Absorption Coefficients Pt 2: Is the "Edge Effect" More Important than Expected?

Introduction

- **In Part 1 of our presentation we covered the questions and the thinking that went into the experiments decided upon.**
- **In Part 2 we will present the results of those measurements and hypothesize the possible reasons and how it could affect our calculations.**

Absorption

- **Types**
- **Function**
- **Area**
- **Perimeter**

Types

- **Flow resistance**
- **Diaphragmatic resistance**

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.**

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:

$T°_C$ 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_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

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

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

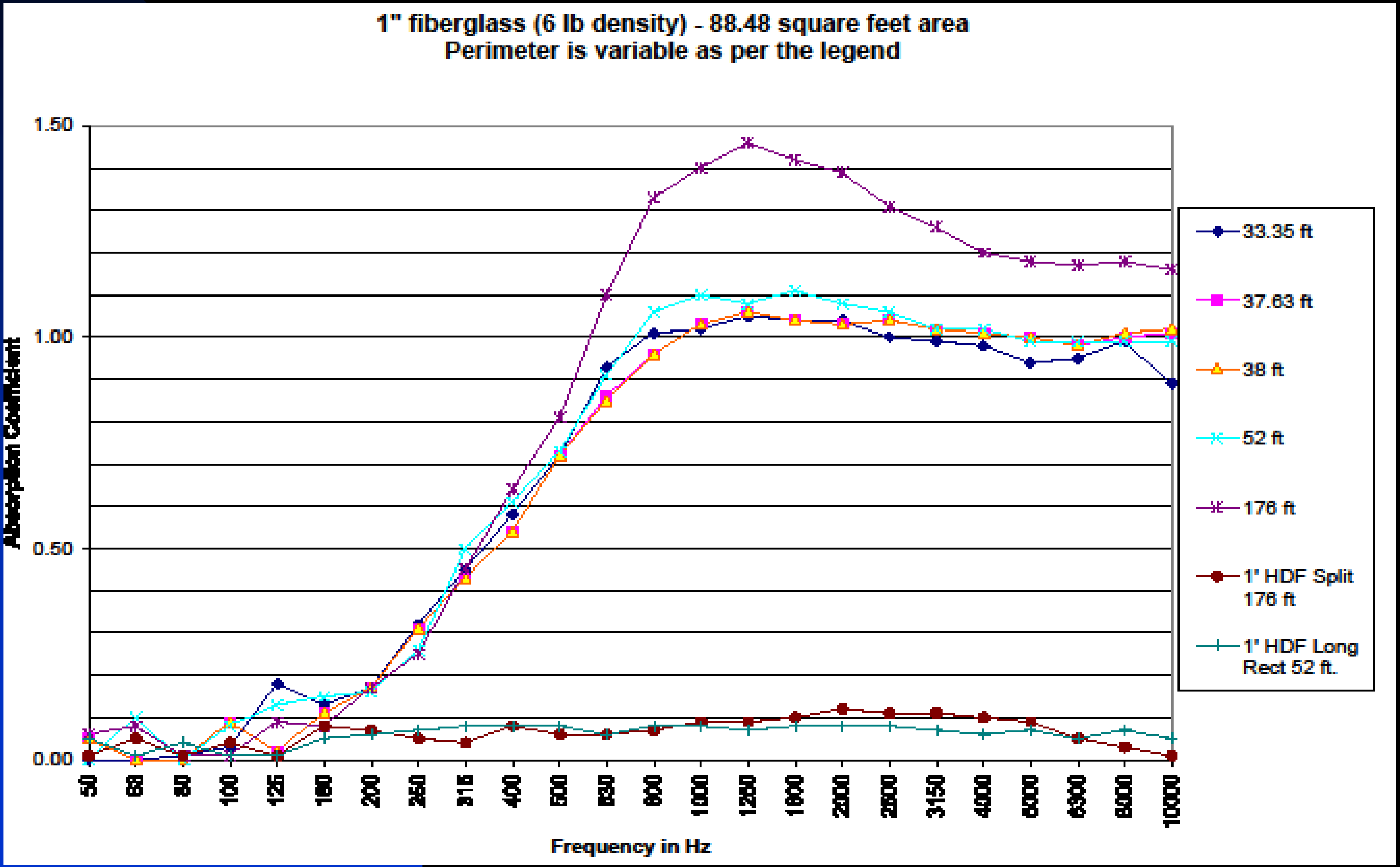
S = the surface area of a single surface expressed in ft^2 or m^2

Perimeter?

