

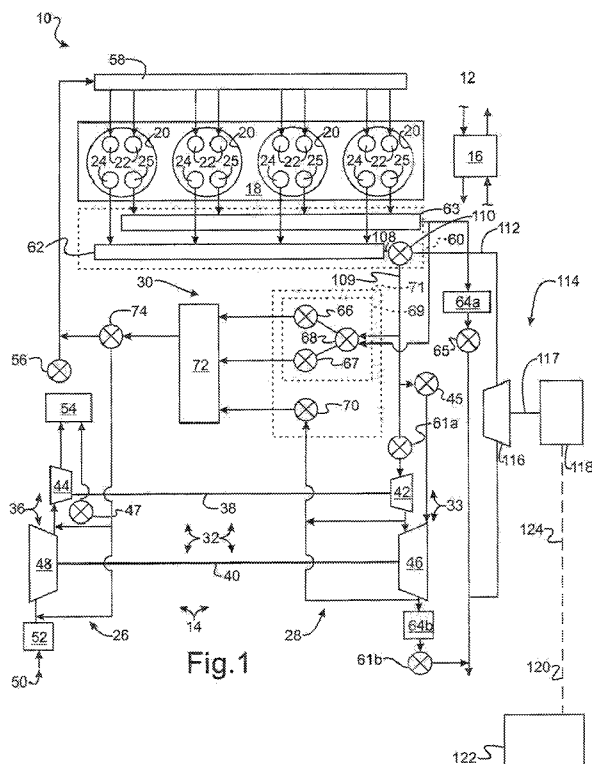


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[Continued on next page]

(54) Title: SYSTEM AND METHOD OF USING A TURBO ALTERNATOR IN AN EXHAUST GAS SYSTEM TO GENERATE POWER

(57) Abstract: Embodiments may include a system and method of generating electrical power using a turbo generator in an exhaust gas flow in an internal combustion engine system.





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SYSTEM AND METHOD OF USING A TURBO ALTERNATOR IN AN EXHAUST GAS SYSTEM TO GENERATE POWER

5

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the filing date of United States Provisional Application No. 61/678,407 filed August 1, 2012.

10

TECHNICAL FIELD

The field to which the disclosure generally relates includes methods of controlling flow of exhaust gases from an internal combustion engine.

BACKGROUND

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Combustion engine systems include engines having combustion chambers in which air and fuel is combusted for conversion into mechanical rotational power. Combustion engine systems also include breathing systems including induction systems upstream of the engine for conveying induction gases to the combustion chambers, and exhaust systems downstream of the engine for carrying exhaust gases away from the combustion chambers.

20

Combustion engine systems may be equipped with turbo alternators in the exhaust system. Turbo alternators include a turbine in the exhaust gas path to spin a rotor. The rotor in turn spins a generator in the turbo alternator creating electricity which may then be used to power a vehicle, vehicle component, or charge the battery system

25

The breathing systems may also include exhaust gas recirculation (EGR) passages and valves to recirculate exhaust gases out of the exhaust system and back to the engine via the induction system for lower NOx emissions.

30

Combustion engine systems also may be equipped with turbochargers to pressurize the induction gases before entry into the combustion chambers to efficiently increase engine power. A turbocharger basically includes a compressor in the induction system for generating induction boost pressure, a turbine rotatably connected to the compressor and disposed in the exhaust system and powered by pressurized exhaust gases

35

for driving the compressor. Pressurized exhaust gases from the engine impinge on a bladed rotor of the turbine to pneumatically spin the rotor. The spinning rotor and a shaft mechanically spin a bladed impeller of the compressor. The spinning impeller pressurizes induction gases to increase the mass of induction gases supplied to the engine, thereby allowing more fuel to be burned for increased combustion so as to increase engine power output for a given engine displacement and speed.

SUMMARY OF ILLUSTRATIVE EMBODIMENTS OF THE INVENTION

One illustrative embodiment of the invention may include an engine with at least one cylinder having at least one blowdown valve and at least one scavenging valve, a turbo alternator, and a blowdown manifold connecting the at least one blowdown valve to the turbo alternator.

Another illustrative embodiment of the invention may include a method of producing power. The method may include providing an engine with at least one cylinder having at least one blowdown valve and at least one scavenging valve, a turbo alternator, and a blowdown manifold connecting the at least one blowdown valve to the turbo alternator. The exhaust gas from the engine travels through the blowdown manifold and powers the turbo alternator.

Other illustrative embodiments of the invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while disclosing select embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative embodiments of the invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. 1 is a schematic view of an illustrative embodiment of an internal combustion engine system;

FIG. 1A is a schematic view of an alternate embodiment of the internal combustion engine system;

FIG. 2 is a diagrammatic view of an illustrative embodiment of a concentric cam phaser device for use in the system of FIG. 1; and

FIG. 3 is a flow chart of an illustrative embodiment of a method of controlling exhaust gas flow divided between at least one turbocharger and
5 at least one exhaust gas recirculation path of the system of FIG. 1;

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The following description of the embodiment(s) is merely illustrative in nature and is in no way intended to limit the invention, its
10 application, or uses.

An illustrative operating environment is illustrated in FIG. 1. A method according to one embodiment may be carried out using any suitable system and, more specifically, may be carried out in conjunction with an engine system such as system 10. The following system description simply
15 provides a brief overview of one illustrative engine system, but other systems and components not shown here could also be utilized.

In general, the system 10 may include an internal combustion engine 12 that may combust a mixture of fuel and induction gases for conversion into mechanical rotational energy and exhaust gases, an engine
20 breathing system 14 that may deliver induction gases to the engine 12 and carry exhaust gases away from the engine 12. The system 10 may also include a fuel subsystem (not shown) to provide any suitable liquid and/or gaseous fuel to the engine 12 for combustion therein with the induction gases, and an exhaust control subsystem 16 to control operation of the engine
25 system 10.

The internal combustion engine 12 may be any suitable type of engine, such as a spark-ignition engine like a gasoline engine, an autoignition or compression-ignition engine like a diesel engine, or the like. The engine 12 may include a block 18 with cylinders and pistons therein (not separately
30 shown), which, along with a cylinder head (also not separately shown), may define combustion chambers 20 for internal combustion of a mixture of fuel and induction gases. The engine 12 may also include any suitable quantities of intake valves 22 and exhaust valves that may include any suitable number

of first or blowdown exhaust valves 24 and second or scavenging exhaust valves 25.

