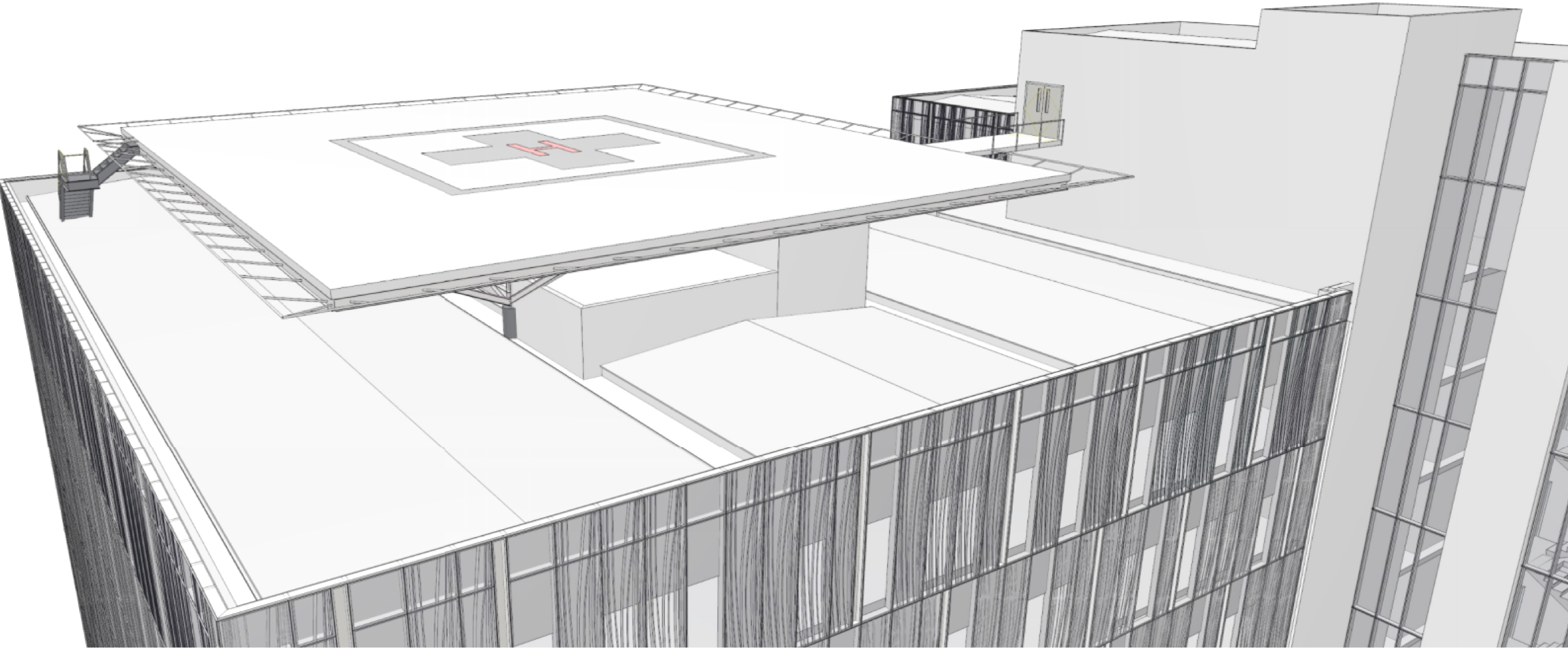
MARSHALL DAY Acoustics

Acute Services Building

Preliminary Acoustic Design Report

Rp 001 R02 2013473C

23 May 2014



MARSHALL DAY Acoustics

Level 3, 69 Cambridge Terrace
Christchurch 8140 New Zealand
T: +64 3 365 8455 F: +64 3 365 8477
www.marshallday.com

Project:	**ACUTE SERVICES BUILDING**
Prepared for:	**Warren And Mahoney** **PO Box 25086** **Christchurch 8144** **New Zealand**
Attention:	**Bill Gregory**
Report No.:	**Rp 001 R02 2013473**

Document control

Status:	Rev:	Comments	Date:	Author:	Reviewer:
Draft			14 Nov 2013	Stuart Camp	Jon Farren
Complete	01	Helipad sections updated	20 Dec 2013	Stuart Camp	
Complete	02	Summary, façade, genset	23 May 2014	Stuart Camp	Gary Walton

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

Whilst the proposed Acute Services Building for Christchurch Hospital presents a number of acoustic challenges, the design and layout of the building is such that many of these will be addressed using standard noise control design methodology. This report provides preliminary recommendations for dealing with these issues.

The project presents two key noise control challenges. First, the construction of a helipad on the roof of the west tower places stringent noise control demands on the façade of the building, necessitating secondary glazing to all noise-sensitive spaces.

Second, large diesel generators require careful consideration, to ensure compliance with relevant noise limits at site boundaries, and to avoid disturbance to other users of the site. The proposed location on level 3 of the east tower represents the best of a number of possible positions around the site.

2.0 INTRODUCTION

Marshall Day Acoustics has been engaged to provide acoustic design advice for the redevelopment of the Christchurch hospital precinct. This report provides preliminary acoustic design recommendations for the Acute Services Building.

The proposed building incorporates a large two-level podium, with two multi-level ward buildings on top, and provision for a third. A proposed helipad is located on top of the western ward tower.

This report outlines some of the key acoustic considerations and provides initial recommendations for initial costing purposes. The acoustic design will need to be developed in more detail during subsequent phases of the project and the acoustic requirements co-ordinated with other design requirements such as security and fire.

Acoustic terminology used throughout this report is explained in 0.

3.0 PRIMARY ACOUSTIC CONSIDERATIONS

There are several key acoustic issues, critical to the successful operation of a hospital facility. The most prominent acoustical aspects are highlighted below.

3.1 Privacy

Adequate privacy is essential within a hospital building, both in areas where confidentiality is required, and in wards where sleep is paramount. Achieving appropriate levels of privacy requires;

- **Sound insulation design:** Cost-efficient partition designs and over-ceiling details.
- **Adequate background masking noise:** This is often overlooked but is as important as sound insulation in achieving sufficient speech privacy. Mechanical services noise will generally provide masking noise in this building.
- **Suitable arrangement of rooms and activities:** Costly sound insulation treatment can often be avoided by consideration of acoustic issues at an early stage.

3.2 Mechanical Services Noise

Controlling mechanical services noise to appropriate levels is essential to avoid annoyance to users. However, as noted above, background noise levels must not be so low as to reduce privacy between spaces.

3.3 External Noise

Adequate control of external noise sources is desirable to minimise distraction and create a comfortable environment for patients and staff. On the Acute Services Building site, traffic noise will not be a significant issue, but control of helicopter noise will be.

Rain noise must also be considered when designing roof systems.

4.0 DESIGN CRITERIA

4.1 Internal Sound Environment

The recommended criteria for intermittent noise sources such as traffic and rain noise, building services noise and reverberation times are detailed in Table 1. These criteria are based on Marshall Day Acoustics' experience on similar projects and noise limits given in the Australian/New Zealand Standard AS/NZ 2107:2000 *"Acoustics - Recommended design sound levels and reverberation times for building interiors"*. We have also referenced the UK Department of Health guideline for acoustics in healthcare facilities (document HTM 08-01: Acoustics).

Table 1: Internal Sound Level Criteria

Space	External Noise[1,2] (dB L_{Aeq})	Building Services Sound[3] ($NC_{63\text{-}4k}$)[4,5]	Reverberation Time[6] (secs)
Wards, Meeting Rooms, Training Rooms	35	35	0.6
Operating Theatres, Consulting / Clinic Rooms, Treatment Rooms, Offices, Family Rooms, Interview Rooms, Staff Stations, Laboratories, Lobbies and Corridors at Wards	40	40	0.6
Reception and Waiting, Team Rooms, Main Lobby, Corridor	45	45	0.7
Toilets, En-suites, Change Rooms	45	45	n/a
Utility / Service Rooms, Stores, Gym, Kitchens	50	50	n/a
Any trafficable outdoor area at 1.5 metres from any noise source		55 dB (L_{Aeq})	

Notes:

1. These internal limits are applicable with windows closed.
2. Rain noise levels within the room should be no greater than 5 decibel higher than the external noise criteria, at a rainfall rate of 10 mm/hr.
3. The space criteria for continuous noise must make allowance for the cumulative effects of noise from all HVAC services including plant break-in noise, downduct noise and air-regenerated noise.
4. NC: Noise Criteria measured between and including the octave band centre frequencies from 63 Hz to 4 kHz. NC is a method used to assess background noise in a number of octave bands and assign a single number.

5. The design levels given are the maximum acceptable on-site. We recommend designing to 5 dB lower than these values to ensure compliance with these upper limits.
6. These values apply to the mid- frequency reverberation time (average of 500 Hz and 1 kHz octave bands), and are a general guide to assist in finish selection, not a definitive design requirement.

4.2 Helicopter Noise

In relation to the protection of sleep against noise from helicopters, recent studies in hospitals, including a comprehensive study in Brisbane, have concluded that an appropriate design criterion for helicopters within wards **is 65 dB L_{AFmax}**, and we recommend this criterion for this project.

This criterion is more lenient than would normally be recommended. From the studies, it appears that the staff and occupants of the hospital make some allowance for the emergency nature of the noise source.

4.3 Internal Sound Insulation

Given the importance of patient confidentiality and control of sleep disturbance within a hospital, it is essential that appropriate levels of speech privacy are achieved between adjacent sensitive spaces. The approach for enclosed spaces is to establish the level of speech privacy necessary for each situation and then determine the level of sound insulation required to achieve this criteria. Speech privacy between adjoining spaces is dependent upon a range of factors discussed in detail in Appendix B.

To assist with the preliminary design, Table 2 provides the recommended sound insulation performance (R_w rating) of partitions for this project. These ratings are given in terms of laboratory performance. Field performance will be discussed during detailed design, and will typically be 3-5 dB lower than these values.

Table 2: Sound Insulation Requirements

	Operating Theatre	Wards	Offices, Interview, Treatment	Waiting, Corridor	Toilets
Operating Theatre	R_w 60	n/a	R_w 60	R_w 60	Special[1]
Wards		R_w 45	R_w 50	R_w 45	Special[1]
Offices, Interview, Treatment			R_w 45	R_w 45	Special[1]
Waiting, Corridor					Special[1]
Toilets					

Notes:

1. Double stud toilet walls (Figure 9) to adjoining wards, offices, etc. No specific rating required between ensuite and associated single bed ward.

2. Double stud toilet walls to dedicated waiting areas. No specific requirements to corridors.

Colours shown in this table are reflected in marked up floor plans shown in section 6.0

The following notes should be read in conjunction with these recommendations:

1. These ratings are based on the use of a constant volume air conditioning system which provides a reliable source of masking noise. If a variable volume system is used, or the rooms do not have a continuous background noise source, these ratings may need to be increased,
2. Partitions requiring a laboratory sound insulation rating of R_w 40 or less can generally terminate at ceiling height, subject to appropriate ceiling construction (see section 7.0),
3. Partitions requiring a laboratory sound insulation rating of R_w 45 may terminate at ceiling height, but will require over-ceiling treatment such as indicated in Figure 2,
4. All partitions requiring a laboratory sound insulation rating of R_w 50 or greater should run full height (slab to slab), as indicated in Figure 1.
5. Double stud walls are required to reduce structure borne noise from one (service) room to the adjacent (sensitive) room, e.g. toilets backing onto a meeting room.

Figure 1: Example Full Height High Performance Partition Highlighting Dominant Flanking Paths

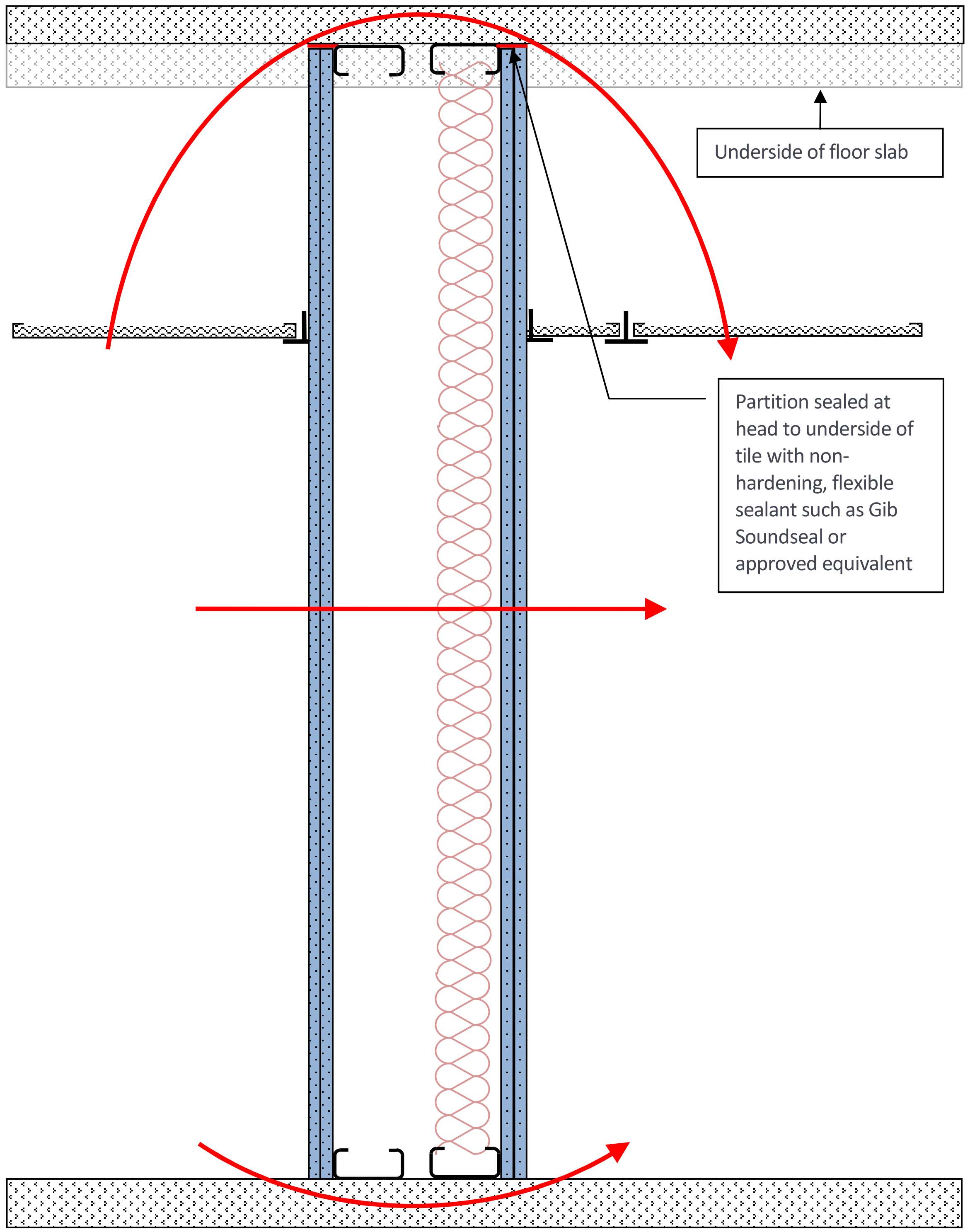
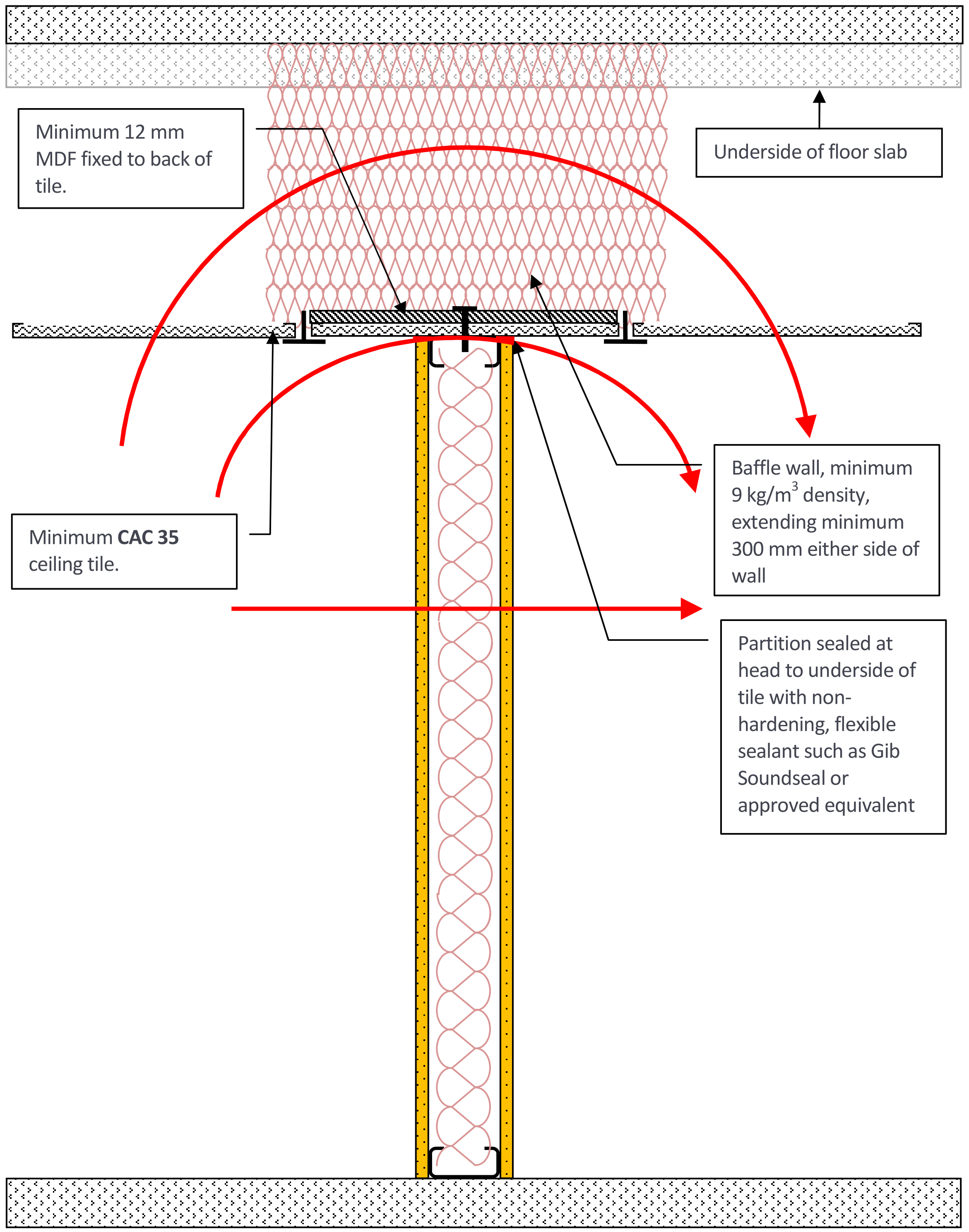


Figure 2: Example Ceiling Height Partition with over-ceiling treatment



4.4 Impact Sound Insulation

Areas with carpeted floors will generally provide sufficient impact sound insulation for this project without specific additional treatment.

