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ACOUSTIC ASSESSMENT OF NOISE FROM
REFRIGERATION/AIR CONDITIONING PLANT AT
CO-OP, PETROL COEDPOETH, WREXHAM

Client: BJA Refrigeration Consulting Engineers Limited
Bridge Mills
Huddersfield Road
Holmfirth
HD9 3TW

Instruction: Sandy Scollick
BJA Refrigeration Consulting Engineers Limited

Brief: To visit the site, assess the existing acoustic environment in the vicinity of the store and the suitability or otherwise of noise from existing refrigeration / air conditioning plant at the premises (as appropriate).

To provide advice regarding suitable acoustic criteria for the selection of future replacement plant, relating this to 'typical' manufacturers' data in order to facilitate plant selection.

Plant Selection: **Plant located to the rear of the store will have several reflective vertical surfaces (walls etc) and will be approximately twelve metres from, with no direct line of sight to the nearest noise sensitive windows. The plant will also be approximately five metres from the nearest noise sensitive outdoor location. The equivalent cumulative global average 'free field' sound pressure level from all new and existing plant should not exceed 36dB(A) at a distance of 10 metres from the plant when operating at maximum night time capacity and 30dB(A) when operating at full capacity during the day. This equates to a sound power level of 64dB(A) at night and 58dB(A) during the day. Ideally this should be achieved with the use of inverter speed control systems. Sound from the plant should not contain significant tonal or impulsive components and should not be significantly directional. In this instance the daytime criterion controls the plant selection.**

Survey: Time – 23:15 hours – 00:10 hours
Date – Tuesday 7th and Wednesday 8th February 2012
Weather – variable light breeze of less than 1ms⁻¹, clear skies, approximately 0-5°C, dry ground surfaces, no precipitation.

Personnel: L Dursley – Belair Research Limited
R A Collman – Belair Research Limited



Instrumentation: Cirrus Optimus Sound Level Analyser Type CR 171, Serial No. G056106
Cirrus Calibrator Type CR 515, Serial No. 57135
Cirrus Windscreen

Tripod

Observations: The Co-op store is of single storey construction integrated into a petrol filling station. The filling station forecourt is immediately to the front of the store and is covered by a canopy. To the left of the store (when viewed from the front) is a service road leading to the service yard at the rear of the store. To the right is a small car parking area.

The closest residential properties are a terrace of bungalows to the rear of the site separated from the site by a substantial wall and timber fence. The gardens of the bungalows behind and the houses to the right of the store adjoin the boundary of the service area to the rear of the store. Further housing is to the left of the service road and on the opposite side of the A525.

Existing plant to the rear of the store was intermittently operational during the survey period and to a great extent inaudible at the measurement locations. Plant to the front (at high level behind the roller shutter doors) and to the left front of the store was frequently operational and dominant within the noise climate.

The location picture towards the end of the report shows the layout of the store and surrounding area, together with the measurement locations. Sources of ambient noise in the vicinity of the store included road traffic, of which nearby vehicles produced relatively short duration variations, whereas more distant vehicles produced longer duration variations but at a lower level of noise. Other sources of residual noise at the time of the survey included, birdsong and the occasional movement of foliage in the breeze.

Measurements: Sound pressure level measurements were taken at three locations in the vicinity of the site. One purpose of the measurements was to assess the residual sound level at the dwellings nearest to the store, in the absence of noise from any plant at the store. A further purpose was to assess the noise level produced by plant at the store, particularly at the nearest noise sensitive locations.

As would be expected, the ambient noise level at locations where noise from plant was dominant tended to remain relatively stable, varying primarily with changes in the operational characteristics of the plant. At locations where the noise from plant was less dominant the residual noise level tended to fluctuate to a greater extent, with the magnitude of such fluctuations depending upon variations in noise from extraneous sources such as road traffic.



