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Acoustical standards and criteria documentation of sustainability in hospital design and construction

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The Leadership in Energy and Environmental Design (LEED) rating system, developed by the United States Green Building Council (USGBC) has multiple categories, including a 2009 version for healthcare buildings. Determination and award of Interior Environmental Quality (IEQ) rating points for Acoustics requires theoretical calculation in design phase of ambient sound, privacy and intrusive outdoor noise relative to allowable criteria or performance validation testing after construction. This case study discusses the required acoustical criteria for IEQ Credits 1 and 2. Floor plans showing patient, procedure, consultation and meeting rooms are presented and discussed with regard to the criteria. Design phase calculation procedures undertaken to document conformance are presented with results. Because conflicts between operational requirements and acoustical criteria create design challenges, commentary is offered about design alternatives that aided or inhibited rating success.

Standards and Criteria covered include:
Leadership in Energy and Environmental Design (LEED); a third-party certification and benchmark system created by U.S. Green Building Council (USGBC),
Guidelines for Design and Construction of Health Care Facilities, Facility Guidelines Institute (FGI), 2010, referenced in LEED Healthcare 2009.
"Sound and Vibration Control," *ASHRAE Handbook of HVAC Applications, 2007* American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc.

1 Introduction

Design for hospitals and medical-healthcare facilities in North America is scored and certified for sustainability under the Leadership in Energy and Environmental Design (LEED), 2009 Healthcare: New Construction & Major Renovations [1]. Interior Environmental Quality (IEQ) is one of the sustainability categories. Other categories include Sustainable sites, Water efficiency, Energy and atmosphere, Materials and resources and Innovation in design.

Within IEQ, two points are available in Credit 2, Acoustic Environment [2]. The explicitly stated intent is to "provide building occupants with an indoor healing environment free of intrusive or disruptive levels of sound." Requirements are: Option 1, one point; available for achieving continuous background noise, sound isolation/privacy and speech intelligibility criteria. Option 2, available if Option 1 is achieved, one point: for controlling exterior noise impact on the facility and for interior acoustical finishes that enhance quiet spaces.

LEED HC 2009 relies on the Facility Guidelines Institute (FGI) "Guidelines for Design and Construction of Healthcare Facilities," 2010 [3], and the companion document from ANSI S12 WG44, "Sound & Vibration for Health Care Facilities, V2.0," 2010 [4], which serves as "reference standard" for FGI 2010 and LEED Healthcare 2009 **[**5**].**

The FGI criteria and guidelines are adopted as code in many states of the US and in several other countries. In other states, including the location of the project in this paper, FGI is a design standard implemented at the discretion of the owner and/or architect [6]. Similarly, LEED requirements are voluntary, to be implemented by the owner and building designers.

This acoustical consultant was retained to document design achievement of the criteria by calculation, based on review and analyses of architectural and engineering designs for a three-story patient wing addition to an existing children's hospital. At the time of this writing, application for the IEQ Acoustic Environment Option 1 point has been completed and submitted for approval. Calculation procedures and documentation format are presented below.

Documentation of Option 2, to proceed after award of the first point, may be discussed in a future case study.

One type of space was found to have functional and operational requirements in conflict with the sound isolation/privacy requirements of the acoustical criteria. A request for exception was submitted, based on general conformance to the criteria, but permitting reduced sound isolation between nurses' station and patient room entries in an area of acute or intensive care. The ruling from the Certification Institute of the USGBC is discussed.

The theoretical calculation of acoustical conditions and orderly documentation of results and the method of application and ruling on exclusions are discussed and illustrated herein. Certification is pending final design.

2 LEED Acoustical Requirements

Using FGI 2010 to achieve LEED for Healthcare credit, the two points that can be achieved by design-phase calculation are presented below. Post-construction validation measurement results are also permitted by LEED to demonstrate conformance in lieu of design calculations.

