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Noise Mitigation in an Organic Rankine Cycle (ORC) Turbine Bypass Line

Team 14

Members:
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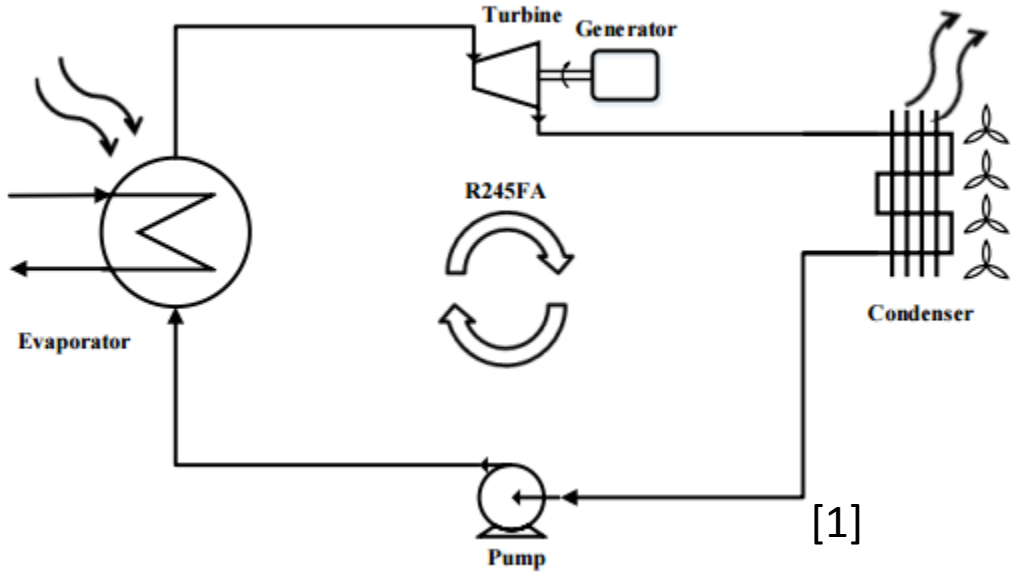
Organic Rankine Cycle (ORC) Overview

- Thermodynamic Cycle used to convert heat energy into work.
- Utilized by Verdicorp to turn waste heat from industrial processes into reusable electricity.



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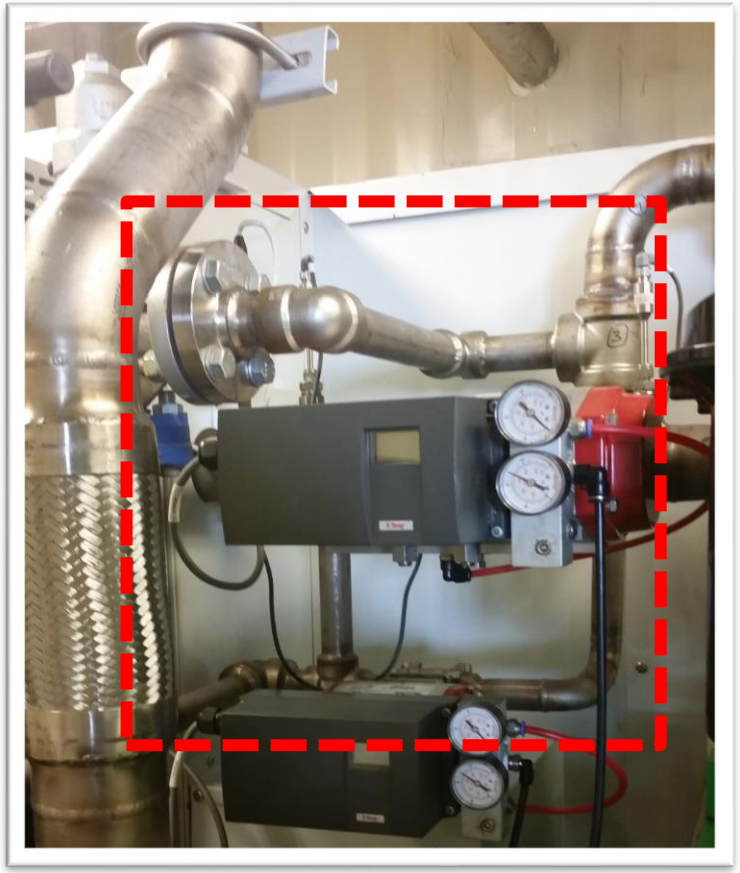
ORC Refrigerant Cycle



ORC Bypass Line

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Project Expectations

Verdicorp Requirements

- 150˚C contact temperature resistance
- Contained to localized piping (no enclosure, 3’’ minimum spacing)
- 10 dB reduction in bypass noise from 88 dB
- Low cost with emphasis on in-house production

Team 14 Requirements

- Concept longevity
- Ease of installation (Improved maintenance and prototyping times)