The measurements consist of consecutive one eighth of a second continuous equivalent sound level measurements ($L_{Aeq,0.125s}$) throughout the measurement period. This method has the advantage of allowing individual events such as vehicles passing by to be identified and quantified, together with providing longer term statistical information where this is appropriate.

A graphical presentation of this data enables far more information to be assimilated than a simple tabular format, which is unsuitable for the quantities of data that are obtained using this methodology. This also assists subsequent analysis and enables relevant comparisons to be made of measurements at different locations or under different operating conditions.

Graph 1 provides details of the measurements taken during the survey. The graph displays three series of measurements. The time history traces are colour coded to denote different sources; the underlying residual level is coded in blue, road traffic movements are in grey and periods when plant at the store was operating are coded in red.

The first series of measurements were taken to the rear left of the store and are considered representative of the boundary between the bungalows to the rear of the site and the service area. The underlying residual level was in the region of 30dB(A) to 35dB(A), frequent vehicles passing on the A525 temporarily elevate the sound level to approximately 60dB(A) to 65dB(A). It was noted that there were a high proportion of heavy goods vehicles passing the site during the survey period. Periods that are coloured red denote times when the plant at the front of the store (behind the roller shutter doors) was operating. The sound level quickly rose to approximately 42dB(A) for approximately two minutes before quickly falling back down again. Plant to the rear of the store was noted to be running towards the end of the first measurement period and caused an increase in the underlying residual level in the region of 2dB(A).

The second series of measurements were taken at five metres from the wall of the store towards the property to the left, approximately half way between the store and the property. The sound level at this position when the plant was operating was in the region of 55dB(A), falling to around 30dB(A) to 35dB(A) when inoperative.

The final series of measurements were taken at the right side of the store and are considered to be representative of the gardens of the properties to the right and rear of the site. Once again the underlying residual sound level was in the region 30dB(A) to 35dB(A). Plant to the rear of the store was not audible at this location. Vehicles passing the site caused the sound level to rise to approximately 65dB(A), with two heavy goods vehicles increasing the level to 70dB(A) to 75dB(A). Again the plant to the front left of the store was dominant here, with measured sound levels in the region 42dB(A).



Criterion: When considering noise sources that operate for 24 hours per day, as is typical for retail refrigeration plant and associated equipment, the most critical time is during the early hours of the morning when people are asleep. In this case, it is important to ensure that a suitable noise level is achieved inside the bedrooms of nearby houses. The World Health Organisation^[1], the European Communities Commission^[2], BS8233^[3] and the professional bodies for Building Services Engineers^[4] provide useful guidance for this assessment.

Primarily due to a lack of alternative guidance, BS4142^[5] is widely mis-applied to a diverse range of situations. The scope of this standard is very precise in that it provides a method for assessing whether an industrial type of noise source in industrial or commercial buildings is likely to give rise to complaints from residents, based on the noise level outside their dwelling. It is not appropriate for the assessment of the noise from fixed plant and equipment, specifically during the early hours of the morning, when the primary concern is to ensure that the noise level inside the dwellings is at a suitable level.

The International Organisation for Standardisation (ISO), Chartered Institute of Building Services Engineers (CIBSE) and the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) recommend suitable limits for the maximum level of sound from mechanical plant and equipment that should be produced inside rooms, depending upon the usage of that room.

For bedrooms of dwellings in a location such as this, the recommended level is NR25. If an NR level is directly converted to a level in dB(A), the difference would be approximately 9. However, a plant noise spectrum will not exactly match an NR level, therefore a more realistic difference is between 6 and 7.

Similarly, there is a difference in sound pressure level between outside a house and inside, even with open windows. For traffic noise this difference is generally recognised to be between 10dB(A) and 15dB(A), but for a typical mechanical plant noise spectrum, a more realistic difference is between 6dB(A) and 7dB(A).

This means that, for mechanical plant noise, the difference between an indoor NR level and the corresponding outdoor level in dB(A) is approximately 13. In this case, the recommended level of NR25 equates approximately to 38dB(A) outside the dwellings.



