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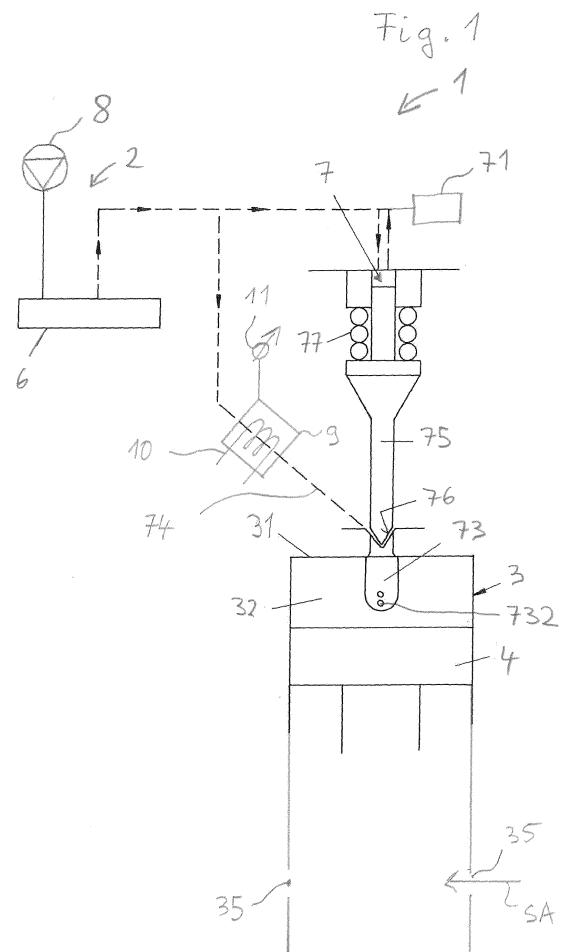
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(54) **METHOD FOR INJECTING A FUEL IN A LARGE DIESEL ENGINE, LARGE DIESEL ENGINE AND INJECTION DEVICE**

(57) A method is proposed for injecting a fuel in a large diesel engine, having at least one cylinder (3) with a combustion chamber (32) for the combustion of the fuel and with a piston (4) for reciprocating movement between a top dead center position and a bottom dead center position, and an injection device (7) for the injection of the fuel into the combustion chamber (32) of the cylinder, wherein the combustion chamber (32) is containing scavenging air under a compression pressure (PC), said method comprising the step of providing the fuel to the injection device (7) in a liquid phase under a fuel pressure (PF), wherein a fuel temperature (TF) is determined such that the fuel converts from the liquid phase to a gaseous phase when the fuel expands from the fuel pressure (PF) to the compression pressure (PC), the fuel is heated to the fuel temperature (TF) and the fuel is injected by the injection device (7) into the combustion chamber (32) of the cylinder (3). In addition, a large diesel engine, especially a large two-stroke diesel engine, and a injection device (7) are proposed.



Description

[0001] The invention relates to a method for injecting a fuel in a large diesel engine, to a large diesel engine and to an injection device for injecting a fuel in a large diesel engine according to the preamble of the respective independent claim.

[0002] Large diesel engines, which can be designed as two-stroke or four-stroke engines, for example as large two-stroke diesel engine with longitudinal scavenging, are often used as main propulsion units for ships or also in stationary operation, for example for driving large generators for the production of electrical power. Here as a rule the engines are in constant operation over a considerable period of time which makes high demands on the operating reliability and availability. For this reason, for the operators, long and predictable intervals between services, low degrees of wear and, an economical use of fuel and operating materials are central criteria for the operation of the machines.

[0003] Modern large diesel engines are electronically controlled and usually comprise a common rail system with a pressure reservoir for supplying the fuel, e.g. heavy oil, to the cylinders. The fuel in the pressure reservoir has a pressure of several hundred bar, for example 700-900 bar, but the pressure may also be higher, even more than 1000 bar.

[0004] For each cylinder at least one, but typically two or three electronically controlled injection devices are provided being connected to the pressure reservoir for receiving pressurized fuel from there. Each injection device has a spring-loaded valve needle cooperating with a valve seat as well as a nozzle head for injecting the fuel into the combustion chamber of the cylinder. The injection device is in fluid communication with the pressure reservoir. If the valve needle is lifted the pressurized fuel can pass between the valve needle and the valve seat and enters the nozzle head for being injected. If the valve needle is pressed into the valve seat the connection to the nozzle head is closed and no fuel can reach the nozzle.

[0005] Especially in view of the growing requirements regarding protection of the environment the operation of large diesel engines becomes more and more demanding. Large diesel engines are mostly operated with heavy oil that requires specific measures with regard to the exhaust resulting from the combustion. In particular the generation of nitrogen oxides NO_x during the combustion is a severe concern. Many efforts are known regarding the quality of the emissions, in particular the nitrogen oxide concentration in the emissions. The legal provisions and the limit values for the corresponding exhaust emission standards have been made increasingly stricter and will be made even stricter in the future. This has the consequence for large two-stroke diesel engines that the combustion of the classical fuel, i.e. heavy oil, which is heavily contaminated with pollutants, but also the combustion of diesel oil or other fuels will become more de-

manding.

[0006] In view of the stronger statutory provisions regarding the limitation of exhaust a need exists now for several years for so-called dual-fuel motors. These are engines that can be operated with two different fuels. In a gas mode a gas, for example natural gas like LNG (liquefied natural gas) or another suited gas for operating an internal combustion engine is used for the combustion in the cylinders. In a liquid mode a suited liquid fuel like gasoline, diesel or heavy oil is used for the combustion in the cylinders of the same engine.

