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(71) Applicant: **KABUSHIKI KAISHA TOYOTA JIDOSHOKKI**
Kariya-shi,
Aichi-ken (JP)

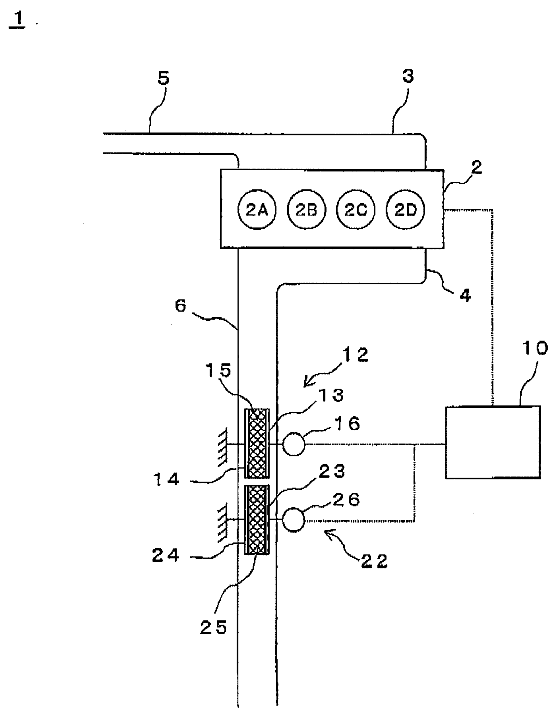
(72) Inventors:
- **Yoshida, Koji**
  Kariya-shi, Aichi 448-8671 (JP)
- **Hoshi, Sakutaro**
  Kariya-shi, Aichi 448-8671 (JP)

(74) Representative: **TBK-Patent**
Bavariaring 4-6
80336 München (DE)

(54) **Exhaust gas treatment system for an internal combustion engine**

(57) An exhaust gas treatment system for an internal combustion engine (1) reduces the amount of NOx in exhaust gas flowing through an exhaust passage (6) of the engine (1). The system has a plasma generator (12) including two electrodes (13, 14) spaced away from each other in the exhaust passage (6), a high-frequency power supply (16) connected to one of the electrodes (13), and a NOx absorber (15) provided between the electrodes (13, 14).

FIG. 1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an exhaust gas treatment system for an internal combustion engine.

[0002] In boilers and internal combustion engines, exhaust gas is produced as a result of the combustion of fuel and discharged into the atmosphere. The exhaust gas contains various substances such as particulate matter (PM) including carbide particles, hydrocarbons (HC), sulfur oxides (SOx: SO, SO_2), nitrogen oxides (NOx: NO, NO_2, N_2O), and carbon oxides (CUx: CO, CO_2. Recent emission standards are very strict because of various environmental issues such as global warming, and therefore establishment of technologies for exhaust gas purification is required. Particularly in transportations like automobile, there are many constraints such as size, weight, cost, efficiency and ease of maintenance, but a demand for such technologies is expected to increase rapidly in the future. Therefore, development of an exhaust gas treatment system with high efficiency is an urgent need.

[0003] In automotive gasoline engines, a catalytic converter with a catalyst such as platinum (a three-way catalytic converter) is commonly used to reduce the amount of PM, HC and NOx in exhaust gas by means of oxidizing and reducing reactions. The engines are generally controlled so as to operate on a stoichiometric air-fuel ratio by using oxygen sensors, In diesel engines having high fuel economy, emission of COx such as CO_2 is 20% to 30% less than that of the gasoline engines, but reducing catalysts are difficult to be used in diesel engines because of the presence of excess oxygen in exhaust gas. Therefore, various methods for reducing NOx emission are used practically. One of the methods is recirculating a part of exhaust gas back to engine cylinders (an exhaust gas recirculation: EGR) and then using a diesel particulate filter (DPF) to collect PM generated in large amounts due to the EGR. Other methods include injecting urea into exhaust gas (a urea selective catalytic reduction: urea SCR), and storing NOx temporarily and then reducing the stored NOx at a proper timing by injection of fuel (a diesel particulate-NOx reduction system: DPNR).

