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A Guide for Building Your Own Test Chamber
By Geoff Hill

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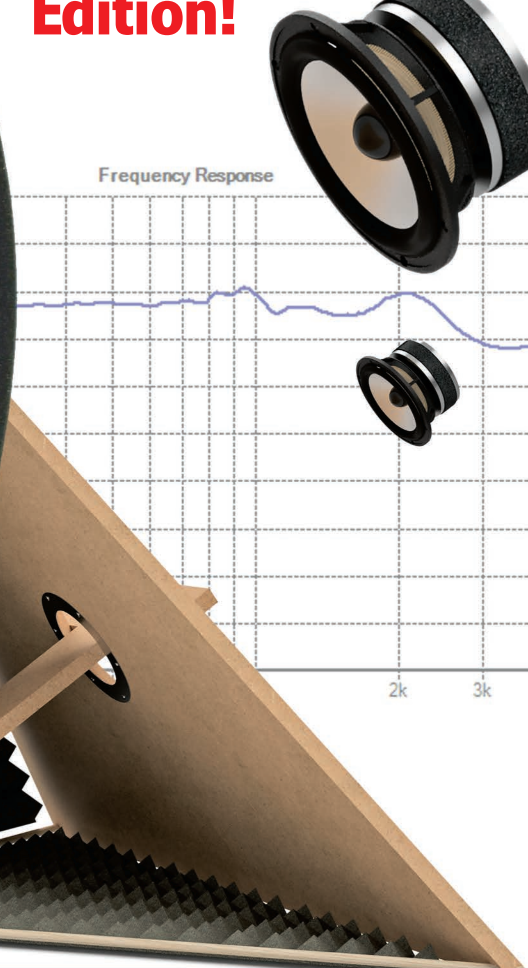

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Loudspeaker Measurements at Home

A Guide for Building Your Own Test Chamber

By
Geoff Hill
(United Kingdom)

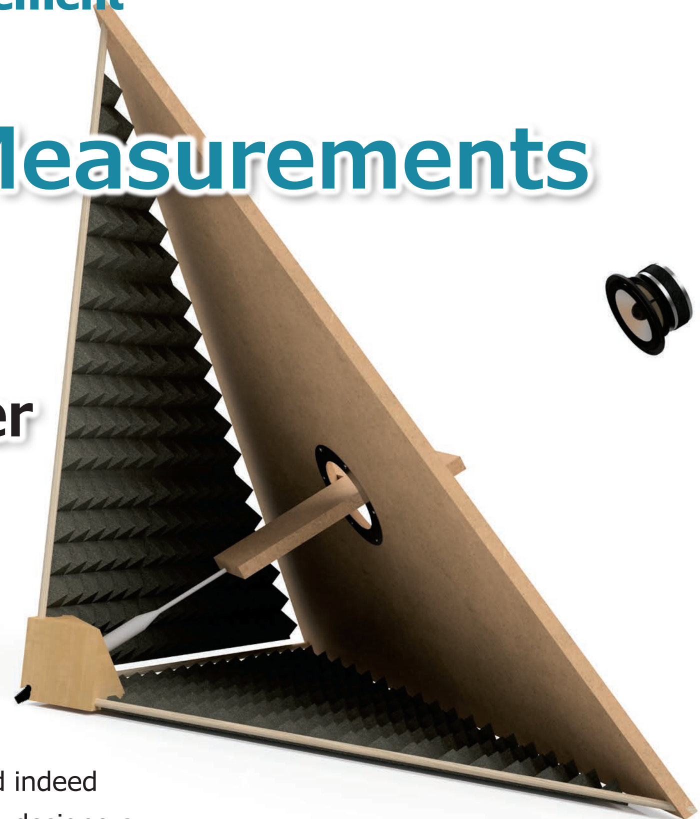


Photo 1: This is the completed tetrahedral chamber, which you can use to to test your loudspeakers when you don't have access to an anechoic chamber.

A lot of Geoff Hill's work is now based at home, and indeed his front room. And like so many acoustics builders, designers, and engineers in these crazy times, he no longer has access to an anechoic chamber, so how is it possible to still make useful loudspeaker measurements? In this article, he explains how to build a basic tetrahedral chamber to use at home, and then put together a measurement system and check the results.

