REVERB ACOUSTICS

Noise and Vibration Consultants

Acoustic Guidelines
Campbell's Corner
Building Refurbishment
Muswellbrook NSW

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Building Acoustics-Council/OEH Submissions - Modelling - Compliance - Certification

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1 INTRODUCTION

This report details our recommendations with regard to architectural (building) acoustics for the Campbell's Corner Building Refurbishment, Muswellbrook. The report outlines proposed design criteria (to be negotiated with the Client and architect) and provides recommendations to achieve the criteria. This report is preliminary in that criteria are not confirmed, details are not addressed (eg. partition junctions, ceiling, etc), and mechanical services issues are based on assumptions and general guidelines given.

2 TECHNICAL REFERENCE / DOCUMENTS

Beranek, L.L and Istvan, L.V. (1992). *Noise and Vibration Control Engineering.* John Wiley and Sons, Inc.

Bies, D.A. and Hansen, C.H. (1996). *Engineering Noise Control: Theory and Practice*. London, E & F.N. Spon.

Harris, C.M. (ed) (1957). *Handbook of Noise Control.* New York, McGraw-Hill.

Gréhant B. (1996). *Acoustics in Buildings.* Thomas Telford Publishing.

AS 2107-2000 *"Acoustics-Recommended Design Sound Levels and Reverberation Times for Building Interiors"*.

AS 1276.1-1999 *"Acoustics – Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation"*.

Plans supplied by Stephen Rose Architects. Note that variations from design, supplied to us may affect the acoustic recommendations.

A Glossary of commonly used acoustical terms is presented in Appendix A to aid the reader in understanding the Report.

3 EXTENT OF WORK

3.1 Sound Insulation

The transmission of noise within a building can occur in two ways, namely, air-borne noise and structure-borne noise. Air-borne sounds can be considerably attenuated by intervening enclosures i.e. walls, floors, ceilings, screens, etc. Control of structure-borne noise is more difficult as it causes vibration of the building structure and is readily transmitted to adjoining areas with little attenuation. Therefore, structure-borne noise needs to be suppressed at the source by provision of isolation mountings and hangers, anti-vibration pads, resilient flooring, etc.

Just as the terms air-borne and structure-borne define the origin of sound, so direct or indirect defines the method of transmission of noise to the receiving room. The direct sound, whether air-borne or structure-borne, is that which impinges directly on the surface of the intervening partition between the source and receiver and is radiated from the source directly to the receiver. Indirect or flanking sound is that component of the source which reaches the receiving room by way of open or inadequate windows, doors, ceiling plenums or ventilation ducts. Increasing the Weighted Sound Reduction Index (Rw) of the dividing partition will have little effect if the acoustic energy of the indirect field dominates. The weaker insulating path is always the critical one.

The critical partitions requiring assessment are detailed below:

- Partitions between adjoining teaching areas, corridors, amenities, etc.
- Floor ceiling system to lower level commercial space.
- Partitions between multi-purpose space and adjoining areas.
- Partitions between meeting rooms/offices and adjoining areas.
- Ceiling systems.
- External glazing.

3.2 Mechanical Services

Mechanical plant can typically be treated within internal spaces using duct lining/lagging, silencers and adequate partitions/floor systems. External plant can be treated in a similar manner with the added inclusion of barriers, closed grid platforms, enclosures, etc.

Mechanical services recommendations are based on general guidelines for typical developments of this type.

3.3 Room Acoustics

Generally, smaller teaching spaces and offices, etc, will be adequately fitted out with soft furnishings, reducing the need to provide reverberation control, whereas consideration of the room acoustics in the multi-purpose space and performance space is critical and must be determined according to the room function. The effect of room shape and size, finish, materials and furnishings needs to be evaluated where appropriate, to enhance speech intelligibility and/or reduce reverberation.

4 DESIGN CRITERIA

4.1 Speech Privacy

The design criteria are set according to the use of adjoining rooms and the likely sources of noise within them. Published sound insulation performance in terms of Rw/STC ratings relate to partitions tested in ideal laboratory conditions or opinions based on such measurements. We therefore recommend selecting partitions with a laboratory Rw rating 3-4dB higher than required, to compensate for loss of performance through installation on-site.

There are differing classes of speech privacy which depend on speech level, absorption and background noise level in the adjoining room, and the sound insulation of the common partitions. The background noise level is typically generated by air-flow over grilles or diffusers in offices and by conversation and general people movements in corridors and reception areas.

4.1.1 Definitions

We have defined the following **classes of privacy**:

Confidential Privacy:
The occupant doesn't want their conversation overheard or to be disturbed by intruding noise. In office situations, executives often need this degree of privacy to be able to converse with a select individual or group without being overheard. Depending on the level of speech, it is either inaudible or audible but not intelligible.

