NWAA Labs, Inc :

Old Problems, New Solutions: Architectural Acoustics in Flux Redux

1. Introduction:

Ron Sauro
President NWAA Labs, Inc.

The Man Behind It

A young boy in a high school physics class builds an "Atom Smasher" (electron accelerator) in 1962 as a science fair project and is told he does not have the discipline needed to be a scientist.

That same year he is the sole survivor of a small aircraft crash during search and rescue operations with CAP. In 1963, he and his friends record a top 10 rock and roll record

The Man Behind It

He volunteers to join the Air Force in 1964, is trained as a radar maintenance technician and survives being shot, as an advisor, in Viet Nam on "Gulf of Tonkin" day. He learns discipline the hard way. During his 4 years in the service he survives two "fatal" car crashes.

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The Man Behind It

Cambria AFS, CA

The Man Behind It

Upon discharge the young man goes to work as a technician for NASA at Ames Research Center, CA in 1968. Because of a shortage of scientists and engineers in 1968-69, he competes and is selected to attend Stanford University under a special program designed by NASA to develop their needed scientists.

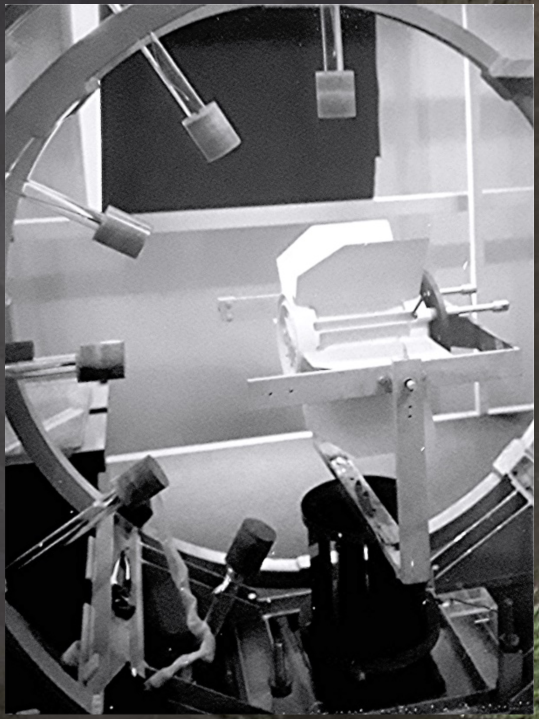
The program is a 1 year, highly compressed, advanced placement program and results in an “Engineering Scientist” certification, with basic degrees in physics, electronics and mechanical engineering.

The Man Behind It

As a result of the first airline hijacking by D.B. Cooper, he is tasked with detecting guns being smuggled onto an aircraft. He invents the first "Metal Detector" used in airports.

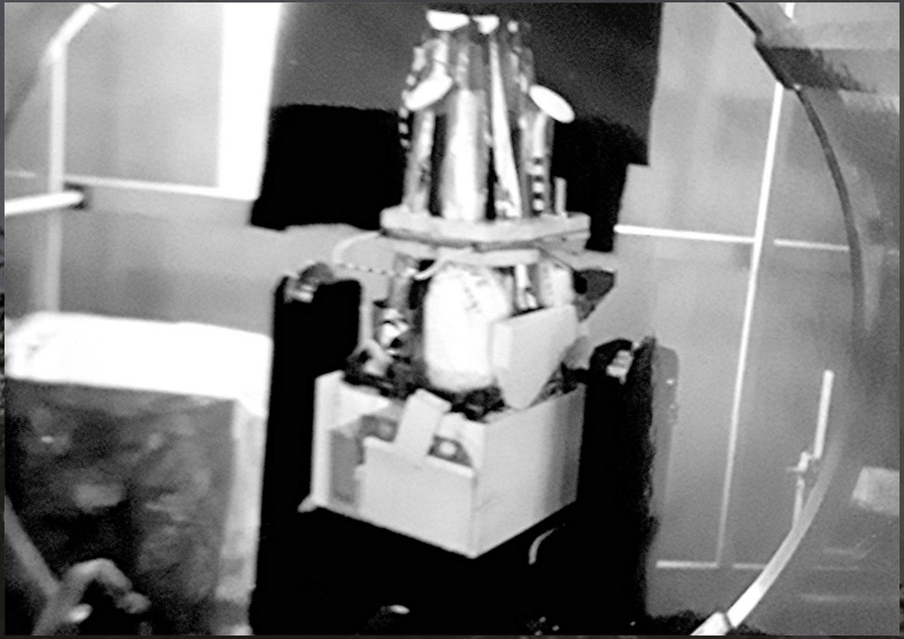
The Man Behind It

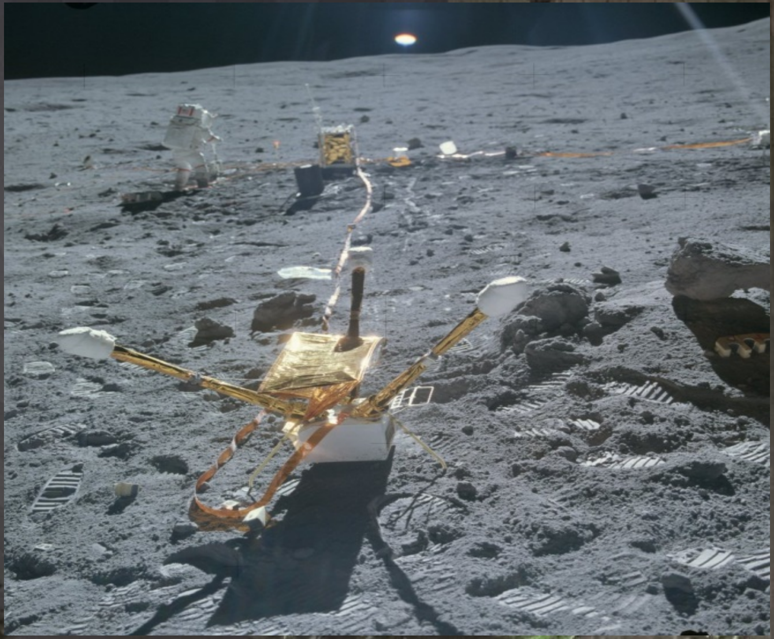
Ron then invents the test equipment needed to measure the magnetic signature of the miniature atomic reactors on space probes. This includes the first multi-channel, solid state magnetometer and multi position magnetometer mounting system. In addition, he designs the first solid state, multi channel, high speed, data acquisition system using a cassette storage medium.



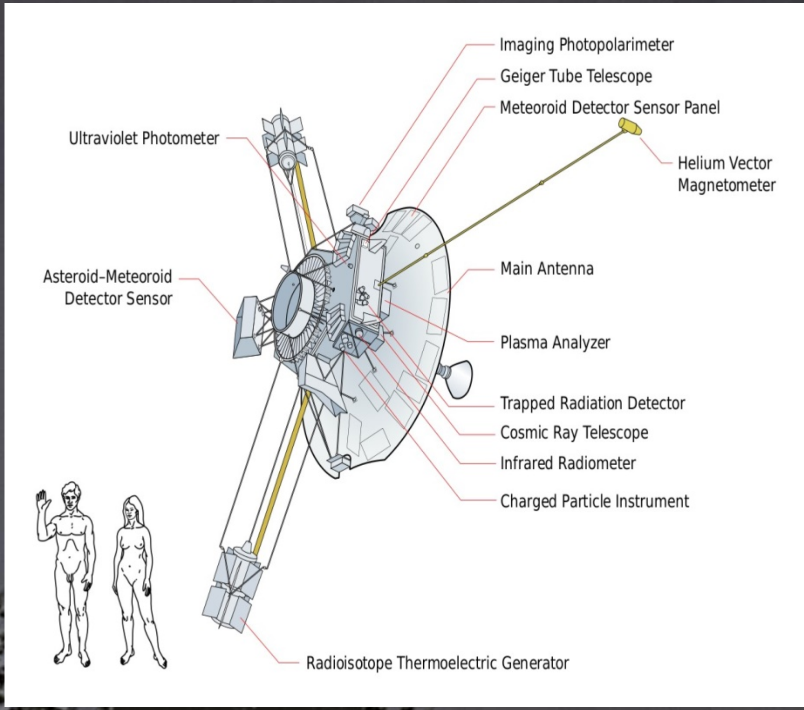
The Man Behind It

As a co-investigator, he designs multiple magnetics experiments for the Apollo, Viking, Pioneer, Voyager and the Cassini programs.

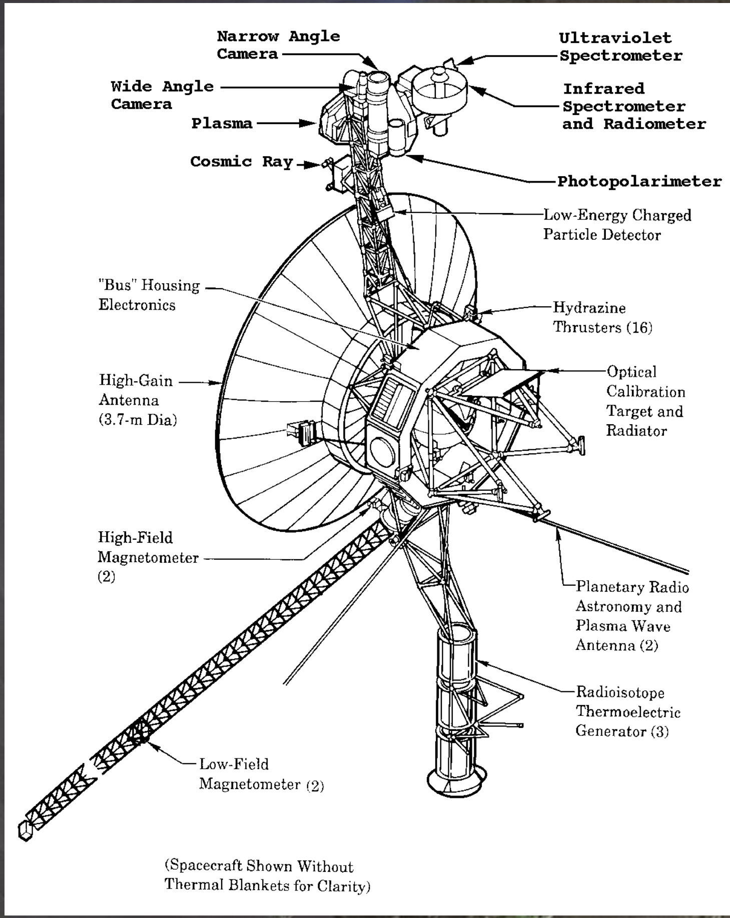




The Man Behind It



Pioneer 10-11



Voyager 1-2

The Man Behind It

He is late one morning to work because of traffic, misses the flight, and avoids being killed in a fatal collision of his flying laboratory aircraft and a Navy aircraft.

After the collision he left NASA and spent many years as a traveling professional musician and many years of working at many other types of jobs.

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The Man Behind It

Ron got tired of living on the road all the time and settled down and opened an electronic repair facility for musical instruments. Later, as part of that he started contracting and designing sound systems.

As part of that he got involved with the development of EASE with Wolfgang Ahnert of Berlin.

After many years of design/build he decided that acoustic consulting was the most important part of "design" since it affected sound the most.

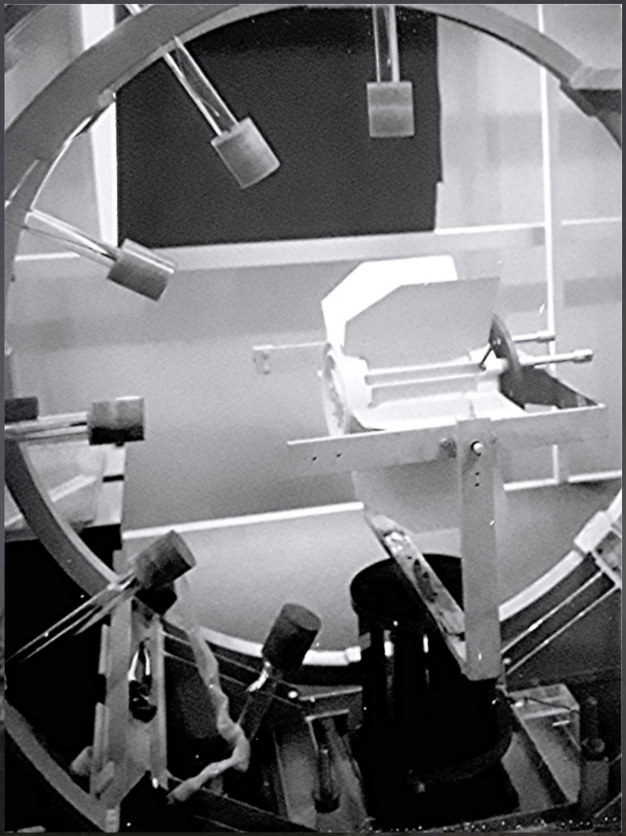
The Man Behind It

As part of the design process using EASE, Ron became frustrated with the inability of making better predictions of project room acoustics After researching the simulation programs he realized that the theory was sound but the databases used had data that was:

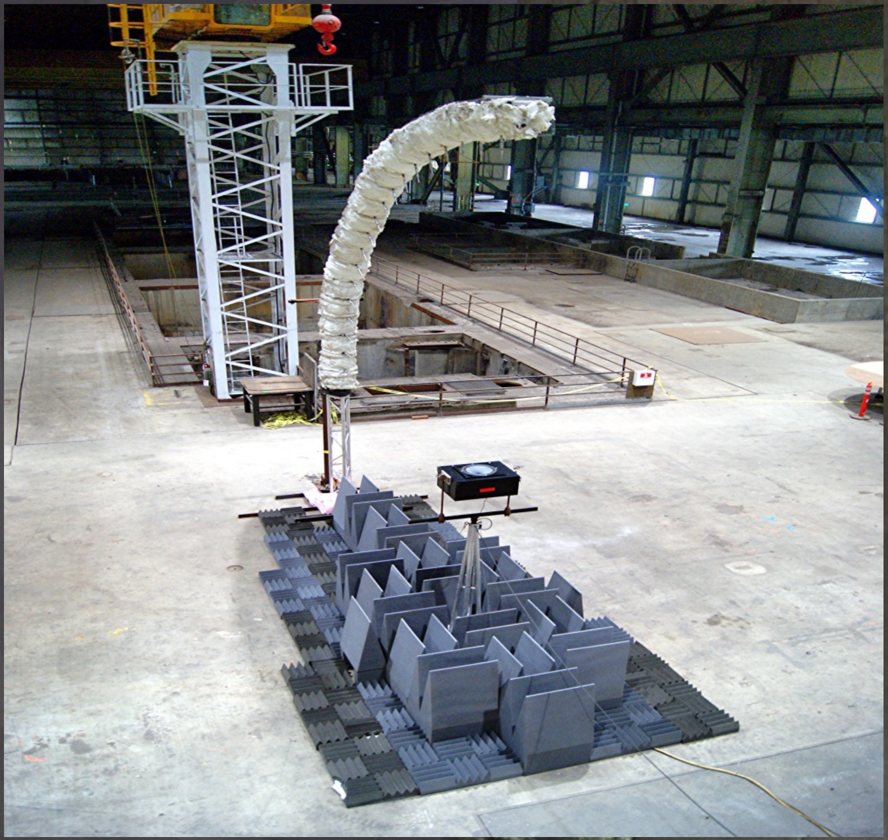
1. Incomplete
2. Full of errors

Ron thought back to his NASA days and realized he could convert a 1968 invention to be used in the area of acoustics and audio, but needed a lab to set it up.

The Man Behind It



1968



CURRENT

The Man Behind It

After encouragement by Ahnert and many others, he returned to his roots as a scientist and opened NWAA Labs, Inc. The lab was funded by using his and his wife’s retirement funds and with help from many friends in the industry. The facilities are to be used to do research in acoustic materials and equipment, supported by commercial testing of acoustic and audio products.

2. Introduction:

NWAA Labs, Inc.

Facilities

NWAA Labs, Inc

It took several companies and people to make it possible to make this laboratory. We would like to recognize them for their efforts:

- **Lab Design: JGL Acoustics/ Jerry Lilly**

- **Noise control products: Kinetics Noise Control**

- **Acoustic Doors: Krieger Doors**

- **Measurement Mics. Model M-30: Earthworks**
- **Measurement Mics. Model 4955: Bruel & Kjaer**

- **Custom Electronic Mic. Preamps: Presonus**
- **Custom Electronic Mic. Preamps: Bruel & Kjaer**

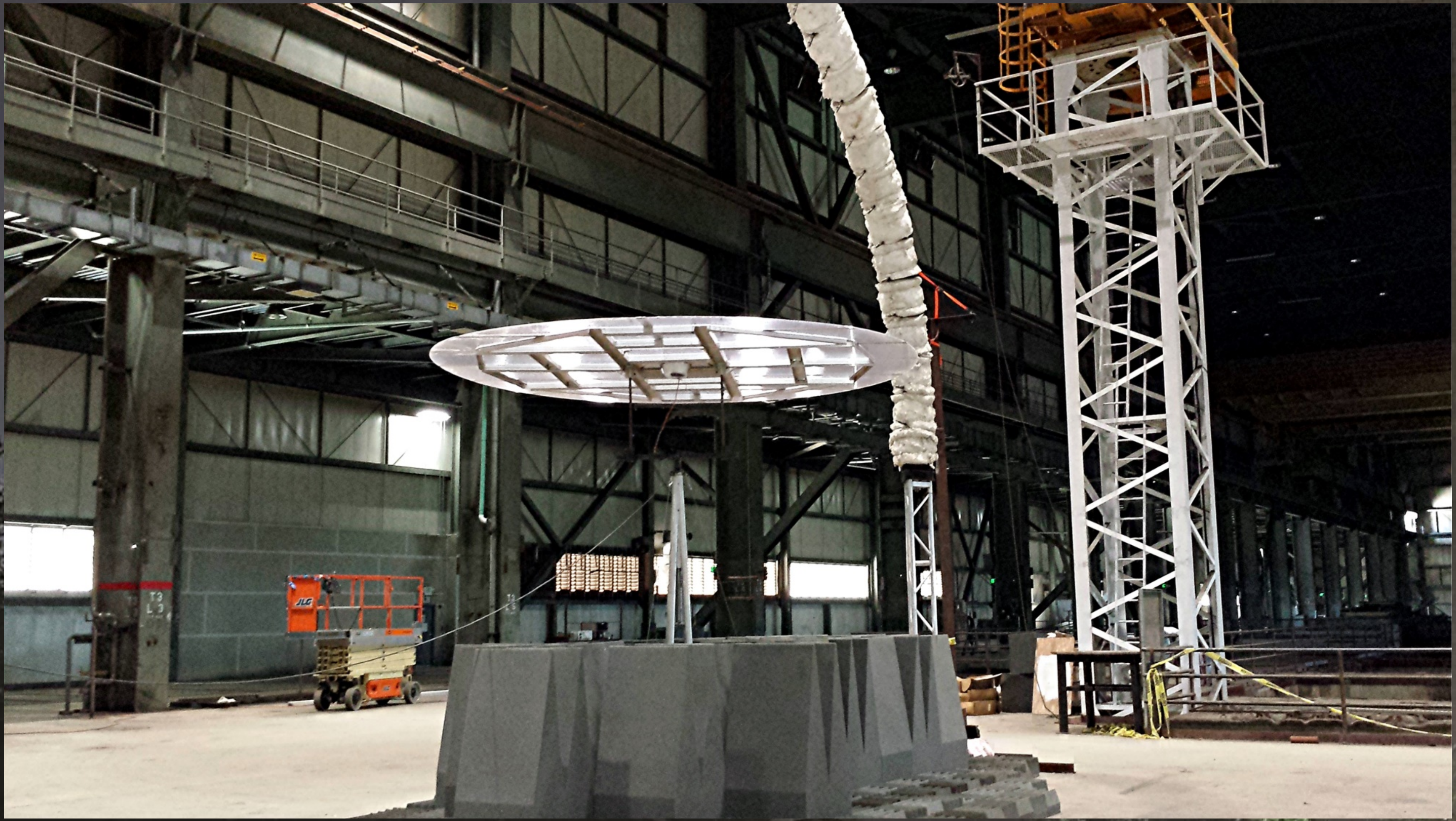
- **Speakers: Real Acoustix, Renkus-Heinz, Mc Cauley Sound**

