



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**25.09.2024 Bulletin 2024/39**

(51) International Patent Classification (IPC):  
**F02M 61/04** (2006.01) **F02M 61/06** (2006.01)  
**F02M 61/16** (2006.01) **F02M 61/18** (2006.01)

(21) Application number: **24165255.1**

(52) Cooperative Patent Classification (CPC):  
**F02M 61/06; F02M 61/042; F02M 61/161;**  
**F02M 61/1806**

(22) Date of filing: **21.03.2024**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB**  
**GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL**  
**NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA**  
Designated Validation States:  
**GE KH MA MD TN**

(71) Applicant: **MAN Energy Solutions,**  
**filial af MAN Energy Solutions SE, Tyskland**  
**2450 Copenhagen SV (DK)**

(72) Inventor: **Peter, Hagen**  
**2791 Dragør (DK)**

(74) Representative: **Nordic Patent Service A/S**  
**Bredgade 30**  
**1260 Copenhagen K (DK)**

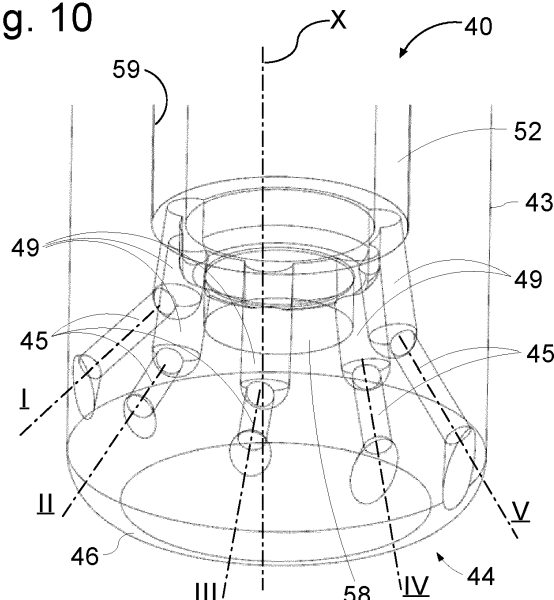
(30) Priority: **24.03.2023 DK PA202370148**

(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 VALVE**

(57) A fuel valve (30) configured for injecting fuel into a large two-stroke turbocharged uniflow scavenged internal combustion engine. It comprises a fuel valve housing (32) with an axis (X), a proximal and distal end (31,35), an axially displaceable valve needle (35), and a nozzle (40) disposed at the distal end of the fuel valve housing (32). The nozzle body extends along the axis, with a cylindrical portion between the base (42) and closed distal end (44). An inlet (48) of the nozzle body receives liquid fuel from the fuel valve housing (32), and a plurality of

straight nozzle bores (45) open to the outer surface of the nozzle body at different radial angles. A single straight main bore (50) extends longitudinally from the inlet (48) into the nozzle body, connected to the straight nozzle bores (45) by individual supply passages (49). The valve needle (35) has a distal section with a cylindrical end section (39) carried by a shank (38) and is journaled with a tight fit in the straight main bore (50) to disconnect individual supply passages (49) from the main straight bore (50) when the valve needle (35) is in the closed position.

**Fig. 10**



## 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.

### 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 in 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 an elongated 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). Thus, the nozzle bores are mainly laterally directed relative to the main axis of the nozzle/fuel valve and typically approximately at a right angle to the main axis of the engine cylinder. Typically, each nozzle is provided with three to seven nozzle bores that are all connected to the main bore.

**[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]** Since the nozzle body projects into the combustion chamber it is exposed to the hot gases of the combustion chamber and parts of the nozzle body will therefore reach relatively high temperatures of up to approximately 400°C. The incoming fuel for heavy fuel oil operated engines is approximately 140°C. Thus, the incoming fuel in the main bore leaving the nozzle through the nozzle bores has a significantly lower temperature than the gas surrounding the outer surface of the nozzle body. Therefore, the material of the nozzle body is exposed to a substantial temperature gradient, causing stresses in the material of the nozzle.

**[0010]** Thus, the nozzles risk developing cracks in the area of the nozzle where the nozzle holes are located, in particular between the nozzle holes, due to thermal fatigue of the material when they are exposed to high operating temperature gas in the combustion chamber and the high cooling effect of the injected fuel.

**[0011]** This problem cannot be solved by simply increasing the distance between the nozzle holes so that there is more material between nozzle holes thereby reducing the temperature gradient since it is highly undesirable to increase the diameter of the nozzle since this would likely increase the amount of heat that is transferred from the combustion chamber to the nozzle and since it is not possible to simply increase the radial spacing between the nozzle holes, since the radial spread of the nozzle holes is limited to an approximately 110° angle due to the two or three fuel valves in the cylinder cover being peripherally positioned. This is especially true when there is a slide valve in the nozzle, requiring that the main bore in the nozzle has a certain diameter and thus the limitation to the resulting wall thickness of the nozzle body. Further, in a fuel valve with a slider in the nozzle body, it is a requirement that the nozzle bores open at substantially the same axial distance from the base of the nozzle to the main bore if the nozzle bores are to inject fuel simultaneously.

**[0012]** US5765755A discloses an injection rate shaping nozzle assembly for a fuel injector is provided which includes a closed nozzle valve element and a rate shaping control device including an injection spill circuit for spilling a portion of the fuel to be injected to produce a

predetermined time varying change in the flow rate of fuel injected into a combustion chamber. The spill circuit includes a spill passage integrally formed in the nozzle valve element. The rate shaping control device may include a spill accelerating chamber formed in the nozzle valve element for creating a rapid increase in the spill flow rate. A spill circuit purge device is provided to remove fuel from the spill circuit and accelerating chamber between each of the injection events thereby ensuring an unimpeded, effective spill fuel flow during the next spill event. The purge device includes a purge passage formed of a predetermined size for restricting the flow of purge gas to ensure sufficient fuel removal from the injection spill circuit while avoiding excessive purge gas flow. The purge passage may include an annular clearance gap formed between the nozzle valve element and the nozzle housing wall, or alternatively, may include an orifice passage formed in the inner portion of the nozzle valve element.

#### SUMMARY

**[0013]** 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.

**[0014]** 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.

**[0015]** According to a first aspect, there is provided a fuel valve for injection of liquid fuel into a large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads, the fuel valve comprising:

an elongated fuel valve housing with a longitudinal axis, a proximal end, and a distal end,  
 an axially displaceable valve needle, the valve needle having a closed position resting on a valve seat and an open position where the valve needle has lift from the valve seat, and  
 a nozzle disposed at the distal end of the elongated valve housing,  
 the nozzle has 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 being attached to the fuel valve housing,  
 the nozzle body comprising: 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 housing,  
 a plurality of straight nozzle bores, each straight nozzle bore opening to the outer surface of the nozzle body at a different radial angle,  
 a single straight main bore extending longitudinally

from the inlet into the nozzle body,  
 at least two of the straight nozzle bores are connected to the straight main bore by an individual supply passage that is arranged at an angle to the straight main bore and to the straight nozzle bore concerned, the valve needle comprises a distal section with a cylindrical end section carried by a shank and which is journaled with a tight fit in the straight main bore in order to fluidically disconnect the individual supply passages from the main straight bore when the valve needle is in the closed position.

