Component And Technology Development For Advanced Liquid Metal Reactors

PI: Mark Anderson, University of Wisconsin-Madison **Collaborators**: N/A

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ABSTRACT:

Liquid metal cooled reactors, such as the sodium-cooled fast reactor (SFR), work safely and effectively, however they suffer from non-competitive economics, with an expectation of being more costly to build and operate than light water reactors. Advancements in materials and technology can potentially add safety margins and design flexibility critical to improving reactor performance and economics. Through increased strength and creep resistance, advanced materials provide greater margins to design limits, leading to longer lifetimes and higher operating temperatures. This will improve the economics of the SFR with concomitant reductions in welding, quality assurance, fabrication costs and design simplifications. Compact heat exchanger designs, which are diffusion bonded (with or with-out interlayers) allow efficient coupling to advanced s-CO_2 Brayton cycles thus further increasing safety, performance and economics. Alloys such as, NF-709, HT-UPS, and ODS steels offer revolutionary gains in high-temperature performance compared to traditional materials such as HT9 and 316ss. Advanced ceramics such as; SiC or CVD SiC composites can be used for pump components, heat exchangers, diagnostic equipment and in the accident tolerant fuel cladding in future reactors. These materials however, have to be tested in sodium and will need further development on joining technology. Based on an analysis by Busby in 2009, the use of advanced alloys has the potential to decrease the construction cost of the SFR. This is especially true for high operating temperature systems (>600^{o}C), due to increased strength and corrosion resistance of the advanced alloys. Based on this work, HT-UPS has the potential to reduce the capital cost of an S-PRISM reactor core vessel and internals by $110 Million dollars.

This proposal has three major objectives with regard to support of the SFR and component technology development, which directly addresses Section RC-2.2 of the NEUP-CFP - "*Component and technology development (e.g. corrosion and oxygen control systems or compact heat exchanger design*".

Objective 1. Testing of advanced alloy materials and heat exchanger components
Under this objective we will conduct materials research on advanced alloys and ceramics with a focus on studying diffusion bonded alloys in contact with liquid sodium. This will support coupling of the SFR with advanced s-CO_2 Brayton cycles and help to increase economics and safety of sodium fast reactors.

Objective 2: Ceramic Materials Testing and Galvanic Cell O_2 Sensor development
Under this objective we will continue current ongoing efforts at the UW-Madison to develop a cheap simple O_2 sensor for liquid sodium. This will aid in sodium testing and could be used as a key diagnostic in the SFR to help reduce long term corrosion and help monitor for potential problems.

Objective 3: Diagnostic and instrument/component development
Under this objective we will test newly developed distributed optical fibers that are capable of acquiring thousands of temperature measurements with a single penetration into a sodium system. This diagnostic can yield data of sufficient spatial resolution to verify CFD models. These probes will also be used to measure local mean and fluctuating velocities by use of advanced cross correlation techniques of temperature fluctuations. Once proven the instrument will be used to improve upon the theory of novel moving magnet pumps previously developed and tested at UW-Madison.