Hallé Concerts Society

Hallé St Peters - Phase 2

RIBA Stage 3 Acoustic Design

249263-00\R01

Issue 1 | 29 July 2016

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Appendix A

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Executive summary

The Hallé Concerts Society is proposing a new extension to the existing Hallé St Peters rehearsal facility. The extension will contain two large ensemble rehearsal rooms along with practice rooms, conductor's room, archive storage, a café/multi-use space and various ancillary spaces.

A number of the proposed spaces have very stringent acoustic requirements to ensure their optimal use. Therefore, the acoustic design of the building will be key to its success.

Stage 3 acoustic design

This report summarises the acoustic design up to RIBA Stage 3. The key areas of acoustic input are summarised as follows:

- **Building envelope sound insulation (Section 3)**: Acoustic design of the building façade (including glazing) to control noise intrusion into acoustically critical spaces, and noise break-out to the environment
- **Internal sound insulation (Section 4)**: The two main rehearsal spaces and practice rooms will have a 'box in box' construction to minimise sound transfer between spaces and limit noise intrusion from external and noise emission from internal sources
- **Room acoustics (Section 5)**: The main rehearsal spaces will incorporate areas of sound absorbing and diffusing finishes to ensure an optimum acoustic for the desired usages. Rehearsal Room 1 will have a variable acoustic system, to reduce loudness during larger ensemble rehearsals. Recommended schemes of acoustically absorbing finishes have also been recommended for the control room, practice rooms, atrium, café, office and circulation areas.
- **Internal services noise control (Section 6.1)**: The main rehearsal spaces will be served by dedicated air handling units (AHUs) which will minimise sound transfer between spaces and enable very low velocity (and therefore quiet) supply of air to the spaces. Practice rooms will be heated and cooled by fan coil units (FCUs) located within the ceiling void. A strategy for reducing noise from these units has been developed with the mechanical engineer.

Planning noise assessment

This report contains limits for plant noise and music noise emissions, which are in accordance with Manchester City Council (MCC) technical guidance. An environmental noise survey was undertaken to establish the typical background noise levels (L_{90}) in the vicinity of the site.

Sections 2.4 and 2.5 provide a summary of the policies relating to plant and entertainment noise emissions, and Section 6.2 outlines the proposed noise limits for the development.

1 Introduction

The following report summarises the acoustic design up to RIBA Stage 3 for the proposed Hallé St Peters extension at Blossom Street, Manchester.

The new building contains two large ensemble rehearsal rooms (referred to as Rehearsal Rooms 1 and 2) along with practice rooms, conductor's room, archive storage, a café/multi-use space and various ancillary spaces. The existing St Peters Church building, which houses the main rehearsal space, will be opened up and linked to the new extension.

Prior to this report, Arup has issued acoustic advice in the form of marked up architectural and mechanical services layouts.

This report outlines the current status of the acoustic design, covering the following areas in detail:

- Room acoustics of spaces
- Sound insulation of building envelope
- Sound insulation between internal spaces
- Control noise and vibration from building services within the building
- Control of noise emissions from building services to the environment

Appendix A contains a glossary of specialist acoustic terminology used in this report.

2 Acoustic criteria

2.1 Reverberation control

2.1.1 General criteria

The most common parameter used to describe the acoustic of a space is the reverberation time (RT). In some spaces, such as concert halls, a longer RT is desirable to provide warmth to the sound. In other spaces, such as recording studios and spaces used for amplified music, a shorter RT is preferable.

The RT of a space is a function of a number of factors; the most influential being the physical volume of the room and the amount of sound absorption provided by its finishes.

The proposed target RTs for each key space are given in Table 1. They are the average mid frequency reverberation times, and relate to fully furnished but unoccupied spaces.

Space	RT design range, s
Rehearsal Room 1	1.2 – 1.5 [1]
Rehearsal Room 2	1.2 – 1.5
Control room	≤ 0.2 in 125-4kHz octave bands, ≤ 0.3 at 63Hz
Practice rooms	0.5 – 0.8 [2]
Conductor's room	0.5 – 0.8 [3]
Café/multi-use space	≤ 1.2
Entrance atrium	≤ 1.5
Office/admin areas	≤ 0.8

Table 1: Target reverberation time criteria

[1] With variable acoustic system retracted
[2] 0.5s when acoustic curtain is deployed. 0.8s retracted
[3] 0.5s when acoustic curtain is deployed. 0.8s retracted

2.1.2 Rehearsal Rooms 1 and 2

In the main rehearsal spaces, there will need to be some degree of balance when selecting an appropriate RT. If the RT is too long (a 'live' acoustic), the room may be too loud for a larger ensemble and players may find it hard to hear other instruments clearly. However, if the RT is too short (a 'dead' acoustic) this can lead to a harshness and unpleasant sound, and lack of 'blending' between different instruments.

It is proposed to use a variable acoustic system to reduce the RT of this space to around 1 second when fully occupied. This will enable a larger ensemble of up to 60 players to rehearse without excessive loudness, whilst retaining the option of a more reverberant acoustic for choral use.

2.1.3 Control room

It is important that the control room achieves a 'dead' acoustic which is also well controlled at low frequencies. Failure to control low frequency reverberation is likely to result in boominess due to the uniform room dimensions (this has been identified as an issue in the current control room at St Michael's).

2.1.4 Practice rooms

Small practice rooms should be reasonably acoustically 'dead' to control excessive loudness and provide increased clarity and control loudness for musicians.

2.2 Internal sound insulation

In general terms, the level of sound insulation required between two spaces depends on the location of the space and its sensitivity to noise. For example, the wall between a music practice room and a store will require a lower degree of sound insulation than that between a music practice room and recording studio.

Due to their acoustic sensitivity, the main rehearsal rooms and small practice rooms are proposed to have box-in-box constructions.

Required sound insulation performances between key spaces, expressed as a weighted level difference (D_w), are provided in Table 2. These values are measurable on-site, and include contributions from all sound flanking paths and take into account the absorption within the completed rooms.

Adjacency	Minimum weighted sound level difference, D_w
Main rehearsal rooms ← → Adjacent spaces	70 – 75
Practice rooms ← → Adjacent spaces	65 – 70
Control room ← → Adjacent spaces Conductor's room ← → Adjacent spaces	55

Table 2: Target sound insulation performances between key spaces

2.3 Internal noise levels

The total ambient noise level inside a space is a function of the noise ingress from external sources (e.g. road, rail, aircraft) and the noise generated by building services systems servicing the space. It is important that both noise sources are suitably controlled to achieve an optimum background noise level in each space.

Target internal noise criteria are provided in Table 3, and apply to fully furnished but unoccupied spaces. In box-in-box spaces, external intrusive noise is expected to be very well controlled and therefore no criteria are necessary

Where applicable, BREEAM criteria for total ambient noise level are also given.

Space	Services noise level	External intrusive noise level, dBL_{Aeq}	Total internal noise level (BREEAM), dBL_{Aeq}
Rehearsal room 1	NR20	n/a	n/a
Rehearsal room 2	NR25	n/a	n/a
Control room	NR25	n/a	n/a
Practice rooms	NR30	n/a	n/a
Conductor's room	NR30	30[4]	n/a
Café/multi-use space	NR45	40	50-55
Entrance atrium/circulation	NR45	40	45-55
Office	NR35	30	35-40
Plant room	NR70 and 70dB in each octave band	n/a	n/a

Table 3: Internal noise limits for key spaces

The building services noise criteria should be reduced by a further 5dB in the event of any plant items exhibiting an identifiable noise character (eg tonality, impulsiveness, intermittence etc).

[4] Openable window required in this space. Limit relates to closed window scenario

Achieving the external intrusive noise criteria will comply with the BREEAM requirements.

