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(54) Resonator

(57) The present invention relates to a resonator for attenuation of preferably low-frequency noises. More specifically, the invention relates to a resonator, wherein the stream is split into one primary stream and one secondary stream, the secondary stream being produced by short-circuiting the flow tube of said stream. In this manner the part of the flow pipe delimited by the short-circuit in which said primary stream flows forms a resonance volume in a resonator of Helmholtz type. Thus, the main part of the stream may be made to flow through the resonance volume and this volume may be used for other types of attenuation.

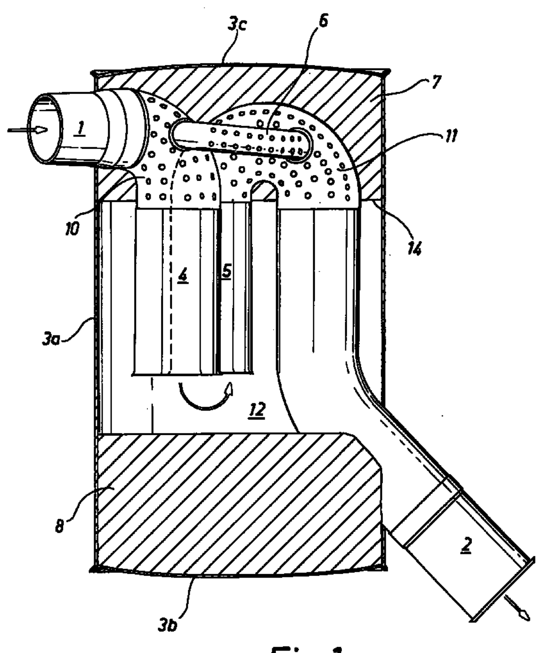

Fig. 1

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Description

Technological Field

The present invention relates to a device for reactive or non-dissipative attenuation of noise generated in stagnant or flowing gaseous media. More particularly, the invention concerns a device for attenuating low-frequency noise by means of a resonator structure similar to a Helmholtz-type resonator. The invention is primarily applicable for noise attenuation in internal combustion engine systems but could likewise be used in fan systems, pneumatic systems and in closed systems.

Background

Many different types of prior art noise attenuating devices or mufflers are known. Generally, methods of noise attenuation may be placed in two general classifications: resistive or dissipative attenuation and damping by reflection. Damping by reflection comprises i.e. interference attenuation and attenuation by introduction of flow resistance. Resistive attenuation is effected with the aid of absorbing material and the like, and preferably it is used for higher frequency attenuation. Attenuation by reflection is based on sudden volumetric changes of the moving stream, whereby a part of the noise is reflected back upon such volumetric changes. By introducing flow resistance, the flow energy is reduced, and thus the energy of the noise waves. Attenuation by interference, finally, is based on the principle of two waves, in anti-phase, cancelling each other out. Attenuation by interference may be achieved by splitting the moving stream into substreams flowing over different-length distances, causing noise of certain wave-lengths to be in anti-phase condition when recombined, thus being cancelled out. Attenuation by interference could also be achieved by means of an expansion chamber wherein the reflections cause standing waves to form inside the chamber, thus attenuating certain frequencies of the noise in the moving medium. Another manner of achieving noise attenuation by means of interference is to use resonance volumes, so called resonators. These are based on branching off a tube from the main tube into a resonance volume whereby the moving stream in the main tube will cause the resonance volume and the branch tube to oscillate as a spring-mass system at certain resonance frequencies, thus causing attenuation of this frequency of the noise in the main tube by interference.

The majority of prior-art noise attenuators combine a number of different attenuation methods in order to produce a device attenuating noise within as large a frequency band as possible.

One example of a noise attenuater based on the introduction of flow resistance is disclosed in the publication SE 441 205. The noise attenuator described in this publication utilizes changes of direction and different transitional cross-sections for the moving stream in order to thus attenuate the noise. In this noise attenuator, voids are likewise used as resonance volumes juxtaposed to the main stream. A disadvantage of this type of attenuator is however, the considerable pressure drop across the attentuator, leading to unnecessarily high energy consumption.

