

Description

[0001] The present invention relates to an internal combustion engine comprising a system for exhaust gas recirculation and a method for running an internal combustion engine.

[0002] The present invention preferably relates to an internal combustion engine like a large marine or ship engine or a stationary engine whose cylinders have an inner diameter of at least 200 mm. The engine preferably is a two-stroke engine or a two-stroke cross head engine. The engine can be a diesel or a gas engine, a dual fuel or a multi fuel engine. Burning of liquid and or gaseous fuels in such engines is possible as well as self-igniting or forced igniting.

[0003] The engine has at least one cylinder having a piston therein. The piston is connected to a crankshaft. The piston reciprocates between a top dead centre (TDC) and a bottom dead centre (BDC) during operation of the engine. The cylinder typically has at least one air passage opening for intake, the air inlet in particular arranged in the liner of the cylinder, and at least one air passage opening for exhaust, the exhaust outlet in particular arranged in the cover of the cylinder.

[0004] The internal combustion engine can be a longitudinally flushed two-stroke engine.

[0005] The term internal combustion engine also refers to large engines which can be operated not only in diesel mode, which is characterised by the self-ignition of the fuel, but also in Otto mode, which is characterised by the positive ignition of the fuel, or in mixtures of the two. Furthermore, the term internal combustion engine includes in particular dual-fuel engines and large engines in which the self-ignition of the fuel is used for the positive ignition of another fuel.

[0006] Engine speed is preferably below 800 RPM (4-stroke) and more preferably below 200 RPM (2-stroke) which indicates the designation of low speed engines.

[0007] Fuel can be diesel or marine diesel oils or heavy fuel oils or emulsions or slurries or methanol or ethanol as well as gases like liquefied natural gas (LNG), liquefied petroleum gas (LPG) and so on.

[0008] Further possible fuels which might be added on request are: LBG (Liquefied Biogas), biological Fuels (e. g. Algae fuel or Seaweed Oil), hydrogen, synthetic fuels from CO₂ (e. g. made by Power-To-Gas or Power-To-Liquid).

[0009] To reduce the reactivity of gas/air mixture and methane slip, it is known to provide exhaust gas recirculation (EGR), in particular low pressure exhaust gas recirculation (EGR) as shown for example in EP 3 722 572 A1. A part of the exhaust gas is recirculated into the cylinder, while another part of the exhaust gas is guided to a funnel and is released into the environment.

[0010] After switching off exhaust gas recirculation, exhaust gas may remain in the pipes of the EGR path. As the pipes cool down, condensation may arise on the pipes' inner walls. This can lead to corrosion or damage

to the components of the EGR path and the compressor when exhaust gas recirculation is restarted.

[0011] Furthermore, when the engine is stopped, no exhaust gas must remain in the system so that the crew is not exposed to exhaust gas in case some maintenance needs to be performed.

[0012] Hence, the remaining exhaust gas should be purged.

[0013] From DE10260220A1 it is known to guide air through a high pressure EGR System. An engine control module controls the pressure on the intake side relative to the exhaust side to selectively direct air through the EGR system. DE 10 2013 225133 B4 teaches to flush an EGR path during interruption of the fuel supply.

[0014] However, air supply may be needed without interruption of the fuel supply.

[0015] It is an object of the present invention to avoid the drawbacks of the prior art and in particular to provide internal combustion engines comprising a system for exhaust gas recirculation and methods for running an internal combustion engine for supplying air to the EGR path to avoid or minimize accumulation or condensation of the EGR gases in the EGR path.

[0016] According to the invention an internal combustion engine, namely a large vessel engine or a stationary engine, comprises at least one cylinder having an inner diameter of at least 200mm.

[0017] The internal combustion engine comprises a turbocharger with a turbine and a compressor. During operation, the turbine is driven by exhaust gas and the compressor provides pressurized gas to be guided into the cylinder.

[0018] The internal combustion engine comprises a system for exhaust gas recirculation with an EGR path fluidly arranged between an exhaust outlet and an air inlet of the cylinder.

[0019] According to a first aspect of the invention the system for exhaust gas recirculation is a low-pressure system, wherein exhaust gas is guidable via the turbine of the turbocharger and at least a part of the exhaust gas may be branched off downstream the turbine and is guidable to the air inlet of the cylinder through the compressor of a turbocharger.

[0020] For example, 10%-70%, preferably 30%-60%, of the exhaust gas is recirculated.

[0021] The low-pressure EGR path comprises a flow regulating valve, preferably arranged upstream of the compressor and a shut-off valve, preferably arranged downstream of the turbine and upstream of the flow regulating valve.

[0022] Within this context the terms upstream and downstream are related to the flow direction of recirculated exhaust gas.

[0023] The EGR path may further comprise an exhaust gas-cooling device arranged between the flow regulating valve and the shut-off valve.

[0024] The internal combustion engine comprises an air-supply system for guiding scavenging air from a scav-

enge air-line and/or from a scavenge air-receiver into the EGR path on demand.

[0025] In the scavenge air-receiver scavenging air may be collected before it is introduced or sucked into the cylinder.

[0026] The scavenge air-line fluidly connects the compressor of the turbocharger which pressurizes fresh air with the air inlet of the cylinder or with the scavenge air-receiver.

[0027] The air-supply system may provide scavenging air for purging the EGR path, in particular after exhaust gas recirculation has ended or before exhaust gas recirculation starts, to clean the EGR path from exhaust gas residues and/or from condensed materials.

[0028] Alternatively, a small amount of scavenging air may also be provided for establishing a pressure within the EGR path to avoid leakage of exhaust gas through the closed but not sealed shut-off valve.

[0029] Typically, the flow regulating valve and the shut-off valve have a leakage of 0.5% of their full capacity. Thus, even if the shut-off valve is closed some exhaust gas may get into the EGR path. A sealing pressure within the EGR path may prevent this unwanted recirculation.

[0030] While for purging the air-supply system may provide a large amount of scavenging air for a limited time, for establishing a sealing pressure the air-supply system may provide a small amount of scavenging air during the time, when the internal combustion engine is operated without exhaust gas recirculation.

[0031] The air-supply system may comprise an air-supply line for guiding scavenging air. The air-supply line may be fluidly connected to the EGR path upstream of the flow regulating valve.

[0032] The air-supply line may be fluidly connected to the scavenge air-line and/or to the scavenge air-receiver.

[0033] Scavenging air contains fresh air. In case exhaust gas is or has been recirculated, scavenging air may also contain exhaust gas to a certain degree.

[0034] A flow limiting device, which preferably comprises at least one valve, may be arranged in the air-supply line.

[0035] The flow limiting device defines the amount of scavenging air which is guided into the EGR path.

[0036] The flow limiting device may be configured to take at least a state in which a first flowrate through the flow limiting device is allowed, which preferably is sufficient to purge the EGR path. The flow limiting device may also be configured to take a further state, wherein no flowrate through the flow limiting device is allowed.

[0037] Preferably, the flow limiting device may allow a variety of flowrates through the flow limiting device.

