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ACOUSTICS BULLETIN

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Approaches to noise control prioritisation for industrial plant

What is the Background Sound Level?

Institute of **Acoustics**

Approaches to noise control prioritisation for industrial plant

By Nathan Thomas

Introduction

Over recent decades the negative health impacts of noise pollution and noise exposure have become better understood. This has led to a range of environmental regulation and workplace health and safety legislation which requires noise to be controlled at source.

The Noise Policy Statement for England (Reference 1) reflects changing policy priorities, with industrial plant operators having a requirement to mitigate and minimise adverse impacts on health and quality of life; and where possible contribute improvements.

Industrial sites have a number of drivers requiring the control of noise at source. This can be as a result of permitting requirements the demonstration of best available techniques, or to reduce occupational noise exposure. Retrofitting noise control to existing industrial plant can present engineering challenges and potentially high cost, therefore it is important to ensure that the most significant noise polluters are identified along with effective mitigation measures.

During industrial plant upgrades, when existing plant noise emissions are close to environmental noise limits, engineers are often required to design extremely low noise equipment. This can present complex engineering challenges and high cost. In many cases upgrade projects focus on the noise control options available for new plant, without considering potential control options for existing plant.

This paper presents a roadmap for identifying effective noise control mitigation measures at the lowest cost to industry. It includes considerations for a combined approach to identifying the most significant noise polluters which can reduce survey time and therefore cost. It also presents an approach to cost benefit analysis to assist in identifying the most cost-effective combination of noise control mitigation measures.

Environmental noise modelling

Environmental noise can be evaluated by the specific noise level due to the industrial plant received at chosen receptor locations. Noise limits will often be defined with reference to noise levels at the closest sensitive receptor.

All the individual noise sources on an industrial plant combine together to give the cumulative noise emission from the plant and contribute to noise levels at receptor locations. In order to select the most appropriate noise control solution an understanding is required of the most significant contributors to noise at receptor locations.

Evaluation of the impact of key noise sources at receptor locations and the benefits of various control options is most easily achieved using a noise model. If the sound power of all existing

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and proposed plant items can be determined, a noise model can predict the cumulative noise imission at receptor locations and identify the most significant noise polluters. These items can then be targeted for noise control mitigation measures.

Determining plant noise emission

A common approach to determining the existing noise emission of an industrial plant can be termed as the “full detail” method, whereby measurements are conducted to determine the sound power of every individual plant item. These are entered into a noise model which is used to predict specific noise levels at receptor locations.

Measurements at receptor locations can then be used to calibrate the noise model, correcting for factors such as source directivity, reflections, absorption, screening and ground effects. When the noise model and environmental measurements have a good correlation, this gives confidence to the accuracy of the model, and allows different noise control scenarios to be evaluated.

Whilst an effective approach, the “full detail” method is time consuming, potentially impacting both survey cost and schedule. This method does however give us two key pieces of information:

- Overall noise emission of the plant; and
- Most significant contributors to plant noise emission.

Knowledge of these is key to developing a noise control strategy. The question that arises is whether these key pieces of information can be determined without obtaining full details of every individual plant item.

In some cases it is possible to estimate the overall noise emission of the plant using environmental measurements and measurements at the plant boundary. This however, doesn’t demonstrate the key noise sources. Identifying areas of plant containing the key noise sources, and excluding less significant areas of plant from a detailed study, can give similar results with a significantly reduced survey time.

If the plant is broken down into discrete modules, sound power estimates can be conducted for these. It will then be possible to identify modules which do not make a significant contribution to plant noise emission. These modules can be included in the noise model, but discounted from a more detailed measurement exercise.

Figure 1 presents an industrial plant with discrete modules identified.

Modules identified as making a significant contribution to noise emission can be rank ordered and detailed measurements conducted to identify the key plant noise sources. In this way both the overall plant noise emission and key sources can be identified, potentially with a significant saving in survey time.

Module sound power estimation

If plant modules are spaced far enough apart distance measurement methods can be used to estimate the sound power of individual modules. If a module does not contain significant numbers of elevated sources, measurements of sound pressure level can be conducted at a distance of at least one times the largest source dimension, back from the assumed acoustic centre of the plant. Normally four directions will suffice, with measurements ideally conducted at a height of at least 4 m.

Figure 2 outlines this approach to measuring at distance.

