ACOUSTICS

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

DESIGN STANDARDS

Document Register

Issue	Date	Description	Initials
Revision 1	18/10/21	Project Use	CH

Contents

Acoustic Engineering

17.1 INTRODUCTION

The aim of this design guideline is to indicate what is required by the University in the general field of acoustics. This includes the measurement, control and recording of airborne noise and structureborne sound and vibration, as well as required acoustic and vibrational design goals.

17.2 SCOPE

The purpose of this document is to provide guidance to the acoustic design of projects. the built environment of the University of Queensland.

The scope is limited to acoustic technical guidance on the following topics:

- Emergency system noise levels
- Sound insulation
- Room acoustics
- Internal noise levels
- Noise egress
- Construction noise and vibration
- Audio systems
- Vibration
- Hydraulic services

17.3 OVERVIEW OF LEGISLATION AND POLICY FRAMEWORK

The regulatory documents applicable to the acoustic engineering design include:

- Applicable QLD Legislation
- Applicable UQ policies and procedures
- Association of Noise Consultants: Measurement and Assessment of Groundborne Noise and Vibration (Red Book)
- ASTM E1414:1991 - Standard Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum
- AS1045: 1991AS ISO 354:2006 – Measurement of sound absorption in a reverberation room
- AS1055:2018 – Description and measurement of environmental noise
- AS1668.1:2015 – Fire and smoke control in buildings
- AS1670.1:2018 Fire detection, warning, control and intercom systems – System design, installation and commissioning
- AS 2021:2015 - Aircraft noise intrusion – Building siting and construction.
- AS 2436:2010 - Guide to noise and vibration control on construction, demolition and maintenance sites

- AS 2822:1985 – Methods of assessing and predicting speech privacy and speech intelligibility
- AS3671:1989 – Road traffic noise intrusion – Building siting and construction
- AS/NZS2107:2016 – Recommended design sound levels and reverberation times for building interiors
- AS/NZS2 ISO 8253.3:2019 – Audiometric test methods
- BCC Planning Policies and Guidelines Design Standards for DETE Facilities Version 3: 2014
- DECC (NSW) Assessing Vibration: a technical guideline
- EPA Environmental Protection Amendment Regulation No 2 1999EPA Environmental Protection Policy (EPP Noise) 1997
- *International Organization for Standards ISO10141-2:2010 –* Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation.
- *International Organization for Standards* ISO 3382-3:2012 – Measurement of room acoustic parameters
- *International Organization for Standards* ISO 60268-16:2011 – Sound system equipment – Part 16: Objective rating of speech intelligibility by speech transmission index
- Safe Work Australia Noise Guidelines
- Transport Noise Management Code of Practice: Volume 2 – Construction Noise and Vibration: 2016 ('the CoP')
- UK *Building Bulletin 93* BB93:2014 – Acoustic design of schools – performance standards
- Norwegian Standard NS 8178:2014 Acoustic criteria for rooms and spaces for music rehearsal and performance
- Work Health and Safety Act 2011

References to documents, guidelines and standards in this Guideline also include updated versions of these documents as released over the life of this Guideline.

17.4 ACOUSTIC TECHNICAL GUIDANCE

17.4.1 Emergency Systems

17.4.1.1 Sound Systems for Emergency Purposes (EWIS)

Noise levels associated with emergency use amplified sound systems are to comply with AS1670.4:2018 and associated standards, including:

- AS7240.24:2018 - Fire detection and alarm systems Fire alarm loudspeakers

The warning signals shall meet the following requirements:

- The temporal patterns and pre-recorded speech messages shall be synchronized through an emergency zone and adjacent area except where the sound pressure level from an adjacent area is at least 30 dB lower
- The minimum SPL shall exceed by at least 10 dB the ambient sound pressure level but shall not be less than 75 dB (A). The maximum SPL shall not exceed 105 dB (A) throughout the emergency zone
- Where more than one SPL measurement is required within the emergency zone, the difference between the minimum and maximum shall not exceed 15 dB

Speech intelligibility for emergency announcements containing speech shall be in accordance with the requirements outlined in AS1670.4. That is - all areas within the evacuation zone with ambient noise levels less than 85 dB(A) and a reverberation time (T60) of less than 1.5 seconds shall demonstrate speech intelligibility of no less than 0.7 on the Common Intelligibility Scale (CIS).

Speech intelligibility shall always be met within a 6m radius of the approach to a required exit (as defined by the NCC).

17.4.2 Internal Noise Levels from Emergency Equipment

Emergency equipment noise levels (including warning signals, smoke exhaust systems, stair pressurisation fans, make-up air fans, emergency generators, fire pumps, diesel exhaust pipes etc) shall comply with the following internal noise requirements.

- The noise level due to the operation of emergency equipment shall not exceed 65 dB(A) in occupied spaces (where the background noise level in the occupied space is 60 dB(A) or lower). Where the background noise level is higher than 60 dB(A), noise from the emergency equipment shall not exceed 5dB(A) above the background noise level, up to a maximum level from emergency equipment of 80 dB(A).

- Noise levels in fire-isolated exits shall not exceed 80dBA.

Compliance with the criteria outlined above may require acoustic housing of equipment and/or location of equipment (and inlet/exhaust systems) away from noise-sensitive spaces.

17.4.3 Environmental Noise Levels from Emergency Equipment

Emergency system noise levels at nearby residential receivers must comply with the external requirements in Table 17.4.1.3-1 (based on the acoustic quality objectives outlined in the EPP (Noise)2019 with a 10dB concession to account for short-term emergency conditions):

Table 17.4.1.3-1 Environmental Noise Criteria for Emergency Equipment

Period	$L_{Aeq,1hr}$	$L_{A10,1hr}$	$L_{A1,1hr}$
Daytime and Evening	60	65	75
Night	50	55	60

17.4.4 Sound Insulation Between Spaces

17.4.5 General

Sound insulation criteria for university spaces have been generally developed based on the following references:

- UK *Building Bulletin 93* BB93:2014 – Acoustic design of schools – performance standards.
- ASTM Standard E2638-10 (Speech Privacy Class)

In setting sound insulation criteria, the following principles have been followed:

- Criteria for partitions are generally provided in terms of the $D_{nT,w}$ value, generally based on the guidance of BB93
- Additional criteria for spaces requiring acoustic privacy are based on meeting minimum Speech Privacy Class requirements in accordance with ASTM E2638-10.
  (Note that the SPC requirement concurrently requires control of the background noise level within the rooms)
- Additional criteria for acoustically-critical spaces include additional requirements for low-frequency control via specification of minimum $D_{nT,w}$ +C_{tr} and low-frequency (63 Hz octave band) requirements.

Alternate criteria may be used where detailed consultation with end-users of the building has been conducted and where UQ PF signs off on alternate criteria.

Any field measurements undertaken, or laboratory test data used in informing the design shall be compliant with any/all the relevant standards from the following:

- *International Organization for Standards ISO16283-1:2014* – Field Measurement of Sound Insulation in Buildings and of Building Elements – Part 1: Airborne Sound Insulation
- *International Organization for Standards ISO16283-2:2015* – Field Measurement of Sound Insulation in Buildings and of Building Elements – Part 2: Impact Sound Insulation
- *Australian Standard* AS 1191:2002 – Method for Laboratory Measurement of Airborne Sound Transmission Insulation of Building Elements
- *International Organization for Standards ISO10141-2:2010* – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation.
- *Australian Standard* AS 1469:1983 – Methods for Determination of Noise Rating Numbers
- *Australian / New Zealand Standard* AS/NZS ISO717.1:2013 – Rating of Sound Insulation in Buildings and of Building Elements (Airborne Sound Insulation)
- *Australian / New Zealand Standard* AS/NZS 2460:2002 – Measurement of the Reverberation Time in Rooms
- *Australian / New Zealand Standard* AS/NZS 2499:2000 – Acoustics - Measurements of sound insulation in buildings and of buildings elements - Laboratory measurement of room-to-room airborne sound insulation of a suspended ceiling with a plenum above it
- *American Society for Testing and Materials ASTM E2638-10* - Standard test Method for Objective Measurement of the Speech Privacy Provided by a Closed Room

Where off-the-shelf products are selected to meet a specified insulation performance, a laboratory certificate that validates the claimed level difference shall be provided (e.g R_w for partition elements, CAC / $D_{n,c,w}$ or $D_{n,f,w}$ for ceiling or raised floor systems where these form part of the sound insulation strategy).

17.4.6 Partition Performance Requirements - General

The minimum acceptable sound insulation criteria ($D_{nT,w}$ dB) between rooms are defined in Table 17.4.2.2-2 based on the room source activity noise levels and receiving noise tolerances provided in Table 17.4.2.2-1.

Activity noise/ noise tolerance classifications may be adjusted if reasonable justification is provided for doing so, to be signed off by UQ.

Activity noise levels and noise tolerance levels for any spaces not included in Table 17.4.2.2-1 shall be agreed with the end users on a case by case basis and confirmed by UQ.

Table 17.4.2.2-1 Activity Noise Levels and Noise Tolerance Levels for Functional Spaces

Space	Activity Noise (Source)	Noise Tolerance (Receiver)
Open plan teaching area	Average	Medium
Open plan breakout	High	High
Lecture room small (less than 50 people)	Average	Medium
Lecture room large (more than 50 people, speech reinforcement)	High	Medium
General teaching area (enclosed): -Seminar rooms -Tutorial rooms -Study room -Art studio -Computer teaching room	Average	Medium
Teaching spaces for students with special hearing or communication needs	Average	Low
Teaching laboratories Engineering workshops (teaching)	High	Medium
Research laboratories (non-teaching)	Average	Medium
Engineering laboratories (non-teaching) Workshops	Very High	High
Specialist acoustic laboratories	High	Low
Animal handling facilities	Average	Low
Audiology rooms	Low	Low
Music classrooms	High	Medium
Music practice ≤ 30m²	High	Medium
Music practice > 30m²	Very High	Medium
Music Ensemble rooms	Very High	Medium
Music performance or recital space (unamplified)	High	Low
Music performance space (amplified)	Very High	Low
Music recording studio – live room	Very High	Low
Control room: -for recording -no recording	High	Low
Control room / biobox (no recording)	Average	Medium
Drama theatres	High	Low
Drama studio	High	Medium
Dance studios	Very High	Medium
Multi-purpose halls	High	Medium
Gymnasium/ activity studios	High	High
Swimming pool	High	High
Library - general area	Average	Medium

Space	Activity Noise (Source)	Noise Tolerance (Receiver)
Library - reading areas	Low	Medium
Atriums Foyers Entrance halls	Average	High
Corridors	Average	High
Dining rooms, cafeterias	High	High
Videoconference rooms Boardrooms Meeting rooms Conference rooms Seminar rooms	Average	Medium
Interview rooms Counselling rooms	Average	Low
Academic office areas – open plan	Average	Medium

Space	Activity Noise (Source)	Noise Tolerance (Receiver)
Academic offices – enclosed	Low	Medium
Administrative and ancillary spaces: -First aid rooms -Staff rooms -Utility rooms	Average	High
Kitchens Changing areas Toilets	High	High
Plantrooms	High	None

The required $D_{nT,w}$ between spaces is determined from the Activity Noise level and the Noise Tolerance level in Table 17.4.2.2-2 below for new-build partitions. Note that the minimum airborne insulation requirements apply to both horizontal and vertical adjacencies.

Table 17.4.2.2-2 Required $D_{nT,w}$ For Partitions Based on Activity Noise Level and Noise Tolerance

Minimum $D_{nT,w}$ dB		**Activity noise in source room**			
		Low	**Average**	**High**	**Very High**
Noise tolerance in receiving room	High	n/a	35	45	50
	Medium	40	45	50	55
	Low	45	50	55	55

The requirements in Table 17.4.2.2-2 apply to new-build partitions where there is no door within the partition.

For refurbished partitions (or retained existing partitions) a performance 5 $D_{nT,w}$ below the new-build targets shall be targeted.

For partitions containing doors a reduced performance 5 $D_{nT,w}$ below the requirements in Table 17.4.2.2-2 is required.

17.4.7 Acoustic Confidentiality

The following spaces are defined as requiring acoustic privacy or confidentiality:

- Boardrooms
- Videoconference Rooms
- Meeting rooms
- Private executive offices
- Counselling or interview rooms
- Clinical consultation rooms

Acoustic confidentiality shall be rated via Speech Privacy Class. (SPC) as defined in ASTM E2638-10:2017.

The corresponding category and subjective description for each SPC is provided in Table 17.4.2.3-1 below for reference.

Table 17.4.2.3-1 Speech Privacy Class Categories for Rating Acoustic Privacy/Confidentiality

Category	Speech Privacy Class	Subjective description
Minimal Speech Privacy	70	One or two words will be intelligible at most once each 3 minutes, and speech sounds will frequently be audible (at most once each 0.6 minutes).
Standard Speech Privacy	75	One or two words will be occasionally intelligible (at most once each 18 minutes) and frequently audible (at most once each 2 minutes)
Standard Speech Security	80	One or two words will very rarely be intelligible (intelligible at most once each 2.3 hours) and occasionally audible (at most once each 12.5 minutes)
High Speech Security	85	Speech essentially unintelligible (as most once each 16 hours) and very rarely audible (at most once each 1.5 hours)
Very High Speech Security	90	Speech not intelligible and very rarely audible (at most once each 11 hours)

The following acoustic privacy/confidentiality ratings are to be achieved (Table 17.4.2.3-2):

Table 17.4.2.3-2 Required SPC Ratings for Spaces Requiring Acoustic Privacy

Space	Speech Privacy Class Criteria
Meeting rooms	80
Executive offices	80
Counselling or interview rooms Boardrooms Videoconference rooms	85
Clinical consultation rooms	85

17.4.8 Acoustically Critical Spaces

The following are considered acoustically critical spaces either due to high source noise levels and/or low sensitivity to noise:

- Auditoria or performance spaces
- Music spaces
- Lecture theatres / halls
- Teaching rooms with >30 occupants or voice amplification system.

