

Acoustic design approach for hospitals

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ABSTRACT

Hospitals include a multitude of different spaces with a wide range of sensitivity and privacy requirements. Each space may be used for a variety of activities that have differing sensitivity levels and generate varying levels of noise. Similar types of spaces within the same hospital can also have quite different design considerations depending on the department and users. This information is often not fully captured in the project brief, nor in prescriptive healthcare guidelines. Consequently, the practicality of achieving acoustical criteria must be considered. Operational constraints such as cleanability, hygiene and access requirements can limit the use of some acoustic treatments, and in some circumstances restrict the ability of a space to achieve certain acoustic outcomes. This paper provides a discussion of the approach to acoustic design of hospital projects and the factors that should be considered in the acoustic design approach. A review of international healthcare guidelines has been undertaken and the requirements qualified against real world mitigating factors. Two case studies are included to highlight the difficulties that occur in the design of real healthcare facilities. These case studies demonstrate that while health care guidelines are a useful starting point, these guidelines must be moderated with an understanding of the user groups and design constraints. In this way, project specific design criteria and solutions can be developed that are workable and still deliver key design outcomes.

INTRODUCTION

Hospitals and healthcare buildings offer a significant challenge to acoustic consultants and designers. These buildings include a multitude of different spaces with a wide range of sensitivity and privacy requirements. Each space may be used for a variety of activities that have differing sensitivity levels and generate varying levels of noise. Similar types of spaces within the same hospital can also have quite different operational and design considerations depending on the department and users. This information is often not fully captured in the project brief.

This paper provides a discussion of the approach to acoustic design of hospital and healthcare projects, and the factors that should be considered in the acoustic design.

WHY IS ACOUSIC DESIGN IMPORTANT

Good acoustic conditions are fundamental to the quality of healthcare facilities. Excess noise has the potential to increase blood pressure, heart and respiration rates, and contribute to cognitive impairment and sleep disturbance (Ampt, Harris, & Maxwell. 2008).

Guidance (Ampt, Harris, & Maxwell. 2008) indicates that good acoustic design can:

- Improve patient comfort, privacy and dignity
- Assist in providing essential sleep patterns to aid the healing process
- Improve staff comfort, privacy, efficiency and accuracy

In short, control of unwanted noise is of critical importance. Design of efficient, effective hospitals must incorporate noise control as a primary consideration.

REFERENCE GUIDELINES

The following documents provide guidance on acoustic design criteria and design considerations:

- Australasian Health Facility Guidelines Revision v4.0 (AusHFG)
- Health Technical Memorandum HTM 08-01: Acoustics, UK Department of Health (HTM 08-01)
- Sound & Vibration, Design Guidelines for Health Care Facilities, Version 2.0 (SVDG)
- AS/NZS 2107:2000 Acoustics—Recommended design sound levels and reverberation times for building interiors (AS2107)
- Green Building Council of Australia, Green Star – Healthcare v1 2009 (Green Star Healthcare)

Australasian Health Facility Guidelines Revision v4.0

The AusHFG set out to define the base requirements to be considered in the design and planning of healthcare facilities. AusHFG is a very large document, with over 1000 pages that discuss a broad range of requirements as they apply to different elements in the design of healthcare facilities. Check lists are provided at the end of each section to confirm understanding or application of specific considerations within that section.

Part A outlines an introduction to the use of the document. In terms of acoustics, Part B of the document provides useful background briefing information and basic guidance on acoustic requirements for different spaces and uses. These requirements are generalised, with a focus on identifying spaces which require noise control and/or acoustic privacy. Some ambiguous terminology is used, for example “acoustically-treated” or “acoustically separated”. Specific criteria for acoustic separation or privacy are not discussed. AS2107 and Australian Standard AS 2670.1:2001 *Evaluation of human exposure to whole-body vibration, Part1: General Requirements* (AS2670.1) are referenced under environmental considerations for some areas.

