(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 January 2007 (25.01.2007)

PCT

(10) International Publication Number
WO 2007/010301 A1

(51) International Patent Classification:
F02M 25/07 (2006.01) *F02B 33/42* (2006.01)
F01N 5/02 (2006.01)

(21) International Application Number: PCT/GB2006/050201

(22) International Filing Date: 13 July 2006 (13.07.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0514732.7 19 July 2005 (19.07.2005) GB
0521422.6 21 October 2005 (21.10.2005) GB

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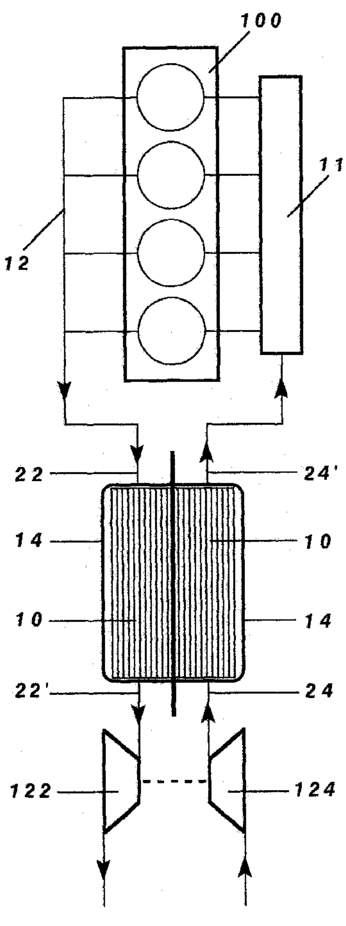
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: EGR DISPENSING SYSTEM IN IC ENGINE



(57) Abstract: An EGR dispensing system is described which comprises a reciprocating piston internal combustion engine (l00)having exhaust and intake ducts (22,24) , a rotary gas exchanger having a housing (14) containing a rotating matrix (10) , and first and second sets of entry and exit ducts in the housing (14) . The first set of entry and exit ducts forms part of the engine exhaust duct (22,221) connecting an engine exhaust gas stream from the engine (100) through the housing (14) and matrix (10) to the ambient atmosphere . The second set of entry and exit ducts (22, 241) forms part of the engine intake duct connecting an engine intake air stream from the ambient atmosphere through the housing (14) and matrix (10) to the engine (100) . The matrix (10) is rotated at a sufficient speed for a substantial volumetric gas exchange to occur between the engine exhaust gas stream and the intake air stream.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

EGR DISPENSING SYSTEM IN IC ENGINE

Field of the invention

The present invention relates to a dispensing system for Exhaust Gas Recirculation (EGR) into a reciprocating internal combustion engine.

Background of the invention

In a conventional reciprocating internal combustion engine EGR system, a metered proportion of the exhaust gas stream from the engine exhaust system is diverted to enter the engine intake system by an EGR pipe connected between the two. In order to drive a sufficient flow of recirculated exhaust gases from the exhaust system to the intake system of the engine, a substantial pressure drop (delta-P) in the desired direction along the EGR pipe is required. However this delta-P is not always available in the desired direction especially when the engine is operated in an unthrottled or in a boosted mode where the local pressure in the intake system could be substantially the same or higher than the local pressure in the exhaust system. In such cases, it is necessary to apply partial throttling of the intake system to reduce the air induction pressure or partial throttling of the exhaust system to increase the exhaust back pressure, neither of which is desirable because of the reduced volumetric efficiency and increased pumping work in the engine as a result. It is therefore common practice to keep delta-P as small as possible in such cases, but this would limit the maximum flow of EGR that can be delivered by the conventional EGR system which may fall short of the EGR demand in some advanced technology engines where more and more EGR is used for NOx control under highly boosted conditions and for initiation and regulation of special combustion modes such as controlled auto-ignition (CAI) and homogeneous charge compression ignition (HCCI).

In attempting to provide high EGR under highly boosted conditions in a turbo-charged engine, partially throttling the intake or partially throttling the exhaust in order to produce sufficient delta-P across the EGR pipe could risk stalling the turbo-charger.

There is also increasing demand for the EGR gases to be cooled before they are delivered to the intake system of the engine. This is conventionally provided by an EGR cooler connected along the EGR pipe and this further increases the demand for delta-P to drive the EGR through the system.

Hot EGR may also be used for fuel reforming where some of the engine fuel is mixed with exhaust gases drawn along an EGR pipe which includes a catalytic reactor on the way to the engine intake system. This again further increases the demand for delta-P to drive the EGR.

Summary of the invention

With the aim of mitigating at least some of the above problems, there is provided according to the present invention an EGR dispensing system comprising a reciprocating piston internal combustion engine having exhaust and intake ducts, a rotary gas exchanger having a housing containing a rotating matrix, and first and second sets of entry and exit ducts in the housing, characterised in that the first set of entry and exit ducts forms part of the engine exhaust duct connecting an engine exhaust gas stream from the engine through the housing and matrix to the ambient atmosphere, and the second set of entry and exit ducts forms part of the engine intake duct connecting an engine intake air stream from the ambient atmosphere through the housing and matrix to the engine, and means for rotating the matrix at a sufficient speed for a substantial volumetric gas exchange to occur between the engine exhaust gas stream and the intake air stream.

