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THE EFFECT OF VARIATION OF METHOD OF GENERATION OF THE INCIDENT SOUND FIELD ON THE STATIC INSERTION LOSS MEASUREMENTS FOR AIR-CONDITIONING SILENCERS

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ABSTRACT

The method of testing silencers in the UK was formalised in 1971 by the publication of BS4718. This standard specified the details of the testing facilities required and generally confirmed the current test methods except for the manner of generation of the incident sound field. The standard states that the incident sound field shall be propagated down a long (5D or at least 4m) straight inlet duct by a number of loudspeakers mounted on a baffle located across one end of this duct, presumably attempting to produce a plane wave at normal incidence to the silencer face.

In-service installation rarely achieves this inlet condition and a series of tests were undertaken to determine the effect of departure from this condition on the measured insertion loss. A significant improvement in insertion loss was achieved by increasing the range of angles of incidence for the generated sound field, particularly for the higher performance silencers.

1. INTRODUCTION

The method of testing silencers in the UK was formalised in 1971 by the publication of BS4718 (1). This standard specified testing facilities required and generally confirmed the current test methods except for the manner of generation of the incident sound field. The standard states that the incident sound field shall be propagated down a long (5D or at least 4m) straight inlet duct by a number of loudspeakers mounted on a baffle located across one end of this duct. The loudspeakers are to be excited in phase and arranged evenly and occupying at least 40% of the cross sectional area.

Early data available in the UK was often derived from tests carried out in the USA following ASHRAE standards or test in the UK using similar methods. These tests generally used a single loudspeaker placed at the end of a side duct, or in the side wall, adjacent to the silencer under test. Figure 1 is reproduced from the IAC catalogue circa 1969 and shows the arrangements used and proposed in the USA. The principal difference between these methods is that the British Standard attempts to produce a plane wave at normal incidence to the silencer face whereas the ASHRAE method encourages a range of angles of incidence, presumably to simulate in service conditions. This program of tests attempts to increase the range of angles of incidence at the silencer face by mounting two loudspeakers inside the inlet duct and angled at 45° to the silencer face, Figure 2. This pair of speakers could be moved within the inlet duct. The four silencers used in these tests had an open area of 20%, 25%, 33% and 50%. A single test on the 25% open area silencer using the correct set of loudspeakers mounted on a 90° bend adjacent to the silencer was also carried out as a pilot study for a further test programme.

2. RESULTS

The tests comprised the measurement of insertion loss with the angled loudspeaker placed at the edge of the transition duct, one and two metres from this edge. The pair of loudspeakers were also rotated through 90° for the above positions. As the insertion loss is the difference between two sets of results, namely silencer and substitution duct, determining the effect of changing the method of sound generation is the difference of differences and thus sensitive to measurement error. These possible discrepancies were controlled by extensive retesting of set positions, as this considerably increased the time required for testing a rotating microphone method as specified in BS4196 Part 1 1981 (2) was used. Table 1 gives the comparison of this method with the results using BS4718.

Table 1 Comparison of use of fixed stations with rotating microphones

	Octave Band Frequency							
Insertion loss difference	125	250	500	1K	2K	4K	8K	16K
20% open area	-1.0	+1.5	-0.1	-1.3	-1.6	-1.6	-1.6	-0.9
25% open area	+0.2	+1.5	+1.0	0	+0.3	-1.1	-1.0	-1.5
33% open area	-0.4	+0.9	+1.5	+0.4	-0.4	+0.1	-1.3	-0.2
50% open area	+0.1	+0.8	+0.2	-0.1	-0.2	+0.2	-0.6	-0.6

It is considered that this agreement is sufficient for the purpose of these tests. The measurement sequence was as follows:

Silencer installed : Pair of speakers at edge of transition duct (0m), moved to 1m, moved to 2m, returned to 0m and retest.

