BRITISH STANDARD

BS 4718:1971

Methods of test for

Silencers for air distribution systems

Co-operating organizations

The Heating and Ventilating Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Association of Consulting Engineers*
British Refrigeration and Air-Conditioning Association
British Steel Industry
Department of the Environment*
Department of the Environment — Building Research Station*
Department of Health and Social Security*
Engineering Equipment Users' Association
Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales*
Gas Council*
Heating and Ventilating Contractors' Association
Heating and Ventilating Research Association*
Hevac Association*
Institute of Fuel
Institute of Refrigeration
Institution of Gas Engineers
Institution of Heating and Ventilating Engineers*
National Coal Board
Royal Institute of British Architects
Royal Society for the Promotion of Health
British Mechanical Engineering Confederation

The Government departments and scientific and industrial organizations marked with an asterisk in the above list together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Greater London Council
Unit Heater Manufacturers' Association

This British Standard, having been approved by the Heating and Ventilating Industry Standards Committee, was published under the authority of the Executive Board on 22 April 1971

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Contents

Foreword

This standard makes reference to the following British Standards:

BS 848, *Methods of testing fans for general purposes, including mine fans.*

BS 848-1, *Performance.*

BS 848-2, *Fan noise testing.*

BS 1042, *Methods for the measurement of fluid flow in pipes.*

BS 2475, *Octave and one third octave band-pass filters.*

BS 2750, *Recommendations for field and laboratory measurement of airborne and impact sound transmission in buildings.*

BS 3638, *Method for the measurement of sound absorption coefficients (ISO) in a reverberation room.*

BS 4196, *Guide to the selection of methods of measuring noise emitted by machinery.*

BS 4197, *A precision sound level meter.*

This British Standard has been prepared under the authority of the Heating and Ventilating Industry Standards Committee in response to requests from the industry.

The Committee acknowledges its indebtedness to the work of the Heating and Ventilating Research Association on "The measurement of the performance of unit silencers" (Report No. 55:1969). The principles laid down in that report have been embodied in this British Standard. The acoustic performance of a silencer, used in ventilating and air conditioning systems, is expressed in terms of:

1) its insertion loss; this is the reduction in the rate of flow of sound energy (sound power) after a silencer arising solely from the insertion of the silencer into the system;

2) its airflow generated noise; a silencer presenting obstructions to straight-through flow will generate more noise than an ordinary straight duct. In high velocity systems or critical noise control applications this "serf noise" of the silencer may limit the amount of attenuation it can provide;

3) its pressure loss; this is a measure of the pressure required to pass air through the silencer.

The precise requirements of this British Standard, as to dimensions and layout of the test facility, are necessary to ensure a good degree of repeatability in test results between those on one silencer tested at different laboratories or even between those on one silencer tested at different times in the same laboratory. The dimensions and layout of the test installation are unlikely to be found in practical air distribution systems and, consequently, the performance of silencers in situ may vary from the test results; in most cases the variations are small and can be minimized especially for generated noise by good standards of duct manufacture, layout and design.

The Appendix E and Appendix F offer guidance on:

1) the extrapolation from the results of tests carried out in accordance with this British Standard on a particular silencer, to estimate the performance of similar silencers of different size;

2) the measurement of casing radiation.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 22, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 General

1.1 Scope

This British Standard deals with the objective measurement and determination of the performance of unit silencers and silencing elements for ducted ventilating and air conditioning systems. It considers three aspects of the performance of a silencer:

1) The attenuation of broad band airborne sound (insertion loss).

NOTE The test methods specified in this standard measure insertion loss without airflow. It may be that these methods do not give accurate insertion loss data for applications where the air velocity between silencing elements is in excess of about 20 m/s. Significant variation of insertion loss with velocity may occur at higher velocities and hence insertion loss data obtained by the methods recommended in this standard should be interpreted with caution if the air velocity within the silencer is in excess of 20 m/s.

2) The generation of aerodynamic noise by air flowing through the silencer (generated noise level).

3) The change in pressure of air flowing through the silencer. This may be expressed as a static pressure loss or a total pressure loss. It is normal practice in assessing the pressure loss of an air distribution system to consider the total pressure loss of the components forming that system. The silencer is rated in terms of total pressure.

This British Standard should not be used to determine the performance of silencers providing selective attenuation over narrow frequency bands (i.e. less than 1/3 octave).

The results obtained from tests carried out using the standard should not be used to determine the performance of:

1) Silencers which are designed for direct coupling to a fan. Such combinations are considered as a single unit and the performance in terms of inlet or outlet sound power levels should be obtained by one of the methods recommended in BS 848-2[1)].

2) Silencers designed to be installed to increase the sound insulation of a partition having a ventilation opening. The sound insulation provided by such silencers can be assessed by tests carried out in accordance with BS 2750[2)].

1.2 General

1.2.1 For the purposes of this British Standard the term silencer is used to describe either a unit silencer or an arrangement of silencing elements.

Silencers may be divided into two classes:

Type A: Silencers having the same dimensions and direction for the inlet and outlet connections.

Type B: Silencers having different dimensions and/or different directions for the inlet and outlet connections.

1.2.2 Mean band sound pressure levels shall be calculated as in Appendix A.

1.2.3 The end reflection shall be calculated as in Appendix B.

[1)] BS 848, "*Methods of testing fans for general purposes, including mine fans*", Part 2, *"Fan noise testing"*.

[2)] BS 2750, "*Recommendations for field and laboratory measurement of airborne and impact sound transmission in buildings*".

1.3 Definitions

For the purposes of this British Standard the following definitions apply:

1.3.1
unit silencer

a device to carry air as part of an air distribution system to provide an attenuation of sound

1.3.2
silencing element

an element designed to be introduced within a passage-way in an air distribution system to provide an attenuation of sound

1.3.3
insertion loss

the difference between the output sound power levels of the system before and after insertion of the silencer

1.3.4
generated noise level

the sound power level that is radiated through either the inlet or outlet duct connection of a silencer and which arises from airflow within the silencer

1.3.5
total pressure loss

the difference between the mean total pressure at the silencer inlet and the mean total pressure at the silencer outlet. The pressure loss is specified for air of standard density, 1.2 kg/m^3

1.3.6
silencer-in test

test carried out with the unit silencer inserted into the test installation

1.3.7
silencer-out test

test carried out with a plain substitution duct replacing the unit silencer in the test installation

1.3.8
silencer face velocity

the mean air velocity at the silencer inlet connection

1.3.9
silencer airway velocity

the mean air velocity, at the minimum airway section, between silencing elements

1.4 Symbols

The following general symbols are used in this standard:

Symbol	Quantity	Unit
P	Sound pressure	N/m^2
P_0	Reference sound pressure	2×10^{-5} N/m^2
L_p	Sound pressure level $= 20 \log_{10} \frac{P}{P_0}$	dB
W	Sound power	W
W_o	Reference sound power	10^{-12} W
L_w	Sound power level $= 10 \log_{10} \frac{W}{W_o}$	dB
Xr	End reflection factor	dB
IL	Insertion loss	dB
ΔP	Pressure loss	N/m^2
D	Duct size = diameter (circular duct) or major dimension of rectangular duct	m
D_H	Duct hydraulic diameter $= \frac{4 \times \text{cross-sectional area}}{\text{perimeter}}$	m
$\bar{p}_v$	Velocity pressure corresponding to average duct velocity $= \frac{1}{2} w v^{-2}$	N/m^2
$\bar{v}$	Average velocity in test duct	m/s
Q	Volume flow rate in test duct	m^3/s
P	Air density	kg/m^3
t	Air temperature	°C

1.5 Instrumentation

1.5.1 Acoustic instrumentation

1.5.1.1 *Measuring equipment.* Sound measuring equipment which complies with BS 4197[3)] shall be used. An extension cable shall be available to separate the microphone from the instrument cases and the observers.

The filters shall comply with BS 2475[4)].

The use of high speed level recorder or similar automatic recording apparatus is permitted provided that the overall performance of the complete equipment meets the requirements of BS 4197.

1.5.1.2 *Calibration.* The acoustical performance of the sound analysis equipment shall be checked, and any specified adjustments made, immediately before each series of noise measurements and rechecked immediately after each series.

The measuring equipment should be tested periodically for compliance with BS 4197[3)] at a laboratory equipped with the necessary calibration facilities.

A random incidence calibration shall be employed for generated noise level tests.

[3)] BS 4197, "A precision sound level meter".

[4)] BS 2475, "Octave and one third octave band-pass filters".

1.5.2 Air flow rate measurement. The measurement of the air volume flow rate through the test installation shall be carried out by one of the following standard methods:

1) Orifice plate, nozzle or venturi installed in a straight section of ductwork in accordance with the requirements of BS 1042-1[5].

2) Test Methods 1, 2 or 3 of BS 848-1[6]. Test Method 1 of BS 848-1 (inlet cone method) is recommended as being particularly suitable.

1.5.3 Pressure loss measurement. The manometer used for pressure measurements should be capable of resolving pressures to 5 N/m^2.

1.6 Installation

1.6.1 Unit silencers. Unit silencers shall be mounted in as representative a manner as possible with the degree of vibration isolation from associated ductwork and supporting structure normally recommended by the manufacturer.

1.6.2 Silencing elements. Silencing elements shall be installed in accordance with manufacturers' recommendations and in a steel casing with a minimum thickness of 1.5 mm.

