

SANDY BROWN

Consultants in Acoustics, Noise & Vibration

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Rutherford Building, University of Manchester

Stage 4 acoustic design report

London, Manchester, Edinburgh, Birmingham, Belfast, Leeds

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A	23 Oct 23		Daniel Shaw	James Atha
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Summary

Sandy Brown has been appointed by IBI (UK) Group Ltd to provide acoustic advice to the design of the refurbishment of the Rutherford Building for the University of Manchester.

The refurbishment works will provide meeting and seminar rooms, open plan offices for researchers, academics and post-graduates, as well as associated common room, library, amenity space and comms room.

This report sets out the acoustic performance criteria and design strategies for the refurbishment works.

Handover acoustic testing requirements are set out within this document.

The Contractor is ultimately responsible for meeting and providing all necessary evidence as required to satisfy the acoustic requirements set out within this document.

Any deviations from the acoustic performance standards or testing regimes set out in this document would need to be submitted to and agreed with the Client.

This report is commensurate with RIBA Stage 4 Technical Design.

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1 Introduction

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The Contractor is ultimately responsible for meeting and providing all necessary evidence as required to satisfy the acoustic requirements set out within this document.

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This report sets out the acoustic performance criteria, design strategies and acoustic testing requirements for the refurbishment works at RIBA Stage 4.

2 Approach

Acoustic design standards appropriate for the proposed spaces have been specified based on experience and BB93 Acoustic Design for Schools, Refurbishment standards.

Base-building visits have been carried out on 12 December 2022 and 6 February 2023 to inspect and test the retained elements and inform the acoustic design strategy.

During Stages 2, 3, and 4, advice has been provided on the performance of relevant architectural elements including interfaces which are often an important issue in relation to achieving good sound insulation.

The provision for acoustic finishes has been reviewed and advice given in relation to noise & vibration control from building services systems together with requirements for cross-talk attenuators, where necessary.

At tender stage, acoustic performance requirements are set out for all relevant architectural elements and for building services noise & vibration criteria. These are important to ensure that the necessary performance requirements are clear and are included within the relevant contract documentation.

3 Basis

3.1 Design information

- Previous Stage 3 design information summarised in Sandy Brown Stage 3 design report 22582-R02-A
- Sandy Brown Design memos M005-M010
- IBI Internal partition plans 20 September 2023
- IBI floor finishes 21 April 2023
- CAD21 MEP WIP Stage 4 package 20 October 2023
- Meetings with the design team throughout Stage 4

3.2 Design guides and standards

- *BB93 - Acoustic design of schools: performance standards* dated February 2015
- BS 8233:2014 *Guidance on sound insulation and noise reduction for buildings*
- The Chartered Institute of Building Services Engineers (CIBSE) Guide A 2015 Environmental criteria for design
- BS 6472 Part 1: 2008 *Guide to evaluation of human exposure to vibration in buildings: Part 1 Vibration sources other than blasting*
- The Control of Noise at Work Regulations 2005
- The Disability Discrimination Act 2004
- The Construction (Design and Management) Regulations 2015.

4 Rutherford Building

4.1 Site inspection

A site inspection of the Rutherford Building was carried out on 12 December 2022.

External walls and internal walls to the corridor consist of thick solid masonry.

Windows were not particularly well-sealed but environmental noise ingress was low due to building location.

The existing floors are generally lightweight. Impact sound transfer was prominent from a space with hard floor finish. Carpeted floors or use of resilient layers are to be provided to help mitigate this.

Internal doors were not well-sealed and include thin inset timber panelling. This limits the acoustic performance.

4.2 Testing

4.2.1 Background noise levels

Measured background noise levels are summarised in Table 1. Noise was due to general ingress via windows, as well as internal heating pipe flow noise and computer fans in the case of the comms room.

Noise levels are generally acceptable for the proposed uses of meeting rooms and open plan researcher/academics/post grad office space (ie NR 35-40). The circulation space outside the comms room marginally exceeds the desired level of around NR 45.

Table 1 Summary of measured background noise levels

Test reference	Location	Measured sound pressure level (dB)	
		L_{Aeq}	NR
1	Level 1 stairwell outside comms	50	48
2	Level 1 stairwell outside comms	52	49
3	Level 1 stairwell outside comms	49	48
4	1.005	34	29
5	1.005	32	27
6	1.005	34	30
7	Level 1 corridor	38	33
8	Level 1 corridor	36	31
9	Level 1 corridor	37	33
10	1.001	32	27
11	1.001	31	27
12	1.001	31	26
13	Level 2 corridor	34	30
14	Level 2 corridor	32	28
15	Level 2 corridor	33	30
16	2.001	31	26

Test reference	Location	Measured sound pressure level (dB)	
		L_{Aeq}	NR
17	2.001	29	23
18	2.001	25	21

4.2.2 Sound insulation

The sound insulation measurements are summarised in Table 2. Walls and floors generally performed well, except where specific weaknesses are noted. Heating pipe penetrations were also noted to be weaknesses throughout. Entrance doors were generally poorly sealed, with some panels in the doors themselves being loose.

Table 2 Summary of measured sound insulation performances

Test ref	Source	Receiver	Element type	Measured sound insulation performance, $D_{nT,w}$ (dB)
19	2.001	2.002	Wall	50
20	2.001	2.012 Mezz	Wall	35 ^[1]
21	0.007	Corridor	Room-front	D_w 23
22	0.007	0.006	Wall	50
23	0.007	1.003	Floor	52
24	1.001	1.002	Room-front	D_w 26
25	1.001	1.019	Wall	41 ^[2]
26	1.005	Corridor	Room-front	D_w 25
27	1.005	1.006	Wall	50
28	1.005	2.006	Floor	40 ^[3]

^[1] Limited by small, poorly sealed doors

^[2] Limited by flanking via room front

^[3] Potentially limited by a poorly sealed interface between the floor and facade, with coping used to seal off the junction now containing significant cracks.

5 Building envelope

5.1 Noise ingress criteria

The maximum cumulative internal noise levels due to environmental noise ingress are provided in Table 3.

Table 3 Maximum internal noise criteria

Space	Maximum internal ambient noise level, <i>L</i> _{Aeq, 30min} (dB)
Meeting room	40
Informal meeting space / open plan academic study space / post-graduate researcher space	40
Rutherford room	40
Researcher room	40
Professional staff room	40
Common room	40
Corridors	45
Tea point	50
WCs	50

5.2 Internal noise measurements

Environmental noise ingress was notably low during the initial site inspection visits, and were measured to be significantly lower than the values set out above. As such, building services noise can be allowed to dominate the internal noise levels in the rooms.

Windows were not particularly well-sealed but environmental noise ingress was low due to the building location. The majority of the windows are to be refurbished using double glazing units and new seals in the existing frames, except the small windows on the mezzanine level, which are to use secondary glazing. As such, noise ingress will be minimised further.

6 Floors

The principal acoustic design requirements for internal floors are:

- Airborne sound insulation – to control airborne sound transfer from one space to another on an adjacent floor (above or below)
- Impact sound insulation – to control of impact sound transfer from one floor to another below.

6.1 Airborne sound insulation criteria

The minimum floor airborne sound insulation performance criteria is *D*_{nT,w} 40 dB, which is consistent with the BB93 refurbishment standards.

6.2 Existing floors

The sound insulation performances of a sample of floors have been measured and assessed against the sound insulation criteria.

All tested floors met the requirement of *D*_{nT,w} 40 dB, with some floors performing significantly better.

Where weaknesses were noted, this was due to poor sealing of the crown moulding in the room below at the interface between the floor and north facade masonry, with gaps noted.

The existing floors are noted to be replaced like-for-like and constructed from:

- Carpet
- T&G floorboards (assumed 18 mm)
- Timber joists (assumed 200 mm)
- Expanded metal lath with lime plaster (assumed 13 mm standard coat)
- Optional Class A acoustic spray plaster, with 50 mm mineral fibre slabs attached on battens behind.

By refurbishing the ceilings, the noted weaknesses will be addressed, with layers made continuous and well-sealed.

In addition, the voids between the floor joists shall be insulated with 50 mm mineral fibre insulation.

6.3 Plant room

The plant room is located above toilets, which are less noise sensitive than the occupiable spaces. However, any vibration producing plant shall be provided with suitable anti-vibration mounts to avoid structure-borne noise and vibration transfer.

Proposals for items within the plant rooms are not currently available. Based on plant items meeting the limits in Table 10, airborne noise transfer via the existing floor is likely to be acceptable.

6.4 Floor impact sound insulation

Based on the currently proposed spaces, floors shall achieve a maximum impact sound insulation performance of $L'_{nt,w}$ 60 dB.

This is expected to be achieved with either a carpeted floor finish, or by incorporating a resilient layer beneath hard floor finishes.

6.5 Proposed floor finishes

Carpet is expected to reasonably control impact noise transfer to spaces below and is proposed to most workspaces. Vinyl flooring shall incorporate a resilient backing where located above sensitive spaces, such as WCs above the touchdown space.

It is acknowledged that changes would not be possible to the existing tiled corridor flooring above the meeting rooms. Rugs will help to mitigate noise from footfall and chairs, though there would be some residual impact noise transfer.

7 Internal walls

7.1 Crosswall partitions

The laboratory sound insulation performance (Weighted Sound Reduction Index, R_w) is the sound insulation provided by a given construction when tested in a laboratory. It is used to select the drywall construction from relevant manufacturer’s technical literature such as the British Gypsum White Book.

The site sound insulation performance (Weighted Level Difference, $D_{nT,w}$) is the sound insulation provided by a given construction when installed on site. Ultimately it is this performance that is of greater importance. It is accepted that there will be a reduction in the sound insulation performance of a drywall between laboratory and site.

For this project the following maximum laboratory to site tolerances has been proposed:

Based on the BB93 standards, the crosswall partitions sound insulation performance requirements are set out in Table 4, and marked-up in Appendix C.

Crosswall partition sound insulation performance requirements are in terms of on-site performances ($D_{nT,w}$). For reference, the corresponding laboratory sound insulation performances (R_w) have been provided. This is based on a 7 dB drywall partition lab to site tolerance.

Table 4 Crosswall partition sound insulation performance requirements

Source room	Receiver room	On site sound insulation performance, $D_{nT,w}$ (dB)	Laboratory sound insulation performance, R_w (dB)
Meeting room	Meeting room	40	47
Meeting room	Common room	40	47
Meeting room	Informal meeting / open plan academic study space	45	52
Researcher room	Informal meeting / open plan academic study space	45	52
Common room	Informal meeting / open plan academic study space	45	52
Researcher room	Post-graduate researcher space	45	52
Open plan academic study space	Informal meeting	45	52
Server room	Admin support	45	52

The BB93 refurbishment standards generally allow for a 5 dB reduction in sound insulation. Internal glazing is proposed for the meeting cluster at ground floor. Crosswalls shall provide a minimum performance of R_w 43 dB to meet $D_{nT,w}$ 40 dB on site.

7.2 Structure-borne noise control

In certain locations, staggered / twin stud partition constructions may be required to control structure-borne noise transfer. Sources of structure-borne noise include:

- Electrical socket switches
- Objects dropping onto work surfaces/credenzas/lockers
- Wall mounted loudspeakers/AV screens with audio capabilities
- Plumbing and plant items fixed or adjacent to partitions.

WCs are proposed to be adjacent to a number of noise sensitive spaces as listed below.

Where new partitions are proposed for the WC adjacencies, staggered or twin stud drywalls are to be provided in the locations noted above (132 mm zone for staggered or 200 mm zone for twin).

Where walls are existing, independent linings shall be applied, that comprise 2 x 12.5 mm plasterboard on 48 mm studs spaced 10 mm from the existing walls between the following spaces:

- WCs and lift to Researchers
- WCs to Touchdown
- Lift to common room

A lining shall be provided to the WCs adjacent to the Rutherford room.

7.3 Plant rooms

The ground floor server room is adjacent to the meeting room cluster and the admin office. A performance of R_w 52 dB is specified to control noise transfer from equipment in the room.

7.4 Room fronts

Based on the BB93, room front partitions of spaces intended for teaching or learning shall achieve R_w 40 dB.

7.5 Proposed new partition constructions

The proposed new partition types are set out below.

Table 5 Summary of proposed new partition types

Description	Comments
4 m high acoustic door and screen system (dB rating to acoustician’s recommendations) with slimline steel frame, transom to door head, bulkhead detail to top of frame – Schueco Jansen ECO 60	Proposed to meeting room fronts. If specified separately, glazed screen to achieve R_w 40 dB, door to achieve R_w 30 dB. If specified together, system to achieve R_w 33 dB.
3.2 m high acoustic screens (dB rating to acoustician’s recommendations) slimline steel framework.	Proposed as dividers within open-plan offices. No acoustic rating to apply.
Glazed door and screen fire system with slimline steel frame, arch profiled head, transom to head of doors with slimline door closer, smoke seals to doors. To achieve Ei30.	Generally specified to doors without acoustic ratings – acceptable in those locations. Unclear if specified to existing wall infill behind doors, though Proposed to corridor meeting rooms - these are likely to be acceptable based on typical constructions.
Glazed door and screen fire system with slimline steel frame, arch profiled head, transom to head of doors with slimline door closer, smoke seals to doors. To achieve Ei60.	Specified to doors without acoustic ratings – acceptable.
Glazed door and screen fire and acoustic system with slimline steel frame, arch profiled head, transom to head of doors with slimline door closer, smoke seals to doors. To achieve Ei30. (dB rating to acoustician’s recommendations) Schueco Jansen ECO 60	Proposed to corridor meeting rooms. If specified separately, glazed screen to achieve R_w 40 dB, door to achieve R_w 30 dB. If specified together, system to achieve R_w 33 dB.

