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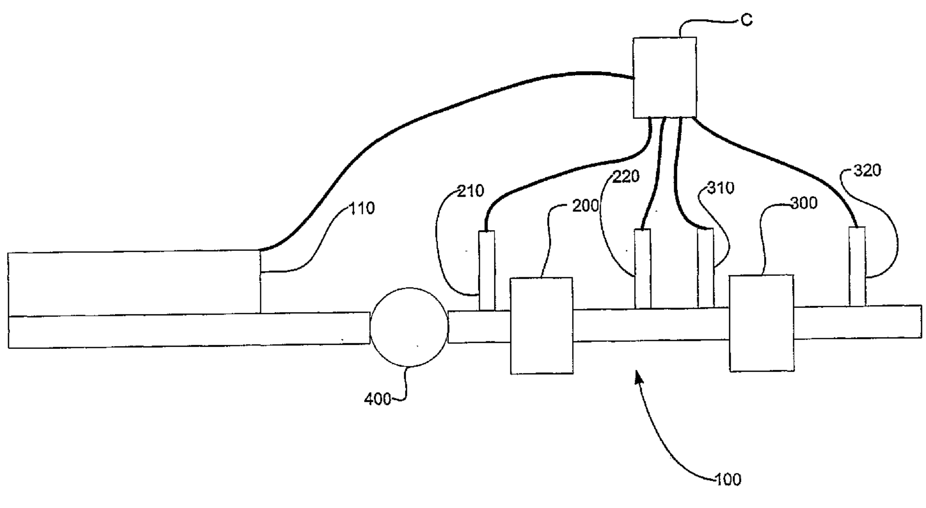
(54) **Title:** DIESEL CATALYST SYSTEM



(57) **Abstract:** A selective catalytic reduction system (100) for reducing nitric oxides emission levels from a compression ignition engine (110) comprises a first reductant injector (210) located upstream a first catalyst (200) comprising a selective catalytic reduction coating. A second reductant injector (310) is located downstream the first catalyst; and a second catalyst (300) is placed downstream the second reductant injector and comprises a selective catalytic reduction coating.

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DIESEL CATALYST SYSTEM

FIELD OF THE INVENTION

The present invention relates to a selective catalytic reduction system for reducing nitric oxide emission levels from a compression ignition engine, comprising a first reductant injector located upstream a first catalyst comprising a selective catalytic reduction coating.

PRIOR ART

In the art of combustion engines, there has been a growing concern regarding emissions, at least since the early 1970:s. For SI (spark ignition) engines, the emissions can hardly be regarded as a problem after the three-way catalyst was put on the market in the mid 70:s.

For CI (compression ignition) engines, the situation is, however, slightly more complicated; CI engines have inherently high emission levels of nitric oxides (NO_X) and particles (soot). Due to the nature of the engine combustion in a CI engine, a large amount of air is namely inducted into the cylinders, whereupon the air is compressed. Thereafter, an amount of fuel varying as a function of engine load is injected into the compressed air. The injected fuel will auto-ignite due to the high temperature resulting from the compression of the air.

The injected fuel will burn in a diffusion mode, i.e. the combustion speed will be more or less controlled by the mixing rate between the injected fuel and the compressed air. Soot will form in fuel rich zones and NO_X will form in combustion zones where the temperature is high and enough oxygen is left to form NO_X.

One obstacle concerning exhaust aftertreatment for reducing NO_X in CI engine exhausts is the presence of oxygen; as implied earlier, a large amount of air is inducted in the cylinders prior to fuel injection. Hence, there is always a surplus of air in the cylinders, compared to the amount of air necessary to completely combust all the injected fuel. An air surplus in the exhausts makes it impossible to use a standard three-way catalyst in order to reduce NO_X emissions.

Soot (or particles) is/are also a major problem for CI engines; soot forms, as mentioned, in fuel rich combustion zones. High fuel injection pressures, that form small fuel droplets, can reduce soot formation significantly, but there are design limitations on how high injection pressure that can be accepted.

There are methods to reduce NO_X formation in CI engines; the most common way is to delay injection timing. By delaying injection timing, the maximum combustion temperature can be reduced, which in turn will decrease NO_X formation. The NO_X reduction comes, however, with some severe penalties, namely that both soot formation and fuel consumption increase with later injection timing.

