Seaborg, Weinberg, and the molten salt breeder reactor

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Carolyn Krause concludes her series looking at Stan Thompson, Glenn Seaborg, and Alvin Weinberg with this look at the Molten Salt Reactor Experiment. She enlisted the help of Ronnie Borgard, the Weinberg Project lead at the Children's Museum of Oak Ridge. She provides a link at the end of the article for anyone seeking more information. Enjoy a deep dive into history of nuclear power and the political infighting that helped change the course Alvin Weinberg was attempting to set.

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Glenn Seaborg, the co-discoverer of plutonium who won a Nobel Prize in chemistry in 1951, was chairman of the Atomic Energy Commission (AEC) from 1960 to 1971. Shortly before he began his 10-year term, he enthusiastically supported the construction of the High Flux Isotope Reactor at Oak Ridge National Laboratory. The reason: HFIR would produce large quantities of californium-252 that Seaborg's colleagues at the University of California at Berkeley, where he was chancellor, could irradiate in a cyclotron to produce even heavier elements.

"With Glenn's backing, this was an easy sell – and by 1960, ORNL was told to proceed with its most ambitious research reactor," wrote Alvin Weinberg, who was ORNL director in 1960, in his 1994 book "The First Nuclear Era: The Life and Times of a Technological Fixer."

But, during Seaborg's tenure as AEC chairman, the molten salt breeder reactor (MSBR) concept developed at ORNL was not such an easy sell. As Weinberg wrote in his book, "the center of gravity of breeder development moved strongly to the liquid metal fast breeder reactor (LMFBR); the thermal breeder, as represented by the molten-salt reactor project, was left to dwindle and eventually to die."

Many people associated with the AEC, including the members of the Joint Committee on Atomic Energy in the U.S. Congress and the nuclear industry, pushed for federal funding for the LMFBR. Perhaps the most powerful advocate for funding and building an LMFBR was Milton Shaw, the AEC's director of reactor development who had Tennessee connections. Because of Weinberg's strong support for developing molten salt reactors and molten salt breeder reactors (MSBRs), as well as for ORNL researchers' willingness to tell the truth (no matter how negative) in their testimony about the safety of larger light-water nuclear reactors, Shaw played a strong role in getting Weinberg fired from his position as ORNL director in 1973.

Breeder reactors produce more nuclear fuel than they consume. The sodium-cooled LMFBR breeds plutonium while burning enriched uranium, and the MSBR, running on uranium-233 fuel and based on the thorium cycle, would theoretically breed additional uranium-233 through the neutron irradiation of thorium-232 in the reactor's blanket. Thorium is present in most rocks and soil throughout the world.

Seaborg claimed in his 1993 autobiography that he supported the inclusion of both the LMFBR and MSBR in the 1970 budget of President Richard Nixon's administration. He told the Bureau of Budget director that the ORNL team developing the MSBR merited funding support because it might achieve a breakthrough on its inexpensive source of nuclear power.

Seaborg had visited ORNL in 1965 in response to Weinberg's invitation where the Nobelist was photographed at the controls of the lab's Molten Salt Reactor Experiment, the world's first reactor to run on uranium-233 fuel. When Seaborg started the MSRE, he exclaimed, "Wow, it jumped!"

According to his autobiography, after much negotiation and with the knowledge that the MSBR had little industry support, the MSBR almost was cut from the 1970 Nixon budget.

"On November 25, 1969, the AEC and members of its principal staff met with Alvin Weinberg," Seaborg wrote. "Unaware of our negotiations on his behalf two weeks earlier, he had come to plead for greater financial support for the molten salt approach. Learning from us that the project was still alive seemed a relief to Weinberg, but the reduced level was an obvious disappointment."

Seaborg continued: "Not long afterward, in a wide-ranging letter to Joint Committee on Atomic Energy chairman Chet Holifield, Weinberg wrote: 'I believe the country's almost single-minded commitment to fast breeder reactors, and its

corresponding inability to support alternatives, particularly the molten salt breeder, is an error which I hope the Joint Committee can somehow correct in the not-too-distant future.'"

This appeal was unlikely to produce results – nor did it – because the Joint Committee itself had a strong bias in favor of the LMFBR, according to Seaborg. He stated later that he agreed Weinberg was right.

As it turned out, the LMFBR was authorized by the U.S. Congress in 1970, and funds were appropriated to build the Clinch River Breeder Reactor Project at a Tennessee Valley Authority site in Oak Ridge. Westinghouse had the contract to construct the 250-megawatt sodium-cooled breeder. The project was later called "unnecessary and wasteful" (uranium was no longer seen as scarce, and the cost to ensure its safety was deemed too high). So, the Senate terminated the project's funding by a vote of 56 to 40 almost 40 years ago, on Oct. 26, 1983. Earlier this year, TVA announced the CRBRP site as its first location for a small modular reactor as part of its new nuclear program.

Weinberg, who, according to Seaborg, had stated his belief that the breeder "would have to be ranked as of extraordinary importance in the history of mankind, only a little less important than the discovery of fission," wrote in his book that another objection to CRBRP was that the reactor, "with its coupled chemical reprocessing system, lent itself to the clandestine diversion of plutonium for nuclear weapons. But in my view the real aim of some of the more dedicated opponents of Clinch River was the extirpation (destruction) of nuclear energy. The Clinch River Breeder was a handy and vulnerable target, particularly since it could not produce power at a competitive cost. And the opponents eventually won."