The engine 12 may include any quantity of cylinders, and may be of any size and may operate according to any suitable speeds and loads.

5 Illustrative idle speeds may be on the order of about 500 to about 800 RPM, and typical maximum engine speed may be on the order of about 5500-6500 RPM but may even exceed that range. As used herein, the term low speeds and loads may include about 0% to 33% of maximum engine speeds and loads, intermediate speeds and loads may include about 25% to 75% of
10 maximum engine speeds and loads, and high speeds and loads may include about 66% to 100% of maximum engine speeds and loads. As used herein, low to intermediate speeds and loads may include about 0% to 50% of maximum engine speeds and loads, and intermediate to high speeds and loads may include about 50% to 100% of maximum engine speeds and loads.

15 Valve timing may be regulated by camshafts or valve solenoids or the like to open the valves. In a typical engine cycle, an exhaust valve opens just before a piston reaches a bottom dead center (BDC) position and soon thereafter about half of all combusted induction gases exit the combustion chambers under relatively high pressure. This is commonly
20 referred to as a blowdown phase of the exhaust portion of the engine cycle. The piston sweeps back upward toward a top dead center position (TDC) and displaces most if not all of the remaining combusted induction gases out of the combustion chambers under relatively lower pressure. This is commonly referred to as a scavenging phase of the exhaust portion of the engine cycle.

25 Referring now to FIG. 2, engine 12 may include any suitable variable valve timing devices to actuate the exhaust valves 24, 25. In one example, individual actuators such as solenoids, electromechanical valves or electrohydraulic valves (not shown) may be used to actuate the exhaust valves 24, 25. In yet another example, a dual acting concentric cam device
30 13 may be used to actuate each of the exhaust valves 24, 25 independently of the other. The device 13 may include a camshaft assembly 201 that may include concentric shafts including a cam shaft 203 carried by a cam tube 205. The cam shaft 203 carries blowdown or scavenging valve cams 207, 209 and the cam tube 205 carries the other of the blowdown or scavenging

valve cams 207, 209. In one embodiment, the shaft or tube coupled to the blowdown valve cams may be of fixed phase relationship with respect to an engine crankshaft and another concentric shaft coupled to the scavenging valves may be of variable phase relationship with respect to the engine crankshaft varied by a cam phaser 211. In another embodiment, offering somewhat greater performance and efficiency, one or more cam phasers 211 may vary the phase relationship of the cam shaft 207 and tube 209 independently with respect to one another and with respect to the engine crankshaft. The timing and/or lift of the exhaust valves can be controlled by adjusting the phase or angle between the cam shaft 207 and tube 209 with the phaser(s) 211.

The cam device 13 may be controlled by the exhaust control subsystem 16, such as an engine electronic control module, based on engine testing and calibration to produce good engine emissions and efficiency at all speeds and loads. The cam device 13 may be the primary device in conjunction with the exhaust valves 24, 25 to vary energy delivered to the turbocharger turbine and thus control turbocharger boost without need for a turbo wastegate device.

In general, optimal valve timing of blowdown and scavenging valves will be application specific and, thus, will vary from engine to engine. But, the blowdown valves 24 may have relatively advanced timing, have longer valve opening duration, with higher lift than the scavenging valves 25. In one example, the lift of the blowdown valves 24 may be the maximum lift attainable in approximately 180 degrees of crank angle, and the lift of the scavenging valves 25 may be the maximum lift attainable in approximately 160 degrees of crank angle.

Illustrative valve timing including duration and/or lift for the blowdown valve(s) 24 may be on the order of about 70 to 100% of valve timing for the same or similar engine equipped with conventional exhaust valves. More specific illustrative valve timing for the blowdown valve(s) 24 may be about 85-95% (e.g. 90%) duration and about 90-100% (e.g. 95%) lift of valve duration and lift timing for the same or similar engine equipped with conventional exhaust valves. Valve opening timing of the blowdown valve(s) 24 generally may be similar to or retarded at minimum turbocharger boost

condition, and advanced to increase boost. Illustrative phase authority for the cam device 13 for the blowdown valve(s) 24 may be on the order of about 25 to 40 degrees (e.g. 28 degrees) of crankshaft angle between about 2000 and 5500 RPM.

5 Illustrative valve timing including duration and/or lift for the scavenging valve(s) 25 may be on the order of about 60 to 90% of valve timing for the same or similar engine equipped with conventional exhaust valves. More specific illustrative valve timing for the scavenging valve(s) 25 may be about 75-85% (e.g. 80%) duration and about 80-90% (e.g. 85%) lift of
10 valve duration and lift timing for the same or similar engine equipped with conventional exhaust valves. Valve closing timing of the scavenging valve(s) 25 generally may be similar to valve closing timing of the same or similar engine equipped with conventional exhaust valves. Illustrative phase authority for the cam device 13 for the scavenging valve(s) 25 may be on the
15 order of about 30 to 60 degrees (e.g. 40 degrees) of crankshaft angle between about 2000 and 5500 RPM.

The exhaust subsystem 28 may include, in addition to suitable conduit and connectors, an exhaust manifold 60 to collect exhaust gases from the combustion chambers 20 of the engine 12 and convey them downstream
20 to the rest of the exhaust subsystem 28. The exhaust manifold 60 may include a first or blowdown exhaust manifold 62 in communication with the blowdown exhaust valves 24, and a scavenging exhaust manifold 63 in communication with the scavenging exhaust valves 25. The exhaust manifold 60 may be separate from, or integrated with, the cylinder head (not separately
25 shown). The blowdown and scavenging exhaust manifolds 62, 63 may be separate, or integrated with one another.

Referring to FIG. 1, the engine breathing system 14 may include a turbo alternator 114 connected to the blowdown exhaust manifold 62 via turbo alternator exhaust gas conduit 112. The turbo alternator 114 contains a
30 turbine portion 114 containing turbine blades (not shown) in the exhaust gas stream. Pressurized exhaust gas causes the turbine blades to turn which in turn cause the shaft 117 to turn. Shaft 117 may be connected to generator 118 causing the generator to turn producing electricity in a well-known manner. The generator 118 may be connected to the vehicle electrical

system 122 via electrical conduit 120. The vehicle electrical system 112 may be a battery system or vehicle components which require electricity to function. The turbo alternator may capture at least a portion of a waste product such as exhaust gas and uses it to generate useful electric power. A
5 by-pass may be provided to flow some or all of the exhaust gas around the turbo alternator 14, if desired.

