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THE DIVISION OF SOUND POWER AT DUCT BRANCHES

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INTRODUCTION

The reduction in sound power occurring at duct branches is frequently assessed by use of figures and tables, such as those given in the design guides of the Chartered Institution of Building Services Engineers [1] and the American Society of Heating, Refrigeration and Airconditioning Engineers [2].

The CIBSE Guide states that it may be assumed that the sound power divides in direct proportion to the areas of the ducts and that for most practical situations this procedure may be simplified by using the air volume ratios in place of the areas. The attenuation in a branch is given by:

$$A = 10 \log_{10} \frac{a_1 + a_2}{a_1} \quad \text{dB}$$

Where a_1 is the area of the branch duct
a_2 is the area of the main duct after the branch

The Guide does not distinguish between branch types nor whether the duct after the branch is at 90^0 to the approach duct or in line with it.

The ASHRAE Handbook is often used by practising engineers in the UK, where the guidance presented by CIBSE is not substantial or is not available at all. In this instance the guidance presented by ASHRAE is no more comprehensive, assuming that sound power reduces in proportion to the air volumes down each duct. No referance is made to the areas of the ducts, presumably because the assumption is vague and for practical use it is far easier to use the air volumes than the areas. The noise reduction is given by:

$$\text{Noise Reduction} = 10 \log_{10} \frac{(\text{Branch Air Quantity})}{(\text{Total Air Quantity})} \quad \text{dB}$$

The present investigation was undertaken to establish whether the assumptions made in the design guides were justified.

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EXPERIMENTAL RIG

A study was made of apparatus used in the testing of ductwork fittings and it was found that an adaptation of the apparatus described for the static testing of silencers in BS4718[3] would be suitable for this work. The apparatus was further adapted to comply with economic, space and time constraints.

To comply with economic constraints it was decided that the straight ducts used in the construction of the test rig should be fabricated in accordance with DW142 Class A [4] as opposed to a more rigid material. This approach presented the problem that some of the sound power would be attenuated in the test rig and not just at the branch. However, it was decided that this attenuation could be accounted for within reasonable limits of accuracy in the processing of the results.

The duct branches were also fabricated in accordance with DW142 Class A. This, being the most commonly used specification in practice in this country, would provide the most useful results. The sizes of the branches tested were made up of combinations of three duct sizes:- 300 mm square, 200 mm square and 100 mm square.

The apparatus was to be set up in two formats. The first was to allow measurement of noise entering from the main duct and passing down each branch. This represents the more normal situation of fan noise passing down the ducts to the spaces being served. The second format was to allow measurement of noise entering a branch duct and passing along the main duct. This represents situations such as where cross talk would be unacceptable, or where a system serves a noisy space as well as a noise sensitive space.

The anechoic terminations that were used were designed based on similar terminations used by Sound Attenuators Limited. They were simple in design to comply with economic constraints, but nevertheless were expected to give reasonable accuracy at frequencies above 63Hz.

The noise was produced using a signal generator connected to a loudspeaker/baffle and adjusted to produce white noise at a set generator output. To produce approximate plane waves in the ducts, the speakers (one for each duct size) were mounted on baffle boards and were of the largest sizes possible that could be accommodated by the particular duct.

Sound pressure level was detected using a half inch microphone with a 1mm diameter x 75mm long probe set a quarter of the way into the duct. At this location the sound pressure level measured would approximately represent the average sound pressure level across the duct cross section. The microphone was connected to a measuring amplifier and, using the appropriate filters, it was possible to read the sound pressure level for one third octave bands at each centre frequency.

To avoid transmission of vibration from/to the laboratory floor, the speaker/baffle assemblies and the ductwork were each placed on mineral wool slabs. The speaker/baffle assemblies were placed 5-10 mm from the duct flange to prevent vibration transmission from the speaker to the ductwork. The flanged ductwork was bolted together with mastic sealant joints, care being taken to avoid any air gaps.

MEASUREMENT PROCEDURE

For the measurement of sound pressure level in the approach duct the apparatus was set up as shown in Figure 1 for each duct size and the duct size recorded on a test sheet. The background sound pressure level in the duct was measured at each centreband frequency and the results recorded. The signal generator was then switched on and set to produce a sound pressure level in the duct at least 10dB above the background sound pressure level at each frequency, but not so high as to distort the speaker. The sound pressure level was measured for each frequency at each test point and the results recorded.