Impact noise transmission will need to be considered where hard floor finishes are used above occupied rooms. Generally a rating of between IIC 50 and 55 will be required to all occupied rooms.

This level of impact insulation can be achieved using carpet or a high quality vinyl flooring, provided that;

- The selected vinyl must have some "resilience". Marshall Day Acoustics will need to be involved in the final product selection, and,
- All areas must be fitted with a good quality mineral fibre ceiling tile or a flush painted Gib ceiling. Lightweight ceiling tile systems will not be acceptable.

See section 6.3 for more detail on floor finishes, and section 7.0 for recommended ceiling systems.

4.5 Noise to Boundary

The Christchurch hospital site is zoned Special Purpose Hospital in the Christchurch City Plan. The land surrounding the hospital is zoned Conservation 2. Both of these zones are considered noise sensitive, and the relevant noise rules are listed as part of the Group 1 Zones.

In summary, the noise rules relevant to noise emanating from the building must comply with the following noise limits at the boundary of any other site, including Hagley Park.

Group 1 Zones—Noise Rules

	Development Standards	Critical Standards
Daytime 0700-2200	50 dB L_{Aeq}, 75 dB L_{AFmax}	57 dB L_{Aeq}, 85 dB L_{AFmax}
Night-time 2200-0700	41 dB L_{Aeq}, 65 dB L_{AFmax}	49 dB L_{Aeq}, 75 dB L_{AFmax}

Activities which comply with development noise standards are permitted. Activities which exceed development standards are discretionary with respect to noise, and activities which exceed the critical standards are non-complying.

5.0 BUILDING ENVELOPE CONSTRUCTION

The proposed Acute Services building is located in the north-west corner of the hospital site, and is therefore reasonably remote from traffic. As such, any modest sealed glazing system would comfortably address traffic noise issues.

The key design requirement for the building is therefore the control of helicopter noise.

To provide reliable noise data for helicopters on this site, we undertook noise measurements during mockup flights on 11 December 2013, using the Westpac Rescue Helicopter, operated by Garden City Helicopters.

During the tests, the helicopter "arrived at", and "departed from" the proposed helipad on the southernmost flight path, briefly hovering at the helipad location. We also undertook measurements of landings and takeoffs in Hagley Park, to allow us to refine predictions for the proposed Acute Services building.

5.1 External Noise Environment

Based on our mockup measurements, the noise level at the façade of hospital buildings from helicopter arrivals/departures will be;

- Acute Services Building 97 dB L_{AFmax}
- Women's Hospital 93 dB L_{AFmax}

These levels are very similar to our expectations based on other helicopter measurements which we have undertaken on other projects. However, the flypast noise which affects the Women's hospital does not have as much low frequency (bass) energy as a landing, and as such is better controlled by windows than we originally expected.

5.2 Women's Hospital

Our measurements show that during a southern approach and/or a southern departure, the noise level within individual rooms at the western end of the Women's hospital will be up to 60 dB L_{AFmax}. This is 5 dB lower than our recommended criterion of 65 dB L_{AFmax}. As such, we are satisfied that any adverse effects from helicopter noise within the Women's hospital will be minor.

5.3 Acute Services Building

To ensure compliance with our recommended criterion of 65 dB L_{AFmax}, we recommend allowing the following construction for the proposed Acute Services Building.

5.3.1 Roof

A concrete roof is essential for both towers. A lightweight roof is not an option, although a lightweight construction could be added above the concrete for waterproofing if required.

Acoustically, the construction of the helipad is not critical. However, during detailed design, we will need to investigate whether any form of vibration isolation is required, and this will depend to some degree on the type of helipad chosen.

A standard lightweight roof is acceptable over the podium plantroom.

5.3.2 Glazing

From the information provided to us, we understand that the original design intention was for a curtain-wall glazing system consisting of 6/12/8 thermally double glazed units. Parts of the curtain-wall will be fitted with an internal wall such that they are not visible within the building.

Secondary acoustic glazing will be required to all "noise-sensitive" areas of the **western tower**. We recommend one of two options for this;

- A secondary pane of glass at least 6 mm thick, and spaced at least 80 mm inside the curtain wall system, or,
- 50 mm glazing units offered by G James. These consist of one 8 mm thick pane and one 10 mm pane, separated by a 50 mm airgap. At least one of the panes of glass will need to be laminated to achieve the required noise reduction.

It may be possible to reduce the extent of the secondary glazing slightly during detailed design, but at this stage, we recommend allowing it to all four faces of the western tower.

Thermal double glazing, with 6/12/8 or thicker construction, is acceptable for the **eastern tower** (no secondary glazing required).

In the context of this recommendation, "noise-sensitive" shall mean all habitable areas. Secondary glazing need not be applied to storerooms or service areas, for example.

Where an internal wall is proposed inside the curtain-wall, this should be lined with either a single layer of 13 mm high density plasterboard (such as Gib Noiseline), or 36 mm Triboard as proposed. Thermal insulation must be fitted to the cavity of this system as currently shown on drawings.

Specific detailing will be required at the floor spandrels to achieve sufficient privacy between floors. This will be addressed during the detailed design.

5.3.3 Natural Ventilation

Our recommendations are made on the basis that the entire building will be fully air-conditioned, and that there will therefore not be any opening windows in noise-sensitive areas.

6.0 INTERNAL SOUND INSULATION

6.1 Partitions

Partition details have been developed with the range of sound insulation performances given in Table 2, taking into consideration the effect of all contributing building elements including walls, floor slab, ceiling system and mullion details.

It is important to note that consideration not only has to be given to the construction of the partition itself, but also its interaction with the ceiling system and the treatment of the ceiling cavity space.

Figure 5 to Figure 8 provide generic construction arrangement drawings for each of the sound insulation design criteria performances.

Recommended partition allowances have been provided for typical areas within the development. These sketches are colour coded by sound insulation performance summarised in Table 3.

The information provided is indicative only at this stage. Refined partition construction arrangements would also be developed in line with the confirmed speech privacy criteria and coordinated with other design requirements, e.g. security and fire.

Figure 3 and Figure 4 show indicative sound insulated partition types for a typical ward floor and a typical operating theatre area respectively. Note that partitions shown in black are part of the base architectural drawing (converted to gray scale) and have no specific acoustic rating.

Not all of the wall ratings appear on the marked up drawings.

Table 3: Sound Insulation Colour Coding

Colour	R_w Rating
Red	60
Yellow	55
Green	50
Blue	45
Purple	Toilet (double stud)

6.1.1 Partition Heights

Partitions are shown as full height at this stage, and this is preferred option acoustically. However, where there are areas with large ceiling voids, it may be more cost effective, and better for services reticulation, for walls to run to just above ceiling level. With this arrangement the over ceiling path would require careful consideration and for many partitions would depend on heavy plasterboard ceilings. Any ventilation openings would require ducted attenuation. This will be examined in more detail during the detailed design.

6.1.2 Floor construction below high performance walls

In areas where a sound insulation rating of at R_w 60 is recommended, horizontal transmission via the floor slab itself will limit the on-site performance of the partition.

To ensure this is not an issue, the concrete thickness of the floor slab shall be not less than 150 mm thick. This could be achieved using either a uniform slab of this thickness, or by providing localised thickening of the slab over a strip around 400 mm wide centred on the partition location.

Figure 3: Typical Ward Floor (part level 5), Indicative Partition Types

Colour	R_w Rating
Red	60
Orange	55
Green	50
Blue	45
Purple	Toilet (double stud)