1.6.3 Substitution ducting. This duct shall connect the inlet duct to the outlet duct so that measurements can be made with the silencer removed.

1.6.4 Associated ducting. Associated ducting used in the test installations shall be made airtight by sealing openings and cracks except where an opening is required for the insertion of the microphone during an in-duct insertion loss test. It is recommended that sheet metal (steel or aluminium) ducting should have a minimum thickness of 1.5 mm for square or rectangular sections and 1.2 mm for circular ducts. In addition square or rectangular sheet metal ducts of sides greater than 650 mm should have angle girths for stiffening at 650 mm maximum centres.

The substitution duct shall be constructed of material of the same type and thickness as that used for the inlet duct and shall be sealed to the same standard.

Type A silencers. The substitution duct for this type shall be a straight uniform duct of the same length as the silencer and shall have the same inlet and outlet dimensions (see Figure 1).

Type B silencers. The substitution duct shall be a straight uniform duct of the same length as the centre-line length of the silencer and with the same cross-sectional dimensions as the silencer inlet connection (see Figure 1).

NOTE For tests using Type B silencers having a change of dimensions two outlet ducts will be required. One will have the dimensions of the silencer outlet (silencer-in test) and the other the dimensions of the silencer inlet (silencer-out test).

1.7 Quantities to be measured

The following quantities should be measured.

1.7.1 Sound pressure levels, in frequency bands of one octave width having geometric mean frequencies of 125, 250, 500, 1 000, 2 000, 4 000 and 8 000 Hz. Measurements in the 63 Hz octave band may be reported, but will have a lower order of accuracy.

1.7.2 The air volume flow rate through the silencer.

1.7.3 The static air pressures, at specified measuring stations.

1.8 Methods of measurement

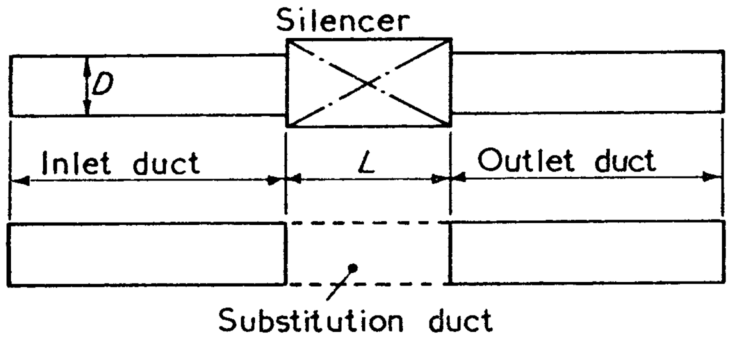
1.8.1 Methods of measurement of insertion loss. The recommended methods for the determination of insertion loss are substitution tests without air flow through the silencer. These methods are:

1) the in-duct method, and

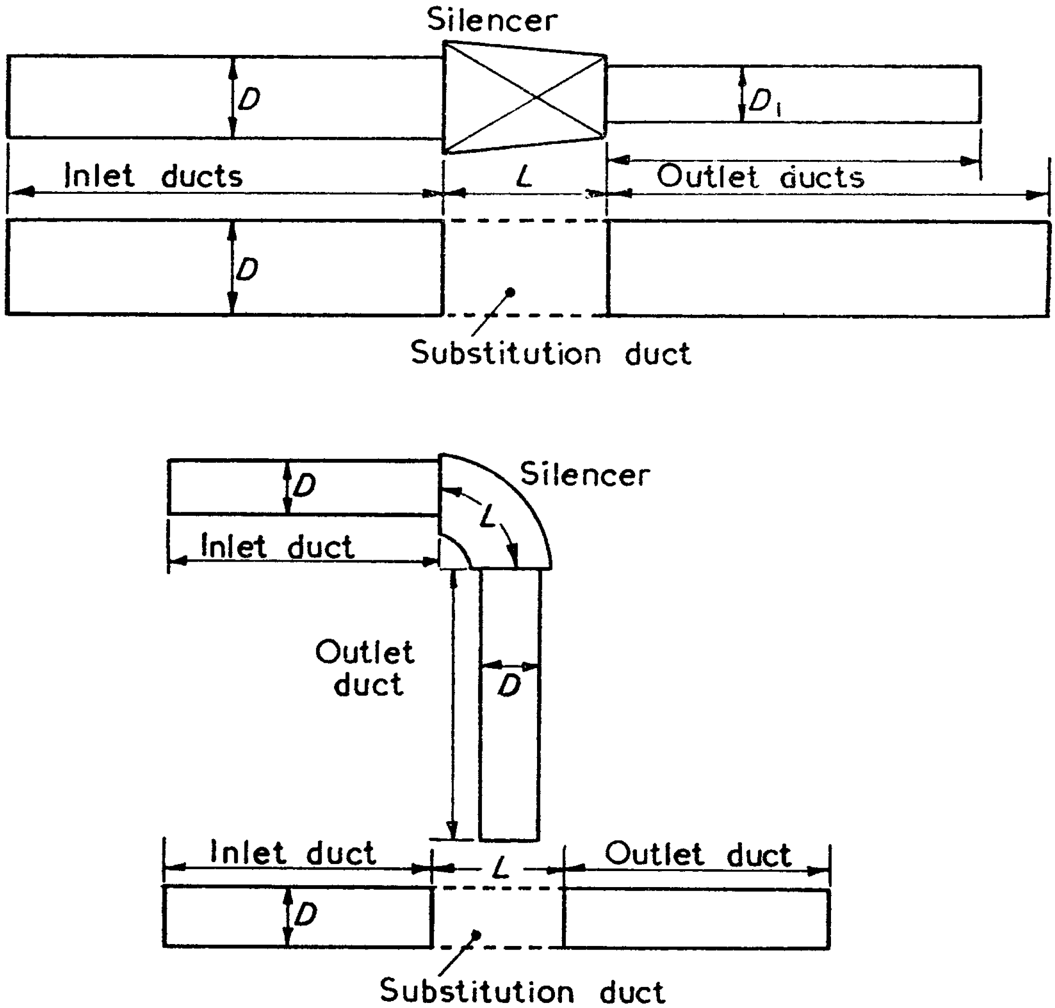
2) the diffuse field method.

[5] BS 1042, "*Methods for the measurement of fluid flow in pipes*" — *Part 1:* "*Orifice plates, nozzles and venturi tubes*".

[6] BS 848, "*Methods of testing fans for general purposes, including mine fans*" — *Part 1:* "*Performance*".



Type A



Minimum duct lengths

inlet duct	$5D$	or 4 m whichever is greater
outlet duct (D)	$5D$	or 4 m whichever is greater
or outlet duct (D_1)	$5D_1$	or 4 m whichever is greater

Types B

Figure 1 — Substitution duct arrangements

1.8.2 Methods of measurement of generated noise level. The recommended methods of test for the measurement of generated noise level are:

1) the diffuse field — direct method, and

2) the diffuse field — substitution method.

1.8.3 Methods of measurement of pressure loss. A substitution method is recommended for the measurement of the pressure loss.

NOTE Whilst the minimum dimensional requirements for the test installations referred to in **1.8.2** and **1.8.3** are not identical, it may be found convenient to design a single test installation which meets the requirements of both.

1.9 Thermal environment

The following maximum variations in temperature and relative humidity shall not be exceeded during a performance test on a silencer:

Performance test	Position of temperature and humidity measurement	Maximum permitted variations	
		Temperature	Relative humidity
		°C	%
Insertion loss	measurement room	± 5	± 5
Generated noise level	ducted airstream and measurement room	± 5	± 5
Pressure loss	ducted airstream	± 2	not critical

The mean temperature at the measurement positions should be included with the pressure loss test results.

1.10 Accuracy of measurements

Variations in measured performance data can arise through inaccuracies inherent in test measurements. The following tolerances can be expected to cover such inaccuracies.

Insertion loss Generated noise level	± 3 dB in the 125 Hz band ± 2 dB in higher bands
Pressure loss	± 5 %

2 Measurement of static insertion loss

2.1 General requirements

2.1.1 Test installations. The arrangement of the test installation for the insertion loss tests shall be as described in **2.2.1** and **2.3.1**.

The connecting ducts shall preferably be of the same cross section as the inlet and outlet connections of the silencer. It is permitted, however, to use ducts whose cross-sectional dimensions differ from those of the silencer, provided the included angle of the sides of the connecting pieces does not exceed 15° and the area ratio does not exceed 4 : 1.

2.1.2 The noise source. The noise source shall be made up of a loudspeaker, or a bank of loudspeakers arranged symmetrically on a flat baffle and the diaphragms excited *in phase*. The following conditions shall apply to the noise source:

1) For ducts with diameter or one side greater than 300 mm a minimum of two loudspeakers shall be used.

2) The total projected area of the loudspeakers shall occupy at least 40 % of the cross-sectional area of the inlet duct.

3) The source shall be supported a short fixed distance away from the inlet duct, in such a manner as to prevent transmission of mechanical vibration to the duct.

It is permitted to use a loudspeaker baffle smaller in area than the cross-sectional area of the inlet duct, provided the ratio of areas is not greater than 2 : 1 and that the included angle between the sides of the connecting piece does not exceed 15°. In this case, 2) above shall refer to the inlet of the connecting piece.

