Mobile Anechoic Test Chamber

Team: 506

Nick Ajhar, Marissa Jackson, Bryce Lankford

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Team Introductions

Marissa Jackson
Project Manager

Bryce Lankford
Systems Engineer

Nick Ajhar
Mechanical Engineer

Sponsor

This engineering project, "Mobile Anechoic Test Chamber," is funded by Danfoss Turbocor.

Objective

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

Project Background

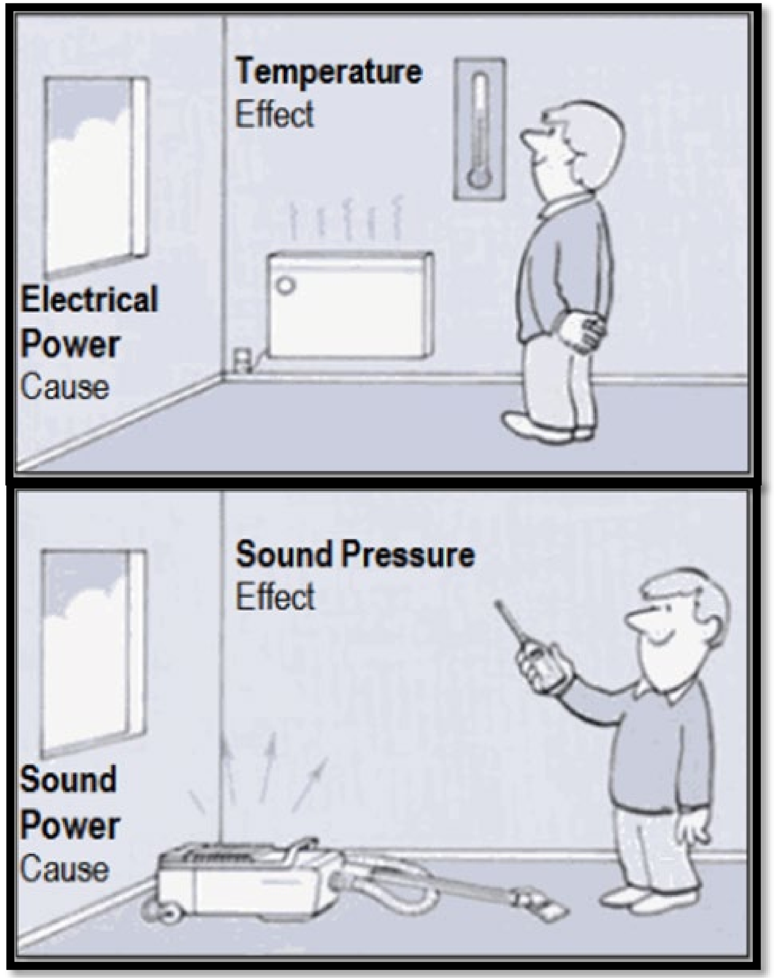
Nick Ajhar

Centrifugal Compressors

- TT Series
  - 4 Different Models: 300, 350, 400, 700
- Capacities: 211-702 kW
- Quiet Operation (92 dB)
- Background noise (78 dB)

Sound Power

- Rate at which sound is emitted
- Measured in Watts (W)
- Deviated from sound pressure (dB)
- Indicator for how intense the sound of a machine will be



