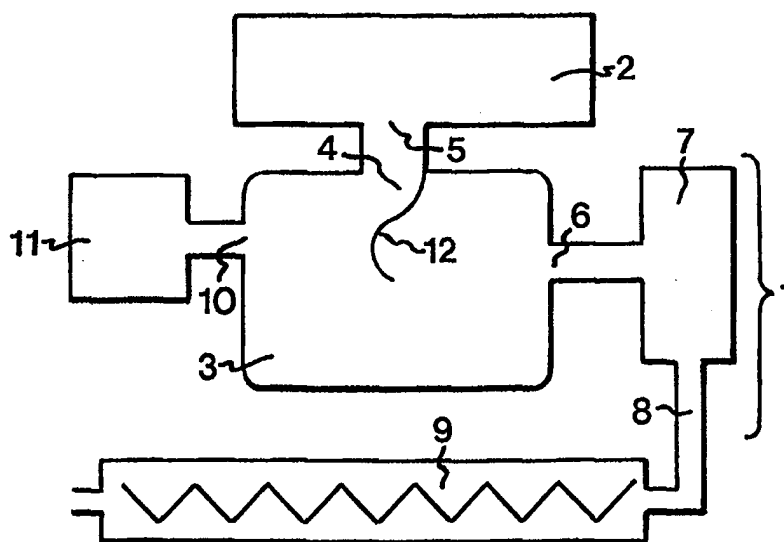




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(54) Title: DEVICE AND METHOD FOR PURIFYING EXHAUST GASES



(57) Abstract

A device for purifying exhaust gases from a combustion apparatus (2), such as an internal combustion engine, comprises a closed vessel (3) and a negative pressure means (7), which is in fluid communication with the vessel (3) and is adapted to generate a negative pressure therein. The vessel (3) is so connectible to the combustion apparatus (2) that hot exhaust gases therefrom flow, under expansion, into the vessel (3). The device operates according to a purification method, in which the exhaust gases are caused to flow out of the combustion apparatus (2) and are expanded in a closed space (3), in which negative pressure prevails in relation to the ambient atmospheric pressure.

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DEVICE AND METHOD FOR PURIFYING EXHAUST GASESField of the Invention

The present invention relates generally to the purification of exhaust gases from various types of combustion apparatus, such as engines, furnaces, heating
5 boilers etc. More specifically, the invention concerns a device and a method for purifying such exhaust gases.

Background Art

Combustion is a chemical reaction in which a combustible substance combines with oxygen to form one or
10 more combustion products. To an ever increasing extent, attention has in recent years been paid to the fact that some of these products, such as carbon monoxide (CO), nitric oxides (NO_x), unburnt hydrocarbon compounds (HC) and carbon dioxide (CO₂), are unhealthy to human beings
15 and animals and besides may contribute to environmental problems, for instance smog and climatic influence. Therefore efforts are made to remove such undesired products in the exhaust gases from combustion apparatus. Although merely problems and measures in connection with
20 internal combustion engines will be described below, the discussion is applicable to all types of combustion.

As early as the sixties, requirements prescribed by law in respect of purification of exhaust gases from car engines were introduced in California. These purification
25 requirements, which have been made more stringent year by year, have urged the development of various exhaust gas purification processes. To be able to satisfy these requirements, for instance separate devices for after-treatment of exhaust gases have been developed.

30 Such a device is known from, for instance, WO 93/02279 and is designed for afterburning of exhaust gases from an internal combustion engine. The device, which is arranged after the engine and through which the exhaust gases flow, mixes secondary air with the exhaust

gases and then ignites the exhaust-gas-air mixture by means of a spark igniter. As a result, exhaust gas substances such as carbon monoxide, hydrocarbons and particles are oxidised. This type of device, however, is
5 difficult to control and is not capable of purifying the exhaust gases from a car engine in compliance with today's stringent requirements.

A further device for aftertreatment of exhaust gases is the catalytic converter, which is known from e.g. WO
10 93/24745 and which, by catalytic oxidisation, reduces the contents of some combustion products. The converter comprises a vessel through which exhaust gases flow and which contains a catalytic material having a large surface area. By controlling very accurately the ratio of
15 fuel to air in the engine so as to achieve exact stoichiometry, the subsequent catalytic converter can be caused to drastically reduce the contents of carbon monoxide, hydrocarbons, particles and nitrogen oxides in the exhaust gases. Among the drawbacks of the catalytic
20 converter, it may be mentioned that it requires a high working temperature, normally at least 900°C, that it only functions at an exact stoichiometric mixing ratio, that it is expensive and not very lasting, that it is sensitive to certain substances, such as lead, that
25 may be present in the fuel, and that it can be used only for purification of emissions from gasoline engines.

