



University of Idaho

College of Engineering

FITS LIKE A GLOVE

IDAHO NATIONAL LABORATORY:

HIGH STRENGTH TENSILE

TESTING SYSTEM

Team Members: James Bradley, Jared Gray, Logan Matti,
Matthew Uptmor

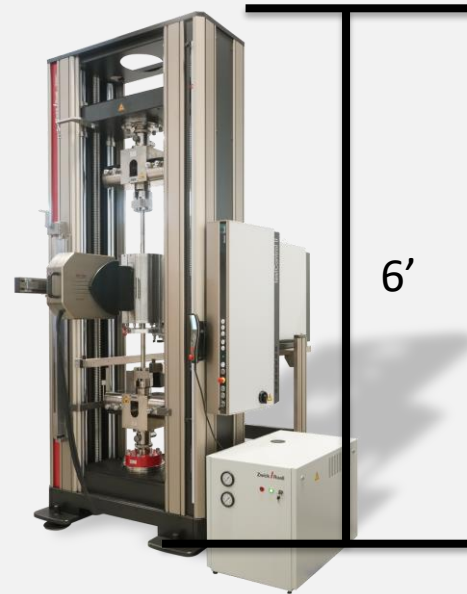
Team Instructor: Dr. Michael Maughan

Mentor: Anas Nawafleh

Sponsor: Randall Fielding, Idaho National Laboratory

BACKGROUND

- A glove box is required to protect people from the potentially harmful conditions that could arise from the testing of certain alloy such as INL's current project using U-Pu-Zr alloys.



Current Tensile Testing Systems:

- Too large.
- Not easily disassembled.
- Price starts at \$150,000.

OBJECTIVE

- Design a high temperature tensile testing system that will fit through an 8-inch access port inside a glovebox and can perform tensile tests at temperatures reaching 700° C.

REQUIREMENTS

- Easily fit disassembled parts through 8" port and assemble system in glovebox
- Have a base of no more than 1 foot square with minimal height
- Apply a force of at least 750 pounds (3340 N) to the specimen
- Heater and specimen must be able to reach a max of 700°C
 - Exterior temperature of heater should not exceed 50°C
- Provide accurate data regarding sample extension and applied force
- Capable of running a test from outside glove box after initial setup
- External electronic components and controls contained in one location



FRAME CONCEPT



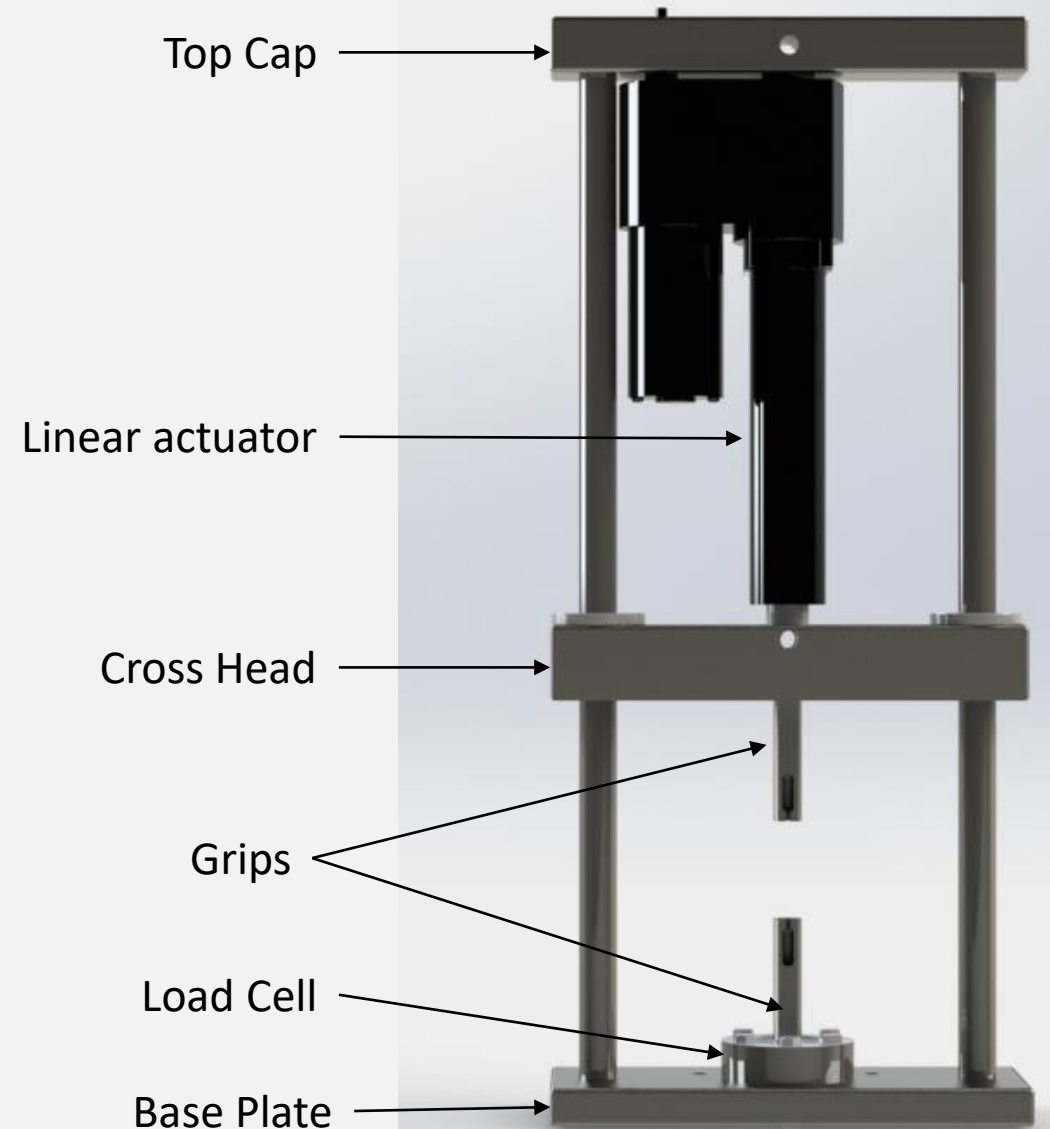
- Pre-Existing frame
- Could be disassembled into pieces that could fit in glovebox
- Grips and attachment solutions could be made to fit stand
- Used it to familiarize ourselves with basic components
- Capabilities below requirement to break the specimen



FRAME DESIGN

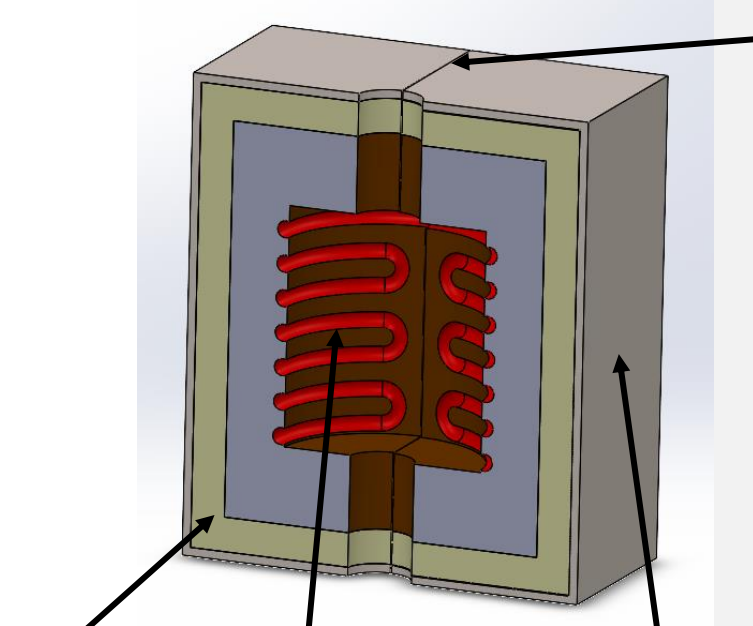


- Moved force to central vertical axis
- Designed stronger frame
- Linear Actuator provides up to 2000 pounds (8896 N) of force
- Grips designed to with stand 1500 pounds (6672 N) of force





