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HOTLINE

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Lithium Tokamak Experiment Assembly Begins

New Tokamak to Operate at PPPL Next Spring

By Anthony DeMeo

PPPL's Current Drive Experiment-Upgrade (CDX-U) machine completed its last phase of experiments in July. It is now being converted to a new device, the Lithium Tokamak Experiment (LTX). The LTX will continue promising, innovative work started on CDX-U in 2000, involving the use of pure lithium metal on surfaces facing or contacting the plasma. PPPL researchers believe that LTX may herald a new regime of plasma performance with improved stability, lower impurity levels, better particle and temperature control, and more efficient operation. "Even in a small machine like LTX, we expect a dramatic change in plasma parameters, and that's what we're quite excited about," said Bob Kaita, one of LTX's co-investigators. This improved performance may be possible by enclosing the plasma in a heated, conductive shell coated with molten lithium on the inside, and shaped to conform to the boundary of the plasma.

"In LTX the biggest, most obvious change to the casual observer is the introduction of a shell consisting of a one-centimeter layer of copper with a 1.5-millimeter layer of

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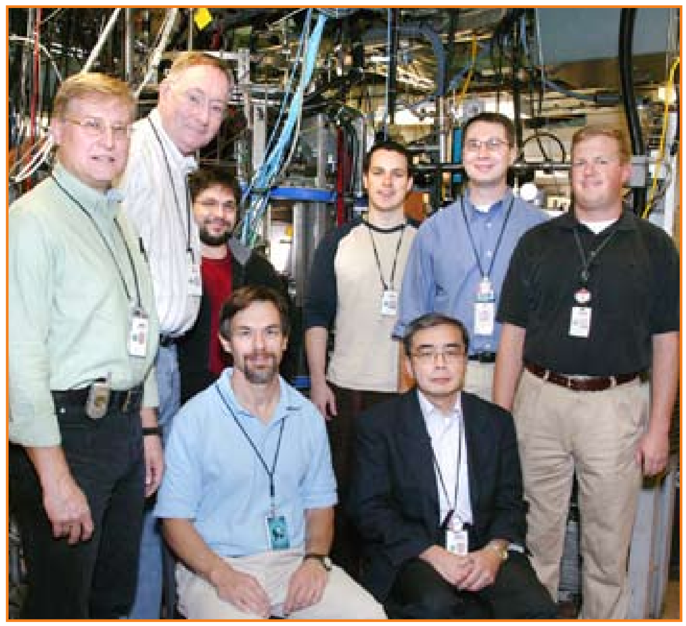

Members of the LTX team are (standing, from left) Tom Kozub, John Timberlake, Jeff Spaleta, Tim Gray, Vlad Soukhanovskii, and Craig Priniski; (sitting, from left) Dick Majeski and Bob Kaita.

Chinese Institute of Engineers Honors Tang

PPPL Chief Scientist Bill Tang has been selected to receive the Chinese Institute of Engineers-USA (CIE-USA) Distinguished Achievement Award. The Institute is honoring Tang "for his outstanding leadership in fusion research and contribution to fundamentals of plasma science." He received the award at the 2005 CIE Convention on October 15 in Newark.

Bill Tang

PPPL Director Rob Goldston said, "Bill has been a world leader in the development of the theory of microturbulence — the key means by which heat leaks out of the very hot gases used for fusion — and in the development of computational tools to simulate this turbulence. This award is richly deserved."

In addition to serving as Chief Scientist at PPPL, Tang is the Associate Director for the Princeton Institute for Computational Science and Engineering. The Institute was recently established at Princeton University to stimulate progress in innovative computational science via interdisciplinary alliances involving computer science, applied mathematics, and prominent applications areas in the physical sciences and engineering disciplines. Tang received a Ph.D. in physics from the University of California, Davis, in 1972

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stainless steel explosively bonded to its inner surface," notes Dick Majeski, an LTX co-investigator. In mid-September, the last of LTX's 28 shell segments were delivered to PPPL where they are now being trimmed and welded together, with inner and outer support rings added. When fully assembled, the shell will have vertical and horizontal gaps to limit the currents induced in the shell. New diagnostics and a new ohmic heating (OH) power supply are the only other substantial changes planned for the first year of LTX operation. More extensive upgrades will occur in later years.