[0007] Within the scope of this application the term "large diesel engine" or the like encompasses also such large engines, which can be operated beside the diesel operation that is characterized by the self-ignition of the fuel, also in an Otto operation, that is characterized by an external ignition, or in a mixed form of these two operations.

[0008] Nevertheless, both for the dual-fuel engine when operated in the diesel mode and for the large diesel engine that only uses liquid fuel like heavy oil there is a strong desire to improve the quality of the exhaust gas and especially to reduce the amount of nitrogen oxides in the exhaust gas.

[0009] Therefore, it is an object of the invention to propose a method for injecting a fuel in a large diesel engine that results in a reduction of detrimental components in the exhaust of the engine, especially in a reduction of the nitrogen oxides NO_x and the smoke. Furthermore, it is an object of the invention to propose a large diesel engine being designed to perform such a method. It is a further objective of the invention to propose an injection device for injecting a fuel, which is suited for such a method or such a large diesel engine.

[0010] The subjects of the invention satisfying these objects are characterized by the features of the independent claim of the respective category.

[0011] Thus, in accordance with the invention a method is proposed for injecting a fuel in a large diesel engine, having at least one cylinder with a combustion chamber for the combustion of the fuel and with a piston for reciprocating movement between a top dead center position and a bottom dead center position, and an injection device for the injection of the fuel into the combustion chamber of the cylinder, wherein the combustion chamber is containing scavenging air under a compression pressure, said method comprising the step of providing the fuel to the injection device in a liquid phase under a fuel pressure, wherein a fuel temperature is determined such that the fuel converts from the liquid phase to a gaseous phase when the fuel expands from the fuel pressure to the compression pressure, the fuel is heated to the fuel temperature and the fuel is injected by the injection device into the combustion chamber of the cylinder.

[0012] Accordingly, the liquid fuel is injected into the combustion chamber such that the fuel undergoes a phase transition from the liquid to the gaseous phase during the injection process. Since at least in modern

large diesel engines, that are electronically controlled and operated, all the operating parameters like the compression pressure in the combustion chamber, the temperature in the combustion chamber and the pressure of the liquid fuel in the pressure reservoir or the pressure of the fuel in the injection device are known at any time. Knowing the temperature and the pressure in the combustion chamber at the time of the fuel injection as well as the pressure of the fuel prior to injection it is no problem to determine a suited fuel temperature such that the fuel converts from the liquid to the gaseous state during the injection. For example the fuel temperature is determined such that it is higher than the saturation temperature of the fuel at the compression pressure in the combustion chamber. Then, the fuel will change from the liquid to the gaseous phase when the liquid fuel expands from the fuel pressure to the compression pressure.

[0013] Due to the phase transition of the liquid fuel to the gaseous phase prior to the combustion of the fuel the combustion process is very similar to the combustion of pre-mixed gases rather than the diffusion burning process of a liquid fuel in the combustion chamber that usually causes the production of soot. Especially, the NO_x production and the generation of smoke are a function of the flame temperature, the oxygen available and the residence time. In a gas-gas phase reaction as it is proposed by the present invention the flame temperature is somewhat higher as compared to a liquid phase-gas phase reaction, however the residence time is much shorter, which results in an lower absolute value of the amount of NO_x produced. With the method according to the invention a reduction of the NO_x production of up to 60% is possible. In addition, a considerably lower smoke level, i.e. a reduced amount of generated smoke, is achievable.

[0014] According to a preferred embodiment the fuel is heated to the fuel temperature by a heating chamber that is an integral part of the cylinder cover or is attached to the cylinder cover. Thus, the heating of the fuel is performed quite close to the location of the injection, which allows a reliable control of the temperature of the liquid fuel.

[0015] It is a particularly preferred measure that the fuel is heated to the fuel temperature by a heating chamber that is an integral part of the injection device or is attached to the injection device. This measure enables a heating of the fuel to the defined fuel temperature very close to the location of injection.

[0016] According to a preferred embodiment of the method the fuel is heated to the fuel temperature by an electrical heating device or a microwave heating device. Electrical or microwave heating are very easy to implement and allow a reliable control of the temperature of the fuel.

[0017] Of course, there are many other possible solution how the liquid fuel may be heated to the fuel temperature prior to the injection. For example the heat of the exhaust gas may be used to heat the fuel, either by a direct contact of the fuel supply line with the exhaust

gas system or by transferring heat from the exhaust gas to the fuel by way of a heat exchanger.

[0018] Furthermore, the invention proposes a large diesel engine, in particular large two-stroke diesel engine, comprising at least one cylinder with a combustion chamber for the combustion of a fuel and with a piston for reciprocating movement between a top dead center position and a bottom dead center position, an injection device with a nozzle head for injecting the fuel into the combustion chamber, a common rail system with a pressure reservoir for delivering the fuel in a liquid phase under a fuel pressure to the injection device, wherein the cylinder comprises at least one scavenging air opening for introducing scavenging air into the cylinder, and wherein the piston compresses the scavenging air to a compression pressure in the combustion chamber, wherein a heating chamber for the fuel is provided, for heating the fuel to a defined fuel temperature such that the fuel converts from the liquid phase to a gaseous phase when the fuel expands from the fuel pressure to the compression pressure, wherein the heating chamber is connectable to the nozzle head for supplying the liquid fuel to the nozzle head.

[0019] The large diesel engine according to the invention is particularly designed and suited for performing the method according to the invention. Thus, the large diesel engine according to the invention renders possible a considerably cleaner combustion of the fuel and a remarkable reduction in the NO_x production.

