PPPL PRINCETON PLASMA PHYSICS LABORATORY
A Collaborative National Center for Fusion & Plasma Research
U.S. DEPARTMENT OF ENERGY
WEEKLY
September 8, 2014

At PPPL THIS WEEK

THURSDAY, SEPT. 11

The Laboratory will be observing a moment of silence at 8:46 a.m. to honor those lost during the tragic events of Sept. 11, 2001. The time marks the moment when a plane struck the first of the two World Trade Center towers.

UPCOMING EVENTS

September 24

PPPL Colloquium
4:15 p.m. ◆ MBG Auditorium

Evolution of Coil Design and Manufacturing at PPPL

Jim Chrzanowski - PPPL

October 27-31

56th Annual Meeting of the APS Division of Plasma Physics
New Orleans

http://www.aps.org/

PPPL's dynamic diagnostic duo

By John Greenwald

Kenneth Hill and Manfred Bitter are scientific pioneers who have collaborated seamlessly for more than 35 years. Together they have revolutionized a key instrument in the quest to harness fusion energy — a device called an X-ray crystal spectrometer that is used around the world to reveal strikingly detailed information about the hot, charged plasma gas that fuels fusion reactions.

"Ken and Manfred are consummate diagnosticians," said Michael Zarnstorff, deputy director for research at PPPL, where the duo has worked for nearly four decades. "Over the years they have developed highly innovative and uniquely capable tools for analyzing the results of fusion experiments."

These tools record key plasma parameters on fusion facilities in the United States, China, Japan and South Korea. They are being designed for a new German facility and will play a key role on ITER, the huge international experiment under construction in France to demonstrate the feasibility of fusion power.

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Kenneth Hill and Manfred Bitter inspect an X-ray crystal spectrometer to be used to study laser-produced plasmas. The vertically mounted silicon crystal has a thickness of 100 microns, about the average diameter of a human hair.

Complex MG repairs cap months of safety and technical planning

By Jeanne Jackson DeVoe

Months of safety and technical planning took place before a team of technicians climbed into a tight space in a pit 31 feet below ground to weld cracks in the massive 700-ton steel flywheel of one of PPPL's motor generators this summer.

The motor generator, which is one of two adjacent devices at D Site, will be needed to provide additional power for the National Spherical Torus Experiment (NSTX-U) after it begins operating next year.

"I think the job went very well," said John Lacenere, head of the Electrical Engineering Power Branch. "The workers were very professional. This was the right group of people to do this kind of work. "

"It worked very well," agreed Mounir Awad, the systems engineer for the motor generator system. "It was very successful and I'm happy with the results."

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Sparks cascade as a welder assisted by another worker uses an electric arc welder or gouge to remove metal from a defective weld. They are working in a 3-foot space beneath the metal platform called the stiffening ring. The ring in turn is beneath the motor generator. Work on the repair project concluded last month. Photo by Steve Tureikas.

Dynamic duo

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New applications expanding

New applications for the spectrometers are rapidly expanding. Prospective new uses range from medical and industrial applications to the study of high energy-density physics. "An abundance of contexts is opening up," Zarnstorff said.

Behind all these efforts are two low-key physicists. "I have known and worked with Ken and Manfred for over 30 years and have always admired their scientific work and polite demeanor," said Philip Efthimion, who heads the Plasma Science and Technology Department at PPPL.

The two divvy up tasks based on "whatever one of us is interested in and needs to do," said Hill. "We have to try to check each other and make rational decisions instead of emotional ones." Bitter puts it this way: "We are in this business together some 35 years. Everything that comes up is discussed between us."

The physicists first joined forces at PPPL in the late 1970s when the Princeton Large Torus, the Lab's major experiment at the time, was reaching temperatures of more than 10 million degrees Celsius. That blistering heat stripped light-emitting electrons from the hydrogen atoms in the plasma, eliminating light as a source of information about the atomic nuclei, or ions, in the plasma and creating the need for a new diagnostic tool.

Enter the X-ray crystal spectrometer, which gleans vital data from the X-rays that ions emit. At the heart of this tool is a hair-thin crystal that separates the X-rays into their wavelengths, or spectrum, and sends them to a detector. Shifts in the wavelengths reveal the temperature of the ions and other key data through a process called Doppler broadening — the same process that causes sirens to sound higher when speeding toward someone and lower when rushing away.

