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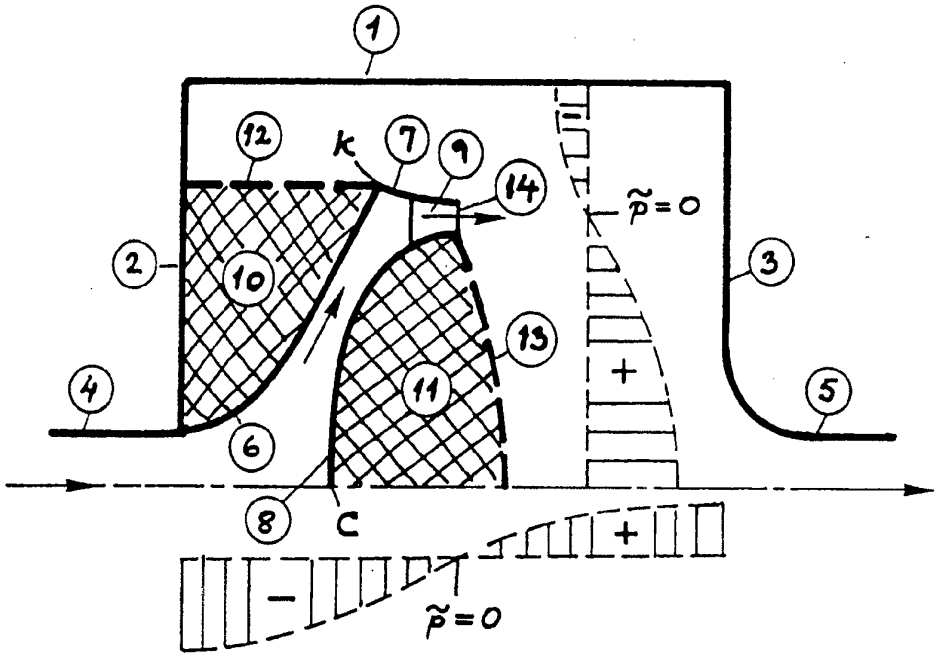

(57) Abstract

A silencer, preferably for exhaust gases from internal combustion engines, consisting of a container having a shell (1) formed essentially as a cylinder face, and two end bottoms (2, 3) as well as at least one admission pipe (4) and one discharge pipe (5) for exhaust gas, wherein the flow prior to entering the internal volume of the container is converted to a slot flow between an outer plate (6) and an inner plate (8), said plates being so shaped at their periphery as to form an exhaust gas discharge opening (14), which is positioned radially substantially symmetrically around the pressure node of a transverse oscillation in the container, said plates (6, 8) having a contour direction at the discharge opening (14) which is substantially perpendicular to the radial direction. Improved damping of transverse oscillations in the chamber of the silencer is hereby obtained by simple means.

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A silencer

The present invention concerns silencers to reduce noise in flowing gas media, preferably for incorporation into exhaust pipes from internal combustion engines.

Silencers for such uses are frequently either of the reflection silencer type, absorption silencer type or a combination of these two types. Both are characterized by giving a wideband damping in the acoustic frequency spectrum. Such a wideband damping is generally needed, since the unsilenced spectrum from the engine, although it may contain peaks, also contains a considerable share of all frequencies within the audible range.

Both reflection and absorption silencers are based on silencing mechanisms in connection with one or more chambers, typically in a container having an admission pipe and an exhaust pipe. The silencing effect is obtained in the reflection silencer in that sound energy is reflected at cross-sectional transitions between pipes and chambers. The effect of the absorption silencer is obtained in that sound energy is transmitted to a sound absorbing material, e.g. mineral wool, in which oscillatory energy is dissipated by internal friction in the gas and by interaction between the gas and the fibres of the absorbent.

The damping range in the frequency spectrum is different for the two silencer types. Since the effect of the absorption silencer requires standing waves in the absorbent, this gives a downward limitation in the spectrum. Also the effect of the reflection silencer is limited downwardly in the spectrum, viz. by the filter natural-frequency. This, however, is generally considerably lower. Thus, in many uses for internal combustion engines it is

difficult to obtain sufficient low frequency damping with absorption silencer alone. This is of importance, since precisely the most powerful frequency in the unsilenced spectrum, generally the ignition frequency of the engine (attributable to the cyclic process of the engine) is relatively low. A pure reflection silencer, or a combined reflection and absorption silencer is thus generally necessary.

