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Report on Road Traffic Sound
For
Persimmon Homes North Scotland
At
Gillburn Road, Dundee

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1.0   Introduction

1.1   Persimmon Homes North Scotland proposes to apply for planning permission to construct houses on land formerly occupied by Kingspark School, to the south of Gillburn Road, in Dundee. The location of the proposed development is shown outlined in red below in Figure 1(a), and overleaf in Figure 1(b), both of which are reproduced with the permission of Ordnance Survey.

Figure 1(a)

Location of Proposed Development
(Courtesy of Ordnance Survey)
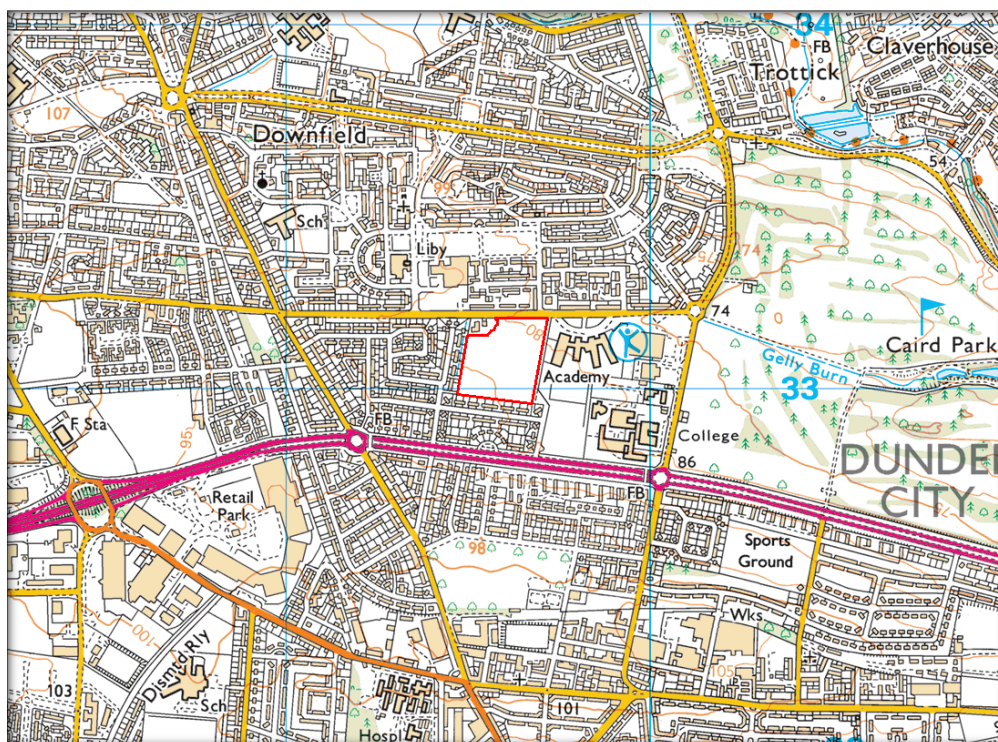
1.2   It was anticipated that officers of Dundee City Council would require an assessment of the sound of the traffic on Gillburn Road. Charlie Fleming Associates was appointed, by Mr Gordon Souter, of Persimmon Homes North Scotland, to prepare the assessment.

1.3   Section 2.0 of this report describes how the road traffic sound levels were measured and the results of the measurements are presented in Section 3.0. The internal levels of traffic sound are calculated as described in Section 4.0, and compared to the limits usually imposed by the Council.

Section 5.0 concludes the main text of the report and the two documents referred to herein are referenced in full in Section 6.0. The Appendix describes basic principles of acoustics, the measurement of sound and explains the technical terms used in the report.

Figure 1(b)

