October 23, 2020

Development and Qualification of an Anechoic Termination

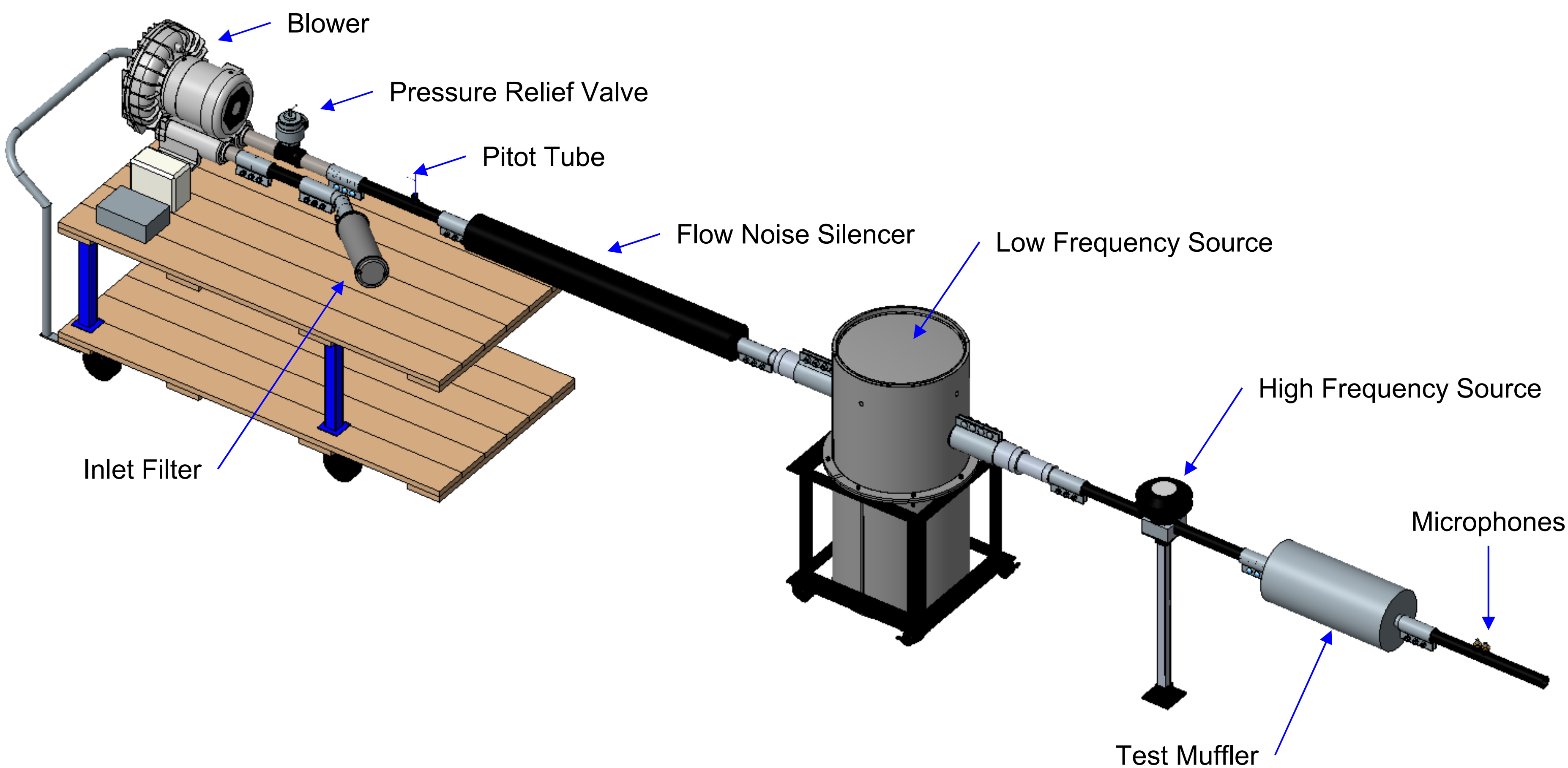
Seth Donkin
University of Kentucky

Vibro-Acoustics Consortium

Objective

Develop and qualify an anechoic termination for use with muffler test flow rig.

Background Flow Rig



Background Flow Rig

Background Specification Summary

Pressure Range: $0 - 110\ \mathrm{H_2O}$

Flow Velocity Range: $0 - 0.17\ \mathrm{Ma}$

Plane Wave Cutoff Frequency

$$f_{cutoff} = \frac{1.84c}{\pi D_o}\sqrt{1 - M^2}$$

Mach Number [Ma]	Cutoff Frequency 2" OD - [Hz]
0	3957
0.05	3952
0.1	3936
0.15	3911

Background Qualification Summary

The flow rig is currently qualified for:

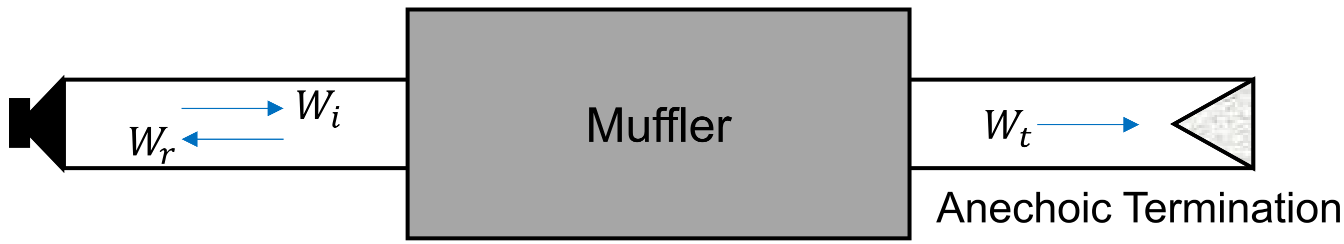
i. Flow rate
ii. Pressure Drop
iii. Transmission Loss (No Flow)
iv. Noise Reduction (No Flow)
v. Insertion Low with Flow

Rationale for Anechoic Termination

Uses for anechoic terminations

I. Measurement of the sound power of fans and other air-moving devices

II. Measurement of transmission loss (TL) – No reflected wave in tailpipe so TL can be measured directly with only a single acoustic load.



$$TL(dB) = 10\log_{10}\frac{W_i}{W_t}$$

Anechoic Termination Standard

ISO-5136

- Standard to determine sound power for ducted fans and other air-moving devices.
- Prescribes a maximum pressure reflection coefficient for qualifying an anechoic termination
- Provides examples of anechoic termination designs