The pure reflection silencer has the weakness that interfering passage frequencies occur in its damping spectrum, i.e. declines in the damping spectrum. These declines can be attributed to standing gas oscillations in the chambers. In some cases a decline may be so pronounced that it actually involves negative damping at the characteristic frequency, i.e. this frequency is amplified.

Incorporation of a sound absorbent in a reflection silencer can reduce the detrimental effect of passage frequencies to some degree, since standing oscillations in the chambers can be reduced by dissipation of oscillatory energy in the absorbent. In particular the basic natural frequency of a chamber can still occur with a considerable decline in the damping spectrum. The basic natural frequency of the chamber is frequently somewhat higher in the frequency spectrum than the filter natural frequency.

A known method of counteracting this decline comprises extending the admission pipe to the center of the first chamber. Such a geometry is expedient, because the basic natural frequency of a chamber has a pressure node precisely at the center. This means that oscillatory energy emitted here can excite the basic natural oscillation in the chamber only to a limited degree. Furthermore, this avoids excitation of all higher order natural frequencies which also have a pressure node in the center of the

chamber.

If such a positioning of pipe mouths to the chamber center is realized by a simple termination of the pipe, the positioning will be somewhat indistinct, since the sound emission takes place via a certain zone in the axial direction, a zone whose length is related to the pipe diameter.

This problem is solved according to Danish patent No. 128427 by terminating the admission pipe with a radial diffuser, from which the gas flow is directed into the chamber in the form of a thin veil whose extent in the axial direction is very small and therefore enables accurate positioning to the pressure node.

The change in direction, from axial to radial flow, involved by the radial diffuser does not necessarily entail significant irreversibility in the flow. If the geometry of the diffuser is appropriate, flow separation can be avoided.

A further advantage of using radial diffusers in reflection silencers according to DK patent No. 128427 is that the transverse plate of the diffuser reflects sound. This provides a sound reducing effect which is added to the initially mentioned reflection effect caused by the cross-sectional transition (from pipe to chamber), and to the above-mentioned effect that can be obtained by pressure node positioning.

The present invention is based on the finding that reflection silencers having radial diffusers enable almost complete elimination of passage frequencies corresponding to standing gas oscillations axially in the chambers, but not standing gas oscillations transversely thereto. In some uses this is not considered to be a serious drawback,

viz. when the mounting conditions make it natural to make the silencer elongated, so that the standing transverse waves correspond to relatively high frequencies that can be reduced relatively efficiently by means of the sound absorbent incorporated in the chambers.

However, there are uses of silencers, e.g. where the mounting conditions make it necessary or expedient to select a shorter embodiment with a container diameter which is large with respect to the pipe diameter. In such cases the use of a radial diffuser involves reflection of sound at the transverse wall in the diffuser and pressure recovery, two of the properties which are advantageous, as described above. On the other hand, positioning to the chamber center in an axial direction, while being expedient in principle, is of less importance because of the disadvantage that exact positioning to the node of the basic natural frequency, which is more serious in this case owing to lower frequency, of standing waves transversely in the chamber is not possible.

Transverse oscillations of passage frequencies are therefore of greater importance in short silencers. But this may also be important in those cases where the length of the silencer is somewhat greater than the diameter, viz. in the event that the silencer contains several chambers, one or more of which being shorter than the diameter.

In addition, e.g. French patent No. 800850 discloses a silencer of the type stated in the introductory portion of claim 1. This silencer is provided with a slot outlet along the shell walls in the silencer, which causes the gas flow to be conveyed into the chamber in the form of a thin veil. Since all rotation-symmetrical transverse oscillations have their pressure maximum on the inner side of the shell, they will hereby be excited. Of this basi-

cally infinite amount of oscillation modes, it is in practice primarily the lower order modes, and in particular the basic oscillation in the transverse direction which may give rise to interfering passage frequencies.