[0004] However, the combination of EGR and DPF not only reduce NOx emission insufficiently, but also adversely affects the drivability and performance of the automobiles. The urea SCR requires installation of an additional urea tank and periodic replenishment of urea. The DPNR requires periodic injection of extra fuel, thereby lowering fuel economy. Furthermore, implementation of the above methods need to be controlled precisely depending on combustion condition of the engine, and therefore engine control becomes complex. Such complex engine control results in enlargement of engine development and period thereof, thereby increasing a cost of the engine development. Furthermore, any of the methods needs a precious metal catalyst such as platinum, which is not preferable from the viewpoint of cost and procurement of catalyst material.

[0005] In a known engine disclosed in Japanese Unexamined Patent Application Publication No. 61-31615, exhaust gas is introduced through an exhaust pipe into a dissociation cylinder (reformer) having corona discharge needles at the outer surface thereof, NOx in the exhaust gas is decomposed into oxygen atom (oxygen radical) and nitrogen atom (nitrogen radical) by the discharge in the dissociation cylinder. The oxygen atom is reacted with carbon monoxide contained in large amounts in the exhaust gas to produce carbon dioxide, and the nitrogen atom is reacted with the other nitrogen atom to produce nitrogen (N_2). As a result, the amount of NOx in the exhaust gas is reduced.

[0006] However, NOx concentration in the exhaust gas is low, and therefore discharge decomposition of low concentrated NOx in the exhaust gas is not efficient.

[0007] The present invention is directed to an exhaust gas treatment system that reduces the amount of NOx in exhaust gas more efficiently.

SUMMARY OF THE INVENTION

[0008] In accordance with an aspect of the present invention, an exhaust gas treatment system for an internal combustion engine reduces the amount of NOx in exhaust gas flowing through an exhaust passage of the engine. The system has a plasma generator including two electrodes spaced away from each other in the exhaust passage, a high-frequency power supply connected to one of the electrodes, and a NOx absorber provided between the electrodes.

[0009] Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a schematic view of a diesel engine having an exhaust gas treatment system according to a first embodiment of the present invention; and

Fig. 2 is a schematic view of a diesel engine having an exhaust gas treatment system according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] The following will describe the first embodiment of the present invention with reference to Fig. 1. A diesel engine 1 includes a cylinder block 2, an intake manifold 3 and an exhaust manifold 4. The cylinder block 2 is formed with four combustion chambers 2A, 2B, 2C and 2D defined in respective cylinders (not shown in the drawings). The intake manifold 3 introduces air from an intake pipe 5 into the combustion chambers 2A to 2D, and the exhaust manifold 4 collects exhaust gas from the combustion chambers 2A to 2D into an exhaust pipe 6. In the exhaust pipe 6 as an exhaust passage, two plasma generators 12 and 22 are disposed in series. The diesel engine 1 further includes an electronic control unit (ECU) 10 as a controller.

[0012] The plasma generator 12 includes a high-frequency power supply 16 electrically connected to the ECU 10, two plate-shaped electrodes 13 and 14 spaced away from each other in the exhaust pipe 6, and a NOx absorber 15 provided between the electrodes 13 and 14. The electrodes 13 and 14 are disposed parallel to each other. The electrode 13 is electrically connected to the high-frequency power supply 16, and the electrode 14 is grounded. The electrodes 13 and 14 are covered with a dielectric material. The NOx absorber 15 is of a porous body made of electrically conductive Al_2O_3 and supporting NOx-storage particles made of BaO. As with the plasma generator 12, the plasma generator 22 includes two electrodes 23 and 24, a high-frequency power supply 26, and a NOx absorber 25 provided between the electrodes 23 and 24.

[0013] The following will describe the operation of the exhaust gas treatment system according to the first embodiment. When the diesel engine 1 is started, air in the intake pipe 5 is introduced through the intake manifold 3 into the combustion chambers 2A to 2D, and compressed by pistons (not shown in the drawings). Diesel fuel injected from injection nozzles (not shown in the drawings) into the compressed air is ignited spontaneously for combustion, and exhaust gas is discharged from the combustion chambers 2A to 2D into the exhaust manifold 4.