2.1 Sound isolation & speech privacy

Option 1: One point for achieving three sets of goals for representative adjacencies:

- Sound Isolation. Calculate composite STC (STCc) ratings for typical spaces and show that partitions designated in plans partition schedule achieve the minimum STC or STCc ratings.
- Speech Privacy. Calculate the results using a choice of descriptor (PI, AI, STI or SII, or the simple calculation method of STCc + dBA = at least 75).
- Room Noise. Calculate the background noise results using choice of descriptor (NC, RC(N), or dBA). ASHRAE 2007, Ch. 47, Sound and Vibration Control, is a supplemental reference.

2.2 Acoustical finishes & exterior noise

Option 2: After achieving Option 1, above: one additional point for achieving two sets of goals:

- Acoustical Finishes. Calculate reverberation decay time, RT60 in seconds.
- Site Exterior Noise. Calculate STCc for exterior shell using combination of exterior wall, window and other components for comparison with requirements that vary with exterior sound levels.

3 FGI and ASHRAE Criteria

FGI and ASHRAE criteria, as published in their 2010 and 2007 editions, respectively, are copyrighted and will not be presented here in total, but criteria categories and representative levels are presented for typical spaces.

3.1 Sound isolation & speech privacy

- Sound Isolation. FGI Table 1.2-3, "Design Criteria for Minimum Sound Insulation Performance between Enclosed Rooms." [7]. Example: Demising partition between Patient Rms.: STC-45, Patient Rm. to Public Demising Partition: STC-50, Patient Rm. corridor partition with entry STCc-35.
- Speech Privacy. FGI Table 1.2-4, "Design Criteria for Speech Privacy for Enclosed Rooms and Open-Plan Spaces." [8]. (PI is minimum value, but AI, STI and SII are maximum values). Example: Normal speech privacy: PI $\geq$ 85%, AI $\leq$ 0.15, STI $\leq$ 0.19, SII $\leq$ 0.20.
- Room Noise. FGI Table 1.2-2, "Minimum-Maximum Design Criteria for Noise in Interior Spaces." [9]. Example:
  Patient Room: NC/RC(N) 30-40, 35-45 dBA
  Corridors, Public: NC/RC(N) 35-45, 40-50 dBA

3.2 Acoustical finishes & exterior noise

- Acoustical Finishes. FGI Table 1.2-1, "Design Room Sound Absorption Coefficients" [10]. Ex: Private patient room, NRC 0.15, "average room."
- Site Exterior Noise. FGI Table A1.2-a, "Categorization of Health Care Facility Sites by Exterior Ambient Sound" [11], minimal, moderate, significant or extreme categories based on day-night average (Ldn) or maximum hourly L01 (dBA) and distances to major noise sources.

4 Hospital Wing Addition

4.1 Location and Functional Occupancies

The existing children's hospital has public areas, including reception lobby, corridors, physician exam, treatment and procedure spaces, operating rooms and two patient room wings. The new three-story wing addition, Fig. 1, incorporates core areas with consultation, treatment, conference and support spaces, including mechanical and electrical equipment rooms plus the patient wing.

Figure 1: Hospital plan showing new wing location.

4.2 Upper Level Standard Patient Floors

The two levels above ground have patient rooms clustered around nurse stations in the wing with drywall demising and corridor partitions, as illustrated in Fig. 2. The core area contains office, consultation, playroom and family waiting, multi-purpose conference, on-call staff sleep and lounge plus various support spaces. All demising and corridor partitions are drywall. Ceilings are generally suspended acoustically absorptive tile.

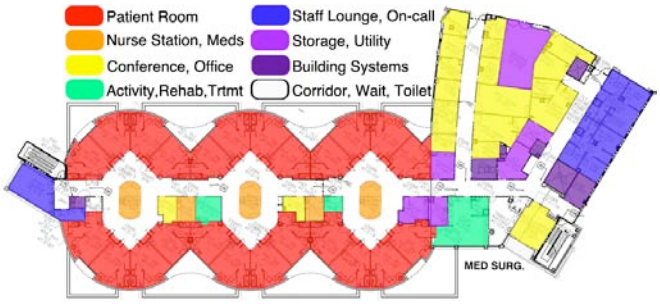

Figure 2: Floor plan: General layout configuration of upper level wing addition with regular patient rooms on left and core areas on right.

