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EXPLORATION OF ACOUSTIC APPLICATIONS OF AIR-INFLATED LATEX BALLOONS BEYOND IMPULSIVE SOURCES FOR REVERBERATION TIME MEASUREMENT

Giovanni Amadasi[1], Antonella Bevilacqua[2], Gino Iannace[3], Amelia Trematerra[3]

[1] *SCS-ControlSys—Vibro-Acoustic, Padova, Italy*
[2]*Department of Architecture and Engineering, University of Parma, Area delle Scienze, Parma, Italy*
[3]*Department of Architecture and Industrial Design, University of Campania "L. Vanvitelli", Aversa, Italy*

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Abstract

Air-filled balloons are commonly used for party celebrations and, in acoustics, as simple impulsive sources when burst for measuring sound decay in rooms. However, their potential applications in other acoustic fields, particularly as sound-absorbing elements, have not yet been extensively investigated. This paper examines the sound absorption performance of air-inflated latex balloons. Acoustic measurements were carried out on air-inflated latex balloons with a diameter of 100 mm, arranged either as single or double layers. Two measurement methods were compared: results obtained using the impedance tube and those measured in a reverberation chamber. The results show that the absorption coefficients obtained from the reverberation chamber and impedance tube are qualitatively similar trends. This research suggests that such configurations could be applied as rapid, low-cost mitigation measures in temporary installations or spaces where permanent acoustic treatments are not feasible.

Keywords: *AIR-INFLATED LATEX BALLOONS, REVERBERATION TIME, IMPEDANCE TUBE, ABSORPTION COEFFICIENT.*

1. Introduction

Good acoustics within a space are achieved through an appropriate balance between reflective surfaces, typically the standard boundaries of a room (e.g. glazed windows, plastered walls) [1, 2], and sound-absorbing materials (e.g. acoustic panels, soft furnishings). This balance is essential for controlling reverberation, thereby making the space suitable for its intended acoustic functions, as indicated by reference curves based on room volume. When this balance is not achieved, acoustic treatment becomes necessary to bring other parameters, such as speech intelligibility and clarity [3], within optimal ranges. Common materials used for acoustic correction include sound-absorbing panels [4], resonant systems [5, 6], and more recent innovations such as sustainable acoustic tiles [7]. Even in ancient times, the acoustics of theatres were enhanced through invisible interventions [8], such as resonant vases placed beneath the steps of the cavea, which amplified specific frequencies according to their dimensions [9]. Churches represent another challenging case, where the requirements for speech intelligibility during sermons and for choral music are often in conflict [10]. As a result, achieving an optimal compromise across a broad range of acoustic parameters can be difficult. While early experiments by C. W. Sabine involved simple interventions, such as placing cushions within a room to measure changes in reverberation, modern solutions are far more advanced [11, 12]. These developments have been enabled by innovations in metamaterials and technologically advanced polymers, which can be tailored to meet a variety of acoustic requirements. This research study investigates the sound absorption properties of standard latex air-filled balloons. The focus on this common material arises from its ease of preparation and placement within a room. Typically, such balloons are used in acoustics as mechanical impulsive sources when they burst [13, 14]. For this reason, their acoustic absorption properties have not been widely documented in previous literature [15, 16]. The study of air-inflated balloons for sound absorption could be used indoors for temporary installations or for specific artistic or architectural purposes. In the present study, the balloons, both individually and when one was inserted into another, were inflated to a pressure of 20 mmHg (2.7 kPa). To measure the pressure inside balloons, a manometer derived from a medical sphygmomanometer was used.

2. Methodology for measuring the absorption coefficients of a material

Different techniques have been developed to measure the sound absorption coefficient of materials [17]. Among them, the most common, also regulated by standards, are the following:

- Impedance tube, also known as Kundt's tube.
- Reverberation chamber.

Corresponding author: *gino.iannace@unicampania.it*

The Kundt's tube (or impedance tube) method is a laboratory technique used to measure the sound absorption coefficient and acoustic impedance of materials under controlled conditions. It operates by generating plane soundwaves, typically using an equalized pink noise signal, from a loudspeaker at one end of a rigid tube. These waves travel down the tube and strike the test sample at normal incidence, while two microphones placed along the tube record pressure variations to determine the material's acoustic response, in accordance with the standard EN ISO 10534-2. Figure 1 illustrates the scheme.