One efficient way of reducing NO_X emissions is to use an SCR (Selective Catalytic Reduction) emission aftertreatment system. A common SCR system comprises a substrate coated with e.g. zeolites, V-oxides (e.g. V_2O_5), Cu-zeolites, Fe-zeolites or any other known material suitable for SCR. Unlike three-way catalysts for SI engines, SCR systems cannot work in an environment consisting of exhausts only; some additional agent, e.g. a reductant, must be added to the exhaust gas. A common such agent is urea, i.e. $(NH_2)_2CO$, as well as hydrocarbons or hydrogen.

The efficiency of an SCR catalyst, related to the driving cycle, is limited to about 65-80 percent, and its function is severely impaired by the presence of soot.

For exhaust after-treatment of soot emission, a filter is used; such a filter does however require regeneration at intervals varying with engine load conditions. The regeneration mostly means that the exhaust temperature is increased by any means, e.g. by extremely late fuel injection, a post injection, by inlet air throttling, or by any other suitable means. The increased exhaust temperature allows soot particles trapped in the filter to "burn off", i.e. react with oxygen in the exhausts to form carbon dioxide and water. However, every regeneration sequence results in a fuel economy penalty.

Present and future legislation concerning NO_X emissions will make it virtually necessary to combine late fuel injection, SCR systems and soot filters. This leads to a "vicious circle", ultimately resulting in a high fuel consumption, which in turn leads to an increased greenhouse effect and a bad driving economy.

If the NO_X exhaust aftertreatment could be improved, then the vicious circle should be broken; the fuel injection timing could be set to a setting giving a minimum fuel economy, from which would follow decreased soot formation, which in turn would make NO_X reduction easier.

The object of the present invention is therefore to provide an exhaust aftertreatment system enabling a high NO_X conversion factor.

SUMMARY OF THE INVENTION

The present invention solves the above and other problems by a second reductant injector located downstream the first catalyst and a second catalyst placed downstream the second reductant injector and comprising a selective catalytic reduction coating.

In one embodiment of the invention, the first catalyst comprises a filter function to trap particles formed by the CI combustion. In this embodiment, the first catalyst could comprise a multitude of elongate cells with alternately closed and open top and bottom ends, respectively, wherein an exhaust gas flow is forced to pass through cell walls constituting the cells, and wherein the selective catalytic reduction coating is coated on either or both sides of the walls.

In order to further provide the system according to the invention with an oxidizing capability, an oxidizing catalytic coating could be coated on an upstream side of the cell walls.

For fine-tuning of the amount of reductant to be injected by the reductant injectors, sensors sensing presence of nitric oxides and/or ammonia in the exhaust gas could be arranged in the exhaust gas stream. One embodiment of the fine-tuning comprises placing the sensors downstream the filter function and downstream the second catalyst, respectively. Another embodiment comprises just one sensor for NO_X or NH_3 being placed downstream the second SCR catalyst.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described with reference to the appended drawings, wherein:

Fig. 1 is a schematic view of a catalyst system according to the present invention,

Fig. 2a is a top view of a portion of a filter medium that could be used as a catalyst, and

Fig. 2b is a sectional side view of the filter medium shown in Fig. 2a.

DESCRIPTION OF EMBODIMENTS

In Fig. 1, a schematic view of a catalyst system 100 according to the present invention is shown. The catalyst system 100 is connected to an exhaust system of an engine 110 and comprises a first catalyst 200, the design of which will be described later, a second catalyst 300, and an exhaust pressure governor (EPG) 400. Moreover, first and second reductant injectors 210 and 310, respectively, are mounted upstream the first catalyst 200 and upstream the second catalyst 300, respectively. The reductant may e.g. be urea, hydrocarbons, hydrogen, or any other suitable species with reducing properties. NO_X- and /or NH_3 sensors 220, 320 are mounted downstream the first and second catalysts, 200, 300, respectively. Alternatively, the first NO_X- and /or NH_3 sensor 220 could be omitted.

