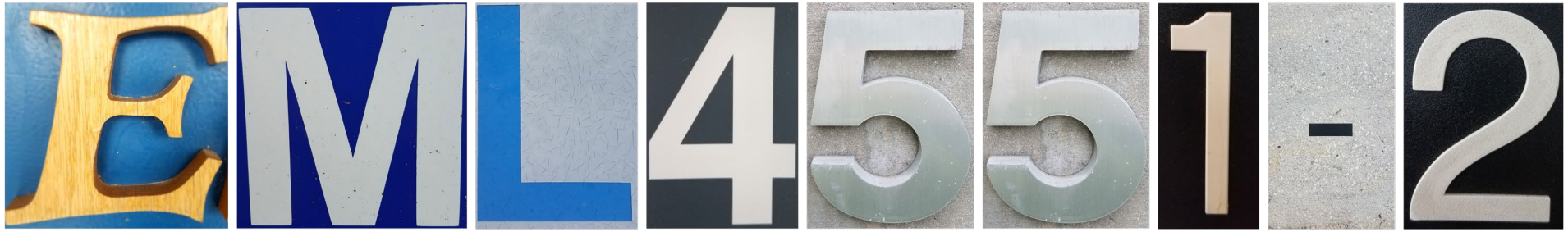



# Virtual Design Review

Nick Ajhar, Bryce Lankford, Marissa Jackson
Team 506: Mobile Anechoic Chamber

13-Nov-18

Danfoss

TURBOCOR

FAMU-FSU COLLEGE OF ENGINEERING

# Team Introductions

## Team 506: Mobile Anechoic Chamber

**Marissa Jackson**
Project Manager

**Bryce Lankford**
Systems Engineer

**Nick Ajhar**
Mechanical Engineer

# Objective

Design a way to efficiently and consistently record sound for centrifugal compressors while managing surrounding noise

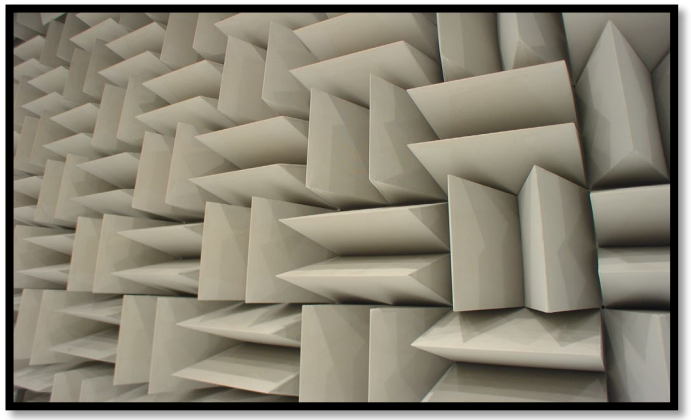
# Customer Needs

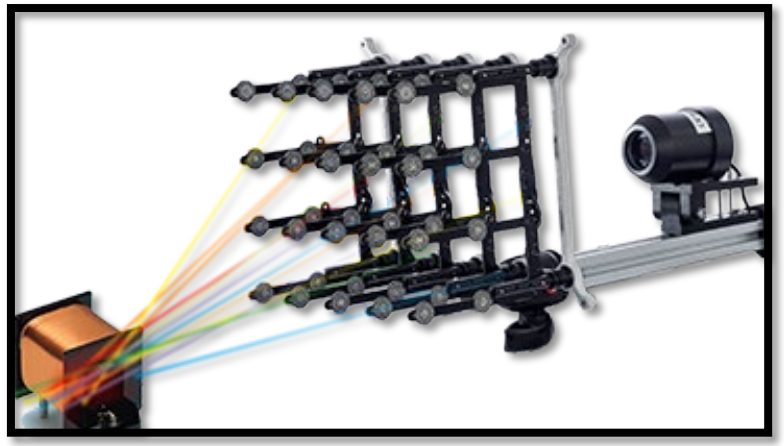
- Measure sound across compressors
  - Be able to convert to sound power
  - Consistent reading
- Reduce ambient sound to get most accurate recording
- Store and display the results
- Easy setup and breakdown of system


Bryce Lankford

# Project Scope- Goals

- Consistently measure the sound power across TT series compressors
- Determine best solution- Anechoic Chamber vs. Sound Transducers
- Chosen design will complete our task with high efficiency for the budget





Bryce Lankford

# Project Summary

- Measure the sound power of the TT series compressors
- Sound power is the energy emitted by the source and is measured in Watts
- Reduce the surrounding sound to get a consistent reading from the compressors
- Must be able to be easily assembled and portable

