# ACOUSTIC CLASSIFICATION SCHEME FOR CONFIGURABLE PODS

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## 1 INTRODUCTION

Meeting pods are everywhere. Over the past 4 or 5 years they have grown in popularity from the occasional one-person phone booth up to modular and relocatable rooms that can accommodate up to 20 people. The idea is to have alternatives to fixed meeting rooms that can be located in the centre of an office or meet a future need for flexibility. The trend for their use has been boosted post-COVID with workers tending to attend offices to meet with other people, not just to ‘work’.

This paper discusses the need, and methodology, for a new classification scheme of meeting pods, of all shapes and sizes.

The scheme concentrates solely on sound reduction. Most pods are well treated with sound absorption, with negligible reverberation time internally, so this was not considered necessary to assess. Another element is the ventilation, and how much noise is produced by fans; however, this was also discounted from the scheme due to there already being well-established methods for measuring fan noise levels. Both elements can be experienced representatively in a showroom environment by a client, unlike sound reduction.

## 2 CONTEXT AND THE NEED FOR A SCHEME

### 2.1 Speech privacy and communication in offices

Prior to the 1940s, office workers tended to have their own cellular spaces. With the advent of Bűrolandschaft[1] in the 1950s the movement began to take down walls and open plan was born. This brought significant economies in construction and desk densities, also having benefits of allowing natural light to permeate deep into floorplates. However, styles of autonomous working were still prevalent and expectations for the privacy afforded by cellular offices remained.

So it is that many of the acoustics and ergonomics standards and guidance from the 1950s onwards chase the ideal of having speech privacy between workstations, even in the open plan.

However, over the last 10 years or so, the methods of working in the UK (and in other locations such as the Netherlands and the US) have moved more towards a collaborative model. People work in teams and on common tasks, and it is actually beneficial to be able to hold conversations at desks and in break-out areas rather than meeting rooms. This introduces the complex issue of requiring good conditions for speech *communication*, as well as *privacy*, in the open plan.

The British Council for Offices[2] introduced the concept of a variety of working zones within an office. This facilitates different activities, as well as giving workers the choice of which environment suits them best (an early acknowledgment that different personality types work differently, and that neurodivergent workers may want to have greater control over their environment).

The wide variety of tasks and working styles within businesses and workforces requires a variety of working spaces and options, all of which have their own acoustic benefits and drawbacks. At one end of the spectrum, open plan working spaces and team areas have the least amount of speech privacy but are designed to promote collaboration and teamworking; for a greater degree of privacy (mainly achieved by attenuation due to distance and perhaps some furniture) there are break-out areas; for the greatest degrees of privacy there are enclosed meeting rooms. Meeting pods bridge the gap between open break-out areas and cellular spaces: they are enclosed but can be located close to the main working areas rather than in another part of the floorplate, and will have greater privacy than break-out, but less than fixed cellular spaces.

### 2.1.1 ISO 23351-1: 2020 Acoustics – Measurement of speech level reduction of furniture ensembles and enclosures — Part 1: Laboratory method

An ISO Standard is available that gives a methodology for testing meeting pods. However, there are several issues with this Standard that make its use in practice challenging:

- It is a laboratory test method and therefore does not directly correlate with how pods will work in-situ
- The test methodology requires the use of a reverberation chamber. The test sample must be no greater than 5% of the room volume and be no nearer than 1 m from any wall or ceiling. This poses difficulties with most commercial laboratories; for example, the reverberation chamber at the University of Salford[3] is 220 $m^3$, which would mean that a pod of no greater than around 11 $m^2$ in footprint could be tested. Only 1- and 2-person pods can therefore be tested to this Standard, unless a significantly larger test chamber is available.
- The Standard gives a single-figure result; however, due to the variety in panel constructions used for pods this does not give directional information that a practitioner would need to aid specification. For example, a glazed frontage with a door will have a significantly lower sound insulation than a solid panel back.

### 2.1.2 The Wild West

As mentioned above, there are many pods on the market available commercially, from tens, if not hundreds, of suppliers. Whilst some manufacturers have had pods tested to ISO 23351-1, more have not. Because there has not been universal adoption of the Standard, there are a multitude of claims made in relation to acoustic performance.

