Retractable Sensors for In-Core Service in Material Test Reactors

Principle Investigators: Ge Yang (NC State University), Joe Palmer (INL)
Emails: gyang9@ncsu.edu, joe.palmer@inl.gov

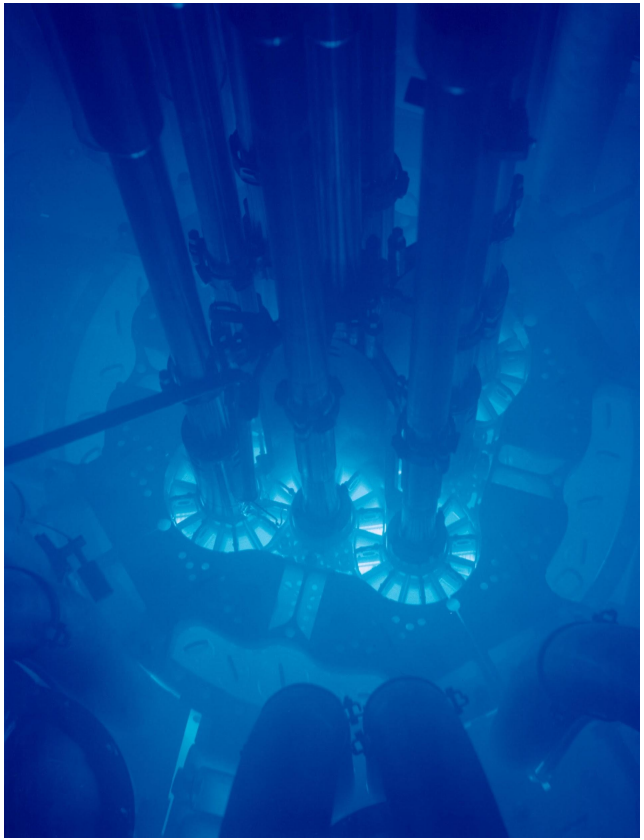
Student Researchers: Nik Fikenscher (Nuclear Engineering, NCSU), Alex Chrystler (Nuclear Engineering, NCSU), Caleb Jolley (Mechanical Engineering, NCSU), Henry Osborne (Nuclear Engineering, NCSU)

NC STATE UNIVERSITY

INL Idaho National Laboratory

Outline

- Project Motivation
- Design Constraints
- Sensor Insertion Device Design
- Research Prototyping
- Control System Design
- Mechanical Challenges
- Testing the Design
- Results
- Conclusions and Perspectives



https://en.wikipedia.org/wiki/File:Advanced_Test_Reactor.jpg

Motivation

Thermocouples Experience Drift in High-Temperature, High-Flux Environments

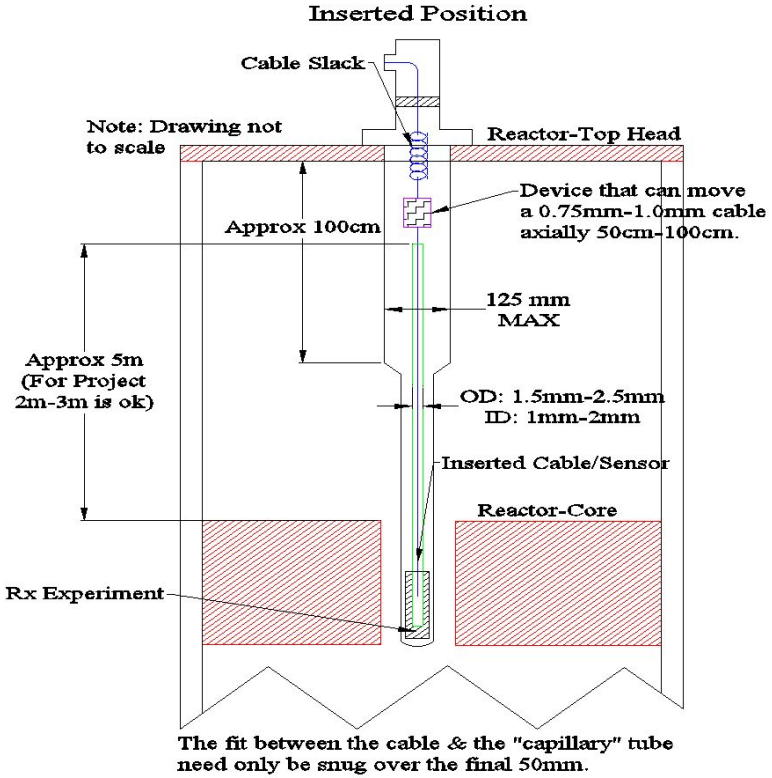
- Idaho National Labs' Advanced Test Reactor (ATR) performs material Irradiation experiments
  - Experiments require very specific temperatures
  - 1 temperature measurement per day is ~95% complete data set

