Part G – Acoustics

International Health Facility Guidelines

2025

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1 Introduction

This Guideline (Part G) is intended to provide supporting guidance and recommendations on the acoustic design of new and refurbished healthcare buildings. It provided ready-to-use performance standards, sketches and diagrams for design and constructions aiming to offer and maintain a pleasant and comforting acoustic climate for the patients, visitors and the employees of the healthcare buildings.

Part G is a combination of prescriptive & performance-based requirements. Its provisions represent the design methods, criteria and minimum standard considered acceptable. Designers are encouraged to further develop these requirements and exceed the minimum standards.

1.1 General requirements

The acoustic requirements outlined in this part of the guidelines are provided as a guide for all type of healthcare facilities such as hospitals, clinics, primary care centres, outpatient facilities, diagnostic centres etc. These requirements should not override other more stringent mandatory requirements by the national, and local authorities and applicable legislations.

Acoustic requirements within Part G are in addition to any other non-acoustical requirements such as structural integrity, fire rating, material compatibility, etc.

1.2 Abbreviations and acronyms

Abbreviation	Meaning
ASHRAE	American Society of Heating, Refrigeration and Air - conditioning Engineers
ASTM	American Society for Testing and Materials
BRADE	British Regulations Approved Document E
BS EN	British Standards European Norm
CIBSE	Chartered Institution of Building Services Engineers
DM EN	Dubai Municipality Environmental Noise
GRDs	Grilles, Registers, and Diffusers
HTM	Health Technical Memorandum
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association

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2 Disclaimer

The material and information contained within this document are provided as a guide. These requirements should not override other more stringent requirements as mandated by the national, and local authorities, applicable legislations and municipality requirements. Acoustic requirements within this acoustic guideline are in addition to any other non - acoustical requirements such as structural integrity, fire rating, material compatibility, etc. It is the designers' responsibility to adopt and if necessary tailor accordingly the guidelines within this document.

3 Acoustic criteria

3.1 Establishing the acoustic criteria

It is important to establish adequate acoustic design criteria for healthcare premises. This document presents the minimum recommended criteria. Developments may differ considerably, so some of the recommendations may not suit each and every unique situation. Therefore, the application of common sense and good design is also expected.

At the outset it is recommended to prepare a brief statement of acoustic criteria for each project an discuss with the project stakeholders. This will establish the acoustic requirements and any particular acoustic issues that affect the development.

The presumption will be that these criteria will equate to those listed in this document. The responsibility will be on designers to identify if the identified acoustic criteria can be achieved. If that is not possible, set out a mitigation strategy or an argument for changing them.

If in doubt, seek the advice of a specialist Acoustic Engineer.

3.2 Pre-design noise survey

It is important to assess the development site layout to optimise the acoustic performance. The building location/ plot can be investigated in terms of noise exposure during the planning stage.

Following that, a noise survey can be carried out before the design starts. Ambient noise levels would be required during the design. Vibration readings may also be required e.g. site being close to a railway. A qualified, competent acoustical consultant can be engaged to carry out the noise survey at suitable locations and times.

As a minimum, the survey should cover the highest daytime noise and if relevant vibration levels. In addition, capturing the night time lowest levels for the same area is necessary.

The design needs to account for any future changes on and around the site e.g. construction of a new highway. Evaluate and assess the noise generated by nearby buildings that are to be retained and the impact of the new development. The recorded noise levels on site, may dictate the ventilation strategy, space planning, building massing and layout.

4 Architectural Acoustics

Architectural acoustics deals with the transmission of sound between two rooms or spaces, or from the inside to the outside of a room (and vice-versa).

4.1 Noise ingress

The table in Appendix B sets out the recommended criteria for noise ingress for the completed building (including furniture).

4.2 Controlling background sound

It is important to control the perceived levels of background sound as they have an impact on the levels of privacy and can affect the speech intelligibility. For rooms where it is critical to achieve onerous design criteria, high-quality electronic sound masking systems should be considered. Attention is required to the commissioning works in order to operate effectively.

The application of such systems can lead to a 5 dB reduction in terms of sound insulation criteria. Electronic devices such as a radio or a TV can have a similar effect.

Sound masking could be installed for areas such as open-plan clinical areas, multi-bed rooms, waiting areas, office areas, consulting and examination rooms, areas placed near birthing rooms – and rooms placed at very quiet sites or areas that have low noise levels. The provisions can be adjusted for daytime and night time operation.

4.3 Outdoor noise generating events and factors

The typical outdoor noise sources can be addressed in the following manner:

- Implement a no siren policy on site, unless it is mandatory;
- Helicopter take-offs and landings could cause disturbance. This can be minimised by suitable planning of the hospital and its flight path;
- Rain noise needs to be controlled to avoid annoyance. Heavy rainfall should not exceed the noise criteria in Appendix 2 by more than 20 dB(A) or be more than 65 dB(A);
- Any lightweight roof construction can consist of multiple layers so as to offer adequate sound resistance;
- Laboratory acoustic data are to be used in order assess the resulting interior noise levels

4.4 Airborne sound insulation for rooms

Each space requires adequate sound insulation. Noisy activities should not interfere with the need for quiet in adjacent rooms. Private conversations should not be overheard. The right to privacy for hearing-impaired patients and staff must be taken considered.

This document allows for the impact of raised voices in healthcare facilities.

The following tables present the acoustic requirements for partitions and floors. They are to be followed when designing and specifying the acoustic rating of these elements. Relevant explanation is included on how to use the tables and to undertake the sound insulation calculations. Table 1 below presents the noise parameters for each room.

Room	Privacy requirements for source room	Noise generation of the source room	Noise sensitivity of receiving room
Clinical areas			
Single bed room, Adult	Confidential	Typical	Medium
Multi-bed room, Adult	Moderate	Typical	Medium
On-call room	Confidential	Typical	Medium
Children & older people (single bed)	Private	High	Medium
Children & older people (multi-bed)	Moderate	High	Medium
Consulting room	Confidential	Typical	Medium
Examination room	Confidential	Typical	Medium
Treatment room	Confidential	Typical	Medium
Counselling/ bereavement room	Confidential	High	Medium
Interview room	Confidential	Typical	Medium
Operating theatre suite	Private	Typical	Sensitive
Nurseries	Moderate	Very High	Medium
Birthing room	Private	Very High	Medium
Laboratories	Moderate	Typical	Medium
Dirty utility/sluice	Not Private	High	Not sensitive
Clean utility	Not Private	Low	Not sensitive
Speech and language therapy	Confidential	High	Sensitive
Snoezelen / multi - sensory room	Confidential	High	Sensitive
Public areas			
Multi-faith/ chapel/ prayer room	Private	High	Sensitive
Corridor (no door)	Not Private	Typical	Not sensitive
Atrium	Not Private	High	Not sensitive
Dining	Not Private	High	Not sensitive
Toilets (not cubicles)	Moderate	Typical	Not sensitive
Waiting (large > 20 people)	Not Private	High	Not sensitive
Waiting (small ≤ 20 people)	Not Private	Typical	Not sensitive
Staff areas			
Toilets (not cubicles)	Moderate	Typical	Not sensitive
Main kitchen	Not Private	Very High	Not sensitive
Ward kitchen, pantry	Not Private	Typical	Not sensitive
Storeroom	Not Private	Low	Not sensitive
Rest room	Moderate	High	Medium
Locker / changing room	Moderate	Typical	Not sensitive
Large training / seminar (>35 m2)	Private	High	Medium
Small training / seminar (≤35 m2)	Private	Typical	Medium
Lecture theatre	Private	High	Sensitive
Library / archiving room	Moderate	Low	Sensitive
Single - person office	Private	Typical	Medium
Multi-person office (2 – 4 people)	Moderate	Typical	Medium
Open-plan office (≥5 people)	Not private	Typical	Medium
Boardroom	Confidential	High	Medium
Large meeting room (>35 m2)	Private	High	Medium
Small meeting room (≤35 m2)	Private	Typical	Medium

Table 1 – Sound insulation parameters of rooms

Table 2 below presents the sound insulation ratings in the field.

Privacy requirement for source room	Noise generation of the source room	Noise sensitivity of receiving room		
		Not sensitive	Medium sensitivity	Sensitive
Confidential	Very high	47	52	★
	High	47	47	52
	Typical	47	47	47
	Low	42	42	47
Private	Very high	47	52	★
	High	42	47	52
	Typical	42	42	47
	Low	37	42	42
Moderate	Very high	47	52	★
	High	37	42	47
	Typical	37	37	42
	Low	No rating	No rating	37
Not private	Very high	47	52	★
	High	No rating	42	47
	Typical	No rating	No rating	42
	Low	No rating	No rating	37

Table 2 – Sound insulation rating to be met on site - DnTw in dB

★ Avoid these adjacencies by careful planning. If this is unavoidable, aim for a minimum of $D_{nT,w}$ 57 dB. In practice this is extremely difficult since it would translate to very wide partitions and onerous demands on the building structure to appropriately minimise flanking noise.

Definition of terms in tables 1 and 2

The below definitions apply to the terms used in the above tables 1 and 2.

Abbreviation	Meaning
Confidential	Raised speech would be audible but not intelligible, and normal speech would be inaudible.
Private	Normal speech would be audible but not intelligible.
Moderate	Normal speech would be audible and intelligible but not intrusive.
Not private	Normal speech would be clearly audible and intelligible.
Sensitive	Room cannot accommodate any noticeable noise from rooms next door
Medium sensitivity	Room generally needs to be free from noise of other rooms.
Not sensitive	Noise from other rooms does not affect the use of the receiving room.

Understanding Tables 1 and 2

Table 2 makes reference to the privacy of a source room, anticipated levels of noise generation and the room sensitivity. It references the necessary rating of sound insulation considering Table 1 requirements. The parameter is the weighted standardised level difference - DnTw as measured in the field.

The sound-insulation requirement is assessed between a pair of rooms in each direction (room A to room B and room B to room A) using the privacy requirement for the source room, the noise generation of the source room and the noise sensitivity of the receiving room indicated in Table 1.

Example of how to calculate this is given at the Appendix of the document i.e. Example of sound insulation calculation.

The above Table 2 and calculation method in the Appendix references Rw. If during design stage there is a requirement for a STC rating then the approximate difference from Rw to STC is ± 1 unit.

4.5 Long term accommodation

When dealing with the design of spaces that are used for long term patients e.g. nursing homes, mental health wards, long term care and slow stream rehabilitation, the sound insulation criteria should meet the criteria for rooms for residential purposes.

When installing a wall/ partition, build it slab to slab, apply appropriate filling at junctions and joints and back fill with mortar any chasing in the walls. Acoustic sealant used should meet both acoustical and fire life safety requirements.

4.6 Impact sound insulation considerations

It is imperative that the impact noise is controlled at source wherever possible. Care is needed during the planning of the healthcare facilities so that heavily trafficked corridors are separated from sensitive spaces such as inpatient areas.

Try to avoid placing inpatient units under heavily trafficked corridors. If this is unavoidable, allow for impact sound insulation treatments.

Maintain a maximum field value rating of L'_{nTw} 65 for floors over noise-sensitive areas. There may be scenarios where extra sound insulation is required e.g. floors located above multi-sensory rooms.

4.7 Doors

When a door is included in a partition, the partition's acoustical performance will be significantly downgraded. A typical door performance will range from R_w 30 to R_w 35 dB. For scenarios where great sound insulation is required, suitable high-performance door sets or lobbied doors would be required.

In order to achieve an appropriate acoustic performance for the doors/ door sets, installation of doors seals will be necessary. Door seals around the whole door perimeter, including threshold and meeting stiles will be required. Avoid air gaps between the door leaf and the door frame.

In some situations, acoustic requirements may present conflicts with other requirements. For example, opening force of the doors during emergency conditions, infection control issues, ventilation requirements through door undercut etc. In such cases, it is up to the designers to balance these requirements and make the best overall decision.

Recommended door acoustic performance requirements are outlined below.

Area	Door performance – Rw (dB)
Corridors	30 – 35
Patient rooms – single or multi bed	35
Examination room	30
Consulting room	30
Bereavement room	35 - 40
Interview room, dining, laboratories	30
Operating theatre	30
Birth room	35 - 40
Waiting rooms	30
Speech and language therapy	35
Kitchen	30
Offices	30
Meeting room	35
Boardroom	35
Toilets	30
Plantroom	45

Table 3 – Airborne sound insulation rating for doors

4.8 Examples of door configurations

Here are some typical examples of door construction and acoustic rating they achieve.

A 45 mm thick solid core door with a mass per unit area of 27 kg/m^2 fitted with appropriate door seals at the perimeter, undercut and head jamb will achieve a rating of R_w 30 dB. Seals can be compression or wipe seal type and must be well fitted.

A 54mm thick solid core door with a mass per unit area 29 kg/m^2, fire rated with appropriate door seals at the perimeter, undercut and head jamb will achieve a rating of R_w 35 dB. Seals can be compression or wipe seal type and must be well fitted.

