Measuring Absorption: Bad Methods and Worse Assumptions

I apologize, in advance, if this is YOUR Ox that is gored

Introduction

This presentation will explore the definitions of absorption, the different methods of measuring absorption and the assumptions that lead to creating an unworkable “Coefficient of Absorption”

Absorption

- **Types**
- **Function**

Types

- Flow resistance
- Diaphragmatic resistance
- Possible other types?

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.**

Standards

- **ASTM C-423**
- **ISO-354**
- **ISO-17497-1**

Sample Sizes

- ASTM-C423 requires a rectangular sample of 72 sq ft with a L of 9 ft and a of 8 ft.
- ISO-354 requires a rectangular sample of 10-12 sq m with a ratio width to length of between 0.7 and 1.
- ISO-17497-1 requires a full scale circular sample of a minimum diameter of 3.0 meters = 7.068 sq meters.

Similarities

- ASTM–C423 and ISO-354 require similar shaped samples.
- Calculation of Coefficient in ASTM-C423, ISO-354 and ISO-17497-1.

Differences

- 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 “Coefficient of Absorption”.

Measurements of RT

- Interrupted Noise
- Impulse Response

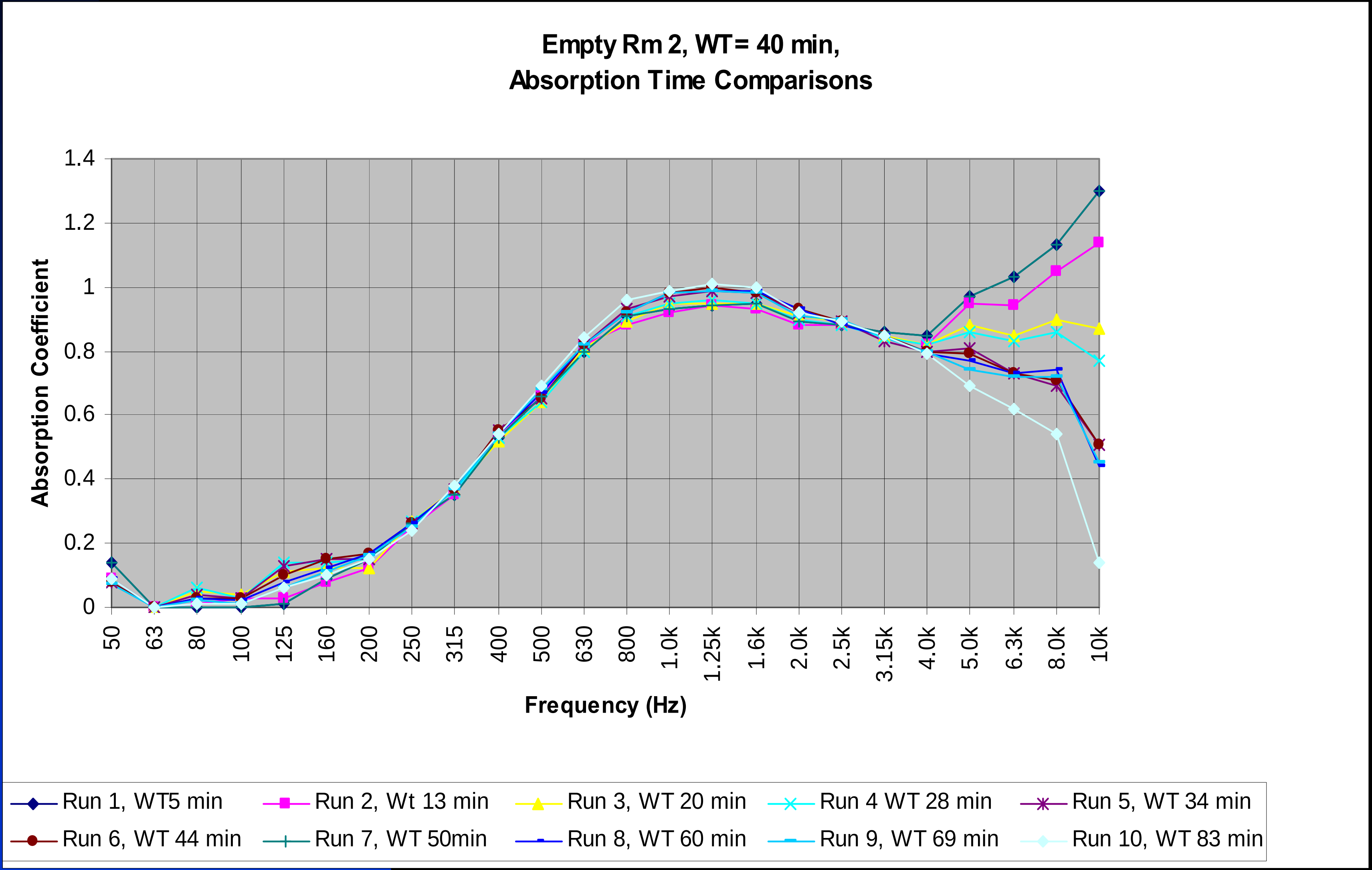
Parameters that are required to be controlled