Objects of the Invention

One object of the present invention is to overcome, wholly or partly, the above-discussed problems of prior
30 art, i.e. to provide a device and a method for purifying exhaust gases from combustion apparatus, both the device and the method resulting in purification of the exhaust gases in accordance with stringent environmental requirements, i.e. accomplishing a considerable reduction of
35 the contents of one or more of: carbon dioxide, carbon monoxide, nitrogen oxides and hydrocarbons in the exhaust

gases. Moreover, the construction of the device should be as simple and robust as possible.

A further object of the invention is to provide a device and a method which are capable of purifying the exhaust gases independently of which type of fuel is used in the combustion apparatus.

It is also an object of the invention to provide a device and a method which, when used for purifying the exhaust gases from an internal combustion engine, are capable of yielding an increased output power from the internal combustion engine.

It is also desirable to provide a device which gives a sound-attenuating effect when arranged after an internal combustion engine.

Summary of the Invention

According to the invention, these and other objects that will appear from the following specification have now been achieved by means of a device and a method according to the accompanying claims 1 and 12, respectively. Preferred embodiments are defined in the accompanying dependent claims.

It has surprisingly been found that the combination of a closed vessel and a negative pressure generating means according to the invention results in a considerable reduction of the contents of undesired substances in the exhaust gases from a combustion apparatus. In contrast to all prior-art purifying devices, also a reduction of the amount of carbon dioxide is obtained.

This simple and robust construction has been found usable for various types of combustion apparatus using various types of fuels.

Brief Description of the Drawings

The invention will now be described for the purpose of exemplification with reference to the accompanying drawing, which illustrates the presently preferred embodiments. In the drawing, equivalent parts have been given the same reference numerals.

Fig. 1 is a schematic view of an inventive device.

Fig. 2 illustrates an inventive device that is used in a first experiment for purifying the emissions from a gasoline engine.

5 Fig. 3 illustrates an inventive device that is used in a second experiment for purifying the emissions from a diesel engine.

Description of the Preferred Embodiments

10 Fig. 1 is a schematic view of an embodiment of an inventive purifying device 1 which is connected to a combustion apparatus 2, such as an internal combustion engine. The purifying device 1 comprises a closed vessel or collecting chamber 3, which, through a first inlet 4, is in fluid communication with the outlet 5 of the combustion apparatus 2. An outlet 6 of the collecting chamber 3 is in fluid communication with a negative pressure generating means 7, such as a vacuum pump or a fan. The negative pressure generating means 7 is in turn connected by an exhaust pipe 8 to a silencer 9. A second inlet 10
15 of the collecting chamber 3 is in fluid communication with a means 11 for supplying additional oxidising agent.

20 During operation, a negative pressure is established in the collecting chamber 3 with the aid of the negative pressure means 7. The negative pressure causes hot combustion gases to be sucked out of the combustion apparatus 2 and into the collecting chamber 3, which preferably is arranged in the immediate vicinity of the combustion apparatus 2. The negative pressure also results in additional oxidising agent, such as air, being suckable into
25 the collecting chamber 3 from the supply means 11. The collecting chamber 3 has an internal, turbulence-producing profile 12 which generates an efficient mixture of the combustion gases expanding in the chamber 3 and the added oxidising agent. The gas mixture is then sucked
30 into the negative pressure means 7 and is ejected thereby into the exhaust pipe 8. All combustion gases thus leave
35

the collecting chamber 3 through the negative pressure means 7.

In conducting experiments with the invention, it has been found that the negative pressure in the collecting chamber 3 preferably is in the range of 0.25-0.8 atm absolute pressure (25-80 kPa). It was noted that the purifying effect is enhanced in the lower part of the pressure range. To a certain degree, the aimed-at purification was obtained also slightly above the negative pressure of 0.8 atm (80 kPa).

It should be emphasised that the negative pressure established in the collecting chamber assists in the emptying of the combustion chamber of the engine during the exhaust stroke, whereby the output power of the engine increases since a greater amount of fuel-air mixture can be sucked into the combustion chamber during the subsequent intake stroke. The pressure prevailing in the collecting chamber should be lower than the ambient atmospheric pressure as well as the pressure in the combustion apparatus when emitting the combustion gases to the purifying device. The negative pressure, however, should not be so large as to unfavourably affect the combustion in the apparatus.

