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(54) Benævnelse: **A self-igniting internal combustion engine having a gaseous fuel supply system with pilot oil injection**

(56) Fremdragne publikationer:
US 4563982 A
WO 2005/108770 A
WO 2008/000095 A1
CA 2633846 A1
WO 2013/003888 A1
US 2013/0081593 A1

(57) Sammendrag:
A selfigniting internal combustion engine. The engine has a plurality of cylinders (1) and is provided with a gaseous fuel supply system. The cylinders (1) are provided with at least one gaseous fuel valve (50) for injecting a gaseous fuel from an outlet of the fuel valve (50) into the cylinder (1) concerned. The at least one gaseous fuel valve (50) has an inlet connected to a gaseous fuel supply conduit (62,63,64) that supplies pressurized gaseous fuel to the gaseous fuel valve (50). The engine further comprises at least one dedicated pilot oil valve (55) for each cylinder (1). The dedicated pilot oil valve (55) has an inlet connected to a source of pressurized pilot oil (57) and an outlet for injecting pilot oil fuel into the gaseous fuel supply conduit (62,63,64).

Fortsættes ...

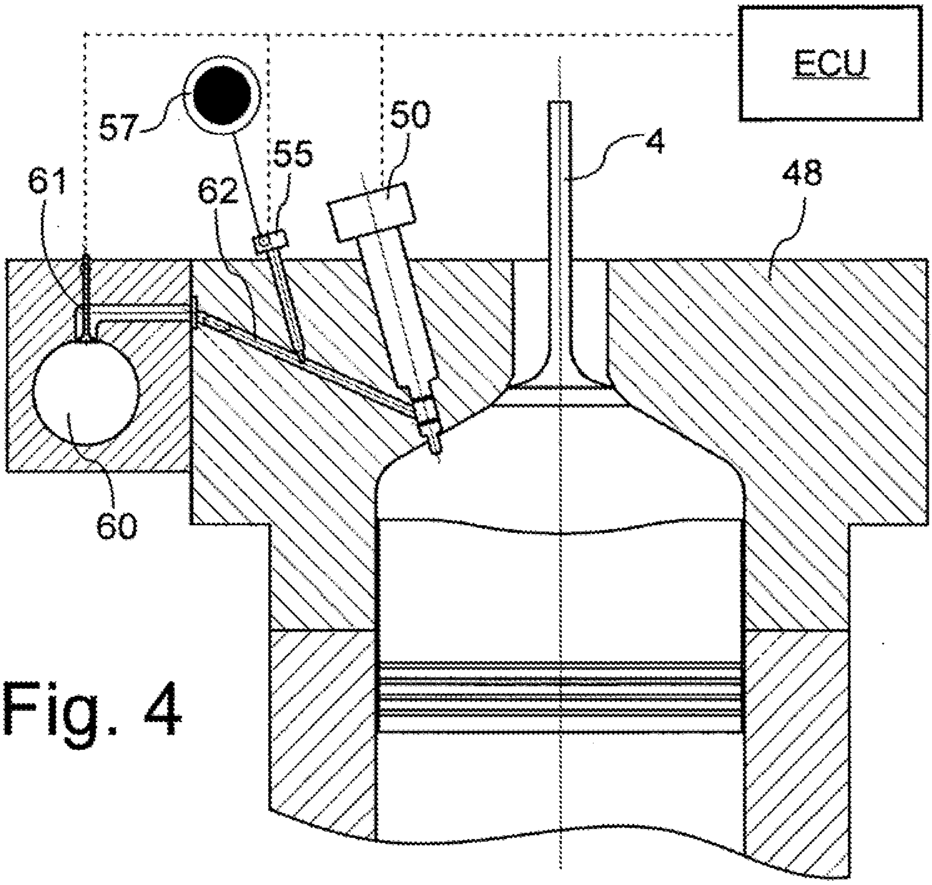

Fig. 4

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A SELF-IGNITING INTERNAL COMBUSTION ENGINE HAVING A GASEOUS FUEL SUPPLY SYSTEM WITH PILOT OIL INJECTION

FIELD OF THE INVENTION

The present invention relates to a self-igniting internal combustion engine with a gaseous fuel supply system, in particular to a large low-speed uniflow turbocharged two-stroke internal combustion engine with a gaseous fuel supply system and pilot oil injection.

BACKGROUND ART

Large low-speed two-stroke diesel engines of the crosshead type are typically used in propulsion systems of large ships or as prime mover in power plants. Very often, these engines are operated with heavy fuel oil or with fuel oil.

Recently, there has been a demand for large two-stroke diesel engines to be able to handle alternative types of fuel, such as gas, coal slurry, petroleum coke and the like, in particular gas.

Gaseous fuels, such a natural gas are relatively clean fuels that result in significantly lower levels of sulfurous components, NOx and $CO2$ in the exhaust gas when used as fuel for a large low-speed uniflow turbocharged two-stroke internal combustion engine when compared with e.g. using Heavy Fuel Oil as fuel.

However, there are problems associated with using a gaseous fuel in a large low-speed uniflow turbocharged two-stroke internal combustion engine. One of those problems is the willingness and predictability of gas to self-ignite and both are essential to have under control in a self-igniting (Diesel) engine. Therefore, existing large low-speed uniflow turbocharged two-stroke internal combustion engine use pilot injection of oil simultaneously with the injection of the gaseous fuel to ensure reliable and properly timed ignition of the gaseous fuel.