Part C includes a generalised discussion of acoustic issues as they relate to treatment types and surface finishes, which

builds on the information provided in Part B. Part D discusses infection prevention and control. This section is important as the requirements relating to surfaces and finishes have the potential to impact upon the suitability of acoustic treatments.

Health Technical Memorandum HTM 08-01: Acoustics, United Kingdom Department of Health

This guideline was developed by a working group for the Department of Health in the United Kingdom to brief healthcare professionals on the acoustic requirements for healthcare facilities.

The document is structured as follows:

- Chapter 1 – Introduction: as per title.
- Chapter 2 – Acoustic criteria: discusses recommended acoustic criteria and their application as well as important design considerations.
- Chapter 3 – Construction noise and vibration: outlines the strategy for assessment of construction noise and vibration impacts.
- Chapter 4 – Temporary healthcare facilities: as per title.
- Chapter 5 – Refurbished accommodation: as per title.
- Chapter 6 – Inspecting works during construction: as per title
- Chapter 7 – Testing and validation: discusses the test methodology for verifying acoustic requirements have been met.
- Chapter 8 – Checklists: for review of most critical acoustic issues.

Sound & Vibration, Design Guidelines for Health Care Facilities, Version 2.0

This document was developed by a working group for the Facility Guidelines Institute in the United States of America to provide a reference standard for acoustics in healthcare facilities. It outlines minimum acoustic design requirements intended to ensure “satisfactory acoustical and privacy environments”.

The document is structured as follows:

- Section 1 – Site Exterior Noise: provides generalised classifications/categories and indicative treatments on that basis.
- Section 2 – Acoustical Finishes and Details: provides guidance on simplified assessment of finishes based on mid frequency sound absorption coefficients assessed against design room average sound absorption coefficients.
- Section 3 – Room Noise Levels: based on ANSI S12.2 Criteria for Evaluating Room Noise and ASHRAE Applications Handbook, Chapter 47 Sound and Vibration Control.
- Section 4 – Sound Isolation Performance of Constructions: provides minimum recommended sound isolation between enclosed spaces, indicative constructions, discussion of composite performance, and speech privacy.
- Section 5 – Paging & Call Systems, Clinical Alarms, Masking Systems, & Sound Reinforcement: discusses intelligibility and audibility of electro-acoustic systems as well as guidance on sound masking.
- Section 6 – Building Vibration: discusses assessment of footfall vibration against American Institute of Steel Construction (AISC) Design Guide 11 and ASHRAE Applications Handbook, Chapter 47 Sound and Vibration Control for guidance on plant vibration.

AS/NZS 2107:2000 Acoustics—Recommended design sound levels and reverberation times for building interiors

This standard outlines recommended design sound levels and reverberation time for Health Buildings. Criteria provided for other occupancies may also be useful in assessing spaces not covered under Health Buildings, for example the Educational Buildings section may be useful in designing teaching spaces in a teaching hospital.

AS2107 gives ‘satisfactory’ and ‘maximum’ recommended design levels. The satisfactory design sound level is “the level of noise found to be acceptable to most people for the environment in question and also to be not intrusive”. The maximum design sound level is “the level of noise above which most people occupying the space start to become dissatisfied with the level of noise”.

A comparison of AS2107 recommended design sound levels to similar A-weighted criteria provided in HTM 08-01 and SVDG is included in **Table 1**.

Table 1. Comparison of A-weighted design sound levels between different healthcare guidelines

Occupancy/activity	AS2107	HTM 08-01 ¹	SVDG
Conference and meeting rooms	35-40 ²	35-40 ³	30-40
Wards	35-40	Single 35-40 ⁴ Multi 35-45 ⁴	35-45
Small office type spaces i.e. consult, treatment, and interview rooms etc.	40-45	40	30-40
Operating theatres	40-45	40	35-45
Open clinical areas	40-45	45	40-50
Corridors and lobbies	40-50	50-55 ⁵	40-50

Notes:

1. HTM 08-01 gives a single value rather than a range. Where a range is stated this is for different design conditions.
2. Criteria based on Educational Buildings
3. Lower value applies where floor area is >35m²
4. Lower limit applies at night
5. Lower limit applies to public spaces, upper limit applies to circulation spaces.

