

MSRE Remediation Project
Salt Melt, Transfer, and Process Demonstrations

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The Molten Salt Reactor Experiment (MSRE) was an 8-MW, fluid-fueled test reactor that operated from 1965 through 1969 in support of a program to develop a thermal breeder power reactor using the thorium-uranium fuel cycle. The fuel consisted of a mixture of lithium, beryllium, and zirconium fluoride salts, to which uranium was added as UF_4 . The molten salt circulated through a reactor vessel, pump, and heat exchanger at temperatures above $600^\circ C$, but it is solid at room temperature. After reactor shutdown, the salts were returned to their drain tanks and allowed to freeze. Three batches of salt were left in the reactor. The 4,650 kg of fuel salt is divided between two drain tanks, and another 4,265 kg of flush salt, slightly contaminated with fuel salt, is in a third drain tank. A single batch of 2,610 kg of coolant salt was left in another drain tank. The coolant salt was not contaminated with either fuel or fission products, but contains a small amount of tritium.

Over the years, fluorine was released from the fuel and flush salt matrix due to radiolysis. This fluorine in turn oxidized UF_4 to volatile UF_6 and thus provided the means to spread ^{233}U throughout an off-gas system and into a charcoal bed. The MSRE Remediation Project was formed to recover and stabilize uranium from the MSRE and to remove and process the fuel and flush salt for safe storage and ultimate disposition.

The loss of fluorine from the salt matrix leaves the salt in a net reducing state. The addition of fluorine during the melting process is necessary to completely melt the salt and to prevent the uranium left in the salt from precipitating or interacting with the vessel walls. Salt expands when it melts, and heat must be added in such a way that excess stress on the vessel walls is avoided. A progressive “poolmelt” process has been developed to melt the salt with an internal thermal probe, while sparging a growing pool of molten salt

with dilute HF/H₂ in helium to restore the chemical balance in the salt as it is melted. The insertion of a melt probe in one of the fuel salt drain tanks is depicted in Fig. 1. This presentation describes three tasks performed to demonstrate the technology of safe melting and transfer of the MSRE fuel and flush salts.

The coolant salt was melted and transferred into five vessels for interim storage. The objectives of this task were to demonstrate the safe melting of a large batch of salt and the transfer of over a ton of salt and to prepare one vessel for a demonstration of the pool melting process. This demonstration also provided the staff experience with the reactivation of a portion of the MSRE salt handling equipment. The equipment used for the demonstration is shown in Fig. 2. The existing drain tank heaters were reconfigured such that heat could be progressively added from the top of the tank, ensuring a free surface at all times during the melt. The five transfer vessels were set up in series, with dip tubes arranged so that salt would be evenly distributed through all of the vessels. The last vessel was a special configuration to support the poolmelt demonstration. The melt and transfer was conducted in the winter of 1999 and proceeded as intended.

The poolmelt test vessel, filled with coolant salt, was then transferred to a hood set up in another ORNL facility. A prototype melt probe, with an internal sparge tube, was obtained from a local vendor. This demonstration consisted of two melts. The salt was warmed to near its melting temperature with an external blanket heater. Power was then added to the melt probe, and the probe was lowered into the salt. A series of thermocouples on the probe, in the salt, and on the vessel wall were used to monitor the progress of the melt. A moveable dip tube was also used to sense the progression of the melt. Both demonstrations were successful. Data from the first demonstration were used to refine the operating parameters of the melt process, and the shape of the pool was more effectively controlled in the second melt.

A separate test was used to demonstrate the adjustment of salt chemistry during the melt process. A vessel containing about a liter of simulated fuel salt was irradiated in the gamma field of a High Flux Isotope

Reactor spent fuel element. This salt took on a black color upon irradiation, and a fluorine evolution greater than that expected in the actual fuel salt was measured. The salt was then brought into a laboratory hood, partially melted, and a sparge tube inserted for the remainder of the melt. A sparge of HF was initiated, and HF utilization and salt appearance were monitored. The consumption of HF proceeded as expected, rapid at first and asymptotically decreasing to no consumption at the end. The appearance of the salt after treatment confirmed that a single-phase material had been produced with no heels, precipitates, or significant wall deposits. Without chemical treatment of the salt, a significant heel remains, and deposits are found along the tank wall. This demonstration showed that HF utilization can be used to monitor the progress and completion of fluorine restoration to the salt.

These demonstrations provide confidence in the overall plan to safely melt and transfer the MSRE fuel and flush salts. They confirm the chemistry and provide data for use in flowsheet development, equipment design, and procedure development. They also provide operating experience that will be useful in preparation for the actual melting of the fuel and flush salts.