[0014] The exhaust gas then flows in the exhaust pipe 6 and passes through the NOx absorber 15 of the plasma generator 12, so that NOx in the exhaust gas is stored on the NOx-storage particles of the NOx absorber 15. The plasma generator 12 thus reduces NOx concentration of the exhaust gas passing therethrough, When the amount of NOx on the NOx absorber 15 reaches a predetermined limit, the plasma generator 12 cannot reduce the NOx concentration of the exhaust gas any more. In such a case, the exhaust gas passes through the NOx absorber 25 of the other plasma generator 22, so that NOx in the exhaust gas is stored on the NOx-storage particles of the NOx absorber 25. The plasma generator 22 thus reduces NOx concentration of the exhaust gas passing therethrough, as with the plasma generator 12.

[0015] When the amount of NOx on the NOx absorber 15 reaches a predetermined level, the ECU 10 drives the high-frequency power supply 16 so that discharge occurs (that is, plasma is generated) between the electrodes 13 and 14. The discharge energy is set in a range of 642 to 942 kJ/mol. This energy range is higher than a range wherein NOx can be decomposed into nitrogen and oxygen atoms (N, O), but lower than a range wherein nitrogen (N_2) can be decomposed into nitrogen atoms. Therefore, NOx on the NOx absorber 15 is decomposed into N_2 and O_2 at a given rate, thereby being released from the NOx absorber 15. If NOx is newly produced from the nitrogen and oxygen atoms, the NOx is stored on the NOx absorbers 15 or 25 again, and finally all NOx on the NOx absorber 15 is decomposed. Since the above discharge energy is lower than the energy for decomposition of N_2, the newly produced N_2 is prevented from being decomposed to produce NOx again. While the discharge occurs in the plasma generator 12, the plasma generator 22 stores NOx in the exhaust gas on the NOx absorber 25.

[0016] In the meantime, the amount of NOx on the NOx absorber 25 of the plasma generator 22 reaches a predetermined limit. However, the previously stored NOx on the NOx absorber 15 of the plasma generator 12 is decomposed into N_2 and O_2 by the discharge between the electrodes 13 and 14 to be released from the NOx absorber 15. Therefore, exhaust gas passing through the NOx absorber 15, NOx in the exhaust gas is stored on the NOx-storage particles of the NOx absorber 15 again. While the NOx is stored on the NOx absorber 15, plasma is generated between the electrodes 23 and 24 in the plasma generator 22, as in the case of the plasma generator 12. As a result, the NOx on the NOx absorber 25 is decomposed into N_2 and O_2 to be released from the NOx absorber 25.

[0017] The above-described operations of the plasma generators 12 and 22 are repeated alternately, so that NOx concentration of the exhaust gas is reduced. In the first embodiment, the plasma is generated alternately by the plasma generators 12 and 22, but may be generated intermittently at a predetermined time interval by each plasma generator. Alternatively, the plasma may be generated by each plasma generator at any time depending on the exhaust gas amount determined by the ECU 10, based on the engine operating condition such as engine speed.

[0018] The exhaust gas treatment system according to the first embodiment has two plasma generators 12 and 22. The plasma generator 12 has the electrodes 13 and 14 spaced in the exhaust pipe 6, the high-frequency power supply 16 connected to the electrode 13, and the NOx absorber 15 provided between the electrodes 13 and 14. The plasma generator 22 which is of substantially the same structure as the plasma generator 12 is provided in series with the plasma generator 12 in the exhaust pipe 6. Therefore, while NOx is newly being stored and concentrated on a NOx absorber in one of the two plasma generators, concentrated NOx on a NOx absorber can be decomposed by the plasma between the two electrodes in the other of the two plasma generators. As a result, the amount of NOx in exhaust gas is reduced more efficiently. In addition, plasma decomposition of highly concentrated NOx on a NOx absorber reduces the amount of NOx in exhaust gas more efficiently, as compared to plasma decomposition of low concentrated NOx in exhaust gas without using a NOX absorber.