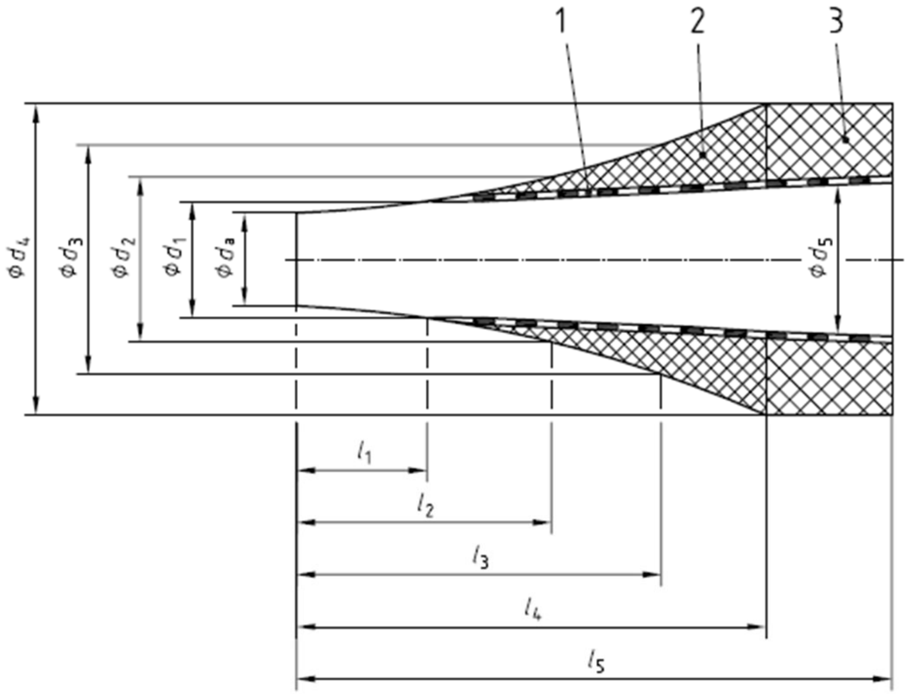
Table 5 — Maximum permissible values of the pressure reflection coefficient of the anechoic termination

One-third-octave-band centre frequency	Maximum pressure reflection coefficient	
Hz	Test duct	Terminating duct
50	0,4	0,8
63	0,35	0,7
80	0,3	0,6
100	0,25	0,5
125	0,15	0,3
160	0,15	0,3
> 160	0,15	0,2

NOTE 1 An open duct end of 1,6 m diameter fulfils the maximum pressure reflection coefficient requirements for terminating ducts.

NOTE 2 The anechoic termination for the termination duct is needed only to establish a basically non-reflective acoustic load impedance; no sound pressure measurements are to be made in the terminating duct. Therefore, the maximum permissible pressure reflection coefficient of the anechoic termination of the terminating duct is greater than that of the test duct.

Catenoid Termination ISO-5136



Inlet diameter (m)		0.46	
d_1	0.529	l_1	0.6624
d_2	0.7544	l_2	1.3294
d_3	1.035	l_3	1.7894
d_4	1.5824	l_4	2.3506
d_5	0.7682	l_5	2.9624