A valve 110 may be disposed in the exhaust system having an inlet connected blowdown manifold conduit 108 which in turn is connected to the blowdown manifold 62. The valve 110 may have a first outlet connected
10 to the turbo alternator exhaust gas conduit 112 which may be connected to the turbine alternator 114. The valve 110 may have second outlet connected to the turbo charger exhaust gas conduit 109. The valve 110 may be controlled by the exhaust control subsystem 16 to controls the amount of exhaust gas that goes into the turbo charger exhaust gas conduit 109 and the
15 turbo alternator exhaust gas conduit 112 to allow for optimum turbo charging and electrical generation. The valve 110 may have a single movable flap or vane or be comprised of multiple flaps and vanes as is well-known in the art.

Alternatively, as shown in Figure 1b, a valve 110a may be present in the turbo alternator exhaust gas conduit 112 and a separate valve
20 110b may be present turbo charger exhaust gas conduit 109. Both valves 110a and 110b may be controlled by the exhaust control subsystem 16 to allow for optimal exhaust gas flow to allow for optimum turbo charging and electrical generation.

A conduit 124 may connect the turbo alternator 114 to the
25 exhaust system to allow the exhaust gas to be processed through the appropriate emission control components or other components of the system.

The exhaust control subsystem 16 may include one or more controllers (not separately shown) in communication with the actuators and sensors for receiving and processing sensor input and transmitting actuator
30 output signals. The controller(s) may include one or more suitable processors and memory devices (not separately shown). The memory may be configured to provide storage of data and instructions that provide at least some of the functionality of the engine system 10 and that may be executed by the processor(s). At least portions of the method may be enabled by one or more

computer programs and various engine system data or instructions stored in memory as look-up tables, formulas, algorithms, maps, models, or the like. In any case, the exhaust control subsystem 16 may control engine system parameters by receiving input signals from the sensors, executing instructions or algorithms in light of sensor input signals, and transmitting suitable output signals to the various actuators. As used herein, the term "model" may include any construct that represents something using variables, such as a look up table, map, formula, algorithm and/or the like. Models may be application specific and particular to the exact design and performance specifications of any given engine system.

The engine breathing system 14 may also include an induction subsystem 26 that may compress and cool induction gases and convey them to the engine 12 and an exhaust subsystem 28 that may extract energy from exhaust gases and carry them away from the engine 12. The engine breathing system 14 may also include an exhaust gas recirculation (EGR) subsystem 30 in communication across the exhaust and induction subsystems 26, 28 to recirculate exhaust gases for mixture with fresh air to reduce emissions and pumping losses from the engine system 10. The engine breathing system 14 may further include a turbocharging system 32 between the induction and exhaust subsystems 26, 28 to compress inlet air and thereby improve combustion to increase engine power output. As used herein, the phrase induction gases may include fresh air, compressed air, and/or recirculated exhaust gases.

The turbocharging subsystem 32 may be a single stage system or, as shown, may be a multi-stage or sequential turbocharging subsystem. The turbocharging subsystem 32 may include a turbine side 34 in the exhaust subsystem 28 and a compressor side 36 in the induction subsystem 26. Multi-stage turbocharging may allow for continuously variable adaptation of the turbine and compressor sides 34, 36 of the subsystem 32 over most or all engine operating points. The turbocharging subsystem 32 may include one, two, or more turbochargers of any size and type, that may be connected in series, parallel, or both, and that may or may not use wastegate valving or bypass regulation. In other words, the subsystem 32 may also include any

suitable compressor and/or turbine bypass or wastegate valves of any suitable type. But it is contemplated that the method and apparatus disclosed herein will reduce or eliminate need for turbine bypass valves.

An illustrative turbocharging subsystem 32 may include a first
5 turbocharger 38 and may also include a second turbocharger 40 according to first and second stages. For example, the first turbocharger 38 may be a relatively small high-pressure (HP) turbocharger, and the second turbocharger 40 may be a relatively large low-pressure (LP) turbocharger. One or both of the turbochargers 38, 40 may be variable turbine geometry (VTG) types of
10 turbochargers, dual-stage turbochargers, or turbochargers with wastegate or bypass devices, or the like. Although VTG turbochargers tend to cause increased backpressure and concomitant reduced fuel economy in engines equipped with conventional exhaust systems, VTG turbochargers may be more efficient when used with a divided exhaust engine such as engine 12.
15 This is because pumping mean effective pressure (PMEP) penalties, due to pumping parasitic losses, at small nozzle openings may be greatly reduced when turbine energy is delivered by the blowdown exhaust valve path because exhaust backpressure acting on engine pistons during exhaust are typically minimally affected by high backpressure at a turbocharger turbine
20 inlet. In any case, the turbochargers 38, 40 and/or any turbocharger accessory device(s) may be adjusted to affect any one or more of the following exemplary parameters: turbocharger boost pressure, air mass flow, and/or EGR flow.

The first turbocharger 38 may include a first turbine 42 and a
25 first compressor 44 mechanically coupled to the first turbine 42. The second turbocharger 40 may include a second turbine 46 and a second compressor 48 mechanically coupled to the first turbine 46. A turbine bypass valve 45 may be located between the second turbine 46 and a location just upstream of the first turbine 42, and may be integrated into the second turbine 38.
30 Similarly, a compressor bypass valve 47 may be located between the second compressor 48 and a location just downstream of the first compressor 44 such as at the cooler 54, and may be integrated into the second compressor 48.

The bypass valves 45, 47 may be actively controlled, such as with any suitable actuators (not shown) controlled pneumatically, electrically, electronically, or in any other suitable manner. In this arrangement, the turbochargers 38, 40 may be tuned in such a manner that one or both of them are active at all engine operating points. For example, at relatively low engine loads and speeds, i.e. when exhaust mass flow rate is low, much of the exhaust gas mass flow may be expanded by the first turbine 42. This may result in a very quick and high rise in boost pressure in the induction system 26. But as engine load and speed increases, exhaust gas expansion may be continuously shifted to the second turbine 46 by increasing the opening of the bypass valves 45, 47 over a period of time. This is an example of regulated two-stage series turbocharging, which allows for continuous adaptation of the turbine and compressor sides 34, 36 to the actual requirements of the operating engine 12.

