NOISE / NEWS INTERNATIONAL

Volume 33, Number 4
2025 December

A quarterly news magazine and online digital blog published by I-INCE and INCE-USA

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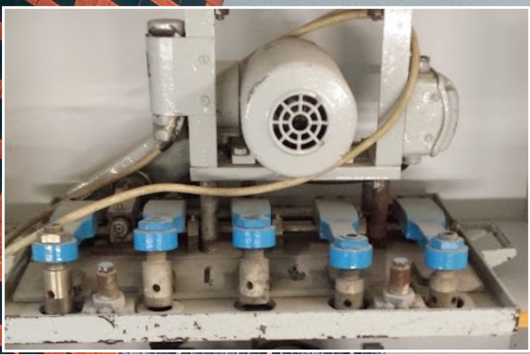

Cracking the Code: Demystifying Acoustical Standards

NOISE / NEWS INTERNATIONAL

Volume 33, Number 4 2025 December

FEATURES

DEPARTMENTS

A quarterly news magazine and online digital blog published by I-INCE and INCE-USA

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NOISE / NEWS INTERNATIONAL

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Editor's Message

In this issue, we are trying something unique. During a recent survey on what would you, as readers, would like to read from future issues of *Noise News International*, we got an overwhelming response on measurement standards and practices. It's a topic that affects every corner of noise control engineering, yet one that often feels opaque, overly technical, or simply overwhelming. With hundreds of standards across various organizations, each with enough nuance to fill entire textbooks, it's easy to see why. So, while we can't cover everything, and certainly not in one issue, we felt it was important to begin.

This edition offers a curated selection of articles that introduce and clarify several foundational acoustics and noise control standards. We explore the ASTM laboratory and field methods for floor–ceiling impact noise, unpack the measurement approach behind floor covering performance, highlight the AHRI standards governing HVAC noise, and provide an accessible introduction to the ISO sound insulation standards. We also were fortunate enough that our industry sponsors wrote an article on heavy/hard impact noise standard for this issue. Individually, each of these topics could fill an entire issue of NNI; together, they represent a meaningful starting point for anyone looking to strengthen their understanding of acoustic measurement framework.

Our goal with this collection isn't to turn you into a standards expert in one sitting. Rather, we hope to demystify some of the terminology, structure, and intent behind these documents; because the truth is, even seasoned professionals can find standards confusing or counterintuitive at times. A baseline understanding can go a long way in improving communication, streamlining project work, and elevating the quality of noise control across industries.

Sunit Girdhar,
Westside Acoustics and Vibration Engineering

We also recognize that standards play a crucial role in how our field collaborates and evolves. They define common language, set expectations for performance, and provide clarity in a profession where small measurement differences can have major real-world consequences. As noise control continues to intersect with emerging technologies, sustainability goals, and evolving building practices, familiarity with these frameworks becomes more important than ever.

As part of this issue, we also bring you a special interview with **Noral Stewart**, a household name in the field of Acoustics and Noise Control, whose work has played a meaningful role in shaping current practices. We sat down with Noral to hear firsthand about the challenges, lessons, and realities of working in the field of Noise Control. His insights offer a rare opportunity to learn directly from someone who has helped build the foundation on which much of our industry relies.

We hope this issue offers both insight and confidence as you navigate the standards that guide our work. And as always, your feedback helps us shape future editions, so if there are specific standards you'd like to see explored next, please let us know. ■

Up Next in Noise News International

As we look ahead, our next issue will shift from buildings to the broader world around us—with a deep dive into **environmental noise, soundscapes, and the science of how communities experience sound**. From transportation corridors to urban greenspaces, from policy frameworks to real-world monitoring, the upcoming edition will explore the tools, challenges, and innovations shaping how we understand and manage noise in our shared environments.

We'll bring you fresh perspectives from researchers, practitioners, and policymakers working at the intersection of acoustics and public health. Whether you're designing quieter infrastructure, studying natural soundscapes, or developing noise regulations, this upcoming issue will give you insights you can take straight into your work. Stay tuned!

History and Development of ASTM E1007

Standard Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures

By **Wayland Dong,** *Acoustician, Westside Acoustics*

By the 1960's, multifamily housing in the United States was in the unhappy situation of large and increasing numbers of complaints of sound isolation [1], without even a defined method to measure, much less design or enforce, the sound isolation of separating walls and floor-ceiling assemblies. Despite a generally higher standard of living, especially in those immediate post-war years, the USA trailed far behind most countries in Europe in developing sound isolation methods and building codes [2], a lamentable condition that in many ways continues to the present. Since "it is better to adopt an approximate answer today than to wait 10 or 20 years for the perfect answer based on the necessary research" [2], the expeditious solution was undertaken to borrow European means and methods for measuring impact sound insulation.

The measurement method was based on the German DIN 4109 standard [3], [4], which was first published in 1938 as DIN 4110 [5] and was also the basis of ISO recommendation R140, which became today's standards 10140 and 16283. The impact source is what we now refer to as the standard tapping machine, which drops five cylindrical steel hammers spaced 100 mm apart on the floor from a height of 40 mm. The hammers are 30 mm in diameter and weigh 500 g with a slightly curved impact face and drop sequentially at an overall rate of 10 Hz. The spatial- and time-averaged sound pressure level generated by the operation of the tapping machine on the source floor is measured in the receiving room.

The standard tapping machine was adopted as the impact sound source and formed the basis of Impact Insulation Class (IIC) published by the Federal Housing Administration (FHA) in a Guide in 1967 [6]. The test method was described only as that "currently at use at the National Bureau of Standards" but eventually became ASTM E492. No explicit mention was made of a field test version of the standard, although many of the floor-ceiling assemblies in the FHA guide note that the data was obtained from field testing. Clearly field testing of impact noise isolation using a similar method to what became E1007 was being performed for decades, but the formal test method was not published until 1984.

The method described in the FHA Guide averages the impact sound pressure level (ISPL) over time and space in the 16 third-octave bands from 100 – 3150 Hz using 6 stationary positions or a slowly moving microphone, which is similar to the current E1007. The tapping machine is to be placed in "at least three specified locations on the floor". These locations were not specified in that document, but they were standardized in ASTM E492 as four tapping positions all near the center of the room (see figure). The positions are clearly intended to excite the floor both on and between joists, and in several orientations, but the precise rationale for these positions has not been published. The standard does not distinguish between reflections or rotations of the positions, and therefore the set of four tapper positions is not uniquely determined.

E1007 uses the same positions as the laboratory test. Floors in the field can be much larger than the roughly 10 m² of the laboratory specimen, so that the distance from the center of the floor to measurement points can vary considerably, but no consideration is given to the size of the rooms. By comparison, ISO 16283 specifies random tapper positions throughout the floor and increases the recommended number of tapper positions as floor size increases.

This is typical of the early versions of E1007 in that it appears to be making as few changes as possible to the method in E492. In addition to the same source, source positions, and sound measurement method, it used the same interrupted noise method of measuring the decay in the receiving room and the same calculation method of L_n, the normalized ISPL:

$$L_n = L_p - 10\log\frac{A_0}{A_2} \quad (1)$$

where L_p is the average SPL in the receiving space, A_2 is the calculated absorption in the receiving space per ASTM E2235, and A_0 is the reference amount of absorption of 10 m². This reference absorption level is the same as the laboratory test, the importance of which is discussed below.

The name of the classification rating originally defined in the standard, Field Impact Insulation Class (FIIC),

Figure 1: Early examples of tapping machines at the Center for Acoustic and Thermal Building Physics at the University of Applied Sciences in Stuttgart, Germany. Dates of construction are not known.

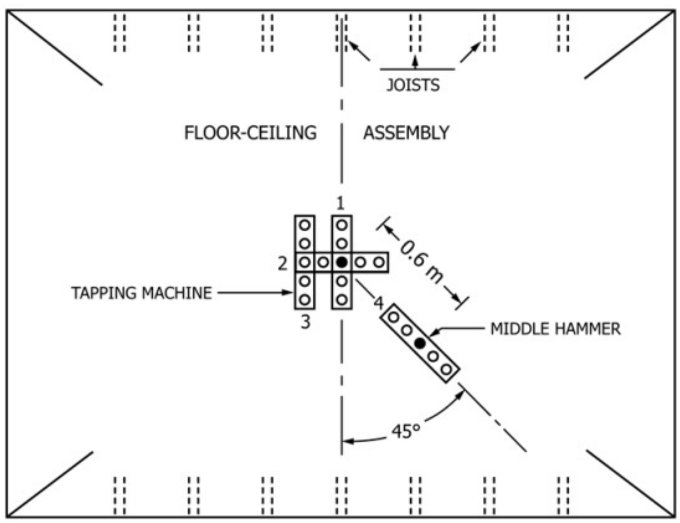

Figure 2: Definitions of the four tapping machine positions in ASTM E492 and E1007

clearly indicates the minimal changes between it and the laboratory rating, IIC. The name is also in parallel with Field Sound Transmission Class (FSTC) defined in the contemporary version of E336.

Normalization

The normalization in Eq. (1) was intended to allow comparison of results from receiving rooms with differing amounts of absorption. There were two versions of the normalization procedure in the existing standards of the time, either to a standard amount of absorption (10 m^2) or a standard reverberation time (0.5 second). The 1963 FHA document used reverberation time normalization to avoid the necessity of calculating the volume of the receiving room [3], but by the 1967 FHA guide, only normalization to absorption was included [6]. The airborne sound isolation standard, E336, included ratings with both normalization methods since 1977, but E1007 only included the absorption option. At any rate, it was generally believed that the two methods were "equivalent and comparable" [3].

Explicitly, since the absorption is calculated from the Sabine formula, $A_2 = \frac{0.16V}{T_2}$, where V is the volume of the receiving room and T_2 is the measured reverberation time, the difference between the methods is

$$10\log\frac{T}{T_0} - 10\log\frac{TA_0}{0.16V} = 10\log\frac{0.16V}{T_0A_0} \approx 10\log\frac{V}{31\text{ m}^3}$$

so that the difference in normalization methods depends entirely on the receiving room volume. The difference vanishes for receiving room volumes of about 31 m^3 or 1100 cu. ft. The fact that the typical amount of absorption in a reverberation chamber (10 m^2) is approximately what is required to achieve a reverberation time of 0.5 second in a small room is an unfortunate coincidence, which misled many to assume that these normalization methods were "equivalent and comparable."

Schultz states that "for the typical range of room volumes" (about 22 – 60 m^3, 775 – 2100 cu. ft.) the difference (-1.5 to +2.8 dB) was "no greater than the uncertainty of typical field measurements" and was therefore not consequential [3]. There is no source given for the range of room volumes, but it was presumably based on the available test data. When this exercise is repeated for more modern testing, the 90th percentile receiving room volume was 110 m^3 (3885 cu. ft.) with a resultant difference of 5.5 dB [7]. This is nearly twice what it was in the 1960's and clearly too large to be ignored. The normalization method in Eq. (1) penalizes large rooms by demanding an unreasonably small amount of absorption; for a 110 m^3 room, the sound level is effectively normalized to a reverberation time of 1.75 seconds!

The issues with absorption normalization were identified in a paper published in 2005 [8] with a resultant major revision to the standard in 2011. In addition to the existing absorption normalized ISPL (ANISPL), reverberation time normalized ISPL and non-normalized ISPL were added to the standard. These became the basis for new single number ratings, Normalized Impact Sound Rating (NISR) and Impact Sound Rating (ISR), respectively, parallel to NNIC and NIC in E336. Field IIC (FIIC) was renamed Apparent IIC (AIIC) in recognition of the presence of flanking paths and to parallel ASTC defined in E336.

It is not often recognized that the absorption normalized ratings like AIIC are measurements of apparent sound power (the performance of the separating assembly), whereas the reverberation normalized ratings (NISR) are measurements of sound pressure (sound isolation between any two spaces). Sound power measurements require significant constraints such as limited receiving room absorption, well defined specimens and rooms, and accurate determination of receiving room volumes. The resultant level is of limited use because the sound from flanking paths is attributed to the specimen. By contrast, the sound pressure measurement is indicative of the sound environment experienced by an occupant and is therefore the preferred measurement. The International Building Code section 1206, which is the basis of sound isolation code requirements in most jurisdictions in the United States, now explicitly requires NISR/NNIC be used for evaluation of sound isolation between residences in the field [9]. In the author's opinion, AIIC is at best redundant with NISR and one day may be removed from the standard.

Lateral measurements

Even in early versions of the standard (at least to 1997), the standard said the receiving room was "located beneath or adjacent to the floor specimen under test," although this is somewhat contrary to use of absorption normalization as described above. The situation was clarified with the 2011 revision, when AIIC was specified to apply only to the receiving space directly below the tapping machine, while ISR/NISR could be measured in any space. However, the location of the tapping machine is not adjusted, and the center of the floor is a varying and potentially large distance from a laterally adjacent room.

For this reason, a modified method has been proposed for lateral or diagonal adjacencies (i.e., receiving rooms that share a junction with the source floor) in which the tapping machine is at a fixed distance of 5 feet or 1.5 m from the separating junction [10], [11], [12]. This revision may be adopted in future versions of the standard.

Volume requirements

Early versions of the standard defined acceptably diffuse sound fields as requiring minimum volumes of 60 m^3 at 100 Hz, 40 m^3 at 125 Hz, and 25 m^3 at 160 Hz, and required the report to note where this requirement was not met. As noted above, this applied only to FIIC (AIIC).

In 2011, AIIC was limited to receiving rooms of at least 40 m^3 with a 2.3 m minimum dimension and absorption less than 2 $V^{2/3}$. NISR was permitted for receiving rooms up to 150 m^3. No reason for the upper limit is given, although it is parallel with E336 where a similar requirement exists. No lower volume limit exists for NISR, although this is a matter of current discussion.

In 2014, additional requirements for coupled receiving spaces were added for AIIC measurement, required volume weighted SPL measurements. As discussed above, such care in defining the volumes for calculation of the absorption are required for sound power calculations but are ultimately of little use. The method could be significantly simplified without detriment if the AIIC rating was removed.

ASTM Committees

ASTM membership is low cost and the committees are open to all interested parties. All researchers and consultants working in the field of sound insulation are invited to join ASTM and participate in the discussions of future revisions of this standard.

