Foreword

Special issue on Salt-Cooled Reactors

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This special issue of *Nuclear Technology* contains reviews and papers describing recent work on salt-cooled reactors—an area where there has been an explosion of interest, including the growth of startup companies such as Kairos Power, TerraPower, and Commonwealth Fusion. The increase in interest partly reflects technology developments in salt systems but is also a consequence of the development of other technologies that synergistically couple with salt coolants.

Molten-salt reactors (MSRs) with fuel dissolved in the salt were originally developed in the 1950s at Oak Ridge National Laboratory (ORNL) for the Aircraft Nuclear Propulsion program with the goal of a jet-powered aircraft that had unlimited range. MSRs were chosen because they efficiently coupled to jet engines by delivering heat near 800°C to the jet engine. While the nuclear-powered aircraft did not prove practical, after 60 years of advances in gas turbines for power generation we are seeing renewed interest in coupling salt reactors to gas turbine cycles[1] at temperatures between 600°C and 700°C. Equally important, advances in steam cycles now enable full utilization of high-temperature heat delivered to the power cycle by most proposed salt-cooled reactors. In this context, salt reactors deliver heat at a higher average temperature than any other class of reactors (Table I). Like other liquid-cooled reactors, the temperature drop across the reactor core is small. This characteristic has the potential to improve the economics of all salt reactor systems relative to other reactor systems.

In the 1960s, ORNL developed the classical MSR—a thermal-neutron-spectrum breeder reactor that was the backup option to the sodium fast reactor (SFR). The operation of the small 8-MW(thermal) Molten Salt Reactor Experiment demonstrated the technology. Recent developments have created the options for fast-spectrum fluoride and chloride MSRs. The molten chloride fast reactor has a very high breeding ratio relative to other reactor concepts because of (1) the hard neutron spectrum and (2) the intrinsic characteristic of a liquid-fuel reactor where selected fission products can be removed from the salt, reducing parasitic neutron capture.

There are potential safety advantages, including a low-pressure, high-temperature coolant and the choice to reduce the reactor radioactive accident source term by online removal and solidification of fission products.

TABLE I

Temperatures of Delivered Heat from Different Reactors

Coolant	Inlet Temperature (°C)	Exit Temperature (°C)	Average Temperature (°C)
Water	270	290	280
Sodium	450	550	500
Helium	350	750	550
Salt	600	700	650

Advances in separations have created new options for salt processing. The high-temperature coolant enables use of heat pipes and other passive decay heat removal system technologies originally developed for SFRs.

The low-pressure, high-temperature characteristics of these salts have created two other reactor concepts. The fluoride salt–cooled high-temperature reactor (FHR) combines clean salt with the carbon-matrix coated-particle fuel developed for high-temperature gas-cooled reactors (HTGRs) to enable a higher-power-density, low-pressure, high-temperature reactor. The FHR was enabled by advances in HTGR fuels and passive safety systems from SFRs, which also use a low-pressure liquid coolant. At the same time, the Concentrated Solar Power community[2] is examining high-temperature chloride salts for next-generation systems with operating temperatures up to 750°C.

Within the past decade the fusion community has begun development of magnetic confinement fusion reactors with new high-power superconducting magnets. These magnets can shrink the size of a fusion reactor by a factor of ten for a given power level; however, that implies increasing the power density in the fusion blanket by an order of magnitude. The extreme power densities make it very difficult to cool a solid blanket; thus, work is underway to develop liquid-salt blankets to (1) convert high-energy neutrons into heat, (2) produce tritium fuel, and (3) provide radiation shielding.

The combination of advances in outside technologies and within the salt community has created the new interest in this family of reactors. It also implies existence of multiple users for salt technologies and that the development work has broad applicability beyond a single salt reactor concept. The papers in this special issue of *Nuclear Technology* provide a snapshot of work that is underway.

References

1. C. W. FORSBERG, P. J. McDANIEL, and B. ZOHURI, "Nuclear Air-Brayton Power Cycles with Thermodynamic Topping Cycles, Assured Peaking Capacity, and Heat Storage for Variable Electricity and Heat," *Nucl. Technol.* (2020); https://doi.org/10.1080/00295450.2020.1785793.

2. M. MEHOS et al., "Concentrating Solar Power Gen3 Demonstration Roadmap," NREL/TP-5500-67464, National Renewable Energy Laboratory (Jan. 2017); https://www.nrel.gov/docs/fy17osti/67464.pdf (current as of Aug. 11, 2020).