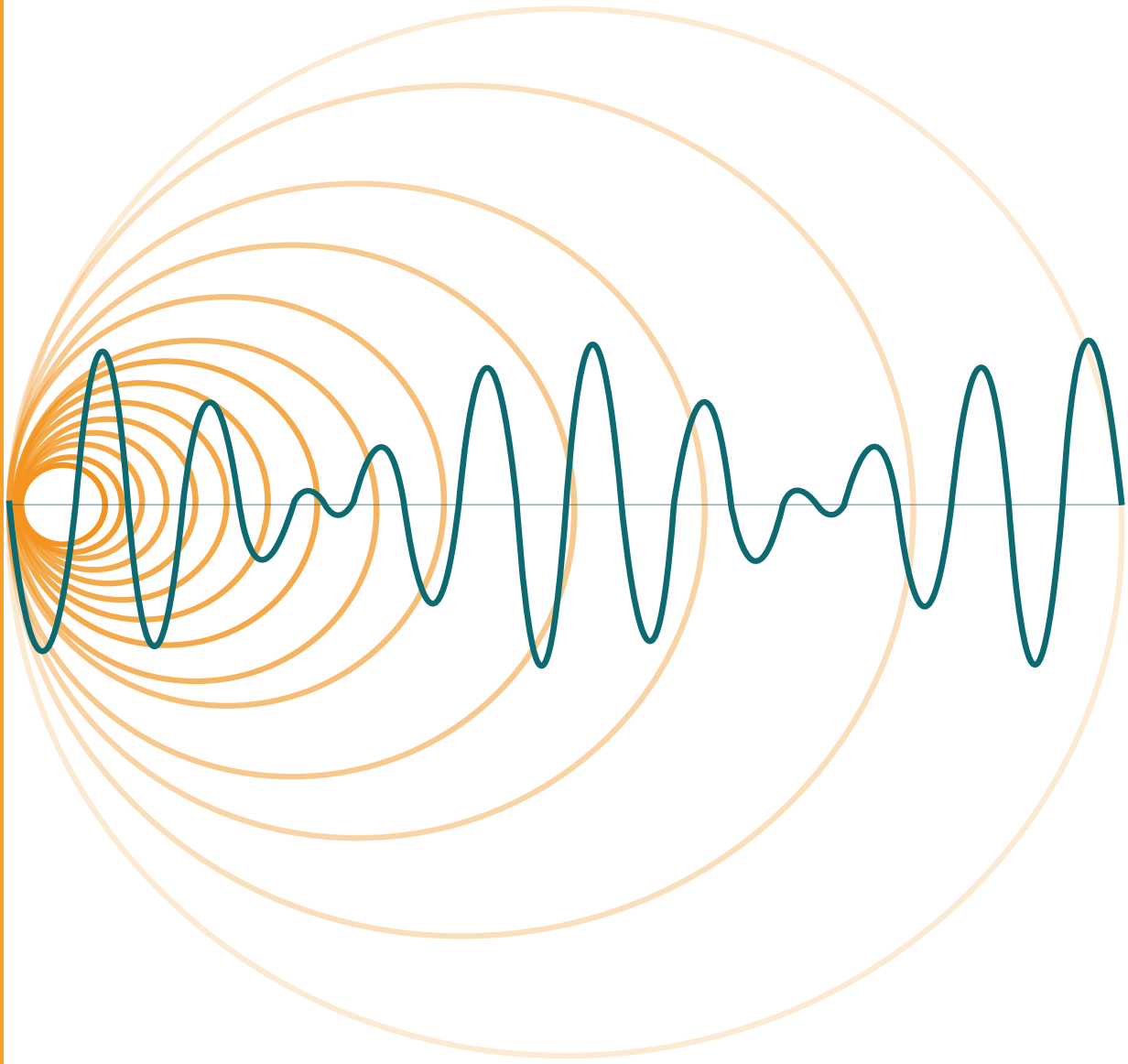
ACOUSTICS IN HEALTHCARE ENVIRONMENTS



CISCA
Ceilings & Interior Systems Construction Association

INTRODUCTION

Acoustics in Healthcare Environments is a FREE tool for architects, interior designers, and other design professionals who work to improve healthcare environments for all users. It is an introduction to the acoustical issues commonly confronted on healthcare projects. Practical design responses to these issues derived from a broad review of information is provided by CISCA, using "practitioner-friendly" language. The following issues are addressed:

- **THE CURRENT STATE OF ACOUSTICS IN HEALTHCARE ENVIRONMENTS**
- **WHY ACOUSTICS MATTER IN HEALTHCARE ENVIRONMENTS**
- **UNDERSTANDING THE PRIMARY ACOUSTIC ISSUES**
- **UNDERSTANDING HOW ACOUSTICS ARE MEASURED**
- **DESIGN STRATEGIES FOR IMPROVED ACOUSTIC ENVIRONMENTS**
  - GENERAL DESIGN CONSIDERATIONS
  - SPECIFYING MATERIALS AND FINISHES
  - MINIMIZING MECHANICAL AND MEDICAL EQUIPMENT NOISE
  - DESIGNING FOR PRIVACY AND CONFIDENTIALITY
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  - EMERGENCY DEPARTMENTS (EDs)
- **MEETING THE STANDARDS**
- **GLOSSARY OF TERMS**
- **ENDNOTES**

Considerations when applying this research:
The content of this white paper only relates to the literature accessed and does not reflect information available outside/beyond those sources, whether by a specific author or others. Research findings from a singular source should not be used as the basis for design solutions or other judgments and decisions by users of this white paper, but must be considered in the larger context of a full search of all available information and the user's synthesis of that collective information. Consider the date of publication of the individual sources to determine the timeliness of the information, especially if study data were used.

ACOUSTIC CONSIDERATIONS

Many sounds are present in hospital environments, including those from beepers, alarms, machines, rolling carts, HVAC systems, and conversations, among other sources. These can be severely irritating and at times harmful to patients, depending on their current conditions (i.e., age, hearing ability, medication intake, cultural background, and pre-existing fears and anxieties).[1,2] Acoustics in healthcare environments are complex and require a careful, strategic design.

Specific acoustical considerations in healthcare settings include supporting patient well-being and privacy; supporting communication among staff; and meeting standards and regulations (e.g., HIPAA).[3,4] In recent years, these issues have received much attention. As evidence, acoustics are a key component of several new healthcare design guidelines; many studies identifying design strategies to improve acoustical conditions in healthcare environments have been conducted; and hospitals throughout the United States have taken initiatives to improve their acoustic environments.

Acoustics in Healthcare Environments (1) provides an overview of common acoustic problems in healthcare environments throughout the United States, (2) discusses the impact of acoustics on occupants of these environments, and (3) presents evidence-based design considerations that can be used to improve acoustic conditions in healthcare environments.

[Specific acoustical considerations in healthcare settings include supporting patient well-being and privacy; supporting communication among staff; and meeting standards and regulations (e.g., HIPAA).][3,4]

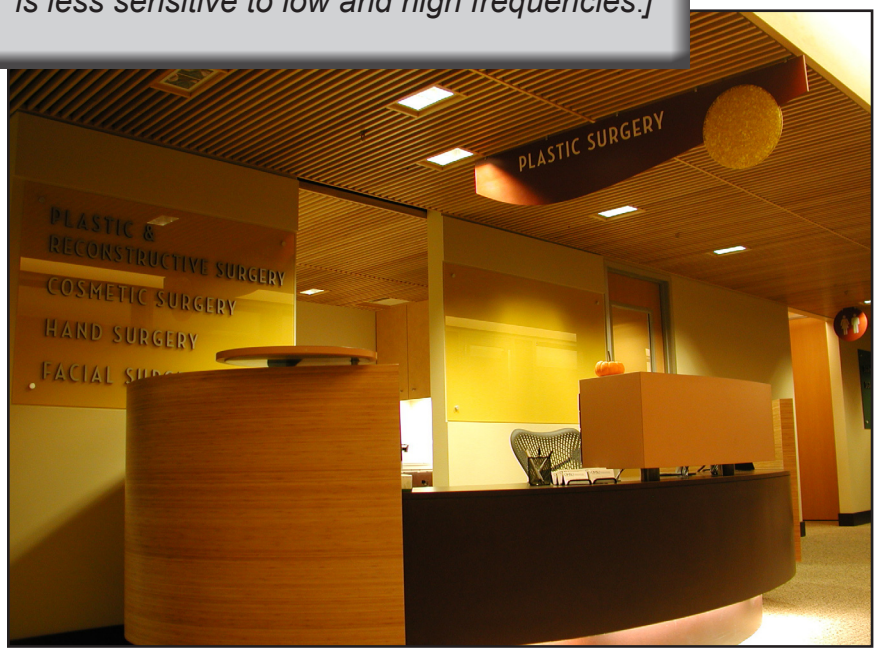
THE CURRENT STATE OF ACOUSTICS IN HEALTHCARE ENVIRONMENTS

Acoustic levels in today's hospitals are very high. A study conducted by Busch-Vishniac et al. in 2005 found that sound pressure levels have risen significantly and consistently since 1960. On average, daytime levels have risen 0.38 dB and nighttime levels have risen 0.42 dB—each year. In general, these findings remained true no matter what type of hospital or facility was examined, indicating that acoustical issues persist in hospitals of all types and acoustical solutions to these issues may be widely applicable.[5]

