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noise notes

ISSN 1475–4738

noise notes is published quarterly by

Multi-Science Publishing Co. Ltd.

5 Wates Way, Brentwood, Essex, UK

Tel: +44 (0)1277 224632 · Fax: +44 (0)1277 223453

email: mscience@globalnet.co.uk · ©Multi-Science Publishing Co. Ltd.

Noise from air-cooled chillers

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The use of air-cooled chillers in external locations requires careful assessment of the level of noise generated. Peter Brown gives an acoustic consultant's view of some of the potential pitfalls associated with noise levels and equipment selection.

Packaged chillers, comprising closed circuit refrigeration, with a compressor, evaporator and condenser in one unit, have long replaced evaporative cooling systems for most applications.

The air-cooled chiller is often located outside the building - usually at roof level, to ensure an unrestricted supply of air to the condenser fans. This external location means that noise generated by the chiller must be assessed carefully in terms of break-back into the building through smoke vents, atria etc., and also to nearby property. In this latter case it is very possible that there would exist a Local Authority Planning Condition in relation to maximum permissible environmental noise emissions.

Any form of acoustic assessment would require equipment manufacturers' data. This can vary in form and needs careful technical interpretation to make sure that appropriate comparisons are being made. The acoustic specification can be an important influence on the cost and space requirement of the final equipment selection.

MEASURED NOISE DATA

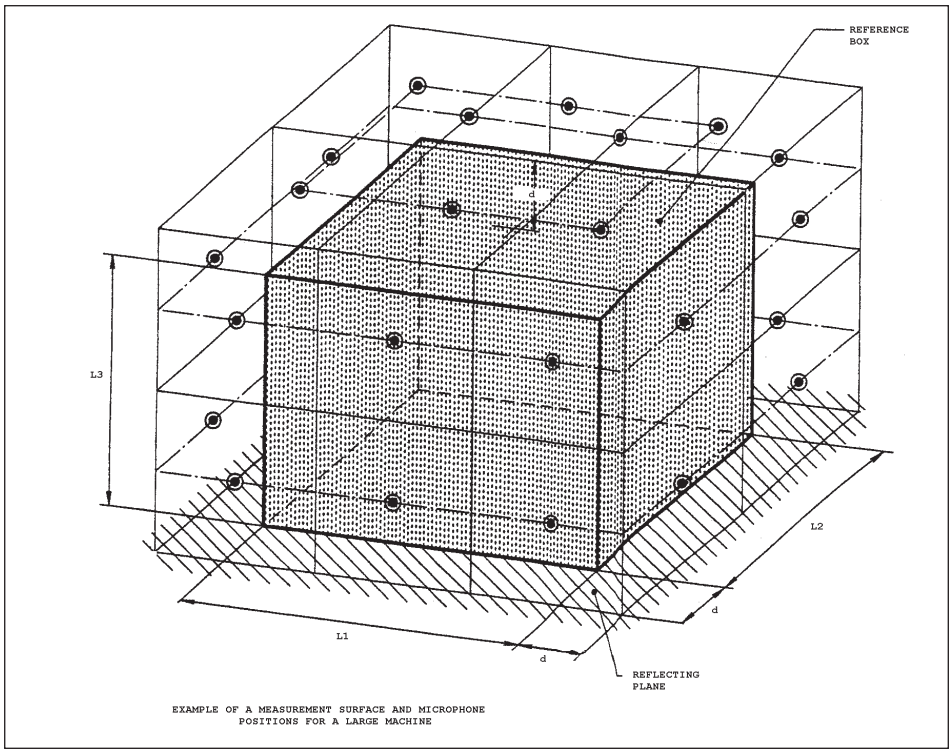
It is necessary to make objective comparisons between the noise output of different makes and models of chiller – and this is where confusion can exist.

Noise data can be expressed as sound *power* level or sound *pressure* level at a distance.

