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Environmental Noise - Difficult Areas

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INTRODUCTION

Most evaluation of noise for the estimation of annoyance makes use of the 'A' weighting scale - the familiar dB(A) - and for many situations this procedure works reasonably well. The measured dB(A) level is compared with a criterion, either a measured background level, or some prescribed standard, and from this comparison it is possible to make some prediction of the likelyhood of complaints. See, for example, BS 4142 (1).

There are, however, a number of situations where this procedure breaks down, it may give answers that are at variance with complaints experience, or it may just not be possible to apply it. Two such areas are low frequency and impulsive sounds.

Most of the difficulties with low frequency sounds arise in the region below 200 Hz where it is found that the subjective adverse reactions are more severe than dB(A) levels would indicate, and are sometimes of a different type from those which arise in response to higher frequency noises.

Impulsive noise usually arises from explosive sources, in most cases small-bore guns, and in this situation the problem is to find a measure of the noise which relates to the annoyance. The initial problem is to decide whether to measure individual rounds, or to look at some form of average level such as Leq. The next stage is to decide upon suitable units of measurement and how the resulting data may be evaluated.

LOW FREQUENCY NOISE

Although text books often quote 20 Hz - 20 kHz as the range of hearing, in fact perception occurs down to 1 Hz or lower. This has led to the definition of 'Infrasound' as the region below 20 Hz and to various studies of perception in this region.

Main features of the infrasonic region are;
a) The ear is of low sensitivity needing high sound pressures for perception
b) Below about 18 Hz perception of tonality disappears, ie separate sound pulses become individually audible, but the sound does not have a discernable pitch.

Initial research concentrated on high levels in the lowest frequency ranges. Up to 171 dB at the ear by Johnson (2), and 154 dB whole body by Mohr et al (3). These experiments demonstrated unpleasant effects but did not cause any permanent injury. This early research was largely undertaken in response to the needs of the NASA Space Agency, who were concerned with the intense levels of infrasound generated by large rocket motors. Sound pressure levels below 10 Hz sufficient to be perceived are almost never met in the environment.

ANNOYANCE

The frequency region where low frequency noise causes annoyance can roughly be defined as 10 Hz to 200 Hz with the majority of instances lying between 20 and 100 Hz.

THE AUDIBILITY OF LOW FREQUENCY SOUND

Environmental low frequency sounds can make themselves evident in two different ways, either by simply being heard or, in the case of intense low frequency sounds, by rattling, particularly of windows. Figure 1 shows the thresholds of audibility and rattling. The former is based firmly on the results of a number of studies, see for example, Yeowart (4).

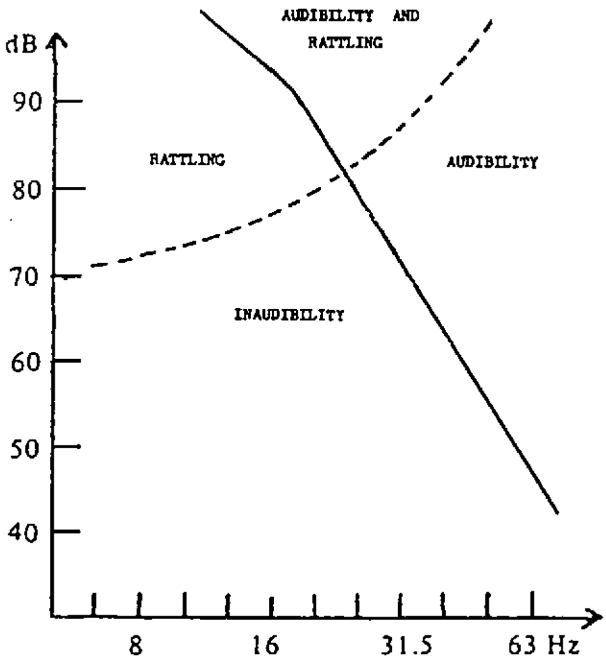

Fig 1. The hearing threshold - full line ; and the 'rattling' threshold - broken line (from Yamada, 1982)

Although quantitative data on the rattling phenomenon is somewhat limited, sufficient reports have appeared in the literature to indicate that it is fairly widespread at frequencies below 20 Hz, see Yamada (5).

In the low frequency region the subjective response to audible sound appears to be somewhat different from that at higher frequencies. When people are exposed to low frequency environmental noise above the hearing threshold and asked to describe the experience they rarely complain about loudness but instead refer to other characteristics, such as 'an oppressive environment', or 'an unpleasant place to work in'. Some complain of headaches and ill defined sensations of unease or disturbance.