Large low-speed uniflow turbocharged two-stroke internal combustion engines are typically used for the propulsion of large ocean going cargo ships and reliability is therefore of the utmost importance. Gaseous fuel operation of these engines is still a relatively recent development and reliability of the operation with gas has not yet reached the level of conventional fuel. Therefore, existing large low-speed two-stroke diesel engines are all dual fuel engines with a fuel system for operation on gaseous fuel and a fuel system for operation with fuel oil (Heavy fuel Oil) so that they can be operated at full power running on the fuel oil only.

Due to the large diameter of the combustion chamber of these engines, they are typically provided with three fuel injection valves per cylinder, separated by an angle of approximately 120° around the central exhaust valve. Thus, with a dual fuel system there will be three gas injection valves per cylinder and three fuel oil injection valves per cylinder with one fuel oil injection valve placed close to each respective gas injection valve so as to ensure reliable ignition of the gas and thus, the top cover of the cylinder is a relatively crowded place.

In the existing dual fuel engines the fuel oil valves have been used to provide the pilot oil injection during operation with gaseous fuel. These fuel oil valves are dimensioned so as to be able to deliver fuel oil in an amount required for operating the engine at full load on fuel oil only. However, the amount of oil injected in a pilot injection should be as small as possible to obtain the desired reduction in emissions. Dosage of such a small amount with a fuel oil valve that can also deliver the large amount necessary for operation at full load poses significant technical problems, and is in practice very difficult to achieve and therefore the pilot oil dosage has in existing engines been with a larger quantity per fuel injection event than desirable.

CA 2 633 846 discloses a self-igniting internal combustion engine wherein the cylinders are provided with a fuel valve for co-injecting a gaseous fuel and a pilot oil from an outlet nozzle of the fuel valve into the cylinder concerned.

US 4 563 982 discloses a method and apparatus for introduction of a fluid or liquid medium into the working or operating chamber of an internal combustion engine is disclosed. For the purpose and object of reduction of nitric oxide emission as well as for an improvement of the efficiency US 4 563 982 proposes a method and apparatus for introduction of the fluid or liquid medium into the working or operating chamber of an internal combustion engine operated with gaseous fuels to admix the fluid continuously or intermittently as to the gaseous fuel and subsequently to blow-in the fuel or power gas/fluid or liquid mixture into the working or operating chamber of the internal combustion engine under the pressure of the fuel or power gas. Hereby, there can in US 4 563 982 be utilized or employed advantageously besides the water also alcohol and alcohol/water mixtures, which means media with bound OH-groups.

US 5 243 932 discoses fuel injection method for diesel internal combustion engines uses main injection of a gas main fuel and pilot injection of a liquid secondary fuel to initialize combustion of the main fuel. The liquid fuel is injected by an injector pump designed to enable the engine to achieve its maximum power with the liquid fuel only. The pilot injection comprises a mixture of water and liquid fuel.

DISCLOSURE OF THE INVENTION

On this background, it is an object of the present application to provide a self-igniting internal combustion engine that overcomes or at least reduces the problems indicated above.

This object is achieved by providing a self-igniting internal combustion engine, the engine comprising a plurality of cylinders, the cylinders being provided with at least one gaseous fuel valve for injecting a gaseous fuel from a nozzle of the fuel valve into the cylinder concerned, the at least one gaseous fuel valve having an inlet connected to a gaseous fuel supply conduit that supplies pressurized gaseous fuel to the gaseous fuel valve, and at least one dedicated pilot oil valve for each cylinder, the pilot oil valve having an inlet connected to a source of pressurized pilot oil and a nozzle for injecting pilot oil fuel into the gaseous fuel supply conduit.

By injecting the pilot oil from a nozzle of a dedicated pilot oil valve upstream of the gaseous fuel valve, it becomes possible to use a small and thus a precise valve which in turn allows more precise dosage of the fuel oil and a reduction of the pilot fuel consumption.

Further, by injecting the pilot oil upstream of the gaseous fuel valve it is avoided that the small and sensitive pilot oil valve is exposed to the harsh environment of the combustion chamber. Moreover, by injecting the pilot oil into the gaseous fuel upstream of the fuel valve, the timing of the injection of the pilot oil becomes relatively noncritical and thus the control of the timing of the pilot oil injection is facilitated can be obtained by less advanced technology.

In an embodiment each cylinder is provided with a gaseous fuel accumulator, and the gaseous fuel supply conduit extends between the gaseous fuel accumulator and the at least one gaseous fuel valves of the cylinder concerned and the outlet of the at least one dedicated pilot oil valve is configured to inject pilot fuel oil into the gaseous fuel supply conduit.

In an embodiment a window valve is arranged at the outlet of the gaseous fuel accumulator and the window valve controls the flow of gaseous fuel from the gaseous fuel accumulator to the gaseous fuel supply conduit.

In an embodiment the at least one dedicated pilot oil valve is configured to inject the pilot oil when the at least one gaseous fuel valve is closed.

In an embodiment the at least one dedicated pilot oil valve is configured to inject the pilot oil before the gaseous fuel valve performs a gaseous fuel injection event.

In an embodiment the at least one dedicated pilot oil valve atomizes the pilot oil into the gaseous fuel supply conduit.

In an embodiment the engine is configured to use a small fuel oil valve for take home or emergency power when the gaseous fuel system is out of order.

In an embodiment one or more of the cylinders are provided with a plurality of regular or full size fuel oil injection valves for injecting fuel oil into the cylinder.