- Specialist acoustic laboratories (e.g. anechoic chamber, audiology etc)
- Engineering laboratories
- Plantrooms

For these spaces, the control of sound transfer at low frequencies is also important.

Partition design for acoustically critical spaces must additionally demonstrate compliance with the following normalised level differences with low frequency adaption terms ($D_{nT,w}$ +C_{tr}). See table 17.4.2.4-1

Table 17.4.2.4-1 Minimum Extended Frequency Range ($D_{nT,w}$ + C_{tr}) Performance Requirements for Acoustically-Critical Spaces

Minimum $D_{nT,w}$ +C_{tr} dB		**Activity noise in source room**			
		Low	**Average**	**High**	**Very High**
Noise Sensitive Receiving Room	High	30	35	45	50
	Medium	40	45	50	55
	Low	45	50	55	55

Partitions for acoustically critical spaces shall also meet a level difference performance requirement in the 63 Hz octave band of 10 dB below the D_w + C_{tr} value – e.g. a minimum level difference of 25 dB at 63 Hz if the overall $D_{nT,w}$+C_{tr} requirement is 35 dB.

Sound insulation design for acoustically critical spaces, such as music spaces, audiology labs, acoustic labs (e.g. anechoic chambers), must be undertaken through consultation with an acoustic specialist.

17.4.9 Additional Partition Construction Requirements

17.4.9.1.1 Non-Full Height Partitions

For partitions that are not constructed full height (up to the slab or roof above), the ceiling will limit the acoustic performance. The feasibility of constructing partitions full height shall be assessed on a case-by-case basis.

Where partitions cannot be constructed full height, the ceiling system has to provide sufficient sound insulation so that the overall acoustic performance requirement for the partition is met.

The following table outlines the minimum performance requirements of suspended ceilings and raised floors for each partition rating and for different partition configurations (e.g. whether the partition extends past the ceiling or not).

For a room with varying partition constructions, the ceiling and floor performance shall be selected in accordance with the highest rated partition.

Table 17.4.2.5-1 Minimum Ceiling and Floor Construction Requirements For Partitions Not Constructed Full-Height

$D_{nT,w}$	**Minimum Ceiling Construction Requirements**	**Minimum Raised Floor Construction Requirements**
≤ 30	**Partition to underside of ceiling:** • Set plasterboard or ceiling tile with CAC/$D_{n,c,w}$ ≥35 **Partition to 100mm above ceiling:** • Set plasterboard or ceiling tile with CAC/$D_{n,c,w}$ ≥33 **Partition to slab/roof above:** • No ceiling sound insulation requirement	Raised floor acceptable (minimum floor surface mass 25 kg/m²)
31-35	**Partition to underside of ceiling:** • Set plasterboard with 1200mm insulation either side of partition or • Ceiling tile with CAC/$D_{n,c,w}$ ≥40. **Partition to 100mm above ceiling:** • Set plasterboard or • Ceiling tile with CAC/$D_{n,c,w}$ ≥38. **Partition to slab/roof above:** • No ceiling sound insulation requirement	Raised floor acceptable (minimum floor surface mass 25 kg/m²)
36-40	**Partition to underside of ceiling:** • 2x layers of set plasterboard or • Ceiling tile with CAC/$D_{n,c,w}$ ≥45 **Partition to 100mm above ceiling:** • Set plasterboard with 1200mm insulation either side of partition or • Set plasterboard ceiling (13 mm fire-rated plasterboard) or • Ceiling tile with CAC/$D_{n,c,w}$ ≥43 **Partition to slab/roof above:** • No ceiling sound insulation requirement	Raised floor acceptable (minimum floor surface mass 37.5 kg/m²)

$D_{nT,w}$	Minimum Ceiling Construction Requirements	Minimum Raised Floor Construction Requirements
41-45	***Floor to slab/roof construction for $D_{nT,w}$ > 40.*** **Partition to underside of ceiling:** • 2x layers of fire-rated 16 mm set plasterboard or • Ceiling system with CAC/$D_{n,c,w}$ ≥50 or • CAC/$D_{n,c,w}$ ≥45 ceiling with ceiling void barrier **Partition to 100mm above ceiling:** • 13 mm fire-rated plasterboard ceiling with insulation blanket 1200mm either side of partition or • 2 layers of 13 mm fire-rated ceiling or • Ceiling tile with CAC/$D_{n,c,w}$ ≥48 or • CAC/$D_{n,c,w}$ ≥43 ceiling with ceiling void barrier **Partition to slab/roof above:** • No ceiling sound insulation requirement	Raised floor acceptable with floor void barrier (minimum floor surface mass 37.5 kg/m²). Floor void barrier to be densely packed insulation (minimum 14 kg/m³) at least 600 mm depth.
46-50	Partition must extend to slab/roof above.	Raised floor acceptable with floor void barrier (minimum floor surface mass 37.5 kg/m²). Floor void barrier to be densely packed insulation (minimum 14 kg/m³) at least 600 mm depth.
>50	Partition must extend to slab/roof above.	Partition must be slab-to-slab (i.e. break through floor)

*Where called for, the acoustic insulation blanket (75 mm, 11 kg/m³ density or equivalent acoustic performance) shall extend 1200 mm on both sides of any acoustically rated partition (i.e. 2.4 m width of blanket total per partition).

The Ceiling Attenuation Class (CAC) for ceiling systems shall be measured in accordance with ASTM E1414:1991 – Standard Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum.

The element normalized level difference ($D_{n,e,w}$. previously denoted as $D_{n,c,w}$ or $D_{n,f,w}$) for floor or ceiling systems shall be measured in accordance with either:

- ISO 10140-2:2010
- AS2499:2000

17.4.10 Flanking Paths

All acoustically rated partitions, sound insulating ceilings or raised floors must consider flanking paths including but not limited to the effect of building services and other penetrations, crosstalk, ceiling transfer, floor transfer and mullion/façade transfer in design so as to achieve the specified $D_{nT,w}$ rating for partitions.

Flexible ductwork shall not be used to cross acoustically rated full height partitions.

Where necessary, acoustically treated transfer ducts and/or crosstalk attenuators shall be provided to maintain the acoustic performance of partitions.

17.4.11 Build Quality and Installation

For multiple layers, all joints shall be overlapped, taped and sealed before applying further layers.

Metal stud framing or furring channels shall be installed at minimum 400-600 mm centres. Head and foot channels shall be mechanically fixed to the ceiling slab and floor slab (except where a resilient fixing is required e.g. structurally isolated partitions), and be fully sealed with a bead of acoustic sealant as per the requirements of Section 17.4.2.13.

Cavity infill absorbent materials shall be inert, incombustible, non-hygroscopic and rot and vermin proof.

Walls must be fit with a maximum 10mm tolerance and caulked at the edges to prevent sound leaks.

17.4.12 Determination of Required R_w for Partitions

Building material manufacturers typically provide sound insulation data in the form of weighted sound reduction index (R_w), which is based on laboratory measurements. Due to workmanship/ build quality and site-specific details, once installed, partitions on site almost always perform lower than their specified R_w.

The site performance of a partition is denoted R'_w. The required R'_w for each partition shall be calculated from the required $D_{nT,w}$ for each partition taking into account the (potentially) different $D_{nT,w}$ requirements across the partition in each direction (i.e. the $D_{nT,w}$ requirement from Room 1 to Room 2 may be different to the $D_{nT,w}$ requirement from Room 2 to Room 1).

$R'_w\ (+C_{tr}) = D_{nT,\ w}\ (+C_{tr})\ +10\log(S)-10\log(V)+5$

where S is the area in m^2 of the shared element and V is the volume of the receiving room (in m^3).

The required R'_w rating for the partition thus calculated, is the required composite R'_w for the partition as a whole including any doors, glazing etc.

The required design R_w (or $R_w + C_{tr}$) for each partition element (e.g. wall, door, glazing etc) must be determined based on the required R’w (or R'_w +Ctr) for the entire partition, the area of the element in the partition and a suitable site factor to account for differences between laboratory acoustic data and as-installed performance.

$R_w\ (+C_{tr}) = R'_w\ (+C_{tr})$ + *site factor*

The site factor shall be selected to make appropriate allowance for build quality and the effect of service or other penetrations through the partition.

Notwithstanding the designer and contractor’s responsibility to meet the $D_{nT,w}$ targets for each partition, the following minimum site factors shall be used. Site factors have been generally based on the guidance of BB93 and the UK Healthcare Acoustics: Technical design manual 4032:0.3:2011

- 10 dB for operable partitions
- 7 dB for lightweight partitions (non-isolated)

- 5 dB for site-built doors or glazing
- 4 dB for masonry partitions (non-isolated)
- 3 dB for structurally isolated partitions or factory-assembled acoustically rated door sets.

Use of alternative site factors may be justified on a case by case basis, however, the ultimate performance responsibility remains achieving the $D_{nT,w}$ requirements.

17.4.12.1.1 Example Partition Constructions

Example acoustic partition constructions are provided in Table 17.4.2.6-1 below. Alternative constructions may be used provided that the R_w (or R_w+C_{tr}) requirement is met.

Table 17.4.2.6-1 Example Partition Constructions for Each R_w Rating

Sound Insulation Performance Requirement	Example Wall Build-up
≤ R_w 30	**Lightweight** • 1 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) ≥ 64 mm steel stud 1 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) **Masonry** • 75 mm Hebel **Glazing** • 6 mm glazing
R_w 35	**Lightweight** • 1 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) ≥ 64 mm steel stud 50 mm fibreglass (33 kg/m3) in cavity (or equivalent) 1 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) **Masonry** • 75 mm Hebel Powerpanel or • 100 mm Hebel Powerwall **Glazing** • 10.38 mm laminate glazing or • 6.5 mm acoustic laminate

Sound Insulation Performance Requirement	Example Wall Build-up
R_w 40	**Lightweight** • 1 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) ≥ 92 mm steel stud 50 mm fibreglass (32 kg/m³) in cavity (or equivalent) 1 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) **Masonry** • 125 mm Hebel Sonoblock OR • 110mm single brick **Glazing** • 12.5 mm acoustic laminate or double glazing
R_w 45	**Lightweight** • 2 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) ≥ 92 mm steel stud 50 mm fibreglass (32 kg/m³) in cavity (or equivalent) 1 x 13 mm plasterboard (≥ 8.5 kg/m² per sheet) **Masonry** • 100 mm concrete or • 140 mm hollow concrete block or • 100 mm Hebel ≥ 64 mm stud 50 mm fibreglass (33 kg m-3) in cavity 1 x 13 mm plasterboard (≥ 8.5 kg m-2 per sheet) **Glazing** • Typically requires large airgap (>50 mm) double glazing

Sound Insulation Performance Requirement	Example Wall Build-up
R_w 50	**Lightweight** • 2 x 13 mm plasterboard (≥ 8.5 kg/m2 per sheet) ≥ 92 mm stud 50 mm fibreglass (33 kg/m3) in cavity (or equivalent) 2 x 13 mm plasterboard (≥ 8.5 kg/m2 per sheet) **Masonry** • 120 mm concrete or 140 mm core-filled concrete block or 190 mm hollow concrete block **Glazing** • Not practicable without large airgap double glazing
R_w 55	**Lightweight** • 2 x 16 mm high density plasterboard (≥ 13 kg/m² per sheet) ≥ 150 mm cavity with separate stud 50 mm fibreglass (33 kg/m3) in cavity (or equivalent) 2 x 16 mm high density plasterboard (≥ 13 kg/m² per sheet) **Masonry** • 160 mm concrete or • 190 mm core-filled concrete block **Glazing** • Generally, not practical. • Typically requires a very substantial airgap (500 mm or more). Glazing is typically not the most cost-effective solution for high Rw ratings and should only be used on a case-by-case basis.

Sound Insulation Performance Requirement	Example Wall Build-up
R_w 60	**Lightweight** • 3 x 16 mm high density plasterboard (≥ 13 kg/m² per sheet) ≥ 200 mm cavity with separate stud 50 mm fibreglass (33 kg/m3) in cavity (or equivalent) 3 x 16 mm high density plasterboard (≥ 13 kg/m² per sheet) **Masonry** • 210 mm concrete **Glazing** • Generally not practical

Partitions rated higher than R_w 65, if necessary shall be developed on a case-by-case basis.

17.4.13 Plant Room Requirements

The minimum requirement for plant room partitions is $R_w + C_{tr}$ 40.

The $D_{nT,w}$ requirements for partitions surrounding plantrooms and other equipment rooms are provided for general guidance during early design stages.

Once plant selections are made, plantroom sound insulation requirements must be determined based on the sound power levels of the selected plant to be located in the plantroom so that the internal noise requirements in Table 17.4.2.2-2 are met. The more stringent of the requirement based on plant selections or the $D_{nT,w}$ requirement from Table 17.4.2.2-1 shall take precedence.

