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

Team 14

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Overview

- Project Background
- Methodology
- Concept Design & Selection
- Manufacturing & Assembly
- Results & Analysis
- Closing Statements

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Project Background

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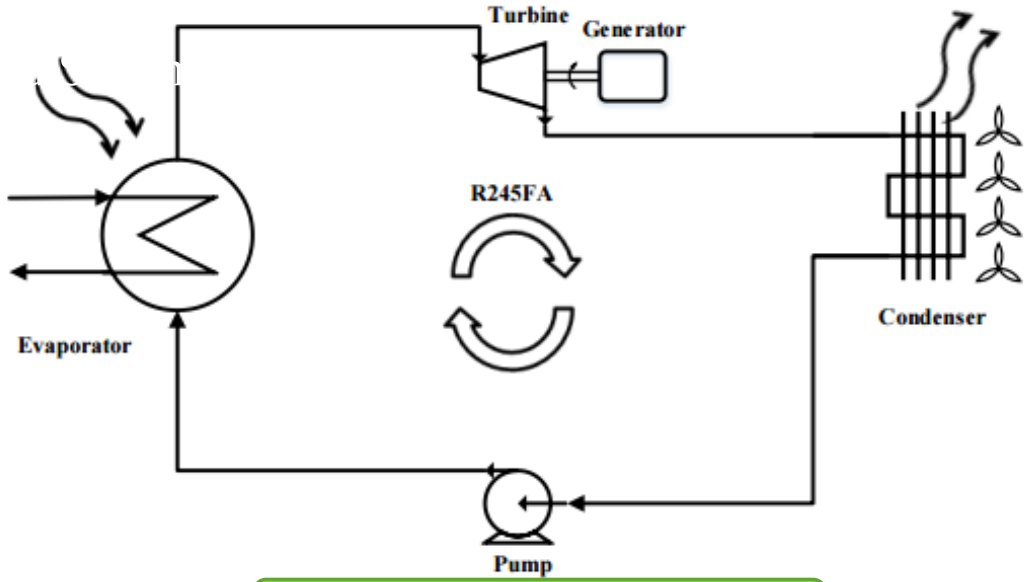
Project Background

Organic Rankine Cycle (ORC)

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



ORC Refrigerant Cycle

ORC Turbo Generator

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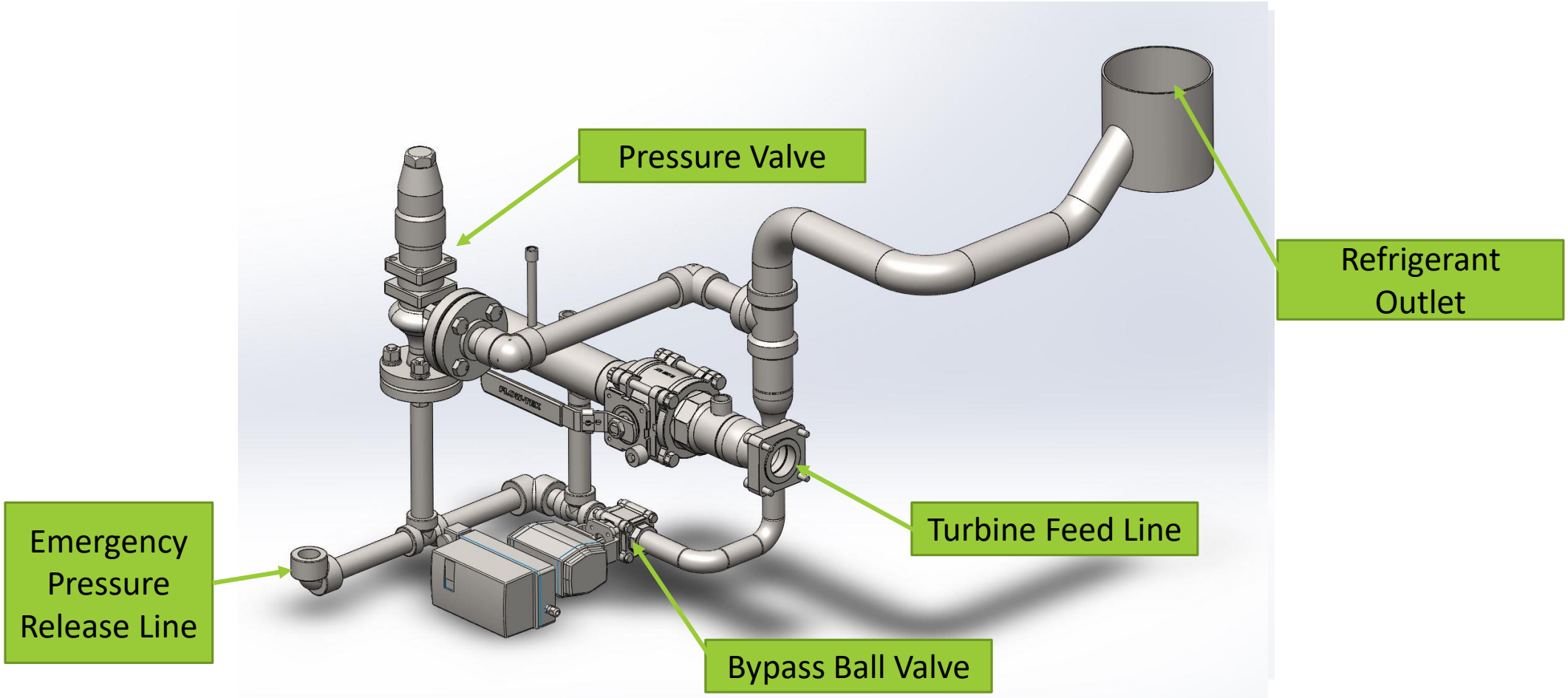
Project Background

Bypass Line



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Project Background

Project Definition

Need Statement

- When operating in bypass, the ORC system generates an unacceptably loud amount of noise.
- 1 in 9 reported manufacturing illnesses are a result of noise induced hearing loss (NIHL)
- Noise ordinances limit acceptable locations

Goal Statement

- A solution needs to be found to mitigate the bypass line noise while not impeding the performance of the system nor requiring significant modification of existing components.

