Advancing the Technology and Practice of Noise Control Engineering

An Evaluation of the Additional Acoustic Power Needed to Overcome the Effects of a Test-Article's Absorption during Reverberant Chamber Acoustic Testing of Spaceflight Hardware

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Exposing aerospace test-articles (e.g. spacecraft and payload fairings) to simulated, launch-event, high intensity acoustics is accomplished by one of two methods:

- Direct Field Acoustic Testing (up to 148 dB OASPL)
- Reverberant Field Acoustic Testing (up to 163 dB OASPL)

The Reverberant Acoustic Test Facility (RATF) at the NASA Glenn Research Center Plum Brook Station in Sandusky, OH is an example of a large-volume (101,000 ft^3), very powerful (163 dB OASPL) reverberant acoustic test chamber which uses GN2 as its sound medium.

The SpaceX Falcon 9 Payload Fairing was successfully tested at the NASA Glenn Research Center Plum Brook Station’s Reverberant Acoustic Test Facility (RATF) during May-June 2013.

This paper describes a method to mitigate the test risk of achieving a customer's target sound pressure level (SPL) spectrum during reverberant acoustic testing due to the absorption inherent to the test-article. Each particular test-article will have its own absorption values as a function of frequency.

To address the effects of the test-article's absorption on quantifying the maximum achievable SPL versus OTOB frequencies of a company's reverberant acoustic test chamber, the following parameters are needed:

- *The test chamber's linear dimensions (width, depth, and height) and geometry.*
- *The Reverberation Time (RT_{60}) values per OTOB for the empty chamber condition (i.e. no test-article inside the chamber).*
- *The Reverberation Time (RT_{60}) values per OTOB for the chamber with the test-article installed.*

METHOD FOR DETERMINATION OF ADDITIONAL ACOUSTIC POWER

The following steps are the approach taken to determine if the empty chamber test was performed with adequate sound power to ensure that the target SPL spectrum can be reached when testing with the test-article installed in the chamber. Equations below were developed using metric units and GN2 sound medium.

Step A - Overview of Fundamental Acoustic Equations:

Room Equation $$\langle p^2 \rangle = W_c \frac{4\rho c}{R}$$

Room Constant $$R_c = \sum_i S_i \alpha_i + 4mV$$

Sabine Equation $$R_c = \frac{V}{1.086c} \frac{60}{RT_{60}}$$

<u>Room Equation combined with Sabine's equation</u>

$$\langle p^2 \rangle = W_c \frac{4.343}{60} \frac{\rho c^2}{V} RT_{60}$$

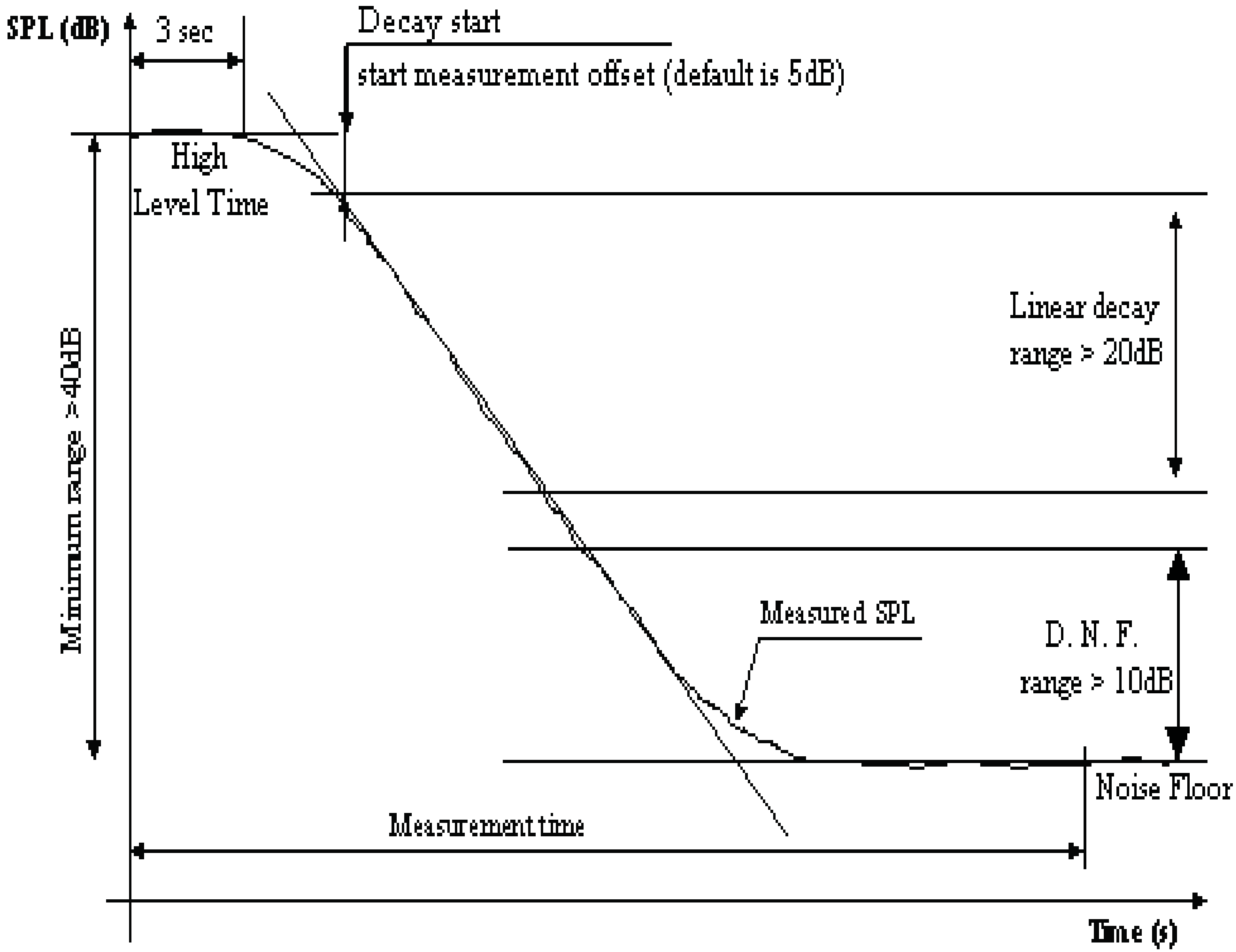
<u>Compact relationship between the SPL and acoustic Power Level (PWL)</u>

