

THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

Silencers and acoustic enclosures

A Guide to selection and assessment

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ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

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Preface

Noise control measures such as silencers and enclosures are required within industrial installations to reduce noise for a variety of reasons, including meeting health and safety work area noise limits and environmental noise criteria for community noise. It is therefore important that the acoustic properties for noise control equipment are correctly specified. Whilst specifying and meeting the acoustic properties is fundamental, the choice of noise control can potentially have a major impact on mechanical issues that can affect plant operation and maintenance.

This document gives guidance on the acoustic properties required for silencers and acoustic enclosures to assist in the specification of these during the design phase and procurement process. The acoustic properties that need to be included within the specification along with the test procedures to demonstrate the criteria can be met are outlined. The mechanical issues that need to be considered within industrial installations are described.

This Guide should assist those involved in specifying, supplying or procuring noise control equipment so that the correct acoustic information is obtained taking into account practical operational considerations. This will assist in ensuring that the installed plant meets the noise criteria for industrial developments.

The previous version of this Publication was issued in 1988. The purpose of this Edition 2 is to take into account new revisions of standards and advances in acoustic technology. In particular the Section on silencer performance testing has been changed to reflect changes to the available standards. The Section on acoustic enclosures has been included within the main document, rather than as a separate supplement.

Abbreviations and definitions

Approved	Unless otherwise qualified, means formal, written agreement by the Purchaser to a proposal by the Vendor
ANSI	American National Standards Institute
Bara	Bar (absolute pressure)
BS	British Standards Institute
CACA	cool air, cool air
C_v	Flow coefficient of device
C_g	Coefficient of isothermal compressibility
dB	decibel
dB(A)	A-weighted sound pressure level
Purchaser	Refers the client who has placed the order for the silencer or acoustic enclosure
Shall	This term is used to indicate that the Purchaser/Vendor is required to take action
Should	This term is used to indicate that the Purchaser/Vendor is advised to take action
TEFC	Totally Enclosed Fan Cooled
Vendor	Refers to the fabricator/supplier to whom the contract has been awarded

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1. Introduction

Industrial installations use silencers for a wide variety of applications to reduce noise from machines and fluid-flow systems. They may range from devices small enough to hold in the hand - for use with pneumatic systems - to large installations weighing several tonnes for large steam vents in power stations. In all these applications, the essential feature of a silencer is that it allows the flow of a gas and reduces the transmission of acoustic energy; it may therefore be distinguished from an acoustic enclosure, where gas flow, say, for cooling or purging, is a secondary feature.

The primary purpose of a silencer or acoustic enclosure is to reduce noise to some required level, so the correct specification of its acoustic properties is the key aspect of its purchase. Other aspects, however, can be equally important; for example, operational life and safety features. For silencers the possible effect on the fluid flow and its compatibility with the fluid and operation of the plant is important. Maintenance issues also need to be considered. If a silencer is expensive, or if its replacement causes an expensive shutdown of the plant, the operating life will be important. This will require careful specification of the materials of construction, its weather protection in outdoor operation, and its ease of replacement. If it is associated with expensive equipment, the effect of damage to the equipment caused by any disintegration of the silencer should be considered. So a careful specification of the silencer construction can be as important as its acoustic specification.

A silencer or acoustic enclosure may be required to:

- reduce the noise level inside a plant, for hearing conservation;
- improve speech communication within work areas;
- meet environmental noise criteria or to avoid annoyance to neighbours; and/or
- to meet noise criteria within accommodation spaces.

In any of these cases, the noise control equipment will be required to reduce the noise level in dB(A) at one or more locations. If the noise source contains tonal components, these will require additional consideration so that they are reduced to a level where they are masked by the broadband noise. This is discussed in Section 5.1.5 and it means that the acoustic properties of silencers need to be specified in more detail.

There are various types of silencers and it is useful to have a basic understanding of how they operate and the typical applications in which they are used, so that the appropriate type can be selected for a particular application. Chapter 2 of this Guide gives a brief description of the different basic types of silencers for the benefit of the non-specialist engineer.

The structure of this Guide is based mainly on the applications for which silencers may be used. For each application there is a summary of the main features of the silencer which should be considered in its selection given in Chapter 3. Many of these features are common to different applications and they are only given as headings to avoid repetition in the appropriate sections. A more detailed discussion of the mechanical considerations is given in Chapter 4.