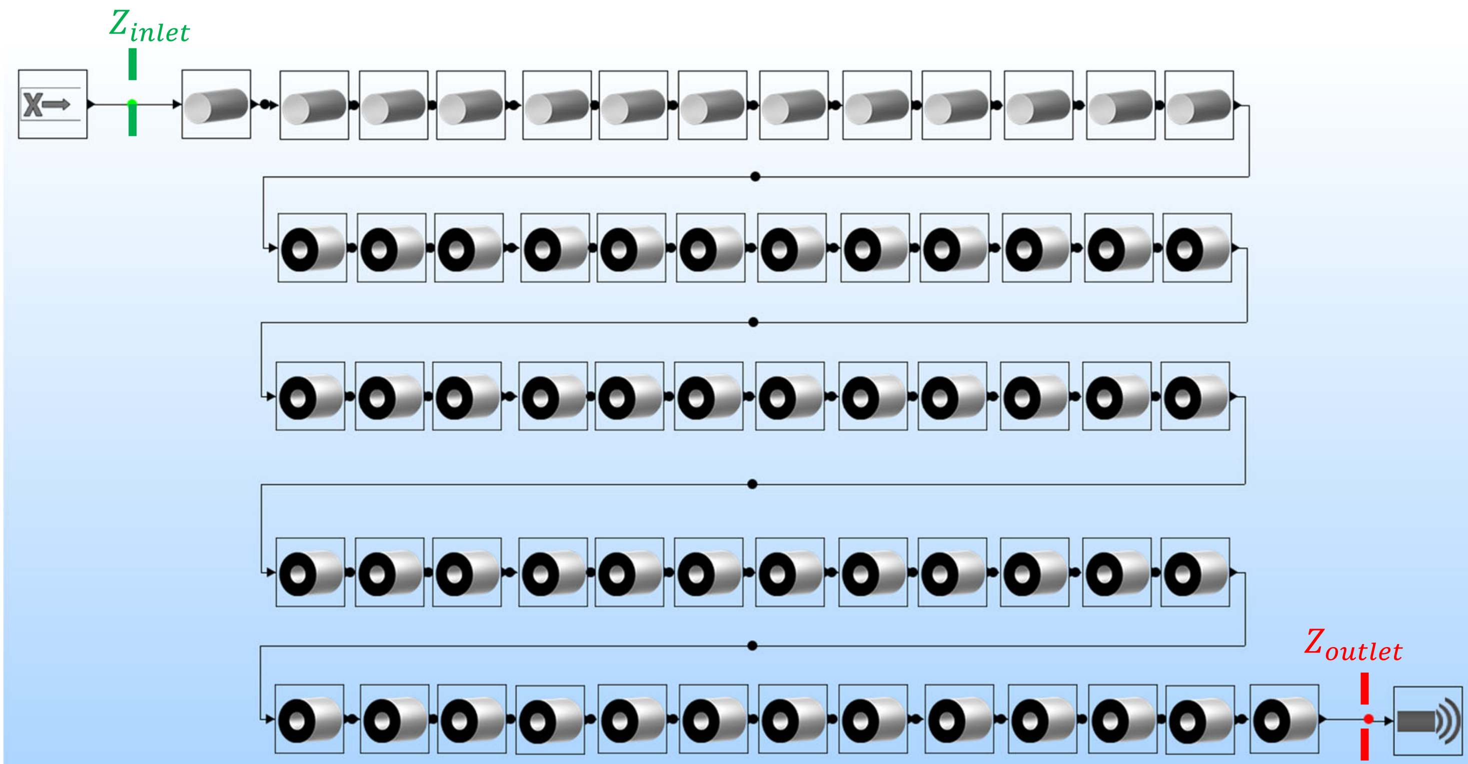
Key

1 perforated metal, approximately 58 % open

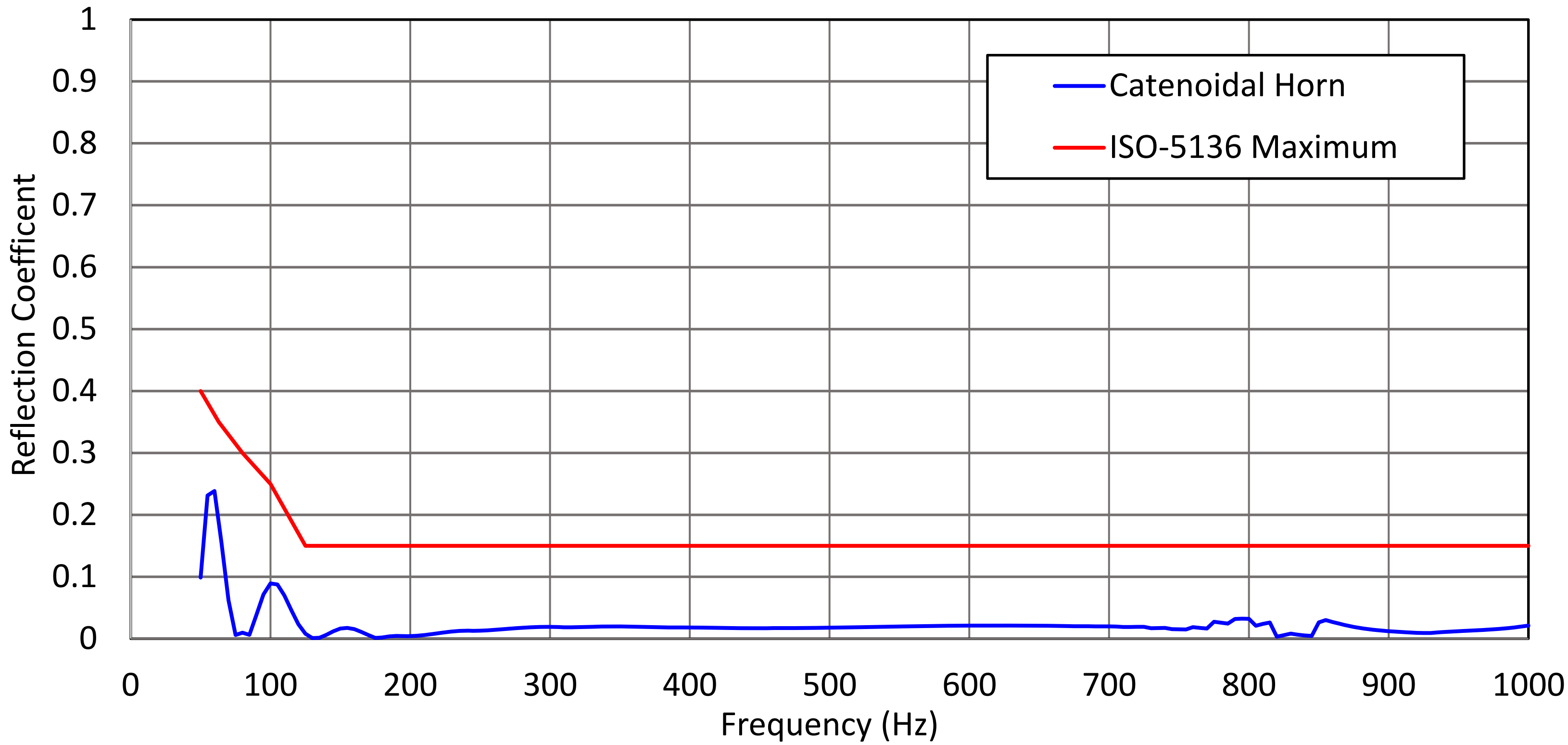
2 open-celled foam or fibreglass having a density of 24 kg/m^3

