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THE MEASUREMENT OF THE SOUND ABSORPTION OF AN ARRAY OF BAFFLES

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ABSTRACT

ASTM E795-23 specifies a Type J mounting WITHOUT A SURROUND for the measurement of the sound absorption of sound-absorbing units and requires that the measured sound absorption be reported. ISO 354:2003(E) specifies a Type J mounting WITH A SURROUND for the measurement of the sound absorption per unit of rectangular unit sound absorber pads or baffles. ISO 354:2003(E) also says that for a specified array of objects, the result is given as the sound absorption coefficient, and that in the case of a test specimen WITH A SURROUND, it is the area enclosed by the surround that is used. However, ISO 354:2003(E) also allows an array of objects to be measured WITHOUT A SURROUND and requires the sound absorption coefficient to be reported using the area covered by the test specimen. A baffle array could be regarded as being in a Type A mounting without covered edges. ISO 354:2003(E) says that if the edges are not covered, the area of the edges shall be included in calculating the test specimen area. Consultants want sound absorption coefficients so that they can enter in their ray tracing programs. The existence of different ways of measuring and/or reporting sound absorption is unacceptable.

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1. INTRODUCTION

There appear to be a number of different ways in the current version of ISO 354:2003(E) [1] that the sound absorption of an array of baffles can be reported. 6.2.2.1 says "Rectangular unit sound absorber pads or baffles shall be installed in a Type J mounting as specified in Annex B." B.7 Type J mounting says "This mounting shall be used for the general specification of the sound absorption per unit of rectangular unit sound absorber pads or baffles." This means that the sound absorption per individual baffle and not the sound absorption coefficient needs to be reported. B.7 Type J mounting allows for the use of two different measurement methods, which are the well approach where “the height of the barrier shall be the same as the height of the baffles or pads”, and the deep well approach where “the barrier shall be 0,8 m higher than the baffles or pads, but the height of the barrier shall not exceed half of the height of the reverberation room”. It also says that “one or two walls of the reverberation room may be used as part of the barrier. This will probably lead to more possible different measurement results.
8.1.4 Calculation of equivalent sound absorption area of discrete absorbers says "For a specified array of objects, the result is given as the sound absorption coefficient." Thus, if the array of baffles is treated as a specified array of objects, the sound absorption coefficient needs to be reported. 3.8 Area of the test specimen NOTE 2 says "In the case of a test specimen surrounded by a structure (type E mounting or

type J mounting), it is the area enclosed by the structure." Thus, the floor area enclosed by the structure is used if an enclosure is used.

Baffle arrays are becoming much more complicated than was envisaged when the type J mounting in ISO 354:2003(E) [1] was written, as is shown in Figure 1 and Figure 2.

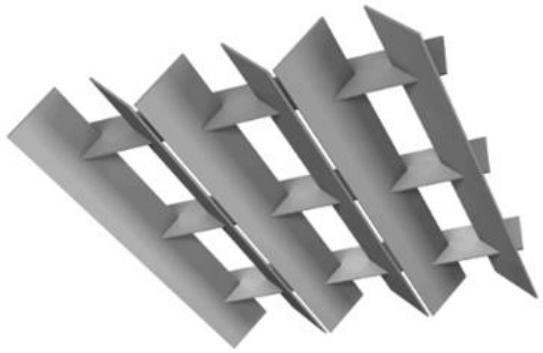

Figure 1. A baffle array with some baffles which are not vertical or horizontal, more than 3 rows of baffles in a measurement size specimen, and baffles running in two perpendicular directions.