Improved Performance

The new OH power supply will enable LTX researchers to program the rise and fall of OH coil current. The change in the magnetic field caused by this current swing drives the plasma current. "Controlling the OH current is of paramount importance for LTX. With a lithium-coated shell, the LTX plasma will be much more efficient in using the power from the OH coils to drive the plasma current," said Majeski. The loop voltage is the amount of voltage it takes to generate the LTX goal of 100 kA of plasma current. Far lower loop voltages will be needed to maintain the plasma current with the lithium shell. This prediction is based on results obtained in lithium experiments on CDX-U during the last three years.

The LTX researchers couple this experimental evidence with a solid theoretical explanation. "We expect the plasma temperature to be higher with lithium, but more significantly, we expect a 'fatter' current channel in the plasma. Without lithium, the current is highest in the middle of the plasma and falls off rapidly as you go toward the edge. With lithium, the current is expected to remain fairly constant across the plasma. For a given loop voltage, more current can flow through the fatter channel than through the usual skinny one," said Majeski.

But why does lithium have such a big effect on the plasma? Majeski explained, "When the plasma hits the solid wall of a conventional tokamak, some of its particles are neutralized. These cool particles reenter the plasma where they are re-ionized. This "recycling" cools the plasma edge. With a lithium boundary, we expect the plasma to hit the shell and stay there, so there will be no recycling. The lithium will soak up the particles at the plasma edge, because lithium loves hydrogen." During CDX-U experiments, PPPL researchers produced a 50 percent recycling coefficient, the lowest of any magnetically confined plasma. This means that only 50 percent of the particles escaping the plasma reentered it. TFTR's lowest recycling coefficient was 70 percent. Without edge cooling, researchers expect uniformity in the plasma temperature and therefore a fatter current profile. In a fusion reactor, this would mean that the whole plasma could participate in the reaction, not just its hot core. An important added bonus is the fact that lithium absorbs impurity elements such as carbon and oxygen that can enter the plasma from the wall and cool it.

The decrease in the plasma temperature between its core and its edge — the temperature gradient experienced in conventional tokamaks — causes instabilities detrimental to performance. The loss of plasma confinement from these instabilities should disappear in LTX. Furthermore, without recycling, researchers will have external control over where particles enter the plasma. For example, they can choose the size and velocity of pellets of frozen hydrogen or deuterium injected into the plasma. This will determine how far the pellets can go before they vaporize, and enable physicists to study particle transport to a far greater extent in LTX than ever before possible.

Applying Lithium

To prepare for LTX experiments, physicists developed different ways to coat the inside walls of CDX-U with lithium. They utilized a toroidal tray of liquid lithium situated at the bottom of the plasma. The most obvious technique was to simply heat the tray above the 400 degrees Celsius required for lithium evaporation. To improve wall coverage, they tried heating the lithium with an electron beam (e-beam). It provided roughly a kilowatt and a half of power on a spot about six millimeters across — amounting to a power density of 50 megawatts per square meter. The duration of this intense e-beam was 240 seconds, comparable to the plasma lifetime in ITER, the international fusion project scheduled to operate in 2016.

Said Kaita, "The heat loads delivered were more than those expected at the plasma contact region in ITER. We thought this enormous, localized power would quickly heat

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Hotline

Editor/Writer:	**Patti Wieser**	**Graphic Artist:**	**Greg Czechowicz**
Photographer:	**Elle Starkman**	**Layout:**	**Patti Wieser**

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the lithium immediately under the beam and evaporate it. Surprisingly, we observed evaporation only after all of the lithium in the tray was liquefied and its entire volume exceeded the evaporation temperature. We took motion pictures with visible and infrared cameras that showed all of the lithium swirling rapidly. Evidently the intense heat of the e-beam was quickly distributed much the same way stirring makes all the soup in a pot reach the same temperature. This 'self-stirring' is thought to be driven by either thermal or electromagnetic forces, but the cause is still under investigation."

Another technique for coating lithium is one developed by PPPL's Dennis Mansfield. It consists of a can of lithium that is heated resistively and sprays lithium around the machine. This method was successfully tested in CDX-U. Researchers plan to compare the e-beam and the resistively heated can in LTX. The e-beam will enter from the top of the shell and focus on a small lithium spot at the bottom of the shell. Eventually there could be as many as four e-beams in LTX. The resistively heated can could be deployed at two locations through opposite ports on the mid-plane of the device.

