Proceedings of the Institute of Acoustics

NOISE FROM AN INDUSTRIAL RIFLE RANGE

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1. INTRODUCTION

Many of the noise control problems involved in the planning of an industrial rifle range are similar to those found in the planning of any factory where high sound levels are experienced.

For example, the noise problem can be divided into two distinct categories, as shown below:

1) The protection of the operator from hearing damage.

2) The protection of the neighbours from noise annoyance.

Two factors which can make the noise problems of an industrial rifle range particularly difficult are the very high and impulsive nature of the sound source and the general requirement for rifle ranges to be outdoors.

These, coupled with other complications, such as the wide range of guns that may be required to be used (yet cannot be fired until the range is licenced) and the psychological associations of gunfire which could cause annoyance out of all proportion to the sound pressure level, make the planning of a rifle range more difficult.

As with any noise control engineering problem it is advantageous to have a knowledge of the basic principals of the noise generation. In the case of gunfire noise this is covered in the science known as ballistics.

2. SOME BASIC BALLISTICS

The gun is a mechanical device, in which heat is generated from the burning of propellant. As the propellant burns, its surface undergoes chemical reactions, which generate high pressure (and temperature) in the surrounding gases.

As the propellant burns within the fixed volume, the pressure rises until the projectile starts to move along the barrel. This increases the volume and hence moderates the pressure. The propellant burns so rapidly that the motion of the projectile cannot fully compensate and the peak pressure is reached at approximately one tenth of the total length of the barrel.

Even after the propellant has passed the all-burnt position a considerable pressure remains, causing the projectile to continue to accelerate. As it approaches the muzzle some of the propellant gases which have leaked passed the projectile are expanded, causing the pressure to fall and reduce the projectile acceleration.

This sequence takes approximately 1 ms for a handgun, 15 ms for a rifle and up to 25 ms for a large artillery gun [1].

The noise generated from the firing of a gun is relatively complex [2] and is derived from several sequential stages:

1) Before the projectile reaches the muzzle, high pressure turbulent gases are released. This causes a shock wave which travels both away from the muzzle and towards it, at speeds slightly greater than the speed of sound in air and it is heard as a sonic boom.

2) The ingoing noise forms a shock wave which travels towards the muzzle against the flow of gas. If the speed of the ingoing noise equals the speed of the gas flow the shock wave will be in a quasistatic form. This shock wave is bottle shaped and is known as a 'bottle shock'. The curved sides are known as the barrel shock and the flat base is known as the Mach disc.

3) Once the projectile passes the muzzle the high pressure propellant gases are released and a powerful blast shock is generated.

3. THE DAMAGE TO HEARING RISK

The magnitude of the unweighted sound pressure from guns at the operators ear position can range from 200 Pascals (Pa)(140 dB re 20 μPa) for a 0.22" rim-fire rifle to over 2 000 Pa (160 dB) for a service rifle [3].

These magnitudes are either at, or clearly in excess of, the 200 Pa stated by the Council of the European Communities directive on the protection of workers from the risks related to exposure to noise at work [4] and the Noise at Work Regulations 1989 [5], for a magnitude where measures are required to be taken [4].

These measures include:

- providing adequate information and training on the potential risks to the operators hearing arising from the noise exposure.

- the obligation to comply with protective and preventative measures.

- the wearing of personal ear protectors.

- a technical programme to reduce the noise exposure as far as is reasonably practicable.

The unweighted sound pressure of 200 Pa, stated as an action level in the directive, is irrespective of the duration. However there is strong evidence to support the claim that hearing damage caused by high level impulsive sound pressures are related to the duration [6],[7],[8].

3.1 Exposure Limits for Gun Fire Noise.

More detailed limits for the estimate of the hearing hazard are found in the United Kingdom Defence Standard 00-27/1 (1986) [8] which gives limits based on 100 firings per day, on an occasional basis. These limits are dependent on duration, giving a straight line relationship (on a log/log graph) from 3000 Pa (163 dB re 20 μPa) for a duration of 1 ms down to 500 Pa (148 dB) for a duration of 200 ms.

The standard also gives a preferred limit, approximately 10 dB lower, where the risk of noise-induced hearing loss is very low. Where hearing protectors are used an allowance is permitted of 20 dB or 25 dB (depending on the type).

If the firings per day are other than 100, a further correction factor is used, ranging from +10 dB for one firing per day to -10 dB for a thousand firings per day.

This implies that pressures up to 158 000 Pa (198 dB) can be tolerated provide that the duration is less than 1 ms, only one shot is fired per day, and good quality hearing protectors are used.

3.2 The Effects of High Pressure Impulsive Noise on Man.

Exposure to high pressure impulsive noise can cause a hearing loss which has the characteristic 4 kHz peak. This is similar to the hearing loss due to continuous noise at a lower pressure level. However, hearing loss caused by high pressure impulsive noise is more frequently accompanied with the symptom of tinnitus (a constant 'ringing' in the ear) [9]. This system is known to cause subjective discomforts such as speech discrimination problems, concentration difficulties and insomnia. Extreme cases of tinnitus have even resulted in suicide. Tinnitus is difficult to predict and it is known that, of two people with the same audiometric threshold shift as a result of noise induced hearing loss, one may and one may not have tinnitus [10].