The induction subsystem 26 may include, in addition to suitable conduit and connectors, an inlet end 50 which may have an air filter 52 to filter incoming air, and one or both of the turbocharger compressors 48, 44 downstream of the inlet end 50 to compress the inlet air. The induction subsystem 26 may also include a charge air cooler 54 downstream of the turbocharger compressors 48, 44 to cool the compressed air, and an intake throttle valve 56 downstream of the charge air cooler 54 to throttle the flow of the cooled air to the engine 12. The induction subsystem 26 also may include an intake manifold 58 downstream of the throttle valve 56 and upstream of the engine 12, to receive the throttled air and distribute it to the engine combustion chambers 20. The induction subsystem 26 may also include any other suitable devices.

The exhaust control subsystem 16 also may include one or both of the turbocharger turbines 42, 46 in downstream communication with the exhaust manifold 60 and, more particularly, with the blowdown manifold 62. The exhaust subsystem 28 may also include any quantity of suitable emissions devices, such as emission device(s) 64a, 65b downstream of the exhaust manifold 60. The emission device(s) 64a, 64b may include one or more catalytic converters like a close-coupled diesel oxidation catalyst (DOC) device, a nitrogen oxide (NOx) adsorber unit, a particulate filter, and/or the

like. One more variable restriction valves 65, such as backpressure valve(s), may be located in communication with the scavenging exhaust manifold 63 before and/or after the first emissions device 64a to enable increases in exhaust energy delivered to the turbocharger turbine(s) 42, 46 at low engine speed. Also, one or more valves, such as shutoff valves 61a, 61b may be located in communication with the blowdown exhaust manifold 62 before an inlet of the turbine(s) 42, 46 and/or after an exit of the turbine(s) 42, 46. The exhaust subsystem 28 may also include any other suitable devices, such as one or more other emissions devices located downstream of the valve(s) 61b, 65.

The EGR subsystem 30 may recirculate portions of the exhaust gases from the exhaust subsystem 28 to the induction subsystem 26 for combustion in the engine 12, and may be a single path EGR subsystem, or may be a hybrid or dual path EGR subsystem. As shown, the EGR subsystem 30 may include a high pressure (HP) EGR path connected to the exhaust subsystem 28 upstream of one or both of the turbocharger turbines 42, 46 but connected to the induction subsystem 26 downstream of one or both of the turbocharger compressors 48, 44. A low pressure (LP) EGR path may be connected to the exhaust subsystem 28 downstream of one or both of the turbocharger turbines 42, 46 but connected to the induction subsystem 26 upstream of one or both of the turbocharger compressors 48, 44. Any other suitable connection between the exhaust and induction sub-systems 26, 28 is also contemplated including other forms of HP EGR such as the usage of internal engine variable valve timing and lift to induce internal HP EGR. According to internal HP EGR, operation of engine exhaust and intake valves may be timed so as to communicate some exhaust gases generated during one combustion event back through intake valves so that exhaust gases are combusted in a subsequent combustion event.

The EGR subsystem 30 may include, in addition to suitable conduit and connectors, one or more HP and/or LP EGR valves to control recirculation of exhaust gases from the exhaust subsystem 28 to the induction subsystem 26. For example, a first or blowdown EGR valve 66 may be used to control or apportion EGR from the blowdown manifold 62 to the induction subsystem 26, and a second or scavenging blowdown EGR valve 67 may be

used to control or apportion EGR from the scavenging manifold 63 to the induction subsystem 26. Further, a third or proportional valve 68 may be used just upstream of the first and second valves 66, 67 to control or apportion EGR flow from the exhaust manifold 60 between blowdown and scavenging exhaust gas flows. Instead, the third valve 68 may be omitted wherein the blowdown manifold 62 may be in direct communication with the blowdown EGR valve 66 and the scavenging manifold 63 may be in direct communication with the scavenging EGR valve 67. Opening of the proportional valve 68 and one or both of the other EGR valves 66, 67 may reduce the boost level delivered by one or both of the turbochargers 38, 40 at engine operating points where turbocharger boost levels cannot be sufficiently reduced by control of the exhaust valves 25, 25 alone. Also, a fourth or LP EGR valve 70 may be used to control or apportion EGR from a location in the exhaust subsystem 28 downstream of one or both of the turbines 42, 46 to the induction subsystem 26.

The EGR subsystem 30 may also include an EGR cooler 72 downstream of the valves 66, 67, 68, 70, and a fifth or downstream EGR valve 74 located downstream of the EGR cooler 72 to apportion EGR flow between a location in the induction subsystem 26 downstream of the turbocharging subsystem 32 and a location upstream of one or both of the compressors 44, 48. The fifth EGR valve 74 may be a stand-alone device having its own actuator or may be integrated with the intake throttle valve 56 into a combined device having a common actuator. The valves 66, 67, 68, 70, 74 and cooler 72 may be individual devices or, two or more of the valves 66, 67, 68, 70, 74 and/or the cooler 72 may be integrated into one or more multifunctional devices such as a three-way valve 69, four-way valve 71, or the like. The EGR architecture may include an engine internal HP EGR flow path, a dual stage turbo EGR flow path, EGR flow paths without coolers, and/or the like. In any case, one or more of the EGR valves 66, 67, 68, 70, 74 may be used to apportion scavenging and/or blowdown exhaust gas flows through the EGR path(s) between the exhaust and induction subsystems 28, 26.

