United States Patent

[11] 3,561,561

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[45] Patented **Feb. 9, 1971**

[54] **SOUND ATTENUATING DEVICE**
17 Claims, 10 Drawing Figs.

[52] **U.S. Cl.** **181/55,** 181/37, 181/60, 181/72, 181/61
[51] **Int. Cl.** **F01n 1/10,** F01n 7/18
[50] **Field of Search** 181/60, 55, 36.1, 72, 36, 37, 61

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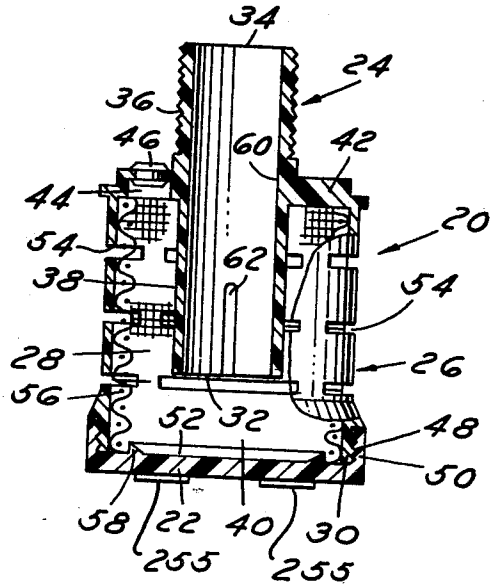
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Primary Examiner—Robert S. Ward, Jr.
Attorney—Burton and Parker

ABSTRACT: This disclosure relates to improved sound attenuating devices for exhaust gas, such as is presently utilized in various industries to muffle the sound of pneumatically operated industrial equipment. The basic embodiment includes an exhaust entrance tube, a shell encircling the tube defining a gas expansion chamber or plenum having exhaust slots, and a screen overlying the exhaust slots. The tube and shell are integrally formed of plastic to improve the sound attenuating characteristics and reduce the safety hazard of separate secured parts.

The second disclosed embodiment includes a sound absorbing medium in the form of a cellular disc opposite the gas exit of the tube and a floating perforated disc located between the tube exit and the sound absorbing medium. A baffle deflector is also provided at the gas exit of the tube, deflecting the gas into the sound absorbing medium and then into the annular expansion chamber surrounding the tube. The third embodiment includes a metering valve having a nonrotatable, axially shiftable cylindrical plug telescopically received in the gas exit end of the tube. The metering plug has a plurality of longitudinal V-shaped tapered slots increasing in width toward the plug end received in the tube, accurately controlling the flow of gas.



