Prepared by Team Lubricant

Lubricant Effectiveness Characterizer

Sponsored by *Nye Lubricants Inc.*

Presented by:

Peter Lunn

Nathen Arruda

Cameron Whittle

Peter McGrory

Ryan Proulx

Overview

- The Team and Sponsor
- Design Criteria
- Mechanical Engineering Aspect
- Electrical Engineering Aspect
- Fully Operational Machine
- Conclusion
- Q&A

The Team and Sponsor

Team Lubricant

- Mechanical Engineers
  - Peter Lunn (team lead)
  - Nathen Arruda
  - Ryan Proulx
- Electrical/Computer Engineers
  - Cameron Whittle
  - Peter McGrory

Academic Advisors

- Dr. Vijaya Chalivendra
- Dr. Jun Li
- Dr. Hamed Samandari

The Sponsor

- Nye Lubricants Inc.
  - Richard Raithel

Design Criteria and Logistics

Design Criteria

- Obtain torque readings from bearing
- Heat the bearing and lubricant to 200°C
- Cool the bearing and lubricant to 0°C
- Spin the bearing at a maximum of 3500 RPM
- Apply axial load on the bearing up to 100 lbs
- Be safe

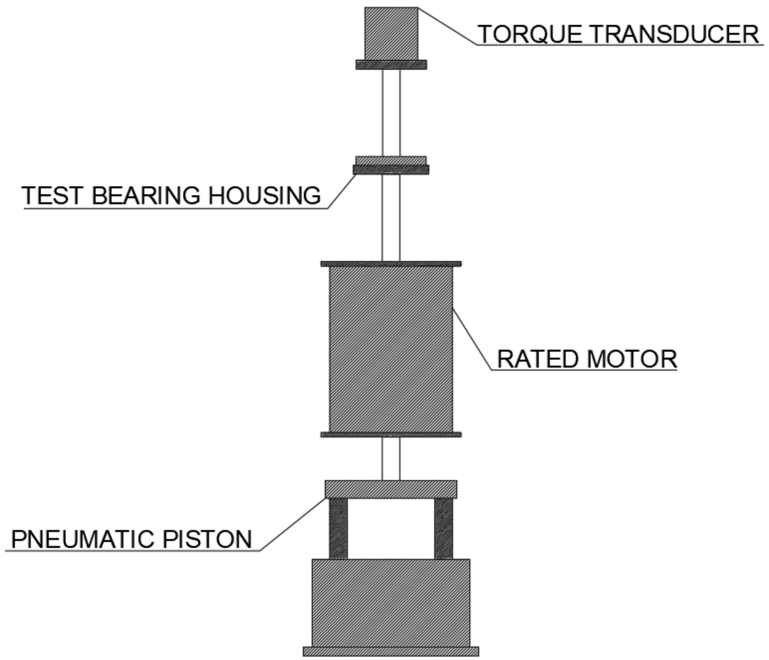
Budget

- Tentatively $30,000 to spend
- Will provide a cost breakdown later

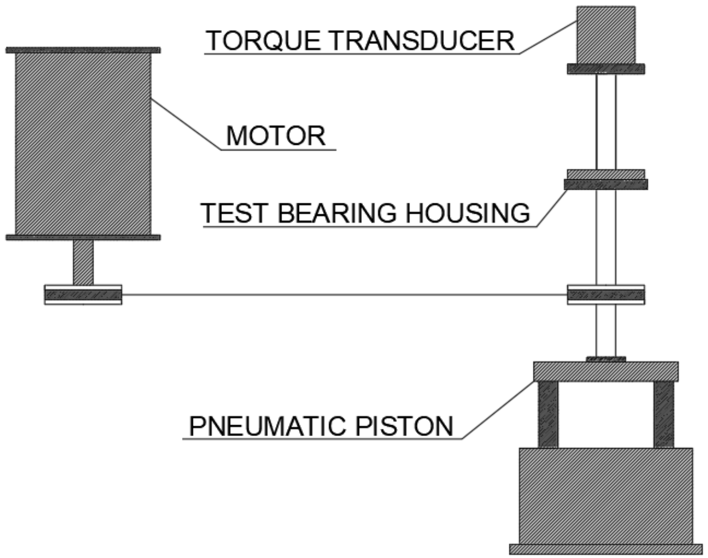
Mechanical Engineering Aspect

Three Primary Design Considerations

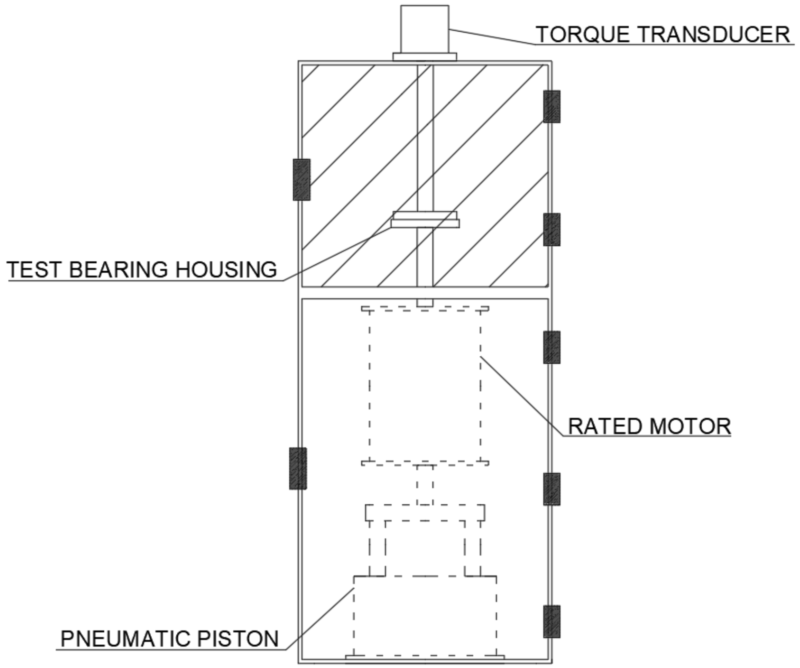
Inline Shaft-Motor Design



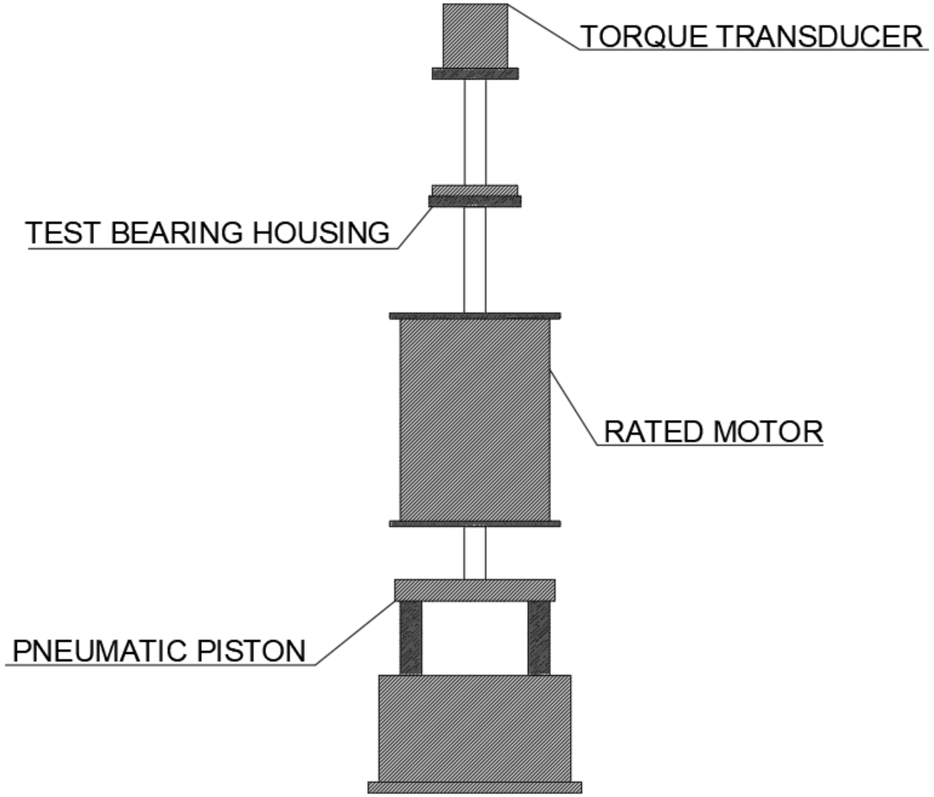
Parallel Shaft-Motor Design



Fully Enclosed Shaft-Motor Design



Design Considerations (INLINE DESIGN)



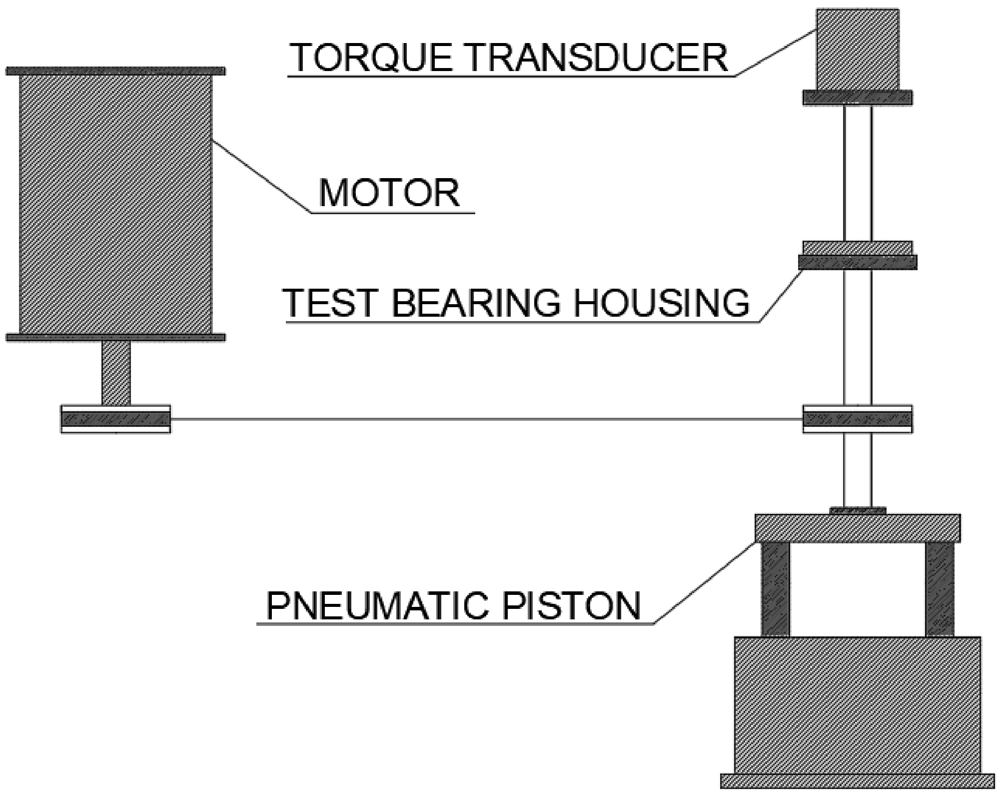
POSITIVES

- SMALL FORM FACTOR
- LESS COMLICATED
- EASY CONSTRUCTION

NEGATIVES

- MORE COMPLEX SPECIFICATIONS FOR COMPONENTS
- LOW RIGIDITY
- VERY TALL (TIPPING ISSUE)