AES56 “MACH” Testing System

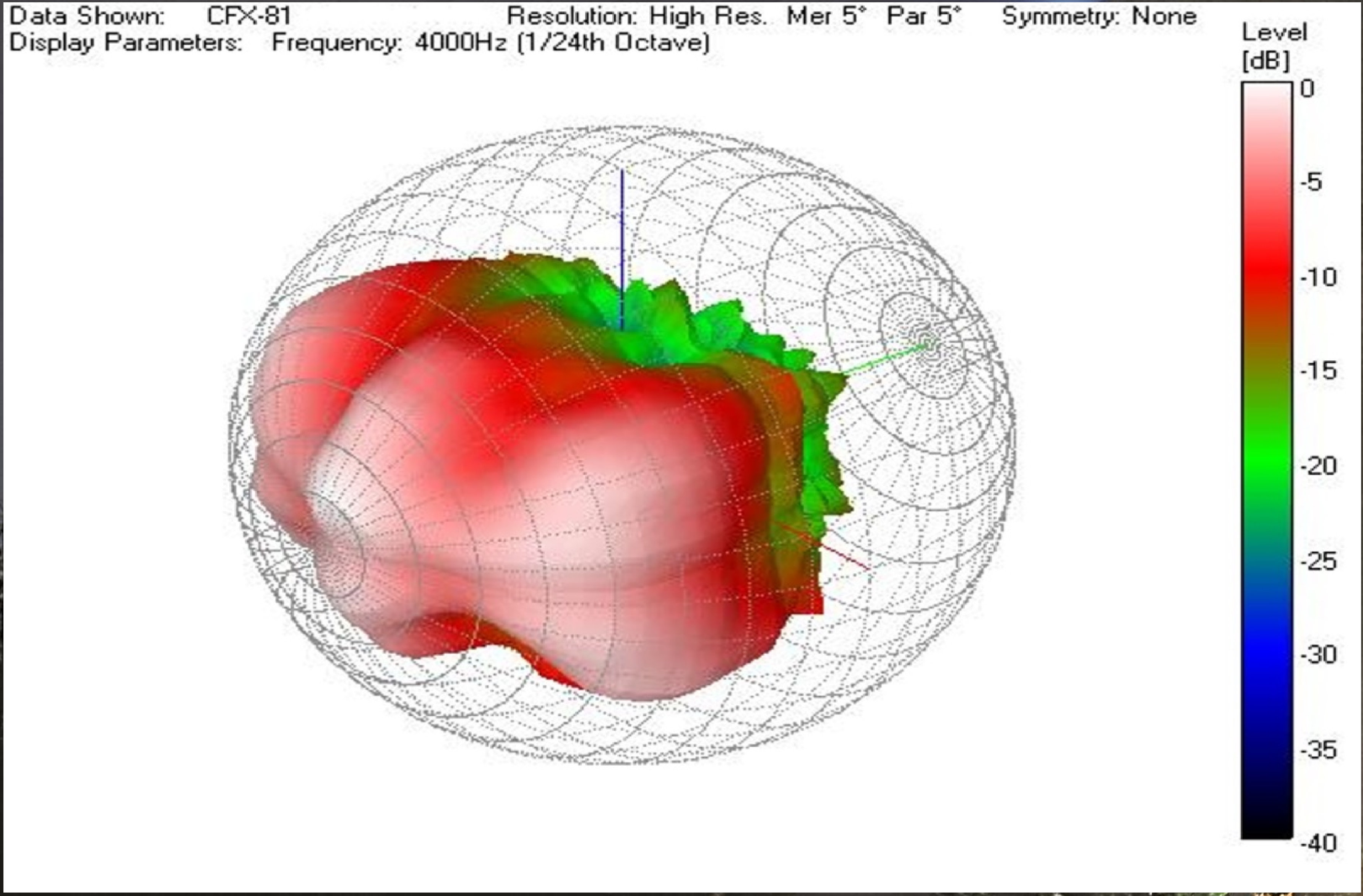
Multi Angle Computerized High Speed Testing System

AES56 “MACH” Testing System

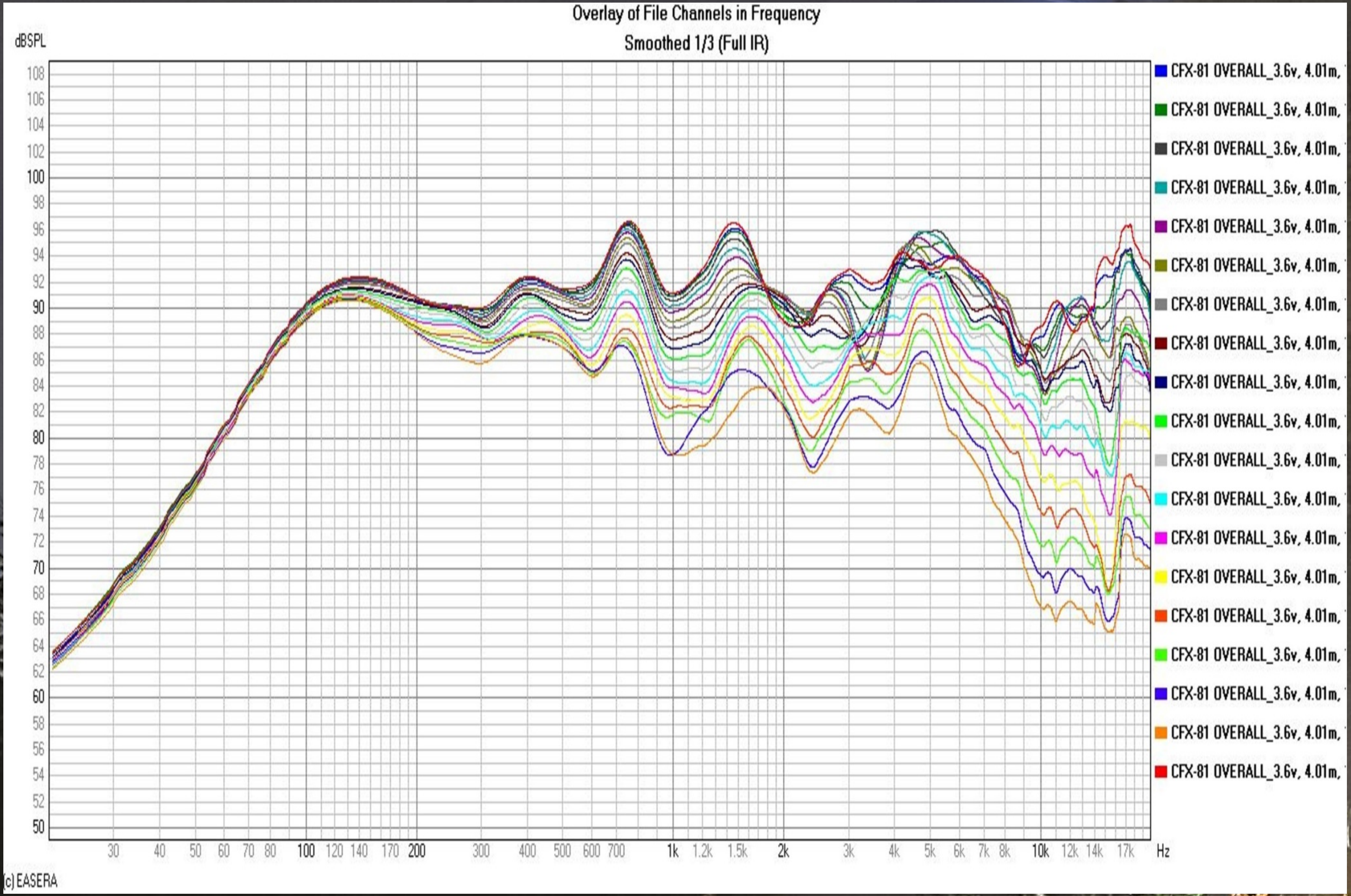
Multi Angle Computerized High Speed Testing System



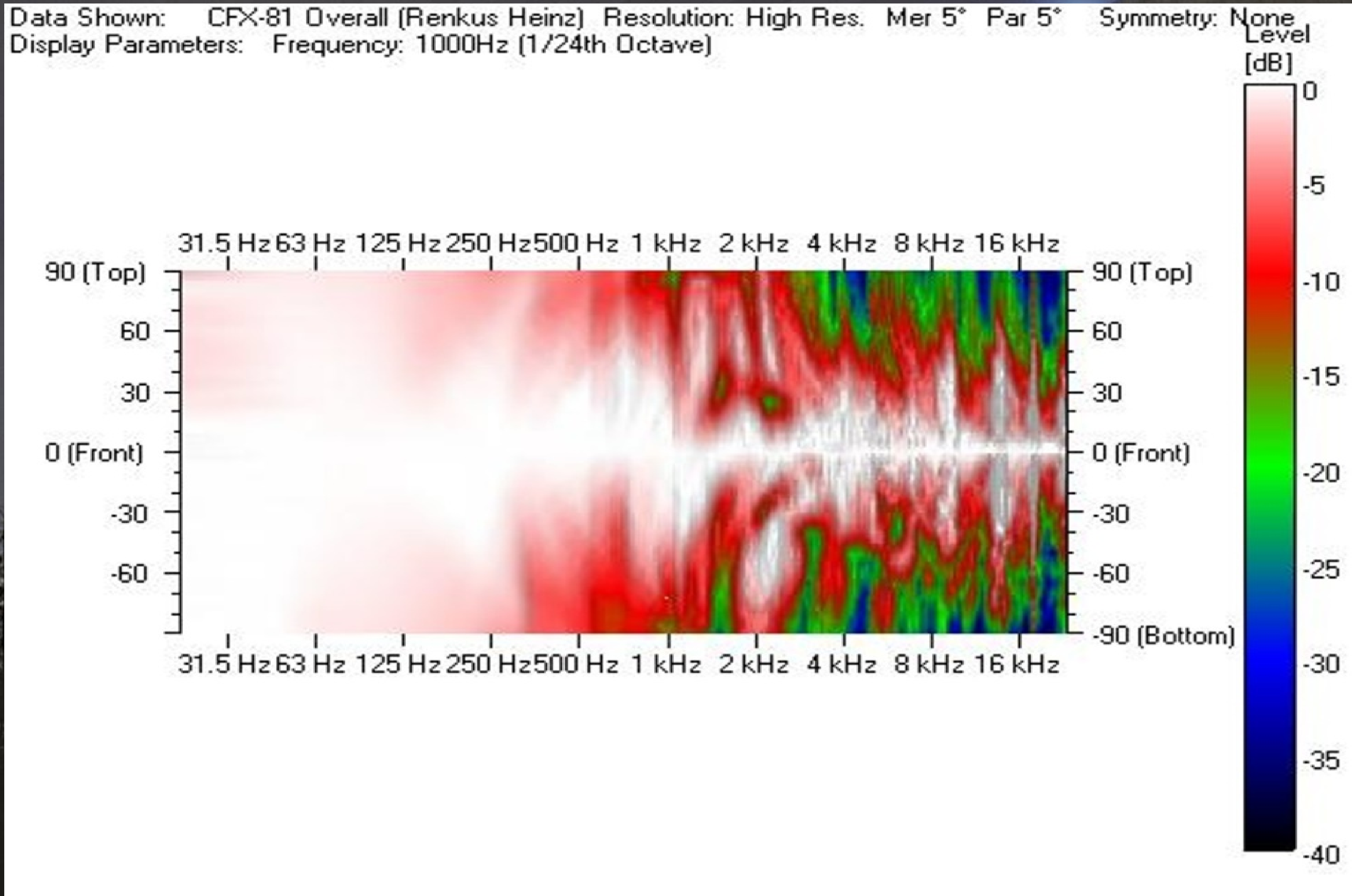
GLL Directivity Balloon.