Of those pods that have been tested by alternative means, there is a significant variation, with manufacturers claiming results in $R_{\mathrm{w}}$, $D_{\mathrm{w}}$, $D_{\mathrm{n}T,\mathrm{w}}$, or even just ‘dB’. Some test inside-to-out, some outside-to-in. Many are branded as ‘soundproof’, which is not only physically impossible (and a possible breach of trading standards), but also gives a false sense of benefit.

With so much variation in performance claims, and no credible method of testing all types and sizes of pods, there is no hope of this situation improving.

### 2.1.3 Precedent schemes

The FIS[4] (a trade body representing the fit-out industry suppliers and contractors) have a history of developing verifications schemes. These include schemes for Operable Walls and Glazed Partitions[5], the purpose of which was to give specifiers confidence that manufacturer’s information can be trusted and comes from a reputable source. Both schemes were developed based on a market need, with some manufacturers making performance claims for their systems which were not based on laboratory testing, or inferred performance from other tests.

For Operable Walls, the scheme was based on a third-party verification of laboratory (UKAS or international equivalent) test reports to BS EN ISO 10140-3: 2010.

For Glazed Partitions, the scheme had two verification routes, both by third parties. The first route mirrored that of Operable Walls, where test data is available. For systems where there is no laboratory test data to reflect a specific configuration of partitions and doors, an assessment is made on a report produced by a suitably qualified acoustics consultant, which must be based on a set of test data then using prediction software or calculation, demonstrate how a claimed, informed $R_{\mathrm{w}}$, has been arrived at.

Both schemes have been very successful in being a recognized source of reliable information in amongst an often unreliable market place.

FIS have involved the authors, in addition to Danny McCaul (Salford University, now retired) in developing a similar type of scheme for configurable pods.

# 3 THE PROPOSED SOLUTION AND OTHER OPTIONS CONSIDERED

## 3.1 Assessment parameters

Three main parameters were considered to be used for the scheme, namely $D_{\mathrm{n}T,\mathrm{w}}$, $D_{\mathrm{A,S}}$ and $D_{\mathrm{S,A}}$. All three were parameters to assess the sound insulation of a pod 'in-to-out' rather than 'out-to-in' due to speech privacy being the primary concern within an office scenario where such products are typically used. All three parameters were considered based on conversations with manufacturers of different products to determine the industry-wide opinion, in addition to the considerations detailed below.

The main difference between these parameters are the factors that they consider in their measurement or calculation. The calculation process for each in the context of a pod or panel separating two rooms is indicated in Figure 1.

For a measurement of $D_{\mathrm{S,A}}$, a comparison is made between the sound power levels of a reference source and the same source located inside a pod. This accounts for the room acoustic properties inside the pod, as well as the size and performance of the wall/ceiling panels. Measurements of $D_{\mathrm{n}T,\mathrm{w}}$ and $D_{\mathrm{A,S}}$ on the other hand compare sound pressure levels inside and outside the pod. This accounts for the performance of the wall/ceiling panels, the acoustic properties of the room the pod is located in, and any distance attenuation.

