High-Temperature Liquid Metal Compatibility Testing

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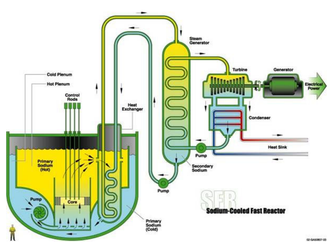
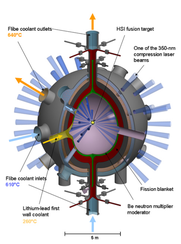
Project Overview

- Fusion reactors with a liquid metal first wall and sodium-cooled fast reactors (SFRs) require materials and components that can withstand liquid metal attack at temperatures up to 600°C.
- Our current experimental setup is capable of testing new alloys and equipment for a variety of liquid metals in order to study the effects of temperature, flow rate and impurity concentration.



Concept design for a sodium cooled fast reactor.

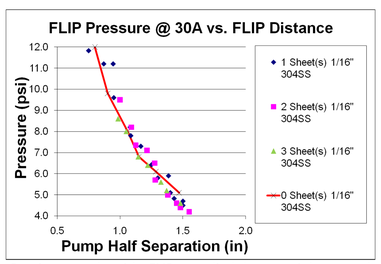


LIFE reactor design with liquid metal first wall.

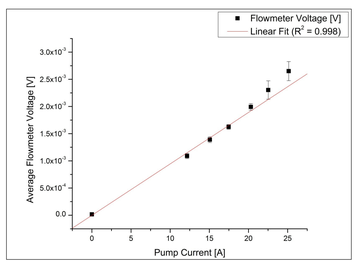
Component Testing

- The pumped corrosion testing loop uses a flat linear induction pump (FLIP) to pump 600°C sodium @ 13 gpm / 15 psi.
- Advanced cooling system enables inexpensively made pumps to be placed very near the 600°C liquid metal duct.
- Pre-existing infrastructure allows for the safe calibration of high-temperature pumps and equipment.

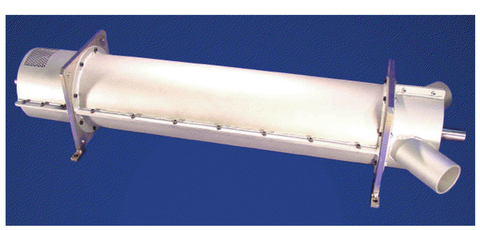
The coils of the FLIP are impregnated with an epoxy that can withstand temperatures up to 180°C. The coils are also oil resistant.



Previous work with FLIPs studied how stainless steel sheeting and pump configuration affected performance. This study was essential in designing the cooling system.



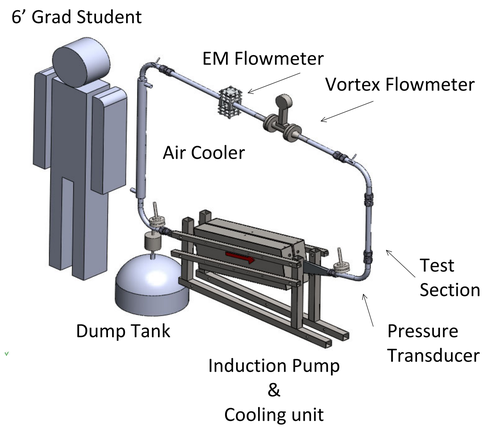
Sodium flowing in the ceramics testing loop enabled the calibration of a small scale EM flowmeter. This flowmeter design has been incorporated into the larger loop.

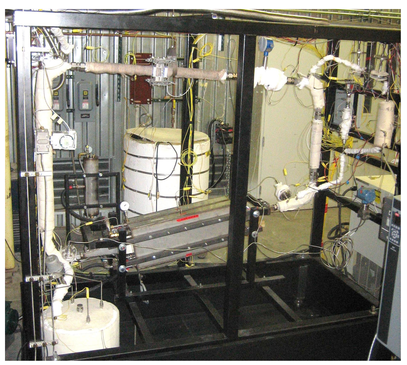


A photo of an air-cooled annular linear induction pump (ALIP) designed and built by CMI-Novacast Inc. that was tested and calibrated at UW-Madison.

