



A Parametric Study of Sound Leakage Through Openings and Fittings

Michael Hayne (1), Richard Devereux (2), and Andrew Steel (3)

(1) SoundBASE Consulting Engineers, Brisbane, Australia

(2) Acran Sound Control, Brisbane, Australia

(3) Ultrafonic, Brisbane, Australia

Abstract - How much does sound leakage due to openings and the installation of fittings in ceilings and walls impact upon overall sound reduction performance? In this paper, the results of a parameter study conducted in the Acran Sound Control Acoustic testing Laboratory are presented. The parametric study involved drilling holes in a sheet of 13mm plasterboard to investigate how the sound reduction and noise reduction performances changed as the hole size increased. Larger openings were then cut in the plasterboard to match common downlight sizes and the testing repeated with and without downlights installed to determine whether sound leakage through downlights is significant. Finally, a range of fittings such as power points and an exhaust fan were tested to determine their influence on sound leakage.

1 INTRODUCTION

The impact of sound leakage through openings and fittings is of major concern to anyone who practices in building acoustics. The acoustic treatments to minimise sound leakage are usually time-intensive and expensive to implement, making them unpopular with builders who do not specialise in acoustic construction.

Publications such as *The Red Book* (CSR Building Products, 2023) contain opinions that state a bulkhead or ceiling may incorporate five evenly distributed downlights per 5 m² of area without compromising acoustic performance. While that opinion might be applicable to acoustically rated downlights, what is the impact of modern lightweight LED downlights, open backed downlights or other openings for fixtures such as exhaust fans?

The parametric study is designed to give acousticians some insight into the impact sound leakage has on design. It is intended that additional testing will be conducted in the future to utilise different plasterboard constructions (for example two layers of fire-resistant plasterboard) and stud partitions to see the impact of sound leakage. The range of fittings will also be expanded to account for other common installations such as flexible ducts and patch panels, with the ultimate aim of confirming the efficacy of different construction methods to attenuate sound.

2 TEST FACILITY

The testing was conducted at the Acran Sound Control Testing Laboratory. The laboratory consists of two resiliently isolated reverberation chambers, a source room of 95 m³ and receiver room of 170 m³, separated by a test sample aperture of 9.55 m². Both the source room and receiver room have a double set of back-to-back doors (1,935 mm wide x 2,905 mm high) to allow external access to the reverberation chambers to install and remove test samples.

To prepare the laboratory for testing, in-fill walls were constructed in the aperture between the source room and receiver room and the double door opening to the source room. A test aperture opening 970 mm x 970 mm was left in the middle of the in-fill wall to the double door opening to the source room. At the top and bottom of the test aperture opening metal channels were installed to hold the plasterboard sample in place.

3 TEST SAMPLES

The test samples consisted of a single layer of 13 mm Knauf Firestop with a nominal density of 10.9 kg/m², cut to fit the test aperture. Flexible mastic was used on both sides of the plasterboard to seal around the edges. Due to the number of openings, two sheets of Firestop were required. Each sheet of Firestop was tested before the test samples listed in Table 1.

Table 1 – Summary of the test samples

Openings	Fittings
3 mm drilled hole	DL1: 90 mm LED low profile dimmable downlight (Samsung LED302WH-13-40), IP20, all metal base
6 mm drilled hole	
9 mm drilled hole	DL2: 90 mm LED downlight, (LEDVANCE LDV-SSDL-8W-TRI), IP20, plastic base
12 mm drilled hole	
16 mm hole saw	DL3a: 90 mm GU10 gimbal downlight, open back – gimbal centred, no IP rating
32 mm hole saw	
50 mm hole saw	DL3b: 90 mm GU10 gimbal downlight, open back – gimbal angled, no IP rating
90 mm hole saw	
150 mm sawed hole	230 mm exhaust fan and grille
230 mm sawed hole	Plastic surface mounting box and power point (DETA single outlet)
300 mm sawed hole	
Power point cutout (75 mm wide x 55 mm high)	Surface mounted power point (normal installation) Surface mounted power point with metal fire-rated wall box

4 TEST METHODOLOGY

A parametric study can only be successful if the test methodology is designed to eliminate extraneous factors that might impact upon the results. For this reason, testing using a reverberant-to-reverberant field method was discounted due to potential coupling between the source room and receiver room when the sound reduction performance is less than 15 dB (Mulholland & Parbrook, 1965). While methods existing to account for this coupling (Bies & Pickles, 1974), it is outside the scope of the current study.

