THE NOISE EMISSION IN THE ENVIRONMENT BY EQUIPMENT FOR USE OUTDOORS DIRECTIVE 2000/14/EC

F Buckle Directive Negotiator, Standards and Technical Regulations Directorate (STRD), Department of Trade and Industry

1. INTRODUCTION

This paper describes the new Directive relating to the noise emission in the environment by equipment for use outdoors. This Directive will replace the current noise emission legislation and covers 57 types of outdoor equipment first placed on the market or put into service within the Community. The obligations of this Directive apply to manufacturers or their authorised representatives established within the EC. It will not be applied retrospectively nor is it 'in use' legislation.

2. CURRENT EUROPEAN LEGISLATION

There are currently 7 product specific Directives as listed below setting noise emission limits for about 10 types of outdoor equipment. These Directives require EC type examinations by Approved Bodies as the means of conformity assessment.

- 84/533/EEC (compressors)
- 84/534/EEC (tower cranes)
- 84/835/EEC (welding generators)
- 84/536/EEC (power generators)
- 84/537/EEC (concrete breakers and picks)
- 84/538/EEC (lawnmowers)
- 86/662/EEC (hydraulic excavators, rope-operated excavators, dozers, loaders and excavator-loaders)

When the new Directive becomes mandatory on 3 January 2002, these Directives will be repealed, type examination certificates issued will become invalid, and Approved Body status will cease.

3. THE NEW DIRECTIVE

3.1 Aims of the New Directive

The European Commission Green Paper on Future Noise Policy (COM(96) 540 final) identified noise in the environment as one of the main local environmental problems in Europe. The Commission announced its intention in the Green Paper to propose a framework directive to control the noise emission of more than 50 types of equipment used outdoors.

The aims of the proposed Directive were, and still are:

- to remove technical barriers to trade arising out of member States' differing noise requirements for outdoor equipment.
- to simplify existing legislation by creating a framework for future noise reduction as and when developments in technology allow, as well as broadening the scope of Community legislation with regard to noise emissions from outdoor equipment.
- to protect the health and well-being of citizens by reducing overall noise exposure and noise nuisance caused by outdoor equipment.

3.2 Main Requirements of Directive 2000/14/EC

The main requirements of the new Directive are to measure the noise levels of 57 types of equipment and to fix labels showing the "guaranteed" noise levels of each machine. The Directive also sets noise limits for 22 of the 57 categories, which are laid down in two stages. Many of these categories subject to noise limits already have limits set under the current legislation.

Article 12 lists the 22 categories of equipment that are subject to noise limits together with a table denoting the permissible sound power levels. These categories of equipment require the services of a Notified Body. Article 13 lists the remaining 35 categories of equipment that require noise labelling only and do not require the services of a Notified Body.

Annex III of the Directive lays down the methods of measurement of airborne noise that shall be used for the determination of the sound power levels of equipment covered by the Directive. For the purposes of the Directive, "sound power level LWA" means the A-weighted sound power level in dB in relation to 1 pW as defined in EN ISO 3744:1995 and EN ISO 3746:1995.

3.3 Scope of the Directive

Equipment subject to noise limits and noise marking as listed in Article 12 of the Directive are as follows:

Builders' hoists for the transport of goods (combustion-engine-driven)
Compaction machines (only vibrating and non-vibrating rollers, vibratory plates and vibratory rammers)
Compressors (<350 kW)
Concrete-breakers and picks, hand-held
Construction winches (combustion-engine driven)
Dozers (<500kW)
Dumpers (<500 kW)
Excavators, hydraulic or rope-operated (<500 kW)
Excavator-loaders (<500 kW)
Graders (<500 kW)
Hydraulic power packs
Landfill compactors, loader-type with bucket (<500 kW)
Lawnmowers (excluding: agricultural and forestry equipment; multi-purpose devices, the main motorised component of which has an installed power of more than 20 kW)
Lawn trimmers/lawn edge trimmers
Lift trucks, combustion-engine driven, counterbalanced (excluding "other counterbalanced lift trucks" with a rated capacity of not more than 10 t)
Loaders (<500 kW)

Mobile cranes
Motor hoes (< 3 kW)
Paver-finishers (excluding paver-finishers equipped with a high-compaction screed)
Power generators (<400 kW)
Tower cranes
Welding generators

Equipment subject to noise marking only as listed in Article 13 of the Directive is as follows:

Aerial access platforms with combustion engine
Brush cutters
Builders' hoists for the transport of goods (with electric motor)
Building site **band saw machines**
Building site **circular saw benches**
Chain saws, portable
Combined **high pressure flushers and suction vehicles**
Compaction machines (only explosion rammers)
Concrete or mortar mixers
Construction winches (with electric motor)
Conveying and spraying machines for concrete and mortar
Conveyor belts
Cooling equipment on vehicles
Drill rigs
Equipment for **loading and unloading tanks or silos** on trucks
Glass recycling containers
Grass trimmers /grass edge trimmers
Hedge trimmers
High pressure flushers
High pressure water jet machines
Hydraulic hammers
Joint cutters
Leaf blowers
Leaf collectors
Lift trucks, combustion-engine driven, counterbalanced (only "other counterbalanced lift trucks" with a rated capacity of not more than 10 t)
Mobile waste containers
Paver finishers (equipped with a high-compaction screed)
Piling equipment
Pipelayers
Piste caterpillars
Power generators (≥ 400 kW)
Power sweepers
Refuse collection vehicles
Road milling machines
Scarifiers
Shredders/chippers
Snow-removing systems with rotating tools (self-propelled, excluding attachments)
Suction vehicles
Trenchers
Truck mixers
Water pump units (not for use under water)

Definitions for each type of equipment can be found in Annex I of the Directive.

3.4 Conformity Assessment Procedures

Annex V of the Directive lists the Internal control of production procedure. This is the self-certification route to compliance for equipment subject to marking only (listed in Article 13). Manufacturers must draw up and keep technical documentation. Manufacturers must also affix the CE marking and indication of the guaranteed sound power level and draw up an EC declaration of conformity. There is no requirement for Notified Body intervention in this module.

Annex VI of the Directive lists the Internal control of production with assessment of technical documentation and periodical checking procedure. This procedure is for equipment subject to limits (listed in Article 12). The requirements are as in Annex V, but the manufacturer must submit the technical documentation to a Notified Body for confirmation of compliance. Product testing by the Notified Body not generally necessary. Further evaluation is required by the Notified Body by periodical checks during production to verify continuing compliance of the products.

Annex VIII of the Directive lists the Unit verification procedure. This procedure is for equipment subject to limits (listed in Article 12). A Notified Body undertakes an examination on a single unit and provides a certificate of conformity if the equipment meets the provisions of the Directive. The manufacturer affixes the CE marking and indication of the guaranteed sound power level and draws up an EC declaration of conformity.

Annex VIII of the Directive lists the Full quality assurance procedure. This procedure is for equipment subject to limits (listed in Article 12). The manufacturer must operate an approved quality assurance system for design, manufacture and final product inspection. A Notified Body assesses the manufacturer's quality assurance system in relation to the provisions of the Directive. The manufacturer affixes the CE marking and indication of the guaranteed sound power level and draws up an EC declaration of conformity.