Normal Privacy:
The occupant wants freedom from disturbing intruding speech. Depending on the level of speech it is either occasionally intelligible or audible but not intelligible, i.e. general office areas.

Poor Privacy:
No requirement for privacy. Speech is clearly audible and intelligible, i.e. corridors, open plan offices, reception areas, etc.

We have defined the following **speech efforts**:

Soft: Lowest level of speech possible but still audible to a listener in close proximity.

Restrained: Less than normal speech but not soft.

Normal or Conversational: The situation in offices.

Raised: In conference rooms or lobbies people usually increase their speech effort to a raised voice level.

Loud: Exceptional cases such as auditoriums, function rooms, etc.

We recommend the following Rw ratings based on a typical background noise level and a modest degree of absorption:

Privacy Class	Code	30-35dB(A) Rw Rating	35-40dB(A) Rw Rating	40-45dB(A) Rw Rating
Raised voice-Confidential privacy	RV-CP	50-55	45-50	40-45
Raised voice-Normal privacy	RV-NP	45-50	40-45	35-40
Normal voice-Normal privacy	NV-NP	40-45	35-40	30-35

The required rating will depend on user/client requirements, space limitations, budgetary constraints and practicalities. A meeting with the client and appropriate colleagues is essential to ensure the client's expectations are realised. Should the use of a variable air volume system be considered, it should be noted that background noise levels will vary, therefore necessitating higher sound insulation ratings to achieve the same level of privacy.

4.2 Mechanical Services

The maximum noise levels (in dBA) for mechanical services have been set in accordance with AS/NZS 2107-2000 *"Acoustics-Recommended Design Sound Levels and Reverberation Times for Building Interiors"* and are detailed below:

Room Type	*dBA*
EDUCATIONAL BUILDINGS	
Engineering workshops	50 – 60
Teaching spaces	35 – 45
Office areas	40 – 45
Music studios	30 – 35
Music practice rooms	40 – 45
Manual arts workshops	40 – 45
Corridors and lobbies	45 – 50
STUDIO BUILDINGS	

4.3 Room Acoustics

The reverberation times (T_{60}) have been set in accordance with AS/NZS 2107-2000 *"Acoustics-Recommended Design Sound Levels and Reverberation Times for Building Interiors"* and are detailed below:

Room Type	Reverberation Time, T_{60} (seconds)
EDUCATIONAL BUILDINGS	
Teaching spaces	0.5 – 0.6
Office areas	0.4 – 0.6
Music studios	1.2
Music practice rooms	0.7 – 0.9
Corridors and lobbies	0.6 – 0.8

5 DESIGN INTENT / ACOUSTICAL RECOMMENDATIONS

Meetings with our client enabled us to establish the desired level of acoustic privacy within the allowable budget. Shown below is the range of sound insulation ratings and the expected acoustic result:

Rw/CAC 30-35	Raised speech can be easily heard and usually understood
Rw/CAC 35-40	Raised speech can be easily heard and occasionally understood.
Rw/CAC 40-45	Raised speech is difficult to hear and unintelligible.
Rw/CAC 45-50	Raised speech is difficult to hear although music is audible.
Rw/CAC 50-55	Raised speech inaudible and music is occasionally audible.
Rw/CAC 55-60	Raised speech is inaudible and music is difficult to hear.

5.1 Partition Walls – Performance Space/Multi-Purpose Space

We recommend *"Raised Voice-Confidential Privacy"* for both the Performance Space and Multi-Purpose Space, necessitating full-height partitions with at least an Rw55-60 rating. Existing masonry walls will be adequate, and we understand that new proposed partition walls will be lightweight construction. We recommend the following:

Option 1:
- Staggered stud wall, minimum 92mm track
- 2 layers 16mm fire rated plasterboard to both sides.
- 75mm glasswool or polyester cavity infill.

Option 2:
- 2 rows steel studs separated by minimum 20mm airspace.
- 2 layers 13mm fire rated plasterboard to both sides.
- 75mm (11kg/m^3) glasswool or polyester cavity infill to one side.

NOTE: 10mm sound rated plasterboard may be used where 13mm fire rated plasterboard is specified. 13mm sound rated plasterboard may be used where 16mm fire rated plasterboard is specified.

General Partition Design
Where double-layers of plasterboard are specified, sheets must be staggered (min 600mm), i.e. do not line up the joins, or the first sheet is to be fixed horizontal and the second sheet vertical.

Light switches and power points must not be back-to-back, and should preferably be limited to one per stud opening, if unavoidable we recommend installing fire rated switch boxes. (i.e. PROMAT, CLIPSAL or HPM).

