The birth and life of the first molten salt reactor

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This is the second in a series of articles by Carolyn Krause on the history of the Molten Salt Reactor developed at the Oak Ridge National Laboratory.

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The molten salt reactor invented at Oak Ridge National Laboratory rose out of the ashes of the nuclear airplane project.

In 1944 Harold Urey and Eugene Wigner (later an ORNL research director) suggested designing a reactor with circulating fluid fuel instead of solid fuel, which could become deformed from neutron bombardment and heat. The first aqueous homogeneous reactor (AHR) built at ORNL went critical in October 1952. It combined uranium with heavy water.

The design power level of one megawatt was attained at the AHR in February 1953. Its high-pressure steam twirled a small turbine that generated 150 kilowatts of electricity, which was fed into the Tennessee Valley Authority's grid. The AHR was the second reactor in the world to generate power.

Before World War II was over, some scientists envisioned the use of nuclear reactors to propel submarines. Thanks to Admiral Hyman Rickover, the U.S. Navy later built nuclear submarines, powered by pressurized light-water reactors, a concept that Alvin Weinberg helped develop and that he suggested to one of Rickover's closest assistants.

After the war, some people espoused the idea of nuclear propulsion for aircraft bombers; such manned bombers propelled by reactors could fly from the U.S. and deliver atomic bombs to the hostile U.S.S.R. without refueling for days. Many scientists and engineers in the U.S., including Oak Ridge, laughed at the idea because of the weight of shielding likely to be required to protect the crew and the possibility of a plane crash that could spew dangerous radioactivity. One concern, however, was that intercontinental ballistic missiles (ICBMs) tipped with nuclear warheads were still in the visionary stage in the late 1940s.

The first to propose that nuclear propulsion for aircraft be taken seriously was Gordon Simmons, an engineer at the K-25 gaseous diffusion plant in Oak Ridge. He conveyed his ideas in 1945 to the Fairchild Engine and Airplane Company president, who was close to Air Force officials and proposed the idea at a Senate hearing.

By January 1946, the Fairchild company started assembling a team to study the feasibility of nuclear-powered manned aircraft. "Fairchild's headquarters in the old S-50 plant were five miles from Clinton Laboratories," wrote Weinberg, director of ORNL from 1955 to 1973, in his 1994 book "The First Nuclear Era: The Life and Times of a Technological Fixer." "Gordon Simmons, as the originator of the idea, was placed in charge." Simmons enlisted Ed Bettis, a mechanical engineer from Cornell, who later became a key figure in the invention of the molten salt reactor.

Few people in the reactor development world considered Fairchild's nuclear energy for propulsion of aircraft (NEPA) project respectable, including Weinberg and his colleagues. On Dec. 31, 1947, the Atomic Energy Commission (AEC) took away funding for ORNL's reactor work, largely on the recommendation of the famous scientists Robert Oppenheimer and James Conant.

"But the nuclear airplane refused to disappear," Weinberg wrote. "The Air Force simply had too much political strength to allow it to be ignored. So, shortly after ORNL was thrown out of reactors, it was thrown back in: we were to take responsibility for aircraft-reactor design, shielding, and certain aspects of materials research." Weinberg saw this opportunity as "the only avenue open to ORNL for continuing in reactor development."

Weinberg turned to Ray Briant, a brilliant mathematician and chemical engineer, to head the Aircraft Nuclear Propulsion (ANP) reactor project. Because of the high temperature required (1600°F) for a nuclear aircraft to work, Briant thought liquid nuclear fuel should be used instead of solid-fuel elements, which could be deformed by the high heat. Various liquid compounds were proposed.

"Ed Bettis," Weinberg wrote, "came up with an alternative: molten fluorides of the alkali metals (lithium, sodium, potassium) or alkaline earths (beryllium, zirconium) in which uranium fluoride was dissolved. Thus began ORNL's love affair with molten fluorides" as reactor fuel salts and salt coolants.

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Bettis headed the Aircraft Reactor Experiment, which achieved the goal of reaching 1620°F and operating for 100 hours in November 1954. Its salt consisted of fluorides of sodium, zirconium and uranium. Briant died of lymphoma before the experiment was complete. President Kennedy canceled the ANP project in 1961.

