Proceedings of the Institute of Acoustics

HEARING CONSERVATION FOR SMALL TO MEDIUM SIZED FIRMS

C. M. Hammond

Michelin Tyre Plc., Stoke-on-Trent.

ABSTRACT

This is an expert view of the problems facing firms with little or no previous experience in the evaluation of daily exposures to noise, hearing conservation and noise control. Practical advice is given on how to overcome these problems in a cost effective manner.

1. INTRODUCTION

Many large firms will already be familiar with the requirements of the Noise at Work Regulations due to come into effect in 1990 and will be in a position to properly assess the noise exposure of their employees and to set up appropriate hearing conservation programmes by the use of specialists either inside or outside the company. However, what of the small to medium sized firm that has neither the expertise nor the knowledge to cope with the new situation that the new legislation will precipitate?

Such firms will need to grapple with the mysteries of sound pressure levels, pascals, decibels, 3dB rules, Leq's and the like before they can finally master all of the intricacies of workshop noise surveys, worker noise exposure assessments, noise control and hearing conservation. Alternatively, they may feel compelled to call in a consultant to solve their dilemma.

However, much can be achieved through simple, clear and concise advice to achieve a start to a cost-effective approach to the problem. This is the object of this paper.

2. BASIC QUESTIONS

Some of the questions to be answered relate to the requirements of legislation, which in turn leads to questions of the basic terminology used to define noise units and personal exposures. The concept of equivalent continuous sound levels, i.e. Leq's, or in layman's terms, the average noise levels, needs to be clearly understood. This allows a single figure to indicate the effective daily noise dose referenced to an eight hour period Noise level variations are unimportant during the exposure period provided that the peak exposure limit of 140 dB is not exceeded.

There is no need to be overfaced by complex mathematical equations. This is automatically calculated by a sound level meter which integrates sound level over the measurement period (i.e. by an integrating sound level meter).

HEARING CONSERVATION FOR SMALL FIRMS

At the heart of this whole subject lies this question of the technique of actually measuring noise levels and assessing noise exposure. A strategy for this is outlined later. At this stage it is important to appreciate that it is difficult to measure noise at the entrance to the ear canal. A microphone works best in an uncluttered area i.e. in a free field. So measurements are carried out with the microphone away from reflective or absorptive surfaces wherever possible and all measurements need to relate to free microphones. If such surfaces cannot be avoided, e.g. in personal noise dose measurements, also called dosimetry, there at least needs to be an understanding of the likely corrections that need to be made to simulate free field conditions.

The question of cost will be paramount, of course, but more importantly the equipment purchased (or hired) should be cost-effective. A good salesman will offer simple devices to get a programme going. There are many simple to use noise meters available with sufficient precision. Noise meters are in three grades with type 2 (general field grade) meters suitable for most situations being accurate to within ± 3dB from 20 to 4000 Hz, but less accurate at higher frequencies. So noise sources such as compressed air releases, arc welding or other high frequency content sources may need a type 1 (laboratory or field grade in appropriate acoustic environments) which is accurate to + 3 and - 6 dB up to 12,500 Hz. Better than type 1 is type 0 which is used primarily as a laboratory reference standard.
Poorer than type 2 is type 3 with an accuracy of ± 3dB from 50 to 2000 Hz with even less accuracy at higher frequencies, BS:5969[1].

It is advisable to have some frequency analysis capability, at least in octave bands over the range 63 to 8000 Hz. This is necessary to evaluate the adequacy of hearing protection, which is discussed later. Other uses include the noise rating of noise levels and some basic noise control investigation work. More detailed frequency analysis work using 1/3 octave bands or narrower bands should be left to those with proper training and experience.

The question of audiometry is one that also needs consideration. While the 1989 Noise at Work Regulations do not require audiometry, i.e. the testing of an individual's hearing ability, one needs to be aware of the various advantages and uses of the technique. It is a useful tool for detecting early signs of Noise Induced Hearing Loss (NIHL) of which the subject will be quite unaware. Consequently, the success of a hearing conservation programme can be monitored and the results used to encourage the use of noise control devices and/or hearing protection. In addition, pre-employment audiometric screening is invaluable for determining initial hearing abilities and possible previous damage to hearing that could otherwise be blamed on the new employment.

