New Residential Development
Swinbourne Grove, Manchester

Building Services Noise Assessment

Project: Swinbourne Grove - Plant Noise Assessment (Addendum)

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1. Introduction

1.1 RS Acoustic Engineering Ltd have been appointed by Truman Design and Build Ltd to undertake a noise impact assessment with regard to new building services plant for the apartment building off Swinbourne Grove, Manchester, M20.

1.2 The external plant associated with the apartment building includes 13 Daikin outdoor compressor units mounted at roof-top level (associated with the air source heat pump system) and a 500 kVA transformer installed within a new substation at ground floor level.

1.3 The development was granted full planning permission subject to a number of conditions. With regard to noise, condition no's 13 and 28 are relevant in this instance (further details are given overleaf).

1.4 There are semi-detached dwellings located along Swinbourne Grove to the east and an extra-care residential property immediately south of the new apartment building.

1.5 A noise assessment has been undertaken taking into consideration the guidance given within BS 4142:2014+A1:2019 *Methods for rating and assessing industrial and commercial sound*.

1.6 An environmental noise survey has been conducted in order to determine the lowest and typical background sound levels during the daytime and night-time period.

1.7 The manufacturer's octave band sound level data has been used to determine the roof-top compressor unit sound pressure levels at adjacent dwellings.

1.8 The manufacturer's sound level data for the transformer and the substation construction details have been used initially to determine the noise break-out levels at adjacent dwellings.

1.9 The survey and assessment was conducted by Mr Ryan Swales ($BSc_{(Hons)}$, MIOA), Principal Acoustic Consultant and Corporate Member of the Institute of Acoustics.

1.10 The report provides the survey results, details of the proposed building services plant, calculated sound levels at adjacent receptors and the anticipated impact.

1.11 Following the submission of the assessment report in April 2021, further surveys have been conducted in July 2021 in order to verify both the assessment and the noise levels emanating from the installed plant.

2. Assessment Guidance & Criteria

Manchester City Council, Planning & Noise (Technical Guidance)

2.1 With regard to noise from fixed plant and equipment, Manchester City Council's guidance document states the following:

Any noise assessment needs to consider not only the overall level of noise emitted but also its particular characteristics. The noise assessment should be based on BS 4142:2014 and any application for fixed plant, equipment or machinery must demonstrate that:

Externally mounted ancillary plant, equipment and servicing shall be selected and/or acoustically treated in accordance with a scheme designed so as to achieve a rating level of 5dB (L_{Aeq}) below the typical background (L_{A90}) level at the nearest noise sensitive location.

Manchester City Council Planning Conditions

2.2 The following noise related planning conditions have been attached to the permission:

Condition No.13:

Externally mounted ancillary plant, equipment and servicing shall be selected and/or acoustically treated in accordance with a scheme designed so as to achieve a rating level of 5dB (L_{Aeq}) below the typical background (L_{A90}) level at the nearest noise sensitive location. The scheme shall be submitted to and approved in writing by the City Council as local planning authority in order to secure a reduction in the level of noise emanating from the site. The approved scheme shall be completed before the premises is occupied.

Upon completion of the development a verification report will be required to validate that the work undertaken throughout the development conforms to the recommendations and requirements in the approved acoustic report. The report shall also undertake post completion testing to confirm that the noise criteria has been met. Any instances of nonconformity with the recommendations in the report shall be detailed along with any measures required to ensure compliance with the agreed noise criteria.

Condition No.28:

The electrical substation shall be acoustically insulated and treated to limit the break out of noise in accordance with a noise study of the premises and a scheme of acoustic treatment that has been submitted to and approved in writing by the City Council as local planning authority. The scheme shall be implemented in full before the use commences. Upon completion of the development a verification report will be required to validate that the work undertaken throughout the development conforms to the recommendations and requirements in the approved acoustic consultant's report. The report shall also undertake post completion testing to confirm that acceptable criteria has been met. Any instances of non-conformity with the recommendations in the report shall be detailed along with any measures required to ensure compliance with the agreed noise criteria.

British Standard 4142:2014+A1:2019 Methods for rating and assessing industrial and commercial sound

2.3 BS 4142 (amended June 2019) describes methods for rating and assessing sound of an industrial and/or commercial nature, such as sound from manufacturing processes and fixed mechanical plant/machinery.

2.4 Outdoor sound levels are used to assess the likely effect on people who might be inside or outside a dwelling or premises used for residential purposes upon which sound is incident.

2.5 BS 4142 is not intended to be applied to the derivation of indoor sound levels arising from sound levels outside, or the assessment of indoor sound levels.

2.6 The standard has three different methods (subjective, objective and reference) of applying a penalty to tonal, impulsive and intermittent noises, as separate entities.

2.7 The current standard no longer indicates significance of noise impacts as giving rise to a '*likelihood of complaint*' but rather as an '*indication*' of varying degrees of '*adverse impact'*.

2.8 BS 4142:2014 states that a difference of around +10 dB or more (excess of rating level above the background sound level) is likely to be an indication of a significant adverse impact, depending on the context.

2.9 A difference of around +5 dB is likely to be an indication of an adverse impact, depending on the context.

2.10 The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound source will have an adverse impact or a significant adverse impact.

2.11 Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact, depending on the context.

3. Environmental Noise Survey

Survey methodology

3.1 Continuous sound level monitoring was conducted over a 50-hour period near to the south east boundary line, adjacent to Swinbourne Grove.

3.2 The microphone was fixed to scaffolding at 2nd floor level on the south east facing elevation of the new apartment building.

3.3 Measurements were performed from 15:45 hours on Friday 26th through to 17:45 hours on Sunday 28th February 2021.

3.4 A measurement interval of 15 minutes was used throughout the survey and measurements were considered to be subject to reflections from the building facade (as opposed to free-field).

3.5 Continuous sound level monitoring was also previously conducted at the site in April 2019 over several days directly adjacent to Wilmslow Road. However, the previous data is not representative of the receptor positions or background sound levels when set-back from Wilmslow Road.

3.6 The site location and survey measurement position are shown in Figure 3.1. The photographs in Figure 3.2 also show the survey measurement position.

Figure 3.1 – Site location and survey measurement position (Source: Google Earth)