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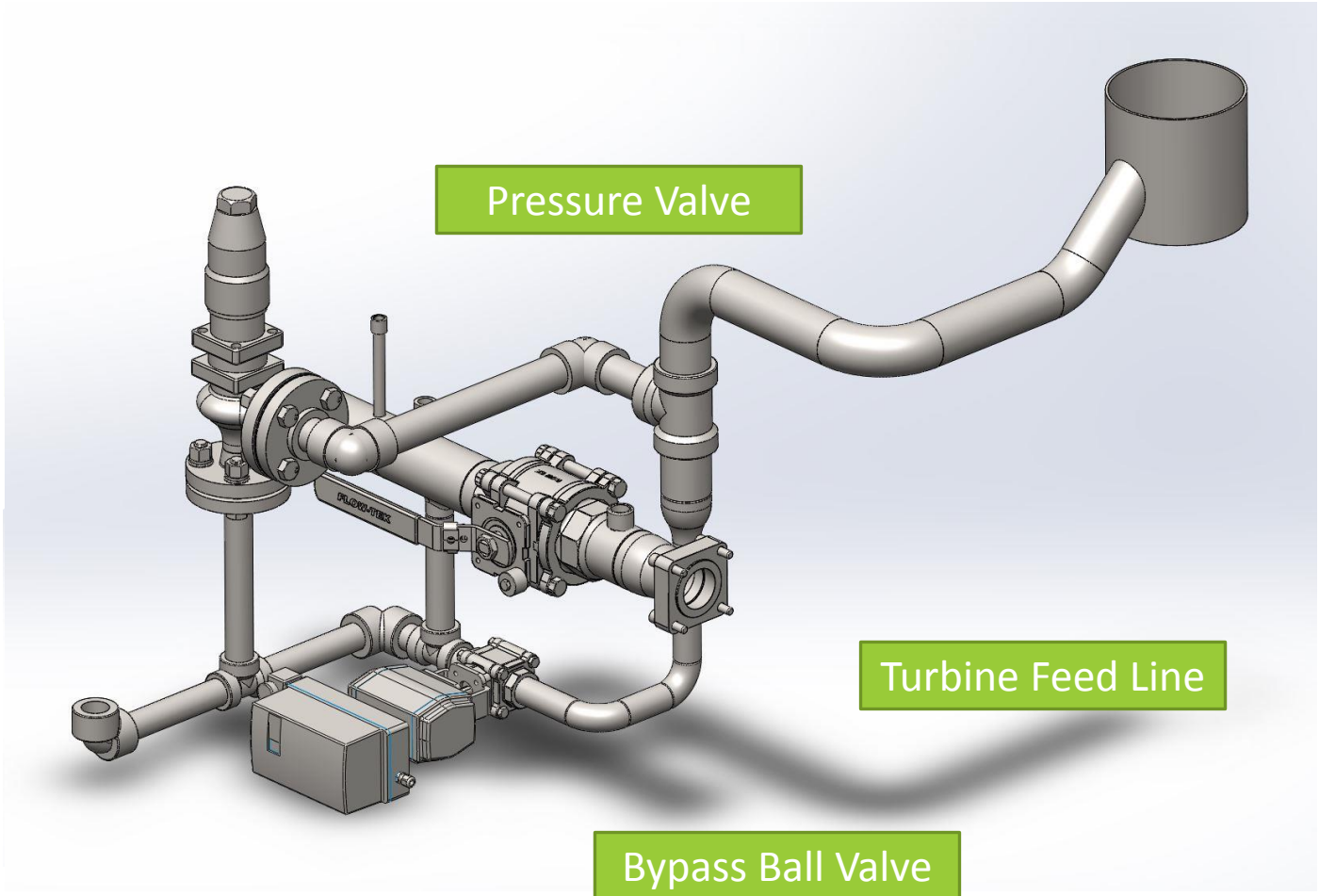
Project Introduction