This assumes that other modules will be far enough away not to influence the measurements. Modules on many industrial sites will be placed too close together for such an approach to be valid, so other methods are required.

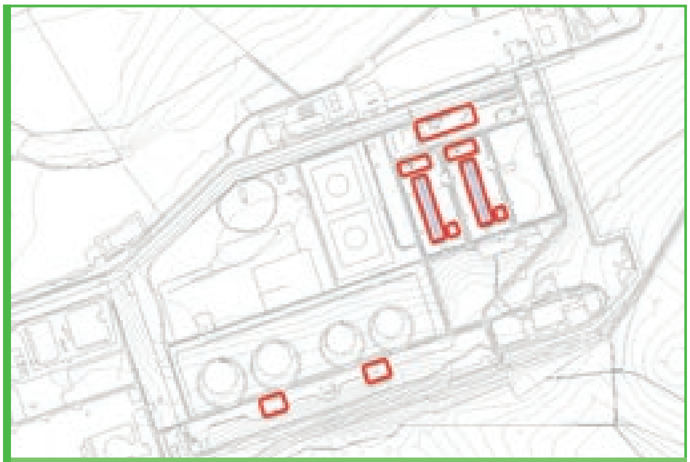

Figure 1. An industrial plant represented as discrete blocks

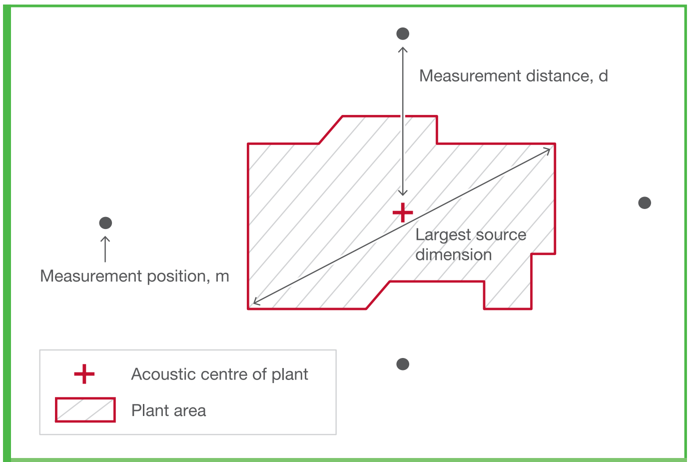

Figure 2. Distance measurement method

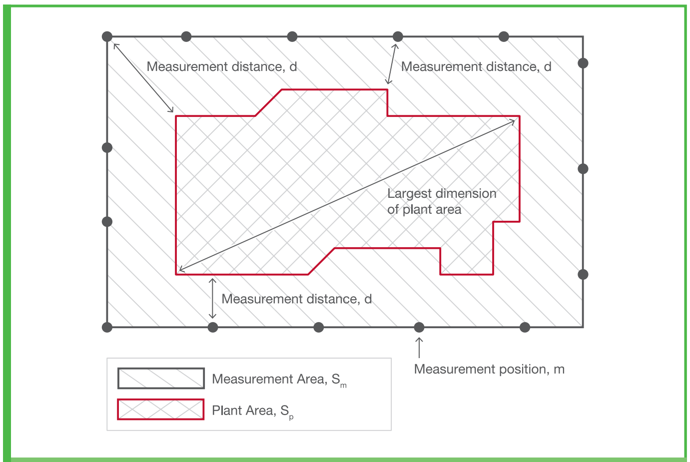

Figure 3. ISO 8297 measurement method

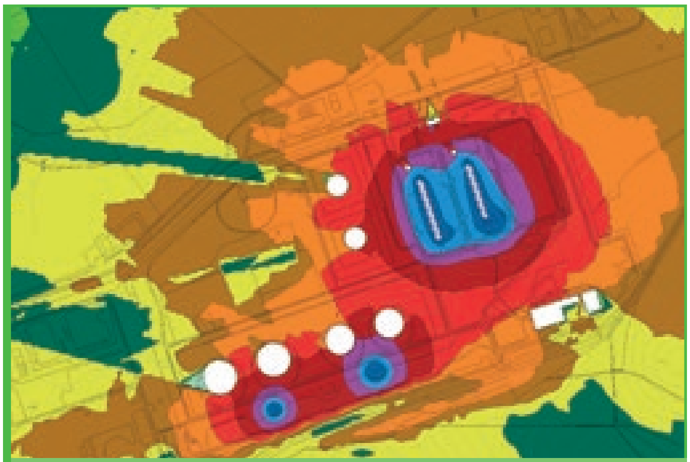

Figure 4. Noise contour plot of an industrial plant, obtained using the ISO 8297 measurement method