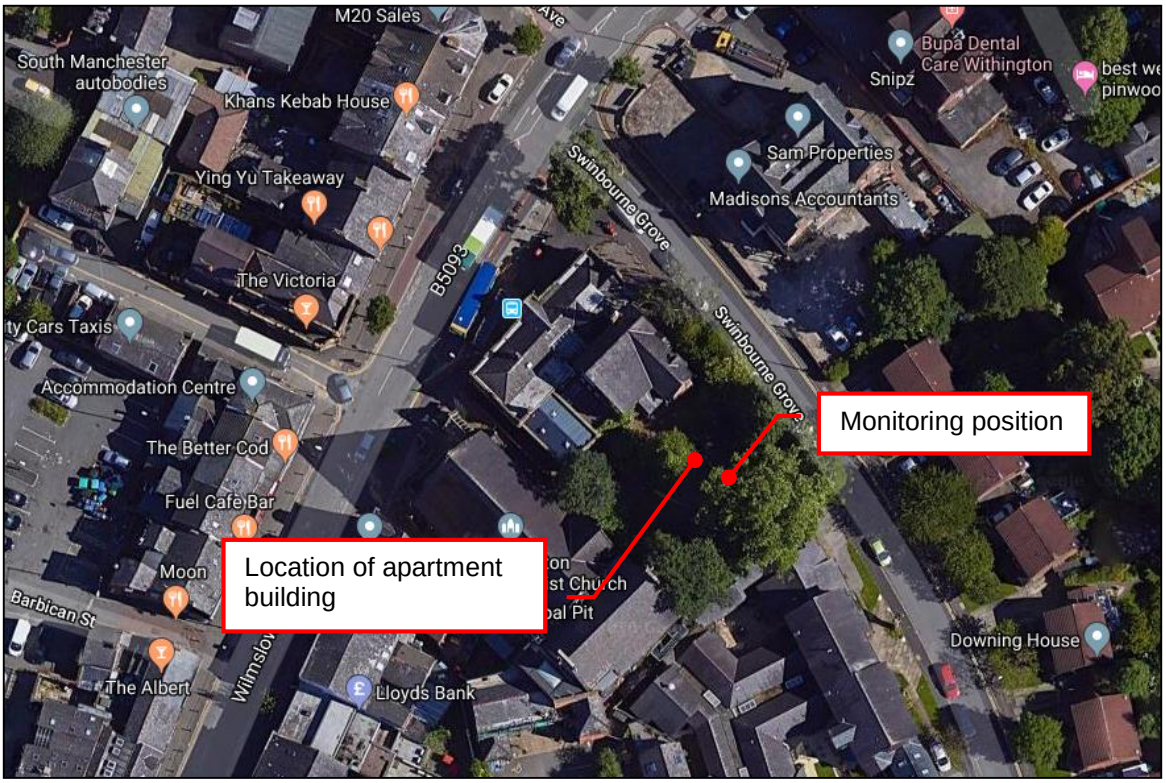


Figure 3.2 – Photographs showing survey measurement position



Survey equipment

3.7 The survey was performed using the following Class-1 specification equipment:

- Brüel & Kjaer 2250-Light data logging sound level meter, with microphone type 4189 and pre-amplifier type ZC0032.
- Brüel & Kjaer 4231 acoustic calibrator.

3.8 Calibration of the sound level meter and microphone used for the measurements are traceable to UKAS accredited laboratories (calibration certificates are available on request).

3.9 The calibration of both sound level meter and microphone was checked using a 1 kHz tone at 94 dB prior to and following the survey. The drift in calibration was less than 0.1 dB.

Weather conditions

3.10 The weather conditions during the survey were dry and fine with clear sunny spells. Wind speed measurements taken on site were generally less than 2 m/s^{-1}.

3.11 The air temperature during the survey ranged between 2°C and 11°C. The overall weather conditions were considered suitable to obtain representative measurements.

Subjective observations of the acoustic environment

3.12 The dominant noise source at the site was observed to be road traffic on Wilmslow Road. Noise from sporadic vehicle movements on Swinbourne Grove was considered negligible.

3.13 A number of local commercial premises on Wilmslow Road were closed at the time of the survey due to the ongoing pandemic.

3.14 Building services noise associated with the adjacent extra-care accommodation was audible when positioned close to the southern boundary line. The noise was continuous in nature, of a relatively low-level and was emanating from the east facing elevation of the property.

3.15 Other noted noise sources include intermittent activity at adjacent dwellings, pedestrians, birdsong and high altitude aircraft. There was no construction related work on-site over the weekend period.

Results summary

3.16 Table 3.1 presents a summary of the measured background L_{A90} sound pressure levels from the continuous monitoring position. Measured values have been rounded to the nearest whole number.

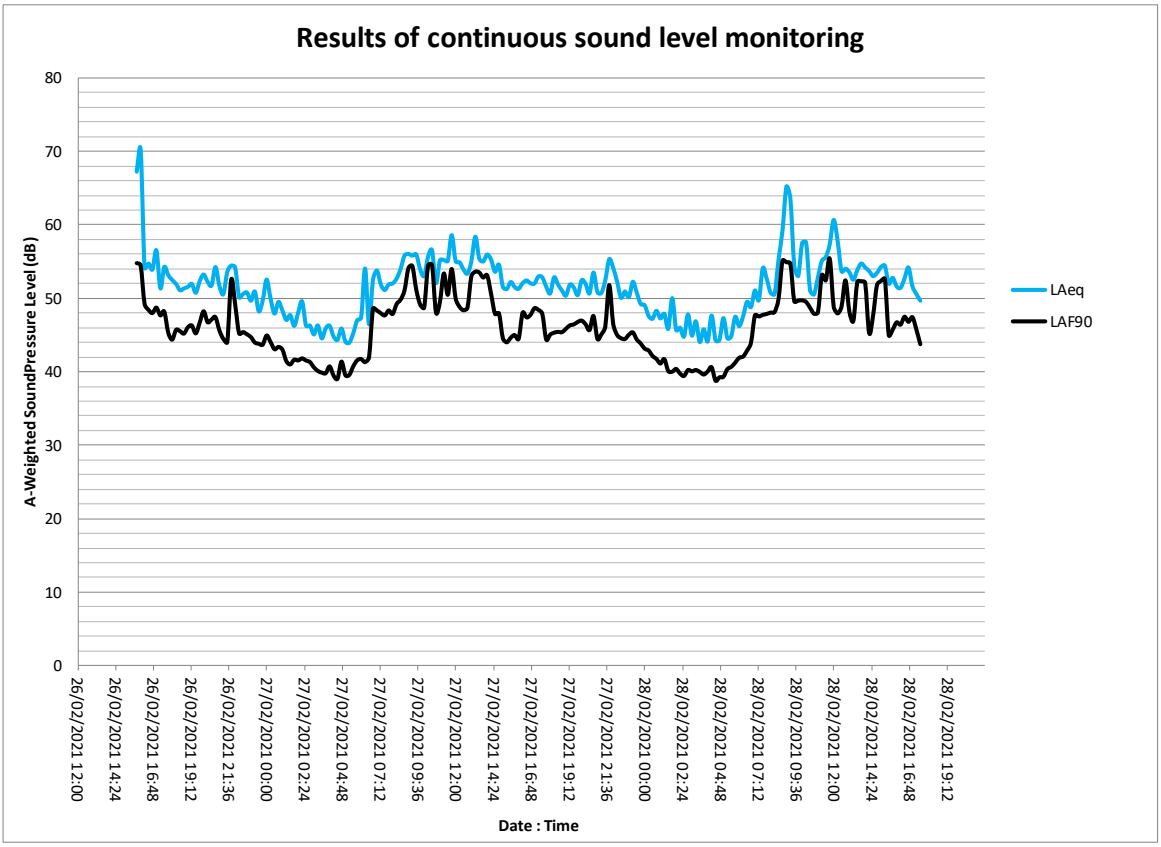
Table 3.1 – Summary of measured background sound pressure levels

Date	Period, Hours	Typical[1] $L_{A90,15min}$ dB	Lowest $L_{A90,15min}$ dB	Highest $L_{A90,15min}$ dB
Friday 26/02/2021 - Saturday 27/02/2021	Daytime (15:45-23:00)	45	44	55
	Night-time (23:00-07:00)	41	39	49
Saturday 27/02/2021 - Sunday 28/02/2021	Daytime (07:00-23:00)	48	44	55
	Night-time (23:00-07:00)	40	39	45
Sunday 28/02/2021	Daytime (07:00-17:45)	48	44	55

[1]Considered to be the representative background sound level (from a statistical analysis)

3.17 The results of the sound level monitoring are presented graphically in Figure 3.3. Additional tabulated survey data is presented within Appendix C.

Figure 3.3 – Graph showing results of continuous sound level monitoring



4. Assessment & Discussion

Sound level targets for new building services plant

4.1 Taking into account MCC's requirements, the sound rating level ($L_{Aeq,T}$) from all new building services plant should be at least 5 dB below the typical background sound level ($L_{A90,T}$).

4.2 BS 4142 states '*Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact, depending on the context'.*

4.3 The Environmental Health Department have previously stated that the lowest background sound level should ideally be used to determine the appropriate plant noise limits/targets.

4.4 Table 4.1 presents the applicable sound level targets for new fixed plant items. The sound level targets should be achieved at approximately 1 metre from the nearest noise sensitive window.

