Modeling and Mitigating Noise in an Industrial Material Handling Environment

Julie B. King, Ph.D., CSP

juking@AState.edu

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DR. JULIE B. KING

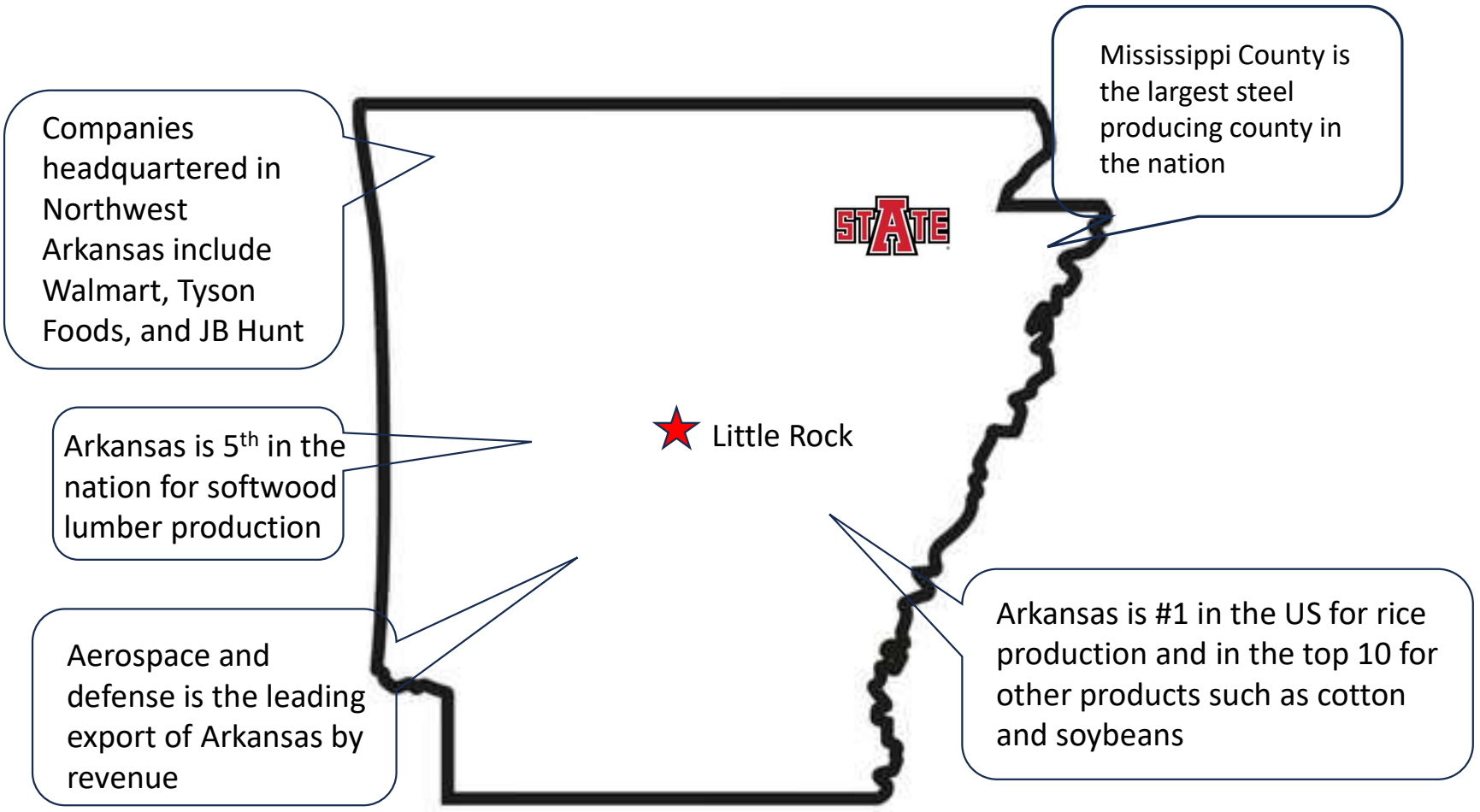
- **Education**
  - **B.S. in Chemistry**
  - **Ph.D. in Chemistry**
  - **M.S. in Environmental Sciences**
- **Current Roles and Responsibilities**
  - **Assistant Professor**
  - **Program Director for the Occupational and Environmental Safety and Health Program**
- **Research Interests**
  - **Mitigating Noise Exposures in Occupational Settings**
  - **Investigation of Pesticide Exposures in Agricultural Workers**

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A little about Arkansas



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Learning Objectives

- Review the basics of sound and the occupational exposure limits regarding noise
- Identify key noise sources from a basic sound survey contributing to worker exposure in industrial manufacturing and material-handling environments.
- Apply noise-modeling outputs to assess the impact of equipment and air handling systems on facility-wide sound levels.
- Evaluate engineering control options such as enhanced ductwork, acoustical barriers, and silencing technologies for reducing occupational noise.

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Introduction

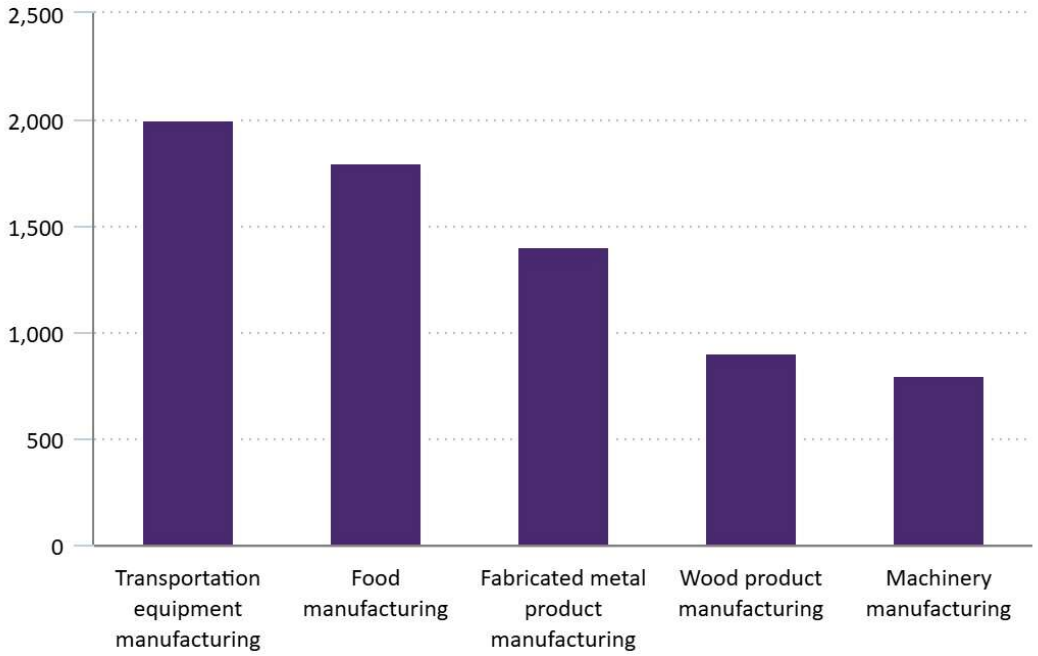
- Occupational noise exposure poses significant risks to worker health, safety, and productivity
- Especially challenging in industries that rely on metal fabrication and machining equipment
  - Can be a difficult problem
  - Sometimes, employers focus solely on PPE as the answer
- Not only is hearing loss a problem with industrial noise, but it can lead to stress, fatigue, cardiovascular strain, and an increased risk in workplace accidents

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Hearing Loss Statistics

Number of hearing loss illness cases in selected manufacturing industries, private industry, 2019



Hover over chart to view data.
Source: U.S. Bureau of Labor Statistics.

Hearing loss accounted for 11.4% of all illnesses reported in 2019.

There were a total of 14,500 hearing loss illness cases in 2019

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Typical Sound levels

Sound	dB level
Hearing threshold	0
Library	30
Normal conversation	60
Vacuum cleaner	70
Noisy restaurant	80
Inside car in city traffic	85
Table saw	95
Jackhammer	100
Gas engine lawnmower	105
Chainsaw	110
Siren	120
Threshold of pain	120-140
Gunshot	140-165

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Compliance with OSHA

- OSHA sets the *Permissible Exposure Level (PEL)* at 90 dB
  - 100% Dose
  - Exposure is defined as a time-weighted average over an 8-hour workday
  - When exposures exceed this level, feasible administrative and **engineering** controls should be used before personal protective equipment
- When exposures reach 85 dB for an 8-hour TWA, employees must be enrolled in a Hearing Conservation Program (HCP) (1910.95(g)(1))
  - 50% Dose

https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.95

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Requirements of HCPs

- Noise Monitoring
- Audiometric Testing
- Hearing Protection Devices
- Employee Training and Education
- Recordkeeping and Access to Information

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Other Relevant Standards

- National Institutes of Occupational Safety and Health (NIOSH)
  - 85 dB Recommended Exposure Level (REL)
    - The 100% dose under NIOSH
  - 3 dB Exchange Rate
  - Ceiling Limit 140 dB
- American Conference of Governmental Industrial Hygienists (ACGIH)
  - 85 dB Threshold Level Value (TLV)
  - 3 dB Exchange Rate

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Case Study

- Introduction
  - A large manufacturing operation handling metal all the way from metal sheets to finished product.
  - Has typical machining equipment including brake presses, punch presses, shears, cutters, grinders, etc.
  - Also has indoor air handling units throughout the facility
    - These air handlers are run from Mid-May until Mid-Septeber

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Case Study

- Preliminary Data
  - The organization's safety team worked with an industrial hygienist to measure workers' noise exposures with noise dosimeters
  - The data found areas in the facilities where personnel exceeded the (8-hour TWA) 85 dB Action Limit for OSHA for workers to be enrolled in a hearing conservation program.
  - Hearing protection is required of everyone on the production floor.

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Case Study

- Our research questioned whether there were ways to reduce noise in the facility for
  - Improved employee comfort and well-being
  - Reduced need for a Hearing Conservation program for some employees
    - Could some employees even be exempt from wearing hearing protection?

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Case Study

- Areas of Interest
  - Areas close to air handlers
  - Product fabrication and assembly areas
  - Product crating areas

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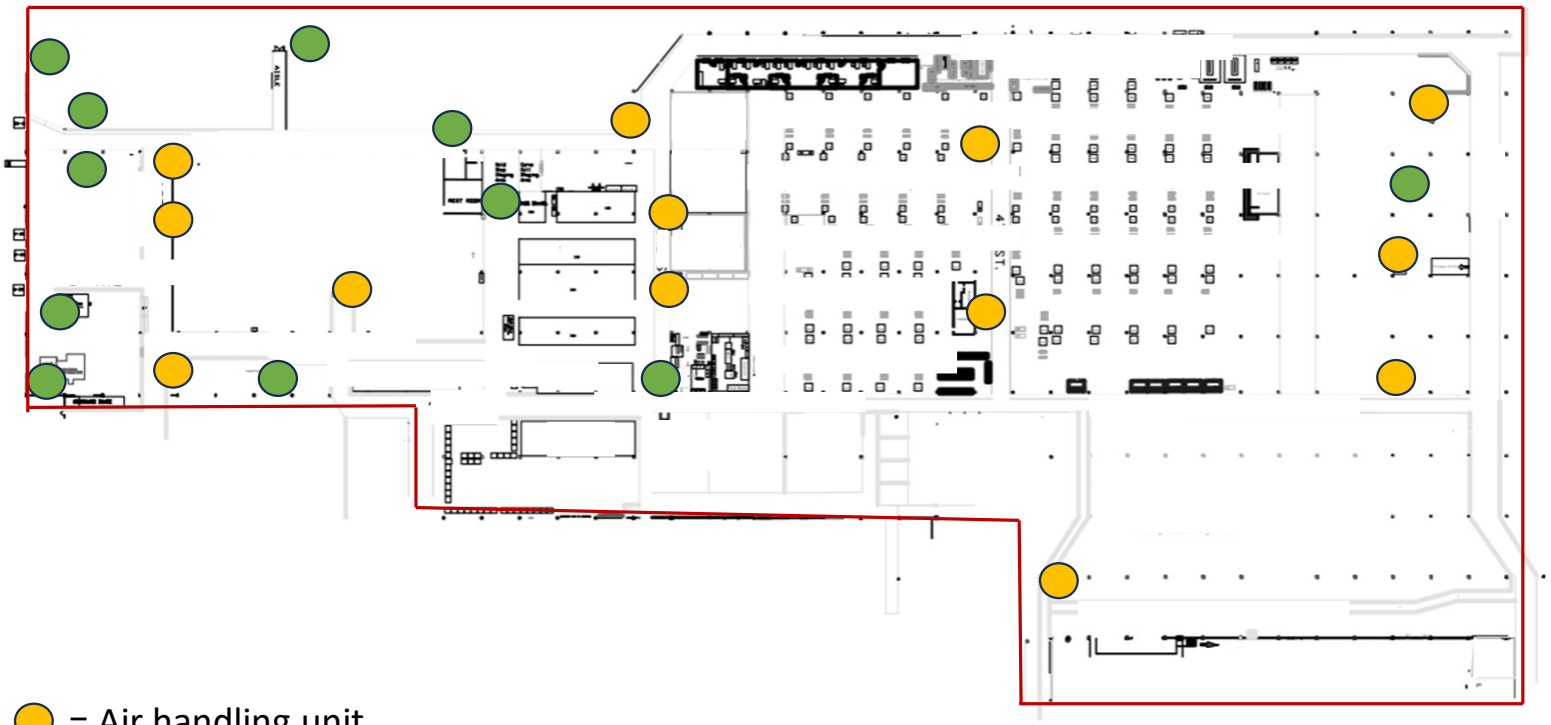
Preliminary Questions

- Are air handling units significant contributors to elevated noise levels in key production areas?
- Beyond air handling units, what other sources contribute to elevated noise levels in production areas?
- What additional engineering controls or operational changes are most effective and feasible for further reducing facility noise?

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Main Facility Layout



= Air handling unit

= Other significant sound source

Approximately 120,000 sq.ft footprint of the main fabrication facility

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Air Handling Units

- Carrier Rental Units
- Between 18,000 and 19,000 CFM
- 13 units for the main fabrication facility observed



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Benefits of Acoustic Modeling

- Some software is commercially available
- Fast prediction and visualization of new noise levels if new noise sources such as additional machinery is added in a facility
- Impacts of changes in noise levels perceived by workers in a facility
- Estimate changes in noise levels if acoustical treatments (e.g., acoustical ceiling tiles or silencers) are applied before investing **$$**

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Acoustic Modeling

- Full 3D model based on provided facility layouts
- Major sound sources (AC chillers, major equipment, etc.) modeled as omnidirectional point sources; this results in a conservative estimate for the measured facility noise
- What's important is the *reduction in noise* from modeled solutions

Notes on Model Implications

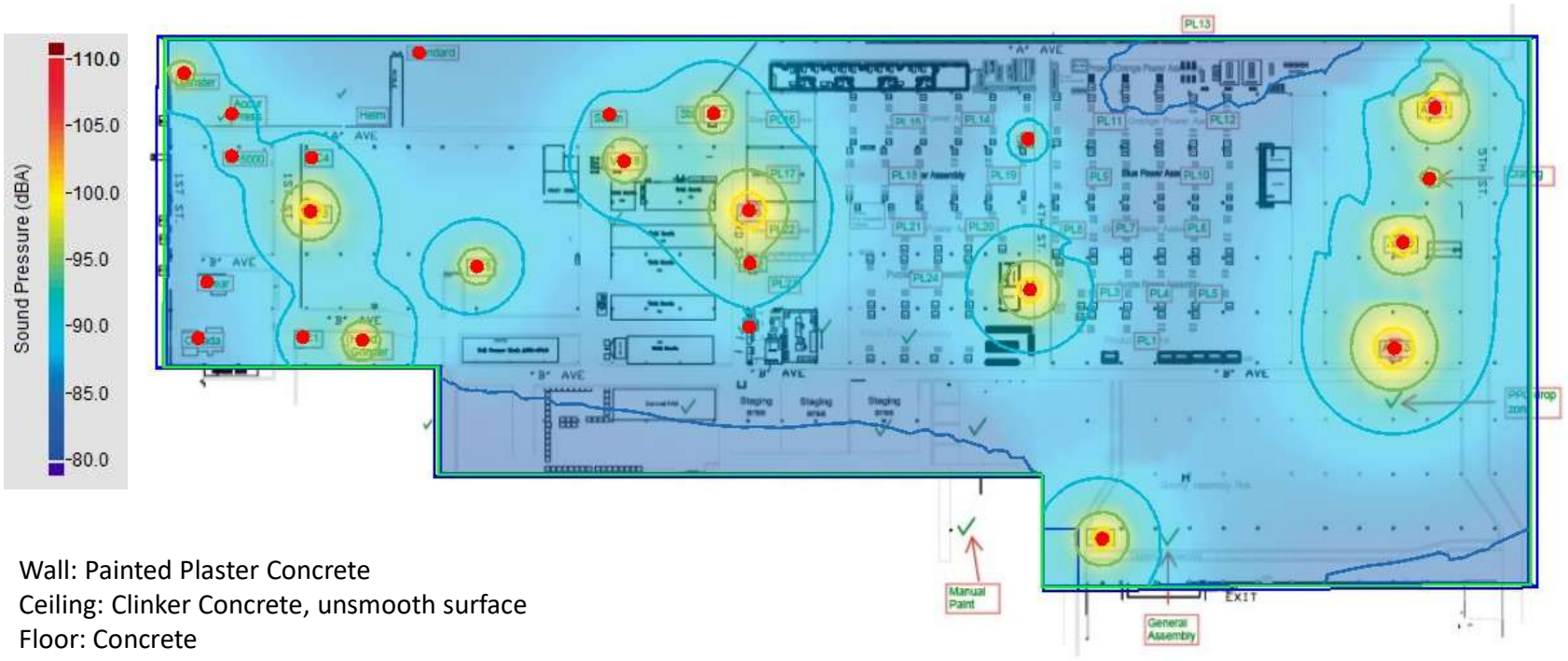
- The AC units are a major contributor to overall facility noise and focus of the models
- Measurements show that the primary acoustic source is the blower



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Main Facility



Wall: Painted Plaster Concrete
Ceiling: Clinker Concrete, unsmooth surface
Floor: Concrete
Source height: 6.56 ft (2 m) for AC units; 5’ 7” for equipment
Receiver level: 5’ 7”
Room height: 15.65 ft (average over whole facility)
Source strength estimated from sound survey measurements

$$(L_p)_{ave} = 89.8\ dB$$

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Potential Solutions for mitigating noise levels

- Ducting of the AC blower vents to the ceiling
- Installing Acoustic Tiles along the ceiling
- Acoustic Barriers around significant noise sources
- Acoustical silencers for the air handling units

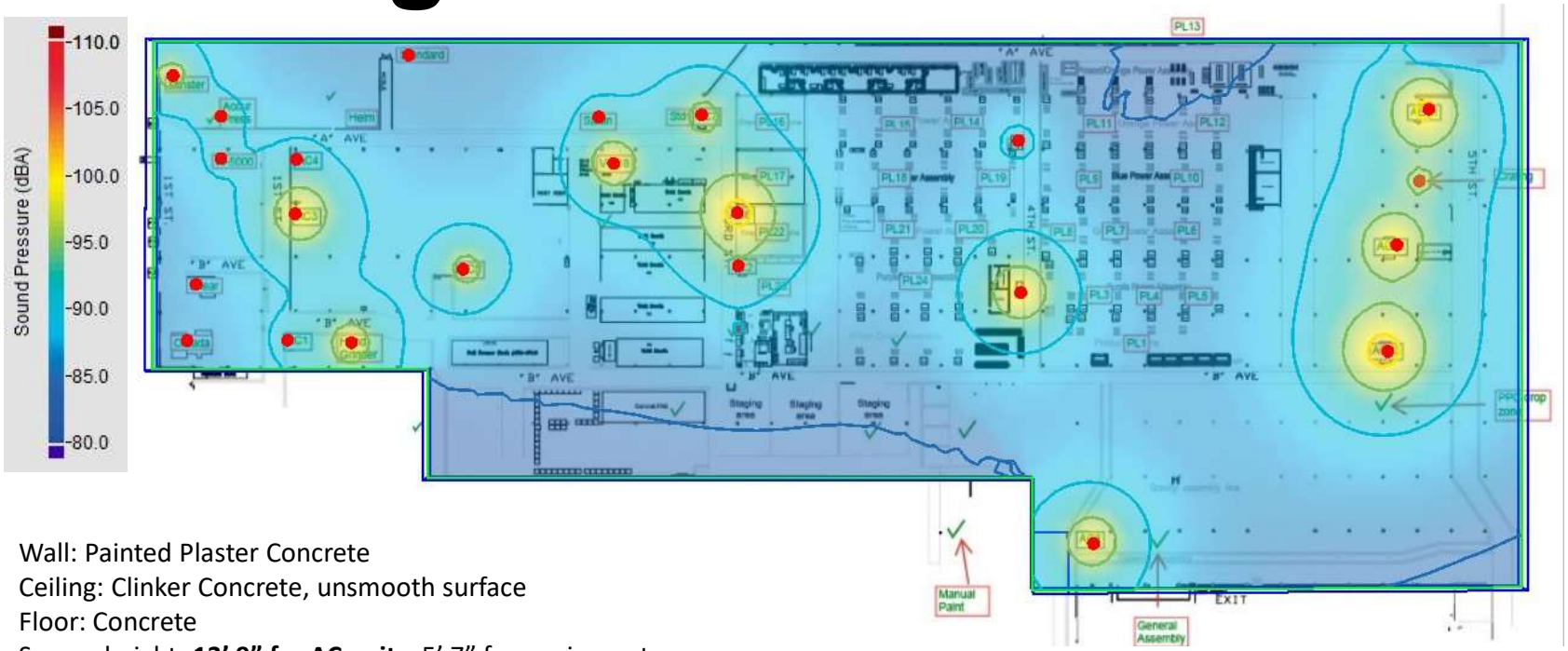
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Solution 1 – Ducting of AC units to Ceiling

- Replace and add ductwork from the air handlers to the ceiling.
  - Inexpensive engineering solution
    - Using high-quality materials: Approx. $8500 for the main facility
  - Can be done almost right away
  - Very little expertise is involved

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Solution 1 – Ducting of AC Units to Ceiling



Wall: Painted Plaster Concrete
Ceiling: Clinker Concrete, unsmooth surface
Floor: Concrete
Source height: **13’ 9” for AC units**; 5’ 7” for equipment
Receiver level: 5’ 7”
Room height: 15.65 ft (average over whole facility)

$$(L_p)_{ave} = 89.7 \text{ dB}$$
$$\Delta L_p = -0.1 \text{ dB}$$

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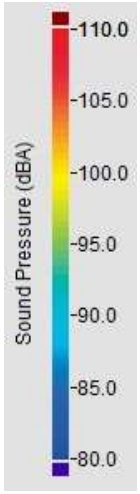
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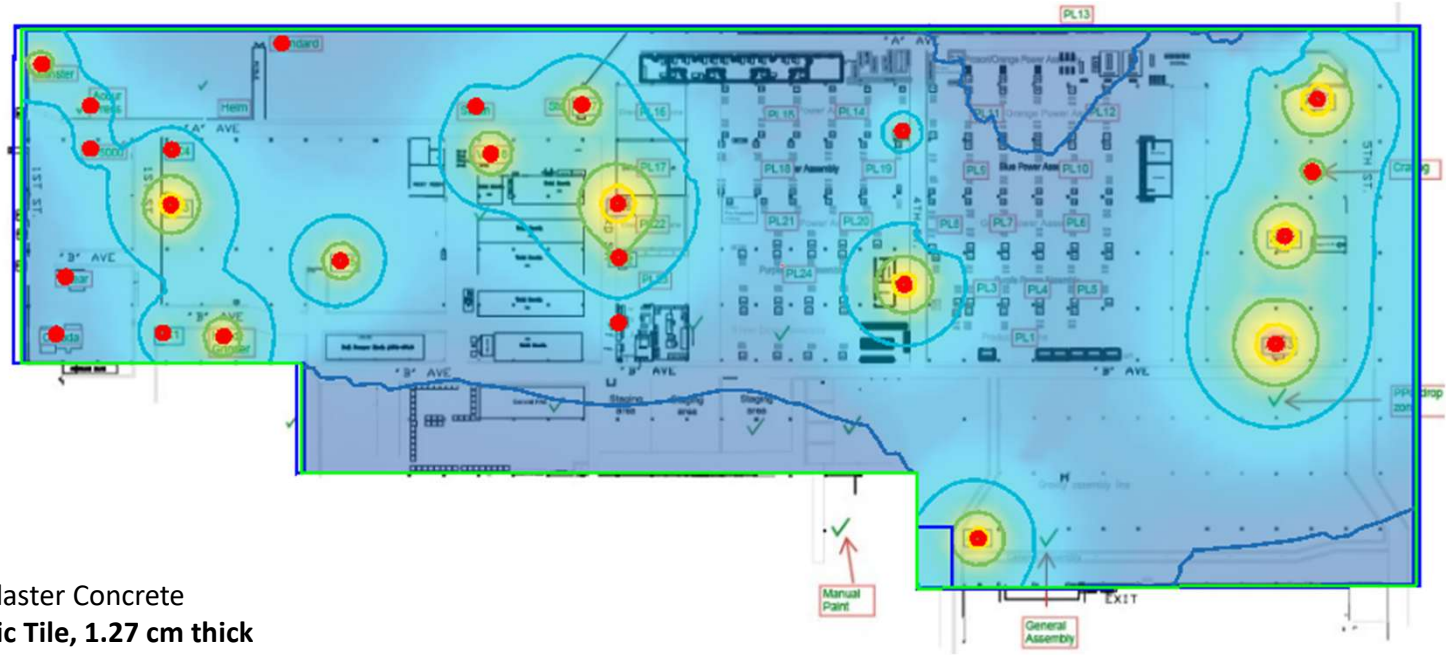
Solution 2 - Acoustic Tiles

- Potentially complicated
  - Many utilities are run along the ceiling
- 1.27 cm or 0.5 inches thick acoustic ceiling tiles
- Main Fabrication area: ~$200,000

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Solution 2 – Acoustic Tiles on the Ceiling





Wall: Painted Plaster Concrete
Ceiling: Acoustic Tile, 1.27 cm thick
Floor: Concrete
Source height: 6.56 ft (2 m) for AC units; 5’ 7” for equipment
Receiver level: 5’ 7”
Room height: 15.65 ft (average over whole facility)

$$(L_p)_{ave} = 88.6 \text{ dB}$$
$$\Delta L_p = -1.2 \text{ dB}$$

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Solution 3

- Add noise-cancelling partitions around the facility
- Done with soft fiberglass insulation as fiberglass is known to be sound-absorbing
- For the estimation:
  - Height of 3m (10ft) was used for all partitions.

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Solution 3 - Fiberglass Partitions

- All measurements are estimations and not exact. (1m = ~3.28ft)
- Thickness of the barrier of 5.1 cm or ~2 inches was used.
- Main Fabrication area
  - A running length of vertical barrier needed: 4500 ft.
  - At a height of 10 ft. for the barrier, the total area needed is 45,000 sq. ft.

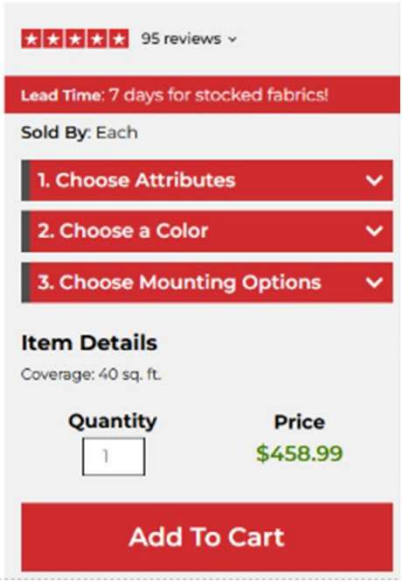
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Solution 3 – Soft Fiberglass Panels cost estimate

- Online retailers for acoustical fiberglass panels were used
  - Prices range from ~$450-$600 per panel
  - Different attributes and mounting options are available
  - Come in height of 10 ft panels
  - 2 inches thick
  - Coverage of 40 sq.ft. Per panel





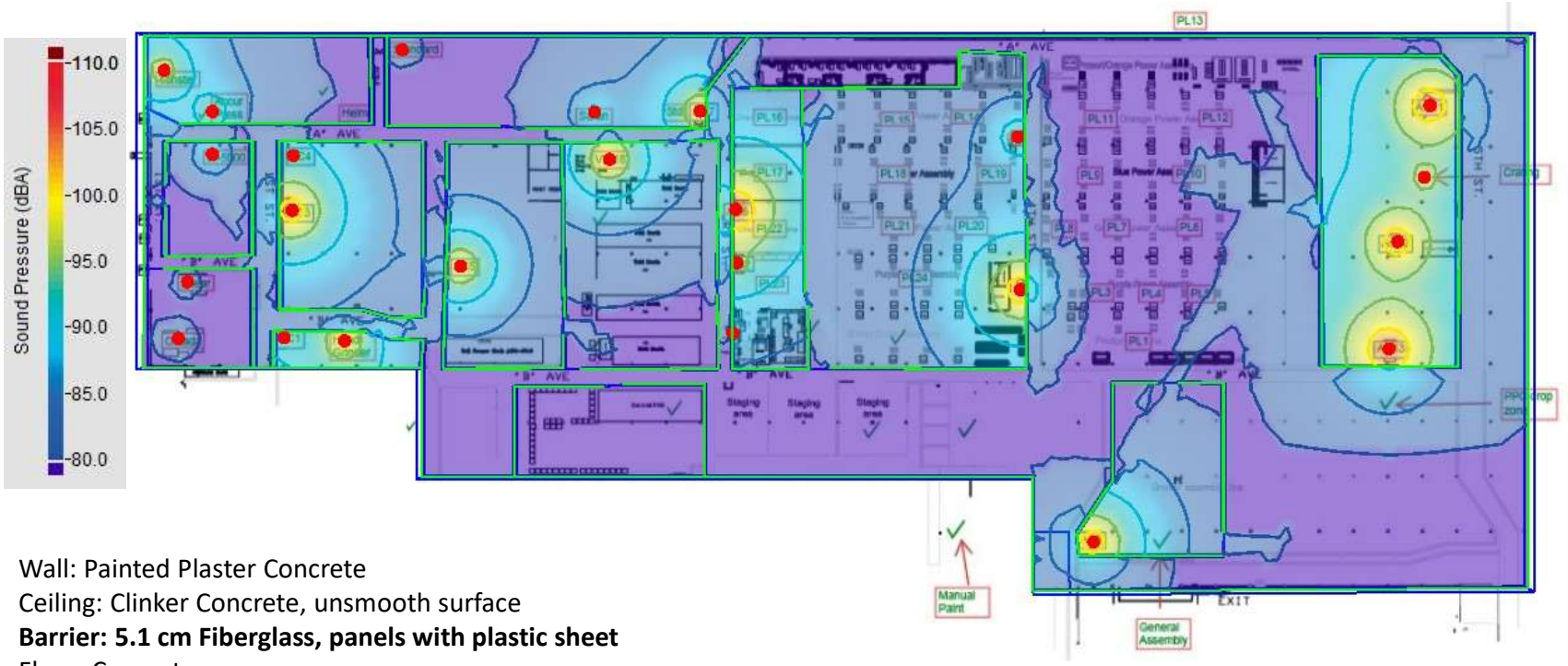
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Solution 3 - Costs

- ~$500 for a 4ft x 10ft unit
- Need about 1125 units for 45,000sq.ft.
- Plus installation (mobile or fixed)
- $562,500+

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Solution 3 – Acoustic Barriers



Wall: Painted Plaster Concrete
Ceiling: Clinker Concrete, unsmooth surface
Barrier: 5.1 cm Fiberglass, panels with plastic sheet
Floor: Concrete
Source height: 6.56 ft (2 m) for AC units; 5’ 7” for equipment
Receiver level: 5’ 7”
Room height: 15.65 ft (average over whole facility)
Barrier Height: 10 ft

$$(L_p)_{ave} = 79.2 \text{ dB}$$
$$\Delta L_p = -10.6 \text{ dB}$$

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Solution 4 - Circular silencers for the air handling blowers

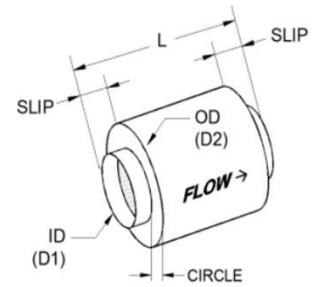
Revision Date	

Silencer Dimension (in)	
Tag	DIS 1
Model	19.5-KCCS-F-4-B0-48
Quantity	2
System	carrier
Diameter D1	19.5
Length	48
Circle Type	4
Bullet Code	0
Total Weight (lb)	234

Configuration	Circular
Face Velocity (fpm)	4,101
Flow Volume (cfm)	8,500
Pressure drop (in wg)	0.08

Silencer Module Dimension (in) / Weight (lb)	
Number of Pieces	1
Diameter D1	19.5
Diameter D2	28
Piece L	48
Weight each (lb)	117

Dynamic Insertion Loss		Airflow Generated Noise	
Hz	dB	Hz	dB
63	1	63	74
125	5	125	69
250	15	250	59
500	25	500	56
1000	26	1000	56
2000	13	2000	56
4000	11	4000	55
8000	5	8000	54



1. Silencer dimensions to be confirmed by customer prior to fabrication
2. The installed silencer pressure drop may be higher due to system effects caused by the location of duct elements upstream and downstream of the silencer
3. Tolerances are ±1/4" on all silencer units. If silencers are banked in series, the length tolerance needs to be allotted by the contractor
4. Silencer acoustic and aerodynamic performance data are in accordance with ASTM E477-13
5. Flame spread/smoke developed indexes in accordance with ASTM E84, NFPA Standard 255, UL 723, or ULC S102
6. Tested data tolerances are in accordance with AMCA 1011-03

Silencer Construction Options	
Casing Thickness	18 Gauge
Perforated Lining Thickness	22 Gauge
Material	Galvanized Steel
Acoustic Media	Fiberglass (Standard)
Media Covering	None
Inlet Connection	3" Slip Connection (Std)
Inlet Attachment Method	None

Notes



Special Note: Each one of these circular silencers are 48 inches long. *these are not something you just attach and go.

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Solution 4 - Silencer Cost

- For a set of duct silencers for the blowers, the noise reduction would be close to 25 dB at low frequencies – per the manufacturer of the silencers
- Total cost per air handler is $12,600 (not including installation)
- 13 units for main facility ~$164,000 + installation

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Solution 4 – Acoustic Silencers



Wall: Painted Plaster Concrete
Ceiling: Clinker Concrete, unsmooth surface
Floor: Concrete
Source height: 6.56 ft (2 m) for AC units; 5’ 7” for equipment
Receiver level: 5’ 7”
Room height: 15.65 ft (average over whole facility)
Source strength determined from sound survey measurements
AC unit source strength estimated from sound survey measurements with silencers installed at each one

$$(L_p)_{ave} = 76.8\ \text{dB}$$
$$\Delta L_p = -13\ \text{dB}$$

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Main Facility Summary

	Description	Average L_p (dB)	ΔL_p (dB)
Current	-----	89.8	-----
Solution 1	Ducting	89.7	-0.1
Solution 2	Ceiling Acoustic Tiles	88.6	-1.2
Solution 3	Acoustic Barriers	79.2	-10.6
Solution 4	Acoustic Silencers	76.8	-13



Current Configuration



Silencers

Acoustic Barrier

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Conclusions

- Air handling unit blowers are confirmed as a major source of excessive noise and can be addressed with targeted engineering solutions.
- Engineering controls—such as ductwork modifications and acoustic barriers—can reduce noise by up to 13 dB
- Addressing non–air handling sources of facility noise will require a combination of equipment upgrades, acoustic treatments, and operational adjustments.
- Implementing cost-effective solutions could reduces reliance on personal protective equipment and enhance employee well-being.

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Continuing Studies

- Evaluate additional available noise modeling software
- Evaluate the effectiveness of mitigation strategies for equipment, layout, and workflow changes.
- Explore advanced materials and technologies for noise reduction beyond air handling systems.
- Assess long-term impacts of noise mitigation on employee health, safety, and productivity.

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Contact Information

- Julie King, Ph.D., CSP
- Email: juking@astate.edu

Scan to receive contact information

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