Figure 4: Typical Operating Theatre Partition Types

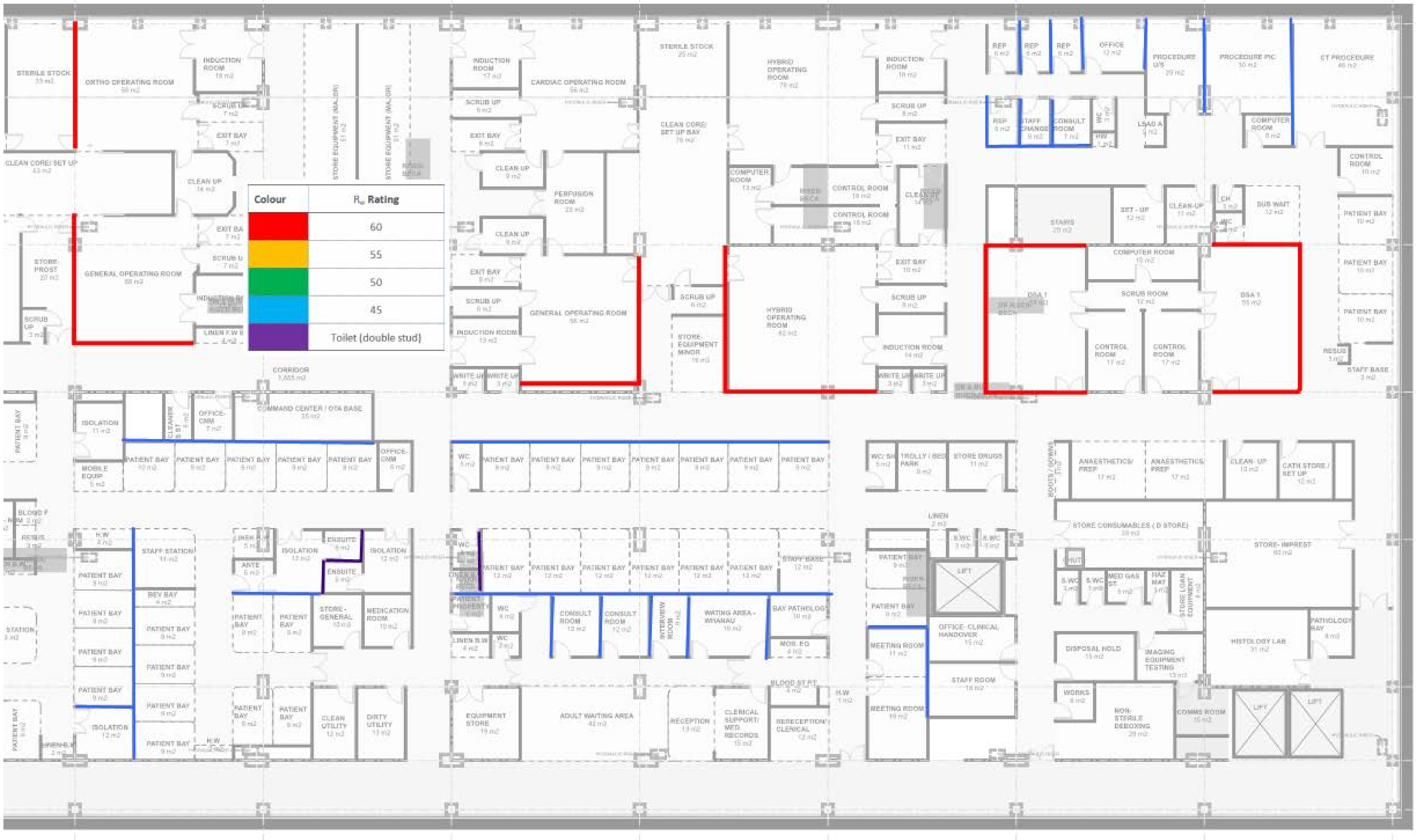


Figure 5: R_w 60 – Lightweight Partition

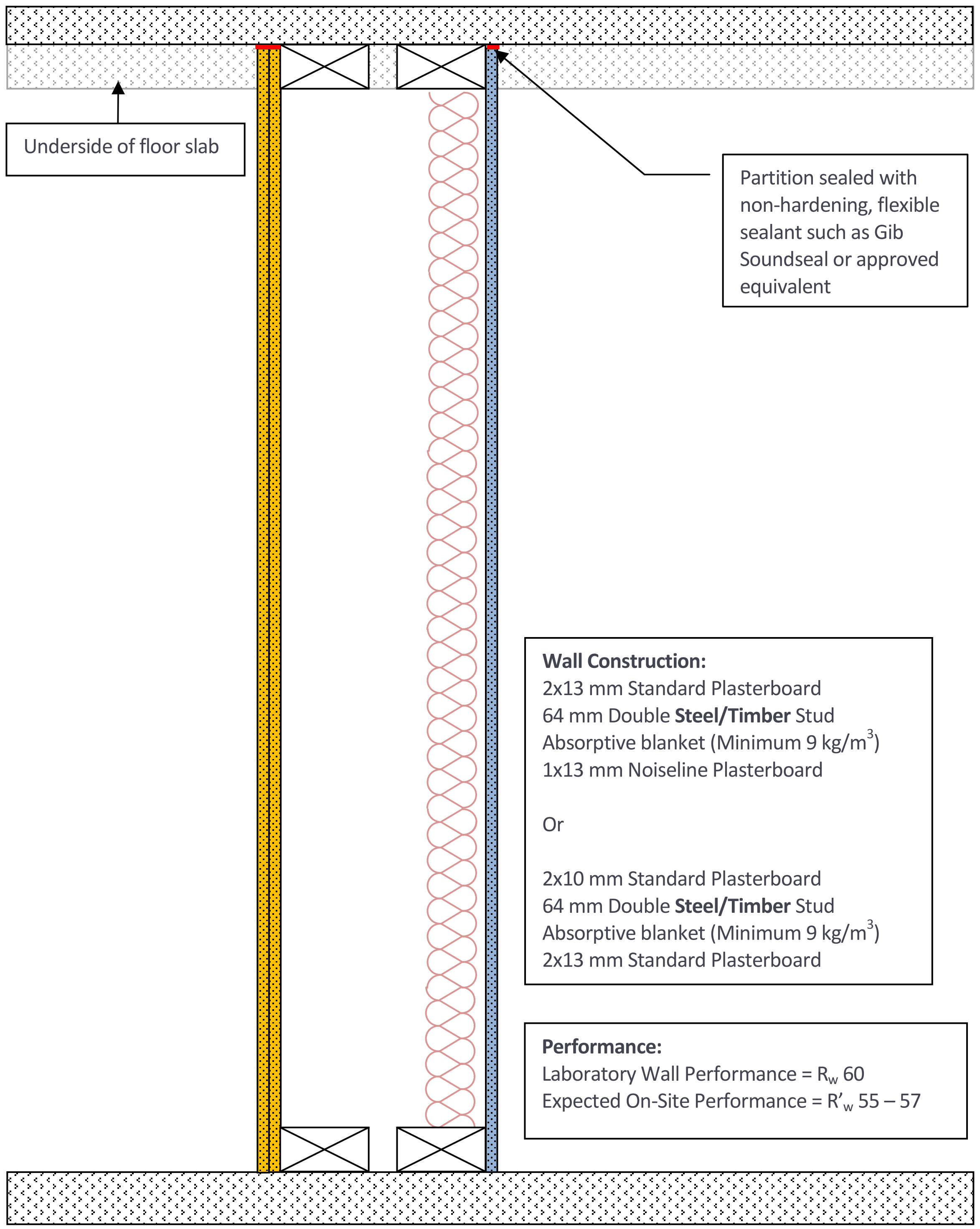


Figure 6: R_w 50 Partition – Double Stud Arrangement

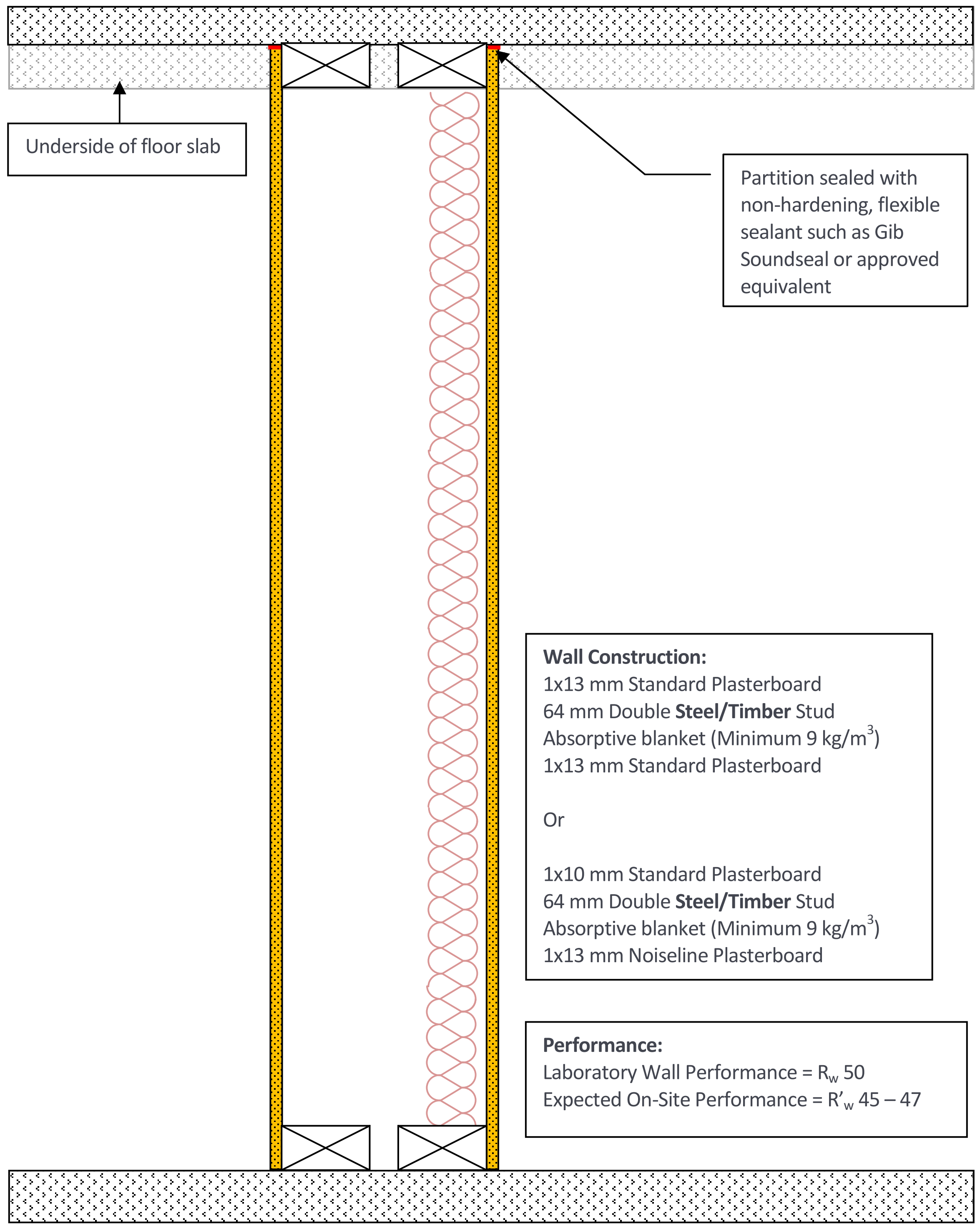


Figure 7: R_w 50 Partition – Staggered Stud Arrangement

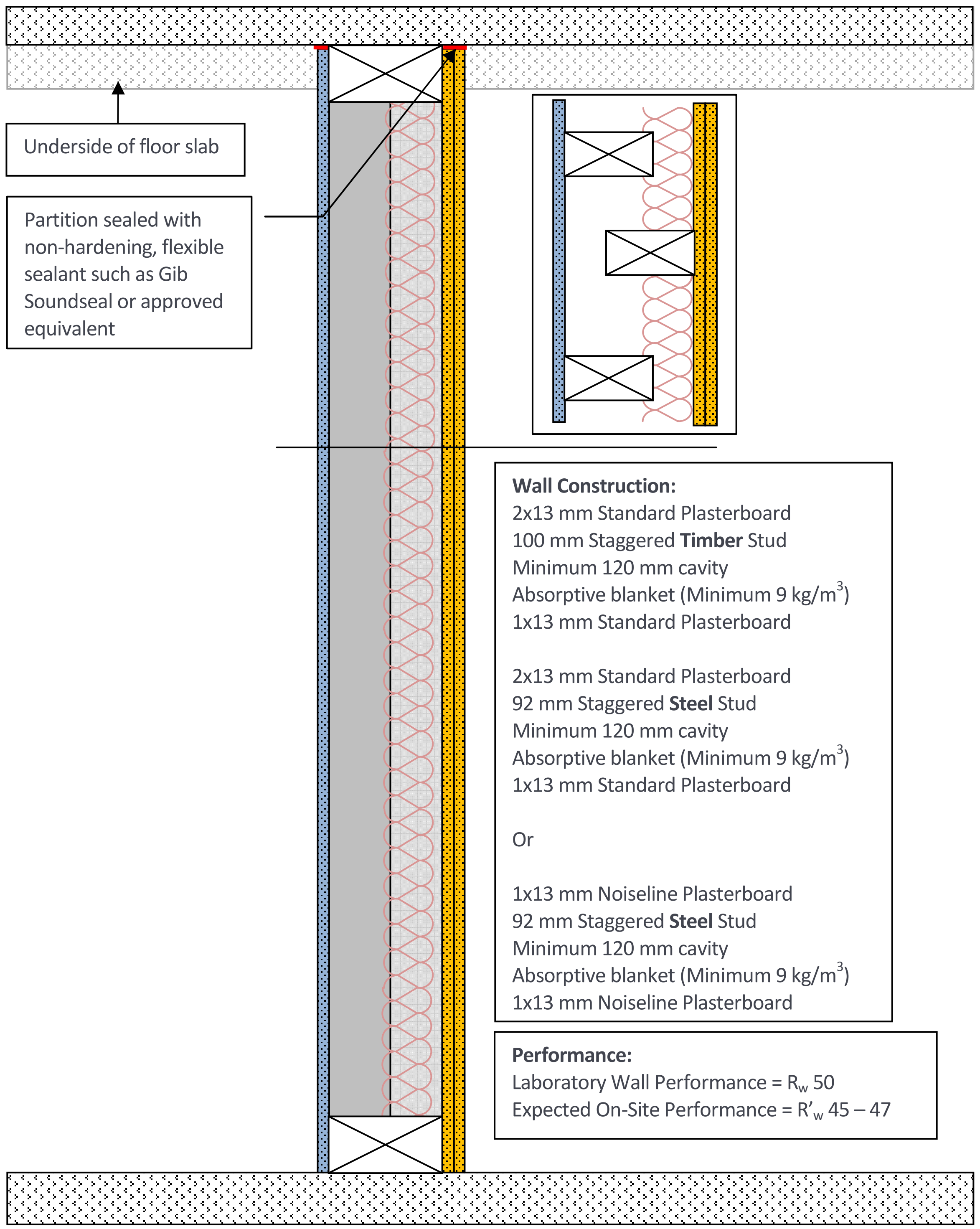


Figure 8: R_w 45 Partition – Full Height Arrangement

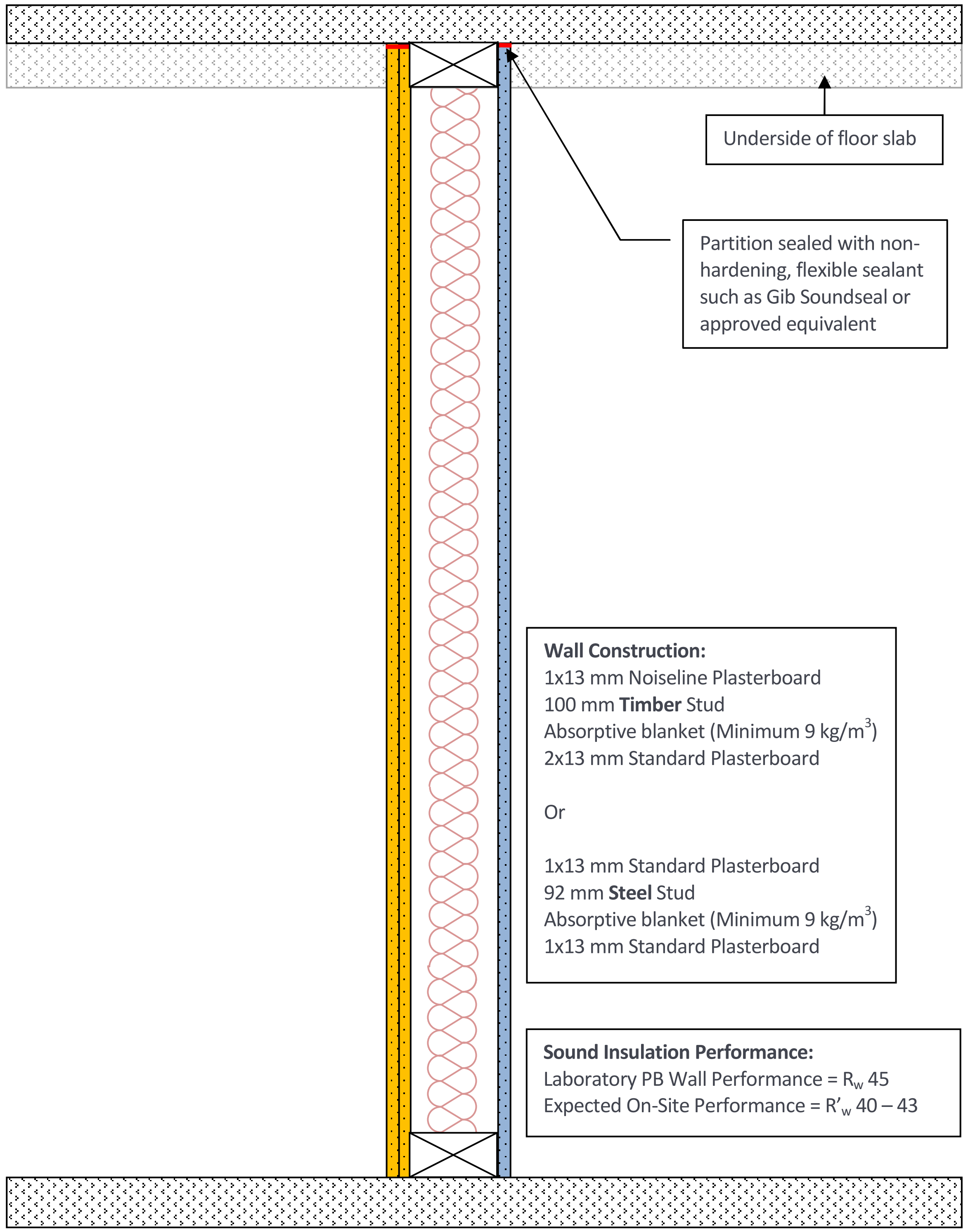
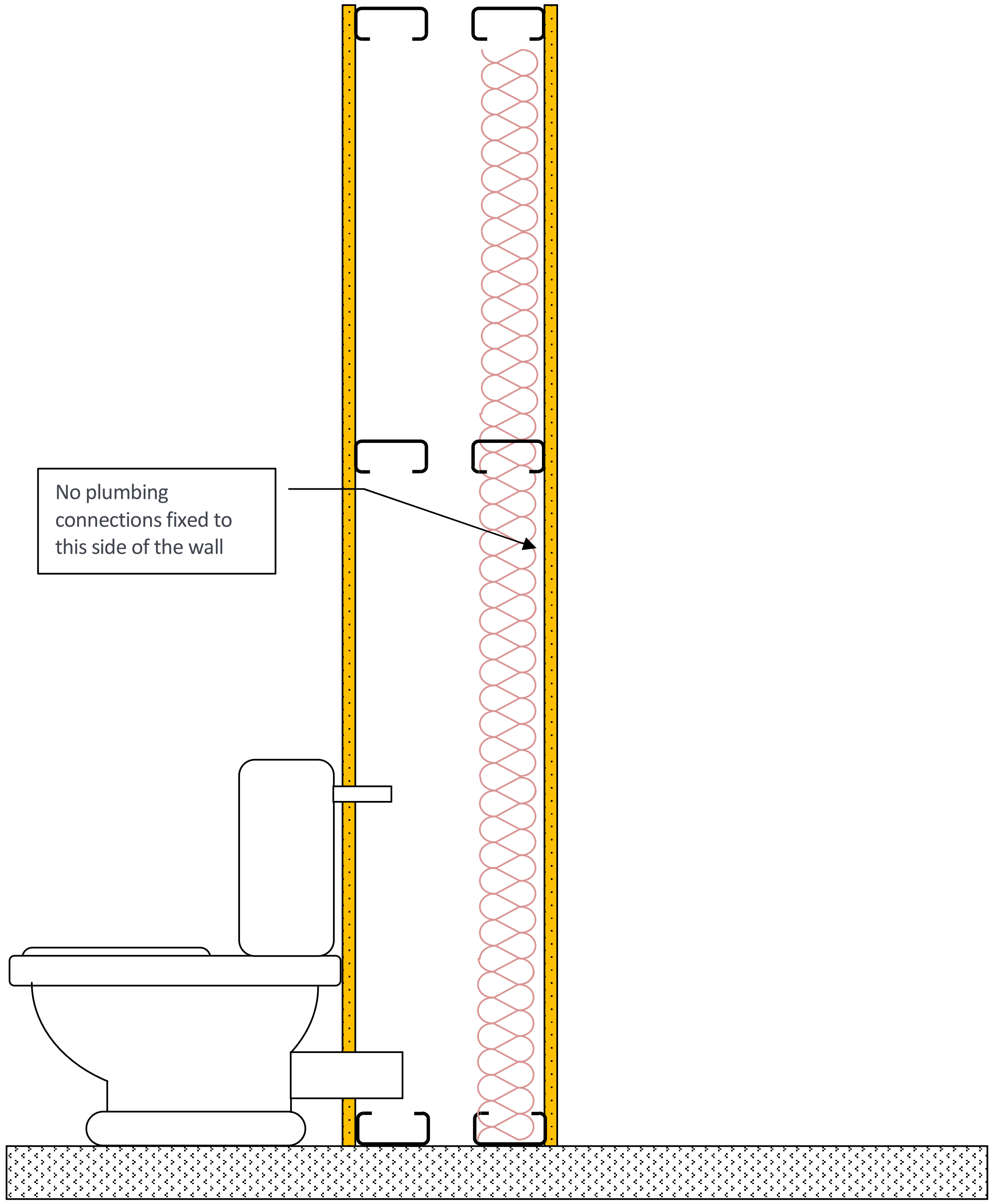


Figure 9: Toilet Partition: Adjacent To Sensitive Areas



Where toilets are adjacent to noise sensitive spaces a full height (to underside of slab), double stud walls shall be constructed around the toilets.

6.2 Doors

6.2.1 General

Where there is a door adjoining two adjacent spaces, the sound insulation performance will generally be limited to R_w 35 - 40 and the subsequent level of speech privacy generally limited to 'Normal Voice – Normal Privacy'.

We recommend that all doors within acoustically rated partitions are of solid core construction (minimum 24 kg/m^2) with compression seals to the head, threshold and jambs of the doors. Table 4 lists the recommended doors seals. Fully glazed doors should be constructed from minimum 10.38 mm laminate glass. Frameless glass doors should be avoided. Table 5 provides door construction recommendations based on the wall construction sound insulation performance.

Where privacy is paramount, we strongly recommend that a sound lock lobby is provided to the entrance, i.e. a double set of doors.

Table 4: Door Seals

Head and Jambs seals	Threshold Seals	Meeting Stile Seals
Lorient LE151BT, LE121BT Raven RP10, RP 24, RP 47, RP120 or RP150 Schlegel Aquamac 21, 124, or 836	Raven RP38	Raven RP71Si (Double Row), RP16 or RP85

Table 5: Door Constructions

Partition Rating	Door Description	Minimum Door Performance (R_w)	Suitable Proprietary Product
R_w 40	Solid core door of minimum mass 24 kg/m^2 with perimeter compression seals	30	N/A
R_w 45	Proprietary acoustic door of minimum mass 28 kg/m^2 with perimeter compression seals	37	Pacific Doors SPA 37-FD
R_w 50	Proprietary acoustic door of minimum mass 35 kg/m^2 with perimeter compression seals	40	Pacific Doors AD3000
R_w 55	Proprietary acoustic door of minimum mass 35 kg/m^2 with perimeter compression seals	43	Pacific Doors AD4000
R_w 60	Sound lock lobby is strongly recommended	2 x 30	N/A

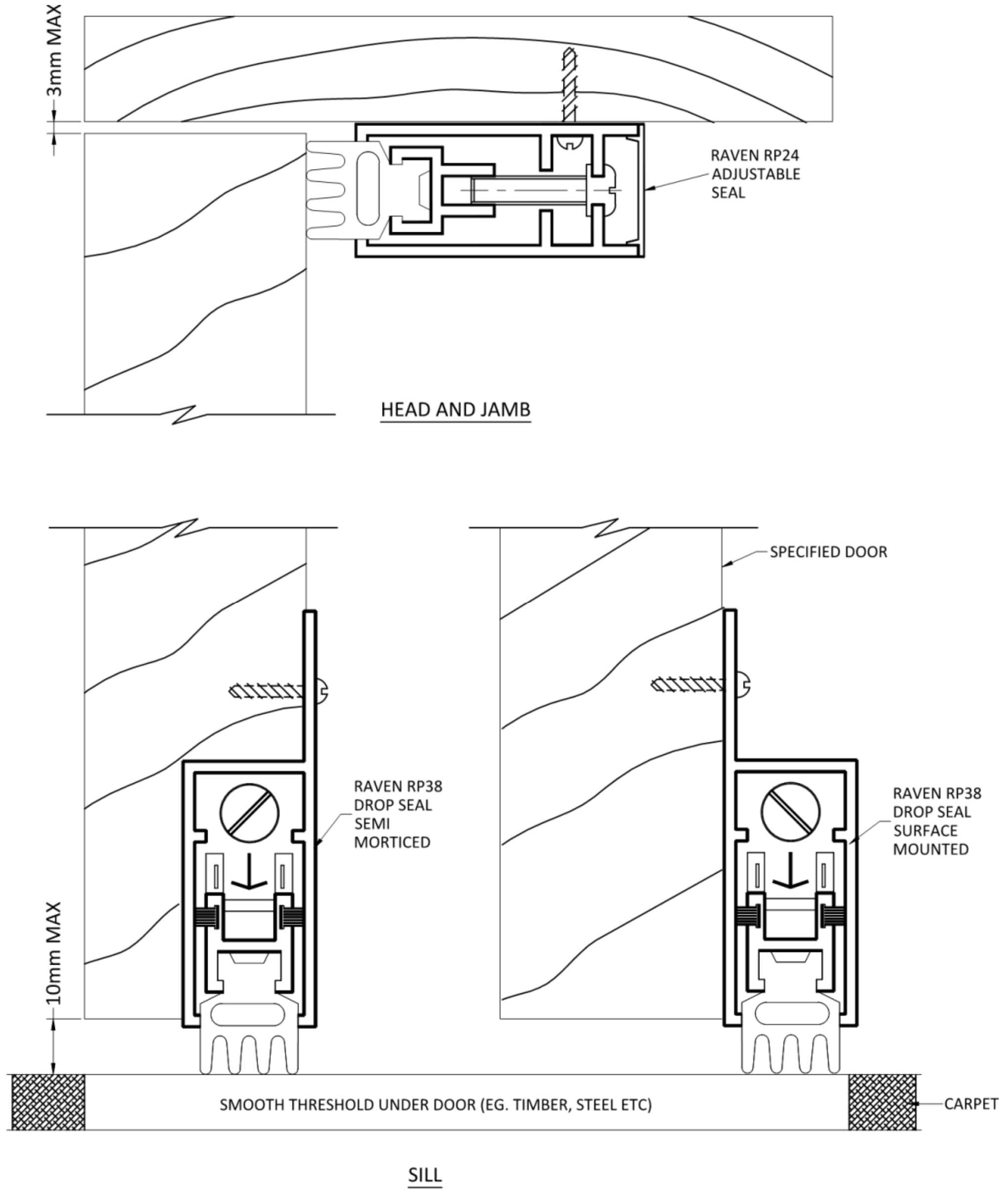
Careful consideration of door locations will often allow the privacy performance between rooms to be maintained at a reasonable standard. Doors should be located as far as practical from one another.