Location of Proposed Development
(Courtesy of Ordnance Survey)
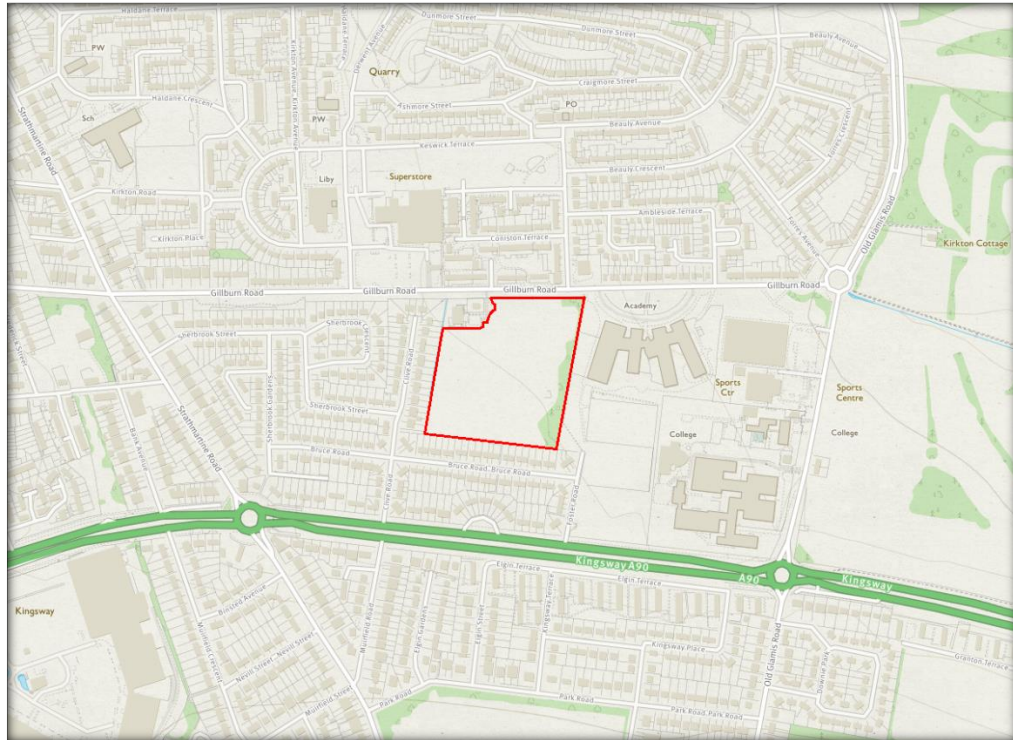
2.0   Road Traffic Sound Level Measurement Procedures

2.1   The limits which apply to road traffic sound have a bearing on how it is measured. A typical planning condition relating to traffic sound affecting a proposed residential development in Dundee is as follows.

A scheme for protecting the proposed dwelling units from road traffic noise shall be incorporated into the design of the houses hereby approved to ensure that the internal noise levels within all habitable rooms and with windows closed, do not exceed LAeq(16 hours) 40/45dB daytime and LAeq(8hours) 30/35dB night-time. For the avoidance of doubt, day time hours shall be between 0700and 2300hours and, night time shall be between 2300 and 0700hours.

It extremely rare for the Council to request that a full 24-hour sound survey be carried out. The day-time levels can be calculated very accurately based on measurements of the sound made over 3 consecutive one-hour periods. Details of this measurement technique are specified in the Department of Transport document titled *Calculation of Road Traffic Noise*[1]. This technique has been used by Charlie Fleming Associates many times before in Dundee, the results it produces accepted by the Council's officers, and so it has been used in this case.

2.2   Mr ⬛⬛⬛⬛⬛⬛⬛, of Charlie Fleming Associates, visited the site of the proposed development on Monday 11th September 2017 to measure the sound levels of the traffic on Gillburn Road.

2.3   The following instrumentation was used to conduct the measurements.

Brüel & Kjær Hand-held Analyzer Type 2250
Serial No. 3008181

Brüel & Kjær Prepolarised Condenser Microphone Cartridge Type 4189
Serial No. 2983295

Brüel & Kjær Sound Level Calibrator Type 4231
Serial No. 2035477

Brüel & Kjær Windscreen Type UA0237

2.4   It is usual, in an assessment such as this, to measure the sound where one of the houses which will be most exposed to it will be built. The principle in this is that, if the sound at one of the most exposed houses is acceptable, it follows that it will also be acceptable at the other, less exposed, ones. It was thus decided to measure the sound where the northern elevation of Plot 4 will be built. The measurement position is shown by the blue arrow overleaf on Figure 2, which is reproduced from Revision G of drawing number PER-16-07 PL-01, titled *Development Layout*, by Crawford Architectural Design Services.

In detail, the measurement position was 14.3m back from, and at 90 degrees to, the kerb of Gillburn Road. It was also 88.5m, in a westerly direction, along the post and wire fence defining the northern boundary of the proposed development site, from its north-eastern corner. The microphone of the sound level analyzer was horizontal and at a height of 1.40m above the ground.