- Thermocouple degradation contributes to sources of error in experiments, inexplicable material failures

- Solution: Make the thermocouple retractable!
- Challenges:
  - Driving small thermocouple cable
  - Cable Storage
  - Controlling the system

Design Constraints

- Device must move thermocouple ~50-100 cm
- Device must be contained 125mm instrumentation lead
- Must drive in 1 mm thermocouple
- Must stop when the thermocouple is fully inserted
- Needed to manage excess cable



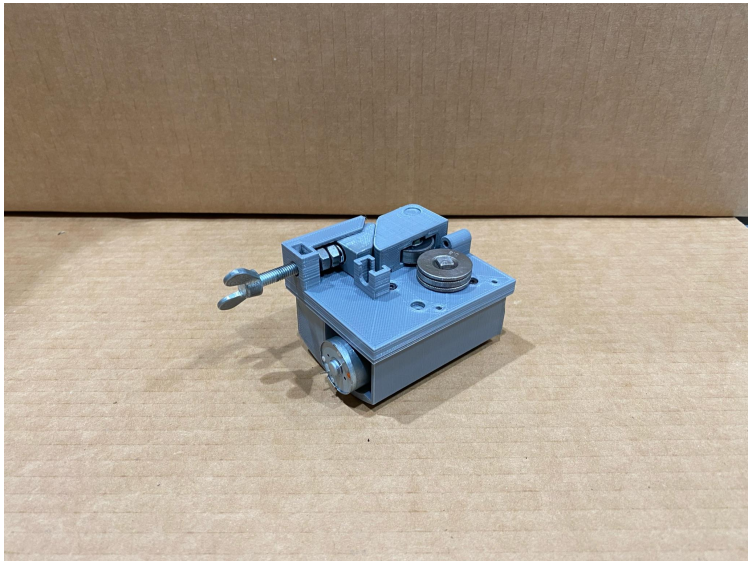
Objectives

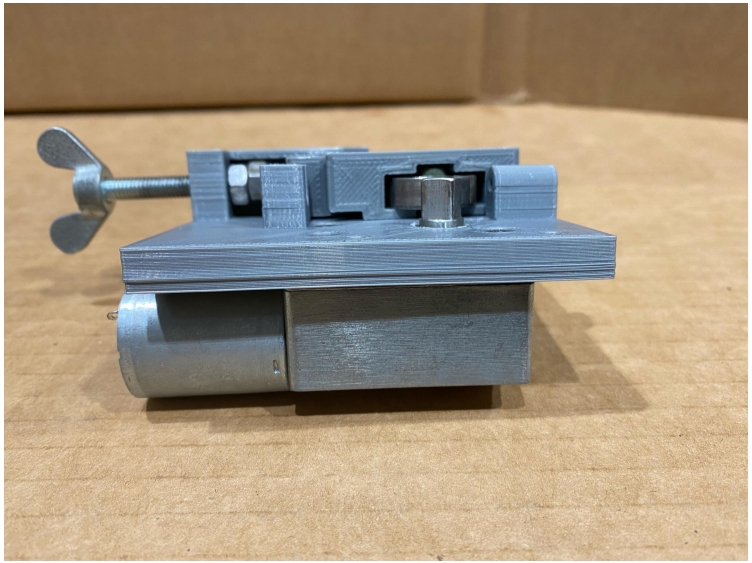
- Modify the motor drive system so it takes up a low profile and fits in a 5” diameter tube
- Manage the slack from the thermocouple wire in a neat and effective way
- Demonstrate that the motor drive can push a 1/16” thermocouple wire through 6m of capillary tubing
- Demonstrate that the motor drive can insert and retract the thermocouple wire 40 cm forward and back 50 times once the wire is fully inserted in the capillary tubing.
- Obtain accurate temperature readings from the thermocouple during the life-cycle test

