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Team 14: Noise Mitigation in Turbine Bypass Line

Members:
Chad Adams
Austin Houser
William Mauch
Luis Figueroa

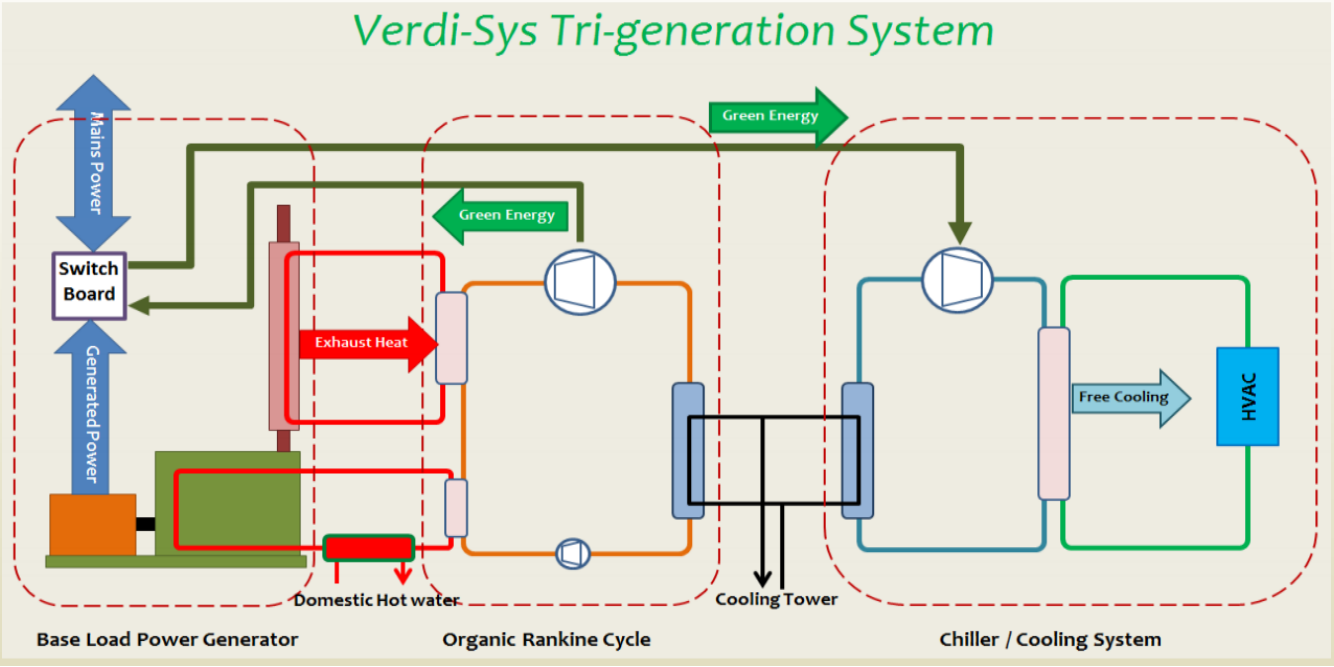
Faculty Advisor
Dr. Louis Cattafesta

Sponsor Representative
Corey Nelson

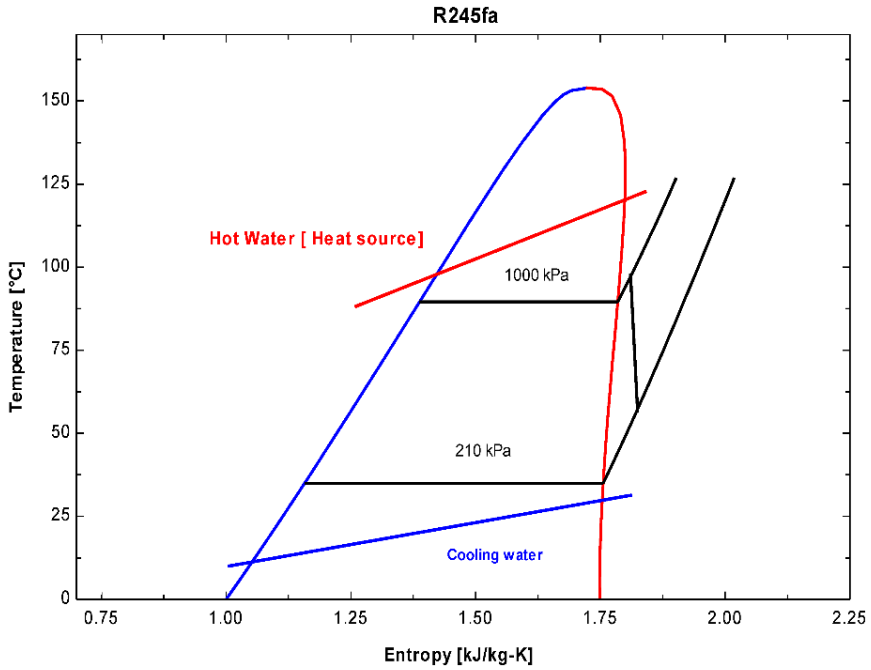
Instructors
Dr. Nikhil Gupta
Dr. Chiang Shih