In fact; the 1986 EEC directive on which the new legislation of all Member States is based, requires employees exposed to 85 dB(A) daily dose to be audiometrically screened. This can be arranged through the NHS, a commercial audiometry service (often mobile) or by the purchase of a simple audiometer (which will need annual calibration) for in-house use.

3. LEGAL REQUIREMENTS

The Noise at Work Regulations 1989 refer to two action levels, these being daily exposures of 85 and 90 dB(A) respectively, with an overriding condition that no exposures to more than 140 dB peak due to impulsive noise can be allowed during work periods.

The Noise at Work Regulations 1989 refer to two action levels, these being daily exposures of 85 and 90 dB(A) respectively, with an overriding condition that no exposures to more than 140 dB peak due to impulsive noise can be allowed during work periods.

Daily Leq's above 90 dB(A) cannot be allowed and must be reduced by engineering or administrative means as far as reasonable practicable. If that fails to reduce levels to below 90 dB(A), adequate hearing protection must be worn.

Daily Leq's between 85 and 90 dB(A) require hearing protection to be offered. For both action levels suitable information and training must be provided. Records of the assessments of noise exposures of individuals or groups of employees need to be kept until employment ceases.

4. A NOISE MONITORING STRATEGY

The monitoring strategy outlined here involves three basic stages: a preliminary general survey, measurement or estimation of daily exposures including peak levels and frequency analysis.

Preliminary Survey

The purpose of this survey is to allow a general categorization of the work areas which are below, between or above the two action levels of 85 and 90 dB(A) Leq (8h) respectively. It may also help later in the estimation of daily exposures, especially those moving between areas of different categories.

It is very useful to mark the results on a workroom layout concentrating on locations one metre from all main parts of the process with the microphone at standing ear height, i.e. at about 1.5m. The spaces in between the machines should also be checked. Easily identifiable locations on the plan, e.g. stanchions, make the plotting of the results easier.

When the checks are completed, lines of equal sound level can be estimated and drawn on the layout. This is a very simple process and valuable in gaining an impression of the distribution of noise in the workshops and will help in the identification of noise sources for noise control work later. However, these surveys need to be carried out both during normal full production conditions and also when abnormally noisy conditions exist.

Of course, the survey will be very simple in the case of densely packed similarly noisy machines. Here, the drawing of lines of equal noise level will be difficult and largely unnecessary.

Daily exposures
To obtain an accurate idea of personal daily exposures to noise is a more difficult procedure and one that can usually only roughly be estimated from the preliminary survey especially if noise levels are very variable. However, that survey will at least identify the main problem areas.

Two main approaches can be used; one which needs no extra equipment, especially if the general survey meter is of Type 1 accuracy; and the other approach using personal dosimeters.

Calculation of daily exposure from fractional exposures
The first approach is reasonably feasible if the various work areas are relatively easy to define because noise levels are relatively constant and continuous. The method used is to catalogue the noise levels in the occupied areas along with the length of time spent in each. Fractional exposures can then be calculated either by using the nomogram in Department of Employment [2] or by using the formula:

$f = t/8 \text{ antilog } 0.1\,(L-90)$..........(1)
where f is the fractional exposure, t is the time in hours and L is the sample Leq for the operation concerned.

The values of f are added up and converted back to the daily exposure using the formula:

$\text{Leq} = 10 \log_{10} f + 90$ dB(A)................(2)

as shown in the following example:

Table 1: Adding fractional exposures

	Leq(s)	Time(h)	f
(a) Preparing ingredients	85	2	0.079
(b) Operating mill	95	4	1.58
(c) Operating cutter	88	1.5	0.118
(d) Workpost clean up	80	0.5	0.006
			1.783

Thus daily exposure, Leq (8h) = $10 \log_{10} 1.783 + 90$
using formula 2.
= 92.5 dB(A)

If each operation can be assessed without the operator actually present, e.g. with automatic or semi-automatic machinery, and with the microphone in his normal head location this method will be reasonably accurate. Otherwise, the microphone should be measured on each side of the head not closer than about 150mm from the body or head. The two results need to be averaged by antilogging one tenth of each value, adding these, halving that result, taking logs and multiplying by 10 due to the logarithmic nature of the decibel unit, e.g 89 and 86 dB(A) would give an average value of 88 dB(A).

