FAMU-FSU College of Engineering

Team 501
Tribometer in Spacelike Conditions

VDR2 231113

Team Introductions

Branham Channell
Materials Engineer

Cobi Johnson
Systems Engineer

Madison Retherford
Mechatronics Engineer

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Structural Engineer

Joshua Wesley
Computer Hardware Engineer

FAMU-FSU College of Engineering

Sponsor and Advisor

Dr. Brandon Krick

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Dr. Shayne McConomy

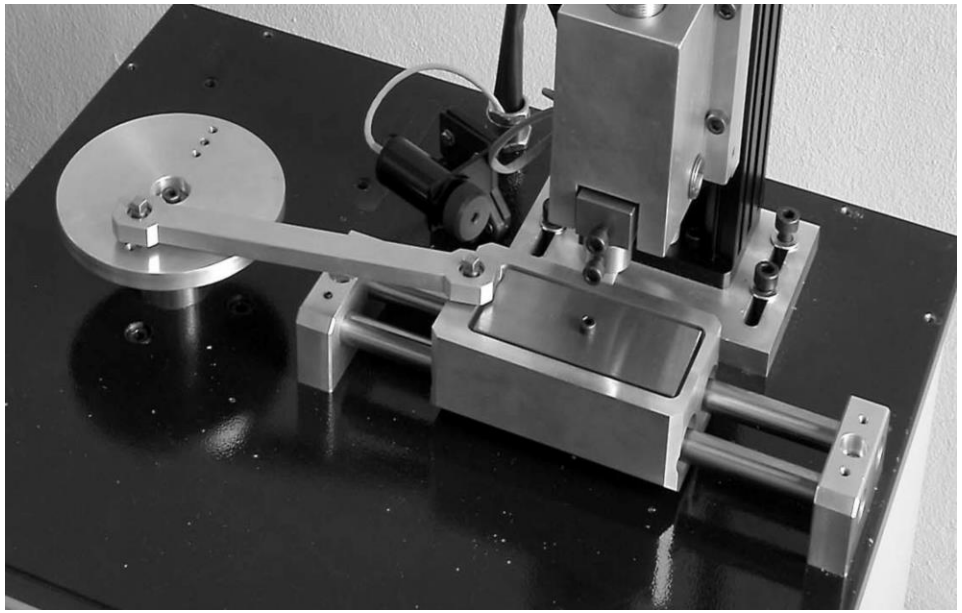
FAMU-FSU College of Engineering

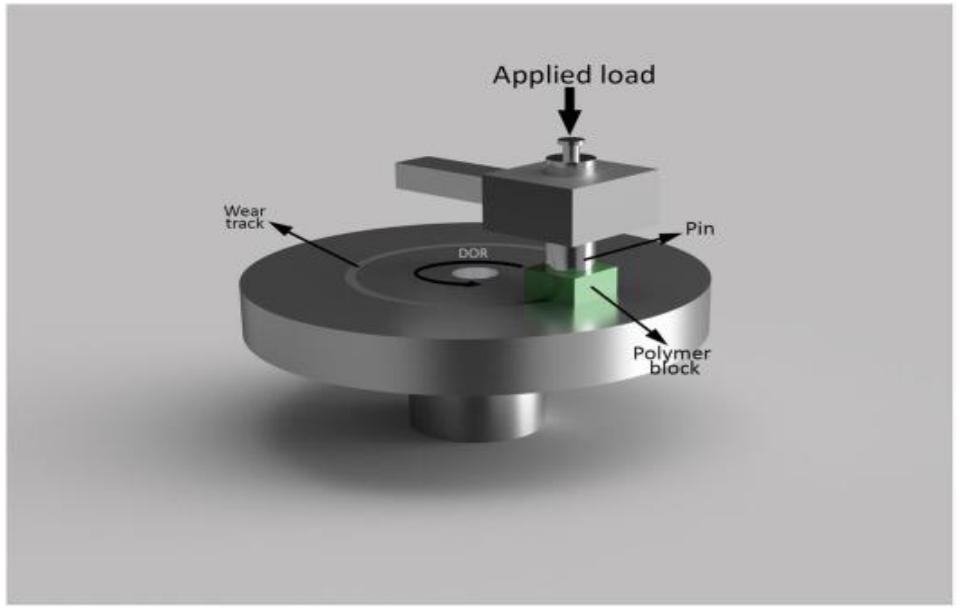
Objective

The objective of this project is to design, develop, and implement a system that enables the simultaneous testing of multiple samples within a vacuum chamber using a tribometer. This system aims to increase testing throughput and enhance overall efficiency while maintaining prior accuracy and control.

What is a Tribometer?

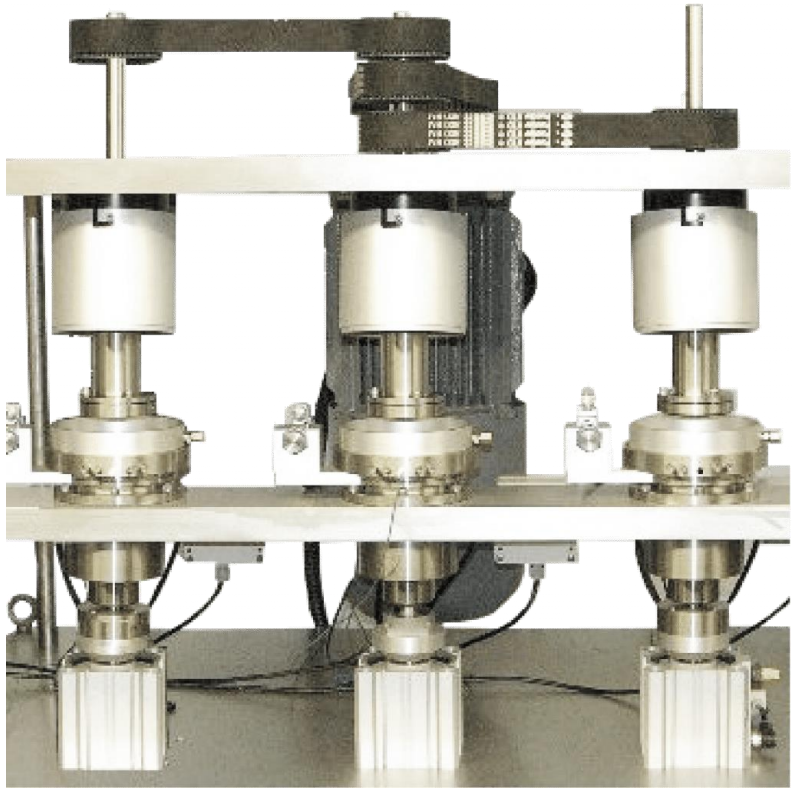
Tribometers measure quantities such as coefficient of friction, friction force, and wear volume on two surfaces in contact by simulating friction in controlled conditions.