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Project Background

Constraints

Verdicorp Requirements

- 150˚C contact temperature resistance
- Contained to localized piping (no enclosure, 3’’ maximum spacing)
- Reduce bypass noise to steady state levels of approximately 87 dBA
- 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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Methodology

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Methodology

Areas of Focus

Bypass Line Geometry

- Comprised of 1” and 2” nom. 304 Stainless Steel piping, exiting into 6” nom. piping.
- Includes multiple 90° and 45° elbow bends.

Sound Propagation

- The ORC system used is located in a 23.5’ x 8’ x 8.5’ modified shipping container with metal walls.
- This leads to noise reverberation within the container, possibly increasing overall noise levels.

Locating the Noise

- It is necessary to identify obtrusive noise locations and frequencies to determine the proper mitigation technique.

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Methodology

Approach

1. Initial Measurements – Noise Classification
2. Concept Design & Materials Selection
3. Prototype Assembly & Installation
4. Follow-up Measurements – Post Prototype Installation
5. Implement Design Iterations
6. Final Iteration Measurements

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Methodology

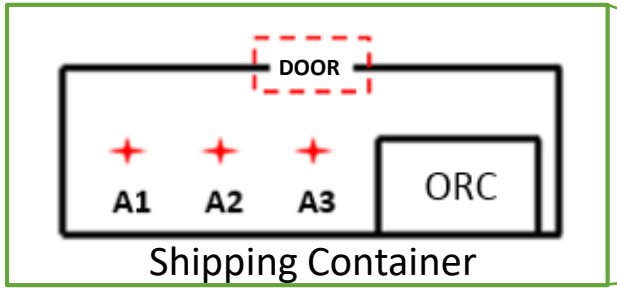
Sound Pressure Level (SPL)

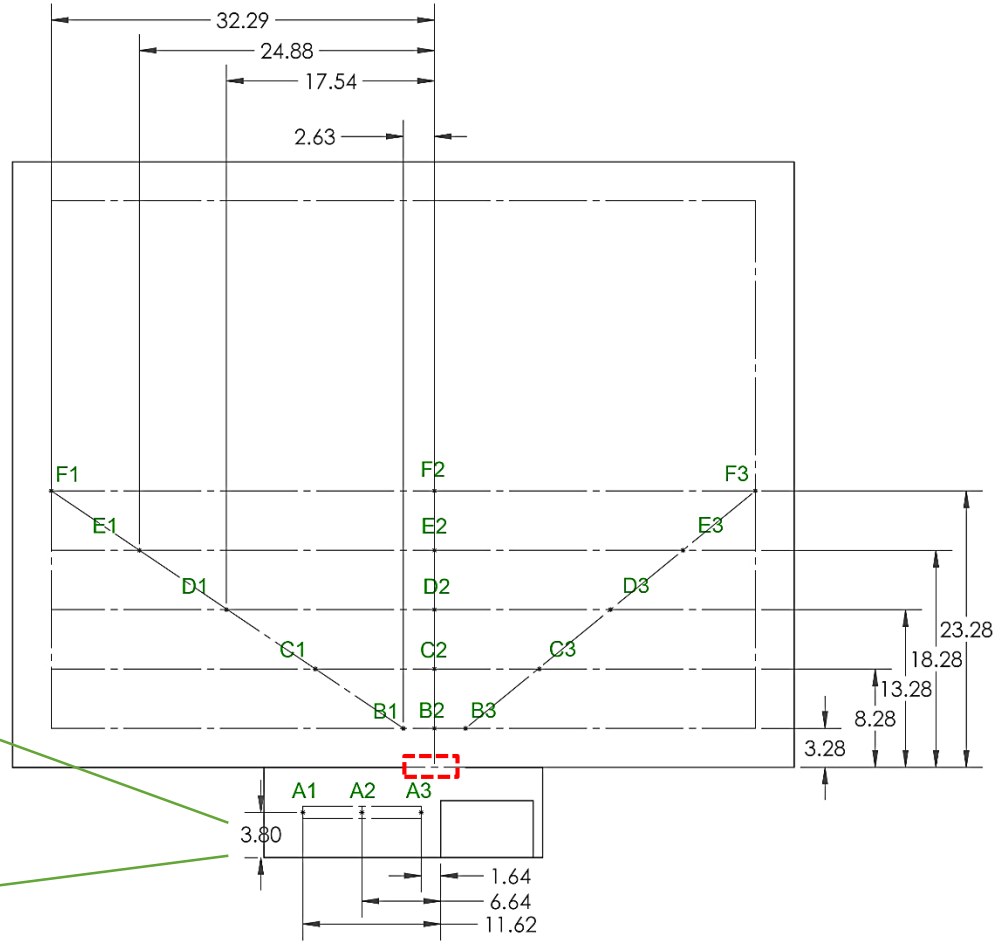
Sound Pressure Level

- Scalar values
- Near field measurement noise
- Frequency Spectrum

Procedure

- Diffuse field inside container
- Measurements taken 1 m from walls, 1.2 m from ground at 1.5 m intervals.
- SPL drops drastically outside of container