[0038] The flow limiting device may be configured to take at least three states. In a first state a first flowrate through the flow limiting device is allowed, preferably a flow rate sufficient to allow purging the EGR path. In a second state a second flowrate smaller than the first flowrate through the flow limiting device is allowed, preferably suitable to establish a sealing pressure in the EGR path.

In a third state no flowrate through the flow limiting device is allowed and the air-supply line is closed.

[0039] The states of the flow limiting device may correspond to respective positions or opening degrees of at least one valve.

[0040] Alternatively, the flow limiting device can be operated to give the required flow rate for each state of the air-supply system. The flow limiting device may for example be actively controlled based on a concentration, flow rate, temperature or pressure signal measured in the scavenge air-line, in the scavenge air-receiver, in the air-supply line and/or in the EGR path.

[0041] The air-supply system may comprise an air-supply control unit which is configured to control the amount of scavenging air flowing into the EGR path.

[0042] The air-supply control unit particularly is configured to set at least one valve arranged in the air-supply line. The air-supply control unit may be configured to set the flow limiting device as described above.

[0043] For purging a scavenging air amount of 1-3 times the volume of the EGR path is needed. This might cause a drop in the scavenge air-line of ca. 0.2 bar which is not critical.

[0044] A drop of ca. 0.2 bar in the scavenge air-line approximately corresponds to a flow of 4% of the engine air consumption.

[0045] For purging with the above parameters the flow limiting device has to be open for approximately 1-5 minutes when the engine is operating at full load.

[0046] For sealing, the flow limiting device shall allow a continuous flow of 0.3%- 0.8%, preferably 0.55%-0.65%, of the engine air consumption.

[0047] The system for exhaust gas recirculation may comprise an EGR-control unit configured to control the amount of exhaust gas recirculated to the air inlet. The EGR-control unit in particular is configured to set a valve. The EGR-control unit may be configured to set the flow regulating valve, the shut-off valve, a back pressure valve between the EGR path and the funnel and/or a blower arranged in the EGR path.

[0048] The air-supply control unit may be a part of the EGR-control unit or the air-supply control unit and the EGR-control unit may be a part of an engine control unit.

[0049] Preferably, the scavenge air-line comprises a scavenge air-cooling device. The scavenge air-cooling device may comprise a scavenge air-cooler and a water mist-collector.

[0050] The air-supply line may be branched off the scavenge air-line upstream of the scavenge air-cooling device. In this case hot air may be supplied into the EGR path. For the same mass of gas, hot gas has a higher volume. If scavenging air is branched off upstream of the scavenge air-cooling device, the loss of scavenging air can be minimized.

[0051] Alternatively, the air-supply line may be branched off the scavenge air-line downstream of the scavenge air-cooling device, for example from the scavenge air-receiver, and cooled scavenging gas may be

guided into the EGR path.

[0052] The air-supply line of an internal combustion machine as described above may be connected to the EGR path between the exhaust gas-cooling device and the flow regulating valve. Alternatively, the air-supply line may be connected to the EGR path between the shut-off valve and the exhaust gas-cooling device.

[0053] In case the air-supply line is connected to the EGR path between the exhaust gas-cooling device and the flow regulating valve, for purging the EGR path the flow regulating valve may be closed and the scavenging air may be guided through the opened shut-off valve towards the funnel. In this case, the scavenging air is directed against the direction of recirculated exhaust gas, that is, in reverse direction.

[0054] In case the air-supply line is connected to the EGR path between the shut-off valve and the exhaust gas-cooling device, for purging the EGR path the shut-off valve may be closed and the scavenging air may be guided through the opened flow regulating valve towards the compressor and the air inlet. In this case, the scavenging air is directed in the direction of recirculated exhaust gas, that is, in forward direction.

[0055] As the exhaust gas residues expelled from the EGR path in this case are guided through the cylinder, it takes longer before the cylinders stops receiving exhaust gas.

[0056] If both valves, the shut-off valve and the flow regulating valve are closed, a pressure is established in the EGR path, which prevents exhaust gas from entering the EGR path through a non-sealed shut-off valve.

[0057] The internal combustion engine may comprise an exhaust gas back pressure valve arranged between the EGR path and a funnel and/or a blower in the EGR path. The EGR rate may be influenced by opening or closing the back pressure valve and/or by controlling the speed of the blower, preferably by an EGR-control unit as described above.

[0058] Alternatively, the internal combustion engine may comprise a low pressure system for exhaust gas recirculation and the internal combustion engine may comprise an ambient air-supply system for guiding ambient air into the EGR path on demand. The air-supply system may comprise an ambient air-supply line for guiding ambient air, wherein the ambient air-supply line is fluidly connected to the EGR path upstream of the flow regulating valve and the air-supply line is fluidly connected to the environment.

[0059] A flow limiting device, preferably comprising at least one valve, may be arranged in the ambient air-supply line.

[0060] According to a second aspect of the invention the system for exhaust gas recirculation of the internal combustion engine is a high-pressure system.

[0061] For a high-pressure system the exhaust gas is branched off upstream of the turbine of the turbocharger. At least a part of the exhaust gas is guidable to the air inlet of the cylinder and mixable with scavenging air

downstream of the compressor of the turbocharger.

[0062] The high pressure EGR path comprises an EGR-blower, a first high pressure EGR valve, arranged upstream of the EGR-blower, and/or a second high pressure EGR valve, arranged downstream of the EGR-blower.

[0063] The high pressure EGR path may comprise only a first high pressure EGR valve or only a second high pressure EGR valve. For enabling exhaust gas recirculation the high pressure EGR valve is opened and the EGR-blower is switched on.

[0064] Preferably, the high pressure EGR path comprises a first and a second high pressure EGR valve. For enabling exhaust gas recirculation the first and the second high pressure EGR valves are opened and the EGR-blower is switched on.

[0065] The internal combustion engine comprises a purge control unit configured to allow guiding scavenging air from the scavenge air-line into the EGR path on demand. The purge control unit may be configured to switch the EGR-blower, to set the first high pressure EGR valve and/or to set the second high pressure EGR valve.

[0066] Under regular operating conditions of large two stroke engines, the pressure of the scavenging air is higher than the pressure in the exhaust manifold. Hence, for EGR operation, the EGR-blower has to be switched on.

[0067] In case of a high pressure EGR system, if the first and/or second high pressure EGR valves are temporarily left open after switching to non-EGR operation and switching-off the EGR-blower, the scavenging air flow will purge the EGR path in reverse direction. Reverse direction means a flow direction opposite to the flow direction of recirculated exhaust gas.

[0068] In case of two high pressure EGR valves one of the first and second high pressure EGR valves may be used as a flow restricting device (e.g. a position controlled valve), while the other only needs an open/close functionality.

[0069] When switching the high pressure EGR operation from ON to OFF, the EGR-blower is deactivated. The first and the second high pressure EGR valves may be left open, with either one of the two entering its flow restriction position.

[0070] Since the scavenging air pressure is higher than the exhaust pressure, a small flow of scavenging air will flow through the EGR path in reverse direction, purging exhaust gas from the system.

