

# Effect of Coversheet Materials on the Acoustic Performance of Melamine Foam

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## ABSTRACT

Melamine foam is a highly absorptive material that is often used inside the payload fairing walls of a launch vehicle. This foam reduces the acoustic excitation environment that the spacecraft experiences during launch. Often, the melamine foam is enclosed by thin coversheet materials for contamination protection, thermal protection, and electrostatic discharge control. Previous limited acoustic testing by NASA Glenn Research Center has shown that the presence of a coversheet material on the melamine foam can have a significant impact on the absorption coefficient and the transmission loss. As a result of this preliminary finding a more extensive acoustic test program using several different coversheet materials on melamine foam was performed. Those test results are summarized in this paper. Additionally, a method is provided to use the acoustic absorption and transmission loss data obtained from panel level testing to predict their combined effect for the noise reduction of a launch vehicle payload fairing.

**KEY WORDS:** Absorption, acoustic attenuation systems, acoustic foam, acoustic testing, coversheets, melamine foam noise reduction, payload fairing acoustics, transmission loss

## INTRODUCTION

As NASA continues to develop its new heavy lift launch vehicles, the use of melamine foam to mitigate internal payload fairing (PLF) acoustic noise levels is being considered. The acoustic treatments are necessary to alleviate the concern of high liftoff induced noise levels damaging the spacecraft payloads inside the payload fairing. The increased propulsion capability of the new heavy lift vehicle requires additional mitigation of the acoustic environment beyond what is achieved today by acoustic attenuation systems for typical launch vehicles. This mitigation is especially required below 400 Hz. The reduction of the acoustic levels inside the fairing can be achieved by preventing the sound from reaching the inside of the fairing (high transmission loss) or by reducing the sound once it is inside the fairing (high absorption).

With the goals of achieving such acoustic mitigation, The NASA Space Launch System (SLS) Payload Fairing (PLF) team led by Glenn Research Center (GRC) have explored the acoustic characteristics of melamine foam in two previous test programs. The first phase of testing was a small effort that provided an initial quick look at the feasibility and benefit of using melamine foam (McNelis, A., Hughes, and McNelis, M., NASA/TM-2014-218162 and NASA/TM-218127). The second phase of testing was an in-depth test program characterizing the absorption and

transmission loss (TL) acoustic characteristics of several configurations of melamine foam (Hughes and McNelis, A., NASA/TM-2014-218350). One test configuration included in the second phase of testing was a black reinforced Kapton® coversheet added to the top surface of the melamine ultralight foam test specimen. This coversheet resulted in severe degradation of the foam's acoustic Sabine absorption coefficient.

For payload fairing applications it is necessary to have a coversheet over the melamine foam for payload contamination, thermal control, and electrostatic discharge control purposes. Therefore a third phase of acoustic testing was performed at Riverbank Acoustical Laboratories (RAL) with the primary objective being to quantify the effects of four additional coversheet designs on the acoustic performance of the melamine foam. This paper summarizes the test data obtained from this Phase 3 testing.

## **MATERIALS**

The following section describes the materials that were tested in Phase 3. In addition, the description of some other materials tested in Phase 2, and referred to in this paper for comparison purposes are also described. Photographs of these materials are shown in Figure 1.

### Melamine Foam:

The melamine foam used in the Phase 3 test program was procured from the Soundcoat Company Inc. Sheets of Soundfoam® ML ULb (melamine ultralight) foam were purchased, with some of the foam sheets having coversheets on their top surface. Each foam sheet was 4 ft. × 8 ft. × 2-in. in size. The ML ULb foam is a yellow colored, “ultralight”, flexible, open-cell melamine foam, with a mass density of (0.375 lb/ft.<sup>3</sup>). ML ULb is Soundcoat's current melamine ultralight foam product, replacing their previous ML UL product. The ML ULb foam is similar to the ML UL foam previously tested in Phases 1 and 2 in color, mass density, and acoustic performance, but has been formulated to have lower formaldehyde emissions than the former ML UL product.

### Coversheets:

Four types of coversheets, adhered to only the top surface of 2-in. thick sheets of ML ULb foam, were purchased for testing in Phase 3. The new coversheets tested, with ML ULb foam, were:

- Soundtex®
- Un-reinforced black Kapton®
- Unperforated Aluminized Mylar®
- Perforated Aluminized Mylar®

Thicker 4-in. and 8-in. coversheet test configurations were assembled by layering the 2-in. thick foam sheet with a coversheet, with the appropriate number of additional sheets of 2-in.-thick ML ULb foam (with no coversheets).



***Soundtex® Coversheet with ML ULb foam***



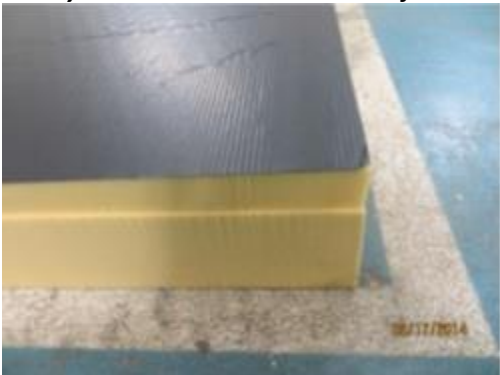
***Un-reinforced Kapton® Coversheet with ML ULb foam***



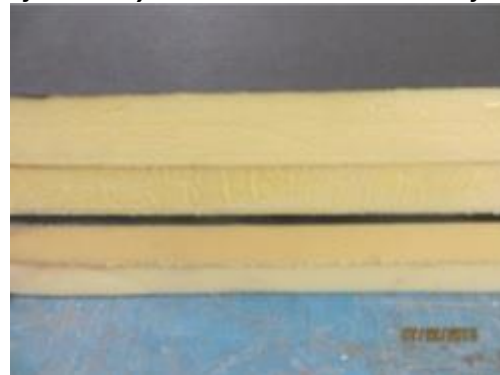
***Mylar® Coversheet with ML ULb foam***



***Perforated Mylar® Coversheet with ML ULb foam***



***Reinforced Kapton® Coversheet with ML ULb foam***



***Soundtex® Coversheet with internal Reinforced black Kapton® Barrier***



***Honeycomb Panel***



***Fiber Reinforced Foam (FRF) Panel***

***Figure 1. Test Material Photographs***

The Soundtex<sup>®</sup> coversheet is a non-woven blend of fiberglass coated with a cellulose binder, with a thickness of 0.010-in., an areal density of 0.012 lb/ft.<sup>2</sup>, and was 100% adhered to the ML ULb foam by a hot melt process.

The un-reinforced black Kapton<sup>®</sup> coversheet is a polyimide film, with a thickness of 0.002-in., an areal density of 0.013 lb/ft.<sup>2</sup>, and was attached to the ML ULb foam with a 25% adhesive pattern.

The unperforated Mylar<sup>®</sup> coversheet is an aluminized polyester film, with a thickness of 0.001-in., an areal density of 0.01 lb/ft.<sup>2</sup>, and attached to the ML ULb foam with a 25% adhesive pattern.

The perforated Mylar<sup>®</sup> coversheet was produced at Soundcoat from an unperforated Mylar<sup>®</sup> coversheet using a standard hole pattern from Soundcoat Company. The perforated Mylar<sup>®</sup> coversheet consists of 32 holes/in.<sup>2</sup>, with the holes having a diameter of 3/32 in., arranged in a ¼ in. diagonal pattern. This resulted in a perforated Mylar<sup>®</sup> coversheet with a 22% open area.

Test results will also be made referencing the following two materials:

The reinforced black Kapton<sup>®</sup> material was tested in Phase 2 as a coversheet, but used in Phase 3 as an internal barrier. It is reinforced with a Nomex<sup>®</sup> rectangular ¼ in. grid pattern for higher strength and conductivity for static dissipation. Its mass density is 0.0175 lb/ft.<sup>2</sup>.

An Aerospace Dura-Sonic<sup>®</sup> 5666 mass barrier (< 0.060-in. thick, 0.42 lb/ft.<sup>2</sup>) was used as an internal mass barrier in Phase 2. For this application the mass barrier was centered in an 8-in. ML UL foam with no coversheet.