Figure 2

Location of Measurement Position
(Courtesy of Crawford Architectural Design)
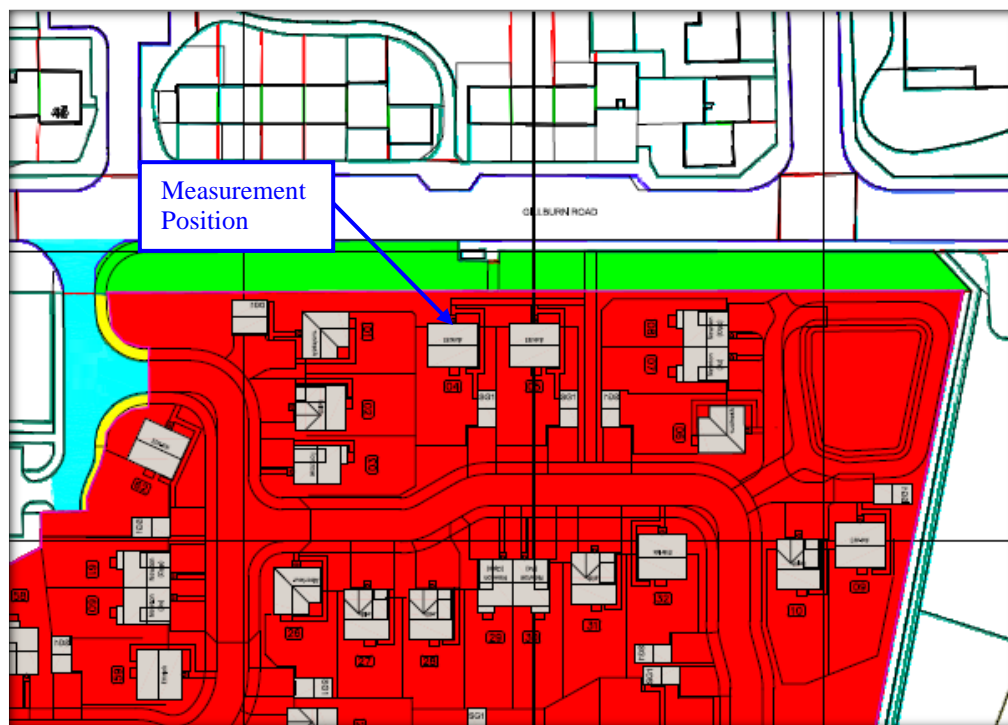
2.5   The shortened measurement procedure suggested in paragraphs 43 and 44 of *Calculation of Road Traffic Noise*[1] involves measuring the sound over 3 consecutive hourly periods. In this instance, this could not be adhered to, because a rain shower during the first hour meant that the sound level meter had to be paused, for 31 minutes and 29 seconds. Once the rain had stopped, the measurements were then resumed. Hence there were actually four separate measurements, varying in length, but totalling 3 hours. Measurement procedures were otherwise as specified in Section III of that document.

2.6   The $L_{AF10\ (1\text{-hour})}$ sound levels were measured. The analyzer also measured the equivalent continuous sound levels both in octave bands and with A-weighting applied. All sound levels were measured in decibels referenced to 2×10^{-5} Pa.

2.7   The sound level analyzer was calibrated before and after conducting the measurements. On completion of the measurements the calibration level was found not to have changed.

3.0   Road Traffic Sound Level Measurement Results and Discussion

3.1   The results of the A-weighted $L_{Aeq\ (1-hour)}$ and $L_{AF10\ (1-hour)}$ sound level measurements are shown below in Table 1.

Table 1

Measured A-weighted Sound Levels, L_{Aeq} and L_{AF10}
(dB re 2 x 10^{-5}Pa)

Start of Measurement (hrs:mins:secs)	Duration of Measurement (hrs:mins:secs)	End of Measurement (hrs:mins:secs)	L_{Aeq} dB(A)	L_{AF10} dB(A)
10:55:31	00:45:47	11:41:15	61.9	65.8
12:12:44	00:42:47	12:55:31	62.5	66.4
12:55:31	01:00:00	13:55:31	61.0	65.0
13:55:31	00:31:26	14:26:57	61.4	65.2
Averages			**61.7**	**65.6**

3.2   The octave band sound levels measured are shown below in Table 2 and overleaf in Figure 3.

Table 2

Measured Octave Band Sound Levels, L_{eq}
(dB re 2 x 10^{-5}Pa)

Start of Measurement (hrs:mins:secs)	Octave Band Centre Frequency (Hz)									A
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	
10:55:31	66.8	67.1	62.8	57.5	55.3	59.6	53.6	46.2	39.8	61.9
12:12:44	64.0	66.3	64.6	58.3	55.2	60.1	54.6	46.0	37.3	62.5
12:55:31	68.8	65.6	61.3	56.3	54.4	58.5	53.0	46.4	40.3	61.0
13:55:31	72.8	67.3	61.1	57.0	54.9	58.8	53.3	48.1	42.8	61.4
Averages	**68.1**	**66.6**	**62.4**	**57.3**	**54.9**	**59.2**	**53.6**	**46.7**	**40.0**	**61.7**

