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 x 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.