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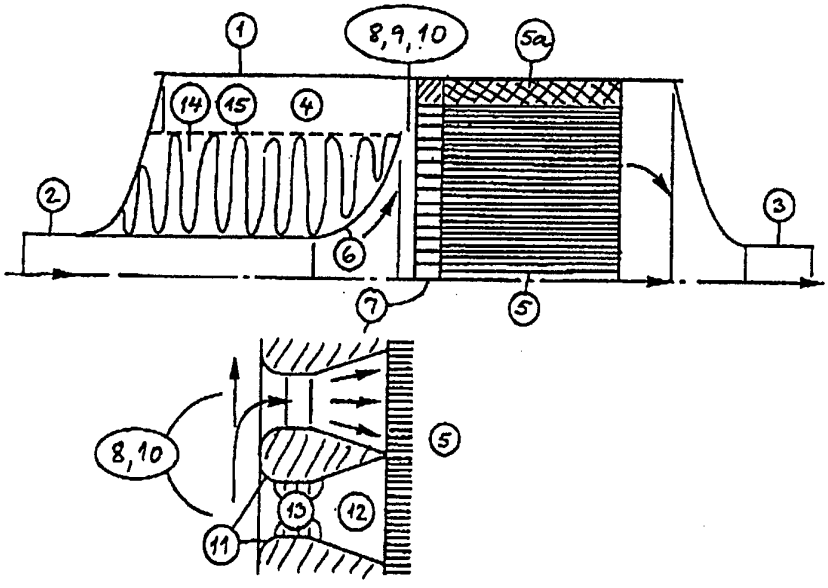

(57) Abstract

Silencer with built-in catalyser which utilises a given total space optimally for simultaneous sound attenuation and catalytic treatment of gases, e.g. exhaust gases from internal combustion engines. The silencer with built-in catalyser comprises a casing (1) connected to an inlet pipe (2) and to an outlet pipe (3), a sound attenuation compartment (4), a downstream catalytic body (5), a flow-area widening diffuser element (6) extending from the inlet pipe and contained within the compartment, and a cross-plate (7) which is positioned between the diffuser element and the catalytic body and from which the flow is distributed evenly across the inlet to the catalytic body. At least two openings (8) are provided between the diffuser element and the catalytic body, at least one such opening (9) providing a communication to the sound attenuation compartment and at least two such openings (10) being pervaded by gas flows.

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A silencer with incorporated catalyst

The present invention discloses a silencer with a built-in catalyser which utilises a given total space optimally for simultaneous silencing and conversion of noxious exhaust gases, typically exhaust gases from prime mover internal combustion engines.

The invention utilises diffuser technology in a novel way, in that a special design of a built-in diffuser is adopted, both for sound attenuation and for even distribution of exhaust gas flow to the inlet face of a catalyser body.

As a consequence of ever more stringent environmental regulations, demands for low exhaust noise levels and for low levels of particle and noxious gas emissions to the atmosphere are increasing all the time. In addition, it is required that the flow resistance provided by silencers, catalysers, etc. be as small as possible, in order that the back-pressure to the engine can be kept as low as possible. This poses a problem to the exhaust system designer, since the available under-vehicle space is normally restricted.

A first step towards space economy, which has been adopted already, is to combine silencers and catalysers by inserting a catalyser inside the casing of a silencer. Even a simple catalyser containing canister causes some noise attenuation, by virtue of its acoustic volume or by throttling of the exhaust flow. In the case of a catalytic body with uninterrupted, straight channels of low pressure drop, however, the attenuation effect of the catalyser as such is only marginal, which can be shown by removing the catalytic body and by measuring how this influences the exhaust noise level outside the exhaust pipe system. Wall-flow catalysers, in which gases are forced to follow tortu-

ous pathways inside the catalyser body, are more effective in suppressing noise, but such devices also cause rather high pressure drops.

In diesel engine exhaust systems accumulation of particulate matter is sometimes a problem. In catalysers particulate matter which is not converted tends to hamper the conversion process and to cause increased pressure drop. This problem, which at present receives much attention, primarily refers to the design of the catalyser as such, but should also be addressed when developing concepts for combined silencer /catalysers.

