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Acoustical conformance to FGI for tenant improvements in clinic, medical office or outpatient facility sound isolation/privacy design

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ABSTRACT

Acoustical privacy and noise control design and implementation guidance is needed, regarding Facility Guidelines Institute (FGI) criteria for outpatient medical facility tenant improvements (TI). TI in existing commercial buildings or medical office buildings may not have the capital budgets or expected facility/lease life that hospitals enjoy. Full conformance to FGI criteria and guidelines may be limited by economic feasibility and by constructability. Design professionals can use "good practice" space planning, demising assembly selection, and electronic sound masking to achieve appropriate acoustical privacy within reasonable capital expense budgets.

FGI criteria for demising partition, ceiling, door and window selections, infrastructure equipment and material selections can provide cost-effective lightweight, common construction solutions. The objectives are to protect the privacy of patient information and to provide quiet spaces, free of transient disturbance for clear speech communications. Continuous ambient background sound increases speech privacy, including speech transmitted from enclosed quiet spaces. Criteria for acoustics, speech privacy, continuous noise and masking exists in FGI. Temporal level changes (on/off, transients) and tonality (spectrum smoothness or balance) should be considered in basis-of-design (BoD). This paper will present design guidelines for selecting demising assemblies and supplemental sound masking for outpatient clinical spaces in commercial or medical office buildings.

1. INTRODUCTION

The Facility Guidelines Institute's (FGI) Guidelines for Design and Construction are adopted into building codes of many jurisdictions, and used as "good practice" basis of design (BoD) where not mandated by code. The Guidelines are published on a revolving 4-year cycle. The 2022 amendments have been underway since the current 2018 edition was published. There are three separate FGI volumes for i) hospitals, ii) outpatient facilities and iii) residential health, care and support facilities. This paper focusses on outpatient facility [**1**] acoustic privacy, background noise, sound isolation criteria and guidelines. Many clinical, medical office and outpatient facilities are constructed as tenant improvement (TI) build-outs within existing building lease spaces, where building structure, shell and

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core construction may limit sound isolating interior construction performance.

Given economic and constructability limitations, can design professionals achieve acceptable "good practice" or code-mandated acoustical privacy performance in outpatient facilities? Guidelines herein may assist in construction of cost-effective improvements. Space planning and designs for partitions, ceilings and interior finishes should be carefully managed. Sound masking may be appropriate to augment sound-isolation for improvement of privacy performance, particularly where partition and/or ceiling assemblies cannot meet FGI recommended STC criteria.

The co-authors, as members of the FGI's Acoustics Proposal Review Committee (APRC), have participated in reviews and adoptions of acoustical, noise and vibration amendments for the 2022 edition. Only a few changes from the 2018 edition were adopted for 2022; i) add Telemedicine Rooms, ii) change Noise Criteria from NC/RC(N)/RNC to only NC, iii) eliminate the "secure" category from Speech Privacy criteria and SPC metric from open spaces and iv) modify floor vibration criteria for treatment rooms. Reference the current FGI, 2018, in regard to matters discussed herein.

2. FGI OUTPATIENT FACILITY ACOUSTICAL CRITERIA

Outpatient interior acoustical and floor vibration criteria are found in the FGI Outpatient volume in the following tables and their footnotes (Exterior site noise criteria are outside scope of this paper).

- 1.2-4: Minimum Design Room Sound Absorption Coefficients ($\overline{\alpha}$)
- 1.2-5: Maximum Design Criteria for Noise in Interior Spaces Caused by Building Systems (NC, dBA)
- 1.2-6: Design Criteria for Minimum Sound Isolation Performance Between Enclosed Rooms (STCc)
- 1.2-7: Design Criteria for Speech Privacy - Enclosed Rooms and Open-Plan Spaces (PI, AI, SII, SPC)
- 1.2-8: Maximum Limits on Floor Vibration Caused by Footfalls in Outpatient Facilities (μ-in/s)

Table 1: Summary of Outpatient Acoustical and Vibration Criteria (some categories combined) [**2**]

Space Category	**Room Type** [#]	$\overline{\alpha}$	**NC/dBA**	**STCc***	**μ-in/s**
Patient Care, Diagnostic	Multi-Occ. Patient	0.15	45 / 50	**	- -
	Exam/Treat/ Procedure	0.15	40 / 45	50	8k/6k/4k
	Class 2 Imaging	0.15	40 / 45	50	4k
	O.R./Cl 3 Imaging	- -	50 / 55	50	4k
Support Areas	Medication Safety Zone	0.15	40 / 45	- -	- -
	Test/Research Lab minimum speech	- -	55 /60	**	- -
	Research Lab extensive speech	- -	50 / 55	**	- -
	Group Teaching Lab	**	45 / 50	**	- -
Public Areas	Corridor, Public & Waiting	0.15 0.25	45 / 50	35	8k
	Conference	**	35 / 40	**	8k
	Aud., Large Lecture Rm	**	30 / 35	**	8k
	Teleconference Rm	**	25 / 30	**	8k
Admin Areas	Private Office	0.15	40 / 45	**	8k