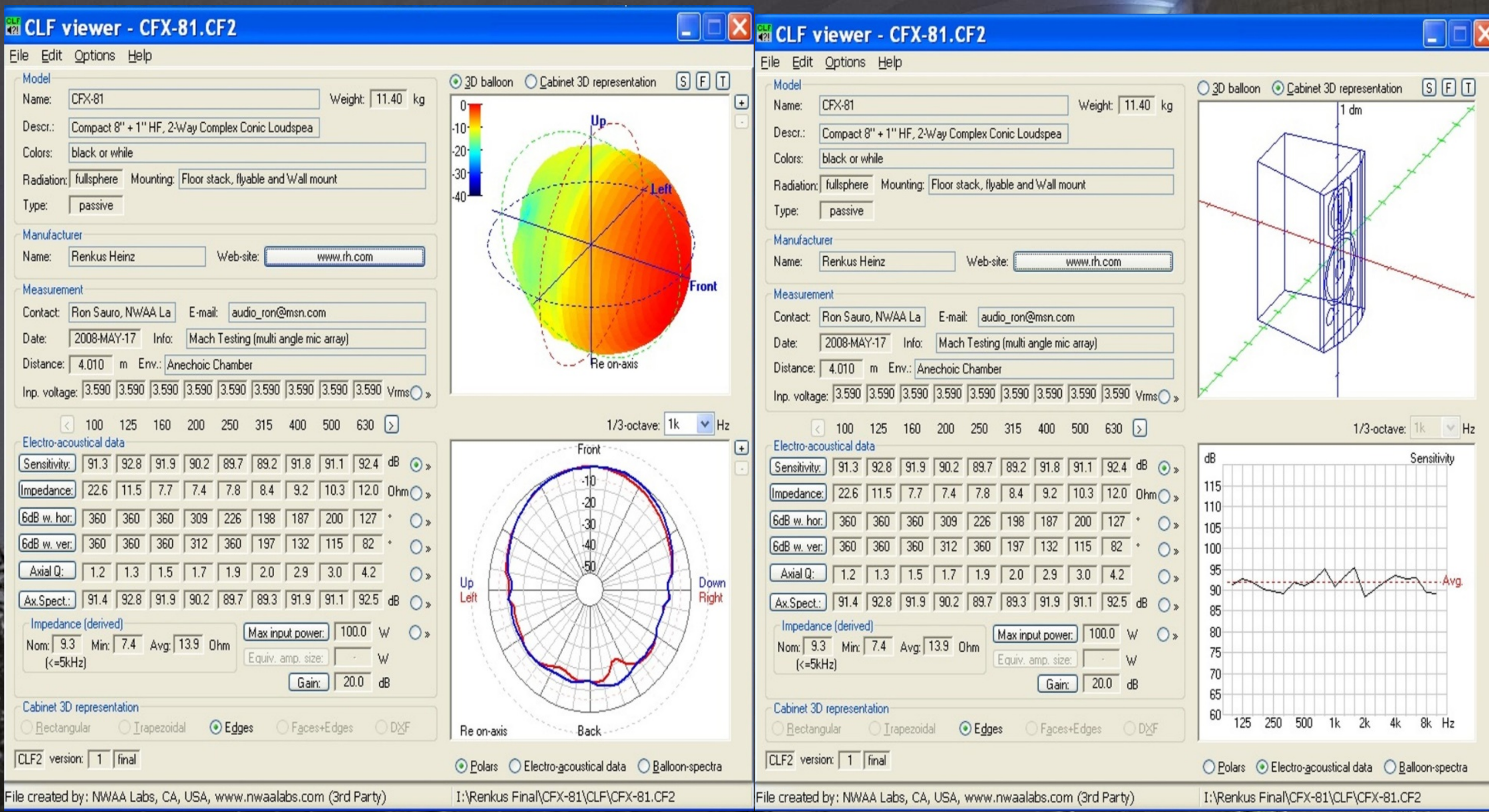
GLL Frequency Responses



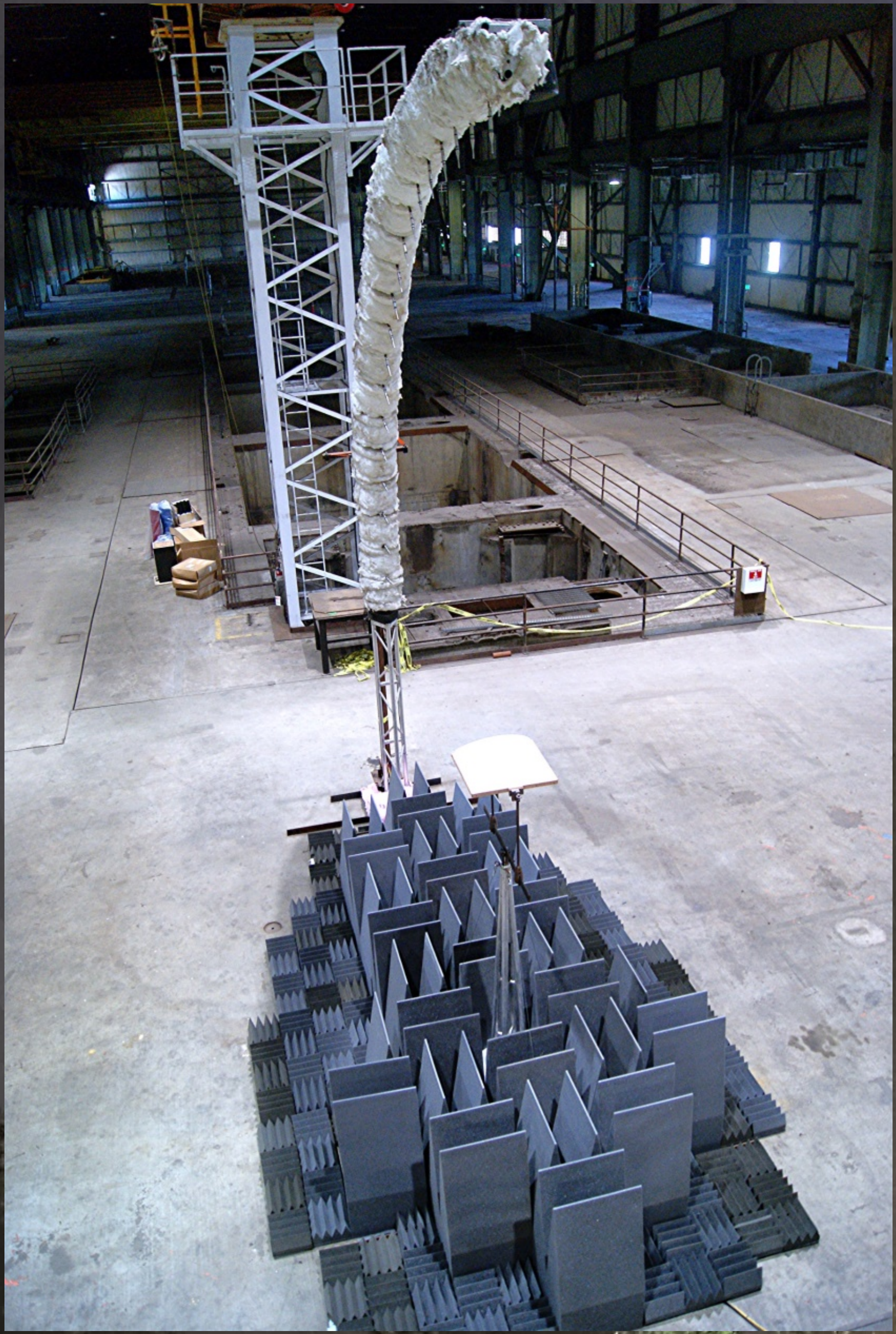
GLL Directivity Mapping



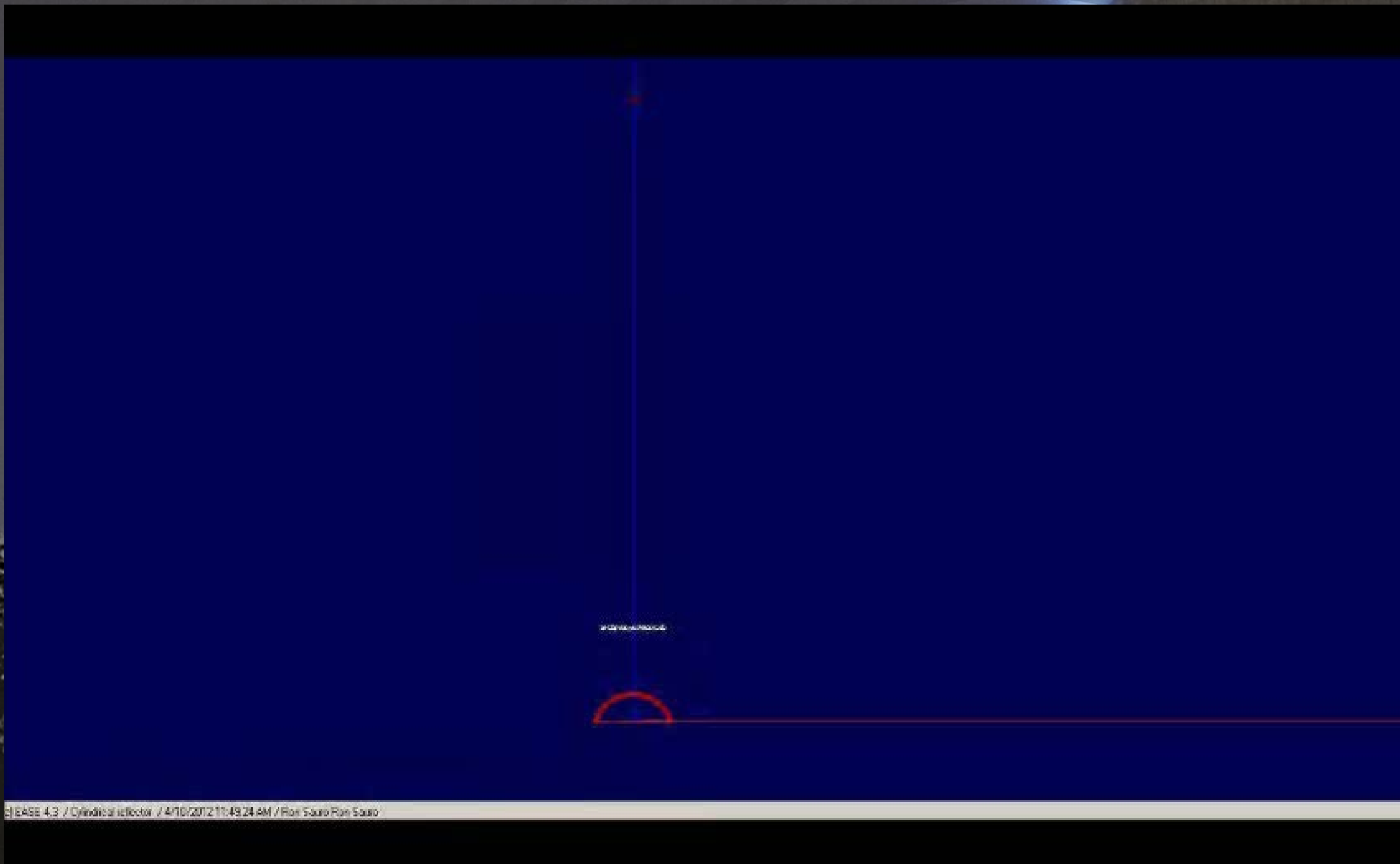
CLF1 and CLF2 Data



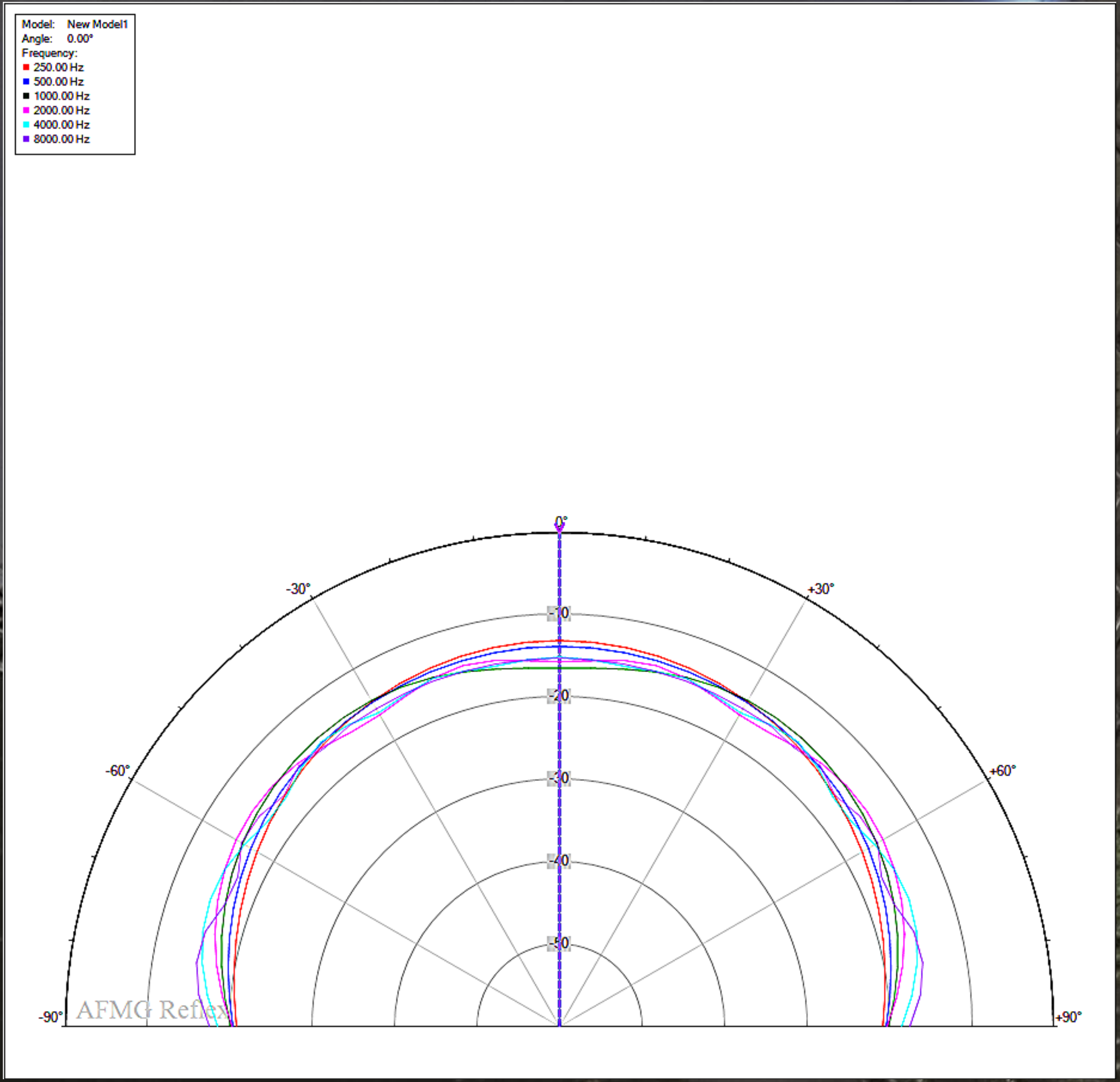
NWAA Labs Experimental Diffusion and Scattering Test



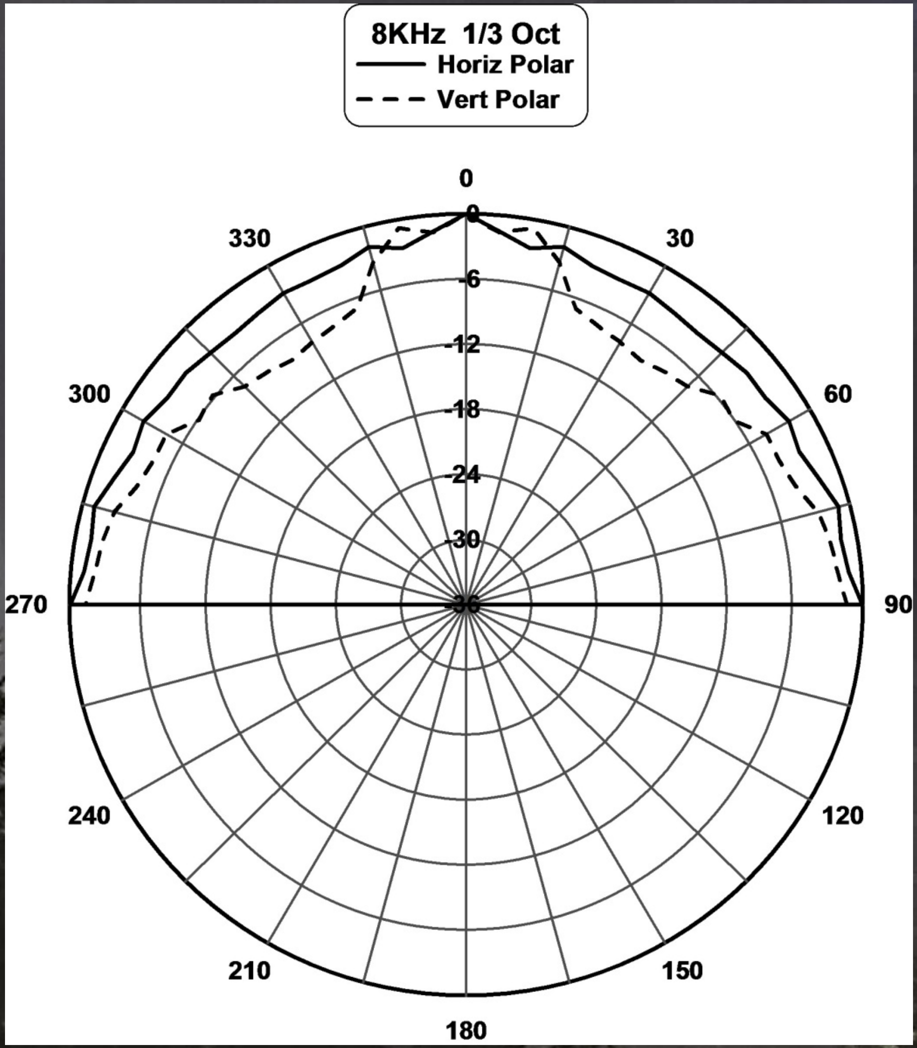
Cylindrical Model Beam Behavior Prediction



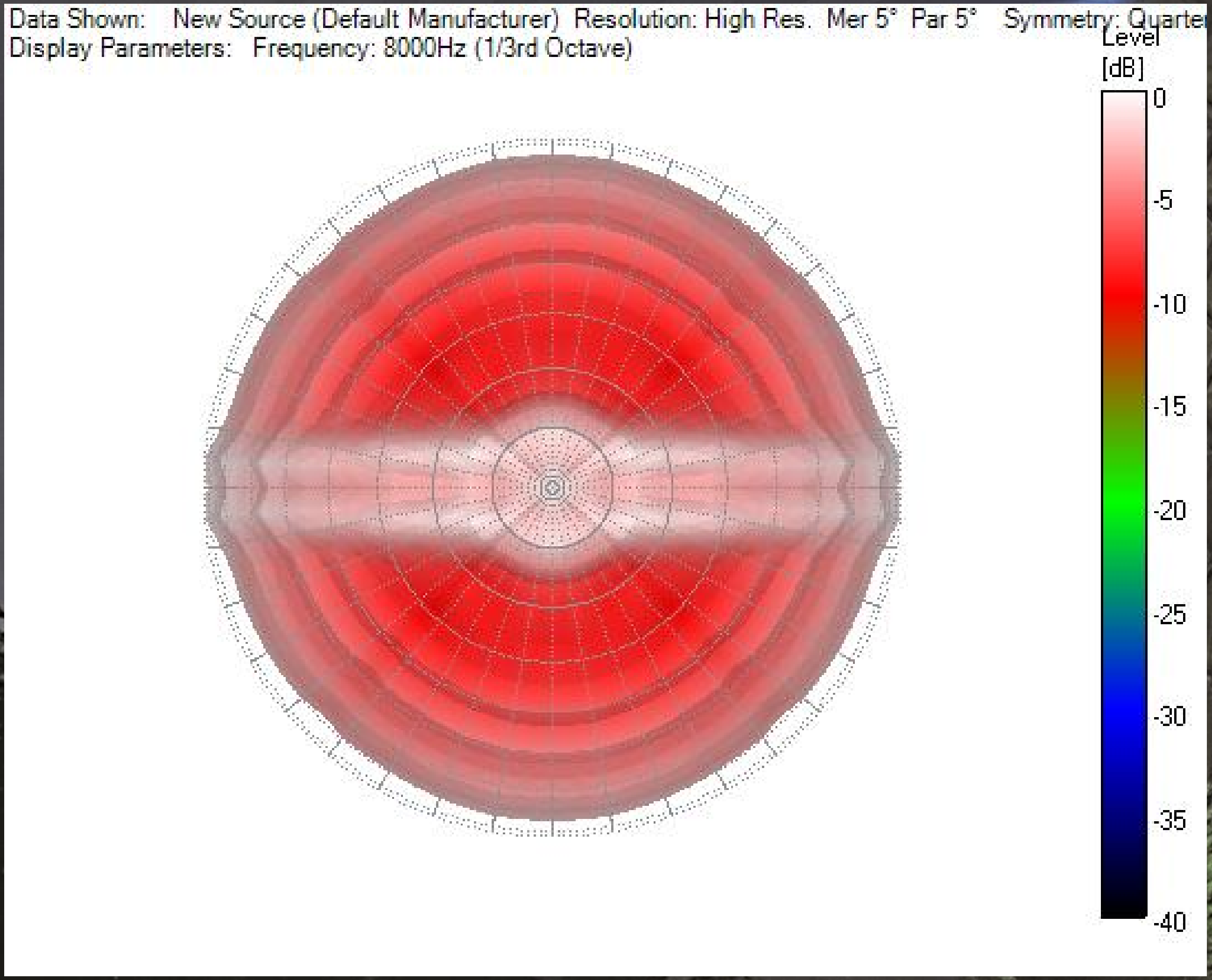
Cylindrical Model Beam Behavior Prediction



Cylindrical Model Actual Measurements



Cylindrical Model Actual Measurements



Reverb Rooms

- The largest in the world
- 737 cu meters
- The quietest non anechoic rooms in the world
- 10 ft. by 12 ft. TL opening

