AECOM

Coopers Gap Wind Farm
AGL Energy Ltd
23-Aug-2016
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Coopers Gap

Facade Sound Insulation Assessment Report

Coopers Gap

Facade Sound Insulation Assessment Report

Client: AGL Energy Ltd

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Prepared by

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Quality Information

Document Coopers Gap

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Reviewed by Rhys Brown (Brisbane) & Michael Smith (Christchurch)

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
1	11-Aug-2016	Draft	Mark Herod Principal Environmental Engineer	
2	23-Aug-2016	Final	Mark Herod Principal Environmental Engineer	

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Executive Summary

AECOM Australia Pty Ltd (AECOM) was commissioned by AGL Energy Ltd (AGL) to conduct a façade sound insulation assessment at five homestead residences adjacent to the proposed Coopers Gap Wind Farm site in Queensland.

The testing was conducted in general accordance with international standard ISO 16283-3:2016 *Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 3: Façade sound insulation*.

This report provides results for the tests that were conducted at five homesteads, located in close proximity to the proposed wind farm site, between Monday 11 July 2016 and Wednesday 13 July 2016.

A description of the tests conducted is presented in the body of this report. Full test results are provided in Appendix A to Appendix E.

The results of these measurements have been used to estimate the wind farm noise levels inside the measured spaces for the scenario when windows are fully open.

Results of this calculation are presented in the table below. It should be noted that these results are provided for information purposes only as the calculation of indoor wind farm noise is not prescribed in ISO 13283-3:2016 and the noise impacts of wind farms in Queensland are to be assessed **outdoors**, as prescribed in the Queensland Wind Farm State Code and Planning Guideline (Department of Infrastructure, Local Government and Planning, 2016), effective 22 July 2016.

It was found that with windows fully open, the expected wind farm noise attenuation is between 8-13 dB(A).

Based on the measurements taken, it was found that the overall background noise levels inside the dwellings may exceed the wind farm internal noise levels. Sources of internal noise included typical household appliances, such as refrigerators and other white goods, clocks, generators, pumps, etc.

Receptor	House construction	Forecast external wind farm noise level, dB(A)	Estimated internal wind farm noise level (forecast external level minus $D_{ls,2m}$) with open window, dB(A)	Estimated overall wind farm noise reduction of façade with open window, dB(A)
House A Bedroom	Pre-fabricated (fibro)	29	19	10
House B Bedroom	Steel cladding	29	21	8
House B Living room	Steel cladding	29	16	13
House C Bedroom	Weatherboard	37	27	10
House C Living room	Weatherboard	37	25	12
House D Living room	Concrete	33	23	10
House E Living room	Log	22	12	10

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was commissioned by AGL Energy Ltd (AGL) to conduct a façade sound insulation assessment at five homestead residences located at the Coopers Gap Wind Farm site in Queensland.

The testing was conducted in general accordance with international standard ISO 16283-3:2016 *Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 3: Façade sound insulation*.

This report provides details of test conducted at five homesteads nearby the wind farm site between Monday 11 July and Wednesday 13 July 2016.

A description of the tests conducted is presented in the following sections. Full test results are provided in Appendix A to Appendix E.

2.0 Tested Facade Types

The following wall types were tested:

- House A: Pre-fabricated (fibro)
- House B: Metal cladding
- House C: Weatherboard
- House D: Concrete
- House E: Log cabin.

The materials listed above are typical materials used for the construction of homestead residences nearby the Coopers Gap Wind Farm site.

Sound insulation tests were conducted under the following configurations:

- Window fully closed
- Window partially open (10cm open)
- Window fully open.

Windows were tested in the partially open window scenario as this reflects a common mode of providing ventilation to a space.

3.0 Sound Insulation Test Details

3.1 Instrumentation

A Bruel and Kjaer 2250 sound level meter (serial 2600406) was used to measure the sound levels. The instrument was calibrated in the field with a RION NC-74 Class 1 (serial 34662248) field calibrator before, during and after each measurement set. No calibration drifts in excess of 0.5 dB were measured. As such, all measurements are valid, as per ISO 16283-3.

The Sound Level Meter (SLM) used for measuring sound pressure levels, including microphone and field calibrator met the requirements for a Class 1 instrument according to IEC 61672-1 *Electroacoustics – Sound Level Meters – Part 1: Specifications*. The SLM and the acoustic calibrator had a valid calibration certificate from a National Testing Authorities Association (NATA) accredit laboratory at the time of testing. The instruments had been calibrated by the NATA laboratory within one year prior to the time of testing.

Copies of the NATA calibration certificates are provided in Appendix F.

A NTI Minirator MR-PRO (serial G2P-RACSV-G0) signal generator was used to feed a Pink Noise signal to a YAMAHA DXR10 (serial EEVP01248) loudspeaker mounted on a tripod. The speaker output level was adjusted to a sound pressure level of approximately 110 dB(Linear) at 1 metre in front of the loudspeaker.

3.2 Measurement Frequency Range

As per ISO 16283-3:2016, the acoustic quantities were measured using one-third octave filters for at least the following centre frequencies, in hertz (Hz):

- 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 160, 2000, 2500, 3150

Measurement of additional information in the low- and high-frequency ranges is optional, in accordance with ISO 162983-3:2016. Additional information in the low-frequency and high frequency ranges in hertz was also obtained using the below 1/3 octave filters:

- Low frequency: 50, 63, 80
- High frequency: 4000, 5000.

It is noted that the values below 100 Hz presented in this report may have been affected by the following:

- Small volume acoustics conducive to modal behaviour, affecting measurements of reverberation time at low frequencies. It is noted that the reverberation time at the 50 Hz 1/3 octave band could not be measured at all residences. As such, the value had to be extrapolated
- Mechanical noises inside some spaces and/or windy conditions affecting background noise.

3.3 Measurement Procedure

The following measurement procedure was followed:

1. The room dimensions were measured with a laser range finder and tape measure
2. The loudspeaker was placed at a minimum distance (D) at least 5 m from the centre of the measured room facade, at an angle of 45°± 5°
3. The loudspeaker level was adjusted to generate a pink noise signal at approximately 110 dB (linear) at 1m
4. The noise level was measured outside the tested façade whilst the speaker was generating the pink noise signal, using the following two methods:
    a. The SLM microphone was attached to the tested façade surface. The microphone was placed with its axis parallel to the plane of the façade and directed upwards, with a distance between the test specimen and the centre of the microphone diaphragm <10mm. A hemispherical wind shield was applied to the microphone

       An averaging time of at least 20 seconds was used per measurement sample. A minimum of five measurements were conducted and the overall sound level difference between measurement positions was generally 2 dB or less

    b. Microphone mounted on a tripod, at a fixed location 2 m in front of the tested façade, at 1.5 m above finished floor level. A spherical wind shield was applied to the microphone
5. The noise level was measured inside the tested room at minimum five positions separated by a minimum 0.7 m and at a minimum 0.5 m distance from the walls to determine the average sound level in the receiving room with the loudspeaker in operation. Where possible, the instrument was positioned such that no two microphone positions were in the same plane relative to the room boundaries and they were not in a regular grid
6. The background noise level was measured inside the tested room whilst the loudspeaker was OFF. An averaging time of at least 30 seconds was used
7. The reverberation time was measured using the interrupted noise method. A pink noise signal was fed to the loudspeaker placed inside the room and the energy decay was recorded by the instrument whilst the pink noise signal was turned OFF. A minimum six measurements (sound decays) were recorded at either three fixed microphone positions and two measurements at each position, or six fixed microphone positions and one measurement at each position, located at a distance greater than 1 m from the loudspeaker

The BK2250 sound level meter reverberation time module was used to record the sound decays and automatically calculate the averaged reverberation time in 1/3 octave bands. This module implements the requirements from ISO 3382-2: *Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms* for the calculation of reverberation time indexes, as specified by the instrument manufacturer.

The information obtained during measurements was combined using the formulae in ISO16283-3 to obtain the following sound insulation indexes:

- **$R'_{45°}$ (Apparent sound reduction index):** Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface
- **$D_{ls,2m}$ (Level difference):** Level difference between the sound level measured at 2m from the façade and the internal sound level
- **$D_{ls,2m,nT}$ (Standardized level difference):** Level difference between the sound level measured at 2 m from the façade and the internal sound level that is standardised to a reference value of reverberation time in the receiving room of 0.5 seconds.
- **$D_{ls,2m,n}$ (Normalised level difference):** Level difference between the sound level measured at 2 m from the façade and the internal sound level that is normalised to a reference value of the absorption area in the receiving room of 10 m^2.

Example test setup photos are shown in Figure 1 to Figure 4.

For practical purposes, the deviations from the standard listed in Table 1 were adopted:

Table 1 Deviation from standard

ISO 16283-3 specification	Deviation from ISO 16283-3 adopted	Implication
Loudspeaker placed on the ground	Loudspeaker mounted on a tripod with axis at approximately 1.8 m	A loudspeaker on tripod allows for more homogeneous sound radiation to the façade and is not expected to significantly influence the measurement results
Omnidirectional source for reverberation measurement	Standard loudspeaker for reverberation measurement	The loudspeaker used for the test has wide horizontal and vertical radiation, therefore sufficiently excited the room to accurately measure reverberation time
Reverberation measurement at all standardized 1/3 octave frequency bands	Extrapolation of reverberation value at 50 Hz 1/3 octave band at some residences	The reverberation values at 50 Hz could not be measured by the instrument because the recorded decay did not meet the requirements from ISO 3382-2. Thus they had to be extrapolated. This is expected to be due to modal behaviour of small rooms and/or high background noise; however, the extrapolated values are typical of reverberation time inside small rooms and the extrapolation has as a negligible effect in estimating the overall internal wind farm noise levels

Figure 1 Example instrument microphone attached to the tested façade

Figure 2 **Example instrument microphone placed at 2m from façade and at 1.5m above finished floor level**

Figure 3 Example background noise measurement setup

Figure 4 Example reverberation time measurement setup

4.0 Façade Sound Insulation Test Results

Table 2 to Table 4 present results for the overall measured façade sound insulation ratings. Test results presenting measured values for the individual 1/3 octave frequency bands are presented in Appendix A to Appendix E.

Table 2 Overall measured sound insulation values (windows closed)

House	Façade construction	Overall façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
House A - Bedroom	Pre-fabricated (Fibro)	20	19	17	16
House B - Bedroom	Steel cladding	24	18	18	18
House B - Living room	Steel cladding	24	24	25	18
House C - Bedroom	Weatherboard	24	21	19	18
House C - Living room	Weatherboard	23	23	23	19
House D - Living room	Concrete	24	27	28	22
House E - Living room	Log	22	22	22	14

Table 3 Overall measured sound insulation values (1 window 10cm open)

House	Façade construction	Overall façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
House A - Bedroom	Pre-fabricated (Fibro)	17	16	15	14
House B - Bedroom	Steel cladding	20	14	15	15
House B - Living room	Steel cladding	19	19	20	13
House C - Bedroom	Weatherboard	19	16	14	13
House C - Living room	Weatherboard	19	19	19	15
House D - Living room	Concrete	17	20	21	15
House E - Living room	Log	20	20	20	11

Table 4 Overall measured sound insulation values (window fully open)

House	Façade construction	Overall façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
House A – Bedroom*	Pre-fabricated (Fibro)	13 (12)	12 (10)	10 (9)	9 (8)
House B - Bedroom	Steel cladding	16	10	11	11
House B - Living room	Steel cladding	15	15	16	9
House C - Bedroom	Weatherboard	14	10	8	7
House C - Living room	Weatherboard	12	12	13	8
House D - Living room	Concrete	9	12	12	7
House E - Living room	Log	13	13	13	5

*: Two tests with open windows were conducted. Test one was conducted with one open window and Test 2 was conducted with two open windows (results for Test 2 in brackets). The second test was conducted on the residence owner's request.