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.



ORC Operation Cycle [1]



R245fa T-S Diagram [2]

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Turbine Bypass Line

Purpose: Divert refrigerant R245fa from flowing through the turbine.

- Runs refrigerant through filter
- Removes risk of damage to turbine blades from liquid refrigerant.
- Takes place during start up and shut down of the system.

ORC Turbine Bypass Line

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Project Definition

Need Statement

- When operating in bypass, the ORC system generates an unacceptably loud amount of noise. A solution needs to be found to mitigate the bypass line noise while not impeding the performance of the system or requiring significant modifications of exiting components.

Goal Statement Objectives

- Solution must be cost effective.
- Must not impede performance of the system.
- Reduce Bypass line noise levels toward turbine steady-state noise levels.
- Can be manufactured in Verdicorp machine shop.

Tallahassee Noise Ordinance

TABLE 2

Residential Property	
Times	*Sound Limits*
7:00 a.m. to 10:00 p.m.	55 dB(A) or 65 dB(C)
10:00 p.m. to 7:00 a.m.	50 dB(A) or 60 dB(C)
Non-Residential	
Times	*Sound Limits*
7:00 a.m. to 10:00 p.m.	70 dB(A) or 85 dB(C)
10:00 p.m. to 2:00 a.m.	70 dB(A) or 80 dB(C)
2:00 a.m. to 7:00 a.m.	55 dB(A) or 65 dB(C)

Tallahassee Code of Ordinances Sec. 12-94. - Maximum permissible sound. [3]

Measurement Methodology

Proposed Measurement Setup

- 10, 20, 40, and 60 meters increments
- Multiple measurements during startup and shutoff transient states
- Record and average steady state noise levels as baseline

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Measurement Equipment

Sound Level Meter (SLM)

- Type 2, ± 2dB
- Must be calibrated prior to and after use

[4]

DAQ System

- Nyquist Criterion: $f_s > 2f_c$
- Audible frequencies, 20Hz to 20KHz
- LabVIEW data logging

[5]

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Engineering House of Quality

	ENGINEERING CHARACTERISTICS						
CR	**CI**	**Meets OSHA standards**	**Material Choice**	**Fasteners and Fixtures**	**Temperature Resistance**	**Acoustic Transmission**	**Vibration Transmission**
Adaptable	7			6		7	7
Low Cost	8		10	6			
In-house Manufacturing	8	10	10	4			
Non-Intrusive to Performance	10		8	5			
Steady-State Noise Levels	10	10	10			10	8
Compact	2		6	8	5	6	
Ease of Installation	5			10		8	
Maintenance	3		10	8	10		8
Score		180	382	262	40	201	153
Relative weight		14.78	31.36	21.51	3.28	16.50	12.56
Rank		4	1	2	6	3	5

