lot of work has gone into resolving these problems," he said.

All the loose bolts were tightened, which posed some difficulty

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because so many are in inaccessible locations. Special tools developed by Tom Burgess of Oak Ridge National Laboratory made the tightening possible without disassembling TFTR. "We brought in crews to work on them using the special tightening tools and the work was completed in the fall of 1993. Once the loose bolts were retightened, a material that does not conduct electricity replaced water as a coolant so that minor leaks would not compromise the coils' insulation," said Woolley.

He noted that the work on the toroidal-field system is not over. The group is presently analyzing whether additional performance can be made available from the power supplies to use in future experiments at the higher field, six tesla.

Vacuum Vessel

More recently, in September, during ICRH experiments on TFTR, highly energetic particles trapped in the magnetic-field ripple between the toroidal-field coils actually spiralled down and melted welds on flanges at the bottom of the TFTR vacuum vessel, said Engineering Head Michael Williams. This resulted in tiny leaks that had to be sealed in preparation for the November experiments. "We had to come up with creative solutions that would externally repair these leaks," said Williams.

"This has been a major accomplishment for the entire Laboratory. I think we can do even better yet." —Rich Hawryluk

PPPL Engineer Jim Chrzanowski, who oversaw the design for the vacuum vessel repair, said the leaks were detected using helium leak detection equipment. "These leaks are so small you can't see them with your eyes, but any one of them can be a real show stopper."

The Vacuum Vessel Repair Team are, from left, (front row), Robert Tucker (plaid shirt), Jerry Gething, George Labik, Fred Simmonds, Jr., Vincent Smith, John Vaccaro, Robert Delany, (middle row), Carl Bunting, Nick Dereka, Joe Winston, Joe Stacy, Jim Chrzanowski, Joel Hosea, Joe Bartolick, Frank Polom, John Mazzella; (back row) Ed Bush, Dennis Ferguson, Pete Szaro, Carl Tilson, Robert Keilbach, George Barnes, Jan Wioncek, Tom Provost, Barry Dashefsky, John Collins, Tom Meighan, Jack Mount, William Zimmer, John Desandro, Les Gereg, John Boscoe, Mike Candelori, and Dave Cylinder. Not pictured are Mike Anderson, Ken Andreas, Bill Blanchard, Mike Dimattia, Glenn Feller, Buddy Kearns, Steve Kemp, Doug Loesser, Dave Miller, Kingston Owens, George Peak, Jr., Steve Raftopoulos, Tom Steer, Tim Tracy, Andy Vanisko, Joe Vannozzi, and Nazia Zakir.

Chrzanowski noted that the type of repair solution used depends on where the leak is located, and there is seldom an "easy" fix. "We decided to break into five separate design groups, each investigating a different type of repair solution," he said.

The task of instituting the repairs was complicated by the tight spaces in which the repair team had to work. The repairs had to be completed under the vacuum vessel where there was barely enough room to turn around. Several of the repair tasks had to be performed using mirrors because those on the repair team could not directly see their work, said Chrzanowski.

The design solutions that ultimately sealed the leaks on the vacuum vessel were nurtured by the engineers' ingenuity. "The group broke new ground as far as engineering," said Chrzanowski. "But it was ultimately the hard work and dedication of all the participants that provided TFTR with a successful leak repair."

Neutral Beams

The increase in neutral-beam power also led TFTR to the new highs in fusion power. The 'beam team' — the engineers and technicians involved in the neutral-beam project — prodded the neutral-beam heating system to produce a record 39.5 million watts of power. The neutral-beam system, which heats the plasma, was originally designed to operate at a maximum of 33 million watts of power in deuterium.

"Basically, the beam team pushed the sources and the power supplies associated with the beams to their operating limits," said Williams. "The higher neutral-beam power enabled us to increase the fusion power produced by TFTR, which in turn increases the amount of alpha physics that can be studied."

TFTR Heating Systems Division Head Al von Halle said, "We found

From left, (kneeling) are Tom O'Connor, Al von Halle, and Jim Kamperschroer; (standing) Brian McCormack, Tim Stevenson, Mark Oldaker, and Richard Newman. All are neutral-beam operations engineers except for Kamperschroer, who works on neutral-beam diagnostics.

ways of optimizing the beam operation, the gas usage, and the focus of the beam so that we were able to deliver more neutral-beam power to the TFTR plasma."