5.0 Wind Farm Noise Reduction and Internal Noise Levels

The measured sound reduction of the different tested building facades allows for the internal wind farm noise level to be estimated. The internal wind farm noise levels can be estimated by subtracting the measured $D_{ls,2m}$ to predicted external noise levels at the residences in 1/3 octave bands. The resulting 1/3 octave noise levels can then be logarithmically summed to obtain the overall forecast level (dB(A)) from the potential wind farm inside the tested spaces.

5.1 Estimated Internal Wind Farm Noise Levels

A calculation was conducted to estimate the wind farm noise levels inside the tested spaces with the windows open. The calculation used the measured sound insulation results presented in this report and noise predictions as 1/3 octave noise levels outside the spaces. The external noise levels were obtained using the noise model developed as part of the Coopers Gap Wind Farm Noise and Vibration Impact Assessment, detailed in document 60489152-AC-RP-0001-Rev2.

The internal noise levels were estimated by subtracting the measured $D_{ls,2m}$ to the predicted external noise levels at the residences, in 1/3 octave bands. The resulting 1/3 octave noise levels were then logarithmically summed to obtain the overall dB(A) value inside the tested space. No correction (e.g. normalization or standardisation) has been made for measured reverberation time levels.

Results from this calculation are presented in column 3 and column 4 in Table 5. It was found that when the tested spaces have the windows open, the expected wind farm noise attenuation is 8-13 dB(A).

It is noted that the results presented in Table 5 are provided for information purposes only as the calculation of indoor wind farm noise is not prescribed in ISO 16283-3:2016 and the noise impacts of wind farms in Queensland are to be assessed **outdoors**, as prescribed in the Queensland Wind Farm State Code and Planning Guideline (Department of Infrastructure, Local Government and Planning, 2016), effective 22 July 2016.

Table 5 Estimated wind farm noise attenuation and internal noise levels with open windows

Receptor	House construction	Forecast external wind farm noise level, dB(A)	Estimated internal wind farm noise level (forecast external level minus $D_{ls,2m}$) with open window, dB(A)	Estimated overall wind farm noise reduction of façade with open window, dB(A)
House A Bedroom	Pre-fabricated (fibro)	29	19	10
House B Bedroom	Steel cladding	29	21	8
House B Living room	Steel cladding	29	16	13
House C Bedroom	Weatherboard	37	27	10
House C Living room	Weatherboard	37	25	12
House D Living room	Concrete	33	23	10
House E Living room	Log	22	12	10

6.0 Internal Ambient Noise Levels

Table 6 provides results of measured ambient noise levels measured inside the tested spaces, prior to construction of the wind farm. Where possible, noise peaks resulting from human activity inside and outside the dwellings were filtered, but some contamination remained, as noted in the table.

Audible sources of noise inside the dwellings include wildlife, wind and rain, and internal sources include refrigerators and other white goods, clocks, generators, and human activities.

Table 6 Measured internal ambient noise levels

Receptor	House construction	Internal noise level with windows open, $L_{Aeq,T}$, dB(A)	Internal noise level with windows closed, $L_{Aeq,T}$, dB(A)
House A Bedroom	Pre-fabricated (fibro)	26	25
House B Bedroom	Steel cladding	41	41*
House B Living room	Steel cladding	33	27
House C Bedroom	Weatherboard	31	34*
House C Living room	Weatherboard	30	31*
House D Living room	Concrete	Not measured	33
House E Living room	Log	Not measured	31

*: Measurement contaminated by human noise.

7.0 Conclusion

AECOM conducted a façade sound insulation assessment at five homestead residences located adjacent to the proposed Coopers Gap wind farm site, between Monday 11 July 2016 and Wednesday 13 July 2016.

The testing was conducted in accordance with international standard ISO 16283-3:2016 *Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 3: Façade sound insulation*.

The methodology and results of ISO 16283-3:2016 sound insulation indices are presented in this report. In addition, an estimation of internal wind farm noise levels was conducted. It was found that when the windows are open at the tested spaces, the expected internal wind farm noise levels range between 12-27 dB(A) with a wind farm noise attenuation of 8-13 dB(A) for the tested spaces.

Appendix A

House A Sound Insulation Test Results

Appendix A House A Sound Insulation Test Results – Main Bedroom

House A Test Details – Main bedroom				
Date:	11-07-2016		**Operator:**	Rodrigo O.
Time:	1:45pm start		**Company:**	AECOM Australia Pty Ltd
Sound level meter Model & Serial:	Bruel and Kjaer 2250, serial 2600406		**SLM Calibration Start:**	93.7
Acoustic calibrator Model & Serial:	RION NC-74, serial 34662248		**SLM Calibration End:**	93.7
Signal Gen Model & Serial:	NTI Minirator MR-PRO, serial G2P-RACSV-G0		**Loudspeaker Model & Serial:**	YAMAHA DXR10, serial EEVP01248
Room name and type:	Main bedroom			
Room dimensions, internal:	4m x 4m x 2.4m			
Room volume, m^3:	38			
Tested façade area, m^2:	19			
Window Type: sliding window	**Glass thickness:**	3mm approx.	**Window condition:**	Old. One portable AC unit installed in one window
Window Dimensions (m):	Two windows 1.9m x 1.2m, one window per façade			
Exposed Façade Dimensions (m^2):	2 walls: 4m x 2.4m each		**Tests conducted:**	1. Windows closed 2. 1 window 10cm open 3. 1 window open 4. 2 windows open
Reverberation time (overall):	T20: 0.34 sec – T30: 0.33 sec			
Façade construction:	Pre-fabricated (fibro)			
Test Standard:	ISO 16283-3:2016 Acoustics - Field Measurement of sound insulation in buildings and of building elements - Part 3: Façade sound insulation			

GLOSSARY

$R'_{45°}$ (Apparent sound reduction index)

Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface

$D_{ls,2m}$ (Level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level.

$D_{ls,2m,nT}$ (Standardized level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is standardized to a reference value of reverberation time in the receiving room of 0.5 seconds.

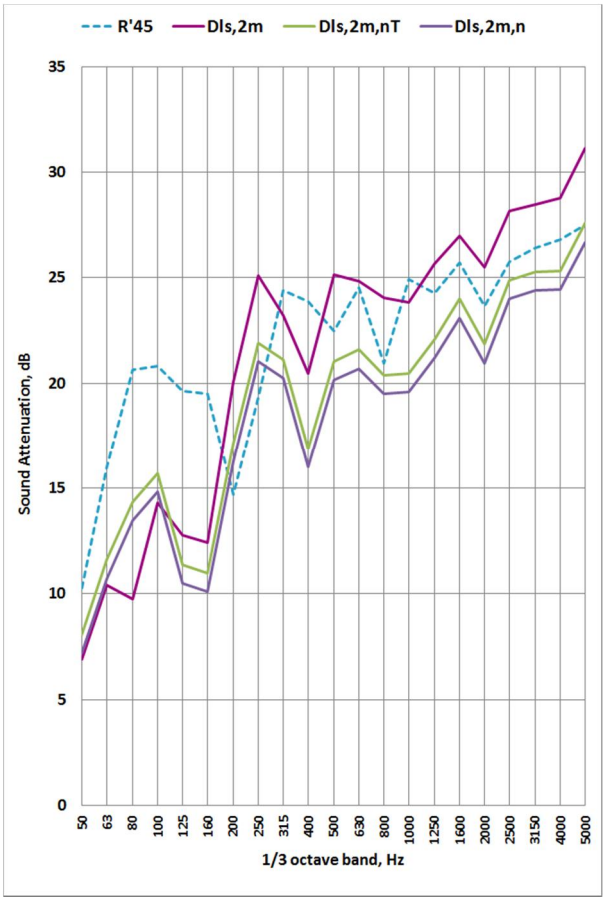
$D_{ls,2m,n}$ (Normalised level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is normalized to a reference value of the absorption area in the receiving room of $10m^2$.

T20, T30 (Reverberation time)

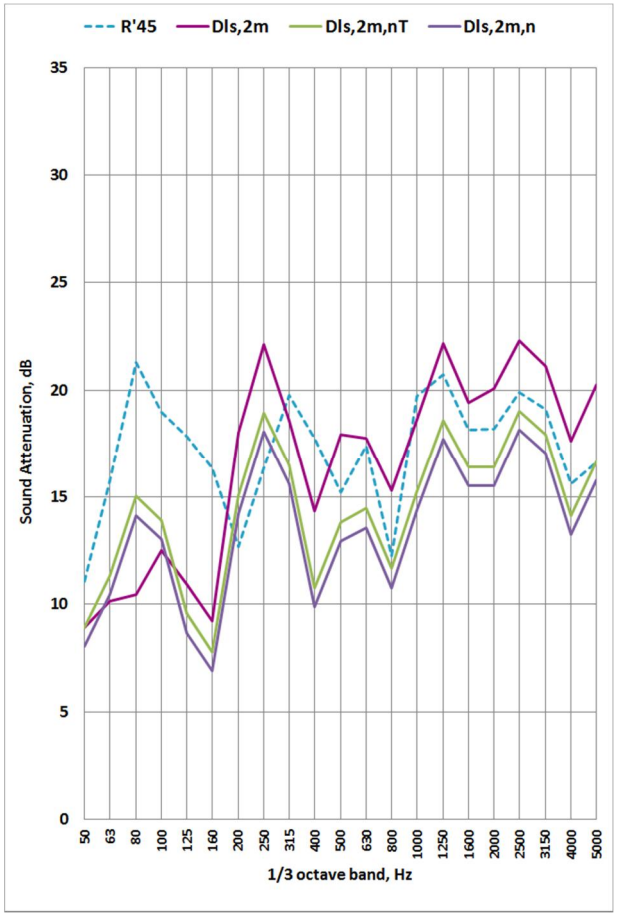
Reverberation time measured by extrapolation of the sound energy decay time measured for the first 20 dB and 30 dB, respectively, to a 60 dB decay time.

Test 1 – Main bedroom: All windows closed		Façade sound insulation, dB			
		$R'_{45°}$	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	**20**	**19**	**17**	**16**
	50Hz	10*	7	8*	7*
	63Hz	16	10	12	11
	80Hz	21	10	14	13
	100Hz	21	14	16	15
	125Hz	20	13	11	10
	160Hz	20	12	11	10
	200Hz	15	20	17	16
	250Hz	19	25	22	21
	315Hz	24	23	21	20
	400Hz	24	20	17	16
	500Hz	22	25	21	20
	630Hz	25	25	22	21
	800Hz	21	24	20	20
	1kHz	25	24	20	20
	1.25kHz	24	26	22	21
	1.6kHz	26	27	24	23
	2kHz	24	26	22	21
	2.5kHz	26	28	25	24
	3.15kHz	26	28	25	24
	4kHz	27	29	25	24
	5kHz	28	31	28	27



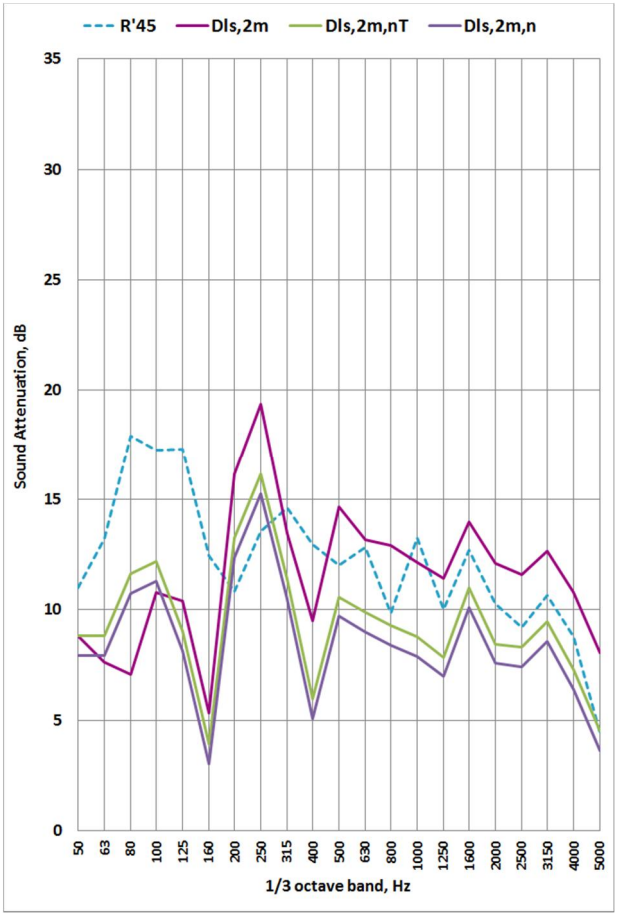
*: Value calculated using extrapolated value of reverberation time, due to problems measuring reverberation in small volume room

