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**BONHAMS FIELD
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ASSESSMENT OF SUBSTATION NOISE v.1

Client:

SEAWARD PROPERTIES LIMITED

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2 February 2022
Ref: M5162

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1. SUMMARY

- 1.1 An assessment has been conducted at Bonhams Field, Yapton, to consider the potential impact of noise from a new electricity substation.
- 1.2 Noise from the 500 kVA transformer has been determined from the data available from the manufacturer, and published acoustic papers on substations.
- 1.3 Noise from the transformer has then been predicted within the nearest residential properties. This calculation has been based on a situation with their bedroom windows open by nom. 200mm.
- 1.4 The criterion of acceptability has been agreed with the Local Authority, and is taken from the NANR45 report from Salford University (ref Section 3.4 of this report). The Low Frequency Criterion Curve (LFCC) is here to be considered in the range 25 - 160 Hz.
- 1.5 Table 1.1 confirms the predicted noise levels inside the nearest building, alongside the LFCC:

Frequency	Hz	25	31.5	40	50	63	80	100	125	160
Predicted SPL	dB	6	1	-4	0	2	6	12	-3	-7
NANR45 LFCC	dB	64	56	49	43	42	40	38	36	34

Table 1.1 – Predicted Sound Pressure Level in Plot 41 Bedroom

- 1.6 It can be seen that the predicted noise is significantly below the threshold limits. As such, it may be concluded that the substation will have no adverse impact on the residential occupiers, and will therefore be compliant with the overriding requirements of the NPPF.

2. INTRODUCTION

- 2.1 An assessment of noise has been undertaken at a residential development by Seaward Properties Ltd at Bonhams Field, Yapton.
- 2.2 The site is located on the edge of the village of Yapton, adjacent to the B3322 Main Road.
- 2.3 Planning consent has been granted for the construction of 56 new dwellings on the site (Figure 1 – Proposed Site Plan).
- 2.4 Within the development there will be a new 500kVA substation, and this is subject to a separate planning application (Ref. Y/177/21/PL).
- 2.5 In early consultation, Local Authority Environment Health department requested that the noise impact of the substation be considered. The memo from the EHO referenced the 'Procedure for the assessment of Low Frequency Noise Complaints' (NANR45 Rev 1 – December 2011).
- 2.6 The objectives of the current exercise may therefore be summarised as follows:
- (i) To determine the source levels of noise associated with a substation of this size.
 - (ii) To predict the residual noise from the substation within the nearest residential properties.
 - (iii) To assess the predicted levels against the criteria set out in NANR45.
 - (iv) As necessary, to recommend remedial works to ensure acceptable levels within the houses.
- 2.7 This report details the investigations carried out in respect of each of these objectives and summarises the conclusions which have been reached.

3. ASSESSMENT OF NOISE

3.1 National Planning Policy Framework (July 2021)

- 3.1.1 The National Planning Policy Framework (NPPF) sets out the Government's planning policies for England and how these should be applied. It provides a framework within which locally prepared plans for housing and other development can be produced.
- 3.1.2 Planning law requires that applications for planning permission be determined in accordance with the development plan, unless material considerations indicate otherwise. The National Planning Policy Framework must be taken into account in preparing the development plan and is a material consideration in planning decisions. Planning policies and decisions must also reflect relevant international obligations and statutory requirements.
- 3.1.3 The purpose of the planning system is to contribute to the achievement of sustainable development. At a very high level, the objective of sustainable development can be summarised as meeting the needs of the present without compromising the ability of future generations to meet their own needs.
- 3.1.4 Achieving sustainable development means that the planning system has three overarching objectives, which are interdependent and need to be pursued in mutually supportive ways (so that opportunities can be taken to secure net gains across each of the different objectives):
- a) an economic objective – to help build a strong, responsive and competitive economy, by ensuring that sufficient land of the right types is available in the right places and at the right time to support growth, innovation and improved productivity; and by identifying and coordinating the provision of infrastructure.
 - b) a social objective – to support strong, vibrant and healthy communities, by ensuring that a sufficient number and range of homes can be provided to meet the needs of present and future generations; and by fostering a well-designed and safe built environment, with accessible services and open spaces that reflect current and future needs and support communities' health, social and cultural well-being; and
 - c) an environmental objective – to contribute to protecting and enhancing our natural, built and historic environment; including making effective use of land, helping to improve biodiversity, using natural resources prudently, minimising waste and pollution, and mitigating and adapting to climate change, including moving to a low carbon economy.
- 3.1.5 These objectives should be delivered through the preparation and implementation of plans and the application of the policies in this Framework; they are not criteria against which every decision can or should be judged. Planning policies and decisions should play an active role in guiding

development towards sustainable solutions, but in doing so should take local circumstances into account, to reflect the character, needs and opportunities of each area.

3.1.6 So that sustainable development is pursued in a positive way, at the heart of the Framework is a presumption in favour of sustainable development

3.1.7 Paragraph 185 of the NPPF states:

185. Planning policies and decisions should also ensure that new development is appropriate for its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development. In doing so they should:

- a) mitigate and reduce to minimum potential adverse impacts resulting from noise from new development – and avoid noise giving rise to significant adverse impacts on health and the quality of life¹ ;*
- b) identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason; and*
- c) limit the impact of light pollution from artificial light on local amenity, intrinsically dark landscapes, and nature conservation.*

3.1.8 The Framework continues:

187. Planning policies and decisions should ensure that new development can be integrated effectively with existing businesses and community facilities (such as places of worship, pubs, music venues and sports clubs). Existing businesses and facilities should not have unreasonable restrictions placed on them as a result of development permitted after they were established. Where the operation of an existing business or community facility could have a significant adverse effect on new development (including changes of use) in its vicinity, the applicant (or ‘agent of change’) should be required to provide suitable mitigation before the development has been completed.

188. The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where a planning decision has been made on a particular development, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities.

¹ Refers here to the NPSE, discussed in Section 4.2 of this report.