Modifying the Motor Drive

The previous motor drive (shown left) that was used was fairly bulky mainly due to the large gearbox shown below. The motor itself protrudes about 2 inches from the gearbox. If the contraption were smaller, more experiments could be run in a reactor at a time because more instruments would fit. To solve this issue, the gears were eliminated completely. Instead, a much smaller metal gearbox inside of a 6 RPM Greartisan motor was used. The wheel was fitted to a steel shaft extender that was orthogonal to the gearbox.

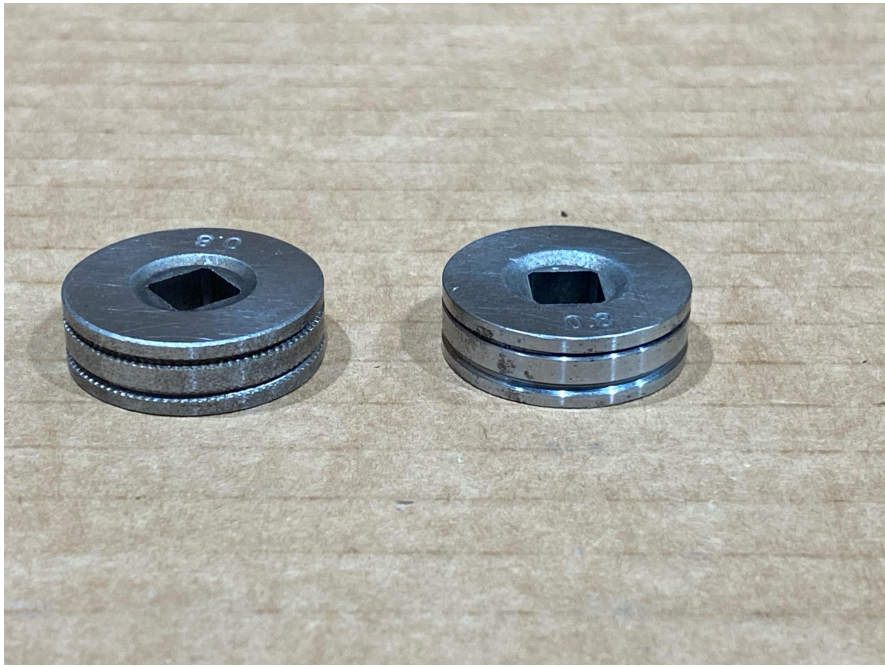
Modifying the Motor Drive





The improved motor drive comes in two pieces. The bottom piece is a shell with a diameter of 5” that matches the diameter of the clear tube. The housing top consists of a drive wheel, an idle wheel, and a screw-lock system that locks the idle wheel into place.

Modifying the Motor Drive

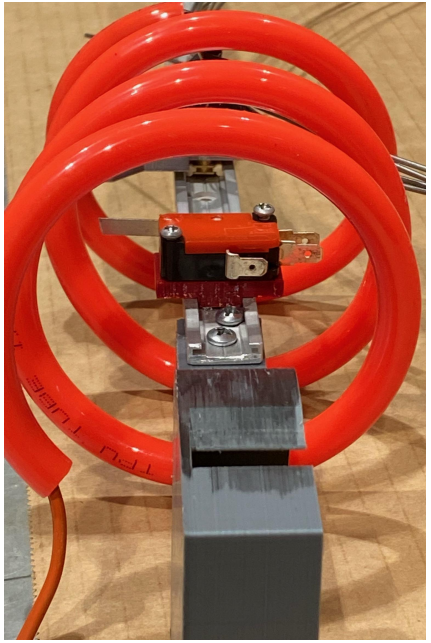


A stainless steel shaft extender was machined onto out Greartisan motor in order to avoid the bulky gearbox used on the previous motor drive. The wheels tested are shown above to the right. The wheel on the right had a 1/16” groove cut into it so it could accept a 1/16” thermocouple wire.