A reverberant to free-field method was used based upon a modification of the HEVAC Guide Test Procedure for Acoustic Louvres (Acoustic Group of the HEVAC Association, 1991). A diagram showing the test setup is presented in Figure 1. Two speakers playing pink noise were located pointing into opposing diagonal corners of the source room, ensuring that the speaker closest to the test sample was located more than 1.5 m from the sample. A time and space integrated measurement was conducted within the source room, with three single position microphones located externally in free-field conditions at angles of 90°, 60° and 30° and a distance of 1.5 m from the centre of the test sample.

The test instrumentation consisted of two Norsonic Nor140 Sound Analysers and two Nor139 Environmental Sound Meters. All microphones were fitted with G.R.A.S. AM0069 90mm windscreens. Field calibrations before and after the measurements were conducted using a Norsonic Nor1256 Calibrator. All instrumentation was Class 1 with current NATA calibrations.

Measurements were made in one-third octave bands over a 1-minute period. For each sample a minimum of six 1-minute measurements were made and averaged. Background measurements made at the start and end of each test session were averaged and used to adjust the measured test levels as detailed in EN ISO 16283-1:2014/A1:2017 (European Committee for Standardization, 2018). The measured levels at 90°, 60° and 30° were then averaged to determine the average free-field sound pressure level in each octave band, $L_{pext,oct}$.

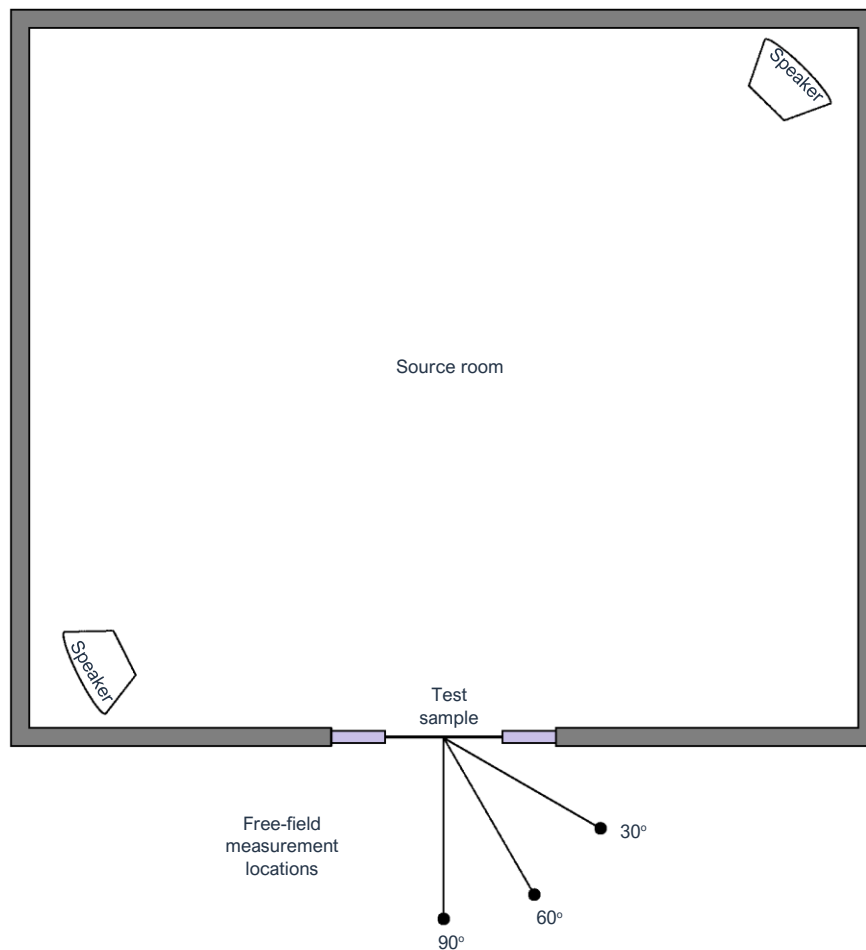


Figure 1 – Test set-up showing the three external measurement locations and speaker locations

The noise reduction in each octave band (NR_{oct}) was determined using:

$$NR_{oct} = L_{p,rev,oct} - L_{p,ext,oct} \quad (1)$$

Where $L_{p,rev,oct}$ is the time and space averaged reverberant sound pressure level in the source room. The noise reduction in one-third octave band noise levels between 50 Hz and 16 kHz were able to be determined.