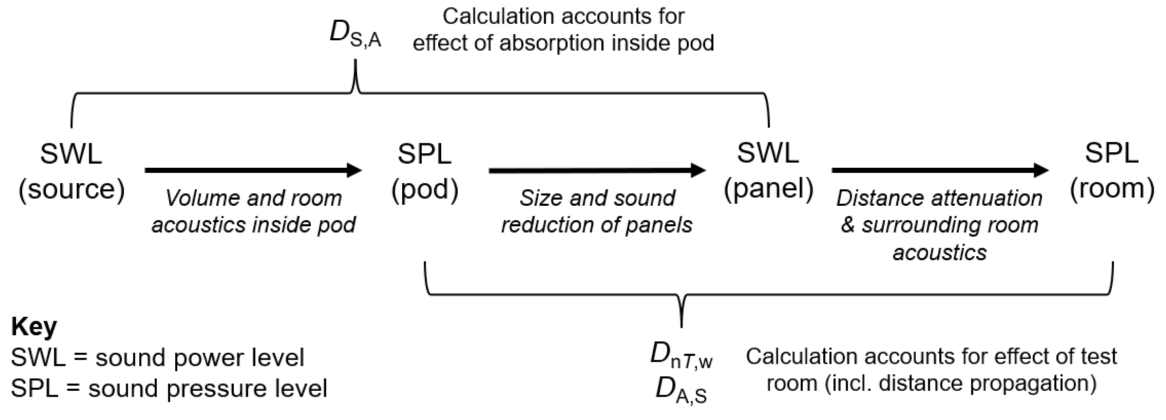


*Figure 1 Differences between calculation methods for $D_{S,A}$, $D_{nT,w}$ and $D_{A,S}$*

The other factor differentiating these parameters is how the single figure number is calculated based on the spectral levels. $D_{nT,w}$ is calculated based on the reference curve method for single figure sound insulation values, as described in BS EN ISO 717-1: 2020. The single figure values for $D_{S,A}$ and $D_{A,S}$ are based on the difference between A-weighted levels, relative to a reference speech spectrum. Whilst the two approaches can yield similar results, the latter tends to better account for weaknesses at mid-frequencies which are of primary importance in the assessment of speech.

The most commonly adopted of these parameters within current test data was $D_{nT,w}$ due to its relatively straightforward measurement technique in-situ and use with other metrics, such as speech privacy potential. However, whilst it does make some correction for the effects of the reverberation time within the test environment, this correction does not fully account for all room acoustic effects such as room volume and distance attenuation. Its use would also raise the question of a suitable reference reverberation time within an open plan office.

Use of $D_{S,A}$ or $D_{A,S}$ was considered, with the former (as detailed in ISO 23351-1) being eventually chosen. The key reason for this was the need for consistency across the market. With the increasing adoption of ISO 23351-1 amongst manufacturers of smaller phone booth products, adopting the same parameter for larger products would allow an equal comparison. Particularly, this would be beneficial for manufacturers of both sized products. Use of $D_{S,A}$ would result in a more controlled lab-based performance, rather than one which may vary dependent on test location.

## 3.2 Assessment method

In the first instance, the scheme was proposed to involve testing of the larger pods that cannot be tested in accordance with ISO 23351-1 in a specialist test facility. However, after an initial search, this was considered impractical, largely due to the lack of suitable test spaces, a pod to test and test personnel all available at the same time, amongst other factors.

The proposed scheme was therefore proposed to incorporate an assessment of the pod to provide a single $D_{S,A}$ value, based on the same assumptions of the ISO standard. This is in effect a calculation of sound breakout for each of the constituent elements (i.e., walls and ceiling), which are combined to give an overall performance.

Initially, the assessment calculates the sound pressure level incident on the walls of the pod assuming a person sat in either the middle of the pod, or the seating position (where this is fixed). This is calculated using the equations 1-3.

$$L_{p,\mathrm{reverb}} = L_{\mathrm{W,RSS}} + 10\log(T) - 10\log(V) + 14 \qquad (1)$$
$$L_{p,\mathrm{direct}} = L_{\mathrm{W,RSS}} - 20\log(r) + 10\log(Q) - 11 \qquad (2)$$
$$L_{p,\mathrm{total}} = 10\log\left(10^{L_{p,\mathrm{reverb}}/10} + 10^{L_{p,\mathrm{direct}}/10}\right) \qquad (3)$$

Where $L_p$ represents sound pressure level, $L_{\mathrm{W,RSS}}$ represents sound power level of the reference sound source, $T$ represents the reverberation time within the pod (in seconds), $V$ represents the internal volume of the pod (im$^3$ m$^3$), $r$ represents the distance between the sound source and the pod walls (in m) and $Q$ represents the directivity of the sound source (which is assumed to be 1).