In the system, the rotating matrix is of thin wall structure having a plurality of flow passages aligned substantially parallel with the axis of rotation of the matrix for guiding a flow of gases from one exposed end of the matrix to the other exposed end of the matrix, the housing contains and supports the rotating matrix and seals the unexposed ends of the matrix, and the respective sets of ducts are disposed in the housing with the entry and exit ducts of each set opposite one another facing the ends of the rotating matrix and positioned eccentrically to the axis of rotation of the matrix apart from and in rotational sequence with the entry and exit ducts of the other set.

In the invention, each set of entry and exit ducts in the housing can only make through flow connection via a passing group of flow passages of the matrix which are instantaneously aligned with the flow cross-sections of the said ducts as the matrix rotates, such that the passing flow passages are sequentially exposed to the exhaust gas stream in the first set of ducts and then to the intake air stream in the second set of ducts, thereby intercepting and isolating a quantity of exhaust gases trapped within the lengths of the passing flow passages from the exhaust gas stream in the first set of ducts and carrying and depositing the said exhaust gases into the intake air stream in the second set of ducts as the matrix rotates.

The flow passages in the matrix may have porous walls allowing seepage of gases from one passage to an adjacent passage while guiding a flow of gases from one exposed end of the matrix to the other exposed end of the matrix.

A very small minimum clearance is maintained between the end faces of the rotating matrix butting with the end walls of the housing in order to prevent to all intents and purposes any gas leakage at the perimeters of the entry and exit ducts and to maintain different gas pressures within the respective sets of ducts. The rotating matrix may be driven by a motor or by the engine and may be stopped when no EGR is required.

The above configuration of engine exhaust and intake ducts connected directly to separate parts of a rotary gas exchanger constitutes a system for dispensing EGR in the present invention with the conspicuous absence of an EGR pipe connecting between the exhaust duct and the intake duct of the engine as in a conventional EGR system. In the invention, there is no direct connection (such as an EGR pipe) between the exhaust system and the intake system of the engine. The exhaust gas stream and intake air stream are completely separate from one another, the former flowing from the engine through the housing and matrix to the ambient atmosphere, the latter flowing from the ambient atmosphere through the housing and matrix to the engine, the two streams flowing adjacent to one another within the housing but are kept apart by the matrix with no lateral connection between the two that would allow connecting flow from one stream to the other.

Thus the invention is also a method for dispensing EGR in a system as described above, comprising the steps of connecting the first set of entry and exit ducts of the gas exchanger for through flow of gases along the exhaust duct of the engine, connecting the second set of entry and exit ducts of the gas exchanger for through flow of gases along the intake duct of the engine, and rotating the matrix at a sufficient speed such that there is substantial volumetric gas exchange between the flows in the engine exhaust and intake ducts.

The present invention is to be distinguished from the system described in GB1136122 in which a rotary regenerative heat exchanger is used across the inlet and outlet of a flame burner supplying combustion heat to a heating head of a hot-gas engine which is an external combustion engine. Unlike an internal combustion engine where exhaust gas recirculation EGR is used to introduce inert exhaust gases to dilute the combustible charge and lower the instantaneous cycle peak temperature, there is no similar requirement in a flame burner with relatively low combustion temperature. The design of the rotary heat exchanger shown in GB1136122, which was for the purpose of heat exchange, took no account of any volumetric gas exchange in any significant amount which might take place between the flue gas and the supply air flowing through the heat exchanger.

US4542782 described a rotary heat exchanger designed for the purpose of efficient heat exchange but took no account of any volumetric gas exchange in any significant amount which might take place between the heating and heated gas streams. EP0924489 described a rotary heat exchanger in which measures were taken to minimise gas exchange between the heating and heated gas streams. Hence there is no teaching in the prior art connecting a rotary gas exchanger for the purpose of dispensing substantial quantities of EGR into a reciprocating internal combustion engine.

A unique feature of the present invention as a consequence of the absence of the EGR pipe is that the dispensing of EGR gases into the intake air stream is not dependent on the pressure drop (delta-P) between the exhaust and intake systems of the engine. Indeed, the invention will work equally well in cases where the local pressure in the intake system is lower or higher than the local pressure in the exhaust system. EGR is delivered from the exhaust pipe to the intake pipe, not by a connecting flow, but by transport of discrete packages of exhaust gases trapped within the flow guiding passages of the matrix from one part of the housing to another part of the housing as the matrix rotates. The quantity of EGR gases transferred in this manner is determined by the passing train of discrete packages which is dependent on the volume of the passing flow passages in the matrix and the speed of rotation of the matrix, and independent of the delta-P between the exhaust gas and intake air streams. Very large quantities of EGR gases may be transferred to the engine intake air using the present invention without increasing the engine exhaust back pressure or decreasing the engine intake air induction pressure, thus maintaining high volumetric efficiency and low pumping work in the engine.