To evaluate the impact upon single number weightings used to characterise the sound reduction performance, the weighted level difference (D_w) and spectrum adaptation terms (C and C_{tr}) were determined from the NR_{oct} in accordance with AS/NZS ISO 717.1:2004 (Standards Australia, 2004).

5 TEST RESULTS

The preliminary test results are presented in terms of the noise reduction, D_w , C and C_{tr} . The data have not been corrected to account for the in-fill wall as usually required for small sample testing and hence represent the composite performance of the infill wall and test sample.

5.1 Circular Hole Size

The impact of circular hole size on noise reduction is shown in Figure 2. It is seen that for smaller hole sizes (up to 32 mm diameter) the noise reduction level across the low- to mid-frequencies does not change significantly from the 13mm Firestop with no hole. When the hole diameter is 50 mm and greater, Figure 2 shows that there is a noticeable difference in the noise reduction across all frequencies above 80 Hz.

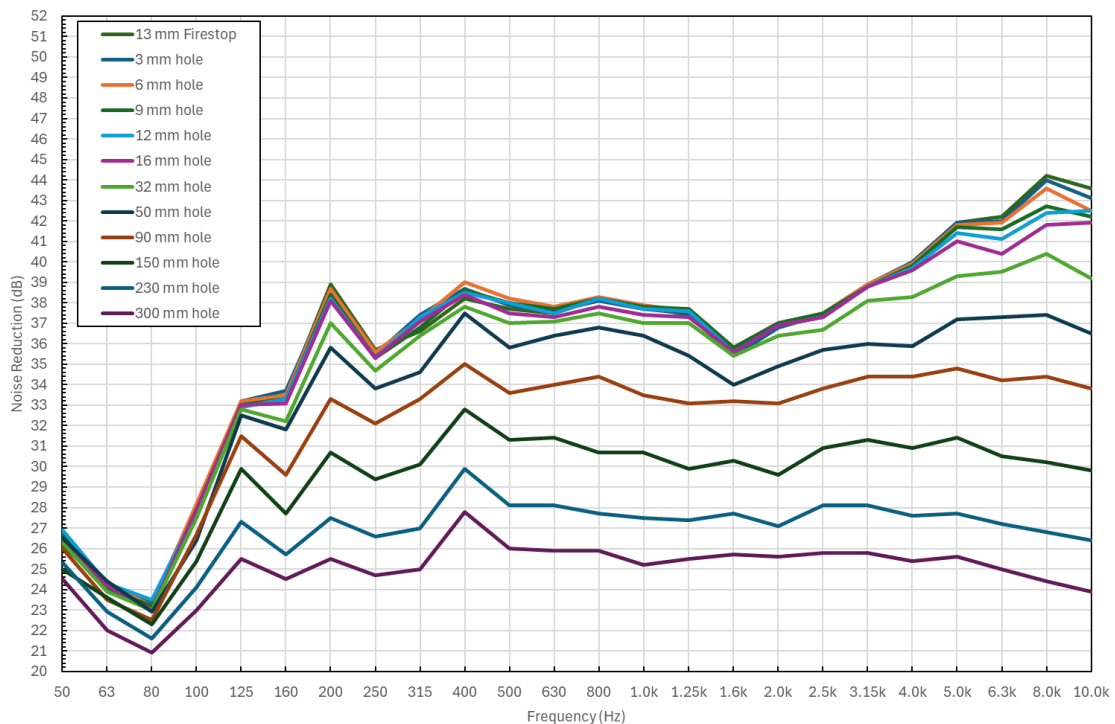


Figure 2 – Impact of circular hole size on noise reduction

The impact of Circular Hole Size on D_w , C and C_{tr} is shown in Table 2. The measurement results indicate that for holes up to 12 mm diameter, there is negligible impact upon D_w , C and C_{tr} . For holes between 16 mm and 50 mm diameter, there is a minor 1-2 dB decrease in the D_w , while for holes 90mm and above there is a significant decrease in sound reduction performance, abet with no or minor changes to the spectrum adaptation terms C and C_{tr} .