Key Goals

- **Test multiple samples**
- **Control parameters**
- **Operate in specific conditions**



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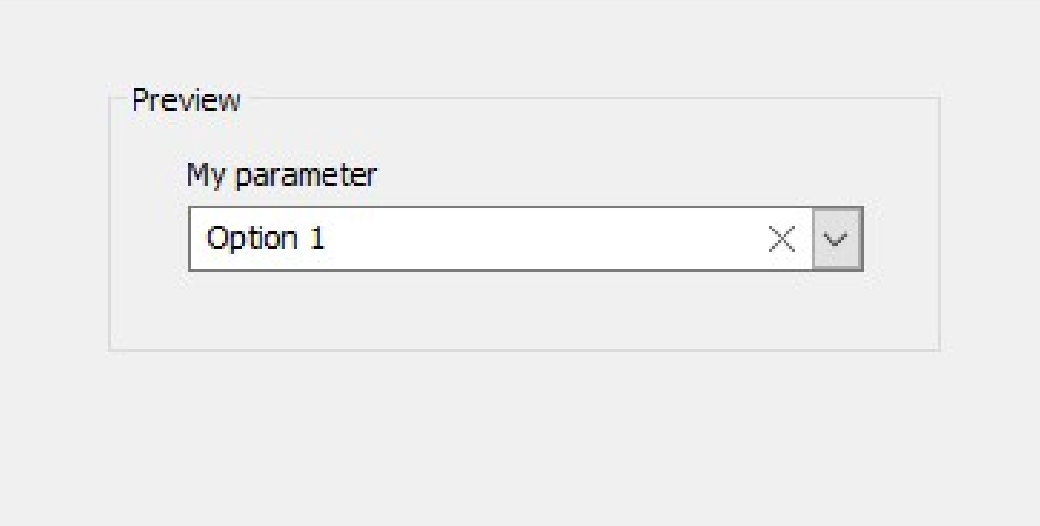

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Key Goals

- Test multiple samples
- Control parameters
- **Operate in specific conditions**

Primary Market

Secondary Market

Tertiary Market

Dr. David Larbalestier
Chief Materials Scientist of the National High Magnetic Field Laboratory

Dr. Lance Cooley
Director, Applied Superconductivity Center

Assumptions

Test will be run by individuals with proper training.

Materials that will be tested are polymers and coating.

High-vacuum chamber will be provided.

Applied load and temperature will not be tested outside of the established range.

Stakeholders - Sponsors

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Stakeholders - Manager

Dr. Brandon Krick

Stakeholders - Experts

Dr. Mark Vanderlaan

Dr. Brandon Krick

Dr. Camilo Ordóñez

Stakeholders - Operators

Adam Delong

Kylie Van Meter

Customer Needs

1
Tests multiple samples simultaneously

2
System can apply different inputs to different samples

3
System reads in and stores inputs

4
System returns outputs and critical targets from test results

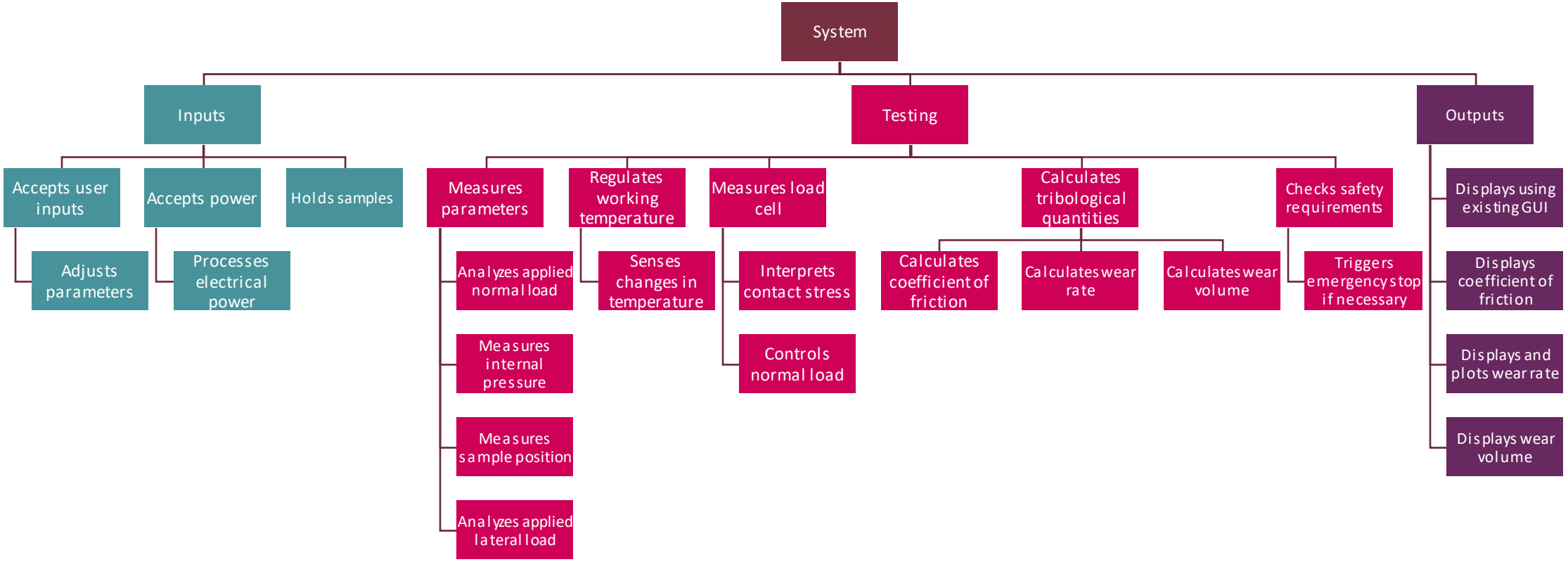
5
System can operate under high vacuum conditions

6
System is compatible with previous graphical user interface

7
Vacuum chamber needs no modification

8
Tests 4-6 samples

Functional Hierarchy Chart



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Targets and Metrics: Inputs

System	Function	Metric	Target	Unit
Inputs	Holds samples	Number of samples held	4-6	Count
		Types of samples held	2	Count
		Time to load samples	30	Minutes (min.)