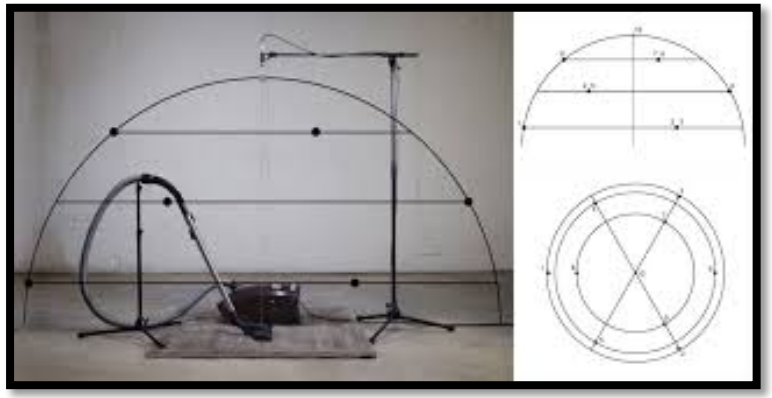
# Targets

| Function | Target |
|---|---|
| Vibration Detection Device | 20-20000 Hz |
| Measure Sound Pressure | 92 dB |
| Reduce Ambient Sound | ± 5 dBA |
| Weight | 50 lbs. |
| Input Recorded Data | 16 Bits |
| Convert Recorded Sound to Sound Power | ± 5W |
| Output Data | 64 GB |
| Store Data | 250 GB |
| Display Live Feed | 1 ms |
| Compatible with Testing Stand | 30 min |