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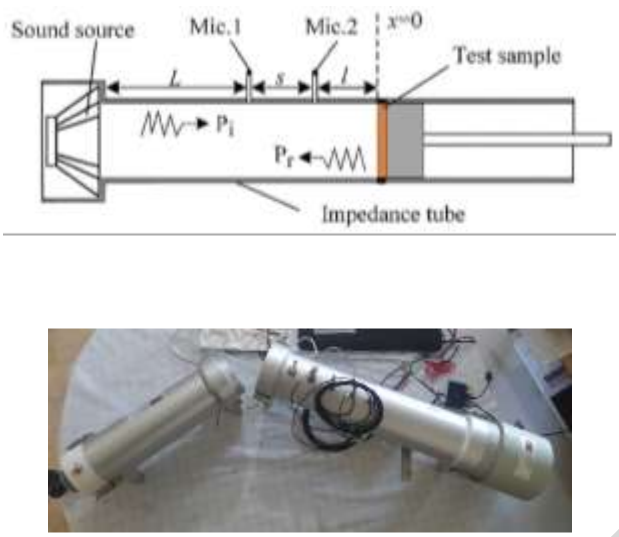

Figure 1. Impedance tube.

The second method uses the reverberation chamber, and measures the reverberation time difference between the reverberation times measured in the empty room and in the room containing the material to be tested [16]. Once the average reverberation times (with and without sample) have been determined, the equivalent absorption area of the material (in square meters) is calculated.

3. Measurement sets

Based on two different methods, two sets of acoustic measurements were carried out:

- Measurements using the impedance tube.
- Measurements in a reverberation chamber.

The samples considered during the measurements consisted of air-inflated latex balloons with a diameter of 100 mm [17]. Each balloon was tested either as a single layer or as a double layer, where one balloon was inflated inside another; in the latter case, the external balloon remained unsealed at the neck.

3.1 Measurements with Impedance Tube

The two types of balloons (single- and double-layer) were tested in the impedance tube both as single elements and as paired elements arranged in series (one after the other) within the tube.

3.2 Measurements in a Reverberation Chamber

For the tests carried out in the reverberation chamber, the balloons were placed on the floor, covering a surface area of 5 m². The reverberation chamber has dimensions of 10 × 7.0 × 3.0 m, with a volume of 210 m³. Figure 2 shows the arrangement of the balloons on the floor during the acoustic tests. The walls and ceiling of the chamber are smooth plaster, and the floor is tiled with stoneware. This configuration provides a sufficiently long reverberation time. The surface area occupied by the balloons, 5 m², is limited compared to the standard allowance, but this choice is due to the large number of balloons in use (approximately over 100) for each configuration. The floor area occupied by the balloons was marked off with vertical boards, ensuring a clear, visible surface. The area covered by the balloons was delimited with vertically arranged boards, so as to limit the effects of lateral absorption and have the effects of absorption on the visible surface. Figure 2 shows the image of air-inflated balloons arranged on the floor within a confined surface area during acoustic testing in the reverberation chamber. The air pressure inside the balloons was 20 mmHg. This measurement was obtained using a manometer derived from a medical sphygmomanometer. The sound source is of the impulsive type, placed in three different positions; the microphone is positioned in six different points. Once the measurement is completed, the reverberation time of the room in each frequency band is expressed by the arithmetic mean of the total number of reverberation times measured. The mean reverberation time of the empty chamber is denoted by T1, whereas T2 represents the mean reverberation time measured with the test specimen installed. Once the average reverberation times have been evaluated, the equivalent absorption area of the material in square meters is calculated using the following formula, c1 and c2 are the speed of sound propagation in air; c2. V is the volume of the room (m³):

$$A_T = A_2 - A_1 = 55{,}3 \cdot V \cdot \left(\frac{1}{c_2 T_2} - \frac{1}{c_1 T_1}\right) \cdot$$

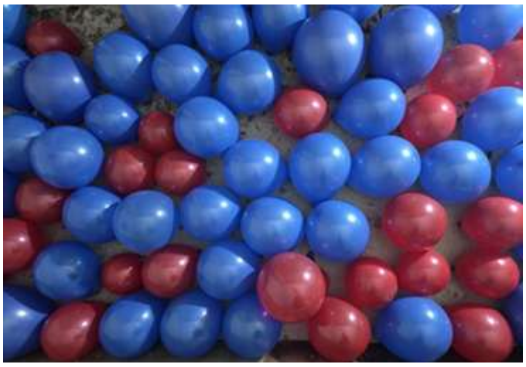

Figure 2. View of air-inflated balloons arranged on the floor within a confined surface area during acoustic testing in the reverberation chamber.