2.4 Plant noise emissions

It is important that the noise of any externally mounted building services equipment and air intake and exhaust louvres does not cause disturbance to any nearby noise sensitive areas (eg dwellings, the school etc). Manchester City Council (MCC) provides criterion for limiting plant noise emissions (Planning & Noise: Technical Guidance, December 2015). The document states that the design objective should be:

- *The development should be designed so as to achieve a rating level of 5dB (L_{Aeq}) below the typical background (L_{A90}) level at the nearest noise sensitive location*

2.5 Entertainment noise emissions

It is anticipated that orchestras of up to 60 players will use Rehearsal Room 1. This number of instruments playing simultaneously can generate high sound levels, and so the transmission of this sound to the surrounding environment should be limited so as not to affect nearby residents.

The space may also be used for occasional amplified music rehearsals and performances. Amplified music can generate high levels of low frequency sound, which can be harder to control. It is understood that the new rehearsal spaces will only be used during daytime and evening periods (07:00-23:00).

MCC's Technical Guidance also advises on limiting music noise. It provides two possible criteria which could be applied to a new entertainment/music venue depending on the prevailing noise conditions:

- *Music noise levels in the 63Hz and 125Hz octave centre frequency bands (L_{eq}) should be controlled so as not to exceed (in habitable rooms) 47dB and 41dB (L_{eq}), respectively*
- *Entertainment noise (L_{Aeq}) should be controlled to 10dB below the background noise level (L_{A90}) without the entertainment noise present, in each octave band at the nearest noise sensitive location*

Which criterion takes precedent in the case of this development will depend on the measured noise levels. This is discussed in Section 6.2.3 of this report.

2.6 BREEAM Pol 05

To achieve the BREEAM credit for Pol 05: *Reduction of noise pollution*, it should be demonstrated that the noise level from the proposed site, as measured in the locality of the nearest or most exposed noise-sensitive development, is a difference no greater than +5dB during the day (07:00 to 23:00) and +3dB at night (23:00 to 07:00) compared to the background noise level.

Achieving the criteria set out in Sections 2.4 and 2.5 should ensure compliance with Pol 05 by default.

3 Design: Building envelope

The sound insulation performance of the building envelope is critical to the success of the building, as it will control both noise breaking in to the development (noise *ingress* from sources such as roads and aircraft) and noise breaking out of the development (noise *egress* which could impact upon local residents).

Detailed calculations will follow at the next design stage to determine the exact acoustic requirements for the external glazing and other façade elements.

3.1 External walls

It is recommended that all external walls consist of 140mm dense (>1850kgm^{-3}) blockwork plus any external lightweight cladding.

3.2 External glazing to main spaces

It is proposed to incorporate areas of external glazing to the two main rehearsal spaces. To maintain the sound insulation of the building envelope and inner boxes, these should be ‘double windows’ consisting of two double glazed units separated by a minimum 200mm cavity (exact sound reduction performance to follow after detailed analysis).

See Figure 1 below for principles. A similar principle should also apply to the rooflight in Rehearsal Room 2.

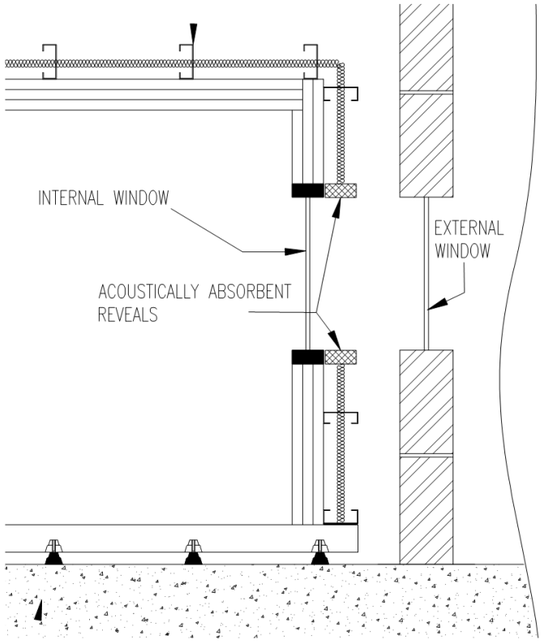


Figure 1: Principles of external glazing to box-in-box spaces

3.3 External glazing to other spaces

To achieve the desired internal noise criteria by controlling external noise intrusion, certain other spaces will need higher performance glazing requirements. This will be confirmed by detailed analysis at the next stage, but spaces likely to require secondary glazing are:

- First floor practice rooms
- Control room

4 Design: Internal sound insulation

4.1 General

In general terms, the level of sound insulation required between two spaces depends on the location of the space and its sensitivity to noise. For example, the wall between a music practice room and a store will require a lower degree of sound insulation than that between a music practice room and recording studio.

Due to the high sensitivity of some spaces to both internal and external sources of noise, some spaces are proposed to have a 'box in box' sound insulating construction. The general principle behind this consists of a structurally independent inner box built off a floating slab, with no rigid connection to the outer box structure.

Two grades of box-in-box are proposed, which provide 'high' and 'very high' sound insulation respectively. The details of each grade are provided in Table 4. Figure x and Figure y show the principles for 'high' and 'very high' sound insulating constructions respectively.

Level of sound insulation	Floor	Walls	Lid	Applies to
High (>D_w65)	100mm floating concrete slab	3 × 15mm Soundbloc, with resilient head detail 50mm mineral wool (45kg/m^3). Min **200mm** cavity to outer box	3 × 15mm Soundbloc on resilient hangers 50mm mineral wool (45kg/m^3)	Practice rooms
Very high (>D_w70)	100mm floating concrete slab	3 × 15mm Soundbloc on independent frame 50mm mineral wool (45kg/m^3) Min **300mm** cavity to outer box	3 × 15mm Soundbloc on independent frame 50mm mineral wool (45kg/m^3)	Rehearsal Room 1 Rehearsal Room 2