3.2 Noise Policy Statement for England (March 2010)

- 3.2.1 The document "Noise Policy Statement for England" sets out the following vision for on-going noise policy (Para. 1.6):

"Promote good health and quality of life through the effective management of noise within the context of Government policy on sustainable development."

- 3.2.2 This vision should be achieved through the following Noise Policy Aims (Para 1.7):

"Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

avoid significant adverse impacts on health and quality of life.

mitigate and minimise adverse impacts on health and quality of life.

and where possible, contribute to the improvement of health and quality of life".

- 3.2.3 To achieve these objectives the Noise Policy Statement sets out three noise levels to be defined by the assessor:

- **NOEL** - No Observed Effect Level

This is the level below which no effect can be detected. In simple terms, below this level there is no detectable effect on health and quality of life due to the noise.

- **LOAEL** - Lowest Observed Adverse Effect Level

This is the level above which adverse effects on health and quality of life can be detected. Where levels lie between the LOAEL and SOAEL, the Statement requires that all reasonable steps should be taken to mitigate and minimise adverse effects on health and quality of life while also taking into account the guiding principles of sustainable development, as set out in the NPPF.

- **SOAEL** - Significant Observed Adverse Effect Level

This is the level above which significant adverse effects on health and quality of life occur. It notes, however, that "it is not possible to have a single objective noise-based measure that describes SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times".

- 3.2.4 Paragraph 3.7 states that "... the application of the NPSE should enable noise to be considered alongside other relevant issues and not to be considered in isolation. In the past, the wider benefits of a particular policy, development or other activity may not have been given adequate weight when assessing the noise implications".

- 3.2.5 This provides clear guidance that noise must not be considered in isolation but as part of the overall scheme, taking into account the overall sustainability and associated impacts of the proposed development; there is no benefit in reducing noise to an excessively low level if this creates or increases another adverse impact. Similarly, it may be appropriate in some cases for noise to have an adverse impact if this is outweighed by the reduction or removal of some other adverse impact that is of greater significance to the development as a whole.
- 3.2.6 The Noise Policy Statement considers that noise levels above the SOAEL would be seen to have, by definition, significant adverse effects and would be considered unacceptable. Where the assessed noise levels fall between the LOAEL and the SOAEL noise levels, the Policy Statement requires that (Para 3.24):

"all reasonable steps should be taken to mitigate and minimise adverse effects on health and quality of life while also taking into account the guiding principles of sustainable development... .. This does not mean that such adverse effects cannot occur."

- 3.2.7 Where noise levels are below the LOAEL it is considered there will be no adverse effect. Once noise levels are below the NOEL there will be no observable change. An indication of the numerical definition of LOAEL may be derived from the following guidance.

3.3 DHCLG Guidance Note, 'Noise' (July 2019)

- 3.3.1 The Department of Housing, Communities and Local Government provided further guidance to support the NPPF. The section, Noise, published in July 2019 advises:

When is noise relevant to planning?

Noise needs to be considered when development may create additional noise, or would be sensitive to the prevailing acoustic environment (including any anticipated changes to that environment from activities that are permitted but not yet commenced). When preparing plans, or taking decisions about new development, there may also be opportunities to make improvements to the acoustic environment. Good acoustic design needs to be considered early in the planning process to ensure that the most appropriate and cost-effective solutions are identified from the outset.

What are the observed effect levels?

- *Significant observed adverse effect level: This is the level of noise exposure above which significant adverse effects on health and quality of life occur.*
- *Lowest observed adverse effect level: this is the level of noise exposure above which adverse effects on health and quality of life can be detected.*

- *No observed effect level: this is the level of noise exposure below which no effect at all on health or quality of life can be detected.*

Although the word 'level' is used here, this does not mean that the effects can only be defined in terms of a single value of noise exposure. In some circumstances adverse effects are defined in terms of a combination of more than one factor such as noise exposure, the number of occurrences of the noise in a given time period, the duration of the noise and the time of day the noise occurs.

How can it be established whether noise is likely to be a concern?

At the lowest extreme, when noise is not perceived to be present, there is by definition no effect. As the noise exposure increases, it will cross the 'no observed effect' level. However, the noise has no adverse effect so long as the exposure does not cause any change in behaviour, attitude or other physiological responses of those affected by it. The noise may slightly affect the acoustic character of an area but not to the extent there is a change in quality of life. If the noise exposure is at this level no specific measures are required to manage the acoustic environment.

As the exposure increases further, it crosses the 'lowest observed adverse effect' level boundary above which the noise starts to cause small changes in behaviour and attitude, for example, having to turn up the volume on the television or needing to speak more loudly to be heard. The noise therefore starts to have an adverse effect and consideration needs to be given to mitigating and minimising those effects (taking account of the economic and social benefits being derived from the activity causing the noise).

Increasing noise exposure will at some point cause the 'significant observed adverse effect' level boundary to be crossed. Above this level the noise causes a material change in behaviour such as keeping windows closed for most of the time or avoiding certain activities during periods when the noise is present. If the exposure is predicted to be above this level the planning process should be used to avoid this effect occurring, for example through the choice of sites at the plan-making stage, or by use of appropriate mitigation such as by altering the design and layout. While such decisions must be made taking account of the economic and social benefit of the activity causing or affected by the noise, it is undesirable for such exposure to be caused.

At the highest extreme, noise exposure would cause extensive and sustained adverse changes in behaviour and / or health without an ability to mitigate the effect of the noise. The impacts on health and quality of life are such that regardless of the benefits of the activity causing the noise, this situation should be avoided.