[0071] After a suitable length of time, the first and/or the second high pressure EGR valves may be closed completely and the purging process is complete. A sealing function is not required, since a small natural sealing flow of scavenging air will occur through the leakage of the two valves.

[0072] The high pressure EGR system may comprise an EGR-control unit for operating the first high pressure EGR valve, the second high pressure EGR valve and/or the EGR-blower.

[0073] The purge control unit may be part of the EGR-

control unit. The purge control unit and/or EGR-control unit may be part of an engine control unit.

[0074] According to a further aspect of the invention a method for running an internal combustion engine as described above comprises the following steps. Exhaust gas recirculating is switched on, at least a part of the exhaust gas is recirculated from the exhaust outlet to the air inlet and the exhaust gas recirculating is switched off. Subsequently scavenging air is guided from the scavenge air-line and/or from the scavenge air-receiver into the EGR path.

[0075] For an internal combustion machine with a low pressure EGR system as described above the flow limiting device may be opened, scavenging air may be guided through the flow limiting device arranged in the air-supply line. Subsequently the flow limiting device may be closed.

[0076] For switching on exhaust gas recirculation of a low pressure EGR system the shut-off valve and the flow regulating valve of an internal combustion engine with a low pressure EGR system as described above may be opened.

[0077] Additionally, an exhaust gas back pressure valve arranged between the EGR path and a funnel may at least partly be closed and/or a blower may be switched on.

[0078] For switching off exhaust gas recirculation of a low pressure EGR system the flow regulating valve may be closed.

[0079] Additionally, the exhaust gas back pressure valve may be completely opened and/or the blower may be switched off when or after the flow regulating valve is closed.

[0080] After guiding scavenging air into the EGR path the shut-off valve may be closed, preferably before the flow limiting device is closed.

[0081] Scavenging air may be guided through the EGR path in reverse or in forward direction.

[0082] For an internal combustion machine with a high pressure EGR system as described above the EGR-blower may be stopped.

[0083] The first high pressure EGR valve and/or the second high pressure EGR valve may be opened or may be kept open and scavenging air may be guided through the EGR path to purge the EGR path.

[0084] At least one of the first high pressure EGR valve and the second high pressure EGR valve may be set to a fully opened position and the other valve may be set to a partly opened position, such that the purging flow rate is limited.

[0085] Subsequently the first high pressure EGR valve and the second high pressure EGR valve may be closed.

[0086] Even after closing the first high pressure EGR valve and the second high pressure EGR valve a small amount of scavenging air may enter the EGR path and may establish a pressure within the EGR path, such that exhaust gas is prevented from entering the EGR path when EGR recirculation is switched off.

[0087] In the following, the invention is further explained in embodiments by means of figures. Same reference numbers refer to functionally corresponding features.

5 Figure 1: shows a schematic view of an internal combustion engine;

Figure 2: schematically shows a first example of a low pressure EGR system;

10 Figure 3: schematically shows a second example of a low pressure EGR system;

Figure 4: schematically shows an example of a high pressure EGR system;

15 Figure 5: schematically shows a first example for a flow limiting device;

Figure 6: schematically shows a second example for a flow limiting device;

20 Figure 7: schematically shows a third example of a low pressure EGR system.

[0088] Figure 1 shows an internal combustion engine 100, namely a large vessel engine, comprising at least one cylinder 1 having an inner diameter 2 of at least 200mm.

25 **[0089]** The internal combustion engine 100 comprises a turbocharger 5 with a turbine 6 driven by exhaust gas and a compressor 7 for providing pressurized scavenging air.

30 **[0090]** The internal combustion engine 100 comprises a low-pressure system 10 for exhaust gas recirculation with an EGR path 11 arranged between an exhaust outlet 3 and an air inlet 4 of the cylinder 1.

35 **[0091]** Figure 2 schematically shows a first example of a low pressure EGR system, which corresponds to the low-pressure system 10 for exhaust gas recirculation shown in Figure 1.

40 **[0092]** Exhaust gas is guided via the turbine 6 of the turbocharger 5. At least a part of the exhaust gas is guided towards the air inlet 4 of the cylinder 1 through the compressor 7, while another part is released to the environment by a funnel 17.

45 **[0093]** The low pressure EGR path 11 comprises a flow regulating valve 12, arranged upstream of the compressor 7, and a shut-off valve 13, arranged downstream of the turbine 6 and upstream of the flow regulating valve 12. For exhaust gas to be recirculated, the shut-off valve 13 is open. The amount of exhaust gas being recirculated can be influenced by setting the opening degree of the flow regulating valve 12 and a back pressure valve 15, arranged between the EGR path 11 and the funnel 17.

50 **[0094]** The low pressure EGR path 11 comprises an exhaust gas-cooling device 18 arranged between the shut-off valve 13 and the flow regulating valve 12.

55 **[0095]** The internal combustion engine 100 comprises an air-supply system 20 for guiding scavenging air from a scavenge air-line 8 into the EGR path 11 on demand. The air-supply system 20 comprises an air-supply line 21 which on the one hand is fluidly connected to the EGR

path 11 upstream of the flow regulating valve 12, and on the other hand is fluidly connected to the scavenge air-line 8.

[0096] Alternatively, the air-supply line 21 may be fluidly connected to a scavenge air-receiver 9 (shown with dashed lines).

[0097] A flow limiting device 22 is arranged in the air-supply line 21.

[0098] The scavenge air-line 8 comprises a scavenge air-cooling device 28.

[0099] In this example the air-supply line 21 is branched off the scavenge air-line 8 upstream of the scavenge air-cooling device 28. The air-supply line 21 is connected to the EGR path 11 between the exhaust gas-cooling device 18 and the flow regulating valve 12.

[0100] The internal combustion engine 100 comprises an air-supply control unit 23, which is configured to set the flow limiting device 22 and thus to control the amount of scavenging air flowing into the EGR path 11. The air-supply control unit 23 is part of an EGR control unit 14, which is configured to set the flow regulating valve 12, the shut-off valve 13 and the back pressure valve 15.

[0101] When exhaust gas recirculation has been ended typically the shut-off valve 13 as well as the flow regulating valve 12 are closed. The shut-off valve 13 may be opened while the flow regulating valve 12 remains closed and a large amount of scavenging air may be guided into the EGR path 11, which purges exhaust gas residues out of the EGR path via the open shut-off valve 13 towards the funnel 17.

[0102] Alternatively or successively, the shut-off valve 13 as well as the flow regulating valve 12 are closed and the flow limiting device 22 may be opened such that a small amount of scavenging air may be guided into the EGR path 11. A pressure may be established in the EGR path 11, which prevents exhaust gas from overcoming the closed but not sealed shut-off valve 13.

[0103] The purging direction is opposite to the flow direction during recirculation. Hence, this example is for so called "reverse purging".

[0104] To the contrary, Figure 3 schematically shows a second example of a low pressure EGR system for "forward purging".

[0105] In this example the air-supply line 21 is also branched off the scavenge air-line 8 upstream of the scavenge air-cooling device 28. A water mist catcher 31 is arranged downstream the scavenge air-cooling device 28.