Both catalysts 200 and 300 are so called SCR (Selective Catalyst Reduction) catalysts, whose function is well known by persons skilled in the art and briefly described above in the prior art section. The catalyst 200 is however further provided with a filter function in order to filter the particles emanating from the CI engine. Such a catalyst is basically designed as a particulate filter, which is coated with an SCR coating in order to obtain a double function, as both a filter and an SCR catalyst. The SCR coating could be provided on either the upstream side of the filter or on the downstream side of the filter or on both, and could be any suitable coating serving as an SCR catalyst.

In Fig 2a, a portion of SCR coated filter medium 250 constituting the first catalyst 200 is shown in a top view; in Fig. 2b, the same portion of the filter medium 250 is shown in a side section view. The filter medium 250 comprises several elongate filter cells 260, each filter cell being defined by four walls 260a, b, c and d and either an upstream surface 265 or a downstream surface 270; every other cell will be provided with the upstream surface, and its neighboring cells will be provided with downstream surfaces.

The walls 260a, b, c and d are made of a porous material, with a pore size that is sufficiently small to trap particulates emanating from the combustion in the engine. The function of the filter is basically that unfiltered exhaust gases will enter filter cells with an open upstream end, and pass the walls of that cell to cells with an open downstream end, hence being able to escape the filter medium through the downstream open end. Hereinafter, the surface of the walls 260a, b, c and d facing a cell with an open upstream end will be referred to as the "upstream wall surface", whereas the other wall surface will be referred to as the "downstream wall surface". A filter system such as described above is often referred to as a "wall-through-flow" filter.

According to the invention, either or both of the upstream and downstream wall surfaces of the cells are coated with an SCR coating; this enables double functions of the first catalyst, namely the functions of filtering particulates and enabling an SCR reaction between NO_X and reductant, in order to reduce emissions of NO_X. Such a double function is, of course, beneficial in terms of production economy, but there is also another benefit, namely that the SCR reaction could help burning off particles stuck in the filter, which would make it possible to prolong the periods between filter regenerations, or, in the best case, make them superfluous.

There is also a possibility to use different SCR coatings on the upstream and downstream sides of the wall surfaces 260a, b, c and d; different SCR coatings have different temperature regions where they have their maximum performance. Hence, it is possible to obtain a catalyst having a wide temperature range.

If, under any circumstances, the exhaust temperature should need adjustment, this could be achieved by the exhaust pressure governor 400; as is well known by persons skilled in the art, the exhaust temperature could be elevated by letting the engine work against a high exhaust pressure. From a fuel economy point of view, it is, however, always most beneficial to run an engine towards an as low exhaust pressure as possible.

In another embodiment of the invention, either of the upstream wall surface or the downstream wall surface is coated with an oxidizing catalytic coating. This coating will oxidize possible contents of fuel, i.e. hydrocarbons, in the exhausts, which oxidation will increase exhausts temperature and reduce emission of hydrocarbons to the environment. According to the invention, the wall surface not coated with oxidizing catalytic coating is coated with an SCR coating. Examples of oxidizing catalytic coatings include various noble metals, e.g. platinum (Pt), palladium (Pd), rhodium (Rh), or iridium (Ir), base metal oxides, or mixtures thereof.

In order to burn off particles stuck in the pores of the filter, it might be necessary to elevate the exhaust temperature under a certain period. This could be done in a number of ways, e.g. by injecting fuel at a late timing, use a post injection, by inlet air throttling, variable valve actuation, exhaust gas recirculation, or by any other method known by persons skilled in the art.

Use of an oxidizing catalyst enables elevation of the exhaust gas temperature by injecting fuel in the exhaust gas stream upstream the oxidation catalyst; this fuel will burn catalytically on the oxidation catalyst, and hence increase the exhaust temperature downstream the oxidation catalyst. To achieve the maximum benefit regarding burning off particles in the catalyst 200, the catalytic coating is preferably coated on the upstream surface of the cell walls 260a, b, c and d.

Of course, it is also possible to use a separate oxidation catalyst mounted upstream the first catalyst 200. The use of a clean-up catalyst function, for limiting the emission of injected reductant, located downstream catalyst 300, is also normal practice for any SCR system, and is hence not shown in the figures. The first catalyst 200 could also consist of a filter substrate that has less filtration efficiency than a wall through flow filter.

The second catalyst 300 could be similar to the first catalyst 200, but is preferably of a more conventional catalyst design.