The AS2107 recommended design sound levels are comparable to those provided in SVDG and HTM 08-01. Noting that that the SVDG document specifies a 10 dB(A) range; and the HTM 08-01 criteria apply to noise intrusion rather than the overall design sound level. Both SVDG and HTM 08-01 use alternative parameters for noise from building services (i.e. NC or RC(N) for SVDG, NR for HTM-08).

Green Building Council of Australia, Green Star – Healthcare v1 2009

Green Star is an environmental rating system developed by the Green Building Council of Australia. Green Star rating tools are available for a number of different building uses including healthcare. Points are awarded where compliance with a particular credit is achieved. Under Green Star requirements for healthcare two Indoor Environment Quality (IEQ) credits relate to acoustics:

- IEQ-7 Internal Noise Levels; and
- IEQ-19 Places of Respite.

The credit criterion for IEQ-7 Internal Noise Levels assesses internal building services noise levels against the recommended design sound levels provided in AS2107. One point is awarded where compliance is achieved.

The credit criteria for IEQ-19 Places of Respite assess a number of different requirements. The criterion which directly relates to acoustics applies to places of respite located outdoors. The criterion requires that such spaces achieve a noise exposure category of ‘A’ or ‘B’ as defined in Table 1.3-1 of the Draft Interim Sound and Vibration Design Guidelines for Hospital and Healthcare Facilities (this document has been superseded by the SVDG discussed previously).

Summary and Comments

A simplified comparison of the criteria provided in the different guidelines is outlined in **Table 2**.

Table 2. Summary of criteria discussed in the guidelines.

<i>Guideline</i>	<i>Acoustic separation</i>	<i>Reverberation</i>	<i>Internal noise levels</i>	<i>Vibration</i>
<i>AusHFG</i>	Some-times, qualitative only	Some spaces reference AS2107	Some spaces reference AS2107	Some spaces reference AS2670.1
<i>HTM 08-01</i>	Yes	Yes ¹	Yes	Yes
<i>SVDG</i>	Yes	Yes ²	Yes	Yes
<i>AS2107</i>	No	Yes	Yes	No
<i>Green Star Healthcare</i>	No	Not clear ³	Yes	No

Notes:

1. Reverberation criteria provided as recommended minimum absorption area.
2. Reverberation criteria provided as design room sound absorption coefficients.
3. It is not clear whether IEQ-7 requires compliance with AS2107 recommended reverberation times. The only reference to recommended reverberations times is provided under ‘Additional Guidance’ which states that compliance with these is not required for base build. However the credit does not specifically request compliance.

In summary, the AusHFG contains some excellent briefing information but is not particularly well structured for consultants trying to understand and apply specific requirements for a particular design outcome. As such, it is recommended that this document be used as a starting point in understanding user requirements, supplemented with additional briefing with user groups to resolve some design elements and develop project specific criteria.

HTM 08-01 is a thorough and well structured document which provides excellent guidance on the recommended acoustic design approach for healthcare facilities. SVDG is a good alternative to HTM 08-01, although some elements, such as Site Exterior Noise may benefit from more detailed assessment. It should be noted that these guidelines whilst similar in approach yield differing results.

Table 3 provides a comparison of HTM 08-01 and SVDG for the performance of two common partitions.