The sound level is attenuated by 6dB(A) for every doubling of distance from a relatively small noise source. Unless the position of a noise source is known and fixed, there is no direct equivalent between the sound pressure level outside a house and that at the boundary of the site. This is best illustrated by an example:

If a noise source is located 2 metres inside the boundary and the nearest house is 30 metres away from the boundary, there will be a doubling of distance from the source (relative to the boundary) at distances of 4m, 8m, 16m and 32m (at the house) from the source. These four doublings of distance mean that the noise level at the house will be 4×6 i.e. 24dB(A) less than the level measured at the boundary.

This should be compared with a source located 30 metres inside the boundary, for the same house. In this case, the house is exactly twice the distance from the source than the boundary is, so the noise level at the house will be only 6dB(A) lower than at the boundary.

Clearly, for the two different sources to produce the same noise level at the house, one must be 18dB(A) lower than the other when measured at the site boundary.

A boundary noise limit designed to protect off-site noise sensitive locations from noise sources at unspecified locations on a site will either inadequately protect the noise sensitive locations or will potentially require massive over attenuation of noise sources which are close to the site boundary. A better location for the specification of noise limits is outside any noise sensitive locations (houses). This is consistent with guidance regarding planning conditions such as the examples in PPG24 (Planning and Noise).

If the speed of fans is halved the corresponding aerodynamic noise level falls by approximately 16dB(A) to 18dB(A). If instead the number of fans operating is halved, the corresponding reduction in noise is only 3dB(A). This means that acoustically it is far better to keep all plant operating at lower speed, when lower capacity is required, than simply to switch some of the plant off and keep the remainder operating at full capacity. For the vast majority of the time when refrigeration or air conditioning plant does not need to operate at its full capacity (which is intended to cope with the greatest demand during the peak of the summer), the plant can operate at lower capacity. Inverter speed control systems provide this capability, consequently producing significantly lower levels of noise than the 'worst case' situation with the plant operating at maximum capacity.



During the day the ambient noise level is generally significantly higher than during the night. Nearby locations are also less sensitive to noise. This means that the corresponding 'suitable' day time level is significantly higher than at night. Inverter control systems can take advantage of this, by limiting the speed and noise of plant at night (when lower capacity is required) and operating at higher speeds during the day when the higher levels of noise are acceptable. However at this site plant will only be five metres from the nearest noise sensitive location during the day, with a direct line of sight between the plant and noise sensitive garden to the right of the site. It appears that it would be appropriate to ensure that noise from the plant does not exceed 45dB(A) at this location.

Some motor/inverter combinations can produce higher levels of noise than is the case without an inverter. This is due to the interaction between the inverter and motor and often tends to be of a 'tonal' nature. Tonal noise can also be produced by other factors, such as the rate at which fan blades pass an obstruction.

Where the noise level rapidly changes by a significant amount this 'impulsive' characteristic tends to draw a listener's attention to the changing level of noise. This can happen when non inverter controlled units suddenly start or stop (particularly with noise from relays).

Care must be taken to ensure that noise from the plant does not contain any tonal or impulsive characteristics that would otherwise draw a listener's attention to this source of noise otherwise this may increase any apparent intrusiveness of the noise source.

The plant should therefore be selected to achieve a 'free field' level of 38dB(A) at the nearest dwelling when operating at maximum night time capacity and 45dB(A) at the nearest appropriate noise sensitive location when operating at full capacity during the day. This means that the actual level produced under normal conditions will be lower than this, particularly if inverter speed control systems are used. However, care must also be taken to ensure that noise from the plant does not contain any significant tonal or impulsive components.