Preferably a bifurcated exhaust pipe coming from the engine is provided having a first branch connected to the first set of entry and exit ducts in the housing, and a second branch bypassing the first set of entry and exit ducts, and a diverter valve at the bifurcated junction of the exhaust pipe for proportioning the flow of exhaust gases between the two branches. This enables the dispensing of EGR to be controlled quantitatively in two ways: 1) diverting a predetermined proportion of the engine exhaust gas stream to the first entry and exit ducts and rotating the matrix at a sufficient speed to transfer all the diverted gas stream to the intake air stream in which case the diverter valve will set the quantity of EGR, or 2) diverting an arbitrary proportion of the engine exhaust gas stream to the first entry and exit ducts and rotating the matrix at a variable slower speed so that only a fraction of the diverted gas stream is transferred to the intake air stream while the remaining is discharged from the first exit duct in which case the rotating speed of the matrix will set the quantity of EGR. Of course when no EGR is required, the diverter valve may be moved to divert all the exhaust gases to the second branch completely bypassing the housing, or the rotation of the matrix may be stopped.

An inherent feature of the invention is that the exhaust gas stream leaving the first exit duct will have ambient air carried across and deposited into it in the same way as the intake air stream leaving the second exit duct will have EGR gases carried across and deposited into it as the matrix rotates. Thus in the first control method described above, the gas stream discharged from the first exit duct will be entirely air which could be released directly to the ambient atmosphere. In the second control method, the gas stream discharged from the first exit duct will be exhaust gases diluted with air and this may be treated in the variety of ways for cleaning up the exhaust before being discharged to the ambient atmosphere.

Brief description of the drawings

The invention will now be described further by way of example with reference to the accompanying drawings in which

Figure 1 is a schematic view of a system for dispensing EGR according to the present invention,

Figure 1a is a schematic view of an alternative system for dispensing EGR according to the invention,

Figure 2 is a schematic axial cross-section of a rotating matrix within a housing forming part of the EGR dispensing system of Figure 1,

Figures 2a and 2b are developed views of the rotating matrix of Figure 2, and

Figure 3 is a schematic lateral cross-section of the rotating matrix and housing of Figure 2.

Detailed description of the preferred embodiment

Figure 1 (also Figure 1a) shows a reciprocating internal combustion engine 100 with intake manifold 114 admitting intake air from the ambient atmosphere through an air blower 124 and a housing 14 containing a flow guiding matrix 10 to the engine cylinders along an intake duct comprising elements 124, 24, 14, 10, 24', 114 in the flow direction indicated by arrows, and exhaust manifold 112 discharging exhaust gases from the engine cylinders through the housing 14 and matrix 10 to the ambient atmosphere via an exhaust turbine 122 along an exhaust duct comprising elements 112, 22, 14, 10, 22', 122 in the flow direction also indicated by arrows. The matrix 10 is supported for rotation within the housing 14 with good seals at each end of the matrix 10 butting against the end walls of the housing 14.

The above configuration of engine exhaust and intake ducts 112, 22, 22' and 24, 24', 114 respectively, connected directly to separate parts of a rotary gas exchanger 14, 10 (with or without the turbo-charger 122, 124) constitutes a system for dispensing EGR in the present invention with the conspicuous absence of an EGR pipe connecting between the exhaust duct and the intake duct of the engine as in a conventional EGR system. In the invention, EGR is delivered from the exhaust duct to the intake duct, not by a connecting flow, but by transport of discrete packages of exhaust gases trapped within the flow guiding passages of the matrix from one part of the housing to another part of the housing as the matrix rotates. When the matrix 10 is stationary, no package is transferred and the exhaust and intake streams will simply flow past one another along separate parts of the matrix 10. When the matrix 10 is rotated at a variable speed driven by an electric motor or by the engine drive train (not shown), discrete packages of exhaust gases will be intercepted from the exhaust gas stream 22, 22', trapped locally within part of the matrix 10, carried across to the intake air stream 24, 24' as the matrix rotates, and deposited into the intake air stream. Thus EGR is dispensed according to the rotating speed of the matrix and this could take place at any exhaust or intake pressure, not relying on delta-P to drive a connecting flow as in a conventional EGR system. Very large quantities of EGR gases may be transferred to the engine intake air using the present invention without increasing the engine exhaust back pressure or decreasing the engine intake air induction pressure, thus maintaining high volumetric efficiency and low pumping work in the engine.

Figures 2 and 3 show a rotating matrix 10 of thin wall structure forming a plurality of flow passages aligned substantially parallel with the axis of rotation of the matrix for guiding a flow of gases from one exposed end of the matrix to the other exposed end of the matrix. A flow passage element 20 fed with an advancing column of exhaust gases is highlighted as example in Figure 2. The matrix 10 is contained within a housing 14 which seals the ends of the unconnected part of the matrix and supports the matrix for rotation about an axis 12 driven by a variable speed motor or by the engine drive train (not shown). This assembly constitutes a rotary gas exchanger and is a key part of the EGR dispensing system of Figure 1 (also Figure 1a) with like components annotated by the same numerals.