Additional spaces or room types with similar characteristics may be added to functional programs.
* May be reduced for examination, offices and similar rooms where electronic masking is used.
** Designer discretion for interior acoustics, sound containment or freedom from intrusive noise

3. SOUND ISOLATION AND NOISE CONTROL FOR ACOUSTICAL PRIVACY

Clinic, medical office and outpatient facilities generally do not operate 24-hours or overnight, so except for temporary recovery spaces, there are no patient care/sleeping rooms. Acoustical privacy is a priority for reception/waiting, examination, procedure, treatment lab, office and conference spaces. In the future, Outpatient facilities may include "Extended Stay" services where patients stay overnight for a few days while recovering from outpatient procedures. The intent is to fill the gap between Urgent Care and Hospitals for patients who do not have a home caregiver to assist them when discharged. Extended stay patient rooms will need to meet acoustical privacy criteria.

Acoustical design objectives are to provide quiet spaces, with limited transient disturbances for: i) intelligible speech and ii) for analytic, non-routine "thought" work, with sufficient continuous ambient sound to supplement speech privacy and reduce perception of personal information being overheard. Consider parameters for sound quality, such as control of temporal change (modulation, on-off, transience) and tonality (spectrum smoothness and balance) in addition to sound level controls for continuous background sound and for transient or disturbance noise.

Utilize early planning to determine infrastructure equipment and material selections for building partitions, ceilings, doors and windows that provide the best sound isolation/privacy from lightweight, common and low-cost construction standards. Space planning should consider compatible versus dissimilar use space adjacencies. Full-height acoustic demising partitions are preferred, but where demountable or field-fabricated partitions only extend to ceiling elevations, partition and ceiling selections should each consider sound transmission loss properties to protect privacy. To maintain acoustical integrity, minimize or treat flanking pathways (acoustical leaks) from openings such as return air registers, penetrations, ducts connecting adjacent spaces, inset video monitors, doors, sidelights, window glazing and mullion-partition interfaces.

When appropriate, supplement physical demising assemblies with control of building systems' continuous background noise and/or add sound masking to increase speech privacy. Inconsistent, modulating or off/on transient sounds do not effectively mask speech. Sound masking should be utilized throughout an outpatient facility, i.e., in corridors, open areas and utility-work, so that level changes are less noticeable to occupants moving through spaces, with lower levels used in private offices, exam, consultation or patient treatment spaces, to reduce audibility or intelligibility of any transmitted speech.

3.1. Partitions

- By definition STC values are for full width and height sound barriers, i.e., wall-to-wall and floor-to-structural deck above. For demountable or partial height partitions that are built on site and designed to extend only from floor to ceiling height, ceiling should be considered with the partition as an envelope for overall room-to-room noise reduction.
- FGI provides +/- 2 STC point tolerance for noise reductions, because of slight variations in lab test results. Partitions with laboratory test results as much as 2 points below the FGI minimum may be used. Field testing results are not appropriate to use when selecting wall partitions performance because of much larger variations, i.e., +2 to -5 in the result due to non-ideal field conditions with variations in materials, workmanship and flanking paths.
- Manufactured demountable partitions should be selected based on laboratory noise ratings for the specific partition panel and door units desired for the project; STC 50 and/or STCc35 with doors.
  - Construction documentation specifications should require submittal of laboratory STC test results for the demountable system.
  - Select suspended ceiling performance for CAC $\geq$ 35 in rooms with demountable partitions.
- For similar framed drywall cavity partition constructions from floor to structural deck, variations in transmission loss may result from multiple variables: [**3, 4, 5, 6**]
  - gypsum board thickness: ½" (12.5 mm) or +1 STC point for 5/8" (16 mm)
  - stud spacing: 16" (400 mm) or +3 to +4 STC points for 24" (600 mm)
  - stud material: wood or +2 to +4 STC points for light gauge metal studs
  - stud width, wider studs increase STC: 2-1/2" (63 mm), 3-5/8" (90 mm), 6" (150 mm), etc.

- metal stud thickness gauges: 16 gauge (heavy) to +3 to +5 STC points for 20-25 gauge (light).
- Performance enhancements may be achieved by incorporation of:
  - Acoustically absorptive sound attenuation blankets (SAB) within stud cavities (amount of improvement reduces as partition mass or number of gypsum board layers increases).
  - Addition of gypsum board layers on one or both sides of the partition framing, with unbalanced assembly, different mass or numbers of layers on each side to limit resonances, performing somewhat better than balanced assemblies.
  - Use of damping compound between gypsum board layers or substitution of internally damped gypsum board products. Improvement increments vary with damping product and by how they are incorporated in partition assembly.
  - Resilient mountings between gypsum board and stud framing or use of decoupled stud framing (double or staggered studs in framing cavity that do not connect opposite sides of wall). Improvement amounts vary with resilient mounting product or type of framing decoupling.
  - Window mullion noise reduction improvement to close flanking paths where demising partitions abut exterior walls; at the partition mullion interface and through the mullion.
  - Avoid structure borne vibration transmission and resulting wall surface sound radiation by carefully considering and specifying resilient mountings for loudspeakers and user equipment.