The breakout sound power level for each element forming the pod is then calculated based on the surface area and the sound reduction index (including corrections for lab-to-site tolerance). The sound reduction indices used are based on manufacturers data (where possible), reference lab test data for comparable build-ups and predictions of performance using INSUL sound insulation prediction software[6]. A composite sound insulation performance for each panel is then calculated, from up to three sub-elements. This accounts for the panels themselves, any openings for ventilation and other elements which may have a bearing on the overall sound insulation performance. The overall sound power level for each pod wall/ceiling panel is calculated using equation 4.

$$L_{\text{W,panel}} = L_{p,\text{total}} + 10\log(S) - SRI - 6 \quad (4)$$

Where $S$ is the surface area of the panel $m^2$ n $m^2$) and $SRI$ is the composite sound reduction index of the panel (in dB).

Once the sound power level of each panel is calculated, the total sound power radiated from the pod is calculated using equation 5.

$$L_{\text{W,P,1},i} = 10\log(10^{L_{\text{W,panel,1}}} + 10^{L_{\text{W,panel,2}}} + \cdots 10^{L_{\text{W,panel,5}}}) \quad (5)$$

Where $L_{\text{W,P,1},i}$ is the total sound power level radiated from the pod and $L_{\text{W,panel,1-5}}$ is the sound power level radiated from each of the five panels forming the pod.

These values are then used within the formulae presented in ISO 23351-1 to calculate the overall $D_{\text{S,A}}$ value. A prediction of $D_{nT,\text{w}}$ is also calculated based on the user-defined parameters for the test room properties. This can then be used as a sense check where on-site tests of the assessed pod have also been undertaken.

## 3.3 Benefits and limitations

There are several benefits of the proposed solution with it being a desktop-based assessment. These include the ability to quickly assess multiple configurations and determine improvement of different arrangements. The output of the scheme also provides the relative contribution from each of the five panels. This allows manufacturers to determine how their products can be improved and also allows acousticians/designers to understand how to optimise the use of pods by orienting weaker/stronger elements as needed.

There are of course also limitations with this approach. Most significantly are the reliance on accurate test data, consistency of assessment and identification of potential weak points. To mitigate these risks, verification testing was undertaken to validate the scheme, as discussed in Section 4. Furthermore, the scheme would be assessed and reviewed by two independent parties, helping to ensure any assessments are undertaken consistently.

There are other limitations with a smaller overall impact, as listed below:

- SRI data is often tested in the 50 Hz to 4,000 Hz third-octave bands, so data in the 8,000 Hz octave band is unavailable. In reality, this is unlikely to affect the single figure $D_{\text{S,A}}$ value.
- The assessment could not be used for furniture ensembles or pods with large open areas (eg, an openable roof where the SRI would be 0 dB).
- The assessment assumes an omnidirectional source within the pod, so'doesn't account for directivity of source (e.g., as could be achieved if using an artificial mouth within a lab test).
- Sound absorbent finishes to the outside of the pod are not factored into the assessment. These may affect the reverberation time in the reverberation chamber and thus the measured sound pressure level during a lab test.

These limitations are relatively negligible, or have been mitigated with the proposed approach.

## 3.4 The future ISO 23351-2

To address some of the limitations of ISO 23351-1, Part 2 of the same standard has been proposed to undertake tests within a non-laboratory environment. This is currently in development, but initial research forming the basis of the new standard was presented in a paper by Keränen et al.[7]. The proposal is to provide a $D'_{\text{S,A}}$ performance, and allow manufacturers to undertake tests within a large semi-reverberant space (e.g., a factory). Whilst this may at first seem at odds with the work presented within this paper, it is expected that both could co-exist, each having their own benefits and limitations.

Firstly, measurements in accordance with the proposed ISO 23351-2 would be much more intensive to undertake, with comparisons of multiple test configurations taking time to allow for construction and adjustment of the pod. Furthermore (and similarly to Part 1 of the standard) this would also not give the same level of detail with respect to directionality of the pod. There would be benefits of the new standard, allowing a credible alternative where measurements rather than assessment are sought. However, as this is in the early stages of development, it is unlikely to be released any time soon.

