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(71) Applicant: VOLVO TRUCK CORPORATION

[SE/SE]; 405 08 Göteborg (SE).

(72) Inventors: ANDERSSON, Lennart; Torpavägen 58, 432

95 Varberg (SE), MOHLIN, Anders; Höögs Lid 9, 434 35 Kungälv (SE).

(74) Agent: ZACCO SWEDEN AB; P.O. Box 5581, Valhallavägen 117N, 114 85 Stockholm (SE).

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(54) Title: AN INTERNAL COMBUSTION ENGINE SYSTEM AND A METHOD OF OPERATING AN INTERNAL COMBUSTION ENGINE

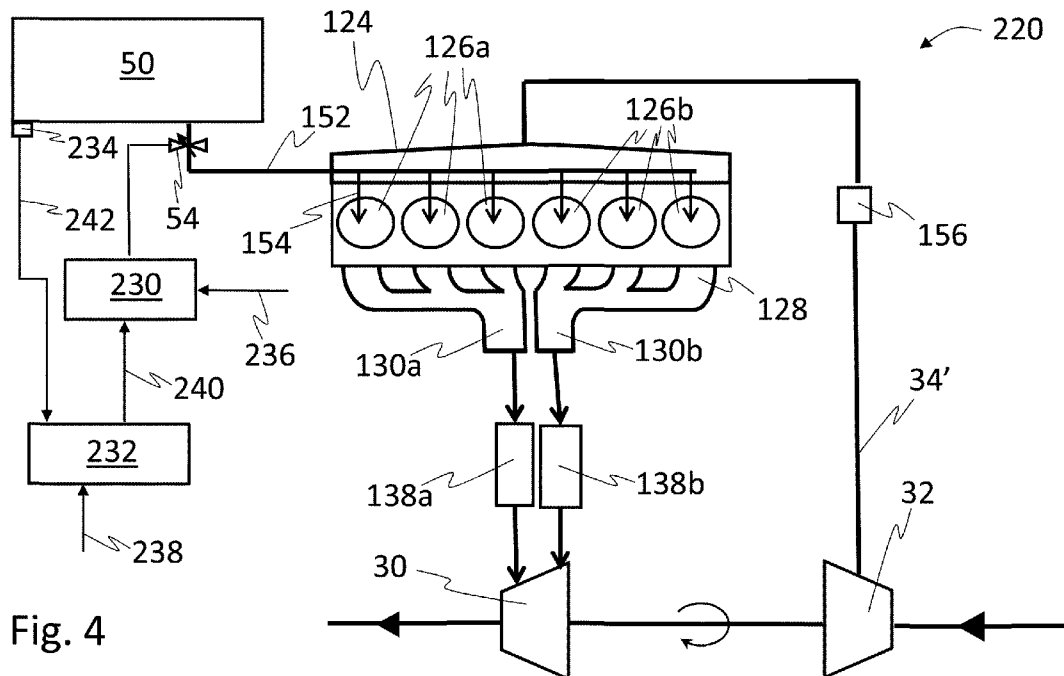


Fig. 4

(57) Abstract: The invention relates to an internal combustion engine system, comprising an internal combustion engine (ICE), a turbocharger comprising a turbine, and an exhaust gas after treatment system (EATS) arranged to receive and treat exhaust gas from said set of cylinders, wherein one or more components of the EATS is/are located downstream of the internal combustion engine and upstream of the turbine of the turbocharger. The system further comprises a tank for pressurized gaseous medium, a flow passage extending from the tank to at least one cylinder of the ICE, and a control valve provided in said flow passage and operable between a closed state and an open state for selectively injecting pressurized gaseous medium into the cylinder. The invention also relates to a method of operating an ICE.



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An internal combustion engine system and a method of operating an internal combustion engine

TECHNICAL FIELD

- 5 The invention relates to an internal combustion engine system and to a vehicle comprising such a system. The invention also relates to a method of controlling an internal combustion engine system, a computer program, a computer readable medium and a control unit.
- 10 The invention can be applied in heavy-duty vehicles, such as trucks, buses and construction equipment. Although the invention will be described with respect to a truck, the invention is not restricted to this particular vehicle, but may also be used in other vehicles such as cars.

15

BACKGROUND

- Most trucks today are powered by internal combustion engines having cylinders in which fuel is combusted whereby exhaust gases are generated. The exhaust gases are normally transferred to an exhaust gas aftertreatment system (EATS) where the exhaust gases are
- 20 treated and at least some of the pollutants in the exhaust gases are converted into harmless substances. The EATS may comprise an oxidation catalyst suitable for converting hydrocarbons and carbon monoxide to carbon dioxide and water, a particulate filter catching soot and ashes, and a reduction catalysts reducing nitrogen oxides to nitrogen, sometimes with the help of a reductant fluid. During cold start or low exhaust
- 25 temperature it is desirable to heat the EATS to its working temperature, and occasionally it is desirable to heat the EATS to a higher temperature than the normal exhaust temperature. Such events could be to burn off collected soot, poisonous matter, e.g. sulphur, collected on the catalysts, or deposits created by the reductant. These elevated temperatures can be reached by applying different heat mode strategies on the internal
- 30 combustion engine, which however may have a negative impact on the fuel consumption. A more fuel efficient alternative to using heat mode strategies is to move the EATS or parts of it to a position before the turbine where the exhaust temperature is higher compared to the more common position after the turbine.

Relocation of the EATS to a position before the turbine brings considerable emission advantages due to the increased exhaust temperature. However, there is also a downside with respect to the engine transient response time due to the increased pre-turbine
5 volume.

WO 2016/001281 discloses an internal combustion engine and an EATS arranged before a turbine in an exhaust system. WO 2016/001281 reduces the problem of turbo lag when having a pre-turbine EATS component by providing an electrically driven machine to
10 increase the charger pressure in the fresh-air system. Although this reduces the problem of turbo lag, the transient response time can still be improved. In particular, when increasing the charger pressure in the fresh-air system as taught by WO 2016/001281, increasing injected fuel amount can only be done after the turbo lag has been overcome and the compressor delivers the increased air mass flow needed.

15

Thus, it would still be desirable to improve the transient response time for an internal combustion engine system comprising a pre-turbine EATS.

20 SUMMARY

An object of the invention is to provide an internal combustion engine system, which alleviates the above mentioned drawbacks of the prior art.

According to a first aspect, the object is achieved by an internal combustion engine
25 according to claim 1. The internal combustion engine system comprises

- an internal combustion engine comprising a set of one or more cylinders,
- a turbocharger comprising a turbine, and
- an exhaust gas aftertreatment system (EATS) arranged to receive and treat exhaust gas from said set of cylinders, wherein one or more components of the EATS is/are located
30 downstream of the internal combustion engine and upstream of the turbine of the turbocharger,

characterized in that the internal combustion engine system further comprises:

- a tank for pressurized gaseous medium,
- a flow passage extending from the tank to at least one cylinder of said set of cylinders,
35 and

- a control valve provided in said flow passage for selectively injecting pressurized gaseous medium into said at least one cylinder, wherein the control valve is operable between:

a closed state, in which flow of pressurized gaseous medium from the tank, via
5 said flow passage, into said at least one cylinder is prevented, and

an open state, in which flow of pressurized gaseous medium from the tank, via
said flow passage, into said at least one cylinder is enabled.

The invention is based on the realization that by injecting a pressurized gaseous medium
10 (such as pressurized air) directly into a cylinder, the injected fuel amount in the cylinder
can be increased simultaneously with the injection of the pressurized medium. Thus, the
need for waiting for the turbo lag to be overcome, as in the prior art, can be avoided, and
thus an improved transient response time may be achieved. A further advantage of
injecting pressurized gaseous medium directly into a cylinder is that the combustion
15 chamber volume of a cylinder is much smaller (i.e. quick and efficient pressurization)
compared to the much larger manifold and conduits which would also have to be
pressurized when increasing the charger pressure in the fresh air system of the prior art.

It should be understood that in this application, a “set” can include any number of items,
20 i.e. it can be a single item or it can be plural items. Accordingly, a set may include one or
more cylinders in an internal combustion engine. The term “set” may thus be used to
distinguish one or more cylinders from one or more other cylinders. This is reflected in at
least some of the exemplary embodiments discussed below, in which there is provided a
first set of one or more cylinders and a second set of one or more cylinders which is
25 separate from the first set. Furthermore, it should be understood that, for simplicity and
ease of reading, in this application reference may be made to the “first set of cylinders”
and to the “second set of cylinders”, instead of the first “set of one or more cylinders” and
the “second set of one or more cylinders”. Thus, it should be understood that as far as the
term a “set of cylinders” is concerned, the number of cylinders in each set may for
30 example be one, two, three, four or more.

According to at least one exemplary embodiment, each cylinder in said set of one or more
cylinders is provided with an intake port and an intake valve for regulating an inflow of gas
through the intake port into the cylinder, wherein pressurized gaseous medium from said
35 tank is configured to be injected into the cylinder separately from said inflow of gas. This

has the advantage that the point of injection may be selected so that the volume to be pressurized is relatively small.

According to at least one exemplary embodiment, the inflow of gas surrounds the outside
5 of the intake valve when the intake valve is open to enable said inflow of gas into the cylinder, wherein the intake valve comprises a internal channel extending internally of the intake valve and debouching into the cylinder, which internal channel is configured to form part of the flow passage for pressurized gaseous medium when pressurized gaseous medium is injected into the cylinder. This is advantageous as it does not require an
10 additional opening through the walls of the cylinders to be made. Instead, the pressurized gaseous medium, may be injected into the cylinders at the already existing intake, however, from the inside of the intake valve, as opposed to from the outside where said inflow of gas occurs.

15 According to at least one exemplary embodiment, when said intake valve is closed and prevents inflow of gas into the cylinder, an opening to the internal channel is aligned with a part of the flow passage thereby completing the flow passage from the tank to the cylinder, and wherein when said intake valve is open to allow inflow of gas into the cylinder, the opening to the internal channel is displaced relative to said part of the flow
20 passage such that a discontinuity of the flow passage from the tank to the cylinder is formed. By closing the intake valve, the available volume to be pressurized is limited to the volume enclosed in the cylinder, which is relatively small and which can therefore easily and quickly become pressurized when injecting the pressurized gaseous medium.

25 According to at least one exemplary embodiment, the internal combustion engine system comprises a control unit configured to control the opening and closing of the control valve for selectively injecting pressurized gaseous medium into said at least one cylinder. This is advantageous since a control unit may be operatively connected to activate the opening/closing of the control valve in response to different input signals, such as for
30 example from an accelerator pedal, a pressure sensor, engine speed sensor, other control units etc. The control unit for opening and closing the control valve may include a microprocessor, microcontroller, programmable digital signal processor or another programmable device. The control unit may also, or instead, include an application specific integrated circuit, a programmable gate array or programmable array logic, a
35 programmable logic device, or a digital signal processor. Where the control unit includes a

programmable device such as the microprocessor, microcontroller or programmable digital signal processor mentioned above, the processor may further include computer executable code that controls operation of the programmable device.

- 5 According to at least one exemplary embodiment, said one or more components of the EATS located upstream of the turbine is one or more of: a particle filter, an oxidation catalyst, a reduction catalyst, and a urea injector. By placing said one or more components upstream of the turbine they will be subjected to a higher temperature compared to if they would be placed downstream of the turbine, thus reaching their
10 working temperature more quickly. For instance, placing a particle filter upstream of the turbine will facilitate the burning of soot.

According to at least one exemplary embodiment, all components of the EATS are located upstream of the turbine. In analogy to above, this will lead to the components of the EATS
15 reaching their working temperature more quickly.

According to at least one exemplary embodiment, said set of one or more cylinders comprises a plurality of cylinders, wherein the flow passage extends from the tank and is branched into a plurality of flow passage branches, each flow passage branch extending
20 to a respective cylinder of said plurality of cylinders. By injecting the pressurized gaseous medium into each one of the cylinders, the transient response time can be reduced.