Design Considerations (PARALLEL DESIGN)



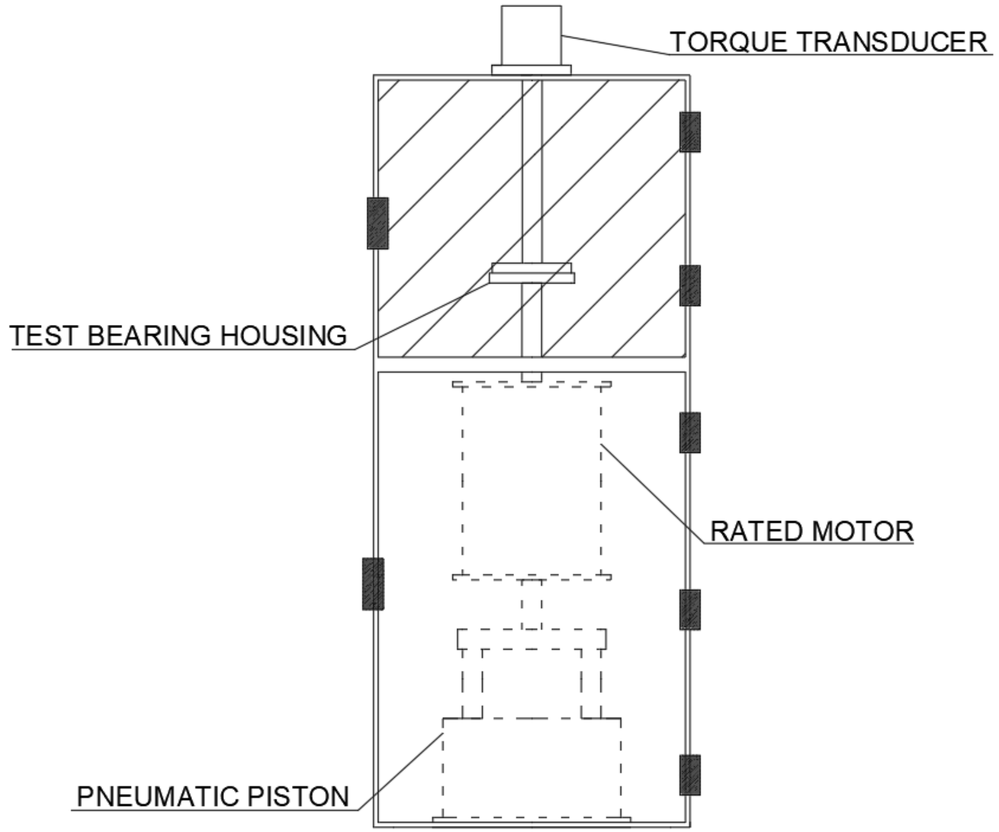
POSITIVES

- MODULAR
- ADDED RIGIDITY
- WIDER VARIETY OF COMPONENTS AVAILABLE
- SHORTER FORM FACTOR

NEGATIVES

- EXPENSIVE
- COMPLEX ASSEMBLY

Design Considerations (FULLY ENCLOSED INLINE DESIGN)



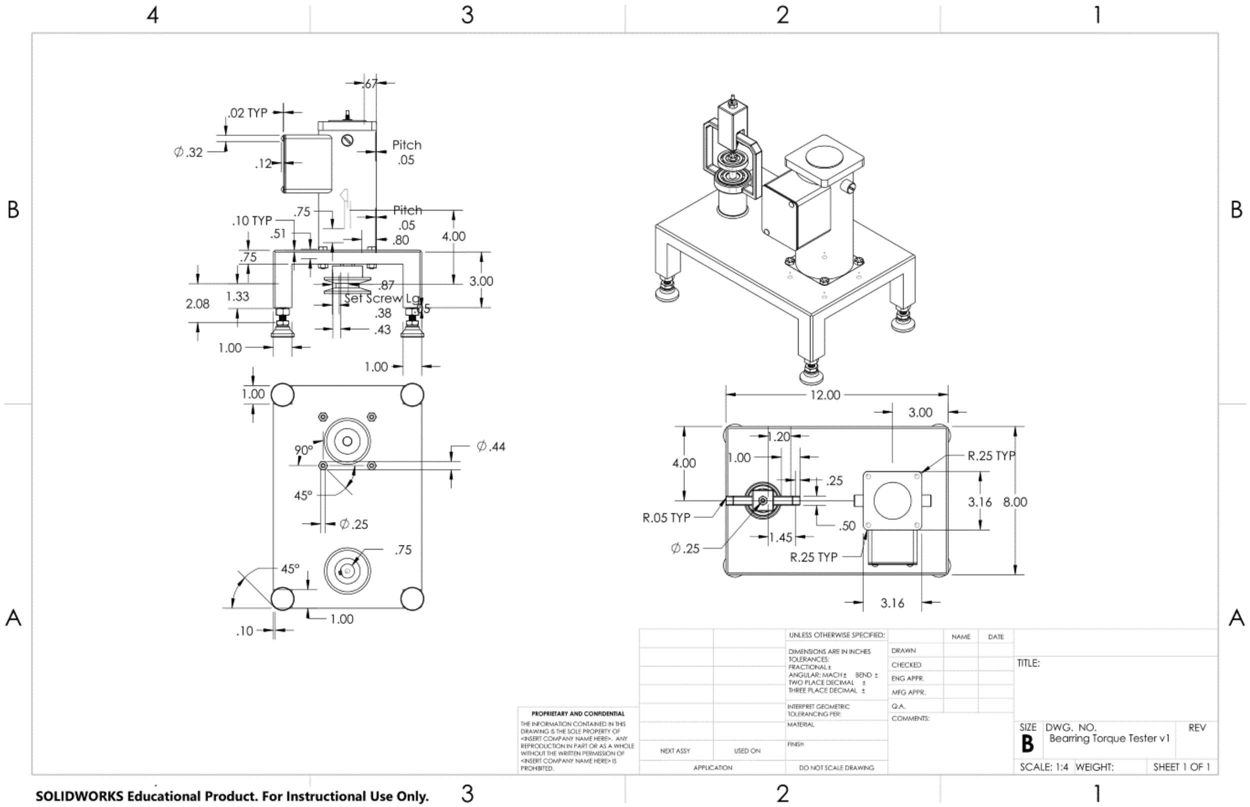
POSITIVES

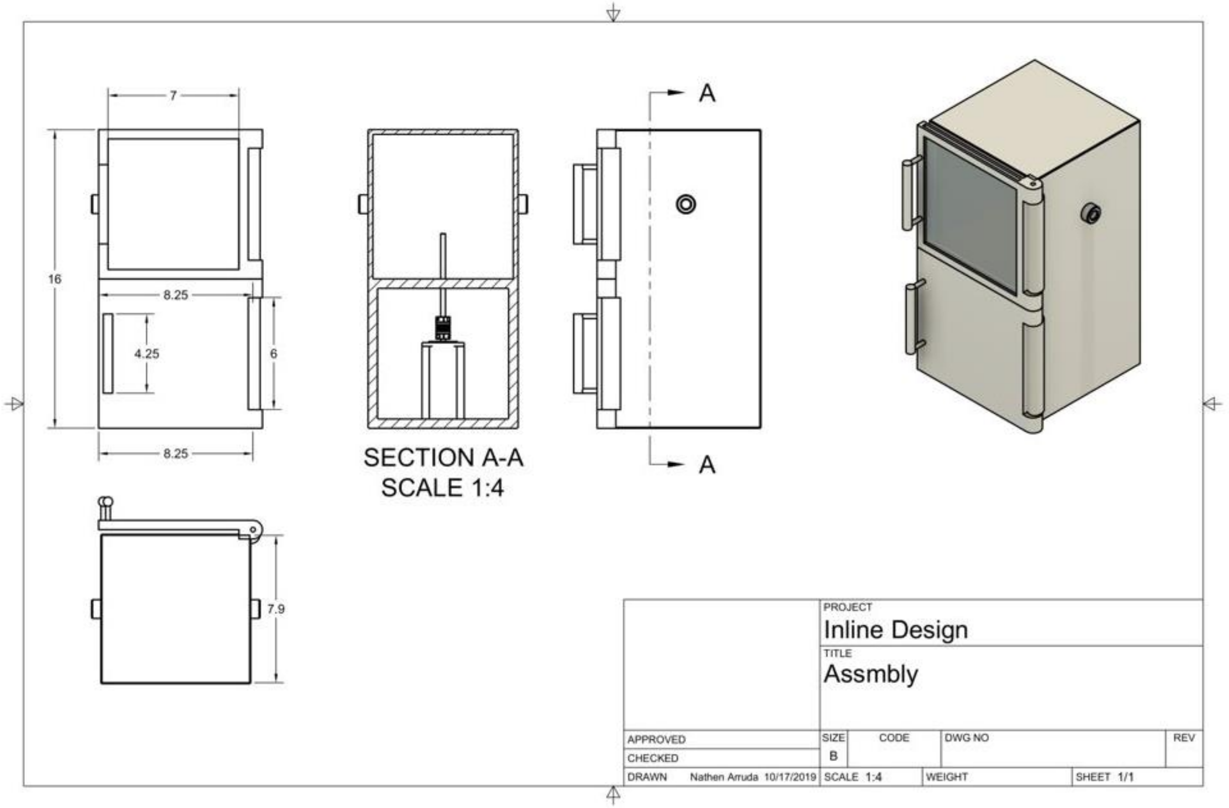
- CONTROLLED ENVIRONMENT (ACCURATE DATA)
- RIGID DESIGN
- ESTHETICALLY APPEALING

NEGATIVES

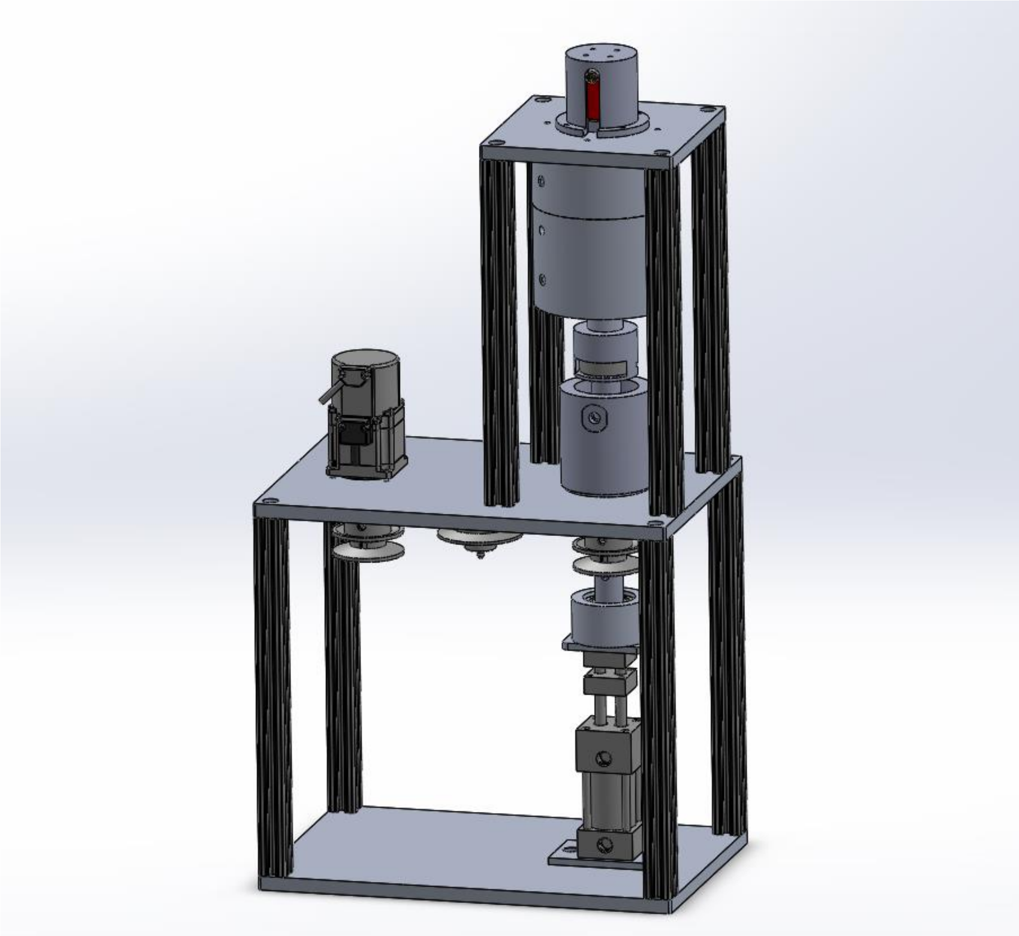
- MORE COMPLEX SPECIFICATIONS FOR COMPONENTS
- EXPENSIVE
- VERY TALL (TIPPING ISSUE)
- UNMODULAR