Bypass Line



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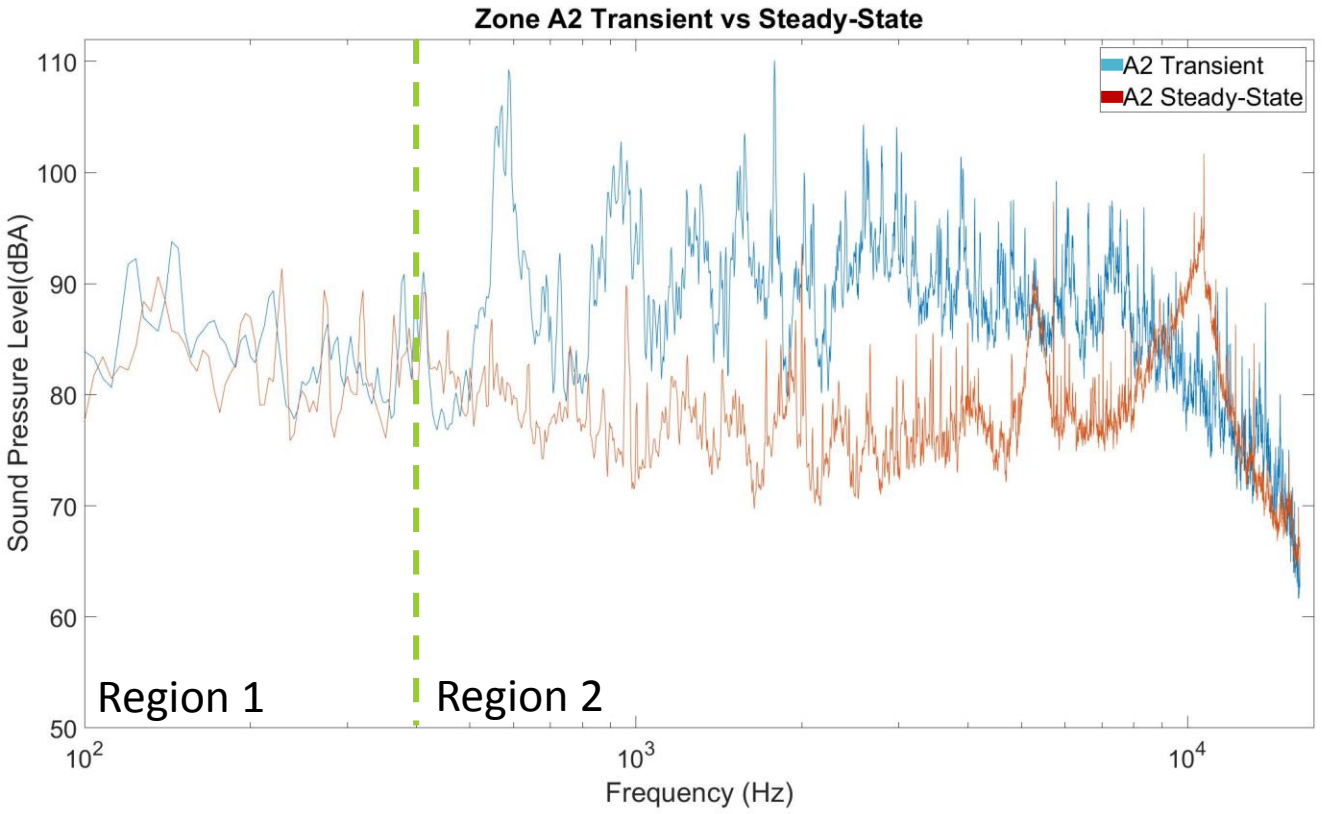
Project Results

Steady-State vs. Bypass



Region 1 & 2	Average (dB)	Max (dB)
Steady-State	78	102
Transient	83	110

Steady-State	Sound Pressure Level (dB)
Average	81
Maximum	102 at 10.7 kHz
Transient	**Sound Pressure Level (dB)**
Average	88
Maximum	110 at 1784 Hz

