G.2.9

ZARAGOZA'89 ENVIRONMENTAL ACOUSTICS

8º SYMPOSIUM FASE'89
«ACUSTICA AMBIENTAL»
Zaragoza, Abril 1989

NEW TECHNIQUES FOR THE MEASUREMENT AND RATING OF IMPULSIVE NOISE

B F Berry* and A D Wallis**

*National Physical Laboratory, Teddington, Middlesex. TW11 0LW England

**Cirrus Research Ltd, Acoustic House, Bridlington Rd, Hunmanby, North Yorkshire YO14 0PH England

INTRODUCTION

The Joint Project on Impulse Noise, funded by the CEC under the Fourth Environment Programme (1986–90) has two related parts. 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, University of Düsseldorf have been studying the problem of physical quantification methods in order to derive an optimum objective rating. This paper describes the methods and techniques used by NPL and presents results of comparisons between the subjective ratings and physical analyses. New instrumentation for use in such analyses is introduced.

SUBJECTIVE EXPERIMENTS

The three laboratories each used similar facilities, simulating the living room environment. Each used 16 subjects who had to rate 64 noises, each presented for 20 seconds. A ten-point category scale was used and subjects rated firstly the annoyance of the total noise (Question 1) and then the impulsiveness (Question 2). In Question 3 they were asked to give a Yes/No decision on whether the noise was "clearly impulsive". Question 4 asked for a rating of the annoyance of the impulsive part of the noise.

The 64 noises consisted of a common core of 40 noises, presented at L_{Aeq} 55 dB, used by all three laboratories, and then a set of 24 noises specific to each laboratory, used to investigate particular topics, eg. the effect of level on impulsiveness. In this first phase of the Joint Project the physical analysis has been confined to the 40 common noises. Further analysis and comparison will be undertaken later.

PHYSICAL ANALYSES

Six descriptors of the impulsiveness were derived.

(1) $L_{Aeq(I)} - L_{Aeq}$

This is the difference between the value of L_{Aeq} determined with time-weighting I and the normal L_{Aeq}. Measurements were made using a Brüel and Kjaer type 4426 Noise Level Analyser.

(2) Crest factor

For this and all the other methods, signals were A-weighted, digitised in a 12-bit A-D converter and stored on disc in contiguous one-second duration intervals. Crest factor for each interval was calculated by searching for the highest instantaneous value in the individual samples (sampling rate 20 kHz), dividing its amplitude by the RMS value for the whole interval and then calculating 20 times the logarithm of the result.

(3) Standard deviation of L_{Aeq} (10 ms)

For each 10 ms period in the one-second interval a value of L_{Aeq} was calculated to give a time-series. As a measure of the variability in this time-series, the standard deviation σ of the values of L_{Aeq} (10 ms) was calculated.

(4) Salience

This is calculated from the difference between the maximum value of L_{Aeq} (10 ms) in a one-second interval and the value of L_{Aeq} for that interval. Thus

$$S = L_{Aeq}\ (10\ \text{ms})\text{max} - L_{Aeq}\ (1\ \text{s})$$

(5) Increment

Differences between successive values of L_{Aeq} (10 ms) are calculated and the maximum positive difference found. This is termed the "increment".

(6) ISO method (10 log$\bar{I}$)

This was developed during previous NPL work on helicopter noise (1). Using a sampling rate of 5 kHz, and taking each half-second interval in the signal, the digitised sample values, v_i, were processed according to the formula

$$\bar{I} = \frac{1}{2500} \sum_{i=1}^{2500} \left[\frac{v_i^2 - S}{S}\right]^2 \quad \text{where} \quad S = \frac{1}{2500} \sum_{i=1}^{2500} v_i^2$$

COMPARISONS OF PHYSICAL AND SUBJECTIVE DATA

Each of the physical analysis methods described in the previous section produces a series of values for each noise. For example Figure 1 shows the variation of the crest factor during one of the noises - a motorcycle pass-by - in which the impulsiveness reaches a peak and then reduces. As a single figure to describe the impulsiveness of each noise the maximum value of each descriptor during the 20 seconds has been used.

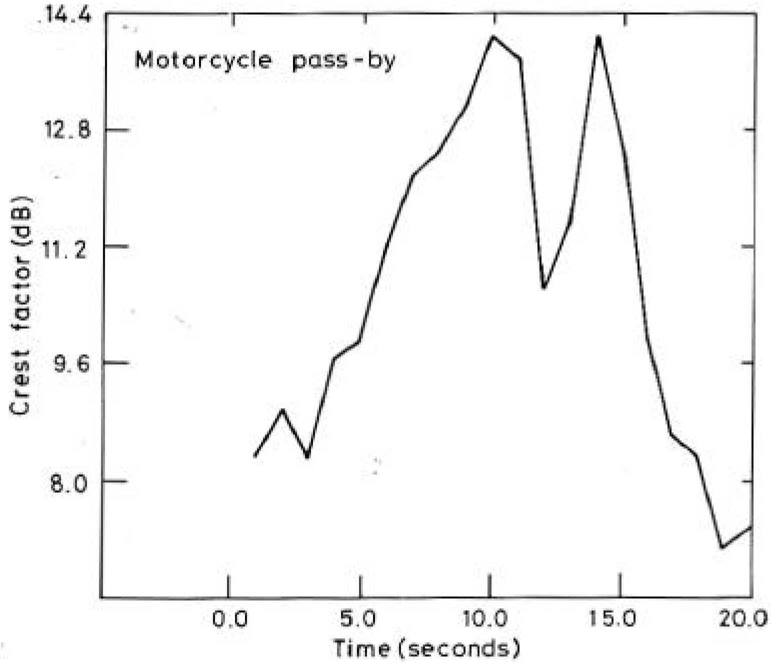

Figure 1. Crest factor–time plot for motorcycle pass–by.

