

Noise from pneumatic systems

Guidance Note PM 56



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This guidance gives practical advice on how to reduce noise resulting from the use of compressed air, which is widely used throughout industry for a variety of purposes.

It considers the noise characteristics and the different designs of compressed air jets, as well as how to reduce noise by the fitting of exhaust silencers and the factors to take into consideration when selecting a suitable exhaust silencer.

Additionally, it contains useful information for the cleaning, installation and maintenance of compressed air equipment.

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Introduction

1 This Guidance Note gives practical advice on how to reduce noise resulting from the use of compressed air, which is widely used throughout industry for a great variety of purposes. Compressed air is a convenient and flexible means of transmitting energy, which can also provide power to sophisticated mechanisms which control the operation of complex machinery. The excessive noise levels associated with the use of compressed air are in general caused by the release of pressurised air to atmosphere. The most common noise sources are therefore pneumatic exhausts and compressed air jets.

Pneumatic exhausts and jets

2 Pneumatic exhausts are provided on a wide range of machinery and tools solely for the purpose of dispensing with the unwanted compressed air after it has performed its useful work. While some pneumatic exhausts are in continuous operation (e.g. hand held grinders), the majority work on an intermittent basis dictated by the operating cycle of the machine or tool.

3 Compressed air jets are normally used to either eject the workpiece or swarf (debris) from a machine or to clean or cool a machine or process by means of continuous supply of compressed air. With the exception of construction machinery and tools most pneumatic equipment is fed from a common source via the factory airline.

The factory airline

4 The typical factory airline is usually adapted over a period of time to deal with changing production requirements as new machinery is added or existing equipment resited. Such changes usually follow a piecemeal pattern, with little time being allowed to redesign the airline system or optimise its layout. Airline filters, separators and drainage points are rarely resited to cope with changing airflow requirements. As a consequence it is inevitable that fluid pollutants, such as water and oil, and solids, such as rust, are found in factory airlines. Even well designed and properly maintained airlines providing clean, dry air require a lubricating mist to ensure the correct operation of equipment. All such pollutants will attempt to pass through the airline, pneumatic equipment and exhaust to atmosphere. Where the air passage is obstructed, the resulting back pressure can have serious consequences on the operation of the machinery served by the pneumatic equipment. This matter is particularly important with regard to the choice and use of pneumatic exhaust silencers and, to a lesser extent, certain uses of air jets.

The noise characteristics of compressed air jets

5 An unsilenced pneumatic exhaust can be considered as an air jet. The noise produced by a compressed air jet is closely related to jet velocity. Depending upon the installation and application of the jet, the noise level can be expected to vary between the fourth and eighth power of the jet velocity ($V^4 \rightarrow V^8$). For most industrial applications, where the jet stream interacts with obstructions, such as the surfaces of machines, tooling etc, the noise level varies as the sixth power of the jet velocity. For airlines operating above 1.9 Bar (28 psi abs), which covers most situations, the airflow will be at a constant velocity, due to the choking effect of the jet orifice. Since the noise of an air jet is so heavily dependent on the jet velocity, only marginal noise reduction can be achieved by reducing the airline pressure.

6 The size of the nozzle (its area) affects the noise produced, but not to any marked extent. For instance, if the nozzle area were to be halved, a 3 dB noise reduction should result.

7 With such constraints it follows that sizeable reductions in noise level cannot be achieved by simple expedients alone and that some modification of jet characteristics is required.

Pneumatic exhausts

8 The most important consideration when fitting pneumatic silencers is the effect the chosen unit will have on the air flow. Any significant interference with the airflow will reduce the working capacity of the compressed air, due to the back pressure developed. This matter is particularly important when fitting exhaust silencers to the clutch mechanism of power presses and press brakes. Back pressure in the pneumatic system can cause repeat strokes of these machines, which can be dangerous. The most usual source of back pressure is the progressive blockage of silencers. This can only be avoided by the correct selection, installation and maintenance of silencers as discussed later.