Bryce Lankford

# Subsystems

Reduce Ambient Sound



Record Sound

Convert to Sound Power

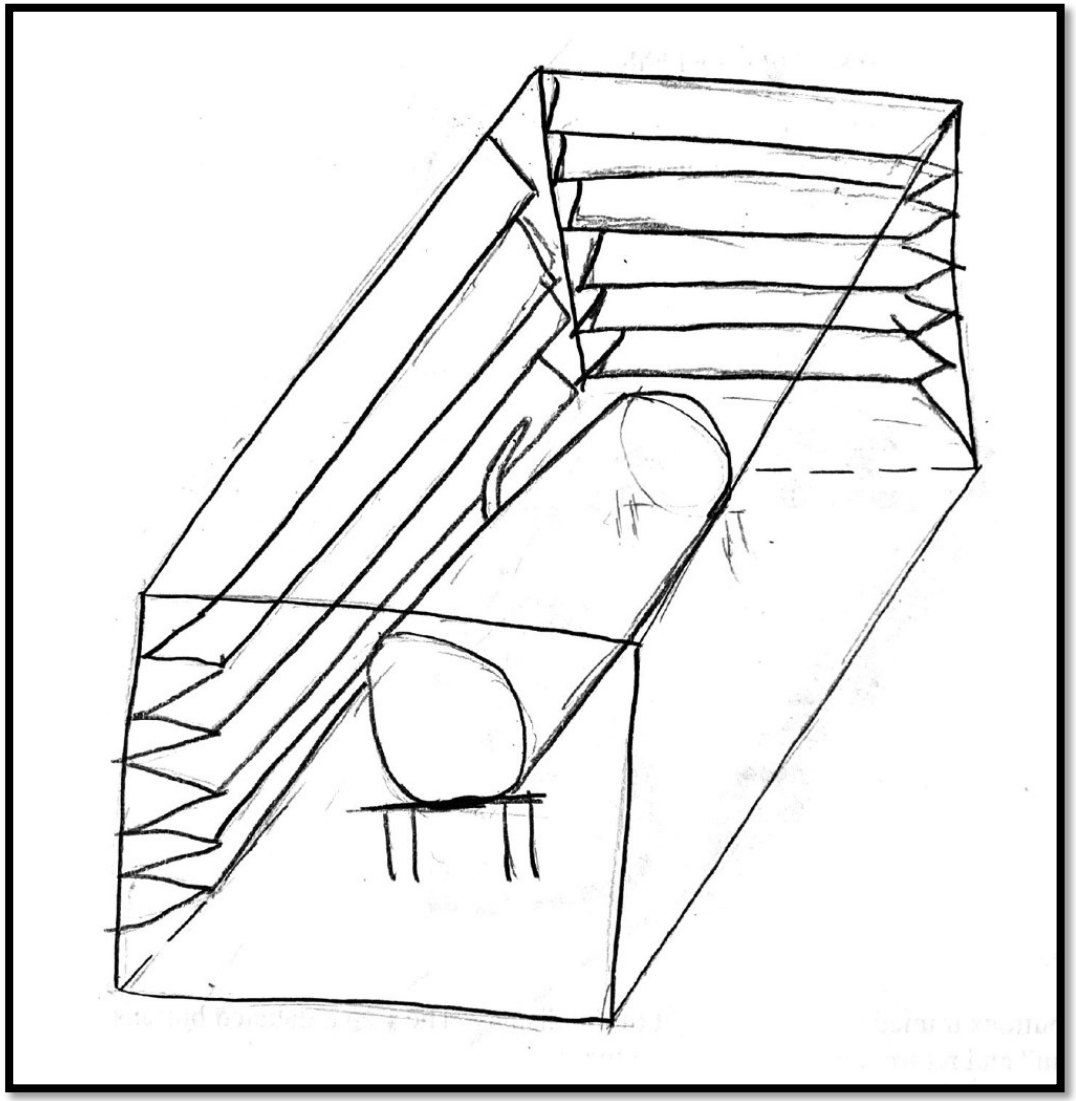
Bryce Lankford

# Reduce Ambient Sound

**Concept Generation**

# Concept 1: Full Coverage of Compressor

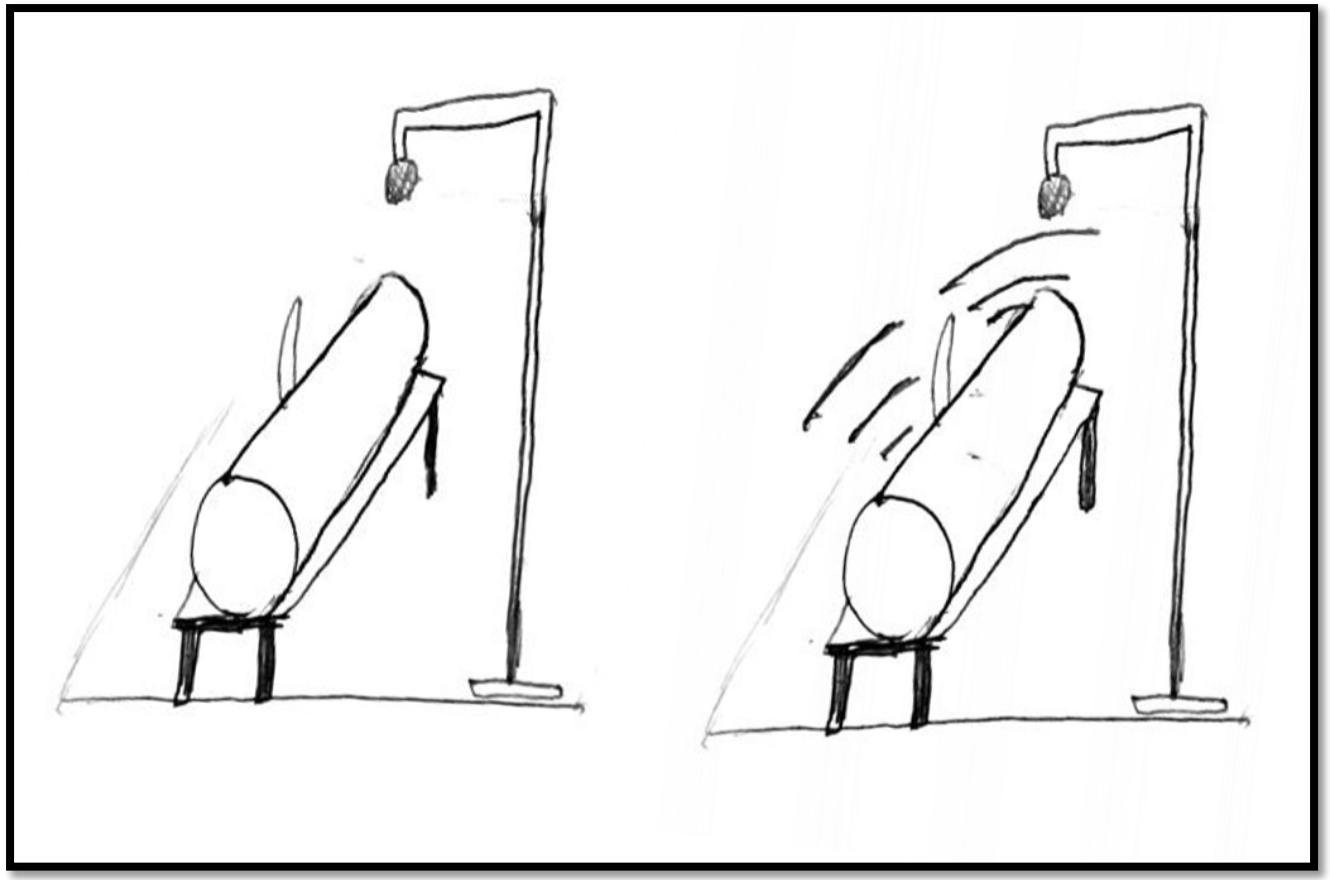
- Completely surrounds compressor in Anechoic Box structure
- Would dampen sound more fully by isolating the compressor stand from the production floor



