(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 September 2012 (20.09.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/123713 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/GB2012/050492

(22) International Filing Date: 6 March 2012 (06.03.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1104174.6 11 March 2011 (11.03.2011) GB

(71) Applicant *(for all designated States except US)*: **BHP GENERATION LIMITED** [GB/GB]; c/o Whittaker Engineering (Stonehaven) Limited, Hindwells, Stonehaven, Aberdeenshire AB39 3UT (GB).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **WHITTAKER, Kenneth** [GB/GB]; Hindwells, Stonehaven, Aberdeenshire AB39 3UT (GB).

(74) Agent: **MURGITROYD & COMPANY**; Scotland House, 165-169 Scotland Street, Glasgow Strathclyde G5 8PL (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: AN IMPROVED STEAM ENGINE

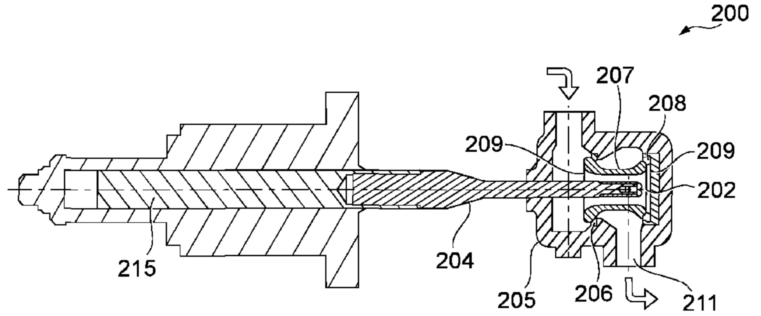


Fig. 2C

(57) **Abstract**: A steam engine comprising a chamber having a first inlet valve (200, 312) and a second outlet valve (200, 314); a reciprocating piston moveable within the chamber; wherein at least one of the first inlet and second outlet valve is coupled to a computer controlled mechanism (704) operable to open and close the valve. A double beat valve for use with the stem engine of the invention and a method of optimising steam supply to the engine chamber are also provided.

WO 2012/123713 A2

AN IMPROVED STEAM ENGINE

This invention relates to an improved reciprocating piston steam engine. The steam engine is a well known propulsion means, originating in the 19th century. Later, steam engines were effective at propelling trains and indeed some steam cars were built in the early 20th century.

More recently internal combustion engines have replaced the steam engine as the preferred mode of propulsion for vehicles. Steam turbines, based on the Rankin cycle, remain in power stations. But the use and development of steam engines with reciprocating pistons, especially for propelling vehicles, has declined significantly in the last 50 years.

According to a first aspect of the present invention there is provided a steam engine comprising:

a chamber having a first inlet valve and a second outlet valve; a reciprocating piston moveable within the chamber; wherein at least one of the first inlet and second outlet valve is coupled to a computer controlled mechanism operable to open and close the valve.

The invention also provides an apparatus, especially a vehicle, comprising a steam engine according to the first aspect of the invention, the steam engine operable to power movement of the apparatus.

Embodiments on the invention benefit in that they can optimise the amount of steam provided to the chamber. For example, during acceleration the first inlet valve will be held open for longer to allow more steam to enter the chamber. During a period of constant speed, the first inlet valve will open for a shorter period of time. Also, during hot conditions or cold conditions the amount of steam in the chamber can also be optimised.

Preferably, the at least one valve has a first face upon which pressure from the chamber acts, and a second face opposite the first face. Said valve is adapted so the resultant force due to the working pressure on each valve is less than that in a poppet valve with a single seat thereby reducing the valve opening load against the steam pressure.

Embodiments of the invention benefit in that the provision of a similar amount of pressure on both faces of the valve allow the valve to be opened and closed in a more precise timescale thus allowing a more precise optimisation of the chamber pressure.

The inventors of the present invention have found that the precise timing of a valve is surprisingly more difficult with a computer control mechanism than a direct mechanical linkage due to the required speed of valve response. Nevertheless, despite the difficulties, the invention provides benefits and certain embodiments include further features adapted to improve the timing such as the provision of a double-beat valve.

The double beat valve may be provided in the shape of a cylinder, preferably a waisted cylinder. The cylinder may be connected to an actuating rod via a web, such that fluid may pass through the web. Other than the connection with the actuating rod, the valve may have no face resisting flow of the fluids through the cylinder. Rather in a closed position, fluid flow through the cylinder is resisted by a valve seat.

Preferably, the valve has an inlet and an outlet each having a main axis and the cylinder has a longitudinal axis and the cylinder is arranged to move axially along its longitudinal axis and, preferably, the axial movement of the cylinder is perpendicular to the main axes of the inlet and outlet of the valve.

Preferably the double-beat valve has a longitudinal axis and two valve seats, preferably, axially spaced apart. Preferably one of said seats is compliant in the axial direction, that is it can move or be compressed. This allows the valve to have a better seal with the valve seat when closed and may allow for the slight difference in the valve diameter size which is a requirement of double-beat valves.

The at least one of the first inlet and second outlet valve coupled to a computer controlled mechanism may also be mechanically coupled to a crankshaft and the computer control may be arranged to vary the movement of the valve caused by the mechanical linkage. Nevertheless in preferred embodiments there is no mechanical linkage and the valves are exclusively controlled via the computer controlled mechanism.

Typically steam is added through the inlet into the chamber/working space and steam or steam/condensate is removed from the chamber/working space through the outlet.

In a preferred embodiment, the engine comprises a steam generator, as opposed to a steam boiler. Thus the steam is heated through a small bore tube of less than 2” in diameter, preferably less than 1” diameter, and preferably heated on demand.

Thus such embodiments of the invention are inherently safer since they do not include a potentially explosive steam boiler.

It is preferable that the fuel to heat the steam is a phase change material capable of storing and releasing heat when the material changes from solid to liquid and vice versa. In alternative embodiments, more conventional fuel may be used such as gas, diesel, petrol or coal.

Thus in a preferred embodiment, the apparatus comprises a mechanism suitable to transfer heat from a phase change material to a stream of water/steam.

The phase change material is a high temperature phase change material, that is phase change material with a melting point of at least 500 ºC, preferably more than 700 ºC, typically around 800 ºC and preferably less than 1000 ºC.

