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ACOUSTIC ASSESSMENT OF NOISE FROM REFRIGERATION/AIR CONDITIONING PLANT AT CO-OP, HIGH STREET, SHOREHAM

PLANNING DEPARTMENT
PLAN No. AS/0146/09
15 APR 2009

Client: The Co-operative Group
Old Bank Building
Hanover Street
Manchester
M60 0AB

Instruction: Mr Kumar Gajula
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: **If the plant is located on the roof of the Store at an appropriate location, the cumulative global average 'free field' sound pressure level should not exceed 35dB(A) at a distance of 10 metres from the plant when operating at maximum night time capacity. If the plant is located at ground level in the well, this criterion should be reduced to 24dB(A). In either case, this should be achieved with the use of inverter speed control systems and noise from the plant should not contain significant tonal or impulsive components.**

Survey: Time – 21:00 hours – 21:30 hours and 22:50 hours – 23:30 hours
Date – Monday 7th January 2008
Weather – Light breeze, no cloud, approximately 5°C – 10°C, dry ground surfaces, no precipitation.

Personnel: R A Collman – Belair Research Limited

Instrumentation: B&K Modular precision sound analyser type 2260, Serial No. 2350037
B&K Calibrator Type 4231, Serial No. 2085051
B&K Windscreen Type UA 0237

Tripod

Observations:

The Store is a single storey building on High Street, Shoreham. It is between multiple storey premises at both sides with Church Street to the right (when viewed from the front of the Store) and Middle Street to the left. Dwellings are located to either side of the Store and above shops along the opposite side of High Street approximately 20 metres in front of the Store.

Two three fan condensers and one air conditioning condensing unit are located on the flat roof of the Store at a distance of approximately 8 metres from the nearest dwellings. An acoustic plant enclosure is situated in a well at ground level beside the Store approximately 3 metres from the nearest dwelling.

The location plan towards the end of the report shows the layout of the Store and surrounding area, together with 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 pedestrians – particularly when conversing, occasional aircraft and plant located elsewhere.

Close to the plant at the Store, the noise level from the plant tends to dominate the soundscape when the plant is operating. At greater distances, the significance of noise from the plant decreases but still remains a significant component of the ambient sound level at the nearest dwellings.

Measurements:

Sound pressure level measurements were taken at two 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 instantaneous sound pressure levels recorded every one tenth of a second 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 in 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 first series of measurements shows the ambient sound level at a distance of 2.5 metres from one of the condensers. The residual sound level (in the absence of noise from plant at the Store) varied between approximately 45dB(A) and 55dB(A). However, when one of the condenser fans started operating at approximately 23:06:50 hours, the ambient sound level rose to approximately 60dB(A).

The second series of measurements was taken at the same location with the fan running continuously. This is consistent with the first series of measurements, showing an ambient sound level of approximately 60dB(A whilst the fan was running.

The third series of measurements was taken at another location on the roof when plant at the Store was not operating. This shows that, as for the first part of the first measurement series, the ambient sound level varied between approximately 45dB(A) and 55dB(A) at this location.

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 to NR30. 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 to NR30 equates approximately to 38dB(A) to 43dB(A) outside the dwellings.

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 operating fans 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. This means that by selecting plant to achieve suitable noise levels at night, suitable levels of noise are produced during the day time.

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 43dB(A) at the nearest dwelling when operating at maximum night time capacity. 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 higher 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 lower than 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.

Correcting the measured level of approximately 60dB(A) at 2.5 metres from the condenser for the additional distance to the nearest dwellings gives a corresponding level of approximately 50dB(A). However, this level was measured with only one fan operating. The corresponding level will therefore increase as more fans operate, rising to approximately 53dB(A) with two fans and 55dB(A) with three fans, for example. In addition to the excess above a 'suitable' level of noise, the relatively sudden change in level, particularly as the first fan commences or ceases operation will tend to draw a listener's attention to this source of noise. Therefore, if complaints were to be received from these residents regarding this level of noise, it is likely that they would be found to be justifiable.

Manufacturers generally state the noise (sound pressure – Lp) level that their plant will produce at a specific distance from the plant. The sound power level (Lw) 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.

Much 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 8 metres from the nearest noise sensitive windows the noise level at the windows will be 2dB(A) higher than at a distance of 10 metres from the plant. As there will be a direct line of sight between the plant and windows the noise level at the windows will be the same as that measured under 'test' conditions. Sound will also be reflected from other surfaces in the area where the plant will be installed. This will increase the resultant sound level at the nearest noise sensitive windows by 6dB(A) in comparison with the 'free field' conditions used for manufacturer's stated performance.

This is based on plant being installed on the roof of the Store. If it is installed in the well at ground level, it will be approximately 3 metres from the nearest dwellings, which means that the corresponding sound level will be 10dB(A) higher than at a distance of 10 metres from the plant. Furthermore, the reverberant effects will be more significant than on the roof of the Store, increasing the corresponding sound level by approximately 9dB(A) instead of 6dB(A).

This means that, for plant located on the roof of the Store, the noise level at the windows nearest to the plant will be 8dB(A) higher than at a distance of 10 metres from the plant under 'free field' conditions. Therefore, in order to achieve the identified 'suitable' level of 43dB(A) at the nearest noise sensitive windows, the plant should be selected based on a cumulative global average free field sound pressure level of 35dB(A) at a distance of 10 metres from the plant, when operating at maximum night time capacity. 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.

