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(54) **Title**: INTERNAL COMBUSTION ENGINE ARRANGEMENT COMPRISING AN EXHAUST GAS RECIRCULATION SYSTEM WITH A THERMOELECTRIC DEVICE

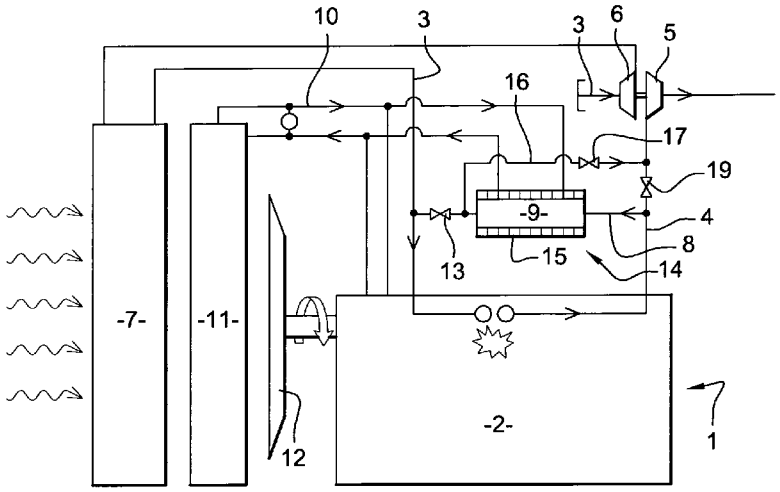


Fig. 1

(57) **Abstract**: The invention provides for an internal combustion engine arrangement comprising: an air intake line (3); at least one exhaust line (4) comprising an exhaust manifold; at least one turbine (5) located in the exhaust line (4); an exhaust gas recirculation (EGR) system comprising an EGR line (8) including an EGR valve (13) and a thermoelectric device (14); the EGR valve (13) is located downstream from the thermoelectric device (14) and the EGR system further comprises a return conduit (16) having an inlet connected to the EGR line (8) downstream from the thermoelectric device (14) and upstream from the EGR valve (13) and an outlet, said EGR system being arranged so that, when said EGR valve (13) is closed, the whole flow of exhaust gases coming out of the exhaust manifold passes through the turbine (5).

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INTERNAL COMBUSTION ENGINE ARRANGEMENT COMPRISING AN EXHAUST GAS RECIRCULATION SYSTEM WITH A THERMOELECTRIC DEVICE

Field of the invention

The present invention relates to an internal combustion engine arrangement comprising an exhaust gas recirculation system, especially such an engine arrangement for a vehicle.

Technological background

In order to meet the regulations concerning the upper limit of NOx (nitrogen oxide and nitrogen dioxide) emissions in internal combustion engines, it is known to recirculate a portion of the exhaust gases back to the engine cylinders. Such an exhaust gas recirculation (EGR) system results in lowering the combustion temperatures and, as a consequence, limits NOx generation as NOx generation is promoted by the presence of oxygen and of high temperatures. Additionally, it is possible to provide an EGR cooler whereby the EGR gases may be cooled before they are reintroduced into the engine, which further reduces NOx emissions as this allows the introduction into the cylinders of a greater mass of exhaust gas.

A significant amount of energy is included in the exhaust gases, which have a high speed and a high temperature, and in particular in EGR gases.

Several systems have been designed to recover at least part of this energy, in order to improve the vehicle efficiency, more particularly the engine arrangement efficiency, which has a direct impact on fuel consumption.

One conventional system consists of equipping the EGR line rerouting a portion of the engine's exhaust gas into the air intake line with a thermoelectric device using the Seebeck effect. Such a thermoelectric device is capable of producing electricity by the conversion of a heat flux between the hot exhaust gases flowing in the EGR line and a cold source. The generated electricity can then be used for the operation of various elements of the vehicle, and/or can be stored in an energy storage component such as a battery.

However, one important limit of this conventional system is that the flow of exhaust gases in the EGR line depends on the engine operating conditions, and can be very low, or even nonexistent if the valve provided in the EGR line is closed. As a consequence, the thermoelectric device is not fully used. In particular, when the EGR valve is closed, the thermoelectric device cannot produce electricity since there is no hot source. Therefore, the significant amount of energy contained in the hot exhaust gases is lost.

It therefore appears that, from several standpoints, there is room for improvement in engine arrangements regarding energy recovery.

Summary of the invention

It is an object of the present invention to provide an improved internal combustion engine arrangement, which can overcome the drawbacks encountered in conventional engine arrangements.