There are many examples of noise attenuators based on interference. The publications GB-2 222 852 and DK-142 467 furnish examples of attenuators by interference wherein the stream is split into several substreams which, when recombined, have travelled over different distances and therefore cause attenuation of the noise waves which are in anti-phase owing to the difference in the length of travel. In accordance with the latter publication only the acoustical stream is subdivided whereas the moving stream in principle remains undivided. This is effected by providing the noise attenuator with diaphragms capable of transmitting noise waves but essentially impermeable to the moving medium. A disadvantage with this type attenuators is, however, the comparatively poor attenuation capacity.

Expansion volume mufflers are exemplified for instance in DE 716 329, SU 1 423 755, FR 2 261 414 and DE 3 711 029. These mufflers are based both on interference by the formation of standing waves in the expansion volumes and on the reflection of the noise waves generated by the sudden cross-sectional changes of the flow tubes. Furthermore, several of the described mufflers are combined with other attenuation methods, such as absorbtion or velocity barriers. A disadvantage inherent in this kind of mufflers is however, that the expansion volumes are highly space-requiring, making these mufflers comparatively large and unmanagable.

A resonator provides highly satisfactory attenuation near the resonance frequency. Examples of resonance attenuators, resonators, are found in the publications DE 760 362 and US 4 892 168. The resonator of DE 760 362 comprises a considerable volume surrounding a flow tube, which volume communicates with said tube via one or several openings. A disadvantage of this resonator is however, that like the expansion volume mufflers referred to above it has a considerable volume, resulting in poor space economy. The flow past the opening into the resonance volume likewise causes undesired edge effects and interference phenomena to occur readily, resulting in less efficient noise attenuation from the resonator, particularly at high flow rates of the moving stream. This disadvantage is partly overcome by the resonator described in US 4 892 168. The noise attenuating device described in this publication is formed with separate inlet and outlet openings into and out of the resonance volume, causing a reduced flow through this volume. The noise attenuation of the main stream flowing past the resonance volume will be less affected by interfering effects around the openings. The disadvantage that the resonance volume is space-requiring while at the same time it cannot in any efficient manner be utilized for any other kind of attenuation remains also in the case of this resonator.

Object of the Invention

The object of the subject invention is to provide a noise muffler of resonator type which efficiently attenuates particularly low frequency noises.

A further object of the subject invention is to design the resonance volume in such a manner that it may simultaneously be used as an expansion chamber and/or an absorbtion chamber.

A further object of the invention is to configure the inlet to the resonance volume in such a manner that interference phenomena, particularly upon high flow velocities of the gas medium, are avoided.

An object of the invention also is to make it sufficiently flexible to allow it to be early adapted for attenuation of different predetermined frequencies, and to cause a low pressure drop across the muffler and thus to reduce the energy consumption.

Summary of the Invention

The present invention concerns a resonator for attenuating preferably low frequency noises. More specifically, the invention concerns a resonator, wherein the stream is split into a primary stream and a secondary stream, the secondary stream being achieved by short-circuiting the flow tube of the stream. In this manner the part of the flow tube delimited by the short-circuiting and in which the primary stream flows forms the resonance volume of a resonator of Helmholtz type. In this manner the main part of the stream may be conducted through the resonance volume and this volume may be used for other types of attenuation.

Brief Description of the Drawings

Fig. 1 illustrates a resonator in accordance with the present invention in a cross-sectional view as seen coaxially with the chamber volume axis.

Fig. 2 illustrates a resonator in accordance with the invention in a cross-sectional view as seen perpendicularly to the chamber volume axis.

Fig. 3 is measurement diagram illustrating the attenuation in a resonator in accordance with the subject invention.