Various sorts of diffusers have been utilised as flow distribution arrangements in front of catalysers and as flow elements in silencers.

In the first case these arrangements are answers to the following problem: Supposing that a catalyser is positioned close to an inlet pipe of substantially smaller diameter, how can an even flow distribution across the diameter of the catalyser be achieved? The demand for a close positioning results from an overall demand for compactness.

Many types of diffusers have been suggested as solutions to this flow distribution problem. Examples of this are: German Offenlegungsschrift no. 24 28 966, which describes a pure flow line diffuser and German Offenlegungsschrift no. 24 29 002, which describes arrangements with a plurality of flow dividing cones. The latter type of solution resembles well-known arrangements incorporating guide vanes in front of steam boiler exhaust catalysers, as well as ´splitter´ type diffusers commonly used in ventilating ductwork. German Offenlegungsschrift no. 24 28 964 and Norwegian utlegningsskrift no. 169581 both disclose more original diffuser /catalyser arrangements.

German Offenlegungsschrift no. 2 307 215 describes a diffuser-type arrangement in which a perforated, conical member is inserted into a conical end cap at the inlet to a catalyser. This arrangement divides the rather small cavity in front of the catalyser into a flow distributing first cavity with radial diffuser properties and a second, flow mixing cavity immediately in front of the catalyser.

However, none of these solutions take acoustic aspects into consideration. To an extent this is inherent in the above formulation of the catalyser flow distribution problem, according to which the space in front of the catalytic body should be minimised, thereby significantly reducing the acoustic chamber effect. Of course, the gas volume contained within the catalystic body as such may provide some acoustic chamber effect. But from a sound attenuation point of view it is less expedient to arrange the inlet pipe / chamber flow area expansion at the upstream end of the casing. The reason is that this type of geometry tends to excite the fundamental acoustic chamber resonance maximally. This mode corresponds to a wavelength twice the acoustic chamber length, with a pressure node in the middle and maximum pressure variations at each end of the chamber.

Danish patent no. 128427 discloses a type of silencer in which a radial diffuser is utilised for achieving a low pressure drop and for positioning the outflow from the inlet pipe exactly in the middle along the length axis of a chamber, which suppresses the fundamental acoustic mode of the chamber. Danish patent no. 169823 discloses how special type diffusers with narrow, axial outflows into a acoustic compartments can be adopted for suppressing lateral, resonant gas vibrations, which is particularly relevant in the case of silencers with a large casing diameter compared to pipe diameters.

This last-mentioned patent in a sub-claim also describes the possibility of utilising a radial flow property of axial outflow diffusers to obtain a flow distribution effect in front of a catalyser inserted into the silencer. However, due to the narrow lateral extension of the diffuser outflow, this tends to require that the catalytic body be of a ring-type cross section. In the case of a large diameter casing this could for instance be provided for by dividing the catalytic body into several parallel elements. But in the case of long and not too wide casings, as are generally required for under-vehicle installations, much speaks in favour of retaining a simple cylinder form of the catalytic body. In such a case the rather narrow axial outflow at a considerable distance from the centerline is less expedient in providing flow to the center of the inlet face of the catalytic body.

In the present invention the silencing and flow distributing objectives are met simultaneously by utilising a novel, special type of diffuser provided with, as a minimun 2, but in general further, apertures, as can be seen from fig. 1 which shows a first embodiment of the invention.

Here, an acoustic compartment 4 and a catalytic body 5 are both fitted into a casing 1, which is connected to an inlet pipe 2 and to an outlet pipe 3. An elastic layer 5a holds the catalyser and protects it from undue mechanical forces. The diffuser element 6 and the juxtaposed cross-plate flange 7, provided with apertures 8, 10, together constitute a pressure recovering and flow distributing cross-plate diffuser. Due to the rather big aperture 8, 9, 10 it is ensured that a significant proportion of the acoustic energy present in the gas is transmitted into the compartment 4, in which sound-absorbing material 14 is inserted inside a perforated pipe 15.