17.4.14 Impact Noise Requirements

Maximum allowable impact sound pressure levels for floor-ceiling constructions are provided in Table 17.4.2.8-1:

Table 17.4.2.8-1 Maximum Allowable Impact Sound Pressure Levels for Floor/Ceiling Systems

Type of Room (Receiving)	**Maximum Impact Sound Pressure Level $L'_{nT,w}$ dB For Floor/Ceiling System Above Receiving Room**	
	New Build	**Refurbishment**
Teaching spaces intended for students with special hearing or communication needs Meeting room Counselling room	50	55
Music: Practice room Ensemble room Recording studio Control room	40	45
Classroom Library Lecture room Science Laboratory Drama studio Design and technology spaces Sports hall Gymnastics hall / activity studio	55	60
Atrium (non-teaching or learning) Dining room Kitchen Office Staff room Medical room Corridor Stairwell Change areas Locker rooms Toilet	65	65

The requirements in Table 17.4.2.8-1 are based on general activities in spaces above, principally footfall noise. Higher performance (i.e. lower values of $L_{nT,w}$) will be required if the space above has high levels of impact noise e.g. gymnasium, workshops, some engineering laboratories. These requirements are to be developed on a case-by-case basis. Particularly sensitive spaces such as recording studios or specialist acoustic laboratories may also require impact noise to be designed for inaudibility.

Unfavourable vertical adjacencies (where a high impact noise space such as gymnasium, workshops, engineering laboratories is located above a noise-sensitive space) shall be avoided during space planning.

The requirements for any spaces not identified in Table 17.4.2.8-1 above must be developed on a case-by-case basis including consultation with the end users of the building and signed-off by UQ.

Floor to ceiling insulation design for unfavourable adjacencies such as gymnasiums or rooftop sports halls above noise-sensitive spaces etc. shall be undertaken in consultation with an acoustic specialist experienced in vibration and noise control and may require coordination with the structural engineer e.g., by adjusting the designed natural frequency of the suspended floor slab.

17.4.15 Verification Testing

Field tests shall be performed at or prior to Practical Completion for a sample of partitions to demonstrate compliance with the performance requirements of this Guideline. The required proportion of partitions to be tested is determined by the partition rating as outlined in Table 17.4.2.9-1 below:

Table 17.4.2.9-1 Minimum Verification Test Requirements for Acoustically-Rated Partitions

Partition Rating	Percentage of Partitions Requiring Testing
$D_{nT,w} \leq 30$	20
$31 < D_{nT,w} \leq 35$	40
$36 < D_{nT,w} \leq 40$	50
$41 < D_{nT,w} \leq 45$	60
$46 < D_{nT,w} \leq 50$	80
$51 < D_{nT,w} \leq 55$	90
$D_{nT,w} \geq 55$	

On site testing shall conducted in accordance with:

- ISO 16283.1
- ASTM E2638-10

17.4.16 Verification Testing

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$36 < D_{nT,w} \leq 40$	50
$41 < D_{nT,w} \leq 45$	60
$46 < D_{nT,w} \leq 50$	80
$51 < D_{nT,w} \leq 55$	90
$D_{nT,w} \geq 55$	

On site testing shall conducted in accordance with:

- ISO 16283.1
- ASTM E2638-10

17.4.17 Flanking Sound at Façade

Sound transfer via the façade mullion can limit the performance of façade-located partitions, depending on the construction and resulting sound insulation characteristics of the façade and mullion. Treatment of the mullion is typically required for partitions rated at ~$D_{nT,w}$ 40 and higher.

The façade/mullion flanking path shall be considered in design and acoustically treated (where necessary) such that the $D_{nT,w}$ requirements are met.

17.4.18 Doors and Operable Walls

17.1.1 Doors

Doors will limit the overall sound insulation of a partition since they are generally of much lighter construction than the partition, and they are difficult to effectively seal.

Although proprietary high acoustic performance doors are available, they are typically heavy, more difficult to operate and relatively expensive and typically require factory-assembly of the door/frame/hardware/seals in order to reach the required acoustic performance. Site assembly of high-performance acoustic doors (R_w 35 and higher) almost invariably results in the required acoustic performance not being achieved.

The requirement for high-performance acoustic doors shall be minimised as much as possible via space planning to avoid acoustically incompatible adjacencies and using soundlocks (allowing lower-performance doors to be used) in preference to acoustically rated doorsets. Use of acoustically-rated proprietary doors shall only be considered when the need is identified in the briefing process and/or when confirmed by UQ PF.

Swing doors shall be used within all acoustically rated partitions in preference to pivot doors or sliding doors which are both difficult to seal effectively and typically have low acoustic performances.

Partitions to sensitive spaces such as music spaces, lecture theatres or auditoria where the partition acoustic rating is D_{ntw} 45 or greater must include soundlocks unless sign-off to use acoustically rated doorsets is provided by UQ.

The required partition $D_{nT,w}$ ratings (i.e. the values from Table 17.4.2.2-22 minus 5 $D_{nT,w}$) must be met by the combination of the wall performance and door performance taking into account the relative areas of the door and the partition.

Typical door constructions and nominal door sound insulation ratings are provided in the Table below.

Table 17.4.4.11-1 Typical Acoustic Door Construction and Sealing Details

Nominal Door Rating	**Typical Door Construction and Sealing Arrangement**
R_w 20	• Hollow core (minimum 40 mm) or glazed door with maximum 5mm gap between door and frame • Sweep seals
R_w 25	• Solid core (minimum 40mm) or specialist acoustic glazed door, well fitted to effective frame • Compression seals to head, jambs, meeting stiles and threshold • Vision panel (if required) to comprise 6mm laminated glass
R_w 30	• Solid core (minimum 45mm) or specialist acoustic glazed door, well fitted to effective frame • High performance compression seals to head, jambs, meeting stiles and threshold (can be drop seal) • Vision panel (if required) to comprise 10.38mm laminated glass
R_w 35	• Proprietary factory-assembled acoustic rated door set
R_w 40	• Proprietary factory-assembled acoustic rated door set • OR • Two back-to-back lobbied R_w 25 doors with not less than 200mm void between them

R_w 45	• Proprietary factory-assembled acoustic rated door set
	  • OR
	  • Two back-to-back lobbied R_w 30 doors with not less than 200mm void between them

Individual doors (as opposed to doors within sound locks etc) rated R_w 35 or higher shall be proprietary acoustic door sets. An acoustic doorset is a factory-supplied product consisting of a door factory-assembled within a frame with all seals installed and for which the door manufacturer warrants a minimum level of acoustic performance. The supplied assembly is installed within the door aperture within the partition on site. Acoustic doorsets shall not be site-assembled.

For all doors, the door ironmongery shall provide effective compression of the door seals. Sealing mechanisms shall allow for the accommodation of building tolerances and of floor level variations.

17.4.19 Operable Walls

The use of operable partitions between spaces is likely to limit the level of sound insulation. This is due mainly to the seals around the perimeter of any demountable wall which generally become less effective over time. The maximum R_w performance of commercially available operable partitions is in the order of R_w 50-55. Accounting for site factors and the inevitable degradation of performance of an operable partition over time, a site factor of at least 10 dB shall be used for any operable partition.

Operable walls shall provide and meet the equivalent acoustic insulation criteria as a fixed partition would in their place. Ceiling baffles shall be used to provide a full height partition wherever operable walls are installed instead of acoustically rated fixed partitions. Ceiling baffle construction shall be specified to meet at least the same R_w rating as the operable partition.

Operable wall and door frames shall be acoustically sealed. Screws shall not penetrate acoustic seals. Operable doors with seals shall always be selected over operable doors that cannot be sealed (e.g. pivot doors).

To maximise the operable partition performance the following shall be observed:

- The top support shall be designed and installed so that the overall performance of the wall system is not degraded by sound transmission via the track assembly, or via the interface between the track assembly and the building structure.
- Effective airtight seals shall be provided at all inter-panel and perimeter junctions. The form and material of the seals shall be such that normal operation of the wall does not result in the seal degradation, loss of acoustic performance or visibly uneven sealing lines. Seals shall have a compressed density of not less than 100 kg/m³.
- Sealing mechanisms shall allow for the accommodation of building tolerances without loss of performance. Seals shall not be used to take up tolerances greater than ±30% of the design dimension.
- A threshold plate beneath the operable wall shall be used where possible.
- Bottom seals shall allow for floor unevenness and consist of a double seal compressed along its full length by a jack mechanism. The seal pressure must be sufficient to ensure an airtight seal and prevent panel movement. Double top seals of commensurate performance shall be provided.
- Vertical astragal shall be double wipe or compression action. Vertical perimeter sealing will be achieved with telescoping panel sections, twin compression seals and fixed jamb frames.

17.4.20 Switched Socket Outlets and Other Wall Penetrations

Notwithstanding the overall $D_{nT,w}$ performance requirements, wall outlets such as SSOs, data outlets, facility panels etc are to comply with the requirements outlined below, corresponding to the partition rating in which they are installed:

< $D_{nT,w}$ / $D_{nT,w}+C_{tr}$ 30

Penetrations shall be minimised as far as practical and sealed wherever practical.

$D_{nT,w}$ / $D_{nT,w}+C_{tr}$ 30-34

A standard backing box shall be installed for all SSOs and other outlets (including data, AV etc). E.g. 3-PDL 140C concrete flush/wall box or approved equivalent

$D_{nT,w}$ / $D_{nT,w}+C_{tr}$ 35-39

A standard backing box shall shall be installed for all single sided SSOs and outlets. Back to back GPOs and outlets will require an acoustically rated backing box. E.g. Clipsal STC50 or approved equivalent

≥ $D_{nT,w}$ / $D_{nTw+Ctr}$ 40

Acoustically rated backing boxes shall be installed for all SSOs and outlets. Back-to-back outlets shall also be separated by a minimum 300mm.

17.4.20.1 Acoustic Sealants

All penetrations in acoustically rated partitions are to be sealed to maintain their acoustic rating. All penetrations for cables must be acoustically sealed after cable installation is complete.

Where an acoustic sealant is specified, the material shall be a flexible non-hardening compound. Acceptable products are outlined in the table below. Alternate products may be used at the discretion of the project acoustic consultant with sign-off by UQ.

Table 17.4.2.13-1 Approved Acoustic Sealants

Type	Manufacturer	Name	Specific gravity
Acrylic fire and acoustic rated sealants	HB Fuller	Firesound (VOC Compliant)	1.5
	Promat	Promaseal AN Acrylic Sealant	1.6
	Selleys	ProSeries Fireblock (Low VOC)	1.5
	Sika	Firerate	1.5
	Hilti	CP606	1.5
	Bostik	Firecaulk	1.6
Polyurethane fire and acoustic rated sealants	Bostik	Fireban One (Low VOC)	1.45
	Sika	Firerate PU	1.6

Unless otherwise approved by the acoustic consultant or outlined in manufacturer's data sheets (for acoustic applications), the following is to be adopted:

- Maximum gap width of 10 mm
- Depth of sealant no less than the gap dimension
- Open-cell foam backing rod to be fitted in the cavity behind the sealant
- Apply to both sides of the material/partition

17.4.21 Room Acoustics

17.4.21.1 Speech Intelligibility

Spaces intended for teaching must provide clear conditions for both natural (unamplified) speech, as well as amplified speech (for any spaces fitted with amplification systems).

The requirements in this section apply to the "natural" room – i.e. the behaviour of the room with no amplification system operational. Requirements for amplified speech are included in Section 17.4.7.

Open plan spaces, in particular collaborative learning spaces, shall be designed with particular consideration to speech intelligibility. The layout for open plan collaborative learning spaces places occupants within "clusters" (e.g. collaboration "pods", tables in open plan leaning areas, or bays of desks in offices) and care shall be taken to maintain intelligibility with a cluster, whilst simultaneously minimising disruption (i.e. minimising speech intelligibility in order to provide acoustic privacy) between clusters. The furniture design (particularly the presence or absence of desk screens) typically has a very strong influence on the acoustic privacy of open-plan spaces.

The following target STI values shall apply as outlined in Table 17.4.3.1-1. The target values are the minimum/maximum values across the listener area from an unamplified source (e.g. a person talking within the space) under noise conditions corresponding to the background noise level in the room from Table 17.4.4.1-1. The level of vocal effort (e.g. normal voice, raised voice etc) for calculation of STI shall be based on the typical expected usage of the space.

(For open-plan spaces the maximum STI requirement for transfer between "clusters" may be assessed under occupied conditions where occupancy-generated noise is present in the room).

Where the position/orientation of the talker is generally constant (e.g. lectern in a traditional lecture theatre) the directivity pattern of the source shall be included in the STI predictions. Where the source location/orientation may vary (e.g. a flexible or open plan space) then the STI shall be determined using an omnidirectional source.

Note for open plan spaces there is a **maximum** acceptable STI value for sound propagation between clusters in order to provide for acoustic privacy. These maximum STI values apply during occupied conditions.

Table 17.4.3.1-1 STI Requirements for Unamplified Speech in Rooms

Space	**Speech Transmission index (STI) from unamplified source**
Open plan spaces: within cluster	≥ 0.6
Open plan spaces: between clusters	≤ 0.3
Lecture theatres, teaching spaces, seminar rooms etc	≥ 0.6
Auditoria primarily used for speech	≥ 0.6
Auditoria primarily used for music	≥ 0.45
(Video)conference rooms, boardrooms, large meeting rooms	≥ 0.6

STI shall be calculated in accordance with IEC 60268-16.

For context, the quality descriptors for the speech transmission indices from IEC 602686-16 are provided in the table below.