3.4 Notified Bodies

As stated in the section, Notified Bodies will be involved in three of the four conformity assessment procedures. The DTI will appoint Notified Bodies in the UK. The United Kingdom Accreditation Service (UKAS) will assess potential Notified Bodies and monitor appointed Notified Bodies on behalf of the Secretary of State for Trade and Industry. Assessment of applicants will be against the Interim Guidelines for Organisations seeking Notified Body status to undertake Noise Emission Testing, Inspection and Certification.

3.5 Timetable

There are three key dates concerning the Directive:

- 3 July 2000 - The Directive was adopted and entered into force.

- 3 July 2001 – National legislation must be implemented. The 6-month transition period commences whereby manufacturers may either apply the provisions of the new Directive or legislation currently in force. The DTI <u>must</u> appoint some UK Notified Bodies by this date so that UK manufacturers will not be disadvantaged or be forced to use the services of Notified Bodies appointed in other member States.

- 3 January 2002 - The provisions of the Directive become mandatory.

3.6 Associated Work

Since the Directive's adoption, the DTI have commenced an awareness campaign via mail shots to companies, trade associations and other interested parties informing them of the new legislation and availability of DTI Guides. They have also given presentations to industry.

The DTI are now drafting the Regulations that will implement Directive 2000/14/EC. It is hoped that the draft Regulations will go out to public consultation in December 2000. A major issue in the implementation will be who enforces the Regulations in the UK.

3.7 Available Publications

The following publications are available from the STRD website:

www.dti.gov.uk/strd/

or DTI Publications Orderline:
Tel: 0870 1502 500
Fax: 0870 1502 333

- Guidance notes on the Directive - URN 00/525
- A Guide for Manufacturers to the evaluation of uncertainties - URN 00/605
- Interim Guidelines for Organisations seeking Notified Body status to undertake Noise Emission Testing, Inspection and Certification – URN/526

A New Method of Measuring Noise From Pipes

J. Richards M.W. Kellogg Ltd.
J.N. Pinder ISVR, University of Southampton

Introduction

Improved methods for the control of noise from industrial equipment on large oil and gas plants has turned more attention to the remaining sources such as the noise radiating from plant piping. Noise from piping can be the dominant contribution to the noise in the surrounding community from a modern petro-chemical plant.

When a number of pipes are located alongside one another in pipe racks, it is often difficult to determine each individual pipe's contribution to the total plant noise by simple noise measurements. Measurement using sound intensity measurements are often not practical due to higher local "background" noise levels.

Estimates of noise from piping are therefore often based on surface vibration levels, but point measurements by accelerometers can be inconvenient and can also give misleading results. Many individual point measurements are required to obtain a spatially averaged level, which avoids local node and anti-node point responses from the pipe surface.

To overcome these problems, a user-friendly spatially averaging "Vibration Velocity Transducer", which rejects components not contributing to the far-field of acoustic radiation has been developed.

This transducer has undergone laboratory testing and has now been subjected to extensive use in the field. It is based on an existing ISVR designed instrument that had been developed by Prof. F.J. Fahy for flat surface measurements in lower noise environment [1]. An earlier instrument has also been built and tested in the U.S.A. [2].

Comparison with Direct Acoustic Measurements

There is an initial attraction in using a purely acoustic method, such as some form of microphone-based instrument in an acoustically insulated housing to exclude noise from other sources. However, there are inherent problems with this method, as the sound field radiated by the limited surface being 'observed' by the microphone is likely to be significantly affected by 'partitioning' it from the remainder of the surface. This response will also be inconsistent between different surfaces. Because the transducer is not therefore a consistent device, the acoustic behaviour of the enclosure will be inconsistent for different sound fields radiated into it since, practically, it cannot be large enough to be anechoic over the frequency range of interest. One consequence of this is that it would not be possible to reliably calibrate such a device.

In contrast, the VVT measures the volume velocity of the surface, which potentially is not affected by the presence of the measurement system. The "standard" ISVR VVT is used as a non-contacting transducer and for normal vibrating surfaces, its presence has no influence on the surface motion. However, to achieve the high noise insulation required for the Pipe-noise VVT, contact with the pipe by a resilient seal is required, but industrial pipes are typically stiff and massive enough for the response not to be affected by this contact.

Having measured the volume velocity (or more correctly, the proportion of surface vibration which causes acoustic radiation into the far-field, which the VVT measures), there is a simple relationship between it and the sound power radiated by the sampled surface [3,4].

The relationship between the elemental sound power and the total sound pressure from a vibrating surface is more difficult to model, but this is an acoustic modelling difficulty, not one introduced by the VVT.

Sound intensity measurement of pipe noise radiation is difficult to undertake successfully because background noise often forces the measurement surface to be in the acoustic near field of the pipe, or the proximity between pipes prevents a suitable measurement surface being available.

The Piping Noise Vibration Velocity Transducer

The transducer consists of a tube containing a microphone (see Figure 1). The tube has an open end, which is placed over the vibrating surface, but is mechanically isolated from it. The other end of the tube is fitted with an anechoic termination. Although described as a 'volume' velocity transducer, it is the pressure of the plane wave propagating away from the vibrating surface that is directly related to the spatially-integrated velocity of the surface.

Now acoustic pressure $p_{rms} = v_{rms} * (\rho c)$,

where: v = integrated surface velocity,
ρ = density,
c = speed of sound of plane wave

therefore, sound pressure level $L_p = 10*\log[(v^2 *(\rho c)^2)/p^2_{ref}]$

where p_{ref} = 20 micropascals.

Using v_{ref} = 5e-8 m/s,

then: $L_p = L_v$ dB.

The sound power level radiated by a pipe can be determined using L_v.

From [3] the sound power radiated from a reference length equal to a quarter of the outside diameter of the pipe is given by:

(Sound power / reference length) $\propto$ (volume velocity) * (radiation efficiency)

In decibel terms:

$$L_{w\ ref} = L_v + 10*\log(\text{surface area of reference length}) + 10*\log(\sigma) \qquad \text{dB re 1e-12 W}$$

where: reference length = d / 4,
d = outside diameter of pipe,
σ = radiation efficiency,

Since the energy in higher order circumferential modes appears from experience to be converted into the beam-bending mode at practical boundary conditions and as this mode is the most efficiently radiated, it is usual to assume that the radiation efficiency of a pipe can be approximated to the value of that mode.

VDI 3733 [4] gives the radiation efficiency for the beam-bending mode of a pipe as:

$$\sigma = 1/[1+(c/(4df)^3]$$

where: f = frequency
c = speed of sound in air.

hence:

$$L_{w\ ref} = L_v + 10*\log(\pi d^2/4) + 1/[1+(c/(4df)^3]\qquad \text{dB re 1e-12 W}$$

By assuming that the pipe acts as a line of non-coherent sources, the total radiated sound power can be determined and hence the radiated sound pressure level can be found [4].