# 4 VERIFICATION TESTS

## 4.1 Test setup

Several validation tests were undertaken as part of the development of the scheme to ensure the assessment results align with real-world measurements. The main part of these tests was undertaken at the University of Salford, within a temporary facility specially commissioned to undertake tests in accordance with ISO 23351-1. There were two main purposes for these tests, namely:

1. Undertake tests for a range of parameters of the same pod to compare the relative differences between them; and
2. Undertake $D_{S,A}$ measurements for varying configurations/panels of the same pod to determine how well the assessment accounts for a range in configurations.

Additionally, in-situ test measurement data was also compared. This included the same brand of pod tested in the laboratory, being a c.3 m x 3 m pod, typically used as a four-person meeting room. These in-situ tests were used to determine common weak points which limit the sound insulation performance of pods, as well as how the performance can vary due to the site conditions.

## 4.2 Determinants in pod performance

When tested (or assessed in accordance with the scheme) the value of $D_{S,A}$ is primarily determined by its 'weak points' rather than an overall average of every panel. From experience, these tend to be:

- Any openings for ventilation (including through fans and plenum boxes)
- The ceiling construction, particularly ceiling tile systems that are held in place by gravity, rather than being closed by compression
- The door, including seals within the frame and at the threshold.

For most pods, the build-up of the walls (typically glazing or timber-based sandwich panels) provide a relatively good performance. Similarly, junctions between panels tend to provide a relatively good performance assuming there are no visible gaps where panels meet. This is also the case for the floor junction, regardless of whether the pod is provided with an in-built floor or not. There can be some influence from the base-building where a pod is placed on a raised access floor, but providing the raised floor does not include ventilation grilles, the limitation of this tends to be above the performance that most pods can achieve.

Each of the elements that a pod is formed from will have their own inherent lab-to-site tolerance. These vary dependent on the type of panel and will be factored into the assessment.

## 4.3 Comparison of parameters

A comparison of all the parameters measured in the verification tests are shown in Table 1. These were measured for the same pod, so are directly comparable. However, some parameters (e.g., $D_{A,S}$ / $D_w$) are unlikely to be representative, given they are best suited to an in-situ test environment, rather than in laboratory conditions (i.e., a reverberation chamber).

Test parameters for speech privacy purposes (i.e., testing from in-to-out) yield higher performances than tests for noise reduction purposes (i.e., testing out-to-in). This is due to the influence of the source and receiver room acoustic properties and would be expected to show the same trend in different test environments.

Test parameters based on a difference in single figure A-weighted values (i.e., $D_{p,A}$ / $D_{A,S}$) were around 4 dB lower than the equivalent parameters based on the sound insulation reference weighting curve (i.e., $D_{p,w}$ / $D_w$, respectively). This was due to the A-weighting and reference speech spectrum primarily focusing on the sound insulation performance at mid-frequencies, in particular in the 500 Hz octave band.

The exact reason for the difference between the measurements of $D_{S,A}$ and $D'_{S,A}$ is unclear. However, this may be due to the use of an abridged measurement method for $D'_{S,A}$ (due to the lack of full test method details available at the time of testing). Further measurements and research, such as undertaken by Keränen et al.[7] would be required as part of the development of ISO 23351-2 to validate the differences between the parameters.

*Table 1 Comparison of parameters measured for the same pod in laboratory conditions*

| Parameter | Standard | Value | Notes |
|---|---|---|---|
| $D_{S,A}$ | ISO 23351-1:2020 | 20.4 | Measurement direction from in to out |
| $D'_{S,A}$ | ISO 23351-2 | 23.8 | Initial proposed standard – abbreviated method in general accordance with proposed method |
| $D_{nT,w}$ | ISO 16283-1:2014 | 42 | Measurement direction from in to out. $T_0$ 0.5 seconds assumed |
| $D_w$ | ISO 16283-1:2014 | 34 | Measurement direction from in to out |
| $D_{nT,w}$ | ISO 16283-1:2014 | 30 | Measurement direction from out to in. $T_0$ 0.5 seconds assumed |
| $D_{p,w}$ | ISO 11957:2009 | 29 | Measurement direction from out to in |
| $D_{p,A}$ | ISO 11957:2009 | 24.9 | Measurement direction from out to in |
| $D_{A,S}$ | ISO 22955:2021 | 30.3 | Measurement direction from in to out |

For comparison with the laboratory tests, the same brand of pod was also tested in a range of in-situ tests. Measurements were taken for 14 different pod walls within several different offices and were measured by different engineers. The test results varied between $D_w$ 32-41 dB (at 1-2 m from the pod) with the most common results around $D_w$ 35-38 dB. Whilst the build-up of each pod tested in-situ was not directly comparable to the one tested in laboratory tests, they do provide a useful comparison in the difference in $D_{S,A}$ and $D_w$ performances.

