

July 27, 1965

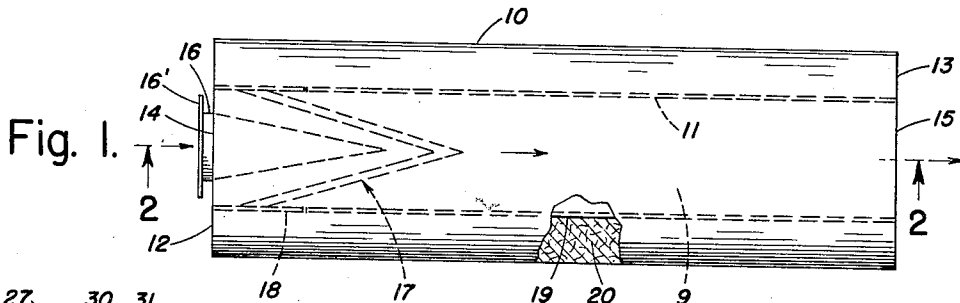
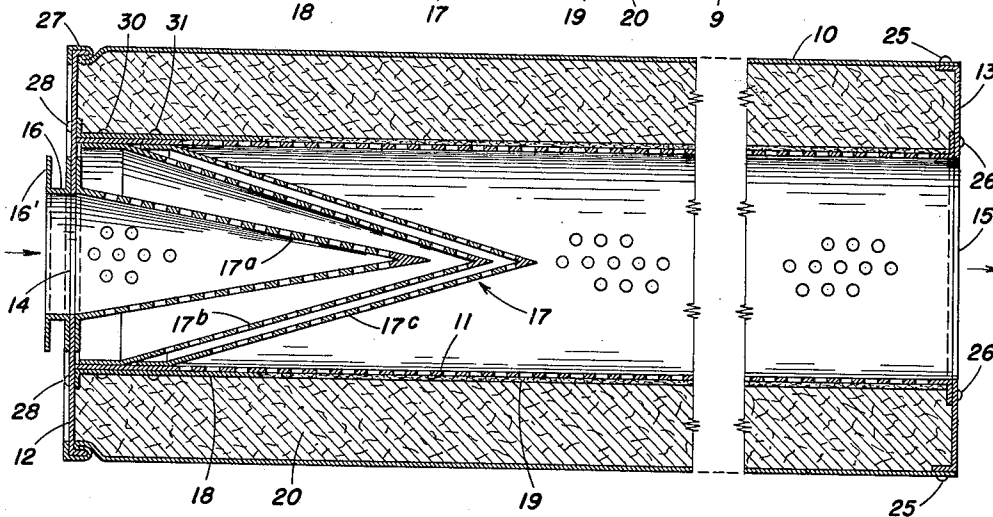
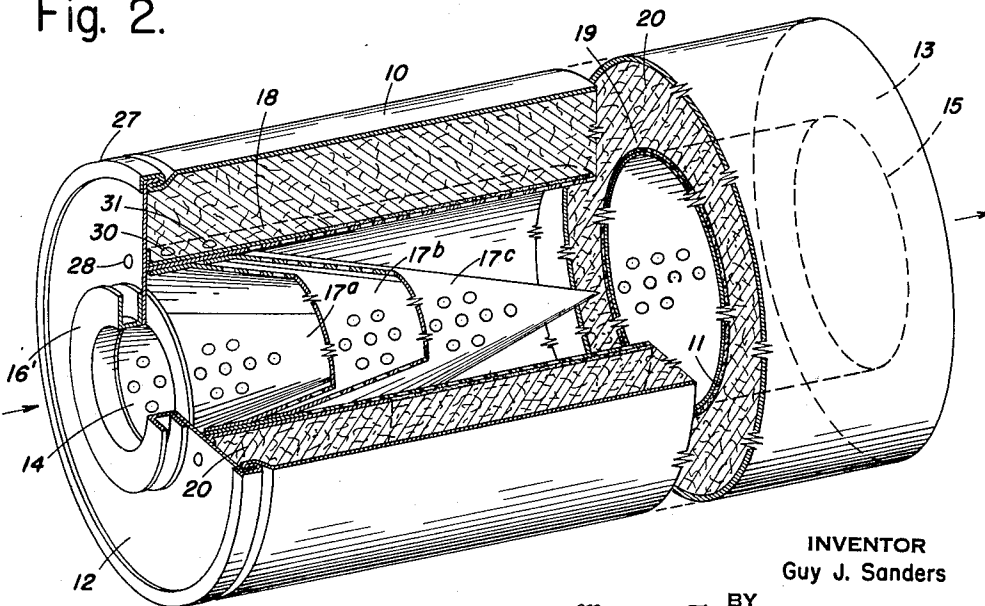
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3,196,977