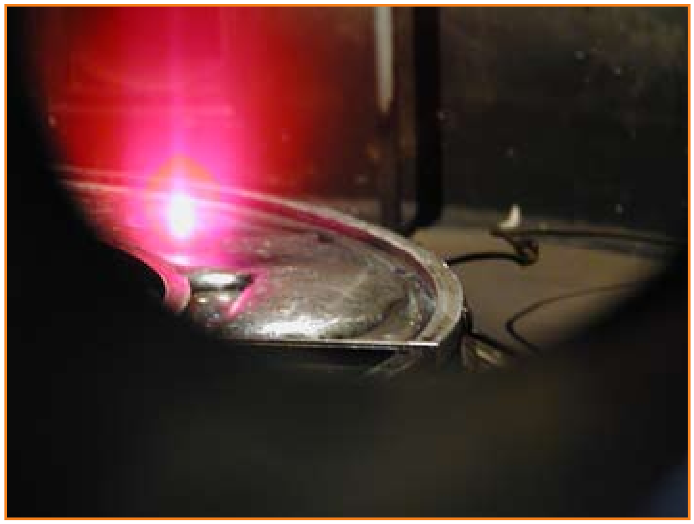
The molten lithium coating on the LTX shell will only be a few ten-thousandths of a millimeter thick, light enough to be held in place by its own surface tension. The LTX team will have the option of recoating the shell after each shot, or after several shots. Good results have been observed in CDX-U with the deposition of 100 or 200 Angstroms (1 A = 10^{-7} mm) of lithium between every shot. The thickness was measured by a quartz crystal deposition monitor — a little crystal oscillator that changes its frequency depending on the weight it supports.

Future Experiments

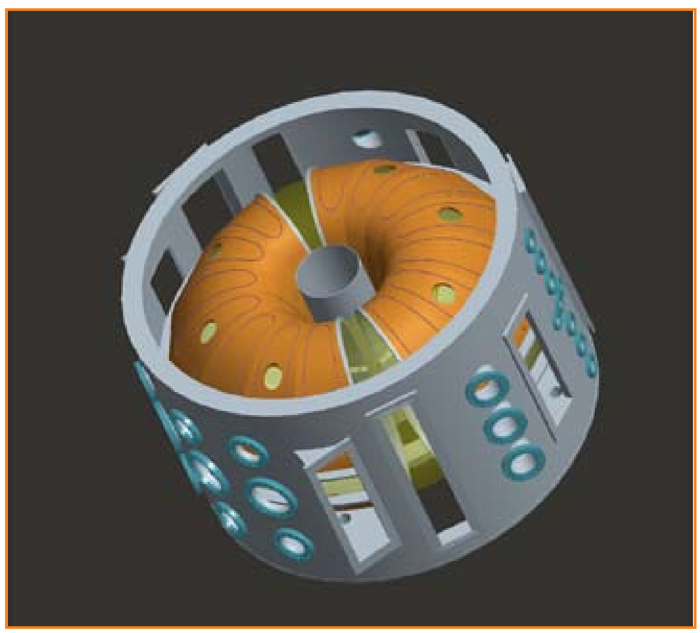
After the initial year of operation, LTX will cease experiments to allow various upgrades. As noted, LTX will afford greater control over how and where particles enter the plasma, so improved studies of particle transport will be possible. For this reason, a pellet injector will be added to LTX for the second phase of experiments, planned to begin in 2008. The injector will permit particles to be deposited at specific locations, for example at the core of the plasma, so that their movement can be observed. The injector will also be used to fuel the plasma with the same kind of particle deposition control. Researchers also plan to clean the LTX shell and install a new pair of poloidal field coils. The existing set is not sufficient to hold the plasma equilibrium with the higher plasma currents expected during the second phase.

In addition, LTX will be fitted with a new shell whose inner surface has been sprayed with a thin coating of porous molybdenum prior to the 2008 run. Physicists believe that molybdenum will act like a sponge, soaking up the lithium and allowing greater amounts to be held on the shell surface.