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SHEET 1 OF 2

FIG. 1

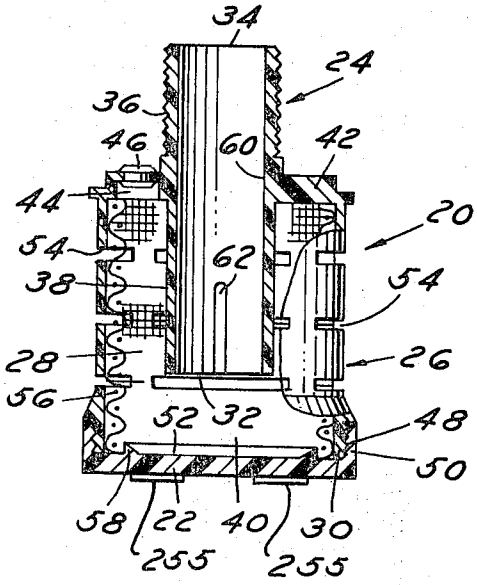


FIG. 2

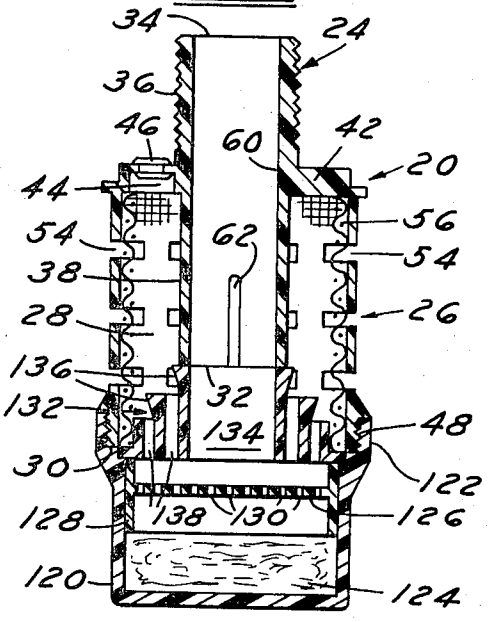
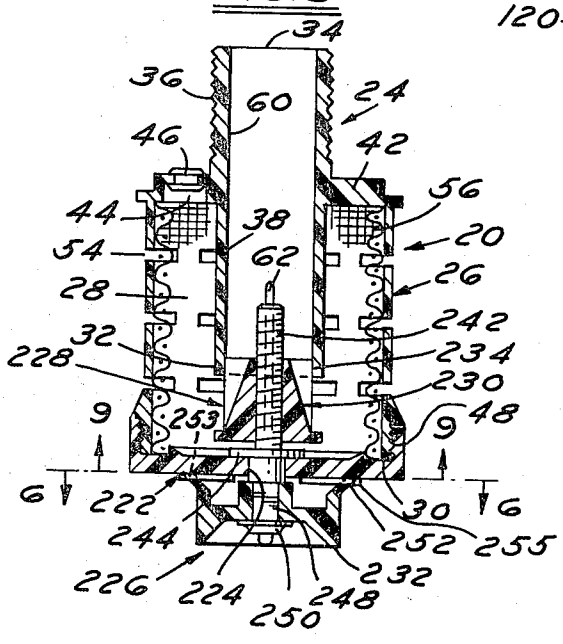


