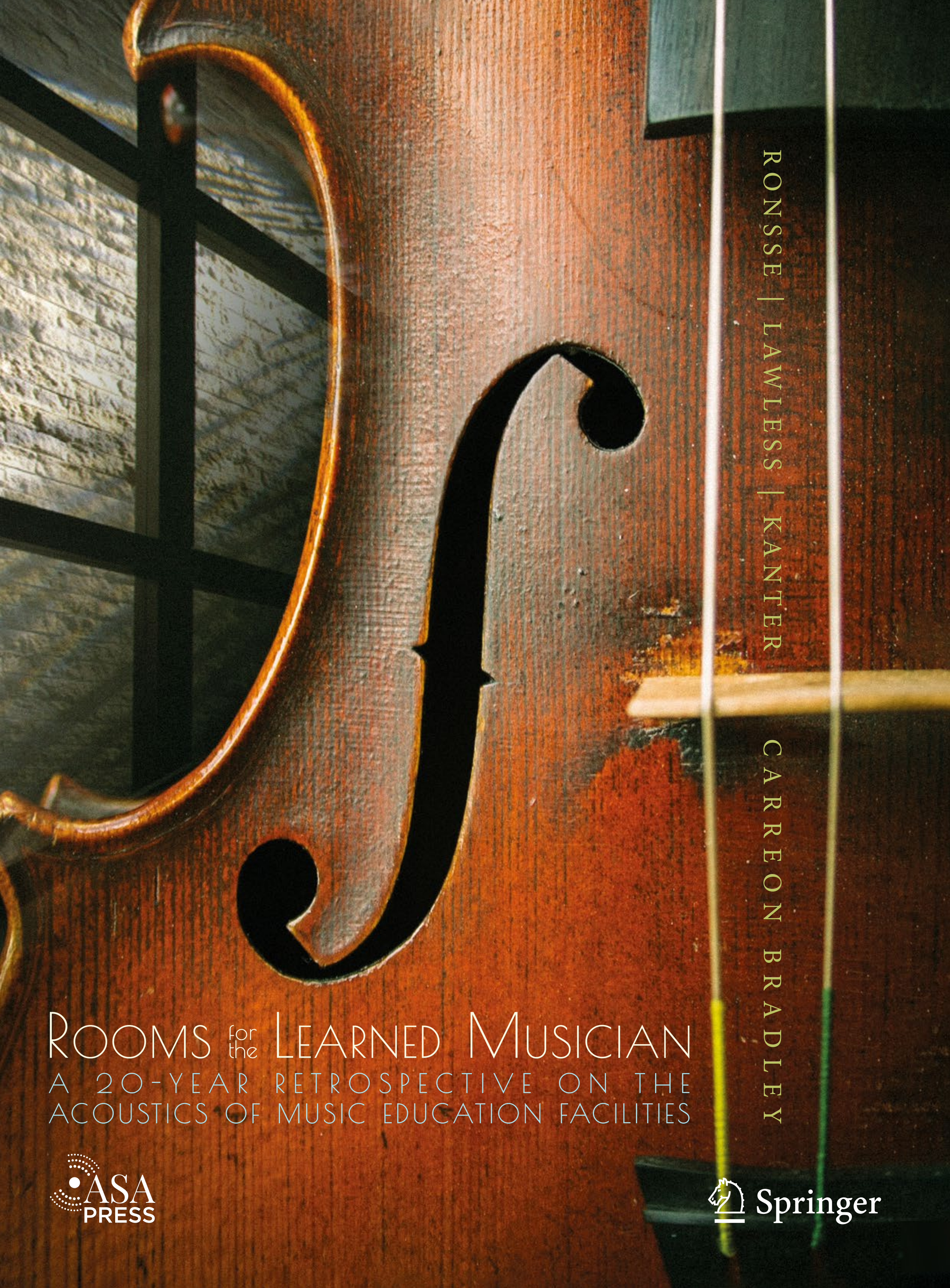

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ROOMS for the LEARNED MUSICIAN

A 20-YEAR RETROSPECTIVE ON THE ACOUSTICS OF MUSIC EDUCATION FACILITIES

ASA PRESS

Springer

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ASA Press, which represents a collaboration between the Acoustical Society of America and Springer Nature, is dedicated to encouraging the publication of important new books as well as the distribution of classic titles in acoustics. These titles, published under a dual ASA Press/Springer imprint, are intended to reflect the full range of research in acoustics. ASA Press titles can include all types of books that Springer publishes, and may appear in any appropriate Springer book series.

