The Construction and Validation of Rotating Electrodes in Molten Salts for the Measurement of Hydrodynamic Properties and Corrosion

PYRO LAB — Pyrochemical Research & Operations

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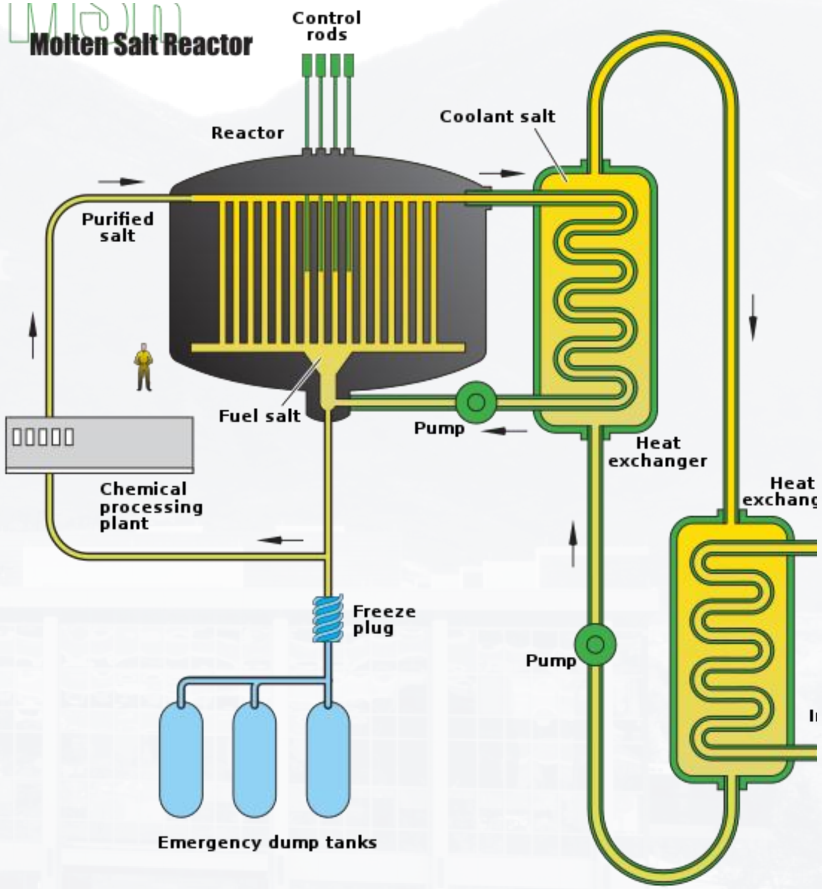
Introduction

- Flowing molten salts in:
  - Concentrated solar power
  - Molten salt nuclear reactors
- Corrosion of materials and properties of the salt need to be quantified



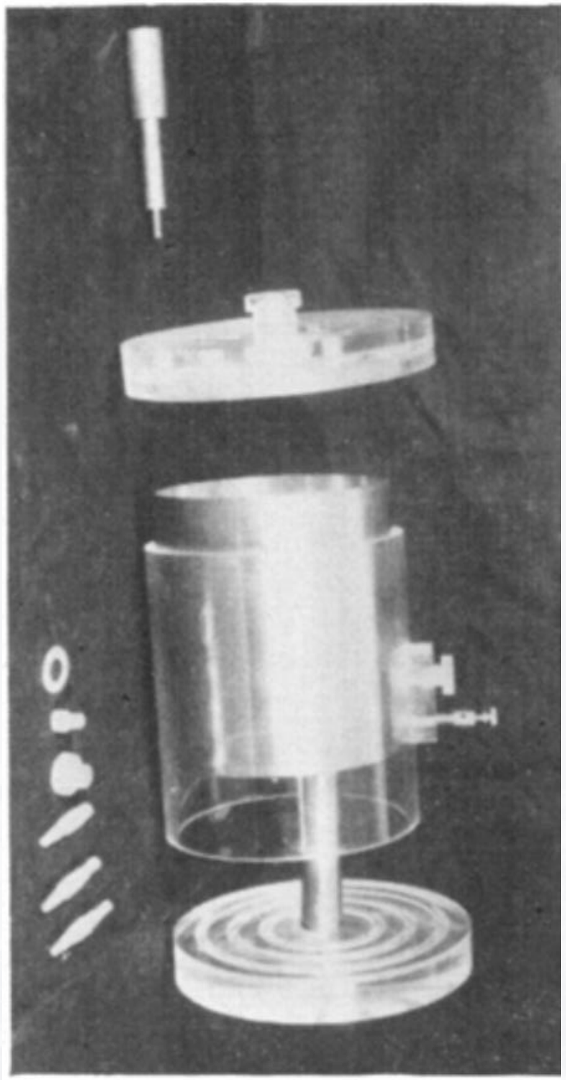
Current Methods of Corrosion Testing

- Static coupon tests
  - Small, simple
- Molten salt flow loops
  - Large, complex
- Rotating electrodes
  - Intermediate solution