Sound Power Comparisons

Turboprop Plane
100 W

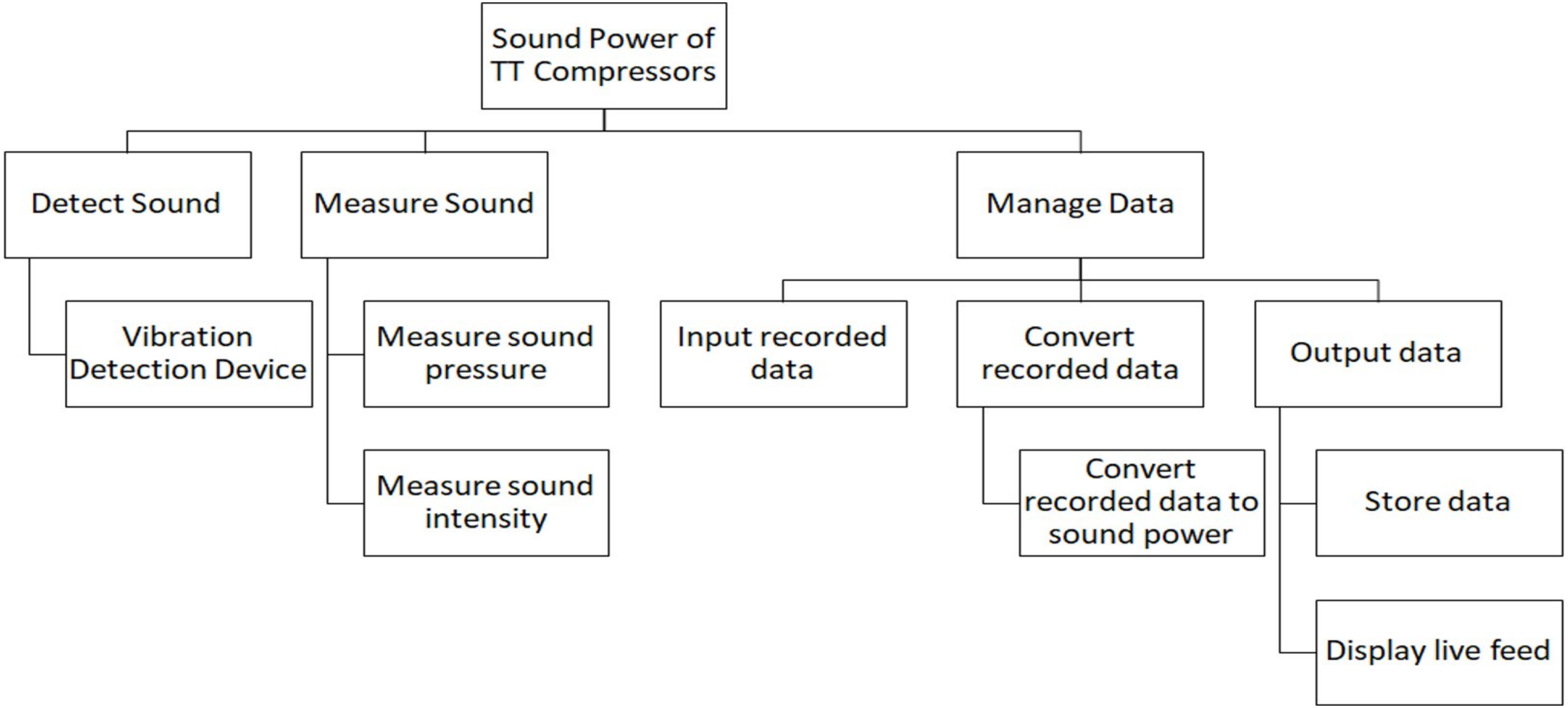
Rifle
1 W

Diesel Truck
0.001 W

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

Functional Decomposition

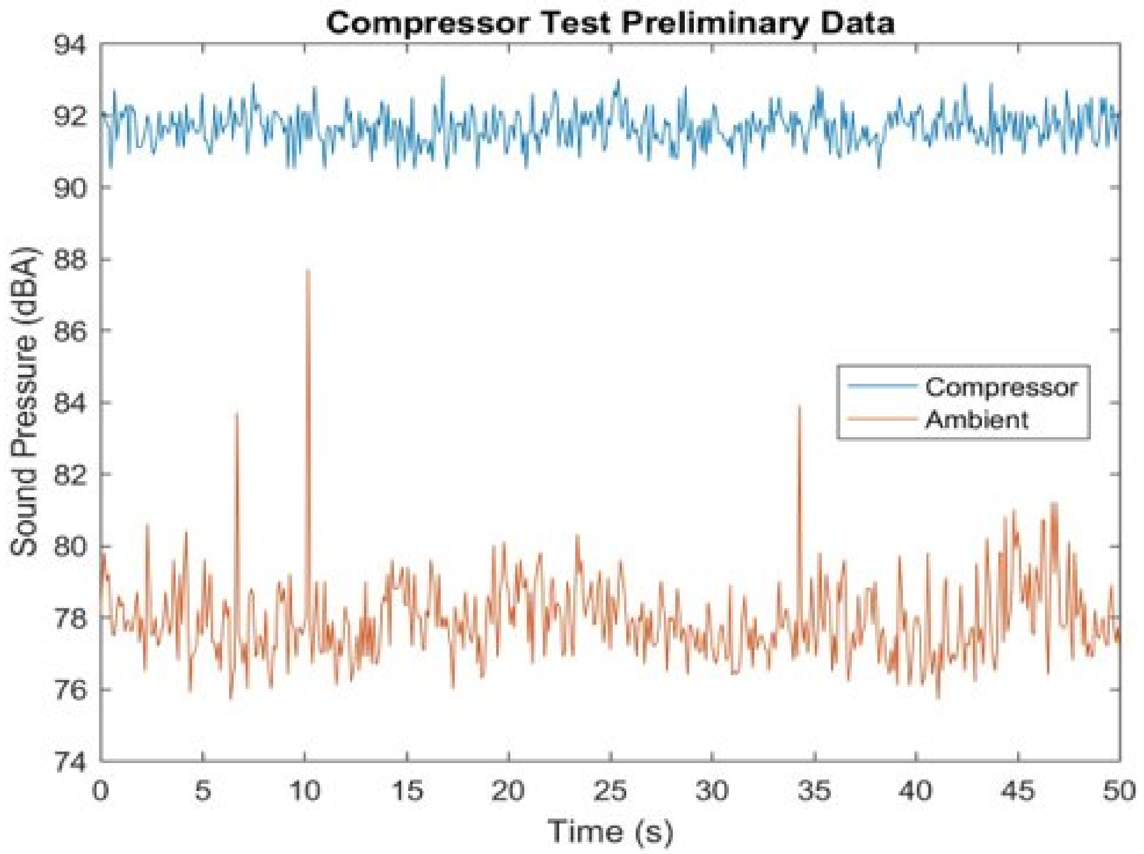