The phase change material may comprise inorganic salts. The phase change material can consist of single high temperature salts such as lithium fluoride or a sodium carbonate or a blend of a number of different salts, such as lithium fluoride or a sodium carbonate, with different latent heat and thermal conductivity values. Other suitable phase change materials include lithium carbonate (Li_2CO_3), magnesium chloride ($MgCl_2$), sodium chloride (NaCl) and potassium chloride (KCl), or a mixture of compounds such as sodium fluoride NaF, magnesium fluoride MgF_2 or potassium fluoride KF or similar chemical blends.

For such embodiments, the efficiency gained in the steam engine through the use of the computer controlled mechanism, limits the demand for the heat from the PCM material and so helps to ensure that there is no premature or uncontrolled solidification of PCM.

Benefits of preferred embodiments result in a very high degree of fuel efficiency which conventional steam engine do not achieve, indeed, most of the exhaust coming out of a conventional steam engine was not smoke but waste steam.

A plurality of chambers may be provided, each having a piston. The computer controlled mechanism of the valves may be applied to multi-cylinder and multi-stage reciprocating steam engines, including combinations of multiple cylinders and stages.

The engine may be a single or double acting reciprocating piston steam engine.

One or more inlet valves and one or more exhaust valves may be provided per cylinder. The size and number of valves in each chamber may vary from cylinder to cylinder within the engine.

The chamber is typically a cylinder and may also be referred to as a ‘working space’.

The computer control of the valves may apply to either the first inlet or second outlet valve(s) or to both.

Control of the valve(s) may be direct acting on the moving valve element or indirect acting via a linkage means, e.g. a linkage mechanism, variable camshaft, variable camshaft and linkage mechanism or other means.

The moving valve element may be of type: poppet, double-beat (also known as drop or equilibrium), rotary (including Corliss valve), disk, slide or sleeve. Double-beat valves are preferred.

The computer controlled mechanism may use a servo-actuator of electro-hydraulic, electro-pneumatic or stepper-motor type to move the valves.

An opening aperture, defined by the valve and its corresponding valve seat, may be in any position and orientation relative to the working piston(s) cylinder bore, but is preferably parallel to the cylinder bore.

The valve and seat may be of any form, for example a valve seat and poppet valve with a stem axis perpendicular to the cylinder axis. Alternatively the opening aperture may be provided in a cylinder head of the chamber and a disk valve with axis of rotation at right angle to and offset from cylinder axis.

The computer controlled mechanism is typically a programmable microprocessor or other electronic computerised system that may be either local or remote to the steam engine.

Preferably the engine comprises one or more sensors for monitoring parameters in the chamber which sensors communicate with the said computer controlled mechanism. Feedback from the sensors on parameters in the chamber preferably form a closed loop system that adjusts the valve operations (open/close) against a prescribed operating map, for example, valve opening displacement and valve timing. The computer control mechanism can also adjust the valve operations (e.g. opening and closing) depending on the engine crankshaft speed and load. This may be based upon the ambient temperature or the degree of steam superheating.

Thus preferably at least one sensor is provided, normally a plurality of sensors.

At least one temperature sensor is normally provided at the inlet or outlet, preferably both.

At least one pressure sensor is normally provided at the inlet or outlet, preferably both.

A sensor is normally provided which determines the power requirement from the engine.

Preferably each sensor is coupled to the computer controlled mechanism in order to provide data thereto. The data received from the sensor(s) can be used by the computer control mechanism to optimise the opening and closing of the valves.

Preferably the valves are lightweight, they may be made from EN57 or titanium for example.

Preferably the weight of at least one (preferably each) valve and an associated valve train is less than 1kg, more preferably less than 800g, especially less than 700g. Embodiments of the invention benefit in that the accuracy and speed of opening and closing the valves is improved because the valves are of a lighter weight than certain known valves for engines.

Embodiments of the present invention provide an improvement over a similar engine with passive, mechanical or manual valve actuation control.

Embodiments of the invention benefit in that pre-mapped inlet and exhaust valve events may form the basis of the valve motion with feedback from the sensor/transducer signals utilised to adjust the inlet and outlet valve motion for optimal operating characteristics, including improved efficiency, improved torque, improved power, improved engine braking or to reduce the loading on one or more components of the steam engine.

An example of reducing the load on components is the so-called cushioning of the piston ahead of top dead centre by the application of 'lead' steam at high engine speeds to cushion the piston and components at high speeds from the sudden load reversal at top dead centre.

The control of the inlet and exhaust valves for the chamber may be controlled separately, in order to achieve a specific performance requirement within the engine, for example, the valve actuation may be adjusted on a cylinder or workspace basis to achieve equal temperature at the sensor location for each cylinder or workspace.

Embodiments of the invention allow variable valve timing relative to the piston position, engine crankshaft or outlet shaft position (in the case of swash-plate type engine).

Embodiments of the invention allow variable opening displacement creating an infinitely variable aperture flow area for inlet and or exhaust steam/condensate flow, thus the steam can be admitted or expelled by a small valve opening displacement over a long duration or a large opening displacement over a short duration.

Embodiments of the invention provide steam flow characteristics, equivalent to and enhanced relative to, traditional steam engine valve-gear, such as 'lead' steam ahead of top dead centre in the engine working cycle and steam 'cut off', being the supply of steam to the working cylinder to less than the full duration of the power stroke.

The computer controlled mechanism may be used in combination with a conventional valve gear; the valve gear providing the base motion of the valve and the computer controlled mechanism providing the fine adjustment required for the enhanced performance.

Preferably the engine is programmed such that the starting procedure includes one or more revolutions of the engine with the exhaust valve open to ensure that no condensate or other liquid is present. The exhaust valve will be open throughout these start up revolutions, preferably except where piston to valve interference would occur. Thus embodiments of the invention will allow a failsafe mechanism to prevent hydraulic lock during start up or any other malfunction.

Thus, an advantage of the invention is that the computer control of the valves allows the valves to be disengaged from the crankshaft and so condensed steam may be flushed out more easily. Similarly, the valves may be opened to run-down the engine at the end of its use to avoid condensation of the steam.

In a second aspect, the invention provides a double beat valve comprising apparatus comprising a valve and at least two valve seats, axially spaced apart, wherein at least one valve seat is compliant, normally in the axial direction.

The double beat valve of the second aspect is preferably the double beat valve described with respect to the first aspect of the invention. In particular it is also preferably formed from a cylinder, normally waisted, with the actuator rod connected to the cylinder by a web.

