“Absorption Coefficient”: Dead or Alive?

(Results of the “ASTM C423 ILS#898 (Inter Laboratory Study)

Derivation of the Absorption Coefficient

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

Where:

α = absorption coefficient of the test specimen, dimensionless.

S = area of the test specimen, m^2 or ft^2

A = absorption of specimen in Sabins / ft^2.

α_1 = absorption coefficient of the surface covered by the specimen

Introduction

Ever since 1929, when the “absorption coefficient” was proposed by Paul Sabine, there have been numerous papers (132) written about the problems with this “constant”.

Because it is described as a coefficient there has been a mathmatical assumption that it cannot exceed the value of 1. Yet, in testing using the C423 standard of the ASTM, this happens quite often. “WHY?”, you ask. THAT is the million dollar question.

It has been proposed that the size of the sample affects it, that the shape of the sample affects it and even the testing conditions affect it.

Introduction

Because of these questions, this question was assigned to the E33-05 sub-committee on Research to make recommendations on correcting the C423 standard or develop another standard. An ILS (Inter Laboratory Study) was proposed to have different labs measure the same sample to see the results that were obtained.

There were 3 series of tests proposed. Each series was to be repeated twice at different times within 24 hrs. This allowed “repeatability” to be calculated as well as “reproducibility” to be calculated between labs.

Introduction

Test 1:

Different sized samples in square area.

6 ft by 6 ft (36 sq ft)

8 ft by 8 ft (64 sq ft)

10 ft by 10 ft (100 sq ft)

12 ft by 12 ft (144 sq ft)

Introduction

Test 2:

Two different configurations of the samples with equal square area.

10 ft by 10 ft (100 sq ft) Monolithic

Introduction

10 ft by 10 ft (100 sq ft) Scattered

Introduction

Test 3 was to test the idea that moving air might inflate the high frequency absorption results because of stratification.

The test was accomplished by turning off any air handling equipment and using fixed microphones. The testing was done at fixed intervals after closing the door(s) of the test chamber. The intervals were:

5 min, 15 min, 25 min, 35 min, 45 min, 55 min and 65 min.

These were done using a standard 10 ft by 10 ft sample

Calculating the 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

How is Absorption Coefficient used?

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

where:

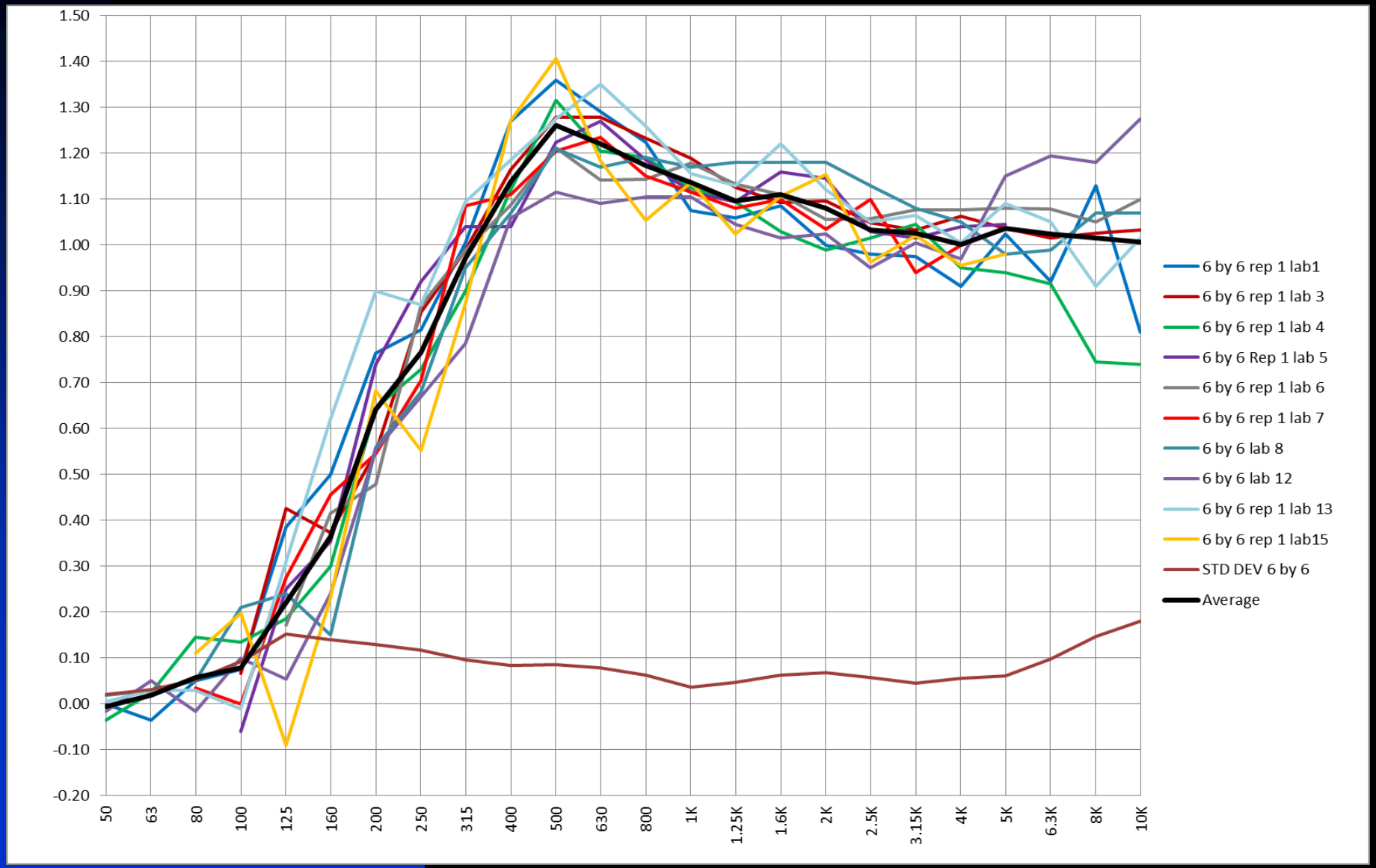
RT60 = time needed for the reverberation energy in the room to decay in level 60dB