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Methodology

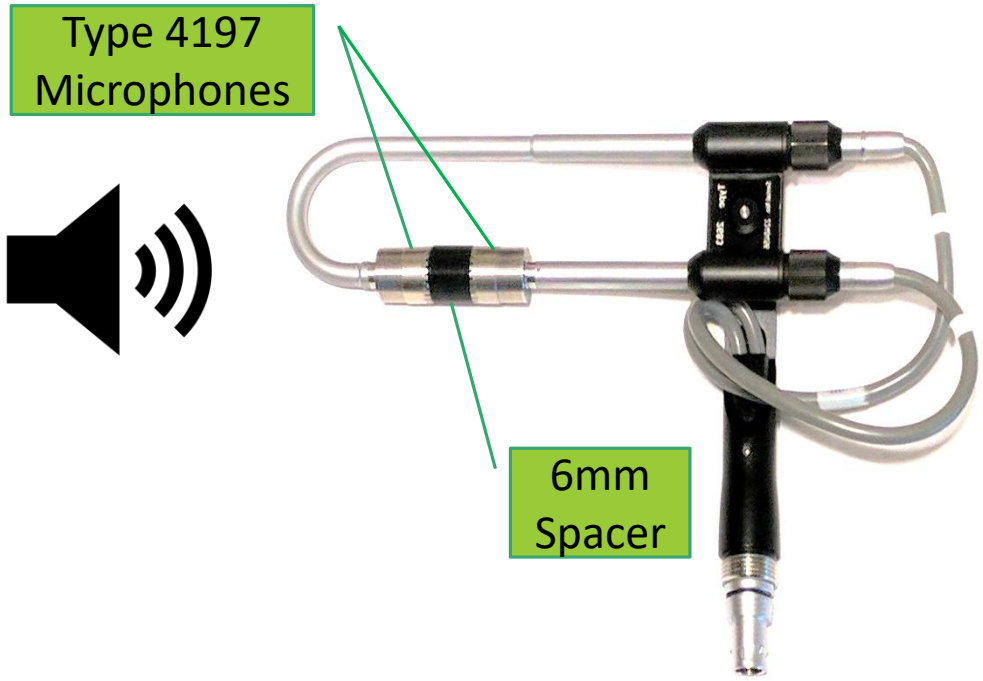
Sound Power & Intensity

Intensity Probe: 2270 Hand Analyzer Kit

- Vector values
- Nearfield recording: improves signal to noise ratio
- 6mm microphone spacer: 250 – 10kHz Range

Procedure

- Set distance and find area of measurement section
- Hold instrument array perpendicular to surface
- Keep array in plane



B & K Sound Intensity Probe

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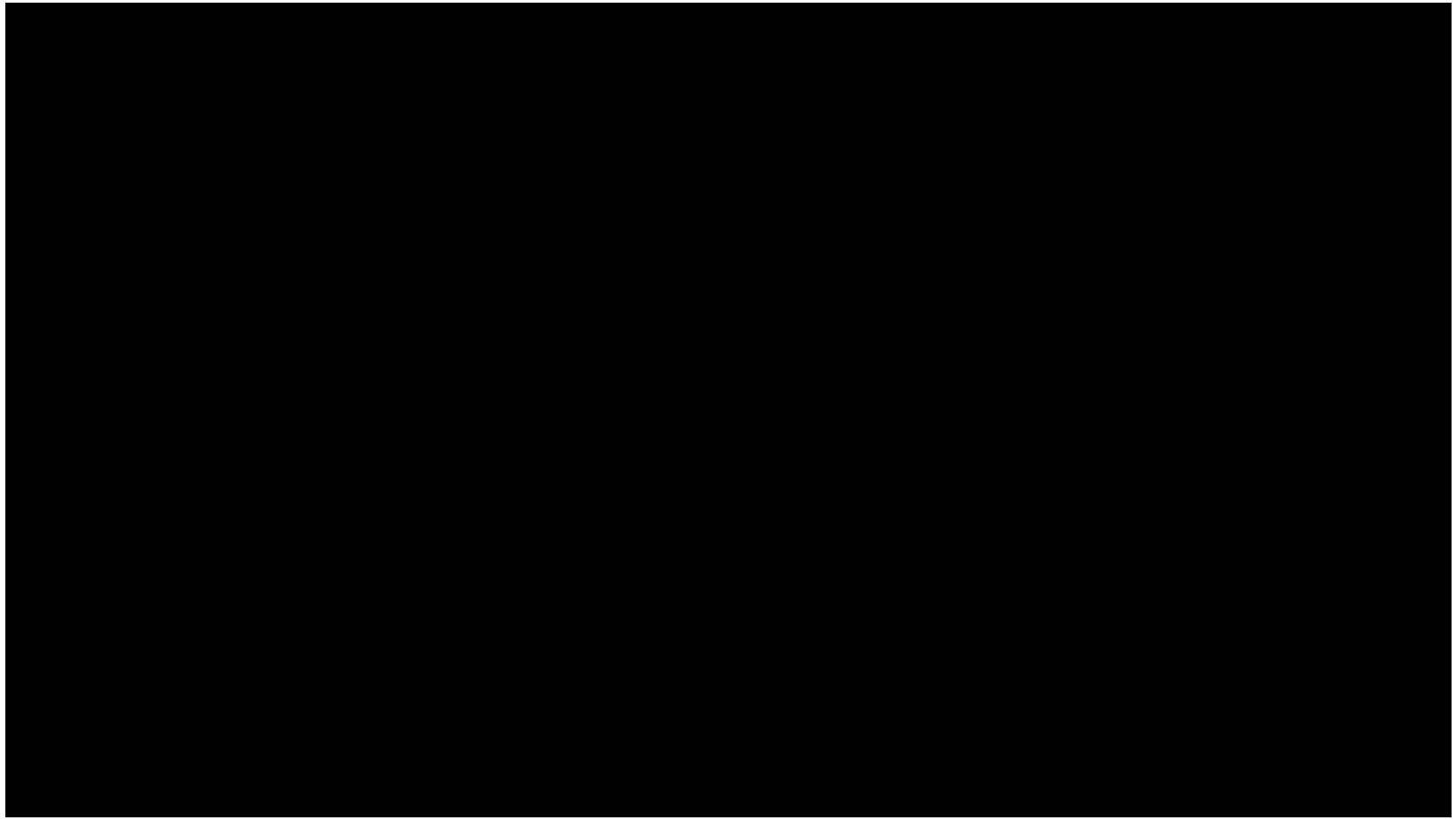
Methodology