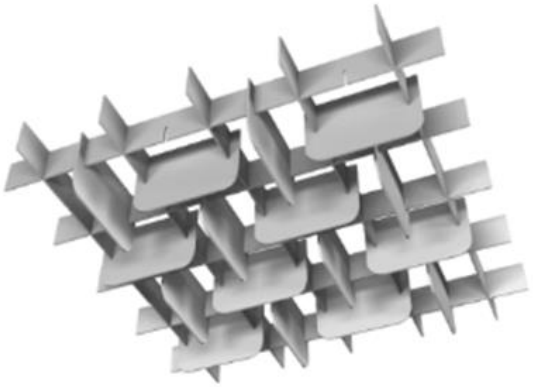

Figure 2. A baffle array with some baffles which are not continuous in their long dimension, more than 3 rows of baffles in a measurement size specimen, and baffles running in two perpendicular directions.

However, because 6.2.2.1 and B.7 Type J mounting only cover rectangular unit sound absorber pads or baffles where "The baffles shall be arranged in two or three parallel rows." most baffle arrays are probably not be covered by the type J mounting because there will usually be more than 2 or 3 parallel rows of baffles, and the baffles may not be rectangular or mounted vertically. In that case the baffle array should probably be tested without an enclosure as a specified array and the sound absorption coefficient should be reported as required by 8.1.4. 8.1.3 says that the area to be used for the calculation of the sound absorption coefficient "is the area, in square metres, covered by the test specimen (see 3.8)." Thus, just the covered floor area is used, and the area of the uncovered sides of the baffle array is not included.

Alternatively, the baffle array could be regarded as being in a Type A mounting without covered edges. B.2 Type A mounting says "If the edges of the test specimen are exposed when the material is normally installed in an actual application, then the edges of the test specimen shall not be sealed or covered during a test. If the edges are not covered, the area of the edges shall be included in calculating the test specimen area." In this case, the areas of sides as well as the area of the top of the cuboid containing the baffle array are used to calculate the sound absorption coefficient.

This possibility in ISO 354:2003(E) [1] to report the sound absorption of a baffle array in many ways is totally unacceptable. Examples of some of the possible different sound absorption coefficients are given later in this paper in Figure 5 and Figure 6 where the sound absorption coefficients differ by up to 0.45.

The Type J Mounting of ASTM E795-23 [2] does not surround the specimens with an enclosing non-absorptive barrier and its Note 13 says “The measured sound absorption is in square metres per unit.” This is because in the absence of an enclosing barrier to define the area, the use of a sound absorption coefficient is completely inappropriate. It is unfortunate that ISO 354:2003(E) [1] used the same Type J mounting name as ASTM E795-23 [2] when specifying a mounting type with a surrounding enclosure when the ASTM E795 Type J mounting is without a surrounding enclosure.

If Sabine’s equation is used, only the sound absorption added to the room by the arrays of baffles is needed. These days, most acoustic consultants use ray tracing programs for which they need the sound absorption coefficient. Also, it is difficult for measurement laboratories to have surrounds with many different lengths, widths and heights to cope with baffle arrays of different lengths, widths and heights. This has led to suppliers of baffle arrays having measurements made without a surround and quoting sound absorption coefficients calculated using only the area of the smallest rectangle covering or enveloping the projection on the nearest room surface of the installed baffle set. The authors of this paper are aware of sound absorption coefficients as high as 1.7 being advertised. This is much greater than the maximum that the edge effect could account for. Because the supplier would not release the

confidential test report, it was impossible to know the area of baffle arrays that had been tested and use that area to back calculate the sound absorption from the advertised sound absorption coefficient to calculate a more realistic sound absorption coefficient. In one case, a supplier advertised practical sound absorption coefficients which were greater than one, in contravention of ISO 11654:1997 [3].

Another complication when considering the best way to report the sound absorption of arrays of baffles, is that they may be installed in different ways. In a meeting room, only one or several baffle arrays may be installed, whereas in a factory or other large space, a large continuous area of baffle arrays may be installed. For a large area installation of baffle arrays, it is more appropriate to measure with a non-sound absorbing surround, because the reflections from the inside surface area of the surround simulate an infinite periodic array in two dimensions of the specimen inside the surround. However, if the installation area is small and the sides of the specimen volume and any airgap are not covered, testing without a non-sound absorbing surround may be more appropriate. If the sound absorption coefficients of the sides and the back side of the specimen volume are very different from the sound absorption coefficient of the front side of the specimen volume, then testing with a non-sound absorbing surround is probably more appropriate.