[0020] Analogously to the method according to the invention it is also preferred for the embodiment of the large diesel engine, when the heating chamber is an integral part of the injection device or is attached to the injection device, or when the heating chamber comprises a heating device being designed as an electrical heating device or a microwave heating device.

[0021] Furthermore, it is a preferred measure when the diesel engine comprises a temperature sensor for controlling the defined fuel temperature.

[0022] In addition, the invention proposes an injection device designed for injecting a fuel in a large diesel engine embodied according to the invention or for a method according to the invention. The injection device comprises a nozzle body and a nozzle head connected to the nozzle body, and a supply line for delivering the fuel in a liquid phase under a fuel pressure from an inlet to the nozzle head, the nozzle head having a longitudinal bore and at least one nozzle hole starting from the longitudinal bore through which the fuel can emerge into the combustion chamber having the compression pressure, wherein a valve needle is arranged in the nozzle body having an end section cooperating with a valve seat for opening or closing a passage for the fuel from the supply line to the nozzle hole, and wherein the injection device comprises a heating chamber for heating the fuel to a defined fuel temperature such that the fuel converts from the liquid phase to a gaseous phase when the fuel expands from the fuel pressure to the compression pres-

sure, wherein the heating chamber is arranged between the inlet and the valve seat.

[0023] With such an injection device the liquid fuel can be heated to a determined fuel temperature such that the fuel undergoes a phase transition from the liquid phase to the gaseous phase when the fuel expands from the fuel pressure to the compression pressure in the combustion chamber.

[0024] According to a preferred embodiment the heating chamber is an integral part of the nozzle body.

[0025] It is an advantageous measure when a part of the supply line is designed as the heating chamber. This enables a simple and space saving embodiment.

[0026] In a preferred embodiment the heating chamber has an integrated heating device which heats the fuel in the heating chamber at the fuel pressure to the fuel temperature.

[0027] The heating device is preferably an electrical heating device or a microwave heating device.

[0028] To support the phase transition of the fuel from the liquid to the gaseous state it is advantageous when each nozzle hole has a variable cross sectional area.

[0029] In particular, it is preferred when cross sectional area of each nozzle hole increases in the flow direction of the fuel.

[0030] The large diesel engine according to the invention may be designed as a dual fuel engine for the combustion of a liquid fuel, preferably heavy oil, and for the combustion of a gas.

[0031] Further advantageous measures and preferred embodiments of the invention result from the dependent claims.

[0032] The invention will be explained in more detail both in view of the method and in view of the devices with the help of the schematic drawings, which show:

Fig. 1: a schematic illustration of essential parts of an embodiment of a large diesel engine according to the invention,

Fig. 2: a schematic cross sectional view of an embodiment of an injector device according to the invention, and

Fig. 3: a schematic phase diagram.

[0033] Fig. 1 shows in a schematic representation of essential parts of an embodiment of a large diesel engine according to the invention being designated in its entity by reference numeral 1. The large diesel engine 1 has at least one cylinder 3 but typically more, for example up to fourteen cylinders 3. Since it is sufficient for the understanding of the invention, in Fig. 1 only one cylinder 3 is shown. In the cylinder 3 a piston 4 is arranged for a reciprocating movement between a top dead center and a bottom dead center. The top side of the piston 4 and a cylinder cover 31 together with the cylindrical wall of the cylinder 3 are limiting a combustion chamber 32 in which

the fuel is injected for the combustion. The exhaust valve of the cylinder is not shown in the schematic Fig. 1.

[0034] In the following description reference is made by way of example to an embodiment, wherein the large diesel engine 1 is designed as a large two-stroke diesel engine 1 with longitudinal scavenging. Since these large diesel engines 1 are well known in the art, there is no need for a detailed description.

[0035] The cylinder 3 of the large diesel engine 1 comprises at least one but typically a plurality of scavenging air openings 35 for introducing fresh air as scavenging air into the cylinder 3 as indicated by the arrow SA in Fig. 1. During the upward movement of the piston 4 from its bottom dead center position to its top dead center position the piston 4 closes the scavenging air openings 35 and after the closing of the exhaust valve (not shown) the scavenging air in the cylinder 3 is compressed by the movement of the piston 4 to a compression pressure in the combustion chamber 32 which compression pressure is reached when the piston 4 is near the top dead center position. The compression pressure is the pressure existing in the combustion chamber 32 when the fuel is injected into the combustion chamber 32.

[0036] Of course, the invention is not restricted to this specific type of a diesel engine. In particular, the engine may be any type of large diesel engine as they are used for example as main propulsion units for ships or also in stationary operation, for example for driving large generators for the production of electrical power. The large diesel engine 1 can be designed as two-stroke or four-stroke engine. It is also possible that the large diesel engine 1 is designed as a dual fuel engine for the combustion of a liquid fuel and for the combustion of a gas, for example natural gas.

[0037] The large two-stroke diesel engine 1 is usually operated with heavy oil. The same is true for the operation of a dual fuel engine in the liquid mode. Nowadays a modern large diesel engine 1 is operated in a fully electronically controlled manner. An engine control unit (not shown) operates and controls all functions of the large diesel engine 1, for example the operation of the exhaust valves for the gas exchange and the injection process for the fuel, by way of electronic signals and commands. In addition the engine control unit receives information from several detectors, sensors or measuring devices.