Figure 3

Measured Octave Band Sound Levels, L_{eq}
(dB re 2 x 10^{-5}Pa)
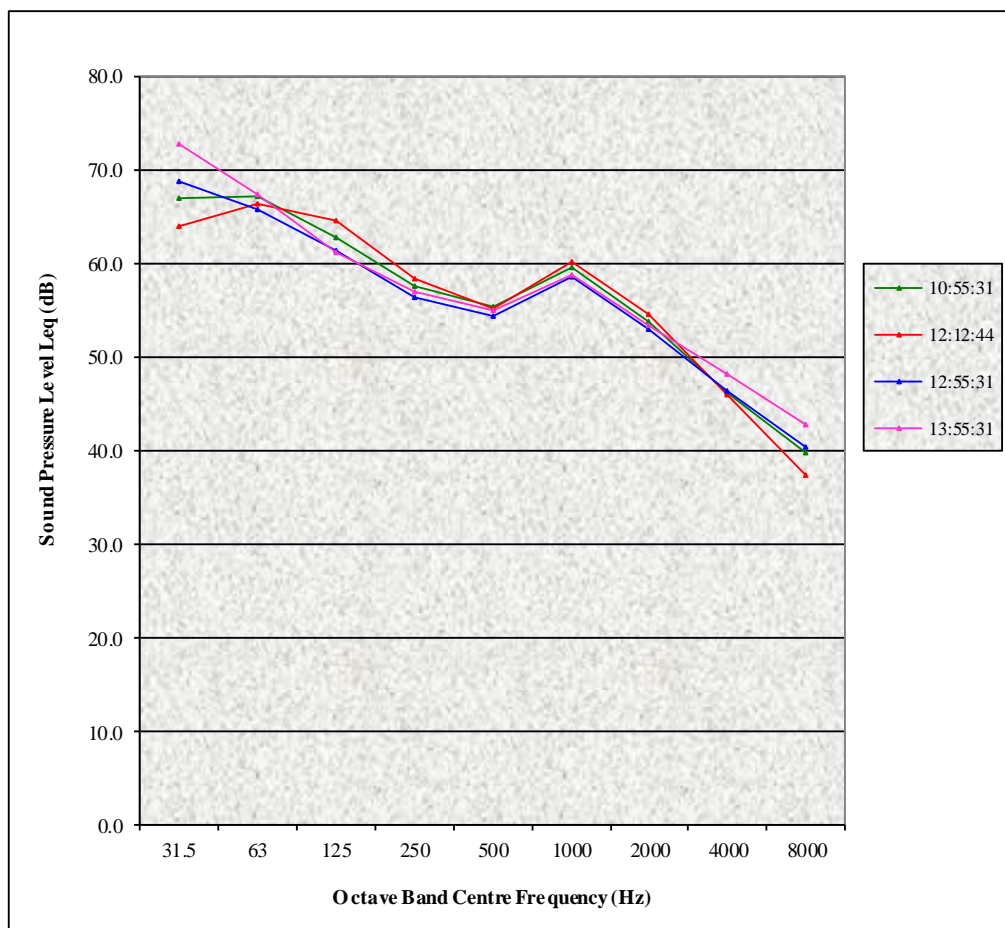
3.3 The sound measured was that of road traffic on Gillburn Road. That traffic sound was measured is apparent on Figure 3, in that the spectra shown are characteristic thereof.

3.4 The meteorological conditions prevailing whilst the sound levels were measured were as shown below in Table 3.

Table 3

Meteorological Conditions Prevailing During Measurements

Time (hrs:mins)	Direction of Wind	Wind Speed (ms^{-1})	Temperature (° Celsius)	Relative Humidity (%)	Atmospheric Pressure (hPa)
10:50	West	4.6	14	88	980
11:50	West-north-west	5.7	15	77	981
12:50	West-north-west	5.1	15	77	982
13:50	West-north-west	7.2	16	72	983

During the measurements, the sky was overcast and it could be described as a cloudy day. The sound level measurements were therefore generally carried out within the meteorological condition "window" given in *Calculation of Road Traffic Noise*[1], (CRTN).