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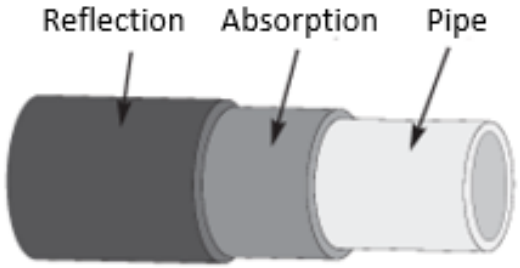
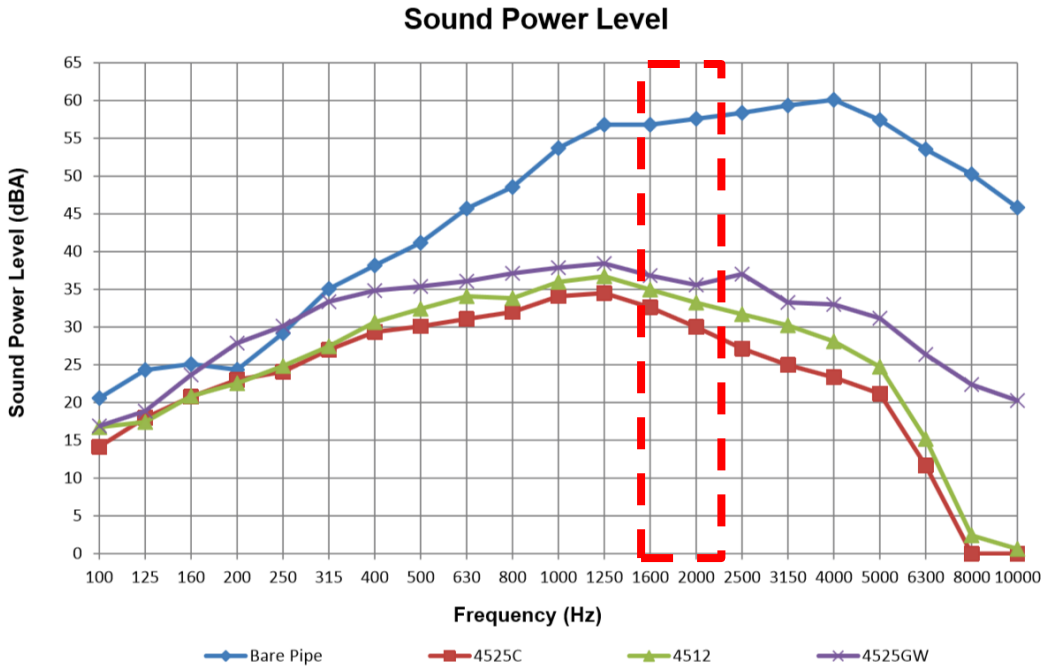
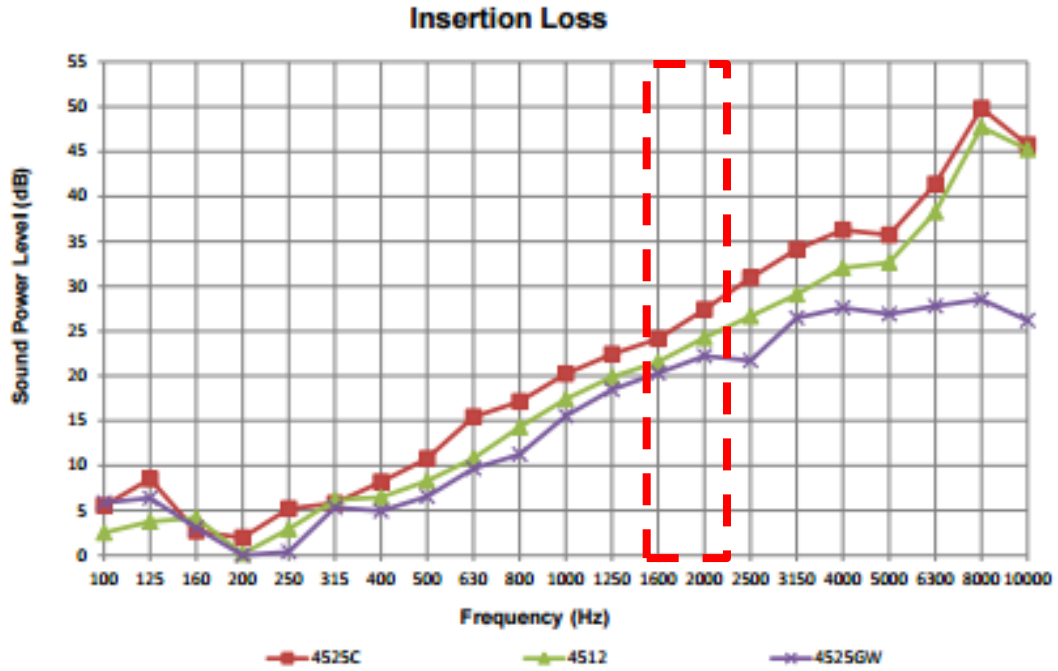
Pipe Lagging

Basic Concept







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Interior Layers

Material Comparison

	Material	Noise Absorption Coefficient Per Frequency (Hz)							Price
		125	250	500	1000	2000	4000	NRC	
Absorption Layer	1“ Fiberglass	.03	.22	.69	.91	.96	.99	.70	$2.76/ft^2
	Polyurethane Foam	.13	.23	.50	.82	.96	.94	.65	$1.72/ft^2
	Rockwool	0.10	0.40	0.80	0.90	0.90	0.90	0.67	$10.70/ft^2

	Material	Thickness	Operating Temperature	Thermal Conductivity $\frac{Btu*in}{hr*ft^2*°F}$	Price
Thermal Layer	Fiberfrax Durablankets	1/2''	1160°C	0.832*	$1.50/ft^2
	Fibermat	1/2''	760°C	.57 at 315°C	TBD
	Pyrogel XT Blanket	5mm (1/5”)	650°C	0.19 at 200°C	$8.44/ft^2