In an embodiment the at least one dedicated pilot oil valve is associated with each gaseous fuel valve.

In an embodiment the engine further comprises an electronic control unit configured to control and to operate the at least one gaseous fuel valve and the at least one dedicated pilot oil valve.

Further objects, features, advantages and properties of the self-igniting internal combustion engine according to the present disclosure will become apparent from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the present description, the invention will be explained in more detail with reference to the exemplary embodiments shown in the drawings, in which:

Fig. 1 is a front view of a large two-stroke diesel engine according to an example embodiment,
Fig. 2 is a side view of the large two-stroke engine of Fig. 1,
Fig. 3 is a diagrammatic representation the large two-stroke engine according to Fig. 1, and
Fig. 4 is a sectional view in diagrammatic representation of an example embodiment of gaseous fuel system with pilot oil injection of the engine of Fig. 1 of the upper part of a cylinder,
Fig. 5 is a top view in diagrammatic representation a cylinder and the gaseous fuel injection system of the embodiment of Fig. 4, and
Fig. 6 is a top view in diagrammatic representation a cylinder and the gaseous fuel injection system of another example embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the following detailed description, the self-igniting internal combustion engine will be described with reference to a large two-stroke low-speed turbocharged internal combustion (Diesel) engine in the example embodiments. Figs. 1, 2 and 3 show a large low-speed turbocharged two-stroke diesel engine with a crankshaft 42 and crossheads 43. Fig. 3 shows a diagrammatic representation of a large low-speed turbocharged two-stroke diesel engine with its intake and exhaust systems. In this example embodiment the engine has six cylinders 1 in line. Large low-speed turbocharged two-stroke diesel engines have typically between four and fourteen cylinders in line, carried by an engine frame 13. 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.

The engine is in this example embodiment a diesel engine of the two-stroke uniflow type with scavenge ports at the lower region of the cylinders 1 and a central exhaust valve 4 at the top of the cylinders 1. The scavenge air is passed from the scavenge air receiver 2 to the scavenge ports (not shown) of the individual cylinders 1. A piston 41 in the cylinder 1 compresses the scavenge air, fuel is injected from fuel injection valves in the cylinder cover, combustion follows and exhaust gas is generated. When an exhaust valve 4 is opened, the exhaust gas flows through an exhaust duct associated with the cylinder 1 into the 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 via a economizer 28 to an outlet 29 and into the atmosphere. Through a shaft, the turbine 6 drives a compressor 9 supplied with fresh air via an air inlet 10. The compressor 9 delivers pressurized scavenge air to a scavenge air conduit 11 leading to the scavenge air receiver 2.

The scavenge air in conduit 11 passes an intercooler 12 for cooling the scavenge air - that leaves the compressor at approximately 200 °C - to a temperature between 36 and 80 °C.

The cooled scavenge air passes via an auxiliary blower 16 driven by an electric motor 17 that pressurizes the scavenge air flow in low or partial load conditions of the engine to the scavenge air receiver 2. At higher engine loads the turbocharger compressor 9 delivers sufficient compressed scavenge air and then the auxiliary blower 16 is bypassed via a non-return valve 15.

Figs. 4 and 5 show the top of one of the plurality of cylinders 1 according to an example embodiment. The top cover 48 of the cylinders 1 is provided with three gaseous fuel valves 50 for injecting a gaseous fuel from an outlet of the fuel valves 50, such as a nozzle, into the combustion chamber in the cylinder 1. This example embodiment shows three gaseous fuel valves 50 per cylinder, but it should be understood that a single or two gaseous fuel valves may be sufficient, depending on the size of the combustion chamber. The gaseous fuel valve 50 has an inlet connected to a gaseous fuel supply conduit that supplies pressurized gaseous fuel to the gaseous fuel valve 50. One of the three gaseous fuel valves 50 is supplied by supply conduit 62, another one of the three gaseous fuel valves 50 is supplied by supply conduit 63, and the third of the three gaseous fuel valves 50 is supplied by supply conduit 64. In this embodiment the supply conduits 62,63,64 are drilled holes in the top cover 48 that connect to a gas accumulator 60 associated with the cylinder 1. The gas accumulator 60 receives high pressure gas from a gas supply system (not shown) that includes gas tanks and high pressure pumps.

In the shown embodiment a dedicated pilot oil valve 55 is associated with each gaseous fuel valve 50, but it is understood that it can suffice to have a least one dedicated pilot oil valve 55 for each cylinder 1.

The pilot oil valve 55 has an inlet connected to a source of pressurized pilot oil 57, such as marine diesel, and an outlet for injecting pilot oil fuel into the respective gaseous fuel supply conduit 62,63,64, i.e.in the gaseous fuel stream that is flowing to the gaseous fuel valve 50. The pilot oil valves 55 are placed in a suitable bore in the top cover 48 with the a nozzle of the pilot oil valve 55 protruding into a fuel supply conduit 62,63,64.

Each cylinder 1 is in this example embodiment provided with a gaseous fuel accumulator 60, The gaseous fuel accumulator 60 contains an amount of gaseous fuel under high pressure that is ready to be delivered to the fuel valves 50 of the cylinder 1. The gaseous fuel supply conduits 62,63,64 extend between the gaseous fuel accumulator 60 and a respective gaseous fuel valve 50 of the cylinder 1 concerned. The outlet (nozzle) of the pilot oil valves 55 is configured to inject pilot fuel oil into the respective gaseous fuel supply conduit 62,63,64, i.e. upstream of the respective gaseous fuel valve 50. Preferably, the dedicated pilot oil valves 55 atomizes the pilot oil into the respective gaseous fuel supply conduit 62,63,64.