[0106] In this example the air-supply line 21 is connected to the EGR path 11 between the shut-off valve 13 and the exhaust gas-cooling device 18, namely between the shut-off valve 13 and an economizer 19, which is arranged adjacently to the exhaust gas-cooling device 18 upstream with respect to the flow direction of the recirculated exhaust gas.

[0107] The exhaust gas-cooling device 18 is supplied by a cooling circuit 32.

[0108] When exhaust gas recirculation has been end-

ed and the shut-off valve 13 as well as the flow regulating valve 12 are closed. The flow regulating valve 12 may be opened while the shut-off valve 13 remains closed and a large amount of scavenging air may be guided into the EGR path 11, which purges exhaust gas residues out of the EGR path via the open flow regulating valve 12 towards the turbocharger 5 and the scavenge air-receiver 9.

[0109] Alternatively or successively, the shut-off valve 13 as well as the flow regulating valve 12 remain closed the flow limiting device 22 may be opened such that a small amount of scavenging air may be guided into the EGR path 11. A pressure may be established in the EGR path 11, which prevents exhaust gas from overcoming the closed but not sealed shut-off valve 13.

[0110] The purging direction corresponds to the flow direction during recirculation. Hence, this example is for so called "forward purging".

[0111] Figure 4 schematically shows an example of a high pressure EGR system 40.

[0112] The EGR path 41 also is arranged between the exhaust gas receiver 29 and the scavenge air-receiver 9.

[0113] The system 40 for exhaust gas recirculation is a high-pressure system, wherein exhaust gas is branched off upstream of the turbine 6 of a turbocharger 5 and at least a part of the exhaust gas is guided to the scavenge air-line 8 and mixed with fresh air downstream of the compressor 7 of the turbocharger 5.

[0114] The high pressure EGR path 41 comprises an EGR-blower 49, a first high pressure EGR valve 43, arranged upstream of the EGR-blower 49, and a second high pressure EGR valve 42, arranged downstream of the EGR-blower 49, as well as an exhaust gas-cooling device 18, arranged between the EGR-blower 49 and the second high pressure EGR valve 42.

[0115] A purge control unit 44 is configured to allow guiding scavenging air from the scavenge air-line 8 into the EGR path 41 on demand.

[0116] The purge control unit 44 is configured to switch the EGR-blower 49, to set the first high pressure EGR valve 43 and to set the second high pressure EGR valve 42.

[0117] The purge control unit 44 is part of an EGR-control unit 14 which also is configured to switch the EGR-blower 49, to set the first high pressure EGR valve 43 and to set the second high pressure EGR valve 42 in order to allow or to prevent exhaust gas recirculation.

[0118] For exhaust gas recirculation the first high pressure EGR valve 43 and the second high pressure EGR valve 42 are opened and the blower is switched on.

[0119] For stopping the exhaust gas recirculation the first high pressure EGR valve 43 and the second high pressure EGR valve 42 may be closed and the blower 49 is switched off.

[0120] After the exhaust gas recirculation has ended the first high pressure EGR valve 43 and the second high pressure EGR valve 42 may be opened such that scavenging air is guided through the EGR path 41 in reverse

direction towards the turbine 6 and the funnel 17, as the pressure in the scavenge air-line 8 is higher than in the exhaust gas line 36 upstream the turbine 6.

[0121] Figure 5 schematically shows a first example for a flow limiting device 22 comprising a butterfly valve 33 with a controllable position. The flow area and hence the allowed flow varies with the angle of the butterfly valve 33.

[0122] By setting the angle of the butterfly valve 33 a respective flowrate can be chosen, for example a flowrate sufficient for purging the EGR path, a flowrate for sealing or no flowrate at all.

[0123] Figure 6 schematically shows a second example for a flow limiting device 22. Two on/off butterfly valves 34, 35 are arranged in parallel. Either a small or a large cross section can be opened.

[0124] By choosing which of the butterfly valves 34, 35 is opened and which of the butterfly valves 34, 35 is closed, a larger, a smaller or no flow can be set.

[0125] Figure 7 schematically shows a third example of a low pressure EGR system 10.

[0126] In this example an ambient air-supply line 51 is fluidly connected to the environment. The ambient air-supply line 51 is connected to the EGR path 11 between the shut-off valve 13 and flow regulating valve 12, namely between the shut-off valve 13 and an economizer 19, which is arranged adjacently to an exhaust gas-cooling device 18 upstream with respect to the flow direction of the recirculated exhaust gas.

[0127] The ambient air-supply line 51 comprises a valve 52.

[0128] After a command to switch off exhaust gas recirculation, the valve 52 receives a command to open from a control unit, not explicitly shown in the figure, whereas the shut off valve 13 closes.

[0129] The back pressure valve 15 opens as well to let the entire stream of exhaust gas through. The flow regulating valve 12 remains open.

[0130] The compressor 7 continues to suck gas and thus ambient air from the environment. Hence, the EGR path 11 is purged. Additionally, the EGR path 11 may comprise an EGR-blower 49 to establish a sufficient pressure in the EGR path 11 and to drive gas through the EGR path 11.

[0131] Valves 13 and 52 are scheduled for opening and closing in a way to prevent the exhaust gases efflux into the environment through the ambient air path 51. During regular operation the pressure upstream the back pressure valve 15 exceeds the atmospheric pressure. Hence, the shut off valve 13 should be closed before the ambient air valve 52 is opened.

[0132] After a predefined purge time, the valve 52 and the flow regulating valve 12 are closed. The time also can be determined by measuring the gas composition inside the EGR path 11.

[0133] The EGR path 11 between can be pressurized between the shut of valve 13 and the flow regulating valve 12 to a required level in order to protect the EGR path

11 from ingress of ambient air or of exhaust gas using an air-supply system 20 as shown in one of figures 1-3.

5 Claims

1. Internal combustion engine (100), namely a large vessel engine or a stationary engine, comprising at least one cylinder (1) having an inner diameter (2) of at least 200mm,

the internal combustion engine (100) comprising a system (10) for exhaust gas recirculation with an EGR path (11) arranged between an exhaust outlet (3) and an air inlet (4) of the cylinder (1) and the internal combustion engine (100) comprising a turbocharger (5) with a turbine (6) and a compressor (7),

wherein the system (10) for exhaust gas recirculation is a low-pressure system, wherein exhaust gas is guidable via the turbine (6) of the turbocharger (5) and at least a part of the exhaust gas is guidable to the air inlet (4) of the cylinder (1) through the compressor (7) of a turbocharger (5),

and wherein the EGR path (11) comprises an flow regulating valve (12), arranged upstream of the compressor (7), and a shut-off valve (13), arranged downstream of the turbine (6) and upstream of the flow regulating valve (12),

characterized in that

the internal combustion engine (100) comprises an air-supply system (20) for guiding scavenging air from a scavenge air-line (8) and/or from a scavenge air-receiver (9) into the EGR path (11) on demand.