3 fibre glass having a density of 48 kg/m^3

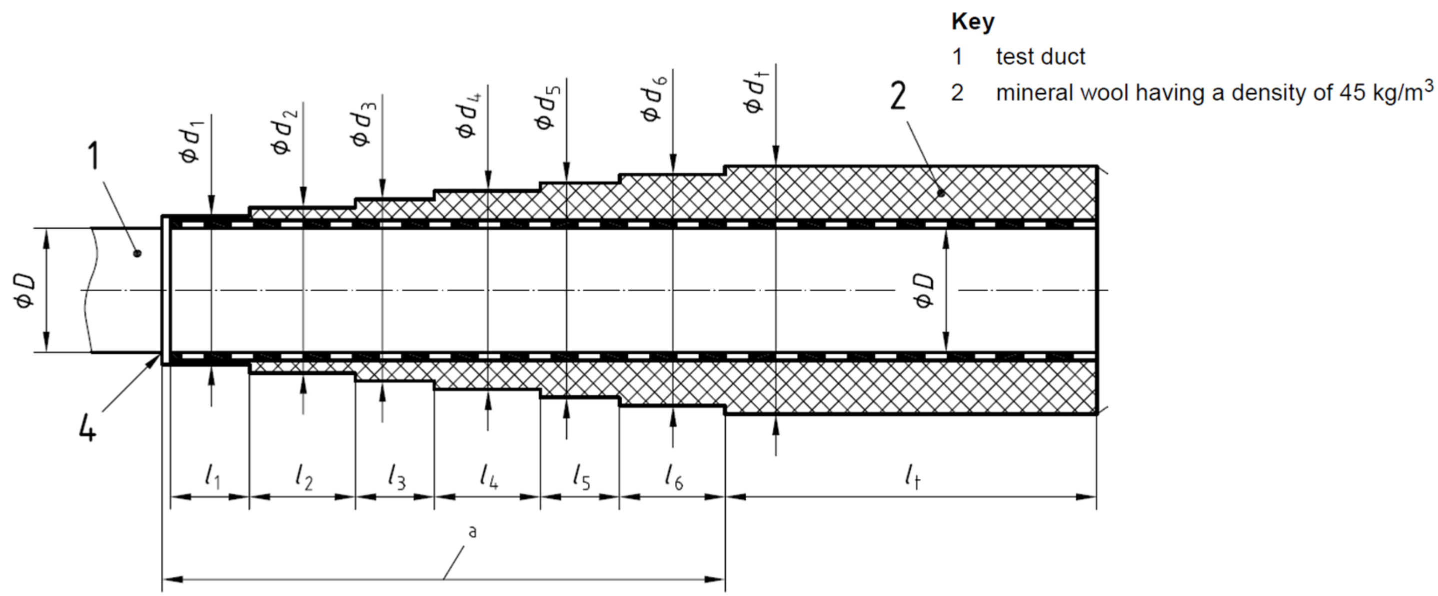
Catenoid Termination SIDLAB



Catenoid Termination SIDLAB



Stepped Termination ISO-5136

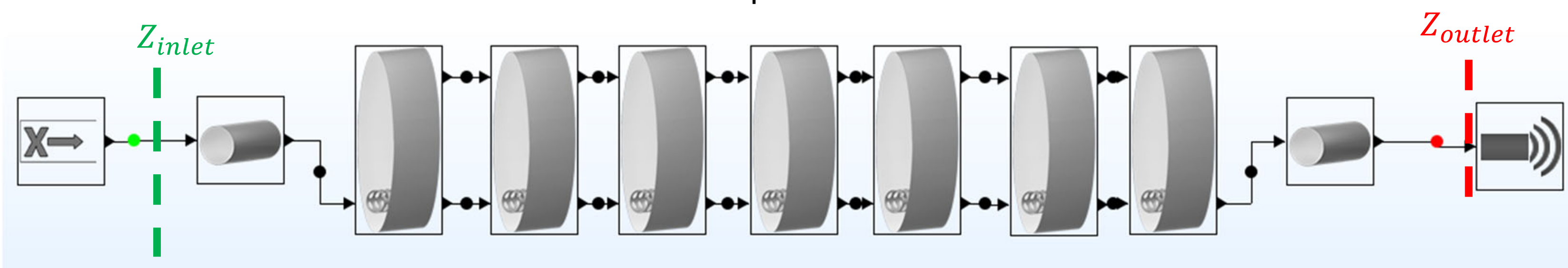


Dimensions in millimeters

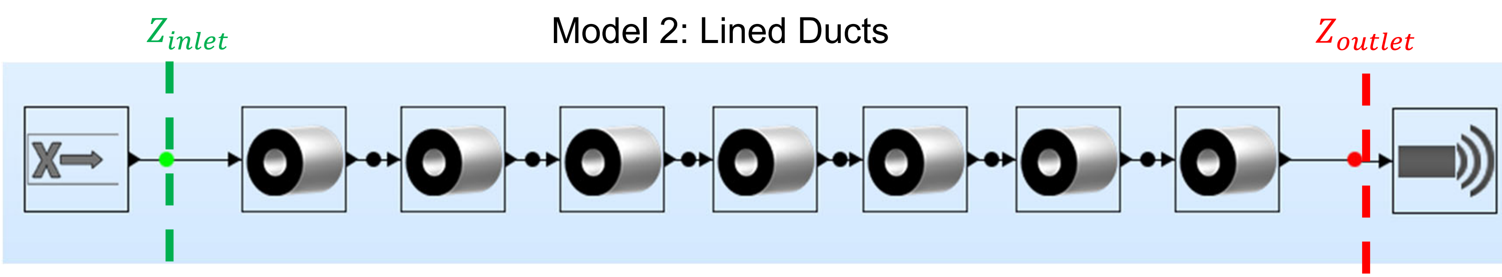
Test duct diameter $\varnothing D$	No. step expansion	d_1	l_1	d_2	l_2	d_3	l_3	d_4	l_4	d_5	l_5	d_6	l_6	Terminator diameter d_t	Terminator length l_t
400	6	450	240	500	320	550	240	600	320	650	240	700	320	750	1 125