A window valve 61 is arranged at the outlet of the gaseous fuel accumulator 60 and the window valve 61 controls the flow of gaseous fuel from the gaseous fuel accumulator 60 to the gaseous fuel supply conduits 62,63,64.

The engine is provided with an electronic control unit ECU that controls the operation of the engine. Signal lines connect the electronic control unit ECU to the gaseous fuel valves 50, to the plot oil valves 55 and to the window valves 61.

The electronic control unit ECU is configured to time the injection events for the gaseous fuel valve correctly and to control the dosage of the gaseous fuel with the gaseous fuel valves 50. The dedicated pilot oil valves 55 and the electronic control unit ECU are configured to inject the pilot oil when the associated gaseous fuel valve 50 is closed.

In an embodiment the dedicated pilot oil valves 55 and the electronic control unit ECU are configured to inject pilot oil before the gaseous fuel valve 50 performs a gaseous fuel injection event. The electronic control unit ECU opens and closes the window valve 61 so as to ensure that the supply conduits 62,63,64 are filled with high pressure gaseous fuel before the start of the gaseous fuel injection event controlled by the gaseous fuel valve 50. In an embodiment the pilot oil injection is performed under control of the electronic control unit ECU after the supply conduits 62,63,64 have been filled with high pressure gaseous fuel from the accumulator 60 and after the window valve 61 has returned to its closed position. In the time slot between the closing of the window valve 61 and the opening of the gaseous fuel valve 50 the pilot oil is in injected. The timing within this slot is not critical and thus the control of the timing and length of the pilot oil injection event does not have to be very precise and the pilot oil injection can be performed with relatively low pressure pilot oil, i.e. a pressure significantly lower than the pressure needed to atomizing the pilot fuel directly into the combustion chamber. In an embodiment the amount of pilot oil per injection event is fixed, regardless of the engine load.

In an embodiment the cylinders are provided with small fuel oil valves that inject fuel oil directly into the combustion chamber and in this embodiment the electronic control unit ECU is configured use the small fuel oil valves for take home power or emergency power when the gaseous fuel system fails or is out of order for other reasons. Hereto, the electronic control unit ECU ensures in a take home/emergency operating mode that the small fuel injection valves are activated and the ECU performs a fuel oil injection event with the appropriate timing relative to the engine cycle. The small fuel oil valves are labeled "small" since their capacity is significantly less than the capacity needed to operate the engine at full load. These small fuel oil valves are in an embodiment also used to start the engine and to reverse the engine.

In another embodiment the engine is provided with an inert or low oxygen content gas system to provide inert or low oxygen content gas(such as exhaust gas). This inert or low oxygen content gas system is used to create a gas flow in the supply conduits 62,63,64 in case of a failure or the gaseous fuel supply system. If the gaseous fuel supply system should fail pressurized inert gas is delivered to the supply conduits 62,63,64 and pilot oil is injected in the inert gas with the dedicated pilot oil valves 55. The gaseous fuel valves 50 inject the mixture of inert gas and pilot oil into the cylinder for proving take home power or emergency power. If possible the take home power or emergency power with the dedicated pilot oil valves 55 is performed with a maximum dosage amount of pilot oil that can be handled by the pilot oil valves.

The embodiment shown in figure 6 is essentially identical to the embodiment of figures 4 and 5, except that the cylinders 1 are provided with a plurality (in this embodiment three) of fuel oil injection valves 52 for injecting fuel oil directly into the cylinder 1 for operation of the engine exclusively on fuel oil such as heavy fuel oil. In contrast to engines where the fuel valves are also used for pilot fuel injection, the fuel oil valves 52 can be placed at a distance from the gaseous fuel valves 55 since they do not need the assist in igniting gaseous fuel from the gaseous fuel valves 50. With the (heavy) fuel oil valves 52 the engine can be operated exclusively with (heavy) fuel oil if desired. The fuel valves 52 are in an embodiment dimensioned sufficiently large to allow to engine to be operated at full load on (heavy) fuel oil.

The term "comprising" as used in the claims does not exclude other elements or steps. The term "a" or "an" as used in the claims does not exclude a plurality. The electronic control unit may fulfill the functions of several means recited in the claims.

The reference signs used in the claims shall not be construed as limiting the scope.

PATENTKRAV

1. Selvtændende intern forbrændingsmotor, hvilken motor omfatter:

en flerhed af cylindre (1),

hvilke cylindre (1) er forsynet med mindst én gasbrændstofventil (50) til indsprøjtning af et gasformigt brændstof fra en dyse tilhørende brændstofventilen (50) og ind i den pågældende cylinder (1),

hvilken mindst ene gasbrændstofventil (50) har et indløb forbundet til en gasbrændstofforsyningsledning (62, 63, 64), som forsyner gasformigt brændstof under tryk til gasbrændstofventilen (50), og

mindst én dedikeret pilotolieventil (55) for hver cylinder (1), hvilken pilotolieventil (55) er forsynet med et indløb forbundet til en kilde (57) for pilotolie under tryk,

kendetegnet ved at den mindst ene dedikerede pilotolieventil omfatter en dyse til indsprøjtning af pilotolie ind i gasbrændstofforsyningsledningen (62, 63, 64).