For example, for a point 1m from the surface of a long pipe:

$$L_p = L_{w\ ref} - 10*\log(\pi(d+2)) + 10\log(4/d)\qquad \text{dB re 2e-5 Pa}$$

Choice of VVT Tube Section

The cross section shape and size of the VVT tube have been selected with three influences in mind:

- i the upper frequency limit of valid measurements,
- ii the range of pipe sizes it can be applied to,
- iii the sound insulation against ambient noise.

The VVT measures the part of the surface vibration field which radiates into the acoustic far-field. This is a result of the spatial filtering effect, arising from the size of the monitored surface area, and can in principle be given by any measurement method. The main advantage of the VVT is that this is inherently achieved simply by limiting the accepted data to the bandwidth of the plane wave that propagates up the tube, i.e. below the first higher-order mode cut-on frequency, which is given by:

$$f_{1,0} = 1.84*c/(\pi*d)$$

where: c = speed of sound propagation in the VVT tube,
d = internal diameter of a cylindrical VVT tube.

The non-radiating sub-sonic surface waves contribute mostly at frequencies above $f_{1,0}$ and so their contribution is discarded by the VVT. Individual point measurements, such as by an accelerometer, are representative only of a single point and measure a level which also includes these non-radiating components. It would be impractical to estimate the required sampling density that would be needed for these non-radiating modes to be identified and removed from point measurement signals without an extensive preliminary survey.

Although it is desirable to be able to measure up to a high limiting frequency value, this would require smaller sampling areas (VVT foot-prints), and thus more measurement locations, until ultimately the VVT would become in effect a point measurement transducer and would loose its spatial integrating capability. The choice of VVT tube size is thus a compromise.

The standard VVT uses a square-section tube in order to allow contiguous spatial sampling areas on a flat surface. For the piping VVT, a cylindrical tube was adopted because the noise reduction across it is much higher than across a square tube of similar cross-section area. The tube size also needed to be small enough to allow measurements on small pipes. Although in principle different VVT's could be used for different pipe sections and frequency ranges, a 'compromise' VVT size of 50 mm diameter was chosen to fulfil the requirement of simple use in the field. This then gives $f_{1,0}$ = 4018 kHz, but with the microphone located on the centreline, in principle the first order higher mode signal will not be detected and the upper frequency limit becomes 6660 Hz. This VVT tube can be used on pipe sizes down to about 100mm outside diameter.

VVT Tube termination

In principle, acoustic reflections in the VVT tube can be accounted for by calibration. However, the calibration would be very frequency and temperature sensitive and it is therefore preferable to use an anechoic termination. In the standard VVT, this is very compact, but it allows too much noise break-in for the proposed high background noise performance requirements. A termination using bulk absorber materials of graduated flow resistance was therefore developed, consisting of three grades of foam and two grades of mineral wool, fitted between the microphone and the end of the tube which was closed. The overall length of the packed section of the tube is 850 mm. The performance of the termination was measured by packing a similar set of materials into a special adapter made to suit a Bruel and Kjaer impedance tube apparatus, which showed good performance down to about 160 Hz.

Noise Insulation

The requirement causing greatest difficulty was the aimed for high level of protection against break-in of ambient noise. Besides the inherent noise reduction available from the tube and its closed end, the open end provides most of the acoustic break-in path.

A triple wall seal assembly was developed to avoid this break-in. A hollow-section sealing strip was bonded onto the end of the VVT tube to seal the tube to the pipe and to prevent structure borne excitation of the VVT. A double wall convoluted rubber gaiter, with a foam insert fitted between the seal on the tube end and the outer assembly was added to enhance sound insulation. The noise reduction between an external flat spectrum reverberant sound field and the VVT microphone was measured as 41 dB(A), as shown in Figure 2, using this seal system.

At frequencies above 100 Hz, this reduction was given within 1 dB(A) by either strapping the VVT to a pipe or pushing the VVT against the pipe by hand. Below 100 Hz, the insulation given by hand-push was much lower, possibly due to structure-borne noise being transmitted to the VVT.

Performance

An example of the difference between surface vibration measured by the VVT and by a single accelerometer position within each VVT footprint is shown in Figure 3 for a length of 14" diameter seam welded industrial pipe. The measured sound pressure level is compared with the value derived from the VVT measurements in Figure 4.

In contrast, a spiral formed ventilation duct (300mm diameter) was excited with a shaker at ISVR. The range of differences between accelerometer and VVT measurements of surface vibration for this pipe was approximately +/- 4 dB as shown in Figure 5. It was noted that the radiation efficiency of this duct would appear to differ significantly from the expression given above and in [4].

References

1. Holland, K.R and Fahy, F.J. "A Simple Transducer of Surface Vibrational Volume Velocity". IoA Proc. Vol. 15. Part 3.pp 247-254.

2. Rainey, J.T., Kushner, F., "Using a "Soundtube" to Measure Noise of Structural Sources in High Background Noise Environments". Proceedings of the 9th Turbomachinery Symposium.

3. CONCAWE "Test Method for the Measurement of Noise Emitted by Pipes in the Petroleum and Petrochemical Industries". Shlichtig CONCAWE, The Hague, 1987.

4. VDI 3733 "Noise at Pipes". September 1983 and July 1996.

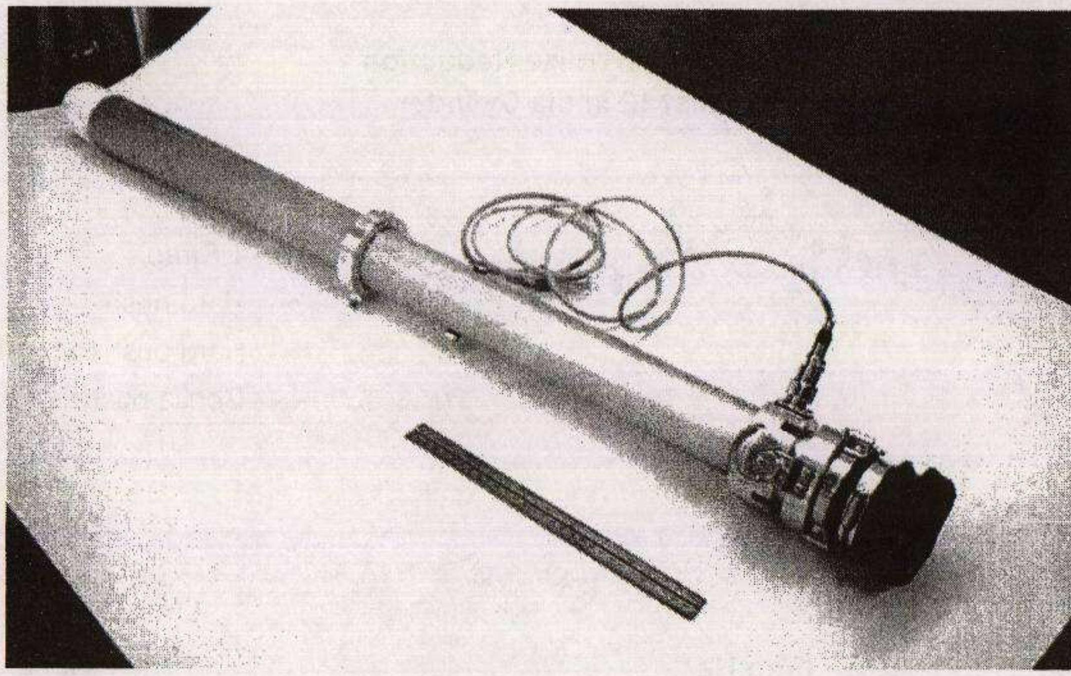


Figure 1A Pipe Noise VVT with Microphone Fitted (300 mm ruler shown for scale)