In addition to Bob Kaita and Dick Majeski, LTX co-investigators include PPPL's Leonid Zakharov and Sergei Krasheninnikov of the University of California, San Diego (UCSD). Oak Ridge National Laboratory's Larry Baylor, Rajesh Maingi, and M. Gouge are developing the LTX pellet injector. Other staff from PPPL, UCSD, Lawrence Livermore National Laboratory, Johns Hopkins University, Sandia National Laboratory, and the University of Illinois at Champaign-Urbana, are also participating. ●



Above is an electron beam striking the lithium in the toroidal tray in CDX-U.



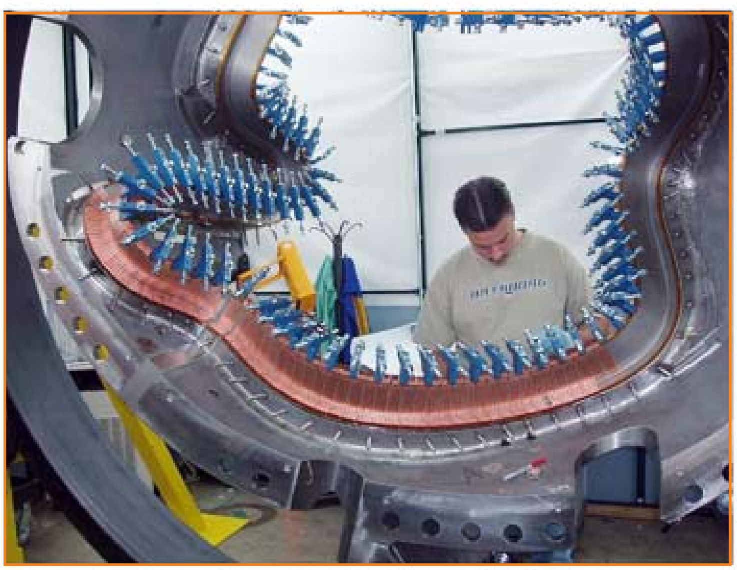
Above is a computer-generated drawing of the LTX shell inside the former CDX-U vacuum vessel.

First NCSX Modular Coil Winding Form Rolls into PPPL

The first modular coil winding form for the National Compact Stellarator Experiment (NCSX) arrived at PPPL on October 3 — a major achievement for the project. Energy Industries of Ohio, which manufactured the form, shipped the three-ton component following a favorable review of the inspection data by the NCSX engineering team. After its arrival, the part was moved into the modular coil manufacturing facility at D-site, where PPPL's coil team immediately began constructing the first NCSX modular coil. They made detailed measurements of the winding form dimensions and began installing the remaining parts of the coil assembly. NCSX Project Head Hutch Neilson called the first form, "a thing of beauty."●

Photos by Jim Chrzanowski and Elle Starkman
Layout by Elle Starkman

(Top) The modular coil winding form, wrapped in black, is driven through the front gate at PPPL. (Bottom, left) The driver makes his way, with the form in tow, to D-site. (Bottom, right) After being safely unloaded, the form rests at the NCSX Coil Winding Facility at D-site during the uncrating and inspection process.



(Top, left) PPPL's Buddy Kearns and Mike Anderson prepare to lift the form out of the crate. (Top, right) Staff uncrate the form. (Bottom, left) PPPL's Mike Anderson installs modular coil parts on the winding form. (Bottom, right) The form after being mounted in PPPL's winding fixture.

Tang

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and carried out his dissertation research at the Lawrence Livermore National Laboratory. By 1979, he advanced to the Principal Research Physicist rank at PPPL and Lecturer with Rank of Professor in Princeton University's Department of Astrophysical Sciences, and also became a Fellow of the American Physical Society.

Tang served as Head of the PPPL Theory Department from 1992 through 2004, leading the establishment of highly productive close working relationships not only between theory and experimental projects within PPPL, but also with international and national plasma physics institutions. Under his leadership, theoretical research at PPPL was diversified into non-fusion areas — especially high-performance computing activities. He also played a prominent leadership role for the Department of Energy's development of its multi-disciplinary program in advanced scientific computing applications, Scientific Discovery through Advanced Computing, known as SciDAC. He is presently the Director of the Plasma Science Advanced Computing Institute for DOE's Fusion Energy Sciences Program.

Tang has more than 200 publications, and has presented more than 40 invited talks at major conferences and prominent venues. He also has contributed strongly to teaching and research training in Princeton University's Department of Astrophysical Sciences for more than 20 years and has supervised numerous successful Ph.D. students who have gone on to highly productive scientific careers. Examples include recipients of the Presidential Early Career Award for Scientists and Engineers in 2000 and in 2005. ●

PPPL Cafeteria Manager Helps Hurricane Victims

PPPL Cafeteria Manager Ron Goley recently went from preparing breakfast and lunch for 400 to joining a team that made breakfast, lunch, and dinner for up to 4,500 people a day.