Table 3. Comparison of sound isolation performance

<i>Partition separating</i>	<i>HTM 08-01¹</i>	<i>SVDG²</i>
<i>Wards</i>	53,56	45-50 ³
<i>Consulting Rooms</i>	53,56	50

Notes:

1. The sound isolation performance is given as a $D_{nT,W}$ in HTM 08-01, tabulated values are estimated R_w based on typical case. The lower value is the partition performance for a masonry construction and the upper value for a lightweight partition.
2. SVDG sound isolation performance is given as an STC value. R_w and STC results are similar for lightweight partitions, with masonry partition yielding a marginally higher STC result than R_w .
3. STC 45 is typical. STC 50 applies where higher speech privacy is required and patient doors of adjacent rooms are typically closed.

As shown by the examples provided in **Table 3** HTM 08-01 typically results in higher sound isolation performance than SVDG for similar spaces. Accordingly these guidelines should not be applied rigidly in an Australian context without considering the specific requirements of that facility.

MITIGATING FACTORS

As per the introduction, healthcare buildings include a multitude of different spaces with a wide range of sensitivity and privacy requirements that may vary over a typical day or between departments. The documents outlined above are important in developing a broad understanding of health care requirements. However, they should not be applied rigidly in an Australian context without considering the mitigating factors outlined below.

Consultation with users

There will be instances where strict compliance with all design guidance is not practicable. As such, it is important to actively engage with users and clients where appropriate to better understand the background behind their requirements, the limitations imposed, and where necessary highlight conflicting design requirements to allow a resolution to be obtained. It is also important to recognise the need for future flexibility. The design should endeavour to consider the likelihood of future upgrades and new technologies that have potential to significantly change the way a space is utilised.

The role of the consultant is to inform the client and/or users such that they can make decisions on what is appropriate for their needs. It can be difficult to qualify the impact of non-complying acoustic criteria to the layman. Tools such as noise thermometers or room auralisation can prove useful in highlighting the resulting impact of non-complying acoustic criteria such that dispensation may be sought.

Infection control

A key consideration that differentiates a healthcare facility from a conventional building design is infection control. Infection control requirements mean that finishes which are smooth and impervious to moisture are preferred as they are easily cleaned. These surfaces also need to be hard wearing and resistant to detergents and disinfectants to ensure they

withstand regular cleaning. Textured or inaccessible surfaces should also be avoided as these have the potential to accumulate dust.

These infection control requirements are at odds with many regular acoustic mitigation methods that rely on porous finishes or exposed insulation blankets.

These requirements impact upon acoustic treatments to the following items:

- Duct-borne mechanical services noise – specialised attenuators with encapsulated absorption typically used rather than traditional absorptive internal linings to ducts. Encapsulating the absorption is important for infection control as well as mitigating fibre-migration.
- Hydraulic services noise – essentially limits hydraulic treatment options to lagging of pipes even in less sensitive areas since loose laid insulation blanket is not acceptable in the ceiling cavity. Cast iron or ‘acoustic’ HDPE may reduce the extent of such lagging, however additional treatment still likely to be required in high sensitivity areas.
- Above ceiling treatments for flanking – baffle block systems or loose laid insulation blankets over the ceiling are not acceptable.
- Soft furnishing and carpet – not acceptable in most clinical areas. Typically limits reverberation control treatments to ceiling areas, since patients and staff are unlikely to come into contact with ceiling surfaces. Alternative hard floor surfaces may require acoustic underlay to mitigate footfall impact noise.

Following construction or refurbishment of a healthcare facility there may also be a requirement to clean down surfaces including ceiling voids to remove dust and other contaminants.

Part D ‘Infection Prevention and Control’ of the AusHFG outlines the following provisions relating to ceilings.

- *“Ceilings in Operating and Delivery Rooms, Isolation Rooms, Nurseries, and Sterile Processing Rooms should be monolithic from wall to wall without fissures, open joints, or crevices that may retain or permit passage of dirt particles. Light fittings should also be recessed, flush fitting and sealed to prevent dust ingress. Mineral fibre ceiling tiles may also need to be reviewed to confirm acceptance/compliance with infection control requirements.”*
- *“Acoustic and/or lay-in ceilings should not be used where particulate matter may interfere with hygienic environmental control.”*

Accordingly mineral fibre ceiling tiles should be reviewed to confirm compliance with infection control requirements.

