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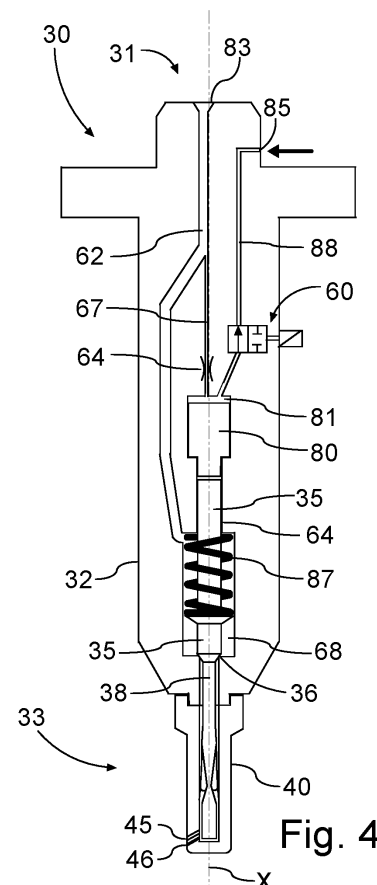
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(54) **A FUEL VALVE FOR INJECTING FUEL INTO THE CYLINDERS OF A LARGE TURBOCHARGED TWO-STROKE UNIFLOW SCAVENGED INTERNAL COMBUSTION ENGINE AND AN ENGINE WITH SUCH FUEL VALVES**

(57) A fuel valve (30) for injection of liquid fuel into a combustion chamber of a large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads, and a large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads with such fuel valves. The fuel valve (30) uses a resiliently biased valve member (35) that obtains lift through the pressure of the fuel supplied to the fuel valve (30) and is configured for performing either a pilot fuel injection or a main fuel injection, using a hydraulically controlled system using fuel as the hydraulic medium and controlled by an electronic control valve for determining whether a pilot injection or for a main injection is performed when the externally supplied fuel pressure is increased to perform an injection event.

**Fig. 4**

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a fuel valve for injecting liquid fuel into the cylinders of a large turbocharged two-stroke uniflow scavenged internal combustion engine and to an engine with such fuel valves.

BACKGROUND

[0002] Large turbocharged two-stroke uniflow scavenged crosshead internal combustion engines are typically used as prime movers in large ocean-going ships, such as container ships or power plants.

[0003] The cylinders of these engines are provided with a single exhaust valve centrally placed in the cylinder cover i.e. at the top of the cylinder and with a ring of piston controlled scavenge ports at the lower region of the cylinder liner. Accordingly, the direction of transport of gas through the cylinder is always from bottom to top, hence the designation uniflow scavenged. The scavenge ports are slanted to create a swirl in the gases in the combustion chamber.

[0004] Two or three fuel valves are disposed in the cylinder cover around the centrally placed exhaust valve, with their nozzles projecting into the combustion chamber. The fuel valves are peripherally disposed (i.e., not central) in the cylinder cover with the nozzle bores of the nozzles substantially directed with the swirl, away from the cylinder wall and into the combustion chamber.

[0005] Occasionally, a single nozzle hole of a nozzle is directed against the swirl in the combustion chamber.

[0006] A nozzle is attached to the forward or distal end of a fuel valve. The fuel valve comprises an elongated housing with the proximal or rear end protruding from the upper surface of the cylinder cover and with the elongated fuel valve housing extending through the cylinder cover and with the nozzle at the forward or distal end of the elongated fuel valve housing projecting into the combustion chamber.

[0007] Known nozzles for large two-stroke diesel engines of the crosshead type typically have a nozzle body comprising a cylindrical section with a straight main bore leading from the base of the nozzle at a proximal end of the nozzle body to nozzle bores that are located near the tip or distal end of the nozzle body. The tip or distal end can be round or flat but is closed since the nozzle bores must not be directed downwardly towards the piston (when the piston is at top dead center, i.e., the moment of fuel injection for a compression igniting engine, the upper surface of the piston is very close to the tip of the nozzle). Typically, each nozzle is provided with three to seven nozzle bores that are all connected to the main bore. Fuel valves that can deliver both the main injection and a pilot injection are typically provided with additional one or two smaller pilot nozzle bores, that are also connected to the main bore. These valves typically have a

displaceable valve member, and the pilot nozzle bores are typically opened with a small amount of lift of the displaceable valve member and, both the pilot nozzle bores and the main nozzle bores are opened at a larger amount of lift of the displaceable valve member.

[0008] Typically, the known fuel valves for injecting liquid fuel are provided with an axially displaceable valve needle that cooperates with a conical valve seat for controlling the flow of fuel to the nozzle. In addition, the forward section of the valve needle comprises a distal cylindrical that is tightly received in the main bore and acts as a slide valve for closing off the nozzle bores when the valve needle is in the closed position to thereby significantly reduce the so-called sac volume, i.e., the residual volume of fuel in the space formed by the main bore in the nozzle. Without such a slide valve arrangement, the volume of residual fuel in the main bore (and in the nozzle bores) would drip into the combustion chamber after a finished fuel injection event, which has detrimental effects on fuel consumption, reliability, and emissions.

[0009] KR102057802 discloses a fuel valve for a dual fuel engine comprising a valve body including a fuel passage through which fuel is supplied, a main injection hole communicating with the fuel passage, and a pilot injection hole; and a valve portion having a single valve needle which is elastically supported and moved in the valve body, and selectively opens and closes the main injection hole and the pilot injection hole in accordance with a fuel supply mode. A moving distance of the valve portion is determined by a pressing force applied inside the valve body. The valve needle simultaneously opens the main injection hole and the pilot injection hole when the fuel supply mode is a diesel mode and opens only the pilot injection hole when the fuel supply mode is a gas mode. Limiting the stroke to obtain only a pilot injection is obtained by applying high-pressure hydraulic oil to a displaceable obstruction plunger in the fuel valve. Accordingly, this known fuel valve requires, in addition to connection to the fuel supply system, a connection to a high-pressure hydraulic system and thus requires the engine to be provided with such a hydraulic system and requires each of the three or four fuel valves of the cylinder to be connected to the high-pressure hydraulic system via double-walled piping and each fuel valve to be connected to a valve block comprising a hydraulic valve that can handle high-pressure hydraulic oil. In this valve, it needs to be ensured that the hydraulic oil does not mix with the fuel or vice versa, and therefore, measures for such contamination such as seals or pressure barriers need to be provided in the fuel valve. These requirements render the fuel valve itself more expensive, render the engine more expensive due to the required additional equipment, and are less reliable since there will always exist a risk of mixing the fuel and the hydraulic oil.

[0010] US4285471A discloses a fuel injection nozzle according to the preamble of claim 1.

SUMMARY

[0011] In view of the above, it is an object of the present invention to provide a fuel valve for injecting liquid fuel into a large two-stroke uniflow scavenged internal combustion engine of the crosshead type that overcomes or at least reduces the problems mentioned above.

[0012] The foregoing and other objects are achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description, and the figures.

[0013] According to a first aspect, there is provided a fuel valve for injection of liquid fuel into a combustion chamber of a large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads, the fuel valve comprising:

- a fuel inlet port,
- a fuel control port,
- one or more main nozzle holes,
- one or more pilot nozzle holes,
- a valve member displaceable between a closed position and an open position and having an intermediate position between the closed position and the open position,

wherein the valve member is resiliently biased towards the closed position and hydraulically urged towards the open position by fuel pressure of the fuel inlet port acting on a first surface of the valve member,

wherein the valve member closes for flow of fuel to the one or more main nozzle holes and closes for flow of fuel to the one or more pilot nozzle bores in the closed position, wherein the valve member closes for flow of fuel to the one or more main nozzle holes and opens for flow to the one or more pilot nozzle bores in the intermediate position, wherein the valve member opens for flow of fuel to the one or more main nozzle holes and opens for flow to the one or more pilot nozzle bores in the open position,

- an arrangement for selectively obstructing displacement of the valve member from the intermediate position to the open position,

wherein the arrangement comprises:

- an obstruction member having a second surface that is exposed to a fuel pressure in a first fuel chamber,
- an electronically controlled valve, preferably a solenoid valve, the electronically controlled valve having at least a first position and a second position, the electronically controlled valve being configured to:

- cause the fuel pressure of the fuel supply port to be present in the first fuel chamber in the first position, and
- cause the fuel pressure of the fuel control port to be present in the first fuel chamber in the second position, the obstruction member being displaceable between an obstruction position wherein the obstruction member obstructs displacement of the valve member from the intermediate position to the open position, and a non-obstruction position wherein the obstruction member does not obstruct displacement of the valve member from the intermediate position to the open position,

wherein the obstruction member is configured to:

- move to the obstruction position when the fuel pressure of the fuel supply port is present in the first fuel chamber, and
- move to the non-obstruction position when the fuel pressure of the fuel control port is present in the first fuel chamber.

[0014] The fuel valve allows for precise control of pilot and main fuel injection into the combustion chamber of a large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads. This ensures optimal fuel-air mixture and combustion efficiency, resulting in improved engine performance and reduced emissions.

[0015] The arrangement for selectively obstructing displacement of the valve member provides enhanced control over the fuel injection process. By obstructing the valve member's movement from the intermediate position to the closed position, the fuel valve delivers an accurate pilot injection (small amount), ensuring accurate timing and duration of fuel injection.