In fig. 1, as well as in the following figures, apertures are numbered according to a systematic which is in precise accordance with the formulation of the first claim. Thus, the number 8 is used for apertures in general, irrespective of type, while 9 is used for such apertures as communicate with the compartment 4, and 10 is used for apertures which are pervaded by a flow. Thus, since the comparatively big aperture foreseen in fig. 1 both communicates with the compartment 4 and is pervaded by a flow, both characterising numbers 9 and 10 have been attached to this aperture.

Fig. 2 shows an enlarged detail of the embodiment of fig. 1, as an example of how apertures 8, 10 of the cross-plate 7 can be designed. Here, at the inlets to apertures, curvatures 11 have been provided for, in accordance with claim no. 2. The width of the cross-plate is shown to be of some size, so that the length of the apertures can be made significant. This in turn makes it possible to design the downstream ends of the apertures with gradually increasing cross-sectional areas, in accordance with claim no. 3. Hereby the apertures become small venturi-like diffusers.

The cross-plate diffuser constitutes an original type of diffuser arrangement, which is very appropriate for the present purpose, and which can be designated as a multiple-double diffuser. In an optimised design, both the flow distribution and the pressure recovery functions are provided for with a high degree of efficiency. This optimisation will include design of the aperture geometries. For instance, the widths of the apertures can be made a function of their distance from the center axis of the casing, in order that exit velocities are equal from individual apertures positioned at various radii.

In embodiments where the apertures are positioned close to each other, as is the case in fig. 2, it is possible to design the cross-plate to be placed immediately adjacent to the inlet face of the catalytic body in such a way that gas flows enter virtually all parallel channels of the catalyser. For instance, this can be done by forming the apertures as peripheral slots. Thus, designing the apertures in accordance with claim no. 3 opens up for the possibility of positioning the cross-plate in a direct mechanical contact with the catalyser, according to claim no. 6.

In apparatuses with small, flow pervaded apertures 8, 10 the risk of blocking caused by accumulation of particulate matter may call for attention. Designing the apertures to a streamlike flow form, avoiding local recirculation zones, tends to lessen the problem. The risk of this unwelcome phenomenon can be further minimised by providing catalytic layers onto the inner surfaces 13 of the apertures, as stated in claim no. 4.

The rather thick cross-plate flange 7 shown in figs. 1 and 2 can be manufactured from cast iron. As an alternative, the cross-plate can be manufactured as part of the catalyser element. Such a radical step of integration can be made in case the catalyser is manufactured from a metallic foil substrate, which easily lends itself to various forms. A further possibility, which provides a simple approximation to the venturi diffuser form, is to manufacture the cross-plate from a composition of several perforated plates with different sizes of the perforations of each plate.

Fig. 3 shows a further embodiment of the invention, in which the number of apertures is much smaller than according to figs. 1 and 2. This calls for the necessity of a certain distance 16 to the catalyser element, as required in claim no. 7. The fewer, but bigger aper-

tures of this figure can be seen as a simple method of preventing accumulated particulate matter from disturbing flows through apertures. In this embodiment the simplest method of manufacturing the cross-plate is to press it from metal sheet. The various parts are held together by means of ribs 17, which are axially aligned with the flow direction.

The flow dynamic design of diffuser forms according to fig. 3 can be made from the theory of axisymmetrical potential flows as a starting point. Mathematical analysis reveals that classes of forms with pervaded cross-plates can be derived as rather simple solutions to the flow field equation. The final choice of diffuser forms will have to take various further aspects into consideration, including the effect of fluid flow friction, as well as manufacturing aspects.

The acoustic optimisation of the apparatus affects a number of design parameters, among them the distance between the cross-plate diffuser and the catalyser body. In case the effective flow cross-sectional area of the catalyser is rather big, the catalyser may only to a minor degree cause an acoustical division of the casing into sub-chambers. In such cases the flow exit inside the casing can be positioned in the middle along the axial direction, with the effect of suppressing the fundamental acoustical chamber mode, which (as previously mentioned) has a pressure node in the middle.

In other apparatuses the effective flow area of the catalyser may be more restricted, causing an effective acoustical division into sub-chambers. In such cases, in terms of suppression of chamber resonances, it is preferable to instead position the cross-plate halfway between the inlet end cap of the casing and the inlet face to the catalyser.