Test 2 – Main bedroom: One window 10cm open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	17	16	15	14
	50Hz	11*	9	9*	8*
	63Hz	16	10	11	10
	80Hz	21	10	15	14
	100Hz	19	12	14	13
	125Hz	18	11	10	9
	160Hz	16	9	8	7
	200Hz	13	18	15	14
	250Hz	16	22	19	18
	315Hz	20	19	16	16
	400Hz	18	14	11	10
	500Hz	15	18	14	13
	630Hz	17	18	14	14
	800Hz	12	15	12	11
	1kHz	20	19	15	14
	1.25kHz	21	22	19	18
	1.6kHz	18	19	16	16
	2kHz	18	20	16	16
	2.5kHz	20	22	19	18
	3.15kHz	19	21	18	17
	4kHz	16	18	14	13
	5kHz	17	20	17	16



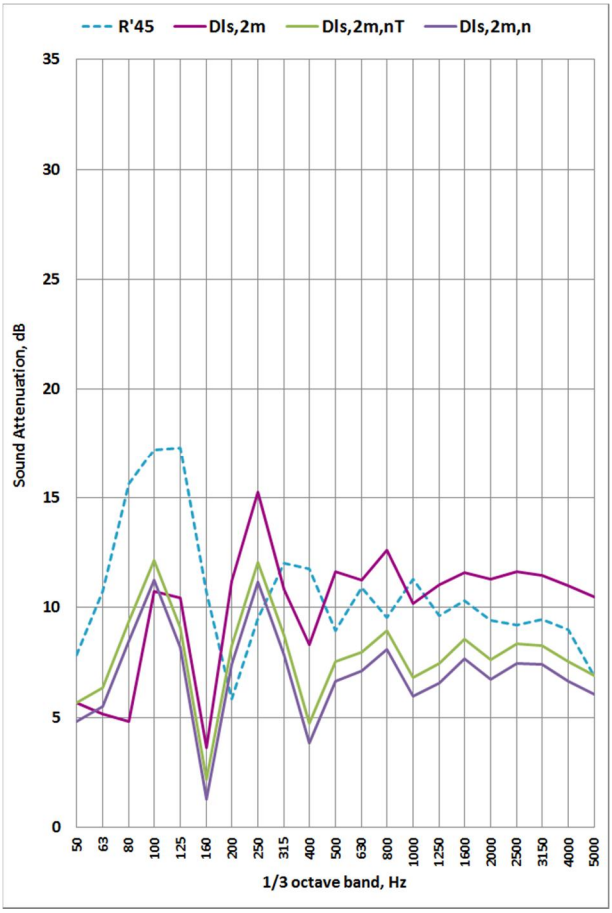
*: Value calculated using extrapolated value of reverberation time, due to problems measuring reverberation in small volume room

Test 3 – Main bedroom: One window open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	13	12	10	9
	50Hz	11*	9	9*	8*
	63Hz	13	8	9	8
	80Hz	18	7	12	11
	100Hz	17	11	12	11
	125Hz	17	10	9	8
	160Hz	12	5	4	3
	200Hz	11	16	13	12
	250Hz	14	19	16	15
	315Hz	15	13	11	10
	400Hz	13	10	6	5
	500Hz	12	15	11	10
	630Hz	13	13	10	9
	800Hz	10	13	9	8
	1kHz	13	12	9	8
	1.25kHz	10	11	8	7
	1.6kHz	13	14	11	10
	2kHz	10	12	8	8
	2.5kHz	9	12	8	7
	3.15kHz	11	13	9	9
	4kHz	9	11	7	6
	5kHz	4	8	4	4



*: Value calculated using extrapolated value of reverberation time, due to problems measuring reverberation in small volume room

Test 4 – Main bedroom: Two windows open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	12	10	9	8
	50Hz	8*	6	6*	5*
	63Hz	11	5	6	5
	80Hz	16	5	9	8
	100Hz	17	11	12	11
	125Hz	17	10	9	8
	160Hz	11	4	2	1
	200Hz	6	11	8	7
	250Hz	9	15	12	11
	315Hz	12	11	9	8
	400Hz	12	8	5	4
	500Hz	9	12	8	7
	630Hz	11	11	8	7
	800Hz	10	13	9	8
	1kHz	11	10	7	6
	1.25kHz	10	11	7	7
	1.6kHz	10	12	9	8
	2kHz	9	11	8	7
	2.5kHz	9	12	8	7
	3.15kHz	9	11	8	7
	4kHz	9	11	8	7
	5kHz	7	10	7	6



*: Value calculated using extrapolated value of reverberation time, due to problems measuring reverberation in small volume room

Figure A-1: Site photos

Appendix B

House B Sound Insulation Test Results

Appendix B House B Sound Insulation Test Results - Bedroom

House B Test Details - Bedroom				
Date:	12-07-2016		**Operator:**	Rodrigo O.
Time:	9:30am start		**Company:**	AECOM Australia Pty Ltd
Sound level meter Model & Serial:	Bruel and Kjaer 2250, serial 2600406		**SLM Calibration Start:**	93.7
Acoustic calibrator Model & Serial:	RION NC-74, serial 34662248		**SLM Calibration End:**	93.7
Signal Gen Model & Serial:	NTI Minirator MR-PRO, serial G2P-RACSV-G0		**Loudspeaker Model & Serial:**	YAMAHA DXR10, serial EEVP01248
Room name and type:	Bedroom			
Room dimensions (internal):	4m x 3m x 2.7m			
Room volume, m^3:	32			
Tested façade area, m^2:	19			
Window Type: sliding window	**Glass thickness:**	3 mm approx.	**Window condition:**	Operable. Good condition.
Window Dimensions (m):	Two windows: 1.7m x 0.9m, 1.2m x 0.9m, one window per façade			
Exposed Façade Dimensions (m^2):	Wall 1: 4m x 2.7m Wall 2: 3m x 2.7m		**Tests conducted:**	1. Windows closed 2. 1 window 10cm open 3. 1 window open
Reverberation time (overall):	T20: 0.52 sec – T30: 0.66 sec			
Façade construction:	Steel cladding			
Notes:	Windy during test			
Test Standard:	ISO 16283-3:2016 Acoustics - Field Measurement of sound insulation in buildings and of building elements - Part 3: Façade sound insulation			

GLOSSARY

$R'_{45°}$ (Apparent sound reduction index)

Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface

$D_{ls,2m}$ (Level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level.

$D_{ls,2m,nT}$ (Standardized level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is standardized to a reference value of reverberation time in the receiving room of 0.5 seconds.

$D_{ls,2m,n}$ (Normalised level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is normalized to a reference value of the absorption area in the receiving room of $10m^2$.

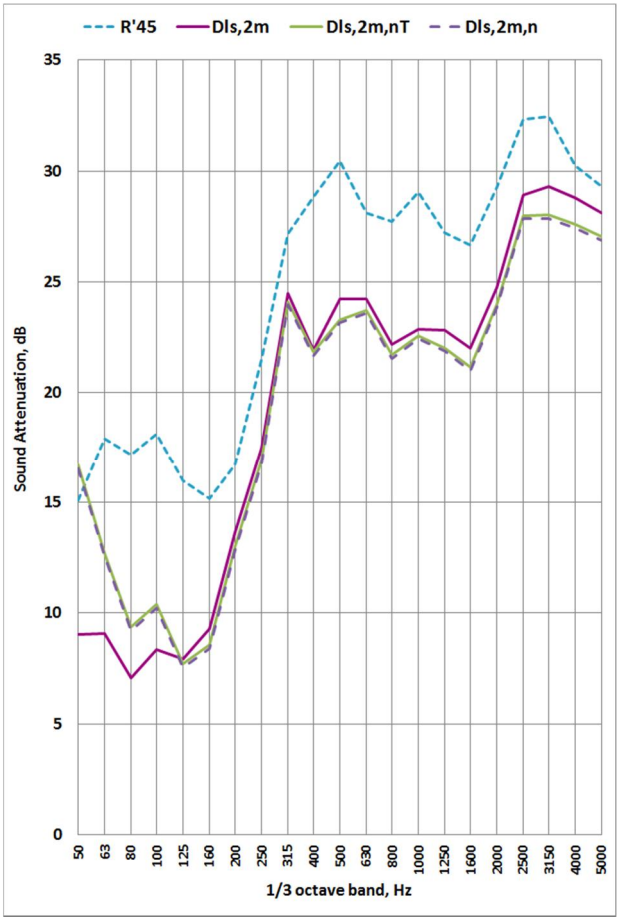
T20, T30 (Reverberation time)

Reverberation time measured by extrapolation of the sound energy decay time measured for the first 20 dB and 30 dB, respectively, to a 60 dB decay time.

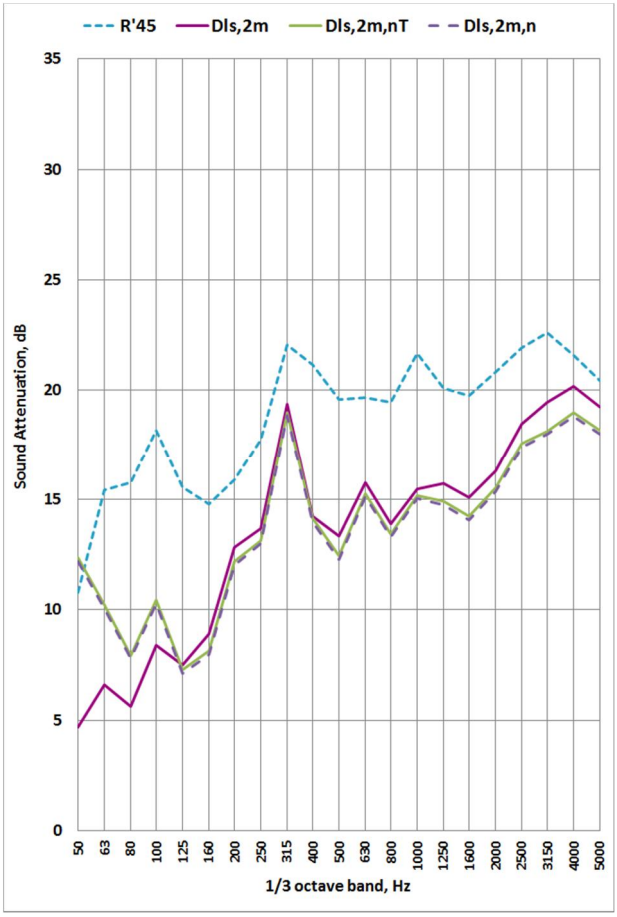
Note:

Sound levels below 100 Hz may have been affected by modal behaviour, low signal to noise ratio and/or high background noise.