[0016] The electronically controlled valve, preferably a solenoid valve, allows for quick and precise switching between the first and second positions, i.e., between pilot injection and main injection. This enables a seamless transition between pilot injection only and main injection, facilitating efficient fuel injection control.

[0017] The fuel valve uses fuel only as the pressure medium for obtaining lift of the valve member/needle and for the arrangement that causes the valve member to open to a position that only provides pilot injection through the smaller pilot nozzle openings or that provides injection through the larger main nozzle openings as well. Since fuel is the only hydraulic medium, there is no risk of mixing another pressure medium, such as hydraulic oil, with the fuel oil. This significantly reduces the need for measures that prevent the mixing of fuel and hydraulic oil, thereby greatly simplifying the construction of the need for creating barriers between two pressure media. Furthermore, the fuel valve does not require an external

control valve for activation, does not require double wall hydraulic pipes for hydraulic medium, does not require hydraulic control blocks associated with a hydraulic medium, and the fuel valve itself does not require internal seals, detection between media and parts adapted specifically for the hydraulic oil. Accordingly, the fuel valve itself and its installation in the engine are significantly simplified. It only requires cabling for installation but no hydraulic control valve and no double wall piping for the hydraulic medium.

[0018] The fuel valve's resilient bias towards the closed position ensures that the valve member remains closed for the flow of fuel to the main nozzle holes and pilot nozzle bores when not in use. This prevents fuel leakage and potential safety hazards.

[0019] The hydraulic urging of the valve member towards the open position by fuel pressure of the fuel inlet port allows for smooth and controlled opening of the valve. This ensures consistent and reliable fuel flow to the main nozzle holes and pilot nozzle bores during operation.

[0020] The valve member's ability to open for flow of fuel to both the main nozzle holes and pilot nozzle bores in the open position and to open for flow of the fuel through the pilot nozzle bores only provides flexibility in fuel injection strategies and enables the fuel injection valves to be used for pilot injection only, e.g. when the main fuel is a different fuel (dual fuel engine), for example, natural gas, that is delivered to the combustion chambers by a separate fuel valve specifically designed for delivering the other (main) fuel. This allows for the optimization of combustion characteristics based on engine operating conditions, resulting in improved performance and fuel efficiency.

[0021] In a possible implementation of the first aspect, the first fuel chamber is permanently connected to the fuel inlet port via a conduit that includes a flow restriction, and wherein the electronically controlled valve connects the first fuel chamber to the fuel control port in the second position.

[0022] The fluidic connection between the first fuel chamber and the fuel inlet port and fuel control port ensures efficient fuel supply and control. This eliminates the need for additional fuel lines or connections, simplifying the fuel valve design and reducing potential points of failure.

[0023] The permanent connection between the first fuel chamber and the fuel inlet port via a conduit that includes a flow restriction allows for the pressure in the first fuel chamber to be changed to the pressure of the fuel control port by opening a conduit that establishes a fluidic connection to the fluid control port since the flow restriction will restrict flow from the fuel supply port to the first fuel chamber and therefore the flow from the fuel supply port will be insufficient for maintaining the pressure of the fuel supply port in the first fuel chamber.

[0024] The electronically controlled valve's ability to connect the first fuel chamber to the fuel control port in

the second position provides precise control over fuel pressure in the first fuel chamber. This allows for adjusting the operation of the fuel valve to pilot injection or main injection.

5 **[0025]** In a Possible implementation form of the first aspect, the electronically controlled valve connects the first fuel chamber to the fuel inlet port in the first position and connects the first fuel chamber to the fuel control port in the second position.

10 **[0026]** The electronically controlled valve's ability to connect the first fuel chamber to the fuel inlet port in the first position ensures that the pressure in the first fuel chamber corresponds to the pressure in the supply port.

[0027] This causes the pressure in the fuel supply port to be such that the obstruction member moves to the position where it limits the movement of the valve member to the intermediate position and obstructs movement to the open position.

[0028] The electronically controlled valve's ability to connect the first fuel chamber to the fuel control port in the second position ensures that the pressure in the first fuel chamber corresponds to the pressure in the fuel control port. This causes the pressure in the first fuel chamber to correspond to the pressure in the fuel control port. Since the pressure in the fuel control port is chosen differently, preferably lower, compared to the pressure in the fuel supply port, this causes the obstruction member to move to a position in which it does not obstruct displacement of the valve member to the open position, thereby allowing the opening of the main nozzle openings.

[0029] The size difference between the first surface of the valve member and the second surface of the obstruction member ensures reliable movement of the obstruction member to the obstructing position. This prevents lift of the valve member to the open position when the fuel pressure of the fuel supply port is present in the first fuel chamber, ensuring pilot injection.

[0030] In a possible implementation form of the first aspect, the size of the first surface of the valve member is smaller than the size of the second surface of the obstruction member.

[0031] The fuel valve's ability to selectively obstruct displacement of the valve member from the intermediate position to the closed position provides control over the operation mode of the fuel valve, i.e. pilot injection or main injection. This allows the fuel valve to be used as a pilot fuel valve for assisting ignition of a main fuel that is delivered by separate fuel valves specifically for delivering the main fuel and to be used as a main fuel valve for a liquid fuel. Accordingly, the present fuel valve is particularly suitable for use in a dual fuel engine, where the person valve can be used for injection of a liquid fuel and for main injection of a liquid fuel. The obstruction member's movement to the obstruction position when the fuel pressure of the fuel supply port is present in the first fuel chamber ensures reliable obstruction of the valve member.

[0032] The obstruction member's movement to the non-obstruction position when the fuel pressure of the fuel control port is present in the first fuel chamber allows for unobstructed displacement of the valve member.

[0033] In a possible implementation form of the first aspect, the obstruction member comprises a plunger received with a tight fit in a bore, the obstruction member having a third surface arranged oppositely to the second surface, and wherein the valve member has a fourth surface opposite to the first surface and contralateral to the third surface. The tight fit between the plunger and the bore of the obstruction member ensures a secure and reliable obstruction position, preventing any leakage or unintended movement.

[0034] The arrangement of the third surface on the obstruction member and the fourth surface on the valve member allows for a precise and stable abutment when the obstruction member is in the obstruction position and the valve member is in the intermediate position, ensuring proper functioning of the valve system.

[0035] The lift of the displaceable valve member from the valve seat in the open- and intermediate positions allows for controlled flow of liquid fuel.

[0036] In a possible implementation form of the first aspect, the fourth surface abuts the third surface when the obstruction member is in the obstruction position, and the valve member is in the intermediate position.

[0037] The attachment of the base of the nozzle body to the distal end of the fuel valve provides a secure and stable connection, minimizing the risk of detachment or leakage during operation.

[0038] In a possible implementation form of the first aspect, the displaceable valve member rests on a valve seat in the closed position and the displaceable valve member has lift from the valve seat in the open- and intermediate positions.

[0039] The use of a plunger received with a tight fit in a bore for the obstruction member ensures a secure and reliable obstruction position, preventing any leakage or unintended movement.

[0040] The arrangement of the third surface on the obstruction member and the fourth surface on the valve member allows for a precise and stable abutment when the obstruction member is in the obstruction position and the valve member is in the intermediate position, ensuring proper functioning of the fuel valve.

[0041] In a possible implementation form of the first aspect, the nozzle comprises a nozzle body extending along the longitudinal axis from a base at a proximal end of the nozzle body to a closed distal end of the nozzle body, the base preferably being attached to the distal end of the fuel valve.

[0042] The attachment of the base of the nozzle body to the distal end of the fuel valve provides a secure and stable connection, minimizing the risk of detachment or leakage during operation.

[0043] In a possible implementation form of the first aspect, the nozzle body comprises:

an elongated, preferably cylindrical portion extending between the base and the closed distal end, an inlet opening to the base for receiving liquid fuel from the fuel valve, and

a single straight main bore extending longitudinally from the inlet into the nozzle body.

[0044] The tight fit between the plunger and the bore of the obstruction member ensures a secure and reliable obstruction position, preventing any leakage or unintended movement.

[0045] The arrangement of the third surface on the obstruction member and the fourth surface on the valve member allows for a precise and stable abutment when the obstruction member is in the obstruction position and the valve member is in the intermediate position, ensuring proper functioning of the valve system.

[0046] In a possible implementation form of the first aspect, the displaceable valve member comprises a distal section with a cylindrical end section carried by a shank and which is journaled with tight fit in the straight main bore in order to:

fluidically disconnect the main nozzle holes and the pilot nozzle holes from the main straight bore when the displaceable valve member is in the closed position,

fluidically disconnect the main nozzle holes from the main straight bore and fluidically connect the pilot nozzle holes to the main straight bore when the displaceable valve member is in the intermediate position,

fluidically connect the main nozzle holes and the pilot nozzle holes to the main straight bore when the displaceable valve member is in the open position.

[0047] In a possible implementation form of the first aspect, the cylindrical end section is hollow to form a fluid passage, the fluid passage preferably opening proximally to the exterior of the shank and the fluid passage preferably opening distally in an axial direction.

[0048] In a possible implementation form of the first aspect, the cross-sectional area of the pilot nozzle holes is smaller than the cross-sectional area of the main nozzle holes.

[0049] In a possible implementation form of the first aspect, the main and/or pilot nozzle holes are bores.