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On 27 December 1928 a group of scientists and engineers met at Bell Telephone Laboratories in New York City to discuss organizing a society dedicated to the field of acoustics. Plans developed rapidly, and the Acoustical Society of America (ASA) held its first meeting on 10–11 May 1929 with a charter membership of about 450. Today, ASA has a worldwide membership of about 7000.

The scope of this new society incorporated a broad range of technical areas that continues to be reflected in ASA's present-day endeavors. Today, ASA serves the interests of its members and the acoustics community in all branches of acoustics, both theoretical and applied. To achieve this goal, ASA has established Technical Committees charged with keeping abreast of the developments and needs of membership in specialized fields, as well as identifying new ones as they develop.

The Technical Committees include acoustical oceanography, animal bioacoustics, architectural acoustics, biomedical acoustics, engineering acoustics, musical acoustics, noise, physical acoustics, psychological and physiological acoustics, signal processing in acoustics, speech communication, structural acoustics and vibration, and underwater acoustics. This diversity is one of the Society's unique and strongest assets since it so strongly fosters and encourages cross-disciplinary learning, collaboration, and interactions.

ASA publications and meetings incorporate the diversity of these Technical Committees. In particular, publications play a major role in the Society. *The Journal of the Acoustical Society of America* (JASA) includes contributed papers and patent reviews. *JASA Express Letters* (JASA-EL) and *Proceedings of Meetings on Acoustics* (POMA) are online, open-access publications, offering rapid publication. Acoustics Today, published quarterly, is a popular open-access magazine. Other key features of ASA's publishing program include books, reprints of classic acoustics texts, and videos. ASA's biannual meetings offer opportunities for attendees to share information, with strong support throughout the career continuum, from students to retirees. Meetings incorporate many opportunities for professional and social interactions, and attendees find the personal contacts a rewarding experience. These experiences result in building a robust network of fellow scientists and engineers, many of whom become lifelong friends and colleagues.

From the Society's inception, members recognized the importance of developing acoustical standards with a focus on terminology, measurement procedures, and criteria for determining the effects of noise and vibration. The ASA Standards Program serves as the Secretariat for four American National Standards Institute Committees and provides administrative support for several international standards committees.

Throughout its history to present day, ASA's strength resides in attracting the interest and commitment of scholars devoted to promoting the knowledge and practical applications of acoustics. The unselfish activity of these individuals in the development of the Society is largely responsible for ASA's growth and present stature.

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RONSSE | LAWLESS | KANTER | CARREON BRADLEY

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Ronsse is an educator in architectural engineering and acoustics and has a Ph.D. in Engineering with a focus in Acoustics from the University of Nebraska—Lincoln. She also has experience in architectural acoustics consulting, including an enriching position as a Collaborating Consultant with Threshold Acoustics. Prior to her current Industry Fellow appointment, she was an Assistant Professor in the Audio Arts & Acoustics Department at Columbia College Chicago.

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Lawless earned his Ph.D. in Acoustics in 2018 from the Pennsylvania State University where he investigated the brain's auditory and reward responses to room acoustics. At the Cooper Union, he continues studying sound perception, including 1) the generation of head-related transfer functions with machine-learning techniques, 2) musical therapeutic inventions for motor recovery after stroke, and 3) active noise control using an external microphone array.

SHANE J. KANTER

Senior Consultant, Threshold Acoustics

Kanter spends his days collaborating on the acoustic performance of his projects at Threshold Acoustics, and his nights and weekends going on adventures with his wife, son, and dog. Prior to arriving at Threshold, Shane received his Master of Arts in Architecture from the University of Kansas by studying with the venerable and beloved Bob Coffeen.