Targets and Metrics: Testing

System	Function	Metric	Target	Unit
Testing	Senses changes in temperature	Resolution of temperature	1	Celsius (°C)
		Ideal error for readjustment	±1	Celsius (°C)
		Marginal readjustment	±5	Celsius (°C)
		Readjustment while transient	±10	Celsius (°C)
		Max temperature	200	Celsius (°C)
		Min temperature	-100	Celsius (°C)

Targets and Metrics: Testing

System	Function	Metric	Target	Unit
Testing	Calculates coefficient of friction	Calculates value	0-1	
		Error of calculation	10	Percent (%)
		Ideal resoluble range	0.01 - 0.5	
		Marginal resoluble range	0.05 - 0.4	

Targets and Metrics: Testing

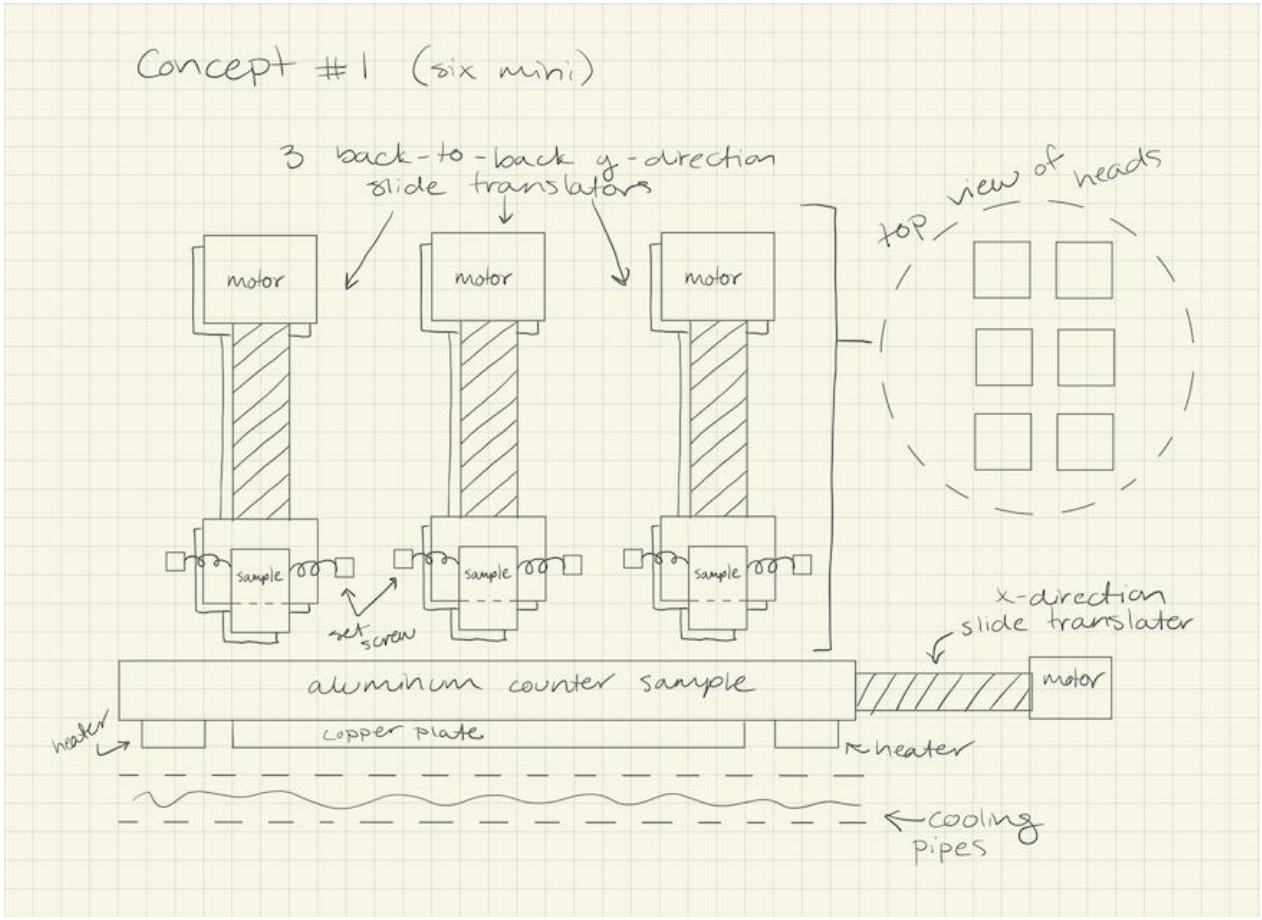
System	Function	Metric	Target	Unit
Testing	Calculates wear volume	Calculates value	0.05 - 50	Millimeters cubed (mm^3)
		Height loss resolution	5-50	Micrometers (μm)
Testing	Calculates wear rate	Calculates value	10^{-4}-10^{-7}	Millimeters cubed per Newton meter (mm^3/Nm)
		Error of calculation	±5	Percent (%)
Testing	Trigger emergency stop	Time to kill	0.3	Seconds (s)

Selection Process

- **Generated concepts for:**
  - Holding the sample
  - Style of the tribometer
  - Regulating temperatures
  - Calculations
  - Emergency protocol