Finally, the exhaust control subsystem 16 may include any suitable hardware, software, and/or firmware to carry out at least some

portions of the methods disclosed herein below. For example, the exhaust control subsystem 16 may include various engine system actuators and sensors (not shown). The engine system sensors are not individually shown in the drawings but may include any suitable devices to monitor engine system parameters. For example, an engine speed sensor may measure the rotational speed of an engine crankshaft (not shown), pressure sensors in communication with the engine combustion chambers 20 may measure engine cylinder pressure, intake and exhaust manifold pressure sensors may measure pressure of gases flowing into and away from the combustion chambers 20, an inlet air mass flow sensor may measure incoming airflow in the induction subsystem 26, and an intake manifold mass flow sensor may measure flow of induction gases to the engine 12. In another example, temperature sensors may measure the temperature of induction gases flowing to the engine 12. In a further example, the engine system 10 may include a speed sensor suitably coupled to one or both of the turbochargers 38, 40 to measure the rotational speed thereof. A throttle position sensor, such as an integrated angular position sensor, may measure the position of the throttle valve 56. A position sensor may be disposed in proximity to the turbochargers 38, 40 to measure the position of VTG blades if provided. A tailpipe temperature sensor may be placed just upstream of a tailpipe outlet to measure the temperature of the exhaust gases exiting the exhaust subsystem. Also, temperature sensors may be placed upstream and downstream of the emissions device(s) to measure the temperature of exhaust gases at the inlet(s) and outlet(s) thereof. Similarly, one or more pressure sensors may be placed across the emissions device(s) to measure the pressure drop there across. An oxygen (O₂) sensor may be placed in the exhaust and/or induction subsystems to measure oxygen in the exhaust gases and/or induction gases. Finally, position sensors may measure the positions of the EGR valves 66, 67, 68, 70, 74.

In addition to the sensors discussed herein, any other suitable sensors and their associated parameters may be encompassed by the presently disclosed system and methods. For example, the sensors may also include accelerator sensors, vehicle speed sensors, powertrain speed sensors, filter sensors, other flow sensors, vibration sensors, knock sensors,

intake and exhaust pressure sensors, and/or the like. In other words, any sensors may be used to sense any suitable physical parameters including electrical, mechanical, and chemical parameters. As used herein, the term sensor may include any suitable hardware and/or software used to sense any engine system parameter and/or various combinations of such parameters.

At very low engine power levels, electric generation may be low. Electric generation may be enhanced at the low engine power levels by retarding the spark timing and/or opening the throttle to send more energy to the turbo alternator or by adjusting the valve 110 to increase the flow to the turbo alternator.

One embodiment of the invention may include a method of producing power using a turbo alternator. Those skilled in the art will also recognize that a method according to any number of embodiments of the invention may be carried out using other engine systems within other operating environments. Referring now to FIG. 3, one embodiment of a method 300 is illustrated in flow chart form. As the description of the method 300 progresses, reference will be made to the engine system 10 of FIG. 1 and FIG 1b.

As shown at act 310, an engine is provided with at least one cylinder having at least one blowdown valve and at least one scavenging valve.

Act 320 includes providing a turbo alternator.

Act 330 includes providing a blowdown manifold connecting the at least one blowdown valve to the turbo alternator wherein exhaust gas from the engine travels through the blowdown manifold and powers the turbo alternator.

The method may include the additional act 340 of controlling the operation of the blowdown valve to control the flow of exhaust gas to the turbo alternator.

The method may also include the additional act 350 of controlling the operation of the scavenging valve to control the flow of exhaust gas to the turbo alternator.

The method may also include the additional act 360 of providing a turbocharger wherein the turbocharger is connected to the blowdown manifold.

5 The method may also include the additional act 370 of providing a valve in the exhaust manifold, the valve having two outputs, the first output in fluid communication with the turbo alternator and the second output in fluid communication with the turbocharger, and further comprising controlling the valve to control the flow of exhaust gas between the turbo alternator and the turbo charger.

10 The method may also include the additional act 380 of controlling the operation about the blowdown valve to control the flow of exhaust gas to the turbo alternator and the turbocharger.

The method may also include the additional act 390 of controlling the operation about the blowdown valve to control the flow of
15 exhaust gas to the turbo alternator and the turbocharger.

The method may also include the additional act 400 of providing a concentric cam to control the blowdown valve.

In one embodiment, the method 300 or any portion thereof may be performed as part of a product such as the system 10 of FIG. 1, and/or as
20 part of a computer program that may be stored and/or executed by the exhaust control subsystem 16. The computer program may exist in a variety of forms both active and inactive. For example, the computer program can exist as software program(s) comprised of program instructions in source code, object code, executable code or other formats; firmware program(s); or
25 hardware description language (HDL) files. Any of the above may be embodied on a computer usable medium, which include storage devices and signals, in compressed or uncompressed form. Illustrative computer usable storage devices include conventional computer system RAM (random access memory), ROM (read only memory), EPROM (erasable, programmable
30 ROM), EEPROM (electrically erasable, programmable ROM), and magnetic or optical disks or tapes.

The following numbered embodiments illustrative in nature of the scope of the invention and are not intended to limit the invention in any way.

Embodiment 1 may include a product comprising: an engine with at least one cylinder having at least one blowdown valve and at least one scavenging valve; a turbo alternator; and a blowdown manifold connecting the at least one blowdown valve to the turbo alternator.

5 Embodiment 2 may include a product as set forth in embodiment 1 and further comprising a turbocharger.

Embodiment 3 may include a product as set forth in any one of embodiments 1-2 wherein the turbocharger is connected to the blowdown valve via the blowdown manifold.

10 Embodiment 4 may include a product as set forth in any one or more of embodiments 1-3 wherein the blowdown manifold splits into at least a turbo alternator exhaust conduit and a turbocharger exhaust conduit wherein the turbo alternator exhaust conduit is connected to the turbo alternator and the turbo charger exhaust conduit is connected to the turbo charger.

15 Embodiment 5 may include a product as set forth in any one or more of embodiments 1-4 wherein the blowdown manifold includes a valve having at least two outlets, a first outlet connected to the turbo alternator exhaust conduit and a second outlet connected to the turbocharger exhaust conduit.

20 Embodiment 6 may include a product as set forth in any one or more of embodiments 1-5 and further including a first valve in the turbo alternator exhaust conduit and a second valve in the turbocharger exhaust conduit.

Embodiment 7 may include a product as set forth in any one or
25 more of embodiments 1-6 and further comprising a valve in the exhaust manifold.

Embodiment 8 may include a product as set forth in any one or more of embodiments 1-7 and further comprising a divided exhaust wherein scavenging manifold is connected to the scavenging valve.

30 Embodiment 9 may include a product as set forth in any one or more of embodiments 1-7 and further comprising a controller to control the operation of the blowdown valve.

Embodiment 10 may include a product as set forth in any one or more of embodiments 1-9 further comprising a controller to control the operation of the blowdown valve.

5 Embodiment 11 may include a product as set forth in any one or more of embodiments 1-10 and further comprising a concentric camshaft to control the blowdown valve and the scavenging valve.