[0019] Though two plasma generators are provided in the exhaust pipe in the first embodiment, three or more plasma generators may be used to achieve the same effect. In the first embodiment, the discharge energy is set in the range of 642 to 942 kJ/mol for each plasma generator, but not limited to this range. If the discharge energy is higher than 942kJ/mol, N_2 produced from NOx on a NOx absorber may be decomposed to produce NOx again. However, since N_2 is decomposed within a NOx absorber, NOx newly produced from the N_2 is stored on the NOx-storage particles of the NOx absorber again without being released from the NOx absorber. Accordingly, the discharge energy may be set at least in a range of 642 kJ/mol or more.

[0020] In the first embodiment, the NOx absorber 15 is of a porous body made of electrically conductive Al_2O_3 and supporting the NOx-storage particles made of BaO, but the present invention is not limited to this structure. According to the invention, the NOx absorber 15 may contain at least a material that allows physisorption of NOx thereon. The material includes, for example, alkali metals such as Na, K, Li, alkali earth metals such as Ba, Mg, Ca, lanthanoids such as La, Ce, and oxides of the alkali metals, the alkali earth metals or the lanthanoids such as MgO. The material further includes, for example, compounds of either the alkali metals, the alkali earth metals or the lanthanoids with elements other than the alkali metals, the alkali earth metals and the lanthanoids such as NaCl, and oxides of the compounds such as $BaSO_4$.

[0021] The following will describe the second embodiment of the present invention with reference to Fig. 2. The second embodiment differs from the first embodiment in that the number of plasma generators is increased, but the other components and structures are substantially the same as those of the first embodiment. Therefore, the following description will use same reference numbers for the common elements or components in both embodiments, and the description of such elements or components for the second embodiment will be omitted.

[0022] Fig. 2 shows a diesel engine 31 having an exhaust gas treatment system according to the second embodiment. The system has the two plasma generators 12 and 22 of the first embodiment and further four plasma generators 32, 42, 52 and 62. The six plasma generators 12, 22, 32, 42, 52 and 62 are provided in series in the exhaust pipe 6 and electrically connected to the ECU 10. As with the plasma generators 12 and 22, the plasma generator 32 includes two electrodes 33 and 34, a NOx absorber 35 provided between the electrodes 33 and 34, and a high-frequency power supply 36. Similarly, the plasma generator 42 includes two electrodes 43 and 44, a NOx absorber 45 and a high-frequency power supply 46. The plasma generator 52 includes two electrodes 53 and 54, a NOx absorber 55 and a high-frequency power supply 56. The plasma generator 62 includes two electrodes 63 and 64, a NOx absorber 65 and a high-frequency power supply 66.

[0023] The following will describe the operation of the exhaust gas treatment system according to the second embodiment. While the diesel engine 31 is in operation, the ECU 10 monitors the operating condition (e.g. engine load) of the diesel engine 31. When the ECU 10 detects that the diesel engine 31 is operating under low engine load, the ECU 10 drives the high-frequency power supplies 16 and 26 alternately, as described with reference to the first embodiment. Therefore, while NOx is newly stored and concentrated on a NOx absorber in one of the two plasma generators, concentrated NOx on a NOx absorber in the other of the two plasma generators is decomposed by the plasma between the two electrodes. As a result, the amount of NOx in exhaust gas is reduced efficiently.

[0024] When the engine load is increased, the ECU 10 drives alternately the four power supplies 16, 26, 36 and 46. When the engine load is further increased, the ECU 10 drives alternately the six power supplies 16, 26, 36, 46, 56 and 66. Since the amount of NOx in exhaust gas is increased with an increase in the engine load of the diesel engine 31, the number of plasma generators to be operated is increased in the second embodiment. That is, in the second embodiment, the number of plasma generators to be operated is changed depending on the varying engine load of the diesel engine 31. As a result, the plural plasma generators are operated properly depending on the variation in the amount of NOx in exhaust gas, and the amount of NOx in exhaust gas is reduced more efficiently.

