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Design and Optimization of a Molten Metal Loop Driven by an Electromagnetic Pump

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MECHANICAL AND NUCLEAR

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CAPSTONE DESIGN EXPO 2016

Introduction

- Liquid Metal Fast Reactor (LMFR) utilizing liquid metal as a coolant is being considered for future nuclear energy.
- In this senior design project, the team is working on design and optimization of a molten metal by using an electromagnetic pump.
- There are several challenges in this study :
  - Operate at temperatures above 250 °C;
  - Control of system at relatively high pumping velocities;
  - Efficiently fill and drain metal from the system; and
  - Accurately collect pressure and flow data.

Proposed Designs

Determining Pressure Drop

- An orifice flow meter manufactured by the previous group would be used to introduced a known pressure drop.
- Another pressure measurement would be taken across the pump itself.
- Three designs had been considered:
  - The first method uses a differential pressure gauge because
    - It is easy to install and accurately obtain data and
    - This type of gauge can be used to introduce gas into the system.
  - The second method utilizes a U-tube manometer because
    - It has a visible pressure difference,
    - This cab be calculate easily, and
    - Gases such as air, helium, and argon can be used as they are relatively safe to use and handle.
  - The third method is using a single manometer per pressure tap
    - Each manometer will be filled with argon gas and will provide visible pressure differences.

Heating and Insulation

- Heating tape would provide high, controllable temperatures but could be unreliable and would require long repair times.
- Heating Canisters are more reliable and easier to repair with equal temperature ranges but would not provide uniform heating.
- Insulation would need to accommodate quick repair of heating elements as well as sustain desired temperatures.
- Rigid ceramic insulation would provide structure to the system as well as a location to secure the heating elements.
- Sheet insulation may provide easier access to component.

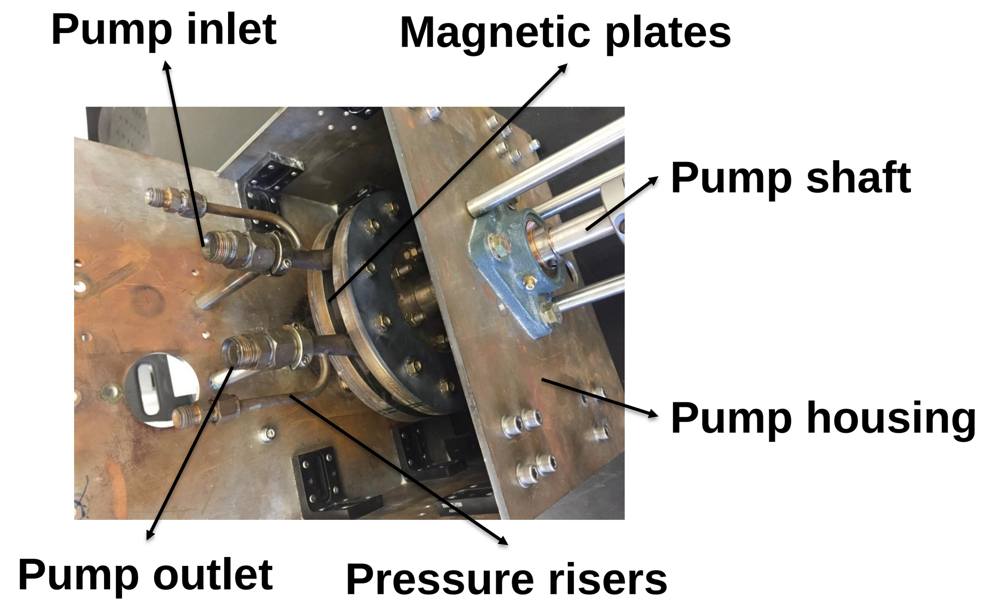

Figure 1: Pumping mechanism which will move the molten tin.