9 It should be noted that rapidly expanding air cools the body of the silencer and encourages the condensation of the fluids contained in the air. This cooling effect becomes important if the equipment is operating in low ambient temperatures and constantly discharging air. In manufacturing industry the icing of silencers rarely occurs, but could be expected if undersized silencers are used such as to restrict the airflow and extend the discharge period, particularly if water is present in the airline or with humid ambient conditions. This problem is usually easily solved by increasing the silencer size using adaptors if necessary.

Noise reduction

10 Adequate noise reduction can sometimes be achieved without silencers by simply discharging the exhaust through a length of piping. This method overcomes the difficulties of blocked silencers, but the noise reduction is less certain. Also, passing the exhaust through a length piping can reduce its flow-rate, so adaptors and piping one size larger than the exhaust port should be used as a precautionary measure. The preferred method of reducing pneumatic exhaust noise is to arrange a controlled pressure drop in the silencer. This is usually achieved by forming a suitable diffusing material into an envelope to cover the air exhaust port. The material should provide a pressure gradient across its section of sufficient magnitude to ensure that the emerging air has reduced velocity with consequent noise reduction. Such controlled pressure drop techniques always restrict airflow. This effect can be offset by increasing the surface area of the diffusing material, so that it is many times the cross sectional area of the exhaust port which it covers.

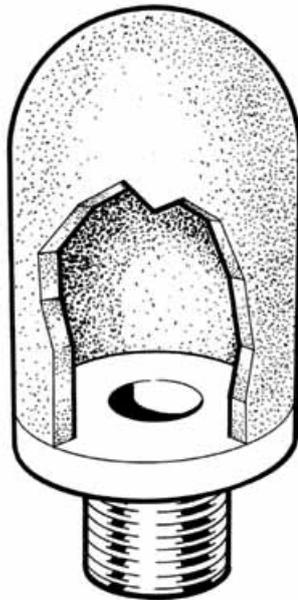
11 The quality of the compressed air is an important consideration in affecting a correct balance between back pressure and noise reduction. This balance can be adjusted by varying the porosity, thickness or surface area of the diffusing material. Porosity is the most usual characteristic to be adjusted, since both surface area and thickness affect the overall size and mechanical strength of the silencer. Small pore size provides compact and effective silencers with reasonable air-flow rates. However, if used in polluted airlines, such silencers quickly become blocked and soon interfere with the working capacity of any machine to which they are fitted. A typical pore size for sintered plastic material is of the order of 0.1 mm. When such a silencer sustains a pressure gradient, the pollutants are forced deep into the body of the diffusing material to a point where the driving force can no longer overcome the resistance to flow. In practice a silencer rarely becomes completely blocked, but its effective flow rate can be severely limited.

12 The progressive flow rate reduction suffered by small pore size silencer membranes used on polluted airlines can be countered by increasing the pore size. This, however, reduces the amount of noise reduction that a silencer can provide. A balance, therefore, has to be struck between pore size and noise reduction. Materials are available which will provide an 18 dB(A) noise reduction with an effective pore size too coarse to sustain a fluid film. These materials are generally formed from several layers of metal wire cloth. Such silencers give long trouble free life, as pollutants usually blow through this material and they can be easily blow cleaned after rinsing in a suitable solvent. The coarseness of the weave assists in the self draining as the pore size, usually of the order of 0.5 mm, is too great for surface tension effects to sustain a fluid film.