Table 6 provides a list of suitable proprietary door sets from a range of manufacturers.

Table 6: Proprietary Acoustic Doors

Manufacturer	Product	R_w	Distributor
Pacific Doors	AD4000	43	www.pacificdoors.co.nz
NZ Fire Doors	AC44	44	www.nzfiredoors.co.nz
NZ Fire Doors	AC46	46	www.nzfiredoors.co.nz
NAP Silentflo	80 mm Timber Door	43	www.cookeindustries.co.nz
NAP Silentflo	77 mm Timber Door	47	www.cookeindustries.co.nz
NAP Silentflo	77 mm Timber Door	48	www.cookeindustries.co.nz

Figure 10: Typical Door Seal Details



6.2.2 Sliding Doors

It is very difficult to achieve a reasonable acoustic seal around sliders, and the acoustic privacy in the vicinity of such doors will be poor.

In general, where speech privacy is required, we recommend hinged doors. Alternatively, sound rated (proprietary) sliding doors could be used, such as Cavity Sliders SoundStop doors (cavity sliding door as opposed to standard sliding door).

In multi-bed wards, where there is provision to close off one space from the next by use of a stacking sliding door arrangement, the overall privacy will at best be moderate. Seals will need to be provided in these situations, and specific detailing will be required for the stub walls and head details around them.

6.2.3 Operable Walls

The use of an operable wall limits the sound insulation that can be achieved between rooms and correspondingly, the best speech privacy rating that would likely be achieved is 'normal voice – normal privacy' (NV-NP).

We recommend that operable walls are only used when the flexible use of the space is more important than the privacy between the two spaces when the wall is closed.

In addition, operable walls should be sourced from a reputable supplier, with a minimum laboratory performance of R_w 47. This is likely to provide an on-site installed performance of R'_w 35 - 37.

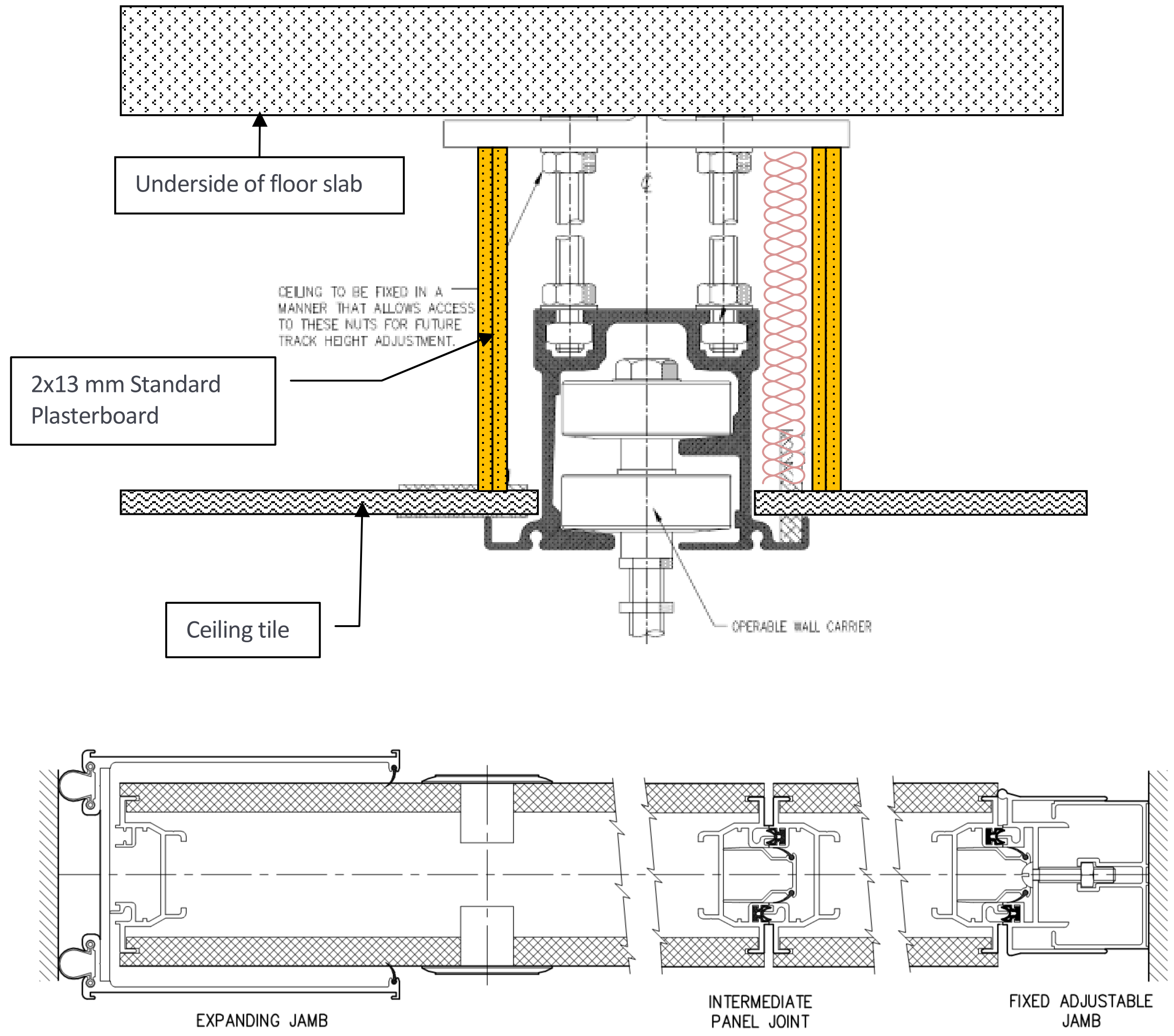
It is important that the operable wall is well sealed and includes an expandable end to accommodate minor variations in set out. Balloon compression seals should be avoided.

Figure 11 shows the recommended ceiling detail arrangement and adjustable compression seal arrangements for operable walls. Table 7 provides a range of suitable operable walls which would achieve the recommended design criteria.

Table 7: Operable Walls

Manufacturer	Product	R_w	Distributor
Hufcor	Series 8000	48	www.hufcor.co.nz
Hufcor	Series 8000	49	www.hufcor.co.nz
Hufcor	Series 8000	51	www.hufcor.co.nz
Hufcor	Series 5000	49	www.hufcor.co.nz
Lotus	Series 100 (minimum 37 kg/m^2)	49	www.trans-space.co.nz
Trans-Space	SpaceSeal 500 Series	47	www.trans-space.co.nz
Dorma	Variflex	49	www.dorma.co.nz

Figure 11: Operable Wall Details



6.3 Floors

In order to achieve the recommended sound and impact sound insulation design criteria, consideration needs to be given to the floor finish surface, the slab arrangement and the ceiling construction. In general, we recommend the following constructions for this project. Some of these recommendations are noted in other sections of this report, but are repeated here for clarity.

Floor slab: minimum 150 mm equivalent thickness of solid concrete. Where a thinner equivalent thickness is proposed then a thickening at the line of critical partitions will be required. See Section 6.1.2.

Floor Finishes: Carpet or a resilient floor finish or underlay (minimum ΔL_w 16.

Ceilings: Good quality mineral fibre ceiling tile with a rating of not less than NRC 0.55 and CAC 35. Alternatively, a solid Gib or fibrous plaster ceiling may be used, but a sound absorbent lining would need to be added below this to achieve suitable room acoustics (see section 7.0).

In some adjacent sensitive areas horizontal transmission may control the on-site performance requirements and a higher performance acoustic floor finish may be required.

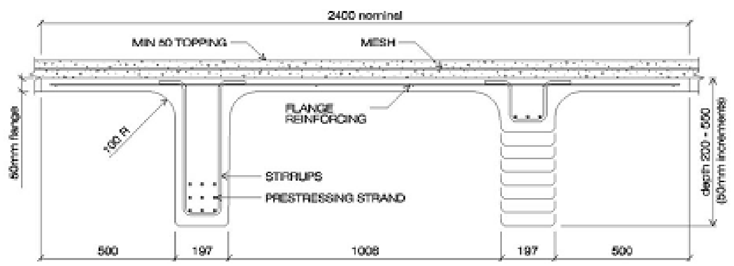
Figure 12 provides a range of floor slab arrangements and the method for calculating the equivalent thickness. Table 8 outlines a suitable range of products.

Table 8: Floor Finish Products

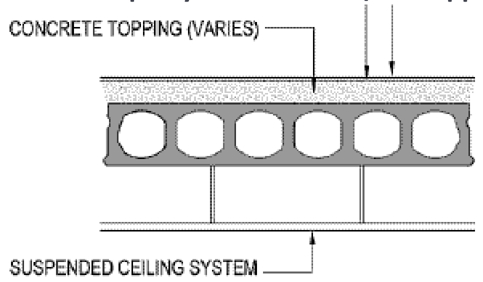
Manufacturer	Product	ΔL_w	Distributor
Vinyl Finishes			
Tarkett	Optima Acoustic	17 dB	www.jacobsens.co.nz
Marmoleum	Marmoleum Decibel	17 dB	www.forbo.co.nz
Rubber Finishes			
Pirelli	Activa Matrix	17 dB	www.rubberflooring.co.nz
Noraplan	Mega Acoustic	17 dB	www.jacobsens.co.nz
Carpet Finishes			
Infini	Syncopation Carpet	23 dB	www.inzide.co.nz
Godfrey Hirst	Statron Collection 18 oz Carpet	24 dB	www.godfreyhirst.co.nz
Stone/Tiled Finishes			
Mapei	Mapesonic CR (2mm) + Eco 350 adhesive	17 dB	www.mapei.co.nz
Ardex	DS40 under ceramic tiles	16 dB	www.ardex.co.nz

Figure 12: Masonry Floors Equivalent Thickness

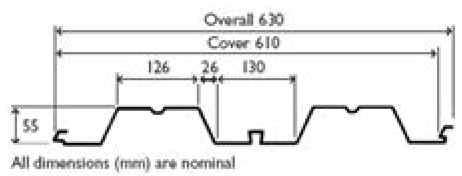
SINGLE T / DOUBLE-T: EqT=Flange + Topping



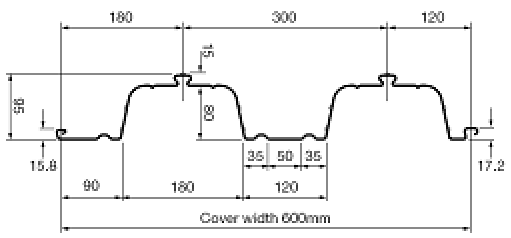
DYCORE: EqT=Dycore Thickness/2 + Topping



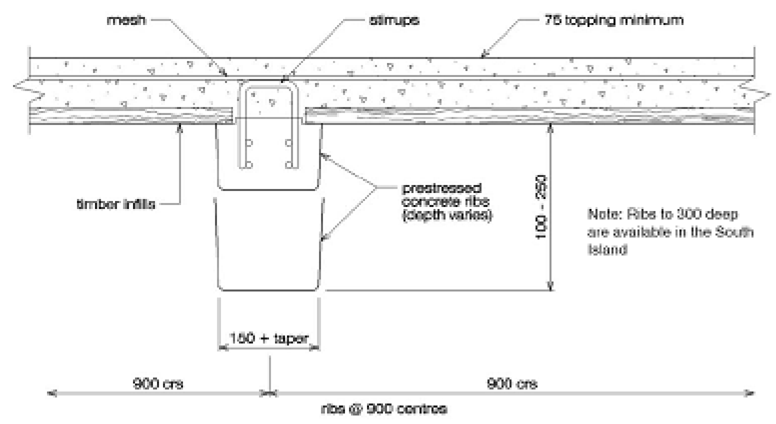
DIMOND HIBOND SLAB: EqT=Total Thickness – 55 + 25



COMFLOR 80: EqT=Total Thickness-80+32



STAHLTON/ RIB & INFILL: EqT=Topping Thickness



EqT=Equivalent thickness of solid concrete

Special attention needs to be given to plantroom floor slab constructions and junction details with the external wall to minimise flanking transmission.

Consideration should also has to be given to the liveliness of the floor slab, i.e. the trampoline effect of the slab. Coordination between the structural and acoustic engineers will be required to ensure a sufficiently damped system is provided. The resonant frequency of the floor should be no less than 8Hz.

7.0 ROOM ACOUSTICS

Room finishes and furnishings control whether the room sounds noisy and reverberant, with sound reflected off hard surfaces, or relatively quiet with sound being absorbed by sound absorbing materials. This behaviour can be quantified by the reverberation time of the room.

In many situations in a hospital, the medical requirements will dictate the room surfaces and hence it is extremely difficult to control the reverberation time. However the aural comfort of users, avoiding hard noisy finishes, and using carpet except where clinically inappropriate has been used successfully in other hospitals.

We are increasingly receiving feedback from hospital staff about "noisy" spaces such as operating theatres, and we therefore recommend aiming to incorporate sound absorptive ceiling systems wherever possible. There are now several hygienic ceiling tile systems which may be acceptable in many areas.

We recommend the use of ceiling tiles with a rating of not less than NRC 0.55 and CAC 35 wherever possible. During the detailed design, we will work with the other project consultants to maximise the use of sound absorptive ceiling systems, within the budget constraints of the project.

Note that the CAC requirement for ceiling tiles is an important element of the chosen ceiling tile system, to assist in achieving partition performance requirements.

Where Gib ceilings are required, alternative sound absorbent surface finishes may need to be considered.

8.0 BUILDING SERVICES CONSIDERATIONS

The following sections outline recommended design considerations for a range of mechanical elements that can significantly influence building services noise levels

8.1 AHU Discharge Velocities

Each air handling unit should include a straight length of ductwork on its discharge prior to any bend or other duct obstacle (damper, attenuator etc.). As an initial guide, the minimum length of straight ductwork required is given as a function of AHU discharge velocity as follows. Specific acoustic treatment may be required if these lengths of ductwork cannot be achieved.

Table 9: AHU Ductwork

	AHU Discharge Velocity (m/s)			
	14	12	10	8
Minimum length straight duct	5D	4D	3D	2D

`D' stands for "duct diameter" which should be taken to be the diagonal dimension in rectangular ducts. The discharge velocity of an AHU shall be determined by the area enclosed by the fan scroll and the cut off.

Air Handling Units supplying areas with design noise criteria of NC 30 or less should have a discharge velocity not greater than 10 m/s.

8.2 Fans

We recommend that 2 pole fans are avoided as our experience indicates these fans can be particularly tonal. There is a high risk of structure borne noise transmission which may cause issues in other locations.

8.3 Fan Coil Units

The noise from fan coil units (if used) and specific treatment will depend on the specific units selected and the duty of the fan.

The following recommendations are intended to assist with selection and costing:

- All air conditioning units operate at low or medium speed, i.e. no high speed fan selections
- All plenums to be internally lined (minimum 25 mm thick linings)
- All dampers shall have a maximum pressure drop of 10 Pa
- All flexible ductwork to be of ‘acoustic’ (perforated, insulated) type, e.g. Westiflex Acoustic, Temperzone Insulated Flexiduct or Holyoake Insulated Spiroflex
- All flexible ductwork runs are of minimum 1.5m length
- All return air grilles to be fitted with lined cushion head (minimum 25 mm thick linings) facing away from the air conditioning unit
- All diffusers to be fitted with lined cushion head (minimum 25 mm thick linings)
- Minimum 2 m separation between the air conditioning unit and any return air grille
- All FCUs must be suitably vibration isolated from the building structure

8.4 Hospital Specific Design Issues

One acoustic challenge with the mechanical services design for hospitals arises with operating theatres. Typically, these spaces require extremely high levels of air filtration, coupled with high air flow rates, and very low air velocities.

To ensure that the design noise levels are achieved in these areas, special attention will be required to duct design and layout. In particular, the design must avoid bends close to other duct obstructions, and incorporate internal duct lining close to the diffusers. Duct velocities should ideally be kept below the design values given in 8.6 if at all possible.

8.5 Transitions

Duct transitions should be designed to have a total included angle of not greater than 25^{o}.

8.6 Duct Velocities

Air conditioning ductwork shall be sized to ensure that the following air velocities are not exceeded.

Table 10: Maximum Duct Velocities

	Main Riser	Main Duct	Branch Duct	Run-out Duct	
				Metal Duct	Flexible duct
NC 45	15.0	10.0	7.5	6.0	4.5
NC 40	13.0	8.5	6.5	5.0	3.5
NC 35	11.0	7.5	5.5	4.0	3.0

Duct velocities for areas with design criteria greater than NC 45 will generally be determined by factors other than noise. As such, the noise from these systems will need to be analysed on a case by case basis.

The following definitions apply for the purposes of these recommendations:

Main Riser
- ducts not in the air-conditioned space
- ducts in plantrooms or masonry risers which are followed by main ducts

Main Duct
- ducts within the air-conditioned space followed by at least one lined bend and run-out ducting, or at least 3 duct diameters of branch duct and run-out ducting

Branch Duct
- all ducts connected directly to run-out ducting

Run-Out Duct
- all ducts within 5 duct diameters of a grille or diffuser

Velocity
- The duct velocity referred to in the table is calculated by dividing the air quantity by the cross-sectional area of the duct.

8.7 Dampers

Splitter blade dampers are preferable to opposed blade dampers.