Table 4: Summary of sound insulation requirements for box-in-box constructions

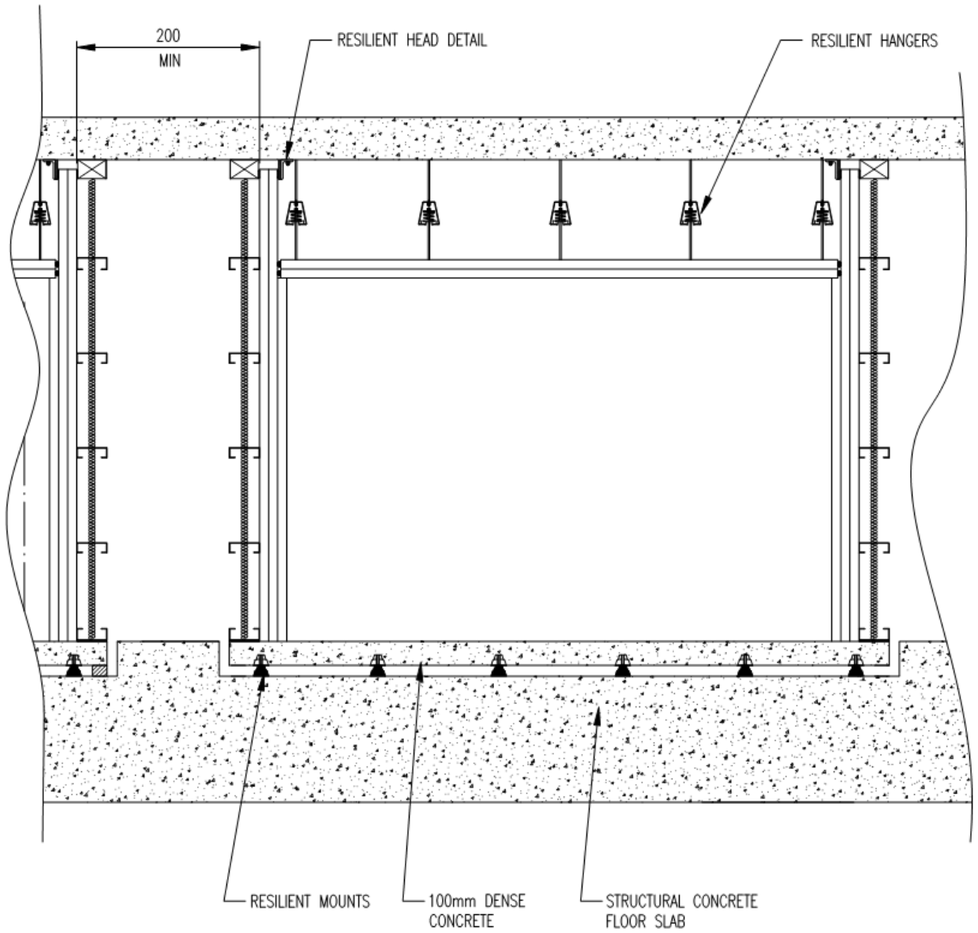


Figure 2: Principles of 'high' sound insulating construction

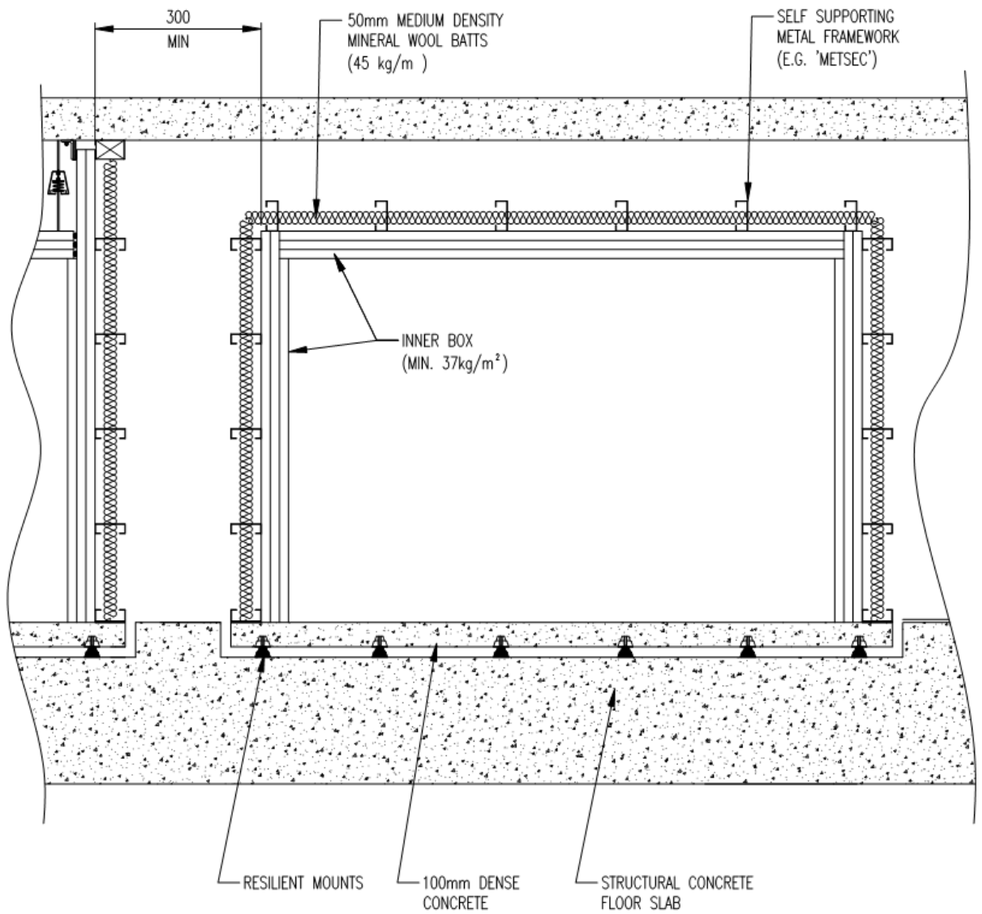


Figure 3: Principles of 'very high' sound insulating construction

4.2 Crosstalk via ventilation ductwork

In many cases crosstalk attenuators will be required to maintain the sound insulation of acoustically critical rooms.

As a guide at this stage, it is recommended that the following methods of attenuation are allowed for in the supply and extract branches at the point of entry to each room (these may already be in place as part of the services noise control strategy):

- 900mm length attenuators OR internally lined ductwork to all 'High' sound insulation rooms
- 1500mm length attenuators to all 'Very High' sound insulation rooms
- 900mm length attenuators to control room
- 900mm length attenuators to **all** ancillary spaces sharing common corridor ductwork with acoustically critical spaces

(NOTE: attenuators may not be necessary to ancillary spaces if the corridor ductwork can be split to allow separate branches for ancillary and acoustically critical spaces.)

The above comments only relate to maintaining the sound insulation performance of the room. The services design needs to be further developed to ensure that the room noise criteria (Table 3) are also achieved, which requires consideration of factors such as fan in-duct noise levels and the necessary primary / secondary attenuators needed to control this, grille regenerated noise levels, and crosstalk attenuator regenerated noise levels.

4.3 Doors

The key acoustic door requirements are as follows:

- Rehearsal room 1 / Control room: sound lobby entrances with minimum R_w35 acoustic doors
- Rehearsal room 2 / Practice rooms / Conductor's room: R_w35 acoustic doors
- Other occupied rooms (office areas, archive store, instrument stores, plant areas): R_w30 acoustic doors

4.4 Rehearsal Rooms 1 and 2

The box-in-box construction of the main rehearsal rooms should follow the principles outlined in Table 4.

It is proposed to locate areas of glazing between the two rehearsal rooms. These should also follow box-in-box principles; essentially these will be double windows, with each window being treated as part of the 'inner box' of each space.

It is important that each window maintains the overall mass of the box it is located in. This could typically be achieved by a 10-12-6 double glazed unit in each box. There should be a minimum 300mm cavity between the two double glazed units.

Acoustically absorbing reveals (e.g. Lamaphon) should be incorporated in the cavity between the double windows. See Figure 4 for details.

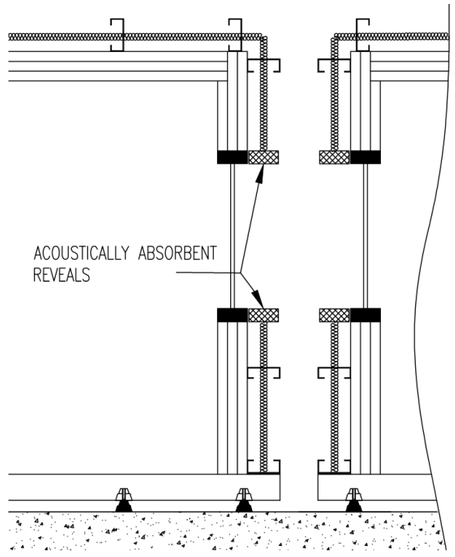


Figure 4: Principles of double window between main rehearsal spaces

4.5 Control room

It is proposed to locate the new control room in the existing bell tower. The existing walls of the bell tower are >1m depth brickwork, and so will provide a very good standard of sound insulation to adjacent areas. If this space was part of the new-build extension, it would have a box-in-box construction to protect against structure-borne noise transfer; however, space constraints of the existing bell tower mean that this is not practical.

The control room should have a sound lobby entrance to the 1st floor circulation area.

The control room should have a sound insulating (ideally concrete) ceiling and floor. In addition, there should be a simple floating floor (typically 18mm chipboard on battens).

4.6 Plant room

The main plant room is currently located at rooftop level, directly above Rehearsal Room 1.

It is understood that there is currently a 250mm roof slab proposed, which is acceptable from a sound insulation point of view.

4.7 Conductor's room

The conductor's room should have a simple floating floor (typically 18mm chipboard on battens).

5 Design: Room acoustics

5.1 Benchmarking

5.1.1 Hallé St Michaels rehearsal space

Reverberation time measurements were undertaken at Hallé St Michaels Church, which is the Hallé's current secondary rehearsal space. It is slightly larger than the proposed Rehearsal Room 1.

The room incorporates fixed acoustic absorption in the form of 50mm panels of unknown manufacturer. There are also two curtains which slightly reduce the reverberation time in the space.

It is understood that the acoustic is generally liked by the musicians, although during choral rehearsals there have been complaints of 'boominess' when underneath the lower height cantilevered area.