Another object of the present invention is to provide an internal combustion engine having an EGR system equipped with a thermoelectric device which can effectively increase the amount of energy recovered.

According to the invention such an internal combustion engine arrangement comprises:

- an air intake line capable of carrying intake air towards the engine;
- an exhaust line capable of collecting exhaust gas from the engine;
- at least one turbocharger having at least one compressor driven by at least one turbine located in the exhaust line;
- an exhaust gas recirculation (EGR) system comprising an EGR line rerouting a portion of the engine's exhaust gases into the air intake line, said EGR line including an EGR valve and a thermoelectric device capable of producing electricity by Seebeck effect by the conversion of the temperature difference between the hot exhaust gases flowing in the EGR line and a cold source.

Additionally, according to the invention, the EGR valve is located downstream from the thermoelectric device and the EGR system further comprises a return conduit having an inlet connected to the EGR line downstream from the thermoelectric device and upstream from the EGR valve

and an outlet by which gases can flow towards the atmosphere, preferably through the exhaust line, said EGR system being arranged so that, when said EGR valve is closed, the whole flow of exhaust gases coming out of the engine passes through the turbine.

Thus, in an internal combustion engine according to the invention, the whole amount of hot exhaust gases entering the EGR line can be used to produce electricity by means of the thermoelectric device, whatever the aperture rate of the EGR valve. Even when the EGR valve is closed, all exhaust gases in the EGR line flow along the thermoelectric device, which means that the energy due to their high temperature can be used.

Moreover, the invention, by forcing all exhaust gases to flow through the turbine when the EGR valve is closed, makes it possible also to use the whole kinetic energy contained in exhaust gases.

As a consequence, when the EGR valve is closed, both the thermal energy of the exhaust gases in the EGR line and the kinetic energy of the exhaust gases are fully used respectively by the thermoelectric device and by the turbine to generate energy, which enables a decrease of fuel consumption.

According to an aspect of the invention, the EGR line inlet and the return conduit outlet may be connected to the exhaust line on a same side of the turbine, with respect to the flow of exhaust gases in the exhaust line.

According to a first embodiment of the invention, the EGR line inlet is connected to the exhaust line upstream from the turbine, and the return conduit outlet is connected to the exhaust line upstream from the turbine. This embodiment will be preferred when the EGR system has a "short route EGR" configuration, where the EGR line is connected to the intake line downstream of the compressor, or a "mixed route EGR" configuration where the EGR line is connected to the intake line upstream of the compressor.

According to a second embodiment of the invention, the EGR line inlet is connected to the exhaust line downstream from the turbine, and the return conduit outlet is connected to the exhaust line downstream from the turbine. This embodiment will be preferred when the EGR system has a "long route EGR" configuration, where the EGR line is connected to the intake line upstream of the compressor. With this configuration, the gas temperatures are lower at the EGR line inlet. Therefore, materials having a lower maximum temperature threshold can be used in the thermoelectric device, which is advantageous since these materials are less expensive.

Preferably, the return conduit outlet is connected to the exhaust line downstream from the EGR line inlet.

In an implementation of the invention, the thermoelectric device is a built-in part of an EGR cooler located in the EGR line.

The cold source can be the engine cooling fluid, an auxiliary cooling fluid, or ambient air.

The thermoelectric device can be connected to an electrical circuit which may comprise a battery and / or one or more vehicular component that are electrically operated. The electrically circuit is preferably equipped with control means for controlling the current in the circuit.

These and other advantages will become apparent upon reading the following description in view of the drawing attached hereto representing, as non-limiting examples, embodiments of a vehicle according to the invention.

Brief description of the drawing

The following detailed description of several embodiments of the invention is better understood when read in conjunction with the appended drawing being understood, however, that the invention is not limited to the specific embodiments disclosed. In the drawing,

Figure 1 is a schematic drawing of an internal combustion engine arrangement according to a first embodiment of the invention;

Figure 2 is a schematic drawing of an internal combustion engine arrangement according to a second embodiment of the invention.

Detailed description of the invention

As illustrated in the figures, an internal combustion engine 1 typically comprises an engine block 2 defining a plurality of cylinders (not shown). Intake air is carried towards the engine, for feeding the cylinders, through an air intake line 3 which can comprise an intake manifold. The gases formed in each cylinder can be collected by an exhaust line 4, which may comprise an exhaust manifold, and the exhaust gases are then carried towards the atmosphere through exhaust line 4 which may comprise various exhaust gases after treatment systems and silencers.