In a third aspect, the invention provides a method of optimising the amount of steam provided to a chamber of a steam engine, the method comprising the steps of

providing a steam engine comprising

a chamber having a first inlet valve and a second outlet valve;

a reciprocating piston moveable within the chamber;

wherein at least one of the first inlet and second outlet valve is coupled to a computer controlled mechanism operable to open and close the valve; and

controlling by means of the computer controlled mechanism the opening and closing of the at least one of the first inlet and second outlet valve in accordance with the parameters in the chamber so as to so as to adjust the opening and closing of the or each valve thereby optimising the amount of steam provided to the chamber of the valve.

Preferably, the method comprises the step of holding open the first inlet valve by means of the computer controlled mechanism during acceleration for longer compared to constant speed to allow more steam to enter the chamber; and holding open the first inlet valve by means of the computer controlled mechanism during a period of constant speed for a shorter period of time than during acceleration.

Embodiments of the third aspect of the present invention may comprise one or more features of the first aspect of the present invention.

An embodiment of the present invention will now be described, by way of example only, and with reference to the accompanying figures in which:

Fig. 1 is a schematic representation of a power system for a vehicle comprising the valves in accordance with the present invention;

Fig. 2A is a schematic representation of a servo actuated double-beat type poppet valve;

Fig. 2B is a side view of servo actuated valve arrangement of Fig. 2A;

Fig. 2C is a partial section view showing an end view through the valve housing of Fig. 2A;

Fig. 3A is a schematic representation of a reciprocating steam engine valve operation arrangement;

Fig. 3B is a section view of a schematic representation of a reciprocating steam engine valve operation arrangement;

Fig. 4 is a top view of steam inlet and outlet ports in relation to the cylinder;

Fig. 5 is a partial section view showing the outboard and inboard cylinder chambers and reciprocating piston;

Fig. 6 is a partial section side view showing the outboard and inboard cylinder chambers of Fig. 5 and servo actuated double-beat type poppet inlet valves; and

Fig. 7 shows a schematic representation of the interconnections of an embodiment of a valve arrangement of the present invention.

As shown in Fig. 1, a phase change material is heated in the container 101 by heating elements 102 and ultimately, as described below, to produce high temperature steam which is used in an engine comprising the valves, shown in Fig. 2. Whilst the valves in accordance with the present invention may be used on a steam engine using other types of fuel to generate the steam, the use of PCM provides many advantages and the efficient use of the steam from such a fuel source (which the valves of the present invention provide) is especially important since the PCM material will cool towards ambient temperatures over time.

A circulation pump 104 circulates high temperature heat transfer fluid to a steam generator 105 where heat from the phase change material, via the fluid, is used to form very high temperature steam from any suitable water source The cooled fluid returns to the container 101. Steam from the steam generator 105 is directed, via a temperature control valve 107, to a de-superheater 108 where the temperature of the steam from the steam generator 105 is reduced to form more steam. A control system may switch the steam from the steam generator 105 to bypass the de-superheater 108 by opening the de-super bypass valve 109. After the de-superheater 108 or bypass 109, the steam is directed to a throttle valve 111 which regulates the quantity of steam being delivered to a downstream steam engine 117 and steam receiver 118.

The steam receiver 118 is an accumulator where a small volume of steam is stored to ensure there is no throttle lag between steam generation and response.

In an alternative embodiment, the heat may be transferred directly to the water/steam from the pipe surrounding the PCM via a ‘thermal bridge’.

The steam engine 117 is a reciprocating piston engine comprising valves (shown in Fig. 2) in accordance with the present invention. A reciprocating piston engine can power the wheels indirectly as above or directly with or without a gearbox. One suitable supplier of a steam engine comprising a reciprocating piston engine may be supplied by Whittaker Engineering (Stonehaven, United Kingdom).

Steam from the engine 117 is used by the waste steam turbine 119 to drive an auxiliary turbine which can be used to generate auxiliary power for the vehicle. One suitable supplier for the waste heat turbine is Global Energy and Infinity Turbine LLC Madison, USA.

The waste heat from the waste heat turbine 119, or directly from the steam engine 117, runs through a condenser 113 to convert the steam into hot water thereby allowing the waste heat to be re-circulated back into either the de-superheater 108 or steam generator 105 or both.

The throttle 112 controls the volume of steam before the steam engine 117 and at the inlet to the steam generator 105.

Thus a vehicle (not shown) can be provided with a circuit described as shown in Fig. 1. The phase change material may be heated before use by connection to mains electricity or at special charging points dependant on the size of the PCM and the duty cycle of the vehicle. Preferred embodiments of the vehicle are charged by electricity made from renewable energy sources.

Figs. 2A and 2B show a servo actuated valve arrangement 200 comprising a connector 213, a servo actuator 209, a connector 210, valve stem 204 and valve housing 205, including valve outlet port 211. The connector 210 connects the servo valve arrangement 200 to an electronic module (not shown) which can control the servo valve.

As shown in Figure 2C, the servo actuated double-beat type steam poppet valve 200 is arranged to allow it to be opened against high pressure with a minimum of force.

The valve is comprised of a housing 205 containing inlet and outlet ports with parallel axes. Between the valve inlet and outlet sits a hollow valve cylinder 207 which rests on two seats 206, 208 of nearly equal diameter. A valve stem is attached to the cylinder via a web 201, though which fluid can flow. In this closed position shown in Fig. 2c, pressure acts upon the web 201 and abuts with the base of the valve seat plug 202 and cylinder 207, thus resisting fluid flow.

The valve 200 is configured to open in a first direction towards the steam input, which is against high pressure. The cylinder moves in an axial direction when the valve stem 204 is retracted. Opening the valve 200 against high pressure is consequently easier since it is not moved against the pressure of the fluid from the inlet against its entire cross section, because only the cylinder and web are moved, not seat 208 and not the plug seat 202. Fluid may then flow past the upper wasted portion 207 as well as through the web and past the seat 208 to the steam outlet 211.

The diameter of the upper valve seat 206 is larger than that of the lower valve seat 208. This difference is kept minimal in order to minimise the force required to open the valve, the relationship between the force required and the difference in diameter being directly proportional.

The seat 208 is also resiliently mounted by a rubber member 209. In use when the valve 200 closes it will contact the seat 208 momentarily before it contacts the seat 206; the rubber member 209 allows for this difference by compressing slightly in an axial direction relative to the valve stem 204 in order to provide an improved seal for the valve 200.

The central portion of the valve cylinder 207 is waisted so that, when open, the flow can pass at the upper valve seat 206 as well as the lower seat 208, increasing the valve opening area for the same degree of lift.

For valves located at the steam inlet port, steam supply enters the valve inlet from the steam supply. When servo-actuated, the valve stem 204 is retracted by the rod 215 lifting the valve cylinder 207 thus allowing the steam to pass to the cylinder.