[0038] Fig. 1 also shows components of the common rail system 2 of the large diesel engine 1 that supplies the fuel, e.g. heavy oil, to the combustion chamber 32 of the cylinders 3. The common rail system 2 is designed for the supply of all cylinders 3 of the large diesel engine 1.

[0039] The common rail system 2 comprises a pressure reservoir 6 also called "fuel rail" which contains the fuel to be delivered to the cylinders 3 under a high pressure that essentially corresponds to the injection pressure. One or more fuel pumps 8 supply the pressure reservoir 6 with the fuel under high pressure. The pressure of the fuel in the pressure reservoir 6 has for example a value of 700-900 bar but may also be higher. A fuel boost-

er pump (not shown) which is connected with a reservoir for the fuel (not shown) delivers the fuel to the fuel pumps 8.

[0040] For maintaining the pressure of the fuel in the pressure reservoir 6 on a constant value a closed-loop control is provided. One or more pressure sensors measure the actual value of the pressure in the pressure reservoir 6. This value is transmitted to the engine control unit. Based upon this comparison the engine control unit sends a signal to flow control valves (not shown) with which the delivery rate of the fuel pumps 8 may be adjusted. By way of this closed-loop control the pressure of the fuel in the pressure reservoir 6 is kept on a constant value during operation of the engine 1. This constant value is designated as the fuel pressure.

[0041] The pressure reservoir 6 is in fluid communication with a plurality of electronically controlled injection devices 7 for injecting the fuel into the combustion chamber 32 of the respective cylinder 3. There is at least one injection device 7 for each cylinder 3, however in most large diesel engines there are two or three injector devices 7 for each cylinder 3. In the embodiment shown in Fig. 1 there are two electronically controlled injection devices 7 for each cylinder 3.

[0042] Preferably, the injection device 7 is designed as an injection device 7 according to the invention. Fig. 2 shows a schematic cross sectional view of an embodiment of an injector device 7 according to the invention

[0043] The electronically controlled injection device 7 (see Fig. 2) is controlled by a control unit 71 for starting and finishing the injection of fuel into the combustion chamber 32. The control unit 71 is in signal communication with the engine control unit and usually operated electric-hydraulically using the fuel from the pressure reservoir 6 as hydraulic medium. This design as such is known in the art and will therefore not be described in any detail.

[0044] The injector device 7 is mounted to the cylinder cover 31 of the respective cylinder 3. The injector device 7 comprises a nozzle body 72 and a nozzle head 73 connected to the nozzle body 72. Furthermore, the injector device 7 is provided with a supply line 74 extending through the nozzle body 72 for delivering the liquid fuel from an inlet 741 to the nozzle head 73. The inlet 741 of the supply line 74 is in fluid communication with the pressure reservoir 6.

[0045] A valve needle 75 is arranged in the nozzle body 72 having an end section cooperating with a valve seat 76. The valve needle 75 is spring loaded by a spring 77 exerting a force that presses the valve needle 75 into the valve seat 76. Directly above the valve seat 76, according to the representation in Fig. 2, a pressure chamber 78 is provided to which the supply line 74 extends such that the inlet 741 of the supply line 74 is in fluid communication with the pressure chamber 78

[0046] The pressurized fuel, as indicated by the dashed lines in Fig. 1, being supplied by the pressure reservoir 6 is fed to the inlet 741 of the supply line 74 to

the pressure chamber 78 at a location upstream of the valve seat 76. Thus, as long as the valve needle 75 is in sealing connection with the valve seat 76 the fuel cannot proceed from the pressure chamber 78 to the nozzle head 73.

[0047] The nozzle head 73 has a longitudinal bore 731 and at least one nozzle hole 732 starting from the longitudinal bore 731, so that the fuel can emerge from the longitudinal bore 731 through the nozzle hole 732 into the combustion chamber 32.

[0048] During operation the injection of fuel is performed in the following manner. As long as no injection is required into the respective cylinder 3 the control unit 71 keeps the valve needle 75 in a sealing engagement with the valve seat 76 so that the passage for the fuel from the pressure chamber 78 along the valve seat 76 to the nozzle head 73 is closed. When an injection into the respective cylinder 3 is required the control unit 71 opens the passage for the fuel along the valve seat 75 by causing a release of the downwardly directed force on the valve needle 75. Thus, the pressure of the fuel in the pressure chamber 78 prevails and removes the valve needle 75 against the force of the spring 77 from the sealing engagement with the valve seat 76. Now, the fuel may pass along the valve seat 76 into the longitudinal bore 731 of the nozzle head 73. To end the injection of fuel the control unit 71 causes an increase of the downwardly directed force on the valve needle thus that with support of the spring 77 the valve needle 75 is pushed into a sealing arrangement with the valve seat 76 which closes the passage for the fuel to the longitudinal bore 731.

[0049] According to the invention the fuel to be injected into the combustion chamber 32 is heated to such a fuel temperature that the liquid fuel converts to the gaseous phase when the fuel expands from the fuel pressure to the compression pressure in the combustion chamber 32 what will now be explained in more detail.

[0050] Fig. 3 shows a general phase diagram demonstrating the state of a substance, for example heavy oil in dependence from the temperature T on the horizontal axis and the pressure P on the vertical axis. There are three regions, namely the region S where the substance is in the solid state, the region L where the substance is in the liquid state and the region G where the substance is in the gaseous state. Such a diagram basically also applies for the fuel in a large diesel engine, in particular heavy oil.