[0050] In a possible implementation form of the first aspect, the main nozzle holes and the pilot nozzle holes connect to the main bore at axially spaced positions.

- This configuration allows for precise control of fluid flow through the nozzle system, as the main and pilot nozzle holes can be independently regulated.

- By connecting the main and pilot nozzle holes at axially spaced positions, the degree of lift of the valve member determines whether there is no injection at all, injection only through the pilot nozzle holes, or

injection through both the pilot nozzle holes and the main nozzle holes.

[0051] In a possible implementation form of the first aspect, the displaceable valve member comprises a distal section with a cylindrical end section carried by a shank, which is journaled with tight fit in the straight main bore.

- The tight fit between the cylindrical end section and the main bore ensures a secure and reliable connection, preventing any leakage or loss of fluid during operation.
- This design also allows for smooth and precise movement of the displaceable valve member, ensuring accurate control of fluid flow through the nozzle system.

[0052] In a possible implementation form of the first aspect the cylindrical end section is hollow to form a fluid passage, the fluid passage preferably opening proximally to the exterior of the shank and the fluid passage preferably opening distally in an axial direction.

- The hollow cylindrical end section provides a dedicated fluid passage, allowing for efficient and controlled flow of fluid through the nozzle system.
- By opening the fluid passage proximally to the exterior of the shank and distally in an axial direction, the fluid can be directed precisely to the desired location, enhancing the overall performance and functionality of the nozzle system.

[0053] In a possible implementation form of the first aspect, the cross-sectional area of the pilot nozzle holes is smaller than the cross-sectional area of the main nozzle holes.

- This configuration allows for precise control of a small flow of fuel through the nozzle system for pilot injection, as the smaller cross-sectional area of the pilot nozzle holes restricts the flow compared to the main nozzle holes.
- By having different cross-sectional areas for the pilot and main nozzle holes, the fuel flow rate can be selected, providing flexibility and versatility in various applications, in particular in dual-fuel engines.

[0054] In a possible implementation form of the first aspect, the main and/or pilot nozzle holes are bores.

- Using bores for the main and/or pilot nozzle holes ensures a smooth and consistent flow of fluid through the nozzle system.
- Bore-based nozzle holes also provide better control over the flow characteristics, allowing for more accurate and efficient operation of the nozzle system.

[0055] In a possible implementation form of the first aspect, the main nozzle holes and the pilot nozzle holes connect to the main bore at axially spaced positions.

- By connecting the main and pilot nozzle holes at axially spaced positions, the magnitude of the flow of fuel can be selected for pilot injection or main injection.

[0056] In a possible implementation form of the first aspect, the displaceable valve member comprises a distal section with a cylindrical end section carried by a shank, which is journaled with tight fit in the straight main bore.

- The tight fit between the cylindrical end section and the main bore ensures a secure and reliable operation, preventing any leakage or loss of fluid during operation.
- This design also allows for smooth and precise movement of the displaceable valve member, ensuring accurate control of fluid flow through the nozzle system.

[0057] In a possible implementation form of the first aspect, the cylindrical end section is hollow to form a fluid passage, the fluid passage preferably opening proximally to the exterior of the shank and the fluid passage preferably opening distally in an axial direction.

- The hollow cylindrical end section provides a dedicated fluid passage, allowing for efficient and controlled flow of fluid through the nozzle system.
- By opening the fluid passage proximally to the exterior of the shank and distally in an axial direction, the fluid can be directed precisely to the desired location.

[0058] In a possible implementation form of the first aspect, the valve member is a valve needle that is slidably received in a longitudinal bore in the elongated valve body, the displaceable valve member resting on a valve seat in the closed position and the valve needle having lift from the valve seat in the open- and intermediate positions.

[0059] The use of a valve needle as the valve member allows for precise control of the fuel flow in the engine, as the needle can be easily adjusted to vary the lift from the valve seat in the open- and intermediate positions.

[0060] By disposing the valve seat and/or the fuel chamber in the elongated valve body, the overall size and complexity of the fuel injection system can be reduced, leading to cost savings in manufacturing and maintenance.

[0061] Ensuring that all of the main nozzle holes have substantially equal main cross-sectional area or diameter, and preferably also substantially equal length, promotes uniform fuel flow distribution over the nozzle

holes, resulting in improved engine performance and efficiency.

[0062] In a possible implementation form of the first aspect, the valve seat and/or the fuel chamber are disposed in the elongated valve body.

[0063] In a possible implementation form of the first aspect, all of the main nozzle holes have substantially equal main cross-sectional area or diameter and preferably also substantially equal length.

[0064] In a possible implementation form of the first aspect, the main nozzle bores and/or the pilot nozzle bores open to the surface of the elongated, preferably cylindrical portion.

[0065] In a possible implementation form of the first aspect, the electronically controlled valve is a spool valve, preferably a sliding spool valve, more preferably a sliding spool solenoid valve.

[0066] In a possible implementation form of the first aspect, the fuel valve comprises a preferably rounded transition surface between the substantially cylindrical portion and a flat distal end surface of the nozzle body.

[0067] In a possible implementation form of the first aspect, the straight nozzle bores each have a nozzle axis, wherein the nozzle axis of each of the nozzle bores is arranged at an obtuse angle α with the main direction X.

[0068] In a possible implementation form of the first aspect, the radial components of each of the nozzle axis relative to the longitudinal axis (X) are distributed, preferably substantially equally distributed, over a circular sector with an arc less than 120 deg.

[0069] According to a second aspect, there is provided a large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads comprising a fuel valve according to the first aspect and any Possible implementations thereof.

[0070] These and other aspects of the invention will be apparent from the embodiments described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0071] In the following detailed portion of the present disclosure, the invention will be explained in more detail with reference to the example embodiments shown in the drawings, in which:

Fig. 1 is an elevated view showing the fore end and one lateral side of a large two-stroke unit flow scavenged turbocharged engine according to an example embodiment,

Fig. 2 is an elevated view showing the aft end and the other lateral side of the engine of Fig. 1,

Fig. 3 is a diagrammatic representation of the engine according to Fig. 1 with its intake and exhaust systems,

Fig. 4 is a sectional view of an embodiment of a fuel valve for use in the engine of Figs. 1 to 3 before a fuel injection event with the valve member in a closed position,

Fig. 5 is a sectional view of the fuel valve of Fig. 4 during a fuel injection event with the valve member in the open position and the obstruction member in a non-obstructing position,

Fig. 6 is a sectional view of the nozzle of the fuel valve of Fig. 4 in greater detail,

Fig. 7 is a sectional view of the nozzle of the fuel valve of Fig. 5 in greater detail,

Fig. 8 shows the fuel valve of Fig. 4 before a fuel injection event with the valve member in the closed position,

Fig. 9 is a sectional view of the fuel valve of Fig. 4 during a fuel injection event with the valve member in the open position and the obstruction member in an obstructing position,

Fig. 10 is a sectional view of the nozzle of the fuel valve of Fig. 8 in greater detail,

Fig. 11 is a sectional view of the nozzle of the fuel valve of Fig. 9 in greater detail,

Fig. 12 is an elevated view of the tip of the nozzle of the fuel valve of Fig. 4,

Figs. 13 and 14 are transparent views of the tip of the nozzle of Fig. 12, and

Fig. 15 is a diagrammatic representation of the position of the nozzles of the fuel valves of Fig. 4 in the cylinder cover of the engine, as seen from the side of the piston and illustrating the orientation of the nozzle bores and the resulting fuel jets.

DETAILED DESCRIPTION

[0072] In the following detailed description, a fuel valve, and a large two-stroke engine in which the fuel valve is used will be described by the example embodiments. Figs. 1 to 3 show a large low-speed turbocharged two-stroke internal combustion engine with a crankshaft 22 and crossheads 23. Fig. 3 shows a diagrammatic representation of a large low-speed turbocharged two-stroke internal combustion engine with its intake and exhaust systems. In this example embodiment, the engine has six cylinders (that are formed by cylinder liners 1) in line. Large turbocharged two-stroke internal combustion engines have typically between five and sixteen cylinders in line, carried by an engine frame 24. The engine may, e.g., be used as the main engine in an ocean-going vessel or as a stationary engine for operating a generator in a power station. The total output of the engine may, for example, range from 5,000 to 110,000 kW.

[0073] The engine can be a diesel (compression-igniting) engine of the two-stroke uniflow type with scavenge ports 19 in the form of a ring of piston-controlled ports at the lower region of the cylinder liners 1 and an exhaust valve 4 at the top of the cylinder liners 1. Thus, the flow in the combustion chamber is always from the bottom to the top, and thus, the engine is of the so-called uniflow type. The scavenging air is passed from the scavenging air receiver 2 to the scavenging air ports 19 of the individual

cylinders that are formed by the cylinder liners 1. A reciprocating piston 21 in the cylinder liner 1 compresses the scavenging air; fuel is injected via the nozzles of two or three fuel valves 30 that are arranged in the cylinder cover 26. Combustion follows, and exhaust gas is generated. When an exhaust valve 4 is opened, the exhaust gas flows through an exhaust duct 20 associated with the cylinder 1 concerned into an exhaust gas receiver 3 and onwards through a first exhaust conduit 18 to a turbine 6 of the turbocharger 5, from which the exhaust gas flows away through a second exhaust conduit 7. Through a shaft 8, the turbine 6 drives a compressor 9 supplied via an air inlet 10.