Table 4.1 – Sound level targets for new building services plant

Period, Hours	Lowest Background Sound Level $L_{A90,15min}$ dB	Target Rating Level $L_{Aeq,15min}$ dB
Daytime (07:00-23:00)	44	39
Night-time (23:00-07:00)	39	34

4.5 The new items of plant will operate during the night-time period and therefore the appropriate target at adjacent/neighbouring windows is 34 dB $L_{Aeq,15min}$.

New building services plant and nearest noise sensitive receptors

Daikin outdoor compressor units

4.6 There are thirteen Daikin outdoor compressor/condensing units to be installed on the flat roof area towards the north west facing elevation.

4.7 The nearest existing dwellings with a potential line-of-sight to the outdoor compressor units are the semi-detached dwellings on the opposite side of Swinbourne Grove. The distance from the outdoor units to the nearest bedroom window is approximately 40 metres (i.e. distance from the approximate mid-point of the units).

4.8 The separation distance from the roof-top units to the extra-care accommodation immediately south of the apartments is approximately 30 metres, however it is anticipated that the windows to habitable rooms will be visually and acoustically screened. The resulting sound level will therefore be notably lower than the sound level experienced at the dwellings on the opposite side of Swinbourne Grove.

4.9 The nearest new apartments/habitable rooms to the roof-top units are the third floor apartments located on the north west facing elevation. The separation distance is approximately 5 metres from the mid-point of the units to the mid-point of the nearest window. However, there is no direct line-of-sight from the plant to the windows (windows are acoustically screened).

4.10 It is understood that the outdoor units are Daikin ERGA04 compressors with a sound pressure level of approximately 48 dBA at 1 metre (i.e. in the slightly louder cooling mode).

4.11 The manufacturer's octave-band sound pressure levels for the Daikin unit are presented in Table 4.2 overleaf (cooling mode). The sound level data for the unit is also presented graphically in Appendix A.

Table 4.2 – Daikin ERGA04 octave band sound pressure levels (L_{eq} dB)

Octave Band Centre Frequency (Hz)								Overall L_{Aeq} dB
63	125	250	500	1000	2000	4000	8000	
50	53	50	47	43	37	30	22	48

4.12 Figure 4.1 shows the roof-top layout and proposed plant location. Figure 4.2 and 4.3 overleaf show the Swinbourne Grove elevation, north facing elevation and proposed roof-top plant.