FIG. 3



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FIG. 6

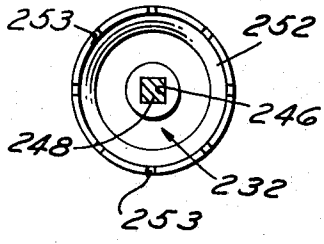


FIG. 4

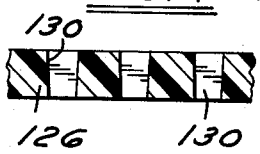


FIG. 5

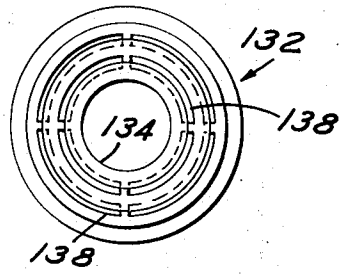


FIG. 7

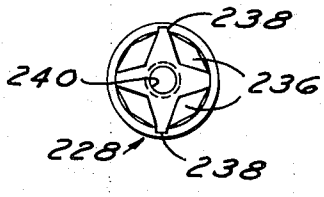


FIG. 8

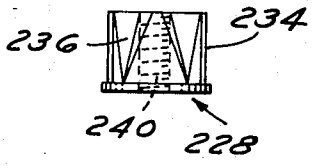


FIG. 9

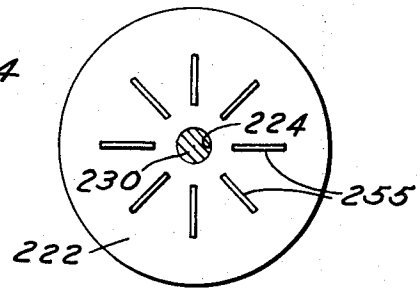
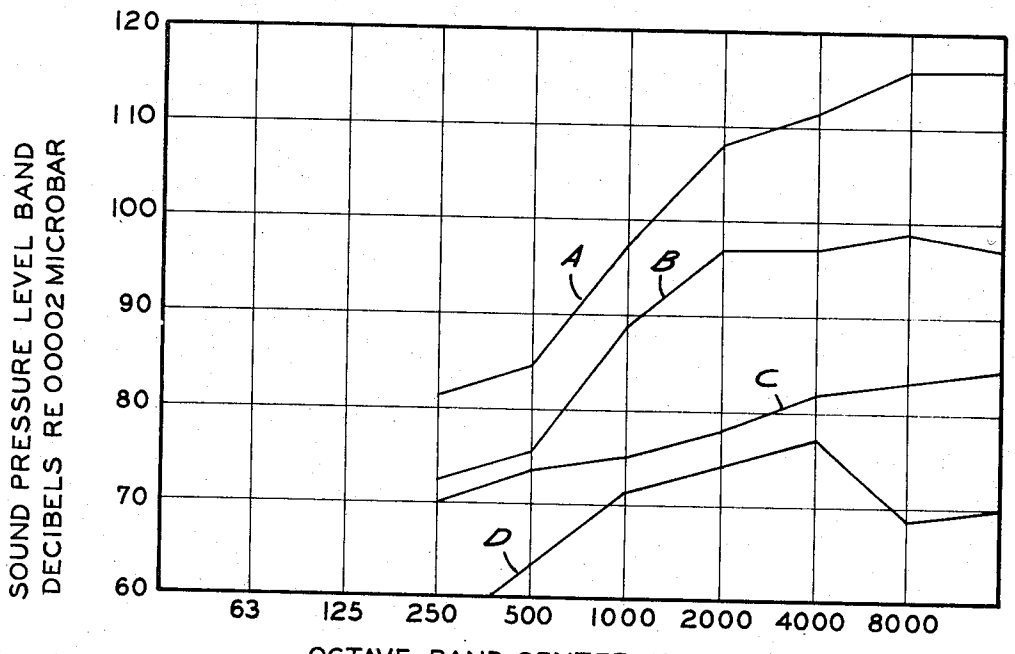


FIG. 10



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SOUND ATTENUATING DEVICE

DESCRIPTION OF THE PRIOR ART

Sound attenuating devices are presently used on various industrial equipment, such as pneumatically operated or controlled welders, presses, air hoists, cutoff tools and the like, generally involving repeated cycles, exhausting relatively high pressure air. These devices are generally connected to the pneumatic air exhaust of the equipment. Industry has now recognized the necessity of sound attenuating devices or mufflers, but the present commercial designs either do not adequately reduce the sound level or are impractical for other reasons.

One important problem in the design of a sound attenuator is back pressure, which may cause malfunctioning of the apparatus, such as "repeat" of a valve, on which the muffler is mounted, or the muffler or attenuator may fracture or explode, any of which circumstances creates a serious safety hazard. The commercial mufflers are generally formed from a number of metal parts which are secured by threaded connections, pins, solder or the like. These parts may become loose or may be thrown from an exploding muffler. Further, commercial mufflers generally include a screen cartridge, which must be changed or cleaned as required. The cartridge is however often difficult to remove and therefore neglected, increasing the back pressure and creating a hazard. The prior art designs which attempt to solve these problems are generally too expensive to be commercially acceptable. Examples of sound attenuators and related devices shown by the prior art, include the following U.S. Pat. Nos.: 3,374,855, 3,339,668, 3,327,809, 3,209,857, 3,208,551, 3,137,365, 2,705,541, and 1,995,071.

SUMMARY OF THE INVENTION

The sound attenuating device of this invention is adapted to reduce the noise level of a pneumatically operated machine or the like to an acceptable level and improve the safety of commercial designs. Further, the screen cartridge may be easily replaced, further reducing the operating back pressure of the muffler. The basic design, shown by the first embodiment of the invention, includes a plastic gas entrance tube, a plastic shell integral with and encircling the tube and providing a gas expansion chamber, and a screen cartridge. In the preferred embodiment, the tube extends into the chamber approximately two-thirds of the axial length of the chamber, but is spaced from the encircling wall of the shell, such that the cross-sectional area of the cylindrical chamber is several times greater than the cross-sectional area of the tube, causing the gas to expand and reducing the noise level. In this embodiment, the area of the expansion chamber, opposite the gas exit end of the tube, is approximately seven times the cross-sectional area of the tube, and the cross-sectional area of the annular chamber, located between the tube and the shell wall, is approximately six times the area of the tube.