3.2. Ceilings

- Ceiling products are rated for acoustical absorption and for room-to-room sound transmission.
  - The Noise Reduction Coefficient (NRC) [**7**], is an arithmetic average of four center-octave (speech frequencies) sound absorption coefficients, 250-2000 Hz [**8**], relating to reverberant noise buildup within an enclosed space, but not the sound transmission into or out of room.
  - Ceiling Attenuation Class (CAC) is a rating of sound transmission from room to room via ceiling, plenum and adjacent room ceiling (2-pass-test) [**9**], but not for acoustical absorption.
- For demountable or field-fabricated framed demising partitions not extending above the ceiling to the structural deck, the ceiling CAC rating should be ≥ 35 for the ceiling and partition envelope to provide privacy. For confidential privacy requirements, use CAC ≥ 45 composite ceiling tiles.
  - Ceiling openings should be treated to minimize degradation of the sound isolation, such as return-air register acoustically-lined boots or ducted return in lieu of open-plenum return air, and closing or sealing penetrations around lighting, sprinklers or other ceiling elements.
  - Solid gypsum board ceilings have a high CAC rating, but lack any interior room absorption.
- Where the partition extends from floor to structural deck above, i.e., blocks transmission through the ceiling plenum, the ceiling may be selected on basis of the (absorption) NRC, only.
- Ceiling framing (solid gypsum board) or suspension grids (acoustical ceiling tile) should be hung only from the structural deck above, and not from any building systems elements in the plenum.

3.3. Doors (Corridor Partitions with Entries to Rooms)

FGI permits *composite* STC (STCc) 35 for partitions with room entry doors and/or sidelights. STCc is essentially an integrated average of STC ratings of the various wall elements. [**10**] STCc values for partitions with doors, windows, penetrations or other openings may be determined by calculation to achieve composite sound transmission class that conforms to requirements, such as STCc 35, using Eq. (1), composite partition noise reduction (NR). [**11**]

$$NR = TL - 10 \cdot \log\left(\frac{Sw}{4}\right) - 10 \cdot \log\left(\frac{1}{Sw} + \frac{4\left(1-\alpha_2\right)}{S \cdot \alpha_2}\right) \quad (1)$$

where Sw is the total area of the demising partition, α_2 is the receive room absorption coefficient, S is the receive room surface area, and composite transmission loss (TL) is calculated using Eq. (2), based on the surface area (S_i) and transmission loss (TL_i) of each individual wall component. [**12**]

$$\mathrm{TL} = 10 \cdot \log\left(\frac{\sum_i \mathrm{S_i}}{\sum_i \mathrm{S_i} \cdot 10^{\left(-TL_i/10\right)}}\right) \quad (2)$$

- For smaller, 100-200 square foot (10-20 square meter) rooms, with limited corridor wall surface area less than ~175 sf (16 sm), the frame and door sound isolation performance can be critical.
  - Overall door and frame performance may need to be equivalent to STC 29-32.
  - A filled-core or solid door with face weight not less than 5 pounds per square foot (22 kg/m^2), a door and frame with no acoustical seal may only achieve +/- STC 22.
  - Good elastomeric door seals, labeled specifically for acoustic service, may be applied to increase door and frame noise reduction up to equivalent of STC-28-30. Brush, felt, dust, smoke or infiltration seals do not provide adequate acoustical seal performance.
- Consider type of door with respect to acoustic seal capability and speech privacy.
  - Sliding glass or barn doors are very difficult to seal. If necessary, to use these, select manufactured assemblies with tested and warranted sound isolation, i.e., STC $\geq$ 30.
  - Universal hinged + sliding doors, are designed for acute, intensive and similar care areas to accommodate emergency or "crash" actions. They have gaps (to prevent smashed fingers, among other perils), which cannot be acoustically sealed. If feasible, these doors should be restricted to limited-access patient care spaces, so that only medical staff may be in the area.

3.4. Windows and/or Sidelights (Corridor Partitions with Glazing)

Glazing features in a corridor partition de-rate partition noise reduction performance. Window or sidelight glass and frame STC ratings should be integrated into the composite STC, similar to or in addition to door to find the overall partition composite STC. Where deficiencies are found, glass mass (thickness) or type (laminated versus plate) should be specified to maintain minimum performance.

The transmission loss of window glass depends on the thickness and weight of the glass. Laminated glass provides increased isolation by adding a dampening layer between two pieces of glass. This lowers the critical frequency by reducing the amplitude of bending waves caused by noise excitation. When the glass is "damped" or less stiff, the critical frequency drops below speech frequency range resulting in higher STC ratings.