Accordingly, the object of the invention is to provide a silencer which exhibits improved properties with respect to damping of transverse oscillations in the chamber. This is achieved by the features defined in the charactering portion of claim 1.

Since the exhaust gas discharge opening is thus positioned radially substantially symmetrically about the pressure node of a transverse oscillation in the container, and so that the outer plate or the discharge opening is spaced from the shell, it is possible to construct a silencer which exhibits improved properties with respect to damping of transverse oscillations in the chamber, in particular as regards lower order transverse oscillations.

In most cases it will be practically interesting to utilize positioning in the pressure node which corresponds to the basic oscillation in the transverse direction, as stated in claim 2. However, there are cases where positioning in a pressure node of a higher order transverse oscillation instead may be expedient, in particular the first overtone, as is expressed in claim 3. It may e.g. be in silencers where the passage frequency corresponding to the basic oscillation is controlled in another manner, e.g. by positioning the discharge pipe from the shell in the pressure node of the basic oscillation. Another case may be that the frequency corresponding to the first overtone in the transverse direction is particularly predominant in the unsilenced spectrum before the silencer, and can therefore be given priority in the design of the frequency characteristic of the silencer.

The subject-matter of claim 4 provides damping of transverse oscillations together with a reasonable damping of axial oscillations in the container.

The subject-matter defined in claim 5 provides a diffuser effect of the medium flow and thus a lower back-pressure for the silencer.

When the discharge opening is constructed as stated in claim 6, the internal reflection of the sound waves is increased, leading to improved silencing.

The subject-matter defined in claim 7 or claim 8 provides an embodiment of the invention which is particularly easy to manufacture and thus inexpensive.

When a catalyst element is incorporated in the silencer, as stated in claim 10, good utilization of the total surface of the catalyst is obtained.

Particularly expedient embodiments of the invention will be explained more fully below with reference to the drawing, in which

fig. 1 shows a schematically axial section in a rotation-symmetrical embodiment of the invention,

fig. 2 shows another embodiment of the invention with a relatively flat design,

fig. 3 shows a distinctly flat embodiment with a reverse flow direction,

fig. 4 shows a fourth embodiment with a deflection of the exhaust gas without sharp bends,

fig. 5 shows an alternative embodiment of the invention,

fig. 5a shows a section at A-A in fig. 5,

fig. 6 shows a multi-chamber embodiment of the invention.

Fig. 1 shows an axial section of a rotation-symmetrical embodiment of the invention. The silencer is here defined by a cylindrical shell 1 and by end bottoms 2 and 3. The gas flow is conveyed into the silencer from the inlet pipe 4 and is discharged from the silencer by the discharge pipe 5. The double-deflecting element is composed of an outer plate 6, which forms an abrupt bend at the contour K to form the cover plate 7, and of the curved inner plate 8 and of a plurality of radial ribs 9, which are welded to both the cover plate 7 and the inner plate 8 to retain the latter. Sound absorbents 10 and 11, respectively, protected by perforated plates 12 and 13, are arranged around the inlet pipe 4 and behind the inner plate 8.

Pressure oscillation modes of basic natural frequencies in the longitudinal direction as well as in the transverse direction are plotted in the figure. The positioning of the gas flow to the pressure node will appear from this.

In a cylindrical chamber the node occurs approximately at two thirds of the radius, calculated from the center axis toward the inner contour of the shell. More precisely, the position can be calculated to 0.63 times radius. This result occurs by the solution of the partial differential equation called wave equation, which describes the rotation-symmetrical, three-dimensional gas oscillation field in the chamber.