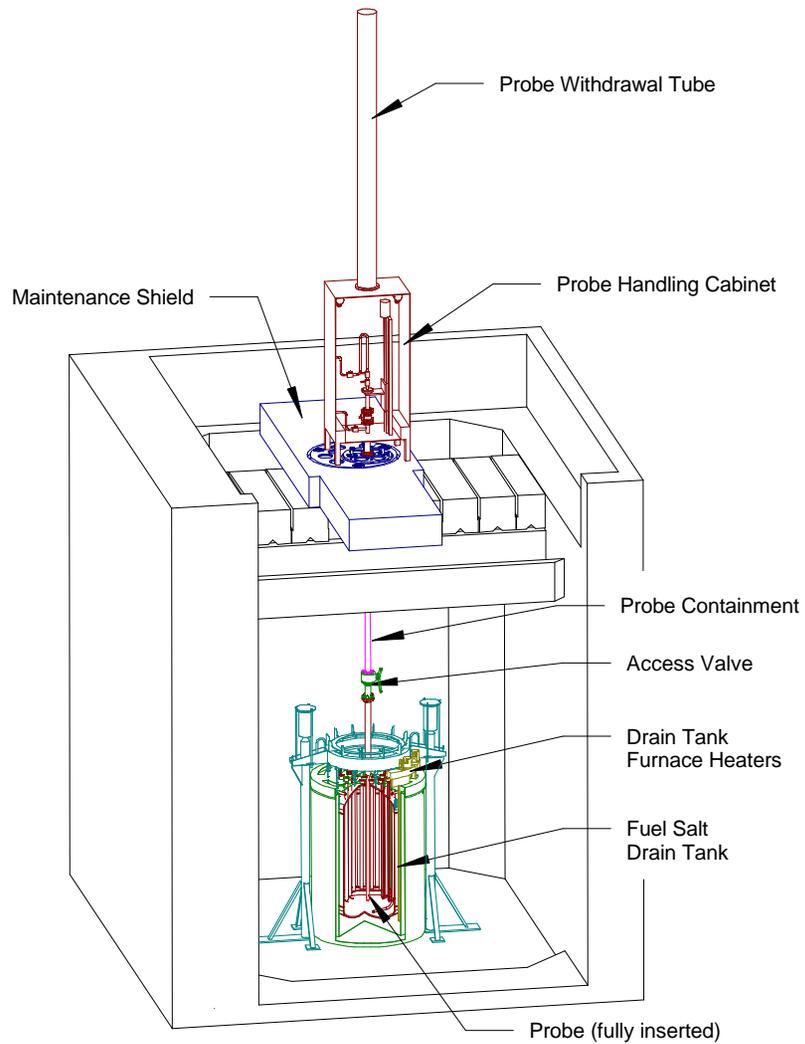


Fig. 1. Fuel salt drain tank with probe inserted.

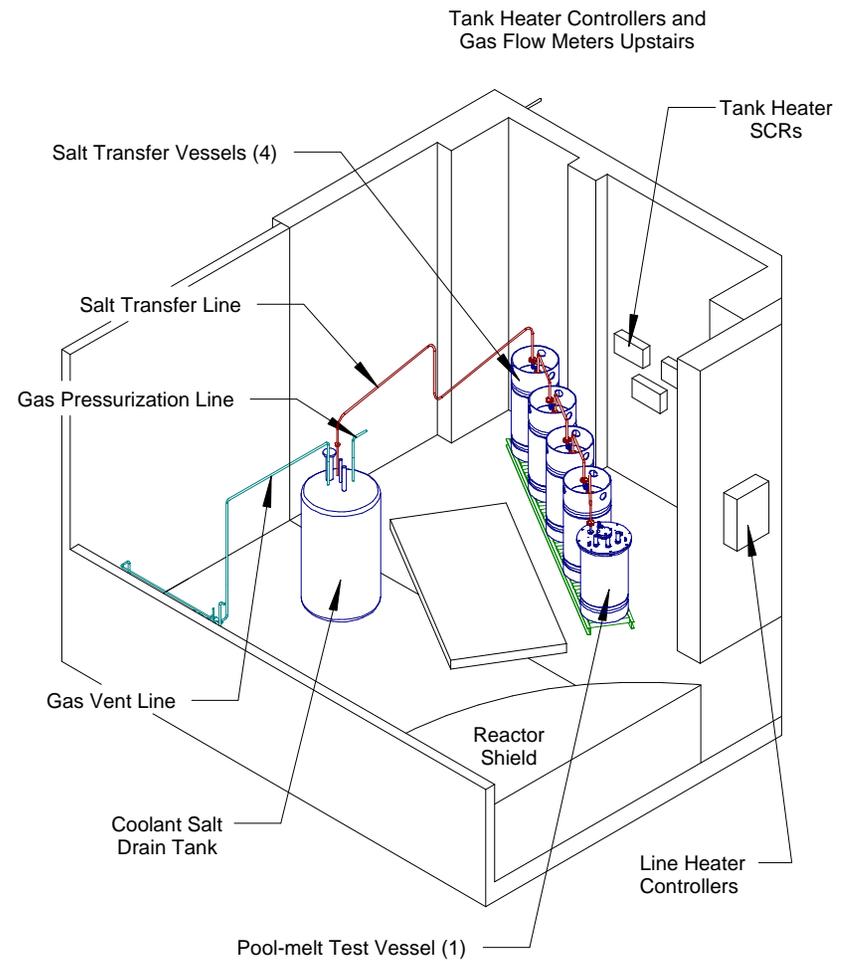


Fig. 2. Coolant salt transfer equipment.