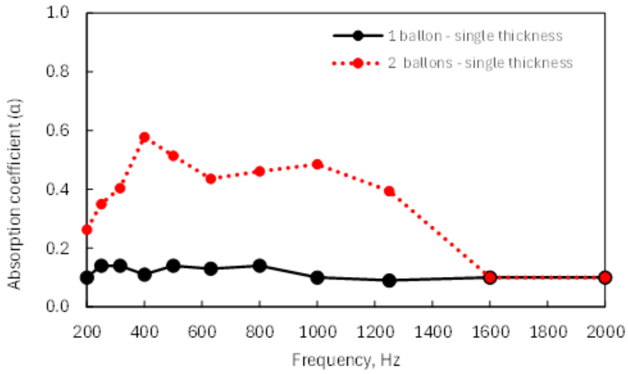

Figure 4. Normal-incidence sound absorption coefficients measured for one and two single-layer balloon specimens arranged in series

4. Results

Figure 3 to 7 show the measured results obtained using different methodologies and test samples: impedance tube and reverberation chamber. Two balloon configurations are considered: single balloons and double-layer balloons. Double-layer balloons are obtained by inserting one balloon into the other and then inflating it, creating a double-skin surface and analyzing the acoustic behavior of this configuration.

4.1 Measurements with Impedance Tube

Figure 4 shows that, when using a single-layer balloon in the impedance tube, an absorption coefficient of approximately 0.1 is obtained with a single element, whereas a higher value of around 0.5 is achieved when two balloons are tested in series within the tube. The difference between the two configurations is particularly evident at low frequencies, up to 1500 Hz, while above 1600 Hz the results become comparable. Figure 3 shows the two measurement configurations: (a) a single balloon in the tube, on a rigid wall; (b) two balloons arranged in series, one on a rigid wall and the other towards the source in the tube.

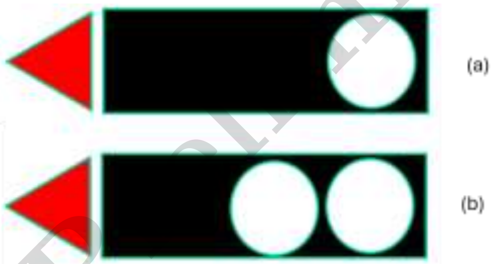

Figure 3. Measurement configurations inside impedance tube: (a) a single balloon in the tube; (b) two balloons arranged in series.

The configuration with balloons inserted one inside the other was analysed, in order to have a double-layer configuration. Figure 5 shows the two measurement configurations: (a) a single balloon in the impedance tube, on a rigid wall; (b) two balloons arranged in series, one on a rigid wall and the other towards the sound source in the impedance tube. Figure 6 shows the sound absorption values with two balloons (inflated one inside the other to create a double skin). In this configuration, there is a significant increase of the sound absorption. With a single element, the sound absorption coefficient is approximately 0.3 between 500 Hz and 1100 Hz, decreasing to around 0.1 at higher frequencies. When two elements are arranged in series, inside the impedance tube, the results are slightly higher at low frequencies (around 0.4), but significantly higher at mid–high frequencies, reaching values of approximately 0.6 between 800 Hz and 1800 Hz.

4.2 Measurements in Reverberation Chamber

For the reverberation chamber measurements, the results are presented in Figure 7. It can be observed that the data obtained for a single thickness are consistent with those measured using the impedance tube. Similarly, the results for the double-thickness configuration closely match those from the impedance tube tests. This agreement indicates that, provided equivalent samples are accurately reproduced, both measurement methods yield comparable results.

