Tritium introduced in fusion experiments at Sandia

More powerful fuel to boost Z Machine's neutron and energy output

By Neal Singer

TRITIUM SHOT PI DEAN ROVANG checks out Z's tritium gas transfer system (Z-GTS), which was built in Sandia/California and filled with trace tritium (0.1 percent) at Sandia/New Mexico. (Photo by Randy Montoya)

Continuing their attempts to create more intense fusion reactions through use of increasingly powerful electromagnetic fields, Z machine researchers have opened a new chapter in their 20-year journey by introducing tritium, the most neutron-laden isotope of hydrogen, to their targets' fuel.

When Z fires, its huge magnetic fields crush pre-warmed fuel, forcing it to fuse. Tritium-enriched fuel should release much more energy than previous maximums. This would provide more detailed data for nuclear weapons simulations and possibly enter the condition known as "high-yield," where more energy is created than the amount needed to provoke the reaction.

"This thing about creating energy where none existed before — we don't yet have a bonfire, but we're squirting starter on the grill," says Mike Cuneo, project manager and senior manager of Pulsed Power Accelerator S&T (1650).

The output of Sandia's Z machine has been used over decades to provide information for computer simulations that test the readiness of America's nuclear stockpile without exploding an actual weapon. It's also used by astrophysicists using the machine's momentarily astounding pressures and temperatures to understand conditions in stars and the cores of planets. And some hope that pressures created mainly by electricity and magnetism one day may reach nuclear fusion conditions suitable for energy production.

The introduction of tritium is of high technical interest because a 50/50 mix of tritium and deuterium — the two isotopes of hydrogen — emits 80 times more neutrons, and 500 times more energy, than deuterium alone. It's a lot to look forward to. Energy from deuterium — in a manner of speaking, a relatively low-octane fuel — has been the upper limit on output at Z.

Cautiously introducing tritium

But this is still an early stage. A dry run on July 12, testing containment hardware and instrumentation, preceded Z's first tritium experiment on Aug. 3, when a fraction of a percent was cautiously introduced into the experiment's fuel.

"We're going to crawl before we walk and run," says Mike. "We will gradually increase that fraction in contained experiments as we go."

Only two other DOE-supported research sites, at Lawrence Livermore National Laboratory and the Laboratory for Laser Energetics at the University of Rochester, had been approved to use tritium, a potential environmental hazard. That's because, says Mike, their method uses lasers to compress spherical targets the size of a thimble in chambers relatively easy to clean.

The Sandia experiments use electromagnetics to smash Z's more massive target and its entire target support area like they were hit by a sledgehammer. Under those conditions, introducing tritium into the target requires extreme care and forethought in the design, transport, and containment of tritium to meet rigorous safety standards.

"Tritium's like sand at the beach, it gets into everything," says Mike. "So for now, we can't let it go anywhere." The isotope is a small molecule with a lot of mobility, and the first big hurdle, he says, is to make sure the radioactive material with its 12-year half-life doesn't migrate to the million-gallon pools of water and oil that insulate Z's pulsed power components. "Laser facilities don't have these pools," he points out.

Tritium could also bond to the metal walls of Z's central area, presenting a potential radioactive hazard where technicians enter daily to scrub after each shot.

However, using the same unique design that has contained plutonium on previous Z shots, no tritium was released. Through a Hostile Environments LDRD Grand Challenge, led by Pat Griffin (1300), researchers brought in people from a variety of organizations to handle each complex detail.

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Building on decades of experience

"There was a high level of integration on facility containment and radiation protection, to do it right," says Brent Jones, manager of Neutron and Particle Diagnostics (1677) and facility integration lead. "The Sandia-California gas transfer group, with decades of experience dealing with tritium, developed a method of housing, delivering, and containing the material. They built a device that could load a small but defined quantity of tritium; the neutron generator people filled the target with tritium; the plutonium confinement folks contributed their shot expertise, and the Grand Challenge enabled us to build what we needed and pull in people from all over the Labs.

"Dean Rovang (1688), tritium project lead, has put together an amazing team through the Hostile Environments Grand Challenge LDRD effort to apply critical thinking and to engineer mitigations that enable us to take this step. It wouldn't have been possible without the support of the Neutron Generator Analytical Lab (Jessica Bierner, Henry Peebles, both 2026, et al.) which is providing the tritium and helping to implement tritium measurements at Z, and the Sandia/California gas transfer team (Dorian Balch 8241 et al.) who have engineered, tested, and delivered the gas fill system for Z. Then Radiation Protection and all of the Z support teams took the final steps to execute the experiment."