3.5. Room Acoustics and Surface Finishes

Reverberant sound buildup within enclosed spaces makes noises due to continuous background and transients slightly louder. The enhanced perception of transient sound events may be distracting to occupants, or may interfere with teleconferencing or virtual meeting speech. Acoustical absorption can reduce buildup from random incidence sound reflection. With specific location or placement, it can control reflection patterns. In smaller rooms, the FGI Table 1.2-4 minimum room absorption may be achieved with suspended acoustical ceilings of moderate to higher NRC 0.75-0.90 ratings. Placement of acoustically absorptive finishes on wall surfaces with higher NRC 0.80-0.99 ratings can control flutter-echo and other undesirable reflections that reinforce disturbance noise sources.

3.6. Building Systems Noise & Vibration Control

Background noise influences speech and privacy. The difference between voice level and background sound is referred to as signal-to-noise ratio or S/N. Optimum speech level is constant when background sound is below 40 dBA, or level is roughly 15 dBA above background noise 40 dBA or greater. [**13**]

- Often, people will self-adjust speech level to be heard and understood above background sound. Given that the partition and ceiling sound isolation is constant, as background noise and speech level increase, the transmitted sound outside a room becomes more audible.
- Building systems noise from HVAC, electrical, plumbing and other elements should be limited to permit good speech communications at comfortable speech levels that do not degrade privacy.
- FGI Table 1.2-5 presents acceptable continuous building systems background noise criteria for speech and listening for various functional room uses. Note that the criteria do not include sound from occupants or user equipment. Building systems include mechanical, electrical and plumbing (MEP).

- Analyze HVAC equipment and distribution systems for source noise levels and natural system attenuation to estimate ambient levels in occupied spaces. Where projected noise spectrum exceeds octave-band criteria, design and implement attenuation, isolation and/or damping.
- Consider MEP equipment locations within occupied spaces, such as air-terminals, transformers or in-line pumps in ceiling plenum spaces above occupied rooms. Strictly avoid placement of noise-radiating equipment above rooms classified NC-35 or lower, such as conference or exam.
- Where noise radiating equipment cannot be avoided from NC 35 rooms, place a sound barrier layer on the ceiling, such as GWB tiles or mass-loaded vinyl sheet over acoustical tiles in the grid.
- Design sound demising partitions between MEP equipment rooms and occupied spaces to attenuate transmitted equipment noise to levels 3-5 points below the receiving room NC classification to help to prevent the added equipment from causing the overall receiving room level from exceeding the noise criteria.
- Provide appropriate vibration isolation mountings, supports and hangers for building systems equipment and distribution to avoid structure borne transmission of vibration that can result in audible sound radiated from room surfaces.
- Consider and limit ability of air ducts (supply, return, exhaust) with connections to room diffusers and registers to act as conduits for sound between rooms, causing loss of speech privacy.

3.7. Space Planning and Operational Control

Administrative and medical staff personnel that work with privacy-sensitive patient medical information, on paper, digitally or audibly with speech, should have work stations configured to minimize the need for raised voices. [**14**]

- In public and open areas, design should consider spatial relationships between speakers and listeners.
  - Admitting, check-in, financial or initial consultation and other facilities should be located to isolate patients, their care-givers and/or staff personnel from waiting or other open occupied areas.
  - Room surface finishes should be acoustically absorptive in the vicinity of privacy-sensitive speech to reduce sensitive sound reflection toward waiting or open spaces.
  - Waiting areas with TV or video monitors with sound should consider the use of audio transcription and should have acoustically absorptive ceilings and walls to improve sound track intelligibility at lower speaker volume levels to avoid nearby annoyance, distraction or disturbance.
  - Consider traffic control for public and for operational personnel to minimize noise interactions.
  - Provide acoustical absorption in elevator lobbies to make arrival chimes easier to hear and locate.
- In patient care areas, the acoustical design should consider noise contributions from medical and operational equipment, such as monitor alarms, ventilators, pneumatic info-transport transfer stations and distribution tubes, etc.
  - Monitors need to be near patients, but their locations within a room and the influences of nearby surfaces may influence effectiveness or interfere with perceptions of other simultaneous alarms. To the extent possible under hygienic requirements, provide acoustically absorptive ceilings and wall surfaces near alarms to make individual alarms acoustically distinct, i.e., avoid reverberant spaces where the alarms cannot be distinguished by location.
  - In addition to continuous building systems noise contributions, transient noise sources may cause individual speech levels to increase temporarily in reaction, with resulting loss of privacy.
  - Consider mobile medical equipment and supply trollies with regard to rolling and floor impact noise, as well as effects on foot-traffic and conversations in the corridor or aisle. New resilient flooring materials, that generate less airborne noise from a rolling cart or when something is dropped, are available for healthcare facilities. [**15**]

4. SOUND MASKING AND SPEECH PRIVACY

Sound masking systems were initially developed as a way to reduce distractions in open offices caused by multiple conversations carrying throughout the space. The objectives were to provide relatively quiet spaces, free of transient disturbance, for speech, analytic, non-routine “thought” work, with sufficient continuous ambient sound to reduce perception of undesirable, distracting or disturbing noise events. Greater background sound in corridors, open-office, work and utility spaces and open or public spaces, were equalized to mask speech including sound transmitted from nearby enclosed quiet spaces. Speech privacy is increased by adding "masking sound" to sound receiver spaces, making it more difficult to understand distant (source sound) conversations. It may be possible to perceive people are talking, but the topic of their conversation is rendered mostly unintelligible.