4.3 Lower Level Universal Care Floor

The lower ground level, Fig. 3, contains "universal" care rooms in a suite, similar to acute or intensive care in other hospitals, where nurses can continuously monitor and tend to patients. Universal room entry partitions are sliding glass door and fixed glass panels along the nursing corridor. Demising partitions between rooms are drywall. The core area contains office, rehabilitation therapy, consultation, multi-purpose conference and lounge spaces. All demising and corridor partitions are drywall and ceilings are acoustically absorptive.

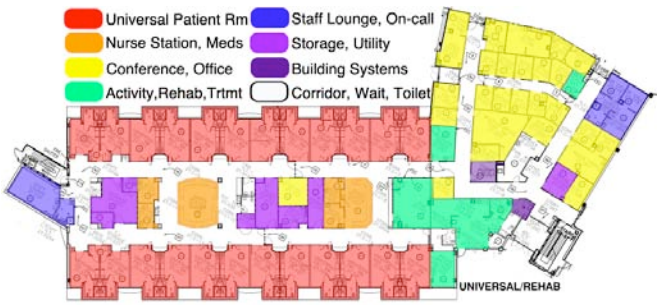

Figure 3: Floor plan: General layout configuration of lower level wing with Universal Care Suite (UCS) on left and core area on right.

5 Calculation Procedures

5.1 Sound Isolation

Demising partitions and floor-ceiling assemblies may be selected based on laboratory sound transmission class (STC) ratings. The lab ratings may be relied upon as adequate documentation of demising assembly performance. STC ratings were submitted for partitions.

Partitions that have doors, windows, penetrations or other openings must be shown by calculation to achieve

composite sound transmission class (STCc) that conforms to requirements, such as STCc 35 for a corridor partition with entry door, using Eq. (1), *composite partition noise reduction* (NR)[12]. Fig. 4 illustrates an STCc calculation.

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

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 the composite transmission loss (TL) is calculated using Eq. (2), based on the surface area (S_i) and transmission loss (TL_i) of each individual demising component [13].

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

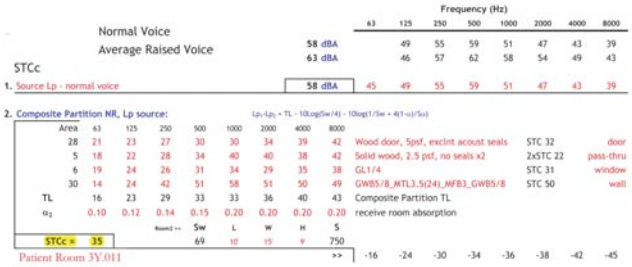

Figure 4: Sound Isolation Calculation: Composite Sound Transmission Class (STCc)

5.2 Speech Privacy

Speech Intelligibility Index (SII) was chosen out of the four descriptors that may be used to verify speech privacy for this project. The SII calculation, as illustrated in Fig. 5, is based on the Octave Band Method, ANSI S3.5-1997 [14], which incorporates estimated speech sound level, continuous background sound, hearing threshold level, masking and other variables.

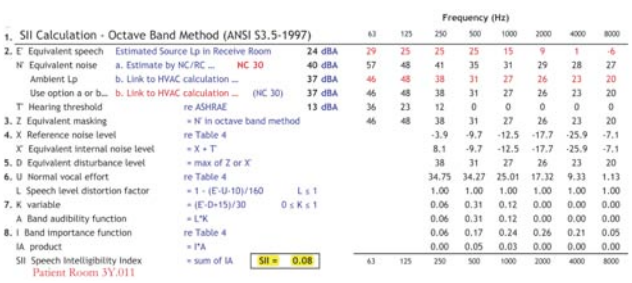

Figure 5: Speech Privacy Calculation: Speech Intelligibility Index (SII)

5.3 Room Noise

Continuous room noise is calculated for heating and air conditioning, using data and procedures from ASHRAE [15].