Alternatively, a simpler method for finding the average of two levels is to use the following table:

Table 2: To find the average of two levels

Difference between two levels being averaged	Subtract from the higher level dB(A)
1	0
2 to 3	1
4 to 9	2
>9	3

Measurement of daily exposures using personal dosimeters

The use of personal noise dosemeters or dosimeters is particularly useful where:

(a) noise levels are very variable;
(b) it is difficult to apply the concept of fractional exposures;
(c) the subject is itinerant or cannot easily be followed with a noise meter e.g. a fork lift truck driver;
(d) other health or safety hazards may exist;
(e) time does not allow a detailed survey with a noise meter, and finally and most importantly;
(f) the case is borderline at either the 85 or 90 dB(A) level of daily exposures.

This list of advantages is probably equally balanced by a list of cautions and special advice which will be discussed here. However first it needs to be appreciated that two basic types of dosimeter exist, namely the simple and the sophisticated, i.e. the simple type only providing a single result at the end of a measurement period and the other type logging data at discrete intervals of say a few minutes at a time over the whole work period up to say eight hours to provide Leq profiles and patterns for different work activities.

Both types of dosimeter consist essentially of a small box of electronics, which can be worn in a pocket or on a waist band, connected to a microphone by an electrical cable.

Basically, the simple type is capable of providing the daily exposure value required by the Regulations, while the sophisticated type is more useful for a detailed study of a complex work routine and the identification of noise sources for noise control purposes. Furthermore, the simple type can be purchased in greater numbers for the same capital outlay. This is important because the more operators that can be checked the more accurate will be the final assessment. In fact, a truly accurate result can probably only be obtained if the same workers are repeatedly checked on a number of occasions.

It is important to appreciate the basis of the last statement. It is often found that quite variable results can be found between operators and from day to day for the same operator even though the work process does not apparently change. If the process does change even more checks are necessary.

Of course, the question that arises from this discussion is : how many checks need to be made and when does this sampling strategy stop? First of all only very few, if any, noise dose checks will be necessary if it is clear from the preliminary survey that levels are well below 85 dB(A) or well above 90 dB(A). If there is no reason to suspect that personal daily exposures will be much different from the results of the preliminary survey in these high or low categories, then only one or two dose checks will be necessary to confirm this and for the high category the emphasis of attention will need to be on noise control together with the provision of adequate hearing conservation measures.

More intensive sampling of daily noise exposures is therefore necessary at the action levels of 85 and 90 dB(A) respectively, simply to determine to which category of values the exposures belong and consequently what action the employer must take. Ideally, sufficient results will be obtained for a group of employees working on the same work activity to allow a statistical analysis to be made and the 95% confidence limits to be established as shown in Figure 1.

The extent to which one can go with this procedure will be limited by the usual resources of time, men, money and machines and a pragmatic approach will be needed to evaluate what is reasonably practicable.

Errors arising from personal dosimetry

It has already been mentioned (under BASIC QUESTIONS) that a microphone gives more accurate results in a free field and by its very nature, personal dosimetry requires the wearing of the microphone close to the ear and hence the body.