Figure 1B View of Noise Insulating Seal Arrangement

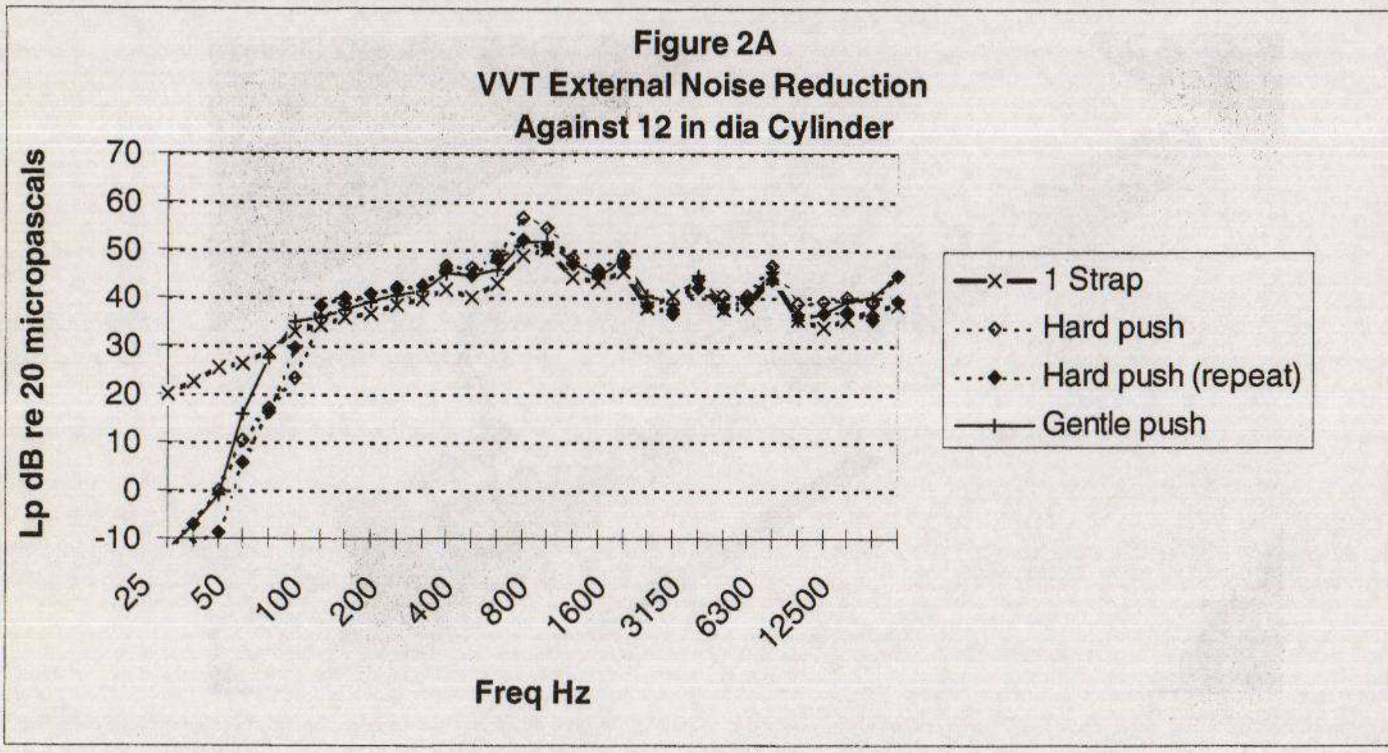


Figure 2A
VVT External Noise Reduction
Against 12 in dia Cylinder
Lp dB re 20 micropascals
70
60
50
40
30
20
10
0
-10
25
50
100
200
400
800
1600
3150
6300
12500
Freq Hz
1 Strap
Hard push
Hard push (repeat)
Gentle push

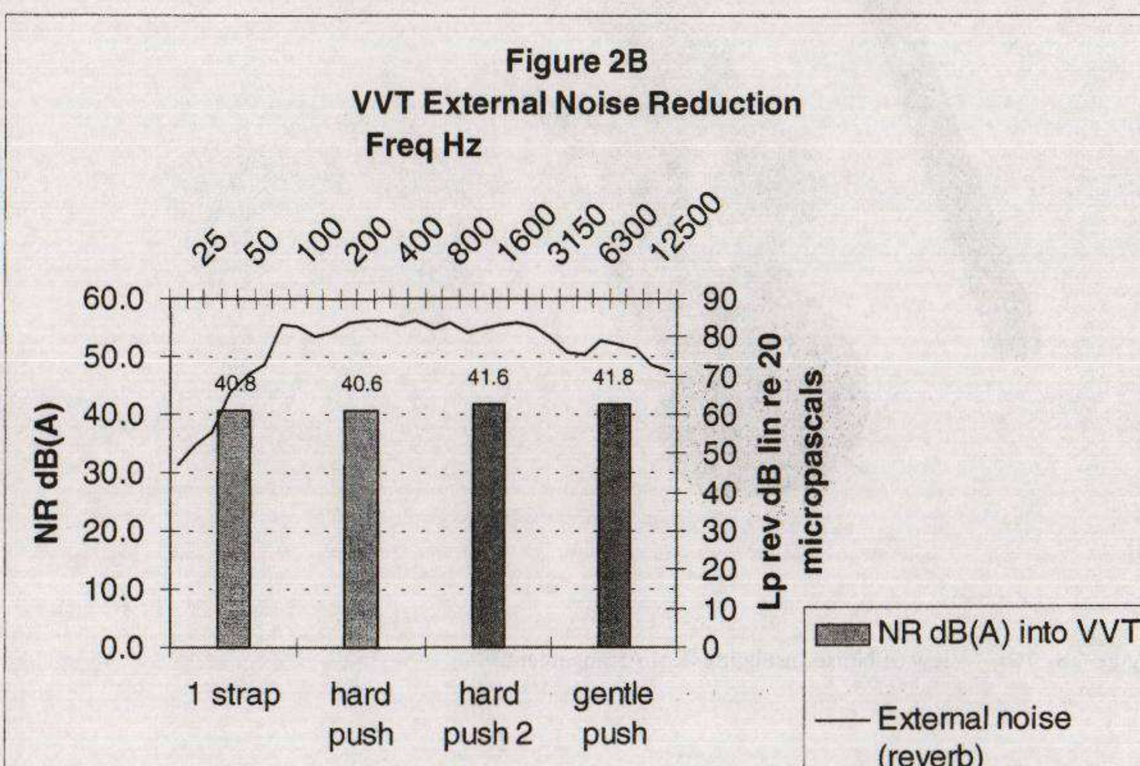


Figure 2B
VVT External Noise Reduction
Freq Hz
25
50
100
200
400
800
1600
3150
6300
12500
NR dB(A)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
40.8
40.6
41.6
41.8
90
80
70
60
50
40
30
20
10
0
Lp rev dB lin re 20 micropascals
1 strap
hard push
hard push 2
gentle push
NR dB(A) into VVT
External noise (reverb)

