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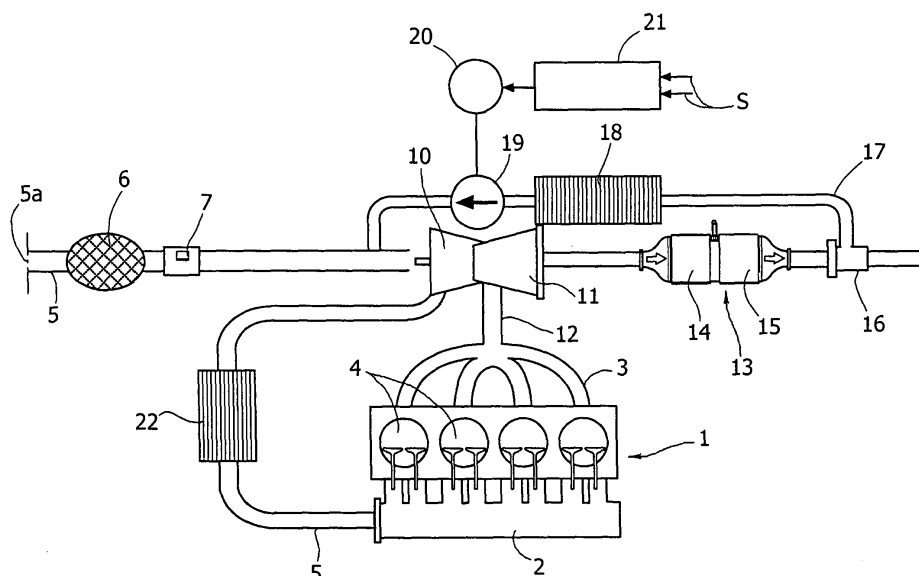
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(54) **Internal combustion engine with a pump for exhaust gas recirculation**

(57) An internal combustion engine, in particular a diesel engine, has a pipe (17) for exhaust gas recirculation (EGR) having an entrance extremity (16) that branches off the engine exhaust pipe (12) downstream of a device (13) for treating the exhaust gas, and an exit extremity that flows into the pipe (5) for air intake into the engine, upstream of a booster compressor (10). Along the EGR pipe (17) a pump is interposed (19) that creates the necessary pressure difference to activate exhaust gas recir-

culatation, thus without the need to provide a butterfly valve on the intake or exhaust and thus avoiding the consequent loss of engine efficiency. In one embodiment, the pump (19) is controlled by a variable speed electric motor (20) that is controlled as a function of the engine operating conditions, to vary the quantity of EGR in the engine. In this way it is also possible to avoid the use of the conventional EGR valve to regulate the quantity of EGR, with consequent simplification and cost reduction.

FIG. 3



Description

[0001] The present invention relates to internal combustion engines, of the type including at least one cylinder, a pipe for the intake of air into the cylinder, a pipe to discharge burnt gas from the cylinder, a compressor for the air sucked into the cylinder, interposed along the intake pipe, a turbine linked mechanically to the compressor, interposed along the exhaust pipe to be driven by the exhaust gas from the engine, a device to treat the exhaust gas, interposed along the exhaust pipe downstream of the turbine, and a pipe to recirculate exhaust gas in the engine, having an entrance extremity branching off the exhaust pipe, downstream of the device to treat the exhaust gas, and an exit extremity that flows into the inlet pipe, upstream of the compressor.

[0002] Internal combustion engines of the type indicated above have already been proposed and produced. The device described above in particular lends itself to be utilised to advantage on diesel engines, in order to reduce harmful emissions from the engine. Diesel engines, compared to other internal combustion engines, are characterised by the production of high quantities of nitrogen oxides and particulates. A substantial reduction in nitrogen oxides is obtained by exhaust gas recirculation (EGR) in the engine. Thanks to EGR, the engine takes in a mixture of fresh air and exhaust gas that, by reducing the percentage of oxygen available and lowering the combustion temperature, reduces the oxidation of nitrogen and of air and thus the production of nitrogen oxides. The need to reduce levels of pollution ever lower brings about an increase in the quantity of recirculated gas and makes it desirable to develop new systems for this purpose.