The LMFBR became a favored concept in France, which built two commercial-scale fast breeders (Phénix and Superphénix) that generated electricity for its power grid; France is well known for producing roughly 80% of its electricity using nuclear power. However, Superphénix closed in 1998, and Phénix was shut down in 2009. Critics of LMFBRs continue to say breeders cost too much to build and operate, and some express the concern that the liquid sodium coolant can have a violent reaction with water in the power plant, including the concrete containment.

Yet Russia still operates two small LMFBRs and India is constructing a fast breeder reactor. Nations considering building molten salt reactors and thermal breeders include Canada, China, Denmark, France, Germany, Indonesia, Japan, South Korea, and the United States.

Although the molten-salt system was never allowed to show its full capability as a breeder, a uranium-233–thorium-232 thermal breeder was demonstrated in 1977 at the nuclear power plant in Shippingport, Pa. (the site of the first land-based reactor built in the 1950s under the leadership of Admiral Hyman Rickover, father of the nuclear navy). Operating with uranium-233 fuel and a thorium blanket, this reactor demonstrated a breeding ratio of 1.03 – for every 100 uranium-233 atomic nuclei consumed as fuel,103 new uranium-233 atomic nuclei were produced from neutron bombardment of a blanket made of thorium atomic nuclei.

Molten salt reactor proponents are excited by the plans of the Indonesia Innovation Agency and the U.S.-based ThorCon company to build in Indonesia by 2030 a prototype 500-megawatt molten salt reactor with a graphite moderator. It would be a passively safe, small modular reactor that is a scaled-up version of the ORNL MSRE invention. As in the MSRE, the fuel would be in liquid form and serve also as the coolant. It would be moved around with a pump and passively drained to a safe, cooled condition during a shutdown forced by an unlikely overheating incident.

Using technology developed in South Korea, the fission power plant would be encapsulated as a sealed unit in a hull, manufactured in a shipyard in 150- to 500-ton blocks, towed by barge to a shallow-water site and ballasted to the seabed.

A proposal to build a prototype in Indonesia has been submitted to the International Atomic Energy Agency. If the ThorCon molten salt reactor is built and if it demonstrates that an MSRE can produce clean, reliable, carbon-dioxide–free electricity at three cents per kilowatt-hour, which is cheaper than power from coal combustion, undoubtedly both Weinberg and Seaborg would have been proud.

Weinberg would also be pleased that Kairos Power plans to build at Oak Ridge's East Tennessee Technology Park the Hermes test reactor, a fluoride-salt-cooled, high-temperature reactor based on a liquid salt coolant tested in the MSRE program at ORNL and on solid nuclear fuel pebbles developed for the lab's High Temperature Gas Cooled Reactor program. The second nuclear era that Weinberg envisioned may be underway.

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For more information on Weinberg, Seaborg, and the correspondence between them, consult the Alvin Weinberg Archive Collection at the Children's Museum of Oak Ridge by clicking on **https://bit.ly/digitalweinberg** or by contacting Ronnie Bogard, who helped Carolyn with this column submission, at rhondabogard@comcast.net .

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Thank you, Carolyn, and Ronnie! This insight into the history of MSRE helps explain the current interest in the concept and sheds light on the resurgence of interest in Alvin Weinberg and his dedication to the idea. Please do check out the link Carolyn provided. You will be amazed at what Oak Ridge's scientist, Alvin Weinberg, has left us in his documents that have now been placed online for the world to see!

Seaborg at the controls of the Molten Salt Reactor Experiment at ORNL in 1965 when it was started up as the first reactor to operate on uranium-233 fuel

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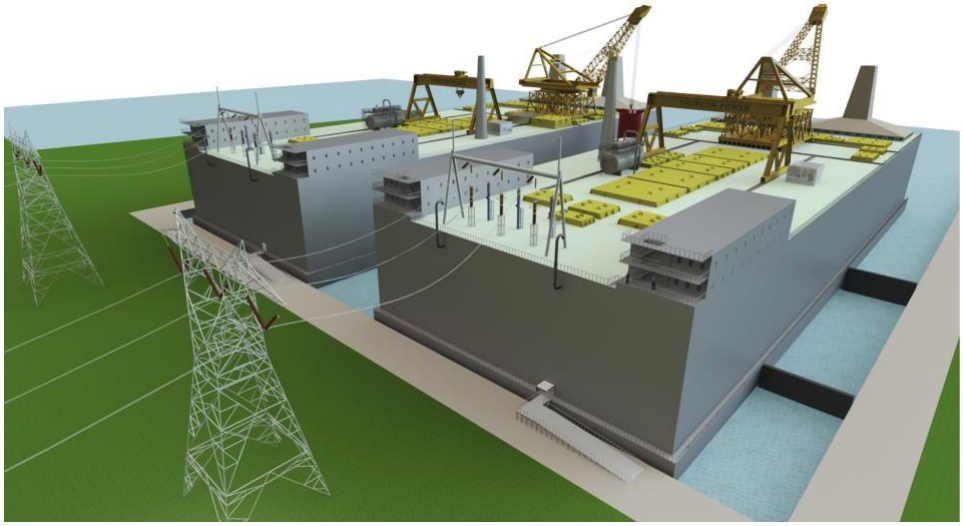
Seaborg with Weinberg at the controls of the Molten Salt Reactor Experiment at ORNL



An artist's concept of two proposed ThorCon 500-megawatt shoreside plants supplying the power grid. The plants will contain molten salt reactors based on the ORNL invention and are expected to be in Indonesia by the end of the decade.