3.3.2 The table below summarises the noise exposure hierarchy, based on the likely average response:

Perception	Examples of Outcomes	Increasing Effect Level	Action
No Observed Effect Level			
Not Present	No Effect	No Observed Effect	No specific measures required
No Observed Adverse Effect Level			
Present and not intrusive	Noise can be heard, but does not cause any change in behaviour, attitude or other physiological response. Can slightly affect the acoustic character of the area but not such that there is a change in the quality of life.	No Observed Adverse Effect	No specific measures required
Lowest Observed Adverse Effect Level			
Present and intrusive	Noise can be heard and causes small changes in behaviour, attitude or other physiological response, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a small actual or perceived change in the quality of life.	Observed Adverse Effect	Mitigate and reduce to a minimum
Significant Observed Adverse Effect Level			
Present and disruptive	The noise causes a material change in behaviour, attitude or other physiological response, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area	Significant Observed Adverse Effect	Avoid
Present and very disruptive	Extensive and regular changes in behaviour, attitude or other physiological response and/or an inability to mitigate effect of noise leading to psychological stress, e.g. regular sleep deprivation/awakening; loss of appetite, significant, medically definable harm, e.g. auditory and non-auditory.	Unacceptable Adverse Effect	Prevent

Table 3.1 – Noise Exposure Hierarchy

3.3.3 The guidance further advises:

What factors influence whether noise could be a concern?

The subjective nature of noise means that there is not a simple relationship between noise levels and the impact on those affected. This will depend on how various factors combine in any particular situation.

These factors include:

- the source and absolute level of the noise together with the time of day it occurs. Some types and level of noise will cause a greater adverse effect at night than if they occurred during the day – this is because people tend to be more sensitive to noise at night as they are trying to sleep. The adverse effect can also be greater simply because there is less background noise at night.
- for a new noise making source, how the noise from it relates to the existing sound environment.
- for non-continuous sources of noise, the number of noise events, and the frequency and pattern of occurrence of the noise.
- the spectral content of the noise (i.e. whether or not the noise contains particular high or low frequency content) and the general character of the noise (i.e. whether or not the noise contains particular tonal characteristics or other particular features), and.
- the local arrangement of buildings, surfaces and green infrastructure, and the extent to which it reflects or absorbs noise.

More specific factors to consider when relevant include:

- the cumulative impacts of more than one source of noise.
- whether any adverse internal effects can be completely removed by closing windows and, in the case of new residential development, if the proposed mitigation relies on windows being kept closed most of the time (and the effect this may have on living conditions). In both cases a suitable alternative means of ventilation is likely to be necessary. Further information on ventilation can be found in the Building Regulations.
- In cases where existing noise sensitive locations already experience high noise levels, a development that is expected to cause even a small increase in the overall noise level may result in a significant adverse effect occurring even though little to no change in behaviour would be likely to occur.
- Noise Action Plans (where these exist), and, in particular the Important Areas identified through the process associated with the Environmental Noise Directive and corresponding regulations should be taken into account. Defra's website has information on Noise Action Plans and Important Areas. Local



authority environmental health departments will also be able to provide information about Important Areas.

- the effect of noise on wildlife. Noise can adversely affect wildlife and ecosystems. Particular consideration needs to be given to the potential effects of noisy development on international, national and locally designated sites of importance for biodiversity.
- where external amenity spaces are an intrinsic part of the overall design, the acoustic environment of those spaces should be considered so that they can be enjoyed as intended.
- some commercial developments including restaurants, hot food takeaways, night clubs and public houses can have particular impacts, not least because activities are often at their peak in the evening and late at night. Local planning authorities will wish to bear in mind not only the noise that is generated within the premises but also the noise that may be made by customers in the vicinity.

When proposed developments could include activities that would be covered by the licensing regime, local planning authorities will need to consider whether the potential for adverse noise impacts will be addressed through licensing controls (including licence conditions). Local planning authorities should not however presume that licence conditions will provide for noise management in all instances and should liaise with the licensing authority.

Are there further considerations relating to mitigating the impact of noise on residential developments?

Noise impacts may be partially offset if residents have access to one or more of:

- a relatively quiet facade (containing windows to habitable rooms) as part of their dwelling.
- a relatively quiet external amenity space for their sole use, (e.g. a garden or balcony). Although the existence of a garden or balcony is generally desirable, the intended benefits will be reduced if this area is exposed to noise levels that result in significant adverse effects.
- a relatively quiet, protected, nearby external amenity space for sole use by a limited group of residents as part of the amenity of their dwellings; and/or
- a relatively quiet, protected, external publically accessible amenity space (e.g. a public park or a local green space designated because of its tranquillity) that is nearby (e.g. within a 5-minute walking distance).

3.4 NANR45 (December 2011)

3.4.1 The DEFRA funded guidance 'Procedure for the assessment of Low Frequency Noise Complaints' set out a methodology for the measurement of low frequency noise

3.4.2 The following extract is taken from the document

1.1. Objective

The objective of this document is to assist Environmental Health practitioners¹ to handle complaints of low frequency noise as efficiently and correctly as possible. In particular, it aims to assist them to distinguish cases where an environmental sound that could account for the disturbance is present, in which case some remedial action may be possible within their remit, from those where no such action is feasible. Thus, this guidance provides a procedure to determine whether low frequency sound that might be expected to cause disturbance is present in a complainant's premises.

The guidance given applies to low frequency noise, excluding traffic noise and entertainment noise. It is not appropriate to include traffic noise because this is not specifically a low frequency issue and in any case is not generally actionable by local authorities. Low frequency noise from entertainment was not considered in the development of the method and is outside the scope of this document.

This document does not specifically provide guidance in locating the source of the LFN. However, it is usually found that the most difficult part of the assessment is to determine the existence or otherwise of a sound that correlates with the disturbance, and if this can be established then the source can usually be found. Thus, it is expected that, whilst not a specific aim, the analysis outlined here will form a significant step in the diagnosis of cases requiring treatment.

The procedure is intended to assist in the evaluation of existing problems. It is not intended as a means of predicting when disturbance might occur, for example in a planning situation, and would not be reliable to use as such. This is because disturbance by LFN depends on a number of factors, such as the character of the sound, whose effects are neither well understood, nor readily predictable. Levels of sound above criteria based on the average threshold of hearing are frequently found to be acceptable and levels falling marginally below can occasionally cause disturbance, so no generic approach to prediction of disturbance appears to be possible.

3.4.3 Particular attention is to the final paragraph.

3.4.4 However, the document does provide a criterion curve, and it notes that low frequency noise which falls below the criteria which are based on the average threshold of hearing are frequently found to be acceptable. Therefore, compliance with that standard should give a good indication than the noise would have low, if any, adverse impact.