Other effects can occur, especially where the duration is increased by reverberation or other acoustic reflection.

Ear drum rupture has been reported at 50 000 to 56 000 Pa, (187 dB to 189 dB) measured at the ear drum, when the duration of the positive phase of the impulse exceeds 2 ms. This pressure at the ear drum can be produced by pressure as low as 15 000 (177 dB) measured in free-field away from reflecting surfaces, if the pressure is reflected from the side of the head. This injury will not usually, of itself, produce total deafness, and can sometimes heal spontaneously.

At peak pressures around 100 000 Pa (194 dB) injury can occur to gas containing organs (lungs and intestines), resulting in haemorrhage. The threshold for lethal injuries is about 270 000 Pa (202 dB). With peak pressures of 500 000 to 700 000 Pa (208 dB to 211 dB) lethal injures will be induced in about 50% of those exposed, although this will depend on duration. The effect will be greater with multiple exposures or exposures in confined spaces. Normally, with such pressures, there is an even greater hazard from fragments or collapsing masonry [3].

4. NOISE ANNOYANCE

When planning the location of a new rifle range, it should ideally be positioned well away from any residential properties. The UK Noise Abatement Society for example recommends that for clay pigeon shooting, no new shoot should be permitted within two miles of the nearest residence. However, in the over populated South East of England, for example, a better compromise may have to be implemented.

The local topography as well as distance can be used. For example, planning consent was given to a rifle range which was 800 m from the nearest dwelling [11]. As this dwelling was the other side of a large hill from the range, the gun noise, although audible, was indistinguishable at 5 dB above the background noise (see figure 1a).

If the nearby dwellings are located near to an established noise source, such as a motorway or busy road, the annoyance from the gun noise is likely to be less. The graphical trace in figure 1b was recorded at a dwelling which was 1200 m from the gun shots along a valley, but close to a busy road. The residents had no objections to the gun noise.

4.1 Evaluation of Annoyance

Several studies have been made of annoyance due to noise from shooting ranges. Sorensen and Magnusson [12] conclude that the annoyance is very low up to a certain threshold, after which it increases relative quickly. The threshold is an 'A' weighted sound pressure level maximum of between 60 dB to 65 dB (r.m.s. fast time weighting). Smoorenburg [13] preferred to use the impulse time weighting due to the inconsistencies found in the maximum hold circuits on fast time weighting in sound level meters.

Smoorenburg quoted Meurers's [14] formula to determine the rating sound level (L_r) ie. the sound level of a steady noise which is assumed to cause the same community response (annoyance) as the shooting noise.

Meurers suggested that:

L_r = L_{AMAX} (impulse time weighting) + 10 log N - 42 dB...(1)

where levels are 'A' weighted and

N = number of impulses per day: 100 > N < 10000

Equation 1 takes no account of the number of occasions in which the range is used or the background noise. Hofmann et al found that the number of occasions the range was used was a more important factor for annoyance evaluation than the number of shots fired.They developed the formula:

L_r = L_{AMAX} (fast time weighting) + 10 log D + 3 log M - 44 dB...(2)

where D = number of shooting occasions per year
M = number of shots per year

In determining D, mornings and afternoons are counted separately and Sundays are weighted with a factor of 3. Formula 2, like formula 1, takes no account of the background noise.

More recently Scannell [16] has suggested a formula based on the work of Hofmann et al but also takes the background noise level (L_{A90}) into account and gives a maximum allowable level from gunshots:

L_{AMAX} = L_{A90} + 10 log D - 30 dB...(3)

where L_{AMAX} is the maximum allowable level from gunshots at any part of any nearby residences (r.m.s. fast)
L_{A90} is the averaged background noise over a period corresponding to the hours operated by the range (r.m.s. fast). Measured at the dwelling in question.

D = the number of shooting occasions per year that range is used with the same weights as used by Hofmann et al.

No account is taken of the number of shots per session. This is to simplify the formula and the assessment procedure. However, a further adjustment may be needed for a large number of shots per session.

(Formula 3 can be used for clay pigeon shooting as well as shooting ranges.)