Analysis:

Graph 1 shows that the residual noise level in the vicinity of the store at the time of the survey was slightly lower than the identified 'suitable' noise level. However, it should also be remembered that this 'suitable' level will be achieved with all plant operating at maximum night time capacity. For the vast majority of time the plant will operate at lower capacity than this during the night which means that the actual noise level at the nearest dwellings will be lower than this. Therefore the actual noise level at the nearest noise sensitive locations will be slightly above the existing residual sound level during the quietest part of the night. This level has also been identified as suitable to ensure that noise from the plant does not disturb the nearest residents, even when sleeping with open bedroom windows.

The existing plant to the front left of the store dominates the noise climate when it is operating. The noise level produced by the plant at residential properties adjacent to the site is above the suitable criterion during the night and, is very likely to be above the daytime criterion at the property to the left.

Should complaints be received it is likely that they would be justified.

Manufacturers generally state the noise (sound pressure – L_p) level that their plant will produce at a specific distance from the plant. The sound power level (L_w) is the actual sound energy produced by the plant and should be corrected to give the corresponding sound pressure level at the required distance from the plant. For many items of plant a default distance of 10 metres is used. This report will therefore recommend suitable levels at this distance from plant for ease of comparison with manufacturers' data.

Most plant emits different levels of sound in different directions. Care must be taken to ensure that the level of noise emitted in the direction of any noise sensitive locations is not higher than may be expected from a simplistic reading of manufacturer's data. For example the sound level 10 metres directly above a vertical airflow flat bed condenser is typically about 6dB(A) to 7dB(A) higher than the corresponding level in a horizontal direction from the fan deck. A 'global average' sound pressure level is the logarithmic average of the levels measured in all directions from the plant. This tends to be biased towards the higher levels of noise.

Manufacturer's data also relates to the sound level measured under 'free field' conditions (without any reflective surfaces nearby). When plant is installed near to reflective surfaces such as walls (often the case) the resultant sound level is increased – generally by between 3dB(A) and 10dB(A).

The level of sound from a 'point' source (where the size of the source is relatively small in comparison with the distance from the source) reduces at a rate of 6dB for every doubling of distance from the source. This means that the level at 20 metres will be 6dB less than at 10 metres and the level at 40 metres (two doublings) will be 12dB less than at 10 metres. Similarly the level at 100 metres will be 20dB less than at 10 metres, although other factors can also affect the sound level at relatively great distances from a noise source.



If there is no direct 'line of sight' between a noise source and listener, the resultant noise level at the listener's location will be lower than would otherwise be the case (typically by between about 5dB and 15dB) due to the 'acoustic screening' along the propagation path.

Where several types of plant are to be installed some may be easier and less costly to attenuate than others. Generally it is relatively easy to attenuate noise from a compressor pack, but more costly to do so for a condenser (which may also be larger in order to achieve a lower noise level). This means that it may be most cost effective to select/attenuate some plant to 'just' comply with the required level and to over-attenuate the remaining plant so that it does not significantly increase the overall noise level. For example, in order to achieve a total level of 40dB(A) at a location, it may be appropriate to select a condenser that produces a level of 39dB(A) at the nearest noise sensitive location with all other plant producing a cumulative level of 34dB(A) at the same location.

If the plant is located at a distance of twelve metres from the nearest noise sensitive windows the noise level at the windows will be 2dB(A) lower than at a distance of ten metres from the plant (based on hemispherical free field distance attenuation from a point source). As there will be no direct line of sight between the plant and windows the noise level at the windows will be 5dB(A) lower than that measured under 'test' conditions. Sound will also be reflected from other surfaces in the area where the plant will be installed. For the anticipated plant location there will be an increase of up to 9dB(A) to the resultant sound level at the nearest noise sensitive windows in comparison with the 'free field' conditions used for manufacturer's stated performance.

This means that the noise level at the windows nearest to the plant will be 2dB(A) higher than at a distance of ten metres from the plant under 'free field' conditions. Therefore, in order to achieve the identified 'suitable' level of 38dB(A) at the nearest noise sensitive windows, the plant should be selected based on a cumulative global average free field sound pressure level of 36dB(A) at a distance of ten metres from the plant, when operating at maximum night time capacity.