3.4.5 The table below confirms the numerical values applicable to this average threshold of hearing:

Frequency, Hz	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
dB, Leq	92	87	83	74	64	56	49	43	42	40	38	36	34

Table 3.2 – Criteria of Acceptability



5. SUBSTATION NOISE LEVELS

- 5.1 The proposed substation is rated at 500 kVA.
- 5.2 Enquiries to the manufacturer, Schneider, confirmed only limited data regarding the acoustic output of such a transformer. One-third octave band data was not available, and the frequency range was limited to the lowest octave band of 31.5 Hz.
- 5.3 Figure 2 details the test data issued by Schneider. This confirms an overall sound power level of 54 dB(A), based on a series of sound pressure level measurements taken in an arc, 1m away from the transformer². These levels represent the emissions from an open set, and any modest acoustic loss offered by a GRP enclosure (with plain ventilation louvres) is subsequently ignored in this analysis.
- 5.4 In order to quantify the acoustic signal at frequencies below 31.5 Hz, and to provide clarity of the one-third octave band distribution, consideration was given to the possibility of measuring noise from an installed transformer of similar rating. However, it was recognised that accurate readings at these very low frequencies, in an uncontrolled external environment, were unlikely to be accurate.
- 5.5 Discussions with the Environmental Health Officer over these constraints yielded an agreement that the assessment of this substation would be limited to the range 25 Hz – 160Hz, and should preferably consider one-third octave bands if possible.
- 5.6 In order to convert the Schneider octave band data into a representative one-third octave band spectrum, reference is made to a paper published in the Australian 'Proceedings of Acoustics, 2011'. The study, entitled 'Low-frequency Tonal Characteristics of Transformer Noise' is copied here in Appendix 1.
- 5.7 The typical transformer one-third octave band spectrum, given in Figure 2 of that paper, has been applied to the octave band data published by Schneider for the proposed transformer here.
- 5.8 Table 5.1 confirms the one-third octave band spectrum which is thus obtained (see Appendix 2 for full calculations):

Frequency	Hz	25	31.5	40	50	63	80	100	125	160
1/3rd Octave Band Spectrum	dB	62	57	52	57	59	59	60	40	35

Table 5.1 – Adopted Sound Power Spectrum for 500 kVA Substation

² The measured value of 51 dB(A) is increased by 3 dB to reflect the uncertainty factor.



6. CALCULATION OF SUBSTATION NOISE

6.1 The location of the substation is highlighted in Figure 1.

6.2 The nearest residential properties are as follows:

Plot 41	c.15m to the south-west
Plot 35	c.20m to the north-west
Plot 47	c. 25 to the south-east

6.3 Plot 41 is considered therefore to be the dwelling most at risk of noise emissions from the substation.

6.4 Appendix 2 continues with a calculation of the noise propagation from the substation to the façade of Plot 41, and then into the building.

6.5 For this second part of the calculation, it is assumed that the window is partially open.

6.6 In order to source accurate data on the likely loss through an open window, reference is made to the work by Napier University. Their April 2007 report 'NANR115: Open/Closed Window Research, Sound Insulation through Ventilated Domestic Windows' describes the acoustic losses across a variety of façade configuration.

6.7 Of greatest interest here is the data provided in Table 5.5 of that report (copied here in Appendix 3). This quotes the normalised element difference, $D_{n,e}$, through a selection of window types (side hung, top hung, sash), all open to create a 200,000m² gap. This equates to a 1m high window being open by 200mm (approximately 8").

6.8 The results from the different configuration are remarkably consistent, but the calculation here adopted the weakest result, 14 dB $D_{n,e,w}$.

6.9 On the basis that the most likely time for adverse impact is at night (when background masking noise is at its lowest), the calculation considered a 25m³, reasonably furnished bedroom (Reverberation Time of 0.5 seconds).

6.10 The results of the calculation are confirmed in Table 6.1 below, alongside the criteria of acceptability provided in the NANR45 document:

Frequency	Hz	25	31.5	40	50	63	80	100	125	160
Predicted SPL	dB	6	1	-4	0	2	6	12	-3	-7
NANR45 Criterion Curve	dB	64	56	49	43	42	40	38	36	34

Table 6.1 – Predicted Sound Pressure Level in Plot 41 Bedroom

- 6.11 It can be seen that the predicted sound pressure levels in each one-third octave band are significantly below the threshold curve.
- 6.12 As such, it is concluded that the noise from the substation will have no adverse impact on the adjacent residential occupiers.



