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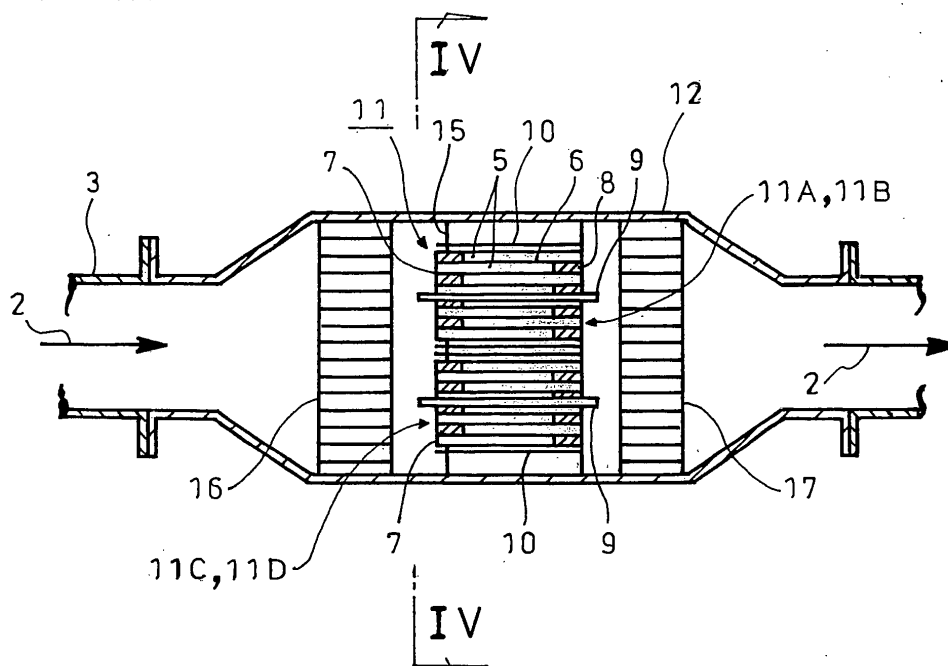
(54) **EXHAUST GAS-PURIFYING DEVICE**

(57) Provided is a plasma assisted exhaust emission control device with less electric power consumption and with no harmful gas discharged into atmosphere.

A filter body (7) is constituted by porous members through which exhaust gas (2) passes for capturing of particulates in the exhaust gas (2) and is provided with rod-like and cylindrical electrodes (9,10) so as to gener-

ate plasma in the filter body (7), thereby providing a plasma regenerative particulate filter (11). The particulate filter (11) is accommodated in a filter casing (12) within an exhaust pipe (3). Oxidation catalysts (16,17) are arranged respectively upstream and downstream of and adjacent to the particulate filter (11) in the filter casing (12) so as to obtain heat insulation effect to the particulate filter (11).

FIG.3



Description

Technical Field

[0001] The present invention relates to an exhaust emission control device for removing particulates in exhaust gas from an internal combustion engine such as diesel engine.

Background Art

[0002] Particulates or particulate matter discharged from a diesel engine is mainly constituted by carbonic soot and a soluble organic fraction (SOF) of high-boiling hydrocarbon and contains a trace of sulfate (misty sulfuric acid fraction). In order to suppress such kind of particulates from being discharged into atmosphere, it has been envisaged as shown in Fig. 1 that a particulate filter 4 is incorporated in an exhaust pipe 3 through which exhaust gas 2 from a diesel engine 1 flows.

[0003] As detailedly shown in Fig. 2, the particulate filter 4 comprises a filter body 7 in the form of a porous honeycomb made of ceramics such as cordierite. The filter body 7 has passages 5 or grid-like compartments with inlets alternately plugged by plugs 8, the passages 5 with the unplugged inlets being plugged by the plugs 8 at their outlets; only the exhaust gas 2 passing through porous thin walls 6, which compartmentalize the passages 5, is discharged downstream and the walls 6 capture the particulates at their inner surfaces.