Gaps at wall junctions are to be filled to a minimum depth of 13mm with a non-setting (gunnable) sealant. If gaps are greater than 10mm in width a backing rod must be inserted prior to sealant. We recommend applying two continuous beads of the same to top and bottom plate tracks, prior to fixing. For fire-rated walls a list of approved sealants can be provided.

5.2 Performance/Multi-Purpose Space Doors

Airlocks (i.e. 2 sets of doors) are ideal for maximum privacy, although due to lack of available area, a single set of doors leading to these areas seems the only option available. This should be satisfactory, providing adjoining transitory areas are not fully occupied during performances. We recommend 30-40mm solid core doors with the following Raven (or equivalent) acoustic seals fitted to doors:

- Raven RP10 acoustic seals should be applied to the vertical sides and top of the door frames and adjusted to provide full contact when doors are closed.
- The vertical gap where double doors meet should be sealed with Raven P71 stile seals. For double acting doors we recommend installing Raven RP71si astragal seals. Two seals should be installed onto one door stile to allow space for a latch between the seals.
- A Raven RP4 bottom door seal should be screwed onto the bottom of each door to effectively seal the gap. This seal is to be used in conjunction with an RP82 or RP77 flush fitting threshold plate to create an airtight seal and maintain wheelchair access. (Note: a gap of 25mm must be left at the bottom of the door to allow correct fitting of seals).

We do not recommend drop seals at the bottom of doors that are used regularly (see RP4 above).

5.3 Reverberation Control – Performance/Multi-Purpose Space

Location	*Minimum Treatment*
Floor:	0% (see note 2)
Ceiling:	60-70%
North/South Walls:	50-60%
East Wall:	75%
West wall:	0% (assumed to be Stage)
Stage Left/Stage Right:	

NOTE 1: For assessment purposes the stage wall is referred to as the west wall.
NOTE 2: Assumed carpet and covered/velour seating.

CEILING TREATMENT
The ceiling contributes significantly to the poor acoustic properties within the hall and must be the first course of treatment. The existing pressed metal ceiling is to be retained and visible. Based on this requirement a number of options were investigated, with the most practical and cost-effective options presented for consideration:

Option 1: Suspend functional absorbers (acoustic baffles) from the ceiling. We recommend a total of twelve (18) 1200mm x 1200mm absorbers (minimum 0.7 NRC), in three (3) evenly spaced rows along the full length of the available area. Care should be taken that baffles are positioned so they do not interfere with lighting, ceiling fans, etc. Products include Echosorb (available through Acoustica Ph. 1300 722 825, suspended melamine (available through Acoustic Answers Ph. 9620 4305). Estimated Cost (labour not included): $150-$300/baffle.

Option 2: Suspend one or several acoustic absorbers from the roof structure to provide the required coverage, i.e. large ceiling panels suspended from hangers or wires. We suggest constructing the absorber from perforated aluminium sheeting, perforated/slotted plywood, or similar such as Ripplesound (available through Renhurst) or Luxalon (available through Hunter Douglass Architectural Products), backed with R2 fibreglass or S2 polyester wall batts.
Estimated Cost (labour not included): $80m².

WALL TREATMENT
We strongly recommend that treatment is evenly distributed to each wall at the percentages specified previously, ideally above head level. However, as a minimum, treatment should be applied to at least one of each parallel surface.

Option 1: Fix 40mm battens to the upper walls, at percentages nominated in Section 7.1, to upper walls above head level. Fix perforated plasterboard or slotted/perforated plywood (minimum 25-30% open area) to the battens and provide a cavity infill of 50mm fibreglass or polyester insulation. Estimated Cost (labour not included): Perforated plywood + insulation $120m².

Alternative methods of providing adequate absorption are available, utilising common building materials. Outlined below are some practical alternatives that may be considered. It should be noted that these products provide comparable performance, although will result in a significant cost saving.

1. Artwork through public donation or advertising may be utilised in the form of large woven tapestries, with polyester or fibreglass material (Bradford Batts, etc) placed behind the fabric, evenly spaced on the wall surrounds, mounted in wooden frames (to keep the material 30-40mm off the wall). This treatment would be a decorative acoustic baffle and is not uncommon in courthouses, shopping centres and private offices. A suggested size for the tapestries is say 2m x 2m, about 2-3 metres apart.

