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Development and Demonstration of Scalable Fluoride Salt Pump Bearings and Seals for FHRs

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ABSTRACT:

Reliable high-temperature molten salt pumps are critical to the successful deployment of Fluoride-salt-cooled High-temperature Reactors (FHRs). The long-shafted pumps are favorable for radioactive, high-temperature fluoride salt applications, but require salt-lubricated bearings to stabilize the shaft and columns during operation. Fluoride-salt-lubricated bearings remain a substantial engineering challenge mainly due to the material corrosion and thermal distortion. In addition, the long-shafted, vertical pumps with salt-lubricated bearings require to be operated before being filled with liquid salt. Therefore, the bearings need to be capable of dry running for a short period of time during startup. Over the past few decades, significant progress has been achieved in high-temperature bearing technologies. Modern ceramic materials may resolve the salt-lubricated bearing performance issues. Two promising candidates are silicon carbide and diamond bearings. Both are compatible with high-temperature fluoride salts, but have not been demonstrated for FHR applications in a prototypical operating environment.

High-temperature shaft seals are especially essential for the FHR primary pumps as the temperatures of fluoride salts are high and large clearances between the shaft and seal leave larger paths for potential gaseous radionuclide releases. Potential seal candidates to separate the primary salt cover gas environment from the external environment are Labyrinth, metal bellow, and diamond mechanical seals. A significant obstacle to their adoption is that they have yet to demonstrate that a leak-tight shaft seal can be maintained in a high-temperature environment under FHR conditions. Finally, the FHR primary pumps with salt-lubricated bearings and high-temperature shaft seals are significantly larger than laboratory models and hence are technically challenging at scale. Therefore, it is important to investigate pump scaling from laboratory size to the industrial scale.

This proposed research aims to develop and demonstrate scalable advanced bearings and seals of fluoride salt pumps for FHRs. Our systematic approach will employ both experimental and numerical methods to investigate the static and dynamic performance of fluoride-salt-lubricated bearings and high-temperature shaft seals for long-shafted, cantilever pumps. The proposed project will test pumps with improved bearings and seals to benchmark both the thermal-hydraulic and thermo-mechanical pump models, which leads to improvements in pump design, fabrication, and operation. The scalability evaluation of fluoride salt pumps provides guidelines and insights for large-scale pump designs that are useful for FHR developers.