Figure 4.1 – Roof-top layout and proposed plant location

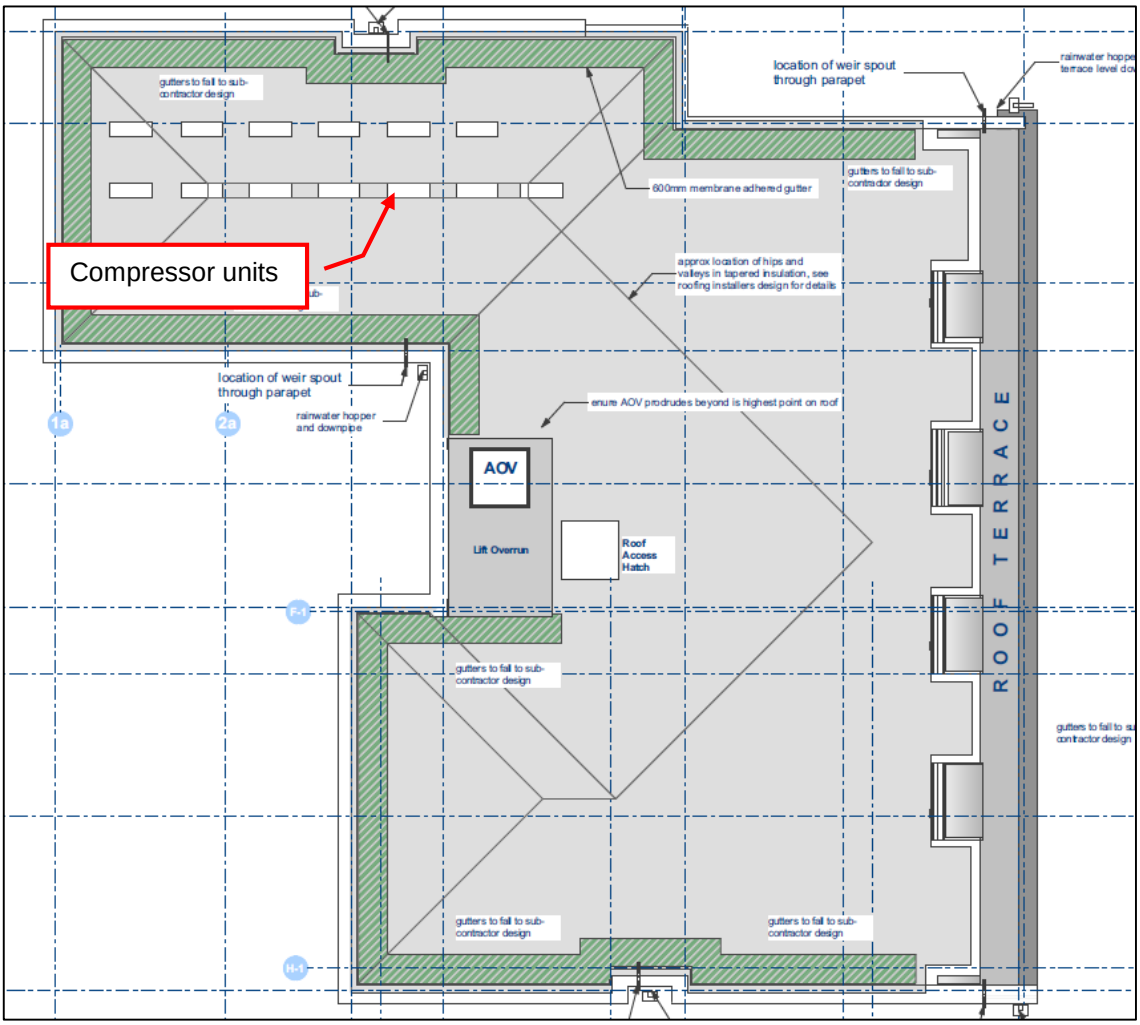


Figure 4.2 – Swinbourne Grove elevation showing proposed roof-top plant

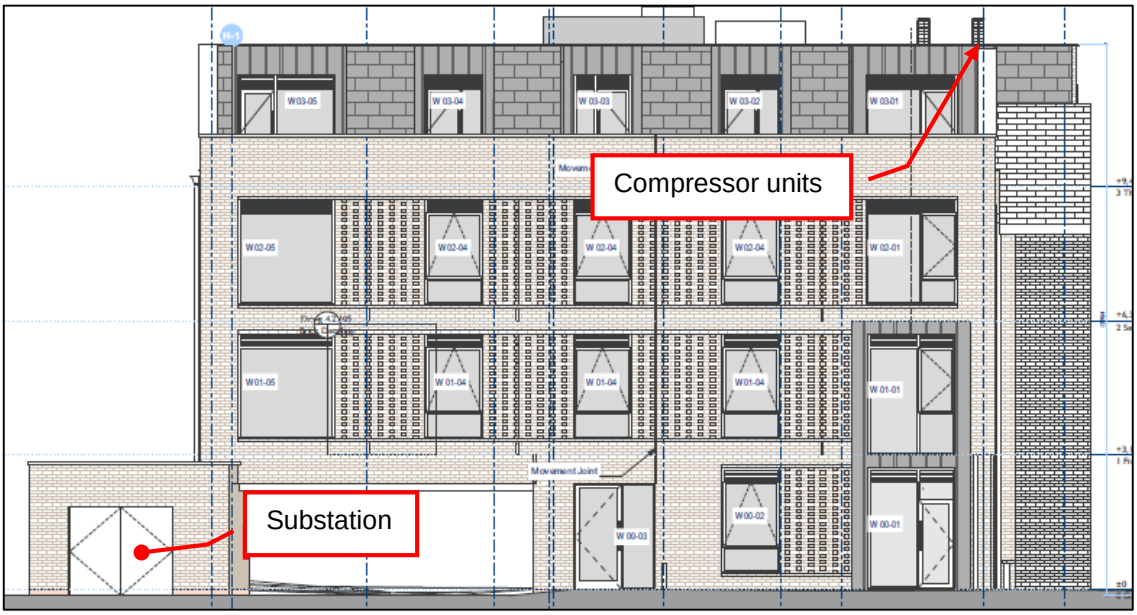
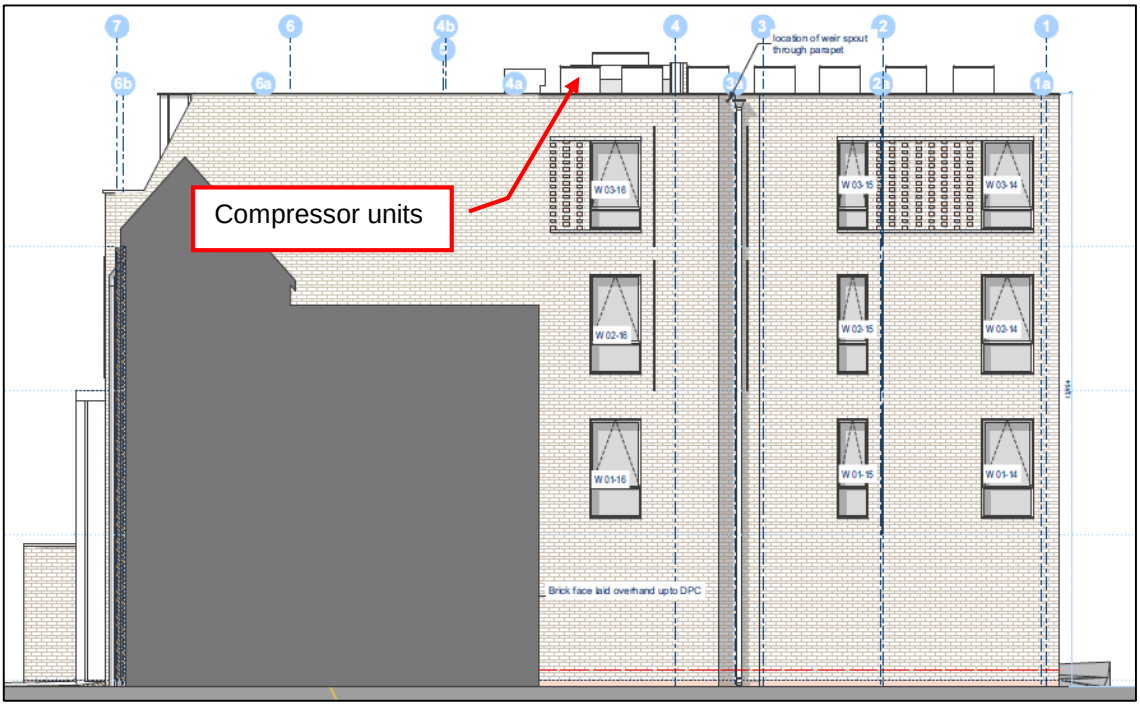


Figure 4.3 – North facing elevation showing proposed roof-top plant



Predicted plant sound levels at adjacent dwellings

Compressor unit sound level

4.13 It is assumed that all of the Daikin outdoor units could operate simultaneously and continuously over a given assessment period (worst-case scenario).

4.14 To determine the level of sound attenuation due to distance separation, standard acoustic principals for a point source have been assumed.

4.15 Table 4.3 overleaf presents a calculation summary for the adjacent dwellings on Swinbourne Grove. The calculations take into consideration the cumulative sound level, frequency spectrum, surface directivity and distance separation.

Table 4.3 – Cumulative compressor sound pressure level at adjacent dwellings on Swinbourne Grove

	Octave Band Centre Frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
13 x Daikin ERGA04 (Cumulative L_{eq} dB)	61	64	61	58	54	48	41	33
Directivity factor dB	+3	+3	+3	+3	+3	+3	+3	+3
Distance attenuation dB (40 metres)	-32	-32	-32	-32	-32	-32	-32	-32
A-weighting correction dB	-26	-16	-9	-3	0	+1	+1	-1
Resulting level dBA	**6**	**19**	**23**	**26**	**25**	**20**	**13**	**3**
Specific sound level $L_{Aeq,T}$ = 31 dB								

4.16 The calculation results indicate a specific sound pressure level of approximately 31 dB $L_{Aeq,T}$ at the nearest dwellings on Swinbourne Grove.

4.17 Taking into consideration the tonal characteristics of the compressor unit and the resulting sound level, it is considered unnecessary to apply a correction (penalty) with regard to the potential tonality or characteristics of the noise as experienced at the receptor position.

4.18 On this basis, the specific sound level is considered to be equal to the rating level (31 dB $L_{Ar,15min}$).

4.19 The target noise limit at adjacent windows is 34 dB $L_{Aeq,15min}$ during the night-time period.

4.20 The sound rating level of the roof-top compressor units therefore achieves the target noise limit.

4.21 It is worth noting that the predicted rating level is 8 dB below the lowest measured background sound level during the night-time period.

4.22 With regard to the anticipated noise impact, BS 4142 states:

The significance of sound of an industrial and/or commercial nature depends upon both the margin by which the rating level of the specific sound source exceeds the background sound level and the context in which the sound occurs...

The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound source will have an adverse impact or a significant adverse impact. Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact, depending on the context.

4.23 On this basis, noise from the roof-top plant is expected to have a low impact at adjacent dwellings on Swinbourne Grove.

4.24 Table 4.4 overleaf presents a calculation summary for the nearest (third floor) apartments on the north facing elevation.

4.25 The calculations take into consideration the cumulative sound level, frequency spectrum, surface directivity factor, distance separation and acoustic screening.

Table 4.4 – Cumulative compressor sound pressure level at apartments on north facing elevation

	Octave Band Centre Frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
13 x Daikin ERGA04 (Cumulative L_{eq} dB)	61	64	61	58	54	48	41	33
Directivity factor dB	+3	+3	+3	+3	+3	+3	+3	+3
Distance attenuation dB (5 metres)	-14	-14	-14	-14	-14	-14	-14	-14
Acoustic screening dB	-13	-14	-16	-19	-22	-25	-27	-29
A-weighting correction dB	-26	-16	-9	-3	0	+1	+1	-1
Resulting level dBA	**11**	**23**	**25**	**25**	**21**	**13**	**4**	**-8**
Specific sound level $L_{Aeq,T}$ = 30 dB								

4.26 The calculation results indicate a specific sound pressure level of approximately 30 dB $L_{Aeq,T}$ at the nearest apartments on the north facing elevation.

4.27 Again, the specific sound level is considered to be equal to the rating level (30 dB $L_{Ar,15min}$).

4.28 The sound rating level of the roof-top compressor units therefore achieves the target noise limit during the night-time period.

4.29 It is worth noting that the predicted rating level in this instance is 9 dB below the lowest measured background sound level during the night-time period.

4.30 On this basis, noise from the roof-top plant is expected to have a low impact at the nearest apartments.

Vibration control

4.31 It is recommended that suitable anti-vibration (resilient) mounts are fitted to the roof-top units in order to eliminate the potential for structure-borne noise. Without appropriate anti-vibration mounts, vibration levels could potentially become audible as structure-borne noise.