The housing 14 has two sets of entry and exits ducts labelled generally 22, 24 in Figure 3. A first set of entry and exit ducts 22, 22' respectively in the housing 14 connects an engine exhaust gas stream from the engine exhaust system (112) through the housing 14 and matrix 10 to the ambient atmosphere. A second set of entry and exit ducts 24, 24' respectively in the housing 14 connects an engine intake air stream from the ambient atmosphere through the housing 14 and matrix 10 to the engine intake system (114). In the invention, the respective sets of ducts are disposed in the housing 14 with the entry and exit ducts of each set opposite one another facing the ends of the rotating matrix 10 and positioned eccentrically to the axis of rotation of the matrix 10 apart from and in rotational sequence with the other set of entry and exit ducts. Each set of entry and exit ducts in the housing 14 can only make through flow connection via a passing group of flow passages in the matrix 10 which are instantaneously aligned with the flow cross-sections of the said ducts as the matrix rotates, such that the passing flow passages are sequentially exposed to the exhaust gas stream in the ducts 22, 22' and then to the intake air stream in the ducts 24, 24', thereby intercepting and isolating a quantity of exhaust gases trapped within the lengths of the passing flow passages in the matrix 10 from the exhaust gas stream in the ducts 22, 22', and carrying and depositing the said exhaust gases into the intake air stream in the ducts 24, 24' as the matrix rotates. For example the flow passage element 20 containing a trapped package of a column of exhaust gases is carried laterally from the duct 22 to the duct 24 along a locus indicated by the rotation arrow in Figure 3.

A very small minimum clearance is maintained between the end faces of the rotating matrix 10 butting with the end walls of the housing 14 in order to stop to all intents and purposes any gas leakage at the perimeters of the entry and exit ducts 22, 22' and 24, 24', and to maintain different gas pressures within each set of ducts. The walls of the flow passages in the matrix 10 may be constructed of thin foils of stainless steel or extruded ceramic in a honeycomb flow guiding structure. The walls may also be porous allowing seepage of gases from one passage to an adjacent passage while guiding a flow of gases from one exposed end of the matrix to the other exposed end.

Figure 2 also shows a bifurcated exhaust pipe 30 coming from the engine exhaust system (112) with one branch connected to the entry and exit ducts 22, 22' and another branch 32 bypassing the entry and exit ducts 22, 22'. A diverter valve 36 is provided at the bifurcated junction for proportioning the flow of exhaust gases between the two branches. In the position shown, the diverter valve 36 diverts substantially the full flow of exhaust gases towards the duct 22. When the valve 36 is moved in the direction of the arrow, a smaller proportion of the exhaust gas flow will be diverted to the duct 22.

This enables the dispensing of EGR to be controlled quantitatively in two ways: 1) diverting a predetermined proportion of the engine exhaust gas stream to the entry duct 22 and rotating the matrix 10 at a sufficient speed to transfer all the diverted gases to the intake air stream in which case the diverter valve 36 will set the quantity of EGR, or 2) diverting an arbitrary proportion of the engine exhaust gas stream to the entry duct 22 and rotating the matrix 10 at a variable slower speed so that only a fraction of the diverted gases is transferred to the intake air stream while the remaining is discharged from the exit duct 22' to join with the exhaust pipe 30' in which case the rotating speed of the matrix will set the quantity of EGR. Of course when no EGR is required, the diverter valve 36 may be moved to divert all the exhaust gases along the branch 32 completely bypassing the housing 14, or the rotation of the matrix 10 may be stopped.

It should be noted that an inherent feature of the system in Figure 1 (also Figure 1a) is that the exhaust gas stream leaving the exit duct 22' will have ambient air carried across and deposited into it in the same way as the intake air stream leaving the exit duct 24' will have EGR gases carried across and deposited into it as the matrix 10 rotates. In Figure 2, in the first control method described in the previous paragraph, the gas stream discharged from the exit duct 22' will be entirely air, whereas in the second control method, the gas stream discharged from the exit duct 22' will be exhaust gases diluted with air. In the first case, the air discharge from the exit duct 22' may be released immediately to the ambient atmosphere without diluting the exhaust gas flow in the bypass branch 32, 30' connected to the exhaust after-treatment system of the engine including a catalytic converter. Accordingly, a two-position valve 38 is shown for releasing the air via a separate duct 30".

The above two cases are better illustrated in Figures 2a and 2b respectively, which are developed views of the rotating matrix shown in Figure 2 moving in the direction of the dashed arrows and carrying the flow passages past the entry and exit ducts 22, 22' which take the exhaust gases from the engine, and then past the entry and exit ducts 24, 24' which take the intake air to the engine. Following one flow passage element moving from left to right, it has initially a column of air trapped between the sealed ends. When this flow passage element is carried past the cross-section of the entry and exit ducts 22, 22', exhaust gases (shown shaded) will enter the passage as an advancing column pushing the air content out of the passage. The extent by which the exhaust gas column fills the length of the flow passage element would depend on the speed of the gas flow along the element and time available for the element to traverse laterally the cross-section of the entry and exit ducts 22, 22'. In Figure 2a where the speed of the gas flow is relatively low and the speed of rotation of the matrix 10 is relatively high, there is no breakthrough of the exhaust gas column reaching the exit duct 22' in the time available so that the gases leaving the exit duct 22' will be entirely air. On the other hand, in Figure 2b where the speed of the gas flow is relatively high and the speed of rotation of the matrix 10 is relatively low, there is breakthrough of the exhaust gas column reaching the exit duct 22' in the time available and the gases leaving the exit duct 22' will be a mixture of exhaust gases and air.