Speakers rotated 90° and at edge (0m)

Speakers removed and BS4718 generation system used

Substitute duct installed : All the above tests repeated

Occasionally, measurements were repeated without disturbing the rig and these values were repeatable to ± 0.1 dB using a 30 second measurement period. Table 2 gives some typical results for two silencers for repeated tests after disturbing the rig. These results suggest an uncertainty of about ½ dB or less.

Table 2 Repeatability Tests

Silencer with 25% open area Loudspeakers adjacent to transition duct

	Octave Band Frequency							
	125	250	500	1K	2K	4K	8K	16K
Repeated Silencer Test	+.2	+.2	-.1	+.1	-.2	-.1	+.2	0
Repeated Substitution Duct Test	-.3	-.2	+.1	+.1	-.1	-.1	-.1	0
Change in Insertion Loss	-.5	-.4	+.2	0	+.1	0	-.3	0

Silencer with 33% open area Loudspeakers adjacent to transition duct, rotated 90°

	Octave Band Frequency							
	125	250	500	1K	2K	4K	8K	16K
Repeated Silencer Test	+.4	0	-.2	-.1	-.1	-.1	0	-.1
Repeated Substitution Duct Test	+.1	-.5	+.1	+.2	+.1	+.1	+.2	+.2
Change in Insertion Loss	-.3	-.5	+.3	+.3	+.2	+.2	+.2	+.3

The increase in insertion loss above the value obtained using BS4718 is shown in Table 3.

Table 3 Increased insertion loss, dB and speaker distance

		Octave Band Frequency							
		125	250	500	1K	2K	4K	8K	16K
Speakers at	0m	0.5	1.8	6.0	4.1	2.1	0.5	3.5	5.8
20% open area	1m	0.2	1.1	6.9	3.8	1.9	0.2	2.5	5.8
	2m	-0.3	0.9	5.4	0.7	2.0	-0.6	1.5	5.8
Speakers at	0m	-0.7	2.4	2.9	1.9	2.5	3.1	2.1	2.6
25% open area	1m	-0.7	0.1	3.5	2.2	3.8	4.1	2.3	0.3
	2m	-0.6	-0.3	2.2	2.5	4.0	4.0	1.8	1.3
Speakers at	0m	-0.2	1.4	2.4	2.1	3.3	1.8	1.5	2.9
33% open area	1m	-0.4	0.9	2.3	2.5	3.3	1.7	2.0	1.3
	2m	-0.7	1.2	2.1	1.9	4.5	3.1	1.7	2.4
Speakers at	0m	-0.2	0.8	1.0	2.4	3.2	1.2	0.1	1.0
50% open area	1m	-0.1	0.3	1.1	2.1	2.6	0.2	0.1	0.9
	2m	-0.5	0.2	0.8	2.2	3.1	1.7	0.3	1.1

Both the silencers and the loudspeaker system in the tests are not symmetrical and so the tests with the speakers at the edge of the transition duct were repeated with the speakers rotated through 90°. These results are shown in Table 4.

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Table 4 Increased insertion loss, dB and speaker orientation

		Octave Band Frequency							
		125	250	500	1K	2K	4K	8K	16K
Speakers at 25% open area	0m 0°	-0.7	2.4	2.9	1.9	2.5	3.1	2.1	2.6
	0m 90°	-0.8	2.7	2.5	2.4	1.4	2.0	1.7	2.2
Speakers at 33% open area	0m 0°	-0.2	1.4	2.4	2.1	3.3	1.8	1.5	2.9
	0m 90°	-0.1	1.3	2.1	3.1	-1.0	2.2	1.5	2.9
Speakers at 50% open area	0m 0°	-0.2	0.8	1.0	2.4	3.2	1.2	0.1	1.0
	0m 90°	0	0.2	1.6	4.8	-0.1	0.5	0.4	0.9

It should be noted that as the silencers differed in size, the transition duct length varied from 190mm to 800mm. Figure 3 interpolated the measured values and normalises to a distance of 1m from the silencer face.