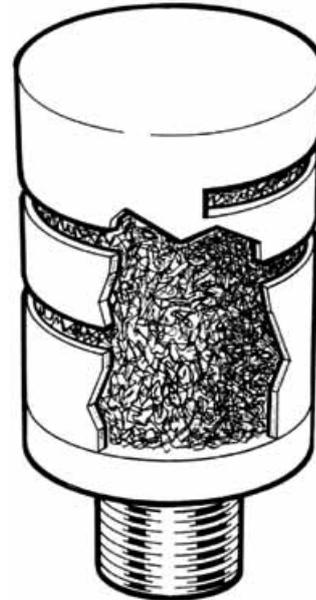
Types of exhaust silencer

13 Exhaust silencers can be approximately divided into three price categories.

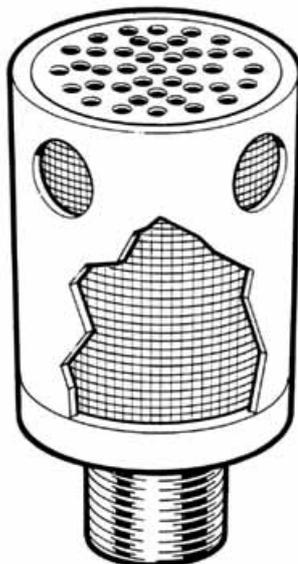
- (a) The lowest priced units usually have injection moulded plastic bodies with sintered polythene as the pressure reducing (silencing) membrane.
- (b) Medium priced units with machined metal bodies incorporating sintered bronze or heavily compacted wire wool as the silencing material.
- (c) The highest priced units with fabricated and assembled metal bodies and layers of coarse woven wire cloth as the silencing material.



a) Injection moulded plastic body and thread with sintered plastic or metal membrane



b) Machined metal body and thread with compacted wire wool as silencing material



c) Fabricated and assembled metal body with layers of coarse woven wire cloth as silencing material

14 Silencers falling into low and medium cost categories are usually compact and offer very substantial noise reductions. They usually require greater maintenance effort and suffer from the problems of progressive airflow restriction if used on contaminated airlines. Many suppliers of these silencers emphasise their disposable qualities as the silencing materials are not easily cleaned.

15 Those silencers in the highest cost category tend to be larger in size and offer usually adequate noise reduction. They can, however, be fitted with some confidence to polluted airlines since they should suffer little progressive airflow restriction. The ongoing maintenance requirements are very low and the units can be easily cleaned, if necessary.

Installation and maintenance

16 If the silencer is to be fitted to machinery, which has been in use for some time, the exhaust port thread should be cleaned. Polluted exhaust air mixed with the dust and dirt that accompanies many production processes tends to fill the threads with a thick paste. If the threads are not cleaned, damage can occur on installation.

17 Wherever possible, silencers should be mounted either horizontally or inverted: this aids gravity draining of pollutants through the silencing material. It should be remembered that expanding air cools the silencer and encourages condensation of fluids in the air. With vertically mounted silencers, any condensate will run back into the airline reducing airflow and affecting exhaust and control valves. In time an oil plug is formed, which is forced into the silencing material each time the air is exhausted.

18 To avoid accidental damage, care should be taken to mount silencers close to machine surfaces with the minimum of protrusion and in a safe place away from access points. Plastic bodied silencers are particularly prone to impact damage.

19 Since progressive blockage of silencers will ultimately reduce the production efficiency of any equipment to which they are fitted, the possibility of cleaning silencers needs to be considered. Blockages can occur due to dirt and dust settling on the exterior surface of the silencer and forming a sludge by mixing with the fluids passing through the silencer and also from pollutants in the airline being forced deep into the pores of the silencing material.

Cleaning of silencers

20 All silencers will benefit from exterior cleaning, but only those silencers using large pore membranes improve significantly from attempts to clear pollutants deeply embedded in the silencing material. Metal silencers can be cleaned with any commercially available solvent. Silencers using porous plastics, particularly sintered polythene, should not be cleaned with solvents based on chlorinated hydrocarbons.

21 The cleaning procedure requires a 5 minute soak in clean solvent followed by scrubbing with a hard bristle or nylon brush. Wire brushes are not recommended as they could damage the silencer. This should be followed by blowing the silencer clear with clean compressed air.

Manifolding silencers

22 So far silencers have been considered as separate units to be fitted to individual exhaust ports. In many situations difficulties arise in finding space to accommodate silencers as separate units. In such cases, it is possible to pipe each exhaust to a manifold fitted with an over-size silencer. As a rough guide, the manifold silencer should be suitable for operating on an exhaust port twice the size of the largest port feeding the manifold. When using this technique, it is important to recognise that exhaust valves are usually rated for discharge directly to atmosphere. Passing the exhaust through a length of piping can reduce its flow rate. It is recommended, therefore, that adaptors and pipes one size larger than the largest exhaust port should be used. The manifold technique is often used in certain industries (e.g. food and pharmaceutical) where the need for clean exhaust air has to be reconciled with lubricated precision machinery. In these situations the use of combined filter silencers is recommended.