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

6 by 6 sample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80
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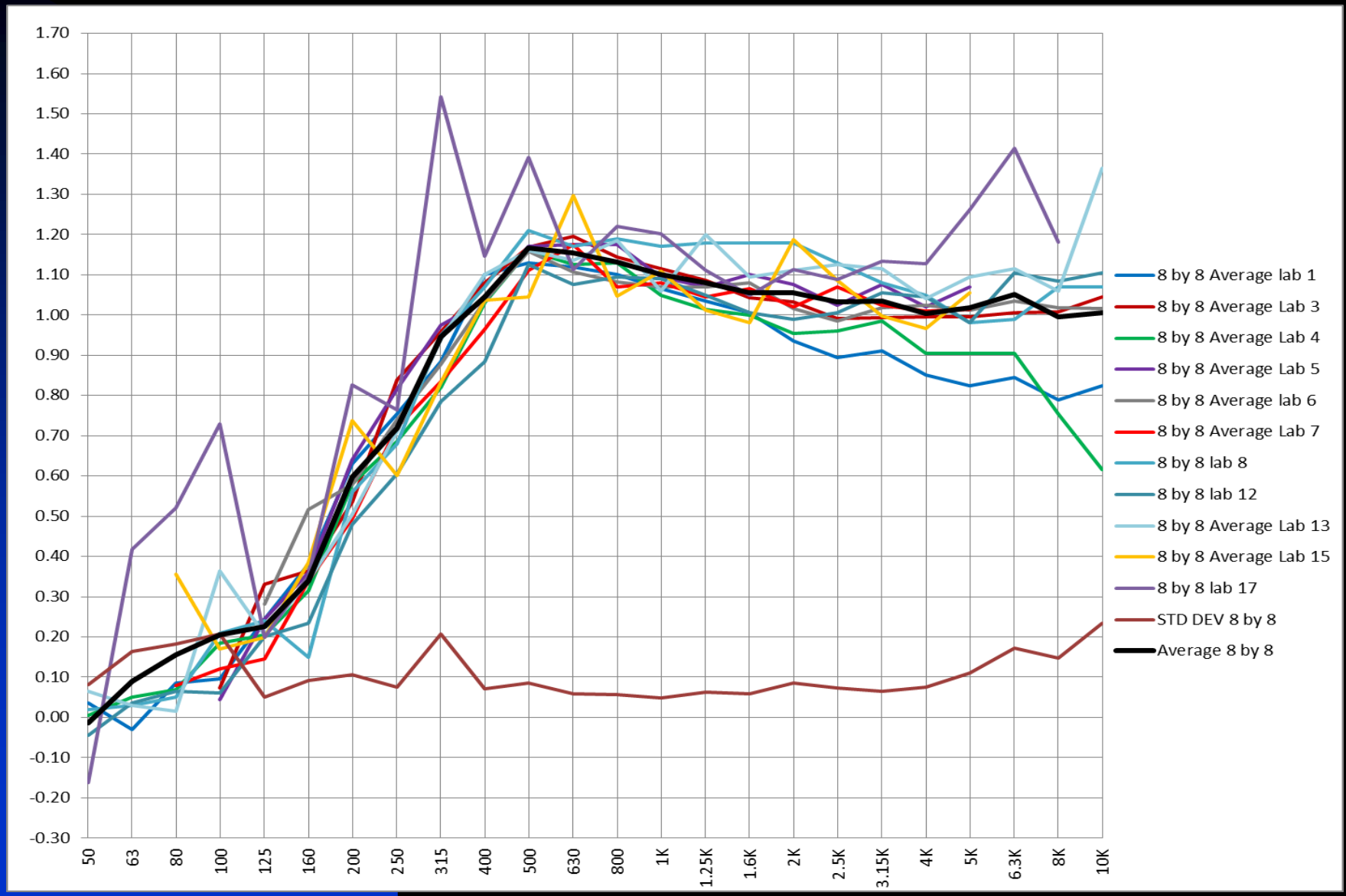
400
500
630
800
1K
1.25K
1.6K
2K
2.5K
3.15K
4K
5K
6.3K
8K
10K
6 by 6 rep 1 lab1
6 by 6 rep 1 lab 3
6 by 6 rep 1 lab 4
6 by 6 Rep 1 lab 5
6 by 6 rep 1 lab 6
6 by 6 rep 1 lab 7
6 by 6 lab 8
6 by 6 lab 12
6 by 6 rep 1 lab 13
6 by 6 rep 1 lab15
STD DEV 6 by 6
Average