[0003] Engines of the type indicated at the beginning of this description use a pipe to recirculate exhaust gas of the so-called "long route" type, in which the exhaust gas is taken up downstream of the device to treat exhaust gas, and is returned upstream of the compressor. In the case of a diesel engine, the treatment device includes both a catalytic converter and a trap for particulates located downstream of the catalytic converter. In a solution of this type, the exhaust gas taken up for recirculation is at relatively low pressure, so that we may also speak of low pressure EGR. In a "long route" or low pressure EGR system, the gas that is made to recirculate in the engine is colder, and thus at higher density, and is free of particulates, which avoids loss of efficiency in the long term in the heat exchanger that is frequently provided for along the EGR pipe in order to cool the gas. Such known solutions are, however, penalised by a relatively low flow speed of the recirculated gas, caused by the small difference in pressure existing between the point where the exhaust gas is taken up and that where it is returned to the inlet pipe. To obviate against this drawback, a butterfly valve is normally situated downstream of the uptake point ("exhaust butterfly") or upstream of the point of return of the recirculated gas into the intake pipe ("intake

butterfly"). The butterfly valve enables the principal flow (respectively of exhaust gas or of fresh air) to be partialised and thus increases the pressure difference between the entrance extremity and the exit extremity of the exhaust gas recirculation pipe. However, this solution in its turn is penalised by fuel consumption, since the constriction that is produced causes an increase in the pumping work of the engine and thus a reduction in its thermodynamic efficiency. Furthermore, in particular operating conditions this system may not be sufficient to guarantee all the necessary recirculation.

[0004] The purpose of the present invention is to obviate against the above drawbacks by proposing a system for recirculating exhaust gas of the "long route" type which is able to guarantee a high flow of recirculated gas without lowering the efficiency of the engine.

[0005] In order to achieve this purpose, the subject of the invention is an engine having all the characteristics that were indicated at the start of this description and also characterised in that a pump is included along the exhaust gas recirculation pipe.

[0006] Thanks to this characteristic, it is possible to achieve the necessary pressure difference without employing any butterfly valve in the exhaust gas recirculation pipe. In particular, this makes it possible to achieve a relatively high flow of recirculated gas without further modifying the system, and in consequence obtaining a reduction in discharged nitrogen oxides. The absence of any butterfly valve avoids the loss in efficiency of the engine that it would cause. Furthermore, thanks to the provision of a pump, the engine operates with a higher air/fuel ratio at equal quantities of EGR, with consequent reduction of smoke in the exhaust. The engine is also more flexible and capable of providing the quantity of EGR most suitable for every engine operating condition.

[0007] According to a further preferred characteristic, the EGR pump is controlled by an adjustable-speed electric motor, to vary the EGR flow. This enables, if desired, the EGR valve usually provided in the EGR circuit to adjust the quantity of EGR to be eliminated. The electric motor operating the pump may indeed be controlled by an electronic control unit to vary the EGR flow as engine operating conditions vary, so that the pump may, if desired, be the sole means of regulating the quantity of EGR provided for in the engine.

[0008] Use of the EGR pump to regulate the flow of EGR provides a more rapid and precise control over EGR. The electronic control system is also simplified since it must control a single device, that is the electric motor operating the pump, instead of two devices (butterfly and EGR valve) as in known systems.

[0009] The invention also has as its subject a procedure to control the quantity of EGR in an internal combustion engine based on controlling the speed of the motor operating an EGR pump.

[0010] Further characteristics and advantages of the invention will appear in the following description with reference to the attached drawings, provided as a simple

example without limiting intent, in which:

- figure 1 is a view in diagram form of an EGR system according to the known technology,
- figure 2 is a view in diagram form of a first embodiment of the system according to the invention, and
- figure 3 is a view in diagram form of a second embodiment of the system according to the invention.