The neutral-beam system, which has been used in TFTR experiments for 10 years, is powered by complex systems. All neutral-beam operations require the support of precision switchtube-based, high-voltage power supplies, high-current power supplies, nitrogen and helium cryogenic systems, vacuum systems, and the ion sources.

Von Halle noted that the beams were not originally designed to run with tritium. "Larry Grisham, the neutral-beam physicist, had always advocated the technical feasibility of tritium neutral-beam operation and had collaborated on the initial planning for the successful Joint European Torus (JET) tritium run," von Halle said.

Timothy Stevenson, Head of the Neutral Beam Operations, added, "Witnessing the JET preliminary tritium experiment helped confirm our expectations in using tritium feedstock gas in TFTR sources."

Stevenson noted that a decade of work on the beams led to the latest highs. "It felt great to take on a challenge like that and to reach a 20-year goal ... We've been working on beams for 10 years to make it happen. The beam team is very excited about the levels we have reached and recognize our part in this 'Technical Superbowl," he said.

Ronald Davidson addresses the group at the TFTR Celebration.

Far From Over

The work on TFTR, which is scheduled to run through next September, is far from over. Hawryluk said the November experiments lead to a new round of studies, with the promise of more strides in fusion energy research.

"I just want to thank everyone for their dedication and extraordinary hard work to get us to this stage. This has been a major accomplishment for the entire Laboratory. I think we can do even better yet," he said. ●

Neutral Beam Group

(not pictured in photo at top)

Ronald Barrett	Edward Hall
James Benchoff	Leonard Halvorsen
Bruce Berlinger	Robert Horner
Ed Brieman	Jack Hynes
Ed Bush, Jr.	Robert Kokal
Joseph Carson, III	Arthur Kolupanowich
Roger Coston	Leonard Kralik
James Cryan	Ed Lawson
Barry Dashefsky	Douglas LeBon
William Derry	Marshall Lewis, Jr.
John Desandro	Raki Ramakrishnan
Bill Edwards, Jr.	Guy Rossi
John Edwards	Fred Simmonds, Jr.
Paul Ernst	Tony Wesson
Victor Garzotto	Doug Westover
Gary Gibilisco	Jan Wioncek
Kris Gilton	Marty Wisowaty
Dennis Gray	Kenneth Wright
Larry Grisham	

The contributors to the six tesla effort are, from left, (standing), Glenn Pearson, Tom Meighan, Jim Strachan, Charles Ancher, Albert Malone, Ray Gernhardt, Steve Tureikas, Harold Anderson, Richard Such, Peter Rogoff, Eugene Baker, and George Bronner; (seated) James Corl, Ed Lawson, Richard Vankirk, Aleksandar Ilic, Jerry Levine, Mounir Awad, Charles Neumeyer, Jr., Robert Woolley, S. (Raki) Ramakrishnan, and Joel Hosea. Some of those seated are holding pictures of Nikola Tesla. Not pictured are Michael Bell, Peter Bonanos, Art Brooks, Guydon Cargulia, Jim Chrzanowski, Robert Ellis III, Norman Fromm, Steve Hreha, Laszlo Lontai, Elaine Lu, Robert Marsala, Don McBride, Westley Reese, Wayne Reiersen, George Sheffield, James Sinnis, John Spitzer, Thomas Steer, Jack Wills, and Irving Zatz.

APS Fellows Named at Annual Meeting

Physicists Monticello and Zarnstorff Receive Lifetime Appointments

Recognizing their contributions to the advancement of physics, the American Physical Society (APS) has named PPPL Principal Research Physicists Donald Monticello and Michael Zarnstorff as Fellows.

Monticello and Zarnstorff received the lifetime appointments at the November APS meeting held in Minneapolis. The APS rules limit the maximum number of Fellows each year to be less than one percent of the Division membership.


Donald Monticello

Monticello, who was elected through the APS's Division of Computational Physics, was cited by the APS "For pioneering advances in the three dimensional simulation of large scale magnetohydrodynamic instabilities in toroidal magnetic confinement configurations."

Monticello, who came to the Lab in 1975, received a Ph.D. in Plasma Physics from the University of Rochester in 1973. He had been at the Institute for Advanced Study prior to coming to PPPL. His current work centers on using the computer to model tokamak discharges.

Zarnstorff, who was elected through the APS's Division of Plasma Physics, was honored by the APS "For contributions to parallel transport in toroidal devices, and for the verifications of the bootstrap current, which has led the way to the design of advanced tokamak reactors."