The above complaints tend to be produced in situations where there is substantial low frequency noise which, in the absence of higher frequency components, tends to be perceived as a rumble. Interestingly enough, when the same low frequency components are present as part of a loud, broad band noise, the above-mentioned effects are not reported. Presumably this is because the low frequencies are masked by the mid- and higher frequencies.

EVALUATION

The most widely used predictor of noise annoyance is the dB(A) sound level measurement, however it is clearly apparent that in the low frequency range annoyance can arise at quite low dB(A) levels which would not, by normal standards, be likely to cause any complaint. This situation has therefore led to some attempts to find alternative evaluation procedures.

The International Standards Organisation (6) has produced a new 'G1' weighting curve for use at frequencies below 20 Hz, (see Figure 2). The G1 weighting

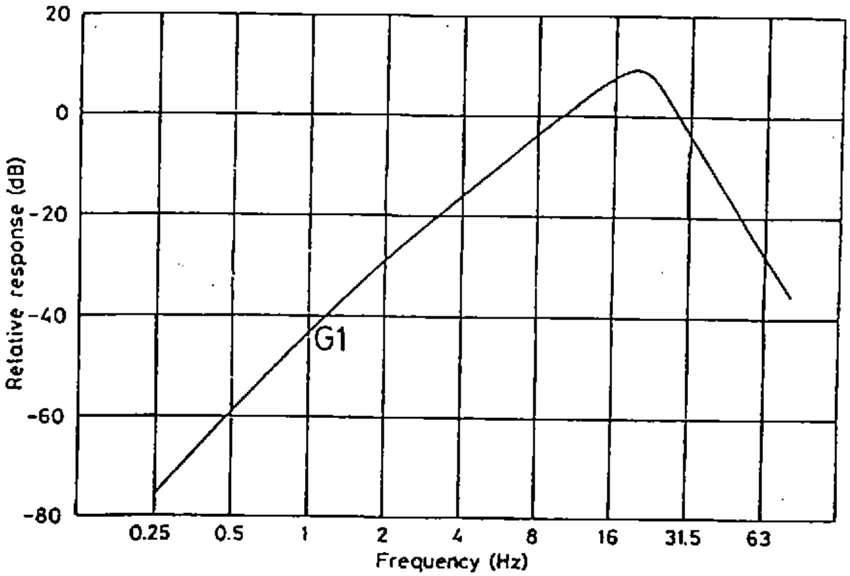

Fig 2. Proposed G1 weighting for infrasound (ISO 1984)

approximates to the inverse of the hearing threshold curve in the frequency range between 2 and 20 Hz. A level of 100 dB(G1) is a close approximation to the hearing threshold in this range. There is evidence from Yamada et al (7) that the annoyance threshold in this range is very close to the hearing threshold, lying in the range 100-110 dB(G1). This conclusion is further supported by the work of Vasudevan and Gordon (8) and Vasudevan and Leventhall (9). This leads to a provisional conclusion that for frequencies below 20 Hz 100 dB(G_1) can be treated as a perception threshold and, if the most sensitive individuals are to be considered, an annoyance threshold.

Both laboratory and field studies support the view that annoyance rises rapidly with increasing sound pressure level. It is therefore suggested that at about 110 dB(G_1) fairly widespread complaints might be experienced. Other evidence of the rapid rise in subjective sensation with level at the lowest frequencies comes from the equal loudness studies of Whittle et al (10), see Figure 3. A somewhat similar weighting curve to G1 for low frequencies,

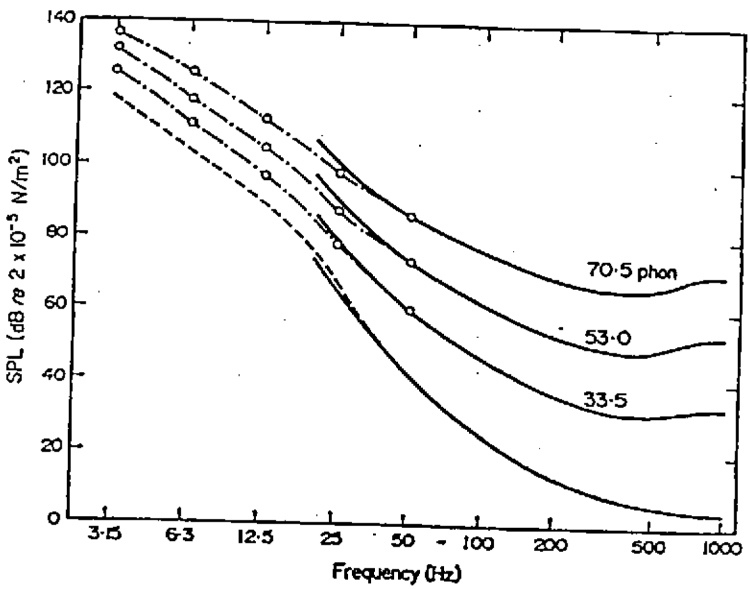

Fig 3. Equal loudness contours at low frequencies (from Whittle et al,1972)

designated 'LSL', has been put forward in Japan by Tokita (11).