Embodiment 12 may include a product as set forth in any one or more of embodiments 1-11 and further comprising a concentric camshaft to control the blowdown valve.

10 Embodiment 13 may include a method of producing power comprising providing engine with at least one cylinder having at least one blowdown valve and at least one scavenging valve; providing a turbo alternator; and providing a blowdown manifold connecting the at least one the blowdown valve to the turbo alternator; and flowing exhaust gas from the
15 engine through the blowdown manifold and powers the turbo alternator.

Embodiment 14 may include a method as set forth in embodiment 13 and further comprising providing a valve in the exhaust manifold and controlling the valve to control the flow of exhaust gas to the turbo alternator.

20 Embodiment 15 may include a method as set forth in any one or more of embodiments 13-14 and further comprising controlling the operation of the blowdown valve to control the flow of exhaust gas to the turbo alternator.

Embodiment 16 may include a method as set forth in any one or
25 more of embodiments 13-15 and further comprising controlling the operation of the scavenging valve to control the flow of exhaust gas to the turbo alternator.

Embodiment 17 may include a method as set forth in any one or more of embodiments 13-16 further comprising providing a turbocharger
30 wherein the turbocharger is connected to the blowdown manifold.

Embodiment 18 may include a method as set forth in any one or more of embodiments 13-17 and further comprising providing a valve in the exhaust manifold, the valve having to outputs, the first output in fluid communication with the turbo alternator and the second output in fluid

communication with the turbocharger, and further comprising controlling the valve to control the flow of exhaust gas between the turbo alternator and the turbo charger.

5 Embodiment 19 may include a method as set forth in any one or more of embodiments 13-18 further comprising controlling the operation about the blowdown valve to control the flow of exhaust gas to the turbo alternator and the turbocharger.

10 Embodiment 20 may include a method as set forth in any one or more of embodiments 13-19 further comprising controlling the operation about the blowdown valve to control the flow of exhaust gas to the turbo alternator and the turbocharger.

 Embodiment 21 may include a method as set forth in any one or more of embodiments 13-20 further comprising providing a concentric cam to control the blowdown valve.

15 The above description of embodiments of the invention is merely illustrative in nature and, thus, variations thereof are not to be regarded as a departure from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A product comprising:

5 an engine with at least one cylinder having at least one blowdown valve and at least one scavenging valve;

a turbo alternator; and

a blowdown manifold connecting the at least one blowdown valve to the turbo alternator.

10

2. The product of claim 1 further comprising a turbocharger.

3. The product of claim 2 wherein the turbocharger is connected to the blowdown valve via the blowdown manifold.

15

4. The product of claim 2 wherein the blowdown manifold splits into at least a turbo alternator exhaust conduit and a turbocharger exhaust conduit wherein the turbo alternator exhaust conduit is connected to the turbo alternator and the turbo charger exhaust conduit is connected to the turbo
20 charger.

20

5. The product of claim 2 wherein the blowdown manifold includes a valve having at least two outlets, a first outlet connected to the turbo alternator exhaust conduit and a second outlet connected to the turbocharger exhaust
25 conduit.

25

6. The product of claim 4 further including a first valve in the turbo alternator exhaust conduit and a second valve in the turbocharger exhaust conduit.

30

7. The product of claim 1 further comprising a valve in the exhaust manifold.

8. The product of claim 1 further comprising a divided exhaust wherein scavenging manifold is connected to the scavenging valve.

5 9. The product of claim 1 further comprising a controller to control the operation of the blowdown valve.

10. The product of claim 2 further comprising a controller to control the operation of the blowdown valve.

10 11. The product of claim 1 further comprising a concentric camshaft to control the blowdown valve and the scavenging valve.

12. The product of claim 6 further comprising a concentric camshaft to control the blowdown valve.

15

13. A method of producing power comprising:
providing engine with at least one cylinder having at least one blowdown valve and at least one scavenging valve;
providing a turbo alternator;

20 providing a blowdown manifold connecting the at least one the blowdown valve to the turbo alternator; and

flowing exhaust gas from the engine through the blowdown manifold and powers the turbo alternator.

25 14. The method of claim 13 further comprising providing a valve in the exhaust manifold and controlling the valve to control the flow of exhaust gas to the turbo alternator.

30 15. The method of claim 13 further comprising controlling the operation of the blowdown valve to control the flow of exhaust gas to the turbo alternator.

16. The method of claim 13 further comprising controlling the operation of the scavenging valve to control the flow of exhaust gas to the turbo alternator.

17. The method of claim 13 further comprising providing a turbocharger wherein the turbocharger is connected to the blowdown manifold.

5 18. The method of claim 17 further comprising providing a valve in the exhaust manifold, the valve having two outputs, the first output in fluid communication with the turbo alternator and the second output in fluid communication with the turbocharger, and further comprising controlling the valve to control the flow of exhaust gas between the turbo alternator and the turbo charger.