8 by 8 sample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2K
2.5K
3.15K
4K
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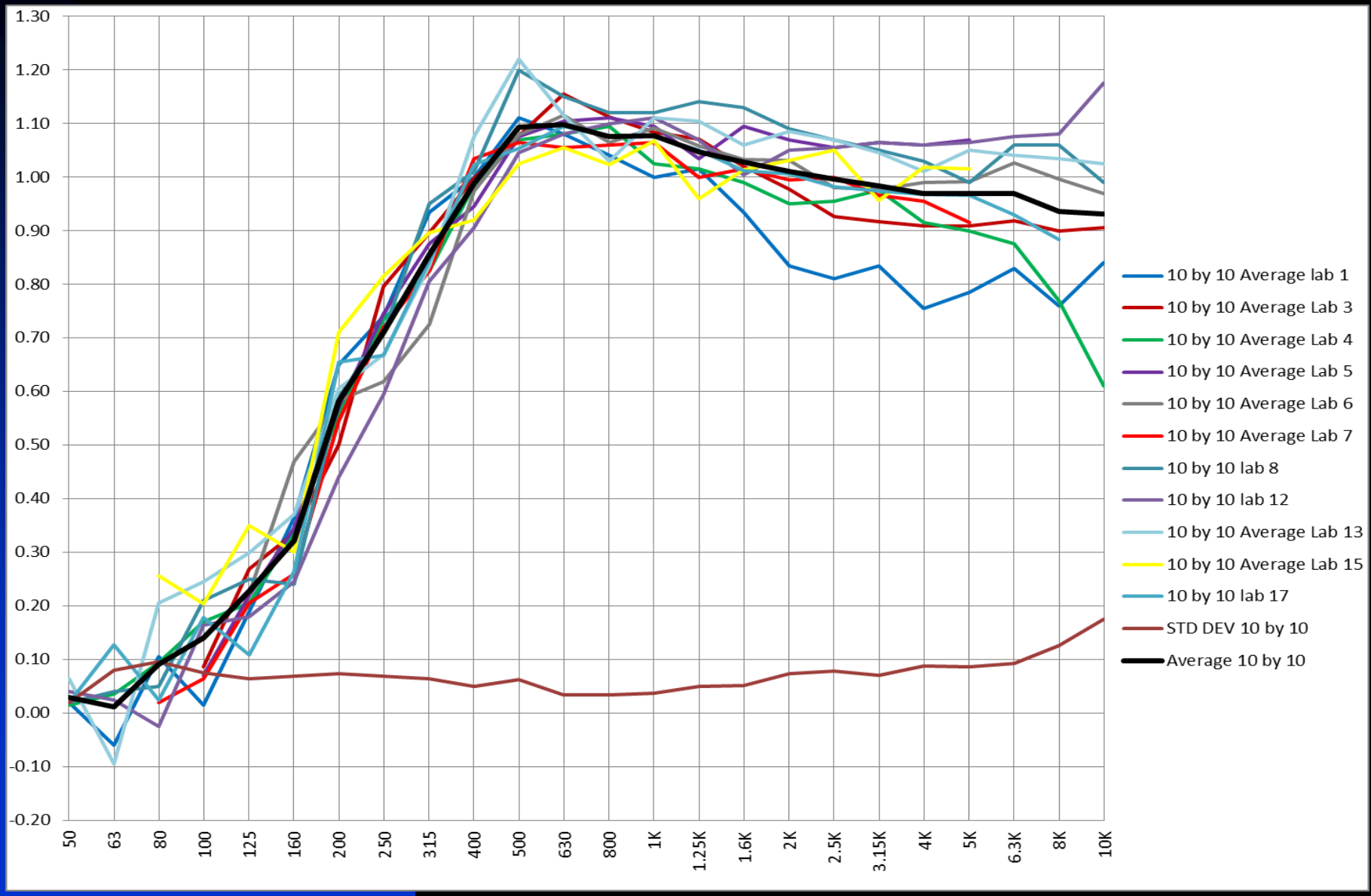
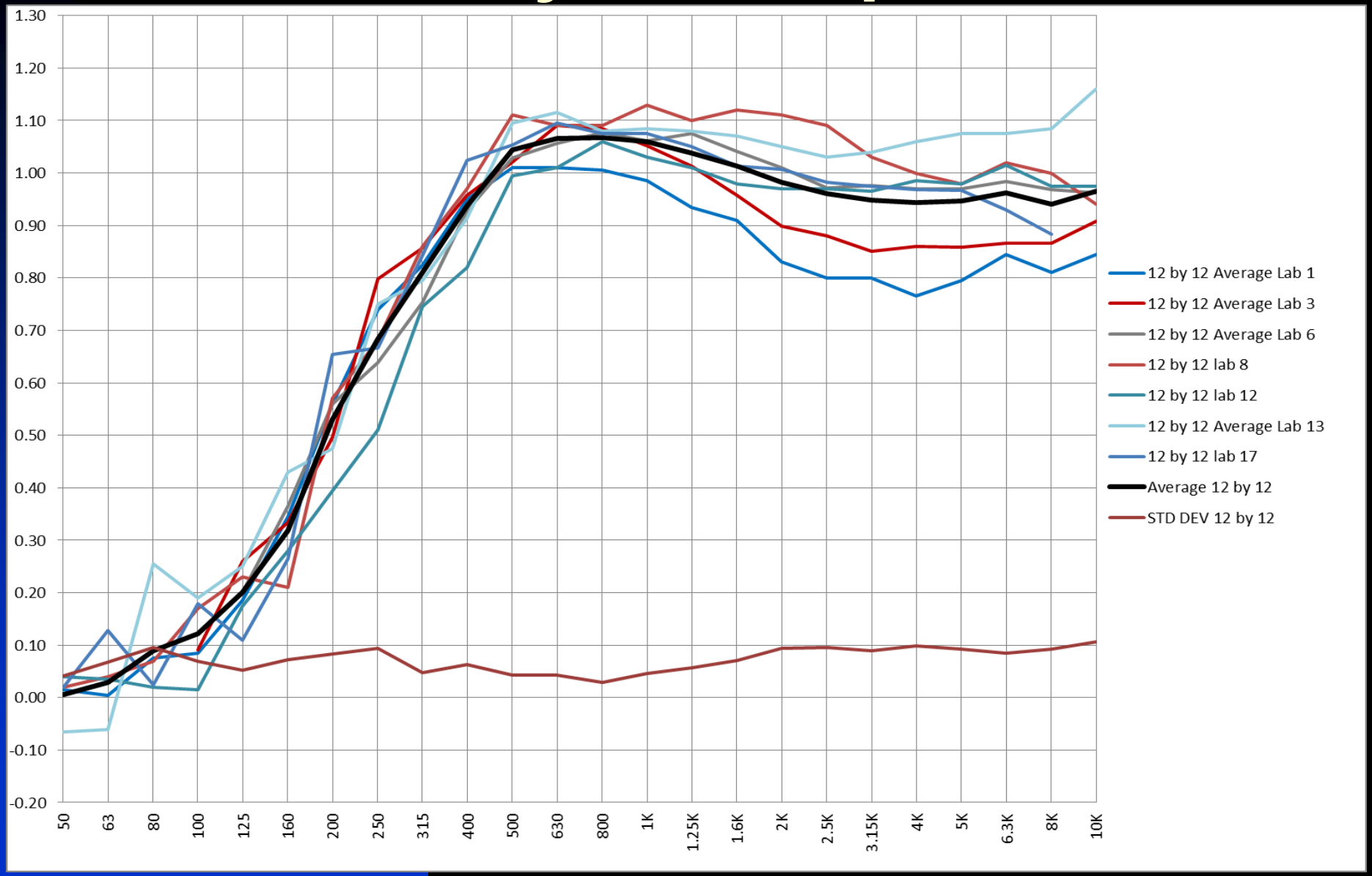
6.3K
8K
10K
8 by 8 Average lab 1
8 by 8 Average Lab 3
8 by 8 Average Lab 4
8 by 8 Average Lab 5
8 by 8 Average lab 6
8 by 8 Average Lab 7
8 by 8 lab 8
8 by 8 lab 12
8 by 8 Average Lab 13
8 by 8 Average Lab 15
8 by 8 lab 17
STD DEV 8 by 8
Average 8 by 8