Selection factors

23 The following factors are considered most important when selecting a suitable exhaust silencer for use in manufacturing industry.

- (a) *Noise reduction*: The peak noise level of a silenced exhaust port should be at least 18 dB(A) less than that of an unsilenced exhaust port. Greater noise reduction is desirable if this is compatible with airflow requirements. In most situations, noise reductions in excess of 25 dB(A) would reduce the exhaust noise well below background noise levels.
- (b) *Flow rate*: This must be adequate to allow valves and equipment to function at their design speeds. Most silencers will provide adequate flow rates when new. The best silencers for general use are those which demonstrate the minimum change in flow rate when used on polluted airlines.
- (c) *Construction*: Many silencers are fitted outside of the external covering of prominent parts of machines in work areas where accidental damage can easily occur. They should, therefore, be capable of sustaining a reasonable impact without fracture.
- (d) *Maintenance*: In most factories, the available maintenance effort is devoted to the central problem of keeping production machinery working efficiently. Since silencers do not increase the productivity of pneumatic equipment they tend to be neglected. Only when silencers reduce the output, due usually to restriction of exhaust air, do they receive maintenance attention. If too much maintenance is required on such non productive units, they will be discarded as impracticable. Minimum ongoing maintenance is, therefore, a prime requirement.

24 These are the most important considerations when drawing up a silencer selection procedure. Noise reduction, providing it is adequate, and cost are both considered of less importance when selecting silencers to give long, effective, maintenance free working lives.

Selection procedure

25 The first step in selecting a suitable silencer is to consult the equipment manufacturers' design guide and determine the airflow requirements for normal operation of the machinery to which the silencer is to be fitted. This information should be compared to the flow rate data supplied by each silencer manufacturer to determine the most suitable unit for these requirements. This step is always necessary to ensure that undersized silencers with their consequent airflow problems are not fitted.

26 If the operating speed of the exhaust through the silenced valve is not important ie back pressure is not likely to be a problem, then any silencer providing adequate air flow can be fitted with prime consideration being given to maximum noise reduction and cost.

27 On the other hand, where the silencer is to be fitted to a polluted airline or the pneumatic controls of a friction clutch power press or press brake, special consideration should be given to those silencers, which will produce the minimum restriction of the exhausted air and ensure long, maintenance free working lives.

Compressed air jets

28 The simplest form of air jet commonly found in manufacturing industry is an open ended pipe blowing continuously across the work area of a machine, with perhaps the end squeezed into a fishtail shape to enhance the jet's directional properties. It is against the proven ability of such simple devices to function efficiently that low noise nozzles have to be compared. The failure of an ejection nozzle to remove the workpiece or swarf from a press tool for instance, could result in serious damage to the tooling, if not the machine.

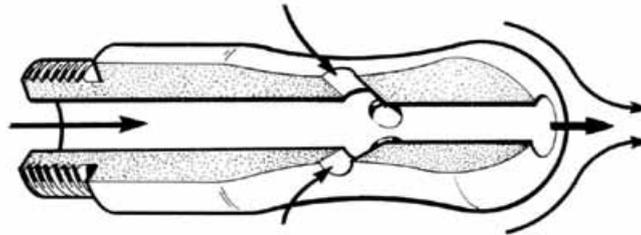
29 The dominant role of jet velocity in determining the noise produced by air ejection jets dictates the design requirements for effective low noise jet nozzles. A substantial noise reduction requires a reduction in jet velocity. Since it is impracticable to achieve this requirement by the simple adjustment of airline pressure, the redesign of the jet nozzle needs to be considered. Two methods are widely used to engineer reductions in jet velocity, (a) pressure drop nozzles and (b) air entrainment nozzles.

Pressure drop nozzles

30 Pressure drop nozzles use a plug of porous material across the nozzle mouth. Such nozzles are always restrictive of airflow and suffer the problems of progressive blockage and loss of thrust when used on polluted airlines.