Concept Generation

Marissa Jackson

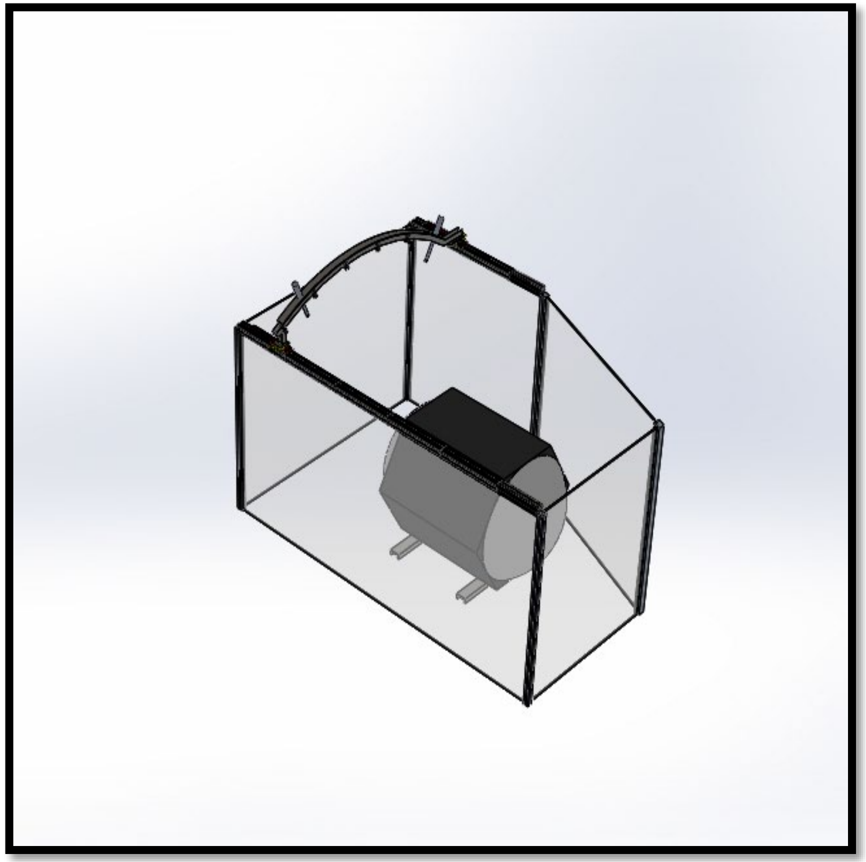
Ambient Noise

- ISO 3746
  - Background noise must be greater than 3dB below the mean sound pressure level of source
- Low pass filter will be used for unwanted sounds