Theory

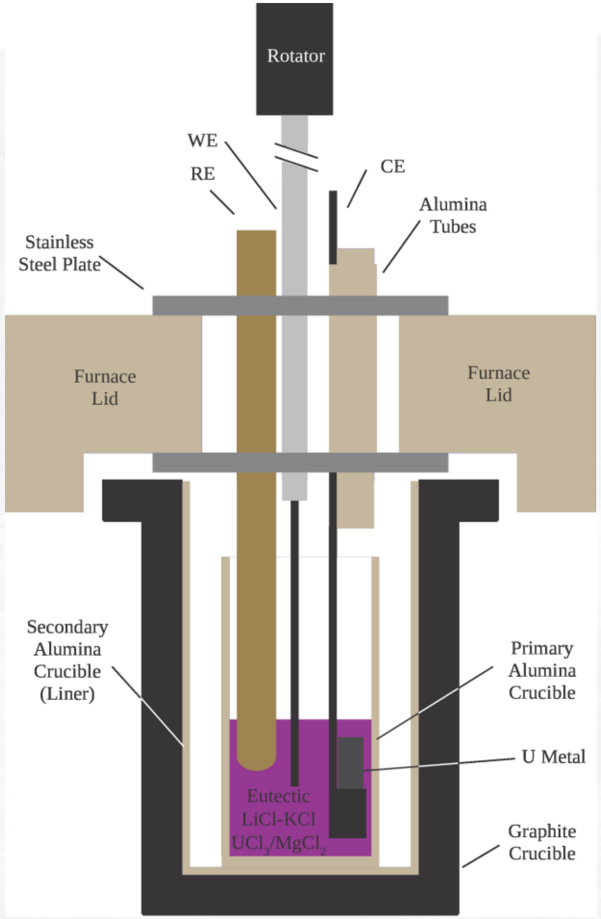
- Eisenburg Equation:
  - $I_L = 0.0791nFC(\pi d\omega)^{0.7}d^{-0.3}\nu^{-0.344}D^{0.644}$
    - Reynolds Number: 1000-100,000

n	Number of electrons	ω	Rotation rate
F	Faraday's Constant	ν	Kinematic viscosity
C	Concentration	D	Diffusion coefficient
d	Diameter of electrode		



Eisenberg, M., Tobias, C. W., & Wilke, C. R. (1954). Ionic Mass Transfer and Concentration Polarization at Rotating Electrodes. *Journal of The Electrochemical Society*, *101*(6), 306-320. https://doi.org/10.1149/1.2781252