Test 1 – Bedroom: Windows closed		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	24	18	18	18
	50Hz	15	9	17	17
	63Hz	18	9	13	13
	80Hz	17	7	9	9
	100Hz	18	8	10	10
	125Hz	16	8	8	8
	160Hz	15	9	9	8
	200Hz	17	14	13	13
	250Hz	22	17	17	17
	315Hz	27	24	24	24
	400Hz	29	22	22	22
	500Hz	30	24	23	23
	630Hz	28	24	24	24
	800Hz	28	22	22	22
	1kHz	29	23	23	22
	1.25kHz	27	23	22	22
	1.6kHz	27	22	21	21
	2kHz	29	25	24	24
	2.5kHz	32	29	28	28
	3.15kHz	32	29	28	28
	4kHz	30	29	28	27
	5kHz	29	28	27	27



Test 2 – Bedroom: One window 10cm open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	20	14	15	15
	50Hz	11	5	12	12
	63Hz	15	7	10	10
	80Hz	16	6	8	8
	100Hz	18	8	10	10
	125Hz	16	8	7	7
	160Hz	15	9	8	8
	200Hz	16	13	12	12
	250Hz	18	14	13	13
	315Hz	22	19	19	19
	400Hz	21	14	14	14
	500Hz	20	13	12	12
	630Hz	20	16	15	15
	800Hz	19	14	13	13
	1kHz	22	15	15	15
	1.25kHz	20	16	15	15
	1.6kHz	20	15	14	14
	2kHz	21	16	16	15
	2.5kHz	22	18	18	17
	3.15kHz	23	19	18	18
	4kHz	22	20	19	19
	5kHz	20	19	18	18



Test 3 – Bedroom: One window open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	16	10	11	11
	50Hz	13	7	14	14
	63Hz	14	5	9	9
	80Hz	16	6	8	8
	100Hz	16	6	9	8
	125Hz	13	5	5	5
	160Hz	12	6	6	5
	200Hz	16	13	12	12
	250Hz	13	9	8	8
	315Hz	17	14	14	14
	400Hz	16	9	9	9
	500Hz	16	10	9	9
	630Hz	16	12	11	11
	800Hz	15	9	9	9
	1kHz	16	10	10	10
	1.25kHz	15	11	10	10
	1.6kHz	15	10	9	9
	2kHz	14	10	9	9
	2.5kHz	14	10	9	9
	3.15kHz	14	11	10	9
	4kHz	13	11	10	10
	5kHz	12	11	10	10

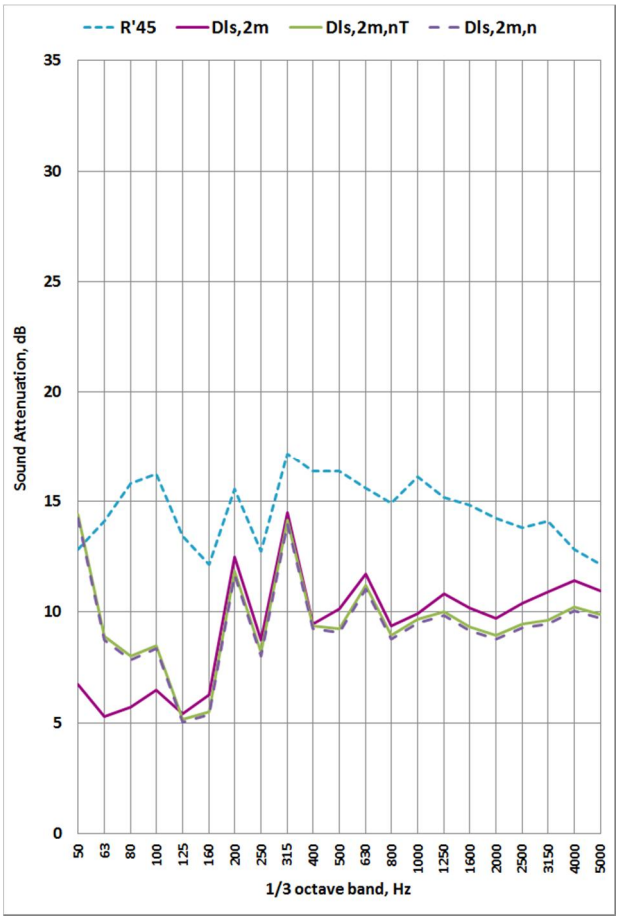


Figure B-1: Site photos

Appendix B House B Sound Insulation Test Results – Living Room

House B Test Details – Living room				
Date:	12-07-2016		**Operator:**	Rodrigo O.
Time:	11:35am start		**Company:**	AECOM Australia Pty Ltd
Sound level meter Model & Serial:	Bruel and Kjaer 2250, serial 2600406		**SLM Calibration Start:**	93.7
Acoustic calibrator Model & Serial:	RION NC-74, serial 34662248		**SLM Calibration End:**	93.7
Signal Gen Model & Serial:	NTI Minirator MR-PRO, serial G2P-RACSV-G0		**Loudspeaker Model & Serial:**	YAMAHA DXR10, serial EEVP01248
Room name and type:	Living room			
Room dimensions:	10.8m x 3.2m x 2.7m			
Room volume, m^3:	93			
Tested façade area, m^2:	29			
Window Type: sliding window	**Glass thickness:**	3mm approx.	**Window condition:**	Operable. Good condition.
Window Dimensions (m):	Sliding glass door: 1.8m x 2.1m, Window 1: 1.6m x 0.9m Window 2: 1.5m x 0.9m			
Exposed Façade Dimensions (m^2)	1 wall: 10.8m x 2.7m	**Tests conducted:**	1. Windows closed 2. Sliding glass door 10cm open 3. Sliding glass door 10cm open	
Reverberation time (overall):	T20: 0.41 sec – T30: 0.45 sec			
Façade construction:	Steel cladding house			
Test Standard:	ISO 16283-3:2016 Acoustics - Field Measurement of sound insulation in buildings and of building elements - Part 3: Façade sound insulation			

GLOSSARY

$R'_{45°}$ (Apparent sound reduction index)

Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface

$D_{ls,2m}$ (Level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level.

$D_{ls,2m,nT}$ (Standardized level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is standardized to a reference value of reverberation time in the receiving room of 0.5 seconds.

$D_{ls,2m,n}$ (Normalised level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is normalized to a reference value of thye absorption area in the receiving room of $10m^2$.

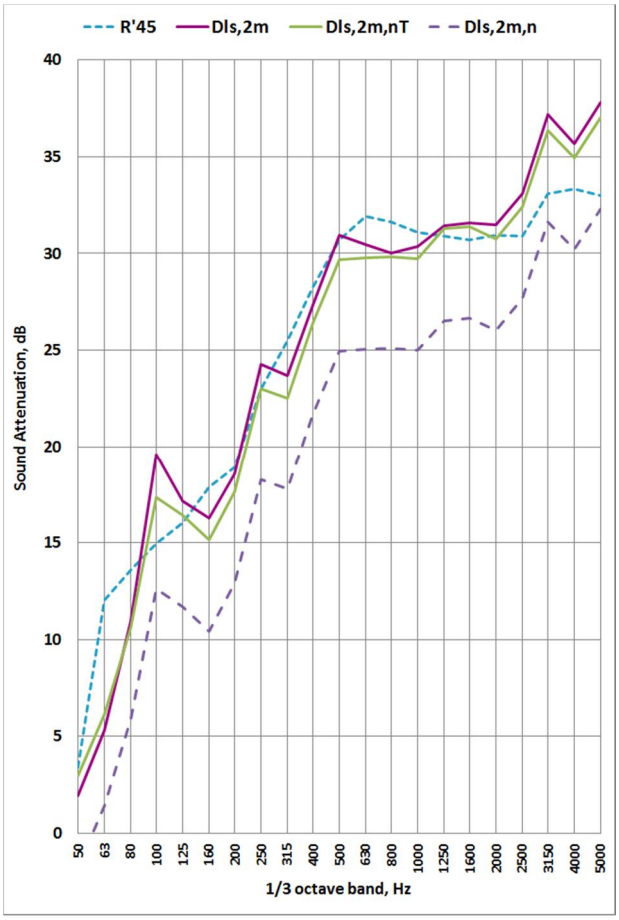
T20, T30 (Reverberation time)

Reverberation time measured by extrapolation of the sound energy decay time measured for the first 20 dB and 30 dB, respectively, to a 60 dB decay time.

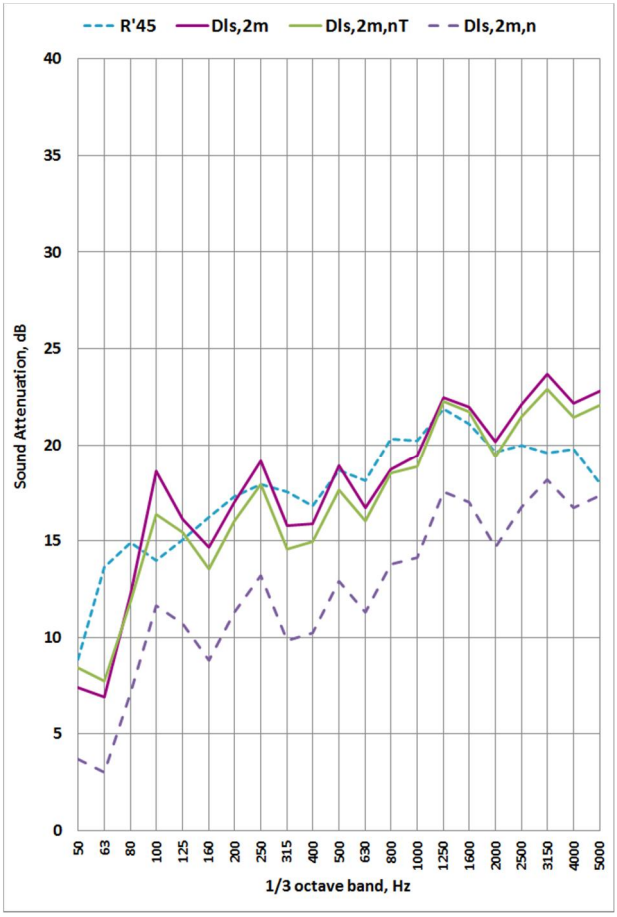
Note:

Sound levels below 100 Hz may have been affected by modal behaviour, low signal to noise ratio and/or high background noise.

Test 1 – Living room: Windows closed		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	24	24	25	18
	50Hz	3	2	3	N.A.
	63Hz	12	5	6	1
	80Hz	14	11	11	6
	100Hz	15	20	17	13
	125Hz	16	17	16	12
	160Hz	18	16	15	10
	200Hz	19	19	18	13
	250Hz	23	24	23	18
	315Hz	25	24	22	18
	400Hz	28	27	26	22
	500Hz	31	31	30	25
	630Hz	32	30	30	25
	800Hz	32	30	30	25
	1kHz	31	30	30	25
	1.25kHz	31	31	31	27
	1.6kHz	31	32	31	27
	2kHz	31	32	31	26
	2.5kHz	31	33	32	28
	3.15kHz	33	37	36	32
	4kHz	33	36	35	30
	5kHz	33	38	37	32



Test 2 – Living room: Sliding door 10cm open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	19	19	20	13
	50Hz	9	7	8	4
	63Hz	14	7	8	3
	80Hz	15	12	12	7
	100Hz	14	19	16	12
	125Hz	15	16	15	11
	160Hz	16	15	14	9
	200Hz	17	17	16	11
	250Hz	18	19	18	13
	315Hz	18	16	15	10
	400Hz	17	16	15	10
	500Hz	19	19	18	13
	630Hz	18	17	16	11
	800Hz	20	19	19	14
	1kHz	20	19	19	14
	1.25kHz	22	22	22	18
	1.6kHz	21	22	22	17
	2kHz	20	20	19	15
	2.5kHz	20	22	21	17
	3.15kHz	20	24	23	18
	4kHz	20	22	21	17
	5kHz	18	23	22	17