Description	Comments
Knauf Performer with Knauf resilient bar, double boarded both sides to WCs and cleaners areas	<p>Proposed to WCs and cleaner areas</p> <p>Partitions to achieve at least R_w 47 dB.</p> <p>Indicative Knauf construction 2 x 12.5 mm Soundshield to both sides of 70 mm metal C stud with resilient bars</p> <p>See notes below on resilient bars.</p>
Knauf Shaftwall to achieve 60 min fire rating.	<p>Partitions to achieve at least R_w 47 dB for mechanical risers.</p> <p>Indicative Knauf construction 2 x 15 mm Firepanel on 92 mm metal C-T studs, 25 mm Earthwool within the cavity. 19 mm Coreboard to the shaft side</p>
Knauf wall liner to achieve 60 min fire rating.	<p>Acceptable – ratings have not been specified for existing walls.</p> <p>In order to ensure the low frequency performance is maintained, lining channels shall contain 25 mm Earthwool.</p>
Knauf Performer with Knauf resilient bar, double boarded both sides.	<p>Proposed for crosswalls separating ground floor meeting rooms and admin.</p> <p>Partition to achieve at least R_w 52 dB.</p> <p>Indicative Knauf construction 2 x 12.5 mm Soundshield to both sides of 70 mm metal C stud with 25 mm Earthwool within the cavity.</p> <p>Resilient bars shall not be used due to the reliance on workmanship to ensure the bars are not bridged by screws.</p>
Glazed door and screen system with slimline steel frame, arch profile head, transom to head of doors.	<p>Specified to doors without acoustic ratings – acceptable.</p>

Resilient bars require an increased reliance on workmanship to ensure the bars are not bridged by screws.

A typical R_w 40 dB glazed partition construction is 16.8 mm acoustic laminate glass. Based on manufacturer data for the proposed Schuco constructions, the framing is not expected to affect the overall performance provided it is well sealed.

7.6 Existing walls

The existing walls generally performed between $D_{nT,w}$ 35 to 50 dB with performances of $D_{nT,w}$ 40 dB and below limited by poorly sealed inter-connecting doors. These are expected to be suitable for the majority of the refurbishment criteria.

All existing walls beimng retained shall be made good and well-sealed to maximise the sound insulation performance.

All infill partitions shall match the performance of the existing walls as a minimum, ie $D_{nT,w}$ 40 dB.

7.7 Zoom pods

The proposed pod types are set out below:

- Academics offices - Configurations A and B (different overall sizes) Verandas single person room, internal acoustic upholstery, pod specified to achieve R_w 35 dB with ventilation also incorporated, internal AV rig with audio.
- Researcher’s offices – Spacestor Residence Connect specified to achieve R_w 35 dB with integrated ventilation and internal sound absorbent finishes.

These are all acceptable for providing a reasonable level of sound insulation and privacy. This would also significantly reduce distraction to other occupants of the spaces.

The pods are to have acoustic moss walls from Acuphon applied to the outside. These have a stated performance of up to Class A. However, the product literature does not set out the construction needed to achieve Class A, or whether backings are required to achieve this performance, so care should be taken when specifying.

This is discussed further in section 10.

8 Doors

Doorsets provide considerably less sound insulation than partitions although this is offset to some extent by the higher background/activity noise level in circulation spaces.

The acoustic performance of doorsets depends on three principal factors, namely:

- The weight of the door leaf and any weaknesses due to vision panels, etc
- The tolerances around the door leaf when hung
- The type and extent of seals including meeting jambs for double doors.

Where acoustically rated doorsets are required, they would need to close onto a frame and have perimeter acoustic seals. Drop threshold seals are required on higher performance doorsets whereas lower ratings typically require a diminishing strip under the threshold in order to close off the gap when the door is shut.

Frameless doors are acoustically weak owing to typically large perimeter gaps. Likewise, doors with integral pivot hinges and standard sliding doors are often acoustically weaker owing to the difficulty of accommodating perimeter acoustic seals. Offset pivot or side hung doors tend to perform better as perimeter seals are easier to fit and can be continuous.

Double doorsets are also inherently weaker than single doorsets due to the additional weakness at the meeting stile of the door leaves.

Doors to spaces intended for teaching or learning should ideally achieve a minimum performance of R_w 30 dB.

The tested roomfronts were heavily limited by the existing doors, which included mis-aligned panels within the doors as well as poor seals at the perimeter, with the doors not closing tightly into the jamb. As it is understood that these doors are to be retained, retrofit acoustic seals are to be provided to improve the sound insulation performance. This includes the inter-connecting doors on the Level 2 mezzanine levels.

Example door constructions are provided in Table 6.

Table 6 Example door co configuration

Minimum sound insulation performance, R_w (dB)	Indicative door construction
40	Specialist acoustic door-set
30	Framed glazed or 44 mm solid core timber, hinged or sliding Full acoustic perimeter seals (batwing/compression seals in addition to wiper seals) Double rebated frame/leaf Minimised threshold gap closed off with drop threshold seal Minimised gap between door leaf and frame when closed

9 Interface detailing

Penetrations for building services pipework through existing partitions were noted to be significant weaknesses during the benchmark testing. These and other similar penetrations shall be well sealed so as not to undermine the performance of each partition.

New partitions are to be constructed full height between structural floors. These will need to incorporate void barriers within the timber floors to minimise flanking.

Interfaces with masonry partitions are expected to be suitable as simple abutments with a bead of non-setting acoustic sealant to the joint on both sides.

9.1 General

Details shall be provided to ensure that all interfaces between acoustically rated elements and all other adjacent elements are made in such a way that the sound insulation performances are not degraded. These adjacent elements may include:

- Partitions
- Door/ window frames
- Cladding
- Floors
- Service penetrations
- Columns and beams
- Roofs

- Ceilings.

All acoustically rated partitions shall be constructed full height (eg, from the structural floor to the structural soffit).

All connections to adjacent elements shall incorporate flexible airtight sealing using non-hardening sealant or other seal acceptable to the Architect.

Joints in successive layers of plasterboard shall be staggered, and joints in the top layer shall be taped and sealed.

Guidance on specific detailing is provided below.

9.2 Partitions

9.2.1 Base

For partitions rated to achieve $\leq D_{nT,w}$ 40 dB on site, ie R_w 47 dB or below, they shall be built the partition from the floor boards, with a dense foil- or intumescent-faced mineral fibre void barrier within the floor void (at least 80kg/m³, 100 mm thick) as shown in Figure 1. Additional floor finishes and boarding shall be independent to each room.

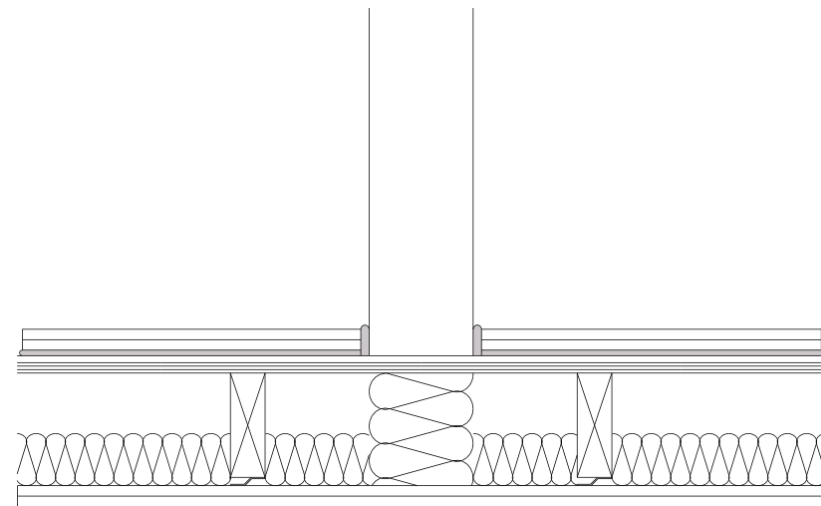


Figure 1 Example sketch detail – base detail for partitions up to and including $D_{nT,w}$ 40 dB

For partitions rated to achieve $\leq D_{nT,w}$ 45 dB on site, ie R_w 52 dB or below, a saw cut shall be added to the floorboards at the partition line in order to introduce a structural break and minimise flanking through the floorboards.

9.2.2 Head

Partitions shall break the ceiling where possible – abutting the underside of the floorboards as shown in Figure 2. A dense mineral fibre void barrier could be used if pipe or cable routing is required, of the same specification as for the floor void.

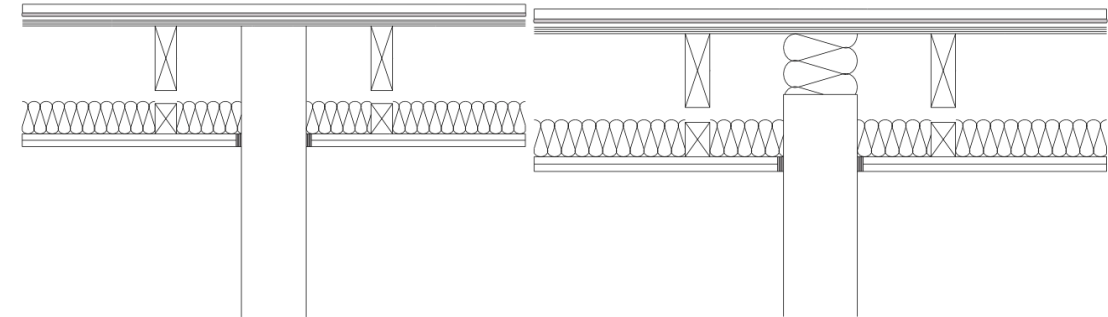


Figure 2 Example sketch detail - partition head interfaces

Where partitions cannot break the existing ceilings, the sound insulation performance is expected to be limited to around $D_{nT,w}$ 40 dB provided there is still a dense mineral fibre void barrier as per the base detail. Alternatively, a saw cut could be added to the ceiling along the partition line as per the floor in order to introduce a structural break.

9.2.3 Junction

Where partitions interface with each other, the boarding shall inter-leave, and not fly past continuously. An example is shown below.

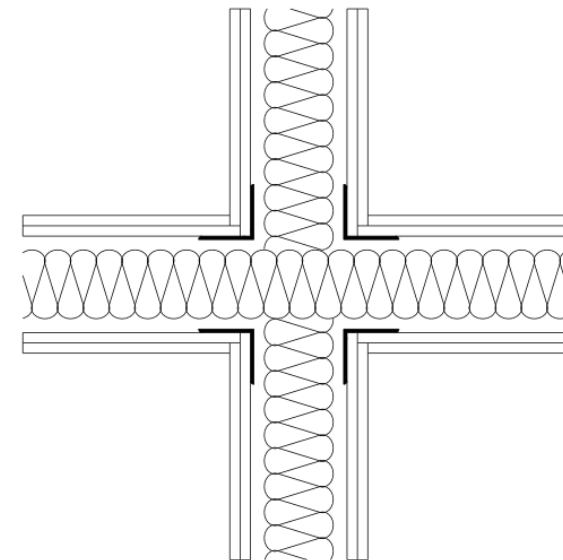


Figure 3 Example sketch partition junction detail

Where drywall directly abuts the masonry facade, this would be acceptable based on the proposed performances of the partitions.

9.2.4 Glazed partitions

Glazed partitions are suitable to directly abut the ceiling and floor boards, with dense foil faced mineral fibre void barriers above and below, as per drywall partitions.

10 Sound absorbent finishes

10.1 General

Sound absorbing finishes assist in controlling reverberation and reducing noise build-up where necessary

For guidance, a sound absorbent ceiling/wall finish would be one that has a Weighted Sound Absorption Coefficient (as defined in BS EN ISO 11654:1997) of at least α_w 0.60.

10.2 Reverberation times

The reverberation time criteria are set out in Table 7.

These criteria are provided in terms of T_{mf} which is the mid-frequency reverberation time, which is the average of the reverberation times at 500 Hz, 1kHz and 2kHz, which are frequencies commonly associated with speech. These are applicable to finished and furnished rooms. Sound absorbent finishes will need to be provided to the spaces to control reverberation.

Table 7 Reverberation criteria

Space	Maximum mid-frequency reverberation time T_{mf} (seconds)
Meeting/seminar rooms	≤ 0.8
Researcher rooms	≤ 0.8
Professional staff rooms	≤ 1.0
Informal meeting spaces / open plan academic study spaces / post-graduate researcher spaces	≤ 1.0 ^[1]
Social spaces /common rooms	≤ 1.2 ^[2]
Tea points	≤ 1.5

^[1] Spaces considered to be open plan study / resource spaces, rather than cellular learning and teaching spaces.