SOUND ATTENUATION CONTROL MEANS INCLUDING
DIFFUSER FOR HIGH VELOCITY STREAMS

Filed April 27, 1960

4 Sheets-Sheet 1



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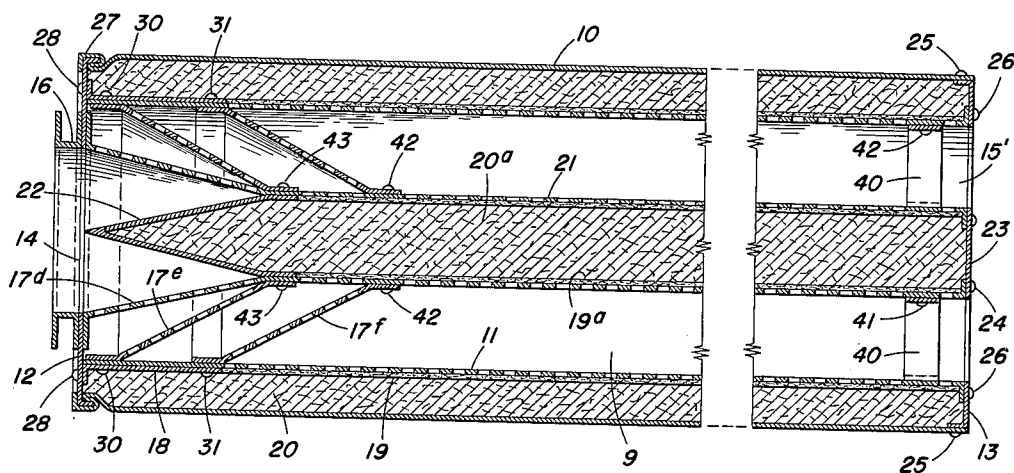


Fig. 4.

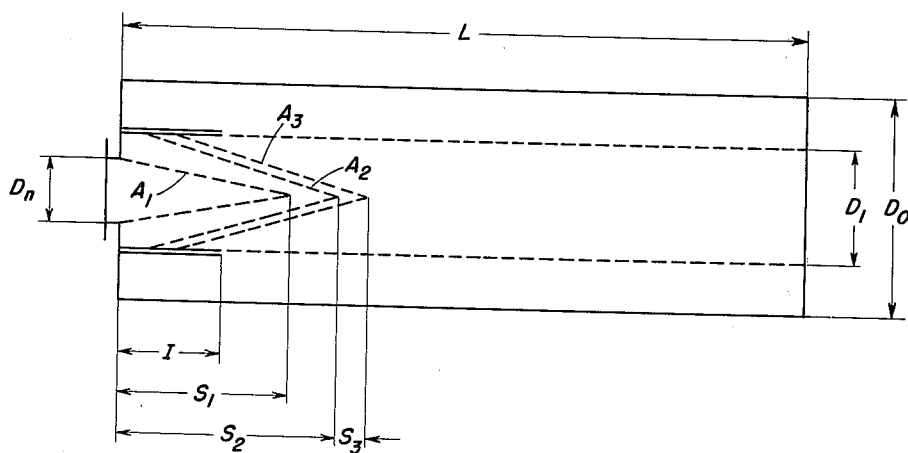


Fig. 5.