[0025] In the second embodiment, operation timing of each power supply is not described specifically, but any one or more of the power supplies may be operated at a different timing from the other power supplies. For example, the power supplies 16, 26, 36, 46, 56 and 66 may be operated one by one in this order For example, the power supplies 16, 36 (and 56) may be operated concurrently, while the power supplies 26, 46 (and 66) may be operated concurrently.

[0026] In the first and second embodiments, the exhaust gas treatment system has a plurality of plasma generators, but may have only one plasma generator, If the system has only one plasma generator 12, the amount of NOx in exhaust gas cannot be reduced during the plasma decomposition of NOx on the NOx absorber 15, but highly concentrated NOx on the NOx absorber 15 is decomposed surely. Therefore, the amount of NOx in exhaust gas is reduced more efficiently, as compared to the case of discharge decomposition of low concentrated NOx in exhaust gas.

[0027] In the first and second embodiments, the exhaust gas treatment system is used for the diesel engine, but may be used for boilers or other internal combustion engines such as a gasoline engine.

[0028] Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.

[0029] An exhaust gas treatment system for an internal combustion engine (1) reduces the amount of NOx in exhaust gas flowing through an exhaust passage (6) of the engine (1). The system has a plasma generator (12) including two electrodes (13, 14) spaced away from each other in the exhaust passage (6), a high-frequency power supply (16) connected to one of the electrodes (13), and a NOx absorber (15) provided between the electrodes (13,14).

Claims

1. An exhaust gas treatment system for an internal combustion engine (1), the system for reducing the amount of NOx in exhaust gas flowing through an exhaust passage (6) of the engine (1),
characterized in that the system has a plasma generator (12) including two electrodes (13, 14) spaced away from each other in the exhaust passage (6), a high-frequency power supply (16) connected to one of the electrodes (13), and a NOx absorber (15) provided between the electrodes (13, 14).

2. The exhaust gas treatment system according to claim 1. wherein a plurality of plasma generators (12, 22) is provided in series in the exhaust passage (6), and the plasma generators (12, 22) are operated at different timings from each other.

3. The exhaust gas treatment system according to claim 2, further comprising a controller (10) that monitors engine load and changes the number of plasma generators (12, 22, 32, 42, 52, 62) to be operated depending on the engine load.

4. The exhaust gas treatment system according to any one of claims 1 through 3, wherein the energy for discharge between the electrodes (13, 14) is set in a range of 642 to 942kJ/mol.

5. The exhaust gas treatment system according to any one of claims 1 through 4, wherein the NOx absorber (15) contains a material that allows physisorprtion of NOx thereon.

6. The exhaust gas treatment system according to claim 5, wherein the material is selected from the group consisting of:

   alkali metals;
   alkali earth metals;
   lanthanoids;
   oxides of the alkali metals, the alkali earth metals or the lanthanoids:
   compounds of either the alkali metals, the alkali earth metals or the lanthanoids with elements other than the alkali metals, the alkali earth metals and the lanthanoids; and
   oxides of the compounds.