STI value	Quality Descriptor
0-0.3	Bad
0.3-0.45	Poor
0.45-0.6	Fair
0.6-0.75	Good
0.75-1	Excellent

17.4.21.2 Reverberation Time

Reverberation time is a key, although not the only, room acoustic parameter to describe the room acoustic conditions for a room.

Spaces such as lecture theatres, performance spaces, teaching rooms, collaborative spaces and speech auditoria all require specialist acoustic design and will require consideration of speech intelligibility in addition to the reverberation time.
For these spaces the intelligibility requirement will take precedence over the RT requirement – i.e. a longer reverberation time may be acceptable provided that the intelligibility requirements from Table 17.4.3.1-1 are met. This may also allow for some multipurpose use of these spaces (e.g. as per the Auditorium within the Advanced Engineering Building at St Lucia campus).

For specialist music spaces (including performance spaces for music, practice rooms ensemble rooms etc), the desirable reverberation time is partly determined based on the styles of music to be played within the spaces. The values provided in this Guideline are appropriate for general music spaces however consultation with end users as to the desired usage of the space shall be conducted and alternative criteria may be agreed with end users and signed off by UQ. Guideline values have been based on Norwegian Standard NS8178 which includes recommendations for controlling occupational noise exposure (loudness) in music spaces and is in process of being adopted as an International Standard.

Specialist music spaces such as performance spaces or auditoria for music will also require additional criteria for loudness (G), musical clarity (C_{80}), lateral energy (LF_{80}) or other specialist parameters, which shall be set on a case-by-case basis in consultation with end users by a suitably experienced acoustic consultant.

Open plan spaces require special acoustic considerations to be included in design. For these spaces, the reverberation time (which describes the “global” acoustic properties of the space) is less appropriate since the acoustic properties of open plan spaces are highly-influenced by “local” acoustic conditions, particularly the materiality of the ceiling surface (absorptive or reflective). Design for open plan spaces shall focus primarily on controlling strong sound reflections between different “clusters” within the open plan space in order to provide acoustic privacy. For this reason, a wider range of RT values is provided than recommended in AS2107 since increased reverberation can sometimes be beneficial by reducing speech intelligibility away from the source.

For any space for which a STI performance index is provided in Table 17.4.3.1-1, the reverberation time target provided below in Table 17.4.3.2-1 is advisory and higher (or lower) RT values may be adopted provided that the STI requirements are met.

The following criteria have been generally adopted from AS2107 and BB93 and generally set maximum acceptable levels of reverberation. For some spaces minimum reverberation time requirements are provided, generally to avoid spaces becoming too “dry” (which can increase the vocal effort required for speech communication and cause vocal fatigue e.g. when lecturers are required to use the space for prolonged periods).

Table 17.4.3.2-1 Performance standards for mid frequency reverberation time

Space	Mid-Frequency Reverberation Time (seconds)
Open plan teaching area	<0.8s
Open plan breakout	≤1.2 s
Lecture room small (less than 50 people)	0.4-0.8s
Lecture room large (more than 50 people)	AS2107 Curve 1 ± 0.15s
General teaching area (enclosed): -Seminar rooms -Tutorial rooms	0.4-0.8s

Space	Mid-Frequency Reverberation Time (seconds)
-Study room	
Teaching spaces for students with special hearing or communication needs	$T \leq 0.4$ averaged from 125 Hz to 4kHz octave band centre frequencies and $T \leq 0.6$ s in every octave band in this range.
Teaching laboratories	0.6-1.0 s
Research laboratories	<1.2 s
Engineering laboratories (non-teaching) Workshops	<1.8s
Specialist acoustic laboratories	To be determined on a case-by-case basis
Animal handling facilities	To be determined on a case-by-case basis
Audiology rooms	$T \leq 0.5$ s in every octave band from 125 Hz to 8 kHz inclusive
Music classrooms	0.6-1.0 s
Music practice ≤ 30m²	0.3-0.5 s (amplified) 0.5-0.9s (unamplified) or as per NS8178
Music practice > 30m²; Music Ensemble rooms	0.5-0.7 s (amplified) 0.7-1.5s (unamplified) or as per NS8178
Music performance or recital space (unamplified)	1.5-2.0 s
Music performance space (amplified)	0.6-1.1 s
Music recording studio – live room	0.5-1.0 s
Control room: -for recording	As per Dolby 5.1 guidelines: $T = 0.25 (V/100)^{1/3}$ where V is room volume in m³
Control room / biobox (no recording)	≤0.5s
Drama theatres	0.8-1.1s
Drama studio	≤1.0s
Dance studios	≤1.2s
Multi-purpose halls	1.0-2.0s
Gymnasium/ activity studios	≤1.5
Swimming pool	≤1.5
Library - general area	≤0.8s
Library - reading areas	<0.6
Atriums Foyers Entrance halls	<1.5 s
Corridors	<1.0s
Dining rooms, cafeterias	≤1
Boardrooms Meeting rooms Interview rooms Counselling rooms	0.6-0.8s
Videoconference rooms	0.4-0.6
Academic office areas – open plan	<0.8 s
Academic offices – enclosed	0.6-0.8 s
Administrative and ancillary spaces: -First aid rooms -Staff rooms -Utility rooms	≤1
Kitchens Changing areas Toilets	≤1.5

17.4.21.2.1 Reverberation Time Spectrum Shape

Some acoustically critical spaces require control of reverberation over a wider frequency range, particularly at low frequency (defined as the average of the 63 Hz and 125 Hz octave band reverberation times).

Additional low frequency reverberation time requirements apply for these spaces as a % of the mid-frequency (T_{mf}) reverberation time as per Table 17.4.2.11.2-1:

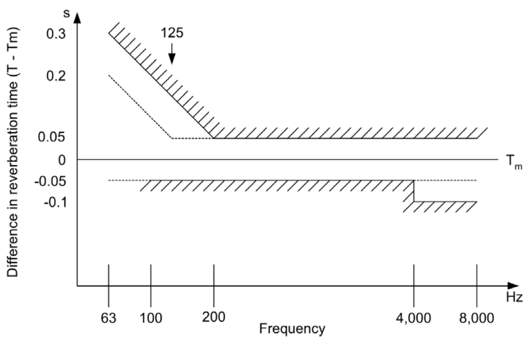
Table 17.4.3.2-2 Low-Frequency Reverberation Time Requirements for Critical Spaces

Space	**Low-Frequency Reverberation Time**
Auditoria for speech	90-100 % of T_{mf}
Auditoria for music	100-125 % of T_{mf}
Music performance or recital space (unamplified)	100-125 % of T_{mf}
Music performance space (amplified)	80-100 % of T_{mf}
Music Practice and Ensemble rooms	100-115 % of T_{mf}

Space	Low-Frequency Reverberation Time
Music recording studio – live room	100-110 % of T_{mf}
Music recording studio – control room	As per Dolby 5.1 guidelines
Lecture theatres	90-100 % of T_{mf}
Boardroom, videoconference room	90-125% of T_{mf}
Specialist acoustic laboratories (e.g anechoic chamber, audiology etc.	To be determined on a case-by-case basis

Recording control rooms for music shall conform with the spectrum shape from the Dolby 5.1 guidelines as shown in Figure 17.4.3.2-1:

Figure 17.4.3.2-1 Dolby 5.1 Guideline Spectrum Shape for Music Recording Control Rooms



In addition, recording control rooms for music shall control early sound reflections to comply with the Dolby 5.1 guidelines (i.e. all reflections within the first 15 ms in the frequency range 1kHz-8kHz attenuated by at least 15 dB relative to the direct sound).

17.4.22 Room Geometry – General Considerations

To mitigate flutter echo, untreated parallel surfaces (walls and ceilings) shall be avoided. A minimum angle of 7 degrees is recommended for any near-parallel room elements to reduce the incidence of flutter echo. Where parallel surfaces are unavoidable surfaces shall include sound absorption or diffusion to mitigate the effects of flutter, particularly at high frequencies (2kHz and above).

Concave curved features such as walls, ceilings or screens can create focusing effects in rooms. Concave geometry where the focal point of the curvature lies at or near an area where room occupants will be located shall also be avoided. Where concave geometry with a focal point near occupants is unavoidable, concave surfaces shall be acoustically treated with sound absorption or sound diffusion to disrupt the focussing effects.

17.5 Room Finishes

Absorptive, diffusive and/or reflective treatments shall be included as required to ensure appropriate reverberation times are met for each space. Where reverberation times are specified, designers shall seek the advice of an acoustic engineer when selecting finishes.

In addition, the location of sound absorptive or diffusive treatments is important for some spaces in order to control individual sound reflections as well as to control the overall room reverberation.

All acoustic finishes shall generally be effective at mid-frequencies unless project-specific requirements apply (e.g. a high frequency absorber/diffuser to address flutter echo, or a low-frequency absorber to control room bass response). This typically means that acoustic finishes shall be at least 25 mm thickness. Thinner products (e.g. "acoustic pinboard" generally does not provide significant absorption at mid-frequencies) and are not permitted.

17.6 Floor Finishes

Soft floor finishes (carpet, or resilient finishes) are generally recommended for all teaching spaces to control foot-fall noise within the space, especially noise from latecomers.

Soft finishes shall be used for all areas with high foot-fall traffic, balanced against cleaning and specialist requirements (e.g. infection or spill control for clinical or laboratory spaces).

Hard finishes (e.g. timber floors) are generally preferable for music spaces for acoustic/unamplified music. Soft finishes (e.g. carpet) are generally preferable for spaces for amplified music.

17.7 Ceiling Finishes

Rooms for natural (unamplified) speech communication shall include areas of reflective surfaces between the sound source (e.g. talker) and the audience/listeners to assist in transferring sound energy from source to receiver. A recommended approach is to use acoustically reflective ceiling finishes in the middle of the space to provide a ceiling reflection to listeners and to use acoustically absorptive ceiling finishes away from the sound source (e.g. at the rear for a traditional end-stage lecture theatre, or around the perimeter of the room for a less-traditional space) to help control potential echoes back to the presenter.

17.4.3.4.2.1 Videoconference

Videoconference rooms with ceiling-mounted or table-mounted microphones shall have a sound-absorptive ceiling above the meeting table.

17.4.3.4.2.2 Laboratories and clinical spaces

Some spaces (e.g. laboratories, clinical spaces) will have functional requirements that may prevent acoustic treatments being located on wall surfaces. In these cases, the ceiling shall be highly absorptive and the overall room shape where possible avoid parallel walls etc to avoid acoustic defects such as flutter echo.

17.4.3.4.2.3 Open plan spaces

Open plan teaching or office spaces shall have ceilings that strongly disrupt sound transfer between individual areas of the open plan space in order to assist with acoustic privacy. This could consist of a combination of sound absorptive treatments and ceiling shaping (e.g. baffles) that disrupt the ceiling reflection between areas.

17.4.3.4.2.4 Musical spaces

Spaces used for music rehearsal and performance shall include areas of sound absorption or (preferably) sound diffusion on the ceiling to help address adverse impacts on the tone quality of music in spaces that typically results from overhead reflections from large plane surfaces. This diffusion/absorption shall typically be effective at high frequencies (2 kHz and above) however a wider bandwidth may be necessary depending on the type of music to be played in the room.

17.8 Wall Finishes

It is recommended that some acoustic finishes be located on the walls of spaces used for speech and music, since the effectiveness of acoustic finishes is typically greatest at addressing individual problematic sound reflections when placed in the same plane as the sound source and listener. Sound diffusive treatments are generally (but not always) preferable to sound absorptive treatments for spaces intended for music.

Sound diffusive surfaces, where used, shall minimise the regularity and repetition of the diffusion profile to avoid frequency-selective behaviour (e.g. avoiding regularly spaced arrays of elements of the same size). In general, diffusive surfaces shall vary the size of elements, the spacing of elements or both.

In instances where parallel surfaces cannot be avoided, to avoid flutter echo wall acoustic treatment is recommended to at least two non-parallel surfaces (i.e. so that at least one surface out of each pair of parallel surfaces has acoustic treatment).

Where parallel glazed surfaces are unavoidable acoustically absorptive curtains shall be considered as a treatment option to mitigate flutter echo. Products (e.g. acoustic sheer curtains or microperforated clear foil absorbers) are available that provide acoustic performance while still allowing for light transmission.

The rear wall in auditoria and lecture theatres shall generally be acoustically treated to prevent echoes back to the presenter. For spaces primarily intended for speech an absorptive rear wall is suitable. For spaces primarily intended for music a diffusive rear wall shall be provided.

In open plan spaces, the bounding surfaces (whether the actual walls of the room or room dividers) around each sub-area will have a significant impact on the acoustic performance. Sound reflections off these surfaces can degrade the acoustic privacy of these spaces. Acoustic absorption shall be provided on these surfaces where necessary and possible.

Localised acoustic absorption is recommended in the vicinity of items of particularly noisy equipment e.g. in laboratories, workshops etc. This will help in reducing the overall noise level in these spaces (and hence the noise breakout to other spaces). The absorption product may be required to be thicker than typical in order to be effective over the frequency range that the equipment produces noise.

17.8.1 Product Selection and Placement

Selection of room treatments and finishes shall be made in alignment with UQ's sustainability guidelines. Sustainable material selection shall be used for all acoustic treatments wherever possible.

Care shall be taken to ensure all finishes specified for clinical spaces meet cleaning and infection control requirements. Consultation with the school shall be undertaken to assess the applicability of anti-bacterial finishes in other applications such as biological or animal laboratories.