The air supply calculation, illustrated in Fig. 6 (top), starts with fan noise at air handler and is reduced by duct attenuation, power divisions, fitting losses, net of turbulence generated noise and is completed with multiple sources addition and room loss power to pressure conversion (Lp-Lw). The result is residual level for supply.

Return air (or exhaust if relevant), shown in Fig. 6 (bottom) is calculated by similar procedure to find residual level in room. Supply and return levels are added together to determine overall room level, plus any significant other sound sources that may contribute. Result is compared with RC or NC criteria to determine Room Noise criteria conformance.

Figure 6: Room Noise Calculation: Supply (top) and Return Air (bottom), based on ASHRAE noise generation and attenuation data

5.4 Acoustical finishes & exterior noise

The Option 2 (2nd) point may be applied for only after the Option 1 point for sound isolation, speech privacy and room noise is achieved. Documentation has not been done for Option 2 at the time this case study is being written.

6 An exception to the criteria

The sound isolation requirements are intended to protect acoustical privacy and reduce intrusive noise that might degrade the healing process. Not all conditions can be reduced to one table of sound transmission limits. Universal Care Suites (UCS) house intermediate and intensive care patients, as shown in Fig. 7. By regulation, it is required to maintain visual contact between Nurse Stations and patient rooms and to a lesser degree some audible exchange. The corridor entry partitions are glass sliding and folding doors, as shown in Fig. 8. Crisis conditions can occur in the UCS, so there are gaps between doors and panels to prevent crushing of fingers if caught between them, making it difficult to provide effective acoustical seals, and difficult or impossible to meet the FGI Table 1.2-3 requirement of STCc 35 for patients' corridor partitions with entry doors. The corridor has access restricted only to medical staff and families. With no public access, privacy is not as important as in other patient rooms that have public corridor entries.

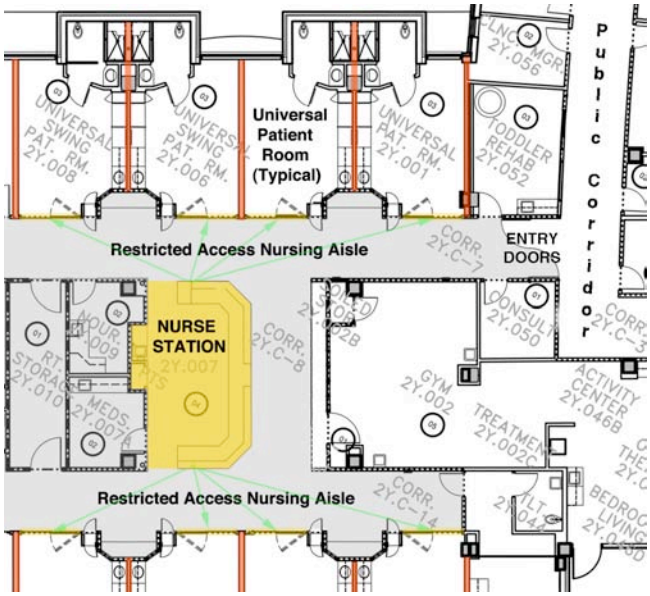

Figure 7: Sound Isolation exclusion was granted for Universal Room glass doors (yellow) to maintain audible and visual contact between Nurse Station and patients. Patient room demising partitions (red) meet criteria.