[0074] The compressor 9 delivers pressurized charging air to a charging air conduit 11 leading to the charging air receiver 2. The scavenging air in the conduit 11 passes through an intercooler 12 for cooling the charging air. The cooled charging air passes via an auxiliary blower 16 driven by an electric motor 17 that pressurizes the charging air flow in low or partial load conditions to the charging air receiver 2. At higher loads, the turbocharger compressor 9 delivers sufficient compressed scavenging air, and then the auxiliary blower 16 is bypassed via a non-return valve 15.

[0075] The cylinders are formed in a cylinder liner 1. The cylinder liners 1 are carried by a cylinder frame 25 that is supported by the engine frame 24.

[0076] Fig. 15 illustrates how the nozzles 40 are peripherally positioned in the cylinder cover 26 around the exhaust valve 4 and illustrates the direction of the fuel jets (which corresponds to the direction of the axes I, II, III, IV, and V of the main nozzle holes 45 in the nozzles 40. There are typically at least four main nozzle holes 45 and typically one or two pilot nozzle holes 46. The direction of the fuel jets from the pilot nozzle holes 46 is similar to that of the direction of the main nozzle holes 45. Typically, each cylinder is provided with three (as shown) or 4 fuel valves 30. In a dual-fuel engine, there will be another 3 or 4 fuel valves (not shown) for injecting the other fuel; when the other fuel valves are in action, the present fuel valves 30 are used for pilot fuel injection only. When the other fuel is not used, the present fuel valves 30 are used for the main fuel injection. The direction of the swirl of the gases in the combustion chamber is illustrated by the curved interrupted arrow 96.

[0077] The cross-sectional area of the pilot nozzle holes 46 is smaller than the cross-sectional area of the main nozzle holes 45, and there are typically fewer pilot nozzle holes 46 than main nozzle holes 45, so the amount of fuel that is injected at a given fuel injection pressure through the pilot nozzle holes 46 only is significantly smaller than the amount of fuel injected through the pilot nozzle holes 46 and the main nozzle holes 45 combined. Preferably, all of the main nozzle holes 45 have substantially equal main cross-sectional area or diameter and preferably also substantially equal length, and preferably all of the pilot nozzle holes 46 have substantially equal pilot cross-sectional area or diameter and preferably also

a substantially equal length. The main cross-sectional area or diameter of the main nozzle bores 45 is larger than the pilot cross-sectional area or diameter of the pilot nozzle bores 46.

[0078] Figs. 4 to 11 illustrate an embodiment of the two to four fuel valves 30 that are mounted in a through-going bore in the cylinder cover 26 of each cylinder with the rear end 31 of the fuel valve 30 protruding from the upper side of the cylinder cover 26 and with the distal end (tip) of the nozzle 40 marginally protruding into the combustion chamber.

[0079] Figs. 12 to 14 illustrate the distal end of the nozzle 40 in greater detail.

[0080] The fuel valve 30 comprises an elongated fuel valve body 32 with a nozzle 40 distal (forward) end 33. Liquid fuel (e.g. ethanol, methanol, diesel, heavy fuel oil) is delivered in a controlled and timed manner by the fuel valve 30 to the combustion chamber 14 via the nozzle 40.

[0081] The fuel valve 30 has an elongated body 32, which at its proximal end 31 has a head by which the fuel valve 30, in a known manner, may be mounted in the cylinder cover 26 and be connected with a fuel pump (not shown) of the internal combustion engine. The fuel pump increases the fuel pressure when a fuel injection event commences and decreases the pressure at the end of the fuel injection event. Typical maximum fuel injection pressures are above 200 bar, preferably above 300 bar.

[0082] The head at the proximal end 31 includes a fuel inlet port 83 which is in flow connection with a duct 62 extending through the valve body 32. An axially displaceable valve member 35, preferably a valve needle, is journaled in the valve housing 32 and has an open position in which the valve member 35 has lift from a preferably conical valve seat 36, an intermediate position, in which the valve member 35 also has lift from the seat 36 and a closed position in which a matching section of the valve member 35 rests in a sealing fashion on the valve seat 36. The valve needle is resiliently biased towards the closed position by resilient means, in the present embodiment, formed by a helical spring 87. Lift of the valve needle 35 against the bias of the helical spring 87 is caused by the pressure of the fuel supplied to the fuel supply port 83 acting on a first surface of the valve member 35. In the present embodiment, the pressure in a second fuel chamber 68 acts on a first surface of the valve member 35 to urge the valve member 35 towards the open position.

[0083] The fuel valve 30 carries at its distal end 33 a nozzle 40. The nozzle 40 is configured to project into the combustion chamber 14 of the engine cylinder liner 1 through 5 nozzle holes 46 or through both the pilot nozzle holes 46 and the main nozzle holes 45.

[0084] In the present embodiment, the fuel valve 30 comprises an axially movable valve member 35 in the form of a needle that comprises a conical section that cooperates with the conical seat 36 in the longitudinal body 32 of the fuel valve 30, the valve seat 36 opening to the second fuel chamber 68 that surrounds the axial

portion valve member 35 and houses the helical spring 87. The fuel duct 62 connects the fuel inlet port 83 to the second fuel chamber 68.

[0085] A fuel control port 85 that opens to the surface of the body of the fuel valve 30, preferably near its rearmost or proximal end, receives a reference or control fuel pressure (by connection to a source of substantially constant fuel pressure). The control fuel pressure is, in the present embodiment, lower than the pressure of the fuel supplied to the fuel inlet port 83 during a fuel injection event. The fuel control port 85 is connected to a first fuel chamber 81 via an electronically controlled valve 60. the electronically controlled valve 60 is preferably a solenoid valve having at least two positions, preferably either open or closed positions, and is controlled by an electronic control unit of the engine (not shown). The electronically controlled valve 60 is preferably a spool valve, preferably a sliding spool valve, and more preferably a sliding spool solenoid valve.

[0086] The first fuel chamber 81 is connected to the fuel inlet port 83 by a duct 67 that comprises a restriction 64, for example, in the form of an orifice or other suitable device to ensure that the flow from the fuel inlet port 83 to the first fuel chamber 81 is relatively small compared to the flow of fuel from the fuel control port 85 to the first fuel chamber 81 when the electronically controlled valve 60 is in the open position. A displaceable obstruction member 80 in the form of a plunger is received with a tight fit in a bore in the valve body 32 to allow it to be displaced axially between an obstructing position and a non-obstructing position. The first fuel chamber 81 is formed in the bore in the valve body, and the obstruction member has a second (axially facing) surface that is exposed to the fuel pressure in the first fuel chamber 81. Opposite the second surface, the obstruction member has a reduced diameter section received in a matching bore in the valve body 32, to limit the stroke of the obstruction member 80 in the direction towards the nozzle 40 and the reduced diameter section of the obstruction member 80 is provided with a third surface that is arranged opposite to the second surface. The most proximal section of the valve member 35 is provided with a fourth surface that is arranged opposite to the first surface and contralateral to the third surface. The size of the first surface of the valve member 35 is smaller than the size of the third surface of the obstruction member 80, so the force in the closing direction of the obstruction member 80 is greater than the force of the valve member 35 in the opening direction when the first and third surfaces are exposed to equal pressure. The fourth surface abuts with the third surface when the obstruction member 80 is in the obstruction position and the valve member 35 is in the intermediate position, as shown in Fig. 9, thereby obstructing movement of the valve member 35 from the intermediate position to the open position.

[0087] The electronically controlled valve 60 is configured to cause the fuel pressure of the fuel supply port 83 to be present in the first fuel chamber 81 in its closed

position and cause the fuel pressure of the fuel control port 85 to be present in the first fuel chamber 81 in its open position. The obstruction member 80 is displaceable between an obstruction position wherein the obstruction member 80 obstructs displacement of the valve member 35 from the intermediate position to the open position and a non-obstruction position wherein the obstruction member 80 does not obstruct displacement of the valve member 35 from the intermediate position to the open position. The obstruction member 80 moves to the obstruction position shown in Fig. 9 when the fuel pressure of the fuel supply port 83 is present in the first fuel chamber 81, i.e. when the electronically controlled valve 60 is open and is free to move to the non-obstruction position when the fuel pressure of the fuel control port 85 is present in the first fuel chamber 81 i.e. when the electronic control valve 60 is closed. In this situation, the fourth surface abuts the third surface, thus preventing further movement of the valve member 35 in the direction towards the open position.

[0088] Figs. 12 to 14 illustrate the nozzle 40 and the distal section of the valve needle 35 in greater detail.

[0089] The nozzle 40 has a nozzle body that extends along the longitudinal axis (X) from a base 42 at a proximal end 41 to a closed distal end 44 that forms the tip of the nozzle 40. A cylindrical portion 43 of the nozzle body extends from the base to the distal end 44. The nozzle body is made from a suitable material, e.g., a suitable alloy as is well-known in the art.

[0090] An inlet 48 opens to the base 42 for receiving liquid fuel from the fuel valve 30 when the valve needle 35 is in the intermediate or open position. A straight main bore 50 extends longitudinally from the inlet 48 into the nozzle body. The closed distal end (tip) 44 comprises a substantially planar end surface 47 with a circular or elliptical outline. The end surface 47 connects to the cylindrical portion via a curved or rounded transition surface 49.