Bryce Lankford

# Concept 2: Record average ambient sound and compare

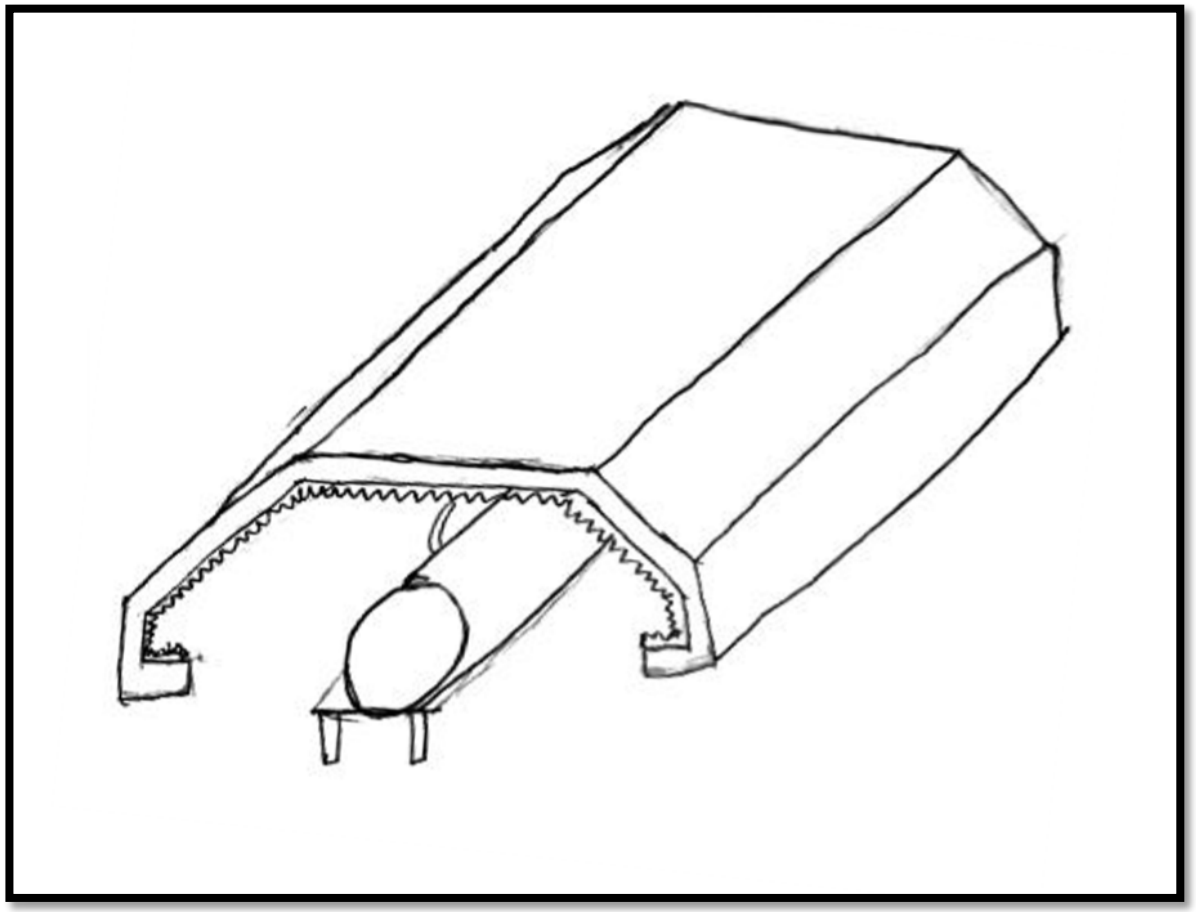
- Record average shop floor sound at a specific location with the compressor off
- Record average sound at same specific location with compressor running
- Determine how much of a difference between the two



Bryce Lankford

# Concept 3: Sound reducing material around compressor

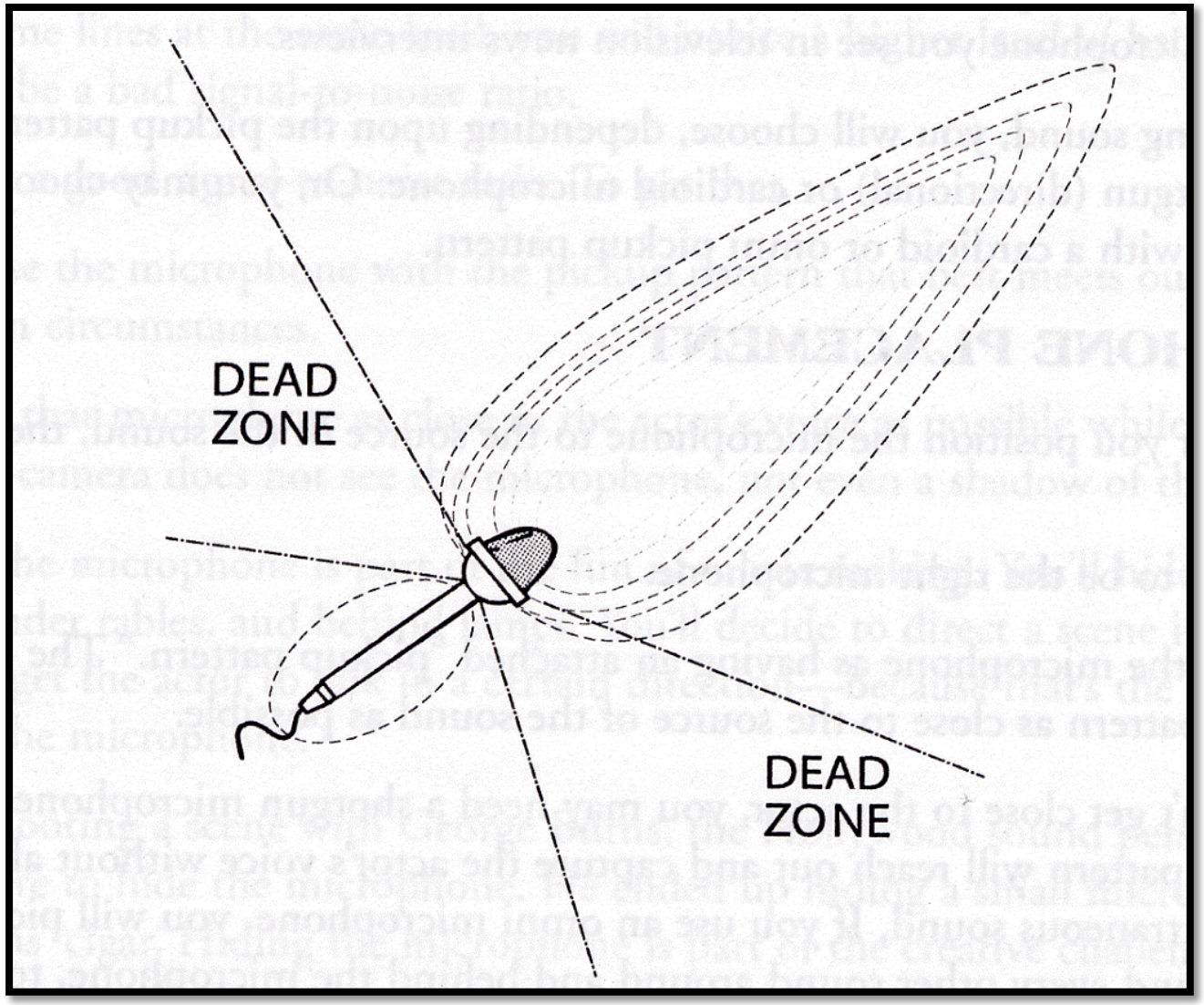
- No special geometric shape
- Material is not anechoic foam but some sort of sound dampening material
- Does not fully encompass the compressor