When the flow passage element is carried completely past the cross-section of the entry and exit ducts 22, 22', the column is sealed again at both ends and transported laterally until it reaches the cross-section of the entry and exit ducts 24, 24' where intake air will enter the passage as an advancing column and push the exhaust gas content out of the flow passage element into the exit duct 24'. These exhaust gases would join with more air breaking through the flow passage element and reaching the exit duct 24' in the time available according to the speed of rotation of the matrix 10, and the mixture is delivered to the engine as EGR mixed with intake air, thus achieving the objective of the invention for dispensing EGR by means of a system comprising the engine exhaust and intake ducts connected directly to separate parts of a rotary gas exchanger, without relying on flow along an EGR pipe.

It should be noted that whilst Figures 2a and 2b show the exhaust gas stream and intake air stream arranged in counter-flow directions as in Figure 1, the EGR dispensing system will operate to similar effectiveness when the two streams are arranged in the same flow direction as shown in Figure 1a.

In the above system for dispensing EGR, very large quantities of EGR may be transferred to the intake system of the engine and this is independent of the delta-P between the any connecting points in the exhaust and intake systems, and is limited only by the EGR tolerance characteristics of the engine combustion system accepting the EGR. The invention is to be contrasted with the conventional EGR system where the quantity of EGR is often limited by the delta-P available, in which case if more EGR is required than can be delivered by the available delta-P, various methods of adjustable valve timing of the engine intake and exhaust valves may have to be used to introduce additional internal EGR to supplement the deficiency of the conventional EGR system. Such methods include positive valve overlap, exhaust valve re-open, negative valve overlap etc designed to trap, re-breathe or re-shuffle some exhaust or burnt gases internally within the engine cylinder without letting them escape into the exhaust system. These methods have been used successfully in some CAI and HCCI engines where the overall EGR could be in the order of 70% of engine cylinder displacement and may go even higher, but they require special valve train systems which are expensive to make and complicated to control, hence the EGR dispensing system of the present invention could provide a simpler and more cost-effective solution by supplying all the EGR that is needed. Moreover, modern IC engines are commonly operated at high boost from a turbocharger or supercharger at the same time with high EGR in order to produce high power and reduced NOx emissions. The EGR dispensing system of the present invention is effective operating under such conditions and can be connected by many different configurations with a turbo-charger 122, 124, such as that shown in Figure 1 and even against rising delta-P as shown in Figure 1a.

CLAIMS

1. An EGR dispensing system comprising a reciprocating piston internal combustion engine having exhaust and intake ducts, a rotary gas exchanger having a housing containing a rotating matrix, and first and second sets of entry and exit ducts in the housing, characterised in that the first set of entry and exit ducts forms part of the engine exhaust duct connecting an engine exhaust gas stream from the engine through the housing and matrix to the ambient atmosphere, and the second set of entry and exit ducts forms part of the engine intake duct connecting an engine intake air stream from the ambient atmosphere through the housing and matrix to the engine, and means for rotating the matrix at a sufficient speed for a substantial volumetric gas exchange to occur between the engine exhaust gas stream and the intake air stream.

2. A system as claimed in claim 1, wherein the rotating matrix is of thin wall structure having a plurality of flow passages aligned substantially parallel with the axis of rotation of the matrix for guiding a flow of gases from one exposed end of the matrix to the other exposed end of the matrix, the housing contains and supports the rotating matrix and seals the unexposed ends of the matrix, and the respective sets of ducts are disposed in the housing with the entry and exit ducts of each set opposite one another facing the ends of the rotating matrix and positioned eccentrically to the axis of rotation of the matrix apart from and in rotational sequence with the entry and exit ducts of the other set.

3. A system as claimed in claim 1 or 2, wherein a very small minimum clearance is maintained between the end faces of the rotating matrix butting with the end walls of the housing in order to prevent to all intents and purposes any gas leakage at the perimeters of the entry and exit

ducts and to maintain different gas pressures within the respective sets of ducts.

4. A system as claimed in any preceding claim, further comprising a bifurcated exhaust pipe coming from the engine having a first branch connected to the first set of entry and exit ducts in the housing, and a second branch bypassing the first set of entry and exit ducts, and a diverter valve at the bifurcated junction of the exhaust pipe for proportioning the flow of exhaust gases between the two branches.

5. A method for dispensing EGR in a system as claimed in any preceding claim, comprising the steps of connecting the first set of entry and exit ducts of the gas exchanger for through flow of gases along the exhaust duct of the engine, connecting the second set of entry and exit ducts of the gas exchanger for through flow of gases along the intake duct of the engine, and rotating the matrix at a sufficient speed such that there is substantial volumetric gas exchange between the flows in the engine exhaust and intake ducts.

6. A rotary gas exchanger constructed for connection with the exhaust and intake ducts of a reciprocating internal combustion engine, constituting a system as claimed in claim 1 and according to a method as claimed in claim 5.