[0091] The nozzle 40 is provided with a plurality of main nozzle bores 45 (typically three to seven main nozzle bores 45), preferably straight main nozzle bores, and one or more of (princes typically two) pilot nozzle bores 46, preferably straight pilot nozzle bores 46.

[0092] Each main nozzle bore 45 opens to the outer surface of the nozzle body 43 at a different radial angle to cause a fan of fuel rays (as shown in Fig. 14) to be injected into the combustion chamber when the fuel valve 30 is in the open position. Each main nozzle bore 45 opens to the outer surface of the nozzle body at a different radial angle. Preferably, the main nozzle bores 45 open to the cylindrical surface 43 and/or to the transition surface 49. Similarly, the pilot nozzle bores 46 open to the cylindrical surface 43 and/or to the transition surface 49 at suitable radial angles.

[0093] The base 42 is provided with an inlet port 48 for receiving fuel from the fuel valve body 32. A main bore 50 extends from the inlet port 48 into the nozzle body and into the cylindrical portion 43 in a direction along a main

axis and X to a position close to the distal end 44 of the nozzle body. in the nozzle body. At a distance from the distal end of the main bore 50. The main bore 50 connects to the main nozzle bores 45 at a first axial distance from the distal end 44 and to the pilot nozzle bores 46 at a second axial distance from the distal end 44. The second axial distance is smaller than the first axial distance, so that the flow from the main bore 50 to the pilot nozzle holes 46 is enabled with smaller lift/less axial displacement of the valve member 35 in the direction of the open position and flow from the main bore 50 to the main nozzle bores 46 is only allowed with a larger lift/more axial displacement of the valve member 35 in the direction towards the open position. This difference in lift of the valve member 35 and its cylindrical portion 39 is illustrated by the longer double-pointed arrow in Fig. 13 compared to the shorter double-pointed arrow in Fig. 14, with Fig. 13 showing the valve member 35 in the open position and Fig. 14 showing the valve member 35 in the intermediate position.

[0094] The valve needle 35 comprises a distal section that comprises a cylindrical end section 39 carried by a shank 38. The cylindrical end section 39 is hollow to form a fluid passage 71 for the fuel from the proximal side of the cylindrical end section 39 to the distal side of the cylindrical end section 39. The fluid passage 71 opens proximally to the exterior of the shank 38 and the fluid passage 71 opens distally in an axial direction.

[0095] The cylindrical end section 39 is journaled with a tight fit in the straight main bore 50 to fluidically disconnect the pilot nozzle bores 46 and the main nozzle holes 45 from the main straight bore 50 when the valve needle 35 is in the closed position, as shown in Figs. 4, 6, and 10 since the cylindrical end section 39 covers the opening of the pilot nozzle bores 46, and the main nozzle bores 45 to the main bore 50 when the valve needle 35 is in the closed position. Thus, any fuel in the space between the valve seat 36 and the distal end of the main bore 50 is prevented from leaking into the combustion chamber 14 when the valve member 35 is in the closed position.

[0096] In the intermediate position of the valve member 35, the lift/axial movement towards the open position of the valve member is such that the cylindrical portion 39 only covers the opening of the main nozzle bores 45 to the main bore, thereby allowing fuel to be injected into the combustion chamber via the pilot nozzle bores 46, but not through the main nozzle bores 45, as shown in Figs. 9 and 11.

[0097] The cylindrical end section 39 fluidically connects the openings of both the pilot nozzle bores 46 and the main nozzle bores 45 to the main straight bore 50 when the valve member 35 is in the open position, as shown in Figs. 5 and 7, by the cylindrical end section 39 not covering the opening of any of the nozzle bores 45, 46 towards the straight main bore 50, thereby allowing fuel to be injected into the combustion chamber through both the pilot nozzle holes 46 and the main nozzle holes 45 for a main fuel injection event.

[0098] In an embodiment of the fuel valve 30 (not shown), the electronically controlled valve 60 connects the first fuel chamber 81 to the fuel inlet port 83 in the first position and connects the first fuel chamber 81 to the fuel control port 85 in the second position, and a restriction in the fluidic connection between the fuel inlet port and the first pressure chamber is not required.

[0099] The invention has been described in conjunction with various embodiments herein. However, other variations to the disclosed embodiments can be understood and effected by those skilled in the art of practicing the claimed invention from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. The reference signs used in the claims shall not be construed as limiting the scope.

Claims

1. A fuel valve (30) for injection of liquid fuel into a combustion chamber of a large two-stroke turbo-charged uniflow scavenged internal combustion engine with crossheads, the fuel valve (30) comprising:

- a fuel inlet port (83),
- a fuel control port (85),
- one or more main nozzle holes (45),
- one or more pilot nozzle holes (46),
- a valve member (35) displaceable between a closed position and an open position and having an intermediate position between the closed position and the open position, wherein the valve member (35) is resiliently biased towards the closed position and hydraulically urged towards the open position by fuel pressure of the fuel inlet port (83) acting on a first surface of the valve member (35),
- wherein the valve member (35) closes for flow of fuel to the one or more main nozzle holes (45) and closes for flow of fuel to the one or more pilot nozzle holes (46) in the closed position,
- wherein the valve member (35) closes for flow of fuel to the one or more main nozzle holes (45) and opens for flow to the one or more pilot nozzle holes (46) in the intermediate position,
- wherein the valve member (35) opens for flow of fuel to the one or more main nozzle holes (45) and opens for flow to the one or more pilot nozzle holes (46) in the open position,

characterized by

- an arrangement for selectively obstructing displacement of the valve member (35) from

the intermediate position to the open position,

wherein the arrangement comprises:

- an obstruction member (80) having a second surface that is exposed to a fuel pressure in a first fuel chamber (81),
- an electronically controlled valve (60), preferably a solenoid valve, the electronically controlled valve (60) having at least a first position and a second position, the electronically controlled valve (60) being configured to:

- cause the fuel pressure of the fuel supply port (83) to be present in the first fuel chamber (81) in the first position, and
- cause the fuel pressure of the fuel control port (85) to be present in the first fuel chamber (81) in the second position,

the obstruction member (80) being displaceable between an obstruction position wherein the obstruction member (80) obstructs displacement of the valve member (35) from the intermediate position to the open position, and a non-obstruction position wherein the obstruction member (80) does not obstruct displacement of the valve member (35) from the intermediate position to the open position, wherein the obstruction member (80) is configured to:

- move to the obstruction position when the fuel pressure of the fuel supply port (83) is present in the first fuel chamber (81), and
- move to the non-obstruction position when the fuel pressure of the fuel control port (85) is present in the first fuel chamber (81).

2. The fuel valve (30) of claim 1, wherein the first fuel chamber (81) is fluidically connected to the fuel inlet port (83) and the fuel control port (85).
3. The fuel valve (30) of claim 1 or 2, wherein the first fuel chamber (81) is permanently connected to the fuel inlet port (83) via a conduit (67) that includes a flow restriction (64), and wherein the electronically controlled valve (60), connects the first fuel chamber (81) to the fuel control port (85) in the second position.
4. The fuel valve (30) of any one of claims 1 to 3, wherein the electronically controlled valve (60) connects the first fuel chamber (81) to the fuel inlet port (83) in the first position and connects the first fuel

chamber (81) to the fuel control port (85) in the second position.

5. The fuel valve (30) of any one of the preceding claims, wherein the size of the first surface of the valve member (35) is smaller than the size of the second surface of the obstruction member (80).
6. The fuel valve (30) of any one of the preceding claims, wherein the obstruction member (80) comprises a plunger received with a tight fit in a bore, the obstruction member (80) having a third surface arranged oppositely to said second surface, and wherein the valve member (35) has a fourth surface opposite to the first surface and contralateral to the third surface, preferably the fourth surface abuts the third surface when the obstruction member (80) is in the obstruction position and the valve member (35) is in the intermediate position and even more preferably the displaceable valve member (35) rests on a valve seat (36) in the closed position and the displaceable valve member (35) has lift from the valve seat (36) in the open- and intermediate positions.
7. The fuel valve (30) of any one of the preceding claims, comprising an elongated fuel valve body (32) with a longitudinal axis (X), the elongated fuel valve body (32) having a proximal end (31), and a distal end (33), wherein the nozzle (40) is disposed at the distal end (33) of the elongated valve body (32), preferably the nozzle (40) comprises a nozzle body extending along the longitudinal axis (X) from a base (42) at a proximal end (41) of the nozzle body to a closed distal end (44) of the nozzle body, the base (42) preferably being attached to the distal end of the fuel valve (30).
8. The fuel valve (30) of claim 7, wherein the nozzle body comprises:
 - an elongated, preferably cylindrical portion (43) extending between the base (42) and the closed distal end (44),
 - an inlet (48) opening to the base (42) for receiving liquid fuel from the fuel valve (30), and
 - a single straight main bore (50) extending longitudinally from the inlet (48) into the nozzle body,
 preferably the main nozzle holes (45) and the pilot nozzle holes (46) connect to the main bore (50) at axially spaced positions.
9. The fuel valve (30) of claim 8, wherein the displaceable valve member (35) comprises a distal section with a cylindrical end section (39) carried by a shank (38) and which is journaled with a tight fit in the straight main bore (50) in order to:

- fluidically disconnect the main nozzle holes (45) and the pilot nozzle holes (46) from the main straight bore (50) when the displaceable valve member (35) is in the closed position, fluidically disconnect the main nozzle holes (45) 5 from the main straight bore (50) and fluidically connect the pilot nozzle holes (46) to the main straight bore (50) when the displaceable valve member (35) is in the intermediate position, fluidically connect the main nozzle holes (45) 10 and the pilot nozzle holes (46) to the main straight bore (50) when the displaceable valve member (35) is in the open position.
- 10.** The fuel valve (30) of claim 9, wherein the cylindrical end section (39) is hollow to form a fluid passage (71), the fluid passage (71) preferably opening proximally to the exterior of the shank (38) and the fluid passage (71) preferably opening distally in an axial direction. 20
- 11.** The fuel valve (30) of any one of claims 1 to 10, wherein the valve member (35) is a valve needle that is slidably received in a longitudinal bore (64) in the elongated valve body (32), the valve member (35) 25 resting on a valve seat (36) in the closed position and the valve needle (35) having lift from the valve seat (36) in the open- and intermediate positions.
- 12.** The fuel valve (30) of claim 11, comprising a second fuel chamber (68) surrounding an axial portion of the valve member (35) and opening to the valve seat (36), the valve seat (36) and/or the second fuel chamber (68) preferably being disposed in the elongated valve body (32). 30 35
- 13.** The fuel valve (30) of any one of claims 8 to 12, wherein the main nozzle bores (45) and/or the pilot nozzle bores (46) open to the surface of the elongated, preferably cylindrical portion (43). 40
- 14.** The fuel valve (30) of any one of claims 1 to 13, wherein the electronically controlled valve (60) is a spool valve, preferably a sliding spool valve, more preferably a sliding spool solenoid valve. 45
- 15.** A large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads comprising a fuel valve (30) according to any one of claims 1 to 14. 50

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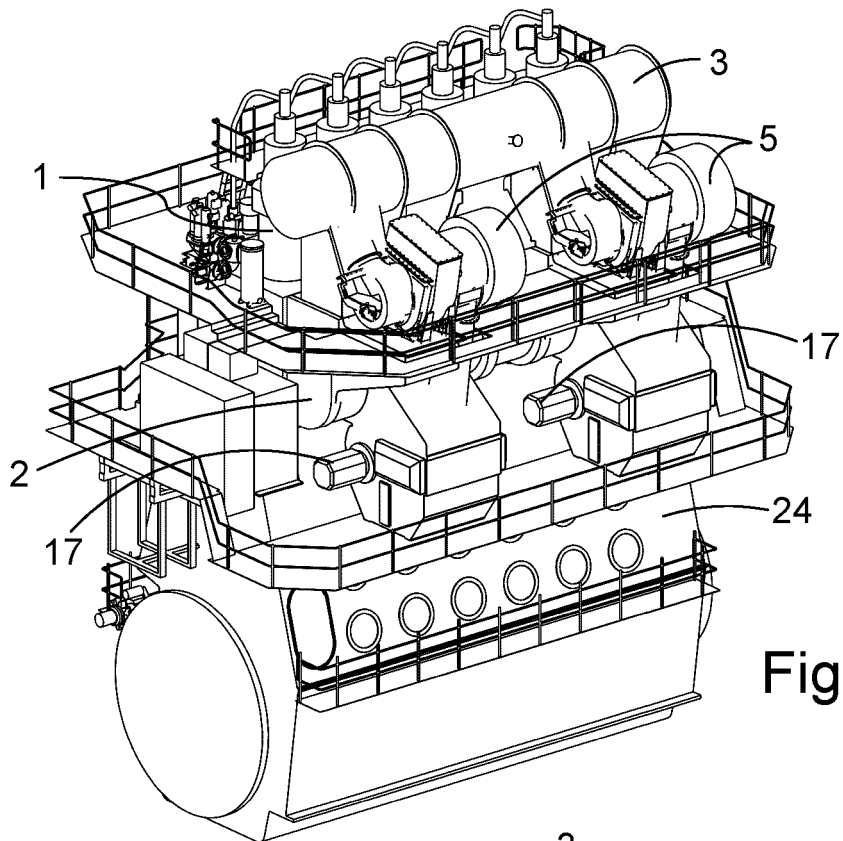