On the face of it, it might be believed that the double-deflection involves considerable irreversibility, i.e.

contributes significantly to increasing the overall flow resistance of the silencer. However, a close analysis of the field of flow in the flow element shows that the double-deflection can be realized with a remarkably low loss. This advantageous property can be ascribed both to the rotation-symmetry of the flow element and to the fact that the center C of the transverse plate as well as the contour K constitute stagnation singularities in the field of flow. This can be explained as follows: In many types of pipe elements deflection of the flow involves a considerable friction loss. This is the case e.g. with a 90° pipe bend, even if it has an arc-shaped center line, e.g. without sharp bends. The reason why considerable losses occur nevertheless is that secondary flows occur in the bend, i.e. vortices having a center axis in parallel with the center line of the axis of the pipe. These vortices cause internal impulse losses in the field of flow. In the double-deflecting flow element of fig. 1 the rotation-symmetry ensures that such secondary flow phenomena can be avoided completely. Likewise a suitable embodiment of the double-deflecting element (e.g. with a geometry as shown in fig. 1) also avoids the type of vortices which can occur in less expediently constructed diffusers (e.g. with a too sudden expansion of area) because of flow separation along the contour wall of the diffuser.

Although it is thus possible to avoid vortex formations in the double-deflecting element, the flow will be turbulent in most cases, i.e. the smooth flow along flow lines will be superimposed by random particle movements in all directions. The average travel of such movements characterizes the degree of turbulence in the flow. This degree of turbulence is somewhat greater in the double-deflecting element than in a straight pipe flow, which involves a somewhat greater friction loss. However, in contrast to vortex flow, this loss is useful in the sense that it contributes

to the resistive acoustic resistance of the element, i.e. is associated with a silencing effect. Thus, it may be said that the double-deflecting element has a controlled turbulence degree.

The above-mentioned stagnation singularities in the flow may be explained as follows: A point singularity occurs in the center C of the inner plate; here the gas stands still. The flow is gradually decelerated along the central axis of the inlet pipe on its way toward C; this deceleration takes place almost completely without any losses (reversibly). Flow of gas particles along lines beginning on a slightly larger radius will also be decelerated on the way toward the inner plate, but not completely. Shortly before the inner plate the particles will be deflected to a preferably radial direction of flow, and then immediately be accelerated in a radial direction. Thus, the deflection takes place at a low flow rate, which contributes to explaining the low deflection loss.

The singularity C is also present in a radial diffuser, and the explanation of the low deflection loss in the change from axial to radial flow just given is well-known per se among those skilled in the field of flow technology. However, the corresponding stagnation effect occurring at the contour K in the double-deflection flow element of fig. 1 has not been described before, not even in the specialized flow literature. Here the greater part of the radial flow up toward the cover plate 7 will be decelerated almost reversibly and then be deflected at low rate toward renewed axial flow, so that, here too, an almost loss-free deflection of the flow is obtained.

Fig. 2 shows another, distinctly flat embodiment of the invention. The outer plate is omitted here, the inlet end bottom 2 serving the dual function of forming part of the

silencer boundary toward the surroundings and of forming the flow directing outer plate. Another difference from the embodiment of fig. 1 is that the discharge pipe 5 is shown to be laterally directed with respect to the longitudinal axis of the otherwise rotation-symmetrical silencer. An embodiment according to fig. 2 may e.g. be expedient in case of a silencer which is positioned below the engine of a truck with a downwardly directed admission pipe from the engine, the extension of the exhaust pipe being horizontal along the undercarriage.

As indicated in the figure, the embodiment may e.g. be combined with an elongate silencer of a known type.

Fig. 3 shows a third, likewise distincly flat embodiment of the invention. In this embodiment the inner plate coincides with the other end bottom 3 in such a manner that the double directional change of the gas flow results in a veil-like inflow to the chamber directly against the flow direction in the admission pipe. Directional changes will here involve a particularly efficient sound reflection in the double-deflecting flow element. Also the embodiment according to fig. 3 is almost rotation-symmetrical; the only deviation from rotation-symmetry is that the discharge pipe 5 is secured to the end bottom 2 on a certain radius.

The embodiment according to fig. 3 may e.g. be expedient in the positioning of a silencer below a truck engine like in fig. 2, but where the extension of the exhaust system is upward e.g. to a mouth at the level of the roof of the driver's cab. In some cases, as indicated in fig. 3, an elongate silencer of a known type may be incorporated in the upwardly directed discharge pipe.

