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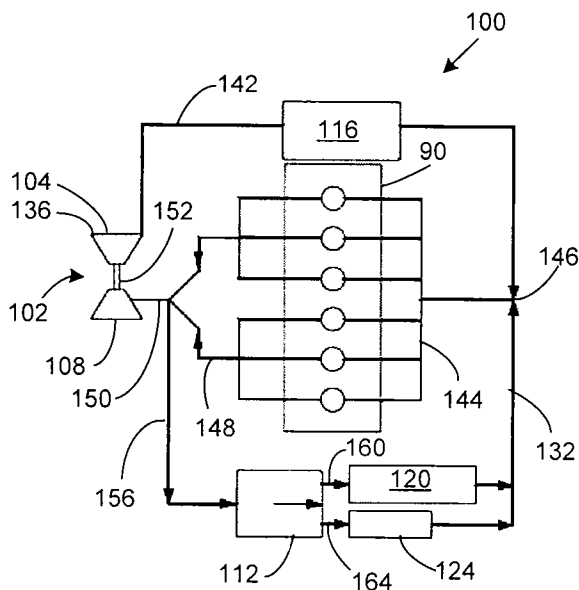
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FIG. 1



(57) Abstract: An exhaust gas recirculation system for distributing a working fluid includes a turbine operable to receive a first portion of the working fluid for driving a compressor, a first cooler and a second cooler arranged in a parallel configuration, and a single valve operable to selectively direct a second portion of the working fluid through at least one of the first cooler and the second cooler.

EXHAUST GAS RECIRCULATING SYSTEM AND METHOD OF OPERATING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Priority is hereby claimed to United States Provisional Patent Application No. 60/963,734, filed on August 7, 2007, the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to an exhaust gas recirculation system for a vehicle engine, and more particularly, to an exhaust gas recirculation system having at least two recirculation coolers arranged in a parallel flow configuration.

SUMMARY

[0003] In some embodiments, the invention provides an exhaust gas recirculation system for transferring heat energy from a vehicle engine to a working fluid. The exhaust gas recirculation system can include a heat exchange circuit providing a flow path for the working fluid and extending between and fluidly connecting a turbine-driven compressor, a first cooler, and a second cooler. The first and second coolers can be arranged in a parallel flow configuration. The heat exchanger can also include a valve positioned along the heat exchange circuit and operable to distribute the working fluid to each of the first and second coolers based on conditions of at least one of the vehicle engine and the working fluid.

[0004] The invention also provides an exhaust gas recirculation system including a compressor, a turbine, a first recirculation cooler, and a second recirculation cooler. In some embodiments, the first recirculation cooler and the second recirculation cooler are differently sized and are arranged in a parallel flow configuration along a heat exchange circuit.

[0005] In addition, in some embodiments, the invention provides a method of controlling an exhaust gas recirculation system. The method can include the acts of directing working fluid through a heat exchange circuit to a valve and operating the valve to selectively direct the working fluid to a first recirculation cooler and to a second differently sized recirculation cooler.

[0006] In one embodiment, the invention provides an exhaust gas recirculation system for distributing a working fluid in a vehicle engine, the exhaust gas recirculation system including a turbine operable to receive a first portion of the working fluid for driving a compressor and a first cooler and a second cooler arranged along a recirculation flow path extending between an engine exhaust manifold and an engine intake manifold. The first cooler can include a different cooling capacity than the second cooler. The exhaust gas recirculation cooler can also include a valve positioned along the recirculation flow path and selectively moveable toward a first position to direct a second portion of the working fluid through the first cooler, a second position to direct the second portion of the working fluid through the second cooler, and a third position to divide the second portion of the working fluid between the first cooler and the second cooler.

[0007] In another embodiment, the invention provides a heat exchange circuit for distributing a first working fluid and a second working fluid, the heat exchange circuit including a turbine operable to receive a first portion of the second working fluid for driving a compressor to compress the first working fluid, a first cooler and a second cooler arranged in a parallel flow configuration along a common flow path, a single valve operable to selectively direct a second portion of the second working fluid through at least one of the first cooler and the second cooler, a third cooler operate to receive the compressed first working fluid, and a mixing chamber operable to receive the compressed first working fluid and the second portion of the second working fluid.

