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FLAMMABILITY ASSESSMENT OF ACOUSTIC INSULATION MATERIALS USING MASS LOSS CALORIMETRY

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Abstract
Acoustic insulation materials are widely used across construction and industrial applications, primarily valued for their noise attenuation capabilities. However, their flammability characteristics are rarely evaluated despite their potential impact on fire safety. This study investigates the fire behavior of three representative sound-insulating materials through cone calorimetry, using a mass loss calorimeter under a constant radiant heat flux of 50 kW/m² in accordance with ISO 13927:2023. The tested samples, differing in thickness and structural rigidity (labeled as 10 mm soft, 4 mm hard, and 6 mm soft), exhibited notably high flammability metrics. Time to ignition ranged from 10 to 12 seconds, with peak heat release rates (HRR) exceeding 200 kW/m² in all cases and reaching a maximum of 275.6 kW/m² for the slimmest sample. Mass loss rates and total heat release values further confirmed the materials' low resistance to sustained combustion. The findings emphasize the need to incorporate flammability testing into routine evaluation protocols for acoustic materials, especially in contexts where fire exposure is a relevant hazard.

***Keywords**: acoustic insulation materials, flammability testing, heat release rate, mass loss calorimeter*

1. INTRODUCTION

Acoustic insulation products are widely deployed in buildings, vehicles, and industrial enclosures for noise control, yet their fire performance is often treated as secondary to acoustic and mechanical criteria. Historical incidents have shown that acoustic foams, especially those based on non-retarded polyurethane, can significantly accelerate early fire growth when exposed to ignition sources, emphasizing the need for systematic screening of such materials [1]. This oversight is particularly concerning given the proliferation of novel polymer and composite materials whose fire behavior is not well-documented.

The fire risk associated with these materials is multifaceted. Properties that can enhance acoustic performance, such as a low-density, can significantly contribute to fire hazard by increasing the surface-area-to-volume ratio and entrapping oxygen. This can potentially lead to rapid flame spread and high heat release rates. While fire standards and building codes exist, they often apply to well-defined material classes. A significant gap remains in the literature regarding the comprehensive flammability characterization of commercially available acoustic products, particularly when their exact chemical composition is not disclosed by manufacturers [2,3]. This lack of data makes it difficult for engineers and safety professionals to conduct accurate risk assessments.

This paper summarizes the results of flammability testing conducted on three acoustic insulation materials with good sound insulation performance but unknown composition, differing primarily in thickness and rigidity (10 mm soft, 6 mm soft, and 4 mm hard).

2. MATERIALS AND METHODS

Three black, rectangular acoustic materials of unknown chemical structure were supplied and cut to 100 mm × 100 mm specimens per ISO 13927 [4] requirements. The samples were labeled 10 mm soft, 6 mm soft, and 4 mm hard based on rigidity and measured thickness. Flammability testing was performed on a Mass Loss Calorimeter - MLC (Fire Testing Technology, UK) in accordance with ISO 13927:2023 at a nominal external heat flux of 50 kW m^{-2} with spark ignition. The apparatus uses a conical radiant heater with thermopile detector and integrated load cell. Exhaust ventilation and data acquisition followed the standard's prescriptions and whole installation is shown and explained in our previous work [5].

Time to ignition (t_{ign}), heat release rate HRR, mass loss rate MLR, and total heat released THR were recorded. Because ISO 13927 determines HRR via thermopile/mass-loss methods (rather than oxygen consumption), absolute HRR values can differ from ISO 5660 cone calorimeter results. However, the MLC provides decision-useful ranking and production control data, particularly for ignitability and mass loss driven HRR behavior.

3. RESULTS AND DISCUSSION

All three acoustic insulation specimens ignited rapidly under a radiant heat flux of 50 kW m^{-2}, with times to ignition in the narrow range of 10–12 s (Table 1).

Table 1. Summary of flammability metrics

Sample	DTT (s)	TTI (s)	pHRR (kW·m^{-2})	tHRR (s)	THR (MJ·m^{-2})	pMLR (g·s^{-1})	Mass loss (%)
10 mm soft	921	10	211.9	474	119.6	0.199	65.9
6 mm soft	489	10	228.1	257	66.3	0.187	66.9
4 mm hard	399	12	275.6	119	58.3	0.214	70.9

Legend: DT - duration of test; TTI - time to ignition; pHRR-peak heat release rate; tHRR-time to attain the PHRR; THR - total released heat; pMLR -peak mass loss rate

Even though their ignitability was similar, their burning patterns differed significantly (Figure 1).