Sound Power & Intensity



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Concept Design & Selection

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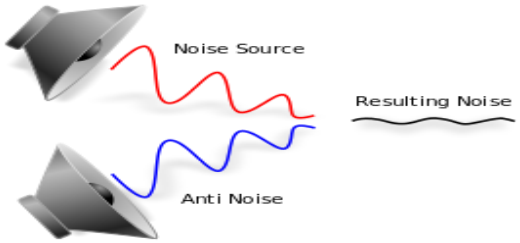
Concept Design & Selection

Active vs. Passive Noise Cancellation

	Solutions	Manufacturing	Assembly Time	Maintenance	Cost	Customer Requirements
Active Noise Cancellation	Noise Cancelling	✗	✓	✗	✗	✗
Passive Noise Cancellation	Pipe Lagging	✓	✓	✓	✓	✓
	Enclosure	✓	✗	✓	✗	✗
	Foam Panels	✓	✓	✓	✓	✗



Noise Cancelling

Pipe Lagging

Acoustic Enclosure

Foam Panels

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Concept Design & Selection

Pipe Lagging Concept Comparison

Concept	Components	Pros	Cons
1	Pyrogel Blanket Polyurethane Foam Mass Loaded Vinyl Cinch Straps Acoustic Tape	• Ease of Iteration • Low Cost • Thin	• Pyrogel handling • Many retailers • Shipping times
2	Rockwool Aluminum Sheet Metal Screws Acoustic Tape	• Thin aluminum shell • Fastener longevity	• Not Repeatable • Rigidity of Rockwool
3	Fiberglass Mass loaded Vinyl Hose Clamps Acoustic Tape	• Ease of iteration • Thermal boundary not needed • Low cost	• Fiberglass handling • Thickness
Pre-assembled Acoustic Layers			
4	Fiberfrax DuraBlanket Pyrotek Composite (w/ Acoustic Tape) Wire	• Less assembly required • High temperature resistance • Includes tape	• Low compliance/customization
5	Pyrogel Blanket S.T.O.P. Noise Composite Cinch Straps Acoustic Tape	• Less assembly required	• Potential high cost

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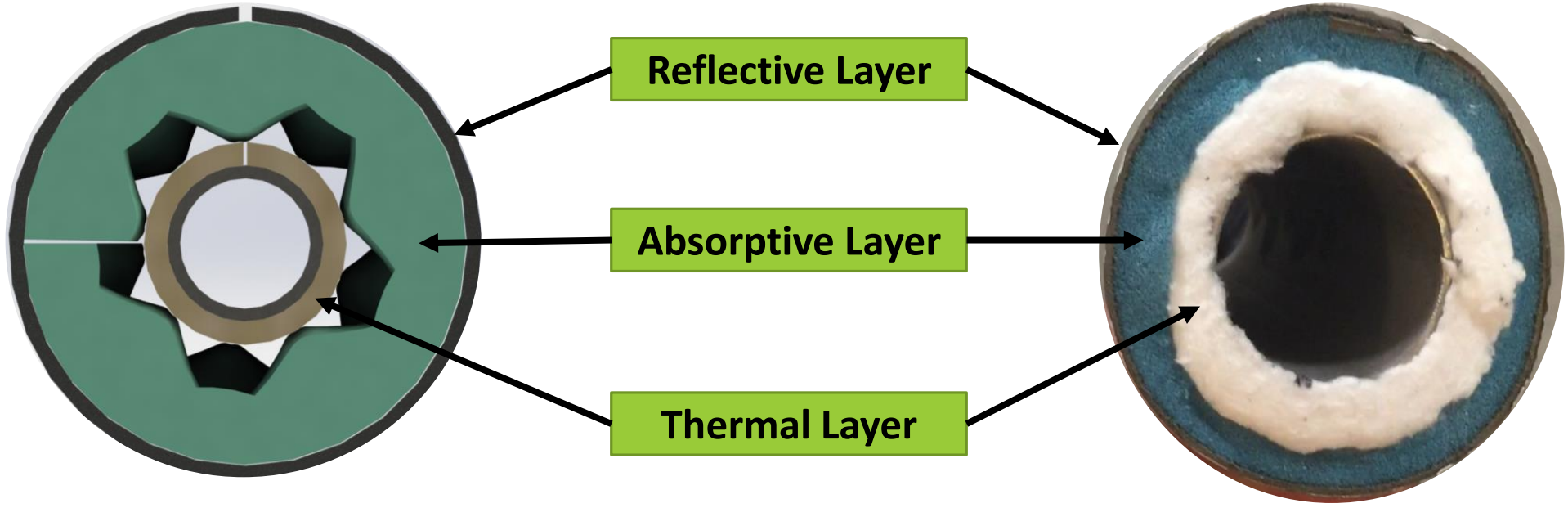
Concept Design & Selection