Facility design and operational priorities for acoustics, noise control and speech privacy include the following. Sound masking in conjunction with architectural acoustics may help achieve the goals.

- Improving patient outcomes by minimizing patient sleep disruption
- Preventing medical errors due to poor speech intelligibility
- Improving Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) scores for hospitals
- Minimizing noise that causes staff fatigue and burnout
- Protecting speech privacy as required by Federal Health Insurance Portability and Accountability Act (HIPAA) regulations.

Speech privacy between two spaces is a function of three factors: i) speech or noise level in the source space, ii) the continuous background noise level in the receiving space (expressed as Noise Criteria rating, NC) [**16**], and iii) the acoustic separation of the total construction between the spaces (expressed as Composite Sound Transmission Class rating, STCc). [**17**] When designing for privacy, the partition rating should be a minimum of STCc 35 (with door and/or window) or STC 50 (solid wall with no door or window). Testing has shown that even partial-height gypsum board wall partitions extending 6" above the acoustical ceiling tile grid can achieve the equivalent of STC 40 when used with CAC 35 or higher rated acoustical tile. Masking sound maintains a consistent, continuous background sound level (when HVAC noise is variable) and/or increases the Noise Criteria of a space so a STC 40 partition with NC 35 background would be achieve a Speech Privacy Potential (SPP) 75 or "excellent" privacy. The combination of these two ratings (STC+NC) has been shown to correlate with the degree of speech privacy as shown in Table 2, Degrees of Speech Privacy below. [**18**]

Table 2: Degrees of Speech Privacy* between closed plan offices

Privacy Class	**Rating**	**Speech Privacy Potential (SPP)**	**Description of Privacy**
A	Total Privacy	85	Shouting is only barely audible.
B	Highly Confidential	80	Normal voice levels not audible.
C	Excellent	75	Normal voice levels barely audible. Raised voices are audible but mostly unintelligible.
D	Good	70	Normal voices are audible, but unintelligible most of the time. Raised voices are partially intelligible.
E	Fair	65	Normal voices audible and intelligible some of the time. Raised voices are intelligible.
F	Poor	60	Normal voices audible and intelligible most of the time.
--	None	Less than 60	No speech privacy.

* This table covers natural human voice levels. Speaker phones and other voice amplification systems require special consideration.

Speech Privacy Potential is best used for design while Speech Privacy Class is preferred for field testing. Speech Privacy Class (SPC) values for minimal or "Normal" speech privacy, increased or "Confidential" speech privacy and "Secure" for closed spaces included in FGI Table 1.2-7 are appropriate for healthcare facilities. They are provided in the guidelines based on ASTM E2638-10 (2017), Appendix X2.1. The appendix is considered "non-mandatory" and identifies values for "Confidential Speech" in closed plan spaces. Those values are intended for secure to highly secure office spaces, not healthcare facilities. The designated “Minimal Speech Privacy” category SPC 70 is very nearly equivalent to PI 95% or complete privacy. SPC 70 is equivalent to “Secure” in the FGI Table 1.2-7.

4.1 System Setup and Control

Typically, masking sound signals are digitally generated randomized “pink noise,” which include all frequencies at equal energy levels. The frequency levels are then adjusted, taking into account the ambient sound levels already in the room, filling in and adding to ambient frequency levels that are too low to mask speech. [**19**]

Sound masking systems have advanced over the years and are now using networking standards for control and distribution of masking sound. Systems features can include time-of-day scheduling of masking levels. This is helpful when the activity in space is reduced, for example, during nighttime hours, when lower levels may be desirable.

Sound masking systems with adaptive technology that employ ceiling microphones are available to sense ambient levels and adjust masking up or down. [**20**] While this may be desirable, there are multiple concerns with the implementation. To accurately detect changes in ambient noise requires sensing microphones in each zone. The number of microphones required increases as the size of the zone increases. This adds complexity. Cost and the functionality are questionable when one considers the fact that the microphones still cannot distinguish between speech and background noise. To prevent abrupt changes in masking levels caused by a short loud event, the systems incorporate a program delay to slow system responses so they are not noticeable. Unfortunately, the noise event responsible may be over by the time the system tries to adapt. And finally, due to patient privacy concerns, information privacy requirements would most likely not allow open microphones to be used.

4.2 Out of Sight, Out of Mind

Sound masking works best when the system goes “unnoticed” by most occupants. To achieve this, the sound masking should be designed and adjusted to provide uniform coverage throughout a facility. It is important for masking to be installed in patient areas such as Exam Rooms, Treatment Rooms, Private Offices, etc. (at lower levels), as well as the corridor and public spaces surrounding the rooms (greater levels).