Like so many of us, I am currently stuck at home in isolation. I know you're probably faced with a similar situation and it's even worse for us acoustic folks—without an anechoic chamber we are stuck!

We all know that anechoic chambers are big and expensive, originally built for the military during World War II to test loud sound sources without creating a public nuisance. So how did we end up making loudspeaker measurements in anechoic chambers?

Around the same time as the Second World War, engineers were still struggling to measure loudspeakers. The measurement equipment was limited, and the anechoic chamber was a big step in the quest toward making accurate, repeatable loudspeaker measurements.

New Normal for Loudspeaker Measurements

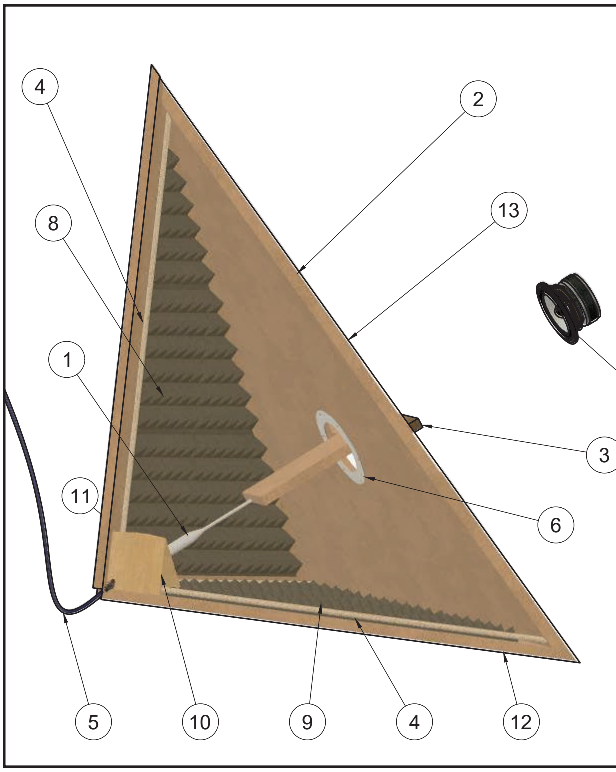
As the pandemic forces us to do a lot of things differently, it's time to take a fresh look at how we can make loudspeaker measurements during the new normal.

First, let us take a look at the alternatives that we have used:

- Free-field measurements
- Ground plane measurements
- Anechoic measurements
- Anechoic IEC baffle or JIS test box measurements
- Windowed/Gated measurements

All of these methods have their advantages and disadvantages, are expensive, and rely upon having a large physical space in which to work. This is not possible when working at home or even in most workplaces, but there are modern standards created to overcome these issues. Using them, we can make accurate, repeatable, calibrated, and transferrable loudspeaker measurements, as an alternative to these traditional methods. We can do this by building our own basic tetrahedral chamber (see **Photo 1**)—giving us a convenient, low-cost approach during the new normal.

The tetrahedral chamber concept was launched



Parts List			
Item	Qty	Part Number	Material
1	1	Microphone	Generic
2	1	Baffle	Plywood, Sheathing
3	1	Mic Setting Jig	MDF Medium Density Fiberboard
4	1	Dowel	Ash
5	1	XLR Cable	Acetal Resin, Black
6	1	Aluminium	
7	1	SEAS H1207-08	
8	1	Acoustic Foam	Polyurethane Foam
9	1	Acoustic Foam (2)	Polyurethane Foam
10	1	Microphone Block	Plywood, Sheathing
11	1	Right Side	MDF Medium Density Fiberboard
12	1	Bottom	MDF Medium Density Fiberboard
13	1	Left Side	MDF Medium Density Fiberboard

Figure 1: The full assembly is shown with acoustic damping on the bottom and the parts list. The chamber is shown without the left side fitted.

at the Loudspeaker and Headphone Conference in Helsinki, Finland, with the theory being published at the Audio Engineering Society (AES) convention in New York. The theory was based upon a tetrahedral structure that can fit into a corner anywhere.