- Temperature
- Humidity
- Atmospheric Pressure

Waiting Times

- ASTM C-423 and ISO-354 does not require a waiting time for measurements of RT
- ISO-17497-1 does RECOMMEND a waiting time of 15 minutes because Impulse response requires a time invariant environment

Waiting Times



Waiting Time Necessity

- Unlike “real life” where air moves around, laboratories require a consistent environment to make measurement that are comparable to other measurements.
- We “require” temperature, humidity and atmospheric pressures to be stable…so why not air movement?

Bad Methods (continued)

- If air movement is bad for consistency of Room RT in a lab setting, then, are we not “standardizing” error by allowing moving microphones and moving vanes in our reverberation room to “maximize” diffuse reverberation in our rooms?

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

α_1 = absorption coefficient of the surface covered by the specimen

How is 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.

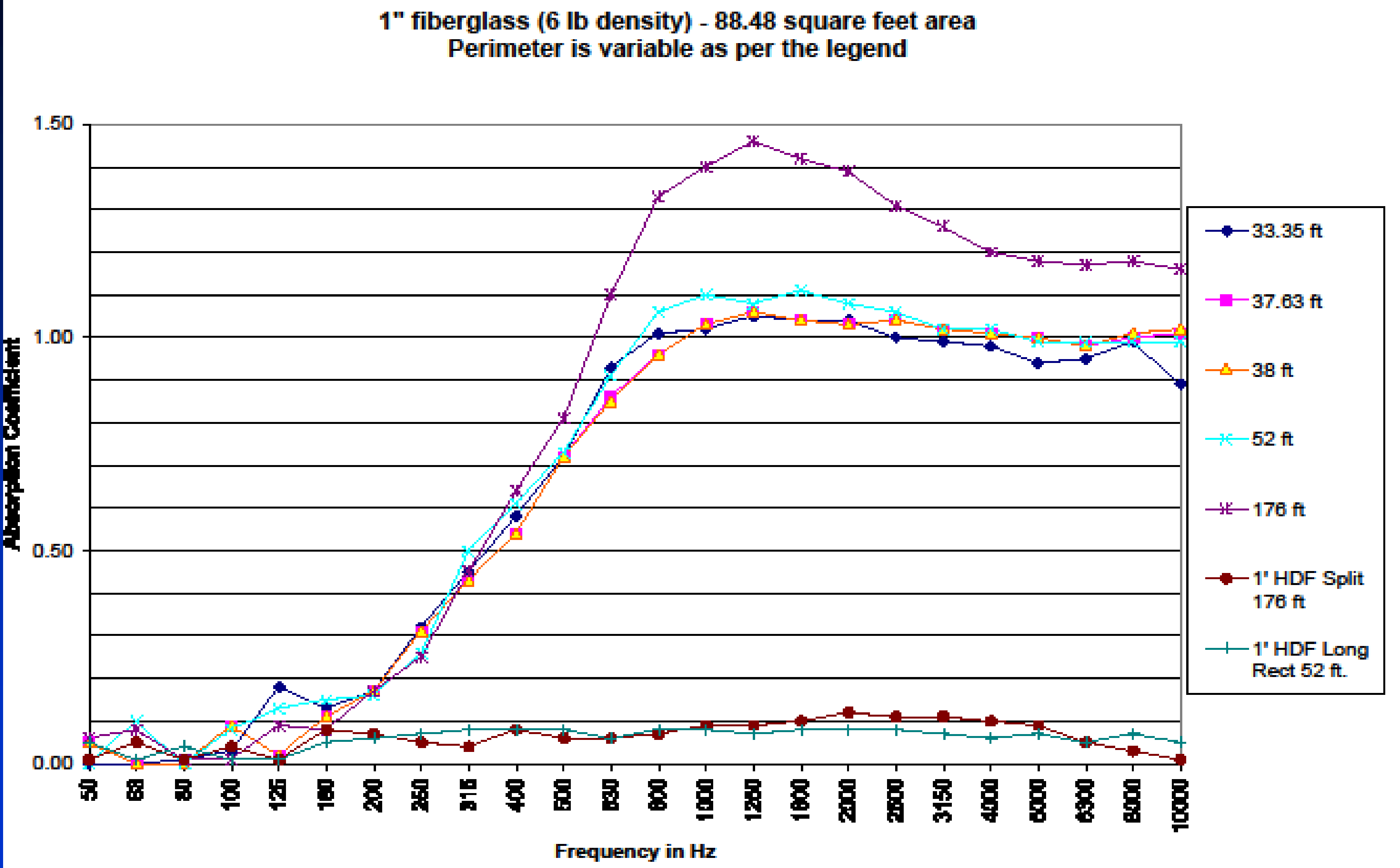
V = the volume of the room

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

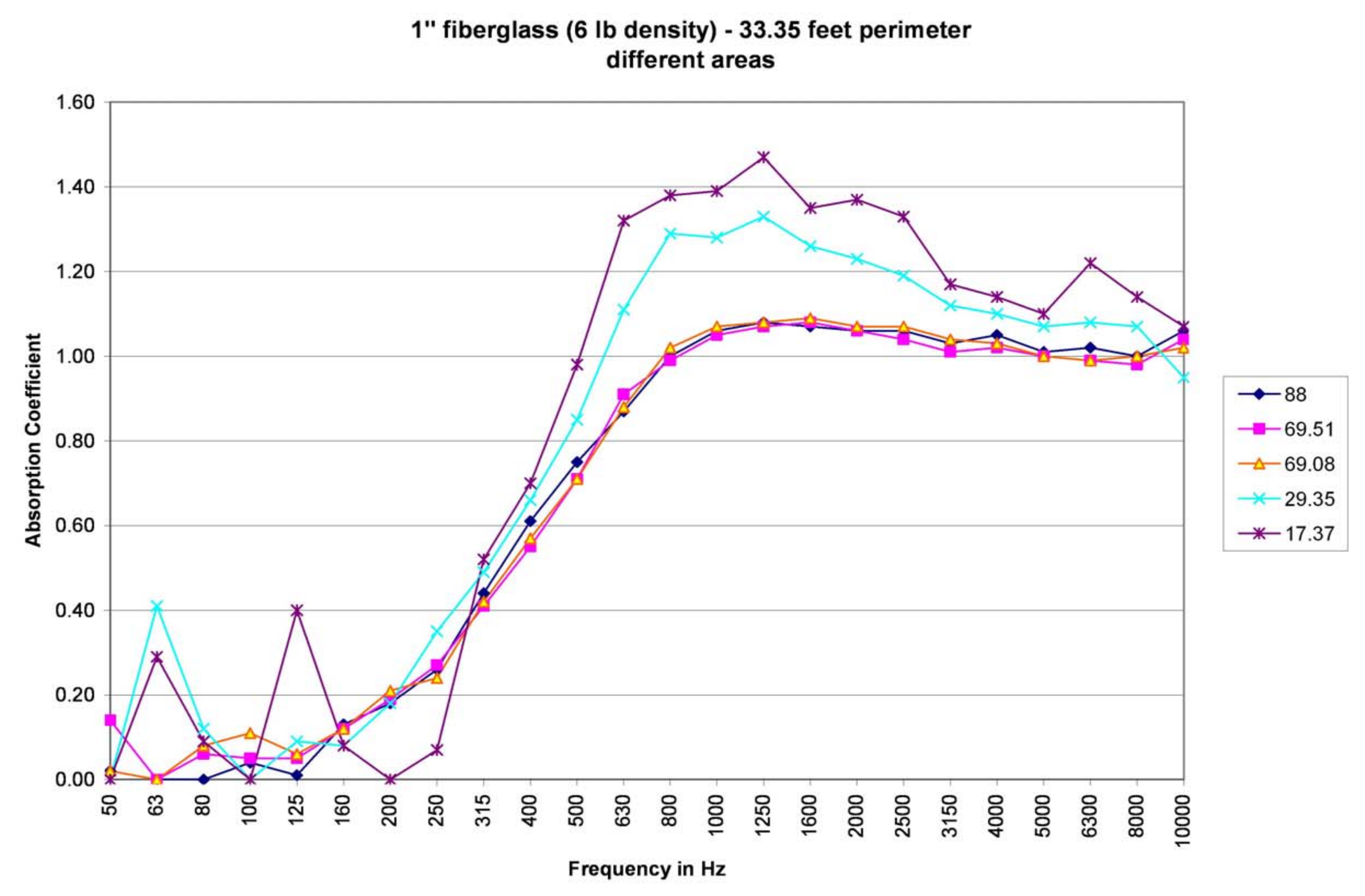
Bad Assumptions

- High Frequencies are not “consistent” because of “air absorption.
- Edges have “some small” effect
- Edges can be removed by measuring a hard sample and subtracting it
- We “MUST” have an “Absorption Coefficient”