Concept Review



Conceptual Prototype Design

Actual Prototype Design

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Concept Design & Selection

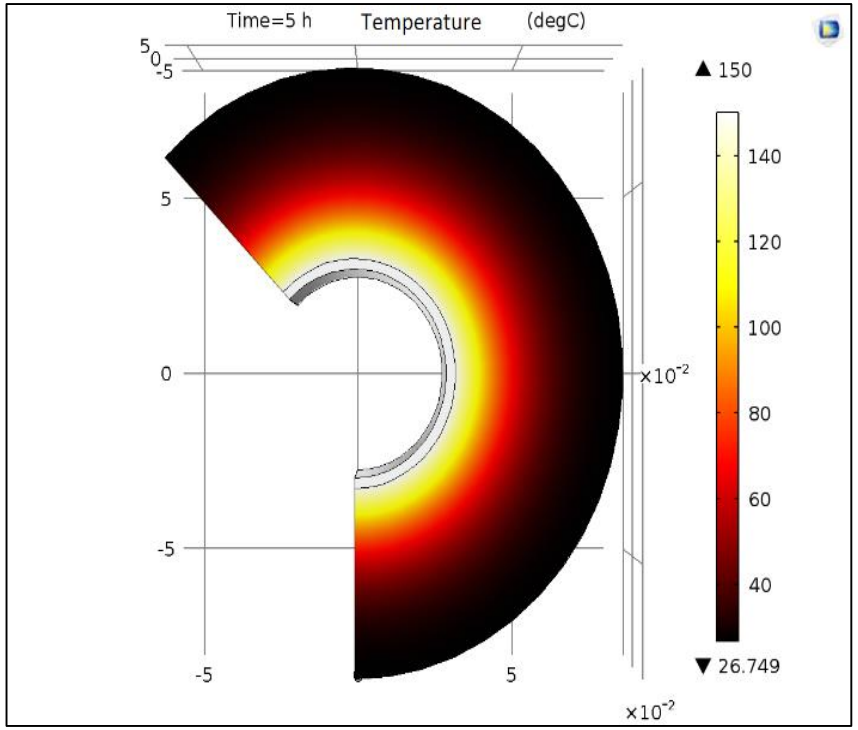
Thermal Layer – Fiberfrax Durablanket

Material Advantages

- Insulates acoustic foam from 150^{o}C bypass line
- Strong, lightweight, flexible needled blanket made from spun ceramic fibers
- Low thermal conductivity & heat storage

Properties

- Thermal Conductivity: 0.12 W/mK
- Heat Capacity: 1130 J/KgK
- Thickness: 1.27 cm



Comsol Simulation of Heat Transfer through Thermal Layer (5 Hours)

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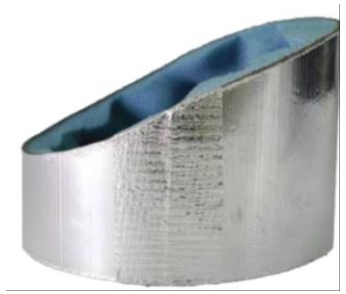
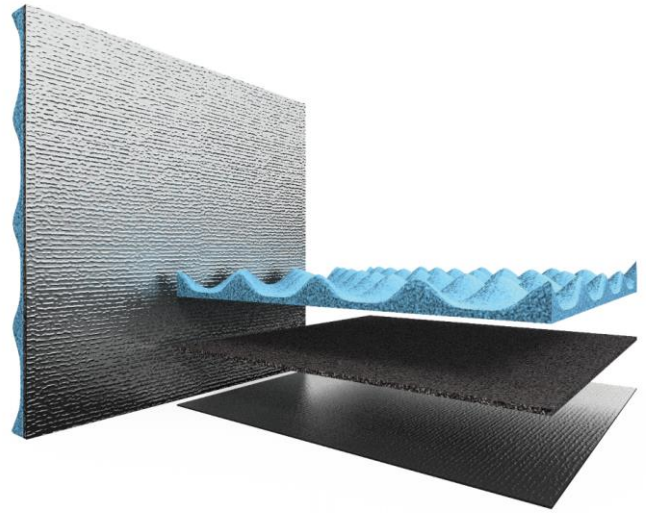
Concept Design & Selection

Acoustic Layer - Pyrotek Acoustic Lagging

- Composite layers:
  - Absorption - Acoustic Foam
  - Reflection - Mass Loaded Vinyl
  - Reflection - Aluminum Foil





Pyrotek Acoustic Lagging

How it Works:

Flexible mass layer provides excellent sound reduction properties

Decoupling reflective layer breaks the vibration path between the substrate and the mass loaded barrier