Rudimentary Initial Application in Molten Salts

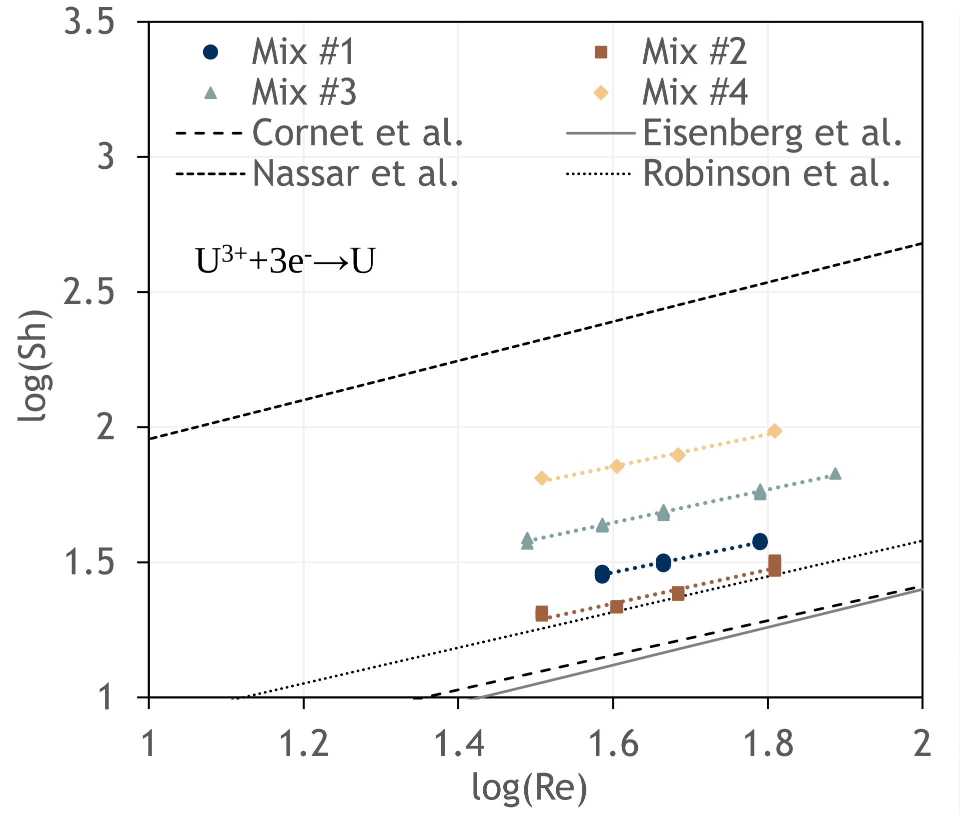


Working Electrode (WE): Tungsten

Counter Electrode (CE): Uranium in S.S. Basket

Reference Electrode (RE): Ag/AgCl(5 mol%)/Mullite

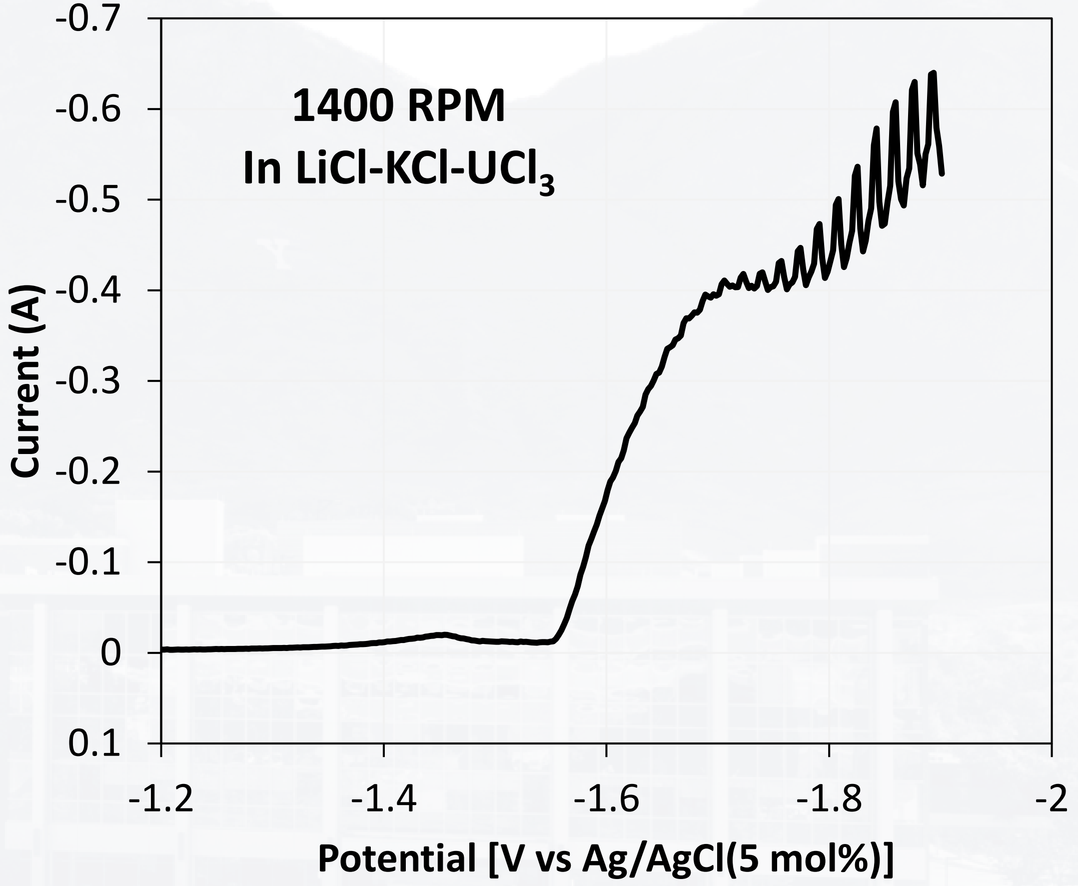
Mix	UCl3 (wt%)
#1	0.51%
#2	0.48%
#3	1.02%
#4	0.89%