According to at least one exemplary embodiment of the invention, the internal combustion engine system comprises an exhaust gas recirculation (EGR) conduit for recirculating
25 exhaust gas from said set of one or more cylinders to an inlet of the internal combustion engine. Recirculation of some of the exhaust gas is beneficial since a low NO_x formation may be maintained. The recirculated exhaust gas dilutes the air/fuel mixture just enough to reduce combustion temperatures to a level that reduces the reaction between nitrogen and oxygen that forms NO_x. By combining the use of EGR with the use of pressurized
30 gaseous medium for injection into the one or more cylinders, the controllability of the EGR amount can be improved.

The above mentioned benefits for using EGR may be implemented in various configurations. For instance, in some exemplary embodiments, the starting point of the
35 EGR conduit may be located downstream of said set of one or more cylinders and

upstream of the turbine. In other exemplary embodiments the starting point of the EGR conduit is located upstream of said one or more components of the EATS.

According to at least one exemplary embodiment, said set of one or more cylinders is a first set, the internal combustion engine further comprising a second set of one or more cylinders, wherein the EGR conduit is configured to receive and recirculate gas from one of the first and second sets, wherein the flow passage extends from the tank to at least one cylinder in one of the first and second sets, or to at least one cylinder in each one of the first and second sets. It may be advantageous to recirculate exhaust gas from one set of cylinders while allowing exhaust gas from the other set of cylinders to pass directly to the one or more components of the EATS. For instance, fuel may be injected into the other set of cylinders for further increasing the temperature of the exhaust gas for improved performance of the EATS, without risking any added fuel into the EGR conduit (which could negatively affect the performance of an EGR cooler, which is often present in an EGR conduit).

According to at least one exemplary embodiment, the EGR conduit is configured to receive and recirculate gas from each one of the first and second sets. By having the possibility of recirculating gas from either one or both of the sets, an increased controllability/flexibility may be achieved, since more EGR options are available.

Furthermore, recirculating from both sets of cylinders means that an equal amount of exhaust gas can be recirculated from both sets of cylinders, thereby avoiding imbalance and achieving higher efficiency.

According to at least one exemplary embodiment, the starting point of the EGR conduit is located downstream of the turbine and extends into an inlet of a compressor rotating with the turbine, the compressor being configured to displace gas such as air, to the inlet of the internal combustion engine. By adding EGR gas to the inlet of the compressor (e.g. in addition to fresh air) the delivery of gas from the compressor to the intake may be further improved.

According to at least one exemplary embodiment, said pressurized gaseous medium is pressurized air. This is advantageous since air is a readily available and controllable gaseous medium.

According to a second aspect of the invention, the object is achieved by a vehicle comprising an internal combustion engine system according to the first aspect, including any embodiments thereof. The vehicle may, for instance, be a truck, a bus, construction equipment or a car.

5

According to a third aspect of the invention, the object is achieved by a method of operating an internal combustion engine system which comprises

- an internal combustion engine comprising a set of one or more cylinders,
- a turbocharger comprising a turbine, and

10 - an exhaust gas aftertreatment system arranged to receive and treat exhaust gas from said set of cylinders, wherein one or more components of the exhaust gas aftertreatment system (EATS) is/are located downstream of the internal combustion engine and upstream of the turbine of the turbocharger,

- a tank for pressurized gaseous medium,

15 - a flow passage extending from the tank to at least one cylinder of said set of cylinders, and

- a control valve provided in said flow passage,

the method comprising the steps of:

selectively injecting pressurized gaseous medium into said at least one cylinder by

20 setting the control valve in an open state, in which flow of pressurized gaseous medium from the tank, via said flow passage, into said at least one cylinder is enabled, and

setting the control valve in a closed state, in which flow of pressurized gaseous medium from the tank, via said flow passage, into said at least one cylinder is prevented.

25

It should be understood that the control unit of disclosed in exemplary embodiments of the system of the first aspect of the invention is configured to perform the steps and include the features of any one of the embodiments of the method according to the third aspect of the invention.

30

The advantages of the various embodiments of the third aspect are largely analogous to the advantages of the corresponding embodiments of the first aspect. Exemplary embodiments of the method of the third aspect include the following.

According to at least one exemplary embodiment, each cylinder in said set of one or more cylinders is provided with an intake port and an intake valve for regulating an inflow of gas through the intake port into the cylinder, wherein said step of injecting pressurized gaseous medium from the tank into the cylinder is performed separately from enabling
5 inflow of gas through the intake port into the cylinder.

According to at least one exemplary embodiment, said step of injecting pressurized gaseous medium from the tank into the cylinder is preceded by the step of closing said intake valve to prevent said inflow of gas when the pressurized gaseous medium is
10 injected from the tank into the cylinder.

According to at least one exemplary embodiment, the step of recirculating exhaust gas from said set of one or more cylinders to an inlet of the internal combustion engine gas via an exhaust gas recirculation (EGR) conduit.

15

According to at least one exemplary embodiment, said step of recirculating exhaust gas comprises recirculating exhaust gas from upstream of the turbine, such as upstream of said one or more components of the EATS.

20 According to at least one exemplary embodiment, said step of recirculating exhaust gas comprises recirculating exhaust gas from downstream of the turbine.

According to at least one exemplary embodiment, said pressurized gaseous medium is pressurized air.

25

According to a fourth aspect of the invention, the object is achieved by means of a computer program comprising program code means for performing the steps of the method according to the third aspect, including any embodiments thereof, when said program is run on a computer.

30

According to a fifth aspect of the invention, the object is achieved by a computer readable medium comprising a computer program comprising program code means for performing the steps of the method according to the third aspect, including any embodiments thereof, when said program is run on a computer.

35

According to a sixth aspect of the invention, the object is achieved by a control unit for controlling the transient response time of an internal combustion engine, the control unit being configured to perform the steps of the method according to the third aspect, including any embodiments thereof. The control unit may suitably be, or be included in, or
5 comprise, the control unit presented in exemplary embodiments of the system according to the first aspect.

Further advantages and advantageous features of the invention are disclosed in the following description and in the dependent claims.
10

BRIEF DESCRIPTION OF THE DRAWINGS

15 With reference to the appended drawings, below follows a more detailed description of embodiments of the invention cited as examples.

In the drawings:

20 Fig. 1 is a schematic view illustrating a vehicle comprising an internal combustion engine system in accordance with at least some exemplary embodiments of the invention.

Fig. 2 is a schematic view illustrating an internal combustion engine system in accordance with at least some exemplary embodiments of the invention.

25

Fig. 3 is a schematic view illustrating an internal combustion engine system in accordance with at least some other exemplary embodiments of the invention.

Fig. 4 is a schematic view illustrating an internal combustion engine system in accordance
30 with at least some further exemplary embodiments of the invention.

Fig. 5 is a schematic view illustrating an internal combustion engine system in accordance with at least some additional exemplary embodiments of the invention.

Fig. 6 is a schematic view illustrating an internal combustion engine system in accordance with at least yet some other exemplary embodiments of the invention.

Fig. 7 is a schematic view illustrating an internal combustion engine system in accordance
5 with at least yet some further exemplary embodiments of the invention.

Fig. 8 is a schematic view illustrating an internal combustion engine system in accordance with at least yet some additional exemplary embodiments of the invention.

10 Fig. 9 is a schematic view illustrating a portion of an intake valve at an intake port, for use in a system or method in accordance with at least some other exemplary embodiments of the invention.

Fig. 10 is a diagram illustrating a method of operating an internal combustion engine
15 system in accordance with the invention.

Fig. 11 is a diagram illustrating optional steps which may be implemented in exemplary embodiments of the method of operating an internal combustion engine system.

20

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

Fig. 1 is a schematic view illustrating a vehicle 2 comprising an internal combustion engine system in accordance with at least one exemplary embodiment of the invention. In
25 this example, the vehicle 2 is illustrated in the form of a truck, powered by an internal combustion engine 4. However, the present invention may well be implemented also in other types of vehicles powered by an internal combustion engine, such as busses, construction equipment and passenger cars.

30 The vehicle 2 is illustrated as being provided with an air intake arrangement comprising an air intake 6 in which air enters and moves vertically down an air duct 8. The air flows to an air cleaner 10 and then to an internal combustion engine system which comprises the internal combustion engine 4. In the depicted embodiment the air cleaner 10 is located in a lower region of the vehicle 2 and the air intake 6 is located in a higher region of the
35 vehicle 2, more specifically the air cleaner 10 is located directly behind a vehicle cab 12,

whereas the air intake 6 is located on top of the cab 12. It should, however, be noted that the locations of the parts detailed above may well be otherwise, as long as air is fed to the internal combustion engine system 4.

5 Fig. 2 is a schematic view illustrating an internal combustion engine system 20 in accordance with at least some exemplary embodiments of the invention. The system 20 comprises an internal combustion engine 24, which in turn comprises a set of one or more cylinders 26. In this schematic representation of the internal combustion engine only one cylinder 26 has been shown. However, it should be understood that the number of
10 cylinders in a set of cylinder may be more than one. For instance, a set may have two, three, four or more cylinders. Furthermore, it should be understood that the system 20 may comprise more than one such set of cylinder/cylinders, such as two or more sets.

The internal combustion engine system 20 further comprises a turbocharger 28
15 comprising a turbine 30. Fig. 2 also illustrates that the turbocharger 28 comprises a compressor 32 for compressing intake air 34. The compressor 32 is via a shaft 36 connected to the turbine 30, which shaft 36 transmits the rotational motion of the turbine 30 to the compressor 32 for delivering compressed intake air 34' to the internal combustion engine 4.

20

Downstream of the internal combustion engine 4 and upstream of the turbine 30 the internal combustion engine system 20 comprises one or more components of an exhaust gas aftertreatment system (EATS) 38. Thus, it should be understood that in some exemplary embodiments, all components of the EATS 38 are located upstream of the
25 turbine 30, while in other exemplary embodiments one or more of the components are located upstream of the turbine 30, while the rest of the components of the EATS are located downstream of the turbine 30. Exemplary components include a particle filter, an oxidation catalyst, a reduction catalyst and a urea injector.

30 The cylinder 26 has an outlet connected to an exhaust duct 40. The exhaust gas is allowed to flow from the exhaust duct 40 via said one or more components of the EATS 38 to the turbine 30, where the exhaust gas flowing through the turbine 30 (and then to the exhaust of the vehicle) will cause the turbine 30 to rotate and thus also the connected compressor 32.

35

In order to improve the transient response time, the internal combustion engine system 20 is provided with a tank 50 for pressurized gaseous medium. The pressurized gaseous medium may suitably be air, however, other gaseous media compatible with the combustion process in the cylinder 26 are also conceivable. A flow passage 52 extends from the tank 50 to the cylinder 26. A control valve 54 is provided in the flow passage 52 for selectively injecting pressurized gaseous medium into the cylinder 26. The control valve 54 is operable between a closed state, in which flow of pressurized gaseous medium from the tank 50, via said flow passage 52, into said at least one cylinder 26 is prevented, and an open state, in which flow of pressurized gaseous medium from the tank 50, via said flow passage 52, into said at least one cylinder 26 is enabled. By injecting the pressurized gaseous medium into the cylinder 26, rather than into a manifold or into the conduit from the compressor 32, a quick and efficient pressurization is achieved, since the combustion chamber of the cylinder 26 has a relatively small volume. This may be compared to if, for instance, the injection would instead be into the manifold in which case both the volume of the manifold and the combustion chamber of the cylinder 26 would need to be pressurized.

The control valve 54 may suitably be an on/off valve, having two discrete states, such as a fully opened state and a fully closed state. However, in other exemplary embodiments, the control valve may have several discrete intermediate opened states or may be continuously controllable between a fully opened and fully closed state.

It should be noted that even though Fig. 2 and the subsequent figures show exemplary embodiments of an internal combustion engine system having a single turbocharger, any one of the exemplary embodiments (and other embodiments) could be modified to have double turbochargers, i.e. a first turbine driving a first compressor via a first common shaft and a second turbine driving a second compressor via a second common shaft.