Notwithstanding, in terms of CRTN, the noise should be measured with the road surface dry. When wet, the noise increases due to the splash of the tyres through water. The primary purpose of CRTN is to determine the traffic noise levels and, in turn, the government's statutory liability under the Noise Insulation Regulations 1975, with respect to the award of sound insulation grants to houses affected by traffic noise. It is for this reason that measurements should be conducted when the road is dry, ie quieter, lessening the financial burden on the paying authority. Whilst measuring the noise with the road surface damp is thus outwith the weather window given in CRTN, the noise levels are greater and it is a worst case scenario. It can, in any event, be seen on Figure 3 that the dampness of the road did not significantly affect the measured sound levels.

4.0   Calculation of Internal Road Traffic Sound Levels

4.1   To determine the daytime sound level, it is firstly necessary to calculate the arithmetic average of the $L_{AF10\,(1\text{-hour})}$ sound pressure levels. This has been done, and it found to be 65.6dB(A).

4.2   Using the procedure given in paragraph 43 of *Calculation of Road Traffic Noise*[1], 1dB(A) is subtracted from the average of the $L_{A10\,(1\text{-hour})}$ levels to give the $L_{A10\,(18\text{-hour})}$. To relate the $L_{A10\,(18\text{-hour})}$ value to the $L_{Aeq\,(07:00hrs\,to\,23:00hrs)}$ specified by the Council, a further 2dB(A) must be subtracted, giving a total reduction of 3dB(A). This gives a level $L_{Aeq\,(07.00hrs\,to\,23.00hrs)}$ of 62.6dB(A).

4.3   One of the most exposed houses to the sound of the road traffic will be Plot 4 and so the sound has been calculated therein. The principle in this is that if the sound in the most exposed room is acceptable, it follows that it will also be acceptable in other, less exposed, ones. The sound has been calculated in the Lounge of Plot 4 using the equation given below.

$$L_{Internal} = L_{External} - R + 10 \log S - 10 \log 0.161\,V + 10 \log T$$

Where, R   = sound reduction index of elevation.
            S   = area of elevation.
            V   = volume of receiving room.
            T   = reverberation time of receiving room.

4.4   The average octave band sound levels, shown earlier in bold print in Table 2, were used as the basis of the external sound level, $L_{External}$, as this is more accurate than using the A-weighted level alone. The A-weighted level corresponding to the average octave band levels is 61.7dB(A), which is 0.9dB(A) less than the $L_{Aeq(07.00hrs\,to\,23.00hrs)}$ of 62.6dB(A). Hence 0.9dB must be added to the octave band levels, as shown overleaf in Table 4, which shows the variables used in the calculations.

4.5   The sound measurements were conducted in free-field conditions. When the house is built, its northern elevation will face Gillburn Road. The sound waves will be reflected off the northern elevation and interfere constructively with the incident ones, causing what is known as façade effect or pressure doubling. This is taken to increase the sound by 2.5dB[1] and so this has been added to the measured levels, as shown on Table 4.

4.6   The ingress of sound through the elevation into the Lounge of Plot 4 will be determined by the transmission path through the glazing, this being far greater than that through the concrete blockwork.

At the time of writing, the glazing had not been specified. It was thus assumed to be at least the minimum standard required in the *Building Standards (Scotland) Regulations* for thermal insulation, of 2 panes of 6mm thick glass separated by a 16mm wide cavity. The sound reduction indices of this glazing have been derived from values given in the literature[2&3].

4.7   The dimensions of the Lounge windows were scaled off the architect's drawings, and the area of glazing calculated to be $1.4m^2$.

4.8   The dimensions of the Lounge were scaled off the architect's drawings, and volume calculated to be $34.1m^3$.

4.9   The reverberation times of the Lounge were taken to be the same as those measured by Charlie Fleming Associates in a similar sized lounge in a flat in Aberdeen.

4.10   The variables discussed in Sections 4.4 to 4.9 have been incorporated into the equation, given earlier in Section 4.3, as shown below in Table 4.

Table 4

Calculation of Internal Road Traffic Sound Levels, L_{eq}
(dB re 2 x 10^{-5} Pa)

Parameter	Octave Band Centre Frequency (Hz)								
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Level $_{External}$	68.1	66.6	62.4	57.3	54.9	59.2	53.6	46.7	40.0
Correction to 16-hour level	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Correction for Façade Effect	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
R $_{Glazing}$	*24.7*	24.7	21.9	20.1	29.5	37.9	35.1	39.6	*39.6*
10log S	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
10log 0.161 x V	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
T	*0.5*	*0.4*	0.3	0.5	0.6	0.5	0.4	0.3	*0.3*
10log T	-3.1	-3.9	-4.7	-2.7	-2.6	-3.4	-3.6	-5.1	*-5.1*
Level $_{Internal}$	37.9	35.6	33.5	32.1	20.5	15.6	12.6	-0.4	-7.0

Figures shown in italicised print have been extrapolated.