2. Motor ifølge krav 1, hvor hver cylinder (1) er forsynet med en gasbrændstofakkumulator (60), og hvor gasbrændstofforsyningsledningen (62, 63, 64) strækker sig mellem gasbrændstofakkumulatoren (60) og den pågældende cylinders mindst ene gasbrændstofventil (50), og hvor udløbet af den mindst ene dedikerede pilotolieventil (55) er konfigureret til indsprøjtning af pilotbrændstofolie ind i gasbrændstofforsyningsledningen (62, 63, 64).

3. Motor ifølge krav 2, hvor en vinduesventil (61) er arrangeret ved udløbet af gasbrændstofakkumulatoren (60), og hvor vinduesventilen (61) kontrollerer strømmen af gasformigt brændstof fra gasbrændstofakkumulatoren (60) til gasbrændstofforsyningsledningen (62, 63, 64).

4. Motor ifølge krav 2 eller 3, hvor den mindst ene dedikerede pilotolieventil (55) er konfigureret til indsprøjtning af pilotolien når den mindst ene gasbrændstofventil (50) er lukket.

5. Motor ifølge et hvilket som helst af kravene 2 til 4, hvor den mindst ene dedikerede pilotolieventil (55) er konfigureret til indsprøjtning af pilotolien før gasbrændstofventilen (50) udfører en handling med indsprøjtning af et gasformigt brændstof.

6. Motor ifølge et hvilket som helst af kravene 1 til 5, hvor den mindst ene dedikerede pilotolieventil (55) atomiserer pilotolien ind i gasbrændstofforsyningsledningen (62, 63, 64).

7. Motor ifølge et hvilket som helst af kravene 1 til 6, hvor cylindrene er forsynet med mindst én lille brændstofolieventil, som er konfigureret til direkte indsprøjtning af brændstof ind i den pågældende cylinder til *take home power* eller *emergency power*, når gasbrændstofsystemet er ude af drift.

8. Motor ifølge et hvilket som helst af kravene 1 til 7, hvor en eller flere af cylindrene (1) er forsynet med en flerhed af brændstofolieindsprøjtningsventiler (52) i fuld størrelse til indsprøjtning af brændstofolie ind i cylinderen (1).

9. Motor ifølge et hvilket som helst af kravene 1 til 8, hvor en af de mindst ene dedikerede pilotolieventiler (55) er forbundet med hver gasbrændstofventil (50).

10. Motor ifølge et hvilket som helst af kravene 1 til 9, yderligere omfattende en elektronisk styringsenhed (ECU) konfigureret til at kontrollere og drive den mindst ene brændstofventil (50) og den mindst ene dedikerede pilotolieventil (55).