ISO 8297 (Reference 2) specifies an engineering method for determining the sound power level of multi-source industrial plants for the assessment of noise in the environment. The standard presents an approach which allows acoustic measurements to occur much closer to a module. This reduces the problem of other nearby noise sources influencing the results. The standard is based on the measurement of sound pressure levels on a closed path surrounding a module with sources combined and treated as a single source at the geometrical centre of the plant.

Figure 3 outlines this approach to closed path measurements

This method was first proposed by Stüber in 1972 and submitted to ISO for consideration as a standard in 1982. The standard is applicable to industrial areas where most of the equipment operates outdoors and for which the largest horizontal dimensions of the plant area lie between 16 m and 320 m. It is understood that these limitations are based on the limits of the measurement exercises carried out when developing the method, rather than acoustical or physical constraints. A key assumption of the standard is that the sound power is uniformly distributed across the module area, with noise radiation substantially uniform in all directions.

The allowable distance of the measurement points to the perimeter of the noise sources is very precisely defined, varying from 5 m to 35 m, with a defined spacing between the measurement points, on a fully closed path. The standard has a requirement for background noise levels to be 6 -10 dB lower than the industrial source, which often requires measuring at the lower distance limit of 5 m from the source.

The height of measurements around the industrial plant needs to be determined from the average height of the sources on the site and the plant measurement area. For modules with a large area, the measurement heights suggested by the standard can be difficult to implement practically; for example, a 1 km^2 area would require a measurement height typically greater than 30 m. The standard does allow for this and states that the microphone should be placed as high as possible above the minimum height of 5 m. Elevated sources of noise (such as airfin coolers and exhaust stacks) are excluded from the method and need to be measurement separately.

The method was initially intended for whole site evaluation, however, reliable results have been obtained when used for measurement of specific modules within industrial sites. Other published work in this field suggests that for larger sites, it can be more effective to determine the sound power of individual modules separately, as proposed in EMMUA 140 (Reference 3) and DEFRA (Reference 4).

An example industrial site noise contour plot with sound power data obtained using this method is shown in Figure 4.

The next phase is to rank order the modules making the most significant noise contribution at sensitive receptors. Detailed measurements can then focus on these specific areas.

Detailed sound power determination

Once key modules have been identified detailed measurements are required to determine key noise sources. Measurement options for detailed source identification include sound pressure, sound intensity and vibration velocity. Some of the benefits, drawbacks and practical considerations of the different measurement systems are discussed here.

Sound pressure measurements can be used to determine the sound power of individual items of plant such as the methodology presented in ISO 3746 (Reference 5). This can be effective when background noise is low, and free-field conditions can be assumed. This is rarely the case on many industrial sites where acoustic environments are often acoustically congested and excluding extraneous noise from measurements is problematic. This can lead to large uncertainties tending to overestimate source strength (if influenced by extraneous noise).

Sound intensity is generally preferred for determining individual source strengths in acoustically congested environments. Sound intensity is a vector quantity which provides a measure of the magnitude of noise travelling in a given direction. As such it can

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reject off axis noise and give a specific measurement of a particular sound source.

Sound intensity can be determined using either two phase matched microphones (p-p probe) spaced apart by a known distance, or by a combination of a microphone and particle velocity transducer (p-u probe) which determines particle velocity using ultrasonic transduction. There is evidence to suggest that this form of p-u probe is more sensitive to turbulence and unsteady flow than p-p probes (Reference 6). P-p probes are therefore currently considered more robust for measurements in outdoor environments. A phase matched microphone arrangement is shown in Figure 5 which measures sound travelling parallel to the probe axis.

Standard intensity measurement methods are either via surface scanning, or by measurement at discrete points. The scanning methodology presented in ISO 9614-2 (Reference 7) is more appropriate for measurements outdoors on industrial plant. Discrete point methodologies can be time consuming, and requires a standard of repeatability which can be hard to achieve in the fluctuating meteorological conditions typically encountered outdoors.