The use of sound power level information is the more accurate way of comparing overall noise output between machines, but it is not a parameter that can be directly measured. To determine sound power level, it is necessary to average a number of sound pressure level measurements at a distance and make corrections for the radiating surface area. International Standard ISO3744 is usually adopted as the preferred method for testing and calculation of sound power level.

Although sound power levels are a convenient and accurate way of comparing overall noise output, information on the directional characteristics of the source is generally not provided. This can make difficult the subsequent prediction of near-field sound levels.

The most useful way to specify a limiting noise level for equipment such as chillers is to detail a maximum permissible sound pressure level at a distance, which could be verified for conformity by way of a job specific factory test. Measurements should be taken in an essentially free field over a reflecting plane. In practice, these are usually taken out-of-doors at a number of prescribed positions around the equipment. Although it is appreciated that a chiller is not easily set up to operate very far from power and heat loads, the unit should not be situated close to reflective surfaces that would influence noise readings. (ISO 3744 provides guidance).



Example of a measurement surface and microphone positions for a large machine

BUILDING ABOVE THE TRACKS

Many urban centres are feeling population pressure: where to put all the extra people? Building residential apartments over railway lines is one possibility that is increasingly being looked at. But a report to Australia's RailCorp had said that any such development is inherently problematic. A major problem is the response of developers to a rail body's vibration standards. The report says, "History has shown us that … developers will always seek to have the rail-imposed requirements relaxed." It goes on to cite the example of a Sydney developer who fought to have vibration standards relaxed on his apartment building. The report's author argues this sort of thing is not just a local problem but that generally rail authorities have found that "developers are not only disappointed at the apparently inordinate costs of development over a railway, they become extremely agitated and feel compelled to raise the issues at political forums, and accuse rail authorities of sterilising good development land through outrageous expense and ill-conceived requirements."

The preferred measurement distance is one metre.

Measurements at distances greater than one metre – commonly 3m or 5m – can also be useful, particularly if the ultimate distance of interest is greater still. If the proposed installation location for the machine is overlooked by a noise sensitive location then measurements above the machine will be necessary and in this context a measurement distance of one metre above a machine is more accessible in practical terms than a position further away. With all measurements, background noise levels should be at least 6dB below – preferably 10dB or more below – the noise source level to be recorded. Once again the requirements are laid out in ISO3744.

MANUFACTURERS' NOISE DATA

At the initial design stage of a project, the consultant is reliant upon data provided by potential suppliers. Busy sales staff often do not focus on the differences between sound power levels and sound pressure levels. In either case, the method of calculation or the standard used is often unclear. This can lead to uncertainty over the accuracy of such figures.

Octave band values are sometimes 'A' weighted, which understates low frequency content. Often it is not clear whether the 'A' weighting has been applied or not. This gives rise to further uncertainty.

It is necessary to assess these different forms of data presentation and to convert them to a common format appropriate for equipment comparison and assessment.

A chiller can be considered a large noise source made up of a number of individual sources. At the preferred measurement distance of one metre from the chiller, an imaginary parallelepiped (or 'square box') measurement surface of total surface area, S m^2, is constructed around the machine. If sound power levels are provided, then the following is true:

Sound Pressure Level at 1 m = Sound Power Level minus 10 log $S_{(1m)}$.

This procedure can be used for computing levels at alternative distances. For distances greater than about five metres, the hemisphere surface area can be used but the distance should be measured from the geometric centre of the chiller and not its surface.

The use of sound *power* level data has the potential to introduce errors. The manufacturer takes many measurements at a given distance, averages them and works out correction factors to produce a sound power level, which is then tabulated for the product data sheet. The engineer evaluating the data for a project will then be working in reverse. A calculation of sound pressure level to the original distance will invariably produce a different value. This is due to variations in the shape of the measurement plane, lack of directivity data and the general complexity of predicting near-field noise levels.