Stepped Termination SIDLAB

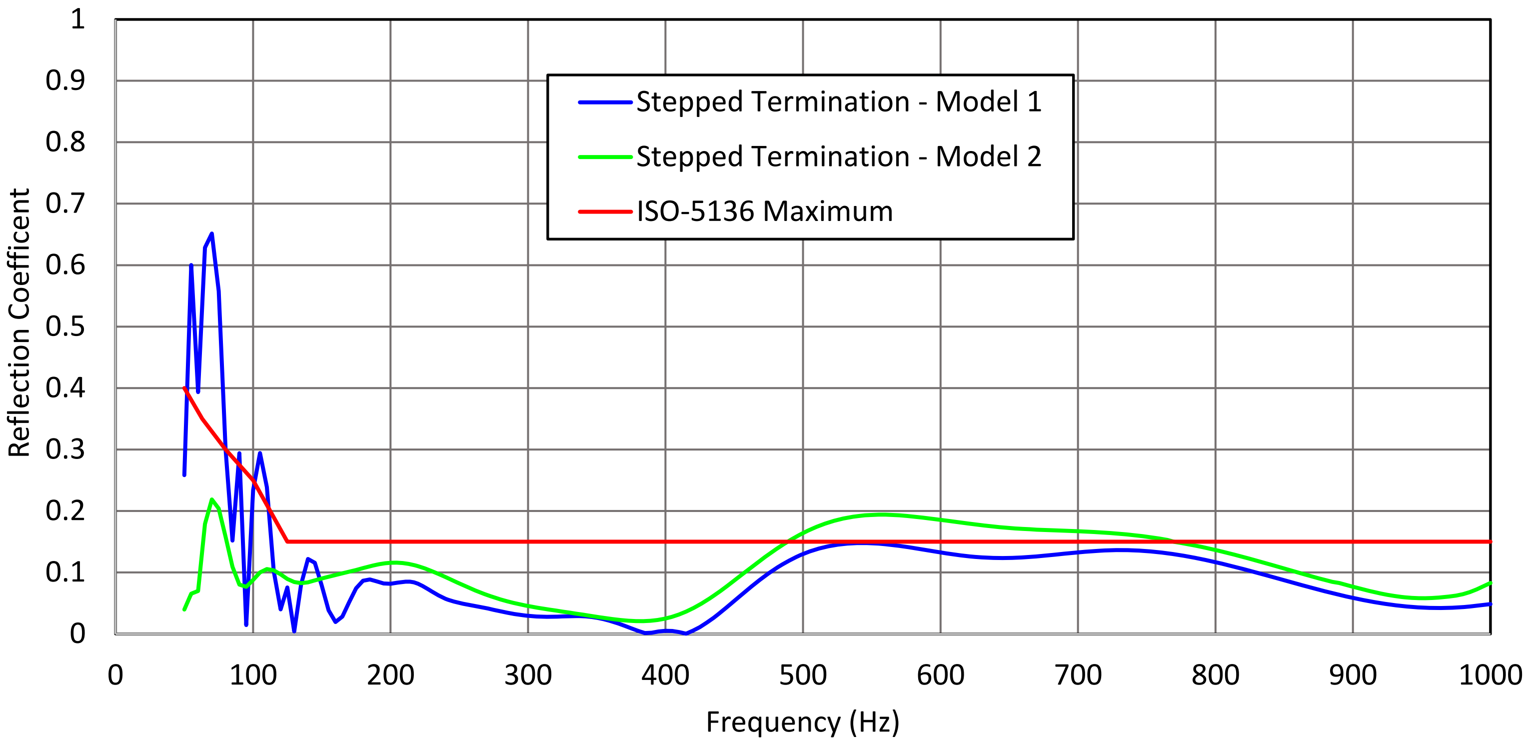
Model 1: 4-pole elements



Model 2: Lined Ducts



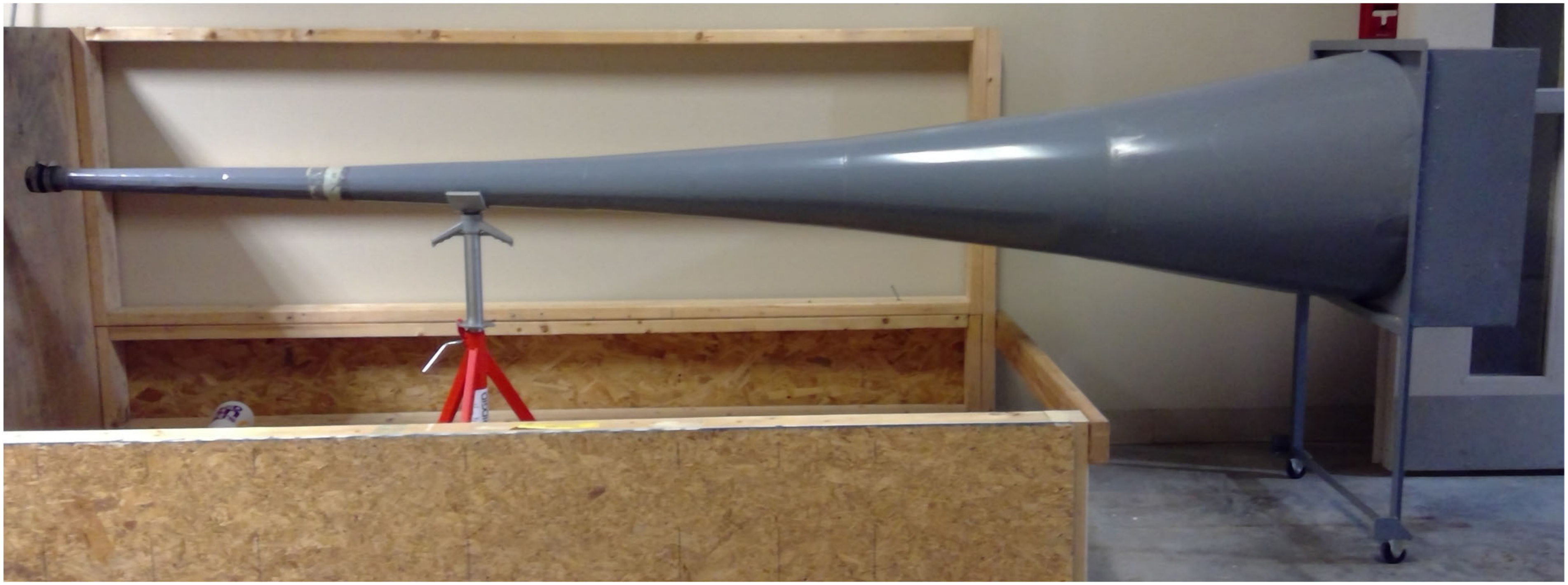
Stepped Termination SIDLAB



Anechoic Termination

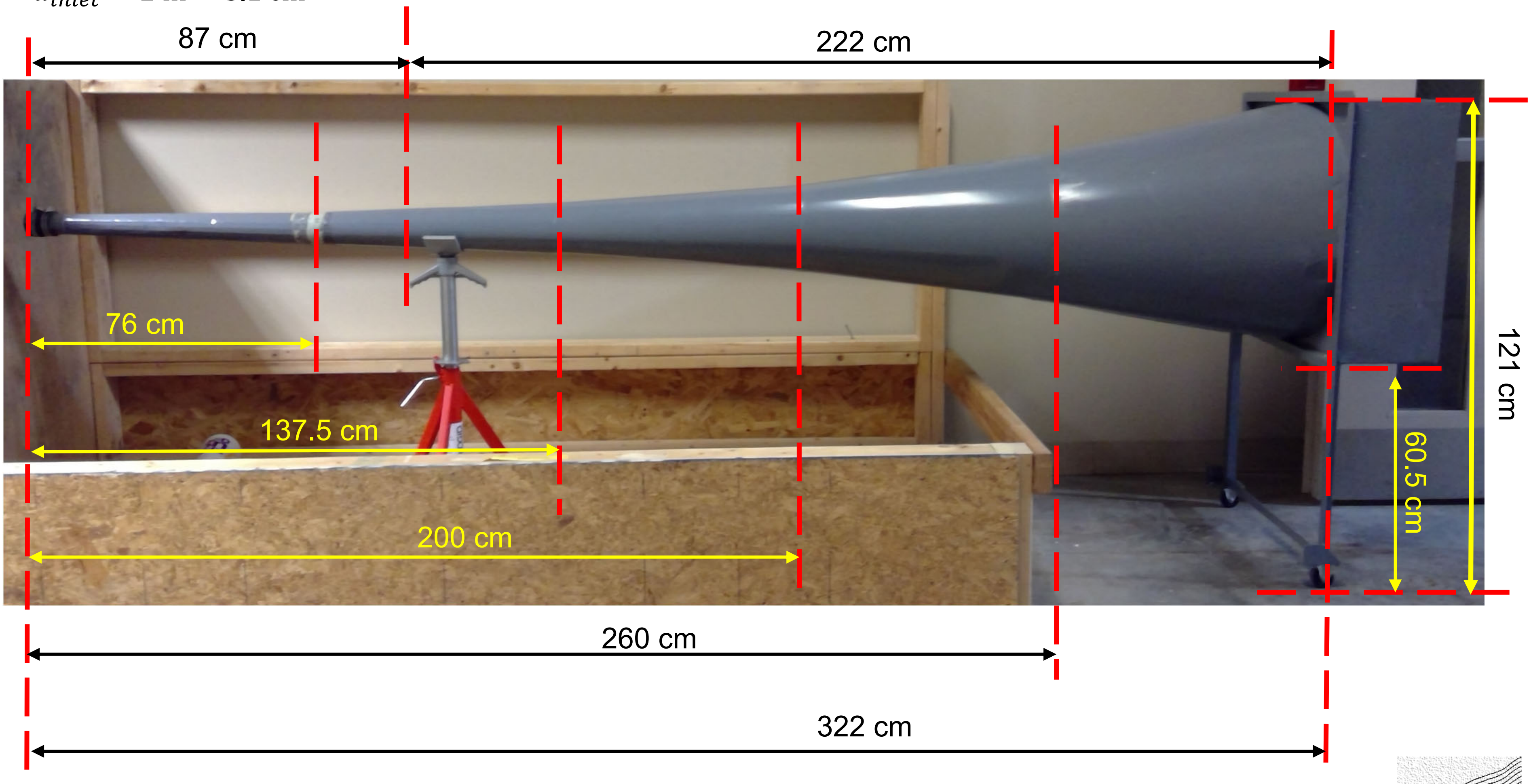
Donated by Dr. Hank Howell.