[0051] As already mentioned the liquid fuel is delivered from the pressure reservoir 6 at a fuel pressure which is for example at least 700 bar. The fuel pressure is designated in Fig. 3 with PF. The compression pressure PC existing in the combustion chamber 32 just prior to the injection of the fuel when the piston 4 is near its top dead center position is lower than the fuel pressure PF, for example 180 bar. The typical temperature of the compressed scavenging air in the combustion chamber 32 just prior to the injection of the fuel, i.e. when the piston

4 is near the top dead center position is designated in Fig. 3 with TC. TC is usually for example 500°C. The conditions in the combustion chamber 32 just prior to the injection of the fuel are designated in Fig. 3 with the point A2 in the phase diagram having the temperature TC and the compression pressure PC. Taking into consideration the location of the point A2 and the fuel pressure PF at which the liquid fuel is delivered to the injection device 7, a fuel temperature TF may be determined which is indicated by the point A1 in Fig. 3 having the fuel temperature TF and the fuel pressure PF. The fuel temperature TF is determined such that a transition of the fuel from point A1 in the phase diagram to point A2 in the phase diagram results in a crossing of a boundary line LG between the liquid phase L and the gaseous phase G of the fuel, e.g. the heavy oil. Thus, upon injection of the liquid fuel into the combustion chamber 32 the fuel moves from point A1 in the phase diagram to point A2 in the phase diagram resulting in a phase transition from the liquid state to the gaseous state.

[0052] Especially in an electronically controlled large diesel engine all the operation parameters are known to the engine control unit, especially the values for the compression pressure PC, the temperature TC in the combustion chamber 32 as well as the fuel pressure PF of the fuel in the pressure reservoir 6. Thus, it is no problem to determine a suited fuel temperature TF for the fuel to be injected which fuel temperature TF assures that the liquid fuel converts from the liquid phase to the gaseous phase when the fuel is injected into the combustion chamber 32 of the cylinder 3.

[0053] The method according to the invention is in particular characterized by the step that a suited fuel temperature TF is determined such that the fuel converts from the liquid phase to the gaseous phase when the fuel expands from the fuel pressure PF to the compression pressure PC, that the fuel is heated to this fuel temperature TF and then injected into the combustion chamber 32.

[0054] As already mentioned the fuel pressure PF is usually at least 700 bar. The appropriate fuel temperature TF depends on the specific application. For many applications the fuel temperature TF is at least 400°C.

[0055] By the phase transition of the fuel from the liquid to the gaseous state the combustion in the combustion chamber 32 is a gas-gas phase reaction rather than a diffusion burning that typically takes place when the fuel merges and reacts as a liquid with the scavenging air. By the gas-gas like reaction the production of soot is avoided and a considerably reduced production of NO_x by the combustion process is achieved. Even if the flame temperature is increased in a gas-gas reaction as compared to a fluid-gas reaction, the residence time is considerably reduced in a gas-gas reaction which results in sum in a reduction of the produced NO_x which may be 60% or even more.

[0056] There are many different possibilities to heat the liquid fuel to the fuel temperature TF prior to the in-

jection. According to a preferred embodiment the fuel is heated by a heating chamber that is integral part of or attached to the cylinder cover 31 or integral part of or attached to the injection device 7. As schematically shown in Fig. 1 the liquid fuel coming from the pressure reservoir 6 is guided through a heating chamber 9 comprising a heating device 10 for heating the fuel in the heating chamber 9. The heating device 10 is designed for transferring heat to the fuel in order to heat the liquid fuel to the defined fuel temperature TF. The heating device 10 is preferably designed as an electrical heating device using electric energy to increase the temperature of the fuel to the fuel temperature, for example by induction heating, or as a microwave heating device, exposing the fuel to microwave radiation for increasing the temperature of the fuel.

[0057] Preferably a temperature sensor 11 is provided to control the temperature of the fuel in or after leaving the heating chamber 9. The temperature sensor 11 may be in signal communication with the engine control unit to communicate the actual temperature of the fuel to the engine control unit. In case this temperature is not in accordance with the determined or pre-defined fuel temperature the engine control unit may adjust the power of the heating device 10 in such a way that the desired fuel temperature TF is realized.

[0058] According to a particularly preferred embodiment the heating chamber 9 with the heating device 10 forms an integral part of the injection device 7 as shown in Fig. 2. The heating chamber 9 is an integral part of the nozzle body 72 and designed as a part of the supply line 74 between the inlet 741 of the supply line 74 and its connection to the pressure chamber 78. The heating chamber 9 comprises the heating device 10 which is designed as an electric or microwave heating device for heating the fuel in the heating chamber 9. This design has the advantage that the liquid fuel is heated to the fuel temperature TF very close to the nozzle head 73. Of course, it is also possible to locate the heating chamber 9 or the heating device 10 near the inlet 741 of the supply line 74 at a position outside the injection device 7.

[0059] The phase transition of the fuel from the liquid to the gaseous state takes place in the nozzle head 73, i.e. downstream of the valve seat 76 or when the fuel enters the combustion chamber 32. In order to support the phase transition of the fuel from the liquid to the gaseous state it is an advantageous measure when each nozzle hole 732 has a variable cross sectional area perpendicular to the flow direction through the nozzle hole 732. In particular, the cross sectional area of each nozzle hole 732 increases in the flow direction of the fuel to facilitate the transition into the gaseous phase. Preferably the injection of the fuel takes place at a crankshaft angle between 60 degree before the top dead center position of the piston 4 and a crankshaft angle of 10 degree after the top dead center position.

[0060] Although it is preferred that the heating of the liquid fuel to the fuel temperature takes place within the

injection device 7 other embodiments are of course possible. For example, the heating chamber 9 or the heating device 10 may be integrated or attached to the cylinder cover 31 of the cylinder and the fuel is guided through this heating chamber 9.