2. Internal combustion engine according to claim 1, wherein the air-supply system (20) comprises an air-supply line (21) for guiding scavenging air, wherein

- the air-supply line (21) is fluidly connected to the EGR path (11) upstream of the flow regulating valve (12),

- the air-supply line (21) is fluidly connected to the scavenge air-line (8) and/or to the scavenge air-receiver (9), and

- a flow limiting device (22), preferably comprising at least one valve (22), is arranged in the air-supply line (21).

3. Internal combustion engine according to claim 2, wherein the flow limiting device (22) is configured to take at least a state, wherein a first flowrate through the flow limiting device (22) is allowed, preferably the flow limiting device (22) is configured to take at least three states:

- a first state, wherein a first flowrate through the flow limiting device (22) is allowed,
 - a second state, wherein a second flowrate smaller than the first flowrate through the flow limiting device (22) is allowed, and
 - a third state, wherein no flowrate through the flow limiting device (22) is allowed.
4. Internal combustion engine according to at least one of the preceding claims, wherein the air-supply system (20) comprises an air-supply control unit (23), configured to control the amount of scavenging air flowing into the EGR path (11), wherein the air-supply control unit (23) particularly is configured to set at least one valve (22) arranged in the air-supply line (21), more particularly to set the flow limiting device (22) of an internal combustion engine according to claim 2.
5. Internal combustion engine according to at least one of the preceding claims, wherein the scavenge air-line (8) comprises a scavenge air-cooling device (28).
6. Internal combustion engine according to claim 2 and claim 5, wherein the air-supply line (21) is branched off the scavenge air-line (8) upstream of the scavenge air-cooling device (28) .
7. Internal combustion engine according to at least one of the preceding claims, wherein the EGR path (11) comprises an exhaust gas-cooling device (18), wherein in particular
- the air-supply line (21) of an internal combustion machine according to claim 2 is connected to the EGR path (11) between the exhaust gas-cooling device (18) and the flow regulating valve (12) or
 - the air-supply line (21) of an internal combustion machine according to claim 2 is connected to the EGR path (11) between the shut-off valve (13) and the exhaust gas-cooling device (18).
8. Internal combustion engine (100), namely a large vessel engine or a stationary engine, comprising at least one cylinder (1) having an inner diameter (2) of at least 200mm,
- the internal combustion engine (100) comprising a system (40) for exhaust gas recirculation with an EGR path (41) arranged between an exhaust outlet (3) and an air inlet (4) of the cylinder (1) and
 - the internal combustion engine (100) comprising a turbocharger (5) with a turbine (6) and a compressor (7), wherein the system (40) for exhaust gas recirculation is a high-pressure system, wherein exhaust gas is branched off upstream of the turbine (6) of the turbocharger (5) and at least a part of the exhaust gas is guidable to the air inlet (4) of the cylinder (1) and mixable with scavenging air downstream of the compressor (7) of the turbocharger (5), and wherein the EGR path (41) comprises an EGR-blower (49), a first high pressure EGR valve (43), arranged upstream of the EGR-blower (49), and/or a second high pressure EGR valve (42), arranged downstream of the EGR-blower (49),
- characterized in that**
- the internal combustion engine (100) comprises a purge control unit (44) configured to allow guiding scavenging air from a scavenge air-line (8) into the EGR path (41) on demand, in particular the purge control unit (44) is configured to switch the EGR-blower (49), to set the first high pressure EGR valve (43) and/or to set the second high pressure EGR valve (42).
9. Method for running an internal combustion engine (100) according to one of claims 1-8, comprising the steps of
- switching on exhaust gas recirculating;
 - recirculating at least a part of the exhaust gas from the an exhaust outlet (3) to the air inlet (4);
 - switching off exhaust gas recirculating;
 - guiding scavenging air from the scavenge air-line (8) and/or from the scavenge air-receiver (9) into the EGR path (11, 41).
10. Method according to claim 9, comprising the steps of
- opening the flow limiting device (22) arranged in the air-supply line of an internal combustion machine according to claim 2,
 - guiding scavenging air through the air-supply line (21),
 - closing the flow limiting device (22).
11. Method according to claim 9 or 10, wherein for switching on exhaust gas recirculation the shut-off valve (13) and the flow regulating valve (12) of an internal combustion engine according to claim 1 are opened.
12. Method according to claim 9, 10 or 11, wherein for switching off exhaust gas recirculation the flow regulating valve (12) of an internal combustion engine according to claim 1 is closed.
13. Method according to claim 9, 10, 11 or 12,

wherein after guiding scavenging air into the EGR path (11) the shut-off valve (13) of an internal combustion engine according to claim 1 is closed,

preferably before the flow limiting device (21) of an internal combustion machine according to claim 2 is closed. 5

14. Method according to claim 9, comprising the steps of 10

- stopping the EGR blower (49) of an internal combustion engine according to claim 8, 10
- preferably opening the first high pressure EGR valve (43) and/or the second high pressure EGR valve (42) of an internal combustion machine according to claim 8, 15
- guiding scavenging air through the EGR path (41),
- preferably closing the first high pressure EGR valve (43) and/or the second high pressure EGR valve (42). 20

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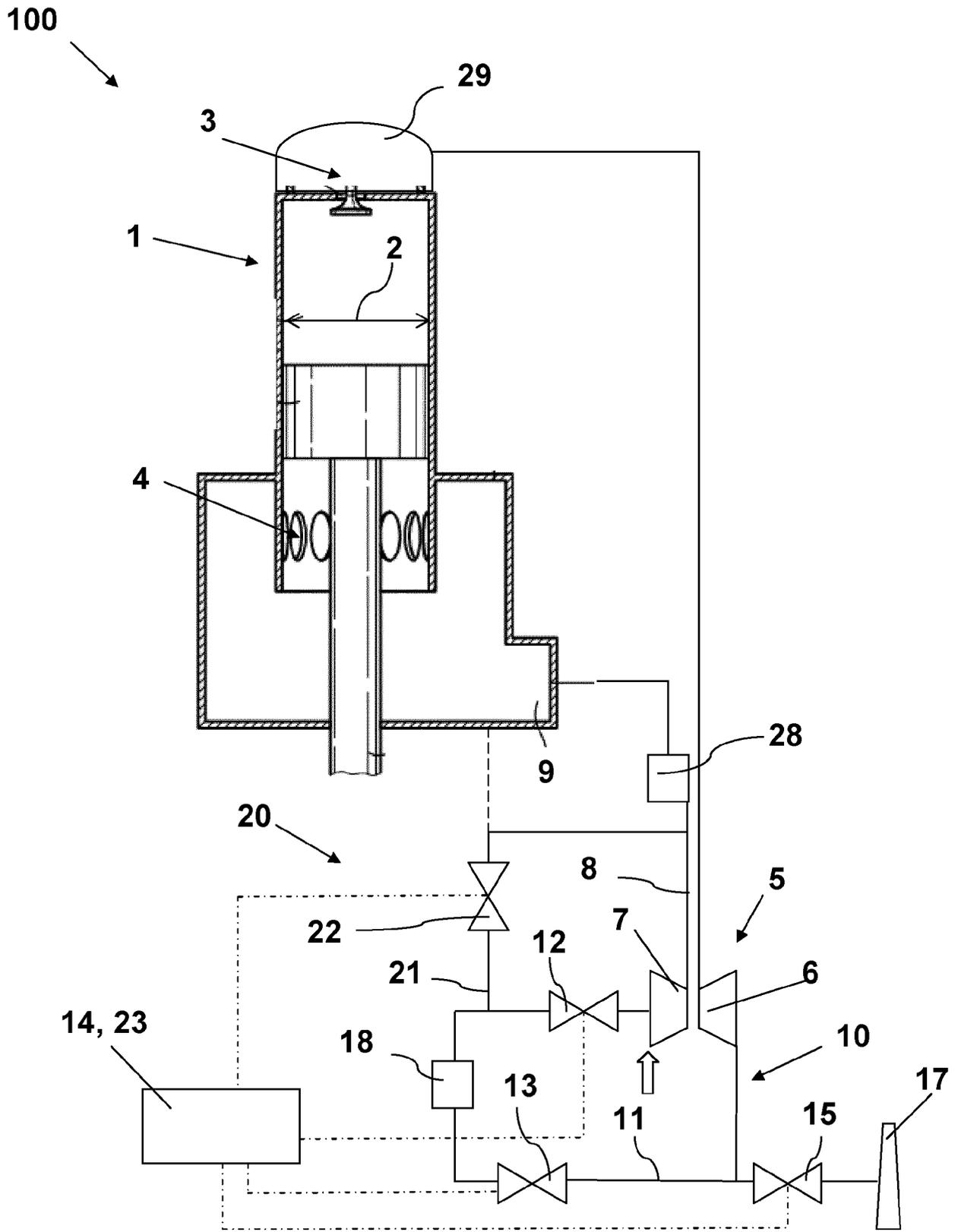