Rooms for the Learned Musician: A 20-Year Retrospective on the Acoustics of Music Education Facilities is the latest volume in a series of architectural acoustics compendiums published by the Acoustical Society of America (ASA). The previous two books in the series, which served as major inspiration for the current publication, are *Acoustical Design of Theatres for Drama Performance: 1985-2010*, published in 2010 and edited by David T. Bradley, Erica E. Ryherd, and Michelle C. Vigeant [1] and *Worship Space Acoustics: 3 Decades of Design*, published in 2016 and edited by David T. Bradley, Erica E. Ryherd, and Lauren M. Ronsse [2]. The first ASA book to focus on music educational facilities is *Acoustical Design of Music Education Facilities*, which was published in 1990 and edited by Edward McCue and Richard H. Talaske [3]. The present volume focuses on music education facilities—rooms for the learned musician—that were designed in the past twenty years and serves as a follow-up and update to the McCue and Talaske volume.

The current book is meant to be a valuable reference, resource, and inspiration to a wide audience, including acoustical designers and consultants, students studying music or building design, architects, music education facility directors, and musicians. The book features full-color spreads showcasing case-studies of 65 music education facilities from six countries across the globe. The architect or acoustical consultant for each facility contributed their project for inclusion in this book, which features 21 different acoustical consultants. The presentation of each facility includes a description of the space, photographs and/or computer-generated renderings, architectural drawings, and acoustical data. Most spaces are accompanied by a full-page architectural plan and section drawing. The descriptions and accompanying data showcase the architectural acoustics features, challenges, and highlights of the particular space.

There is a rich diversity of music education facilities covered in this book, ranging from music conservatories and community centers to primary, secondary, and higher education facilities. The book has been divided into four sections based on the type of facility: (1) Primary & Secondary Education (e.g., grade school and high school), (2) Higher Education (e.g. college and university) - completed from 2000 to 2014, (3) Higher Education - completed from 2015 to 2020, and (4) Music Conservatories, Music Rehearsal, & Community Centers. In cases where the facility type spanned more than one category, the venue was categorized according to the main facility type. For example, if a venue both serves higher education and is a conservatory, it typically appears in the Music Conservatory category.

Each facility has one featured space such as a recital hall or multi-use theatre. For ease of reference, the facility spreads in the book are color coded (see the table at the bottom right of this page) according to the type of featured space: Concert Halls - blue; Multi-Use Theatres - purple; Recital Halls - red; Rehearsal Rooms - green; and Other Spaces - orange. The featured space types are also listed in the information bar at the top of each spread.

In addition to the 65 music education facility case studies, the book also contains a series of essays intended to provide context to readers who may be new to the area of music education facility acoustics, as well as fresh insights for those experienced in the field. The first essay, by Gary Siebein (Professor Emeritus of Architecture and Acoustics at the University of Florida School of Architecture and Senior Principal Consultant with Siebein Associates, Inc.), provides historical context for the acoustical design of music education facilities, documents recent research in the field, and provides insights on the current status and future directions pertaining to the soundscape of music rehearsal and education facilities.

While the acoustical consultant is a critical member of the design team, the coordination and harmony of all design team members is necessary for the creation of a successful music education facility. The architect, audio/video systems designer, and theatrical consultant, to name a few, all play important roles in contributing to the final experience for the musicians and audiences. For this reason, essays from experienced professionals in these roles have also been included to discuss music education facility design issues from

David T. Carreon Bradley, Ph.D.

Faculty Diversity Officer, California State University, Fullerton

Carreon Bradley currently serves as the Faculty Diversity Officer at California State University, Fullerton. He previously served as the Vice President for Inclusion, Diversity, and Equity at Smith College, where he was also an Associate Professor in both the physics department and engineering program. Prior to that, he worked at Vassar College for over 10 years, where he was an Associate Professor of Physics and the chief diversity faculty-administrator. He is also a member of the Board of Trustees for SACNAS (Society for the Advancement of Chicanos/Latinos and Native Americans in Science). He conducts research on higher education organizational development, diversity and inclusion in higher education, access and equity in STEM, and acoustics - the latter for which he won the prestigious NSF CAREER Award.

Featured Space Type	Color
Concert Halls	🟦
Multi-Use Theatres	🟪
Recital Halls	🟥
Rehearsal Rooms	🟩
Other Spaces	🟧

their unique perspective. Clifford Gayley (Principal at William Rawn Associates, Architects Inc.), discusses the combined responsibility of the entire design team when conceiving new spaces. He stresses the importance of meeting current and flexible needs of the community as demands continue to push toward interdisciplinarity. In the next essay, Tim Perez (Senior Consultant with Threshold Acoustics) comments on the audio/video systems design process. He presents an approach that augments the architect's vision for the project, while ensuring that the occupant and end-user needs are met. Finally, Scott Crossfield (Director of Design, Americas at Theatre Projects) pulls from his 25 years of experience as a theatre consultant to provide fundamental guidelines when designing music education facilities that prioritize and support the learning experience of the student. The music education facility case studies reflect the ideas and guidelines from these essays while featuring creative acoustic solutions designed to address some of the most difficult challenges associated with music education facility design.

