Transaction

Safety and Licensing Aspects of the Molten Salt Reactor

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INTRODUCTION

Molten salt reactors (MSRs) are liquid-fueled reactors that can be used for burning actinides, producing electricity, producing hydrogen, and producing fissile fuels (breeding). Fissile, fertile, and fission products are dissolved in a high-temperature, molten fluoride salt with a very high boiling temperature (~1400ºC). The molten salt serves as both the reactor fuel and the coolant (Fig. 1). Heat is generated in the reactor core and transported by the fuel salt to heat exchangers before returning to the reactor core. The MSR is one of six advanced reactor concepts identified by the Generation IV (GENIV) International Forum as a candidate for cooperative development. As the only liquid-fueled reactor concept, the safety and licensing aspects are considerably different than the other GenIV reactor concepts.

INTEREST IN MSRs

Two experimental MSRs were built in the 1950s and 1960s. A renewed interest[1–3] in MSRs occurred because of *changes in goals and technologies*. There is an interest in destroying the long-lived radionuclides in high-level wastes (HLWs). MSRs have unique capabilities for burning actinides from other reactors by avoiding complex and expensive fuel fabrication steps—no fuel elements are needed. The MSR can be operated as a breeder reactor on a ^{232}Th-^{233}U fuel cycle that generates a waste with almost no long-lived actinides. The fuel cycle of the MSR implies minimum transport of radioactive materials: thorium is shipped to a reactor site and only HLW leaves the site. Several new technologies (compact heat exchangers, carbon-carbon composite components, and Brayton power cycles) that are being developed for very high-temperature reactors have the potential of significantly improving the economics while addressing some of the major technical challenges. The characteristics of the MSR also offer the potential for large economics of scale in very large reactors compared to other reactors.

SAFETY AND LICENSING

The safety basis and characteristics of an MSR are different from solid-fuel reactors. This offers major advantages and disadvantages. The safety advantages include (1) low-stored energy (low pressure, no highly energetic chemical reactions, and a high-temperature molten salt solvent that does not easily release the fission products and actinides from the solvent) and (2) a standard procedure in most emergencies of draining the fuel from the reactor into bunkered, critically safe, passively cooled dump tanks. Freeze valves (sections of pipe that are actively cooled) open upon overheating of the molten salt. The reactor has almost no excess fuel reactivity because the fuel is added as needed on-line. The reactor accident source term is significantly less than in solid-fuel reactors because radionuclides are removed on-line from the reactor core. The disadvantages (in addition to its earlier state of development) include remote maintenance of major components, a chemical processing facility for trapping and solidifying the volatile short-lived fission products in the off-gas, and potentially a second processing system for removal of longer-lived fission products from the fuel salt. The salt can be processed on site or off site.

For actinide burning, the MSR may have a unique safety characteristic. The inventory of actinides in an MSR actinide burning system (reactor, storage, reprocessing plants, etc.) per kilogram of actinides destroyed per year may be significantly smaller than any other actinide-burning reactor. For actinide burning missions, the total actinide inventory in the reactor system becomes a potential safety concern. The low inventory is a consequence of several factors.

- *Neutron spectrum*. The MSR has a thermal to intermediate neutron spectrum that implies the fissile inventory is one-fifth to one-tenth that of a fast reactor per kilogram of actinides fissioned.

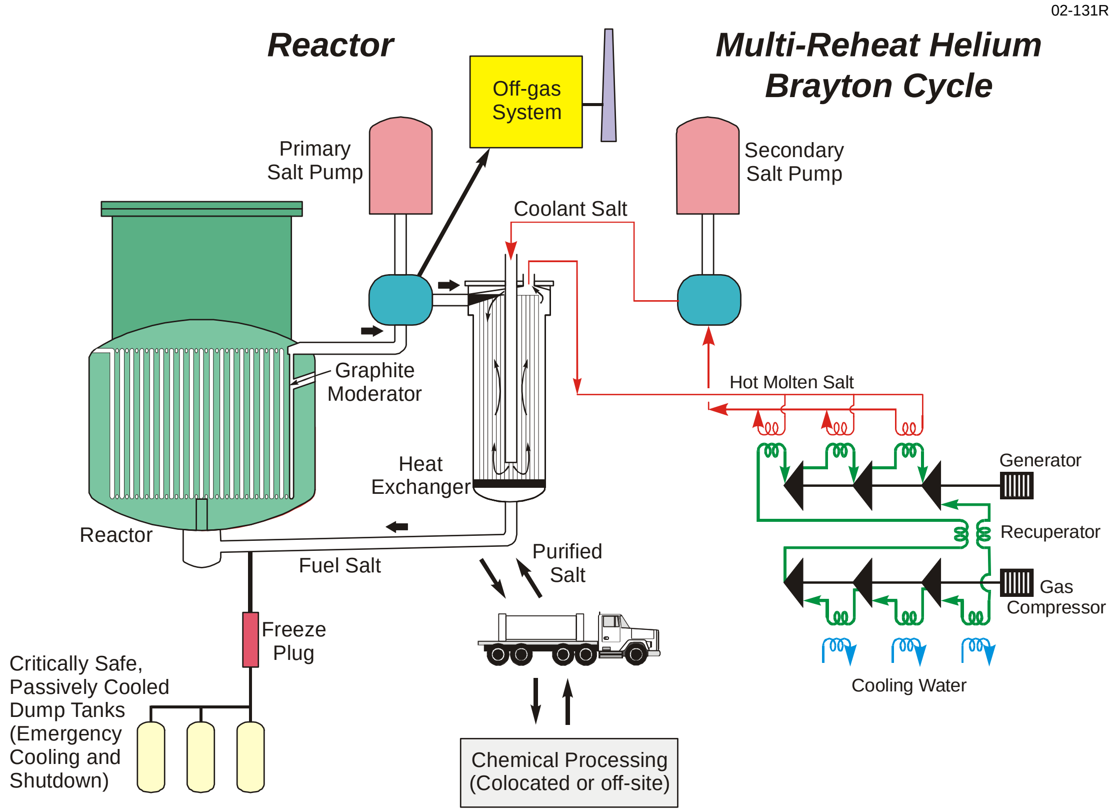

Fig. 1. Molten salt reactor.

- *Power density*. With a molten fuel, the power densities per kilogram of actinides can be much higher than solid-fuel reactors.

- *Fuel cycle inventory*. There is no spent nuclear fuel.

- *Reactor inventory*. The potential development of carbon-carbon composite compact heat exchangers implies very little molten fuel salt outside the reactor.

The licensing-related design and safety features combine those of a reactor and a chemical processing plant. Because prescriptive safety regulations were developed for solid-fuel reactors, many of the prescriptive safety regulations are not applicable to an MSR. The MSR requires that the safety basis be defined in terms of performance goals with a rethinking of how those goals are met.

While a probabilistic safety analysis has not been done on an MSR, the available evidence suggests significantly different concerns. The characteristics of the MSR suggests that the probability and consequences of a large accident to be much smaller than most solid-fuel reactors. At the same time, the processing and other operations indicate greater concerns associated with smaller accidents. The MSR incorporates most of the fuel cycle with the reactor; thus, risk comparisons with other reactors must consider the entire fuel cycle.

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