Molten Salt Reactor Experiment

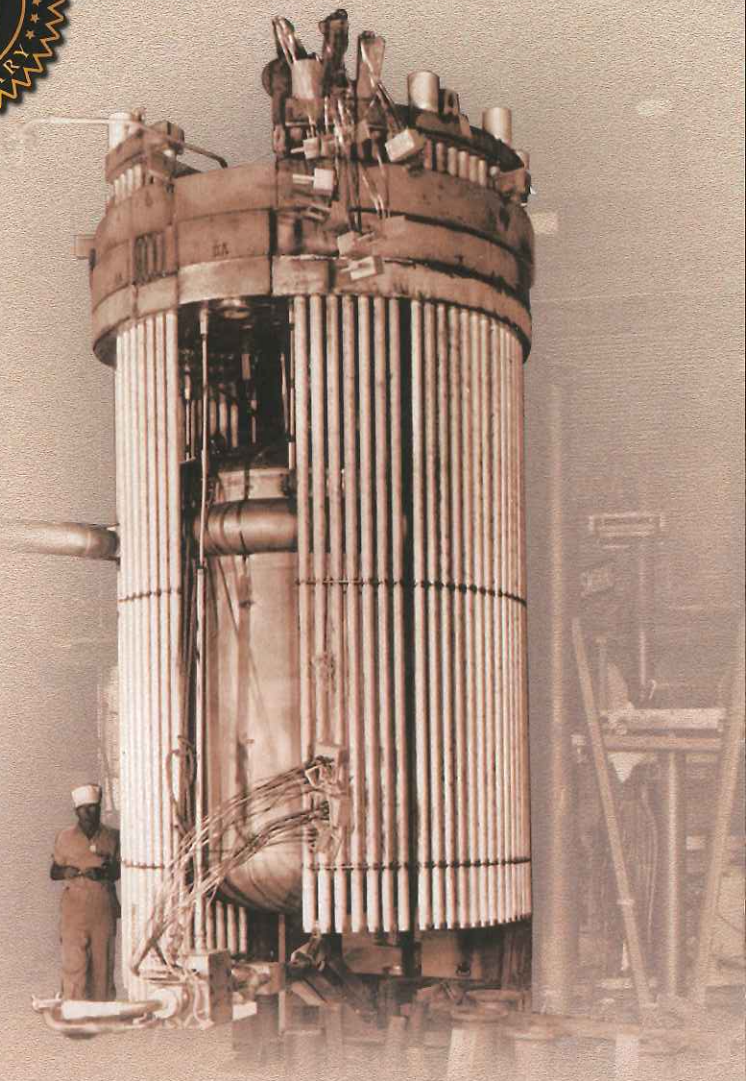
1965 MSRE 50TH ANNIVERSARY 2015

A successful reactor demonstration project

The Molten Salt Reactor Experiment (MSRE), a nominal 8-MW(th) reactor in which molten fluoride salt at 1,200° F circulated through a core of graphite bars, was intended to demonstrate the practicality of key molten salt power reactor features. Following World War II, Ed Bettis and Ray Briant of Oak Ridge National Laboratory proposed MSRs for powering nuclear-powered aircraft. Molten fluoride salts offered great stability as a coolant, both under radiation and at high temperatures.

Following research under the Aircraft Nuclear Propulsion program, ORNL Director Dr. Alvin Weinberg focused the lab's attention on determining if this technology could be adapted for civilian power use. In 1956, he secured $2 million in funding to develop the concept. In the late 1950s, an Atomic Energy Commission task force evaluating three fluid-fueled reactor concepts noted, "The Molten Salt Reactor has the highest probability of achieving technical feasibility."

The MSRE was proposed in 1959, design began in 1960, and construction took place between 1962 and 1964. On June 1, 1965, the MSRE achieved initial criticality. Following 11,515 critical hours of operation on ^{235}U, the MSRE became the first reactor to operate on ^{233}U.



The MSRE was the result of a detailed research and development program in a number of engineering and scientific disciplines. A reactor mockup was constructed to demonstrate the feasibility of remote maintenance on highly radioactive systems. The MSRE was designated a nuclear historic landmark in 1994.

Parameters

Power (heat)	8 MW
Fuel salt	65% Li^7, 29.1%BeF_4, 5% ZrF_4, 0.9% UF_4
Fuel melting point	813°F
Fuel inlet temperature	1175°F
Fuel outlet temperature	1225°F
Fuel flow rate	400 gal/min
Coolant salt	66% Li_7F, 34% BeF_4
Moderator	Graphite
Container	Hastelloy-N (68% Ni, 17% Mo, 7% Cr, 5% Fe)
Critical on U-235	June 1, 1965
Critical on U-233	October 2, 1968
Shut down	December 1969

