Proceedings of The Institute of Acoustics

VELOCITY GENERATED NOISE IN MECHANICAL VENTILATION SYSTEMS

T.K. WILLSON AND R.K. HILLS

ATKINS RESEARCH AND DEVELOPMENT.

INTRODUCTION

Experience of the authors indicated that present prediction methods for noise in mechanical ventilation systems might be underestimating velocity generated noise and led to a close examination of the sources of existing published test data for velocity generated noise. It was found that most data had been obtained from fittings not generally used in the U.K. and only a minority of fittings have ever been tested. A decision was, therefore, made to carry out a test program to establish the airflow generated noise characteristics of the most common duct fittings over a wide air velocity range. At the outset, it was decided that the project should not be designed, or intended, as an investigation into the mechanisms of noise generation, but to produce a prediction method for general application to typical fittings.

The Test Facility

Early in the project, it was decided that, reverberant room, rather than in-duct measurements of sound power level would be made. This ensured that the tests closely represented the situation which could be found in buildings.

The test requirements were quite modest in principle: evenly distributed 'quiet' air was to be delivered to the test section and discharged into a reverberation chamber. In practice, this was difficult to achieve since, to avoid abrupt changes of direction, a linear test rig was required, with a considerable degree of fan noise attenuation. The test set-up was designed by the authors and installed in the existing partial facility at AIRO Ltd. (Fig. 1).

The anechoic chamber was used as a broadband plenum and air settling chamber and, with a suitably designed intake duct, allowed air to enter the test rig with no detectable noise generation and with a uniform velocity profile. The airflow distribution was not intended to be absolutely uniform since this would not be representative of typical systems found in practice. Figure 2 shows the noise levels in the test chamber due to outside influences with 1 and 2 fans operating and the generated noise from a 'quiet' fitting at low velocity.

The Test Program

The most common types of bends and junctions were intended to be tested and were scheduled into the program; but in some cases it was found that similar fittings gave similar results and consequently some tests were dropped. The actual test program executed is shown in Figure 3, representing the final selection from an original total of 500 tests.

Each test consisted of measuring the space-average sound pressure level in the reverberation chamber over the 1/3rd octave bands from 50-10kHz.

Immediately before each test the air flow in each main and branch duct was measured by a pitot static traverse. Air flow through the test section was varied in steps of approximately 5m/sec with a minimum of 3 velocities for each fitting, but in some fittings, velocities in excess of 7000 ft/min were induced and perhaps 6 velocity increments used. Aspect ratio effects were investigated for ducts of the same cross-sectional area. For example a duct area of $0.36m^2$ would be tested at 600 x 600, 1200 x 300, 300 x 1200 and 450 x 800. Figure 4 shows the fitting types tested.

Analysis of Results

The overall aim of the study was to produce a relationship between air velocities in the various types of duct fittings and the generated noise. Analysis of results was carried out by a combination of visual inspection and computer statistical techniques.

The measured space-averaged sound pressure levels were converted to 1/3rd octave band in-duct sound power levels, and the power spectrum level for each individual spectrum was calculated. The power spectrum levels were plotted against Strouhal number and a visual examination made of the results.

A prediction method was devised for each fitting based upon spectrum level and frequency distribution and confidence limits were calculated for the prediction method. Although it is often said that noise levels can be predicted from the pressure drop across any given fitting, the measured pressure drops were found to have no relation to the velocity generated noise.

The results were analysed for dependence of sound power level on Strouhal number, velocity and duct area for each fitting type. While the function generally took a similar shape, the absolute dependence of generated noise varied from fitting to fitting.

A typical result, for mitred 90° bends with turning vanes, was:

(i) $PWL = F_{ns} + 10 \log_{10} F - K$

(ii) (a) $FNS = B \log_{10} \left(\dfrac{10}{10 + \frac{S^C}{10}} \right) \quad S > D$

(b) $FNS = E - G \log_{10} S \quad S < D$

(iii) $LND = FNS = H \log_{10} V_1 + J \log_{10} A + L$

where: PWL = octave band sound power level

F_{ns} = Strouhal number function

S = Strouhal number (Fd/V)