HEATER DEVELOPMENT



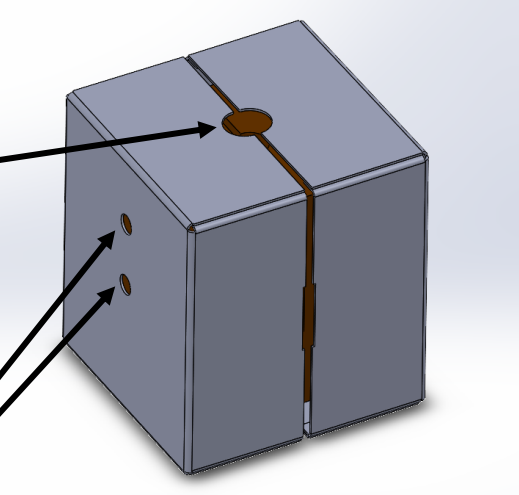
Insulation Liner

Steel Shell

Heating Wire Channel

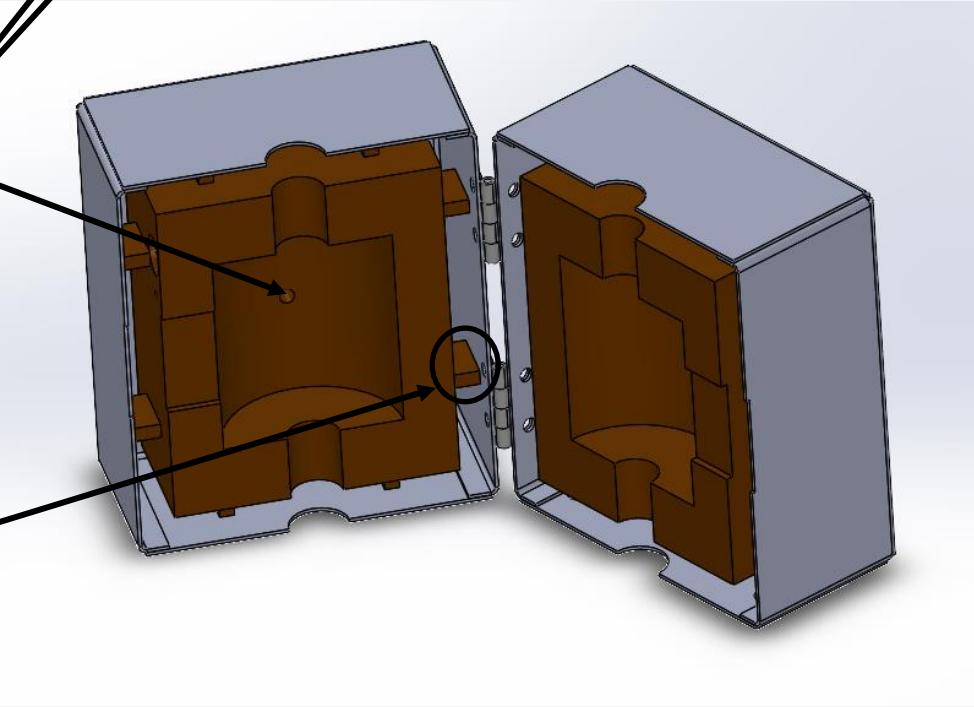
Heater Opening Interface

Sample Grip Pass-Through

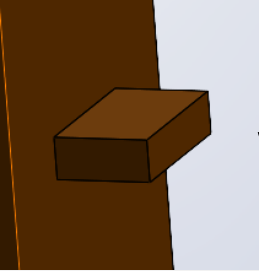


Extensometer Pass-Through

Thermocouple pass-through



Cement Stand-off for air gap



TEMPERATURE CONTROL DEVELOPMENT



Final Design:

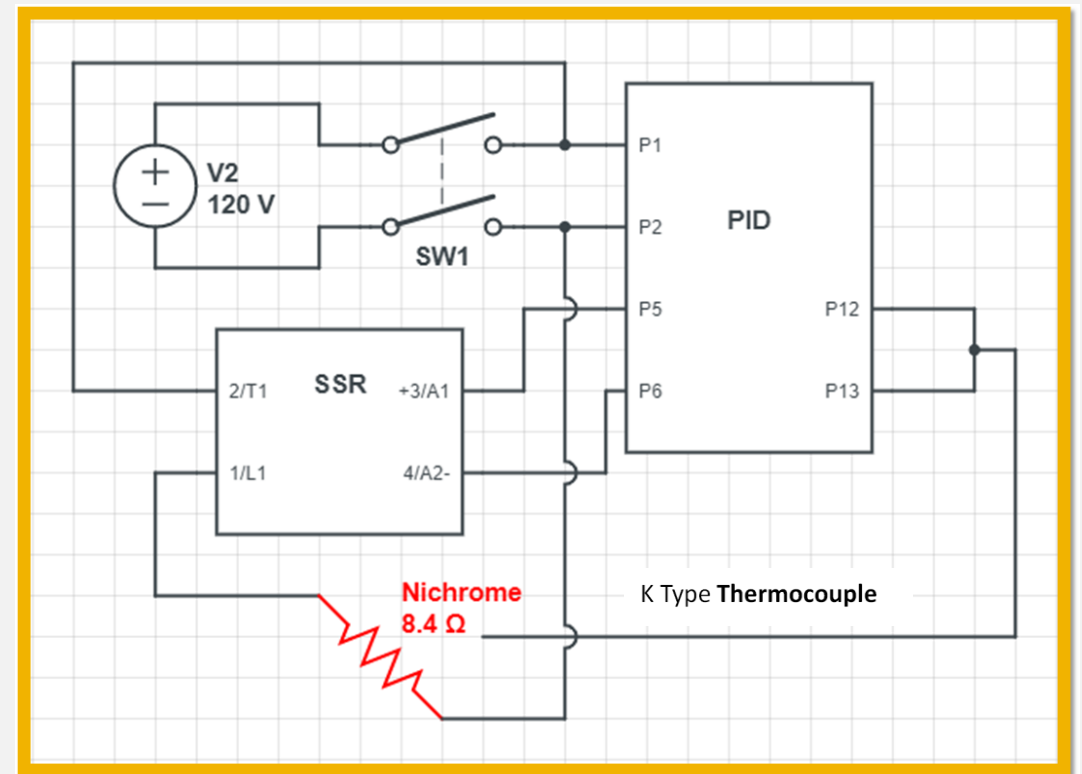
- One Independent System:
 - PID
 - SSR
 - Emergency Stop Switch
 - Nichrome wire needs to be able to reach max temp.
 - AutoTune Feature.
 - Alarm System