#### Base Panels:

The RAL TL window can accommodate a 4 ft. x 8 ft. base panel. The foam and coversheet test configurations are placed against this base panel for the TL testing. For absorption testing at RAL the ASTM C423 requires a minimum of 64 ft.<sup>2</sup> for the test specimen. Therefore, for measuring the absorption of the base panel itself, the TL base panel was combined with two smaller auxiliary base panels to obtain the required surface area. (Unlike the TL testing, the absorption tests of the foam and coversheets test configurations did not use the base panel(s)).

One 4 ft. x 8 ft., and two 4 ft. x 4 ft., flat honeycomb panels were constructed by NASA's Marshall Space Flight Center (MSFC) to serve as the base panels for Phase 3. The honeycomb panels are a newer representative simulation of a payload fairing structural wall. The honeycomb sandwich panels were constructed with approximately a 1-in. thick core. The single large honeycomb panel, used for the TL testing, had dimensions of 4 ft. x 8 ft. x 1.1-in., and weighed 42 lbs.

The Phase 1 and Phase 2 testing utilized a fiber reinforced foam (FRF) panel, which was approximately 4 ft. x 8 ft. x 1.08-in. and weighed 39.5 lbs.

## **TESTING OVERVIEW**

Acoustic testing was conducted from July 27-29, 2015 at the Riverbank Acoustical Laboratories (RAL), located in Geneva, IL. RAL performed the acoustic absorption tests per the American Society for Testing and Materials (ASTM) C423 standard, "*Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberant Room Method.*" RAL performed the acoustic transmission loss (TL) tests per the ASTM E90 standard, *Standard Test*

*Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements.”*

Per these ASTM test standards, RAL is accredited to perform sound absorption coefficient measurements and sound TL measurements for the one-third octave bands (OTOB) in the frequency range of 100 Hz to 5,000 Hz. Additional unofficial representative test data was requested and provided at several extra OTOB frequencies.

The Phase 3 test series as reported within this paper consisted of seven absorption tests and eight TL tests. A test matrix of the various test configurations, with weight and dimensions as measured at RAL, is given in Tables 1 and 2, for the absorption and the TL tests respectively.

**Table 1. Summary of Phase 3 Absorption Test Configurations.**  
(Absorption tests utilize approximately 64 ft.<sup>2</sup> area.)

<b>RAL Test Report #</b>	<b>Test Configuration Description</b>	<b>Panel Weight, lb</b>	<b>Treatment Weight, lb</b>	<b>Total Weight, lb</b>	<b>Overall Dimensions, in. (W x H x T)</b>
A15-180	Honeycomb Panel	86	n/a	86	96.4 x 95.8 x 1.1
A15-182	8-in. ML ULb with black un-reinforced Kapton <sup>®</sup> coversheet	n/a	17.4	17.4	95.5 x 95.8 x 8
A15-183	8-in. ML ULb with perforated Mylar <sup>®</sup> coversheet	n/a	16.9	16.9	95.5 x 95.8 x 8
A15-184	8-in. ML ULb with Soundtex <sup>®</sup> coversheet	n/a	17.4	17.4	95.5 x 95.8 x 8
A15-185	8-in. ML ULb with Mylar <sup>®</sup> coversheet	n/a	17.4	17.4	95.5 x 95.8 x 8
A15-186	4-in. ML ULb with Soundtex <sup>®</sup> coversheet	n/a	9.0	9.0	95.5 x 95.8 x 4
A15-188	8-in. ML ULb/ML UL with Soundtex <sup>®</sup> coversheet with internal reinforced black Kapton <sup>®</sup> barrier	n/a	18.0	18.0	95.5 x 95.8 x 8

**Table 2. Summary of Phase 3 Transmission Loss Test Configurations.**  
(TL tests utilize approximately 32 ft.<sup>2</sup> area.)

<b>RAL Test Report #</b>	<b>Test Configuration Description</b>	<b>Panel Weight, lb</b>	<b>Treatment Weight, lb</b>	<b>Total Weight, lb</b>	<b>Overall Dimensions, in. (W x H x T)</b>
TL15-266	Honeycomb Panel	42	N/A	42	47.8 x 95.8 x 1.12
TL15-267	8-in. ML ULb with un-reinforced Kapton <sup>®</sup> coversheet with Honeycomb panel	42	8.6	50.6	47.8 x 95.8 x 9.1
TL15-268	8-in. ML ULb Aluminized Mylar <sup>®</sup> coversheet with Honeycomb panel	42	8.6	50.6	47.8 x 95.8 x 9.1
TL15-269	8-in. ML ULb perforated Aluminized Mylar <sup>®</sup> coversheet with Honeycomb panel	42	8.4	50.4	47.8 x 95.8 x 9.1
TL15-270	8-in. ML ULb Soundtex <sup>®</sup> coversheet with Honeycomb panel	42	8.6	50.6	47.8 x 95.8 x 9.1
TL15-272	8-in. ML ULb/ML UL with Soundtex <sup>®</sup> coversheet with internal reinforced black Kapton <sup>®</sup> barrier with Honeycomb panel	42	9.2	51.2	47.8 x 95.8 x 9.1
TL15-273	4-in. ML ULb with Soundtex <sup>®</sup> coversheet with Honeycomb panel	42	4.5	46.5	47.8 x 95.8 x 5.1
TL15-274	8-in. ML ULb with Honeycomb panel (no coversheet)	42	8.4	50.4	47.8 x 95.8 x 9.1

## ABSORPTION TESTING RESULTS

A typical absorption test setup at RAL is shown in Figure 2. To avoid the inclusion of the absorption provided by the foam's side surface areas, all of the absorption testing was performed with sealed edges, as shown in Figure 2. Table 1 lists the absorption tests performed in Phase 3.



*Figure 2. RAL's Absorption Test Setup (8-in. thick ML ULb with Soundtex<sup>®</sup> Cover Sheet with Sealed Edges, ASTM C423 Reverberation Room Method).*

- The Sabine absorption coefficients for the 4-in ML ULb foam with (A15-186), and without (A15-043), the Soundtex<sup>®</sup> coversheet are compared in Figure 3. It is observed that the presence of the Soundtex<sup>®</sup> coversheet actually improves the measured absorption: (a) the peak of the absorption is shifted lower in frequency (from the 400 Hz OTOB with no coversheet to the 250-315 OTOBs with the Soundtex<sup>®</sup> coversheet, and (b) the absorption values are higher in the 100 Hz to 400 Hz OTOBs with this coversheet. Note that the Sabine absorption coefficient can exceed a value of 1.0 due to the diffraction edge effects, and also due to the inherent assumptions integral to the use of the Sabine formula in the Reverberant Room Method (Cox and D'Antonio 2009).

