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**N0T** CLASSIFIED

(56) Documents Cited:
**GB 2428465 A** **EP 1586842 A1**
**US 6161528 A**

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Other: **ON-LINE:WPI;EPODOC;OPTICS;TXTE**

(54) Abstract Title: **EGR COOLER FOR A BOOSTED IC ENGINE**

(57) An exhaust gas recirculation system (EGR) cooler for a boosted internal combustion engine has a housing 14 containing a rotating flow guiding matrix 10 (sometimes known as a thermal wheel). The housing has a first set of entry and exit ducts 22, 22' forming a part of the engine exhaust gas flow arrangement (112, 36, 32, 22, 22'; all fig 1) and a second set of entry and exit ducts 24, 24' positioned in rotational sequence after the first set of entry and exit ducts and forming a part of the boosted air intake arrangement (124, 24, 24', 114; all fig 1). The system includes at least one re-expansion duct 28 in the housing positioned in rotational sequence after the second set of entry and exit ducts for discharging a re-expanded cool air stream out of the re-expansion duct, and a third set of entry and exit ducts 26, 26' in the housing positioned in rotational sequence after the re-expansion duct and connected to the re-expansion duct for directing a re-expanded cool air stream from the re-expansion duct back through the housing and matrix to the ambient atmosphere. The system also has means for rotating the matrix, such that matrix is alternately heated by the exhaust gas stream and cooled by the charge air stream.