The signal generator was then switched off and the background sound pressure level at each frequency checked.

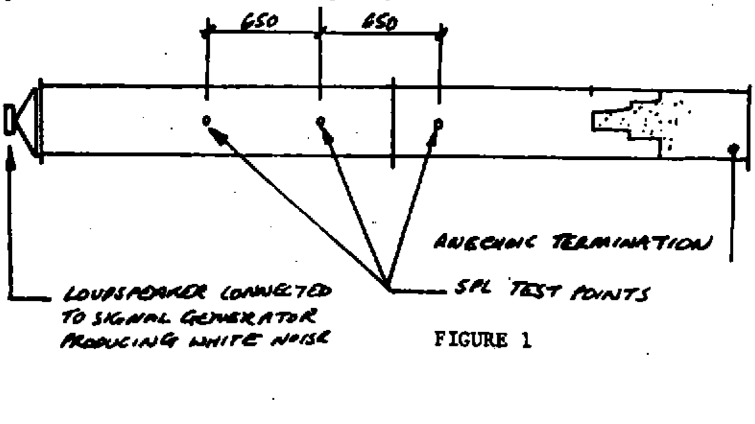

FIGURE 1

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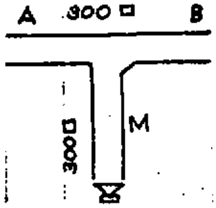
For the measurement of sound pressure level in ducts after branch the apparatus was set up as shown in figure 2a and then as in figure 2b for each branch tested. The measurement procedure then followed that outlined above.

FIGURE 2a



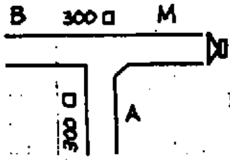


FIGURE 2b

Two factors need to be considered in converting the measured values of sound pressure level to sound power level at the duct branch; first the conversion of sound pressure level to sound power level at the measuring point and second, the attenuation of the sound power in the duct between the measuring point and the branch.

The measured sound pressure levels were converted to sound power levels using the following formula:

PWL = SPL + 10logA dB re 1pW

where PWL = sound power level across the duct at the measuring point

SPL = measured sound pressure level dB re 20 μPa

A = cross sectional area of the duct, m^2

The ductwork used for testing is conventional sheet metal duct, as described in section B12 of the CIBSE guide. As such, predictions for the attenuation along the straight duct lengths forming the test rig can be calculated, based upon table B12.3 of this guide.

The sound power levels at each measuring point were corrected in accordance with Table B12.3.

RESULTS

The reduction in sound power level between the approach duct and the duct after the branch is simply the arithmetic difference between the recorded sound power levels at each frequency for the appropriate ducts.

The attenuations obtained in each branch were plotted against frequency, as shown in figures 3 to 14.

Besides the measured attenuations, two additional lines have been plotted on each graph. First, the attenuation predicted from the CIBSE areas method which is constant across the spectrum and second, the attenuation predicted from a combination of the areas method with the attenuation for a mitred bend without turning vanes obtained from CIBSE table B12.4.

The odd-numbered figures present results for cases where the approach duct is perpendicular to the two branch ducts and the even-numbered figures present those for cases where the approach duct is in line with one and perpendicular to the other branch duct.

Despite the fact that the data presented are too inconsistent to provide a basis for prediction, two definite trends emerge. Where the approach duct is perpendicular to both branch ducts, attenuation in each branch is roughly similar and follows the 'areas and bends' line. the other duct arrangement shows markedly different results. In each case the 'straight through' branch gives results approximating to the CIBSE areas method, with the perpendicular branch following more closely the 'areas and bends' line.

CONCLUSIONS

This was neither a comprehensive nor detailed study, but nevertheless definite trends can be seen in the results.

Generally, it can be seen that where the duct after the branch is in line with the approach duct, the method of prediction laid down in CIBSE Section B12 discussed above, tends to be confirmed.

It can also generally be seen that, where the duct after the branch is at $90^{0}C$ to the approach duct, the areas method does not provide an accurate prediction. In most cases a more accurate prediction is given by combining the areas method with values interpolated from the CIBSE table B12.4, which shows the attenuation predicted for $90^{0}C$ mitred bends without turning vanes.

The results are not considered to be of sufficient accuracy to apply in the practical sizing of duct noise attenuators, but they do provide justification for future study using more sophisticated techniques than those adopted here.

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REFERENCES

(1) CIBSE Guide Volume B, Section B12.
Chartered Institution of Building Services Engineers, London, 1986.