When people walk through a building where only some of the spaces have sound masking, they walk in and out of masking coverage making it very noticeable, especially if the ambient noise levels due to the building systems are low or inconsistent, resulting in spaces with Noise Criteria (NC) less than NC 30. Today, HVAC sound levels vary with time and the variations are not predictable. Sometimes they shut off completely in a room. Speech privacy requires control of the minimum background level with compatible construction. Selections of wall types need to be compatible with the minimum HVAC level for privacy.

Ideally, continuous levels due to the building systems should be a minimum of NC 30 and a maximum of 5 points below NC criteria. If the background sound is more than NC 35, it is very difficult to add masking sound without exceeding the preferred overall maximum levels in the space. Sound masking plus the overall building system noise should not exceed design NC 40 levels. When the frequency spectrum of the masking is adjusted to provide a broadband warm sound without excessive hiss, most think they hear the HVAC system, if they notice at all. Careful tuning is especially important when the masking levels exceed 46 dBA and become increasingly noticeable.

4.3 Masking System Design

To successfully incorporate sound masking, the space program for use, space layout, and furniture arrangements of the various rooms and open areas should be considered when determining sound masking zone types and sizes. To achieve the desired results, it is desirable for the Architect to include the Acoustical Consultant on the design team during the project’s early planning phases. That is when the Owner should agree on the level of privacy needed, criteria for wall constructions and the sound masking to achieve it. It is also when the Noise Criteria goals for the rooms should be coordinated with the Mechanical Engineer. It is important to make sure everyone on the design team understands the goals and that masking does not cancel sound, a very common misconception held by persons unfamiliar with sound masking.

During design, spaces of similar use and size are assigned to the same sound masking "zone type." It is not uncommon to have four or more zone types, usually with different spectrum and levels, to accommodate the various functions of a project. Sound masking is then distributed throughout a facility by zones based on the use of a particular space. Sound masking zones should be as small as practical to allow for future flexibility of use. If the spaces might be reconfigured in the future for different uses, small zones allow readjustment of the masking, as needed, for the new space uses avoiding big system changes. This is especially the case when masking is used with de-mountable partitions.

4.4 Sound Masking Zones

Zoning allows masking levels to be customized based on the program use of spaces. Public areas like Corridors or Lobbies are larger and noisier, as compared to, an individual office, exam or treatment room. Conference, meeting or telemedicine rooms are generally quieter and expected to be so. The expectation in those rooms is for increased speech intelligibility so masking levels are intentionally kept lower to avoid speech interference. Proper zoning and layout of the masking loudspeakers allow speech privacy to be optimized without being considered overly loud.

4.5 Masking Loudspeakers and Layout

There are two types of sound masking loudspeakers: indirect and direct. Masking loudspeakers in the plenum space - either above the acoustical tile ceiling or below the raised floor - helps to keep the system out of sight and out of mind. Loudspeakers in these locations are considered "indirect" sources, because the loudspeakers are aimed into the plenum, away from the occupants. This helps create a uniform sound field in the plenum that uniformly breaks through the ceiling or floor tile and into the room without creating noticeably louder masking "hot spots". With indirect loudspeakers, avoidance of HVAC openings is important. If a loudspeaker is located near a return grill opening, it can produce noticeable levels at that location. The options to correct include, moving the return grille, moving the loudspeaker or installing a transfer air boot that has the opening facing away from the loudspeaker.

Direct field loudspeakers or "emitters" are mounted in the acoustical ceiling or clouds and aimed downward into the space. They rely on being small devices that look similar to a fire sprinkler to remain unnoticeable. Direct emitters avoid issues with return air grill openings, lighting, fire sprinklers and HVAC ductwork but require careful layout to achieve the desired uniformity without gaps in coverage. Proper loudspeaker placement and system adjustment provides area coverage that is then adjusted to be uniform within +/- 2 dB from 100 Hz to 160 Hz and +/- 1 dB from 200 Hz to 3150 Hz.

Loudspeaker layouts need to be coordinated with room sizes, lighting fixtures, fire sprinklers and mechanical HVAC system supply and return air ducts. It is extremely important for loudspeakers to be installed in the locations as shown on the design documents to achieve uniform coverage. Also, in larger spaces, the masking zone should consist of two overlapping loudspeaker feeds. This is done in the event that, if one of the loudspeaker outputs fails, the sound masking continues operating with only a 3 dB decrease in overall level. There would be an accompanying decrease in uniformity of coverage, but that would be much less noticeable to the occupants than losing all masking.

4.6 Sound Masking Levels

There are recommended criteria for use of sound masking in Hospital fand outpatient facilities to increase privacy between patient spaces as shown in Table 3, following. Sound masking is not recommended, however, in Residential and Senior Care facilities, because many of the residents suffer from hearing loss. It is the third most common chronic condition in the United States [**21**] with 34 million adults aged 50 years or older having hearing loss in both ears and 60 million having loss in at least 1 ear. In the next 40 years, the number of adults in the United States who have hearing loss is expected to increase nearly 2-fold because of the increase in aging population. [**22**] It is, however, completely reasonable for any resident to employ a personal sound masking unit in their bedroom, if it helps them sleep. Due to the size and limitations of small masking devices, there is little chance of the levels disturbing neighbors.