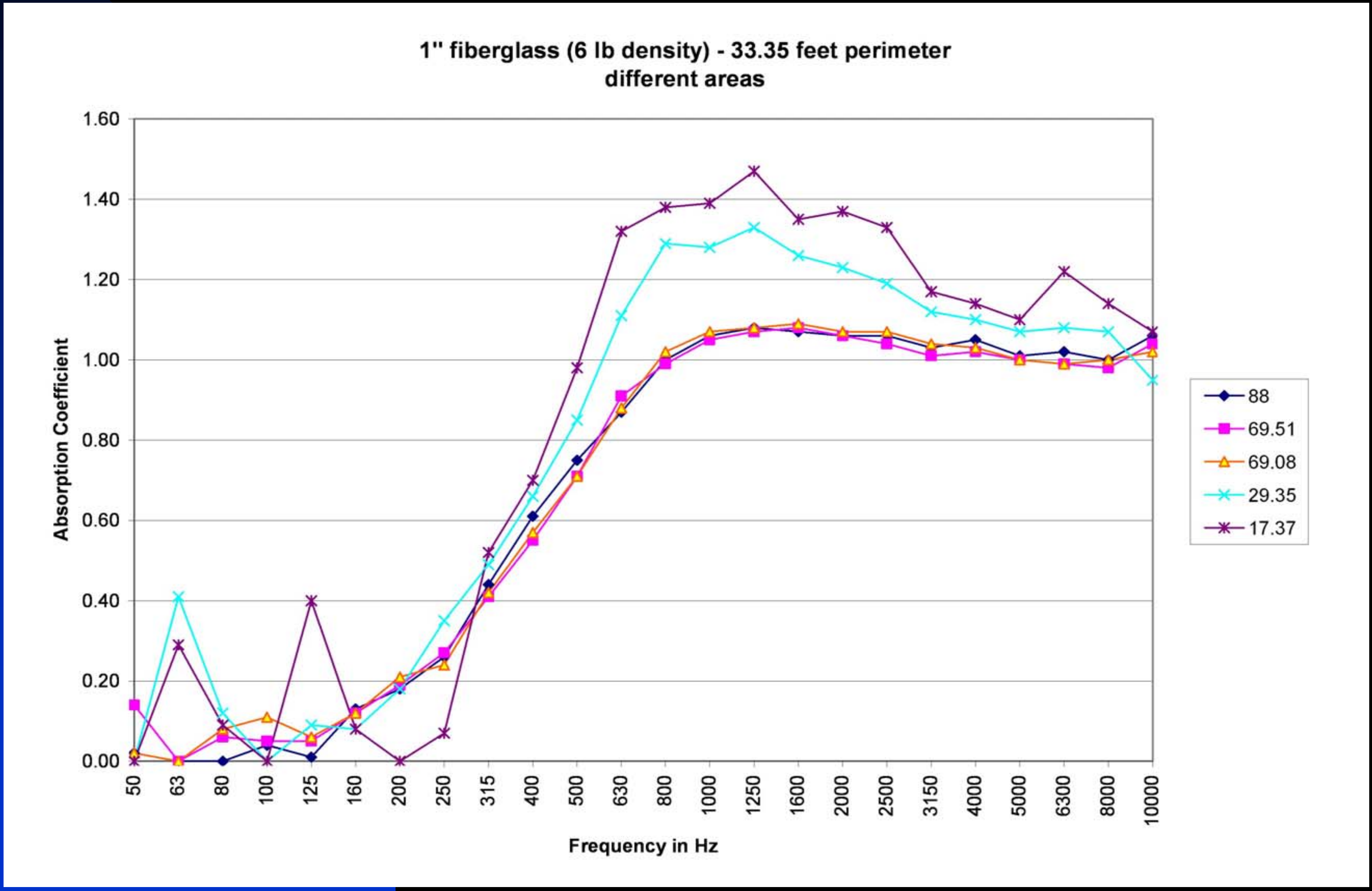
Does it make a difference?

If so, what difference does it make?