If the plant is installed at ground level in the well, the noise level at the windows will be 19dB(A) higher than at a distance of 10 metres from the plant under free field conditions. In this case, the criterion should be reduced to 24dB(A).

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. This is exacerbated by the relatively sudden change in level, particularly as the first condenser fan commences or ceases operation.

If plant is located on the roof of the Store, it should be selected based on **a cumulative manufacturer's free field global average sound pressure level of 35dB(A) at a distance of 10 metres from the plant.** This is to achieve the identified 'suitable' level of 43dB(A) at the nearest dwellings. Alternatively, if the plant is located at ground level in the well, the selection criterion should be reduced from 35dB(A) to 24dB(A).

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. 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.

Richard A Collman

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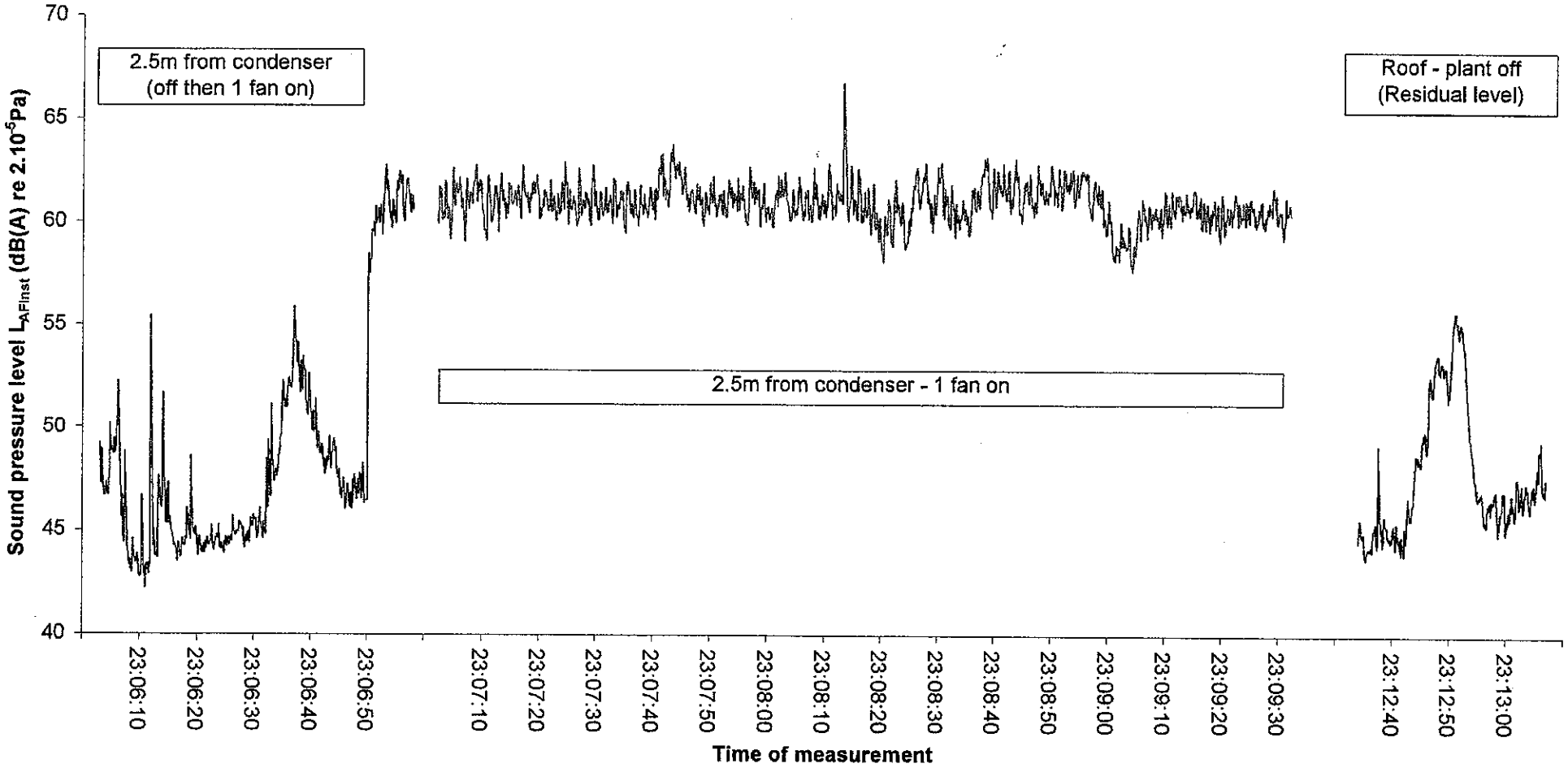
Graph 1 - Existing ambient sound level in vicinity of Store
Measured 7th January 2008



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. Because of this, 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 90% of the measurements obtained. Therefore, although it does have a useful purpose, it takes no account of what happens for 90% 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 (dB)	Increase in Sound Level
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:

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
	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 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 1 piece of machinery against another because it depends upon where the meter is located.

The sound power level 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 I would not want buildings or uneven ground in between the plant and the sound level meter. Lp denotes the sound pressure level, whereas Lw denotes the sound power level.

REFERENCES

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