All specified off-the-shelf absorptive products shall include evidence (NATA certification or other laboratory test certificate) to validate their claimed absorption rating. Laboratory acoustic testing will be required for any custom acoustic finishes developed for a project.

Acoustic treatments, whether diffusive or absorptive, are often fragile. Care shall be taken to place treatments out of reach where possible and where this does not detract from the effectiveness of the treatment, e.g. above head height or behind other means of protection such as handrails, or include a protective facing (e.g. perforated metal) where this is not possible or where the treatment must be located within an accessible area.

17.8.2 Special Considerations for Acoustically Critical Spaces

17.8.2.1.1 Loudness

Music practice, instruction and performance spaces where occupants are exposed to high noise levels for long periods may require additional consideration for workplace health and safety purposes.

The appropriate room volume and treatment options shall be designed to accommodate the Safe Work Australia Noise guidelines:

$L_{Aeq,8hr}$ 85 dB(A)

$L_{C, peak}$ 140 dB(C)

The anticipated use and ensemble size for each room shall be considered with respect to loudness. The loudness at a *forte* dynamic shall be designed with a target level of 90 dB(A) or lower as per the recommendations of NS8178.

Additional volume (typically through increasing the ceiling height) and additional acoustic treatment may be required for spaces for music rehearsal and performance to control loudness.

For preliminary room planning, the following minimum volume guidelines per musician for instruments shall be adopted so that there is sufficient room volume to reduce loudness:

- String instruments 25 m³/player
- Woodwind instruments 30 m³/player
- Brass instruments 50 m³/player
- Percussion instruments 50 m³/player
- Amplified instruments 50 m³/player
- Singers (unamplified) 30 m³/player

Room Shape and Size

Spaces intended for music, particularly for music recording, must consider the room modal response in design.

Distribution of modes in specialty acoustic rooms (any space used to play music or for critical listening) is to be assessed to avoid such unwanted sound colouration.

These rooms include:

- Music instruction, practice, and performance rooms
- Recording studios and control rooms

Modes for these spaces shall be assessed by an acoustic specialist, who shall then provide advice to the architect with regards to the room dimensions in achieving the best possible modal distribution.

17.8.3 Minimum Room Volume Requirement

During preliminary planning of auditoria for speech and music, the following minimum volume guidelines shall be followed to provide sufficient room volume for the required room reverberation.

The table below provides a guideline on room volume per person (where the number of people includes both audience members and performers) and shall be used to guide architectural design of specialist acoustic spaces.

Note that the guideline values typically represent minimum volume per person requirements and that use of particularly absorptive room finishes, unusual room shapes/geometries or other factors may result in the room volume being required to be higher. Additionally, rooms typically lose effective acoustic volume during the design process and a sufficient buffer shall be allowed for so that the required reverberation time is met at completion.

Table 17.4.3.5-1 Minimum Room Volume Requirements Per Person

Space	Approximate Reverberation Time Goal	Required Minimum Volume per Person
Specialty Rooms for Speech (Auditoria for speech, lecture theatres)	1.0 s	4 m³/person
Specialty Rooms for Music (Auditoria for music, performance halls)	1.5s-2.0s	6-10 m³/person

17.8.4 Background Noise Levels

17.8.4.1 Design Sound Level Targets

In general, the recommended design sound levels set out in Australian Standard AS 2107 have been adopted, with some minor adjustments and guidance from BB93.

Criteria are provided for the required range in internal design sound levels (background noise levels) which shall be met by the combination of all steady-state or quasi-steady state building services noise in each receiver room, as well as noise break-in from steady-state external noise sources (e.g. noise from plant located at surrounding buildings). In addition, the maximum acceptable NR (noise rating) curve value for building services noise is provided for some acoustically critical spaces.

Both minimum and maximum internal noise criteria must be achieved to avoid spaces being "too quiet" (which results in problems with decreased acoustic privacy or increased disturbance from external noise) as well as "too loud".

Design levels for intermittent building services noise (e.g. hydraulic services, vertical transport etc) are included in Section 17.4.4.5 and Section 17.4.4.8.

Table 17.4.4.1-1 Design Services Sound Level Requirements

Space	**Design Sound Level Range L_{Aeq}**	**Maximum allowable NR**
Open plan teaching area	40-45	n/a
Open plan breakout	<50	n/a
Lecture room small (less than 50 people)	35-40	35
Lecture room large (more than 50 people, speech reinforcement)	30-35	30
General teaching area (enclosed): -Seminar rooms -Tutorial rooms -Study room -Art studio -Computer teaching room	40-45	n/a
Teaching spaces for students with special hearing or communication needs	30-35	30
Teaching laboratories Engineering workshops (teaching)	40-45	40
Research laboratories (non-teaching)	45-50	n/a
Engineering laboratories (non-teaching) Workshops	<55	n/a
Specialist acoustic laboratories	To be determined on a case-by-case basis	
Animal handling facilities	To be determined on a case-by-case basis	
Audiology rooms	As per AS/NZS ISO 8253.3 2019	n/a
Music classrooms	35-45	n/a
Music practice ≤ 30m²	35-40	35
Music practice > 30m²	35-40	35
Music Ensemble rooms	30-35	30
Music performance or recital space (unamplified)	20-25	20
Music performance space (amplified)	30-35	30
Music recording studio – live room	20-25	20

Space	Design Sound Level Range L_{Aeq}	Maximum allowable NR
Control room: -for recording -no recording	20-25	20
Control room / biobox (no recording)	25-30	25
Drama theatres	25-30	25
Drama studio	35-40	35
Dance studios	40-45	n/a
Multi-purpose halls	35-45	n/a
Gymnasium/ activity studios	<50	n/a
Swimming pool	<55	n/a
Library - general area	40-50	n/a
Library - reading areas	40-45	n/a
Atriums Foyers Entrance halls	45-50	n/a
Corridors	<50	n/a
Dining rooms, cafeterias	<50	n/a
Videoconference rooms Boardrooms Meeting rooms Conference rooms Seminar rooms	30-40	35
Interview rooms Counselling rooms	35-40	n/a
Academic office areas – open plan	40-45	n/a
Academic offices – enclosed	35-40	35
Administrative and ancillary spaces: -First aid rooms -Staff rooms -Utility rooms	<50	n/a
Kitchens Changing areas Toilets	<55	n/a

These design sound levels apply to noise from building services when operational – i.e. for fully air-conditioned spaces or for mixed-mode spaces when operating in mechanically-ventilated mode.

Note for music recording studios, the background noise requirements here are based on “educational” grade spaces. Professional-quality studios would require a lower background noise level (maximum NR15). If required, this shall be briefed by UQ.

17.8.5 Naturally Ventilated Spaces

Spaces with target background noise levels lower than 40 dB(A) are not recommended to be naturally ventilated unless the external noise environment can be demonstrated to be sufficiently quiet.

For other spaces, the acceptable internal noise level in naturally ventilated mode is 10 dB above the maximum noise level in mechanically ventilated mode, up to a maximum internal noise level of L_{Aeq} 65 dB(A).

17.8.6 Adjustment Factors for Subjective Annoyance from Building Services

Building services noise typically has broadband spectral characteristics and is typically quasi-steady state, however in some circumstances the spectral or temporal characteristics of services noise can increase the subjective annoyance of building occupants.

Broadband noise is typically caused by flows of refrigerant, water, and/or air, whereas tonal noise is generally caused by rotation of compressors, motors, gears and fans (but occasionally may result from aerodynamic noise sources).

Sounds with strong tonal content or unbalanced spectral content (“rumble” or “hiss”) increase the likelihood of annoyance, regardless of the overall noise level. Use of equipment with unbalanced sound spectra or tonal characteristics shall be avoided wherever possible.

Unstable airflow conditions or varying load on equipment can result in changes in the noise level from equipment over time. This can be particularly annoying if the changes in level are regular/rhythmic.

Where building services has subjectively more-annoying characteristics such as tonality (defined using the procedure in Appendix D of AS1055), time-varying behaviour ("pulsing" or "surging", defined where the difference between the $L_{Aeq,T}$ and $L_{A10,T}$ over a time period T of at least 30 seconds for the noise source exceeds 5 dB) or prominent spectral imbalances ("rumble" or "hiss" as defined using the ASHRAE Room Criterion Mark II parameter), a penalty of 5 dB shall be added for each subjective characteristic up to a maximum penalty of 10 dB.

17.8.7 Noise Masking

Spaces not meeting the minimum noise level requirement must be provided with sound masking so as to meet the minimum noise level requirement.

Masking techniques include by a well-designed air handling or air conditioning system or the use of an electronic sound masking system.

17.8.8 Compliance Testing

Noise from mechanical services shall be measured at a distance of 1.2m above floor level (or at listener level if the listener plane is significantly elevated relative to the floor) and a minimum distance of 1.5m from any diffuser or room boundary surface (with the exception of swirl-type underfloor diffusers in a displacement supply system). Continuous noise shall be measured in the octave bands 63Hz to 8kHz inclusive as well as the A-weighted noise level. Steady state sound levels are to be measured in terms of the L_{eq} over a period of minimum 60 seconds per room.

Where the sound level varies by greater than 3 dB across the room, or for larger spaces (such as auditoria, lecture theatres etc with a floor area greater than 50 m²), additional measurement positions shall be used to capture the variability of the background noise level in the room. A minimum of 1 position per 50 m² of floor area shall be used.

Compliance against the minimum and maximum requirements in Table 17.4.4.1-1 shall be based on the minimum and maximum noise levels measured in the room, not on the spatial average.

The minimum number of rooms to be tested is based on the noise criterion for each room as per Table 17.4.4.3-2.

Table 17.4.4.3-1 Minimum Verification Testing Requirements for Internal Noise Levels

Maximum Design Noise Level $L_{bg,max}$	Minimum Percentage of Rooms Requiring Testing
$L_{bg,max} \leq 30$	90
$31 < L_{bg,max} \leq 35$	70
$36 < L_{bg,max} \leq 40$	50
$41 < L_{bg,max} \leq 45$	30
$46 < L_{bg,max} \leq 50$	20
$L_{bg,max} \geq 55$	10

On site testing shall conducted in accordance with:

- AS/NZS 2107:2016

17.8.9 Mechanical Services Noise Control

Mechanical services systems shall be designed to include sufficient noise attenuation to meet the internal noise criteria from Table 17.4.4.1-1 from the combination of both equipment noise (e.g. fan noise) and aerodynamic noise from movement of air.

All ducts must be properly designed and sized with the provision of sufficient duct attenuation to meet the room noise criteria.

Return and supply air paths must be designed with sufficient acoustic attenuation (in the form of internal duct lining, attenuators or expansion plena) along the duct to meet the specified internal noise requirements from down duct noise.

Notwithstanding the designers and contractor’s responsibility to meet the internal noise levels in Table 17.4.4.1-1, the following general guidance is provided regarding noise control for mechanical systems.

Silencers may be used to provide desired sound attenuation if equipment can handle the increased air resistance resulting from the silencer. The equipment manufacturer's advice will be sought in relation to its use. All equipment will be installed in accordance with the manufacturer's instructions and checked for proper acoustical, as well as mechanical, operation.

Silencers are generally designed to operate in lengths of straight duct with fully developed airflow conditions on the inlet to the silencer. Where silencers have to be installed in close proximity (within 3-5 characteristic duct dimensions) of flow obstructions such as fans, bends, junctions, contractions/expansions, dampers or other duct fittings, an appropriate installation factor shall be allowed for to account for the reduction in performance of the silencer, or else a specialist silencer used (e.g. an elbow-type silencer).

17.8.10 Selection and Installation of Mechanical Equipment

Sound power generation of a given fan performing under certain duty will be obtained from the fan manufacturer's actual test data taken under approved conditions.

Acoustic test data for all equipment shall be provided as sound power level measured in accordance with ISO 13347-1:2004 or equivalent.

In general, equipment shall be selected to minimise the low-frequency noise generation (63 Hz and 125 Hz) from equipment, even if the overall A-weighted sound power level is higher. This is because low-frequency sound is generally more difficult to control in ductwork.

Use of equipment with unbalanced sound spectra or tonal characteristics shall be avoided wherever possible.

Fan discharge air flow conditions and conditions immediately downstream shall be designed to maximise the aerodynamic efficiency of the fan and minimise flow-generated noise.

Where fan operating speed will be variable, the acoustic design of the system shall be based upon the fan operating speed that corresponds to meeting typical thermal requirements.

17.8.11 Special Requirements For Low-Noise Systems

For low noise systems (defined as systems rated at NR30 or below), careful aerodynamic design of the duct system is required to avoid noise from air movement exceeding the noise criteria.

Radiused bends shall be used in preference to right-angle (mitred) bends, particularly within the vicinity of the room.

Low-noise systems shall be designed to be as self-balancing as possible to minimise the requirement for balancing dampers. Where unavoidable, dampers for system balancing shall be located as far away from the room as possible – i.e., by use of branch dampers in lieu of terminal dampers. Dampers shall be located at least 10 characteristic duct dimensions away from the room and only used for fine balancing (dampers shall not be more than ~15° closed). Major flow adjustments shall be achieved via sizing of branches and use of VSDs. Fire dampers shall be the out-of-airstream type with the same cross-sectional area as the ductwork (i.e. no flow contraction at the damper).