The same study found that sound levels throughout Johns Hopkins Hospital, one of the top-ranked hospitals in the United States, were on average at least 20 dB(A) louder than the recommendations of the World Health Organization (WHO). Average sound levels of Johns Hopkins Hospital exceeded 45 to 50 dB(A), which is the typical conversational speech level, implying it may be difficult for patient care teams (PCTs; doctors, nurses, physician's assistants, etc.) to communicate without resorting to raising their voices or shouting.[5] Many other studies that have examined hospital noise levels found peak levels often exceed 85 dB(A), which has a sound pressure 100,000 times that of 35 dB(A)—the recommended daytime level for patient areas.[6]

Decibel (dB) *def. [A unit measurement of the loudness of a sound. Louder sounds have larger decibel values.]*

A-Weighted Decibel (dB(A)) *def. [A measure of sound pressure level designed to reflect the response of the human ear, which is less sensitive to low and high frequencies.]*



WHY ACOUSTICS MATTER IN HEALTHCARE ENVIRONMENTS

Creating a comfortable acoustic environment in healthcare environments can play an important role in supporting safety, health, healing, and well-being for all occupants. Additionally, maintaining speech privacy in healthcare settings helps reduce medical errors as it supports open conversations among patients, families, and PCTs and is believed to influence patient satisfaction.[7] If patients are not confident that they have complete privacy, they may hesitate to provide complete information about their medical conditions and/or concerns, potentially putting their health at greater risk.[8] The importance of an adequate acoustic environment for patients, family, and PCTs is discussed in this section.

Patients and Families

Poor acoustical conditions may have a negative impact on a patient's physiological health and increase their chances of being readmitted to the hospital.[9] Acoustics can also impact perceptions of privacy, comfort, safety, and security for patients and their families.[1] Consider the following examples of how the acoustic environment can impact the physiological and psychological well-being of patients and their families in healthcare settings:

- Sudden noises can set off "startle reflexes" and can lead to grimacing, increased blood pressure, and higher respiratory rates for patients. Prolonged loud noises can lead to memory problems, irritation, impaired pain tolerance, and perceptions of isolation.[1,10]

- Sleep disruption and deprivation are frequently cited issues in healthcare environments. High acuity patients are especially likely to be negatively impacted by poor environmental conditions.[11] Reduced noise levels in intensive care units (ICUs) may help patients sleep and foster a regular wake/sleep cycle.[12]

- The low-frequency noise often created by mechanical systems in hospitals can potentially be a source of annoyance and result in higher blood pressure and sleep disruption in patients.[13]

- In one study, heart attack patients exhibited higher pulse amplitudes in a poor acoustic environment than in a good acoustic environment (i.e., room with sound absorbing surfaces) at nighttime. These findings support the possibility that raised voices may have a negative impact on patients in a poor acoustic environment. This impact may be greater at night because background noise tends to be lower, making noise disturbances more noticeable and stressful.[9]

Patient Care Teams (PCTs)

Findings from research on the impact of noise on PCTs have varied. They imply that while PCTs may be able to perform tasks in an environment with a high level of noise, they may have to exert more effort to do so, in turn causing more fatigue.[6] When inadequate acoustic conditions exist, poor psychosocial conditions can occur even for highly-trained and educated PCTs that are prepared to handle stressful conditions.[14]

Speech intelligibility is very important to PCTs in healthcare environments. PCTs need to be able to understand and quickly respond to the many types of auditory signals (e.g., conversations, medical equipment, alarms) in hospital settings. Speech recognition systems often used in healthcare environments rely heavily on appropriate speech signals to operate and all building occupants rely on clear speech intelligibility to understand foreign languages, accents, and varying speech patterns.[6] When speech intelligibility is not fully addressed, it may negatively impact patient care and safety.

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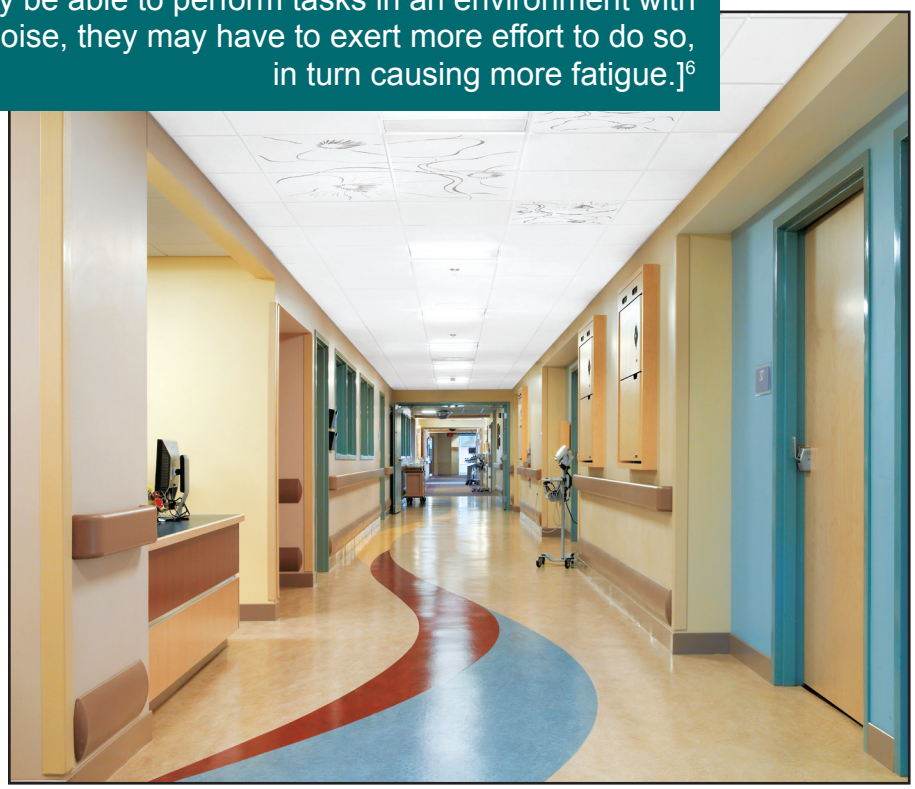


Consider the following findings related to the impact of the acoustic environment on PCTs:

- In a study examining noise in a neurological intensive care unit, many nurses felt noise negatively impacted them. Many indicated they experienced irritation, fatigue, distraction, and tension headaches as a result of the poor acoustic environment. Many nurses also believed the noise levels negatively impacted patients in the ICU.[2]

- In one study, patients in an intensive coronary care unit using sound-absorbing ceiling tiles felt PCTs had better attitudes as compared to the perceptions of PCT attitudes among patients in a unit with sound-reflecting ceiling tiles.[9]

- In one study, sound absorbing materials were installed in corridors of a hematology oncology unit over no more than half of the ceiling and upper wall surface. This acoustic design strategy reduced sound pressure levels in the unit by 5 dB and significantly reduced reverberation times. Nurses and patients perceived an improved acoustic environment, with many of them dissatisfied before the installation and almost all of them satisfied following the installation. Notably, fewer nurses felt it was difficult to concentrate and communicate and fewer patients felt it was difficult to sleep following the installation.[15]

- After acoustical ceiling tiles replaced the existing sound reflective ceiling tiles in the main work area and patient rooms in a Swedish hospital, nurses reported lower work demands and less pressure and strain during their afternoon shift (the noisiest shift studied).[14]

Federal Requirements

As part of the Health Insurance Portability & Accountability Act (HIPAA) initiated by the U.S. Department of Health and Human Services (DHHS), the federal government requires pharmacies and healthcare providers in the United States to provide privacy for patient health information (e.g., medication, symptoms, health conditions) in electronic, written, and oral formats. This is meant to prevent intentional or unintentional privacy breaches. HIPAA privacy standards apply to both new construction and renovations of all types of healthcare organizations including pharmacies, physicians' offices, and hospitals.[6,16,17]

UNDERSTANDING THE PRIMARY ACOUSTIC ISSUES

Sound can be transmitted to a person's ear directly from a source (i.e., direct sound), after reflecting off of one or more surfaces (i.e., reflected sound), after passing through a shared, solid, structural component like a wall or ceiling (i.e., transmitted sound), or after bending over and around partitions (i.e., diffracted sound).[17] Architectural design strategies such as placing staff rest areas away from noise sources, and acoustical environment decisions such as specifying quieter alarms and machines can help reduce noise levels in hospitals.[18] The main acoustic properties that need to be addressed in healthcare settings are discussed below.