Statistics

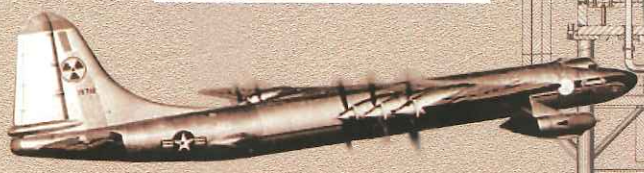
	$^{235}U^a$	$^{233}U^b$	Total[c]
Critical hours	11,515	3,910	15,424
Integrated power, MW(th) h	72,441	20,363	92,805
Equivalent full-power hours	9,006	2,549	11,555
Fuel pump circulating salt, h	15,042	4,363	19,405
Coolant pump circulating salt, h	16,906	6,660	23,566

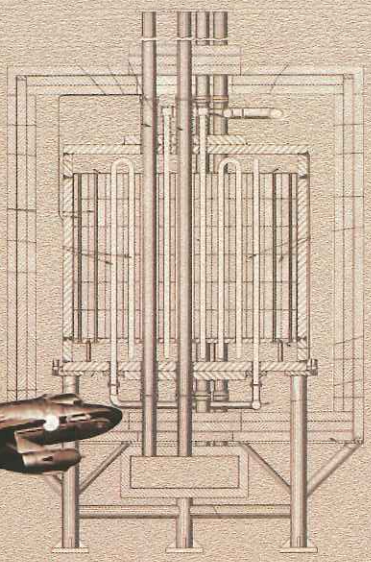
U.S. DEPARTMENT OF ENERGY

OAK RIDGE National Laboratory

1 MSRE's predecessor programs

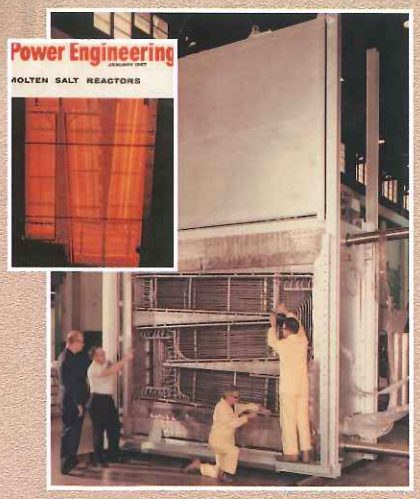
Molten salt reactors first were investigated as a means of providing a compact, high-temperature power plant that would allow a nuclear-powered aircraft to fly continuously for days rather than hours.The 1954 Aircraft Reactor Experiment (ARE) at ORNL demonstrated the molten salt–fueled reactor's feasibility. ARE was followed by the Aircraft Reactor Test (ART), a project of the Aircraft Nuclear Propulsion Program until 1957. The advent of the intercontinental ballistic missile system, which offered very long-range capabilities, diminished the need for nuclear-powered aircraft, and ART ended.





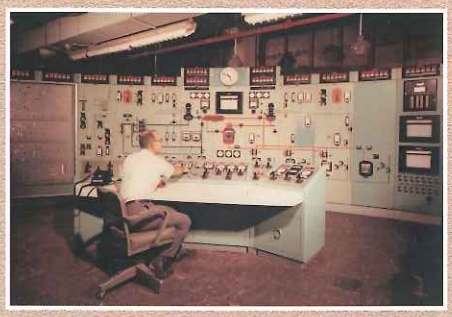
3 Early operation with ^{235}U fuel

The MSRE's first criticality—using ^{235}U as fuel—occurred on June 1, 1965. Later, Weinberg visited the control room when the MSRE reached a milestone of 6,000 hours at full power.



Heat was removed through this air-blast radiator (which glowed red when hot) and was dissipated through a metal stack to the atmosphere.

This reactor vessel drawing stringers pinned to a base The liquid fuel, moderated critical mass within the ves

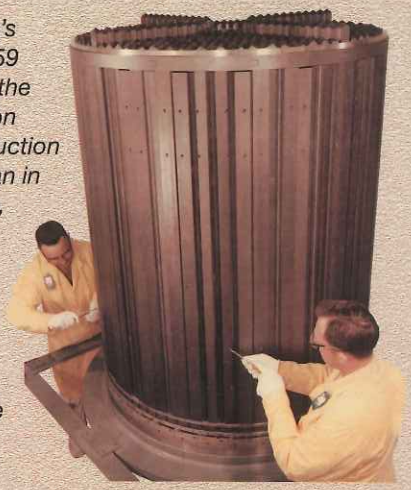


The main control panel displayed information that the reactor operator might need immediately, such as the temperature of the molten salt—if that temperature dropped below 840°F, the salt would begin to freeze. Computers and data handling equipment provided current information and analysis of variables within the reactor system and of potential abnormal conditions.