The loudspeakers shall be excited by a continuously sounding source of broad-band random noise. For measurements in a particular frequency band the loudspeakers should be excited by a signal having at least the same frequency range.

Where a tape recording is used for the noise source, precautions shall be taken to ensure that the output remains constant throughout the duration of the test. A closed loop of tape is recommended to minimize the effects of tape sensitivity variations and the loop should pass the play-back head at least three times during each frequency band measurement. The tape should be of the type recommended for closed loop working, i.e. with a permanently lubricated surface.

2.1.3 Background noise. Background levels shall be measured during both the silencer-in and silencer-out tests.

1) *Silencer-in test.* The background levels should be at least 6 dB below the levels measured with the noise source operating. If the background levels are less than 6 dB below these measured levels then the background will reduce the measured insertion loss. Where this occurs the results may be reported with a note to this effect.

2) *Silencer-out test.* The background levels shall be at least 6 dB below the levels measured with the noise source operating.

2.1.4 Flanking transmission. Noise from the source which reaches the microphone measuring stations without passing through the silencer under test will appear to reduce the insertion loss of the unit. To determine whether this is occurring in the test installation the following procedure is recommended:

1) Measure the octave band sound pressure levels at the microphone measuring stations as for the silencer-in test with noise source operating.

2) Block the inlet duct by means of a high transmission loss barrier immediately upstream of the silencer and repeat test 1).

If the octave band sound pressure level measured in test 2) is at least 10 dB below the octave band level measured in test 1) in each band of interest, the insertion loss measurements made on the silencer under test will not be affected by flanking transmission.

2.2 The in-duct method

2.2.1 Arrangement of test installation. The test installation shall be arranged as shown in Figure 2.

An anechoic termination shall be fitted to the end of the test duct. A termination of larger dimensions than the test duct may be used by connecting a coupler as illustrated in Appendix C.

2.2.2 Suitability of anechoic termination. The anechoic termination shall be designed to reduce reflections of sound to a low level at frequencies above 90 Hz. A microphone survey shall be carried out along the axis of the duct for a distance of 650 mm either side of the measurement plane. A termination shall be regarded as suitable if the longitudinal variation in sound pressure level does not exceed 3 dB in any octave band having a mid-frequency of 125 Hz or greater. A termination which may be found suitable is shown in Appendix C.

2.2.3 Measurement procedure. The measurement plane constitutes a cross section of the duct approximately midway between the silencer and the anechoic termination. Four microphone stations shall be positioned halfway between the duct wall(s) and centre line as shown in Figure 3.

The microphone only shall be inserted in the duct.

1) *Silencer-in test*

a) At one microphone station the background sound pressure level shall be measured in each octave band (refer to **2.1.3**).

b) With noise source operating, the sound pressure levels in each octave band shall be measured at each microphone station.

c) The mean sound pressure level in each octave band ($\overline{L}_{pi}$) shall be determined as the average of the levels at the four microphone stations as described in Appendix A.

2) *Silencer-out test*

a) At one microphone station the background sound pressure level shall be measured in each octave band (refer to **2.1.3**).

b) With noise source operating, the sound pressure levels in each octave band shall be measured at each microphone station.

c) The mean sound pressure level in each octave band ($\bar{L}_{po}$) shall be determined as the average of the levels at the four microphone stations as described in Appendix A.

2.2.4 Calculation of insertion loss. The insertion loss of the silencer shall be determined in each octave band from the following formula:

$$IL = \bar{L}_{po} - \bar{L}_{pi} + 10 \log_{10} \frac{Ao}{Ai} \text{ dB}$$

where $\bar{L}_{po}$ = the mean octave band sound pressure level, silencer-out test,
$\bar{L}_{pi}$ = the mean octave band sound pressure level, silencer-in test,
Ao = cross-sectional area of the test duct at the measurement plane, silencer-out test,
Ai = cross-sectional area of the test duct at the measurement plane, silencer-in test.

NOTE Where the same outlet duct is used for both tests $10 \log_{10} \frac{Ao}{Ai} = 0$.

2.3 The diffuse field method

2.3.1 Arrangement of test installation. The test installation shall be arranged as shown in Figure 4.

The outlet duct shall terminate in a reverberant room. The axis of the outlet duct should preferably not be normal to the opposite wall of the test room. No part of the radiating end of the duct shall be closer to any surface in the room than *D* or 1 m whichever is the greater.

The position of the duct outlet relative to the room surfaces shall be the same for silencer-in and silencer-out tests.

2.3.2 Room suitability and microphone stations. The space in which the noise measurements are made shall be a large enclosure with hard reflecting walls, floor and ceiling.

Measurements of sound pressure level shall be taken at a number of microphone stations in the test room. The number of stations required shall be determined by the range of the measurements obtained during the silencer-in test, as set out below:

Range of measurements dB	Octave band centred on 125 Hz	Octave bands centred on or above 250 Hz
	No. of stations	No. of stations
Up to 2	4	5
3	5	6
4	6	8
5	8	10
6	9	12
7	11	
8	13	

where range of measurements = maximum reading – minimum reading, for required number of measurements.

When determining the number of microphone stations required for measurements, all observations shall be taken into account and the number of stations increased until the relationship between the range of measurements and number of stations complies with the table. If the range of measurements exceeds those given, the room is not suitable for a diffuse field test[7].

[7] The smaller number of microphone stations for the 125 Hz band reflects the greater tolerance permitted in this band (See **1.10**).