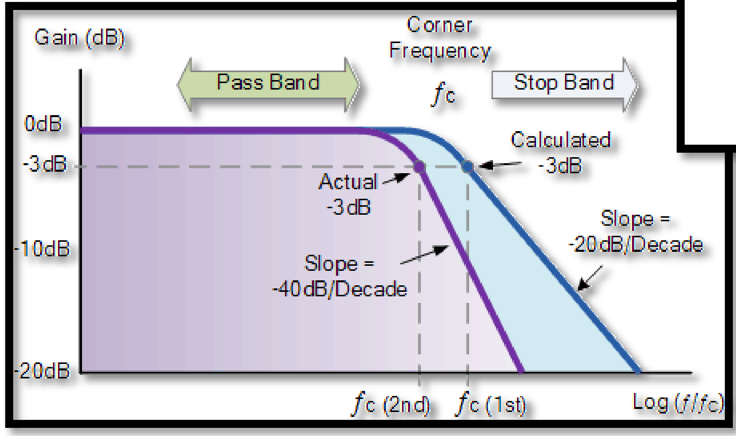
Sound Recording

- Array of Microphones
  - 2 microphones equidistant around compressor
  - Microphones can be moved to different locations about arc
  - Multiple locations can eliminate spatial error



Conversion to Sound Power

- Direct connection from microphones to computer
- Program to convert data to sound power after initial data is converted to decibels
- Low pass filter removes unwanted noise from data



Data Acquisition

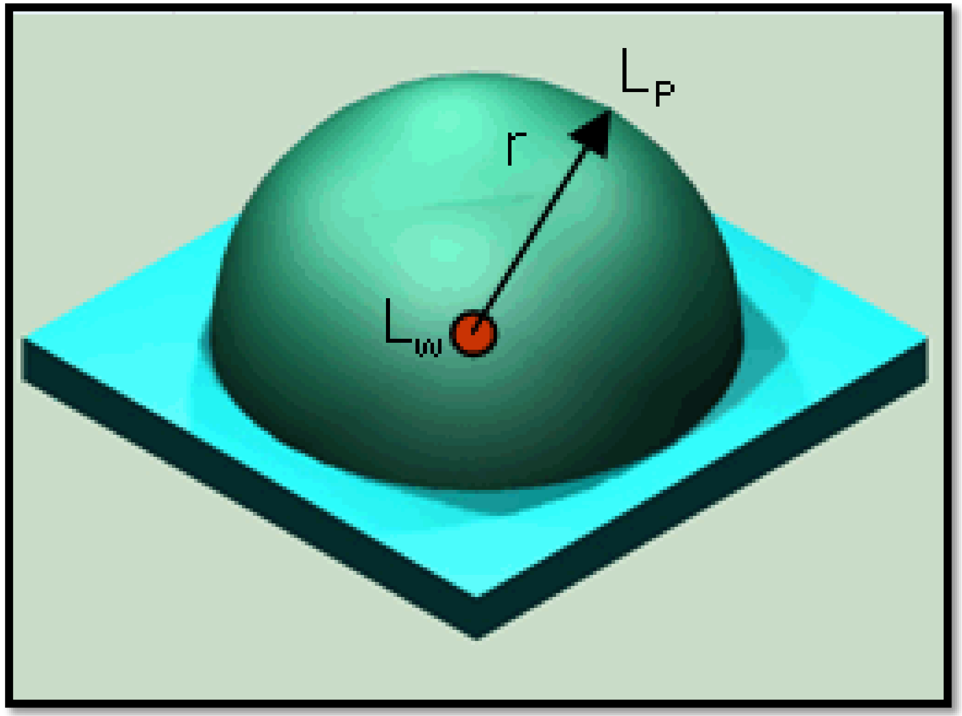
Marissa Jackson

Sound Power Level (dB)