According to Weinberg, the byproducts of the billion-dollar project were molten-salt chemistry and technology and shield design improvements. ORNL and the International Nickel Company developed a high-temperature, corrosion-resistant alloy for use in molten-salt reactors. It is high in nickel and low in chromium and iron. It was later commercialized as Hastelloy-N and is still in use today.

H. G. MacPherson, a Union Carbide employee in Cleveland, Ohio, had been to Oak Ridge to learn about reactors and wished to transfer to ORNL after Carbide became the lab's managing contractor. He contacted Weinberg about his desires. Weinberg's response was to ask MacPherson "to come to Oak Ridge to head up a program to investigate power reactors fueled with molten salts," wrote MacPherson in his paper "The Molten Salt Reactor Adventure," which was published in a 1985 issue of the journal "Nuclear Science and Engineering." He accepted the job.

"In 1956 Alvin Weinberg wished to see whether the molten fluoride fuel technology that had been developed for the aircraft could be adapted to civilian power reactors," MacPherson wrote. "Part of his interest stemmed from the fact that all of the other materials and coolants being suggested for reactors had been anticipated by the reactor design group at the Metallurgical Laboratory in Chicago during World War II. This was new."

In 1959 the AEC formed the Fluid Fuels Reactor Task Force and provided $2 million a year for three fluid-fueled reactor concepts. The task force decided that the most promising of the three concepts was the molten salt reactor.

Under MacPherson and his successor Murray Rosenthal, ORNL researchers successfully demonstrated key molten-salt reactor (MSR) technologies at the MSR Experiment. The design of MSRE started in 1960. In 1961, ORNL received the directive to build and operate MSRE. Construction began in 1962. Salt was loaded into tanks in 1964, and salt was first circulated through the reactor core in 1965.

The MSRE initially went critical on June 1, 1965, with uranium-235 dissolved in molten salt. The reactor was first operated in the megawatt range on Jan. 24, 1966; full power (7.34 MW) was reached on May 23, 1966, and nuclear operation with U-235 was concluded on March 26, 1968.

The U-235 was stripped from the fuel salt in August 1968 and replaced with U-233. The MSRE achieved its first criticality with uranium-233 on Jan. 28, 1969, making it the only reactor to ever operate on U-233. Nuclear operation of the reactor was concluded on Dec. 12, 1969. Weinberg declared, "MSRE stands for not only molten salt reactor experiment but also for mighty smooth-running experiment."

NEXT: Thorium may be the key to the second nuclear era.

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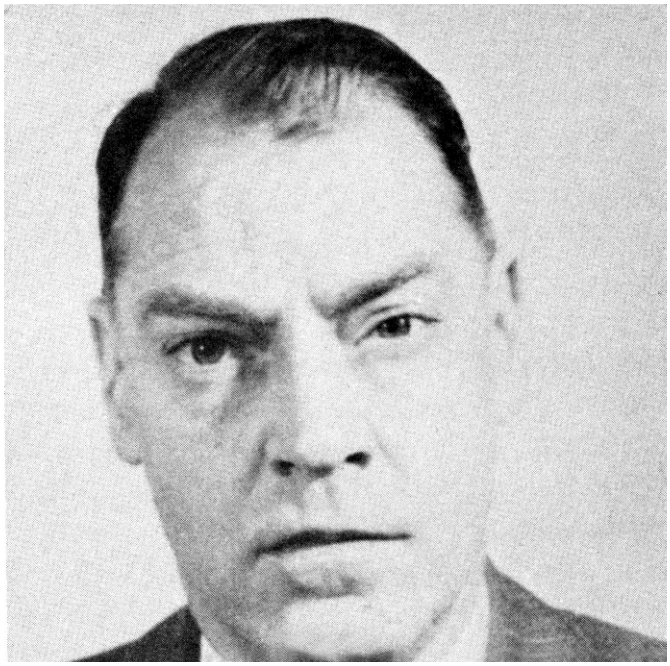

Ray Briant was one of the key figures behind the Aircraft Reactor Experiment at ORNL that led to the design of the Molten Salt Reactor Experiment for power production

In October 1967, ORNL Director Alvin Weinberg marked the Molten Salt Reactor Experiment's 6,000 hours at full power