Worked on early X-ray spectrometers

Bitter and Hill worked on early X-ray spectrometers under Schweickhard von Goeler, who headed diagnostics and whom everyone called "Schwick." Von Goeler and Hill introduced the first such device, whose lower resolution — or ability to distinguish between wavelengths in the spectra — was not yet sufficient to measure Doppler broadening. Responding to this challenge, von Goeler and Bitter built an improved spectrometer with higher resolution for Doppler measurements.

The new PPPL device produced results that astonished solar scientists. The spectrometer revealed far more details of the X-ray spectrum for iron, an element used for diagnostic purposes in the plasma, than instruments aboard satellites that studied the spectra of iron in the sun had been able to show.

But the new spectrometer, which PPPL also installed on the Tokamak Fusion Test Reactor (TFTR), the Laboratory's key fusion experiment in the 1980s and 1990s, had a severe limitation. The cylindrically curved crystal provided only a single line of sight through the donut-shaped plasma and could record only the temperature of ions found at points along that line of sight. "What you really want to know is how hot it is at many points throughout the plasma," said Hill.

To increase the number of sightlines, PPPL put five X-ray spectrometers on TFTR. "They were large," Hill said of the devices, "and you couldn't imagine many more. So Manfred came up with the idea for a single crystal and a 2D [or two-dimensional] detector that would give you a continuous profile of the plasma."

A simple and elegant concept

Bitter's concept, now a worldwide standard for fusion research, was simple and elegant. He envisioned a crystal whose spherically curved surface collected X-ray spectra from the entire plasma and imaged them onto a detector that recorded both the spectra and the location of the ions they came from. The revolutionary result: A complete picture of the plasma's ion temperature, captured with just one X-ray spectrometer.

Bitter and Hill first tested this design in 2003 on Alcator C-MOD, the fusion facility at MIT. While this trial showed that the concept worked, the 2D detector used at the time couldn't record all the spectra that flowed in from the crystal. "The count-rate limit of this detector was very low," recalled Hill. "You couldn't see how the temperature evolved over time."

This problem led to a search for a better detector, which Bitter found on a trip to Europe. While there in 2005, he learned of a device that the European Organization for Nuclear Research (CERN) had developed that could record spectral images in far greater detail than the detector he had been using. "It was like comparing an airplane to a bicycle," Bitter said of the new detector, which made the spherically curved crystal spectrometer fully operational.

MIT became the first to use the new spectrometer when the university's Plasma Science and Fusion Center installed it on Alcator C-MOD in 2006 in a collaboration between MIT and PPPL. "It's been a really great leap forward," said John Rice, the principal research scientist at the MIT facility. "The original detector [on the 2003 spectrometer] had all sorts of problems and with this new system we can image the complete plasma."

Essential tools around the world

Other fusion laboratories quickly followed. PPPL-designed spectrometers are now essential tools on the Korea Superconducting Tokamak Advanced Research (KSTAR) facility in Daejon, South Korea; the Experimental Advanced Superconducting Tokamak (EAST) in Hefei, China; and the Large Helical Device (LHD) in Toki, Japan.

Still to come are spectrometers planned for ITER in Cadarache, France; Wendelstein 7-X (W7-X) in Greifswald, Germany; and the upgraded National Spherical Torus Experiment (NSTX-U) at PPPL. For these projects, Bitter and Hill are providing expert guidance.

"The highlight of my time here has been working with Ken and Manfred," said physicist Novimir Pablant, who led the design of the LHD spectrometer and is developing the devices to be installed on ITER and W7-X. Joining Pablant on the ITER project is physicist Luis Delgado-Aparicio, who is developing the NSTX-U spectrometer and has likewise been inspired by Bitter and Hill. "They are incredible to work with," said Delgado-Aparicio. "The degree of certainty to which they want to test their ideas is acute."

Work on new spectrometers

Bitter and Hill are still collaborating on new spectrometers. Among them are devices to study laser-produced plasmas at the University of Rochester and the Lawrence Livermore National Laboratory. What keeps the two scientists going? "X-ray spectrometry is a field that I find fascinating," said Bitter. "It has so many applications and it's very interesting to design new diagnostics." Hill fully seconds those sentiments. "There's just a lot of interesting physics in this field," he said. "And there are broad applications and interest for this technology."

MG Repairs

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The tight space and potentially hazardous conditions posed by the welding were a challenge for PPPL's Emergency Services Unit, which developed a lengthy and detailed safety plan to rescue workers in the event of an emergency.