Previous Designs





Previous Designs Continued



- Initially started with different layouts, Parallel and Inline
- Simplified loading of bearing
- Air bearing for complete accuracy was initially used
- Minimized height to prevent tipping over

Final Design

1 – Aluminum Structural Plates

2 – Aluminum Structural Legs

3 – Torque Transducer (red component) with Housing for measuring torque

4 – Servo Motor for rotating bearing

5 – Pneumatic Piston for applying axial load to bearing

6 – Pulleys for transferring motion from motor to bearing

7 – Bearing Cup with Controlled Bearing inside

8 – PEEK Thrust Bearing Shaft for connecting outer race of bearing to transducer

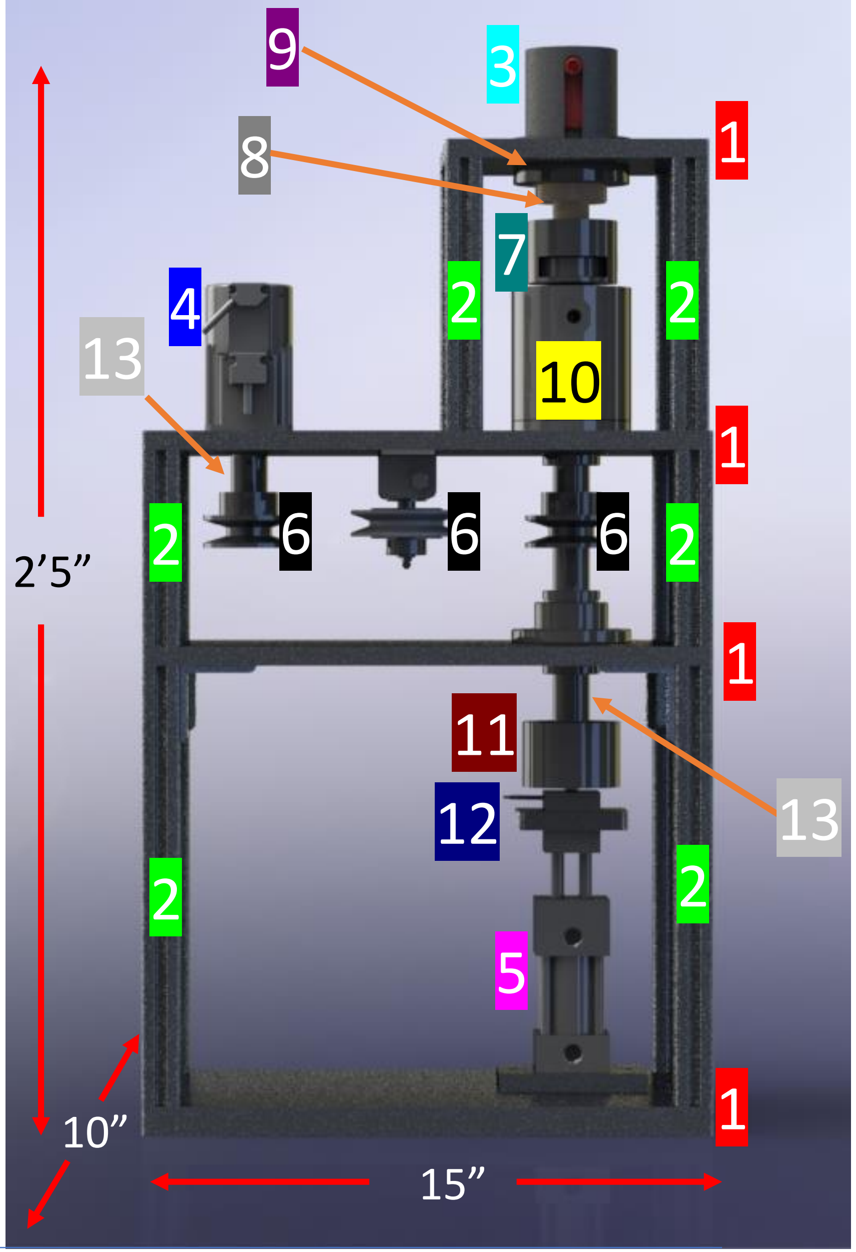
9 – Thrust Bearing for absorbing axial load

10 – Nozzle for delivering hot and cold air to the bearing

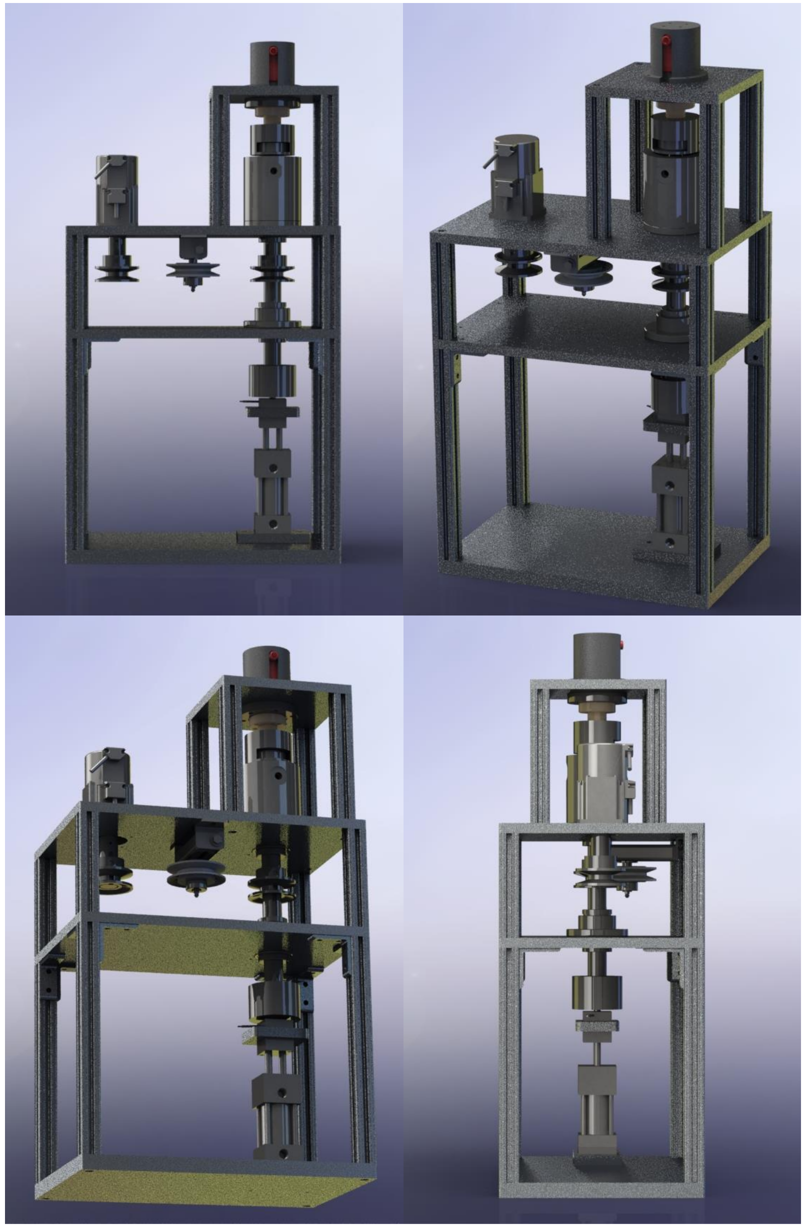
11 – Bearing cup for shaft to sit in

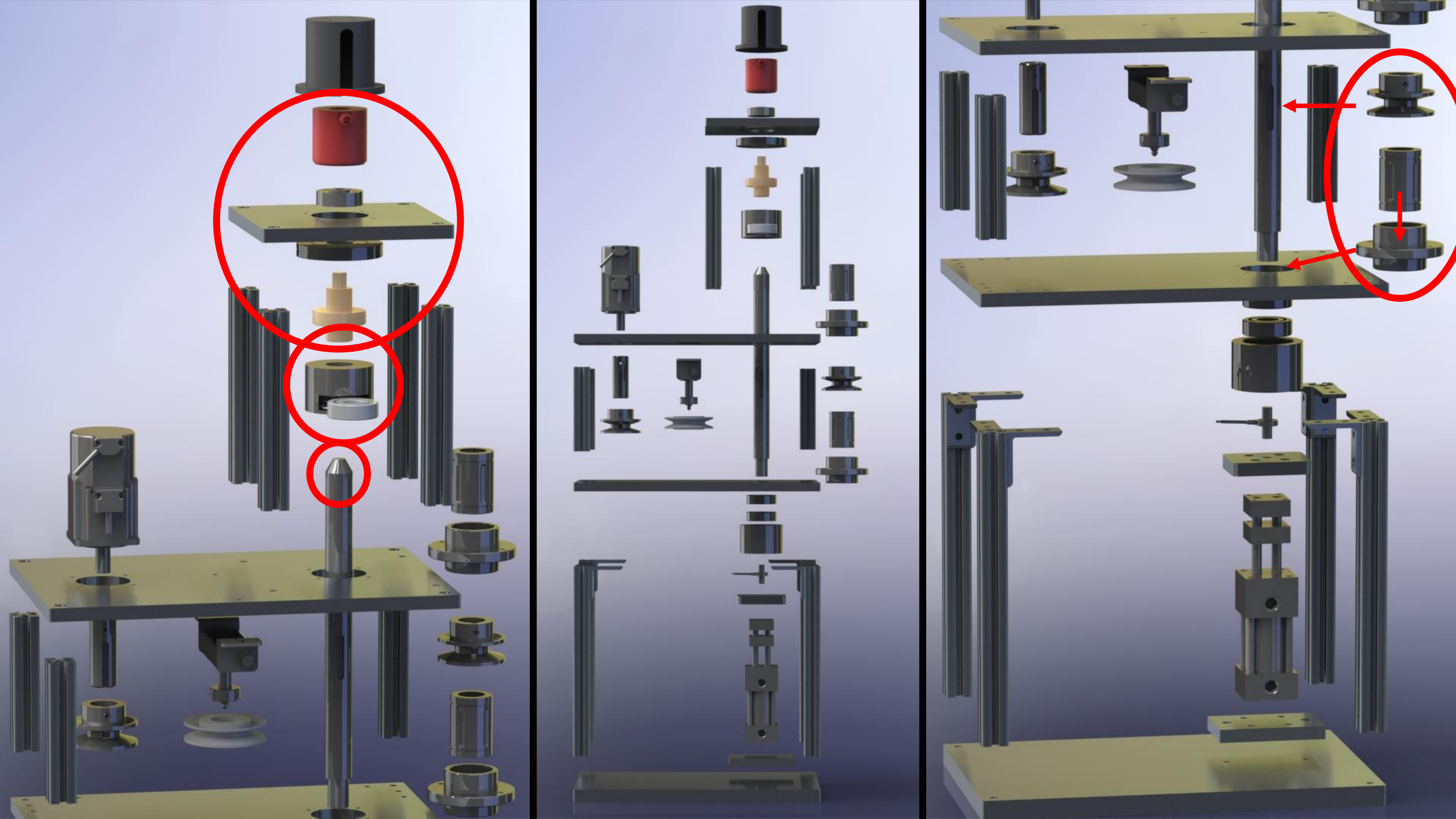
12 – Load cell for ensuring proper loading (thin wire-looking piece)