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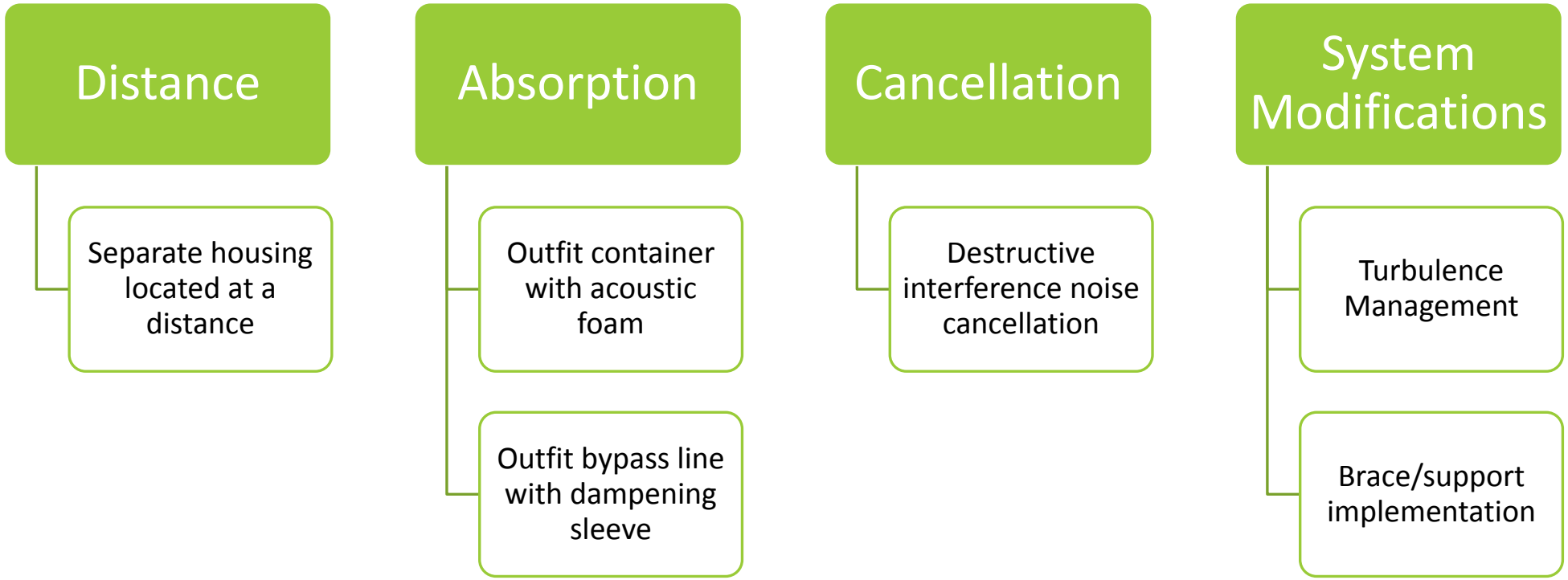
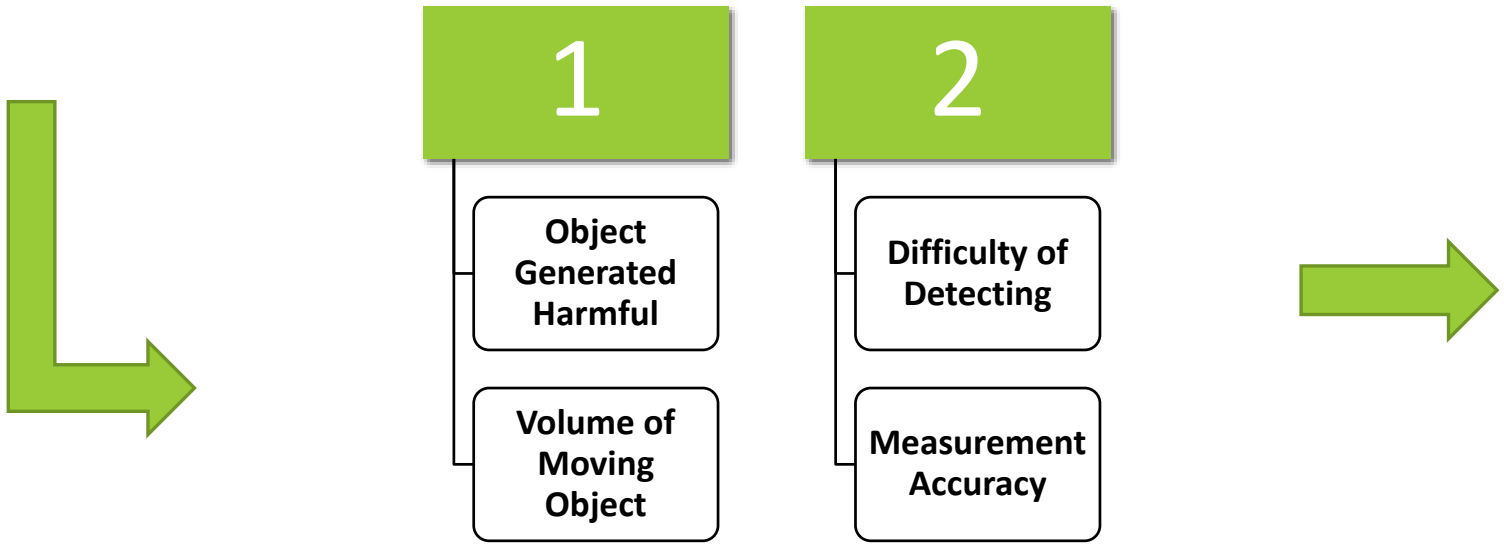
Affinity Diagram