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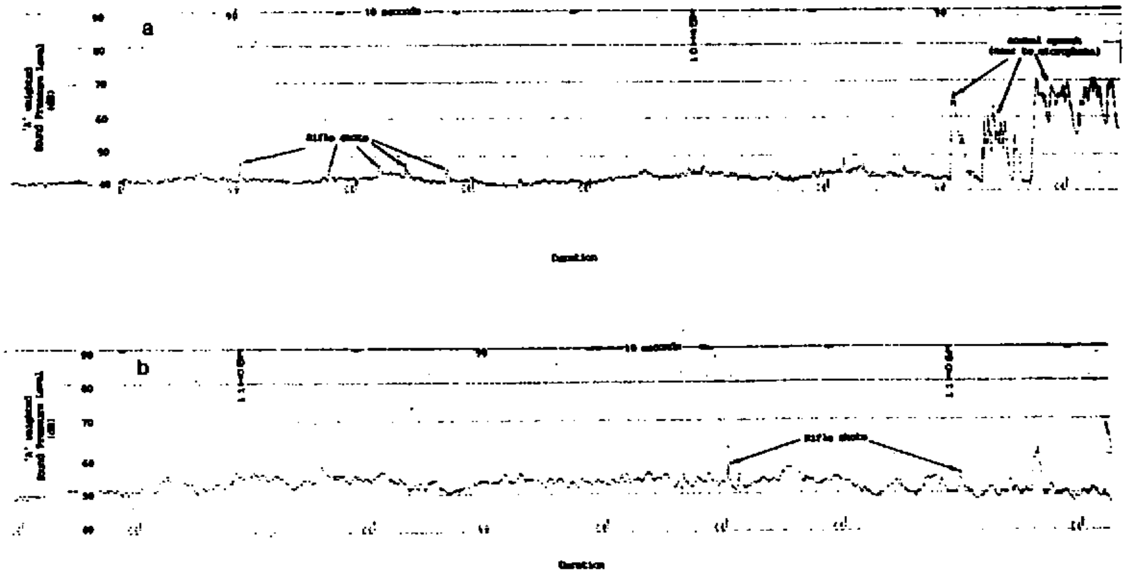

FIGURE 1. GRAPHICAL TRACES OF NOISE FROM A RIFLE RANGE.
(a) At a distance of 800 m from the gun shot noise, on the other side of a large hill, with low background noise. (b) At a distance of 1200 m from the gun shot noise, down a valley with a higher background noise from traffic.

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THE USE OF SHORT-TERM L_{Aeq} IN THE ASSESSMENT OF IMPULSIVE NOISE

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1 INTRODUCTION

The use of L_{Aeq} as a general descriptor of environmental noise is now widespread and is embodied in international standards such as ISO 1996 (1) and in national standards such as the revised BS 4142 (2). Both standards use the concept of a reference time interval, being the specified time interval to which an equivalent continuous A-weighted sound pressure level is referred. Generally such reference time intervals are long such as 8 or 12 hours. Sometimes hourly values of L_{Aeq} are specified but even this gives rather a broad picture of a given situation. At the other extreme we can record the complete noise signal for subsequent analysis back in the laboratory but this is inefficient in the use of data storage and often inconvenient. The advent of cheaper computer disc storage led to a proposal in 1979, in a report to the CEC by Komorn and Luquet (3), of a method of storing data called Short-Leq which compressed the data but ensured its integrity and yet stored a true representation of the original noise.

The method suggested was to integrate the sound level over a short period, typically under 1 second, and produce a non-time weighted Leq for this short period. This "Short Leq" would be stored and a further Leq taken, with no gap between them, continuing with successive Leq's for the duration of the whole measuring period. The advantage of the method is that the Leq is a true integral of the energy and thus accurately describes it for all statistical purposes.

Commins and others (4,5) went on to develop special instrumentation and showed that by varying the integration time and performing correlation analysis between pairs of simultaneous measurements it was possible to discriminate between sources and evaluate their relative importance. More recently Wallis and Luquet (6) have described an instrument which allows the full realisation of IEC Standard 804 (7) and is capable of storing over 100,000 separate L_{Aeq} values whilst at the same time giving conventional values of L_{Aeq}.

However there are situations when integration times of 1/8th of a second can be too long and even more detail is needed. In the course of work at NPL, supported by the Department of the Environment, on the evaluation of impulsive noise (8), a computer-based noise analysis system was programmed to implement an integration time of 10 ms and the subsequent time-series was further processed by various methods which gave good correlations with the results of subjective experiments on judged annoyance in laboratory conditions. More recently in the course of the Joint Project on Impulse Noise, funded by the CEC, this work has been taken further and a CRL 2.36 data acquisition integrating sound level meter made by Cirrus Research has been modified to take the short-term period down to 10 ms and further descriptors based on $L_{Aeq(10\ ms)}$ have been investigated.

This paper outlines the concept of short-term L_{Aeq} and discusses the associated instrumentation. Special rating methods based on processing the time-series of $L_{Aeq(10\ ms)}$ are introduced and their relationships with subjective data are discussed.

2 SHORT-TERM L_{Aeq}

Equivalent continuous A-weighted sound pressure level, $L_{Aeq,T}$, is the value of the A-weighted sound pressure level of a continuous steady sound that within a specified time interval, T, has the same mean-square sound pressure as a sound that varies with time. It is given by the equation:

$$L_{Aeq,T} = 10 \log[1/T \int_{t_1}^{t_2} (p_A^2(t)/p_o^2)dt]$$

where

$L_{Aeq,T}$ is the equivalent continuous A-weighted sound pressure level determined over an interval $T = t_2 - t_1$ (s)

p_o is the reference sound pressure (20 μPa)

$p_A(t)$ is the instantaneous A-weighted sound pressure (Pa).