Goley spent September 18-30 serving victims of Hurricane Katrina at a tent city in Gulf Port, Miss. "I would start at 4 a.m. and wouldn't leave until 8 p.m. every night. I'd take a shower using recycled water, go to bed, and start all over again," said Goley. "I was in constant motion."

He joined a team of other volunteers and Eurest staff at the site. Goley donated one week of his vacation time working at the site and one week being paid his usual salary, which was split by Eurest and Bell South. Eurest is the contractor for cafeteria services at PPPL.

"Victims were elated that we were there, but their dignity was shot. It was about a month after the hurricane and they seemed like they were destroyed," Goley said, describing the scene. In the tent city, there was row after row of tents and RVs. Scattered along the highway were donated clothes for people to pick through for what they needed. "At the tent city, no children were playing. There was no sound of laughter. It was sad. It seemed deserted. Very solemn."

He said after 12 days, he felt burned out, emotionally as well as physically. The cooking crew stayed in tents and RVs, and cooked in tents, which they felt lucky to have air-conditioned. Goley said the chefs tried to make the best food they could. For breakfast, the PPPL chef would fry up ham, pancakes, eggs, and sausages. "We were feeding between 2,500 and 4,500 each day who were staying at the tent city, plus we made dinners to go for another 800 to 1,000 people from outside the site," he said. Dinner, he added, was served from 6 p.m. to 9:30 p.m. because there were so many people who needed to be fed.

Some of the roads were good, but many bridges were out. "While we were down there, Hurricane Rita was coming through. One day we saw three funnel clouds forming. I'd never seen anything like that. We had to break everything down in case we got hit," he said. There was nowhere to go for safety except to lay flat in the woods nearby. Luckily, the area escaped being hit by Rita.

PPPL Cafeteria Manager Ron Goley (standing, third from left) takes a break with the other chefs volunteering at the Gulf Port tent city.

There were glimmers of hope throughout Goley's stay. Everyone was thankful for the food and the help. And one small child — a boy — stuck out amid the desperation. He had been born with no arms and one leg shorter than the other, and now was a victim of the hurricane. "Despite everything, he still kept jumping around like a regular kid, happy. He was an inspiration," said Goley.

Would Goley do it again? "Yes, because of the reaction of the people." He also learned a valuable lesson. "Don't take things for granted," he added.

Goley went to the tent city after responding to an e-mail Eurest had sent to staff asking if anyone wanted to help out at one of the devastated areas hit by Hurricane Katrina. "I thought: I'm not a rich man and I can't give a lot of money, but I could give what I know how to do best," he said. ●

Grad Student Ferraro Mingles with Nobel Laureates at Summer Meeting in Germany

This summer, Princeton University graduate student Nathaniel Ferraro met Nobel laureate after Nobel laureate. And he learned what many attributed their award-winning discoveries to: perseverance, hard work, and a bit of luck.

Ferraro joined several hundred other students from across the globe at the 55th Meeting of Nobel Laureates in Lindau, Germany, this summer. He was one of 61 U.S. student participants at the meeting, held June 26 to July 1. Ferraro had been nominated by PPPL and Princeton University, and sponsored by the U.S. Department of Energy, to be part of the U.S. student delegation.

"I did get to meet a lot of the Nobel laureates, and they were easy to talk to," said Ferraro. "All the students felt privileged to be in that situation."

This year's meeting was interdisciplinary, departing from the traditional rotation of physics, chemistry, and physiology or medicine to include all of the disciplines to reflect a general trend in natural sciences.

"I didn't know I was being nominated. The day of the submission, I was asked to do an essay by 5 p.m. about what I would gain by being given the opportunity to meet Nobel Prize winners," said the third-year graduate student at Princeton. "I said it would be a good opportunity to learn how to become a good scientist and what kind of a mindset they had that led them to make their discoveries."

The meeting included open discussions, receptions, and dinner with laureates and other students, as well as lectures and panel discussion by the Nobel winners.

