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NOISE GENERATED BY CLOSELY SPACED DUCT ELEMENTS

A.U. UKPOHO D.J. OLDHAM

UNIVERSITY OF SHEFFIELD

Introduction

The designer of a mechanical ventilation system can choose between either a low velocity or a high velocity system. Each system has advantages and disadvantages. The particular advantage of a high velocity system is that it takes up less space in a building since a given volume flow of air can be carried in smaller section ducts than would be required for a low velocity system. Smaller ducts can be more readily integrated in a building design than larger ones since they can be made to follow very complicated shapes. The problem often encountered with high velocity systems however is regenerated noise.

When air in a duct meets a discontinuity the result is turbulence and the generation of noise which may be transmitted to ventilated rooms. This noise is termed regenerated noise since it occurs on the quiet side of attenuators fitted to control noise from the fan. Regenerated noise would not cause any difficulty if it could be predicted at the design stage since steps could then be taken to provide appropriate treatment. Unfortunately there is a lack of reliable information on which the building services engineer can base his design. If a system is installed and ventilated spaces are then found to suffer from excessively high noise levels due to regenerated noise the provision of remedial acoustic treatment is often difficult, if not impossible, since the compactness of the system means that there is very little space available for the fitting of additional attenuators.

The aim of the work described in the paper was to investigate the interaction between duct elements in high velocity systems with a view to improving predictive techniques. Methods of predicting the performance of individual elements from a knowledge of their pressure drop characteristics were also investigated. The possibility of such relationships existing has been proposed by Yudin (1), Gordon (2) and Nelson and Morfey (3).

Generalised Predictive Methods

In addition to it being an area worth studying in its own right a technique for predicting regenerated noise levels was necessary for the second stage of the work so that the sound power contributed by two different elements could be separated.

Although Gordon's work was the prime inspiration for this project it was recognised at the outset that his experimental work was unlikely to be directly applicable to ventilation systems since he worked at far higher velocities than those encountered in ventilation systems and with a smaller duct diameter. A systematic investigation was thus carried out to see if

Gordon' work (and in particular his theoretical model) could be applied to ventilation systems. The experimental arrangement is shown in Figure 1. A novel feature is the use of a large anechoic chamber as a plenum to reduce fan noise. The test duct was terminated by an exponential horn in a reverberation chamber. The sound power level resulting from the interaction of the air-stream and the duct spoiler was calculated from the mean of the sound pressure level measured at six points in the chamber and knowledge of the chamber's acoustic characteristics.

Gordon normalised his data to obtain a generalised spectrum on the basis of the following equation.

$$W = K_S(P_O - P_A)^3 d^2 \left[1 + ({}^f/f_o)^2\right] / (\rho^2 c^3)$$

Where W is the aerodynamically generated sound power at frequency f, $(P_O - P_A)$ is the pressure drop across the spoiler, D is the duct diameter, f_o is the duct cut-on frequency, ρ is the density of air and c is the velocity of sound in air. The constant, K_s, is expected to be a function of Strouhal number ($S_n = fd/U_1$) where d is a characteristic dimension of the spoiler and U_L is the localised air velocity at the spoiler.

Attempts to collapse data (essentially determining K_s for each reading) on the basis of the Gordon equation were not successful. However, it did prove possible to collapse data for all systems investigated (dampers and orifice plates in circular ducts) on the basis of the following equation.

$$W = K_S \, \Delta P^3 \, D^2 \, / \, \rho^2 c^3 \, C_L{}^3 \, \beta_e{}^6$$

where ΔP is the static pressure loss across the spoiler, C_L is the pressure loss coefficient and β_e is the blockage factor (ratio of "free" area at spoiler to duct cross sectional area). Figure 2 shows an example of the data collapse for the damper in the circular duct and Figure 3 shows the collapse for the orifice plates in the circular duct. Figure 4 shows the two curves on the same graph and a "mean" curve. It would be possible to use this curve to predict sound power levels arising from these two extreme cases to within ±2.5 dB.

The Interaction of Duct Elements

It is generally agreed that the noise generated by an air duct element depends upon the degree of turbulence of the air-stream impinging on it. However, no quantitative information concerning this phenomenon is available. The objective of this part of the program was to remedy this deficiency. The experimental arrangement was similar to that shown in Figure 1 but two spoilers were employed. An upstream spoiler in the air-stream generated turbulence (+ noise) which impinged on a downstream spoiler.