Duct velocities in low noise systems must not exceed the values in Table 17.4.4.4-1:

Table 17.4.4.4-1 Maximum Duct Velocities for Low-Noise Systems

Distance from terminal	NR20	NR25	NR30
At open terminals (no grilles, diffusers or dampers near terminals)	<1.5 m/s	<2 m/s	<2.5 m/s
Up to 10 duct diameters back from terminal	<2.5 m/s	<3.0 m/s	<4.0 m/s
10-30 diameters back from terminal	<3 m/s	<3.5 m/s	<4.5 m/s
30-50 diameters back from terminal	<6 m/s	<8 m/s	<10 m/s
>50 diameters from terminal	<10 m/s maximum	<10 m/s maximum	<10 m/s maximum

Care must be taken to ensure that disruptions to the velocity profile in the duct, and hence aerodynamic noise from air flow through duct fittings (and particularly through grilles and registers), is minimised. The interaction of closely spaced duct elements must be minimised in any duct layout.

The duct elements in a low noise system must be designed to provide as smooth a flow as possible, avoiding abrupt changes in direction or duct cross-sectional area.

Duct terminal units for low noise systems must be selected based on reliable manufacturers data from laboratory tests.

Flexible duct is in general not suitable for low-noise systems and all efforts shall be taken to design a system not using flexible ductwork. If unavoidable flexible duct shall be restricted to the shortest possible length, be located away from terminal units (i.e. not within the terminal zone) and shall be routed to be essentially straight (no bends). Misalignment of flexible duct (as typically occurs in practice) produces poor flow conditions which can create significant aerodynamic noise.

17.8.12 Duct and Plantroom Noise Breakout

All plant rooms shall be constructed such that attenuation of noise generated by the plant equipment to adjacent rooms will comply with the maximum internal levels laid out in Table 17.4.4.1-1. This also includes break-in from rooftop mounted equipment through the roof to spaces below.

Buffer zones of less-sensitive spaces shall be provided between plantrooms and noise-sensitive spaces wherever possible. Location of plantrooms immediately adjacent (either horizontally or vertically) to noise-sensitive spaces shall be avoided wherever possible.

Where acoustically critical spaces are located over or under a mechanical equipment room or other loud space (e.g. laboratory containing loud equipment), it may be necessary to install a floating floor in the space above and/or to install an resiliently-hung ceiling in the lower space.

Breakout noise from equipment housed in ceilings must also be considered. Where necessary to meet the internal design levels equipment located above ceiling may require acoustic enclosure or changing the ceiling to a sound-insulating ceiling. Equipment shall not be located above the ceiling for any space rated at NR30 or below.

17.8.13 Duct Crosstalk

Ductwork must also be designed to ensure crosstalk paths do not cause the partition to fail to meet the overall partition acoustic rating ($D_{nT,w}$). This may result in the necessity for additional bends, lining and or attenuators. Flexible ductwork shall not be used to cross any full height acoustically rated partition.

To control cross-transmission through the duct system, sound attenuation shall be provided in ducts between air outlets in adjacent rooms, the required attenuation depending on the degree of sound isolation for which the wall is designed.

Return air or relief air paths (e.g. to corridor) through acoustically-rated partitions shall be made via acoustically-attenuated transfer ducts. Door undercuts or door grilles shall not be relied upon for the return/relief air paths through any acoustically rated partition.

17.8.14 Hydraulic Services Noise Control

17.8.14.1.1 Noise Criteria for Hydraulic Services

Short-term noise ($L_{Aeq,30s}$) in occupied spaces from occasional but regular hydraulic sources (such as fluid noise from cisterns, waste and supply pipes) shall not exceed a noise level 5 dB above the maximum level recommended in Table 17.4.4.1-1 for the area.

More-stringent criteria for hydraulic noise may be required for music spaces (particularly recording studios), acoustic laboratories or other particularly noise sensitive spaces, to be determined on a case-by-case basis via consultation with the end users. Design for inaudibility may be required for some spaces.

These criteria apply under wastewater flows resulting from rainfall conditions up to the 63.2% Annual Exceedance Probability (i.e. approximately the 1 in 1 year) rainfall event for the project site.

17.8.15 General Design Considerations

Noise from hydraulic services shall be treated as required to meet the noise criteria.

Routing of non-permanently fluid filled pipework (e.g. drainage or wastewater pipes) through noise-sensitive (NR30 or below) spaces shall be avoided.

A combination of pipe lagging and/or airborne sound insulation (of the ceiling or vertical riser containing the pipework) shall be used to meet the noise criteria.

The use of lower-noise pipe systems may allow pipes to be installed without lagging provided that sufficient airborne sound insulation is provided via the ceiling/riser.

For permanently-fluid filled pipework, any trapped air bubbles within the pipework will significantly increase noise generation and measures must be included to prevent air bubbles from remaining within the pipework.

17.8.16 Vibration Isolation of Pipework

Pipework shall not be rigidly fixed to ceilings or walls of noise critical spaces (any spaces with a maximum services noise level of NR30 or below). Resilient pipe fixings shall be used where pipes run past noise-critical spaces.

A clear gap of at least 10 mm shall be provided between all pipework and wall/ceiling linings so that vibration from pipe flow does not result in direct structureborne noise radiation from room walls/ceilings.

17.8.17 Electrical Services Noise Control

The design sound levels in Table 17.4.4.1-1 shall be met by the combination of all building services noise including electrical services.

All regularly operating electrical equipment shall be provided with noise attenuation as required to meet the criteria in Table 17.4.4.1-1.

Emergency equipment such as backup generators, UPS systems etc shall meet the emergency criteria in Section 17.4.1.2.

Noise during testing of emergency equipment shall also comply with the criteria in Section 17.4.1.2.

Generators that will operate during non-emergency conditions (e.g. cogeneration plant) must comply with the criteria in Table 17.4.4.1-1 when operational. An isolated floating floor is likely to be necessary for any generator plantrooms that will be operational during non-emergency conditions.

Noise from lighting (and associated equipment such as dimmers) can be significant for low-noise spaces (NR30 and below).

Fluorescent lights shall not be used.

Incandescent and halogen luminaires are not permitted for use within any UQ project. LED fixtures may be acceptable with proper choice of fixture if all are fed by a common transformer located outside of the noise critical space. LED fixtures used in low-noise areas (NR30 or below) shall be convection-cooled rather than fan-cooled.

Exit signs in noise-critical spaces shall not contain relays, transformers or contactors and must not be fluorescent. Low-voltage LED fixtures are acceptable if fed by a transformer located outside of the noise-critical space.

Dimmers shall be low-noise dimmers (Sine wave or IBGT type) with a high-rise time specification to minimise noise. Thyristor dimmers are noisy and shall be avoided where possible.

17.8.18 Vertical Transport Services Noise Control

Noise from operation of the lift systems shall not exceed the building services noise limits specified in Table 17.4.4.1-1 when measuring in the space with other building services system operating normally. The noise levels shall be measured through one typical cycle of operation (i.e during a door opening and closing)

Door opening/closing noise when measured at 1.5 m from the floor and 1m from the lift door face shall not exceed 55 dB L_{Aeq} over the open/close cycle.

Lift noise, when measured at 1.5 m from the floor and 1m from the door face with the door closed, shall not exceed 45 dB L_{Aeq} at any time during the lift cycle.

Noise from lift sounders shall be volume adjustable and not exceed 60 dB L_{Amax} when measured at 1.5 m from the floor and 1m from the door face.

Noise levels within lift cars shall not exceed 50 dB L_{Aeq} during a typical lift cycle with the ventilation fans operating.

Vibration from lift operation shall be limited to the criteria in Section 17.4.9.1.

The noise level at 1.5 m from the lift machinery in the machine room shall not exceed 75 dB $L_{Aeq,1min}$ for machine rooms located on occupied floors and shall not exceed 85 dB $L_{Aeq,1min}$ for machine rooms located on plant room floors.

For machine room less lifts, the lift motor shall be vibration isolated and shall not exceed 65 dB $L_{Aeq,1min}$ measured at 1.5 m.

Noise from escalators, when measured at 1.5 m from the floor and 1.5 m away from the upper or lower landing, shall not exceed 55 dB $L_{Aeq,1min}$ at any time during the operational cycle.

Vibration from escalator operation shall be limited to the criteria given in Section 17.4.9.1.

17.8.19 Noise Control for Sources of Intermittent Noise

Automation of buildings building sustainability purposes increases the risk of annoyance if motorised blinds or louvres are frequently activated.

Noise from operation of all motorised blinds, louvres, and other miscellaneous internal equipment shall comply with a L_{Aeq} noise level no higher than 5 dB above the maximum recommended background noise level from Table 17.4.4.1-1 when measured over the period of operation of the equipment.

For particularly noise-sensitive spaces such as music spaces, acoustic laboratories etc additional control requirements may apply, to be determined on a case-by-case basis.

17.8.20 Noise Intrusion

17.8.20.1 Aircraft Noise

All buildings will be designed with aircraft noise as an acoustic consideration and buildings will comply with the internal noise criteria in Table 17.4.5.1-1below.

These maximum allowable internal noise levels from an aircraft flyover are generally based on the requirements of AS2021:2015

Table 17.4.5.1-1 Aircraft Noise Intrusion Requirements

Building type / activity	**Aircraft noise intrusion level, $L_{Amax,slow}$**
Open plan teaching area	50
Open plan breakout	<60
Lecture room small (less than 50 people)	45
Lecture room large (more than 50 people, speech reinforcement)	50
General teaching area (enclosed): -Seminar rooms -Tutorial rooms -Study room -Art studio -Computer teaching room	55
Teaching spaces for students with special	45

Building type / activity	Aircraft noise intrusion level, $L_{Amax,slow}$
hearing or communication needs	
Teaching laboratories Engineering workshops (teaching)	55
Research laboratories	55
Engineering laboratories Workshops (non-teaching)	<70
Specialist acoustic laboratories	To be determined on a case-by-case basis
Animal handling facilities	To be determined on a case-by-case basis
Audiology rooms	To be determined on a case-by-case basis
Music classrooms	55
Music practice ≤ 30m²	55
Music practice > 30m²	55
Music Ensemble room	35
Music performance or recital space (unamplified)	25
Music performance space (amplified)	30
Music recording studio – live room	30
Control room: -for recording	30
Control room / biobox (no recording)	50
Drama theatres	35
Drama studio	50
Dance studios	55
Multi-purpose halls	55
Gymnasium/ activity studios	<75
Swimming pool	<65
Library - general area	55
Library - reading areas	50
Atriums Foyers Entrance halls	60
Corridors	<60
Dining rooms, cafeterias	60
Boardrooms Meeting rooms	50
Conference rooms Seminar rooms	
Interview rooms Counselling rooms Videoconference rooms	55
Academic office areas – open plan	50
Academic offices – enclosed	50
Administrative and ancillary spaces: -First aid rooms -Staff rooms -Utility rooms	55
Kitchens Changing areas Toilets	<65

A concession of +10 dB(A) above the standard aircraft noise ingress criteria will apply to spaces that require natural ventilation. Where the standard criteria are exceeded, ventilation to affected rooms should be such that occupants can leave windows closed, if they so desire, while also meeting the ventilation requirements of the BCA NCC 2016.

17.8.21 Road Traffic Noise

Criteria for road traffic noise break-in have generally been adopted from the approach taken in the QLD Design Standards for DETE Facilities, converted to be expressed as a $L_{Aeq,1hr}$ noise level and is to be met for all learning and teaching spaces throughout the university campus:

The $L_{Aeq,1hr}$ noise level from road traffic intrusion during the loudest hour over which the building is operational shall not exceed the maximum internal background noise level value from Table 17.4.4.1-1.

A concession of +10 dB(A) above the standard road traffic ingress criteria will apply to spaces that require natural ventilation. Where the standard criteria are exceeded, ventilation to affected rooms shall be such that occupants can leave windows closed, if they so desire, while also meeting the ventilation requirements of the BCA NCC 2016.

17.8.22 Rail Traffic Noise

The criterion for road traffic noise break-in has been adopted from the general approach of the DTMR Development Affected By Environmental Emissions from Transport Policy.

Rail traffic noise (L_{Amax}, single event maximum) when measured or calculated in the centre of the room shall generally not exceed 5 dB above the maximum internal noise level value from Table 17.4.4.1-1.

For specialist spaces such as music spaces with a maximum internal noise level below 30 dB(A), a lower acceptable value for airborne rail noise intrusion of L_{max} BG+0 is considered appropriate.

Structureborne or groundborne noise levels from rail movements shall be controlled so as the $L_{Amax,slow}$ level does not exceed the maximum internal design level from Table 17.4.4.1-1.

Additional requirements may apply to specialist acoustic laboratories, music performance or music recording spaces for which rail noise may need to be inaudible, on a case-by-case basis.

17.8.23 Rain Noise

Given that UQ's facilities across QLD include both sub-tropical and near-tropical locations, rain noise is considered a potentially significant noise source which must be considered during the roof design to minimise disturbance.

A criterion of the Background noise level +5 dB is considered generally appropriate to control impacts from rain noise (measured as the L_{Aeq} during rainfall), under a design rainfall rate based on hourly rainfall corresponding to the 63.2% Annual Exceedance Probability (i.e. approximately the 1 in 1 year) rainfall event for the project site. (For Brisbane this corresponds to a rainfall rate of 35 mm/h).

This criterion of BG+5 from rainfall is to be applied to all spaces with a maximum internal noise limit from Table 17.4.4.1-1 of between 30 dB(A) and 50 dB(A).

In demonstrating compliance with this requirement, the rainfall characteristics (drop size distribution) shall be based on "Heavy" rainfall as defined in ISO 140-18:2006.