HEARING CONSERVATION FOR SMALL FIRMS

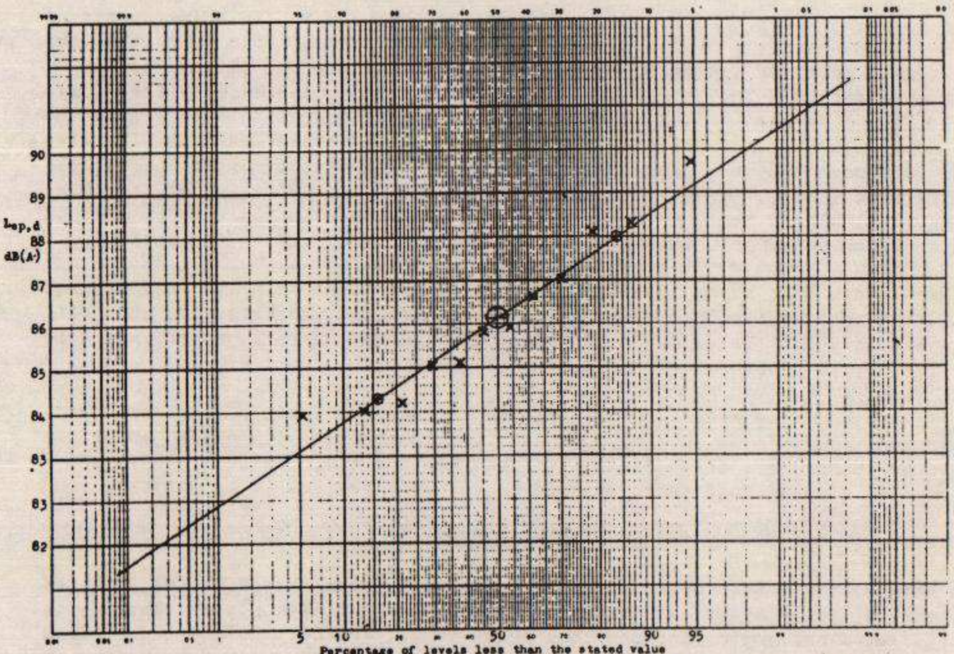

Fig 1 - Probability plot of personal dosimetry results showing 98% less than 90 dB(A) and 73% more than 85 dB(A).

Consequently, corrections need to be made according to the location of the microphone. Some manufacturers give corrections to be made at various frequencies for such locations as breast pocket, lapel, collar, etc. This writer recommends wearing the microphone only on the collar below either the left or the right ear (preferably the noisiest side). This standardises the measurement technique, places the microphone as close as practicable to the ear for most types of clothing and helps to eliminate the effect of shouted speech by the wearer.

The types of microphones vary in respect of their physical attachment; some lie along the fabric which is liable to induce a rustling noise; others clip onto the fabric to stand proud of the fabric. The latter configuration is preferred for obvious reasons.

As far as determining the actual correction that will be necessary, this will vary with different acoustic environments, particularly with the frequency content of the noise. However, there is a very simple technique which can be used. This uses two dosimeters whose microphones are placed on the same side of the body, one fitted onto the collar directly below the ear and the other over the shoulder and level with the ear. This last position can be conveniently achieved by fixing a boom about 75mm long onto the outermost point of a pair of ear muffs with the microphone clipped to the end of the boom. The author has found this to be an essentially free field position, i.e. about 150mm above the shoulder and the same distance from the ear. If simultaneous measurements are made in the noisier parts of the area under study with the meters set to the "calibration" mode a reliable comparison can be made in a short time, say 5 minutes. Two or three locations should confirm the difference in readings and this value used to correct the readings obtained during the dosimetry survey in the workshop.

Other errors can arise due to operator malpractice such as whistling or shouting into each other's microphones or turning the meter on and off. Consequently, it is a definite advantage to have meters which mitigate against these problems.

For example, some meters do not display a reading unless a special key is used and thus if no reading can be seen to change with noise input the novelty soon wears off. Similarly, some meters incorporate a timer, and a permanent elapsed dose store to allowed turn off periods to be noticed.

5. HEARING CONSERVATION

On determining that a group of workers have exposures exceeding the first or second action levels and assuming that no immediate noise control is possible, a hearing protection zone needs to be carefully delineated. This zone needs to be clearly marked with British Standard mandatory warning signs for hearing protection both at the entrances to and at strategic points within the area. Some machines may require signs to indicate the need for hearing protection when they are in use.