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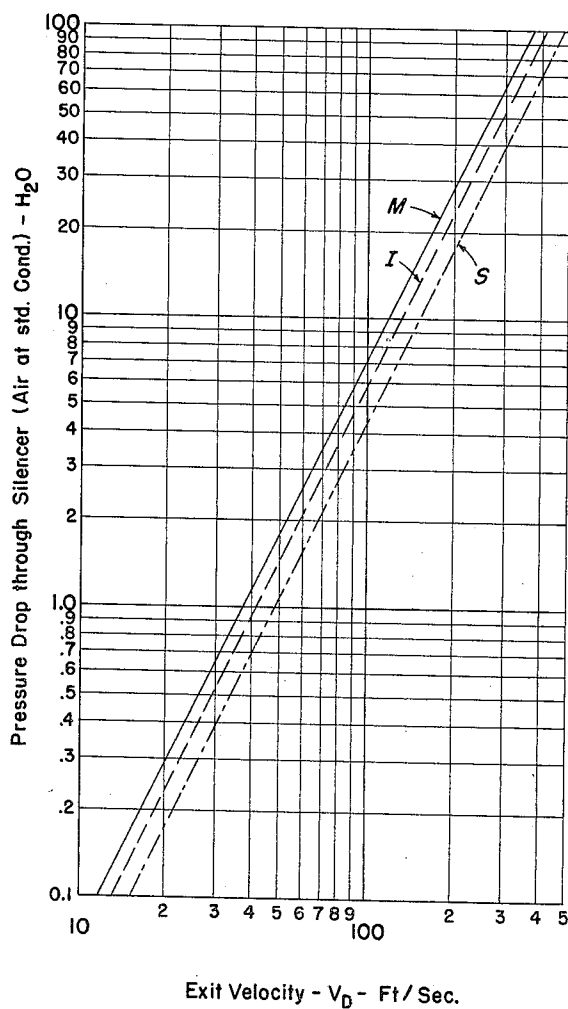


Fig. 6.

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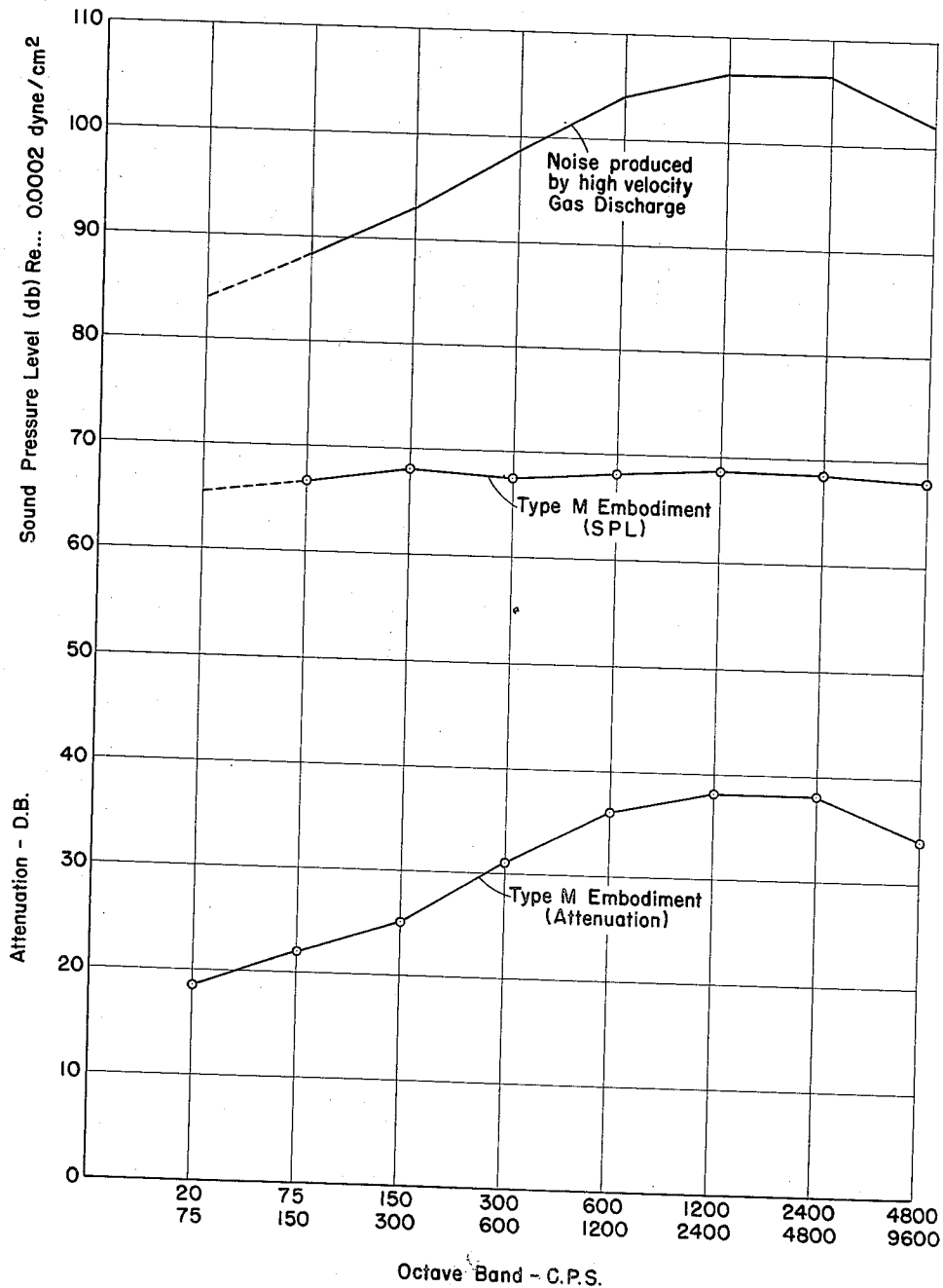