13 – (Left) Steel Motor Shaft; (Right) Hardened Stainless Bearing Shaft



Front	Isometric
Isometric (alternate)	Left Side

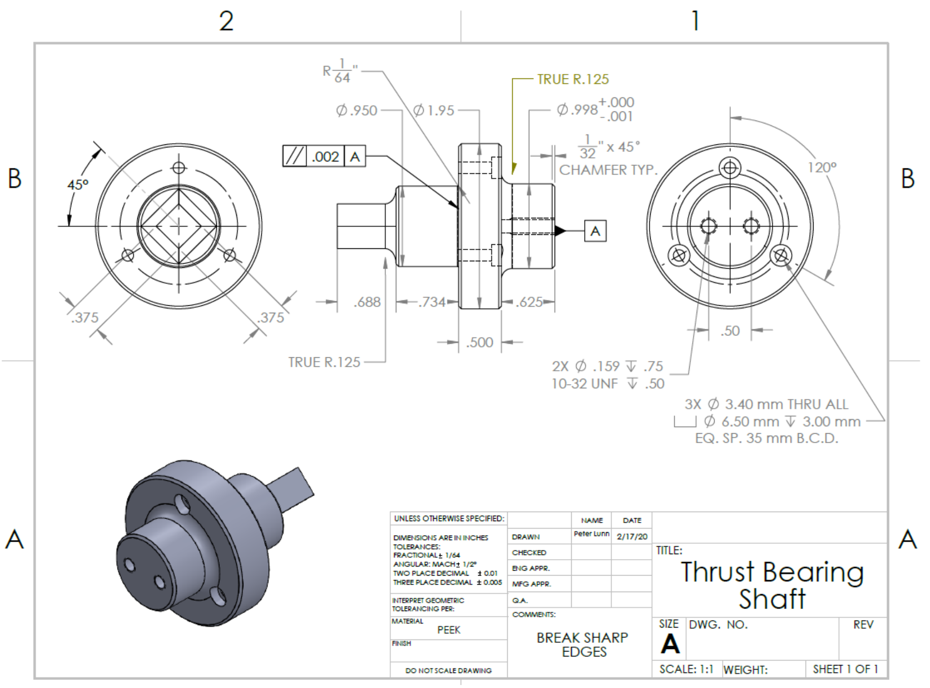


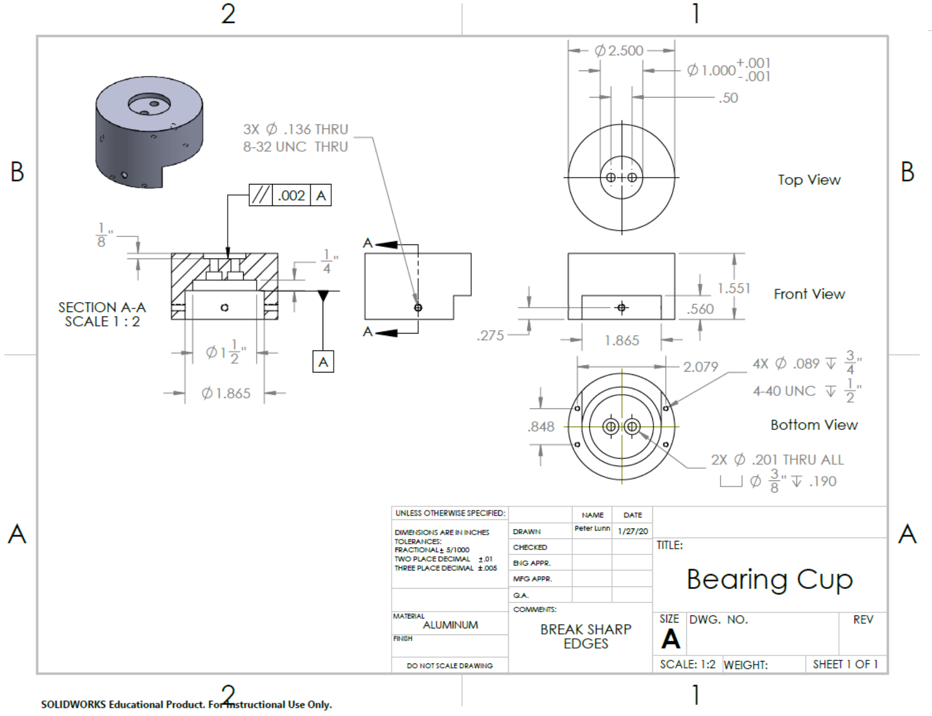


Mechanical Drawings

List of All 18 Component Drawings:

1. Adapter for Piston Cup
2. Bearing Cup Disc
3. Bearing Cup Drawing (shown to the bottom right)
4. Bottom Legs
5. Bottom Plate
6. Frame Bushing Ring
7. Main Plate
8. Mid Legs
9. Mid Plate
10. Motor Shaft
11. Piston Cup Bottom
12. Piston Cup Top
13. Simplified Cylinder Nozzle
14. Test Bearing Shaft
15. Thrust Bearing Shaft (shown to the top right)
16. Top Bracket
17. Top Legs
18. Torque Sensor Housing



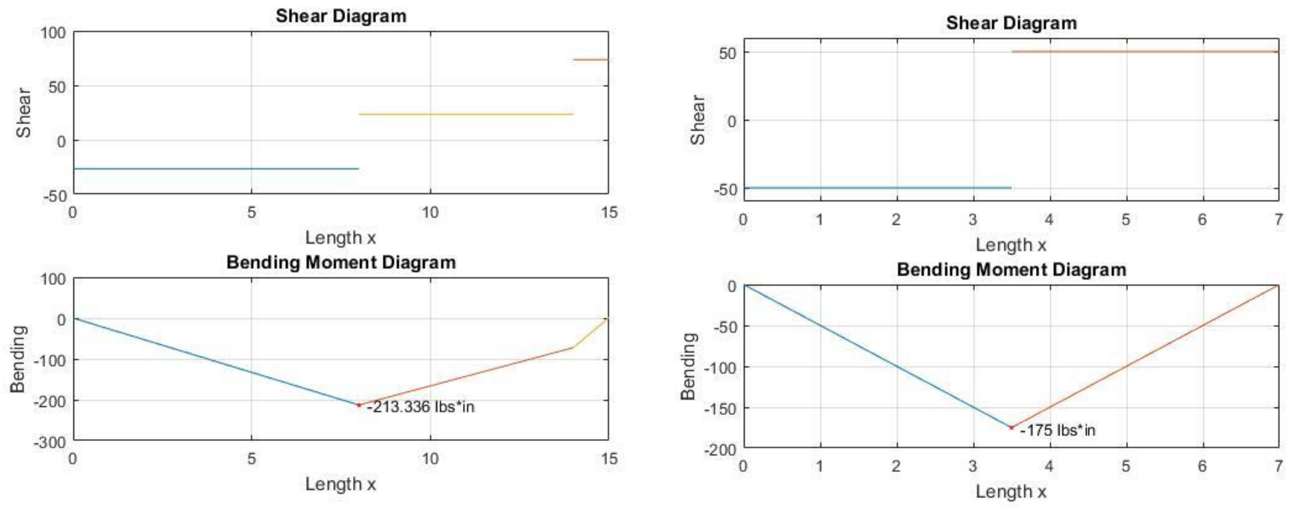


Since 1844 Nye Lubricants TECHNOLOGY IN MOTION®

Theoretical Calculations

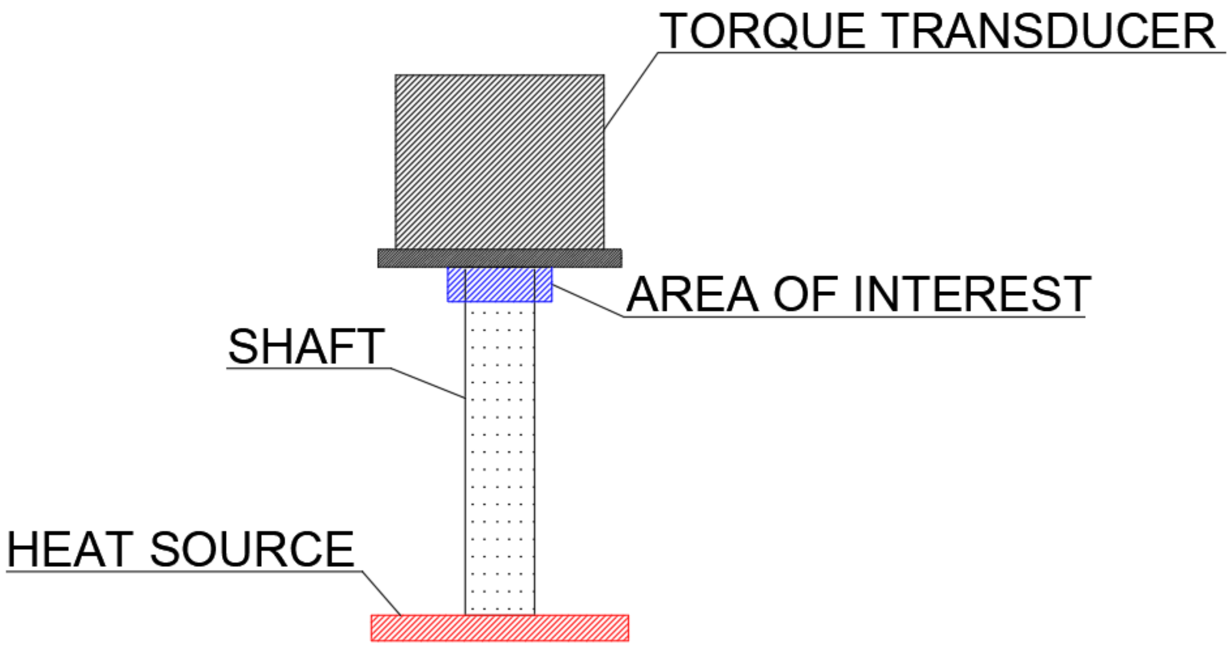
- 2 ALUMINUM PLATES
  - BENDING
  - MAX DEFLECTION