Table 2 – Impact of circular hole size on D_w , C and C_{tr}

Test	Measured			Change		
	D_w	C	C_{tr}	ΔD_w	ΔC	ΔC_{tr}
13 mm Firestop	32	-1	-1	N/A	N/A	N/A
3 mm drilled hole	32	-1	-1	0	0	0
6 mm drilled hole	32	-1	-1	0	0	0
9 mm drilled hole	32	-1	-1	0	0	0
12 mm drilled hole	32	-1	-1	0	0	0
16 mm hole saw	31	0	0	-1	1	1
32 mm hole saw	31	0	-1	-1	1	0
50 mm hole saw	30	-1	-1	-2	0	0
90 mm hole saw	28	0	-1	-4	1	0
150 mm sawed hole	25	0	-1	-7	1	0
230 mm sawed hole	23	0	0	-9	1	1
300 mm sawed hole	20	0	0	-12	1	1

5.2 90 mm Downlights

Images of the 90 mm downlights that were tested are presented in Figure 3. For each downlight the figure shows the front of the downlight, which faced the exterior and the back of the downlight, which faced the source room. The amount of light shining through downlight DL3a and DL3b compared to DL1 and DL2 is notable.

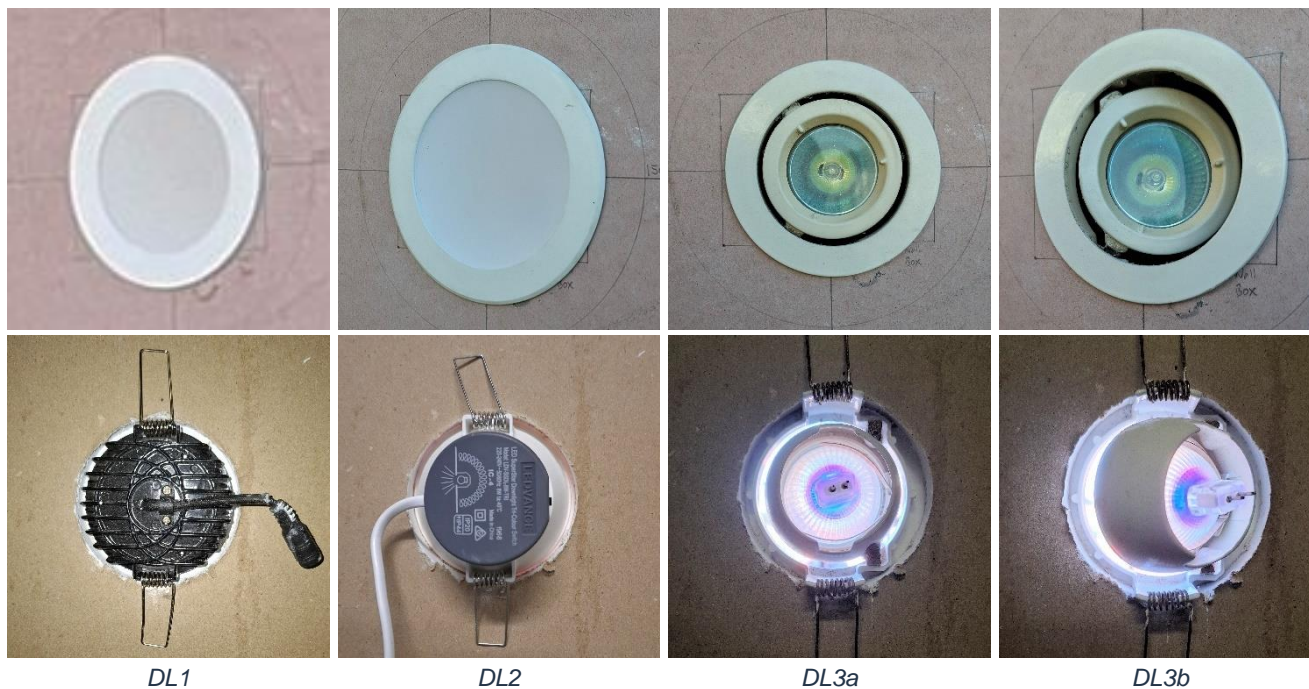


Figure 3 – The four downlight samples that were tested shown from the exterior and inside of the source room

The noise reduction performances of the downlights are compared against the noise reduction performance of the 13 mm Firestop in Figure 4. Above 80 Hz there is a small decrease in noise reduction performance for DL1 and DL2, indicating that closed back LED downlights have a sound reduction performance close to the 13mm Firestop. For DL3a and DL3b, there is a decrease of several Decibels in the noise reduction above 125 Hz.