Following peer review, this type of chamber has now been incorporated into international standards [(1) IEC 60268-21-2018, (2) draft IEC 60268-22, and (3) AES 73id-2019] and widely accepted as a valid methodology for comparative loudspeaker measurements. These standards give us a compact and convenient, defined structure, which is small and relatively low-cost and meets our requirements for making accurate, repeatable loudspeaker measurements.

Can We Use These Modern Standards At Home?

You should be able to build a tetrahedral chamber with a minimum number of tools—this will enable you to take loudspeaker drive unit measurements in the new normal. Further, I will base many of my other measurement suggestions around free, open-source software and hardware, assuming that most people will not have access to professional test equipment.

When compared to a full Tetrahedral Test Chamber (TTC), this implementation will be constrained in a few ways. First and foremost, it will not have the physical integrity of a TTC, and the structure will need to be larger than a TTC would be to measure the same size of loudspeaker. Also, it will be more difficult to calibrate than a TTC, it will not have the stability and accuracy of a TTC, and it will not have the acoustic damping of a TTC. Having said all of that—it's still better than an anechoic chamber!

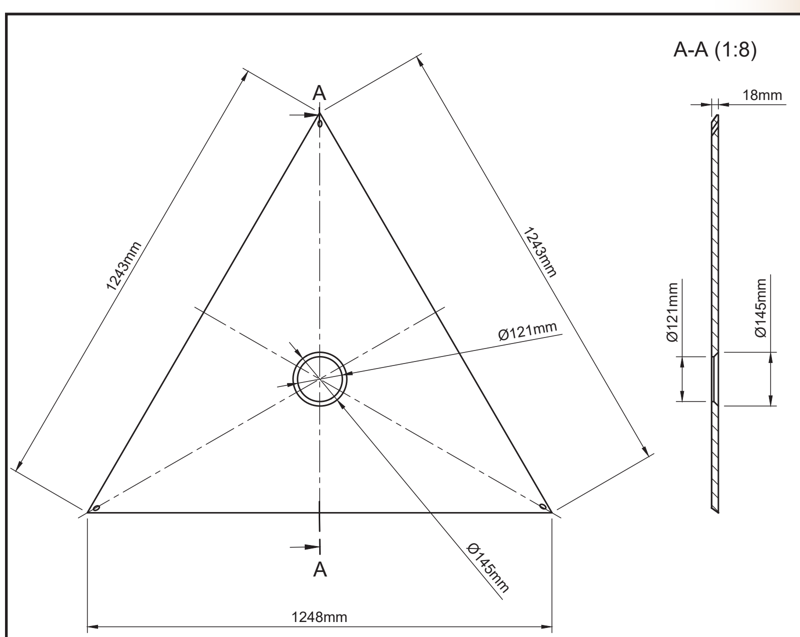


Figure 2: This triangle baffle has been cut in the center to fit my SEAS 4" driver.

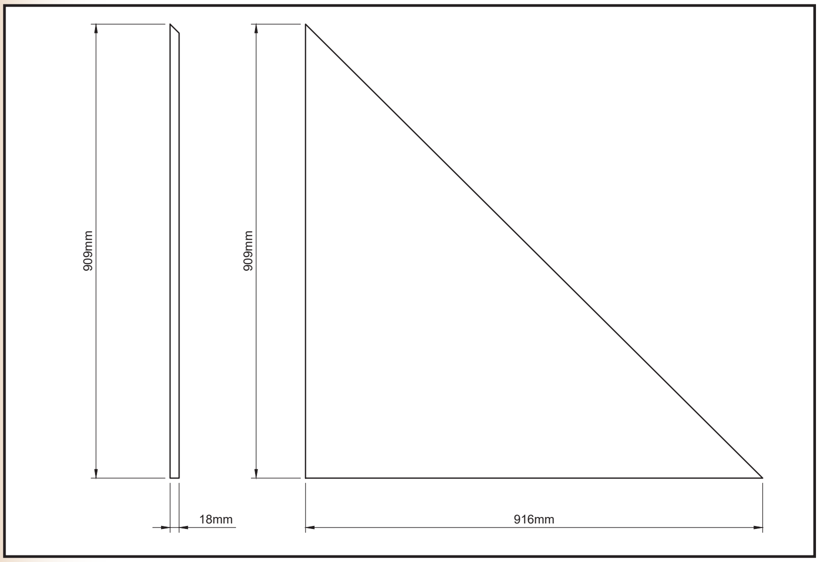


Figure 3: This diagram details the construction of the chamber's sides and bottom.