A 59mm thick solid core door with a mass per unit area 31 kg/m^2, fire rated with appropriate door seals at the perimeter, undercut and head jamb will achieve a rating of R_w 40 dB. Seals can be compression or wipe seal type and must be well fitted.

A 69 mm thick steel acoustic door composed of a frame and leaf manufactured with a 1.5 mm thick polished metal sheet with inner filling of sound proofing and absorbing material and equipped with double perimeter seals will achieve a rating of R_w 45 dB.

Doors with vision panels should achieve the overall door acoustic rating.

4.9 Planning Considerations

Here are some planning recommendations to improve acoustic performance:

- Careful space planning is necessary in order to avoid inappropriate space adjacencies e.g. waiting areas close to doors of consulting rooms or inpatient rooms.
- Avoid placing rooms that generate high or very high noise next to sensitive or medium sensitivity rooms.
- Avoid interconnecting doors between consulting rooms (except in Mental Health consulting rooms).
- Avoid doors of “private” or “confidential” rooms being opposite each other across a corridor.
- Fit soft action closers for doors giving access to “noise sensitive” areas.
- Use intercom for highly sound performing doors.
- Minimise sliding doors should due to difficulties with acoustic performance (as well as cleaning and maintenance difficulties).

4.10 Openable windows

In healthcare facilities openable external windows are generally discouraged due to the impact on the HVAC systems and the ingress of uncontrolled, unfiltered air.

If a facility includes some openable external windows, that face outdoor areas which may be accessed by people, this can lead to seriously compromised acoustic comfort. Suitable controls need to be put place to avoid external noise from people and activities outside the windows.

Furthermore, consideration of possible sound transfer between adjacent spaces by direct reflection of open windows is required.

4.11 Movable / folding partitions

The acoustic performance of the operable partitions is limited and often unreliable.

It is not recommended to use them when the speech privacy is a prerequisite or where high insulation ratings are needed.

4.12 Structure – borne sound and lightweight construction

Some rooms within the healthcare buildings that can generate structure-borne noise to the walls. For example, toilets, kitchens, workshops etc. When lightweight construction is used and there are sensitive adjacencies present, the propagation of the structure-borne noise should be controlled. This may include the use of twin stud frames, resilient board mountings, or spacing the source of impact away from the wall.

In addition, resilient fixings should be used for pipework fixed to lightweight partitions. Examples of these situations include WC waste pipes and rainwater pipes that should not be rigidly fixed to light structure.

Where there are internal glass partitions or viewing panels they also need to meet the requirements of the sound insulation Tables above. If this is not achievable, use a glazing build up that has an Rw rating no less than 10 dB below than required for the partition alone.

Where windows or vision panels are within doors or next to doors the glazing only needs to match the acoustic performance of the doors, not walls.

4.13 Weak construction configurations – flanking control

Sound that propagates indirectly between two spaces such as over or around separating elements (rather than directly through those elements) causes annoyance and results in poor acoustic performance. This is referred to flanking noise. In order to achieve the design criteria and offer a suitable acoustic climate, this effect needs to be controlled.

Both horizontal and vertical flanking routes need to be considered. Junction details are key to the overall sound insulation between spaces. Typically, junctions of acoustic partitions with other walls are the source of potential weaknesses due to flanking sound transfer along the inner skin.

This issue can occur even at external walls, especially when partitions i.e. walls and/ or floors are abutting façade glazing/ building envelope. The internal lining to a lightweight external wall should not be continuous across an acoustic wall or floor. Ribbon windows, shared windows or full-height glazing are low acoustic performing constructions and are not recommended for “private” or “confidential” privacy rooms and/ or “high” or “very high” noise generating rooms.

Ideally walls should be installed slab to slab, slab to the roof or slab to soffit above so as to achieve optimum performance. For raised access floor scenarios, the wall should extent through the floor to the slab below.

Attention is necessary at the head of the walls, which should be carefully sealed against the floor, soffit or the roof above. Extra attention is required where the slab is profiled and therefore sealing is relatively difficult.

When a wall has a junction with a lightweight roof, it should extent to the underlining of that roof.

For scenarios where the wall extends beyond the ceiling but not to the slab/ soffit/ roof above careful detailing is necessary. In this situation, the ceiling would need to offer sufficient sound insulation e.g. suitable density of plasterboard ceiling and insulation.

4.14 Bathroom pods

Bathroom and Ensuite acoustic design is highly important in order to avoid low acoustic performance. They need to meet the relevant sound criteria referenced in the sound insulation tables above.

It is recommended that all the walls of Bathrooms and Ensuites in health facilities should be extended to the slab, soffit or roof above and sealed. This is for both Acoustic performance and control of the air flows.

Where Ensuite Bathrooms are installed back to back, they require an imperforate, acoustically rated partition between them. Attention is necessary for their service penetrations, typically through their ceiling.

For scenarios where an Ensuite Bathroom forms part of a bedroom, it is considered part of it, hence should meet the requirements of the sound insulation tables.

4.15 Audiology facilities

Extra care should be given to the acoustic design of hearing test rooms within audiology facilities.

High acoustic performance is critical to their clinical performance. Individual test rooms are in the very quiet design category. However, there may be hearing test rooms where the noise levels would be very high. Therefore, room acoustics are critical.

It is often more practical to install a commercially available sound insulated audio booth within an audiology room to ensure the best performance during the patient testing.

5 Room Acoustics

Room acoustics deals with the acoustical properties of an enclosed space when the sound source comes from within this enclosed space.

The indoor acoustic climate can be dramatically improved by maintaining suitable reverberation times and installing absorptive treatments.

It is likely that absorptive treatments will be needed for rooms with speech intelligibility requirements.

Care is needed for the implications that the absorptive treatments can have in relation to the infection control, their cleaning, the impact damage etc.

Install sound - absorbent treatment in all areas (including all corridors), except acoustically unimportant rooms e.g. storerooms. Sound absorbent materials should be installed with due consideration of the cleaning requirements, the infection control, patient safety, clinical and maintenance requirements. For example, some sound absorbing acoustic ceiling tiles are not suitable for wet areas, isolation areas or operating theatres. These are not permitted under Part C and D of these Guidelines. So more suitable alternatives should be identified, where necessary.

Typically, the allocation of the absorptive materials will be at the ceiling. However, absorptive floor finishes or wall panels can also be considered.

Acoustically absorbent materials should have a minimum absorption area equivalent to a Class C absorber (as defined in ISO 11654:1997) covering at least 80% of the area of the floor, in addition to the absorption that may be provided by the building materials normally used. If a Class A or B absorbent material is used, less surface area is needed. Refer to the following table with indicative absorptive class range:

Absorption class	Sound absorption coefficient					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Class A	0.20	0.65	0.90	0.95	0.90	0.80
Class B	0.15	0.55	0.80	0.85	0.80	0.70
Class C	0.10	0.35	0.60	0.60	0.60	0.50

Table 4 – Typical sound absorption values / Class

For rooms requiring optimum acoustic conditions i.e. lecture theatres, specialist advice from an Acoustic Engineer should be sought.

Acoustic absorption is likely to be needed in large open spaces such as a large lecture hall, large waiting area or atrium space. Other similar areas include reception areas and cafeterias.

Appropriate reverberation time criteria, based on the specific requirements of the spaces needs to be agreed and incorporated into the design solutions.

In addition to the regular use of the space consider the absorption requirements when there is a need for public address and voice alarm systems.

Examples of absorptive materials can be the following:

- Acoustic ceiling tiles
- Perforated boards
- Acoustic panels on walls or ceilings
- Soft floor coverings
- Soft furnishings

Attention is required when selecting the products. It is necessary that they comply with other design requirements such as:

- Fire requirements- fire resisting materials may be required
- Infection control requirements- porous materials may not be permitted in some areas such as bathrooms, wet areas, operating theatres, laboratories and other clinical areas
- Ceiling access requirements- some engineering systems in the ceilings may require access for maintenance

- Lighting requirements- the required level of lighting should not be compromised
- Moisture resistance- in wet areas the material must resist the penetration of moisture as this may promote the growth of mold
- Floor Cleaning and Maintenance- some floors must be impervious and easily cleaned using wet processes, implying a hard surface

Soft floor finishes such as carpet minimise noise generation and dampen the noise generated by other sources. Carpet use if effective in some corridor areas where a great deal of noise can be generated. However, care is needed since there easy of movement by trolleys, bed trolleys and wheelchairs are equally important. Also refer to Part C of these Guidelines for recommendations on the floor finishes. In many clinical and laboratory areas, carpet may not be used.

The typical uses of Carpet as a solution for sound absorption in healthcare settings include the following:

- Administration areas
- Education areas
- Lecture rooms and classrooms
- Public and visitor corridors
- Inpatient Unit corridors (but not the bedrooms or supporting rooms)
- Waiting areas

Cushioned vinyl is effective in terms of noise generation, however, it does not dampen other noises as effectively as carpet.

Hard surfaces such as ceramic tiles, stone, terrazzo, laminates or similar finishes generate noise from walking staff and visitors, impact such as dropped items and also reflect noise from other sources. These factors should be taken into consideration in the selection of the materials.

Where excessive amounts of hard surfaces are used in potentially noisy areas, mitigation strategies should be considered for the introduction of some acoustically absorbing materials elsewhere within the space.

5.1 Access Panels

In many areas access to the ceiling services or equipment pendants requires proprietary access panels. Install acoustically certified access panels to equal the acoustic performance of the element in which they are installed.

Access panels in ceilings over ensuites, bathrooms and risers containing waste pipes should have a minimum rating of R_w 30. This requirement may be waved if the surrounding walls of the room are taken full height to meet the soffit of the floor above and are sealed.

Ideally access panels for waste piping shall not be located on the sides of risers containing waste pipes facing habitable rooms. However, if this is un-avoidable, the minimum rating of such access panels should be R_w 30

Access panels below fan coil units (if any) should have the same surface density and acoustic properties as the ceiling in which they are installed.

6 Building services noise & vibration transmission control

6.1 Noise impact of surrounding areas

Reference is made to environmental noise emissions generated from the building to surrounding sensitive receivers and vice-versa. The following table is to be used only as a guide for noise emissions at the plot boundary. The table shows the noise levels in the context of different Locations. Suitable adjustments can be made for other locations which are not listed below. Also comply with other criteria which may be mandated by local or national authorities, if they exceed these recommendations.

Location	Allowable limits for noise in dB(A)	
	Day (07:00 – 20:00)	Night (20:00 – 07:00)
Residential Areas with Light Traffic	40 - 50	30 - 40
Residential Areas in Downtown	45 - 55	35 - 45
Residential Areas which include some Workshops, Commercial Business or Residential Areas Near Highways	50 - 60	40 - 50
Commercial Areas & Downtown	55 - 65	45 - 55
Industrial Areas – Heavy Industries	60 - 70	50 - 60

Table 5 –Noise emission criteria

The above levels are to be considered in the acoustic design for two conditions:

- Noise level generated by the healthcare building as measured at the plot boundary
- Noise level in the surrounding environment at the plot boundary and potentially affecting the healthcare building

Noise levels at the plot boundary may need to be agreed with the local authority and need to include some deviations for emergency equipment such as ambulances.

Some local authorities require noise levels to be applied regardless of noise sources. Nevertheless, noise sources could create disturbance if ambient background noise levels fall significantly below the maximum permissible noise levels.

A typical approach would be that outdoor noise levels generated due to the operation of building services or other types of healthcare premises are designed to emit combined noise levels at no more than 5dB $L_{Aeq,T}$ below the existing ambient background noise level; when measured over a 24 - hour period at 1 meter from the nearest affected noise sensitive façade.

Open outdoor areas often used by the public may also need to be protected. In such areas, the perceived noise from services should not exceed the existing daytime background noise level or 50 dB L_{A90} whichever is the higher.

Avoid installing mechanical air intakes and exhausts close to noise sensitive spaces such as public walkways, external seating areas etc.

Acoustic criteria can be relaxed in the event of emergency situations or sporadic events e.g. helicopter flights, ambulance arrival etc. This may be subject to agreement by the local authority or other relevant body.

6.2 Internal noise levels from building services

Typically, an occupant considers the background noise acceptable based on two factors.

- First it is the perceived loudness of the noise relative to that of normal activities. If it is clearly noticeable, it is likely to cause annoyance and generate complaints.
- Second is the sound tonality of the indoor noise by building services. If the noise is perceived as a rumble, roar, throb, hiss or tone, this may cause annoyance and stress. Hence, the occupant is likely to complain.

The acoustical design must ensure that HVAC (Heating, Ventilation and Air Conditioning) noise is at a low level and unobtrusive so as not to interfere with occupancy use requirements. If for example background noise affects speech intelligibility, complaints regarding lost productivity can be expected. Therefore, ideally the HVAC rating methods need to assess both perceived loudness and sound quality.

Noise from mechanical plant inside the development should not exceed the levels given below. The ratings are for finished rooms, furnished but unoccupied. They relate to total noise from mechanical, electrical and plumbing, noise from adjacent and remote plantrooms. Unless stated otherwise, the noise level criteria should not be exceeded with the plant operating under steady, normal operating conditions, and at start-up for intermittently operating plant equipment.