Fig. 7.

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SOUND ATTENUATION CONTROL MEANS INCLUDING DIFFUSER FOR HIGH VELOCITY STREAMS

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11 Claims. (Cl. 181-50)

This invention relates to apparatus for controlling the propagation of high-velocity fluid streams, and more particularly to means for controlling the generation, transmission and propagation of noise associated with the translation of high-velocity gaseous exhausts.

It is the object of the invention to provide stream control apparatus for exhaust streams issuing from machinery, engines, industrial equipment and the like, and particularly apparatus which is adapted to control the generation and attenuation of noise associated with high-velocity gaseous streams such as those with velocities lying in the range of 0.4 Mach to Mach 1.

An additional object of the invention is to provide a novel low-loss diffuser arrangement for diffusing a high-velocity stream, which diffuser is also effective to attenuate input noise and to prevent the generation of that additional noise which normally accompanies the effluence of high-velocity streams.

The requirements, both structural and acoustical, which are placed on control apparatus designed for high-velocity applications are stringent, and this is evidenced by the fact that a muffler currently used on a wide scale in such an application weighs over 1,900 pounds and occupies a space of about 74 cubic feet. In contrast, a typical arrangement according to the invention not only meets all of these requirements with apparatus which weighs slightly more than 600 pounds and occupies a space of less than 30 cubic feet, but also provides acoustical performance which is better, and a pressure drop which is substantially less, than the above-mentioned currently-used muffler.

It is accordingly another object of the invention to provide a muffler for exhaust streams which is substantially smaller and lighter than present units employed by the art and which provides acoustic attenuation superior to these prior art arrangements.

Another object of the invention is to provide such a muffler which has substantially smaller pressure drop than presently employed arrangements.

A further object of the invention is to provide a muffler for high-velocity exhaust streams which is compact and of relatively light weight and which nevertheless reduces noise associated with the stream to a level which is acceptable in residential areas.

A further object of the invention is to provide a muffler for high-velocity discharges which is small, compact, which has no moving parts and which may be operated in rugged and even contaminated environments.

A further object of the invention is to provide such a muffler which is constructed of inexpensive materials which may be readily fabricated.

A still further object of the invention is to provide such a muffler which may be disassembled for servicing.

Another object of the invention is to provide in stream propagation control apparatus, diffuser means having a pressure drop substantially as low as the theoretical drop of an ideal diffuser.

Another object of the invention is to provide in stream propagation control apparatus, diffuser means which also functions to attenuate stream borne noise entering the diffuser means.

Another object of the invention is to provide in stream

propagation control apparatus, diffuser means of a character which prevents the generation of noise normally found in the effluence of high-velocity streams.