SPL = PWL + 10 log (RT_{60}) – 10 log (V) + 14.17 dB

<u>Reverberation time obtained from the measured decay rate, *d* in dB/sec</u>

$$RT_{60} = \frac{60}{d}$$

ISO354 INTERRUPTED NOISE METHOD OF DETERMINING REVERBERANT ROOM DECAY RATES



Step B – Obtain the Reverberation Times of the Empty Chamber

Step C – Estimate the Test-Article Absorption

Step D – Perform (early) Empty Chamber Test using Bolstered Test Levels

Step E – Perform (just prior to test) Empty Chamber Test using Bolstered Test Levels

Step F – Obtain the Reverberation Times of Chamber with Test-Article Installed

Step G - Calculate actual delta dB

Knowing the reverberation times from Steps B and F, one can now calculate the actual delta SPL values needed to overcome the test-article's absorption

Defining the volume of the chamber with the test-article as:

$V_{C\,w/TA} = (V_{EC} - V_{TA})$, where V_{TA} = actual volume of test-article

$PWL_{EC} = SPL_{EC} - 10\log(RT_{60\,EC}) + 10\log(V_{EC}) - 14.17$ dB

$PWL_{C\,w/TA} = SPL_{C\,w/TA} - 10\log(RT_{60\,C\,w/TA}) + 10\log(V_{C\,w/TA}) - 14.17$ dB

Now setting $PWL_{EC} = PWL_{C\,w/TA}$ (i.e. the modulators produce the same amount of power for both cases), one can solve for the change in SPL ($= SPL_{EC} - SPL_{C\,w/TA}$), hereafter known as "delta dB"