Sound Pressure Level (SPL) *def. [The physical loudness of a sound on a decibel scale determined by the air pressure change caused by a sound wave.]*

Background Noise *def. [All direct and indirect sound that is audible to the human ear that has the potential to interfere with wanted (e.g., medical equipment warnings) or unwanted (e.g., private conversations) sound signals.]*

Reverberation Time *def. [The time it takes for sound to decay by 60 dB once the source of the sound has stopped.]*

Sound Pressure Level (SPL)

- SPLs in many modern hospitals are high enough that they may interrupt sleep, impact speech intelligibility, and create occupant discomfort due to noise.[5]
- SPLs in Johns Hopkins Hospital were the loudest in the hallways, followed by the nurses' stations, and occupied patient rooms. Unoccupied patient rooms were the quietest, although they were sometimes noisy during the daytime hours. All other types of spaces were consistently noisy throughout the day and night.[5]
- Alarms, medical equipment, rolling carts, footfalls, and closing doors can all create short-term fluctuations in SPL.[2]

Background Noise

- Background noise levels should meet the criteria set by established standards (e.g., the American Society of Heating, Refrigerating, and Air-Conditioning Engineers; ASHRAE) and should be identified at the onset of a project.[4]
- Certain specialized healthcare environments (e.g., spaces where audiometric testing is conducted, sleep disorder clinics) require minimal background noise and distractions.[4]
- The continuous background noise levels created by building services (e.g., heating, ventilation, and air-conditioning; HVAC) are typically calculated as specified by the manufacturer.[4]
- If background noise is used at a patient's bedside (through sound-masking systems, music, etc.) appropriate levels likely lie somewhere between 40 and 60 dB(A).[19]
- Background noise should be minimal for patients that are at risk for hearing damage as a result of ototoxic (i.e., harmful to the organs or nerves connected with hearing) medications. These patients should be placed in rooms fitted with heavy doors that are exposed to minimal noise from mechanical systems, alarms, or medical pumps.[8,13,19]

Reverberation Time (RT)

- Controlling reverberation in healthcare environments through appropriate finish selection is important for optimizing speech intelligibility, creating a restorative environment, and limiting noise transmission.[4]
- RTs are not always directly related to SPLs. For example, a room can have a long RT without necessarily having a loud SPL. Therefore, SPL and RT should both be assessed to provide a comprehensive understanding of the acoustic environment in a healthcare environment.[14]

[Architectural design strategies such as placing staff rest areas away from noise sources and acoustical environment decisions such as specifying quieter alarms and machines can aid in reducing noise levels in hospitals.][18]

UNDERSTANDING HOW ACOUSTICS ARE MEASURED

Measurement Methods

Acoustic standards are frequently updated to include the newest, most accurate measurement methods. Current standards should always be consulted and spaces should be designed to meet them.[11] Some of the most common measurement methods used in the healthcare design industry are introduced below.

Noise Reduction Coefficient (NRC)

- NRC is a number rating that indicates a material's sound absorbing properties, based on the average absorption for the material over primary speech information frequencies (250 Hz to 2000 Hz). The higher the NRC rating the more efficient the material is at absorbing sound. For example, a material with an NRC of 0.70 absorbs approximately 70% of sound energy, while the remaining 30% reflects back into the space.[20]

- NRC values below 0.50 indicate minimally absorbent surface materials, while NRC values greater than 0.80 typically indicate very absorbent materials.[16]

Sound Transmission Class (STC)

- STC is a comparative value that indicates the efficiency of building materials (e.g., walls, ceilings, floors, glazing) to reduce sound transmission. The larger the number the more successful the material is at preventing noise from passing through.[20]

- STC ratings should be determined before partitions are specified by considering the budget and the importance of each performance factor (i.e., controlling background noise, minimizing distractions, and promoting privacy) for a given space.[4]

- Wall systems with STCs lower than 35 are considered poor sound barriers, while those with STCs at or above 55 are considered very good sound barriers.[16]

Ceiling Attenuation Class (CAC)

- CAC is a rating of a ceiling system's ability to reduce sound transmission. It represents, in decibels (dB), how much sound will be attenuated between rooms sharing a ceiling plenum.[20]

- Higher numbers indicate better performance. Ceilings with a CAC less than 25 are considered to be poor barriers of sound intrusion, while ceilings with a CAC of 35 or greater are considered very good barriers of sound intrusion. Oftentimes, a ceiling with a high CAC (i.e., creates a good sound barrier) can have a low NRC (i.e., absorbs little noise).[16] Some ceiling panels are produced with both high NRC and CAC values.

Articulation Class (AC)

- AC is a measure used to rate the speech privacy performance of acoustical ceilings or acoustical screens in open-plan environments. Privacy increases as the AC value increases, generally ranging between 100 and 250.[20]

- A ceiling must be at least 9' high to perform according to the AC rating it is given.[16]

Privacy Index (PI):

- PI is a measure used to rate the speech privacy in a given space and is calculated based off the Articulation Index.[20]

- Spaces with a PI of 95% to 100% are considered to have confidential speech privacy, meaning that speech in the space will not be at all intelligible (although it may be overheard) outside of the space. Spaces with a PI of 80% to 95% are considered to provide "normal" speech privacy, meaning that conversations in the space may be overheard, but will not be fully intelligible. Spaces with a PI of 60% to 80% are considered to provide only marginal speech privacy, meaning most conversations in the space will be overheard and often times will be fully intelligible. Spaces with a PI less than 60% are considered to have no speech privacy, meaning that all conversations in the space will be clearly intelligible outside of the space.[16]

DESIGN STRATEGIES FOR IMPROVED ACOUSTIC ENVIRONMENTS

To identify solutions for the acoustic problems that persist in healthcare environments, an evidence-based design approach should be taken. Best practices that are based on lessons learned from previous projects (e.g., by conducting post-occupancy evaluations) and industry guidelines and standards (which are often based on evidence-based findings and best practices) should be carefully considered throughout the design process.

There have been many different studies conducted on acoustical design issues in healthcare settings. Several strategies to improve the acoustic environment have been supported multiple times by research and are considered by many to be evidence-based design strategies. These include the specification of noise-reducing materials and the provision of single-occupancy patient rooms.[6,11,21,22] These and other design strategies are discussed in more depth in this section.

General Design Considerations

Design Process

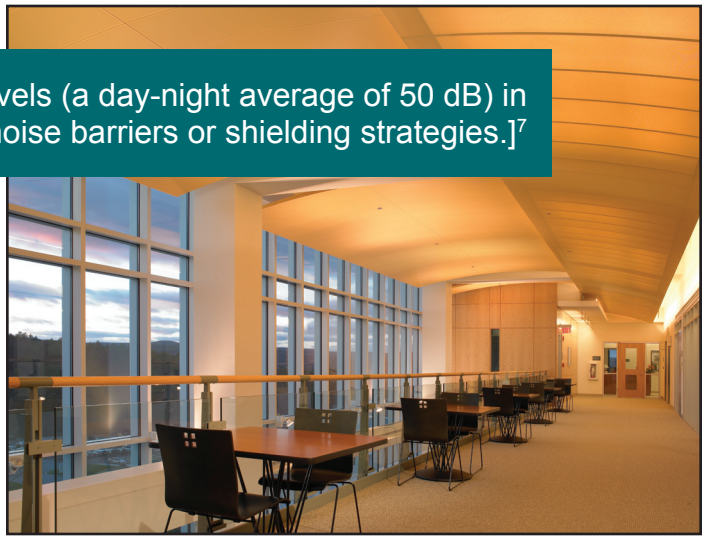
The acoustic environment is an important consideration at every stage of the design process, but also needs to be considered in the context of other important factors (e.g., lighting, hygiene, temperature). To assure that this happens, consider the following:

- Employ an acoustical engineer at the early stages of the design process for healthcare facilities and regularly consult with this engineer through the post-construction stages to assist with mechanical system design, equipment and building construction specifications, and acoustical testing.[7]

- Hire an acoustical consultant to assess speech privacy and speech intelligibility in healthcare settings using the test methods provided by the American National Standards Institute (ANSI) and the American Society for Testing and Materials (ASTM International).[16]