The engine 1 includes a turbocharger which comprises a turbine 5 located on the exhaust line 4 and a compressor 6 located on the air intake line 3, said compressor being driven by the turbine 5. After being compressed by the compressor 6, and before entering the engine, air flowing in the intake line 3 may go through a charge air cooler 7 which can be provided in the intake line.

The engine 1 further includes an EGR (exhaust gas recirculation) system which comprises an EGR line 8 capable of rerouting a portion of the engine's exhaust gases into the air intake line 3. Said EGR line 8 may comprise an EGR cooler 9. In the illustrated embodiments, the EGR cooler 9 uses the engine coolant which flows in an auxiliary coolant circuit 10 equipped with a radiator 11 located close to a fan 12. An EGR valve 13 is located in the EGR line 8 downstream from the EGR cooler 9. The aperture rate of said EGR valve 13 is controlled according to the engine operating conditions to allow an appropriate amount of exhaust gases to be rerouted towards the engine intake line through the EGR line 8.

The EGR line 8 is further provided with a thermoelectric device 14 capable of producing electricity by Seebeck effect. The thermoelectric device can be a built-in part of the EGR cooler 9, but could also be a stand alone unit on the EGR line. In concrete terms, the thermoelectric device 14 comprises thermoelectric elements 15 which are subject, directly or indirectly, on one side to a hot source, namely the hot temperature of the EGR gases flowing in the EGR line 8, and, on the other side, to a relatively cold temperature of a cold source. The cold source can comprise the engine cooling fluid carried by the coolant circuit 10 or by a derivation thereof. The thermoelectric elements 15 may comprise materials such as Bi_2Te_3, PbTe, SiGe, or other appropriate materials which can convert the temperature difference between the hot source and the cold source in to an electric voltage, thereby converting a heat flux between the hot and cold sources into electric power. In any case, the thermoelectric device will have a cooling effect on the EGR gases which flow through it, and can be considered in itself as an EGR cooler.

In another embodiment – not shown – the cold source for the thermoelectric device 14 can comprise, alone or in combination, ambient air or a cooling fluid from an auxiliary cooling circuit such as a charge air cooling circuit or a vehicle cabin air-conditioning circuit.

The EGR system further comprises a return conduit 16 having an inlet connected to the EGR line 8 downstream from the thermoelectric device 14 (i.e., here, downstream from the EGR cooler 9) and upstream from the EGR valve 13. If a separate further EGR cooler is provided downstream of the thermoelectric device 14 on the EGR line 8, the return conduit inlet is preferably arranged between the thermoelectric device and the separate EGR cooler. The return conduit 16 is equipped with a valve 17 and has an outlet by which gases can flow towards the exhaust line 4, preferably downstream from the inlet of the EGR line 8.

A first embodiment of the invention is illustrated in Figure 1.

In this embodiment, the EGR line 8 has an inlet connected to the exhaust line 4 upstream from the turbine 5 and an outlet connected to the intake line 3 downstream from the compressor 6, thereby forming a so-called "short-route EGR". Furthermore, the outlet of the return conduit 16 is connected to the exhaust line 4 upstream from the turbine 5, and downstream from the inlet of the EGR line 8. A flow restriction 19 can be arranged in the exhaust line downstream of the EGR line inlet, and upstream of the return conduit outlet to promote the flow of exhaust gases towards the EGR line 8 rather than directly towards the turbine 5. The flow restriction can be controllable, such as a throttle.

With this arrangement, when the EGR valve 13 is open, either fully or partially, i.e. when part of the exhaust gases are rerouted towards the engine intake line, the thermoelectric device 14 can produce electricity thanks to this hot flow of gases. Moreover, when the EGR valve is open, the flow of exhaust gases through the thermoelectric device can be greater than the flow of EGR gases effectively rerouted towards the intake line, because the difference can be rerouted directly to the exhaust line through the return conduit 16

Moreover, when said EGR valve 13 is closed, part of the exhaust gases can nevertheless enter the EGR line 8 and pass through the thermoelectric device 14 before being reintroduced into the exhaust line 4 by means of the return conduit 16. As a result, the thermal energy of these gases can be used in the thermoelectric device 14 even if no exhaust gas is rerouted towards the engine intake manifold. The proportion of exhaust gases which go through the thermoelectric device can be adjusted by proper control of valve 17 and of flow restriction 19.