Description of Preferred Embodiment

A preferred embodiment of the invention will be described in greater detail with reference to the accompanying drawings. The resonator illustrated in Fig. 1 comprises a closed cylindrical chamber volume 3 having a peripheral face 3a and two circular and slightly outwardly domed end plates 3b, 3c. A flow tube 1 enters the chamber volume in the vicinity of one of the end plates 3c and essentially at right angles to the peripheral face. Interiorly of the chamber volume the flow tube 1 comprises a tube bend 10 bent at 90°. Following the tube bend 10 a straight flow neck 4 descends downwards, towards the opposite end plate 3b. The flow neck 4 debouches in the chamber volume. Closely adjacent this mouth debouches the mouth of a second flow neck 5 which is arranged in parallel with the first flow neck 4. The second flow neck 5 is connected to a tube bend 11 bent at an angle of 180°. This tube bend is in turn connected to a tube 2 leading out of the chamber volume 3. A short-circuiting tube 6 extends between the two tube bends 10, 11. The short-circuiting tube 6 guides a part of the stream along a shorter path through the resonator. Absorbent material 7, 8 is positioned in the parts of the chamber volume that face the end plates in order to attenuate high frequency noises. Advantageously, this material encloses the tube bends 10, 11 and the short-circuiting tube 6. Because the tube bends 10, 11 and the short-circuiting pipe 6 are perforated by minute holes higher-frequency noise waves may be absorbed also in these sections of the tubes. However, in order to prevent a further short-circuiting flow through these perforations, a transverse partition 13 preferably is introduced between the tube bends 10 and 11, and also a partition 14 at right angles to the cylinder axis below the perforated parts of the tubes. In this manner separate volumes 15, 16 are obtained, preventing leakage current from forming on account of the perforations. In this manner, the flow is guided in a controlled manner and the acoustical properties become easier to control.

Preferably, the short-circuiting tube should be short in comparison with the wavelengths of the noise to be attenuated. Short refers to the acoustical length, which does not coincide with the actual length since the perforated parts of the tube may be neglected when the acoustical length is measured. Thus, the acoustical of the short-circuiting tube 6 essentially coincides with the non-perforated tube part 6a. Preferably, the short-circuiting tube should also be of considerably smaller diameter size than the rest of the tube parts since it is desirable that a larger proportion of the stream flows past the short-circuiting tube rather than through the same. In accordance with the embodiment the short-circuiting tube has a diameter of approximately 20-40 mm whereas the rest of the tubes have a diameter of approximately 100-150 mm. In other words, the rest of the tubes have a diameter size four times larger than the diameter of the short-circuiting tube. These dimensional values of the various tubes could, however, be changed in order to optimize the resonator for adaptation to various frequencies and flows. In the shown embodiment the flow necks have a length of about 250 mm whereas the chamber volume is twice that long and has a diameter of approximately 400 mm. Also these values may be varied for optimization of the resonator.

In operation of the resonator a stream flows into the resonator through the inflow tube 1. In the first tube bend 10 a part of the stream is separated into a secondary stream which passes through the short-circuiting tube 6 directly into the second tube bend 11. The remaining part of the stream, the primary stream, is however carried further into the chamber volume via the flow neck 4. At the mouth of the flow neck 4 the primary stream flows into the chamber volume 12, said chamber volume 12 acting as an expansion chamber thus attenuating a part of the noise waves in the stream. The absorbent material present at least on some of the chamber walls contributes to attenuating the noise additionally, in this case essentially noise of higher frequency. The second flow neck 5 then extends out of the chamber volume. In the next tube bend 11 the primary stream recombines with the secondary stream entering from the short-circuiting tube. Since the distance of travel of the secondary stream through the short-circuiting tube is straighter and shorter than the distance travelled by the primary stream, the secondary stream is the main stream acoustically speaking whereas the primary stream is the main stream from a flow point of view. Because the secondary stream is the acoustical main stream the primary stream could be regarded as a resonance volume of Helmholtz character. The Helmholtz resonator is based on a resonance volume positioned to the side of the acoustical main stream, it being possible to regard said volume as a spring-mass-system which at certain resonance frequencies is made to oscillate and thus to attenuate the noise waves in the main stream.