The shell is integrally joined to the plastic tube by a radial wall, and the chamber is open opposite the radial wall. A closure member is threadably received on the shell, providing essentially a two-piece structure. In the preferred embodiment, an aperture is provided in the radial wall which is sealed by a resilient blowout plug. It should be noted that the blowout plug is thereby located adjacent the exhaust gas entrance of the sound attenuating device, such that the resilient plug will normally be blown away from the machine operator, and the release of pressure will prevent fracture or explosion of the device. The inner wall of the closure member, opposite the gas exit end of the tube, is preferably perpendicular to the axis of the tube, reversing or deflecting the direction of the gas into the annular chamber and providing cancellation of impinging noise. The shell is also provided with radial slots which exhausts the gas received in the expansion chamber, and a screen or other porous material cartridge is received in the chamber, overlying the slots.

The second embodiment of the sound attenuating device of the invention may utilize the integral shell and tube described hereinabove, but has been modified to provide additional sound attenuation characteristics. In this embodiment, the flat closure plate has been replaced by a cup-shaped closure member threadably received on the shell. A sound absorbing medium is received in the end of the cup-shaped closure member opposite the gas exit end of the tube. In the disclosed embodiment, the sound absorbing medium is a cellular disc which directly receives the impact of the exhaust gas. A perforated partition is provided between the gas exit end of the tube and the sound absorbing medium, at least a portion of which is movable relative to the tube upon impact of the exhaust gas to distribute the impact force over the full area of the sound absorbent medium. In the disclosed embodiment, the partition is a floating perforated disc which moves relative to the tube upon impact by exhaust gas, and permits sound waves to pass through its perforations into and for absorption by the underlying cellular sound absorbing medium. The exhaust gas is then directed into the annular chamber surrounding the tube by a baffle deflector. In the disclosed embodiment, the deflector includes a plurality of radially spaced, concentric gas baffles, increasing in length toward the axis of the tube. The center baffle has approximately the same internal diameter as the tube, and communicates therewith to provide a closed circuit path between the end of the tube and the cup-shaped closure member. The ends of the baffles, opposite the cup-shaped closure member, may also be radially tapered to direct the gas outwardly, toward the slots in the shell wall. This embodiment therefore combines the important means of sound attenuation in a single device, including; absorption, deflection, cancellation and expansion.

The final embodiment utilizes the integral shell and tube described hereinabove in a muffler and metering valve. The combination of this embodiment therefore provides an important advantage over the mufflers described in the prior art. The metering valve includes a cylindrical valve plug, which is telescopically received in the gas exit end of the tube to control the volume of gas discharged therefrom. The metering valves shown by the prior art are generally conical, and therefore provide an inadequate range of adjustment. The valve plug of the sound attenuating device of this invention includes a plurality of V-shaped, tapered longitudinal notches, which increase in width toward the end of the plug received in the tube. The volume of gas may therefore be controlled by shifting the plug into and out of the tube. In the disclosed embodiment, the plug is prevented from rotating in rotating in the tube, and is threadably received on a male threaded member which will shift the valve plug axially upon rotation of the threaded member. A closure member, similar to the closure member in the first embodiment, is threadably received on the shell, and the male threaded member is received therethrough for controlling the axial position of the valve plug. Other advantages and meritorious features will appear from the following description of the preferred embodiments, claims, and drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of one embodiment of the sound attenuating device of this invention;

FIG. 2 is a cross-sectional view of another embodiment of the sound attenuating device;

FIG. 3 is another embodiment of the sound attenuating device;

FIG. 4 is a partial cross-sectional view of the partition utilized in the embodiment shown in FIG. 2;

FIG. 5 is an end view of the gas baffle utilized in the embodiment shown in FIG. 2;

FIG. 6 is a cross-sectional end view of the embodiment shown in FIG. 3, in the direction of view arrows 6–6;

FIGS. 7 and 8 are end and side elevations respectively of the valve plug utilized in the embodiment shown in FIG. 3;

FIG. 9 is an end cross-sectional view of the embodiment shown in FIG. 3, in the direction of view arrows 9–9; and

FIG. 10 is a comparison graph of the sound level of the sound attenuating device of this invention at various frequencies, compared to commercially available sound attenuating devices.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiment of the sound attenuating device shown in FIG. 1 includes an integral body member 20 and a cover member 22. It will be noted that the embodiments shown in FIGS. 2 and 3 also utilize the integral body member 20, reducing the forming costs and stock requirements. The interchangeability of parts also permits modification of the basic design shown in FIG. 1, as shown in FIGS. 2 and 3. The modifications in FIGS. 2 and 3 do not, however, require the utilization of the body member shown in FIG. 1, and should not be so limited.