Dampers directly behind grilles can create a significant amount of noise and should be avoided in all areas if possible. If they are installed, they should not be used as the primary means of balancing. Balancing dampers should be installed at any duct take-off to provide proportional balancing between each duct run. The dampers at each diffuser should only be used for the fine-tuning between diffusers in each duct. Ductwork must be designed to ensure that the pressure drop across any diffuser mounted damper does not exceed 15 Pascals.

8.8 Internal Duct Lining

Internal duct lining will not generally be required, although some lining may be specified in lieu of attenuators at the detailed design stage.

8.9 Attenuators

The degree of duct attenuation required depends upon the air handling unit Sound Power Level, the degree of internal duct lining, and the design noise criteria for the conditioned space. As a guide, the ductwork design should allow for packaged rectangular attenuators on both the supply air and return air ductwork.

Attenuators should be located either within plantrooms or masonry ducts wherever possible.

The cross sectional dimensions of attenuators shall be sized to give a face velocity of either 7.5 m/s or the recommended duct velocity, whichever is lesser.

The number of attenuators to be allowed in each system and the required length of each attenuator should be as follows:

Table 11: Attenuator Requirements

Design Criteria	Number of attenuators	Length of each attenuator
NC 45	1	1200 mm
NC 40	1	1800 mm
NC 35	1	2400 mm

8.10 Crosstalk Attenuators

The degree of crosstalk attenuation required depends upon the level of speech privacy required between adjacent spaces. However, preliminary allowance should be made for 900 mm long 43 % open area attenuators for crosstalk attenuators where one duct serves adjoining spaces separated by a partition with a sound insulation rating of R_w 45 or greater.

8.11 Diffusers & Grilles

During the detailed design, we will prepare performance specifications for all diffusers and grilles.

At this stage, the recommended run-out duct velocities given in Section 8.6 should be used as throat velocities for all diffusers and grilles. Manufacturers' noise ratings should not be used as a selection guide.

Linear slot diffusers and lighting air diffusers shall be selected with a throat velocity of not greater than 1.5 m/s.

8.12 Toilet and Kitchen Extract Systems

As toilets are not acoustically critical spaces, MDA do not typically review these systems in detail (for internal noise levels).

However, our general recommendation is that all extract fans have a 2D unpodded attenuator attached to the fan and the ductwork incorporates at least one change in direction (90^o bend) before the first take-off with a minimum 1.5 m of flexible ductwork to each grille.

8.13 Carpark Ventilation Systems

A one-diameter pod-type cylindrical attenuator should be allowed on the atmospheric side of any carpark ventilation fan. Either a two-diameter pod-type cylindrical attenuator or a 1200mm long rectangular attenuator should be allowed on the carpark side of any fan. Cylindrical attenuators must be coupled directly onto the fan casing to achieve optimum acoustic performance.

8.14 Hydraulic and Soil and Waste Water Services

Include pressure reducers or regulators (if necessary) such that the pressure at each tap or other appliance does not exceed 150kPa.

If a higher pressure is necessary for any reason, polybutylene pipes may be used to connect between the appliance and nearest point of attachment to any part of the building structure. For example, the copper sweep bend between wingback wall fitting and tap may be replaced with a length of polybutylene pipe, or else the sweep bend may be broken and joined with a polybutylene pipe "straight connector" attachment. This breaks the direct metal contact between tap and building structure.

Do not attach fresh or waste water pipework directly to a single stud wall adjacent to an occupied space. If this is unavoidable, ensure that pipework is resiliently mounted and attached to a false stud or dwang (i.e. one not connected to the wall lining on the occupied face of the wall).

Soft material such as Armaflex etc may be used to provide some isolation. Alternatively, lengths of polybutylene pipe may be used in place of copper pipe at wall connections.

Allow for water hammer arresters where lines take off to individual floors.

Where possible, limit soil and waste water velocity to 1 m/s.

Where waste pipework passes through building cavities adjacent to occupied spaces lag it with a limp membrane of surface mass 4 kg/m² (e.g. "Wavebar" etc) wrapped over 25mm fibreglass pipe insulation. Alternatively, a pipewrap with polyurethane foam insulation may be used (e.g. "Acoustop"). This pipe lagging is especially important at changes in pipe direction. There is no acoustic advantage in using two 135 degree bends rather than one conventional 90 degree elbow.

Copper pipe should be used in preference to uPVC pipe as it is 4–5 decibels quieter.

Waste water pipework should be resiliently supported at floor penetrations.

8.15 Vibration Isolation

Any rotating item of equipment and **any connected pipework** within the plantroom will require suitable vibration isolation mounts or hangers, most likely in the form of springs. Appendix E provides an isolator specification chart for a variety of equipment. We will prepare a detailed specification for these mounts during the detailed design. At this stage, sufficient space should be allowed to incorporate the springs.

A flexible duct connection must be provided between each fan or AHU and any connected ductwork.

9.0 DIESEL GENERATORS

A number of possible locations have been considered for the diesel generators on this project. We have separately reported on preliminary acoustic allowances for treatment to the generator under various scenarios. This report is attached as Appendix F.

Subsequent to this analysis, a final location has been agreed for the generators, on level 3 of the east tower. Our preliminary assessment of this option confirms that high performance packaged gensets (see Appendix F) will be appropriate. A purpose built generator room would also be possible, although we have not assessed noise control requirements for this as yet.

10.0 MRI TREATMENT

The suppliers of MRI machines often stress that they are highly sensitive to vibration from other parts of the building. Whilst this is true, an MRI machine also generates significant vibration. If not appropriately treated, this vibration transmits via the building structure, and re-radiates as audible noise.

The MRI machine for this project shall be fitted with air isolation mounts to address this issue. These mounts will control vibration from the machine, and at the same time ensure that any residual vibration from other parts of the building does not compromise the functioning of the machine.

A detailed specification for the air mounts will be prepared during the detailed design phase.

11.0 VERTICAL TRANSPORTATION

11.1 Lift Car Noise Levels

Noise levels from lift operation encompassing lift cars, lift plant and equipment noise should not exceed the following:

Table 12: Lift Noise Criteria

In the lift car	55 dB L_{Amax} during car travel* 65 dB L_{Amax} during door operation* 55 dB L_{Amax} from adjacent lift cars passing stationary lift*
In the lift lobby	65 dB L_{Amax} from doors opening or closing** 55 dB L_{Amax} when lift passes with doors closed
In adjacent spaces	5 NC less than the Building Services Noise Criteria defined for the adjacent space as outlined in Table 1.

* Measured in the centre of the lift car, at a height of 1.5m above floor level

** Measured at 1m from the lift doors at a height of 1.5 m above floor level

The noise within the car shall have a character free of tones or hums and other impulsive or intermittent sounds.

Lift car exhaust fans should be selected appropriately to ensure that the design criteria are not exceeded. Lift doors must be adjusted to meet slowly and to avoid door to door impacts.

11.2 Lift Car Vibration Criteria

The most significant source of the vibration which impacts upon noise sensitive areas is lift motion. The lateral and longitudinal vibration from the car is transmitted via the rails to the building and re-radiated from the building structure as noise.

Vibration levels from lift operation should not exceed the following:

Table 13: Lift car vibration criteria, acceleration (peak-peak)

Motion	Criteria
Max lateral acceleration over 0- 10 Hz	0.15 m/s^2 (15 m-g)
Max longitudinal acceleration over 0- 10 Hz	0.15 m/s^2 (15 m-g)
Max vertical acceleration/deceleration	1.0 m/s^2
Max jerk rate	1.8 m/s^2

All acceleration should be measured in terms of RMS or peak-peak values and reported by the commissioning engineer as peak to peak acceleration.

11.3 Noise and Vibration Control

To achieve the design criteria, vibration and noise control treatment will be required for the lift and associated machinery. These will include but will not be limited to the following items.

11.3.1 Lift Rail Supports

Lift rail supports must be located at each floor slab level. Careful attention should be given to the installation of lift guide rails to ensure they are correctly aligned and straight, allowing lifts to run smoothly without shudder, and to minimise lift roller vibration.

11.3.2 Roller Guides

Lift and counterweight roller guides or shoes shall be spring loaded and have a smooth running surface, preferably rubber or silicon. If a compensation chain is used, it must be rubber/silicon coated.

11.3.3 Lift Motor Vibration Isolation

All equipment with moving parts located in the lift shaft must be isolated from the building structure. Lift motors and assemblies should be mounted at four points on proprietary isolation mounts suitably sized so that each can accommodate the applicable dead load plus dynamic load of the lift mechanism and having a minimum deflection of 7 mm. Careful attention must be given to ensure that the vibration isolators are not short-circuited by any rigid connections.

11.3.4 Lift Car Construction

All components of the lift car construction shall be sufficiently rigid or damped to ensure that noise generation via panel excitation is kept to a minimum during car movement.

11.3.5 Lift Doors

Doors shall be well damped to minimise the vibration imparted to the building structure as doors open and close.

11.3.6 Lift Position Sensors

Lift position sensors should be quiet in operation.

11.3.7 Lift Guide Rail Isolation

Under exceptional circumstances, lift guide rail isolation may be required. The need for this and required treatments would be developed on a case-by-case basis by the project acoustic consultant.

APPENDIX A GLOSSARY OF TERMINOLOGY

Frequency The number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz).

Hertz (Hz) Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).

Octave Band A range of frequencies where the highest frequency included is twice the lowest frequency. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.

Noise A sound that is unwanted by, or distracting to, the receiver.

Ambient The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.

dB Decibel
The unit of sound level.

Expressed as a logarithmic ratio of sound pressure P relative to a reference pressure of Pr=20 μPa i.e. dB = 20 x log(P/Pr)

A-weighting The process by which noise levels are corrected to account for the non-linear frequency response of the human ear.

L_{Aeq} The equivalent continuous A-weighted sound level. This is commonly referred to as the average noise level.

L_{A95} The A-weighted noise level equalled or exceeded for 95% of the measurement period. This is commonly referred to as the background noise level.

L_{A10} The A-weighted noise level equalled or exceeded for 10% of the measurement period. This is commonly referred to as the average maximum noise level.

L_{Amax} The A-weighted maximum noise level. The highest noise level which occurs during the measurement period.

Sound Isolation Complete acoustical separation between two spaces such that there is no sound transmitted from one to another.

Sound Insulation When sound hits a surface, some of the sound energy travels through the material. 'Sound insulation' refers to ability of a material to stop sound travelling through it.

Transmission Loss (TL) The attenuation of sound pressure brought about by a building construction. Transmission loss is specified at each octave or third octave frequency band.

Impact sound Sound produced by an object impacting directly on a building structure, such as footfall noise or chairs scrapping on a floor.

Flanking Transmission Transmission of sound energy through paths adjacent to the building element being considered. For example, sound may be transmitted around a wall by travelling up into the ceiling space and then down into the adjacent room.

Structure-Borne Transmission The transmission of sound from one space to another through the structure of a building.

R_w Weighted Sound Reduction
A single number system for quantifying the transmission loss through a building element. R_w is the ISO equivalent of the better known STC rating, and is based upon typical speech and domestic noises, and thus is most applicable to these situations. The R_w rating of a building element is measured in approved testing laboratories under ideal conditions.

The term R'_w denotes a field measurement, with the apostrophe indicating that some flanking paths exist. R'_w is the ISO equivalent of FSTC

D_w Weighted Level Difference

The difference in sound level between one side of a partition and another. Typically measured in the 'field'. Building tolerances and flanking noise have an effect on the performance of a partition when it is actually installed, which result in lower site values than in the laboratory.

$L_{n,w}$ Weighted, Normalized Impact Sound Pressure Level
A single number rating of the impact sound insulation of a floor/ceiling when impacted on by a standard 'tapper' machine. $L_{n,w}$ is measured in a laboratory. The lower the $L_{n,w}$, the better the acoustic performance.

$L'_{nT,w}$ Weighted, Standardised Impact Sound Pressure Level
A single number rating of the impact sound insulation of a floor/ceiling when impacted on by a standard 'tapper' machine. $L'_{nT,w}$ is measured on site. The lower the $L'_{nT,w}$, the better the acoustic performance.

NC Noise Criteria
A method used to assess continuous background noise and assign a single value. (Noise sources such as air conditioning are commonly assessed in this method). PNC & NR curves are very similar and are used for the same purpose.

NRC Noise Reduction Coefficient
A single number rating between 0 and 1 of the ability of a material to absorb sound. It is the average of the absorption coefficients in the 250-2000Hz octave bands rounded to the nearest 0.05. The larger the number, the more absorptive the material.

CAC Ceiling Attenuation Class

A single number rating which indicates the sound insulation performance of a ceiling system. In essence, CAC is similar to R_w, but the sound passes through the ceiling tile twice during the test (in one side and out the other), in the same manner as it would when installed over a partition.

PR Privacy Rating
An indicator of the privacy expected between two spaces based on the sound insulation of the intermediate partition and the background noise level in the receiving space.

RT or T_{60} Reverberation Time
The time (in seconds) taken for the sound pressure level generated by a particular noise incident to decay by 60 decibels following the conclusion of the noise event (hence T_{60} abbreviation).

Reverberation Time is used for assessing the acoustic qualities of a space, describing how quickly sound decays within a space. The reverberation time is related to the room volume and total absorption.

AS/NZ 2107:2000 Australian/New Zealand Standard AS/NZ 2107:2000 *"Acoustics - Recommended design sound levels and reverberation times for building interiors"*

NZS 6801:2008 New Zealand Standard NZS 6801:2008 *"Acoustics – Measurement of environmental sound"*

NZS 6802:2008 New Zealand Standard NZS 6802:2008 *"Acoustics – Environmental Noise"*

APPENDIX B SPEECH PRIVACY

This section outlines the design approach for speech privacy which will be incorporated as the design progresses.

The approach for enclosed spaces is to establish the level of speech privacy necessary for each situation and then determine the level of sound insulation required to achieve this criteria. Speech privacy between adjoining spaces is primarily dependent upon three factors:

1. Voice level in the source room.
2. Sound Level Difference between the rooms.
3. Background noise in the receiving room.

B1 Voice Level

The loudness of the voice in the source room will depend upon the individual concerned and the functional use of the room. Generally, two categories of voice level are used for enclosed office speech privacy analysis:

Raised voice - a level of conversation that would be typical for somebody giving a lecture or an enthusiastic reprimand.

Normal voice - a level which would be used for a typical one to one exchange or telephone conversation.

B2 Sound Level Difference

The sound insulation or Sound Level Difference (D_w) between adjoining rooms is crucial to the level of speech privacy achieved. The sound insulation of the wall is an important part of the overall performance, and the partition construction must be selected carefully to ensure the appropriate sound level difference is achieved.

In normal high-rise construction, the ceiling is also important to the overall sound insulation achieved. The conventional practice of running partitions to ceiling height, and providing return air openings in the ceilings, provides a weak link when high sound insulation is required. This problem can be dealt with in many ways, including providing a baffle above the partition in the ceiling space, or by running the partitions slab to slab. Slab to slab partitions are by far the most effective way of achieving high levels of sound insulation (greater than D_w = 38) between rooms.

B3 Background Noise

The background noise level in the receiving room plays an important (and often overlooked) role in masking the intrusive speech from adjacent rooms. Noise from air-conditioning systems and, to a lesser extent, road traffic and general activity within the building, have a significant effect on the speech privacy due to the masking they provide.

A direct trade-off between masking noise and sound insulation applies. If for a given situation the masking noise is reduced by 5 decibel, the sound insulation of the adjoining partition needs to be increased by 5 decibel to maintain the same level of speech privacy.

Low levels of air-conditioning noise provide a comfortable environment. However, noise levels that are too low do cause difficulties with speech privacy due to the lack of masking. An appropriate compromise between noise levels that are too high for comfort and too low for speech privacy, needs to be provided.

B4 Speech Privacy Criteria

To assist with the evaluation of speech privacy in different situations, Marshall Day Acoustics has developed the Privacy Rating (PR) concept which incorporates the factors discussed above. The Privacy Rating (PR) for a typical “office-size” situation is simply obtained by adding the background noise level (PNC) to the sound level difference (D_w) between rooms.

For design or evaluation purposes, speech privacy can be divided into four categories. These are:

RV-CP Raised Voice – Confidential Privacy (PR greater than 75)

Raised voice conversation can just be heard as a muffled sound in the adjoining space, but cannot be understood. Normal voice levels cannot be heard.

NV-CP Normal Voice – Confidential Privacy (PR 70 to 75)

Normal voice conversation can just be heard as a muffled sound in the adjoining space, but cannot be understood. Raised voice can be understood.