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One can consider the value of $L_{Aeq,T}$ as a measure of the actual energy of the signal $p_A(t)$ between t and t + T. We can choose small values of T such as one second or less without giving any statistical significance to these values of $L_{Aeq,T}$ with respect to the $p_A(t)$ process. This integration process over successive periods leads to a time-series which can be analysed for itself. Each value of $L_{Aeq,T}$ is totally independent of previous and succeeding values. Figure 1 shows part of a 2 hour plot of the noise around an Air Force base in France using both a 10 minute and 10 second period for $L_{Aeq,T}$. The detail of events provided by the shorter time is readily apparent.

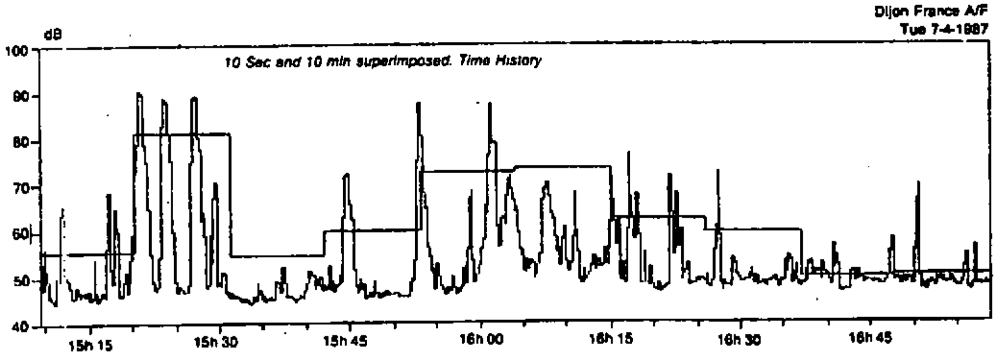

Figure 1. L_{Aeq} time histories

3 INSTRUMENTATION TECHNIQUES

The basic method is to calculate values of L_{Aeq} at intervals of either 125 ms, 1 second or 10 seconds and acquire the data into the non-volatile memory of the instrument where they are available to be used for subsequent analysis by a desktop or laptop computer. Each separate measurement session is identified in the memory by a data header and any number of separate sessions can be made, subject to the total memory limit of the instrument. Four code buttons fitted to the instrument allow particular noises to be identified and coded on-site. These codes are automatically transferred to the computer when the data are read over.

Details of the specific technique used in the CRL 2.36 were published by Wallis and Holding (9). The signal after filtering is passed to an analogue squarer to generate a current proportional to the energy reaching the microphone. This current is integrated in a totally analogue integrator. Only at this stage is it digitised and because there is no sampling done on the raw AC signal the problems of sampling rate error are designed out. The integrated signal is stored and converted to a digital value while the next period is being integrated thus the only lost time between periods is the sample and hold circuit acquisition time which is of the order of a few microseconds.

In the special instrument developed for NPL the basic period was reduced to 5 ms and the values concatenated to give $L_{Aeq(10\ ms)}$. With the decrease of acquisition time from 125 ms on the standard instrument to 5 ms, problems not considered in the original design showed themselves.

For example, the integrator feeds a 12 bit counter. If the instrument had 125 ms to fill this, the maximum speed of the integrator would be 125/4096 × 10^3 microseconds, about 30 microseconds. When this is speeded up to acquire in 5 msec, the fastest time is now just over a microsecond, which generates current supply demands that are impossible to meet in a battery unit. This was the limiting factor in the design. Thus, a trade off was made in the capacity of the counters, which reduced the dynamic span of the unit down to about 90 dB from the normal 120 dB, each 1 bit removed dropping the dynamic span by 3 dB. The final design is such that a single 20 kHz half sine wave, the fastest acoustic impulse we have considered can be acquired to the full system accuracy.

In the instrument we are reporting, the 5 ms elements are combined into a single 10 ms for storage. This approach was chosen as it was not clear at the start of the investigation what actual period would be required and it was felt that a single investigation to get down to 5 ms would leave some headroom for error. The standard CRL 2.36 has a capacity of 114,000 stored integrals which was not increased. With a 10 ms acquisition, this gives a total acquisition time of only 10 minutes although 125 ms and 1 s acquisition periods were included to give operating times of 4 and 30 hours respectively. Further development is in progress to increase the memory size to 1 Megabyte.

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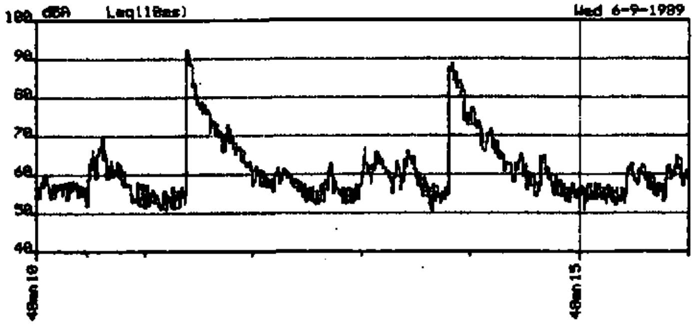
At any time after acquisition the data can be copied to a host computer, normally an IBM PC or compatible, via a RS232 port, and the data stored in permanent form on the disc. The software leads the user through a few simple steps, such as asking the name under which to file the data and the place and time of acquisition. Any one of a number of measurement sessions can be copied to the computer in this way leaving the original data retained in the memory of the instrument until the user chooses to discard it.