EXPECTED RESULTS

According to Page 320 of Noise Control in Mechanical Services, edited by R I Woods (3): "Laboratory tests show that a particular attenuator has a specific capacity for reducing the level of sound which arrives at the unit as a plane wave. It does not follow in a site situation that the only incidence in the attenuating section will be in the form of a plane wave. Indeed, the nearer the sound source is to the attenuator, the more the sound incidence becomes random. In this case, the attenuator will have a better insertion loss performance and Figure 22 (see Figure 4) shows the improvement to be expected." This expected improvement for a 500 x 500mm duct is given in Table 5.

Table 5 Expected Improvement in insertion loss

Frequency	125	250	500	1K	2K	4K	8K	16K
Improvement	2	7	9.5	10	10	10	10	10

The expected improvements shown above do rely on the assumption that the BS4718 tests produce a plane wave at all frequencies. This is unlikely to be the case when the dimensions of the duct are comparable with the wavelength of the propagating sound, that is, for the 500Hz octave band and above for the 500 x 500mm ducting used in these tests. It therefore is to be expected that the improvements above the 250Hz octave band would be less than those shown in Table 5.

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3. CONCLUSIONS

Tables 3 and 4 show the improvement in measured insertion loss which ranges from -1.0dB to + 6.9dB. The graph of improvement with frequency Figure 3 generally follows the expected shape except for the higher frequency values for the highest performance attenuator.

These tests suggest that the 10dB improvement quoted from Woods is optimistic and that a 3dB improvement in the mid-frequency range for the higher performance attenuator is more realistic.

Further tests

A single test on the 25% open area silencer using a 90^{o} round bend between the silencer and loudspeakers gave the following disappointing meagre change in insertion loss

125	250	500	1K	2K	4K	8K	16K
-0.4	-1.4	-0.7	+0.6	+1.7	-0.3	+1.4	+2.1

4. REFERENCES

(1) BS4718: 1971 Method of Test for Silencers for Air Distribution Systems, British Standards Institution, London.

(2) BS4196: 1981 Sound Power Levels of Noise Sources, British Standards Institution, London.

(3) Woods R I (Editor) Noise Control in Mechanical Services Sound Attenuations Ltd. and Sound Research Laboratories Ltd. Colchester, 1972: 320.

Acknowledgement

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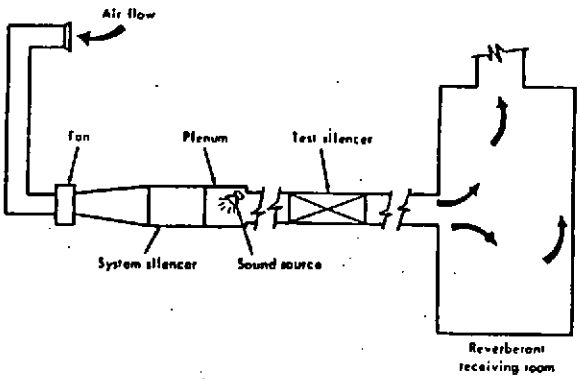
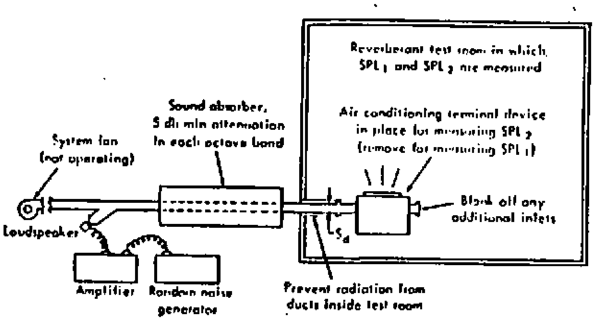
Figure 1 From IAC Bulletin No. 1.0112.0



5 PROPOSED method is extension of duct-to-room method, taking into account the effect of air flow and self-noise by introducing measured quantities of air. Ratings are in terms of dynamic insertion loss.