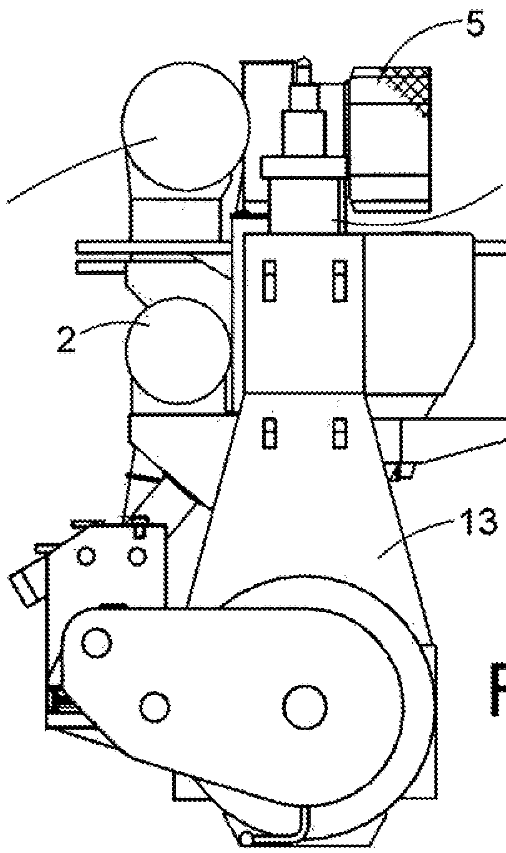


Fig. 1

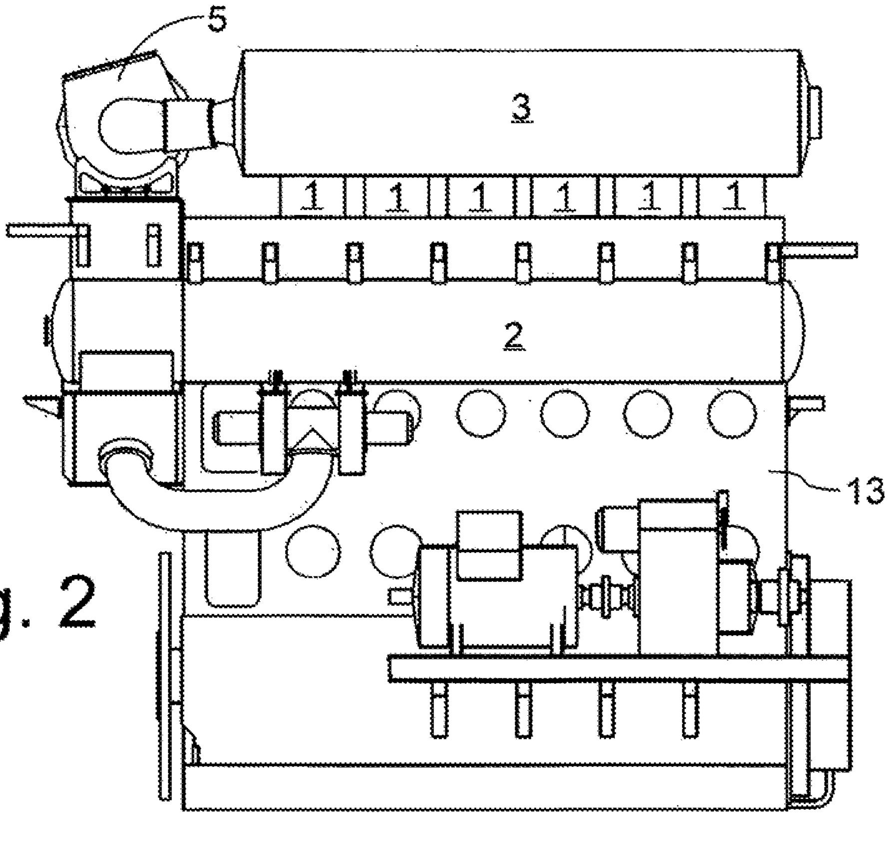


Fig. 2