[0061] There are many other possibilities to transfer heat to the liquid fuel in order to heat the fuel to the fuel temperature TF. For example the heat of the exhaust system may be used by providing a heat contact between the hot parts of the exhaust system and the fuel to be injected. This heat contact may be realized by a heat exchanger transferring heat from the exhaust system to the fuel to be injected.

Claims

1. Method for injecting a fuel in a large diesel engine, having at least one cylinder (3) with a combustion chamber (32) for the combustion of the fuel and with a piston (4) for reciprocating movement between a top dead center position and a bottom dead center position, and an injection device (7) for the injection of the fuel into the combustion chamber (32) of the cylinder, wherein the combustion chamber (32) is containing scavenging air under a compression pressure (PC), said method comprising the step of providing the fuel to the injection device (7) in a liquid phase under a fuel pressure (PF), **characterized in that** a fuel temperature (TF) is determined such that the fuel converts from the liquid phase to a gaseous phase when the fuel expands from the fuel pressure (PF) to the compression pressure (PC), the fuel is heated to the fuel temperature (TF) and the fuel is injected by the injection device (7) into the combustion chamber (32) of the cylinder (3).
2. Method in accordance with claim 1, wherein the fuel is heated to the fuel temperature by a heating chamber (9) that is an integral part of the cylinder cover (31) or is attached to the cylinder cover (31).
3. Method in accordance with claim 1 wherein the fuel is heated to the fuel temperature by a heating chamber (9) that is an integral part of the injection device (7) or is attached to the injection device (7).
4. Method in accordance with anyone of the preceding claims, wherein the fuel is heated to the fuel temperature by an electrical heating device or a microwave heating device
5. Large diesel engine, in particular large two-stroke diesel engine, comprising at least one cylinder (3) with a combustion chamber (32) for the combustion of a fuel and with a piston (4) for reciprocating movement between a top dead center position and a bottom dead center position, an injection device (7) with

a nozzle head (73) for injecting the fuel into the combustion chamber (32), a common rail system (2) with a pressure reservoir (6) for delivering the fuel in a liquid phase under a fuel pressure (PF) to the injection device (7), wherein the cylinder (3) comprises at least one scavenging air opening (35) for introducing scavenging air into the cylinder (3), and wherein the piston (4) compresses the scavenging air to a compression pressure (PC) in the combustion chamber (32), **characterized in that** a heating chamber (9) for the fuel is provided, for heating the fuel to a defined fuel temperature (TF) such that the fuel converts from the liquid phase to a gaseous phase when the fuel expands from the fuel pressure (PF) to the compression pressure (PC), wherein the heating chamber (10) is connectable to the nozzle head (73) for supplying the liquid fuel to the nozzle head (73).

6. Large diesel engine in accordance with claim 5 wherein the heating chamber (9) is an integral part of the injection device (7) or is attached to the injection device (7).
7. Large diesel engine in accordance with claim 5 or claim 6, wherein the heating chamber (9) comprises a heating device (10) being designed as an electrical heating device or a microwave heating device.
8. Large diesel engine in accordance with anyone of claims 5 to 7, comprising a temperature sensor (11) for controlling the defined fuel temperature (TF).
9. Injection device for injecting a fuel in a large diesel engine according to anyone of claims 5-8 or for a method according to anyone of claims 1-4, comprising a nozzle body (72) and a nozzle head (73) connected to the nozzle body (72), and a supply line (74) for delivering the fuel in a liquid phase under a fuel pressure (PF) from an inlet (741) to the nozzle head (73), the nozzle head (73) having a longitudinal bore (731) and at least one nozzle hole (732) starting from the longitudinal bore (731) through which the fuel can emerge into the combustion chamber (32) having the compression pressure (PC), wherein a valve needle (75) is arranged in the nozzle body (72) having an end section cooperating with a valve seat (76) for opening or closing a passage for the fuel from the supply line (74) to the nozzle hole (732), **characterized in that** the injection device comprises a heating chamber (9) for heating the fuel to a defined fuel temperature (TF) such that the fuel converts from the liquid phase to a gaseous phase when the fuel expands from the fuel pressure (PF) to the compression pressure (PC), wherein the heating chamber (9) is arranged between the inlet (741) and the valve seat (76).

10. Injection device in accordance with claim 9, wherein the heating chamber (9) is an integral part of the nozzle body (72).
11. Injection device in accordance with claim 9 or claim 10, wherein a part of the supply line (74) is designed as the heating chamber (9). 5
12. Injection device in accordance with anyone of claims 9 to 11, wherein the heating chamber (9) has an integrated heating device (10) which heats the fuel in the heating chamber (9) at the fuel pressure to the fuel temperature (TF). 10
13. Injection device in accordance with claim 12, wherein the heating device (10) is an electrical heating device or a microwave heating device. 15
14. Injection device in accordance with anyone of claims 9 to 13, wherein each nozzle hole (732) has a variable cross sectional area. 20
15. Injection device in accordance with claim 14, wherein the cross sectional area of each nozzle hole (732) increases in the flow direction of the fuel. 25