- Understand that many of the design strategies used for infection control in healthcare environments can have a negative effect on the acoustic environment if not carefully considered. For example, hard surfaces are often specified for their cleanability but these surfaces often reflect sound, creating reverberation. Also, high efficiency filtration systems are often required in healthcare systems, but these surfaces require more fan horsepower and create more noise than other systems.[13,19]

[Establish lower outdoor sound levels (a day-night average of 50 dB) in outdoor patient areas through noise barriers or shielding strategies.][7]



Site Design

Site design can have a major impact on acoustics in healthcare settings, as noise sources outside can significantly impact noise levels inside. Consider the following when selecting a site for a healthcare facility:

- Understand that facilities typically have different levels of regulatory or functional control over different types of environmental noise. They may have complete (e.g., facility HVAC equipment, emergency generators), limited (e.g., helipads), or zero (e.g., highways, airports) control depending on the source.[7]

- Consider all existing and future sources of noise (e.g., highways and airports in the construction phase) that have the potential to be transmitted through the exterior shell of the building into the building's interior.[7]

- Conduct site measurements to determine the impact of noise from the surrounding, external environment; plan the site and design the building's façade to mitigate any impacts.[4]

- Establish lower outdoor sound levels (a day-night average of 50 dB) in outdoor patient areas through noise barriers or shielding strategies.[7]

- Understand that if exterior noise levels surpass a minimal level (e.g., the ambient noise level found in a rural or suburban residential neighborhood with single-family homes), measures should be taken to monitor site noise levels using "ANSI/ASA S12.9: Quantities and Procedures for Description and Measurement of Long-Term, Wide-Area Sound." Mitigate the impact of this noise by specifying acoustic controls (e.g., mufflers, acoustic louvers) and quieter equipment.[4,7,23]

Space Planning

Space planning can have a significant impact on the acoustic environment. Determining what spaces will be adjacent to each other and how the space should be laid out takes careful consideration of how specific areas are going to be used, the level of privacy that is needed, and the desired background noise level, among other factors. Consider the following design considerations for space planning:

- Create single-bed (as opposed to multi-bed) patient rooms as they are associated with several positive outcomes including reducing the number of hospital-acquired infections; improving patient sleep and privacy; facilitating better communication with parents and families; improving perceptions of social support; decreasing stress for staff; and improving patient satisfaction.[4,6,11] Advocating for single-patient rooms in hospitals (during new construction, expansion, or renovation projects) demonstrates a commitment to meeting patients' privacy, safety, and dignity needs.[6,22,24]
  - The *2010 Guidelines for Design and Construction of Health Care Facilities*, the American Institute of Architects Academy of Architecture for Health, the Facility Guidelines Institute, and the U.S. Department of Health and Human Services all support the provision of single-patient rooms in the construction of new U.S. healthcare facilities (e.g., medical/surgical wards and obstetrical units).[23,24]
  - France has implemented single-patient rooms for hospitals built since the late 1980s. British, Dutch, and Norwegian facilities have increasingly implemented single-patient rooms, and The Ward of the 21st Century in Calgary, Alberta, Canada (a research initiative in hospital design) placed high importance on single-patient rooms.[24]
- Decentralize nurses' stations as this may minimize corridor traffic, in turn reducing noise generation and allowing nurses to see and hear their patients more effectively.[4,22,23]
- Create separate, acoustically private spaces for families of patients to gather to reduce noise levels elsewhere in the hospital.[8]
- Include private meeting rooms for patients, relatives, and healthcare professionals to provide privacy and improve communication between these groups.[6,12,25]
- Close off nursing and chart stations in intensive, postoperative areas.[26]

Specifying Materials and Finishes

Space planning alone will not result in an adequate acoustic environment. Walls, floors, and ceilings should also be designed to support privacy and minimize noise transmission. Materials and finishes selected for ceilings, walls, and flooring can greatly impact the acoustic environment. Research suggests that using noise-reducing finishes in healthcare settings positively impacts patients' sleep, privacy, satisfaction, and PCT stress.[6,11] However, safety issues, namely smoke, flammability, and cleanliness standards, should also be considered when specifying acoustical materials.[15]

When designing for acoustical privacy it is important to include the composite action of all adjacent building components. The composite sound performance of walls, ceilings, doors and floors will greatly impact the overall sound performance. The combination of individual components' acoustical performance and installation details will alter the overall performance.[16,27,28] The acoustical design properties of some common materials and finishes in healthcare environments are discussed in this section.

Ceilings

Acoustical ceiling tile (ACT) can reduce reverberation times and increase speech intelligibility, potentially improving the psychosocial work environment for PCTs.[14] Selecting the appropriate ceiling for spaces in healthcare environments is important in creating the appropriate speech privacy level. Oftentimes, different ceilings are needed in different areas. When selecting a ceiling, consider to what degree noises need to be absorbed, blocked, and/or covered (i.e., masked).[16] Consider the following when specifying ceilings in healthcare environments:

- When space and logistical considerations permit, incorporate a suspended acoustical ceiling system with sound-absorbing ceiling tiles to promote a satisfactory acoustic environment. When this is not possible or feasible, consider mounting sound absorbing panels directly onto the ceiling and upper walls, as this may still provide significant noise reduction.[15]
- Be aware that non-absorbing ceilings may allow sound to reflect from one space to another or be transmitted through the ceiling plenum to another space, possibly resulting in privacy breaches.[6]
- In spaces with noisy equipment above the ceiling plenum or spaces with walls that do not extend above the plenum level, specify ceiling tiles that have a CAC of 35 or more.[26]

Ceilings (cont'd)

- Understand the properties of specific types of ACT. The following are some of the most common types of ACT used in healthcare environments:
  - Glass fiber ACT have high sound absorption qualities, often having NRC ratings of 0.90 or higher. Covering these panels with a thin, anti-microbial film and using a particle-free assembly can make them acceptable for clean room applications, without sacrificing their sound absorption qualities. They do not have very high sound isolation qualities; therefore, they are most appropriate for corridors and open offices because the background noise will often mask the noises coming from the ceiling plenum.[13,19]
  - Mineral fiber ACT have sound absorption properties (maximum 0.80 NRC) lower than glass fiber ACT, but typically have a higher CAC (between 30 and 40), indicating they greatly reduce sound transmission. Mineral fiber ACT may be appropriate for spaces that require both sound absorption and isolation and tend to be effective at minimizing noise from equipment in the ceiling plenum.[13,19]
  - Composite ceiling panels (a combination of a glass fiber facing and a mineral fiber or gypsum board backing) have high sound isolation and sound absorption (i.e., high CAC and NRC) making them a good option for neonatal intensive care units (NICUs).[13,19]
  - Cast mineral fiber composition enhances sound isolation and sound absorption.

Walls

Wall construction and surface materials are important for creating an appropriate acoustic environment. Controlling flanking noise from negating the intended performance of any wall assembly is of key importance. Any breaches in a partition will result in a significant drop of acoustical performance.[28] Consider the following when determining wall construction and specifying wall materials:

Wall Construction

- Understand that the most effective way to achieve wall performance is to penetrate the ceiling membrane.[29] Further improvement is obtained when the partition is non-demising, meaning it is continuous from floor to underside of the next floor's structural deck or concrete slab. In cases where the wall is demising or terminates at the ceiling plane additional detailing may be required.[27]

- Recognize that doors can have a tremendous negative impact on the acoustical performance of a wall.[30] Starting with a 48 STC wall, even with a fully sealed gasketed solid core door, the combined STC will drop to 28. Any glazing in the partition will have the same impact on performance.[28]

- Identify details that may have negative impacts on the sound isolation performance of a wall such as back-to-back outlet placement, lowered wall heights, air gaps, wall openings for services, and direct duct runs.[4,16] For example, a one square inch hole in a 60 STC partition will drop its performance down to a 41 STC.[28] This crack can easily occur at wall-to-wall intersections as well as wall-toceiling interfaces. Another important concept of flanking: where two acoustical partitions meet, it is important to make sure that no gypsum panel membrane is continuous throughout the intersection.[27]

- Be aware that both door positioning and HVAC duct layout can impact the privacy performance of walls. A direct duct run through rooms can reduce privacy and increase distractions in healthcare settings.[4]

Wall Surfaces

- Specify surface-mounted, one-inch thick wall panels or other sound-absorbing wall materials with an NRC of 0.70 or more to effectively absorb noise from common activities in healthcare environments, especially in large areas where noise tends to build up.[13,19,26]

- Cover glass- or natural- fiber wall panels with a thin, impermeable film (e.g., taffeta vinyl, polyvinyl fluoride) to allow for easy cleaning in clinical areas of a hospital.[13,19]