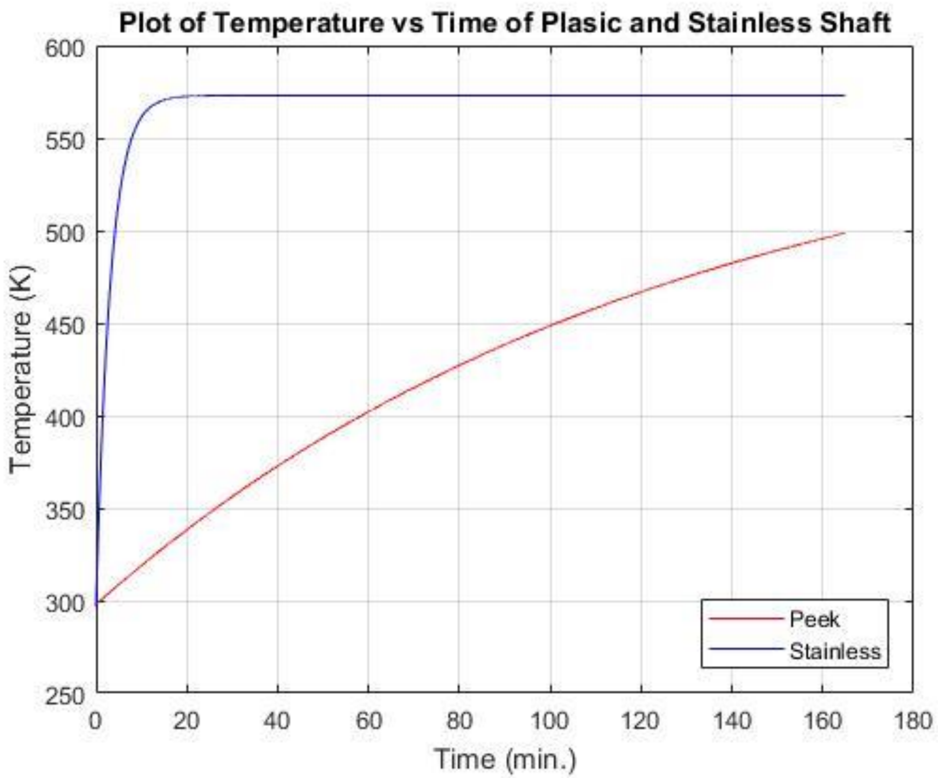
- PEEK THRUST BEARING SHAFT
  - YEILDING
  - BUCKLING



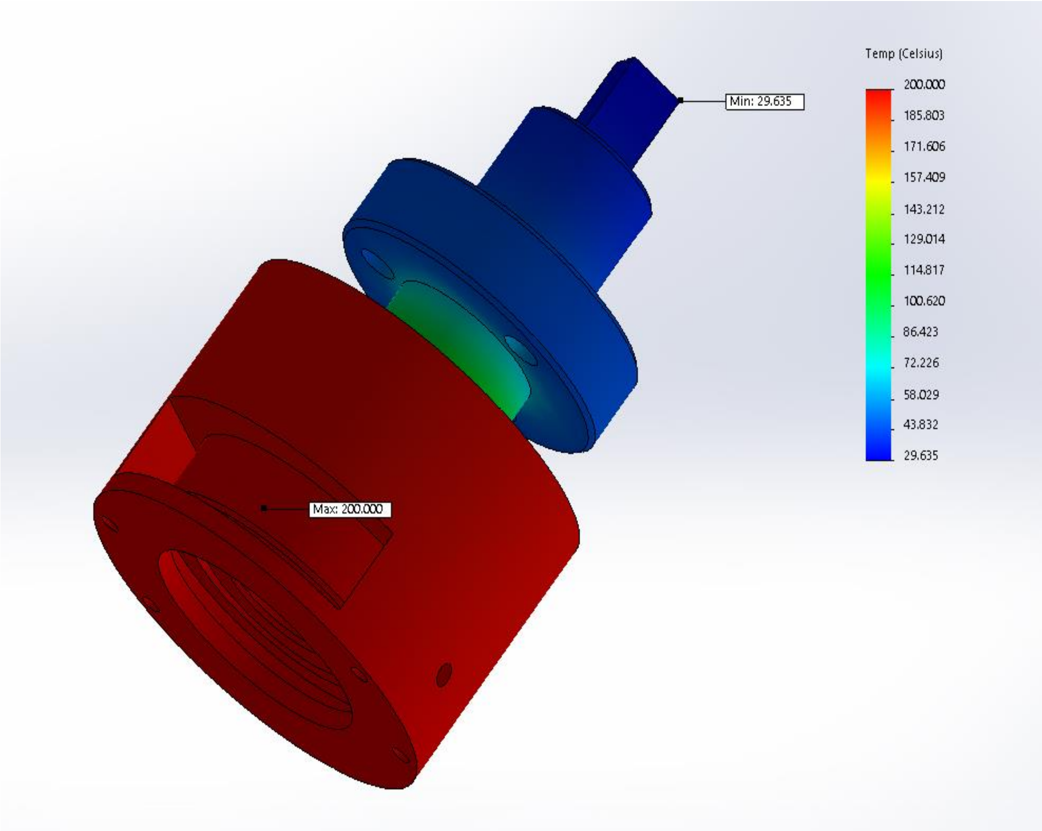
Theoretical Calculations

- DESIGN JUSTIFICATION FOR STAINLESS STEEL SHAFT VS PEEK SHAFT





Simulations



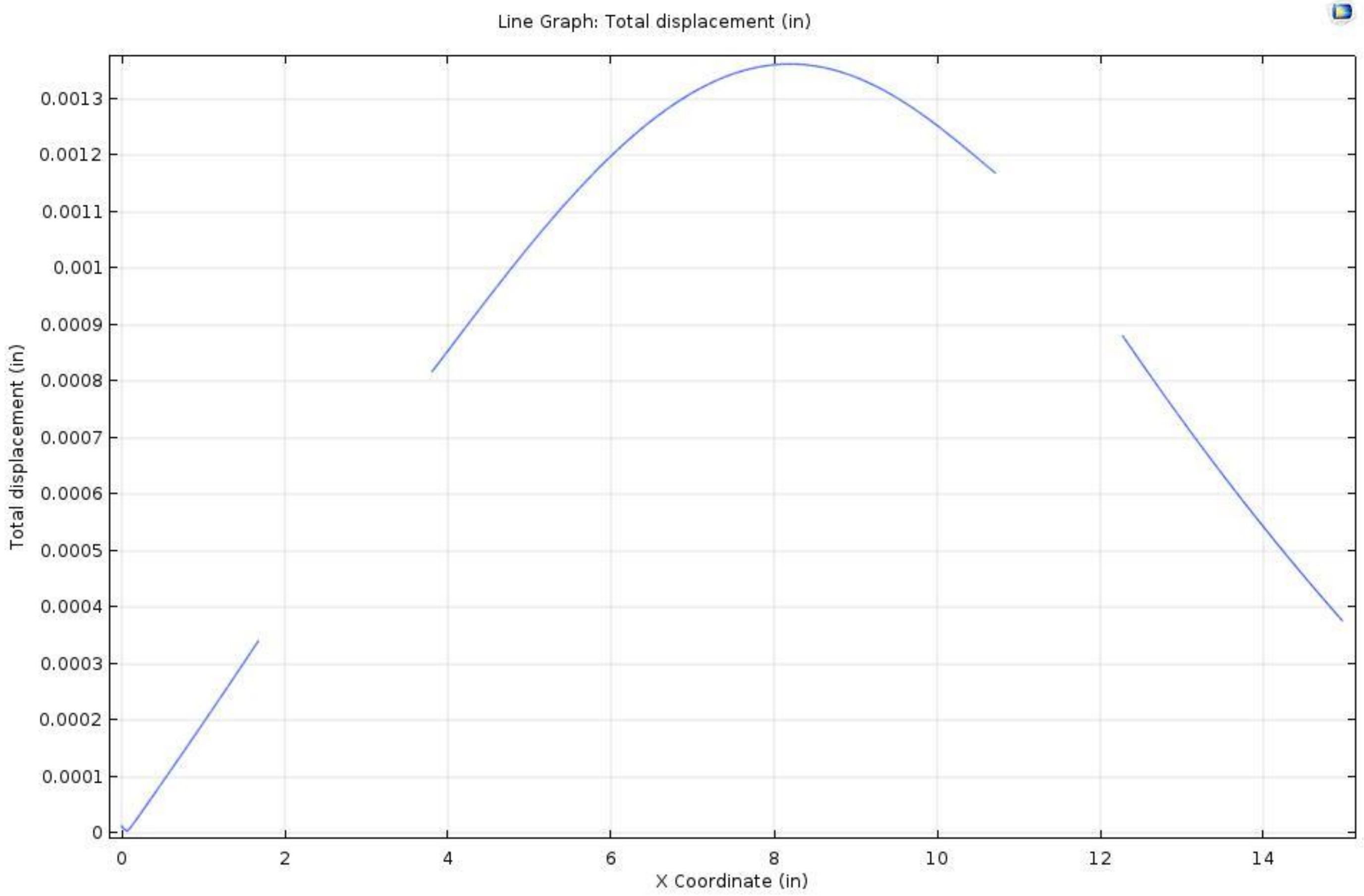
Stress Simulation Parameters:

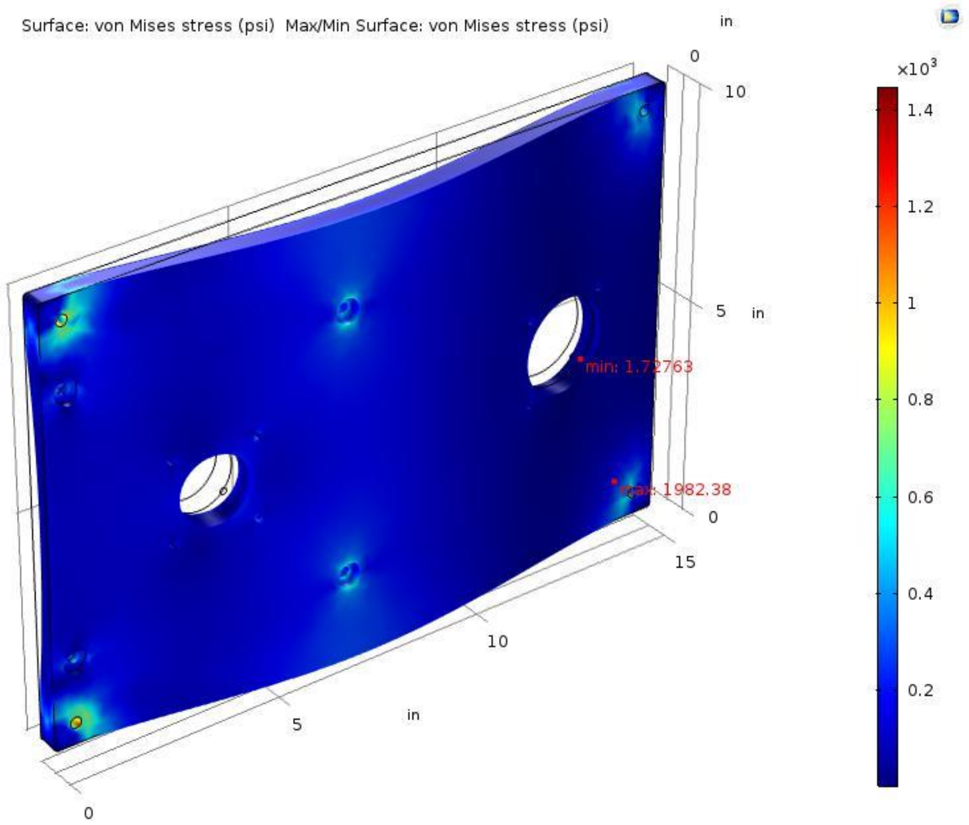
- Material: 6061-T6 Aluminum
- Young's Modulus: 68.9 GPa
- Poisson's Ratio: 0.33
- Density: 2700 kg/m^3
- Yield Stress: 40000 psi
- Mesh: Normal
- Force: 100lbf
- Maximum First Principal Stress: 2293.2 PSI
    - Calculated deflection: 0.003 in
    - Simulated Deflection: 0.00138 in