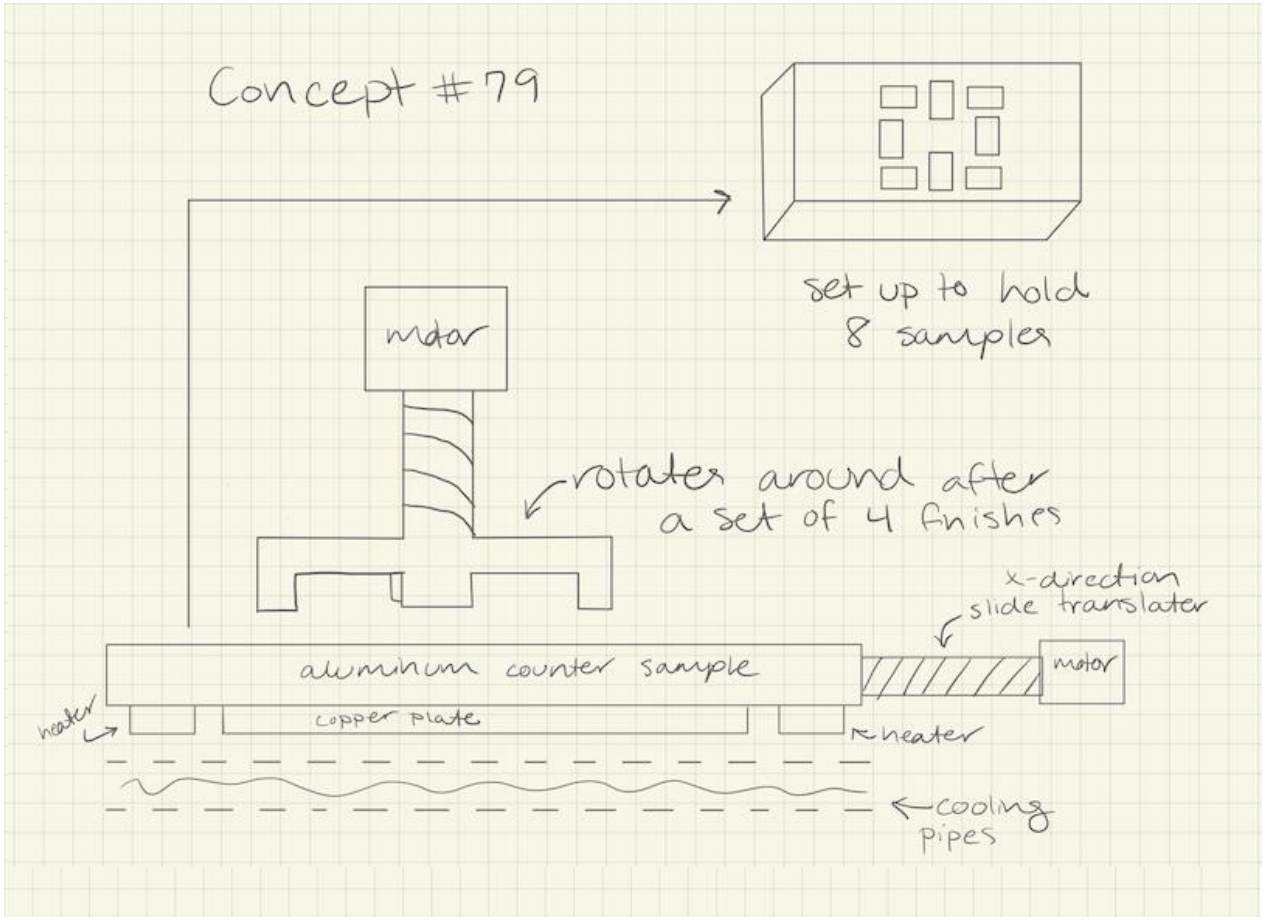
- **Evaluated concepts**
  - Chose 3 high fidelity concepts and 5 medium fidelity concepts

High Fidelity Concept 1



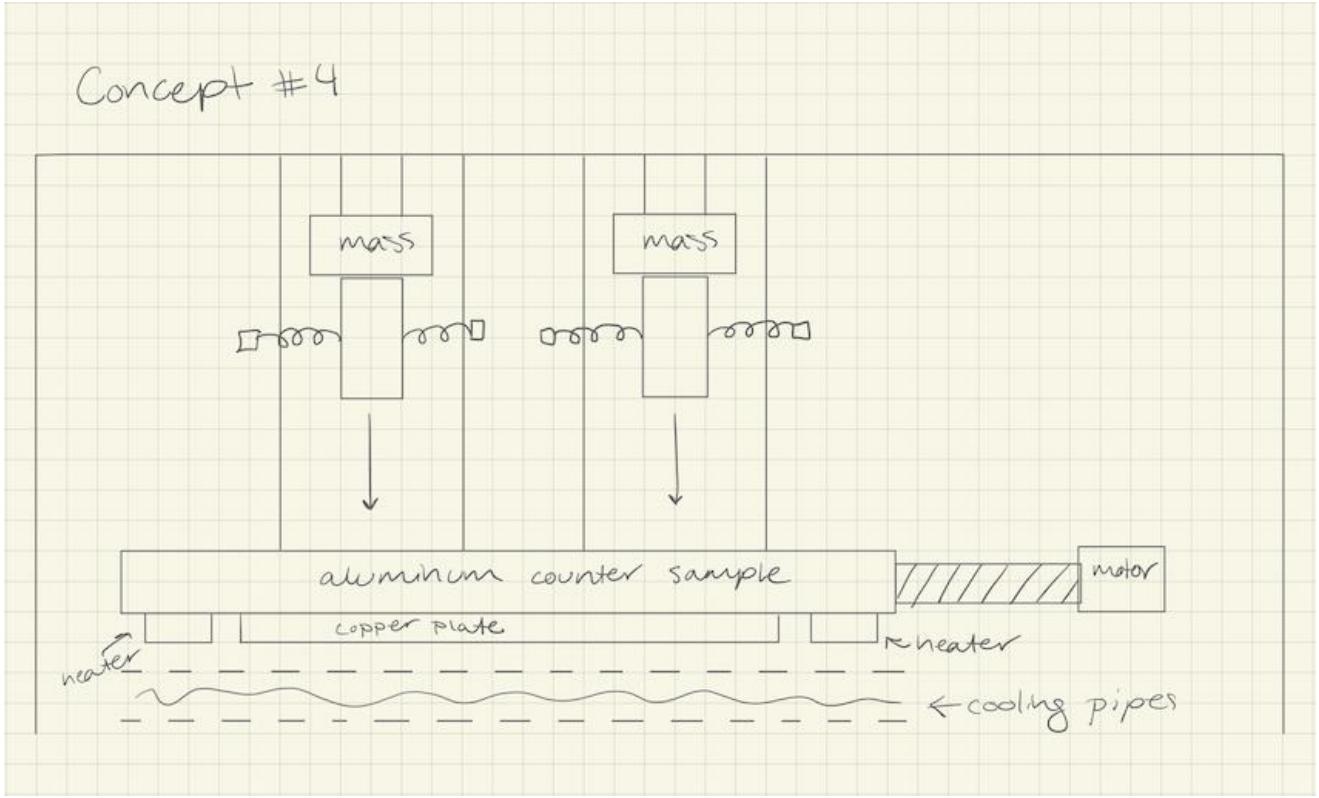
6 mini-identical tribometers.