- Specify fabric-wrapped wall panels in non-clinical areas of a hospital where regular cleaning is not required, as they are more effective and less costly than panels that are encapsulated in film.[13]

- Install sound-absorbing wall materials perpendicular to each other to reduce flutter echoes in spaces where they may cause problems (e.g., conference rooms).[13]

Floors

It is possible to reduce impact noise generated by footfalls and rolling carts by specifying appropriate flooring materials and finishes.[26] Consider the following when specifying flooring in healthcare environments:

- Be aware that of the most common floor surfaces in hospitals, some (e.g., rubber) create less impact noise than others (e.g., vinyl composition tile installed directly on concrete or terrazzo).[13,19]

- Minimize the use of floor discontinuities (e.g., expansion breaks and transitions) to reduce vibrations caused by rolling equipment over them.[7]

- Specify carpet to effectively reduce impact noise (e.g., foot traffic, carts) in healthcare environments. However, understand that it typically provides an NRC of around 0.20 to 0.30 and should be considered one element of several to provide sound absorption.[19]

- Understand that specifying carpeting in corridors may potentially create problems related to efficient movement of computer carts and cleanability. Consider placing computers in each patient room to eliminate the need for carts. Specify carpet tiles, so they can be easily removed and cleaned when needed.[8]

Other Materials

- Consider how movable furniture panels, glass partitions, and acoustically treated curtains can be used in open spaces to block noise. In open-office areas, furniture panels should be at least 60” high and have an STC of at least 24.[16]

- Be aware that open doors significantly negatively impact the noise isolation capability of walls.[7] Specify television headphones, pillow speakers, and/or sound masking devices (providing a continuous nature sound or music) in patient rooms to address the high noise levels created when doors are left open or rooms are shared.[13,19]

Minimizing Mechanical and Medical Equipment Noise

Mechanical Equipment

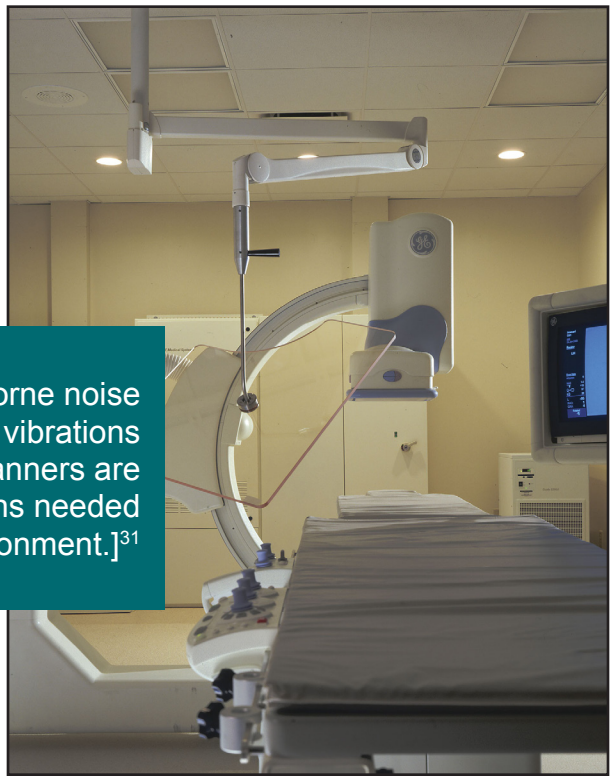
Mechanical equipment noise enters spaces through interior partitions and the façade of the building, through ventilation ducts, and as a result of vibration from mechanical equipment. Mitigating the impact of each requires specific design solutions.[4] To address noise issues related to mechanical systems, consult HVAC engineers and consider the following:

- Specify quieter equipment; acoustic silencers, louvers, and barriers; and vibration isolators.[4,7,13,19]
- Analyze filter performance; partition construction and detailing; airflow velocities; façade design; site planning; and potential cross-talk issues (i.e., situations where sound from one room may be transmitted to another via ducts).[4,13,19]
- Consider the noise impact of terminal boxes and how performance is affected when sound attenuators are used.[13,19]
- Consider alternatives to standard duct attenuation strategies, which are usually prohibited in hospitals due to the potential indoor air quality and hygiene problems they create.[4,13,19]
- Insulate pneumatic tubes and ice machines to reduce noise levels.[11]
- Determine elevator type, location, and surrounding structure with knowledge of their vibration and structure-borne sound impacts (i.e., vibration transmitted from one location to another through the building structure).[7]
- Understand that noise from building services can impact other sensitive spaces within the building through windows. Consider façade design, site planning, and acoustic control to mitigate these impacts.[4]
- Understand that when designing partitions that enclose mechanical equipment it is important to understand that the noise generated by the equipment, in most cases, extends beyond the sound frequencies in which STC tests are run. This implies that designing around STC ratings alone will not assure acoustical privacy. Specifically, STC testing stops at 125 Hz, whereas mechanical equipment can generate noise down to 20 Hz.[28]

Magnetic Resonance Imaging (MRI) Scanners

MRI scanners are sensitive to low-frequency vibration levels (typically less than 100 Hz) that are below those that are sensed by humans. These vibrations can reduce image quality and/or result in missed diagnoses. However, MRI scanners themselves can produce sound pressure levels from 80 to 120 dB.[4,7,31] Containing airborne and structure-borne noise created by MRI scanners and minimizing vibrations from external sources in spaces where scanners are housed are two primary design interventions needed to maintain a safe healthcare environment.[31] Consider the following to achieve these goals:

- Locate spaces sensitive to noise and vibration away or buffered from spaces with MRI scanners.[31]
- Avoid running ducts through both MRI rooms and adjacent spaces.[31]
- Improve sound isolation of walls, floors, ceilings, doors, and windows to contain noise in rooms housing MRI scanners.[31]
- Specify sound-absorbing finishes and materials to minimize airborne noise in rooms housing MRI scanners.[31]
- Be aware that low-noise MRI scanners exist that can reduce the need for additional vibration controls.[31]
- Conduct a vibration survey of the hospital site to ensure the MRI scanners will run properly and accurately given exterior noise and vibration sources.[31]



[Containing airborne and structure-borne noise created by MRI scanners and minimizing vibrations from external sources in spaces where scanners are housed are two primary design interventions needed to maintain a safe healthcare environment.][31]

Designing for Privacy and Confidentiality

Speech privacy needs should be assessed in spaces in healthcare facilities where patient information is shared (e.g., consultation counters, pharmacies) to assure that privacy and/or confidentiality are provided for patients, families, and PCTs.[6,17] Both the background noise level and the noise reduction created by barriers and sound-absorbing finishes need to be considered when addressing speech privacy issues in healthcare settings.[19]

Although normal speech privacy (i.e., PI between 80% and 90%) is sufficient in most commercial settings, due to HIPAA requirements, many patient areas in healthcare facilities require a confidential level of speech privacy.[16] When an absolute secure level of speech privacy is required, analysis of the way the space is used, the level and amount of spoken communication anticipated, how the space is constructed, and the anticipated background noise level all need to be considered.[7] Adequate speech privacy can be accomplished in open and enclosed spaces through the provision of single-occupancy patient rooms, private discussion areas, effective space planning, appropriate partition placement, room finish specification, and sound masking system selection.[6,7] Consider the following when designing to support privacy and confidentiality in healthcare settings:

Measuring Acoustical Privacy

- Be aware that the AI, PI, Speech Transmission Index (STI), and Speech Intelligibility Index (SII) can all be used to quantify the privacy levels in a space. While subjective speech privacy testing methods such as occupant surveys are available, results for such measurements are influenced by the hearing ability, attention span, and perceptions of the listener, and therefore, tend to be less reliable than objective measurements.[4,7,16,23]
- Understand that HIPAA does not give specific criteria for measuring acoustical privacy, only that privacy of patient information is provided.[4,16] ASTM E1130 (R1997 & R2006) and other standards include quantitative methods and procedures for measuring both “normal” and “confidential” speech privacy, as well as equipment and design interventions for monitoring and mitigating speech privacy conditions. These standards should be consulted to meet HIPAA privacy criteria.[7,17,23]

Speech Intelligibility

def. [A measure indicating to what extent speech is understood in a given environment.]