Rappleye, D., & Simpson, M. F. (2017). Application of the rotating cylinder electrode in molten LiCl-KCl eutectic containing uranium (III)-and magnesium (II)-chloride. *Journal of Nuclear Materials*, *487*, 362-372.

Initial Application using Commercial Unit

- Brushless Rotating Electrode (Autolab RDE 2)
  - Whipping
  - Currents > 0.5 A



Commercially Available Rotating Electrodes

Brushless Rotating Electrode

10,000 RPM
0.5 A Max

Carbon Brush Rotating Electrode

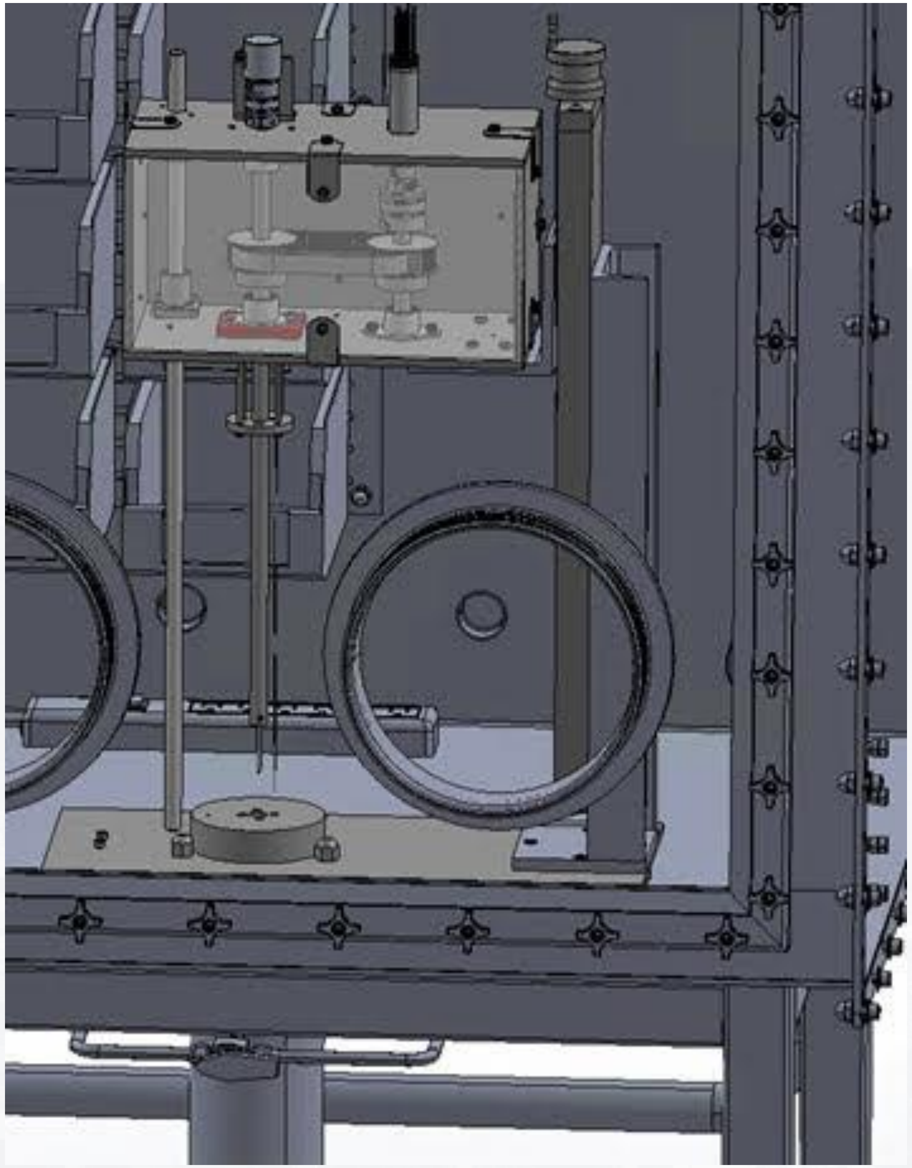
10,000 RPM
28.3 mN·m Max

Design Challenges for Rotating Electrode Experiments in Molten Salts

- High temperatures (up to 1000^{o}C)
- Long distance into hot zone of furnace
- Corrosive environment
- The design needs to be versatile
  - Handle a wide range of rotational speeds
  - Able to perform static and rotating electrode measurements
- Need to be able to precisely control the rotating electrode depth in the molten salt