High Fidelity Concept 2



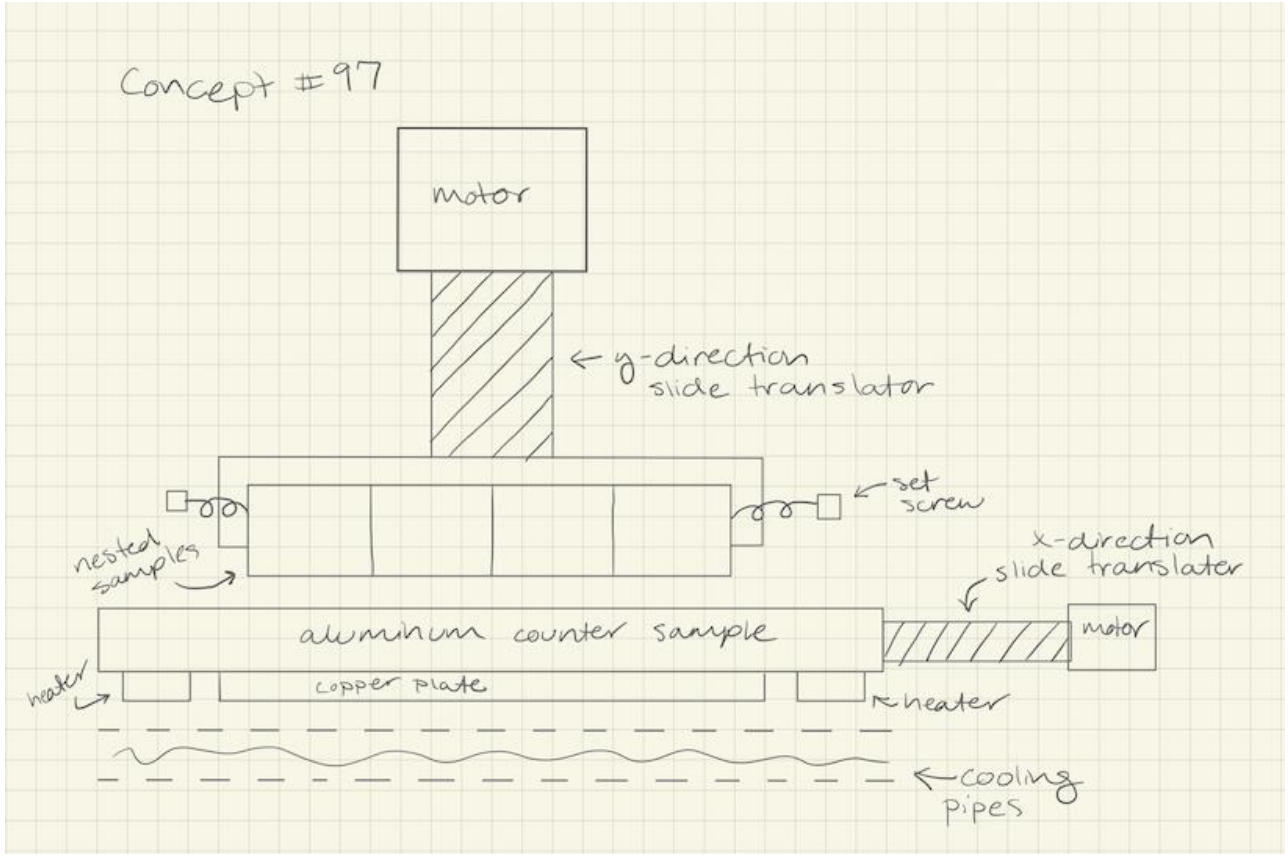
Cross-headed sample holder.

High Fidelity Concept 3



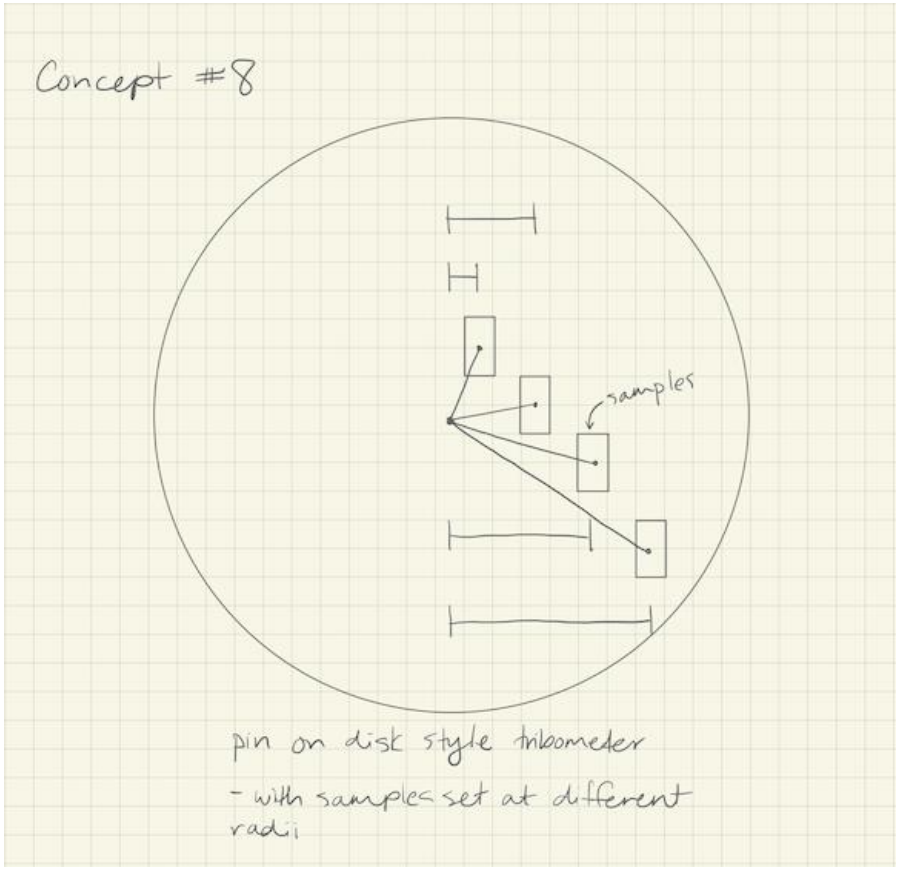
Loading weights on samples to produce normal load.