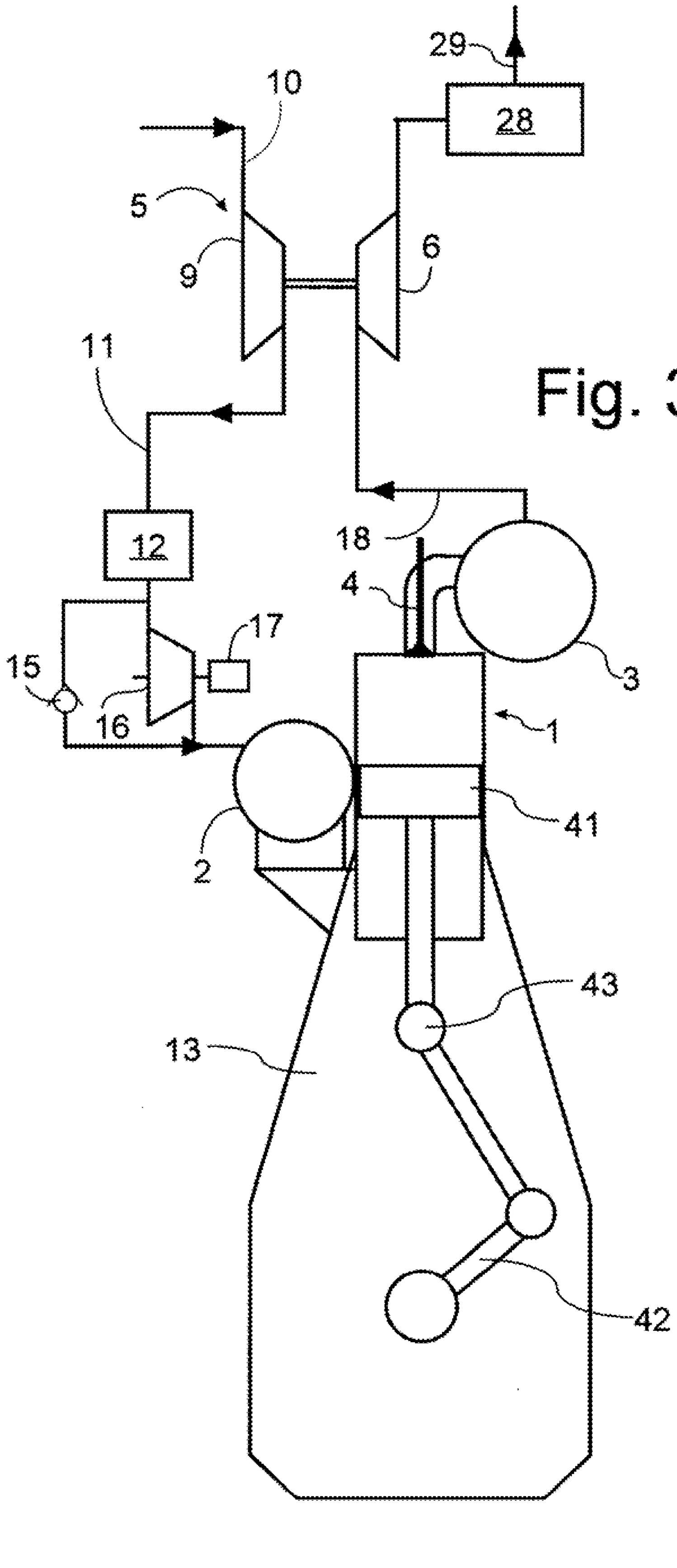


Fig. 3

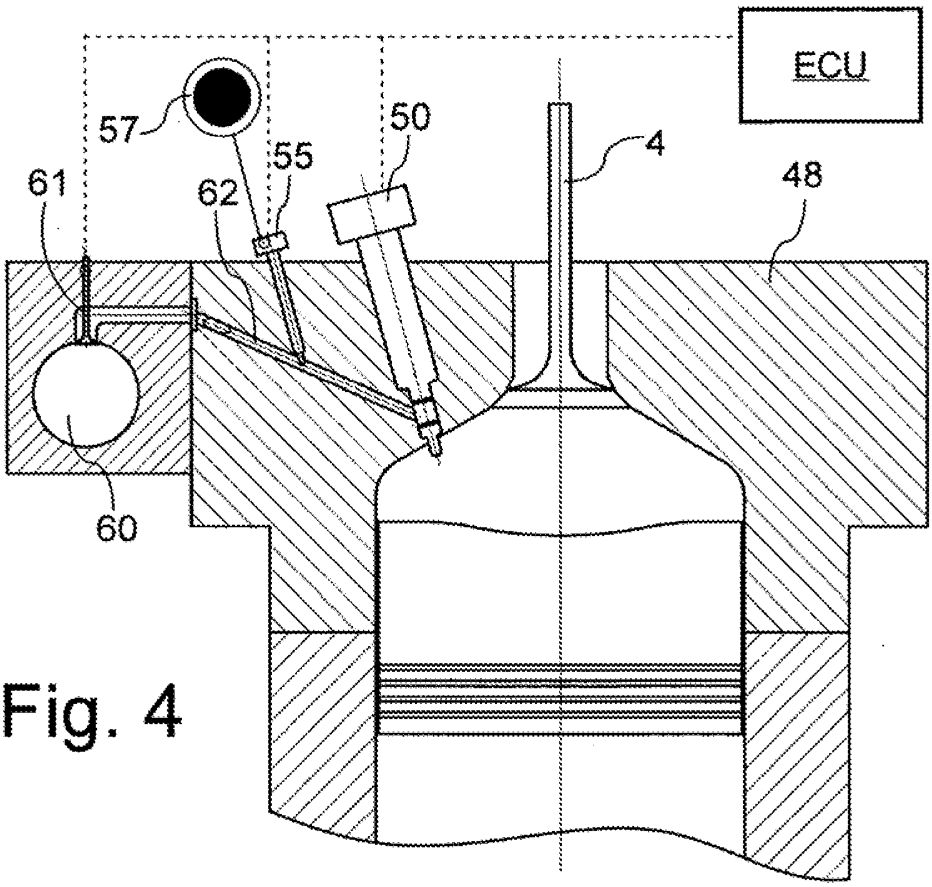
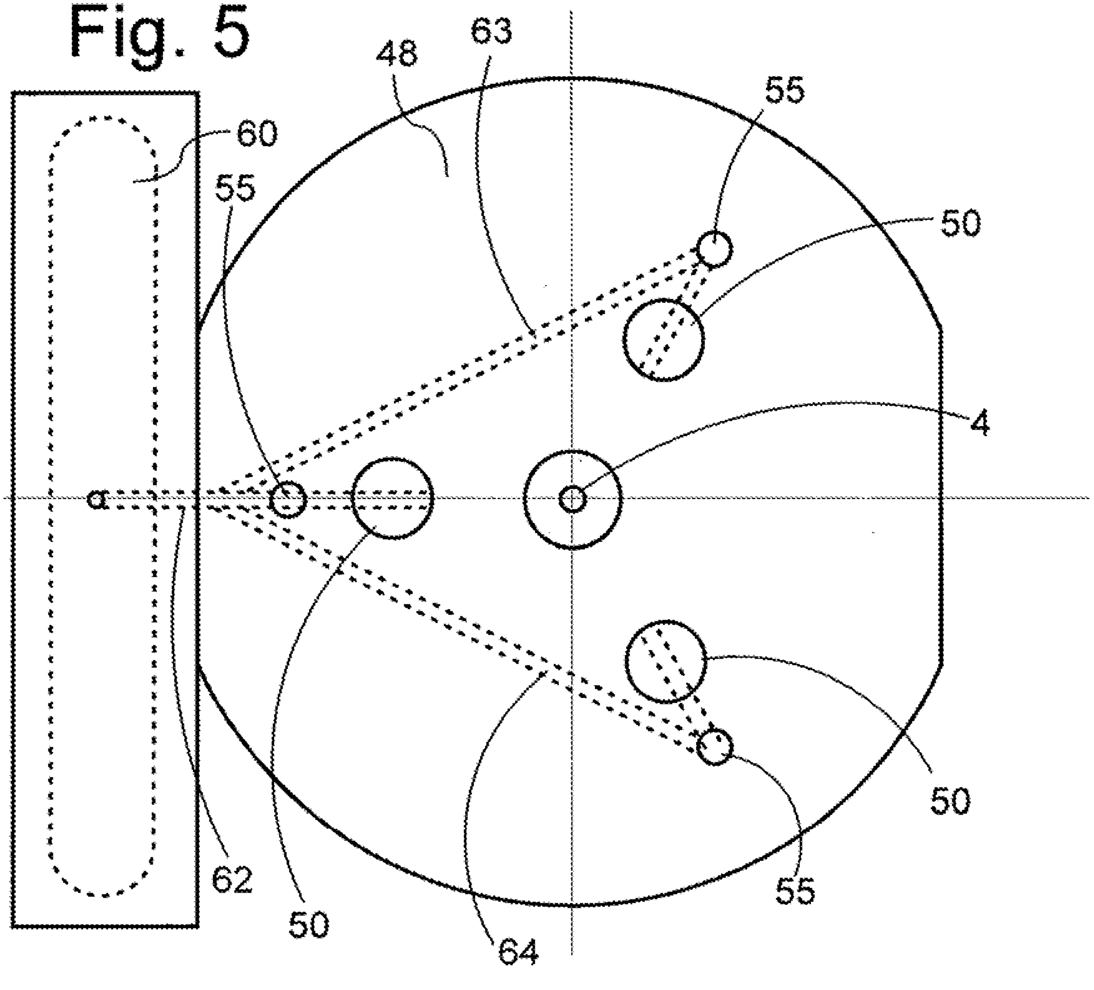