PID: Proportional Integral Derivative Controller

SSR: Solid State Relay

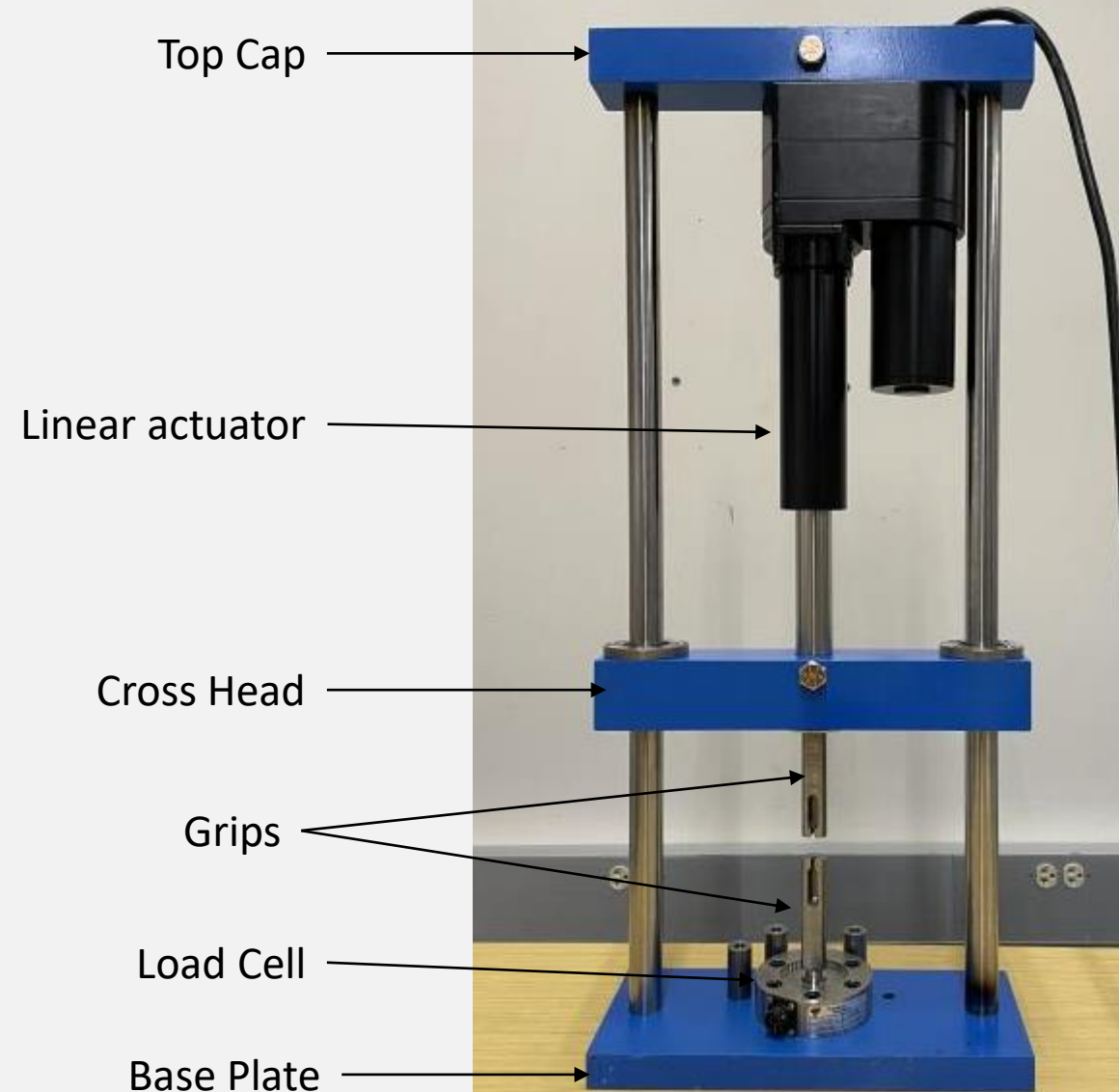
Nichrome: Nickel Chromium

Temperature Control Circuit Diagram:



FRAME MANUFACTURING PROCESSES

- Base Plate
 - Milled A36 Steel
- Cross Head
 - Milled A36 Steel
- Top Cap
 - Milled 1045 Steel
- Guide Rods
 - Case Hardened 1566 Steel
 - HAAS CNC Lathe for threading
 - Grinder to cut to length
- Grips
 - 1045 Steel
 - HAAS CNC Lathe for threading
 - Mill to add the pocket



HEATER MANUFACTURING PROCESSES



Shells Cut:

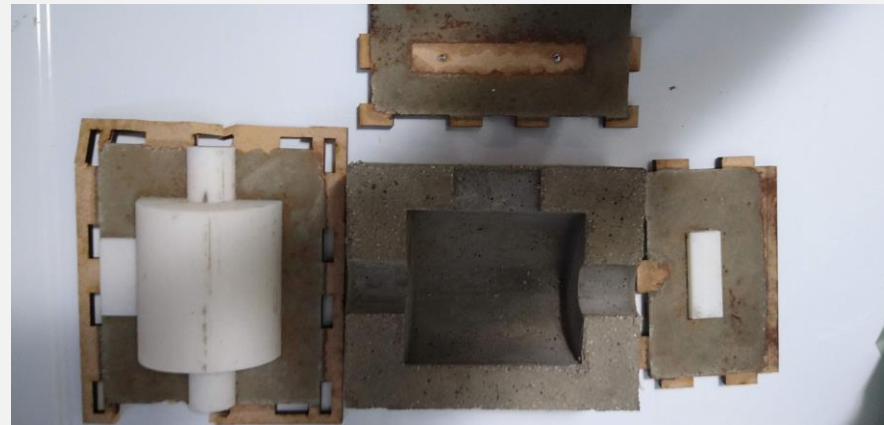


Shell

- Plasma cut shells at the James Martin Lab.
- Material: 18 Gauge Mild Steel.
- Sheet metal bent and riveted in the machine shop on campus

Core

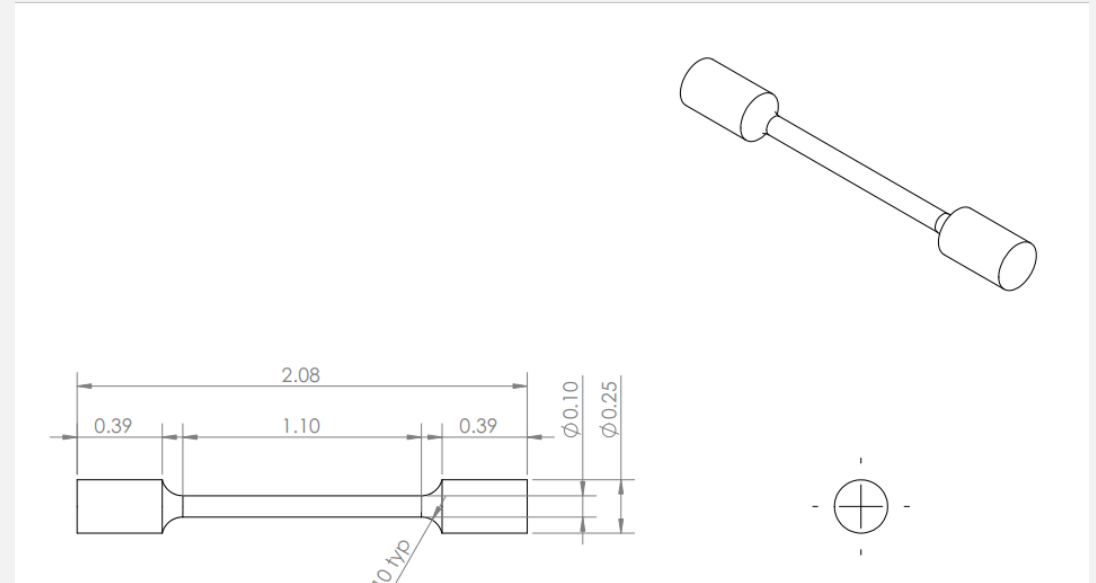
- Cast Rutland Refractory Cement
- 3D printed cavity insert with an MDF mold form