Bryce Lankford

# Concept 4: Directional microphone

- Used on production studio sets
- Records sound emitted directly in front of microphone
- Dampens ambient sound from behind and directly sides of microphone



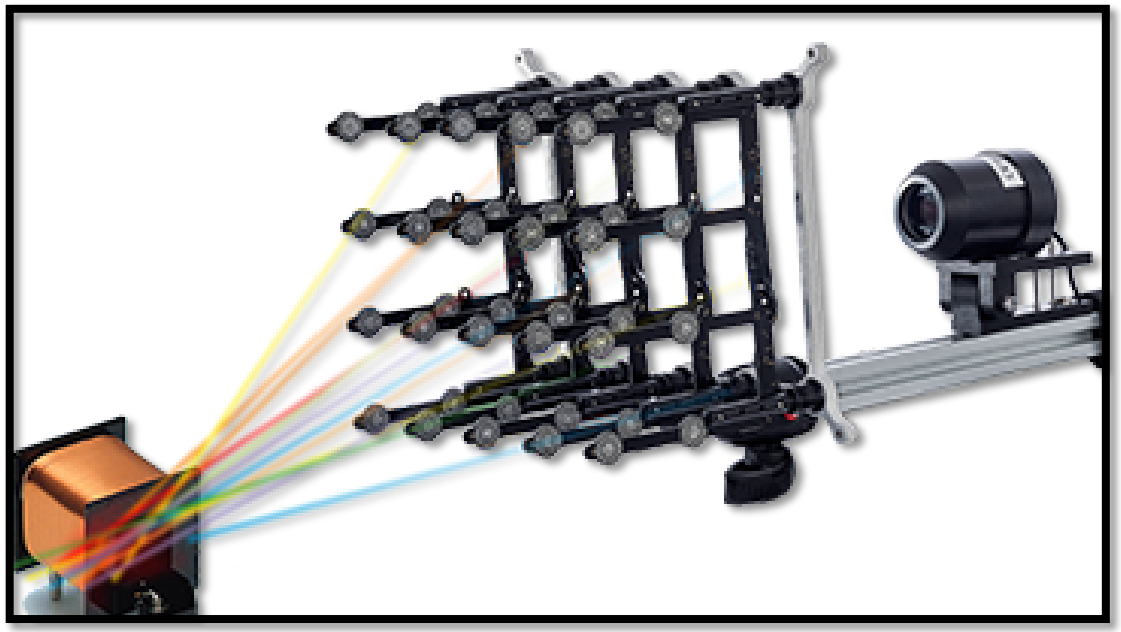

Bryce Lankford

# Measure Sound Pressure

**Concept Generation**

# Concept 1: Array of Microphones

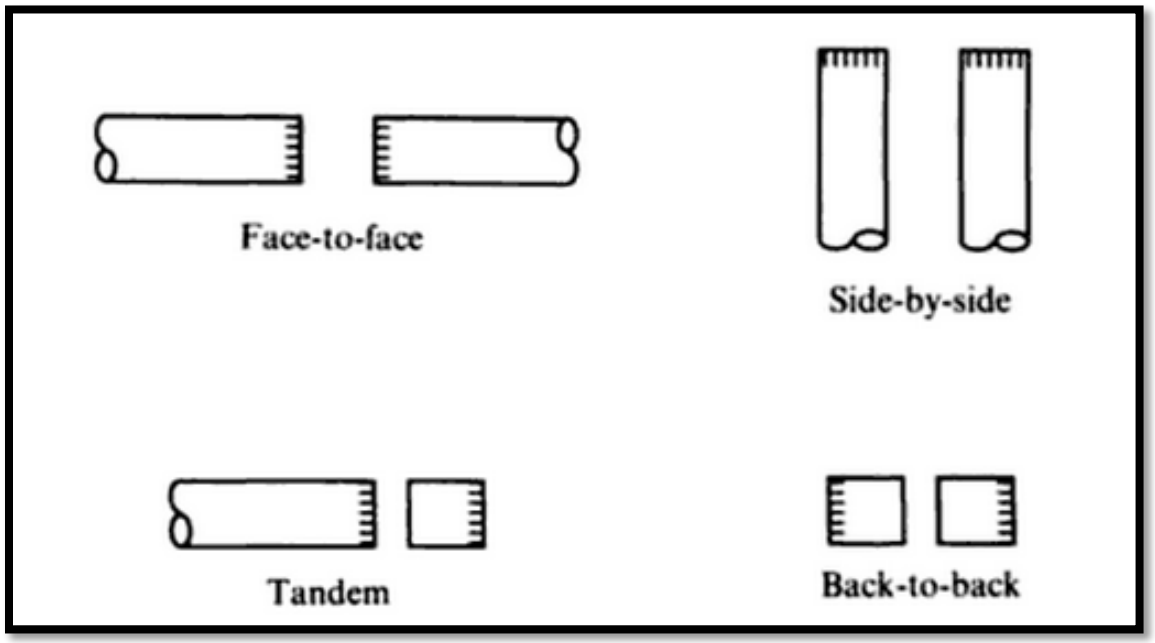
- Can record sound power over a predetermined area
- Array consists of many preset microphones which all record the same sound source simultaneously
- Has the potential to map sound intensity at specific points on the compressor