E-90/ISO-140 Transmission Loss

Walls

25-10kZHz

E-90/ISO-140 Transmission Loss

Windows

25-10kZHz

E-90/ISO-140 Transmission Loss

Curtain Walls

25-10kZHz

E-90/ISO-140 Transmission Loss

Doors
25-10kZHz

C-423/ISO-354 Absorption

A type Mount

40-10kZHz

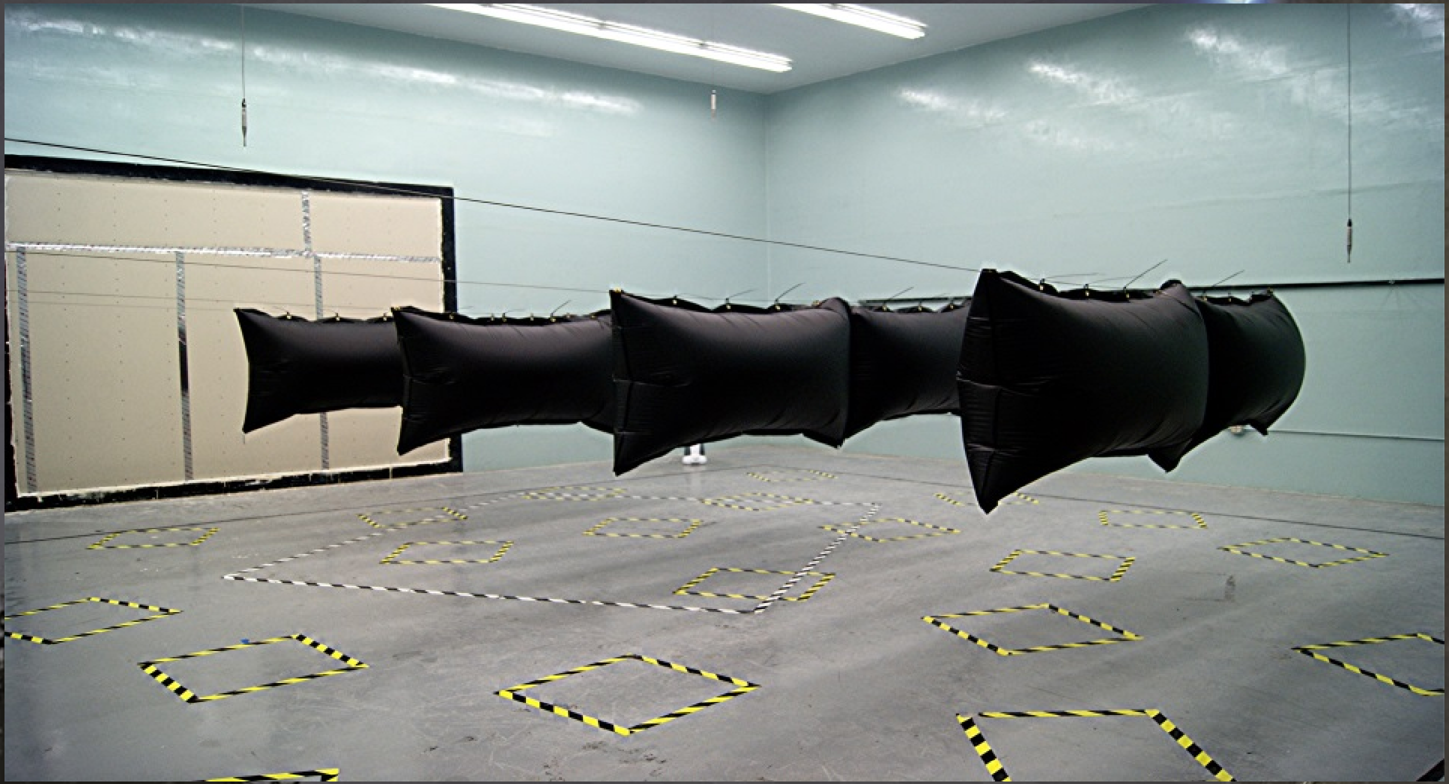
C-423/ISO-354 Absorption

Type E-400 Mount
40-10kZHz

C-423/ISO-354 Absorption

Type M Mount
40-10kZHz

C-423/ISO-354 Absorption



Type J Mount

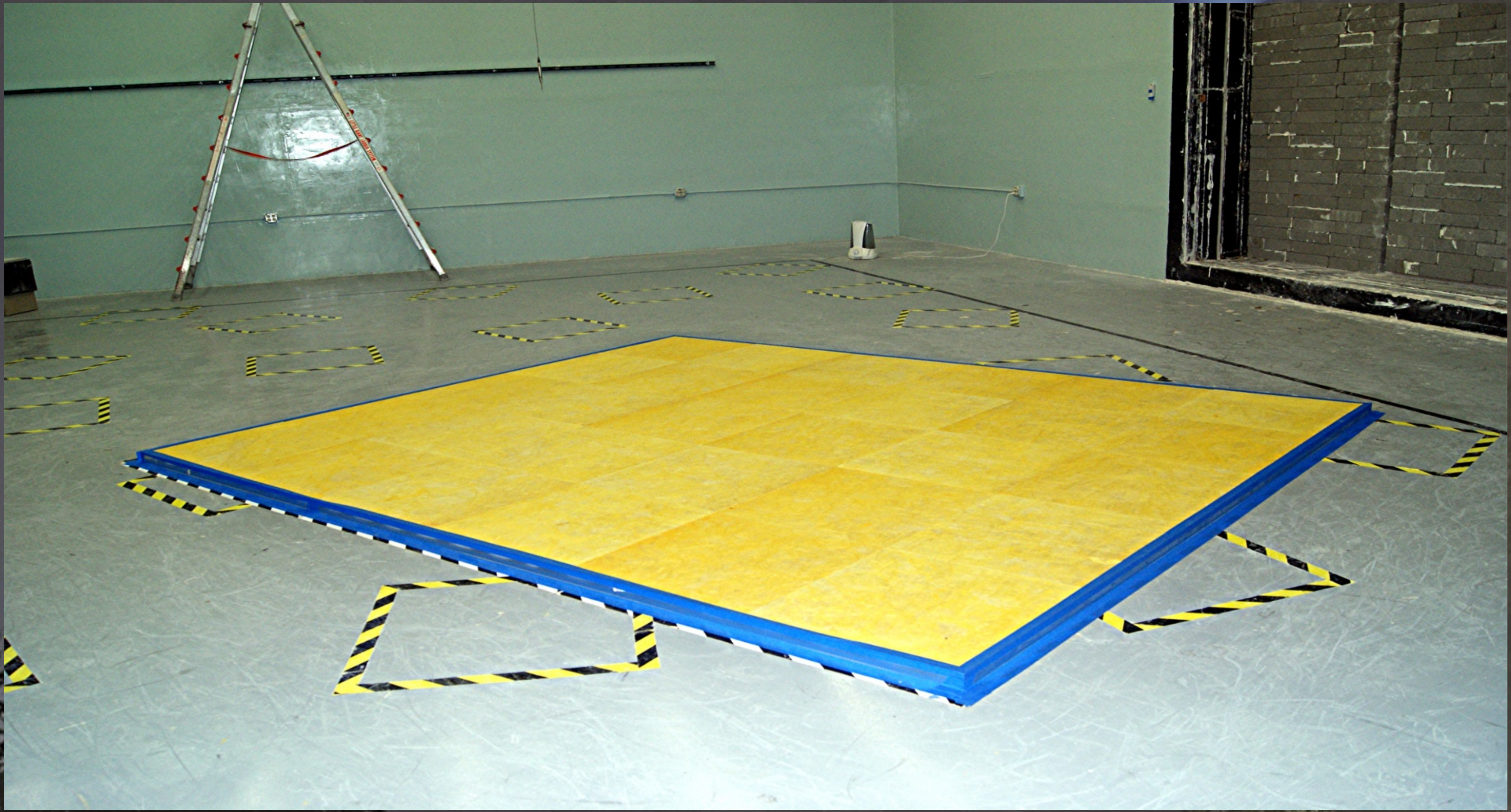
40-10kZHz

3. Introduction

Research and Discoveries

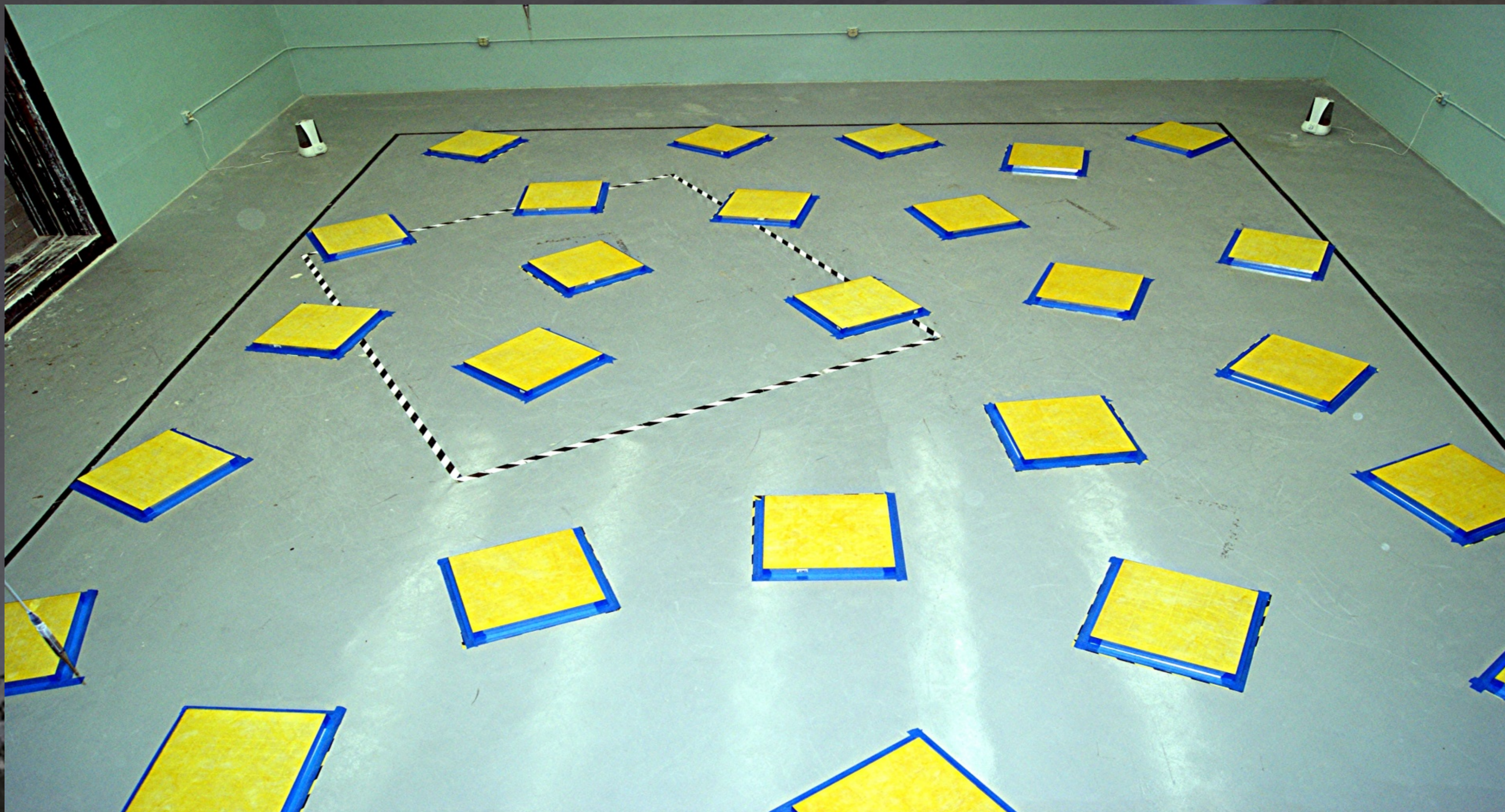
1. Absorption

C-423/ISO-354 Absorption



Experimental A Mount Monolithic

C-423/ISO-354 Absorption



Experimental A Mount Split

C-423/ISO-354 Absorption

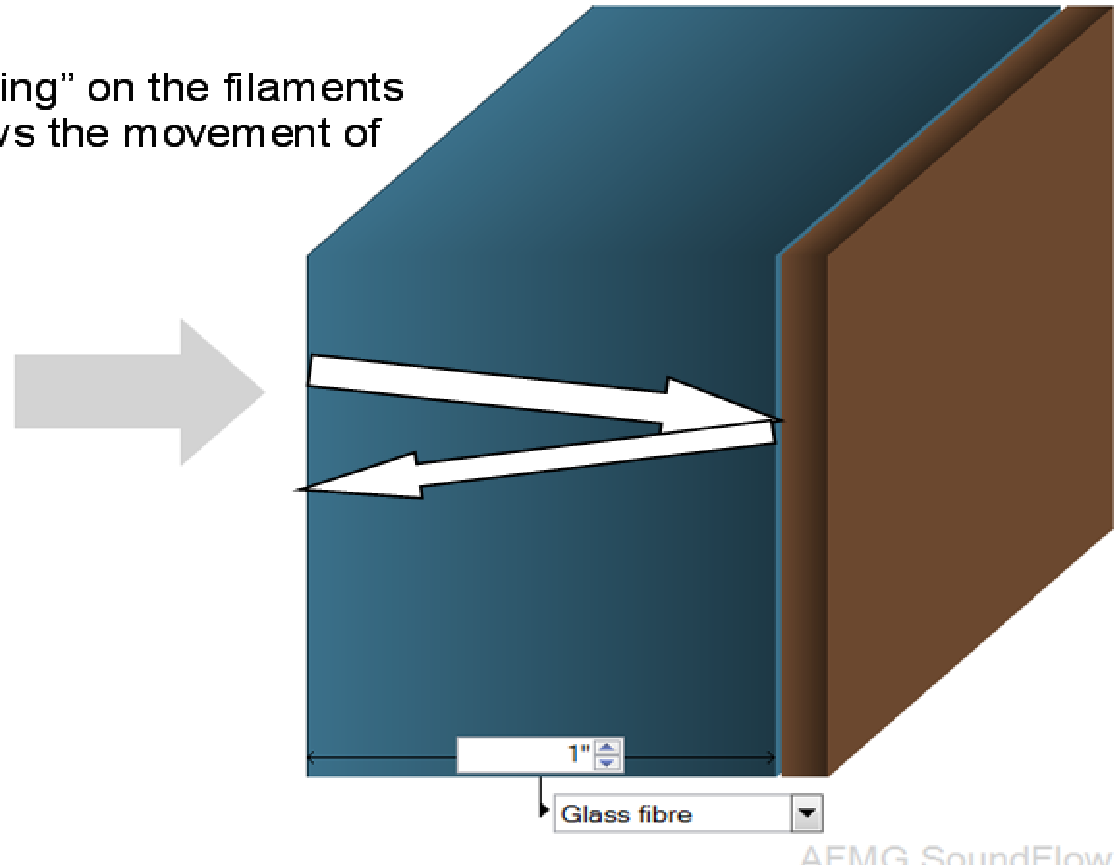
Experimental Wall Mount

Topics of Discussion

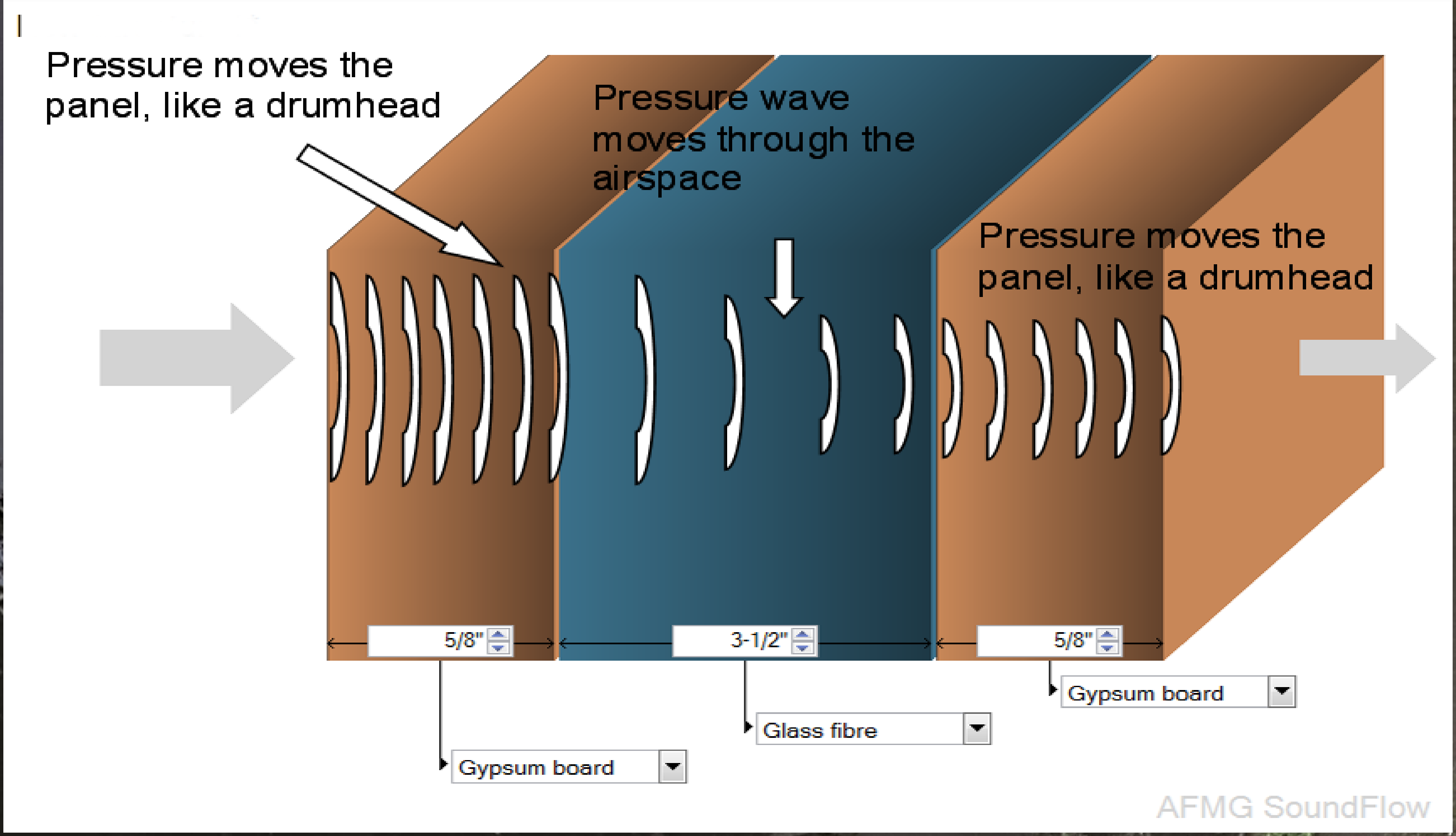
- Material vs Wall Construction
- Frictional Absorption vs Diaphragmatic
- ASTM mounting Methods
- Wall Structure Placement
- Lack of data measured in recent time periods

Friction

Energy is lost by air "rubbing" on the filaments of glass. The rubbing slows the movement of air and turns into heat.



Diaphragm



Pressure moves the panel, like a drumhead
Pressure wave moves through the airspace
Pressure moves the panel, like a drumhead
5/8"
3-1/2"
5/8"
Gypsum board
Glass fibre
Gypsum board
AFMG SoundFlow