The performance achieved by the pod tested in the laboratory is relatively low in terms of a single figure $D_{S,A}$ performance. However, comparable pods tested in-situ performed relatively well. This is primarily due to the effect of the test room on the measured level.

For a typical office environment, values of $D_{nT,w}$ are likely to be 10-15 dB higher than the equivalent $D_{S,A}$ value. This is dependent on the reverberation time and volume of the test space as well as the measurement distance. However, it also depends on the positioning of the pod relative to other surfaces. As tests for $D_{S,A}$ are undertaken within a reverberation chamber, each of the sound insulation weaknesses is exposed. Where these weaknesses are from the ceiling (incl. openings for ventilation fans) then the overall performance will be more affected than a test of $D_{nT,w}$ would be (in particular where there is a sound absorbent ceiling installed above the pod in-situ).

It is also important to consider the size of the pod tested and the influence on the overall performance. Up to a point, smaller pods (e.g., phone booths) are likely to achieve a higher single figure $D_{S,A}$ performance than a larger pod constructed from the same panels. As the $D_{S,A}$ performance is primarily determined by the weaker elements, it does depend on the relative contribution of these to the overall size of the pod.

For a well-designed pod with a relatively homogenous performance, a larger pod (e.g., 3 m x 3 m) would likely achieve a $D_{S,A}$ value 2-3 dB lower than a phone booth (e.g., 1 m x 1 m) with the same performance panels to both. This primarily is due to the smaller panel sizes and the relative benefit of absorption inside the pod. This is true up to a point, dependent on the reverberation time inside the pod, after which the trend starts to reverse due to the increasing effect of distance attenuation of speech between the person speaking inside the pod and the surrounding pod walls. Figure 2 shows this effect for predictions of pod $D_{S,A}$ performance, assuming the same sound reduction performance to all panels.