Figure 1 - Proposed Site Layout

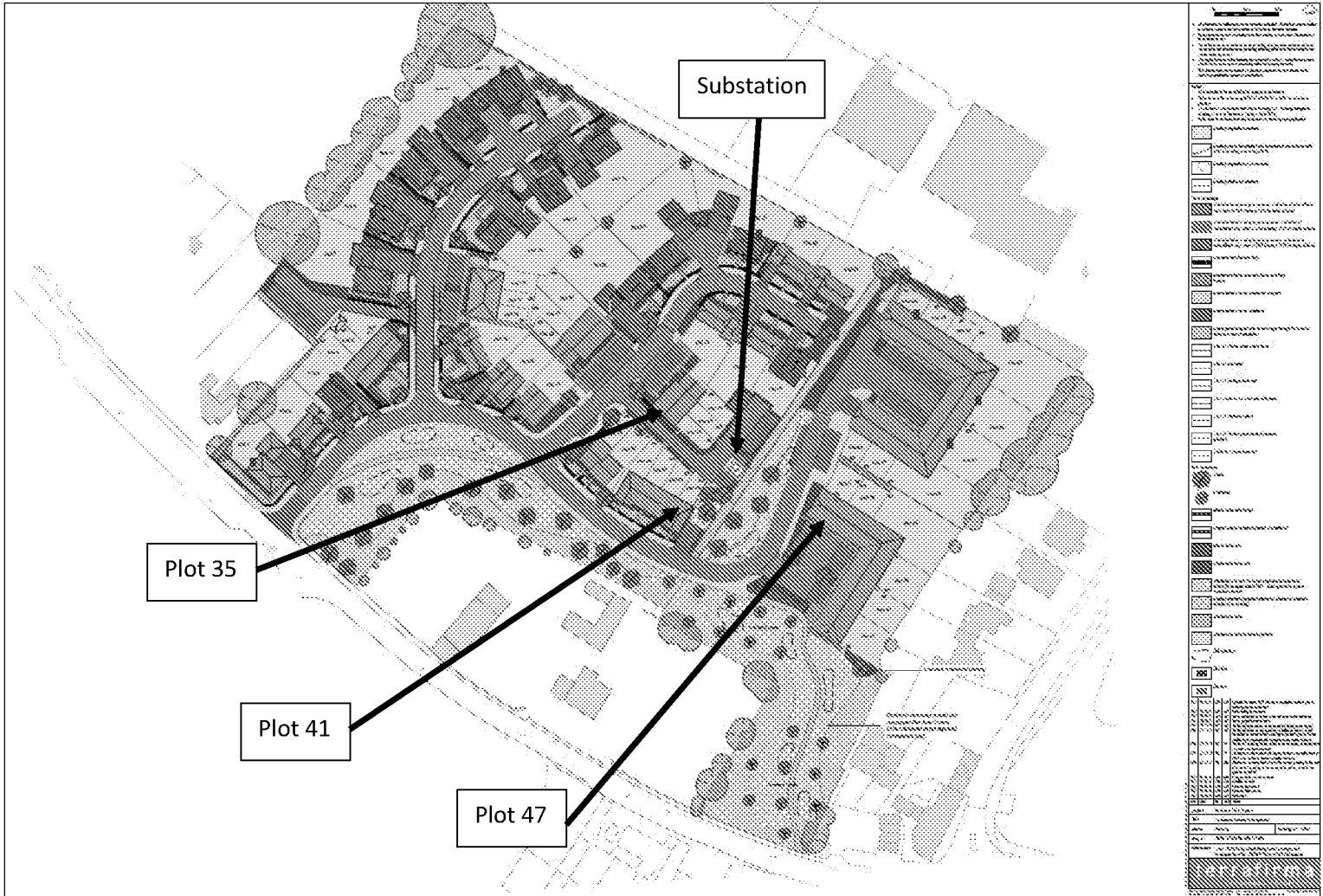


Figure 2 – Schneider 500kVA Transformer Acoustic Data

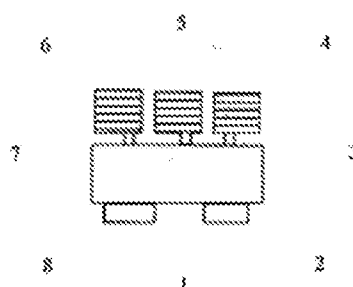


Sound Level Measurement

Transformer Rating 500kVA	Serial No 100205176
Transformer Type USS	Location IN THE TEST AREA
Drawing Number LK50294A0	
EDF Spec ES 4-6001	Date of Test 10/06/07
HV Voltage 11000-6600	Tested in Accordance with BS EN 60076-10:2001 / IEC 60076-10:2001
LV Voltage 423	
Tap position 3	
Witness	Customer EDF Energy
Measurement in dB(A)	
	With Breather Cap

Microphone Position	Ambient Before	Measured Level	Ambient After	Octave filter Frequency Hz	Measured value at point 1 (trf energised)
1	38.5	42.2	38.6	31.5	53.2
2	38.4	43.1	37.6	62.5	52.0
3	38.6	42.9	37.6	125	48.5
4	38.4	42.1	38.3	250	45.8
5	38.7	41.9	38.5	500	34.9
6	37.7	41.6	38.0	1000	29.4
7	38.6	42.1	39.0	2000	24.7
8	38.0	42.2	38.3	4000	24.0
				8000	22.2
				16000	14.7
Average	38	42	38	A	39.2
Difference		4			
Correction		2			
Corrected	Lpa	40			
height	1.66 m	Contour Lm	6.49m	$S=1.25hLm = 13.5 m^2$ $Lwa = Lpa+10\log S$ $= 40 + 11 = 51$	
Sound pressure	40 dB(A)	Sound power Level	51 dB(A)	Guaranteed value 54dB(A)	
Tested by	P. L. G. G. G. Signature		P. L. G. G. G.		

See Drawing LK50294A0 For Plan View



Appendix 1 – Report on Transformer Noise

Paper Number 23, Proceedings of ACOUSTICS 2011

3-4 November 2011, Gold Coast, Australia

Low-frequency and Tonal Characteristics of Transformer Noise

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ABSTRACT

Electricity substations and their associated transformers are necessary for community power needs. In NSW these substations are often located in rural areas where background noise is low. Noise 'hum' from the transformers can be an issue for residents located nearby to the substation, and the tonal and low-frequency nature of the noise can add to the annoyance. The NSW Industrial Noise Policy applies penalties for these noise characteristics when assessing such sources. This paper analyses noise measurements of substations in rural areas. One-third octave band noise measurements were conducted both close up to the transformers, and also in the residential community. The measurement results show that although tonal and low frequency characteristics might be evident close up to the transformers, these characteristics dissipate over distance and the DNP penalties do not necessarily apply at the residential receiver.

INTRODUCTION

The electricity used by households and businesses in NSW is generated at power stations then transmitted through high voltage transmission lines to substations. The substation performs the task of stepping down the voltage suitable for domestic and commercial distribution. There are approximately 91 large zone substations in NSW and many more smaller distribution substations.

Since substations are often located in rural areas, the nearest residential receiver are commonly isolated dwellings on large lots. Background noise is therefore usually very low due to the lack of other industrial development and low levels of traffic noise. Occasionally medium density residential areas on the edge of towns abut the substation land holding.

Since transformers generate noise emissions with a distinct tone at a relatively low frequency, it is sometimes assumed that these characteristics will also be evident at the residential receiver, to the point that a tonality penalty under a low-frequency penalty is automatically applied during an assessment. Particularly when utilising noise modelling say during the planning phase of a substation, the tones and harmonics the substation source are strongly evident in the predicted results at the receiver.