Thermocouple demonstration/Wire

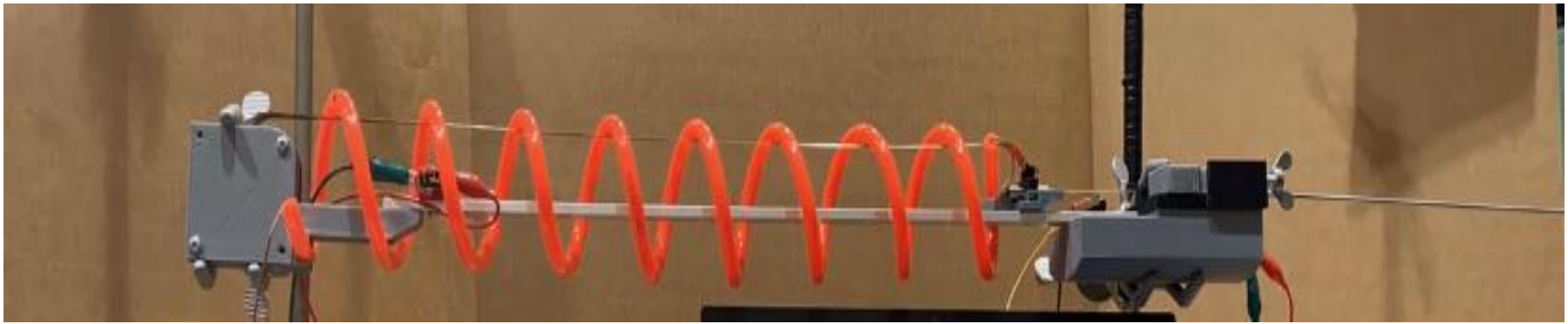
The life cycle testing did not include all 6m of capillary tubing and only used a .040” thermocouple.. In order to prove that a 1/16” thermocouple wire could pass through 6m of tubing and and be inserted/retracted 40cm, it was straightened using a pair of vice grips. In order to reduce the risk of damaging the wires, they were enclosed in scrap plastic. Afterwards, the wires were slightly yielded.

Slack Management



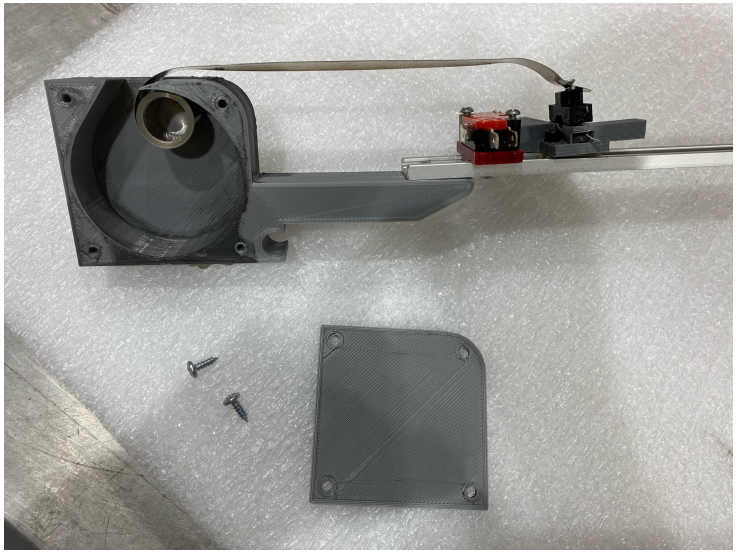
To manage the thermocouple slack, an air hose was cut to the exact length of the thermocouple slack and it was allowed to expand and contract when necessary. One end of the hose was fastened to the moving carriage piece. The other end was fastened to a spring housing piece.