Test 3 – Bedroom: Sliding door open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	15	15	16	9
	50Hz	10	8	9	5
	63Hz	13	6	7	2
	80Hz	12	10	9	5
	100Hz	10	15	13	8
	125Hz	14	15	14	10
	160Hz	15	13	12	7
	200Hz	15	15	14	9
	250Hz	13	15	13	9
	315Hz	13	12	10	6
	400Hz	14	13	12	7
	500Hz	15	15	14	9
	630Hz	16	15	14	10
	800Hz	16	15	14	10
	1kHz	16	15	14	10
	1.25kHz	15	16	16	11
	1.6kHz	15	16	15	11
	2kHz	13	14	13	8
	2.5kHz	13	15	15	10
	3.15kHz	13	17	16	11
	4kHz	13	15	14	10
	5kHz	11	16	15	11

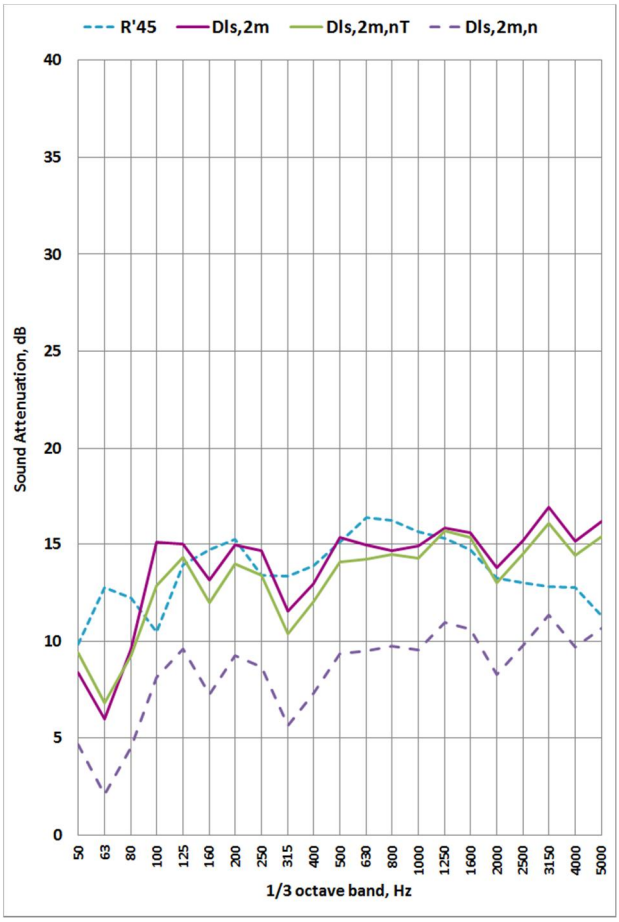


Figure B-2: Site photos

Appendix C

House C Sound Insulation Test Results

Appendix C House C Sound Insulation Test Results – Main Bedroom

House C Test Details – Bedroom				
Date:	12-07-2016		**Operator:**	Rodrigo O.
Time:	04:05pm start		**Company:**	AECOM Australia Pty Ltd
Sound level meter Model & Serial:	Bruel and Kjaer 2250, serial 2600406		**SLM Calibration Start:**	93.7
Acoustic calibrator Model & Serial:	RION NC-74, serial 34662248		**SLM Calibration End:**	93.7
Signal Gen Model & Serial:	NTI Minirator MR-PRO, serial G2P-RACSV-G0		**Loudspeaker Model & Serial:**	YAMAHA DXR10, serial EEVP01248
Room name and type:	Main bedroom			
Room dimensions:	4.2m x 3.9m x 2.4m			
Room volume, m^3:	39			
Tested façade area, m^2:	19			
Window Type: sliding window	**Glass thickness:**	3mm approx.	**Window condition:**	Operable. Good condition.
Window Dimensions (m):	Window 1: 2.1m x 1.2m Window 2: 1.5m x 1.2m			
Exposed Façade Dimensions (m^2)	Wall 1: 4.2m x 2.4m Wall 2: 3.9m x 2.4m	**Tests conducted:**	1. Windows closed 2. 1 window 10cm open 3. 1 window open	
Reverberation time (overall):	T20: 0.31 sec T30: 0.34 sec			
Façade construction:	Weatherboard			
Test Standard:	ISO 16283-3:2016 Acoustics - Field Measurement of sound insulation in buildings and of building elements - Part 3: Façade sound insulation			

GLOSSARY

$R'_{45°}$ (Apparent sound reduction index)

Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface

$D_{ls,2m}$ (Level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level.

$D_{ls,2m,nT}$ (Standardized level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is standardized to a reference value of reverberation time in the receiving room of 0.5 seconds.

$D_{ls,2m,n}$ (Normalised level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is normalized to a reference value of the absorption area in the receiving room of $10m^2$.

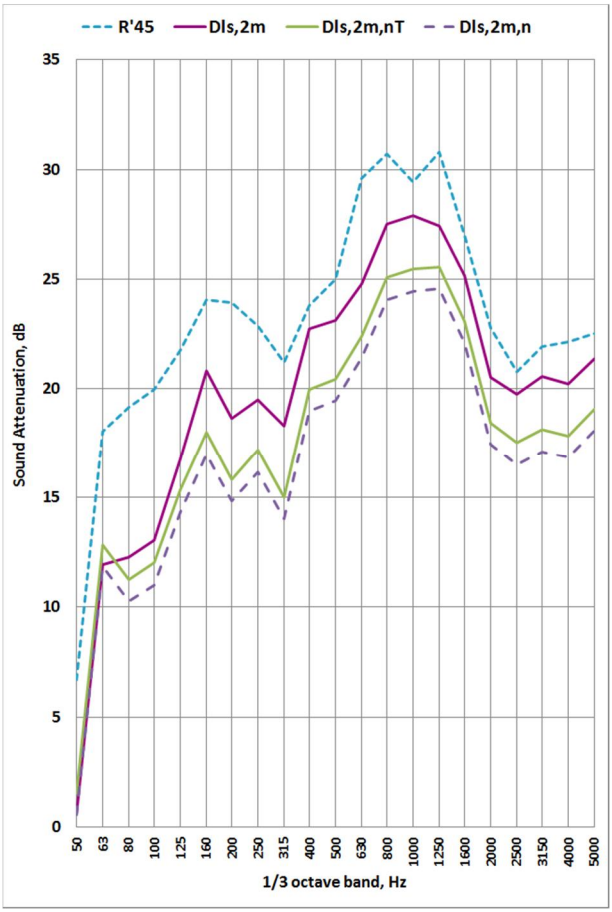
T20, T30 (Reverberation time)

Reverberation time measured by extrapolation of the sound energy decay time measured for the first 20 dB and 30 dB, respectively, to a 60 dB decay time.

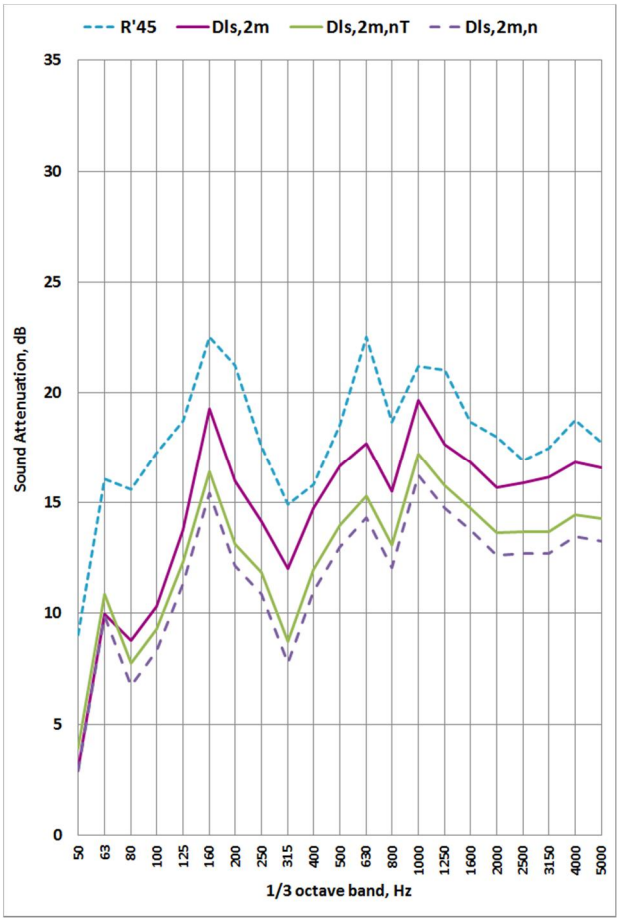
Note:

Sound levels below 100 Hz may have been affected by modal behaviour, low signal to noise ratio and/or high background noise.

Test 1 – Main bedroom: Windows closed		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	**24**	**21**	**19**	**18**
	50Hz	7	1	2	1
	63Hz	18	12	13	12
	80Hz	19	12	11	10
	100Hz	20	13	12	11
	125Hz	22	17	15	14
	160Hz	24	21	18	17
	200Hz	24	19	16	15
	250Hz	23	19	17	16
	315Hz	21	18	15	14
	400Hz	24	23	20	19
	500Hz	25	23	20	19
	630Hz	30	25	22	21
	800Hz	31	28	25	24
	1kHz	29	28	25	24
	1.25kHz	31	27	26	25
	1.6kHz	27	25	23	22
	2kHz	23	21	18	17
	2.5kHz	21	20	18	17
	3.15kHz	22	21	18	17
	4kHz	22	20	18	17
	5kHz	23	21	19	18



Test 2 – Main bedroom: 1 windows 10cm open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	19	16	14	13
	50Hz	9	3	4	3
	63Hz	16	10	11	10
	80Hz	16	9	8	7
	100Hz	17	10	9	8
	125Hz	19	14	12	11
	160Hz	23	19	16	15
	200Hz	21	16	13	12
	250Hz	18	14	12	11
	315Hz	15	12	9	8
	400Hz	16	15	12	11
	500Hz	19	17	14	13
	630Hz	23	18	15	14
	800Hz	19	16	13	12
	1kHz	21	20	17	16
	1.25kHz	21	18	16	15
	1.6kHz	19	17	15	14
	2kHz	18	16	14	13
	2.5kHz	17	16	14	13
	3.15kHz	17	16	14	13
	4kHz	19	17	14	13
	5kHz	18	17	14	13



Test 3 – Main bedroom: 1 window open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	14	10	8	7
	50Hz	9	3	3	2
	63Hz	16	10	11	10
	80Hz	13	6	5	4
	100Hz	16	9	8	7
	125Hz	19	14	12	11
	160Hz	20	17	14	13
	200Hz	16	11	8	7
	250Hz	14	11	9	8
	315Hz	11	8	5	4
	400Hz	12	11	8	7
	500Hz	12	10	8	7
	630Hz	17	12	10	9
	800Hz	15	11	9	8
	1kHz	12	11	8	7
	1.25kHz	14	11	9	8
	1.6kHz	11	10	7	6
	2kHz	11	8	6	5
	2.5kHz	10	9	6	5
	3.15kHz	11	9	7	6
	4kHz	10	8	6	5
	5kHz	9	8	6	5