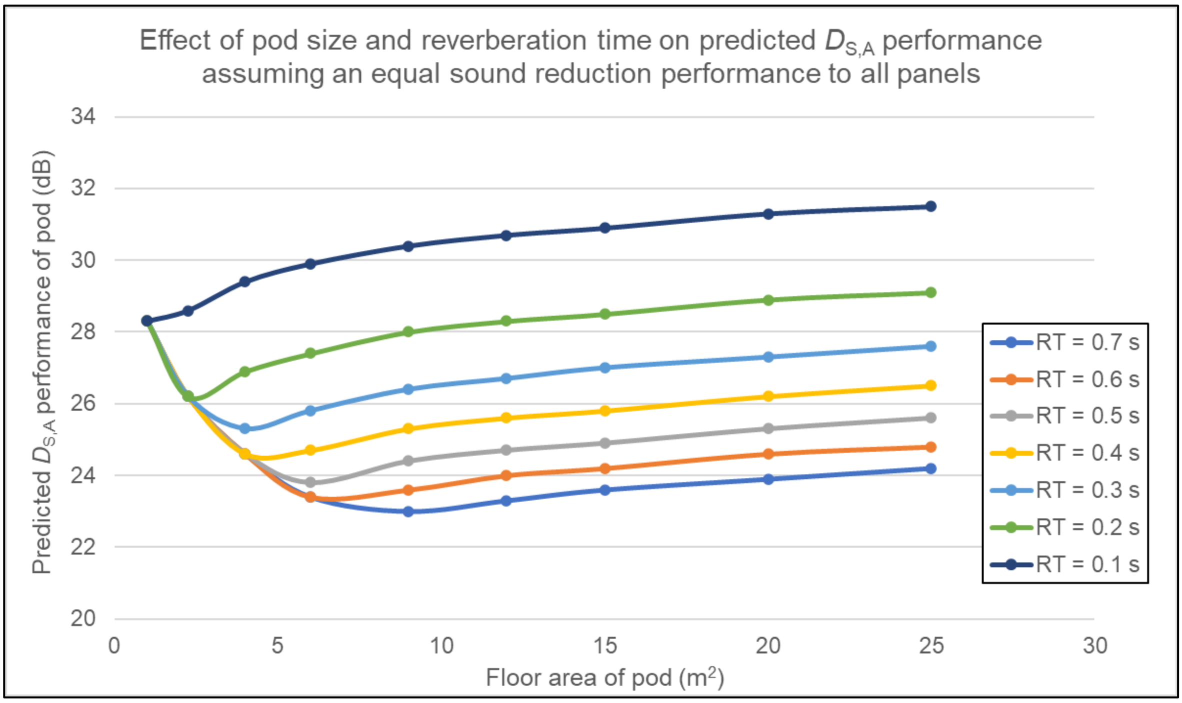


*Figure 2 Graph showing effect of pod size and reverberation time on predicted $D_{S,A}$ performance*

## 4.4 Accuracy of assessment

In addition to the tests shown in Table 1, a range of modifications were undertaken to the same pod to determine relative weaknesses of different panels and see how these could be improved. These modifications included enhancing weaknesses and changing full panels. Each configuration was then retested in accordance with ISO 23351-1 and was also assessed in accordance with the proposed scheme. The difference between the two results was then used to determine the accuracy of the assessment.

The range in differences between the measurement and assessment results was between -2.4 dB and +0.4 dB, with the assessment predicting performances on average 0.9 dB below the measurement result. This indicates that the two generally align well. It is expected that there would be less alignment between the two for smaller pods (e.g., phone booths), though given such pods could be tested in a laboratory to ISO 23351-1, this is unlikely to be problematic.

As the results for $D_{S,A}$ were more limited by sound insulation weaknesses than an average of the overall performance, the assessment of key sound insulation weaknesses (such as ventilation openings and ceilings) are critical in determining the overall performance of pods. Further measurements and research into the performance of these weaknesses is recommended to reduce the uncertainty in the assessment method.

The overall uncertainty of the assessment depends on the type of data used and the availability of test data compared to predictions. Where INSUL prediction software[6] is used within the assessments (rather than using laboratory test data), a more conservative view will be undertaken to account for the increased uncertainty. This software is quoted to have an uncertainty of ±3 dB, which should be factored into the overall assessment uncertainty. Research by Hongisto et al.[8] indicates that measurements in accordance with ISO 23351-1 have a reproducibility standard deviation of 1.1 dB.

# 5 HOW THE SCHEME WILL RUN

Details about the scheme including how to register will be provided on the FIS website[9]. Manufacturers interested in having their products assessed in accordance with the scheme will be provided with details of the information required. This information will be provided to Cundall or Sandy Brown (alternately) to undertake the assessment. To ensure a robust process, both parties will be involved in each assessment, with one undertaking the assessment and the other reviewing.

Following completion of the assessment, a certificate showing the predicted performance will be provided. This will detail the elements assessed, the overall performance and the partial performance of each partition, for reference. Values of $D_{S,A}$ presented within this could be used in manufacturers literature to allow for comparison with other products tested in accordance with ISO 23351-1. Values could also be used by acousticians in their assessments to determine positioning of the pods, with potential alignment into assessments to ISO 22955.

# 6 CONCLUSIONS

Having consistent and comparable sound insulation test data for pods is critical. There are shortfalls with the current ISO 23351-1 standard, particularly in its application to larger configurable meeting pods. A new assessment scheme is proposed to address these needs, which would be aligned to the existing ISO standard.

Verification tests have been used to validate the assessment scheme and determine the relative differences between different sound insulation parameters. These differences can be large and need to be considered when specifying or measuring the sound insulation performance of a pod in-situ. Whilst the proposed scheme aligns well with the measurement results, further work to determine the performance of sound insulation 'weak points' is recommended. Details of the proposed scheme will be provided on the FIS website[9].

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