Finally, figs. 4 and 5 show an embodiment of the invention, in which, according to claim no. 5, some of the apertures 8 are perforations 9, which are not pervaded by flows, and which constitute an acoustical communication to the sound absorption material 14 contained within the compartment 4.

In order that the compartment 4 contributes significantly to the sound attenuation it is imperative that the effective opening area of this compartment to the rest of the apparatus is not too small.

Patent Claims:

1. Silencer with a built-in catalyser for simultaneous sound attenuation and catalytic treatment of gases, e.g. exhaust gases from internal combustion engines, comprising: A casing (1) connected to an inlet pipe (2) and to an outlet pipe (3), a sound attenuation compartment (4), a downstream catalytic body (5), a flow-area widening diffuser element (6) extending from the inlet pipe and contained within the compartment, and a cross-plate (7) which is positioned between the diffuser element and the catalytic body and from which the flow is distributed evenly across the inlet to the catalytic body, **wherein** at least 2 apertures (8) are provided for between the diffuser element and the catalystic body, at least 1 such aperture (9) providing a communication to the sound attenuation compartment and at least 2 such apertures (10) being pervaded by gas flows.

2. Silencer according to claim 1 **wherein** entrances to flow pervaded apertures (10) are provided with a curvature (11).

3. Silencer according to claim 2 **wherein** flow pervaded apertures (10) have lengths which are significant compared to their widths, and at their downstream ends comprise a flow cross-section expanding part (12).

4. Silencer according to anyone of the preceding claims **wherein** surfaces (13) of the flow pervaded apertures (10) are coated by catalytic layers.

5. Silencer according to anyone of the preceding claims **wherein** the diffuser element (6) is provided with perforations (9) which are not pervaded by flows, and which constitute an acoustic communication to sound absorptive material (14) within the compartment

(4).

6. Silencer according to anyone of the preceding claims **wherein** a mechanical contact is established between the cross-plate (7) and the catalytic body (5).

7. Silencer according to anyone of the claims 1 - 5 **wherein** a distance (16) is provided for between the cross-plate (7) and the catalytic body (5).