[0008] In another embodiment, the invention provides a method of operating an exhaust gas recirculation system. The method includes directing a first portion of a working fluid through a turbine driving a compressor, directing a second portion of the working fluid through a valve, and operating the valve to selectively direct the second portion of the working fluid to at least one of a first cooler and a second cooler.

[0009] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a schematic representation of an exhaust gas recirculation system according to some embodiments of the present invention and with a valve in a first position.

[0011] Fig. 2 is a schematic representation of the exhaust gas recirculation system shown in Fig. 1 with the valve in a second position.

[0012] Fig. 3 is a schematic representation of the exhaust gas recirculation system shown in Fig. 1 with the valve in a third position.

[0013] Fig. 4 is a schematic representation of the exhaust gas recirculation system shown in Fig. 1 with the valve in a fourth position.

DETAILED DESCRIPTION

[0014] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

[0015] Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings. In addition, terms such as “first,” “second,” “third,” and “fourth” are used herein for purposes of description and are not intended to indicate or imply relative importance or significance.

[0016] Figs. 1-4 illustrate an exhaust gas recirculation system 100 for use in a turbo-charged internal combustion engine 90 of a vehicle. As shown in Figs. 1-4, the exhaust gas recirculation system 100 can be operable with a six-cylinder, in-line truck engine. In other embodiments, the exhaust gas recirculation system 100 can operate with other vehicle engines having different configurations (e.g., V-shaped, four-cylinder, eight-cylinder, and the like) and/or can be mounted on other vehicles, such as, for example, a tractor-trailer combination, a bus, a van, an automobile, farm equipment, off-road vehicles, etc.

[0017] In some embodiments of the present invention, the exhaust gas recirculation system 100 can include a turbo charger 102 having a compressor 104 and a turbine 108. The exhaust gas recirculation system 100 can also or alternatively include a valve 112, a charge air cooler 116, a first recirculation cooler 120, a second recirculation cooler 124, and a recirculation mixer 146 positioned along and fluidly connected by a heat exchange circuit 132.

[0018] As shown in Figs. 1-4, a first working fluid (e.g., air, an air-water mixture, an oxygen-rich air mixture, a nitrogen-rich air mixture, and the like) enters an air inlet 136 of the compressor 104 and is compressed before being directed out of the compressor 104 through a passage 142 toward the charge air cooler 116. As the first working fluid travels through the charge air cooler 116, heat energy is removed from the compressed first working fluid, thereby lowering the temperature of the first working fluid.

[0019] From the charge air cooler 116, the first working fluid travels along the passage 142 toward an intake manifold 144. In some embodiments, such as the illustrated embodiment of Figs. 1-4 and as described below, a second working fluid (e.g., exhaust, an air-exhaust mixture, a water-exhaust mixture, and the like) can be mixed with the first working fluid in a mixing chamber 146 before the mixture enters the intake manifold 144. In other embodiments, the first and second working fluids can enter the intake manifold 144 through separate inlets and can be combined and/or mixed in the intake manifold 144. From the intake manifold 144, the mixture travels through the vehicle engine 90 to be utilized for engine combustion.

[0020] The second working fluid exits the vehicle engine 90 and travels through an exhaust manifold 148. From the exhaust manifold 148, a first volume of the second working fluid is directed along an exhaust passage 150 and through the turbine 108 to power the compressor 104. In some embodiments, a turbine shaft 152 provides power directly to the compressor 104.

[0021] A second volume of the second working fluid can be directed away from the exhaust manifold 148, through a recirculation passage 156, and toward the first and second recirculation coolers 120, 124. As shown in Figs. 1-4, the valve 112 can be positioned along the recirculation passage 156 and can be operable to selectively direct the second working fluid into the first and second recirculation coolers 120, 124.

[0022] In some embodiments, a third working fluid (e.g. air, an air-liquid mixture, or another conventional coolant) can be directed through one or both of the first and second recirculation coolers 120, 124 to cool the second working fluid flowing through the first recirculation cooler 120 and/or the second recirculation cooler 124. The third working fluid can be supplied from a single source at a first temperature. Alternatively, the third working fluid can be supplied by two sources at a common temperature, or alternatively, at two different temperatures. Additionally, the third working fluid can flow serially through the first and second recirculation coolers 120, 24 along a common flow circuit, in parallel through the first and second recirculation coolers 120, 124 along a common flow circuit or through separate flow circuits, or the third working fluid can flow through each of the first and second recirculation coolers 120, 124 independently. In other embodiments, different working fluids can be supplied to each of the first and second recirculation coolers 120, 124 to cool the second working fluid flowing through the first and second recirculation coolers, 120, 124.