- Conversion to Sound Power Level

$$L_w = L_p + |10 * \log(\frac{Q}{4\pi R^2})|$$

  - L_w – Sound Power Level (dB-SWL)
  - L_p – Sound Pressure Level (dB)
  - Q – Directivity Factor
  - R – Radius (m)



Sound Power (Watts)

- Conversion to Sound Power

$$P_{ac} = P_{ac,o} * 10^{L_w/10}$$

- P_{ac} – Sound Power (W)
- $P_{ac,o}$ – Reference Sound Power ($10^{-12}\,W = 0\,dB - SWL$)
- L_w – Sound Power Level (dB-SWL)

Sample Code

Constants (Q and R) declared and recording device activated → Pressure recorded as voltage → DAQ converts voltage to dB → Pressure value is plugged into L_w equation → Average of all sound power values taken at each position

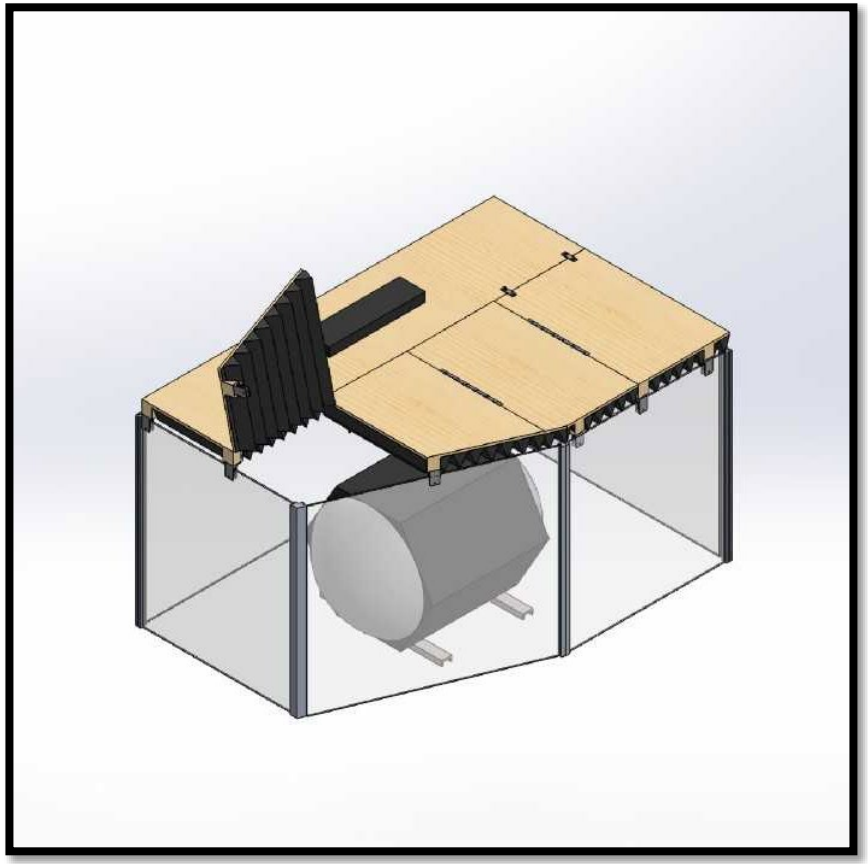
Embodiment

Bryce Lankford

Acquiring Materials

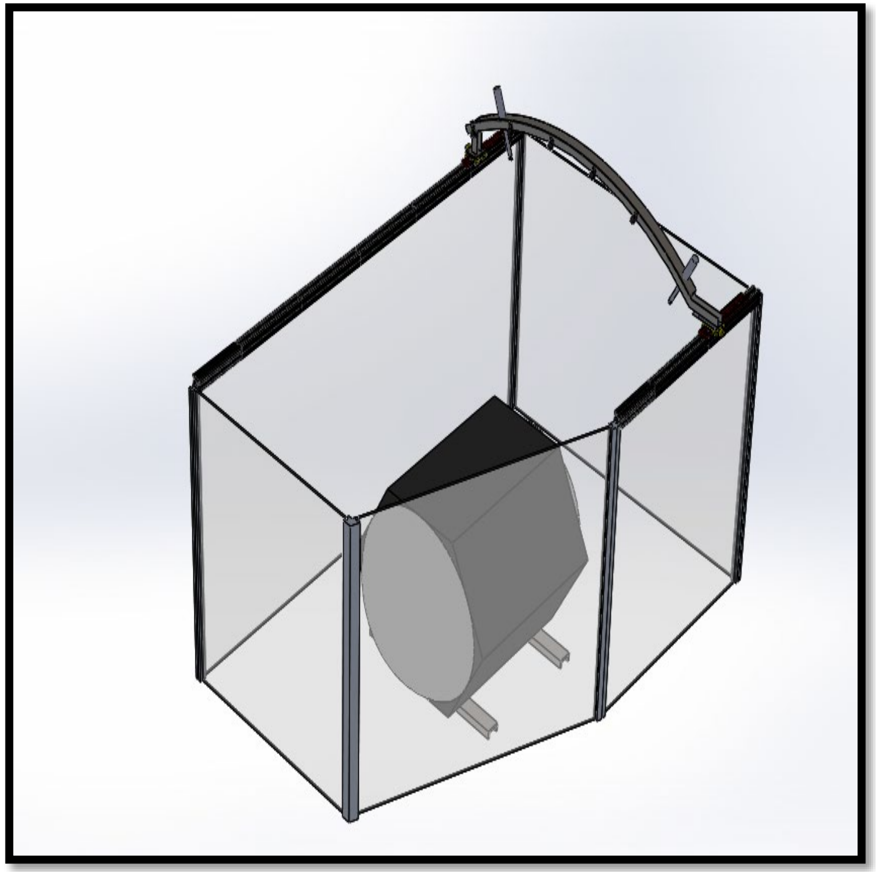