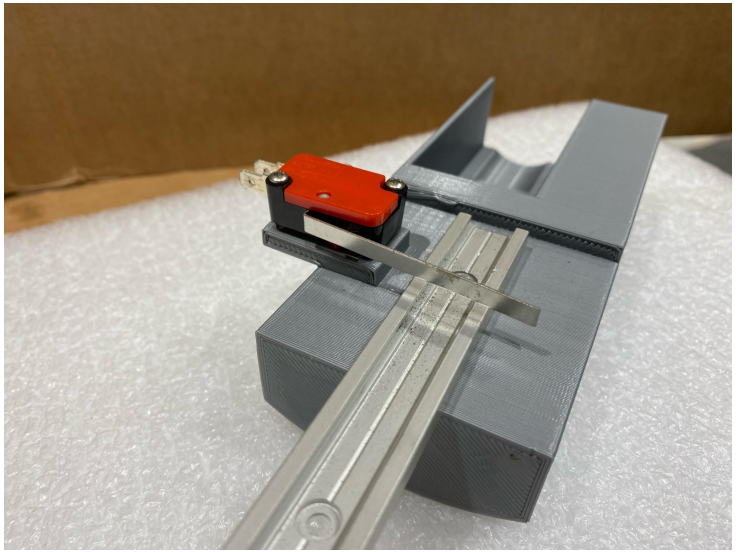
Testing Setup



A .040” thermocouple was run through one capillary tube which entered a furnace heated to around 100 C. Adjustable stands were used to keep every part of the setup at the same height, and a spring with a force of 3.290 lb was used to help the air hose contract 40cm.