SPECIMEN MANUFACTURING



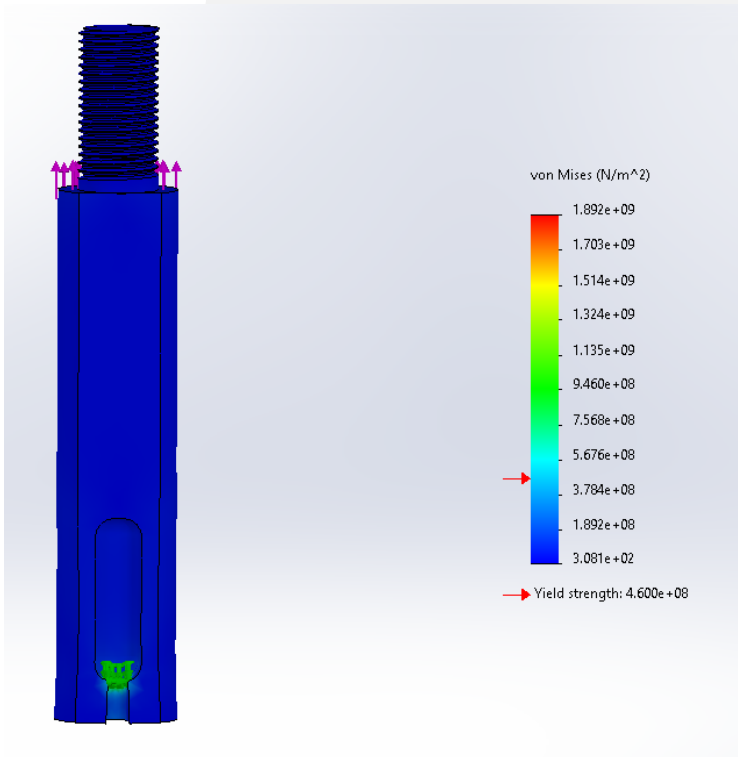
- Example: 7075 Aluminum
- Actual: U-Pu-Zr Alloy
- Turned on a CNC Lathe
- Difficult due to the small cross-sectional area



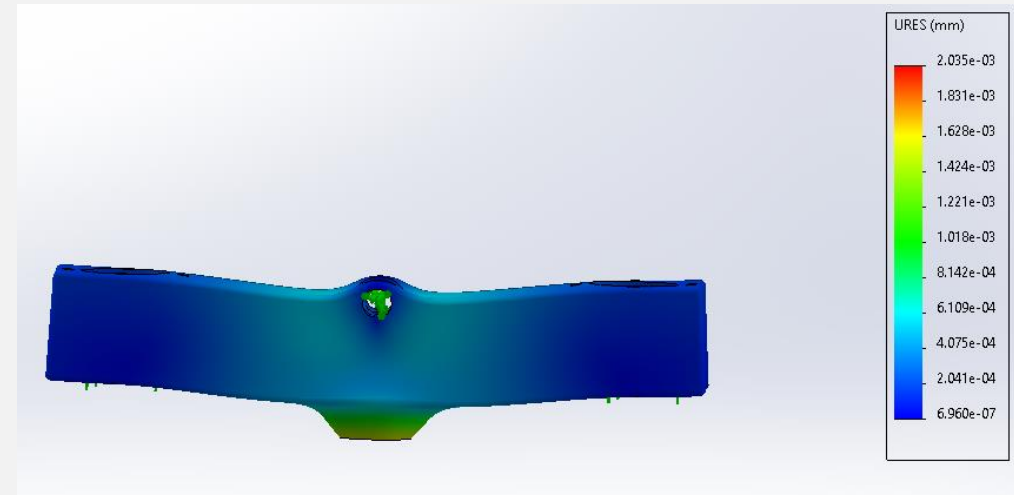
FRAME VALIDATION



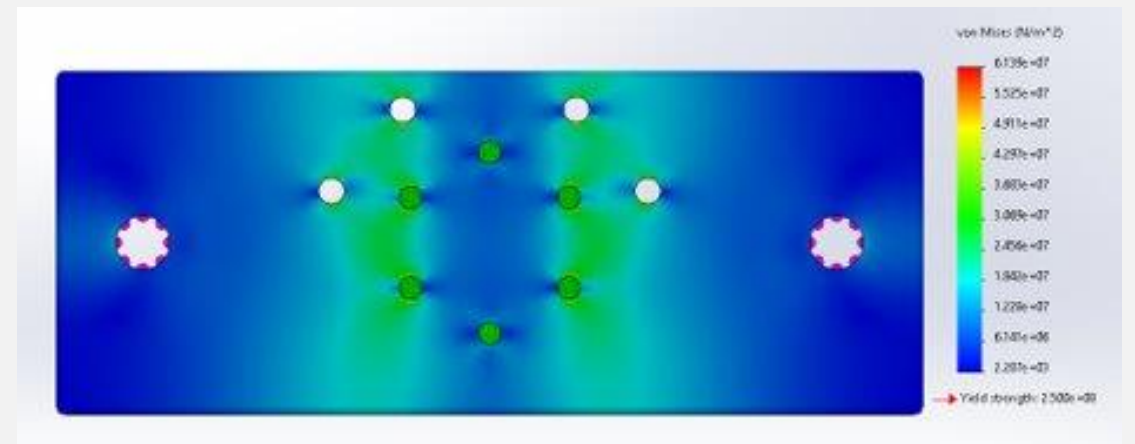
Grip Force Simulation



Cross Head Force Simulation



Base Plate Force Simulation



HEATER VALIDATION

PID TEMPERATURE CONTROLLER:

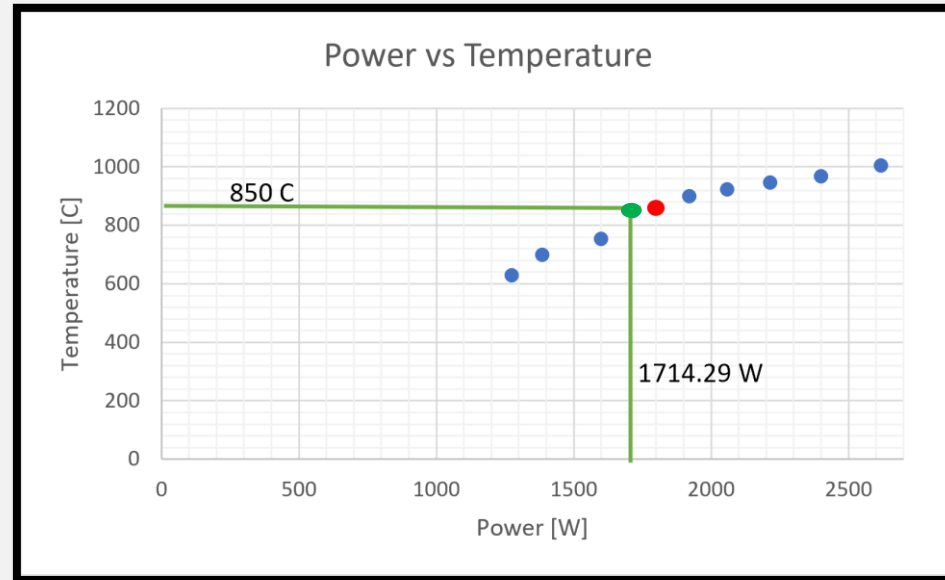
Nichrome Wire: 18 AWG

- Governing Equations:

- $P = \frac{V^2}{R}$
- $I = \frac{V}{R}$

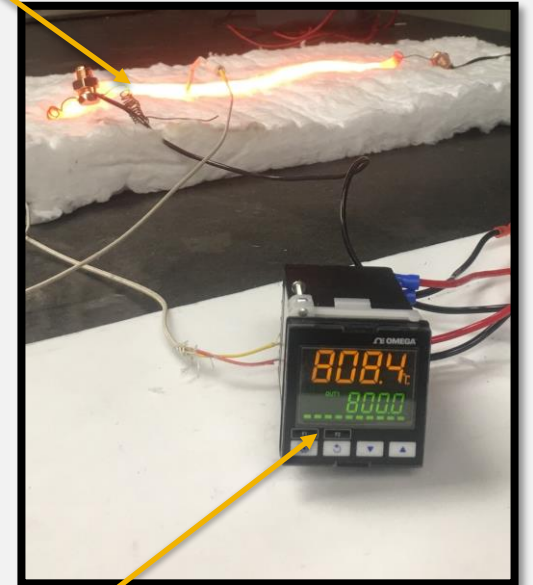
Best Result:

- Current: 14.2857 [A]
- Power: 1714.39 [W]
- Resistance: 8.4 [Ω]
- Wire Length: 16.8 [ft]



Nichrome Wire

Nichrome Wire Test:



PID Controller

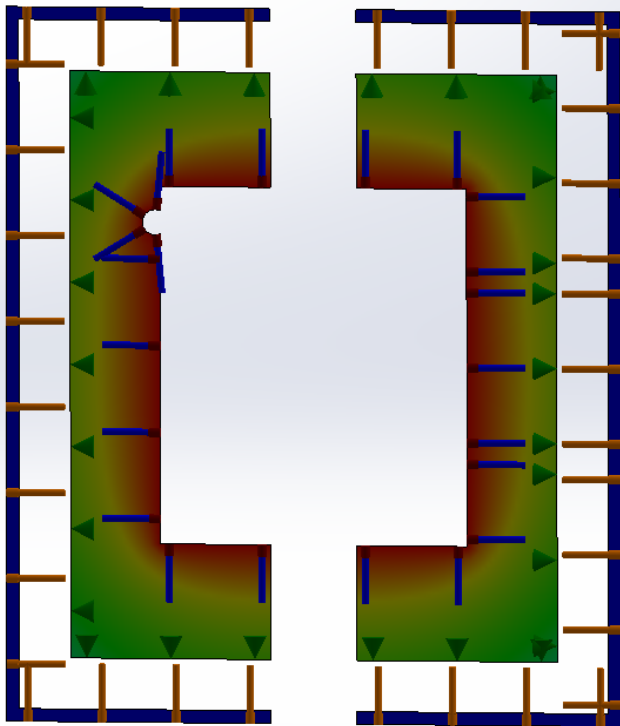
- Nichrome wire resistance properties: 0.5 Ω /ft
 - Gives the length of the wire

HEATER VALIDATION

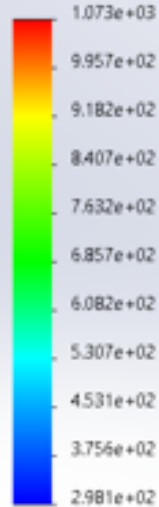


FURNACE CHAMBER

Temperature Simulation

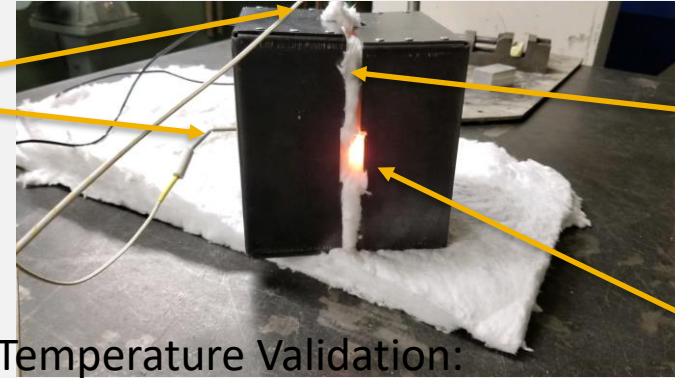


Temp (Kelvin)



Thermocouple
Temp Sensors

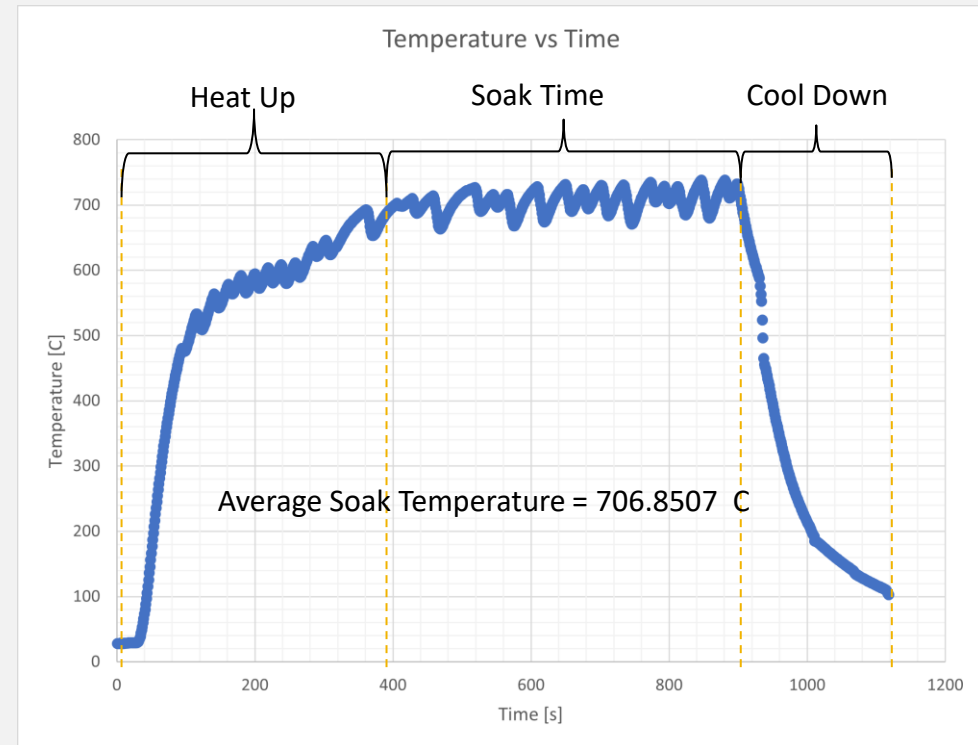
Heater Temperature Test:



Sealing
Gasket

Extensometer
Passage, $T = 250^{\circ}\text{C}$

Heater Temperature Validation:



LOAD CELL CALIBRATION



Calibration Setup



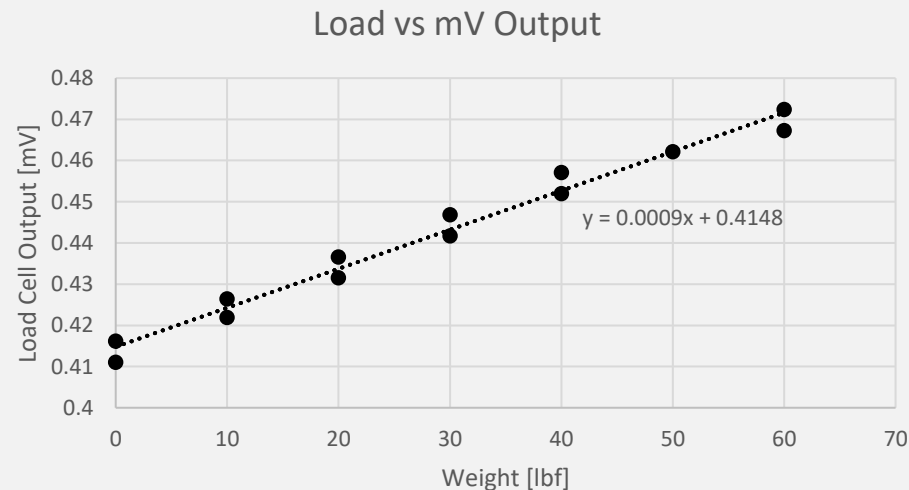
Calibration Procedure

1. Invert load cell
2. Take zero load reading
3. Incrementally add weights
4. Document mV output
5. Analyze data to find conversion constant

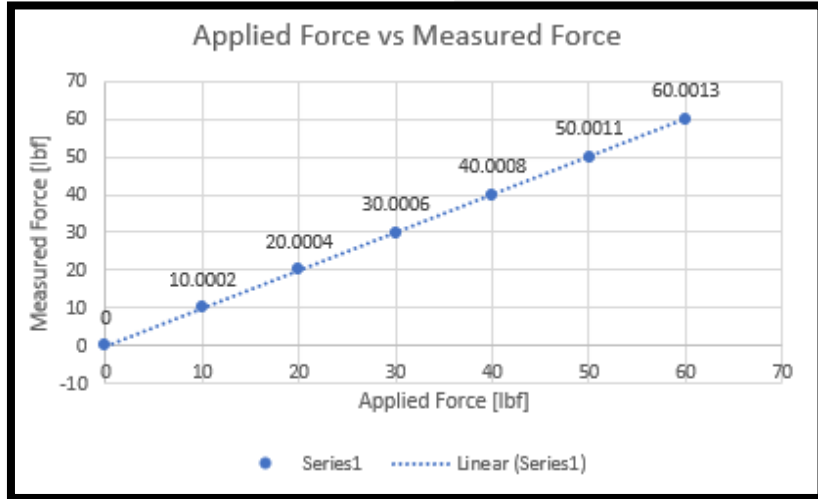
Load Cell Conversion Table:

Weight [lbf]	Reading (mV)	Conversion Constant
0	0.41107	0
0	0.41618	0
10	0.4219	923.3610342
10	0.4264	652.3157208
20	0.431511	978.425713
20	0.436621	782.748229
30	0.441731	978.4416686
30	0.446841	838.6681949
40	0.451952	978.425713
40	0.457062	869.7164724
50	0.462172	978.4352863
60	0.472393	978.425713
60	0.467282	1067.387746

Load Cell Calibration Graph:

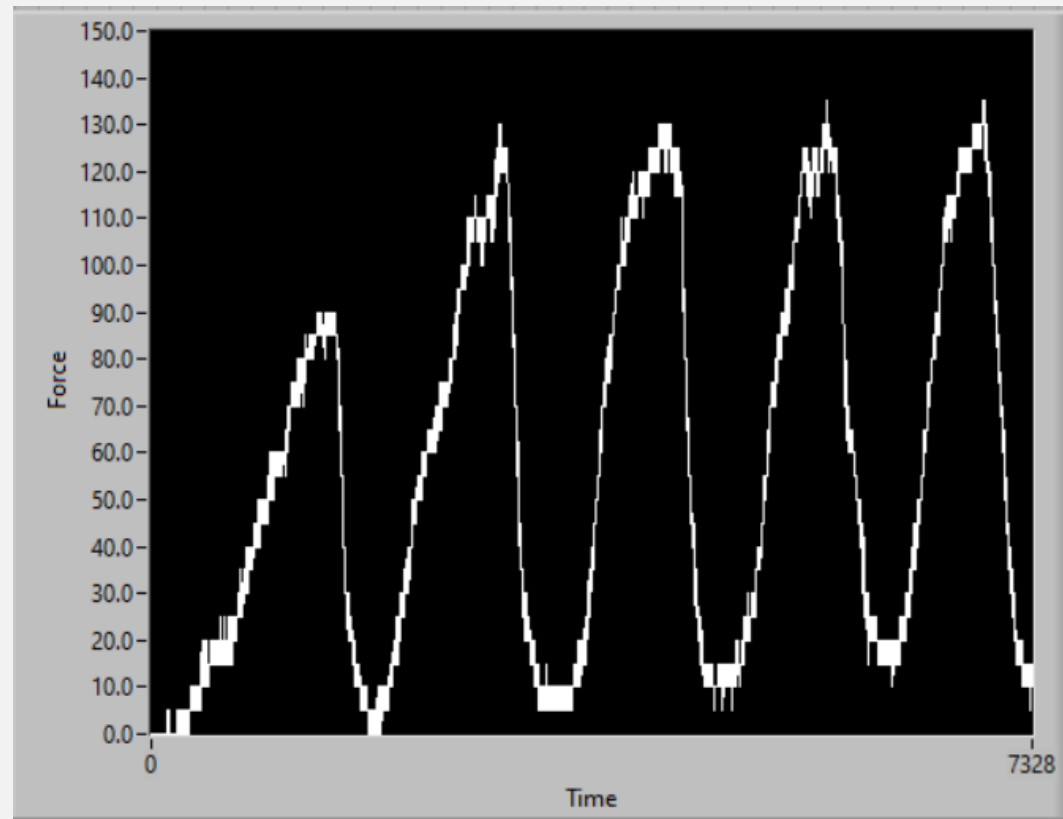


LOAD CELL VALIDATION

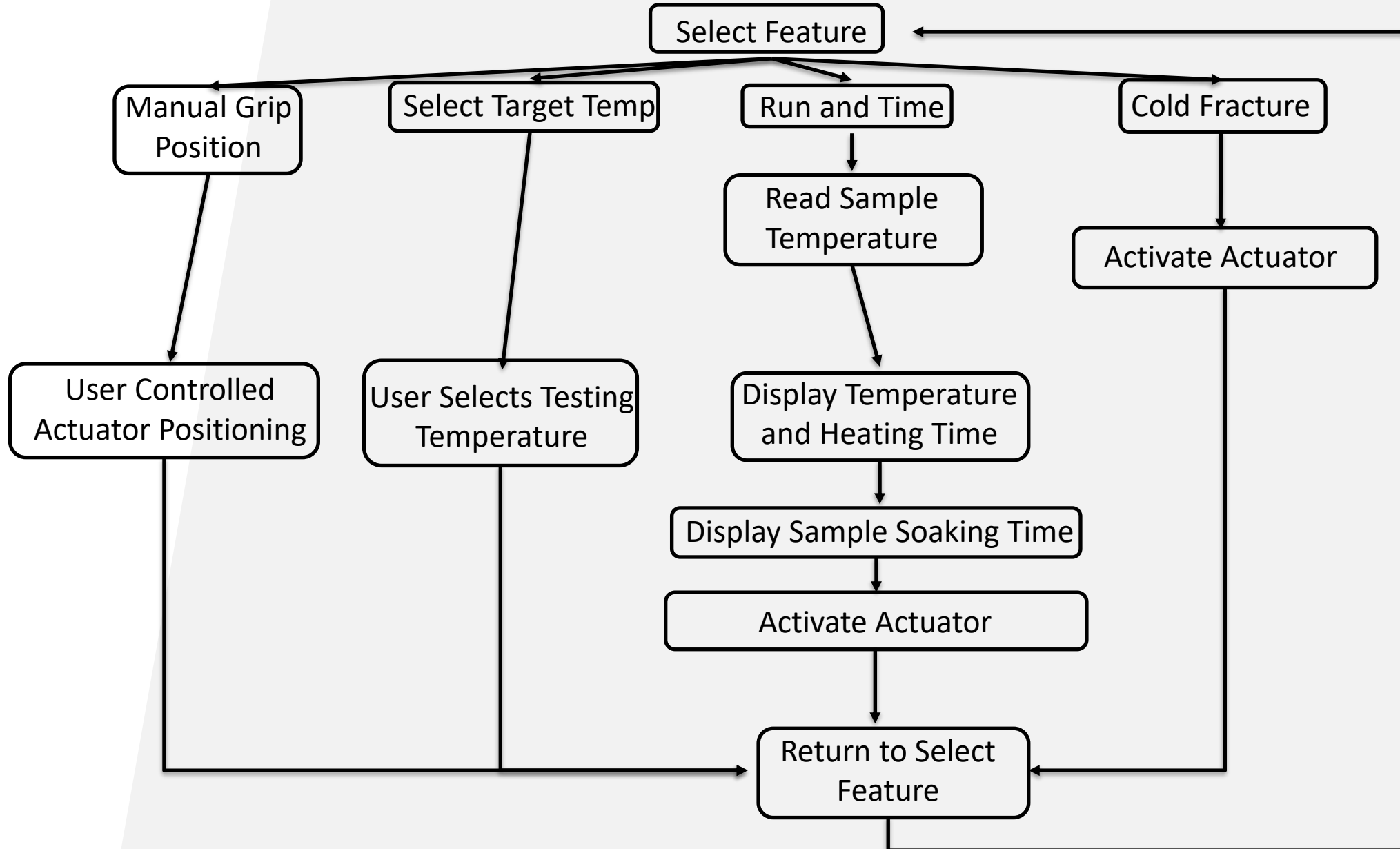


Validation Methods

- Bucket weight testing
- Random Weight Test



CODING OUTLINE: ARDUINO CONTROL



LABVIEW DATA COLLECTION



Linear actuator
voltage output

AIN1 CrossHead Displacement

1.402315

AIN2

0.380408

Voltage reading from
signal amplifier.

error out

code	no error
source	0

Error Message

No Error

quickSample



longSettling



CrossHead Displacement [mm]

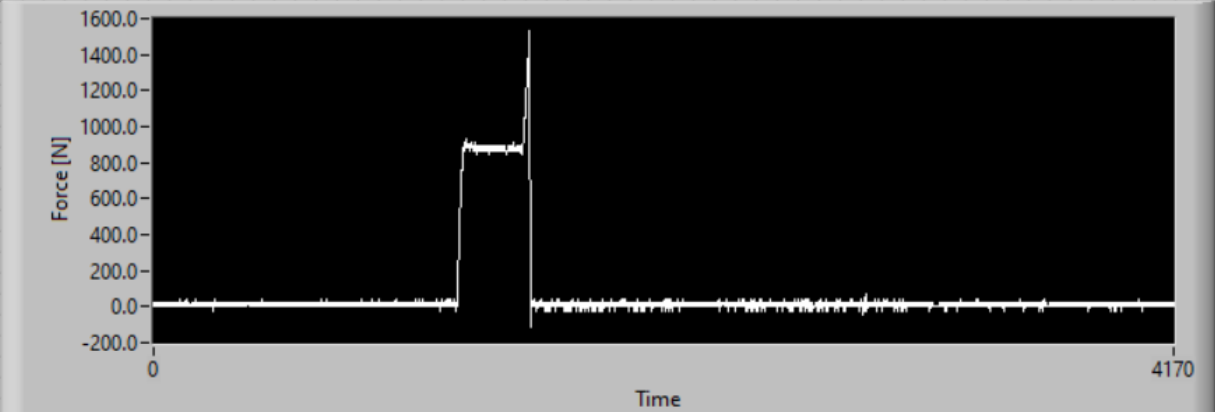
41.5753

Hardware malfunction
warning.

Load Cell Reading [N]

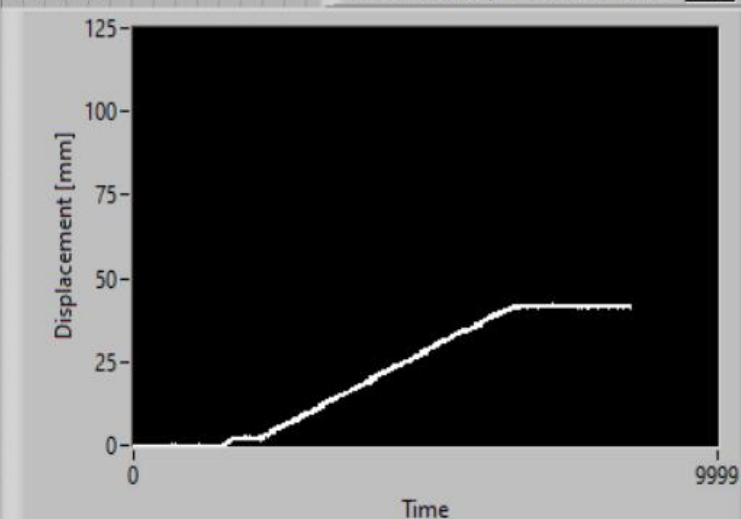
0.00170636

Load Cell



Crosshead

Crosshead Dsplacement vs time



FURTHER DEVELOPMENT



- Heater
 - Redesign to meet safety requirement exterior temperature
- Temperature System:
 - Upgrade Solid State Relay (SSR) to a Silicon-Controlled Rectifier (SCR)
 - 80 A rated Fuse
 - PID: CN243-R1-F2
 - Upgrade to have computer integration/communication
- Extensometer
 - Integrate and calibrate

SCR:



PID:



SUMMARY

To summarize, we have designed and built a machine that:

- Can be disassembled into parts that can fit into an 8" hole and be reassembled in a glovebox
- Has a minimal footprint
- Can apply a tensile force up to 1500 pounds (6670 N)
- Has a heater component that can heat samples up to 700°C
- Can be controlled and monitored from outside the glove box





THANK YOU!

QUESTIONS?



Coding Diagram(Block Diagram)

Displays the process LABView undergoes to identify the LABJack and read the input values from the load cell and Linear Actuator.