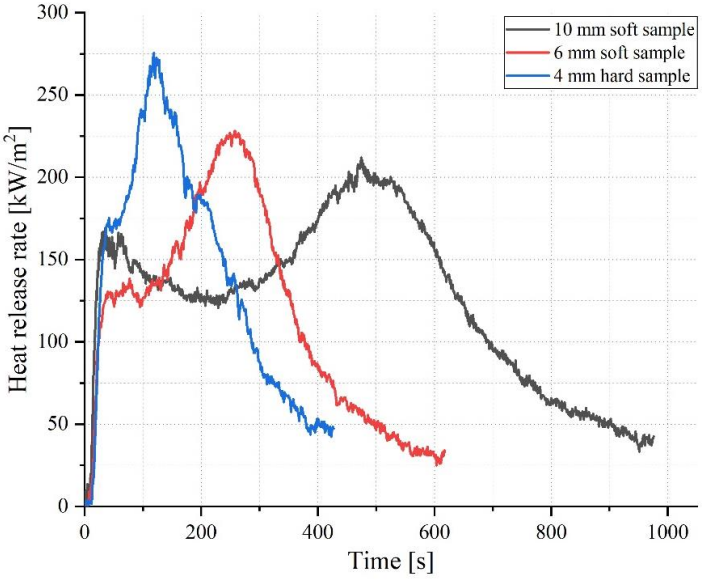

Figure 1. Comparison of heat release rate curves for different material types and thicknesses

The 4 mm hard specimen had the highest peak heat release rate (pHRR) of 275.6 kW m^{-2} and reached this maximum early (119 s). The 6 mm soft specimen produced an intermediate pHRR (228.1 kW m^{-2}) at a later time (257 s). The 10 mm soft specimen displayed the lowest pHRR (211.9 kW m^{-2}) with the most delayed and broadened maximum (474 s). These trends are consistent with the HRR time histories, where the thinnest sample exhibits a sharp release of energy, and the thicker samples burn more progressively.

The materials were further distinguished by their total energy output. The 10 mm soft specimen maintained flaming for the longest duration (app. 15 min) and yielded the largest total heat released (THR) (119.6 MJ m^{-2}), indicating a substantial overall fire load despite its comparatively modest peak intensity. In contrast, the 4 mm hard specimen burned out more quickly and produced a lower THR (58.3 MJ m^{-2}). The 6 mm soft specimen exhibited intermediate behavior in both duration and THR (66.3 MJ m^{-2}). The 4 mm hard specimen showed the highest peak mass-loss rate (0.214 g s^{-1}) and the largest percentage mass loss (70.9%). This behavior suggests an intense devolatilization phase and pronounced flaming during the initial stage of the test. The thicker 10 mm specimen lost mass more gradually over an extended period.

The highest peak heat release rate (pHRR), observed for the slimmest specimen (4 mm thick), can be attributed to the combined influence of two interrelated mechanisms. First, the low thermal inertia of the thinner material significantly reduces the amount of energy required to elevate the entire cross-section to pyrolysis temperatures. This promotes rapid thermal penetration, minimizing internal heat-sink effects and reducing the pre-heating and devolatilization stages. As a result, the mass-loss rate becomes highly concentrated in a shorter time frame, leading to a sharper and more intense HRR peak. Additionally, the surface-level dynamics of thin, rigid materials further reinforce this behavior. When volatile release occurs rapidly and uniformly across the surface, the proximity of the flame zone enhances radiative and convective heat feedback. This heat is efficiently returned to the material surface, accelerating further pyrolysis and establishing a positive thermal feedback loop. The synergy of these effects ultimately drives the HRR to its maximum value in a short span of time. By contrast, thicker specimens typically exhibit slower in-depth heat penetration, greater opportunity for transient char layer formation or structural swelling, and distributed volatile release over a longer time, all of which dampen peak HRR even if the total energy (THR) is larger, because more fuel is present.

The obtained results, in which the slimmest sample exhibited a high peak heat release rate (pHRR) over a short duration and the thicker samples produced a lower pHRR along with a greater total heat release (THR) over an extended period, are consistent with fundamental heat transfer principles and the pyrolysis behavior of materials with differing thermal thicknesses. From a practical perspective, these results indicate distinct fire-hazard profiles. The 4 mm hard material exhibits greater early-stage fire growth potential, which is particularly relevant to flashover propensity and sprinkler activation times. In contrast, the 10 mm soft material contributes a higher overall fire load, with implications for suppression demand and total energy release. The 6 mm soft material demonstrates an intermediate behavior, balancing between early fire growth potential and total fire load contribution. Selection and placement of such products should therefore consider both pHRR and THR, not just ignitability, particularly in enclosures or assemblies with known ignition sources.

4. CONCLUSION

Under a 50 kW m^{-2} radiant exposure, all three acoustic insulation materials ignited rapidly (10–12 s) and exhibited appreciable heat release. The 4 mm hard sample produced the highest peak HRR (275.6 kW m^{-2}) and the highest peak MLR (0.214 g s^{-1}), indicating the most severe early-stage fire growth potential. The 10 mm soft sample yielded the largest THR (119.6 MJ m^{-2}) and the longest burning duration (cca.15 min), implying a larger overall fire load. The 6 mm soft sample fell between these extremes. These findings support the view that flammability screening of acoustic insulation should complement acoustic/mechanical qualification, particularly in enclosures or wall/ceiling assemblies where ignition sources are credible. For design-level decision-making, supplemental ISO 5660 cone calorimetry is advisable to obtain oxygen-consumption HRR data.

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