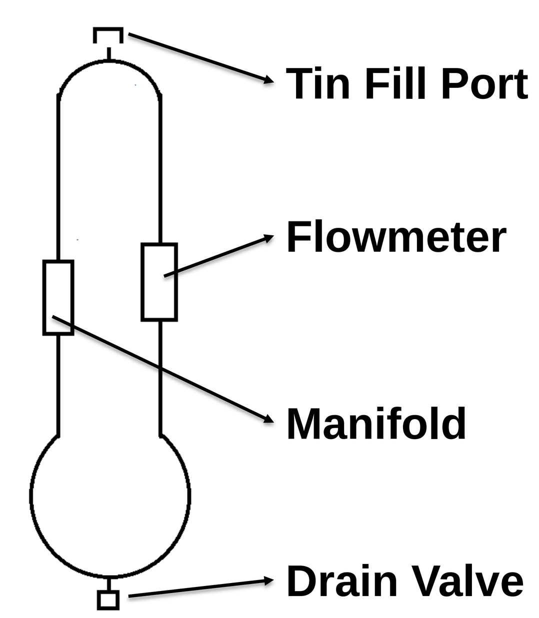

Figure 2: Initial design of the pump, showing U-tube manometers.

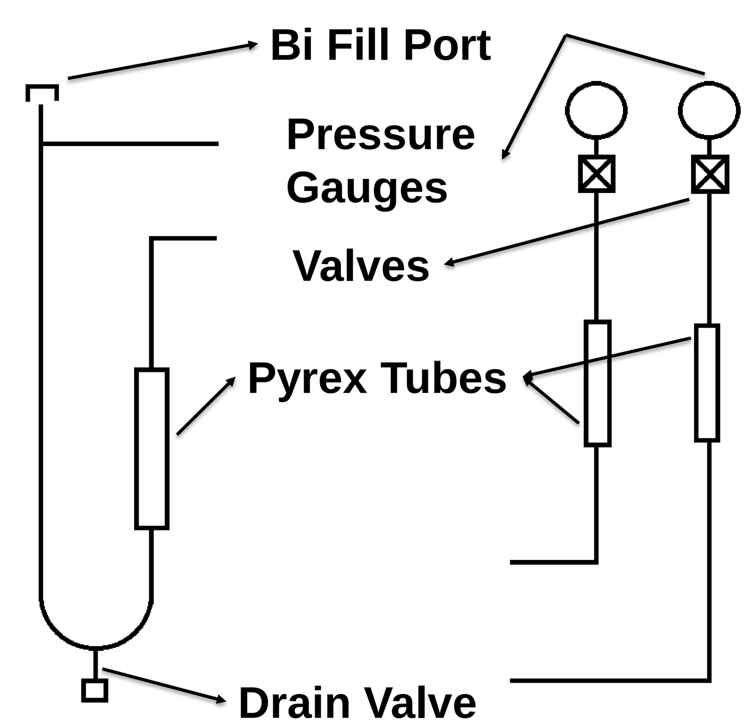

Figure 3: Second design of pump, showing pressure gauges and Pyrex tubes.