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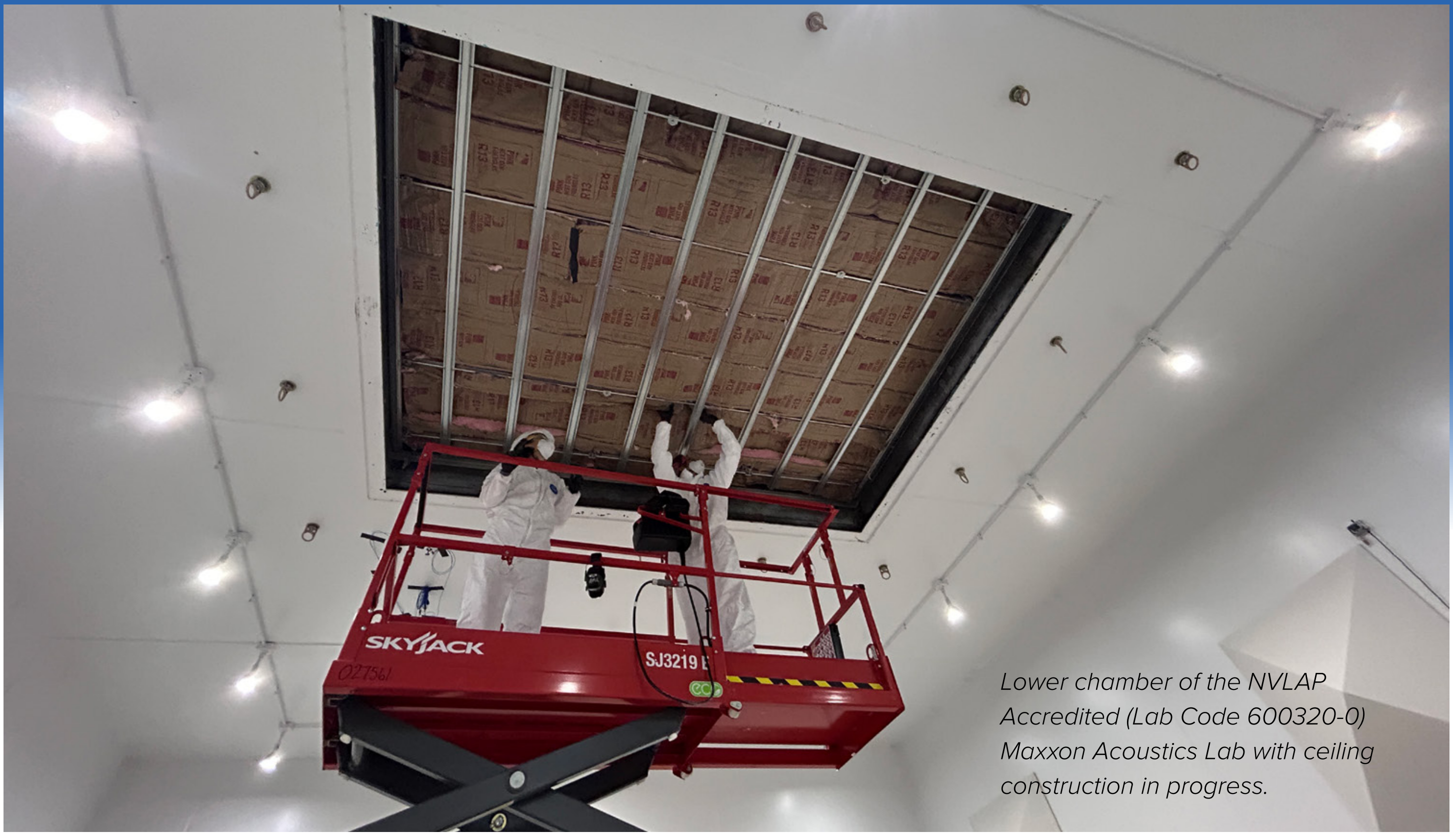
About the author

Wayland Dong has focused much of his career as an acoustical consultant on advancing the science and practice of impact sound insulation in multifamily dwellings. In addition to the work on normalization methods and lateral impact transmission mentioned in this article, he and coauthor John LoVerde have developed a two-rating method of measuring impact sound isolation in which the low and high-frequency components of impact sound are evaluated independently, which has been implemented as new ASTM ratings. He is currently an Acoustician at Westside Acoustics, a consulting firm in Los Angeles. ■



Lower chamber of the NVLAP Accredited (Lab Code 600320-0) Maxxon Acoustics Lab with ceiling construction in progress.

ASTM E492 – Impact Noise Measurement for Floor-Ceiling Assemblies in the Lab

By **Jordan Strybos,** *Intertek, York, PA* and **Mike Raley**, *PAC Intl., Canby, OR and University of Oregon, Portland, OR*

Thump, thump, thump, scrape. Your upstairs neighbor just walked to their dining table and pulled out a chair. Kerplunk. Their cat jumped out of the chair. All too often in apartments and hotels we are aware of the movements of our neighbors; every breath they take, every move they make, you'll be hearing it. Does it have to be this way? No, it doesn't, but controlling sound, in this case impact sound, is a challenge. That's why we have acoustical test standards to help us evaluate the acoustical performance of the floor and ceiling that separate us from our neighbors above and below us.

The primary standard for this purpose is ASTM E492: Standard Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine. This standard is used to measure the acoustic performance of the floor-ceiling assembly that separates a room from the room below it. The floor-ceiling assembly is generally comprised of several types of items: floor finish, underlayment, structure such as joists or a concrete slab, insulation, ceiling board or tiles, etc. The ASTM E492 test method aims to measure how good the specimen is at reducing the transmission of impact noise from the upper room into the lower room. The single-number rating produced by an ASTM E492 test (calculated with reference to ASTM E989) is the Impact Insulation Class (IIC). A higher IIC rating corresponds with higher acoustical performance. IIC 50 is the minimum required performance in the International Building Code (IBC), though acoustical consultants often recommend higher IIC ratings to obtain satisfactory impact isolation.

The ASTM E492 test is similar to the ASTM E90 test (which yields an STC rating) in that both tests aim to characterize the performance of a building partition (in the case of E492, specifically floor-ceiling systems). Since these tests measure the performance of entire assemblies, they can be applied to a wide variety of building; however, each E492 test represents the performance of the ENTIRE assembly rather than any one piece within the assembly. The difference between the two tests lies in the noise source; ASTM E90 utilizes loudspeakers to produce airborne noise, whereas E492 utilizes a specifically designed tapping machine to generate impacts on the floor of the upper room.

The general procedure for the test is fairly simple – the tapping machine (a box with 5 hammers that independently and repeatedly fall on the floor) is placed in multiple positions on the floor in the upper room, and the noise that is transmitted through the system into the lower room is measured. The positions of the tapping machine are dictated by the standard to improve the reproducibility between comparative tests and are designed to excite the floor in specific ways. Different floor-ceiling assemblies will respond differently depending on their structural makeup. For instance, the response of a typical joist floor will vary depending on if the impact is directly above a joist or centered between two joists. The various prescribed positions of the tapping machine are designed to fall both on and between structural support members (if they exist).

A recent development within impact noise testing is the development of high-frequency and low-frequency impact noise metrics. Over years of collecting and analyzing ASTM E492 test data, it has become clear that the impact performance of floor-ceiling structures is a multi-domain problem; the floor finish/underlayment layer (installed on top of the structural system) has large effects on the high-frequency domain, but very little impact (pun intended) on the performance below 315-400 Hz. On the other hand, the lower frequency performance of a system (250 Hz and below) is primarily controlled by the resonances of the structural system itself, and seems to only be affected by large-scale changes to the system such as cavity depth, total mass, structural stiffness, addition of ceiling panel/isolation layers. As a result of these discoveries, two new metrics were developed to characterize these two frequency-domain-dependent behaviors: Low-Frequency Impact Insulation Class (LIIC, ASTM E3207) and High-Frequency Impact Insulation Class (HIIC, ASTM E3222).

Lower chamber of the NVLAP Accredited (Lab Code 600320-0) Maxxon Acoustics Lab

These two metrics serve as helpful informers to further analyze the impact insulation of a system. If a system's overall IIC rating is limited in the low 50s, but it is achieving an HIIC rating in the high 60s, for example, the floor topping layer is likely quite high-performing, and the system is being limited by the structure itself and other elements in the assembly. This tells us that a higher IIC rating would be hard to achieve without modifications to the structure itself, significant changes in the ceiling isolation, and/or adding mass to the system. In other words, going down a rabbit hole searching for other floor toppings or underlayments to increase the IIC performance is likely a fruitless task.

Since its creation, the ASTM E492 test method has been the de facto method for analyzing the effectiveness of floor-ceiling assemblies at mitigating impact noise. The innovation of utilizing a standardized tapping machine as an impact source has created a consistent, repeatable way to synthesize common (but much less reproducible) noise sources that are seen in daily life such as footfalls and object drops. This method has also led to the development of ASTM E1007, the field version of this test method, and ASTM E2179, a floor-covering specific offshoot that evaluates the increase in the IIC rating when a floor finish is added to a concrete slab. Current work is also underway for the development of a laboratory test method that measures the amount of noise within the room where the

Upper chamber of the NVLAP Accredited (Lab Code 600320-0) Maxxon Acoustics Lab

impacts occur. This is different from ASTM E492 which measures the noise from impacts in the room BELOW where the impacts occur. This new standard will be useful for evaluating the effects of flooring on the noise generated by footfalls and rolling objects in places like hotel and hospital corridors.

ASTM E492 has been around for many decades and without it our buildings would be far noisier than they are today. However, E492 is not a perfect test method and meeting the IBC code minimum of IIC 50 does not guarantee a satisfactory level of noise reduction. A recent interlaboratory study (ILS) has shown that there is significant variation in the IIC ratings different labs obtain when conducting an ASTM E492 test on a bare six-inch concrete slab. The ILS is part of an effort in ASTM to improve E492 and to reduce the variability in test results. There are also efforts to develop new test methods that better characterize the impact isolation of an assembly and that are more correlated with our perception of impact noise. If you are interested in these efforts, please consider joining the ASTM E33 committee on acoustics.

About the authors:

Jordan Strybos is a Project Engineer at Intertek's acoustical testing facility in York, PA. He oversees the Vertical Transmission (VT) test chambers, specifically focusing on floor/ceiling acoustics. Jordan has been overseeing the operations of York's VT chambers for over 10 years and has been heavily involved in the ASTM E33 committee since 2018, chairing several task groups and serving as subcommittee vice-chair and secretary for the E33.10 subcommittee on Impact Noise and Vibration. The lab at Intertek-York is a state-of-the-art facility that provides highly-efficient testing, excelling in both project-specific test programs and broader-ranging research projects. The VT chambers at Intertek-York offers a lab testing environment for anyone interested in conducting testing per ASTM E90, ASTM E492, ASTM E2179, ASTM E1222, ASTM E1414, ISO 10140, and ISO 15665.

Mike Raley is the Director of Engineering at PAC International and the Director of the Oregon Acoustic Research Laboratory at the University of Oregon. Mike has worked as an acoustician for 17 years and has been heavily involved with the ASTM E33 committee since 2018. He is currently the membership secretary of E33, the secretary of E33.05, the co-chair of the ILS on E90 for walls and E90/E492 for floor/ceiling assemblies, and active in many task groups, especially those focused on measuring the transmission of impact and airborne sound.

PAC International is a manufacturer of high-performance noise control products including spring ceiling hangers, floating floor isolators, and original sound isolation clip, the RSIC-1. PAC is committed to supporting the acoustic community through extensive acoustical testing and involvement in ASTM, INCE, ASA, and NCAC.

The Oregon Acoustic Research Laboratory (OARL) at the University of Oregon is a new world-class floor-ceiling testing facility set to open in 2027. The test chambers have been designed by Jerry Lilly to provide adequate modal density down to 50Hz and to provide exceptionally high flanking limits for both airborne and impact noise tests. OARL is part of a large innovation hub in Portland focused on supporting the expansion of the mass timber industry. ■

Closeup of the Tapping Machine used in ASTM E492 and ASTM E2179 Testing

ASTM E2179 – Standard Test Method for Laboratory Measurement of the Effectiveness of Floor Coverings in Reducing Impact Sound Transmission Through Concrete Floors

By **Jordan Strybos,** *Intertek, York, PA*

ASTM E2179: Standard Test Method for Laboratory Measurement of the Effectiveness of Floor Coverings in Reducing Impact Sound Transmission Through Concrete Floors. Simply put, this standard is used to characterize the specific acoustic benefit of floor covering products when installed on a concrete slab (or in another manner of speaking, how much quieter does my concrete floor system become when I install a given floor covering on it?). The single-number rating produced by an ASTM E2179 test (calculated with reference to the Method ASTM E989) is ΔIIC, signifying the change in impact sound reduction introduced by the inclusion of a given floor covering on a concrete floor system. The ΔIIC rating is somewhat unique compared to other common laboratory sound transmission metrics (STC and IIC, for example) because it represents the acoustic benefit specific to the floor covering product, rather than the acoustic performance of an entire partition or floor/ceiling system. For this reason, the ASTM E2179 test method can be quite helpful in direct comparisons between floor covering products.

The ASTM E90 and ASTM E492 tests (yielding STC and IIC ratings, respectively) are specifically designed to be applicable test methods for a wide variety of building products. These standard test methods are useful because they do not limit the types of products that can be evaluated; the methods can be used for any product that would be a part of a partition dividing spaces

Lower reverberation chamber at Intertek-York's test facilities

within a building. Floor coverings, structural members, insulation, door panels, windows, gypsum board, and many other products can utilize the standardized methods of measurement detailed in these tests. The tests simply measure the acoustic performance of the entire separating partition between two spaces. Due to this wide-ranging applicability, though, the use of the STC and IIC metrics to directly compare specific products (or individual elements within those partitions) can present a challenge.

If, for example, one wanted to compare two different gypsum wall panel products, simply comparing two separate STC test results featuring these products is not necessarily as helpful as it may initially appear to be. The two STC tests for the products could theoretically have these wall panels featured as elements in wildly differing wall systems. Stud spacing, resilient mounting, cavity size, insulation, and a host of other factors all play a role in the acoustic performance of a wall system, and changes in any of those factors will affect the result of the test. With so many potential variables within the partition, the only way to properly analyze the differences between these two wall panel products would be to compare two tests where the only changed variable is the wall panels themselves. At surface value this seems simple enough to do, but unless the manufacturers of these products are both intentionally aiming for a direct comparison between their products, finding test results that are perfectly comparable can prove to be a difficult task.

This challenge of identifying directly comparable test results has historically been a very prevalent issue in the world of floor coverings, where there is a multitude of differing structures upon which floor coverings can be installed. For this reason, the ASTM E33 committee strived to create a standardized method of comparing floor coverings specifically; to create a test method that would remove the endless potential variables between published tests so that a consumer, contractor, or consultant would have easily digestible comparative data between all floor coverings. Around the turn of the millennium, the seeds of the ASTM E2179 test method were planted, and the test became an official standard test method in 2001.

The focus of this test method is solely on the effect that floor coverings have on the impact sound transmission through the floor system. This is due to the fact that floor covering changes bear very little change (if any at all) on the airborne acoustic performance of a floor/ceiling system, making it unnecessary to analyze that performance change. Focusing on the impact domain led the group within the ASTM E33 committee to develop a test method that incorporated the test method already present in ASTM E492 testing, utilizing a standardized tapping machine as the source of impact vibrations in the floor/ceiling system.

The premise of the procedure is simple: in order to characterize the added benefit of the presence of a given floor covering, one simply conducts an IIC test on a floor system without the floor covering, and conducts a second

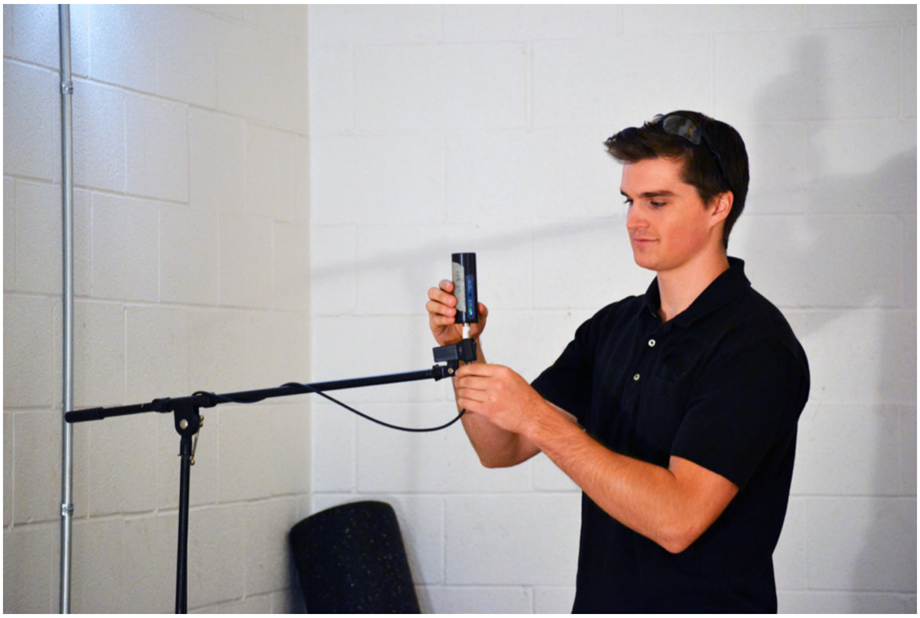
IIC test on the system with the inclusion of the covering. The measured improvement of the system is then analyzed at the third-octave band level and put through a series of calculations to yield the ΔIIC rating, a single number representing the added acoustic benefit from the floor covering. There is one important distinction to make, though: the addition to the performance of the system will vary based on the baseline performance of the system itself (without the floor covering). With improvement in sound transmission reduction being exponentially more difficult as performance increases, the measured improvement could theoretically get smaller if the covering was tested on a system that already effectively reduces impact sound transmission.

