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[54] **METHOD AND DEVICE FOR ATTENUATING THE NOISE GENERATED BY THE EXPANSION OF GASES INTO THE ATMOSPHERE**

[72] Inventors: **Henri Coanda; Constantin Teodorescu,** both of Bucharest, Romania

[73] Assignee: **Institutual Pentru Creatre Stiintifica si Technica,** Bucharest, Romania

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[58] **Field of Search**.......181/33 R, 33 C, 33 E, 33 H, 181/33 HA, 33 HB, 33 HC, 33 HD, 33 HE, 41–43, 48–51, 35 R, 59, 36 R, 36 D, 36 C

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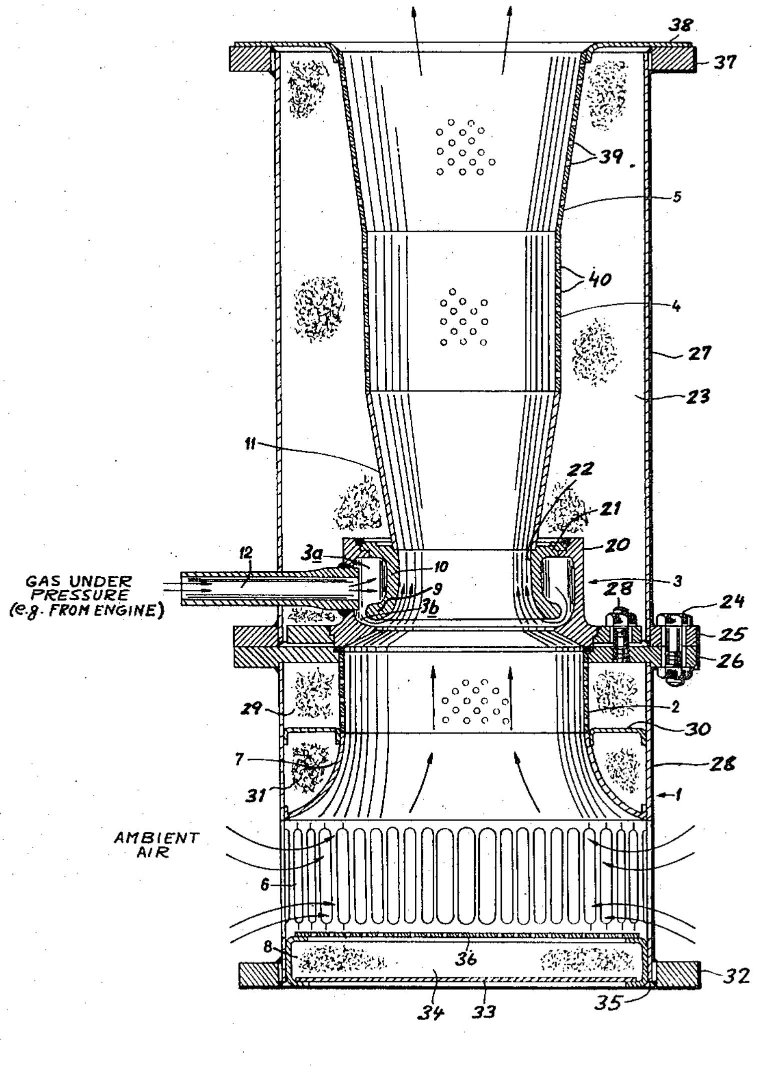
Primary Examiner—Robert S. Ward, Jr.
Attorney—Karl F. Ross

[57] **ABSTRACT**

A noise or sound attenuator useful for a motor vehicle internal-combustion engine has an elongated conduit which is formed at one end with a plurality of laterally opening inlets. The gas is fed into the center of the conduit through an annular slot whose downstream lip is shaped to entrain the gas jet along the wall of the conduit. This Coanda ejector action sucks air into the inlets to mix with the gas, while the noise of the gas being expelled is directed mostly against the flow direction into a sound absorber located in the closed upstream end of the conduit. The walls of the conduit are perforated upstream and downstream of the nozzle and lined externally with sound absorbing material for best noise attenuation.