In an ideal Helmholtz resonator the reduction index R, i.e. the attenuation, may be expressed as

$$R = 10\log\left[1 + \frac{\tau^2}{(f/f_0 - f_0/f)^2}\right]$$

where the transmission factor τ is:

$$\tau = \frac{cA}{4\pi f_0 A_0 l_e}$$

and

$$f_0 = \frac{c}{2\pi}\sqrt{\frac{A}{Vl_e}}$$

the symbols of the equations indicating:

c =	the velocity of noise
A =	the area of the branched tube to the resonance volume
A_o=	area of principal tube
ℓ_e=	length ℓ_o of branched tube to resonance volume plus end correction ℓ_c
V =	volume of chamber
f =	frequency
f_o=	resonance frequency
ℓ_c=	may be neglected since flow velocity is high.

It is obvious that in a Helmholtz resonator the reduction is largest for frequencies around the resonance frequency whereas the attenuation of frequencies further away therefrom rapidly decreases. This behaviour is exhibited also by the resonator in accordance with the present invention, as may be seen in Fig. 3. In Fig. 3 the attenuation is illustrated as a function of frequency and it is quite obvious that the maximum value of the attenuation occurs at a frequency corresponding to the resonance frequency of the resonator.

The resonator in accordance with the embodiment preferably is made from a sturdy, stiff and durable material that is also cheap, such as sheet metal.

The above described embodiment of the present invention presents the advantages of allowing efficient attenuation of noise, also at higher flow velocities of the moving medium. The attenuation is achieved by guiding a large proportion of the stream through the resonance volume, on the one hand avoiding interference effects in the area of the openings into the resonance volumes and on the other hand allowing the resonance volumes to simultaneously be used for other attenuation techniques, for instance as an expansion chamber, to house absorbent material and the like, thus improving attenuation across a wide frequency range. The effects are achieved by short-circuiting the flow tube, the intermediate part of the flow tube serving as the resonator resonance volume. In addition, the resonator in accordance with the present invention lends itself to convenient adaptation to configurations that give efficient attenuation at different noise frequencies by simply changing the dimensions of the flow tubes, the short-circuiting tubes, the chamber volume, etc. In addition, the resonator in accordance with the present invention produces a very low pressure drop, resulting in lower energy consumption.

Several modifications of the above embodiment of the present invention are possible. The resonance volume forming part of the flow tube need not be used for other types of attenuation. Should this nontheless be the case other types of attenuation need not either comprise absorbtion and expansion but other attenuation techniques may be used to attenuate the noise in the stream moving through the resonance volume. Nor it is necessary, in the case of a resonance volume, for the flow necks to debouch in close vicinity to one another but their mouths could be positioned anywhere in the resonance volume and be spaced an optional distance apart. As already mentioned, the dimensions of the components incorporated in the resonator in accordance with the invention obviously may be altered to optimize the resonator for different fields of application and for attenuation of different-frequency noises. These and other obvious and related modifications of the present invention must be regarded as clearly falling within the scope of the invention as the latter is defined in the accompanying claims.

Claims

1. A resonator having a resonance volume for passive, noise attenuation of low-frequency noises in a stream, **characterized** in that the stream is short-circuited, at least once, whereby the stream is split into one primary stream and one secondary stream, the secondary stream being made to travel through the short-circuit and the primary stream delimited by the short-circuit forming the resonance volume.

2. a resonator as claimed in claim 1, **characterized** in that the primary stream is larger than the secondary stream.

3. A resonator as claimed in claim 1, **characterized** in that the primary stream flows through a flow tube (4, 5) and in that the short-circuit comprises a short-circuiting tube (6) having a short length in comparison with the wavelength of the noise to be attenuated and the diameter of which is smaller than the flow tube diameter.

4. A resonator as claimed in claim 3, **characterized** in that the flow tube (4, 5) within the short-circuited section of said tube leads respectively into and out of a closed chamber volume (12) serving as an expansion chamber.

5. A resonator as claimed in claim 4, **characterized** in that the chamber volume (12) is covered at least on one of its walls with an absorbent material (7) to attenuate higher-frequency noises.

6. A resonator as claimed in claim 1, **characterized** in that it is made from sheet metal.

7. A resonator as claimed in claim 3, **characterized** in that the flow tube (4, 5) has a diameter size which is at least three times larger than the diameter size of the short-circuiting tube (6).

