Decades of work at Argonne National Laboratory led to pivotal moment for U.S. nuclear plants

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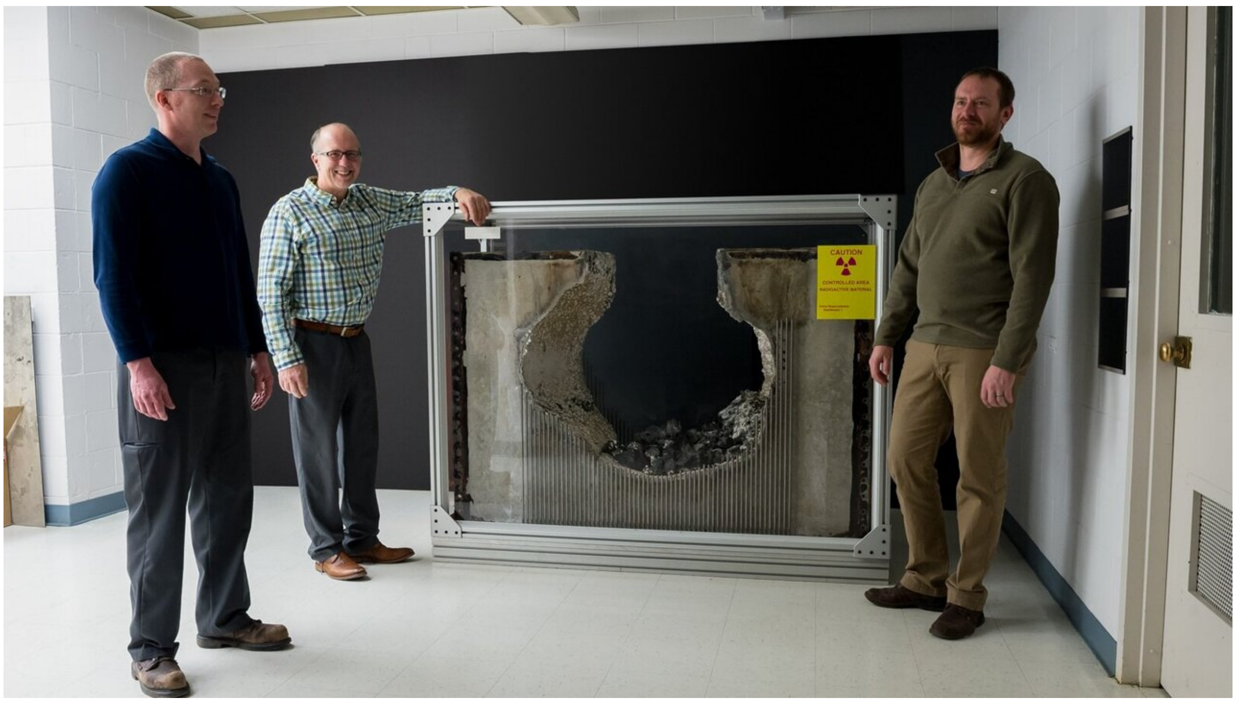

Nathan Bremer, Mitch Farmer (center) and Jeremy Licht (right) highlight a piece of concrete eroded in tests by corium — the lava-like material formed when uranium fuel rods in the reactor core melt, along with their protective metal cladding. The team’s tests helped nuclear plant operators avoid $1 billion in expenses. Not shown: Stephen Lomperski and Dennis Kilsdonk. Credit: Argonne National Laboratory

A few years ago, several nuclear reactors in the United States were facing the possibility of unforeseen shutdowns in the wake of disaster at Japan's Fukushima Daiichi power plant. The 2011 accident prompted worldwide scrutiny of nuclear power safety—especially regarding boiling water reactors, or BWRs.

In the U.S., where BWRs make up nearly a third of the reactors, regulators considered new safety enhancements to avoid another scenario like Fukushima, where an earthquake and tsunami touched off a series of fuel failures that resulted in radioactive leaks. But for BWR operators, some of the new prospective requirements would have meant closure for several reactors and huge costs for the other plants to keep operating.