In still another embodiment of the invention, both the first and the second catalysts 200, 300 are of conventional design. In such a case, a particle filter (not shown) should be mounted upstream the two catalysts. The particle filter of this embodiment must be regenerated using any of the methods mentioned above.

In order to control the amount of reductant injected into the exhaust gases, the two reductant injectors 210, 310 are controlled by the controller C. The controller C in turn gets input from a NO_X formation model based on parameters such as engine load, engine speed, inlet air temperature, charge pressure and other engine parameters on which NO_X formation depend. The NO_X formation model gives a rough estimate of the amount of reductant needed to get a satisfactory NO_X conversion in the first and second catalysts 200 and 300.

In order to further refine the control of the amount of reductant injected into the exhaust gas, and especially if the reductant is urea or ammonia, information from the NO_X/NH_3 sensors 220, 320 could be used to fine-tune the amount of reductant being injected into the exhaust gases. In one embodiment of the invention, both NOX and NH_3 sensors could be used; this gives an increased level of security, since both the level of NO_X and the level of NH_3 could be monitored. If e.g. a NO_X sensor would supply a too high value of the NO_X content in the exhausts, which normally would make the controller C inject too large amounts of reductant, this could be avoided by the provision of an NH_3 sensor, which in such a case would signal presence of large amounts of NH_3 (originating from reductant injected into the exhaust gas) in the exhausts, hence making it possible for the controller C to correct the amount of reductant being injected into the exhausts. Obviously, if the values from the NO_X and NH_3 sensors do not make sense, the controller C must notify the driver, or store such malfunction indication in an onboard diagnostics box (not shown) for later readout at a service station.

Above, exemplary embodiments of a NO_X reduction system for a CI engine have been shown. By the efficiency of the system, it is possible to run a CI engine in a mode optimized for fuel efficiency and low emissions of soot, since the NO_X emissions produced in such a mode will be efficiently reduced in the catalyst system according to the invention.

Above, exemplary embodiments of the present invention have been shown; as could be understood by persons skilled in the art, it is possible to make many diversions from the described embodiments.

P21197, 2006-06-13

CLAIMS

1. Selective catalytic reduction system (100) for reducing nitric oxides emission levels from a compression ignition engine (110), comprising a first reductant injector (210) located upstream a first catalyst (200) comprising a selective catalytic reduction coating, **characterized** by

a second reductant injector (310) located downstream the first catalyst (200); and

a second catalyst (300) placed downstream the second reductant injector (310) and comprising a selective catalytic reduction coating.

2. The selective catalytic reduction system (100) according to claim 1, wherein the first catalyst (200) comprises a filter function to trap particles formed by the CI combustion.

3. The selective catalytic reduction system (100) of claim 2, wherein the first catalyst (200) comprises a multitude of elongate cells (260), alternately having closed and open top and bottom ends, respectively, wherein a gas flow is forced to pass through cell walls (260 a, b, c, d) constituting the cells, and wherein the selective catalytic reduction coating is coated on either or both sides of the walls (260a, b, c, d).

4. The selective catalytic reduction system (100) of any preceding claim, wherein an oxidizing catalytic coating is coated on an upstream side of the cell walls (260a, b, c, d).

5. The selective catalytic reduction system (100) of any preceding claim, further comprising sensors (210, 310) sensing presence of nitric oxides and/or ammonia in the exhausts.

6. The selective catalytic reduction system (100) of claim 5, wherein the sensors (210, 310) are placed downstream the first catalyst (200) and downstream the second catalyst (300), respectively.

7. The selective catalytic reduction system (100) of any of the preceding claims, wherein a means (400) is located upstream any of the components (210, 200, 300, 310) comprised in the selective catalytic reduction system (100), said means being arranged to manage the temperature, and thus the performance window, of the selective catalytic reduction system (100).