Substation and transformer

4.32 There is a new 500 kVA transformer and substation associated with the new apartment building.

4.33 The datasheet for the proposed transformer indicates a sound pressure level of 56 dBA at a distance of 0.3 metres from the unit.

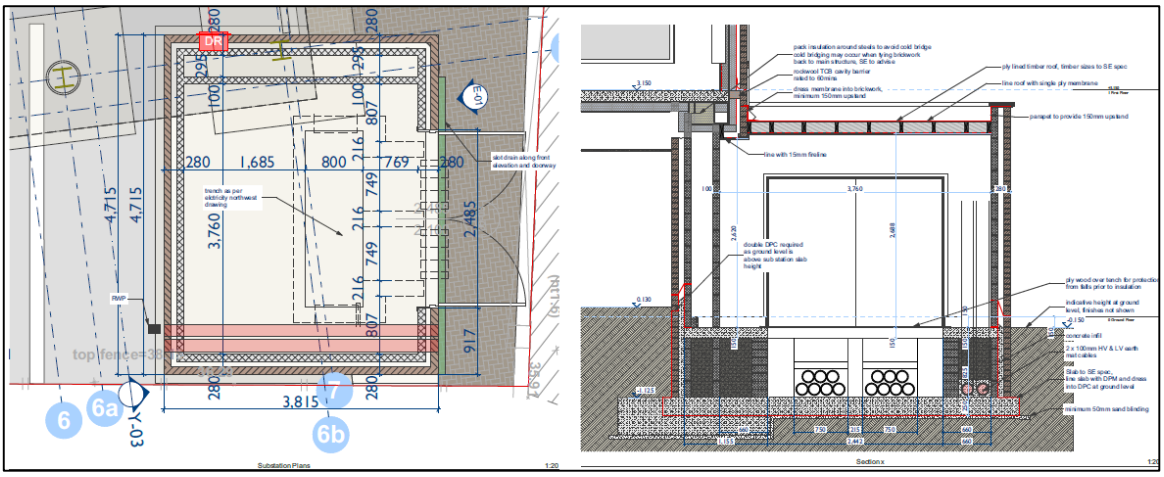
4.34 The external wall construction of the substation consists of a brickwork outer leaf, 75 mm cavity and 100 mm thick blockwork inner leaf. The sound insulation performance of such a construction is typically 50 to 60 dB R_w.

4.35 The roof construction consists of a membrane backed plywood sheet, 150 mm timber joists, insulation fitted between joists and two layers of 15 mm Fireline plasterboard.

4.36 It is estimated that the roof construction will provide a sound insulation performance of approximately 44 dB R_w, which is notably lower than that provided by the external wall. Prediction details are provided within Appendix B.

4.37 Figure 4.4 shows the construction details and orientation of the transformer substation.

Figure 4.4 – Plan and section showing proposed substation



4.38 The nearest window to the substation is a first floor apartment, on the south east facing elevation. The window overlooks the roof of the substation. The distance from the window opening to the roof is approximately 2 to 3 metres.

4.39 Table 4.5 presents a calculation summary for the nearest apartment, taking into consideration the transformer sound level, typical frequency spectrum and estimated roof sound insulation.

Table 4.5 – Transformer sound pressure level at the nearest first floor apartment

	Octave Band Centre Frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
500 kVA transformer (L_{eq} dB)	46	62	59	57	44	35	29	30
Roof sound reduction index (R_w dB)	-22	-30	-37	-42	-46	-43	-48	-50
Internal diffuse sound field to outside (dB)	-6	-6	-6	-6	-6	-6	-6	-6
A-weighting correction dB	-26	-16	-9	-3	0	+1	+1	-1
Resulting level dBA	**-8**	**10**	**7**	**6**	**-8**	**-13**	**-24**	**-27**
Specific sound level $L_{Aeq,T}$ = 13 dB								

4.40 The calculation results indicate a specific sound pressure level of approximately 13 dB $L_{Aeq,T}$ at the nearest apartment on the south east corner of the building.

4.41 Since the frequency of the mains electrical supply is 50 Hz, the noise emissions from transformers are typically characterised by tonal spikes at 100 Hz and also at the 200 Hz and 400 Hz harmonic frequencies.

4.42 However, taking into consideration the very low sound pressure level resulting at the nearest dwelling (i.e. noise will be inaudible at the dwelling), it is considered unnecessary to apply a correction with regard to the potential tonality or characteristics of the noise as experienced at the receptor position.

4.43 On this basis, the specific sound level is considered to be equal to the rating level (13 dB $L_{Ar,15min}$).

4.44 The sound rating level of the transformer therefore achieves the target noise limit of 34 dB $L_{Aeq,15min}$ during the night-time period.

4.45 The predicted rating level is 26 dB below the lowest measured background sound level during the night-time period. Noise from the transformer is therefore expected to have a negligible impact at the nearest apartments.

4.46 There are steel double-doors to the substation that will face the dwellings on Swinbourne Grove. The distance from the doors to the nearest dwelling is estimated to be approximately 17 metres.

4.47 Table 4.6 presents a calculation summary for the nearest dwelling, taking into consideration the transformer sound level, typical frequency spectrum and composite sound insulation of the wall and door combined.

Table 4.6 – Transformer sound pressure level at adjacent dwellings on Swinbourne Grove

	Octave Band Centre Frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
500 kVA transformer (L_{eq} dB)	46	62	59	57	44	35	29	30
Composite wall/door sound reduction index (R_w dB)	-24	-25	-31	-36	-38	-40	-40	-42
Internal diffuse sound field to outside (dB)	-6	-6	-6	-6	-6	-6	-6	-6
A-weighting correction dB	-26	-16	-9	-3	0	+1	+1	-1
Resulting level dBA	**-10**	**15**	**13**	**12**	**0**	**-10**	**-16**	**-19**
Specific sound level $L_{Aeq,T}$ = 18 dB								

4.48 The calculation results indicate a specific sound pressure level of approximately 18 dB $L_{Aeq,T}$ at the adjacent dwellings on Swinbourne Grove.

4.49 Again, the specific sound level is considered to be equal to the rating level (18 dB $L_{Ar,15min}$).

4.50 The sound rating level of the transformer therefore achieves the target noise limit of 34 dB $L_{Aeq,15min}$ during the night-time period.

4.51 The predicted rating level is 21 dB below the lowest measured background sound level during the night-time period. Noise from the transformer is therefore expected to have a negligible impact at the adjacent dwellings on Swinbourne Grove.

4.52 The calculations assume that solid steel doors are fitted to the substation and that an effective acoustic/fire seal is maintained around the doors perimeter when closed. It is also assumed that there are no large ventilation grilles/louvres fitted to the double-doors.

Cumulative plant sound level

4.53 Since the predicted sound level for the transformer is only 13 to 18 dB $L_{Aeq,T}$, the cumulative sound pressure level at the nearest dwellings (i.e. from the transformer and compressors combined) will be unchanged from that presented in Table 4.3.

4.54 In other words, the contribution of noise from the transformer is negligible when considering the higher and more dominant sound level generated by the compressor units. The cumulative plant sound level is therefore expected to achieve the daytime and night-time noise targets.

Sound level measurements of installed building services plant

4.55 Site visits were conducted on the 20th and 28th July 2021 in order to inspect the substation and roof-top mounted plant, conduct subjective observations at the nearest dwellings with regard to audibility and also conduct sample noise measurements where possible.

4.56 With regard to the new transformer and substation, there was no audible noise emanating from the structure and no tonal characteristics audible at neighbouring dwellings during the late evening hours (i.e. there was no tonal mains hum).

4.57 Brief sample measurements conducted at the boundary of the site indicated that there was no increase in background noise at the nearest dwellings when compared to the original survey data.