Engineers must be aware of the limited frequency limits of intensity measurement systems. Increasing the microphone spacing lowers the applicable frequency range of measurements. Measurements using two different spacings may be required if accurate results are needed in each of the nine key octave bands from 31.5 Hz to 8 kHz. It can often be helpful to first evaluate environmental measurements and determine the most critical frequency bands of noise imission at sensitive receptors. For many sources accuracy may not be required at frequencies below the 125 Hz band for instance. If pressure measurements from one of the microphones will suffice at these frequencies then measurement time can be reduced (not to mention the practical implications of changing small intensity spacers on site, whilst wearing industrial gloves).

Figure 5. Sound intensity probe

Sources with a high sound power due to a large radiating surface area (such as pipework and ducting) can have relatively low sound intensity levels. In these cases measuring either sound pressure, or the positive intensity vector on an acoustically congested site can be difficult and direct measurement of surface vibration levels can give more effective and repeatable results. Vibration velocity is directly proportional to surface sound pressure, therefore if the radiation efficiency of the surface can be established, then the item sound power can be determined.

The benefit of this approach is that, like intensity, extraneous noise is excluded from the measurements. A measurement procedure is presented in ISO/TS 7849-1 (Reference 8). The drawback of this standard is that it assumes a radiation efficiency of 1. Figure 6 presents a typical radiation efficiency curve for a steel pipe. This demonstrates that sound radiation is less efficient at low frequencies, tending to 1 at frequencies above the critical frequency.

The inherent assumption of ISO/TS 7849-1 may give acceptable accuracy at higher frequencies, but is generally not applicable for cases where lower frequencies are of interest (which are usually required for environmental noise control).

A method for establishing radiation efficiency is presented in ISO/TS 7849-2 (Reference 9) however this requires determining the radiation efficiency by first establishing machinery sound power using intensity. Clearly for this application, if the sound power can be determined using intensity then there is no requirement for vibration measurement! A more practical approach is to estimate the radiation efficiency for different types of vibrating surfaces using established methods presented in the literature. These include methods for pipes (Reference 10) and plates (Reference 11).

Evaluation and cost benefit analysis

Once a noise model is constructed to include the noise emission from both existing plant and any new plant, the future predicted specific noise level at sensitive receptors can be determined. The most significant noise sources can be evaluated for potential noise control mitigation.

To produce a cost benefit analysis, a measure of benefit needs to be determined. Typically this would be the reduction in specific

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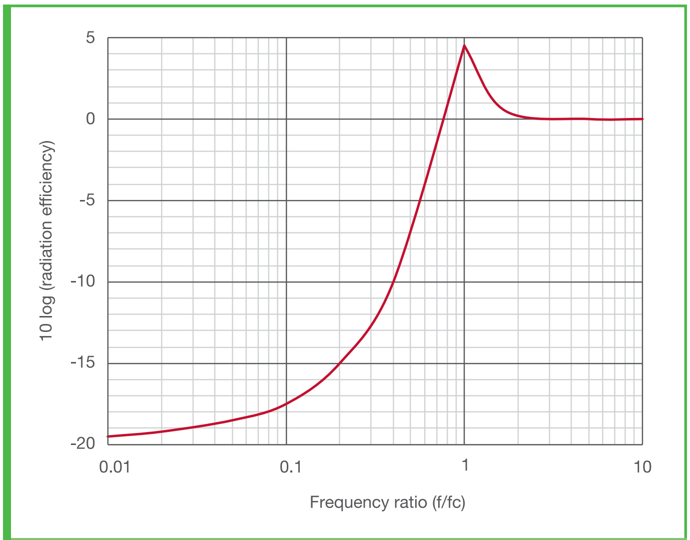