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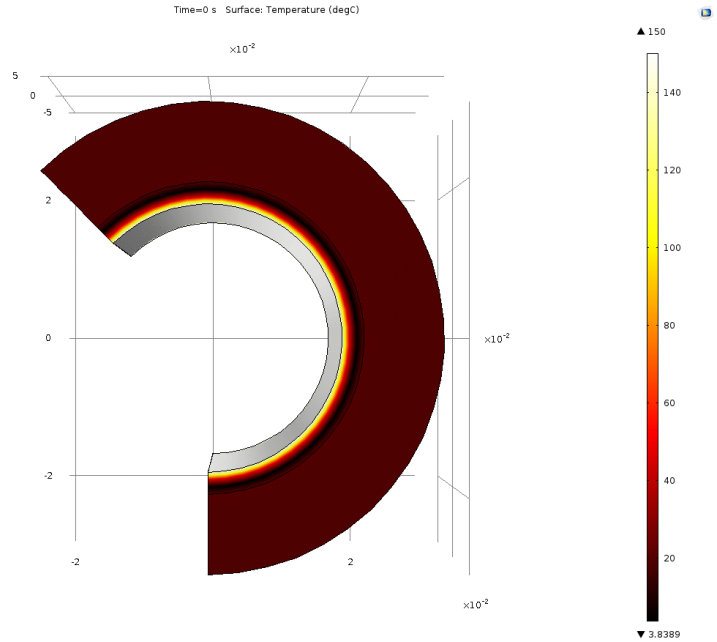
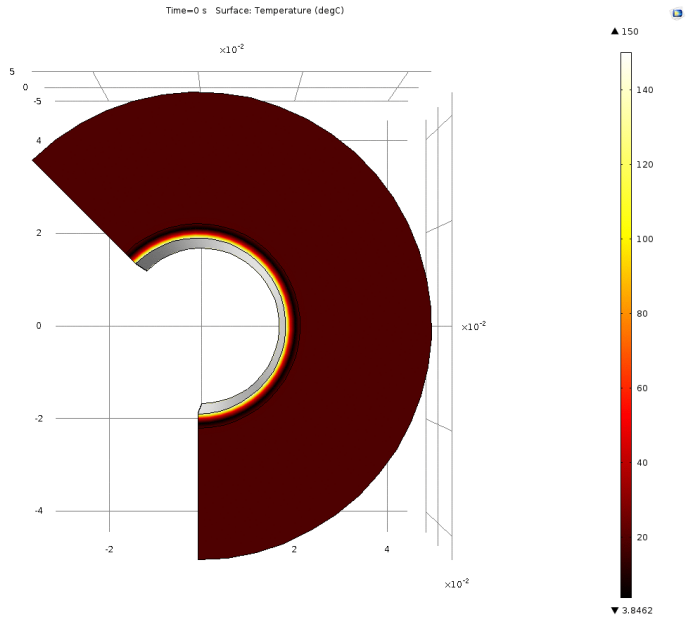
Comsol Simulation

Heat Transfer



Aerogel thermal layer



Fiberglass thermal layer

Pyrogel XT (Silica aerogel)

- Thermal Conductivity: 0.023 W/m*K
- Density: 200 Kg/m^3

Fiberglass(general)

- Thermal Conductivity: 0.035 W/m*K
- Density: 48 Kg/m^3

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Reflection Layer

Material Comparison

Material	Acoustic Transmission Loss (dB)							Price
	Frequency (Hz)							
	125	250	500	1000	2000	4000	STC	
1/8” Mass Loaded Vinyl	16	17	21	26	31	36	26	$2.78/ft^2
½ mm Galvanized Steel	8	14	20	23	26	27	20	$2.97/ft^2
1 mm Aluminum	11	10	10	18	23	25	16	$5.92/ft^2

1/8” Mass Loaded Vinyl

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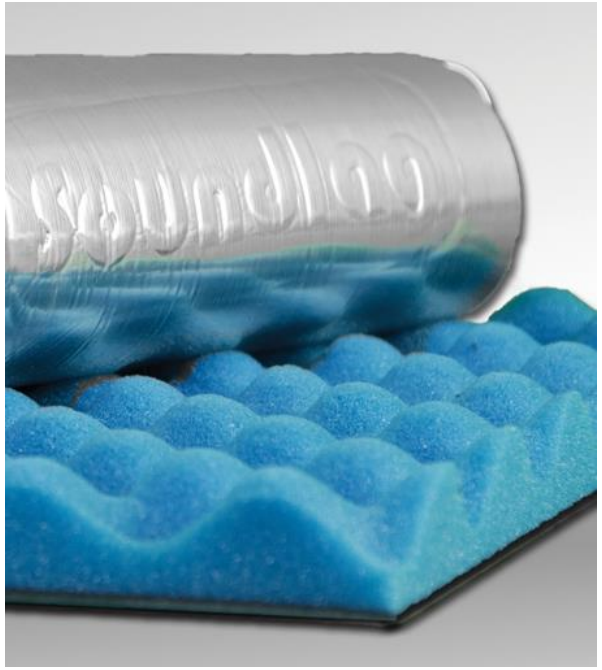
Assembled Products

Material Comparison

Product	Transmission Loss (dB)							Price
	Frequency (Hz)							
	125	250	500	1000	2000	4000	STC	
S.T.O.P. Noise™ Composite	20	21	25	28	32	42	29	TBD
Pyrotek Composite	18	24	30	34	30	23	27	179.58*



Pyrotek Eggshell Composite

*Price includes acoustic tape [6]

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Fasteners

Material Comparison

Elastic Cinch Straps

- **Price**: $1.14 each
- **Pros**: Reusable
- **Cons**: Longevity

Screws

- **Price**: $0.08 each
- **Pros**: Cheap
- **Cons**: Non-reusable

Hose Clamps

- **Price**: $0.76 each
- **Pros**: Reusable
- **Cons**: Installation Difficulty

Thermal Tape

- **Price**: $0.06/ft
- **Pros**: Temperature Reduction
- **Cons**: Non-reusable

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Possible Solutions

Morphological Chart

	Concept 1	Concept 2	Concept 3
Thermal Boundary	Needed (1)	Not Needed (2)	(3)
Absorption Layer	Fiberglass (3)	Polyurethane Foam (1)	Rockwool (2)
Reflective Layer	Steel	Aluminum (2)	Mass Loaded Vinyl (3) (1)
Fasteners	Hose Clamps (3)	Screws (2)	Cinch Straps (1)