Fig. 1

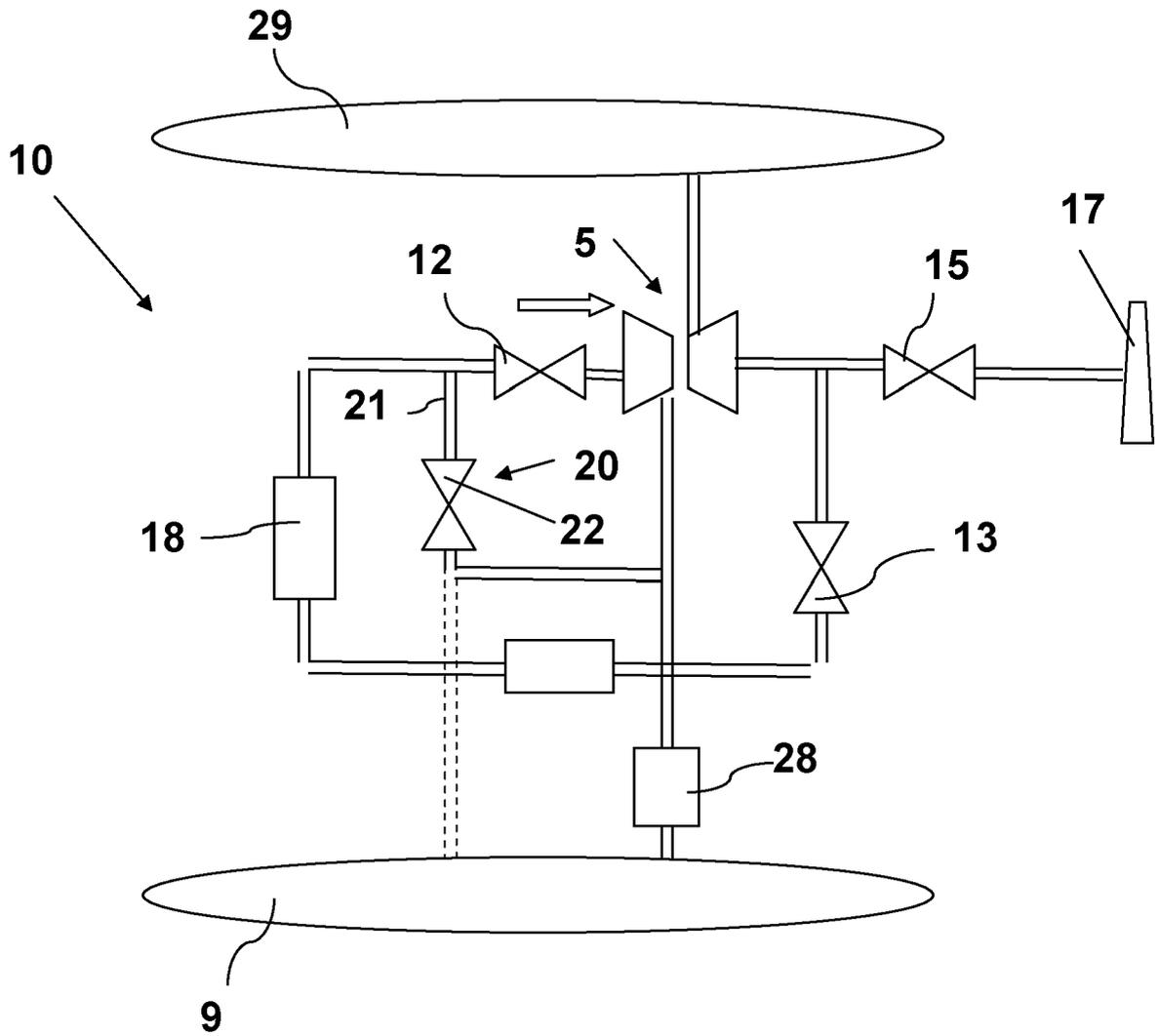


Fig. 2

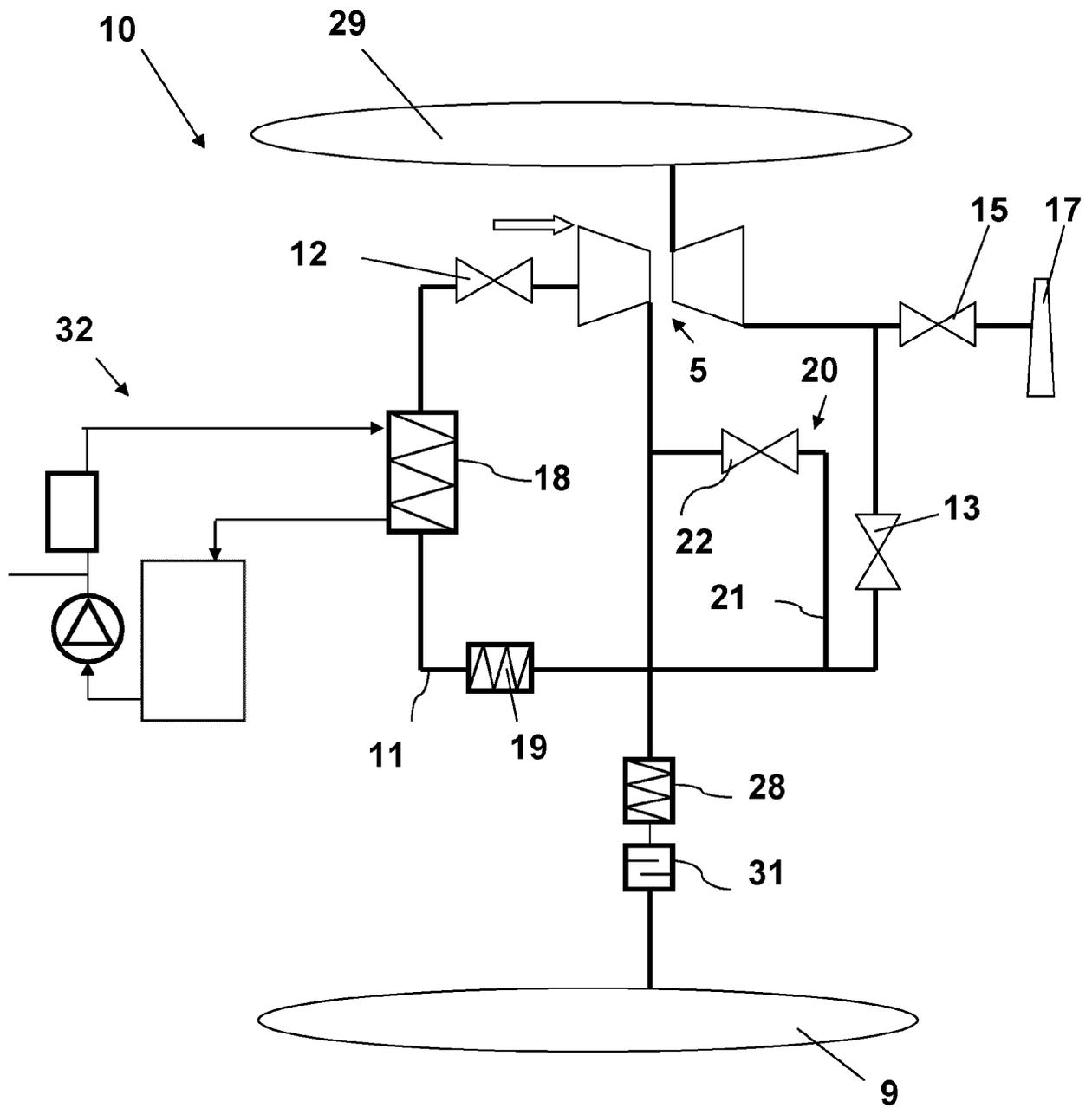


Fig. 3

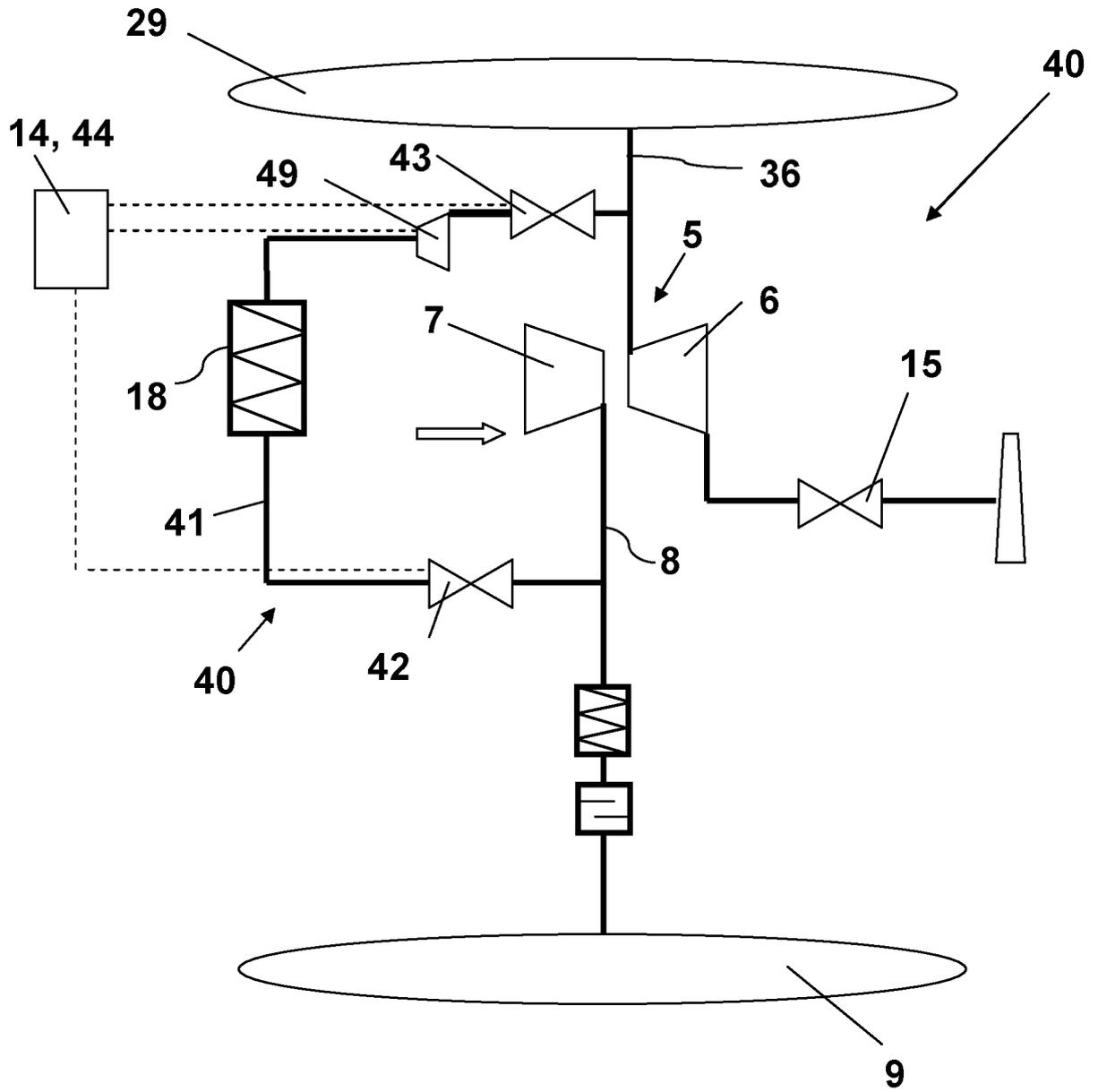


Fig. 4

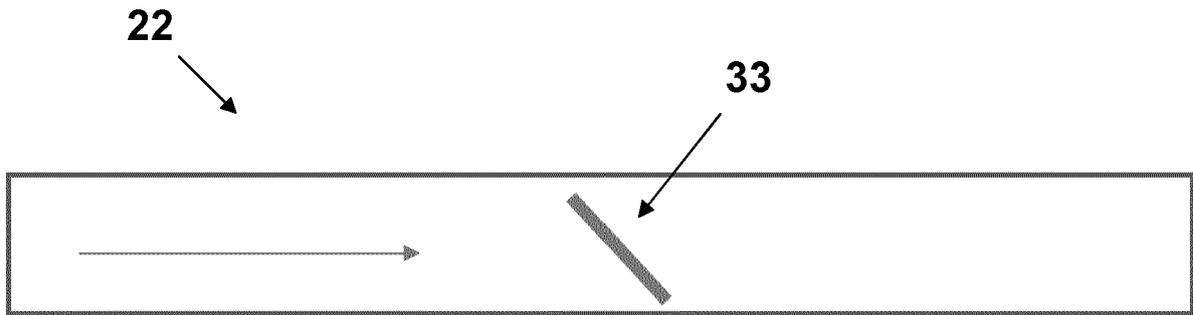


Fig. 5