Allow for any additional acoustic treatments to fully comply with the internal and external noise level requirements, including noise from diffusers, grilles and louvres, ductwork and risers.

Maximum allowable indoor noise levels are listed in the Appendix B.

HVAC noise within rooms should ideally:

- have balanced contributions from all parts of the sound spectrum with no predominant frequency bands of noise;
- be free of tones such as hum or whine;
- be free of any fluctuations in levels such as throbbing or pulsing

It needs to be mentioned that noise from building services can provide useful masking noise for public areas. Those areas do not require over attenuation.

6.3 Duct design

Duct system aerodynamic design should follow the relevant locally accepted specifications for Sheet Metal Ductwork and HVAC System Duct Design guidelines to minimise turbulence1.

The low frequency effect from end reflections at duct outlets can be optimised by providing a number of smaller outlets rather than one large one.

Minimize flow generated noise by locating elbows and duct branch take offs at least four to five duct diameters from each other. Use turning vanes in large 90° rectangular elbows and branch take offs to reduce turbulence. Note that turning vanes near fan outlets can actually increase turbulence and noise if the airflow is not sufficiently uniform.

Wherever possible, ductwork to noise sensitive areas of NC 35 and less should be routed from corridors into the rooms.

It is best practice to minimize the number of duct penetrations and transfer ducts in acoustically rated walls. Where they cannot be avoided, sealing of the ducts against the penetrations is of paramount importance.

6.4 Airflow velocities

The table below shows the recommended unlined duct velocities under ideal transition and spacing conditions when the spacing between fittings is at least three (3) duct widths and turning vanes and radiused elbows are used in all areas with abrupt changes in velocity.

Low pressure duct	
Criteria	**Recommended velocities**
NC / NR 30	Maximum airflow velocity in mains: 5 m/s; Maximum airflow velocity in branches: 3.8 m/s Velocity in branch to diffuser/grille should match neck velocity.
NC / NR 35	Maximum airflow velocity in mains: 6.6 m/s; Maximum airflow velocity in branches: 5.0 m/s; Velocity in branch to diffuser/grille should match neck velocity.
NC / NR 40	Maximum airflow velocity in mains: 8.6 m/s; Maximum airflow velocity in branches: 6.5 m/s; Velocity in branch to diffuser/grille should match neck velocity
NC / NR 50	Maximum airflow velocity in mains: 10.2 m/s; Maximum airflow velocity in branches: 7.6 m/s; Velocity in branch to diffuser/grille should match neck velocity.

Table 6 – Airflow velocities for low pressure ducts

[1] For example: DW 144 Specification for Sheet Metal Ductwork and the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) HVAC System Duct Design guidelines in the UK. Use the most appropriate standards and guidelines applicable to your Country or location.

6.5 Flexible ductwork and diffusers / grilles

To achieve a good acoustic MEP design with respect to flexible ductwork and diffusers / grilles, the following need to be considered:

- In order to achieve considerable attenuation, all the flexible ductwork will be installed fully extended and not in a compressed state
- Manual volume dampers should be located a minimum of five duct diameters from a diffuser / grille inlet
- The ductwork serving a diffuser / grille should be as straight as possible for at least three equivalent duct diameters upstream of the device inlet
- Flexible duct connections to diffusers and grilles should be aligned with the inlet connections

6.6 Attenuators / duct lining / VAV units

All rooms requiring acoustic treatment according to these Guidelines should be provided with adequate attenuation.

Locate Variable Air Volume (VAV) boxes outside the patient occupied spaces for ease of maintenance, where possible.

Car park exhaust and make up air fans should be provided with sound attenuators to reduce the sound during normal mode operation

- Terminal units should be equipped with sound attenuators as necessary to meet acoustic requirements
- CAV/VAV boxes which cannot meet acoustic requirements, should be provided with downstream attenuators in critical areas

Internal duct lining / insulation should have a minimum acoustic absorption as below:

Insulation Thickness	Minimum Absorption Coefficient					
	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
25mm	0.08	0.30	0.64	0.90	0.90	0.90
50mm	0.35	0.72	0.95	0.95	0.95	0.95
75mm	0.45	0.8	0.95	0.95	0.95	0.95
100mm	0.5	0.9	0.95	0.95	0.95	0.95

Table 7 – Internal Duct Insulation

When silencers are used in the duct layout, the below need to be considered:

- Approach velocities to silencer shall not exceed duct velocities. The velocity profile to silencer shall be well developed prior to entering silencer to minimize turbulence.
- Silencers to be installed according to the manufacturer's recommendations. As a minimum, no silencer to be installed closer than 1.5 times the longest length of the duct dimension to fans and all fittings.
- All transitions to and from silencers or other fittings should be ≤ 15˚ included angle to minimize turbulence and low frequency rumble.
- If a silencer manufacturer cannot meet the Dynamic Insertion Loss (DIL) necessary, then the silencer must be increased in length to match the DIL.
- Silencer documentation for submittals must include lab test data from an approved independent laboratory using ASTM E477 duct to reverberant room method or other equivalent standards such as EN ISO 7235 as appropriate. Provide self - generated sound power levels in submittals.
- If required, silencer fill material shall be protected with impervious film and the silencer length adjusted accordingly to meet the required DIL.
- Silencer pressure drop shall not exceed 55 Pa in general and 40 Pa for higher performance attenuators.

6.7 Duct noise breakout

A 22 swg (0.71 mm) thick traditional sheet metal duct weighing 5 kg/m2 achieves an average sound reduction index (SRI) of 18 dB.

To reduce duct noise breakout over occupied noise-sensitive areas, the supply air velocities should firstly be limited to those specified in Table 9, as is appropriate to the duct configuration / transition conditions.

Return air duct velocities can be 0.5 m/s higher than the supply air duct velocities.

Alternative attenuating measures include acoustically lagging the duct, laying mineral wool insulation or boards on top of the suspended ceiling or replacing the suspended ceiling with a heavier one. However, these would need to be considered on a case-by-case basis.

6.8 Cross talk attenuation

It is very likely that crosstalk attenuation would be required for ductwork connecting “private”, “confidential” or “sensitive” rooms. Crosstalk attenuation may be provided by proprietary attenuators in the ducts or internally - lined acoustic flexible duct. In order to reduce the amount of cross talk attenuation for a HVAC system, the HVAC design could include more bends in the duct connecting the grilles. However, it is important to consider that too many bends will cause pressure drops, and tight bends will cause regenerated noise.

6.9 Air outlets

Place grilles, registers, and diffusers (GRDs) as far as possible from elbows and branch take-offs and locate dampers remote from GRD outlets, ideally by at least 3m.

Flexible ductwork in general should only be used in branch duct applications leading to diffusers and grilles. As a guideline for GRD selections, specify a noise level of at least 8 dB below the desired NC / NR rating for the particular space being served.

All GRDs should be selected to have a catalogue rating of NC / NR 20 or less for a single outlet, if the ratings are based on a correction of 10 dB for sound absorption in the room. For multiple outlets in the same space, the additive effects from each outlet must be accounted for.

6.10 Dampers

Where possible, rotating equipment and equipment with static pressure control dampers should be at least 3 m from a noise-sensitive space. HVAC fan equipment serving more than one space should be farther from the rooms than equipment serving only one space.

To reduce the use of volume control dampers, the system should be designed as much as possible on a symmetrical basis so that the pressure drop on secondary runs are as close as possible to the index run.

Avoiding volume control dampers is preferred but it is accepted that some will be necessary, and these should be located on the plant side of the system attenuators. Control dampers on the terminal side of the final attenuators must however be avoided where spaces require NC / NR 30 or below.

Control dampers should not be located within 5 duct dimensions of any element other than a straight length of duct. Preference should be given to air foil splitter dampers.

All fire dampers shall be out-of-the-airstream (curtain) type.

6.11 Fan systems

Centrifugal fans with airfoil - shaped blades are preferred. If forward curved blades are used with total static pressures above 2” swg (500 Pa) the centrifugal fans generate excessive low frequency noise that is difficult to attenuate if space is restricted. In general, the following noise levels should not be exceeded at 1 m from any side of the fans:

- Toilet Extract Fans ≤ NC / NR 40 or 45 dB L_{Aeq}.
- Kitchen Extract Fans ≤ NC / NR 45 or 50 dB L_{Aeq}.
- Kitchen Exhaust Hoods ≤ NC / NR 55 or 60 dB L_{Aeq}.
- Loading Bay Extract Fans ≤ NC / NR 60 or 65 dB L_{Aeq}.
- Plantroom Ventilation Fans ≤ NC / NR 70 or 75 dB L_{Aeq}.

6.12 Lifts

It is recommended to minimize the airborne and structural borne noise from the lifts. All vibration isolation pads are to have design characteristics suitable for the static and dynamic loads imposed upon them. All pipe connections between lifts plant items and the fabric of the building shall be fastened using resilient pipe clamps.

The lift installation should minimize the noise produced by lift doors by ensuring that the doors are correctly aligned and adjusted during installation. Landing doors should be fitted with soft elastic bumper stops.

Measurement Performance Parameter	Passenger	MRL	Freight
Maximum Horizontal Vibration (milli g)	< 15	< 15	< 20
Maximum Vertical Vibration (milli g)	< 12	< 12	< 15
Minimum Acceleration (m/s^2)	> 0.6	> 0.8	> 0.6
Maximum Jerk (m/s^3)	< 1.5	< 1.5	< 1.5
Maximum In-Car Noise Level (Ambient)	< 50 dBA	< 55 dBA	< 60 dBA
Maximum In - Car Noise Level (Doors Operating)	< 55 dBA	< 55 dBA	< 65 dBA
Maximum Landing Noise Level (Ambient)	< 50 dBA	< 50 dBA	< 60 dBA
Maximum Landing Noise Level (Doors Operating)	< 55 dBA	< 55 dBA	< 65 dBA
Maximum Machine Room Noise Level	< 85 dBA	< 75 dBA	< 85 dBA

Table 8 – Lift noise & vibration limits

Deviations from true vertical alignment of the lift shaft and rails will increase the noise generated by the lift car travel. Therefore, accurate alignment of the shaft and rails during the construction is essential.

There should be neoprene isolation pads between the lift car guide rail and the counter-weight guide rail bracket fixings and the lift shaft structure. Rigid contact between the guide rails and the building structure should be avoided. Care should be taken to remove any building materials or metallic connections bridging across vibration isolators or the guide rail and the fabric of the building.

Where practical, guide rails should be supported from the lift shaft structure at points coinciding with the floor slabs. Guide rails should only be supported from a point between two levels if there is no other available fixing point.

Care should be taken during both the installation and maintenance of the lift equipment to ensure that all guide rails and guide shoe linings are free from dirt to prevent excessive noise during the operation.

6.13 Pumps and motors

Where there are pumps and motors located in equipment rooms, the Contractor should provide the maximum "A-weighted" sound power levels, for factory acceptance testing.

The motor's no-load overall sound pressure levels (in dB re 2×10^{-5} Pa) at 1 m from any side of the motor should not exceed the following:

- Motors ≤ 22 kW ≤ 65 dBA
- Motors > 22 kW and ≤ 112 kW ≤ 70 dBA
- Motors > 112 kW ≤ 75 dBA

6.14 Medical equipment

Generally, medical equipment will be placed away from inpatient areas and are not particularly noisy. Therefore, they usually pose little or no concerns in relation to the noise sensitive areas of the building.

6.15 Noise during emergency

During testing regimes, an increase of 10 dB(A) over the noise criteria at either the building interior or exterior is deemed acceptable. This is under the condition that testing happens during the daytime of a weekday. Audible alarms are expected to have sufficient noise levels so that they attract people's attention.

6.16 Pneumatic Tube Systems (PTS)

When Pneumatic Tube Systems (PTS) are utilised within a health facility, a suitable noise breakout study needs to be undertaken. Pipework connecting to PTS stations should be routed carefully, away from noise sensitive spaces.

6.17 Nurse Call systems

The Nurse Call system can potentially disturb the patient's sleeping patterns during nigh time.

Aim for minimum disruption to patients from the use of audible alarms intended for the staff.

6.18 Audio system for Public Address (PA)

Audio systems should meet a minimum STI of 0.5 or equivalent standard.

The audibility and intelligibility of alarms and public address (PA) announcements in noisy or partitioned areas should be assessed, and additional sounders / loudspeakers provided so that messages are audible and intelligible. Intelligibility should be assessed using measurements made at a representative range of evenly spaced locations in the relevant spaces.

In areas where acoustically absorbent materials cannot be used, due to overriding factors such as infection control or clean room conditions, adequate intelligibility may be difficult to achieve. Therefore, a public address system may not be appropriate for emergency announcements, and other indicators may be necessary. This could also apply in areas where there are high noise levels i.e. in plantrooms or some areas deliberately intended for high standards of sound insulation e.g. audiology booths.