Air entrainment nozzles

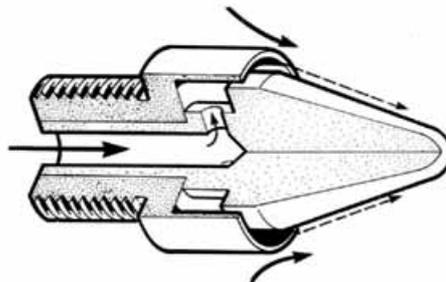
31 Air entrainment nozzles take several forms or combinations using well known principles of fluid mechanics to entrain ambient air. These can in general be divided into the following broad categories.



Aspirated venturi nozzle

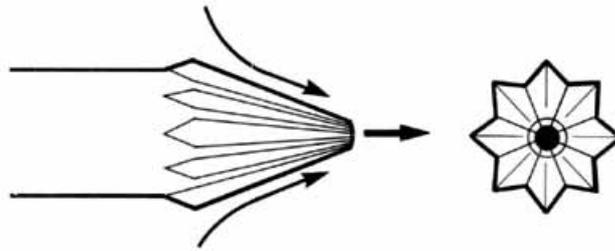
Arrowed lines show airflow and including entrained airflow

Aspirated venturi nozzles use the pressure drop that occurs across a venturi orifice to induce ambient air into the jet stream. The induced air causes exchange of momentum producing a larger airflow moving with lower average velocity. The nozzle is designed as a small diameter downstream pipe with a series of holes through the pipe wall in close proximity to the high pressure jet. The larger diameter downstream pipe becomes the working jet.



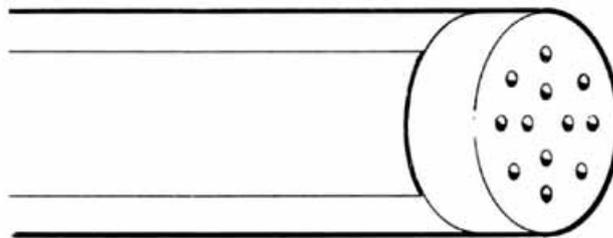
Coanda effect nozzle

Coanda effect nozzles use the principle that a high velocity jet stream will adhere to any smooth adjacent convex surface. A Coanda nozzle is produced by using a truncated outward pointing conical plug to seal the jet pipe. Around the base of the cone a ring of small jets or an annular slot enables high velocity air to flow down the cone surface and merge into a working jet stream. This flow entrains ambient air and the resulting exchange of momentum produces an increased volume of air with reduced velocity.



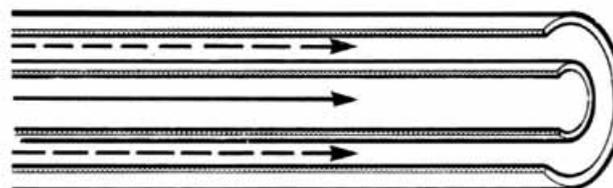
Geometry effect nozzle

Geometry effect nozzles are jet nozzles in which the peripheral shape has been changed to encourage the flow of ambient air into the jet stream. The most usual modification comprises 'V' shaped indentations around the tip of the nozzle. This allows ambient air to be induced into the jet producing a larger flow of lower velocity.



Multi-jet nozzle

Multi jet nozzles comprise a number of individual pipes or a plug with a number of holes. The working area of these small jets is usually smaller than the area of the large jet they replace. This may contribute to the noise reduction, but, as these small jets merge to produce a larger diameter jet stream, they induce ambient air. This is the most usual cause of noise reduction as the average jet velocity is reduced due to exchange of momentum.



Co annular jet nozzle

CoAnnular Jet nozzles comprise two independent jet streams. The outer ring jet has a lower velocity than the central core jet. The outer ring jet stream provides an acoustic shield to help contain the noise generated in the high turbulent shear forces that occur close to the core jet nozzle. It also assists in the mixing process that produces a merged lower velocity jet stream.

32 A number of arrangements exist which bring together more than one of the noise reduction methods described in the preceding paragraphs. The most common and successful combination is the combined Coanda-Coanda effect nozzle.