In servo actuated double-beat type poppet valves located at the steam exhaust port, steam supply enters the valve inlet from the cylinder. When servo-actuated, the valve stem 204 is retracted lifting the valve cylinder 207 thus allowing the steam to be exhausted.

In alternative embodiments the inlet and outlet ports need not have parallel axes.

Figs. 3A and 3B shows an engine cylinder 303 and crankshaft 305, two inlet valves 312 and two exhaust valves 314. Valve apertures 301 are parallel to the cylinder bore, the poppet valve having a stem axis 302 perpendicular to and offset from the cylinder axis 303.

Fig. 4 shows the arrangement of steam inlet ports 401, 402 leading to cylinder 403, and steam outlet ports 404, 405.

In Fig. 5, an increase in pressure in the outboard chamber 501 actuates the piston 503 increasing the depth of a piston rod 504 in a cross-head 505, thus actuating a crankshaft 507 via a connecting rod 506.

Fig. 6 shows the partial section of Fig. 5 and the servo actuated double-beat type poppet inlet valves 601 (the outlet valves not shown).

Fig. 7 shows a schematic representation of the interconnections of the valve arrangement. A signal from a control computer 701 is amplified by a servo amplifier and then converted into a hydraulic motion by a servo valve 703 which controls the actuator 704. The output of the actuator 704 is monitored by any suitable means and a feedback loop provided so that the signal from the computer can be optimised.

Improvements and modifications may be made without departing from the scope of the invention.

Claims:

1. A steam engine comprising

a chamber having a first inlet valve and a second outlet valve;

a reciprocating piston moveable within the chamber;

wherein at least one of the first inlet and second outlet valve is coupled to a computer controlled mechanism operable to open and close the valve.

2. A steam engine as claimed in claim 1, wherein the at least one valve has a first face upon which pressure from the chamber acts, and a second face opposite the first face.

3. A steam engine as claimed in claim 1 or claim 2, wherein valve is adapted so the resultant force due to the working pressure on each valve is less than that in a poppet valve with a single seat thereby reducing the valve opening load against the steam pressure.

4. A steam engine as claimed in any preceding claim, wherein the valve is a double-beat valve.

5. A steam engine as claimed in claim 4, wherein the double-beat valve is provided in the shape of a cylinder.

6. A steam engine as claimed in claim 5, wherein the cylinder is a waisted cylinder.

7. A steam engine as claimed in claim 5 or claim 6, wherein the cylinder is connected to an actuating rod via a web, such that fluid may pass through the web.

8. A steam engine as claimed in claim 7, wherein only the connection with the actuating rod in the valve provides a face resisting flow of the fluids through the cylinder.

9. A steam engine as claimed in claim 8, wherein in a closed position, fluid flow through the cylinder is resisted by a valve seat.

10. A steam engine as claimed in any one of claims 5 to 9, wherein the valve has an inlet and an outlet each having a main axis and the cylinder has a longitudinal axis and the cylinder is arranged to move axially along its longitudinal axis and wherein the axial movement of the cylinder is perpendicular to the main axes of an inlet and outlet of the valve.

11. A steam engine as claimed in any one of claims 4 to 10, wherein the double-beat valve has a longitudinal axis and two axially spaced apart valve seats.

12. A steam engine as claimed in claim 11, wherein one of the valve seats is compliant in the axial direction.

13. A steam engine as claimed in any preceding claim, wherein the at least one of the first inlet and second outlet valve coupled to a computer controlled mechanism is also mechanically coupled to a crankshaft and the computer control is arranged to vary the movement of the valve caused by the mechanical linkage.

14. A steam engine as claimed in any one of claims 1 to 12, wherein the at least one of the first inlet and second outlet valve coupled to a computer controlled mechanism is exclusively controlled via the computer controlled mechanism.

15. A steam engine as claimed in any preceding claim, wherein the fuel to heat the steam is a phase change material capable of storing and releasing heat when the material changes from solid to liquid and vice versa.

16. A steam engine as claimed in claim 15, wherein the phase change material is a high temperature phase change material having a melting point of at least 500 ºC.

17. A steam engine as claimed in any preceding claim, wherein the computer controlled mechanism is in co-operative arrangement with a servo-actuator of electro-hydraulic, electro-pneumatic or stepper-motor type to move the or each valve.

18. A steam engine as claimed in any preceding claim, wherein the computer controlled mechanism is adapted to control of the or each valve by directly acting on a moving valve element.

19. A steam engine as claimed in any one of claims 1 to 17, wherein the computer controlled mechanism is adapted to control of the or each valve by indirectly acting on a moving valve element via a linkage means.

20. A steam engine as claimed in any preceding claim, wherein the engine comprises one or more sensors for monitoring parameters in the chamber, the one or more sensor being arranged to communicate with the said computer controlled mechanism, the or each sensor being coupled to the computer controlled mechanism so as to provide data thereto, wherein the computer control mechanism is configured to process the data received from the or each sensor so as to optimise the opening and

closing of the or each valve.

21. A steam engine as claimed in claim 20, wherein feedback from the sensors on parameters in the chamber form a closed loop system that is arranged to adjust the opening and closing of the or each valve against a prescribed operating map including valve opening displacement and valve timing.

22. A steam engine as claimed in claim 21, wherein the computer controlled mechanism is operable to adjust the opening and closing of the or each valve depending on an engine crankshaft speed and load.

23. A steam engine as claimed in claim 21 or claim 22, wherein the computer control mechanism is operable to adjust the opening and closing of the or each valve depending on an ambient temperature or a degree of steam superheating.

24. A steam engine as claimed in any one of claims 21 to 23, wherein at least one temperature sensor is provided at one or each of the inlet or outlet of the or each valve.

25. A steam engine as claimed in any one of claims 21 to 24, wherein at least one pressure sensor is provided at one or each of the inlet or outlet.

26. A steam engine as claimed in any one of claims 21 to 25, wherein at least one sensor is provided which is configured to determine the power requirement from the engine.

27. A steam engine as claimed in any preceding claim, wherein the

computer controlled mechanism is arranged in co-operative relationship with a valve gear, wherein the valve gear is configured to provide a base motion of the valve and the computer controlled mechanism providing fine adjustments.

28. An apparatus comprising a steam engine according to any one of Claims 1 to 27, the steam engine being operable to power movement of the apparatus.