2. PROPOSED CHANGES TO ISO 354

ISO 354 should state that its primary measurement result is the amount of sound absorption added to the reverberation room by the addition of the specimen minus the sound absorption of any reverberation room surface area that the specimen covers (which is usually considered not to be significantly different from zero). It should require that the sound absorption in square metres be reported for all specimens.

3.8 of ISO 354 which defines the area of the test specimen as the “area of the floor or wall covered by the test specimen” needs to be changed. If a sound absorption coefficient is calculated, ISO 354 should require that any sound which hits the specimen must pass through an imaginary surface whose surface area is the area which is used to calculate the sound absorption coefficient. It should require that, as far as possible, any sound which passes through this imaginary surface hits the specimen, that this imaginary surface, possibly together with part of the room surface and the surface of any surrounding non-absorptive enclosure, encloses a relatively simple volume, and that the area of this imaginary surface is minimized. This enclosing simple volume would normally be expected to be a cuboid or occasionally a cylinder.

If the specimen consists of an array of elements separated by air gaps, the specimen shall consist of the smallest relatively simple volume which enclosures the array of elements. Again, this specimen volume would normally be expected to be a cuboid. This means that the specimen volume will be contained in, and maybe equal to, the enclosing volume used to determine the surface area to be used when calculating the sound absorption coefficient.

If the specimen consists of an array of elements which are placed periodically in a direction with a spacing of d, the specimen volume shall be extended by $d/2$ at each end of the specimen, as shown in Figures B.1 and B.2 of ISO 354:2003(E) [1]. This is because when larger areas of the specimen are installed, the periodic spacing of d would normally be continued in that direction. This extension could apply in two right-angled directions. This would be the case with the Type JV and JH mountings in ASTM E795-23 [2].

For a specimen which has an air gap between it and the room surface from which it is mounted, the enclosing volume will be the extension of the specimen volume to the room surface if the area of the surface of the enclosing volume, excluding the area of the surface of the enclosing volume which is a room surface, is smaller than the surface area of the specimen volume. Otherwise, the enclosing volume will be the specimen volume, and the specimen will be regarded as mounted in free space away from the room surface.

If the specimen volume is a cuboid whose length and width are L and W respectively, the area of the bottom surface of the specimen volume is LW. If the air gap has height H, the area of the skirt around it between the room surface and the specimen volume is $2H(L+W)$. Thus, the enclosing volume is the specimen volume if $H \geq LW/(2(L+W))$. For a specimen volume whose bottom is a square, the enclosing volume is the specimen volume if the height of the air gap is greater than or equal to one quarter of the length of the sides of the square. For a typical ISO 354:2003 specimen size of 3 by 3.6 m, the enclosing volume is the specimen volume if the height of the air gap is greater than or equal to 0.818 m. For a typical ASTM 423-22 [4] specimen size of 2.44 by 2.74 m, the enclosing volume is the specimen volume if the height of the air gap is greater than or equal to 0.645 m.

If a sound absorption coefficient is reported, the area used to calculate the sound absorption coefficient, and the surface used to calculate this area must both be reported.

For type A with a surround, Type B, Type E, Type G with a surround, Type I, and Type J mountings, the above

proposed rules mean that the area used to calculate the sound absorption coefficient is the area of the open top of the non-absorbing surround, as would be expected. For Type A and type G mountings without a surround, the above proposed rules mean that the area of the sides of the specimen volume and if an air gap exists, the area of sides of the air gap, or the area of the bottom of the specimen volume, are also included in the area used to calculate the sound absorption coefficient.

For individual objects which are “arranged randomly, spaced at least 2 m apart” and “mounted at least 1 m from any boundary or room diffusers and at least 1 m from any microphone”, the area of the surface of an enclosing volume should be calculated for each object.