For readers seeking more background information on architectural acoustics specifically related to music education facility design, an acoustical design overview with a general summary of the design process follows this Preface. The appendices include a glossary of key terms and a list of references for readers interested in architectural acoustics and music education facility design.

We are grateful to the many people who have helped this book come to fruition. In particular, we appreciate the work of the contributing architects and acoustical consultants whose firms' designs are featured in this publication. Their assistance was essential in compiling the necessary elements for each music education facility contribution, and they should be credited with much of this book's success. We are also indebted to our guest essay authors for their wonderful insights into the design of music education facilities. We also appreciate our colleagues in the world of acoustics who provided assistance throughout this process, especially Jonathan Weber, who served as a contributing editor for the book, and Michelle Vigeant, who was involved early in the editorial process. We also thank University of Nebraska undergraduates, Christian Espinoza and Ben Ripa, who helped with managing the image assets for the book.

The process of creating this publication has been rewarding and challenging, and we hope that readers will find it to be a useful and valuable reference for many years to come.

Editors,

Lauren M. Ronsse, Ph.D.

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Acoustic Design of Music Education Facilitles:

an overview

A musician was walking home to his Manhattan apartment following a rehearsal. A tourist stopped him to ask, "Can you tell me how to get to Carnegie Hall?"

"Yes," answered the musician, "Practice!"

If you are lost in New York City trying to find Carnegie Hall, you should avoid the adverb "how" because you are only going to be faced with the timeless joke: practice, practice, practice [1]. For the learned musician, practice is the key to success. The acoustic environment in which music students rehearse, whether alone or with an ensemble, must be able to support effectual and meaningful learning, especially during the formative years of their education. Acousticians, architects, audio systems designers, theatrical consultants, building systems engineers, and other members of the design team work together to meet the needs and expectations of the students, music directors, and other stakeholders to provide spaces conducive to learning and practicing music. This section offers a brief overview of the acoustic design process with a specific focus on music education facilities.

Fundamentals of Acoustics

We don't just hear sound; we *feel* it. Music can put a smile on our faces, make the hairs on the back of our necks stand up, and bring tears to our eyes. It moves us, causing visceral feelings such as excitement, happiness, sadness, and surprise. Music activates many regions of the human brain, from the auditory cortex to the prefrontal cortex, involved in higher-order cognition, to the reward processing centers in the basal ganglia [2,3].

How do we hear and feel music? When a musician plays their instrument, the sound is communicated to the listener through *sound waves*. Sound waves are patterns of vibration in a medium (such as air) that travel from one location to another, aptly named the source and receiver locations. The source, e.g. a trumpet or violin, vibrates the air particles around it, generating instances of compression (particles squeezed together) and rarefaction (particles forced apart) in the medium. These air particles in turn vibrate the particles next to them, and so on, propagating the wave to the receivers' ear. Once at the receivers' ear, the wave is shepherded through the ear canal via specially shaped folds and grooves on the ear. The wave excites the air particles inside the ear, which hit the eardrum and cause it to vibrate. The eardrum sends the vibrations on a trip through a series of bones in the ear, continuing through a spiral cavity in the inner ear called the cochlea, ending in the auditory nerve, ultimately producing electrical impulses, which are interpreted by the brain as sound.

For any given vibrating air particle, compression and rarefaction oscillations occur many times over a period. *Frequency*, or the number of cycles of oscillation per second, is used to describe this physical property of the sound wave, and is expressed in *Hertz (Hz)*. The note A4, the A above middle-C, is often used as a general tuning standard to align musicians prior to playing as an ensemble. A4 typically has a frequency of 440 Hz [4] (though, the frequency can vary between 432 Hz and 444 Hz due to local preferences or standards in different parts of the world), which means that the air particles complete a cycle of compression and rarefaction 440 times per second. A listener detects the frequency of a sound wave through the subjective experience of *pitch*. A low-frequency sound wave has a low-sounding pitch, like a cello or double-bass. Conversely, a high-frequency sound wave has a high pitch, like a piccolo.