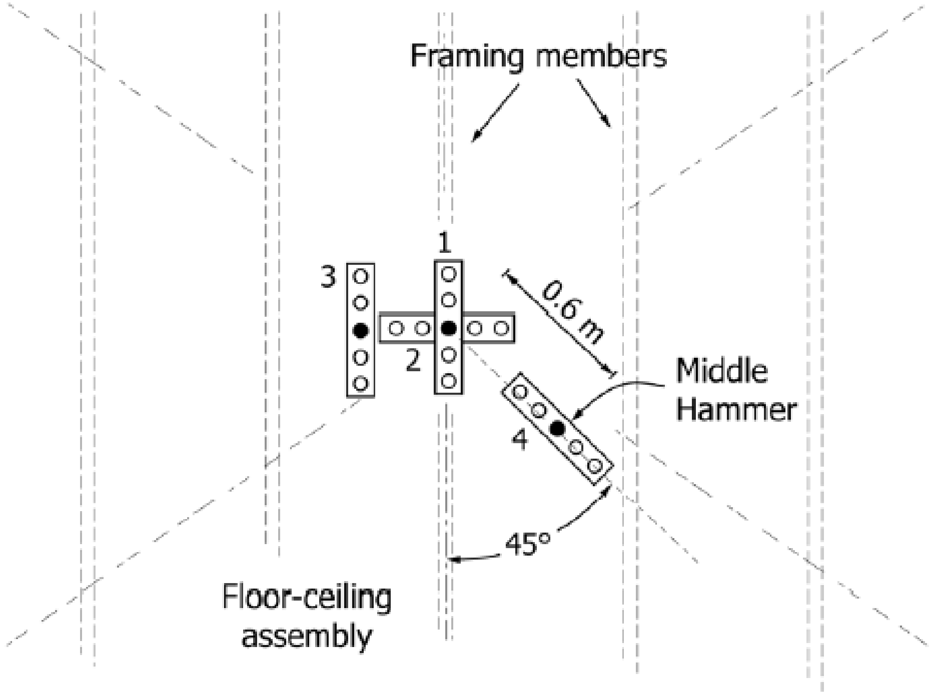
To ensure direct comparability between all ASTM E2179 tests, the choice was made to have a 6” concrete slab as the default floor system. For this reason, the title of the standard clearly states that the effectiveness that is being measured is specific to concrete floors. Discussions are ongoing within the ASTM E2179 task group to potentially increase the scope of the test method to include a lightweight wood structure option (essentially allowing one to calculate a ΔIIC rating for lightweight structures, rather than concrete structures), but this has not become a reality (for now, at least).

One recent addition to the test standard that is important to note is the addition of high-frequency impact metrics. With the adoption of high-frequency impact metrics (HIIC and DHIIC) into ASTM standards in 2020, the potential for inclusion of high-frequency analysis within this test standard (as well as ASTM E492) was immediately discussed. The high-frequency metrics seemed particularly well-fit for inclusion within the ASTM E2179 test standard, because historical data clearly demonstrates that floor coverings largely have very little effect on impact sound transmission performance in the lower frequency range (below 400 Hz). Further investigation into this showed that the newly-created DHIIC metric not only aligned with existing ΔIIC ratings, but in many cases more effectively showcased the audible high-frequency differences between products that were otherwise not captured by the ΔIIC metric alone due to low frequency noise limiting the ratings. For this reason, DHIIC was officially included as a reported metric for ASTM E2179 testing in 2025.

Since its creation in 2001, the ASTM E2179 test method and the ΔIIC rating have been utilized by floor covering manufacturers to easily and simply identify the acoustic performance of their products, allowing for clear identification of performance and easy comparison of competing products. As the science behind these measurements and methods continues to develop, this method of standardized comparative testing is now being proposed as an option for future new standards for other products as well. Within the floor covering world, a new standard is currently being developed for identifying the added effectiveness of topical underlayment products, which features a similar method of calculating the added benefit of these products. This potential development of future standards for use in characterizing the specific acoustic benefits of the individual elements of building

Jordan Strybos calibrating a microphone prior to an ASTM E2179 test





Tapping Machine Positions for ASTM E492 / ASTM E2179 test

partitions will become quite helpful (especially when used in conjunction with STC and IIC ratings for characterizing the overall acoustic performance of a partition) for more-fully understanding building design, and utilizing this understanding to improve productivity and quality of life, in the workplace and at home.

About the author

Jordan Strybos is a Project Engineer at Intertek's acoustical testing facility in York, PA. He oversees the Vertical Transmission (VT) test chambers, specifically focusing on floor/ceiling acoustics. Jordan has been overseeing the operations of York's VT chambers for over 10 years and has been heavily involved in the ASTM E33 committee since 2018, chairing several task groups and serving as subcommittee vice-chair and secretary for the E33.10 subcommittee on Impact Noise and Vibration. The lab at Intertek-York is a state-of-the-art facility that provides highly-efficient testing, excelling in both project-specific test programs and broader-ranging research projects. The VT chambers at Intertek-York offers a lab testing environment for anyone interested in conducting testing per ASTM E90, ASTM E492, ASTM E2179, ASTM E1222, ASTM E1414, ISO 10140, and ISO 15665. ■

International Guides to Measuring Heavy/Hard Impact Noise and the Need for Standardization in North America

By **Wilson Byrick,** *BESc., VP Engineering Services, Pliteq, wbyrick@pliteq.com*

Disturbing noise and vibration caused by fitness activities is a key design consideration for acoustical engineering professionals. Impact noise classified as heavy/hard impact can be particularly difficult to mitigate. While most acoustical design firms have procedures in place to complete site testing and make recommendations, there is no standard to follow. This lack of standardization can result in conflict between owners and tenants and the engineers that represent them. In this article, I will attempt to summarize the international guidelines that exist to highlight the need for standardization in North America.

Association of Australasian Acoustical Consultants (AAAC) Guideline for Acoustic Assessment of Gymnasiums and Exercise Facilities

The AAAC guidelines were developed with the objective of establishing clear procedures for the measurement, prediction, and assessment of noise and vibrations. These guidelines are not regulatory, but are intended to serve the purpose of test data being consistent, accurate, and not misleading. There exists a guideline for Gymnasium and Exercise Facility assessment.

While there is no standard weight or drop height outlined within this guideline, the testing procedure is recommended to simply be consistent with the planned activities in the space. A frequency range of 31.5 - 250 Hz octave bands is considered, A-weighting is applied and a minimum of four drops are suggested. The fast max sound pressure level measured at these four octave bands is converted into a single number rating by applying a logarithmic average (Equation 1)

$$L_{AFmax(\Sigma Oct,31.5-250hz)} = 10log \sum_{i=1}^{N} 10^{0.1L_{A_i}} \quad (1)$$

L_{Ai} = A-weighted sound pressure level at octave band frequency i (dBA)

Acceptable sound pressure levels due to exercise-related vibration-borne sound, for residential and non-residential applications are indicated below.

Residential Receivers:

$L_{AFmax(\Sigma Oct,\ 31.5\ -\ 250Hz)} \leq$ 35 dB for daytime

$L_{AFmax(\Sigma Oct,\ 31.5\ -\ 250Hz)} \leq$ 30 dB for evening

$L_{AFmax(\Sigma Oct,\ 31.5\ -\ 250Hz)} \leq$ 25 dB for night-time

Non-Residential Receivers:

$L_{AFmax(\Sigma Oct,\ 31.5\ -\ 250Hz)} \leq$ 40 dB for general uses

$L_{AFmax(\Sigma Oct,\ 31.5\ -\ 250Hz)} \leq$ 35 dB for sensitive uses

$L_{AFmax(\Sigma Oct,\ 31.5\ -\ 250Hz)} \leq$ 30 dB for critically sensitive uses

Within this guideline, daytime is defined as 7:00 am to 6:00 pm, evening, 6:00 pm to 10:00 pm and night-time 10:00 pm to 7:00 am (8:00 am on Sundays and public holidays). Establishing a receiver as general, sensitive, or critically sensitive requires justification from an acoustical consultant.

IOA/ANC – ProPG Gym Acoustics Guidance

Professional Practice Guidance on gym acoustics (ProPG GAG), is a document developed in the United Kingdom by the **Institute of Acoustics (IOA)**, the **Association of Noise Consultants (ANC)** and the Chartered Institute of Environmental Health (CIEH) to provide a standardized approach for assessing the acoustic impact of gymnasiums, fitness centers, and other exercise spaces. The guidance aims to help manage noise and vibration, assess new or existing gym locations, and resolve noise complaints by offering a consistent methodology for the design and assessment of such facilities.

The International Organization for Standardization developed Noise Rating (NR) curves to set a standard for an acceptable sound pressure level in receiving spaces due to external sound. Noise Rating is determined by comparing the sound pressure level of a data set across octave bands for the frequency range of 31.5 - 8000 Hz with the NR curves. These are like the NC curves widely used in North America but allow higher levels at low frequency.

The ProPG guideline was developed based on the authors' interpretation of said curves, to form G-curves, which are more appropriate for fitness-related noise as well as higher resolution by using one-third octave bands across the same frequency range. The overall rating for an assembly is the highest individual rating of the data set (Equation 3). The target ratings for various receivers are presented in Table 3.

$$G_i = \frac{L_i - A}{B} \quad (3)$$

G_i = G-curve rating at ⅓ octave band frequency i (dB)
L_i = sound pressure level at ⅓ octave band frequency i (dB)
A_i = frequency-dependent coefficient at ⅓ octave band frequency i (unitless, see Table 3)
B_i = frequency dependent coefficient at ⅓ octave band frequency i (unitless, see Table 3)

Table 3: Target rating of assembly for various receiving spaces [5]

Receiver	Heavy Impact Sound L_{Fmax} (31.5 - 8000 Hz)
Commercial Offices	G35-G40
Retail Areas	G35-G50
Residential Areas	G20-G25 (day) G15-G20 (night)

Regarding the testing procedure, the Guide presents two methodologies: Method One involves dropping a 20 - 35 kg spherical impactor from a height of 500 mm, and method 2 testing is like AAAC, where the goal is to measure realistic anticipated/existing resulting noise levels that is representative of the proposed gym activity in the space.

ASTM WK90900

While ASTM has not published anything, there is work being done and sub ballots being voted on. A draft of an ASTM measurement standard is in process, the Standard Guide for Field Measurement of Impact Sound and Vibration Transmission Through Floor-Ceiling Assemblies and Associated Structures When Using Heavy-Hard Impact Objects. It specifies measuring the fast max sound pressure level in a receiving space across a minimum frequency range of 50 - 500 Hz one-third octave bands. The procedure requires that a spherical impactor at a mass of 3, 7.26, or 22.68 kg is dropped from a height of 50 cm.

There currently are no criteria or single number rating derived from this method to assess the performance of an assembly. It is anticipated that a separate standard

will be developed to assign single-number ratings to the performance of these assemblies and associated criteria.

The need for standardization

Acoustical engineers the world over design buildings with heavy/hard impact noise and vibration in mind. Some of the guidelines presented in this article also have information related to vibration which was not addressed here. Numerous groups including the International Green Building Council and ISO noise regulations stipulate noise levels not to be exceeded in receiving spaces. Perhaps these can form a basis of recommendations for performance criteria resulting from standardized heavy/hard impact testing defined by the proposed ASTM WK90900 procedure. A summary table of all the guidelines and criteria relevant to the topic is included below.

Table 8: Summary of various standard testing and analysis methods

Standard	Data analyzed	Frequency range	Drop height specified	Impactor weight specified	Requirement/ Guideline
AAAC	L_{AFmax}	31.5- 250 Hz	Not specified	Not specified	Yes
ASTM	L_{Fmax}	50 - 500 Hz	50 mm	3, 7.26 or 22.68 kg	No
ISO NR	L_{Fmax}	31.5 - 8000 Hz	Not specified	Not specified	Yes
IgCC	dBA/dBC	20 - 2000 Hz	No	No	Yes
IOA/ANC	L_{Fmax}	31.5 - 8000 Hz	Method 1: 50 mm Method 2: Not specified	Method 1: 20 - 35 kg Method 2: Not specified	Yes

More information regarding this article can be found in the NoiseCon 2024 published paper entitled Applying the Association of Australasian Acoustical Consultants (AAAC) guideline for acoustic assessment of gymnasiums and exercise facilities to field measured heavy hard impact data. (Byrick, Edwards 2024) ■

Setting the Standard: AHRI's Role in Shaping the Sound of HVACR

By **Jacob (Cobi) Waxman,** *Standards Manager, AHRI;* **Derrick Knight,** *Lead Acoustic Engineer, Trane Technologies;* **Paul Bauch,** *Engineering Manager, Sound & Vibration, Johnson Controls;* **Regan Spencer,** *Communications Manager, AHRI;* **Ali Burke,** *Graphic Artist, AHRI*

When you step into a library, a hotel room, or an office building, you may not think twice about the hum of an air handler or the drone of a rooftop chiller. Yet those background sounds, and whether they fade unnoticed or intrude on daily life, are shaped in large part by decades of work from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and its member companies. AHRI's sound standards give manufacturers, engineers, regulators, and building owners a common framework to measure, compare, and address equipment noise.

A History of Sound at AHRI

AHRI's involvement in acoustics standards dates back more than 60 years. In 1959, the then-Air-Conditioning and Refrigeration Institute formed a committee on sound to address rising public concern over noise created by HVACR equipment. By 1967, AHRI had issued its first sound rating standard: ARI Standard 270–1967, Standard for *Sound Rating of Outdoor Unitary Equipment*. A few years later came ARI Standard 575–1973 *Method of Measuring Machinery Sound Within Equipment Rooms*.

Fast forward to today, and AHRI's Sound Standards Technical Committee (STC) now oversees an expanding portfolio of 14 active standards that are developed and updated to address evolving industry needs.

Why Sound Standards Matter

Why do sound standards exist in the first place? The answer is two-fold: to ensure fair competition among manufacturers and to provide reliable data that designers and regulators can use to make good decisions.

Left to their own devices, each manufacturer might test and report sound levels in its own way, making "apples-to-apples" comparisons nearly impossible. AHRI standards solve that problem by outlining consistent test conditions and reporting methods, outlining requirements for collecting data through several test methods, including reverberation rooms, free-field setups, or sound intensity mapping.