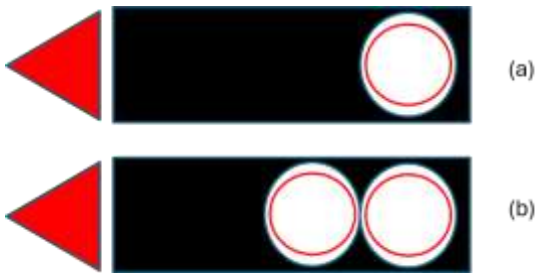

Figure 5. Measurement configurations inside impedance tube: (a) a single balloon in the tube; (b) two balloons arranged in series.

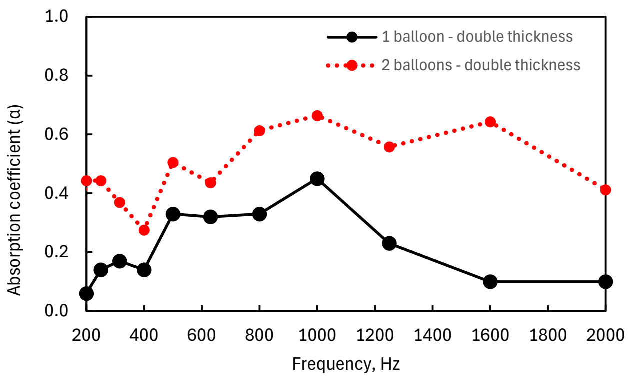

Figure 6. Normal-incidence sound absorption coefficients measured for one and two double-layer balloon specimens arranged in series

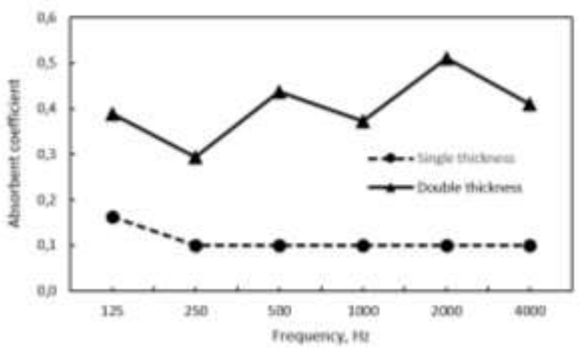

Figure 7. Sound absorption coefficients of the balloons inside the reverberation chamber, single and double thickness.

5. Conclusions

Air-filled balloons are commonly used for party celebrations and, in acoustics, as simple impulsive sources when burst for measuring sound decay in rooms. Due to their classification as tensioned latex membrane systems, they can serve a dual purpose: providing acoustic correction while acting as decorative elements. Considering this, the present study investigates the sound absorption properties of air-inflated latex balloons for temporary or removable installations, particularly in contexts where permanent acoustic treatment is not allowed. The air pressure inside the balloons was 20 mmHg (2.7 kPa). This measurement was obtained using a manometer derived from a medical sphygmomanometer. Measurements were conducted using two methods: the impedance tube for normal-incidence sound absorption and the reverberation chamber method, comparing reverberation times with and without the test material. The samples consisted of balloons inflated up to 100 mm, either as a single layer or placed within another balloon left unsealed at its neck. The measurements obtained using the two methods show broadly similar trends, particularly the improvement associated with the double-membrane configuration. However, direct quantitative agreement should not be expected because the impedance tube and reverberation chamber represent different sound-incidence conditions. From a practical standpoint, air-inflated balloons are not recyclable and thus cannot be considered environmentally friendly. Based on the measured values, the performance may be considered broadly comparable to that of a Class D absorber. However, because the tested specimen area was smaller than that prescribed by ISO 354, this classification should be regarded as indicative rather than as a formal product rating [17]. Latex balloons are significantly cheaper than conventional acoustic panels with similar properties. Measurements in a reverberation chamber and measurements performed with impedance tubes have shown that the double-balloon configuration, i.e., one balloon inserted inside another, increases the sound absorption coefficient. The improvement may be attributed to additional energy dissipation caused by friction and relative motion between the two latex membranes. Owing to their very low cost, such configurations could represent a practical temporary solution for improving acoustics in venues where permanent treatments are not feasible.

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References

[1] U. Berardi, A. Bevilacqua, N. Chiacchio, G. Iannace, A. Trematerra. "From sport to science: the acoustics of a pool transformed into an auditorium". 51st International Congress and Exposition on Noise Control Engineering (INTERNOISE), Glasgow, UK, 21-24 August 2022.