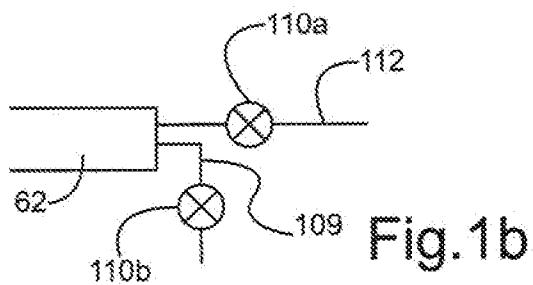
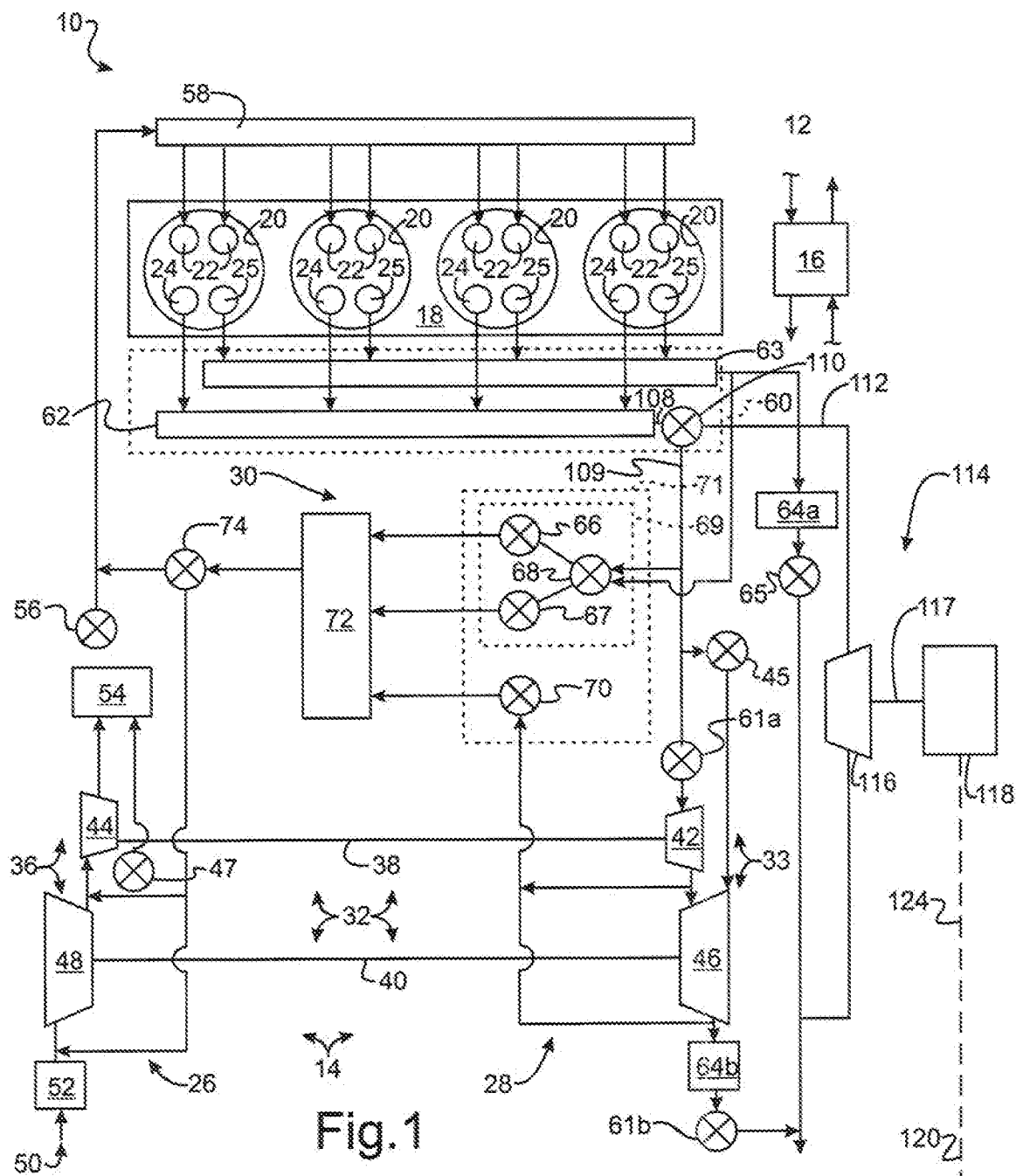
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19. The method of claim 17 further comprising controlling the operation about the blowdown valve to control the flow of exhaust gas to the turbo alternator and the turbocharger.

15 20. The method of claim 18 further comprising controlling the operation about the blowdown valve to control the flow of exhaust gas to the turbo alternator and the turbocharger.

20 21. The method of claim 13 further comprising providing a concentric cam to control the blowdown valve.

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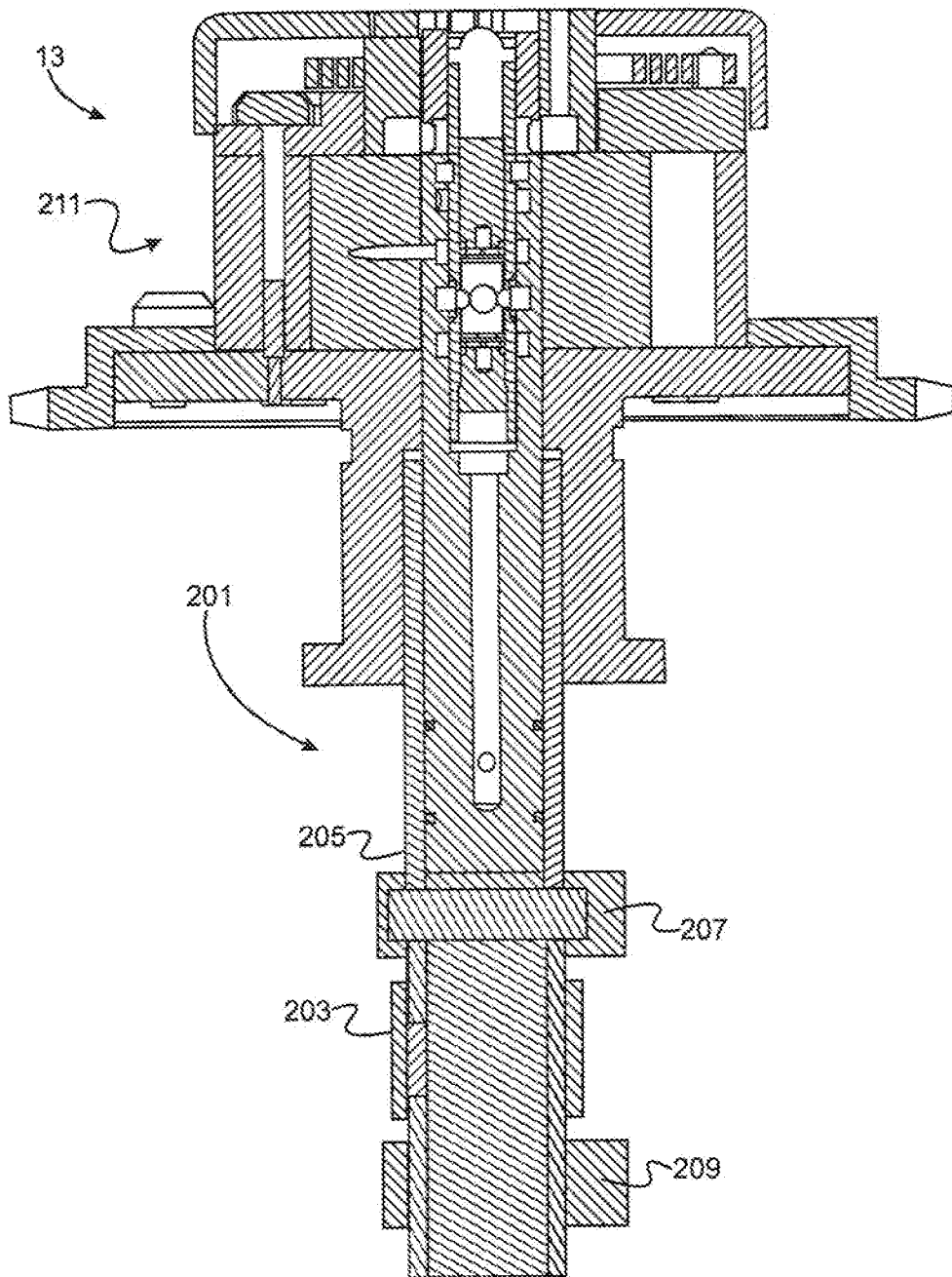


