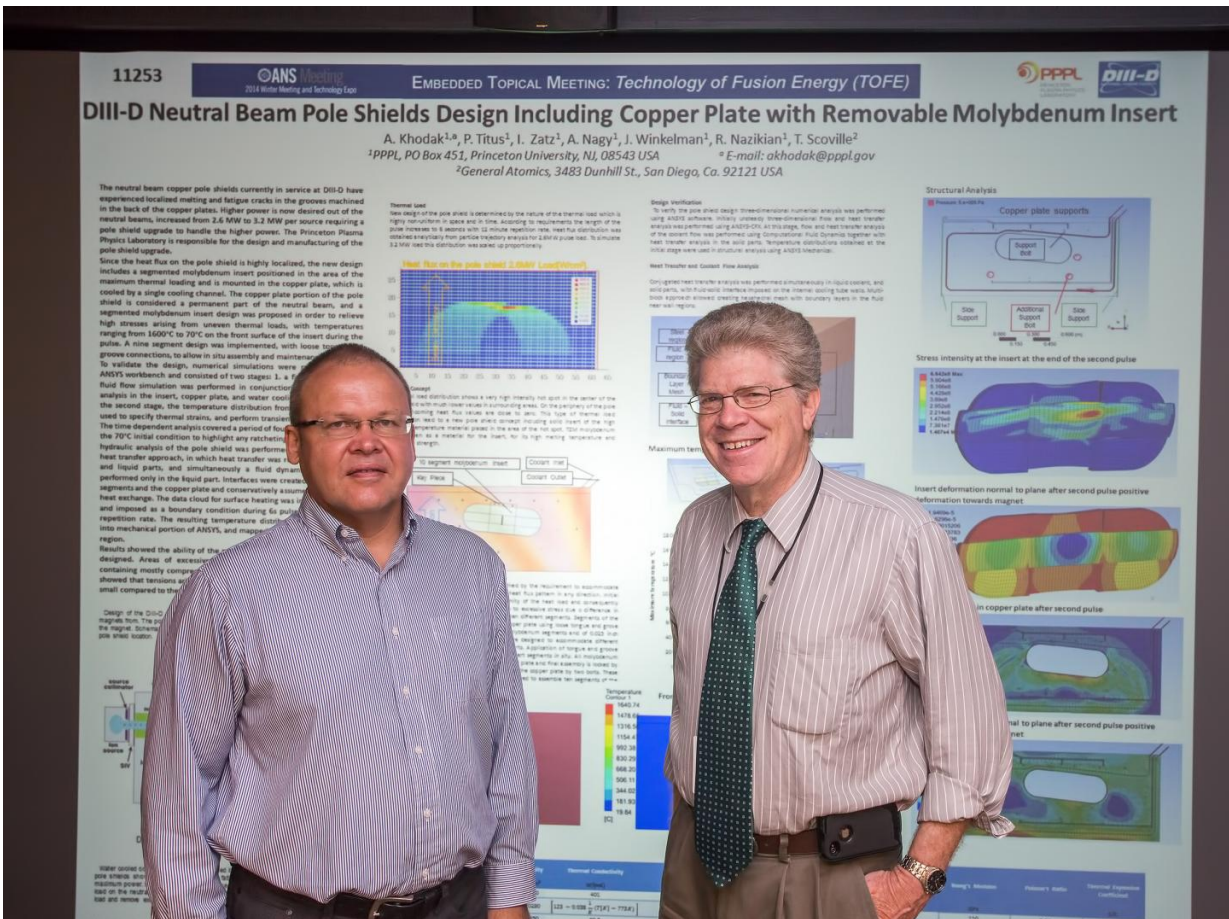


Engineers deliver new key components to help power a fusion energy experiment

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Engineers Andrei Khodak and Irving Zatz with poster for pole shields. Credit: Elle Starkman/Office of Communications PPPL

Fusion power, which lights the sun and stars, requires temperatures of

millions of degrees to fuse the particles inside plasma, a soup of charged gas that fuels fusion reactions. Here on Earth, scientists developing fusion as a safe, clean and abundant source of energy must produce temperatures hotter than the core of the sun in doughnut-shaped facilities called tokamaks. Much of the power needed to reach these temperatures comes from high-energy beams that physicists pump into the plasma through devices known as neutral beam injectors.

At the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL), engineers recently designed and delivered a set of innovative new components for the neutral [beam](#) injectors that heat plasma in the DIII-D National Fusion Facility, the tokamak that General Atomics operates for DOE in San Diego.

The redesigned parts, called pole shields, protect magnets in the injectors from the energetic particles from the beam and will replace units that melted and cracked during previous fusion experiments, resulting in water leaks. The magnets redirect charged atomic nuclei, or ions, in the beams to an ion dump inside the injectors, permitting only neutral atoms to enter into the plasma.

"They had a problem that needed fixing. In the end, we came up with a solution that solved the problem," said PPPL engineer Irving Zatz, who oversaw the design, analysis and delivery of the shields. He teamed with engineers Andrei Khodak, who ran computer analyses to verify the new design, and Alex Nagy, who heads PPPL engineering collaborations on DIII-D. Support for this work comes from the DOE Office of Fusion Energy Sciences.

The new units are similar to shields that PPPL delivered to DIII-D for installation on the first of the facility's four injectors in 2014. Following months of use of those shields, "inspection results showed no signs of wear or damage," Nagy said.

Withstand higher heat loads

The new design will withstand the sharply increased heat loads that the injectors are scheduled to produce. Plans call for an upgrade in the injector's maximum power from 2.6 megawatts in three-second pulses to 3.2 megawatts in pulses that will last twice as long.

The new shields consist of half-inch thick, roughly five-foot long copper plates equipped with inserts of the hard, silvery metal molybdenum in the center of the plates, the area that will absorb the most energy from the beam. The inserts, which resist melting at high temperatures, are a key design innovation originally proposed by General Atomics' Tim Scoville, the head of neutral beam operations at DIII-D.

Each new shield contains 10 molybdenum plates that are grooved together like a puzzle, with a copper key piece holding them in place. This setup will accommodate different degrees of heat expansion and other conditions, and will enable the molybdenum tiles to be easily disassembled and replaced, without injector disassembly.

Khodak used a software code to examine how the shields stood up to factors ranging from the distribution of [heat loads](#) to the stresses in the copper and molybdenum that greater power will exert. Results showed that the design met or exceeded all performance requirements.

"The original, all-copper plates typically fail after about five year of service," Nagy said. "The life of the new pole shield design is unknown, but should significantly increase the time to failure for this critical component. The difference between the old and new shields is like comparing old bias-ply tires to new steel-belted radials."

Pole shields are not the only parts that PPPL is upgrading on the DIII-D neutral beam injectors. The laboratory has designed new collimators,

which align the neutrals in parallel beams, and calorimeters, which measure heat, for the machines. Fabrication is under way and the components are scheduled for delivery in the fall.

PPPL, on Princeton University's Forrestal Campus in Plainsboro, N.J., is devoted to creating new knowledge about the physics of plasmas—ultra-hot, charged gases—and to developing practical solutions for the creation of fusion energy. The Laboratory is managed by the University for the U.S. Department of Energy's Office of Science, which is the largest single supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov.

Provided by Princeton Plasma Physics Laboratory

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