Total Length: 3.4 m (~11 ft)



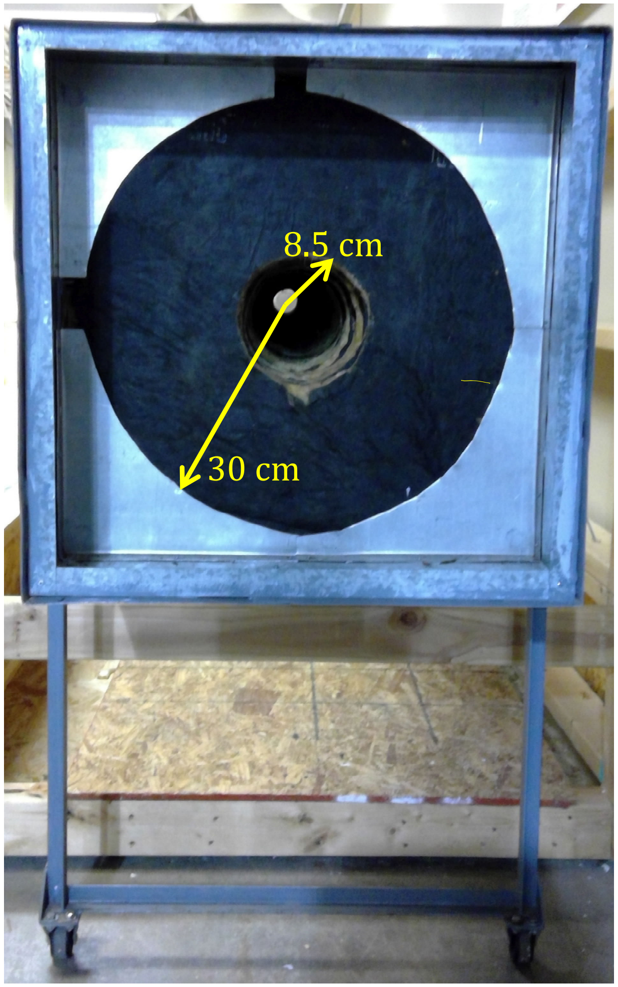
Anechoic Termination

$d_{inlet} = 2 \text{ in} \approx 5.1 \text{ cm}$



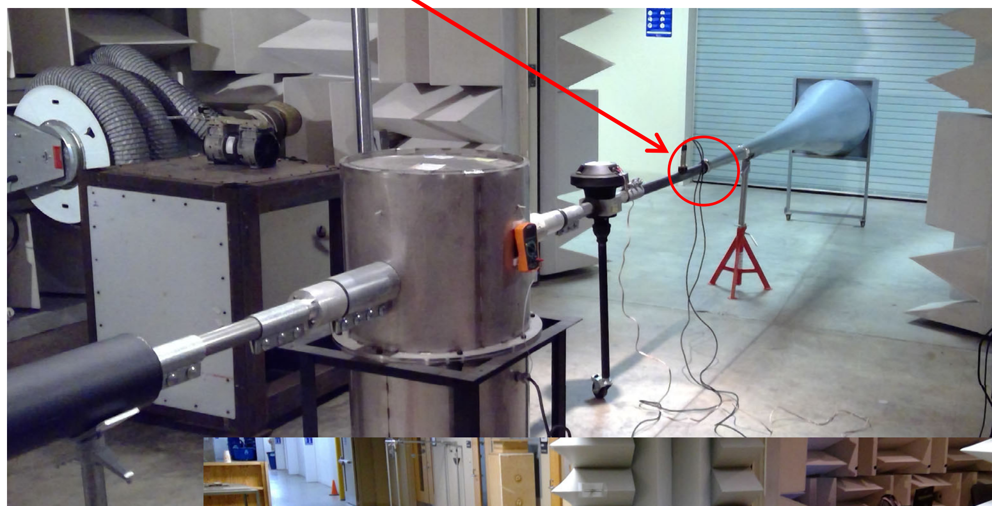
Anechoic Termination

End View

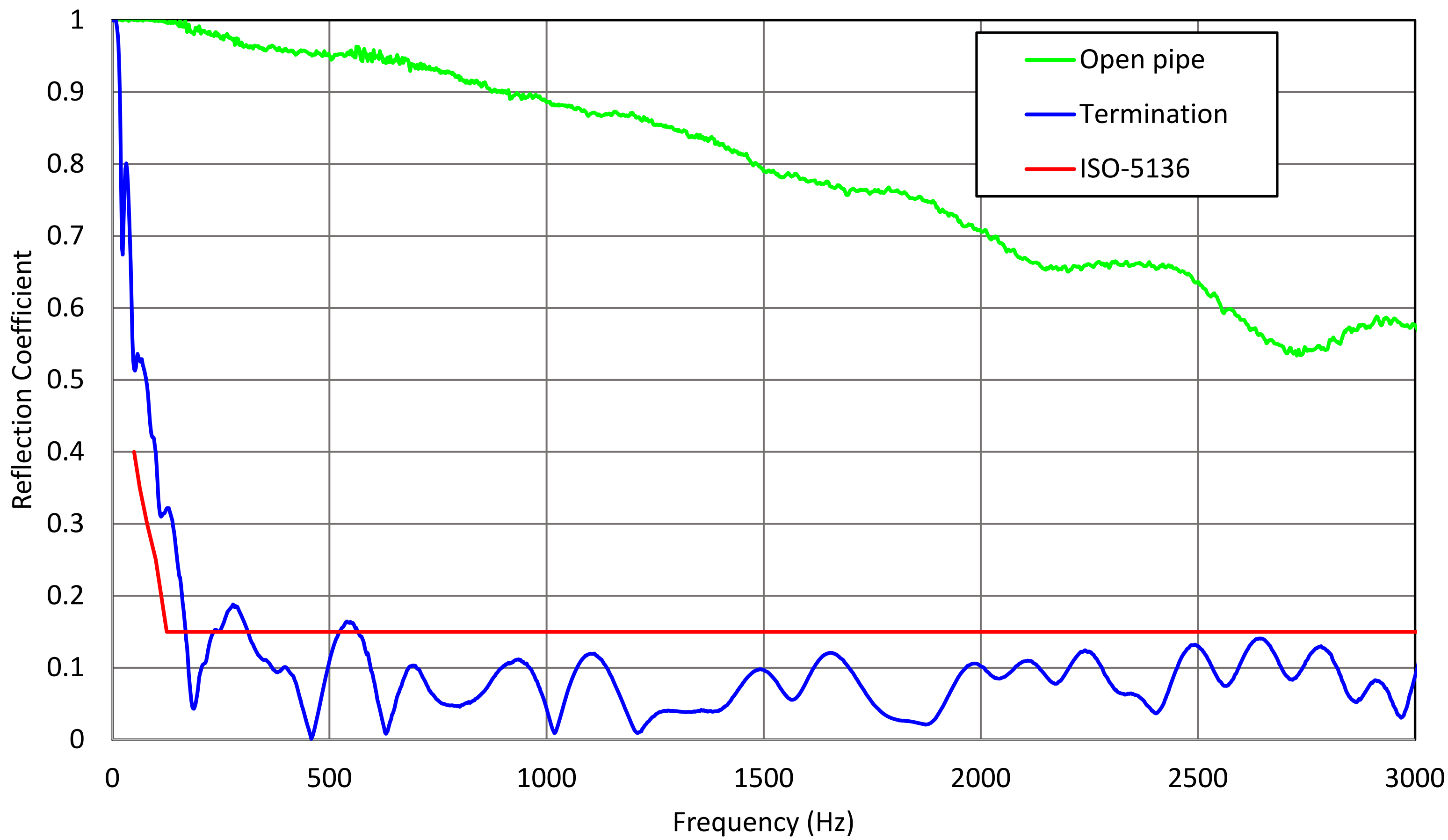


Reflection Coefficient Measurement

Use ASTM E1050 to find $|R|$

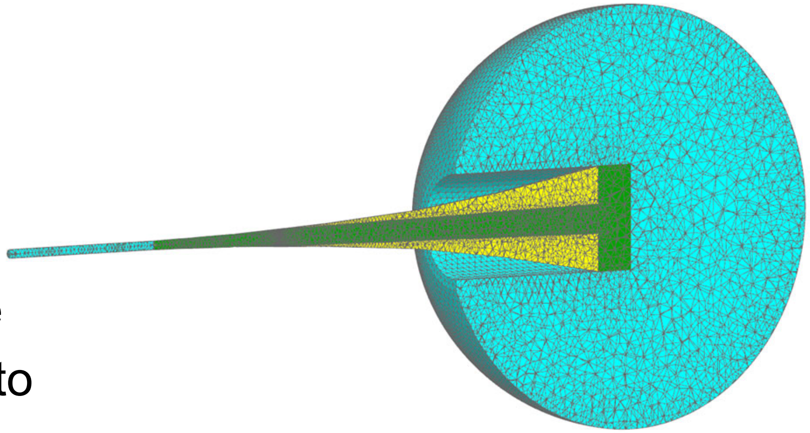