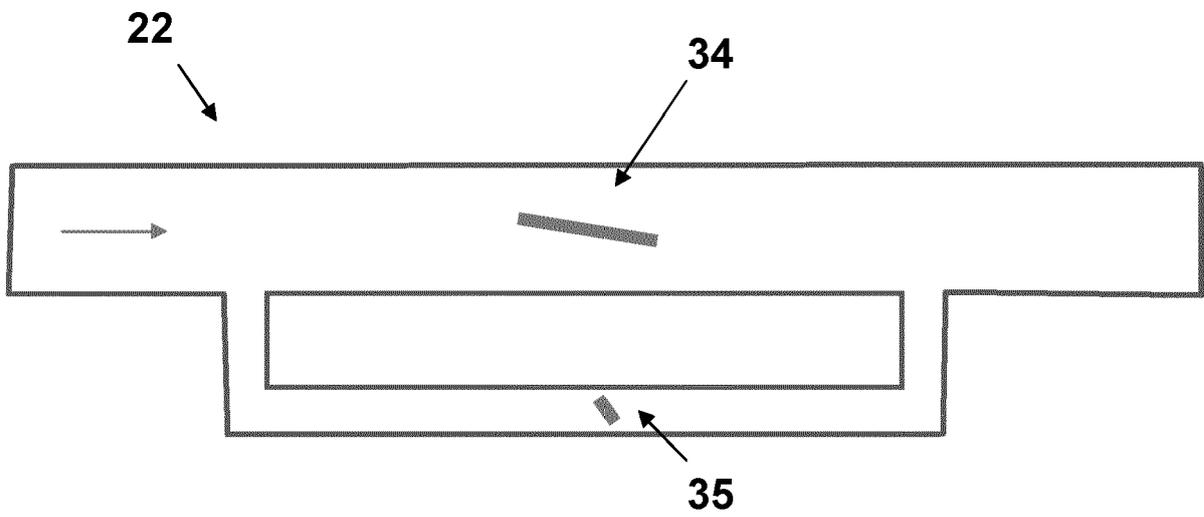


Fig. 6

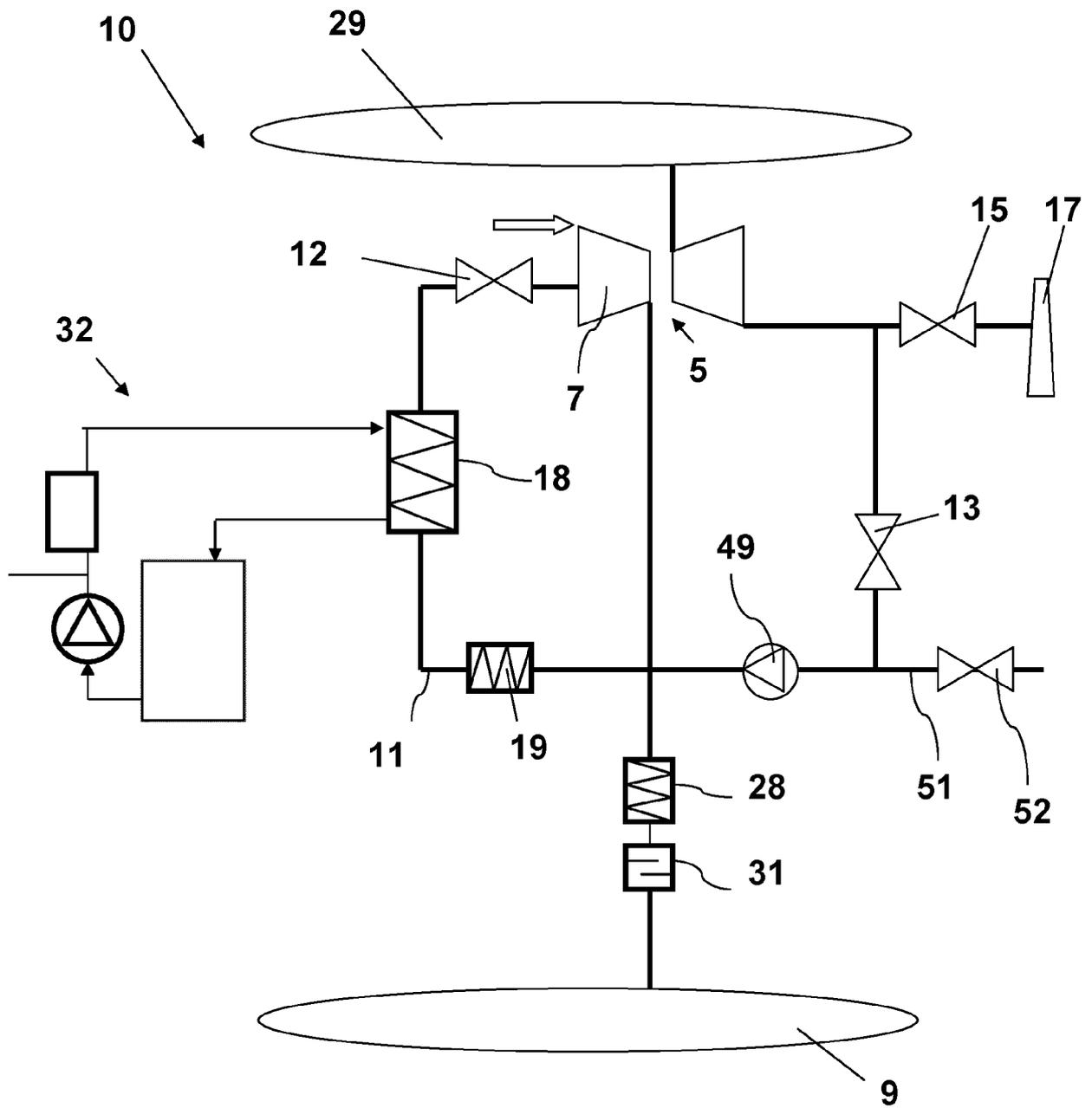


Fig. 7



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Place of search Munich		Date of completion of the search 16 September 2022	Examiner Juvenelle, Cyril
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 16 September 2022	Examiner Juvenelle, Cyril
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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