- Figure 3 also includes the measured absorption data (A94-72) from a 3-in. thick fiberglass “baseline” test blanket (Hughes and McNelis, NASA-TM-107474, -107475) tested for the Cassini spacecraft Project. The fiberglass blanket was encapsulated in a Teflon<sup>®</sup> coated fibrous cover, which is believed to be the cause of the decline in absorption as frequency increases after reaching its peak absorption value at 250 Hz OTOB. From this comparison, it was determined that the 4-in. ML ULb foam, with or without a Soundtex<sup>®</sup> coversheet, has a higher peak Sabine absorption coefficient relative to the 3-in. fiberglass blanket and is more effective over the entire frequency range of 100 Hz to 10,000 Hz OTOBs. Because of the high performing absorption properties of melamine foam, in conjunction with its light weight properties, NASA is strongly considering its use for its heavy lift payload fairing acoustic attenuation systems.
- Figure 4 plots the same two 4-in. ML ULb absorption coefficients as Figure 3 (with and without the Soundtex<sup>®</sup> coversheet), but in addition also plots a similar set for an 8-in. thick ML ULb (with (A15-184) and without (A15-049) the Soundtex<sup>®</sup> coversheet). As the thickness of the foam test article increases, the peak absorption coefficient shifts downward in frequency and increases in magnitude. The thicker foam (8 in.) is a much more effective sound absorber below 250 Hz OTOB compared with the thinner foam (4 in.). The thickness effect trends agree with previous test data obtained from the Phase 1 and Phase 2 testing of melamine foam (NASA-TM-2014-218127, -2014-218350, and 2014-218162). The presence of the Soundtex<sup>®</sup> coversheet for the 8-in. ML ULb configuration is similar to the case without the coversheet. Starting at the 400 Hz OTOB, all of the data with or without a Soundtex<sup>®</sup> cover sheet, reaches a similar plateau level, regardless of the thickness.
- A test result from Phase 2 testing (NASA-TM-2014-218350) showed that the presence of the black reinforced Kapton<sup>®</sup> coversheet caused significant degradation in the Sabine absorption coefficient compared to the 8-in. thick ML UL foam only. To find out if the black un-reinforced Kapton<sup>®</sup> coversheet also produced this effect, testing was performed using 8-in. thick ML ULb with and without this un-reinforced coversheet. Figure 5, shows these results. Both of the two types of black Kapton<sup>®</sup> coversheet (A14-039, A15-182) have a negative effect on absorption when compared to the foam without a coversheet (A15-049) over a large frequency range between 163 Hz and 10,000 Hz OTOB. The degradation of the absorption with the Kapton<sup>®</sup> coversheets gets worse with increasing frequency. Cox and D’Antonio (2009) state that an impervious membrane has been shown in impedance tube test data to reduce high frequency absorption.
- Figure 6 shows the Sabine absorption coefficients for 8-in. thick ML ULb for the foam only (A15-049), with the unperforated Mylar<sup>®</sup> (A15-185) coversheet, and with the perforated Mylar<sup>®</sup> (A15-183) coversheet. The absorption data for the unperforated Mylar<sup>®</sup> shows degradation, and is similar in performance to the Kapton<sup>®</sup> coversheet data. However, the absorption data for the perforated Mylar<sup>®</sup> coversheet configuration is nearly equivalent to that of the foam only configuration, especially at frequencies greater than 200 Hz OTOB. The 22% open area to the melamine foam surface results in the improvement in the Sabine absorption coefficient. Cox and D’Antonio (2009) states that a perforated coversheet with greater than 20% open area over a porous material has no effect on absorption. Note, although these test results for the perforated Mylar<sup>®</sup> coversheet are promising, unperforated coversheets may be required due to payload cleanliness requirements due to potential particulate contamination and outgassing of the open cell foam.



- Test results (NASA-TM-2014-218350) from Phase 2 showed that the reinforced black Kapton<sup>®</sup> coversheet provided a positive effect on transmission loss. It was suggested that using this Kapton<sup>®</sup> coversheet as a low-mass, internal barrier in an acoustic treatment might prove beneficial. Therefore, an 8-in. buildup of melamine foam with an outer Soundtex<sup>®</sup> coversheet and an internal reinforced Kapton<sup>®</sup> barrier at its center (at 4-in. location) was tested. The buildup had 6-in. of ML ULb foam and 2-in. of ML UL foam since the reinforced Kapton<sup>®</sup> barrier was adhered to the older ML UL foam. Figure 7 shows the comparison of the Sabine absorption coefficients of this 8-in. Soundtex<sup>®</sup> coversheet with reinforced Kapton<sup>®</sup> barrier buildup (A15-188), and the 8-in. ML ULb with (A15-184) and without (A15-049) the Soundtex coversheet. The barrier configuration exhibits an improved absorption coefficient at the 100 Hz and 125 Hz OTOBs, but otherwise appears similar to the coversheet only test data.
- For comparison purposes, Figure 8 shows the Sabine absorption coefficient test data for the four coversheets tested in Phase 3. The unperforated Mylar<sup>®</sup> and the un-reinforced black Kapton<sup>®</sup> coversheets have a negative impact on absorption at and beyond 200 Hz OTOB. The perforated Mylar<sup>®</sup> and the Soundtex<sup>®</sup> coversheets appear to be the best choice of coversheets relative to absorption performance. Their absorption performance is better or similar to the foam only, no coversheet, test configuration.

## TRANSMISSION LOSS TESTING RESULTS

A typical TL test setup at RAL is shown in Figure 9. Table 2 lists the TL tests performed in Phase 3.

The receiving and source rooms and the 4-ft. by 8-ft. test window for this two-room test setup are visible in Figure 9. For all of the TL tests with melamine foam in this report the melamine foam treatments were placed against the honeycomb panel on the receive room side of the test window. The opposite, untreated, side of the honeycomb panel was exposed to the source excitation for the ASTM E90 testing. The RAL source excitation levels for the TL testing are approximately 105 dB on average in the OTOB frequencies of 100 Hz to 5,000 Hz.

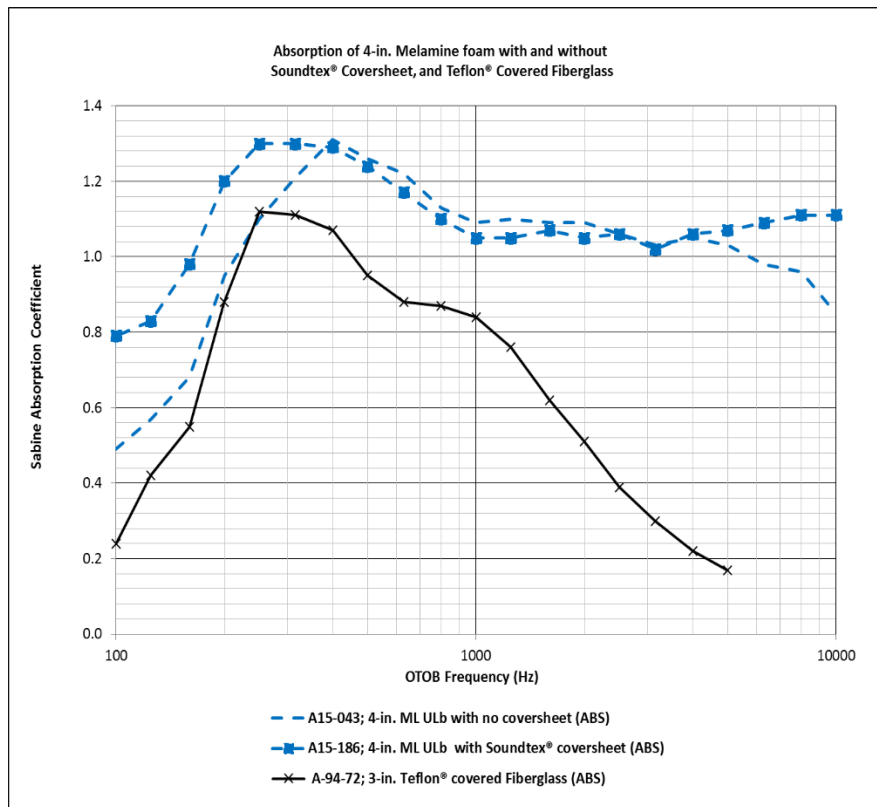
The TL of the honeycomb base panel without any melamine foam treatments was measured in test (TL15-266) and provided as a reference plot on the TL plots for this section. The previously performed Phase 1 and Phase 2 testing utilized a structural fiber reinforced foam base panel (FRF). The TL test result for this panel (TL13-139) is also shown in some of the paper's TL figures when a comparison to previous FRF and melamine foam tests are made.

- The effect of the thickness of the melamine foam for transmission loss is shown in Figure 10. The comparison is made for both 4-in and 8-in of ML ULb foam with (TL15-273, TL15-270) and without (TL14-054, TL15-274) the Soundtex<sup>®</sup> coversheets. For reference the FRF Panel (TL13-139) from testing of ML UL foam and honeycomb panel (TL15-266) from tests of ML ULb foam) TL data are also shown on the plot.