Figure 3.
Accelerometer vs VVT derived Lv for 14" pipe

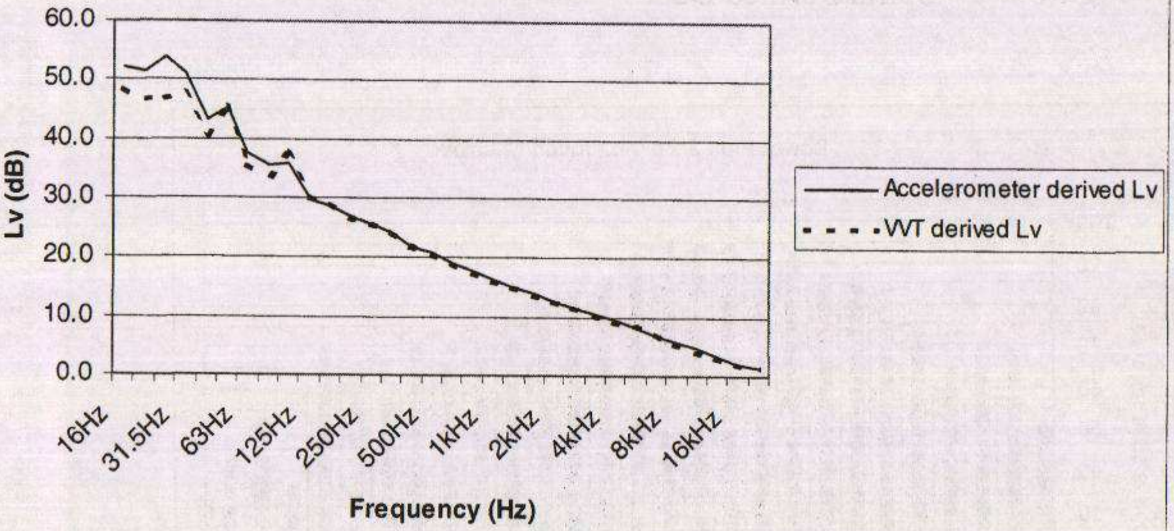
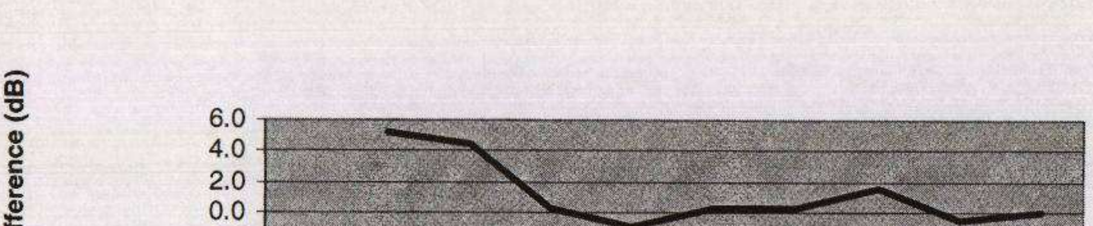
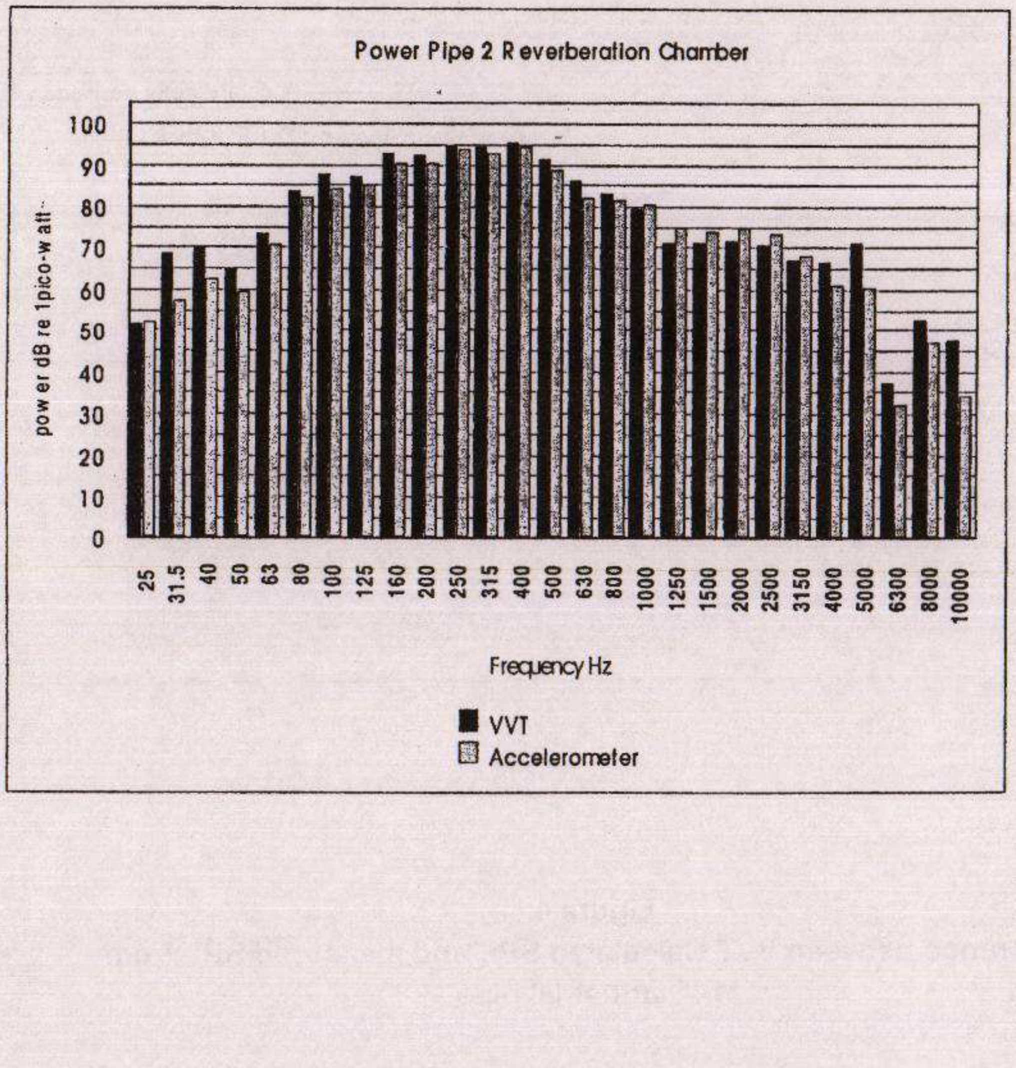


Figure 4.
Difference between VVT Calculated SPL and measured SPL from 14" industrial pipe



	63	125	250	500	1K	2K	4K	8K	dBA
Difference	5.3	4.4	0.3	-0.9	0.3	0.3	1.6	-0.6	0.0

Figure 5 Spiral Formed Duct



MEASURING AND ASSESSING THE SOUND YOU INTEND, NOT EVERYTHING ELSE INSTEAD.