10 Claims, 1 Drawing Figure



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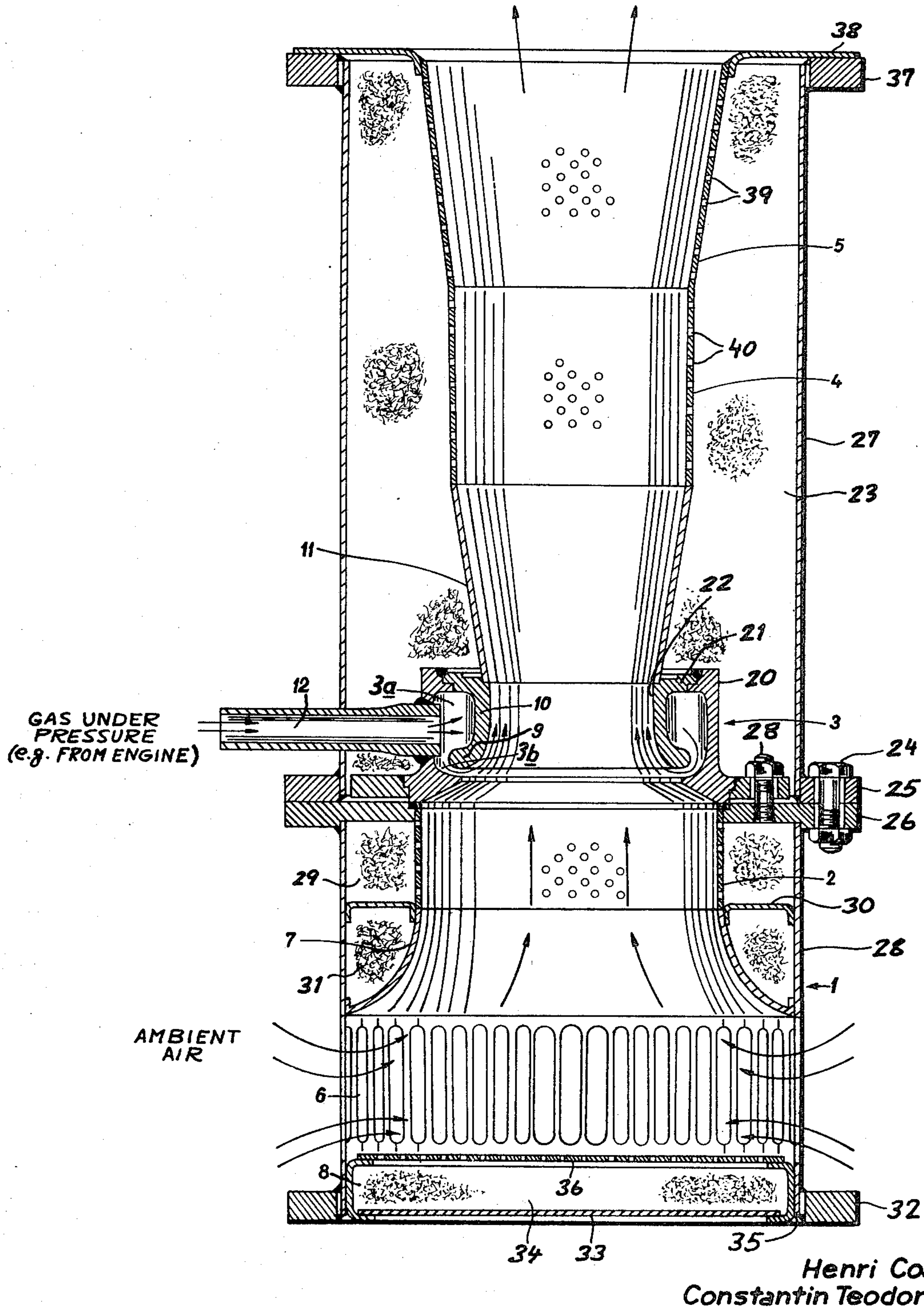

Henri Coanda
Constantin Teodorescu
INVENTORS.