Figure 5 shows typical results obtained from these experiments. The net sound power level generated typically increases with the level of upstream turbulence although the increase is smaller (or the sound power level decreases) at around

500-1000 Hz. The reason for this is not yet understood but it is believed that sound from the upstream spoiler is being absorbed in the region of very high turbulence in the neighbourhood of the downstream spoiler.

The increase in regenerated sound power level is particularly marked at approximately 250 Hz for a spoiler separation of 1.5m and at 125 Hz for a separation of 3m. It is believed that this is due to a resonance effect.

At the present time only qualitative (or semi-quantitative) results have been obtained from this part of the project. Data are still being analysed and it is expected that further experiments will be necessary before the work is finally completed.

References

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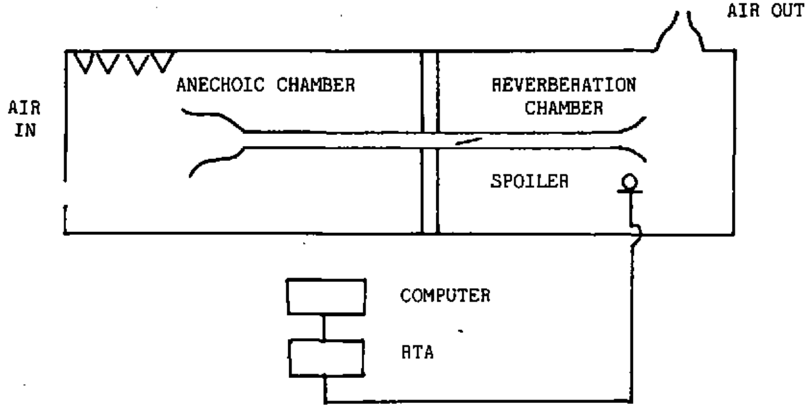