Spatially averaged mid frequency (500-1kHz) reverberation times in both scenarios were as follows:

- Curtains retracted: 1.4s
- Curtains in place: 1.2s

With curtains retracted, the reverberation time agrees with the target of 1.2-1.5s set out in Section 2.1.1. However, the reasonably lightweight curtains were not particularly effective at reducing the reverberation times for larger ensembles.

Some measurements were taken underneath the cantilevered section. On average, the 63Hz reverberation time here was 0.4s higher than when measured elsewhere in the space. Octave band measurements do not accurately reflect the presence of room modes, so it is likely that the issue is more pronounced at a particular frequency.

5.1.2 Hallé St Peters control room

Measurements were also taken at the control room (which doubles as the conductor's room) at Hallé St Peters, to gain an understanding of the current reverberation time. It is understood there have been some issues around low frequency room modes being excited.

The measured mid frequency RT was 0.2s, with a low frequency average of 0.3s. Again, this is likely to underestimate the prevalence of room modal effects. There was a lack of low frequency absorption on the walls (most walls were exposed brick with areas of fixed mid/high frequency absorption).

5.2 Rehearsal space 1

5.2.1 Overview

The largest of the proposed rehearsal spaces, this room is required to accommodate:

- Orchestras of up to 60 players
- Choirs of up to 100 members
- Occasional amplified performances/rehearsals

The room dimensions are currently 13.3 × 10 × 8 metres, providing a floor area of 133m^2 and a volume of 1064m^3.

A key factor in the effectiveness of a space for orchestral rehearsal is the volume per musician. A comparison of the main rehearsal room to other rehearsal and small recital rooms is provided in Table 6.

Room	Volume, V (m^3)	Max no. of musicians, N	V/N
Hallé Rehearsal Room 1 (PROPOSED)	1064	60	18
Chetham's Carole Nash[5]	1400	90	16
RNCM Studio 2	1015	30	34
Copenhagen Opera House rehearsal room	3800	110	35
The Sage rehearsal room	2100	70	30

Table 5: Comparison of volume per performer

Generally, higher values of V/N provide better acoustic environments as this indicates lower loudness.

Rehearsal Room 1 has a low volume for the size of orchestra it will be expected to accommodate. This could lead to excessive loudness at maximum occupancy if the reverberant noise level is not controlled. The only practical method to reduce loudness without losing reverberance is to increase volume; however, this is not possible within the constraints of the scheme.

Therefore, it is proposed to introduce a scheme of acoustically absorbing finishes to control loudness for orchestral rehearsal. The system should be variable, so that during other uses where loudness is not such an issue, the reverberance of the space can be increased.

5.2.2 Variable sound absorption

It is proposed to implement a variable acoustic system in the form of retractable heavy drapes. Initial calculations suggest a minimum draped area of **90m^2** will be required to reduce the reverberation time of the room sufficiently. These will require suitable tracks / deployment

[5] Incorporates variable acoustic to reduce loudness under maximum occupancy

mechanisms, and will need to be stored in suitable enclosures (ie to ensure that they are not exposed to the room) when not in use.

A 200mm zone for variable absorption should be allowed for within the inner box.

5.2.3 Fixed sound absorption (mid/high frequency)

In addition to the above, areas of fixed sound absorption area are required to control the reverberance of the room to suitable levels. It is recommended that at least 50% of the main ceiling area is reserved for a low efficiency (i.e. Class D) sound absorbing finish, such as perforated plasterboard:

5.2.4 Fixed sound absorption (low frequency)

In addition to the above, fixed areas of low frequency panel absorption should be incorporated. This could consist of fabric-faced or painted thin sheet steel in front of 150mm fibreglass, suspended below the plasterboard soffit. This should be incorporated in the following areas:

- 20m^2 across main soffit area
- 14m^2 across underside of cantilevered section (to reduce the potential for 'boominess' caused by modal excitation between parallel surfaces as found at Hallé St Michaels)

5.2.5 Sound diffusing finishes

Due to the rectangular geometry of this space, a significant amount of its wall and ceiling area will require sound diffusing elements which need to be integrated into the architectural / aesthetic design. Generally this involves adding elements to 'break-up' or profile the surfaces. It is proposed that this will be achieved through fixing timber battens to the surface of the lower walls and doors. Typical dimensions perpendicular to the surface would vary within the range 20mm – 40mm. The articulation **shall not** be evenly distributed.

It is proposed that the large glazed window at low level will be angled on the inside.

5.3 Rehearsal space 2

The room dimensions of this space are currently 8.5 × 6 × 3.9 metres, providing a floor area of 51m^2 and a volume of 199m^3. This room should be suitable for rehearsing small ensembles of around 10 players, and may also be used for other non-musical functions.

The room should incorporate the following acoustic finishes:

- Minimum Class D acoustic absorber to at least 50% of ceiling area
- Heavy retractable drapes to one wall

5.4 Practice rooms

Practice rooms should have the following acoustic finishes to control reverberation:

- Minimum Class D acoustically absorbing ceiling (e.g. Gyptone Quattro)
- Heavy retractable curtain to one wall
- Carpeted floor finish

5.5 Control room

In order to achieve the requirement for a low, flat reverberation time in the studio control room, the wall absorption used needs to combine low frequency and mid-high frequency sound absorption. This can be achieved using an in-situ finish known as Zintec on the walls.

The Zintec finish comprises a 150mm thick dense resin bonded fibreglass material with a decorative open-weave fabric or perforated/slatted material stretched over it to finish. The finish would be supported from standard metal studwork. This is a mid-high frequency absorber.

In certain locations, the fibreglass is obscured from the room by the placement of 0.7mm thick sheet steel. This then acts as a low frequency sound absorber. Figure 5 shows the details of the build-up.

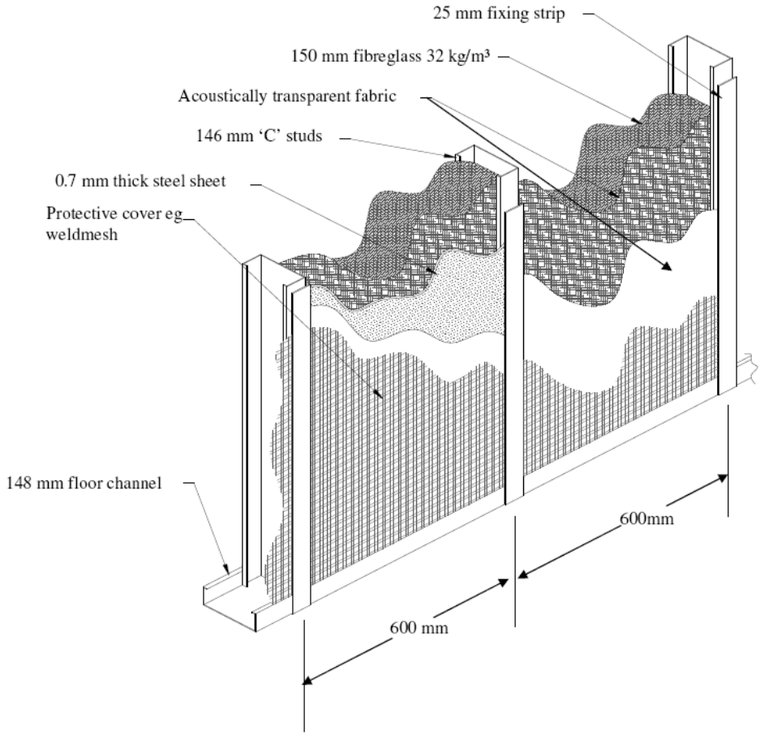


Figure 5: Zintec wall lining

The control room will require the fibreglass finish to all available wall area. The 0.7mm sheet steel should be placed over the fibreglass finish from FFL up to a height of 900mm and from door head height up to the ceiling. The zone in the centre should not be covered by sheet

steel. The whole finish can be covered with an acoustically transparent finish such as fabric to provide a uniform aesthetic.

The control room will require an acoustically absorbing ceiling (e.g. Ecophon Sombra with Extra Bass). The acoustic ceiling should be suspended at least 200mm below the independent 'lid' of the studio.

