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Molten Salt Reactor: A Review

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Abstract: The Molten Salt Reactor (MSR) was first developed in the 1950s. In recent years, there has been increasing interest in molten salt reactors, which were considered at the 4th Generation International Forum because of their different capabilities and characteristics from traditional solid fuel reactors. Traditionally, these reactors were considered thermal breeder reactors operating in cycles from thorium to 233U. MSR is the future of nuclear power, especially with improved sustainability, inherent safety with a strong negative temperature coefficient of reaction, stable coolant, low pressure operation without expensive containment, ease of control, passive decay, etc. Benefiting from past experience in molten salt technology, it heat-cools its unique properties in terms of actinide combustion and waste reduction.

Keywords: *molten salt reactor, nuclear power, breeder reactor.*

I. Introduction

Molten salt reactors (MSRs) are a category of fission reactors, and even the first coolant or even the fuel itself can be a mixture of molten salts. MSR has two main subclasses. In the first subclass, fissile material dissolves in the molten salt. In the second subclass, molten salt acts as a low-pressure coolant for coated particulate fuel cores used in high temperature reactors (HTRs). The MSR operates at temperatures much higher (up to 700-750 ° C) than light water reactors (LWRs) and operates at near gas pressure. Molten salt offers attractive properties as a refrigerant, especially high volumetric heat capacity and high boiling point. In the liquid fuel MSR design, the fuel dissolves in the molten salt reactor as fissionable elements such as UF4, PuF3, smaller fluorinated actinides, and / or fertile elements such as ThF4 and for specific applications (proliferation reactors, actinides). Burner, etc.). In the core, fission occurs in the fuel salt, where the fuel salt flows into the intermediate heat exchanger, where heat is transferred to the secondary molten salt coolant. Fused fluoride salts were first developed because, unlike chloride-based salts, fluorine has only one stable isotope (19F). Liquid fluoride solutions are well known in the aluminium and uranium industry. All uranium used in today's nuclear reactors is converted to fluoride for concentration. MSR has several unique properties that provide a potentially safer, more efficient and more sustainable way to supply nuclear energy in the context of online fuel processing. Steam explosions are not possible because MSRs do not work at high temperatures and are not cooled by water. Fuel salts are often discharged into subcritical storage tanks, especially if the reactor fails.

II. Literature Paper

Molten Salt Reactors (MSRs) and Fluoride Salt Cooling High Temperature Reactors (FHR), which use fuel dissolved in liquid salts, have many common research topics. This paper provides an overview of international R & D efforts on these types of reactors carried out within the 4th Generation Framework. Many countries around the world, including the European Union, France, Japan, Russia and the United States, have contributed to this reactor technology, and in the last, China and India have also contributed. The United States is focusing on FHR, which is a short-term application of liquid salt as a reactor coolant, and China is also focusing on solid fuel reactors as a precursor of molten salt reactors with liquid fuels and thermal neutrons. Future research topics will focus on molten salt technology and material behaviour, fuel and fuel cycle chemistry and modelling, and aspects of nuclear reactor numerical simulation and safety design. The

MSR design is gaining attention each year as it is widely recognized as the most sustainable of the six Generation IV designs with inherently safe features. More joint efforts are needed to advance the joint molten salt reactor technology. (In 2014, Jerom Serp & Michel Allibert, */The Molten Salt Reactor (MSR) in generation IV: Overview and perspectives).

Badawy M. Elsheikh studied the various plant systems in MSRs. This paper also features different safety characteristics of MSR power plants and their assessment in comparison with other solid fueled light water reactors. Here the basic characteristics of MSR safety are discussed. MSRs are safe enough since they don't reach high enough temperatures for melt down and the primary system is a low-pressure operating system even at high temperatures. MSR is not subject to safety concerns due to chemical or mechanical violent reactions or explosions. MSR is the solution for many problems faced by the solid fueled light water reactors. MSRs can prevent many accidents like the one in Chernobyl. (In August 2013, Badawy M. Elsheikh, */Safety assessment of molten salt reactors in comparison with light water reactors)