[0011] In the drawings, number 1 indicates overall a diesel engine with four cylinders having an air intake manifold 2 and an exhaust manifold 3 respectively for the intake of air into the cylinders 4 of the engine and for the discharge of burnt gas from the cylinders 4. The intake manifold 2 receives the air intake from a pipe 5. The pipe 5 presents a mouth 5a for the intake of air and along it are also an air filter 6, an air flow meter 7, a butterfly valve 8, an EGR valve 9, a compressor 10, and an intercooler 22. The compressor 10 is of the centrifugal type and is connected mechanically to a turbine 11 that is interposed along an exhaust pipe 12 that branches off the exhaust manifold 3, in order to drive the compressor 10. Along the exhaust pipe 12, downstream of the turbine 11, a device 13 for treating exhaust gas is present, comprising a catalytic converter 14 and a particulate trap 15. In a zone 16 downstream of the trap 15 and upstream of the silencer (not shown) the entrance extremity of a pipe 17 for exhaust gas recirculation (EGR) branches off, having an exit extremity that flows into the intake pipe 5 in correspondence with the EGR valve 9. A cooler 18 is interposed along the pipe 17.

[0012] The known system illustrated in figure 1 is thus of the type with "long route" EGR, in which the exhaust gas is taken up at low pressure and relatively low temperature, downstream of the particulate trap 15, and returned upstream of the compressor 10. The EGR valve 9, under electronic control, regulates the quantity of EGR in function of the engine operating conditions. As already indicated at the beginning of this description, the butterfly valve is provided for the purpose of increasing the pressure difference existing between the entrance extremity and the exit extremity of the exhaust gas recirculation pipe 17. Instead of being upstream of the EGR valve, the butterfly valve 8 may also be provided along the exhaust pipe 12, downstream of the zone 16.

[0013] Figure 2 illustrates a first embodiment of the invention, in which the butterfly valve 8 is completely eliminated and a pump 19 is interposed along the EGR pipe 17, downstream of the cooler 18. In the case of the embodiment in figure 2, the EGR valve 9 that regulates the quantity of EGR is however maintained, the pump 19 being destined to create the necessary pressure difference to activate recirculation.

[0014] Figure 3 illustrates a second, preferred, embodiment in which the EGR valve 9 is also eliminated. In this case, the pump 19 is controlled by an electric motor 20 of the variable speed type. The motor 20 is controlled by

an electronic control unit 21 as a function of one or more signals S indicative of one or more engine operating parameters, such as engine speed, temperature of cooling water, temperature of metallic body of the engine, etc.

[0015] As already specified above, the pump 19 enables a higher flow of EGR to be achieved without further modifying the circuit, with consequent reduction of the discharge of nitrogen oxides. Elimination of the butterfly valve 8 enables the loss of efficiency of the engine that it would cause to be eliminated, with consequent reduction of fuel consumption.

[0016] Furthermore, for equal quantities of EGR, the engine according to the invention operates with a higher air/fuel ratio, with consequent reduction in smoke in the exhaust, and the engine is also able to respond with greater flexibility and speed, providing the most appropriate quantity of EGR for every engine operating condition.

[0017] In the case of the preferred embodiment illustrated in figure 3, elimination of the EGR valve enables the plant to be simplified and its cost reduced, thanks to the elimination of both the butterfly valve and the EGR valve. Use of a pump to regulate the quantity of EGR also provides more rapid and precise control over EGR. Lastly, the electronic control system is simplified, since it must only control one device, that is the pump, instead of two (the butterfly valve and the EGR valve).

[0018] Naturally, the principle of the invention holding good, construction details and embodiments may be widely varied with regard to what is described and illustrated here as a simple example, without thereby departing from the sphere of the present invention.

Claims

1. Internal combustion engine, including at least one cylinder (4), a pipe (5) for air intake into the cylinder (4), a pipe (12) to discharge burnt gas from the cylinder (4), an air compressor (10) interposed along the intake pipe (5), a turbine (11) connected mechanically to the compressor (10), interposed along the exhaust pipe (12) to be driven by the exhaust gas from the engine, a device (13) to treat the exhaust gas, interposed along the exhaust pipe (12) downstream of the turbine (11), and a pipe (17) to recirculate the exhaust gas in the engine having an entrance extremity that branches off the exhaust pipe (12) downstream of the device (13) for treating the exhaust gas and an exit extremity that flows into the intake pipe (15) upstream of the compressor (10), **characterised in that** a pump (19) is provided along the exhaust gas recirculation (EGR) pipe (17).
2. Engine according to claim 1, **characterised in that** it is a diesel engine and that the device for treating exhaust gas (13) comprises a catalytic converter (14) and a particulate trap (15).