"Joel Lash, senior manager of Z research and development (1670), played an important role in ensuring the trace tritium experiment was done to principles of engineered safety. He also engaged with our DOE partners well in advance," says Mike.

For others who helped, see box below.

First step on a journey

The team now must evaluate whether tritium can be used safely in uncontained experiments, its ultimate goal. Confined tests can evaluate the compatibility of tritium with Z's materials and pressures, but don't accurately measure fusion outputs.

"The use of contained tritium on Z is the first step on this journey," says Mike. "There is much more work to do.

"One idea [for an uncontained experiment] is to purge the tritium immediately after a shot so that it doesn't stick to the walls of the Z chamber," says Mike. "We need to be able to efficiently purge the center section back to a safe level before technicians enter to refurbish it."

Uncontained experiments, he says, will begin with very small levels of tritium and gradually ramp up in a several-year process. "We hope to find that we will able to safely handle 1-3 percent tritium in uncontained experiments, enough to advance Inertial Confinement Fusion applications, other weapons science applications, and neutron effects testing."

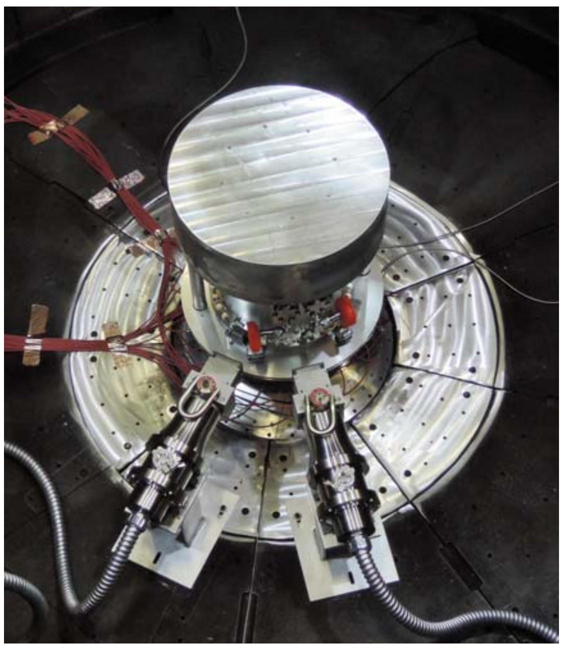
In addition to careful handling of tritium to promote radiation safety, other areas of concern are the Z facility's neutron limit authorization and post-shot activation generated by neutron emissions that might make Z components themselves radioactive.

A path to safe uncontained experiments

"But in our containment experiments over the last few months," says Mike, "it looks like 97 percent of the post-shot inventory is the tritium molecule T_2 rather than triated water, T_2O. T_2 is 10,000 times less hazardous than T_2O to personnel. This provides some confidence that there is a path to safe uncontained experiments."

Another concern is personnel radiation safety from larger numbers of higher energy neutrons — 14.1 MeV instead of 2.45 MeV. "That is a large concern and we will have to design new methods to shield personnel from neutrons," Mike says.

It will be at least three years before experiments approach 50/50, Mike says, depending on funding and Sandia and NNSA priorities regarding Z. While the work over the last three years has been paid for by the "Hostile Environments on Z" Grand Challenge, work going forward will be funded by the NNSA Science and ICF program.



TWO FAST NEUTRON radiation-effects cassettes aim toward the center of the containment system for tritium within the Z vacuum chamber. The setup's gas transfer system is housed within the containment system.

Only some of the support staff for the tritium experiments

According to lead Brent Jones, "Drew Johnson, Shawn Radovich, et al. supported interface of Z-GTS and ion chamber instrumentation at Z. Members of the containment community have engaged with the tritium effort, particularly Pete Wakeland, Lance Baldwin, Kelly Seals, and Jeff Gluth. The gas fill team, Center Section crew, and load hardware team have supported the Z gas transfer system and containment fielding. Terrence Bock has facilitated vacuum activities. Aaron Edens has worked extensively on concept of operations and shot timeline planning. Shawn Howry has stepped in to help with Technical Work Document review, and Heidi Herrera helped earlier with an FMEA exercise. I would also like to thank Z facility management for engaging closely in the planning and supporting the work, especially Hazel Barclay, Michael Jones, Ryan Kamm, and Randy McKee.

In sum, nearly 100 people — more than Lab News can easily name — contributed directly to the effort to field the first tritium experiment on Z. They were from Sandia organizations 1300, 1600, 1800, 2100, 2700, 4100, 5400, 8100, and 8200. Also participating were researchers from General Atomics, Los Alamos National Lab, the University of New Mexico, and Utah State University."