The above proposed rules remove the problematic 8.1.3 which says that the area to be used for the calculation of the sound absorption coefficient "is the area, in square metres, covered by the test specimen (see 3.8)." They also remove the troublesome second sentence of 8.1.4 which says “For a specified array of objects, the result is given as the sound absorption coefficient” because the calculation of a sound absorption coefficient is optional. The proposed rules allow the basic type J mounting to be used for more general items than just two or three rows of rectangular unit sound absorber pads or baffles. In particular, the type J mounting could be used for baffle arrays or theatre seats. The proposed rules also cover functional sound absorbers because they require the sound absorption to always be reported.

In the field, the measured sound absorption coefficient should be applied to the surface calculated using the above proposed rules. This means that the effect of any uncovered sides becomes smaller as the area of the installation increases.

If non-absorbing enclosures are used, it is suggested that the enclosure be allowed to be between 0 and 12.5 mm higher than the object(s) that are being tested for practical reasons. This would enable the stacking of enclosure elements with heights of 12.5, 25, 50, 100, 200, 400 and 800 mm. It is suggested that for each enclosure element height, the enclosure elements consist of two 4.2 m lengths and two 3.6 m lengths so that they can be arranged by adjusting the junction overhangs at all 4 corners to enclose a rectangular area of any size complying with the area and aspect ratio specimen requirements of ISO 354. The areal density of the enclosure should be greater than 5 kg/m^2. The enclosure should not be constructed of gypsum plaster board.

The Type J mounting currently allows one or two of the room walls to be part of the non-absorbing enclosure. It is recommended that this no longer be allowed and that the non-absorbing enclosure be required to be away from all room surfaces except for the room surface that the non-absorbing enclosure is installed on. An exception to this rule would be for full length curtains or drapes and for absorbers that are to be mounted at room edges and corners.

The deep well approach [5] in the Type J mounting is designed to remove the edge effect. However, its use only with the Type J mounting is inconsistent with other mountings. It is recommended that its use be removed from ISO 354.

3. WITH AND WITHOUT AN ENCLOSURE

The sound absorption coefficients of two baffle arrays were measured with (Figure 3) and without (Figure 4) a surrounding enclosure.

Figure 3. The baffle array with 100 mm spacing with a surrounding enclosure.

Both baffle arrays were constructed from the same 12 mm thick polyester material with a density of 192 kg/m^3. The main vertical baffles were 300 mm deep and 3.6 m (2.4 and 1.2 m) long and were held in place by six 80 mm deep and 3 m (1.8 and 1.2 m) cross vertical baffles of the same 12 mm thick material between the floor of the reverberation room and the main baffles. 20 mm deep notches were cut into both types of baffles so that the main baffles and the support baffles could be interlocked together over a depth of 40 mm. This meant that the height of the baffle array was 340 mm.

In the first baffle array the centre planes of the main baffles were 200 mm (200) apart and in the second baffle array the centre planes of the main baffles were 100 mm (100) apart. The support baffle arrays extended half of the main baffle spacing beyond the centre planes of the main baffles at each end of the array. This was done to comply with the

requirement to have half of the main baffle spacing beyond the centre planes of the two outer baffles in the Type J mounting in ISO354:2003(E) [1]. Measurements were made with a 340 mm high non-absorbing surrounding enclosure (Yes) and without this enclosure (No). The enclosure consisted of 32 mm thick 300 mm high medium density fibreboard (MDF) with 1 mm thick 40 mm high steel on top. For the enclosure case, the sound absorption coefficients were calculated using the area of the top surface (Top) of the specimen volume (10.8 m^2). For the no enclosure case, the sound absorption coefficients were calculated using the area of the top surface (Top) of the specimen volume (10.8 m^2) and the area the top and side surfaces (Top+Sides) of the enclosing volume (15.288 m^2).The calculated sound absorption coefficients are shown in Figure 5 and Figure 6.

Figure 4. The baffle array with 100 mm spacing without a surrounding enclosure.