Acousticians assess sound over a wide range of frequencies because of the large frequency response of the human ear (approx. 20-20,000 Hz). Additionally, many acoustic parameters vary with frequency. It is useful to divide frequencies that are similar to one another into groups, otherwise known as *frequency bands*. These ranges of frequencies are denoted by the frequency in the center of the band. When the center frequencies are separated by factors of 2, such as 125 and 250 Hz, the groups are called *octave bands*. Acousticians typically use octave bands from 31.5-8000 Hz to assess rooms for music, though the range can differ depending on the circumstances. In this book, the acoustical data is shown for octave bands from 125-4000 Hz to remain consistent based on the available data for each facility.

Another important physical property of the sound wave is the extent of the compression and rarefaction. The *sound pressure level (Lp)* with units of *decibels (dB)* describes the amplitude of the sound wave. Sound pressure level decibels are calculated using a logarithmic ratio of air pressure with respect to a specific reference. The reference of 20 micro-Pascals is commonly used, and referred to as the threshold of human hearing (0 dB). A listener perceives sound pressure level as *loudness*. For a listener one meter away, a person calmly breathing has a level of approximately 10 dB, a normal conversation falls in the range of 40-60 dB, while traffic from a busy highway is typically between 80 and 90 dB, and a jet engine is around 130 dB.

Architectural Acoustics

Music also has a profound impact on how we connect with others, allowing us to communicate by transcending language and culture. The connections between performers and between performer and audience is a critical relationship that depends on how sound moves through a space. The field of science that studies the relationship between sound and the space in which it is experienced is called *architectural acoustics*. When designing a space with acoustics in mind, there are three main areas of focus: *interior room acoustics*, *sound isolation*, and *background noise control*. While the scope of the present book focuses on music education facilities, architectural acoustics design applies to any space where sound can affect the perception and behavior of people, including concert halls, drama theatres, schools, hospitals, worship spaces, residences, and workplaces.

Interior Room Acoustics

The study and design of interior room acoustics concentrates on the characterization and optimization of sound energy within a space. Each space requires an acoustic character that should facilitate the given use of a space. Whether they are intentionally reverberant or dry, spaces should be free of errant, harsh reflections or excessive noise buildup. These room characteristics are impacted by a room's geometry, volume, layout, and surface finishes.

When a sound wave collides with a surface, some of the energy from the wave is reflected back into the room, while the rest of the energy is either transmitted through or absorbed by the surface. The amount of energy that is reflected, absorbed, or transmitted is determined by the material properties of the surface. Surfaces with soft, fuzzy finishes, such as fiberglass, are efficient at absorbing and dissipating the energy of a sound wave because the moving air particles rub against the material, causing friction. On the other hand, hard and dense materials, such as glass or concrete, tend to reflect sound. Thin surfaces, such as wood paneling, tend to allow sound energy to transmit through. It is important to carefully consider the type and placement of each surface to appropriately distribute sound in the room through the use of absorption and reflection.

The identification of the sound source and receiver is crucial for the successful implementation of room geometries and surfaces. However, the source and receiver may differ depending on the type of space analyzed. This book contains two general types of spaces: *performance* and *rehearsal/practice*. The source for a performance hall is the musician on stage, while the receivers are the audience or the other musicians in the ensemble. In practice rooms, the sources are the same, but the intended receivers are often the musicians, conductor, or music director. Both of these conditions pose interesting design problems in how to effectively and pleasurably communicate sound between sources and receivers by supporting reflections that aid communication and reducing reflections that hinder it.

For example, imagine two musicians sitting on opposite sides of a rehearsal room playing together. The sound that travels in a straight line from one performer to the other is known as the *direct sound*. Reflections from the ceiling and sidewalls can be used to support the direct sound so that the musicians can hear each other better. However, if some strong reflections take too long to travel to the other musicians, these reflections may be perceived as *echoes*, which may be distracting and cause the musicians to play out-of-sync. These delayed, high-amplitude reflections may also cause the listeners to perceive the sound source to be located in the wrong place.