Fig. 1

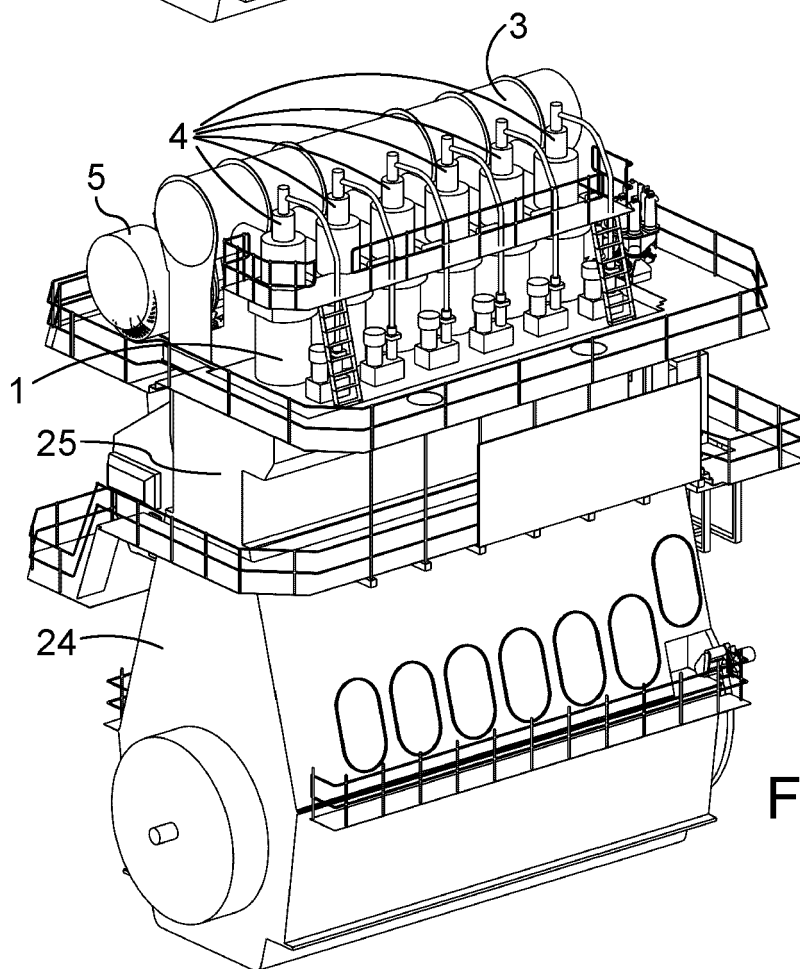


Fig. 2

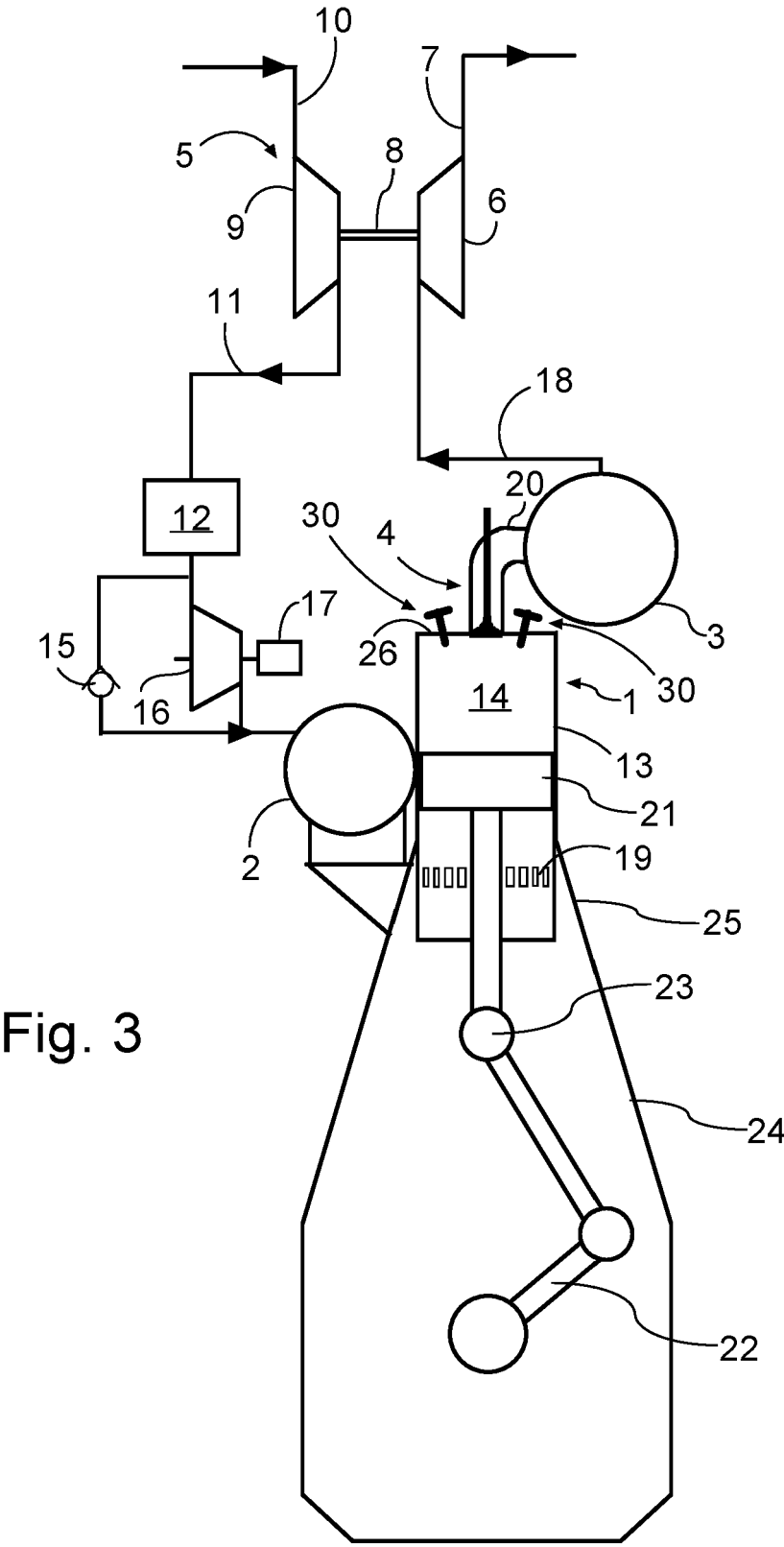
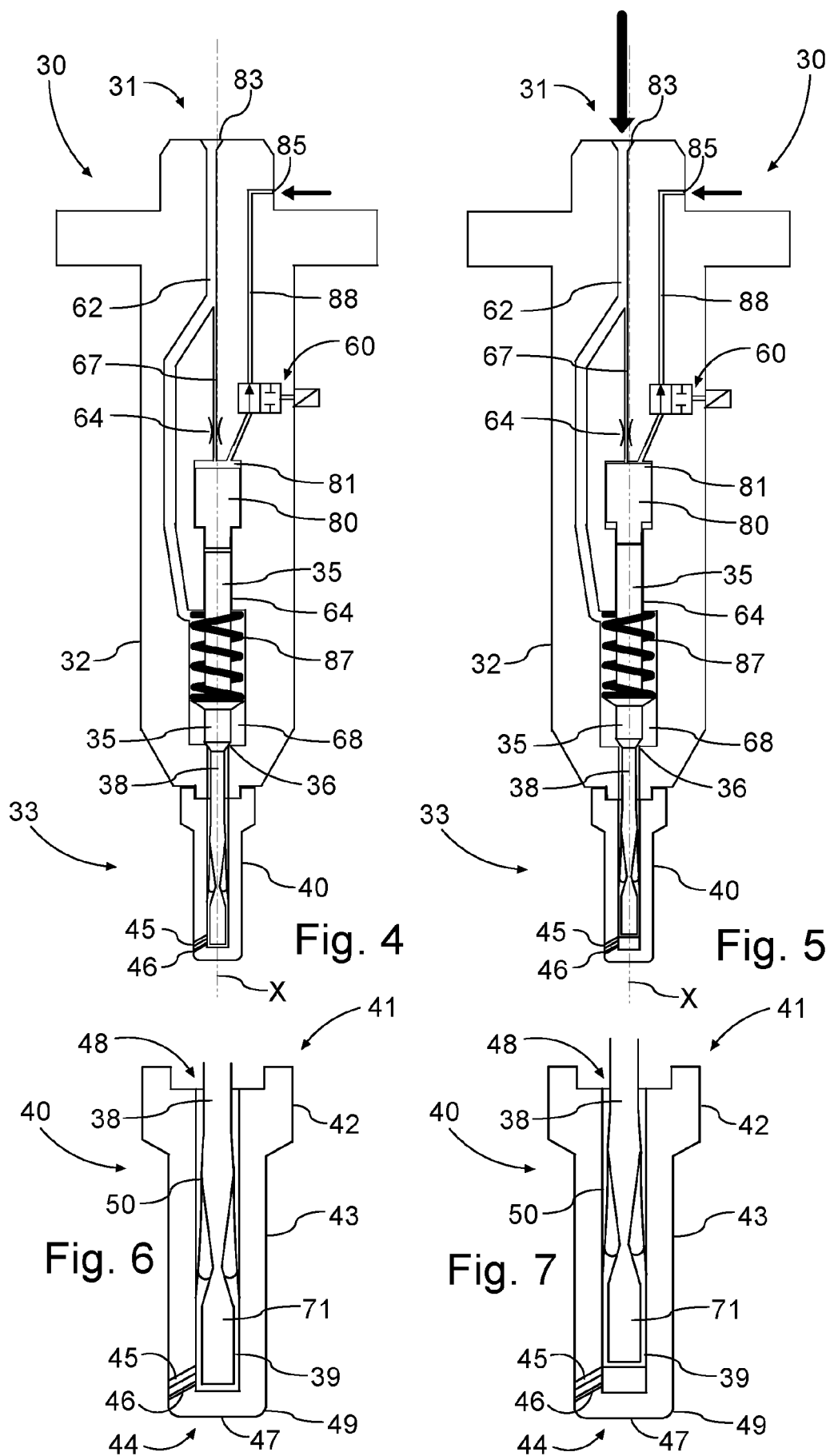