^[2] This is in line with BB93 refurbishment criterion and the existing kitchen/staff room

10.3 Finishes strategy

10.3.1 Proposed treatment

The proposed finishes are understood to be as set out in Table 8.

Baffle arrangements where indicated have been based on 300x40 mm baffles hung at 300 mm centres (providing an equivalent to Class D).

Table 8 Summary of proposed finishes

Space	Proposed finishes
Meeting rooms (4P and 10P)	Carpeted flooring Acoustic baffles to the majority of the ceiling area (≥ 80 % of the soffit) Plastered masonry walls with inset glazed windows and glazed fronts
Corridor meeting rooms (6P)	Tiled flooring Acoustic baffles to the majority of the ceiling area (≥ 40 % of the soffit) Plastered masonry walls with inset glazed windows and glazed fronts
Researcher room	Carpeted flooring Acoustic baffles to the majority of the ceiling area (≥ 80 % of the soffit) Plastered masonry walls with inset glazed windows and glazed fronts Total 5 m ² acoustic wall panels around screens.
Academics	Carpeted flooring Acoustic baffles to the majority of the ceiling area (≥ 80 % of the soffit) Plastered masonry walls with inset glazed windows and glazed fronts Acuphon Class A moss wall panel to meeting pods Small area of acoustic wall panels around screens.
Post Grad	Timber panelling to the structural ceiling, perforated plasterboard (minimum Class C) to the underside of the mezzanine level Carpet flooring Plastered masonry walls with low level timber panelling and glazed windows 9 m ² Wallsorba acoustic wall panelling

Space	Proposed finishes
Common room	Vinyl flooring
	Fabric covered booths
	Central acoustic baffles to 30% of the ceiling area, plaster ceiling
	Plastered masonry walls with inset glazed windows
Rutherford room	Timber flooring
	Plaster ceiling
	Plastered masonry walls with inset glazed windows
Tea point	Vinyl Floor
	Plaster ceiling
	Plastered masonry walls with inset glazed windows and fronts

10.3.2 3D modelling of open plan workspaces

To control risk of disturbance, a typical criterion is to aim for a Speech Transmission Index (STI) of less than 0.5 across as much of the space as possible.

STI is a measure of the ratio of syllables which can be clearly understood. The lower the value, the less likely a conversation is to be understood and hence it is less likely to be attention grabbing and disturbing.

In addition to controlling STI, the absolute level across the spaces from a conversation is considered in comparison to the background noise level.

Calculations have been carried out based on the design building services noise levels on the spaces, with a tolerance to allow for variation in the internal levels i.e. NR 35.

If this can't be ensured as a minimum then sound masking will need to be considered to maintain a minimum constant background noise level.

Academics

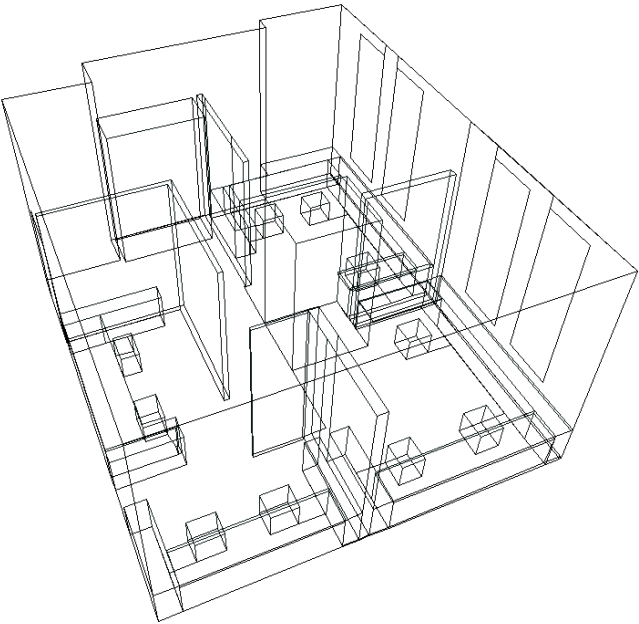


Figure 4 Academic space model sketch

The average predicted reverberation time meets the maximum criterion.

For normal speech such as during a face-to-face conversation, the STI is above 0.5 within the same cluster as each speaker, though is well below 0.5 in all other clusters, and so is likely to be less disturbing. Two-sided conversations are also less distracting as the brain does not try to fill in the blanks within the conversation.

It is noted that this is significantly better than would be expected from untreated spaces.

The figures below show the results for two different speaker positions. In the context of controlling disturbance, a lower STI is better, with the criteria met for yellow, orange and red areas.

Table 9 Summary of STI performances and markup colours

Markup colour	STI performance
	0.75-1.0 (Speech clearly audible and intelligible)
	0.5-0.75 (Speech progressively less intelligible, more effort required to understand and interpolate between sections which can be heard)
	0.4-0.5 (Speech very difficult to understand)
	0.25-0.4 (Speech likely audible but largely unintelligible)
	0-0.25 (Speech briefly audible, unintrusive depending on the frequency content)

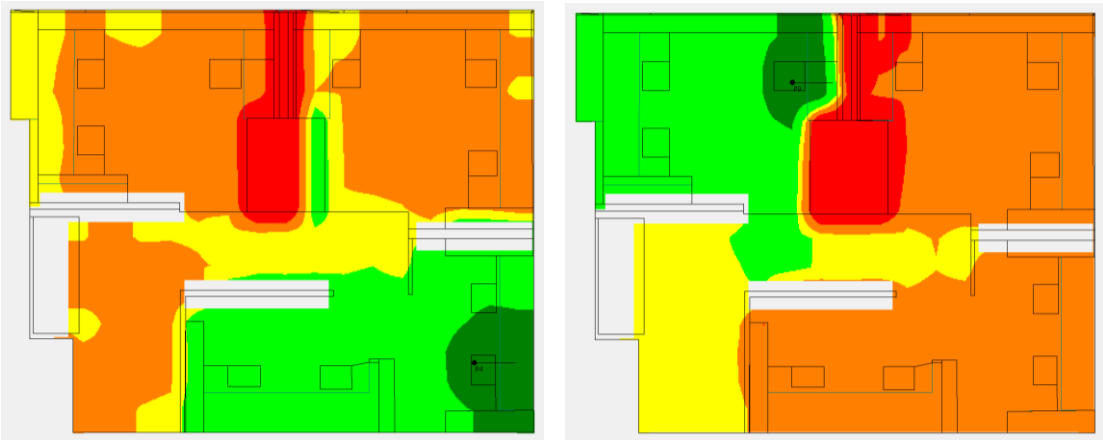


Figure 5 Normal voice as proposed

Raised speech is typical for video conferencing calls. Again, this is predicted to be intelligible within each cluster, while in other clusters the STI is in the region of 0.55-0.4, ie borderline with the STI criteria. This varies depending on the speaker location, and so multiple locations are shown in the figures below.

This would likely be suitable for less sensitive applications, though given the academics are moving from individual cellular offices and expect to work in quiet conditions, there is a potential risk of disturbance if self-management of speech level is not considered fully by occupants.

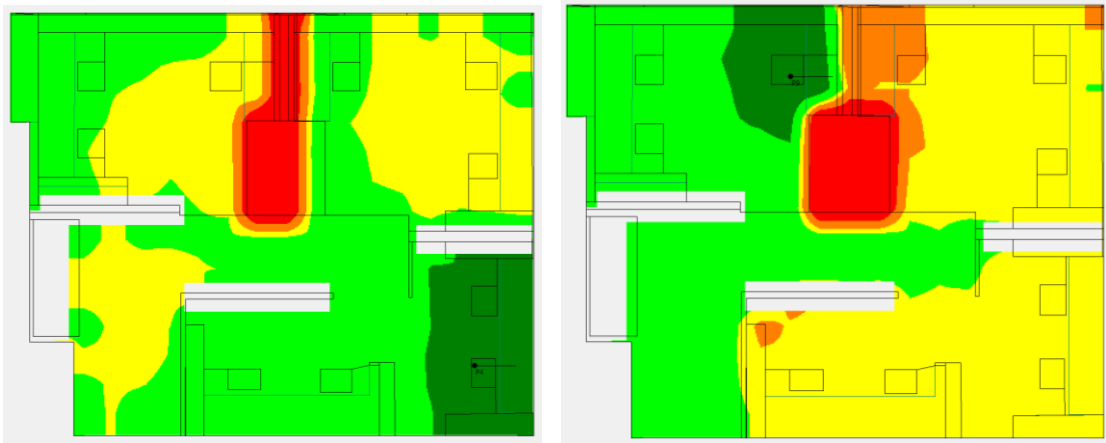


Figure 6 STI for Raised voice as proposed

To improve the control of speech transmission, especially for raised speech, two potential mitigation measures are to be considered:

- Extending the Acuphon sound absorbent moss wall to all exposed sides of the pod.
- Applying Class B sound absorbent finishes to the dividing partitions, as shown in the figure below

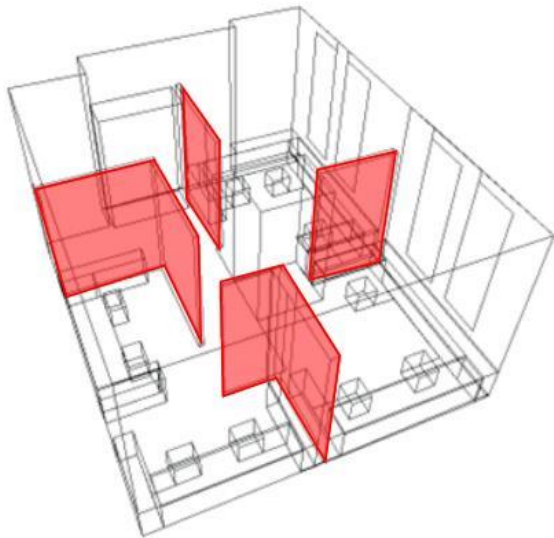


Figure 7 Location of sound absorbent finishes to the dividing partitions

This leads to a marked improvement in the control of speech transmission, especially for raised speech, with STI in other clusters below 0.5 for both raised and normal speech and multiple speaker positions as shown below.

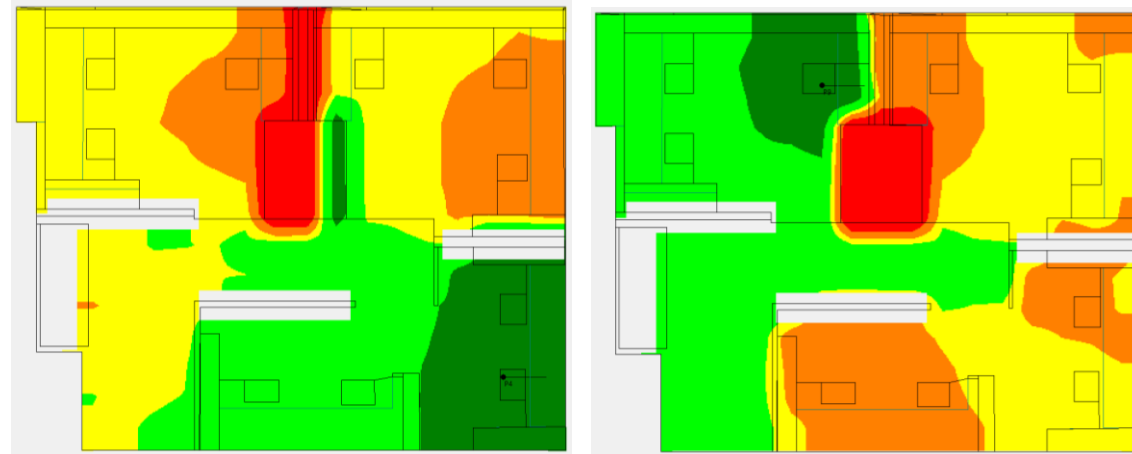


Figure 8 Raised voice with additional mitigation measures

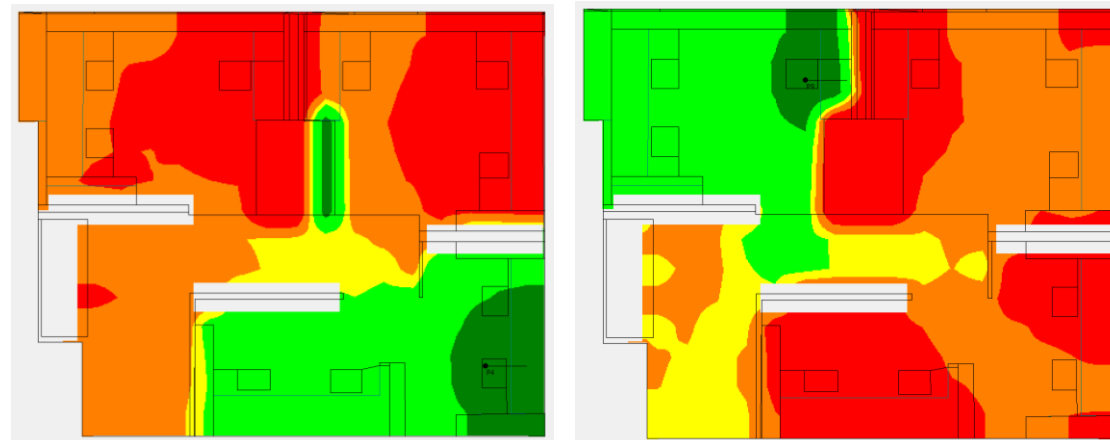


Figure 9 Normal voice with additional mitigation measures

Clearly this will reduce the natural light available within the space, and so the conflicting requirements should be considered with respect to the likelihood for raised conversation by occupants and their ability to self-regulate or use the pod for video conferencing.