However, since tonality is assessed by determining the emergence of a particular tone above the noise level of the adjacent frequency bands, the background noise in an area plays a significant part in determining whether a noise source will be tonal or not. Even where the tone of a substation may still be somewhat audible, it may be that the tone has 'blended' enough with the background noise so that the tone is no longer inherently annoying.

This paper analyses the results of noise measurements conducted in rural areas, in the vicinity of substations, with the aim of determining typical distances from substations beyond which tonal and low-frequency penalties would no longer apply according to the DNP.

ELECTRICITY SUBSTATION TRANSFORMERS

Zone substation typically contain at least two step-down transformers. These transformers operate with a distinct 'hum' which is generated by the periodic mechanical deformation of the transformer core and the winding coils, under the influence of fluctuating electromagnetic flux. The vibration of the core is at twice the frequency of the alternating magnetic flux. Since the line supply frequency is 50Hz, the noise emissions from these transformers are typically characterised by tonal spikes at 100Hz, and also at the 200Hz and 400Hz harmonic frequencies.

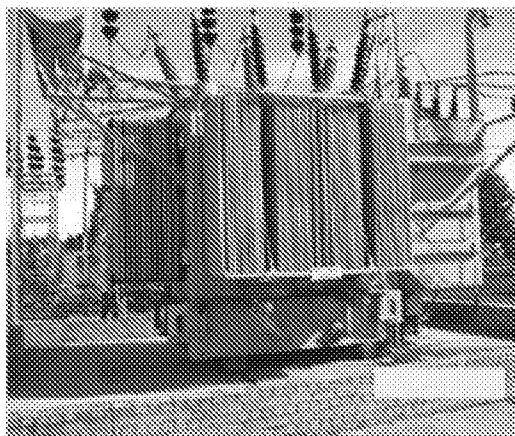


Figure 1 Typical substation transformer

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During a transformer's operation, the vibrations from its core and windings get transmitted to the transformer tank surface through air-borne transmission (the air surrounding the core), and by structure-borne transmission at points where the mounting of the core structure is attached to the tank. The vibrating tank surface eventually radiates noise into the exterior air.

Some of the other sources of noise associated with transformer operation, such as cooling fans and pumps, are usually negligible contributors to the far-field noise.

NSW INDUSTRIAL NOISE POLICY

General Criteria

The NSW Industrial Noise Policy (INP) is generally used for setting noise goals in substation noise assessments in NSW.

The assessment procedure for the Industrial Noise Policy has two components:

- Controlling intrusive noise impacts in the short term for residences
- Maintaining noise level amenity for particular land uses for residences and other land uses.

In setting the project specific noise levels, the more stringent of the intrusive and amenity criteria is adopted. In general, the intrusive criterion tends to be the controlling criterion for substations as there is often little other industrial development in the regional areas where the substation is located.

Penalties for Low-frequency and Tonal Sources

Where a noise source contains certain characteristics (i.e. if it has an inherently tonal, low frequency, impulsive or intermittent character), then it can cause greater annoyance than other noise at the same level. According to the INP an adjustment of 5dBA for each annoyance aspect, up to a total of 10dBA, is to be added to the measured value to penalise the noise for the additional annoyance caused.

The INP provides definitive procedures for determining whether a penalty or adjustment should be applied for increased annoyance.

Tonal noise is defined as noise containing a prominent frequency and characterised by a definite pitch. A one-third octave (or narrow band analysis) is required and a 5dBA penalty is applied to the measured or predicted level when the level of one-third octave band exceeds the level of the adjacent bands on both sides by:

- 5dB or more if the centre frequency of the band containing the tone is above 400 Hz
- 8dB or more if the centre frequency of the band containing the tone is 160 to 400 Hz inclusive
- 15dB or more if the centre frequency of the band containing the tone is below 160 Hz.

Low frequency noise is defined as noise containing major components within the low frequency range of 20Hz – 250Hz. Low frequency noise is considered to be evident where the difference between the measured A and C weighted levels is 15dB or more, and another 5dBA penalty may be applied.

MEASURED TRANSFORMER NOISE LEVELS

Near Field Noise Levels

Australian Standard 60076.10.1-2009 "Power transformers – Determination of sound levels" is the current standard for quantifying noise levels from transformers. The procedure in this standard calls for noise levels to be measured at a series of points around the tank of the transformer.

One-third octave band noise measurements have been conducted in accordance with the standard for the near field noise levels presented in this paper. A typical noise spectrum for these near field measurements is presented in Figure 2. The tone at 100Hz is distinct, being two times the electrical supply line frequency. There is also significant energy at the 200Hz and 400Hz harmonic frequencies.

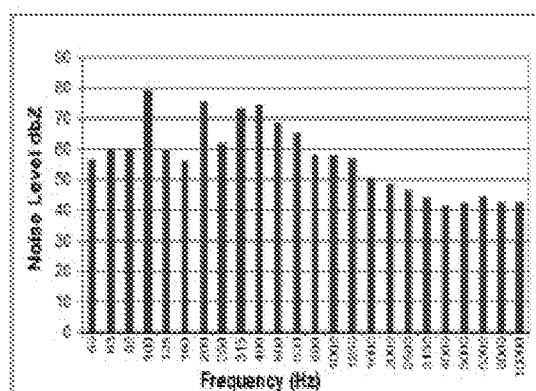


Figure 2. Typical Transformer Noise Spectrum

Noise Levels in the Community

The following three case studies are examples of where residences are affected by audible substation noise. Noise measurements have been conducted late at night at the residential boundaries in a low background noise environment to quantify noise emission levels and to determine whether tonal or low frequency characteristics exist. In each case, noise measurements have also been conducted close up to the transformers in the switchyard to quantify the character of the source.

Case 1

The substation was located in a rural area surrounded by grassy fields and farmland, and is approximately 2km from the main highway. Background noise levels were around 30dBA, although slightly less than 30dBA at some residential locations.