[0004] The particulates in the exhaust gas 2 are thus captured by and accumulated on the inner surfaces of the walls 6 and spontaneously ignite to be burned off upon shifting to a region of operation with increased exhaust temperature. However, when an operation or driving with temperature at or above a predetermined temperature requisite tends not to continue for a long time, for example, in a vehicle such as a shuttle-bus running mainly on congested city roads, there may be a fear that an accumulated particulate amount exceeds a treated amount, disadvantageously resulting in clogging of the particulate filter 4.

[0005] Thus, development of a plasma assisted exhaust emission control device has been promoted so as to satisfactorily burn off the particulates even in a region of operation with lower exhaust temperature. In the kind of plasma assisted exhaust emission control device, electric discharge to the exhaust gas 2 to thereby generate plasma excites the exhaust gas 2 to convert oxygen into ozone and NO into NO₂. Because of these excited exhaust gas components being activated, the particulates can be satisfactorily burned off even in a region of operation with lower exhaust temperature.

[0006] Prior publications on plasma assisted exhaust emission control devices are recited in, for example, the following Reference 1.

[Reference 1] JP 2002-501813A

Summary of the Invention

Problems to be Solved by the Invention

[0007] However, in such conventional plasma assisted exhaust emission control devices, much electric power consumption is required for regeneration of the particulate filter 4 so that power source is needed which has larger capacity to an extent that cannot be afforded by any existing vehicle battery. Moreover, charging is required which matches the consumed electric power, resulting in deterioration of fuel mileage.

[0008] Since the particulates are burned off at relatively low temperature upon regeneration of the particulate filter 4, there may be also a fear that harmful gas such as highly concentrated CO or HC is generated and discharged into atmosphere.

[0009] The invention was made in view of the above and has its object to provide a plasma assisted exhaust emission control device with less electric power consumption and with no harmful gas discharged into atmosphere.

Means or Measure for Solving the Problems

[0010] The invention is directed to an exhaust emission control device comprising a filter body constituted by porous members through which exhaust gas passes for capture of particulates entrained in the exhaust gas and electrodes for generating plasma in said filter body, thereby providing a plasma regenerative particulate filter, said particulate filter being incorporated in a filter casing within an exhaust pipe, oxidation catalysts being arranged upstream and downstream of and adjacent to the particulate filter in the filter casing so as to obtain heat insulation effect to the particulate filter.

[0011] Thus, when the exhaust gas having flown into the filter casing passes through the upstream oxidation catalyst, NO occupying majority of NO_x in the exhaust gas is converted into highly reactive NO₂, which substantially accelerates an oxidization reaction of the particulates to bring about satisfactory burn-off of the particulates in a condition of operation with exhaust temperature over about 250°C.

[0012] However, when a condition of light-load operation with exhaust temperature greatly falling below 250°C continues for a long time, for example, during running or driving on congested city roads, satisfactory burn-off of the particulates cannot be expected; then, at a right moment when an accumulated particulate amount is estimated to exceed a predetermined amount (estimation may be based on, for example, pressure difference between the entering and discharge sides of the filter body or operational time period), voltage is applied across the electrodes of the filter body to discharge electricity in the filter body.

[0013] When voltage is thus applied across the electrodes of the filter body to discharge electricity in the filter

body, inner gas is excited to convert oxygen into ozone and NO into NO₂, these excited gas components which are being activated accelerate the oxidation reaction of the particulates captured by the filter body. As a result, the particulates are satisfactorily burned off even in a condition of operation with lower exhaust temperature.

[0014] The plasma regenerative particulate filter is sandwiched and heat insulated by the upstream and downstream oxidation catalysts in one and the same filter casing, so that the filter body is rapidly elevated in temperature when the oxidization reaction of the captured particulates begins. As a result, the particulates have tendency of being more readily burned off and can be burned off with a shorter electric discharge time than they could conventionally and thus required electric power consumption is less than that required conventionally.