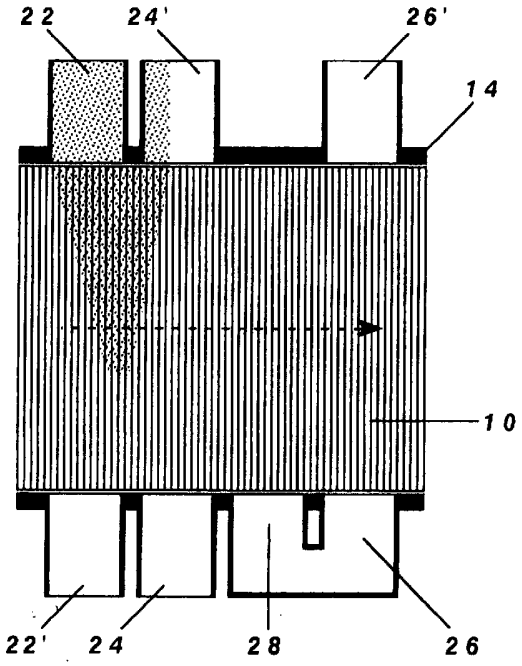


*Fig.2*

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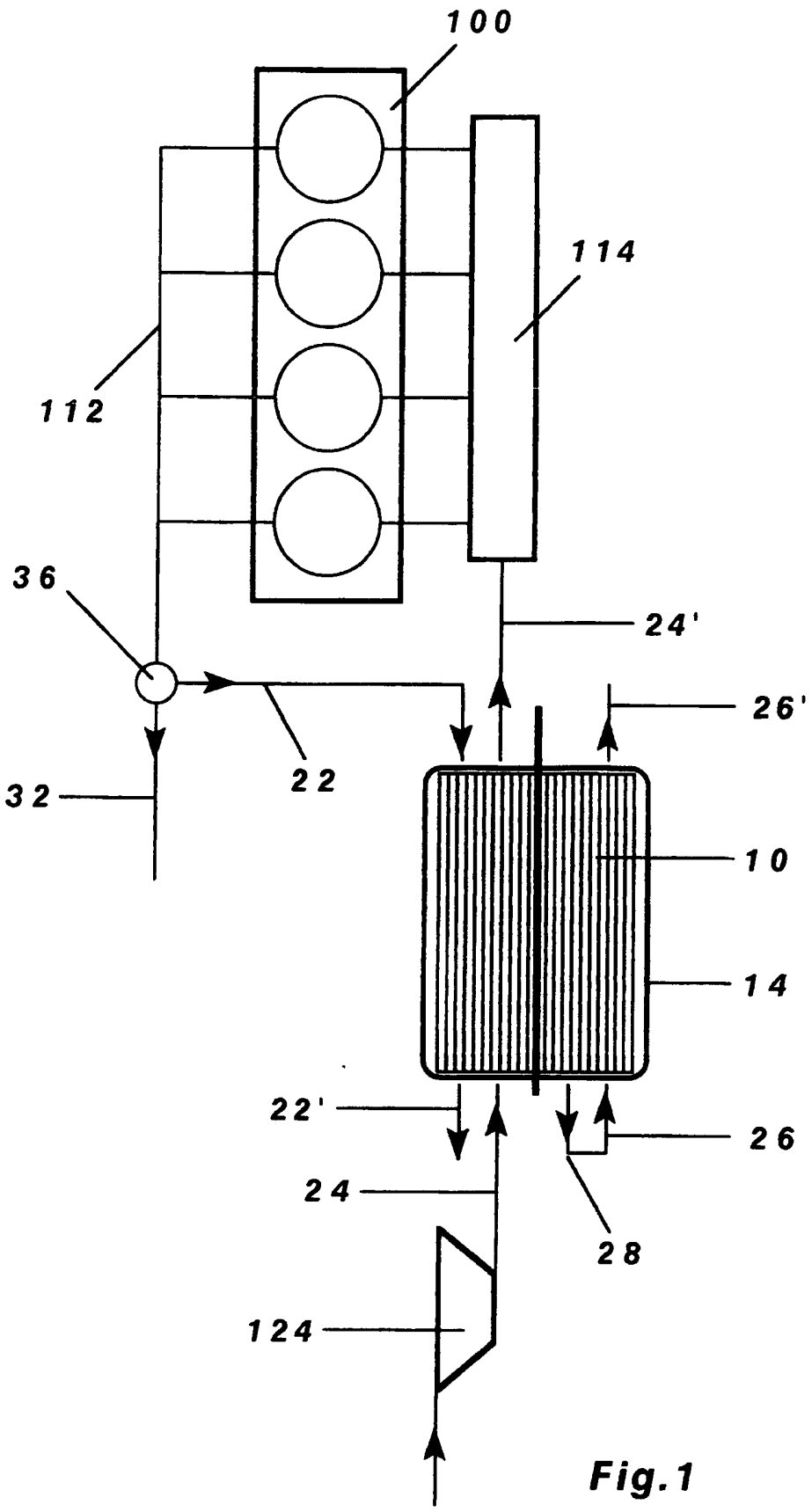