Heat Transfer Simulation Parameters:

Component:	Thrust Bearing Shaft
Material:	Polyether Ether Ketone
Specific Heat:	$1850\ {}^{J}/_{kg * K}$
Thermal Conductivity:	$0.24\ {}^{W}/_{m * k}$
Density:	$1310\ {}^{kg}/_{m^3}$
Component:	Bearing Cup
Material:	6061-T6 Aluminum
Specific Heat:	$896\ {}^{J}/_{kg * K}$
Thermal Conductivity:	$166.9\ {}^{W}/_{m * k}$
Density:	$2700\ {}^{kg}/_{m^3}$
Component:	Bearing
Material:	Alloy Steel
Specific Heat:	$460\ {}^{J}/_{kg * K}$
Thermal Conductivity:	$50\ {}^{W}/_{m * k}$
Density:	$7700\ {}^{kg}/_{m^3}$
Mesh Quality:	High
Convection Coefficient:	$4.2\ {}^{W}/_{m^2 * K}$
Ambient Temperature:	298.15 K

Simulations (cont.) – Top Plate Stress





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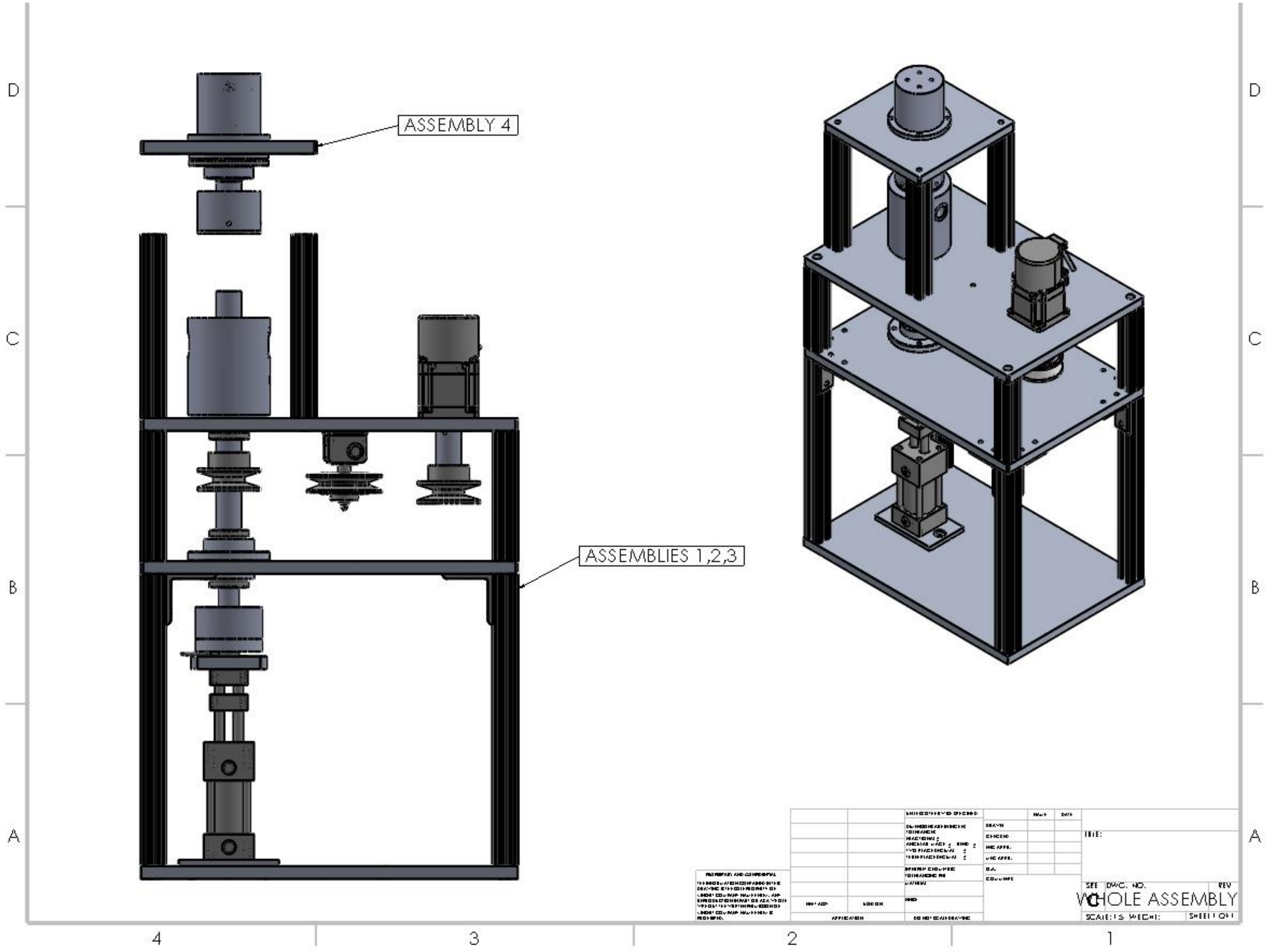
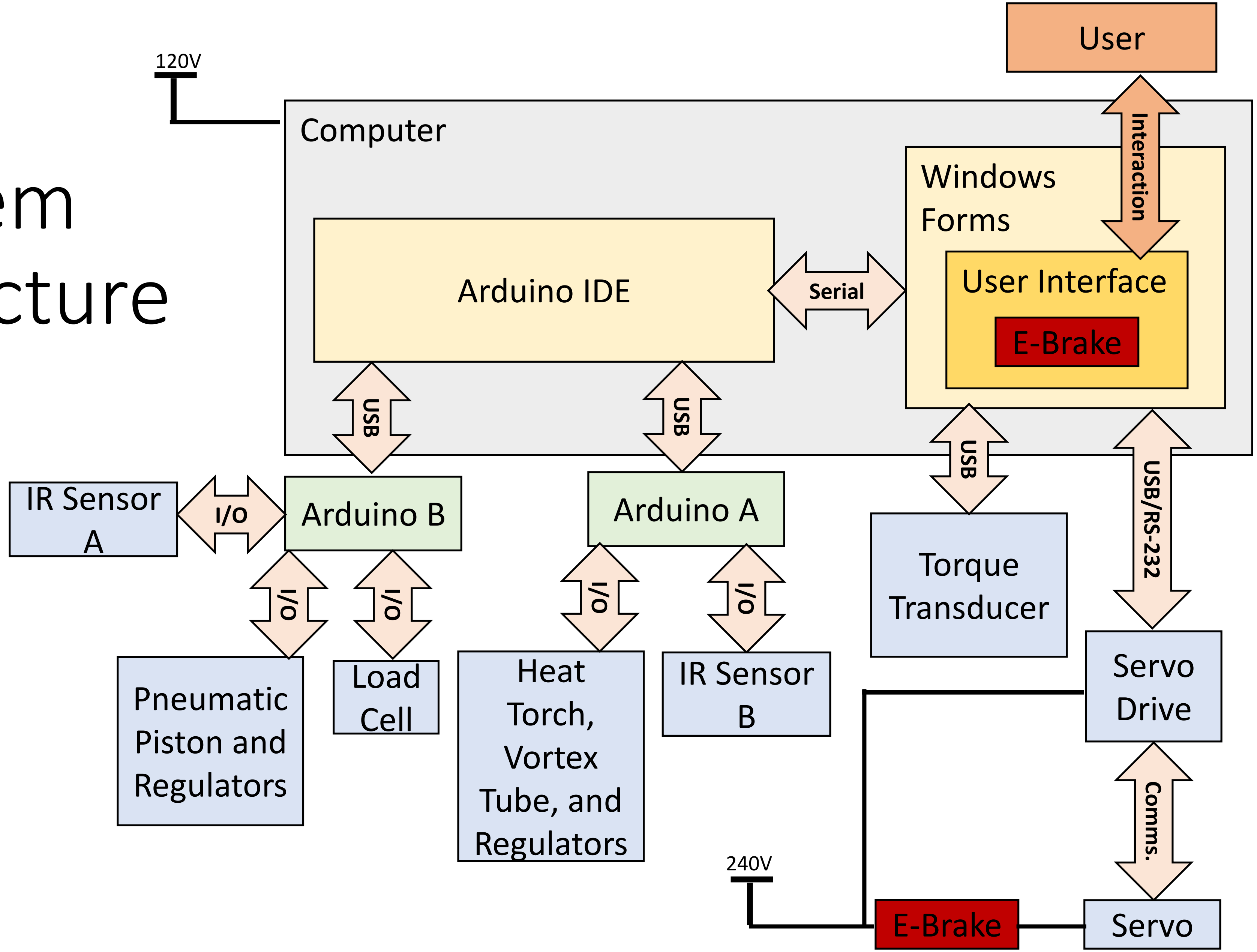
Plans to Assemble