The unwanted reflections may be mitigated by either applying absorptive materials, or in the case where reverberation time should be maintained, diffusive treatments. The effectiveness of a material's absorption depends on the thickness, surface area, and mounting conditions. Thicker materials absorb sound more efficiently than thinner materials because the acoustic wave needs to travel through more material, thereby allowing more opportunities for friction to dissipate the energy from the moving air particles. After a sound wave reflects off of a hard surface, it interacts with itself. This *superposition* of the original and reflected waves induces a large particle velocity at a distance of a quarter of the wavelength from the wall and zero particle velocity at the wall. Since it is important to ensure that a large portion of the wave moves in the material to attenuate the sound, a material will be more effective at absorbing sound if it is thicker than a quarter of the wavelength. Conversely, for a given material thickness, sounds with shorter wavelengths (i.e., higher frequencies) are absorbed more easily than sounds with longer wavelengths (i.e., lower frequencies).

There are instances where designers aim to absorb a targeted frequency in the form of tuned absorption. Examples of this are recording rooms and mastering rooms. These small spaces often suffer from low-frequency buildup due to the development of standing waves. Tuned absorption is a useful solution to disrupt the low-frequency standing waves. Where thick, fibrous absorption is broadly effective at middle and high frequencies, tuned absorbers can be designed to target a narrow band, problem frequency, which is often a lower tone. These low-frequency, bass absorbers are generally rectilinear or triangular boxes with a thin, resonating membrane (e.g., 1/8" plywood) fixed to a rigid frame. A 1-2" thick fiberglass wrapped absorptive panel is typically applied to the resonating panel for additional absorption. The thickness of the face is calculated to resonate at the problem frequency. The depth of the box is calculated such that the resonating face, along with the air entrained within, effectively damp the problem frequency. Generally speaking, the volume of the entrained airspace needs to be larger for lower frequencies.

Sound Isolation

Sound isolation, also referred to as acoustic separation, is the practice of preventing unwanted sounds from reaching a critical space. It is a key aspect in fostering focused practice and uninterrupted performances in music education facilities. There are two general practices for achieving sufficient acoustic separation. First, key rooms can be spatially isolated, ideally during the initial planning and programming phases of a project. Keeping acoustically critical spaces well separated from noisy spaces, such as mechanical rooms and bathrooms, greatly reduces the chance of sound leakage into the key room.

If critical spaces cannot be spatially separated due to project constraints, the walls, floors, and ceilings should be designed to reduce the transmission of sound into the acoustically sensitive spaces. Openings, such as doorways or windows, must be carefully detailed because sound travels through the path of least resistance. As an example, the openings for ductwork or electrical equipment should be sealed to prevent airborne sound from entering. The materials of walls, floors, and ceilings should also be carefully considered. For single-panel constructions, one simple implementation to decrease the transmission of sound from noisy rooms is to increase the thickness and/or mass of the construction. However, the effectiveness of this approach is limited because very thick walls would be required to prevent the transmission of low-frequency sound. Therefore, more complex and robust constructions are typically used to maintain necessary acoustic separation. For example, double-panel structures, such as two free-standing gypsum wall board studs or double wythe masonry walls, exploit the resonance of the airspace between the panels, making it more effective at reducing sound, while maintaining smaller total wall thicknesses. By placing sound absorbing materials inside of the airspace, sound transmission can be further reduced.

In addition to airborne sound (i.e., sound that travels through the air), it is also important to prevent structure-borne sound from external sources, particularly vibrational sources such as a passing train, from entering the critical space. Ideally, vibrational noise is attenuated at the source. There are several different ways to implement vibration isolation of machinery, which is often the noise source, such as damping isolation pads and tuned mass-spring support systems. If the source cannot be modified, the transmission of vibrational energy can sometimes be mitigated by isolating the room using mass-spring support systems for the floor or ceiling, or a box-in-box construction. However, these approaches tend to be expensive and cost-prohibitive.

A material or contstruction's ability to reduce transmission of sound can be determined by measuring the *transmission loss (TL)* across the partition. *Sound transmission class (STC)* is a single-number rating of the effectiveness of the reduction of airborne noise based on the TL in each octave band. Higher TL or STC values signify a better ability to reduce sound transmission. The *impact insulation class (IIC)*, similar to STC, is a measure of how well a floor or ceiling reduces structure-borne noise, specifically impulsive impacts on the partition such as footfall.