The corresponding difference between the level at ten metres from the plant and at the nearest noise sensitive location during the day is 15dB(A), which means that in order to achieve 45dB(A) at this location, the plant should be selected based on a cumulative global average free field sound pressure level of 30dB(A) at a distance of ten metres from the plant when operating at maximum capacity during the day.

The significance of the cumulative requirement is that this level should be produced with all relevant plant operating which means that, when multiple units are to be installed, individual items of plant will need to produce lower levels than this.



Where appropriate, in order to reduce the level of reflected/reverberant sound, acoustically absorptive surface treatment could be applied to some surfaces. This may enable the criteria to be relaxed by a few decibels, which could facilitate plant selection.

Conclusion: The existing ambient sound level in the vicinity of the store is due to a variety of nearby and more distant sources. At the dwelling nearest to the refrigeration and air conditioning plant, noise from this equipment is above a suitable level and dominates the underlying sound level.

Plant should be selected based on a cumulative manufacturer's free field global average sound pressure level of 36dB(A) at a distance of 10 metres from the plant when operating at maximum night time capacity and 30dB(A) when operating at full capacity during the day. This is based on free field hemispherical propagation from a point source with a cumulative sound power level of 64dB(A) at night and 58dB(A) during the day, in order to achieve the identified 'suitable' level of 38dB(A) at the nearest noise sensitive windows and 45dB(A) at the nearest outdoor noise sensitive location during the day. In this instance the daytime criterion controls the plant selection.

Ideally the plant should make use of inverter speed control so that the criterion is achieved with the plant operating at maximum night time capacity. Care must be taken to ensure that noise from the plant does not contain any significant tonal or impulsive content and that it is not significantly directional. As further data becomes available regarding plant selections and location, more specific advice can be provided to acoustically optimise the plant installation. This can minimise the resultant noise level at identified sensitive locations and the cost/difficulty of achieving a 'suitable' noise level in order to protect the occupants of neighbouring premises.