Project is largely completed

Welders from Voith Hydro in York, Pa., a company that builds hydro generators, completed the repairs for the $1 million project. PPPL hired the company because the welding work required specialists that have done this kind of work in the past. Working in teams of two people, the workers clambered into a small space below the floor and worked together to weld 21 thin cracks called "spider weld cracks" that are 3 to 30 inches long and together added up to 305 inches or about 25 feet of weld cracks. Most of the cracks were at the round platform at the bottom of the device called a "stiffening ring." The ring holds the eight steel "spider arms," of the device that are arranged around a center like wedges of pizza with small spaces between them.

The welder must remove the metal from the defective welds using a tool called a carbon air arc gouge, which melts and blows out the metal from the defective weld. He then uses a flux core arc weld to fill in the joints with a bead of metal and join the two sides of the crack together. The challenge in achieving proper welding in the motor generator is to do so without making the flywheel any bigger than it was before the repairs began, Awad explained. If it did get bigger, that would throw off the balance and would not be able to achieve the maximum speed.

It is close, difficult work in the confined spaces beneath the motor generator and between the spider arms. The welder must wear a welding hood with a breathing apparatus to protect his eyes and face, as well as protective gloves and clothing. Air was blown into the space to improve the air circulation and sensors monitored the air quality, sounding an alarm if the level of oxygen was too low or high. An assistant helped the welder in the space by using barriers to block the spray of metal from the welding, handing the welder tools and monitoring him. Meanwhile, a PPPL technician was on a constant safety watch and ESU monitored the work periodically.

Planning for the work took more than a year, Lacenere said. PPPL first had to understand the technical aspects of the weld, he said. Once work began around Memorial Day, PPPL engineers and technicians were at the site

Welders wore a black, flame-retardant hood to protect their eyes and face. The hood was equipped with breathing apparatus. They also wore a harness that could be clipped to a pulley to extricate them from the site in the event of an emergency in which they were incapacitated. The harness was part of a complex rescue plan devised by PPPL's Emergency Services Unit. The work was completed last month without incident. Photo by Steve Tureikas.

A worker lies in a tight space next to the motor generator 31 feet below ground between two spider arms of the motor generator. Photo by Steve Tureikas.

12 hours a day four days a week to supervise the work, which concluded in August.

Awad credits operator and maintenance technicians Colin McFarlane, Steve Tureikas and Harry Krotz, along with engineer Gene Baker, with working on the repair project, and running the system for the past decades. "Their dedication is a major factor in the top availability and reliability of the system during TFTR and NSTX operations," he said.

The Industrial Hygiene and Occupational Safety group, including Styer, Bill Slavin, Neil Gerrish, and Julia Toth, provided their support to address the safety hazards and assist to provide the required controls that make the project as safe as it could be.

Began operating in 1983

The two motor generators powered TFTR from 1983 to 1997. The rotational energy from both motor generators produced 87.5 hertz of power. (Hertz is the frequency per second of oscillations in an alternating current). The normal utility power frequency is 60 hertz. GE provided analysis of weld samples that concluded the cracks were caused by improper welding when the motor generator was manufactured in the late 1970s.

Motor Generator #1 (MG#1) powered NSTX until 2003 when the cracks were discovered. It continued to operate the following year but only ran about 100 times at 15 percent of its full power. MG#1 Operations were halted in 2004 and it was replaced by Motor Generator #2.

The National Spherical Torus Experiment needed only a fraction of the power of TFTR. But NSTX-U will be much more powerful and the "shots" or "pulses" it produces will be up to four seconds, four times longer than NSTX, and will require more power from one motor generator at full rated power and energy.

Operators will pre-test the repaired generator by running it at top speed to see if the motor generator maintains its balance and doesn't vibrate above the limit. If there is too much vibration, the technicians will return to balance the rotor in order to reduce the vibration. Once MG#1 is fully functioning, the next project will be to repair MG#2. MG#2 was partially repaired in 2005 to re-weld the joints where the welds samples were taken. It will be used on a limited basis until it is fully repaired, Awad said.

A challenge for ESU

The motor generator project was also a challenge for the Emergency Services Unit (ESU), which began planning for the project last December. "We didn't want to just have an adequate plan," said Fran White, head of the Site Protection Division. "We wanted a very collaborative plan that represented best practices."

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MG Repairs

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Like the NSTX upgrade, the MG project involves "really intricate work," said White. "But because of extensive planning we get to have very successful outcomes: a high end product and a safe workforce," he added.

Chief concern

The chief concern when people are working in a confined space doing work like welding is ensuring that the workers can easily be removed from the space if they are injured or any emergency occurs, White said. Emergency service experts call the first hour after an injury "the golden hour" because the injured person's chances for survival are greatest if they are taken to the hospital within an hour of being injured.