**[0016]** By providing individual supply passages that are angled to the straight nozzle bores and to the main nozzle bore, more freedom is provided for choosing the angle of the straight nozzle bores to the main axis and their position in the nozzle body material, thereby allowing a choice of position and orientation of the nozzle bores that results in more nozzle body material between neighboring nozzle bores to thereby reduce the thermal coefficient and thermal stress related crack formation, without needing to increase the overall size of the nozzle, in particular the diameter of the cylindrical part of the nozzle.

**[0017]** According to a possible implementation form of the first aspect, the individual supply passages are, seen from the position where the individual supply passage concerned connects to the main bore directed away from the longitudinal axis at a first angle with the longitudinal axis, resulting in the "base" of the of the straight nozzle bore being placed more radially outward, thereby allowing for more distance between neighboring straight nozzle bores and thus more nozzle body material between neighboring nozzle bores. In this context, the "base" positions where a straight nozzle bore connects to the individual supply passage concerned.

**[0018]** According to a possible implementation form of the first aspect, the straight nozzle bore, seen from the position where the straight nozzle bore concerned connects to the individual supply passage, is directed away from the longitudinal axis at a second angle with the longitudinal axis, the second angle being greater than the first angle.

**[0019]** According to a possible implementation form of the first aspect, the individual supply passages are straight bores, preferably with a rounded, i.e. spherical extremity to reduce stress in the nozzle bore material.

**[0020]** According to a possible implementation of the first aspect, the cylindrical end section fluidically connects the individual supply passages to the main straight bore when the valve needle is in the open position.

**[0021]** According to a possible implementation of the first aspect, the cylindrical end section covers the opening of the individual supply passages towards the straight main bore when the valve needle is in the closed position.

**[0022]** According to a possible implementation of the first aspect, the cylindrical end section does not cover the opening of the individual supply passages towards the straight main bore when the valve needle is in the

open position.

**[0023]** According to a possible implementation of the first aspect, the individual supply passages open to the main bore at a given axial distance from the inlet, and the cylindrical end section extends past the given axial distance in the closed position of the valve needle.

**[0024]** According to a possible implementation of the first aspect, an axially displaceable valve needle is slidably received in a longitudinal bore in the elongated valve housing, the valve needle resting on a valve seat in the closed position, the valve seat is preferably a conical valve seat, the valve needle has lift from the valve seat in the open position and the valve needle preferably being biased towards the closed position, and preferably, a fuel chamber is provided that surrounds the valve needle and opens to the valve seat.

**[0025]** According to a possible implementation of the first aspect, the fuel valve comprises a fuel inlet port in the elongated fuel valve housing for connection to a source of liquid fuel.

**[0026]** According to a possible implementation of the first aspect, all of the straight nozzle bores have a substantially equal cross-sectional area or diameter and preferably also a substantially equal length.

**[0027]** According to a possible implementation of the first aspect, all of the straight nozzle bores have an equal diameter, and preferably, the individual supply passages have a diameter greater than that of the straight nozzle bores.

**[0028]** According to a possible implementation of the first aspect, the straight main bore is formed in a bushing that is solidly received in a bore in the nozzle body.

**[0029]** According to a possible implementation 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.

**[0030]** According to a possible implementation of the first aspect, wherein the straight nozzle bores open to the cylindrical surface.

**[0031]** According to a possible implementation of the first aspect, a preferably rounded transition surface is arranged between the substantially cylindrical surface and a flat distal end surface of the nozzle body.

**[0032]** According to a possible implementation of the first aspect, the straight nozzle bores open to the cylindrical surface and/or to the transition surface.

**[0033]** According to a possible implementation of the first aspect, the straight nozzle bores each have a nozzle axis I,II,III,IV,V, and wherein the nozzle axis I,II,III,IV,V of each of the nozzle bores is arranged at an obtuse angle  $\alpha$  with the main direction X.

**[0034]** According to a possible implementation of the first aspect, the radial components of each of the nozzle axes I,II,III,IV,V relative to the main axis X are distributed, preferably substantially equally distributed, over a circular sector with an arc less than 120 deg., preferably less than 110 deg. and even more preferably less than 100

deg.

**[0035]** According to a possible implementation of the first aspect, at least three of the straight nozzle bores are connected to the straight main bore by an individual supply passage that is arranged at an angle to the straight main bore and to the straight nozzle bore concerned.

**[0036]** 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 or any one implementation thereof.

**[0037]** These and other aspects of the invention will be apparent from the embodiments described below.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0038]** 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,

Fig. 5 is a sectional view of another embodiment of a fuel valve for use in the engine of Figs. 1 to 3,

Fig. 6 is an elevated transparent view of a nozzle of the fuel valve of Fig. 4 or 5,

Fig. 7 is a sectional view of the nozzle of Fig. 6,

Fig. 8, is a sectional view of the tip of the nozzle of Fig. 6 with the distal cylindrical portion of the valve needle in the open position,

Fig. 9 is a view of Fig. 8 with the distal cylindrical portion of the valve needle in the closed position,

Fig. 10 is a transparent view of the tip of the nozzle of Fig. 6,

Fig. 11 is another sectional view of the tip of the nozzle of Fig. 6 with the distal cylindrical portion of the valve needle in the closed position, and

Fig. 12 is a diagrammatic representation of the position of the nozzles of the fuel valves of Fig. 5 in the cylinder cover, as seen from the side of the piston and illustrating the orientation of the nozzle bores and the resulting fuel jets.

## DETAILED DESCRIPTION

**[0039]** 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 embodi-

ments. 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.

**[0040]** 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.

**[0041]** 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.

**[0042]** 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.

**[0043]** Fig. 4 illustrates an embodiment of one of the two or three 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. The fuel valve 30 comprises an elongated fuel valve body 32 with a nozzle holder at its

distal (forward) end 33. The nozzle holder connects the nozzle 40 to the elongated fuel valve body 32. 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. The fuel valve 30 illustrated in Fig. 4 has an elongated external housing 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.