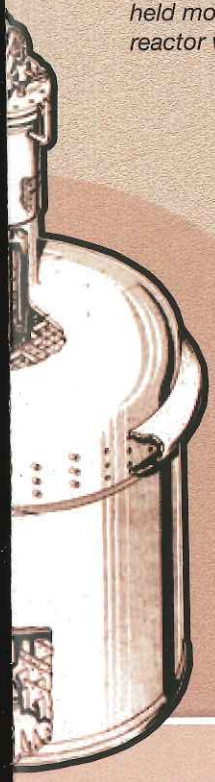
5 End of a

2 The advent and construction of MSRE

ORNL director Alvin Weinberg's continued interest led to a 1959 lab proposal for funding from the US Atomic Energy Commission to develop the MSRE. Construction at the ARE/ART facilities began in 1962. The MSRE reactor core, shown here during assembly, contained 69 cubic feet of graphite formed into 513 graphite core blocks. Passages between the blocks, called fuel channels, held molten salt fuel when the reactor was in operation.



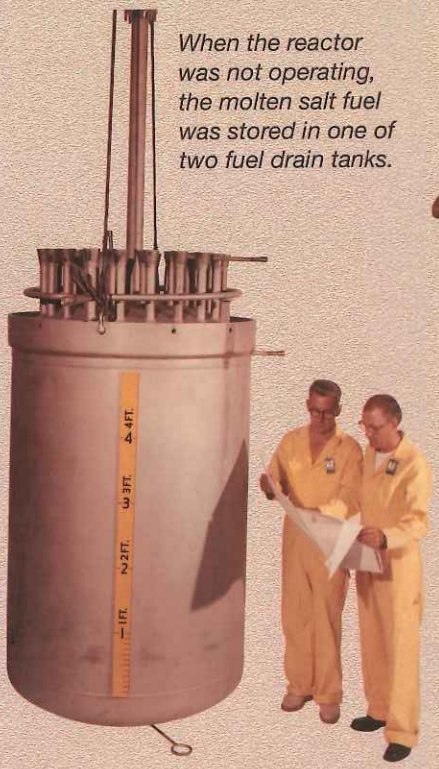
The completed reactor vessel during inspection and before installation in its containment cell. Holes near the vessel's top distributed incoming salt evenly around the vessel in a downward flow. Fully loaded, the MSRE used 11,260 pounds of a fuel salt mixture comprising lithium, beryllium, zirconium, and uranium fluoride. The coolant salt contained 15,300 pounds of lithium and beryllium fluorides.



shows the vertical graphite
of horizontal graphite bars.
by the graphite, reaches its
sel to generate fission heat.

4 Conversion to ^{233}U fuel

When the reactor was not operating, the molten salt fuel was stored in one of two fuel drain tanks.

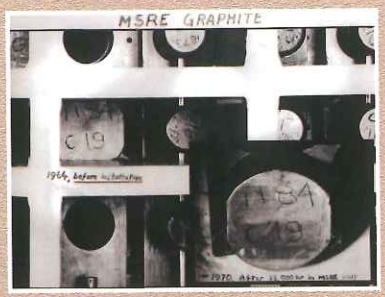


Just under 3 years after the MSRE's first criticality, ^{235}U fuel was removed from the reactor and replaced with ^{233}U in the capsule pictured here. The first ^{233}U criticality was October 2, 1968.

The fuel pump circulated fuel at 1,200 gallons per minute inside the MSRE reactor, which operated until December 1969. Although the MSRE had ended, research into molten salt reactors continued at ORNL for 4 more years.

n era

The Molten Salt Reactor Program ended in 1973 when the US government ended funding for the concept in favor of other technologies. The MSRE was shut down in 1969 but the program ended later, in 1973. Though the program's demise disappointed its advocates, the MSRE had met its useful life and had provided many ORNL researchers with a wealth of reactor technology information.



This image demonstrated the chemical compatibility of the salts, with graphite. The shape of this graphite core is virtually identical in the left image from 1964 (before operation began) and in the right image from 1970 (after shutdown).

"The tone of optimism that pervades these papers is hard to suppress. And indeed, the enthusiasm displayed here is no longer confined to Oak Ridge. There are now several groups working vigorously on molten salts outside Oak Ridge."

Dr. Alvin Weinberg

Alvin Weinberg, then ORNL director, shows the controls of ORNL's Molten Salt Reactor to Glenn Seaborg—Nobel Prize winner, discoverer of plutonium, and chair of the Atomic Energy Commission. Seaborg was at the controls on October 8, 1968, when the reactor started its successful operation using uranium-233 as a fuel. Weinberg called the reactor ORNL's greatest technical achievement.

The Molten Salt Reactor Adventure

This year marks the 50th anniversary of the MSRE's achieving initial criticality. Some 15,000 hours under critical operations between 1965 and 1969 demonstrated the practicality and viability of the MSR concept and now provide the technical foundation for renewed interest in MSRs as an emerging class of advanced reactors that offer an option for meeting future energy needs. Dr. Alvin Weinberg's statement (highlighted above) in a preface for a series of papers published in *Nuclear Applications & Technology* on MSRs and the MSRE remains true today. This is evidenced by the 100+ participants from around the world—representing academia, the nuclear industry including reactor developers and utilities, R&D organizations, the US Department of Energy, and the US Nuclear Regulatory Commission—in attendance at an October 2015 workshop at ORNL not only commemorating this anniversary but looking toward the development of a number of design concepts using molten salt technology.