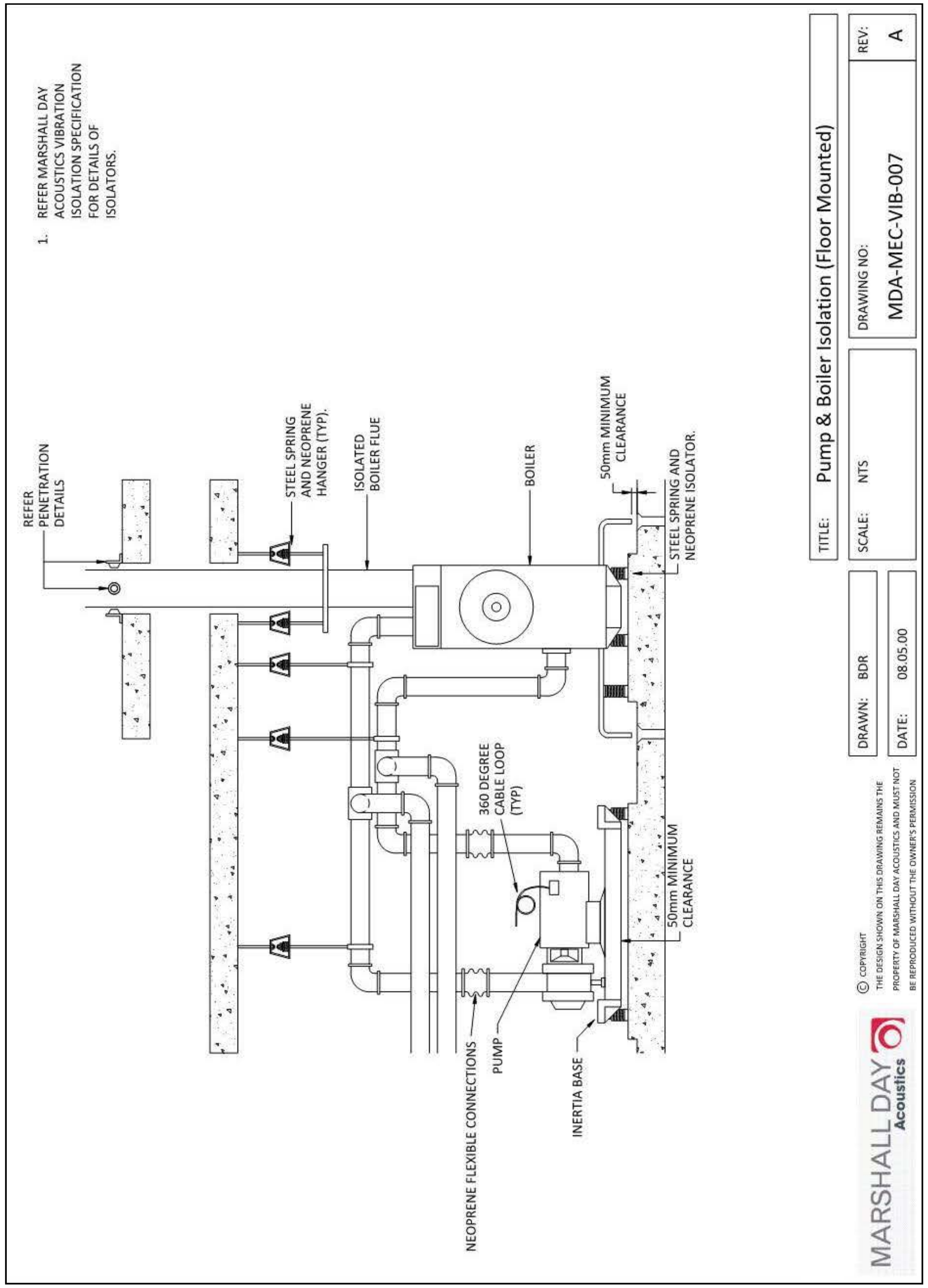
NV-NP Normal Voice – Normal Privacy (PR 65 to 70)

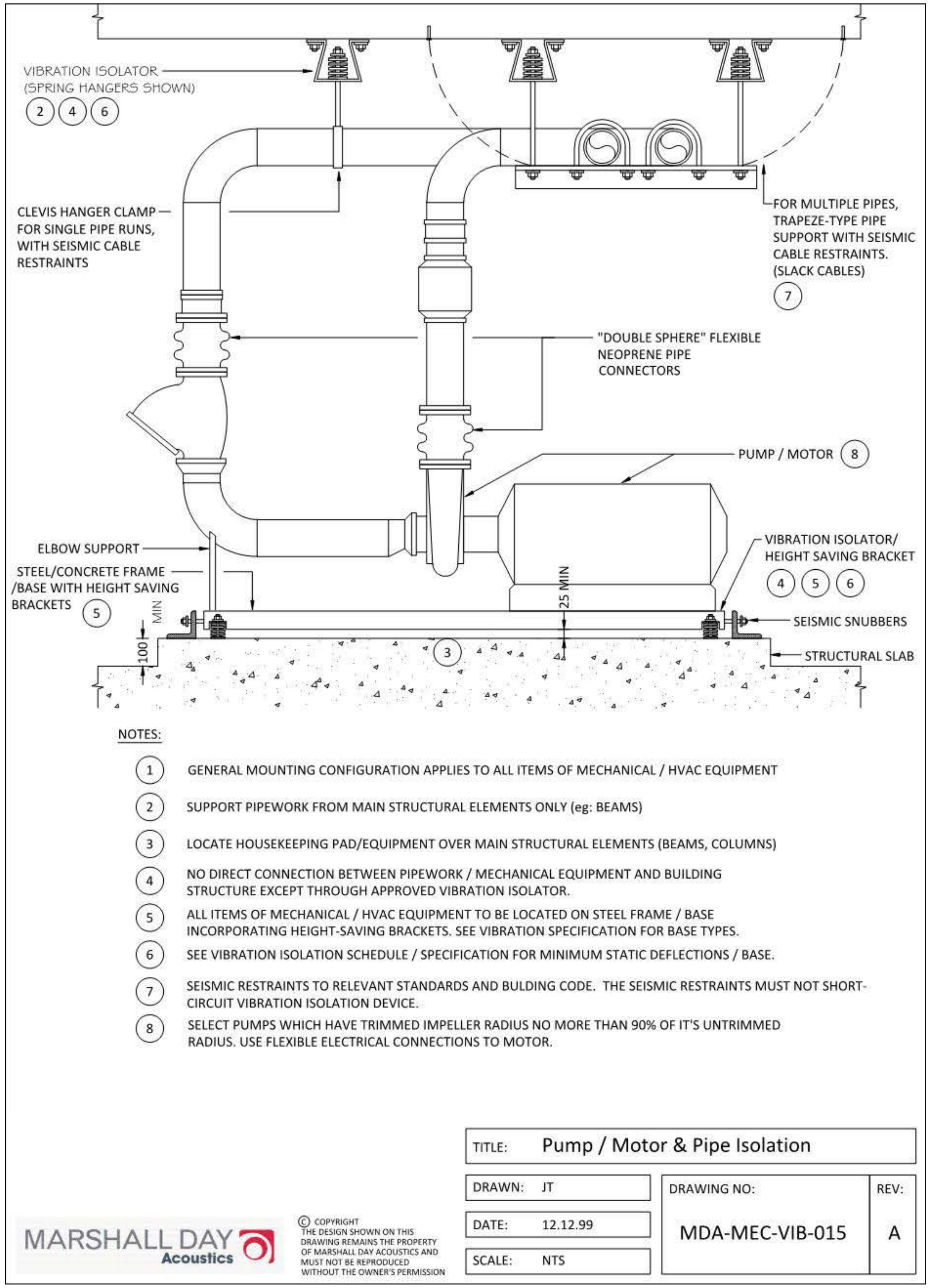
Normal voice conversation can be heard in the adjoining space, with some words distinguishable but without an understanding of the overall context. Raised voice can be understood.

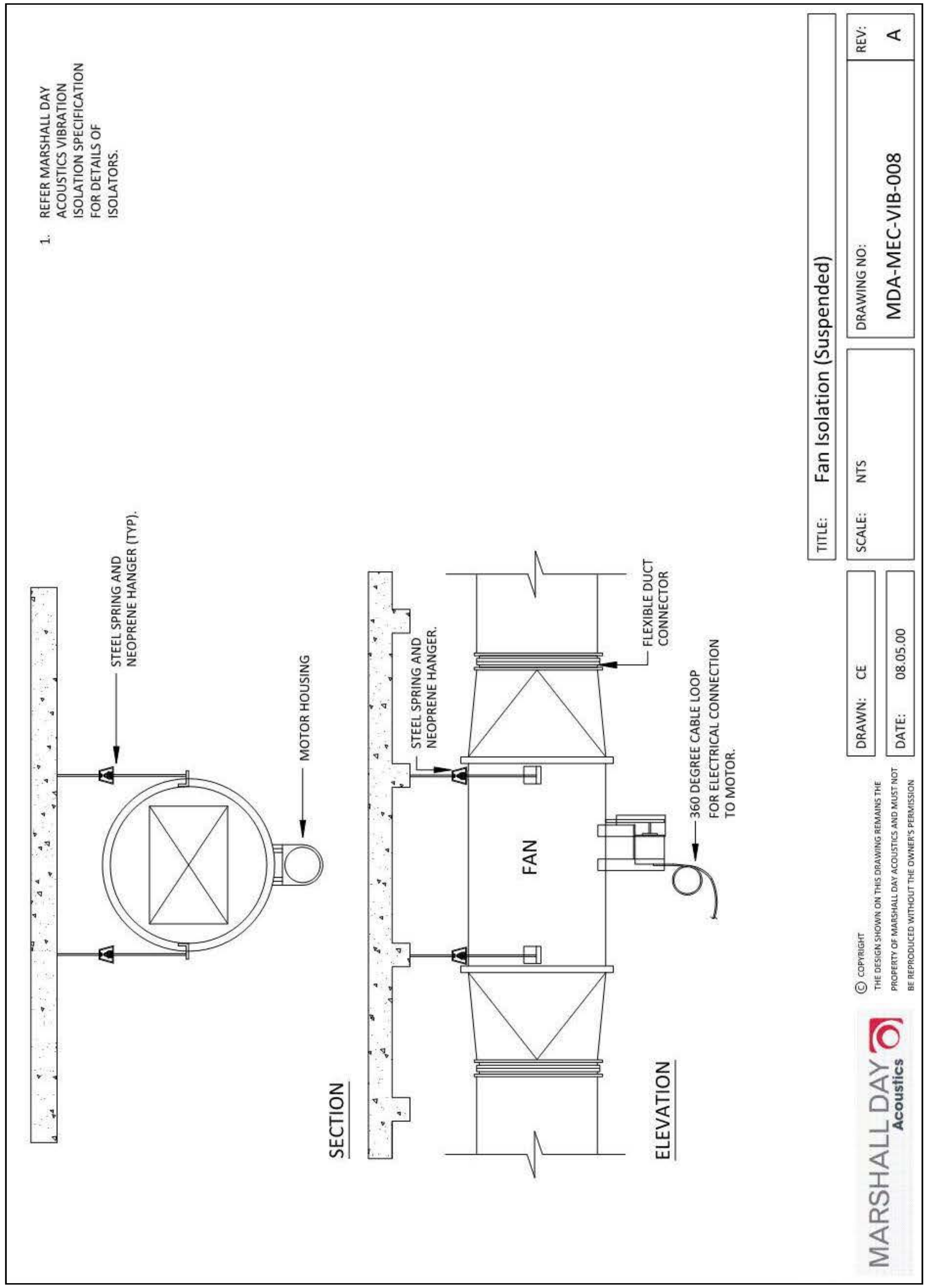
MP Minimal Privacy (PR less than 65)

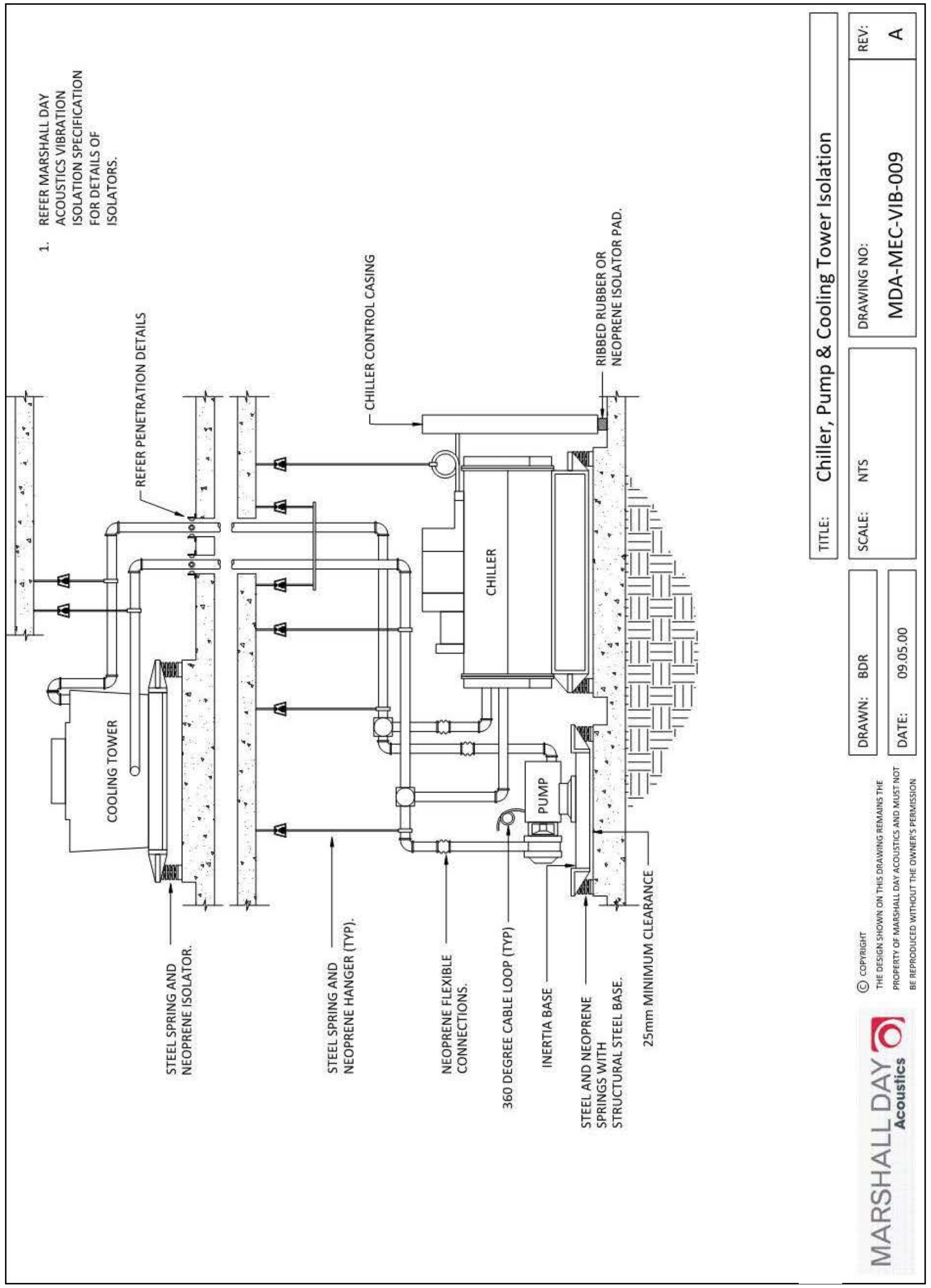
Normal voice conversation can be heard and understood in the adjoining space. Raised voice can be understood clearly.

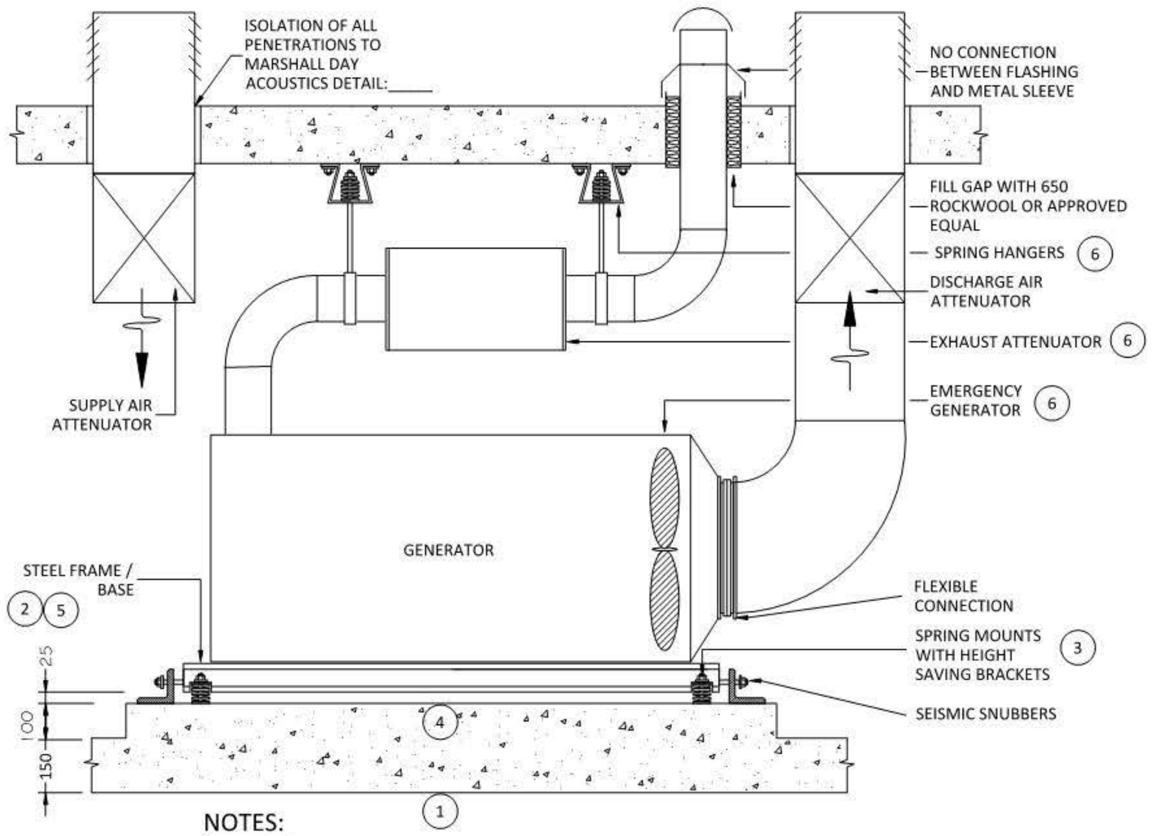
APPENDIX C VIBRATION ISOLATION DETAILS






1. REFER MARSHALL DAY ACOUSTICS VIBRATION ISOLATION SPECIFICATION FOR DETAILS OF ISOLATORS.
STEEL SPRING AND NEOPRENE HANGER (TYP).
MOTOR HOUSING
SECTION
STEEL SPRING AND NEOPRENE HANGER.
FLEXIBLE DUCT CONNECTOR
360 DEGREE CABLE LOOP FOR ELECTRICAL CONNECTION TO MOTOR.
FAN
ELEVATION
TITLE: Fan Isolation (Suspended)
SCALE: NTS
DRAWING NO: MDA-MEC-VIB-008
REV: A
DRAWN: CE
DATE: 08.05.00
© COPYRIGHT THE DESIGN SHOWN ON THIS DRAWING REMAINS THE PROPERTY OF MARSHALL DAY ACOUSTICS AND MUST NOT BE REPRODUCED WITHOUT THE OWNER'S PERMISSION
MARSHALL DAY Acoustics