**[0044]** The head at the proximal end 31 includes a fuel inlet 83 which is in flow connection with a duct extending through the valve body 32. An axially displaceable valve needle 35 is journaled in the valve housing 32 and has an open position in which the valve needle 35 has lift from a preferably conical valve seat 36 and a closed position in which a matching section of the valve needle 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 83. Lift of the valve needle 35 against the bias of the helical spring 83 is caused by the pressure of the fuel supplied to the fuel valve 30 acting on a surface of the valve needle 35 or of a piston or plunger operably connected to the valve needle 35. A fuel chamber 68 surrounds the valve needle 35 and opens to the valve seat 36.

**[0045]** 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 when the fuel valve 30 is mounted on the cylinder cover 26.

**[0046]** In the present embodiment, the fuel valve comprises an axially movable valve needle 35 that comprises a conical section that cooperates with a conical seat 36 in the longitudinal housing 32 of the fuel valve 30.

**[0047]** Fig. 12 illustrates how the nozzles 40 are peripherally positioned in the cylinder cover 26 and illustrates the direction of the fuel jets (which corresponds to the direction of the axes I, II, III, IV, and V of straight nozzle bores 45 in the nozzles 40). The direction of the swirl of the gases in the combustion chamber is illustrated by the curved interrupted arrow 66.

**[0048]** Fig. 5 illustrates a fuel valve 30 according to another embodiment, that is similar to the embodiment of Fig. 4, except for comprising a booster pump to amplify the pressure of the fuel that is supplied to the fuel valve 30. The main component of the booster pump is a booster plunger 80. The other components of the fuel valve 30 according to this embodiment and the nozzle 40 are in concept identical to the fuel valve of Fig. 4.

**[0049]** Figs. 6 to 11 illustrate the nozzle 40 and the distal section of the valve needle 35 in greater detail.

**[0050]** The nozzle 40 has a nozzle body that extends from a base 42 at a proximal end 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.

**[0051]** 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 open position. A single straight main bore 50 extends longitudinally from the inlet 48 into said nozzle body. In the present embodiment, the straight main bore 50 is formed in a bushing 51 that is solidly received in a bore 51 in the valve body, e.g. by a shrink fit, but it is understood that the nozzle can be constructed without the bushing 51 so that the nozzle body is made from one single piece of material.

**[0052]** 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 46.

**[0053]** The nozzle 40 is provided with a plurality of straight nozzle bores 45. The nozzle 40 is provided with any desirable number of nozzle bores 45, preferably between three and seven nozzle bores 45 even more preferably between three and six nozzle bores 45, and most preferably five or six nozzle bores 45. The nozzle 40 according to the present embodiment is provided with five nozzle bores 45.

**[0054]** Each straight 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. 12) to be injected into the combustion chamber when the fuel valve 30 opens. Each straight nozzle bore 45 opens to the outer surface of the nozzle body at a different radial angle. Preferably, the nozzle bores 45 opens to the cylindrical surface 43 and/or to the transition surface 46.

**[0055]** The nozzle holes 45 each have a nozzle axis I,II,III,IV, and V (Fig. 10). The nozzle axis I,II,III,IV, and V of each of the holes 45 is arranged at an obtuse angle  $\alpha$  with the main axis X. The obtuse angle  $\alpha$  can be different for each of the nozzle holes 45. The radial components of each of the nozzle axes I,II,III,IV, and V relative to the main axis X are distributed over a circular sector with an arc of less than 120 deg. preferably less than 110 deg. and even more preferably less than 100 deg. The radial components of each of the nozzle axes (I,II,III,IV, and V) relative to the main axis X are substantially evenly distributed over the circular section, to maximize the amount of nozzle body material between the individual nozzle holes 45.

**[0056]** The base 42 is provided with an inlet port 48 for receiving fuel from said fuel valve 30. A main bore 50 extends from said inlet port 48 into the nozzle body and into the cylindrical portion 43 in a direction along a main axis X to a position close to the distal end 44 of the nozzle body. The main bore 50 connects to a plurality of individual supply passages 49 that are each connected to a nozzle bore 45. The individual supply passages 49 are arranged at an angle to the axis of the straight main bore 50 and to the axis of the straight nozzle bore 45 to which the individual supply passage 49 concerned connects.

**[0057]** The cross-sectional area of the main bore 50 is substantially larger than the total cross-sectional area of

the supply passages 49. The total cross-sectional area of the supply passages 49 is substantially equal to the total cross-sectional area of the nozzle bores 45.

**[0058]** The use of individual supply passages 49 to connect the nozzle bores 45 to the main bore 50 allows for the nozzle bores 45 to be placed anointed in such a way that maximizes the amount of nozzle body material between them, whilst still having the axis I,II,III,IV, and V of the nozzle bores 45 to cover the desired circle sector with the fuel jets.

**[0059]** The inlet port 48 is in an embodiment formed by a bore with a diameter that is larger than the diameter of the main bore 50. Alternatively, the inlet port 48 can have the same diameter as the main bore.

**[0060]** The nozzle 40 provides a wide spread of nozzle bores 45, and thus more nozzle material between the nozzle bores 45 and thus better resistance against crack formation. Further, the nozzle 40 provides uniform inlet conditions to each of the nozzle bores 45, for creating substantially uniform fuel jets.

**[0061]** 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 journaled with a tight fit in the straight main bore 50 to fluidically disconnect the individual supply passages 49 from the main straight bore (50) when the valve needle 35 is in the closed position as shown in Figs. 7,9 and 11, since the cylindrical end section 39 covers the opening of the individual supply passages 49 towards said straight 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 needle 35 is in the closed position.

**[0062]** 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.

**[0063]** The cylindrical end section 39 fluidically connects the individual supply passages 49 to the main straight bore 50 when the valve needle 35 is in the open position, as shown in Fig. 8, by the cylindrical end section 39 not covering the opening of the individual supply passages 49 towards said straight main bore 50.

**[0064]** The individual supply passages 49 open to said main bore at a given axial distance from said inlet 48, and the cylindrical end section 39 extends past the given axial distance in the closed position of the valve needle 35 to obstruct the flow of fuel to the individual supply passages 49.

**[0065]** In an embodiment, the individual supply passage 49 are, seen from the position where the individual supply passage 49 concerned connects to the main bore 50, directed away from the longitudinal axis X at a first angle with the longitudinal axis X, resulting in the "base" of the of the straight nozzle 45 bores being placed more

radially outward, thereby allowing for more distance between neighboring straight nozzle bores 45 and thus more nozzle body material between neighboring straight nozzle bores 45. In this context, the "base" position is where a straight nozzle bore 45 connects to an individual supply passage 49.

**[0066]** In an embodiment, the straight nozzle bore 45, seen from the position where the nozzle bore 45 concerned connects to the individual supply passage 49, is directed away from the longitudinal axis X at a second angle with the longitudinal axis X, the second angle being greater than the first angle.