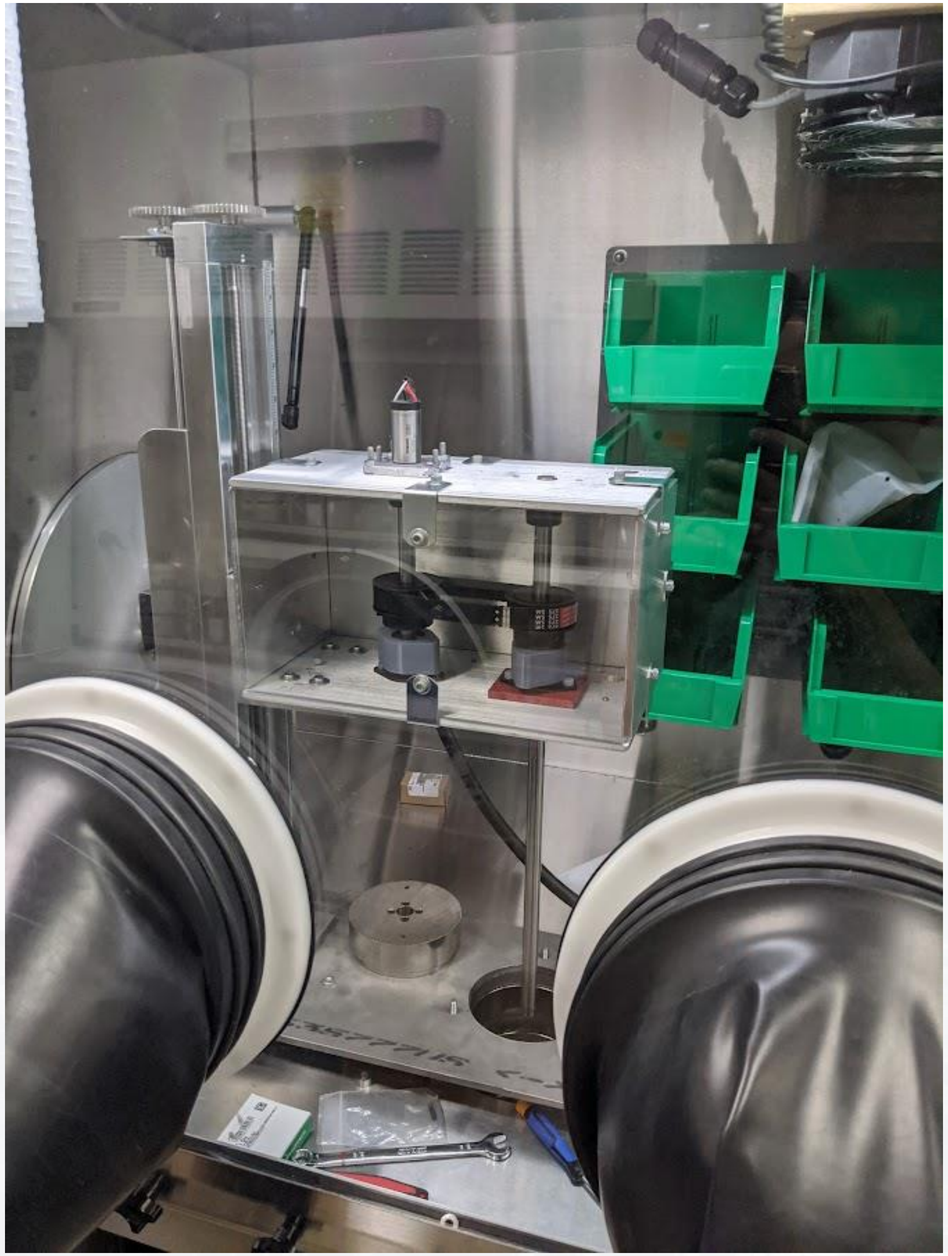
First Design

- A motor drives the rotating shaft via a belt and pulley
- Features a brushless, high-speed slip ring for electrical contact
- High temperature parts made of 304 stainless steel
- Multiple holes for optional electrode placement
- The entire box may be raised and lowered precisely via a vertical translator