Table 3: Preferred Sound Masking Maximum Levels for Various Functional Spaces

Out-Patient Facilities	Sound Masking Levels
Conference, Meeting or Telemedicine rooms	42 dBA
Exam or Treatment rooms	43 dBA
Private Offices	43 dBA
Waiting area	45 dBA
Corridor and public spaces (adjacent to Exam or Treatment Rooms)	45 dBA
Open Office/Administrative areas	47 dBA

There are also criteria for use of sound masking in Hospital facilities to increase privacy between patient spaces. Sound masking is not recommended in Residential and Senior Care facilities, because many of the residents suffer from hearing loss. It is the third most common chronic condition in the United States [**23**] with 34 million adults aged 50 years or older having hearing loss in both ears and 60 million having loss in at least 1 ear. In the next 40 years, the number of adults in the United States who have hearing loss is expected to increase nearly 2-fold because of the increase in aging population. [**24**] It is, however, completely reasonable for any resident to employ a personal sound masking unit in their bedroom, if it helps them sleep. Due to the size and limitations of small masking devices, there is little chance of the levels disturbing neighbors.

FGI guidelines currently identify 48 dBA as the maximum masking sound level in any space. Ideally, the levels should be set as low as possible while still achieving increased privacy. While we may be aware of research where the effects of continuous background sound masking are being studied, to date, we have seen no information showing masking sound is detrimental to occupants.

4.7 Sound Masking Levels

The National Research Council of Canada (NRCC) conducted research on sound masking and privacy. The following are recommended maximum and minimum sound masking levels by 1/3-octave band frequency. [**25**]

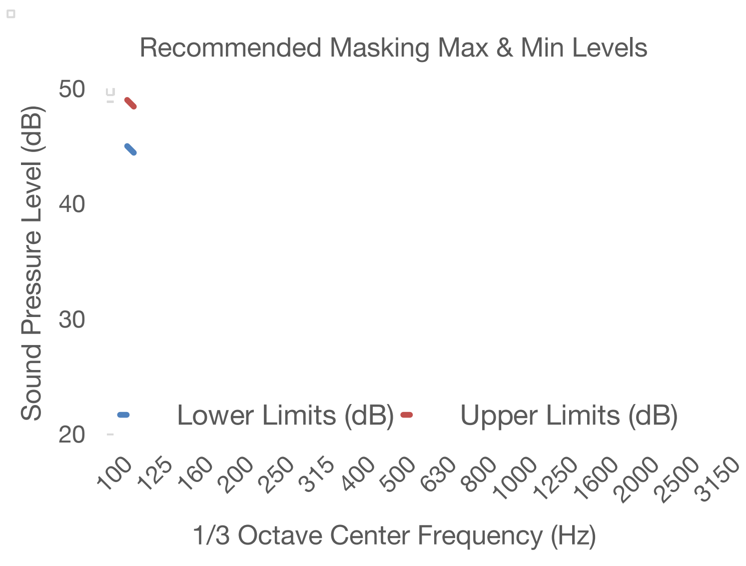

Figure 1: Recommended Minimum and Maximum Masking Sound Levels and Spectra.

4.8 Most Common Sound Masking Issues

Parameters for temporal change (on/off, modulation and transience) and tonality (spectrum smoothness or balance) are lacking in the system specifications. These are common issues that need to be addressed when implementing sound masking systems in new construction or renovation projects.

- Acoustical ratings of the partitions were not considered during the design and layout of rooms and support spaces. There are limits to masking and it cannot replace the benefits of rated walls that physically separate noise from quiet activities.
- The masking loudspeaker layout does not provide uniform coverage resulting in areas with excessive or insufficient masking. Worst of all, spatial level variation makes the system highly noticeable which is not desired. Additional loudspeakers may be needed.
- The HVAC systems are quieter and may cycle on and off. It is important to measure the ambient levels with and without the HVAC operating. The masking levels should be adjusted to provide the desired minimum privacy with the HVAC operating at the minimum level or off. The privacy will increase further when the HVAC is running.
- The masking loudspeaker was not installed as shown on the design documents because other building elements moved during construction. This can require the addition of another loudspeaker to achieve uniformity of coverage.
- The masking loudspeaker is located next to a return-air grille opening in the ceiling or a supply grille in the raised floor. This requires either the loudspeaker or grille to be moved, or the installation of a return-air boot on return-air openings in the ceiling.
- Specifications do not include the tuning and operating levels of the masking in the various zones. ASTM E1573-09, Standard Test Method for Evaluating Masking Sound in Open Offices Using A-Weighted and One-Third Octave Band Sound Pressure Levels, identifies the procedure for evaluating the special and temporal uniformity of masking sound levels.