33 The thrust available from 'quietair' ejection nozzles is in most instances unaffected by the quality of the compressed air passing through. The exception to this are those nozzles employing pressure drop techniques. In these cases the pollutants in the airline are likely to be forced deep into the pressure reducing material. Progressive blockage of the jet will occur and the subsequent loss of thrust could put press tooling at risk. Many quiet nozzles work by inducing ambient air into the jet stream. This induced air mixes to produce a larger airflow with a reduced average velocity. Problems can arise if too great a quantity of ambient air is induced. The nozzle may be very quiet, but its capacity to do useful work would be inhibited.

Specific vs total thrust from jets

34 A further factor to be considered is the thrust available to do work. In this respect, it is necessary to consider specific thrust, ie thrust per unit area and not total thrust. Increasing the nozzle area will increase the total or reactive thrust. If the nozzle area is increased as the jet velocity is reduced, it is possible to maintain total thrust and obtain a noise reduction. However, the specific thrust is the best measure of work capability. An article to be ejected from a machine does not increase in size to accommodate a larger diameter lower velocity jet stream. Therefore, simply increasing the reactive or total thrust is no guarantee that the resulting jet stream will do the required work.

Buried air jets

35 Special mention should be made of another noise reducing technique that has been successfully used during component ejection. The technique is that of merging the jet into the press tooling. This technique cannot be seriously considered as the retrofit conversion since it usually involves the redesign of press tooling. The main advantage of the merged ejection jets is that they deliver the jet stream in close proximity to the component to be ejected so obtaining maximum effect. This enables the jet to operate at lower pressures and using smaller nozzles. A further advantage with the merged jet is that it can be arranged so that, after moving the component, it does not interact with adjacent areas of press tooling, thus avoiding the noise generating vortices that are unfortunately a major part of the air ejection noise for jets that are mounted external to the tooling.

37 Consideration of the possibility of designing air jets into new tooling or at major tool overhauls can offer attractive savings in setting up time, particularly in jobbing shops. It is not uncommon to find that up to half the time for a tool change is devoted to the correct positioning of the air jet to ensure that components are safely ejected from the machine. The knowledge that air ejection can be precisely located for maximum effect simply by the use of a snap on airline connector saves valuable time.

Installation and maintenance

38 Most low noise ejection nozzles use ambient air entrainment techniques to reduce the velocity of the working jet. Such nozzles invariably have jet orifices of sufficient size to accommodate pollutants in the compressed air. Some ejection nozzles use pressure drop membranes to reduce air velocity. Such nozzles should not be used on polluted airlines. If they are, progressive blocking of the membrane will reduce the thrust of the jet to the point of failure to remove components, swarf etc, with consequent risk to machine tooling.

39 A further method of reducing noise from air ejection nozzles is to arrange that they operate only when required during machine cycle and then for the minimum time necessary to do the required work. The amount of noise reduction to be achieved depends upon the ratio of 'air on time' to 'total work cycle time'. Sufficient 'air on time' is necessary for the jet to obtain the necessary momentum to do the required work. For most applications the 'air on time' will probably be in excess one third of a second. It follows then that an automatic machine working at 180 strokes per minute or faster would derive no benefit from this technique. In practice, noise reductions of the order of 6 to 8 dB(A) are possible for hand fed presses using cyclic air ejection.

40 A number of techniques are available to control the airflow. These include ram or cam operation with either air as required or timed air blasts. For the ram operated system, ratchet tripping levers can be provided to ensure the air operates in one direction of the ram only. Suppliers of pneumatic equipment will provide details of suitable control systems for most applications. Practical systems have been found to work satisfactorily using a cam on the press crankshaft operating a 3 way valve directly off the airline.

41 Maintenance requirements for air ejection nozzles are few. Those using pressure drop membranes will require regular inspection and cleaning, though it is not recommended that such nozzles are used on polluted airlines. Nozzles using the coanda entrainment principle should have the nozzle termination plug regularly checked. These plugs can work loose especially if subject to impact. If this occurs, the nozzle tip can become a projectile.

Further information

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