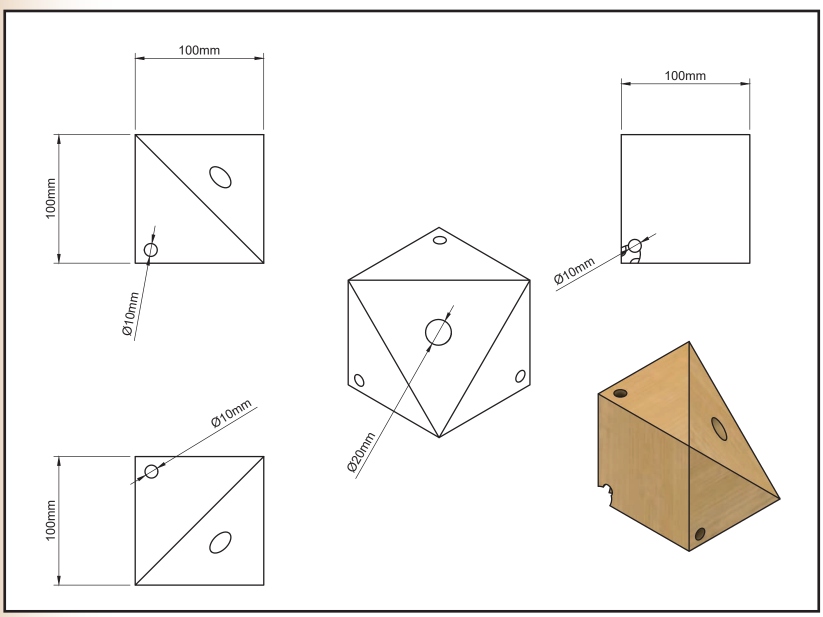


Figure 4: Here is the microphone block assembly.

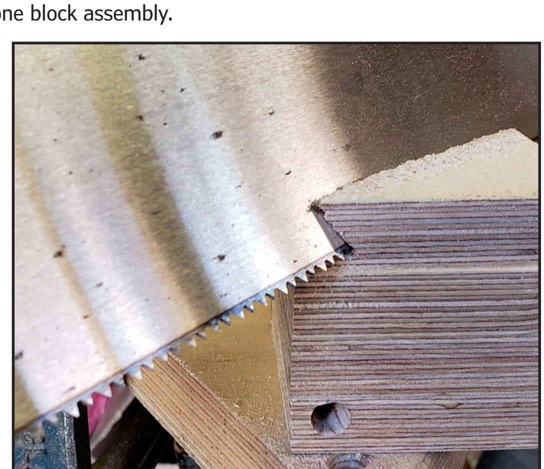


Photo 2: Here we have cut the mic block, note the hole drilled for a dowel.

Assuming you have a loudspeaker to measure, we will also need the following equipment:

- A microphone—we will use an affordable measurement microphone (e.g., a Behringer ECM8000) and/or a USB microphone (e.g., the miniDSP UMIK-1).
- A computer with a freeware analyzer and a sound card
- An audio amplifier
- Leads and connectors

We'll build this basic tetrahedral chamber into an existing corner of a room. For those who have access to woodworking equipment, it will undoubtedly prove easier but not essential. To build the chamber, we will need the following parts:

- One sheet of wood, 18 mm thick (from this you'll make the baffle)
- Chamber sides and bottom
- Mic setting jig
- Mic block

For the chamber's sides and bottom, we will use three lengths of wooden dowels—800 mm long × 10 mm plus diameter—and acoustic damping, foam, or fiberglass insulation, 25 mm thick. We also need a piece of aluminum sheet, 0.8 mm to 1 mm thick.