**[0067]** According to a possible implementation form of the first aspect, the individual supply passages 49 are straight bores, preferably with a rounded, i.e. spherical extremity (a or near the "base") to reduce stress in the nozzle bore material.

**[0068]** 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 large two-stroke turbocharged uniflow scavenged internal combustion engine with crossheads, said fuel valve (30) comprising:

an elongated fuel valve housing (32) with a longitudinal axis (X), a proximal end (31), and a distal end (33),

an axially displaceable valve needle (35), said valve needle (35) having a closed position resting on a valve seat (36) and an open position where the valve needle (35) has lift from the valve seat (36), and

a nozzle (40) disposed at the distal end (33) of said elongated fuel valve housing (32), said nozzle (40) having a nozzle body extending along said longitudinal axis (X) from a base (42) at a proximal end (41) of said nozzle body to a closed distal end (44) of said nozzle body, said base (42) being attached to said fuel valve housing (32),

said nozzle body comprising:

an elongated portion, preferably a cylindri-

cal portion, extending between said base (42) and said closed distal end (44), an inlet (48) opening to said base (42) for receiving liquid fuel from said fuel housing valve (32),

a plurality of straight nozzle bores (45), each straight nozzle bore (45) opening to the outer surface of the nozzle body at a different radial angle,

a single straight main bore (50) extending longitudinally from said inlet (48) into said nozzle body,

### characterized in that

at least three of said straight nozzle bores (45) being connected to said straight main bore (50) by an individual supply passage (49) that is arranged at an angle to said straight main bore (50) and to the straight nozzle bore (45) concerned,

the valve needle (35) comprising 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 individual supply passages (49) from the main straight bore (50) when the valve needle (35) is in the closed position.

2. The fuel valve (30) of claim 1, wherein said cylindrical end section (39) fluidically connects the individual supply passages (49) to the main straight bore (50) when the valve needle (35) is in the open position.
3. The fuel valve (30) of claim 1 or 2, wherein said cylindrical end section (39) covers the opening of the individual supply passages (49) towards said straight main bore (50) when the valve needle (35) is in the closed position.
4. The fuel valve (30) of claim 2 or 3, wherein said cylindrical end section (39) does not cover the opening of the individual supply passages (49) towards said straight main bore (50) when the valve needle (35) is in the open position.
5. The fuel valve (30) of any one of claims 1 to 4, wherein said individual supply passages (49) open to said main bore at a given axial distance from said inlet (48), and wherein said cylindrical end section (39) extends past said given axial distance in the closed position of the valve needle (35).
6. The fuel valve (30) of any one of claims 1 to 5, wherein the axially displaceable valve needle (35) is slidably received in a longitudinal bore (64) in said elongated fuel valve housing (32), said valve needle (32) resting on a valve seat (36) in said closed position and said valve needle (35) having lift from said valve

seat (35) in said open position.

7. The fuel valve (30) of any one of claims 1 to 6, comprising a fuel inlet port (34) in said elongated fuel valve housing (52) for connection to a source of liquid fuel. 5
8. The fuel valve (30) of any one of claims 1 to 7, wherein all of said straight nozzle bores (45) have an equal cross-sectional area or diameter. 10
9. The fuel valve (30) of any one of claims 1 to 8, wherein said straight main bore (50) is formed in a bushing (51) that is solidly received in a bore in said nozzle body. 15
10. The fuel valve (30) of any one of claims 1 to 9, wherein the cylindrical end section (39) is hollow to form a fluid passage (71). 20
11. The fuel valve (30) of any one of claims 1 to 10, wherein said straight nozzle bores (45) open to the surface (43) of said cylindrical end section (39).
12. The fuel valve (30) of any one of claims 1 to 11, comprising a rounded transition surface (46) between said surface (43) of said cylindrical end section (39) and a flat distal end surface (47) of the nozzle body. 25 30
13. The fuel valve (30) of any one of claims 1 to 12, wherein said straight nozzle bores (45) open to the surface (43) of said cylindrical end section (39) and/or to said transition surface (46). 35
14. The fuel valve (30) of any one of claims 1 to 13, wherein said straight nozzle bores (45) each have a nozzle axis (I,II,III,IV,V), and wherein the nozzle axis (I,II,III,IV,V) of each of said nozzle bores (45) is arranged at an obtuse angle  $\alpha$  with said main axis X. 40
15. The fuel valve (30) of any one of claims 1 to 14, wherein the radial components of each of said nozzle axis (I,II,III,IV,V) relative to said longitudinal axis (X) are distributed, over a circular sector with an arc less than 120 deg. 45
16. 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 15. 50

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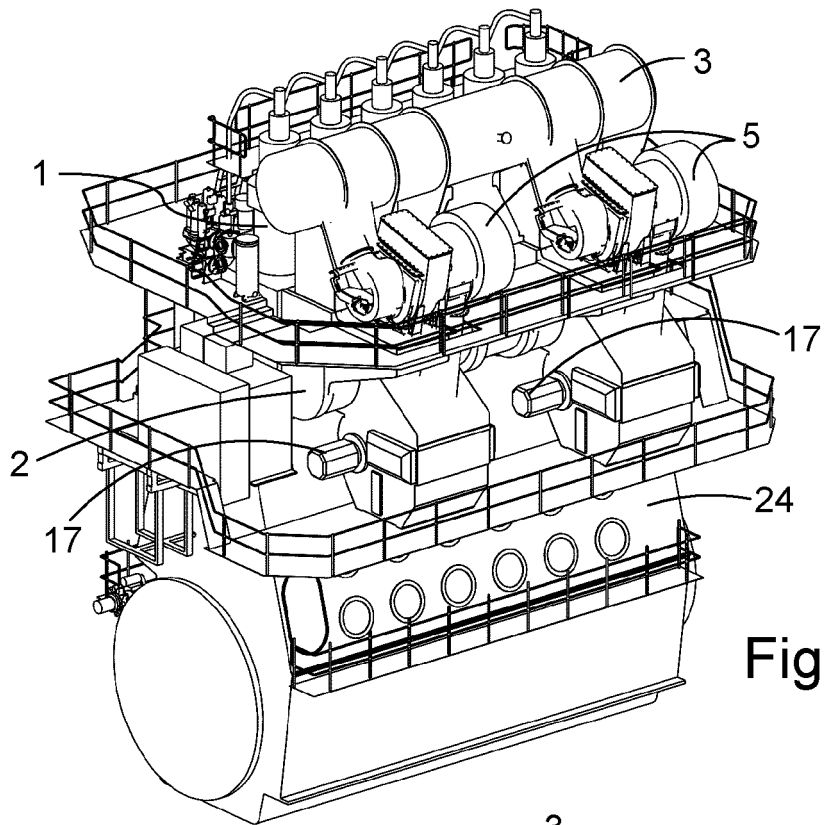