PPPL's Emergency Service Unit set up an incident command post near motor generator #1 while it was undergoing potentially hazardous repairs.

Photo by Darren Thompson

Jamie Dunnigan, Site Protection's emergency planning and training coordinator, developed the safety plan with ESU Captains Howard Caruso, Kevin Rhoades and Darren Thompson, along with those in charge of the repair project, including Awad. It spells out how the ESU would respond to various scenarios based on factors such as the severity of an injury and the physical capability of the injured person, Dunnigan explained. "The whole planning process is worst case scenario-based," he said.

"Both the planning and the execution of this plan really highlight the integrated safety management approach here at PPPL," said White, "because the project brought together contractors, engineers, technicians, emergency services officers, mutual aid emergency partners and the DOE and lab management to develop a safety rescue plan."

Emergency plan for workers

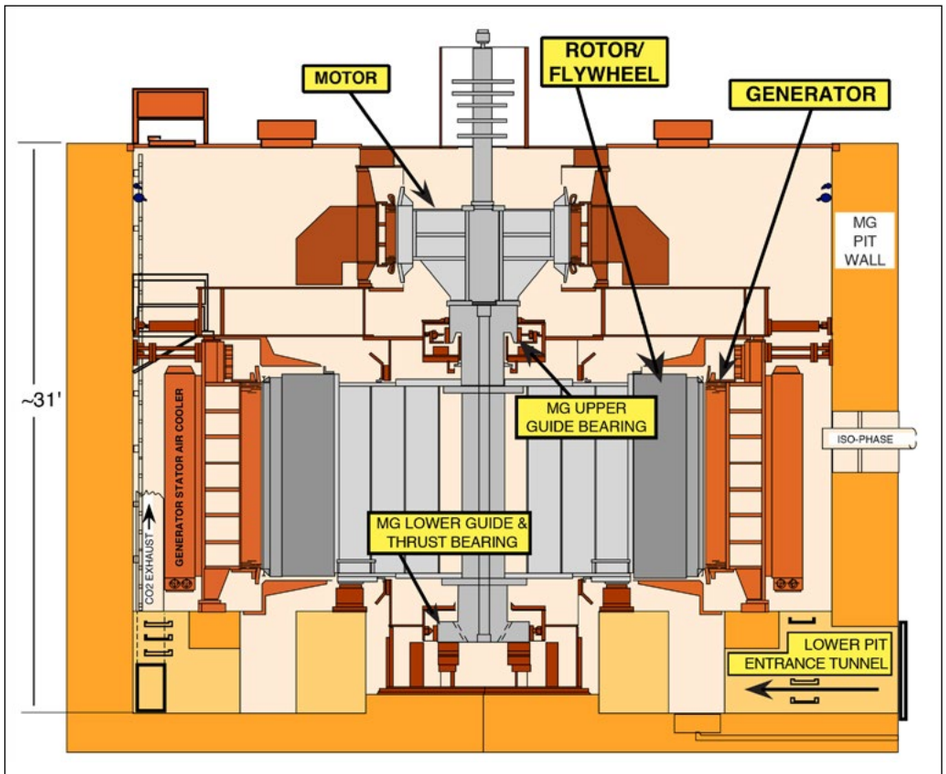
The plan called for workers to wear a harness that would allow them to be quickly hoisted out of the space in an emergency, White said. ESU also kept emergency equipment on hand to be ready for such emergencies and a technical support trailer was kept nearby in case of an emergency.

ESU officers trained the technicians from Voith Hydro (which also had its own safety plan) on how to conduct a fire watch and fire extinguisher training. They also did a drill in the MG "pit." A member of the ESU, usually a captain, was assigned to make sure the command post was ready to go at all times. Patrols stopped by twice a day.

The plan also assigned a rescue operations officer when work was taking place and trained two officers as a "haul team" that would rescue a welder who was unconscious or incapacitated. A confined space rescue entry team would also work on any rescues.

The ESU did not respond to mutual aid calls from the community while the work was taking place. The Site Protection Division also consulted with the Middlesex County Urban Search and Rescue unit, which helped with the planning and took tours of the area. ESU officers met twice with local fire departments and rescue squads who might be called on to assist in an emergency or to be on call at PPPL while PPPL's ESU was responding.

Fortunately, the work was finished without incident. "This was the best kind of rescue plan in the sense that we all came together to think it through but we didn't have to use the plan," said White. "Moving forward, we want to continue to build on this kind of planning process to make PPPL an even safer place to work than it is now."