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Possible Solutions

Concept Comparison

Concept	Components	Individual Price	Quantity	Total Price	Pros	Cons
1	Pyrogel Blanket	$8.44/ft^2	1	$278.52	• Ease of Iteration • Low Cost • Thin	• Pyrogel handling • Many retailers • Shipping times
	Polyurethane Foam	$1.72/ft^2	1			
	Mass Loaded Vinyl	$2.78/ft^2	1			
	Cinch Straps	$1.14 each	10			
	Acoustic Tape	$0.22/ft	1			
2	Rockwool	$10.70/ft^2	1	$348.72	• Thin aluminum shell • Fastener longevity	• Not Repeatable • Rigidity of Rockwool
	Aluminum Sheet Metal	$5.92/ft^2	1			
	Screws	$0.08 each	100			
	Acoustic Tape	$0.22/ft	1			
3	Fiberglass	$2.76/ft^2	1	$126.72	• Ease of iteration • Thermal boundary not needed • Low cost	• Fiberglass handling • Thickness
	Mass loaded Vinyl	$2.78/ft^2	1			
	Hose Clamps	$0.76 each	10			
	Acoustic Tape	$0.22/ft	1			
Pre-assembled						
4	Pyrogel Blanket	$8.44/ft^2	1	$282.2	• Less assembly required • High temperature resistance • Includes tape	• Low compliance/customization
	Pyrotek Composite (w/ Acoustic Tape)	$5.10/ft^2	1			
	Cinch Straps	$1.14 each	10			
5	Pyrogel Blanket	$8.44/ft^2	1	$191.2+TBD	• Less assembly required	• Potential high cost
	S.T.O.P. Noise Composite	TBD	1			
	Cinch Straps	$1.14 each	10			
	Acoustic Tape	$0.22/ft	1			

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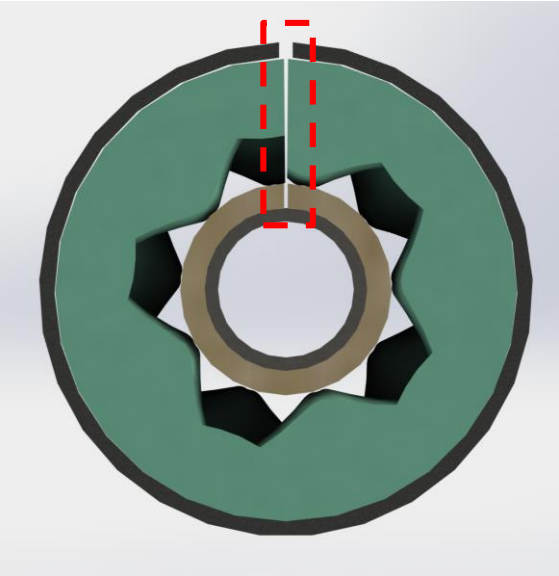
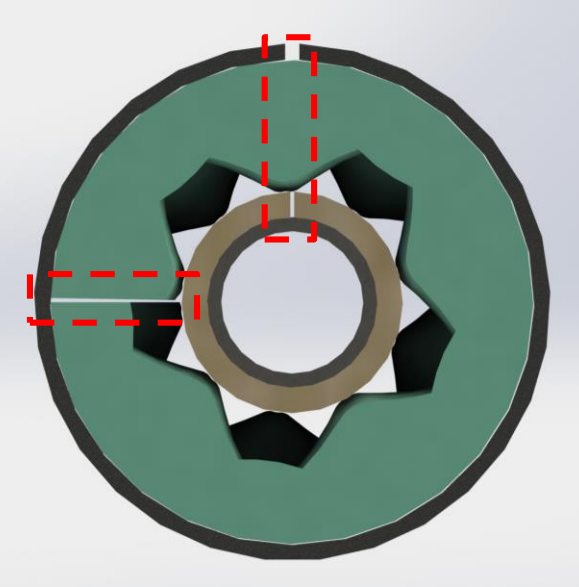
Prototypes