2. Canite may be used on the walls as an effective absorber, and will serve a dual purpose, i.e. pinboards for community bulletins, etc, however care should be taken not to completely cover the boards with brochures and newsletters, as the effectiveness will be reduced. The pinboards may be covered with fire retardant coloured felt to enhance appearance.
3. Commercially available products may be used as an alternative to the above recommendations, although these products tend to be quite expensive. However, products which will achieve the same result are Ecophon Wall Absorber in a connect grid (available through CSR) or Soundsorber Foam (available through Pyrotek) adhered to a plywood backing sheet and covered with a woven fabric.
4. Framed acoustic baffles may be constructed, consisting of a perforated facing of plywood, MDF, aluminium, etc, with polyester or fibreglass behind the perforated sheet, which can be hung on the wall much the same way as a painting. Once again the frame is to be 30-40mm in width to keep the absorbent backing off the wall and aid in low frequency noise absorption (frame construction of your choice). The advantage with this type of treatment is that it can be hung on the walls and removed if desired.
5. Construct a frame with plywood backing, glue 30-40mm thick absorbent foam to the plywood (available through Clark Rubber), and cover foam with velour, or any woven fabric.
6. As a further suggestion, hang medium to heavy pleated, velour drapes along walls (much like movie theatres adopt).

ACOUSTIC QUALITY

High noise levels from amplified music are typical within performance areas. Two types of faults that commonly ruin the acoustic qualities of such a space are echoes and resonances. Echoes and resonances are often referred to as synonyms by musicians when describing the acoustic qualities of a room, although in this case an echo is the repeat of the original sound coming loud and long enough after the original sound that it is heard as a separate entity, while resonance is the accentuation of a particular frequency band of sounds, causing those frequencies to be both louder and die away more slowly.

To reduce the occurrence of echoes, long return sound paths and secondary reflections should be avoided from surfaces, with particular attention to the ceiling and corners of the room. To reduce resonance, parallel reflective surfaces should be avoided and this has been addressed in part by suggested acoustic treatment. A third common fault is flutter echo, which also occurs between parallel reflective surfaces, although it will be heard as a series of echoes diminishing in intensity. Both resonance and flutter echoes will not occur if our recommendations are implemented.

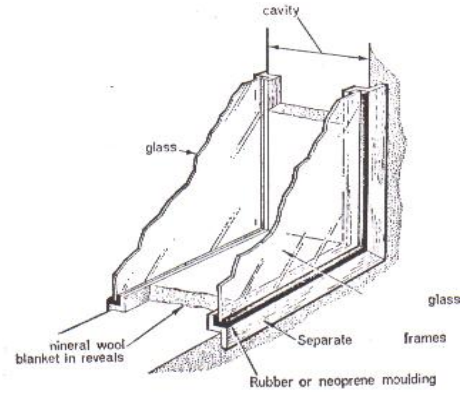
In respect to the above discussion, the performance area should provide adequate diffusion of sound to promote a uniform distribution of sound and accentuate the natural qualities of music. This can be achieved by the alternate application of absorbent and reflective surfaces and the generous application of surface irregularities.

5.4 Glazed Observation Panels

Under an ideal situation glazed observation panels should provide equivalent acoustic insulation as the partition wall, although a lesser design goal will usually suffice. Observation panels should be kept as small as practical, i.e. 500-600mm high. A double-glazed system consisting of 10.38mm laminated glass x minimum 50mm airspace x 6.38mm laminated glass is common in high performance areas. The glass should be mounted in rubber or neoprene mouldings. Provision to remove at least one panel is recommended to aid in cleaning.

For best results the following principles should be applied for installation of double-glazing:

- The larger the airspace, the better the performance, at least 100mm.
- Panes should be mounted in separate frames and held in rubber or neoprene mouldings.
- Panes must be different thickness to avoid coupled resonance.
- Reveals should be lined with acoustic tile, carpet, etc, to reduce cavity resonance.



5.5 External Glazing - Performance/Multi-Purpose/Sensitive Areas

Standard 3-4mm glazing will be inadequate to prevent intruding noise such as road traffic, passing trucks, etc. Due to heritage reasons we assume the existing external windows will be retained. Therefore a secondary fixed pane of laminated glass (minimum 6.38mm) should be mounted inside the existing window. Observe principals outlined in Section 5.4 previously for double glazed partitions.

5.6 Floor/Ceiling System – Teaching Areas/Private Offices

Observations during our site visit revealed that incidental music (background music) played in the lower level commercial area was audible in some sections of the upper level. We suspect speakers are ceiling mounted for the lower level area and noise is passing through gaps in the existing floor. We therefore recommend the following:

1. Retain existing floor and fix 6mm FC sheeting or 10mm construction plywood to entire floor area.
2. Caulk perimeter of sheets and sheet joins with a non-setting sealant. A backing rod must be inserted first for gaps exceeding 10mm in width.
3. Fix 30-40mm battens at 600mm centres on new floor covering.
4. Lay 50mm fibreglass or polyester insulation between battens.
5. Fix yellow tongue flooring or similar to battens.
6. Provide floor covering of choice.

