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Heat Transfer Salts for Nuclear Reactor Systems – Chemistry Control, Corrosion Mitigation, and Modeling

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ABSTRACT

Advanced high-temperature reactors (AHTRs) use clean fluoride salts as coolants for solid, high-temperature TRISO fuel. Because AHTRs have fully ceramic cores, they can operate safely at substantially higher temperatures and higher power conversion efficiencies than conventional water-cooled and sodium-cooled reactors with metal-clad fuels. The most recent baseline AHTR designs operate with a core inlet temperature of 600°C and outlet temperature of 704°C, giving 46% power conversion efficiency. For AHTR reactor designs, conventional Alloy 800H provides an excellent near-term structural material (Caron et al., 2008). Alloy 800H is also used extensively in the chemical and fossil industries, and is ASME Section III code qualified for use in nuclear systems at temperatures up to 760°C.

The current baseline primary coolant for the AHTR is 7Li2BeF4 (flibe), which enables core designs with negative coolant void reactivity and with excellent fuel utilization. However, current purification methods require the use of toxic HF gas, which is costly to handle and is accompanied by severe safety constraints. Salt heat transfer systems will require both initial cleaning and an online chemistry control system to maintain the purity of the salt to limit corrosion and deposition and fouling problems. NF3 has the potential to replace the HF gas purification with substantially reduced costs and safety implications.

Evidence also exists that the readily available Alloy 800H may have excellent corrosion resistance with flibe, if used with purified salt and if the flibe is contacted with beryllium metal to control its redox state. Keiser et al. (1979) demonstrated that corrosion of 316 stainless steel can be reduced greatly using Be metal to control flibe's redox state. Because Alloy 800H has similar chromium content to 316 SS and a higher nickel content, it is reasonable to expect that Alloy 800H will have a similar low corrosion rate with flibe with active redox control.

The AHTR intermediate loop, as well as salt-cooled intermediate loops for the Next Generation Nuclear Plant (NGNP), will use non-beryllium-based salts. The most commonly studied intermediate salt candidate has been flinak, a mixture of LiF, NaF, and KF. Active metal control of flinak redox, using liquid sodium, has also been studied (Laurenty, 2006).

It is difficult to overstate the large reduction in cost and fabrication complexity that could be achieved if unclad Alloy 800H could be used in the primary and intermediate loop of the AHTR and NGNP plants, particularly for the construction of heat exchangers. We therefore propose fundamental modeling and experimental investigation of the corrosion of Alloy 800H by flibe and flinak, introducing new methods of purification and active redox control. The work could make a significant contribution to realizing the benefits of AHTR technology, as well as advanced intermediate loop technology, for the NGNP.