Nick Ajhar

# Concept 2: Sound Intensity Probe

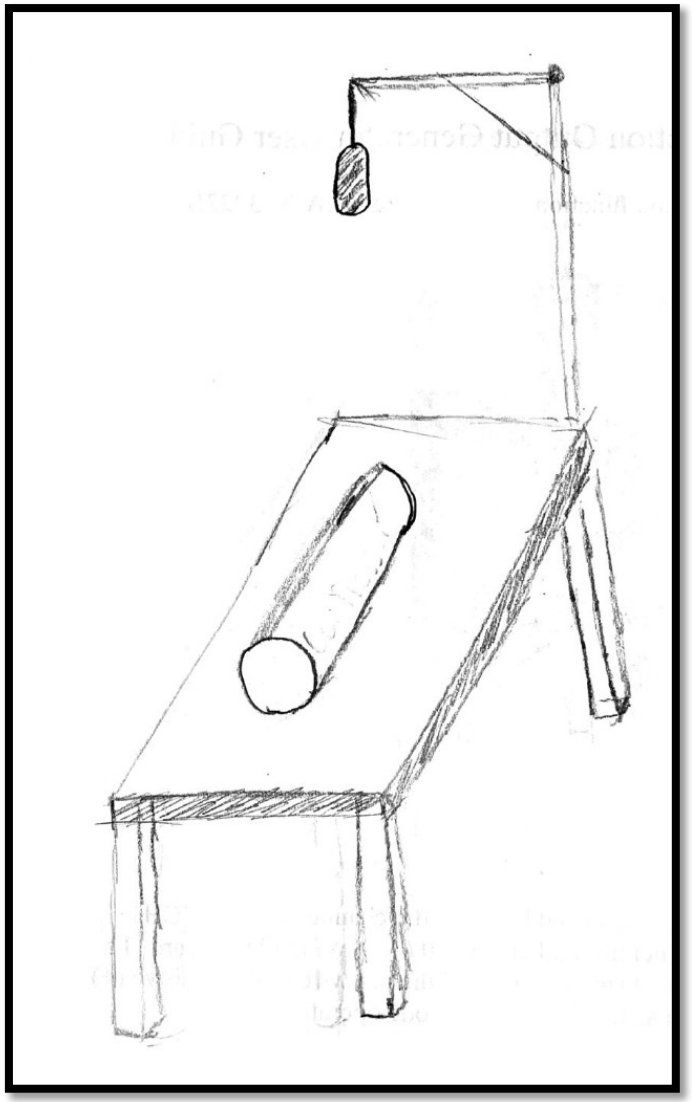
- Uses two microphones in different orientations
- Device is employed by sweeping across a preset path and a sound intensity value is acquired
- Sound Power can be derived from this by multiplying by the area the user has swept over




Nick Ajhar

# Concept 3: Single Fixed Microphone

- Simple Setup
- Minimal Form Factor inside test chamber
- If surrounding noise is low enough could give usable sound power measurement
- Would require a uniform sound distribution around the test chamber