NOTE: Where floor is to be raised follow above construction details.

5.7 Partition Walls/Ceilings – Rehearsal/Percussion/Music Rooms

Partition walls should be consistent with those specified for Performing Spaces.

We understand that partition walls between these areas may not be full height, i.e. will stop at top of stud wall frame. Therefore, flanking noise will occur over the top of the walls. The following ceiling systems are required:

2 layers 13mm fire rated plasterboard with 50mm glasswool ceiling overlay to entire ceiling. Standard ceilings to corridors or adjoining non-sensitive areas.

Standard downlights and recessed tray type fluorescents are not permitted, either install surface mounted lighting, fire rated downlights such as Regal R1012/FRD, or Tenmat FF109 Downlight Covers above all lights (available through Exfoliators (Aust) Pty Ltd Ph. (03) 9706 6049). Recessed fluorescents must be boxed in with recessed plasterboard in situations where the common wall stops at the suspended ceiling.

5.8 Doors – Rehearsal/Percussion/Music Rooms

We recommend 30-40mm solid core doors to all rooms with the vertical sides and top of the door frames fitting neatly to provide close contact when doors are closed. For sensitive areas we recommend installing raven RP10 acoustic seals at door surrounds.

5.9 Reverberation Control – Rehearsal/Percussion/Music Rooms

Ceiling	80% treatment
Walls:	50% treatment to available area on all walls.

5.10 Partition Walls/Ceilings – Teaching Areas/Private Offices

We recommend *"Normal Voice-Confidential Privacy"* for these areas, necessitating full-height partitions with at least an Rw50. Existing masonry walls will be adequate, and we understand that new proposed partition walls will be lightweight construction. We recommend the following:

Option 1:
- Staggered stud wall, minimum 92mm track
- 2 layers 13mm fire rated plasterboard to one side.
- 1 layer 13mm fire rated plasterboard to other side
- 75mm glasswool or polyester cavity infill.

Option 3:
- 2 rows steel studs separated by minimum 20mm airspace.
- 2 layers 13mm fire rated plasterboard to one side.
- 1 layer 13mm fire rated plasterboard to other side
- 75mm (11kg/m^3) glasswool or polyester cavity infill to one side.

NOTE: If amplified music is proposed in these rooms, observe requirements for Performance Spaces

5.11 Reverberation Control – Teaching Areas/Private Offices

As previously stated, achieving appropriate reverberation times within smaller rooms will generally not be an issue, as the rooms will normally be furnished and occupied. This reduces the air volume of the space and supplies additional absorptive surface area so as to disperse echoes and reduce reverberation times. To provide further absorption consideration may be given to providing a canite pinboards on one of each opposite wall. Perhaps a medium pile carpet may also be considered.

For teaching rooms where music is performed/practiced we further recommend an absorbent ceiling, as described in Section 5.3.

5.12 Floor Treatment – Corridors/Stairs

To reduce footfall noise transmission we recommend laying carpet all cushioned vinyl to all corridors and stairs.

6 GENERAL MECHANICAL RECOMMENDATIONS

This Section provides general guidelines and recommendations for the acoustic installation of mechanical equipment. Due to the noise sensitive nature of this building, particularly the performance spaces, stringent noise control will be required for building services. Attention is also drawn to the fact that air conditioning units may be above/adjacent to sensitive areas and structure borne vibration must not be present. In order for this treatment to be acoustically effective, no rigid connections will be permissible between the installed plant and the building structure. Appropriate flexible connections, restraining devices and isolation mounts are detailed within this document. The contractor shall ensure that these details are implemented effectively.

It is vitally important to select and install all plant, equipment, piping and ducting systems to ensure quiet and vibration free operation in compliance with the specified noise and vibration criteria. Replacement and/or modification will be necessary to all systems causing undue noise or vibration exceeding the specified criteria.

6.1 Achievement of Design Objectives

A design objective shall be regarded as achieved if sound levels within the space concerned, meet the following requirements:

- The SPL does not exceed that value corresponding to the specified design objective.
- The sound under consideration is free from specifically annoying characteristics (eg. tones, squeaks, pulsations etc).
- In all cases the noise levels shall be taken with all specified plant and equipment operating.
- Unless otherwise specified, roof-top plant are excluded from sound level restrictions, providing that the operation of the plant as installed does not raise the noise levels above the acceptable limits in any area subject to noise limitation.

6.2 Control of Airborne Noise

Ensure that all penetrations in walls, floors and ceilings as provided for pipes, ducts and conduits etc. are acoustically sealed around the respective services at the points of penetration.