Reflective exterior layer redirects pressure waves back towards absorbing layers

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Manufacturing & Assembly

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Manufacturing & Assembly

Thermal & Acoustic Layers

Thermal Layer

1. Measure bare pipe
2. Cut thermal layer
3. Place and secure layer with wire

Acoustic Layer

4. Re-measure pipe with thermal layer
5. Cut and remove foam
6. Place and secure foam with acoustic tape

Prototyping time: 12-14 hours

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Manufacturing & Assembly

Thermal & Acoustic Layers

1. Bare pipe

2. Thermal layer

3. Acoustic layer

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Results & Analysis

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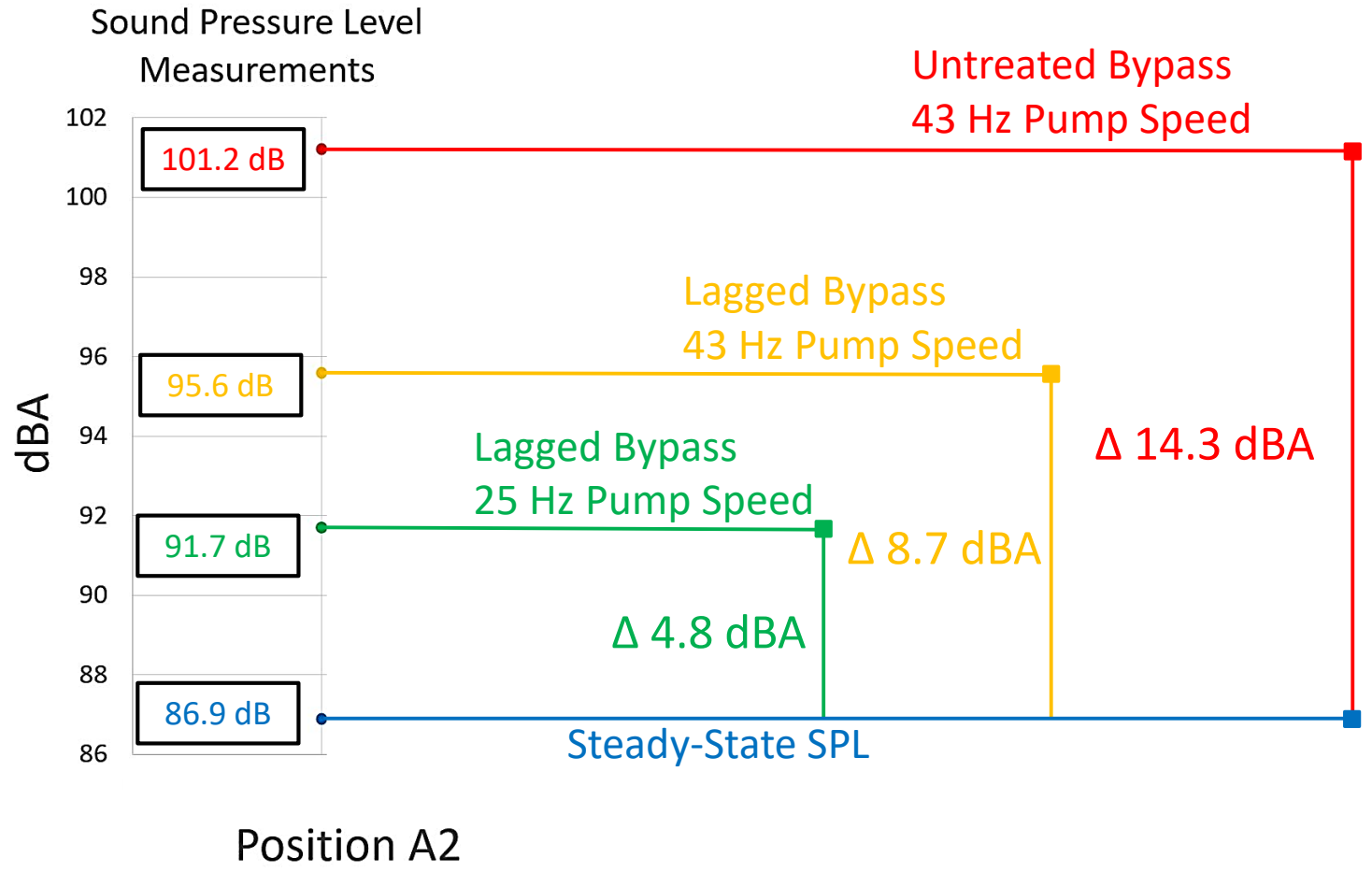
Results & Analysis

SPL Analysis



SPL Results

- 4.8 dBA variance between steady-state and bypass in normal operation
- 5.6 dBA change when lagged at 43 Hz (extreme case)
- May see improvement with flange covers

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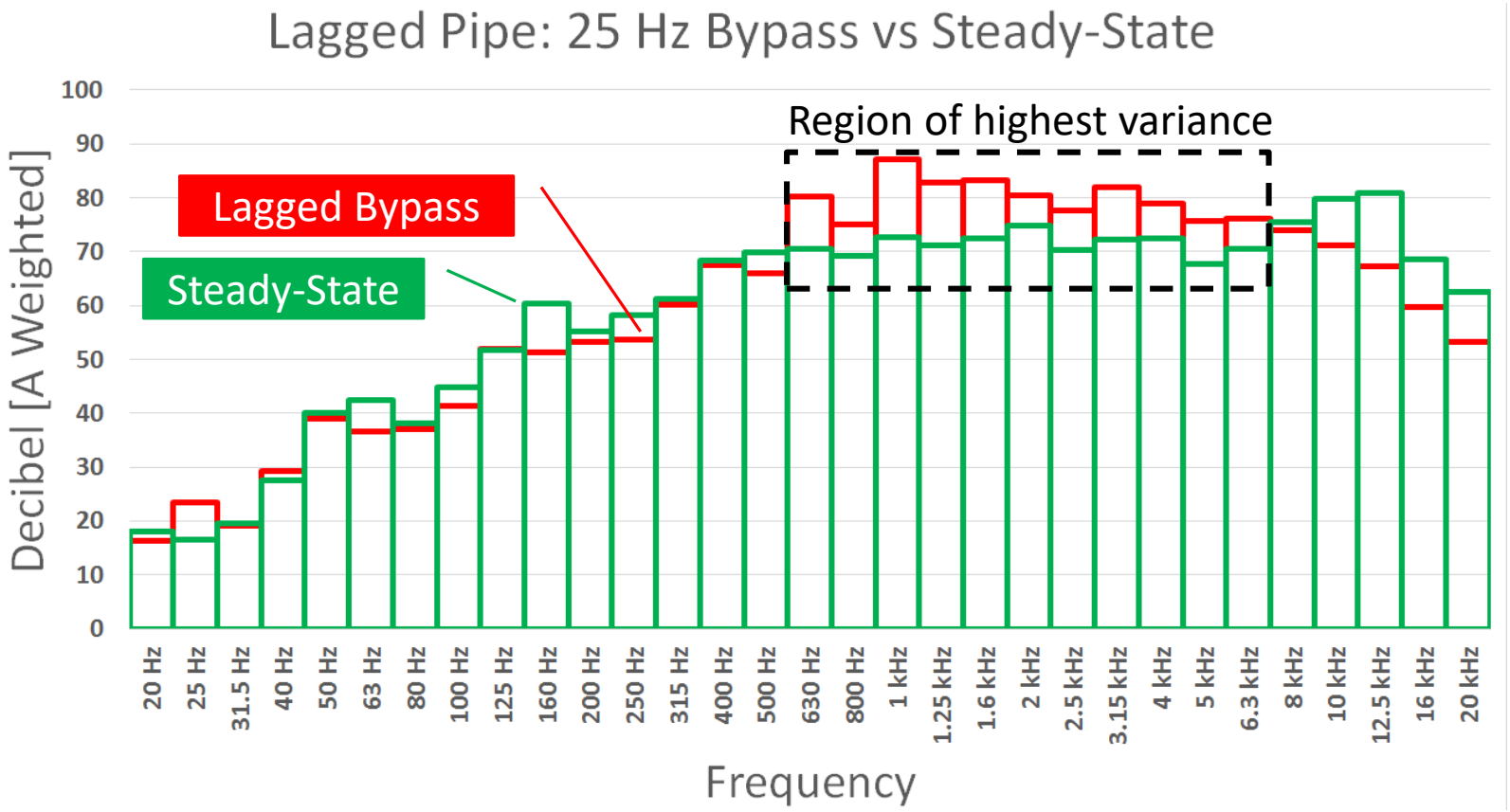
Results & Analysis