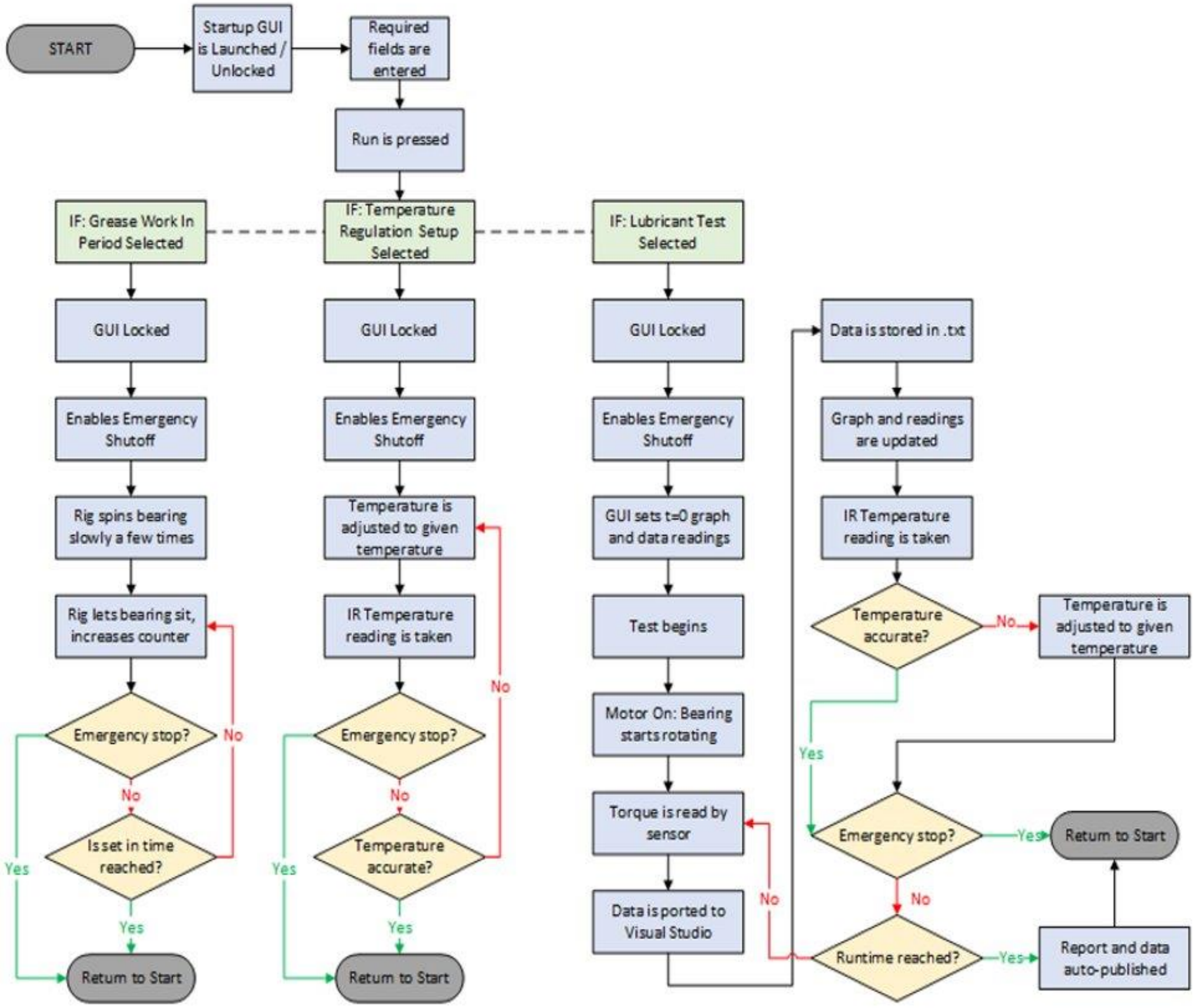
Electrical Engineering Aspect

System Architecture



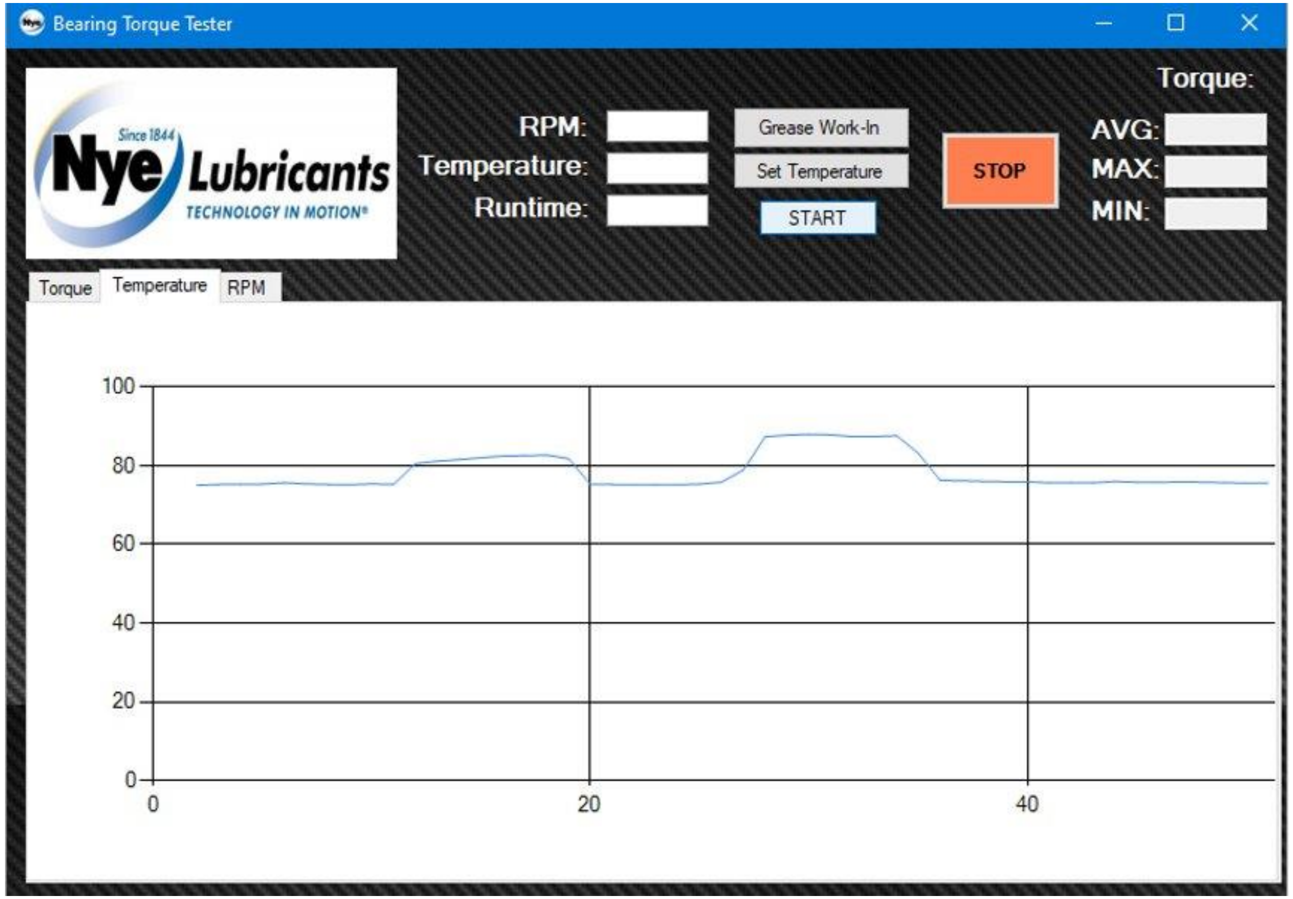
Software Design

- All user controls are available in the UI
- Three Phases:
  1. Grease Work in Period
  2. Temperature Regulation
  3. Lubricant Test
- System ends on one of three criteria:
  1. Timer run completion
  2. Electrical UI emergency brake
  3. Physical motor power brake
- Full reset on completion
- Program was written using the C# object-oriented software language



Graphical User Interface

- Adjustable user parameters
  - RPM
  - Temperature
  - Runtime
- Separate stages with buttons
- Current Torque values
- Emergency STOP
- Different viewing tabs



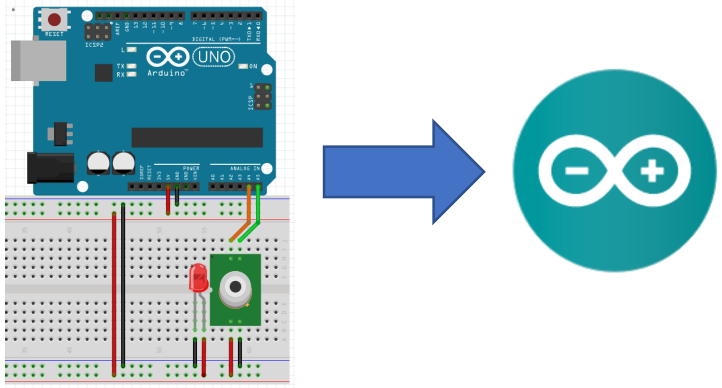
Communications Framework

- The UI in Visual Studio is the central hub:
  - All data is processed here
  - All commands come from here
  - All user inputs are here
- USB interfacing sensors/actuators:
  - Motor Communicates through ModBus RS-232
  - Transducer prints its readings into a .txt to be read by visual studio every instruction cycle
- Arduino UNOs and the IDE:
  - Sub-components are connected through I/O
  - Data is stored in temporary IDE variables in real time
  - Sensors/actuators receive instruction through serial port from VS to the IDE
  - Per cycle, the data is sent from the IDE to VS on command

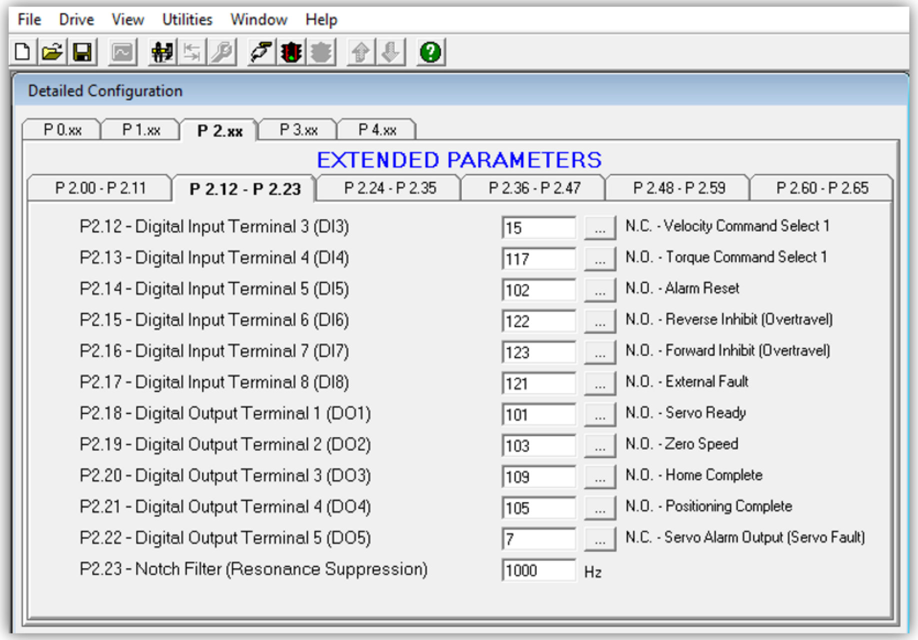
Communications Parameters			
Parameter	Description	Range	Default
P3-00	Communication Address	01 to 254	01
P3-01	Transmission Speed	00: 4800 baud 01: 9600 baud 02: 19200 baud 03: 38400 baud 04: 57600 baud 05: 115200 baud	02
P3-02	Communication Protocol	00: Modbus ASCII mode 7 data bits, no parity, 2 stop bits 01: Modbus ASCII mode 7 data bits, even parity, 1 stop bit 02: Modbus ASCII mode 7 data bits, odd parity, 1 stop bit 03: Modbus ASCII mode 8 data bits, no parity, 2 stop bits 04: Modbus ASCII mode 8 data bits, even parity, 1 stop bit 05: Modbus ASCII mode 8 data bits, odd parity, 1 stop bit 06: Modbus RTU mode 8 data bits, no parity, 2 stop bits 07: Modbus RTU mode 8 data bits, even parity, 1 stop bit 08: Modbus RTU mode 8 data bits, odd parity, 1 stop bit	08
P3-03	Transmission Fault Action	00: Display fault and continue operating 01: Display fault and RAMP to stop	00
P3-04	Communication Watchdog Time Out	0 to 20.0 seconds	00
P3-05	Communication Selection	00: RS-232 01: RS-422 02: RS-485	00
P3-06	Reserved	-	-
P3-07	Communication Response Delay Time	00 to 255ms (increments of 0.5 ms)	00

