Search go!

DOE Pulse
Science and Technology Highlights from the DOE National Laboratories

home about archives subscribe

Number 408 | March 3, 2014

Celebrating the 20th anniversary of the tritium shot heard around the world

PPPL staffers monitor a closed-circuit screen during the historic 1993 experiment.

Tensions rose in the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) as the seconds counted down. At stake was the first crucial test of a high-powered mixture of fuel for producing fusion energy. As the control-room clock reached "zero," a flash of light on a closed-circuit television monitor marked a historic achievement: A world-record burst of more than 3 million watts of fusion energy — enough to momentarily light some 3,000 homes — fueled by the new high-powered mixture. The time was 11:08 p.m. on Thursday, Dec. 9, 1993.

"There was a tremendous amount of cheering and clapping," recalled PPPL physicist Rich Hawryluk, who headed the Tokamak Fusion Test Reactor (TFTR), the huge magnetic fusion facility — or tokamak — that produced the historic power. "People had been on pins and needles for a long time and finally it all came together." It did so again the very next day when TFTR shattered the mark by creating more than six million watts of fusion energy.

The achievements generated headlines around the world and laid the foundation for the development of fusion energy in facilities such as ITER, the vast international experiment being built in France to demonstrate the feasibility of fusion power. The results delivered "important scientific confirmation of the path we are taking toward ITER," said physicist Ed Synakowski, a PPPL diagnostics expert during the experiments and now associate director of the Office of Science for Fusion Energy Sciences at DOE. "I felt an important shift in the understanding of fusion's likely reality with those experiments."

The breakthroughs proved the practicality of combining equal amounts of the hydrogen isotopes deuterium and its radioactive cousin tritium — the same combination that will be used in ITER and future fusion power plants — to form the superhot, charged plasma gas that fuels fusion reactions. The deuterium-tritium (D-T) mix produced some 150 times more power than a reaction fueled solely by deuterium, long the stand-alone ingredient in tokamak experiments, or "shots."

"This was the first test with equal parts D-T and it was technically quite challenging," said Michael Zarnstorff, a task-force leader during the experiments and now deputy director for research at PPPL. "What we did marked a huge advance in integrating tritium into fusion facilities."

Gained insights included precise measurement of the confinement and loss of alpha particles that fusion reactions release along with energetic neutrons. Good confinement of the alpha particles is critically important since they are to serve as the primary means of heating the plasma in ITER, and thereby producing a self-sustaining fusion reaction, or "burning plasma."

Exciting journey

The historic shots capped years of intense preparation for tritium operations, which ran until TFTR was decommissioned in 1997 after setting more records and producing reams of new knowledge. "The journey to tritium was at least as exciting as the first experiments," said former PPPL Director Ronald Davidson, who led the Laboratory during the tritium years. "It was an enormous technical undertaking and one of my greatest elements of pride in the PPPL staff was that the preparations were so good and so thorough that the tritium shots were successful early on in the D-T campaign."

The preparations mobilized physicists, engineers and staffers throughout the Laboratory. "The absolute top priority was to demonstrate that one could carry out the tritium experiments safely," said former Deputy Director Dale Meade. "Everyone focused on this mission as we went through a step-by-step construction and checkout of the tritium systems with rigorous adherence to procedures and strong oversight by DOE."

Leaders of this effort included Jerry Levine, now head of the Environment, Safety, Health & Security Department at PPPL, and John DeLooper, who heads the Best Practices and Outreach Department. Levine's team launched an environmental assessment under the National Environmental Policy Act in 1989 and received DOE and state approval in 1992. "The purpose was to show that there would be no significant environmental impact as a result of tritium operations," Levine noted. DeLooper's team double-checked everything from operator training to preparations for storing and moving the tritium gas, which subsequently arrived in stainless steel containers from the Savannah River National Laboratory in South Carolina.

In the towering TFTR test cell, engineers readied the three-story high, 695-ton tokamak to operate with tritium. Key tasks included adding more shielding, checking all major systems against possible failures and ensuring that every diagnostic device worked. "The major challenge was to bring everything on line so that

HIGHLIGHTS

- PNNL offers 'virtual tour' of Shallow Underground Laboratory
- Pond-dwelling powerhouse's genome points to its biofuel potential
- NREL database WILD about cataloging wildlife's interaction with wind energy
- ORNL microscopy system delivers real-time view of battery electrochemistry
- *Profile* - Following through: Mechanical engineer leaves links for nuclear research
- *Feature* - Celebrating the 20th anniversary of the tritium shot heard around the world

failures didn't happen," said Mike Williams, the head of engineering at PPPL and also deputy head of TFTR at the time.