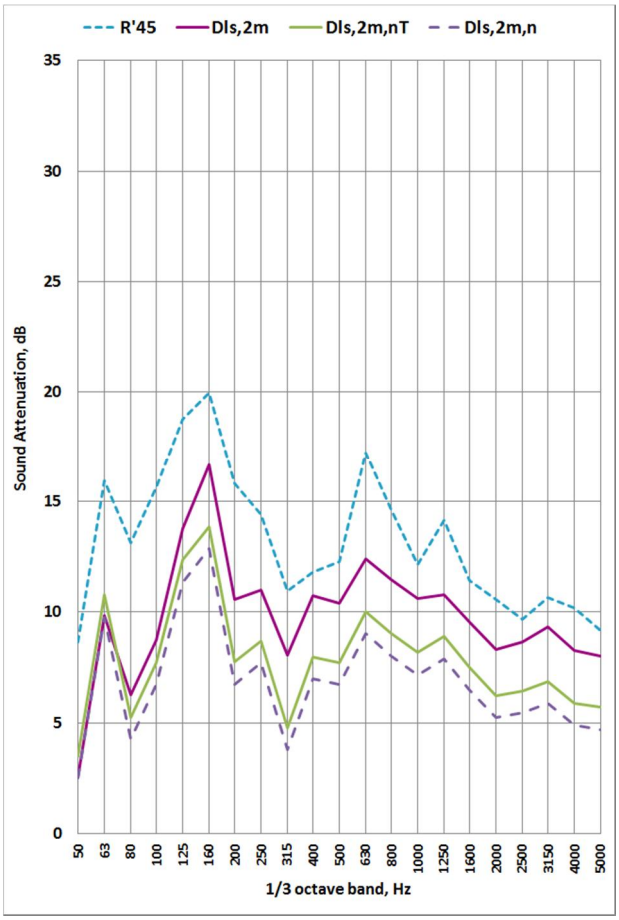





Figure C-1: Site photos

Appendix C House C Sound Insulation Test Results – Living Room

House C Test Details – Living Room				
Date:	12-07-2016		**Operator:**	Rodrigo O.
Time:	04:05pm start		**Company:**	AECOM Australia Pty Ltd
Sound level meter Model & Serial:	Bruel and Kjaer 2250, serial 2600406		**SLM Calibration Start:**	93.7
Acoustic calibrator Model & Serial:	RION NC-74, serial 34662248		**SLM Calibration End:**	93.7
Signal Gen Model & Serial:	NTI Minirator MR-PRO, serial G2P-RACSV-G0		**Loudspeaker Model & Serial:**	YAMAHA DXR10, serial EEVP01248
Room name and type:	Living room			
Room dimensions:	7.2m x 5m x 2.4m (gross dimensions)			
Room volume, m^3:	84 (includes hallways and excludes entertainment room, which access doors were kept closed during the test).			
Tested façade area, m^2:	17			
Window Type: sliding window	**Glass thickness:**	3mm approx.	**Window condition:**	Old but operable
Window Dimensions (m):	Window 1: 2.1m x 1.5m - Window 2: 2.1m x 1.5m - Door: 2.0m x 0.8m			
Exposed Façade Dimensions (m^2)	7.2m x 2.4m		**Tests conducted:**	1. Windows closed 2. 1 window 10cm open 3. Windows open
Reverberation time (overall):	T20: 0.53 sec T30: 0.52 sec			
Façade construction:	Weatherboard			
Test Standard:	ISO 16283-3:2016 Acoustics - Field Measurement of sound insulation in buildings and of building elements - Part 3: Façade sound insulation			

GLOSSARY

$R'_{45°}$ (Apparent sound reduction index)

Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface

$D_{ls,2m}$ (Level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level.

$D_{ls,2m,nT}$ (Standardized level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is standardized to a reference value of reverberation time in the receiving room of 0.5 seconds.

$D_{ls,2m,n}$ (Normalised level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is normalized to a reference value of the absorption area in the receiving room of $10m^2$.

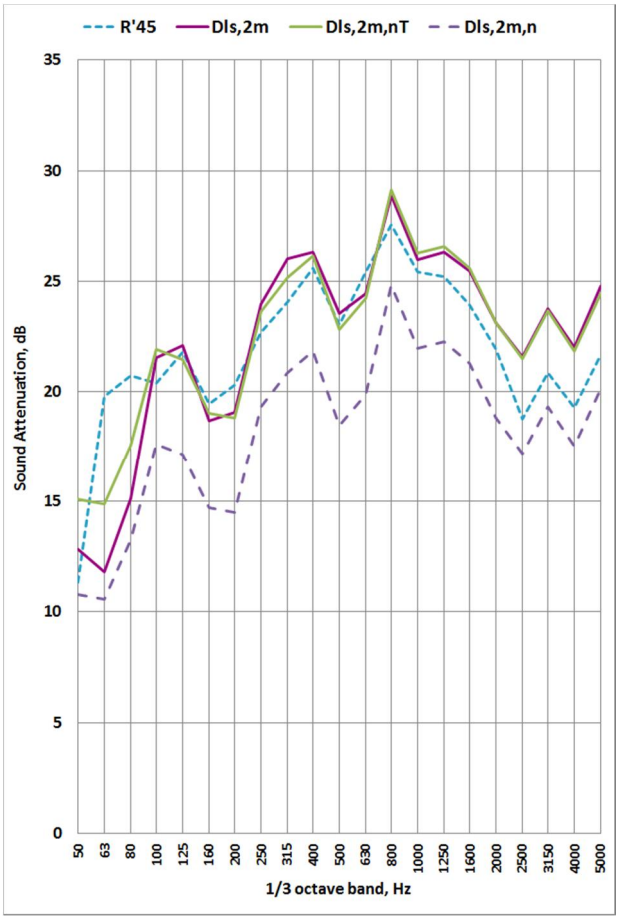
T20, T30 (Reverberation time)

Reverberation time measured by extrapolation of the sound energy decay time measured for the first 20 dB and 30 dB, respectively, to a 60 dB decay time.

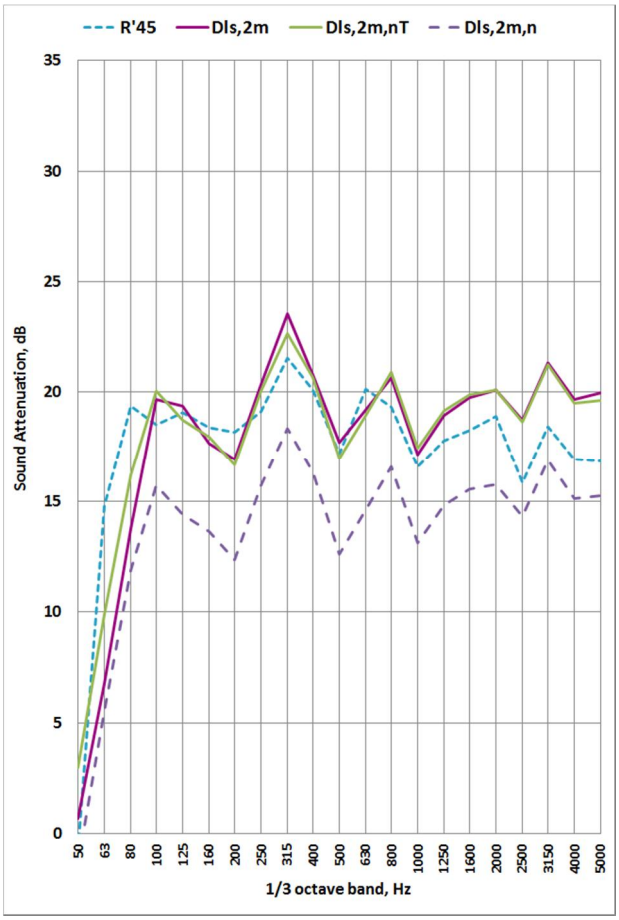
Note:

Sound levels below 100 Hz may have been affected by modal behaviour, low signal to noise ratio and/or high background noise.

Test 1 – Living room: Windows closed		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	23	23	23	19
	50Hz	11	13	15	11
	63Hz	20	12	15	11
	80Hz	21	15	18	13
	100Hz	20	22	22	18
	125Hz	22	22	21	17
	160Hz	19	19	19	15
	200Hz	20	19	19	14
	250Hz	23	24	24	19
	315Hz	24	26	25	21
	400Hz	26	26	26	22
	500Hz	23	24	23	18
	630Hz	25	24	24	20
	800Hz	28	29	29	25
	1kHz	25	26	26	22
	1.25kHz	25	26	27	22
	1.6kHz	24	25	26	21
	2kHz	22	23	23	19
	2.5kHz	19	22	22	17
	3.15kHz	21	24	24	19
	4kHz	19	22	22	18
	5kHz	22	25	24	20



Test 2 – Living room: 1 window 10cm open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	19	19	19	15
	50Hz	N.A.	1	3	N.A.
	63Hz	15	7	10	6
	80Hz	19	14	16	12
	100Hz	18	20	20	16
	125Hz	19	19	19	14
	160Hz	18	18	18	14
	200Hz	18	17	17	12
	250Hz	19	20	20	16
	315Hz	22	24	23	18
	400Hz	20	21	21	16
	500Hz	17	18	17	13
	630Hz	20	19	19	15
	800Hz	19	21	21	17
	1kHz	17	17	17	13
	1.25kHz	18	19	19	15
	1.6kHz	18	20	20	16
	2kHz	19	20	20	16
	2.5kHz	16	19	19	14
	3.15kHz	18	21	21	17
	4kHz	17	20	19	15
	5kHz	17	20	20	15



N.A: Insufficient outdoor-to-indoor sound level difference at 50Hz with window partially open for value to be calculated.

Test 3 – Living room: 2 windows open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	12	12	13	8
	50Hz	16	17	19	15
	63Hz	13	5	8	4
	80Hz	15	9	12	7
	100Hz	13	14	15	10
	125Hz	14	14	14	9
	160Hz	13	13	13	9
	200Hz	13	12	12	7
	250Hz	15	16	16	11
	315Hz	13	15	14	10
	400Hz	13	14	14	9
	500Hz	12	12	11	7
	630Hz	14	13	13	9
	800Hz	12	13	13	9
	1kHz	10	10	11	6
	1.25kHz	10	11	11	7
	1.6kHz	10	12	12	7
	2kHz	10	11	11	7
	2.5kHz	8	11	11	6
	3.15kHz	10	12	12	8
	4kHz	8	11	11	7
	5kHz	9	12	12	7

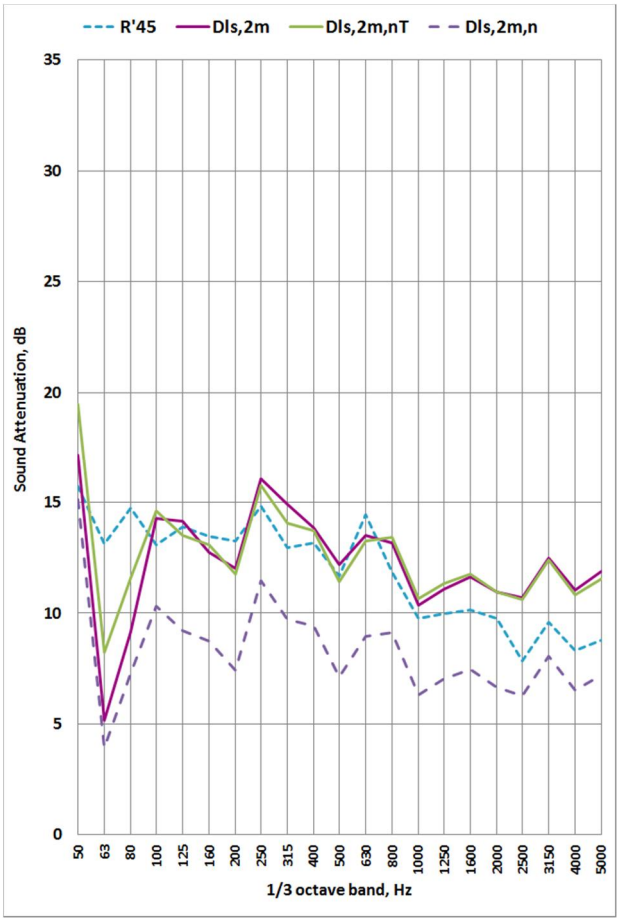


Figure C-2: Site photos

Appendix D

House D Sound Insulation Test Results

Appendix D House D Sound Insulation Test Results – Living Room

House D Test Details – Living Room					
Date:	13-07-2016		**Operator:**	Rodrigo O.	
Time:	09:50am start		**Company:**	AECOM Australia Pty Ltd	
Sound level meter Model & Serial:	Bruel and Kjaer 2250, serial 2600406		**SLM Calibration Start:**	93.7	
Acoustic calibrator Model & Serial:	RION NC-74, serial 34662248		**SLM Calibration End:**	93.7	
Signal Gen Model & Serial:	NTI Minirator MR-PRO, serial G2P-RACSV-G0		**Loudspeaker Model & Serial:**	YAMAHA DXR10, serial EEVP01248	
Room name and type:	Living room				
Room dimensions:	8.1m x 4.7m x 2.6m (gross room dimensions)				
Room volume, m^3:	123 m^3 (includes hallway and excludes kitchen, which is separated from living room by hallway walls).				
Tested façade area, m^2:	21 m^2 (8.1m x 2.6m)				
Window Type: sliding window	**Glass thickness:**	6mm approx.	**Window condition:**	Good	
Window Dimensions (m):	Window 1: 2.1m x 2.0m - Window 2: 2.1m x 2.0m - Door: Not taken				
Exposed Façade Dimensions (m^2)	7.2m x 2.4m		**Tests conducted:**	1. Windows closed 2. 1 window 10cm open 3. Windows open	
Façade construction:	Concrete				
Reverberation time (overall):	T20: 0.58 sec – T30: 0.61 sec				
Notes:	Very windy conditions during test				
Test Standard:	ISO 16283-3:2016 Acoustics - Field Measurement of sound insulation in buildings and of building elements - Part 3: Façade sound insulation				

GLOSSARY

$R'_{45°}$ (Apparent sound reduction index)

Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface

$D_{ls,2m}$ (Level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level.