Fig. 1

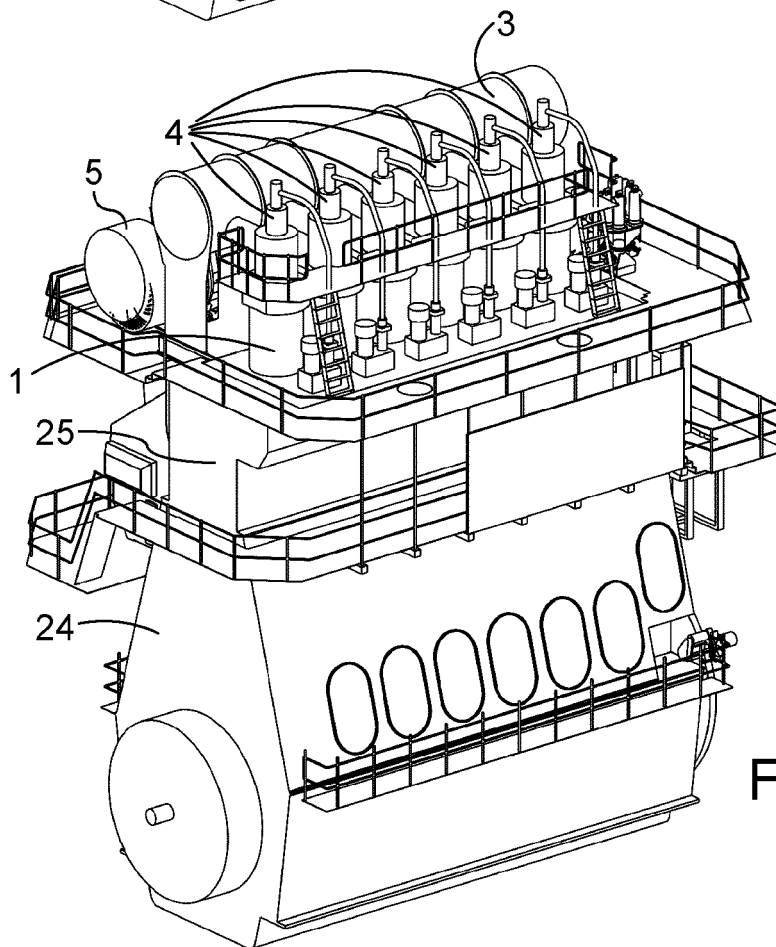


Fig. 2

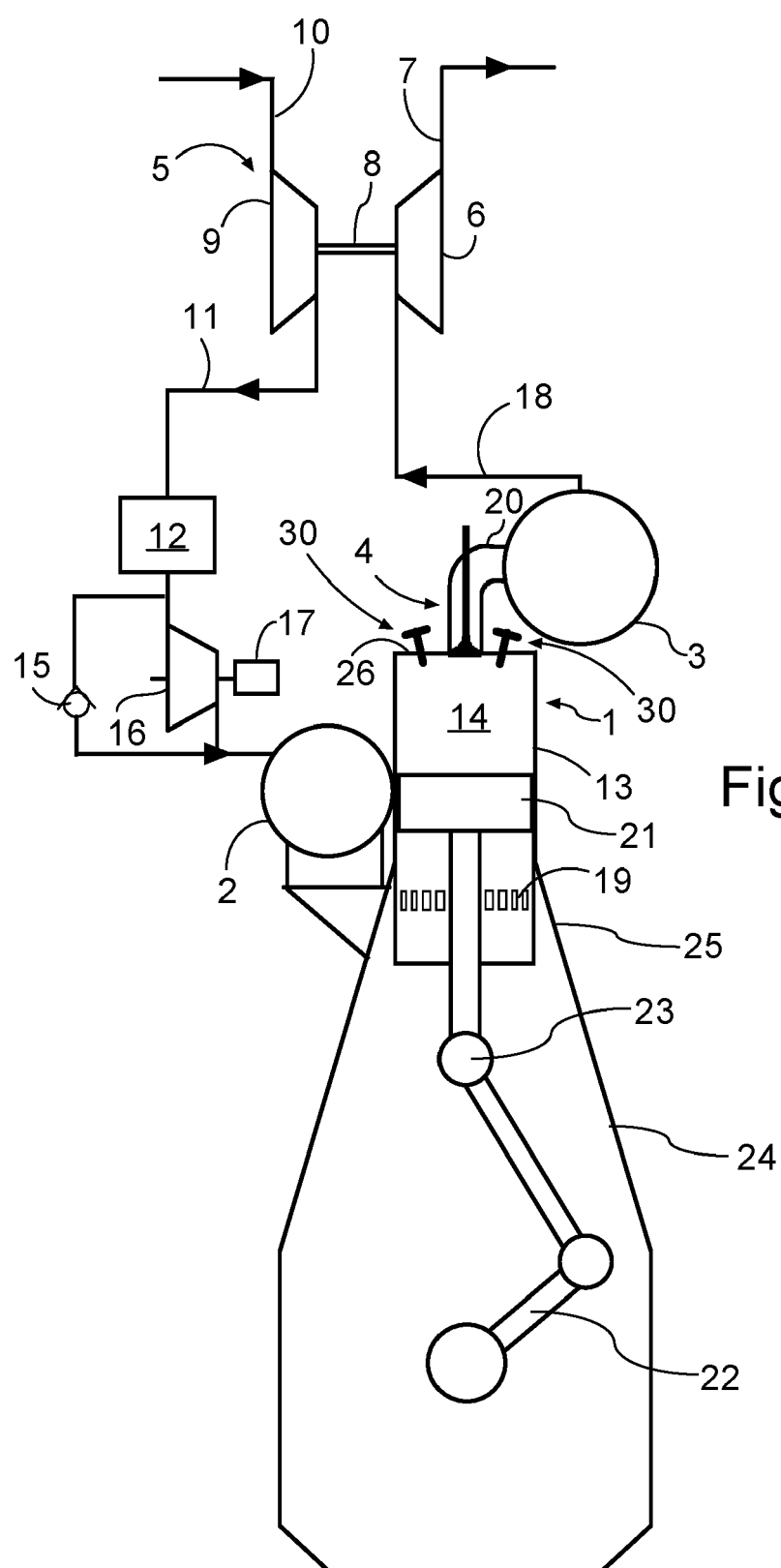