With a copy of the data safely stored on disc the measurement can take place. With short-term L_{Aeq} the acquisition and measurement phases are separated so that each of the two computers, the one in the instrument and the other in the host machine, can operate at full efficiency. The software allows any measurement to be made where peak levels are not involved, thus histograms and cumulative histograms can be plotted and percentile levels calculated. The simple time history of noise level between any two times can be plotted. Figure 2 shows the result for the noise of a pile driver with short term periods of 10 ms and 1 second. Note the detail provided of the individual impulses.



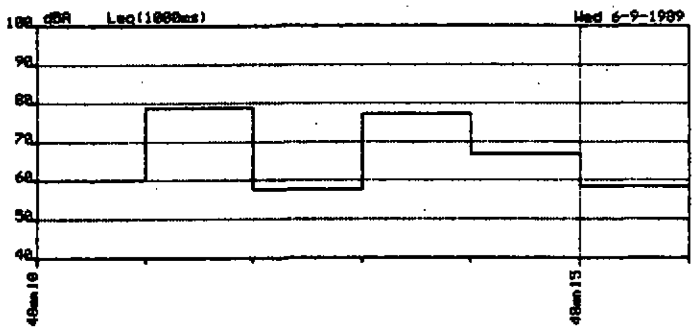


Figure 2. Time histories of pile driver noise, T = 10 ms and 1 second

In addition to the standard software, special routines have been written to analyse the time series and calculate special objective measures or descriptors of impulsiveness.

4 RATING METHODS FOR IMPULSIVE NOISE

The CEC Joint Project on Impulse Noise began in October 1987 with the aim of developing a physical objective method for quantifying impulsive noise. There are essentially two related parts to the project. Three laboratories - the Institute of Sound and Vibration Research, University of Southampton (ISVR), the Medical Institute for Environmental Hygiene, University of Düsseldorf (MIU) and the Institute of Acoustics (IDAC) in Rome - have been conducting listening tests under a common protocol on the subjective rating of impulsivity and annoyance of a wide range of noises.

NPL and the Institute for Medical Psychology (IMP), University of Düsseldorf have been studying the problem of physical quantification methods in order to derive an optimum objective rating.

Both NPL and IMP have focussed on methods based on processing the time-series of $L_{Aeq(10\ ms)}$, with NPL concentrating on time-domain methods and IMP on frequency domain methods.

Time domain

Three descriptors have been assessed - standard deviation, salience and increment. Standard deviation is obtained by taking each of the 100 values of $L_{Aeq(10\ ms)}$ in any one second interval and calculating according to the common formula

$$(\text{standard deviation})^2 = \frac{1}{100} \sum_{i=1}^{100} (L_{Aeq(i)} - \bar{L}_{Aeq(i)})^2$$

Salience is calculated from the difference between the maximum value of $L_{Aeq(10\ ms)}$ in a one-second interval and the overall value of L_{Aeq} for that interval. Increment is found by taking differences between successive values of $L_{Aeq(10\ ms)}$ and noting the maximum positive difference. The concepts of salience and increment are illustrated graphically below for a one-second segment of pile driver noise.

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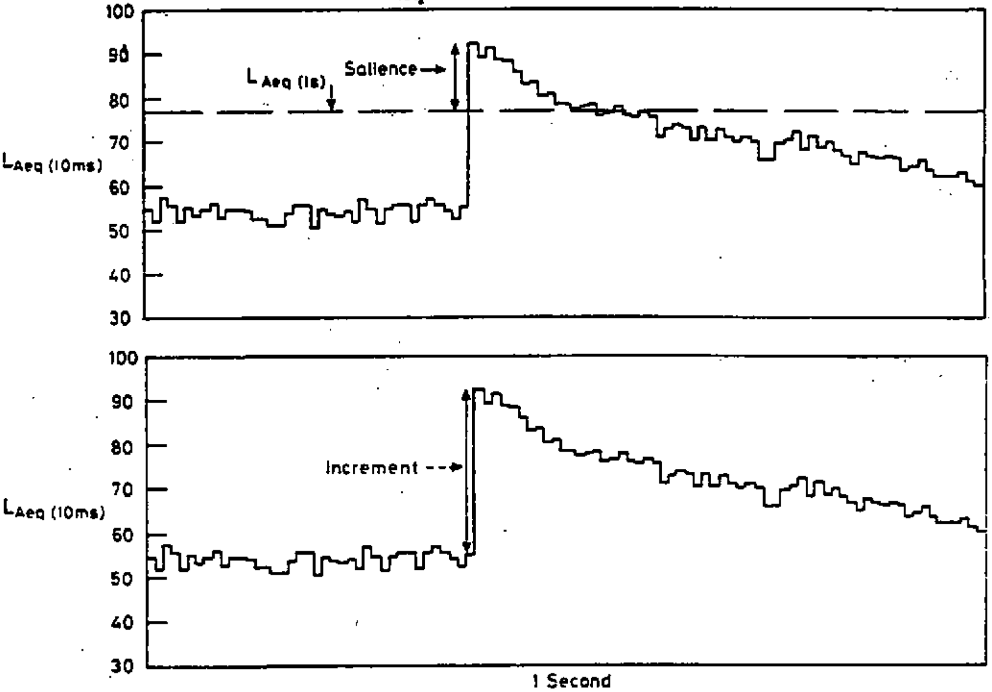