FIG. 1

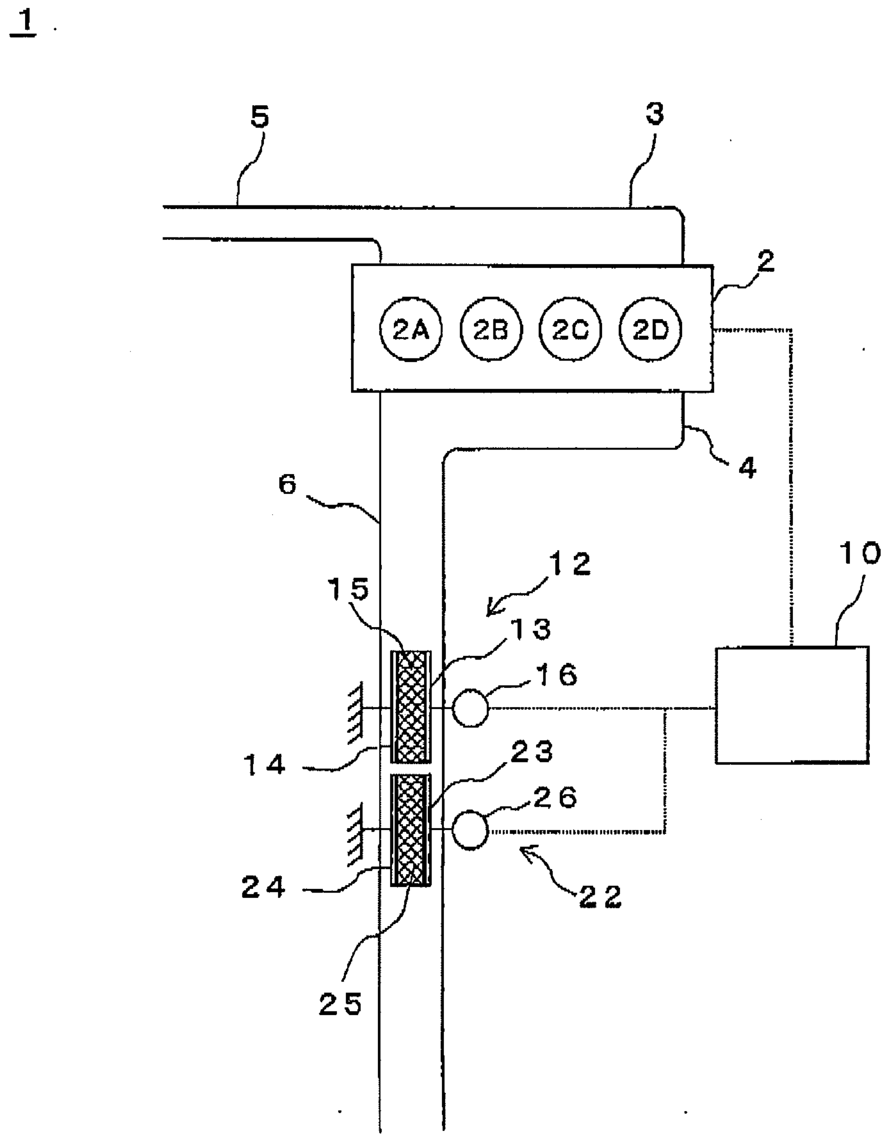
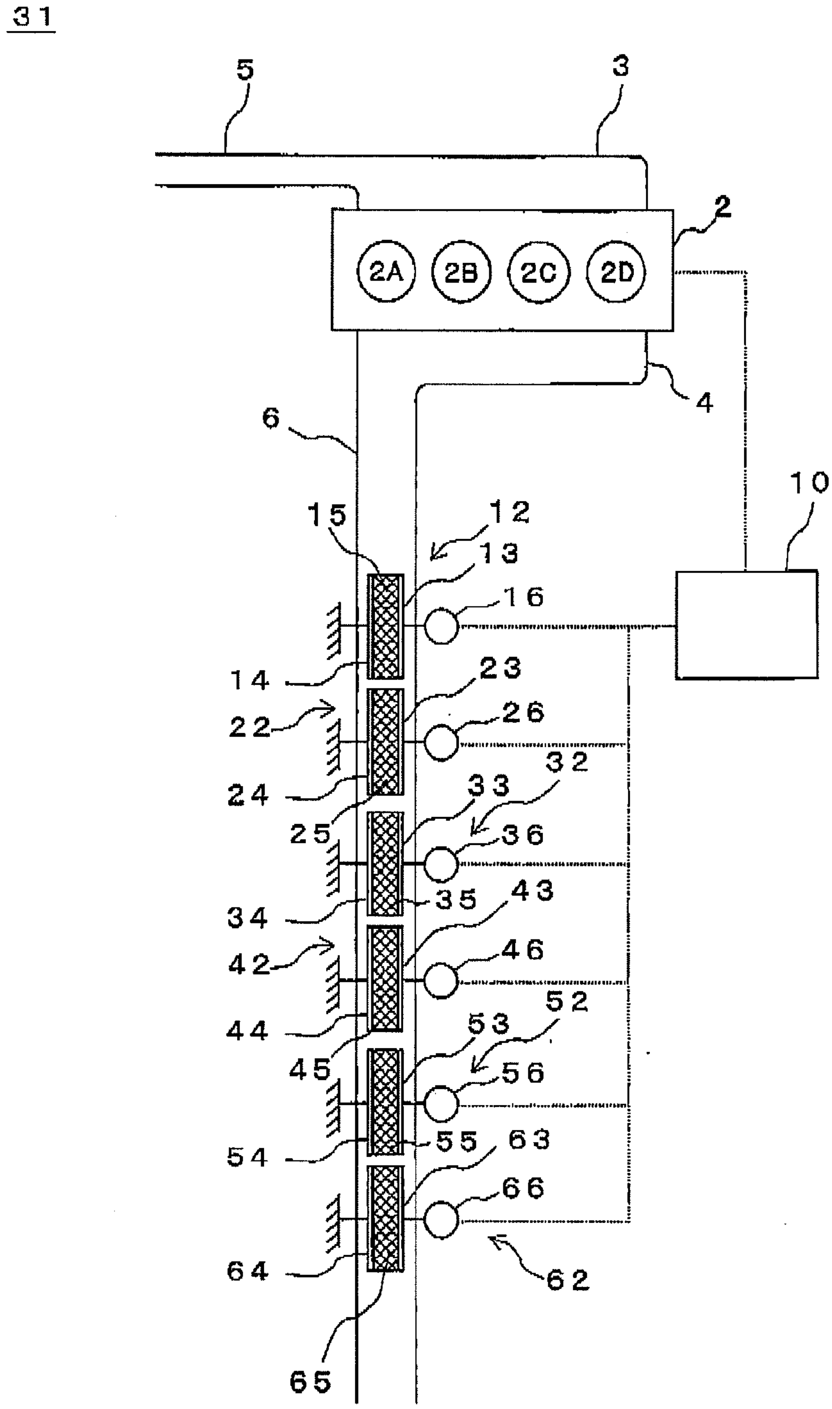