Sound Masking Systems

Research has indicated sound-masking systems have been an effective intervention for promoting speech privacy in office settings. However, research has yet to indicate they are entirely appropriate for healthcare environments, as they may impact speech intelligibility, which is a crucial aspect of communication between PCTs and patients and among PCTs. Therefore, the following recommendations should be carefully considered with full knowledge of their impact on communication and the ability to hear and respond to other important stimuli (e.g., alarms) in healthcare environments.[6]

- Recognize that the development of quieter HVAC systems (e.g., variable air volume, underfloor air delivery systems) make them less effective at masking confidential or private conversations; therefore, in many cases, sound masking systems are necessary.[16]

- Consider using sound-making systems to minimize patient distractions and improve speech privacy. Sound masking incorporates ambient background noise into a space to make speech unintelligible after a certain, user-defined distance (e.g., five to seven feet; the typical distance from a customer to a pharmacy consultation area). For sound masking to be effective in creating speech privacy, it needs to create a sound level louder than that of the unwanted speech information. However, such systems should not exceed 48 dB(A).[7,16,17]

- Avoid using music to provide sound masking, as the sound varies in frequency and loudness and therefore is not guaranteed to provide complete speech privacy at all times.[16]

- Specify sound-masking systems in patient rooms to reduce the impact of interruptions from equipment alarms and signals. Avoid using such systems in corridors or over nursing stations as they may interfere with patient monitoring.[8]

- Specify ceiling-housed, sound-masking systems in open areas (e.g., waiting rooms) that cover the speech frequency range at the lowest volume, as architectural elements that typically block sound (e.g., walls) are minimal in these spaces.[16,19]

[Adequate speech privacy can be accomplished in open and enclosed spaces through the provision of single-occupancy patient rooms, private discussion areas, effective space planning, appropriate partition placement, room finish specification, and sound masking system selection.][6,7]

Enclosed Spaces

Many enclosed spaces in healthcare settings have PIs that are lower than what is needed for confidential speech privacy, and oftentimes, they are not designed with consideration for the raised voice levels sometimes used with elderly patients.[16] Consider the following to assure adequate privacy levels are reached in these areas:

- Maintain a composite STC and A-weighted background noise level of at least 75 dB(A) in enclosed spaces where confidential speech privacy is required.[7]

- Where possible, acoustically separate patient rooms from one another and acoustically separate patient rooms from corridors using sealed doors. Be aware that glass doors or vision panels may provide the desired acoustical privacy and sound isolation, while still allowing for visual access.[8,13,19,26,32]

- Stagger patient room doors along the corridor and/or place the bathroom between the head of the bed and the corridor to reduce the amount of noise that transfers between rooms.

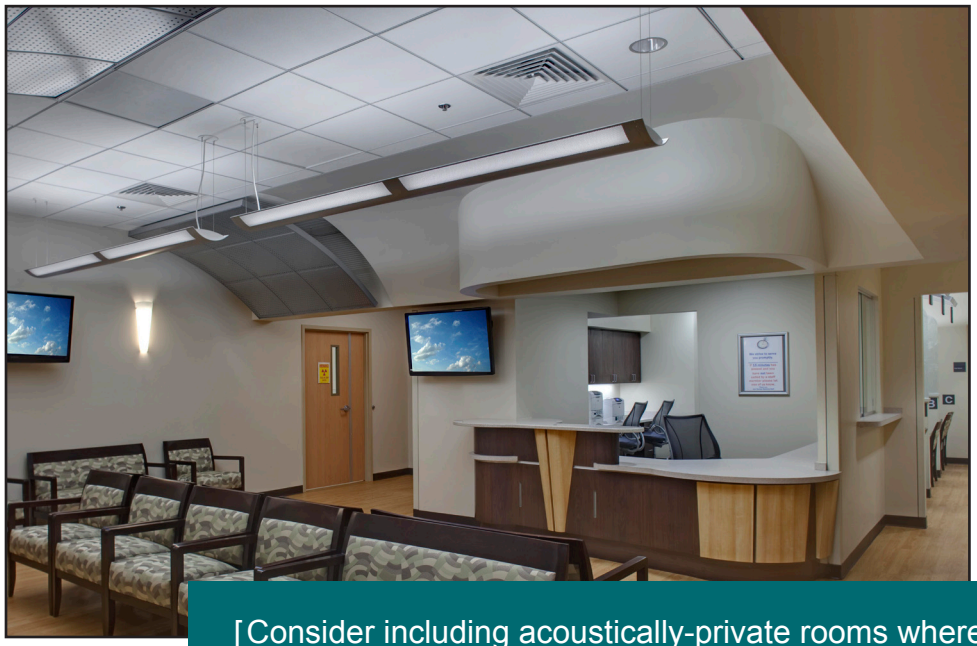
- Understand that according to the Facility Guidelines Institute's *Guidelines for Design and Construction of Healthcare Facilities* (2010) the recommended performance for partitions that separate patient rooms (with doors closed) is 45 STC. If a higher level of privacy is needed in the rooms, a 50 STC is recommended. The *Guidelines* can also be consulted for sound isolation recommendations for adjacencies between exam rooms, consultation rooms, bathrooms, treatment rooms, and NICUs.[7,23]

- Specify floor-to-slab fixed walls with a minimum STC rating of 40 in enclosed rooms where speech privacy is required but flexibility and adaptability are not. In situations where flexibility, adaptability, and speech privacy are all required, specify fixed stud or relocatable walls with a minimum STC rating of 40. Specify walls in combination with a ceiling with a CAC rating of 35 or higher and door and glazing components that are pre-engineered for STC performance.[16]

Open Spaces

Open spaces can pose significant challenges for creating an acoustically private environment, as they often lack partitions that can be used to block or absorb noise. Consider the following to address these challenges:

- Maintain a composite STC and A-weighted background noise level of at least 75 dB(A) in open plan spaces where confidential speech privacy is required.[7]
- Consider including acoustically-private rooms where private or confidential conversations can occur in open-plan spaces.[6,7,16]
- To achieve appropriate levels of speech privacy in open spaces, specify an acoustical ceiling with an AC of 180 or higher and an NRC of 0.80 or higher.[16] Understand that ceiling panels with higher NRC and CAC values are manufactured in many styles and colors that meet both budget and design requirements.[17]



[Consider including acoustically-private rooms where private or confidential conversations can occur in open-plan spaces] [6,7,16]

Integrating Hospital Technology

Patient safety and comfort and PCT comfort and productivity should be considered in the provision of electro-acoustic systems, which can impact the acoustic environment of healthcare facilities.[7] Technology can impact the way the acoustical environment affects the safety and comfort of patients, families, and PCTs in many ways. Consider the following when integrating technology into healthcare environments:

Paging

- To reduce overhead paging, first identify the individuals and departments that are paged most often and then create alternative ways for them to communicate.[33] Consider the following as alternatives to overhead paging systems:
  - Reduced noise or noiseless paging systems, or a nurse call and patient telemetry system;[11,13,19]
  - Wireless communication devices (e.g., hands-free two-way technology, IP phones, communication badges, vibrating beepers); [7,8,33]
  - Wireless asset tracking technologies (e.g., RFID and infrared) to track staff, patient, and equipment location;[7] and
  - Beeper systems to notify a patient's family and/or significant other of patient health status changes or updates.[33]

- Due to the use of a personal communication system as an alternative to an overhead paging system at Johns Hopkins Hospital, noise levels were reduced. However, sound quality was negatively impacted due to the use of small speakers.[5]

Alarms

- Assess alarm levels, and if possible reduce their volume to increase patient comfort. Be aware that alarms are often unnecessarily left at their factory-set level.[7,34]

- Specify alarms with variable volumes, with loudness indicating the urgency of the problem.[13,19]

- Place alarms in remote locations at nurse stations.[19]

ACOUSTIC REQUIREMENTS FOR SPECIALIZED ENVIRONMENTS

Neonatal Intensive Care Units (NICUs)

Acoustics in NICUs should support speech intelligibility, normal or relaxed vocal effort, and speech privacy. Physiological stability, peaceful sleep, and minimal acoustic distractions and interruptions for infants and adults should also be fostered by the acoustic environment.[7] Consider the following to design a supportive acoustic environment in these settings:

- Provide single-occupancy infant rooms in NICUs to help increase parental privacy and visits, increase PCT satisfaction, and reduce PCT stress.[35]
- Minimize noise levels near infants and ensure that equipment alarms, phones, sinks, and other noise sources are placed away from the infant's head.[33]
- Consider ways that space planning can be used to move noise from activities away from the primary infant care area to a more central, common area (e.g., prescribe and check-in drugs in a clean utility room).[7,34]
- Locate equipment that makes loud, continuous noise away from the infants when possible. If equipment is required in an infants' room, consider specifying vibration isolation pads or putting equipment in a glass enclosure.[7,36]
- Specify water supply units and faucets in infant areas that produce minimal noise and that are capable of producing instant warm water to minimize the amount of time water is flowing.[7]
- Utilize specialized wall, floor, and ceiling assemblies to meet speech privacy needs between undesirable adjacencies in NICUs (e.g., break room sharing a wall with infant or adult sleep room).[7]
- Specify carefully-designed acoustical ceilings in NICUs, considering both the NRC and CAC, as they provide the largest area for incorporating sound-absorbing surfaces. Provide ceilings that have an NRC of 0.95 for at least 80% of the surface area or an average NRC of 0.85 for the whole ceiling, and a minimum ceiling CAC of at least 29. For partitions that do not continue above the finished ceiling, a CAC greater than 29 may be required.[7]
- To mitigate the adverse effects of building equipment noise in the NICU, design mechanical, plumbing, and electrical systems to meet the noise requirements for the NICU and if possible locate mechanical systems at a distance from the NICU. This may include specifying HVAC systems with quiet air-handling units and fans, isolating the vibration caused by certain types of equipment, limiting air velocities in ducts, and specifying appropriate air inlet and outlet devices among other considerations.[36]