[0023] In some embodiments and as illustrated in Figs. 1-4, the first recirculation cooler 120 is larger and/or has a greater cooling capacity per unit of time than the second recirculation cooler 124. However, in other embodiments, the first recirculation cooler 120 and the second recirculation cooler 124 can be substantially similarly sized and/or can have a substantially similar cooling capacity per unit of time. In other embodiments, the first recirculation cooler 120 can be a smaller size and/or can have a smaller cooling capacity per unit of time than the second recirculation cooler 124.

[0024] In the illustrated embodiment, the first recirculation cooler 120 and the second recirculation cooler 124 are positioned in a parallel flow arrangement on the heat exchange circuit 132 to receive the second working fluid from the valve 112. During operation and as explained below, the valve 112 selectively directs the second working fluid through one or both of the first recirculation cooler 120 and the second recirculation cooler 124 based on the load conditions experienced by the exhaust gas recirculation system 100 and/or the vehicle engine 90.

[0025] In some embodiments, when the exhaust gas recirculation system 100 experiences a first condition or a first set of conditions (e.g., the ambient temperature is above a first threshold value, the pressure in the intake manifold 144 or the exhaust manifold 148 is below a first threshold value, etc.), the valve 112 is moved toward a first position (shown in Fig. 1)

such that the valve 112 is operable to direct a first quantity of the second working fluid along a branch 160 toward the first recirculation cooler 120 and to direct a second quantity of the second working fluid along a branch 164 toward the second recirculation cooler 124.

Alternatively or in addition, when the exhaust gas recirculation system 100 experiences a second condition or a second set of conditions (e.g., the ambient temperature is between the first threshold value and a second threshold value, the pressure in the intake manifold 144 or the exhaust manifold 148 is between the first threshold value and a second threshold value, etc.), the valve 112 is moved toward a second position (shown in Fig. 2) such that the valve 112 is operable to direct the second working fluid or at least a portion of the second working fluid along a branch 160 toward the first recirculation cooler 120 and to interrupt or substantially interrupt the flow of second working fluid to the branch 164 and/or the second recirculation cooler 124. Alternatively or in addition, when the exhaust gas recirculation system 100 experiences a third condition or a third set of conditions (e.g., the ambient temperature is between the second threshold value and a third threshold value, the pressure in the intake manifold 144 or the exhaust manifold 148 is between the second threshold value and a third threshold value, etc.), the valve 112 is moved toward a third position (shown in Fig. 3) such that the valve 112 is operable to direct the second working fluid or at least a portion of the second working fluid along the branch 164 toward the second recirculation cooler 124 and to interrupt or substantially interrupt the flow of second working fluid to the branch 160 and/or the first recirculation cooler 120.

[0026] Alternatively or in addition, when the exhaust gas recirculation system 100 experiences a fourth condition or a fourth set of conditions (e.g., when the engine 90 is in an idle condition, etc.), the valve 112 is moved toward a fourth position (shown in Fig. 4) such that the valve 112 is operable to interrupt or substantially interrupt the flow of second working fluid or at least a portion of the second working fluid along the branch 164 toward the second recirculation cooler 124 and to interrupt or substantially interrupt the flow of second working fluid to the branch 160 and/or the first recirculation cooler 120.

[0027] More specifically, in operation and with reference to Fig. 1, during a high load condition, the valve 112 functions to the second working fluid through both the branch 160 and the first recirculation cooler 120 and the branch 164 and the second recirculation cooler 124. In some embodiments, the valve 112 directs a substantially equal quantity of second

working fluid through each of the branches 160, 164 and the first and second recirculation coolers 120, 124.

[0028] With reference to Fig. 2, during a medium load condition, the valve 112 directs substantially all of the second working fluid through the first recirculation cooler 120 and the branch 160. With reference to Fig. 3, in a low load condition, the valve 112 directs substantially all of the second working fluid through the second recirculation cooler 124 and the branch 164.