$D_{ls,2m,nT}$ (Standardized level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is standardized to a reference value of reverberation time in the receiving room of 0.5 seconds.

$D_{ls,2m,n}$ (Normalised level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is normalized to a reference value of the absorption area in the receiving room of $10m^2$.

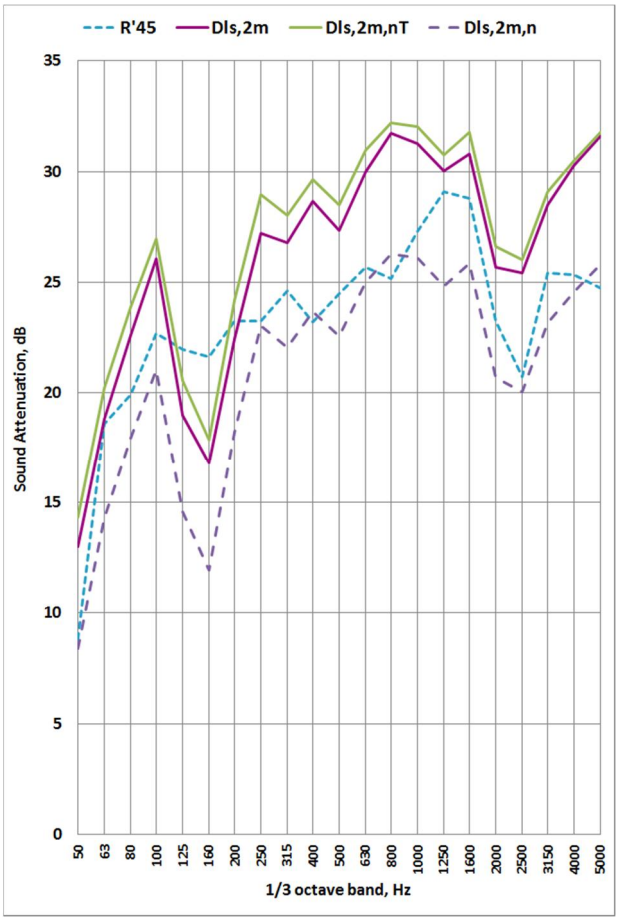
T20, T30 (Reverberation time)

Reverberation time measured by extrapolation of the sound energy decay time measured for the first 20 dB and 30 dB, respectively, to a 60 dB decay time.

Note:

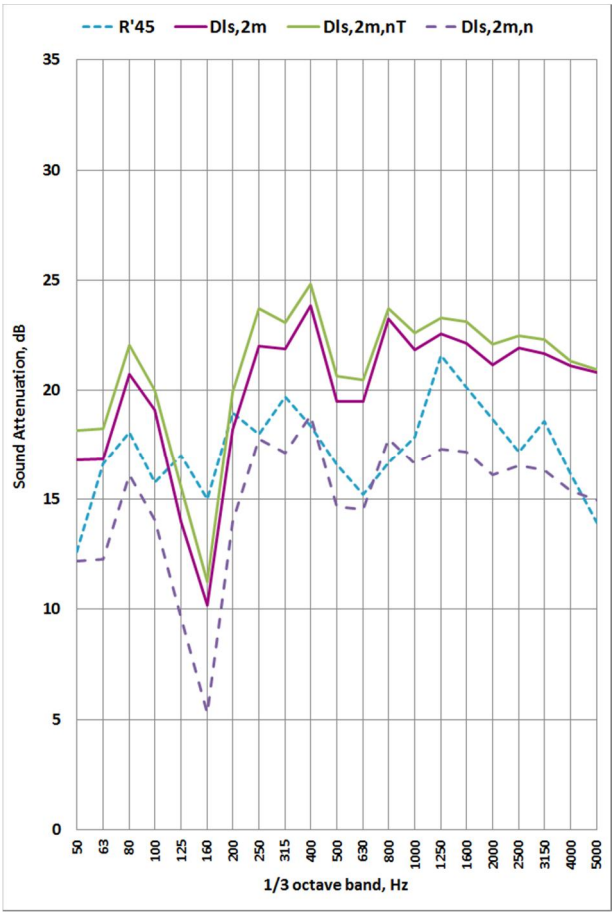
Sound levels below 100 Hz may have been affected by modal behaviour, low signal to noise ratio and/or high background noise.

Test 1 – Living room: Windows closed		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	24	27	28	22
	50Hz	9*	13	14*	8*
	63Hz	19	19	20	14
	80Hz	20	23	24	18
	100Hz	23	26	27	21
	125Hz	22	19	21	15
	160Hz	22	17	18	12
	200Hz	23	22	24	18
	250Hz	23	27	29	23
	315Hz	25	27	28	22
	400Hz	23	29	30	24
	500Hz	24	27	28	23
	630Hz	26	30	31	25
	800Hz	25	32	32	26
	1kHz	27	31	32	26
	1.25kHz	29	30	31	25
	1.6kHz	29	31	32	26
	2kHz	23	26	27	21
	2.5kHz	21	25	26	20
	3.15kHz	25	28	29	23
	4kHz	25	30	30	25
	5kHz	25	32	32	26



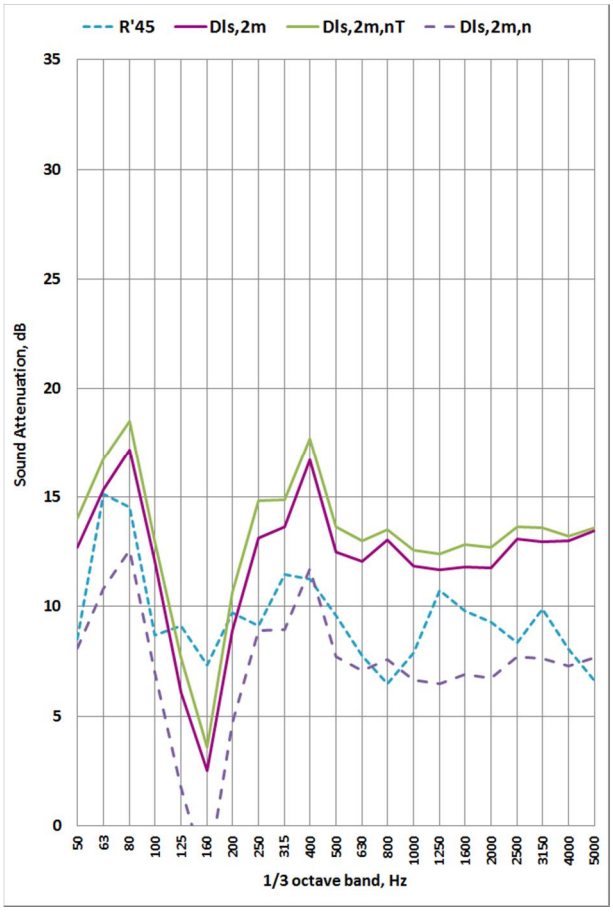
*: Value obtained using extrapolated value of reverberation time

Test 2 – Living room: 1 window 10cm open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	**17**	**20**	**21**	**15**
	50Hz	13*	17	18*	12*
	63Hz	17	17	18	12
	80Hz	18	21	22	16
	100Hz	16	19	20	14
	125Hz	17	14	16	10
	160Hz	15	10	11	5
	200Hz	19	18	20	14
	250Hz	18	22	24	18
	315Hz	20	22	23	17
	400Hz	18	24	25	19
	500Hz	17	19	21	15
	630Hz	15	19	20	15
	800Hz	17	23	24	18
	1kHz	18	22	23	17
	1.25kHz	22	23	23	17
	1.6kHz	20	22	23	17
	2kHz	19	21	22	16
	2.5kHz	17	22	22	17
	3.15kHz	19	22	22	16
	4kHz	16	21	21	15
	5kHz	14	21	21	15



*: Value obtained using extrapolated value of reverberation time.

Test 3 – Living room: 2 windows open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	9	12	12	7
	50Hz	9*	13	14*	8*
	63Hz	15	15	17	11
	80Hz	15	17	19	13
	100Hz	9	12	13	7
	125Hz	9	6	8	2
	160Hz	7	3	4	-2
	200Hz	10	9	11	5
	250Hz	9	13	15	9
	315Hz	11	14	15	9
	400Hz	11	17	18	12
	500Hz	10	12	14	8
	630Hz	8	12	13	7
	800Hz	6	13	14	8
	1kHz	8	12	13	7
	1.25kHz	11	12	12	6
	1.6kHz	10	12	13	7
	2kHz	9	12	13	7
	2.5kHz	8	13	14	8
	3.15kHz	10	13	14	8
	4kHz	8	13	13	7
	5kHz	7	13	14	8



*: Value obtained using extrapolated value of reverberation time.

Figure D-1: Site photos

Appendix E

House E Sound Insulation Test Results

Appendix E House E Sound Insulation Test Results – Living Room

House E Test Details – Living Room				
Date:	13-07-2016		**Operator:**	Rodrigo O.
Time:	1:30pm start		**Company:**	AECOM Australia Pty Ltd
Sound level meter Model & Serial:	Bruel and Kjaer 2250, serial 2600406		**SLM Calibration Start:**	93.7
Acoustic calibrator Model & Serial:	RION NC-74, serial 34662248		**SLM Calibration End:**	93.7
Signal Gen Model & Serial:	NTI Minirator MR-PRO, serial G2P-RACSV-G0		**Loudspeaker Model & Serial:**	YAMAHA DXR10, serial EEVP01248
Room name and type:	Living room			
Room dimensions (internal):	6.7m x 9.6m x 2.7m (gross room dimensions). Pitched roof. Building height 2.7m at shoulder and 3.9m at ridge			
Room volume, m^3:	212 m^3 (includes hallways).			
Tested façade area, m^2:	44 m^2			
Window Type: sliding windows	**Glass thickness:**	3mm approx.	**Window condition:**	Good condition
Window Dimensions (m):	Window 1: 1.8m x 1.8m - Window 2: 1.8m x 1.8m - Window 3: 1.8m x 1.2m Sliding glass Door: 1.9m x 2.2m			
Exposed Façade Dimensions (m^2)	Wall 1: 6.7m x 2.7m Wall 2: 9.6m x 2.6m	**Tests conducted:**	1. Windows closed 2. 1 window 10cm open (wall 1) 3. 2 Windows open (wall1 and 2)	
Façade construction:	Log cabin			
Reverberation time (overall):	T20 0.52 sec – T30 0.52 sec			
Notes:	Very windy conditions during test			

GLOSSARY

$R'_{45°}$ (Apparent sound reduction index)

Measure of the sound insulation of a building element when the sound source is a loudspeaker at an angle of 45° and the outside microphone is on the test surface

$D_{ls,2m}$ (Level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level.