The impact upon D_w , C and C_{tr} is shown in Table 3. For the downlights that were tested, there is a decrease in the D_w compared to the 13 mm Firestop, with no or small differences to the C and C_{tr} .

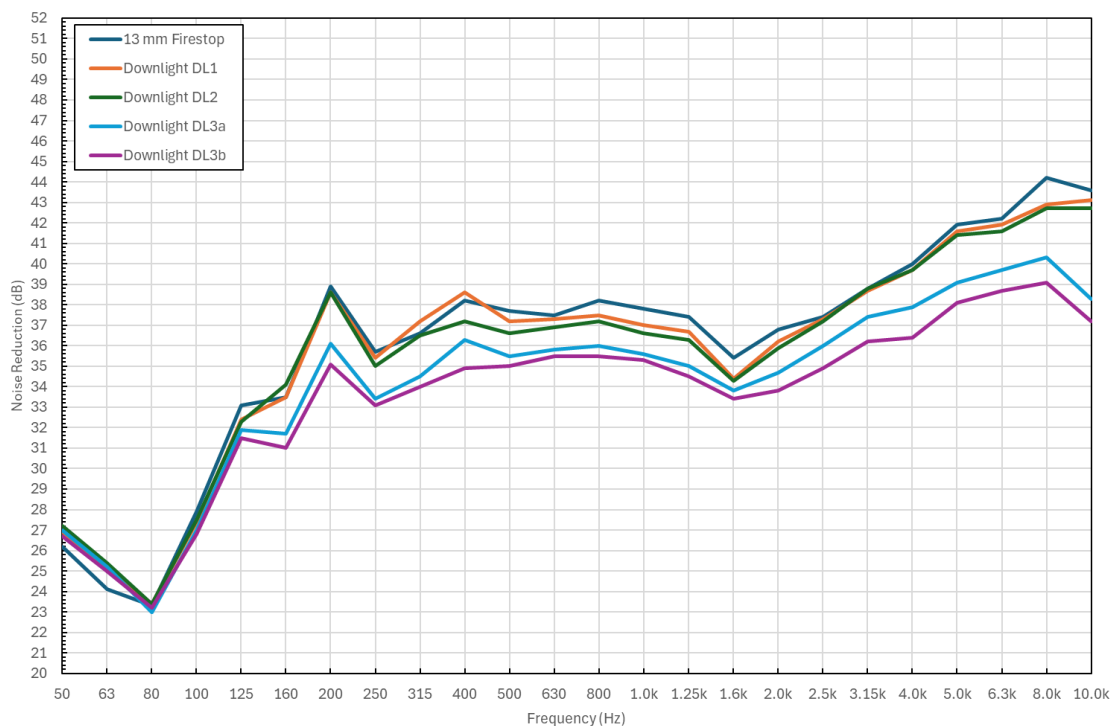


Figure 4 – Effect of different 90 mm downlights on the noise reduction

Table 3 – Impact of 90 mm downlights on D_w , C and C_{tr}

Test	Measured			Change		
	D_w	C	C_{tr}	ΔD_w	ΔC	ΔC_{tr}
13 mm Firestop	32	-1	-1	N/A	N/A	N/A
Downlight DL1	31	0	-1	-1	1	0
Downlight DL2	31	-1	-1	-1	0	0
Downlight DL3a	30	-1	-1	-2	0	0
Downlight DL3b	29	0	-1	-3	1	0

5.3 Exhaust Fan

The noise reduction for the 230 mm hole with and without the exhaust fan is compared against the noise reduction for the 13 mm Firestop in Figure 5. When the exhaust fan is installed, there is a 1 dB improvement in the D_w compared to the hole as shown in Table 4.