Another object of the invention is to provide in stream propagation control apparatus, diffusing means for attenuating input noise and for substantially reducing the velocity of the medium without at the same time generating significant noise, and acoustic treatment means operatively associated with the diffusing means and adapted to provide further complementary attenuation.

These and other objects and advantages of the invention will be set forth in part hereinafter and in part will be obvious herefrom, or may be learned by practice with the invention, the same being realized and attained by means of the instrumentalities and combinations pointed out in the appended claims.

Briefly and generally the apparatus of the invention comprises a tandem combination of a diffuser and an acoustically treated duct, the apparatus being adapted to be secured to the exhaust pipe from which the stream to be treated issues. Except for the entrance which is coupled to the diffuser, the input end of the apparatus including the connection to the exhaust pipe, is sealed off.

In one exemplary embodiment the diffuser means comprise a plurality of nested conical screen oriented in the entrance of the apparatus with their apexes pointing downstream. The screens are arranged to receive the direct impact of the stream which issues at a high velocity from the installation's exhaust port. With the screens so arranged the stream must pass through each of them, and after impingement thereon, is broken up into a plurality of small-diameter component streams. These component streams re-combine a short distance downstream from the perforation to form anew, a substantially continuous main stream. The diffuser action results in a substantial reduction in the velocity of the stream, in one embodiment this being in the order of 5 to 1; it also provides a reduction in amplitude of the noise attending the translation of the stream, particularly a reduction in low-frequency noise components. The reduction in velocity is accomplished without the usual generation of additional noise and this reduction permits the use of absorbent material in the downstream duct region for additional attenuation, such use being in the usual case prohibitive because of the velocities involved. In the preferred embodiment this duct which is coupled to the diffuser section comprises inner perforated walls bounded by an annular chamber filled with absorbent material.

While the diffuser (which is also an attenuator) permits the use of a duct lined with absorbent material, e.g., glass fiber, the diffuser per se does not provide in many cases sufficient attenuation of high-frequency noise components. The applicant has determined, however, that the diffuser and the absorbent lined duct complement each other in a synergistic fashion: The diffuser drastically attenuates low-frequency components, partially attenuates high-frequency components and effects a substantial velocity reduction; the velocity reduction provided by the diffuser enables the exploitation of acoustically absorbent material in the downstream region of the duct to efficiently attenuate to a greater extent the high-frequency noise components. The net result of the combination is an improved noise reduction over the entire spectrum with a substantially smaller unit and with a substantially reduced pressure drop.

The invention consists of the novel parts, constructions, arrangements, combinations and improvements herein shown and described.

Exemplary embodiments of the invention are illustrated in the accompanying drawings of which:

FIGURE 1 is a side elevation view partly in section of one embodiment of the invention;

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FIGURE 2 is a cross-sectional view on larger scale taken along lines 2—2 of FIGURE 1;

FIGURE 3 is a perspective drawing partly in section of the embodiment of FIGURES 1 and 2;

FIGURE 4 is an elevation view in cross-section of an alternate embodiment;

FIGURE 5 is a diagrammatic drawing illustrating certain dimensional features of embodiments of the invention;

FIGURE 6 is a graph of comparative data relating to pressure drop in embodiments of the invention; and

FIGURE 7 is a comparative graph relating to sound pressure levels and attenuation in apparatus built according to the invention.

The embodiment illustrated in FIGURE 1 and in more detail in FIGURES 2 and 3 comprises an outer cylindrical shell 10 and an inner perforated cylindrical shell 11 coaxial therewith. End members 12 and 13 are provided over the annular openings formed at each end of the structure with each having centrally disposed openings 14 and 15, respectively. Opening 14 at the entrance to the silencer is circumscribed by a tube 16 which extends outwardly from the opening and includes a flange 16'. This flange is adapted to be secured to a flange (not shown) on the exit port of the installation which is to be acoustically treated.

The opening 14 communicates with a duct 9 defined by the perforated inner shell 11. At the entrance to this duct just aft of the entrance 14 are diffuser means comprising a plurality of nested conically shaped screens 17 which are perforated. The apexes of the screens point downstream, while the region of duct 9 which corresponds with the bases of the screens is surrounded by an imperforate shield 18. The exterior of perforated inner shell 11 is covered by a layer of acoustically transparent material, preferably glass fiber cloth 19 or fine mesh screen, while the space between this layer and the external casing 10 is filled with absorbent material 20, preferably glass fiber or metal wool. The duct 9 is preferably of constant diameter.