High-Temperature, High Flow Rate Sodium Test Loop

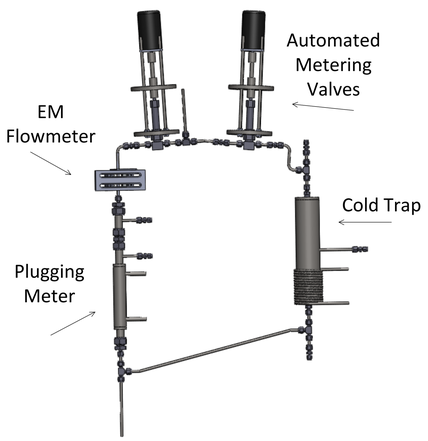
Main Loop

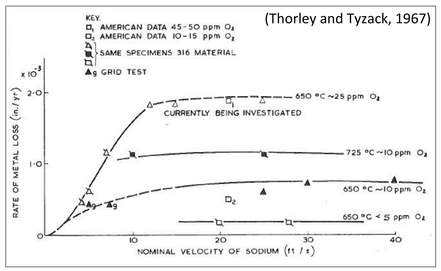




- Constructed from 1" ID 304/316 SS tubing
- 1-25 wppm oxygen concentrations achievable
- Impurity monitoring to 1-2 wppm
- 7+ gallon capacity situated above safety pan

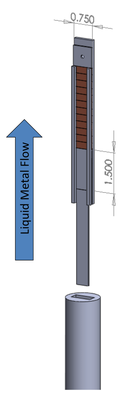
Diagnostic Loop





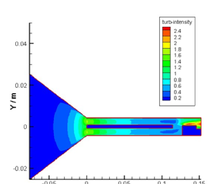
- Corrosion is a function of temperature, flow rate and impurity level.
- The diagnostic loop enables the real time control and measurement of impurities and O_2 levels.

Sample Testing Capability

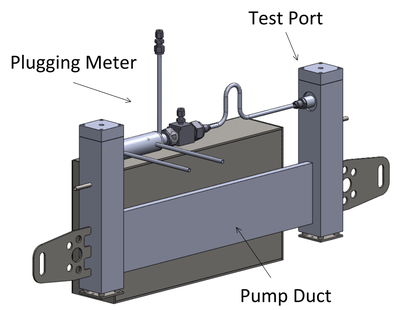


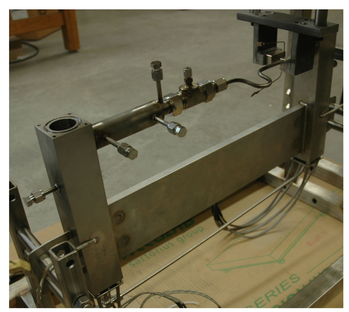
- Ten individual 0.25" x 0.75" x 0.0625" flat samples can be loaded at a time.
- The sample holder was designed to achieve fully developed flow over the samples.
- The reduced cross section of the test section allows for speeds up to 10 m/s with sodium.

- Stress corrosion cracking is studied on ten strained ASME specified "C" samples
- CFD calculations were performed to model the flow over the samples



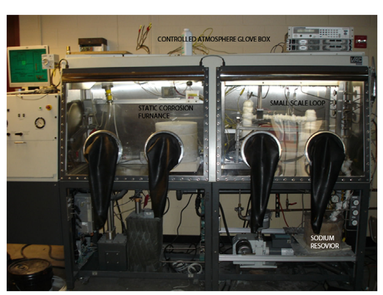
Oxygen Sensor Development



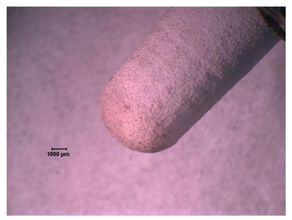


The ceramic corrosion testing loop before insulation and installation into the glove box.

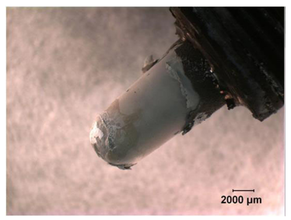
- Corrosion of alloys is highly dependent on O_2 levels within the sodium.
- Plugging meters may need 10-30 min to work based on the O_2 level in the system and have wetted orifices that may need to be changed .
- Galvanic oxygen sensors, like those used in cars, could be used to generate a voltage that is proportional to the impurity level.
- Current work is being undertaken in a 1+ gallon loop held within an oxygen controlled glove box.



The ceramic testing glove box houses a static testing system and a 1+ gallon flowing loop.



Before exposure to 300°C sodium for 100 hrs.



After exposure with obvious degradation.

- Work is underway to modify commercially available automotive oxygen sensors for application with high-temperature sodium.
- This requires testing ceramics to determine oxygen permeability and resistance to sodium attack.

Bibliography

Life Reactor Picture - https://lasers.llnl.gov/about/missions/energy_for_the_future/life/how_life_works.php, Accessed 11/4/2010.

Sodium Cooled Fast Reactor Picture - http://www.usnuclearenergy.org/GEN%20IV%20Reactors.htm, Accessed 11/4/2010.

A. W. Thorley and C. Tyzack. Corrosion behavior of steels and nickel alloys in high-temperature sodium. Alkali Metal Coolants, (SM-85/18), 1967.

Acknowledgements

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