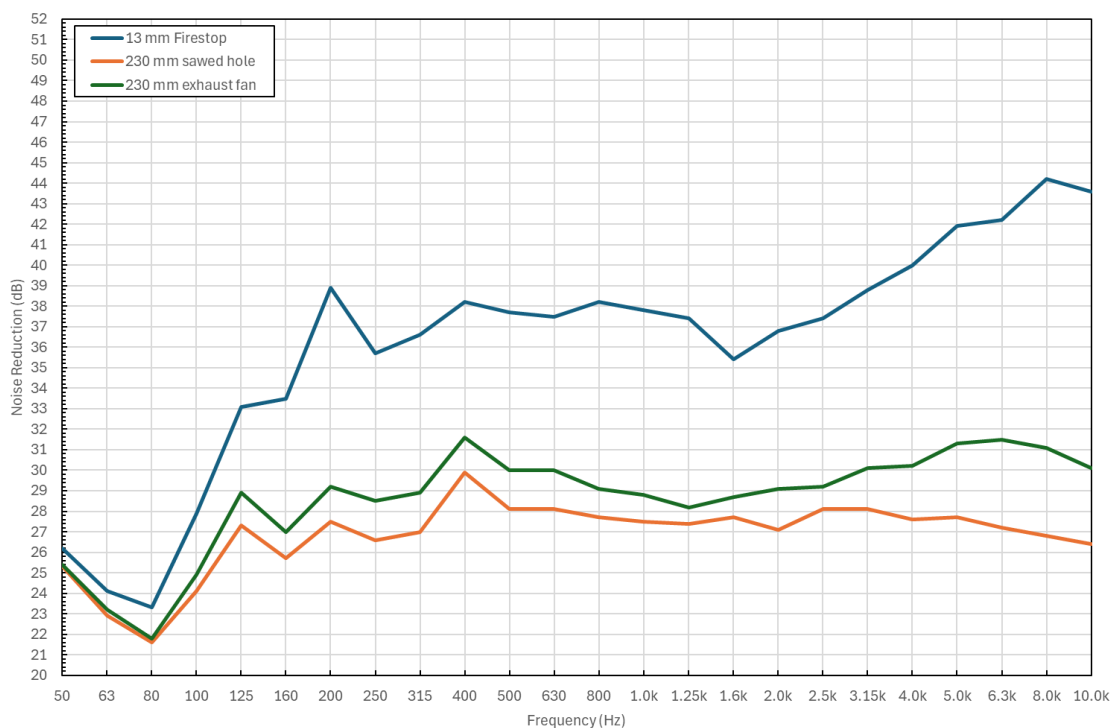


Figure 5 – Effect of a 230 mm opening and exhaust fan on noise reduction

Table 4 – Impact of a 230 mm opening and exhaust fan on D_w , C and C_{tr}

Test	Measured			Change		
	D_w	C	C_{tr}	ΔD_w	ΔC	ΔC_{tr}
13 mm Firestop	32	-1	-1	N/A	N/A	N/A
230 mm sawed hole	22	0	0	-10	1	1
230 mm exhaust fan	23	0	0	-9	1	1

5.4 Power Point Configurations

The power point mounting configurations are shown in Figure 6. Irrespective of which way the power point was mounted, Figure 7 shows that there was minimal difference in the noise reduction performance. Similarly, Table

5 shows that the D_w did not change. The power point opening did cause a reduction in both the noise reduction performance and D_w . The metal fire-rated wall box did not make a significant difference to the results.



Plastic surface mounting box and power point

Surface mounted power point

Figure 6 – Power point test configurations viewed from the exterior and inside of the source room