8. A resonator as claimed in any one of the preceding claims, **characterized** in that it is primarily intended for attenuation purposes in internal combustion engine systems.

9. A resonator as claimed in claim 3, **characterized** in that the short-circuiting tube (6) is bent and perforated to shorten the acoustical length.

10. A resonator as claimed in claim 9, **characterized** in that at least around the perforated section of the short-circuiting tube (6) said tube is surrounded by absorbent material (7) for attenuation of higher-frequency noises.

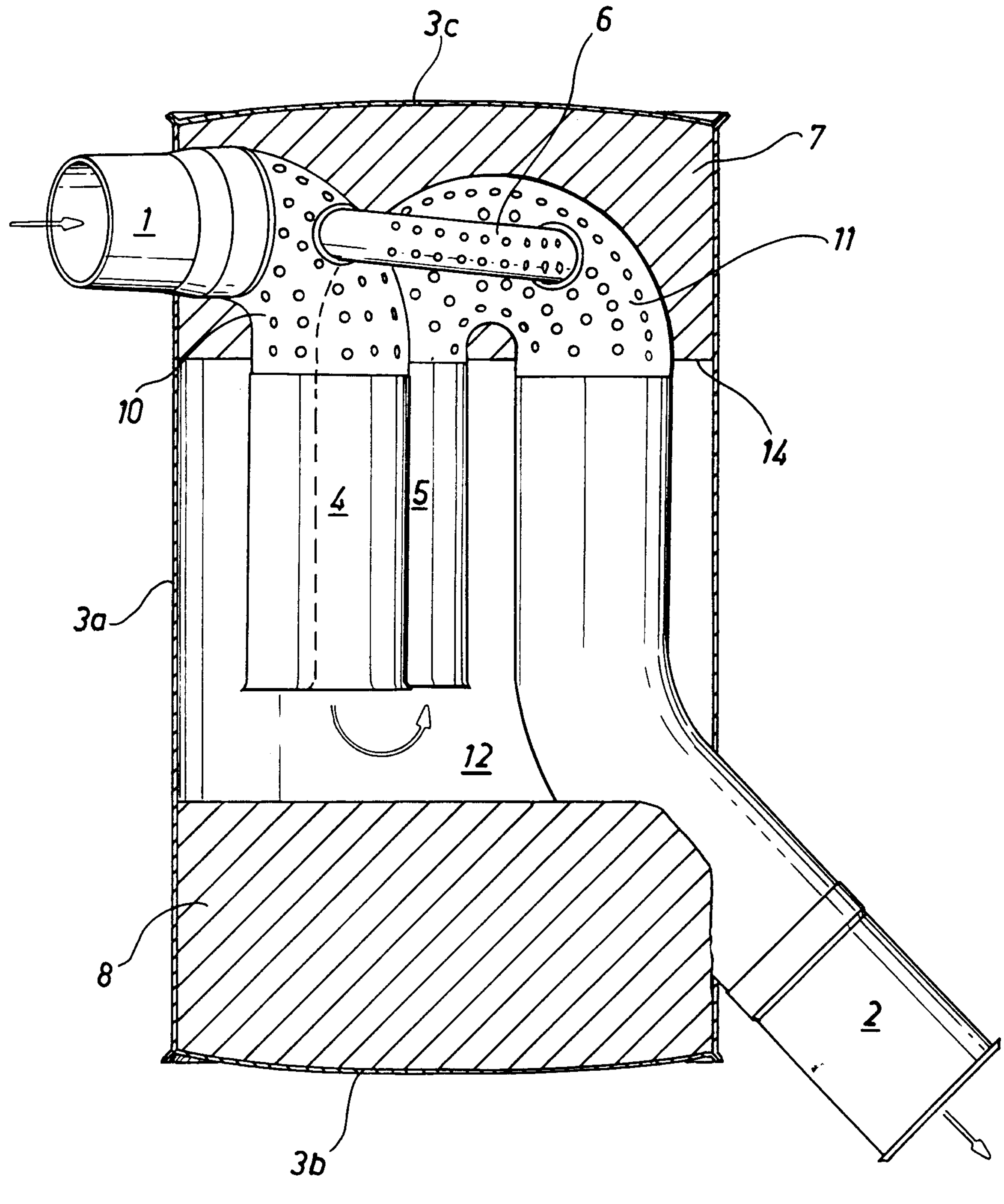


Fig. 1

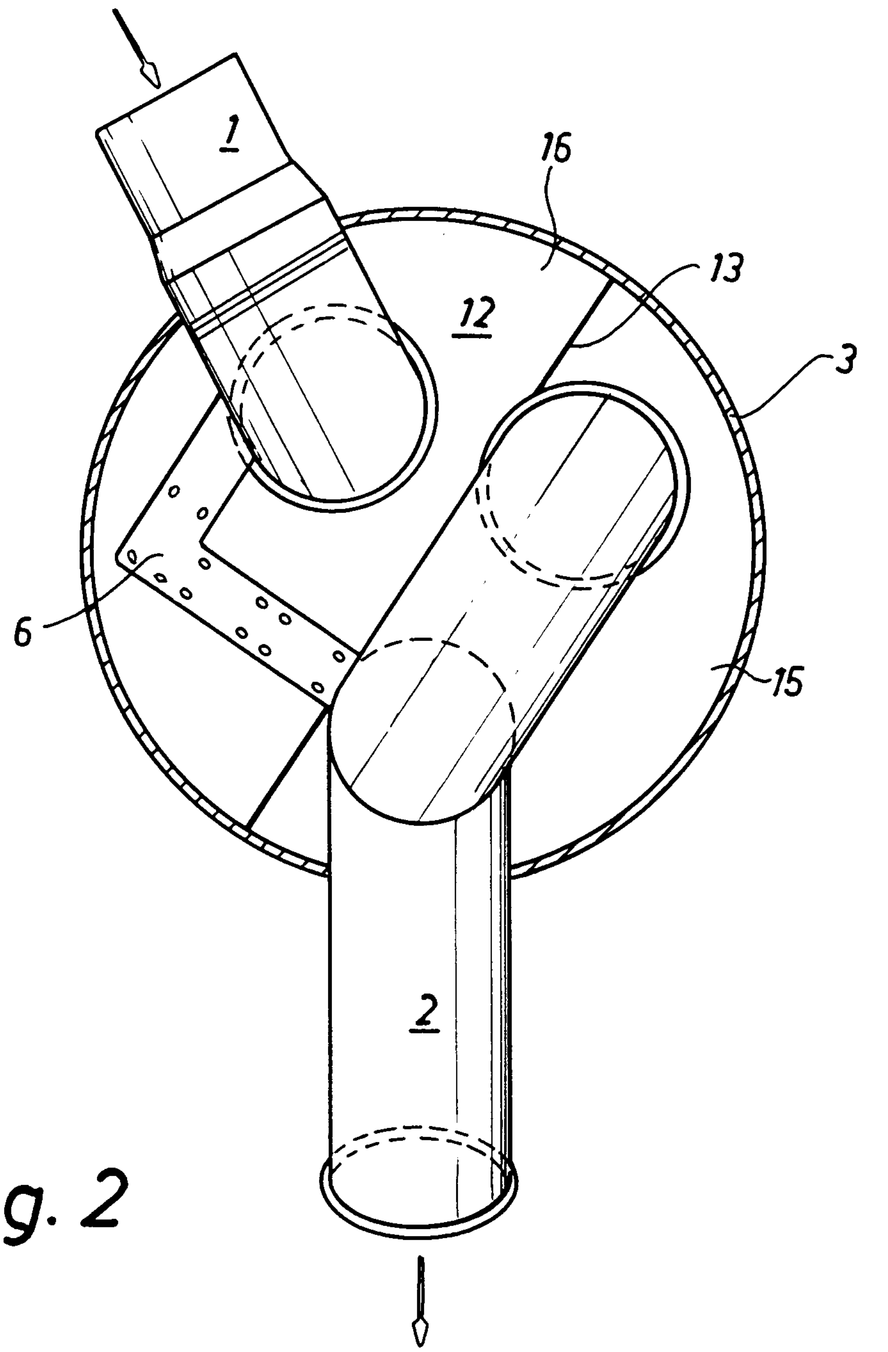
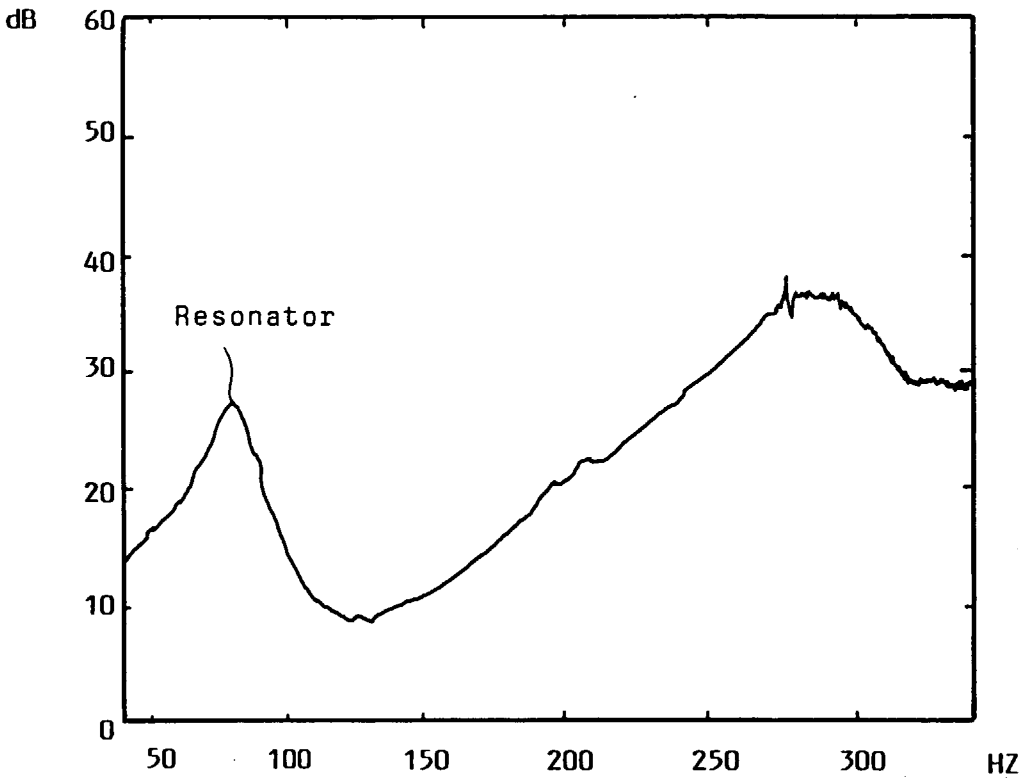


Fig. 2



Measured attenuation (Tl)

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.6)
X	Patent Abstracts of Japan, Vol 13,No 90, M-803, abstract of JP, A, 63-285213 (NISSAN MOTOR CO LTD), 22 November 1988 (22.11.88) --	1,6,8	F01N 1/02
A	SE, B, 441205 (ROBERT BOSCH GMBH), 16 September 1985 (16.09.85) * figures 1,2,3 * --	1	
A	US, A, 4892168 (A. SASAKI ET AL), 9 January 1990 (09.01.90) * figures * --	1	
A	DK, B, 142467 (GLASS CONTROL AB), 3 November 1980 (03.11.80) * figure 1 * --	5,6,8	TECHNICAL FIELDS SEARCHED (Int. Cl.6) F01N
A	GB, A, 2222852 (RUSSELL TIMOTHY BARTLETT), 21 March 1990 (21.03.90) * abstract * -----	1,5,6, 8,9,10	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
STOCKHOLM	6 March 1997	AXEL LINDHULT

CATEGORY OF CITED DOCUMENTS

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