The control room should be carpeted.

5.6 Entrance atrium

Acoustically absorbent finishes will be required in this space to control its reverberance, minimise noise transfer between areas and noise due to the circulation of people.

The following minimum areas of acoustic finishes should be incorporated:

- 30m^2 Class C absorption to full-height wall opposite reception desk (a product such as BASWAphon could give a smooth finish). Alternatively, this area could be placed on the underside of stair treads.
- 20m^2 Class C absorption to wall and soffit around reception desk (this could be timber slats in front of black tissue faced mineral fibre slabs)

5.7 Café/multipurpose area

The café/multipurpose area should have an acoustically absorbing ceiling finish to reduce levels of reverberant noise, promote a calm environment and to improve the intelligibility of speech for other possible uses.

It is recommended that an acoustically absorbing ceiling finish is incorporated. If the desired aesthetic is for an exposed finish, then vertical hung baffles or horizontal suspended rafts could be used to introduce the required areas of absorption.

5.8 Sound lobbies

All sound lobbies should be carpeted and have a Class A sound absorbing ceiling.

5.9 Corridors

It is desirable to introduce acoustic absorption into corridor and circulation areas for the same reasons as discussed in 5.6. Depending on the desired aesthetic, solutions such as perforated plasterboard to walls or vertical hung baffles suspended from the soffit may be suitable.

6 Design: Building services noise control

6.1 Internal noise control

Control of building services noise will be essential to the success of the building. Strategic guidance on noise control for these systems is provided in Appendix B, and acoustic design targets for each space are given in Table 3 above.

In subjective terms, a typical services noise level at PNC15 (Perceived Noise Criterion) is inaudible under most conditions, at NR20 (Noise Rating) the services noise level would be faintly audible to discerning listeners, and at NR30 the services noise level would be audible to most listeners.

Generally it might be considered that the ideal situation is that services noise is inaudible in each room. However, this is not the case, as a constant unobtrusive level of services noise can provide useful 'masking' of intrusive noise (e.g. music noise from an adjacent music practice room). Inaudibility is also usually unachievable from a cost and space planning perspective, as oversized ductwork and long attenuators are likely to be required.

It is however important that the background noise level is not set too high, as this could affect comfort and speech intelligibility.

6.1.1 Practice rooms

It is proposed that practice rooms will be serviced by fan coil units (FCUs) located above the ceiling void but within the inner plasterboard 'box'.

The following steps should be taken to minimise unwanted noise in the practice rooms:

- Oversize unit to allow operation at low fan speed
- Locate supply/extract air attenuator (or lining) in bulkhead outside inner box
- Flexible duct connector should be used when duct passes through line of inner box
- Duct fresh air supply directly into FCU
- Locate supply and return ceiling grilles as far away from FCU as possible
- Mount FCU on anti-vibration mounts to minimise structure-borne noise

A summary of the visit to the Liverpool Philharmonic, where a similar strategy is employed in practice rooms, is provided in Appendix C.

It was found during the visit that noise levels were acceptable when the units were maintaining a constant temperature, but emitted very tonal noise when cooling or shortly after switching on. If desired, a management policy could be implemented by the Hallé to reduce the risk of distracting noise during important rehearsal sessions.

If the noise levels generated by the FCUs during cooling/initial use are deemed unacceptable, an alternative servicing strategy should be implemented. This could consist of locating FCUs outside the space and ducting air in and out, or using another cooling method such as chilled beams.

6.1.2 Rehearsal Room 1 and 2

Rehearsal room 1 requires very low levels of building services noise (NR20). The following steps should be followed:

- Flexible connectors on supply and extract routes through line of inner box penetration
- External acoustic lagging required from inner box penetration up to and including attenuator
- All supply and extract routes to be attenuated
- Supply air to enter room at velocity no higher than 1.5m/s

The above advice also applies to rehearsal room 2.

6.2 External noise emissions

6.2.1 Environmental noise survey

An environmental noise survey was undertaken to establish the existing levels of background noise in the immediate vicinity of the proposed site. An automated noise logger positioned at the south-west façade of the existing Hallé St Peters building at a height of approximately 20m obtained data between 20th and 27th June 2016 (location shown on Figure 1).

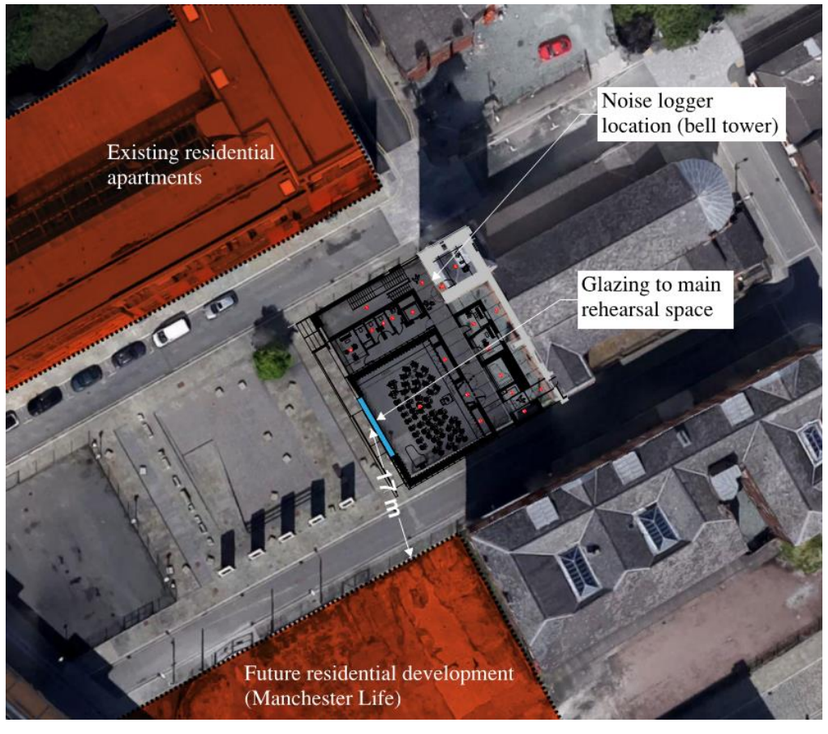


Figure 6: Location of closest noise-sensitive receptor and noise monitor (

6.2.2 Plant noise emissions

The typical measured background noise levels during this period, along with corresponding design targets for plant noise and music noise, are summarised in Table 6 and below. In this case, the 'typical' values were calculated using the following procedure:

- Take arithmetic average of measurements from each specific 15-minute interval across the 7 days (e.g. average of all 22:00-22:15 measurements)
- Take minimum of all averaged values within a particular time period (e.g. minimum of daytime values from 07:00-23:00)

The design targets for plant noise relate to the noise level when measured at the nearest noise-sensitive receiver. These are the future residential apartments which will be located on Hood Street (indicated on Figure 6).

The plant criteria should be reduced by a further 5dB in the event of any plant items exhibiting an identifiable noise character (eg tonality, impulsiveness, intermittence etc).

Time period	Typical measured background noise level, $dBL_{A90,15min}$	Maximum noise rating level for plant, $dBL_{Ar,\ 15min}$
Day/Evening (0700-2300)	50	45
Night (2300-0700)	47	42

Table 6: Summary of measured noise levels and design targets for plant and music

6.2.3 Music noise emissions

Following MCC guidance, both possible criteria for limiting music noise have been investigated.

Criteria for music noise	Resulting music noise limits at nearest residential, $dBL_{eq,15min}$		Notes
	63Hz	125Hz	
Noise levels inside habitable rooms not exceeding 47dB and 41dB in the 63Hz and 125Hz octave bands respectively	53	47	Based on 6dB attenuation through a partially open window at low frequencies[6]
Noise levels at the nearest receptor of 10dB below the typical measured L_{A90} in each octave band	**48**	**42**	Based on typical (average minimum) daytime L_{A90} of 58 and 42

Table 7: Comparison of MCC criteria for limiting music noise

Based on the findings from Table 7, it is proposed that music noise break-out should be limited to 10dB below the background noise levels when measured at the nearest residential window (future residential apartments on Hood Street). Therefore, both sets of criteria will be satisfied.