Fig. 3 is a schematic view illustrating an internal combustion engine system 120 in accordance with at least some other exemplary embodiments of the invention. For convenience, features which are reproduced from Fig. 2 have (at least as far as they are discussed in connection with the explanation of Fig. 3) been provided with the same reference numbers in Fig. 3 as in Fig. 2.

In Fig. 3, the internal combustion engine 124 is illustrated as having a plurality of cylinders 126a, 126b. More specifically, there is provided a first set of cylinders 126a and a second set of cylinders 126b, each set having three cylinders each. It should be understood that in other exemplary embodiments other number of cylinders are conceivable in each set.

5 Furthermore, in some exemplary embodiments there is only one set of a plurality of cylinders.

In the illustrated exemplary embodiment, each cylinder 126a, 126b is connected to a respective exhaust duct 128. The exhaust ducts 128 from the first set of cylinders 126a
10 are joined into a first common duct 130a and the exhaust ducts 128 from the second set of cylinders 126b are joined into a second common duct 130b. From the first common duct 130a the exhaust gas flows to at least one component of an EATS 138a located upstream of the turbine 30. Similarly, from the second common duct 130b the exhaust gas flows to at least one component of another EATS 138b located upstream of the turbine
15 30. From the components of the respective EATS 138a, 138b, the gas continues to the turbine 30 similarly to what was described in connection with Fig. 2. It should be noted that even though Fig. 3 has been illustrated as being provided with two separate EATS 138a, 138b, i.e. receiving exhaust gas emanating from the first and second set of cylinders 126a, 126b, respectively, in other exemplary embodiments, there may be a
20 common EATS for both sets of cylinders 126a, 126b. Thus, in some exemplary embodiments, the first common duct 130a and the second common duct 130b may be joined together into one stem duct from which exhaust gas flows to one EATS upstream of the turbine 30 (or to at least one EATS component upstream of the turbine). Furthermore, irrespective of the case of one EATS or two separate EATS, it should be
25 understood that in some exemplary embodiments all components thereof are located upstream of the turbine 30, while in other exemplary embodiments at least one component thereof is located upstream of the turbine 30 and at least one component thereof is located downstream of the turbine 30.

30 Another difference compared to the example illustrated in Fig. 2, is that in the exemplary embodiment illustrated in Fig. 3, because the internal combustion engine 124 comprises a plurality of cylinders 126a, 126b, the flow passage 152 extends from the tank 50 and is branched into a plurality of flow passage branches 154, each flow passage branch 154 extending to a respective cylinder of said plurality of cylinders 126a, 126b. Furthermore, in
35 Fig. 3 there is provided a charge air cooler 156 for cooling compressed air 34' after it has

passed through the compressor 32 but before it enters the internal combustion engine 124. By cooling the air to a lower temperature the combustion process is improved. It should be understood that a charge air cooler may in similar manner be included in the exemplary embodiment of Fig. 2. Apart from the illustrated differences between the
5 exemplary embodiments in Fig. 2 and Fig. 3, the general operation and fundamental idea is largely the same. Thus, in both illustrated examples, at least one component of an EATS is located upstream of the turbine, and the injection of pressurized gaseous medium into the one or more cylinders is controlled by opening and/or closing a control valve 54 arranged in a flow passage between the tank 50 and the cylinders.

10

As far as the control valve 54 is concerned, in Fig. 3 and in other following figures, one control valve has been illustrated in the flow passage. Thus, opening of the control valve 54 will result in the pressurized gaseous medium being injected into each cylinder 126a, 126b fluidly connected to the flow passage 152 and flow passage branches 154. Likewise,
15 closing of the control valve 54 prevents injection from the tank 50 into the cylinders 126a, 126b. However, in each one of the illustrated exemplary embodiments having a plurality of cylinders, and other exemplary embodiments of the internal combustion engine system including a plurality of cylinders, it would be conceivable to provide two or more control valves. For instance, in case of two or more sets of cylinders, the flow passage could be
20 split into two or more flow passages, one for each set, each one of these two or more flow passage could have its own control valve, thereby enabling independently controlled injection into each set of cylinders. In other exemplary embodiments, it is conceivable to provide one controllable control valve for each individual cylinder. Thus, instead of, or in addition to, having a single control valve as illustrated in the figures, each flow passage
25 branch may be provided with a control valve. For instance, each flow passage branch may comprise an internal channel of an intake valve, such as the one illustrated in Fig. 9, which will be discussed later.

Turning now to Fig. 4, this is a schematic view illustrating an internal combustion engine
30 system 220 in accordance with at least some further exemplary embodiments of the invention. For convenience, features which are reproduced from Fig. 3 have (at least as far as they are discussed in connection with the explanation of Fig. 4) been provided with the same reference numbers in Fig. 4 as in Fig. 3.

As can be seen in Fig. 4, the internal combustion engine system 220 is illustrated as including all the features illustrated in Fig. 3. Additionally, in Fig. 4 there is added a first control unit 230, in the following referred to as an engine control unit 230 and a second control unit 232, in the following referred to as the vehicle control unit 232. Furthermore, a pressure sensor 234 is illustrated as connected to the tank 50 for measuring the pressure of the pressurized gaseous medium inside the tank 50. The engine control unit 230 is configured to control the opening/closing of the control valve 54. The engine control unit 230 may thus control the amount of pressurized gaseous medium to be injected into the cylinders 126a, 126b. This may be based on a number of different parameters 236. Some examples of such parameters include engine speed, amount of injected fuel (proportional to the torque of the engine), charge pressure, charge temperature.

For instance, the control may be used at increased engine speed and load. This may occur when the driver presses the accelerator pedal or when a cruise control in the vehicle control unit transmits a torque request to be able to keep constant vehicle speed, for instance uphill. Such a cruise control may be included in a driver operated vehicle or in an autonomous vehicle. The larger torque increase that is requested (by the driver or the cruise control), the more pressurized gaseous medium will be injected into the cylinders to avoid smoke. The input arrow 238 to the vehicle control unit 232 may, for instance represent, the position of accelerator pedal (i.e. depending on how much the driver presses the accelerator pedal) or it may represent a desired vehicle speed of the cruise control. The output arrow 240 from the vehicle control unit 232 to the engine control unit 230 may represent a torque request based on said input 238.

The pressure inside the tank 50 may be produced by a separate compressor (not illustrated) driven by the internal combustion engine 124. The vehicle control unit 232 may activate such a separate compressor when it receives a signal 242 from the pressure sensor 234, indicating that the pressure in the tank 50 is below a predetermined lower limit value. When the pressure sensor 234 indicates to the vehicle control unit 232 that the pressure in the tank 50 exceeds a predetermined upper limit value, the vehicle control unit 232 will disengage said separate compressor. The pressure sensor 234 is also useful for controlling/determining the amount of pressurized gaseous medium injected into the one or more cylinders.

It should be understood that this and other arrangements and set-ups including the engine control unit 230 for controlling the control valve 54, may be implemented with any exemplary embodiments of the invention, including those shown in the other drawing figures. Thus, in a general sense, the illustrated exemplary embodiments in the various
5 figures may be modified by providing a control unit configured to control the opening and closing of the control valve for selectively injecting pressurized gaseous medium into the one or more cylinders.

According to at least some exemplary embodiments, the internal combustion engine
10 system may comprise an exhaust gas recirculation (EGR) conduit for recirculating exhaust gas from the one or more cylinders to an inlet of the internal combustion engine. EGR may be implemented in any exemplary embodiment, including the already discussed embodiments of Figs. 2-4. An exemplary illustration of the implementation of EGR will now be discussed in connection with Fig. 5.

15

Fig. 5 is a schematic view illustrating an internal combustion engine system 320 in accordance with at least some additional exemplary embodiments of the invention. For convenience, features which are reproduced from Fig. 3 have (at least as far as they are discussed in connection with the explanation of Fig. 5) been provided with the same
20 reference numbers in Fig. 5 as in Fig. 3.

As can be seen in Fig. 5, the internal combustion engine system 320 is illustrated as including all the features illustrated in Fig. 3. Additionally, in Fig. 5 there is provided an EGR conduit 330 taken from the exhaust duct of the second set of cylinders 126b, more
25 specifically from the second common duct 130b. The EGR conduit 330 recirculates the exhaust gas to the internal combustion engine 124, and the recirculated exhaust gas may suitably mix with charge air (compressed intake air 34') from the compressor 32. An EGR cooler 332 may be provided in the EGR conduit 330. Recirculating the exhaust gas may substantially aid in the reduction of heat and pressure in the internal combustion engine
30 124, and provide a reduction in emissions. To control the amount of exhaust gas that is recirculated, there is provided an EGR valve 334 which can be controlled between a closed position (no recirculation at all) to varying opening degrees depending on how much flow of exhaust gas it is desired to recirculate. In the illustrated exemplary embodiment, the starting point of the EGR conduit 334 is located downstream of the
35 cylinders 126a, 126b and upstream of the turbine 30. More specifically, the starting point

is located upstream of said one or more components of the EATS 138a, 138b. In other exemplary embodiments, the starting point may be located between the turbine 30 and said one or more components of the EATS 138a, 138b, and in further exemplary embodiments, the starting point may be located downstream of the turbine 30. It should
5 also be understood that even though the EGR valve 334 is illustrated in Fig. 5 as being located upstream of the EGR cooler 332 in the EGR conduit 330, in other exemplary embodiments the EGR valve 334 may instead be located downstream of the EGR cooler 332.

10 It should furthermore be noted that the injection of pressurized medium into the cylinders 126a, 126b of the first and second set, may be performed independently of if the EGR valve 330 is opened or not. Thus, it should be understood that, in a general sense, the present invention includes exemplary embodiments, wherein said set of one or more cylinders 126a is a first set, the internal combustion engine further comprising a second
15 set of one or more cylinders 126b, wherein the EGR conduit 330 is configured to receive and recirculate gas from one of the first and second sets, wherein the flow passage 152 extends from the tank 50 to at least one cylinder in one of the first and second sets, or to at least one cylinder in each one of the first and second sets.

20 Fig. 6 is a schematic view illustrating an internal combustion engine system 420 in accordance with at least yet some other exemplary embodiments of the invention. For convenience, features which are reproduced from Fig. 5 have (at least as far as they are discussed in connection with the explanation of Fig. 6) been provided with the same reference numbers in Fig. 6 as in Fig. 5.

25

The illustration in Fig. 6 includes all the features of Fig 5. In addition, there is illustrated a recirculation of exhaust gas also from the exhaust of the first set of cylinders 126a. Thus, the EGR conduit has two starting points, one for each set of cylinders 126a, 126b. From each starting point, an EGR conduit branch 330a, 330b is led to the EGR cooler 332
30 where the exhaust gas from the two sets of cylinders 126a, 126b may become cooled and mixed and then recirculated to the internal combustion engine 124. Each EGR conduit branch 330a, 330b is provided with a respective EGR valve 334a, 334b. In at least some exemplary embodiments, the EGR valves 334a, 334b may be independently controllable relative to each other. In other exemplary embodiments, the EGR valves 334a, 334b may

be jointly controllable (for instance, they may be provided on a common shaft and being controlled by a common actuator).

It should furthermore be noted that the injection of pressurized medium into the cylinders
5 126a, 126b of the first and second set, may be performed independently of if one, both, or
neither one of the EGR valves 334a, 334b is/are opened.

Fig. 7 is a schematic view illustrating an internal combustion engine system 520 in
accordance with at least yet some further exemplary embodiments of the invention. For
10 convenience, features which are reproduced from Fig. 3 have (at least as far as they are
discussed in connection with the explanation of Fig. 7) been provided with the same
reference numbers in Fig. 7 as in Fig. 3.