[0015] The harmful gas such as highly concentrated CO or HC generated due to combustion of the particulates with relatively low temperature by the aid of the plasma is oxidized into harmless CO₂ or H₂O when it passes through the downstream oxidation catalyst and is discharged.

[0016] It is preferable in the invention that the plasma regenerative particulate filter is divided into a plurality of smaller units which are arranged in parallel with each other in the filter casing, voltage for electric discharge being separately applied to the respective smaller units.

[0017] Thus, the smaller units of the plasma regenerative particulate filter can be separately regenerated, with an advantageous result that power source with relatively small capacity will suffice. Division into the smaller units improves combustibility of the particulates per unit, so that regeneration of the filter through plasma can be attained during stoppage of an engine for example in a vehicle with an idle stopper.

[0018] In the invention, it is preferable that the porous members constituting the filter body integrally carry oxidation catalysts, which accelerates the oxidation reaction of the particulates captured by the filter body to lower ignition temperature. As a result, combustibility of the particulates in a condition of operation with lower exhaust temperature is further enhanced to attain further satisfactory burn-off of the particulates.

[0019] Upon carrying out the invention more concretely, employable is a filter body having a plurality of passages in the form of honeycomb through which exhaust gas passes, inlet and outlet ends of the passages being alternately plugged. When such filter body is employed, the filter body may have a rod-like electrode inserted at its axis and a cylindrical electrode fitted over an outer periphery of the filter body.

Effects of the Invention

[0020] According to an exhaust emission control device of the invention, various meritorious effects can be obtained as follows.

[0021]

(I) Even in a condition of operation with lower exhaust temperature such as light-load operation, the particulates captured by the filter body can be effectively burned off by the aid of plasma. Moreover, due to the heat insulation effect by the upstream and downstream oxidation catalysts, the filter body can be rapidly elevated in temperature into environment for ready burn-off of the particulates, so that the particulates can be burned off with a shorter electric discharge time than they could conventionally, whereby electric power consumption can be substantially reduced.

[0022] (II) The harmful gas such as highly concentrated CO or HC generated due to combustion of the particulate with relatively low temperature by the aid of plasma can be oxidized into harmless CO₂ or H₂O when it passes through the downstream oxidation catalyst and is discharged. Thus, the harmful gas is prevented from remaining in the exhaust gas finally discharged into the atmosphere.

[0023] (III) NO occupying majority of NO_x in the exhaust gas can be converted into highly reactive NO₂ when the exhaust gas passed through the upstream oxidation catalyst, which can substantially accelerate the oxidation reaction of the particulates under a condition of operation with relatively high exhaust temperature. This promotes spontaneous combustion of the particulates by no aid of plasma to obtain sufficient burn-off.

[0024] (IV) When the plasma regenerative particulate filter is divided into a plurality of smaller units which are arranged in parallel with each other in the filter casing, voltage for electric discharge being separately applied to the respective smaller units, even a power source with relatively small capacity will suffice. Regeneration of the filter through plasma can be also attained during stoppage of an engine for example in a vehicle with an idle stopper.

[0025] (V) When employed are porous members constituting the filter body and integrally carrying oxidation catalysts, the oxidation reaction of the particulates captured by the filter body can be accelerated by the oxidation catalysts, so that the particulates can be further reliably burned off in a region of operation with lower exhaust temperature.

Brief Description of the Drawings

[0026]

[Fig. 1] A schematic view showing arrangement of a conventional particulate filter.

[Fig. 2] A sectional view showing particulars of the particulate filter shown in Fig. 1.

[Fig. 3] A sectional view showing an embodiment of the invention.

[Fig. 4] A sectional view looking in the direction of arrows II in Fig. 3.