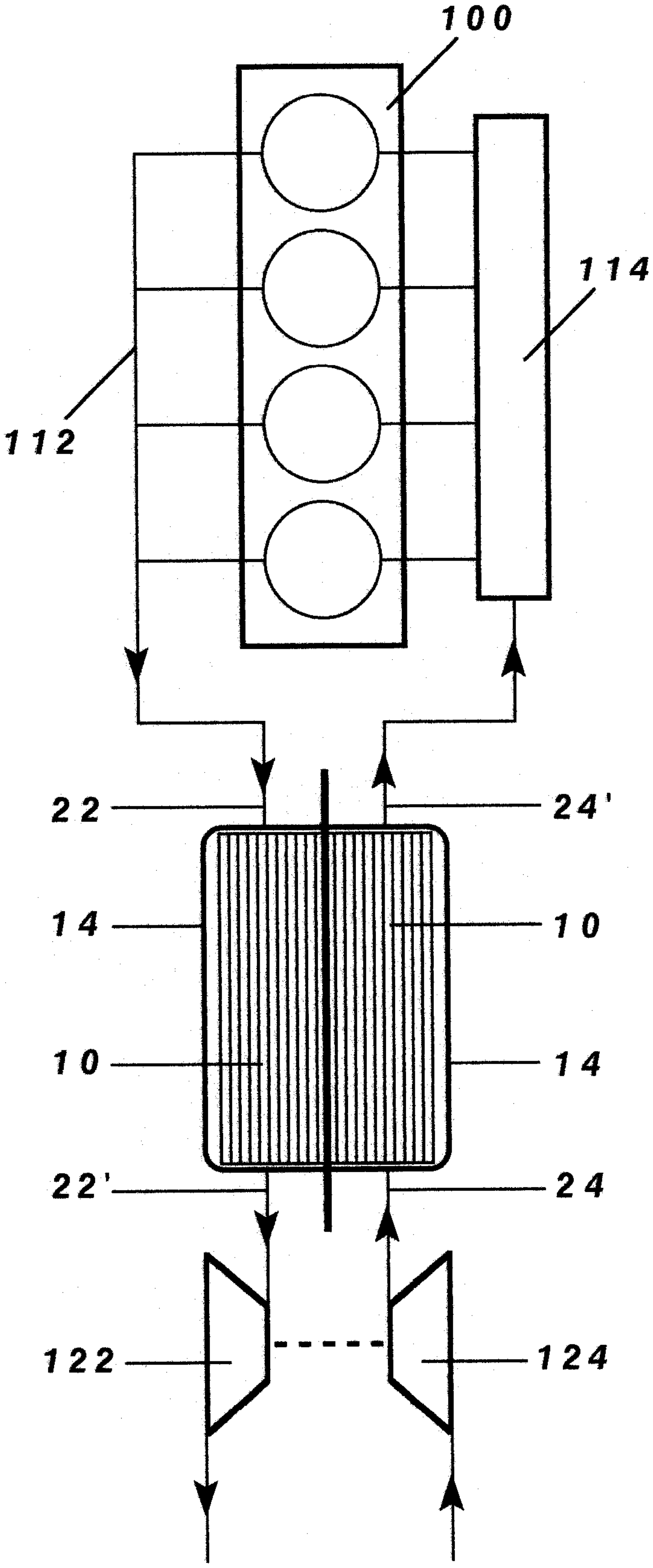

Fig.1

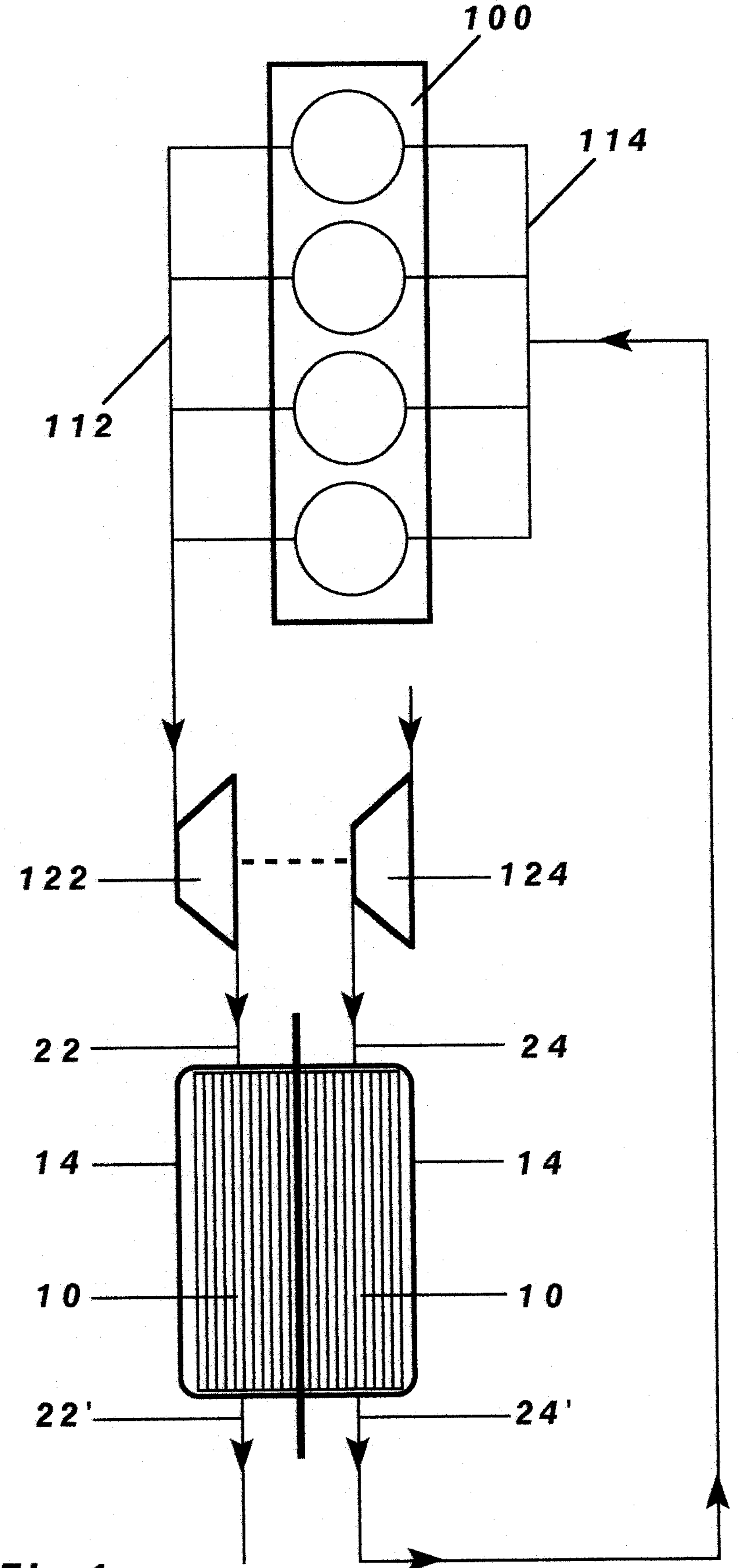

Fig.1a

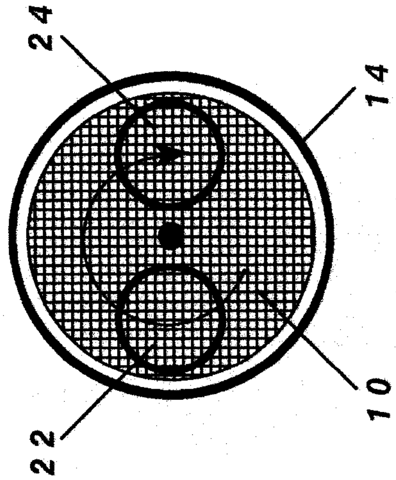

Fig.3

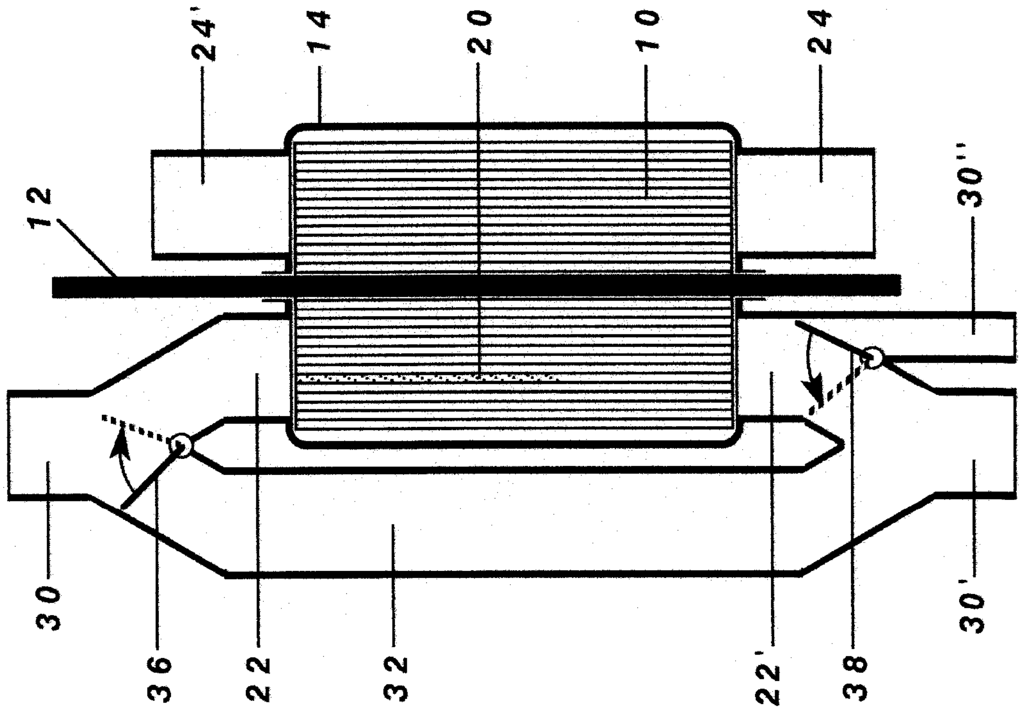

Fig.2

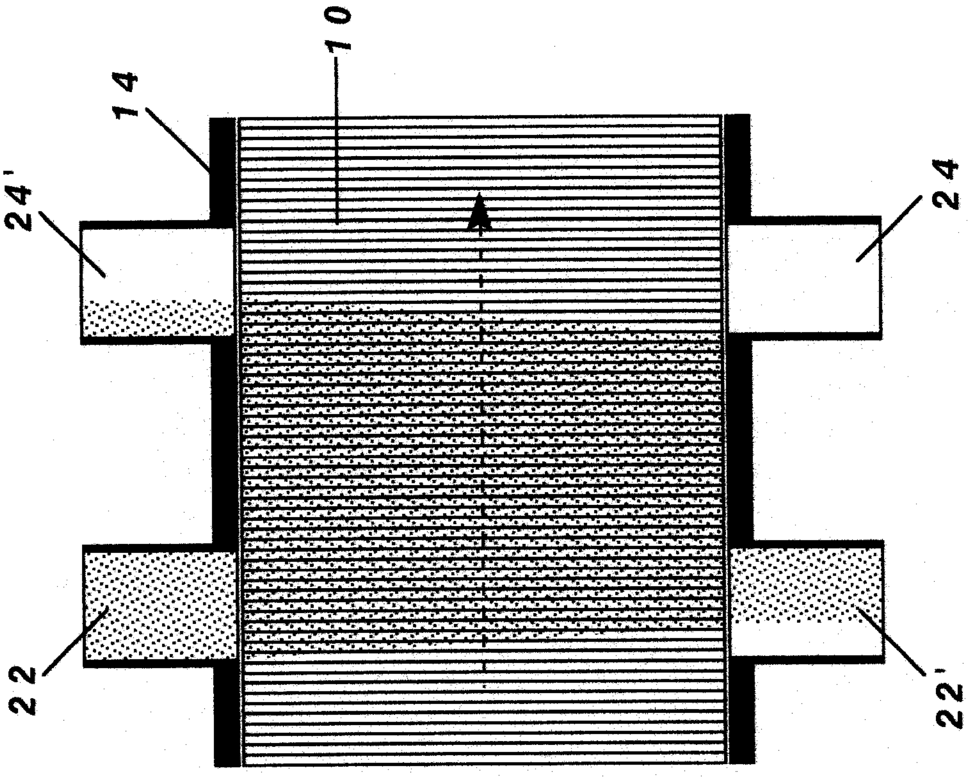

Fig.2b

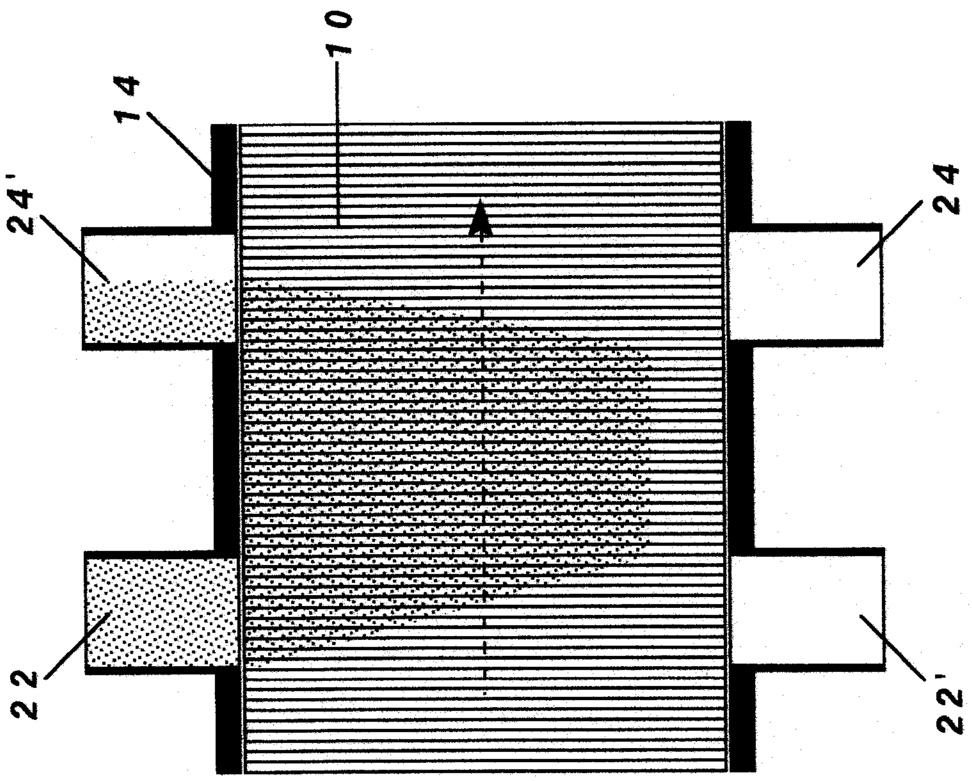

Fig.2a

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/050201

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M25/07
ADD. F01N5/02 F02B33/42

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 F02B F28D F04F

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, 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	DE 197 13 930 A1 (HUBER, MARTIN) 8 October 1998 (1998-10-08) abstract; figures column 1, line 27 - line 39	1,2,5,6
A	column 2, line 3 - line 41 column 3, line 12 - line 41 column 4, line 36 - column 6, line 10	3,4
X	GB 1 136 122 A (N.V. PHILIPS' GLOEILAMPENFABRIEKEN) 11 December 1968 (1968-12-11) cited in the application	1-3
A	figures page 3, line 48 - page 4, line 70	4-6

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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 September 2006	26/09/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Döring, Marcus

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