Figure 3. Concepts of salience and increment.

The individual values of $L_{Aeq(10\ ms)}$ making up the time series are evident in this "zoomed-in" view of the time-history provided by the standard software.

Frequency domain

We can regard the time-series or envelope function of the original signal as a "signal" in itself with frequency components from 0 to 100 Hz. Bisping (10,11) has shown how this signal can be analysed using Prony spectrum techniques. The powerful zooming capabilities of Prony compared to FFT techniques allow high resolution analysis of small bandwidth sinusoidal components embedded in noise. Early work simply considered qualitative effects such as the pronounced frequency spreading effect of impulsive noise compared to steady noise. Later however measures expressing the relevant information contained in the Prony spectra in one single number, such as spectral flatness (12), were investigated.

In Phase 1 of the project October 1987 to April 1988, ISVR, MIU and IDAC conducted experiments with 64 noises. These consisted of a common core of 40 used by all laboratories and a set of 24 noises specific to each laboratory. Each laboratory used 16 subjects who had to rate the 64 noises each presented for twenty seconds. Four questions were used in the questionnaire. NPL analysed all 40 common noises using salience, standard deviation and other methods such as crest factor and $L_{AI} - L_{AS}$. The results of the physical analyses were related to the subjective data for each laboratory. From the resulting correlation matrix it was concluded that the standard deviation was superior to the other methods (13).

In Phase 2 of the project, May 1988 to March 1989, the increment descriptor was included. When applied to the Phase 1 data it was found to be superior in its correlation with subjective data. The various noises used in separate further experiments by MIU, ISVR and IDAC were analysed and it was found that the increment descriptor performed best overall. Details were given at the 13th ICA in Belgrade (14). Also during this phase Bisping (11) found correlations of the order of 0.8 between subjective impulsiveness and the difference between the mean L_{Aeq} and the maximal amplitude of all the poles in the Prony spectrum between 0.3 and 25 Hz.

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The Rating of Impulsive Noise

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1. Introduction

There are many occasions when impulsive noise can be determined using L_{Aeq}, . The use of L_{Aeq} will give satisfactory results. However there are occasions when such techniques fail because of the impulsive noise being embedded in environmental noise.

2. Discussion

I have spent many hours this year listening to Clay Pigeon Shooting and Piling. It is my opinion that I cannot attest that a noise is a nuisance if I cannot hear it because of the high background noise. I am also of the opinion that the greater the specific noise is in excess of the contemporaneous background level the more likely that the noise will be adjudged a nuisance.

At the sites that I have been monitoring the background levels vary from the low thirties to the high fifties. A specific noise level of 55 dB(A) is very noticeable over a background of 32 dB(A) (and gave rise to complaints) but that level was barely noticeable over a background of 49 dB(A). Very high levels for these sites (over 72 dB(A)) normally invoked complaints.

It is my opinion that for impulsive noise the following factors are important:-

- the impulsive noise level
- the background level
- the rate of discernable impulses heard
- the duration, time of day, the number of days per week

Another problem that I have encountered is in determining a fair value for the impulsive noise.

In defining the term **Typical Maximum Level** I have attempted to take account of the atypical result due to the occasional rogue cartridge or the build up of blanks in a power press or the unusual propagational properties.

I wanted a simple way to make allowance for the above and thus decided not to go for the absolute maximum value. I have done a number of statistical analysis of the level of impulses and the figure 4 is a typical distribution.

I am only interested in rating those impulses that I can hear, because the impulses that are inaudible cause no problem. The **Discernable rate of impulses** takes this into account.

The greatest problem that I have met is in assessing what is a reasonable number of occasions that an individual be subjected to impulsive noise. Clearly the complainant will want it to tend toward zero whilst the manufacturer will want no restraint. I have used a correction of ten times the logarithm of the number of days that discernable formula based on there being up to about half the days per month when there was impulsive noise - how justified it would be in extrapolating it to every day per month is speculative but the maximum correction is 7 dB)

Digital meters are superb instruments but care has to be exercised in their use - read the instruction book and know what they are displaying.