From the arrangement described it is evident that the high-velocity stream which is coupled directly into the entrance 14 of the attenuator impinges on the perforated screens 17, thereby being transformed into a large group of small-diameter streams. The perforations are as small as the thickness of the screen material practically permits and are sufficient in number to provide a 50% open area. After passing through the screens, the stream reforms into a continuous medium and traverses the duct 9 being concurrently subjected to the acoustic treatment provided by virtue of the duct geometry and the use of material 19 and 20. The final noise-attenuated stream leaves the attenuator at opening 15 and passes to the atmosphere directly or by an outlet extension (not shown).

As is more clearly evident in FIGURES 2 and 3, the outer and inner tubes 10 and 11, respectively, are joined at one end by way of end plate 13, the external flange of which is secured to outer casing 10 by screws 25 or the like. The inner periphery of annular end member 13 is secured to inner tube 11 by being secured thereto as by screws 26 or the like. At the other end of the apparatus, the outer and inner casings 10 and 11, respectively, are secured together by way of end member 12, which is secured to the outer casing 10 by way of a crimp 27 formed in the outer casing which engages a flange on end member 12. The cones 17b and 17c, together with the shield 18, are secured to inner casing 11 by means of screws 30 and 31, and this entire combination is secured to end member 12 by means of screws 28 or the like. The innermost cone 17a, as well as the fitting 16, are secured to end member 12 by welding or by any other suitable connecting means.

The above-described arrangement provides a high degree of structural integrity in the apparatus and at the

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same time enables the ready disassembly thereof for the purpose of servicing the unit.

As an illustration of the performance of the muffler, particularly the diffuser section, the following computations are provided:

If a jet stream of standard air is discharged to the atmosphere from a pipe, the resultant loss is given by

$$H = C_1 \frac{(60V)^2}{(4005)^2} \quad (1)$$

where

H is the loss in inches of water,

V is the velocity in f.p.s., and

C₁ is a loss coefficient.

For a velocity of 950 f.p.s., the computed loss is

$$H = 203 \text{ in., H}_2\text{O}$$

Hence the pressure drop at the end of the pipe is 203 in., H₂O. If instead of direct discharge to the atmosphere, the jet stream is diffused with an optimum venturi exit expanding at a 5:1 ratio then the loss H is given by

$$H = C_r C_1 \frac{(60V)^2}{(4005)^2} \quad (2)$$

where C_r is a venturi coefficient. The computation, again taking standard air at 950 f.p.s., yields a loss

$$H = 22.1 \text{ in., H}_2\text{O}$$

The discharge loss at the venturi exit based on a 5:1 velocity reduction yields

$$H = \frac{(60V)^2}{(4005)^2} = 2.85 \text{ in., H}_2\text{O}$$

Thus the total loss with an optimum venturi exit is

$$H_t = 22.1 + 2.85 = 24.95 \text{ in., H}_2\text{O}$$

The total measured loss in the same application employing a muffler according to the invention is

$$H_M = 25 \text{ in., H}_2\text{O}$$

(See FIGURE 6 at exit velocity of 950/5=190 f.p.s.) Thus, the loss in a muffler according to the invention is less than ¼ of 1 percent higher than the ideal loss with an ideal venturi diffuser and is less than ⅓ the loss with no muffler at all. These results are tabulated below

[Total loss (inches of H₂O)]

Straight Discharge	Optimum Venturi	Invention
203	24.95	25

The performance of the invention in this respect is particularly significant in view of the impracticability, by virtue of its size, of an optimum venturi diffuser.

Considering now the embodiment of FIGURE 4, it may be noted that this structure comprises a modification in which a center body 21 is provided in duct 9. This inner body comprises an outer perforated tube 21 coaxial with duct 9 and an inner liner of acoustic material 19a, preferably of glass fiber cloth. The remaining interior of center body 21 is also filled with acoustically absorbent material 20a, glass fiber being preferred in this case.