Researchers

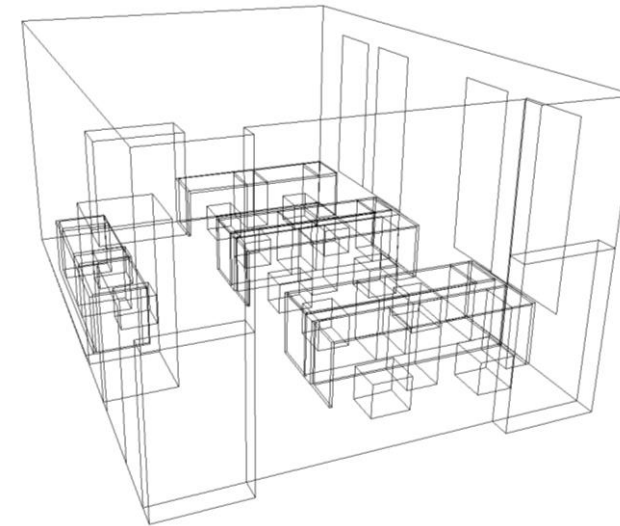


Figure 10 Researcher space model sketch

The average predicted reverberation time complies with the criterion.

Results indicate that STI across the space varied around 0.55-0.75, with raised and normal speech clearly intelligible in most areas.

Only one position is presented as the results do not vary significantly across the space.

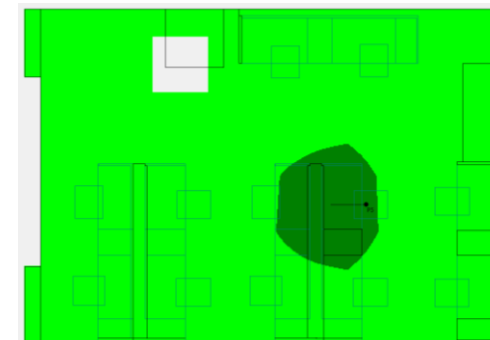


Figure 11 Raised voice as proposed

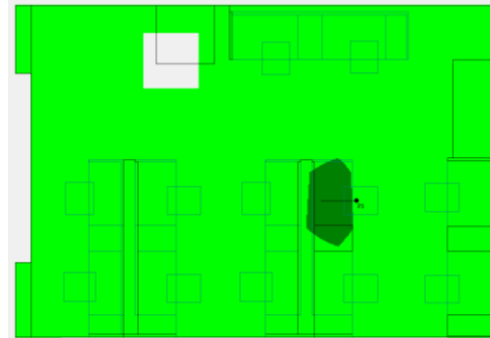


Figure 12 Normal speech as proposed

We assessed the effect of introducing sound absorbent wall panels, which did not significantly improve the STI across the space.

Instead it is proposed to add 0.6 m Class C sound absorbent desk dividers as shown in Figure 13 below.

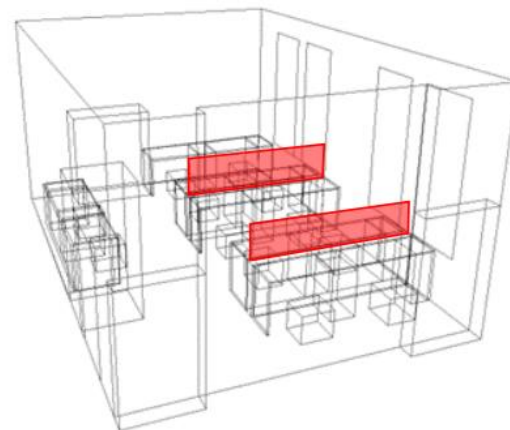


Figure 13 Mark-up of sound absorbent desk dividers

There is a notable benefit for normal speech, with up to half of the space below and STI of 0.5.

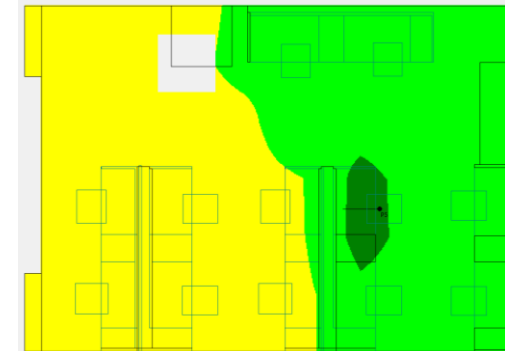


Figure 14 Normal speech with desk dividers

For raised speech there is limited benefit given how open the space still is. This shows that the researcher space will need to rely much more on management of occupants to control disturbance than in the Academics space.

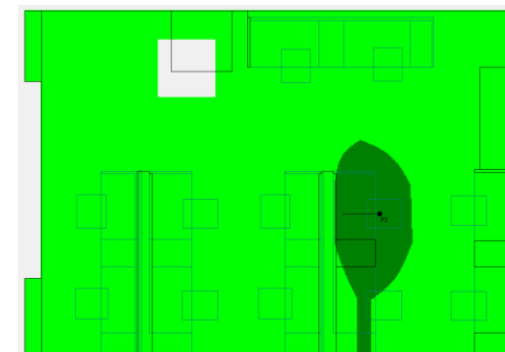


Figure 15 STI for raised voice with desk dividers

10.3.3 Predicted reverberation times

Reverberation time calculations have been carried out which indicate that the majority of spaces are expected to be borderline with their respective criteria once furnished.

The corridor meeting rooms and the double height post-graduate space are expected to significantly exceed the relevant criteria with predicted reverberation times of at least T_{mf} 2.1 s. The teapoint also exceeds the criteria by around 0.5 s.

Additional treatment is to be considered to ensure that the reverberation time criteria are met and improve the acoustic quality of the meetings rooms, as set out below.

10.3.4 Additional treatment

The following extents of additional/enhanced sound absorbent treatment is to be provided:

- Corridor meeting rooms - 8 m² Class A wall panels or free-standing treatment plus a rug covering at least 50% of the floor
- Post grad – 60 m² Class A rafts and 50 m² Class A wall panels (the ratios could be adjusted if required)
- Teapoint – Class D baffles to 40% of the ceiling area, or equivalent area of wall panels.

At least 10% of the floor area is to be provided as Class C wall panels in other sensitive areas used for working or meetings, and that the acoustic plaster is upgraded to Class A. This is to minimise lateral reflections and improve the acoustic quality within the spaces.

Wall panels shall be distributed on two adjacent (non-parallel) walls wherever possible.

Soft furnishings and rugs shall be added to the Rutherford room wherever possible to improve the reverberation.

Sound absorbent wall finishes would be required to provide a minimum sound absorption performance of Class C ($\alpha_w \geq 0.65$), which would typically be achieved with fabric-wrapped mineral fibre panels with a minimum thickness of 25-30 mm. Class A wall panels ($\alpha_w \geq 0.9$) would require 40-45 mm thickness.

Other examples of acoustic treatment are provided below.

Master Solo S

Ecophon

Free-hanging glass wool tiles with painted edges (vertical or horizontal).

www.ecophon.co.uk

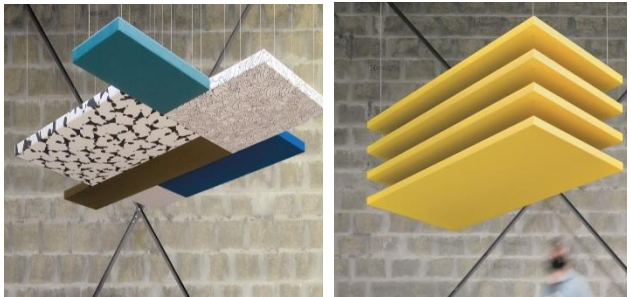


Strato 2 / Stereo

Texaa

Suspended fabric-wrapped foam or glass fibre foam acoustic panels.

www.texaa.com



Foil

Whitecroft

A range of lighting rafts with perforated metal finish and sound absorbent backing

www.whitecroftlighting.com



Thermatex Sonic Line Arc

Knauf Ceiling Solutions

Fleece-coated, frameless mineral fibre rafts in various shapes and concave/convex curves.

www.knaufceilingsolutions.com



10.3.5 Wall finishes

Sound absorbent wall finishes would be required to provide a minimum sound absorption performance of Class C ($\alpha_w 0.65$), which would typically be achieved with fabric-wrapped mineral fibre panels with a minimum thickness of 25 mm.

To achieve Class B ($\alpha_w 0.8$), typically a 35 mm thick panel is required.

To achieve Class A ($\alpha_w 0.9$), typically a 45-50 mm thick panel is required.

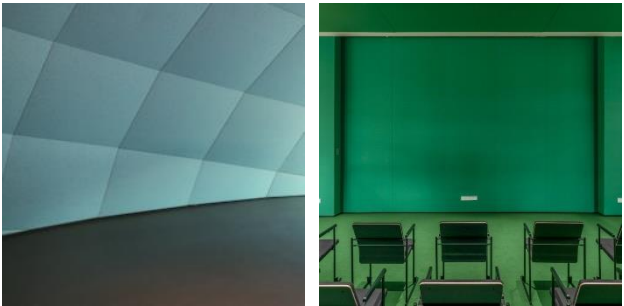
Example wall panels are provided below.

Soft Cells

Kvadrat

Stretched fabric system that offers a unique combination of flexibility, durability and acoustic performance.

www.soft-cells.com



Quietspace Panel

Autex

Sound absorbing panels, Class A, B, and C and available in a range of different colours and artistic prints.

www.autexacoustics.co.uk

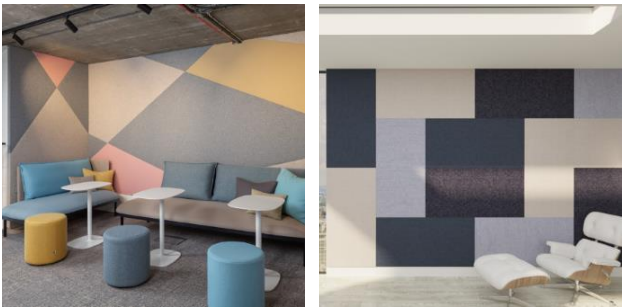


FabricWall

Resonics

Fabric finished floor-ceiling wall linings in an extensive range of decorative finishes.

resonics.co.uk



10.3.6 Open plan workspaces

The acoustic environment within open plan workspaces depends on a range of factors including:

- The acoustic properties of finishes, most importantly the ceiling
- The spacing and layout of workstations
- The design of separating screens including height, extent and acoustic properties
- Reflections off cladding, internal walls, etc
- The location, level and character of noise generated by office equipment including telephones, printers & photocopiers
- Background noise levels (typically from ventilation and traffic)
- The way in which people work/behave in the space – some open plan offices are very quiet whereas others are quite noisy.

Sound attenuation of speech is one of the most important factors in the acoustic design of open plan workspace and is the result of three main factors, namely:

- Distance between the source and the listener
- Obstructions and barriers between the source and the listener
- Sound absorption provided by finishes and furniture.

The sound absorption performance of the soffit is a major factor in providing the attenuation of sound with distance, and therefore very important with regard to speech privacy in open-plan workspaces. Other finishes such as carpeted floors, upholstered seating and loose paper also typically contribute to the overall sound absorption within open plan offices.

Items which obstruct the line-of-sight between two points (eg low level screens) can also be used to improve speech privacy. However, obstructions are effective only when the ceiling is absorbent to reduce sound reflection over the top of the barrier. The absorption of the ceiling is therefore the most important building element affecting speech privacy in open-plan workspaces.

10.3.7 Rutherford room

The Rutherford room is particularly restricted in terms of heritage limitations. Absorption is to be provided in the form of upholstered furniture and acoustic lighting features, either similar linear lighting to the former lecture room, or feature dome style lights.

11 Building services noise & vibration

11.1 Design considerations

The key acoustic issues associated with building services are:

- The control of noise & vibration from plant and equipment to acceptable levels within the building
- The acoustic sealing of penetrations through sound insulating constructions
- The control of cross-talk between rooms in supply and return air systems.

11.2 Internal noise criteria

It is important to ensure that noise from building services systems strikes the right balance between being too noisy such that it gives rise to disturbance and too quiet such that privacy is significantly reduced.

Proposed background noise criteria for the various spaces are summarised below.

Table 10 Maximum internal building services noise criteria

Space	Maximum internal building services noise criteria (NR)
Meeting room	35
Informal meeting space / open plan academic study space / post-graduate researcher space	35
Researcher room	35
Social space	35
Rutherford room	35
Academics	35
Admin/support	35
Touch down	35
Corridors	40
Kitchenette	45
WCs	45

Space	Maximum internal building services noise criteria (NR)
Comms/server	55
Plant room	NR65 with low frequency limits of 75 dB within 63 Hz and 125 Hz octave bands ^[1]

^[1] Plant room noise limits will need to be reviewed as the design progresses

The windcatchers will need to ensure that noise ingress does not cause the internal noise levels to be exceeded.