BY

Karl G. Ross
Attorney

METHOD AND DEVICE FOR ATTENUATING THE NOISE GENERATED BY THE EXPANSION OF GASES INTO THE ATMOSPHERE

FIELD OF THE INVENTION

The present invention is related to a method of and a device for attenuating the noise generated by the discharge of the gases into the atmosphere, in this case for the exhaust of internal-combustion engines, for steam and air purging conduits, as well as for other pipes by which gases are blown off into the atmosphere.

BACKGROUND OF THE INVENTION

There are known methods for the attenuation of the noise of exhaust gases which utilize the sound-absorbing properties of certain materials, the ejection effect of the jet, or modification of the shape of the flow.

The main disadvantage of these methods is that attenuation of the noise is achieved only within a relatively restricted high-frequency range, leaving practically unattenuated the low and the very low frequencies, while for low-frequency sound attenuation bulky installations are necessary.

In the present state of the art, attenuation of the noise generated by the expansion of gases into the atmosphere is achieved by means of active silencers, reactive silencers, multisection silencers, and silencers with depressive shutters.

The active silencers are basically conduits whose inner surfaces are lined with sound-absorbing material. They are built in various versions: with simple chambers, with lamellar or cellular elements, and with chambers and screens.

The simple chamber silencer consists of a tube made out of steel plate or similar material to which the sound-absorbent treatment may be applied only at the walls or may be dispensed with. In the latter case noise attenuation is achieved by restricting the flow and possibly cooling the gas.

For the purpose of increasing the sound-absorbing capacity within a broader frequency range large-section conduits are divided into a series of subconduits with small dimensions by sound-absorbing plates or baffles parallel to the flow direction and arranged in line with one or both axes of the section of the conduit to form a lamellar or cellular silencer.

The chamber-and-screen silencer consists of one or several chambers acoustically treated and separated by means of screens arranged perpendicularly or obliquely to the path of gas flow. Noise attenuation is achieved by reflection of the acoustic waves by the screens.

The reactive silencer is an acoustic system whose particularity lies in the capacity to allow passage practically without attenuation of sounds of a certain frequency while damping or reflecting towards the source sounds of the remaining frequencies. This acoustic system consists of several chambers successively joined to one another by tubes. Each chamber with its junction constitutes a resonator which damps within a certain frequency range.

The multisection silencer achieves the partial attenuation of noise by increasing the mixing of the gas stream with the surrounding air, the increase of initial turbulence being avoided at the same time. In these conditions, quick diminution of the gas velocity is attained along the jet's axis along with attenuation of the low- and medium-frequency noises.

There are likewise known nondirectional silencers used specially for the attenuation of the noise generated by the exhaust of internal-combustion engines. The particularity of these silencers consists in the spiral or baffle form of the conduits which are provided with orifices or groups of orifices arranged in certain arrays and sometimes accompanied by deflecting cups covering the orifices. Noise attenuation by these silencers is obtained by way of the fragmentation of the gas flow and reflection of the sound waves upstream.

The depressive-shutter silencers achieve the attenuation of the noise by diffraction of the acoustic waves as they pass through depressive networks, the absorption of the waves which have undergone the diffraction being obtained by a sound-absorbing treatment on the lined shutters of the networks and by the intensification of the turbulent mixture of the elementary jets which leave the depressive networks with a surrounding air in the deviating process by way of the Coanda effect (see *Time*, p. 49, Dec. 2, 1966, and *Scientific American*, pp. 81 ff., December 1964). Except for the depressive-shutter-type silencers, the above silencers all have the disadvantage that they attenuate noise only within a very restricted frequency range, leaving unattenuated the low and the very low frequencies. In order to combat this, large overall dimensions of the silencer are necessary making its construction expensive and limiting its usability. Furthermore, in lamellar silencers, cellular silencers, and silencers with chambers and screens, the high-velocity and high-temperature gases rapidly degrade the inner elements of the silencer, putting it out of use after a short working period.

The depressive-shutter silencers while achieving a good attenuation of the noise within a broad frequency range present nevertheless the disadvantage of large overall dimensions and excessive complexity.

OBJECTS OF THE INVENTION

It is therefore an object of the present invention to provide an improved method of and apparatus for attenuating noise at a high-pressure gas outlet.