Fig. 4

Fig. 5



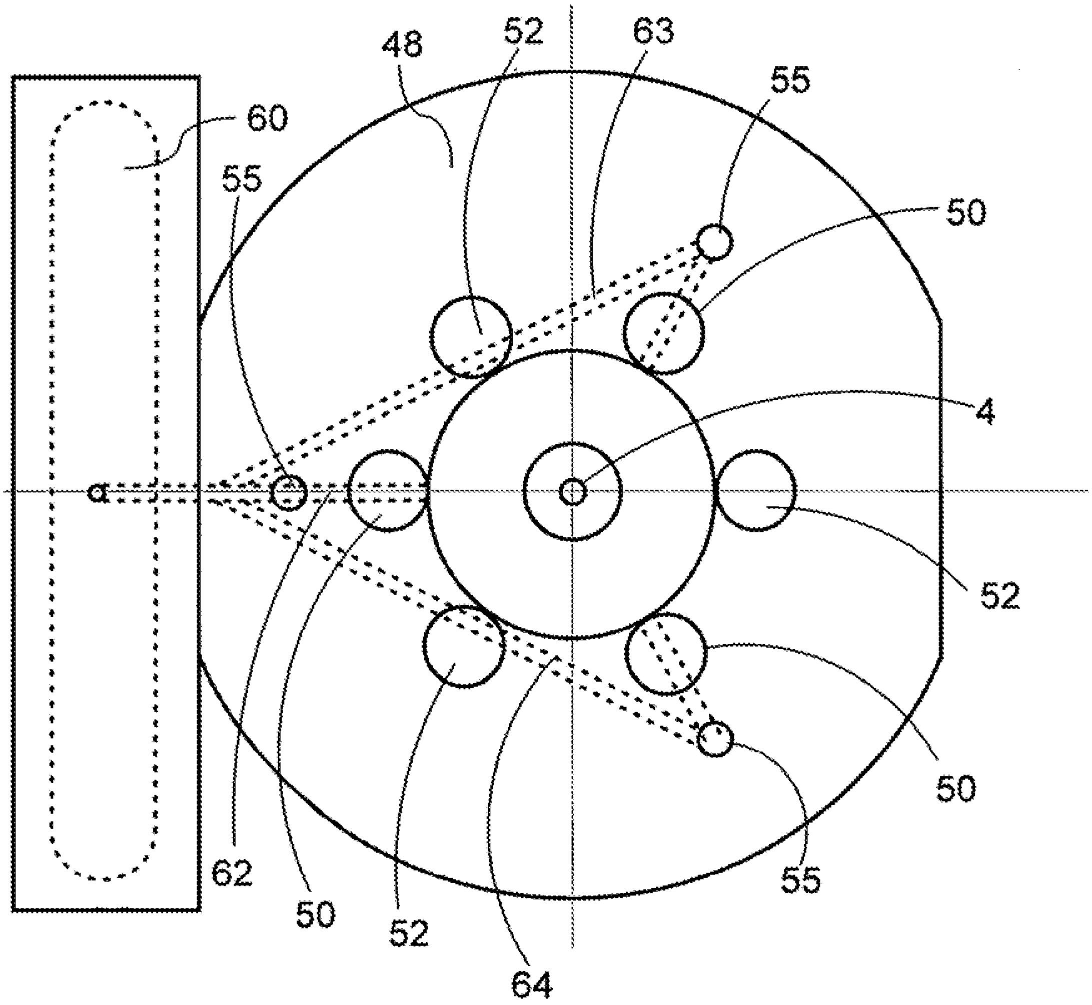


Fig. 6

DANISH PATENT AND TRADEMARK OFFICE

SEARCH REPORT - PATENT	Application No. PA 2013 00600

1. ☐

2. ☐

A. CLASSIFICATION OF SUBJECT MATTER

F02D 19/10 (2006.01)

According to International Patent Classification (IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F02B, F02D, F02M; CPC: F02B, F02D, F02M; FICLA: F02B, F02D, F02M.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

None

Electronic database consulted during the search (name of database and, where practicable, search terms used)

EPODOC, WPI, English language full text patent databases.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant for claim No.
X	US4563982 A (PISCHINGER, F. et al.) 14 January 1986 See in particular the abstract, column 1 lines 7-16, from column 5 line 27 to column 6 line 51.	1, 6, 9, 10
X	WO 2005/108770 A (STATOIL ASA) 17 November 2005	1, 9
A	WO 2008/000095 A1 (UNIVERSITY OF BRITISH COLUMBIA) 03 January 2008	1-10
A	US 2013/0081593 A1 (COLDREN, D.) 04 April 2013	1-10

☒ Further documents are listed in the continuation of Box C.

*	Special categories of cited documents:
"A"	Document defining the general state of the art which is not considered to be of particular relevance.
"D"	Document cited in the application.
"E"	Earlier application or patent but published on or after the filing date.
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"O"	Document referring to an oral disclosure, use, exhibition or other means.
"P"	Document published prior to the filing date but later than the priority date claimed.
"T"	Document not in conflict with the application but cited to understand the principle or theory underlying the invention.
"X"	Document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone.
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Date of completion of the search report
3 June 2014

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SEARCH REPORT - PATENT		Application No. PA 2013 00600
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant for claim No.
A	CA 2633846 A1 (WESTPORT POWER INC) 09 September 2008	1-10
A	WO 2013/003888 A1 (ORBITAL AUSTRALIA) 10 January 2013	1-10