$D_{ls,2m,nT}$ (Standardized level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is standardized to a reference value of reverberation time in the receiving room of 0.5 seconds.

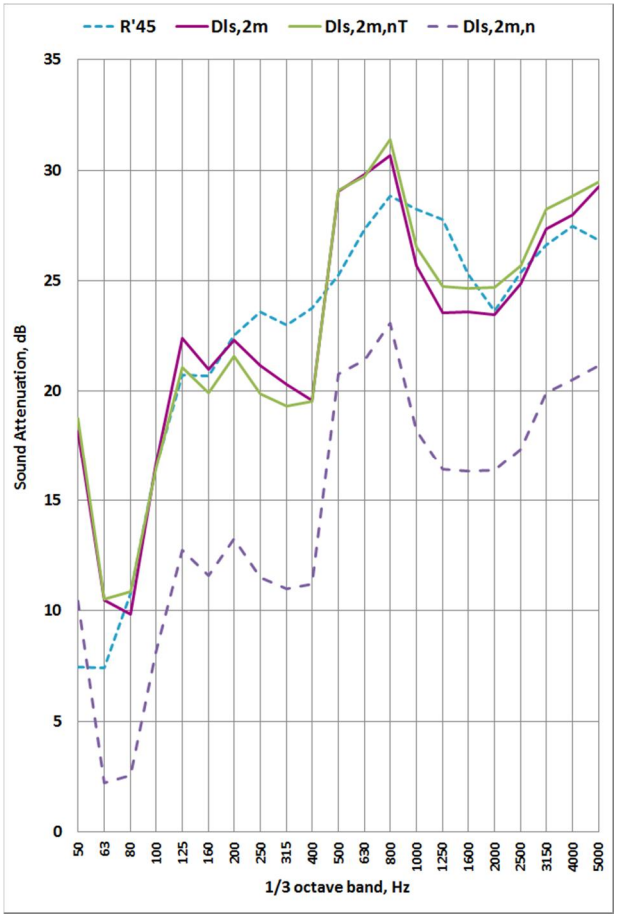
$D_{ls,2m,n}$ (Normalised level difference)

Level difference between the sound level measured at 2m from the façade and the internal sound level that is normalized to a reference value of thye absorption area in the receiving room of $10m^2$.

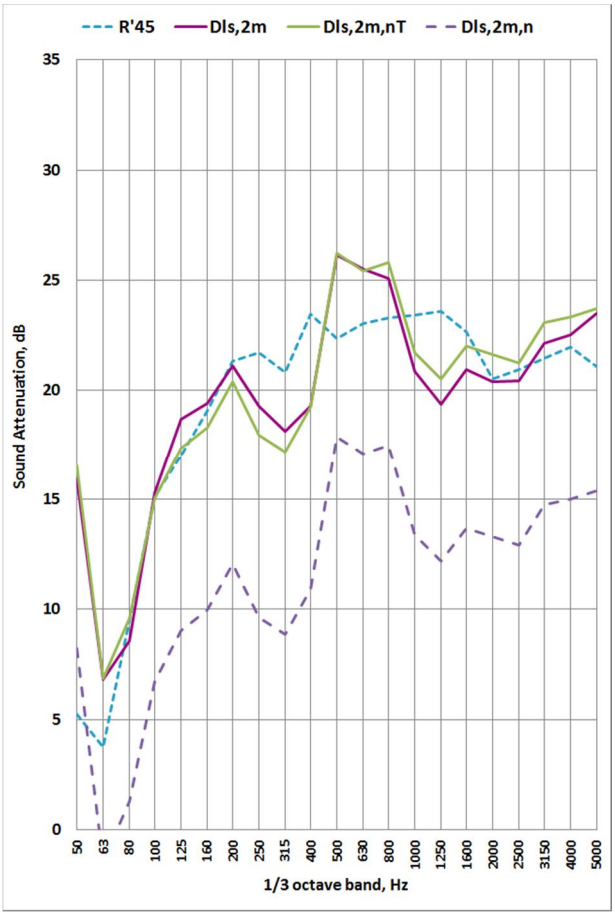
T20, T30 (Reverberation time)

Reverberation time measured by extrapolation of the sound energy decay time measured for the first 20 dB and 30 dB, respectively, to a 60 dB decay time.

Test 1 – Living room: Windows closed		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	22	22	22	14
	50Hz	7	18	19	10
	63Hz	7	10	11	2
	80Hz	11	10	11	3
	100Hz	17	17	16	8
	125Hz	21	22	21	13
	160Hz	21	21	20	12
	200Hz	23	22	22	13
	250Hz	24	21	20	12
	315Hz	23	20	19	11
	400Hz	24	20	20	11
	500Hz	25	29	29	21
	630Hz	27	30	30	21
	800Hz	29	31	31	23
	1kHz	28	26	27	18
	1.25kHz	28	24	25	16
	1.6kHz	25	24	25	16
	2kHz	24	23	25	16
	2.5kHz	25	25	26	17
	3.15kHz	27	27	28	20
	4kHz	27	28	29	20
	5kHz	27	29	29	21



Test 2 – Living room: 1 window 10cm open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	20	20	20	11
	50Hz	5	16	17	8
	63Hz	4	7	7	-1
	80Hz	9	9	10	1
	100Hz	15	15	15	7
	125Hz	17	19	17	9
	160Hz	19	19	18	10
	200Hz	21	21	20	12
	250Hz	22	19	18	10
	315Hz	21	18	17	9
	400Hz	23	19	19	11
	500Hz	22	26	26	18
	630Hz	23	26	25	17
	800Hz	23	25	26	17
	1kHz	23	21	22	13
	1.25kHz	24	19	21	12
	1.6kHz	23	21	22	14
	2kHz	21	20	22	13
	2.5kHz	21	20	21	13
	3.15kHz	21	22	23	15
	4kHz	22	22	23	15
	5kHz	21	23	24	15



Test 3 – Living room: 2 windows open		Façade sound insulation, dB			
		R'_{45}	$D_{ls,2m}$	$D_{ls,2m,nT}$	$D_{ls,2m,n}$
	Overall value (all frequencies)	13	13	13	5
	50Hz	3	13	14	6
	63Hz	-1	3	3	-6
	80Hz	5	4	5	-4
	100Hz	10	10	10	1
	125Hz	11	13	12	3
	160Hz	14	15	14	5
	200Hz	16	16	15	7
	250Hz	14	12	11	2
	315Hz	13	10	9	1
	400Hz	14	10	10	1
	500Hz	18	21	21	13
	630Hz	17	19	19	11
	800Hz	17	18	19	11
	1kHz	16	13	14	6
	1.25kHz	17	12	14	5
	1.6kHz	15	13	15	6
	2kHz	12	12	14	5
	2.5kHz	12	12	13	4
	3.15kHz	10	10	11	3
	4kHz	10	11	12	3
	5kHz	6	8	9	0

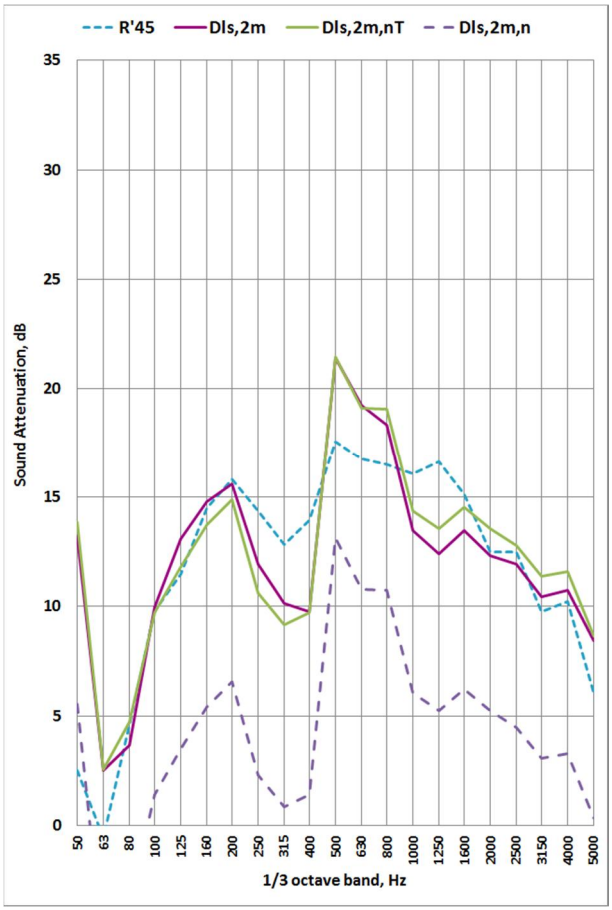


Figure E-1: Site photos

Appendix F

Calibration Certificates

Appendix F Bruel & Kjaer SLM Calibration Certificate

Brüel & Kjær

Australian Calibration Laboratory
Suite 2, 6-10 Talavera Road, North Ryde NSW 2113, Australia

NATA
WORLD RECOGNISED ACCREDITATION
Laboratory No. 1301

CERTIFICATE OF CALIBRATION

Certificate No: CAU1500531 Page 1 of 10

CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær	2250	No: 2600406
Microphone:	Brüel & Kjær	4189	No: 288742
Preamplifier:	Brüel & Kjær	ZC-0032	No: 7318
Supplied Calibrator:	Brüel & Kjær	None	No: N/A
Software version:	BZ7222 Version 4.4	Pattern Approval:	PTB
Instruction manual:	BE-1712 Version 18	Identification:	

CUSTOMER:

AECOM
Level 21, 420 George Street
Sydney NSW 2000

CALIBRATION CONDITIONS:

Preconditioning: 4 hours at 23 °C
Environment conditions: *see actual values in **Environmental conditions** sections*

SPECIFICATIONS:

The Sound Level Meter has been calibrated in accordance with the requirements as specified in IEC61672-3:2006 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests.

PROCEDURE:

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System B&K 3630 with application software type 7763 (version 5.0 - DB: 5.00) and test procedure 2250-4189.

RESULTS:

	Initial calibration		Calibration prior to repair/adjustment
X	Calibration without repair/adjustment		Calibration after repair/adjustment

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of Calibration: 2015-07-02 Certificate issued: 2015-07-02

Craig Robert Patrick
Calibration Technician

Jan Rasmussen
Approved signatory

Appendix F RION NC-74 Calibrator Calibration Certificate

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: 18211

EQUIPMENT TESTED: Sound Level Calibrator

Manufacturer: Rion
Type No: NC-74 **Serial No:** 34662248
Owner: AECOM Australia Pty Ltd
Level 1, 21 Stokes Street
Townsville, QLD 4810

Tests Performed: Measured output pressure level was found to be:

Parameter	Pre-Adj	Adj Y/N	Output: (db re 20 µPa)	Frequency: (Hz)	THD&N (%)
Level 1:	NA	N	93.87	1002.00	1.41
Level 2:	NA	N	NA	NA	NA
Uncertainty:			±0.11 dB	±0.05 Hz	±0.2 %
Uncertainty (at 95% c.l.) k=2					

CONDITION OF TEST:
Ambient Pressure: 1004 hPa ±1.5 hPa **Relative Humidity:** 52% ±5%
Temperature: 23 °C ±2° C
Date of Calibration: 07/12/2015 **Issue Date:** 08/12/2015
Acu-Vib Test Procedure: AVP02 (Calibrators)
Test Method: AS IEC 60942 - 2004
CHECKED BY: ... **AUTHORISED SIGNATURE:** .....
Per Jack Kidd

Accredited for compliance with ISO/IEC 17025
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.

NATA
ACCREDITATION
Accredited Lab. 9262
Acoustic and Vibration Measurements

ACU-VIB
ELECTRONICS
HEAD OFFICE
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
Tel: (02) 96808133 Fax: (02)96808233
Mobile: 0413 809806
Web site: www.acu-vib.com.au

Page 1 of 1 End of Calibration Certificate
AVCERT02 Rev.1.3 11.02.14