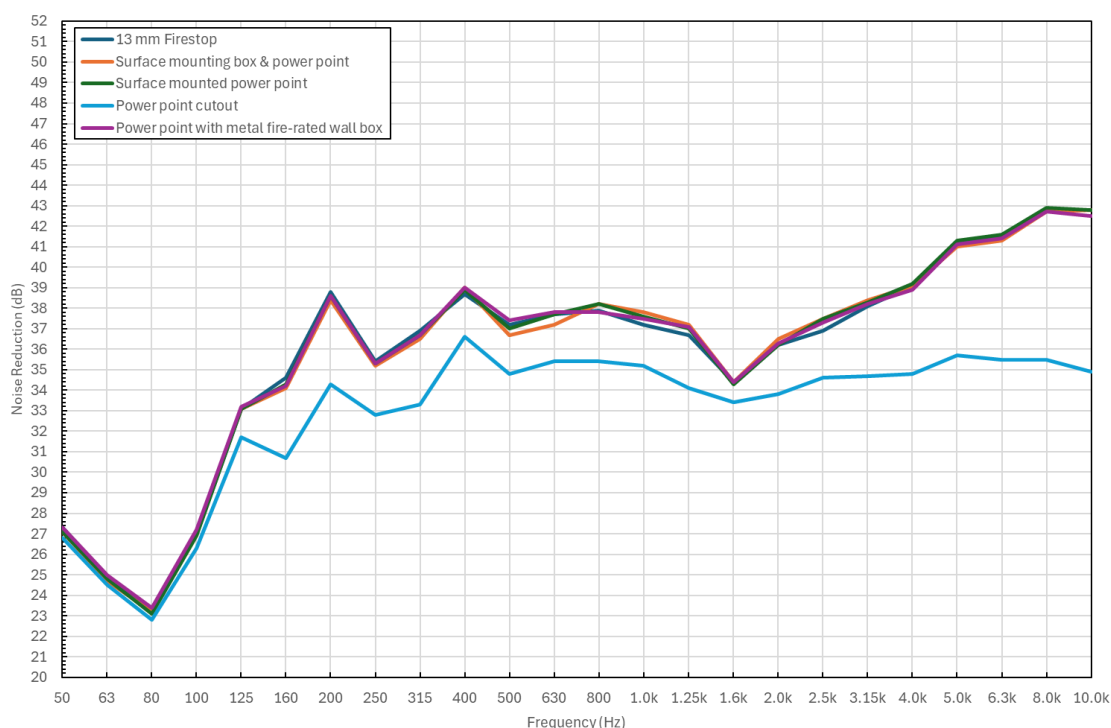


Figure 7 – Effect of power point cutout and different power point configurations on noise reduction

Table 5 – Impact of power point cutout and different power point configurations on D_w , C and C_{tr}

Test	Measured			Change		
	D_w	C	C_{tr}	ΔD_w	ΔC	ΔC_{tr}
13 mm Firestop	31	0	-1	-1	1	0
Surface mounting box & power point	31	0	-1	0	0	0
Surface mounted power point	31	0	-1	0	0	0
Power point with metal fire-rated wall box	31	0	-1	0	0	0
Power point cutout	29	-1	-1	-2	-1	0

6 CONCLUSION

Understanding the acoustic impact of open penetrations and fittings in single leaf construction is beneficial. By keeping all parameters, except for the opening size and fitting type constant, the effect on noise reduction can be seen on a single leaf construction for a range of opening sizes and fitting types.

The data obtained for the downlights indicates that caution is required when installing non-acoustically rated LED downlights in a ceiling or bulkhead, irrespective of what the downlight distribution is. Similarly, the presence of a large opening in a ceiling such as that required for an exhaust fan significantly compromises the sound reduction performance of a ceiling.

The magnitude of the noise reduction for the different openings and fittings presented in this paper can be used to select the limit of allowable penetration size in a single leaf construction. Alternatively, the data can be used to evaluate the cost/benefit of properly sealing penetrations.

7 FUTURE WORK

The results presented in this paper are intended to be the first in a series of parametric studies analysing openings, fittings and penetrations. Future testing will expand the range of fittings and penetrations and also test other common wall constructions such as single stud with plasterboard each side. The test methodology will also be expanded to include sound reduction testing using the reverberant-to-reverberant method to enable a comparison between the results obtained using the current method.

REFERENCES

- Acoustic Group of the HEVAC Association. (1991). *HEVAC Guide Test Procedure for Acoustic Louvres (Issue 1)*. Buckinghamshire: Federation of Environmental Trade Associations.
- Bies, D., & Pickles, J. (1974). The measurement of transmission loss on a low noise reduction test item. *Proceedings of the Noise Shock and Vibration Conference* (pp. 144-153). Melbourne: Australian Acoustical Society.
- CSR Building Products. (2023). *The Red Book 01 Design Guide, Fire Acoustics & Thermal - October 2023*. North Ryde: CSR Gyprock.
- European Committee for Standardization. (2018). EN ISO 16283-1:2014/A1:2017 Acoustics - Field measurement of sound insulation in buildings and of building elements Part 1: Airborne sound insulation. Brussels.
- Mulholland, K., & Parbrook, H. (1965). The measurement of sound transmission loss of panels with small transmission loss. *Journal of Sound and Vibration*, 2(4), 502-509.
- Standards Australia. (2004). AS/NZS ISO 717.1:2004 Acoustics - Rating of sound insulation in buildings and of building elements Part 1: Airborne sound insulation. Sydney, NSW, Australia: Standards Australia International Ltd and Standards New Zealand.