Medium Fidelity Concept 1



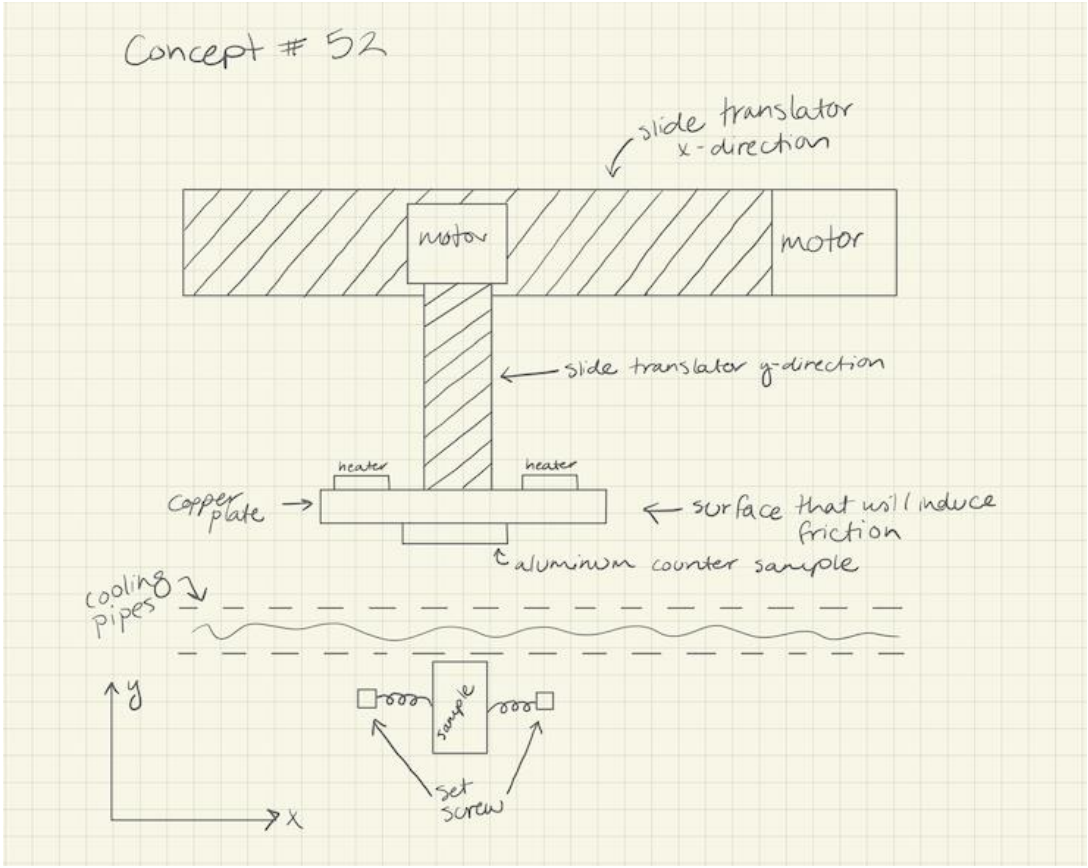
Nesting samples.

Medium Fidelity Concept 2



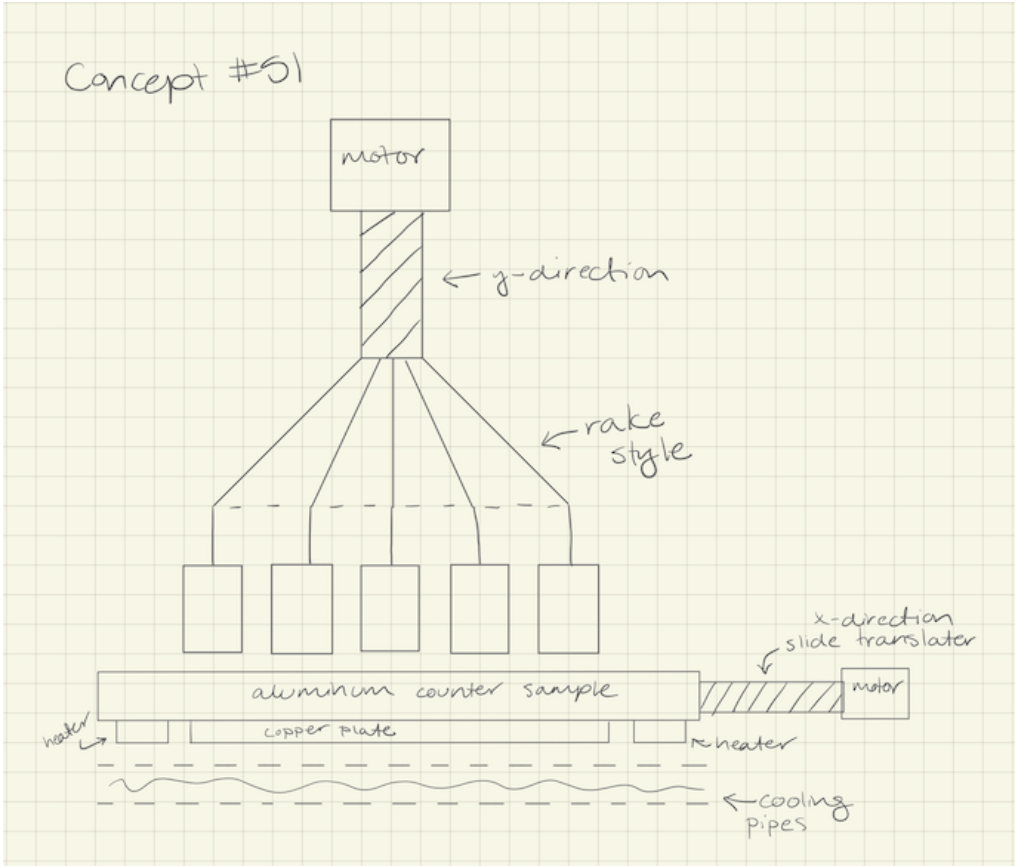
Pin-on-disk tribometer with 4 samples at different radii.