Correlation analysis

For all 40 noises, correlation coefficients were calculated between each of the sets of subjective data (Questions 1 to 4) and the values of each physical descriptor. The subjective data from MIU were not available at the time of this analysis, so the results are given separately for IDAC and ISVR.

Correlation matrix

SUBJECTIVE	Crest Factor	X-10logT	$L_{AeqI}-L_{Aeq}$	Salience	Standard Deviation	Increment
Question 1						
ISVR	0.139	0.109	0.174	0.194	0.197	0.381
IDAC	-0.006	0.026	0.030	0.020	0.054	0.268
Question 2						
ISVR	0.502	0.489	0.644	0.645	0.692	0.712
IDAC	0.513	0.532	0.650	0.623	0.733	0.750
Question 3						
ISVR	0.488	0.440	0.634	0.654	0.661	0.671
IDAC	0.521	0.513	0.670	0.645	0.744	0.746
Question 4						
ISVR	0.460	0.450	0.573	0.607	0.620	0.668
IDAC	0.386	0.392	0.504	0.487	0.564	0.673

for $N = 40$ and $p \leqslant 0.01$ $r \geqslant 0.393$
$p \leqslant 0.001$ $r \geqslant 0.489$

The highest values in any row are underlined. It can be seen that the increment descriptor performs best.

Figure 2 shows the plot of the increment descriptor against subjective data for the case with the highest correlation coefficient.

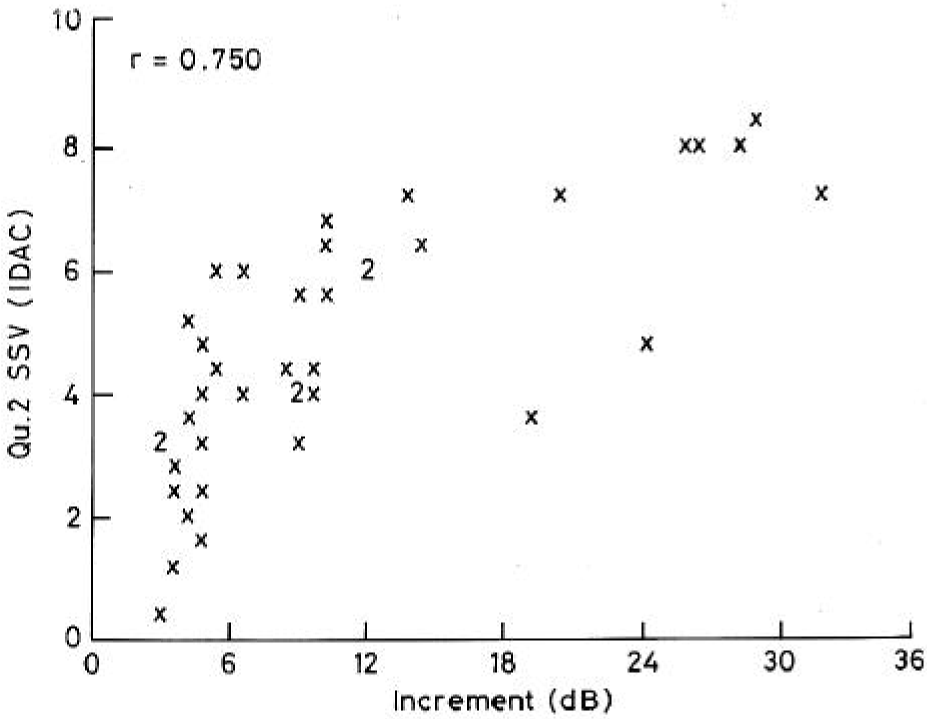

Figure 2. Mean impulsiveness (IDAC) and the increment descriptor.

MEASUREMENT OF SHORT-TERM L_{Aeq}

To assist in this research, a CRL 2.36 data acquisition integrating sound level meter made by Cirrus Research has been specially modified by them to take the short-term period down to 10 ms. The basic instrument has been described by Wallis and Luquet (2). The internal non-volatile store holds 114,000 values of L_{Aeq} (10 ms), thus measurements can be made over a period of 19 minutes. After acquisition the values are copied across to a file on an IBM-PC microcomputer, where the time-series can be displayed and the impulsivity descriptors calculated. Examples of the application of the meter will be presented at the Symposium. The system will be demonstrated in the Exhibition.

REFERENCES

1. Berry, B.F., Fuller, H.C., John, A.J. and Robinson, D.W. *The rating of helicopter noise: development of a proposed impulse correction.* NPL Acoustics Report Ac 93 1979.

2. Wallis, A.D. and Luquet, P. *Computer acquisition of large data sets.* Proc Inter-Noise 87, 1423-1426, 1987.