Explanation of the Reference Numerals

[0027]

2 exhaust gas
3 exhaust pipe
4 particulate filter
5 passage
7 filter body
9 rod-like electrode (electrode)
10 cylindrical electrode (electrode)
11 plasma regenerative particulate filter
11A, 11B, 11C and 11D smaller unit
12 filter casing
16 upstream oxidation catalyst
17 downstream oxidation catalyst

Best Mode for Carrying Out the Invention

[0028] An embodiment of the invention will be described in conjunction with the drawings.

Figs. 3 and 4 show an embodiment of the invention in which parts similar to those in Figs. 1 and 2 are represented by the same reference numerals.

[0029] As shown in Figs. 3 and 4, used in an exhaust emission control device of the invention is a plasma regenerative particulate filter 11 comprising a filter body 7 similar to that shown in Fig. 2 above and rod-like and cylindrical electrodes 9 and 10 so as to generate plasma in the filter body 7. Shown is an example of the plasma regenerative particulate filter 11 divided into a plurality of (four in the figure shown) smaller units 11A, 11B, 11C and 11D which are arranged in parallel with each other within the filter casing 12.

[0030] The filter body 7 in each of the smaller units 11A, 11B, 11C and 11D has the rod-like electrode 9 inserted into an axis of the filter body 7 and the cylindrical electrode 10 fitted over the outer periphery of the filter body 7. The rod-like electrodes 9 of the smaller units 11A, 11B, 11C and 11D are connected to an anode of a power source or battery 14 through change-over relays 13a, 13b, 13c and 13d, respectively. The cylindrical electrodes 10 of the smaller units 11A, 11B, 11C and 11D are connected to a cathode of the power source 14 through an electrically conductive support member 15 and the filter casing 12 so that voltage for electric discharge may be separately applied to the respective smaller units 11A, 11B, 11C and 11D.

[0031] The support member 15 serves for support of the smaller units 11A, 11B, 11C and 11D of the particulate filter 11 in the filter casing 12 and also serves as partition or filler for gap between the smaller units 11A, 11B, 11C and 11D.

[0032] The above-mentioned particulate filter 11 divided into the plural smaller units 11A, 11B, 11C and 11D

is accommodated in the filter casing 12 within the exhaust pipe 3. Arranged upstream and downstream of and adjacent to the particulate filter 11 in the filter casing 12 are oxidation catalysts 16 and 17, respectively, so as to obtain heat insulation effect to the particulate filter 11.

[0033] Each of the upstream and downstream oxidation catalysts 16 and 17 is of flow-through type and comprises a carrier with a honeycomb structure made of ceramics such as cordierite, said carrier carrying an appropriate amount of platinum. The upstream catalyst 17 may have its capacity and platinum-carrying amount less than those of the downstream catalyst 16.

[0034] The porous members constituting the filter body 7 of each of the above-mentioned smaller units 11A, 11B, 11C and 11D may carry oxidation catalysts so as to promote the oxidation reaction of the particulates captured by the filter body 7.

[0035] In the exhaust emission control device thus constructed, when the exhaust gas 2 having flown into the filter casing 12 passes through the upstream oxidation catalyst 16, NO occupying majority of NO_x in the exhaust gas 2 is converted into highly reactive NO_2 , so that oxidation reaction of the particulates is substantially accelerated into satisfactory burn-off of the particulates under a condition of operation with exhaust temperature over about 250°C.

[0036] However, when a condition of light-load operation with exhaust temperature greatly falling below 250°C continues for a long time, for example, during running or driving on congested city roads, satisfactory burn-off of the particulates cannot be expected; for this reason, at a right moment when an accumulated particulate amount is estimated to exceed a predetermined amount (estimation may be based on, for example, pressure difference between the entering and discharge sides of the filter body or operational time period), voltage for electric discharge is applied separately to the smaller units 11A, 11B, 11C and 11D to discharge electricity across the respective rod-like electrodes 9 and cylindrical electrodes 10, thereby generating plasma in the inner gas of the filter body 7.