4.58 Since there was no increase in background noise and the operation of the transformer is inaudible, this indicates that the specific sound level generated by the transformer is achieving the sound level targets specified within Table 4.1 of this report.

4.59 With regard to the roof-mounted compressor units, the operation of the units is again inaudible both at ground floor level and also at the nearest 3rd floor apartments.

4.60 During the site visit, it was not possible to operate all of the units simultaneously since the operation is temperature dependent. It is not possible to operate (or switch-off) all of the units from a central control unit.

4.61 However, condenser units were operating during the site visit and from both observations and sample measurements taken on-site, it appears that there is no increase in background noise level and there is no tonal element audible at the nearest dwellings.

4.62 On the basis of our observations on-site, it is anticipated that the roof-mounted units are also achieving the sound level targets specified within this report.

5. Conclusion

5.1 The lowest measured background sound levels have been used to determine appropriate noise targets for the daytime and night-time period.

5.2 During the night-time period, the target noise limit at neighbouring windows is 34 dB $L_{Aeq,15min}$.

5.3 The sound rating level of the roof-top compressor units achieves the daytime and night-time targets at the nearest dwellings on Swinbourne Grove and also at the nearest new apartments.

5.4 The predicted rating level is 8 to 9 dB below the lowest measured background sound level during the night-time period.

5.5 The sound rating level of the transformer achieves the daytime and night-time targets at the nearest dwellings on Swinbourne Grove and also at the nearest new apartments.

5.6 The predicted rating level of the transformer is 21 to 26 dB below the lowest measured background sound level during the night-time period.

5.7 The calculations assume that solid steel doors are fitted to the substation and that an effective acoustic/fire seal is maintained around the doors perimeter when closed.

5.8 On the basis of this assessment and BS 4142 guidance, plant related noise is expected to have a low to negligible impact at adjacent dwellings.

5.9 Specific noise mitigation measures are considered unnecessary for the proposed plant.

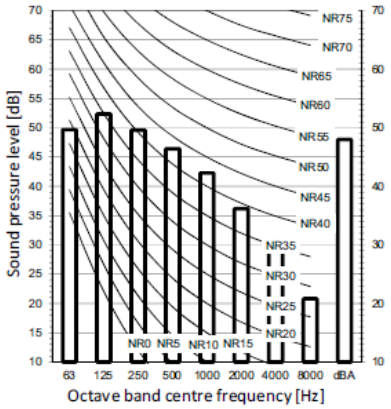
5.10 Following further site visits in July 2021, noise from the transformer and roof-mounted plant is inaudible at the nearest dwellings and there is no audible tonal element (no hum) due to the plant operation. It is anticipated that the sound level targets identified within this report are being achieved during the daytime and night-time period.

Appendix A
Daikin compressor sound level data

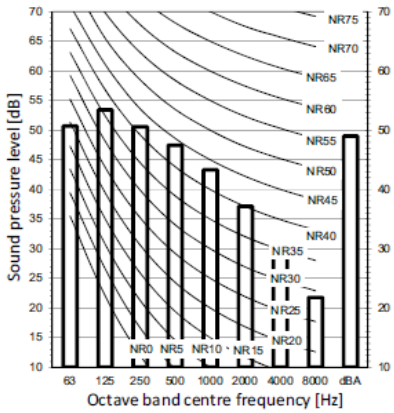
Figure A.1 – Sound level data for Daikin ERGA04 outdoor unit

Cooling

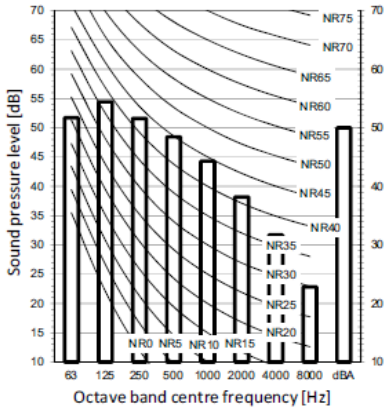
RGA04



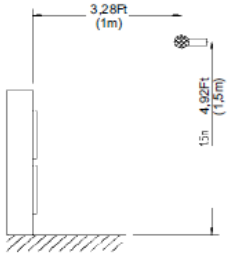
RGA06



RGA08



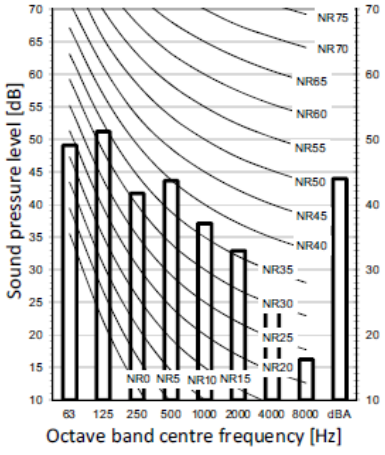
Notes
1. Data is valid at free field condition.
   Measured in a semi-anechoic chamber
2. Data is valid at nominal operation condition.
3. dBA = A-weighted sound pressure level (A scale according to IEC).
4. Reference acoustic pressure 0 dB = 20 µPa
5. If the sound is measured under actual installation conditions, the measured value will be higher due to environmental noise and sound reflections.



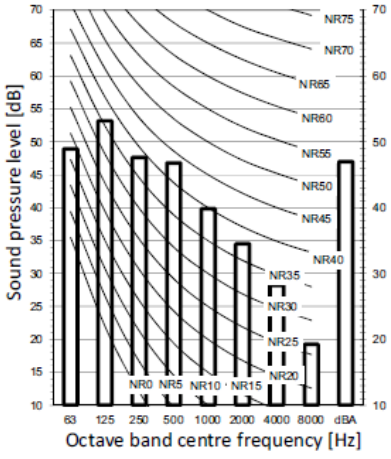
Measuring location (discharge side)

Heating

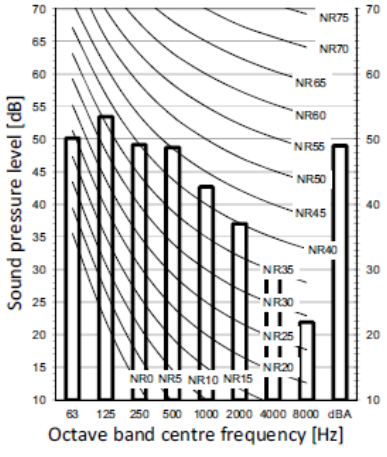
RGA04



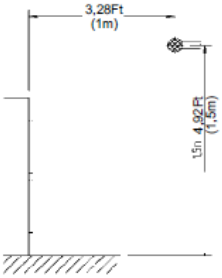
RGA06



RGA08



Notes
1. Data is valid at free field condition.
   Measured in a semi-anechoic chamber
2. Data is valid at nominal operation condition.
3. dBA = A-weighted sound pressure level (A scale according to IEC).
4. Reference acoustic pressure 0 dB = 20 µPa
5. If the sound is measured under actual installation conditions, the measured value will be higher due to environmental noise and sound reflections.