Different types of modes/ room use require different sound output. The following categories apply for the healthcare buildings:

- Acoustics characteristics of the built environment shall be taken into consideration while designing PA systems to ensure audio intelligibility.
- The PA system to be zoned to suite the operational requirements of the facility.
- Zone-wise volume control should be considered so that different volume levels can be set depending on the areas. Volume control knobs should be placed near respective staff stations.
- IP based solutions are recommended over conventional analogue systems.

The needs of people with hearing impairment should also be considered when designing alarm systems. Additional requirements will apply for systems that are intended for emergency use. For the design of sound systems for emergency purposes, designers may refer to the European standard EN 50849.

6.19 Private and Public mode audibility:

Voice messages in private mode/ areas shall be 10 dB above the ambient sound level having a duration of 60 seconds, measured 1.5 m above the floor area required to be served using A-weighted scale dB(A).

Voice messages in public mode/ areas shall be 15 dB above the ambient sound level having duration of 60 seconds, measured 1.5 m above the floor area required to be served using A-weighted scale dB(A).

6.20 Sleeping area audibility:

Voice messages in sleeping areas shall be 75 dB measured at the pillow level in the area required to be served using A-weighted scale dB(A).

If there are any alarm requirements for greater than 105 dB(A) output, a visible notification should be used. The total sound emissions combining ambient and notification devices should never exceed 110 dB(A) at a hearing distance.

6.21 Plantrooms

The noise emissions within a plantroom should at that level where maintenance personnel do not need to wear ear protection. Select relatively quiet plant equipment and apply appropriate noise controls when necessary to reduce the noise levels as far as reasonably possible.

If the above measures cannot be implemented, then include warning signs, training procedures for the personnel, including the need to wear ear protection etc.

When possible, place major plant items such as chillers, generators and boilers far from the acoustically sensitive parts of healthcare buildings.

6.22 Hydraulic noise transmission

Hydraulic services are required to be designed in such a way that there is minimum audibility within the building. A series of control measures are recommended below:

- Minimize the risk of water hammer by lowering operating pressures and/ or using pressure valves.
- Regulate water pressure to the minimum satisfactory working pressure and, in any case, do not exceed 350 kPa. Do not exceed a fluid velocity of 2.5 m/sec. In acoustically sensitive rooms, fluid velocities less than 1.5m/s are recommended.
- Depending on the pipe diameter; fluid velocity is to be within 0.6m/sec and 3m/sec. The higher velocity relates to pipe size of 355mm and larger.
- Avoid hard grouting and chasing of water pipes in masonry walls, particularly where walls are common with noise sensitive areas.
- Where pipework passes through walls, penetrations shall ensure effective acoustic sealing around the pipes. This would be achieved initially by providing all pipework with a resilient sleeve (detail-steel sleeves are recommended).
- Opening sizes should be kept to a minimum and where required should be loosely packed with mineral fibre insulation and closed-off with plasterboard.
- Any gaps remaining around pipework penetrations must be sealed with a continuous bead of non-hardening sealant.
- Pipe material for drainage systems must be one of the following: HDPE, UPVC, cast iron, acoustic mineral reinforced polypropylene.

6.23 Risers

Risers in plantrooms and other spaces might need an acoustic treatment depending on the condition. Refer Appendix C for construction examples for acoustically treated risers for services.

7 Vibration Management

7.1 Vibration Criteria

Ensuring human comfort against vibration emissions is paramount. Vibration caused by plant, medical equipment and activities within the building should not affect the use of the building.

Health facilities, may include medical equipment which are sensitive to vibration. The same applies to people. Excessive vibration can lead to adverse comment from the building occupants and can impair the operation of sensitive equipment.

The following table has been shown to be adequate for medical equipment in certain common areas of health facilities.

Area	Multiplying factors
Operating theatre, precision laboratory, audiometric testing booth	1
Inpatient Units	2
General laboratories, Treatment areas	4
Offices, Consulting rooms	8

Table 9 – Multiplying factors for rooms corresponding to a low probability adverse comment

Plant vibration is to meet the structure–borne noise criteria shown in Table 12.

7.2 Continuous vibration

Assess continuous vibration in terms of the root mean square (RMS) value (averaged over one second) of the frequency – weighted acceleration on the floors of occupied areas.

The frequency weighting should be W_g as specified in BS 6841. The frequency – weighted acceleration base value is 0.005m/sec^2.

Multiplying factors that relate to the referenced base values are derived from dividing the weighted RMS acceleration by the base value.

7.3 Intermittent vibration

Intermittent vibration is when there are interrupted periods of continuous emissions or repeated periods of impulsive vibration or continuous vibration that varies significantly in magnitude i.e. rapid rise or drop of magnitude. Conservatively can be assumed to be continuous. Alternatively, if the duration and frequency of event occurrence is known, the vibration dose value (VDV) can be used. Refer to low values of probability adverse comment for different types of spaces:

Area	VDV (m/s$^{1.75}$)
Wards	0.2
General laboratories, treatment areas	0.4
Offices, consulting rooms	0.8

Table 10 – VDV criteria for different spaces

For operating theatres and precision laboratories, there is no allowance made for intermittent events. Thus, the criteria relate to the maximum frequency–weighted acceleration of continuous vibration.

7.4 Critical areas and building structure vibration

The following figure recommends the appropriate vibration curves for different room types. Relevant curves are extracted below:

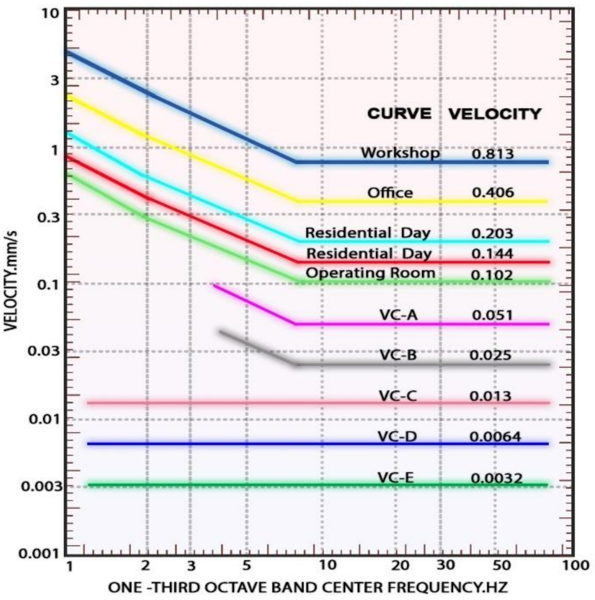


Figure 1 – Building vibration criteria for vibration measured on building structured

Note:

- When the vibration source is constant (as generated by plant), the rms (average) level is to be used.
- When the vibration source is intermittent (as generated by footfall during normal walking), the rms (max 1 second) level is to be used.

7.5 Vibration isolation and material selections

It is recommended that system components containing rotating machinery be isolated for vibration both in physical mounting and in all duct and pipe connections. This includes, but is not necessarily limited to, the following equipment:

- AHUs. FAHUs & Ecology Units
- Boilers
- FCUs and VAVs
- Fan Systems
- Generators
- Motors and Pumps
- Transformers
- Vertical Transportation Systems

Specifics on isolator types (spring, neoprene, etc.), mounting (floor, hanger, etc.), and required deflection can be determined on a case-by-case basis if required. General vibration isolator requirements are shown in Tables below:

Equipment Type	Base Type	Isolator Type	Deflection (mm)
Reciprocating Air Compressors and Vacuum Pumps	Concrete Inertia	Spring Type	19 mm
Tank-Mounted horizontal Air Compressor up to 7.5 kW	None	Spring Type	19 mm
Axial Fan Over 500 RPM, up to 500 Pa	Steel or Concrete	Spring Type	19 mm
Centrifugal Fan 37 kW & Over 500 RPM	Steel or Concrete	Spring Type	25 mm
Packaged Air Handler Over 115 kW & Over 300 RPM	Steel or Concrete	Spring Type	19 mm
Packed Pump System	None	Spring Type	19 mm

Table:11 Vibration isolation criteria for slab on grade

Equipment Type	Base Type	Isolator Type	Deflection (mm)
Reciprocating Air Compressors and Vacuum Pumps	Concrete Inertia	Spring Type	38 mm
Tank-Mounted horizontal Air Compressor up to 7.5 kW	None	Spring Type	38 mm
Axial Fan Over 500 RPM, up to 500 Pa	Concrete Inertia	Spring Type	38 mm
Centrifugal Fan 37 kW & Over 500 RPM	Concrete Inertia	Spring Type	38 mm
Packaged Air Handler Over 115 kW & Over 300 RPM	Concrete Inertia	Spring Type	64 mm
Packed Pump System	None	Spring Type	38 mm

Table 12 - Vibration isolation criteria for slab above grade, floor span 6-9m

Vibration isolators should be sized and selected with knowledge of the loads exerted by the item being isolated to meet the specified deflection requirements.

The information regarding the equipment should be verified including:

- Equipment identification
- Isolator type
- Weight of the item
- Static deflection of each mount under the load of the item

The vibration isolation system should have levelling screws and locking nuts to allow the deflection of each mounting to be adjusted to the design value at the operating condition of the supported equipment.

Housed spring isolators are not preferred as they are prone to misalignment and short-circuiting. It is recommend that un-housed spring isolators should be specified.

7.6 Air handling units (AHU's)

All AHU's should be installed on double deflection neoprene type mounts that provide a minimum static deflection of 10 mm. The internal spring mounts for the fans must be bolted down before installation.

The plenum manufacturer should provide all factory fabricated panels, joiners, access doors, structural supports, channels, fasteners, sealing accessories, assembly drawings and all other items necessary for erection.

Coils and filters in built-up AHU's should be supported from the housekeeping pad on neoprene pads. Any remaining gap beneath the coil/filter frame must be sealed airtight with a suitable non-hardening sealant.

7.7 Conduit isolation

Where isolated containment is ganged on a trapeze, it should rest on the trapeze and the trapeze should be isolated from the structure with the appropriate isolators. Neoprene pipe riser guides should be used where lateral restraint is required.

The first three containment support vibration isolators should provide the same static deflection as the equipment vibration isolators.

Wiring conduit to panel boards, ballast panels and any electrical equipment enclosures containing relays, small transformers or choke coils do not require special isolation.

7.8 Duct and pipe isolation

Pipes, ducts, and their contents, or other services connected, should be supported to avoid load on equipment items.

Flexible duct connectors at connections to fans or AHU's should be coated fabric 200 mm across a clear gap of 100 mm.

The first five supports for ductwork on either side of the vibration source shall also be provided with vibration isolators equal in static deflection to that of the Fan/ AHU.

Electrical connections to equipment mounted on vibration isolation bases should be made through flexible conduit which changes direction by at least 90° in a minimum length of 25 conduit diameters.

Mineral insulated cables should be looped through at least 360° at 75 mm radius or double the permissible minimum radius, whichever is larger.

7.9 Fan coil units and VAVs

All FCU's and VAV's serving occupied areas should be hung from 10 mm thick neoprene isolation hangers with the internal isolators and to avoid rigid connections to the walls, soffits and ceilings. If there are no internal springs, then spring isolators as recommended shall be provided.

7.10 Fan systems

To reduce the degree of vibration transmitted into the base structures, it is recommended that all fans serving occupied areas and located in plant rooms adjacent to occupied areas are installed on steel bases with spring type vibration isolation mounts having a static deflections of 50 mm.

Suspended fans from overhead structures should be hung on steel spring hangers. The static deflection of the isolators should be 50 mm. If the fan does not contain a frame with mounting brackets of suitable rigidity and strength, or if there is an extreme overhang condition, then a structural steel base should be used.

Fans should be suspended from above only if expressly noted as such on the design drawings and schedules. Any required thrust restraint should only be by pre-compressed isolators.

7.11 Flexible pipe connectors

Reinforced flexible pipe connectors should be used where pipes are to be located adjacent to acoustically sensitive spaces needing to achieve NC 35 or below and as recommended in the Table below:

Equipment	Isolator type
Pump connections (< 16 bar(g)	Flexible connectors (FC)
Pump connections (> 16 bar(g)	Multiple grooved couplings (MGC) to provide adequate vibration isolation
AHU connections (< 80 mm)	Direct connection
AHU connections (> 80 mm)	Flexible connector (FC) or multiple grooved couplings to provide adequate vibration isolation
FCU connections (< 25 mm)	Direct connection
FCU connections (> 25 mm)	Flexible hose (FH)
Connections to expansion tanks, desecrators, heat exchangers etc.	Multiple grooved couplings (MGC) to provide adequate vibration isolation
Connections to chillers, cooling towers and similar plant	Multiple grooved couplings (MGC) to provide adequate vibration isolation

Table 13 - Flexible pipe connections

Flexible pipe connectors of corrugated metal, or rubber, neoprene or other flexible liner with braided metal or other similar internal or external reinforcing, and intended for use without tie rods, shall have the minimum live lengths given in the table below when used for anti-vibration purposes.