FIG. 2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EUROPEAN SEARCH REPORT

Application Number
EP 08 17 2767

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2005/284137 A1 (SON GEON S [KR] SON GEON-SEOG [KR]) 29 December 2005 (2005-12-29) * paragraph [0017]; figures 2,3,7 * -----	1-6	INV. F01N3/08
X	EP 0 953 375 A (DEGUSSA [DE] UMICORE AG & CO KG [DE]) 3 November 1999 (1999-11-03) * paragraph [0031]; figures 5,7 * -----	1-6	
X	EP 1 479 430 A (TOYOTA MOTOR CO LTD [JP]) 24 November 2004 (2004-11-24) * paragraphs [0031] - [0035]; figures * -----	1,3-6	
X	WO 98/00221 A (LOW EMISSIONS TECHNOLOGIES RES [US]) 8 January 1998 (1998-01-08) * page 5, line 24 - line 25 * * page 6, line 13 - line 21 * -----	1,3-6	
X	JP 2001 182525 A (TOYOTA CENTRAL RES & DEV) 6 July 2001 (2001-07-06) * abstract; figures * -----	1,3-6	TECHNICAL FIELDS SEARCHED (IPC)
			F01N

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	1 April 2009	Blanc, Sébastien

CATEGORY OF CITED DOCUMENTS

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01-04-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005284137 A1	29-12-2005	NONE	
EP 0953375 A	03-11-1999	DE 19819372 A1	04-11-1999
		JP 4112740 B2	02-07-2008
		JP 11347356 A	21-12-1999
		US 6238525 B1	29-05-2001
EP 1479430 A	24-11-2004	JP 2004344719 A	09-12-2004
		US 2004234430 A1	25-11-2004
WO 9800221 A	08-01-1998	AU 3403397 A	21-01-1998
		US 5746984 A	05-05-1998
JP 2001182525 A	06-07-2001	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 61031615 A **[0005]**