Definitions

Background Noise Level is the Level in the absence of the Specific noise (in this case the impulsive noise) and shall be determined in terms of $L_{A90,T}$ using the F time-weighting.

Impulsive Background Noise Level is the background level whilst impulsive noise is in progress and shall be determined in terms of $L_{A90,T}$ using the F time-weighting.

Specific Noise Level is the noise level of the source (in this case the impulsive noise) and shall be determined as the Representative Maximum Level.

Typical Maximum Level $L_{AMAX9000}$ is that level which is exceeded on at least fifteen occasions in a fifteen minute period and shall be determined using the F time-weighting.

Alternatively it may be determined by measuring the $L_{AMAX9000I}$ using the I time-weighting and subtracting 5 dB to obtain the estimation of the $L_{AMAX9000}$ using the F time-weighting.

Discernable Impulse is any impulsive noise whose level exceeds the impulsive background level by 6 dB when measured using the F time-weighting.

Note care should be exercised to endeavour to exclude all impulses from other sources.

Discernable Rate of Impulses per minute R shall be determined by obtaining the average rate of impulses of discernable impulses.

The average rate of impulses shall be determined over at least five one minute periods distributed through a fifteen minute period.

Rate correction value C_r is given by the formula

$$C_r = 10 \lg (R/10) + 10 \lg(n/6) \quad \text{dB}$$

where $1 < R < 40$,

$1 < n < 16$

and n is the number of days in the previous month when there were discernable shots at any of the measurement positions.

Corrected Maximum Level LAc is given by Typical Maximum Level plus the Rate correction value.

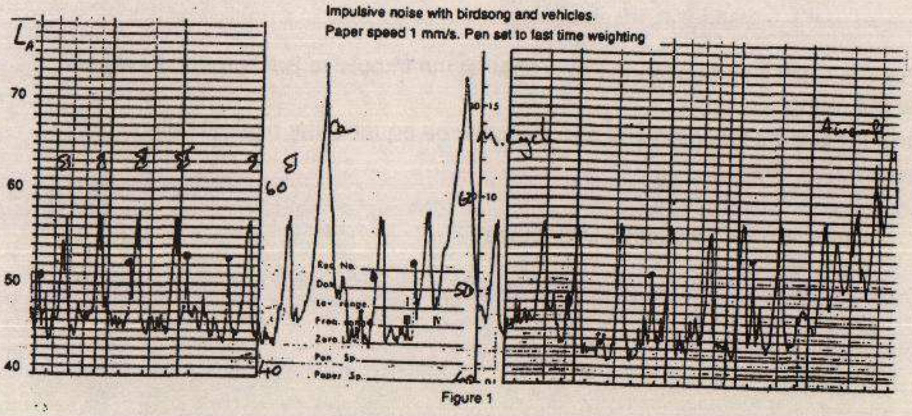

Figure 1

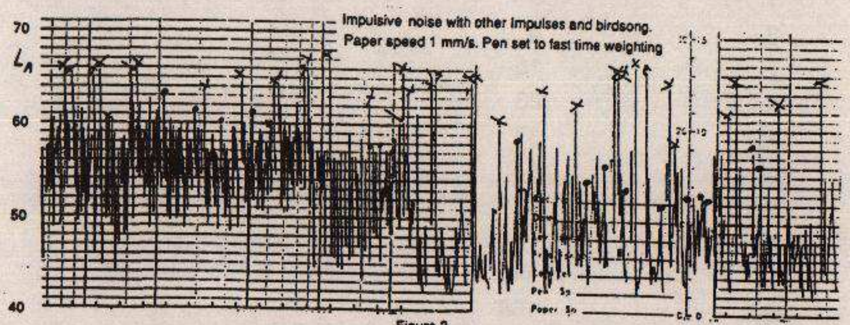

Figure 2

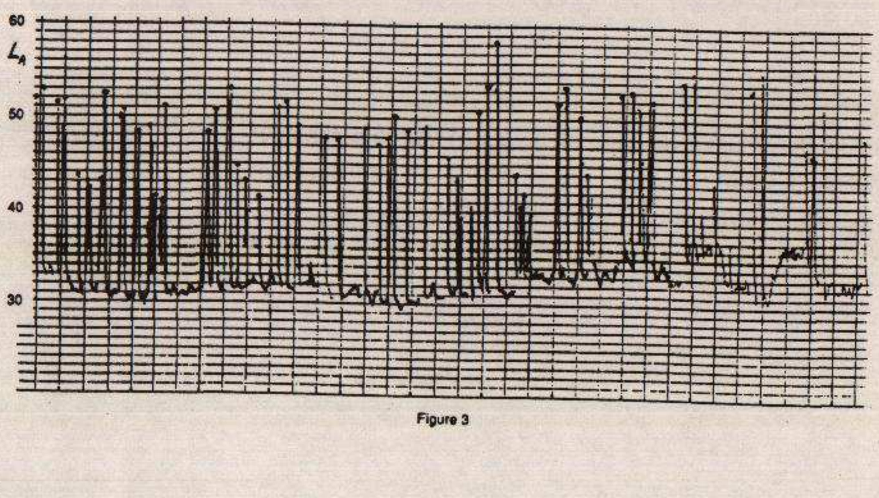

Figure 3

Rating Plot the Corrected Maximum Level against the Impulsive Background Level and determine the rating.