11.3 External noise

It will be important to ensure that noise from any new external plant does not give rise to nuisance to the occupants of neighbouring buildings. This is outside the scope of this report.

11.4 Noise characteristics

Noise from building services plant and systems will need to be designed such that it does not contain any distinguishable attention catching characteristics (eg, whine, hiss, screech, hum, bangs, clicks, clatters or thumps) and is not irregular enough to attract attention.

Where this is not possible, noise limits for new plant will be at least 5 dB lower than those identified in Table 10 or as part of the landlord/planning requirements.

11.5 Vibration

It is important to establish appropriate criteria such that vibration does not cause:

- disturbance in terms of perceptibility
- the maximum noise criteria to be exceeded in terms of structure-borne noise.

When all building services are operating at normal duty they shall not:

- Exceed a Vibration Dose Value (VDV) of 0.4 m/s^{-1.75} as given in BS 6472-1: 2008 in all occupiable spaces
- be of a magnitude which causes the internal noise criteria to be exceeded
- be of a magnitude which causes the vibration criteria for specific equipment to be exceeded.

In addition, vibration transfer from plant to occupied areas shall not exceed 0.01 m/s² peak acceleration, based on W_b weighting as defined in clause 3.3 of BS 6472-1: 2008.

11.5.1 Vibration control measures

All rotating and reciprocating plant such as Fans, motors, chillers, AHUs, MVHRs and all other vibration producing equipment should be fitted with suitable anti-vibration equipment (anti-vibration mounts, flexible connections, resilient hangers etc) to reduce the transmission of vibration. The degree of vibration isolation should be such that the noise and vibration criteria are met.

Ductwork and pipework in the plant rooms and ductwork & pipework in contact with structures bounding occupiable areas shall be supported on anti-vibration hangers/supports.

All anti-vibration equipment shall be specifically selected for the duty it has to perform. Design strategy

11.5.2 General

Services shall ideally be run within the corridors where possible thereby avoiding penetrations through crosswalls which typically have a much higher sound insulation performance than room fronts. It is noted that the MVHR routing currently passes through crosswalls due to the need for atmospheric connections.

Enclosed cellular spaces shall be served by their own terminal units(s) wherever possible. Spaces that share terminal units, or are without a terminal unit are likely to be very quiet which will reduce speech privacy across enclosing partitions. MVHRs are currently shown to serve multiple spaces. Crosstalk attenuation will likely be needed to maintain the speech privacy between the rooms such as the meeting room cluster.

Existing redundant services shall be stripped out and any holes/penetrations made good and sealed. Penetrations to any existing retained building services shall also be acoustically sealed.

11.5.3 Ventilation strategy

All rooms with openable windows will be naturally ventilated. This is understood to be in line with the existing ventilation strategy for the building, so noise ingress via opening windows would match with the existing conditions. Mechanical ventilation systems in the form of MVHRs only serve spaces that are located away from the facade, with specific locations discussed in the following sections.

All building services will need to be carefully selected such that the internal noise level criteria are met. Attenuators are specified to each of the MVHR inlet and outlet ducts, and all ductwork is to be internally lined.

Casing noise breakout is expected to dominate the internal noise levels based on the attenuation proposed

Ground floor

MVHR 01 is located in the WC block lobby and serves the remainder of the ground floor WC block. The atmospheric terminations are located on the north side of the building.

MVHR 02 is located in the 8P meeting room and serves the meeting room lobby and larger 10P meeting room. The atmospheric terminations are located on the south side of the building. This unit will need to be carefully selected to meet the onerous NR 35 criterion.

Extract fan 01 serves server room 2 and has an atmospheric termination at the south side of the building. The extract fan shall be located as close as possible to the separating partition and its associated attenuator as possible to minimise noise breakout. Ideally the fan would be located within the server room itself to minimise noise breakout from its casing.

First floor

MVHR 03 is located in touch down 1 and serves the first floor WC block and touch down 1. The atmospheric terminations are located on the north side of the building. It is possible the unit may need to be boxed-in or relocated to the lobby to achieve the criterion.

Second floor

MVHR 04 is located in the WC block lobby and serves the second floor WC block. The atmospheric terminations are located on the north side of the building.

Third floor windcatchers

Three total windcatchers are proposed to the roof above the third floor spaces and are the only form of ventilation in these spaces. The windcatchers shall be selected such that the internal noise level criteria noise ingress criteria are met. Wind-induced noise (whistling/tones) can sometimes be an issue for windcatchers.

An internal sound absorbent lining shall be provided for the wind-catchers to help control both noise ingress and wind-induced noise.

11.5.4 Crosstalk and routing

Where MVHR 2 serves multiple spaces, crosstalk across the roomfront is expected to be suitably controlled through the use of internally lined ductwork, and as such crosstalk attenuators would not be required.

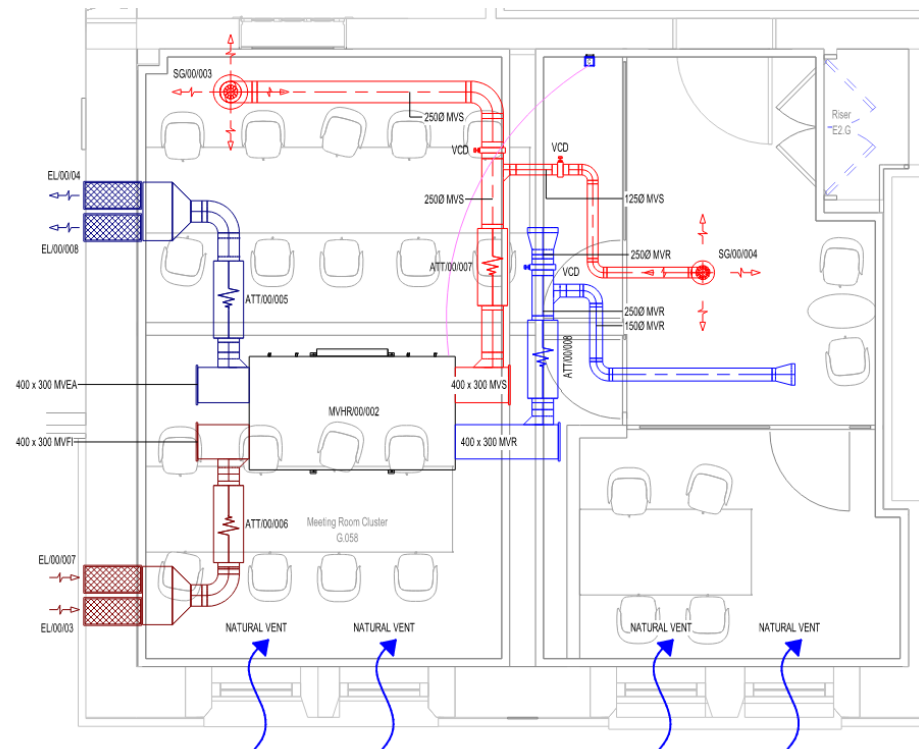


Figure 16 MVHR 2 ductwork layout

11.5.5 Pipework

It is understood that the existing radiator systems and pipework are to be retained. Where pipework penetrates acoustically rated partitions, the pipe shall be well sealed on both sides. It was noted during the site visit on 12 December 2022 that the radiator pipework did not significantly limit the sound insulation performance of acoustically rated partitions below the criteria, so those tested will not require significant further action other than making good the partitions and ensuring good seals.

It is expected that drainage pipework serving the WCs and shower on the second floor would pass down through the touch down spaces on the first floor or horizontally through the floor void. If the pipework passes vertically through the touch down space, it is to be acoustically lagged with 25 mm foil-faced mineral fibre incorporating a 4.5 kg/m² mass layer between attenuators and the crosswall and boxed-in. Pipework is to be acoustically lagged if it passes through the floor void. In either case, resilient clips shall be provided to the pipework to minimise structure borne noise transfer.

11.5.6 Electrical sockets

Where practicable, electrical sockets shall be installed with furniture (eg credenzas/tables) or the raised floor rather than in enclosing partitions, particularly crosswalls.

Should this be unavoidable, the plasterboard wall linings shall be returned around the rear of the sockets to maintain sound insulation and sockets offset (ideally by at least 600 mm) on either side of partitions. An alternative would be to use acoustic putty pads (www.hilti.co.uk) or equivalent as shown in Figure 17.



Figure 17 Hilti putty pad

11.5.7 Acoustic lagging

In some locations, acoustic lagging to supply or extract air ducts may be required to control cross talk between spaces. This will need to be assessed once final ductwork layouts become available.

11.5.8 Services penetrations

All services passing through acoustically rated walls shall be acoustically sealed.

Existing penetrations for radiator heating pipes were noted to be minor weaknesses during the benchmark test visit, though the requirements were still achieved. These will be simply sealed with mastic to improve the sound insulation performance.

Indicative details for ductwork/pipework is shown in Figure 18. The same principles shall be adopted for cable trunking/trays which shall be packed to full wall depth with mineral fibre before over-boarding, and shown in Figure 19.

Where there is a suspended ceiling on both sides, it would be acceptable to seal services with 2x50 mm ablative coated fire batt (minimum density 140 kg/m³), with each layer positioned in line with the outer face of the wall and leaving as large a cavity as possible between the two layers. The size of the fire batt shall be no more than 50 mm larger than the service penetration in all directions.

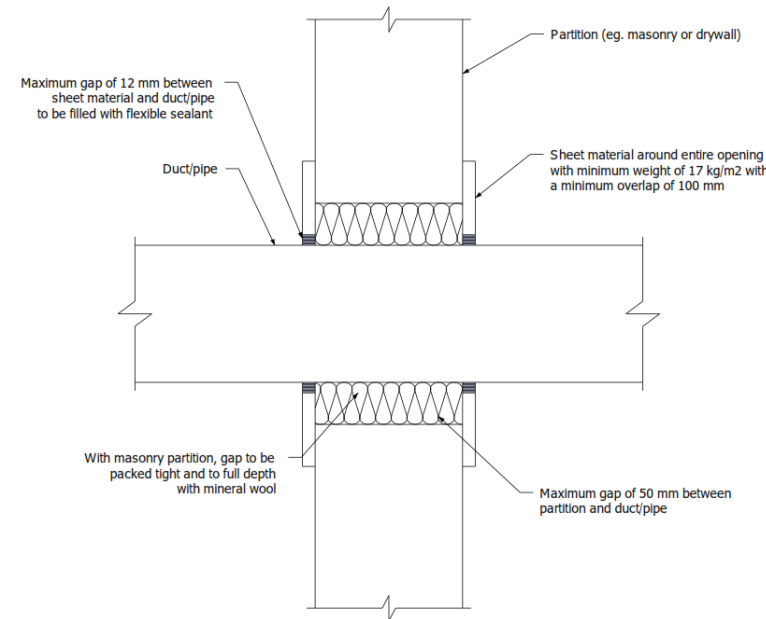


Figure 18 Example duct/pipe penetration detail through a single partition (indicative only, not for construction)

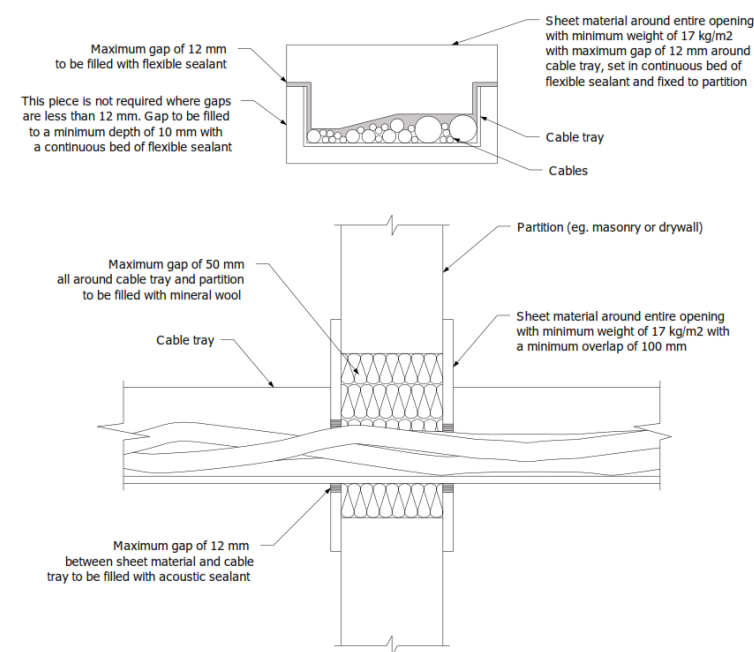


Figure 19 Example cable tray penetration through a single partition

12 Construction (Design and Management) Regulations

The Construction (Design and Management) Regulations places legal duties on virtually everyone involved in construction work. Those with legal duties are commonly known as ‘dutyholders’ and include clients, designers, contractors and workers.

Typical risks specifically associated with acoustic design are:

- Access at height to install and to maintain such elements as acoustic reflectors/absorbers
- Manual handling of heavy building elements such as high density concrete blocks.