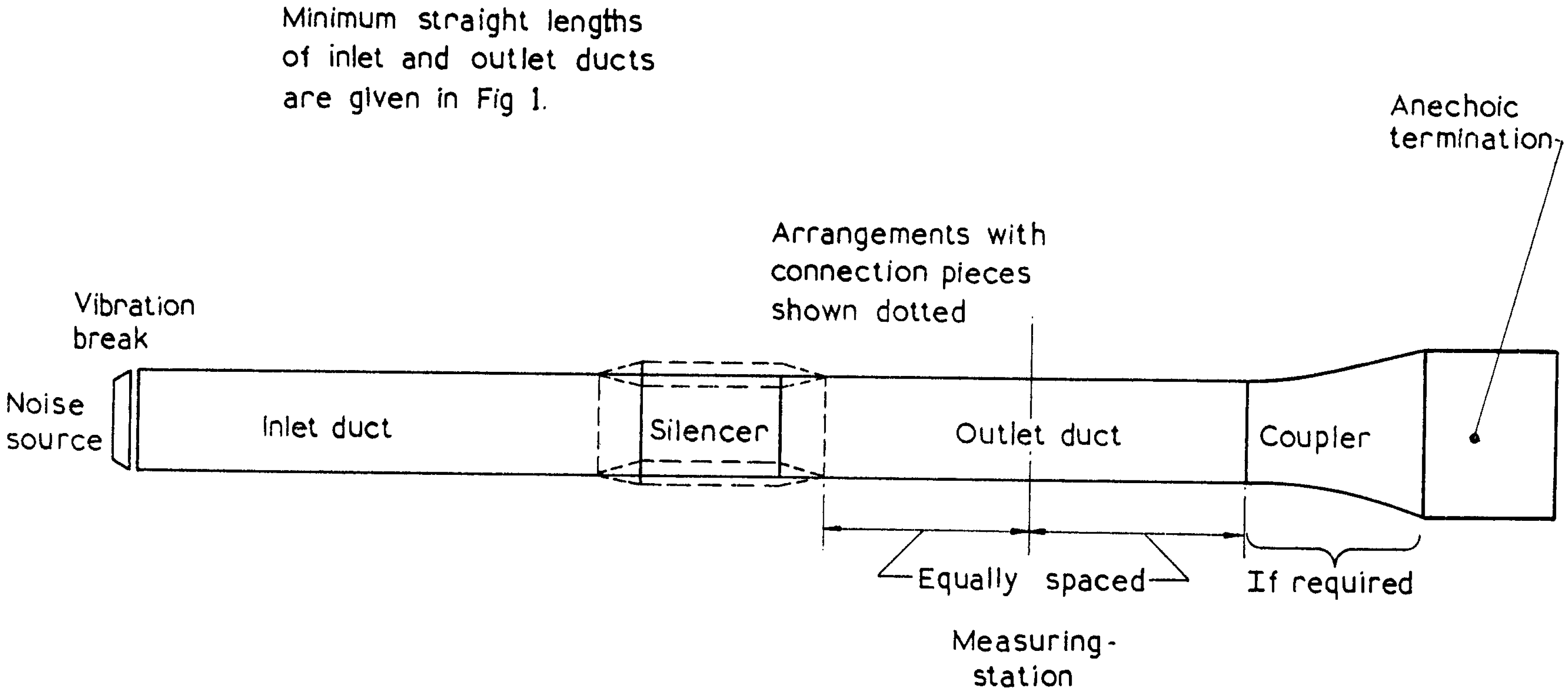


Figure 2 — Arrangement of test installation for in-duct tests

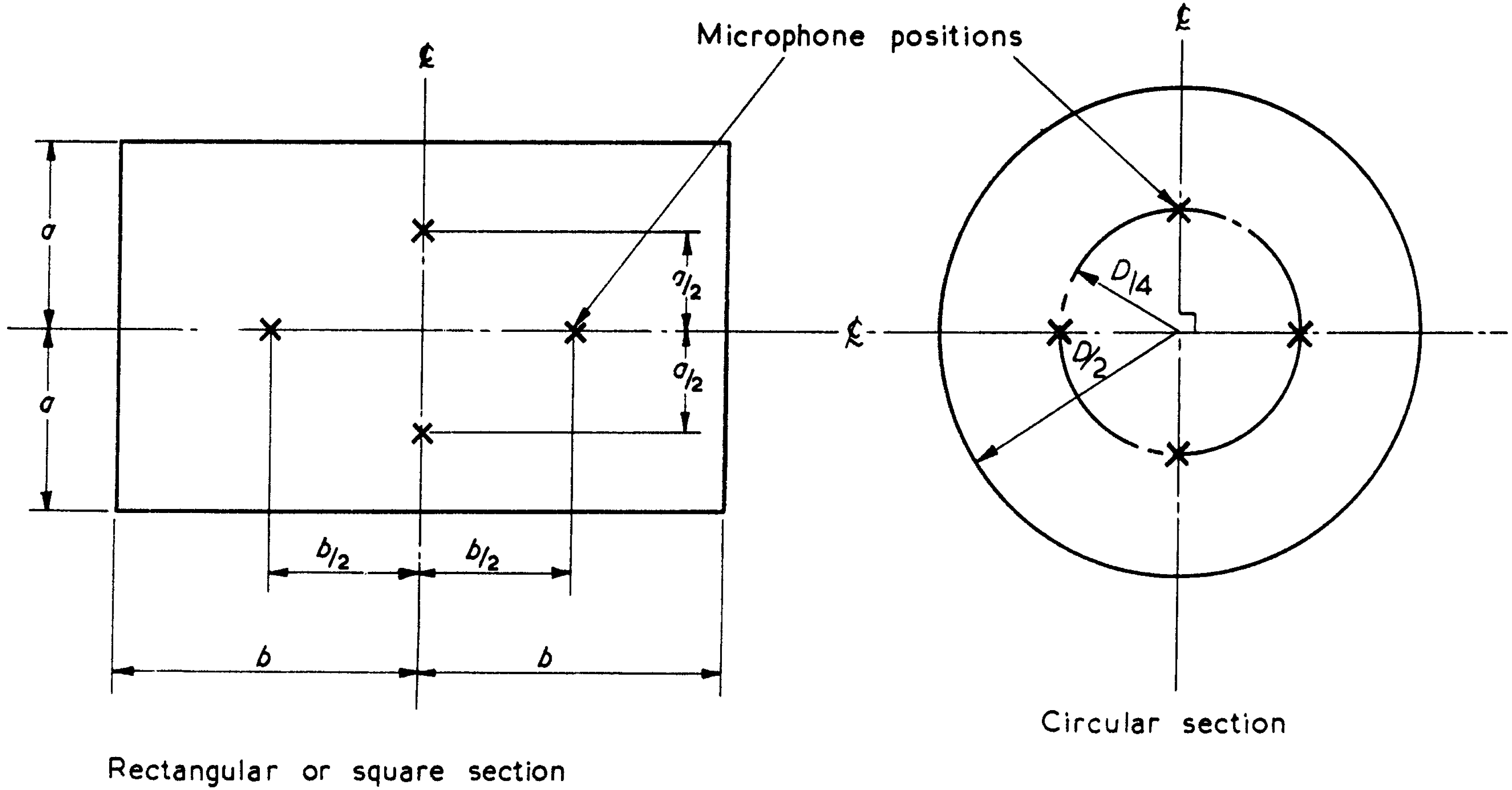


Figure 3 — Microphone positions at in-duct measuring plane

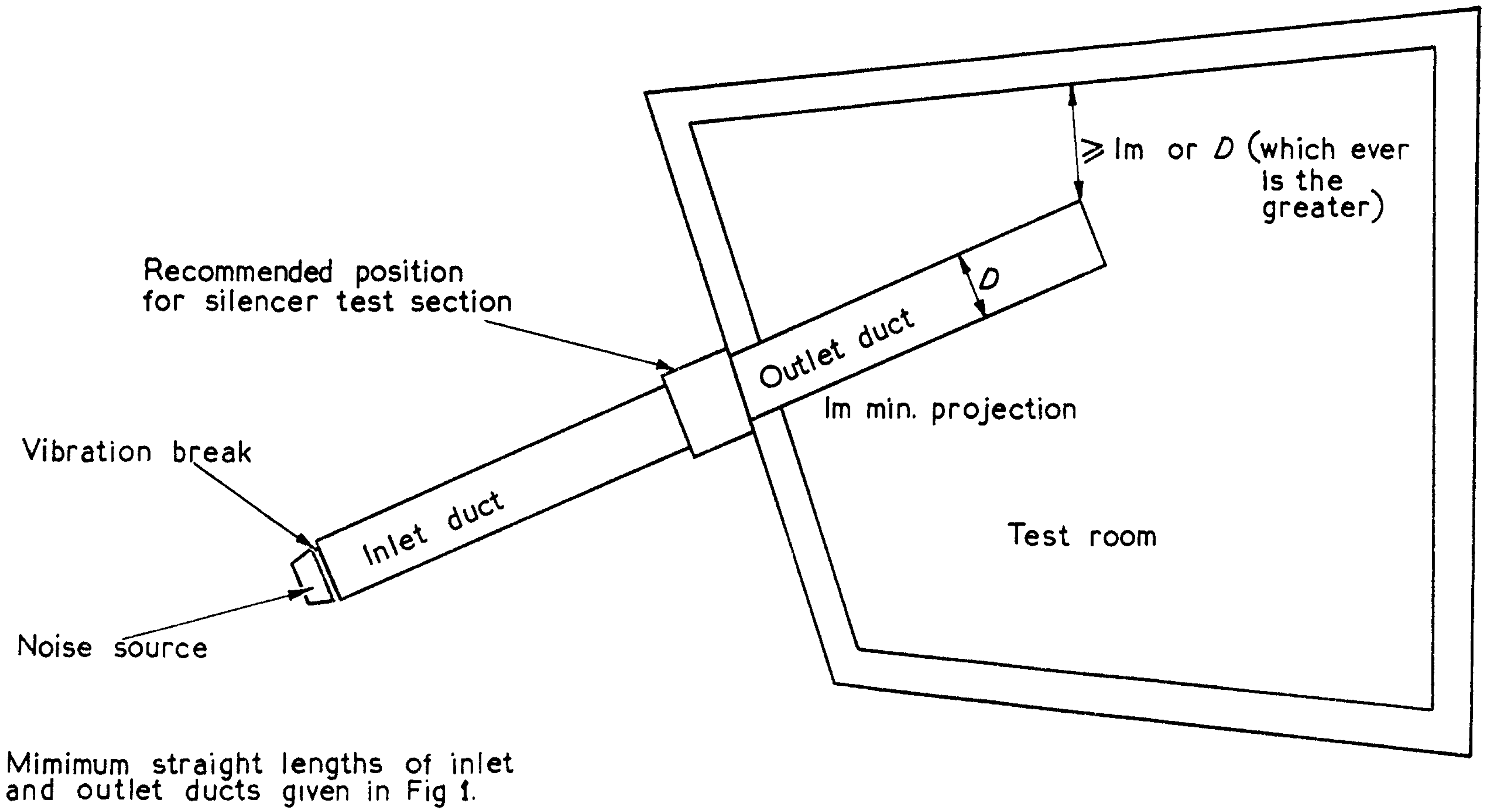


Figure 4 — Arrangement of test installation: diffuse field method

NOTE A test room with a volume of 180 m^3 will probably be found to be satisfactory. In smaller rooms, difficulty may be experienced in meeting the requirements of this section.
It may be possible to reduce the range of measurements by modifying the absorption characteristics of the room, e.g. by introducing large reflecting surfaces.

The microphone stations shall be positioned so that they are:

1) at a minimum radius of 2 m from the open end of the duct;

2) at a minimum distance of 1 m from any surface of the room or test installation;

3) at least 1 m from any other microphone station.

2.3.3 Measurement procedure. An extension cable shall be used to separate the microphone from the instrument cases and the observer so as to minimize errors due to reflection and absorption. It is preferable that the observer is stationed outside the room.

1) *Silencer-in test*

a) At one microphone station the background sound pressure level shall be measured in each octave band (refer to **2.1.3**).

b) With noise source operating, the sound pressure levels in each octave band shall be measured at each microphone station.

c) The mean sound pressure level in each octave band ($\bar{L}_{pi}$) shall be determined as the average of the levels at the microphone stations as described in Appendix A.

2) *Silencer-out test*

a) At one microphone station the background sound pressure level shall be measured in each octave band (refer to **2.1.3**).

b) With noise source operating, the sound pressure levels in each octave band shall be measured at each microphone station.

c) The mean sound pressure level in each octave band ($\bar{L}_{po}$) shall be determined as the average of the levels at the microphone stations as described in Appendix A.

2.3.4 Calculation of insertion loss. The insertion loss of the silencer shall be determined in each octave band from the following formula:

$$IL = \bar{L}_{po} - \bar{L}_{pi} + Xr_o - Xr_i \quad \text{dB}$$

NOTE Where the same outlet duct is used for both tests $Xr_o — Xr_i = 0$.

where $\bar{L}_{po}$ = mean octave band sound pressure level, silencer-out test.
$\bar{L}_{pi}$ = mean octave band sound pressure level, silencer-in test.
Xr_o = reduction of sound power radiated due to duct end reflection, silencer-out test (Appendix B).
Xr_i = reduction of sound power radiated due to duct end reflection, silencer-in test (Appendix B).