Hospitals – where activity and sleep collide

Ward spaces pose additional challenges for a design team since sleeping activities are not restricted to the night-time period. As such, there may be high levels of activity in wards or intensive care units that must be controlled to allow sleep in adjoining ward areas. High noise levels in hospitals often occur due to staff activity and equipment that are outside the control of the design team. Reductions in ambient noise levels or noise transients (spikes, impacts etc) may be possible through staff education and the setting of noise limits in selection and procurement of equipment that is to be located in or close to sleep spaces.

However, it may be difficult to control these noise sources and may therefore be beneficial to have higher background noise levels to assist in masking.

Medical equipment and instrumentation

Medical equipment associated with healthcare facilities may be noisy in operation. For example, magnetic resonance imagers (MRI) generate noise levels between 80 to 120 dB(A) at the patient position depending on the scanning operation and strength of the magnetic field (Price et al. 2001). The proximity of sensitive uses to such items should be considered.

Furthermore, many items of medical instrumentation rely on the use of audible alarms. Numerous instances of this may occur in an intensive care unit where such instrumentation is critical in monitoring the condition of patients. Consideration should be given to noise levels in the procurement of such equipment and where appropriate visual warnings be used as an alternative.

Some items, such as microscopes and medical imaging instrumentation may also be sensitive to vibration depending on their location within the building and the resolution of the instrument. Items of potentially vibration-sensitive equipment should be determined during user group meetings. The sensitivity of these items will require review against manufacturer’s specifications or other appropriate guidance. Liaison with the structural engineer is typically required to confirm the ability of the building to comply with these criteria.

The structure of a building is a key contributor to the overall project cost. As a result the structure may be optimised early in the design before the locations and requirements for vibration sensitive instrumentation are fully understood. In these instances, mitigation measures may involve the use of high performance vibration isolation benches or by locating these sensitive items in areas of high structural stiffness. A similar approach applies to refurbishments where the building structure is existing with little scope for change.

Another example where equipment or instrumentation impacts upon the design of a space is audiological test rooms. AS2107 references AS/NZS 1269.4:2005 *Occupational noise management Part 4: Auditory assessment for the design sound levels in Audiological test rooms*. Appendix D of that standard recommends maximum acceptable background noise levels for workplace audiometry programs in octave bands based on the earphone and enclosure combination connected to the audiometer. Accordingly, it is important to survey users to understand the equipment to be used as well as the typical usage of Audiology Rooms in order to achieve an appropriate acoustic design.

Doors

Acoustic door seals in highly trafficked areas may not be suitable due to concerns regarding durability and ongoing maintenance. If identified early, this issue may be mitigated via room layout and planning. It is recommended that solid core doors be provided in these areas to allow acoustic door seals to be retrofitted should concerns be raised regarding noise and/or privacy.

The provision of doors, acoustically rated or otherwise, will degrade the resultant/overall performance of the partition in which they are located. Where there is a specific need for very high performance as well as access then a sound lock

lobby should be considered. Where performance is less critical there may be opportunity to reduce the acoustic rating to the surrounding partition.

Care should be taken to avoid the provision of air-relief grills or undercuts to doors as these items will significantly degrade the acoustic performance of the door.

Case study – separation between wards

Doors between the wards are typically left open to allow staff to effectively monitor patients. Should a staff member decide to undertake a sensitive discussion with a patient they may close the door to that ward however they are unlikely to close the doors to neighbouring wards. As a result the flanking via the corridor to a neighbouring ward effectively limits the separation between wards, negating the benefit of a very high performance partition. On this basis AECOM was able to reduce the partition rating between wards to R_w 45 dB.