Acoustic treatment is proposed which will require installation at height, eg soffit of spaces. However, this would be required in any event for installation of ceiling finishes, lighting, etc and is therefore not a risk specifically related to the acoustic design.

Man-made mineral fibres (MMMF) are used extensively in the construction industry and these are sometimes specified for their acoustic properties. When contractors make use of MMMF they shall act on relevant legislation and the latest guidance issued by the Health and Safety Executive.

The above risks are not unusual and would be appropriately managed by a competent contractor.

13 Acoustic testing and submissions

The contractor is to be responsible for all acoustic testing.

In order to demonstrate compliance with the requirements, acoustic testing shall be carried out to a representative sample of spaces, including:

- Internal ambient noise levels
- Airborne sound insulation of walls and floors
- Reverberation time.

This shall be undertaken once the building services installation has been commissioned and services are running under typical conditions.

The locations of these tests are to be agreed with the employer’s acoustician with sufficient notice prior to the tests.

Appendix A

Glossary of acoustic terms

General terms

Absorptive material	Material that absorbs sound energy. Soft or porous finishes such as mineral fibre are effective sound absorbers.
Acoustic absorption	The conversion of sound energy, often by the use of a porous material. It is a term used to describe the amount of sound absorbed by a finish or object within a room.
Airborne sound	Sound propagating through the air.
Airborne sound insulation	The ability of building elements or structures to reduce airborne sound transmission.
Density	Mass per unit volume, expressed in kilograms per cubic metre (kg/m³).
Direct sound transmission	The process in which sound that is incident on one side of a building element is radiated by the other side.
Flanking element	Any building element that contributes to the sound transmission between rooms in a building that is not the separating element in question. It is typically an element which continues past the separating element
Flanking sound transmission	Sound transmitted between rooms via flanking elements instead of directly through separating elements, or along any path other than the direct path.
Floating/isolated floor	A floating or isolated floor consists of a floating layer that is decoupled from the main structure by a resilient layer or other resilient element (see also ‘Resilient layer’ and ‘Floating/isolated layer’). The type of resilient element depends on the level of isolation required.
Floating/isolated layer	A surface that rests on a resilient layer or other resilient element and is therefore isolated from the main structure (see also ‘Floating/isolated floor’ and ‘Resilient layer’).
Frequency	The number of cycles per second. The unit of frequency is the Hertz (Hz). Frequency gives a sound its distinctive tone.
Frequency band	A continuous range of frequencies between stated upper and lower limits (see also ‘Octave band’ and ‘One-third octave band’).
Impact sound	Sound resulting from direct impact (such as footsteps) on a building element.
Impact sound insulation	The ability of building elements or structures to reduce impact sound transmission.
Independent ceiling or lining	A ceiling or lining which is mounted independently of (ie with no direct physical connections to) a separating floor or wall.
Isolation	The absence of rigid connections between two or more building elements.
Mass per unit area	The mass per unit area, expressed in terms of kilograms per square metre (kg/m²). Also known as ‘surface density’.
Resilient layer/element	A layer or other resilient element that isolates a floating layer from a base floor and the surrounding walls.

Resiliently mounted ceiling or lining	A ceiling or lining which is mounted resiliently from (ie connected only via specialist resilient hangers or ties) a separating floor or wall.
Reverberation	The persistence of sound in a space after a sound source has stopped.
Reverberation time	The time, in seconds, taken for the sound in a room to decay by 60 dB after a sound source has been stopped.
Separating element	An element (such as a wall, floor, door, window) which separates buildings or parts of buildings.
Sound pressure level	A logarithmic measure of the effective sound pressure of a sound relative to a reference value, measured in decibels, dB. Sound pressure levels are dependent on the conditions under which they are measured.
Sound power level	A logarithmic measure of the sound power in comparison to specified reference level, measured in decibels, dB. Unlike sound pressure, sound power is not room or distance dependent.
Spectrum	The composition of a particular sound in terms of separate frequency bands.
Surface density	The surface density, expressed in terms of kilograms per square metre (kg/m²). Also known as ‘mass per unit area’.
Structure-borne sound	Sound which is transferred by vibration via the structure of a building.

Acoustic parameters

‘A’ weighting	Frequency weighting based on the frequency response of the human ear which has been found to correlate well with the subjective response to sound.
Decibel (dB)	A logarithmic unit used for many acoustic values to indicate the level with respect to a reference level
Hz	Hertz (Hz) is the unit of frequency (see also ‘Frequency’)
$L_{A90,T}$	The A-weighted sound pressure level exceeded 90% of the measurement period (T) over which a noise is measured (ie, the quietest 10% of the period). When not weighted it is denoted $L_{90,T}$. This parameter is generally considered to be representative of a constant noise source, or background noise level.
$L_{Aeq,T}$	Equivalent A-weighted sound pressure level of a steady noise that has the same acoustic energy as a fluctuating noise over the measurement period (T). When not weighted it is denoted $L_{eq,T}$.
$L_{A10,T}$	The A-weighted sound pressure level exceeded for 10 % of the measurement period (T) over which a noise is measured. When not weighted it is denoted $L_{10,T}$.
$L_{Amax,T}$	The highest A-weighted sound pressure level measured in the period (T) with either fast (L_{AFmax}) or slow (L_{ASmax}) time weightings. When not weighted it is denoted L_{Fmax} or L_{Smax} .

$L_{A90,T}$	The A-weighted sound pressure level exceeded 90% of the measurement period (T) over which a noise is measured (ie, the quietest 10% of the period). When not weighted it is denoted $L_{90,T}$. This parameter is generally considered to be representative of a constant noise source, or background noise level.
Octave band	A frequency band in which the upper limit of the band is twice the frequency of the lower limit.
One-third octave band	A frequency band in which the upper limit of the band is the cube root of two times the lower limit of the band or more simply one third of an octave band.

International organization of standardization (ISO)

C_{tr}	The correction to a sound insulation quantity (such as R_w or $D_{nT,w}$) to take account of a specific sound spectrum with low frequency sound energy.
D	The difference in sound level between a pair of rooms, in a stated frequency band. A higher numerical quantity represents a better performance.
D_w	A single number weighted quantity which characterizes the airborne sound insulation between rooms. It is not corrected for reverberation or element size and is therefore representative of the sound insulation heard on site. A higher numerical quantity represents a better performance.
$D_{n,f}, D_{n,c}$	The difference in sound level between a pair of rooms via a specified flanking sound transmission path in a stated frequency band. $D_{n,c}$ relates specifically to ceilings but has been superseded by $D_{n,f}$ which can relate to any specified path. A higher numerical quantity represents a better performance.
$D_{n,f,w}, D_{n,c,w}$	A single number weighted quantity which characterizes the airborne sound insulation between rooms via a specified flanking path. $D_{n,c,w}$ relates specifically to ceilings but has been superseded by $D_{n,f,w}$ which can relate to any specified path. A higher numerical quantity represents a better performance.
$D_{n,e}$	The difference in sound level via a specified small element in a stated frequency band. A higher numerical quantity represents a better performance.
$D_{n,e,w}$	A single number weighted quantity which characterizes the airborne sound insulation via a specified small element. A higher numerical quantity represents a better performance.
D_{nT}	The difference in sound level between a pair of rooms, in a stated frequency band, normalized for the reverberation time. A higher numerical quantity represents a better performance.
$D_{nT,w}$	A single number weighted quantity which characterizes the airborne sound insulation between rooms, corrected for reverberation time. A higher numerical quantity represents a better performance.

$L_{n,f}$	The impact sound pressure level in a stated frequency band, flanking via a floor connecting adjacent rooms. A lower numerical quantity represents a better performance.
$L_{n,f,w}$	A single number weighted quantity used to characterize the flanking impact sound pressure level via a floor connecting adjacent rooms. A lower numerical quantity represents a better performance.
L'_{nT}	The impact sound pressure level in a stated frequency band, corrected for the reverberation time. A lower numerical quantity represents a better performance.
$L'_{nT,w}$	A single number weighted quantity used to characterise the impact sound insulation of floors. A lower numerical quantity represents a better performance. The ASTM parameter, IIC, rates the performance of the floor, meaning a higher numerical quantity represents a better performance).
NR (Noise Rating)	Noise Rating. Single figure term used to reflect the spectral content of noise. This is generally applied within rooms in relation to building services noise. Broadly equivalent to the ANSI term, NC (Noise Criterion) for typical spectra.
R	Sound reduction index. A quantity, measured in a laboratory, which characterises the airborne sound insulation of a material or building element in a stated frequency band. A higher numerical quantity represents a better performance. Broadly equivalent to the ASTM term, TL.
R_w	Weighted sound reduction index. A single number quantity which characterises the airborne sound insulation of a material or building element in the laboratory. A higher numerical quantity represents a better performance. Broadly equivalent to the ASTM term, STC.
R'	Apparent sound reduction index. The on-site equivalent of the sound reduction index, R which is measured in presence of flanking paths. A higher numerical quantity represents a better performance. Broadly equivalent to the ASTM term, ATL
R'_w	Apparent weighted sound reduction index. The on-site equivalent of the weighted sound reduction index, R_w . A higher numerical quantity represents a better performance. Broadly equivalent to the ASTM term, ASTC.
T_{mf}	The arithmetic average of the reverberation time in the 500 Hz, 1 kHz and 2 kHz octave bands (see also ‘Reverberation time’).
α_w	Weighted absorption coefficient. A quantity characterising the effectiveness of a sound absorbing surface. The proportion of sound energy absorbed is given as a number between zero (for a fully reflective surface) and one (for a fully absorptive surface). Broadly equivalent to the ASTM term NRC and SAA.
ΔL_w	The measured improvement of weighted impact sound insulation resulting from the installation of a floor covering or floating floor on a test floor in a laboratory. A higher numerical quantity represents a better performance.

Appendix B

Site inspection notes

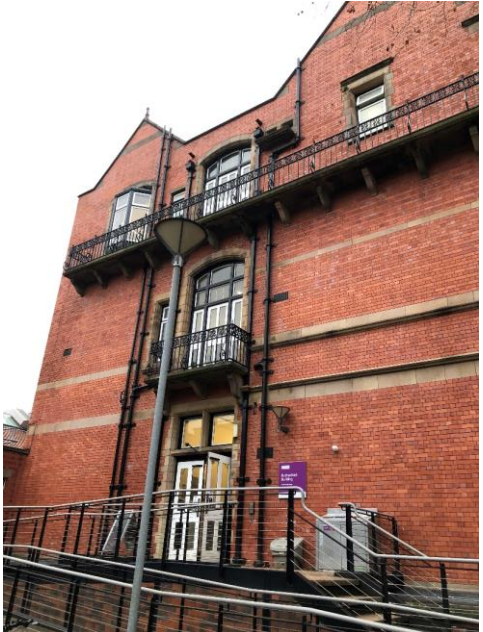
The following notes are from the site inspection carried out on 12 December 2022.

Present:	James Atha (Sandy Brown) Chris Pickup (IBI) Martin Thompson (Arcadis) Fire consultant Heritage consultant
Location of inspection and purpose of visit:	Initial site visit to inspect existing elements which may be retained to help inform the acoustic design strategy All accessible and unoccupied spaces from ground floor to the upper floor mezzanine levels were inspected.
General comments	Windows were not well-sealed but environmental noise ingress was low due to building location. Retrofitting of acoustic seals required. The existing floors are generally lightweight. Impact sound transfer was prominent from a space with hard floor finish. Carpeted floors or use of resilient layers required to help mitigate this. Internal doors were not well-sealed, limiting the acoustic performance. Acoustic seals to be provided.

Description/comments	Photographs/images
<p><i>Windows</i></p> <p>The windows were noted to consist of timber framed casement type with varying types of seals including brush, rubber and foam, generally in poor/perished condition.</p> <p>Environmental noise ingress was noted to be low generally as the building is set back and screened from dominate noise sources such as the nearby roads.</p> <p>Some excessive construction noise ingress was noted via the large windows to the high volume office space (with mezzanine) on Level 2. These works are temporary and associated with the museum refurbishment works that are currently on-going.</p>	

Description/comments	Photographs/images
Seals to be replaced with good quality acoustic seals to maximise the acoustic performance of the windows. It is understood that secondary or double glazing may be considered to improve the thermal performance, which would also be beneficial for the acoustics.	
	