Medium Fidelity Concept 3



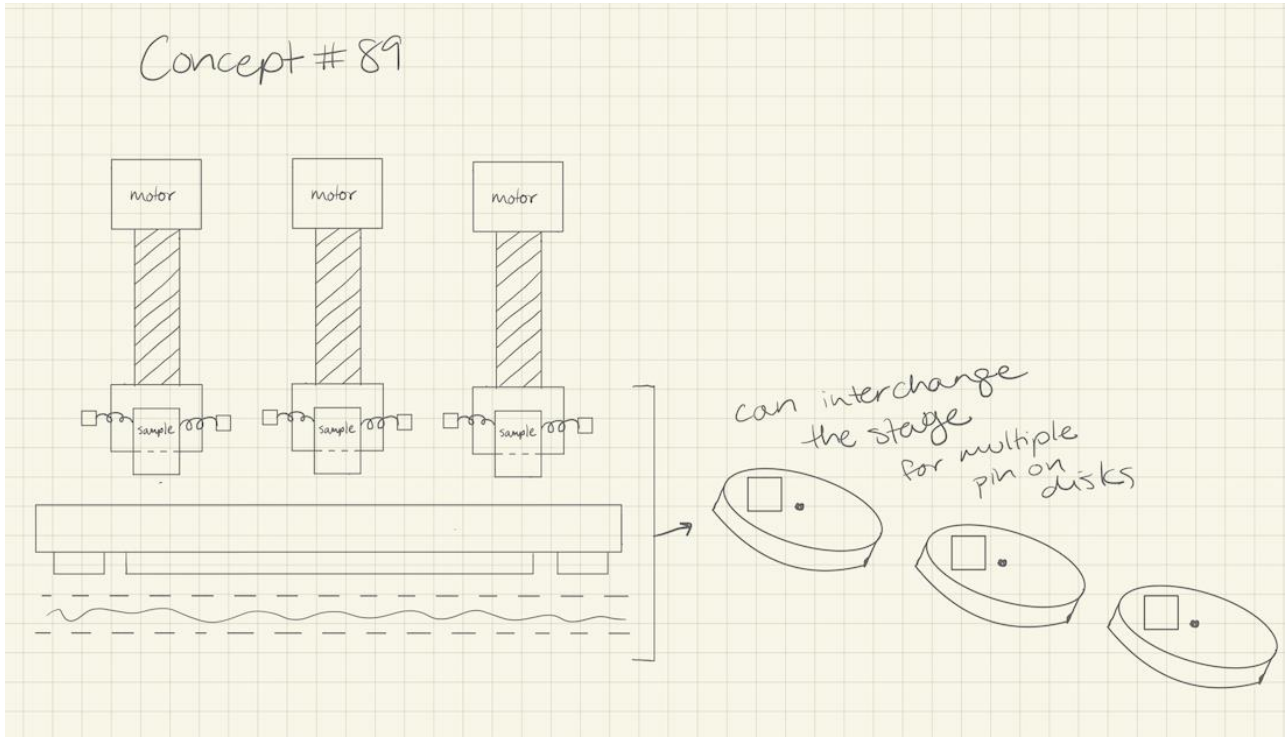
Inverted existing tribometer.

Medium Fidelity Concept 4



Rake-style tribometer.

Medium Fidelity Concept 5



Modular tribometer.

Selection Process

- **Concept selection utilizing:**
  - Binary pair-wise comparison
  - House of quality
  - Pugh charts
  - Analytical hierarchy process
  - Final concept selection chart

BPwC

Binary Pairwise Comparison	1	2	3	4	5	6	7	8	Total
1. Test Multiple Samples Simultaneously	-	0	0	0	0	0	1	0	1
2. Reads and Stores Inputs	1	-	1	0	0	0	1	1	4
3. Returns Outputs and Critical Targets	1	0	-	0	0	0	0	0	1
4. Compatible with Previous GUI	1	1	1	-	0	0	0	0	3
5. Operate in Spacelike Conditions	1	1	1	1	-	0	1	1	6
6. Works Inside a Vacuum	1	1	1	1	1	-	1	1	7
7. Applies Unique Inputs to Unique Samples	0	0	1	1	0	0	-	0	2
8. Test 4-6 Samples	1	0	1	1	0	0	1	-	4
Total	6	3	6	4	1	0	5	3	n-1=9

HoQ: Ranked Characteristics

Ranked Engineering Characteristics
1. Holds Samples
2. Analyzes Applied Loads
3. Processes Electrical Power
4. Measures Internal Pressure
5. Senses Changes in Temperature
6. Emergency Stop
7. Display Outputs
8. Calculates Outputs

Initial Pugh Chart

Market Pugh Chart						
			Concepts			
Selection Criteria	**Criteria Weight**	**AME Humidity Tribometer**	**Pin on Disk Tribometer that Can Run Four Different Samples at Four Radii**	**Inverted Existing Tribometer**	**Rake Tribometer**	**Modular Tribometer**
Processes Electrical Power	13.4%	Datum	S	S	S	S
Holds Samples	22.4%		-	+	-	-
Measures Internal Pressure	12.6%		+	+	+	+
Analyzes Applied Loads	16.8%		-	+	-	-
Senses Changes in Temperature	12.6%		+	+	+	+
Calculates Outputs	6.4%		S	S	-	-
Emergency Stop	8.1%		+	+	+	-
Display Outputs	7.6%		S	S	S	-
Pluses			3	5	3	2
Minuses			2	0	3	5

Initial Pugh Chart

Market Pugh Chart Cont'd.						
			Concepts			
Selection Criteria	**Criteria Weight**	**AME Humidity Tribometer**	**Six Mini-Identical Tribometers Side by Side**	**Cross Headed Sample Holder**	**Weights Loaded on Samples to Produce Normal Load**	**Tribological Samples are Nested Together**
Processes Electrical Power	13.4%	Datum	S	S	S	S
Holds Samples	22.4%		+	+	+	-
Measures Internal Pressure	12.6%		+	+	+	+
Analyzes Applied Loads	16.8%		S	-	+	-
Senses Changes in Temperature	12.6%		+	+	+	+
Calculates Outputs	6.4%		S	S	S	S
Emergency Stop	8.1%		+	+	+	+
Display Outputs	7.6%		+	S	S	S
Pluses			5	4	5	3
Minuses			0	1	0	2

Final Pugh Chart

Concept Pugh Chart				
			Concepts	
Selection Criteria	**Criteria Weight**	**Inverted Existing Tribometer**	**Six Mini-Identical Tribometers Side by Side**	**Weights Loaded on Samples to Produce Normal Load**
Processes Electrical Power	13.4%	Datum	S	S
Holds Samples	22.4%		S	-
Measures Internal Pressure	12.6%		S	S
Analyzes Applied Loads	16.8%		S	+
Senses Changes in Temperature	12.6%		S	S
Calculates Outputs	6.4%		S	+
Emergency Stop	8.1%		S	S
Display Outputs	7.6%		S	S
Pluses			0	2
Minuses			0	1

AHP Holds Samples

Holds Samples			
	Inverted Existing Tribometer	Six Mini-Identical Tribometers Side by Side	Weights Loaded on Samples to Produce Normal Load
Inverted Existing Tribometer	1.00	3.00	1.00
Six Mini-Identical Tribometers Side by Side	0.33	1.00	3.00
Weights Loaded on Samples to Produce Normal Load	1.00	0.33	1.00
Concepts			
SUM	2.33	4.33	5.00

Normalized Comparison of Holds Samples

Normalized Comparison				DAP
	Inverted Existing Tribometer	Six Mini-Identical Tribometers Side by Side	Weights Loaded on Samples to Produce Normal Load	
Inverted Existing Tribometer	0.429	0.692	0.200	0.440
Six Mini-Identical Tribometers Side by Side	0.143	0.231	0.600	0.325
Weights Loaded on Samples to Produce Normal Load	0.429	0.077	0.200	0.235
Concepts				
SUM	1.000	1.000	1.000	1.000