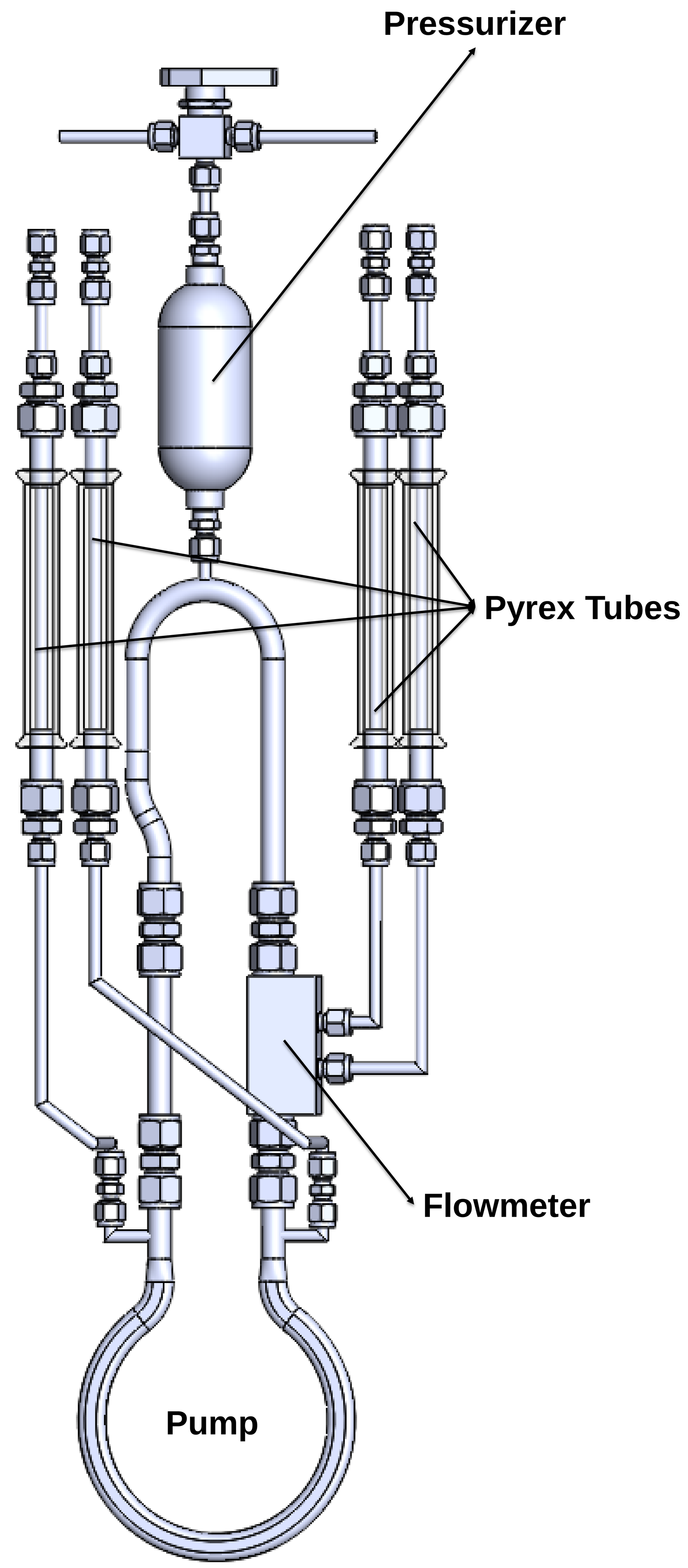

Figure 4: Final design of pump, showing risers, Pyrex tubes, and pressurizer on top.

Current Design

- The current system includes the electromagnetic pump and a flowmeter attached as a closed loop system with four pressure taps.
- The pressure differences will be visually observed and can be calculated through four Pyrex tubes, acting as manometers, affixed to four risers filled with argon gas.
- Additionally, the risers for the manometer tubes have been equipped with union fittings that allow pressure gauges to be attached for better pressure measurements.
- A pressurizer was implemented to prevent over and under pressurization of the system with the Pyrex tubes, as well as the pressurizer system, serve as a visual aid to prevent this cavitation.
- Argon was chosen over air as it does not interact with tin, even at high temperatures.
- In regards to heating and insulation, the system is being placed in between rigid ceramic insulating sheets.
  - Heating tape is being attached to the insulation, instead of wrapped around the tubing; this will allow for a manageable maintenance and repair.

Future Considerations

- The current system is designed such that the return loop may be fitted with a manifold:
  - This would allow for instrumentation to be inserted directly into the fluid flow
  - Adding a quartz windows would allow the use of Laser Induced Breakdown Spectroscopy (LIBS) for near real time chemical analysis of the flow.
  - This could expand the scope of the project into detection of impurities and contaminants in the molten metal flows.
  - Such research could be used to determine the usability of LIBS in molten metal flows, including nuclear applications.

Acknowledgements

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