Theory of Inventive Problem Solving(TRIZ)

Design Contradictions		Feature to Improve	Features to Preserve
1	Mitigate noise generation without interfering with pipe flow or pipe length/structure	Noise Generation	Pipe Flow
2	Take noise measurements in one location, while measuring noise during transient and steady-state without contaminating results	Measurement Accuracy	Difficulty in Detecting



TRIZ Generated Principles
Copying
Intermediary
Color Changes
Mechanical Substitution
Another Dimension
Taking Out
Composite Material

[6]

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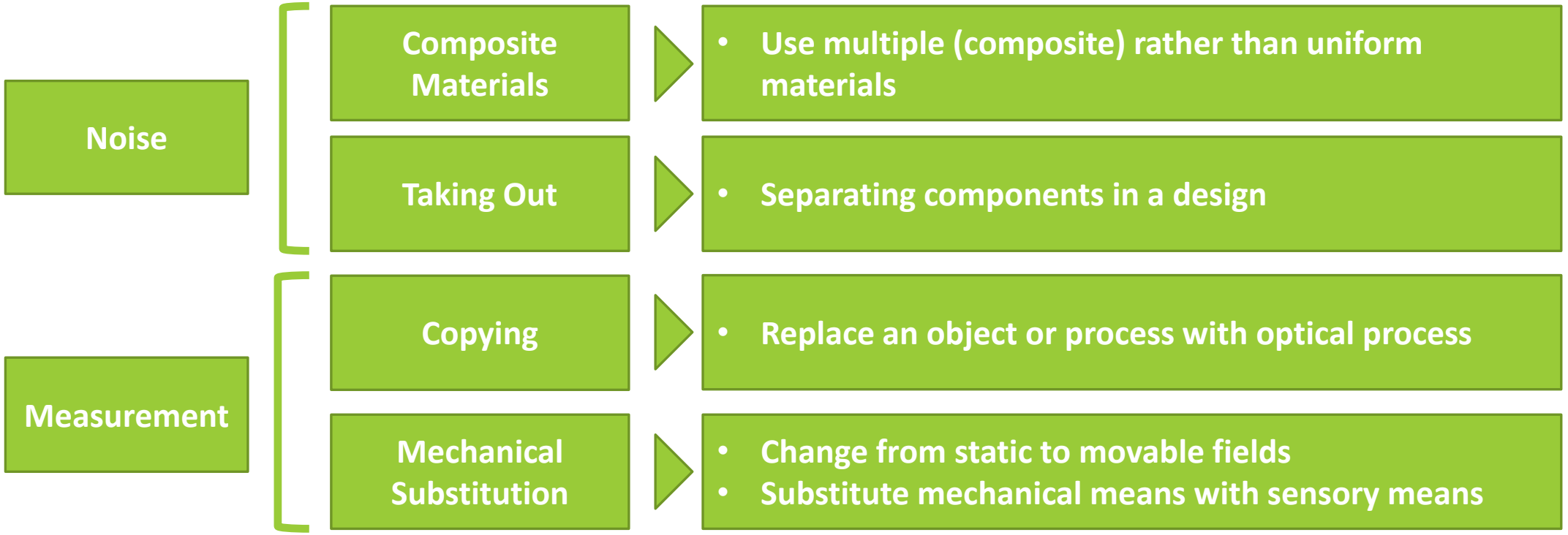
TRIZ: Principles