Similarly to the example in Fig. 6 (which is also illustrated with all the features of Fig. 3), in
15 Fig. 7 there are provided two EGR valves 534a, 534b for controlling the recirculation of
the exhaust gas from the first and the second set of cylinders 126a, 126b, respectively.
However, the starting points in Fig. 7 are not located upstream of said one or more
components of the EATS 138a, 138b, but instead the starting points are located
downstream of said one or more components of the EATS 138a, 138b and upstream of
20 the turbine 30. The EGR conduit branches 530a, 530b extend to and join the conduit for
charge air (compressed intake air 34') between the compressor 32 and the internal
combustion engine 124, where all gases will mix. Since the recirculated gases will pass
through the charge air cooler 156, a separate EGR cooler as shown in Fig. 6, may be
omitted from the exemplary embodiment of Fig. 7.

25

Fig. 8 is a schematic view illustrating an internal combustion engine system 620 in
accordance with at least yet some additional exemplary embodiments of the invention.
For convenience, features which are reproduced from Fig. 3 have (at least as far as they
are discussed in connection with the explanation of Fig. 8) been provided with the same
30 reference numbers in Fig. 8 as in Fig. 3.

The starting point of the EGR conduit 630 is located downstream of the turbine 30 and
extends into the inlet of the compressor 32 rotating with the turbine 30. Apart from an
EGR valve 634, there is also illustrated an EGR cooler 632 in Fig. 8. However, in other

exemplary embodiments, the EGR cooler 632 may be omitted, since the recirculated gas will be cooled down by the charge air cooler 156.

It should be understood that in each one of the illustrated exemplary embodiments, and in
5 other embodiments, it is conceivable to modify the internal combustion engine system to comprise an additional second turbocharger, comprising a second turbine driving a second compressor (the existing turbocharger comprising the first turbine which drives the first compressor). Furthermore, it should be understood that in such double turbo
10 systems, the starting point of an EGR conduit or an EGR conduit branch may be located upstream of both the first and the second turbine, downstream of both the first and the second turbine, or downstream of the first turbine but upstream of the second turbine (i.e. between the two turbines).

Fig. 9 is a schematic view illustrating a portion of an intake valve 700 at an intake port
15 702, for use in a system or method in accordance with at least some other exemplary embodiments of the invention. The intake valve 700 is configured to regulate an inflow of gas 704 (such as fresh air from a compressor and/or exhaust gas recirculated via an EGR conduit) through the intake port 702 into the combustion chamber 726 of the cylinder. The pressurized gaseous medium 706 from the tank is configured to be injected separately
20 from said inflow of gas 704. Although in some exemplary embodiments, the injection of pressurized gaseous medium could be performed through a separate injection port, in the illustrated exemplary embodiment the same intake port 702 is utilized as for said separate inflow of gas 704. The separation of the pressurized gaseous medium 706 from the inflow of gas 704 is accomplished by providing one of the flows externally of the intake valve 700
25 and the other one internally of the intake valve 700.

With reference to Fig. 9, the intake valve comprises a valve stem 708 and a valve plug 710 integral with the valve stem 708. In the following they will be referred to as an outer valve stem 708 and an outer valve plug 710. The outer valve plug 710 is configured to
30 abut against a valve seat 712 in order to provide the intake valve 700 in a closed state and to move away from the valve seat 712 to allow a flow between the valve seat 712 and the outer valve plug 710 so that inflow of gas 704 into the combustion chamber 726 is enabled. The outer valve stem 708 is movable in its axial direction, and is suitably biased towards a normally closed state by means of a spring member 714 (only part of which is
35 shown in Fig. 9). In Fig. 9, the spring member 714 would be biased upwardly, urging the

upper side 716 of the outer valve plug 710 towards a mating surface of the valve seat 712. An actuator (not illustrated) may be connected to a control unit such as a vehicle control unit for moving the outer valve stem 708 towards an open state (i.e. urging the outer valve stem 708 downwardly so that the valve plug 710 moves away from the valve
5 seat 712).

The intake valve 700 comprises an internal channel 720 debouching into the combustion chamber 726 of the cylinder. More specifically, the internal channel 720 extends through the outer valve stem 708 and the outer valve plug 710. An opening 722 in the outer valve
10 stem 708 provides the internal channel 720 in fluid communication with a conduit 724 from the tank for pressurized gaseous medium. Thus, the internal channel 720 and said conduit 724 are comprised in the flow passage for pressurized gaseous medium 706 when pressurized gaseous medium 706 is injected into the combustion chamber 726 of the cylinder. In the internal channel 720 there is provided an inner valve stem 730,
15 suitably concentrically with the outer valve stem 708, and an inner valve plug 732 integral with the inner valve stem 730, suitably concentrically with the outer valve plug 710. The inner valve stem 730 is controllable by means of a control unit, such as an engine control unit, to move between a closed state and an open state. In the closed state, an upper side 734 of the inner valve plug 732 abuts an internal surface 736 of the outer valve plug 710,
20 said internal surface 736 thus forming a valve seat for the inner valve plug 732. The inner valve stem 730 is controllable to move the inner valve plug 732 downwardly away from the mating internal surface 736, in order to open the flow passage to allow pressurized gaseous medium 706 to be injected into the combustion chamber 726 of the cylinder.

25 In operation, in order to move the outer valve plug 710 from a closed state to an open state, the outer valve stem 708 is advanced downwardly, whereby the outer valve plug 710 moves away from the valve seat 712. Hereby, the inflow of gas 704 from the compressor/EGR will allow to enter the combustion chamber 726 of the cylinder through the intake port 702. As the outer valve stem 708 is moved downwardly the opening 722 in
30 the outer valve stem 708 (i.e. the opening to the internal channel 720) is displaced relative to the conduit 724 (i.e. relative to a part of the flow passage from the tank) such that a discontinuity of the flow passage from the tank to the cylinder is formed. Thus, the displacement and misalignment of the opening 722 will prevent pressurized gaseous medium 706 from the tank to become injected into the cylinder. Suitably, in addition, the
35 inner valve plug 732 is pressed against said internal surface 736 (i.e. closed state).

Subsequently, when the outer valve stem 708 is retracted, to move the outer valve plug 710 upwardly into contact with the valve seat 712, the intake valve 700 becomes closed and said inflow of gas 704 through the intake port 702 is prevented. In this closed state, the opening 722 in the outer valve stem 708 has become re-aligned with the conduit 724, i.e. the other part of the flow passage between the tank and the cylinder, wherein pressurized gaseous medium 706 is allowed to enter the internal channel 720. However, the inner valve plug 732 is still pressed against the internal surface 736 preventing injection of pressurized gaseous medium 706. Upon request of injection of pressurized gaseous medium 706, the internal valve stem 730 is advanced, thereby moving the internal valve plug 732 away from the internal surface 736 whereby injection of the pressurized gaseous medium 706 into the combustion chamber 726 of the cylinder is accomplished. Because of the direct injection into the cylinder, the volume to be pressurized is relatively small. The outer valve plug 710 seals off the volume of the injection port 702 and the manifold upstream of the intake port 702. If the outer valve plug 710 would be open, i.e. increasing the volume to be pressurized, it would require more time and more pressurized gaseous medium to reach a desired pressure level in the combustion chamber 726 of the cylinder, and thereby a longer transient response time. By this exemplary embodiment, a quick transient response is obtainable, by enabling the injection of pressurized gaseous medium 706 to be separate from said inflow of gas 704. However, as pointed out above, other exemplary embodiments are conceivable, such as having two completely separately located ports, for instance one intake port for said inflow of gas and one injection port for the pressurized gaseous medium, which would also provide a short transient response time.

It should be understood that although directional terms such as “downwards” and “upper” have been used in connection with the description of Fig. 9, these terms have been used in order to simplify the explanation of the illustrated example, and are not necessarily related to a normal direction from a horizontal ground surface on which the vehicle stands/drives. Thus, in this application “downwardly” is a direction towards the cylinder, i.e. an advancing direction of the outer and/or inner valve stem. Conversely, “upwardly” and “upper” are directions away from the cylinder, i.e. a retracting direction of the outer and/or inner valve stem. To be clear, in this application the outer and inner valve stems are described as located upwardly of the outer and inner valve plugs, respectively.

From the above discussion in connection with Fig. 9 and the other drawing figures, it should be understood that in at least some exemplary embodiments, the herein discussed control valve for selectively injecting pressurized medium, may comprise an inner valve stem 730 and inner valve plug 732 as illustrated in Fig. 9. In other exemplary
5 embodiments, said control valve may be a control valve located externally of the intake valve (i.e. externally of the outer valve stem), such as in a conduit extending from the tank to an opening in fluid communication with the internal channel, such as illustrated in Figs. 2-8. In yet other exemplary embodiments, the control valve is located in a flow passage which debouches into the cylinder at a location separated from the location of the intake
10 valve and intake port.

Fig. 10 is a diagram illustrating a method 100 of operating an internal combustion engine system in accordance with at least one exemplary embodiment of the invention. The internal combustion engine system may, for instance, be in accordance with the
15 exemplary embodiments illustrated in Figs. 2-8, and/or as described elsewhere in this disclosure.

As illustrated in Fig. 10, the method 100 comprises:

- in a first step S1, selectively injecting pressurized gaseous medium into said at
20 least one cylinder.

The first step S1, i.e. the selective injecting step, comprises the following sub-steps:

- in a first sub-step S1a, setting the control valve in an open state, in which flow of pressurized gaseous medium from the tank, via said flow passage, into said at least one cylinder is enabled, and
25 - in a second sub-step S1b, setting the control valve in a closed state, in which flow of pressurized gaseous medium from the tank, via said flow passage, into said at least one cylinder is prevented.

Fig. 11 is a diagram illustrating optional steps S2 and S3, which may be implemented in
30 exemplary embodiments of a method 200 of operating an internal combustion engine system. Thus, in addition to the first step S1 (including its sub-steps S1a and S1b), which are the same as in Fig. 10, the following steps may be included in the method 200 of Fig. 11.

As illustrated in Fig. 11, the method 200 may comprise:

- in a second step S2, preceding the first step S1, closing an intake valve to prevent inflow of gas when the pressurized gaseous medium is injected from the tank into the cylinder, wherein the cylinder is provided with an intake port and an intake valve for regulating said inflow of gas through the intake port into the cylinder, and
- 5 - in a third step S3, recirculating exhaust gas from the cylinder to an inlet of the internal combustion engine gas via an exhaust gas recirculation (EGR) conduit.

It should be noted that although step S3 has been illustrated as being performed after step S1, it should be understood that it could be performed before step S1, and even
10 before step S2. Furthermore, it is even conceivable to perform the step S3 simultaneously with one of the steps S1 and S2. For instance, exhaust gas from a first set of cylinders may be recirculated by EGR to said first set of cylinders at the same time as pressurized gaseous medium from the tank is injected into a second set of cylinders.

15 Furthermore, it should be understood that one of the steps S2 and S3 may be omitted. In other words, in some exemplary embodiments, step S3 may be omitted, but step S2 is included, i.e. the intake valve may be closed according to step S2. In some exemplary embodiments, step S2 may be omitted, but step S3 is included, i.e. recirculating exhaust gas according to step S3.

20

It should also be understood that numerous other exemplary embodiments are conceivable which include other steps. For instance, according to at least some exemplary embodiments, either one of the method 100 in Fig. 10 or the method 200 in Fig. 11 may be modified to include an initial step of detecting a torque demand which
25 demands more air (or other gaseous medium) than the actual intake manifold pressure can deliver to the cylinders. Such modified embodiments may also include the step of calculating a desired amount of air (or other gaseous medium) to be injected. These additional steps may suitably precede the previously mentioned steps S1-S3.