Above 20 Hz the use of dB(A) is very widely established, but clearly has serious limitations in the 20 - 200 Hz region. There is some evidence that the old dB(B) weighting might be more appropriate in this range, and there would seem to be strong arguments for redefining the validity of dB(A) to recognize its reduced applicability below about 200 Hz. It is certainly my conclusion that the use of dB(A) in the evaluation of noise annoyance below 200 Hz is simply not valid.

CRITERION CURVES

Numerous field studies of low frequency noise show that many workers evaluate low frequency sound by measuring the spectrum (either octave, $\frac{1}{3}$ octave or narrow band), and then superimposing this spectrum on the hearing threshold curve. This method immediately reveals which frequencies are above threshold, and, by the extent which they exceed the threshold, which are likely to give rise to annoyance. This procedure has proved particularly valuable for noise control purposes, since it provides information as to the frequency of the offending sound. It has not, however, as yet, been successfully developed as a predictor of annoyance magnitude. This deficiency is however not necessarily a serious one since noise grows so quickly with level that quite modest supra-threshold levels can give rise to complaints.

IMPULSIVE NOISE

The general problem of evaluating the annoyance to be expected from an impulsive sound presents a number of difficulties which do not occur with continuous sounds. These difficulties arise mainly from the number of different parameters needed to define impulsive sounds. While some progress has been made in tackling the general problem, see for example Berry (12),it would seem more appropriate in the present context to concentrate attention on one area where field studies have provided some useful data, ie noise from small-bore guns.

Shooting clubs, and in particular clay pigeon clubs, are the most widespread source of impulsive noise in the environment. A typical commercial shoot, ie one which is open to the public and organized as a business, may involve firing 2,000 shot gun cartridges per hour for 4 to 6 hours, frequently on a Sunday. Such clubs often provoke complaints from their neighbours.

Two quite different procedures for the evaluation of gunfire noise have been put forward. One method considers the level produced by a single shot, and then argues that the number of shots is not a material factor. On this basis Sorensen and Magnusson (13) in Sweden have put forward 60 - 65 dB(A) 'Fast' as the level at which annoyance rises rapidly. Some Australian work (Bullen and Hede (14), Hede and Bullen (15)) quotes the level of 80 dBL 'Peak', (the peak level measured with a flat frequency response, or a dB(C) response), which they report is equivalent to 55 dB(A) SEL (A-weighted sound exposure level).

This approach suffers from two fairly clear weaknesses, firstly, the measurement units used are such that a different impulsive noise (ie from a significantly different source) may give rise to a different relationship between annoyance and dB level - this is acknowledged by the authors. The other difficulty arises from the exclusion of the firing rate from the annoyance evaluation. In a recent County Court an expert witness was asked (by the Judge) whether this meant that one shot was as annoying as, say, 10,000 shots. The witness replied this was so, but the Court was not convinced.

The alternative approach (see Smoorenburg (16) for a review) is to measure dB(A) Leq, a unit which takes into account both intensity and number of shots fired, and then apply a 'penalty' to allow for the special annoyance due to gunfire. Smoorenburg's analysis of a number of studies suggests that (dB(A) Leq + 12) provides a figure which allows impulsive noise to be successfully compared with other sources of annoyance, or with the background level of the area.

The writer's experience in a number of situations involving small-arms firing, is that the 'dB(A) Leq + 12' approach is of value, and gives results in broad agreement with complaints and observations.

PLANNING CRITERIA

There have been suggestions that outdoor shooting clubs should not be permitted within a specific distance from residential areas. Figures of 750m, 1 km and 3 km have been proposed. This approach is not really practical, since sound transmission depends so much on terrain, that it is not feasible to predict levels over such distances, except for fairly simple cases. It is essential that each case be considered in its own situation, and for planning purposes it will probably be necessary to carry out a series of trial firings at which noise levels are evaluated in any sensitive areas.

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