The integral body member 20 includes a fluid or gas entrance tube 24 and an integral shell 26 encircling a portion of the tube and defining an expansion chamber 28, having an open end 30 opposite the gas exit end 32 of the tube. The gas entrance end 34 of the tube may be externally threaded, as shown at 36, to permit threaded receipt of the sound attenuating device in the gas exhaust or exit port of the machine or device utilizing the muffler. The tube portion 38 preferably extends into the chamber approximately two-thirds the axial length of the chamber, defining an annular chamber at 28 between the tube and the encircling wall of the shell 26, communicating with a cylindrical chamber 40 opposite the gas exit end 32 of the tube. The chamber provides a plenum or expansion chamber for the gas reducing the noise level, and is therefore preferably large relative to the tube. In this embodiment, the area of the cylindrical chamber 40 is approximately seven times the internal area of the tube, measured perpendicular to the longitudinal axis, and area of the annular chamber 28 is approximately six times the internal area of the tube.

In this embodiment, the shell 26 is integrally joined to the tube 24 by a radial wall 42 having a greater thickness than the shell or tube. The radial wall includes a countersunk aperture 44, which is sealed by a resilient blowout plug 46 adapted to relieve the pressure in the chamber 28 prior to fracture or explosion of the device. It is important to note that the blowout plug is located adjacent the gas entrance end 34 of the tube, which is normally pointed away from the machine operator. If the pressure in the chamber, therefore, exceeds a predetermined safety level, the plug will be blown from the device, away from the operator; substantially reducing the safety hazard, especially compared to the prior art devices which may fracture or explode.

The open end 30 of the shell, in this embodiment, is externally threaded at 48 and receives the internally threaded lip 50 of the cover member 22, sealing the open end of the chamber. The internal wall 52 of the cover member is preferably flat opposite the gas exit end 32 of the tube and substantially perpendicular to the axis of the tube, such that a portion of the sound impinging on the internal wall will be deflected back, toward the tube, to cancel a portion of the noise entering the chamber. The gas from the tube is deflected into the annular chamber 28 and is exhausted through radial slots 54 in the shell wall. A screen, in the form of an annular cartridge 56, is disposed within the chamber 28 and overlies the radial slots 54 in the shell wall. The screen cartridge in this embodiment is a roll of wire screen, and is slightly compressed between the radial wall 42 of the shell and the cover member 22. A flange 58 is provided on the internal wall 52 of the cover member to entrap the screen cartridge 56 and prevent gas from blowing between the cartridge and the cover member.

The gas received in the gas entrance end 34 of the tube is normally turbulent, especially exhaust gas from pneumatically operated or controlled equipment. The gas is normally exhausted in repeated cycles of relatively high pressure of widely varying pulse frequencies. The internal surface 60 of the tube is preferably smooth to convert the turbulent flow to laminar flow, which is channeled into the cylindrical chamber 40 through the tube portion 38. The grooves 62 adjacent the gas exit end 32 of the tube are utilized in the embodiment shown in FIG. 3, as described hereinbelow. The gas expands in the chamber, as described hereinabove, and is deflected by the wall 52 of the cover member, to cancel a portion of the noise and to direct the air toward the gas exit slots 54 in the shell wall. The screen cartridge 56 further absorbs noise, and traps foreign particles in the exhaust gas.