Figure 6. Typical radiation efficiency curve

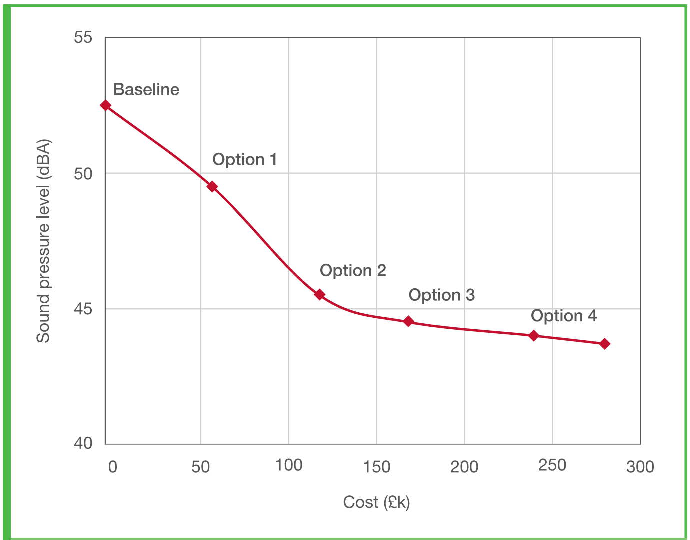

Figure 7. Typical cost benefit analysis curve

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noise level at the closest sensitive receptor, however for very large sites with multiple receptors, more complex analysis may be appropriate.

The base cost of each noise control option can be acquired from hardware vendors, for input into a cost-benefit analysis. When estimating costs, consideration should be given to materials, installation cost and any ongoing maintenance that may be required for a particular control option.

Inclusion of cost benefit analysis is recommended for the evaluation of Best Available Techniques (BAT). Cost may be a factor in justifying whether particular options can be considered 'available'.

Once the costs and benefits have been determined it is often useful to plot the cumulative cost and benefit. An example cumulative cost benefit plot is presented in Figure 7. The relationship shown, between cost and benefit, is typical for such an exercise. There is often a point where additional noise control will increase cost but give diminishing returns in noise reduction. Treating the most significant noise sources first will typically yield the best result, unless costs are an order of magnitude higher than costs for treating less significant sources.

Conclusion

A roadmap for identifying effective noise control mitigation measures at the lowest cost to industry has been presented. It includes considerations for a combined approach to sound power determination and cost-benefit analysis.

When applied intelligently, combining sound power estimation techniques with detailed sound intensity and vibration velocity measurements can offer significant efficiencies in survey cost and schedule.

Conducting a full plant noise survey in this way, allows a full range of noise control options to be evaluated. This enables detailed cost-benefit analysis to be conducted and the most cost-effective combination of noise control mitigation measures to be determined.

This approach will give plant operators confidence to robustly demonstrate the use of best available techniques and meet their obligations under environmental legislation.

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Design and acoustic performance of a spring isolated outdoor rooftop sports court

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Abstract

The proposal of a rooftop sports court created an issue of significant impact/footfall noise and structural vibration ingress to the sensitive environment beneath. As part of a new building now occupied by Medibank in a dense urban environment in Melbourne, a unique solution had to be designed due to the maximum weight capacity of the underlying rooftop structural slab and FFL design controls. Further challenges were faced in the form of fluctuations of up to 30 mm in the level of the underlying structural slab and subsequent excessive deflection caused by a relatively high live load. The final design incorporated the use of over 300 cast in 'jack-up' style mounts complete with 25 mm deflection springs within a 100 mm secondary concrete slab covering an area of approximately 630 m^2. Installation of the court encountered few problems and upon completion small deflections of the slab could be felt underfoot however there were no unfavourable 'trampolining' effects generated by live loads. Completion testing showed a significant reduction in impact noise levels between the isolated court and an exposed portion of the structural slab.

Keywords: Impact, Sports, Transmission
I-INCE Classification of Subjects Number(s): 51.4

Introduction

Basketball courts are subject to frequent impact forces from bouncing balls and people jumping. Typically basketball courts are constructed at grade to avoid issues of noise and vibration transmission through connected structures. In this case, a combined basketball/netball/tennis court was to be constructed in a dense urban environment, and limited spatial availability necessitated that it had be located on a rooftop directly above commercial space. Without sufficient vibration isolating measures, the impact forces from activity on the court would likely cause distracting noise to the people below in the connected structure.

The structural floor was a 150mm composite slab with large transfer beam spans which yielded a relatively low natural frequency for the structural slab (see Section 3.1). The natural frequency of the courts system needed to be calculated carefully to avoid resonance with both the underlying structural slab and with activities such as footfall and ball bouncing.

The proposed court size was approximately 630m^2 and the finished court height was restricted to 150mm from the structural floor. The court system was also to contain several large penetrations for poles which were to be supported from the structural slab. Other design constraints included the support capacity for a live load of 5kPa and an allowance for appropriate drainage measures.

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