Chapter 5 gives details of the acoustic requirements that are necessary for specifying a silencer for a particular application. It indicates the acoustic parameters to be specified and methods for testing the silencer when it is in operation.

Chapter 6 summarises the acoustic performance requirements for enclosures and the mechanical aspects which need to be considered. A list of details to be agreed between the Purchaser and Vendor has been included.

Appendix A gives a glossary of the acoustic terms used in this document. Appendix B gives a model specification for a silencer to provide a guide for a purchase specification.

It is not intended that this Guide should be a textbook on the detailed design of silencers or enclosures. This is an aspect best left to the manufacturer and specialist acoustics engineer. However, by giving a better understanding of their acoustic and mechanical features, it is hoped that a Purchaser will be able to specify and receive silencers that meet all the requirements of the plant. A detailed and realistic specification from the Purchaser of the precise requirements should be of mutual benefit to both the manufacturer and the Purchaser.

This Guide deals only with the situation where the installation of a silencer or enclosure is found to be the most suitable means of noise reduction. It may not be the only option for noise control, and consideration should be given to other options such as using acoustic insulation, or choosing alternative equipment which emits less noise (such as valves with low noise trims or fans with lower tip speeds). The best choice will depend on economic and operational factors. It is not within the scope of this Guide to discuss how this decision should be made.

However, it is worth emphasising the importance of making this choice early in the design phase so that space and installation requirements are considered in the layout. Later decisions are normally much more expensive and, potentially, less effective.

1.1 Scope

This EEMUA Publication is intended as a guide to the selection of silencers and enclosures which are appropriate for use with various noise sources. It is aimed at the practising engineer with a limited knowledge of acoustics to assist in the specification of the most suitable silencer for a particular purpose and to assess its operation when it is installed. In addition it should assist in reviewing different proposals submitted by vendors. However, the experienced acoustic engineer may also find it useful as an aide-memoire.

The Guide places considerable emphasis on the mechanical aspects of silencers which have to be considered for various applications so that due consideration can be given to engineering design, operational aspects, safety, and cost. It does not include detailed specification of test methods and reference will need to be made to the appropriate standards for full test method details.

1.2 About this Edition

The previous Edition 1 of this Publication was issued in 1988. The purpose of Edition 2 is to update it, taking into account changes in standards which have

occurred since then. Therefore some changes are relatively minor. The main changes to the previous Edition are the test method for silencer acoustic performance measurement. In addition the Chapter on acoustic enclosures was included as a supplement to Publication 161. This has now been merged within the main document. Some additional items for details to be agreed between Purchaser and Vendor have been added based on updated international standards.

2. Types of silencer

This Chapter gives a general description of the various types of silencers which will be discussed in the following sections. It is intended to serve as a definition of the terms to be used and as an introduction to the engineer unfamiliar with the principles on which silencers operate.

2.1 Reactive silencer

A reactive silencer, as shown in Figure 1, consists of one or more chambers which give changes in volume and restrictions in the duct so that there is a change in the acoustic impedance of the total system of source and silencer. This is analogous to an electrical circuit and an appropriate change in impedance can reduce the sound power generated. However, in some cases, an incorrect design may even increase the sound power output of the total system (for example, when resonance occurs).