If the manufacturer provides sound *pressure* levels though, then the reduction from one distance to another can be obtained by:

$$10\log\frac{S1}{S2}$$

…where S1 is the parallelepiped surface area based on distance d1 from side of chiller, and S2 is the parallelepiped surface area based on distance d2 from side of chiller.

Again, this may be applied for distances up to about five metres. Hemispherical considerations would normally be used at greater distances, that is, at distances beyond the 'near-field' of the equipment.

CONSIDER A CHILLER OF 5M LONG X 2.5M WIDE X 2M HIGH.

The surface area of the imaginary five-sided 'square box' constructed at a distance of one metre from the chiller faces equals

$$S1 = 100.50\ m^2.$$

At a distance of five metres, the total surface area equals

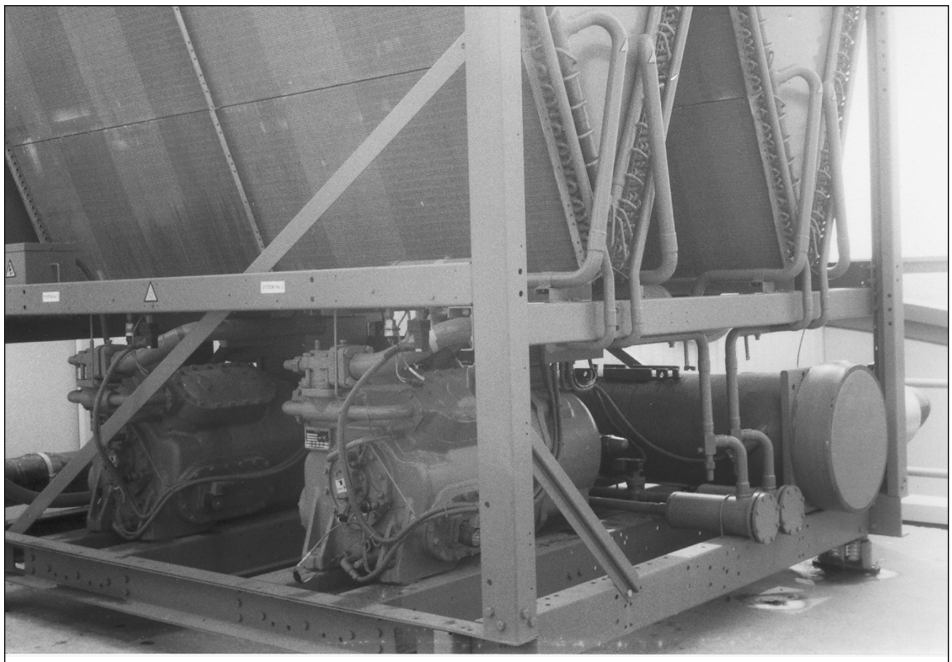
$$S2 = 572.50\ m^2.$$

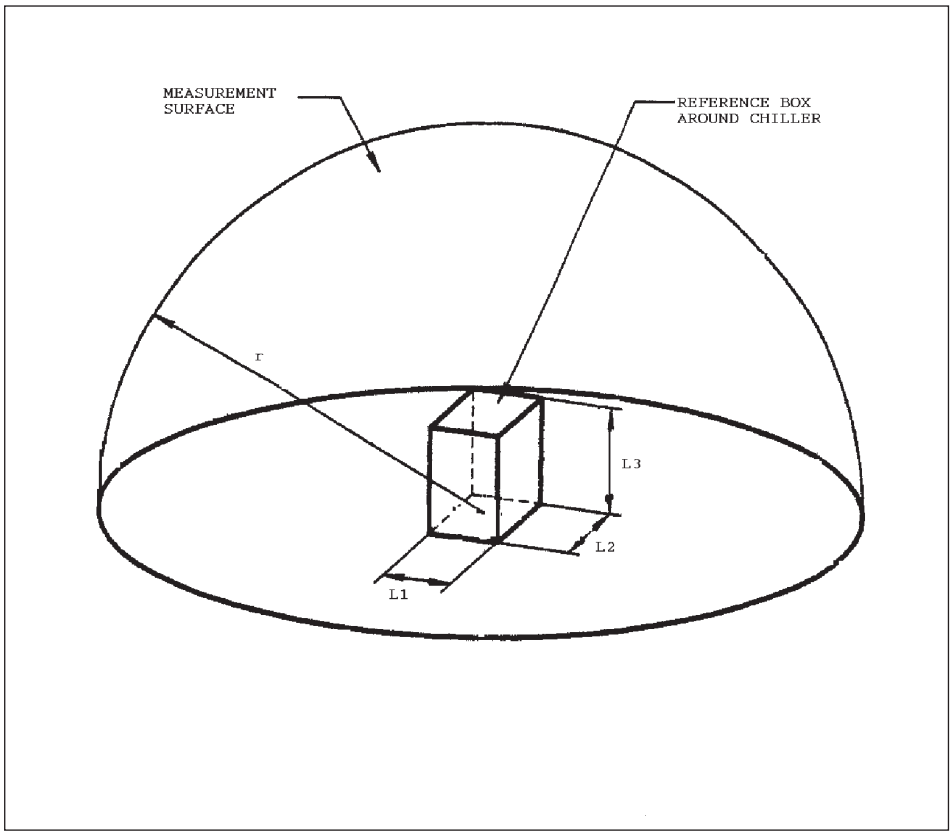
The sound reduction from one to five metres is given by:

$$10\log\frac{572.50}{100.50} = 7.6dB$$

This is significantly different from the theoretical distance correction change used in most textbooks for a point source. That would give a value based on:

$$20\log\frac{1m}{5m} = -14\,dB$$





For distance r greater than about 5m use the hemispheric surface area

Chiller duty	Achieved by	Total noise level
100%	All fans running at full speed	XdB
50%	50% of fans running at full speed	XdB minus 3dB
50%	All fans running at half speed	XdB minus 12–15dB [1]

[1] Compressor noise well controlled.

A large chiller can hardly be considered a point source. When measuring close to the chiller, the distance from the planes of the imaginary 'square box', to the geometric centre of the machine varies according to its dimensions. It is often found that there is no attenuation at all from, say, one metre to two metres. On the other hand, measurements taken close to the machine are in a diluted sound field and so may be lower than predicted by a surface area calculation from sound power level. Near-field noise predictions are notoriously problematic.