According to Ferraro, one Nobel winner noted that his fellow laureates are like everyone else — some are really smart and others are not. "Ivar Giaever, who won the physics prize in 1973, said, 'Nobel laureates are like the rest of the world — some are smart, some are average and some are dumb,'" recalled Ferraro.

Ferraro said laureates he met and listened to seemed to share two things — tenacity and serendipity. Said Ferraro, "What I learned is that there's a good deal of luck involved in making discoveries that lead to winning a Nobel, but there is also much hard work involved." He added of the intelligence range comment, "The laureates I talked to all seemed pretty smart."

Nathaniel Ferraro

Ferraro, who is working with PPPL's Steve Jardin on numerical simulations, and earlier worked on the spectroscopic measurement of electron temperatures in Sam Cohen's Field Reversed Configuration device at PPPL, said he spent mornings listening to lectures, afternoons in small discussion groups led by a Nobel winner, and nights either at organized dinners or informal get-togethers with other students.

"It was a great, unique experience. While Princeton University has many Nobel Prize winners, students don't really get the chance to meet them all together," he said, noting the largest thing he learned through the experience. "You can't predict where a new discovery will come from."●

Thank You

To my PPPL and DOE Princeton Site Office Family,

*On behalf of the MacTaggart family, I wish to thank all who gave words, cards of sympathy or visitation to us during the loss of our mother. It is great to know that you are surrounded by so many friends during such a time of need. Thank you. — **James D. MacTaggart***

PPPL Responds to a National Energy Emergency

The United States government has been responding to the aftermath of Hurricanes Katrina and Rita. A key component of the government's overall commitment to alleviate the resulting energy supply disruptions is to improve energy conservation at federal facilities. On September 26, President Bush issued a directive to the heads of executive departments and agencies to take actions to conserve natural gas, electricity, gasoline, and diesel fuel at their facilities. Since PPPL is a federally funded, Department of Energy facility, the Laboratory falls under this directive. There is special concern for the period of November 1st through April 30th due to the winter heating season.

With possible energy shortages this winter, the federal government must lead by example by reducing its own energy use, particularly in regions where electricity and natural gas shortages may occur and during periods of high energy consumption. Such conservation and energy efficiency improvements will save public money, protect the environment, and help to minimize shortages.

Besides the impact on the supply of fuel across the country, there has also been a marked increase in the cost of energy.

"At PPPL, we estimate that our boiler room fuel costs will increase 45 percent over last year, from a cost of $450,000 to $650,000, if we consume the same amount of fuel as last heating season," said PPPL Pollution Prevention-Energy Coordinator Thomas J. McGeachen.

The chart at the bottom of the page shows the rising cost of electricity paid by PPPL. "We have seen even more dramatic increases in the cost of natural gas, which is our primary fuel for heating the Laboratory," McGeachen noted.

He stressed that PPPL must save as much energy as possible during Fiscal Year 2006, which began October 1. "We have set a target of reducing our energy consumption by 5 percent during the next six months. We can succeed in this effort, if everyone pulls together," McGeachen said. "We are all in this together — we can save now or pay later!"

To reach this goal, PPPL is implementing the following:

- The Maintenance Division is closely examining the operation and maintenance of operating equipment and the central steam plant and distribution system for maximum efficiency.
- The Laboratory will be lowering building heating in all possible areas during the upcoming winter to 68-70°F during regular working hours and 55°F for unoccupied time and weekends. The staff is encouraged to dress accordingly and to avoid using electric space heaters.
- The Laboratory will begin a driver education campaign focused on fuel efficiency.
- The Laboratory will reduce fleet vehicle fuel usage.
- Everyone is encouraged to temporarily curtail non-essential travel and other non-essential activities that use gasoline or diesel fuel.
- Employees are encouraged to consider carpooling to reduce fuel use. A carpool coordination service has been established in the Human Resources area.

On Thursday, November 3, McGeachen is scheduled to present a brown-bag lunch titled, "How You Can Save Energy at Your Home This Winter and All Year," in the Training Room, S-213 at 11:30 a.m.

If you notice any situations or equipment problems that may result in inefficient use of energy, please submit an electronic work order to the Maintenance Division via the PPPL Homepage by using http://bones.pppl.gov/xmWEB/. Also, please contact Tom McGeachen at ext. 2948 or Shawn Connolly at ext. 3182 if you have any suggestions about saving energy at PPPL. ●