Zarnstorff came to PPPL in 1984 after receiving a Ph.D. in Physics from the University of Wisconsin. He is Deputy Head of the TFTR Physics Program Division and is the TFTR Task Force Leader for Transport and Advanced Tokamak Physics.

Commenting on Monticello, Theory Division Head Bill Tang, said, "I believe that Don's expertise in the computational magnetohydrodynamic arena has long been well appreciated by the national, as well as the international community. All of us in the Theory Division at PPPL are very happy that his many contributions have been accorded this official recognition."


Michael Zarnstorff

TFTR Project Head Richard Hawryluk said of Zarnstorff, "Mike has been one of the international leaders in the study of transport in tokamaks and a key participant in the TFTR experiments. I am very happy that the American Physical Society has recognized his contribution to our field." ●

Preische Elected to APS Exec Committee

When PPPL graduate student Sherrie Preische wanted to get the word on fusion out to the public, she decided to seek a seat on the Executive Committee of the American Physical Society's Division of Plasma Physics (APS-DPP).

"I decided to run because I believe the DPP can do a lot more to represent the work of fusion scientists to the public," said Preische, who was elected to the Executive Committee this fall. "I think the public feels we're sitting in our little lab completely isolated from society. And to a large extent, they're right."

Preische, who will receive her Ph.D. in Plasma Physics from Princeton during the next couple of months, is the only student on the committee. PPPL Assistant Director Rush Holt called it a "remarkable" feat for a student and attributed Preische's success to her push to educate the public about fusion.


Sherrie Preische

In her position statement, printed in the APS newsletter along with those of other candidates, Preische wrote, "The government is presently reevaluating its reasons for funding science research and there is no outcry from the public in support of physics. This tells us that we need to increase our efforts both in communicating with the government about policy decisions that affect plasma physics and in educating the public about our research and its possible benefits."

Preische, whose run for office entailed preparing the statement and collecting signatures to get on the ballot, was elected with two others to three-year terms on the nine-person committee.

The graduate student's bid for the seat was prompted by an incident last year at the annual APS-DPP meeting. When she asked why no press releases had gone out about the

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Preische
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annual conference, she was told there weren't any big results to announce.

"We need to keep people informed about more than just the 'big results.' Press releases let people know you are in town and that you are still working on fusion. We don't want the public to just hear about fusion every 40 years. We need to have constant interaction," said Preische, recalling that a few people asked her after the meeting what could be done to get the word out.

Two projects she co-developed in response were an exhibit and an open house on fusion co-sponsored by the APS-DPP and the Science Museum of Minnesota in St. Paul. Both events coincided with the annual APS meeting in November held in nearby Minneapolis.

"Those of us in the DPP were thinking about things the Division could do and Bob Heeter, another PPPL graduate student, suggested the exhibit. He is from Minneapolis and made a lot of arrangements with the museum," said Preische. She and Heeter worked several months preparing the exhibit and then spent 14 hours one day setting it up at the museum.

Represent Plasma Physics

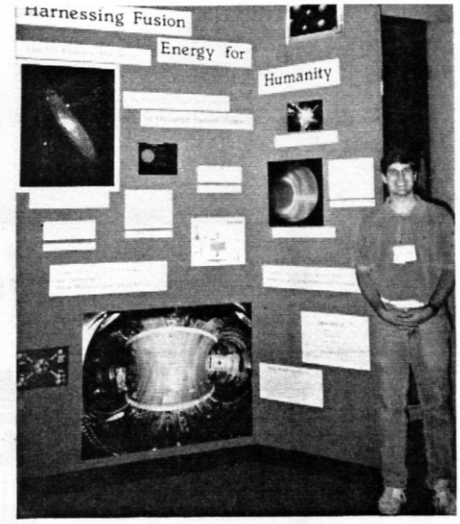
"I think the Division ought to be able to represent plasma physics to the public, which was the kind of thing I was trying to start through this museum exhibit," she said, adding that she is also urging the Division to develop an official position statement on fusion energy research that could be presented to the Department of Energy (DOE) and to Congress.

The exhibit and open house were successes, drawing about 200 people to the open house lectures. "We had a great turnout in the auditorium. There was such a variety of people there, from high school kids to a trial lawyer that had served in the Carter Administration checking out the Three-Mile Island accident," said Preische, noting that as a result of the success, the DOE hopes to create a permanent traveling exhibit on fusion.