The final assembly with acoustic damping on the bottom is shown in **Figure 1**.

Our first task is to produce these parts, and we should start by making the triangular baffle. I have drawn an example (see **Figure 2**) to accept the SEAS 4" driver with a hole through the middle of the baffle.

Next, you should make the chamber's sides and the bottom (see **Figure 3**), cut the dowels to

About the Author

Geoff Hill, the inventor of the Tetrahedral Test Chamber (TTC) and CTO at Hill Acoustics, has been working in the loudspeaker and audio industry for more than 40 years. He is the vice-chair of the Audio Engineering Society's AES SC-04-03 Working Group on loudspeaker modeling and measurement and a member on the International Electrotechnical Commission's IEC Working Group TC 100/TA 20/PT 60268-22. Hill is also the author of *Loudspeaker Modelling and Design: A Practical Introduction* (Routledge 2018). He welcomes your comments and can be contacted via email at geoff@hillacoustics.com.

length and from the 18 mm sheet cut five squares each 90 mm on the side. Use these five layers of plywood to produce a cube. Drill the three holes for the dowels on the sides of the cube. This is then cut on the diagonal into two parts (see **Figure 4** and **Photo 2**).

Then, make the Microphone Setting Jig. Produce the aluminum ring, which ensures the loudspeaker is flush with the baffle and is essential. Then screw it into the baffle as this prevents the loudspeaker from falling through the baffle. Next, cut some acoustic foam into three parts and put the parts together as shown in Figure 1. More detailed diagrams can be found in the Supplementary Materials section on the *audioXpress* website (see Project Files).

The Measurements

So how do we go about making our measurements? I will describe the basic steps.

First, we start by measuring the external very-near-field frequency response of the loudspeaker (Step A). Next, we measure the internal pressure frequency response (Step B) and we create the difference curve between A and B (Step C), allowing us to create the correction curve for the low frequencies (Step D). Finally, we apply the correction curve to get the equivalent free-field measurement (Step E).

Our Step A is to make a measurement outside of the chamber! Yes, I know that sounds crazy but let me explain. What we need to do is to measure the very-near-field response of the rear of loudspeaker not the front which we usually do. This yields the true low-frequency response. However, the high frequencies are not correct because of four things: reflections from the magnet and basket;

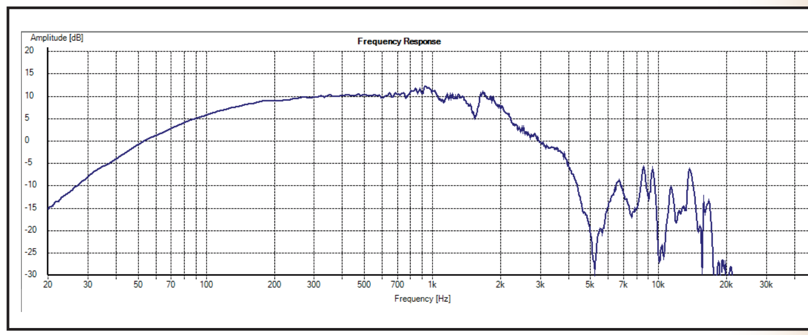


Figure 5: This is the external very-near-field response.

the magnet is physically blocking the sound; the cone is not working pistonically at frequencies above 1300 Hz for a driver of this size; and because the front of the cone is not contributing to the high-frequency response. See **Figure 5** for the measurement results.

We save this response and move to Step B by placing the microphone inside the tetrahedral structure. We need to use the microphone setting jig placed inside the chamber to guarantee the critical mic to baffle distance, which ensures