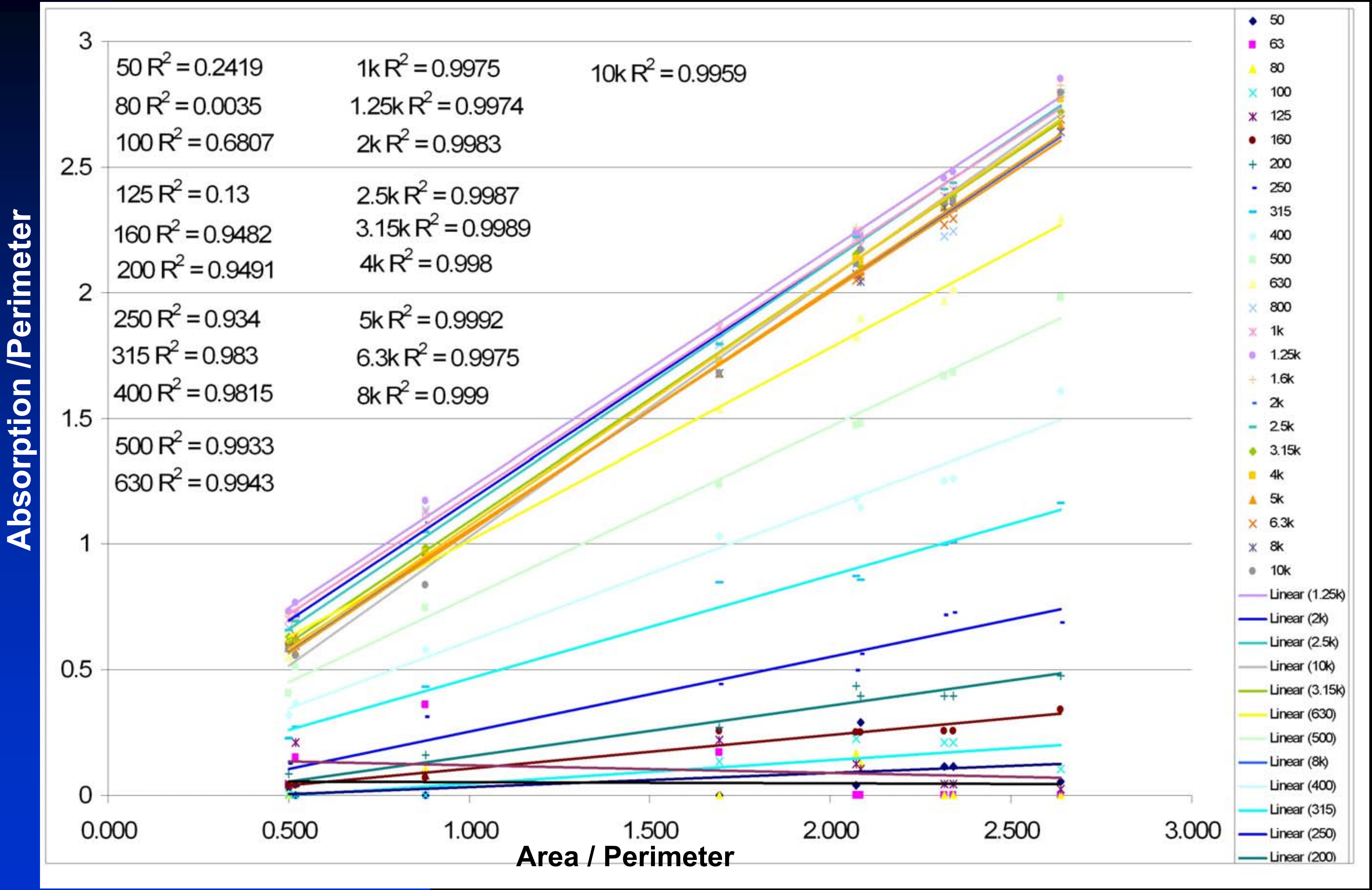
Constant Area Comparisons



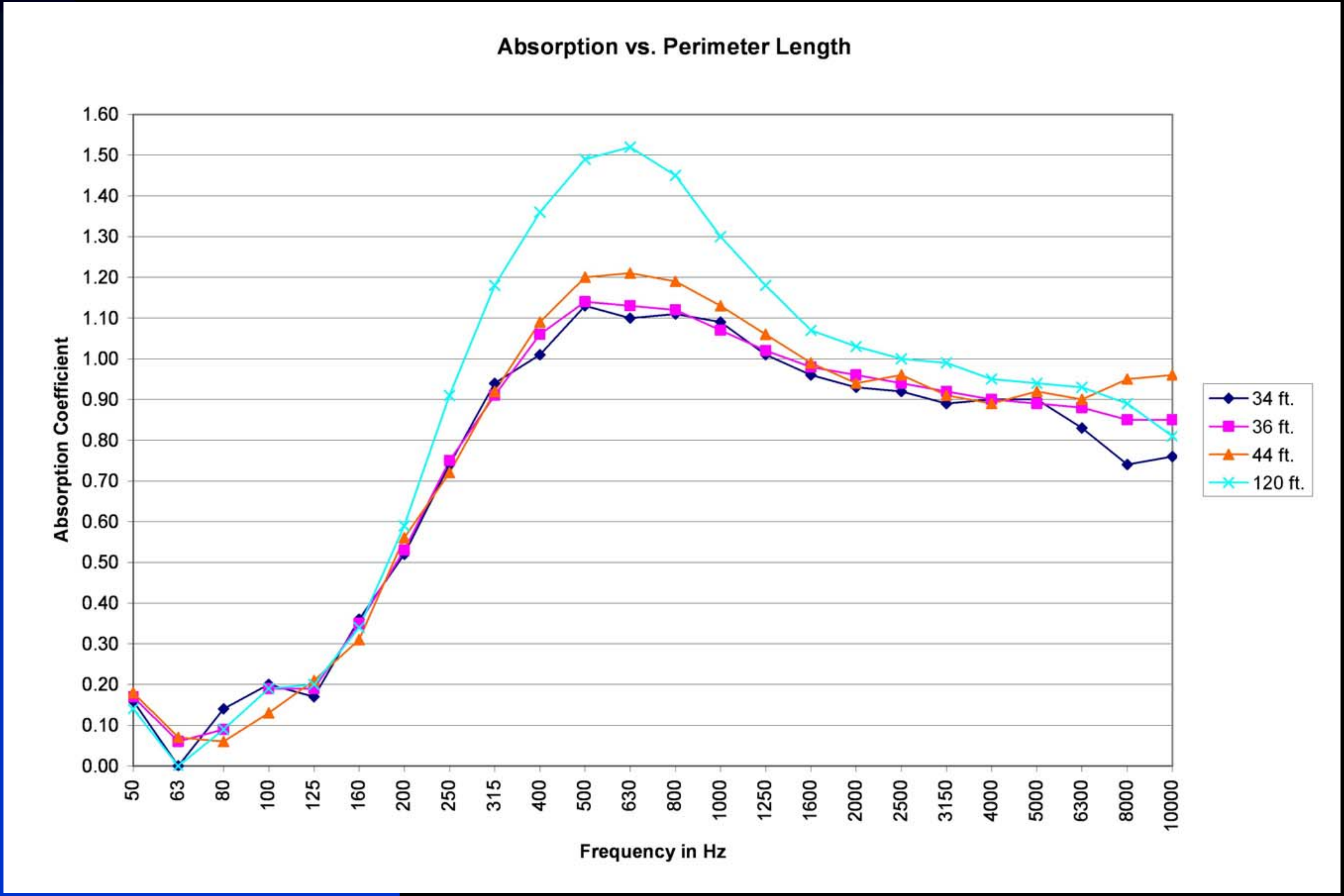
Constant Perimeter Comparisons



Data Correlations



2 inch standard sample 2nd test



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 in/on the air surrounding 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 must have a phase function as well. Physics indicates that a ray from any direction always diffracts in a direction that is “normal” to the direction of the edge at that point. It will also bend to ½ of the angle to the face creating the edge.

Diffraction Effects?

A 90 degree bend will cause the affected ray to bend 45 degree in the direction of the adjacent face. Since all of the random rays are now all normal to the edge and all bending the same direction that the phase would also be the same and could be considered “coherent”. 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 would have different phase information and is not “coherent” and therefore will not be additive in its nature.