Part Name	Part Number	Quantity	Ordered	Ordered Date	Cost	Expected delivery
Microphone (1/2")	SD506001	2	Yes	2/15/2019	$ 495.00	3/1/2019
Digital ICP – USB Signal Conditioner	SD506002	1	Yes	2/15/2019	$ 950.00	3/15/2019
BNC Cable (6 Feet)	SD506003	2	Yes	2/6/2019	$ 8.95	2/8/2019
Sleeve Bearing Carriage	SD506004	2	Yes	2/6/2019	$ 95.85	2/13/2019
Guide Rail (250mm)	SD506005	2	Yes	2/6/2019	$ 20.00	2/13/2019
M5 Fastener (Pack of 4)	SD506006	1	Yes	2/6/2019	$ 4.27	2/13/2019
Microphone holder (Clip)	SD506007	2	Yes	2/6/2019	$ 5.95	2/13/2019
M4 Fastener (Pack of 25)	SD506008	1	Yes	2/6/2019	$ 4.13	2/13/2019
				Sum	$ 2,293.34	

Design Overview

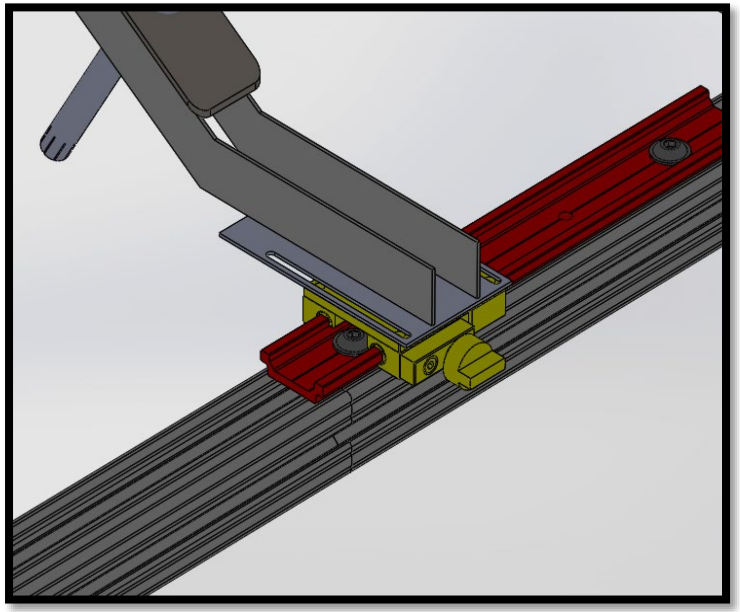


- Smaller structure for holding microphones
- No need for anechoic foam
- Movable microphones