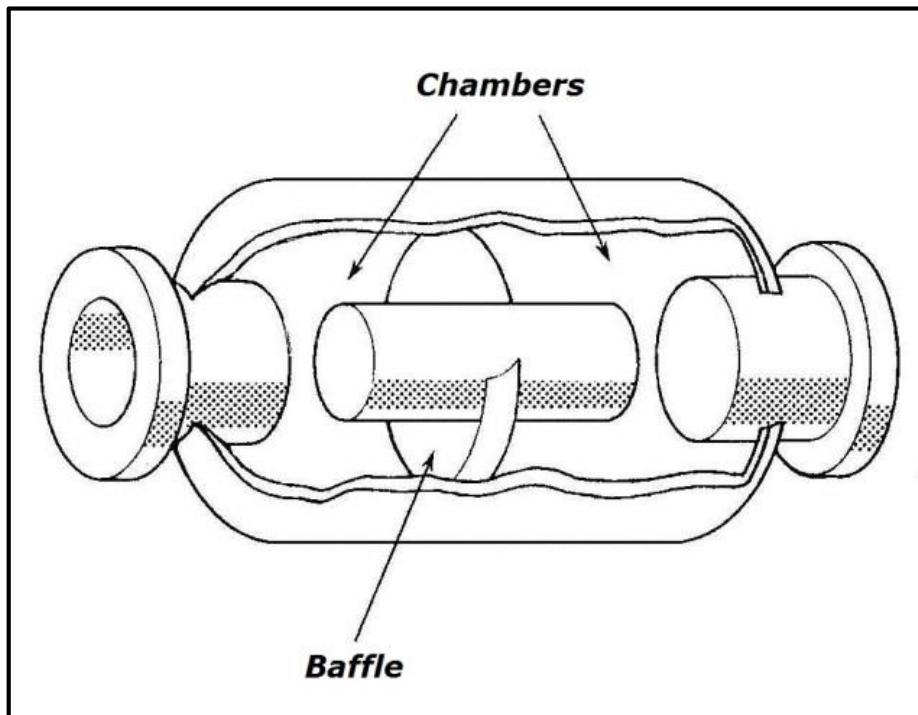


Figure 1 Reactive silencer

The behaviour of a reactive silencer depends very much on the relationship between the dimensions of the chambers and the wavelengths of the noise. It is strongly frequency dependent. A single chamber, for example, is only effective over a narrow range of frequencies.

To extend the range of frequencies the silencer may therefore be designed with several chambers of different dimensions. The relationship between frequency and dimension means that, for silencers of practical dimensions, reactive silencers are most effective for reducing low frequency noise. Their narrow frequency range can sometimes be useful when the noise has distinct components (from, say, a reciprocating machine) or when it contains pulsations.

2.2 Absorptive silencer

Absorptive silencers, as in Figure 2, depend on the sound energy being absorbed in layers of fibrous or porous materials. The fraction of the sound energy absorbed by the material generally increases with frequency so that absorptive silencers are less effective at low frequencies and become more efficient as the frequency increases.

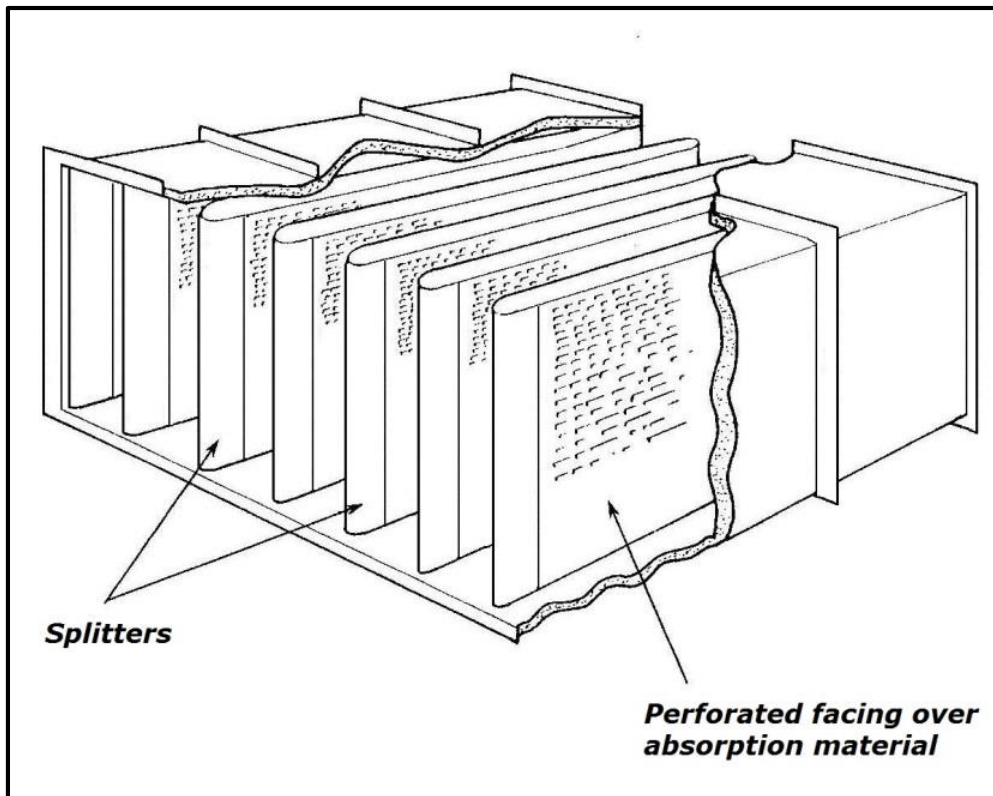


Figure 2 Rectangular absorptive silencer

They are therefore effective over a wide range of frequencies. The low frequency behaviour of the absorptive material can be enhanced by careful choice of the material thickness and components and the separation of the absorptive layers.