The perforated conical members 17e and 17f of the embodiment of FIGURE 4 are secured to center body 21 by screws 42 and 43 or the like, and at their base regions are secured along with imperforate shield 18 to tube 11 by means of screws 30 and 31. Conical screen 17d is formed as a flared end portion of center body 21, the base of the screen being along with fitting 16 to end member 12 as by welding or the like. Closing off the entrance region of center body 21 is a conically shaped imperforate member 22 which is secured to center body 21 along with perforated conical member 17e by means of the afore mentioned screws 43. The other end of center body 21 is closed off by means of cap 23

which is secured to flanges integral with the center body by means of screws 24 or the like.

Connection of inner casing 11 and outer casing 10 at the entrance region of the apparatus is accomplished through end plate 12 as described hereinbefore, while at the other end these casings are connected together through end member 13 which is secured to each by means of screws 25 and 26, respectively. For providing additional support of center body 21 within duct 9, a plurality of radially extending struts 40 are provided, the inner ends of which are secured to center body 21 by means of screws 41, and the outer ends of which are secured to casing 11 by means of screws 42.

The general principles of operation of the device of FIGURE 4 are similar to those governing the embodiment of FIGURES 1 to 3. Greater attenuation is provided, however, by virtue of center body 21 which provides a greater perimeter/area ratio in the regions of duct 9 for a given duct outside diameter.

The acoustic properties of the muffler according to the invention depend in part upon the dimensional characteristics thereof. A set of representative and approximate dimensions are indicated in FIGURE 5 for one embodiment and are tabulated below:

D ₁ —duct diameter	-----	A value necessary to make the area of the duct, A _d , approximately five times the area of the installation's discharge nozzle.
L	-----	4-6D ₁ .
I	-----	D ₁ .
S ₁	-----	1.7D ₁ .
S ₂	-----	1.8D ₁ .
S ₃	-----	¼D ₁ .
D _n	-----	D.N. ¹ .
D _o	-----	D ₁ +4".
A ₁ —open area of screen 1	-----	1.15A _d .
A ₂ —open area of screen 2	-----	2A _d .
A ₃ —open area of screen 3	-----	2A _d .
¹ Diameter of discharge nozzle.		

For maximum attenuation, designated "M," dimension L=6D₁. For intermediate attenuation, designated "I," dimension L=5D₁ while for least attenuation, "S," dimension L=4D₁. The number of screens corresponding with M, I and S installations are conveniently 3, 2 and 1 respectively. Type M would normally be used in a plant near a residential area; type I would normally be used in semi-residential and small industrial areas; and type S in commercial and non-residential areas.

Absolute dimensions will depend of course on the particular installation to be treated and on the attenuation requirements thereof. In order to provide some exemplary data the following examples are given:

	Nominal mass flow in muffler, lbs./hr.	D ₁ , inches	Gauge No.				L		
			Casings		Screens	Shield 18	M	I	S
			10	11					
A...	6,500	4.5-5	16	22	16	16	6D ₁	5D ₁	4D ₁
B...	2,320,000	85-96	¼	¼	¼	¾	6D ₁	5D ₁	4D ₁

Lining material: 6 lbs./ft.³.

By way of illustrating the performance of mufflers built according to the invention, reference may be had to the graphs of FIGURES 6 and 7. The pressure drop characteristic based on a 5:1 velocity reduction is illustrated in FIGURE 6 for the three different embodiments of the invention, M, I and S designated hereinbefore.

The pressure drop in the graph of FIGURE 6 is specified in terms of inches of water with air at standard conditions, and is plotted as a function of muffler exit velocity,

V_d, in feet per second. It may be observed from the graph that an unusually low pressure drop is attained with the silencers of the invention.

In FIGURE 7 the performance of an M type embodiment dimensioned according to the first set of data of the example is illustrated. In terms of sound pressure level, it is evident that the embodiment provides a substantial reduction over the level existing with the stream issuing directly from a bare 2-inch nozzle. The high performance of the muffler is also evident in the attenuation curve which reflects a high order of sound suppression over the entire audible spectrum.

The invention in its broader aspects is not limited to the specific mechanisms shown and described but departures may be made therefrom within the scope of the accompanying claims without departing from the principles of the invention and without sacrificing its chief advantages.