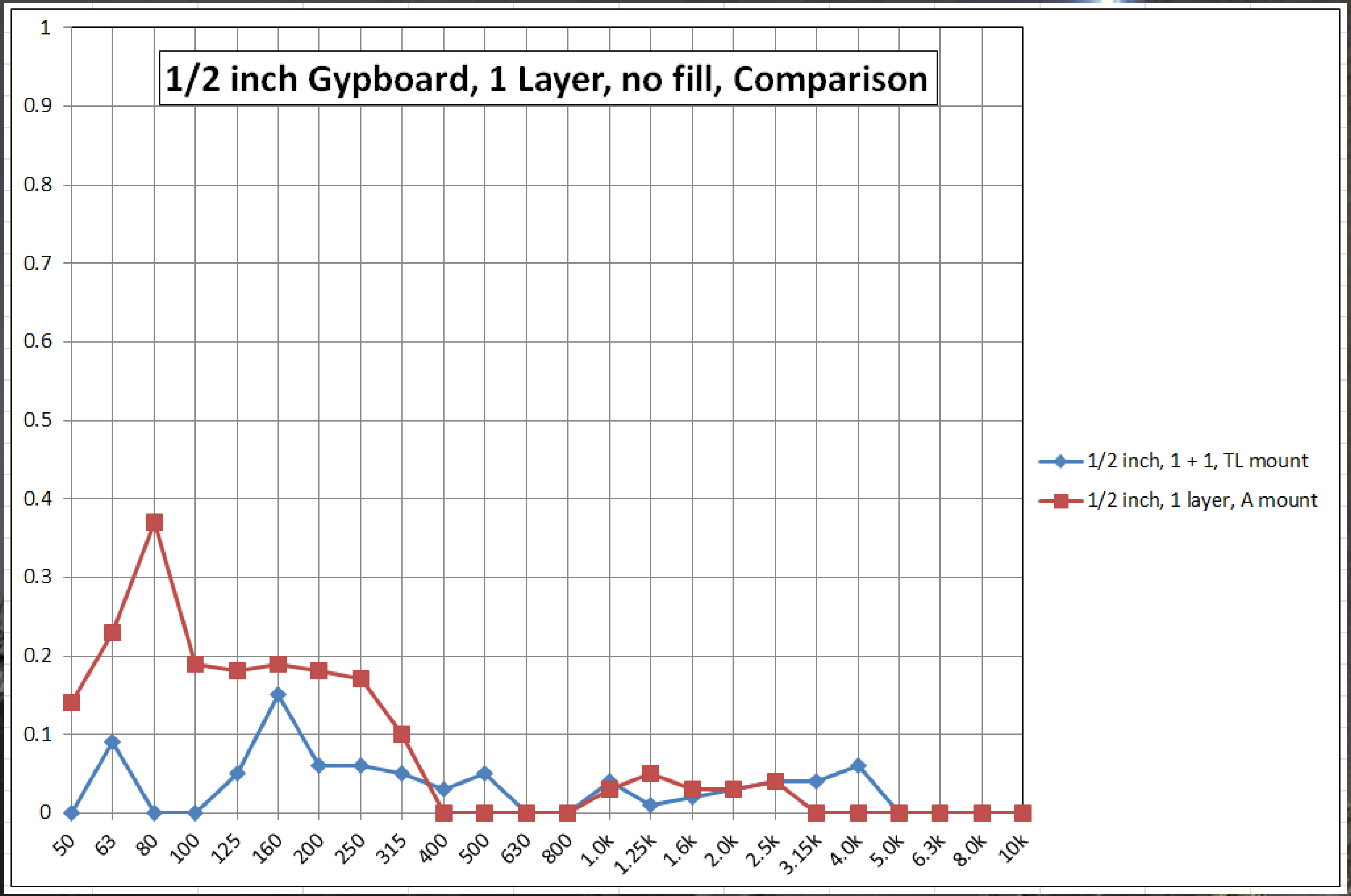
Reverberation Room

A Type Mount

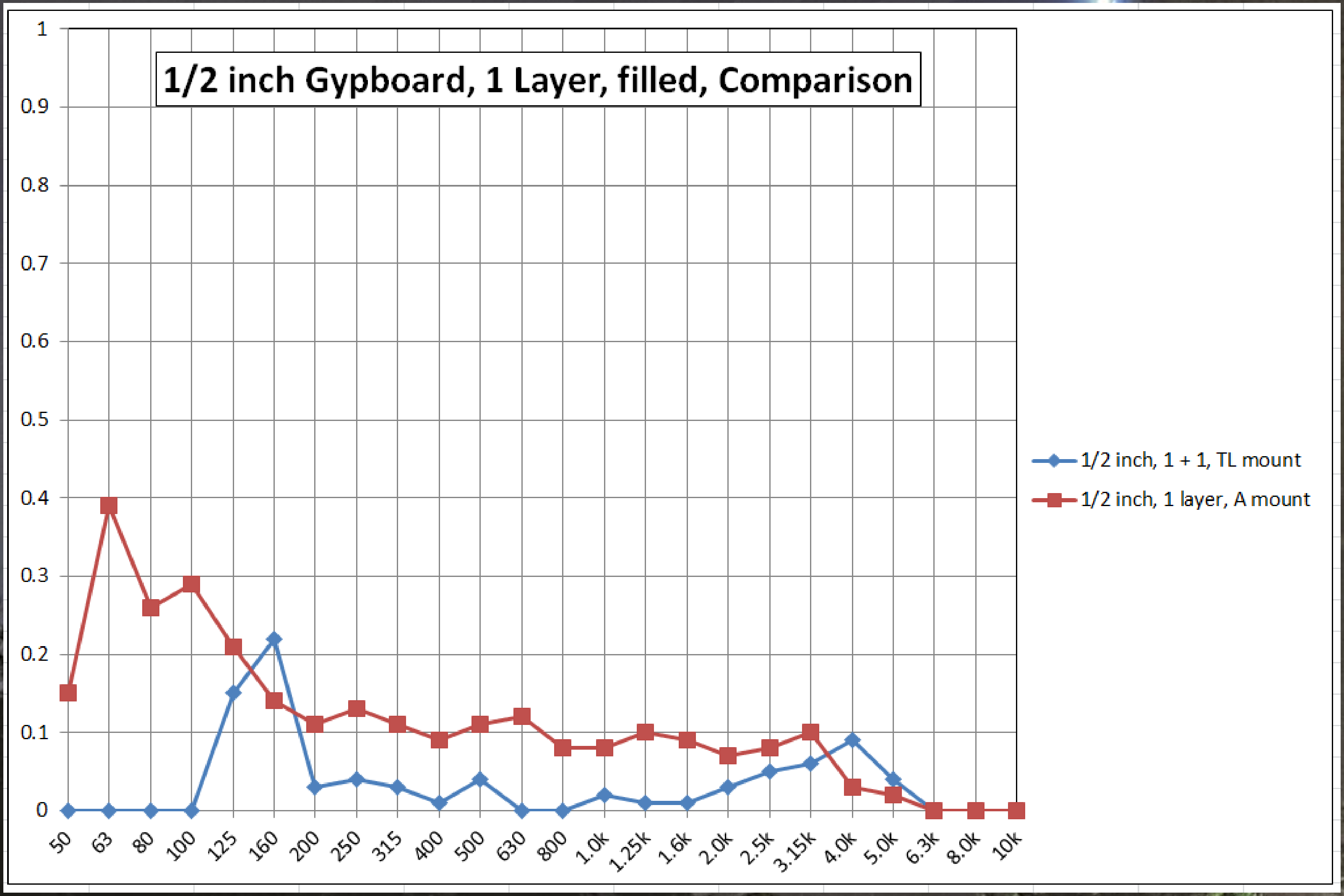
Proposed TL Mount

T Type Mount
Fill Wall

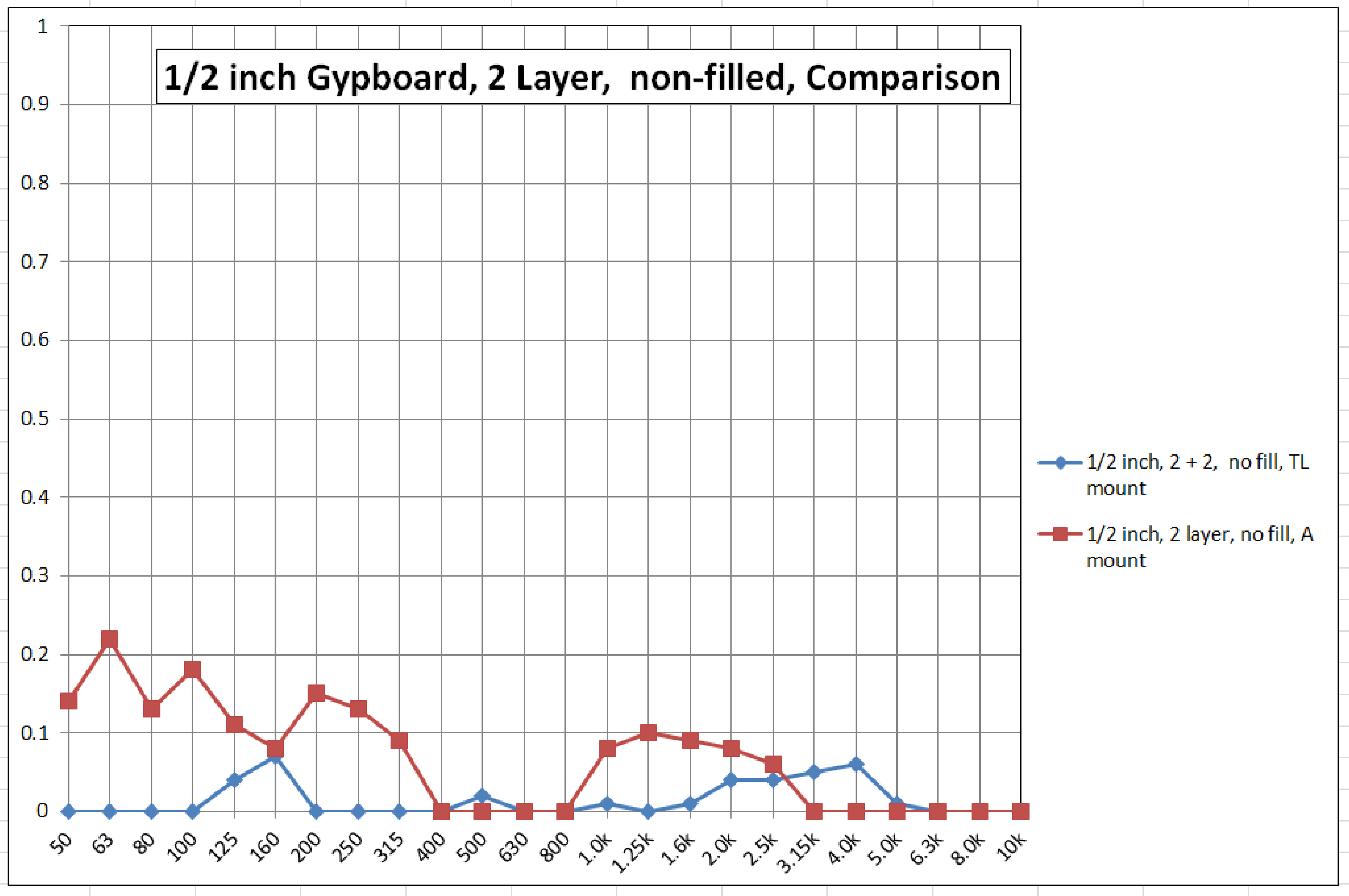
A Mount vs TL Mount



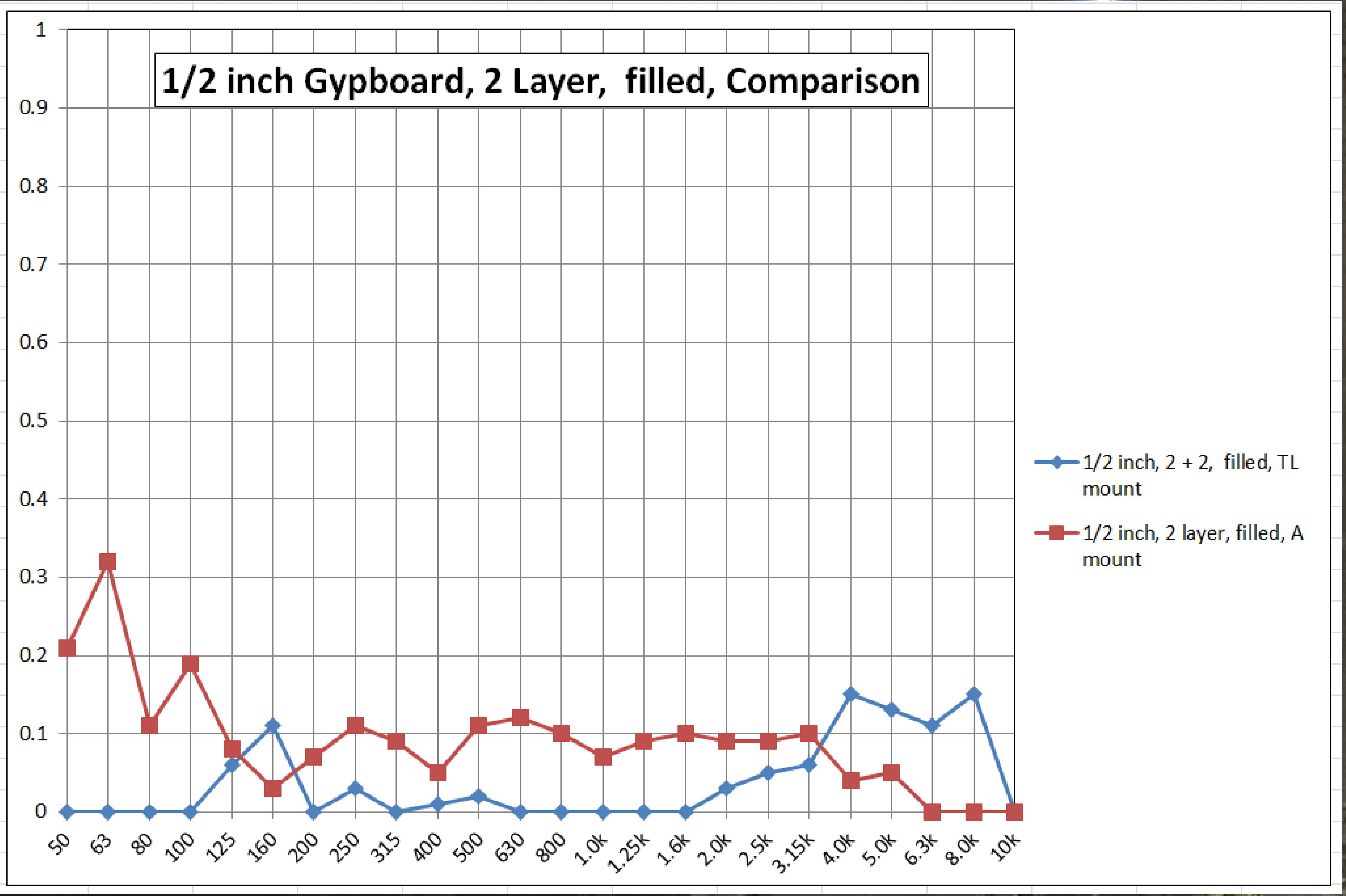
A mount vs TL Mount



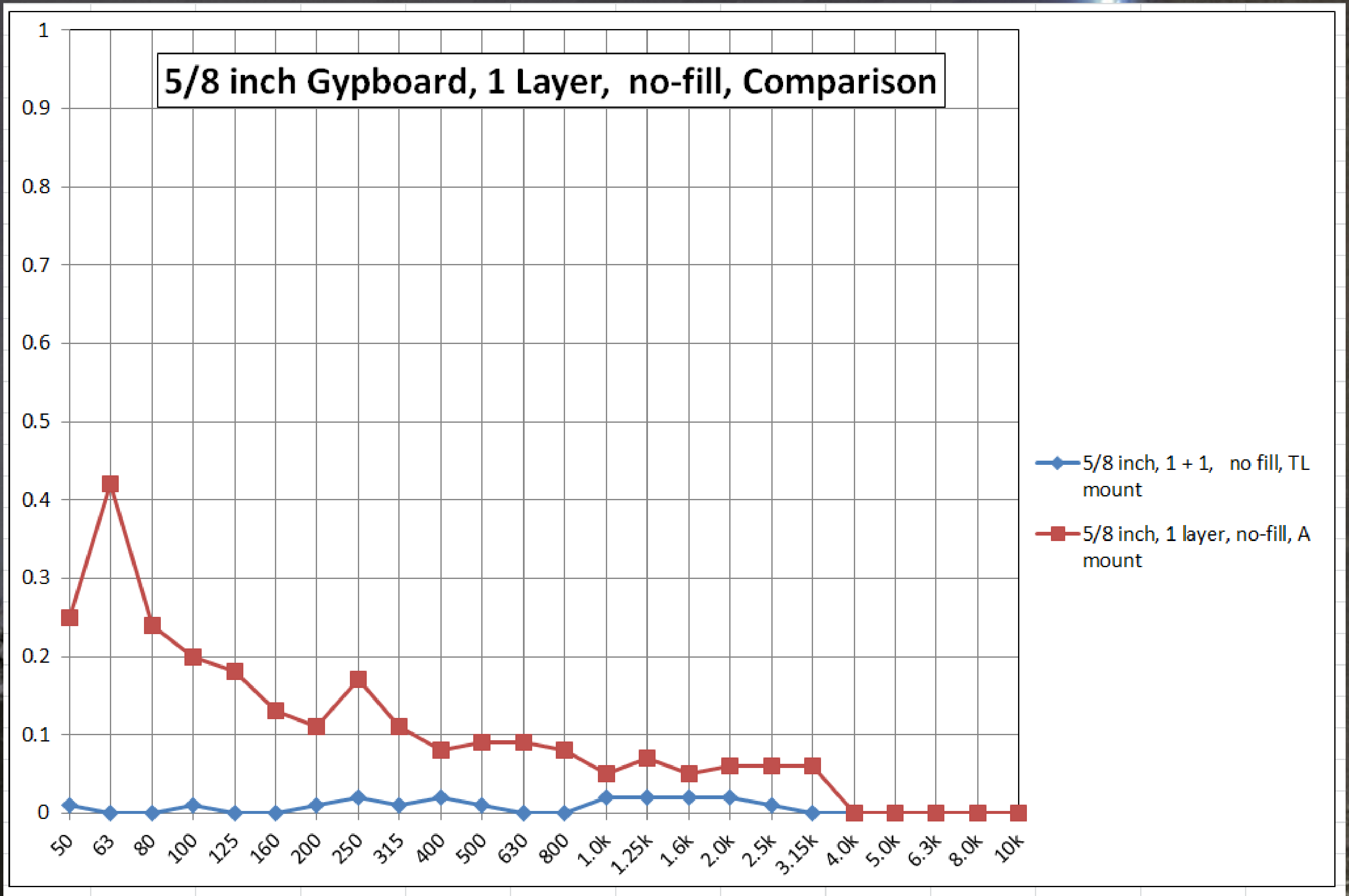
A mount vs TL Mount



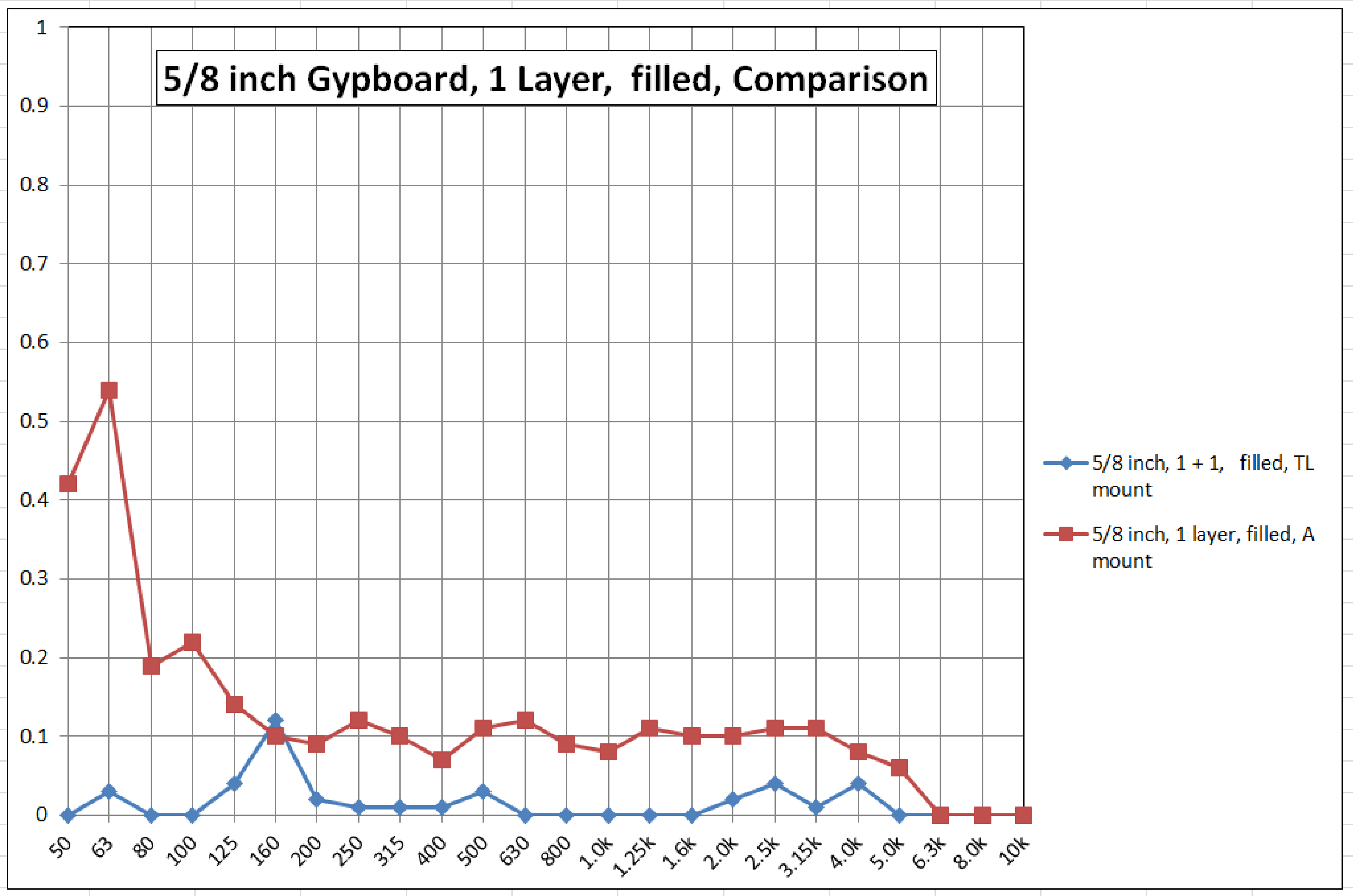
A mount vs TL Mount



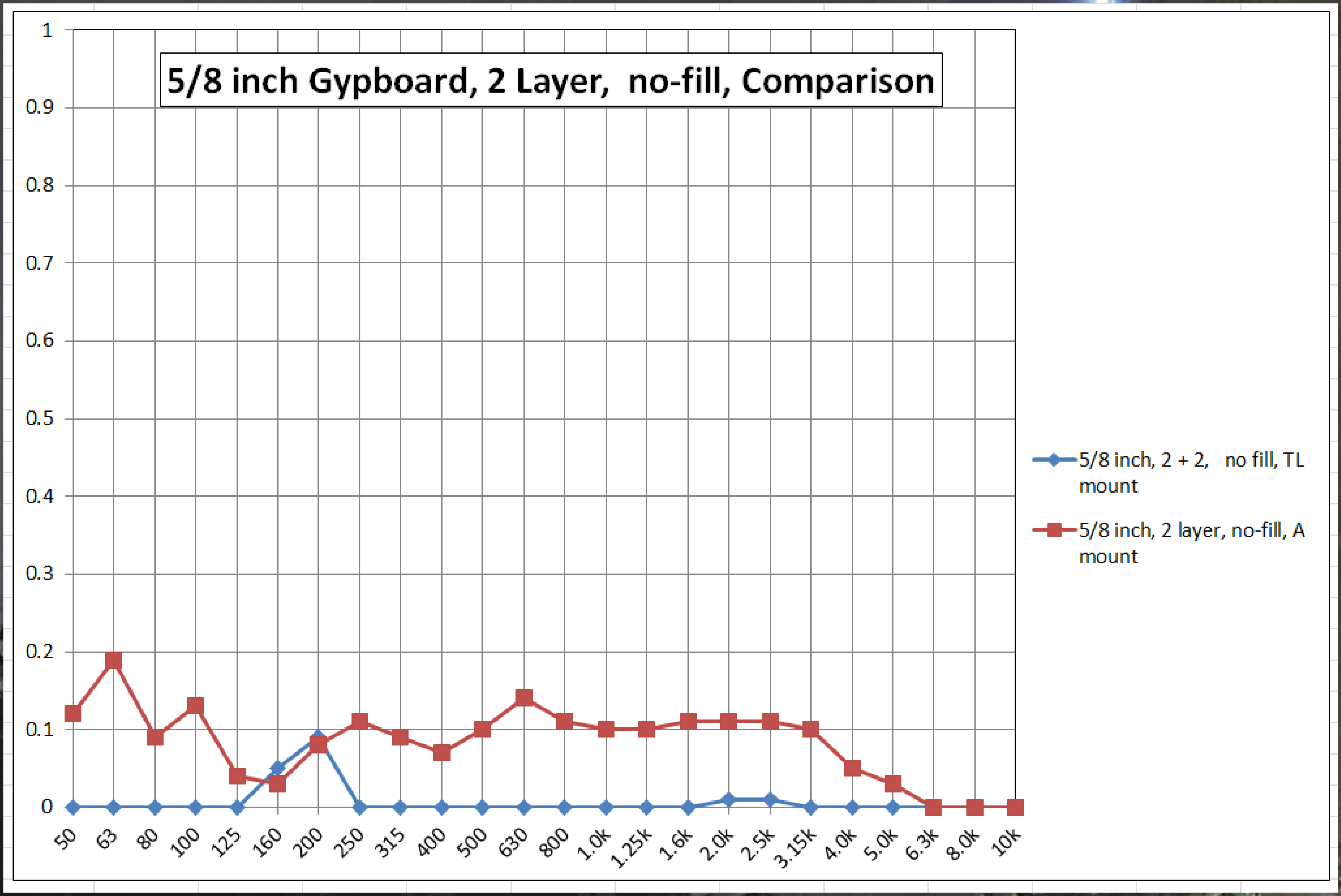
A mount vs TL Mount



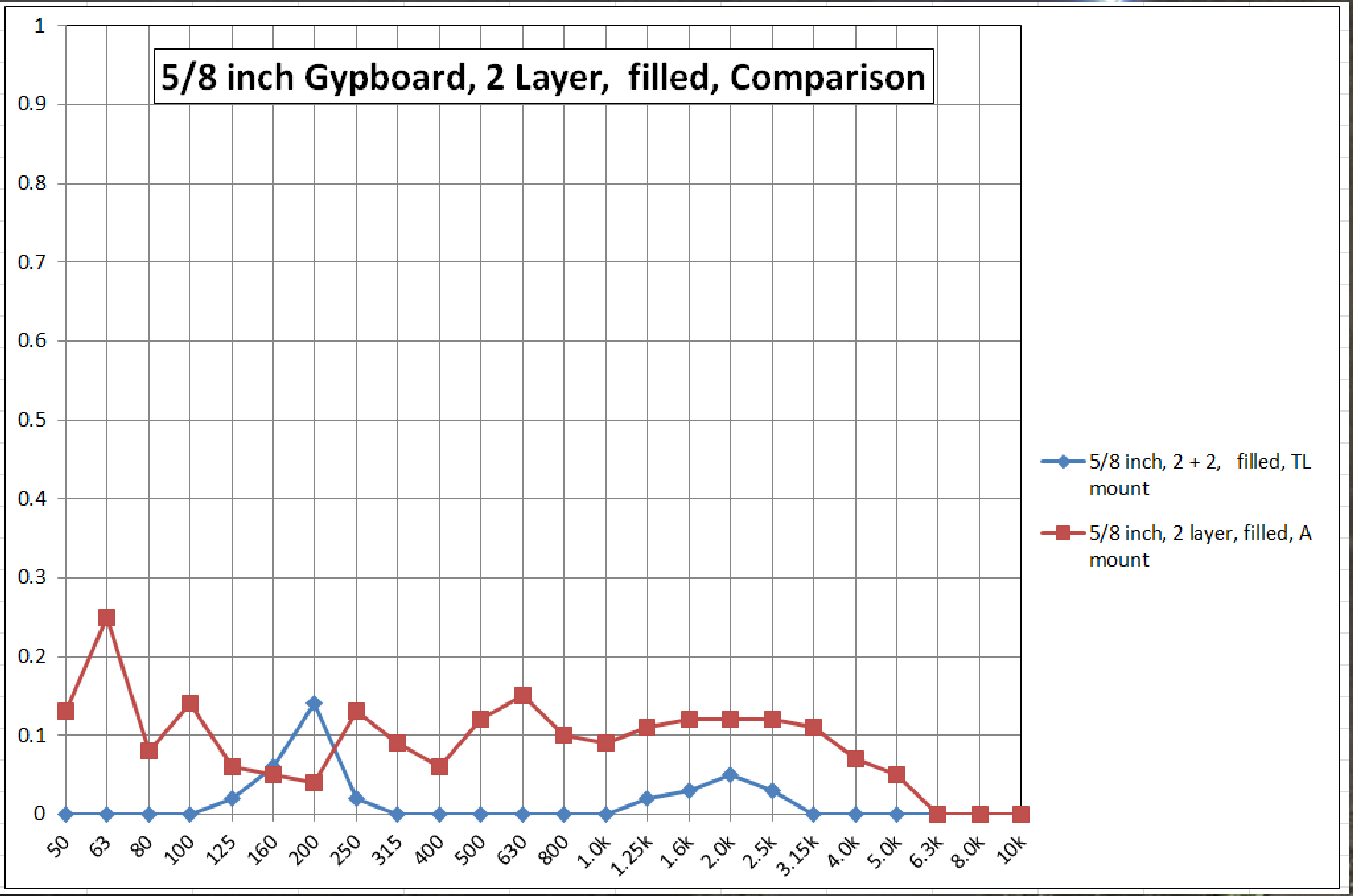
A mount vs TL Mount



A mount vs TL Mount

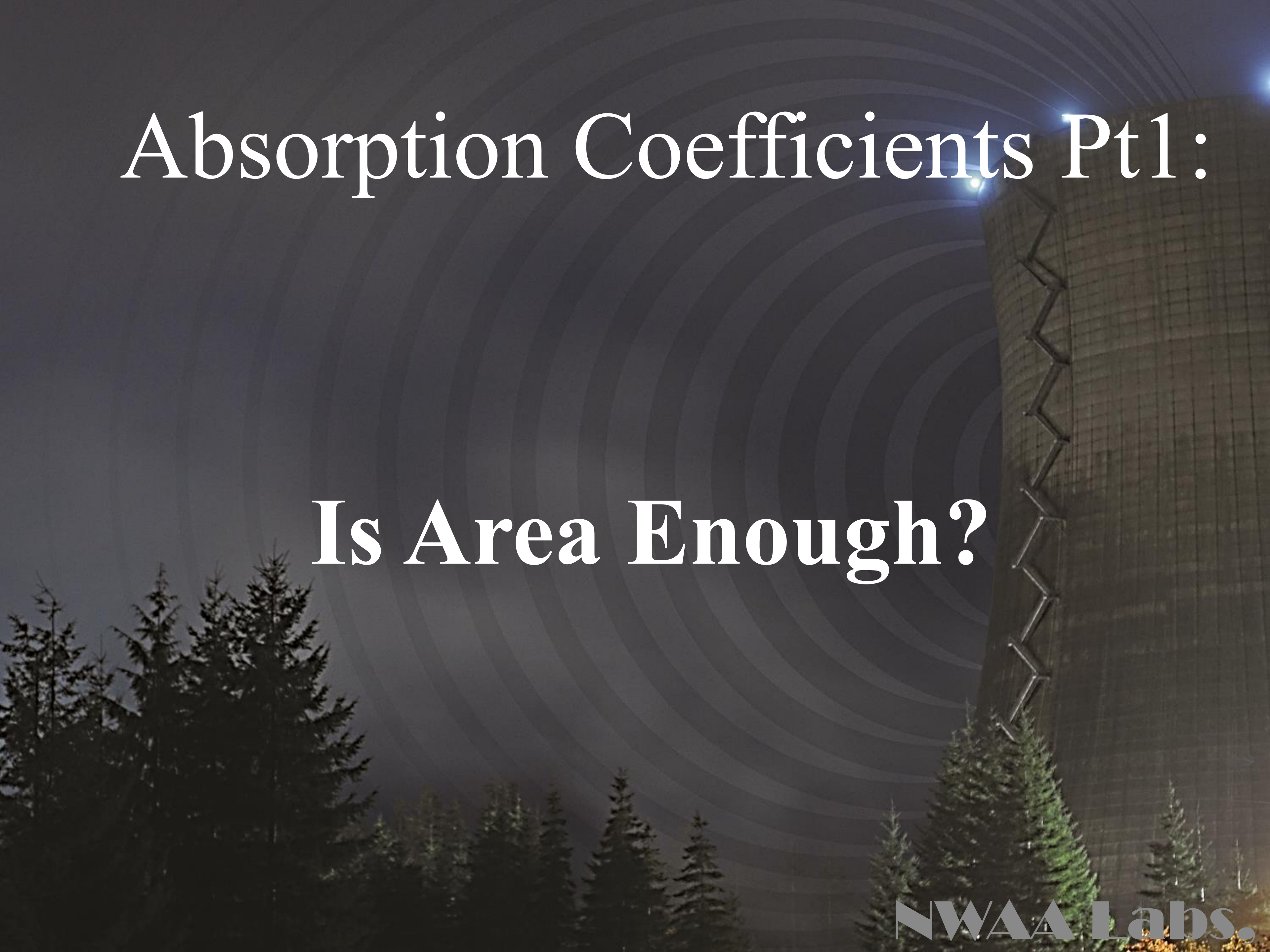


A mount vs TL Mount



Conclusions

- A Mount simulates a wall built over an exterior wall only
- Interior wall adjoining another room should be measured using the TL mount
- Modeling programs should include both types of data


Absorption Coefficients Pt1:
Is Area Enough?
NWAA Labs.