A manufacturer may be required to prove his noise levels in a factory or site test so accurate prediction is very important. Data taken from a number of distances would provide a more complete picture.

NOISE CONTROL

Having determined the noise level of the chiller at the point of interest and possibly found that it is too noisy, the next step is to consider how it should be quietened. Should the fans or the compressors be treated – or both? In general, noise data for these components separately is not available. Typically, compressor noise is the dominant source once fan speeds drop below around 750-900rpm. If compressor noise is controlled effectively by a purpose designed acoustic enclosure then fan noise will predominate at much lower speeds.

For chiller noise reduction for the quieter night time periods, fan speed control is a better option to reducing the number of fans operating, but it is important to ensure that compressor noise is well controlled. In extreme cases, coolant flow noise can become noticeable. The following is a typical example of this principle.

These days, many manufacturers of chillers offer a wide range of acoustic control solutions, often as part of their standard range of options.

Acoustic screening can also provide a benefit, but it would not help where chillers are overlooked.

If sited in a very onerous acoustic environment then the machine may have to be contained within a full acoustic enclosure incorporating attenuated air inlet and discharge openings.

CONCLUSION

Chiller noise levels vary enormously dependent upon duty and specification. Manufacturers cannot be expected to have acoustic test data for every conceivable option so it is not uncommon to be presented with estimated or extrapolated noise data. Add to that the uncertainties discussed above, then it becomes clear that the whole matter of chiller noise emission needs to be assessed with care to establish whether or not project design noise parameters are likely to met, and to avoid programme delays and potential difficulties with Planning Authorities.