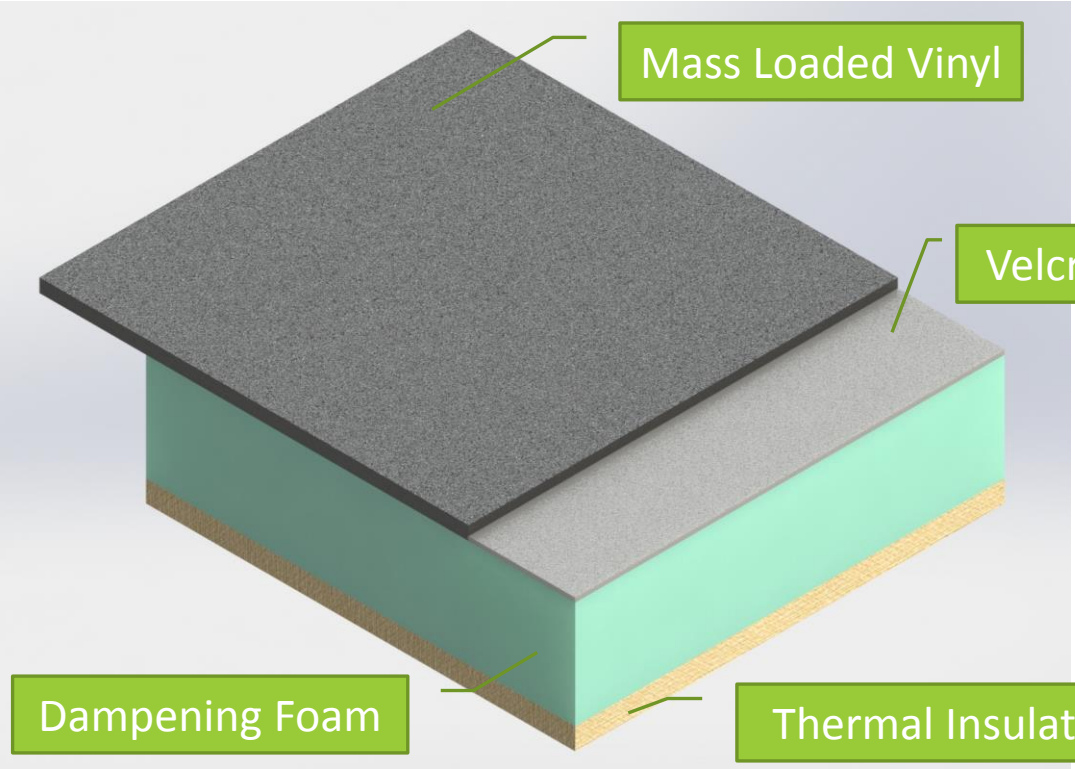
Manufacturing



Collinear Layer Construction



Offset Layer Construction



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Material Handling Safety

Prototype Fabrication

Safety measures followed according to:

- Team 14 Risk Assessment
- Material Safety Data Sheets (MSDS)

When preparing and cutting prototype materials the team members are required to wear the following:

- Eye Protection – Safety Glasses that completely cover eyes from debris.
- Skin Protection – Well fitting safety gloves along with long sleeve shirt/pants, to avoid direct contact with the material.
- Respiratory Protection – Dust mask to avoid the inhalation of material particles that may become airborne during cutting materials.

Aerogel Pryogel XT – NFPA Rating

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Future Work

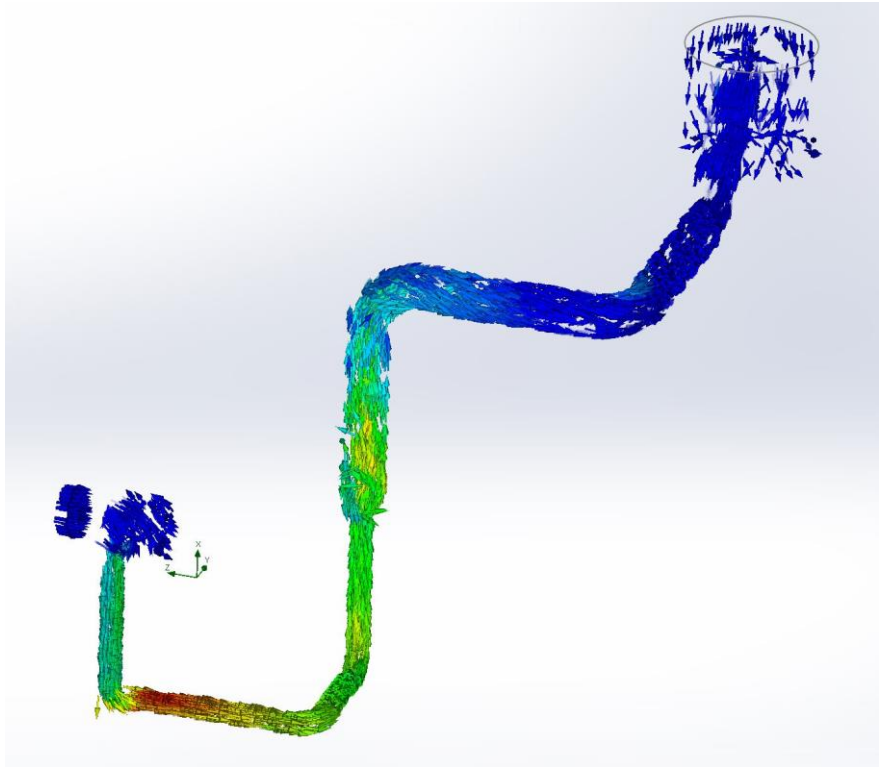
Fluid Simulation

Simulation conditions

- 566 kPa entrance pressure
- Atmospheric exit pressure (1 atm)

Refinement Steps

- Apply analysis on complex model
  - Fittings
  - Check valves
  - Material thickness variances