Emergency Departments (EDs)

EDs in hospitals are often very noisy due to many patients, doctors, nurses, and medical equipment regularly moving through the space. In a study by Orellana, Busch-Vichniac, and West in 2007, SPLs in Johns Hopkins Hospital were 5 to 10 dB(A) higher in EDs than the in-patient units in the hospital. High noise levels can create problems in EDs, potentially negatively affecting care quality when patients have immediate and sometimes critical needs that need to be met. SPLs in EDs may not be loud enough to cause hearing damage to occupants; however, there is concern that they may prompt occupants to raise their voices to speak to each other, which may be hazardous to patient safety, patient privacy, and contribute to PCT fatigue.[37]

EDs are also highly susceptible to privacy breaches resulting from the many patients and staff present, severity of patient conditions, multiple conservations taking place that include private patient information, and frequent use of multi-occupancy patient rooms with only curtains separating beds.[11] In a study examining patient privacy and confidentiality in EDs, patients in walled rooms were less likely to experience privacy breaches than patients in curtained rooms. Patients were also more comfortable discussing their medical history and being examined in walled rooms than in curtained rooms.[38] Consider the following to create a quieter acoustic environment in EDs:

- Specify highly-absorptive ceiling materials in open patient treatment areas (e.g., EDs, recovery rooms).[26]
- Consider providing walled rooms instead of curtained rooms for ED patients to support patient comfort and avoid privacy breaches.[38]

[Sound pressure levels may prompt occupants to raise their voices to speak to each other, which may be hazardous to patient safety, patient privacy, and contribute to PCT fatigue.][37]

MEETING THE STANDARDS

Several healthcare design guidelines released in recent years have emphasized the importance of acoustics in the design of healthcare environments. Healthcare environments should be designed to meet published standards. Among these are the *Sound and Vibration Design Guidelines for Hospital and Healthcare Settings*, *HIPAA*, *2010 FGI/ASHE Guidelines for Design and Construction for Health Care Facilities*, and the *Green Guide for Health Care*™. Additionally, *LEED® for Healthcare* is currently in draft form. Although selected acoustic considerations in existing standards have been referenced in this paper, original standards should be accessed for further information and acoustic design strategies.

Sound and Vibration Design Guidelines for Hospital and Healthcare Settings

The *Sound and Vibration Design Guidelines for Hospital and Healthcare Settings* are intended to guide the provision of satisfactory acoustics and privacy in all types of healthcare settings (new and renovated), including, but not limited to, large general hospitals, specialized care facilities, and ambulatory care facilities. These guidelines were developed with the intention of being a comprehensive and practical document that is based on both technical standards and professional best practices in acoustics. They provide minimum standards that are achievable using currently available methods and products, based on relevant evidence-based and/or clinical research. These guidelines serve as the reference standard for the acoustics section of the *2010 FGI/ASHE Guidelines for Design and Construction for Health Care Facilities*; the *Green Guide for Health Care™ v2.2*; and *LEED® for Healthcare*, which is currently under development.[7]

2010 FGI/ASHE Guidelines for Design and Construction for Health Care Facilities

The *2010 FGI/ASHE Guidelines for Design and Construction for Health Care Facilities* addresses design considerations for healthcare settings and were developed through a consensus process. They serve as a guide for regulatory codes and laws, but also as a guide of best practices for designers, healthcare administrators, and others involved in the design of healthcare facilities. These guidelines address design and construction considerations for a wide range of healthcare facilities including general hospitals, primary care hospitals, psychiatric hospitals, rehabilitation facilities, outpatient care facilities, and residential healthcare facilities, among others. The 2010 edition updates a previous edition and includes a new section that directly addresses acoustics in healthcare environments.[23]

Green Guide for Health Care™ v2.2.

The *Green Guide for Health Care™ v2.2* includes a two-point credit for improving the acoustic environment in healthcare settings. At a minimum, this guide and others recommend that acoustical issues related to exterior noise, acoustical finishes, room noise levels, sound isolation, paging systems, and building vibration be addressed in healthcare facilities.[19] Acoustic design strategies and test and measurement data should be documented to provide evidence of adherence to *Green Guide for Health Care* criteria.[26]

LEED® for Healthcare

The new *LEED® for Healthcare* rating system responds to design issues that are under unique conditions in the healthcare industry. The five main areas of the traditional LEED rating systems (sustainable sites; water efficiency; energy and atmosphere; materials and resources; and indoor environmental quality) include new considerations especially for healthcare. A credit is included for acoustic environment improvement.[39]

[The *Green Guide for Health Care* and other standards and guidelines recommend that acoustical issues related to exterior noise, acoustical finishes, room noise levels, sound isolation, paging systems, and building vibration be addressed in healthcare facilities.][19]

GLOSSARY OF TERMS

This Glossary of Terms offers basic definitions for terms that can be found in this document.

A-Weighting (dB(A)): A measure of sound pressure level designed to reflect the response of the human ear, which is less sensitive to low and high frequencies.

Acuity: The degree to which patients' conditions require direct nursing care. The highest acuity patients (e.g., intensive care) usually require a 1:1 or 1:2 nurse-to-patient ratio.

Articulation Class (AC): A measure used to rate the speech privacy performance of acoustical ceilings or acoustical screens in open-plan environments. Privacy increases as the AC value increases, generally ranging between 100 and 250.

Articulation Index: A measure of speech intelligibility ranging from 0 (renders speech unintelligible) to 1.00 (no interference with speech clarity), influenced by the way the elements and properties of a space affect the ability to understand speech.

Background Noise: All direct and indirect sound that is audible to the human ear that has the potential to interfere with wanted (e.g., medical equipment warnings) or unwanted (e.g., private conversations) sound signals.

Ceiling Attenuation Class (CAC): A rating of a ceiling panel's ability to reduce sound transmission. It represents, in decibels (dB), how much sound will be kept from transmitting between rooms sharing a ceiling plenum.

Decibel (dB): A unit measurement of the loudness of a sound. Louder sounds have larger decibel values.

Diffusion: The scattering of sound in all directions caused by sound striking a surface.

Flutter Echo: A ringing echo created when two parallel hard surfaces rapidly reflect sound back and forth across a room.

Frequency: The number of sound waves created in a given amount of time, indicating the pitch of the sound, expressed as Hertz (Hz).

Noise Reduction Coefficient (NRC): A measure of the average sound absorption of a surface used to compare the sound-absorbing characteristics of building materials.

Privacy Index (PI): A measure used to rate the speech privacy in a given space that is calculated based on the Articulation Index.

Reverberation Time (RT): The time it takes for sound to decay by 60 dB once the source of sound has stopped.

Sound Absorption: Sound deadened upon striking a surface.

Sound Pressure Level (SPL): The physical loudness of a sound on a decibel scale determined by the air pressure change caused by a sound wave.

Sound Reflection: The change of direction caused after sound waves strike a surface.

Sound Transmission: Sound which passes through a surface to the space beyond it.

Sound Transmission Class (STC): A numerical rating of the sound control performance of a wall or ceiling; the higher the number, the better the sound control.

Speech Intelligibility: The extent to which speech is understood in a given environment.

Speech Transmission Index (STI): An index measuring the speech intelligibility in a given area ranging from 0 (no intelligibility) to 1 (perfect intelligibility).

Transmission Loss (TL): The reduction in sound power caused by placing a wall or barrier between the sound source and receiver.

Universal Room: A hospital patient room that can be adapted to treat different medical conditions and acuity levels, as they vary between patients and over time.

ENDNOTES

These references form the basis of this white paper's content and can be consulted for further information.

1.) Mazer, S. E. (2005, March/April). Reduce errors by creating a quieter hospital environment. *Patient Safety & Quality Healthcare*. Retrieved March 25, 2010, from http://www.psqh.com/marapr05/noise.html

2.) Ryherd, E. E., Waye, K. P., & Ljungkvist, L. (2008). Characterizing noise and perceived work environment in a neurological intensive care unit. *Journal of the Acoustical Society of America, 123*(2), 747-756.