Introduction

- **We will discuss the measurement of material absorption and coefficients**
- **The discussion includes ASTM-C423, ISO-354 and ISO-17497-1.**
- **We will talk about their similarities and differences.**
- **We will plan a set of experiments to test these differences.**

Common Questions

- **Q: What is sound absorption?**
- **A: It is the conversion of acoustic energy to thermal energy.**
- **Q: What is the Absorption Coefficient?**
- **A: Result of dividing the amount of absorption by the sample area**

Differences in Standards

- **ASTM–C423 and ISO-354 require similar shaped samples and ISO-17497-1 requires a circular sample.**
- **ASTM-C423, ISO-354 and ISO-17497-1 can use different methods of measuring the RT of the reverb room.**
- **All use different areas.**
- **All use different perimeters.**
- **All provide different answers for absorption coefficients.**

Experimental Tests

Measure recommended samples of the same material in the two prescribed ways.

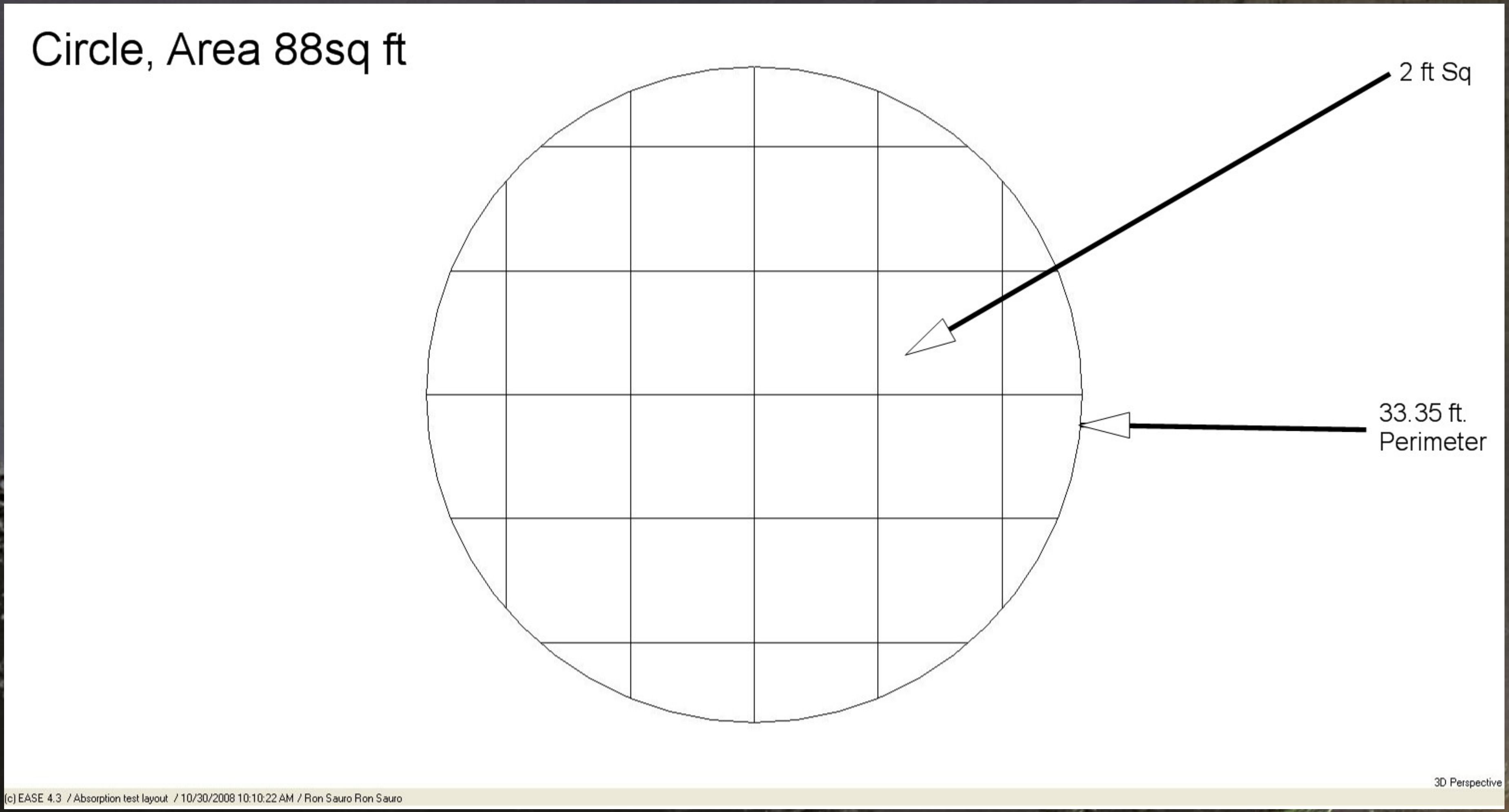
Measured similar area samples in the two prescribed ways.

Measure perimeter lengths in the two prescribed ways.

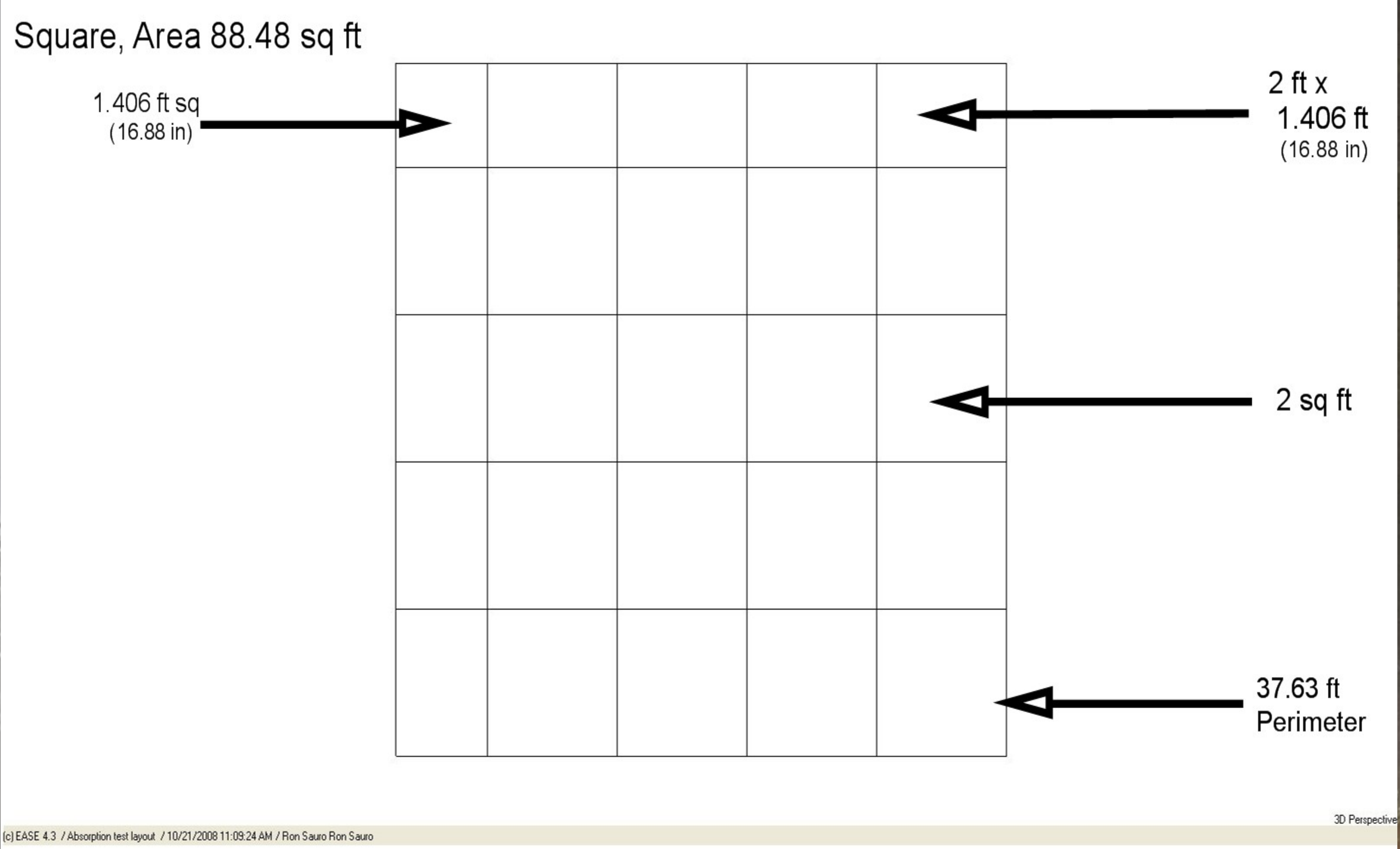
Measure a non absorptive surface with same area and shapes as the above described tests.


IF NOT AREA WHAT
ELSE?