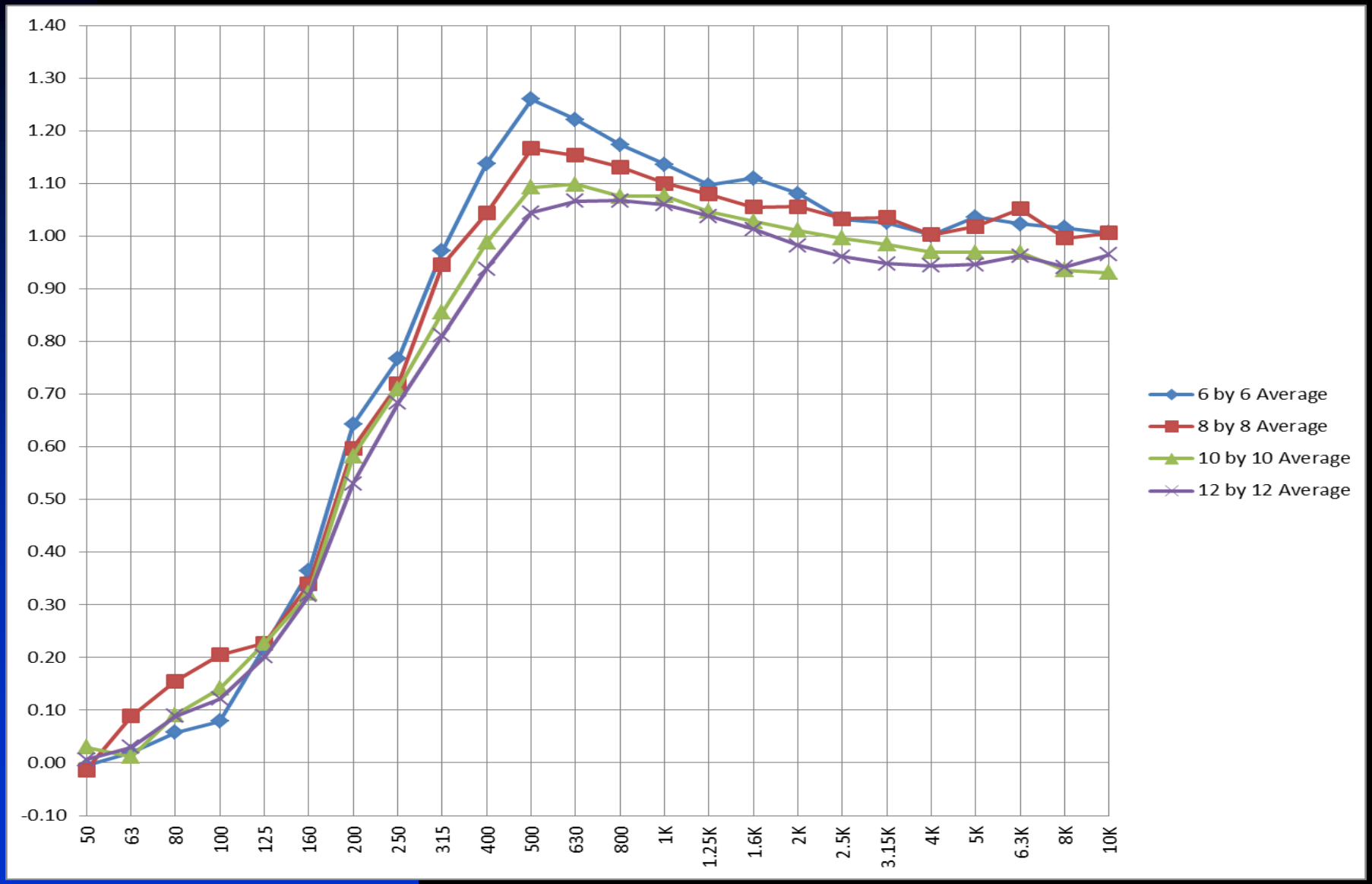
10 by 10 sample



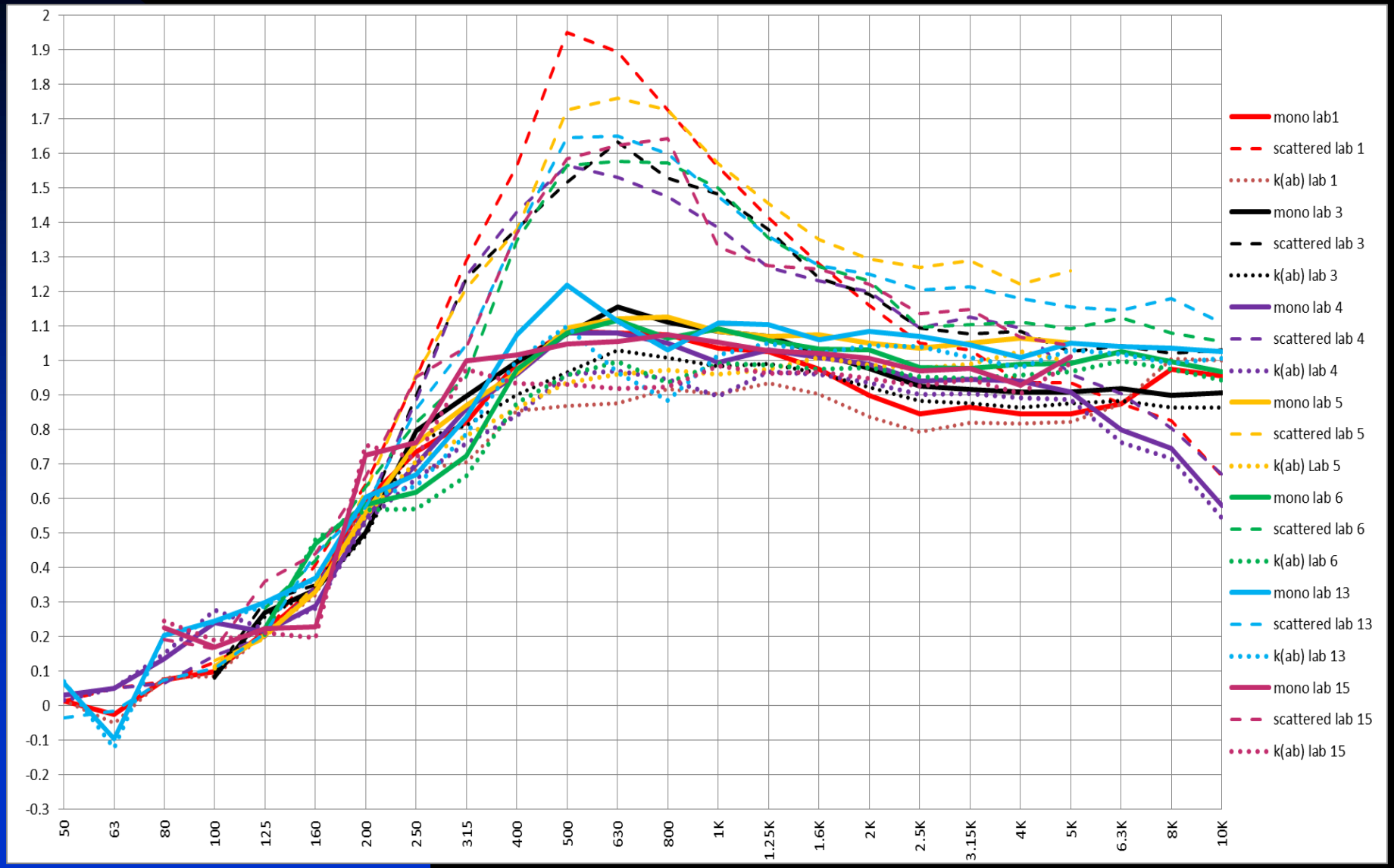
12 by 12 sample



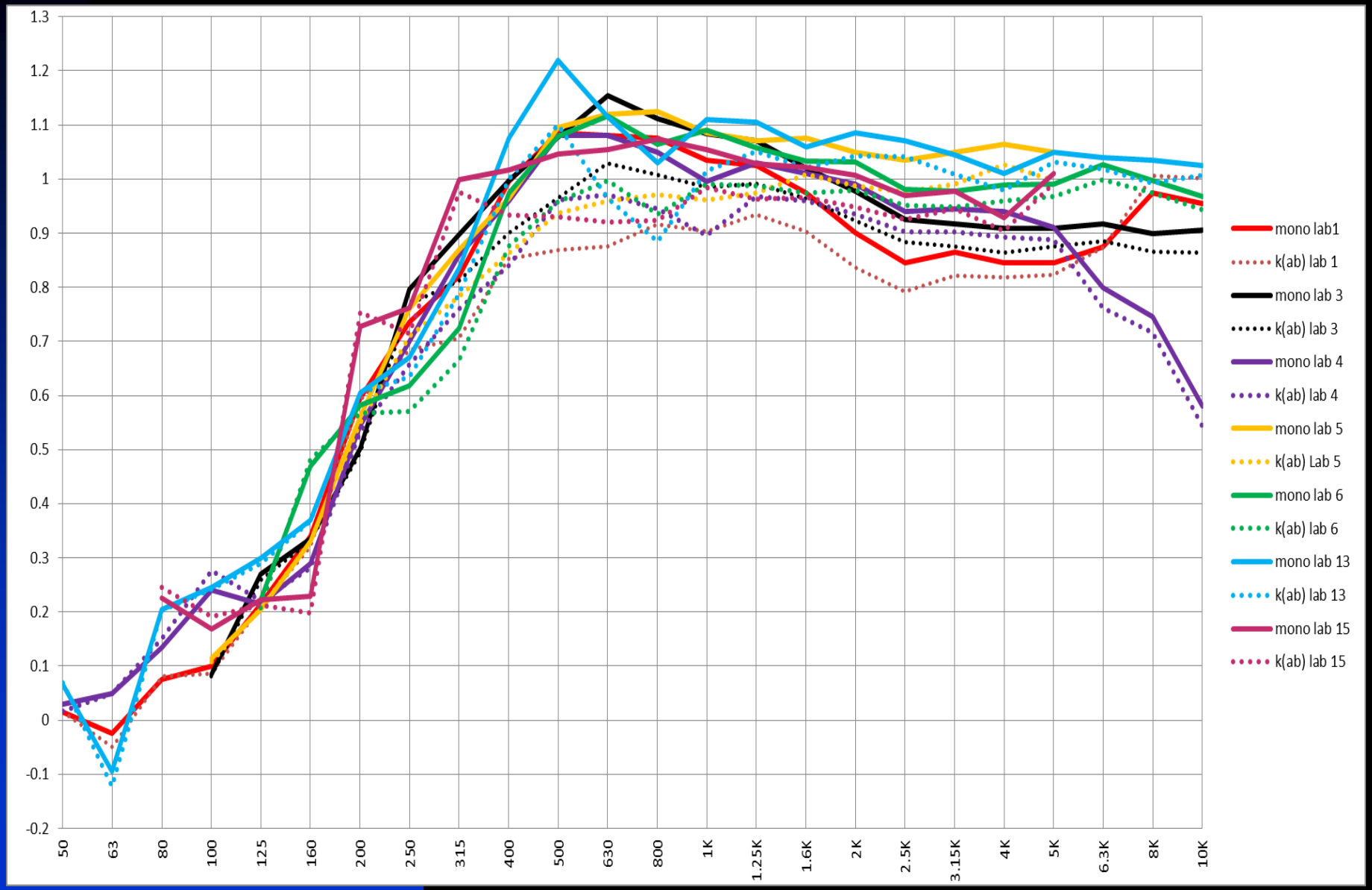
Size Comparisons



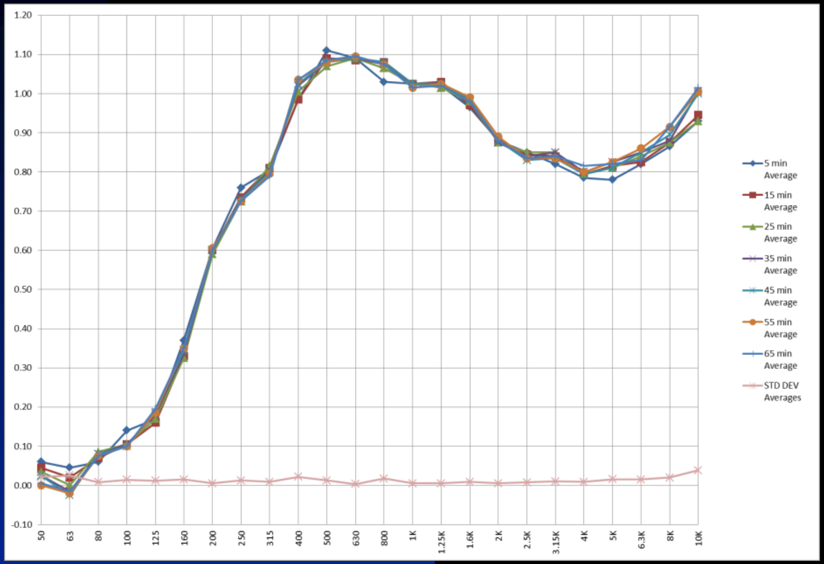
Test 2 Comparisons

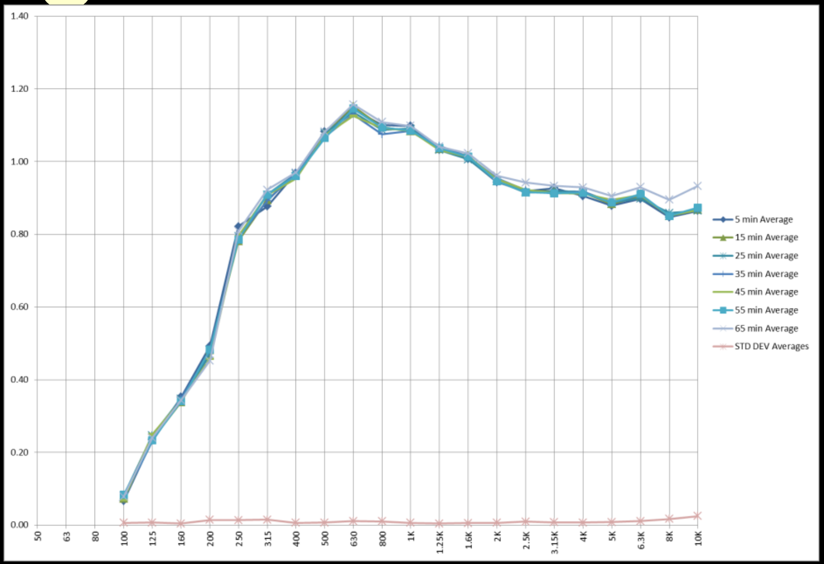


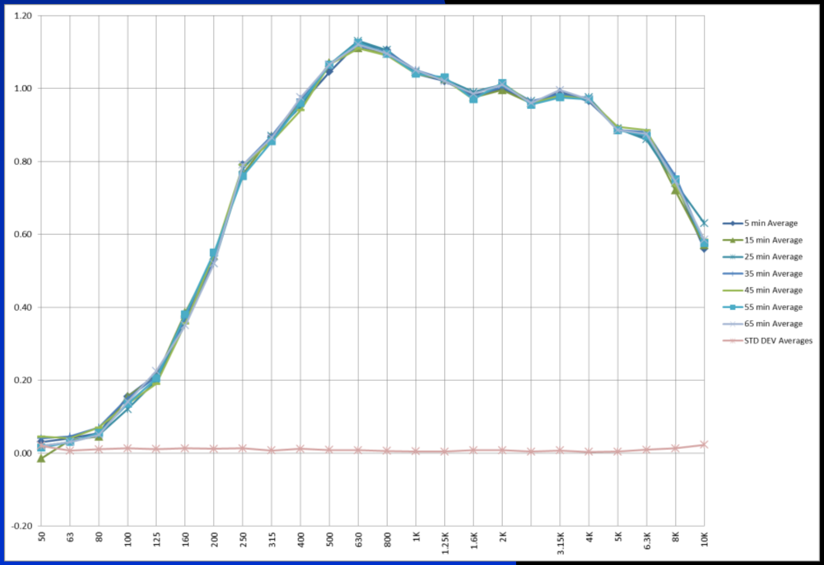
Abs. Coef. vs k(ab)

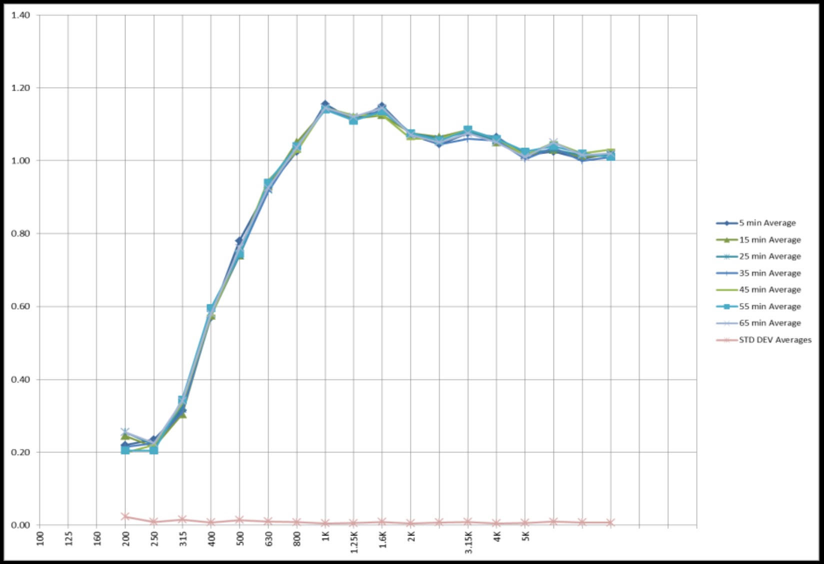


Test 3: Moving Air









Calculating the Absorption Constant

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

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

Conclusions

Out of 18 labs that signed up to do the ILS only 12 submitted data for inclusion.

Of those 12 labs, 5 submitted data that was not traceable to the C423 method.

The “repeatability” of measurements inside of the same lab seemed to be excellent.

The “Reproducibility” between labs indicated that additional study is needed.

It seems that humidity has to be better controlled. A larger sample is also needed.

A square sample is preferred instead of a rectangular sample.

Conclusions

- It seems that the sample size should be adjusted depending of the size of the testing chamber.
- Because of the extensive existing database most of the committee agrees that “fixing” C423 may cause more trouble than writing a new standard.
- The E33 committee agreed and has tasked the sub-committee with writing a new standard to eventually supplant C423.

Thank You for your attention. If you have additional questions please contact me at:

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