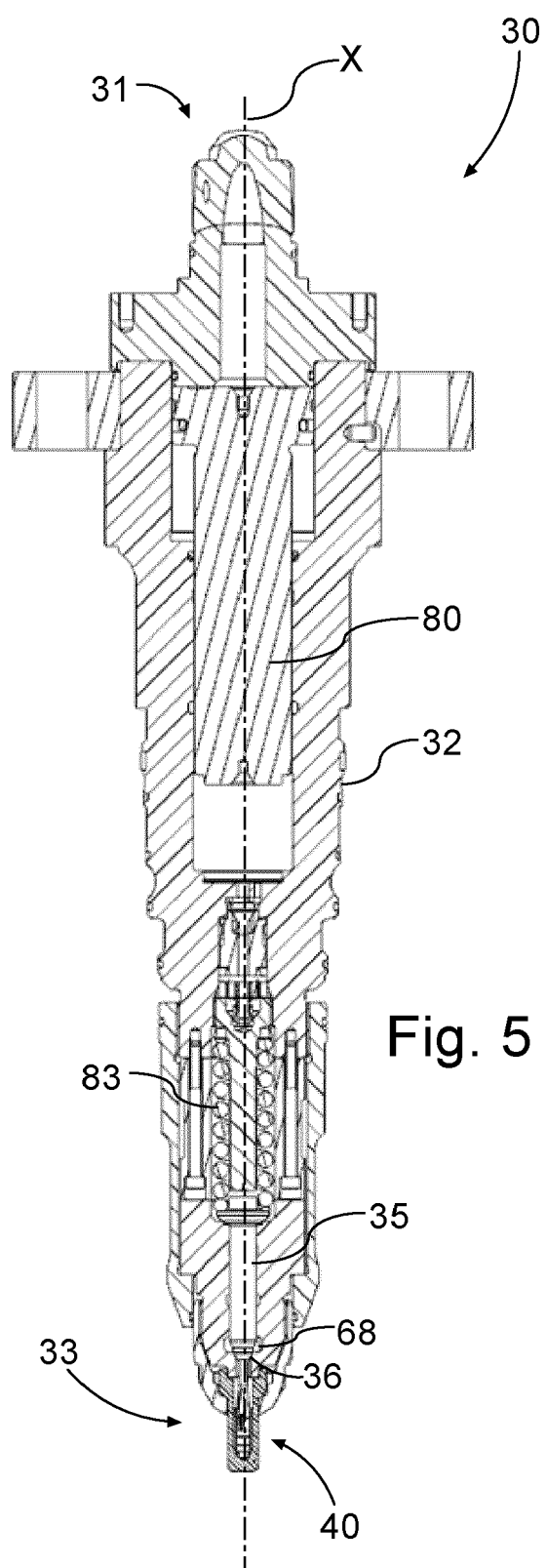
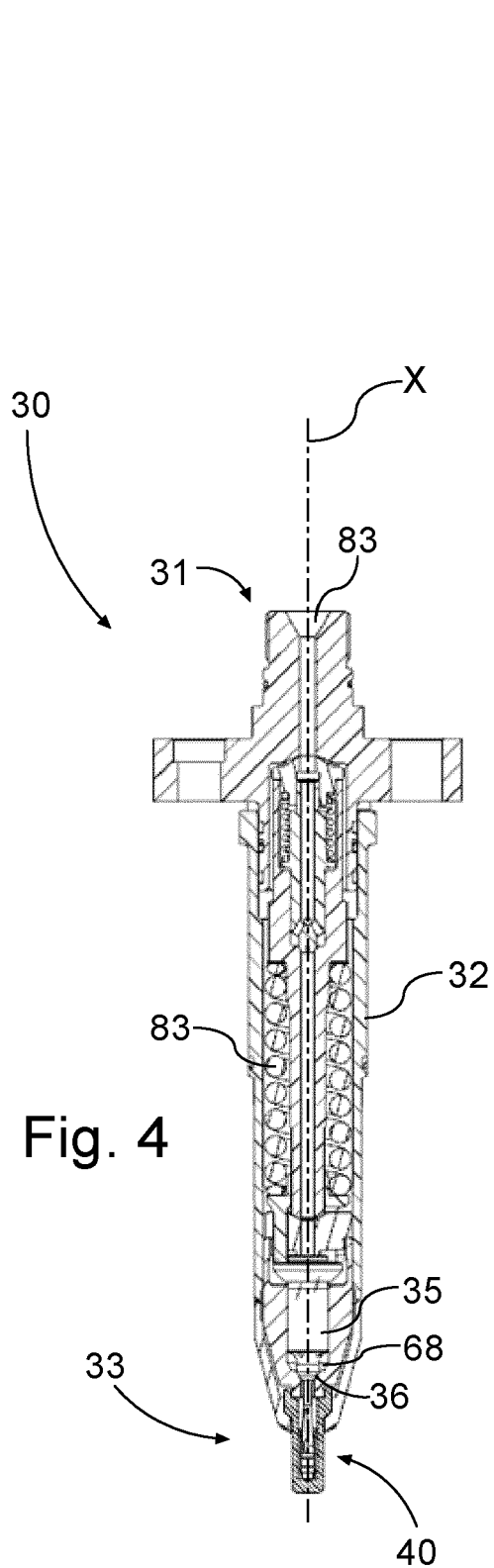