Absorptive silencers therefore vary in design from a simple duct with an internal lining of fibrous or porous material to a multiple sandwich of alternate absorptive layers and open spaces for the passage of gases (often called 'splitter silencers', 'acoustic pods' or 'inserts').

When good low frequency performance is required (for example, in silencing gas-turbine exhausts) and an absorptive silencer is the only practical option, it may be necessary to use thick layers of absorptive filling with wide spacings. This can lead to a silencer with large dimensions.

The absorption of noise depends on the sound waves passing through the material and being converted into heat energy by friction so it is important that the material should permit the passage of the sound waves. Glass fibre, mineral wool and open-cell plastic foams are commonly used, depending on the operating environment of the silencer.

High pressure gases cause a considerable reduction in the performance of absorptive silencers. So when an in-line silencer is used in a high-pressure system it is important to appreciate that its quoted performance is likely to refer to low pressure applications and may not give a true indication of its actual in-service performance. Guidelines for the recommended test method are given in Section 5.2.

2.3 Reactive/absorptive silencer

Reactive and absorptive silencers, as shown in Figure 3, have complementary properties in terms of their behaviour with frequency. The former are most effective at low frequencies and the latter at high frequencies. By combining these properties a silencer can be designed to extend the frequency range in which it is effective.

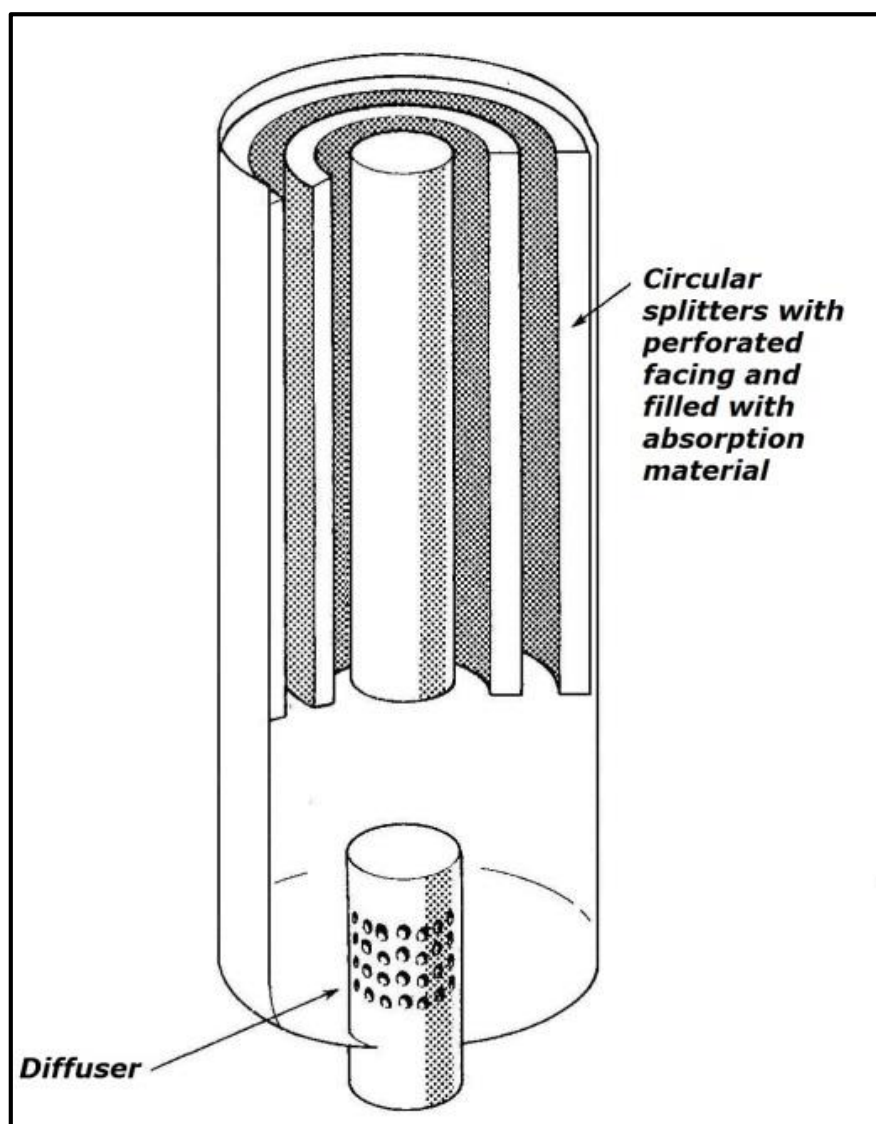


Figure 3 Combined reactive and absorptive silencer