Appendix B
Calculation details

Figure B.1 – Predicted sound insulation of substation roof

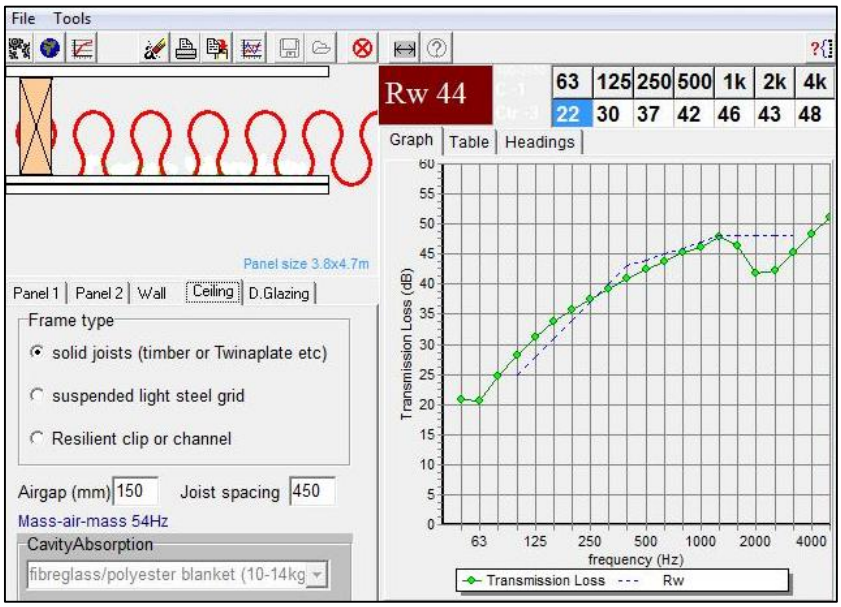


Figure B.2 – Predicted composite sound insulation of substation wall and door

Title: Sound Transmission Loss (ISO 12354-1)			Rev. Originated	RS	Job Nr. Checked		Reviewed		Date: Authorised			
Formula/Comment	*Single Value*		*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*	*Rw*	*(C,C_{tr})*
R = -10 log Σ 10^(-$R_{0,i}$/ 10)	ΔR		24.2	25.2	31.2	36.0	38.2	40.2	40.3	42.3	38	(-1,-3)
$R_{Flanking}$												
R			24.2	25.2	31.2	36.0	38.2	40.2	40.3	42.3	38	(-1,-3)
D_{nT} = R -10 log (S_{tot} / A)												
$D_{nT,flanking}$												
D_{nT}		Mass										
Materials with additional layer												
Steel doorset (2.485x2.1m=5.22m2)		5.2	20.0	21.0	27.0	32.0	34.0	36.0	36.0	38.0	34	(-1,-3)
Brickwork,75mm cavity,100mm blockwork 4.7mx3m=14.1-doors=8.88		8.9	38.0	40.0	44.0	45.0	51.0	56.0	63.0	65.0	51	(-1,-4)

Appendix C
Tabulated survey data

Start Time	$L_{AFmax,15min}$ dB	$L_{Aeq,15min}$ dB	$L_{A90,15min}$ dB
26/02/2021 15:45	86.6	67.2	54.8
26/02/2021 16:00	90.6	70.2	54.5
26/02/2021 16:15	72.7	54.1	49.2
26/02/2021 16:30	77.7	54.7	48.4
26/02/2021 16:45	71.4	53.9	48.0
26/02/2021 17:00	77.8	56.5	48.7
26/02/2021 17:15	66.8	51.3	47.7
26/02/2021 17:30	79.6	54.2	48.2
26/02/2021 17:45	81.0	53.1	45.3
26/02/2021 18:00	70.8	52.5	44.4
26/02/2021 18:15	77.7	51.9	45.7
26/02/2021 18:30	70.1	51.0	45.5
26/02/2021 18:45	69.4	51.3	45.2
26/02/2021 19:00	65.8	51.5	46.1
26/02/2021 19:15	66.2	51.9	46.3
26/02/2021 19:30	64.5	50.7	45.2
26/02/2021 19:45	64.7	52.3	46.7
26/02/2021 20:00	66.4	53.2	48.2
26/02/2021 20:15	66.2	52.2	46.8
26/02/2021 20:30	65.4	51.7	47.1
26/02/2021 20:45	69.9	54.2	47.4
26/02/2021 21:00	70.5	51.6	45.6
26/02/2021 21:15	68.1	50.5	44.5
26/02/2021 21:30	75.2	53.6	44.0
26/02/2021 21:45	67.7	54.4	52.5
26/02/2021 22:00	69.7	54.2	49.2
26/02/2021 22:15	62.4	50.1	45.2
26/02/2021 22:30	66.4	50.5	45.4
26/02/2021 22:45	66.8	50.7	45.1
26/02/2021 23:00	68.4	49.6	44.7
26/02/2021 23:15	67.3	50.9	44.0
26/02/2021 23:30	59.9	48.2	43.8
26/02/2021 23:45	68.4	49.7	43.7
27/02/2021 00:00	67.1	52.5	44.9
27/02/2021 00:15	60.7	49.9	44.0
27/02/2021 00:30	57.7	47.9	43.1
27/02/2021 00:45	66.2	49.5	43.4
27/02/2021 01:00	57.6	48.3	43.0
27/02/2021 01:15	59.4	47.0	41.4
27/02/2021 01:30	67.0	47.7	41.0
27/02/2021 01:45	60.0	46.2	41.6
27/02/2021 02:00	66.7	48.0	41.5
27/02/2021 02:15	70.1	49.5	41.8
27/02/2021 02:30	60.4	46.2	41.5
27/02/2021 02:45	60.0	46.2	41.3

Start Time	$L_{AFmax,15min}$ dB	$L_{Aeq,15min}$ dB	$L_{A90,15min}$ dB
27/02/2021 03:00	56.6	45.0	40.6
27/02/2021 03:15	57.0	46.3	40.1
27/02/2021 03:30	55.9	44.5	39.9
27/02/2021 03:45	60.1	45.8	39.8
27/02/2021 04:00	63.5	46.2	40.7
27/02/2021 04:15	57.7	44.7	39.5
27/02/2021 04:30	57.1	44.3	39.0
27/02/2021 04:45	63.2	45.8	41.4
27/02/2021 05:00	55.3	44.0	39.5
27/02/2021 05:15	55.2	43.9	39.6
27/02/2021 05:30	60.3	45.2	40.7
27/02/2021 05:45	59.9	47.0	41.5
27/02/2021 06:00	62.2	47.3	41.7
27/02/2021 06:15	77.0	54.0	41.3
27/02/2021 06:30	60.7	46.4	42.0
27/02/2021 06:45	66.3	52.5	48.6
27/02/2021 07:00	75.9	53.7	48.4
27/02/2021 07:15	66.4	51.8	48.0
27/02/2021 07:30	63.4	51.1	47.7
27/02/2021 07:45	64.2	51.8	48.4
27/02/2021 08:00	63.6	52.0	47.9
27/02/2021 08:15	72.2	52.6	49.2
27/02/2021 08:30	67.2	53.9	49.8
27/02/2021 08:45	71.2	55.8	51.1
27/02/2021 09:00	69.9	56.0	54.1
27/02/2021 09:15	69.6	55.8	54.4
27/02/2021 09:30	70.4	55.9	51.2
27/02/2021 09:45	73.2	53.9	49.1
27/02/2021 10:00	74.7	53.0	48.7
27/02/2021 10:15	64.9	55.6	54.5
27/02/2021 10:30	73.8	56.5	54.6
27/02/2021 10:45	63.9	52.0	48.1
27/02/2021 11:00	68.0	55.1	49.5
27/02/2021 11:15	72.8	55.2	53.4
27/02/2021 11:30	68.1	55.1	50.5
27/02/2021 11:45	85.1	58.6	54.0
27/02/2021 12:00	72.9	55.0	50.0
27/02/2021 12:15	68.3	54.9	48.8
27/02/2021 12:30	76.3	53.9	48.4
27/02/2021 12:45	67.9	53.3	48.7
27/02/2021 13:00	67.3	55.0	53.0
27/02/2021 13:15	77.7	58.4	53.6
27/02/2021 13:30	67.3	55.4	53.5
27/02/2021 13:45	66.0	55.0	52.8
27/02/2021 14:00	71.3	55.9	53.2