Above 200 Hz, the sound absorption coefficients calculated from the measurements made without a non-absorbing surrounding enclosure using the area of the top and sides of the enclosing volume are closer to those calculated from the measurements made with a non-absorbing surrounding enclosure using the area of the opening at the top of the enclosure, than those made using only the area of the top of the enclosing volume. This is a strong justification for adopting the changes to ISO 354:2003(E) [1] recommended in this paper.

However, there are still differences between sound absorption coefficients calculated with and without a non-absorbing surrounding enclosure. It is suggested that ISO:354 should recommend that sound absorption coefficients should normally be calculated from measurements made with a non-absorbing surrounding enclosure, unless there are very good reasons for measuring without a non-absorbing surrounding enclosure. If sound absorption coefficients are reported, it is further recommended that different names be given to sound absorption coefficients calculated using measurements made with or without a non-absorbing enclosure.

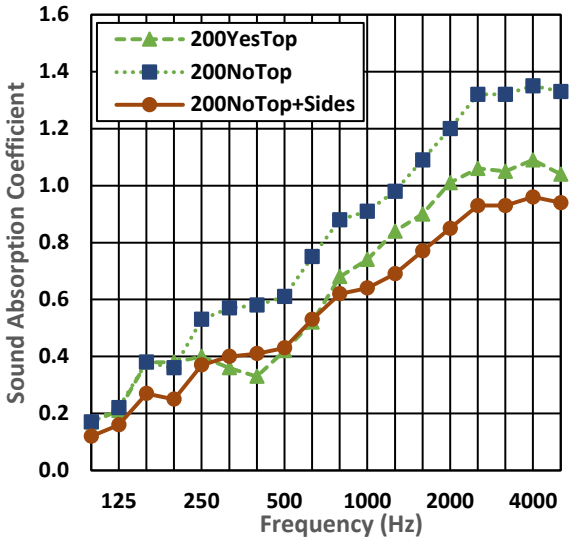

Figure 5. The calculated sound absorption coefficients of the baffle array with 200 mm spacing.

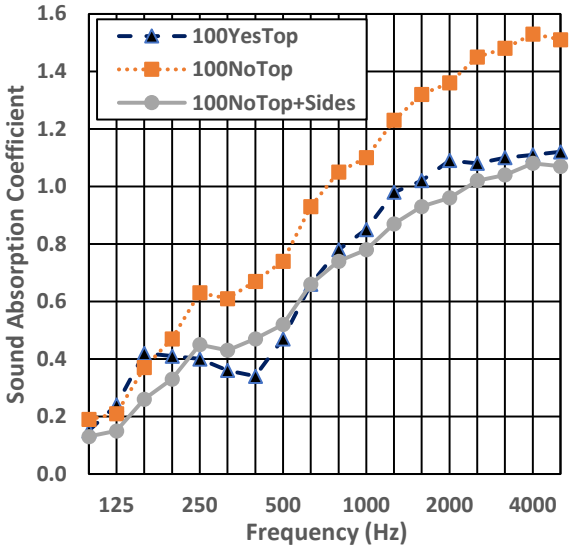

Figure 6. The calculated sound absorption coefficients of the baffle array with 100 mm spacing.

4. CONCLUSION

It is recommended that sound absorption be the fundamental result that is required to be given in ISO 354 reports. If sound absorption coefficients are reported, it is recommended that ISO 354 requires that they be calculated using the rules given in this paper. It is also recommended that different symbols be used for sound absorption coefficients calculated using measurements made with (α_e) or without (α_{ne}) a non-absorbing enclosure and that sound absorption coefficients calculated from measurements made with a non-absorbing enclosure are the preferred ones. These recommendations are made to stop suppliers advertising sound absorption coefficients as high as 1.7.
It is recommended that the room surfaces are not allowed to be part of a non-absorbing enclosure and that, in most circumstances, the only room surface close to a non-absorbing enclosure is the room surface that it is mounted on. It is recommended that the deep well approach be removed from ISO 354 for consistency.

5. REFERENCES

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