5. CONCLUSIONS

Outpatient facility interior improvements, whether in purpose-built or within existing commercial or lease facilities, are subject to practical and/or economic restrictions on design and construction that can limit acoustic performance of demising wall and floor-ceiling assemblies. Careful selection and fine-tuning of wall types, suspended ceiling products and door-frame assembly seals may incrementally improve performance. Sound masking can supplement demising assembly sound isolation to improve speech privacy. Acoustical criteria to provide the desired sound isolation and background noise levels to achieve patient privacy should be established early in the project planning phase. Preferred NC levels, demising partition STC ratings, ceiling CAC ratings and average room absorption for the various rooms and adjacencies should be defined. When renovating a building, the existing conditions need to be verified in order to determine most feasible and efficient design and construction solutions. The combination of early planning and coordination with the Owner and Architect allows proper design and detailing of acoustical partitions and other elements to achieve the project acoustical design goals. Implementation of criteria, recommendations and guidelines presented above can result in more economical, but cost-effective performance necessary to achieve FGI criteria in outpatient facilities.

6. REFERENCES

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1 The Facility Guidelines Institute, *Guidelines for Design and Construction of Outpatient Facilities*, 2018 Edition

2 The Facility Guidelines Institute, *Guidelines for Design and Construction of Outpatient Facilities*, Tables 1.2-4, 1.2-5, 1.2-6, and 1.2-8, 147-150, 2018 Edition

3 "Design Data for Acousticians," Architectural and Construction Services of United States Gypsum, Feb. 1985

4 Quirt, J., Warnock, A., & Birta, J., "Sound Transmission Through Gypsum Board Walls: Sound Transmission Results," National Research Council Canada [NRC] Institute of Research in Construction [IRC], Internal Report IRC-IR-693, Oct. 1995
5 Halliwell, R., Nightingale, T., Warnock, A. & Birta, J., "Gypsum Board Walls: Transmission Loss Data," National Research Council Canada [NRC] Institute of Research in Construction [IRC], Internal Report IRC-IR-761, Mar. 1998
6 Dupree, R., "Catalog of STC and IIC Ratings [for Wall and Floor/Ceiling Assemblies]," Report from the California Department of Health Services, Local Environmental Health Services Branch Office of Noise Control, Sep. 1981
7 Farrell, W. "Acoustical Materials for Use in Monumental Spaces". *Noise Control* (1958).
8 ASTM C423-17, Standard Test Method for Sound Absorption and Sound Absorption Coefficients by Reverberation Room Method, ASTM International, West Conshohocken, PA, 2017
9 ASTM E1414 / E1414M-21, Standard Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum, ASTM Int'l., West Conshohocken, PA, 2021
10 Evans, J. & Himmel, C., Acoustical standards and criteria documentation of sustainability in hospital design and construction. Acoustics 2012, pp. 3217-3222, Nantes, FR, Apr 2012. Hal-00810802
11 Beranek, L.L. Acoustics, pg. 326, American Inst of Physics, New York (1954)
12 *Ibid.,* Beranek, pg. 330.
13 Mic University, *Facts about Speech Intelligibility*, https://www.dpamicrophones.com, Mar 2021
14 Evans, J. & Philbin, K, The Acoustic Environment of Hospital Nurseries: Facility and Operations Planning for Quiet Nurseries. *Journal of Perinatology,* **20**: S105-S112 (2000).
15 ASTM E3133-18e1, Standard Test Method for Laboratory Measurement of Floor Impact Sound Radiation Using the Tapping Machine , ASTM International, West Conshohocken, PA, 2018
16 American National Standards Institute/Acoustical Society of America (ANSI/ASA), *Criteria for Evaluating Room Noise,* S12.2-2019 Edition.
17 Pettyjohn, S. "*Method of predicting Composite Sound Transmission Class rating of composite wall assemblies that do not extend to deck".* The Journal of the Acoustical Society of America, 144, 1918, 2018
18 ASTM E90-09-2016, "*Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements".*
19 Hongisto, Valtteri, Oliva, David & Rekola, Laura, "Subjective and objective rating of spectrally different pseudorandom noises – Implications for speech masking design". The Journal of the Acoustical Society of America 137, 1344 (2015)
20 Chanaud, R. & Zuydervliet, R., "*Adaptive Sound Masking*", The Journal of Acoustical Society of America, Vol 123, pp. 3195, May 2008
21 Gorman AM, Lin FR, "*Prevalence of hearing loss by severity in the United States"*, American Journal of Public Health, pp. 1820-1822, 2016
22 Adele M. Gorman, PhD; Reed, Nicholas S.; Frank R. Lin, MD, PhD, "*Addressing Estimated Hearing Loss in Adults in 2060"*, JAMA Otolaryngology Head and Neck Surgery, pp. 733-734, 2017
23 Bradley, National Research Council of Canada (NRCC), Canada Acoustics, Vol 27, No.3, "*Acoustical Design of Conventional Open Plan Offices*", (NRCC-46274), 2003