Acoustically, the weakest parts of the building envelope will be the glazed elements. These are where the highest levels of sound break-out can be expected. Initial calculations have been performed based on:

- A distance of 17m from the nearest (future) residential window to the centre of the large window to Rehearsal Room 1 – see Figure 6
- Window area of $24m^2$
- Secondary glazing with deep (>300mm cavity)

The calculations indicate that reverberant sound levels of up to $100dBL_{eq}$ at low frequencies (63 and 125Hz) can be accommodated inside Rehearsal Room 1 whilst still satisfying the external noise limits in Table 7.

[6] DEFRA, NANR116: 'OPEN/CLOSED WINDOW RESEARCH' SOUND INSULATION THROUGH VENTILATED DOMESTIC WINDOWS, April 2007

Appendix A

Acoustic Terminology

A1 Decibel (dB)

The ratio of sound pressures which we can hear is a ratio of 10^6:1 (one million:one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound pressure level' (L_p) and the associated measurement unit is the decibel (dB). As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply.

A2 dB(A)

The unit used to define a weighted sound pressure level, which correlates well with the subjective response to sound. The 'A' weighting follows the frequency response of the human ear, which is less sensitive to low and very high frequencies than it is to those in the range 500Hz to 4kHz.

In some statistical descriptors the 'A' weighting forms part of a subscript, such as L_{A10}, L_{A90}, and L_{Aeq} for the 'A' weighted equivalent continuous noise level.

A3 Equivalent continuous sound level

An index for assessment for overall noise exposure is the equivalent continuous sound level, L_{eq}. This is a notional steady level which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level.

A4 Frequency

Frequency is the rate of repetition of a sound wave. The subjective equivalent in music is pitch. The unit of frequency is the hertz (Hz), which is identical to cycles per second. A 1000Hz is often denoted as 1kHz, eg 2kHz = 2000Hz. Human hearing ranges approximately from 20Hz to 20kHz. For design purposes the octave bands between 63Hz to 8kHz are generally used. The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the band below it. For more detailed analysis, each octave band may be split into three one-third octave bands or in some cases, narrow frequency bands.

A5 Impact sound pressure level, $L'_{nT,w}$

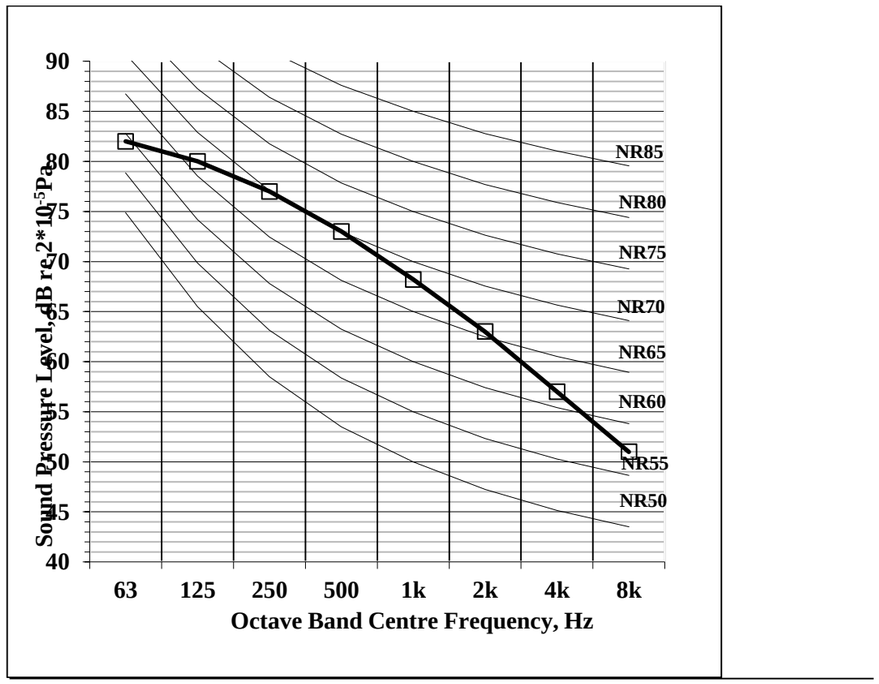
The impact sound insulation of floors is evaluated by measuring the sound pressure level in the receiving room resulting from a standard tapping machine placed on the floor of the source room. The measured values, in each of the third-octave bands from 100Hz to 3150Hz, are adjusted to allow for the acoustic of the receiving room and compared with a standard reference curve, in accordance with the procedure defined in BS EN ISO 717-2: 2013 to obtain the single figure weighted standardised impact sound pressure level, $L'_{nT,w}$.

Where there are no flanking routes to modify the performance the results are described by $L_{nT,w}$.

The improvement in impact sound insulation provided by a floor finish is the ΔL_{nw}, which is the measured improvement in L_{nw} achieved by a floor finish when placed on a 200mm depth reference concrete slab.

A6 Noise rating (NR) curves

Noise rating (NR) curves are a set of internationally-agreed octave band sound pressure level curves, based on the concept of equal loudness. The curves are mathematically derived and defined in BS 8233 and commonly used to define building services noise limits. The NR value of a noise is obtained by plotting the octave band spectrum on the set of standard curves. The highest value curve which is reached by the spectrum is the NR value. Shown below is a plant noise spectrum that is equivalent to NR70.



Reverberation time (RT60)

The time in seconds taken for a sound within a space to decay by 60dB after the sound source has stopped. The RT is an important indicator of the subjective acoustic within a space.

A7 Sound level difference (D)

The sound insulation required between two spaces may be determined by the sound level difference needed between them. A single figure descriptor, the weighted sound level

difference, D_w, is sometimes used (see BS EN ISO 717-1). Additionally, the term D_{nTw} may be used, which has been standardised to a reverberation time of 0.5s.

A8 Sound power level

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 volume or mass), which is not affected by the environment within which the source is located.

A9 Sound pressure level

The sound power emitted by a source results in pressure fluctuations in the air, which are heard as sound.

The sound pressure level (L_p) is 10 times the logarithm of the ratio of the measured sound pressure (detected by a microphone) to the reference level of 2 x 10-5Pa (the threshold of hearing).

Thus L_p (dB) = 10 log $(P_1/P_{ref})^2$ where P_{ref}, the lowest pressure detectable by the ear, is 0.00002 pascals (ie 2x10-5 Pa).

The threshold of hearing is 0dB, while the threshold of pain is approximately 120dB. Normal speech is approximately 60dBLA and a change of 3dB is only just detectable. A change of 10dB is subjectively twice, or half, as loud.

A10 Sound reduction index (R)

The sound reduction index (or transmission loss) of a building element is a measure of the loss of sound through the material, ie its attenuation properties. It is a property of the component, unlike the sound level difference which is affected by the common area between the rooms and the acoustic of the receiving room. The weighted sound reduction index, R_w, is a single figure description of sound reduction index which is defined in BS EN ISO 717-1: 1997. The R_w is calculated from measurements in an acoustic laboratory. Sound insulation ratings derived from site (which are invariably lower than the laboratory figures) are referred to as the R'_w ratings.

A11 Statistical noise levels

For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index which allows for this variation. The L_{10}, the level exceeded for 10% of the time period under consideration, and can be used for the assessment of road traffic noise (note that L_{Aeq} is used in BS 8233 for assessing traffic noise). The L_{90}, the level exceeded for 90% of the time, has been adopted to represent the background noise level. The L_1, the level exceeded for 1% of the time, is representative of the maximum levels recorded during the sample period. A weighted statistical noise levels are denoted L_{A10}, dBL_{A90} etc. The reference time period (T) is normally included, eg $dBL_{A10, 5min}$ or $dBL_{A90, 8hr}$.

A12 Structureborne noise

This is the transmission of noise energy as vibration of building elements. The energy may then be re-radiated as airborne noise. Structureborne noise is controlled by structural discontinuities, ie expansion joints and floating floors.