The graph in Figure 3 presents a comparison of measured noise levels both close up to the transformer in the substation, at the substation boundary, and at the residential boundary. The results are in one-third octave bands to enable analysis of tonality.

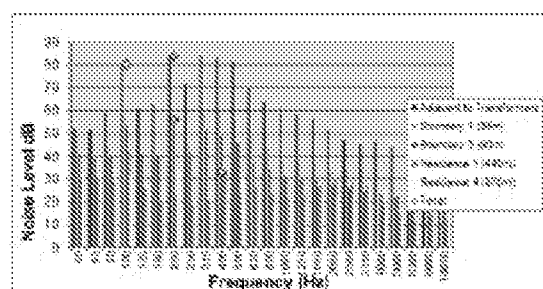


Figure 3. Measured Noise Levels (Case 1)

As shown by the arrowed notations, the following conclusions can be drawn for Case 1 according to the annoyance test procedures outlined in the INP

- Close up to the transformers, noise emissions are clearly tonal, with the obvious tones being at 100Hz, and at the 200Hz harmonic.
- Noise is still considered tonal at both the boundary locations (35m and 60m away), however the tones are only evident at 200Hz, but no longer at 100Hz.
- At the residential boundary 440m away, tonality was determined at 400Hz, but not at 100Hz or 200Hz.
- At the residential boundary 570m away, noise from the substation was not considered tonal according to the INP procedure.

Comparison of the A-weighted and C-weighted overall noise levels confirmed that a penalty for low frequency noise would not need to be applied at any residence.

Case 2

The substation was located in an area with farmland and some industry, and is approximately 400m from the main highway. Background noise levels were between 30 - 32dBA at night and truck traffic from the highway was audible at night.

The graph in Figure 4 presents a comparison of measured noise levels both close up to the transformer in the substation, at the substation boundary, and at the residential boundary.

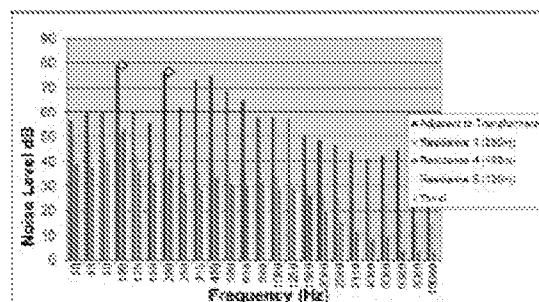


Figure 4. Transformer Noise (Case 2)

The following conclusions can be drawn for Case 2:

- Close up to the transformers, noise emissions are clearly tonal, with the obvious tones being at 100Hz and 200Hz.
- Noise is not considered tonal according to the INP at residences 120m, 180m or 260m away in any frequency.

Comparison of the A-weighted and C-weighted overall noise levels confirmed that a penalty for low frequency noise would not need to be applied at any residence.

Case 3

The substation was located in a rural residential with no industry. The nearest main road was approximately 1km away, and the nearest highway many kilometres away. Background noise levels were less than 30dBA at night.

The graph in Figure 5 presents a comparison of measured noise levels both close up to the transformer in the substation, at the substation boundary, and at the residential boundary.

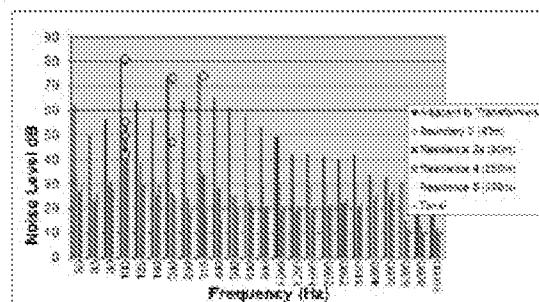


Figure 5. Transformer Noise (Case 3)

The following conclusions can be drawn for Case 3:

- Close up to the transformers, noise emissions are tonal at 100Hz, 200Hz and 315Hz.
- Tonality still exists at 100Hz at 40m and 90m. It is not calculated at 250m but is just triggered at 350m.

Comparison of the A-weighted and C-weighted overall noise levels confirmed that a penalty for low frequency noise would not need to be applied at any residence.

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AUDIBILITY VERSUS INP PENALTIES

At each residential measurement location referenced in this paper, transformer hum could be described as being 'clearly audible' within the ambient noise. However, according to the INP procedures, penalties for tonality would not apply at all locations.

Table 1 summarises where tonality is evident for each case scenario, according to the INP procedures.

Table 1. Application of INP Tonality Penalty

Case	Receiver Distance	INP Penalty Applicable	Audibility of substation 'hum'
1	440m	Yes, tonal at 400Hz	Clearly audible
	578m	No	Clearly audible
2	260m	No	Clearly audible
	180m	No	Clearly audible
	120m	No	Clearly audible
3	90m	Yes, tonal at 100Hz	Clearly audible
	250m	No	Clearly audible
	350m	Yes, tonal at 100Hz	Clearly audible

Where a penalty for tonality is not required to be applied, the INP's 'background + 5dB' intrusiveness criterion is the remaining instrument for limiting noise impacts.

CONCLUSION

When acoustic engineers are planning for new substation installations in accordance with the NSW Industrial Noise Policy, the set of measured data in this paper suggests that:

- Where background noise levels are around 30dBA at night, application of the tonality penalty is appropriate for residences within about 500m of the transformers if the aim is simply to comply with the INP.
- Transformer hum can be clearly audible at a residential location without the INP procedures necessarily identifying that noise as being tonal. For additional protection of residences, particularly where background noise levels are below 30dBA at night, application of the tonality penalty for all receivers in the surrounding area may be appropriate, generating a more conservative outcome and additional mitigation measures so that that audible noise from the substation is reduced.
- Where receivers are exposed to existing traffic or industrial noise, or where background noise levels are greater than 30dBA, the INP penalty for tonality may not be triggered even for residences within a few hundred meters of the transformers.
- According to the INP procedures, an additional penalty for low-frequency noise is not warranted for substation installations.