3. Engine according to claim 1, **characterised in that** the pump (19) is controlled by an electric motor (20) with adjustable speed.

4. Engine according to claim 3, **characterised in that** the electric motor (20) is controlled by an electronic control unit (21) to vary the flow of EGR, as a function of one or more signals (S) received by the electronic control unit (21) and indicative of one or more parameters relating to the engine operating conditions.

5. Engine according to claim 4, **characterised in that** the pump (19) constitutes the sole means of regulating the quantity of EGR.

6. Procedure to control the quantity of exhaust gas recirculation (EGR) in an internal combustion engine, in which the engine comprises at least one cylinder (4), a pipe (5) for air intake into the cylinder (4), a pipe (12) to discharge burnt gas from the cylinder (4), an air compressor (10) interposed along the intake pipe (5), a turbine (11) mechanically linked to the compressor (10) and interposed along the exhaust pipe (12) to be driven by the exhaust gas from the engine, a device (13) to treat the exhaust gas interposed along the exhaust pipe (12) downstream of the turbine (11) and a pipe (17) to recirculate exhaust gas in the engine having an entrance extremity (16) that branches off the exhaust pipe (12) downstream of the device (13) for treating exhaust gas, and an exit extremity that flows into the intake pipe (5) upstream of the compressor (10), said procedure being **characterised in that** a pump (19) is provided in the pipe (17) for recirculating exhaust gas, an electric motor with variable speed is provided to control said pump (19), and the speed of said electric motor (20) is controlled as a function of one or more parameters indicative of the engine operating conditions to vary the quantity of EGR.