Emergency or Standby Plant

HTM 08-01 paragraph 2.30 allows a relaxation in criteria for emergency or standby plant by up to 10 dB(A) compared to that typically applied to continuously operating plant. However, the application of such a correction should consider the frequency and duration requirements related to the testing of emergency and standby plant. Due to the critical nature of essential services to a hospital, this testing is often more rigorous than at other facilities. For example Item B3.2 in Appendix B of AS/NZS 3009:1998 - *Electrical installations—Emergency power supplies in hospitals* recommends regular testing to occur at load for a minimum 4.0 hour period at least once a month. This duration is significantly longer than that typically imposed for testing of standby generators (i.e. up to 1.0 hour). Consequently, it may not be appropriate to relax criteria by 10 dB(A) in that instance.

Acoustic ceiling tiles

One of the primary noise mitigation methods typically recommended for hospitals is sound absorptive ceiling tiles (Ampt, Harris, & Maxwell. 2008). Due to infection control requirements, ceilings typically offer the largest available area for absorptive treatments. This can be important in controlling noise generation in the space, improving speech intelligibility and even reducing noise intrusion. Some guidance recommends highly absorptive ceiling tiles (e.g. minimum NRC 0.90 to 0.95) be implemented to achieve the highest acoustic benefit, particularly for neonatal intensive care units (White 2006; Australasian Health Infrastructure Alliance 2010; Facility Guidelines Institute 2010). However it is important to note that ceiling tiles in hospital and healthcare environs typically need to meet a broad range of criteria, including humidity resistance, cleanability and infection control requirements. As such, the arbitrary application of a high absorption rating may limit the availability of suitable product options.

The sound insulation performance (e.g. CAC, D_{ncw}) also plays an important part in the selection of an acoustic ceiling tile. A ceiling tile with a higher sound insulation performance may be preferred to control noise intrusion from ceiling mounted services such as hydraulic pipes and mechanical ductwork. To further complicate things, ceiling tiles which are highly absorptive typically have poor sound insulation performance. Accordingly, a balance must be achieved.

From the point of view of cost and future flexibility it may be preferable to maintain consistency across the project with regard to ceiling tile selections. Noting however that non-clinical areas such as offices may not have the same requirements for infection control.

A ceiling tile with a high CAC may offer opportunities to reduce the number of full height partitions required. This reduces direct costs associated with this ceiling, but also simplifies the services design and the need for services such as smoke detectors and sprinklers.

Other tradeoffs may also come into play, for example whilst ceiling tiles offer greater access to ceiling mounted services, plasterboard may be preferred in areas where security is a concern such as mental health units.

Case study – alternative above ceiling treatments

AECOM were involved in the fitout design of medical suites where the floor to soffit height was limited. Due to the location of the main mechanical plant room and the layout of the spaces there were a large number of services running along the ceiling void. In one particular area the amount of ductwork was such that there was insufficient space remaining to run a layer of plasterboard to the underside of the soffit to form an above ceiling barrier. Conventional alternative above ceiling treatments, such as baffle block, were not allowed due to infection control requirements. Due to the shallow ceiling void and maintenance access requirements a set plasterboard ceiling was also not practicable. The agreed solution was the addition of plasterboard tiles behind the mineral fibre ceiling tiles. Whilst this approach reduced the effective sound absorption of the tile, this was considered a fair trade off as privacy was of greater concern.

Sound Masking Systems

Sound masking can be an effective method of enhancing acoustic privacy. The ear quickly acclimatises to this constant noise source, reducing the difference between the intrusive sound level and the background level. The background sound can be in the form of pink/white noise, natural sounds, or music. Both HTM 08-01 and SVDG make reference to electronic sound masking systems as a means of controlling background noise levels. Sound masking introduces a continuous background sound in to an environment in order to mask the effects of a transient or fluctuating noise source. The implementation of properly designed systems may offer opportunities to reduce the performance requirements between spaces whilst maintaining the same level of privacy.

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