For specialist spaces such as music spaces with a maximum internal noise level below 30dB(A), a lower acceptable value for rainfall noise of BG+0 is considered appropriate.

Additional requirements may apply to music recording spaces for which rain noise may need to be inaudible, on a case-by-case basis.

For spaces with an internal noise limit from Table 17.4.4.1-1 above 50 dB(A), rain noise at the design rainfall rate shall not exceed 65 dB(A).

17.8.24 Wind Noise

Wind noise is typically generated through two mechanisms:

- Broadband aerodynamic noise generated from turbulent airflow on exposed surfaces, and/or
- Tonality of vortex shedding off façade components.

To minimise internal noise disturbance; external elements on the building such as façade details, louvres and shading devices shall not result in creaking, audible tones or whistling from thermal, structural or wind movements.

Vortex shedding shall be mitigated by avoiding:

- Apertures and exposed elements with sharp edges and dimensions less than 80mm.
- Regular arrays of grillages, meshes or similar elements.
- Small diameter wires or hollow sections with a diameter less than 50mm.
- Cavities which might be excited when excited by vortices generation by other elements.

For particularly sensitive buildings (e.g. music spaces, specialist acoustic laboratories) a more detailed assessment of wind noise risk may be required.

17.8.25 Sporting Noise and Other Campus-Based Noise Sources

Noise from sporting events on campus, and operational noise from other buildings on campus (e.g. noise from operation of gyms, sports halls, workshops and laboratories etc. shall not exceed 5 dB above the maximum internal noise level from Table 17.4.4.1-1 (when the intrusive noise is measured as the $L_{Aeq,15min}$ noise level in the centre of the room).

For some specialist spaces (e.g. music recording studios, acoustic laboratories) a lower criterion may be necessary, to be developed on a case by case basis in consultation with end users. In extreme circumstances this may require design for inaudibility.

17.8.26 Noise Egress

Consideration shall be given to noise egress from mechanical and electrical plant, from noisy activities within buildings and from operation of specialty equipment to reduce impacts on neighbouring educational and or residential receivers.

Space planning of buildings shall be conducted to locate noisy equipment or activities as far as possible from points of possible complaints. Installation in confined or restricted locations, such as courtyards and alleyways, shall be avoided wherever possible.

Where equipment is highly directional, wherever possible the equipment shall be oriented to avoid the direction of maximum sound radiation being oriented towards noise-sensitive receivers.

Noisy activities within buildings likely to give rise to noise egress issues include (but are not limited to) music, dance or drama classrooms involving playback of amplified music, operation of gymnasiums and sports halls, operation of workshops and engineering laboratories.

Examples of speciality equipment include noisy laboratory equipment such as wind and or shock tunnels and any associated sirens or warning tones.

Building envelopes shall be constructed to control noise in accordance with the quality objectives outlined within the EPP Noise 2019 to:

- Protect neighbouring residential receivers from noisy activities.
- Protect neighbouring educational receivers from noisy activities, and
- Protect internal spaces from neighbouring noisy facilities.

Construction Noise and Vibration

The following list provides a summary of the regulatory documents that inform, and are referred to, in this section:

- *Australian Standard* AS 2436:2010 – Guide to Noise and Vibration Control on Construction, Demolition and Maintenance Sites
- British Standard BS 7385.2 Evaluation and measurement for vibration in buildings. Part 2 – Guide to damage levels from groundborne vibration
- German Standard DIN 4150.3 2016 Vibration in buildings – Part 3: Effects on structures.
- DTMR Code of Practice for Transport Noise Management, Volume 2 – Construction Noise and Vibration

17.8.27

17.8.27 General

Construction noise and vibration is a necessary consequence of development activities on campus and is by its nature relatively short-term.

However, impacts to other buildings on campus or to external receivers may occur and therefore measures must be taken to reduce the extent of impacts so far as is reasonable and practicable.

AS 2436 provides recommendations for construction site noise and vibration reduction measures.

Planning of construction activities to minimise noise (e.g. by substituting quieter or lower-vibration construction methodologies, such as the use of bored piling in place of impact piling; or adjusting the layout of the construction compound to maximise the distance between plant and equipment and sensitive receivers) is an important part of controlling impacts. Where feasible and reasonable equipment and methodologies shall be selected so as to minimise noise.

Planning of the site layout and (where feasible) incorporating portable barriers shall be considered to separate noisy work processes from potentially exposed workers and receivers. In scheduling construction activities on campus, it may be necessary to build in respite periods as part of the construction programme e.g. to allow for vibration-sensitive equipment to operate, or to avoid impacts during particularly noise-sensitive times such as examinations. These periods will necessarily increase the construction programme and therefore the need for any respite periods shall be agreed between UQ and the project considering the balance between rapid completion of the project and managing impacts to the greater campus.

Works programming and timing in general shall be undertaken to minimise impacts on:

- Day to day operations
- Student accommodation
- Sensitive facilities and laboratories
- Neighbours
- Medical research or clinical facilities, and
- Exam periods

Further advice on work scheduling can be found in AS2436:2010 section 4.4.6.

17.9 Construction Noise Management Levels

QLD best practice for management of construction noise is contained in DTMR's Code of Practice Volume 2 (COPV2).

Construction noise targets have been adopted from the CoP V2 and are based on the pre-construction background noise level at the receiver (measured as the Rating Background Level, RBL) The lower limit represents a level at which adverse reaction to construction noise is likely. The upper limit represents a level at which significant adverse reaction is likely.

All reasonable and practicable measures shall be implemented to achieve the lower limit. If the lower limit is still exceeded after all reasonable and practicable measures are implemented, then no further action is required.

Exceedance of the upper limit requires immediate remedial action and determination of further mitigation measures (which may include administrative measures such as provision of respite periods).

Table 17.4.7.2-1 Noise Management Levels for Construction Noise

<table>
<tr><th colspan="2" rowspan="2">Work Period</th><th colspan="2">Airborne External Noise Level $L_{Aeq,15min}$</th></tr>
<tr><th>Lower Limit</th><th>Upper Limit</th></tr>
<tr><td colspan="2" rowspan="3">Standard Hours</td><td rowspan="3">RBL + 10</td><td>75 Where: RBL > 55</td></tr>
<tr><td>70 Where: 40 < RBL ≤ 55</td></tr>
<tr><td>65 Where: RBL ≤ 40</td></tr>
<tr><td rowspan="2">Non-standard hours</td><td>Evening</td><td rowspan="2">-</td><td rowspan="2">RBL + 5</td></tr>
<tr><td>Night-time</td></tr>
</table>

Note that outside of standard hours only the upper limit applies.

For non-residential receivers such as university buildings the acceptable construction noise level is set as an internal noise limit, which applies during the operational hours of the facility:

- $L_{Aeq,15min}$ 45 dB (internal)

If the building façade loss is unknown a value of 20 dB(A) shall be assumed for a typical sealed-façade university building and 10 dB(A) for any building with an operable façade.

Construction traffic shall not increase the pre-construction traffic noise level $L_{A10,1hr}$ by more than 3 dB.

17.9.1 Construction Vibration Requirements

Construction vibration targets have been adopted from the CoP V2. Note that the following criteria do not apply to the vibration sensitive equipment listed in Section 17.4.9.1. These equipment/facilities require consultation with an acoustic specialist to determine an applicable criterion.

All reasonable and practicable measures shall be implemented to achieve the lower limit. Exceedance of the upper limit requires immediate action and determination of further mitigation measures.

Table 17.4.7.3-1 – Human Comfort Vibration Criteria

<table>
<tr><th rowspan="2">Building</th><th rowspan="2">Period</th><th colspan="2">Resultant PPV, mm/s</th></tr>
<tr><th>Lower limit</th><th>Upper limit</th></tr>
<tr><td>Medical / clinical or health buildings</td><td>All</td><td rowspan="2">0.3</td><td rowspan="2">1</td></tr>
<tr><td>Educational Facilities for teaching purposes</td><td rowspan="3">While in Use</td></tr>
<tr><td>Libraries and places of worship</td><td rowspan="2">1</td><td rowspan="2">2</td></tr>
<tr><td>Office and retail areas</td></tr>
</table>

Criteria for building damage shall be based on the guidance of BS7385.2:1993 for general buildings and DIN 4150.3 2016 for buildings of heritage significance.

17.9.2 Audio Systems

17.9.2.1 Audio Reproduction

Audio reproduction systems shall meet the following:

- Signal to Noise Ratio (including crosstalk): 55 dB minimum.
- Total Harmonic Distortion: 1% maximum from 30 Hz to 15,000 Hz.
- Self-noise requirements:
  - free from objectionable distortion, rattles, or buzzes, employing as test signals several different samples of recorded music and microphones applied at each system input
  - hum and system noise shall be inaudible (inaudibility is here defined as more than 20 dB below background noise level at the nearest point in the listening plane) under normal operation

A typical small teaching space shall meet the following standard design criteria for audio reinforcement system:

Table 17.4.8.1-1 Audio Reproduction System Performance Requirements – Typical Small Teaching Space.

Criteria	Specification
SPL (Direct)	85 dB(A) +10 dB headroom across 85% of the listening plane
SPL Uniformity	±3 dB at 4 kHz across listening plane using pink noise source
Speech Intelligibility	0.65 STI (subject to acoustic design)
Frequency Response	100Hz -20 KHz ± 3dB

The audio reproduction system in larger teaching spaces such as lecture theatres shall be achieving the following performance:

Table 17.4.8.1-2 Audio Reproduction System Performance Requirements – Lecture Theatres and Large Teaching Spaces.

Criteria	Specification
SPL (Direct)	95 dB(C) + 6dB headroom to 95% of listening area
Consistency of SPL	+/- 3dB within 2 kHz octave band to 95% of the listening area.
Frequency Response	+/- 3dB 85Hz to 20kHz to 95% of the listening area
Speech Intelligibility	Minimum 0.65 STI to 95% of the audience areas
System Self Noise	System idle self-noise shall be at least 5dB below the unoccupied background noise condition with other building services off.

17.9.3 Amplification

Amplification shall meet the following performance requirements:

Parameter	Technical Specification
Electrical Headroom	Minimum of 3dB in addition to acoustic headroom.
Total Harmonic Distortion (at Full Power)	<0.02%

17.10 Hearing Augmentation

Hearing augmentation systems are required and shall be installed as specified under the National Construction Code (2017) Section D3.7.

There are various types of hearing augmentation systems available. The type currently used most commonly within Universities is infrared. Commonality with existing UQ systems shall be considered in selection of hearing augmentation systems on new projects where reasonable.

Where the required hearing augmentation system is installed, it shall be available to not less than 95% of the space, with a minimum number of receivers for the 16.7% of the capacity of the space. A minimum of 20% of these receivers shall include neck loops.

The infrared transmission wavelength (eg 870nm) and modulation frequencies (eg >2MHz) shall be selected to be immune to interference from artificial lighting and shall comply with IEC 61603-PART7, and all other national or international standards relating to IR transmission systems.

The transmission of audio signals across the IR system including modulator, radiator and receiver (but excluding headphones) shall achieve the following minimum requirements:

- Audio frequency response: 20 Hz – 20 kHz -3dB (all channels)
- Signal to Noise Ratio (A-weighted): > 80 dB(A)
- Total Harmonic Distortion: < 0.05% @ 1kHZ
- Dynamic Range: > 70dB

- Crosstalk rejection (adjacent channel): > 70dB

The system shall include:

- all necessary interconnections to the audio systems
- infra-red modulators and radiators sufficient to provide a minimum 40 dB signal to noise ratio under typical operational lighting levels
- any other necessary items, cables, etc. to provide a fully working system

17.10.1 Vibration

University buildings may contain vibration sensitive facilities which can be disrupted by even 'minimal' vibration. Care shall be taken to assess and mitigate vibration impacts for the following (but not limited to):

- Animal facilities / laboratories
- High/ Ultra high-resolution scanning / transmission electron microscopes
- Ion beam equipment
- Optical equipment
- Medical equipment including CT/ MRI/ MR-PET scanners

In addition, human comfort vibration impacts must be considered to avoid vibration disturbance to building occupants.

Vibration may also result in structureborne noise issues throughout a building at distances beyond which airborne noise is audible. Structureborne noise levels must comply with the design criteria for airborne noise presented in this Guideline. In general, control of vibration to prevent structureborne noise is more stringent than control of vibration to prevent human comfort impacts.

17.11 Design Targets for Vibration

The rms vibration level from vibration sources on campus (whether from plant/equipment, operation of the building including footfall vibration or from external vibration sources) must be designed to meet the applicable ASHRAE/VC curves based on the usages in the building as per Table 17.4.9.1-1 and Figure 17.4.9.1-1.

Where actual manufacturers data regarding the vibration sensitivity of individual items of equipment is known, vibration levels shall be assessed against the manufacturer's specification in place of the ASHRAE/VC curves.