Yet nothing could be certain until the experiment began. "The whole world was going to show up and we had lots of opportunity to fall on our faces," said engineer Tim Stevenson, who headed the neutral beam operations that heated the plasma to temperatures of more than 100 million degrees centigrade during the shots. "All the instruments were tuned up," Stevenson said, "but we still had to play the symphony."

Keeping the local community informed was another high-priority. PPPL leaders held open houses, met with local executives and government officials and conducted two public hearings before the arrival of tritium. Attendees at one hearing included a local college class that arrived at the urging of its professor.

Scientists from around the world

By the day of December 9, press coverage and Laboratory outreach had made PPPL a focus of attention. "Scientists from around the world flew in to witness the experiment," recalled Rich Hawryluk. More than 100 local visitors flocked to the PPPL auditorium, where a closed-circuit TV feed displayed the control room and Ron Davidson and Dale Meade briefed the audience on unfolding developments. PPPL staffers and their families crowded around the viewing area that overlooked the control room.

Reporters from several major newspapers covered the event. Also there was Mark Levenson, a reporter from New Jersey public TV station NJN whom the Lab hired to produce a video that subsequently received worldwide exposure.

The source of all this excitement was surprisingly small: Just six-millionths of a gram of tritium was consumed that night in the shot that made global news. "Such tiny amounts generate huge energy because of the formula E = mc2" explained Charles Gentile, the head of tritium systems at PPPL. The celebrated Einstein equation states that the amount of energy in a body equals the mass of that body times the speed of light squared — an enormous number since light travels at 186,000 miles per second.

The media seemed as eager as the scientists to watch the famed formula work. "The press people were enormously excited," said now-retired physicist Ken Young, who headed the PPPL diagnostics department and led efforts to measure the confinement and loss of alpha particles during the experiments. "These reporters were seeing science as it happens and kept waiting for the shot."

Also anxiously waiting were more than 100 scientists, engineers and invited guests inside the control room, which normally held about 40 people. All sported red passes that the Laboratory gave to PPPL staffers and guests from DOE and institutions that collaborated on TFTR. "Everybody who could be in there was in there," recalled Forrest Jobes, a now-retired physicist who kept those in the rear of the L-shaped room abreast of what was happening.

Calling the shots

Up front, physicist Jim Strachan was too intent on his job to be caught up in the exuberance. His task was literally to call the shots — to decide how much heating power to use, for example, and when to start the countdown. "Everyone in the group was out to get the most D-T power from reproducible shots," the now-retired Strachan recalled. "I felt a lot of responsibility and didn't want to foul up."

All eyes followed a closed-circuit TV monitor that displayed a neutron-sensitive scintillator screen in the TFTR test cell that glowed when struck by the neutrons that a D-T shot produced. Artfully covering this test-cell screen was a cardboard poster — designed by PPPL graphic artist Gregory Czechowicz at the behest of Dale Meade — with holes cut into the shape of a light bulb and letters spelling "Fusion Power." Engineer George Renda designed the scintillator itself. A flash of light from the bulb and the letters in the 3-foot-by-3-foot poster that covered the screen signaled a successful shot. "We came to really count on that image," said Ed Synakowski. "No need to wait for the computer system to process the data."

But there still was plenty of waiting while a series of hardware glitches dragged out the schedule. "Many people in the audience thought we were doing this intentionally to increase the suspense," Meade recalled.

By 11 p.m. the problems were solved — setting the stage for the record-breaking shot at 11:08 signaled by the brightly lit light bulb and "Fusion Power" sign on the TV monitor. The control room erupted in jubilation over the shot, which produced 3.8 million watts of power. The excitement reached even the normally staid control-room log, where an operator noted the historic event with the exclamation, "EEYAH"!

On that high note the experiments ended and the control room opened for press interviews. NJN reporter Levenson returned to his studio to assemble a video news release that he uploaded to a satellite for worldwide distribution, sending the piece off at about 4 a.m. Key parts of the footage — including the control-room jubilation — were shown on nationwide newscasts the following evening.

Looking back at these events, Hawryluk reflected on the sense of excitement, anticipation and relief that came with them. "We had worked so hard to finally get to that stage and we had done it," he said. "That night on December 9 established a research capability that has enabled us to pursue a whole host of opportunities to advance the development of fusion energy."

Submitted by DOE's Princeton Plasma Physics Laboratory