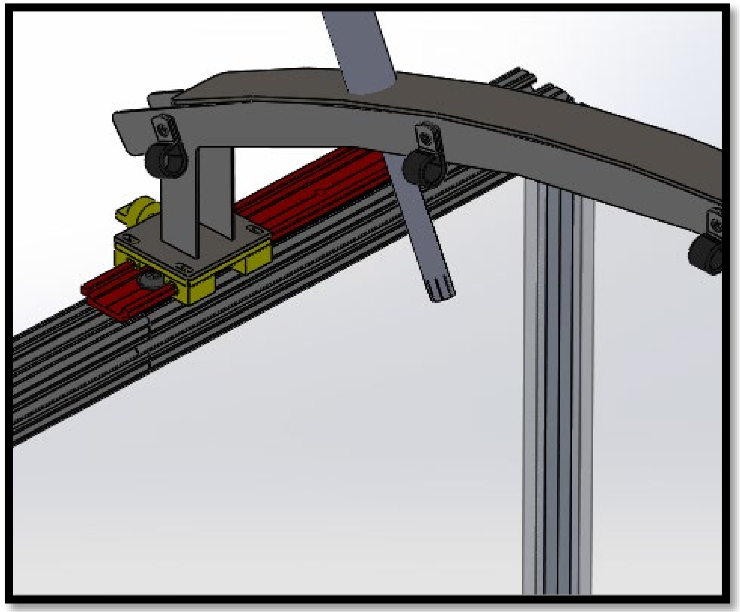
- Better accessibility to compressor
- Consistent radius for microphone placement
- Room for additions



Detailed Design



- Sliding mechanism to maneuver array to different positions
- Arc is welded to plate on sleeve carriage
- Track fits 80/20 posts



- Microphones can be positioned into different pre-drilled holes
- Holes will be at 15° increments
- More microphones can be added

Testing Protocol – Microphones

1. Find reference source
2. Attach microphones to DAQ system
3. Play audio from source
4. Record sound with microphones at 37 in
5. DAQ converts recorded data to pressure values in dB
6. Conversion program converts pressure values to power values
7. Check outputted data with reference values
8. Redo steps with compressor

Testing Protocol – Mobility

1. Start timer
2. Bolt rail system onto 80/20 on the test stand
3. Bolt arc bracket to sleeves on rail system
4. Screw microphones onto holsters on the arc bracket
5. Plug BNC cables into microphone and DAQ system
6. Plug DAQ system into computer
7. Stop timer

Testing of Targets

Function	Target	Pass or Fail Target
Vibration Detection	20-20,000 Hz	PASS
Measure Sound Pressure	92 dB	N/A
Deviation of Sound Power	$\pm$0.05 Watts	N/A
Compatible with Testing Stand	30 min	N/A

Problems Encountered and Solutions

Problems	Solutions
Laser to cut metal parts broke down	Outsourced laser cutting of parts
Data acquisition system lead time extended	Reached out to PCB to have next day shipping
Bolts would not sit flush on curved bracket	Ordered rubber grommets to press fit into holes

Future Work

- Program the microphones and DAQ system
- Calibrate and test microphone system with reference speaker
- Testing protocol for mobility
- Implement any changes necessary
- Final testing
- Engineering Design Day

Questions?

Most Important Points from this Lecture

1. The quick brown fox jumps over the lazy dog.
2. The quick brown fox jumps over the lazy dog.
3. The quick brown fox jumps over the lazy dog.
4. The quick brown fox jumps over the lazy dog.
5. The quick brown fox jumps over the lazy dog.
6. The quick brown fox jumps over the lazy dog.

Reference

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Questions (be sure to design your own)

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