Bypass line acoustic pressure distribution

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Future Plans

Intensity Probe Measurements

Sound Intensity Theory

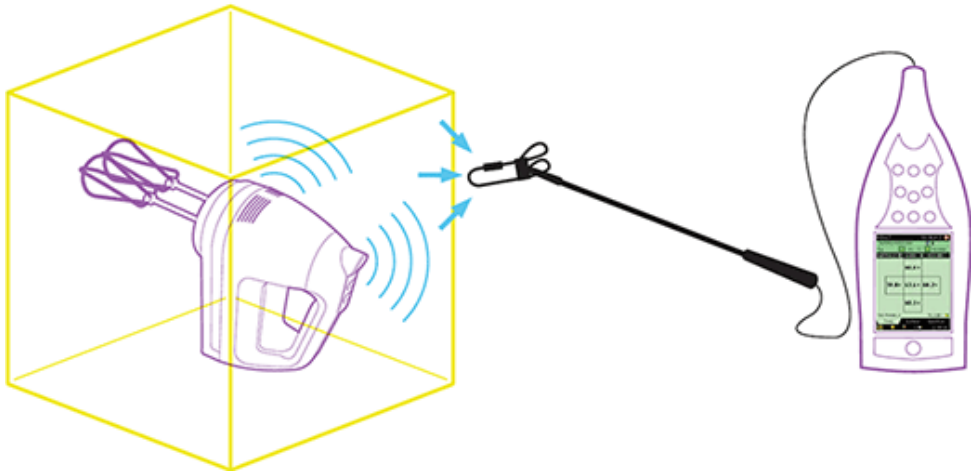
- Vector quantity vs scalar
- Records both instantaneous pressure and particle velocity

Probe Design

- Two face-to-face pressure microphones
- Microphone spacer variations

Project Advantages

- Near field measurements
- Planar contour plots
- Highlights high sound pressure locations



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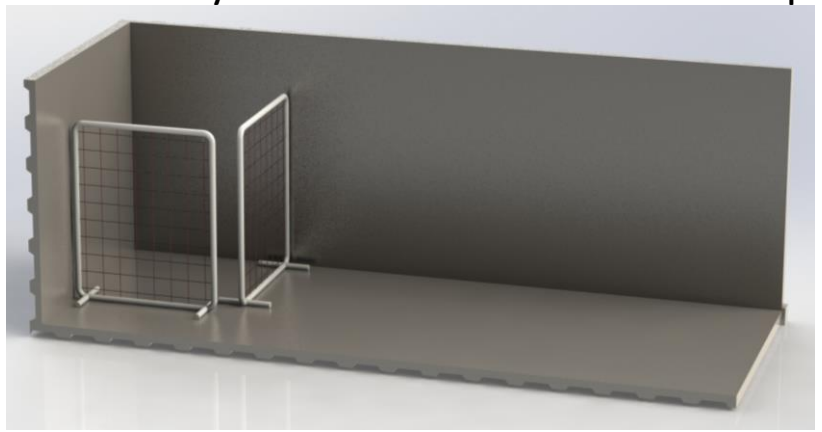
Intensity Probe measurement technique



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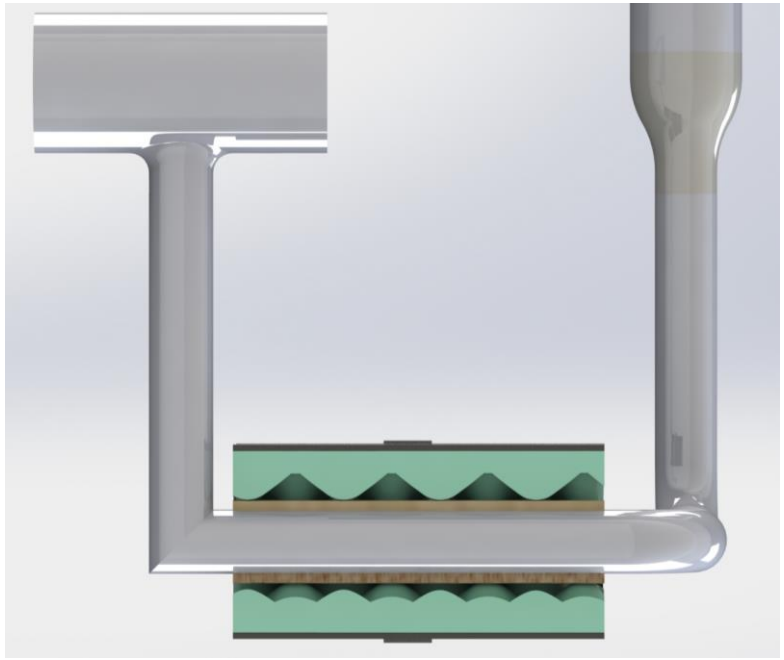
Summary

Current Work

- Ordering Materials
- Material and construction modeling
- Preparing cut templates for materials

Future Work

- Preliminary intensity probe measurements
- Prototype Manufacture/ Installation
- Post-Installation Measurements



Acoustic lagging placement

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Resources

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Questions?