Nominal Pipe Bore Diameter	Live Length
0 – 65 mm	300 mm
80 – 100 mm	450 mm
125 – 250 mm	600 mm
300 mm or greater	900 mm

Table 14 - Flexible pipe connecter live lengths

Note that the live length applies to the end-to-end length for flanged flexible rubber hose. For other types of hose, the live length applies to the overall end-to-end length less the fitting length. Where hose connectors are used to connect equipment with high pressures > 16 bar(g) multiple grooved couplings are recommended

All flexible connectors require end restraint to counteract pressure thrust, as. Over-extension caused by pressure thrust on isolated equipment will cause failure which must be avoided. It is recommended that the manufacturer's recommendations on restraint, pressure and temperature limits are followed.

Where tie rod systems are used for vibration isolation on expansion joints or arched-type connectors, these should be designed to achieve the vibration isolation required across the entire joint. The tie rod fixings should use rubber/neoprene bushed washers to prevent metal to metal contact throughout the normal range of movement of the joint.

7.12 Generators

For vibration control, each engine-generator should be bolted to a separate sub-frame with resilient mountings which is then in turn attached to a main frame, to provide complete vibration isolation of the control gear, radiator and other components. Skid vibration isolators with a minimum 50 mm static deflection and restrained spring isolators, mounted on a 100 mm thick housekeeping pad, should be considered

7.13 Boilers

Install boilers on waffle pad mounts with minimum static deflection of 6 mm.

7.14 Motors and electrical equipment

All wiring connections to motors and electrical equipment supported on vibration isolators should be made with a minimum of 1 m long flexible conduit in a 360° loop.

The vibration severity quality of the motor in any direction, due to all sources are recommended as follows:

- Motors with shaft centre height greater than 400 mm and speeds of 10 Hz or more, as Table 2, Column 1 of BS 4999.
- Motors with shaft centre heights less than 400 mm and speeds of 10 Hz or more, Grade R.
- Motors operating at speeds below 10 Hz, as severity grades (or tabulated values of Table 2 of BS 4999) for 10 Hz motors.
- Motors in occupied spaces, or on fan convectors, canned rotor pumps etc., vibration velocity limits as for Grade R for motors with shaft heights between 80 and 132 mm.
- Variable or multi-speed motors shall satisfy the balance quality grade required for their highest operating speed.

The resonant frequency of vibration isolation systems for electric motors with stepped speed starting arrangements (star delta, tapped resistor and transformer etc.) should not correspond to any of the speeds at the step changes and shall allow for long “run-up” and “run-down” times.

7.15 Piped services

Provide vibration isolation to all distributed piped services following the guidelines provided in Table below which refer to the use of Resilient Inserts (RI) within the pipe clamps, Neoprene Hangers (NH), Spring Hangers, Neoprene Mounts (NM) and Spring Mounts (SM).

Service	Pipe Diameter	Isolator Types	Static Deflection
Heating	Less than 50 mm	NH, NM	8 mm
	50 – 150 mm	SH, SM	25 mm
	More than 150 mm	SH, SM	50 mm
Chilled Water	Less than 50 mm	NH, NM	8 mm
	50 – 150 mm	SH, SM	25 mm
	More than 150 mm	SH, SM	50 mm
Domestic Water	Less than 50 mm	NH, NM	8 mm
	More than 150 mm	SH, SM	25 mm
Heat Recovery	Less than 50 mm	NH, NM	8 mm
	More than 150 mm	SH, SM	25 mm
Condenser Cooling	Less than 50 mm	NH, NM	8 mm
	More than 150 mm	SH, SM	25 mm
Rainwater	Less than 50 mm	RI	Not required
	More than 150 mm	RI	Not required
Sprinkler	All	RI	Not required
Dry Riser / Vent	All	RI	Not required
Hose Reel	All	RI	Not required

Service	Pipe Diameter	Isolator Types	Static Deflection
Compressed Air	All Steel	RI	Not required
Sanitary Sewer	All	RI	Not required

Table 15 - Pipe services and resilient isolators

7.16 Plant without pumps and motors

Expansion tanks, desecrators, heat exchangers, water heaters, etc., without pumps or motors which are floor mounted should be supported on neoprene pads. Where pipes on isolators are connected to the units the connection should be made with a neoprene flexible connector.

7.17 Pumps and inertia bases

Base mounted pumps ≥ 1.1 kW should be bolted and grouted to prefabricated, reinforced concrete inertia bases, which weigh not less than 1.5 times the combined weight of the fluid filled pump(s) and motor(s).

Any rigid pipe elbows at the pump suction and discharge connections should be supported from the inertia base. Each inertia base should be supported on spring isolators.

Base-mounted pumps < 1.1 kW and installed on floors above grade should be installed on concrete inertia bases on at least four neoprene mounts. Base-mounted pumps under 1.1 kW and located on grade should be mounted directly on a concrete housekeeping pad on at least four neoprene mounts.

In-line pumps ≥ 1.1 kW should be supported by the piping which is isolated on spring isolators. If support is required below the pump, the pump should be supported on spring hangers or mounts as appropriate. In-line pumps < 1.1 kW and adjacent pipework should be supported on neoprene isolating hangers unless other provisions call for greater static deflections.

If an associated circulation pump or chemical feed pump is to be mounted on the unit and if the pump is < 0.4 kW then the pump should be mounted to the unit through restrained neoprene isolators. Such pumps ≥ 0.4 kW should be supported from the building structure on neoprene mounts or neoprene hangers. Pumps ≥ 1.2 kW should be supported on concrete inertia bases supported on un-housed steel spring isolators. All connections to these circulation pumps should be with flexible connections.

Inertia bases should be designed to the thicknesses stated in Table below.

Motor Size in kW (Approximate HP)	Inertia Base Thickness (mm)
< 15 kW (< 20 HP)	150 mm
15 – 45 kW (20 – 60 HP)	200 mm
50 – 75 kW (65 – 100 HP)	250 mm
80 – 150 kW (105 – 200 HP)	300 mm
155 – 195 kW (205 – 260 HP)	350 mm
200 – 225 kW (265 – 300 HP)	400 mm
> 225 kW (> 300 HP)	450 mm

Table 16 - Inertia base thicknesses

Concrete inertia bases for pumps should be sized to support the suction elbow of end suction pumps and both the suction and discharge elbows of horizontal split-case pumps. The bases should be T - shaped where necessary to conserve space and sized to extend a minimum of 100 mm beyond the base of the equipment, and in the case of belt-driven equipment, 100 mm beyond the end of the drive shaft.

7.18 Vertical transportation systems (Lifts)

Lift vibration should be controlled, so far as is reasonably practicable, to the limits specified in Table below:

Measurement Performance Parameter	Passenger Lifts	MRL Goods Passenger Lifts	Freight Lifts
Maximum Horizontal Vibration (milli g)	< 15	< 15	< 20
Maximum Vertical Vibration (milli g)	< 12	< 12	< 15
Minimum Acceleration (m/s2)	> 0.6	> 0.8	> 0.6
Maximum Jerk (m/s3)	< 1.5	< 1.5	< 1.5

Table 17 - Elevator vibration transmission criteria

Lifts to be located away from sensitive areas in consideration of vibration and acoustics, and with respect to magnetic distortion for MRIs.

7.19 Vibration for sensitive medical equipment

Medical equipment such as scanners and microscopes are sensitive to vibration. The aforementioned criteria do not necessarily cover the negative effects of vibration on sensitive medical equipment. It is recommended that designers seek specialist advice on this subject. Reference should be made to their position within the building, their equipment vibration performance criteria and consideration of other generated vibration emissions within the building.

Laboratory furniture may amplify ambient vibration. This depends on their design e.g. benches for sensitive microphones. This should be taken into consideration in design.

8 Acoustic design for electrical outlets/ sockets

Service penetrations e.g. power outlets/ sockets and IPS panels reduce the acoustic performance of walls especially when they are installed back-to-back. These need to be installed with an offset distance.

Sockets, switches, medical gas outlets and integrated plumbing systems should not be back-to-back in walls that have an acoustic rating.

For high insulation partitions, an acoustic backing box behind the outlets/ sockets may be necessary. Stood–off IPS panels and surface–fixed sockets and switches are preferable from an acoustic perspective, although these may not be preferred for other design reasons.

Avoid designing WC cisterns and waste pipes, etc within the cavity of a lightweight partition where a partition is between a “medium” and a “sensitive” space. The only scenario where this is allowed is where there is an ensuite room within a bedroom. In other situations if partitions are preferred, adequate acoustic insulation needs to be used to prevent sound transmission.

Similarly, if Medical Service Panels are recessed into an acoustic partition wall, maintain the acoustic wall sound insulation performance. Where necessary, install a suitable metal box in the wall cavity behind the panel and seal air–tight any penetrations in and around the box.

9 Testing on Completion

Following the installation of mechanical plant and equipment and their subsequent treatments, carry out field testing for a number of factors:

- building element airborne testing;
- building element impact testing;
- noise and if necessary vibration readings from building services operation;
- intrusive noise;
- audio system intelligibility;
- environmental noise;
- audiometric rooms;

Once the readings / data has been validated and analysis completed, the testing report will identify compliance for the aforementioned factors. For any design and construction aspects where compliance fails, remediation works should be initiated.

10 Construction noise and vibration

During the building construction in or adjacent an existing occupied area, it is necessary to adopt a strategy to control the noise and vibration where it is likely to affect sensitive areas. Each project will have it's own characteristics and requirements, however the below points help to prepare a strategy for the management of noise and vibration emissions during the construction stage:

- develop a policy for the operating hours
- develop a policy for planning noisy activities and agreeing to a protocol between the contractors and the healthcare staff
- develop a policy that will be in place when emergency situations arise
- acoustically treat any disturbing plant
- carefully place the access roads
- treat the noisy equipment such as concrete cutters
- install temporary screening
- practise care with site equipment such as pile works and temporary generators
- prepare noise and vibration monitoring schemes

11 Temporary healthcare facilities

Whilst ongoing construction, there may be a need for putting up temporary facilities. The aim would be to meet the referenced criteria within the document. Nevertheless, this might be not practical due to existing limitations. When this arises, it would be important to understand the implications and agree to specific acoustic requirements. Non compliances to design standard need to be identified and a decision is to be made on the basis of a case by case scenario and on the fact that the premise will be temporary.

12 Refurbishment works

During refurbishment works the design criteria would be the same as referenced within this document. There may be scenarios where this is not achievable or practical since the building structure is already existing. In this case, it is important to investigate on the non – compliances, and agree to a specific plan and design regime. This can be relevant to the type of works relate to the refurbishment and what is the extent of the works e.g. if the existing window / glazing façade is to be retained, then the intrusive noise criteria may not be met.

13 Inspection during construction stage

During the construction stage of the project there will be a need for acoustic inspections in order to ensure that the design has been followed, and that the materials and workmanship are procured correctly and installed in a proprietary manner. A competent acoustical consultant should monitor the works on a regular basis. They can also offer site training on the spot so as to deal with non – appropriate work execution, remediate the false scenarios on time, and contribute to the avoidance of repeated wrong practices. If all of the above are followed, the construction methods are likely to be improved and the acoustic testing at completion is likely to present great deviations from the design targets.

14 Appendix A – Glossary

Sound

Sound is a cyclic change in air pressure. The rate at which the air pressure cycles occur determines whether

sound is high pitched (e.g. piccolo) or low pitched (e.g. tuba). The rate at which the air pressure cycles, or

the frequency is measured in cycles/per second or Hertz. The amount the air pressure fluctuates determines

the loudness of the sound.

Sound Pressure Level (SPL)

The sound pressure level closely corresponds to human hearing, converted into a logarithmic scale with units

of decibel, or dB as follows:

Sound Pressure Level (SPL) = 20 log*log10 (P/Pref)

Where:

P - Pressure in Pa

Pref - reference pressure which roughly corresponds to the threshold of human hearing (2*10-5 Pa)

Sound Power Level (SWL)

The sound power level is the energy emitted by a noise source. It is also a logarithmic scale and is defined as:

Sound Power Level (SWL) = 10 *log10 (W/Wref))

Where:

P - sound power in Watts (W)

Pref - reference sound power (10-12 W)

Sound Power is the sound energy that is emitted whereas sound pressure is the result of this as perceived by

the ear or meter. The ear and microphones measure sound pressure, not sound power.

Room Correction factor

Room Correction factor is an indicative factor in the absorption of sound level in dB when inclusion of typical furnishings as per a subject area is taken into consideration. The inclusions generally result in improvement in absorption within the room, thereby reducing the resultant noise level for accurate measurements.

Absorption

Conversion of sound energy to heat, often by the use of a porous material.

Absorption coefficient

A quantity characterizing the effectiveness of a sound absorbing surface. The proportion of sound energy absorbed is given as a number between zero (for a fully reflective surface) and one (for a fully absorptive

surface). Note that sound absorption coefficients determined from laboratory measurements may have values

slightly larger than one.

Absorptive material

Material that absorbs sound energy.

Airborne sound

Sound propagating through the air.

Audiometric facilities

Rooms used for hearing tests and associated activities.

Bathroom pod

A prefabricated ensuite bathroom.

Competent Person

Someone with appropriate training, qualifications, experience and skill. The person will normally have a diploma or degree in acoustics or a related subject.