Adequate information and training is the key to a successful hearing conservation campaign. Employees need to be made aware of the noise survey results, the legal requirements, the potential damage to hearing, the effectiveness of hearing protection, the necessity to wear the protection absolutely all of the time when in noise (ELSE, [3]) and the purpose and use of audiometry. Plans for noise control may also be available and the duty to use and maintain any existing controls should been explained.

The adequate effectiveness of hearing protection needs to be ascertained by an octave band analysis of a typically noisy part of the workplace and the assumed protection of the hearing protector as given in the manufacturer's literature according to BS 5438. The ability to then combine octave bands to give an 'A' weighted level is necessary to confirm that levels reaching the ear are not more than 85 dB(A) and preferably much less than this figure. Some authors have found that the assumed protection should be the mean attenuation minus twice the standard deviation (RAWLINSON & WHEELER [8])

Ideally, a range of suitable ear plugs and muffs need to be made available to encourage wearer comfort and acceptability. For some monotonous tasks radio ear muffs are an attractive though rather expensive option, which are usually very popular and can attract almost 100% user acceptance. These have the choice of two radio programmes or the radio facility can be turned off. Studies by the author have found adequate protection in noise environments up to 102 dB(A) daily exposure with the radio turned on at a preset and audible level.

6. NOISE CONTROL

The simpler approaches to noise control need to be tackled first. Air exhausts from compressed air tools can be easily silenced, sometimes most effectively by a tube taking the noise to a remote point back along the supply hose. Otherwise, correctly sized and maintained pneumatic silencers are the answer.

Old noisy fans can often be replaced by new, quieter and more efficient fans that will pay for themselves in saved energy costs and are well worth investigating. Sometimes the process can be changed to a quieter method. Classically, this is demonstrated by the use of welding instead of rivetting to joint metal plates or sheets.

The larger and more difficult problems relate to large old electric motors and gearboxes and here expert help is probably needed. Guard against boxing in with acoustic enclosures as overheating can occur. Similarly a noise barrier will be ineffective in reverberant rooms. It is important to appreciate that absorptive acoustic treatment of ceilings or walls relatively remote from noise sources may well not effectively reduce noise exposures near machines. It will make a difference to the more remote or reverberant noise field and help those in such areas. Again this needs expert advice to confirm that these areas will benefit cost effectively.

The most important approach to noise control is to examine the noise source and the way in which they may be coupled to supporting structures to excite other surfaces more remotely. If vibration isolation is an important factor it also needs to be approached with expert advice which the isolator supplier should be able to provide.

Good, practical references on noise control are shown in the References.

7. REFERENCES

[1] BS 5969:1981. 'Sound level meters'. British Standard Institution.

[2] DEPARTMENT OF EMPLOYMENT, 'Code of Practice for reducing the exposure of employed persons to Noise', HMSO, 1972.

[3] D. ELSE, 'A note on the protection afforded by hearing protectors - implications of the energy principle'. Ann. Occup. Hyg. Vol.16, pp. 81-83. Pergamon Press 1973.

[4] F. S. GILL & I. ASHTON, 'Monitoring for Health Hazards at Work', Blackwell Scientific Publications, 1982.

[5] J. R. HASSALL & K. ZAVERI, 'Acoustic Noise Measurements', Bruel & Kjaer 1979.

[6] HEALTH & SAFETY EXECUTIVE, 'Noise control in the rubber industry', Rubber Industry Advisory Committee. To be published.

[7] HEALTH & SAFETY EXECUTIVE, '100 Practical applications of noise reduction methods'. HMSO 1983.

[8] R. D. RAWLINSON & P. D. WHEELER, 'The effects of industrial use on the acoustical performance of some earmuffs'. Ann.occup.Hyg. Vol 31, No 3, pp. 291-298, 1987.

[9] I. SHARLAND, 'Practical Guide to Noise Control'. Woods of Colchester Ltd., 1979.

[10] D. J. WEBB (Ed.), 'Noise Control in Industry' Sound Research Laboratories, 1976.