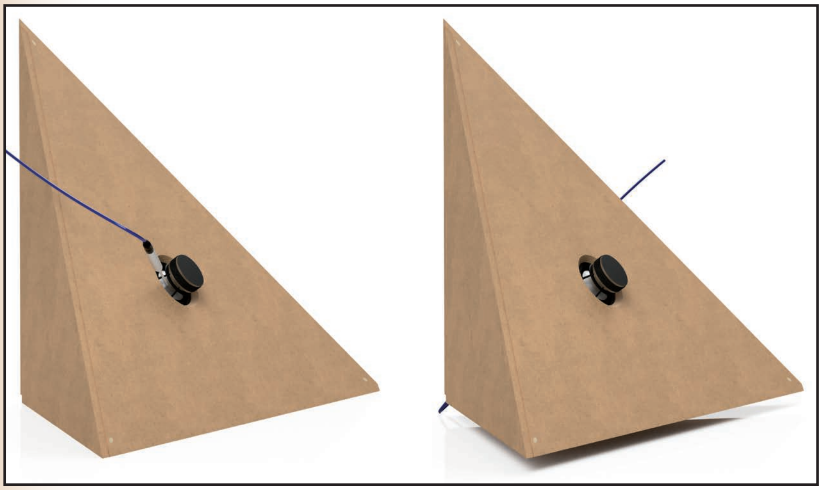


Photo 3: The test chamber is shown during the external near-field microphone measurement and during normal internal measurements.

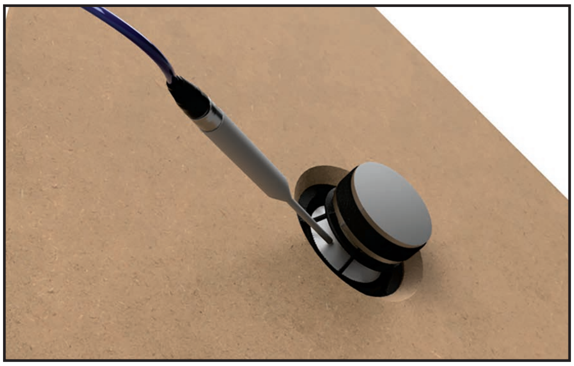


Photo 4: This image shows a microphone 2 mm to 3 mm from the rear of the cone making the external very-near-field frequency response measurement. Note: The microphone must not touch the cone.

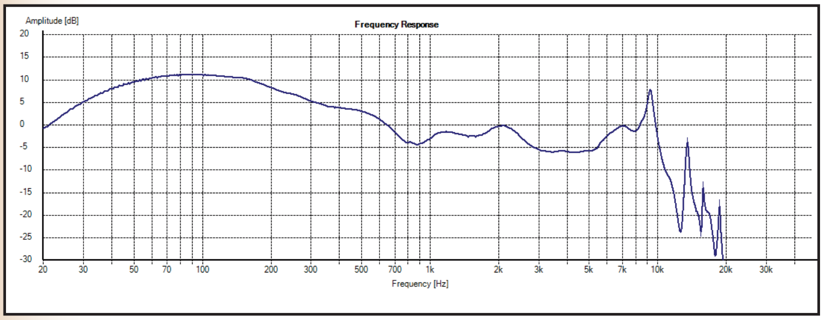


Figure 6: The internal pressure frequency response is obtained as part of Step B—placing the microphone inside the tetrahedral structure.

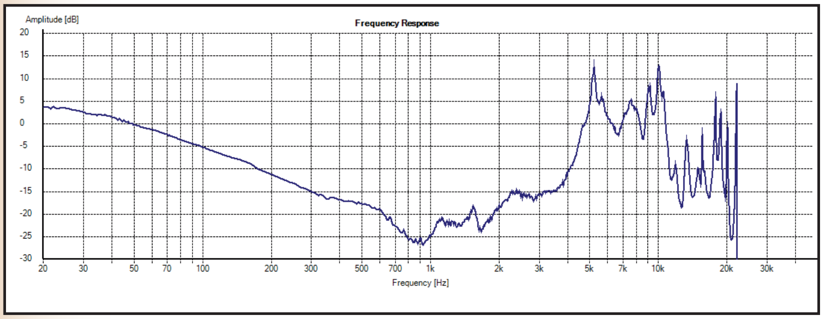


Figure 7: We obtained this difference curve between the two measurements shown in Figure 5 and Figure 6.

Project Files

To download additional material and files, visit http://audioxpress.com/page/audioXpress-Supplementary-Material.html

Resources

International Electrotechnical Commission (IEC) standards: Sound system equipment. Acoustical (output-based) measurements, IEC 60268-21-2018; Sound system equipment - Electrical and mechanical measurements, IEC 60268-22 (Draft due 2020).