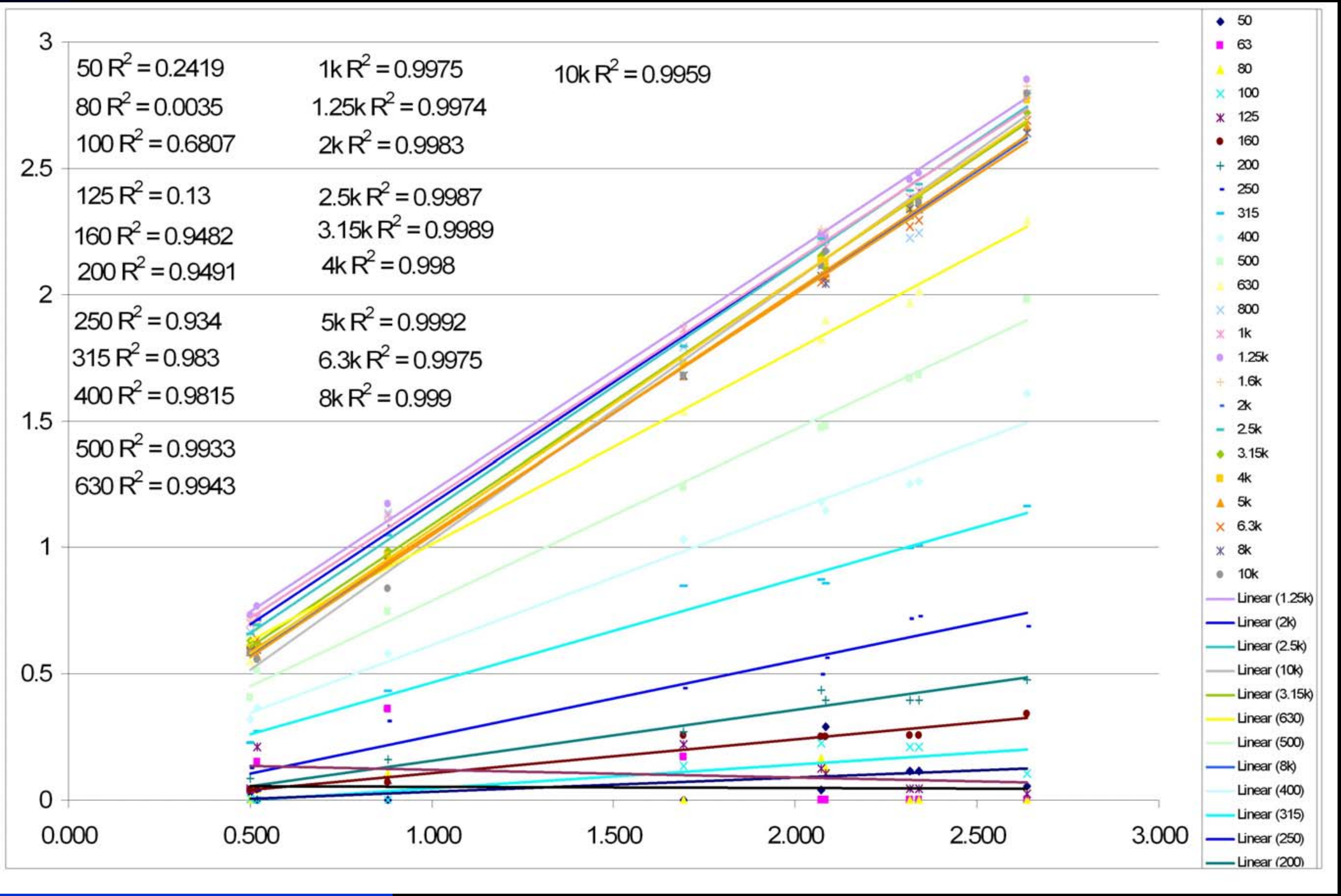
Constant Area Comparisons



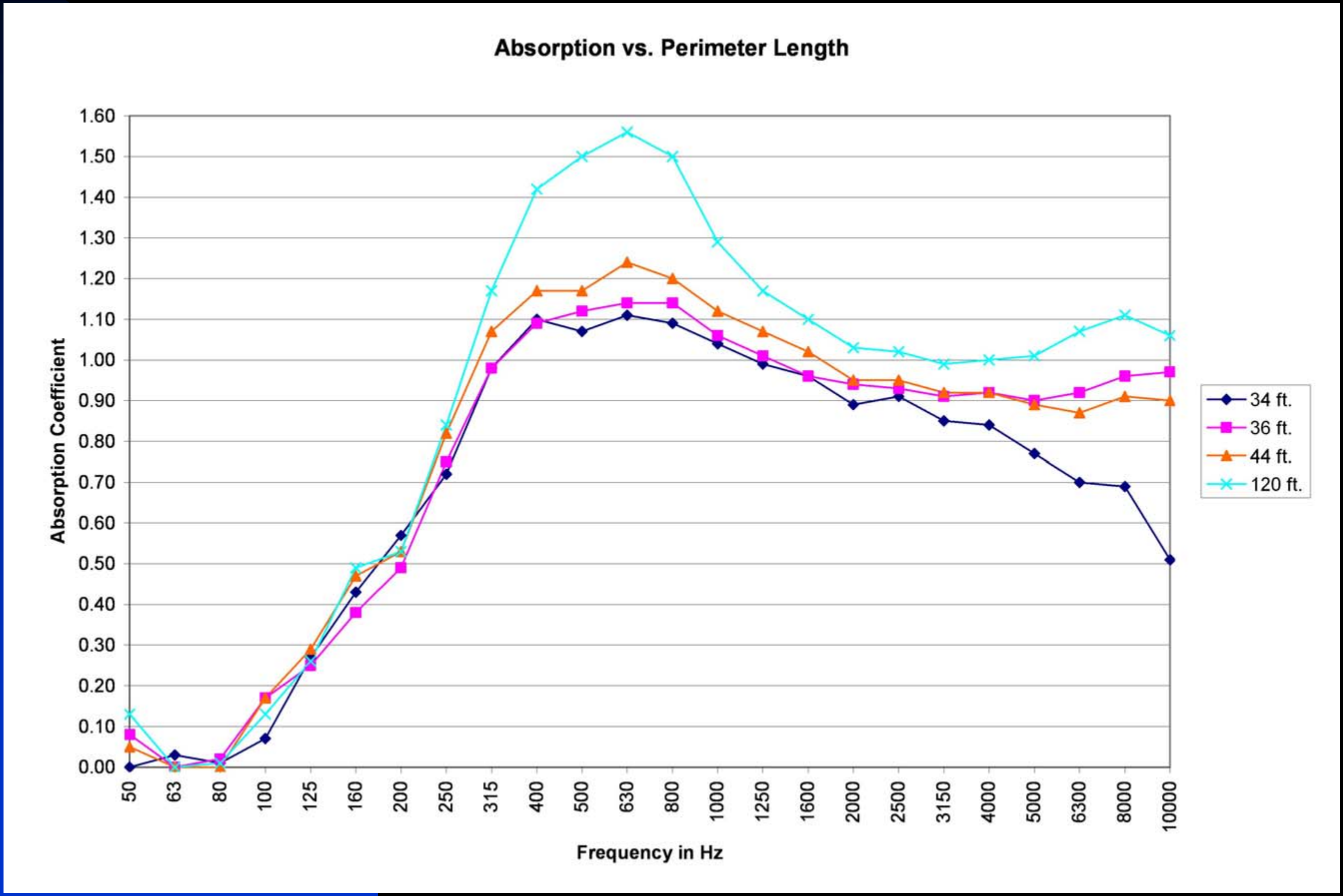
Constant Perimeter Comparisons



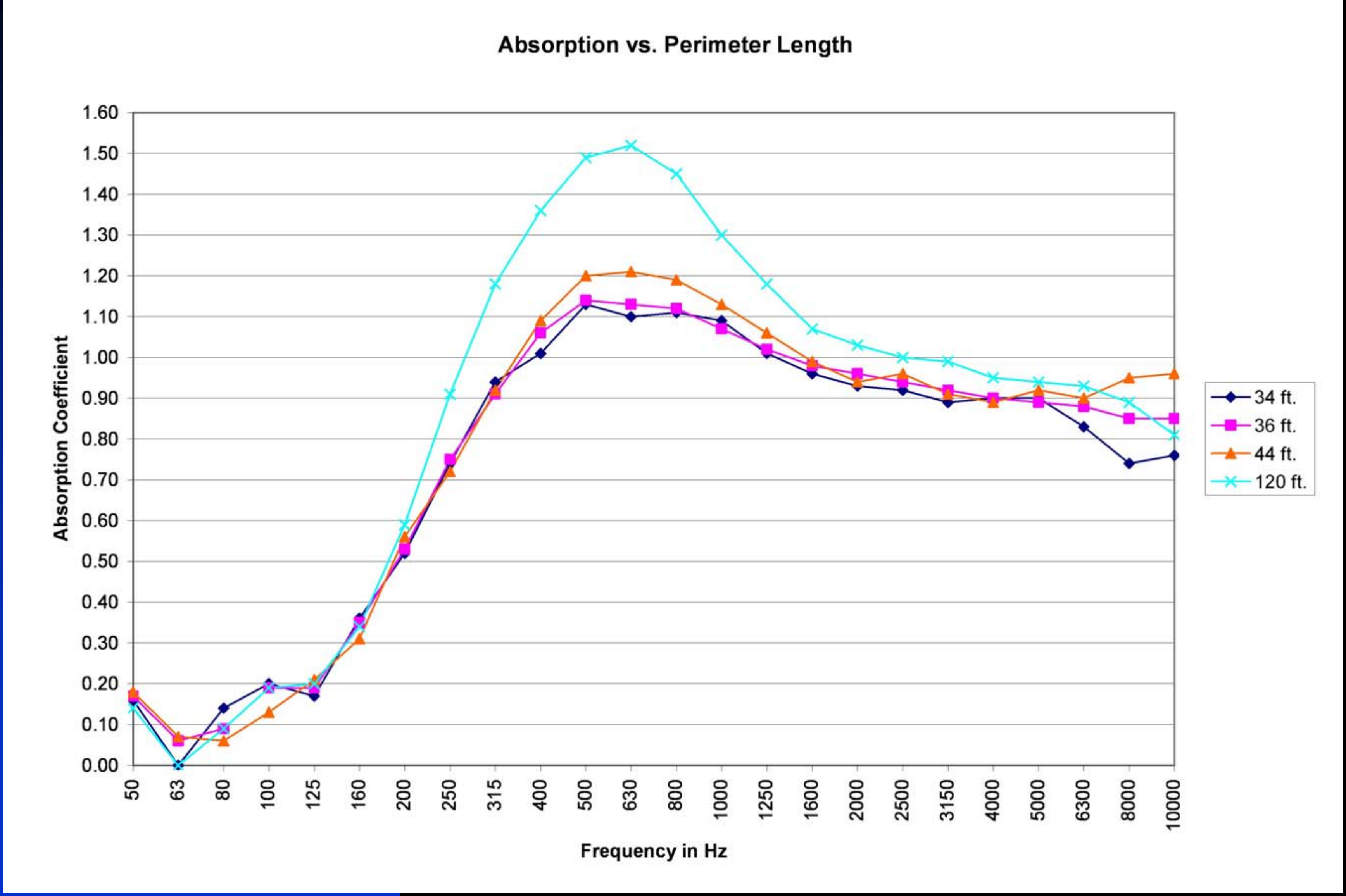
Data Correlations



2 inch standard sample 1st test



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 on the tip of the wedge and the air surrounding it. 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.

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”. 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.

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 calculated using 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.

Recommendations

Formula Based on Charts

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

Expanded version

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

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

Recommendations

After calculating the absorption for each surface they should be combined using the simple calculation:

$$A_{(Total)} = A_1 + A_2 + A_3 \ldots$$

where:

$A_{(Total)}$ = the total absorption of the room expressed in m^2 or Sabins.

A_1, A_2... = the absorption of a given surface expressed in m^2 or Sabins.

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.

Acknowledgements

This paper would not have been possible without the help of Gary Mange, Laboratory Manager of Western Electro Acoustic Laboratory, who did the actual tests for us. He is a member of the ASTM Standards committee for Absorption Measurements.

Michael Vargas was of great help creating the mathematical correlations of the measured data.

THANKS!

- **Ron Sauro**
- **NWAA Labs, Inc**
- 25132 Rye Canyon Loop
- Santa Clarita, CA 91355