Richard A. Collman Acoustical Control Engineers Limited and Belair Research Limited

1. INTRODUCTION

In order to make sound measurement more accessible, a great deal of very useful work has been undertaken towards simplifying the expression of sound levels, first by transforming frequency content to a single number, in terms of dB(A). Even though it is also mis-applied on occasions, the use of this single figure 'A' weighted sound level has provided many benefits including acting as a platform for further simplification.

The subsequent development of statistical parameters such as L_{Aeq}, L_{A90} and L_{AMax}, integrating variation with time, into the single figure value, has further assisted with the measurement and assessment of acoustic environments. Indeed this approach underpins many standards, guidance documents and even legislation such as BS4142: 1997, PPG 24 and the Noise at Work Act.

This concept is now being extended still further with parameters such as L_{den}, which is specifically intended to provide a single number that encompasses the variations of sound in frequency, magnitude and time at a particular location, for a longer period of time, such as an entire year.

Long term averaging is appropriate for many assessments of 'environmental noise' and noise sources that are relatively stable or change gradually such as road traffic noise. However, this is not suitable for other noise sources, such as those that produce significant variations of sound level over short periods of time, particularly when such changes are themselves subject to considerable variation.

One of the greatest difficulties faced by many practising acousticians is that of obtaining reliable sound level measurements under site conditions rather than in a laboratory. Although this paper does not provide a magic solution for all situations, it has been found that the technique presented in this paper overcomes some of the difficulties for a variety of different sound level measurement requirements.

The author and other colleagues have successfully used this technique for many varied projects and different applications for several years. Throughout this time the methodology has consistently provided high quality, reliable data that has facilitated subsequent analysis of the measurements obtained, whilst minimising the overall costs of the measurement and analysis involved.

2. EXISTING MEASUREMENT AND ANALYSIS TECHNIQUES

There are certain principles involved in the measurement and analysis of sound levels when using long term statistical parameters. These can be broadly summarised as follows.

2.1 Measuring the sound level

Identify suitable measurement locations such that the required sound level can be measured and quantified and extraneous noises will be minimised. If it is possible, any extraneous noises should also be quantifiable. Measure the sound level for the required period of time, using consistent averaging periods unless there is a valid reason for not doing so such as changing from day to night at 11pm for an assessment in accordance with BS 4142:1997. If extraneous noises affect the measurement either re-start the measurement, or use a 'Pause' function, whilst ensuring that the extraneous noise is excluded before it affects the measured parameter.

One possibility is to concurrently tape record the sound so that more detailed analyses can be undertaken later, particularly if extraneous noises affect the 'on site' parameter measurement. Whether measurements are paused or not, it is necessary to ensure that the statistical parameters reflect a combination of the intended source noise and of other ambient noise levels.

A concurrent 'log' should also be made recording details of any acoustically significant events that may affect the subsequent analysis, together with the time of such events so that it can be identified which parameters each such event has affected.

2.2 Analysing the data

Record the statistical parameters for the various time periods. Compare the statistical parameters and the timed notes and try to quantify the various compromising effects of extraneous noise so that different statistical parameters can be reliably compared to achieve an appropriate assessment.

Report on the findings of the analysis including an estimate of any uncertainties such as that due to extraneous noise sources.

3. AN ALTERNATIVE MEASUREMENT TECHNIQUE

The preceeding discussion shows that, for a reliable assessment of long-term statistical parameters, it is critical to ensure that the effects of extraneous noise sources are minimised and also quantified. However, even where it is possible to undertake such an assessment, there are many situations where it is not appropriate to consider only one or two parameters that condense many subtleties of time and frequency into a single number. This is due to the loss of information that occurs when all of the variation with time is coalesced into a single, average value.

The reliability of the measurement and analysis techniques outlined above is usually significantly affected by extraneous noise sources such as passers by asking 'what you are doing'; police helicopters; nearby guard dogs doing what they are good at ie. 'barking'; or any of the many other noise sources that always seem to appear as soon as a sound level meter is switched on.

A further complication arises when assessing noise sources having different acoustic characteristics. For example, an assessment of the acoustic impact on residents living beside a reasonably busy road, of the noise associated with deliveries to a factory, should consist of at least two comparisons. The delivery vehicle noise should be compared against the existing road traffic noise, whereas the unloading activity noise has very different acoustic characteristics.

The problem with the use of a long term eg. 5 minutes or 1 hour, statistical average is that this averaging process destroys most of the information about different acoustic characteristics of the noise sources. In addition to this, such long term averages are almost always affected by several different noise sources, making it even more difficult to accurately quantify the significance of any specific noise producing activity.

3.1 Principle of the method

The principle is very straightforward – instead of just taking an average value over the measurement period, it is better to monitor how the sound level changes throughout the measurement period and to make use of this information for any assessment of the noise. This means that it is then possible to more accurately quantify the effects of the noise source under consideration and of other extraneous noise sources.

With suitable instrumentation, there is relatively little additional work involved in obtaining this information. From the author's experience, is likely that the overall time for measurement and analysis will not be significantly different, indeed with the improved quality of the data, the reduction in analysis time may well outweigh the slight additional time required to capture the data prior to analysis. The analysis will also be far more specific than is possible with only long term average data, allowing a more reliable analysis and providing your client with better information that may well enable other cost savings.

In order to monitor how the sound level changes over time, the only difference compared to taking a longer term average measurement is using the sound level meter to log consecutive short duration L_{eq} values and then down-loading this data for subsequent analysis.

For most applications, a convenient short duration measurement averaging time is one second. This is short enough to provide several samples for most events such as vehicles passing; conversation; dogs barking or intermittent plant operation, but does not result in unmanageable quantities of data. It also has the advantage that the maximum or minimum value during a specific measurement period is also the L_{Max} or L_{Min} value. For very short duration events such as impulsive sound, a shorter period such as 0.1 seconds may be appropriate.

Most applications involving statistical parameters are concerned with the 'overall noise level', rather than with more detailed data such as octave band frequency analyses for noise control purposes. Where only the overall noise level is of interest, it is only necessary to log the single figure 1 second L_{Aeq} values. Even where additional octave band or similar more detailed information is required, it is generally possible to measure spectral data relatively quickly and to then investigate the time dependent characteristics of the overall sound level separately to this, providing the required information without excess data.