Decibel (dB)

The unit used for many acoustic quantities to indicate the level with respect to a reference level.

Decibel (dB(A))

The measure of sound pressure level ("A" weighted) in decibels as specified in British Standard BS EN 61672-2: 2003(a).

Frequency

The number of pressure variations (or cycles) per second that gives a sound its distinctive tone. The unit of

frequency is the Hertz (Hz).

Frequency band

A continuous range of frequencies between stated upper and lower limits (see also octave band and one-third octave band).

Frequency-weighted acceleration

The acceleration multiplied by a specified weighting value.

Hertz (Hz)

The unit of the frequency of a sound (formerly called cycles per second).

Noise

Unwanted sound.

Noise intrusion

Noise from external noise sources.

Octave band

A frequency band in which the upper limit of the band is twice the frequency of the lower limit.

One-third octave band

A frequency band in which the upper limit of the band is 21/3 times the frequency of the lower limit.

Impact sound insulation

The reduction of sound created by impacts e.g. footfalls on floor slabs over a room.

IPS panel

Integrated plumping systems i.e. pre–plumped and prefabricated panels sometimes used for clinical hand wash basins etc.

Reverberation

The persistence of sound in a space after a sound source has been stopped.

Reverberation time-T60

The time, in seconds, taken for the sound to decay by 60dB after a sound source has been stopped.

Spectrum

The composition of a particular sound in terms of separate frequency bands.

Ambient Noise

Noise level measured in the absence of the intrusive noise or the noise requiring control

LAeq(t)

The equivalent continuous (time-averaged) A-weighted sound level. The suffix "t" represents the time period to which the noise level relates to.

LA90(t)

The A-weighted noise level equaled or exceeded for 90% of the measurement period. The suffix "t" represents the time period to which the noise level relates to.

L'nT,w

The weighted standardized impact sound pressure level, a single-number quantity used to characterize the impact sound insulation of floors over a range of frequencies. The lower the rating, the better is the impact sound insulation.

IIC

The Impact Insulation Class (IIC) is a single number rating derived from measured values of normalized impact sound pressure levels, in accordance with ASTM E492, when measured under controlled laboratory conditions. It provides an estimate of the impact sound insulating performance of a floor / ceiling assembly.

IIC is a laboratory value. The higher the IIC rating, better is impact sound performance.

D_w

Weighted sound level difference which is a measure for rating the airborne sound insulation on the field.

The higher the IIC rating, the better is impact sound performance.

DnT,w

The weighted standardized level difference, a single-number quantity that characterized the airborne sound insulation between rooms. Note: The higher the rating, the better the airborne sound insulation.

DnT,w + Ctr

The weighted standardized level difference with spectrum adaptation term, single quantity which DnT, w characterizes the airborne sound insulation between rooms using the Ctr : spectrum adaptation term. The higher the rating, the better the airborne sound insulation.

Rw (Weighted Sound Reduction Index)

Single number quantity which characterizes the airborne sound insulation properties of a material or building

element over a range of frequencies. Rw is a laboratory value. The higher the rating, the better the airborne sound insulation.

STC (Sound Transmission Class)

The STC is a single number rating of a material's or assembly's ability to resist airborne sound for transfer frequencies ranging from 125-4000 Hz. In general, a higher STC rating blocks more noise from transmitting through a partition. The higher the rating, the better the airborne sound insulation.

Sound Insulation

The ability of a building element or building structure to reduce the sound transmission through it. The sound insulation is measured at different frequencies, normally 100-3150 Hz. Airborne sound insulation is expressed by a single value, Dn,f,w, Rw, R'w or STC. Impact sound insulation is expressed by a single value Ln,w or L' n,w.

Correction Terms (dB)

"C" is a correction for incident sound typical of living activities (talking, music, radio and TV); it is typically represented in frequency bands 50-3150, 50-5000 or 100-5000 Hz. "Ctr" is a low frequency correction term for transportation etc.

Mechanical service noise

Noise generated by mechanical and electrical services.

Crosstalk

Noise transfer between rooms, often via ventilation ductwork

Flanking transmission

Transmission of sound from a source room to an adjacent receiving room but not via the common partition.

Transmission loss

Reduction in sound pressure level between two designated locations in a sound transmission system, one location often being at a reference distance from the source.

Insertion loss

The reduction of noise level by the introduction of a noise control device: established by the substitution method of test.

Tmf

Tmf is the mid-frequency reverberation time. The sound absorption of surfaces usually varies with frequency and therefore the reverberation time in a space also varies with frequency. Tmf descriptor is widely used in standards for speech sensitive areas.

NRC (Noise Reduction Coefficient)

A single number rating system used to compare the sound absorbing characteristic of building material, calculated by averaging its sound absorption co efficient at mid-frequency, expressed to the nearest value.

Speech Intelligibility

A measure of how comprehensible a speech is. Directly dependent on the level of background noise, reverberation time and the shape of the room.

STI – speech intelligibility index

A measure of how intelligible speech is.

Attenuator

A device that reduces noise, particularly plant noise and crosstalk – also known as a silencer.

Vibration Dose Value (VDV)

The vibration dose value (VDV) is the measure of vibration exposure used in ISO 2631, BS 6841 or BS 6472.

It gives better correlation with human response than RMS-based measures when the vibration includes short bursts of high amplitudes such as impulses and shocks. It is the fourth root of the integral of the fourth power of vibration value with respect to time.

$$VDV = \left(\int_0^T a^4\,(t)dt\right)^{1/4}$$

VDV is the vibration dose value in m/s1.75

a(t) is the frequency weighted acceleration in m/s2

T is the total measurement period in seconds

RMS

The root-mean-square pressure (abbreviated as rms pressure) is the square root of the average of the square of the pressure of the sound signal over a given duration

Warble tones

Sounds used in audiometric testing, normally played over loudspeakers in paediatric test rooms.

15 Appendix B – Table for noise ingress and building services noise emissions

Room typology	Details	Noise levels due to noise ingress(dB)	Details	Noise levels due to building services operation (NC / NR)
Bedroom – single person	Single - bed ward, single - bed recovery areas and on - call room, relatives' overnight stay	40 $L_{Aeq, 1hr}$ daytime 35 $L_{Aeq, 1hr}$ night 45 $L_{Amax, f}$ night	Single bed, on–call rooms, overnight stay recovery rooms	NC / NR 30 NC / NR 35
Bedroom – multi-bed	Multi - bed wards, recovery areas	45 $L_{Aeq, 1hr\ daytime}$ 35 $L_{Aeq, 1hr\ night}$ 45 $L_{Amax, f\ night}$	multi – bed ward	NC / NR 30
Small office-type spaces	Private offices, small treatment rooms, interview rooms, consulting rooms	40 $L_{Aeq, 1hr}$	Private offices, treatment rooms, interview rooms, consulting rooms	NC / NR 35
Open clinical areas	A & E	45 $L_{Aeq, 1hr}$	A&E	NC / NR 40
Circulation spaces	Corridors, hospital street, atria	55 $L_{Aeq, 1hr}$	Corridors, hospital street, atria	NC / NR 40
Public areas	Dining areas, waiting areas, playrooms	50 $L_{Aeq, 1hr}$	Dining areas, waiting areas, playrooms	NC / NR 40
Personal hygiene (en - suite)	Toilets, showers	45 $L_{Aeq, 1hr}$	Toilets, showers	NC / NR 40
Personal hygiene (public and staff)	Toilets, showers	55 $L_{Aeq, 1hr}$	Toilets, showers	NC / NR 45
Small food-preparation areas	Ward kitchens	50 $L_{Aeq, 1hr}$	Ward kitchens	NC / NR 40
Large food-preparation areas	Main kitchens	55 $L_{Aeq, 1hr}$	Main kitchens	NC / NR 50 and NC / NR 55 below extract hoods
Large meeting rooms (>35 m2 floor area)	Lecture theatres, meeting rooms, board rooms, seminar rooms, classrooms	35 $L_{Aeq, 1hr}$	Lecture theatres, meeting rooms, board rooms, seminar rooms, classrooms	NC / NR 30
Small meeting rooms (≤35 m2 floor area)	Meeting rooms, seminar rooms, classrooms, board rooms	40 *L*Aeq, 1hr	Meeting rooms, seminar rooms, classrooms, board rooms	NC / NR 35
Operating theatres	Operating theatres	40 $L_{Aeq, 1hr}$ 50 $L_{Amax, f}$	Operating theatres	NC / NR 40
Laboratories	Laboratories	45 $L_{Aeq, 1hr}$		NR 40 when laboratory has no fume cupboards NR 60 at 1m from fume cupboards with open sash
Laminar flow theatres			Operating Theatres	NC / NR 50
Utility rooms			Clean utility / dirty utility	NR / NC 40
Plantrooms			MEP plant	NC / NR 70

Table – Criteria for noise intrusion from external sources and building services emissions

*Notes:

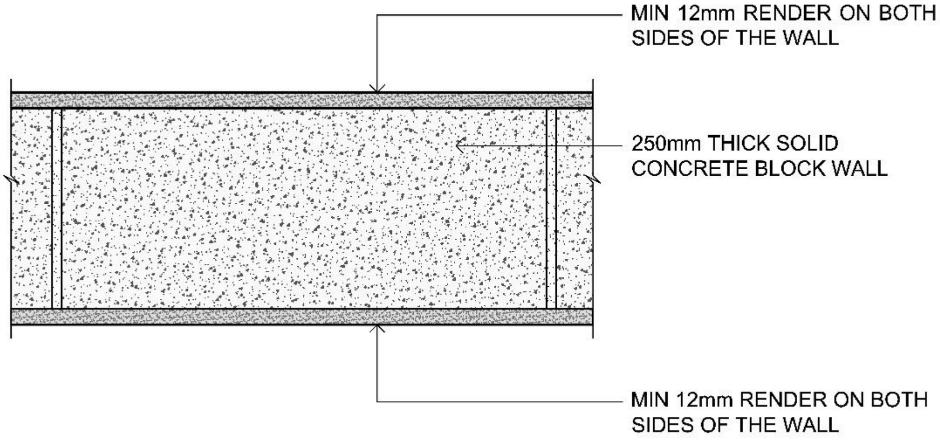
- Night is defined as 23:00 to 07:00.
- A LAmax, f limit for short-term events is included for sleeping areas and operating theatres. The intention is that this should apply to events that occur several times during the night (for example passing trains) rather than sporadic events.
- If windows have trickle vents, the criteria would normally apply with the windows closed but trickle vents open. If natural ventilation is used by means other than trickle vents, the acoustic criteria are to be met whilst the ventilation is operational.
- When the facility is built on noisy sites, acoustically treated trickle vents or mechanical ventilation may be required.

- High performing, suitably sealed façades may be necessary for the noisiest sites. The acoustic advisor should liaise with the building services designer for the same.

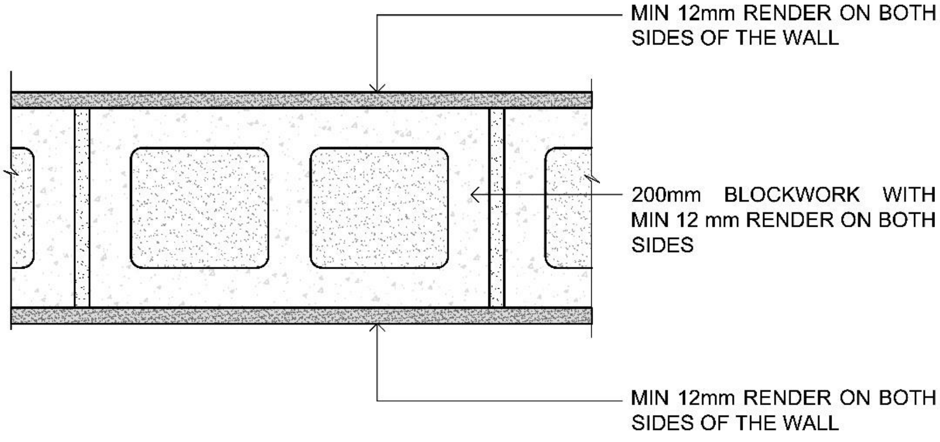
16 Appendix C - Examples of Wall Constructions

Refer below typical examples of wall configurations and their acoustic insulation rating .