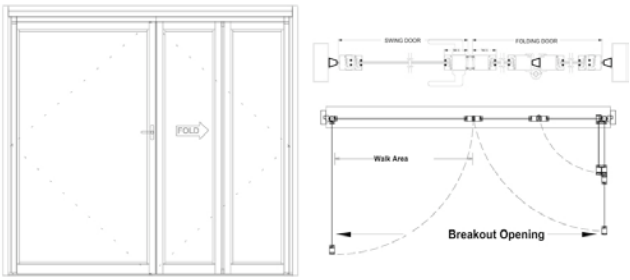

Figure 8: UCS breakaway sliding, folding glass door.

A Formal Inquiry (FI) or exemption from the composite partition sound transmission class STCc 35 was requested, because few, if any design alternatives were available, given the mandated use of folding, sliding glass doors and view panels in te UCS. The FI indicated that demising partitions between patient rooms would meet STC 45 criteria, but the sliding glass doors were estimated to achieve only STC 28. Other performance, personnel access and operational requirements were included in the exemption request. Therefore, in lieu of considering the interior corridors within the UCS as "public," the UCS should be regarded as one large suite and the entry door between public corridor and suite interior corridors should be where the FGI sound isolation criteria is applied.

The Credit Interpretation Ruling (CIR) from the Green Building Certification Institute (GBCI) permitted the requested exclusion, "given that all other requirements of IEQc2 Acoustic Environment are met, … the entrance partitions to the Universal Care Suites (UCS) can be excluded from the STCc 35 requirements found in Table 1.2-3 of the 2010 FGI Guidelines. This is acceptable because the UCS houses patients that require close and constant attention from the medical staff" [16].

7 Reporting LEED HC Compliance

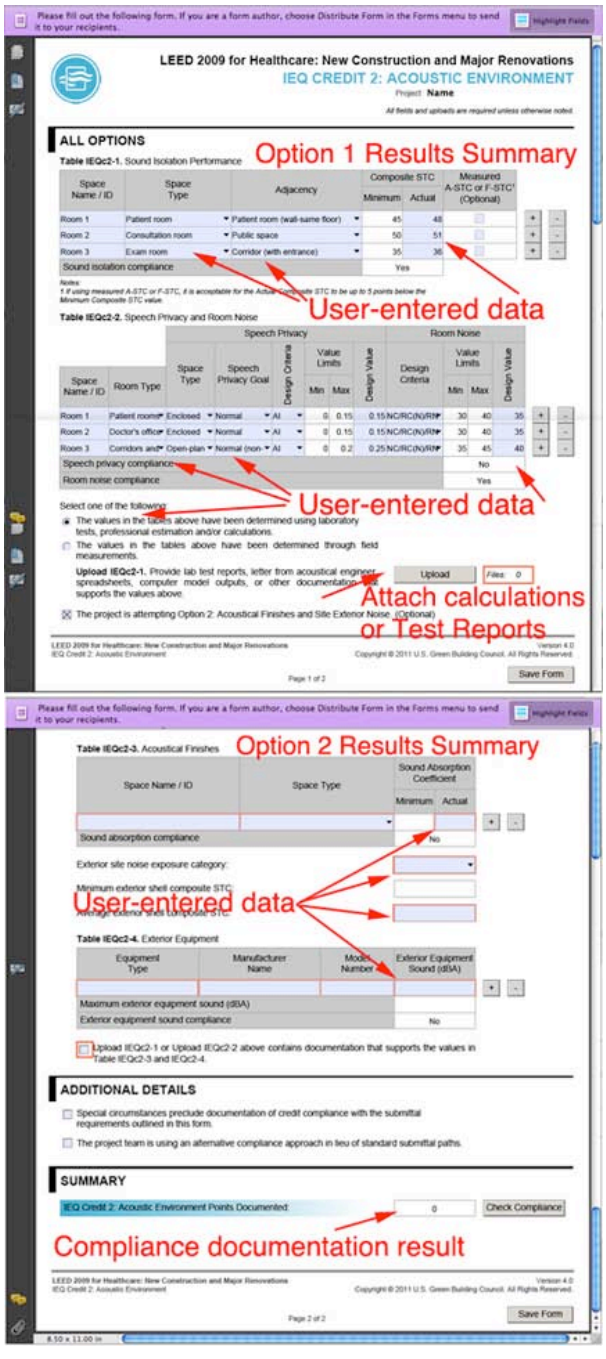

Figure 9: Interactive spreadsheet results reporting form. User adds lines for each room evaluated to summarize Option 1 and Option 2 calculation or measurement results.