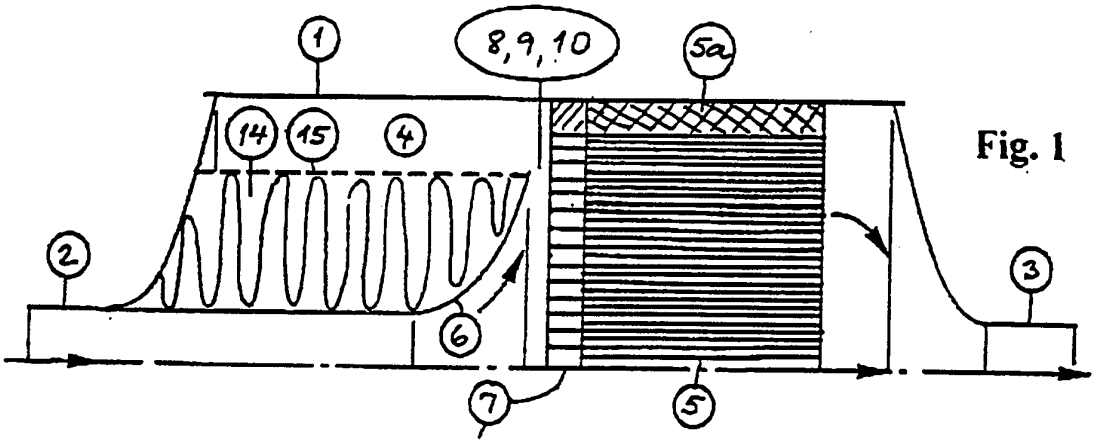

Fig. 1

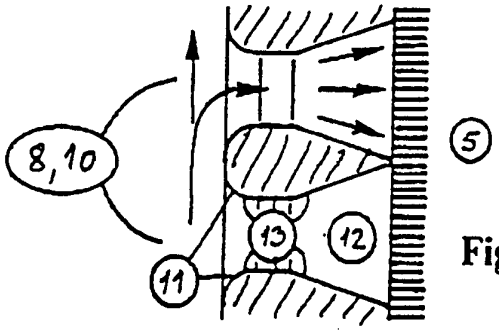

Fig. 2

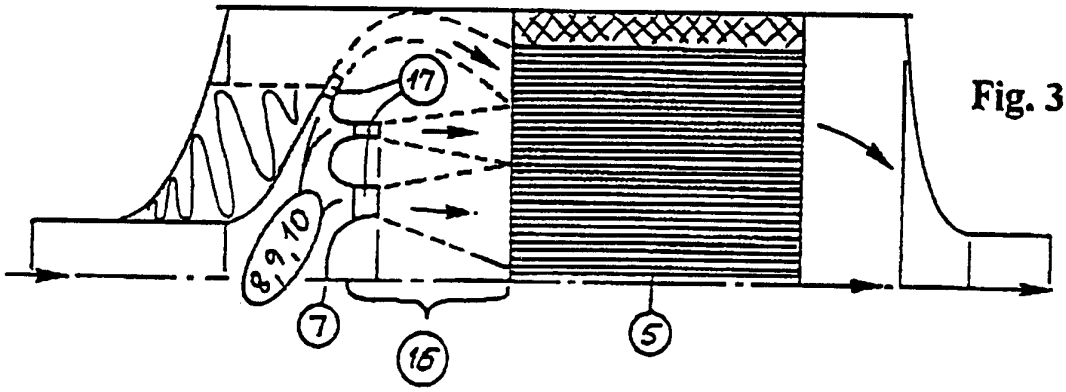

Fig. 3

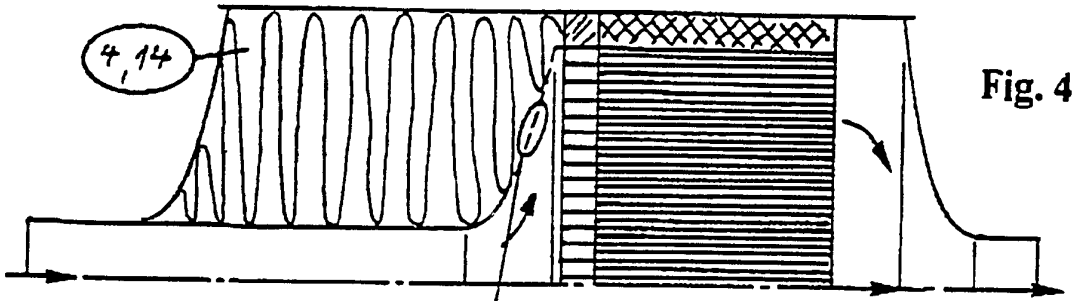

Fig. 4

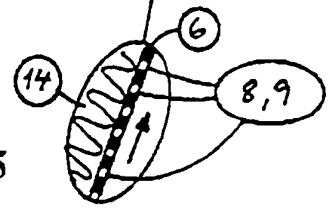

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F01N 1/10, F01N 3/28
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)

IPC6: F01N

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

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9418438 A1 (SILENTOR A/S), 18 August 1994 (18.08.94), claims 1-10, abstract	1
A	US 5150573 A (WOLFGANG MAUS ET AL), 29 Sept 1992 (29.09.92), abstract	1
A	DE 4130113 A1 (VOLKSWAGEN AG), 26 March 1992 (26.03.92), figures 1-2, abstract	1
A	DE 2307215 A1 (VOLKSWAGENWERK AG), 22 August 1974 (22.08.74), figure 1	1

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

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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	DE 2429002 A1 (ROBERT BOSCH GMBH), 8 January 1976 (08.01.76), figures 1-4	1
A	DE 2428964 A1 (ROBERT BOSCH GMBH), 2 January 1976 (02.01.76), figures 1-3, claim 1	1
A	WO 9410430 A1 (AITTA, EERO ET AL), 11 May 1994 (11.05.94), abstract	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

30/10/95

International application No.
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WO-A1- 9418438	18/08/94	NONE	
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