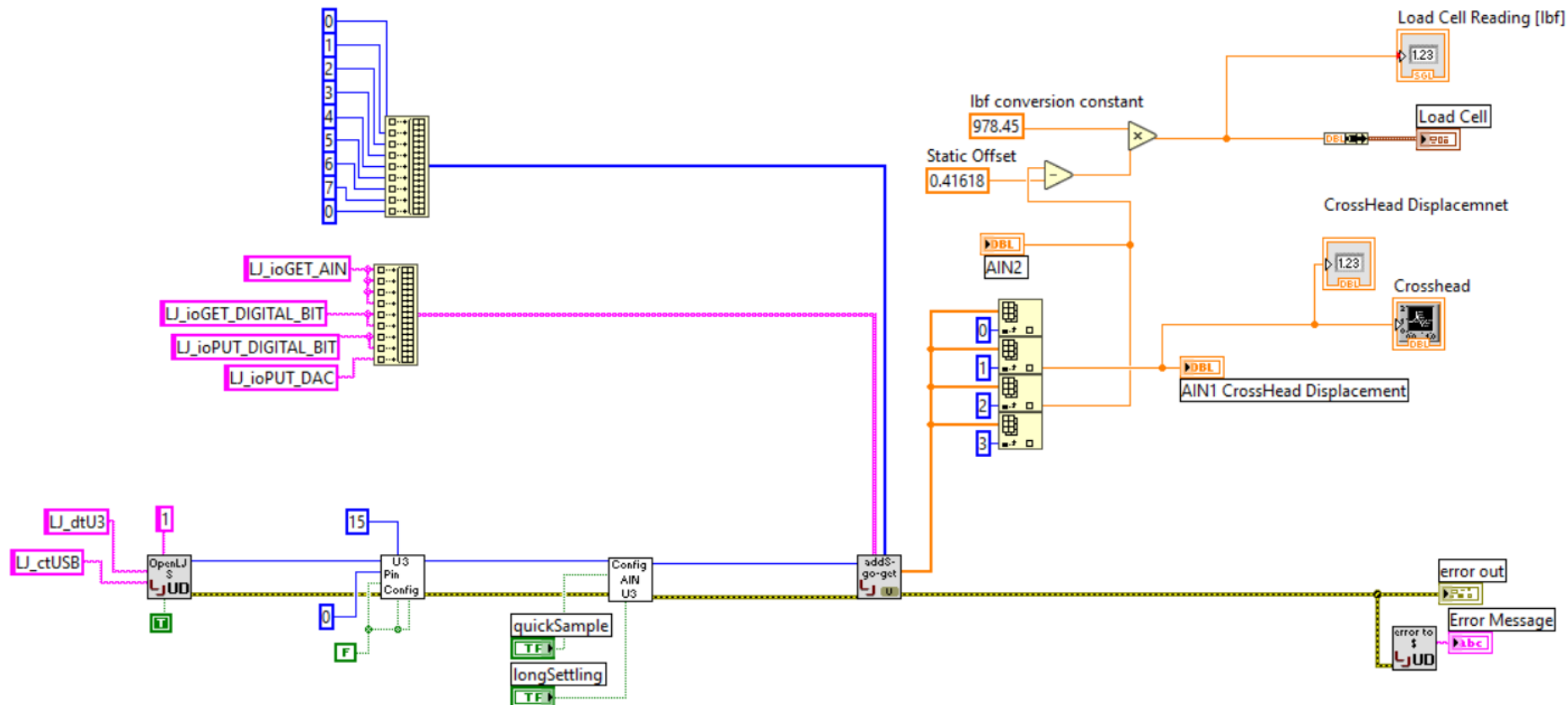


TABLE V
 Tensile Properties

Sample Number	Composition (wt%)	Temperature (°C)	Ultimate Tensile Strength (kg/mm ²)	Yield Strength (0.2% offset; kg/mm ²) ^a	Elastic Modulus (kg/mm ²) ^b	Reduction of Area (%)	Elongation (%)	Reference
1	U-15Pu-6Zr ^b	25	68.2	—	1758	—	Nil	26
2	U-11.1Pu-6.3Zr ^a	25	18.1	—	17 400	<1	<1	9, 17, and 34
		500	30.1	—	6 800	<1	<1	9
		625	9.5	8.7	3 000	>5	>10	9
		675	1.2	1.1	1 400	>10	>20	9, 17, and 34
3	U-16.6Pu-6.3Zr ^a	25	4.0	—	10 600	<1	<1	9, 17, and 34
		500	15.8	—	—	<1	<1	9
		625	8.9	4.1	2 100	<1	<1	9
		700	1.2	1.6	1 700	>10	>10	9
4	U-15Pu-10Zr ^a	25	6.7	—	12 500	—	—	9
		500	13.3	—	6 600	<1	<1	9
		625	8.1	7.2	1 600	>5	>5	9
		675	2.1	1.7	3 300	>10	>10	9
5	U-15Pu-10Zr ^b	25	49.2	—	1 547	—	Nil	26
		300	27.4	—	1 476	—	Nil	26
		350	30.9	30.9	633	—	3	26
		400	9.8	7.0	281	—	53	26
6	U-19Pu-10Zr ^c	—	—	—	8 691	—	—	35
7	U-14Pu-11.7Zr ^b	25	53.4	—	1 617	—	Nil	26
		100	56.2	—	1 547	—	Nil	26
8	U-15Pu-12.2Zr ^b	25	42.9	—	984	—	—	26
9	U-15Pu-12.5Zr ^b	25	67.3	—	1 898	—	Nil	26
		300	45.6	—	1 828	—	Nil	26
		350	39.2	38.7	1 758	—	Nil	26
		450	5.7	4.8	281	—	31	26
		525	4.0	2.9	352	—	62.5	26
10	U-15Pu-13.5Zr ^b	25	59.1	—	703	—	Nil	26
11	U-12.3Pu-14.1Zr ^a	25	4.9	—	10 200	—	—	9

(Continued)

TABLE V (Continued)

Sample Number	Composition (wt%)	Temperature (°C)	Ultimate Tensile Strength (kg/mm ²)	Yield Strength (0.2% offset; kg/mm ²) ^a	Elastic Modulus (kg/mm ²) ^b	Reduction of Area (%)	Elongation (%)	Reference
12	U-18.5Pu-14.1Zr ^a	25	7.7	—	13 000	<1	<1	9, 17, and 34
		25	14.7	—	11 400	<1	<1	9
		650	4.6	4.1	2 100	>10	>25	9
		675	2.9	2.8	1 900	—	—	17 and 34
		700	1.7	1.6	1 700	>10	>20	9

^aResearchers at Argonne reported the ultimate tensile strength, yield strength, and elastic modulus of U-11.1Pu-6.3Zr, U-16.6Pu-6.3Zr, and U-18.5Pu-14.1Zr (nominal weight percent)



Capstone Project Budget Template - Fall/Spring

Project: Fits Like a Glove

Last Updated 4/18/2021

Expense Items	Year								Item Total
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Supplies / Parts / Services:									
Frame									\$ 1,991
Steel Shipping & Tax				\$ 113.75					
Guide rods				\$ 97.61					
Top Plate				\$ 167.98					
Bottom Plate				\$ 39.15					
Ball Bearings				\$ 127.82					
Grips				\$ 13.91					
Cross Head Plate				\$ 42.37					
Linear Actuator				\$ 465.00					
Load Cell				\$ 821.45					
Wiring						\$ 24.00			
Fasteners					\$ 50.96				
Test Material								\$ 26.83	
Instrumentation									\$ 1,179
Shipping/Taxes								\$ 120.05	
LabJack						\$ 135.00			
LJTick							\$ 79.61		



Capstone Project Budget Template - Fall/Spring

Project: Fits Like a Glove

Last Updated **4/18/2021**

Expense Items	Year							
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Arduino High Temp Sensor								\$ 24.90
MegaMoto Plus						\$ 62.98		
Toggles							\$ 10.99	
PID Wire								\$ 26.95
Emergency Stop Button							\$ 13.38	
Mini Breaker Switch (2)							\$ 25.98	
TE Connectivity AMP Connectors Male (20)								\$ 8.46
TE Connectivity AMP Connectors Female (20)								\$ 5.84
SSR (2)							\$ 82.80	
PID Controller (2)							\$ 160.96	
Copper Bolt Connectors (2)								\$ 14.16
Extensometer Rod Length Change								\$ 50.00
Extensometer (Separate INL Order)							\$ -	
Thermocouples							\$ 124.95	
Power Supply (Linear Actuator)						\$ 119.30		
24 AWG Nichrome Wire								\$ 14.56
Control Box								\$ 37.82
Misc						\$ 20.00	\$ 20.00	\$ 20.00

Item

Total

USER CONTROL