The simplest type of combination is the plenum chamber, which is basically a box in which the flowing gas enters and leaves on opposite sides so that it undergoes a change of direction. The frequency range of its reactive properties as a chamber can be extended by lining the interior walls with an absorptive material. Other combinations consist of reactive and absorptive sections being placed in series in the silencer (the more expensive car silencers use this principle, for example).

2.4 Helmholtz resonators

A Helmholtz resonator shown in Figure 4 differs from the silencers described above in that it is installed as a closed side arm to the duct and there is no net flow of gas through it. Its essential features are a narrow passage leading into a large cavity and the relative dimensions of these determine a resonant frequency at which the silencer will reduce the overall sound energy. The resonant response of the cavity reduces sound energy in a narrow band of frequencies only.

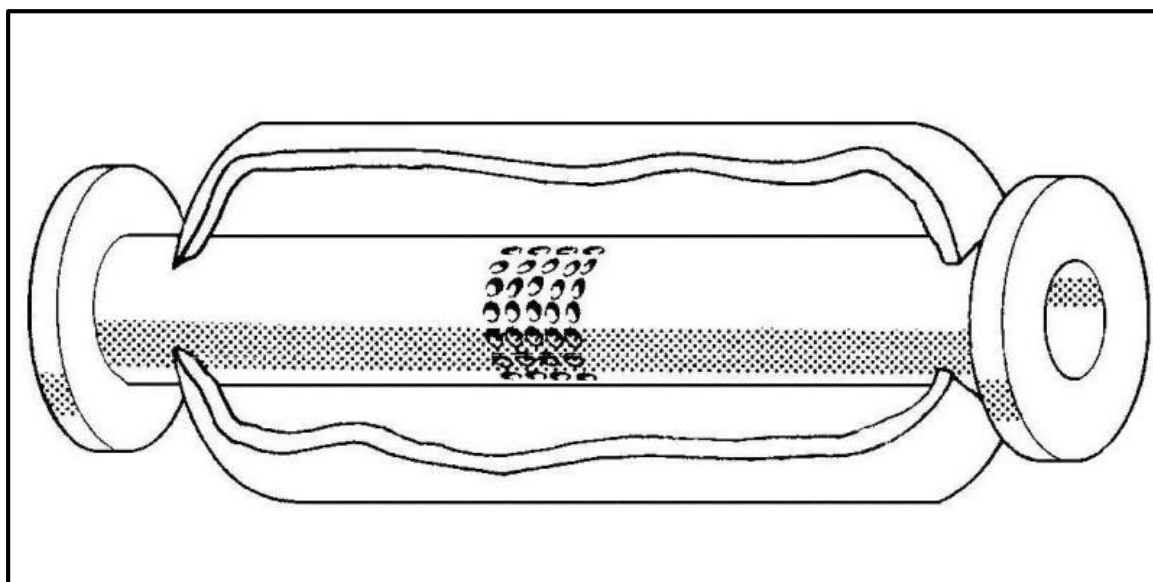


Figure 4 Form of Helmholtz resonator

Owing to the narrow frequency range over which it is effective, the Helmholtz resonator has a limited application for most industrial purposes, although it may be useful in cases where there is a prominent single tone to be silenced.

2.5 Diffuser silencers

Diffuser silencers, as shown in Figure 5, depend on the absorption of sound energy by friction losses as the gas flow passes through a labyrinth of passages in a porous material. The energy loss is similar in principle to that in absorptive materials but the difference is that the gases flow through the material rather than over it.

The absorptive material may vary from a packing such as Raschig rings or stainless steel wool to a sintered metal plug, depending on the volume flow of the gas and the allowable back pressure of the silencer.

