ACOUSTICS TO HEALTHCARE AND MEDICAL FACILITIES

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ACOUSTIC CONSIDERATIONS

Many sounds are present in hospital environments, including those from beepers, alarms, machines, rolling carts, 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 regulation. In recent years, these issues have received much attention. Acoustics are now a key component of healthcare design guidelines; many studies identifying design strategies to improve acoustical conditions in healthcare environments have been conducted; and medical facilities have taken initiatives to improve their acoustic environments

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 staff and influences patient well-being.

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.

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. Acoustics can also impact perceptions of privacy, comfort, safety, and security for patients and their families. 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.

- 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. Reduced noise levels in intensive care units (ICUs) may help patients sleep and foster a regular wake/sleep cycle.

- 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.

- 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 night-time. 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.

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. When inadequate acoustic conditions exist, poor psychosocial conditions can occur even for highly-trained and educated PCTs that are prepared to handle stressful conditions.

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.

After acoustical ceiling panels 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).


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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). 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.

Background Noise

Background noise levels should meet the criteria set by established standard and should be identified at the onset of a project.

Certain specialized healthcare environments (e.g., spaces where audiometric testing is conducted, sleep disorder clinics) require minimal background noise and distractions.

- The continuous background noise levels created by building services (e.g., heating, ventilation, and air-conditioning ;) are typically calculated as specified by the manufacturer.

- 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).

- 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.

Reverberation Time (RT)

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Key considerations include:

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- Controlling reverberation in healthcare environments through appropriate finish selection is important for optimizing speech intelligibility, creating a restorative environment, and limiting noise transmission.

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.

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.

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. Some of the most common measurement methods used in the healthcare design industry are introduced below.

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.

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

Sound Transmission Class (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.

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.

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.

Ceiling Attenuation Class (CAC0 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.

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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 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

Privacy Index (PI) is a measure used to rate the speech privacy in a given space and is calculated based off the Articulation Index.

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.

General Design Considerations

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).

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.
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.

It is important to ensure that the acoustical consultant is asked to assess speech privacy and speech intelligibility in healthcare settings using proven test methods.

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:

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

- Understand that if exterior noise levels surpass a minimal level (e.g., the ambient noise level found in a rural or suburban residential neighbourhood with single-family homes), measures should be taken to monitor site noise levels. Mitigate the impact of this noise by specifying acoustic controls (e.g., mufflers, acoustic louvers) and quieter equipment.


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- 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.

- 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.

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:

- 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.

- Create separate, acoustically private spaces for families of patients to gather to reduce noise levels elsewhere in the hospital.

- Include private meeting rooms for patients, relatives, and healthcare professionals to provide privacy and improve communication between these groups.

- Close off nursing and chart stations in intensive, postoperative areas.

- 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. 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.

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.

However, safety issues, namely smoke, flammability, and cleanliness standards, should also be considered when specifying acoustical materials.

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. The acoustical design properties of some common materials and finishes in healthcare environments are discussed in this section.

Ceilings

Acoustical ceiling panel systems can reduce reverberation times and increase speech intelligibility, potentially improving the psychosocial work environment for PCTs. 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). Consider the following when specifying ceilings in healthcare environments:

- 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.

- 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.

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.

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.

Consider the following when determining wall construction and specifying wall materials:

- 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, 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 to ceiling 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.

- 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.

- 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.

- Recognize that doors can have a tremendous negative impact on the acoustical performance of a wall.

Wall Surfaces

- Specify fabric-wrapped wall panels in non-clinical areas of a hospital where regular cleaning is not required, as they are from common activities in healthcare environments, especially in large areas where noise tends to build up more effective and less costly than panels that are encapsulated in film.

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

- 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

Floors

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

- 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.

- 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.

- 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).


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

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. 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.

- Analyse 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).

- Consider the noise impact of terminal boxes and how performance is affected when sound attenuators are used.

- 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.

- Insulate pneumatic tubes and ice machines to reduce noise levels.

- 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).

- 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.

- 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.

Designing for Privacy and Confidentiality

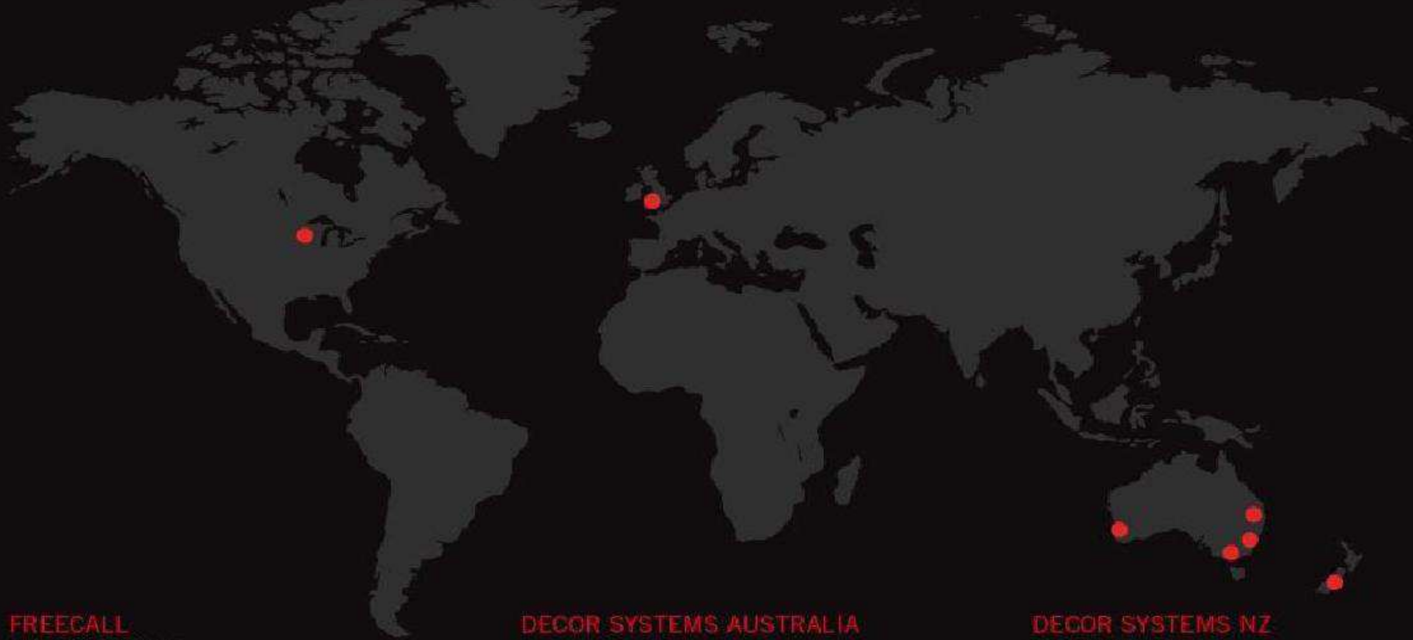
Speech privacy needs should be assessed in spaces in healthcare facilities where patient information is shared (e.g., consultation counters, pharmacies) to assure that privacy and/or confidentiality are provided for patients, families, and PCTs.

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.

Although normal speech privacy (i.e., PI between 80% and 90%) is sufficient in most commercial settings, many patient areas in healthcare facilities require a confidential level of speech privacy. 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.

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. Consider the following when designing to support privacy and confidentiality in healthcare settings.



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