Figure 17.4.9.1-1 ASHRAE/VC Curves

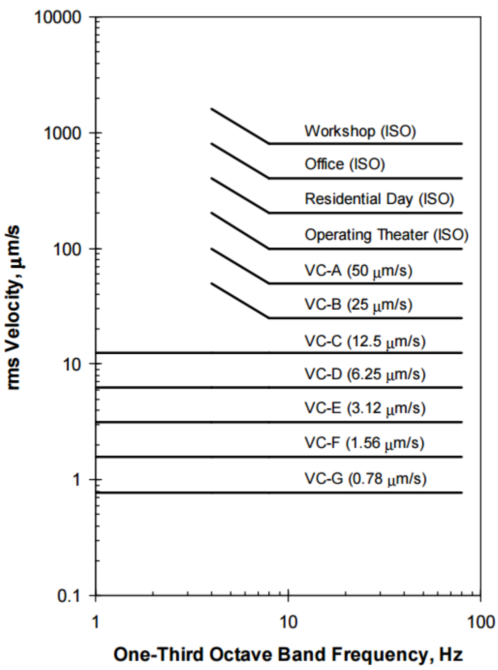


Table 17.4.9.1-1 ASHRAE/VC Curves for Vibration Sensitivity

Curve	Nominal Curve Vibration Level, rms (mm/s)	Usage
Workshop	0.8	Distinctly felt vibration. Appropriate for workshops and other non-sensitive areas
Office	0.4	Felt vibration. Appropriate for offices and teaching spaces
Residential (Day)	0.2	Barely felt vibration. Appropriate for computer equipment, probe test equipment and low power (to 40x) microscopes. Appropriate for residential areas (Day)
Residential (Night)	0.14	Just perceptible vibration. Suitable for sleep areas.
Operating Theatres	0.1	Vibration not perceptible. Suitable for critical work areas requiring concentration, bench microscopes up to 100x magnification and laboratory robots.
VC-A	0.05	Bench microscopes up to 400× magnification; optical and other precision balances; coordinate measuring machines; metrology laboratories; optical comparators; microelectronics manufacturing equipment; proximity and projection aligners, etc
VC-B	0.025	Microsurgery, eye surgery, neurosurgery; bench microscopes at magnification greater than 400×; optical equipment on isolation tables; microelectronic manufacturing equipment, such as inspection and lithography and inspection equipment (including steppers) to 3mm line widths
VC-C	0.0125	Electron microscopes up to 30 000× magnification; microtomes; magnetic resonance imagers; microelectronics manufacturing equipment, such as lithography and inspection equipment to 1mm detail size
VC-D	0.00625	Electron microscopes at magnification greater than 30 000×; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment, such as aligners, steppers, and other critical equipment for photolithography with line widths of 1/2 μm; includes electron beam systems
VC-E	0.00312	Uninsulated laser and optical research systems; microelectronics manufacturing equipment, such as aligners, steppers, and other critical equipment for photolithography with line widths of 1/4 μm; includes electron beam systems
VC-F	0.00156	Generally only used as a research criterion. Exceptionally sensitive equipment may require this level of vibration on a case-by-case basis.
VC-G	0.00078	Generally only used as a research criterion. Exceptionally sensitive equipment may require this level of vibration on a case-by-case basis.

17.11.1.1 Structural Design for Low Vibration

Structural design of buildings to meet low vibration levels requires input from a specialist engineer. The building foundations, spans and slab thickness may require significantly heavier constructions than for a typical building.

Even with careful structural design, it is sometimes only possible to achieve low-vibration levels for a slab-on-grade.

Input from a suitably qualified structural dynamics specialist engineer is required for any projects requiring vibration levels of VC-A or lower.

17.12 Equipment Isolation

All mechanical, hydraulic and electrical equipment must have sufficient vibration isolation to reduce transmission of vibration to the supporting floor such that vibration exceeding human comfort requirements does not occur within occupied areas, structureborne noise levels from equipment complies with the design background noise levels in Table 17.4.4.1-1 and (where applicable) vibration requirements for vibration-sensitive equipment are maintained.

17.12.1.1.1 Inertia Bases

Spring supported concrete inertia bases are necessary for the stability of most pumps, air compressors, and equipment with a high centre of gravity or with high unbalanced forces during normal operation (or starts and stops).

Inertia bases shall be at least 150mm thick (or 1/12th of the longest dimension of the base in plan, whichever is greater) and shall weigh 1-2x as much as the equipment they support (including associated piping, fluid and/or dynamic loads).

It is important that the requirements for inertia bases is coordinated with the structural engineer in order to ensure that total loads (i.e. equipment plus concrete inertia bases) are incorporated into their design.

The effects of floor stiffness and flexibility must be considered in the design of vibrational isolation devices.

17.12.1.1.2 Isolation Requirements for Equipment

Notwithstanding the designer/contractor's responsibility to comply with the vibration standards, the following guidance regarding building isolation is provided for reference.

All vibration isolation systems shall provide a minimum isolation efficiency of 95% at the dominant forcing frequency of the equipment being isolated.

The following TABLE and accompanying notes provide the minimum recommended vibration isolation requirements for equipment.

Table 17.4.9.3-1 Typical Equipment Isolation Requirements

Equipment Type		Equipment Location					
		Up to 6 m Floor Span			6 to 9m Floor Span		
	RPM	Base Type	Isolator Type	Min. Deflection mm	Base Type	Isolator Type	Min. Deflection mm
Generators	All	C	1	45	C	1	65
Chillers							
Bare compressors	All	C	2	20	C	2	45
Reciprocating	All	A	2	20	A	2	45
Centrifugal	All	A	2	20	A	2	45
Absorption	All	A	2	20	A	2	45
Pumps							
Closed coupled	All	C	1	20	C	1	20
Large inline	All	A	1	45	A	1	45
End suction and split case	All	C	1	20	C	1	45
Cooling Towers	Up to 300	A	2	90	A	2	90
	301 to 500	A	2	65	A	2	65
	> 500	A	2	20	A	2	20
Boilers	All	B	2	20	B	2	45
Axial Fans							
Up to 560 mm diameter	All	A	1	20	A	1	20
>610 mm diameter and up to 500 Pa	Up to 300	C	1	90	C	1	90
	300 to 500	B	1	45	C	1	65
	>500	B	1	45	B	1	45
Axial Fans > 501Pa	Up to 300	C	1	90	C	1	90

Equipment Type	RPM	Equipment Location: Up to 6 m Floor Span: Base Type	Isolator Type	Min. Deflection mm	6 to 9m Floor Span: Base Type	Isolator Type	Min. Deflection mm
	300 to 500	C	1	45	C	1	65
	> 500	C	1	45	C	1	45
Centrifugal fans							
Up to 560 mm diameter	All	B	1	20	B	1	20
> 610 mm and up to 30 kW	Up to 300	B	1	90	B	1	90
	300 to 500	B	1	45	B	1	65
	> 500	B	1	20	B	1	20
> 610 mm and 37 kW and over	Up to 300	C	1	90	C	1	90
	300 to 500	C	1	45	C	1	65
	> 500	C	1	45	C	1	45

Base Types

A: Direct fix onto isolation mounts

B: Structural base – rigid bases to maintain alignment of component parts or where equipment cannot be supported at individual locations.
Must be able to resist all start up and operational forces

C: Concrete inertia base

Vibration Isolator Type

- Type 1: Steel spring with rubber acoustical barrier such as, 8mm neoprene noise stop pads (See Section 6.3)
- Type 2 Restrained steel spring isolators with hold down bolts to limit vertical movement (See section 6.4)

Where the vibration isolator type is not specified in Table 17.4.9.3-1, the method of mounting machinery and the size, type and active material of the mountings shall be agreed between the machinery and isolator manufacturers, and shall comply with the vibration isolator efficiencies given above.

Vibration isolators shall be sized and selected with the proper loading to meet the specified deflection requirements. Vibration isolators shall be provided with means of adjustment of deflections to allow for unevenness in bases, unless they are located between prefabricated accurately parallel frames. The amount of adjustment for floor mounted isolators shall not be less than twice the permitted tolerance in the levelling of the floor. Levelling bolts or studs shall be provided with lock nuts.

Alternatively, the means of adjustment of deflections may be located between the supported machine and the isolators, or between the isolators and the basic supporting structure.

The lateral stiffness of vibration isolators shall be selected to suit the lateral isolation efficiency required without causing instability. For rotating machines with horizontal shafts, the horizontal stiffness perpendicular to the shaft shall not be less than the vertical, if floor mounted, and vice versa if side mounted.

Vibration isolation systems shall be selected to suit the environment in which the equipment is to be located. Components of the system located in the open air shall be weatherproof, non-rusting and be resistant to or protected from rodent and insect attack by choice of materials and design of components.

17.13 Services Isolation

Notwithstanding the designer/contractor's responsibility to comply with the vibration performance requirements, the following guidance regarding services isolation is provided for reference.

The first five service supports for ductwork on either side of a vibration source (typically a fan) shall be provided with vibration isolators.

Pipework shall incorporate flexible details and supports to minimise the transmission of pipe-borne noise to acoustically critical areas such as auditoria, lecture halls, music practice or performance spaces, acoustic laboratories and meeting rooms.

Where pipework is joined to vibration isolated equipment with flexible connections, for effective vibration isolation and not just alignment purposes, the first three service supports next to the equipment shall include vibration isolators giving minimum 80% efficiency at the fundamental forcing frequency of the equipment, or the efficiency required for similar service supports in the plant space if it is higher. The supports shall be designed to prevent movement of the connected pipe or duct due to static or dynamic forces exerted by the fluid weight or velocity.

Spring or combination spring and rubber hangers with 20 mm static deflection are required wherever ducts are attached to a space incorporating vibration sensitive equipment or has an NR30 or lower room criterion.

Where pipes are supported directly above, below or adjacent to a noise sensitive area of NR30 or below, they shall be vibration isolated with 25mm static deflection spring in series with neoprene hangers or equivalent at the supporting points up to a minimum of 10m from the boundary of the noise sensitive area.

All pipes of diameter 100mm or above shall be rested on appropriately sized neoprene inserts of minimum 8mm thick regardless of their locations.

All pipes inside plantrooms shall be vibration isolated with minimum 25mm static deflection springs in series with neoprene vibration hangers or equivalent.

An additional 10m length of pipes from the plantroom boundary walls shall be vibration isolated with 25mm static deflection spring in series with neoprene vibration hangers or equivalent.

Vibration isolated pipework shall be restrained using isolated sway braces, buffers and similar devices to prevent strain due to pipework movement during start up and shutdown of equipment.

Electrical connections to equipment mounted on vibration isolation bases shall be made through flexible conduit that changes direction by at least 90° in a minimum length of 25 conduit diameters. Mineral insulated cables shall be looped through at least 360° at 75 mm radius or double the permissible minimum radius whichever is larger.

Vibration isolation supporting points shall not interfere with other services and shall not be in touch with other pipe runs which may result in vibration transmission or otherwise adversely affect the noise levels of other areas.

Vibration isolation systems shall be selected to suit the environment in which the equipment is to be located. Components of the system located in the open air shall be weatherproof, non-rusting and be resistant to or protected from rodent and insect attack by choice of materials and design of components.

17.14 Submittal Requirements

After award of the contract, the Contractor shall submit the following information for review by the Principal's Acoustic Consultant, Architect and Principal. Prior to submission, the Contractor's Acoustic Consultant shall review the data for adequacy:

- Product Data: Submit a schedule of items to be provided along with specifications, installation proposals, and construction details (as applicable) including seal types and arrangements, jointing, and assembly of various members, anchorage, and supports.
- Laboratory test reports for airborne sound insulation of acoustically rated doors and a schedule of doors and their acoustic performance.
- Drawings showing the intended construction of the partitions, floors/ceilings and roofs to achieve airborne sound insulation ratings.
- Acoustic finishes/material samples and sound absorption data.
- Details relating to the proposed floating floor constructions (mount type and spacing, stiffness, deflection, supplier, etc.)
- Shop Drawings: Where applicable, provide details of products showing installation methods, thickness, fixings, arrangement of seals, etc. necessary to show intent and complete installation methods.
- All equipment noise level data indicating compliance with the specification, including fans, diffusers, grilles, AHUs, Chillers, Generator, etc.
- Calculations to demonstrate compliance with acoustic criteria
- Shop drawings showing details for duct layouts, duct lining, balancing dampers and external lagging requirements and attenuators
- Schedules and product data for attenuators
- Product data for duct lining, flexible pipe and duct connectors, and other accessories
- Schedule of vibration isolators selections, including calculations and product data showing minimum static deflection, plant operating speeds (where applicable), deflected height and actual loading.

17.14.1 Hold Points

The following minimum 'hold points' shall apply. For each hold point, the Contractor shall arrange for an inspection by the Contractor's Acoustic Consultant prior to proceeding and requesting an inspection by the Principal. The Principal shall be notified by the Contractor of each 'hold point' inspection date/time scheduled with a minimum of a 10-working day notice period for optional inspection.

- Installation of formwork prior to pouring of isolated floating floor slabs and isolated walls
- On completion of floating floor slabs prior to the installation of any partitioning.
- On completion of the framework for isolated partitions or ceilings

17.15 Abbreviations and Definitions

Acoustically Critical Space
Acoustically Critical Spaces are defined as those with a target noise level of NR 30 or less or spaces where the surrounding partitions are rated at Rw 50 or higher.

RBL
A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or nighttime period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey.

Sound Power
The sound power level (L_w) of a source is a measure of the total acoustic power radiated by a source. The sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located.

SPL
The sound pressure level (SPL) is the pressure level of a sound measured in decibels. The SPL varies as a function of the environment and distance from a source.

Decibel
The logarithmic scale used to measure sound and vibration levels.

Human hearing is not linear and involves hearing over a large range of sound pressures, which would be unwieldy if presented on a linear scale. Use of a logarithmic scale allows all sound levels to be expressed based on how loud they are relative to a reference sound (typically 20 µPa, which is the approximate human threshold of hearing). For sound in other media (e.g. underwater noise) a different reference level (1 µPa) is used instead.

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB

SSO
Switch Socket Outlet - Any outlet with a switch that requires a wall penetration.