MIRAMAR AIR BASE

A new report produced by the U.S. Marine Corps says efforts to reduce helicopter and jet noise at Miramar Marine Corps Air Station in northeast San Diego continue to improve the sound environment around the base. The report says those efforts, which have been under way for years, are also having an effect on reducing noise pollution in communities such as Mira Mesa, Scripps Ranch and Carmel Valley, which are immediately adjacent to the 23,000-acre air station. The report includes a breakdown of noise levels surrounding the base and concludes that negative impacts are virtually nonexistent. "The report assesses the area around Miramar to see if our operations were affecting the area negatively," spokesman Marine Corps Sgt. Joshua Stueve said. "It concludes there are no negative impacts and says to the San Diego community that Miramar is approved to continue running its operations."

THUMPS

Solving the mystery of the eerie noise emanating from the Rose Garden and Eight Lakes area could cost Cape Coral, Florida, taxpayers $47,300. The city council will consider paying a local engineering firm this amount to find the source of the noise residents have been hearing since the 1980s. Councilman Richard Stevens requested the city staff look into the problem after residents complaints. The noise, described as a series of low-pitched thumps, occur only in the winter and can be heard only inside certain homes. "It's horrible," said Marilyn Cicero, who has heard the noise at her Skyline Boulevard home since 1983. "It starts out slow and low and builds to a crescendo." Cicero invited all council members to visit her home and hear the noise for themselves. Her home is further north than the area where previous complaints originated. Councilwoman Gloria Tate visited Cicero's home and heard a sound she described as either humpback whales or a distant concert. She wants to find out more about what the city has done in the past to locate the source of the noise and how many people are affected by it. Tate said $47,000 is too much to spend to resolve the problem for one person but could be reasonable if many residents are affected. The noise has been attributed to everything from creaky sewer pipes to drum fish. While some residents consider the noise a community joke, it's a serious problem for others who are unable to sleep at night "If we can find out what this noise is and resolve it, I'm for it," Councilman Paul Asfour said. He said $47,300 is a lot of money to spend, but if it solves the problem, it will be well spent. Mayor Arnold Kempe, who lives across from the Rose Garden area, said he hears a noise at night that appears to be coming from the sewer pipes. But it's not disruptive enough to spend $47,000 to find it, he said. "I could see a few thousand," Kempe said "This price seems substantially too much."

LIVERMORE

"Livermore airport, whether you use it or not, is a public facility," says a spokesman from the FAA's northern California office. It's a public facility because it was built using public funds: grants from the FAA. And because it is a public facility, neither the local Council, which operates it, nor the airport itself, can ban noisy planes, business jets, nor even impose a curfew. So the local Council's intention to oppose lengthening one of the runways, on noise nuisance grounds, looks doomed.

MANAGEMENT OF DRUNKS

As the spectre of all-night, or very late night opening of licensed premises looms larger in the UK, more thought is being given to how to deal with the possibility that, instead of crowds of noisy, drunk and perhaps violent people emerging from pubs at 11 pm, as at present, the problem will instead occur at, say, 3 am, with a greater impact. While Whistler, British Columbia, may seem a strange place to be an exemplar, nonetheless it has been facing this problem of early-morning alcohol induced asocial behaviour for quite some time, and has found some ways to deal with it. One problem area was the central taxi rank. Everyone wanted to get home: drunks did not want to wait in line. So Whistler built a fenced, gated line: you can't get a taxi without behaving in an orderly way; you can't jump the queue either. On noise, liquor licences are renewed annually, and any complaints through the year could lead to non-renewal of the licence. However, mediation is the preferred course: by-law enforcement officers put managers of a bar with noise complaints against it in a nearby hotel room, and conduct decibel readings there, so that the managers can see and hear what the fuss is about, regarding noise from their establishment. It's a truth common to all noise-makers, that they themselves do not think their noise is unreasonable. This objective method shows them at least that it definitely is illegal.