Eventually, a third path emerged, informed by research conducted at the U.S. Department of Energy's (DOE) Argonne National Laboratory. Data from years of tests at Argonne supported an approach that could both preserve safety and avoid a crippling $1 billion in expenses for plant operators.

Ahead of the safety curve

Nuclear reactors are protected by a steel-lined containment building reinforced with concrete both inside and out. In an accident, the challenge is to prevent corium—the lava-like material formed when uranium fuel rods in the reactor core melt, along with their protective metal cladding—from entering the environment if the corium escapes the reactor vessel and erodes the concrete floor below. At the Fukushima Daiichi plants, this sort of event is thought to have contributed to the escape of highly radioactive material that contaminated nearby soil and leaked into the Pacific Ocean.

Nuclear plant operators needed a way to ensure that radioactive releases would be minimized to protect people and the environment in the event of an accident. One option involved installing large filters on the vents for these plants, a solution so costly—up to $50 million per plant—that in some cases a plant shutdown would have been more practical.

As an industry team known as the BWR Owners Group explored how to address these issues, they learned about research that had been under way at Argonne for decades. Staff at the laboratory, which has a long history of nuclear energy science, were also supporting the DOE in their response to the accidents at Daiichi.

Experiments guide path forward

As a response to the 1979 partial meltdown at Pennsylvania's Three Mile Island power plant, Argonne researchers had been simulating the process of a reactor core melting. They studied how the resulting corium interacts with concrete, and how that interaction can be halted by flooding with water. The experiments were some of the largest of their kind in the world, and nuclear energy companies co-sponsored them to support safety improvements at their plants.

"We were basically wrapping this work up, and then the accidents happened at Fukushima Daiichi," said Argonne nuclear engineer Mitch Farmer, who has led severe accident analysis and experiments at the lab since 1988. "At that point, there was a renewed interest in the work we were doing—particularly how it could support the industry's efforts to address the new regulatory requirements."

The U.S. Nuclear Regulatory Commission (NRC) wanted BWR operators to ensure that radioactive releases from a plant during a severe accident could be avoided or made as low as possible.

But Argonne's research had shown that if corium were to migrate outside the reactor vessel, it could effectively be cooled by injecting water through the vessel while keeping radioactive material inside the containment building—an approach that wouldn't require new equipment or modifications to the plants.

The research also helped establish parameters for determining when corium had cooled adequately, another key piece in preventing the confusion seen among plant operators at Fukushima.

"Just as important as cooling corium debris is being able to recognize that you've stabilized it," said Bill Williamson, a reactor engineer specialist at Tennessee Valley Authority's Browns Ferry facility in Alabama who is also an emergency procedure chair for the BWR Owners Group. "Argonne's research helped us understand that what we should look for and what we should expect."

The $1 billion breakthrough

The ability to inform safety strategy with a better understanding of corium interactions was an important breakthrough for both the industry and the country, given that nuclear power plants supply about a fifth of U.S. electricity without producing greenhouse gas emissions.

The Nuclear Energy Institute, an industry trade association, credited Argonne researchers with saving the BWRs overall fleet more than $1 billion in potential modification costs.

"The team at Argonne helped prevent several BWR reactors from being shut down," said Phillip Ellison, a project manager with the BWR Owner's Group (managed by General Electric-Hitachi). "We were able to identify a strategy that worked for both operators and regulators, and the work from Argonne was essential to that."

Work in this area at Argonne has historically been supported by the NRC, the Electric Power Research Institute (EPRI), and U.S. plant operators, as well as international partners. Following the accidents at Daiichi, the technical support that Argonne was able to deliver to industry in addressing evolving regulatory requirements was provided through the Light Water Reactor Sustainability program within DOE's Office of Nuclear Energy. Research in this area continues to be conducted at Argonne under support from the NRC, EPRI, and international partners to further inform plant operators of the best actions that should be taken during a severe accident.

Provided by Argonne National Laboratory