Preische has come a long way in the field of plasma physics since she was introduced to the subject of physics as a high schooler in East Hampton, New York. Her interest focused on fusion when she was encouraged by a professor at Randolph-Macon Woman's College to do her senior thesis on plasma physics.

She went on to do graduate thesis research at Princeton, where she developed a unique diagnostic for PBX-M to obtain radially localized electron cyclotron emission from the superthermal electrons produced by lower hybrid current drive in order to study radial transport. After completing her doctorate, she will continue similar work during a one-year post-doc at Tore Supra in France.

Since Preische will be in France in 1995, she will probably only attend one of the two DPP Executive Committee meetings next year, but she will continue to be an active member. "I will communicate regularly with all the people involved through e-mail and send my contributions to the meetings," said Preische.



PPPL graduate student Bob Heeter stands near the fusion exhibit at the Science Museum of Minnesota.

Preische said her duties on the committee largely entail carrying out her own recommendations for getting the message on fusion to the public. For instance, she devoted her efforts to the exhibit and open house in Minneapolis, crafted press releases about the two events, and is currently in charge of creating a glossy brochure for public distribution about plasma science. These tasks came from her own suggestions or from ideas she supported for keeping plasma physicists in touch with the public.

"There's much feeling in the public that scientists are not to be trusted. I think if we work on trying to be more open, we can build the public's trust in science. The Division of Plasma Physics can be one of the main avenues for this," she said. ●

HOTLINE

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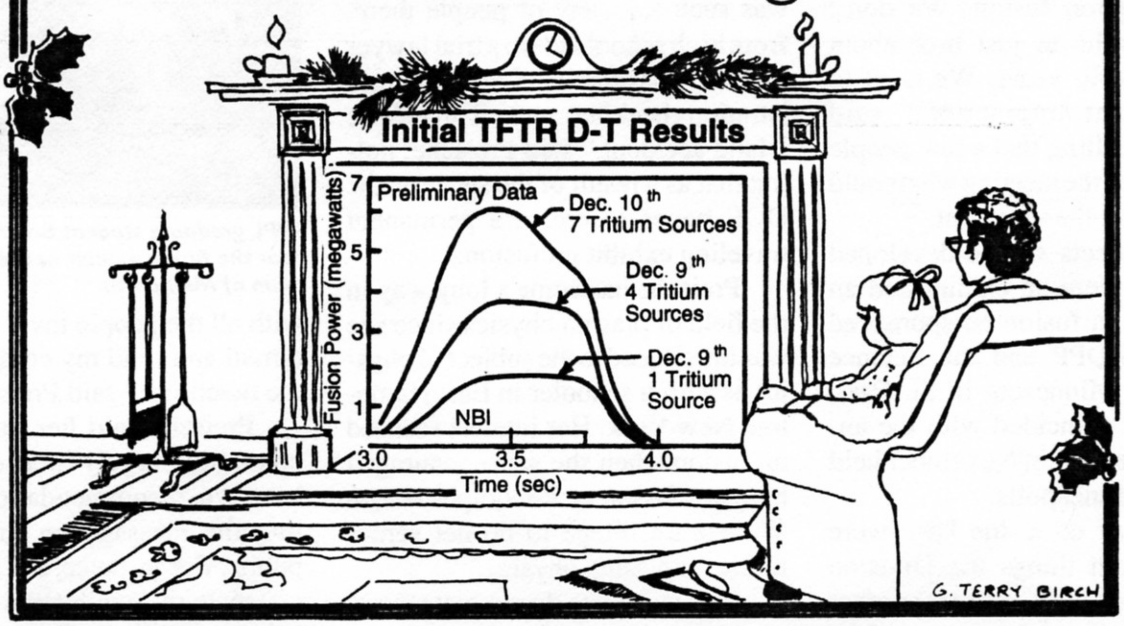
Layout: Patti Wieser
Photography: Dietmar Krause
Reproduction: Teri Daynorowicz

The HOTLINE is issued by the Princeton University Plasma Physics Laboratory, a research facility supported by the United States Department of Energy. It is primarily an internal publication. Correspondence and requests to reprint material should be directed to the Editor, PPPL HOTLINE, P.O. Box 451, Princeton, NJ 08543; fax 609-243-2751 or telephone 609-243-2754; Interoffice correspondence should be addressed to Room B366, LOB Bldg., C-Site.

Seasons Greetings



Best Wishes

For a Happy Holiday Season and a Happy New Year

Princeton Plasma Physics Laboratory