Another object is the provision of an apparatus for attenuating exhaust gas noise of an internal-combustion engine.

Yet another object is to provide such a noise attenuator or silencer which is effective over a broad frequency range, is of simple and inexpensive construction, and has a long service life.

SUMMARY OF THE INVENTION

The above objects are attained according to the present invention by releasing the high-pressure and high-temperature exhaust gases through an annular nozzle of a so-called Coanda ejector into the passage of a conduit. The ejector, which functions according to the well-known Coanda effect, entrains gases longitudinally while it is fed transversely with the fluid. More specifically this ejector has a nozzle which is so shaped that the gases tend to flow around one lip and thence travel along the conduit in one direction while the noise of the escaping gases travels down the conduit in the opposite direction, since this sound is in no way influenced by the Coanda effect. Thus the escaping gases define a flow direction in the conduit and act as a jet pump to draw air in through the upstream end of the conduit. This inlet end is provided with lateral openings for air ingress while its inner surface is provided with sound-absorbing material to deaden the noises of the escaping gases.

Due to the high velocity of the escaping gases the sound they produce will be relatively high-pitched, so that attenuation can be carried out with little difficulty. At the same time the mixing of the exhaust gases with large quantities of air reduces their heat substantially while possibly causing oxidation of many of their harmful constituents.

For the purposes of the present invention, a Coanda ejector will be defined as a fluid ejector wherein the entraining fluid is caused to flow through the ejector constriction, upstream of a coaxially diverging passage or chamber, by the Coanda effect adhesion of the boundary layers of fluid to the surface of the constriction which, as already noted, form an outwardly turned annular lip defining a slot into which the fluid is introduced transversely. Consequently, air or other sound-damping, temperature-reducing and diluting fluid is caused or induced to flow through the constriction and is entrained by the Coanda effect fluid hugging the walls of the Coanda ejector. In practice, therefore, the transverse introduction of the Coanda effect fluid, in which sound-damping or noise attenuation is desired, constitutes a direction change and velocity-reducing type of absorber because, while the fluid passes along the walls of the Coanda ejector by a direction change attributable to the Coanda effect, noise or sound propagation continues with the direction substantially unchanged until it is intercepted by the transverse flow of air passing longitudinally through the passage. While air is induced to flow through the ejector because of the Coanda entrainment, a pressure differential is established across the constriction because of the ejector effect with the relatively high-pressure side upstream. Both the movement of the air through the ejector and this somewhat elevated pressure constitute a sound interference barrier causing substantial noise attenuation apart from the attenuating effect of the sound-absorbing material at the upstream side of the ejector and the perforations in the wall of the passage at this upstream side.

At the downstream side of the ejector, any sound transmitted in the longitudinal direction of flow of the Coanda fluid is attenuated by the relatively long flow path and the sound-absorbing material lining same.

The method according to the invention envisages in a first phase the expansion of the gases within a Coanda inner-type ejector, such that simultaneously with throttling of the jet, structural modification of the acoustic spectrum and its direction takes place, as well as a substantial lessening of its velocity, of its temperature, and of the concentration of its gases, a process continued in a second phase by the absorption of the acoustic waves by two active silencers mounted upstream and downstream of the inner-type Coanda ejector.

The device according to the above method consists of a convergent inlet nozzle for air connected to an inlet attenuator of decreasing cross-sectional area, an inner-type Coanda ejector followed by a diffuser, an outlet attenuator and a discharge nozzle. The converging inlet nozzle, which is formed by a network of laterally opening slits and a converging channel, has a damping screen placed at an adequate distance such that the penetration of the surrounding air through the slit network is possible, while the propagation of noise of the ejector is impossible. The Coanda ejector has an annular chamber into which the exhaust gases are fed through a pipe, and whence they pass through an annular slit in the shape of a jet, the gases adhering to the wall or surface of the converging part of the Coanda ejector, flowing along a neck to the inferior part of the outlet diffuser, and thence to the outlet attenuator end of the discharge nozzle. Sound-absorbing walls similar to those of the inlet nozzle and of the damping screen are provided in the outlet side of the apparatus.