[0037] Thus, the inner gas of the filter body 7 is excited to convert oxygen into ozone and NO into NO_2 . These excited exhaust gas components are being activated so that oxidation reaction of the particulates captured by the filter body 7 is accelerated by the excited exhaust gas components, whereby the particulates are satisfactorily burned off even in a condition of operation with lower exhaust temperature.

[0038] In this case, the plasma regenerative particulate filter 11 is sandwiched and heat insulated by the upstream and downstream oxidation catalysts 16 and 17 in one and the same filter casing 12, so that when the oxidation reaction of the captured particulates begins, the filter body 7 is rapidly elevated in temperature. As a result, the particulates have tendency of being more readily burned off and can be burned off with a shorter electric discharge time than they could conventionally and thus

required electric power consumption is less than that required conventionally.

[0039] Since voltage is applied across each of the smaller units 11A, 11B, 11C and 11D in the particulate filter 11 so as to discharge electricity, the power source 14 with relatively small capacity will suffice. Division into the smaller units 11A, 11B, 11C and 11D improves combustibility of the particulates per unit, so that regeneration of the filter through plasma can be attained during stoppage of an engine for example in a vehicle with an idle stopper.

[0040] The harmful gas such as highly concentrated CO or HC generated due to combustion of the particulates with relatively low temperature by the aid of plasma is oxidized into harmless CO₂ or H₂O when it passes through the downstream oxidation catalyst 17 and is discharged.

[0041] Thus, according to the above embodiment, even in a condition of operation with lower exhaust temperature such as light-load operation, the particulates captured by the filter body 7 can be efficiently burned off by the aid of plasma; the filter body 7 can be rapidly elevated in temperature due to heat insulation effect by the upstream and downstream oxidation catalysts 16 and 17 into environment for ready burn-off the particulates, so that the particulates can be burned off with a shorter electric discharge time than they could conventionally, whereby electric power consumption can be substantially reduced.

[0042] The harmful gas such as highly concentrated CO or HC generated due to combustion of the particulates with relatively low temperature by the aid of plasma is oxidized into harmless CO₂ or H₂O when it passes through the downstream oxidation catalyst 17 and is discharged. As a result, the harmful gas is prevented from remaining in the exhaust gas 2 finally discharged into the atmosphere.

[0043] NO occupying majority of NO_x in the exhaust gas 2 can be converted into highly reactive NO₂ when the exhaust gas passes through the upstream oxidation catalyst 16, which substantially accelerates the oxidation reaction of the particulates under a condition of operation with relatively high exhaust temperature, whereby spontaneous combustion of the particulates is promoted by no aid of plasma, thereby providing satisfactory burn-off of the particulates.

[0044] As especially shown in the embodiment, when the particulate filter 11 is divided into the plural smaller units 11A, 11B, 11C and 11D which are arranged in parallel with each other within the filter casing 12, voltage for electric discharge being separately applicable to the respective smaller units 11A, 11B, 11C and 11D, even the power source 14 with relatively small capacity will suffice; regeneration of the filter through plasma can be attained during stoppage of an engine, for example, in a vehicle with an idle stopper.

[0045] In a case where employed are the porous members constituting the filter body 7 and integrally carrying

oxidation catalysts, the oxidation reaction of the particulates captured by the filter body 7 can be accelerated by the oxidation catalysts, so that further reliable burn-off of the particulates can be attained in a region of operation with lower exhaust temperature.

[0046] It is to be understood that an exhaust emission control device of the invention is not limited to the above-mentioned embodiment and that various changed and modifications may be made without leaving the gist of the invention. For example, the plasma regenerative particulate filter may be constituted by a single unit. The filter body may or may not carry oxidation catalysts. Shapes and arrangement of the filter body and electrodes are not limited to those shown.