Fig. 3



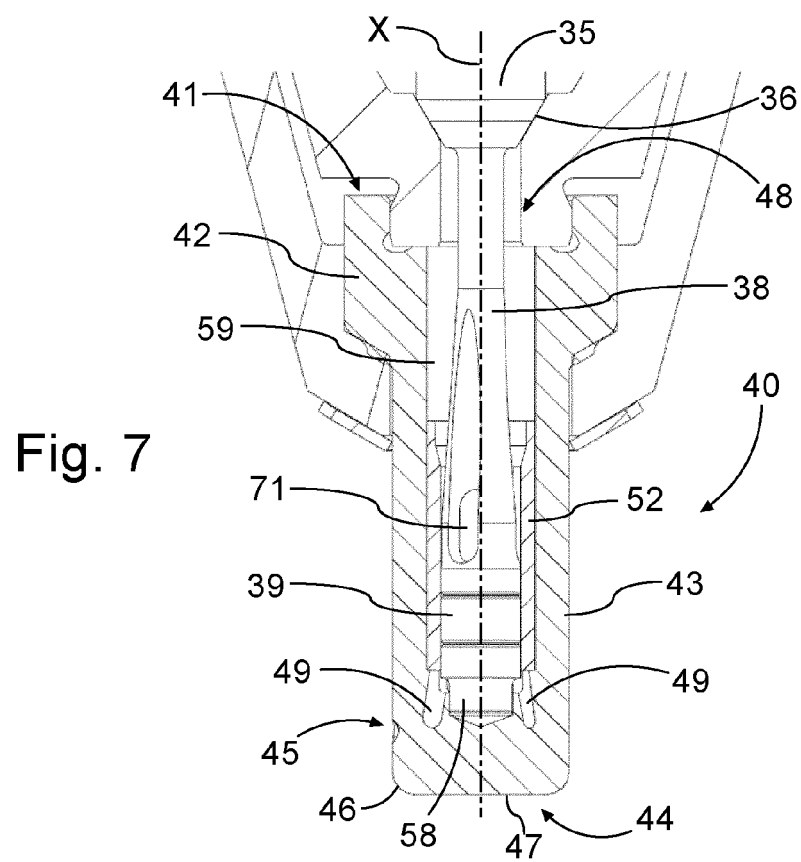
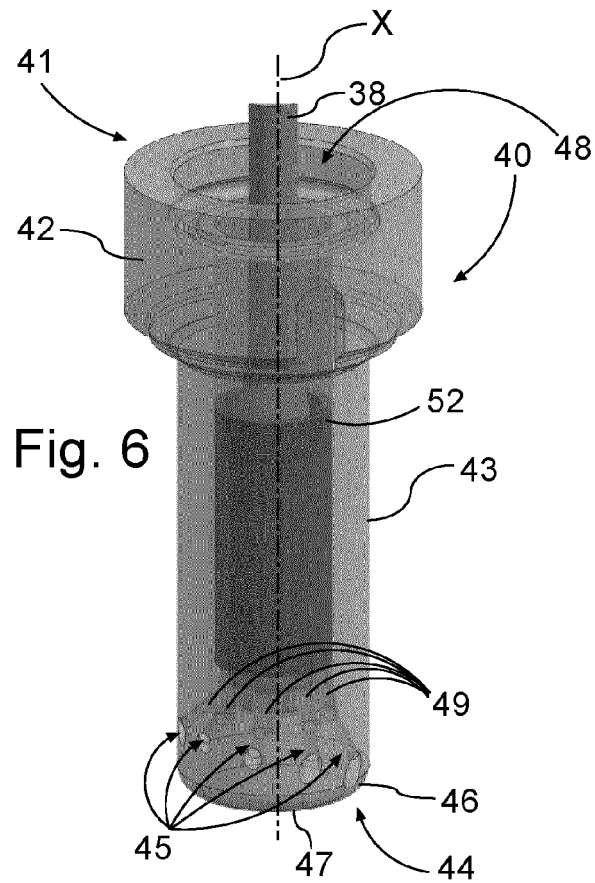