3. Measurement of generated noise level

3.1 General requirements

3.1.1 Test installation. The basic arrangement of the test installation for the generated noise tests is shown in Figure 5. Essential requirements are:

1) A fan providing a stable air supply for the test installation and permanent silencers to reduce fan and any damper generated noise, to meet the requirement of **3.1.4**.

2) A smooth contraction of minimum area ratio 3 : 1 shall be included upstream of the test section to stabilize the flow at the test section. The contraction may take the form of a uniform duct reducing section or alternatively the flow can be from a plenum chamber into the silencer inlet duct. Between this contraction and the silencer inlet the duct shall be straight and have the same cross-sectional dimensions as the silencer inlet.

The outlet duct shall be straight and have the same cross-sectional dimensions as the silencer outlet.

This duct shall discharge into a reverberant room and its axis should preferably not be normal to the opposite wall of the test room. No part of the radiating end of the duct shall be closer than *D* or 1 m, whichever is the greater, to any surface of the room. The position of the duct outlet relative to the room surfaces shall be the same for all the noise measurements.

3) Stations for measuring air flow. The duct shall be made airtight between a station for measuring air flow and the test section.

4) Outlets from terminal room to discharge air from the system should be shielded as shown in Figure 5.

The test installation described is suitable for the determination of the generated noise level radiated through the silencer outlet duct connection.

NOTE If the generated noise level radiated through the inlet connection is specifically required (e.g. for silencers in return air ducts) then the test installation in Figure 5 may be used with the air flow direction reversed, and the silencer arranged to free the incoming flow. In this case it may be necessary to provide a flared inlet at the duct termination in the terminal room to reduce the self noise of the installation.

3.1.2 Room suitability and microphone stations. The requirements for the reverberant room and the selection of microphone station shall be as set out in **2.3.2**, except that no microphone station shall be within the boundaries of the air-jet discharging from the open end, or in any other position where the wind velocity affects the measurements.

3.1.3 Air flow measurement. The measurement of the air volume flowing through the test installation shall be carried out by one of the standard methods described in **1.5.2**.

Air flow measurements are required during generated noise tests with both silencer in and silencer out. The air flow rate shall be maintained constant during each test and the variation of air flow rate between the two tests shall not exceed ± 2 %.

Where a test is required at a particular face velocity, this should be carried out at a velocity within ± 2 % of the particular value, as indicated by the measurement equipment. The silencer face velocity shall be derived from the air flow rate during the silencer-in tests.

NOTE Where the purpose of the testing is to provide data at selected silencer face velocities, it is recommended that the ratio of the two consecutive velocities does not exceed 1 : 5.

3.1.4 Background levels. The background levels, in the context of the generated noise level tests, include system noise reaching the terminal room and are determined from the silencer-out test. Levels measured during the silencer-in test should be at least 6 dB greater than during the silencer-out test. When the increase in level due to air flow through the silencer is less than 6 dB then the background is too high to determine accurately the generated noise level, but the results can be noted as being the maximum that can be attributed to the silencer for this test. This position could arise if the generated noise levels are very low or the background levels relatively high.

3.2 Diffuse field: direct method

3.2.1 Measurement procedure

1) *Silencer-in test*

a) With the stated air flow through the test section the sound pressure levels in each octave band, at each microphone station, shall be measured.

b) The mean sound pressure level in each octave band ($\bar{L}_{pi}$) shall be determined as the average of the levels at the microphone stations as described in Appendix A.

2) *Silencer-out test (background levels)*

a) Adjust the air flow controls to give the stated air flow.

b) With the stated air flow through the test section the sound pressure levels in each octave band, at each microphone station, shall be measured.

c) The mean sound pressure level in each octave band ($\bar{L}_{po}$) shall be determined as the average of the levels at the microphone stations as described in Appendix A.

3) *Reverberation time test.* The reverberation time of the room, with the test installation complete, shall be determined for each octave band. It is recommended that the procedure outlined in BS 3638:1963[8] should be used to measure the reverberation times.

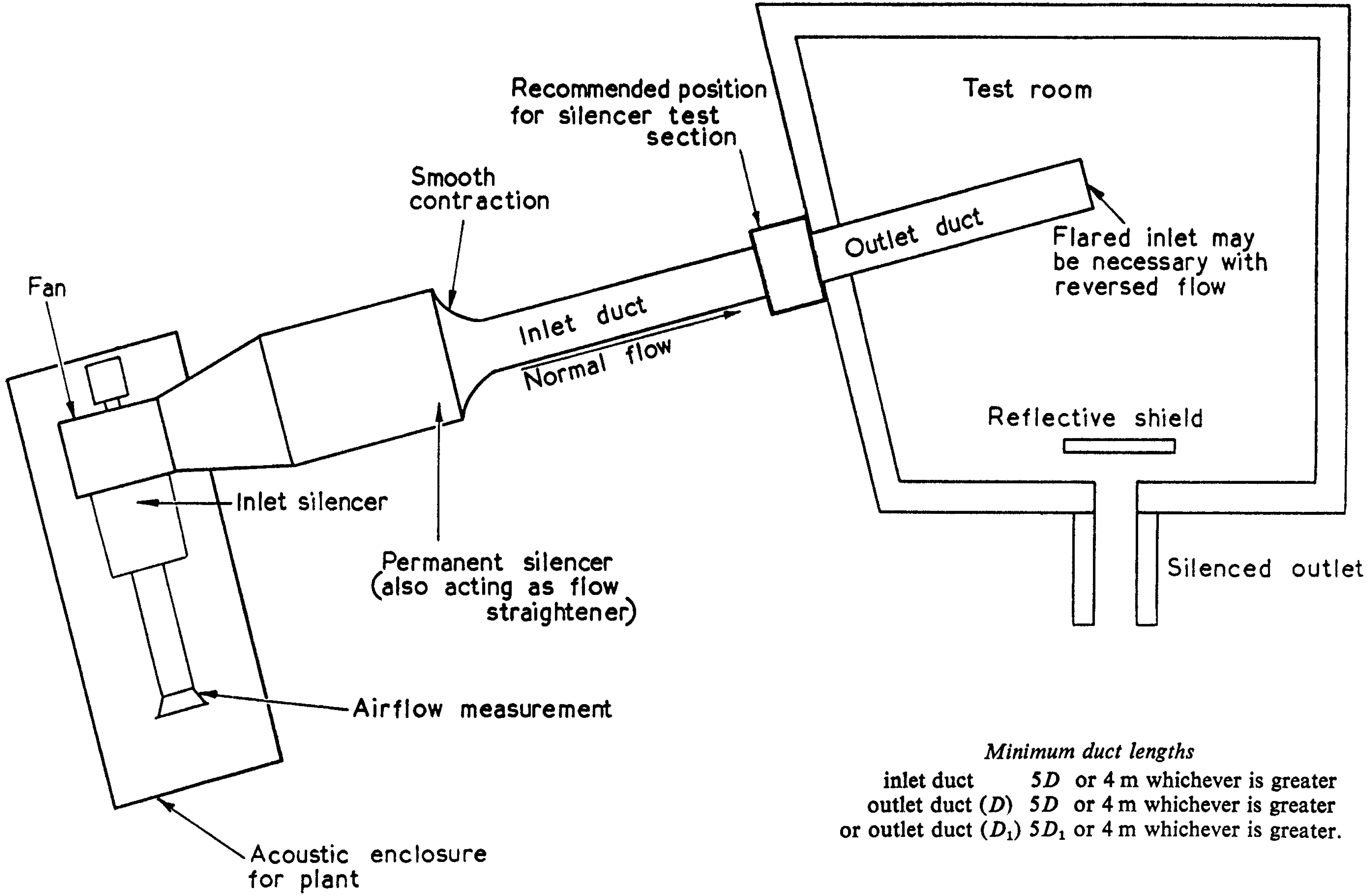
3.2.2 Calculation of generated noise level. The octave band sound power level of air flow generated noise of the silencer radiated from one ducted end shall be determined from the following formula:

Octave band generated noise level

$$L_w = \bar{L}_{pi} - 10 \log_{10} T + 10 \log_{10} V - 14 + Xr \quad \text{dB}$$

where T = reverberation time,
V = volume of reverberation room (m^3),
Xr = end reflection factor, Appendix B.

[8] BS 3638, "*Method for the measurement of sound absorption coefficients (ISO) in a reverberation room.*"



Minimum duct lengths

inlet duct	$5D$	or 4 m whichever is greater
outlet duct (D)	$5D$	or 4 m whichever is greater
or outlet duct (D_1)	$5D_1$	or 4 m whichever is greater.

Figure 5 — Typical arrangement of installation for generated noise level measurement

3.3 Diffuse field: substitution method

3.3.1 Reference sound source. The reference sound source shall preferably be aerodynamic in character, emitting sound with energy distributed over the frequency range of 88 Hz to 11 300 Hz and free from significant pure tones. An impeller which may be found suitable is illustrated in Appendix D.

This device shall have been calibrated, previously in accordance with either Appendix B or Appendix C of BS 4196[9], so that its sound power level is known to within 1 dB in the octave bands having mid-frequencies of 250 Hz to 4 000 Hz and to within 3 dB in the 125 Hz and 8 000 Hz bands. The reference sound source shall be run at a speed within 2 % of the speed at which it was calibrated.