An often-understated advantage of product sound rating standards, specifically, is that equipment manufacturers are encouraged to collect substantial sound data on their products to compete. This price of entry into the market pushes manufacturers to invest in testing facilities that are also used for product development projects, leading to quieter designs and a variety of noise control features. As more AHRI sound standards are adopted, companies will follow with lower-noise products to compete, pushing the industry forward.

Categories of AHRI Standards

AHRI's sound standards fall into three main categories:

Test Standards, which specify laboratory methods and the required details for testing setup.

Rating Standards, which cover the scope of equipment, operating conditions, and reporting requirements. These standards make the so-called "apples-to-apples" comparison possible by establishing a benchmark approach that can achieve reliable results across manufacturers.

Application Standards, which provide guidance on how to use ratings data for specific installations, accounting for both environmental and construction detail to help predict what occupants will actually hear. These standards are often used to predict sound pressure levels for a given installation where rating standards all produce sound power levels.

Test Standards

Ratings for HVAC equipment start with a basic understanding of how the equipment is tested. There are three general categories of test standards: comparison method in a reverberation room, sound intensity, and sound pressure in a free-field. Table 1 is an overview of all the test standards referenced by AHRI sound standards.

One of AHRI's objectives is to ensure that all AHRI sound standards methods-of-test have equivalent uncertainty (reproducibility). Thus, when these standards are referenced, there is no question about the "grade" or quality of the test data. Figure 1 shows several test environments and methods of test that satisfy AHRI standards.

Figure 1: (a) Reverberation room used for testing HVAC equipment in accordance with AHRI 220 (b) Microphone grid for sound testing air-cooled chiller in a free-field according to AHRI 370 (c) AHU testing using sound intensity in accordance with AHRI 230 (d) Microphone grid for sound testing water-cooled chiller in a free-field according to AHRI 1280. Photos Courtesy of Johnson Controls

Table 1: AHRI methods of test for sound standards.

METHOD OF TEST	AHRI SOUND RATING STANDARD							
	260	270	300	350	370	575	880	1280
REVERBERATION ROOM								
AHRI 220, AHRI 250 (RSS), ASHRAE 130[A]	✓	✓	✓	✓	✓		✓	✓
SOUND INTENSITY								
AHRI 230[B], ISO 9614-PARTS 1&2	✓	✓	✓	✓	✓			✓
FREE-FIELD								
ISO 3745[C], ISO 3744[C]					✓			✓
SOUND TRANSMISSION								
ASTM E90 (TL), ASTM E413 (STC), ASTM E1332 (OITC)			✓					
SOUND PRESSURE								
AHRI 575						✓		

[A] *AHRI 880 setup & configuration per ASHRAE 130. Sound power determination per AHRI 220.*
[B] *Historically ISO 9614 was used until AHRI 230 was introduced.*
[C] *As adapted for large AC chillers in Appendix D of AHRI 370.*

Table 2: AHRI equipment sound rating standards.

EQUIPMENT TYPE	AHRI SOUND RATING STANDARD							
	260	270	300	350	370	575	880	1280
Air Handling Units, Fan Coils, etc.	✓			✓				
Water-Cooled Chillers [A]						✓		✓
Air-Cooled Chillers		✓			✓			
Outdoor Condensing Units		✓			✓			
Air-Terminal Devices							✓	
Water Source Heat Pumps	✓			✓				
Ducted Packaged Equipment								
Indoor	✓							
Outdoor		✓			✓			
PTAC/PTHP			✓					
Heat Pump Water Heaters		*	*					
OCTAVE BAND SOUND POWER								
Lw (63 – 8000 Hz)	✓	✓[B]	✓[B]	✓[B]	✓			✓
Lw (125 – 8000 Hz)		✓	✓	✓				
Lw (125 – 4000 Hz)							✓	
LwA		✓		✓	✓			
TL, STC and OITC			✓					
OCTAVE BAND SOUND PRESSURE								
Lp (63 – 8000 Hz)						✓		
LpA						✓		

[A] *AHRI Standard 575 is not a rating standard, but it is used like one. Standard 1280 is the appropriate rating standard for water-cooled chillers.*
[B] *Denotes that the 63 Hz band is optionally rated in the standard.*
* *Denotes that these standards are in development for this product type.*

Ratings Standards

AHRI ratings standards consider variable operating conditions. Determination and stability of the operating point can be a significant cause of variability in sound test data between laboratories. Catalog sound ratings are required at the standard thermal rating conditions for the type of equipment. Some standards, such as AHRI 260, offer guidance on reporting sound across the full operating range of the unit.

Application Standards

Application standards are often used to predict sound pressure levels (what you hear) for a given installation, whereas rating standards all produce sound power levels (what the equipment emits). AHRI Standards 275, 575, and 885 provide a good starting point for application guidance. For more detailed analyses refer to the ASHRAE Application Handbook or a qualified acoustic consultant.

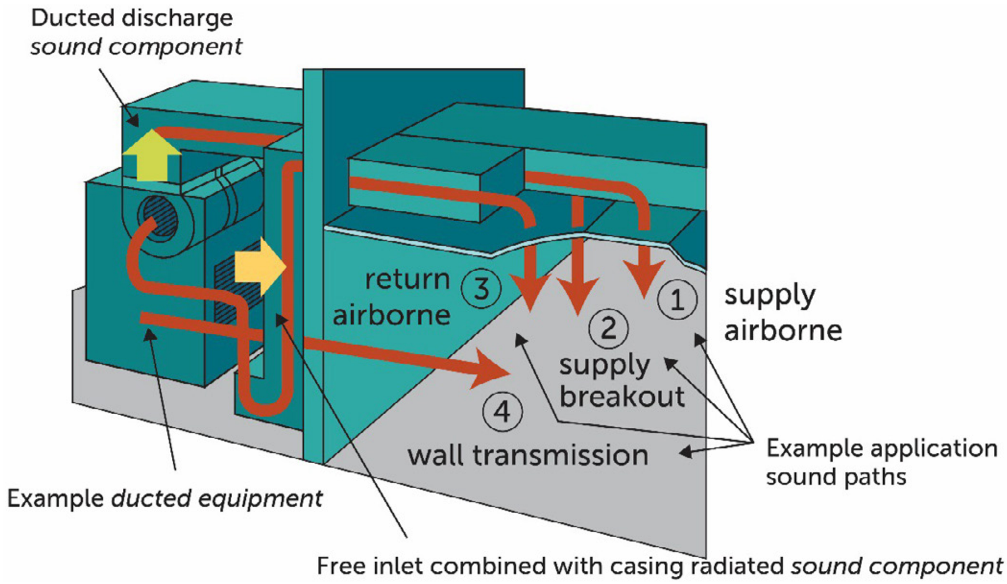


Figure 2: Example of a Ducted Product Application from AHRI Standard 260.

Discerning readers might recognize that AHRI Standard 575 (SI/I-P), *Method of Measuring Machinery Sound Within an Equipment Space*, is an applications standard, even though it is included in the rating standard table. AHRI Standard 575 is the only rating standard that reports sound pressure levels. It was originally written to define a method of measuring the sound pressure level in equipment rooms, where the risk of hearing loss was the primary concern. AHRI Standard 575, which has since been replaced in part by AHRI Standard 1280, remains a useful tool for measuring noise in the field.

Sound Power vs. Sound Pressure

Standards must consider both sound pressure and sound power. When determining sound pressure, manufacturers must account for the environment in which the equipment is being used and the listeners' distance from the equipment, neither of which they can control. However, when equipment manufacturers report sound power at the selected operating point, building designers are then able to use that data to predict sound pressure levels in the unique building being designed.

AHRI Standard 260 defines many sound components so as to standardize how manufacturers separate out the sound power around the idea of sound paths. That way, designers can propagate each sound power component along its unique sound path to a listener. The paths are added into a single value, but can then be individually optimized with changes to the path design to focus attenuation on the loudest path. Figure 2 shows an example of how AHRI Standard 260 data could be used to predict sound in an occupied space.

For example, air handlers are often found far from listeners. Measuring the total power emitted from an air handler is possible, but not very useful for building designers. Some portion of the sound power will be sent to the space via the supply ductwork (Figure 3), another portion will be sent via the return ductwork (Figure 4), and some radiates directly from the casing (Figure 5). Each of these sound paths will have different effects, which need to be accounted for in building design.

What's Next?

As mentioned above, AHRI's portfolio of active standards regularly evolves to meet industry needs. To do this, the member companies working to maintain AHRI sound standards are also engaged with customers and design engineers to make sure the industry delivers the information needed for intelligent design decisions. As the population and economy require new structures, we are able adapt to promote both efficiency and human comfort.

Recently, AHRI and member companies have begun exploring the idea of directionality in sound, specifically in relation to AHRI 370, which measures total sound power emission of large outdoor equipment (Figure 6) that can have significant community impact. There is a growing demand for this type of information as the landscape of new building construction changes. For example, consider dozens of air-cooled chillers installed on the roof of a data center (Figure 7). If sound propagates unevenly, designers need to know, so that they can build sound attenuation to meet noise codes.

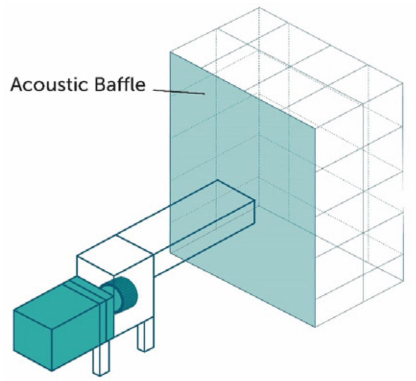


Figure 3: Sound power sent through supply ductwork

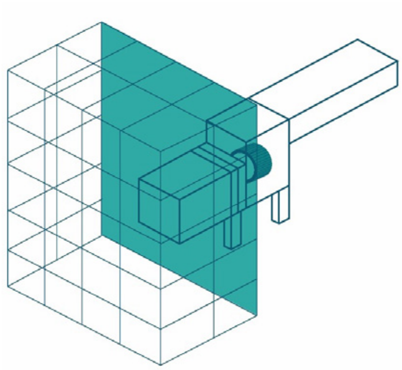


Figure 4: Sound power sent through return ductwork

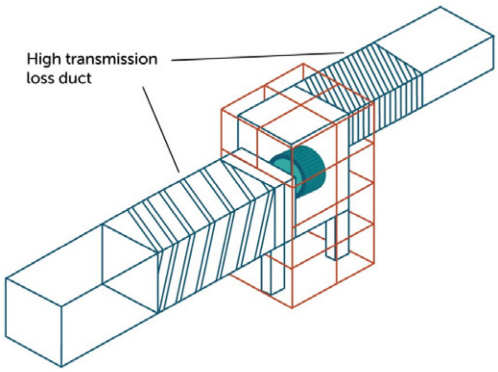


Figure 5: Sound power sent through casing

However, large sound blocking walls are expensive and greatly increase the embodied carbon both from the construction of a sound wall and the building's enhancement required to support the added weight. In addition, tall sound walls can impede the airflow of the chillers, reducing their efficiency. This means it is essential for building designers to have access to directionally accurate sound power data to optimize designs.

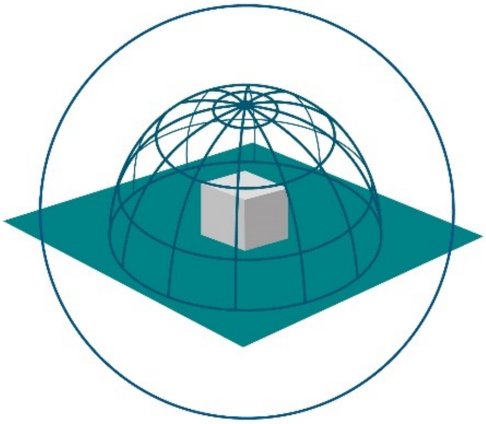


Figure 6: Measuring directionality of sound

These new efforts reflect the continuous commitment of AHRI and its member companies in advancing the field of sound standards. As the industry adapts to meet the changing needs of building design and other emerging fields, AHRI's work on sound will remain an important component in ensuring that decisions are made with reliable data that promotes innovation and intelligent design.

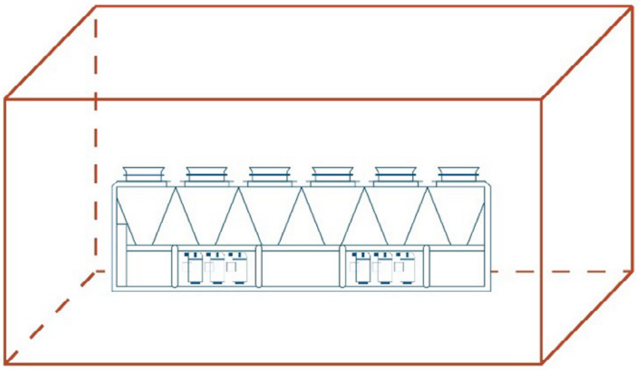


Figure 7: Air-Cooled Chillers are a popular choice for use in data centers.

A North American association with global interests and services, AHRI serves its membership of 325-plus HVACR and water heating equipment manufacturers through operations in the United States, Canada, China, UAE, India, Mexico, and Singapore.

AHRI members manufacture quality, efficient, and innovative HVACR equipment and components for sale around the world. These products account for more than 90 percent of the residential and commercial equipment manufactured and sold in North America.

Through AHRI's certification, standards, advocacy, and analytics programs and more, we help ensure safety, comfort, and productivity for all. For more information on AHRI's portfolio of 100+ performance standards and guidelines, visit our website: ahrinet.org/standards. ■

Sound insulation measurements according to ISO standards

By **Jens Holger Rindel**

Origin of ISO methods for sound insulation measurements

Sound insulation in buildings can basically be divided into two different kinds of measurements, the airborne sound insulation between two rooms and the impact sound transmission through a floor construction. While it is relatively straight forward to provide a loud sound source for the airborne sound insulation measurement, it is trickier how to generate a well-defined impact sound source. Forerunners of the tapping machine, which is used today for the impact sound measurements were developed around 1940 independently in Germany[1,2] and America[3]. Measurements were made either as a broad-band level in Phon or in octave bands.

The first ISO recommendation for sound insulation measurements ISO R 140 appeared 1960.[4] For measurements in a laboratory, any flanking transmission should be avoided. In all cases, measurement results should be adjusted to a reference absorption in the receiving room. The airborne sound insulation could be expressed either as the normalized level difference D_n (using 10 m^2 as the reference absorption area), or as the sound reduction index R (Transmission Loss in American terminology) in dB:

$$R = L_1 - L_2 + 10 \lg (S/A)$$

where L_1 and L_2 are the average sound pressure levels in the source room and in the receiving room, respectively, S is the area of the test specimen, and A is the absorption area of the receiving room. While R was meant for laboratory measurements of building elements, the D_n was meant for field measurements where some flanking transmission is unavoidable. However, for comparison

1 DIN 4110 (1938).

2 M. Schneider, H.-M. Fischer, B. Zeitler (2025). Development of Sound Insulation Requirements in German DIN 4109. Proceedings of DAS/DAGA 2025, Copenhagen, Denmark, 259-262.