4.11   In the Lounge of Plot 4, the "Level $_{Internal}$", $L_{Aeq\ (07:00hrs\ to\ 23:00hrs)}$, is 26.0dB(A), which is well within the 40dB(A) limit usually applied by Dundee City Council.

4.12   At night, the external sound level, $L_{Aeq\ (23:00hrs\ to\ 07:00hrs)}$, will be around 53dB(A)[4]. The sound level has also been calculated in Bedroom 4 of Plot 4. The sound has been calculated as described above, with the variables being changed appropriately. In Bedroom 4, the $L_{Aeq\ (23.00hrs\ to\ 07:00hrs)}$ will be around 15.6dB(A), which is well within the 30dB(A) limit usually applied by the Council.

5.0   Conclusions

5.1   Persimmon Homes North Scotland proposes to apply for planning permission to construct houses on land formerly occupied by Kingspark School, to the south of Gillburn Road, in Dundee. It was anticipated that officers of Dundee City Council would require an assessment of the sound of the traffic on Gillburn Road. Charlie Fleming Associates was appointed, by Persimmon Homes North Scotland, to prepare the assessment.

5.2   The sound of the traffic was measured as described in Section 2.0 of this report, and the results are presented in Section 3.0. In Section 4.0, the internal sound levels have been calculated and compared to the limits usually applied by the Council. The internal sound levels were found to be well within the limits.

Eur Ing ▮▮▮▮▮▮▮▮▮▮ **BSc MSc CEng FIOA MCIBSE MIET**

6.0   References

1)   Department of Transport, *Calculation of Road Traffic Noise*, HMSO, London, 1988, ISBN 0-11-550847-3.

2)   Saint Gobain, *Acoustic Performance of Glazing*.

3)   Inman C., *A Practical Guide to the Selection of Glazing for Acoustic Performance in Buildings*, Acoustics Bulletin, **19**, (5), September/October 1994, pp19-24.

4)   Highways Agency, *Design Manual for Roads and Bridges: Volume 11 Environmental Assessment*, Section 3, Part 7, paragraph 3.7, The Stationery Office, London 2006, ISBN 10: 0115527648.

A1.0   Appendix: Basic Principles of Acoustics

A1.1   Sound Pressure
The sound we hear is due to tiny changes in pressure in the air, caused by something disturbing the air, such as a loudspeaker cone moving back and forward, the blades of a fan heater going round, the moving parts of a car engine, and so on. From the initial point of the disturbance the sound travels to the receiver in the form of a wave.   It is not like a wave in water, rather like one that would travel along a stretched spring, such as a child's *Slinky* toy laid flat on the ground and "pinged" at one end.   Whether the human ear can hear the sound wave as it travels through the air, however, depends on the size of the disturbance and the frequency of it.   That is, if the loudspeaker moves very slightly we may not be able to hear the changes in air pressure that it causes because they are too small for the ear to detect. The magnitude of sound pressures that the human ear can detect ranges from about 0.00002Pascals (Pa) to 200Pa. This enormous range presents difficulties in calculation and so, for arithmetic convenience, the sound pressure is expressed in decibels, dB.   Decibels are a logarithmic ratio as shown below:

Sound Pressure Level *L (dB) = 20Log₁₀{ ᵖ/ₚ}*
Where p = the sound pressure to be expressed in dB
and P = reference sound pressure 0.00002Pa

Hence, if we substitute 0.00002Pa, the smallest sound the ear can hear, for p, the result is 0dB.   Conversely, if we substitute 200Pa, the loudest sound the ear can hear, for p, the result is 140dB. Hence, sound is measured in terms of sound pressure level in dB relative to 0.00002Pa.

A1.2   Range of Audible Sound Pressure Levels
An approximate guide to the range of audible pressures is presented overleaf in Table A1. The sound pressure levels noted are typical of the source given and should not be considered to be precise. The notes in the "Threshold" column of the Table are for general guidance, the sound pressure levels of those thresholds varying between individuals.

