Purification of Liquid-Metal Nuclear Reactor Simulator through Cold Trapping

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1. Abstract

Hardware to filter oxide precipitates from a liquid-metal in a simulated nuclear reactor has been designed and fabricated. Presently, the working fluid proposed for use in space fission power systems is a sodium-potassium (NaK) eutectic, which remains liquid from room temperature all the way up to the reactor operating temperature of greater than 900 K. Oxide contamination of the NaK is a leading cause of corrosion in these high temperature reactor systems. The oxide-filtering hardware implemented consists of NaK flowing within a gaseous nitrogen jacket, which allows for cooling of the fluid, causing oxide to precipitate out of the solution. Within this "cold trap," the liquid metal flows through an elaborate combination of mesh screen, baffles, and mesh discs that are designed to collect and entrap the precipitated contaminates. Tests performed using water at similar pressures and flow rates to simulate operating conditions have been conducted to determine the fluid residence time in the trap. The efficiency of the cold trap in filtering impurities from the Nak may significantly influence the performance of the system.

2. Background

Space fission power systems are an alternative for providing power for manned lunar and Martian bases. In order to develop a reactor in a safe and cost effective manner, components are tested using a simulated reactor core that uses liquid metal as the heat transfer medium. The liquid metal used in both the actual reactor and the simulated system is a sodium-potassium (NaK) eutectic, which remains liquid from room temperature to the reactor operating temperature of greater than 900 K. In previous NaK-fed systems, impurities consisting of sodium and potassium oxides were found to cause performance hindering corrosion of the test loop. To prevent corrosion and increase system efficiency, a filtering device has been developed to remove oxide contaminants from the NaK. The filter utilizes cold trapping to precipitate the oxide contaminants out of solution and contain them.

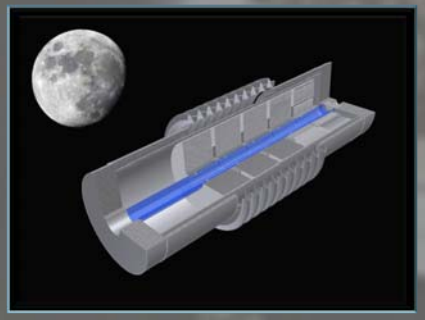
3. Theory

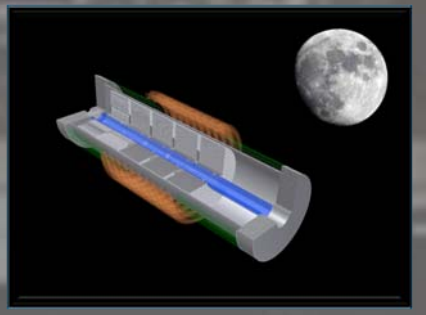
This particular cold trap is a forced circulation trap, which operates along a bypass line of the test loop as opposed to the main line. The components of the trap will theoretically accomplish the following:

- The nitrogen jacket surrounding a system of baffles, mesh discs, and screen provides a low temperature environment.
- As the NaK flows through the trap, the induced cold point is equal to or lower than the temperatures where oxides precipitate out of solution.
- A contamination level of 1000 parts per million molecules of oxygen was assumed to begin preliminary design, which is a significantly higher contamination than the research grade NaK used in this test.
- It was calculated that 150 grams of oxide precipitate is capable of forming at that of contamination level .
- The design of the trap and surface area provided by the mesh and screen is more than adequate to collect 90% of the assumed contaminants present.

4. Methodology

- A nitrogen jacket surrounding the cold trapping system provides a cold environment, causing precipitation of oxide contaminants.
- The flute-like design of the inner tube allows NaK to disperse through the trap at several axial locations.
- An elaborate system of mesh screen and disks spanning 2 inches in diameter and 7 inches in length provide sufficient surface area to trap precipitants.
- Baffles through the trap force the NaK to spread to the coldest portions of the trap (the outer walls) to promote maximum precipitation of contaminants.
- Valves in line with the trap allow for manual adjustment of pressure drop and flow rate through the trap.





5. Conclusions

- The cold trap is predicted to effectively filter contaminants from the NaK, providing a method to clean the working fluid in both reactor simulators and flight reactor units.
- The cold trap will be incorporated in the Annular Linear Induction Pump (ALIP) Test Circuit for the NASA/MSFC Propulsion Research and Technology Branch Nuclear Propulsion Group
- Future tests to determine fluid residence time are to be performed