DESCRIPTION OF THE DRAWING

The above and other objects, features, and advantages will become apparent from the following, reference being made to the drawing whose sole FIGURE is an axial sectional view through the apparatus according to the present invention.

SPECIFIC DESCRIPTION

The device according to the invention is formed of an inlet nozzle **1** for the inspired air, an inlet attenuator **2**, a Coanda ejector **3** of the inner type, an outlet attenuator **4**, and a discharge nozzle **5**.

The inlet nozzle **1** of the ejected air is made of a network of laterally opening slits **6**, a converging channel **7**, and a damping screen **8**. This nozzle **1** insures the entry of the surrounding air into the device and hinders the propagation of the ejector's noise to the exterior.

The inlet attenuator **2** is a conduit of circular or rectangular section whose walls are perforated and lined externally with sound-absorbing material. The length of the conduit and the type of acoustic material being dictated by the attenuation degree required.

The inner-type Coanda ejector **3** consists of an annular chamber **3*a***, having a lip **9** formed continuously with a cylindrical neck **10**, downstream of which is provided a diffuser **11**. The converging part **9** is precided by an annular slit **3*b*** through which is discharged the gas under pressure arriving in the annular chamber **3*a*** through a pipe **12**. The outlet attenuator **4** is similar to the inlet attenuator **2**, its geometry being determined by the diameter of the downstream end of the diffuser **11** and the type of noise generated by the annular jet at the planar annular slot or nozzle **3*b***.

The discharge nozzle **5** is a diffuser whose shape is determined according to the shape of the inner-type Coanda ejector **3** and by the parameters of the expansion gases.

The drawing also shows that the inlet pipe **12** opens radially into the annular chamber **3*a*** which is defined by a ring **20** into which the tube **12** is welded and which, in turn, is welded to the nozzle-forming ring **21**. The interior of the latter defines the Coanda constriction and surface **22** which, in combination with the axially outwardly divergent wall **11**, forms a laval-type nozzle. The wall **11** and the ring **20** are shown to be surrounded by the body **23** of sound-absorbing material within the cylindrical sheet-metal casing **1** and to be nonperforated. The sound-absorbing material, which may be a fleece or wool of refractory sound-absorbing materials, e.g. asbestos fiber or glass wool. The housing **1** is assembled by bolting together at **24** a pair of flange rings **25** and **26**, respectively welded to the housing sections 27 and 28, these rings serving also as supports for the Coanda ejector. The Coanda ejector 3 is bolted at 28 to the inner portion of the ring 26 which serves as a spacer supporting the perforated cylindrical metal wall 2 which, as illustrated, is surrounded by a body of the sound-absorbing material represented at 29. This body of sound-absorbing material is separated by an annular partition 30 from the annulus 31 of sound-absorbing material surrounding the rearwardly outwardly flared unperforated intake cone 7 previously described.

At the rearmost end of the muffler, we provide a reinforcing end support ring 32 in which the sound-absorbing wall 8 is mounted. This wall comprises a sheet-metal disk 33 retaining the layer 34 of sound-absorbing material within the flat cylindrical housing 35 whose face, turned toward the passage, is provided with the perforated wall 36.

Another reinforcing and mounting ring 37 at the opposite end of the sound-absorber supports a sheet-metal disk 38 which, in turn, carries the downstream end of the frustoconically diverging outlet-conduit portion 5 which, as illustrated, is formed with perforations 39. The cylindrical conduit section 4 immediately upstream thereof is provided with perforations 40 and both conduit sections are surrounded by the body 23 of sound-absorbing material.

The device works as follows:

The gases which are to be discharged into the atmosphere are directed by means of the pipe 12 into the annular chamber 3*a* and from here they traverse the annular slit 3*b* in the form of an annular jet. Due to the Coanda effect the annular gas jet adheres to the surface of the converging nozzle 9, passes up over the neck 10, and creates within the restriction at this intermediate conduit region a violent sucking-in of the upstream air. The gases or steam mix with the cold air, cool intensely, and advance through the diffuser 11 and the outlet attenuator 4 with a substantially reduced velocity. From the outlet attenuator 4 the gas and air mixture passes into the discharge nozzle 5 where it is throttled further because of the gradual increase of the transverse cross-section, and from here it is discharged into the atmosphere.