8. The selective catalytic reduction system (100) of claim 7, wherein said means (400) is an exhaust pressure governor.

9. Method for reducing emission of nitric oxides from a compression ignition engine (110), whose exhaust system comprises:

a first reductant injector (210) located upstream a first catalyst (200) comprising a selective catalytic reduction coating,

a second reductant injector (310) located downstream the first catalyst (200); and

a second catalyst (300) placed downstream the second reductant injector (310) and comprising a selective catalytic reduction coating, wherein the method is **characterized** by the following steps:

a. predicting a content of nitric oxides in an exhaust flow upstream the first catalyst (200),

b. calculating, based on said prediction, an amount of reductant to be injected upstream the first catalyst,

c. injecting such predicted amount of reductant upstream the first catalyst,

d. measuring a level of remaining nitric oxides in the exhaust stream downstream the first catalyst (200) and upstream the second catalyst (300),

e. adjusting the injected amount of reductant accordingly,

f. predicting, based on the level of remaining nitric oxide upstream the second catalyst, an amount of reductant to be injected upstream the second catalyst,

g. measuring the level of nitric oxides downstream the second catalyst (200), and

h. adjusting the injected amount of reductant upstream the second catalyst (200) accordingly.

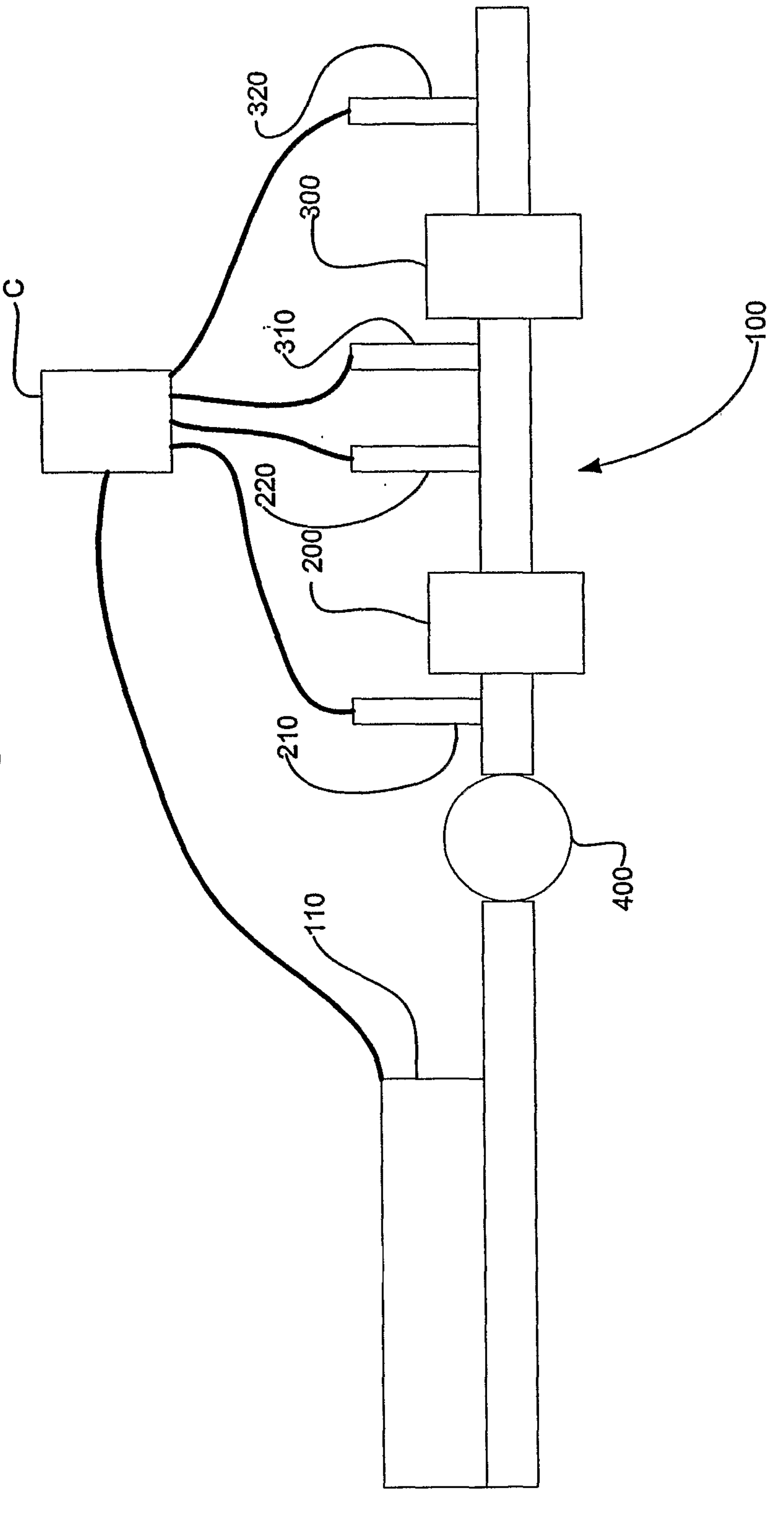

Fig. 1

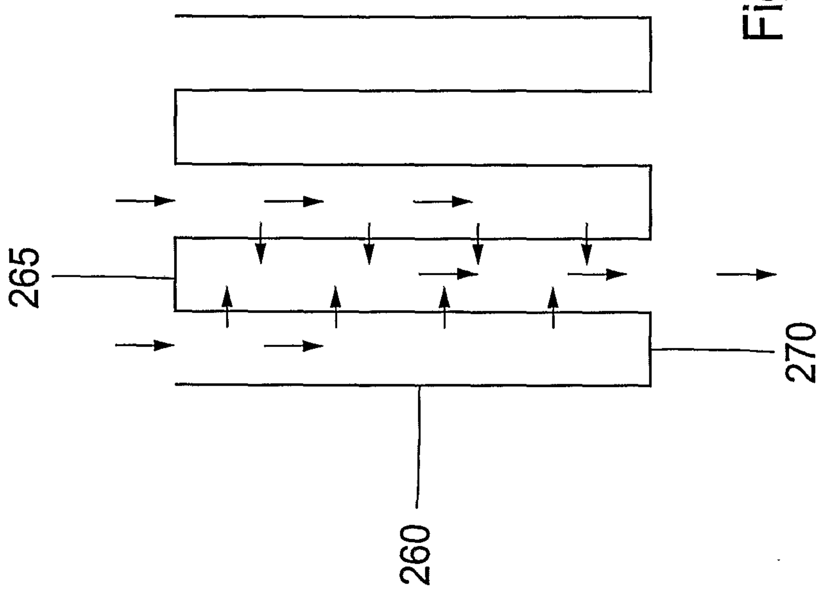

Fig. 2B

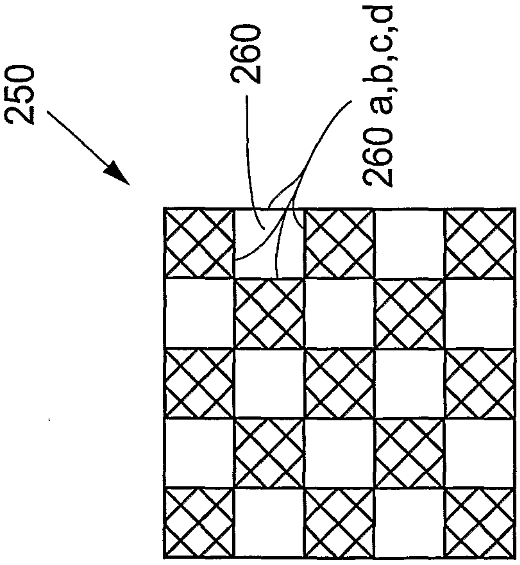

Fig. 2A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2006/000703

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F01N

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0037780 A1 (ROBERT BOSCH GMBH), 29 June 2000 (29.06.2000), page 4, line 31 - page 5, line 3, figure 2, abstract	1
Y		2-8
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X	US 6182443 B1 (JARVIS ET AL), 6 February 2001 (06.02.2001), figure 1, abstract	1
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Y	WO 03091551 A1 (ARVIN TECHNOLOGIES, INC), 6 November 2003 (06.11.2003), figures 1-5, abstract	2
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
8 January 2007	10-01-2007
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Dan Ionesco / JA A Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	EP 1403477 A2 (TOYOTA JIDOSHA KABUSHIKI KAISHA), 31 March 2004 (31.03.2004), figures 1A-8, abstract --	3,4
Y	WO 0064566 A1 (VOLKSWAGEN AKTIENGESELLSCHAFT), 2 November 2000 (02.11.2000), figure 1, abstract --	5-7,9
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International patent classification (IPC)

F01N 3/20 (2006.01)
F01N 3/035 (2006.01)

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Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

Cited literature, if any, will be enclosed in paper form.

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