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Development and Validation of a Dual-Purpose Instrument for On-line Monitoring of Molten Salt Composition and Thermal Behavior

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ABSTRACT:

Molten salt reactor (MSR) licensing requires designers, operators, and regulators to understand the conditions of a reactor at nominal and off-nominal conditions. Thermophysical properties control the temperature and fluid behavior of the salt, but there is a dearth of data on all the necessary salt properties, and the uncertainty of the existing measured or predicted properties can be large (for example, FLiBe's thermal conductivity and viscosity have uncertainties of at least 34% and 30%, respectively). The simplest way to obtain these properties across temperature, pressure, and compositional ranges is to measure salts undergoing these processes *in-situ*, rather than going to extreme efforts to reproduce conditions ex-situ. **We propose the development of an instrumented in-core capsule to study heat transfer and salt composition of molten salts with impurities (**$NaCl\text{-}MgCl_2$ for TerraPower, $LiF\text{-}BeF_2$ for Kairos, and LiF-NaF for AlphaTech**).** By combining both capabilities into a single device and creating its digital twin, we expect to manufacture a robust, easily producible device that can provide repeatable measurements of thermophysical properties and electrochemistry for salt monitoring.

The *goal* of this proposal is to develop the capability to measure the thermophysical and electrochemical properties of molten salt with a multifunctional, *in situ* probe. The dual electrochemistry/thermal conductivity probe (DETP) will consist of a needle probe which will measure thermal conductivity simultaneously with volumetric heat capacity, and it will also be the counter electrode within the cyclic voltammetry (CV) electrode system. Baseline values for thermophysical properties of salts will be obtained for thermal conductivity (k), thermal diffusivity (α), heat capacity (c_p), density (ρ), and surface tension using commercial and custom devices. Salt purity will be achieved by filtration and electro-refining.

The ***specific objectives*** of this project are to:

1. Develop dual purpose instrument for on-line monitoring of molten salt.
2. Develop a digital twin of the DETP for further testing, analysis, and validation of system.
3. Determine and validate the CV peaks of actinide, fission products, and corrosion products in a variety of salts by measurement of these components in salt using ICP-MS and performing square-wave CV sweeps.
4. Validate the DETP through the analysis of pure and impure salts of known composition with known thermophysical properties.

The *major deliverables* of this research are: **(1)** A dual electrochemical and thermophysical probe that can characterize several properties of molten salt simultaneously; **(2)** Database of electrical potential and CV peaks of impurities in a variety of molten salts; **(3)** Thermophysical data to populate the MSTDB-TP.

Innovations include: **(1)** The needle probe is the only device capable of measuring properties of k and ρc_p within a reactor, **(2)** BYU's electrode system is capable of measuring 10 ppm of O_2 using cyclic voltammetry compared to other systems that have difficulty detecting O_2 lower than 100 ppm. **(3)** By combining both into the DETP, measurements of thermophysical properties and electrochemistry can provide redundancy for salt monitoring.