3 R. Lindahl & H.J. Sabine (1940). Measurement of impact sound transmission through floors. JASA 11, 401-405.

4 ISO R 140 (1960). Field and laboratory measurements of airborne and impact sound transmission.

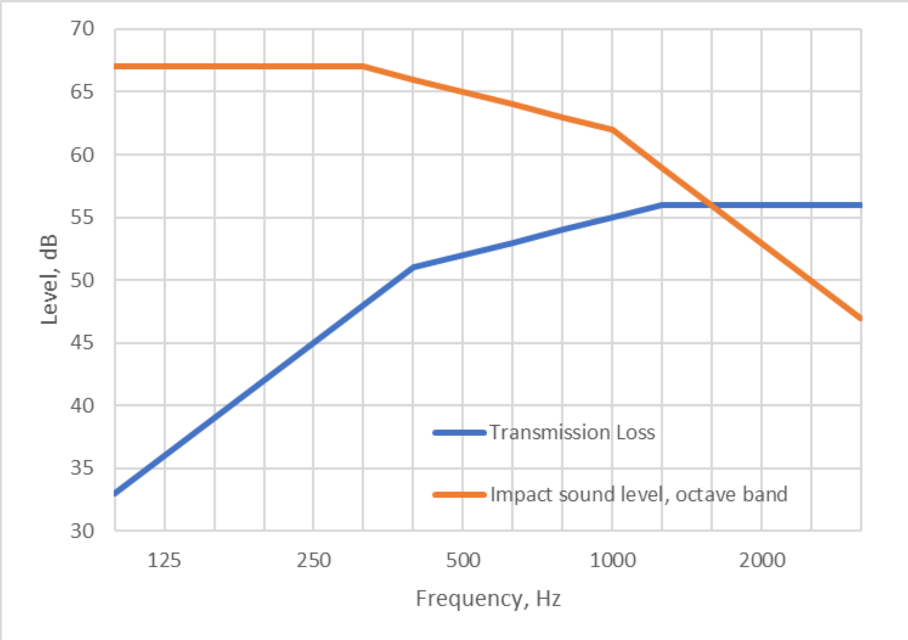


Figure 1. The weighting curves for airborne and impact sound transmission in ISO R 717 (1968). NB: In the current ISO standard, the curve for impact sound transmission is 5 dB lower.

with laboratory results, the field measurements could also be expressed as an apparent sound reduction index *R*'.

The impact sound transmission is expressed as the normalized impact sound pressure level *Ln* in dB:

$$L_n = L - 10 \lg (A_0/A)$$

where *L* is the average sound pressure level produced by the tapping machine in the receiving room, $A_0 = 10\ m^2$, and *A* is the absorption area of the receiving room.

Measurements should be made in octave bands (center frequencies from 125 Hz to 4000 Hz), or in 1/3 octave bands (center frequencies from 100 Hz to 3200 Hz). Measurement results should be reported as function of frequency in tables or graphs.

International methods for deriving single-number values from the measurement results were established 1968 in the ISO recommendation ISO R 717.[5] The principle is that a frequency-dependent weighting curve is compared with the measured curve of sound insulation, adjusted up and down to fulfill some rules for a fit, and in addition the unfavorable deviation at any frequency should not exceed 8 dB. The single-number index was the value of the shifted reference curve at 500 Hz, see Figure 1. The results were the airborne sound insulation index I_a and the impact sound index I_i. The measurements should preferably be made in 1/3 octave bands. However, impact sound levels could either be measured in octave bands, or the 1/3 octave band levels should be corrected to octave band levels by adding 5 dB.

It is remarkable, that ISO R 717 refers specifically to field measurements, but the normalized level difference D_n is not mentioned. The measures to be evaluated are the apparent sound reduction index *R*' and the normalized impact sound pressure level. The proposal was very similar to the German practice at the time, but several countries voted against the proposal, probably because they were using the normalized level difference in the building codes. However, ISO R 717 was accepted by the majority as an international standard.

Current ISO standards on sound insulation

Measurements

The measurement methods are basically the same as in the first recommendations from 1960, although some details have been further developed. The current measurement methods on sound insulation are divided into laboratory measurements on building elements and performance measurements in the field. In addition to the impact sound insulation of floor constructions and the airborne sound insulation of partition walls or floors, there are methods for the sound insulation of windows and facades. An overview of the relevant current ISO and ASTM standards is presented in Table 1[6].

5 ISO R 717 (1968). Rating of sound insulation for dwellings.
6 J.H. Rindel (2018). Sound insulation in buildings. CRC Press, Taylor & Francis Group, Boca Raton, London, New York.

	Building elements measured in a laboratory	Performance measurements in the field
Airborne sound insulation, walls and floors	ISO 10140-2 (2021) ASTM E90-23	ISO 16283-1 (2014) ASTM E336-25
Airborne sound insulation, windows and façades	ISO 10140-2 (2021) ASTM E90-23	ISO 16283-3 (2016) ASTM E966-18
Impact sound insulation	ISO 10140-3 (2021) ASTM E492-25	ISO 16283-2 (2020) ASTM E1007-25

Table 1. International (ISO) and American (ASTM) standards for measurement of sound insulation. (Adapted from Rindel 2018, Table 12.1).

The frequency range of measurements in a laboratory is in 1/3 octave bands from 100 Hz to 5000 Hz, optionally down to 50 Hz. Field measurements are made from 100 Hz to 3150 Hz, optionally down to 50 Hz and including also 4000 Hz and 5000 Hz.

Single number values

Single-number values for sound insulation are defined in ISO 717. The current version of ISO 717 from 2020 is divided into two parts for airborne and impact sound insulation, respectively. The weighting curves in Figure 1 are kept, except that the curve for impact sound is shifted down by 5 dB when applied to 1/3 octave band measurements. The former 8 dB rule for maximum unfavorable deviation is no longer in the standards.

For laboratory measurements of airborne sound insulation, the main result is the weighted sound reduction index R_w, which is approximately equal to the sound transmission class STC as defined in ASTM E413-16. The weighting curve for STC is the same as in ISO, except that the frequency range is from 125 Hz to 4000 Hz and the 8 dB rule is applied.

The main result of a laboratory measurement of the impact sound transmission is the weighted impact sound pressure level $L_{n,w}$. This can be compared to the impact sound insulation class IIC as defined in ASTM E989-06. The frequency range and the weighting curve is the same as in ISO, but the 8 dB rule is applied. The IIC number is approximately equal to 110 dB - $L_{n,w}$. Thus, a floor with good impact sound insulation is represented by a low value of $L_{n,w}$ but a high value of IIC.

Normalized or standardized measures

When it comes to field measurements of sound insulation, the ISO standards open up for two options: Either the normalized results using a reference absorption area as in laboratory measurements, or the standardized results using an adjustment to a reference reverberation time of 0.5 s in the receiving room. The airborne sound insulation can be expressed either as the weighted apparent sound reduction index R'_w or as the weighted standardized level difference $D_{nT,w}$. Similarly, for impact sound measured in a building, the result can be expressed either as the weighted normalized impact sound pressure level $L'_{n,w}$ or as the weighted standardized impact sound pressure level $L'_{nT,w}$. As could be expected, the result is that some countries are using the normalized measures in their building codes, while other countries are using the standardized measures.

Spectrum adaptation terms

Since the 1996 edition of ISO 717, there has been a set of spectrum adaptation terms that apply to the weighted single-number results. For the airborne sound insulation this can be seen as a compromise between German and French methods. While the method with the weighting curve has a German origin, the traditional French method was to calculate the A-weighted level difference assuming a certain spectrum of the sound in the source room. These measures were called R_{rose} and R_{route}, referring to a pink noise spectrum or a road traffic noise spectrum, respectively. With the spectrum adaptation terms C and C_{tr} defined in ISO 717, it was possible to make the following relationships:

$$\mathrm{R_{rose}} \cong \mathrm{R_w} + \mathrm{C} \quad \text{and} \quad \mathrm{R_{route}} \cong \mathrm{R_w} + \mathrm{C_{tr}}$$

	Frequency range 100 Hz – 3150 Hz	Extended frequency range
Normalized airborne sound insulation	R'_w or $R'_w + C$	$R'_w + C_{50\text{-}3150}$
Standardized airborne sound insulation	$D_{nT,w}$ or $D_{nT,w} + C$	$D_{nT,w} + C_{50\text{-}3150}$
Normalized impact sound insulation	$L'_{n,w}$ or $L'_{n,w} + C_I$	$L'_{n,w} + C_{I,50\text{-}2500}$
Standardized impact sound insulation	$L'_{nT,w}$ or $L'_{nT,w} + C_I$	$L'_{nT,w} + C_{I,50\text{-}2500}$

Table 2. Some possible measures for sound insulation in dwellings according to ISO 717 part 1 and 2.

The relationships can be made exact if the spectrum adaptation terms include the frequencies up to 5000 Hz. Then the spectrum adaptation term for R_{rose} is written $C_{100\text{-}5000}$.

The introduction of spectrum adaptation terms opened up for extension of the frequency range applied in the evaluation of measured sound insulation. Thus, it became a way to include frequencies below 100 Hz without changing the weighting curves. For airborne sound insulation, the spectrum adaptation term $C_{50\text{-}3150}$ means that the 1/3 octave bands 50 Hz, 63 Hz, and 80 Hz are included in the evaluation using a pink noise spectrum. The importance of including the low frequencies in airborne sound insulation between dwellings has been documented in several research projects.[7]

A spectrum adaptation term has also been defined for impact sound insulation, denoted C_I. It normally covers the frequency range 100 Hz to 2500 Hz and is so defined, that it is close to zero for massive floors with an effective floor covering, while it becomes positive for timber joist floors with domination low frequency transmission. With extended frequency range down to 50 Hz the impact spectrum adaptation term is $C_{I,50\text{-}2500}$. When added to the weighted impact sound pressure level, the result has been shown to correlate well with subjective evaluation of floor constructions, lightweight as well as heavyweight with or without a floating floor on top.[8] The referred investigation also showed that the weighted impact sound pressure level without the $C_{I,50\text{-}2500}$ adaptation term had no correlation at all with the subjective evaluation. This emphasizes the importance of including the low frequencies in measures for impact sound.

With all possible combinations of normalized or standardized measures and possible extended frequency ranges, see Table 2, the ISO methods for evaluation of sound insulation has become like a catalogue of options, far from harmonization.[9]

Method for low frequencies in small volumes

The extended frequency range below 100 Hz raises an issue about how to measure a meaningful average sound pressure level in small volumes, because the modal density is low and the sound field is far from being a diffuse sound field at these low frequencies. In volumes smaller than 25 m^3 a special low-frequency procedure is prescribed in ISO 16283-1 for the 50 Hz, 63 Hz, and 80 Hz 1/3 octave bands. In addition to measurements in the central zone of the room, the sound pressure level is measured in a corner of the room. The energy-averaged sound pressure level is calculated with 1/3 weighting factor on the corner result and 2/3 weighting factor on the central result.

The measurement of reverberation time at these low frequencies may be difficult or even impossible. Therefore, the low-frequency procedure prescribes that the reverberation time at the 63 Hz octave band is measured and applied to the 1/3 octave bands 50 Hz, 63 Hz, and 80 Hz.

7 J.H. Rindel (2017). A Comment on the Importance of Low Frequency Airborne Sound Insulation between Dwellings. Acta Acustica/Acustica 103, 164-168.

8 C.O. Høsøien, J.H. Rindel, A. Løvstad, R. Klæboe (2016). Impact sound insulation and perceived sound quality. Proceedings of InterNoise 2016, Hamburg, Germany, 903-910.

9 B. Rasmussen & J.H. Rindel (2005). Concepts for evaluation of sound insulation in dwellings – from chaos to consensus? Proceedings of Forum Acusticum, Budapest, Hungary, 2081-2092.

Windows and facades

Field measurements of the sound insulation of windows and facades are described in ISO 16283-3. There are two different kinds of measurement, the global method that evaluates the entire façade, and the element method that evaluates a particular building element (a window).

The sound source can be either the traffic noise at the location or a loudspeaker in a prescribed outdoor position. For the global method, the traffic noise source is preferred. The outdoor sound pressure level $L_{1,2m}$ is measured 2 m in front of the façade, and the indoor sound pressure level L_2 is measured as a spatial average using a moving microphone or five fixed microphones. Measurements are made in 1/3 octave bands and the result can be the standardized level difference:

$$D_{2m,nT} = L_{1,2m} - L_2 + 10 \lg(T/T_0)$$

where T is the reverberation time and T_0 = 0.5 s.

Measurements after the element method should preferably be made with a loudspeaker that emit sound towards the element at an angle of 45°. The outdoor sound pressure level $L_{1,s}$ is measured at the surface of the test element (window), while the indoor sound pressure level L_2 is measured as usual. The results can be the apparent sound reduction index at 45°:

$$R'_{45^\circ} = L_{1,s} - L_2 + 10 \lg(S/A) - 1.5 \text{ dB}$$

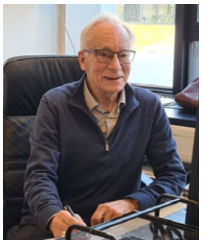
where S is the area of the test element and A is the absorption area of the receiving room.

Single-number results can be derived using the spectrum adaptation term for traffic noise C_{tr} with normal frequency range or extended frequency range.

Summary

This article is a brief overview of the ISO methods for measuring and evaluating sound insulation in a laboratory and in the field. Several more special kinds of measurements exist but have not been mentioned here. That includes measurement of flanking transmission through junctions, walls, suspended ceilings, etc.

About the author



Jens Holger Rindel has more than 50 years of experience in architectural acoustics and has been professor in acoustics at the Technical University of Denmark until 2007. He is the founder of Odeon A/S developing room acoustics software. He is a Fellow of the Institute of Acoustics and of the Acoustical Society of America, and Honorary Member of the acoustical societies of Denmark and Norway. He has published textbooks on building acoustics and on architectural and environmental acoustics. He was chairman of the Technical Committee for Building and Room Acoustics of European Acoustics Association 2001-2007. For more than 35 years he has been involved in international standardization and has been convenor of several ISO working groups. In 2000-2006 he was the leader of EU-projects within cultural heritage studying the acoustics of ancient worship spaces and Roman theatres. ■

Noral Stewart on Acoustics and Noise Control

Let's go back to the beginning: How did you first become interested in Acoustics?

"It was something that sort of hit me in the face. I never grew up thinking much about acoustics. I went to NC State to study mechanical engineering. I know for a fact that when I was a high school senior I did not know what an octave was.

I was not doing very well my freshman year in my mind, and in the fall of my sophomore year I got called to the departmental office along with a few other guys. They asked who was interested in a summer job in the acoustics group at NASA Langley — and of course I was.

We went up there, and the NASA staff (group headed by Harvey Hubbard) taught us classes in acoustics that summer. I was working on a project on a jet engine compressor stage. One day while we were running the engine in different conditions, the technician, who was an older guy, suddenly started saying that something was wrong. His microphones weren't picking up anything. My manometers still showed pressure, but the dang thing had gone quiet. Nobody anticipated it.

That got me hooked. I went back to school, a young professor starting an acoustics program arranged classes for us and more summer jobs. I was on my way."

What other pivotal moments shaped your approach to Acoustics?

"As a consultant, it is very important to work on your ability to communicate. Right after my bachelor's, I wasn't working in acoustics. I had a job that forced me to write letters, meet with high-level management and sometimes tell them they didn't know what they were doing — gracefully. I consider this a very important part of my education.

The company I was working for started a scholarship program and I got selected for a scholarship for a master's degree. I wasn't planning on doing a thesis, but I wound up working on a project that needed security clearance, and thankfully I already had it! I worked on punch press noise, and I finished my master's in 13 months.

Then the university offered me a position on a new research project on noise control in the textile industry. My employer — the Bell System — told me to take it because 'there's not going to be any future for you here.' Because they knew the company may be coming to an end.