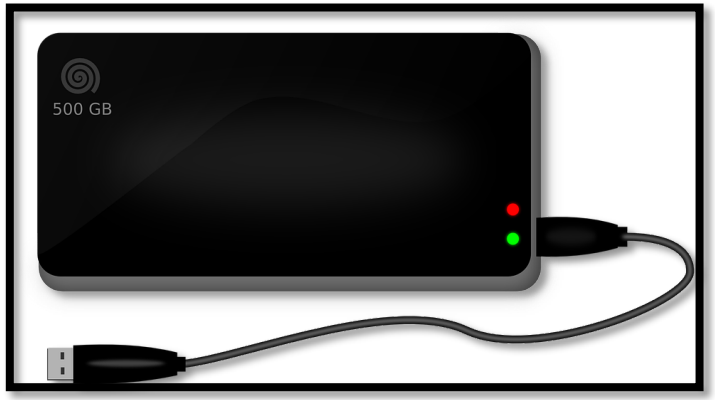
Nick Ajhar

# Convert to Sound Power

## Concept Generation

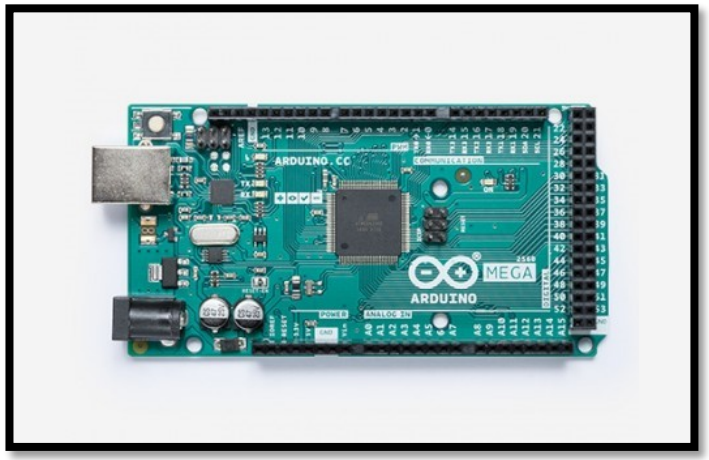
# Concept 1: External Storage

- Device would store the data until it is inputted into computer
- Raw Data converted later




# Concept 2: Direct Connection

- Setup of a microcontroller that will perform the needed conversions
- Computer program will simultaneously convert data during recording




Nick Ajhar

# Concept Selection

- Pairwise Selection
  - Determines the most important customer requirements
- House of Quality
  - Uses results of pairwise selection to determine the relative weight of functional requirements

| | | Functional Requirements | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | Hz | Pa or dB | W/m^2 | Bits | W | - | Bytes | Sec | Min | lbs | dBA |
| Importance Weight Factor | Customer Requirements | Wave length frequency detected | Measured sound pressure | Measured sound intensity | Amount of data that can be input | Sound power conversion | Output Data Digital Format | Memory of storage | Delay of live feed | Time to set up ad break down | Weight of System | Recorded ambient Sound |
| 6 | 1. Measure Sound | 9 | 9 | 9 | | 3 | | | | | | 9 |
| 5 | 2. Compatible with Testing Station | | 3 | 3 | | | | | | 9 | 9 | |
| 3 | 3. Store Data | 3 | | | 9 | 3 | 3 | 9 | | | | |
| 2 | 4. Display Data | 3 | | | 9 | 3 | 9 | 1 | 9 | | | |
| 7 | 5. Consistent Recording | 9 | 9 | 9 | 3 | 3 | 1 | | | | | 9 |
| 8 | 6. Convert to Sound Power | 9 | 9 | 9 | | | | | | | | 9 |
| 1 | 7. Ease of Conversion | 1 | 1 | 9 | 3 | | | | 1 | | | 3 |
| 2 | 8. Reduce ambient sound | 3 | 9 | 1 | | 3 | | | | | | 9 |
| 3 | 9. Mobility of system | | 1 | 1 | | | | 1 | | 9 | 9 | |
| | Relative Weight | 21% | 22% | 22% | 7% | 6% | 3% | 3% | 2% | 7% | 7% | 21% |
| | Rank Order | 3 | 1 | 2 | 6 | 7 | 8 | 9 | 10 | 5 | 5 | 4 |

Nick Ajhar

# Concept Selection

- Pugh Chart
  - Determines the best concept out of concept generation
  - Subsystem 1:
    - Anechoic Chamber
    - Sound Dampening Container
  - Subsystem 2:
    - Array of Microphones
    - Sound intensity probe

| Initial Pugh Matrix for Subsystem 1 | | | | | |
|---|---|---|---|---|---|
| Selection Criteria | | Concepts | | | |
| | Datum | 1 | 2 | 3 | 4 |
| Measure Sound Pressure | | + | S | + | + |
| Wavelength frequency detected | | S | S | S | S |
| Recorded ambient sound | | + | - | + | + |
| Time to set up and break down system | | - | S | - | - |
| Weight of system | | - | S | - | - |
| Cost | | - | S | - | - |
| Ease of Conversion | | + | - | + | + |
| Sum of Positive | | 3 | 0 | 3 | 3 |
| Sum of Negative | | 3 | 2 | 3 | 3 |