Reflection Coefficient Measurement



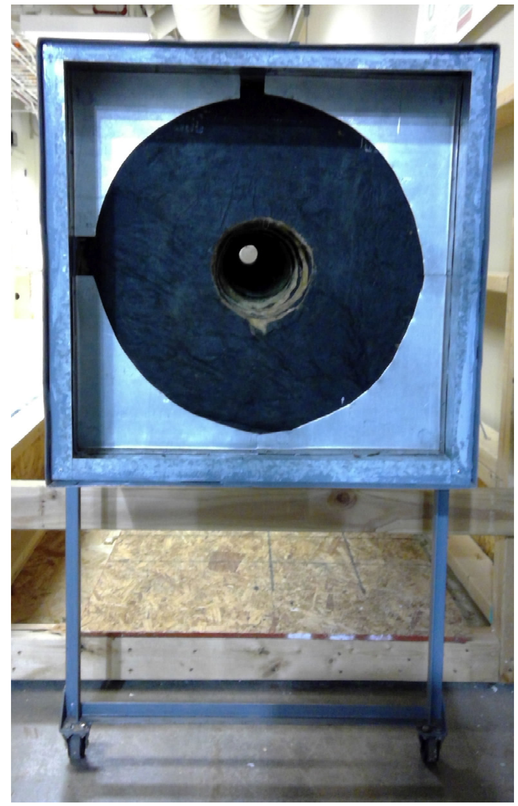
FEM Simulation

- Anechoic source.
- No flow.
- Unit normal velocity at the inlet.
- To replicate the outlet condition a "mushroom" of air is modeled around the outlet of the horn and an AML is applied to outer surface.
- Sound pressure is measured at two positions to determine reflection coefficient.

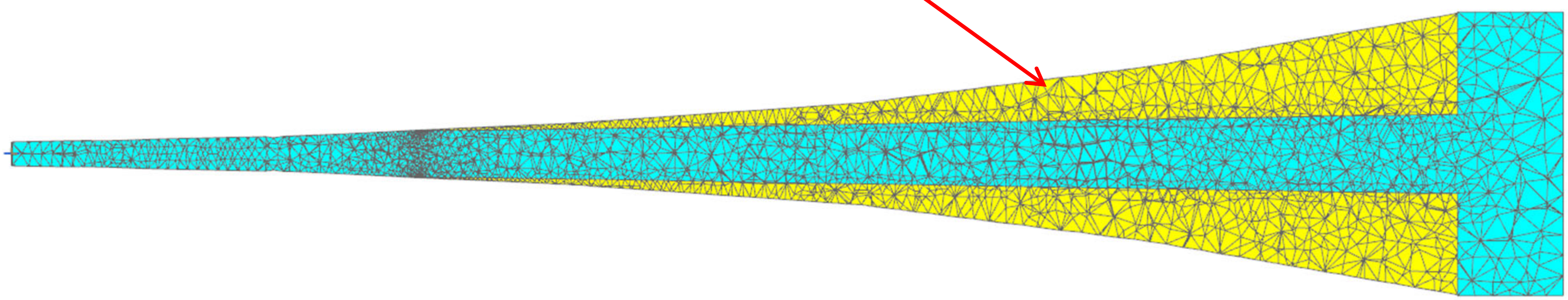


FEM Simulation

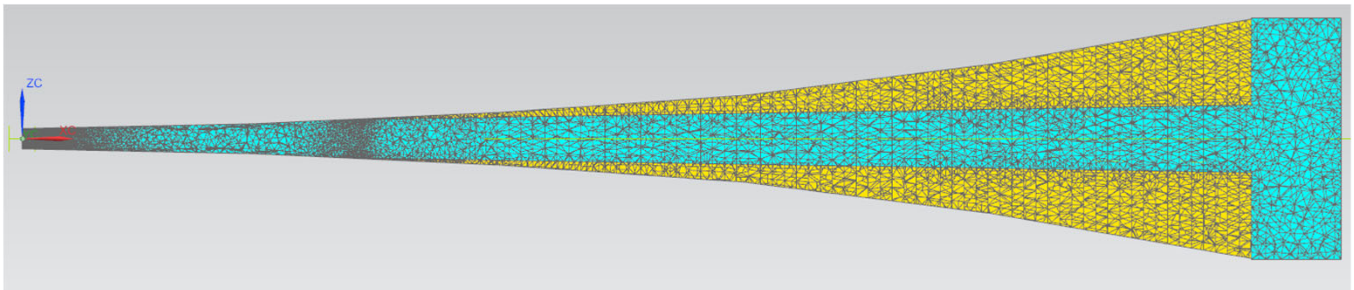
- Currently it assumed to be a porous material defined using the Delany-Bazley-Miki model with the properties:
  - Mass density: 30 kg/m^3
  - Static Flow Resistivity: 12,000 Rayls
  - Porosity: 0.95

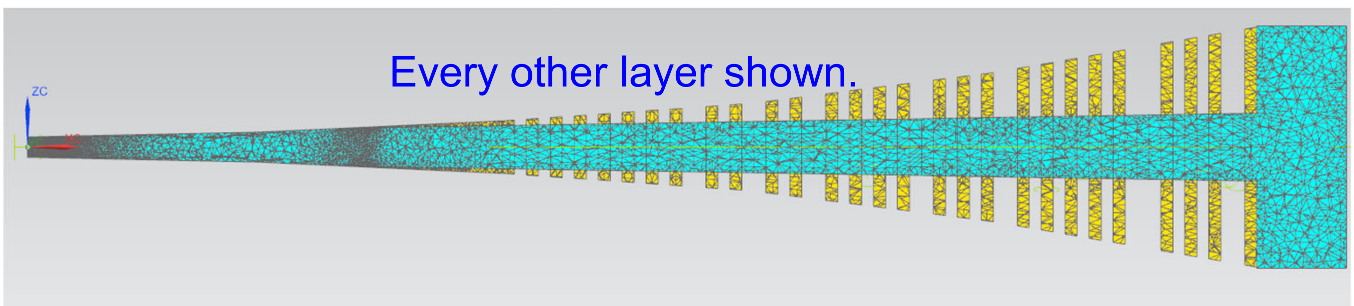


FEM Simulation Method 1



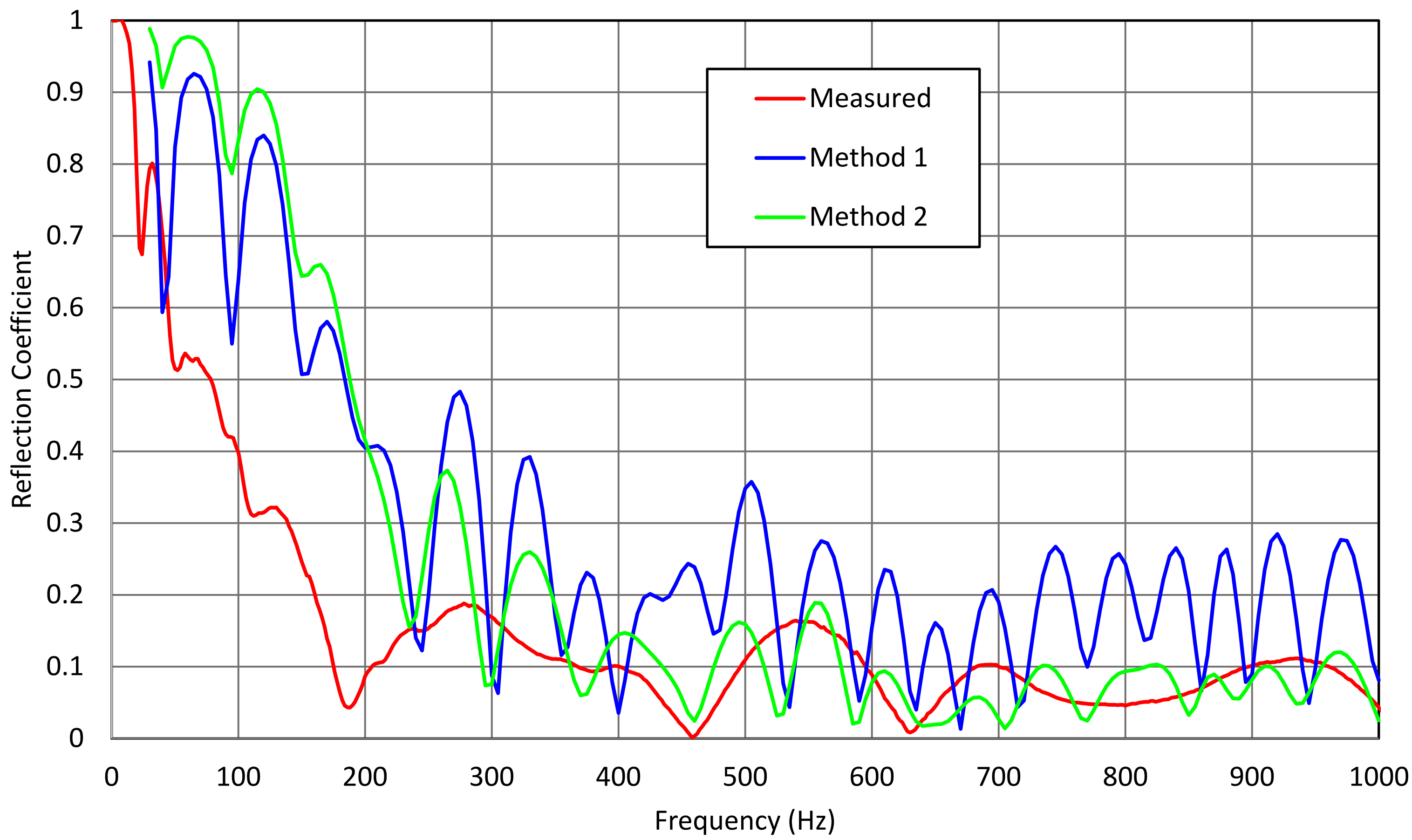
FEM Simulation Method 2





Independent sections are modeled to force a local reacting model.
Simulates high resistive fabric layer between fiber sections.

FEM Simulation



Future Work

- Further improve the Siemens Simcenter simulation.
- Measure reflection coefficient of the anechoic termination under a range of flow conditions.
- Measure transmission loss of simple mufflers with flow.