Practical tests have shown that the overall efficiency of the engine may be increased from about 30% in a standard engine to about 40% in an engine provided with a device of the invention.

This inventive purifying device has been tested in two different experiments, which will be described in detail below.

Experiment 1

In the first experimental arrangement, which is schematically illustrated in Fig. 2, an inventive purifying device was connected to a combustion apparatus in the form of a gasoline engine, more specifically a 1974 VOLVO B20 having a volume of about 2,000 cm³. The engine was dismantled from a vehicle which before the tests had

a mileage of around 350,000 kilometres. No adjustments of the engine were made before the tests, but the engine was mounted together with gear box, starting motor, battery and fuel tank in a test bench. During the experiment, the engine was run without braking at 1,000 rpm.

The collecting chamber 3 was cylindrical and had a diameter of 200 mm and a length of 400 mm. The volume of the chamber 3 thus was 12.6 dm³. A first inlet 4 of the chamber 3 was connected to a 90° pipe bend 13, whose diameter was 130 mm. The pipe bend 13 had a flange 14 which during the experiment was connected to the exhaust manifold (not shown) of the engine.

The outlet 6 of the collecting chamber 3 was connected, by means of a pipe 15 having a diameter of 50 mm and a length of 100 mm, to a negative pressure generating means 7 in the form of a standard-type turbocharger (VOLVO), which during the experiment was constantly operated by compressed air (0.8 MPa; 8 bar) for the purpose of generating a negative pressure in the collecting chamber 3. This negative pressure was measured during the experiment to be about 0.7 atm (70 kPa) absolute pressure by means of an air pressure gauge (not shown) mounted on the collecting chamber 3.

A second inlet 10 of the collecting chamber was connected to an air supply means in the form of a manually operable stopcock 11. A second air supply means, also in the form of a stopcock 11', was connected to the pipe bend 13. During the tests, either of these stopcocks 11, 11' was fully open, whereby additional oxidising agent was supplied to the chamber 3 by self-suction. This oxidising agent consisted either of air only or of air containing about 2 ppm ozone. The volume flow rate of oxidising agent was measured to be about 2.8% of the volume flow rate of exhaust gases from the engine.

An exhaust pipe 8 having a diameter of 50 mm and a length of 800 mm was connected to the turbocharger 7 for releasing the purified exhaust gases. After the turbo-

charger 7, the temperature of the exhaust gases was measured to be about 100°C, and therefore the temperature decrease over the collecting chamber 3 will probably have amounted to about 800-1000°C. In order to quantify the degree of purification, use was made of a conventional measuring apparatus (Hackman & Brum MG and URAT P), probes (not shown) being arranged about 200 mm from the far end of the exhaust pipe 8.

Furthermore, reference measurements were carried out without purification, in which the purifying device 1 was replaced by a standard-type exhaust pipe with a silencer. Otherwise, the test conditions were unchanged.

The results of three tests involving a purifying device as described above are shown in Table 1 below, TEST I concerning the supply of air only through the stopcock 11, TEST II concerning the supply of air only through the stopcock 11', and TEST III concerning the supply of an air-ozone mixture through the stopcock 11'. As is evident from the Table, the contents of harmful combustion products decreased heavily in TESTS I-III. Surprisingly enough, also the content of carbon dioxide decreased by about 50%.

Table 1 Contents of substances in exhaust gases from a gasoline engine run at 1000 rpm without braking.

	Reference, without purification	TEST I	TEST II	TEST III
O ₂ (%)	3.17	13.6	13.2	14.0
HC (ppm)	270	115	110	110
CO ₂ (%)	10.0	4.5	4.9	4.7
NO ₂ (ppm)	24.2	5.4	3.0	2.6
CO (%)	5.1	0.8	1.2	1.7
NO (ppm)	-16	-40	-46	-44

Experiment 2

In the second experimental arrangement, which is schematically illustrated in Fig. 3, an inventive purifying device was connected to a combustion apparatus in the form of a diesel engine, more specifically a 1977 Peugeot 504 having a volume of about 2,300 cm³. Before the tests, the motor had a mileage of around 300,000 kilometres. No adjustments of the engine were made before the tests, but it was mounted together with gear box, starting motor, battery and fuel tank in a test bench. A brake system was mounted on the output shaft of the gear box, and during the experiment, the motor was run either at 6,000 rpm with full braking or at 1,000 rpm without braking.