Start Time	$L_{AFmax,15min}$ dB	$L_{Aeq,15min}$ dB	$L_{A90,15min}$ dB
27/02/2021 14:15	68.3	55.2	50.6
27/02/2021 14:30	72.2	53.6	47.9
27/02/2021 14:45	75.1	54.5	47.9
27/02/2021 15:00	72.3	51.5	44.5
27/02/2021 15:15	70.8	51.2	44.0
27/02/2021 15:30	68.1	52.2	44.6
27/02/2021 15:45	72.0	51.5	45.0
27/02/2021 16:00	68.8	51.3	44.5
27/02/2021 16:15	68.8	52.0	48.0
27/02/2021 16:30	68.1	52.4	47.4
27/02/2021 16:45	67.9	52.0	47.7
27/02/2021 17:00	66.7	52.0	48.7
27/02/2021 17:15	74.1	52.9	48.4
27/02/2021 17:30	68.8	52.8	47.9
27/02/2021 17:45	71.1	51.5	44.4
27/02/2021 18:00	67.1	50.6	45.0
27/02/2021 18:15	83.2	52.8	45.3
27/02/2021 18:30	67.8	51.8	45.4
27/02/2021 18:45	63.9	51.0	45.4
27/02/2021 19:00	64.1	50.3	45.8
27/02/2021 19:15	66.5	51.8	46.3
27/02/2021 19:30	63.3	51.4	46.4
27/02/2021 19:45	60.3	50.4	46.8
27/02/2021 20:00	68.9	52.4	47.0
27/02/2021 20:15	71.1	51.9	46.5
27/02/2021 20:30	62.2	50.6	45.7
27/02/2021 20:45	65.8	53.5	47.6
27/02/2021 21:00	69.7	50.8	44.5
27/02/2021 21:15	68.3	50.7	45.1
27/02/2021 21:30	65.6	52.4	46.1
27/02/2021 21:45	72.1	55.3	51.8
27/02/2021 22:00	80.7	54.1	46.5
27/02/2021 22:15	72.9	52.2	45.0
27/02/2021 22:30	62.4	50.0	44.6
27/02/2021 22:45	66.2	50.9	44.5
27/02/2021 23:00	64.6	50.1	45.0
27/02/2021 23:15	71.8	52.2	45.4
27/02/2021 23:30	67.7	50.7	44.4
27/02/2021 23:45	64.9	49.2	43.8
28/02/2021 00:00	67.6	49.0	43.1
28/02/2021 00:15	58.5	47.6	42.9
28/02/2021 00:30	64.1	47.2	42.1
28/02/2021 00:45	69.3	48.2	41.7
28/02/2021 01:00	61.8	47.2	41.1
28/02/2021 01:15	62.4	47.8	41.7

Start Time	$L_{AFmax,15min}$ dB	$L_{Aeq,15min}$ dB	$L_{A90,15min}$ dB
28/02/2021 01:30	57.3	45.8	40.1
28/02/2021 01:45	73.4	50.0	40.0
28/02/2021 02:00	56.4	45.6	40.4
28/02/2021 02:15	64.5	45.9	39.7
28/02/2021 02:30	58.1	44.7	39.4
28/02/2021 02:45	70.2	47.8	40.2
28/02/2021 03:00	56.6	44.9	40.0
28/02/2021 03:15	67.4	46.8	40.2
28/02/2021 03:30	56.0	44.0	40.0
28/02/2021 03:45	58.9	45.7	39.6
28/02/2021 04:00	55.4	44.1	40.0
28/02/2021 04:15	70.3	47.6	40.6
28/02/2021 04:30	56.9	44.2	38.8
28/02/2021 04:45	60.4	44.3	39.2
28/02/2021 05:00	72.7	47.2	39.3
28/02/2021 05:15	56.5	44.5	40.3
28/02/2021 05:30	63.7	44.8	40.7
28/02/2021 05:45	65.3	47.4	41.2
28/02/2021 06:00	57.9	46.2	41.9
28/02/2021 06:15	72.6	47.5	42.1
28/02/2021 06:30	59.6	49.5	42.9
28/02/2021 06:45	62.4	48.8	43.9
28/02/2021 07:00	68.1	51.0	47.7
28/02/2021 07:15	61.2	49.7	47.5
28/02/2021 07:30	71.6	54.1	47.7
28/02/2021 07:45	63.5	52.6	47.9
28/02/2021 08:00	59.8	50.7	48.1
28/02/2021 08:15	57.6	50.5	48.1
28/02/2021 08:30	74.0	55.2	49.9
28/02/2021 08:45	80.7	59.2	55.2
28/02/2021 09:00	76.2	65.2	54.9
28/02/2021 09:15	74.2	63.6	54.8
28/02/2021 09:30	73.4	54.4	49.6
28/02/2021 09:45	70.7	53.0	49.7
28/02/2021 10:00	74.7	57.5	49.7
28/02/2021 10:15	73.7	57.6	49.5
28/02/2021 10:30	69.5	51.1	48.7
28/02/2021 10:45	65.3	50.5	47.9
28/02/2021 11:00	68.7	52.8	48.1
28/02/2021 11:15	63.7	55.1	53.2
28/02/2021 11:30	70.2	55.6	52.5
28/02/2021 11:45	73.4	57.3	55.4
28/02/2021 12:00	77.4	60.6	48.9
28/02/2021 12:15	74.1	57.8	47.9
28/02/2021 12:30	63.5	53.6	48.9

Start Time	$L_{AFmax,15min}$ dB	$L_{Aeq,15min}$ dB	$L_{A90,15min}$ dB
28/02/2021 12:45	67.2	54.0	52.5
28/02/2021 13:00	65.4	53.5	48.2
28/02/2021 13:15	63.9	52.5	46.9
28/02/2021 13:30	76.2	53.8	52.3
28/02/2021 13:45	76.9	54.7	52.3
28/02/2021 14:00	70.3	54.2	52.1
28/02/2021 14:15	69.3	53.7	45.3
28/02/2021 14:30	63.2	53.0	47.6
28/02/2021 14:45	63.4	53.4	51.8
28/02/2021 15:00	72.0	54.2	52.4
28/02/2021 15:15	69.5	54.4	52.7
28/02/2021 15:30	66.0	52.0	45.0
28/02/2021 15:45	73.3	52.7	45.7
28/02/2021 16:00	64.6	51.6	46.7
28/02/2021 16:15	66.4	51.4	46.4
28/02/2021 16:30	73.6	52.7	47.5
28/02/2021 16:45	76.6	54.2	46.8
28/02/2021 17:00	68.9	51.6	47.4
28/02/2021 17:15	63.3	50.5	45.8
28/02/2021 17:30	63.8	49.6	43.7

Appendix D
Assessment terminology

Assessment terminology

Term	Description
dB (decibel)	The scale on which sound pressure level is expressed. It is defined as 20 times the logarithm of the ratio between the root-mean-square pressure of the sound field and a reference pressure ($2x10^{-5}$Pa).
dB(A)	The most widely used weighting mechanism that best corresponds to the response of the human ear is the 'A'-weighting scale. This is widely used for environmental noise measurement, and the levels are denoted as dB(A) or L_{Aeq}, L_{A90} etc, according to the parameter being measured.
Acoustic environment	Sound from all sources as modified by the environment.
Ambient sound level	The totally encompassing sound in a given situation at a given time; it is usually composed of sound from many sources, near and far.
Background sound level	The sound level in the absence of a specific noise source under consideration (e.g. plant/machinery), measured as $L_{A90,T}$.
Residual sound	Ambient sound remaining at the assessment location when the specific sound source is suppressed to such a degree that it does not contribute to the ambient sound.
Specific sound source	Sound source being assessed.
Specific sound level	Equivalent continuous A-weighted sound pressure level produced by the specific sound source at the assessment location over a given reference time interval, T.
Rating level $L_{Ar,T}$	Specific sound level plus any adjustment for the characteristic features of the sound.