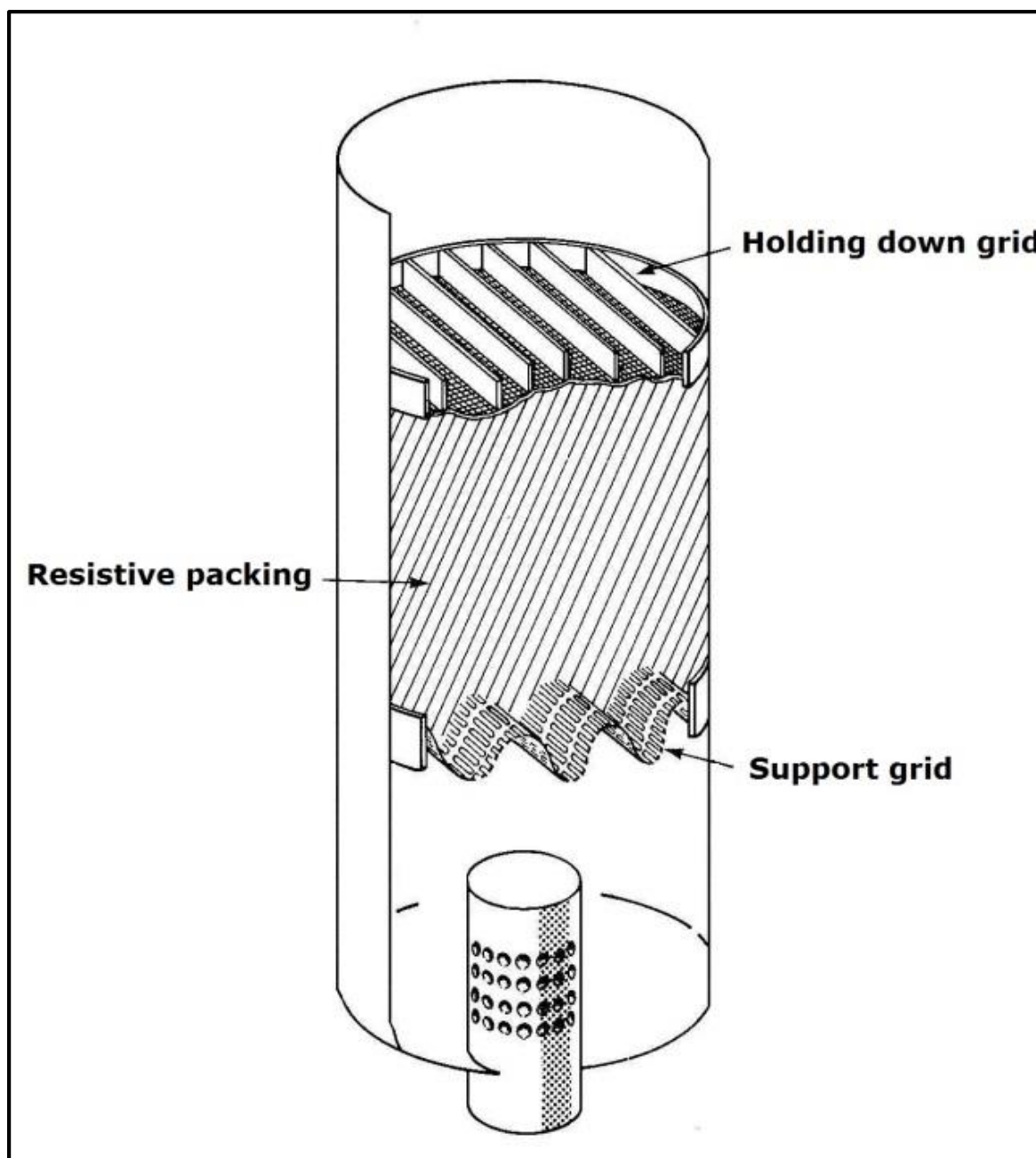


Figure 5 Diffuser silencer

2.6 Multiple orifice silencer

Multiple orifice silencers, as shown in Figure 6, consist of many orifices which convert the gas stream into a number of jets of small diameter. The first effect of this is to change the quality of the noise so that the maximum of its spectrum shifts to very high frequencies. This renders it more amenable to absorption in an absorptive silencer section or to increased attenuation in the air as the noise propagates into the environment. A secondary effect is to reduce the total acoustic power of the source due to interaction between closely packed jets.