[0029] In the illustrated embodiment of Figs. 1-4, the valve 112 is a four position valve having substantially similarly sized outlets. In other embodiments, the valve 112 can have two, three, or more positions, and two or more of the outlets can be similarly or differently sized.

[0030] As the second working fluid travels through the first and or second recirculation coolers 120, 124, heat energy is removed from the second working fluid, thereby lowering the temperature of the second working fluid. In some embodiments, the second working fluid exiting the first recirculation cooler 120 has a lower temperature than the second working fluid exiting the second recirculation cooler 124. In other embodiments, the second working fluid exits the first and second recirculation coolers 120, 124 at approximately the same temperature. From the first and second recirculation coolers 120, 124, the second working fluid travels along the recirculation passage 156 toward the mixing chamber 146 where the second working fluid is combined and/or mixed with the first working fluid as explained above.

[0031] In some embodiments, the valve 112 is manually operable. In other embodiments, the exhaust gas recirculation system 100 includes a controller operable to control the valve 112 and to move the valve 112 between the first, second, third, and fourth positions based, at least in part upon, load conditions of the vehicle engine 90 and/or the heat exchange circuit 132. In some embodiments, the controller is operable to control the valve 122 based, at least in part, upon data recorded by sensors distributed around the vehicle engine 90 and/or the heat exchange circuit 132.

[0032] In some embodiments, the exhaust gas recirculation system 100 can be operated more efficiently than conventional recirculation systems. For example, in some

embodiments, the valve 112 can be operated to closely control the temperature of the second working fluid entering the intake manifold 144, thereby preventing unnecessary cooling and/or overcooling of the second working fluid, reducing emissions, and/or preventing fouling of the exhaust gas recirculation system 100. Alternatively or in addition, the exhaust gas recirculation system 100 can include relatively small and efficient first and second recirculation coolers 120, 124, which can, in some embodiments, be operated significantly more efficiently than a single recirculation cooler, which is generally selected to be oversized to accommodate losses in performance caused by fouling.

[0033] In some embodiments, the exhaust gas recirculation system 100 can include the valve 112 fluidly connected to a single recirculation cooler (e.g., first recirculation cooler 120, second recirculation cooler 124). The valve 112 can be operated to control the amount of the second working fluid flowing therethrough and to the single recirculation cooler based, at least in part upon, load conditions of the vehicle engine 90 and/or the heat exchange circuit 132.

[0034] The embodiments described above and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present invention. As such, it will be appreciated by one having ordinary skill in the art that various changes are possible.

CLAIMS

What is claimed is:

1. An exhaust gas recirculation system for distributing a working fluid in a vehicle engine, the exhaust gas recirculation system comprising:
 - a turbine operable to receive a first portion of the working fluid for driving a compressor;
 - a first cooler and a second cooler arranged along a recirculation flow path extending between an engine exhaust manifold and an engine intake manifold, the first cooler including a different cooling capacity than the second cooler; and
 - a valve positioned along the recirculation flow path and selectively moveable toward a first position to direct a second portion of the working fluid through the first cooler, a second position to direct the second portion of the working fluid through the second cooler, and a third position to divide the second portion of the working fluid between the first cooler and the second cooler.
2. The exhaust gas recirculation system of claim 1, wherein the valve is moveable between the first, second, and third positions to adjust the flow path in response to changing cooling demand.
3. The exhaust gas recirculation system of claim 1, wherein substantially all working fluid entering the recirculation flow path passes through the valve.
4. The exhaust gas recirculation system of claim 1, wherein, when the valve is in the third position, the valve directs substantially equal parts of the second portion of the working fluid to each of the first cooler and the second cooler.
5. The exhaust gas recirculation system of claim 1, wherein the working fluid is an exhaust gas generated by the engine, the exhaust manifold providing the working fluid to the turbine and the valve and the intake manifold receiving the second portion of the working fluid from the first cooler and the second cooler.

6. The exhaust gas recirculation system of claim 1, wherein the first cooler and the second cooler are arranged in a parallel flow configuration along the recirculation flow path.
7. A heat exchange circuit for distributing a first working fluid and a second working fluid, the heat exchange circuit comprising:
 - a turbine operable to receive a first portion of the second working fluid for driving a compressor to compress the first working fluid;
 - a first cooler and a second cooler arranged in a parallel flow configuration along a common flow path;
 - a single valve operable to selectively direct a second portion of the second working fluid through at least one of the first cooler and the second cooler;
 - a third cooler operable to receive the compressed first working fluid; and
 - a mixing chamber operable to receive the compressed first working fluid and the second portion of the second working fluid.
8. The heat exchange circuit of claim 7, wherein the first cooler includes a larger cooling capacity than the second cooler.
9. The heat exchange circuit of claim 8, wherein the single valve is moveable toward a position to direct substantially all of the second portion of the second working fluid to the first cooler.
10. The heat exchange circuit of claim 8, wherein the single valve is moveable toward a position to direct substantially all of the second portion of the second working fluid to the second cooler.
11. The heat exchange circuit of claim 8, wherein the single valve is moveable toward a position to divide the second portion of the second working fluid between the first cooler and the second cooler.
12. The heat exchanger circuit of claim 11, wherein the single valve is moveable toward the position to direct substantially equal parts of the second portion of the second working fluid to each of the first cooler and the second cooler.

13. The heat exchange circuit of claim 7, wherein the third cooler is a charge air cooler.
14. The heat exchange circuit of claim 7, wherein the mixing chamber is operable to receive the compressed first working fluid from the third cooler and the second portion of the second working fluid from the at least one of the first cooler and the second cooler.
15. The heat exchange circuit of claim 7, wherein the second working fluid is an exhaust gas generated by an engine having an exhaust manifold and an intake manifold, the exhaust manifold providing the second working fluid to the turbine and the valve, and the mixing chamber directing the compressed first working fluid and the second portion of the second working fluid to the intake manifold.
16. The heat exchange circuit of claim 15, wherein the second working fluid exiting the exhaust manifold is divided between the turbine and the single valve.
17. The heat exchange circuit of claim 7, wherein the single valve is selectively moveable toward a first position to direct a second portion of the working fluid through the first cooler, a second position to direct the second portion of the working fluid through the second cooler, and a third position to divide the second portion of the working fluid between the first cooler and the second cooler.
18. The heat exchange circuit of claim 17, wherein the single valve is moveable between the first, second, and third positions in response to changing cooling demand.
19. A method of operating an exhaust gas recirculation system, the method comprising the acts of:
 - directing a first portion of a working fluid through a turbine to drive a compressor;
 - directing a second portion of the working fluid through a valve; and
 - operating the valve to selectively direct the second portion of the working fluid to at least one of a first cooler and a second cooler.

20. The method of claim 19, wherein the first cooler includes a larger cooling capacity than the second cooler.
21. The method of claim 20, wherein operating the valve includes directing substantially the entire second portion of the working fluid to the first cooler.
22. The method of claim 20, wherein operating the valve includes directing substantially the entire second portion of the working fluid to the second cooler.
23. The method of claim 20, wherein operating the valve includes directing substantially equal parts of the second portion of the working fluid to each of the first cooler and the second cooler, and wherein operating the valve includes dividing the second portion of the working fluid between the first cooler and the second cooler.
24. The method of claim 19, wherein the first cooler and the second cooler are arranged in a parallel flow configuration along a flow path extending between an engine exhaust manifold and an engine inlet manifold.
25. The method of claim 19, wherein the working fluid is an exhaust gas generated by an engine having an exhaust manifold and an intake manifold, the method further comprising
directing a first portion of the working fluid from the exhaust manifold to the turbine,
directing a second portion of the working fluid from the exhaust manifold along a recirculation flow path through the first and second coolers toward the intake manifold, and
at least one of the first cooler and the second cooler providing the second portion of the working fluid to the intake manifold.
26. The method of claim 25, wherein directing the first portion of the working fluid along the recirculation flow path includes directing substantially all of the working fluid from an inlet of the recirculation flow path through the single valve.

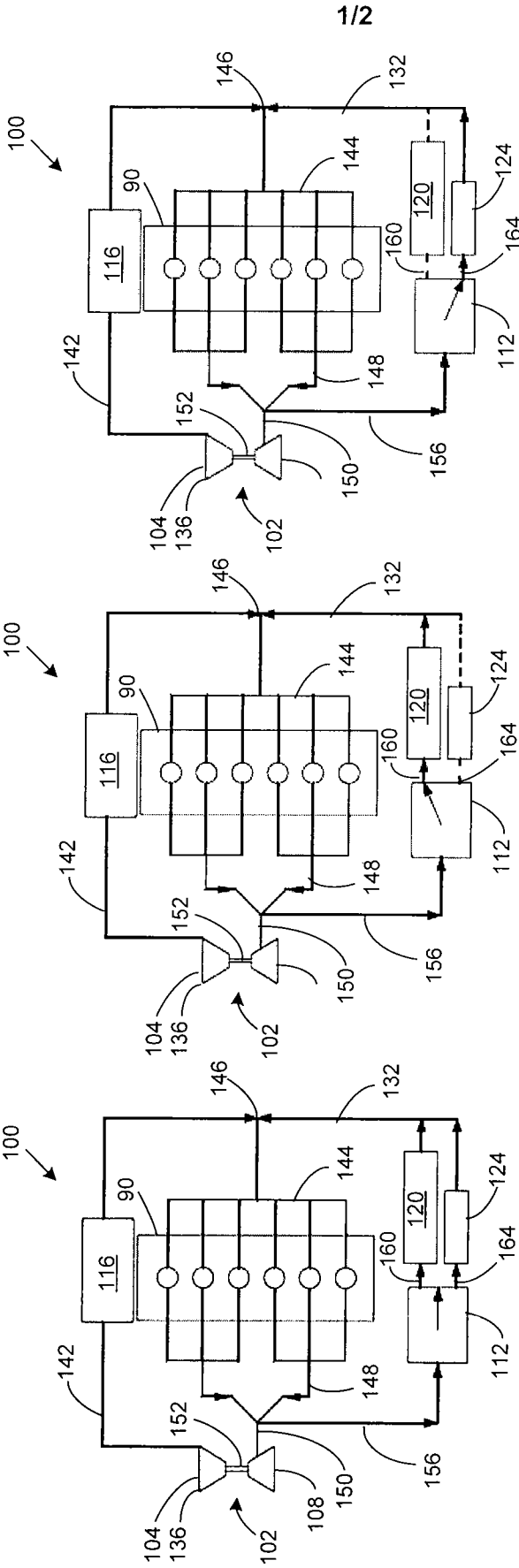


FIG. 1

FIG. 2

FIG. 3

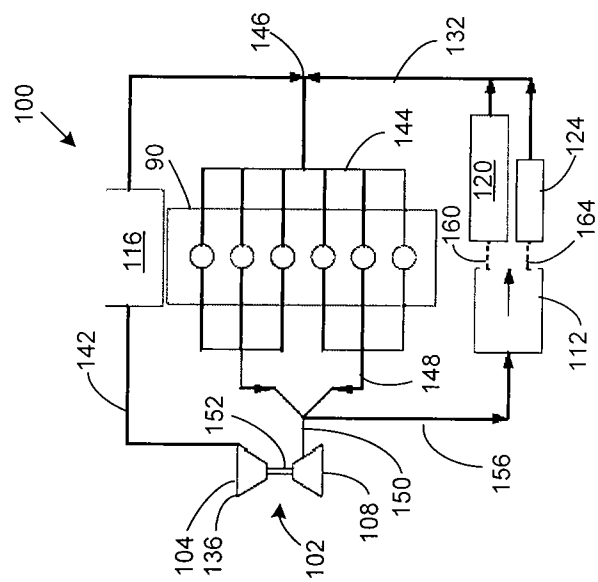


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/072403**A. CLASSIFICATION OF SUBJECT MATTER****F02M 25/07(2006.01)i, F02B 37/00(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 : F02B 37/00, F02D 13/02, 21/08, 23/00, F02M 25/07

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

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and application for Utility modes since 1975

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

eKIPASS (KIPO internal) & keywords: "exhaust", "turbine", "cooler", "injector", and "gas"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 2001-090616 A (CUMMINS ENGINE CO INC.) 03 APR 2001 See fig 2 and page 5, paragraph 20 - page 7, paragraph 34.	1-26
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A	JP 2005-307963 A (CRF SOC CONSORTILE PER AZIONI) 04 NOV 2005 See fig 1 and page 3, paragraph 07 - page 4, paragraph 18.	1-26



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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