3.3.2 Location of reference sound source. The reference sound source shall be placed in the room so that its position satisfies the following conditions:

1) Its position relative to the floor shall correspond to that employed during its calibration.

2) It shall be placed in the plane normal to the centre line of the duct, at the end of the duct and shall be positioned at a distance > 1 m from the nearest duct wall (see Figure 6).

3) It shall be at least 1.5 m from all room surfaces other than its mounting surface.

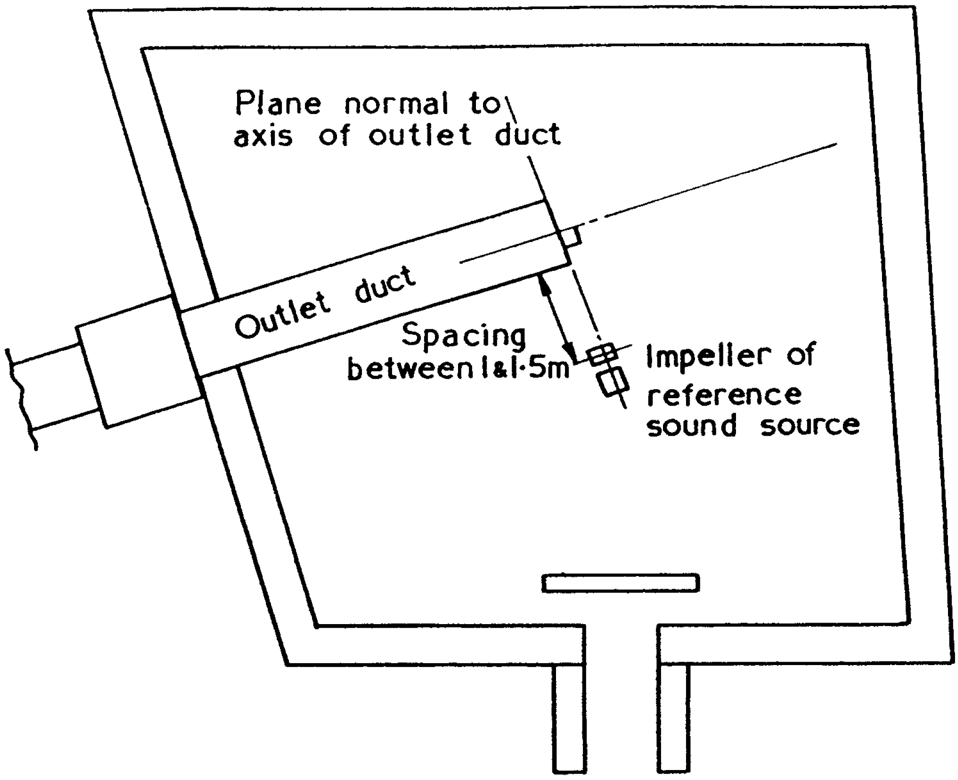


Figure 6 — Positioning of reference sound source, diffuse field substitution method

3.3.3 Measurement procedure

1) *Silencer-in test.* Procedure as in **3.2.1** 1).

2) *Silencer-out test.* Procedure as in **3.2.1** 2).

3) *Test with reference sound source.* The tests shall be conducted with the silencer in but without air flow through the silencer. Microphone stations equal in number to those employed in the "silencer-in" test shall be positioned in accordance with **2.3.2**, but additionally such that they are at a minimum distance of 2 m from the reference sound source.

[9] BS 4196, "*Guide to the selection of methods of measuring noise emitted by machinery.*"

NOTE It may be found possible to select microphone stations which are common to this test and the silencer-in test.

a) With the sound source inoperative, the background sound pressure levels, in each octave band, at each microphone station, shall be measured.

b) With the sound source operating, the sound pressure levels, in each octave band, at each microphone station, shall be measured. At each microphone station, these sound pressure levels shall be least 6 dB above the corresponding background levels measured in *a*.

c) Subject to the provision *b*, the mean sound pressure level in each octave band shall be determined as the average of the levels at the microphone stations, as described in Appendix A ($\bar{L}_{pr}$).

3.3.4 Calculation of the generated noise level. The octave band sound power level of the air flow generated noise of the silencer, radiated from one ducted end, shall be determined from the following formula:

Octave band generated power level

$$L_w = \bar{L}_{pi} - \bar{L}_{pr} + L_{wr} + X_r \quad \text{dB}$$

where Xr = end reflection factor, Appendix B.

4 Measurement of pressure loss

4.1 Test methods

4.1.1 Test installation. The basic arrangement of the installation for the pressure loss test is shown in Figure 7.

Two pressure measuring planes shall be provided, one upstream and one downstream of the silencer test section. The upstream plane shall be at least 2*D* from the silencer inlet connection. The minimum distance of the downstream plane from the silencer outlet connection shall be 6*D* for "straight-through" silencers and 12*D* for silencers that involve a change in direction.

For silencers with different dimensions for the inlet and outlet connections two outlet ducts are necessary. One shall match the silencer outlet connection (silencer-in test) and the other the inlet duct (silencer-out test).

The downstream pressure measuring plane shall be the same distance from the silencer outlet connection for both outlet ducts. This distance shall be 6*D* or 12*D*, where *D* refers to the larger of the two outlet ducts.

At each measuring plane, pressure measuring stations shall consist of four wall tappings spaced uniformly around the circumference of the duct. In the case of rectangular or square ducts the tappings shall be positioned in the centre of each side.

The tappings and their connections shall comply with the following requirements:

1) the internal bore of the tappings shall not exceed 5 mm diameter,

2) the tappings shall be straight and perpendicular to the duct for a minimum distance of 10 mm,

3) the openings shall be flush with the inside surface of the duct,

4) the four tappings shall be interconnected with tubing having airtight joints to provide one connection for attachment to a manometer,

5) the connections from the two planes shall be connected to the two limbs of a manometer.

Air flow and pressure measurements shall be in accordance with **1.5.2**.

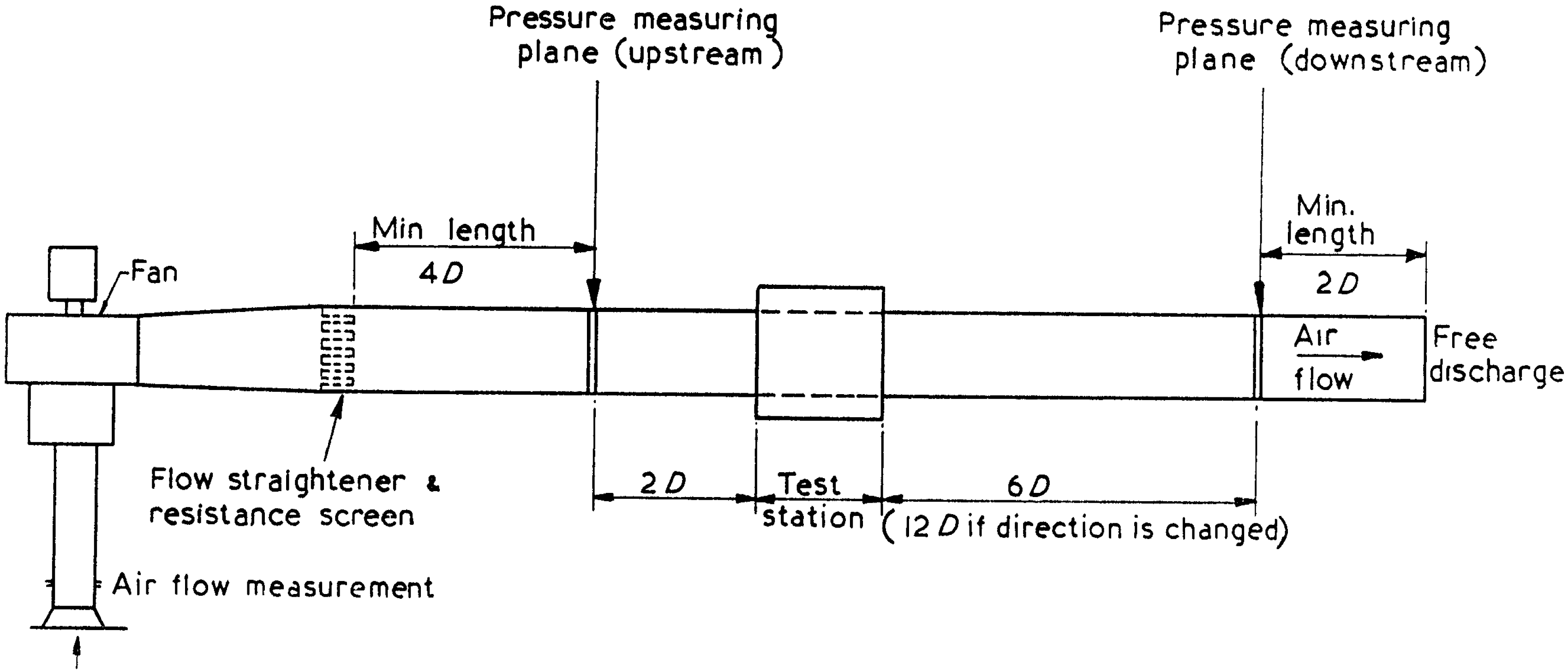


Figure 7 — Installation for pressure loss measurements

4.1.2 ***Measurement procedure***

1) *Silencer-in test.* With the stated air flow through the silencer test section, the differential pressure (Δpi) is measured. The air temperature in the duct is measured and the air density determined:

$$\rho = 1{\cdot}2\left(\frac{293}{273 + t}\right)$$

2) *Silencer-out test.* The air flow controls are adjusted to give the stated air flow through the silencer test section, and the differential pressure (Δpo) is measured.