1. REFER MARSHALL DAY ACOUSTICS VIBRATION ISOLATION SPECIFICATION FOR DETAILS OF ISOLATORS.
REFER PENETRATION DETAILS
CHILLER CONTROL CASING
RIBBED RUBBER OR NEOPRENE ISOLATOR PAD.
COOLING TOWER
CHILLER
PUMP
STEEL SPRING AND NEOPRENE ISOLATOR.
STEEL SPRING AND NEOPRENE HANGER (TYP).
NEOPRENE FLEXIBLE CONNECTIONS.
360 DEGREE CABLE LOOP (TYP)
INERTIA BASE
STEEL AND NEOPRENE SPRINGS WITH STRUCTURAL STEEL BASE.
25mm MINIMUM CLEARANCE
TITLE: Chiller, Pump & Cooling Tower Isolation
SCALE: NTS
DRAWING NO: MDA-MEC-VIB-009
REV: A
DRAWN: BDR
DATE: 09.05.00
© COPYRIGHT THE DESIGN SHOWN ON THIS DRAWING REMAINS THE PROPERTY OF MARSHALL DAY ACOUSTICS AND MUST NOT BE REPRODUCED WITHOUT THE OWNER'S PERMISSION
MARSHALL DAY Acoustics



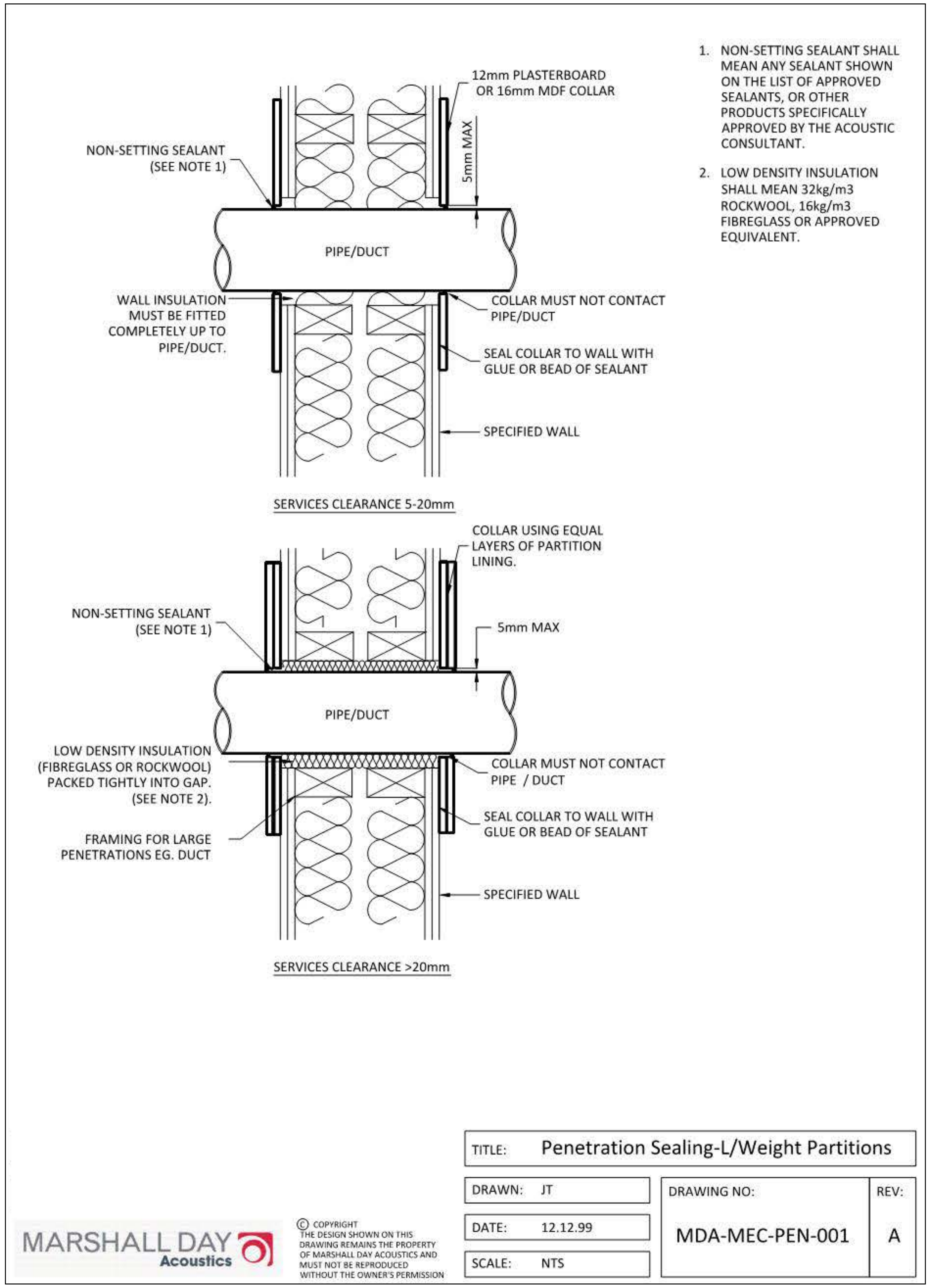
NOTES:

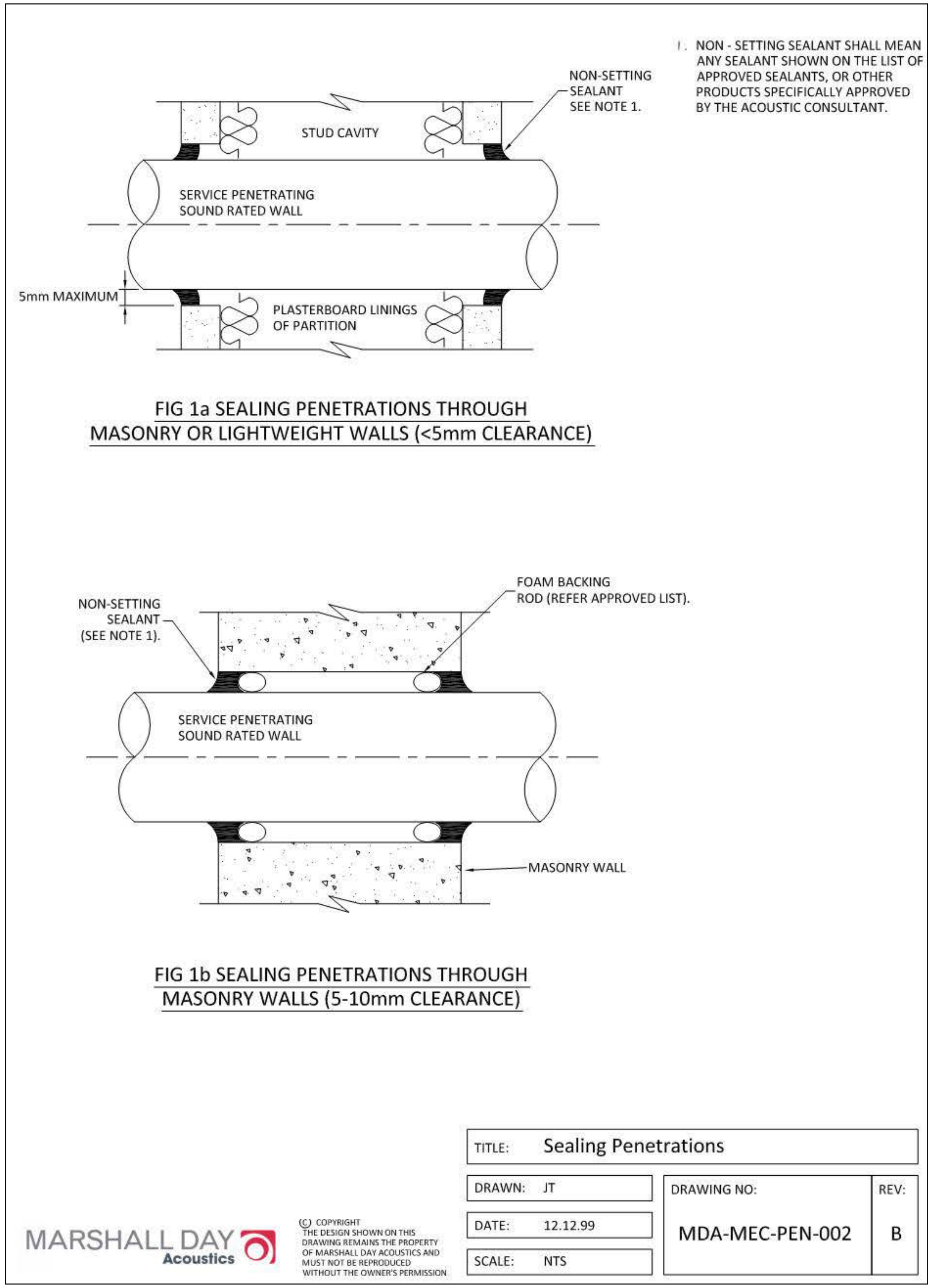
1. LOCATE GENERATOR OVER MAIN STRUCTURAL ELEMENTS (BEAMS / COLUMNS).
2. EMERGENCY GENERATOR TO BE ON STEEL FRAME / BASE.
3. STEEL BASE TO BE SUPPORTED VIA STEEL SPRING ISOLATION MOUNTS, INCORPORATING HEIGHT SAVING BRACKETS.
4. MINIMUM 100 MM HOUSE KEEPING PAD BENEATH GENERATOR.
5. MINIMUM 25 MM GAP BETWEEN STEEL FRAME / BASE AND HOUSEKEEPING PAD WHEN FULLY LOADED AND OPERATIONAL.
6. GENERATOR, MUFFLER AND EXHAUST LINE MUST BE SEISMIC ALLY RESTRAINED IN ACCORDANCE THE RELEVANT STANDARDS AND THE BUILDING CODE. SEPARATE SEISMIC RESTRAINTS ARE RECOMMENDED
7. SEISMIC RESTRAINTS MUST NOT SHORT CIRCUIT VIBRATION ISOLATON DEVICES.
8. SEE VIBRATION ISOLATION SCHEDULE / SPECIFICATION FOR MINIMUM STATIC DEFLECTIONS
9. SEE ATTENUATOR SCHEDULE / SPECIFICATION FOR INSERTION LOSS REQUIREMENTS FOR SUPPLY / DISCHARGE ATTENUATORS AND MUFFLER.

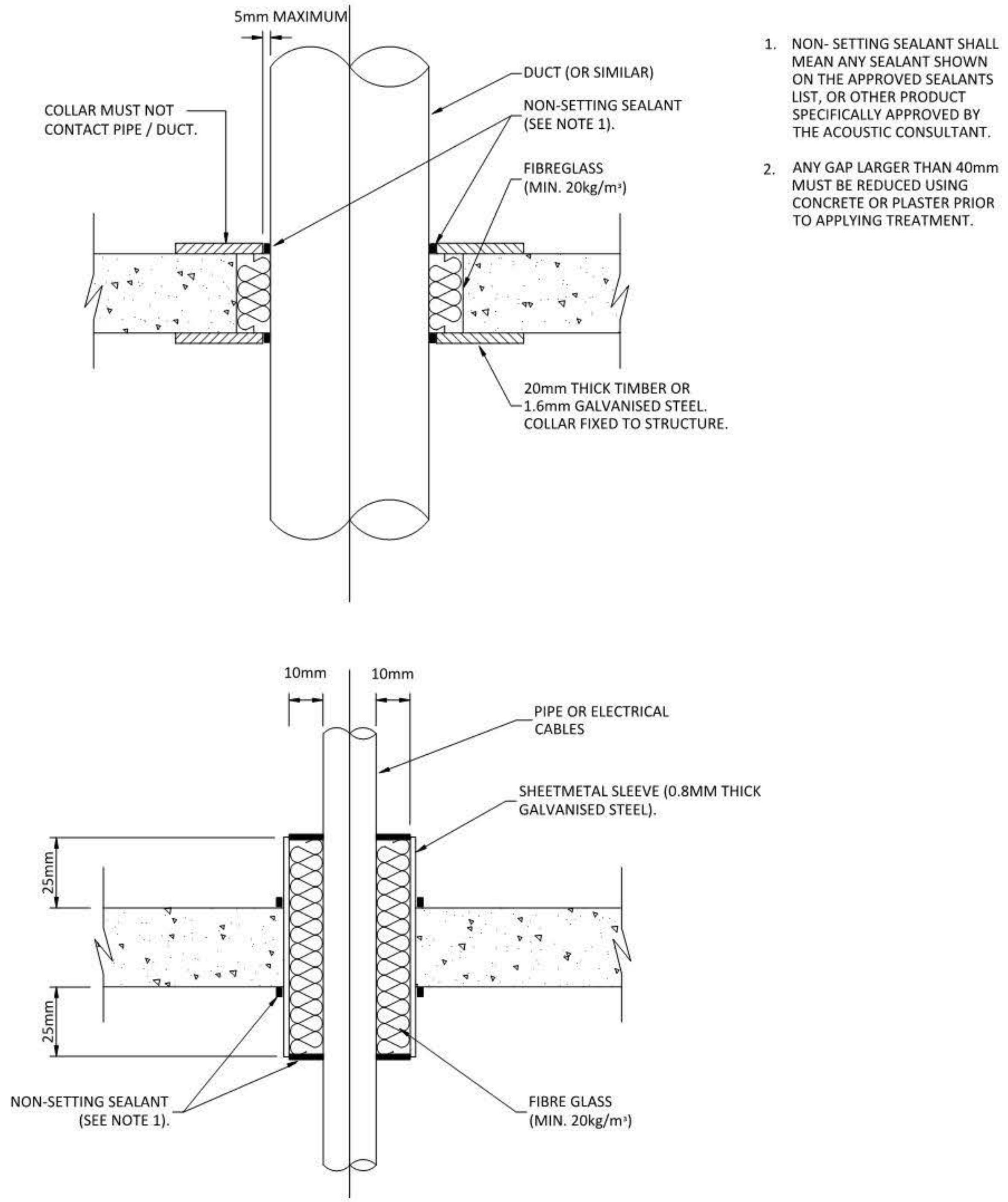
TITLE:	Emergency Generator Isolation		
DRAWN:	JT	DRAWING NO:	REV:
DATE:	12.12.99	MDA-MEC-VIB-016	A
SCALE:	NTS		

MARSHALL DAY Acoustics

APPENDIX D PENETRATION DETAILS



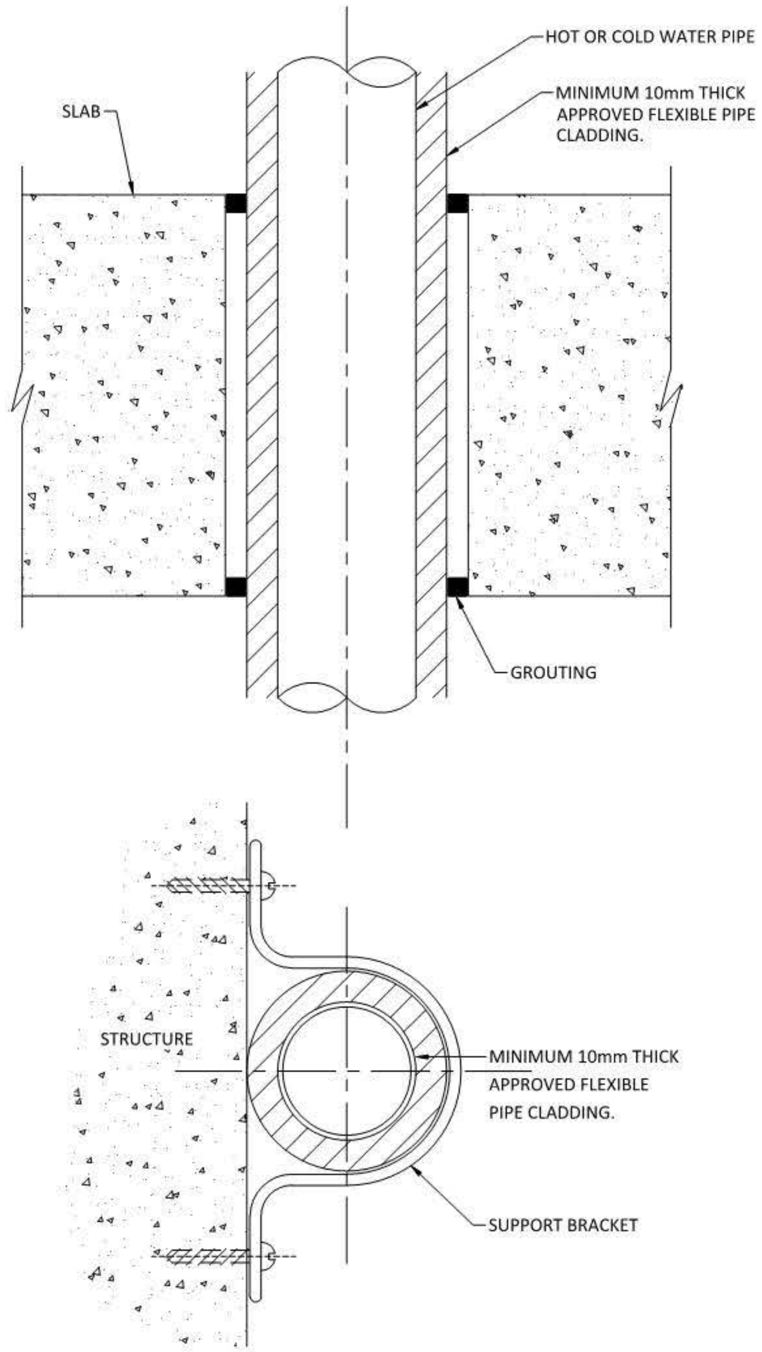




1. NON- SETTING SEALANT SHALL MEAN ANY SEALANT SHOWN ON THE APPROVED SEALANTS LIST, OR OTHER PRODUCT SPECIFICALLY APPROVED BY THE ACOUSTIC CONSULTANT.
2. ANY GAP LARGER THAN 40mm MUST BE REDUCED USING CONCRETE OR PLASTER PRIOR TO APPLYING TREATMENT.