Day Rating the overall rating on any one day shall be equal to the highest rating determined on that day.

Level dB(A)	Distribution	Cumulative Distribution
66	2	2
65	1	3
64	1	4
63	1	5
62	3	8
61	7	15
60	8	23
59	14	37
58	27	64
57	28	92
56	24	116
55	29	145
54	23	168
53	15	183
52	14	197
51	3	200
50	3	203

Thus absolute maximum level	= 66 dB(A) fast time constant
Typical Maximum Level	= 61 dB(A) fast time constant
$L_{Aeq\ 15\ min}$	= 53.6 dB(A)
Background Level	= 45 dB(A) fast time constant

Figure 4

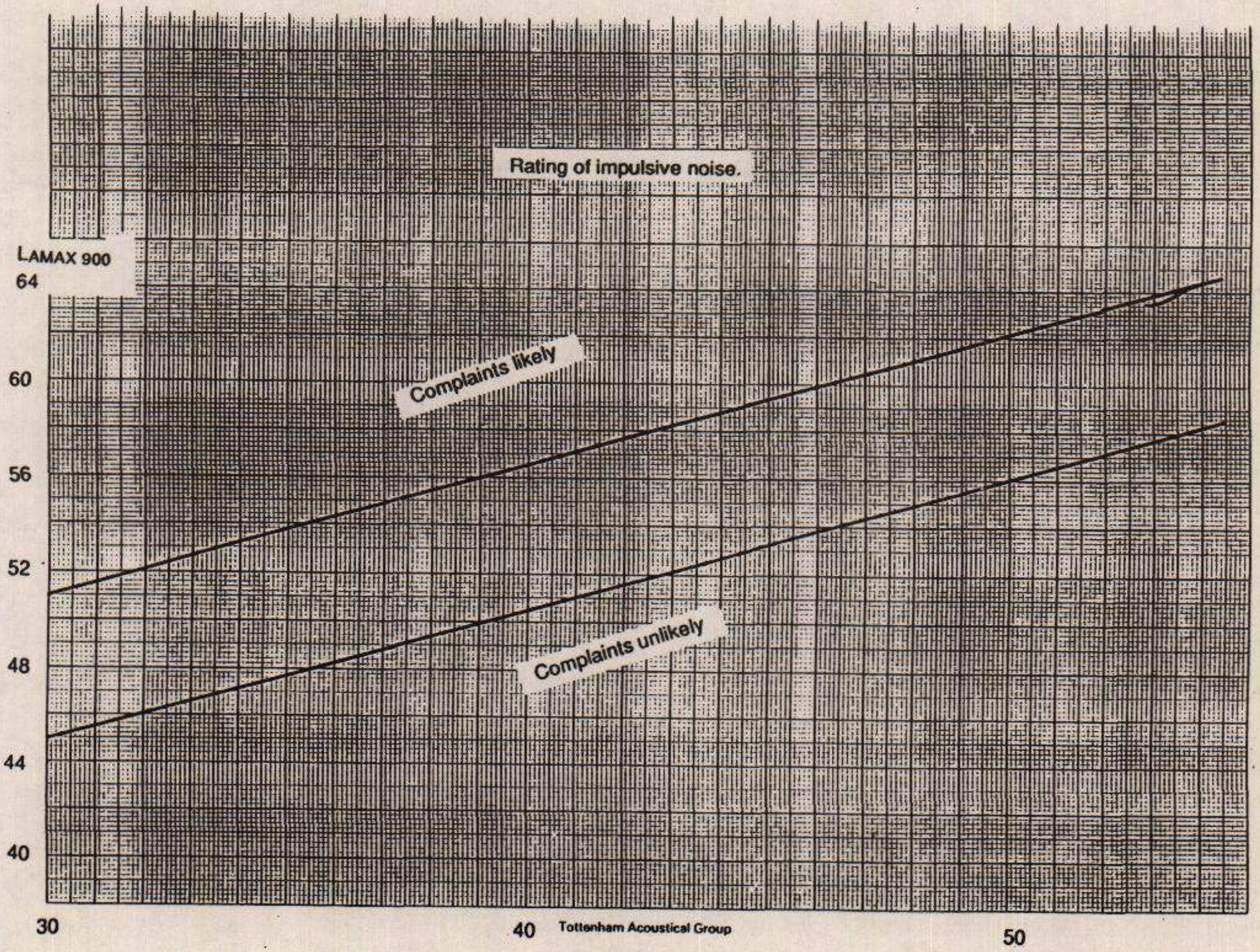
Rating of impulsive noise.
LAMAX 900
64
60
56
52
48
44
40
Complaints likely
Complaints unlikely
30
40
Tottenham Acoustical Group
50
Impulsive Background Level dB(A)

Figure 5