Fig. 4 shows a fourth embodiment of the invention. This embodiment differs from those described above in that the cover plate forms an extension of the outer plate 6 without sharp bends, so that the contour K is omitted. This reduces the sound-reflecting effect of the double-deflecting pipe element to some degree. But e.g. in case of gas flows having a great content of soot, this embodiment may be appropriate in order to prevent accumulation of soot in the corner which is included in the double-deflecting flow element embodied with the contour K.

Figs. 5 and 5a show an embodiment of the invention in which the double-deflecting flow element is fork-shaped, enabling a split tangential flow veil into a silencer chamber. In all of the variants described above the veil flow is axial. An embodiment with a tangential veil may be expedient in those cases where the mounting conditions make it advisable to mount the admission pipe transversely to the shell 1, and not via the end bottom 2.

The tangential veil flow in the embodiment according to fig. 5 involves a slightly reduced possibility of positioning at the pressure node of transverse oscillations in the chamber in comparison with embodiments having an axial veil. The reason is that on an average the veil flow, which has a length of the order of some times the veil width, follows a cylinder face having a somewhat varying radius, seen in relation to a cylinder face concentric with the shell. When the shell diameter is not too small, this deterioration of the positioning is not of great importance however. It may moreover be reduced if the veil-like tangential flow to the chamber is withdrawn slightly (as shown in fig. 5), so that the center of the veil (seen in the axial direction of the admission pipe) is on the cylinder face of the pressure node in the chamber.

Fig. 6 shows an example of a two-chamber embodiment. The last one of the chambers here utilizes a flow element of the same type as in fig. 3, while a variant of a flow element according to the invention is additionally provided in the first chamber. Here, a ring channel 15 is interposed between the admission pipe 4 and the discharge opening 14. This variant enables an axial veil flow to the first chamber, even though the axial direction of the admission pipe is transverse to the axis of the container (like in fig. 5). Peripheral flow takes place in the ring channel, so that the exhaust gas, without a major loss of total pressure, can be distributed evenly along the periphery before flowing axially into the slot at the discharge opening.

The examples of embodiments of the invention shown above are built with a circular cylindrical shell and with a considerable degree of rotation symmetry. The basic ideas of the invention, however, are not bound to the circular cylinder shape. The shell may e.g. be conical or elliptic. This may e.g. be of interest in uses where the mounting conditions make it advisable for the silencer to have a flat shape.

In addition, it is possible to incorporate a catalyst or a heat exchanger such that these are positioned between the discharge opening 14 and the discharge pipe 5. The geometry of the discharge opening 15 will ensure a particularly good efficiency of the catalyst or the heat exchanger, since these are supplied with an even flow of exhaust gases over the entire active surface.

Patent Claims:

1. A silencer, preferably for exhaust gases from internal combustion engines, consisting of a container with a shell (1) formed essentially as a cylinder face, and two end bottoms (2, 3) as well as at least one admission pipe (4) and one exhaust pipe (5) for exhaust gases, wherein the flow prior to entering the internal volume of the container is converted to a slot flow between an outer plate (6) and an inner plate (8), said plates (6, 8) being so shaped at their periphery as to form an exhaust gas discharge opening (14), said plates having a contour direction which is substantially perpendicular to the radial direction, characterized in that the discharge opening (14) is positioned radially substantially symmetrically around pressure nodes of a transverse oscillation in the container, and so that the outer plate (6) at the discharge opening (14) is spaced from the shell (1).

2. A silencer according to claim 1, characterized in that the discharge opening (14) is positioned radially substantially symmetrically around pressure nodes of the basic oscillation in the container.

3. A silencer according to claim 1, characterized in that the discharge opening (14) is positioned radially substantially symmetrically around pressure nodes of the first overtone in a transverse direction.

4. A silencer according to one of claims 1-3, characterized in that the discharge opening (14) is positioned axially around the pressure node of an axial oscillation in the container.

5. A silencer according to one of claims 1-4, c h a r a c t e r i z e d in that the total cross-sectional area of the discharge opening is greater than the cross-sectional area of the admission pipe.

6. A silencer according to one or more of the preceding claims, c h a r a c t e r i z e d in that at a location between the admission pipe (4) and the discharge opening (14) the outer plate (6) has an abrupt directional change in the contour of the plate (6) to form the cover plate (7).