For purposes of showing design conformance with LEED Healthcare 2009 requirements, sound isolation, speech privacy and room noise results are summarized on a scoring spreadsheet [17], as illustrated in Fig. 9. User selects specific indication that either, "the values … have been determined using laboratory tests, professional estimation and/or calculations," or "the values … have been determined through field measurements."

LEED does not prescribe procedures for calculating or measuring parameters to determine conformance, but procedures or methodology may be obtained from the reference documents, FGI 2010, S&V 2.0 and ASHRAE 2007. Each performance value is calculated for representative rooms of each category covered by FGI criteria, such as STC or STCc for isolation, PI, AI, STI or SII for privacy and NC, RC(N) or dBA for continuous ambient noise. Results are entered and compared to determine compliance. When all covered rooms achieve compliance for each criteria set, the required performance is documented. Results are submitted for certification.

8 Conclusion

Conformance with requirements for LEED Healthcare 2009, IEQ Credit 2: Acoustic Environment, may be determined and documented using basis of design and performance criteria published in (a) Facility Guidelines Institute, 2010, (b) laboratory data and (c) generally accepted calculation formulas and procedures published in ANSI standards and the ASHRAE Applications Handbook. Summarized results are entered in a standard USGBC form to be submitted with copies of data and calculations for each room covered by LEED requirements. A Formal Inquiry and Credit Interpretation Ruling procedure exists for spaces with functional, operational or regulated conditions outside of or in conflict with LEED requirements or FGI criteria.

References

[1] *LEED 2009 for Healthcare: New Construction & Major Renovations*, U.S. Green Building Council, Washington, DC (2009)

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[3] *Guidelines for Design and Construction of Health Care Facilities*, The Facility Guidelines Institute, ASHE, Chicago (2010) http://www.fgiguidelines.org

[4] *Sound & Vibration, V2.0,* ANSI S12 WG44, The Joint ASA/INCE/NCAC Subcommittee on Healthcare Acoustics & Speech Privacy, Cambridge, MA (2010)

[5] ARC, The Acoustics Research Council, http://speechprivacy.org/joomla//index.php?option=com_content&task=view&id=34&Itemid=45

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[7] *Guidelines for Design and Construction of Health Care Facilities*, page 36, The Facility Guidelines Institute, ASHE, Chicago (2010)

[8] *Ibid*, FGI, pg. 36

[9] *Ibid*, FGI, pg. 35

[10] *Ibid*, FGI, pg. 35

[11] *Ibid*, FGI, pg. 37

[12] Beranek, L.L. *Acoustics,* pg. 326, American Inst of Physics, New York (1954)

[13] *Ibid,* Beranek, pg. 330.

[14] ANSI 1997. S3.5-97, American National Standard "Methods for Calculation of the Speech Intelligibility Index," Standards Secretariat, Acoustical Society of America, New York (1997)

[15] ASHRAE. 2007. "Sound and Vibration Control," Chap. 47, *ASHRAE Handbook of HVAC Applications.* American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc., Atlanta (2007)

[16] Green Building Certification Institute, *Credit Interpretation Ruling* (unpublished), U.S. Green Building Council, Washington, DC (2012)

[17] EQc2.pdf, "IEQ Credit 2: Acoustic Environment," *Version 4.0 LEED 2009 for Healthcare*, Green Building Certification Institute, U.S. Green Building Council, Washington, DC (2011)