Furthermore, the whole flow of exhaust gases, except for the EGR gases which are effectively rerouted to the intake line when the EGR valve 13 is open, passes through the turbine 5, whether these gases come directly from the exhaust manifold in the exhaust line 4 or have passed through the thermoelectric device 14 and have been rerouted towards said exhaust line 4 by the return conduit 16. This invention therefore makes it possible to fully use the kinetic energy of the exhaust gases.

According to a second embodiment, illustrated in Figure 2, the EGR line 8 has an inlet connected to the exhaust line 4 downstream from the turbine 5 and an outlet connected to the intake line 3 upstream from the compressor 6, in a so-called "long-route EGR" configuration. Furthermore, the outlet of the return conduit 16 is connected to the exhaust line 4 downstream from the turbine 5, and downstream from the inlet of the EGR line 8. A flow restriction 19 can be arranged in the exhaust line downstream of the EGR line inlet, and upstream of the return conduit outlet to promote the flow of exhaust gases towards the EGR line 8. The flow restriction can be controllable, such as a throttle.

When the EGR valve 13 is open, either fully or partially, the thermoelectric device 14 can produce electricity thanks to this hot flow. When said EGR valve 13 is closed, part of the exhaust gases can nevertheless enter the EGR line 8 and pass through the thermoelectric device before being reintroduced into the exhaust line 4 (or released in the atmosphere) by means of the return conduit 16. As a result, the thermal energy of these gases can be used in the thermoelectric device 14 even if no exhaust gas is rerouted towards the engine intake manifold.

Furthermore, the whole flow of exhaust gases passes through the turbine 5, whether these gases will remain in the exhaust line 4 or pass through the thermoelectric device 14 and be rerouted towards said exhaust line 4 by the return conduit 16. This invention therefore makes it possible to fully use the kinetic energy of the exhaust gases.

In case the exhaust line of the internal combustion engine 1 is equipped with two turbines arranged one downstream of the other, the EGR system is arranged so that, when said EGR valve 13 is closed, the whole flow of exhaust gases coming out of the exhaust manifold passes through at least one turbine, and preferable both turbines.

In a "short route EGR configuration", as shown in figure 1, the outlet of the return conduit 16 can be connected to the exhaust line between the two turbines, and preferably upstream from the turbine located most upstream. In a "long route EGR configuration", as shown in figure 2, the inlet of the return conduit 16 can be connected to the exhaust line between the two turbines, and preferably downstream from the turbine located most downstream.

The invention has been described in an engine arrangement comprising only one exhaust line. It can also be implemented in an arrangement having two parallel exhaust lines, which can each have a separate exhaust manifold or which can share a common exhaust manifold. In both cases, only one or both of the exhaust lines can be implemented according to the invention.

Of course, the invention is not restricted to the embodiments described above by way of non-limiting examples, but on the contrary it encompasses all embodiments thereof.

CLAIMS

1. An internal combustion engine arrangement comprising:

- an air intake line (3) capable of carrying intake air towards an engine;
- at least one exhaust line (4) comprising an exhaust manifold capable of collecting exhaust gas from the engine;
- at least one turbocharger having at least one compressor (6) driven by at least one turbine (5) located in the exhaust line (4);
- an exhaust gas recirculation (EGR) system comprising an EGR line (8) rerouting a portion of the engine's exhaust gas into the air intake line (3), said EGR line (8) including an EGR valve (13) and a thermoelectric device (14) capable of producing electricity by Seebeck effect by the conversion of the temperature difference between the hot exhaust gases flowing in the EGR line (8) and a cold source;

characterized in that the EGR valve (13) is located downstream from the thermoelectric device (14) and in that the EGR system further comprises a return conduit (16) having an inlet connected to the EGR line (8) downstream from the thermoelectric device (14) and upstream from the EGR valve (13) and an outlet by which gases can flow towards the atmosphere, said EGR system being arranged so that, when said EGR valve (13) is closed, the whole flow of exhaust gases coming out of the exhaust manifold passes through the turbine (5).

2. The internal combustion engine arrangement according to claim 1, characterized in that the EGR line inlet and the return conduit outlet are connected to the exhaust line (4) on a same side of the turbine (5).

3. The internal combustion engine arrangement according to claim 2, characterized in that the EGR line inlet is connected to the exhaust line (4) upstream from the turbine (5), and in that the return conduit outlet is connected to the exhaust line (4) upstream from the turbine (5).