[2] G. Iannace, A. Bevilacqua, A. Trematerra, G. Amadasi. "Acoustic characteristics of an hydroponic material". Proceedings of Forum Acusticum Euronoise, Malaga, Spain, 23-26 June 2025.

[3] A. Bevilacqua, G. Amadasi, G. Iannace, A. Trematerra. "Acoustic Simulations Applied to the Garden of Rufolo's Villa in Ravello: Comparison between Different Scenarios". Appl. Sci., 14, 1223, 2024. https://doi.org/10.3390/app14031223.

[4] A. Trematerra, A. Bevilacqua, G. Iannace. "Noise Control in Air Mechanical Ventilation Systems with Three-Dimensional Metamaterials". Appl. Sci., 13, 1650, 2023. https://doi.org/10.3390/app13031650.

[5] A. Bevilacqua, G. Iannace, I. Lombardi, A. Trematerra. "2D Sonic Acoustic Barrier Composed of Multiple Row Cylindrical Scatterers: Analysis with 1:10 Scaled Wooden Models. Appl. Sci., 12, 6302, 2022. https://doi.org/10.3390/app12136302.

[6] G. Iannace, A. Bevilacqua, A. Trematerra, G. Amadasi. "Sound Absorption of Hydroponically Grown Plants. Acoustics, 7, 24, 2025. https://doi.org/10.3390/acoustics7020024.

[7] A. Bevilacqua, G. Iannace, F. Giuri, I. Ferrari. "Through the history of the acoustic response within the theatre of Taormina: From Greek and Roman periods to our

days". Building Acoustics, 31(4), pp. 469–484, 2024. /doi.org/10.1177/1351010X241290060.

[8] A. Bellia, A. Bevilacqua. "Rediscovering the Intangible Heritage of Past Performative Spaces: Interaction between Acoustics, Performance, and Architecture. Heritage, 2023, 6, 319–332. https://doi.org/10.3390/heritage6010016.

[9] G. Iannace G., Ciaburro, M. Abeti, M. "The acoustics of the church of the holy family in Salerno (Italy)", In Proc. of. 18th Conference on Applied Mathematics, APLIMAT, 1, pp. 539–551, 2019.

[10] A. Trematerra, G. Ciaburro, G., Iannace, "The effects of the sound box choir stalls on the acoustics of the church of the Certosa of San Martino in Naples", In Proc. of 18th Conference on Applied Mathematics, APLIMAT, 2, pp. 1198–1209, 2019.

[11] A. Bevilacqua, S. Sukaj, G. Iannace. "The acoustic importance of velaria in Roman amphitheaters: Investigations on the effects of different coverage percentages in Durres and Capua". Building Acoustics, 31(4), pp. 377–398, 2024. https://doi.org/10.1177/1351010X241270235.

[12] G. Iannace, G. Amadasi, A. Bevilacqua, M. Cairoli, A. Trematerra. "Resonant Acoustic Metamaterials". Appl. Sci., 14, 5080, 2024. https://doi.org/10.3390/app14125080.

[13] L. Gomez-Agustina, A. Bevilacqua, P. Vazquez-Barrera. "Noise exposure and auditory risk from air-filled balloon bursts". Applied Acoustics, 232, 110568, 2025. https://doi.org/10.1016/j.apacoust.2025.110568.

[14] A. Bevilacqua, S. Dance. "Acoustic evolution and new performative analysis of the Royal Festival Hall". Building Acoustics, 2026, DOI: 10.1177/1351010X261421483.

[15] A. Trematerra, S. Sukaj, G. Amadasi. "Sound absorption measurements of air-filled latex balloons". Proceedings of the I3DA Conference: from Architecture to Automotive, Bologna, Italy, 10-12 September 2025.

[16] A. Bevilacqua, G. Iannace, E. Navarra, N. Manzo, L. Gomez-Agustina. "New Acoustic Design for the Piscina Mirabilis Located nearby the Port of Misenum". Heritage, 7, pp. 4423–4439, 2024. https://doi.org/10.3390/heritage7080208.

[17] ISO 354:2003. Acoustics — Measurement of sound absorption in a reverberation room.