Functional Prototypes

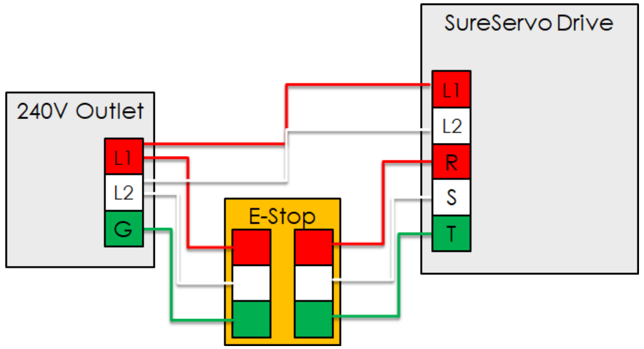
- IR Sensor/Laser Diode



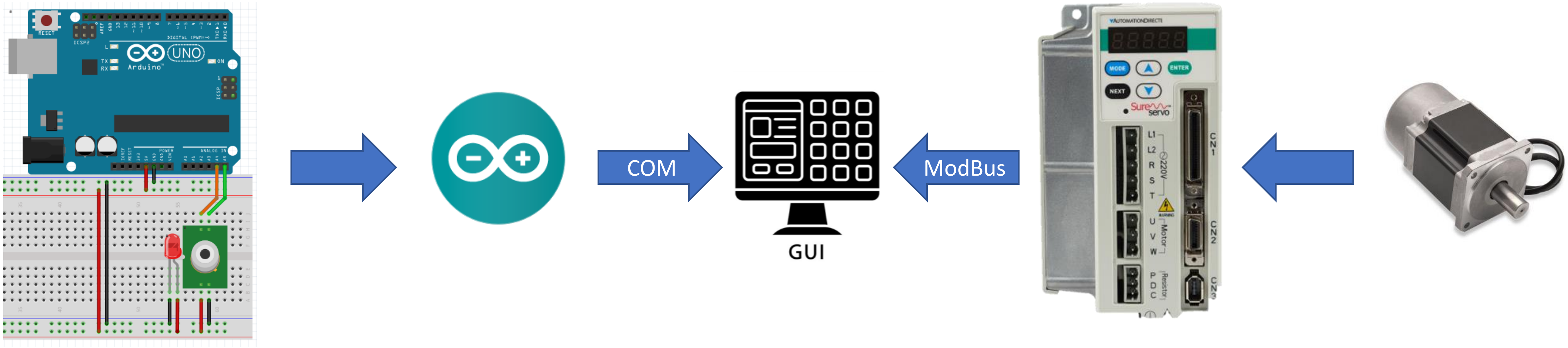
- ModBus SureServo



Final Systems Integration



- IR Sensor/Laser Diode
- ModBus SureServo



Fully Operational Machine

Physical Work Completed Until Shutdown

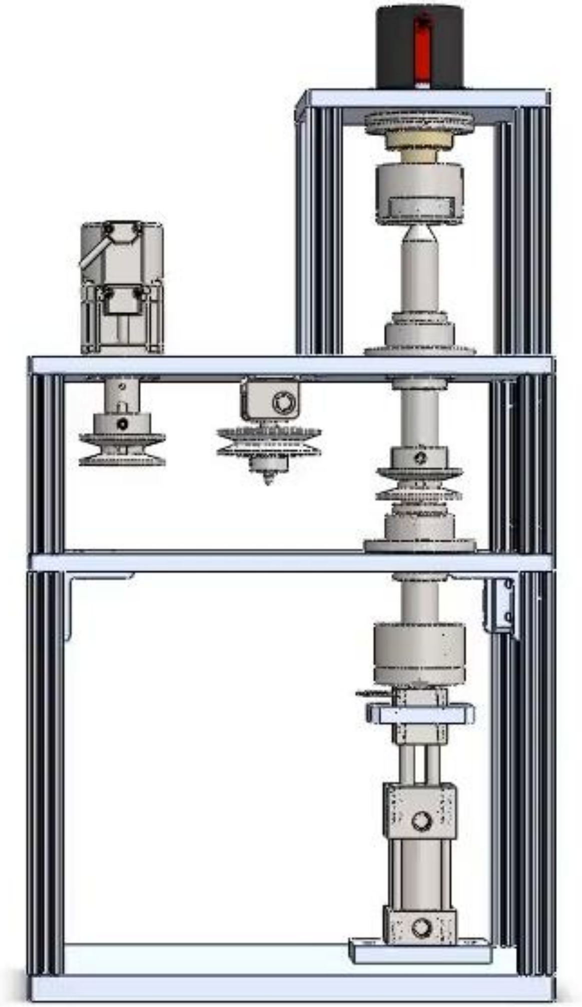
Mechanical Work

- Product Design Specifications table developed
- Mechanical design fully developed in SolidWorks
  - Went through numerous redesigns
- Stress and Heat Transfer calculations performed for design justification
- FEA Stress simulations performed
- Manufacturing quote received from shop
- SolidWorks animations of rig

Electrical/Computer Work

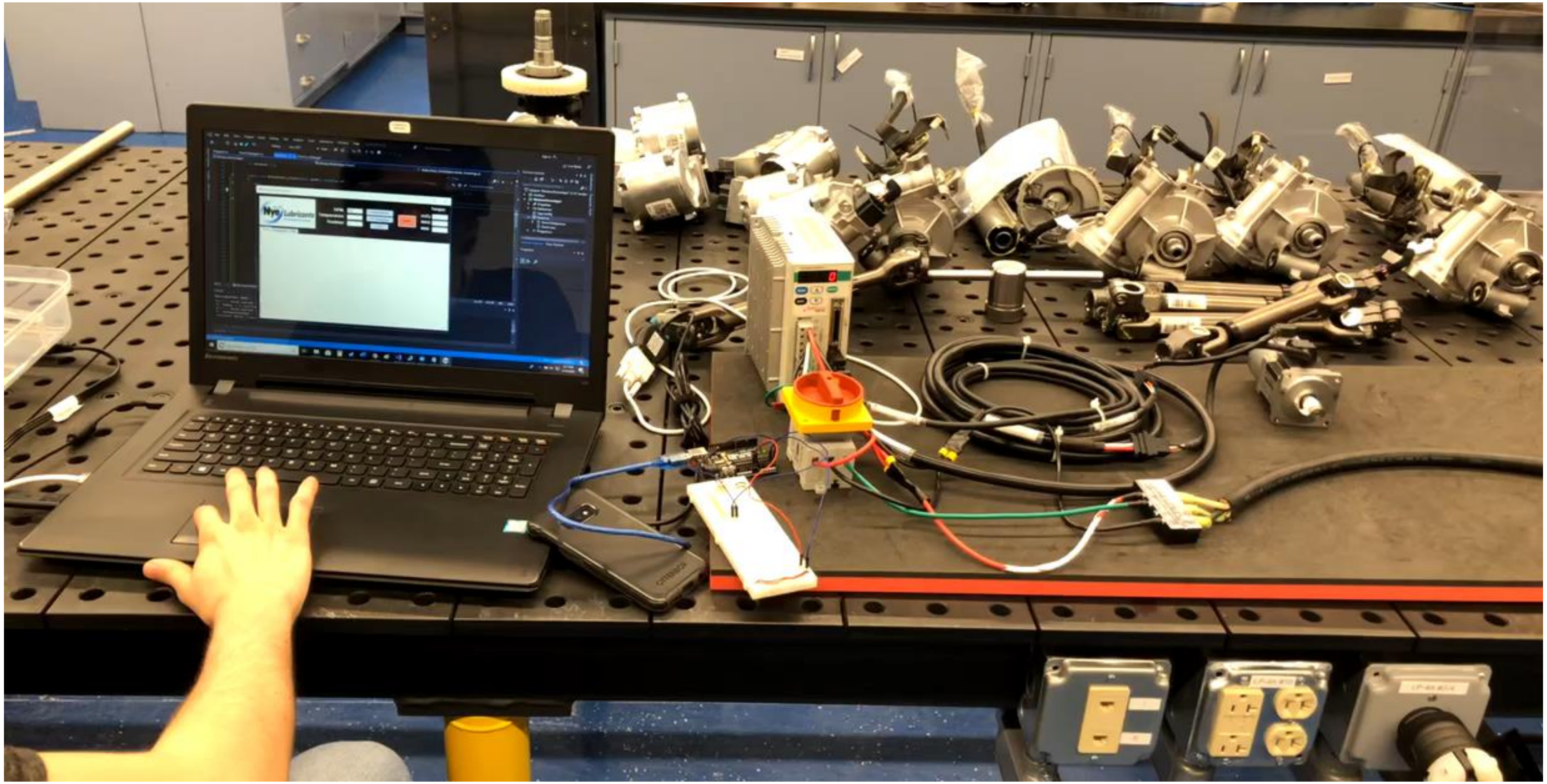
- GUI fully prototyped
- Visual Studio to Arduino IDE framework implemented
- IR Sensor Arduino Prototype
- Realtime temperature graph implemented
- IR sensor final system integration
- SureServo motor and drive prototype
- ModBus Visual Studio prototype
- Servo final system integration
- Runtime timers implemented
- Electrical E-brake implemented
- Physical E-brake Implemented
- Major/minor bug fixes on UI

Mechanical Simulation



GUI and Temperature Prototype

Servo Motor and Drive Prototype



Conclusion

Challenges Faced

- COVID-19 Pandemic
  - Nye and UMassD facilities closed down
- Budgetary Concerns and Restrictions
  - Triggered several time-costly redesigns
    - Air Bearing to Thrust Bearing
    - Heat Torch not Purchased
- Complex Design
  - Required several moving components
- High Temperature Materials
  - Forced the team to get extremely creative
- Servo Motor Selection
  - Software restrictions

Final Spending

- Largest Purchases
  - Servo Motor - $483
  - Torque Transducer, Interface, and Calibration - $2,450
  - Vortex Tube - $197
  - Piston - $326
  - Air Regulator - $287
  - Manufacturing Cost - $4700 (Not Done Due to Pandemic)
- Team was awarded $30,000
  - Multiple redesigns were performed to save substantial money
  - Spent $10,655 (including manufacturing)
  - **Saved Nye $19,345**

Purpose of Project

- Analyze Effectiveness of a Nye-Produced Lubricant
- Analyzed via Torque Values Between Inner and Outer Race of Bearing
  - Higher torque values = less/more effective based on grease purpose
- Provides Customer with Peace of Mind
  - Grease will function as expected even under harsh conditions
- Provides Nye with a Selling Point over Competitors
- Further Solidifies Nye as a World Leader in Lubrication

The Future of the Project

- Machining of the Tester
- Program Heating/Cooling Mechanisms
- Program Piston
- Program Torque Transducer
- Assemble Tester
- Fully Integrate Electronics and GUI into Tester

Acknowledgements

- *Nye Lubricants Inc.*
  - Jason Galary (Director of R&D)
  - Gus Flaherty (R&D Lab Manager)
  - Richard Raithel (Project Overseer)
  - Mason Wood (Machining Advise)
- *University of Massachusetts Dartmouth*
  - Hamed Samandari (Senior Design Professor)
  - Vijaya Chalivendra (Project Advisor)
  - Jun Li (Project Advisor)
  - Raymond Laoulache (Associate Dean of Engineering)
- *Team Lubricant*

Thank You

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Questions?