III. History and Development

The history of molten salt reactors dates back to the 1950s. This design was first proposed in as a nuclear-powered aircraft propulsion system at Oak Ridge National Laboratory. Upon completion of the program, the focus shifted to the study of MSRs running on the thorium fuel cycle. In the 1960s, the project focused on breeding opportunities, resulting in a Molten Salt Breeder Reactor (MSBR) design of**.** From 1965 to 1969, an experiment called the Molten Salt Reactor Experiment (MSRE) was conducted. Reactor was operating at 233U in early 1969. This was the first time that 233U fuel was used as a reactor fuel. The salt in this reactor did not contain thorium as it was intended solely to simulate the fuel flow of a double fuel breeder reactor. The results of the experiment were promising, but the MSR program was discontinued in 1976. Without the complex chemical removal process, MSR is a high conversion converter reactor with thorium added to the fuel (Perry, 1975).
Oak Ridge continued its modest program until the early 1980s, with the focused on maximizing its resistance to proliferation**.** ORNL examined performed in a denaturation cycle in which all uranium remained below the weighted average. The results were surprisingly successful, two routes were investigated, and both were designated as DMSRs for modified molten salt reactors. The first uses the DMSR break-even design with fission product treatment similar to MSBR, and because the fertile composition remains, the depleted 238U and Th are used to make break-even even in the denatured state. It has been shown that branch point culture can be achieved. The second is a very simplified DMSR converter design called "30 Year Once Through Design" (Engel et al., 1980), which maintains a very high conversion rate and for a total of for 30 years. No fuel processing beyond chemical control was performed. It was an excellent development of uranium resources. Both designs feature a larger, lower power density core and a 30-year graphite life.

IV. Working of Molten Salt Reactor

The goal of each reactor is to utilize a nuclear chain reaction to generate thermal energy. The way this happens varies significantly between reactors, and molten salt reactors are probably one of the most unique. Modern reactors now use solid fuels for operation, with uranium being the main fuel. However, MSR dissolves the fuel in a mixture of molten salts. This has many advantages. In a simple molten salt reactor, enriched uranium (Uranium 235 or 233) is dissolved in a single molten salt solution. The neutron moderator core is capable of flowing brine at temperatures above 700 ° C while maintaining a fairly low pressure. The use of low pressure is an important safety feature as it greatly reduces the risk of equipment malfunction. The heat generated by the salt nuclear reaction heats the water into steam, which is then transferred to a secondary circuit that produces electricity. This basic MSR concept can be extended to a variety of other operational characteristics. Probably the most promising is its use as a breeder reactor.

V. Breeder Reactor

The Liquid Salt Breeder Reactor (MSBR) extends the basic operating principles of MSR. Instead of a single liquid system like above, a second molten salt liquid is introduced for the growth of fissile isotopes. The first liquid contains a fissionable fuel (uranium-235 or other). This is the "propulsion" of a nuclear reaction, whose fission supplies medium to slow neutrons into the second loop, which is emitted by a normal chain reaction. The second fuel cycle contains fertile fuels that can absorb these neutrons and eventually convert them into fissile fuels. This new fissile fuel breeds more than it are used, hence the name "breeding". The operation of MSBR has great potential for the use of thorium as a nuclear fuel, as thorium has great potential in reactor technology, but is no longer in use. One type of MSBR that uses thorium is the Liquid Fluoride Thorium

Reactor (LFTR). In this reactor, thorium absorbs neutrons from the fissile loop and produces uranium-233 through a series of beta decays. Uranium-233 is chemically extracted from this cycle and injected into the fissile cycle to extend the fuel life of the reactor and reduce nuclear waste.

VI. COMPARISON WITH LIGHT WATER REACTORS:

MSRs, especially those with fuel dissolved in salt, are very different from traditional reactors. The core pressure is low and the temperature can be much higher. In this respect, MSRs are more like liquid metal cooled reactors than traditional lightweight water-cooled reactors. MSRs are often designed as closed fuel cycle breeder reactors. The safety concept limits reactivity fluctuations by relying on a negative temperature coefficient of reactivity and a large potential temperature rise of. As an additional shutdown method, another passive cooling tank can be installed under the reactor. In the event of a problem, the reactor will be discharged with fuel and will be discharged for regular maintenance. This stops the nuclear reaction and the acts as a secondary cooling system. Neutron generation accelerators have been proposed for approximately ultra-safety subcritical test equipment. The cost estimate from the 1970s was, which is slightly lower than traditional light water reactors. The temperatures of some proposed designs are high enough to generate process heat for hydrogen production or other chemical reactions. Because of them were included in the GEN IV roadmap for further research.