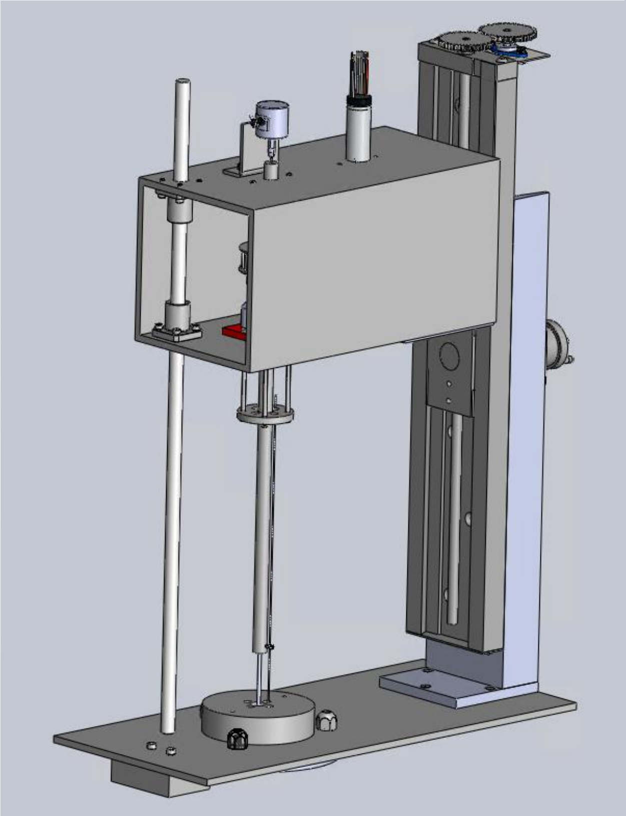
Issues with First Design

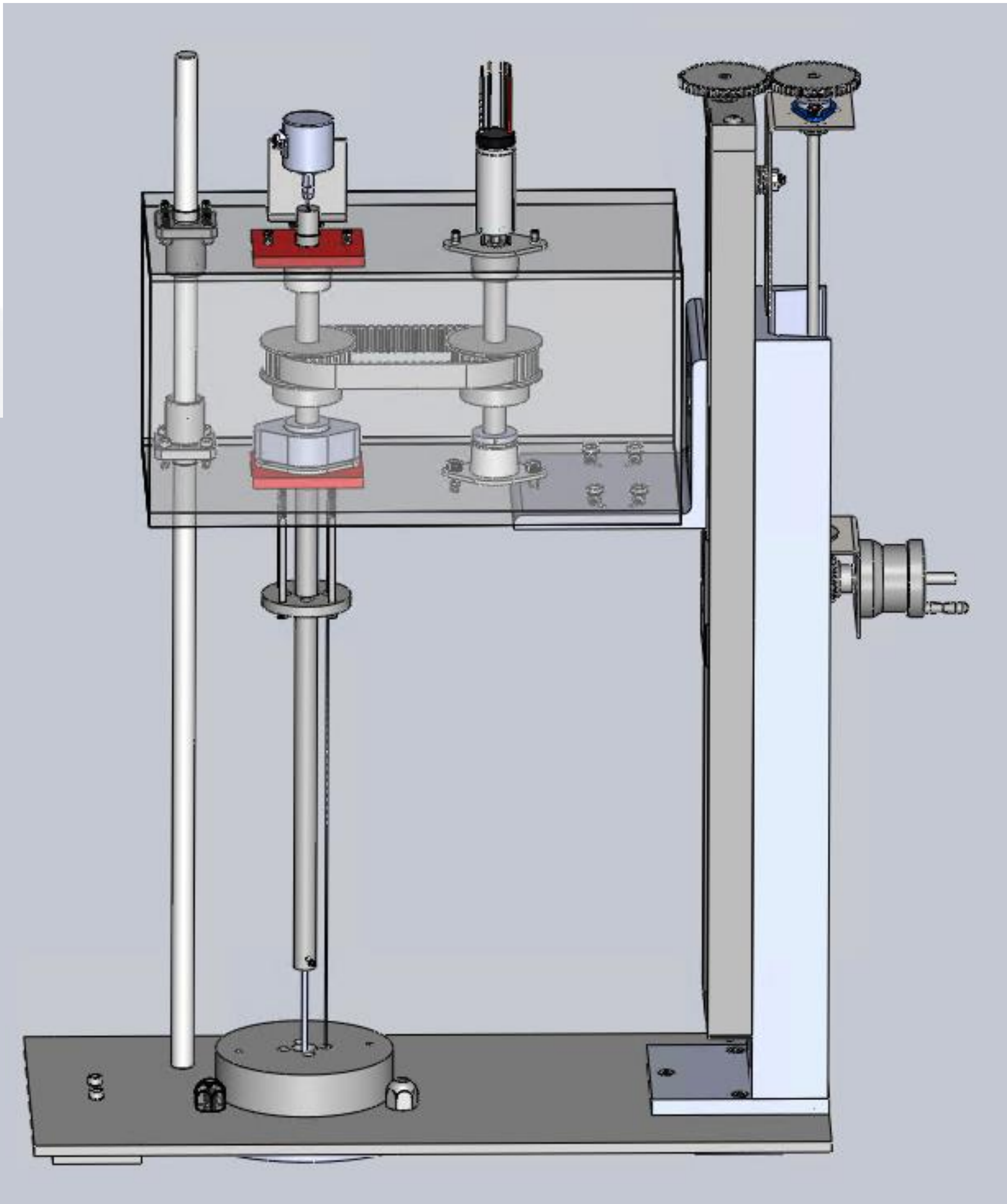
- The tolerance with the screws holding the box together was much too loose
  - Could not get the box to hold together straight