Description/comments	Photographs/images
<p><i>External walls</i></p> <p>External walls were noted to consist of thick solid masonry with an internal brickwork layer and external stone/brick. The overall wall build-up was in excess of 400 mm thick.</p> <p>The external walls will be capable of controlling environmental noise ingress.</p> <p>Appropriate interface details will need to be provided for any new sound insulating partitions interfacing with the brick.</p>	 

Description/comments	Photographs/images
<p><i>Roof</i></p> <p>The roof is a pitched tiled construction with internal plaster type/plasterboard linings.</p> <p>Roof vents were noted above the high volume space on level 2 with the mezzanine floor.</p> <p>The roof was not accessible during the visit and it is not known whether there is any existing noise generating rooftop plant installed.</p> <p>No significant rooftop plant items are visible on an image sourced from Google Earth. There may be some toilet extract fans to the southwest corner of the building (above the existing toilets). It is understood that the WCs are proposed to be relocated and as such, if these are fans, they would likely be redundant.</p>	  <p>(image Courtesy of Google Earth)</p>
<p><i>External doors</i></p> <p>There are external doors to small balconies at the ends of the upper floor corridors, where new small meeting rooms are proposed to be located.</p> <p>These doors were timber framed and single glazed closing onto a rebated frame with full-perimeter rubber acoustic seals, which were in notably good condition.</p> <p>No significant environmental noise ingress was noted via these elements.</p>	

Description/comments	Photographs/images
	
<p><i>Floors</i></p> <p>Four key floor types were noted (albeit with differing floor finishes):</p> <ol style="list-style-type: none">1) Solid tiled/masonry floors to corridors with plastered ceilings below2) Lightweight timber floors to all rooms off the corridor, with plasterboard/solid panelled ceilings below3) Lightweight timber/steel upper mezzanine floor constructions with solid plasterboard ceilings4) Concrete floors/landings in stairwells and top floor lobby space to the plant room. The plant room was not accessible during the visit <p>Carpeted floor finishes were generally installed to all occupiable rooms. This helps control impact sound transfer and reduce reverberation in the rooms. Carpeted floors to be provided for the new spaces wherever possible for this reason.</p>	

Description/comments	Photographs/images
<p>A hard laminated type floor finish was installed to the kitchen/staff room on Level 1. Impact sound transfer due to footfall was prominent in the room below and was noted to be a known acoustic issue with the existing building by one of the users.</p> <p>Interface details for any new partitions built from/to lightweight floors/plaster/plasterboard ceiling will need careful consideration.</p>	
<p><i>Internal walls/glazing</i></p> <p>The corridor walls were noted to consist of solid brickwork in excess of 200 mm thick with ceramic period tiling features. These walls are capable of providing a high sound insulation performance.</p> <p>The cellular rooms appears to be a mix of newer lightweight drywalls which sounded hollow and will likely provide a low sound insulation performance, and dry-linings, likely with masonry inner leaf as per the photographs.</p> <p>There were also a number of newer cellular meeting rooms/office spaces which included a mix of single glazing and double glazing. It is understood that the proposals generally are for these spaces to be stripped out.</p> <p>A feature/original single glazed window in a timber was noted between one of the rooms on the ground floor and the stairwell.</p>	

Description/comments	Photographs/images
	 

Description/comments	Photographs/images
<p><i>Internal doors</i></p> <p>The main (original) internal doors consisted of solid timber (Oak or Pine) closing onto rebated solid timber frames. The door leafs included large and thin panels of wood within them approximately 10-20 mm thick which is expected to limit the maximum acoustic performances achievable to be R'_w 25-28 dB.</p> <p>Interconnecting doors of a similar construction were noted between many of the rooms which will limit the sound insulation performances (and privacy) between the rooms.</p> <p>Brush seals were generally noted to the original doors which provide a low sound insulation performance. These shall be replaced with acoustic seals to maximise the sound insulation performance.</p> <p>Two small original doors were installed between one of the mezzanine spaces and the large double height open plan office area on Level 2. These limit the sound insulation performance between these areas. Use of acoustic door seals or providing new dry linings to close these off may need to be considered depending on the uses of the adjacent spaces.</p> <p>Single glazed doors and newer doors were installed to the newer cellular offices/meeting rooms. It is understood that these will generally be stripped out.</p> <p>Noise transfer was noted via the doors to the telecoms room on the landing of Level 1 and from the plant room on the top floor due to gaps around the doors.</p>	

Description/comments	Photographs/images
	
<i>Sound absorbent finishes</i>	
No specific sound absorbent finishes were installed within the building.	

Description/comments	Photographs/images
Soffits were noted to be solid plasterboard or solid period feature panels.	
Carpeted floor finishes were generally installed which help control reverberation.	
Use of strategies such as suspended sound absorbent rafts will need to be considered to help control reverberation in key spaces as the design progresses.	
<i>Lift shafts</i>	
Lift shafts were noted to be of a solid masonry construction.	
<i>MEP</i>	
No mechanical or cooling plant was seen during the inspection.	
Electrical services are currently distributed at via high level containment and conduits along the corridors.	
Central heating pipes were noted around the perimeter of the building with penetrations to the partitions between the rooms. For most spaces, the only notable noise associated with MEP was a low level hiss noise from the central heating pipework.	
Noise from equipment in the telecoms room at Level 1 was notably prominent both in the stairwell (via the door as discussed above) and in the adjacent toom (via a lightweight partition). It is understood that this room is proposed to be replaced with new WCs.	
Some noise transfer from the upper floor plant room into the lobby via the door was noted.	
All redundant MEP shall be stripped out and openings/penetrations acoustically sealed to maximise the sound insulation performances of the partitions.	



Description/comments	Photographs/images
	

Appendix C

Sound insulation markups



- 4m high acoustic door and screen system (dB rating to acoustician's recommendations) with slimline steel frame PPC, RAL colour TBC, transom to door head, bulkhead detail to top of frame - Schueco Jansen ECO 60
- 3.2m high acoustic screens (dB rating to acoustician's recommendations) slimline steel framework, PPC, RAL colour TBC
- Glazed door and screen fire system with slimline stainless steel frame, PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity), arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop

- Glazed door and screen fire system with insulated steel frame. System to achieve Ei60 (insulation+integrity) impact resistant in place of existing timber fire screens, slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop
- Glazed door and screen fire and acoustic system with slimline steel frame PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity) impact resistant, (dB rating to Acoustician's recommendations), Smoke seals to doors - Schueco Jansen ECO 60
- Delta Mono stainless steel M310 balustrade system to mezzanine and staircase

- Knauf Performer with Knauf Resilient Bar, double boarded both sides to wcs and cleaners areas
- Knauf Shaftwall to achieve 60min fire rating
- Knauf wall liner to achieve 60min fire rating (existing wall construction requires further investigation)
- Knauf Performer with Knauf Resilient Bar, double boarded both sides
- Venesta Frame duct solid laminate IPS panels
- Glazed door and screen system with slimline stainless steel frame, PPC, RAL colour TBC., arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame

Title	Partition and door sound insulation performance
Project	Rutherford Building, University of Manchester
Project no.	22582
Version	D
Marked-up by	Ellen Crockett
Reviewed by	James Atha
Date	23 October 2023

Mark-up key minimum laboratory ratings

- R_w 52 dB partition
- R_w 47 dB partition
- Risers: Elect R_w 42 dB/ Mech R_w 47 dB
- Independent partition lining
- R_w 40 dB door
- R_w 30 dB door
- New acoustic door seals to be provided
- ▲ R_w 43 dB glazed screen
- ▲ R_w 40 dB glazed screen

SANDY BROWN
Consultants in Acoustics, Noise & Vibration

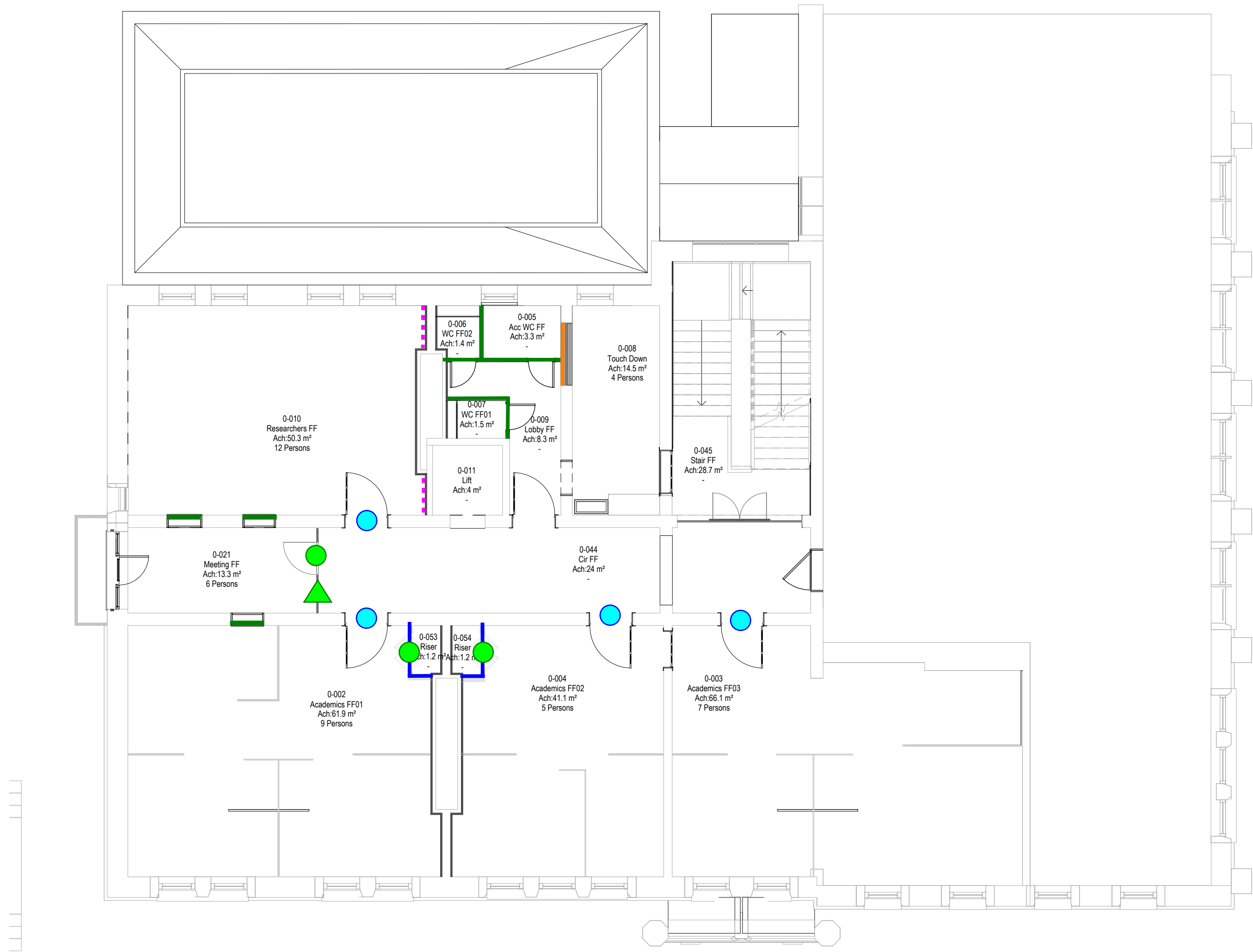
P2	2023/06/09	Stage 3 Preliminary	AB	RM
P1	2023/06/02	Stage 3 Preliminary Issue for costing	AB	RM
Rev	Date	Revision Notes	Drawn	Review



Project
Rutherford Building

Drawing Title
Internal Partition Plan - Level GF

Job Number 141532	Date FEB'23	Security Classification	Drawn By MTW
Scale@A2 1 : 100	Purpose STAGE 3 - FOR COSTING		Reviewed By RM
Drawing Number 2520-RBUM-ARC-XX-GF-DR-A-2520			Revision P2



- 4m high acoustic door and screen system (dB rating to acoustician's recommendations) with slimline steel frame PPC, RAL colour TBC, transom to door head, bulkhead detail to top of frame - Schueco Jansen ECO 60
- 3.2m high acoustic screens (dB rating to acoustician's recommendations) slimline steel framework, PPC, RAL colour TBC
- Glazed door and screen fire system with slimline stainless steel frame, PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity), arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop

- Glazed door and screen fire system with insulated steel frame. System to achieve Ei60 (insulation+integrity) impact resistant in place of existing timber fire screens, slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop
- Glazed door and screen fire and acoustic system with slimline steel frame PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity) impact resistant, (dB rating to Acoustician's recommendations), Smoke seals to doors - Schueco Jansen ECO 60
- Delta Mono stainless steel M310 balustrade system to mezzanine and staircase

- Knauf Performer with Knauf Resilient Bar, double boarded both sides to wcs and cleaners areas
- Knauf Shaftwall to achieve 60min fire rating
- Knauf wall liner to achieve 60min fire rating (existing wall construction requires further investigation)
- Knauf Performer with Knauf Resilient Bar, double boarded both sides
- Venesta Frame duct solid laminate IPS panels
- Glazed door and screen system with slimline stainless steel frame, PPC, RAL colour TBC., arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame

Title	Partition and door sound insulation performance
Project	Rutherford Building, University of Manchester
Project no.	22582
Version	D
Marked-up by	Ellen Crockett
Reviewed by	James Atha
Date	23 October 2023

Mark-up key minimum laboratory ratings

- R_w 52 dB partition
- R_w 47 dB partition
- Risers: Elect R_w 42 dB/ Mech R_w 47 dB
- - - Independent partition lining
- R_w 40 dB door
- R_w 30 dB door
- New acoustic door seals to be provided
- ▲ R_w 43 dB glazed screen
- ▲ R_w 40 dB glazed screen