Appendix B

Guidance for noise control of building services

B1 Introduction

The control of building services noise is critical to the success of the building. Some key internal spaces will require very low levels of background noise to create environments suitable for performance and rehearsal. Other spaces, such as plant rooms, will require noise and vibration to be limited to reduce the risk of airborne and structure-borne noise transfer to the critical spaces.

B2 Internal noise criteria

Arup's proposed internal noise criteria from building services for key spaces are given in Table 8, subject to the client's agreement. Limits are provided as Noise Ratings (NR) which are defined in BS8233:2014 'Guidance on sound insulation and noise reduction for buildings'. These criteria apply to all services operating normally and together (including lighting), in furnished but unoccupied spaces.

Room function	Proposed services noise limit
Space 1 (large rehearsal space)	NR20
Space 2 (small rehearsal space) Control room	NR25
Conductor's room Practice rooms	NR30
Office	NR35
Corridors WC/showers Stores	NR40
Kitchen Café	NR45
Basement plant room	NR70 and 70dB in each octave band

Table 8 Proposed services noise limits

In subjective terms:

- NR20 would be faintly audible to discerning listeners
- NR30 would be audible to most listeners (but not obtrusive)

B3 General considerations and guidelines

B3.1 Fan Coil Units (FCUs)

The initial M&E drawings show FCUs in some of the music practice rooms. These units can be problematic in relation to achieving the low noise levels required and can have sound insulation issues. Also, the noise produced by FCUs will be different to what the client has experienced in the benchmark practice rooms at Chetham's (which have chilled beams), even though it may achieve the noise criterion recommended above.

We understand that FCUs have successfully been used in music practice rooms at Liverpool Philharmonic and that MF will send us details of these installations so that we can review and advise on whether they would be appropriate for this project. If the decision is taken to progress with an FCU strategy then we recommend that the client visits the Liverpool Philharmonic practice rooms to experience the FCU noise levels and confirm their acceptance. We would be happy to assist with this visit.

It would be prudent to ensure that an alternative strategy can be adopted if the FCU solution is not acceptable.

B3.2 Ductborne fan noise

Fan generated noise should be attenuated by a combination of the methods outlined in the following sections.

B3.2.1 Duct attenuators

To provide adequate noise control, it is likely that primary, secondary and possibly tertiary silencers will be required.

Primary attenuators should be fitted in the AHUs or in the ductwork before it leaves the plantroom.

Secondary attenuators will most likely also be required on systems serving noise sensitive spaces (eg studios, rehearsal rooms etc). Crosstalk attenuators will also be required in certain situations in order to maintain the sound insulation integrity of acoustic structures, if secondary attenuators do not fulfil this function.

External acoustic lagging will be required to ductwork between secondary attenuators and the point of entry to a noise sensitive space (studio etc). Similar provision will be required to ductwork associated with crosstalk attenuators.

It is particularly important that there is sufficient space between AHUs / fans and the noise sensitive area served to accommodate the required attenuation, and to allow space between duct fittings to minimise regenerated noise.

Outline indications of attenuator sizes are given in Figure 1.

B3.2.2 Internal duct lining

Certain sections of ductwork serving noise-critical areas (e.g. main rehearsal spaces) will need to be internally lined with a mineral fibre lining (density 24 to 48kg/m^3) with woven facing to retain fibres or melamine foam (such as Melatech).This applies to both supply and extract systems.

B3.2.3 External duct lagging

External acoustic duct lagging or enclosures may be required to reduce low-frequency fan noise breakout in critical spaces, and to help maintain sound insulation where ducts penetrate high performance partitions.

These may take the form of a mineral fibre/mass layer wrap such as Mufti-Lag or an independent plasterboard enclosure. Specific cases will be considered.

B3.3 Airflow noise

Noise in ventilation systems is generated by the flow of air past diffusers, grilles, dampers, sound attenuators, turning vanes and duct fittings, as well as by the fan. The noise level generated at each location in the system depends on the air velocity and the local geometry and fittings. The ventilation systems need to be effectively designed to minimise airflow regenerated noise as far as possible.

Grilles and terminals produce airflow noise and so should ideally not be used. However, if they are necessary then they need to be carefully selected having regard to their noise characteristics.

If at all possible, balancing dampers should not be used on systems serving acoustically critical spaces (eg studios, rehearsal rooms etc). However, if these are absolutely necessary they must only be located on the fan side of the secondary / crosstalk attenuator, and only be used to provide a slight balancing resistance.

Air velocities in systems serving noise critical spaces must be tapered down in ductwork approaching the terminals to allow air to enter the space silently.

Guidelines on limiting air velocities are provided in Table 9 and Figure 1.

Criterion	Air velocity, ms^{-1}		
	Within room	Distribution outside room	In plant room
NR20	1.5	3.0	6.0
NR25	2.0	3.5	6.0
NR30	2.5	4.5	6.0

Table 9 Limiting air velocities for ductwork serving noise-critical spaces

B3.4 Routing of ducts

No ductwork shall enter the outer or inner boxes of any box-in-box rooms, other than the supply and extract ducts servicing the spaces.

Similarly, no ductwork or pipework shall pass through other noise-critical spaces (control room, practice rooms, conductor's room).

Avoid service penetrations in sound insulating constructions wherever possible.

B3.5 Plantroom and Plant Spaces

All Air Handling Units (AHUs), fans, pumps, and other rotating and reciprocating plant should be fitted with efficient anti-vibration mountings (AVMs).

Plant mounted on AVMs should be isolated by flexible connections from ducts, pipes and conduits.

Ideally, plantrooms should be located as far away as possible from noise sensitive spaces (music practice rooms etc).

Ducts between the AHU and associated primary attenuator (where this is duct mounted) should be externally acoustically lagged. Ductwork lagging will be required in other situations, especially where crosstalk could be an issue.

Ductwork and pipework in the plantroom / plant space, and ductwork and pipework in contact with structures bounding noise sensitive areas (music practice rooms etc) will need to be supported on anti-vibration hangers.

Riser shafts to and from plantrooms should be sealed so that they do not become noise transmission paths to other parts of the building.

B3.6 Routing of Services in or near Acoustically Sensitive Spaces

The routing of building services should be considered carefully by the design team early in the design. Services serving acoustically sensitive spaces must not be routed through noisy spaces or through other acoustically sensitive spaces. Services serving (only) other areas must not be routed through acoustically sensitive spaces. Noise can enter a duct or pipe in one space and be transmitted down the duct or pipe to another. Pipework should not be routed through acoustically critical spaces (rehearsal rooms etc).

Rainwater pipes transmit noise from outside and radiate flow noise in storms. They should be routed outside acoustically sensitive spaces, and should not be attached to the structure of acoustically sensitive spaces. Similar care must be taken in routing of drainage pipes from showers, washbasins and toilets.

Services passing into floating structures (eg studios etc) must not bridge the inner 'floating' room to the external building structure, and so will require flexible connections and other vibration isolation measures.

B3.7 Crosstalk Attenuation

Control of 'crosstalk' (noise from one room entering a duct and being transmitted through the duct to another room), will be needed between spaces that require acoustic separation but are served by a common air system, and also where ductwork passes through high performance structures (eg box-in-box room walls etc). In many cases attenuators and areas of external acoustic lagging will be required. Ducts serving adjacent acoustically sensitive rooms should be routed via the circulation spaces and not directly room-to-room, to reduce the requirements for crosstalk attenuation.

B3.8 Special Precautions for Services Entering Box-in-Box Spaces

Ensure that all services entering isolated, box-in-box structures incorporate flexible elements as they cross the isolation joint. In the case of ductwork, this will be a flexible element. For conduit, a flexible section should be used; trunking should have a physical gap in it.

B4 Building services penetrations

Service penetrations (ducts, pipes and electrical services) through walls, floors, and ceilings must be sealed in such a way that the acoustic integrity of the structure is maintained and vibration transfer is eliminated. We will advise on penetration sealing methods in due course; however, the following table gives typical guidance on this:

Perimeter gap (mm)	Sealing details
<12	Ram pack gap with mineral fibre and seal with non-hardening, silicone based sealant.
12-20	A close fitting cover plate comprising 12.5 mm gypsum plasterboard, or building board of similar surface mass, shall be bedded in mastic and fitted round the duct on both sides of the wall. The joint between cover plate and duct shall be sealed with a non-hardening silicone based sealant.
20-50	As above but with two layers of 12.5mm Soundbloc.
50-100	As above but with three layers of 12.5mm Soundbloc.