The air temperature in the duct is measured and checked to ensure that it lies within the limits given in **1.9**.

4.1.3 Calculation of pressure loss. The pressure loss (Δp) for a silencer with identical inlet and outlet connections is given by:

$$\Delta p = (\Delta p_i - \Delta p_o) \times \frac{1{\cdot}2}{\rho}\ \mathrm{N/m^2}$$

The pressure loss (Δp) for a silencer with different dimensions for inlet and outlet connections is given by:

$$\Delta p = \left[\Delta p_i - \Delta p_o + \bar{p}_{vi}\left(1 + \frac{0{\cdot}02L}{D_{Hi}}\right) - \bar{p}_{vo}\left(1 + \frac{0{\cdot}02L}{D_{Ho}}\right)\right] \times \frac{1{\cdot}2}{\rho}\quad \mathrm{N/m^2}$$

where $\bar{p}_{vo}$ = velocity pressure corresponding to average velocity in outlet duct (N/m^2)

$\bar{p}_{vi}$ = velocity pressure corresponding to average velocity in inlet duct (N/m)^2

D_{Ho} = hydraulic diameter of outlet duct (m)

D_{Hi} = hydraulic diameter of inlet duct (m)

L = distance of downstream pressure tappings from silencer outlet connection (m)

4.2 Presentation of results

All relevant information obtained during a test may be presented but the following headings describe the data which should be regarded as a minimum presentation.

1) Description of silencer or silencing elements tested.

2) Description of installation of silencer or silencing elements.

3) Statement that tests were conducted in full accordance with this standard.

4) Insertion losses per octave:

a) Results for the octave band centred on 63 Hz may be presented but with a statement that a lower order of accuracy is expected.

b) Background noise levels shall be stated if they were less than 6 dB below the levels measured with the noise source operating and the silencer-in position [see **2.1.3** 1)].

5) Generated noise levels per octave band for each volume flow rate. Results for the octave band centred on 63 Hz may be presented but with a statement that a lower order of accuracy is expected. If the increase in level due to air flow through the silencer was less than 6 dB, this should be stated (see **2.4.4**). It shall be stated whether the generated noise levels given are for the silencer inlet or outlet side.

6) Total pressure losses for stated volume flow rates, at the stated temperature.

Appendix A Calculation of mean band sound pressure level

The mean band sound pressure level is calculated from the results of the measurements at all the test positions by averaging according to the following equation:

$$\bar{L}_p = 10 \log_{10} \frac{1}{n}\left(\text{antilog}_{10} \frac{L_{p1}}{10} + \text{antilog}_{10} \frac{L_{p2}}{10} \ldots \text{antilog}_{10} \frac{L_{pn}}{10}\right)$$

where $\bar{L}_p$ = mean band sound pressure level in dB,

L_{p1} = band sound pressure level at first station,

L_{p2} = band sound pressure level at second station,

L_{pn} = band sound pressure level at nth station,

n = number of measuring stations.

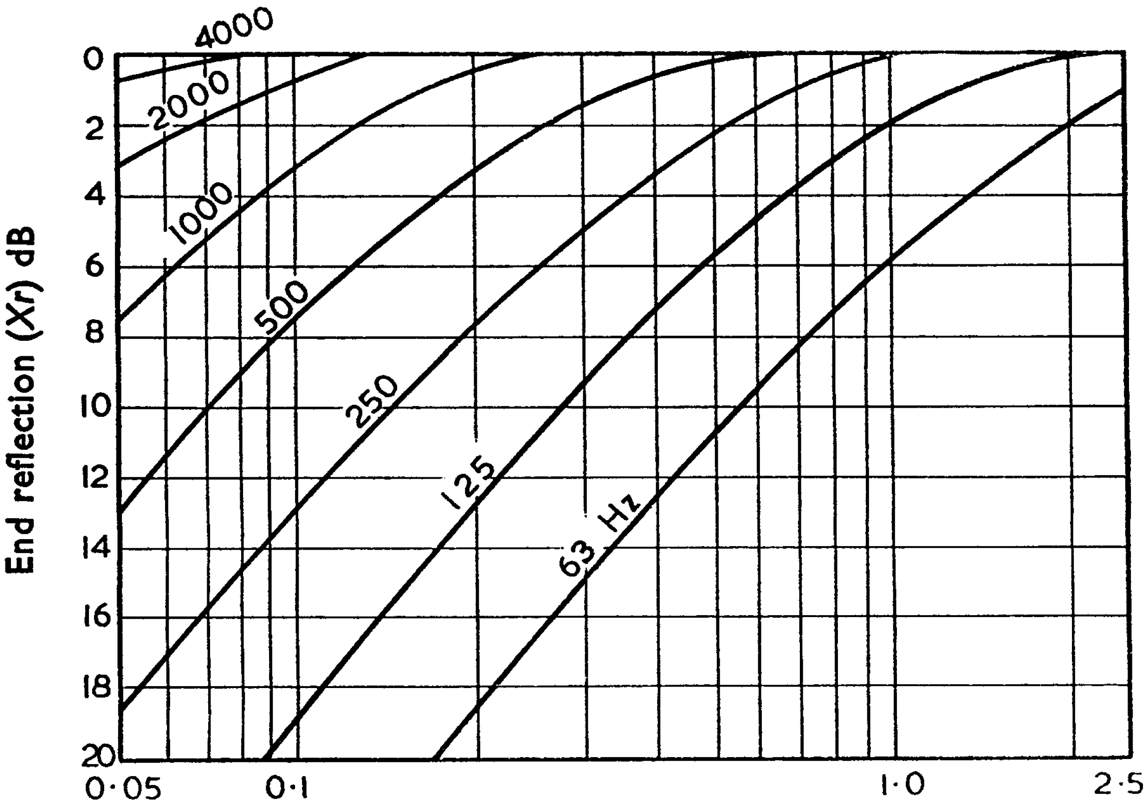
Appendix B End reflection

Due to end reflections the sound power radiated from the test duct in the diffuse field method will be reduced in passing through the duct termination. A correction for this end reflection will need to be applied to measurements obtained by the diffuse field method in the following cases:

Insertion loss. Type B silencers that have different cross-sectional dimensions between inlet and outlet.

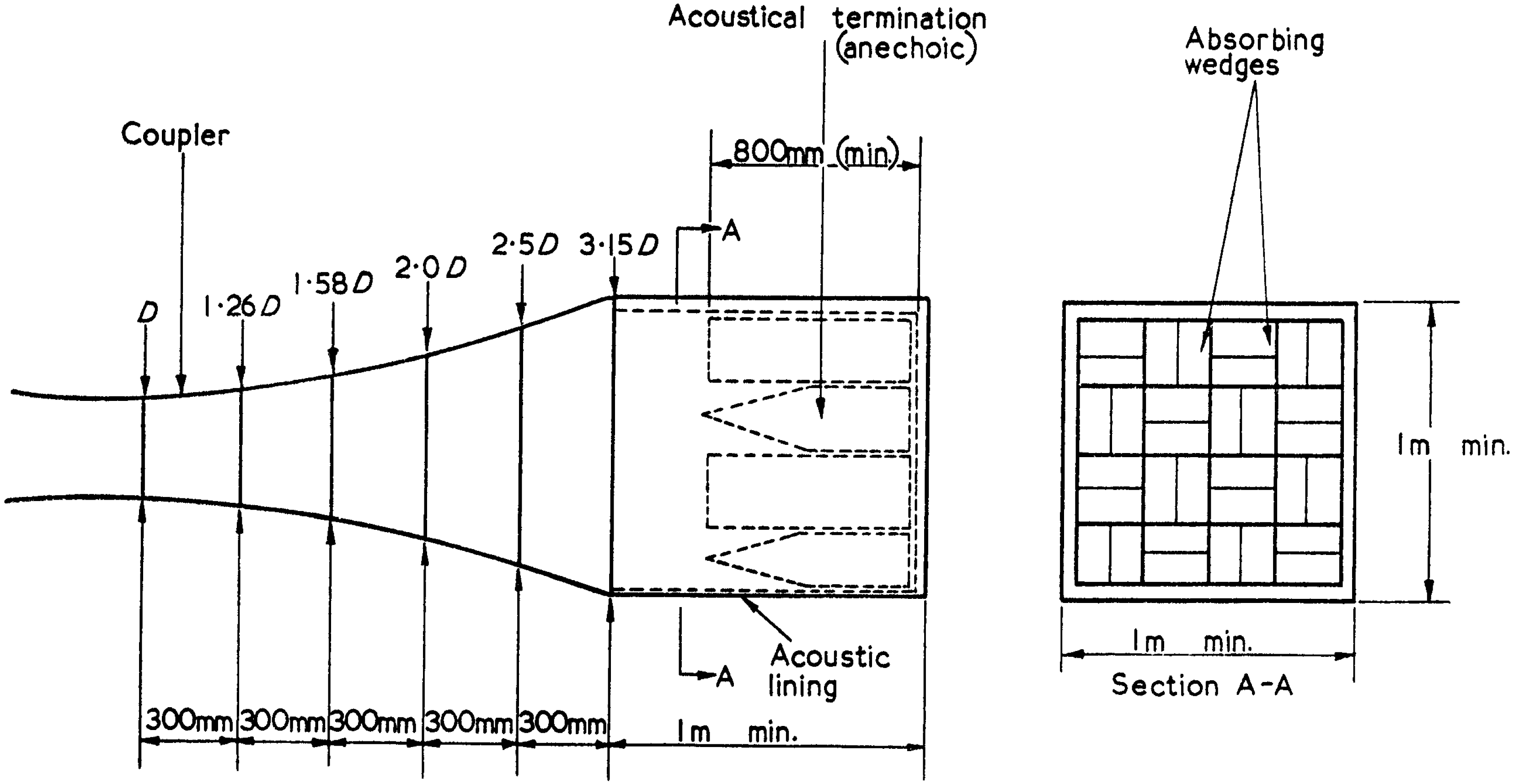
Generated noise level — all tests. Where a flared inlet is used in the terminal room the end reflection factor *Xr* shall be taken as the arithmetic average of two end reflection factors, one based on the outlet duct size *D* and the other on the maximum opening size of the flared inlet.