SANDY BROWN
Consultants in Acoustics, Noise & Vibration

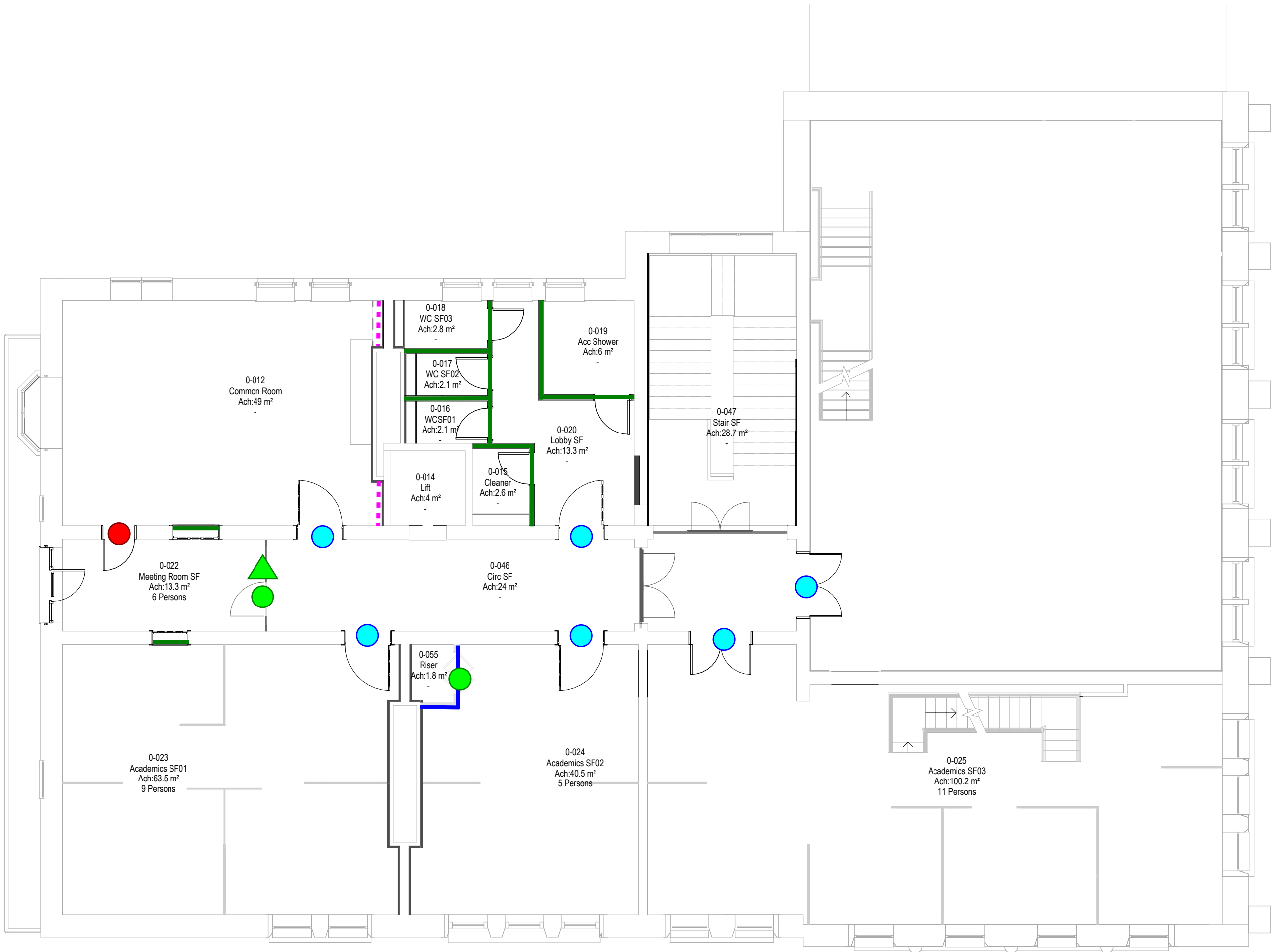
P2	2023/06/09	Stage 3 Preliminary	AB	RM
P1	2023/06/02	Stage 3 Preliminary Issue for costing	AB	RM
Rev	Date	Revision Notes	Drawn	Review



Project
Rutherford Building

Drawing Title
Internal Partition Plan - Level 01

Job Number 141532	Date FEB'23	Security Classification	Drawn By MTW
Scale@A2 1 : 100	Purpose STAGE 3 - FOR COSTING		Reviewed By RM
Drawing Number 2521-RBUM-ARC-XX-01-DR-A-2521			Revision P2



- 4m high acoustic door and screen system (dB rating to acoustician's recommendations) with slimline steel frame PPC, RAL colour TBC, transom to door head, bulkhead detail to top of frame - Schueco Jansen ECO 60
- 3.2m high acoustic screens (dB rating to acoustician's recommendations) slimline steel framework, PPC, RAL colour TBC
- Glazed door and screen fire system with slimline stainless steel frame, PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity), arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop

- Glazed door and screen fire system with insulated steel frame. System to achieve Ei60 (insulation+integrity) impact resistant in place of existing timber fire screens, slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop
- Glazed door and screen fire and acoustic system with slimline steel frame PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity) impact resistant, (dB rating to Acoustician's recommendations), Smoke seals to doors - Schueco Jansen ECO 60
- Delta Mono stainless steel M310 balustrade system to mezzanine and staircase

- Knauf Performer with Knauf Resilient Bar, double boarded both sides to wcs and cleaners areas
- Knauf Shaftwall to achieve 60min fire rating
- Knauf wall liner to achieve 60min fire rating (exisitng wall construction requires further investigation)
- Knauf Performer with Knauf Resilient Bar, double boarded both sides
- Venesta Frame duct solid laminate IPS panels
- Glazed door and screen system with slimline stainless steel frame, PPC, RAL colour TBC., arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame

Title	Partition and door sound insulation performance
Project	Rutherford Building, University of Manchester
Project no.	22582
Version	D
Marked-up by	Ellen Crockett
Reviewed by	James Atha
Date	23 October 2023

Mark-up key minimum laboratory ratings

- R_w 52 dB partition
- R_w 47 dB partition
- Risers: Elect R_w 42 dB/ Mech R_w 47 dB
- - - Independent partition lining
- R_w 40 dB door
- R_w 30 dB door
- New acoustic door seals to be provided
- ▲ R_w 43 dB glazed screen
- ▲ R_w 40 dB glazed screen

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Consultants in Acoustics, Noise & Vibration

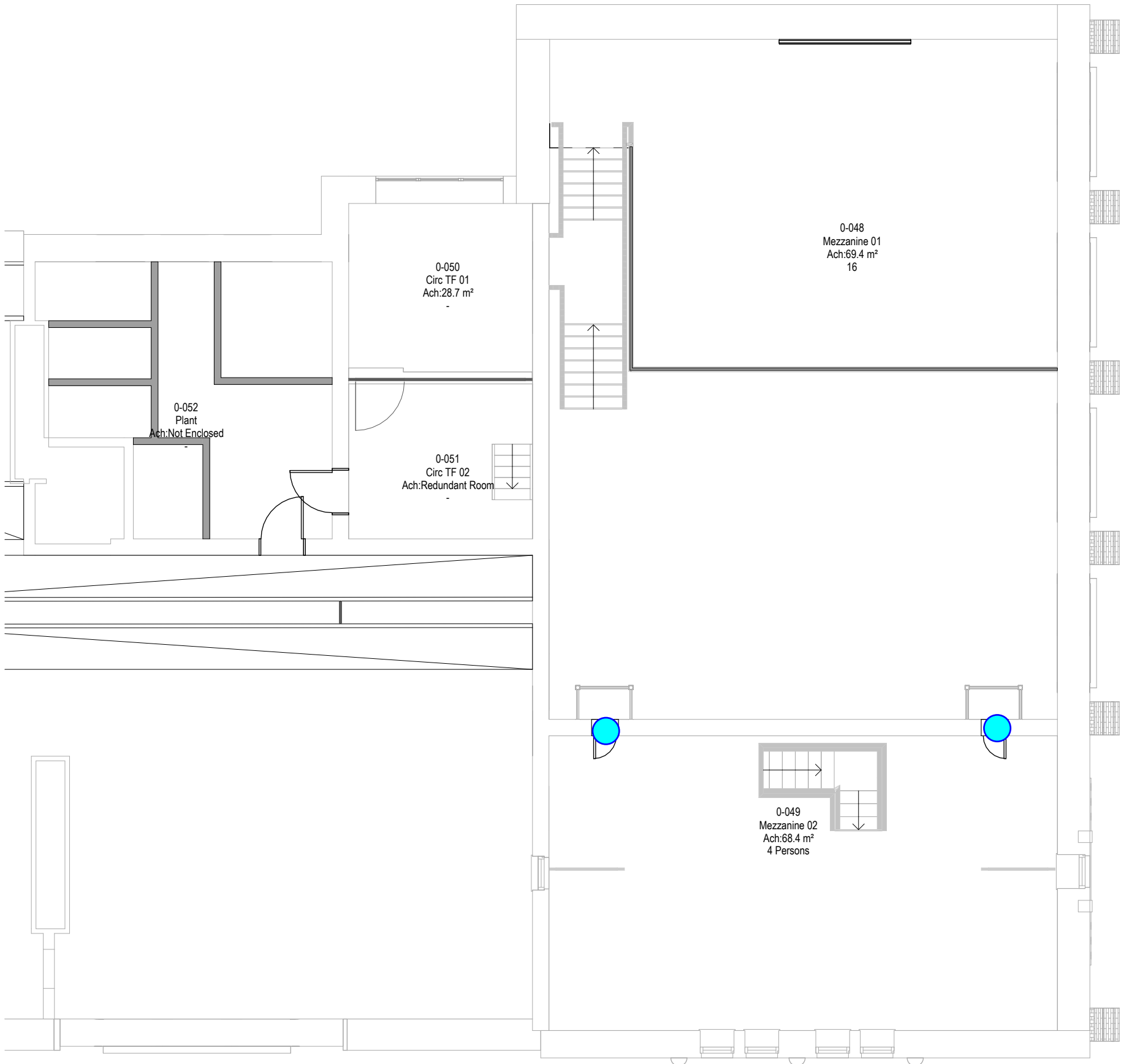
P2	2023/06/09	Stage 3 Preliminary	AB	RM
P1	2023/06/02	Stage 3 Preliminary Issue for costing	AB	RM
Rev	Date	Revision Notes	Drawn	Review



Project
Rutherford Building

Drawing Title
Internal Partition Plan - Level 02

Job Number 141532	Date FEB'23	Security Classification	Drawn By MTW
Scale@A2 1 : 100	Purpose STAGE 3 - FOR COSTING		Reviewed By RM
Drawing Number 2522-RBUM-ARC-XX-02-DR-A-2522			Revision P2



- 4m high acoustic door and screen system (dB rating to acoustician's recommendations) with slimline steel frame PPC, RAL colour TBC, transom to door head, bulkhead detail to top of frame - Schueco Jansen ECO 60
- 3.2m high acoustic screens (dB rating to acoustician's recommendations) slimline steel framework, PPC, RAL colour TBC
- Glazed door and screen fire system with slimline stainless steel frame, PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity), arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop

- Glazed door and screen fire system with insulated steel frame. System to achieve Ei60 (insulation+integrity) impact resistant in place of existing timber fire screens, slimline door closer and integrated power contained within frame, Smoke seals to doors - FireStop
- Glazed door and screen fire and acoustic system with slimline steel frame PPC, RAL colour TBC. System to achieve Ei30 (insulation+integrity) impact resistant, (dB rating to Acoustician's recommendations), Smoke seals to doors - Schueco Jansen ECO 60
- Delta Mono stainless steel M310 balustrade system to mezzanine and staircase

- Knauf Performer with Knauf Resilient Bar, double boarded both sides to wcs and cleaners areas
- Knauf Shaftwall to achieve 60min fire rating
- Knauf wall liner to achieve 60min fire rating (exisitng wall construction requires further investigation)
- Knauf Performer with Knauf Resilient Bar, double boarded both sides
- Venesta Frame duct solid laminate IPS panels
- Glazed door and screen system with slimline stainless steel frame, PPC, RAL colour TBC., arch profiled head, transom to head of doors with slimline door closer and integrated power contained within frame

Title	Partition and door sound insulation performance
Project	Rutherford Building, University of Manchester
Project no.	22582
Version	D
Marked-up by	Ellen Crockett
Reviewed by	James Atha
Date	23 October 2023

Mark-up key minimum laboratory ratings

- R_w 52 dB partition
- R_w 47 dB partition
- Risers: Elect R_w 42 dB/ Mech R_w 47 dB
- ... Independent partition lining
- R_w 40 dB door
- R_w 30 dB door
- New acoustic door seals to be provided
- ▲ R_w 43 dB glazed screen
- ▲ R_w 40 dB glazed screen

SANDY BROWN
Consultants in Acoustics, Noise & Vibration

P2	2023/06/09	Stage 3 Preliminary	AB	RM
P1	2023/06/02	Stage 3 Preliminary Issue for costing	AB	RM
Rev	Date	Revision Notes	Drawn	Review



Project
Rutherford Building

Drawing Title
Internal Partition Plan - Level 03

Job Number 141532	Date FEB'23	Security Classification	Drawn By MTW
Scale@A2 1 : 100	Purpose STAGE 3 - FOR COSTING		Reviewed By RM
Drawing Number 2523-RBUM-ARC-XX-03-DR-A-2523			Revision P2