A good estimate of a longer term L_{A90} (or other statistical parameters) can be derived from the 90th centile of the consecutive 1 second L_{Aeq} values ranked in descending value. From the author's experience, if the sound level meter also logs 1 second L_{A90} values (even though these are relatively meaningless in isolation), the 90th centile of the 1 second L_{Aeq} and of the 1 second L_{A90} values will bracket the longer term L_{A90} value that the meter would calculate. Under most conditions these two values are consistent to within a few tenths of a decibel for periods of 5 minutes or more. This means that in addition to the better quality data available from the consecutive 1 second L_{Aeq}s, the longer term statistical values can also be derived, for comparison with other data.

4. TWO EXAMPLES OF A MORE DETAILED LOOK AT THE VARIATION OF SOUND LEVEL WITH TIME

Although this technique has been used for a wide variety of projects, the two examples below provide an indication of the power and flexibility of this approach.

4.1 Assessing railway noise as part of the ambient sound level

This project involved the assessment of the ambient noise level and particularly the contribution from railway noise, around a proposed residential development site. The site is adjacent to a railway line, a few miles from Heathrow airport and subjected to road traffic noise. In addition to this, an enthusiastic guard dog complete with rattling chain protected the neighbouring commercial site.

With the variety of different noise sources having different propagation and other acoustic characteristics, any long term statistical parameter could not provide suitable information about the relative significance of the different ambient noise sources. This information was essential for any modelling of acoustic propagation around the proposed residential development, particularly with the proposed acoustic barrier towards the railway line and the lack of any screening benefit for aircraft noise. In addition to this, the noise from the guard dog had to be excluded from the assessment because the presence or absence of a guard dog is not a significant planning issue.

Using consecutive 1 second L_{Aeq} values together with a synchronised log of events, it was relatively easy to determine the contribution from the different noise sources. The example Graphs 1 to 5 together with the log in Table 1 show this analysis. The black lines on each graph identify the time when that particular source was dominant, whereas other sources dominance is shown in grey. Where colour graphs are used, a single graph with the different noise sources shown in different colours, makes visual comparisons even more straightforward.

Table 1 – Example of log showing acoustically significant events for railway noise assessment

Start Time	Duration	T	A	O	Details
07:15:10					Gate opening
07:15:35	19s				Dog barking – 8m
07:16:02					Dog moving - chain noise
07:16:13				B	
07:16:23	17s			B	
07:16:37	43s		A		
07:17:10		T			
07:17:22					Barking & car noise
07:17:52		T			
07:25:56					Pigeon
07:28:13					Adjacent premises activity – speech / impulsive
07:30:15	15s				Adjacent premises – roller shutter door
07:34:16					Distant traffic

Key: T(rain), A(ircraft), Other – B(arking)

Graphs 1 to 5 show that the long term L_{Aeq} of 69dB(A) is affected by the neighbouring dog almost as much as by train noise. This also shows that, a reduction of 10dB(A) to the train noise level would mean that the aircraft noise will be equally dominant and other sources such as road traffic noise will become the most significant noise source at this location. None of this information could be determined by only using long term statistical data.

4.2 Assessing the effect of delivery vehicle noise

This project involved the assessment of the acoustic impact that early morning deliveries would have on neighbouring residents. A few months before the author's involvement, a separate survey had been undertaken, based only on long term statistical parameters. Some of the data provided in a report of this survey is shown in Table 2.

Table 2 – Example of delivery noise log (based solely on long term averaging)

Time	L_{Aeq}	L_{AMin}	L_{AMax}	L_{A90}	Notes
04:54	44.2	37.3	62.1	39.1	
05:07	45.8	37.6	62.6	39.6	Roller shutter door opened, trolley wheeled outside
05:19	44.9	39.5	58.4	41.1	
06:03	48.8	41.9	67.4	44.1	3+ cars from cul de sac
06:14	48.1	42.9	65.4	44.1	2 cars from cul de sac
06:24	48.0	42.8	65.1	44.1	
06:57	56.1	44.2	82.3	45.6	Gate open, 2 del vehicles in, 2 cars on side road
07:09	52.9	44.8	70.7	46.1	1 del vehicle out
07:20	54.0	45.1	74.1	46.6	2 cars from cul de sac, van on side road

Based on the variation in L_{Aeq} and L_{A90}, the perhaps surprising conclusion, was that deliveries were not acoustically significant because 'deliveries did not significantly alter L_{Aeq} or L_{A90} values'. However, the opposite conclusion could also be drawn from the L_{AMax} value of 82.3dB(A) from 06:57. This contradiction provides an example of problems that can arise when using only long term statistical data.

The author subsequently recorded series of consecutive 1 second L_{Aeq} values, together with synchronised logs of events at different locations both during deliveries and without deliveries occurring. Graph 6 shows some of the information that was obtained and this is summarised in Table 3. Based on this more detailed information, it can be seen that at the residential cul de sac, the underlying background noise level varies between 43dB(A) and 49dB(A) at this time of the day. Vehicles on the Ring Road or side road produce typically levels of 50dB(A) to 55dB(A) whereas delivery vehicles typically produce levels of 47dB(A) to 51dB(A), however the delivery vehicles also produce maximum levels of 59dB(A).

Table 3 – Comparison of noise levels based on consecutive 1 second L_{Aeq} graphical analysis

	Facing Ring Road	From Ring Road	Cul de sac
Underlying background noise level	50+	45-50	43-49
Vehicles on Ring Road	65-75 typ, 90 max	60-70 typ, 75 max	50-54 typ.
Vehicles on Side Road			55 typ.
Delivery Vehicles			47-51 typ, 59 max

5. COMPARISON OF THE TWO TECHNIQUES

5.1 Similarities and differences

Although the two techniques of long term averaging and consecutive short duration logging may appear to be fairly similar, there are some very distinct differences due to the very different philosophies behind the two methods. Both methods involve measuring the sound level for periods of time such as 5 or 10 minutes to 1 hour or longer. Conventional long term averaging aims to gather a few values that provide an overview of the acoustic environment, but which are often significantly affected by extraneous noise sources. This method aggregates all noise sources into single figure values for each averaging period, making assessments of different noise sources extremely difficult and unreliable.

Consecutive logging aims to show how the noise level varies over time, in a way that allows individual events to be easily identified and quantifiable. This provides a much clearer understanding of how the acoustic environment is constituted, facilitating better analysis of alternative attenuation schemes for example. However, consecutive logging also enables single figure long term average values to be easily derived, where these are required for a broader overview, or for comparison with other data.