4. The internal combustion engine arrangement according to claim 2, characterized in that the EGR line inlet is connected to the exhaust line (4)

downstream from the turbine (5), and in that the return conduit outlet is connected to the exhaust line (4) downstream from the turbine (5).

5. The internal combustion engine arrangement according to any one of claims 1 to 4, characterized in that the return conduit outlet is connected to the exhaust line (4) downstream from the EGR line inlet.

6. The internal combustion engine arrangement according to any one of claims 1 to 5, characterized in that the thermoelectric device (14) is a built-in part of an EGR cooler (9) located in the EGR line (8).

7. The internal combustion engine arrangement according to any one of claims 1 to 6, characterized in that the cold source is the engine cooling fluid.

8. The internal combustion engine arrangement according to any one of claims 1 to 7, characterized in that the cold source is ambient air.

9. The internal combustion engine arrangement according to any one of claims 1 to 8, characterized in that the thermoelectric device (14) is connected to a battery.

10. The internal combustion engine arrangement according to any one of claims 1 to 9, characterized in that the thermoelectric device (14) is connected to one or more vehicular component that are electrically operated.

11. The internal combustion engine arrangement according to any one of claims 1 to 10, characterized in that a flow restriction (19) is arranged in the exhaust line downstream of the EGR line inlet, and upstream of the return conduit outlet.