30 It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims.

CLAIMS

1. An internal combustion engine system (20, 120, 220, 320, 420, 520, 620), comprising:
- an internal combustion engine (24, 124) comprising a set of one or more cylinders (26, 126a, 126b),
 - 5 - a turbocharger (28) comprising a turbine (30), and
 - an exhaust gas aftertreatment system (EATS) (38, 138a, 138b) arranged to receive and treat exhaust gas from said set of cylinders, wherein one or more components of the EATS is/are located downstream of the internal combustion engine and upstream of the turbine of the turbocharger,
- 10 **characterized in that** the internal combustion engine system further comprises:
- a tank (50) for pressurized gaseous medium,
 - a flow passage (52, 152, 720, 724) extending from the tank to at least one cylinder of said set of cylinders, and
 - a control valve (54, 700) provided in said flow passage for selectively injecting
- 15 pressurized gaseous medium (706) into said at least one cylinder, wherein the control valve is operable between:
- a closed state, in which flow of pressurized gaseous medium from the tank, via said flow passage, into said at least one cylinder is prevented, and
 - an open state, in which flow of pressurized gaseous medium from the tank, via
- 20 said flow passage, into said at least one cylinder is enabled.
2. The internal combustion engine system (20, 120, 220, 320, 420, 520, 620) according to claim 1, wherein each cylinder (26, 126a, 126b) in said set of one or more cylinders is provided with an intake port (702) and an intake valve (700) for regulating an inflow of gas
- 25 (704) through the intake port into the cylinder, wherein pressurized gaseous medium (706) from said tank (50) is configured to be injected into the cylinder separately from said inflow of gas.
3. The internal combustion engine system (20, 120, 220, 320, 420, 520, 620) according to claim 2, wherein the inflow of gas (704) surrounds the outside of the intake valve (700) when the intake valve is open to enable said inflow of gas into the cylinder, wherein the intake valve comprises a internal channel (720) extending internally of the intake valve and debouching into the cylinder, which internal channel is configured to form part of the flow passage for pressurized gaseous medium (706) when pressurized gaseous medium
- 35 is injected into the cylinder.

4. The internal combustion engine system (20, 120, 220, 320, 420, 520, 620) according to claim 3,

wherein when said intake valve (700) is closed and prevents inflow of gas (704) into the cylinder, an opening (722) to the internal channel (720) is aligned with a part (724) of the flow passage thereby completing the flow passage from the tank (50) to the cylinder, and

wherein when said intake valve is open to allow inflow of gas into the cylinder, the opening to the internal channel is displaced relative to said part of the flow passage such that a discontinuity of the flow passage from the tank to the cylinder is formed.

5. The internal combustion engine system (220) according to any one of claims 1-4, comprising a control unit (230) configured to control the opening and closing of the control valve (54, 700) for selectively injecting pressurized gaseous medium into said at least one cylinder (26, 126a, 126b).

6. The internal combustion engine system (20, 120, 220, 320, 420, 520, 620) according to any one of claims 1-5, wherein said one or more components of the EATS (38, 138a, 138b) located upstream of the turbine (30) is one or more of:

- a particle filter,
- an oxidation catalyst,
- a reduction catalyst, and
- a urea injector.

7. The internal combustion engine system (20, 120, 220, 320, 420, 520, 620) according to any one of claims 1-6, wherein all components of the EATS (38, 138a, 138b) are located upstream of the turbine (30).

8. The internal combustion engine system (120, 220, 320, 420, 520, 620) according to any one of claims 1-7, wherein said set of one or more cylinders comprises a plurality of cylinders (126a, 126b), wherein the flow passage (152) extends from the tank (50) and is branched into a plurality of flow passage branches (154), each flow passage branch extending to a respective cylinder of said plurality of cylinders.

9. The internal combustion engine system (320, 420, 520, 620) according to any one of claims 1-8, comprising an exhaust gas recirculation (EGR) conduit (330, 330a, 330b, 530a, 530b, 630) for recirculating exhaust gas from said set of one or more cylinders (126a, 126b) to an inlet of the internal combustion engine (124).

5

10. The internal combustion engine system (320, 420, 520) according to claim 9, wherein the starting point of the EGR conduit (330, 330a, 330b, 530a, 530b) is located downstream of said set of one or more cylinders (126a, 126b) and upstream of the turbine (30).

10

11. The internal combustion engine system (320, 420) according to claim 10, wherein the starting point of the EGR conduit (330, 330a, 330b) is located upstream of said one or more components of the EATS (138a, 138b) .

12. The internal combustion engine system (320, 420, 520, 620) according to any one of claims 9-11, wherein said set of one or more cylinders (126a) is a first set, the internal combustion engine (124) further comprising a second set of one or more cylinders (126b), wherein the EGR conduit (330, 330a, 330b, 530a, 530b, 630) is configured to receive and recirculate gas from one of the first and second sets, wherein the flow passage (152) extends from the tank (50) to at least one cylinder in one of the first and second sets, or to at least one cylinder in each one of the first and second sets.

13. The internal combustion engine system (420, 520, 620) according to claim 12, wherein the EGR conduit (330a, 330b, 530a, 530b, 630) is configured to receive and recirculate gas from each one of the first and second sets of one or more cylinders (126a, 126b).

14. The internal combustion engine system (620) according to claim 9, wherein the starting point of the EGR conduit (630) is located downstream of the turbine (30) and extends into an inlet of a compressor (32) rotating with the turbine, the compressor being configured to displace gas such as air, to the inlet of the internal combustion engine (124).

15. The internal combustion engine system (20, 120, 220, 320, 420, 520, 620) according to any one of claims 1-14, wherein said pressurized gaseous medium is pressurized air.

35

16. A vehicle (2) comprising an internal combustion engine system (20, 120, 220, 320, 420, 520, 620) according to any one of claims 1-15.

17. A method (100, 200) of operating an internal combustion engine which comprises

- 5 - an internal combustion engine comprising a set of one or more cylinders,
- a turbocharger comprising a turbine, and
- an exhaust gas aftertreatment system arranged to receive and treat exhaust gas from said set of cylinders, wherein one or more components of the exhaust gas aftertreatment system (EATS) is/are located downstream of the internal combustion engine and
10 upstream of the turbine of the turbocharger,
- a tank for pressurized gaseous medium,
- a flow passage extending from the tank to at least one cylinder of said set of cylinders, and
- a control valve provided in said flow passage,
15 the method comprising the steps of:

selectively injecting (S1) pressurized gaseous medium into said at least one cylinder by

- setting (S1a) the control valve in an open state, in which flow of pressurized gaseous medium from the tank, via said flow passage, into said at least one cylinder is
20 enabled, and

setting (S1b) the control valve in a closed state, in which flow of pressurized gaseous medium from the tank, via said flow passage, into said at least one cylinder is prevented.

- 25 18. The method (100, 200) according to claim 17, wherein each cylinder in said set of one or more cylinders is provided with an intake port and an intake valve for regulating an inflow of gas through the intake port into the cylinder,
wherein said step of injecting (S1) pressurized gaseous medium from the tank into the cylinder is performed separately from enabling inflow of gas through the intake port into
30 the cylinder.

19. The method (200) according to claim 18, wherein said step of injecting (S1) pressurized gaseous medium from the tank into the cylinder is preceded by the step of closing (S2) said intake valve to prevent said inflow of gas when the pressurized gaseous
35 medium is injected from the tank into the cylinder.

20. The method (200) according to any one of claims 17-19, comprising the step of recirculating (S3) exhaust gas from said set of one or more cylinders to an inlet of the internal combustion engine gas via an exhaust gas recirculation (EGR) conduit.

5

21. The method (200) according to claim 20, wherein said step of recirculating (S3) exhaust gas comprises recirculating exhaust gas from upstream of the turbine, such as upstream of said one or more components of the EATS.

10 22. The method (200) according to claim 20, wherein said step (S3) of recirculating exhaust gas comprises recirculating exhaust gas from downstream of the turbine.

23. The method (100, 200) according to any one of claims 17-22, wherein said pressurized gaseous medium is pressurized air.

15

24. A computer program comprising program code means for performing the steps of any one of claims 17-23 when said program is run on a computer.

25. A computer readable medium carrying a computer program comprising program code
20 means for performing the steps of any one of claims 17-23 when said program product is run on a computer.

25. A control unit (230) for controlling the transient response time of an internal combustion engine (124), the control unit being configured to perform the steps of the
25 method (100, 200) according to any one of claims 17-23.