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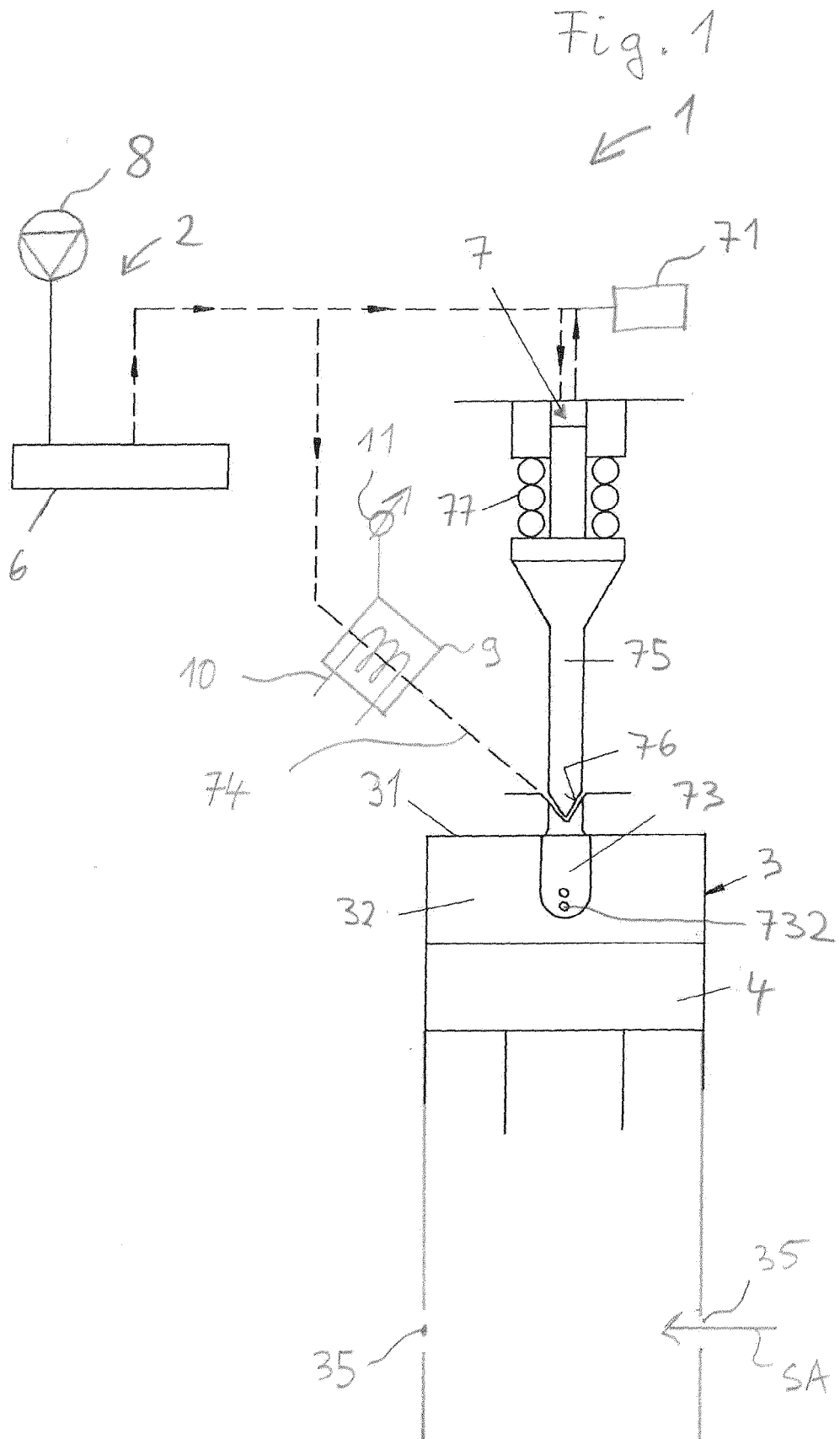
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7 Fig. 2