My early work was noise control on machinery and factories. That gave me a good analytical basis. I started consulting when I was still at the university. When I started my own firm, I didn't have mentors or even a consulting partner. I had to learn things like environmental noise, community noise, and architectural acoustics on my own. I decided early to narrow the scope — I couldn't do everything like sound systems and advanced vibration; I had to narrow it down so I could be an expert in those things.

Back then, I wasn't in the position that I am in today. I didn't have the experience, so I had to analyze everything. I wouldn't make recommendations without carefully analyzing them, and I wrote reports so clients would understand why.

There were some lean years in the 80s but we stuck it out and by the 90s, things started looking up and here we are today."

Are there any super fun memorable or unusual projects?

"A lot of strange things. One project in '83, someone measured 65 dBA as an almost steady level in a rural area and said it was road noise from a two-lane rural road. It didn't sound right. Not something you would expect. When I arrived to investigate, it was quiet.

Same Person, Same Seat

About 79 years

Locals said the guy was there in winter; the area had heavy concentrations of wild geese. Now you can guess who the culprit of the 65 dBA levels was. People make measurements without paying attention to what they're measuring.

I worked on airport noise cases in Charlotte and Raleigh-Durham. I was working for the neighbors, and Andy Harris was the airport consultant. We developed a strong respect for each other, and I later teamed up with him on a project in our last consulting years.

I worked on a potential problem at a 1740s era home that was the home to two signers of the Declaration of Independence. I got to sleep in their bedroom. I also worked on projects for the White House, which I can't talk about here, but those were unique experiences.

In later years, after Joe Bridger joined me and started concentrating on architectural projects, I moved toward environmental and community noise: power plants, racetracks, amphitheaters, cooling towers, chillers; all kinds of outdoor environmental noise issues and outdoor-indoor isolation issues."

The technology we use in Acoustics has dramatically changed over the years. What changes have you witnessed over the course of your career?

"When I started at NASA, we used graphic level recorders and water manometers. In the 70s for graduate work, we used heavy B&K meters — twisting knobs, reading one frequency at a time. You had to carry the meter, and a clipboard to take notes, everywhere through textile mills. You then write a report with a pencil and hand it to a typist.

As I started consulting, we didn't have personal computers, no e-mail. You got your mail at a post office box early in the morning because that's how you communicated with everyone. Needless to say, you couldn't get nearly as much work done.

Later we moved to Larson Davis 800B meter, which could be hooked to a mini-computer and data cassette. We basically guinea-pigged those meters. We constantly kept finding problems and Larson Davis was very responsive. Once, a dog pulled the power cord out of the meter and I asked Larson Davis why it couldn't automatically switch to battery when this happens? Next day, we had a new meter which could do exactly that.

We then got a RadioShack computer, I think around 1983 with two floppy disks. One with an operating system and one with 40 kilobytes of data storage.

Then in the early 90s I bought a Larson Davis 2800 — 13 pounds, about the same as my newborn son. Everything I used to haul in a station- wagon or a pickup truck in grad school could be done with that instrument. FFT, recording, third octave, just about anything I wanted to do.

Of course, today you can do it in one pound or less, even on a cell phone with the right microphone. People today don't appreciate how difficult it was to get and process data in those earlier days. We have come a long way."

In talking with clients or other acoustical professionals, are there any common misconceptions about Acoustics that you often come across?

"Everybody gets confused over sound blockage and sound absorption. It's always difficult to get people to understand the effects of why you hear things at night and not necessarily during the middle of the afternoon from distant sources. People don't understand the atmospheric effects.

That reminds me of an interesting project. I had a case where a neighbor suddenly heard noise from an industrial plant they hadn't heard of before. The plant hadn't changed anything making noise. There was a building between the industrial plant and the resident that recently shut down. So, I asked if anything inside that building was making any noise. The plant said no.

So, no one knew why they could hear this noise suddenly. They hear it in the morning and sometimes in the evening. Okay, atmospheric effects. So, I started explaining the concept to them. After a while of me talking, the plant engineer says that the building that recently shut down didn't make any noise, but it generated a lot of heat. See where I am going with this?

The building in the between created a heat barrier that would move the sound up and away. Without that thermal barrier, the resident could hear the noise from the industrial plant. I hadn't thought about the building giving off heat, but when I explained the atmospheric effects to the client, he figured it out.

Another thing I normally encounter is that people don't understand the nonlinearity of perception. If you want it half as loud, you eliminate 90% of the sound. And whether you can understand speech depends not just on level but on background interference. So many people don't understand that.

Low-frequency wavelengths are long and hard to control as compared to high frequencies, which can lead to problems. Take a hotel room with a PTAC unit at one end and a headboard at the other. The right dimension can put a 60 Hz maximum at your pillow. I've experienced that several times."

Let's switch gears a little bit. Would you like to talk about your involvement in ASTM and developing Noise standards

"I joined ASTM E33 in 1985 when Rich Pepin got me to come to a meeting. Rich, and also Bill Cavanaugh, were arm-twisters that got a lot of people involved in a lot of things.

At first I was just another member, casting votes and discussing. Leaders were Alf Warnock, Ron Mulder, and Howard Kingsbury. Around 2000–2005 I started taking more responsibility and was asked to take over leadership of E336. Alf and Trevor Nightingale were doing a major overhaul but didn't want to be task group chair, so I was put in that position.

E336 is my main standard, but occasionally I have led others to it. I was asked to chair the research subcommittee and was vice-chair of E33 committee for 12 years. I was more or less asked to not become the chair of E33 so I could concentrate on the standards instead of administrative problems of the chair.

ASTM functions because good, qualified people are a part of it, to write standards, review them, critique them, debate them with one another, and produce the best results we can. I am convinced that the ASTM methodology is the best that it can be.

Anyone with interest can join, participate, and be heard. As long as you participate, you will be heard. If you make a good argument, it will be heard and debated. And as a result, we put out good documents.

About 20 years ago I was worried, where are the young people? But in recent years I have been pleasantly surprised by the quality of young people such as yourself. I think they can keep things going."

Do you think there are some underexplored or underutilized ideas in Acoustics today?

"I'm a little at a loss because I haven't been heavily active in field consulting for a few years. But I know the office acquired acoustic cameras, and they've been useful. Others are finding good applications for them.

There is a ripe opportunity to develop better computer models — room acoustics using the wave equation, outdoor propagation modeling. I'm not satisfied with the quality of what we have today. With the programs we have today, there are a lot of assumptions that don't always hold.

It takes people who know acoustics and computer programming. I've seen kids who were primarily programmers digging into acoustics enough to solve wave equations. That could be an advance."

Do you have any advice for the next generation of acousticians?

"Make use of technology but remember the basics. Understand what you are doing. Develop your ability to communicate. That basic understanding and the ability to communicate it to people who won't know acoustics is very important.

Don't get dependent on Artificial Intelligence answers. They can throw you down the wrong path. Same with books; every book I have ever read has had a mistake or two in it somewhere. Don't take everything for granted.

I worry that some people today may not have had enough real training in analytics. There's a lot you can do in architectural acoustics with simple understanding. But if you encounter an unusual problem, you won't know what's going on unless you can go back to basics and figure it out." ■

Specifically focused on all aspects of noise control and acoustics, NOISE-CON 2026 is the premiere conference for professionals and students in this field.

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The conference venue, the Westin Long Beach, is overlooking the marina and tranquility of the Pacific Ocean and very close to popular area attractions including the Aquarium of the Pacific and the Queen Mary. In addition, the hotel/venue is one block from a light rail line connecting to LAX, near two other airports, and is walkable to numerous restaurants, entertainment, and recreational activities — fun for the whole family!

IMPORTANT DATES

Abstract submission: December 10, 2025 – February 20, 2026

Registration: Early rate expires May 20, 2026

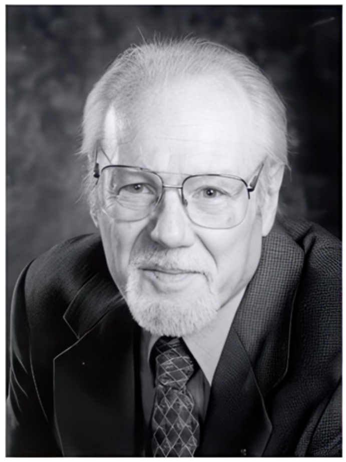
Papers: Due May 26, 2026

Core conference days are Thursday-Saturday, July 9-11

What is All the Noise About?

Bad noise problems can turn into positives

By **Jim Thompson**



We have all been there. A project or a test is going badly and there seems to be no way to make it work. Over the course of my career, I have learned to stay calm and sometimes it does work out. This is one example that I always remember when things look bad.

I was working for a tire company, and we were working with an original equipment manufacturer (OEM) on a new vehicle. This program was a major departure for the OEM – they were using four-wheel independent suspension on a mainstream sedan. I was called in because there was a major noise problem.

It only took a little time for me to determine that the real problem was wear. We had a major problem with uneven wear on the vehicle, and this wear problem was creating noise issues. Although everyone understood the issue was irregular wear, I went to the next test session with the customer to answer questions about noise.

We were still seeing uneven wear, and the tires design team was at a loss as to how to fix the problem. We were talking about this when one of the OEM mechanics walked up and told us we should not be so upset that they were shooting shocks through the read windows a few weeks ago. At least ours was not the only problem. I was in the position of having to say I would do what I could about the noise while knowing there was nothing I could do if the wear problem continued. I got the usual question from my higher-level management. Isn't there something you can do to show the customer we are trying? There was not a thing I could do. The product development team had done all they could do to fight the wear issue. The problem was the vehicle, not our tires.

Later as we were in the final stages of the vehicle program, a decision was made to decline the business on

this vehicle. The company had never done this before. At times, business had been declined in the past because the price the customer was willing to pay was too low, but never had it been done for a technical reason. There was a lot of concern about this decision.

An important aspect was that the OEM had told us we were the only tire with this problem. Some of the high-level people in our organization were pointing fingers at the tire designers. Those of us who were involved int the program knew the problem was the vehicle and suspected that our competitors were having the same problem.

The vehicle went into production. There was a great deal of publicity, and the OEM won awards for the innovative design of the vehicle. Roughly four months after the vehicle was in full production the two largest car rental companies in the US came to us. They wanted us to provide a tire that did not have this irregular wear problem. They were getting complaints from customers about the noise from the tires.

We explained that we could not fix the problem with tires. Taking a risk, we went on to explain the problem was in the manufacture of the vehicles. Evidently, the two competitors who were sourced on the vehicle never brought this up to the rental car companies. They asked if we could show the OEM how to fix the problem. We said yes, but it would require a big investment from the OEM.

The rental car companies had some influence on the OEMs. They buy a lot of cars, and many customers buy cars after experiencing them as rentals. So, when they took our story to the OEM who was also getting complaints from regular customers around the country, they got action. We ran a large program with the OEM and several other vendors to make changes to the OEM production lines. This work generated millions of dollars in income – far surpassing what we would have gotten from the original tire sourcing. In addition, we were sourced exclusively on this vehicle for the next few years.

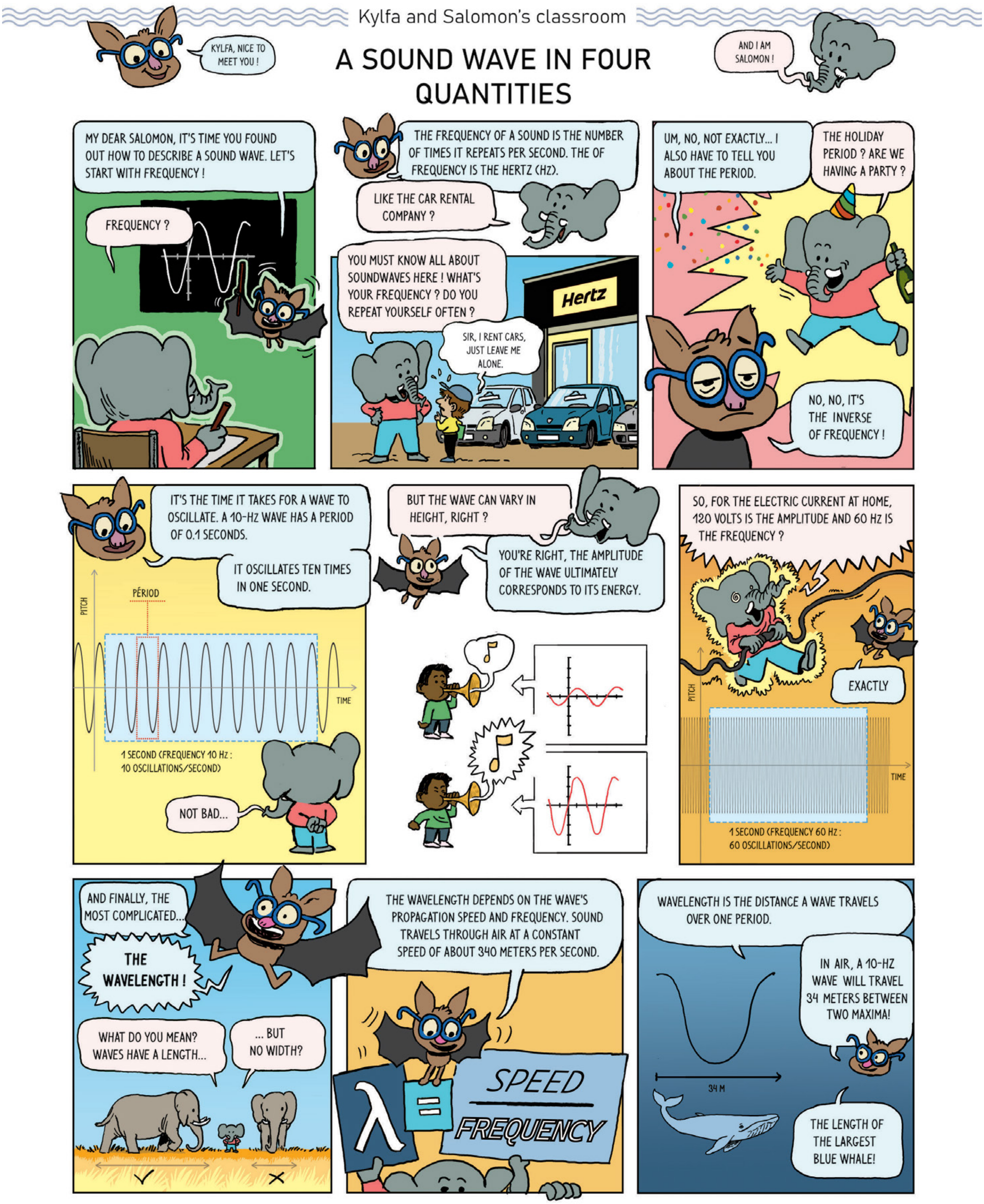
At the point where we declined the business, there were major concerns. Would the OEM take other business from us? Would they see us negatively in other programs because of this? How would this loss of income affect our bottom line? After we talked with the car rental companies, there still were people saying we should not get involved in OEM production. Even if we were successful, the OEM's production people would hate us, and they could cause a lot of problems for us.

The result was good for our bottom line. Our relationship with the OEM and the car rental companies dramatically improved. We learned a lot about the OEM's production process and potential improvements. It is not an exaggeration to say we went from the depths of despair to the heights of success over the course of this program. After the production process was modified, there were some car magazines that noted the low vehicle interior noise.