6.3 Doors

All doors to sensitive areas are to be of solid core construction with the door frames fitting neatly when the doors are closed. Standard aluminium grills are not to be installed in any air relief door leading to sensitive areas. We recommend *either* installing "cross-talk" doors *or* air relief silencers in the ceiling plenum (or the wall) above the door.

6.4 Penetrations

Where pipes and conduits with diameters over 300mm, as well as ducts penetrate a structure, tightly pack the space between the penetrating member and the building construction with fibrous material (eg fire-rated flexible fibreglass, mineral wool or ceramic wool or "Fire Stop Collars" where fire rated walls are penetrated) the full depth of the penetration and seal both sides of the penetration with a non-hardening, resilient sealant (a list of approved sealants is available on request). The space around penetrating members should be limited to between 12 and 25mm. If spaces left are larger than 25mm, close in the additional space using materials that provide at least the same surface mass as the structure being penetrated.

Pipes and conduits with diameters up to 250mm shall be isolated where they penetrate a structure by installing factory fabricated metal sleeve devices. Metal sleeves should consist of formed and stiffened galvanised steel sleeves or pipe, lined on the inside with 12-20mm Neoprene, sponge, felt, fibreglass or equivalent, bonded to the metal sleeves. The inside diameter of the isolation material should equal the outside diameter of the encased pipe in each application; use sleeve lengths equal to the wall thickness or as recommended by the manufacturer for the given diameters, but not less than 50mm.

6.5 Schedule of Generated Noise & Vibration Control Systems

Accurately balance, both statically and dynamically all rotary machinery. Comply with the requirements of Australian Standard 1359 Parts 50 and 51 - General Requirements for Rotating Electrical Machines and Australian Standard 2625 - Rotating and Reciprocating Machinery - Mechanical Vibration.

Provide flexible connections to all rotary machinery and equipment containing rotary machinery, including flexible connections between ductwork and fans and flexible conduits/coiled cables to motors and other operating devices subject to vibration.

Install acoustic lining to ductwork as scheduled and acoustic seals to pipe duct and conduit penetrations through walls and acoustic barriers.

Select plant and equipment with operating noise ratings and rotational speeds less than the specified requirements.

Select air diffusion equipment with noise ratings at all operating conditions to ensure specifications are met.

Install vibration isolation mounts and hangers, plinths and floating slabs as scheduled.

6.6 Vibration Isolation

Provide Vibration isolation mounts selected to comply with the scheduled isolation efficiency and static deflection requirements. Calculate total static deflection from the scheduled static deflectors plus the floor deflection.

Incorporate restraining devices to prevent excessive movement of plant, equipment and piping systems. Incorporate restraining devices, to all plant, equipment and piping systems, complying with the requirements of Australian Standard 1170 - Part 4 - Earthquake Loads.

Construct all brackets, housings, base plates, restraining devices and supports from galvanised steel and rubber/neoprene components from oil resistant materials. Install all mounts in accordance with manufacturer's recommendations.

Chillers which have screw compressors are to be mounted on either air spring isolators – SLM Series (available through Barry Controls) or Embleton BT or CT Series, with "Shear Flex Red" pad and steel spreader over. All piping connections to the chillers are to be isolated from the connected piping by flexible connectors. Care shall be taken to ensure that the pipe alignment is within the manufacturer's specification. Tie-rods should not bridge across the flexible vibration isolators and if fitted, shall be loosened to minimise bridging of vibration.

All pipe work both entering and leaving the plant shall be supported from either floor mounted or ceiling mounted 25 mm static deflection spring hangers for the first 200 pipe diameters from the plant item. Sub-Contractors are responsible for providing vibration isolators of the appropriate size and capacity to meet the static deflection and other requirements as stated in the Vibration Isolator Schedule, and are required to follow the instructions from the manufacturer or vendor of these products. Note that effective vibration isolation will be required for all fans, pumps, chillers, transformers and lift motors. Where any such item is not included on the Vibration Isolator schedule it shall be the Contractor`s responsibility to submit proposed vibration isolation details for the approval of the Architect and Acoustic Consultant.

6.7 Concrete Plinths

Provide 75mm deep metal surround concrete plinths for all pumps and floor mounted packaged air conditioning units. Inertia blocks for pumps shall have a frame depth of approximately 1/12th of the longest dimension of the equipment but not less than 150mm deep. Minimum clearance of 50mm shall be allowed between the bottom of inertia block and supporting slab.

6.8 Balancing & Speed of Rotation

Accurately balance, both statically and dynamically all rotary machinery.

Comply with the requirements of Australian Standard 1359 Parts 50 and 51 - General Requirements for Rotating Electrical Machines and Australian Standard 2625 - Rotating and Reciprocating Machinery - Mechanical Vibration.