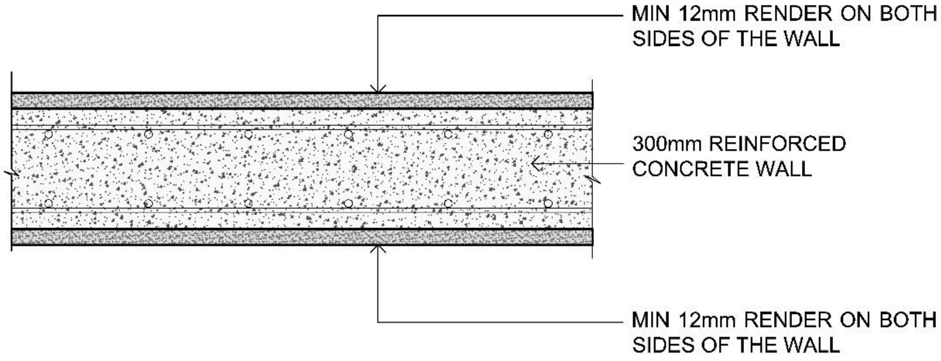
Masonry wall configurations:



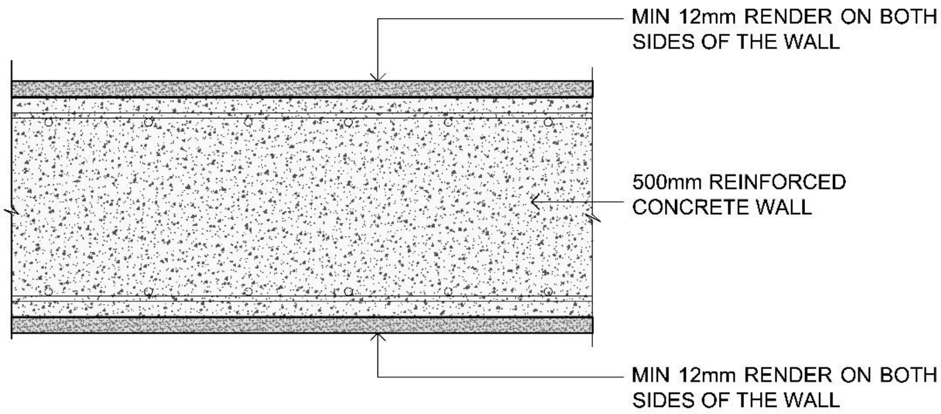
Wall A - R_w / STC 60, 250 mm solid concrete block wall (surface mass > 490 kg/m^2) painted and sealed with 12 mm render on both sides (plan view - NTS)



Wall B - R_w / STC 60 / D_{nTw}, + C_{tr} 45, 215mm blockwork, 1840kg/m^3 with 13mm lightweight plaster on either side (plan view - NTS)

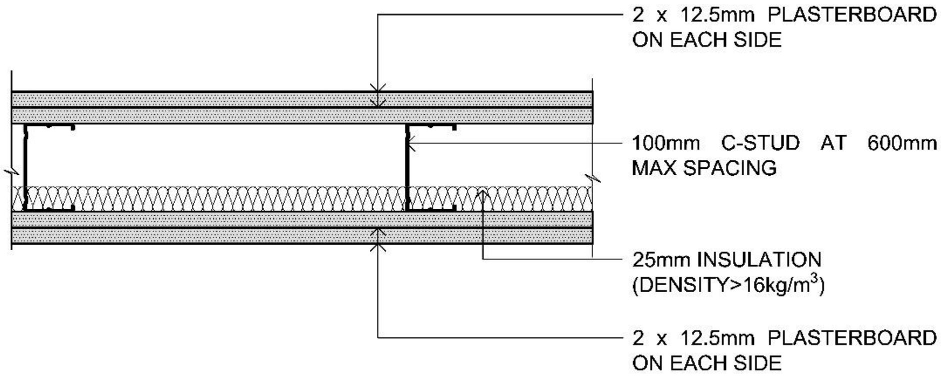


Wall C - R_w / STC 60, 300mm dense reinforced concrete (plan view - NTS)

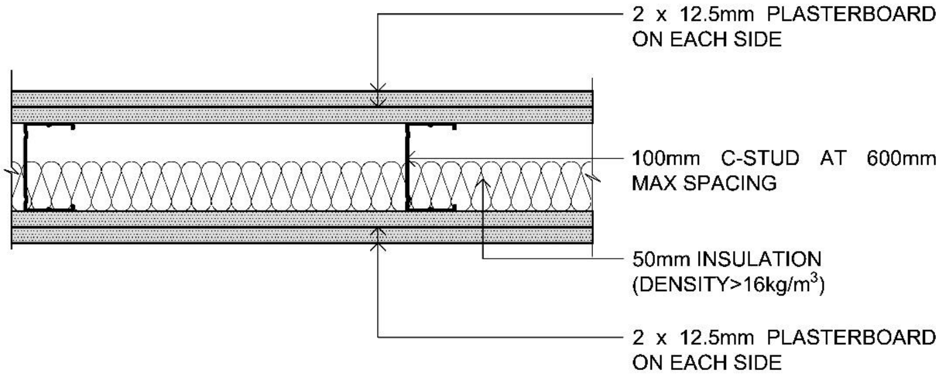


Wall D - R_w / STC 65, 500mm dense reinforced concrete (plan view - NTS)

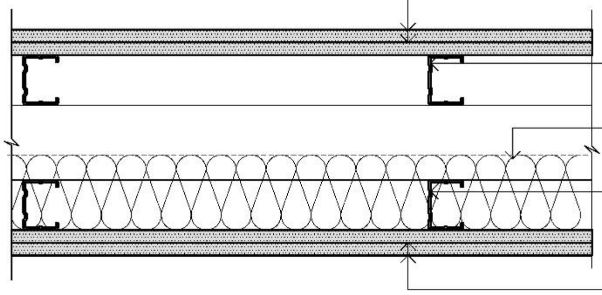
Drywall configurations:



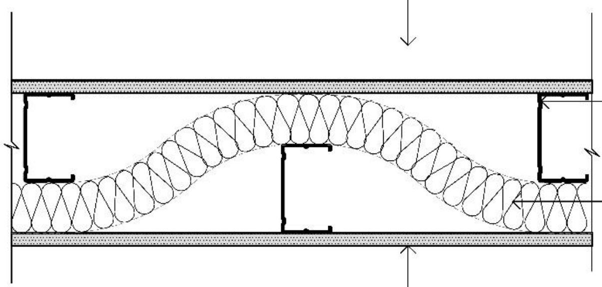
Wall E - R_w / STC 50, 2 x 12.5 mm plasterboards each side, 100mm studs at 600 mm centers, 25 mm insulation in the cavity (plan view - NTS)



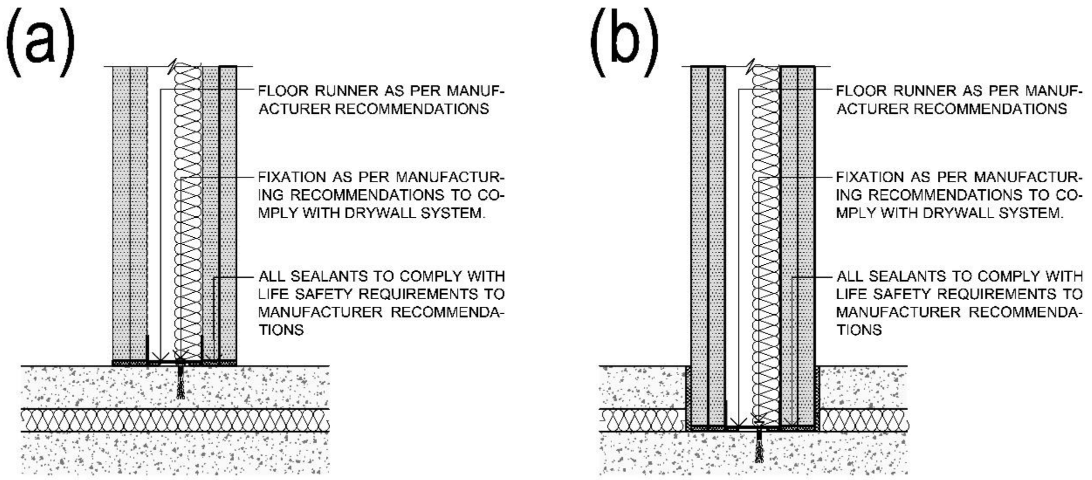
Wall F - R_w / STC 52, 2 x 12.5 mm plasterboards each side, 100mm studs at 600 mm centers, 50 mm insulation in the cavity (plan view - NTS)



Wall G - R_w / STC 65 , 1 x 15mm impact resistant plasterboard + 1 x 15mm fire rated plasterboard on each side of # 2 separate 50mm C studs, 75mm insulation in cavity (16 – 24 kg/m3), (plan view - NTS)



Wall H - R_w / STC 54, 15mm dense plasterboard on either end with two rows of 100MM C-Studs alternate studs staggered in the channel at 300mm centres and 50mm mineral wool insulation in the cavity (16 – 24 kg/m3), (plan view - NTS)



Architectural Detail 1 - Junction detail between floating floor and drywall installation - Building Option (b) is advised-(section view / NTS)

17 Appendix D - Building services installation / penetrations

The #6 sent building services penetration details – new Graphics, will be inserted here and omitted from the main body of the document. Also, refer pre-existing graphics below:

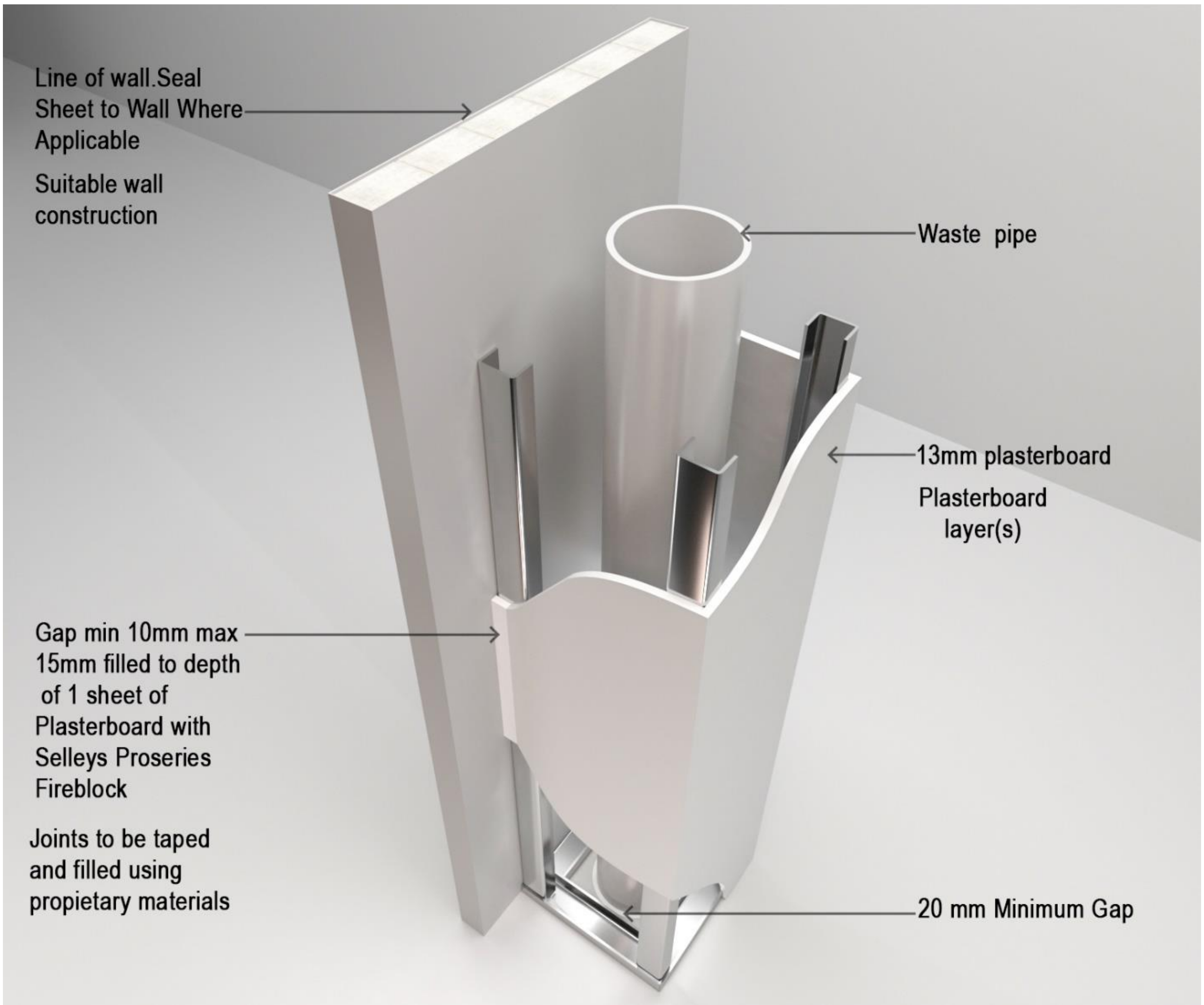


Figure 1 - Recommended constructions for riser in wet area

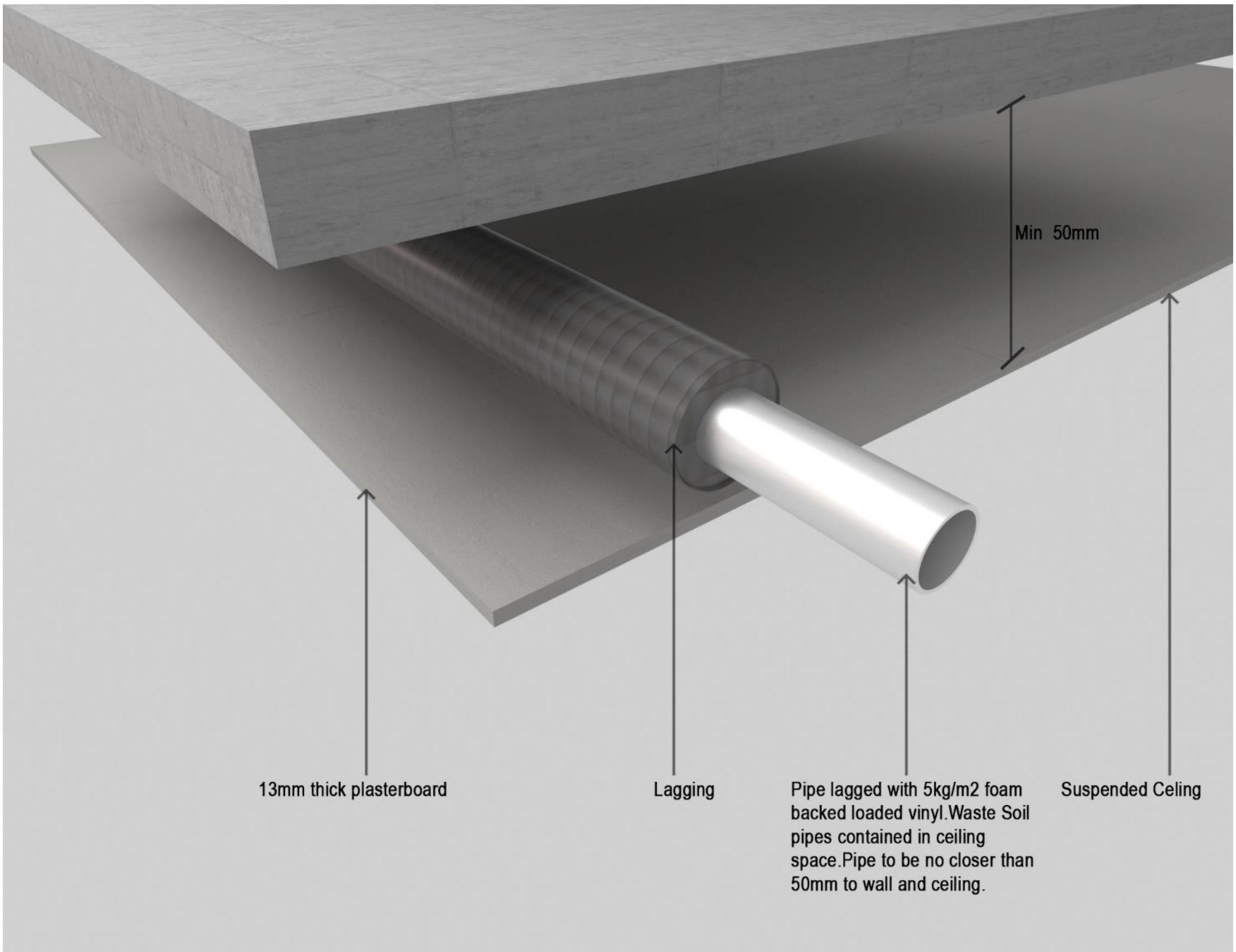


Figure 2 – Pipes crossing noise sensitive spaces

18 Appendix E - Example of sound insulation calculations

The target sound insulation between adjacent rooms is specified in terms of the in-situ room-to-room weighted standardised level difference $D_{nT,w}$. It is important to know the partition configuration or if this is not known, the equivalent value in terms of laboratory – tests i.e. weighted sound-reduction index R_w. This will assist in providing an anchor in terms of building element performance, offer examples of building element constructions and communicate the result effectively to other project stakeholders and manufactures or product suppliers. The difference between the two values depends on a number of factors, including:

- the surface area of the separating wall / floor (m^2);
- the volume of the receiving room (m^3);
- the standard of workmanship;
- the acoustic integrity of flanking constructions, junction details and service penetrations.

Typically, values of 7 dB (lightweight construction) and 4 dB (masonry construction) are typical to allow for a reasonable standard of workmanship and a small amount of flanking i.e. a lightweight partition on site is likely to be at least 7 dB below its laboratory - tested performance.

a. To calculate the R_w required to meet a given $D_{nT,w}$, the following relationships should be used:

For lightweight walls / floors:

$Rw \equiv D_{nT,w} - 10 \log (T/Tr) + 10 \log(ST/0.16V) + 7$

For masonry walls / floors:

$Rw \equiv D_{nT,w} - 10 \log (T/Tr) + 10 \log(ST/0.16V) + 4$

Where:

S = common area of separating element being considered (m^2);

V = volume of receiving room (m^3);

T = measured reverberation time in receiver room as per BS EN ISO 140-4;

T_r = the reference reverberation time taken to be 0.8 seconds.

Simplified versions of the aforementioned equations are:

For lightweight walls / floors:

$R_w \equiv D_{nT,w} + 10 \log (S/V) + 14$

For masonry walls / floors:

$R_w \equiv D_{nT,w} + 10 \log (S/V) + 11$

Calculations are to be undertaken using both rooms as source and selecting the most onerous figure e.g. consulting room to waiting room and waiting room to consulting room.

For very small receiving rooms that do not generate noise and are not noise sensitive e.g. linen store, the sound insulation derived from the above equations is unnecessarily high, owing to the small dimensions. Provided the receiving room is not normally occupied or if it is its only by staff, the receiving room may be assumed to have the same dimensions as the source room. If a person was to spend time for the referenced example i.e. in the linen store the level of privacy from the adjacent room would be low.

Note: ≡ means - equivalent to.

19 Appendix F – Matrix of room adjacencies for airborne sound insulation performance

Matrix showing sound - insulation performance required in $D_{nT,w}$ (dB)

Source Room	Receiving Room																																							
	Clinical Area																	Public Areas							Staff Areas															
	Single bed / on call room	Multi – bed room	Children & older people (single bed)	Children & older people (multi bed)	Consulting room	Examination room	Treatment room	Counselling / bereavement room	Interview room	Operating theatre suite	Nurseries	Birthing room	Laboratories	Dirty utility / sluice	Clean utility	Speech and language therapy	Snoezelen / multisensory room	Multi faith / chapel / prayer room	Corridor – no door	Atrium	Dining	Toilets (not cubicles)	Waiting ≥20 people	Waiting ≤ 20 people	Toilets (not cubicles)	Main kitchen	Ward kitchen pantry	Storeroom	Rest room	Locker / changing room	Large training / seminar > 35m2	Small training / seminar < 35m2	Lecture theatre	Library / archiving room	Single – person office	Multi – person office i.e. 2-4 people	Open plan office > 5 people	Boardroom	Large meeting room ≥35 m2	Small meeting room ≤35m2
Clinical areas																																								
Single bedroom / on-call room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Multi–bed room	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37
Children & older people (single bed)	47	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	47	42	47	47	52	52	47	47	47	47	47	47
Children & older people (multi bed)	42	42	42	42	42	42	42	42	42	47	42	42	42	37	37	47	47	47	37	37	37	37	37	37	37	37	37	37	42	37	42	42	47	47	42	42	42	42	42	42
Consulting room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Examinatio n room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Treatment room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Counsellin g / bereaveme nt room	47	47	47	47	47	47	47	47	47	52	47	47	47	47	52	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	47	47	52	52	47	47	47	47	47	47
Interview room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Operating theatre suite	42	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	42	42	47	47	42	42	42	42	42	42
Nurseries	52	52	52	52	52	52	52	52	52	★	52	52	52	47	47	★	★	★	47	47	47	47	47	47	47	47	47	47	52	47	52	52	★	★	52	52	52	52	52	52
Birthing room	52	52	52	52	52	52	52	52	52	★	52	52	52	47	47	★	★	★	47	47	47	47	47	47	47	47	47	47	52	47	52	52	★	★	52	52	52	52	52	52
Laboratorie s	37	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37
Dirty utility / sluice	42	42	42	42	42	42	42	42	42	47	42	42	42	N/A	N/A	47	47	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	N/A	42	42	47	47	42	42	42	42	42	42
Clean utility	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37	N/A	N/A	N/A	N/A	N/A	37	37	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37	37	N/A	N/A	N/A	N/A	N/A	N/A
Speech and language therapy	47	47	47	47	47	47	47	47	47	52	47	47	47	47	47	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	47	47	52	52	47	47	47	47	47	47
Snoezelen / multisensor y room	47	47	47	47	47	47	47	47	47	52	47	47	47	47	47	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	47	47	52	52	47	47	47	47	47	47
Public areas																																								
Multi faith / chapel / prayer room	47	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	47	42	47	47	52	52	47	47	47	47	47	47
Corridor – no door	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	N/A	N/A	N/A	N/A	N/A	42	42	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	42	N/A	N/A	N/A	N/A	N/A	N/A
Atrium	42	42	42	42	42	42	42	42	42	47	42	42	42	N/A	N/A	47	47	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	N/A	42	42	47	47	42	42	42	42	42	42
Dining	42	42	42	42	42	42	42	42	42	47	42	42	42	N/A	N/A	47	47	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	N/A	42	42	47	47	42	42	42	42	42	42

Source Room	Receiving Room																																							
	Clinical Area																	Public Areas							Staff Areas															
	Single bed / on call room	Multi – bed room	Children & older people (single bed)	Children & older people (multi bed)	Consulting room	Examination room	Treatment room	Counselling / bereavement room	Interview room	Operating theatre suite	Nurseries	Birthing room	Laboratories	Dirty utility / sluice	Clean utility	Speech and language therapy	Snoezelen / multisensory room	Multi faith / chapel / prayer room	Corridor – no door	Atrium	Dining	Toilets (not cubicles)	Waiting ≥20 people	Waiting ≤ 20 people	Toilets (not cubicles)	Main kitchen	Ward kitchen pantry	Storeroom	Rest room	Locker / changing room	Large training / seminar > 35m2	Small training / seminar < 35m2	Lecture theatre	Library / archiving room	Single – person office	Multi – person office i.e. 2-4 people	Open plan office > 5 people	Boardroom	Large meeting room ≥35 m2	Small meeting room ≤35m2
Toilets (not cubicles)	37	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37
Waiting ≥20 people	42	42	42	42	42	42	42	42	42	47	42	42	42	N/A	N/A	47	47	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	N/A	42	42	47	47	42	42	42	42	42	42
Waiting ≤ 20 people	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	42	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	42	N/A	N/A	N/A	N/A	N/A	N/A
Staff areas																																								
Toilets (not cubicles)	37	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37
Main kitchen	52	52	52	52	52	52	52	52	52	★	52	52	52	47	47	★	★	★	47	47	47	47	47	47	47	47	47	47	52	47	52	52	★	★	52	52	52	52	52	52
Ward kitchen pantry	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	N/A	N/A	N/A	N/A	N/A	42	42	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	42	N/A	N/A	N/A	N/A	N/A	N/A
Storeroom	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37	N/A	N/A	N/A	N/A	N/A	37	37	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37	37	N/A	N/A	N/A	N/A	N/A	N/A
Rest room	42	42	42	42	42	42	42	42	42	47	42	42	42	37	37	47	47	47	37	37	37	37	37	37	37	37	37	37	42	37	42	42	47	47	42	42	42	42	42	42
Locker / changing room	37	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37
Large training / seminar > 35m2	47	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	47	42	47	47	52	52	47	47	47	47	47	47
Small training / seminar ≤35m2	42	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	42	42	47	47	42	42	42	42	42	42
Lecture theatre	47	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	47	42	47	47	52	52	47	47	47	47	47	47
Library / archiving room	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37	N/A	N/A	N/A	N/A	N/A	37	37	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37	37	N/A	N/A	N/A	N/A	N/A	N/A
Single – person office	42	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	42	42	47	47	42	42	42	42	42	42
Multi – person office i.e. 2-4 people	37	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37
Open plan office ≥ 5 people	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	N/A	N/A	N/A	N/A	N/A	42	42	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	42	N/A	N/A	N/A	N/A	N/A	N/A
Boardroom	47	47	47	47	47	47	47	47	47	52	47	47	47	47	47	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	47	47	52	52	47	47	47	47	47	47
Large meeting room>35 m2	47	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	47	42	47	47	52	52	47	47	47	47	47	47
Small meeting room ≤35m2	42	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	42	42	47	47	42	42	42	42	42	42

Note: N / A – no rating, ★ - refer Table 3

20 Appendix G – Useful reading material

The following web links offer useful references in terms of the healthcare acoustic design:

https://trakhees.ae/en/ehs/env/Documents/Regulations/Regulation%20EN-12.0,%20Noise%20Control.pdf

https://www.england.nhs.uk/wp-content/uploads/2021/05/HTM_08-01.pdf

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/468870/ADE_LOCKED.pdf

https://www.warrington.gov.uk/sites/default/files/2020-08/cf48_bs_8233_2014.pdf

https://www.dm.gov.ae/municipality-business/planning-and-construction/dubai-building-code/