Although this was not totally about acoustics, it is not uncommon to find noise problems being part of larger product or production issues. I would be interested to hear about your similar experiences. ■

The **“Fantastic Acoustics”** series is a unique blend of comics and science featuring Kylfa, a bat specialized in acoustics, and Solomon, a funny elephant. It is a collaboration between artists and research students from four Québec universities - Université de Sherbrooke, École de Technologie Supérieure, McGill and Université du Québec à Rimouski. To learn more about this series, visit https://doi.org/10.1121/2.0002008.

Downloadable PDFs in French and English are available at https://en.fantastiqueacoustique.net/home



QUIET, WE'RE SLEEPING

Sleep is an essential part of our daily lives, almost as important as eating, drinking and laughing. Unfortunately, some people suffer from a variety of sleep disorders, ranging from nocturnal bruxism - a veritable tap-dancing concert with our teeth at night, to sleep apnea - snorkeling in your sleep, or insomnia - the pleasure of counting sheep for hours on end.

Science is working hard to treat these disorders, but is struggling to find definitive solutions. Fortunately, sleeptechs have arrived with some brilliant features. They promise to help poor sleepers fall back into the arms of Morpheus without the need for drugs or surgery.

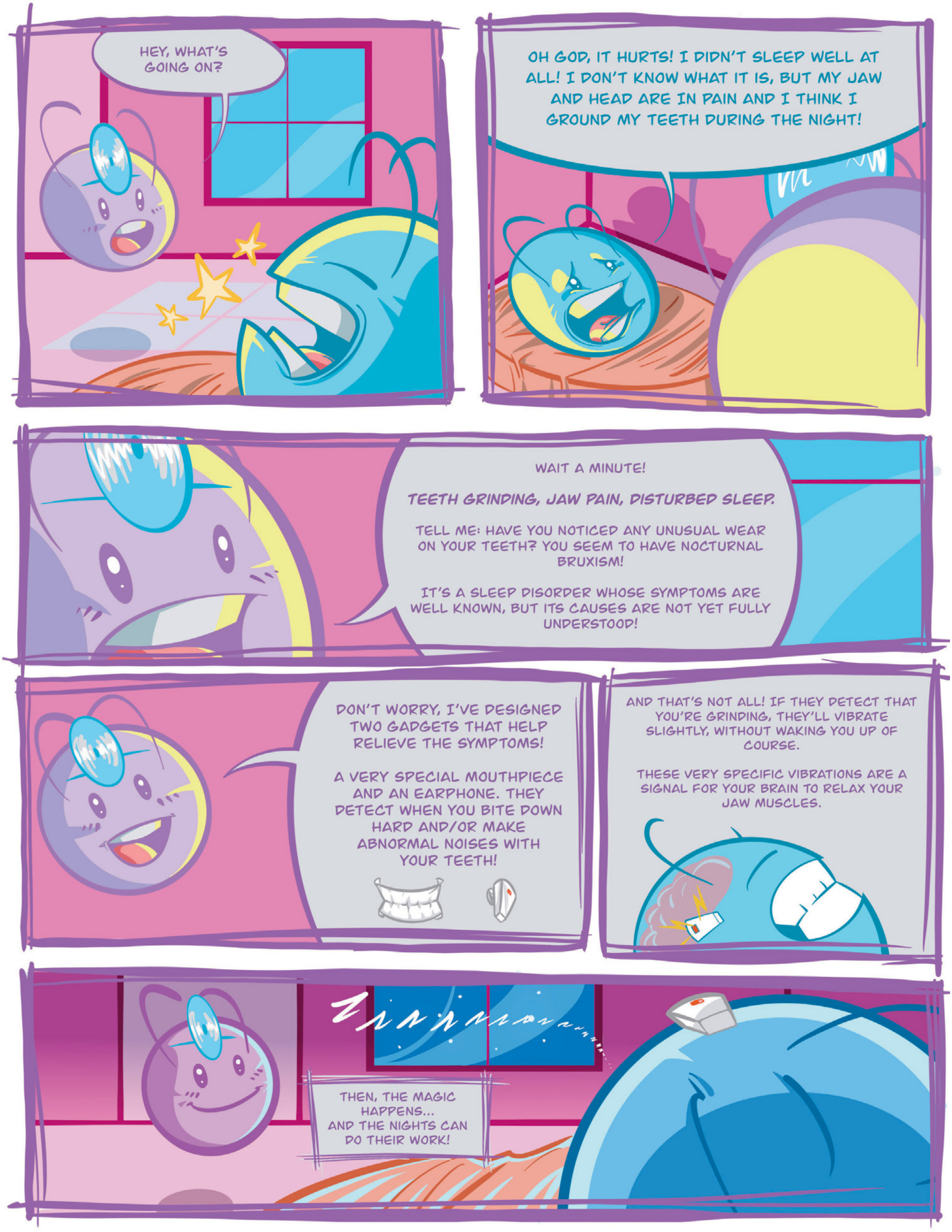
Imagine a pillow that plays relaxing sounds, dentures that vibrate or headphones that communicate with the throat. With all this in your arsenal, it's hard not to make the sandman jealous!

Team member

Student at École de technologie supérieure (ÉTS)
Michel Demuynck

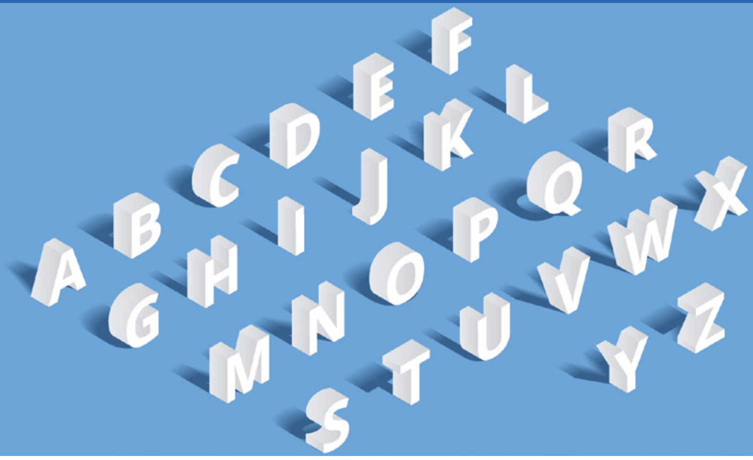
artist/cartoonist

Simon Bergeron (ESBÉ)


HEY, WHAT'S GOING ON?
OH GOD, IT HURTS! I DIDN'T SLEEP WELL AT ALL! I DON'T KNOW WHAT IT IS, BUT MY JAW AND HEAD ARE IN PAIN AND I THINK I GROUND MY TEETH DURING THE NIGHT!
WAIT A MINUTE!
TEETH GRINDING, JAW PAIN, DISTURBED SLEEP.
TELL ME: HAVE YOU NOTICED ANY UNUSUAL WEAR ON YOUR TEETH? YOU SEEM TO HAVE NOCTURNAL BRUXISM!
IT'S A SLEEP DISORDER WHOSE SYMPTOMS ARE WELL KNOWN, BUT ITS CAUSES ARE NOT YET FULLY UNDERSTOOD!
DON'T WORRY, I'VE DESIGNED TWO GADGETS THAT HELP RELIEVE THE SYMPTOMS!
A VERY SPECIAL MOUTHPIECE AND AN EARPHONE. THEY DETECT WHEN YOU BITE DOWN HARD AND/OR MAKE ABNORMAL NOISES WITH YOUR TEETH!
AND THAT'S NOT ALL! IF THEY DETECT THAT YOU'RE GRINDING, THEY'LL VIBRATE SLIGHTLY, WITHOUT WAKING YOU UP OF COURSE.
THESE VERY SPECIFIC VIBRATIONS ARE A SIGNAL FOR YOUR BRAIN TO RELAX YOUR JAW MUSCLES.
THEN, THE MAGIC HAPPENS...
AND THE NIGHTS CAN DO THEIR WORK!


HEY, WHAT'S THE MATTER WITH YOU? YOU LOOK WOOZY!
I'M EXHAUSTED! I'M SUPER SLEEPY, EVEN THOUGH I SLEPT 10 HOURS LAST NIGHT!
MY GIRLFRIEND HITS ME WHEN I SNORE. THAT'S HOW SHE STOPS THE RACKET!
!
DID YOU KNOW THAT SNORING AND EXCESSIVE FATIGUE ARE SIGNS ASSOCIATED WITH SLEEP APNEA?
HAVE YOU EVER HAD A POLYSOMNOGRAPHY? IT'S A MEDICAL EXAMINATION WHERE YOU SPEND A NIGHT IN A ROOM EQUIPPED WITH CAMERAS AND MICROPHONES TO RECORD YOU. VARIOUS SENSORS PLACED ON YOUR BODY MEASURE YOUR HEART RATE, BREATHING, EYE MOVEMENT AND MORE.
IT'S NOT VERY PRIVATE FOR SURE, BUT IT'S MORE EFFECTIVE THAN A QUESTIONNAIRE!
SO PLEASE, BY ALL MEANS, GIVE ME THAT TEST!
LISTEN UP! AS SOON AS YOUR AIRWAYS BECOME BLOCKED, YOU SNORE OR YOU STOP BREATHING!
IS IT TREATABLE? IF SO, HOW? DOES IT HURT? HOW MANY NIGHTS BEFORE I CAN BREATHE NORMALLY AGAIN? CAN YOU HELP?
SEVERAL GADGETS ARE AVAILABLE TO HELP YOU!
SNORING AND BREATHING DETECTOR (PUT ON THE NOSE)
VIBRATION CUFF (PUT ON THE ARM)
THROAT STIMULATOR (PUT BEHIND THE EAR)
TONGUE STIMULATOR (PUT ON THE CHIN)
PATIENT #THX-1138
SLEEP STUDY
APNEA DETECTED.
USEFUL GADGETS!
Z Z Z Z Z


I CAN'T TAKE IT ANYMORE, I WANT TO SLEEP!
I LIE DOWN IN BED, THEN I CAN'T SLEEP, SO I WORRY, WHICH KEEPS ME AWAKE, SO I WORRY EVEN MORE, AND SO ON, AND SO ON!
YOU PROBABLY SUFFER FROM MILD INSOMNIA. ARE YOU FAMILIAR WITH SLEEPING PILLS?
WELL, LET ME TELL YOU ABOUT MY NEW SECRET: AUDITORY STIMULATION!
IT CONSISTS IN PLAYING BACKGROUND NOISE IN YOUR ROOM TO HELP YOU RELAX!
MILD INSOMNIA? 5 HOURS OF SLEEP IN 4 NIGHTS! IS HE KIDDING ME OR WHAT?
CLASSICAL MUSIC WORKS VERY WELL, WITH A SLOW TEMPO, NO PERCUSSION AND NO LYRICS. GUIDED MEDITATION WITH BACKGROUND MUSIC ARE ALSO VERY GOOD!
IF THERE'S TOO MUCH NOISE, OPT FOR WHITE NOISE INSTEAD. IT'S A UNIFORM, CONTINUOUS "PSHHHH" SOUND THAT CREATES A KIND OF SOUND WALL BLOCKING OUT OTHER DISTRACTING SOUNDS!
OTHERWISE, PINK NOISE! IT'S A COUSIN OF WHITE NOISE, MORE PLEASANT AND HARMONIOUS TO THE EAR. WATERFALLS ARE A GOOD EXAMPLE.
A SMARTPHONE, THE AUDIO APP OF YOUR CHOICE AND THAT'S IT!
EVEN BETTER! THERE'S A MAGIC CUSHION THAT VIBRATES TO THE RHYTHM OF YOUR BREATHING AND PLAYS SOOTHING SOUNDS LIKE A SPEAKER!
THE ICING ON THE CAKE IS THAT IT'S BEAN-SHAPED, SO YOU CAN SLEEP SPOONED UP AGAINST IT!
NIIIIIIIIIICE!!
DODOMAN



Editor's Note: We are republishing Eric Ungar's Acoustics from A to Z and Stig Ingemansson's Noise Control: Principles and Practice from previous NNI issues as part of our initiative to include more educational articles. Their lessons are just as valid today. Look for more in future issues and on noisenewsinternational.net.

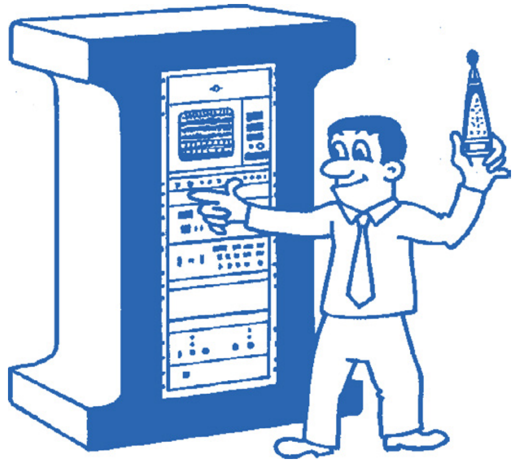
Acoustics from A to Z

By **Eric E. Ungar**

Ted Schultz, with whom I worked at BBN for many years, liked to tell the story of how he made measurements of airframe noise in one of the earlier Douglas transport aircraft. He used the only suitable filters available then, namely an analog system that permitted him to measure the noise level in one octave-band at a time. So, he had the pilot climb to a comfortable altitude and shut off the engines so that engine noise would not drown out the airframe noise, and then he measured the noise in one octave-band during a gliding descent. Then the pilot would restart the engines and repeat the process until Ted got data in all eleven octave-bands.

With today's instrumentation, one short glide would have sufficed to acquire all the data, analyze it in octave, one-third-octave, or narrow bands, display it and even print it out. And, today's equipment would weigh at most only a kilogram or two, where Ted's 'portable' system was portable by perhaps two people or a mule.

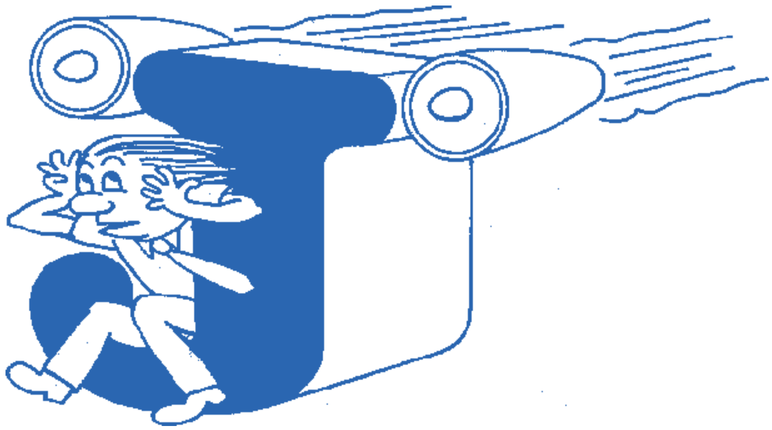
Modern microelectronics and digital technology have made possible all sorts of compact and energy-efficient signal processors and recorders, with features too numerous to mention. Similar technology also has led to accelerometers with built-in processing chips that condition (e.g., amplify, filter, limit, integrate) the acceleration signal. It also has given rise to accelerometers that weigh only a few carats, where a carat (equal to 0.2 grams) is the unit in terms of which the weight of precious stones is usually stated.



INSTRUMENTS for measuring sound
For many years have been around.
Recent years have seen improvement
In sensing sound, and also movement.
Some systems are so fast and small
They almost aren't there at all.

Modern technology also has led to laser systems that allow one to measure the vibrations of objects without attaching anything to them. These systems enable one to measure the motions of a given point on a vibrating object over a wide range of frequencies. Some such systems can even scan the surface of an object and generate a plot of its amplitude distribution. These systems have at least one drawback, in addition to their cost – they only work if the gross motion of the test object relative to the laser is small.