Consistency Check for Holds Samples

Consistency Check		
{Ws}=[C]{W}	{W}	Cons={Ws}./{W}
Weighted Sum Vector	Criteria Weights	Consistency Vector
1.649	0.440	3.745
1.177	0.325	3.626
0.784	0.235	3.332

λ	3.568
RI	0.520
CI	0.284
CR	0.546

Consistency Check CR Values

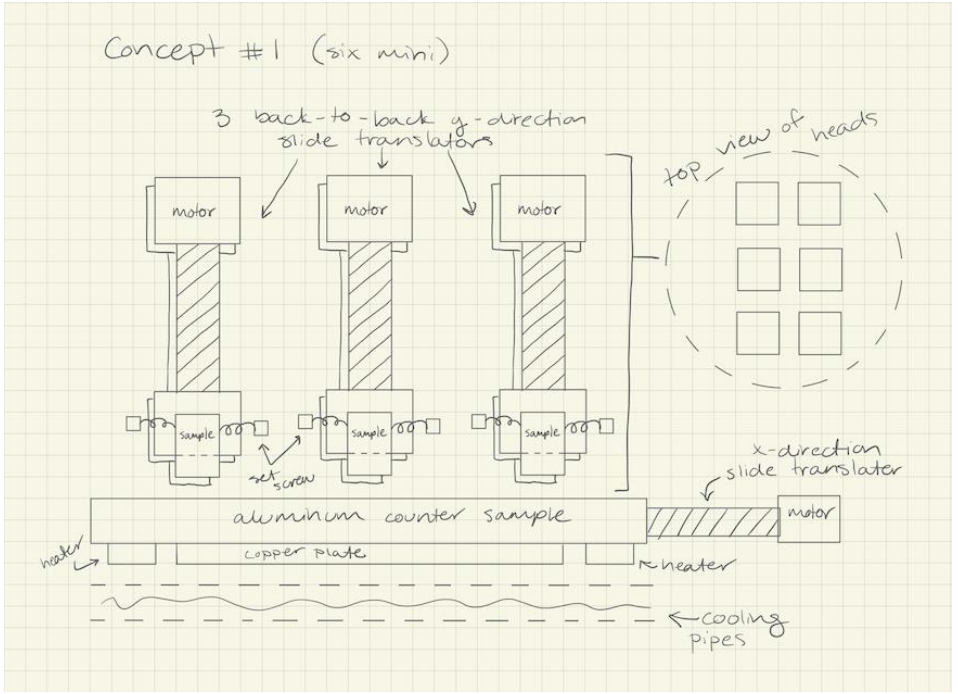
AHP, normalized comparison, and consistency checks performed for each criteria.

Criteria	CR Value
Holds samples	0.546
Processes electrical power	0.132
Measures internal pressure	0.000
Analyzes applied loads	0.132
Senses changes in temperature	0.000
Calculates outputs	0.000
Emergency stop	0.037
Display outputs	0.000

Final Concept Selection

Concepts	Alternative Value	RANK
Six Mini-Identical Tribometers Side by Side	0.344	2
Weights Loaded on Samples to Produce Normal Load	0.418	1
Inverted Existing Tribometer	0.237	3

Final Concept Selection



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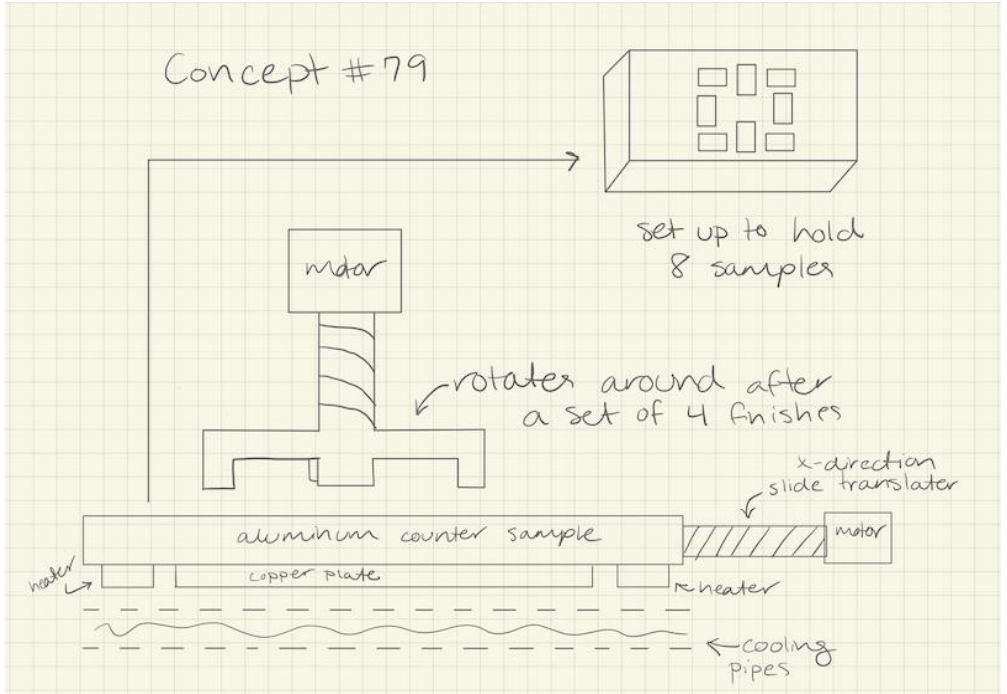

Cross-headed sample holder.

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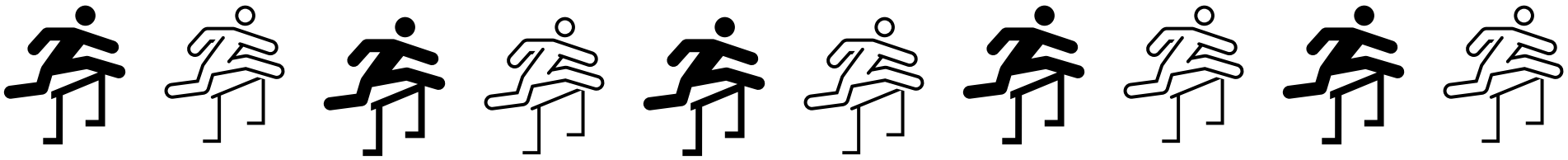
Project Reflection

- For this stage of the design process everything was based on the functional decomposition.
- The team came in with a less than ideal decomposition that had to be fixed before moving forward.
- One of the larger struggles of the project thus far but we adapted and overcame.



Future Work

Verify final selection with sponsor.

Research parts.

Determine what vacuum compatible parts the AME lab has.

Plan first prototype!