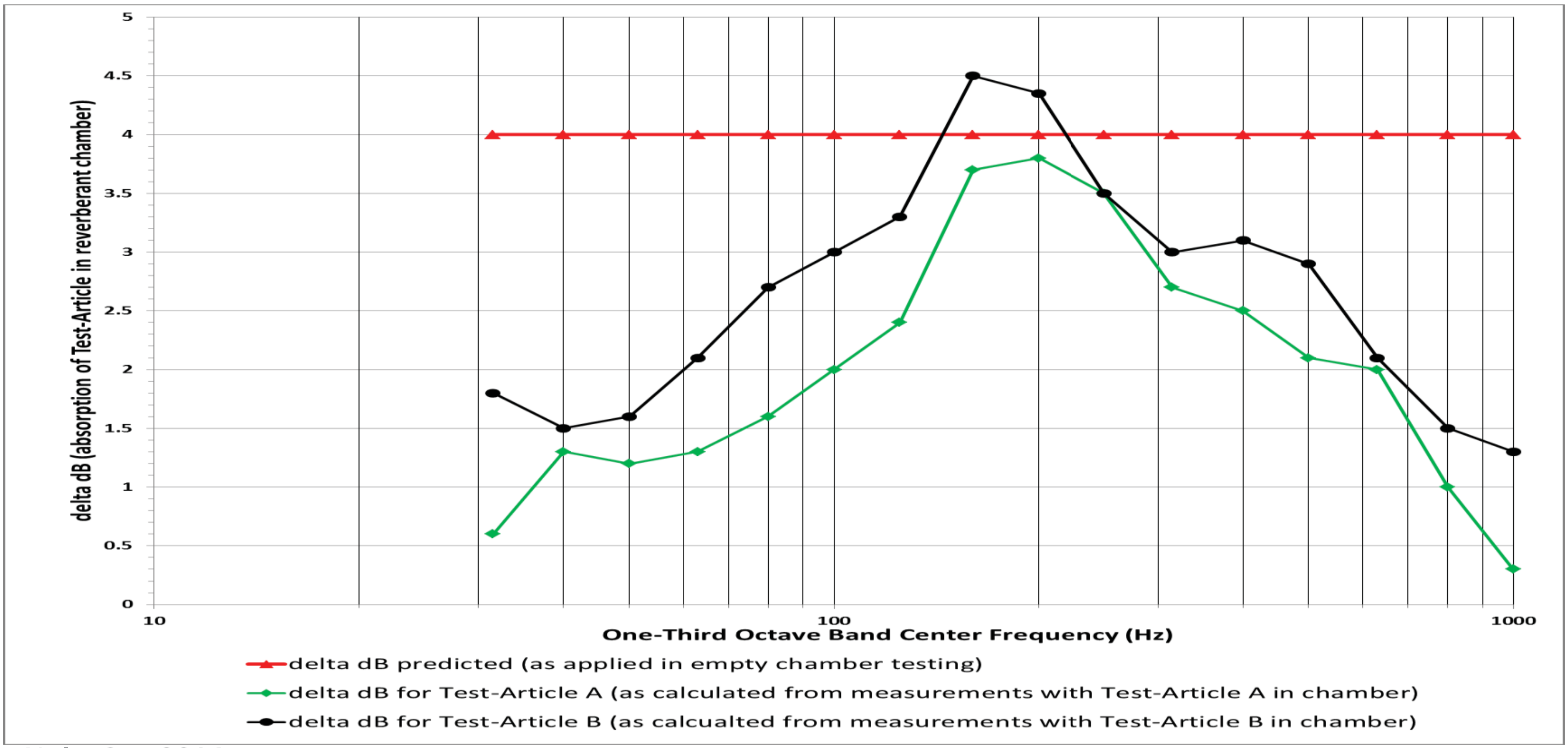
$SPL_{EC} - SPL_{C\,w/TA} = 10\log(RT_{60\,EC} / RT_{60\,C\,w/TA}) + 10\log((V_{EC} - V_{TA}) / (V_{EC}))$

$$\text{delta dB} = 10\log[(RT_{60\,EC} / RT_{60\,C\,w/TA}) \times (1 - (V_{TA} / V_{EC}))]$$

For the special case when the volume of the test-article (V_{TA}) is less than 10% of the volume of the empty chamber (V_{EC})

$$\text{delta dB} \approx 10\log[RT_{60\,EC} / RT_{60\,C\,w/TA}]$$

<u>Example:</u> a +4 dB of delta dB (red) was predicted/used for both of the test-article's absorption during their empty chamber tests. A notional representation of two test-articles' calculated delta dB (from their low-level test measurements) are shown. The calculated delta dB for Test-Article A (green) is below the applied predicted delta SPL dB and therefore the full level testing can proceed with confidence, with minimal risk relative to the test chamber's available acoustic power. However, the situation is different for Test-Article B (black) where the calculated delta dB exceeds the applied predicted delta dB in two of the OTOBs and options would be discussed with the customer on how to proceed.



SUMMARY

It is important to realize that some test-articles may have significant sound absorption that may challenge the acoustic power capabilities of a test facility.

Therefore, to mitigate this risk of not being able to meet the customer's target spectrum, it is prudent to demonstrate early-on an increased acoustic power capability which compensates for this test-article absorption.

This paper describes a concise method to reduce this risk when testing aerospace test-articles which have significant absorption.

This method was successfully applied during the SpaceX Falcon 9 Payload Fairing acoustic test program at the NASA Glenn Research Center Plum Brook Station's RATF.

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