Fig. 3



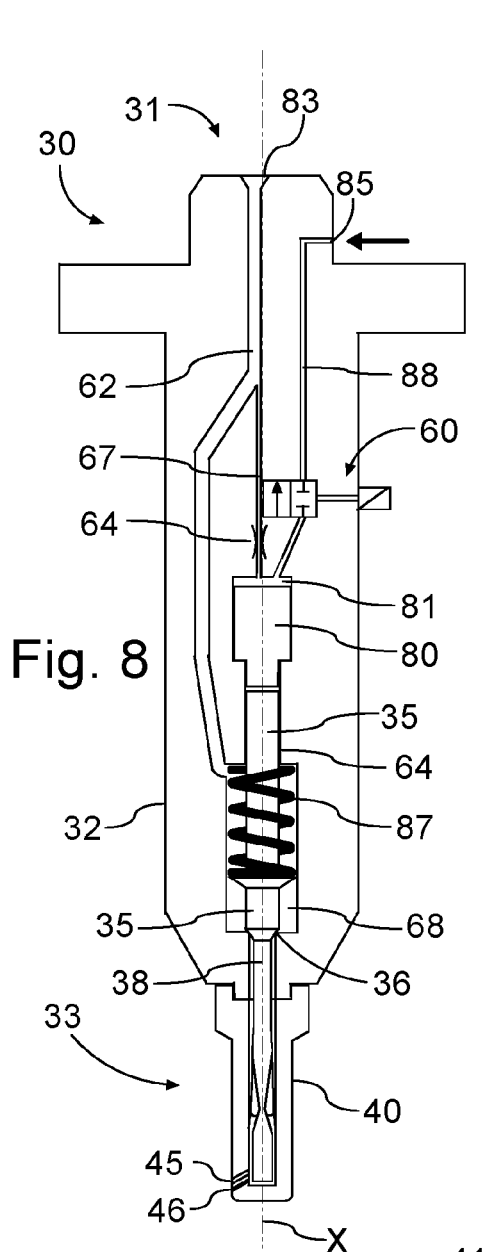


Fig. 8

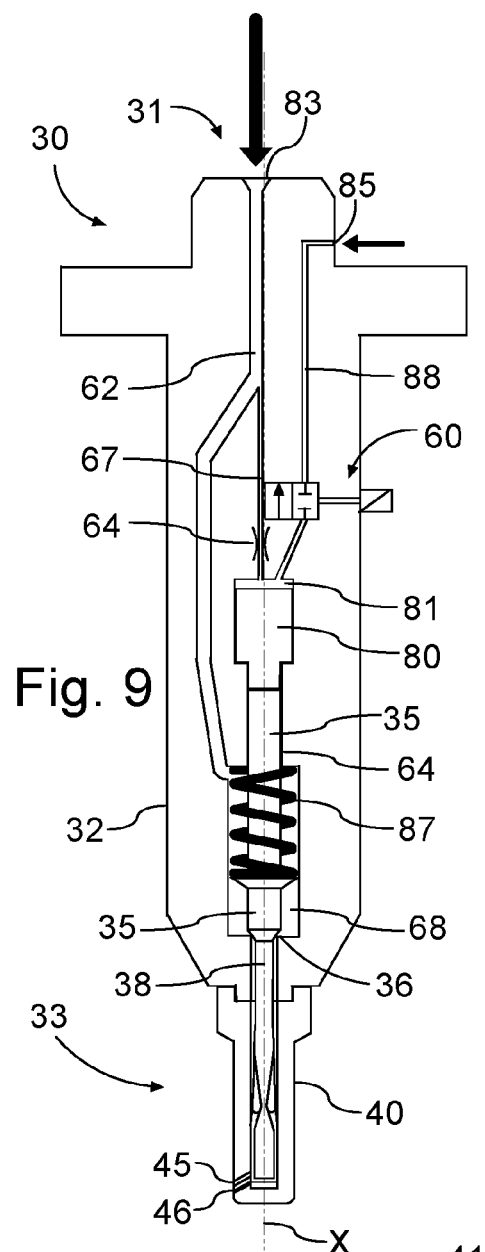


Fig. 9

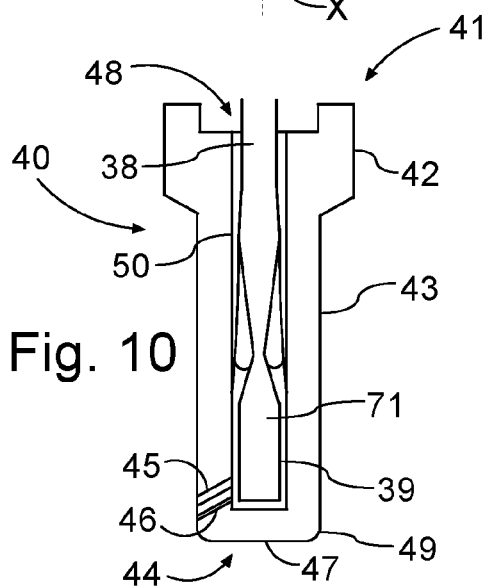


Fig. 10

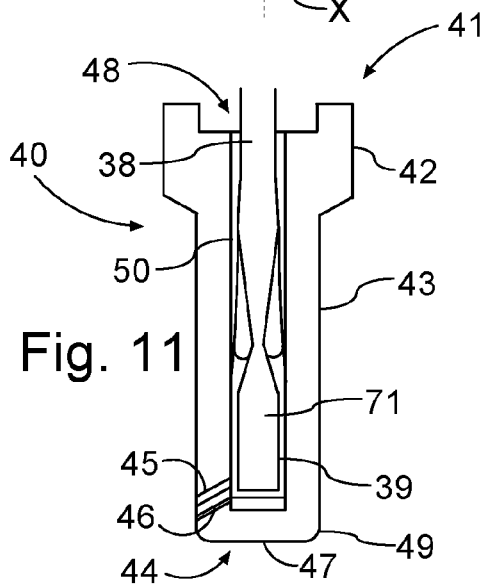


Fig. 11

Fig. 12

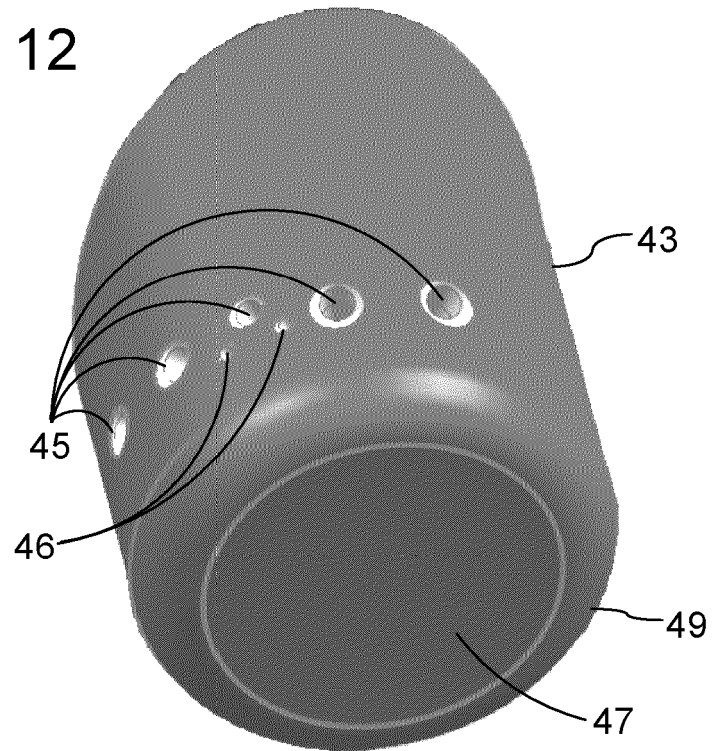


Fig. 13

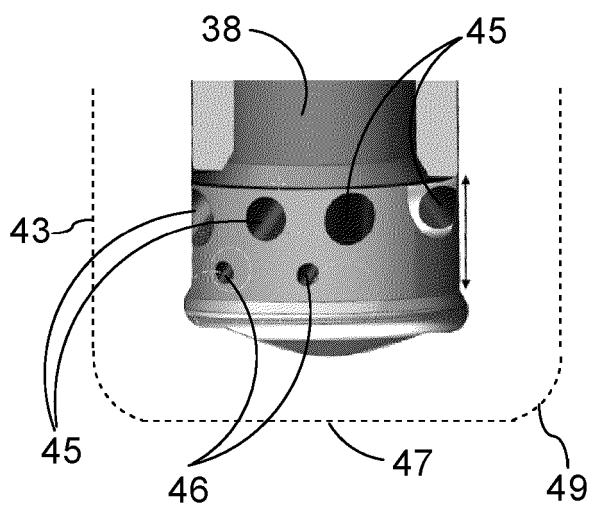


Fig. 14

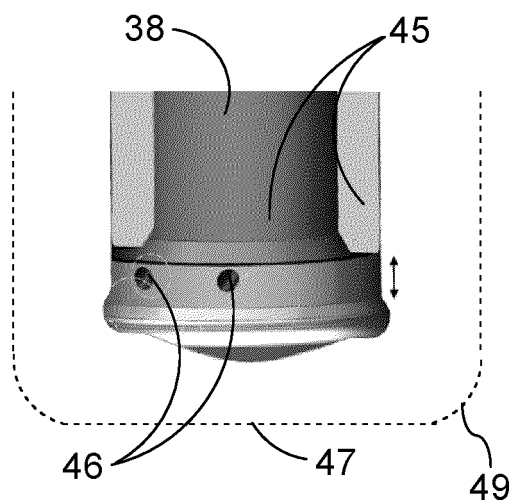
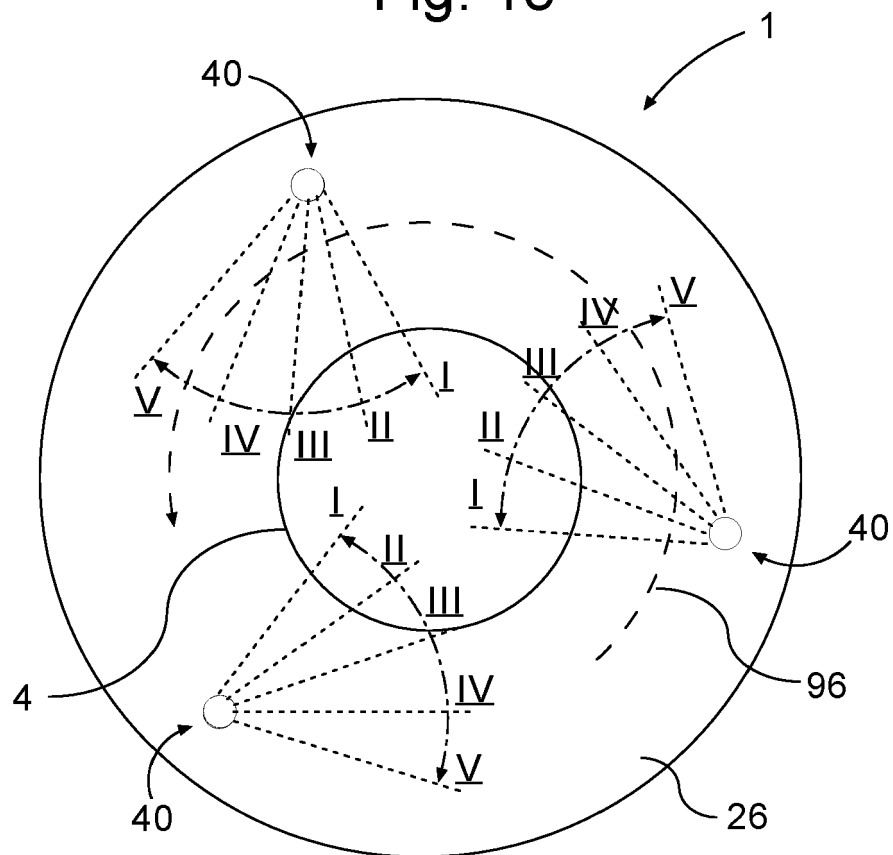


Fig. 15





EUROPEAN SEARCH REPORT

Application Number

EP 24 19 7941

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 252 301 A1 (CATERPILLAR MOTOREN GMBH & CO [DE]) 6 December 2017 (2017-12-06)	1-6, 14, 15	INV. F02M43/04
Y	* paragraphs [0020] - [0041]; figures 1-4, 5a, 5b *	7-13	F02M45/08 F02M47/02 F02M61/18
Y	DE 197 55 062 A1 (BOSCH GMBH ROBERT [DE]) 17 June 1999 (1999-06-17) * column 2, line 67 - column 5, line 30; figures 1, 2 *	7-13	F02B25/04 F02D19/06
A	EP 2 562 410 A1 (HYUN DAI HEAVY IND CO LTD [KR]) 27 February 2013 (2013-02-27) * paragraphs [0058] - [0073]; figures 1-15 *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02M F02D F02B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		22 January 2025	Nobre Correia, S
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 24 19 7941

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3252301 A1	06-12-2017	NONE	

DE 19755062 A1	17-06-1999	DE 19755062 A1	17-06-1999
		FR 2772430 A1	18-06-1999

EP 2562410 A1	27-02-2013	CN 202883194 U	17-04-2013
		EP 2562410 A1	27-02-2013
		JP 5740467 B2	24-06-2015
		JP 2013525672 A	20-06-2013
		KR 20110117374 A	27-10-2011
		US 2013037004 A1	14-02-2013
		WO 2011132832 A1	27-10-2011

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 102057802 [0009]
- US 4285471 A [0010]