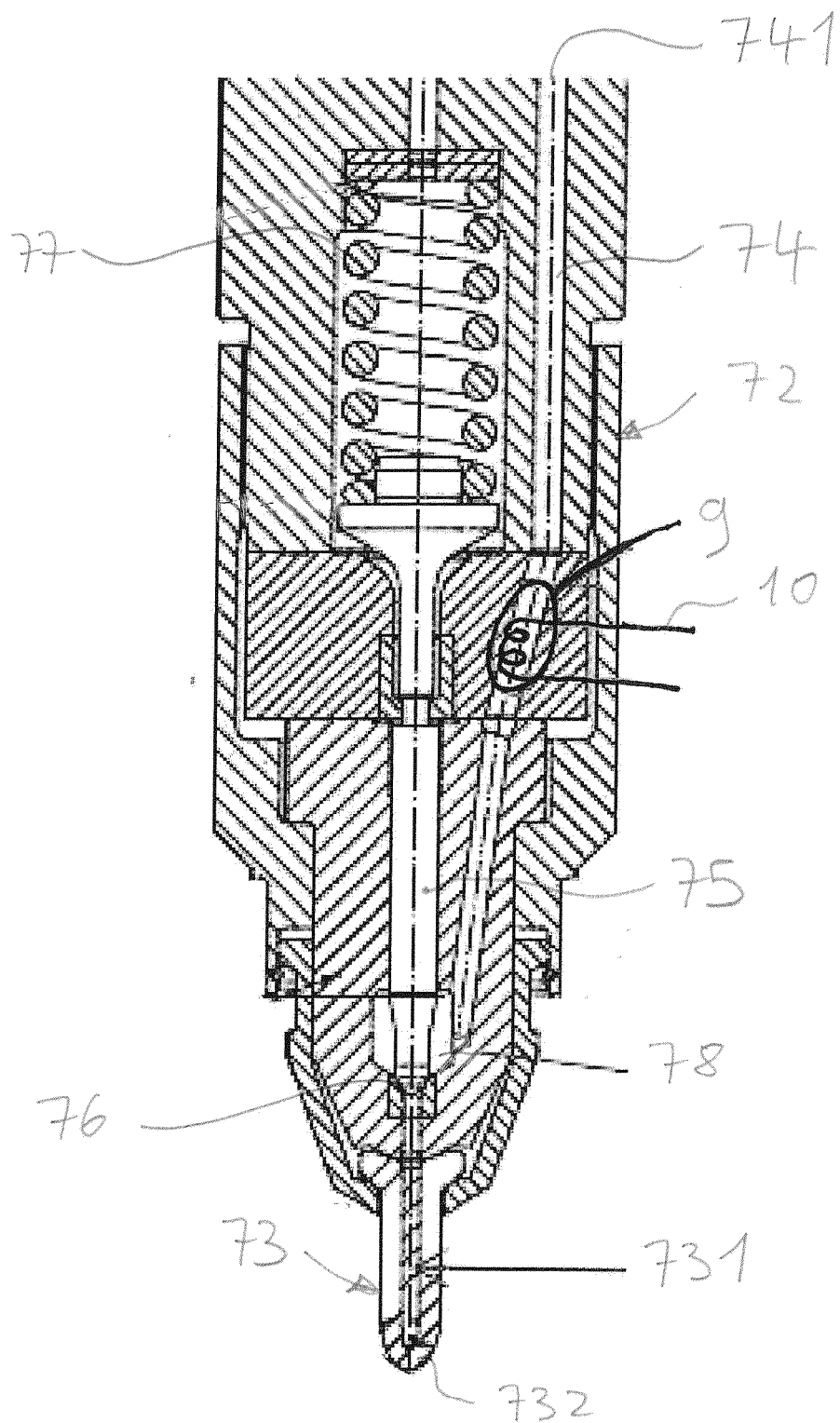
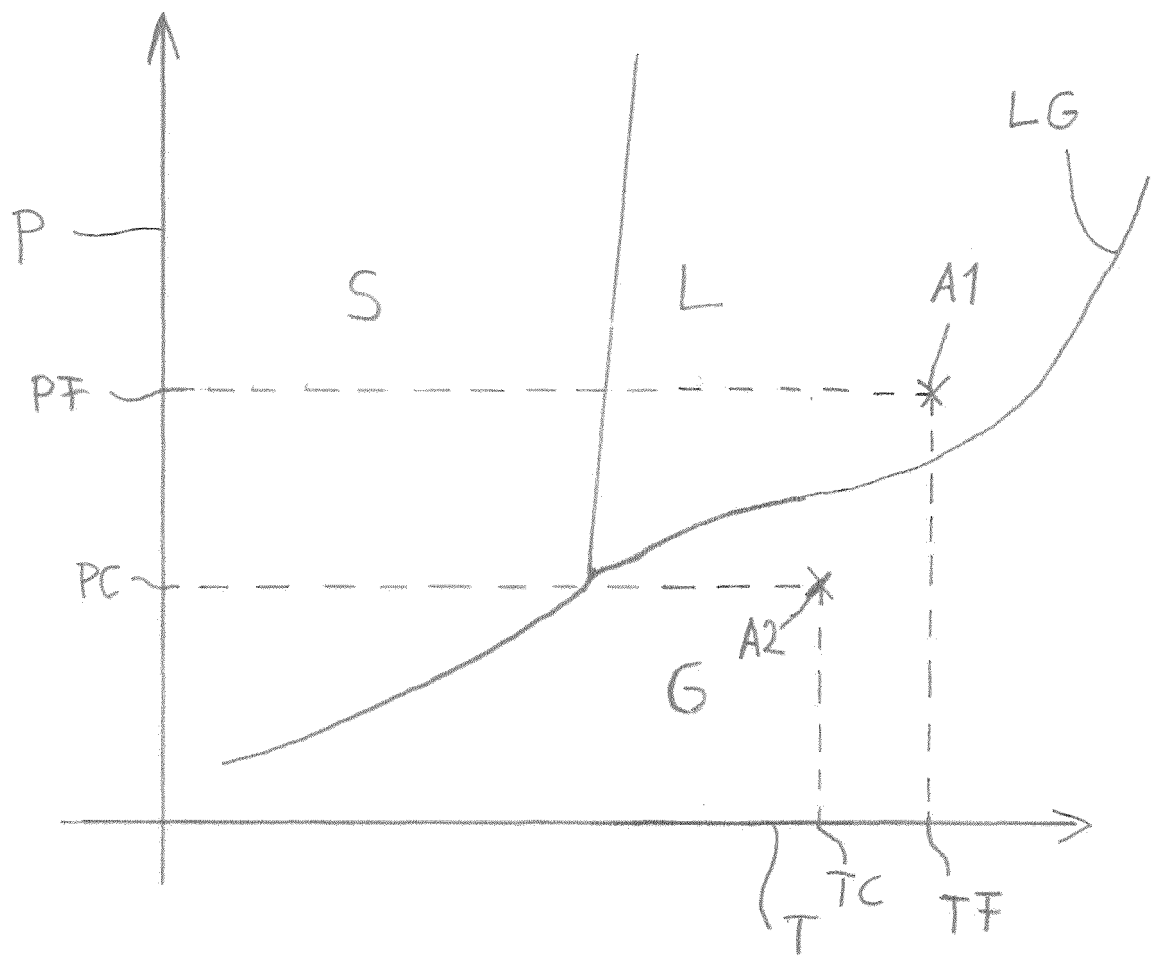


Fig. 3





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