G. Hill, "Loudspeaker Driver Comparison Chambers, AES73id-2019," Audio Engineering Society (AES), 2019.

G. Hill, *Loudspeaker Modelling and Design: A Practical Introduction*, Routledge 2018.

G. Hill, "Thoughts on AES X223 and X241 Speaker Measurement Projects," *audioXpress*, September 2018.

G. Hill, "Hill Acoustics Tetrahedral Test Chamber," Whitepaper, 2015. www.hillacoustics.com.

G. Hill, "Comparative Results between Loudspeaker Measurements Using a Tetrahedral Enclosure and Other Methods," e-Brief 143, Audio Engineering Society (AES), 2014.

G. Hill, "Consistently Stable Loudspeaker Measurements using a Tetrahedral Enclosure," e-Brief 123, Audio Engineering Society (AES) 135th Convention, October 2013.

D. B. Keele, "Low-Frequency Loudspeaker Assessment by Near Field Sound-Pressure Measurement," presented at the 45th Convention of the Audio Engineering Society, May 1973.

R. H. Small, "Simplified Measurements at Low Frequencies," published by the Audio Engineering Society (AES), January and February 1972.

the repeatability of the measurements (see **Photo 3**). Then, we make a conventional pressure measurement inside the airtight tetrahedral structure (see **Photo 4**), which yields the true high-frequency response. However, the low frequencies are boosted because of the pressurized environment, which raises the sound pressure level. This is shown in **Figure 6**.

In Step C, we create a difference curve between the above two measurements as shown in **Figure 7**. And for Step D, we create the correction curve from the difference curve in Figure 7. Keep in mind when creating the correction curve that above 1300 Hz, the difference is meaningless and the difference is set to the last valid value (see **Figure 8**).

In the final step, Step E, we apply the correction curve to the internal measurement resulting in an accurate, repeatable, and transferrable loudspeaker measurement. **Figure 9** shows the resulting frequency response of the loudspeaker in the chamber.

With this simple but effective loudspeaker measurement system we have a solution for the new normal and into the future.

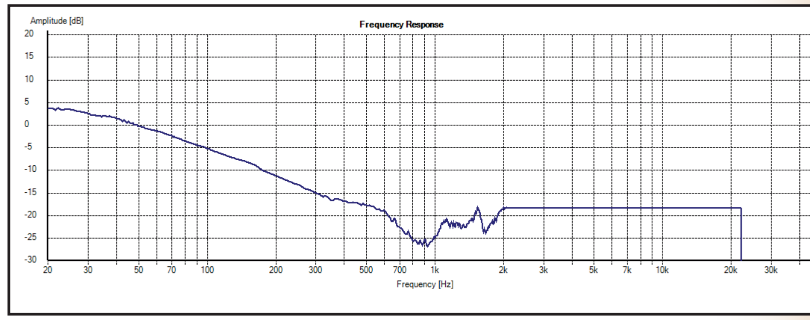


Figure 8: To create the correction curve, we ignore information above 1300 Hz.

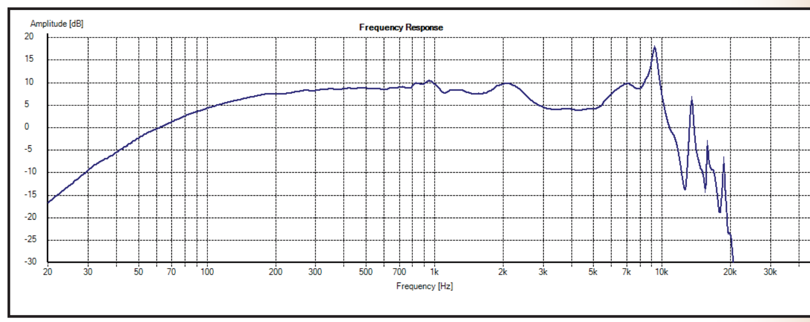


Figure 9: Applying the correction curve, we obtain the frequency response of the loudspeaker in the chamber.