Frequency Analysis

Frequency Measurement

- Highest variance is between the 630 Hz and 6.3 kHz range
- Turbine whine is present during steady-state operation above 8 kHz
- Variance should decrease with attention to uncovered flanges



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Results & Analysis

Intensity Plots

Power Source	Total Power (dB)	Flange Power (dB)
Uncovered Flanges	91.1	86.5
Covered Flanges	83.7	78.8

- 7.7 dB (W) decrease between covered and uncovered flanges
- No significant change in SPL measurement indicates that the flanges were not a major contributor

Bare Flanges

Covered Flanges

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Closing Statements

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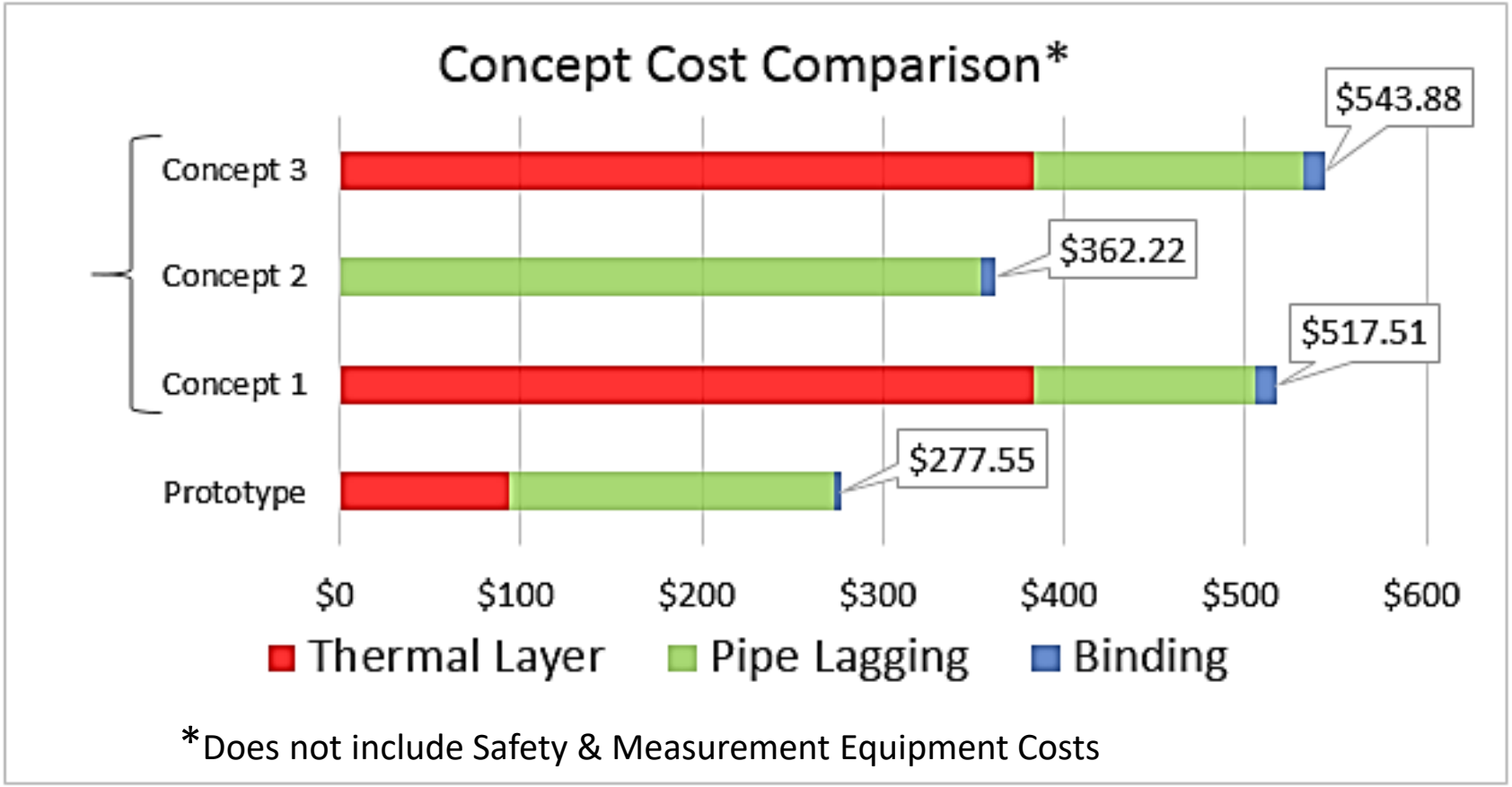
Closing Statements