Datum: Current testing lab they have with standard microphone

Nick Ajhar

# Concept Selection

- Criteria Comparison Matrix
  - Determines the importance of requirements for different subsystems
  - Selects best concept of remaining options

| Final Concepts | | |
|---|---|---|
| Reduce Ambient Sound | Measure Sound Pressure | Convert to Sound Power |
| Anechoic Chamber | Array of Microphones | Direct Connection |

Nick Ajhar

# Summary

- From targets that were established based on customer needs, concept generation was completed
- Based on customer needs and targets a house of quality was established
- From House of Quality and Pugh Matrix concept selection was completed
- Final concept is an anechoic chamber, array of microphones, and direct connection

# References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# Questions?

# Preliminary Data

From a test Danfoss previously conducted, the level of sound from the compressors was measured and averaged.

- Ambient Sound Level – 78 dB(A)
- Compressor Sound Level – 92 dB(A)

# Next Steps

- Targets and Metrics
  - Consistency of sound power range
  - Display the data collected
- Concept Generation and Selection
  - Design of various systems
  - Selection of design using house of quality

# Pairwise Selection

| Pairwise Selection | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Sum |
| 1. Measure Sound | - | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 6 |
| 2. Compatible with Testing Station | 0 | - | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 5 |
| 3. Store Data | 0 | 0 | - | 1 | 0 | 0 | 1 | 0 | 1 | 3 |
| 4. Display Data | 0 | 0 | 0 | - | 0 | 1 | 1 | 0 | 0 | 2 |
| 5. Consistent Recording | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 7 |
| 6. Convert to Sound Power | 1 | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 8 |
| 7. Ease of Conversion | 0 | 0 | 0 | 0 | 0 | 0 | - | 1 | 0 | 1 |
| 8. Reduce ambient sound | 0 | 0 | 1 | 1 | 0 | 0 | 0 | - | 0 | 2 |
| 9. Mobility of system | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | - | 3 |
| Sum | 2 | 3 | 5 | 7 | 1 | 1 | 7 | 6 | 5 | n-1=7 |

# Pugh Matrix

| Secondary Pugh Matrix for Subsystem 1 | | | |
|---|---|---|---|
| Selection Criteria | | Concepts | |
| | Concept 4 | 1 | 3 |
| Measure Sound Pressure | | + | + |
| Wavelength frequency detected | | S | S |
| Recorded ambient sound | | + | + |
| Time to set up and break down system | | - | - |
| Weight of system | | - | - |
| Cost | | - | + |
| Ease of Conversion | | + | + |
| Sum of Positive | | 3 | 4 |
| Sum of Negative | | 3 | 2 |

# Criteria Comparison Matrix

| Criteria Comparison Matrix for Subsystem 1 | | | | | | |
|---|---|---|---|---|---|---|
| | Measure Sound Pressure | Wavelength Frequency Detected | Recorded Ambient Sound | Time to set up and break down | Weight of system | Sound power conversion |
| Measure Sound Pressure | 1.00 | 3.00 | 0.14 | 0.20 | 0.20 | 3.00 |
| Wavelength frequency detected | 0.33 | 1.00 | 0.14 | 0.20 | 0.14 | 3.00 |
| Recorded ambient sound | 7.00 | 7.00 | 1.00 | 7.00 | 7.00 | 7.00 |
| Time to set up and break down system | 5.00 | 5.00 | 0.14 | 1.00 | 0.33 | 5.00 |
| Weight of system | 5.00 | 5.00 | 0.14 | 3.00 | 1.00 | 1.00 |
| Sound power conversion | 0.33 | 0.33 | 0.14 | 0.20 | 1.00 | 1.00 |
| Sum | 18.67 | 21.33 | 1.71 | 11.60 | 9.68 | 20.00 |

| Normalized Criteria Comparison Matrix for Subsystem 1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Measure Sound Pressure | Wavelength Frequency detected | Record ambient sound | Time to set up and break down system | Weight of system | Sound power conversion | Weight |
| Measure Sound Pressure | 0.05 | 0.14 | 0.08 | 0.02 | 0.02 | 0.15 | 7.76% |
| Wavelength frequency detected | 0.02 | 0.05 | 0.08 | 0.02 | 0.01 | 0.15 | 5.50% |
| Recorded ambient sound | 0.38 | 0.33 | 0.58 | 0.60 | 0.72 | 0.35 | 49.39% |
| Time to set up and break down system | 0.27 | 0.23 | 0.08 | 0.09 | 0.03 | 0.25 | 15.94% |
| Weight of system | 0.27 | 0.23 | 0.08 | 0.26 | 0.10 | 0.05 | 16.63% |
| Sound power conversion | 0.02 | 0.02 | 0.08 | 0.02 | 0.10 | 0.05 | 4.79% |
| Sum | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |