NASA/TM—2014-218350

Acoustic Test Results of Melamine Foam With Application to Payload Fairing Acoustic Attenuation Systems

William O. Hughes and Anne M. McNelis
Glenn Research Center, Cleveland, Ohio

August 2014

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI Program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, organizing and publishing research results.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at *http://www.sti.nasa.gov*

- E-mail your question to *help@sti.nasa.gov*

- Fax your question to the NASA STI Information Desk at 443–757–5803

- Phone the NASA STI Information Desk at 443–757–5802

- Write to:
  STI Information Desk
  NASA Center for AeroSpace Information
  7115 Standard Drive
  Hanover, MD 21076–1320

NASA/TM—2014-218350

Acoustic Test Results of Melamine Foam With Application to Payload Fairing Acoustic Attenuation Systems

William O. Hughes and Anne M. McNelis
Glenn Research Center, Cleveland, Ohio

Prepared for the
Noise-Con 2014
sponsored by the Institute of Noise Control Engineering of the USA (INCE/USA)
Fort Lauderdale, Florida, September 8–10, 2014

National Aeronautics and
Space Administration

Glenn Research Center
Cleveland, Ohio 44135

August 2014

Acknowledgments

The authors would like to thank Mr. Joseph Roche and Mr. Timothy Tyburski of the NASA Glenn Research Center for their support with this testing effort.

Level of Review: This material has been technically reviewed by technical management.

Available from

NASA Center for Aerospace Information
7115 Standard Drive
Hanover, MD 21076–1320

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312

Available electronically at http://www.sti.nasa.gov

Acoustic Test Results of Melamine Foam With Application to Payload Fairing Acoustic Attenuation Systems

William O. Hughes and Anne M. McNelis
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Abstract

A spacecraft at launch is subjected to a harsh acoustic and vibration environment resulting from the passage of acoustic energy, created during the liftoff of a launch vehicle, through the vehicle's payload fairing. In order to ensure the mission success of the spacecraft it is often necessary to reduce the resulting internal acoustic sound pressure levels through the usage of acoustic attenuation systems. Melamine foam, lining the interior walls of the payload fairing, is often utilized as the main component of such a system. In order to better understand the acoustic properties of melamine foam, with the goal of developing improved acoustic attenuation systems, NASA has recently performed panel level testing on numerous configurations of melamine foam acoustic treatments at the Riverbank Acoustical Laboratory. Parameters assessed included the foam's thickness and density, as well as the effects of a top outer cover sheet material and mass barriers embedded within the foam. This testing followed the ASTM C423 standard for absorption and the ASTM E90 standard for transmission loss. The acoustic test data obtained and subsequent conclusions are the subjects of this paper.

1.0 Introduction

The increased propulsion capability requirements of NASA's future heavy lift launch vehicle will likely result in the payload fairing and the spacecraft contained within the fairing being exposed to extremely high external acoustic environment during liftoff. Of particular concern are the predicted high acoustic levels occurring at low frequencies internal to the fairing.

Expendable launch vehicle (ELV) fairings typically utilize acoustic treatments (e.g., foam blankets, fiberglass blankets, and passive Helmholtz resonator devices) to reduce the acoustic energy that transmits through the fairing wall and reaches the spacecraft region. The typical acoustic blanket treatments applied to launch vehicle fairings are effective in reducing the acoustic noise in the 400 Hertz (Hz) and higher frequency range. Something beyond the traditional and current state-of-the-art acoustic reduction methodologies may be required for future vehicle acoustic noise reduction, especially at lower frequencies (<400 Hz).

A similar situation occurred in the 1990's for the NASA Cassini mission to Saturn, which required specialized acoustic treatments to address a radioisotope thermoelectric generator (RTG) vibration concern at the 200 and 250 Hz one-third octave bands (OTOB). From an extensive and successful acoustic blanket development test series performed for the Titan IV/Cassini Project, NASA accumulated a wealth of knowledge and acoustic characterization data on fiberglass blankets (Refs. 1 to 3). The Titan IV/Cassini Project evaluated 19 different fiberglass configurations of varying blanket thicknesses, blanket densities, and internal mass barriers with varying placement locations and densities, in a series of flat panel acoustic testing at the Riverbank Acoustical Laboratory (RAL), in Geneva, Illinois, in March–April 1994. This data was then used to down-select to the two most promising new blanket designs for full-scale acoustic testing at the Lockheed-Martin (Denver) reverberant acoustic chamber in January–February 1995. As a result, a new fiberglass barrier blanket, denoted as "V5," was chosen for implementation on the Titan IV/Cassini mission and flew in October 1997. This V5 fiberglass barrier blanket successfully reduced the acoustic environment to the Cassini spacecraft as needed (Ref. 4).

Given the trend within the aerospace industry today to use melamine foam for payload fairing acoustic attenuation, it was deemed prudent to try to assemble a database of acoustic performance panel test data for melamine foam, similar to what was achieved for the fiberglass blankets for the Titan IV/Cassini Project. The initial step for obtaining this database was performed at the RAL in July 2013 with funding from the NASA Engineering and Safety Center (NESC). This NESC Enhanced Melamine Foam Acoustic Test (NEMFAT) series of acoustic tests (Refs. 5 and 6) provided an initial quick look at the benefit of using melamine foam, and the impetus to follow-up with a second more extensive test program.

This new acoustic test series was performed at RAL in February and April 2014 with discretionary funding provided by the NASA Glenn Research Center. The objective of this test program was to obtain relevant acoustic test data characterizing the acoustic performance of melamine foam. This data will be used as a baseline for analytical modeling, designing and testing future acoustic attenuation systems. This paper summarizes a subset of the overall absorption and transmission loss test data obtained from this second acoustic test program.

2.0 Testing Approach and Overview

For this test program numerous sheets of both ML and ML UL foam were purchased from the Soundcoat Company. The gray-colored melamine (ML) foam is the "standard" density (0.562 lb/ft^3) foam. The yellow-colored melamine "ultralight" (ML UL) foam has a lighter density (0.375 lb/ft^3) than the standard ML foam. All the foam sheets were 4-ft by 8-ft. The purchased foam had thicknesses of 1-in., 2-in. or 6-in. The thicker foam test configurations (i.e., 4-in., 6-in., 8-in., and 10-in.) were assembled by layering a number of foam sheets with the appropriate thickness.

Also purchased were ML and ML UL 2-in. thick foam sheets with an internal center-positioned Aerospace Dura-Sonic 5666 mass barrier 1X (<0.060-in. thick, 60 oz/yd^2), as well as a ML UL 2-in. sheet with a 2X Sonic barrier (2 layers of the 1X barrier material). ML and ML UL 2-in. thick sheets with a thin, black-colored, reinforced Kapton (DuPont) film (0.0016-in. thick, 2.5 oz/yd^2) used as a top cover sheet were also purchased.

Acoustic testing was conducted at the RAL in February and April of 2014. RAL performed the absorption tests per the American Society for Testing and Materials (ASTM) C423 standard (Ref. 7), and the transmission loss (TL) tests per the ASTM E90 standard (Ref. 8). A representative fiber-reinforced foam (FRF) panel was utilized as the mounting base panel for the transmission loss testing. The acoustic test results are summarized in Section 3.0.

3.0 Data Analysis

RAL is accredited to perform sound absorption coefficient measurements and sound TL measurements for the OTOBs in the frequency range of 100 to 5,000 Hz. Additional unofficial representative test data was requested and provided at several extra OTOB frequencies, both at lower (40 to 80 Hz) and higher (6,300 to 10,000 Hz) frequencies than the ASTM standard frequencies. The data presented here is from the 100 to 10,000 Hz OTOBs, as the data below the 100 Hz OTOB may possibly be affected by the unique test room modal characteristics.

A summary of the various test configurations discussed in this paper is given in Table 1.

TABLE 1.—SUMMARY OF TEST CONFIGURATIONS

RAL test report no.	Test configuration description	Panel weight, lb	Treatment weight, lb	Total weight, lb	Overall dimensions, in. (W × H × T)
Absorption Test					
A13-173	2-in. ML (unsealed)	No panel	6	6	96 × 96 × 2
A13-175	4-in. ML (unsealed)	No panel	12	12	96 × 96 × 4
A14-033	FRF Panel (sealed)	79.7	N/A	79.7	95.75 × 96 × 1.07
A14-034	6-in. ML UL (sealed)	No panel	12	12	96 × 96 × 6
A14-035	8-in. ML UL (sealed)	No panel	16	16	96 × 96 × 8
A14-036	10-in. ML UL (sealed)	No Panel	20	20	96 × 96 × 10
A14-037	4-in. ML UL (sealed)	No Panel	8	8	96 × 96 × 4
A14-038	4-in. ML UL (unsealed)	No Panel	8	8	96 × 96 × 4
A14-039	8-in. ML UL with Kapton (sealed)	No Panel	17.2	17.2	96 × 96 × 8
A14-040	4-in. ML with Kapton (sealed)	No Panel	13	13	96 × 96 × 4
A14-041	8-in. ML UL with 1X Barrier 2-in from Floor (sealed)	No Panel	46	46	96 × 96 × 8
A14-095	4-in. ML (sealed)	No Panel	12	12	96 × 96 × 4
Transmission Loss Test					
TL13-139	FRF Panel	40	N/A	40	47.75 × 95.75 × 1.07
TL13-140	4-in. ML	40	6	46	48 × 96 × 5.07
TL14-054	4-in. ML UL	40	4	44	48 × 96 × 5.07
TL14-055	6-in. ML UL	40	6	46	48 × 96 × 7.07
TL14-056	8-in. ML UL	40	8	48	48 × 96 × 9.07
TL14-057	10-in. ML UL	40	10	50	48 × 96 × 11.07
TL14-058	8-in. ML UL w/Kapton	40	8.6	48.6	48 × 96 × 9.07
TL14-059	8-in. ML UL w/1X Barrier 2-in. from FRF Panel	40	23	63	48 × 96 × 9.07
TL14-060	8-in. ML UL w/1X Barrier 4-in. from FRF Panel	40	23	63	48 × 96 × 9.07
TL14-063	8-in. ML w/Kapton	40	12.5	52.5	48 × 96 × 9.07
TL14-069	4-in. ML w/Kapton	40	6.5	46.5	48 × 96 × 5.07
TL14-070	8-in. ML UL w/2X Barrier 2-in. from FRF Panel	40	37	77	48 × 96 × 9.13
TL14-133	6-in. ML	40	8.5	48.5	48 × 96 × 7.07
TL14-135	8 in. ML w/two 1X Barriers 1-in. and 7-in. from FRF panel	40	40.3	80.3	48 × 96 × 9.07

3.1 Absorption Testing

For absorption testing, ATSM C423 recommends (Ref. 7) that the area of the test specimen be at least 60 ft^2 and recommends using 72 ft^2. Since the foam sheets were each 4-ft by 8-ft. (32 ft^2), an area of 64 ft^2 was used as it was achievable by placing two foam sheets next to each other. Figure 1 shows a typical absorption test setup at RAL. Note that all the side edges of the foam material as it lies on the floor of the test chamber are sealed with a combination of reflective Masonite wood strips and steel beams to block the foam's side surface area from contributing to the measured absorption. It is generally thought that sealing the edges provides a more realistic measurement of the material's absorption although the actual installation and application (e.g., installed layout of foam on the payload fairing walls) would be the determining factor.

In Figure 2, a plot of the measured absorption coefficient (Sabine absorption) is shown versus frequency for four different thicknesses (4, 6, 8, and 10 in.) of the ML UL foam. One observes that as the thickness of the foam test specimen increases the peak absorption coefficient shifts downward in frequency and increases in magnitude. This trend is expected from theory and also agrees with previous test data obtained for fiberglass blankets for the Cassini program (Ref. 1). At ~400 Hz and above the absorption coefficients tend to converge for all these test specimens with sealed side edges regardless of the thickness.

Note that the Sabine absorption coefficient sometimes exceeds a value of 1.0 due to edge diffraction effects and to the Sabine formulation itself (Ref. 9). The edge diffraction effects seems to be more pronounced for highly absorptive test specimens (such as melamine foam) with significant edge surface area (such as thick test specimens) (Refs. 10 and 11).

Figure 3 shows another example of the effect of thickness on absorption this time for the standard density ML foam. This data shows the similar trend of increasing absorption with thickness at the lower frequencies. However, in this case the convergence of the absorption values at the higher frequencies is not as evident; this is likely because these particular test specimens were tested with unsealed edges whose different exposed side edge surface areas may be contributing to the absorption at these frequencies.

Figure 4 shows the effect of sealed versus unsealed edges on absorption. It is observed that if the side edges of the foam test specimen is unsealed then the absorption coefficient at frequencies ~400 Hz and above will be greater than the corresponding sealed test specimen's absorption. This effect is observed for both the 4-in. ML foam material and for the 4-in. ML UL foam material.

Figure 4 also gives some insight on the effect of the foam's mass density on absorption. For the 4-in. test specimens it is observed that the higher density (0.562 lb/ft^3) ML foam has slightly more absorption than the lower density (0.375 lb/ft^3) ML UL foam below ~300 Hz. Above 300 Hz, the absorption of the ML and ML UL samples are very similar.

The effects of adding an internal mass barrier for absorption are illustrated in Figure 5. There appears to be no significant difference in the absorption coefficient between the 8-in. of ML UL foam with and without a 1X mass barrier (that is located 2-in. from the floor). Prior to the test it was expected that the barrier layer might make the test specimen appear "thinner" for absorption but that was not observed as the data is quite similar for these two tests.

When utilizing the foam in a payload fairing, it may be necessary to apply a top outer cover sheet to the foam. The cover sheet may be needed for contamination control and/or electrostatic discharge control purposes. Figure 6 shows that adding a cover sheet, thin Kapton in this case, can have a major effect on the absorption coefficient. For both a 4-in. ML foam material and 8-in. ML UL foam material the Kapton cover sheet greatly reduced the absorption coefficient at high frequencies starting around 160 Hz, while increasing the absorption below that. If a cover sheet is required, then its material and design may be very critical to its acoustic performance.

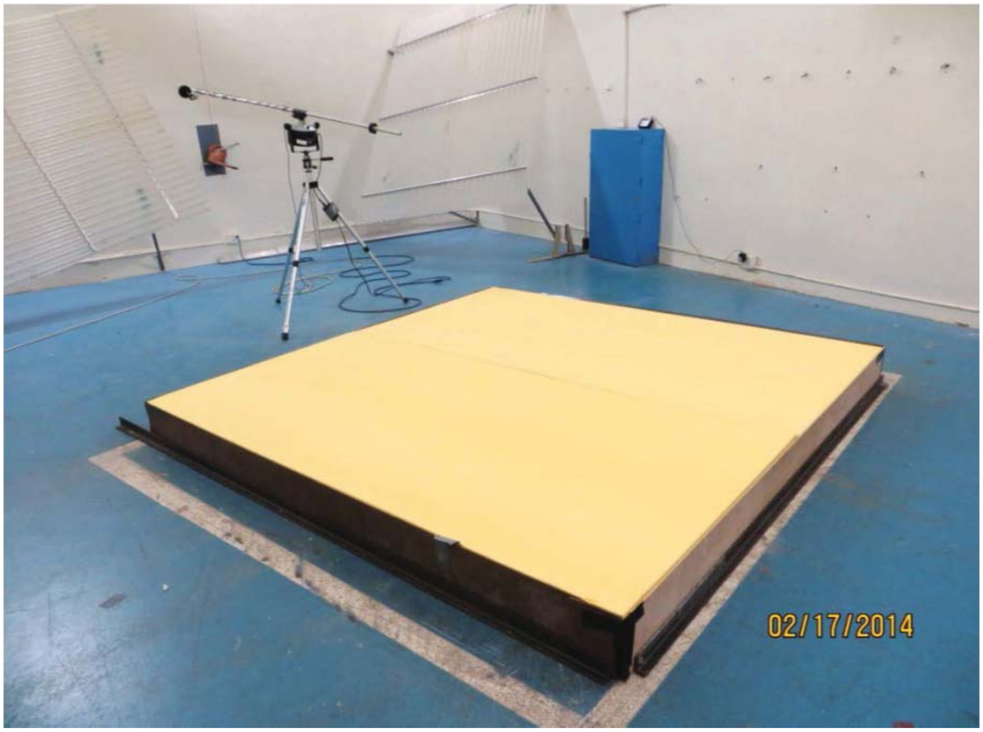

Figure 1.—RAL's ASTM-C423 absorption test setup.

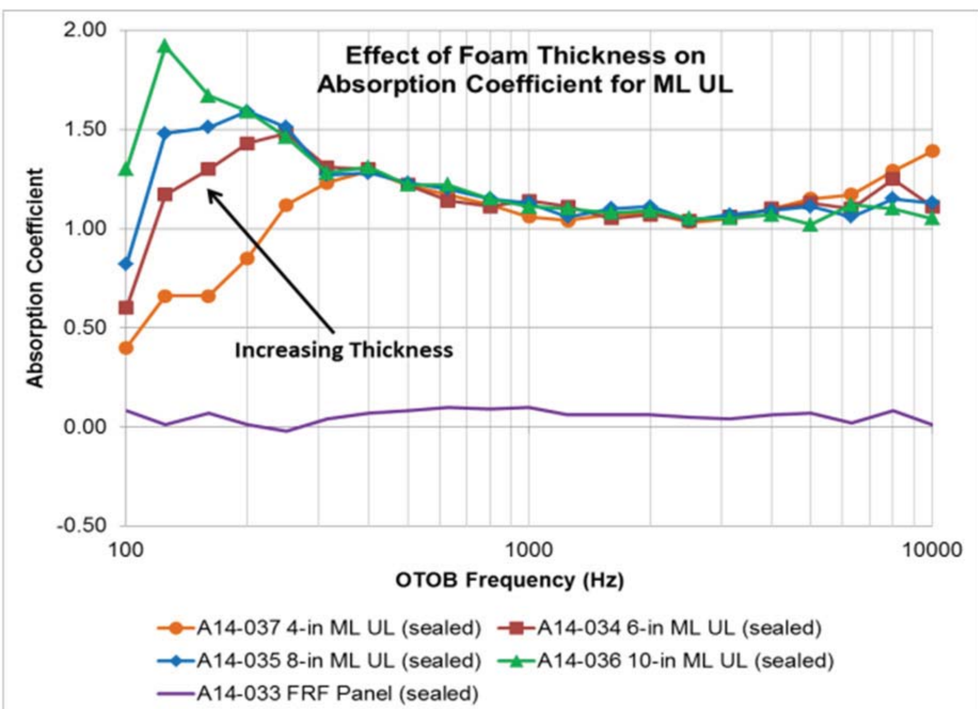

Figure 2.—Effect of foam thickness on absorption.

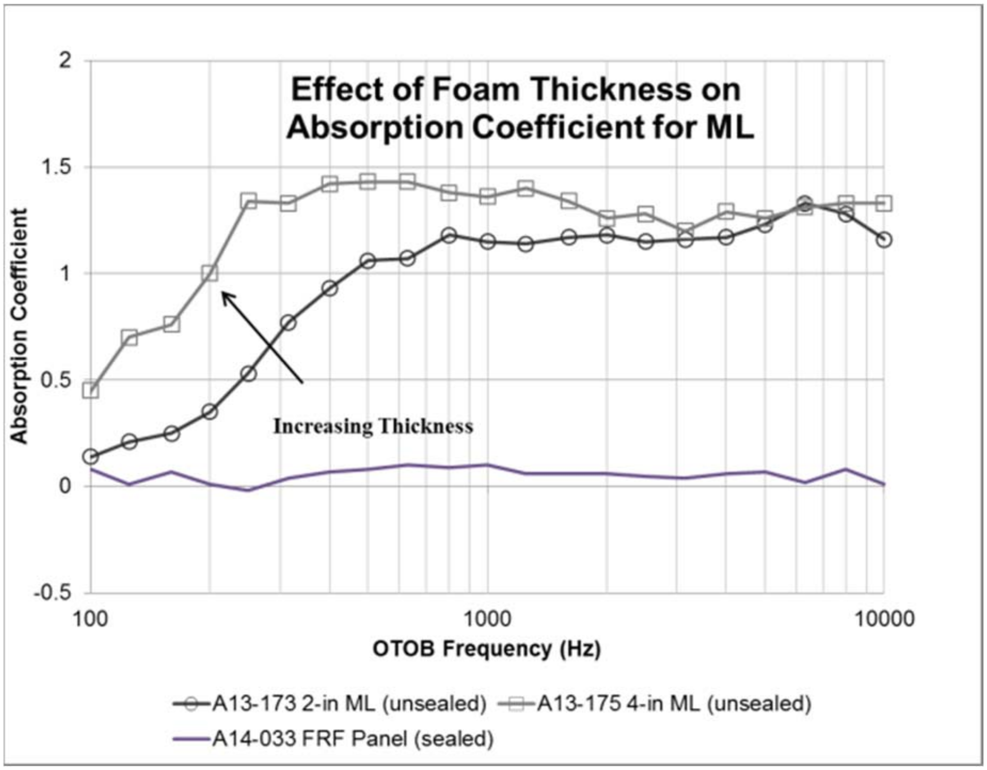

Figure 3.—Effect of foam thickness on absorption.

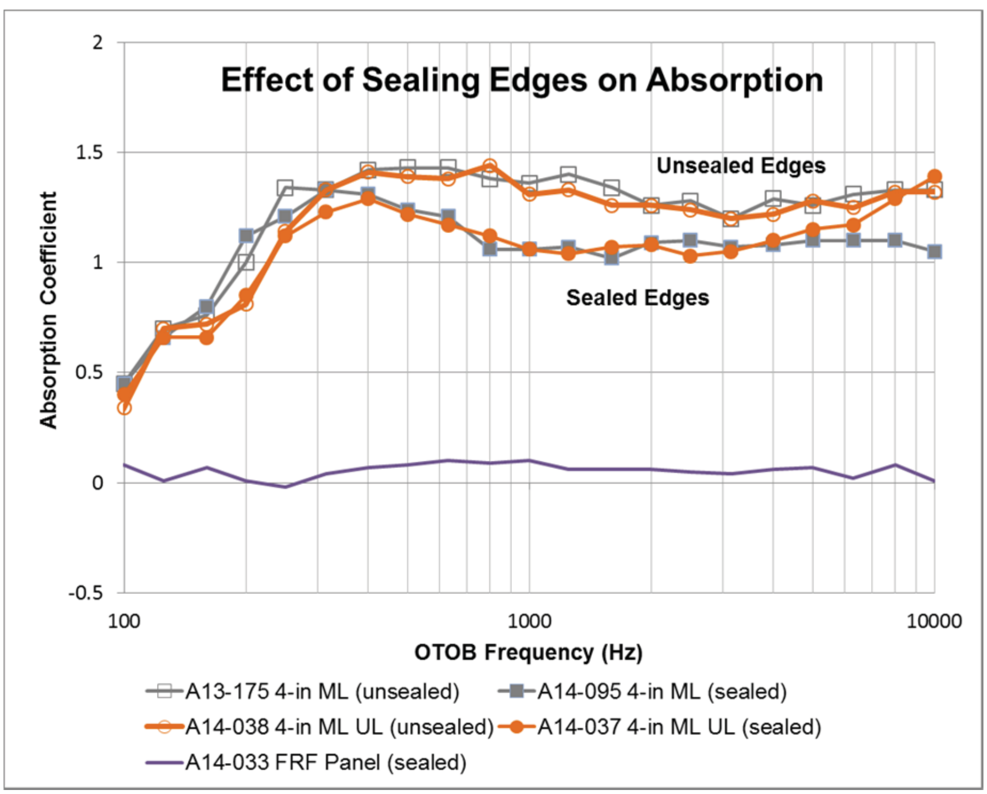

Figure 4.—Effect of sealing edges on absorption.

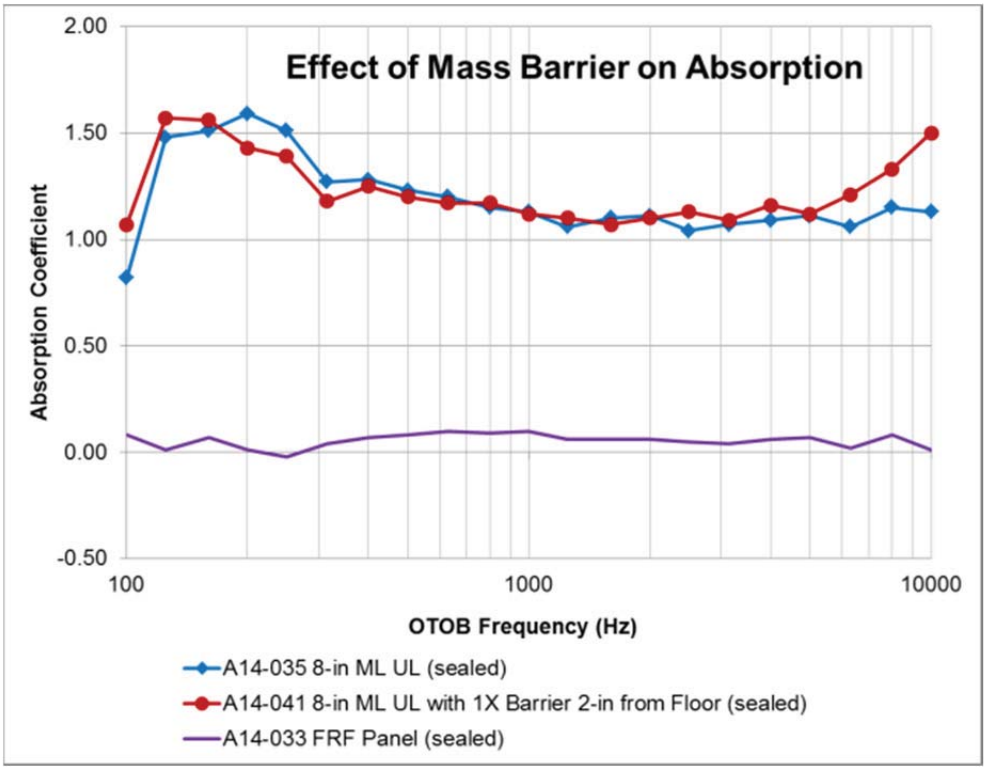

Figure 5.—Effect of mass barrier on absorption.

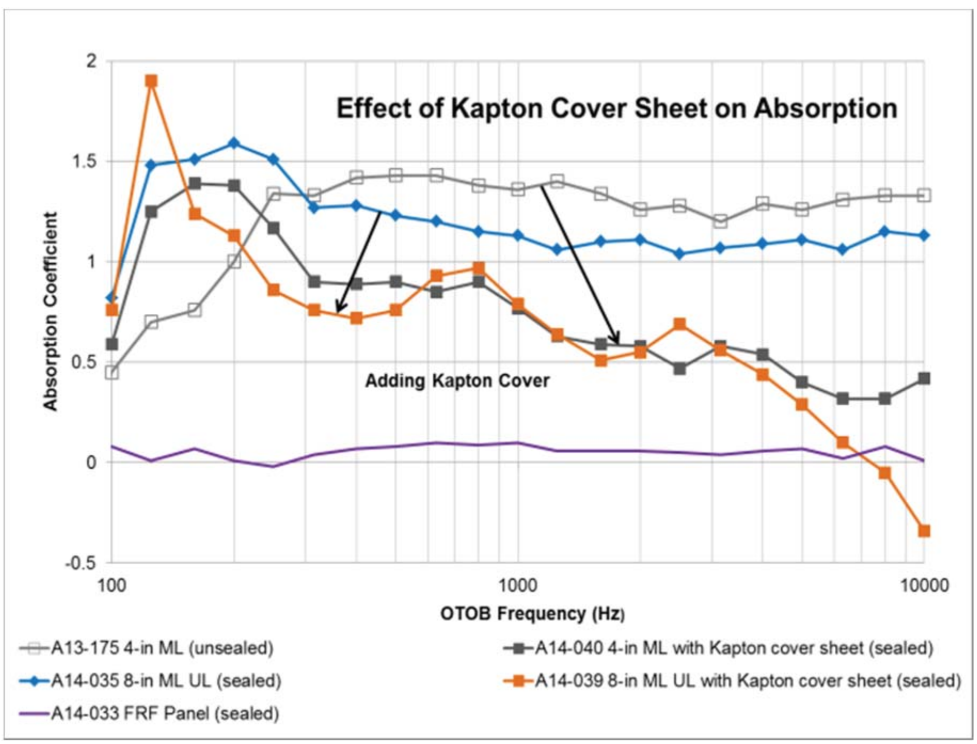

Figure 6.—Effect of Kapton cover sheet on absorption.

3.2 Transmission Loss Testing

A typical ASTM E90 Transmission Loss test setup at RAL is shown in Figure 7. The receiving room and the 4-ft by 8-ft test window for this two-room test setup are visible in Figure 7. For all the TL tests reported in this paper the melamine foam treatments were placed against the FRF panel on the receive room side of the test window. The opposite side of the FRF panel was exposed to the source excitation for the ASTM E90 testing. The TL of the FRF panel itself (without any foam treatments) was measured in test TL13-139 and provided as a reference plot on all the TL plots.

In Figure 8 the TL of the ML UL foam treatment of various thickness (4-in., 6-in., 8-in., and 10-in.) on the FRF panel is shown. The presence of the foam results in significant increases in TL well beyond what the FRF panel by itself provides. For example, adding the 4-in. ML UL treatment (4 lb) to the FRF panel (40 lb) increased the TL at 1000 Hz by 10 dB while only increasing the mass by 4 lb (10 percent). The observed increases in TL are well beyond the ~1 dB of TL which could be attributed to the mass law effect. Figure 8 shows that additional increases in TL are realized by increasing the thickness of the foam treatment.

Figure 9 compares the TL for a 4-in. thick ML and a 4-in. thick ML UL. It is observed that the standard density ML foam has greater TL. The same conclusion is reached from the TL test data for a 6-in. thick ML and ML UL test specimens as shown in Figure 10. A visual comparison of Figures 9 and 10 also shows that the 6-in. ML foam's TL is greater than the 4-in. ML foam's TL, which is consistent with the conclusions of Figure 8.

Various melamine foam treatments were also tested with the inclusion of a thin mass barrier layer since as mentioned earlier the Cassini V5 fiberglass barrier blanket and design was very successful. For these tests, the Dura-Sonic 5666 mass barrier layers (1X: <0.060-in., 60 oz/yd^2) were placed at various locations internal to the 8-in. ML UL foam layup. Four different 8-in. thick ML UL foam barrier design concepts were tested and the resulting TLs are shown in Figure 11. It can be seen that significant increased TL is possible with the use of barriers. For example at 400 Hz, relative to the TL for the 8-in. ML UL with no barrier, the TL increases between 6 to 14 dB depending upon the barrier design tested. The design using two separated 1X barriers within the 8-in. foam (TL14-135) was the best of the four barrier designs tested particularly between 125 to 1000 Hz. When comparisons are made to the TL for the FRF Panel only, substantial TL improvement is measured for these four barrier designs. For example, at 400 Hz, the FRF Panel's TL is 14 dB, whereas the two barrier design concept's TL is 37 dB which is an increase of 23 dB; the mass law would have only predicted a 6 dB TL increase.

The introduction of the Kapton top cover sheet was observed to improve the acoustic TL performance, unlike the effect on the absorption coefficient. Two examples of this improvement in TL are provided in Figure 12. The comparison of the 4-in. ML treatment with (TL14-069) and without (TL13-140) the Kapton cover sheet shows a 2 to 9 dB improvement starting at 315 Hz. A somewhat smaller improvement is observed for the 8-in. ML UL treatment with (TL14-058) and without (TL14-056) the Kapton cover sheet. Finally, the 8-in. higher density ML (TL14-063) treatment with Kapton has even higher TL values compared to the 8-in. lower density ML UL (TL14-058) treatment with Kapton. This supports the conclusions of Figures 9 and 10 that the ML foam has higher TL than ML UL foam for similar thickness, even when the Kapton top cover sheet is present.

Figure 7.—RAL's ASTM-E90 TL test setup.

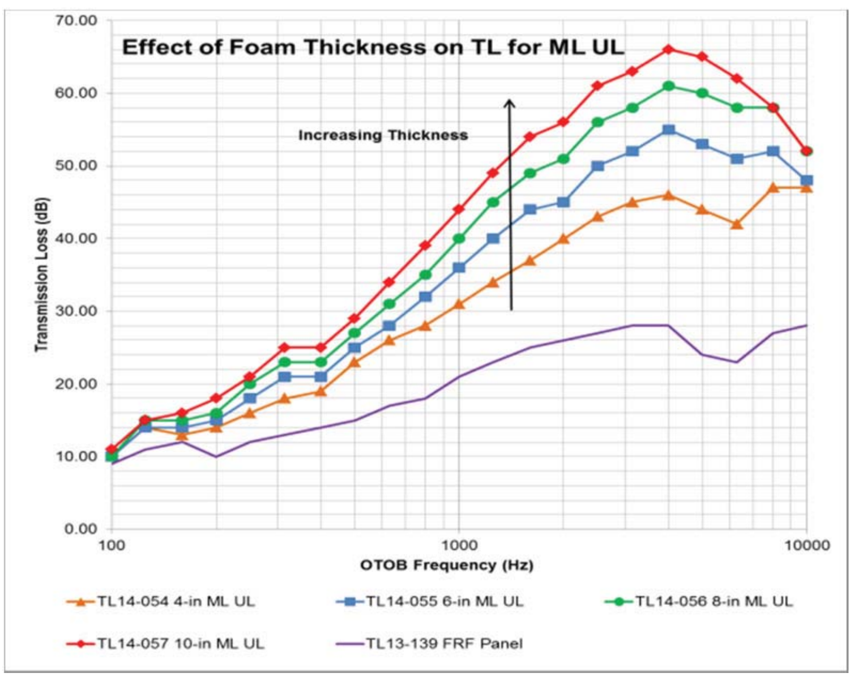

Figure 8.—Effect of foam thickness on TL.

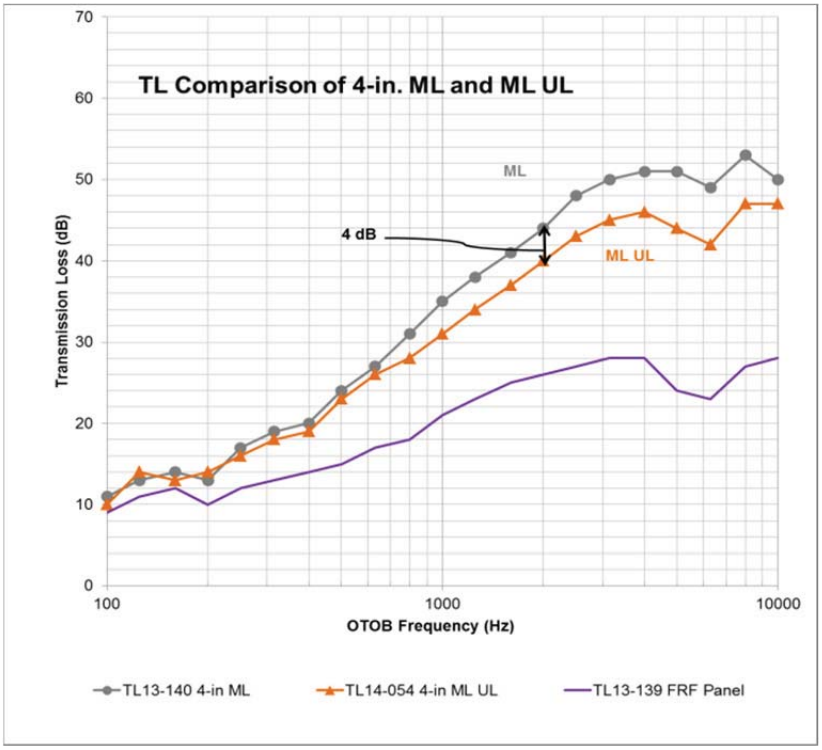

Figure 9.—Effect of foam density on TL (4-in.).

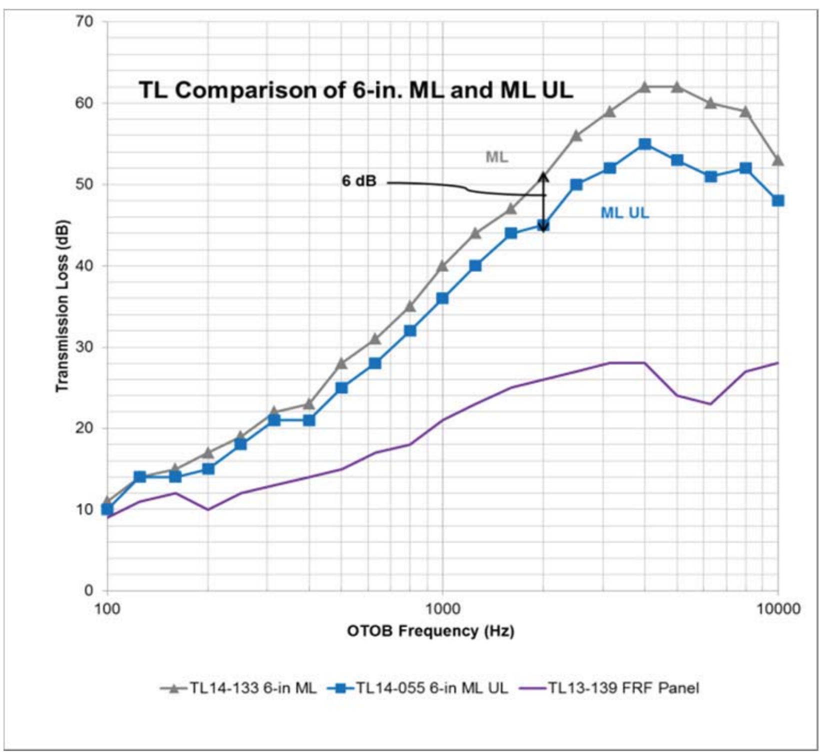

Figure 10.—Effect of foam density on TL (6-in.).

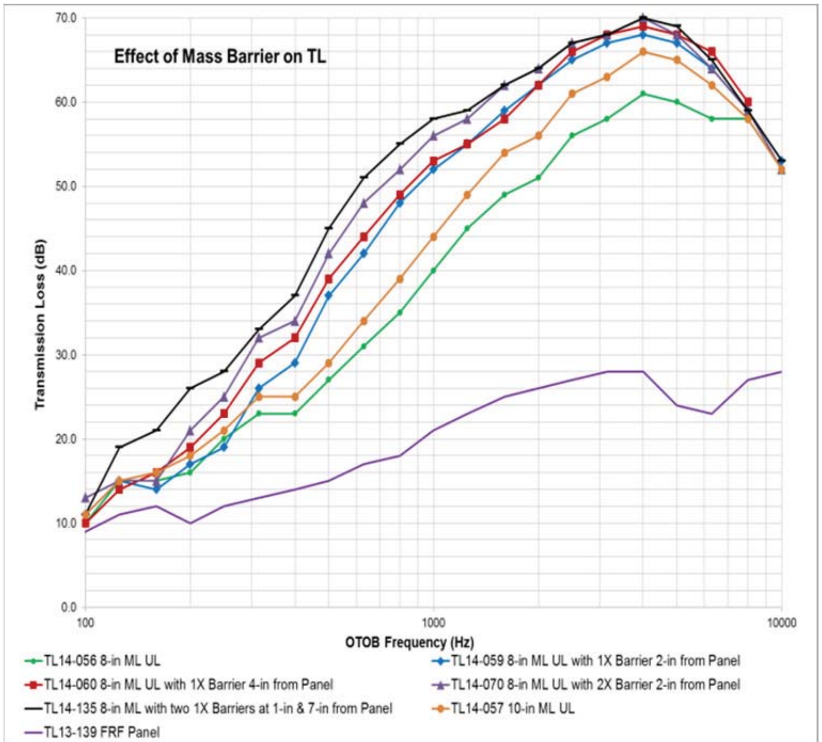

Figure 11.—Effect of mass barrier on TL.

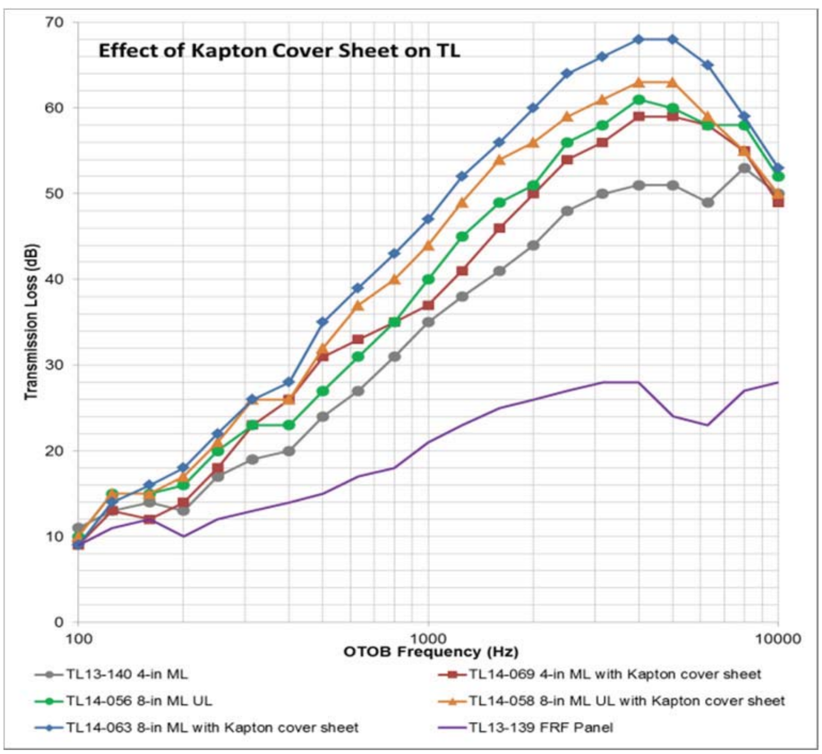

Figure 12.—Effect of Kapton cover sheet on TL.

4.0 Conclusions

The melamine foam testing was successful in that it established a database of acoustic properties of melamine (ML, ML UL) foam for NASA, especially with respect to effects of thickness, density and mass barriers. The importance of the cover sheet was also realized through this testing. The Kapton cover sheet tested was found to have a negative effect on absorption and a positive effect on TL. Other specific cover sheet materials would need to be tested to see how they might affect the acoustic performance of the underlying foam treatment. Because of the foam's improved acoustic performance (Refs. 5 and 6) and lighter mass relative to fiberglass blankets (Ref. 2), the use of melamine (ML, ML UL) foam is being strongly considered for future acoustic attenuation systems for future NASA payload fairings.

References

1. Hughes, W.O. and A.M. McNelis, "Cassini/Titan IV Acoustic Blanket Development and Testing," NASA-TM-107266, July 1996.
2. Hughes, W.O. and A.M. McNelis, "Acoustic Testing of the Cassini Spacecraft and Titan IV Payload Fairing, Part 1 – Introduction and Test Configuration," NASA-TM-107474, July 1997.
3. Hughes, W.O. and A.M. McNelis, "Acoustic Testing of the Cassini Spacecraft and Titan IV Payload Fairing, Part 2 – Results," NASA-TM-107475, July 1997.
4. Hughes, W.O., A.M. McNelis, and H. Himelblau, "Investigation of Acoustic Fields for the Cassini Spacecraft: Reverberant Versus Launch Environments," NASA/TM—2000-209387, September 2000.
5. McNelis, A.M., W.O. Hughes, and M.E. McNelis, "NASA Engineering and Safety Center (NESC) Enhanced Melamine (ML) Foam Acoustic Test (NEMFAT)," NASA/TM—2014-218162, February 2014.
6. Hughes, W.O., A.M. McNelis, and M.E. McNelis, "Acoustic Test Characterization of Melamine Foam for Usage in NASA's Payload Fairing Acoustic Attenuation Systems," NASA/TM—2014-218127, June 2014.
7. American Society for Testing and Materials, "Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method," ASTM C423-09a, October 15, 2009.
8. American Society for Testing and Materials, "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements," ASTM E90-09, July 1, 2009.
9. Cox, T.J. and P. D'Antonio, "Acoustic Absorbers and Diffusers," Taylor & Francis, New York, 2004, pp. 399–407.
10. Sauro, R., M. Vargas, and G. Mange, "Absorption coefficients-part 1: is square area enough?," INTER-NOISE 2009, Ottawa, Canada, August 23–26, 2009.
11. Sauro, R., M. Vargas, and G. Mange, "Absorption coefficients-part 2: is "edge effect" more important than expected?," INTER-NOISE 2009, Ottawa, Canada, August 23–26, 2009.