29. An apparatus of claim 28 wherein the apparatus is a vehicle.

30. A double beat valve apparatus comprising a valve having a longitudinal axis and at least two axially spaced apart valve seats, wherein at least one valve seat is compliant in the axial direction.

31. A double beat valve apparatus as claimed in claim 30, wherein the valve is provided in the shape of a cylinder.

32. A double beat valve apparatus as claimed in claim 31, wherein the cylinder is a waisted cylinder.

33. A double beat valve apparatus as claimed in claim 31 or claim 32, wherein the cylinder is connected to an actuating rod via a web, such that fluid may pass through the web.

34. A double beat valve apparatus as claimed in claim 33, wherein only the connection with the actuating rod in the valve provides a face resisting flow of the fluids through the cylinder.

35. A double beat valve apparatus as claimed in claim 34, wherein in a

closed position, fluid flow through the cylinder is resisted by a valve seat.

36. A double beat valve apparatus as claimed in any one of claims 30 to 35, wherein the valve has an inlet and an outlet each having a main axis and the cylinder has a longitudinal axis and is arranged to move axially along its longitudinal axis and wherein the axial movement of the cylinder is perpendicular to the main axes of the inlet and outlet of the valve.

37. A method of optimising the amount of steam provided to a chamber of a steam engine, the method comprising the steps of

providing a steam engine comprising

a chamber having a first inlet valve and a second outlet valve;

a reciprocating piston moveable within the chamber;

wherein at least one of the first inlet and second outlet valve is coupled to a computer controlled mechanism operable to open and close the valve; and

controlling by means of the computer controlled mechanism the opening and closing of the at least one of the first inlet and second outlet valve in accordance with the parameters in the chamber so as to adjust the opening and closing of the or each valve thereby optimising the amount of steam provided to the chamber of the valve.

38. A method of claim 37 comprising the step of holding open the first inlet valve by means of the computer controlled mechanism during acceleration for longer compared to constant speed to allow more steam to enter the chamber; and

holding open the first inlet valve by means of the computer controlled mechanism during a period of constant speed for a shorter period of time than during acceleration.

39. A method of claim 37 or claim 38 comprising the step of adjusting the amount of steam in the chamber during hot conditions or cold conditions by means of the computer controlled mechanism.

40. A method of any one of claim 37 to 39 comprising the step of providing one or more sensors for monitoring parameters in the chamber, arranging the one or more sensors to communicate with the said computer controlled mechanism, coupling the or each sensor to the computer controlled mechanism so as to provide data thereto, the computer control mechanism being configured to process the data received from the or each sensor so as to adjust the opening and closing of the or each valve thereby optimising the amount of steam provided to the chamber of the valve;

using pre-mapped inlet and exhaust valve events to form the basis of the valve motion; and

utilising feedback from one or more sensor signals to adjust the inlet and outlet valve motion to achieve optimal operating characteristics, including improved efficiency, improved torque, improved power, improved engine braking or to reduce the loading on one or more components of the steam engine.

41. A method of any one of claims 37 to 40 comprising the step of reducing the load on components by cushioning of the piston ahead of top dead centre by the application of ‘lead’ steam at high engine speeds to cushion the piston and components at high speeds from the sudden load reversal at top dead centre.

42. A method of any one of claims 37 to 41 comprising the step of controlling the inlet and exhaust valves separately so as to achieve a specific performance requirement within the engine.

43. A method of any one of claims 37 to 42 comprising the step of during the starting procedure allowing one or more revolutions of the engine with the exhaust valve open to ensure that no condensate or other liquid is present.

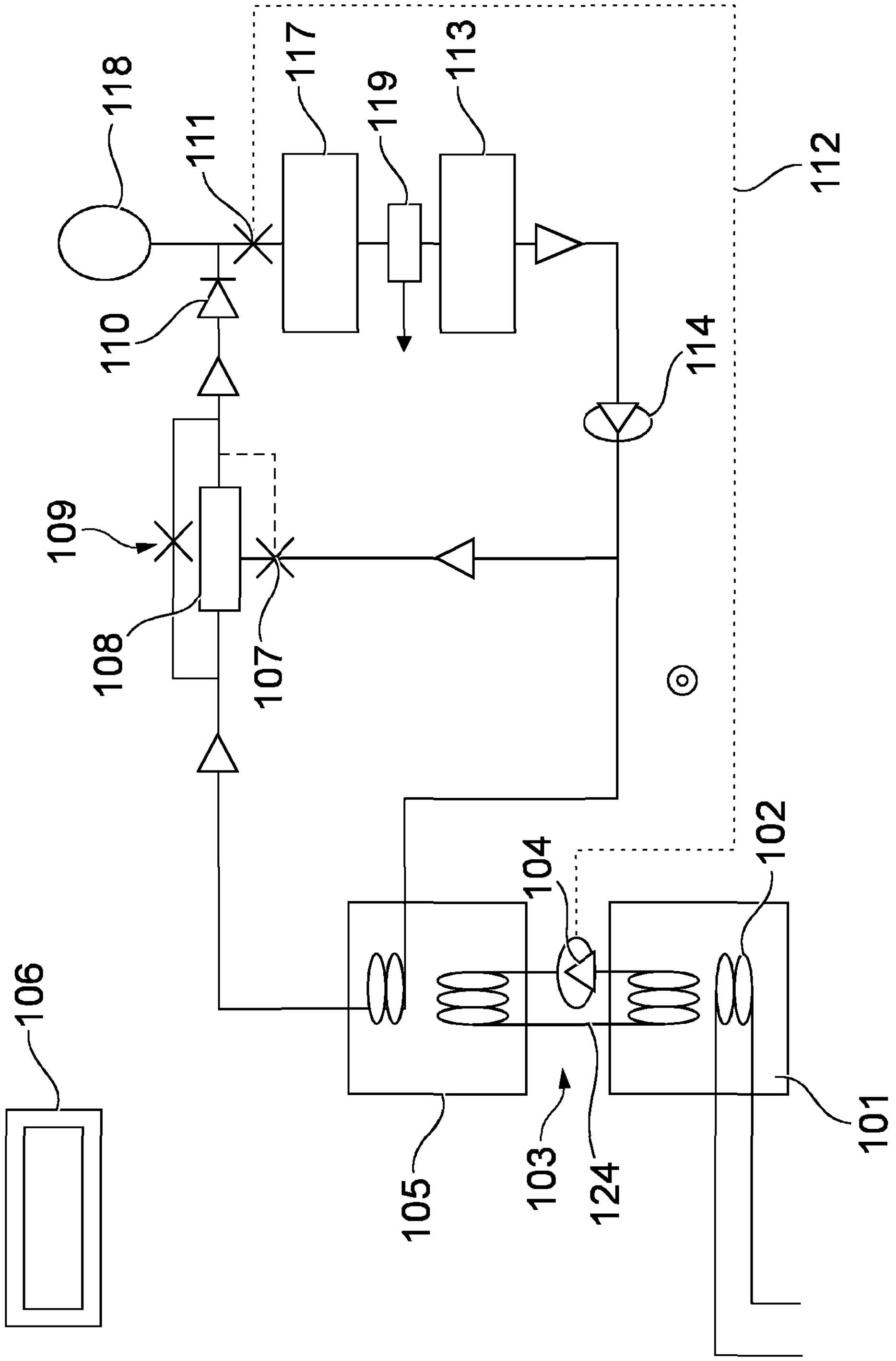
44. A method of any one of claims 37 to 43 comprising the step of by means of the computer control mechanism disengaging the valves from the crankshaft and allowing the condensed steam to be flushed out.