Fig.1

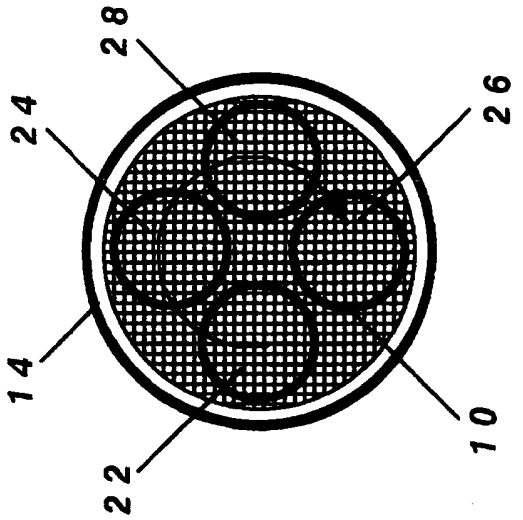


Fig.3

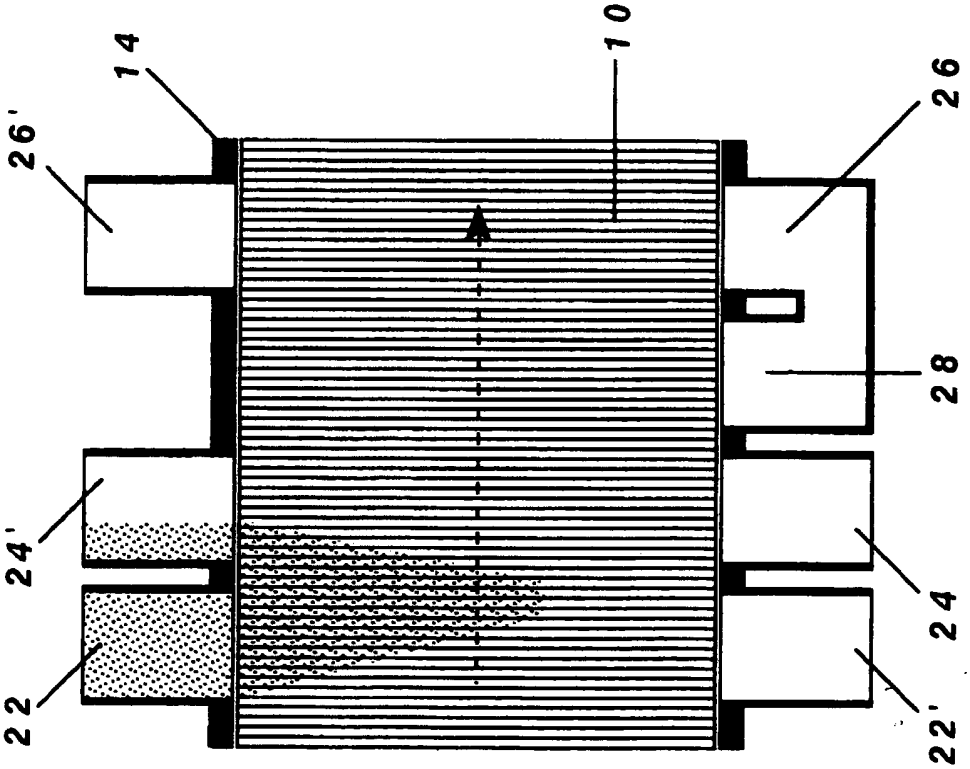


Fig.2

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# EGR COOLER FOR BOOSTED IC ENGINE

## Field of the invention

The present invention relates to a device for providing EGR cooling in a boosted internal combustion engine.

## Background of the invention

The present invention draws priority from Patent Application GB0609674.7 in which an EGR cooler is integrated with a rotary gas exchanger which forms part of an EGR dispensing system for a boosted internal combustion engine.

## Summary of the invention

According to the present invention, there is provided an EGR cooler for a boosted internal combustion engine with a supercharger and/or turbocharger, wherein the EGR cooler is a rotary gas and heat exchanger comprising a housing containing a rotating flow guiding matrix, a first set of entry and exit ducts in the housing forming part of the engine exhaust duct connecting an engine exhaust gas stream from the engine through the housing and matrix to the ambient atmosphere, a second set of entry and exit ducts in the housing forming part of an engine intake duct for connecting a boosted intake air stream from the supercharger or turbocharger through the housing and matrix to the engine, at least one re-expansion duct in the housing positioned in rotational sequence after the second set of entry and exit ducts for discharging a re-expanded cool air stream out of the re-expansion duct, a third set of entry and exit ducts in the housing positioned in rotational sequence after the re-expansion duct and connected to the re-expansion duct for directing the re-expanded cool air stream from the re-expansion duct back through the housing and matrix to the ambient atmosphere, and means for rotating

the matrix at a sufficient speed for a substantial volumetric gas transfer to occur from the exhaust gas stream contained within the matrix along the first set of entry and exit ducts to the boosted air stream leaving the matrix along the second set of entry and exit ducts and from the boosted air stream contained within the matrix along the second set of entry and exit ducts to the cool air stream leaving the matrix along the re-expansion duct and re-entering the matrix along the third set of entry and exit ducts, whereupon the body of the matrix is alternately heated by the exhaust gas stream and cooled by the cool air stream as the matrix rotates resulting in cooling of the recirculated exhaust gases delivered to the engine.

In the invention, a substantial proportion of the boosted air stream from the turbocharger or supercharger is isolated within the flow passages of rotating matrix and transported laterally away from the main air supply stream to the engine. The transported compressed air is then re-expanded (hence reversibly cooled) and the re-expanded cool air is re-routed back through the body of the rotating matrix for cooling the matrix, which in turn acts as a cold sink when it is subsequently exposed to the hotter exhaust gas stream as the matrix rotates thus cooling the exhaust gas stream which is the EGR delivered to the engine. There is no need of a separate air blower for supplying cooling air to the EGR cooler of the present invention since the supercharger and/or turbocharger of the engine is used to supply the total air flow to the engine and the EGR cooler. As a matter of fact, it is important to note that the invention helps to alleviate an undesirable side-effect of the rotary gas exchanger (when it is used as an EGR dispenser in a boosted engine as described in GB0609674.7) and turn it into an advantage, in that the proportion of boosted air which would have been lost to the exhaust system of the engine in the process of EGR gas exchange is put to good use for cooling the EGR.

## 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 boosted internal combustion engine provided with an EGR cooler of the present invention,

Figure 2 is a developed view of the rotating matrix of the EGR cooler of Figure 1, and

Figure 3 is a schematic lateral cross-section of the EGR cooler with the developed view of Figure 2.