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FIG. 1

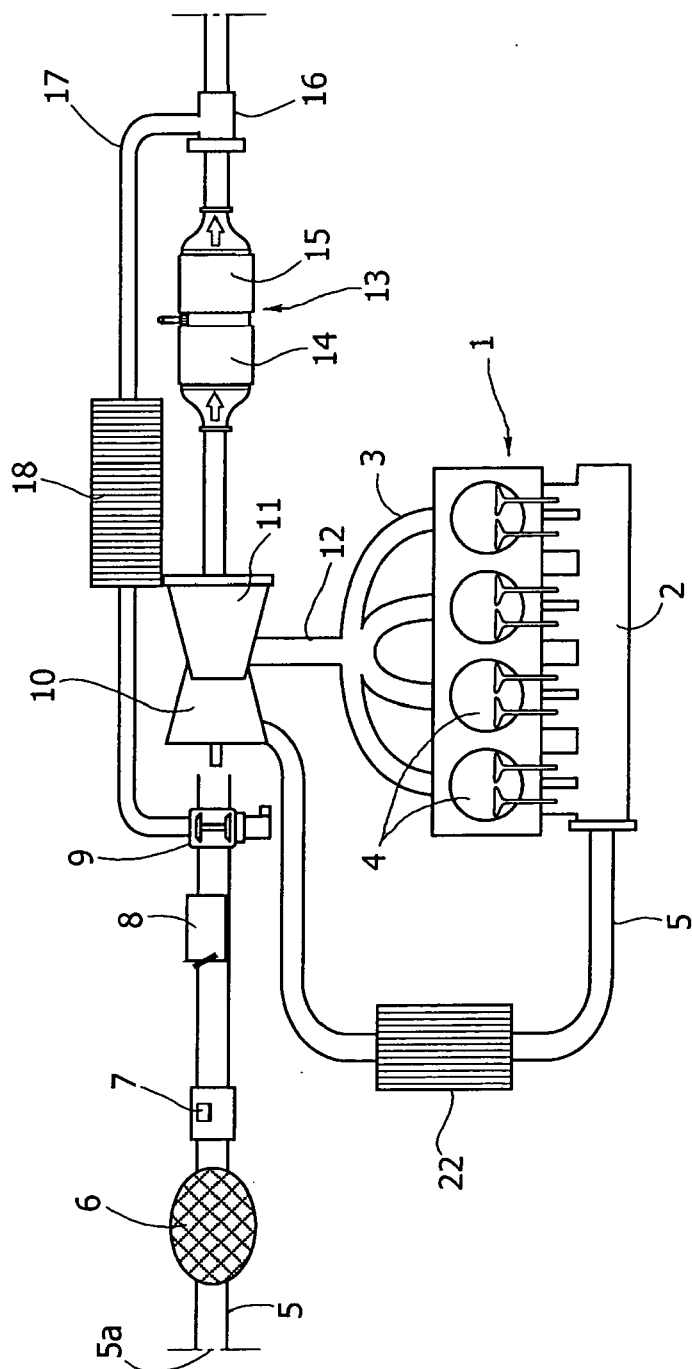


FIG. 2

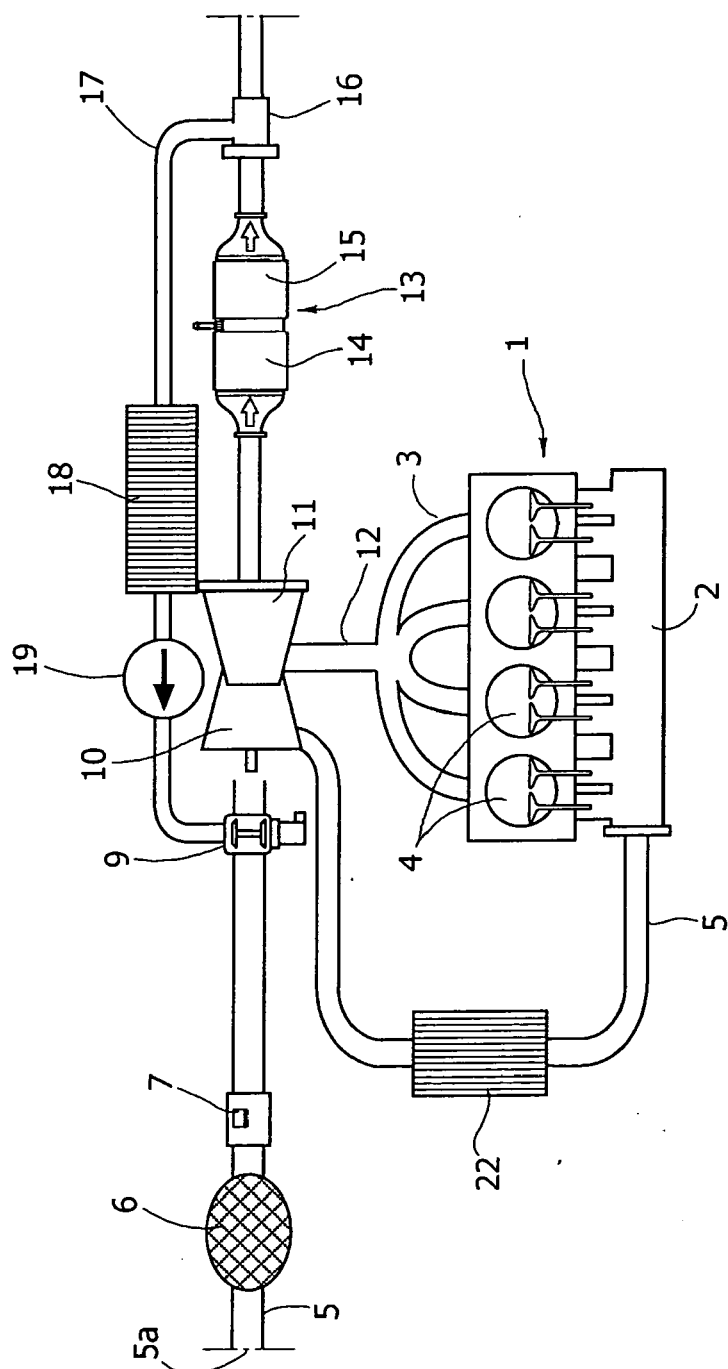
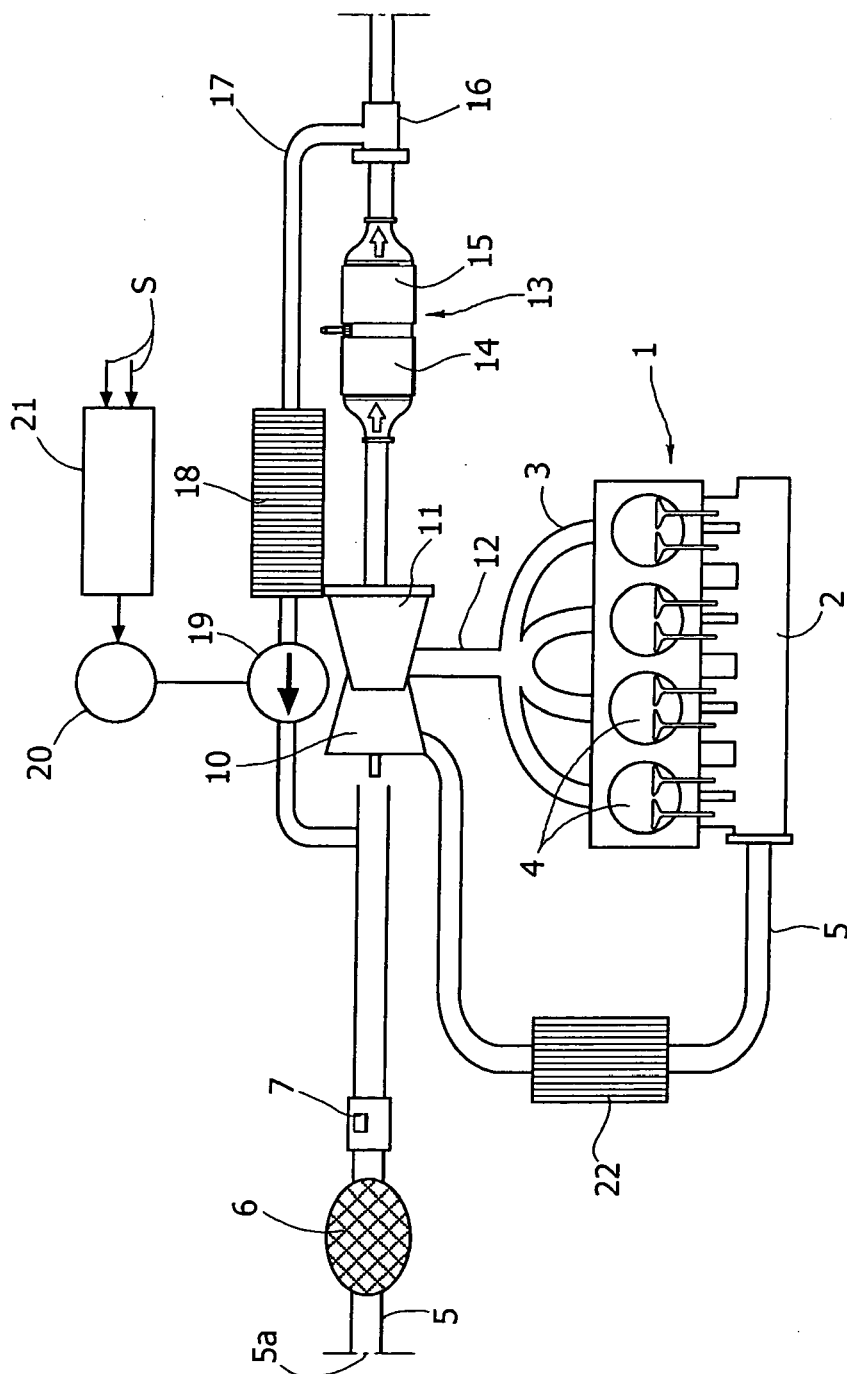


FIG. 3





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	EP 1 672 208 A (PIERBURG GMBH) 21 June 2006 (2006-06-21) * abstract; figure *	1,3-6	INV. F02M25/07
A	* column 3, paragraph 16 - column 4, paragraph 17 * * column 4, paragraph 20 - paragraph 22 *	2	
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A	* page 6, line 15 - page 9, last line *	2-6	
X	EP 1 186 767 A2 (TOYOTA JIDOSHA KK) 13 March 2002 (2002-03-13) * abstract; figures *	1	TECHNICAL FIELDS SEARCHED (IPC) F02M
A	* column 4, paragraph 15 - column 6, paragraph 22 *	2-6	
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 27 October 2006	Examiner Döring, Marcus
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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