The collecting chamber 3 was cylindrical and had a diameter of 110 mm and a length of 920 mm. Thus, the volume of the chamber 3 was about 8.7 dm³. A first inlet 4 of the chamber 3 was connected by a tube 13 having a flange 14 to the exhaust manifold of the engine.

The outlet 6 of the collecting chamber 3 was connected directly to a negative pressure generating means 7 in the form of a fan (Nederman, Model N16) having a capacity of 0.44 m³/s. The fan 7, which was operated by an electric motor 15 at 2,870 rpm, generated a negative pressure in the collecting chamber 3, which during the experiment was measured to be about 0.7 atm (70 kPa) absolute pressure by means of an air pressure gauge (not shown) mounted on the collecting chamber 3.

Like in Experiment 1, a second inlet 10 of the collecting chamber 3 was connected to an air supply means in the form of a manually operable stopcock 11. During the tests, the stopcock 11 was either fully open, whereby additional oxidising agent in the form of air was supplied to the chamber 3 by self-suction, or fully closed such that no oxidising agent was supplied to the chamber 3. The volume flow rate of air was measured to be about

2.8% of the volume flow rate of exhaust gases from the engine.

An exhaust pipe 8 having a diameter of 60 mm and a length of 1000 mm was connected to the fan 7 to release the purified exhaust gases. After the fan 7, the temperature of the exhaust gases was measured to be about 100°C, and therefore the temperature decrease over the collecting chamber 3 will probably have amounted to about 800-1000°C. The same measuring apparatus as in Experiment 1 was used to quantify the purification degree. Reference measurements were carried out in the same manner as in Experiment 1.

The results of the experiment are shown in the Tables 2a-2b below, Table 2a concerning a first operating state at 6000 rpm with full braking, and Table 2b concerning a second operating state at 1000 rpm without braking. In the Tables 2a-2b, TEST I relates to measurements in which additional air is supplied through the stopcock 11 and TEST II relates to measurements with no supply of additional air.

As appears from the Tables, the contents of harmful combustion products decreased heavily in all cases. The content of carbon dioxide decreased by about 60-80%. The measurements indicate that the supply of additional oxidising agent can improve the degree of purification.

Table 2a Contents of substances in exhaust gases from a diesel engine that was run at 6000 rpm with full braking.

	Reference, without purification	TEST I	TEST II
O ₂ (%)	15.5	20.0	19.8
CO ₂ (%)	4.0	0.70	0.88
NO ₂ (ppm)	21.8	9.7	11.1
CO (ppm)	214	158	193
NO (ppm)	105	-29	-32

Table 2b Contents of substances in exhaust gases from a diesel engine that was run at 1000 rpm without braking.

	Reference, without purification	TEST I	TEST II
O ₂ (%)	18.2	20.1	20.0
CO ₂ (%)	2.0	0.63	0.73
NO ₂ (ppm)	19.1	8.9	11.3
CO (ppm)	755	246	279
NO (ppm)	-3.7	-25	-20

In both experiments 1 and 2 related above, it was also established that the purifying device had a sound-attenuating effect thanks to the negative pressure means levelling out the compression pulsations in the exhaust pipe.

Model

Without committing oneself to a theory, it is assumed that the surprising results regarding the purification can be explained by the following model. The model is based on the theories regarding irreversible systems far from equilibrium which have been formulated by the Belgian scientist Ilya Prigogine, who in 1977 was awarded the Nobel Prize in chemistry for precisely these theories. For an introduction to the field, reference is made to "Order out of Chaos", I. Prigogine and I. Stengers, Bantam Books, New York, 1984, and "Self Organization in non-equilibrium Process", G. Nicolis and I. Prigogine, John Wiley Interscience, New York, 1977.

According to the model, a non-equilibrium process in the exhaust gases is created when these are subjected to a sudden expansion and accompanying sudden changes in pressure and temperature when flowing into the collecting chamber. This means that HC, CO₂ and CO molecules convert wholly or partly into C₂ inert gas, O₂ and H₂O molecules.

The model, which should not be interpreted to be limiting to the invention, seems to explain the results of the above experiments to a large extent.

The model predicts that the ratio of engine volume
5 to volume of the collecting chamber should be greater than about 1:1, preferably in the range from 1:1 to 1:10, and most preferred about 1:3. A large volume of the collecting chamber would certainly result in satisfactory purification but at the same time cause a reduced output
10 power from the engine. A smaller volume of the collecting chamber will, according to the model, probably result in inferior purification. At present, 1:3 is considered the optimum ratio.