Background Noise Control

Background noise control generally refers to mitigating noise from building systems, such as the noise emitted by mechanical, electrical, and plumbing (MEP) equipment. Absolute silence is not required in most spaces in a building; however, the background noise level must be low enough so that it does not distract from a performance or practice. Typically, acoustical consultants recommend that the background noise in a music performance space be approximately 15 dB lower than the quietest note being played. This design parameter will help both the performers and audience to hear and enjoy a musician playing a piece at pianissimo. The recommendation for rehearsal rooms and practice rooms is slightly higher: a background noise of 5-10 dB louder than that of a music performance space is acceptable because these spaces are less critical and may even benefit from the masking noise offered by higher background noise levels. Lobbies, offices, lounges, and support spaces, are less noise-sensitive, and can be 10-15 dB louder than rehearsal and practice rooms. However, these spaces should still be controlled to prevent bothersome tones, hums, or buzzes.

The predicted or measured background noise in a room can be expressed in several ways, all of which are based on the octave band sound pressure levels. The sound pressure levels are often represented as a single number rating using one of a variety of methods, including: *Noise Criteria Rating (NC)*, *Room Criteria Rating (RC)*, *Noise Rating (NR)*, *Noise Reduction*, or overall *A-weighted Sound Pressure Level* (L_A). More information on these rating systems can be found in the Glossary.

Acousticians work closely with the project MEP engineers, and the rest of the design team to assure that concerning noise sources are well controlled. Special consideration should be taken to properly select MEP equipment within the building. It is best to select equipment that output low noise levels. However, if such equipment is not available, must be located above grade, or near acoustically critical spaces, acousticians work closely with the project structural engineer to utilize a combination of vibration isolation elements and structural stiffening to limit vibration from transmitting through the building structure.

Noise from air-handling-units is controlled by re-routing ductwork, conduit, and piping; internal duct liners; duct attenuators; and following velocity guidelines for airflow and liquid flow. The routing of ductwork, conduit, and piping should be carefully reviewed to reduce any unwanted noise and vibration. This review also helps to control potential isolation breaches caused by these services. Internal duct liner is sound absorptive material (typically 1-2 inch thick fiberglass or foam) that lines the internal walls of an air distribution duct. As fan noise travels down the duct, it interacts with the liner and is attenuated. Fan noise is reduced more effectively as the length of internally lined duct increases. Similar to fibrous absorbers within a room, duct liner is generally most effective at reducing mid-to-high frequency noise. Since most problematic fan noise is in the 125-Hz and 250-Hz octave bands (lower frequencies), a passive sound attenuator can replace sections of duct with thick baffles lined with sound absorptive material. Attenuators can either target problem frequencies or act more broadly across a wider range of octave bands when necessary. Finally, the flow rate of air or liquid within ducts or pipes can also cause noise, which will impact the background noise levels in a given space. Slower movement of air and liquid within ducts or pipes yields lower noise levels. In critical spaces, the airflows are designed to be slow and smooth so as not to introduce distracting noise.

Vibration-induced noise can also be controlled by introducing vibration isolation elements at the mounting points of reciprocating or otherwise noise-making equipment. Neoprene isolators provide damping material that dissipates the vibration, while spring isolators can be tuned to match the resonances of the vibrating equipment, thereby attenuating the noise. By choosing the appropriate isolators for the specific equipment, vibration noise can be reduced by up to 90%. Vibration can be further reduced by adding a flexible connection between the vibrating equipment and the associated ductwork, piping, and conduit. This limits the amount of vibration transmitted directly from the vibrating equipment into distribution routes (e.g., ductwork, piping, and conduit).

Additional Resources

As described above, and as shown in many of the music education facilities presented in this book, acoustic design metrics and strategies are often interrelated, such that only a holistic approach will ensure success. The discussion above is only a brief overview of this approach, articulating some of the major aspects involved in designing the acoustics of a space, and is not intended to be a comprehensive design guide. A list of helpful textbooks is given in the References [5,6] for readers interested in a more extensive explanation of the various topics discussed in this overview and other nuances involved in the art and science of architectural acoustics. To learn more about the science of acoustics and to search for educational programs, please visit the Acoustical Society of America website (acousticalsociety.org). Also, more information about acoustical consulting companies, many of whom work in the area of music facility design, can be found through the National Council of Acoustical Consultants (www.ncac.com).

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Reflections

FROM KEY DESIGN TEAM MEMBERS