Multiple orifice silencers and diffuser cap silencers may be installed on their own or more commonly in combination with a following absorptive section. The increase in the frequency of noise then leads to increased sound absorption in this section and to higher noise attenuation through the pipe walls and any piping insulation.

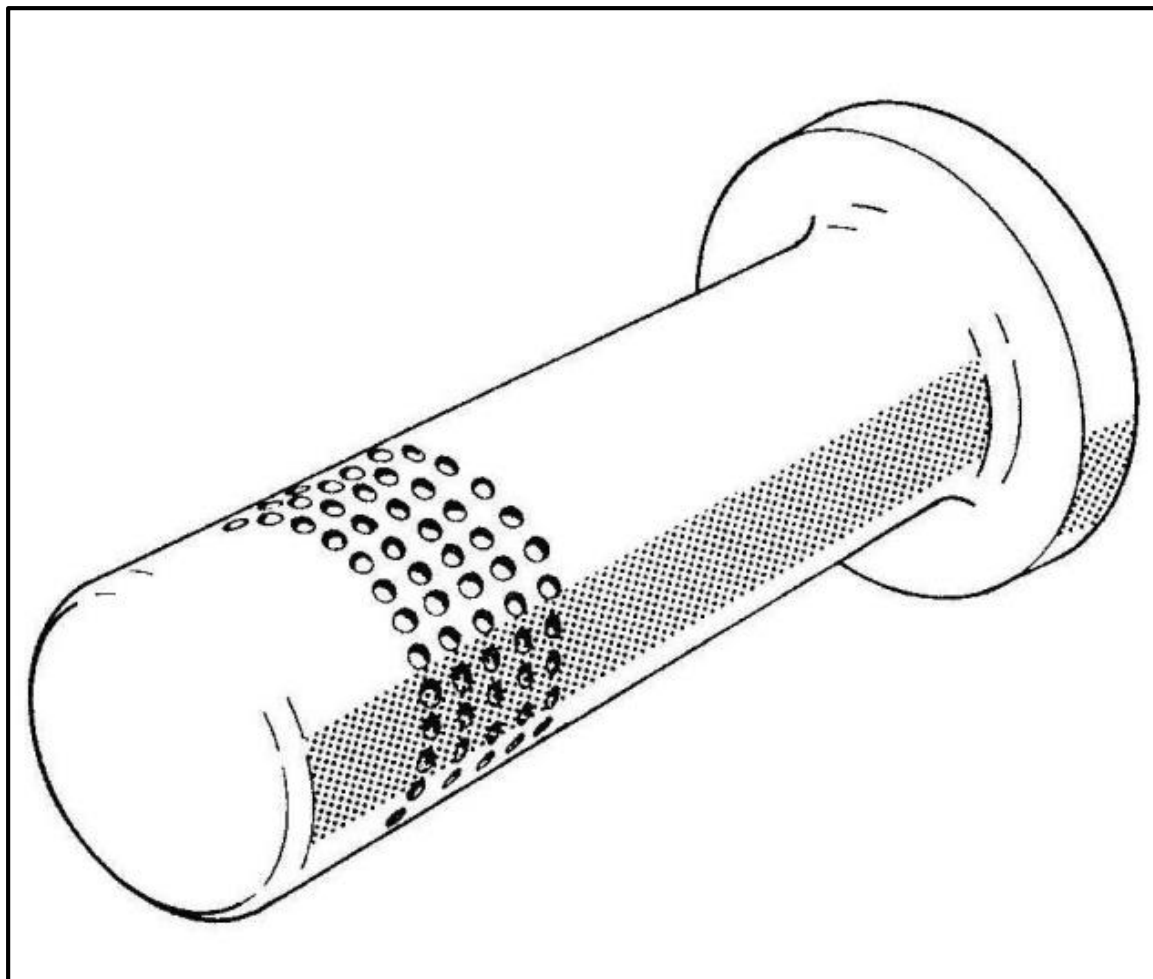


Figure 6 Multi-orifice silencer

2.7 Air entrainment screen silencer

An air entrainment screen silencer is used where there needs to be no impediment to the flow of a gas or steam vent, but noise levels need to be reduced. By entraining air to mix with the jet at the nozzle, shear noise is reduced. Then by the screen body extending from below the vent opening to beyond the turbulent mixing zone of the jet as shown in Figure 7, direct line of sight of the main noise generation process is achieved, hence reducing the noise. The screen body can also be lined with an absorbent layer increasing the attenuation performance.