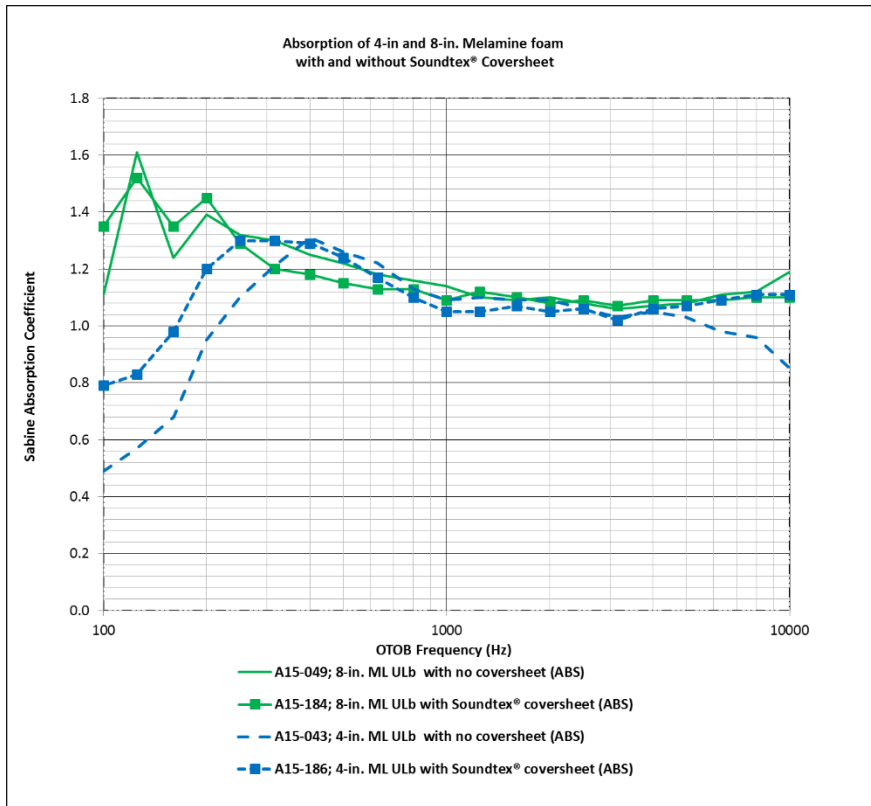
As was found in Phase 1 and Phase 2 tests, the addition of the melamine foam treatments over the base panel, increases the TL significantly beyond what would be predicted by the mass law. This is evident in Figure 10 for the 8-in ML ULb foam with Soundtex<sup>®</sup> coversheet. The additional 8.6 lbs. of melamine foam/coversheet treatment in test TL15-270 provides an additional 20 dB in TL at the 1,000 Hz OTOB when compared to the (42 lbs.) honeycomb panel without any foam or coversheet treatment. This increase in TL can be attributed to the presence of the melamine foam itself and how it keeps a portion of the

sound energy internal to the foam. From the assessment of the TL result in test TL15-274 for 8-in. of ML UL foam without a coversheet, it is evident that the result is nearly equivalent in TL to the ML ULb with the Soundtex<sup>®</sup> coversheet transmission loss test (TL15-270) for the same foam thickness.

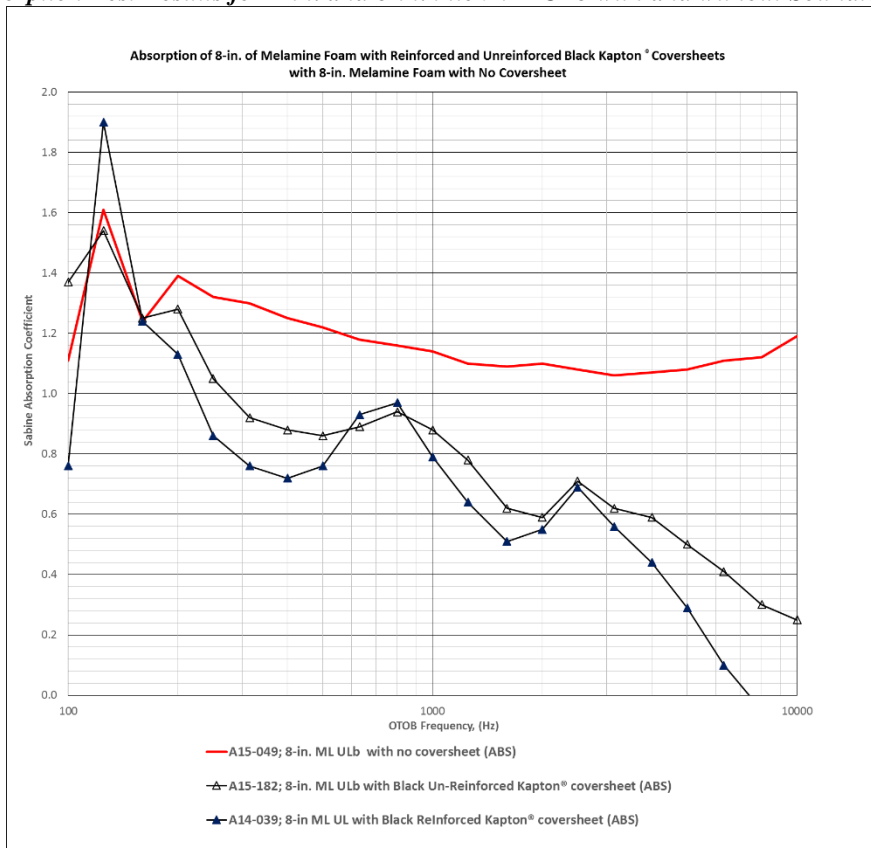
Figure 10 also shows that the 4-in. of ML ULb foam with a Soundtex<sup>®</sup> coversheet increases the transmission loss by 11 dB (at 1,000 Hz OTOB) over the honeycomb panel without foam treatment. The difference noted between the 4-in ML ULb with Soundtex<sup>®</sup> coversheet and 4-in ML UL foam only TL test results (TL14-054, TL15-273) is due to the different base panel used for the TL test. The TL of the honeycomb panel is approximately 4 dB greater (at 1,000 Hz OTOB) than that of the FRF panel previously used in melamine foam testing of the 4-in ML UL foam as shown in this figure.



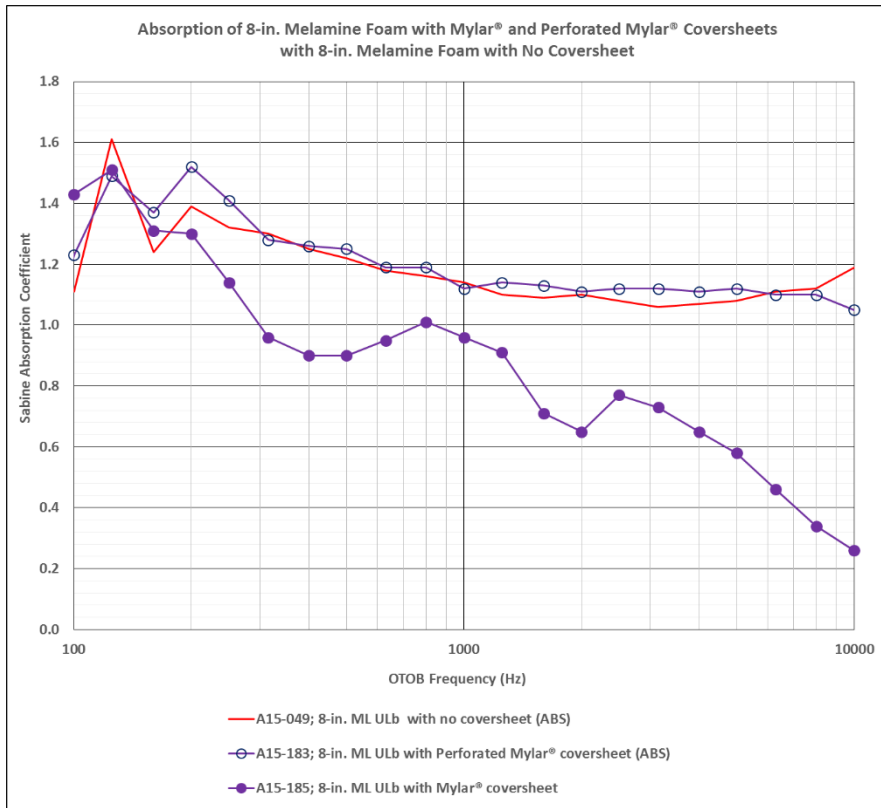
**Figure 3. Absorption Test Results for 4-in. thick ML ULb with and without the Soundtex<sup>®</sup> Coversheet, and for 3-in. thick Fiberglass with a Teflon<sup>®</sup> Coversheet.**