(2) ASHRAE Handbook 1984, Systems Volume, Chapter 32.
American Society of Heating, Refrigerating and Airconditioning Engineers, Atlanta, USA, 1984.

(3) BS 4718, Method of Testing Silencers.
British Standards Institution, London, 1971.

(4) DW 142, Specification for Sheet Metal Ductwork.
Heating and Ventilating Contractors Association, 1982.

FIGURE 3 Att 1

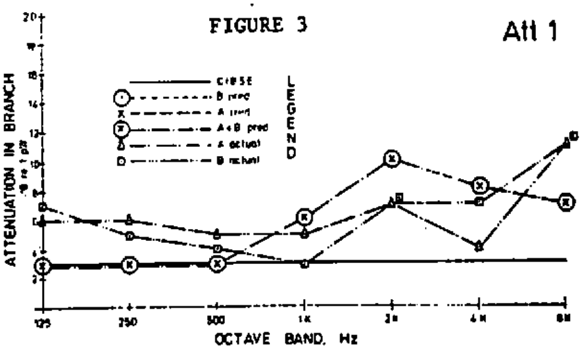


FIGURE 4 Att 2

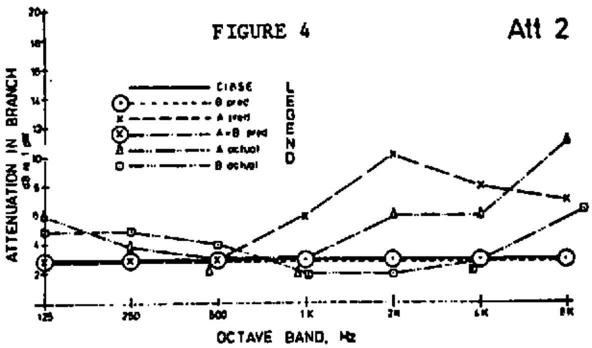


FIGURE 7

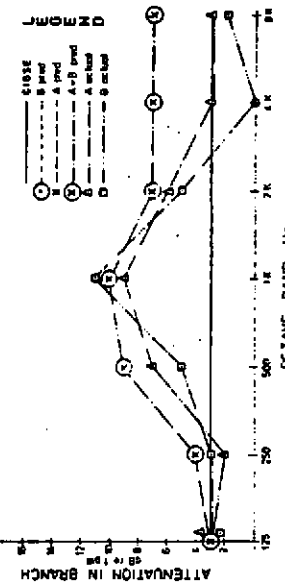


FIGURE 5

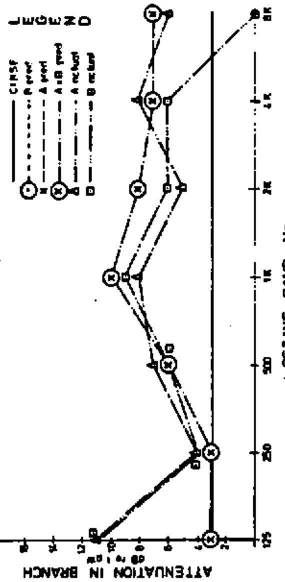


FIGURE 8

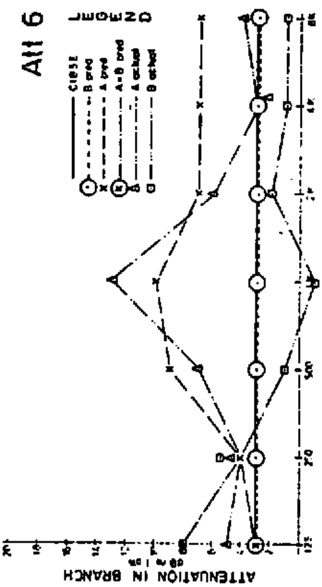
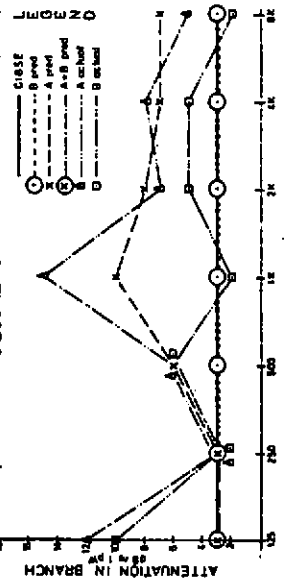


FIGURE 6



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