The integral construction of the tube 24 and shell 26 substantially reduces the hazard in high pressure, repeated cycle systems. The blowout plug 46 further reduces the hazard of explosion or fracture. In the preferred embodiment, the body member 20 is integrally formed from a relatively tough resilient plastic material, which has better sound attenuating characteristics than metal. The unique integral construction of this device permits the utilization of plastic, which is an important advantage of this device. A suitable material for the integral body member 20 and the cover member 22 is Delrin, a trade name of E. I. DuPont de Nemours & Co. (Inc.), an acetal resin plastic composition of polymerized formaldehyde.

The embodiment of the sound attenuating device shown in FIG. 2 may utilize the integral body member 20 described hereinabove and shown in FIG. 1, and has been given the same reference numerals. In this embodiment, a cup-shaped closure member 120 is received over the open end 30 of the shell 26. The lip 122 of the closure member is internally threaded and is threadably received on the externally threaded end 48 of the shell. A sound absorbent medium, such as the cellular disc 124, is received in the end of the closure member, opposite the gas exit end 32 of the tube. A "floating" gas deflector or partition 126 is disposed between the tube and the sound absorbent medium to distribute the gas impact force over the full area of the medium 124. The deflector in this embodiment includes a cylindrical piston portion 128, telescopically slidable in the cup-shaped closure member, and the partition 126 is perforated as best shown in FIG. 4. In this embodiment, the apertures 130 are generally cone-shaped, with the largest diameter adjacent the gas exit end 32 of the tube, increasing the flow resistance and therefore the deflection. The sound absorbent medium is preferably resilient to permit movement of the partition 126 upon impact of the exhaust gas. A suitable sound absorbent medium is polyurethane foam, however other materials may also be used.

A plurality of radially spaced concentric gas baffles 132 are provided in this embodiment between the gas exit end 32 of the tube and the partition 126. The baffles are adapted to direct the gas first into the cup-shaped closure member 120 and then into the annular chamber 28 surrounding the tube, and toward the slots 54. The inner baffle 134 is concentric with the tube and has approximately the same internal diameter to provide a "closed circuit" gas path between the end 32 of the tube and the cup-shaped closure member 120. It should be noted that each baffle is longer toward the axis, and the ends 136 are tapered radially outwardly to direct the air toward the radial slots 54 in the shell wall. The baffles 132 are preferably integral, as shown in FIG. 5, wherein slots 138 are provided between the concentric baffles.

Exhaust gas enters the tubular portion 24 of the sound attenuating device shown in FIG. 2, providing a laminar flow as described hereinabove, and is directed into the cup-shaped closure member 120 by the internal baffle 134. The cyclic variations in pressure of the exhaust gas moves the perforated partition 126 substantially parallel to the axis of the tube, deflecting the gas and distributing the impact force over the entire surface of the sound absorbing medium 124. It should be noted that the resiliency of the medium 124 urges the piston 128 to the position shown in FIG. 2, providing a cyclic movement for the partition. The partition also provides protection for the cellular material of the medium. The gas expands within the cup-shaped closure member, and the noise is

partially absorbed in the medium **124**, the waves passing through the perforations **130** in the partition. The gas is then directed through the slots **138** into the annular chamber **28** surrounding the tube. The configuration of the baffle **132**, including the tapered end portion **136**, also directs the gas outwardly toward the slots **54**, where the gas is exhausted from the device. The screen cartridge **57** traps foreign matter in the exhaust gas and further reduces the noise level, as described hereinabove.

The embodiment of the sound attenuating device shown in FIG. **3** incorporates an improved flow-metering valve which accurately controls the back pressure in the tube **24**. This embodiment may also utilize the integral body member **20**, as described hereinabove, and has been given the same reference numerals. In this embodiment, however, the closure member **222** may be identical to the closure member **22** in FIG. **1**, except that an aperture **224** is provided to receive a portion of the valve, identified generally at **226**.

This embodiment of the valve includes a generally cylindrical valve plug **228**, best shown in FIGS. **7** and **8**, a male threaded member **230** and a control knob **232** also shown in FIG. **6**. One end **234** of the valve plug is telescopically received in the gas exit end **32** of the tube. A plurality of V-shaped tapered longitudinal slots **236** are provided in the plug which transmit the gas into the chamber. The tapered slots **236** increase in width toward the end **234** received in the tube end **32**, and the flow of gas is controlled by telescoping the plug into and out of the tube, as shown in FIG. **3**. The plug is provided with two radially extending ribs **238** which are received in the grooves **62** in the gas exit end **32** of the tube, see also FIGS. **1** and **2**, to prevent the plug from rotating as it is shifted axially. The plug is also provided with an internally threaded aperture **240** which threadably receives the male threaded end **242** of the threaded member **230**.