## Detailed description of the preferred embodiment

Figure 1 shows a boosted internal combustion engine 100 with an intake manifold 114 admitting pressurised intake air from a supercharger 124 (and/or from an exhaust gas driven turbocharger) via a housing 14 containing a rotating flow guiding matrix 10 to the engine cylinders along an intake path comprising elements 124, 24, 14, 10, 24', 114 in the flow direction indicated by arrows, and an exhaust manifold 112 discharging exhaust gases from the engine cylinders via exhaust ducts 32, 22. An EGR proportioning valve 36 is also shown for regulating the relative flows within the ducts 32, 22 where the latter duct 22 is connected for EGR via the housing 14 and matrix 10 along an exhaust path comprising elements 112, 22, 14, 10, 22' 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 matrix 10 is a thin wall honeycomb 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. The matrix 10 is contained

within a housing 14 which seals the ends of the unexposed part of the matrix and supports the matrix for rotation about a longitudinal axis driven by a variable speed motor or by the engine ancillary drivetrain (not shown).

In the invention, the rotating matrix 10 is used as a combined gas and heat exchanger for EGR cooling in which the heat from the EGR is rejected to cooling air extracted from another part of the gas exchanger supplied indirectly by the supercharger and/or turbocharger. Unlike a conventional EGR cooler of the heat regenerating type such as those described in US6161528 and EP1586842 where a supply of cooling air from an external air blower or from an external branch of a supercharger or turbocharger is delivered to the duct 26 for removing heat from the body of the rotating matrix 10, the EGR cooler of the present invention makes use of an available stream of cooling air extracted internally from one part (duct 28) of the rotary gas exchanger and re-routed back to the duct 26 for removing heat from the body of the rotating matrix 10.

As a matter of fact, the invention helps to alleviate an undesirable side-effect of the rotary gas exchanger (when it is used as an EGR dispenser in a boosted engine as described in GB0609674.7) and turn it into an advantage, in that the proportion of boosted air which would have been lost to the exhaust system of the engine in the process of EGR gas exchange is put to good use for cooling the EGR. Thus, as shown in Figure 1, an available stream of cooling air is extracted at one stage of the rotary gas exchange process in which the proportion of boosted air from the supercharger 124, which is isolated within the flow passages in the matrix 10 along the ducts 24, 24' as the matrix rotates, is transferred laterally towards a re-expansion duct 28 where it is released out of the duct 28 and re-routed back to the duct 26 for another pass through the matrix 10. As the pressurised air is released from the duct

28, it cools as it expands so that the stream passing through the ducts 26, 26' will be cool air at substantially ambient pressure, coming indirectly from the supercharger 124.

Figure 2 shows a developed view of the rotating matrix 10 opened out along the plane of rotation of the arrow shown in the lateral cross-section view in Figure 3. The EGR gas stream along the ducts 22, 22' is the first stream connected to the rotary gas exchanger in rotational sequence of the rotating matrix 10. This is shown as the gases in the shaded region which are transferred and mixed with a second stream in the unshaded region which is the boosted air along the ducts 24, 24' as the matrix rotates. A re-expansion duct 28 is positioned in rotational sequence downstream of the boosted air duct 24 and into this duct 28 is released the pressurised air transferred from the boost air stream by the flow passages in the rotating matrix 10 as they move past the duct 28. The released air, which cools as it expands, is then re-routed back through the body of the matrix 10 as a third stream of cooling air along the duct 26, 26' positioned downstream of the re-expansion duct 28 in rotational sequence. Thus the body of the matrix 10 is alternately heated by the EGR stream 22, 22' and cooled by the re-expanded cool air stream 26, 26' as the matrix rotates resulting in cooling of the EGR gases delivered to the engine 100 along the boosted air duct 24, 24'. Finally, some air at ambient pressure in the cooling air stream 26, 26' is transferred and discharged via the exhaust duct 22' thus completing all the gas exchange stages through one revolution of the matrix 10.