Table A1

Range of Audible Sound Pressure Levels and Sound Pressures

Sound Pressure Level (dB re 2x10⁻⁵ Pa)	Sound Pressure (Pa)	Source	Threshold of:
160	2000	Rifle at ear	Damage
140	200	Jet aircraft take off @ 25m	Pain
120	20	Boiler riveting shop	Feeling
100	2	Disco, noisy garden centre	
80	0.2	Busy street	
60	0.02	Conversation @ 2m	
40	0.002	Quiet office or living room	
20	0.0002	Quiet, still night in country	
0	0.00002	Acoustic test laboratory	Hearing

A1.3   Frequency and Audible Sound

Returning to the example of the loudspeaker cone, if it moves back and forward very slowly, for example once or twice a second, then we will not be able to hear the sound because the ear cannot physically respond to such a low frequency sound. Human ears are sensitive to sound pressure waves with frequencies between about 30Hertz (Hz) and 16,000Hz, where Hz is the unit of frequency and is also known as the number of cycles per second.   That is, the number of times each second that the loudspeaker cone moves in and out, the fan blade goes round, etc. At the other end of the frequency spectrum, a sound with a frequency of 30,000Hz will also be inaudible, again because the ear cannot physically respond to sound pressure waves having such a high frequency.

Across the audible frequency range, the response of the ear varies. For example, a sound having a frequency of 63Hz will not be perceived as being as loud as a sound of exactly the same sound pressure level, having a frequency of 250Hz.   A sound having a frequency of 500Hz will not be perceived as being as loud as a sound of the same sound pressure level with a frequency of 1,000Hz. Indeed, for a given sound pressure level, the hearing becomes progressively more sensitive as the frequency increases up to around 2,500Hz.   Thereafter, from 2,500Hz upwards to about 16,000Hz, the sensitivity decreases, with sounds having frequencies above 16,000Hz being inaudible to most adults.

Virtually all sounds are made up of a great many component sound waves of different sound pressure levels and frequencies combined together. To measure the sound pressure level contributed at each of the frequencies between 30Hz and 16,000Hz, that is, 15,970 individual frequencies, would require 15,970 individual measurements. This would yield a massive, unwieldy amount of data.

A1.4   Octave Bands of Frequency

As a compromise, the sound pressure level in particular ranges, or "bands", of frequencies can be measured.   One of the commonest ranges of frequency is the octave band. An octave band of frequencies is defined as a range of frequencies with an upper limit twice the frequency of the lower limit, eg 500Hz to 1,000Hz.   This octave is exactly the same as a musical octave, on the piano, violin, etc, or *doh* to high *doh* on the singing scale. Octave bands are defined in international standards and are identified by their centre frequency.   Sound measurements are generally made in the eight octave bands between 63Hz and 8,000Hz.   This is because human hearing is at its most sensitive, in terms of its frequency response, over this range of frequencies. Furthermore, the sound waves that make up speech have frequencies in this range.

A1.5   Linear, (Lin) Measurement of Sound

A measurement that encompasses all the frequencies making up the sound. It is the most basic of measurements as it only provides a single value of the magnitude of the sound or vibration, with no information as to the frequency content of the sound, which is useful in the analysis of problems. It is also used to describe sounds which have approximately equal contributions across the frequency range.

A1.6   "A-Weighting" and dB(A)
Whilst an octave band analysis gives quite detailed information as to the frequency content of the sound, it is rather clumsy in terms of presenting results of measurements, that is, having to note sound pressure levels measured at eight separate octave bands. Furthermore, the ear hears all these separate frequency components as a whole and thus it would seem sensible to measure sound in that way.

When sound pressure level is measured with a sound level meter, the instrument can analyse the sound in terms of its octave band content as described above in section A1.4, or measure all the frequencies at once. Bearing in mind that the response of the ear varies with frequency, the sound level meter can apply a correction to the sound it is measuring to simulate the frequency response of the ear. This correction is known as "A-weighting" and sound pressure levels measured with this applied are described as having been measured in dB(A).

A1.7   Variation of Sound Level With Time
Virtually all sounds vary with time. For example, speech, music, a person hammering, road traffic, an aircraft flying overhead, all vary with respect to time. Various terms can be applied to describe the temporal nature of a sound as shown in Table A2.

Table A2

Examples of the Temporal Nature of Sound

Description	Example of Sound Source
Constant or steady state	Fan heater, waterfall
Impulsive	Gun shot, hammer blow, quarry blast
Irregular or fluctuating	Road traffic, speech, music
Cyclical	Washing machine, grass mowing
Irregular impulsive	Clay pigeon shooting
Regular impulsive	Regular hammering, tap dripping, pile driving

In practice, combinations of virtually any of the above can exist. In measuring sound it is necessary to deal with the level as it varies with respect to time.

A1.8   Time History
Consider the time history, as it is known, shown overleaf in Figure A1. Note that it is not an actual time history, rather an approximate representation of that which a person might experience some 100m away from a building site on which a man is operating a pneumatic drill.