The male threaded member is prevented from moving axially by the integral flange **244**, disposed within the chamber, and the external control knob **232**. The control knob is provided with a square aperture **246**, which receives the square end **248** of the threaded member **230**, as shown in FIG. **6**, and which prevents relative rotation between the threaded member and the control knob. The control knob is secured on the threaded member by a locking cap **250**. A resilient annular flange **252** is provided on the control knob and includes a plurality of notches or indentations **253** mating with ribs **255** on the bottom of the cover **222** to prevent inadvertent rotation of the knob. The flange **252** is tensioned against the closure member **222**, as shown, and provides frictional resistance to rotation.

The valve is operated by rotating the control knob **232**, which rotates the threaded member **230**. The valve plug **228** is prevented from rotating by the ribs **238**, and therefore the plug is shifted axially within the gas exit end **32** of the tube as the threaded member is rotated. As the plug is shifted further into the tube, the tapered slots **236** decrease the gas flow rate and thereby increase the back pressure in the tube; conversely, the flow rate increases as the plug is shifted toward the closure member **222**. The sound attenuating portion of the device may be identical to the embodiment shown in FIG. **1**, and therefore the mechanism need not be described again.

FIG. **10** graphically compares the tested sound level of the sound attenuating device of this invention with commercially available devices. The sound level is plotted in decibels on the vertical axis using a standard microbar reference of 00002, and the octave frequency is plotted on the horizontal axis in cycles per second. Curve A illustrates the noise level of an open 1-inch line, curve B illustrates the sound level of a commercial 1-inch silencer, and curve C illustrates the sound attenuating characteristic of a 1-inch silencer similar to the embodiment shown in FIG. **2**. It will be noted that the sound level of the commercial silencer plotted in curve B exceeds the accepted maximum of 90 db. at frequencies greater than 1,000 cycles per second, whereas the embodiment shown in FIG. **2** does not exceed 90 db. in the tested octave band. Curve D illustrates the sound level of the embodiment shown in FIG. **1**, which would be similar to the embodiment shown in FIG. **3** when the valve is wide open. The sound level of the embodiment shown in FIG. **3** will, however, decrease as the flow rate is decreased, and therefore the sound attenuation will depend upon the position of the valve plug **228**. The silencer tested in Curve D was, however, a ½-inch silencer, which normally has a lower sound level than a similar 1-inch silencer. The dimensions cited hereinabove of "one inch" and "one-half inch" refer to the diameter of the gas entrance pipe or tube **34**. The improved sound attenuating characteristics of the embodiments disclosed is however evident.

Although various materials may be utilized for the sound attenuating devices of this invention, plastic is preferred for the integral body member **20**, as described hereinabove. Delrin may also be utilized for the cover members, the floating partition **126**, the baffle **132** and the valve assembly **226**, except the cap fastener **250**. The blowout plug **46** may be formed from a resilient plastic or synthetic rubber, for example, such as neoprene. The advantages of an all plastic silencer have already been described, including the improved sound attenuating characteristics, reduced safety hazard and reduction in cost.

I claim:

1. A sound attenuating device for exhaust gas, comprising: a plastic cylindrical gas entrance tube, a plastic shell integral with and encircling said tube and defining a cylindrical expansion chamber receiving the gas from said tube, said tube extending into said chamber approximately two-thirds the axial length of said chamber, but spaced from the encircling wall of the shell such that the cross-sectional area of the cylindrical chamber is at least four times the internal area of the tube, said shell having an open end opposite the gas exit end of said tube and said encircling wall provided with a plurality of circumferential gas exhaust slots, a closure member threadably received over the open end of said shell, and an annular screen member received within said chamber overlying the slots in the shell wall.