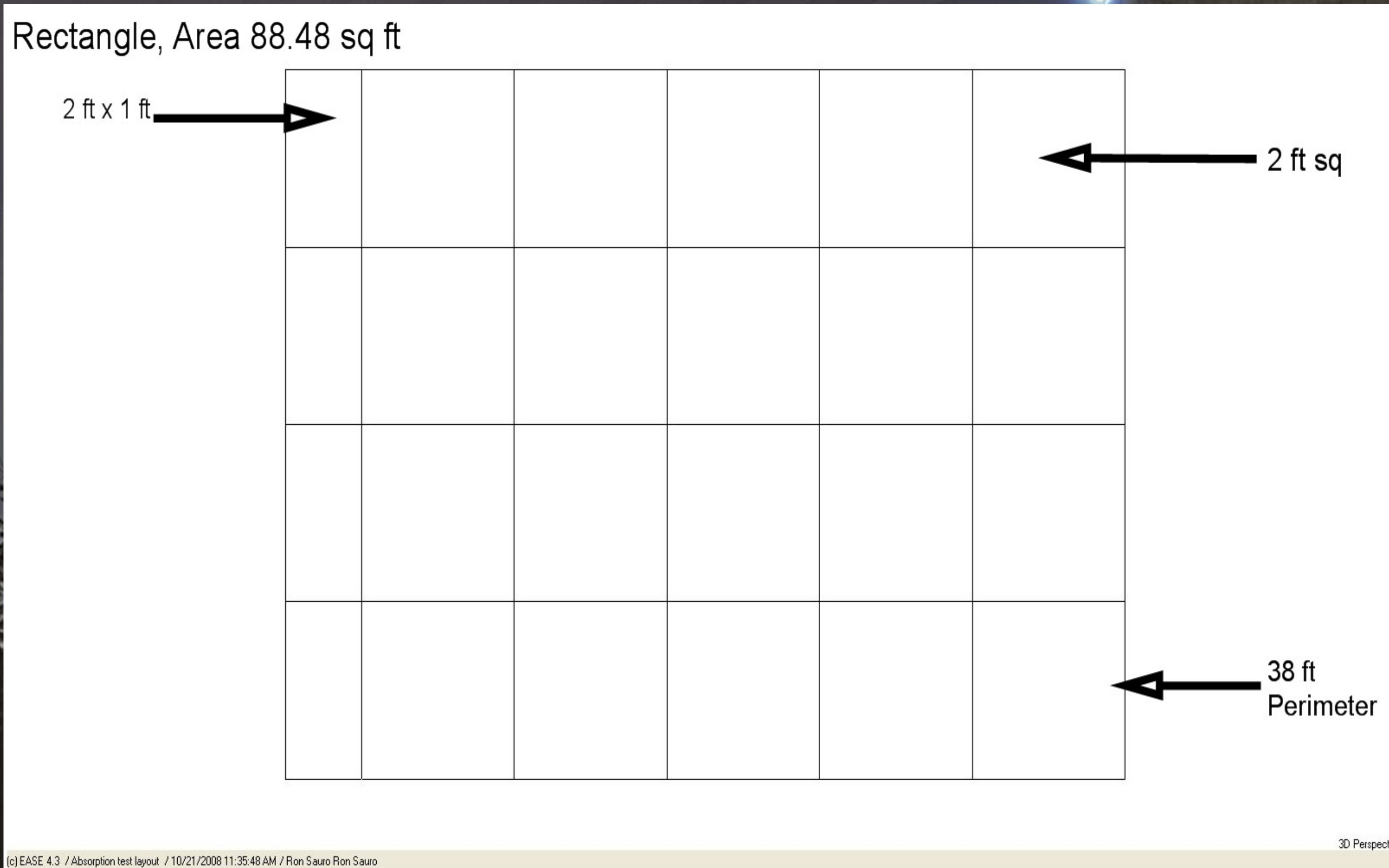
Circle with constant area



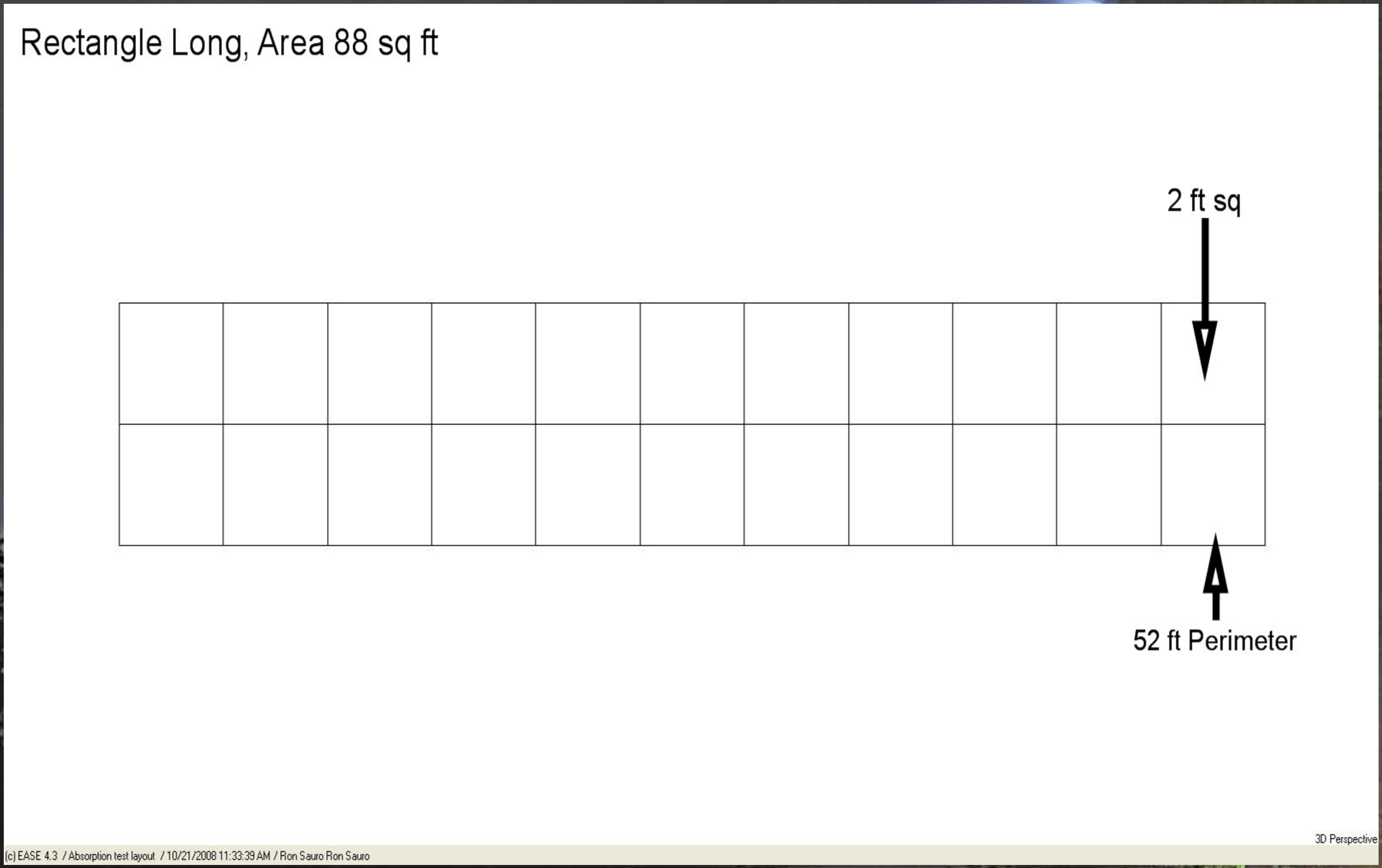
Square with constant area



Rectangle Standard Area

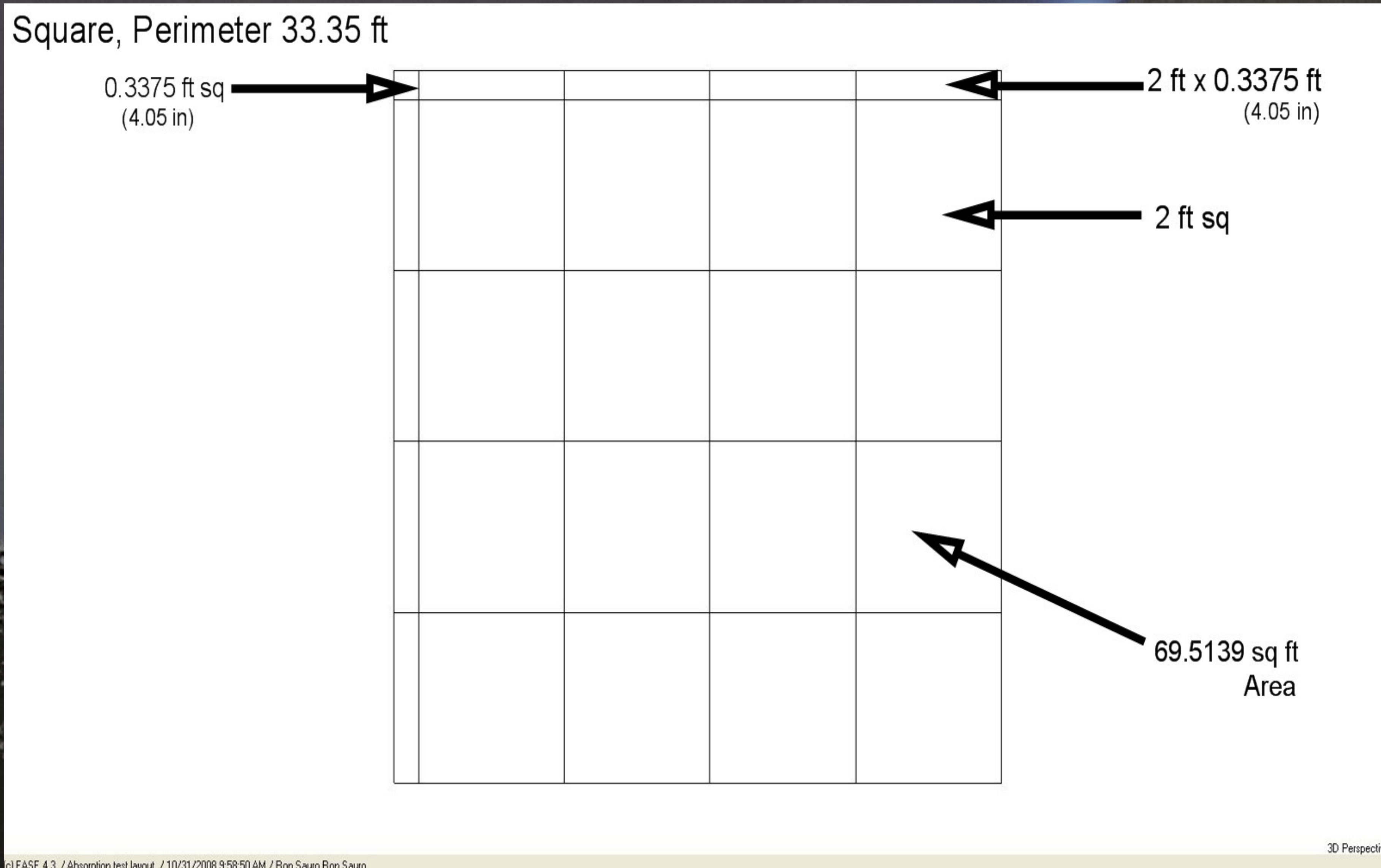


Rectangle Long Area

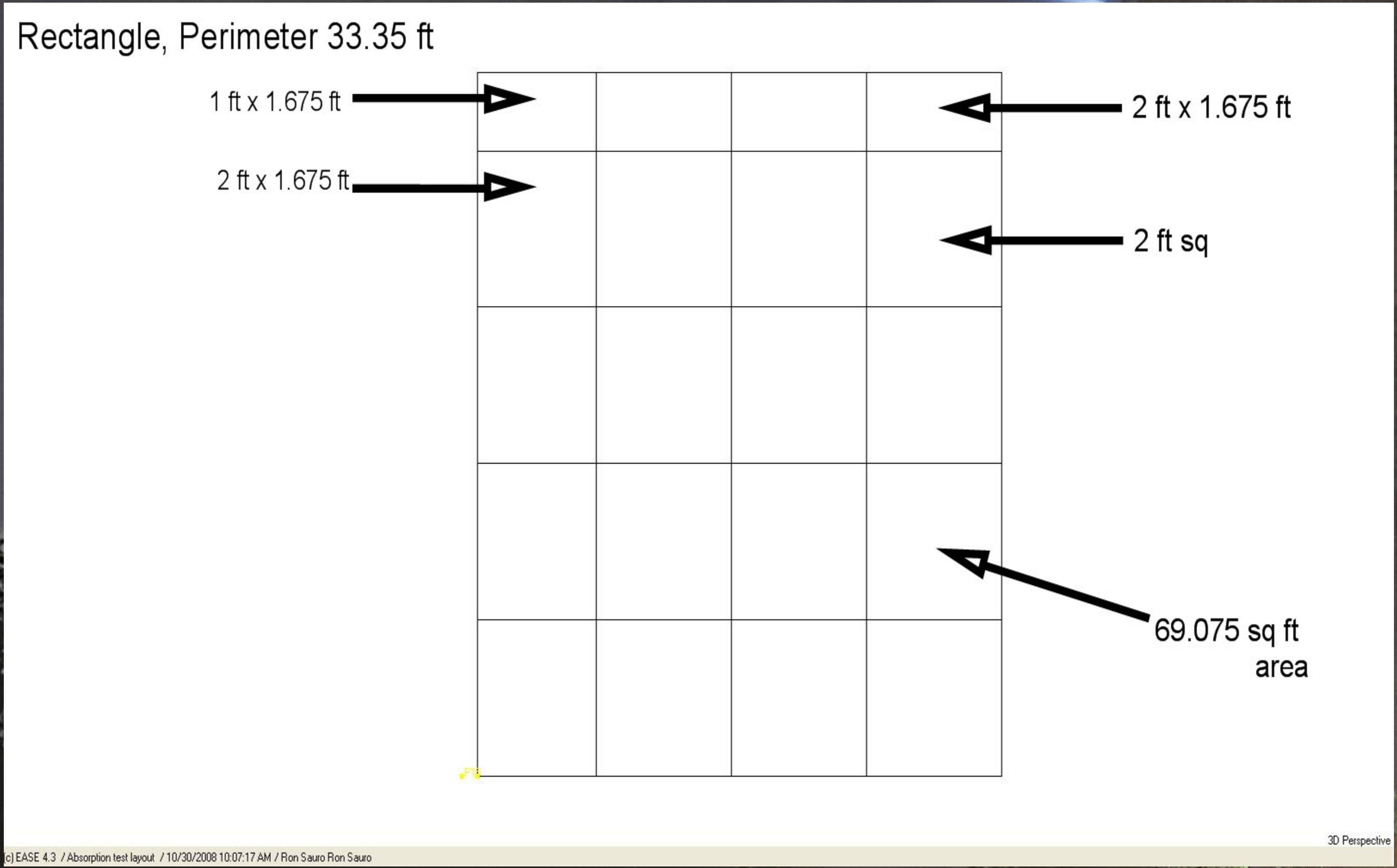


Scattered Pieces Area

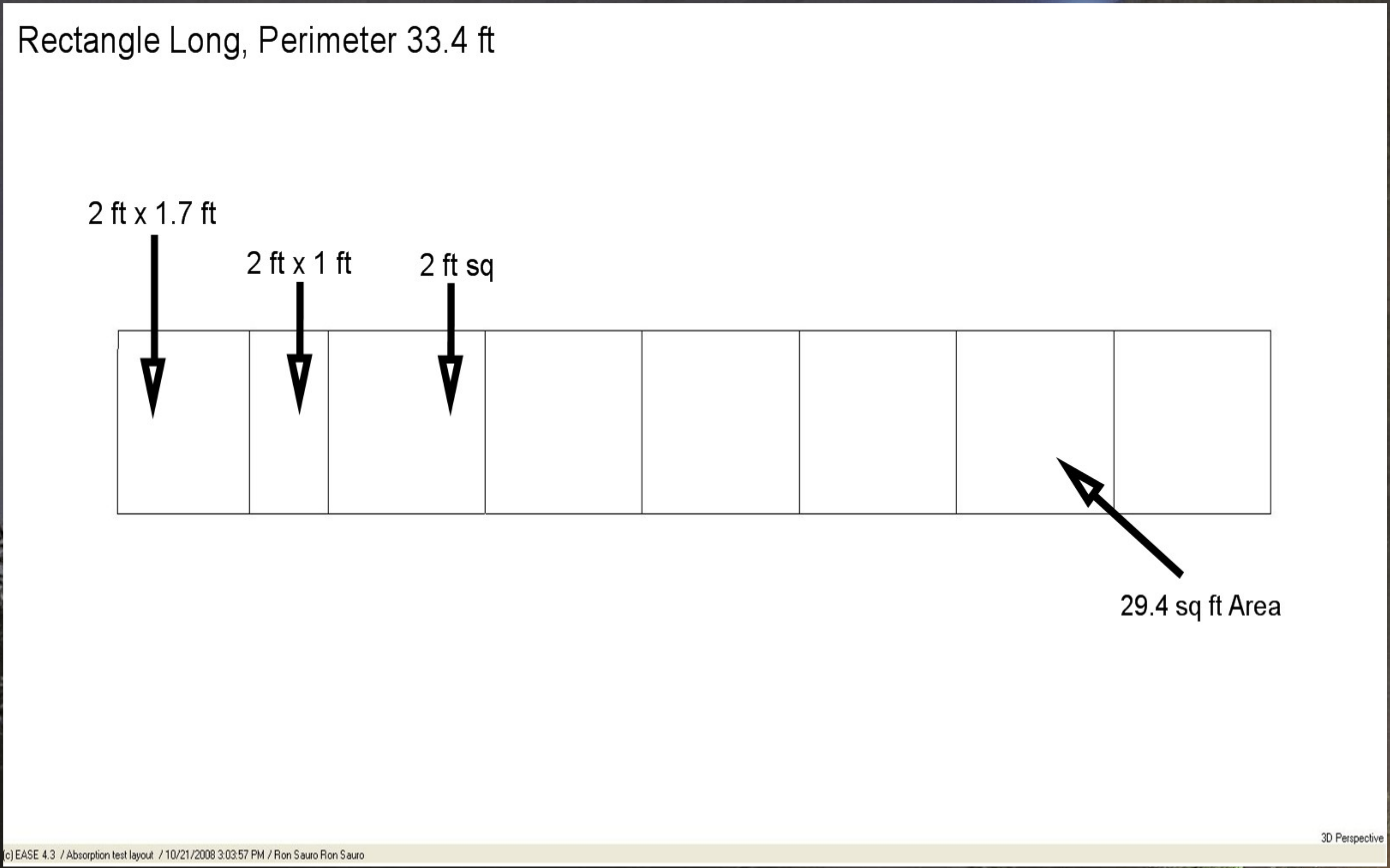
Square Perimeter



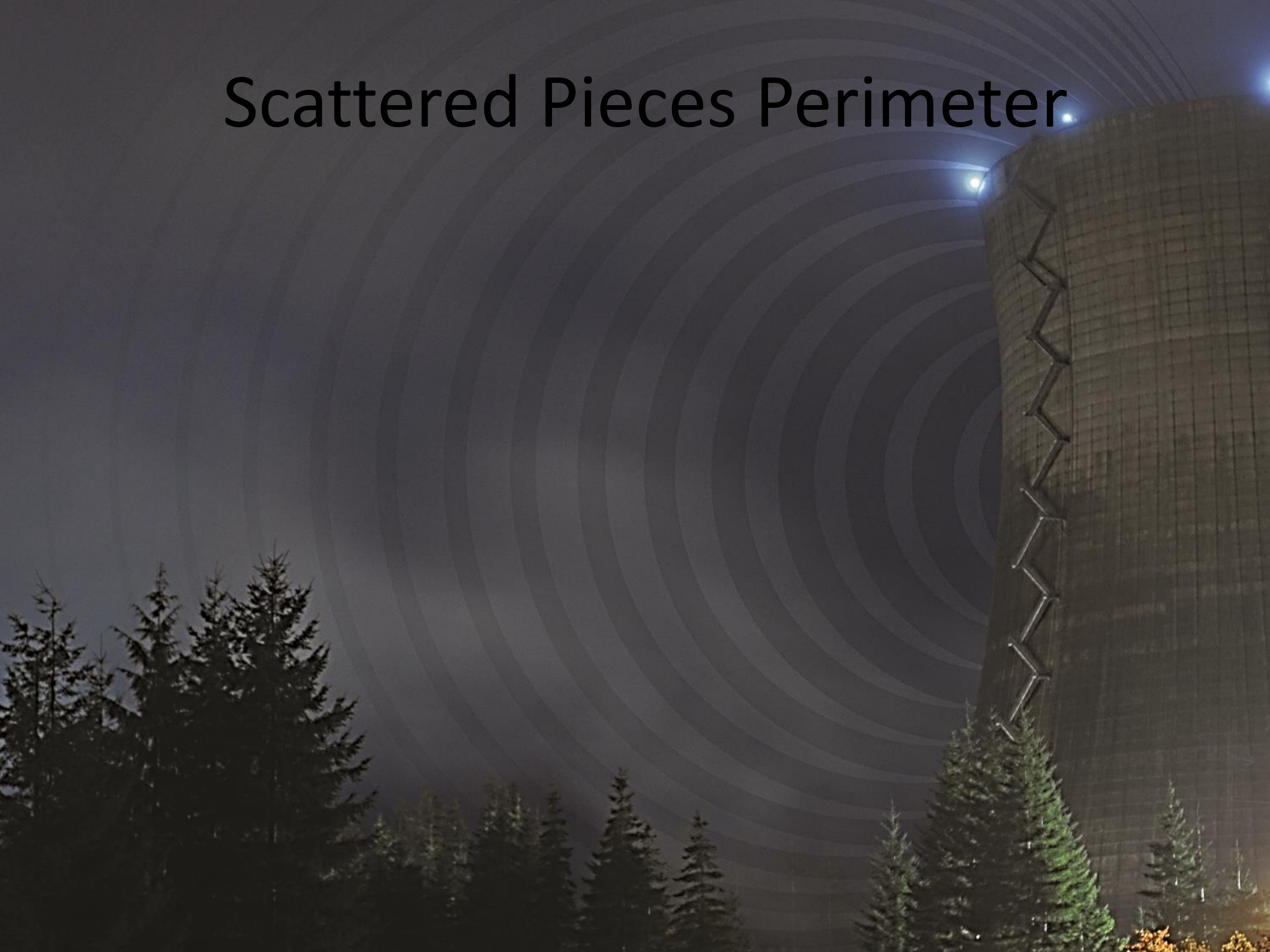
Rectangle Standard Perimeter



Rectangle Long Perimeter



Scattered Pieces Perimeter



1” UHD HDF (sealed)

1” UHD HDF (sealed)

Absorption Coefficients Pt 2:

Is the “Edge Effect” More Important than Expected?

NWAA Labs,

Absorption

- **Types:**

  Flow resistance

  Diaphragmatic resistance

  Air resistance (resonance)

Type Function

- **Flow resistance converts acoustic energy directly to heat created by the friction of air passing through different materials.**

- **Diaphragmatic resistance converts the acoustic energy to heat based on the bending action causing molecular friction and air pressure changes in the volume of air trapped by the membrane.**

- **Resonance converts acoustic energy to heat by alternate compression and decompression of a contained airspace with limited relief.**

Absorption

$$A = 0.9210 \frac{Vd}{c}$$

Where:

A = sound absorption, m^2 or Sabins,

V = volume of reverberation room, m^3 or ft^3,

d = decay rate, dB/s, and

c = speed of sound (calculated in m/s or ft/s)

Speed of Sound

$$c = 20.047\sqrt{273.15 + T°C}\ m/s$$

or

$$c = 49.022\sqrt{459.67 + T°F}\ ft/s$$

Where:

$T^o{}_C$ and $T°{}_F$ are temperature in degrees Celsius and degrees Fahrenheit, respectively

Absorption

$$A = A_2 - A_1$$

Where:

A = absorption of the specimen, m^2 or Sabins,

A_1 = absorption of the empty reverberation chamber, m^2 or Sabins, and

$A = A_2 - A_1$

A_2 = absorption of the reverberation room after the specimen has been installed, m^2 or Sabins.

Absorption Coefficient

$$\alpha = (A_2 - A_1)/S + \alpha_1$$

Where:

α = absorption coefficient of the test specimen, dimensionless, Sabins / ft^2.

S = area of the test specimen, m^2 or ft^2, and $A = A_2 - A_1$

α_1 = absorption coefficient of the surface covered by the specimen

How is the Absorption Coefficient used?

$$RT_{60} = k\left(\frac{V}{S_a}\right)$$

where:

RT60 = time needed for the reverberation energy in the room to decay in level 60dB

k = the speed of sound that equals 0.161 when units of measurement are expressed in meters and 0.049 when units are expressed in feet.

$A = A_2 - A_1$

V = the volume of the room

S_α = the total surface absorption of the room expressed in m^2 or Sabins

Total Surface Absorption of a room

$$S_\alpha = a_1 S_1 + a_2 S_2 + \ldots.$$

where:

S_a = the total surface absorption of the room expressed in m^2 or Sabins.

a_1 = the absorption coefficient associated with a given area S

$A = A_2 - A_1$

S = the surface area of a single surface expressed in ft^2 or m^2

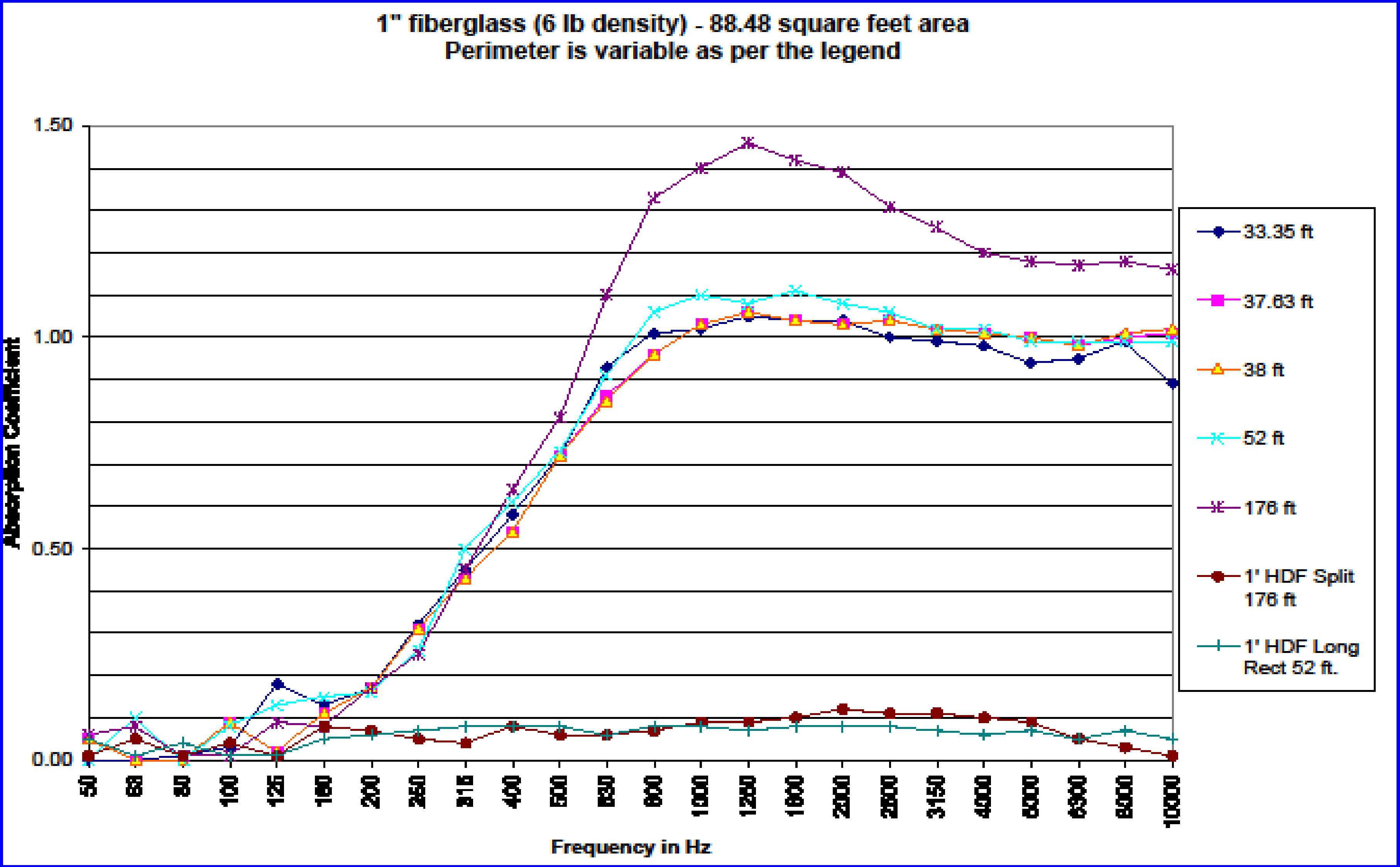
Perimeter Length?

Does it make a difference?

If so, what difference does it make?

$A = A_2 - A_1$

Constant Area Comparisons



Constant Perimeter Comparisons

Data Correlations

Diffraction Effects?

A paper written by DeWitt and Burnside about the edge diffraction of radar waves showed that when radar waves are bent over the edge of a wedge by diffraction there is a heating effect on the air surrounding it transferring to the tip of the wedge. This author knows of nothing in physics that would restrict this effect from applying to acoustic energy as well. If this is the case then we would have to now include diffraction as a form of absorption and a type of absorber.

$A = A_2 - A_1$

Diffraction Effects?

Why does a circular sample have less absorption than a square of the same perimeter. It can be hypothesized that because diffraction has an absorptive function it might have a phase function as well. A square has four straight edges with each of the 4 edges going in 4 directions and any diffractions along that edge could have a common phase function and could be considered "coherent".

$A = A_2 - A_1$

If they are "coherent", then the energy contained could be additive.

Diffraction Effects?

A circle has an edge that is constantly changing direction and the diffractive energy could have different phase information and is not "coherent" and therefore may not be additive in its nature.

$A = A_2 - A_1$

Conclusions

Is Area Enough?

Based on the results shown in this paper, it is believed that an area based "Absorption Coefficient" alone is not adequate to describe the total absorption of a surface.

Conclusions

Is “Edge Effect” More Important Than Expected?

It can be seen in the prior data that “Edge Effect” is much more important than previously thought. It can introduce considerably more absorption to a specimen than just a surface area based calculation would indicate.

Conclusions

The author now thinks that “Absorption Coefficients” that are derived from the methods recommended in ASTM-C423 and ISO-354 may be inaccurate at best.

Recommendations

A New Formula for Calculation of Absorption in Rooms.

It is thought that a new formula should include the perimeter. This should ideally be used based on the charts previously presented.

The absorption should not be a coefficient since it is variable but should be expressed and used in m^2 or Sabins.

Formula for absorption constant

$$A_{x(f)} = \left(\frac{\frac{A_{2(f)}}{P_2} - \frac{A_{1(f)}}{P_1}}{\frac{S_2}{P_2} - \frac{S_1}{P_1}}\right) * S_x + \left(\left(\frac{A_{1(f)}}{P_1}\right) - \left(\frac{\frac{A_{2(f)}}{P_2} - \frac{A_{1(f)}}{P_1}}{\frac{S_2}{P_2} - \frac{S_1}{P_1}}\right) * \frac{S_1}{P_1}\right) * P_x$$

where:

A_x	=	absorption of the surface being calculated, m2 or Sabins.
A_1	=	absorption of sample 1, m^2 or Sabins.
A_2	=	absorption of sample 2, m^2 or Sabins.
S_x	=	area of surface being calculated, ft^2 or m^2
S_1	=	area of sample 1, ft^2 or m^2
S_2	=	area of sample 2, ft^2 or m^2
P_x	=	perimeter of surface being calculated, ft or m
P_1	=	perimeter of sample 1, ft or m
P_2	=	perimeter of sample 2, ft or m
(f)	=	frequency of interest in calculation

C-423/ISO-354 Absorption

Recommendations

A New Formula for the Calculation of Absorption in Rooms.