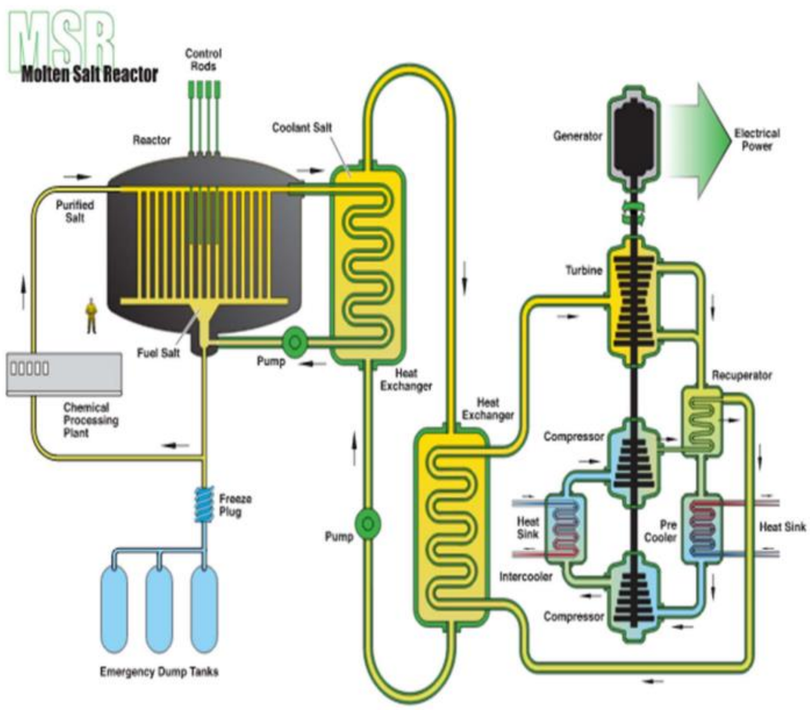

Figure 1. Schematic representation of Molten Salt Reactor.

VII.ADAVANTAGES OF MSR

As with all low-pressure reactor designs, the MSR provides passive decay heat removal. In some designs, the fuel and coolant are the same liquid, so the reactor fuel is removed when the coolant is lost, just as the coolant loss also removes the LWR's moderator.

- No need to create fuel rods (replaced by fuel salt synthesis).
- Some designs are compatible with fast neutron spectra, allowing you to "burn" problematic trans uranium elements such as Pu240, Pu241 and above (reactor-plutonium) from conventional light water reactors.
- The MSR can respond to load changes in less than 60 seconds (unlike the "traditional" solid fuel nuclear power plants that suffer from xenon addiction).
- Molten salt reactors can be operated at high temperatures, resulting in high thermal efficiency. This reduces size, cost, and environmental impact.
- MSR can provide high “specific power”. Low mass and high performance, as demonstrated by ARE.
- Perhaps due to the good neutron economy, MSRs are attractive for the neutron-poor thorium fuel cycle.

VIII. Applications of MSR

The initial goal of the Li, Be, Th, U / F MSR is in breeder (MSBR) or converter mode (MSCR, DMSR), using either continuous fuel processing or simple helium to efficiently power. Fuel circuit spray technology. The current goals also include a variety of different fuel cycle missions, with or without support from U. MSR's Reactor physics can be operated as both a burner and a breeder, depending on the purpose, enabling a flexible system that provides optimal resource utilization. Converting TRUs to MSRs in combination with on-site fuel salt treatment is efficient and reduces the amount of waste generated. While the MSR is intended for power generation, solid and liquid fuel MSRs operate at temperatures, which are significantly higher than traditional lightweight water-cooled nuclear power plants, making them an industrial heat source for industries such as cement, steel and petroleum. Such "Nonelectric" applications could concern coal gasification, conversion of coal to olefin or diesel.

IX. Conclusion

Molten salts as coolants provide exciting functions including chemical inertia, excellent delivery properties, sturdy irradiation resistance, excessive thermal balance and boiling points. They proportion a few blessings with liquid steel coolants like reactor operation at low pressure. This constitutes an extensive protection and value advantage. The MSR has many advantages just like the functionality of burning actinides or breeding fissile gas, no want for gas production and an excessive degree of sustainability due to the fact MSR may be run as a breeder reactor withinside the uranium gas cycle or withinside the thorium gas cycle or as a transmuter of long-lived actinides from spent nuclear gas. Worldwide, most of these operation modes of the MSR are investigated. The protection evaluation techniques of their present-day shape cannot be implemented to liquid fuelled MSRs, specially because of the truth that the gas is molten in the course of regular operation and because of the absence of cladding. Its exceptional protection degree is ensured via way of means of the strongly terrible comments coefficients, even in a speedy neutron spectrum, and the functionality to empty the liquid gas in unload tanks, which excludes overheating because of stagnant decay warmness elimination. A novel technique for the layout and protection reviews of liquid furled MSRs is needed, counting on present day established protection ideas such because the precept of the defense-in-depth, the usage of a couple of limitations and the three simple protection functions: reactivity control, decay warmness elimination and radioactive merchandise confinement.

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