3.) Daly, P. (2009, June 15). Shhhh! Hospital acoustic upgrades under construction. *Grand Rapids Business Journal*. Retrieved March 3, 2010, from http://www.grbj.com/GRBJ/ArticleArchive/Article+Archive.htm?Channel={A7AFA10B-CAAB-4988-BAC9-B10793833492}

4.) RWDI Consulting Engineers (n.d.). Noise and acoustics for healthcare design. *Technotes,* 32. Retrieved March 3, 2010, from http://www.rwdi.com/cms/publications/51/t32.pdf

5.) Busch-Vishniac, I., West, J., Barnhill, C., Hunter, T., Orellana, D., & Chivukula, R. (2005). Noise levels in Johns Hopkins Hospital. *Journal of the Acoustical Society of America*, *118*(6), 3629–3645.

6.) Joseph, A., & Ulrich, R. (2007). *Sound control for improved outcomes in healthcare settings*. The Center for Health Design. Retrieved April 28, 2010, from http://store.healthdesign.org/catalogsearch/result/?q=Sound+Control+for+Improved+Outcomes+in+Healthcare+Settings

7.) ANSI S12 WG44 & the Joint Subcommittee on TC-AA.NS.SC ("The Acoustical Working Group"). (2010, January). *Sound and vibration design guidelines for health care facilities. Public draft 2.0*. Available from: http://www.speechprivacy.org

8.) Montague, K. N., Blietz, C. M., & Kachur, M. (2009). Ensuring quieter hospital environments: Nurses provide valuable input during a unit redesign at one hospital. *The American Journal of Nursing, 109*(9), 65-67.

9.) Hagerman, I., Rasmanis, G., Blomkvist, V., Ulrich, R., Eriksen, C. A., & Theorell, T. (2005). Influence of intensive coronary care acoustics on the quality of care and physiological state of patients. *International Journal of Cardiology, 98*(2), 267–270.

10.) Cmiel, C. A., Karr, D. M., Gasser, D. M., Oliphant, L. M., & Neveau, A. J. (2004). Noise control: A nursing team's approach to sleep promotion. *The American Journal of Nursing, 104*(2), 40-48.

11.) Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H., Choi, Y., Quan, X., & Joseph, A. (2008). *A review of the research literature on evidence-based healthcare design.* Georgia Institute of Technology. Retrieved April 28,2010, at http://www.healthdesign.org/hcleader/HCLeader_5_LitReviewWP.pdf

12.) Fontes Pinto Novaes, M. A., Knobel, E., Bork, A. M., Pavao, O. F., Nogueira-Martins, L. A., & Bosi Ferraz, M. (1999). Stressors in ICU: Perception of the patient, relatives, and health care team. *Intensive Care Medicine, 25*(12), 1421-1426.

13.) Davenny, B. (2010, January). Auditory assistance: Strategies to reduce hospital noise problems. *Health Facilities Management*, 16-19.

14.) Blomkvist, V., Eriksen, C. A., Theorell, T., Ulrich, R., & Rasmanis, G. (2005). Acoustics and psychosocial environment in intensive coronary care. *Occupational and Environmental Medicine, 62*(3), Article 1e. doi:10.1136/oem.2004.017632.

15.) MacLeod, M., Dunn, J., Busch-Vishniac, J., & West, J. E. (2007). Quieting Weinberg 5C: A case study in hospital noise control. *Journal of the Acoustical Society of America, 121*(6), 3501-3508.

16.) Armstrong Ceiling Systems. (2003). *Rx for healthcare speech privacy: A balanced acoustical design.* Retrieved April 1, 2010, from http://www.armstrong.com/common/c2002/content/files/7728.pdf

17.) USG & Lencore Acoustics Corp. (2004). *Achieving HIPAA oral privacy complicance: USG and Lencore Acoustics helping you meet healthcare privacy requirements.* Chicago: USG Interiors, Inc. Retrieved April 28, 2010, from http://www.lencore.com/files/_usg_lencore_hipaa.pdf

18.) Sánchez, M., Pardo, A., Sánchez, D., Gelado, Y., & Garcia, M. (2008). Nurses' perception of noise levels in hospitals in Spain. *Journal of Nursing Administration, 38*(5), 220-222.

19.) Davenny, B. (2007). *Acoustic environment technical brief: Green guide for health care™ environment quality credit 9.* Green Guide for Health Care™. Available from http://www.gghc.org

20.) InformeDesign® (2010). *Glossary of terms.* Retrieved May 21, 2010, from http://www.informedesign.umn.edu/Glossary.aspx?r=t-z

21.) Sadler, B. L., DuBose, J.R., Malone, E. B., & Zimring, C. M. (2008). *The business case for building better hospitals through evidence-based design.* Georgia Institute of Technology: Atlanta. Retrieved May 21, 2010, from http://www.healthdesign.org/hcleader/HCLeader_1_BusCaseWP.pdf

22.) The Joint Commission. (November, 2008). *Health care at the crossroads: Guiding principles for the development of the hospital of the future.* Oakbrook Terrace, Illinois: Author.

23.) The Facility Guidelines Institute (FGI). (2010). *Guidelines for the design and construction of health care facilities.* American Society for Healthcare Engineering (ASHE) of the American Hospital Association. Available from http://www.fgiguidelines.org/index.html

24.) Detsky, M. E., & Etchells, E. (2008). Single-patient rooms for safe patient-centered hospitals. *Journal of the American Medical Association, 300*(8), 954-956.

25.) Leventhal Stern, A., MacRae, S., Gerteis, M., Harrison, R., Fowler, E., Edgman-Levitan, S., Walker, J., & Ruga, W. (2003). Understanding the consumer perspective to improve design quality. *Journal of Architectural Research and Planning, 20*(1), 16-28.

26.) Green Guide for Health Care™ (GGHC). (2007). *Green guide for health care version 2.2.* Available from http://www.gghc.org

27.) United States Gypsum Company (USG). (2006). *Acoustical assemblies: Making sound choices.* [brochure - SA-200]. Chicago: Author.

28.) Waropay, V. M., & Roller, H. S. (1986). Design aid for office acoustics: How to determine composite sound-isolation ratings for offices by combining performance of walls, ceilings, and floors. *USG Form Function, 4*, 9-14.

29.) United States Gypsum Company (USG). (2009). *TechNOTES: Sheetrock ceiling sound isolation comparison tests* (TechNOTE No. AA015). Chicago: Author.

30.) United States Gypsum Company (USG). (1972). *Sound control construction principles and performance (2nd Edition).* Chicago: Author.

31.) Pridham, B. (n.d.). MRI noise and vibration effects on building design. *Technotes,* 33. Retrieved March 3, 2010, from http://www.rwdi.com/cms/publications/52/t33.pdf

32.) Buelow, M. (2001). Noise level measurements in four Phoenix emergency departments. *Journal of Emergency Nursing, 27*(1), 23-27.

33.) Johnson, P. R., & Thornhill, L. (2006). Noise reduction in the hospital setting. *Journal of Nursing Care Quality, 21*(3), 295-297.

34.) Bailey, E., & Timmons, S. (2005). Noise levels in PICU: An evaluative study. *Paediatric Nursing, 17*(10), 22-26.

35.) Harris, D. D., Shepley, M. M., White, R. D., Kolberg, K. J. S., & Harrell, J. W. (2006). The impact of single family room design on patients and caregivers: Executive summary. *Journal of Perinatology, 26*, S38-S48.

36.) Siebein, G. W., & Skelton, R. (2009, August). *Soundscape analysis of a neonatal intensive care unit.* Paper presented at the meeting of Inter-Noise 2009: Innovations in Practical Noise Control, Ottawa, Canada. Retrieved April 12, 2010, from http://www.siebeinacoustic.com/main/research/publications/Papers/INCE%202009%20Ottowa/Soundscape%20Analysis%20of%20a%20Neonatal%20Intensive%20Care%20Unit.pdf

37.) Orellana, D., Busch-Vichniac, I. J., & West, J. E. (2007). Noise in the adult emergency department of Johns Hopkins Hospital. *Journal of the Acoustical Society of America, 121*(4), 1996-1999.

38.) Olsen, J. C., & Sabin, B. R. (2003). Emergency department patient perceptions of privacy and confidentiality. *The Journal of Emergency Medicine, 25*(3), 329-333.

39.) Pulsinelli, O. (2009). Health care industry to get new LEED system. *Mlive.com.* Retrieved from March 5, 2010, from http://www.mlive.com/business/west-michigan/index.ssf/2009/05/health_care_industry_to_get_ne.html

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CISCA is to be the recognized authority and resource for the acoustical ceiling and wall systems industry.

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