Table 3 Critical sealing of ductwork penetrations

This is of critical importance at the plantroom penetrations and penetrations to studios, control rooms, music practice rooms etc, and other areas where a high level of sound insulation is required.

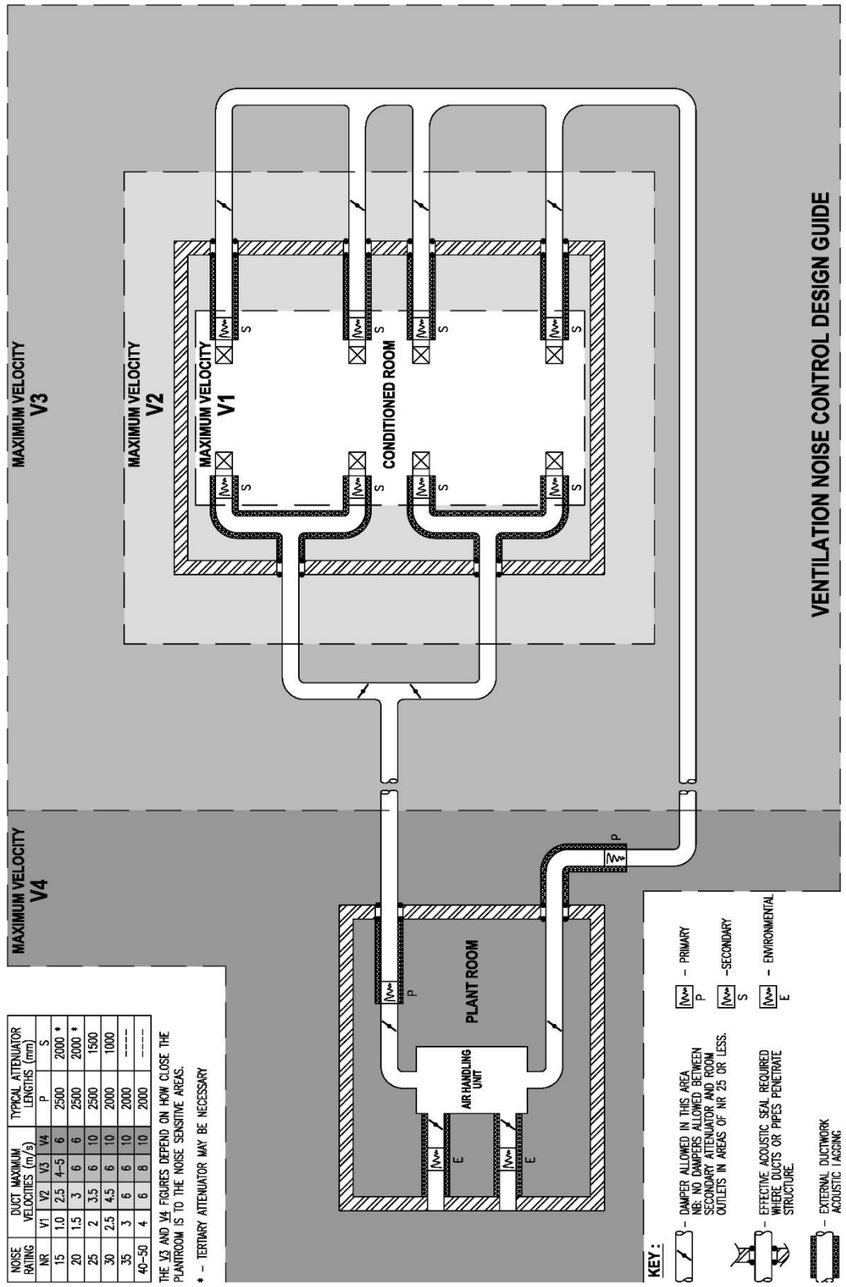


Figure 1 – Guidelines for attenuators (location and typical sizes) and duct velocities

Appendix C

Summary of visit to Liverpool Philharmonic

This note summarises the Hallé St Peters design team's visit to the Liverpool Philharmonic (LP) on Thursday 14 July 2016. In particular this note concerns the building services strategy in practice rooms.

Those in attendance from the design team were John Boardman and Roger Stephenson (Stephenson Studio), Ian Knowles and Sam Peckham (Arup Acoustics), Stewart Burns (Max Fordham), Andrea Manenti (Booth King) and Martin Glynn (The Hallé).

Basis for visit

It is proposed that practice rooms at the Halle St Peters will be serviced by fan coil units (FCUs) located in ceiling voids. The same strategy was used at the LP.

Generally, it is hard to achieve very low levels of building services noise in rooms serviced by FCUs located within the space, and there are other heating/cooling strategies (such as chilled beams) which can provide lower noise levels.

The aim of the visit was to reach a conclusion on whether the proposed FCU strategy would be acoustically acceptable.

Max Fordham informed the team that there had been no previous complaints regarding noise levels in the LP's practice rooms.

Findings

Two practice rooms at the Liverpool Philharmonic were visited. In both rooms, the design team discussed the noise levels generated by different FCU settings. Additionally, Arup Acoustics took noise level measurements to quantify each setting.

The measured noise levels in each space are summarised below.

Ref	Room	Description	L_{eq}, dB(A)	Noise Rating (NR)
1	D (small)	FCU on, cooling	32	31
2		FCU on, steady	26	23
3	A (large)	FCU on, cooling	35	34
4		FCU on, steady	29	21

Table 10 Summary of measured noise levels

Small practice room (D)

Initially, the FCU was working hard to cool the room. This produced a noticeable tonal noise (**measurement 1**) which persisted for around 20 minutes. The movement of air through ductwork was also generating a tonal hum.

After about 20 minutes the unit had reached a steady state of cooling in the room. The character of this noise was a slight 'whoosh', but was no longer tonal or intrusive (**measurement 2**).

Large practice room (A)

Similarly to the smaller room, the FCUs were initially producing a noticeable tonal noise when working to cool the space (**measurement 3**).

When the FCUs were maintaining a steady temperature, the noise levels were again much lower and not tonal (**measurement 4**).

For reference, Arup has recommended a maximum building services noise level of **NR30** for the Hallé practice rooms. This target assumes that the noise does not contain any tonal or otherwise distracting characteristics – if this is the case, then the noise limit should be reduced by 5dB.

Assessment

The noise levels generated by the FCUs during the cooling phase were between NR31 and NR34, and were also very tonal in nature. It was agreed during the visit that it would be hard to rehearse an instrument under these acoustic conditions. From observation, the units are likely to be in the noisy 'cooling phase' for between 5-15 minutes after a new temperature is selected, or immediately after the unit is switched on

When the units were maintaining steady temperatures, the noise levels were both subjectively and objectively acceptable.

For reference, Arup has recommended a maximum building services noise level of **NR30** for the Hallé practice rooms. Comparing against this target, the practice rooms were 1-4dB above the desired noise limit when the FCUs were working to cool the spaces.

In summary, it is reasonably likely that a performer would find it distracting to rehearse whilst the FCU is working to cool the room, due to the noticeable tonal noise it emits during this phase. However, this would likely to only be for a short period of time (between 5-15 minutes) after which the unit would settle to a low noise level.

Options

The final decision on whether the proposed FCU strategy is acceptable rests with the Hallé.

If the Halle deem the approach acceptable, then:

- The strategy can proceed
- The strategy can proceed, with an element of management to ensure the FCUs are in not in a 'cooling phase' during important rehearsals

If the Halle deems the approach unacceptable, then:

- An alternative FCU-based strategy could be investigated, involving locating the units outside of the rooms and ducting the air in and out of the rooms
- An alternative low-noise ventilation strategy (such as chilled beams) could be investigated