REFERENCES

- Australian Standard 60076.10.1-2009 "*Power transformers – Determination of sound levels*", Standards Australia, Sydney.
- Jane Ann Verner, *Sound Tutorial*, March 2006
- NSW Environment Protection Authority 2000, *Industrial Noise Policy*, EPA, Sydney.
- Ravish S. Masti, Wim Desmet, Ward Heylen. *Influence of core laminations upon power transformer noise*, K.U. Leuven, Department of Mechanical Engineering, Division PMA, Celestijnenlaan 300B, B-3001 Leuven, Belgium.

Appendix 2 – Calculation of Noise Transmission from Substation

	Frequency	Hz	25	31.5	40	50	63	80	100	125	160
1	Measured SPL @1m, 1/1 Bands	dB		53			52			49	
2	Area Correction, 13.5m ²	dB		11			11			11	
3	Sound Power Level, 1/1 Bands	dB		64			63			60	
4	Tolerance for Uncertainty	dB		3			3			3	
5	Adopted 1/1 Band Sound Power	dB		67			66			63	
6	Reference 1/3rd octave Spectrum	dB	65	60	55	58	60	60	80	60	55
7	Equivalent 1/1 Band Spectrum	dB		67			64			80	
8	Difference to measured 1/1 Bands (Line 7 - Line 3)	dB		-3			-1			-20	
9	Extrapolated 1/3rd Octave Band Spectrum (Line 6 + Line 8)	dB	62	57	52	57	59	59	60	40	35
	Calculation to Flat 41										
10	Directivity (Point source)	dB	-8	-8	-8	-8	-8	-8	-8	-8	-8
11	Distance, 15m	dB	-24	-24	-24	-24	-24	-24	-24	-24	-24
12	Façade Correction	dB	3	3	3	3	3	3	3	3	3
13	SPL at façade	dB	34	29	24	28	30	30	31	11	6
14	Loss through open window (14 Dn,e,w)	dB	29	29	29	29	29	25	20	15	14
15	Absorption in Typical Bedroom (0.5secs RT, 25m ³)	dB	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05	8.05
16	Absorption Adjustment, ref Ao=10m ²	dB	1	1	1	1	1	1	1	1	1
17	Predicted SPL within overlooking bedrooms	dB	6	1	-4	0	2	6	12	-3	-7
18	NANR45 Criterion Curve	dB	64	56	49	43	42	40	38	36	34

Appendix 3 – Extract from Napier University NANR115 Report

	Octave Band Centre Frequency (Hz)							D_{max} (C;C ₅₀)
	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	
Opening A-1	18.7	14.0	12.0	18.7	17.4	19.9	21.4	19 (-1; -2)
Opening A-2	18.9	15.1	12.1	18.5	18.0	19.5	21.3	19 (-1; -2)
Opening A-3	19.7	13.7	17.1	14.9	13.9	18.7	21.5	17 (-1; -2)
Opening B	20.8	13.3	12.9	18.1	12.0	18.3	20.5	16 (-1; -2)
Opening C-1	22.8	17.0	21.2	17.0	15.4	21.1	25.6	19 (-1; -2)
Opening C-2	22.3	18.0	17.8	18.3	14.9	20.4	25.0	19 (-1; -2)
Opening C-3	23.0	17.7	23.3	17.1	15.9	21.5	26.6	19 (0; -1)
Opening C-4	22.5	18.8	20.2	18.5	15.6	20.6	25.7	19 (0; -1)
Opening D-1	21.9	15.2	17.5	15.0	15.1	17.2	18.8	16 (0; 0)
Opening D-2	23.1	14.6	11.5	20.8	10.2	14.9	14.2	14 (-1; -2)
Opening D-3	23.5	15.2	13.0	21.3	18.8	17.3	17.9	18 (-1; -1)
Opening E	23.1	17.4	18.4	17.2	17.7	19.1	19.5	18 (0; 0)
Opening F	23.2	18.5	17.9	17.0	18.1	18.7	20.6	18 (0; 0)
Opening G	22.7	18.1	18.6	17.3	18.5	18.6	17.8	18 (-1; -1)

Table 5-5 Derived D_{max} result for “200,000 mm²” open windows (L6, S1, R2-6) (dB)

Appendix 4 – Glossary of Terms

Sound Pressure	Sound, or sound pressure, is a fluctuation in air pressure over the static ambient pressure.
Sound Pressure Level	The sound level is the sound pressure relative to a standard reference pressure of 20µPa (20x10 ⁻⁶ Pascals) on a decibel scale.
Decibel (dB)	A scale for comparing the ratios of two quantities, including sound pressure and sound power. The difference in level between two sounds s_1 and s_2 is given by $20 \log_{10} (s_1 / s_2)$. The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20µPa.
A-weighting, dB(A)	The unit of sound level, weighted according to the A scale, which takes into account the increased sensitivity of the human ear at some frequencies.
Noise Level Indices	Noise levels usually fluctuate over time, so it is often necessary to consider an average or statistical noise level. This can be done in several ways, so a number of different noise indices have been defined, according to how the averaging or statistics are carried out.
Leq,T	A noise level index called the equivalent continuous noise level over the time period T. This is the level of a notional steady sound that would contain the same amount of sound energy as the actual, possibly fluctuating, sound that was recorded.
Lmax,T	A noise level index defined as the maximum noise level during the period T. Lmax is sometimes used for the assessment of occasional loud noises, which may have little effect on the overall Leq noise level but will still affect the noise environment. Unless described otherwise, it is measured using the 'fast' sound level meter response.
L90,T	A noise level index. The noise level exceeded for 90% of the time over the period T. L90 can be considered to be the "average minimum" noise level and is often used to describe the background noise.
Free-Field	Far from the presence of sound reflecting objects (except the ground), usually taken to mean at least 3.5m.
Façade Noise Level	At a distance of 1m in front of a large sound reflecting object such as a façade.
Fast/Slow Time Weighting	Averaging times used in sound level meters.
Octave Band	Range of frequencies whose upper limit is twice the lower limit.
DnT,w	The single number quantity that characterises airborne sound insulation between rooms over a range of frequencies.
Rw	Single number quantity that characterises the airborne sound insulating properties of a material or building element over a range of frequencies.