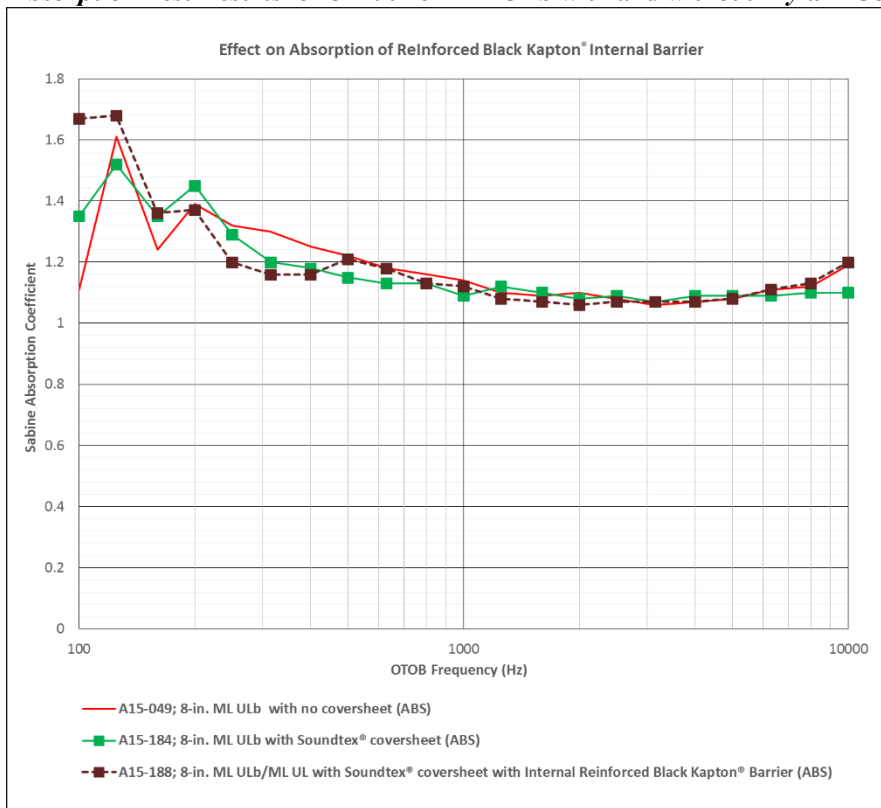
**Figure 4. Absorption Test Results for 4-in. and 8-in. thick ML ULb with and without Soundtex® Coversheet.**



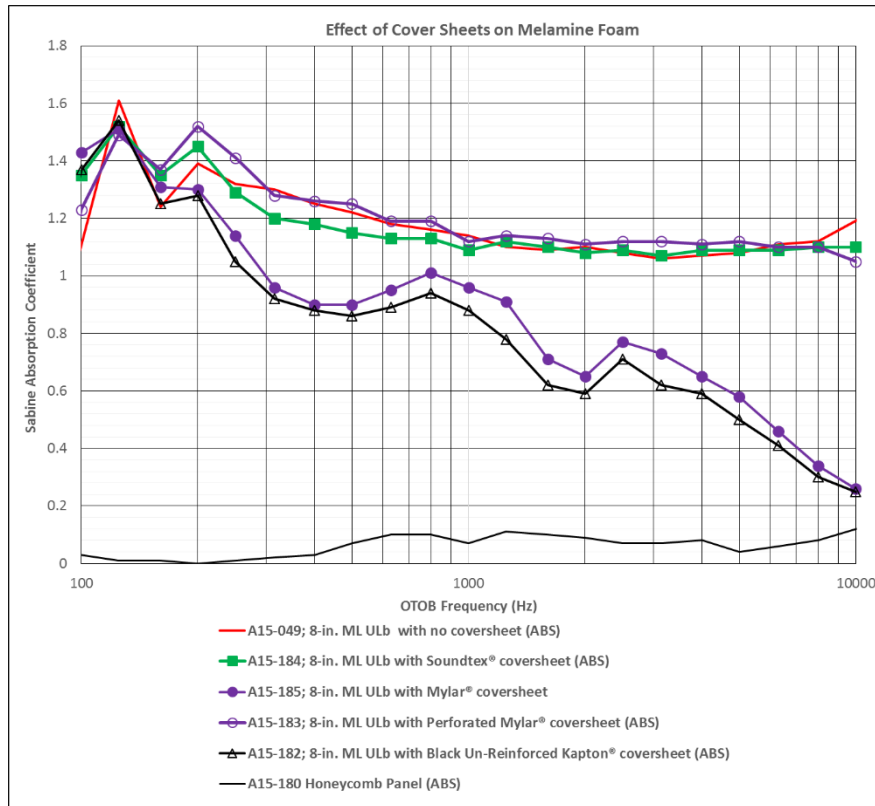
**Figure 5. Absorption Test Results for 8-in thick ML ULb with and without Kapton® Coversheets.**



**Figure 6. Absorption Test Results for 8-in. thick ML ULb with and without Mylar® Coversheets.**



**Figure 7. Absorption Test Results for Reinforced Black Kapton® Barrier with Soundtex® Cover Sheet.**



**Figure 8. Absorption Test Results for Phase 3 8-in. ML ULb with Coversheets.**

- In Figure 11 the effect on TL of the reinforced (TL14-058) and un-reinforced (TL15-267) black Kapton® coversheets are presented for the 8-in. ML ULb foam thickness, with similar conclusions as above for the Soundtex® coversheet TL comparison. The un-reinforced Kapton® melamine foam treatment has a greater TL than the reinforced Kapton® melamine foam treatment at about 5,000 Hz OTOB, where there is a peak in TL for both tests. However, this effect is likely due to the difference in base panels used in this TL comparison. The reinforced Kapton® was tested with the FRF panel, and it exhibits a lower peak TL result; however, the FRF base panel's TL contribution is much lower at the coincidence dip (~ 6,000 Hz) for the FRF panel.
- In Figure 12 the TL is displayed for 8-in of ML ULb with Aluminized Mylar® (TL15-268) and Perforated Aluminized Mylar® coversheets (TL15-269) that were tested with the honeycomb panel. The TL data for these tests are similar to the results for the 8-in of ML ULb foam without a coversheet (TL15-274). The perforated Aluminized Mylar® has a lower TL test result in comparison to the unperforated Aluminized Mylar. The maximum TL difference between the two Mylar® coversheet tests is about 4 dB, in the 1,600 Hz to 2,000 Hz OTOBs.



Left, Transmission Loss Receiver Room



Right, Transmission Loss Source Room

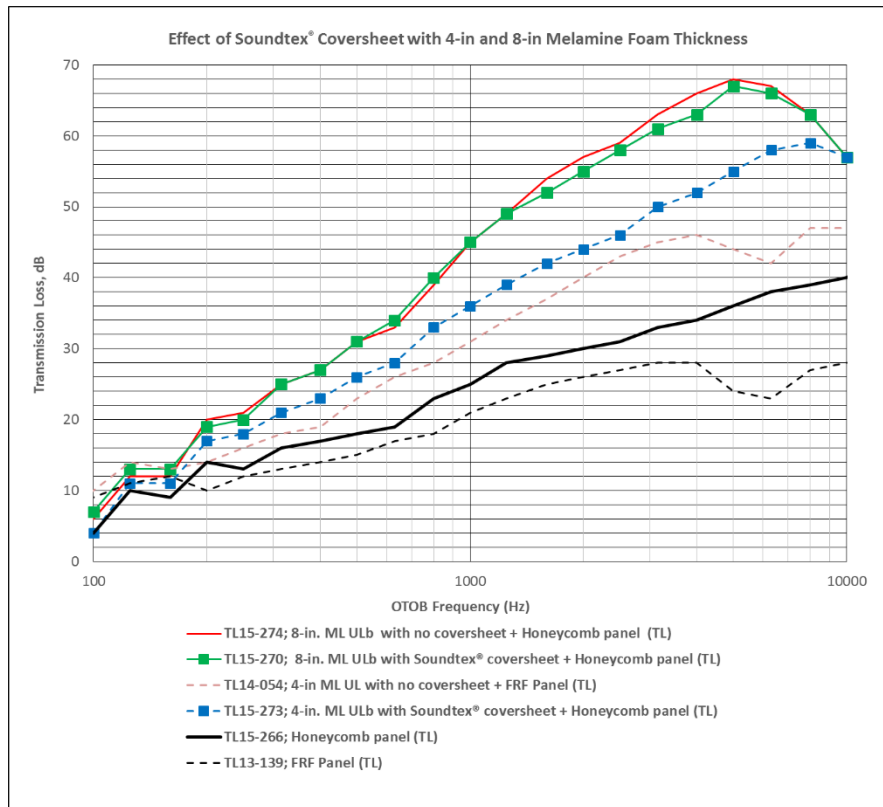
**Figure 9. RAL's Test Setup for Transmission Loss (TL) Testing (ASTM E-90 Airborne Sound TL for Building Partitions and Elements Method).**

- The transmission loss test of the 8-in. foam with Soundtex coversheet and the reinforced Kapton® lightweight internal barrier is compared to a heavy mass barrier TL test result from Phase 2 testing in Figure 13. The lightweight Kapton® barrier layup with the honeycomb panel was a total of 51 lbs. The TL14-060 test configuration from Phase 2 (NASA-TM-2014-218350) was a heavy mass barrier centered at 4-in. within the 8-in. ML UL foam treatment with no coversheet. The total weight of this heavy barrier configuration with the FRF panel was 63 lbs.

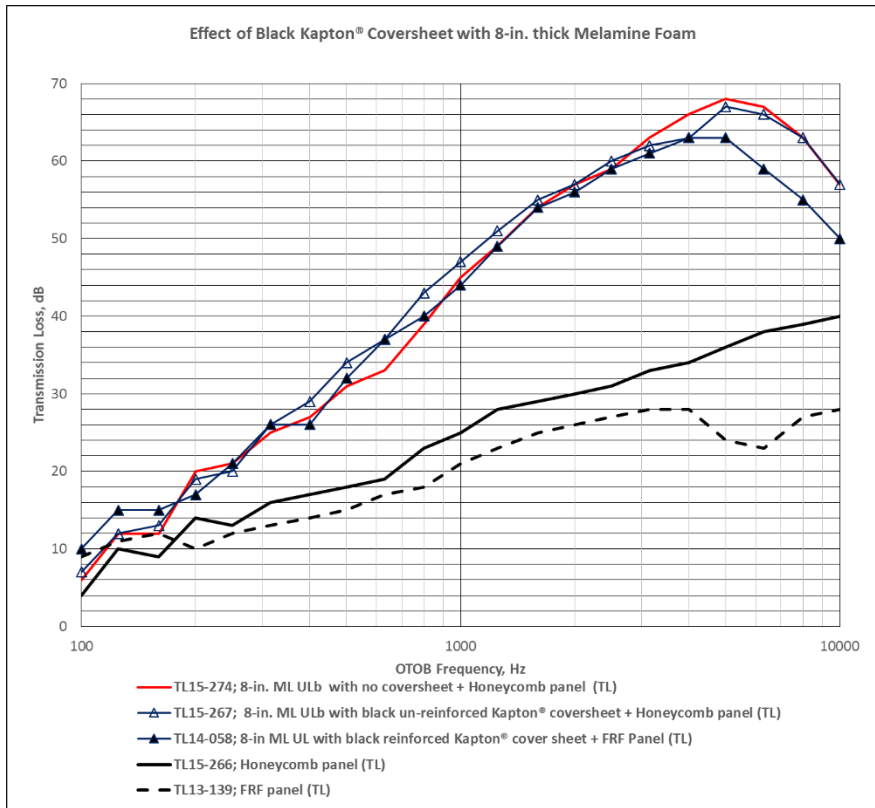
From these test article results in Figure 13 it can be seen that the heavier mass barrier treatment (TL14-060) that was utilized with a less performing (FRF) structural panel for transmission loss, exhibits a greater TL test result over the light reinforced Kapton® barrier treatment tested with a honeycomb panel in (TL15-272) between 200 Hz to 5,000 Hz OTOBs. This trend is supported by the mass law. However, the majority of the TL difference between these two barrier test configurations is due to the difference in the TL performance of their respective base panels. When one compares the TL result of the lightweight Kapton® barrier treatment (TL15-272) to that of no coversheet with ML ULb (TL15-274) with the same thickness ML ULb and with the same honeycomb structural

base panel, the lightweight Kapton® barrier treatment has a 4-5 dB increased TL between 500 Hz to 2,000 Hz OTOBs.

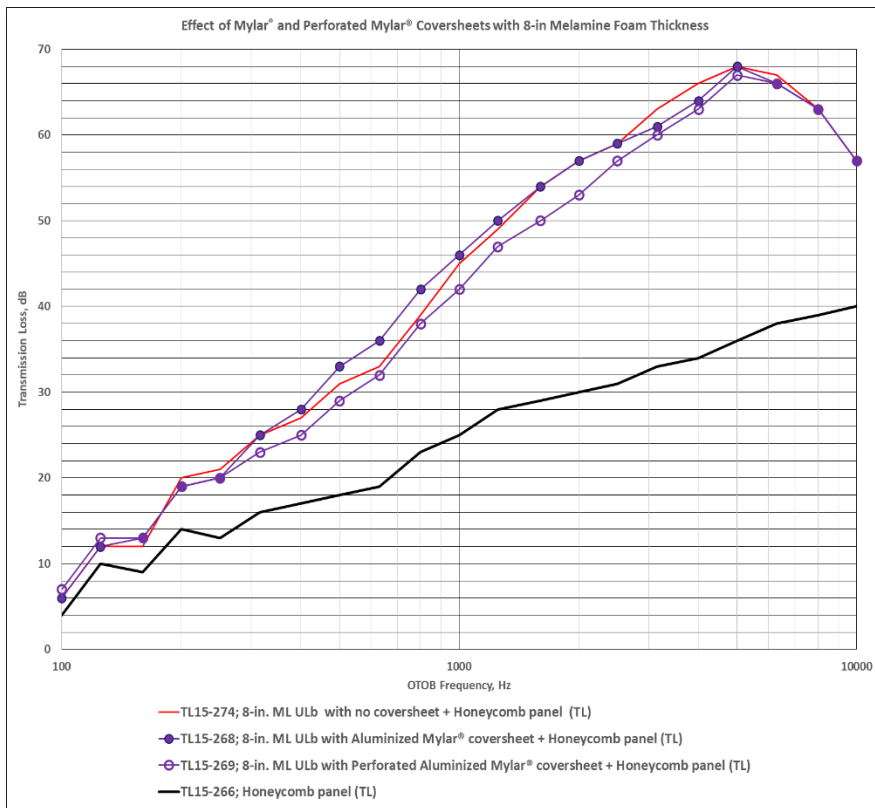
- Figure 14 provides the TL test results for the four coversheets tested in Phase 3 with 8-in. thick ML ULb foam. The perforated Aluminized Mylar® had the lowest transmission loss test data between 315Hz to 4,000 Hz OTOBs. The best performing coversheet with the ML ULb in this test series is the Black un-reinforced Kapton®. The coversheet data comparisons vary by as much as ~5 dB in transmission loss performance over the 315 Hz to 4,000 Hz OTOB.



**Figure 10. TL Test Results for 4-in. and 8-in. thick ML ULb with and w/o Soundtex® Coversheet.**

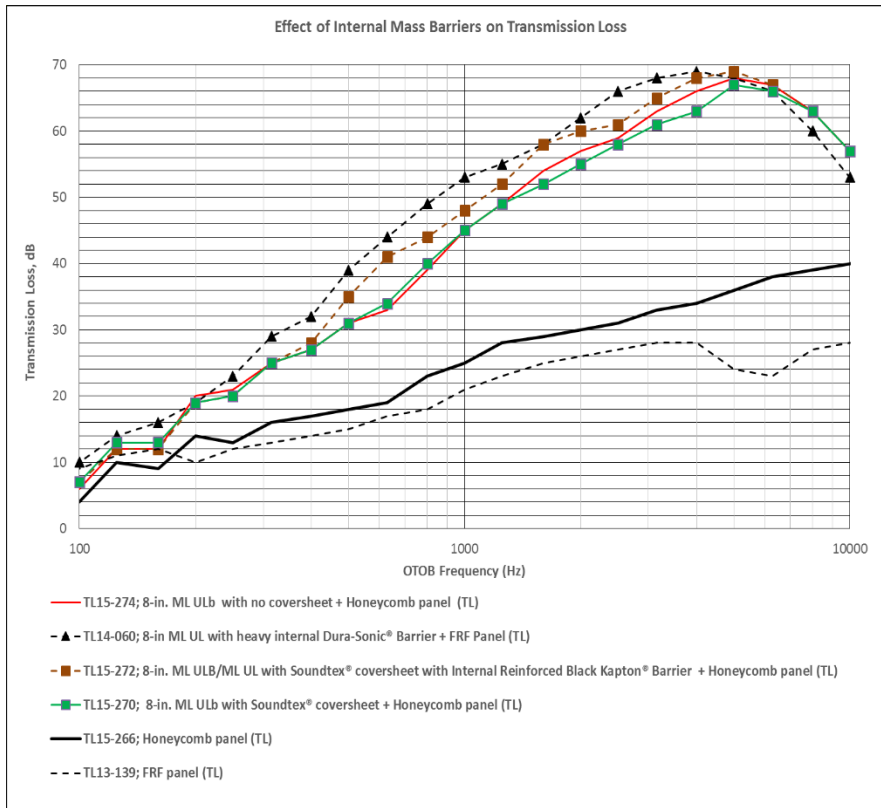


**Figure 11. TL Test Results for 8-in. ML ULb with and without Black Kapton® Coversheets.**

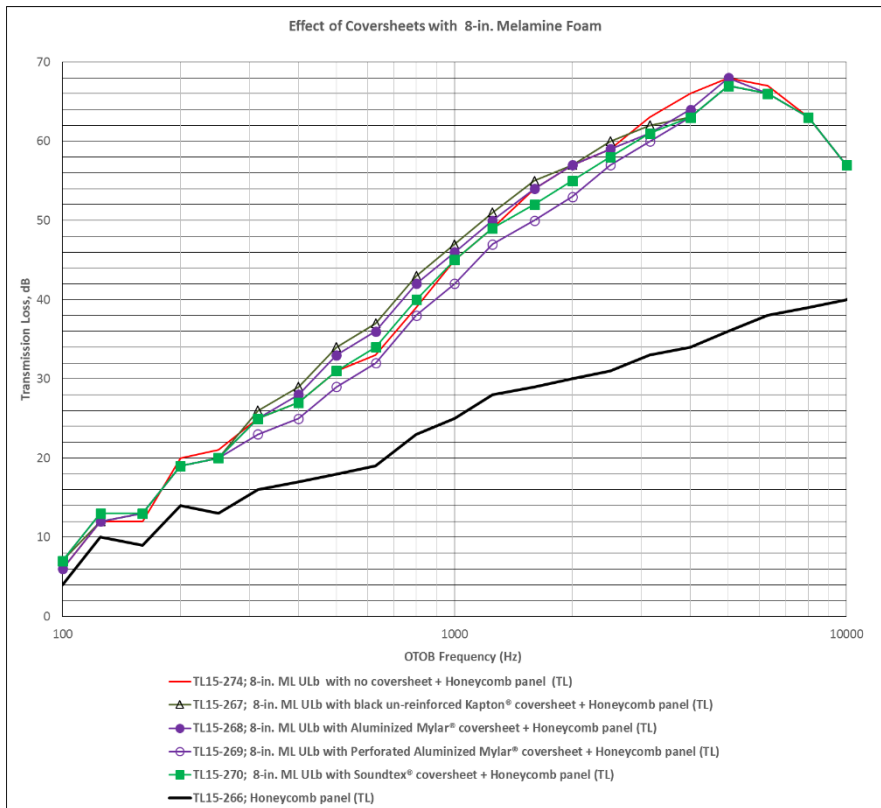


**Figure 12. TL Test Results for 8-in. ML ULb with and without Mylar® Coversheets.**





**Figure 13. TL Test Results for Barrier Test Configurations.**



**Figure 14. TL Test Results for the Phase 3, 8-in. thick ML ULb with Coversheets configurations.**

## NOISE REDUCTION PREDICTIONS

The ultimate goal from NASA SLS PLF team's melamine foam acoustic absorption and TL test phases is to predict the full-scale payload fairing acoustic noise reduction with this RAL test data. In the future this will be done using detailed analytical models (such as FEM, SEA, hybrid, BEM models) when the necessary design and environmental details are known, with eventual verification obtained by full-scale reverberant acoustic testing. For now, to help assess the relative merit of various melamine foam acoustic attenuation system designs, a quicker approximate approach is desired.

For NASA GRC's Titan IV/Cassini Project blanket development test program, absorption and TL flat panel test results from RAL were utilized in a steady state dynamic power balancing equation developed by Cambridge Collaborative Inc. to predict a quick relative assessment of the noise reduction in the Titan IV payload fairing (Hughes and McNelis, NASA-TM-107266) of a number of new acoustic blanket designs. This approach utilizes Equation 1 as shown below, and requires a "baseline treatment" reference design point. In other words, delta improvements in dB relative to the noise reduction given by the baseline treatment is predicted. This approach showed realistic magnitude and frequency correlation with the NASA Cassini test data, and was shown to be a good first order approximation prediction when its results were later compared to full scale reverberant acoustic test data for the Titan IV payload fairing.

### Equation 1:

$$\Delta_{Improvement (dB)} = 10 \log_{10} \left( \frac{\alpha_{new\ treatment}}{\alpha_{baseline\ treatment}} \right) + 10 \log_{10} \left( \frac{\tau_{baseline\ treatment} + \frac{1 - S^*}{S^*}}{\tau_{new\ treatment} + \frac{1 - S^*}{S^*}} \right)$$

where,

$\Delta$  = Improvement (dB) of New Treatment above Baseline Treatment

$\alpha$  = Measured Treatment Absorption Coefficient

$\tau$  = Treatment Transmission Coefficient =  $10^{\left(\frac{-\Delta TL}{10}\right)}$

TL = Measured Transmission Loss (dB)

$\Delta TL$  = TL of Treatment with Structural Panel – TL of Structural Panel

$$S^* = \left( \frac{\text{Treatment Surface Area for PLF}}{\text{Total Surface Area for PLF}} \right)$$

This same approach was used again for this Phase 3 test series to derive a relative dB improvement prediction of a treatments in a full scale cylindrical payload fairing configuration. This method