6.9 Circular Flexible Ductwork

The ductwork shall be sheathed with aluminium foil to comply with AS 1668 - Mechanical Ventilation and Air Conditioning Code.

Form bends with a centre-line radius of not less than 1.5 times the diameter of ducts.

6.10 Acoustic Lining Materials & Installation

Manufacture acoustic lining from materials complying with Australian Standard 1530 - Part 3 - "Test for Early Hazard Properties of Materials" and having test results of Ignitability Index 0, Spread of Flame Index 0, Heat Evolved Index 0, & Smoke Developed Index not greater than 3. Face lining with perforated aluminium foil laminate sheet similar to "Sisalation 450" or 0.6mm thick perforated zinc anneal sheet and having a free area of no less than 10%.

Fasten lining to sheet metal ducts with weld pins and speed clips located at no more than 75mm from the edges of the ducts and spaced at no more than 400mm centres.

Lap, adhere and tape joints in the aluminium foil laminate sheets. Pop rivet joints in zinc anneal sheets.

Minimum sound absorption coefficients:-

Acoustic Lining	Octave Band Centre Frequency Hz)				
	125	250	500	1000	2000
25mm foil laminate	0.1	0.18	0.43	0.71	0.86
50mm foil laminate	0.17	0.45	0.74	0.90	0.93
50mm zinc anneal	0.3	0.49	0.79	0.85	0.9
100mm zinc anneal	0.58	0.71	0.83	0.88	0.92

Maximum Sound Power Levels of Supply Air Diffusers & Return Air Grills

NOISE CRITERIA dB(A)	OCTAVE BAND CENTRE FREQUENCIES (Hz)							
	63	125	250	500	1000	2000	4000	8000
30	58	47	38	32	28	25	23	22
35	62	51	43	37	33	30	28	26
40	66	55	47	42	38	35	33	31
45	70	60	52	47	43	40	38	36
50	74	64	57	52	48	45	43	41

6.11 Schedule of Acoustic Lining

All supply and return air ductwork leading from air conditioning units located in the ceiling void is to be internally lined with 50mm thick insulation.

Assumptions

System Component	Acoustic Lining Requirements
Ductwork	Ductwork detailed as cross hatched on the drawings. 25mm thick insulation with perforated aluminium foil facing.
	Ductwork details as double cross hatched on the drawings. 50mm thick insulation with perforated aluminium foil facing.
Cushion Heads	25mm thick insulation to top and sides with perforated aluminium foil facing or 25mm thick bonded polyester "TBL 3225 - Black Welty" to top and sides, or similar.
Filter plenums and condition casings	50mm thick insulation to top and sides with perforated zinc anneal sheet steel facing, or similar.

6.12 Duct Movement & Vibration

Provide flexible connections and vibration isolators as required ensuring vibration and/or noise is not transmitted to the building elements.

Provide flexible connections at all fans, air conditioning units and air handling units. Construct flexible connections from a material (eg. Woven glass fabric, loaded vinyl etc) having a density of not less than 8kg/m2.

Flexible connectors should be sufficiently taut to ensure minimal intrusion into the airflow. Flexible connectors should be located no closer than one duct diameter (or maximum rectangular dimension) from the fan intake. Flexible collar connections between fans and ductwork shall be correctly aligned.

6.13 Pipework

The first three hangers/supports from all mechanical equipment shall be spring in series with neoprene types as specified in the schedule of vibration isolators. All other supports/hangers unless otherwise specified shall incorporate an isolation medium of 8mm thickness such as waffle pattern neoprene, felt or high density fibreglass between pipe and hanger/support or between hanger/support and wall.

In general, piping systems shall be installed with sufficient bends and flexibility to prevent transmission of vibration from the connected equipment to the surrounding structure without the need for flexible connections. Where this is not possible, use approved type flexible pipe connections of standard proprietary type.

All flexible connections shall be provided with isolated tension members and other fittings as necessary to prevent excessive elongation and springing of pipes during assembly. Flexible connections shall be installed so that their axis is parallel to the axis of rotation of the equipment to which they are connected. Connecting pipes shall be anchored adjacent to all flexible connections.

6.14 Air Distribution

Systems shall be balanced with minimum throttling and fans shall run at the lowest speed consistent with obtaining specified air flows at terminals. Air control devices shall be shaped to avoid unnecessary generated noise and all air distribution fittings shall be constructed to avoid rattles.

Ensure velocities in duct work do not exceed those specified. Where these guidelines are violated, special provisions will be required to prevent excessive noise in the occupied space.

No transition, bend, attenuator or other flow restriction should be located closer than 1.5 times the largest discharge duct dimension for centrifugal fans. Air control devices should be located at least 1.5m from the diffuser with the intermediate duct lined internally. Minimise flow generated noise from elbows and take-offs by separating them by at least 4 to 5 duct diameters from each other (10 duct diameters for critical noise areas).