Conclusions

Is Area Enough?

Based on the results shown in this presentation 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 calculated using the methods recommended in ASTM-C423 and ISO-354 and ISO17497-1 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 coefficient can be replaced by a slope constant .

Recommendations

Formula Based on the Correlation Chart

$$A = (\frac{y_2 - y_1}{x_2 - x_1}) * Area + (y_1 - (\frac{y_2 - y_1}{x_2 - x_1}) x_1) * Perimeter$$

Expanded version

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

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

Simple version

$$A_{x(f)} = (k)*S_x + ((\frac{A_{1(f)}}{P_1}) - (k)*\frac{S_1}{P_1})*P_x$$

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.

k = constant defined by a slope number

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

S_1 = area of sample 1, ft^2 or m^2

P_x = perimeter of surface being calculated, ft or m

P_1 = perimeter of sample 1, ft or m

(f) = frequency of interest in calculation

Recommendations

1. **A New Way of Testing**

The author recommends that at least one additional test be added to the ASTM-C423 and ISO-354 test to allow the calculation of the slope and intersect from a linear regressed calculation of measured data. A 3rd test would increase the accuracy but based on this data and other data done in preparation of these tests it is not absolutely needed.

Recommendations

ISO17497-1 shows a “Scattering Coefficient” that is used in similar way as absorption in simulation programs. Perhaps it might be time to recognize “scattering” is the part of absorption that is missing in the “Coefficient of Absorption”. This new method unites these two functions into a way of calculating absorption that only uses a single absorption amount instead of two separate functions added together from different tests.

NWAA Labs would appreciate not shooting the messenger because of the message

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