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Low Frequency Noise in Road Vehicles

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In the course of making a series of sound pressure level measurements in moving vehicles, it was noticed that in some cases overall sound pressure levels appeared to be exceedingly high in relation to the measured octave band and dB(A) readings obtained in the same conditions. It was found for example, in a large car that the measured overall sound pressure level was 103 dB while the level obtained by summing the octave band figures over the range 22 Hz to 22 kHz was only 97 dB. This difference suggests that there must be excess energy lying outside the range mentioned above, and the falling nature of the frequency spectrum suggests that it is much more likely to be below 22 Hz than above 22 kHz.

The sound level meter in use (B and K impulse meter, type 2204, with cartridge type 4145) was therefore calibrated at frequencies down to 0.75 Hz, using a calibrated infrasonic source[1] and was found to have a response falling to -3dB at 1.5 Hz. The meter was then used to drive a frequency modulation tape recorder[2] to make a series of recordings of low frequency sound in vehicles, a second sound level meter was used to obtain direct readings of the octave band noise levels from 32 Hz upwards.

Analysis of the Data

The recorded tapes were played back through a demodulator and a set of octave filters[3] into a slow response r.m.s. voltmeter. The recordings were always played back in real time (i.e. at the same speed as recorded) and the meter readings were noted down manually. This procedure was chosen in preference to an automated recording system since it was found that the recordings sometimes contained substantial 'peaks' which were due to various causes, but were not a basic part of the vehicle noise, and could be ignored by an intelligent operator. An example was the peak caused when the vehicle overtook a heavy lorry in an adjacent lane of the road, this produced a peak of about + 10 dB in the lower frequency bands (2-8 Hz) lasting for a few seconds.

The same length of tape (normally of about two minutes duration) was analysed through each octave filter from 2 to 32 Hz and a measurement was also made of the 220 Hz signal recorded by the pistonphone. As a further check on the overall calibration of the system the sound pressure level in the 32 Hz band was compared with that obtained directly from the other sound level meter.

Results

Measurements were made under steady speed conditions in a range of vehicles on the M6 and other roads of motorway standard, the speeds chosen ranging from 40 to 70 mph.

In general the results confirmed the initial supposition that high sound pressure levels occur in the octave below 32 Hz, and that in many cases much of the sound energy is in this frequency region. The octave band frequency spectrum obtained in a large (3-litre) saloon car showed the way in which sound pressure levels continue to increase with decreasing frequency down to the 2 Hz band. A suspicion of a slight peak around 64-125 Hz was presumably due to an engine-exhaust noise component at the firing rate of the engine.

Figure 1 for a small (1-litre) saloon car shows a very similar pattern to the larger vehicle but the recorded levels are higher in all frequency bands below 1 kHz, as before the highest levels are found in the lowest frequency bands. Both the 40 and 60 mph curves show clear peaks which can be related to the firing rate of the engine. The subjective opinion of the testers was that this car was considerably noisier than the 3-litre.

Further data was obtained in a 4-wheel drive utility vehicle with a diesel engine (2-litres). At the lowest frequencies the levels were similar to the small car but a combination of engine and gear noise makes the levels much higher at all frequencies from about 16 Hz upwards. This vehicle was regarded subjectively as extremely noisy.

Figure 1 includes a curve[4] representing the binaural threshold of hearing at low frequencies and illustrates that (ignoring the effects of masking) there are audible pressure levels down to about 8 Hz in cars with closed windows.

In the case of the small (1 litre) car some measurements were made with one front sliding window opened 6 inches.

In this condition the highest measured level was 115 dB in the 2 and 4 Hz octave bands. The increase in noise level in the range 2-32 Hz appears to be in the form of turbulence noise of a random nature, and, judging from both the shape of figure 2, and the subjective assessment of the observers, was not a resonant effect of the type described by Aspinall[5]. In this case the measured levels were above the hearing threshold at all frequencies down to (and including) 4 Hz.

Conclusions

A simple system for the measurement of noise in vehicles over the frequency range 1.4 Hz to 22 kHz has been described, together with details of some typical results.

The results of the tests in general confirm the hypothesis on which the work was based, that high levels of noise occur in the range below 32 Hz in cars travelling at speed. The data obtained in testing a range of passenger cars show, as a general trend, that the highest octave band sound pressure levels are found in the range 2-16 Hz and are around or in excess of 100 dB. All the vehicles tested, (including a number additional to those mentioned specifically in the text) conform to the same general pattern, that the larger vehicles are less noisy than the small ones. Since, however, the larger cars were invariably more generously upholstered and carpeted this effect may be due in part to interior furnishings as well as dimensional differences.