45. A method of any one of claims 37 to 43 comprising the step of by means of the computer control mechanism opening the valves to run-down the engine at the end of its use.

46. A method of any one of claims 37 to 45 comprising the step of controlling the or each valves exclusively via the computer controlled mechanism.

47. A method of any one of claims 37 to 46 comprising the step of varying valve timing relative to one of the piston position, engine crankshaft or outlet shaft position.

48. A method of any one of claims 37 to 47 comprising the step of varying opening displacement creating an infinitely variable aperture flow area for inlet and or exhaust steam/condensate flow; and allowing the steam to be admitted or expelled by a small valve opening displacement over a long duration or a large opening displacement over a short duration.



118
111
117
119
113
112
110
114
109
108
107
104
102
106
105
103
124
101

Fig. 1

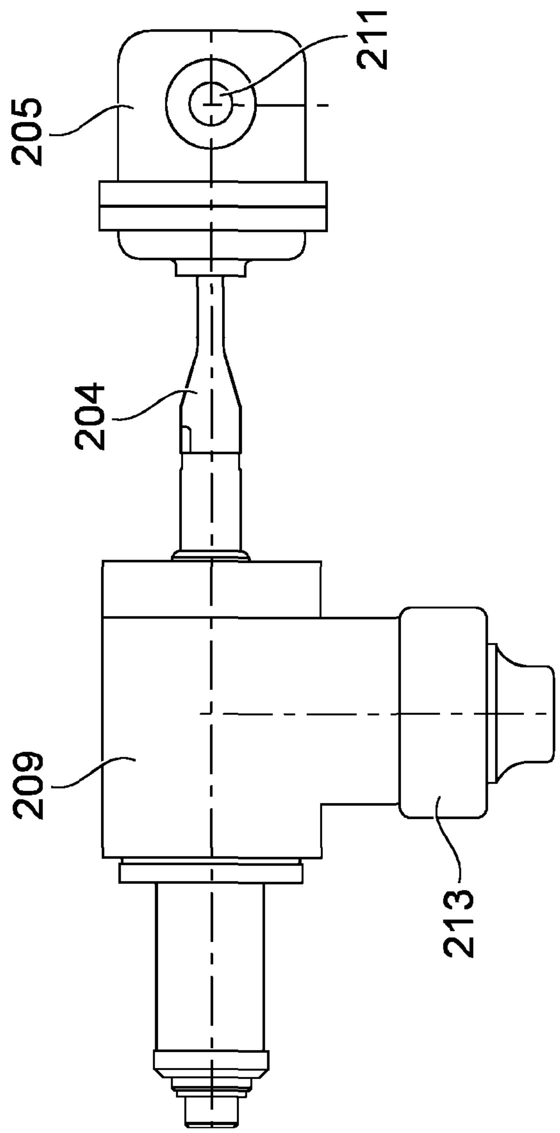


Fig. 2A

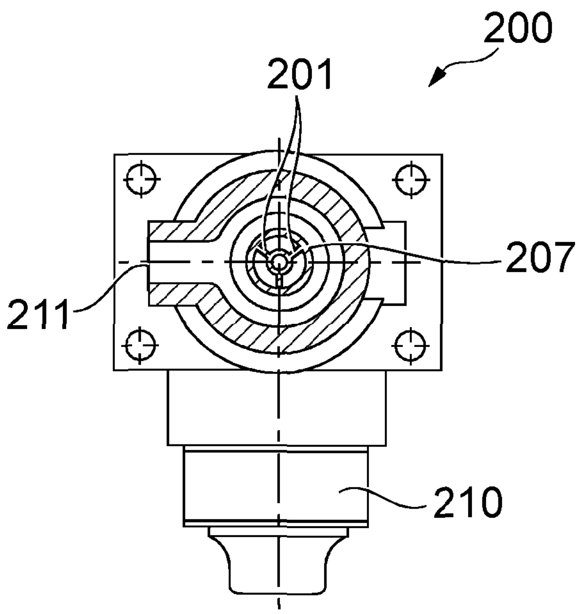


Fig. 2B

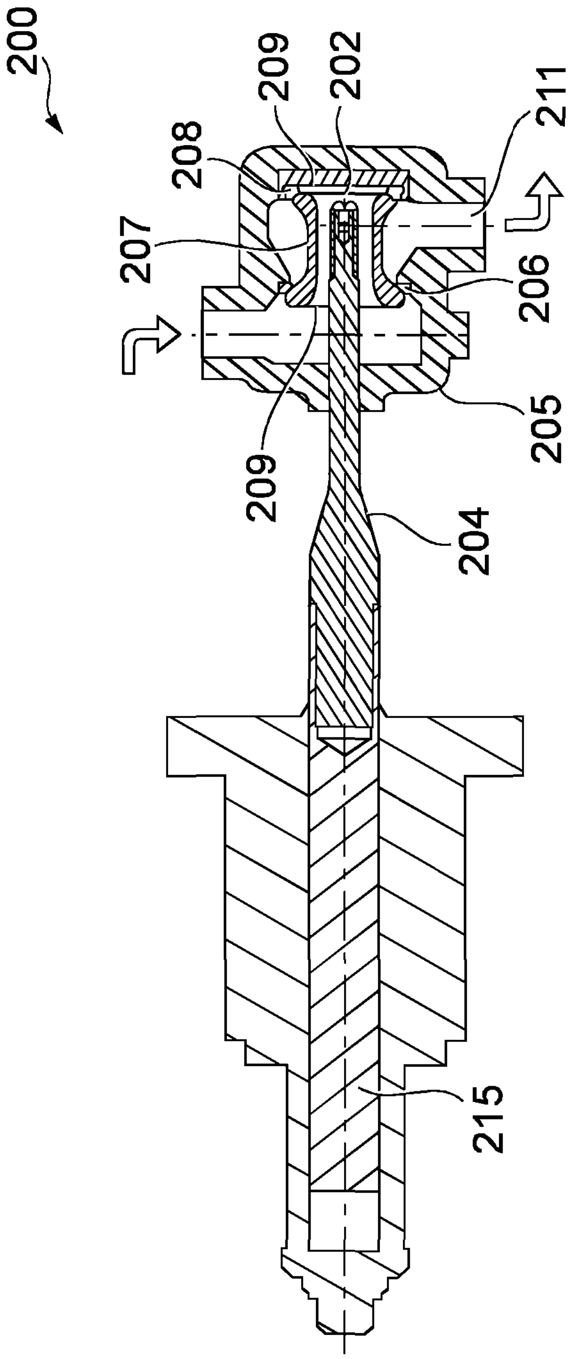


Fig. 2C

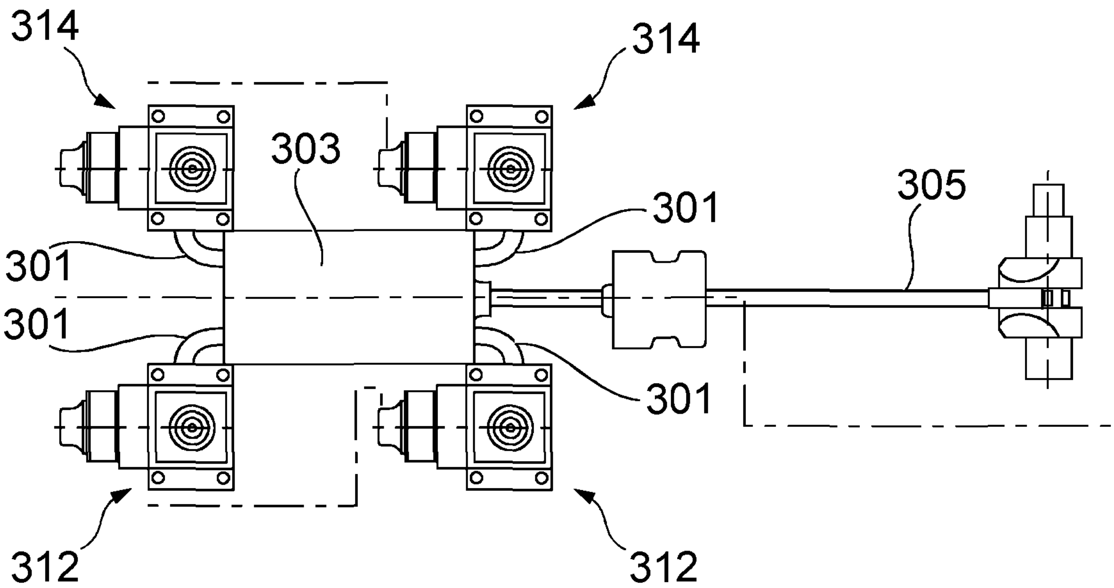


Fig. 3A

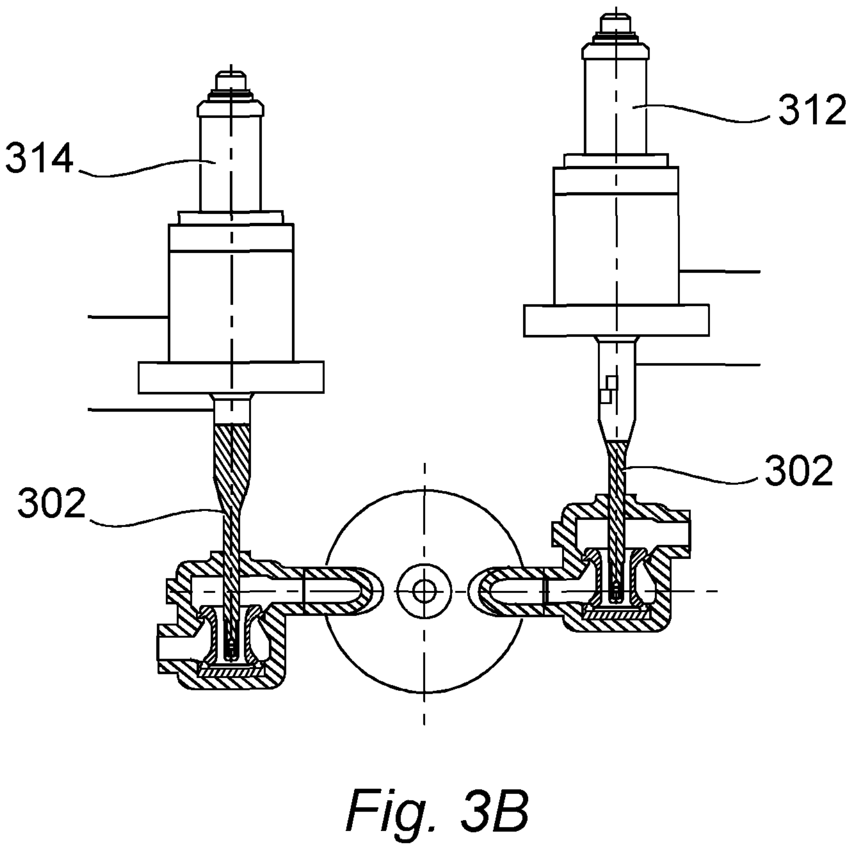


Fig. 3B

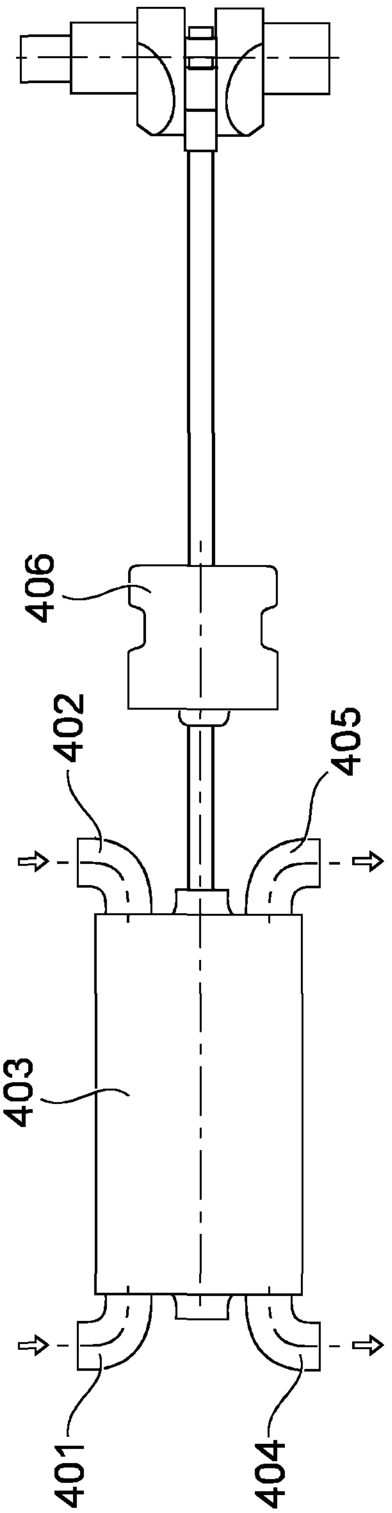


Fig. 4

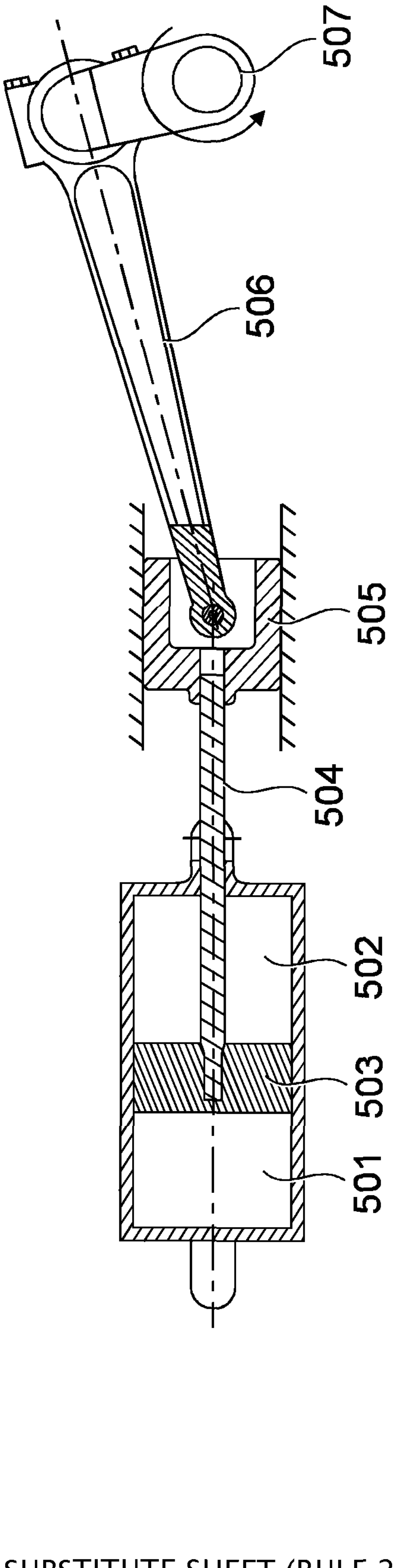


Fig. 5

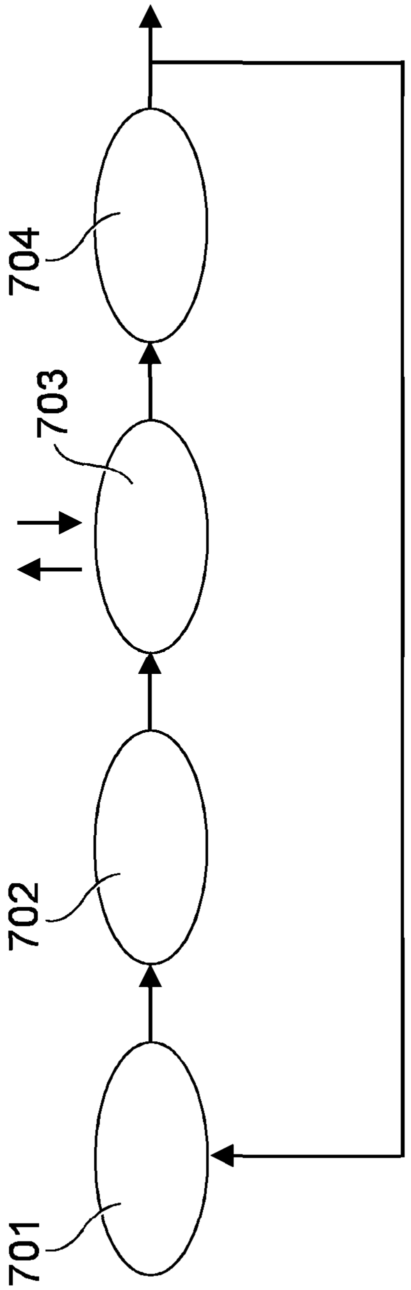


Fig. 7

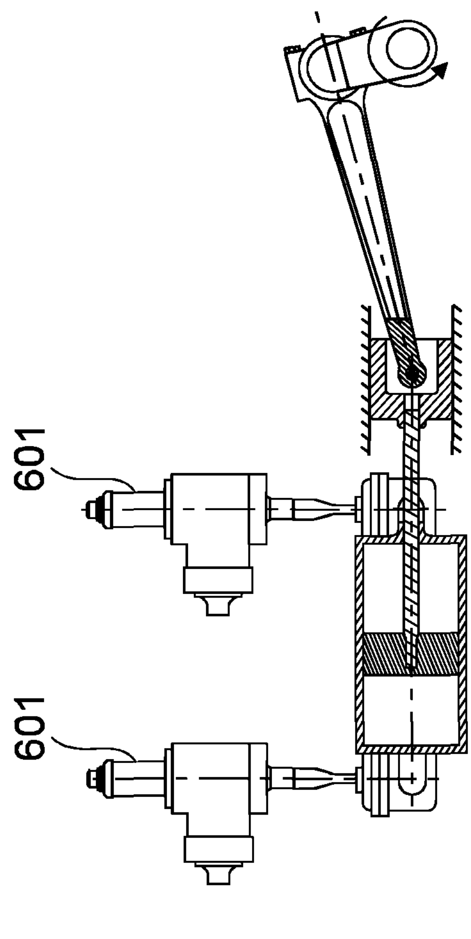


Fig. 6