During operation of the EGR cooler, the rotating speed of the matrix 10 should equate or exceed a minimum speed which would transfer all the exhaust gases in the duct 22, 22' to the boosted air duct 24, 24' as EGR regulated by the proportioning valve 36, and the quantity of the boosted air

delivered to the re-expansion duct 28 for cooling of the EGR is controlled by varying the rotating speed of the matrix 10 from the minimum speed to higher speeds. Alternatively, the rotating speed could be varied according to a fixed speed ratio or a variable speed ratio with engine speed when the matrix 10 is driven by the engine ancillary drivetrain, and the speed ratio equals or exceeds a minimum speed ratio which would transfer all the exhaust gases in the duct 22 to the boosted air duct 24 as EGR, regulated by the EGR proportioning valve 36. Under these conditions, no exhaust gas will escape from the ducts 22' and 26' hence the streams from these ducts may be safely discharged into the ambient atmosphere.

The EGR cooler of the present invention may be used in series with another intercooler (not shown in Figure 1) along the intake path to the engine 100 for cooling the boosted air or the boosted mixture of EGR and air delivered by the supercharger 124 or the EGR cooler 14 respectively. In the former case, the intercooler is positioned downstream of the supercharger 124 but upstream of the EGR cooler 14 so that the boosted air delivered to the EGR cooler is already cooled and would cool further as it expands out of the duct 28 within the EGR cooler 14 thus improving the efficiency of the EGR cooler. In the latter case, the intercooler is positioned downstream of the EGR cooler 14 and cools further the EGR and air mixture that is delivered to the engine 100.

Another exhaust gas cooler of the liquid-cooled type (not shown in Figure 1) may be connected along the exhaust gas duct 22 before the exhaust gases are delivered to the EGR cooler 14. This would provide a first stage cooling of the EGR followed by a second stage cooling within the EGR cooler 14. In the case where there is no EGR coming from the exhaust gas duct 22, the cooler 14 would still provide some cooling of the boosted air from the supercharger 124 and serve at least as a supplementary air intercooler.

**CLAIMS**

1. An EGR cooler for a boosted internal combustion engine with a supercharger and/or turbocharger, wherein the EGR cooler is a rotary gas and heat exchanger comprising a housing containing a rotating flow guiding matrix, a first set of entry and exit ducts in the housing forming part of the engine exhaust duct connecting an engine exhaust gas stream from the engine through the housing and matrix to the ambient atmosphere, a second set of entry and exit ducts in the housing positioned in rotational sequence after the first set of entry and exit ducts and forming part of an engine intake duct for connecting a boosted intake air stream from the supercharger or turbocharger through the housing and matrix to the engine, at least one re-expansion duct in the housing positioned in rotational sequence after the second set of entry and exit ducts for discharging a re-expanded cool air stream out of the re-expansion duct, a third set of entry and exit ducts in the housing positioned in rotational sequence after the re-expansion duct and connected to the re-expansion duct for directing the re-expanded cool air stream from the re-expansion duct back through the housing and matrix to the ambient atmosphere, and means for rotating the matrix at a sufficient speed for a substantial volumetric gas transfer to occur from the exhaust gas stream contained within the matrix along the first set of entry and exit ducts to the boosted air stream leaving the matrix along the second set of entry and exit ducts and from the boosted air stream contained within the matrix along the second set of entry and exit ducts to the cool air stream leaving the matrix along the re-expansion duct and re-entering the matrix along the third set of entry and exit ducts, whereupon the body of the matrix is alternately heated by the exhaust gas stream and cooled by the cool air stream as the matrix rotates resulting in cooling of recirculated exhaust gases delivered to the engine.

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**Application No:** GB0705063.6 **Examiner:** Mr Brian A Woods

**Claims searched:** 1 **Date of search:** 17 July 2007

# Patents Act 1977: Search Report under Section 17

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance |
|---|---|---|
| A | | EP1586842 A1 (BEHR GMBH) See whole document noting a rotating heat exchanger for cooling exhaust gas from a vehicle engine, comprising a heat exchange zone with its primary side in the exhaust gas recirculation system of the engine and its secondary side in the air supply system of the engine. |
| A | | US6161528 A (MITSUBISHI) See whole document noting an EGR heat exchanger utilizing a rotating core and using a gas as the coolant. |
| A | | GB2428465 A (MA THOMAS TSOI HEI) See whole document noting fig 4a and associated description. |

Categories:

| | | | |
|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC$^{X}$ :

F4K

Worldwide search of patent documents classified in the following areas of the IPC

F02M; F28D

The following online and other databases have been used in the preparation of this search report

WPI;EPODOC;OPTICS;TXTE

**International Classification:**

| Subclass | Subgroup | Valid From |
|---|---|---|
| F02M | 0025/07 | 01/01/2006 |
| F28D | 0019/04 | 01/01/2006 |