It was found that opening a window by a few inches caused, in all cases, a large increase in the measured levels at frequencies in the 2-32 Hz octave bands, raising these bands to 110 to 120 dB. It was the opinion of the observers who took part in the tests (and who were all experienced in the evaluation of noise and infrasound) that the increase in low frequencies when a window was opened was responsible for a considerable deterioration in passenger comfort.

A further possible hazard of low frequency sound is its effect on balance, it has been shown[6,7] that intense low frequency sounds (around 140 dB and higher) can cause a balance disturbance in normal observers, and this effect can occur at lower levels in some ear disorders.

It was concluded that, in general, low frequency sound below 20 Hz, probably plays a part in influencing comfort in passenger transportation, and may, via its effects on balance, have an influence on safety. Low frequency sound should therefore be considered seriously in any overall evaluation of the transportation environment.

References

1 N.S. Yeowart, M.E.Bryan and W. Tempest, The Monaural M.A.P. Threshold of Hearing at Frequencies from 1.5 to 100c/s. J. Sound Vib. 6 (1967) 335-342.

2 W. Tempest and M.E. Bryan, A Simple Frequency-Modulation Tape Recorder System. Electronic Engineering 39, (1967) 87-89.

3 W. Tempest and N.S. Yeowart, Octave and One-Third Octave Filters for Sub-sonic Frequencies. Electronic Engineering 38 (1966) 397-399.

4 N.S. Yeowart, M.E. Bryan and W. Tempest, Low Frequency Noise Thresholds. J. Sound Vib. 9 (1969) 447-453.

5 D.T. Aspinall, An Empirical Investigation of Low Frequency Wind Noise in Motor Cars. M.I.R.A. Report No 1966/2 (1966).

6 C.C. Mohr, J.W. Cole, E.O. Guild and H.E. von Gierke. Effects of Low Frequency and Infrasonic Noise on Man, Aerospace Medicine 36 (1965) 817-824.

7 Margaret J. Evans, M.E. Bryan and W. Tempest. Clinical Applications of Low Frequency Sound. Sound 5 47-51 (1971).

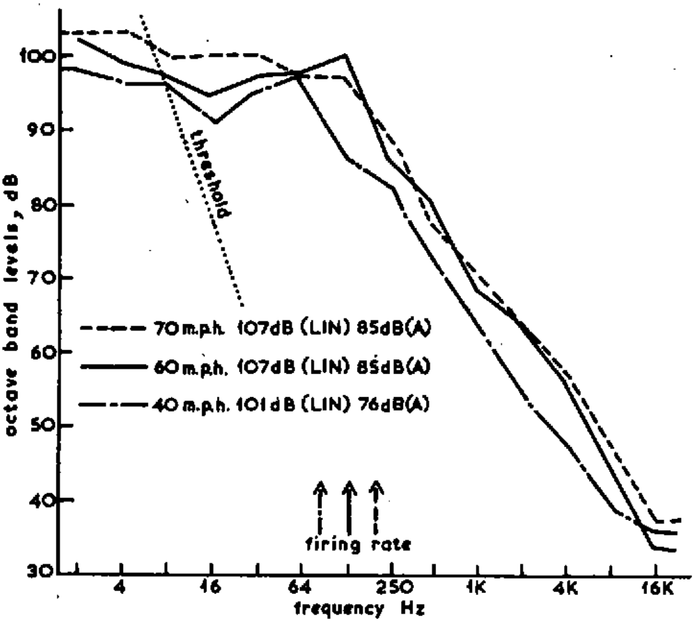

Fig 1 Noise levels in a 1-litre car

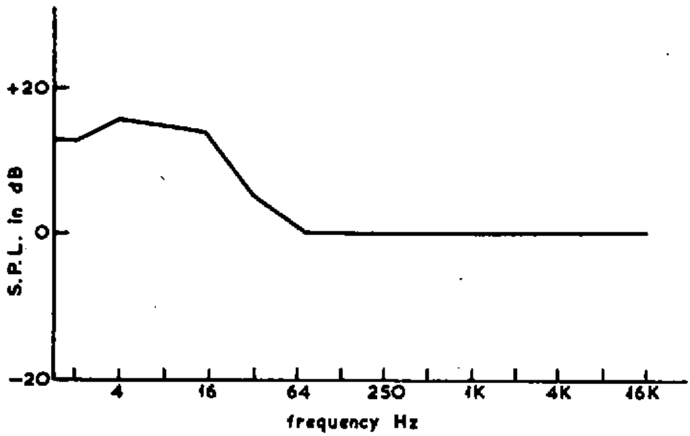

Fig 2 Noise level increase due open window (1-litre car)