7. A silencer according to one or more of the preceding claims, c h a r a c t e r i z e d in that the outer plate is formed completely or partly by the container end bottom at the admission pipe.

8. A silencer according to one or more of claims 1-6, c h a r a c t e r i z e d in that the inner plate is formed completely or partly by the container end bottom opposite the admission pipe.

9. A silencer according to one or more of the preceding claims, c h a r a c t e r i z e d in that a ring channel (15), to which the admission pipe (4) is connected, is interposed between the admission pipe (4) and the discharge opening (14).

10. A silencer according to one or more of the preceding claims, c h a r a c t e r i z e d in that a catalyst element is incorporated in the container between the discharge opening and the exhaust pipe.

11. A silencer according to one or more of the preceding claims, c h a r a c t e r i z e d in that the container shell (1) is formed by a circular cylindrical pipe.

12. A silencer according to one or more of claims 1-10, c h a r a c t e r i z e d in that the container shell (1) is formed by an elliptic pipe.

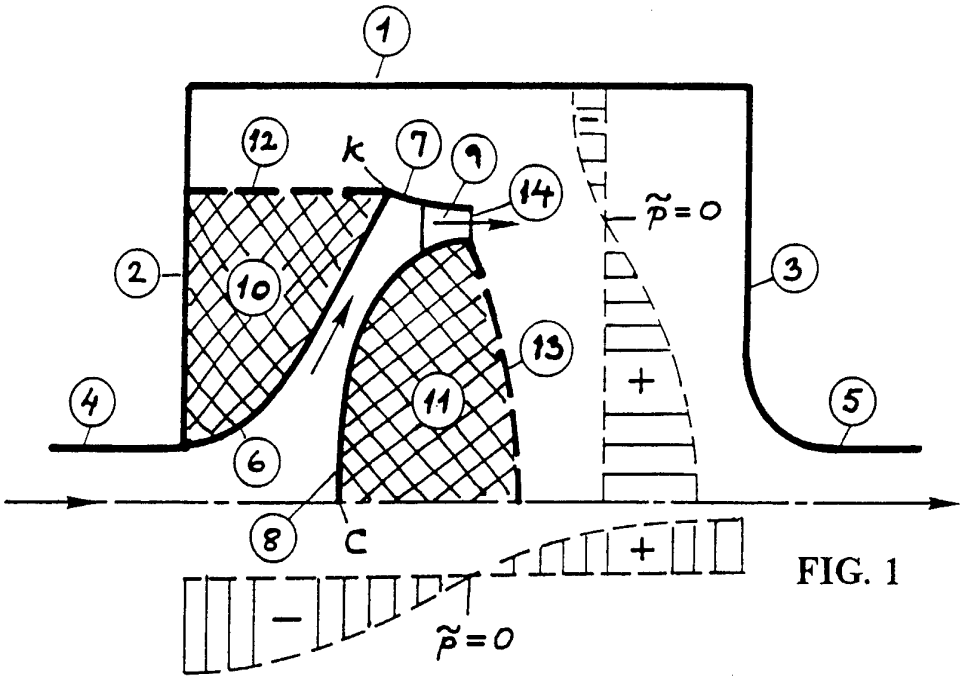

FIG. 1

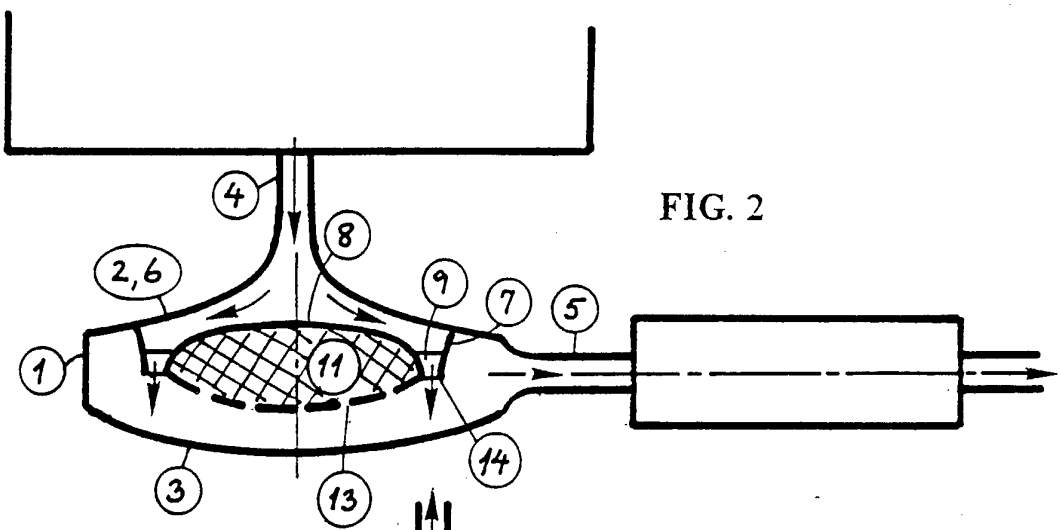

FIG. 2

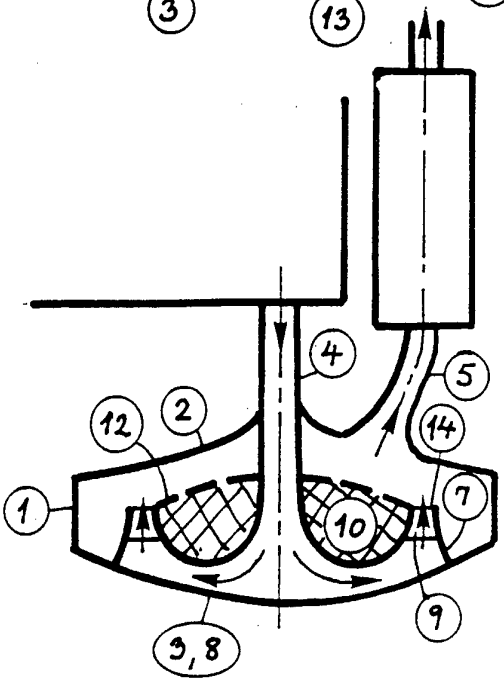

FIG. 3

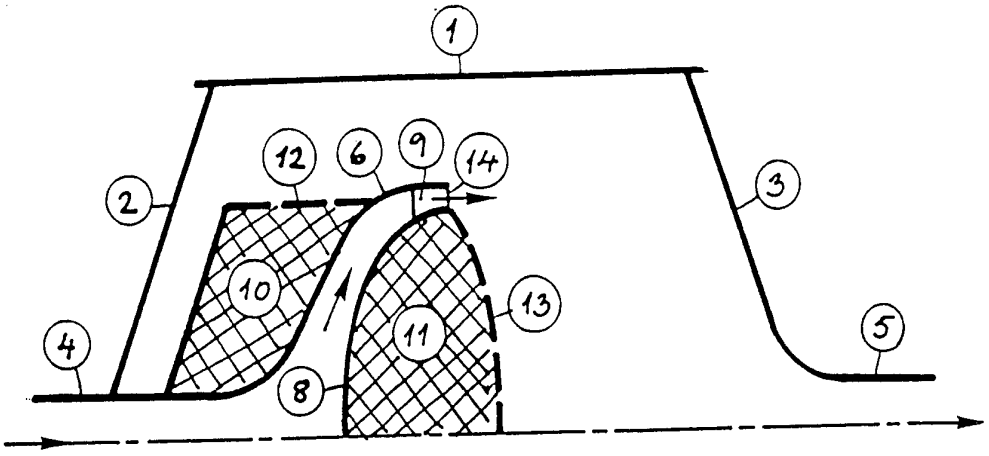

FIG. 4

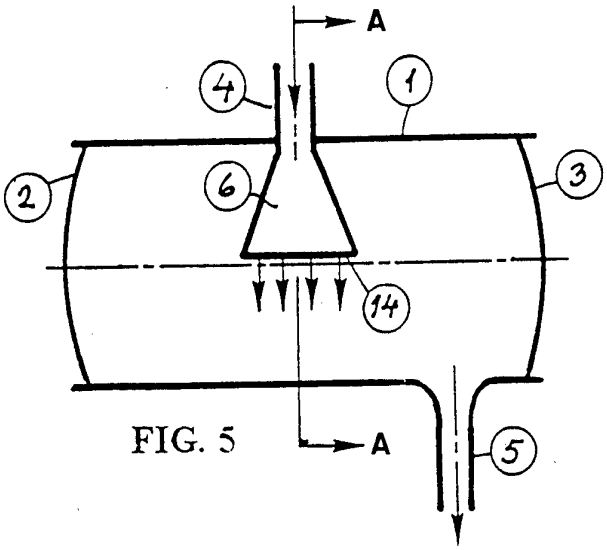

FIG. 5

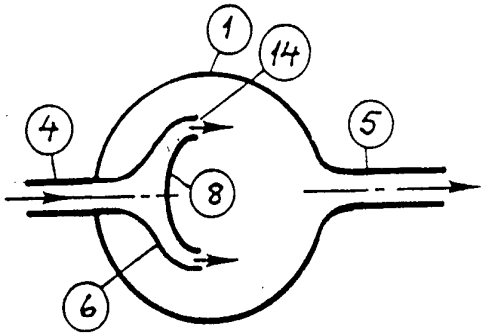

FIG. 5a

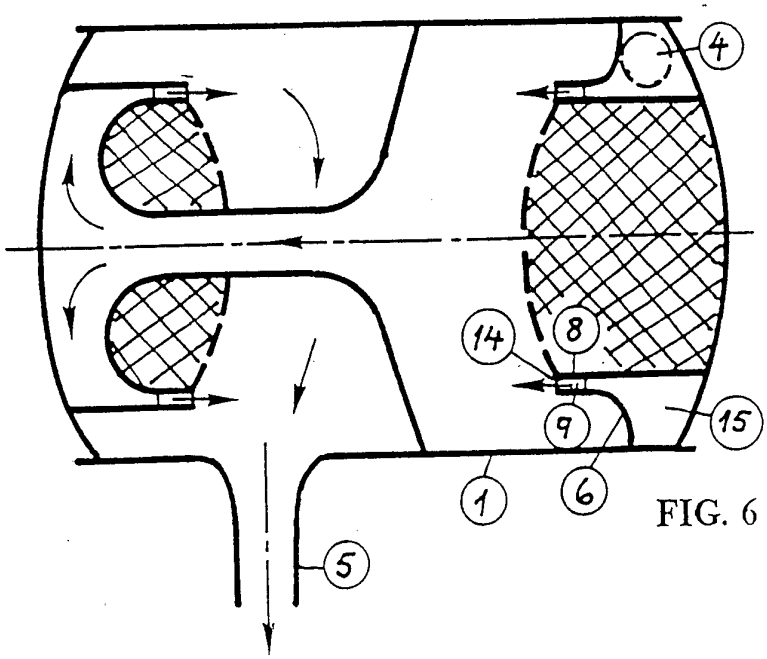

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 94/00049

A. CLASSIFICATION OF SUBJECT MATTER

IPC[5]: F01N 1/10
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC[5]: F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR, A, 1226438 (M. SIGISMOND WILMAN), 11 July 1960 (11.07.60), page 4, column 2, line 3 - line 18, figure 9	1
A	--	2-12
Y	EP, A1, 0020823 (FOTHERGILL, LIONEL), 7 January 1981 (07.01.81), figure 1, abstract, details 13-15	1
A	--	2-12

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
4 May 1994	09 -05- 1994
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Jesper Stenström Telephone No. +46 8 782 25 00

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International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 2990906 (R.R. AUDETTE), 4 July 1961 (04.07.61), column 3, line 6 - line 20, figures 1-3	1-12

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INTERNATIONAL SEARCH REPORT

Information on patent family members

16/04/94

International application No.
PCT/DK 94/00049

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR-A- 1226438	11/07/60	NONE	
EP-A1- 0020823	07/01/81	NONE	
US-A- 2990906	04/07/61	NONE	