30

35

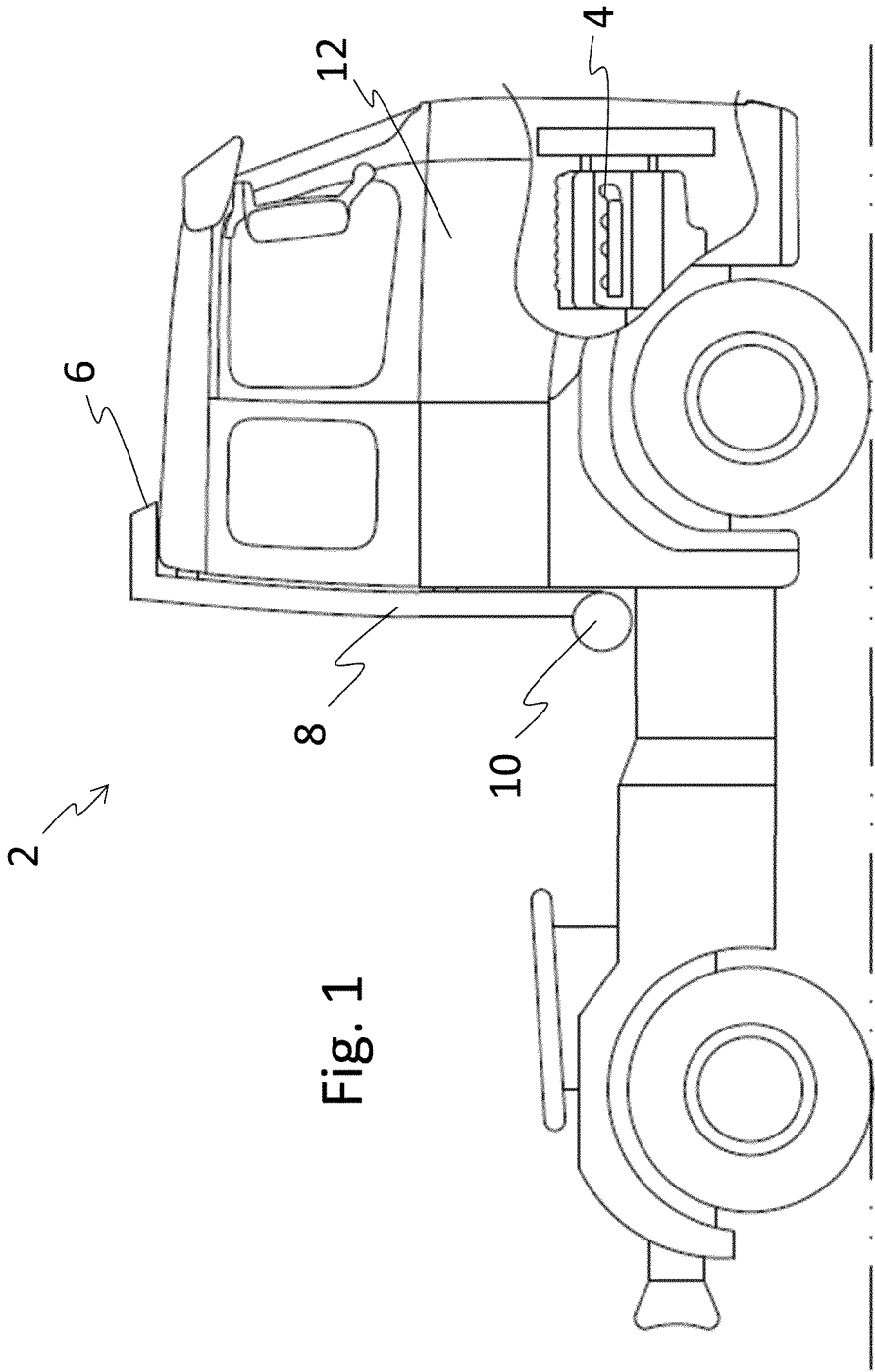


Fig. 1

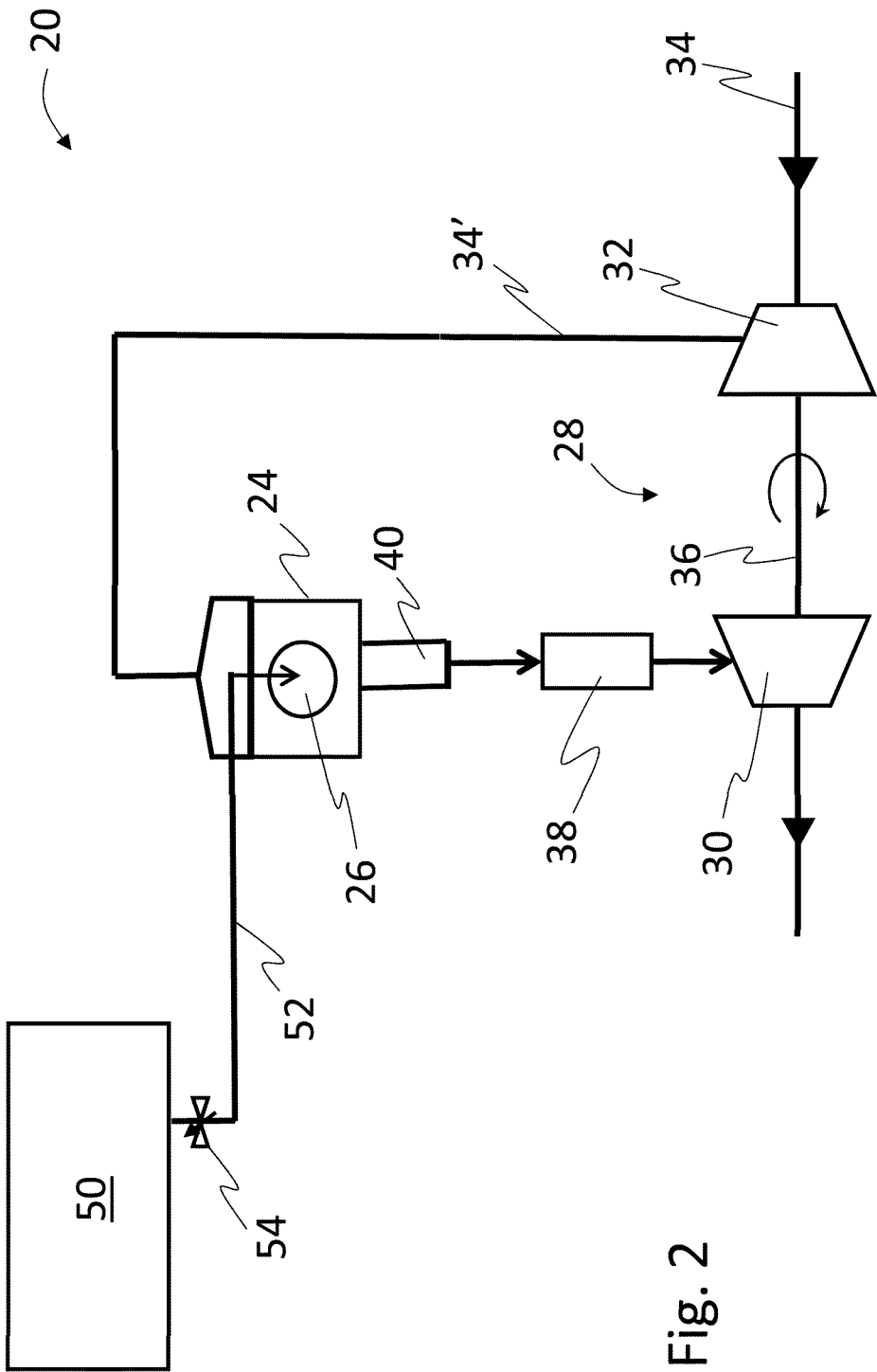


Fig. 2

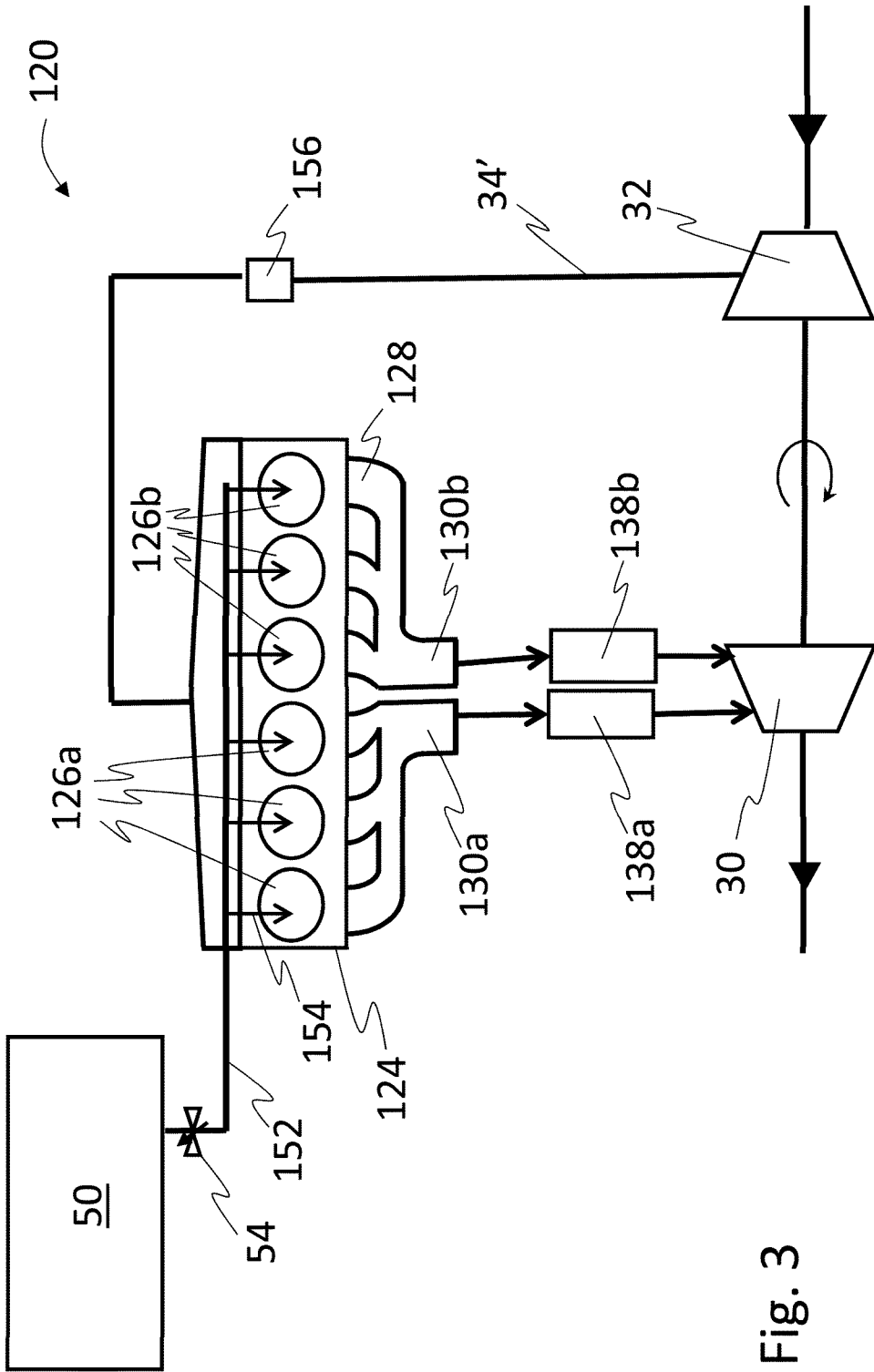


Fig. 3

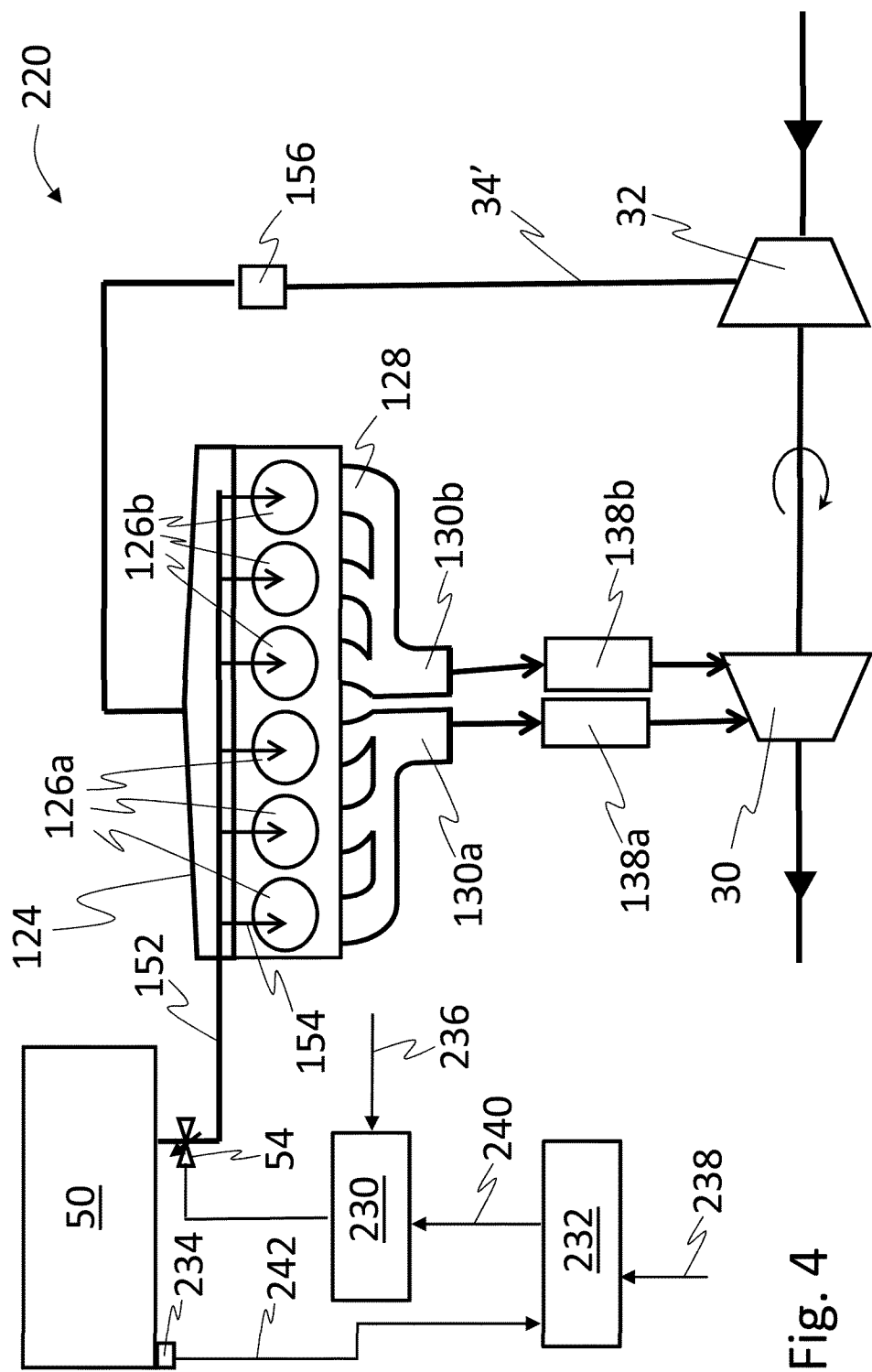


Fig. 4

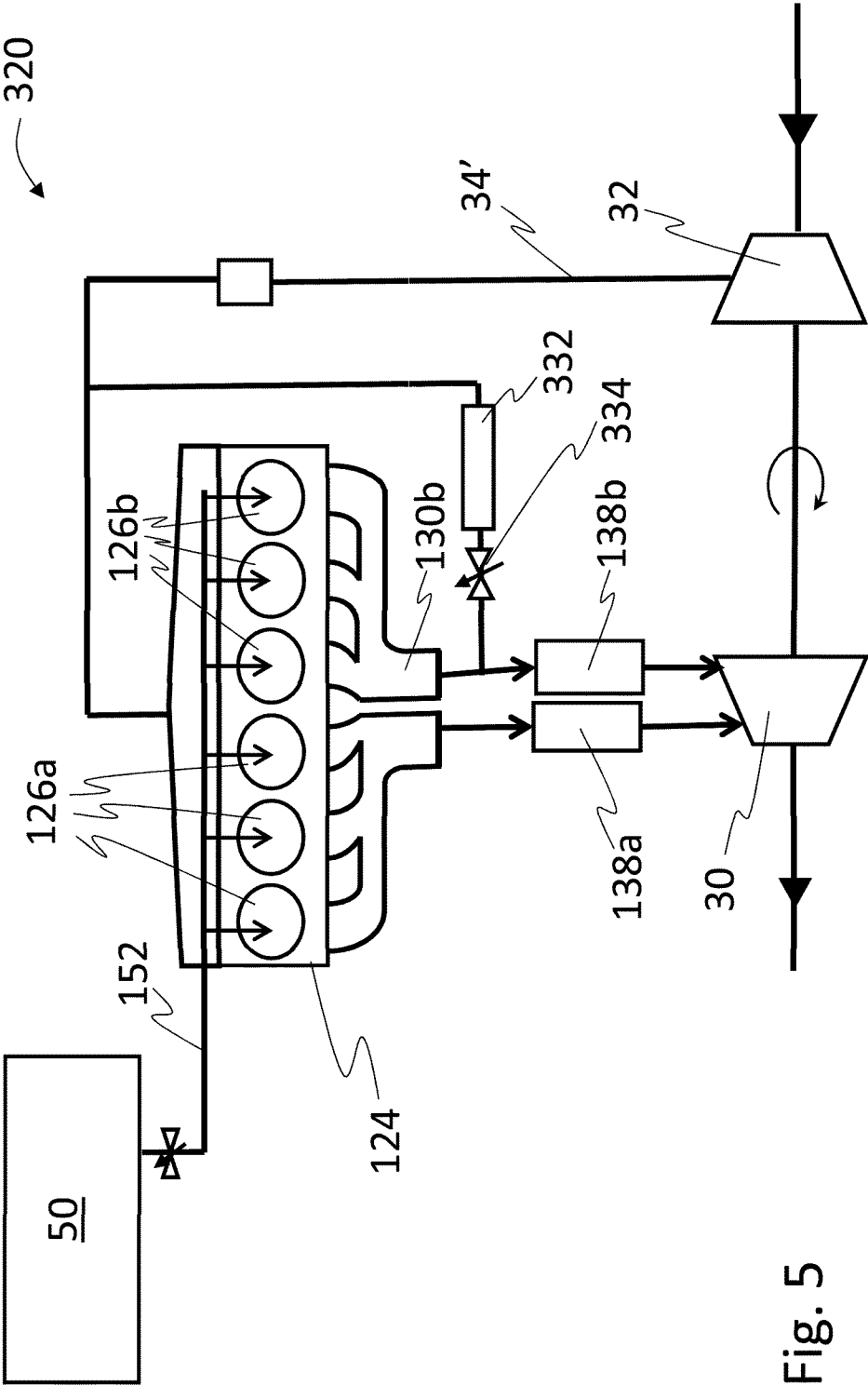


Fig. 5

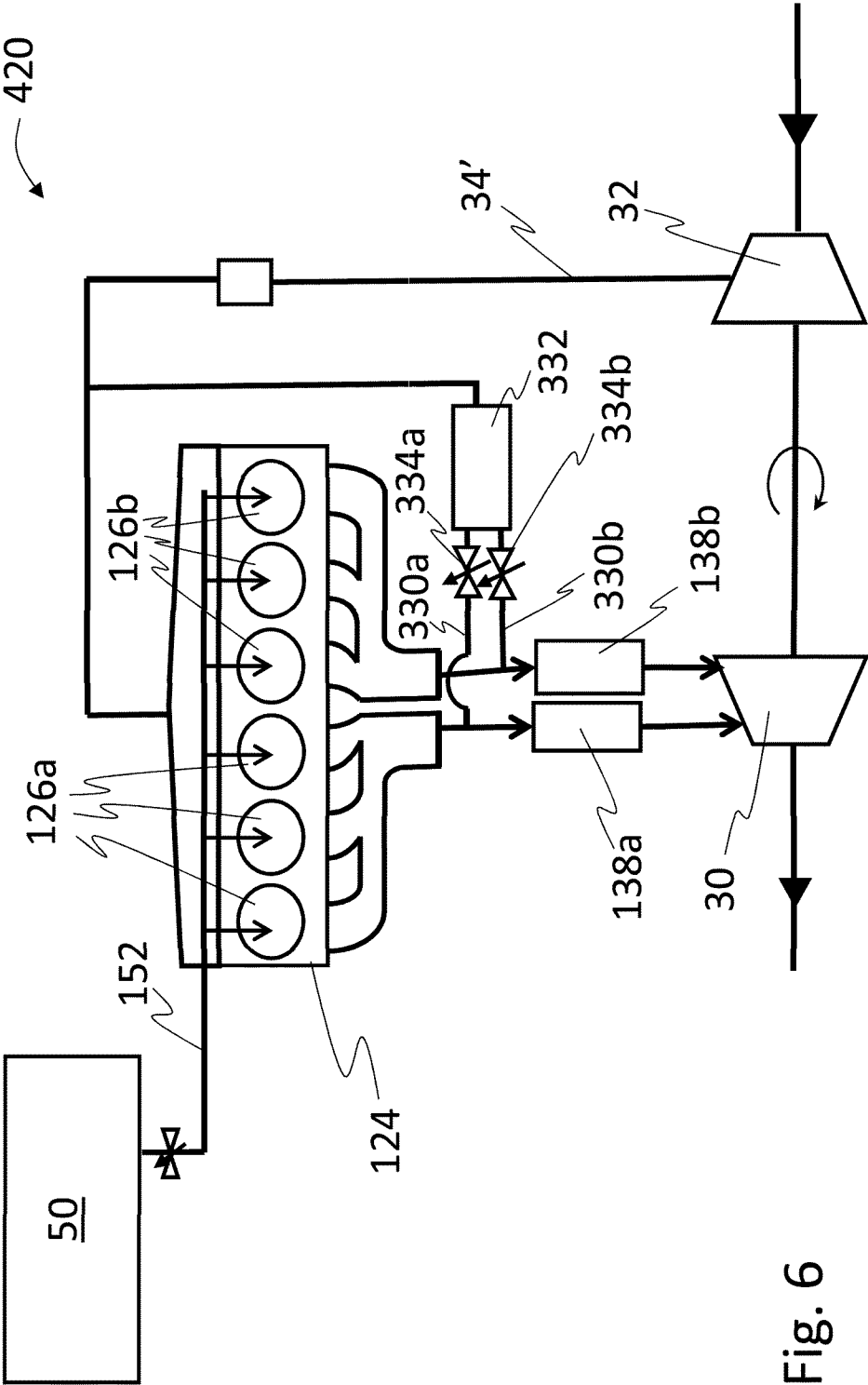


Fig. 6

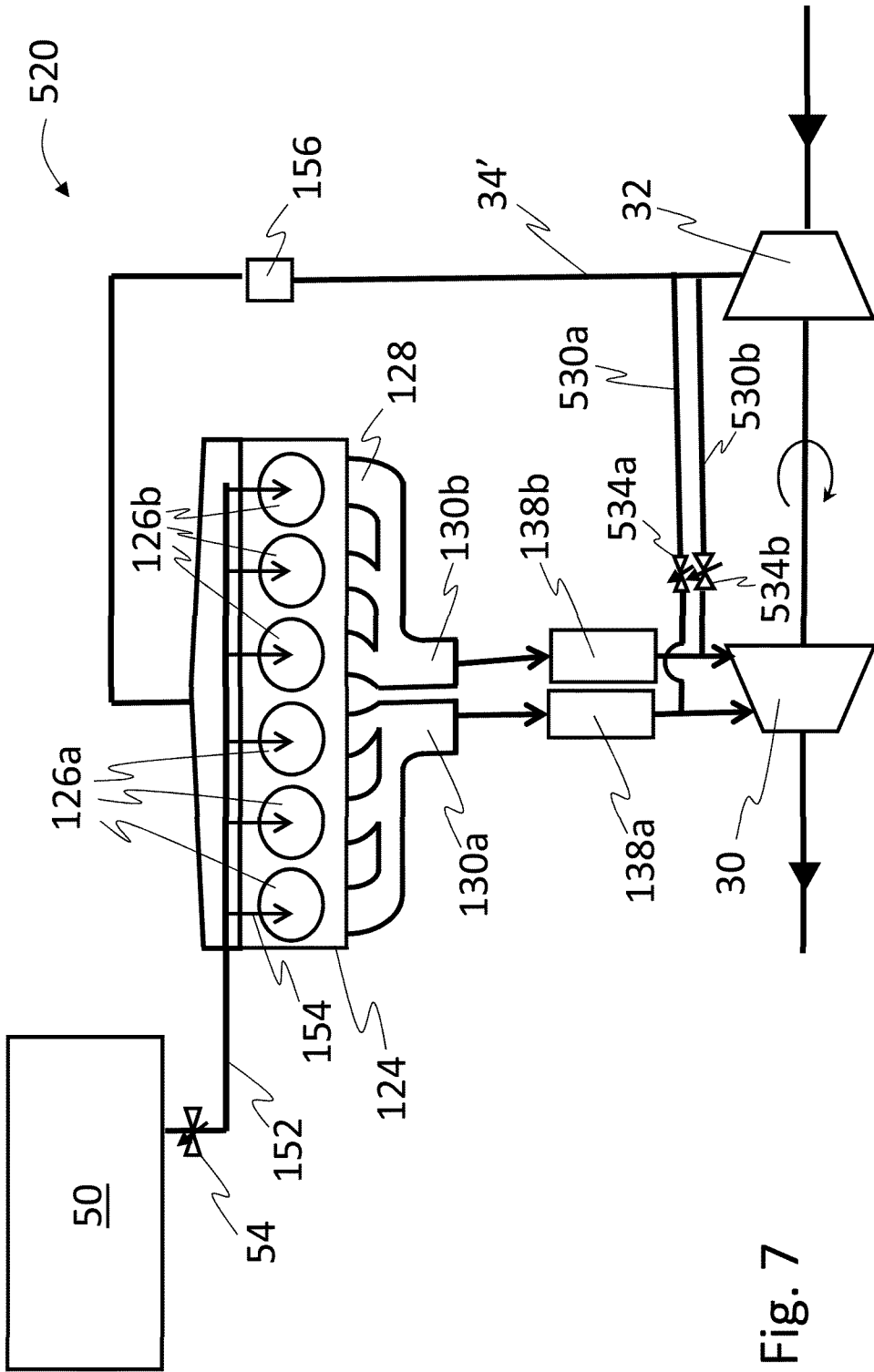


Fig. 7

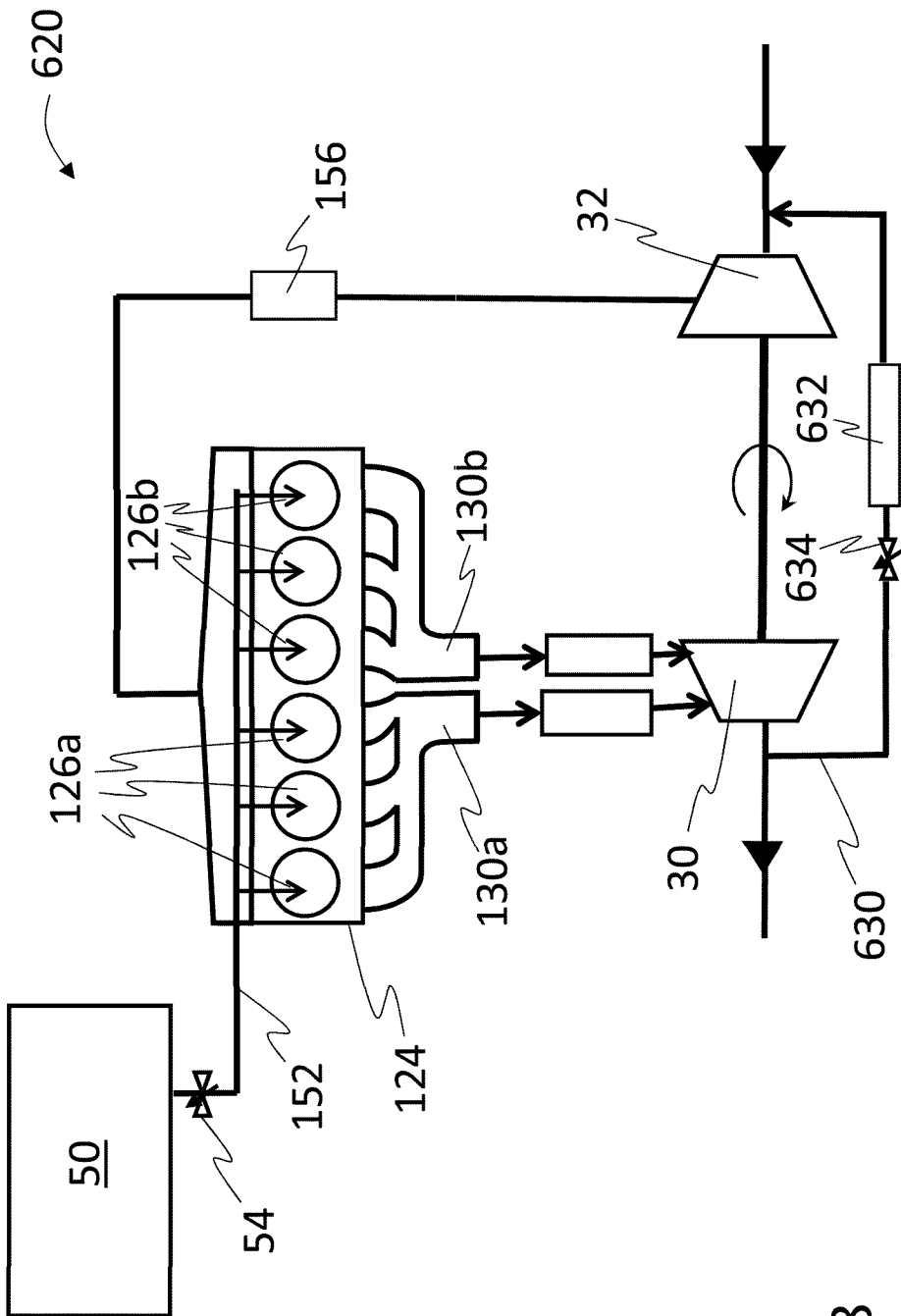


Fig. 8

9/11

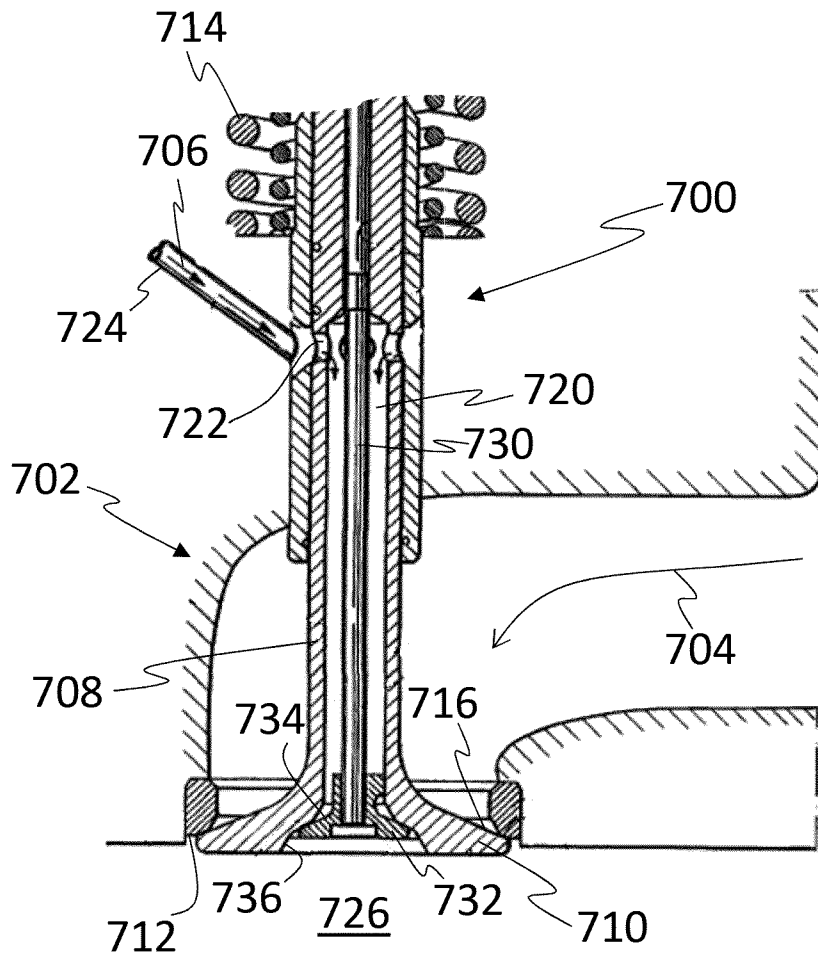


Fig. 9

10/11

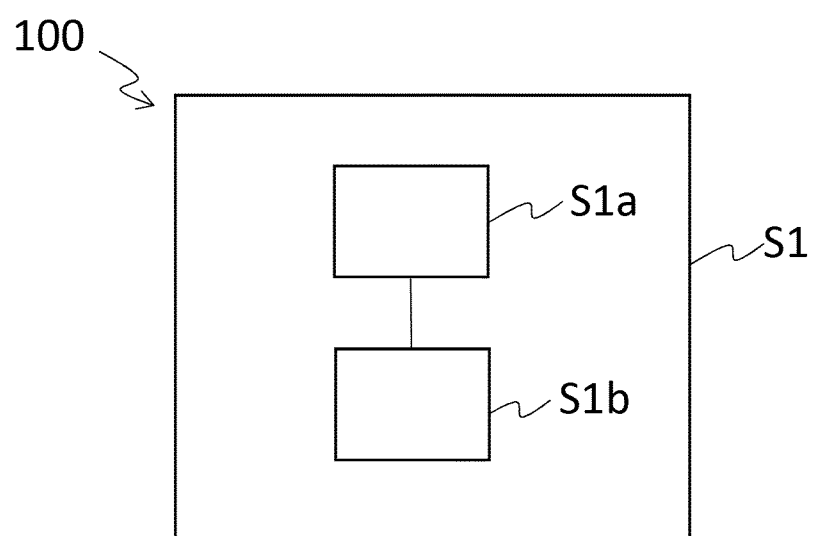


Fig. 10

11/11

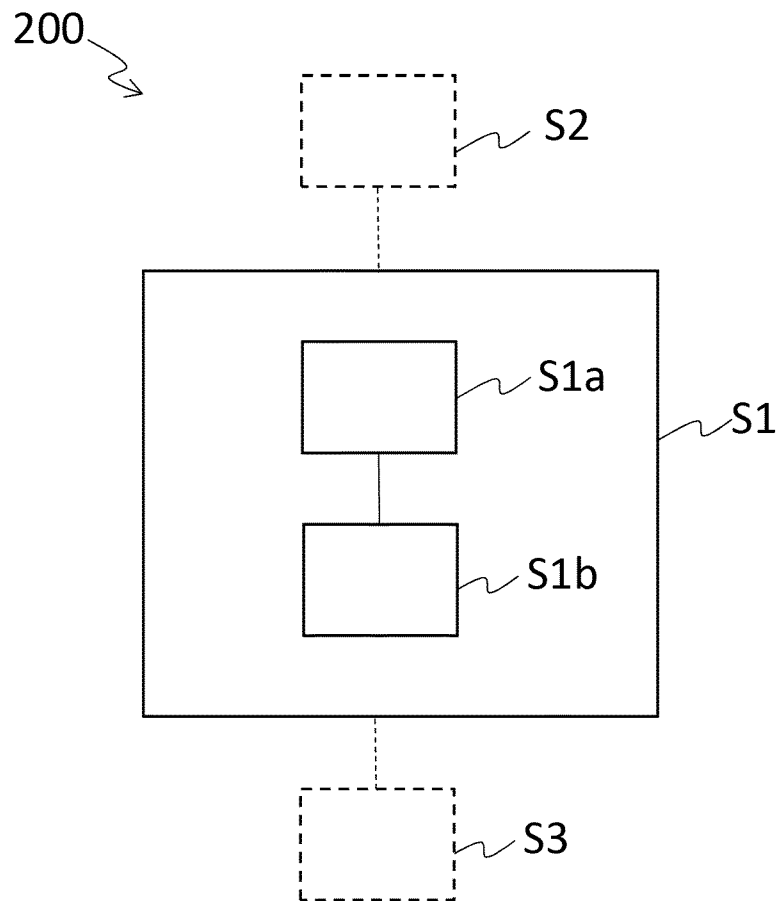


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/065075

A. CLASSIFICATION OF SUBJECT MATTER INV. F02B21/00 F02B33/44 F02B29/00 F01N3/00 F02M26/05 F02M26/06 F02M26/15 F02M26/43 ADD. 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) F01N F02B F02M Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data																				
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td style="vertical-align: top;">US 2011/251743 A1 (HU LUNG-TAN [CA] ET AL) 13 October 2011 (2011-10-13)</td> <td style="vertical-align: top;">1,2,5-8, 15-19, 