The above measuring results indicate that the purification process functions without any supply of additional oxidising agent. According to the model, the purification, however, will be improved if, as soon as possible after combustion, the collecting chamber is supplied with additional oxidising agent, such as air, in
20 amounts of up to about 5 per cent by volume.

Moreover, the model predicts that the combustion gases flowing into the collecting chamber should have a temperature of at least 500°C for accomplishing satisfactory purification.

25 Possible Modifications

It will probably be possible to increase the purification efficiency still more by optimising various parameters. Since a large portion of the undesired combustion products are normally formed when the combustion
30 gases are gradually cooled on their way down through the exhaust pipe, the purification efficiency of the device will probably be better the closer to the engine it is arranged and the hotter the entering combustion gases, and therefore the purifying device should preferably be
35 arranged in the immediate vicinity of the combustion.

Of course, the purifying device can be supplemented with a control unit which, for instance in dependence on

the speed of the engine, gas flow rates and temperatures, controls the negative pressure means and the supply means.

5 An increased purification efficiency will probably also be achieved if the additional oxidising agent is supplied through a plurality of openings distributed over the collecting chamber, since this would improve the mixing of the oxidising agent with the exhaust gases.

10 It will also be appreciated that the invention is not restricted to internal combustion engines, but is also applicable to the purification of exhaust gases from all sorts of combustion.

15 The inventive device can be used as an auxiliary device on existing combustion apparatus for the purpose of improving the degree of purification of the exhaust gases. It may also be designed as an integrated part of newly manufactured combustion apparatus.

CLAIMS

1. A device for purifying exhaust gases from a combustion apparatus (2), such as an internal combustion engine, characterised by a closed vessel (3) and a negative pressure means (7), which is in fluid communication with the vessel (3) and is adapted to generate a negative pressure therein, the vessel (3) being connectible to the combustion apparatus (2) in such manner that hot exhaust gases therefrom flow, under expansion, into the vessel (3).

2. The device as claimed in claim 1, wherein all exhaust gases leave the vessel (3) through the negative pressure means (7).

3. The device as claimed in claim 1 or 2, wherein the vessel (3) is designed for arrangement in the immediate vicinity of the combustion apparatus (2).

4. The device as claimed in any one of claims 1-3, further comprising a means (11) for supplying an oxidising agent to the vessel (3).

5. The device as claimed in claim 4, wherein the supply means (11) is self-sucking.

6. The device as claimed in claim 4 or 5, wherein the supply means (11) comprises an opening which is formed in connection with the vessel (3) and which is in fluid communication with the atmosphere surrounding the device.

7. The device as claimed in any one of claims 4-6, wherein said oxidising agent is air.

8. The device as claimed in any one of claims 4-7, wherein said oxidising agent is air and ozone.

9. The device as claimed in any one of the preceding claims, which is adapted to be connected to at least one cylinder of an internal combustion engine, the volume of the vessel (3) being at least equal to the volume of said at least one cylinder.

10. The device as claimed in any one of the preceding claims, further comprising a means (12) for generating turbulence in the vessel (3).

11. The device as claimed in any one of the preceding claims, wherein said negative pressure is within the
5 range 0.25-0.8 atm (25-80 kPa) absolute pressure.

12. A method for purifying exhaust gases from a combustion apparatus (2), such as an internal combustion engine, characterised by causing exhaust
10 gases to flow out of the combustion apparatus (2) and expanding the same in a closed space (3), in which negative pressure prevails relative to the ambient atmospheric pressure.

13. The method as claimed in claim 12, wherein the
15 space (3) is supplied with additional oxidising agent.

14. The method as claimed in claim 12 or 13, wherein the space (3) is supplied with additional oxidising agent by self-suction.

15. The method as claimed in claim 12, 13 or 14,
20 wherein said negative pressure is kept within the range of 0.25-0.8 atm (25-80kPa) absolute pressure.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/00335

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F01N 3/26, F23J 15/02

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, F23J

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)

DIALOG: ALLSCIENCE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3990233 A (WILL ET AL), 9 November 1976 (09.11.76) --	1,11
A	US 4110976 A (OYA ET AL), 5 Sept 1978 (05.09.78) --	1,11
A	US 4192846 A (OYA ET AL), 11 March 1980 (11.03.80) -- -----	1,11



Further documents are listed in the continuation of Box C.



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INTERNATIONAL SEARCH REPORT

Information on patent family members

02/04/98

International application No.

PCT/SE 98/00335

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