Fig. 8

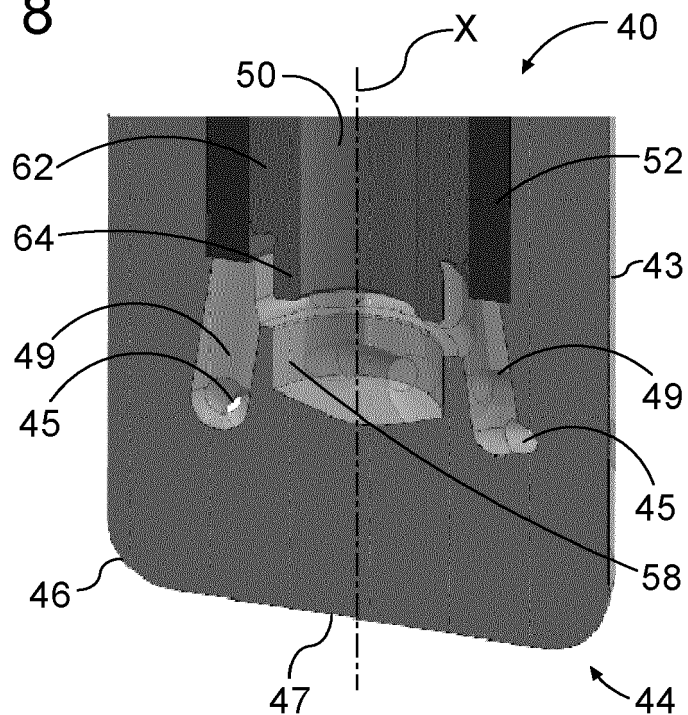


Fig. 9

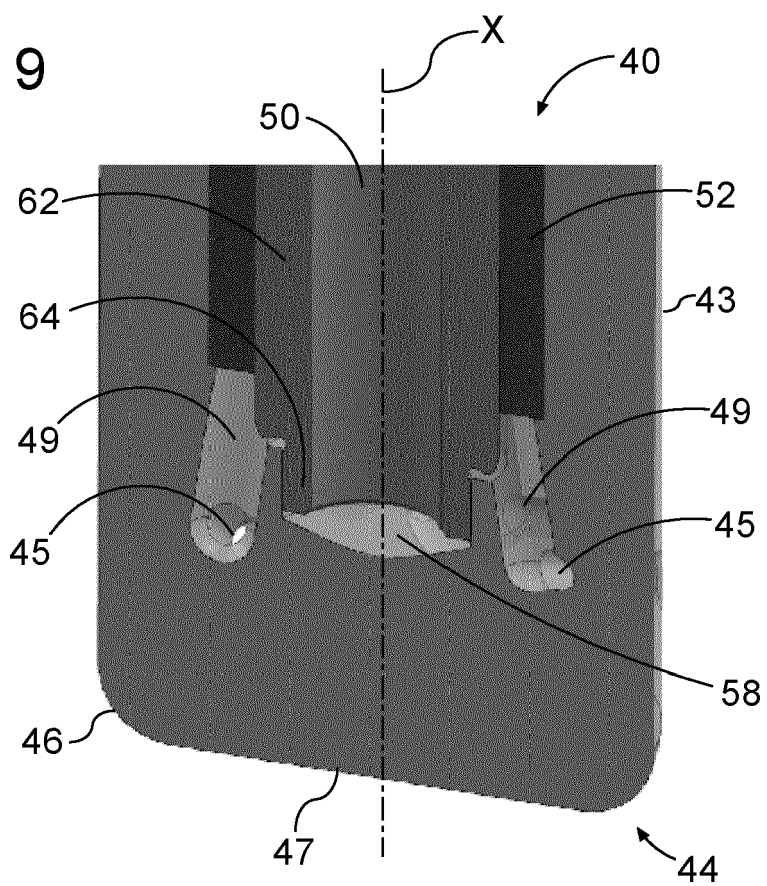


Fig. 10

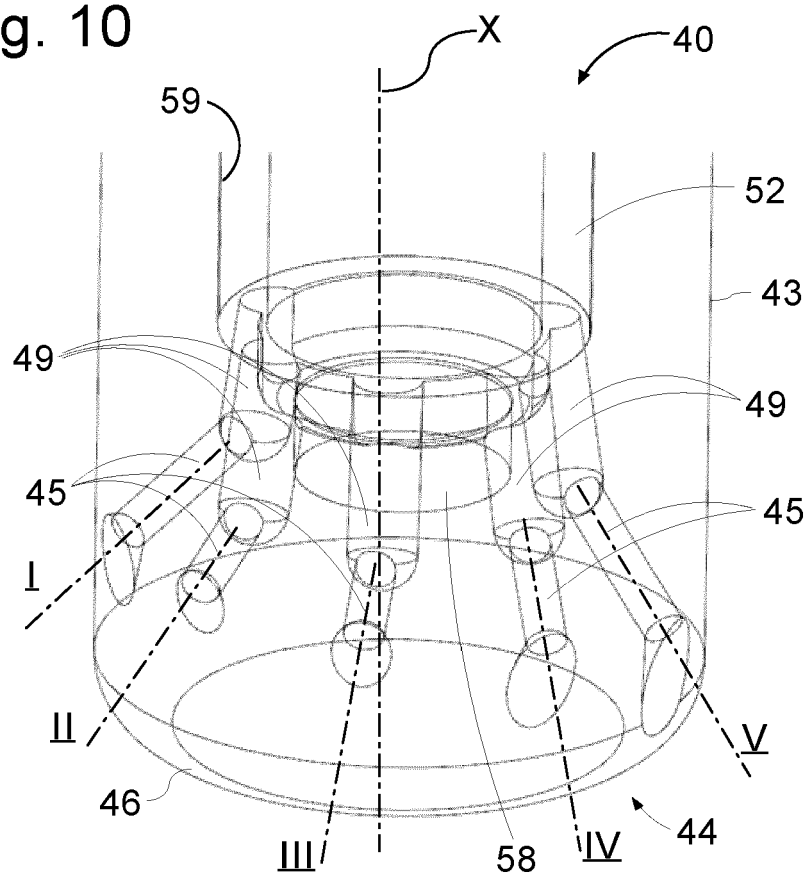
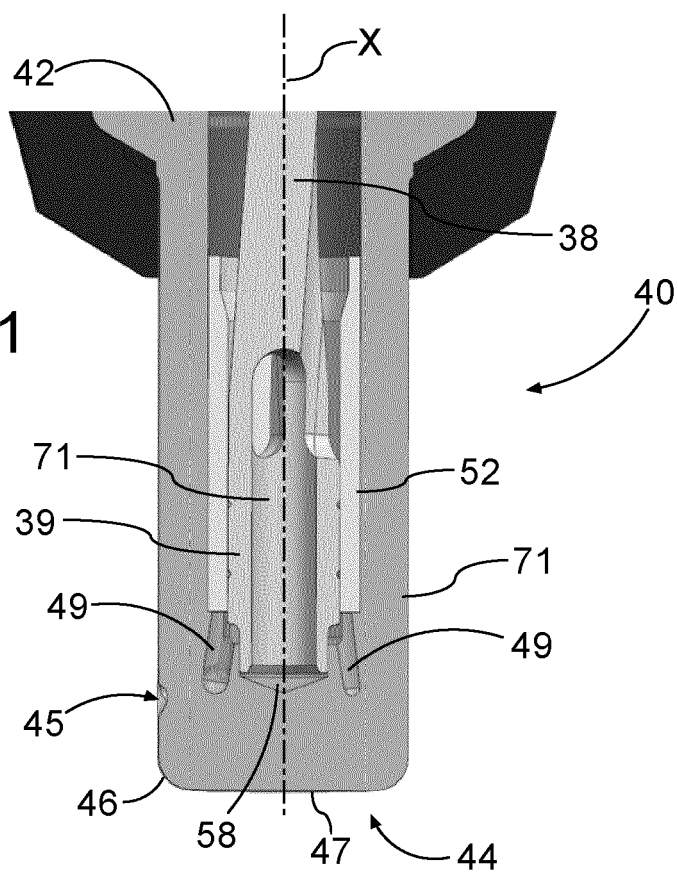
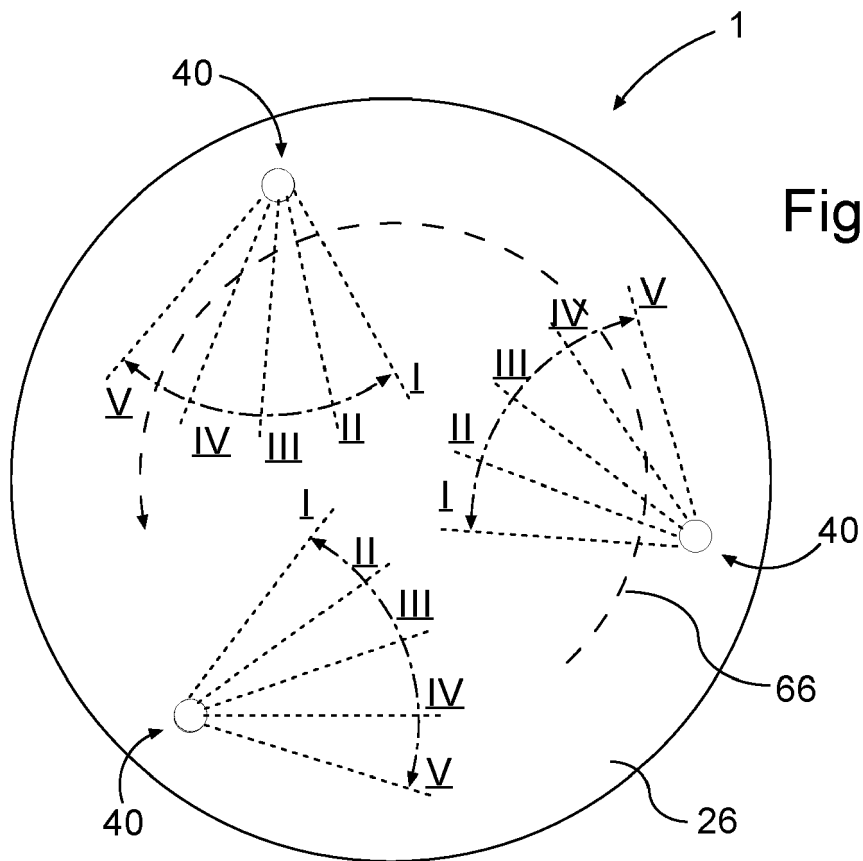


Fig. 11







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| The present search report has been drawn up for all claims                                                                                                                                                                                             |                                                                                                                      |                                                                                                                                                                                                                                                                                       |                                                          |
| Place of search<br><b>The Hague</b>                                                                                                                                                                                                                    |                                                                                                                      | Date of completion of the search<br><b>31 July 2024</b>                                                                                                                                                                                                                               | Examiner<br><b>Morales Gonzalez, M</b>                   |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |                                                                                                                      | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>.....<br>& : member of the same patent family, corresponding document |                                                          |

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