F = Octave band centre frequency

V_1 = Duct average velocity

A = Duct cross-sectional area

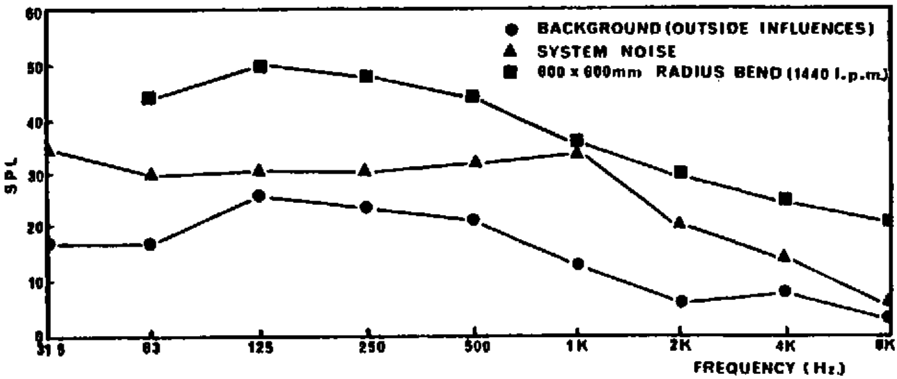

FIGURE 2.

Rectangular junctions	600x600 main duct -	diverging airflow		65 tests
.. ..	400x400 ..	.. ..	..	80 tests
.. ..	.. ..	converging	..	42 tests
Circular ..	450 dia. ..	diverging	..	39 tests
.. ..	.. ..	converging	..	42 tests
Rectangular 90° bends, with/without turning vanes/splitters				91 tests
Circular 5 section "lobster back" bends				11 tests
				370 tests

FIGURE 3.

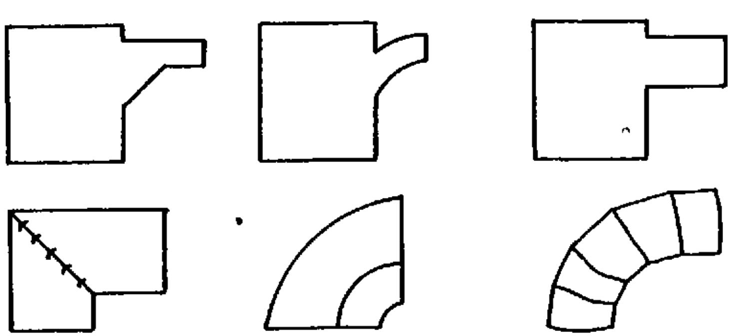

FIGURE 4.

VELOCITY GENERATED NOISE IN
MECHANICAL VENTILATION SYSTEMS

Comparison of Results with Other Published Data (ASHRAE)

The most complete work carried out previously has been that of Ingard et al, which has been used as a basis for the ASHRAE method presented in that guide (Chap. 35, 1973). Attempts have been made, therefore, to compare the predictions derived from the present series of tests with the results given by Ingard et al.

However, many factors limit the validity of this comparison, and the major of these are:

(i) ASHRAE took only a few sizes of duct, with irregular dimensional variations. The present test program was orientated around a matrix of dimensional variations with only one parameter changing each time and included a reasonable range of sizes found in normal ventilation systems.

(ii) There are only two fittings - radiussed bends and mitred bends without turning vanes - which can be related. Other fittings tested by ASHRAE are not normally encountered in this country. No ASHRAE data is available for circular ductwork which renders comparison almost impossible.

(iii) ASHRAE specifically states that no corrections were made for end corrections of duct terminations thus it would be necessary to compare in-room power levels.

(iv) The data for junctions is presented quite comprehensively in ASHRAE, but with no indication as to the dimensions of the branch ducts.

Generally, however, if the ASHRAE guide method were used to predict velocity generated noise for the fittings used in the U.K., the results would be lower than those indicated by the authors' work, particularly at low frequencies - a conclusion which has been borne out in practice by the authors' experience.

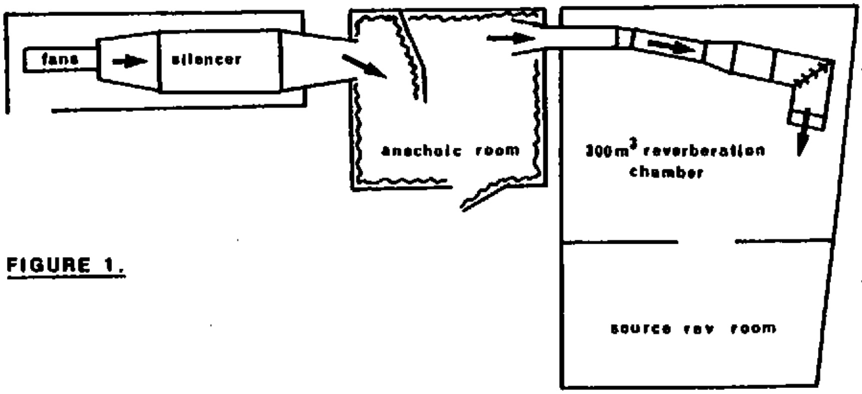

FIGURE 1.