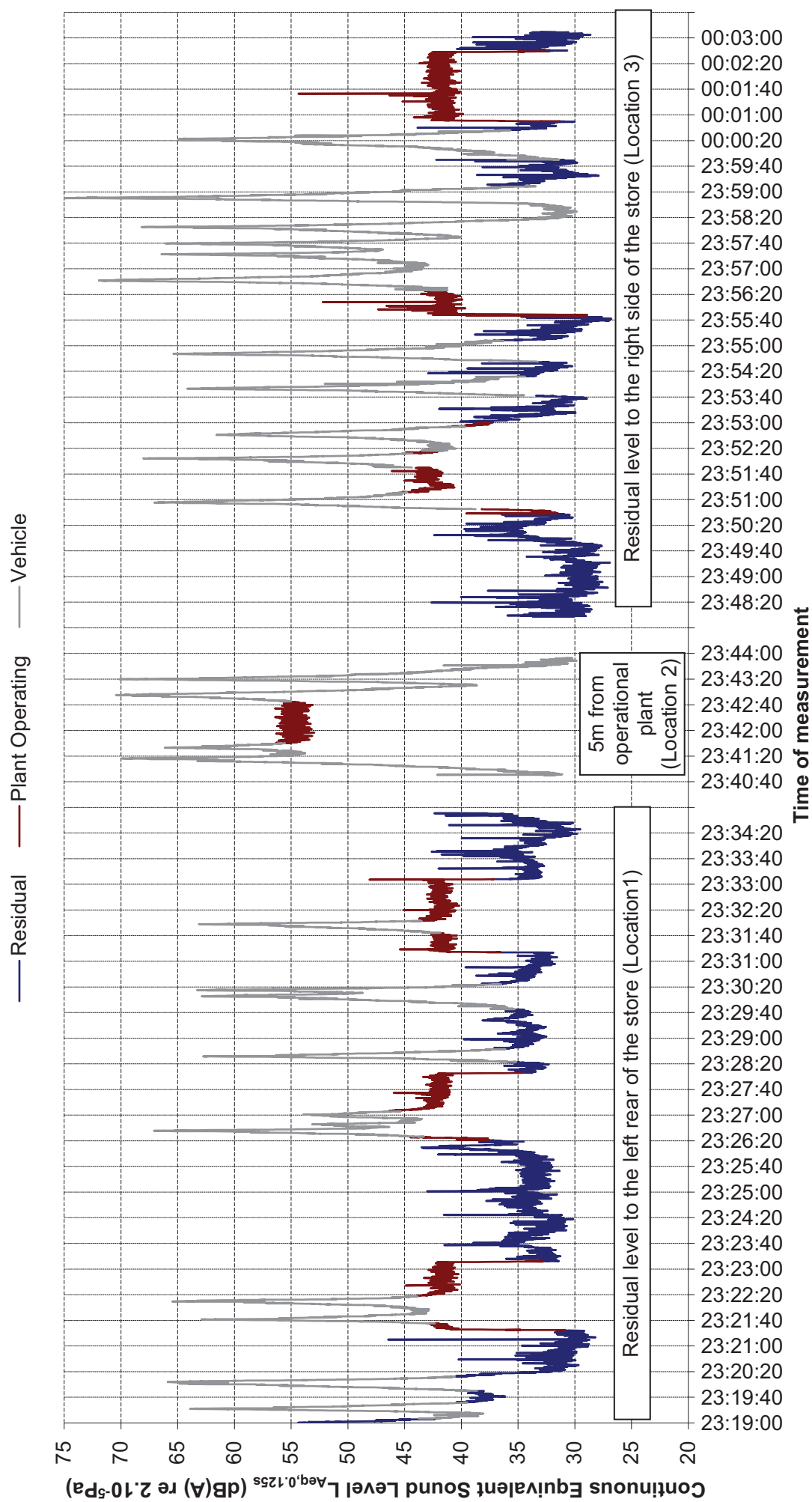
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Graph 1 - Existing ambient sound level in vicinity of Petrol Coedpoeth Store, Wrexham
Measured 7th and 8th February 2012





EXPLANATION OF SOME ACOUSTIC TERMINOLOGY

Sound is measured in terms of decibels (dB). There are many different methods of assessing the loudness of a sound. The most frequently used is the 'A Weighting', which simulates the effect of the human hearing mechanism. This method is widely used for sound assessment and the resulting level is expressed as dB(A). The table below gives an indication of different sound levels in terms of dB(A).

Sound Level dB(A)	Sound Source
0	Threshold of hearing
20	Recording Studio
40	Living Room
60	Conversational Speech
80	Light Factory Noise
100	Discotheque
120	Road Breaker
140	Threshold of pain

For a steady, continuous sound, a change of 1dB(A) is just perceptible to the ear. In the case of intermittent sounds, the change must be at least 3dB(A) to be perceptible. For steady sounds, a difference of 10dB(A) sounds twice as loud.

Unwanted sounds are classed as noise, these are a fundamental part of life. The level of such noise changes constantly. This may be due to dogs barking, telephones ringing or even during normal conversation. As a consequence, some method of quantifying the overall level of noise is required.

The equivalent continuous sound level (L_{Aeq}) is the level averaged over a specified period of time. This is widely used for both measurement and assessment. Because the L_{Aeq} is an average level over a specified period of time, a steady continuous sound and a shorter duration sound at a higher level can have the same L_{Aeq} over the same time period.

The level exceeded for 90% of the time (L_{A90}) is frequently used to determine the level of background noise. It ignores the loudest 10% of the measurements obtained. Therefore, although it does have a useful purpose, it takes no account of what happens for 10% of the time. This parameter together with the L_{Aeq} and the level exceeded for 10% of the time (L_{A10}) give a fairly good overview of the prevailing acoustic environment.

When A weighted, the maximum sound pressure level measured during a period is termed L_{AMax} . This gives an indication of the intrusiveness of a noise event, which is lost with the averaging effect of the corresponding L_{Aeq} .



EXPLANATION OF SOME ACOUSTIC TERMINOLOGY Cont'd

Different sound sources produce an overall level that depends upon the louder source and the difference in sound level between the two sources. If the difference is within 1dB, they act as identical sources, with the overall level being 3dB greater than the louder source. If the difference is 2dB or 3dB, the overall level is only 2dB greater than the louder source. For example, if a machine produces 84dB and a second machine produces 82dB, the overall sound level will be 86dB. This is summarised in the table below:

Difference in Levels (dB)	Increase in Level (dB)
0,1	3
2,3	2
4..9	1
10+	0

The sound level rises as a point source becomes closer. This increase is 6dB for every halving of distance. The effect is similar to the addition of sound sources, but with changes of 6dB rather than 3dB. A machine that produces 80dB at 200m will produce 86dB at 100m and 92dB at 50m. This effect is summarised in the table below:

Ratio of Distances	Increase in Sound Level (dB)
2	6
3	10
4	12
10	20
20	26

The **A Weighting** system attempts to replicate the way in which the human hearing mechanism works. An A Weighted sound is expressed as a single value in terms of **dB(A)**. This allows the loudness of different sounds to be compared, the louder having a higher level in dB(A).

Whilst a single figure value is ideal for noise assessment purposes, it is inadequate for noise control requirements. This is because the most appropriate control techniques will be dependent upon the characteristics of the noise.



EXPLANATION OF SOME ACOUSTIC TERMINOLOGY Cont'd

In this case, the noise is analysed in terms of its frequency content, from a low frequency rumble to a high frequency hiss. To achieve this, eight octave bands are normally used. This set of eight values is termed a **sound spectrum** and analyses a sound in terms of frequency content as the table below shows:

<u>Octave Band Centre Frequency (Hz)</u>	<u>63</u>	<u>125</u>	<u>250</u>	<u>500</u>	<u>1k</u>	<u>2k</u>	<u>4k</u>	<u>8k</u>
	low frequency				high frequency			

The A Weighting system simulates the effect of the average human hearing mechanism by weighting each frequency and adding the corresponding levels. In an attempt to improve on this, Beranek developed the Noise Criterion (NC) curves. These show equal loudness levels at different frequencies. As such, if a sound spectrum matches a given NC curve e.g. NC 40, all octave bands will sound equally loud. This would equate to a level of approximately 49dB(A).

Kosten and Van Os then adapted the NC system specifically for room design and produced the Noise Rating (NR) system. Broadly speaking the two systems are equivalent. A major advantage of the NC or NR system for noise control purposes is that noise which meets a required curve will not have a significant tonal content, making it much less intrusive.

While the sound pressure level (L_p) is useful, this only provides information about the sound level produced by a source at a particular point in space. It cannot immediately let us compare one piece of machinery against another because it depends upon where the meter is located.

The sound power level (L_w) is used to describe the sound energy output from a machine, independent of location. This is the amount of energy that the machine converts to sound energy, considered on the decibel scale. There are conversion factors we can use to convert a sound pressure level reading into a power level reading. These conversion factors rely on the surroundings of the machine being reasonably simple. For example, to rely on the conversion factors, we would not want buildings or uneven ground between the plant and the sound level meter.



REFERENCES

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- 2 CEC. EUR Report 5398e.
Damage and Annoyance Caused by Noise (1975).
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- 4 CIBSE & ASHRAE:

Guide to Current Practice,
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- 5 BS 4142 : 1997
Method for Rating industrial noise affecting mixed residential and industrial areas
BSI, 1997