Claims

1. An exhaust emission control device comprising a filter body (7) constituted by porous members through which exhaust gas (2) passes for capture of particulates entrained in the exhaust gas (2) and electrodes (9,10) for generating plasma in said filter body (7), thereby providing a plasma regenerative particulate filter (11), said particulate filter (11) being incorporated in a filter casing (12) within an exhaust pipe (3), oxidation catalysts (16,17) being arranged respectively upstream and downstream of and adjacent to the particulate filter (11) in the filter casing (12) so as to obtain heat insulation effect to the particulate filter (11).
2. The exhaust emission control device according to claim 1, wherein the plasma regenerative particulate filter (11) is divided into a plurality of smaller units (11A, 11B, 11C, 11D) which are arranged in parallel with each other within the filter casing (12), voltage for electric discharge being separately applicable to the respective smaller units (11A, 11B, 11C, 11D).
3. The exhaust emission control device according to claim 1 or 2, wherein the filter body (7) is constituted by porous members integrally carrying oxidation catalyst.
4. The exhaust emission control device according to claim 1 or 2, wherein the filter body (7) is employed which comprises a number of passages in the form of honeycomb through which exhaust gas (2) passes, inlet and outlet ends of the respective passages being alternately plugged.
5. The exhaust emission control device according to claim 3, wherein the filter body (7) is employed which comprises a number of passages in the form of honeycomb through which exhaust gas (2) passes, inlet and outlet ends of the respective passages being alternately plugged.

6. The exhaust emission control device according to claim 4, wherein the filter body (7) has a rod-like electrode (9) inserted at an axis of the filter body (7) and a cylindrical electrode (10) fitted over an outer periphery of the filter body (7). 5
7. The exhaust emission control device according to claim 5, wherein the filter body (7) has a rod-like electrode (9) inserted at an axis of the filter body (7) and a cylindrical electrode (10) fitted over an outer periphery of the filter body (7). 10