What is claimed is:

1. In apparatus for controlling the effluence of a high-velocity stream at 0.4 Mach or greater from discharge means, means for diffusing said stream, for preventing the generation of noise and for attenuating noise associated with said stream, particularly low-frequency components thereof, comprising a casing lined with acoustic absorbent material and having an inlet section adapted to enclose said discharge means, and a plurality of nested perforated conical members the apexes of which point in the direction of movement of said stream, said members being mounted in said inlet section in a position to be directly and successively impacted by said stream.

2. Apparatus according to claim 1, in which at least one of said conical members has an open area of approximately 50%.

3. Apparatus according to claim 1, in which one of said conical members substantially encloses at least one other of said members.

4. Apparatus according to claim 1, in which the height to base ratio of at least one of said conical members is greater than 1.5.

5. In apparatus for controlling the effluence of a stream from a discharge port, means for diffusing said stream at velocities near Mach 1, for preventing the generation of noise and for attenuating noise associated with said stream, particularly low-frequency components thereof, comprising an acoustic attenuating duct, and a plurality of nested perforated, generally conical members within said duct, the apexes of which members point in the direction of movement of said stream and the bases of which are adapted to directly receive said stream as it issues from said exit, said conical members having substantially unobstructed perforations sized and distributed to provide concurrently both diffusion and attenuation, said duct comprising a casing enclosing a single, straight, substantially unobstructed passageway.

6. Apparatus according to claim 5, in which said conical members are coaxial with said duct such that line-of-sight transmission is provided through the combination of said conical members and said duct.

7. Apparatus according to claim 5, in which at least two of said members are secured to said duct.

8. In apparatus for controlling the effluence of a high-velocity stream from a discharge port, means for diffusing said stream at velocities of 0.4 Mach and greater, for preventing the generation of noise and for attenuating noise associated with said stream comprising a plurality of tandem nested conical perforated members having substantially unobstructed perforations, having their apexes pointing downstream and arranged to be directly and successively impacted by said stream as said stream issues from said discharge port and acoustic attenuating duct means having an entrance section, an exit port and a passageway therebetween, said passageway being oriented relative to said perforated members to receive said

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stream after it passes successively through said members, said tandem perforated members being disposed within said duct means adjacent said entrance section and said entrance section being adapted to enclose said discharge port.

9. Noise attenuating apparatus for controlling the effluence of a high velocity stream at 0.4 Mach and greater from a discharge port comprising a casing having an inlet section adapted to be coupled with and to substantially enclose said discharge port, diffuser means mounted within said casing in said inlet section in a position to be directly impacted by substantially all of said high velocity stream as it leaves said discharge port, said diffuser means comprising a plurality of nested, perforated, generally conical members having apexes pointing downstream, and acoustic attenuation means comprising a further section of said casing downstream of said inlet section enclosing a single, substantially unobstructed acoustic attenuating passageway, said passageway comprising a generally straight perforated conduit substantially coaxial with said diffuser means and spaced from said casing for defining an annular space, and acoustic absorbent material within said space.

10. In apparatus for controlling the effluence of a stream at velocities near Mach 1 from a discharge port, means for diffusing said stream, for preventing the generation of noise and for attenuating noise associated with said stream, particularly low-frequency components thereof, comprising an acoustic attenuating duct, a plurality of nested perforated generally conical members within said duct, the apexes of which members point in the direction of movement of said stream and the bases of which are adapted to directly receive said stream as it issues from said exit, said duct comprising a casing enclosing a single, straight, substantially unobstructed passageway and including an acoustically transparent duct liner backed by acoustically absorbent material.

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11. In apparatus for controlling the effluence of a stream at velocities near Mach 1 from a discharge port, means for diffusing said stream, for preventing the generation of noise and for attenuating noise associated with said stream, particularly low-frequency components thereof, comprising an acoustic attenuating duct, and a plurality of nested perforated, generally conical members within said duct, the apexes of which members point in the direction of movement of said stream and the bases of which are adapted to directly receive said stream as it issues from said exit, said duct comprising a casing enclosing a single straight, substantially unobstructed passageway and a center body including acoustic attenuation means within said duct and spaced from the boundaries thereof.

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