It is thought that a new formula should include the perimeter. This should ideally be used based on the chart previously presented.

The absorption should not be a coefficient but can be expressed as a constant.

Calculating the Absorption Constant

$$k_{ab(f)} = \frac{\left(\left(\frac{As_{(f)}}{Ps}\right) - \left(\frac{Am_{(f)}}{Pm}\right)\right)}{\left(\left(\frac{Ss}{Ps}\right) - \left(\frac{Sm}{Pm}\right)\right)}$$

$$k_{ab} = \left(\frac{\frac{Am}{Pm} - \frac{As}{Ps}}{\frac{Sm}{Pm} - \frac{Ss}{Ps}}\right)$$

where:

k_{ab} = absorption constant
A_s = absorption of scattered sample, m^2 or Sabins.
A_m = absorption of mono sample, m^2 or Sabins.
S_s = area of scattered sample, ft^2 or m^2
S_m = area of mono sample, ft^2 or m^2
P_s = perimeter of scattered sample, ft or m
P_m = perimeter of mono sample, ft or m
(f) = frequency of interest in prediction

Proposed Formula using the Absorption Constant

$$A_{x(f)} = k_{ab(f)} * S_x + \left(\left(\frac{A_{m(f)}}{P_m} \right) - k_{ab(f)} * \frac{S_m}{P_m} \right) * P_x$$

where:

K_{ab} = absorption constant

A_x = absorption of the surface being predicted, m2 or Sabins.

A_s = absorption of scattered sample, m^2 or Sabins.

S_x = area of surface being predicted, ft^2 or m^2

S_m = area of mono sample, ft^2 or m^2

P_x = perimeter of surface being predicted, ft or m

P_s = perimeter of scattered sample, ft or m

P_2 = perimeter of mono sample, ft or m

(f) = frequency of interest in prediction

C-423/ISO-354 Absorption

Research

- This research resulted in a new way to measure and produce a better absorption constant than the "Absorption Coefficient" .

NWAA Labs, Inc
2018 ASA MINN

A coefficient is not a percentage!!!!

0.9 absorption coefficient is NOT 90% absorption!!

NWAA Labs, Inc
2018 ASA MINN

A coefficient is not a percentage!!!!

0.9 absorption coefficient is NOT 90% absorption!!

Absorption

Myth: Acoustics is a "settled" branch of physics

Fact: There is fundamental research going on today and new facts are being written daily that are as basic as Sabines work

Absorption

Myth: We can measure absorption

Fact: We cannot measure absorption directly

Absorption

Myth: We can measure absorption

Fact: We cannot measure absorption directly. We measure the differences in the reverberation time in a reverberation room and use that to determine the amount of absorption needed in the room to effect that change.

Absorption

Myth: BIG ONE!! Absorption is controlled
by the size (area) of the absorber.
$\alpha = A/S$ or $A = \alpha * S$

Fact: This is not true at all.
Previous presentations have shown this to be the case.
The ratio of perimeter length to the area
is a controlling factor.

Absorption

Myth: BIG ONE!! Absorption is controlled by the size (area) of the absorber.

a = A/S or A=a * S

NEW Fact: This is not true at all.
The spacing of absorption is also controlling factor.

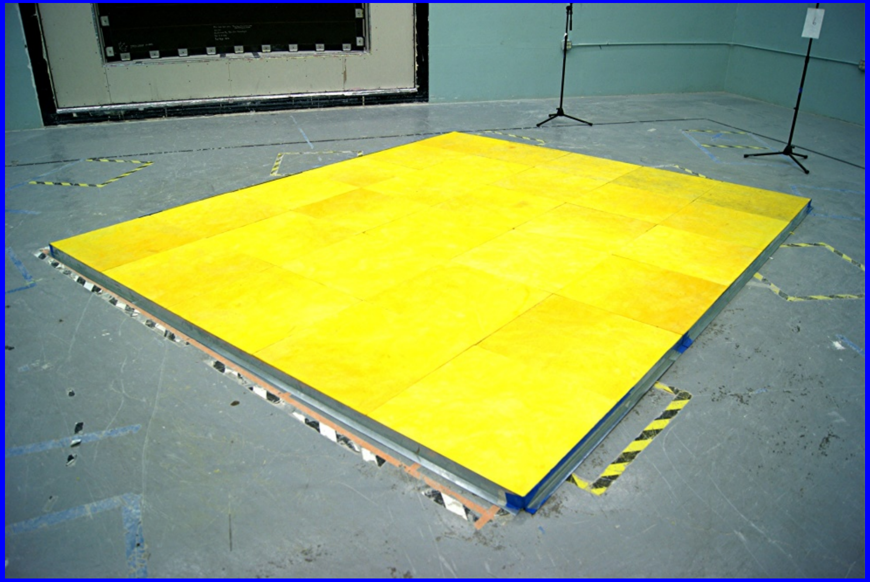
Absorption

We know that the configuration of an absorber affects the absorption from previous presentation but what effect does the spacing between these unit have on the absorption and what is the effect of the orientation of the absorber have on the absorption.

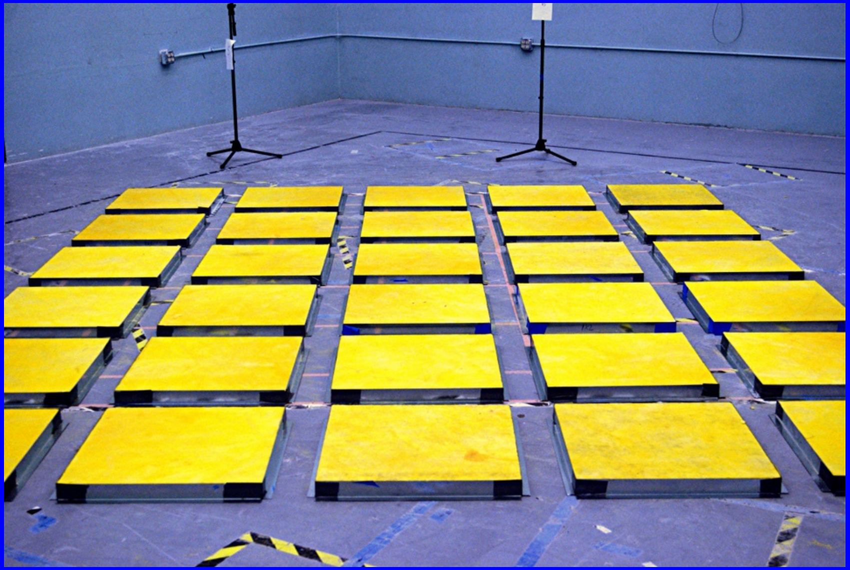
Absorption Experiments

We designed a series of experiments to test these questions. First we tested the spacing differences between 2 ft by 2 ft pieces compared to a monolithic specimen. The spacing varied from 6 inches in both directions to 24 inches in both direction with edges parallel to each other and the walls. (See following four slides)

Absorption

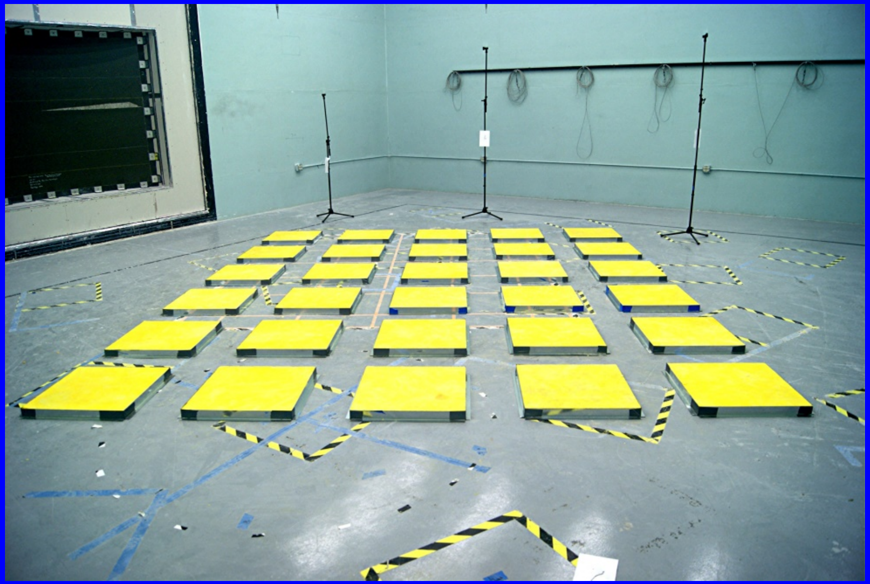


Monolithic



6 inch spacing

Absorption



12 inch spacing

18 inch spacing

Absorption

24 inch spacing

Absorption

Spacing comparisons

Absorption Experiments

We designed a series of experiments to test these questions. Second we tested the spacing differences between 2 ft by 2 ft pieces compared to a monolithic specimen. The spacing varied from 6 inches in both directions to 24 inches in both direction with edges not parallel to each other and the walls. (See following six slides)

Absorption

24 inch aligned

24 inch unaligned

Absorption

24 inch unaligned

Absorption

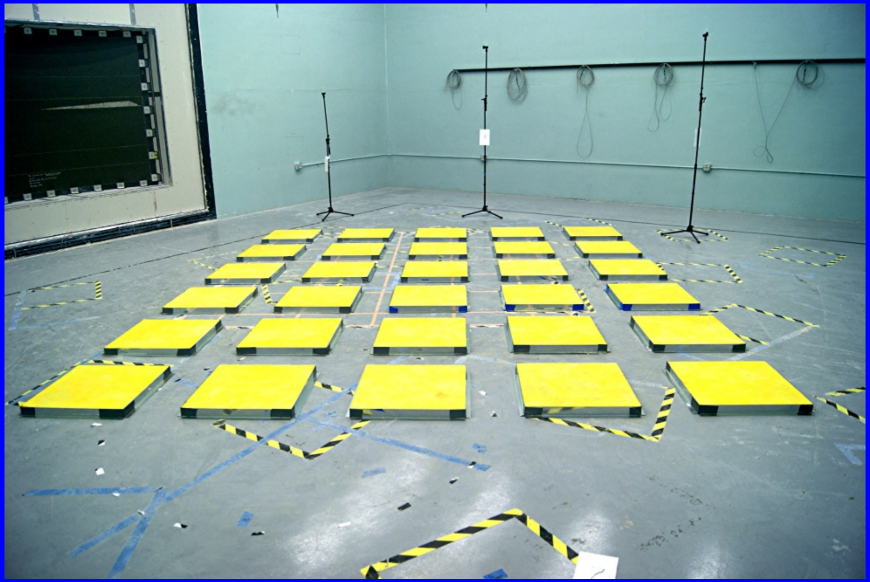
18 inch aligned

18 inch unaligned

Absorption

18 inch unaligned

Absorption



12 inch aligned

12 inch unaligned

Absorption

12 inch unaligned

Absorption

Myth: Baffles have twice as much absorption when both sides are exposed to the room

Fact: Baffles measured have an average of 1.2-1.3 times more absorption when hung in a room

Absorption

Myth: Baffles have effect
depending on their arrangement.
i.e. Parallel, Boxed, Herring bone and others.

Fact: None of these makes any significant
difference to the absorption of a room.
The spacing between individual units can
be used to increase the real absorption of the units

Absorption

Myth: Wall mounted panels that are spaced off of the walls will increase their low frequency absorption as the space behind increases.

Fact: This is only partially true. The low frequency absorption only increases when the spacing from the wall does not exceed 1 inch. The effect disappears after 1 inch. This only applies to unimpeded airspace.

Absorption

Myth: BIG ONE!! Absorption is controlled by the size (area) of the absorber.

$a = A/S$ or $A = a * S$

Fact: This is not true at all.
Previous presentations have shown this to be the case.
The ratio of perimeter length to the area and spacing between units are the controlling factors.

NWAA Labs Experimental Diffusion and Scattering Test

Diffusion:

(Better Ways of measuring it, displaying the data and using it in Room Simulations)

ISO 17497-1, ISO17497-2

A 4d world being crammed into a 2d box for 3d acousticians

6.3.2 Structural depth of test sample
The measurement method is intended for surface roughness. Thus, the results are only reliable if the structural depth is sufficiently small compared to the size of the test sample. The structural depth should be $h < d/16$, where d is the diameter of the turntable.

ISO 17497-1, ISO17497-2

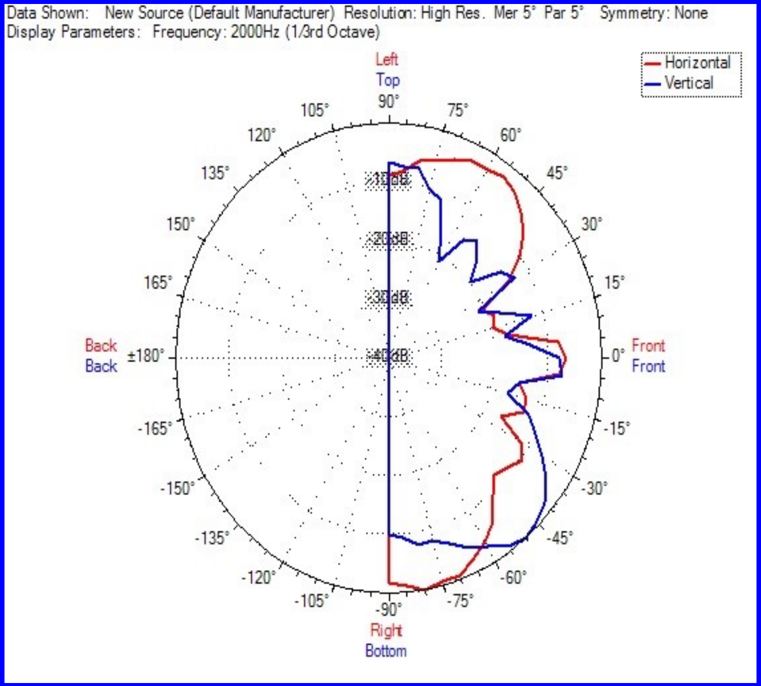
A 4d world being crammed into a 2d box for 3d acousticians

Not applicable to geometric reflectors or to seating areas or large surface constructions that have surfaces sufficiently large enough to specularly reflect energy at needed frequencies.

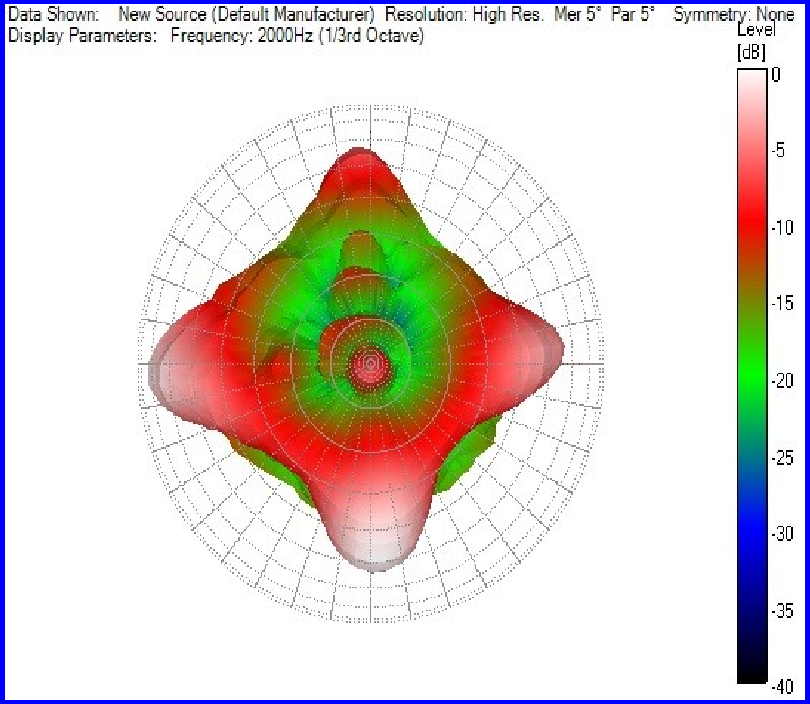
A Pyramidal

Question?

What do you see and use more of?

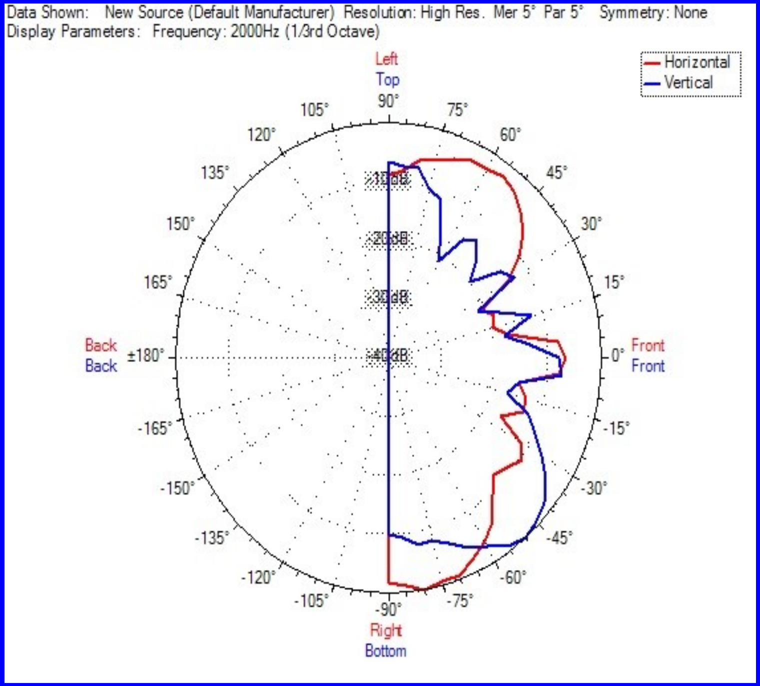


or



Question 2A?

What can we learn from this 2d view?

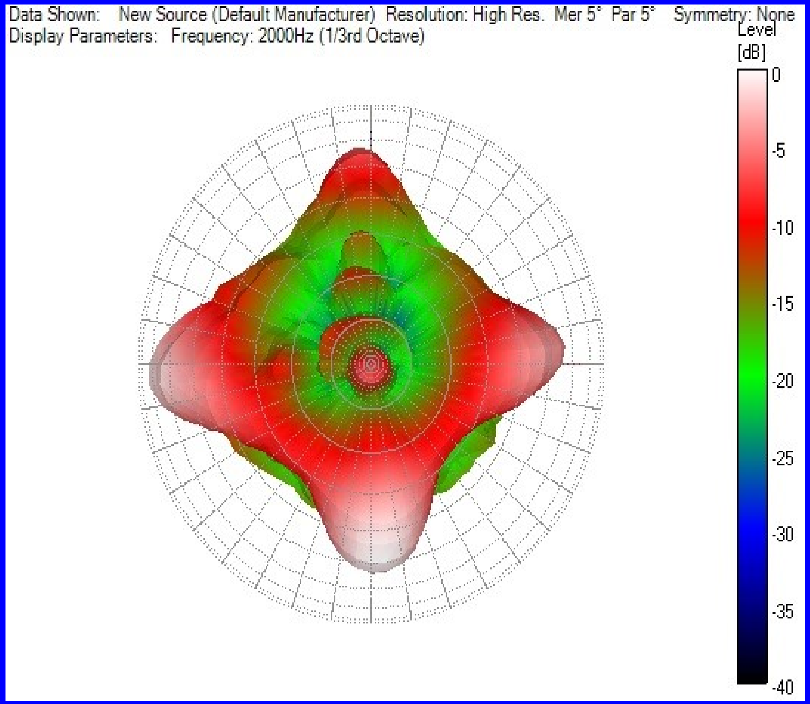


We can look at both horizontal and vertical directivity polars of that frequency.

We can see directly the attenuation of energy along that polar of that frequency.

Question 2B?

What can we learn from this 3d view?



We can look at all angles of directivity of that frequency. We can see directly the attenuation of energy along any angle of directivity of that frequency.

Measuring system for speakers

A diffuser is a speaker without a voice coil

Measuring system for diffusers

Conclusions

What you have seen today is the results of a preliminary standard that has been written at ASTM and is based on the AES 56 standard used to measure directivity balloons for speakers and other sound sources.

As of last week at least 12 manufacturers have had their diffusers measured using this method and have data available and ready.

The simulation programs are NOT directly ready for this but can be made to work with this data using work arounds

We hope this will change in the near future and will allow basic diffusion to be used in simulation programs in a better way than just coefficients that tell us very little.

Acknowledgements

I want to thank certain people without whose help this paper and potential ASTM standard would not have been possible.

Jim DeGrandis of Acoustics First Corporation

His animations are without parallel and always help explain how this whole system will help in simulations. He has helped solidify what formats data can be distributed. If we can see, we can do!

Richard Lenz of RealAcoustix

His help in formulating and helping make clear how this applies mathematically as well as his help in the field of electro acoustics helped make this idea fly at the ASTM level. Great writer that can make ideas come alive.

Acknowledgements

I want to thank certain people without whose help this paper and potential ASTM standard would not have been possible.

Wolfgang Ahnert and Stefan Feistel of AFMG
They designed and wrote the code for Speaker Lab and made possible the visualizing of the phase balloon that will eventually revolutionize how we understand diffusion and diffraction.

Peter D' Antonio of RPG Acoustics
He was the first person to bring diffusion into normal discussion when all we had was absorption and geometric reflectors as sound control tools.

Thank You for your time and attention