Concept Costs



*Does not include Safety & Measurement Equipment Costs

Concept	Cost per sq. ft.
3	$18.13
2	$12.07
1	$17.25
Prototype	$9.25

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Prototype Final Cost

Qty	Description	Estimated Cost	Unit Price	Total
1	Fiberfrax Durablanket S (1/2'') (2' x 25' Roll)		$75.00	$75.00
	+ Shipping		$18.09	$93.09
1	Pyrotek Noise Control Lagging 26'' x 16.25 ' (includes acoustic tape)		$179.58	$272.67
1	Personal Safety Gear (Gloves & masks)		$28.81	$301.48
1	Bruel & Kjaer Shipping Cost		$46.64	$348.12
1	Bruel & Kjaer Equipment Lease	$3000	$0	$348.12
1	National Instruments PXI 1031 purchase	$1199	$0	$348.12
			Total	$348.12
			Sales Tax	N/A
			Subtotal	$348.12

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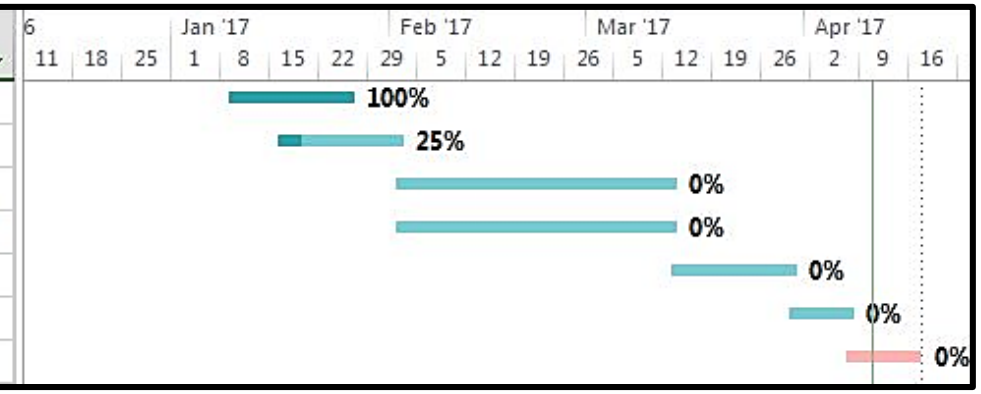
Closing Statements

Timeline

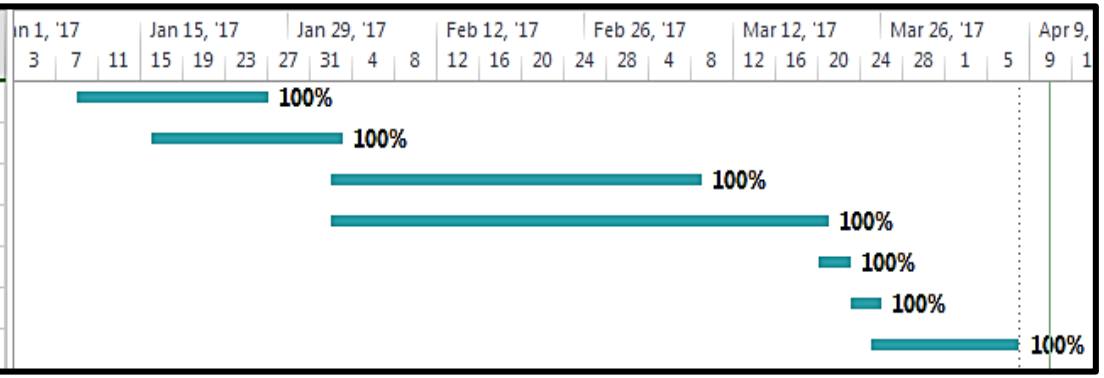
Original Spring Gantt Chart (01/20/17)

Task Name	Duration	Start	Finish
Conclude Data Analysis	14 days	Mon 1/9/17	Thu 1/26/17
Concept Development	14 days	Mon 1/16/17	Thu 2/2/17
Measurement Confirmation	28 days	Thu 2/2/17	Mon 3/13/17
Procurement of Materials	28 days	Thu 2/2/17	Mon 3/13/17
Prototype Manufacturing	14 days	Mon 3/13/17	Thu 3/30/17
Prototype Measurements	7 days	Thu 3/30/17	Fri 4/7/17
Prototype Iteration & Measurements	7 days	Fri 4/7/17	Mon 4/17/17



Revised Spring Gantt Chart (04/05/17)

Task Name	Duration	Start	Finish
Conclude Data Analysis	14 days	Mon 1/9/17	Thu 1/26/17
Concept Development	14 days	Mon 1/16/17	Thu 2/2/17
Measurement Confirmation	25 days	Thu 2/2/17	Wed 3/8/17
Procurement of Materials	33 days	Thu 2/2/17	Mon 3/20/17
Prototype Manufacturing	3 days	Mon 3/20/17	Wed 3/22/17
Prototype Measurements	3 days	Thu 3/23/17	Sat 3/25/17
Prototype Iteration & Measurements	11 days	Sat 3/25/17	Fri 4/7/17



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Closing Statements

Summary & Potential Improvement Areas

Summary

- Pipe lagging prototype manufactured, assembled, and tested on ORC
- **4.8 dBA** variance between steady-state and bypass in normal operation, representing **57.5% dBA** change in SPL between current and desired levels
- **5.6 dBA** variance between bare and lagged bypass line during peak operation, representing **52.5% dBA** SPL difference

Potential Areas for Improvement

- Determine method for measuring the backend of the ORC system were noise leakage from the heat exchangers
- Create modular CAD based template models for reduced manufacturing and assembly time

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Resources

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Questions?