TITLE:	Sealing Penetrations - Masonry		
DRAWN: JT	DRAWING NO:		REV:
DATE: 12.12.99	MDA-MEC-PEN-003		A
SCALE: NTS			

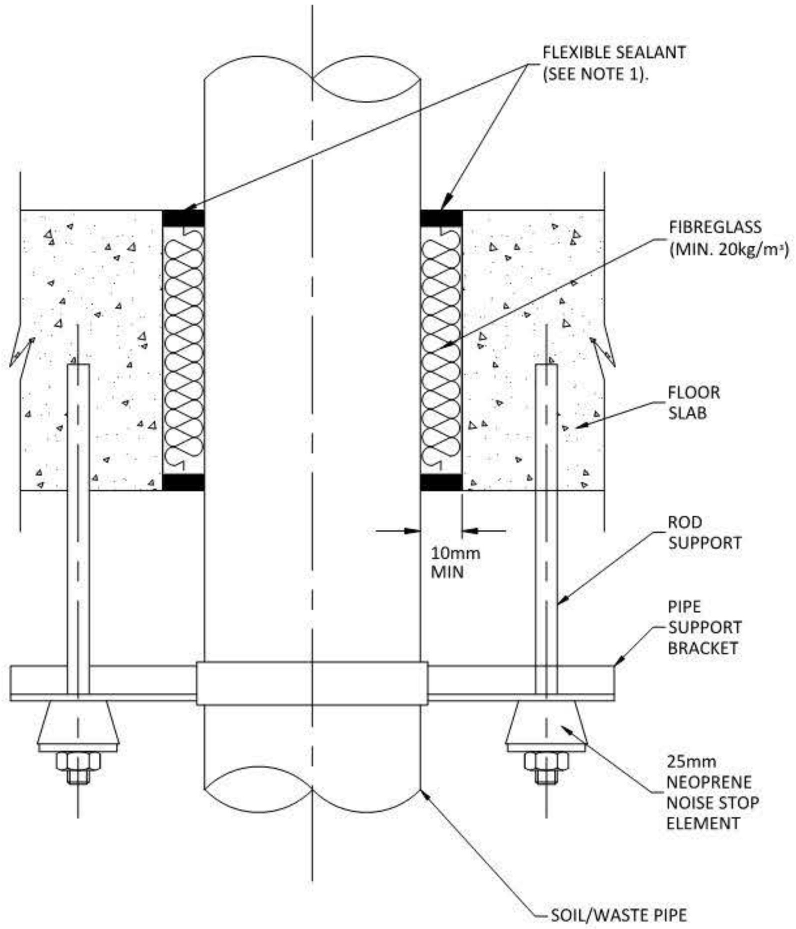
MARSHALL DAY Acoustics



TITLE:	Hot & Cold Water Pipe Isolation Details.		
DRAWN: JT	DRAWING NO:		REV:
DATE: 12.12.99	MDA-MEC-PEN-004		A
SCALE: NTS			

MARSHALL DAY Acoustics

1. FLEXIBLE SEALANT SHALL MEAN ANY SEALANT SHOWN ON THE APPROVED SEALANTS LIST, OR OTHER PRODUCT SPECIFICALLY APPROVED BY THE ACOUSTIC CONSULTANT.



TITLE:	Waste Pipe Penetration Through Slab		
DRAWN:	JT	DRAWING NO:	REV:
DATE:	12.12.99	MDA-MEC-PEN-005	A
SCALE:	NTS		

APPENDIX E VIBRATION ISOLATION SELECTION CHART

Equipment type	Shaft power, kW	Rpm	At grade			On suspended floor slab		
			Base type	Isolator type	Deflection, mm	Base type	Isolator type	Deflection, mm
Refrigeration machines and chillers								
Reciprocating	All	All	A	NM	6	A	SM	65
Centrifugal, screw	All	All	A	NM	6	A	SM	65
Air compressors and vacuum pumps								
Tank mounted (horizontal / vertical)	Up to 11kW	All	A	SM	20	A	SM	45
	>11kW	All	CB	SM	20	CB	SM	45
Base mounted	All	All	CB	SM	20	CB	SM	45
Large reciprocating	All	All	CB	SM	20	CB	SM	45
Pumps								
Closed coupled	Up to 6kW	All	SB	NM	6	CB	SM	20
	> 6kW	All	CB	SM	20	CB	SM	45
Large inline	4 to 20kW	All	A	SM	20	A	SM	45
	>20kW	All	A	SM	45	A	SM	45
End suction and split case	Up to 30kW	All	CB	SM	20	CB	SM	45
	30 to 100kW	All	CB	SM	20	CB	SM	45
	>100kW	All	CB	SM	20	CB	SM	45
Cooling towers	All	Up to 500 rpm	A	NM	6	A	VSM	65
		>500 rpm	A	NM	6	A	VSM	20
Boilers	All	All	A	NM	6	SB	VSM	45

Equipment type	Shaft power, kW	Rpm	At grade			On suspended floor slab		
			Base type	Isolator type	Deflection, mm	Base type	Isolator type	Deflection, mm
Axial fans, fan heads, cabinet fans and fan sections								
Up to 600mm diameter	All	All	A	NM/NH	6	A	SM/SH	19
600mm diameter and over	Up to 500 Pa	Up to 500rpm	SB	SM/SH	19	CB	SM/SH	65
		>500rpm	SB	SM/SH	19	SB	SM/SH	44
600mm diameter and over	>500Pa	Up to 500rpm	CB	SM/SH	45	CB	SM/SH	65
		>500rpm	C	SM/SH	20	CB	SM/SH	45
Centrifugal fans								
Up to 560mm diameter	All	All	SB	NM	6	SB	SM	20
610mm diameter and over	Up to 30kW	Up to 500rpm	SB	SM	45	SB	SM	65
		>500rpm	SB	SM	20	SB	SM	20
610mm diameter and over	>30kW	Up to 500	CB	SM	45	CB	SM	65
		>500rpm	CB	SM	25	CB	SM	45
Heat pumps	All	All	A	SM	20	A	SM	20
Condensing units	All	All	A	NM	6	A	VSM	45

Equipment type	Shaft power, kW	Rpm	At grade			On suspended floor slab		
			Base type	Isolator type	Deflection, mm	Base type	Isolator type	Deflection, mm
Packaged AHU, AC, H and V units								
All	Up to 7.5 kW	All	A	SM/SH	20	A	SM/SH	20
Up to 1 kPa	7.5 kW and over	Up to 500 rpm	A	SM/SH	20	A	SM/SH	65
		>500 rpm	A	SM/SH	20	A	SM/SH	45
1 kPa and over	11 kW and over	Up to 500 rpm	SB	SM/SH	20	CB	SM/SH	65
		>500 rpm	SB	SM/SH	20	CB	SM/SH	45
Packaged rooftop equipment	All	All	A/D	NM	6			
Ducted rotating equipment								
Small fans, fan powered boxes	Up to 300 L/s	All	A	SM/SH	15	A	SM/SH	15
	300 L/s and over	All	A	SM/SH	20	A	SM/SH	20
Engine driven generators	Up to 100 kW	1500 rpm	A	SM	20	CB	SM	65
	>100 kW		CB	SM	45	CB	SM	75

KEY:			
SM	Steel Spring Mounts	VSM	Vertically Restrained Spring Mounts
LSM	Laterally Restrained Spring Mounts	NM	Neoprene or Rubber Mount
SH	Spring and Rubber Hanger	NH	Neoprene Hanger
SB	Structural Steel Base	CB	Concrete Inertia Base
WP	Waffle Pad	A	No base isolators, directly attached
MWP	Metal Shimmed Waffle Pad		

Steel Springs (S, SM, VSM, LSM)

Springs should be selected to provide a horizontal stiffness at least 100% of the vertical stiffness to ensure stability. Springs shall allow 50% travel beyond rated load. Springs shall incorporate a ribbed neoprene noise stop pad of the following thickness:

- <50 mm spring static deflection: minimum 10 mm thick pad
- >50 mm spring static deflection: minimum 20 mm thick pad (two layers of double ribbed rubber or neoprene of maximum 60 durometer separated by 2 mm stainless steel)

Neoprene, Rubber or Fibreglass Mounts (N, NH, NM)

High frequency vibration isolators shall be of rubber or neoprene of hardness less than 60 durometer, or high density, pre-compressed moulded fibreglass. Isolators should incorporate integral steel plates to permit bolting to the supported equipment and structure.

Hangers (SH)

Vibration hangers shall contain a steel spring and noise stop element in series. Spring diameters and hanger box lower hole sizes must be large enough to permit the hanger rod to swing through a 30^{o} arc before contacting the hole. The noise stop element shall be neoprene, rubber or fibreglass and have a minimum thickness of 25mm.

APPENDIX F DESIGN ADVICE DA002 - GENERATOR ACOUSTIC TREATMENT OPTIONS

DESIGN ADVICE

Project:	Acute Services Building	**Document No.:**	Da 002		
To:	Warren & Mahoney	**Date:**	8 November 2013		
Attention:	Bill Gregory	**Cross Reference:**			
Delivery:	bill.gregory@wam.co.nz	**Project No.:**	2013473c		
From:	Stuart Camp	**No. Pages:**	5	**Attachments:**	No
CC:	Beca – Richard Walsh <Richard.walsh@beca.com> W&M - Brad Sara < brad.sara@wam.co.nz>				
SUBJECT	**Generator Acoustic Treatment Options**				

This design advice supersedes our design advice 001 with respect to generator noise.

Marshall Day Acoustics (MDA) have analysed the five preferred options for diesel generators on site.

The MDA assessment is based on an aim of achieving compliance with the District Plan night-time noise limit of 41 dB L_{Aeq} at the boundary of Hagley Park and/or any site zoned living. Compliance with this rule is necessary for generators which may be used for peak lopping. MDA have noted where compliance is not possible.

MDA have adopted a pragmatic approach to compliance at this stage, in that although the site boundary nominally extends to infinite height, any effects will occur within Hagley Park at ground level. MDA have therefore assessed to a ground level location.

SUMMARY OF FINDINGS

Marshall Day Acoustics' ranking of the five options, based on noise issues is as follows, with 1 being the preferred option:

1. Option 2: Lower ground floor,
2. Option 5b: Avon site, within building,
3. Option1: Above Loading Dock,
4. Option 5a: Avon site, containerised,
5. Option 6: Level 2 Podium Plantroom.

The following sections discuss specific details and recommendations used by Marshall Day to arrive at this ranking.

OPTION 1: PACKAGED GENSETS ABOVE LOADING DOCK

MDA have recently obtained detailed information on an acoustically treated containerised genset designed by Noise Control Services in Auckland, and this information provides a useful indication of

what is possible within the constraints of a **40' container**. MDA are not aware of any other packaged units which achieve as low a noise level as these.

The information provided is based on a slightly smaller genset (1100 kVA) than proposed for this site, and hence should be scaled up by the difference in generator cost. MDA do not expect the cost of acoustic treatment to change significantly.

In summary, there are two designs available. We understand that these indicative costs are for a turnkey unit, including generator ;

1. Base acoustic treatment $490,000 67 dB L_{Aeq} at 7 metres
2. High performance treatment $530,000 57 dB L_{Aeq} at 7 metres

Marshall Day Acoustics notes the following for Option 1;

- A high performance packaged unit would be essential in this location,
- The noise level at the site boundary is unlikely to be less than about 55 dB L_{Aeq}—well above the night-time noise limit. As such, consent would be required for a non-complying activity if this option is selected, although this is likely to be fairly straightforward given than the adjoining area of Hagley Park is not particularly sensitive to noise at night,
- It is essential that the eastern end of the podium façade is primarily concrete. Any areas of glazing would likely require heavy secondary glazing,
- Of the two containerised options being considered, this is Marshall Day's preference. Acoustically, MDA rank this option **3rd of the five**.

OPTION 2: LOWER GROUND FLOOR

The key acoustic issues under this option are noise to the existing Oncology building, and noise to adjoining lower ground floor areas. At this stage, MDA have based their assessment on all adjoining spaces being carparking.

Under option 2, Marshall Day Acoustics notes the following;

- Allow for a ceiling of 2 layers of 13 mm Gib suspended below the proposed concrete structure,
- Incorporate concrete walls to all sides of the room,
- Avoid having any structural columns within the generator room,
- Provide acoustic louvres and attenuators (inlet and discharge) as discussed in detail for Option 6.
- Acoustically, this is the **preferred option** of the 5. Compliance with District Plan noise limits will be reasonably straightforward, and noise within the hospital site is easily managed.

OPTION 5A: CONTAINERISED

Acoustically, Option 5A is very similar to option 1, being quite close to the site boundary. However, in this location, there are existing residential buildings on the opposite side of Cambridge Terrace, around 75 metres from the proposed generator location. At this distance, the high performance containerised generators would comply with the night-time District Plan noise limit. As such, whilst the generators would be non-complying with respect to noise, MDA do not envisage any significant problems obtaining consent on the basis that any adverse effects will be minor.

The generators are sufficient distance from existing hospital buildings in this location that there are unlikely to be any noise issues.

Marshall Day Acoustics notes the following for Option 5A;

- A high performance packaged unit would be essential in this location,
- MDA do not rate this option as highly as Option 1. Whilst it is a very similar distance from the site boundary, the relatively close proximity of existing residential dwellings adds a risk that may result in additional cost during detailed design. This would **rank number 4** of the 5 options with respect to noise.

OPTION 5B: WITHIN BUILDING

Option 5B is acoustically very similar to Option 5A, except that the proposed use of a concrete building to enclose the generators would potentially enable lower noise levels than with the containerised option.

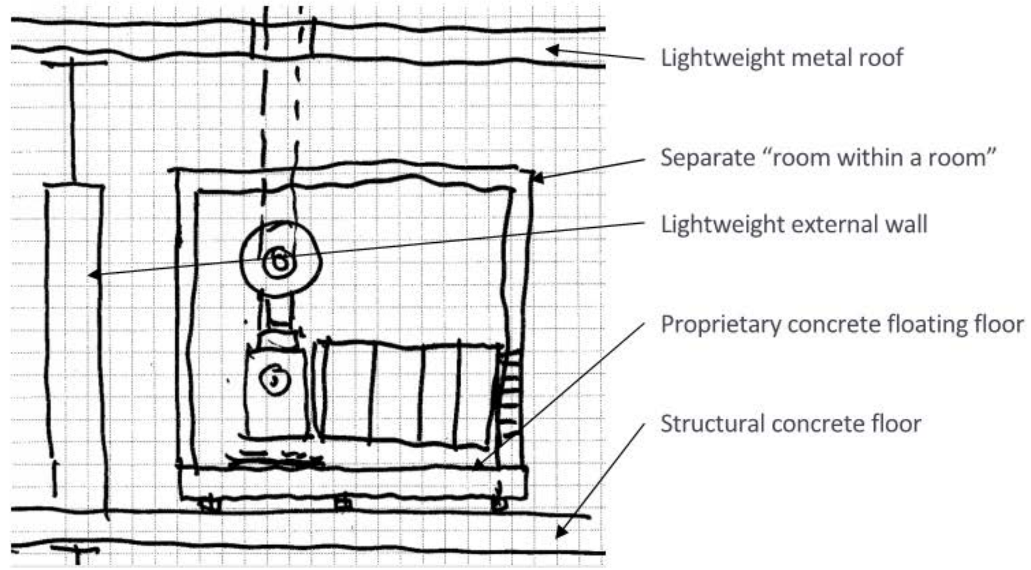
For this option, Marshall Day Acoustics note the following;

- Allow for a heavy steel floor (say 6 mm thick) as a minimum,
- Utilise precast concrete façade panels for all walls as proposed,
- Provide a lightweight metal roof with a ceiling of 2 layers of 13 mm Gib and insulation in the cavity,
- Allow acoustic louvres and attenuators as described in detail for Option 6.
- This option is preferable to 5A because a building allows for more cost effective noise control solutions to be considered during detailed design, thereby minimising the risk to existing residential buildings,
- This option would **rank second** behind Option 2 with respect to noise.

OPTION 6: LEVEL 2 PODIUM PLANTROOM

MDA calculations confirm that controlling noise to critical theatre spaces directly below would require a “room within a room” construction to house the generators.

Marshall Day Acoustics notes the following for Option 6;



- Allow for a lightweight metal using standard profiled roof cladding,
- The walls and ceiling of the “room within a room” could be built in a number of ways. Acoustically, the linings need to be something equivalent in mass to 2 layers of 13 mm Gib. This could be a single stud wall lined with one layer each side (or 2 layers under framing as ceiling). Alternative lining materials and/or proprietary panels could be investigated at detailed design stage,
- The external wall of the generator area can be standard profiled metal cladding as currently proposed. Louvres should not be used in the area housing the generators (except as discussed below with respect to ventilation),
- The proprietary concrete floating floor will be a 100 mm thick concrete slab over the area of the generators. This slab will be raised 50 mm above the structural slab. There will need to be a concrete nib (or similar) around the perimeter to prevent moisture and dirt entering the cavity. Contact Noise Control Services in Auckland for budget pricing,
- MDA have based their calculations on a minimum structural concrete floor thickness of 120 mm,
- Avoid having any structural columns within this generator room,
- Based on indicative flow rates taken from the HG Wilson website for a model P1825 generator, MDA recommend a 300 mm deep acoustic louvre, plus an air inlet attenuator. To serve both generators, allow a single 50% open attenuator 2400 mm long x 6000 mm wide x 3500 mm high,
- Allow two air discharge attenuators (one for each generator), discharging into a plenum, with a 300 mm deep acoustic louvre in the external wall of the building. Each attenuator will typically need to be 50% open, and be 2400 mm long x 3500 mm high x 3000 mm wide. Ensure that the

MARSHALL DAY Acoustics

transitions from radiator fan to attenuator are as shallow as practical. As a guide, do not exceed 25 degrees on any face,

- The need for a floating floor and "room within a room" construction will add a significant cost to this option,
- Balanced against this, compliance with the night-time noise rules should be possible, and hence no specific resource consent would be needed with respect to noise,
- Acoustically, this option arguably carries the greatest risk, given that it is located directly above critical spaces such as operating theatres. This risk can be largely offset by use of the proposed floating floor, but this carries a hefty financial penalty. This would be the **least preferred option** with respect to noise.

This document may not be reproduced in full or in part without the written consent of Marshall Day Acoustics Limited