6 TEST FACILITY illustrated is specified by ASHRAE Standard 36B-63, which could readily be extended to embrace proposed test method.

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Figure 2 Modification to BS4718 testing

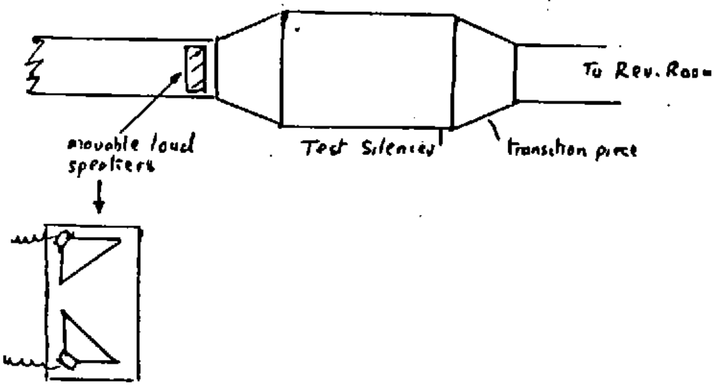

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Figure 3 Test results standardised to 1m

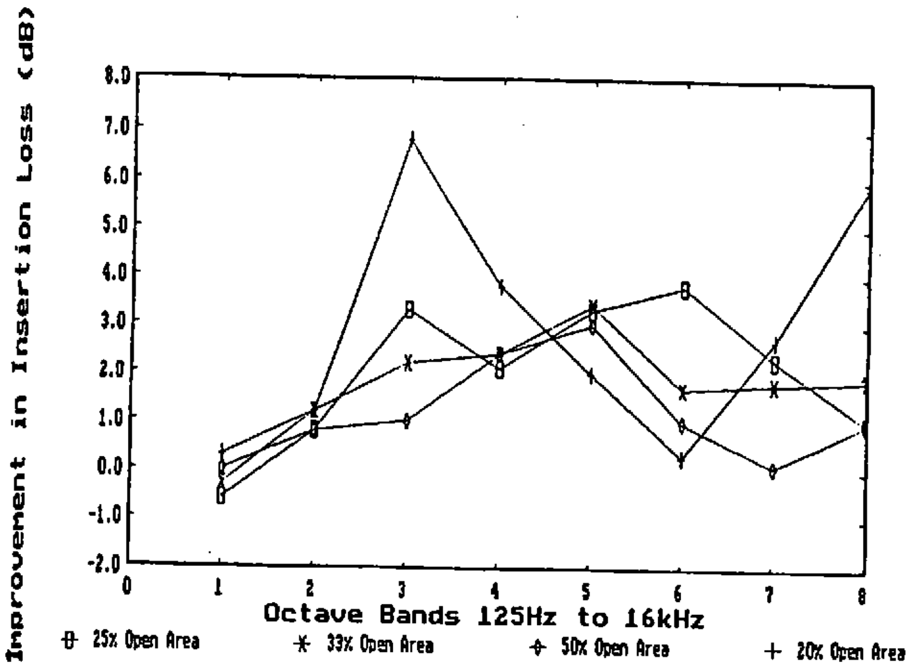
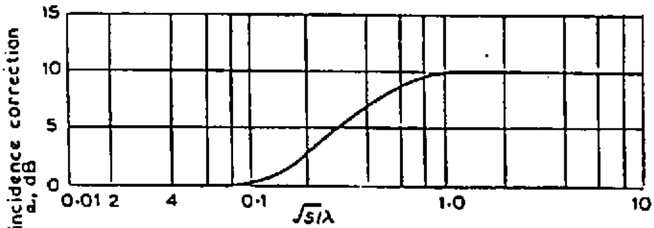


Figure 4   From R I Woods



Correction a to be added to plane-wave incidence insertion loss of a duct to obtain the insertion loss for a random incidence of sound S = open area of duct; λ = wavelength of sound

Figure 22.