The passage of the gases transversely through the annular slit 3*b* determines the change of the structure of the noise generated by the free jet by displacing the acoustic spectrum into the range of the high and of the very high frequencies which can easily be attenuated by the sound absorbing portions 2, 4, 5, and 8 of the device. The deviation of the annular jet within the ejector 3 is not followed by its noise so that the predominant components of this noise are directed towards the sound absorber 8 of the entry attenuator. In this way the acoustic energy of the incident waves is quickly dissipated along with the noise propagated downstream of the device. Likewise, due to the higher pressure existing ahead of the ejector, the propagation upstream of the acoustic waves generated by the annular jet is rendered more difficult. Since in the discharge nozzle 5 the velocity of the gas and air mixture is correspondingly diminished, the discharge of the mixture into the atmosphere takes place practically noiselessly.

The present invention offers the following advantages: it achieves a strong attenuation within the whole audible frequency range, it has both constructive and working simplicity, it has small dimensions and requires a minimum of materials, it has a long service life, and it diminishes the polluting effect of the escaping gases.

We claim:

1. A method of attenuating the sound of a gas released under pressure into the atmosphere comprising the steps of:
   - feeding said gas under pressure transversely into an intermediate region of an elongated passage;
   - passing said gas in only one direction along a wall of said passage by the Coanda effect while projecting the sound of said gas principally in the opposite direction;
   - drawing ambient air longitudinally through said passage in said one direction by entrainment of said air by the gas passing along said wall; and
   - absorbing the noise of the ejected gas upstream and downstream of said region.

2. The method defined in claim 1 wherein said ambient air is drawn laterally into said passage, thereafter is mixed with said gas, and thereafter is expelled into the atmosphere.

3. An apparatus for attenuating the sound of a gas released under pressure into the atmosphere comprising:
   - a conduit forming an elongated passage open at both ends to the atmosphere;
   - means including an annular transversely open nozzle for feeding said gas under pressure transversely into said passage;
   - means forming an annular surface in said conduit at said nozzle for entraining said gas by the Coanda effect along the interior of said conduit and drawing air through said passage; and
   - means for absorbing sound along said passage upstream and downstream of said surface.

4. The apparatus defined in claim 3 wherein said conduit has a closed upstream end and an open downstream end, said conduit being formed with at least one transversely open inlet at said upstream end and being outwardly tapered from said surface to said downstream end.

5. The apparatus defined in claim 4 wherein said gas is the exhaust of a heat engine or steam or air from a purging channel and said means for absorbing sound includes at least one sound absorber in said closed end upstream of said inlet.

6. The apparatus defined in claim 3, further comprising a housing surrounding said conduit and said nozzle, said means for absorbing sound along said passage including at least one body of sound-absorbing material filling said housing around said conduit and said nozzle.

7. The apparatus defined in claim 6 wherein said conduit includes an outwardly divergent diffuser section immediately downstream of said nozzle, a perforated cylindrical outlet attenuator section immediately downstream of said diffuser section and surrounded by said body, and an outwardly flared discharge nozzle section opening directly into the atmosphere and immediately downstream of said attenuator section, said discharge section being perforated and being surrounded by said body.

8. The apparatus defined in claim 7 wherein said conduit further comprises a perforated cylindrical inlet

attenuator section surrounded by said body and disposed immediately upstream of said nozzle, and a rearwardly flared section communicating with and immediately upstream of said inlet attenuator section, said apparatus further comprising a cylindrical inlet immediately upstream of said rearwardly flared section and provided along its periphery with a multiplicity of axially extending slits communicating between the atmosphere and said conduit, and a sound-absorbing wall

spanning the end of said cylindrical inlet.

9. The apparatus defined in claim **8** wherein said means forming said annular surface is a Coanda ejector of the inner type.

10. The apparatus defined in claim **9**, further comprising means for connecting said Coanda ejector to the exhaust outlet of an internal combustion engine or to a steam or air purging channel.

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