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FIG.1

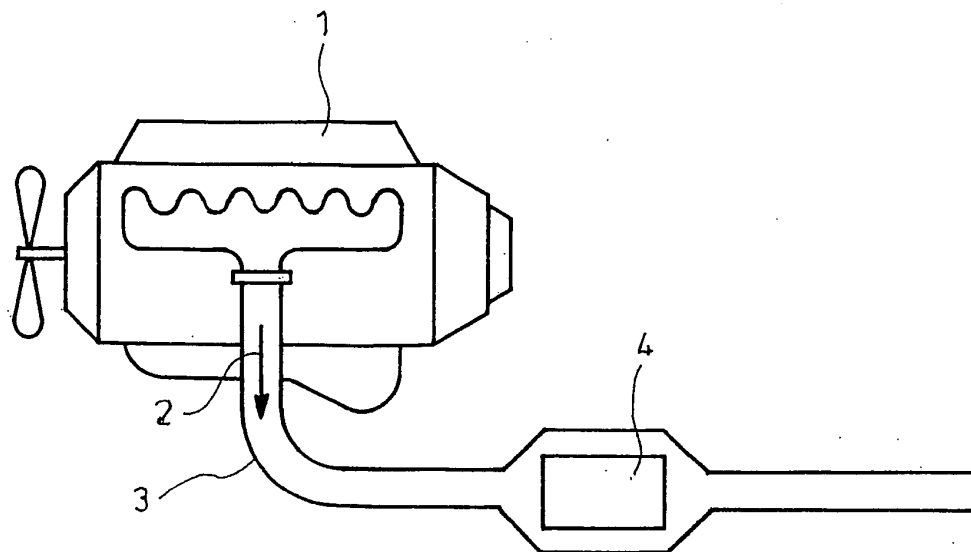


FIG.2

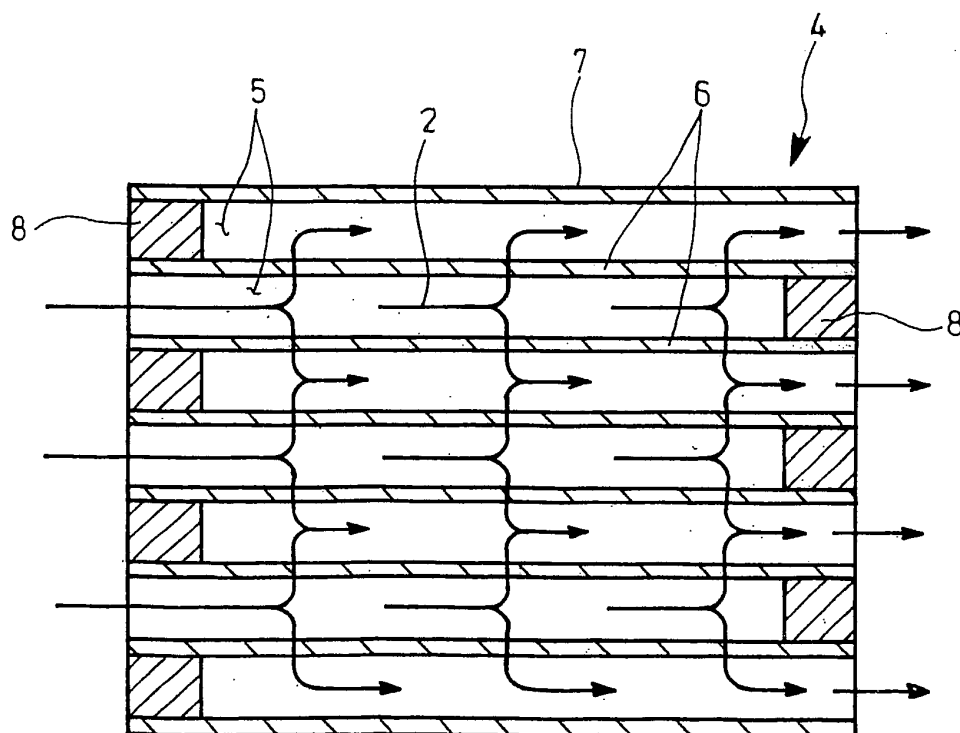


FIG.3

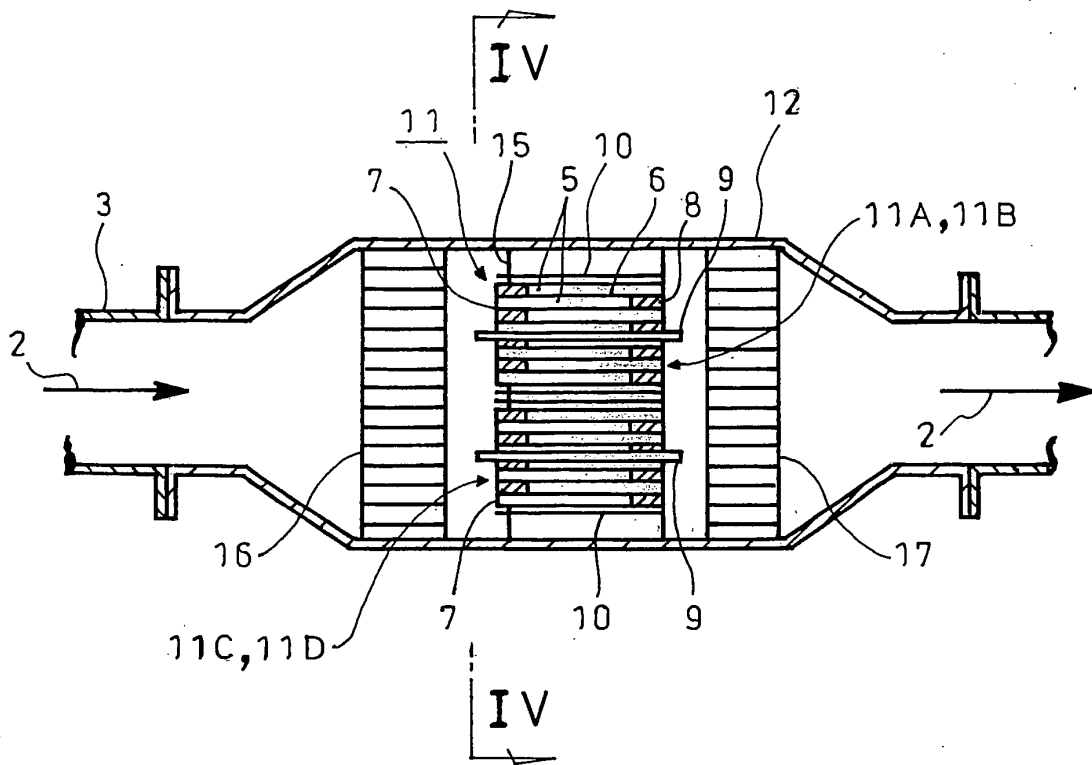
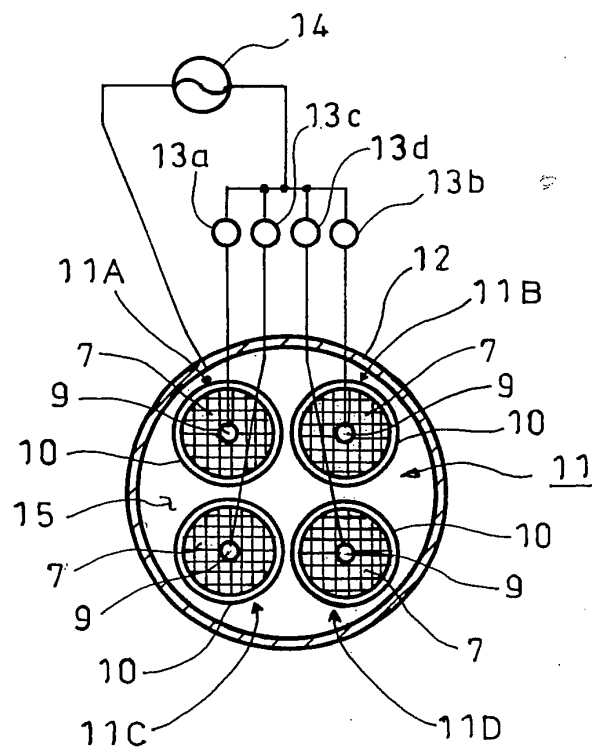


FIG.4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/013225

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ F01N3/02, F01N3/08		
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) Int.Cl ⁷ F01N3/02, F01N3/08		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2004 Kokai Jitsuyo Shinan Koho 1971-2004 Toroku Jitsuyo Shinan Koho 1994-2004		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-276333 A (Mitsubishi Heavy Industries, Ltd.), 25 September, 2002 (25.09.02), Par. Nos. [0028], [0031]; Fig. 4 (Family: none)	1-7
Y	JP 11-336527 A (Toyota Motor Corp.), 07 December, 1999 (07.12.99), Fig. 1 (Family: none)	1-7
Y	JP 10-121946 A (Hino Motors, Ltd.), 12 May, 1998 (12.05.98), Fig. 1 (Family: none)	1-7
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 10 December, 2004 (10.12.04)		Date of mailing of the international search report 28 December, 2004 (28.12.04)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/013225

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-214141 A (Toyota Motor Corp.), 30 July, 2003 (30.07.03), Fig. 4 (Family: none)	1-7
Y	JP 4-47113 A (Nissan Motor Co., Ltd.), 17 February, 1992 (17.02.92), Fig. 6 (Family: none)	1-7
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 64012/1989 (Laid-open No. 104830/1991) (Mitsubishi Heavy Industries, Ltd.), 21 August, 1990 (21.08.90), Figs. 2, 3 (Family: none)	2

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