Second Design

- To overcome the difficulty of making our own box, we switched to using a piece of rectangular tubing of the same dimensions



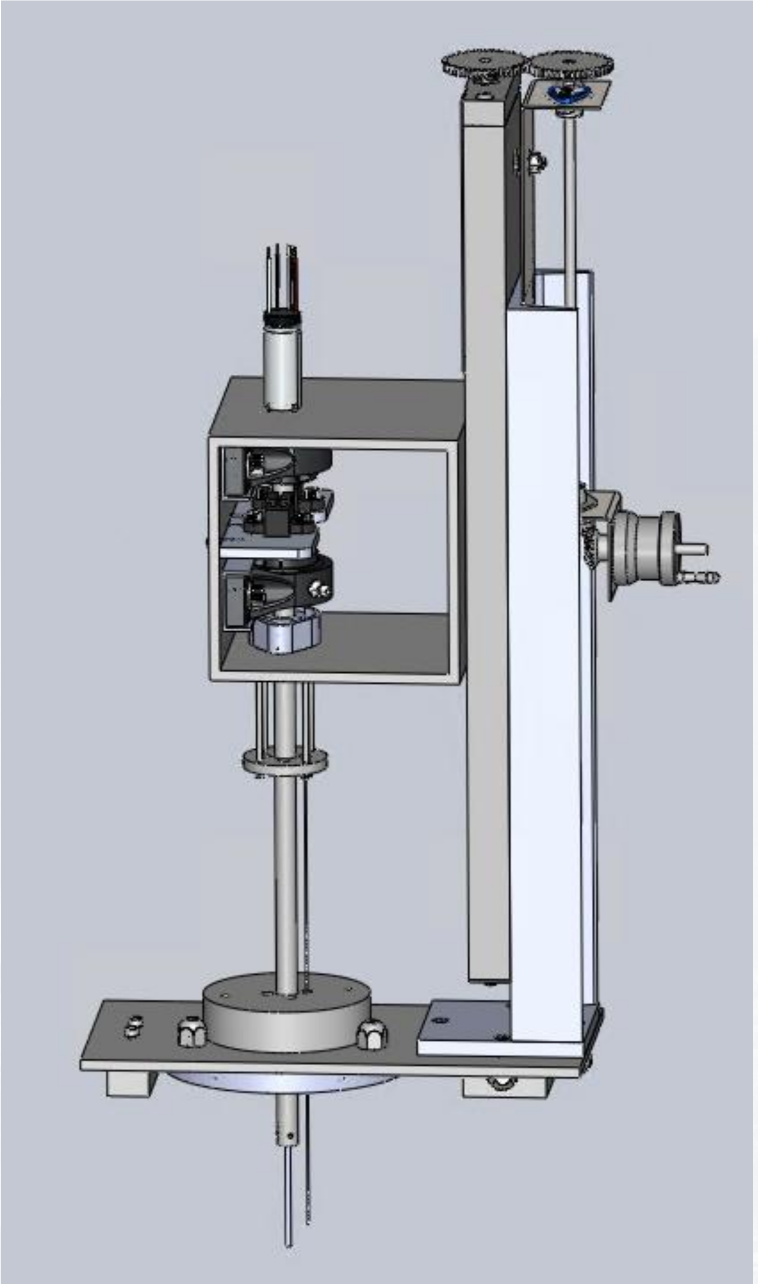


Issues with Second Design

- This design was never completed
  - Tested the motor spinning the belt and pulley before completing
- Speed Test
  - The motor was not able to produce enough torque to turn the belt and pulley
  - After removing the belt and pulley and attaching the motor directly to the rotating shaft the motor was able to rotate up to 10,000 rpm

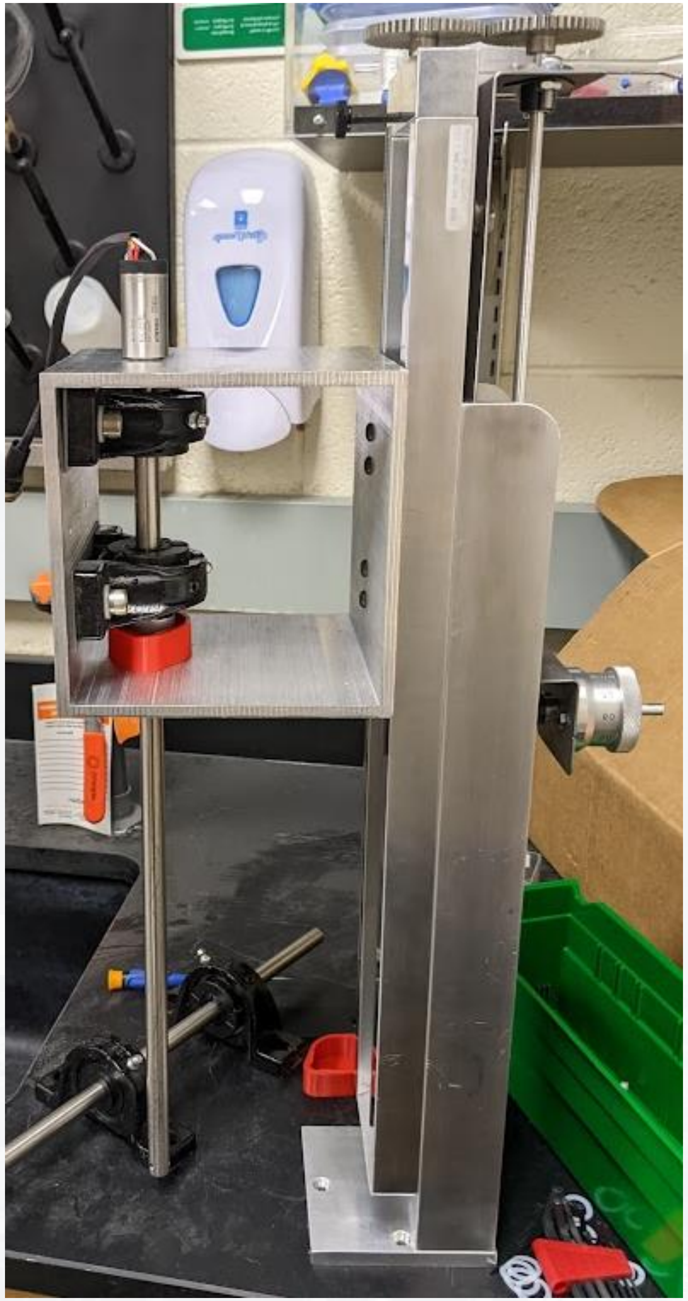
Third Design

- The belt and pulley design was discarded
- Switched to graphite brushes as electrical contact
- Smaller design with direct drive



Issues with Third Design

- Resistance to rotate rod is higher than expected
- Torque required to turn the bearings (56.48 mN m) is higher motor rating
- A stronger motor and improved alignment of bearings and motor are required



Summary and Future Work

- Design difficulties have delayed experimental data acquisition
  - Alignment
- Seeking for ways to ease and replicate exact assembly
- Final design will
  - Achieve 10,000 RPM
  - Allow high currents (>0.5 A)
  - Provide enough torque to overcome resistance from supporting parts