2. The sound attenuating device defined in claim **1**, characterized in that said plastic shell is integrally joined to said plastic tube by a radial wall opposite said open end of the shell, and said radial wall includes an aperture sealed by a resilient blowout plug adapted to relieve pressure in the chamber if the pressure exceeds a predetermined limit.

3. The sound attenuating device defined in claim **1**, characterized in that said closure member is generally cup-shaped and includes a sound absorbing medium opposite the gas exit end of said tube.

4. The sound attenuating device defined in claim **3**, characterized in that a partition means is disposed between the outlet of said tube and said sound absorbing medium, at least a portion of said partition means movable relative to the tube upon impact of exhaust gas.

5. The sound attenuating device defined in claim **4**, characterized in that said partition means is a perforated plate movable generally in the axis of said tube.

6. The sound attenuating device defined in claim **4**, characterized in that a plurality of radially spaced concentric gas baffles are provided adjacent the gas exit of the tube directing the gas first into the sound absorbing medium, and then into the chamber surrounding the tube.

7. The sound attenuating device defined in claim **6**, characterized in that the inner baffle has an internal diameter approximately equal to the internal diameter of said tube and provides a closed circuit gas path between said tube and said cup-shaped closure member.

8. The sound attenuating device defined in claim **7**, characterized in that the ends of said gas baffles, spaced from said closure member, are tapered radially outwardly, directing the gas into said chamber surrounding the tube and radially outwardly toward said slots.

9. The sound attenuating device defined in claim **1**, characterized in that a partition is disposed between the gas exit of

said tube and said closure member, said partition having at least a portion movable relative to said tube in response to the impact of gas exhausted from said tube.

10. The sound attenuating device defined in claim **9**, characterized in that said partition is a perforated circular disc slidably received between said tube and said closure member.

11. The sound attenuating device defined in claim **1**, characterized in that a gas metering valve is disposed within said chamber, metering the volume of gas exhausted from said tube, said metering valve including a valve plug partially received within the gas exit end of said tube having a plurality of tapered V-shaped longitudinal notches increasing in width toward the end of the plug received within said tube and providing an accurate control of exhaust gas volume entering said chamber as the valve plug is moved into and out of the tube end.

12. The sound attenuating device defined in claim **11**, characterized in that said valve plug is telescopically received within the gas exit end of said tube and interfits therewith to prevent circumaxial movement of said plug as it is shifted axially to control the volume of the exhaust gas.

13. The sound attenuating device defined in claim **12**, characterized in that said valve plug is threadably received on a threaded male member extending through said closure member.

14. The sound attenuating device defined in claim **1**, characterized in that said plastic shell is integrally joined to said plastic tube by a radial wall opposite said open end of the shell, and said blowout plug is in an aperture in such radial wall.

15. The invention defined in claim **9** characterized in that means are provided between the partition and said closure member biasing the partition toward the end of the tube and yieldable to impact of exhaust gas against the partition from the tube to cushion shock waves thereof.

16. The invention defined in claim **13** characterized in that a knob is fixed on said male member outside the closure member and has a resilient skirt portion bearing against the exterior of the closure member, and cooperating detent means on the skirt and exterior of the closure member for yieldingly locking the knob against rotation.

17. A sound attenuating device for exhaust gas, comprising: a plastic cylindrical gas entrance tube, a plastic shell encircling the tube and defining a cylindrical expansion chamber receiving the gas from the tube, said tube extending along the length of the chamber spaced from the encircling wall thereof and having a length to convert turbulent gas flow to substantially laminar flow, said chamber having a cross-sectional area around the tube several times the cross-sectional area of the tube, plastic end walls closing opposite ends of the chamber, one of said end walls being integral with and encircling the tube and provided with an aperture sealed by a resilient blowout plug and the other end wall being spaced from the end of the tube within the chamber providing an unrestricted flow path for exhaust gas out of the tube, one of said end walls of the chamber being integral with the shell and the other end wall being threadably connected to the shell for access to the interior of the chamber, the wall of said shell provided with a plurality of exhaust ports for escape of exhaust gas from the chamber, and an annular porous member received within the chamber overlying the ports in the shell wall.