FIGURE 1 SCHEMATIC OF APPARATUS

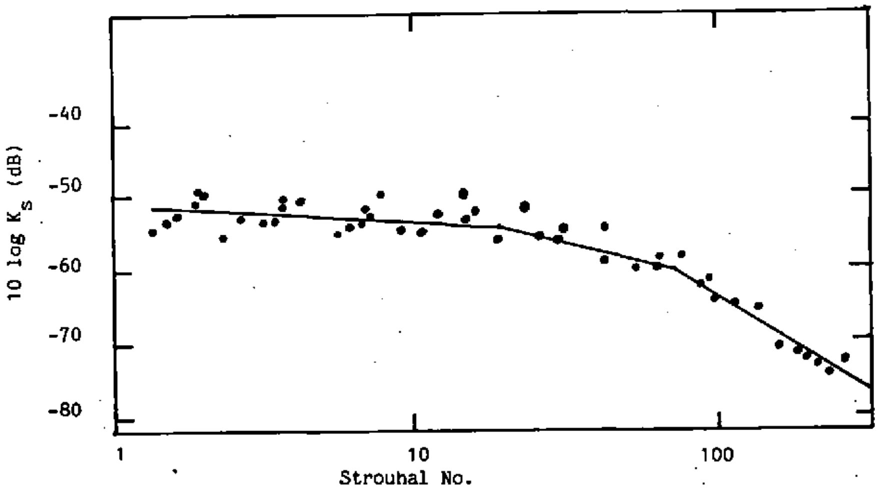

FIGURE 2 COLLAPSE OF DATA-DAMPER IN 300mm DIAMETER DUCT

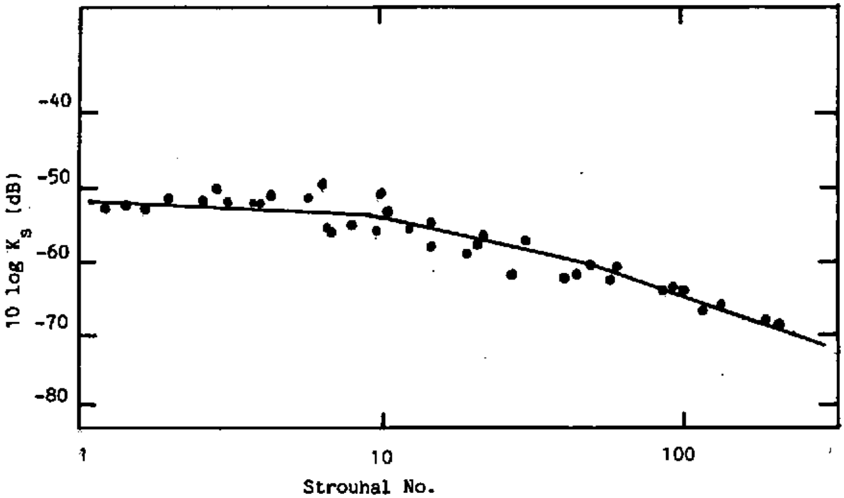

FIGURE 3 COLLAPSE OF DATA ORIFICE PLATES IN 300mm DIAMETER DUCT

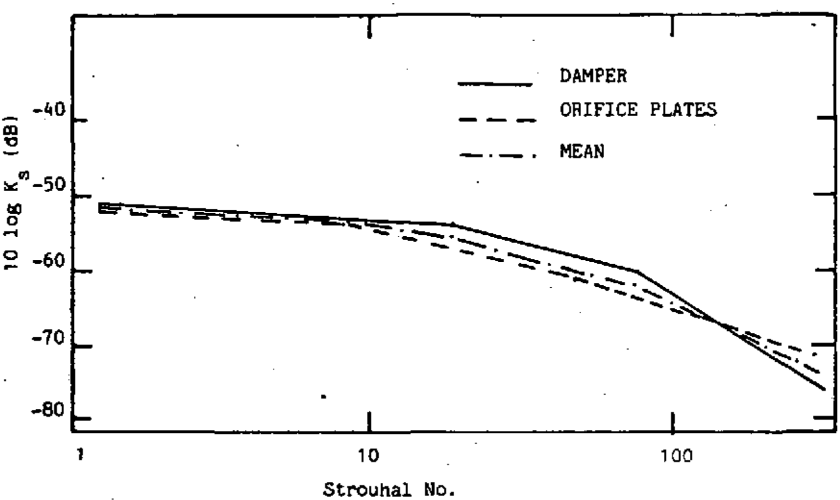

FIGURE 4 COMBINATION OF RESULTS

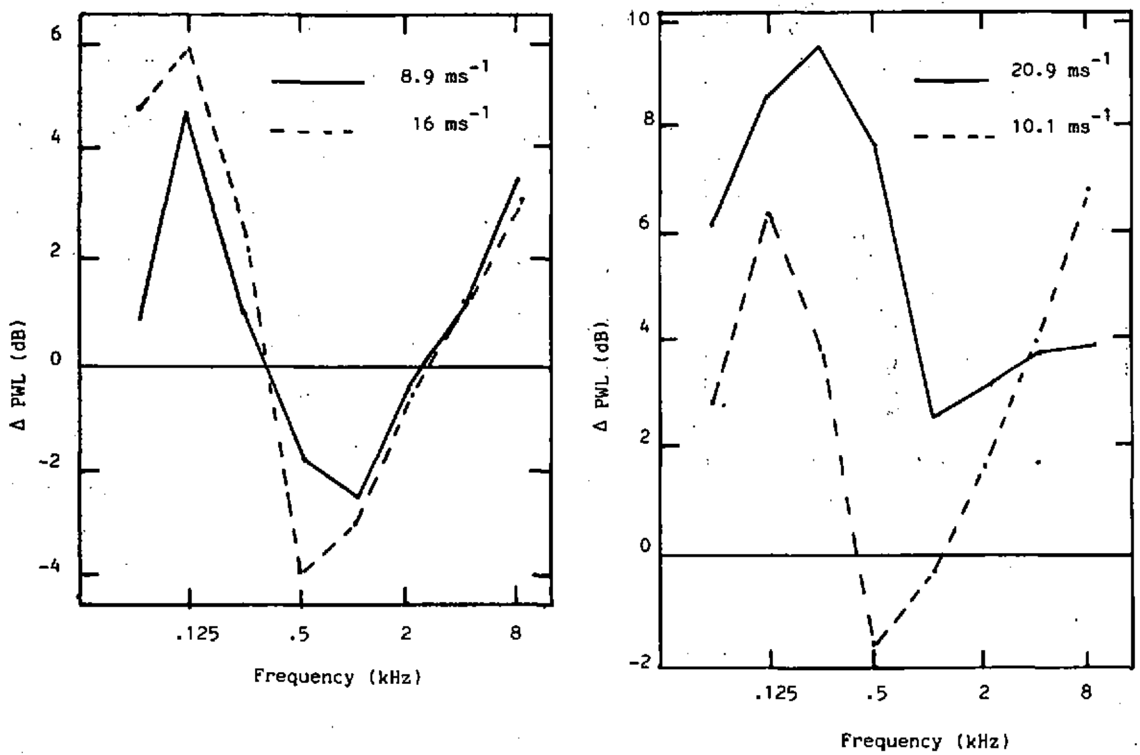

FIGURE 5 INCREASE IN PWL FOR COMBINATION OF DAMPERS -20°/30° INCLINATIONS