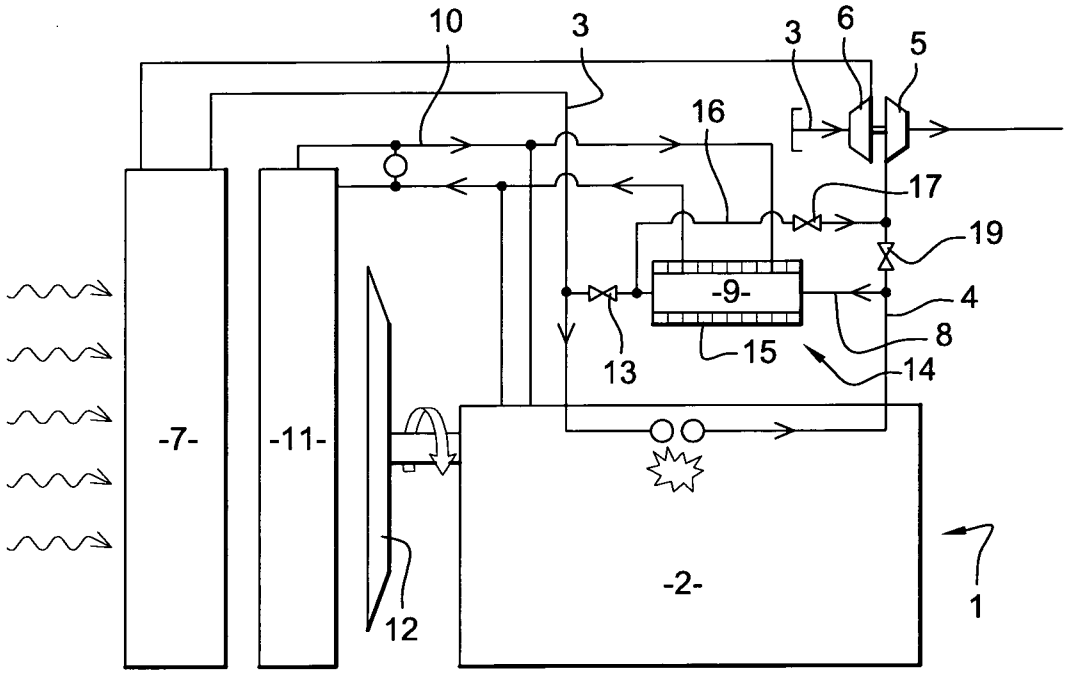

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Fig. 1

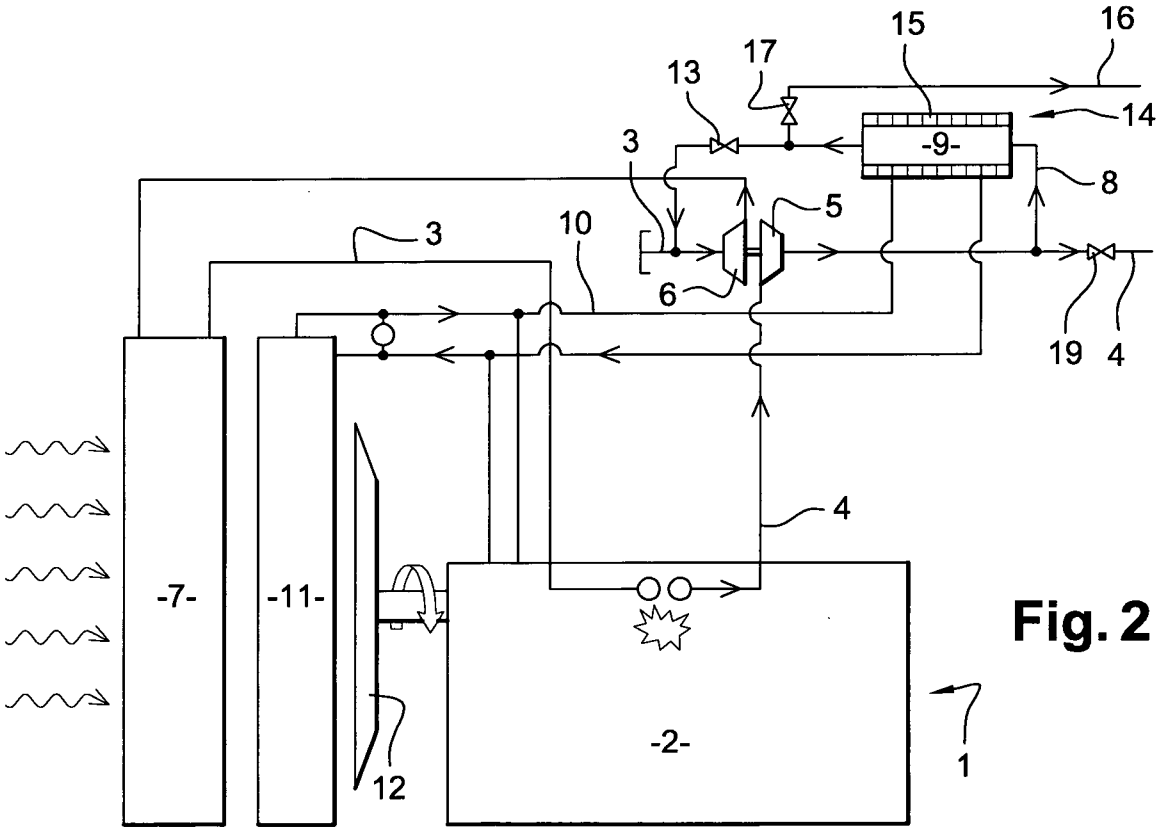

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Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/005627

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M25/07 F01N5/02 F02G5/02 H01L35/00

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)
F02M F01N F02G H01L

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/026432 A1 (HITACHI LTD [JP]; NISHIOKA AKIRA [JP]; MINEGISHI TERUHIKO [JP]; MUNAKA) 8 March 2007 (2007-03-08) abstract; figures 1,10 page 1, line 4 - line 8 page 8, line 5 - line 6 page 8, line 23 - line 24 page 14, line 24 - page 15, line 2 page 16, line 3 - page 18, line 27	1-11
Y	DE 10 2006 019282 A1 (BAYERISCHE MOTOREN WERKE AG [DE]) 31 October 2007 (2007-10-31) abstract; figures 1,2,3 paragraph [0022] - paragraph [0028] paragraph [0037]	1-11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
19 January 2010	01/02/2010

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/005627

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR 2 920 834 A1 (VALEO SYS CONTROLE MOTEUR SAS [FR]) 13 March 2009 (2009-03-13) abstract; figures 1,2	1-11
A	EP 1 475 532 A2 (DENSO CORP [JP]) 10 November 2004 (2004-11-10) abstract; figure 1 paragraph [0014] - paragraph [0016]	1-11
A	EP 0 913 561 A2 (VALEO THERMIQUE MOTEUR SA [FR]) 6 May 1999 (1999-05-06) abstract; figures 1-3	1-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2009/005627

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007026432 A1	08-03-2007	NONE	
DE 102006019282 A1	31-10-2007	NONE	
FR 2920834 A1	13-03-2009	WO 2009071754 A2	11-06-2009
EP 1475532 A2	10-11-2004	US 2004221577 A1	11-11-2004
EP 0913561 A2	06-05-1999	BR 9804244 A	14-12-1999
		DE 69817294 D1	25-09-2003
		DE 69817294 T2	09-06-2004
		FR 2770582 A1	07-05-1999
		JP 11193753 A	21-07-1999
		MX PA98009109 A	09-12-2004
		US 6155042 A	05-12-2000