23-26</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td style="vertical-align: top;">figures 1, 5C, 8, 12C, 16, 31</td> <td style="vertical-align: top;">3,4, 9-14, 20-22</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td style="vertical-align: top;">----- US 2014/158087 A1 (SILVER RONALD [US] ET AL) 12 June 2014 (2014-06-12) paragraph [0030] - paragraph [0032]; figure 1</td> <td style="vertical-align: top;">9-11,14, 20-22</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td style="vertical-align: top;">----- US 2015/260068 A1 (KUENZEL STEFAN [DE]) 17 September 2015 (2015-09-17) figure 1</td> <td style="vertical-align: top;">12,13</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td style="vertical-align: top;">----- US 6 138 616 A (SVENSSON ARNE [SE]) 31 October 2000 (2000-10-31) figure 2 -----</td> <td style="vertical-align: top;">3,4</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	US 2011/251743 A1 (HU LUNG-TAN [CA] ET AL) 13 October 2011 (2011-10-13)	1,2,5-8, 15-19, 23-26	Y	figures 1, 5C, 8, 12C, 16, 31	3,4, 9-14, 20-22	Y	----- US 2014/158087 A1 (SILVER RONALD [US] ET AL) 12 June 2014 (2014-06-12) paragraph [0030] - paragraph [0032]; figure 1	9-11,14, 20-22	Y	----- US 2015/260068 A1 (KUENZEL STEFAN [DE]) 17 September 2015 (2015-09-17) figure 1	12,13	Y	----- US 6 138 616 A (SVENSSON ARNE [SE]) 31 October 2000 (2000-10-31) figure 2 -----	3,4
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☐ 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 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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 29 January 2020	Date of mailing of the international search report 05/02/2020																			
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Kolodziejczyk, Piotr																			

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2019/065075

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1, 2, 5-8, 15-19, 23-26

Air injection system and method

2. claims: 9-14, 20-22

EGR system and method

3. claims: 3, 4

Air intake valve

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/065075

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011251743	A1	13-10-2011	NONE
US 2014158087	A1	12-06-2014	NONE
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