Fig. 2

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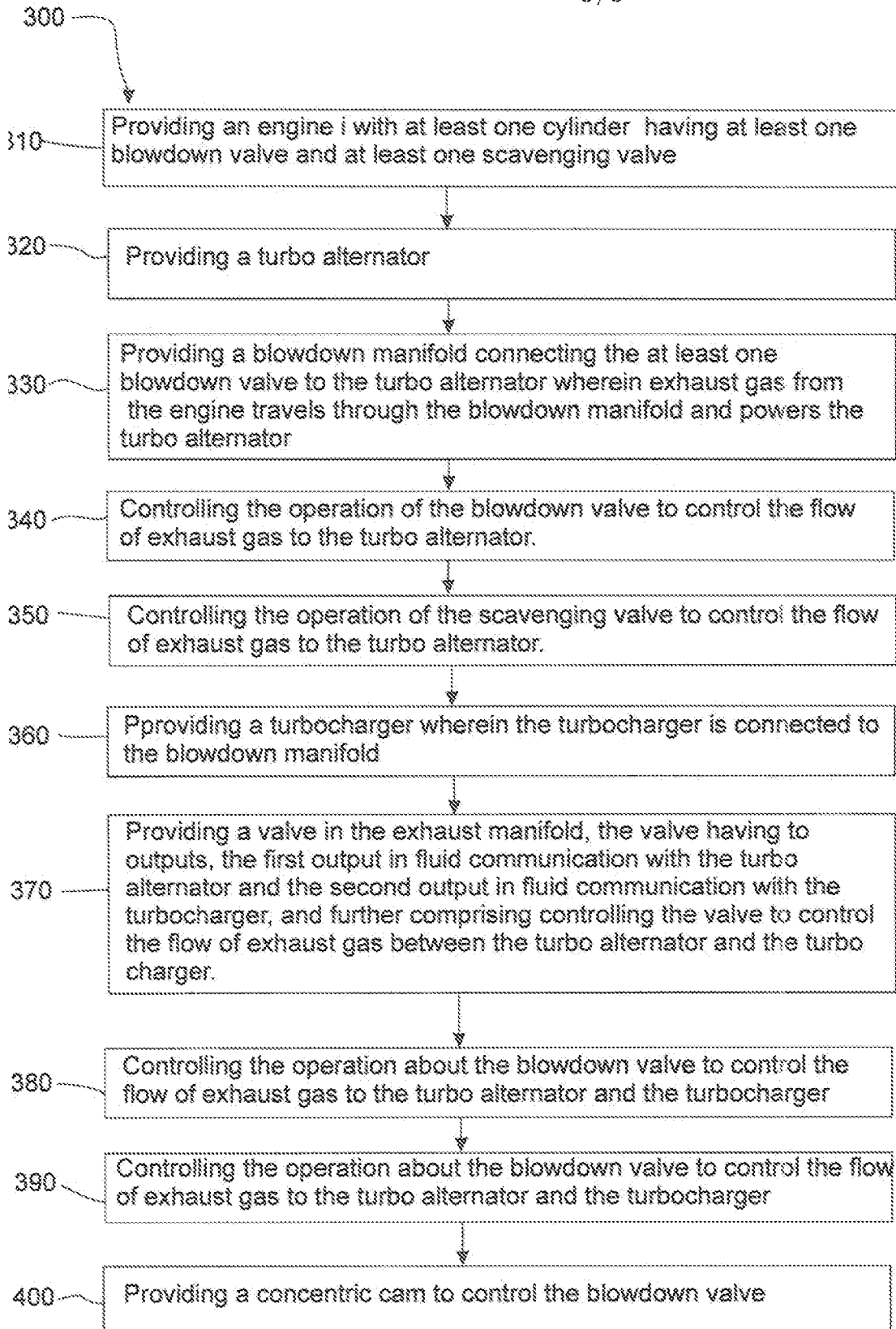


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/052188**A. CLASSIFICATION OF SUBJECT MATTER****F02B 67/00(2006.01)i, F02B 65/00(2006.01)i, F02C 6/00(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)

F02B 67/00; F02B 29/04; F01N 5/04; F01K 23/10; F02B 47/08; H02K 7/18; F02B 33/44; F02B 37/00; F02B 37/007; F01D 15/10; F02B 65/00; F02C 6/00

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

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: engine, turbo alternator, turbocharger, manifold, and valve

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2012-0068924 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 27 June 2012 See paragraphs [0008],[0019]-[0035]; figures 1-4.	1-8, 11-14, 17, 18, 21
Y		9, 10, 15, 16, 19, 20
Y	US 7,891,185 B2 (VUK, CARL T.) 22 February 2011 See column 2, lines 28-39; figures 1,2.	9, 10, 15, 16, 19, 20
A	KR 10-2012-0020266 A (SAMSUNG HEAVY INDUSTRIES CO., LTD.) 08 March 2012 See paragraphs [0022]-[0097]; figures 1,2.	1-21
A	US 2012-0124992 A1 (FIVELAND, SCOTT B.) 24 May 2012 See paragraphs [0010]-[0018]; figures 1,2.	1-21
A	US 4,760,702 A (AMMANN, et al.) 02 August 1988 See column 2, line 34 - column 4, line 55; figure 1.	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 October 2013 (24.10.2013)

Date of mailing of the international search report

24 October 2013 (24.10.2013)

Name and mailing address of the ISA/KR

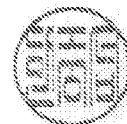
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/052188

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