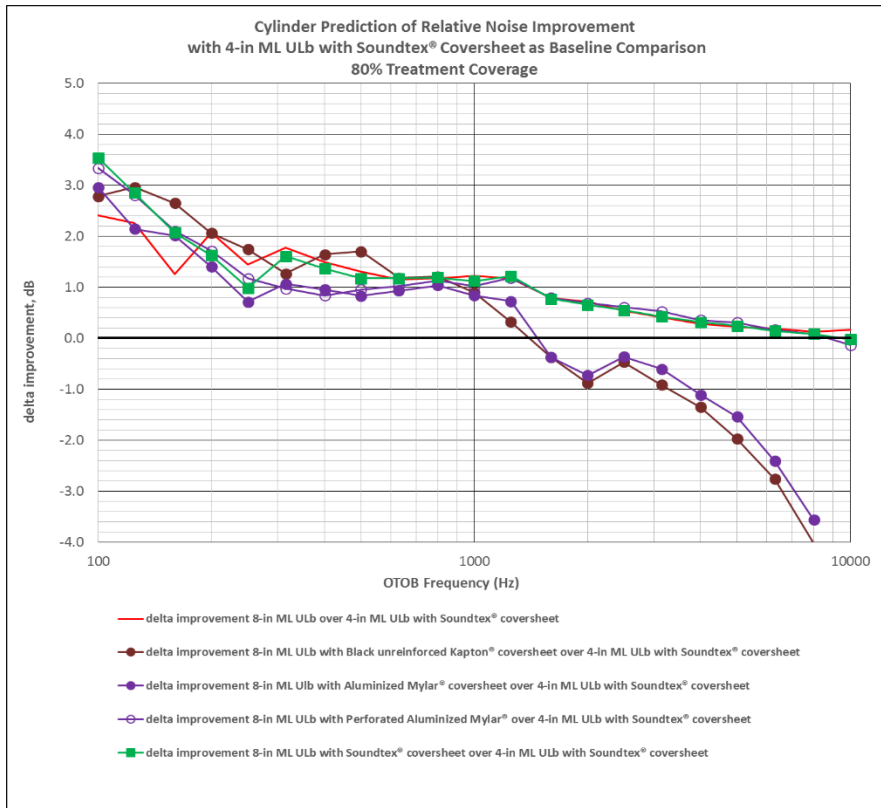
combines both the absorption test data and the transmission loss test data obtained from the flat panel Phase 3 testing. The Sabine absorption coefficient test data (which can be greater than 1.0) is converted to the Eyring absorption coefficient for this method.

Since a flight configuration would require a coversheet it was decided that the baseline treatment for this prediction should contain a coversheet for relative dB improvement comparisons. Since the perforated Mylar® treatment performs well for absorption it was considered as the baseline treatment for this analysis but was not chosen due to potential contamination issues with this treatment in a flight configuration. The baseline treatment chosen here was the 4-in. ML ULb with Soundtex® coversheet test configuration, with the honeycomb panel for TL. A typical payload fairing acoustic treatment percentage of 80% was also used.

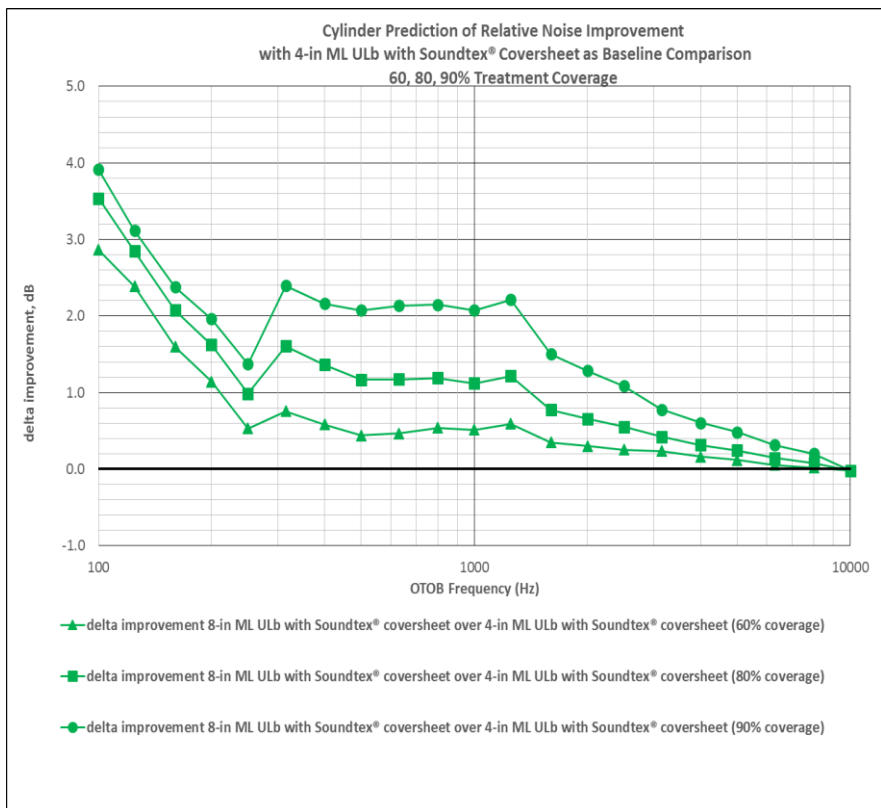
Having a payload fairing with a high noise reduction is beneficial to the survivability of the spacecraft and its components inside the launch vehicle's payload fairing. The noise reduction of a launch vehicle payload fairing has two components which relates to the two major terms of Equation 1. The first term relates to the absorption; it is beneficial to have high absorption such that the acoustic energy that is inside the payload fairing is reduced. The second term relates to transmission loss; it is beneficial to have high TL, such that the amount of acoustic energy reaching the inside of the payload fairing is reduced.

In Figure 15 the predicted PLF dB improvement of various melamine foam treatments with respect to this baseline treatment are shown. The relative improvements of each treatment assessed are between 1 dB and 2 dB, between 100 Hz to 1,250 Hz OTOBs. The Mylar® and un-reinforced Kapton® treatments have a "negative improvement" relative to the baseline treatment. This result is dominated by the reduced Sabine absorption coefficient test results at these frequencies as shown in Figures 5 - 6. Relative to 4-in. of ML ULb foam with Soundtex® coversheet, the best performing coversheet configurations are the 8-in. of ML ULb foam with the Soundtex® coversheet, or with the Perforated Aluminized Mylar® coversheet.

The second term in Equation 1 which factors in the TL data, is highly dependent upon the  $S^*$  value, the percentage of the total payload fairing surface area that has acoustic treatment. Equation 1 can be utilized to vary the percent coverage of the treatment in the payload fairing. In Figure 16 the Soundtex® coversheet with 8-in. of ML ULb is characterized for three different treatment coverage effects representing 60%, 80%, and 90% treatment coverage. A full 100% coverage is unrealistic in a true flight vehicle configuration as there are structural joints, access doors, and other limitations that prevents the full treatment of the interior of the payload fairing. Starting at the 250 Hz OTOB, the effect of varying the % of treatment coverage can be seen. Differences of about 1.6 dB are observed in Figure 16.



**Figure 15. Delta Noise Reduction Predictions over a 4-in. ML ULb with Soundtex® Coversheet Treatment.**



**Figure 16. Effect of Percentage of Acoustic Treatment Coverage in the Payload Fairing.**

## **SUMMARY**

The test results obtained in this NASA test series have provided great insight into the effect of a coversheet on absorption and TL for melamine ultralight foam. Four new coversheets were tested in Phase 3 testing at RAL. Some lessons learned are the following.

- An increase in absorption and TL may be affected for a porous material with the addition of a coversheet. Examples would include the Soundtex<sup>®</sup> and Perforated Mylar<sup>®</sup> coversheets.
- The addition of an impervious coversheet is likely to have a negative effect on absorption at high frequencies. Examples would include the unperforated Mylar<sup>®</sup>, and both the reinforced and un-reinforced black Kapton<sup>®</sup> coversheets.
- For the limited number of coversheets tested, the perforated Mylar<sup>®</sup> and Soundtex<sup>®</sup> coversheets gave the best acoustic performance for absorption.
- For the limited number of coversheets tested the transmission loss test data was the most improved with the black un-reinforced Kapton<sup>®</sup> and unperforated Aluminized Mylar<sup>®</sup> coversheets.
- To assess the impact of the effect of the added coversheet a transmission loss and absorption test can reveal the expected improvement or reduction in acoustic performance.
- The relative overall acoustic noise reduction for a payload fairing for various acoustic treatments can be predicted as a first order approximation as referenced in this report. This method requires a selection of the baseline treatment from which the delta improvements are based on. From the four coversheets tested, the best performing configurations were Soundtex<sup>®</sup> and Perforated Aluminized Mylar<sup>®</sup>.

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