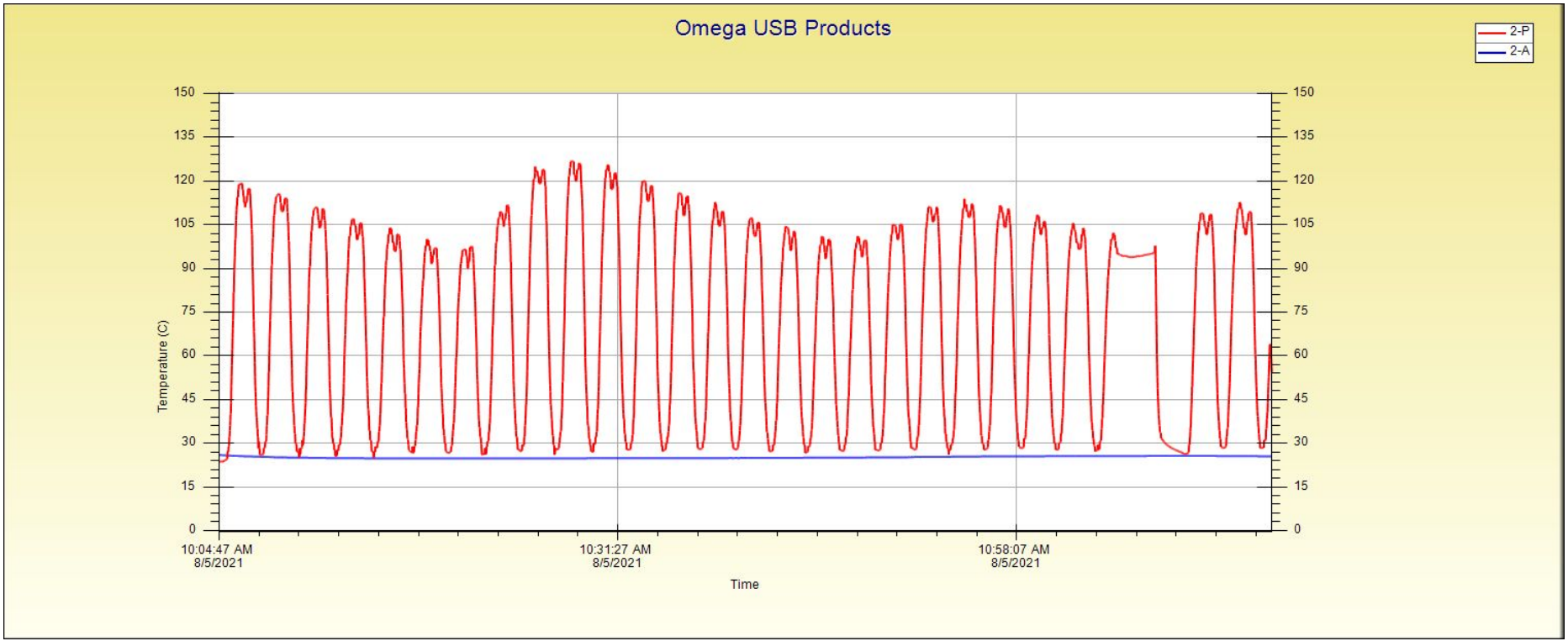
Testing Setup





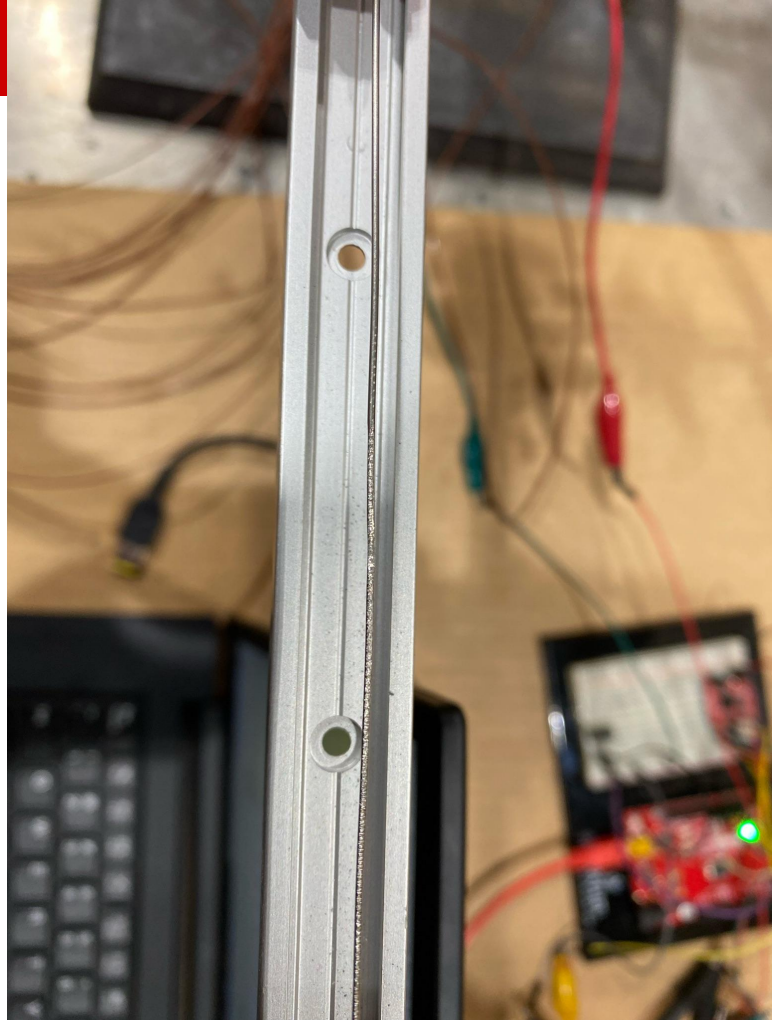
The 3D printed spring housing unit contains a longer platform so the aluminum track could be fastened to it. Limit switches were also placed on each end of the track and an arduino code was written to program the carriage to change directions each time a switch was activated.

Life-Cycle Test Results



Perspectives for further improvements

In the preliminary tests, the thermocouple was inserted and retracted about 25 times before it failed. During this test, the knurled wheel was used because it had a tendency to grip onto the wire better than the grooved wheel. The knurling ended up indenting the thermocouple wire and slightly reducing its diameter after each insertion/retraction. Because of this, the wire became harder to grip and the contraption eventually failed. Appropriate modifications need to be done to address this issue.



Future work

- We have developed a design for enabling a retractable thermocouple insertion device for in-core service.
- Component fabrication, prototype development and preliminary tests have been conducted.
- Continuous improvements and modifications are on-going.

Acknowledgements

We appreciate the support from Idaho National Lab (INL).

Questions

Thank you for your attention!