The chart below gives the end correction to be used.

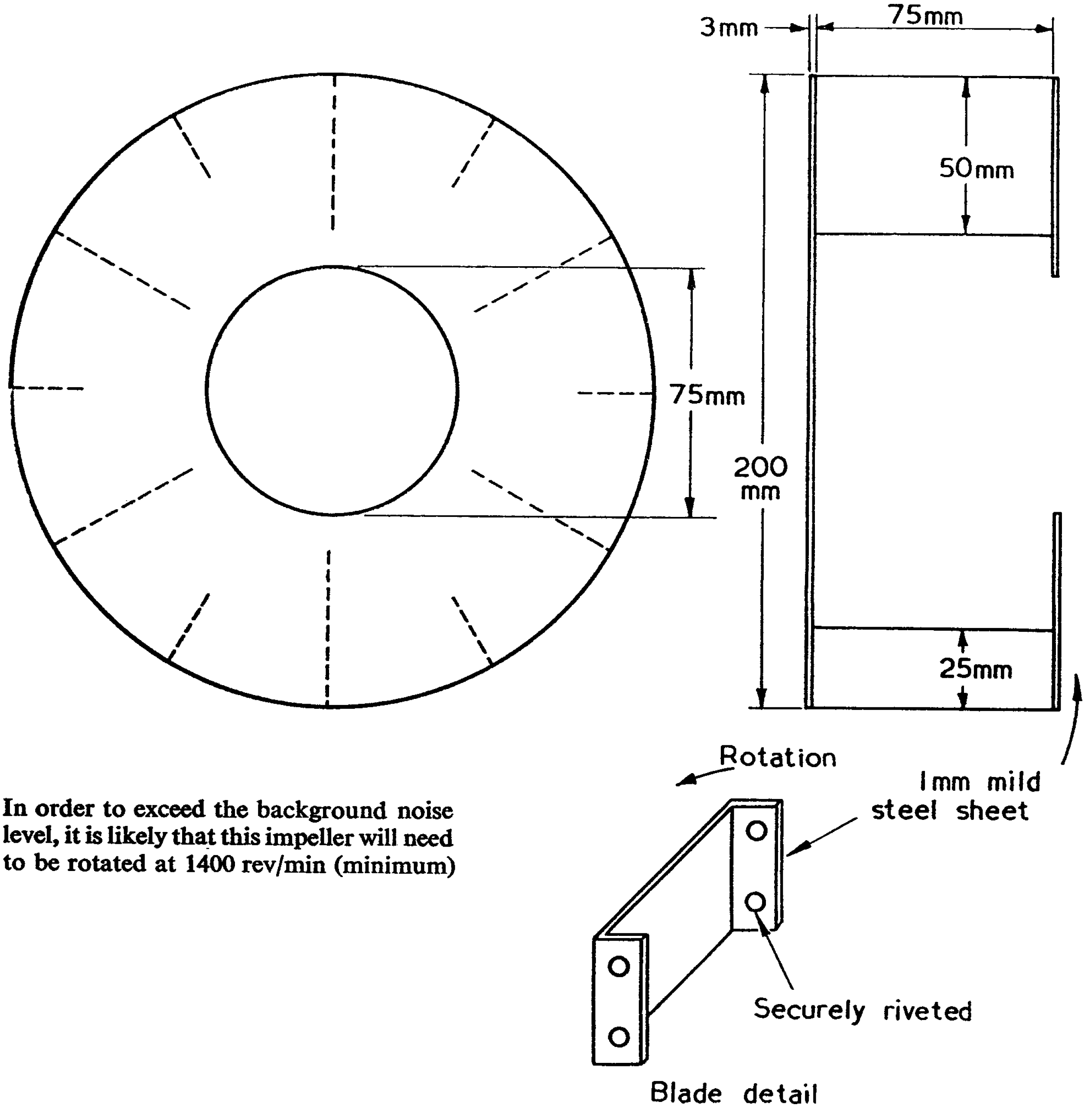


Duct diameter (m) or $1 \cdot 13\sqrt{A}$ where A is the cross-sectional area of the duct (m^2).

Appendix C Typical coupler and anechoic termination



Appendix D Illustration of reference sound source



In order to exceed the background noise level, it is likely that this impeller will need to be rotated at 1400 rev/min (minimum)

Appendix E Extrapolation from results of individual tests

The results of a test conducted in accordance with this standard are applicable to the particular silencer under test or to nominally identical silencers of the same design and construction.

A proper degree of caution should be observed when extrapolating from the results of a test on a particular silencer to estimate the performance of silencers of similar acoustic design but of different size. It is a matter for agreement between the supplier and the purchaser of a silencer as to whether a test in accordance with this standard should be conducted as part of the contract.

The following observations are offered as guidance.

1) *Insertion loss.* The most important design parameters in this connection are the thickness of the silencing element and the width of the silencer airway. Extrapolation from tests with particular values of these parameters to other values is not recommended.

Extrapolation from one cross-sectional area to another (with the same silencing element thickness and airway width) represents a common practice.

Where very large silencers are called for, such extrapolation may be difficult to avoid. There is little documentary evidence on which the reliability of this extrapolation may be judged.

Extrapolation from one length to another should also be undertaken with caution. In general the insertion loss should not be assumed to be proportional to length, i.e. doubling the length will not necessarily double the insertion loss. As a general guide the insertion loss appears to have a component which is independent of length, to which is added a component which is proportional to length the whole being subject to a limit of insertion loss which is dependent upon the silencer construction (especially the casing construction).

It is unwise to assume an insertion loss in excess of 40 dB where sheet metal casings are employed. Although extrapolation to greater lengths is subject to difficulty, interpolation to intermediate lengths between two tested lengths may be carried out with reasonable confidence.

Extrapolation from tests using one silencer casing design to another (especially a lighter construction) are not recommended.

2) *Generated noise.* The most important parameters in this connection are the mean air velocity in the airways and the airway width. The generated noise is strongly dependent on the mean air velocity and an increase in velocity may result in an increase in generated noise of the order of 50 $\log_{10}$ (velocity ratio), i.e. a doubling of velocity may result in an increase in generated noise of 15 dB. Extrapolation to other air velocities is not recommended but may be unavoidable in special cases. Extrapolation to other airway widths is not recommended and is avoidable.

Extrapolation to greater cross-sectional areas, maintaining air velocity and airway width, is less hazardous. The generated noise may be expected to be proportional to the silencer cross-sectional area, i.e. a term of 10 $\log_{10}$ (area ratio) may be appropriate.

The generated noise may be found to be weakly dependent on silencer length and a silencer of greater length may be assumed to offer no more generated noise than a silencer which has been subject to test.

Extrapolation from tests from one range of silencers to another range having modified aerodynamic attachments, i.e. bull noses or fairings, is not recommended.

3) *Pressure loss.* A silencer employing the same silencing element thickness and airway width, but of different cross-sectional area, may be reasonably assumed to have the same pressure loss characteristic as a silencer which has been tested.

Pressure loss is only weakly dependent on silencer length. A change of length involving a ratio of less than 2 : 1 may be assumed to result in no significant change in pressure loss. For greater ratios testing may be required.

Appendix F Measurement of casing radiation

In certain circumstances it may be necessary to determine the acoustic power radiated from the casing of a silencer. This may be found by installing the silencer in a reverberant room with a ducted inlet connected to a sound source outside the room and an outlet duct of length specified in **1.6.4** of this standard, connected to a closed anechoic termination either inside or outside the room. These duct connections have to be of such form that radiation from them is at a much lower level than the radiation from the casing of the silencer under test. This may be achieved either by:

1) using very heavy duct materials,

or

2) an efficient acoustic lagging of the ducts, if they are similar in thickness to the silencer casing.

The total acoustic power radiated from the silencer casing may be measured in accordance with Appendix C of BS 4196[10)] in octave bands.

The sound pressure level in the inlet duct should be measured in accordance with **2.2.3** of this standard, to provide a basis for application of the data.

[10)] BS 4196, "*Guide to the selection of methods of measuring noise emitted by machinery*".

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