A schematic of the motor generator shows how tight space is around and beneath the device where welders repaired cracks in the spider arms.

Schematic by Gene Baker.

SPD • TIP • OF • THE • WEEK •

Rules of the Road for School Bus Safety

September is back-to-school month and, with classes resuming, drivers will encounter more school buses on the road.

School buses typically drive more slowly than other vehicles and make frequent stops to pick up and drop off passengers. Drivers must be aware of buses in front of them as well as buses approaching from the opposite direction. Whether you are on a public or private road, you are required to stop for a school bus loading or unloading passengers. If a school bus stops, you must stop regardless of the direction you are driving. (When traveling on a dual-lane highway, a motorist should slow to 10 mph if on the other side of a safety island or raised median.)

Follow these safety tips when school buses are on the road:

- Never pass a stopped school bus with its red lights flashing on the right or left.
- Watch for children who cross in front of the bus when the bus is stopped.
- Look for children at bus stops and those running to bus stops.

Please use this interactive tool provided by the New Jersey Division of Motor Vehicles to learn more about school bus safety.

COLLOQUIUM

Evolution of Coil Design and Manufacturing at PPPL

JAMES CHRZANOWSKI
Princeton University

Wednesday, September 24

4:15 p.m. (Coffee/Tea at 4 p.m.)
M.B.G Auditorium, Lyman Spitzer Building

COLLOQUIUM

Antibiotic Resistance: A Global Challenge

RAMANAN LAXMINARAYAN
Princeton University - Princeton Environmental Institute

Wednesday, October 15

4:15 p.m. (Coffee/Tea at 4 p.m.)
M.B.G Auditorium, Lyman Spitzer Building

BROCK Café at PPPL Menu

BREAKFAST ..... 7 a.m. • 10 a.m.
CONTINENTAL BREAKFAST ..... 10 a.m. • 11:30 a.m.
LUNCH ..... 11:30 a.m. • 1:30 p.m.
SNACK SERVICE ..... until 2:30 p.m.

*— **MARK GAZO**, Chef Manager*

	MON. 8 SEPT.	TUE. 9 SEPT.	WED. 10 SEPT.	THU. 11 SEPT.	FRI. 12 SEPT.
					
COMMAND PERFORMANCE CHEF'S FEATURE	Ota Ya Sushi	Vegetable Fried Rice served with an Egg Roll	Homestyle Meatloaf with Mac & Cheese & Stewed Tomatoes	Create Your Own Pasta	Seafood, Sausage & Chicken Paella
EARLY RISER	Blueberries & Cream French Toast	Apple Pancakes served with Homemade Turkey Sausage	English Muffin with Peanut Butter, Honey & Banana with Fruit Salad	Hearty Chicken, Apple & Kale Breakfast Strata	Vegetable Egg White Omelet served with Potatoes
COUNTRY KETTLE	Beef Rice	Potato Leek with Mushroom	Spicy Louisiana Seafood Chowder	Tomato with Spinach & Lentils	Navy Bean with Ham
GRILLE SPECIAL	Meatball Parmesan Torpedo	Andouille Sausage Torpedo with Peppers & Onions with Dirty Rice	Mozzarella Sticks with Marinara Sauce & French Fries or Side Salad	BBQ Blue Turkey Burger with Onion Rings	Fried Potato Cheese Pierogies with Apple Sauce & Coleslaw
DELI SPECIAL	Veggie Burger Parmesan on a Kaiser Roll	Roast Beef with Blue Cheese, Arugula & Tomato on a Wheat Roll	Bologna & American Cheese on White with Lettuce & Tomato	Shrimp Salad Platter	Chicken Salad Club Sandwich
PANINI	Buffalo Chicken over Mixed Greens	Classic Vegetable Reuben on Multigrain Bread	Chicken Pot Pie with Puff Pastry	Eggplant, Portobello Mushroom, Basil, Tomato and Mozzarella	Meatloaf Sandwich with Cheddar Cheese, Lettuce & Tomato

MENU SUBJECT TO CHANGE WITHOUT NOTICE

VEGETARIAN OPTION

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WEEKLY

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The **PPPL WEEKLY** is published by the PPPL Office of Communications on Mondays throughout the year except for holidays. Deadline for calendar item submissions is noon on Thursday. Other stories should be submitted no later than noon on Wednesday. Comments: commteam@pppl.gov ◆ **PPPL WEEKLY** is archived on the web at: http://w3.pppl.gov/communications/weekly/.