- Taking the pertinent principles from the previous list



[6]

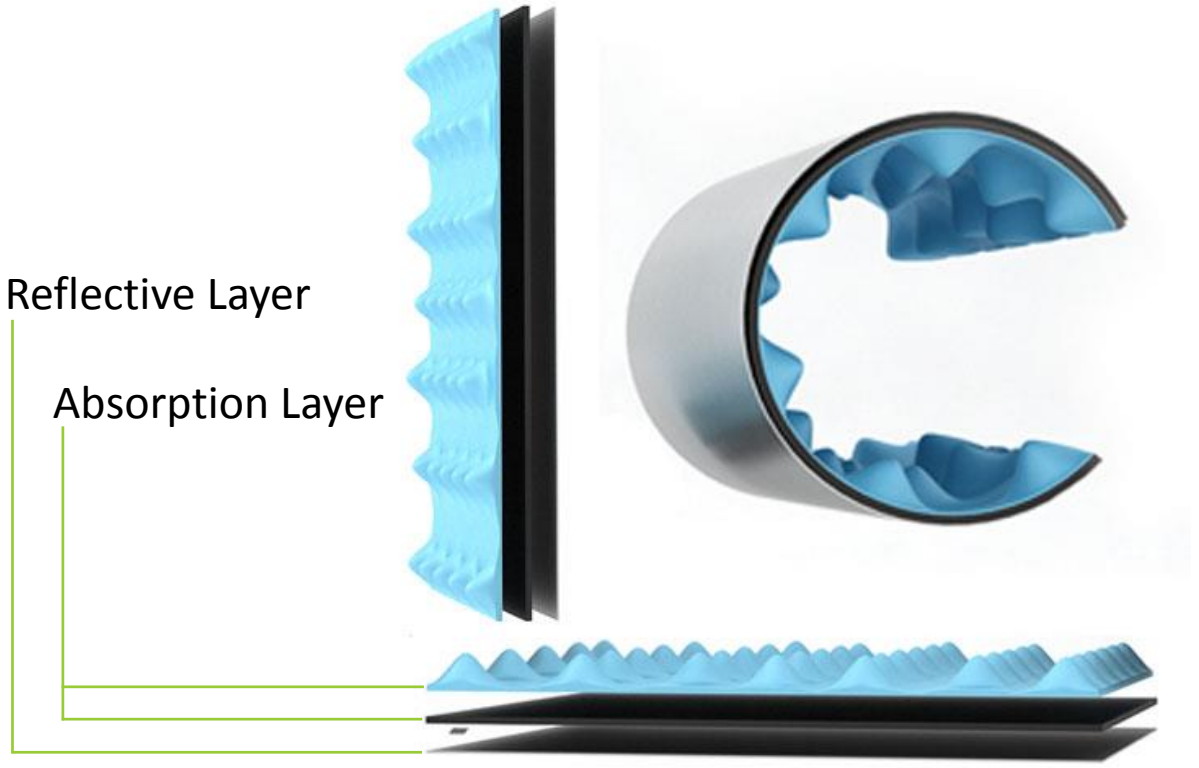
Concept 1: Acoustic Lagging

- TRIZ principle: Composite Material

Acoustic Lagging Function

- Noise propagates through pipe
- Absorbing material reduces sound pressure
- Reflective exterior layer redirects pressure waves back towards absorbing layers

Pros	Cons
• Cheap • Easy installation and manufacture • Simple and durable	• Spacing around piping • Does not interfere with transducer function



Fletcher Insulation Pipe Lagging [7]