Place grilles, diffusers and registers as far as possible from elbows and branch take-offs. Use turning vanes in large 90 degree rectangular elbows and branch take-offs. Fans exhibiting unduly high levels of discreet tones under normal operating conditions will not be acceptable.

6.15 Sound Attenuators

Supply and install sound attenuators complying with the following performance and construction criteria. Performance data for air flow, pressure drop and insertion loss of the attenuators shall be verified by tests carried out in a recognised independent Australian laboratory.

Casing
Galvanised sheet steel to Australian Standard 1397 - Sheet Steel and Strip - Hot Dipped Zinc Coated or Aluminium/Zinc Coated.

Casings shall be constructed to comply with the requirements specified for ducts of the same category and outside dimensions but in no case lighter than 1.0 mm minimum thickness.

Utilise galvanised rolled steel angles for connections to ducts and fans

6.16 Hydraulics

Noise associated with hot and cold water supply pipework is typically structure borne (therefore isolation from the building structure is of utmost importance) while noise associated with soil and waste pipework is air-borne.

Hot & Cold Water Reticulation

All rigid hot and cold water pipes (copper, galvanised, cast iron, etc) should be externally sheathed in armaflex/aerofoam or equivalent of minimum thickness 10mm. Alternatively, isolate pipes, fittings and fixtures from building structures, especially lightweight partitions, by means of resilient sleeves, mounts and underlayments.

If Thermoplastic water pipes are preferred, isolation from the structure is not required.

Include pressure reducers or regulators at intermediate floors to maintain primary hot and cold water line pressures at a minimum.

Allow for water hammer resistors where lines take off to individual floors and where appliances are equipped with quick closing valves. Water hammering can also occur when pipes are loosely supported, therefore ensure pipework is fixed as above.

Use fully ported faucets, valves etc. to reduce hissing noise, as well as aerators to reduce general noise. Defective, loose or worn valve stems, tap washers or seals give rise to intense chattering of the plumbing system. Such items must be made good/replaced.

Flexible connectors shall be used when coupling supply and drain pipes to vibrating appliances such as pumps, chillers, etc.

Soil Waste and Vent Pipes

Where possible, limit soil and waste fluid velocities to no greater than 5m/s. (Don't install elbows to slow down the water velocity). Use simple design pipe layouts (i.e. long straight runs with minimum of elbows and T-connections).

Soil and waste water pipes/stacks should be resiliently supported at floor penetrations. There should be no solid connection between soil and waste pipes and the floor slabs or walls. If possible, separate soil and waste pipes should be provided from each habitable space to the common stack.

7 CONCLUSION

A preliminary acoustical assessment for the Campbell's Corner Building Refurbishment, has been completed. We have provided minimum recommendations in regard to partition details, ceilings, mechanical services, etc, within budgetary constraints. While we suggest that the recommended treatments will result in each area having acceptable acoustic properties, the wide range of activities that may take place imply there is also a wide range of different "optimum" privacy requirements for each of the occupied spaces. With this in mind we have designed partitions in regard to the activity in adjoining areas.

We have designed for an acoustically dead environment within performance areas, which is ideal for multi-purpose situations. However, this may prevent total acceptance of the acoustic environment by the occupants for individual situations.

The aim of this assessment is to provide guidance with regard to design of the building and selection of appropriate building components and surface finishes. Internal noise levels will be consistent with the requirements of relevant Australian standards, subject to our recommendations.

REVERB ACOUSTICS

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APPENDIX A
Definition of Acoustic Terms

Definition of Acoustic Terms

Term	Definition
dB(A)	A unit of measurement in decibels (A), of sound pressure level which has its frequency characteristics modified by a filter ("A-weighted") so as to more closely approximate the frequency response of the human ear.
Rw/STC	Weighted Noise Reduction Index/Sound Transmission Class. The ability of a partition to attenuate sound, in dB. Given as a single number representation.
Lw	Sound Power Level radiated by a noise source per unit time re 1pW.
IIC	Impact Isolation Class. The ability of a floor/ceiling to attenuate impact sound. Given as a single number representation.
CAC	Ceiling Attenuation Class. Sound travelling through a suspended ceiling in one room and back through the ceiling in the adjoining room.
NRC	Noise Reduction Coefficient. The level of noise absorbed by a particular material. A single number representation over a broad frequency range. 0 is perfect reflection and 1 is total absorption.
T_{60}	Reverberation Time. The time required for a noise to reduce by 60dB after the cessation of the noise source. It is widely accepted as the most reliable parameter in determining the acoustic properties of a room.