5.2 Suitable Instrumentation

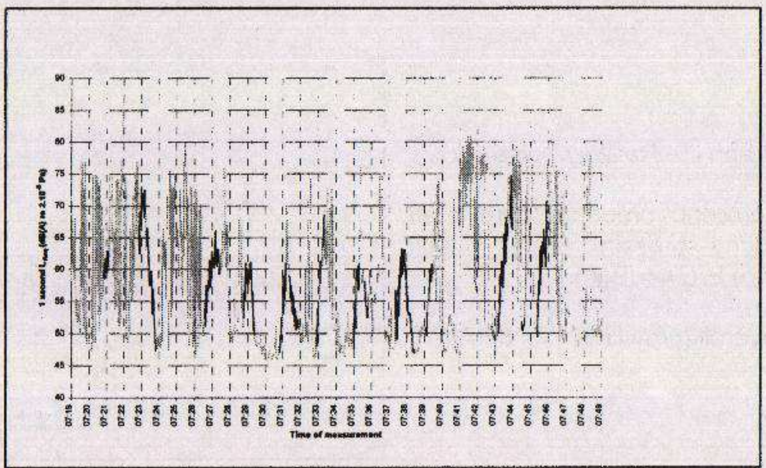
By today's standards, this technique does not require particularly sophisticated instrumentation and a large proportion of the integrating sound level meters that provide long term statistical data can also provide the necessary logging and downloading capabiliies for this analysis. With apologies to organisations that have been omitted from the list, the following is an alphabetical list of several different providers of acoustic instrumentation that the author understands, produce suitable instrumentation for this methodology. This list does not reflect any views that the author may have regarding different providers of acoustic instrumentation.

AcSoft - Bruel & Kjaer - Casella CEL - Castle Group - Cirrus Research - Norsonic

6. CONCLUSION

Although the developments in producing single figure parameters have a wide range of uses for the assessment and comparison of sound, there are also many situations where more detailed information is required. The advantages of a single figure dB(A) value combined with a visual (graphical) analysis of the variation with time, provide a powerful technique for identifying and quantifying what is actually happening, rather than the more obscure information provided by only using long term statistical parameters.

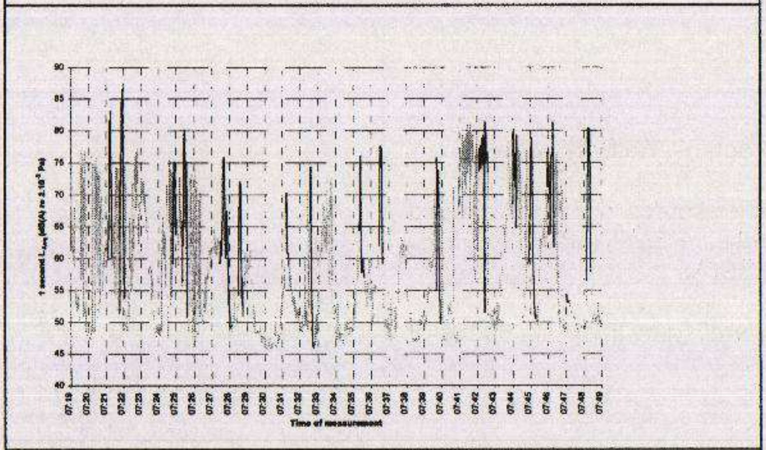
Any additional measurement time is likely to be offset by savings in analysis time. The overall result is more specific data and a more reliable analysis, providing clients and other interested parties with a better understanding of what the numbers actually mean to the listener. This technique is effectively a hybrid of older methods plotting sound pressure level, together with newer methods of averaging, combined using modern instrumentation and computerisation.



Graph 1 – Railway noise

Aircraft dominated sound pressure level (black line) L_{Aeq} 56dB(A).

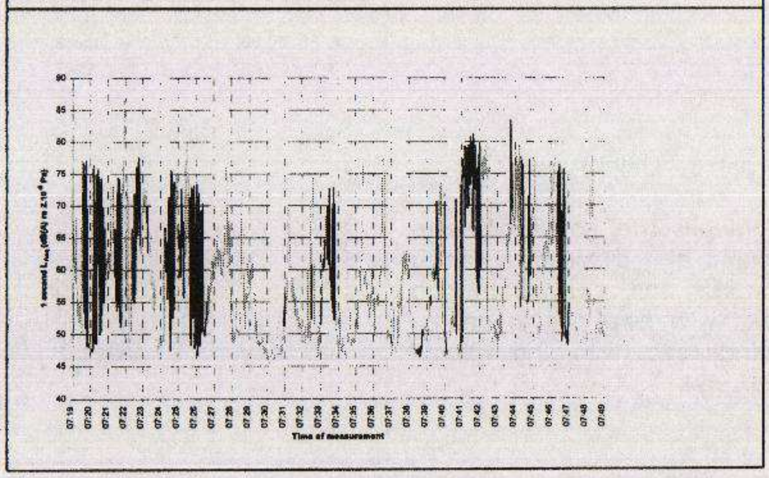
Overall (grey line) L_{Aeq} 69dB(A)



Graph 2 – Railway noise

Train dominated sound pressure level (black line) L_{Aeq} 66dB(A).

Overall (grey line) L_{Aeq} 69dB(A)



Graph 3 – Railway noise

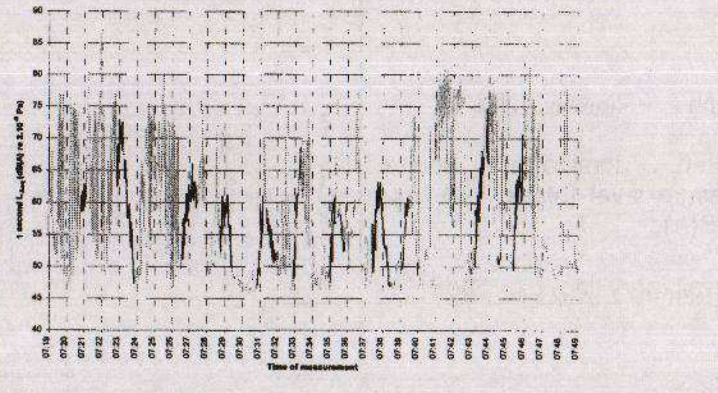
Dog dominated sound pressure level (black line) L_{Aeq} 65dB(A).

Overall (grey line) L_{Aeq} 69dB(A)

Graph 4 – Railway noise

Adjacent property dominated sound pressure level (black line) L_{Aeq} 44dB(A).

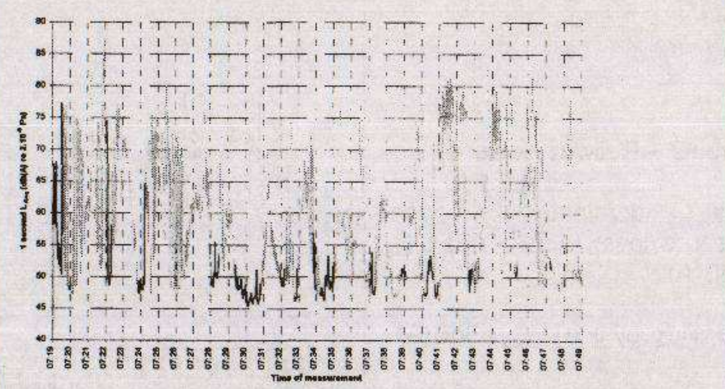
Overall (grey line) L_{Aeq} 69dB(A)



Graph 5 – Railway noise

Other source dominated sound pressure level (black line) L_{Aeq} 59dB(A).

Overall (grey line) L_{Aeq} 69dB(A)



Graph 6 – Delivery noise

Comparison of sound pressure level at dwellings facing towards and away from ring road with dwellings in nearby cul de sac (with and without delivery).