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Figure A1

Example of Time History of Construction Site Sound
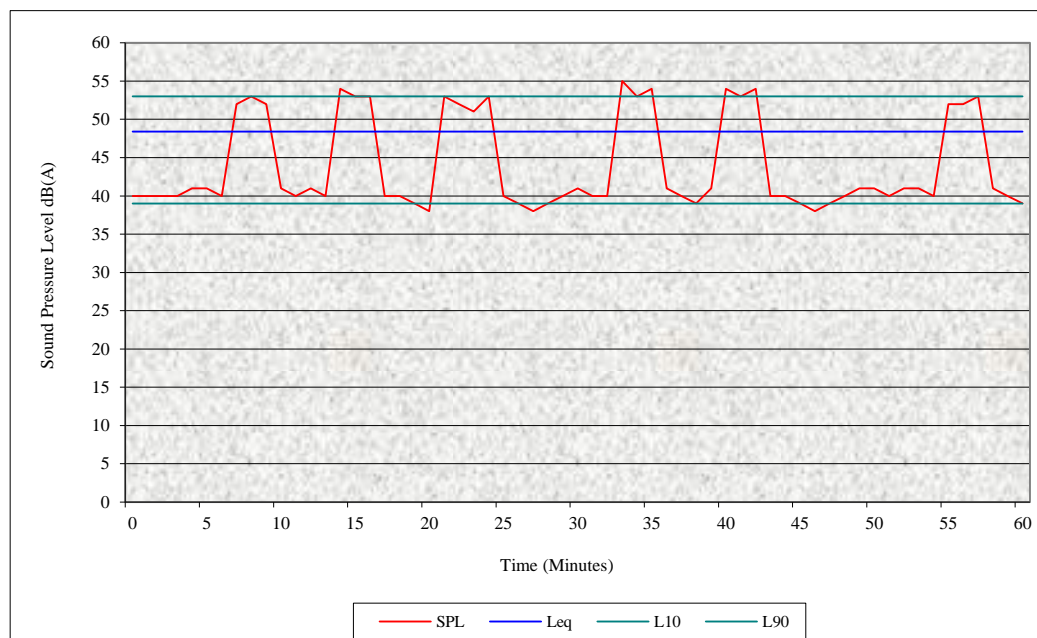
The sound of the compressor and other activity on the site is reasonably constant with time, having a level of between 38dB(A) and 41dB(A). When the drill operates the sound level rises to between around 51dB(A) and 55dB(A).

A measurement of the sound between the 25th minute and the 32nd minute, when the sound is that of the compressor, would result in a level of about 40dB(A). This is very different from the result of a measurement made between the 33rd minute and the 35th minute, when the drill is operating, which would give a sound level of about 54dB(A). In the past acousticians therefore had to develop some way of measuring the sound which gives us information as to its variation in time. The easiest parameters to understand are the maximum and minimum levels, in this case 55dB(A) and 38dB(A) respectively. These do not tell us much about the sound other than the range of levels involved. The most widely used parameter is the equivalent continuous sound level, L_{eq}, which is explained in Section A1.9.

A1.9   Equivalent Continuous Sound Level, L_{eq}
A representative measurement of the sound to which the person in the example is exposed must deal with these changes in level. This can be done by measuring what is known as the equivalent continuous sound level, denoted as L_{eq}. If the measurement has been made in dB(A) it can be denoted as L_{Aeq} and expressed in dB. This is the sound level which, if maintained continuously over a given period, would have the same sound energy as the actual sound (which varied with time) had. In the example the L_{eq} is 48.4dB(A) and it is shown on Figure A1 as a blue line. In layman's terms it may be considered to be the average of the sound over a period of time.

A1.10   Percentiles, L_x , L_{10}

Another parameter often used in describing sound is the percentile.   This is a statistical parameter and with respect to sound is that level exceeded for x% of the measurement period.   Hence the L_{10} is that level which was exceeded for 10% of the measurement period.   In the example this is 53dB(A) and it is shown in green on Figure A1. It can be seen to be a reasonable representation of the typical value of the peaks in the time history. The L_{10} is often used to describe road traffic sound, such as in the *Calculation of Road Traffic Noise* by the Department of Transport and in the *Noise Insulation Regulations 1975/1988*.

A1.11   Time Weighting, Fast, L_F, or Slow, L_S

Time weighting refers to the speed at which the sound level meter follows variations in the time history. The "fast" weighting of 125 milli-seconds corresponds to the way in which the human ear follows sound. The "slow" weighting effectively introduces more averaging of the sound. Note that the L_{eq} is independent of the time weighting, which only applies in the measurement of maxima, minima and percentiles.