Sir James Lighthill, who died in July1998 at age 74, is credited with development of the theory of jet noise. (You may have read that he succumbed while attempting a nine-mile swim around one of the islands in the English Channel – a swim that he had done earlier at least a dozen times.) One of his students, John E. Ffowcs Williams, tried to explain this theory to some of my colleagues and me while we worked together at Bolt Beranek and Newman some time ago. He showed us the basic equation, which covered an entire blackboard which wrapped around the room, and he discussed the meaning and implication of each term. Although he was unsuccessful in making me understand everything, he later went on to high academic positions at prestigious British establishments and was responsible for much work related to control of noise of the Concorde supersonic transport.



JETS make noise from mixing flow
Of their exhausts with air that's slow.
Their turbines may act siren-like
To generate a spectrum spike.
Bypass fans give quiet thrust,
For modern aircraft they're a must

According to Lighthill's eighth-power law, the sound power produced by a jet mixing with the ambient air varies as the eighth power of the jet velocity. So, a slower jet should be a lot quieter. This is precisely what is behind the relative quiet of fan-jet engines, which in essence produce a wider, slower air jet than do pure jet engines, yet provide the same thrust. In the newer large-diameter high bypass-ratio turbofan engines, jet mixing noise usually is not the dominant component; so-called core noise generated within the engines (due to combustion and density inhomogeneities) and the siren-like noise from fans, compressors and turbines take on more prominent roles.

Powell and Preisser[1] reviewed the advances in aircraft noise reduction: "When normalized to total engine thrust, today's new transports are about 20 dB quieter than those introduced in the 1950s. This reduction resulted from major engine cycle changes that improved fuel efficiency and incremental efforts that required careful optimization to preserve thrust and efficiency. Low-bypass-ratio turbofan engines introduced in the 1960s provided greater propulsive efficiency and lower noise. But with jet exhaust no longer the primary noise source, further improvements in total engine noise required reductions in fan-generated noise. These resulted mainly from elimination of inlet guide vanes, a decrease in the number and rotational speed of fan blades and improved blade aerodynamic design. A major breakthrough was the fan blade passage frequency 'cutoff' design concept in which the BPF tone does not propagate outside the engine nacelle. In addition, advances allowed acoustic treatments to be designed or tuned for enhanced absorption of the fan tones.

Active noise cancellation is also in the works but hasn't quite been reduced to practical installations, as far as I know. Eventually, only noise due to flow over the airframe itself will be left. This airframe noise should be relatively benign in general; in tests some years ago researchers at Wright Field were unable to measure noise from aircraft in unpowered flight past a microphone array at times when crickets were active. ■

1 "Research for quieter skies," C. A. Powell and J. S. Preisser, Aerospace America, August 1999.

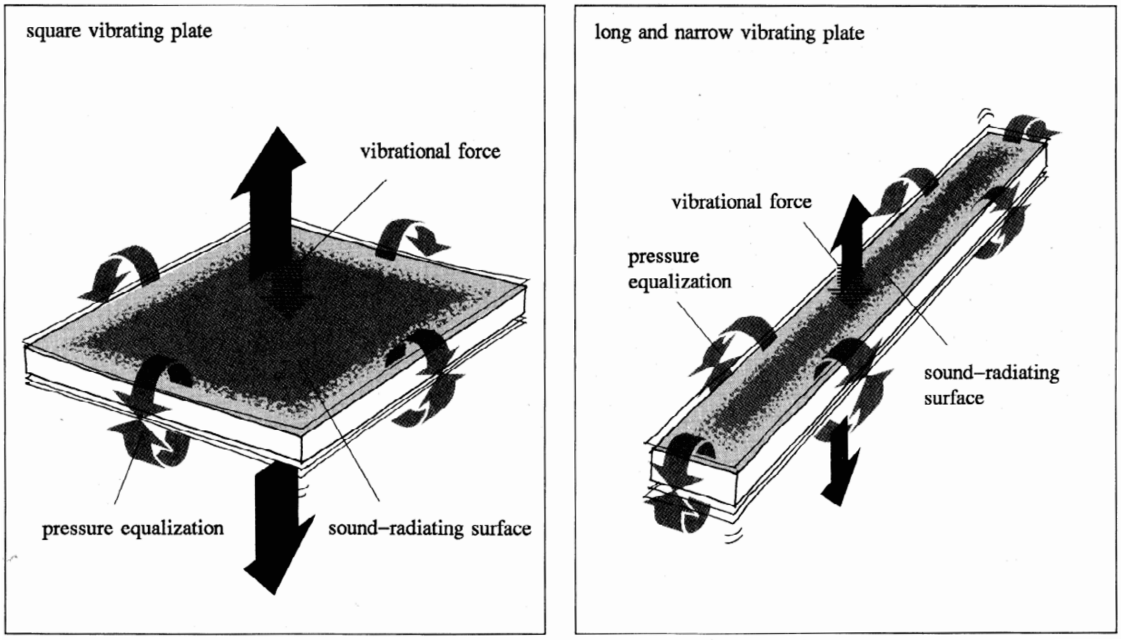
Stig Ingamansson's Noise Control: Principles and Practice

B3 – Sound from Vibrating Plates – Size and Thickness

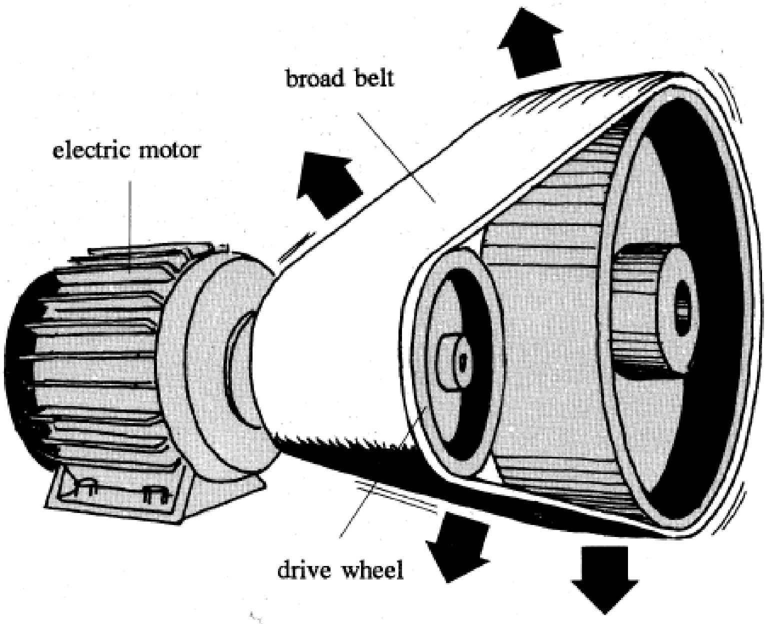
A LONG, NARROW PLATE PRODUCES LESS SOUND THAN A SQUARE ONE

When a plate is set into vibration, excess air pres— sure forms on one side of the plate and then the other. Sound comes from both sides. The pressure difference balances out close to the edges so that the radiation there is slight. Thus, a long, narrow plate radiates less sound than a square plate.

Principle

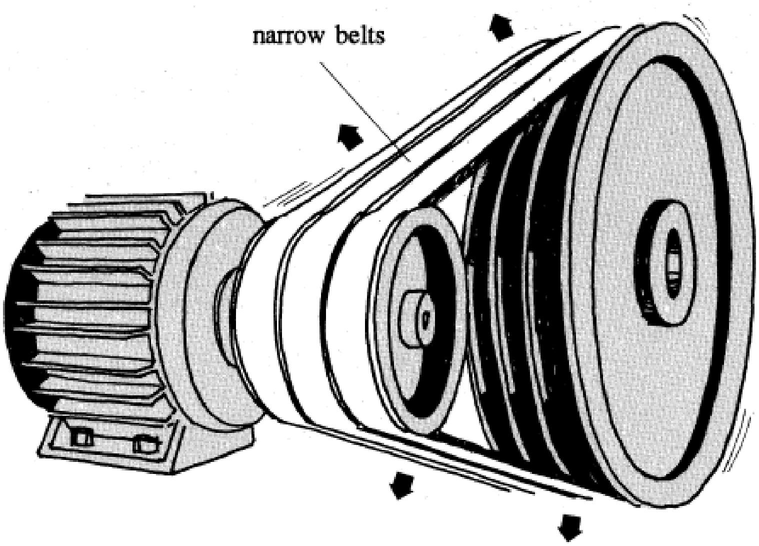


Application with drive belts



Example

A belt drive creates a large amount of low frequency noise because of the vibration of the broad belt.



Control Measure

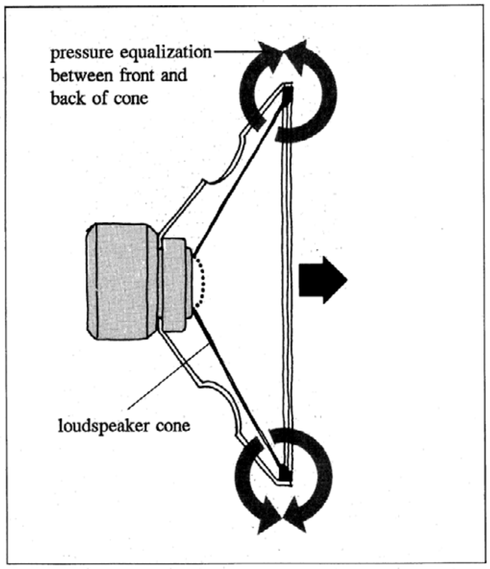
The broad drive belt is replaced by narrower belts separated by spacers. This reduces the noise radiated.

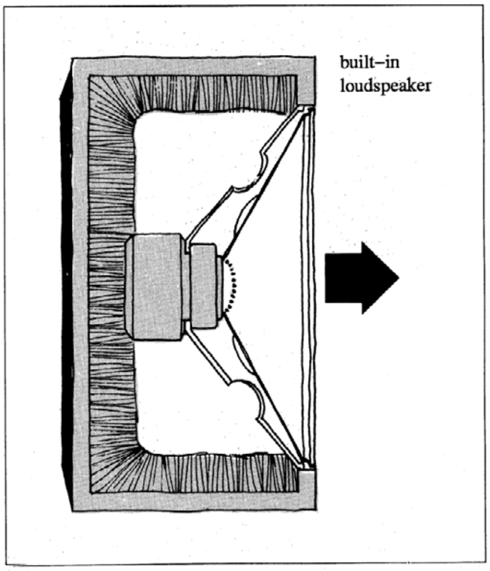
B4 – Sound from Vibrating Plates – Size and Thickness

PLATES WITH FREE EDGES PRODUCE LESS LOW FREQUENCY NOISE

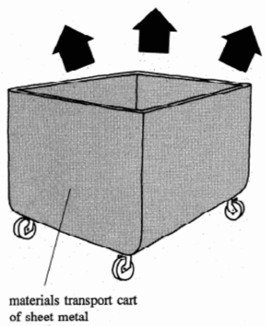
If a plate vibrates with free edges, pressure equalization takes place between the two sides of the plate, thus reducing sound emissions. Enclosing the comers prevents pressure equalization and the sound emission is greater, especially at low frequencies. For example, loudspeakers produce more bass if they are enclosed in a cabinet.

Principle





Application of transporting materials

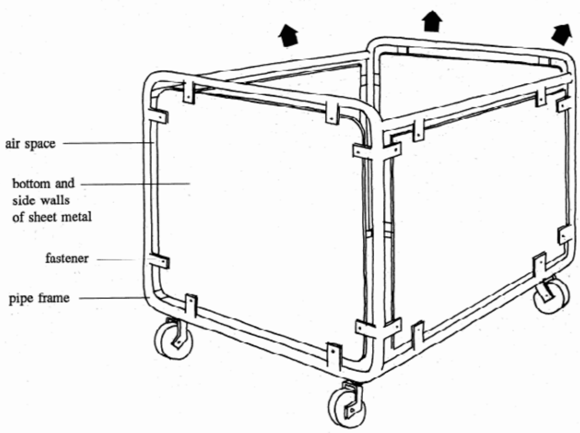


Example

Bumps in the floor produce noise from the bottom and side plates of a cart when the cart is pushed. Sound is also emitted when material strikes the bottom of the plate. Pressure equalization only takes place at the top edges of the side plates.

Control Measure

The walls are replaced by new ones constructed with a pipe frame. Plates are fastened with a gap between the plates and the frame. Pressure equalization takes place along all the edges, and the low frequency noise is reduced.



Recent Noise Control Engineering Journal Papers Related to Building Acoustics Standards

1. ***Structure-borne sound in buildings: Advances in measurement and prediction methods***
   Authors: Gibbs, Barry Marshall; Villot, Michel
   Source: Noise Control Engineering Journal, Volume 68, Number 1, 20 January 2020, pp. 1-20(20)
   Publisher: Institute of Noise Control Engineering
   DOI: https://doi.org/10.3397/1/37681

2. ***Improved low-frequency sound measurements for impact insulation class (IIC) rating using a comparison technique***
   Authors: Girdhar, Sunit; Barnard, Andrew
   Source: Noise Control Engineering Journal, Volume 68, Number 1, 20 January 2020, pp. 72-86(15)
   Publisher: Institute of Noise Control Engineering
   DOI: https://doi.org/10.3397/1/37686

3. ***Input force and floor impedance measurement for the standard tapping machine and the standard impact ball***
   Authors: Girdhar, Sunit 1 ; Barnard, Andrew 2 ; Blough, Jason 1 ; LoVerde, John 3 ; Dong, Wayland 3 ;
   Source: Noise Control Engineering Journal, Volume 71, Number 1, 1 January 2023, pp. 57-74(18)
   Publisher: Institute of Noise Control Engineering
   DOI: https://doi.org/10.3397/1/37716

4. ***Limitations and applicability of a new small-scale measuring setup for sound insulation characterization***
   Authors: Ramšak, M.; Nikonov, A.
   Source: Noise Control Engineering Journal, Volume 67, Number 4, 1 July 2019, pp. 295-306(12)
   Publisher: Institute of Noise Control Engineering
   DOI: https://doi.org/10.3397/1/376726

5. ***Low-frequency impact sound pressure fields in small rooms within lightweight timber buildings – suggestions for simplified measurement procedures***
   Authors: Olsson, Jörgen; Linderholt, Andreas
   Source: Noise Control Engineering Journal, Volume 66, Number 4, 1 July 2018, pp. 324-339(16)
   Publisher: Institute of Noise Control Engineering
   DOI: https://doi.org/10.3397/1/376628

6. ***Proposal of a simplified method for the prediction of impact sound insulation between rooms, from below to above***
   Authors: Mateus, Diogo; Pereira, Andreia; Godinho, Luis
   Source: Noise Control Engineering Journal, Volume 66, Number 3, 1 May 2018, pp. 276-286(11)
   Publisher: Institute of Noise Control Engineering
   DOI: https://doi.org/10.3397/1/376623

7. ***Variations in sound insulation from 20 Hz in lightweight dwellings***
   Authors: Öqvist, Rikard; Ljunggren, Fredrik
   Source: Noise Control Engineering Journal, Volume 66, Number 1, 1 January 2018, pp. 56-65(10)
   Publisher: Institute of Noise Control Engineering
   DOI: https://doi.org/10.3397/1/37666

Noise Control Engineering Journal

Volume 73, Issue 4

Research Articles

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- **JULY 9–11, 2026**
  NOISE-CON 2026
  Long Beach, California

- **AUGUST 9–12, 2026**
  INTER-NOISE 2026
  Adelaide, South Australia

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