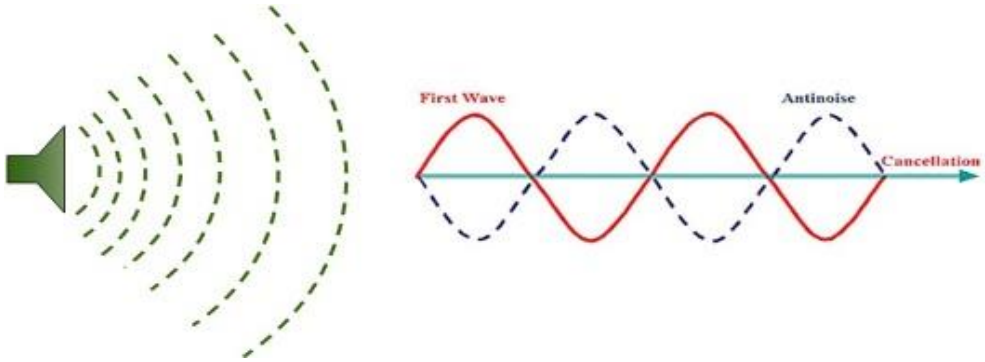
Concept 2: Active Noise Cancelling

- TRIZ principle: Mechanical Substitution

Active Noise Cancellation

- Noise propagates through pipe
- Active noise cancellation system detects noise frequencies
- System expels noise waves opposite of detected waves in order to decrease wave magnitude.

Pros	Cons
• Reactive noise cancellation • Will lower steady-state noise level in addition to bypass line	• Expensive • Efficiency decreases at higher frequencies



Active Noise Cancellation Process [8]

Concept 3: Turbulence Management

- TRIZ principle: Mechanical Substitution

Turbulence Management

- Reducing pipe bends and certain types of control valves can greatly effect the noise levels in the pipe.

Pros	Cons
• Can have drastic reductions of the noise levels • Can assist in decreasing damaging pipe vibrations	• Effects flow properties in the pipe • Increased installation and replacement time • Addition manufacturing costs

Webtec FV202 pneumatic ball valve [9]

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Challenges

- **Measurement Equipment**
- **Finding specific location of noise source**
- **Schedule Conflicts**

Future Plans

- **Rent/ Borrow Equipment**
- **Noise Measurements and Analysis**
- **Determine the source of the noise**
- **Generate prototypes**

Gantt Chart

Still finishing it up

Resources

1. “Energy, Exergy and Performance Analysis of Small-Scale Organic Rankine Cycle Systems for Electrical Power Generation Applicable in Rural Areas of Developing Countries,” *MDPI*. [Online]. Available: http://www.mdpi.com/1996-1073/8/2/684/htm. [Accessed: 04-Oct-2016].

2. “High performance tri-generation,” *Verdicorp Environmental Technologies*. [Online]. Available: http://www.verdicorp.com/trigeneration brochure 20120428.pdf. [Accessed: 25-Sep-2016].

3. “City of Tallahassee Code of Ordinance ,” *Municode Library*. [Online]. Available: https://www.municode.com/library/fl/tallahassee/codes/code_of_ordinances?nodeid=ptiicogeor_ch12ofmipr. [Accessed: 08-Oct-2016].

4. “Noise Measurement,” PPE Safety Solutions. [Online]. Available: http://solutions.3m.com/wps/portal/3m/en_eu/ppe_safetysolutions_eu/safety/product_catalogue/~/3m-soundpro-se-dl-series-sound-level-meter-sp-dl-1-1-3?n=5158380 3294756793 3294857473. [Accessed: 08-Oct-2016].

5. “NI 9218 Dynamic Universal Simultaneous Analog Input, 51.2 kS/s, 2 Ch,” NI 9218. [Online]. Available: http://sine.ni.com/nips/cds/view/p/lang/en/nid/212730. [Accessed: 09-Oct-2016].

6. “TRIZ Matrix / 40 principles / TRIZ contradictions table,” *TRIZ Matrix / 40 principles / TRIZ contradictions table*. [Online]. Available: http://www.triz40.com/triz_gb.php. [Accessed: 08-Oct-2016].

7. “Thermal Insulation Materials For Residential - Fletcher Insulation,” Fletcher Insulation. [Online]. Available: http://insulation.com.au/product/pipe-acoustic-lagging/. [Accessed: 10-Oct-2016].

8. By detecting the unwanted noise with a reference microphone, the ANC system can automatically generate the correct signal to send to the speaker, which will produce the anti-noise, canceling out the unwanted noise. The size of the quiet zone created near the error microphone depends on the wavelength of the noise., “Quieting the Home,” Appliance Design Magazine RSS. [Online]. Available: http://www.appliancedesign.com/articles/92572-quieting-the-home. [Accessed: 11-Oct-2016].

9. “2FV2V (Variable priority flow divider valve),” Webtec. [Online]. Available: http://www.webtec.com/en/productgroup/hfcv_2fv. [Accessed: 10-Oct-2016].

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Questions?